Exeter River Geomorphic Assessment and Watershed-based Plan

Fordway Brook, Upper Exeter River, Dudley-Bloody Brook, and Lower Exeter River

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Bear Creek Environmental

Fitzgerald Environmental Associates, LLC.

Applied Watershed Science & Ecology

Exeter River Geomorphic Assessment and Watershed-based Plan

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1.0 EXECUTIVE SUMMARY

The Exeter River watershed is located in southeastern New Hampshire and spans fifteen towns in Rockingham County. The watershed area is approximately 109 square miles, and the river outlets to the Great Bay via the Squamscott River. The Exeter River headwaters are found in the Towns of Raymond and Chester, and the main stem flows in an easterly direction for approximately 32 miles before cascading over the Great Falls in Exeter into the tidal zone of the Squamscott River. The Exeter River is one of fifteen rivers in New Hampshire designated for greater protection of outstanding natural and cultural resources according to the State's Rivers Management and Protection Act. The Lower Exeter River is also the municipal drinking water source for the Town of Exeter. The watershed contains some of the fastest growing towns in New Hampshire, which has led to increased development pressure on the ecological health of the river in recent years. Increases in impervious cover, forest fragmentation, and ground water withdrawals accompanying this growth have led to heightened concerns about the protection of the river's water quality. In response to these concerns, the New Hampshire Department of Environmental Services (NHDES), the Exeter River Local Advisory Committee (ERLAC), and other stakeholder groups have made the Exeter River watershed a priority for protection and restoration.

The Exeter River Geomorphic Assessment and Watershed-based Plan presented in this report was preceded by numerous background studies and significant stakeholder involvement to identify restoration planning needs. NHDES and ERLAC previously sponsored the collection of biological sampling data and GIS-based surveys of the watershed to identify high priority subwatersheds for future study. As a result, four subwatersheds were identified for the current study: Fordway Brook; Upper Exeter River; Dudley-Bloody Brook; Lower Exeter River. The main objectives of this study are to assess fluvial geomorphic and habitat conditions in the four subwatersheds and develop a watershed-based restoration and protection plan for Exeter River stakeholders. A planning strategy based in fluvial geomorphic science (see glossary for associated definitions) was chosen because it provides a holistic, watershed-scale approach to identifying the stressors on river ecosystem health. This science also gives planners and resource managers the ability to predict stable and unstable river reaches, and provide recommendations for avoiding property damage over the long term. The NHDES sponsored and administered the project, while ERLAC provided a local match by contributing volunteer time. This study was funded by the Federal

Emergency Management Agency (FEMA), the United States Environmental Protection Agency (EPA), the Town of Exeter and the National Oceanic and Atmospheric Administration (NOAA). Bear Creek Environmental, LLC and Fitzgerald Environmental Associates, LLC were retained by NHDES and the Town of Exeter to conduct the study. Many project partners contributed to the assessment and watershed plan including: ERLAC, Town of Exeter, Rockingham Planning Commission, Raymond Water Resources Committee, NH Coastal Program, NH Rivers Management and Protection Program, NH Geological Survey (NHGS), interested citizens, and riverfront property owners. A list of acronyms, including federal and state agencies, used in this plan is provided for the reader at the end of this document (Section 12.0) to serve as a reference.

The methods used for collecting remotely sensed and field-based data were developed by the Vermont Agency of Natural Resources (VTANR) over the past decade. These include the Phase 1 and 2 Rapid Geomorphic Assessment (RGA) Protocols, a recently revised Rapid Habitat Assessment (RHA) protocol, two Culvert Screening Tools, a River Corridor Management Guide, and a protocol for the development of Fluvial Erosion Hazard (FEH) Zones. The VTANR methods were designed to support management efforts that: 1) protect and restore aquatic and riparian habitat protection, 2) reduce sediment and nutrient loads in waterways, and 3) mitigate fluvial erosion hazards. In addition to the VTANR methods, a widely-used hydrologic model developed by the Natural Resources Conservation Service was used to estimate flow magnitudes through bridges and culverts for various flood events.

NHGS was responsible for conducting the Phase 1 Stream Geomorphic Assessment of the Exeter River watershed and split the watershed into 290 reaches based on valley confinement, slope, tributary influence, surficial geology, and soils. A total of 48.4 river miles were targeted for field data collection in the four subwatersheds, encompassing 53 reaches from the Phase 1 study. Based on more detailed field observations, reaches were further divided into a total of 91 river segments during the Phase 2 assessments. Forty (40) of the 91 river segments were fully assessed using the Phase 2 protocol. The remaining 51 river segments were assessed for riparian bank and buffer conditions only; full RGA and RHA surveys were not possible at these sites due to wetlands, beaver dams, or river impoundments. These segments were not governed by fluvial processes and therefore, the RGA and RHA protocols were not applicable.

Based on the field data, subwatershed stressor and departure maps were developed to guide the identification of site-specific restoration projects. Types of projects identified included: protecting river corridors, planting and improving stream buffers, placing streams in former channel locations, replacing or retrofitting problematic bridges and culverts, and mitigating stormwater runoff. A total of 21 high priority restoration and protection projects have been identified within the study area. At the watershed scale, FEH Zones were identified for municipalities in the study area for planning purposes. FEH zoning ordinances are intended to prevent increased river encroachment in areas prone to fluvial erosion hazards to reduce property loss and damage, and encourage long-term river stability.

NHDES and ERLAC will use the results of this study to guide future restoration efforts and educate the larger community in the watershed about the importance of protecting the Exeter River. An implementation schedule has been developed to focus previously allocated resources on high priority restoration projects.

2.0 PROJECT OVERVIEW

2.1 Project Objectives

This project includes four subwatersheds in the Exeter River basin: Fordway Brook, Dudley-Bloody Brook, Upper Exeter River and Lower Exeter River for a total of 48.4 river miles. Three of these sub-watersheds (Dudley-Bloody Brook, Fordway Brook and Upper Exeter River) do not meet the state standards for aquatic life use based on habitat and biological surveys completed by the NHDES. Stream geomorphic assessment data collected during 2008 by the Project Team will: 1) aid NHDES and the ERLAC in the analysis of the fluvial geomorphic and biotic habitat conditions in the watershed; 2) result in preliminary project identification for the protection and restoration of important river reaches; 3) lead to a watershed restoration plan to address and mitigate the stressors leading to impairments; and 4) assist towns within the study area with a planning tool to identify fluvial erosion hazard zones.

The value of Exeter River geomorphic data to New Hampshire will be significant in that it addresses an information need as identified by the New Hampshire Water Resources Primer (Burack et al., 2008).

> "New Hampshire has very limited data on the geomorphic characteristics of its rivers and streams. River morphology, or their form and shape, is a naturally dynamic process; rivers are not static systems. By knowing how a river system will achieve a stable morphology over time, significant human infrastructure and aquatic resource impacts could be prevented."

The Exeter River Geomorphic Assessment and Watershed-based Plan is a pilot effort to collect geomorphic data at the watershed scale for local restoration and planning purposes.

2.2 Local Planning Efforts

Local Conservation Groups

In 1995, a group of watershed residents were successful in enrolling the Exeter River in the State of New Hampshire's Rivers Management and Protection Program. This program is administered by the NHDES and its purpose is to "ensure the continued viability of New Hampshire's rivers as valued economic and social assets for the benefit of present and future generations."

ERLAC was established in 1996 to oversee the development and implementation of a river management plan. Committee members are residents from watershed communities working to protect and maintain the river's natural character. ERLAC completed the Exeter River Corridor and Watershed Management Plan in 1999 and since that time has designed many public education and outreach programs to increase awareness of the natural resources in the watershed. ERLAC partners with watershed communities, state and federal agencies and the Rockingham Planning Commission (RPC) to advocate for the

protection of water quality and quantity, wildlife habitat, and recreational and scenic resources.

The communities in the Exeter River watershed are active participants in natural resource protection. Land use decisions are made at the local level by volunteers serving on Planning Boards, Zoning Boards of Adjustment, and Conservation Commissions, in cooperation with state and federal agencies. Development proposals located in the watershed are also reviewed by ERLAC. All of the communities have local regulations designed to protect wetlands and shoreland, prevent the disturbance of steep slopes, and minimize the impacts of stormwater. Some of the communities have regulations to restrict the percentage of a lot covered by impervious surfaces and regulations requiring the conservation of land. Access to watershed specific information, such as this report, is critical to increasing the protection of natural resources because this information enables local decision makers to make the most efficient and effective use of scarce municipal dollars and volunteer time. Planning Boards and Conservation Commissions in the Exeter River watershed in partnership with ERLAC also work closely with landowners to identify land protection opportunities. Several communities in the watershed have completed Natural Resource Inventories and/or Open Space Plans that have identified local priorities for land protection.

Guidance Documents

Several guidance documents[1] have been completed in the last few years to strengthen local efforts to protect water quality and other natural resources. These documents are being used by ERLAC, Planning Boards, and Conservation Commissions at the local and watershed level to identify opportunities for resource conservation. Watershed communities are partnering with Piscataqua Region Estuaries Project (PREP), RPC, NHDES, the NH Coastal Program, and other organizations to develop and implement activities to address impervious surfaces and sprawl. These activities include land use regulations to protect riparian buffers and prime wetlands, conservation subdivision regulations designed to minimize impacts to natural resources, and the purchase of land or development rights for conservation.

Source Water Protection

The Exeter River and its watershed serve as a water supply to the Town of Exeter. In addition to surface water supply, there are numerous public and private water supplies throughout the watershed. The surface water supply comes from the Exeter Reservoir (aka Dearborn Reservoir), Skinner Springs (located in Stratham), and the main stem of the Exeter River. The groundwater supply for the Town of Exeter comes from the Lary Lane well in Exeter. The average daily demand of the system is approximately 1.0 to 1.1 million gallons per day. In addition, well head protection areas in the study area's four focus subwatersheds, as well as the surface water of the river and its tributaries, provide an important source of drinking water for watershed residents. This Plan provides a

[1] Wildlife Action Plan (WAP) – NH Fish and Game 2005; Land Conservation Plan for New Hampshire's Coastal Watersheds – The Nature Conservancy, Society for Protection of New Hampshire Forests, Rockingham Planning Commission, and Strafford Regional Planning Commission 2006; The Great Bay Resource Compendium – The Nature Conservancy and the University of New Hampshire 2006.

framework for restoring and maintaining river processes. Natural river stability will reduce sedimentation and other water quality impacts resulting from alterations to the river corridor and channel. The watershed-based protection and restoration actions proposed in this Plan will positively impact the quality of the drinking water supply provided by the Exeter River and its tributaries. The 2002 NH DES Source Water Assessment Report for the Exeter River (NHDES, 2002) showed this source water receiving three *high* susceptibility ratings, five *medium*, and four *low*.

The criteria to determine susceptibility reflect the potential vulnerability of a public water supply system to draw water contaminated by inventoried sources based on density, proximity, and type of existing or potential sources of contamination. The Exeter River has a relatively *high* susceptibility to contamination according to criteria associated with highways/rail roads, animals, and lagoons. The river (source) has a *medium* susceptibility to contamination based upon criteria associated with potential contamination sources (PCSs), pesticides, septic systems, and agricultural land cover. The remaining criteria indicate a *low* susceptibility to contamination based upon detects of certain contaminants, integrity of intake, urban land cover (based on satellite images prior to 2000 which do not account for recent development and population growth), and dry weather discharges. Contamination threats to the river as summarized in the 2002 report are provided below.

<u>Stormwater runoff</u>: This existing threat is expected to increase as development increases throughout the watershed. Contaminants include polycyclic aromatic hydrocarbons, sediment, bacteria, metals, pesticides and salts.

<u>Nonpoint sources</u>: Failing septic systems and agricultural runoff are existing sources. Contaminants include nutrients, sediment, and pathogens.

<u>Point sources</u>: Threats continue to increase as development expands across the watershed. Contaminant sources include floor drains, uncovered fertilizers, petroleum products, and chemicals.

<u>Eroding stream banks</u>: Throughout the watershed stream and river banks are destabilizing especially those downstream of new subdivisions. These small streams receive increased runoff volumes and as a result banks erode while sediment load and turbidity increase. This threat will increase with development. Increased sediments in streams can lead to turbidity problems associated with surface water supplies. Increased turbidity has the potential to damage water treatment pumps, reduce reservoir volume, and increase treatment costs. Additionally, riparian buffers play an important role in reducing impacts from erosion and sedimentation. Removing vegetation adjacent to streams and tributaries can destabilize banks, resulting in sedimentation.

The geomorphic assessment and planning elements conducted through this project will benefit source water supplies by providing (1) an inventory of potential and existing sources of contamination through the detailed stream assessment surveys of four selected subwatersheds and (2) subwatershed management plans that identify and prioritize protection measures and restoration actions. Protection measures will focus on land use

regulations, land acquisition and education/outreach programs. Restoration projects identified by the Plan will address construction of stormwater BMPs, buffer plantings, and bank stabilization. The goal of this Plan is to identify local actions to maintain or restore waters in the Exeter River watershed to support four of the State's seven designated uses. These uses are primary and secondary contact recreation, drinking water (after adequate treatment), and aquatic life.

2.3 Project Partners

The planning team for the Exeter River watershed Plan is comprised of the following partners:

- Exeter River Local Advisory Committee
- Town of Exeter
- Rockingham Planning Commission
- Raymond Water Resources Committee
- New Hampshire Department of Environmental Services
  - Coastal Program
  - Source Water Protection
  - New Hampshire Geological Survey
  - Watershed Assistance
- Interested citizens and riverfront property owners

In the spring of 2008, the NHGS created the preliminary datasets for stream reach definition and river corridor delineation within the Exeter River Watershed. This phase of the project involved remote sensing to provide an overview of general physical characteristics of the watershed. Steve Couture, NHDES Rivers Coordinator, provided coordination for the Phase 1 geomorphic assessment.

Bear Creek Environmental, LLC (BCE) and Fitzgerald Environmental Associates, LLC (FEA) were retained by NHDES and the Town of Exeter in 2008 to conduct a Phase 2 Stream Geomorphic Assessment of the four subwatersheds of the Exeter River: Fordway Brook, Upper Exeter River, Dudley-Bloody Brook and Lower Exeter River and to prepare a watershed plan.

2.4 Previous Studies

The Exeter River and its watershed have been the focus of numerous past studies to assess conditions of water quality, in-stream aquatic habitat, fish passage, and hydrologic and hydraulic processes related to dam management. In addition, a recent GIS-based study was conducted to assess the vulnerability of Exeter River subwatersheds to water quality impacts from existing land uses. The following section summarizes the key findings of previous studies (in chronological order) about the watershed. The results of previous work in the watershed have been informative for the identification of priority subwatersheds and other planning needs in this study.

Exeter River Watershed Vulnerability Analysis, January, 2008
This study was prepared by Geosyntec Consultants under contract to NHDES to assess the vulnerability of Exeter River subwatersheds to impacts on water quality. The study assessed the following criteria related to protection assets and threats to maintaining water quality in the watershed: forest cover and wetlands, conservation land, stream buffers, water demand, wellhead protection, barriers to fish passage, stream impairments, and high-intensity land uses. The results of the vulnerability analysis ranked Dudley-Bloody Brook and the Lower Exeter River as the two most vulnerable subwatersheds. The Upper Exeter River and Fordway Brook were ranked as moderately and least vulnerable, respectively. In addition to the vulnerability analysis, Geosyntec worked with ERLAC to identify potential water quality restoration sites within the watershed. A total of ten sites were evaluated, including erosion mitigation in the Fordway and Upper Exeter River subwatersheds, and stormwater treatment in the Dudley Brook-Bloody subwatershed.

New Hampshire Volunteer River Assessment Program (VRAP) – Exeter River Water Quality Report, 2006, 2007 and 2008
Since 1998 the Exeter Conservation Commission has been monitoring water quality at a number of sampling stations along the Exeter River and its tributaries within the town limits. The purpose of the sampling effort has been to develop a water quality data base for the river to assess its condition relative to the NHDES surface water quality standards for aquatic life use. The long-term sampling effort can also help to determine trends in water quality, and to identify specific areas of water pollution. Two published reports, prepared by NHDES in 2007 and 2008, summarize the data collected during the previous year's sampling season. During 2006, the following water quality parameters were monitored: temperature, dissolved oxygen (DO), pH, specific conductance, and turbidity. The results of the 2006 sampling indicated that a number of the sampling sites on the Exeter River did not meet the NHDES standards for pH (no other parameters), while only one site on the Little River had a single value for DO that did not meet the standards. In 2007, the sampling effort was expanded in scope to include additional monitoring stations on Dudley Brook, Fordway Brook, and Towle Brook. In addition, NHDES staff assisted the ERLAC volunteers with biological sampling of macroinvertebrates at 8 sites to build on an NHDES "screening" study conducted in autumn of 2006 to identify suitable sites for long term biological monitoring. The 2007 and 2008 sampling results again showed some sites did not meet the NHDES standards for pH and DO on the Exeter River and the Little River. During 2008, two sites on Fordway Brook also did not meet the NHDES standards for pH. The results of the ERLAC biological sampling indicated good or excellent conditions at all sampling sites on the Exeter River, Towle Brook, Fordway Brook, and the Little River during 2007 and 2008.

Evaluation of Human Disturbance on Macroinvertebrate Assemblages at Selected Sites in the Exeter River Basin (Progress Report), New Hampshire, May, 2007
This study was implemented by the NHDES Coastal Program and the U.S. Geological survey in 2005 to assess the effects of human disturbance on stream macroinvertebrate communities in the Exeter River watershed (U.S. Geological Survey, 2007).

Macroinvertebrate samples were collected at 24 sites in the watershed during low flow conditions in August, 2005 using a Surber sampler (1ft^2) at representative riffles. In addition, a disturbance index was calculated using upslope urban land use and in-stream habitat conditions to assess the relationship between watershed and reach-scale stressors and biotic integrity. The results showed a significant response of the biological community to different levels of disturbance. As expected, sensitive macroinvertebrates (EPT index) declined with increasing levels of disturbance, as did overall taxa richness (total number of macroinvertebrate species). Unexpectedly, the macroinvertebrate group associated with worms (Oligochaeta), which are typically found to increase in abundance in urban watersheds, decreased with increasing levels of disturbance. Results of this study were referenced in recommendations for Aquatic Life Use (ALU) status per the EPA's 303(d) listing for New Hampshire in 2008.

Exeter River Study – Phase I Final Report for the Town of Exeter, NH, March, 2007

This study was prepared by Wright-Pierce and Woodlot Alternatives, Inc under contract to the Town of Exeter in response to flooding concerns raised by residents along the lower river. The purpose of the study was to summarize information about the hydrology and hydraulics of the Exeter River watershed for the Town, with a particular focus on three dams in the lower watershed: Great Dam and Pickpocket Dam on the Lower Exeter River, and the Colcord Pond Dam on the Little River (Dudley-Bloody Brook subwatershed). Field surveys were conducted to collect data needed to develop hydraulic models to predict river profiles during flood events at the three dams. In addition, an extensive field survey upstream of the Great Dam was conducted to evaluate the extent of the backwater effect of the dam. With respect to the hydraulic analyses, the study found that under high flow conditions the limiting channel controls on the Exeter River in the town center are the Great Bridge (High Street)

Great Bay Estuary Restoration Compendium, September, 2006

The Compendium (The Nature Conservancy 2006) was created by a collaboration of scientists from UNH, New Hampshire Fish and Game Department (NHFGD), The New Hampshire Coastal Program, and the Nature Conservancy. The Compendium is intended to provide guidance for an ecosystem approach to restoration in the Great Bay and its watershed. A discussion of the Compendium in the context of the Exeter River watershed is provided in Section 3.5, Ecological Setting.

Stream Buffer Characterization Study, July, 2006

This study was carried out by the University of New Hampshire (UNH) Complex Systems Research Center and was funded by the New Hampshire Estuaries Project through an EPA grant. The scope of the study included second order streams in the Piscataqua River basin (includes Exeter watershed), and summarized the impact of human land use on stream buffers through the use of GIS data layers. The final characterizations were used to describe a gradient of impacts: intact (<10% impacted), mostly intact (10-25% impacted), somewhat modified (25-50% impacted), and altered (>50% impacted). Using stream buffer widths of 150 and 300 feet, the results showed that the dominant area at both scales had a rating "intact", with decreasing land areas in categories with the highest impacts (i.e.,

"altered" had smallest land coverage). The study also quantified impervious surfaces in the buffers at both scales. At the 150 foot buffer, a historical review of impervious surfaces revealed increases from 4.4% in 1990 to 7.5% in 2005.

State of the Estuaries Report, 2006
The 2006 State of the Estuaries Report by the New Hampshire Estuaries Project, now known as the Piscataqua Region Estuaries Partnership (PREP), highlights the status of twelve of the thirty four environmental indicators being tracked by PREP. These indicators include water quality trends in the watersheds draining to the estuaries, health of plant and animal communities, land conservation, watershed impervious surface tracking, and sprawl development.

New Hampshire Wildlife Action Plan, October, 2005
The Wildlife Action Plan (WAP) provides information on critical wildlife habitat across New Hampshire and includes several tools to assist communities with integrating wildlife habitat conservation into decisions about land use. These tools include detailed descriptions about wildlife species at risk and the habitats they depend on, dynamic and adaptable Geographic Information Systems (GIS) data, maps that depict the different habitats throughout the state, habitat quality and conservation focus area maps. Habitat quality is broken down into four tiers, with Tier 1 providing the highest quality habitat in New Hampshire. For the analysis of the Exeter River watershed, the WAP divided the watershed into its five Hydrologic Unit Code (HUC) zones and ranked the habitat in each zone. The overall summary for the Exeter River ranked the watershed habitat quality (as a percent of total area) as follows: Tier 1: 13%, Tier 2: 6%, Tier 3: 47%, and Tier 4: 34%.

Exeter River Buffer Analysis for the Towns of Fremont and Chester, May, 1998
As part of their senior research for undergraduate degree credit for the University of New Hampshire's Department of Natural Resources (DNR), a group of students worked on a service-learning project for the Exeter River Conservation Commission (ERCC) to assess river buffer conditions during 1998. The assessment project and final report was carried out by the following DNR students: Sarah Holt, Sara Callaghan, Robin Reed, Tim Sheahan, and Evan Fitzgerald. Theresa Walker acted as the primary liaison between the ERCC and the student group. The purpose of the study was to assess buffers at 14 sites along a 5.5 mile stretch of the river in the Towns of Fremont and Chester using a methodology developed by UNH called the *Evaluation of Buffer Functions*. This method evaluates the quality of the buffer with respect to flood control, water quality, wildlife habitat, recreation and aesthetics. With the exception of the sites nearest road crossings where the floodplain has been impacted by the roadway, most of the 14 assessed sites had high to very high scores for all of the parameters listed above.

3.0 BACKGROUND WATERSHED INFORMATION

3.1 Geographic Setting

The Exeter River rises from a group of spring-fed ponds in Chester, New Hampshire and flows 33 miles to downtown Exeter where it changes its name to the Squamscott River, and becomes a tidal river and a primary tributary to Great Bay. The river often meanders,

frequently doubling back on itself, and passes through several short stretches of rapids in Brentwood before falling over the Great Dam in Exeter. The watershed includes sizeable portions of ten municipalities, including Chester, Sandown, Danville, Fremont, Raymond, Brentwood, East Kingston, Kingston, Kensington, and Exeter.

The freshwater portion of the watershed has a drainage basin of about 108 square miles. The highest elevation can be found in Raymond, 649 feet. The largest community is Exeter with a 2007 population of 14,533, according to the NH Office of Energy and Planning. The other nine watershed towns lie upstream of Exeter and can be described as rural and suburban residential communities. Land use in the watershed was categorized in 2006 as 58% forested, 9% developed, 15% farmland, 15% wetlands, 2% shrub/scrub, and 1% open water (NOAA, 2008). Developed lands in the watershed are primarily residential. Commercial and industrial is scattered throughout communities with concentrations along state highways, including NH Routes 125, 111 and 102.

The Exeter River is one of seven rivers draining into New Hampshire's Great Bay. According to the 2006 Great Bay Estuary Restoration Compendium (The Nature Conservancy, 2006), Great Bay is a unique estuarine system often noted for being less impacted by human activity than other estuaries along the eastern seaboard. Human activity along the Exeter River has led to the alteration and degradation of water quality and fish and shellfish habitat in Great Bay.

Historically, many sites along the Exeter River were used as a source of power for sawmills and grist mills. Dam building and diversions date back to the early 1600's when the coastal area was being colonized (Tardiff, 2004). Most of the dams and mills were built on natural falls; however some areas of the lower Exeter River in Exeter with only minor elevation changes were used to power mills (e.g., Kings Falls near present-day Powder Mill Road). From Chester down to Exeter, the river supported at least 10 mill sites despite relatively limited topographic relief of the watershed. In essence, mills were built wherever there was potential to divert or dam the river for power. None of the historic dams or mills is presently used for power generation. Some mills, such as the Cavil Mill in Fremont, are still standing and many dams are still maintained for recreational or other management purposes. The remnants of other dams in ruins can also be seen throughout the watershed, especially in the upper subwatersheds. All of these in-stream structures, whether intact or in ruins, still exert a strong influence on the form and condition of the river. Some continue to act as barriers to aquatic organism passage, and many prevent stream ecosystem recovery in nearby river reaches.

The Exeter River includes some of the fastest developing towns in New Hampshire. According to the US Census Bureau, the Town of Danville's population grew 59% between the period 1990 - 2000, the Town of Chester's increased 41% and the Town of Fremont's grew 36% during the same period. Population growth and the accompanying residential and commercial development have resulted in sprawling impervious surfaces, forest fragmentation, and increasing groundwater withdrawals. This growth has also strained municipal budgets, and in some instances has prevented best management practices to address threats to the environment such as non-point source pollution.

The concept of impervious cover or impervious surface is relatively new to local land use boards in the watershed. Data about impervious cover was first introduced for general discussion and education by PREP in their 2006 State of the Estuaries Report. Working with the University of New Hampshire's Complex Systems Research Center, PREP mapped impervious cover in the coastal watershed, including the towns in the Exeter River watershed. This information was used to educate local decisions makers and residents about the relationship between impervious cover and water quality and quantity.

The data collected by PREP illustrated the increase in impervious surface coverage in the watershed between the period 1990 – 2005 (Table 3.1). It is a goal of the PREP's Management Plan to limit impervious cover to less than 10% in order to protect water quality, since impervious cover above this level has been associated with impaired stream conditions (CWP, 2003). As of 2005, only one town in the watershed exceeds this goal, Exeter, with 12.4% impervious cover, however, every community in the watershed experienced significant increases in impervious cover during the study period.

Table 3.1
Increase in Impervious Surface Cover
1990, 2000, 2005
NH Estuaries Project, 2006

Town	1990	2000	2005
Brentwood	5.0%	7.7%	9.5%
Chester	2.5%	4.3%	5.1%
Danville	3.5%	6.0%	7.2%
East Kingston	3.5%	5.3%	7.0%
Exeter	7.5%	11.0%	12.4%
Fremont	3.0%	4.9%	5.9%
Kensington	3.2%	5.0%	6.2%
Kingston	5.2%	8.2%	9.7%
Raymond	5.3%	8.0%	9.3%
Sandown	3.8%	6.1%	7.9%

The Exeter River Geomorphic Assessment includes four subwatersheds in the Exeter River basin: Fordway Brook, Upper Exeter River, Dudley-Bloody Brook, and Lower Exeter River for a total of 48.4 river miles. As illustrated in Figure 3.1, the project area for Fordway Brook begins in the headwaters in Candia and extends 8.6 miles through Raymond to the confluence with the Exeter River. The Dudley-Bloody Brook project area includes 8.7 miles on the Dudley Brook mainstem, 2.3 miles along Bloody Brook, and 4.5 miles on the Little River within the towns of Exeter and Brentwood. The study section for the Upper Exeter River is 18.8 miles, and includes the towns of Chester, Sandown, Danville, Raymond and Fremont. Located within the towns of Exeter and Brentwood, the Lower Exeter River study area includes 10.0 river miles.

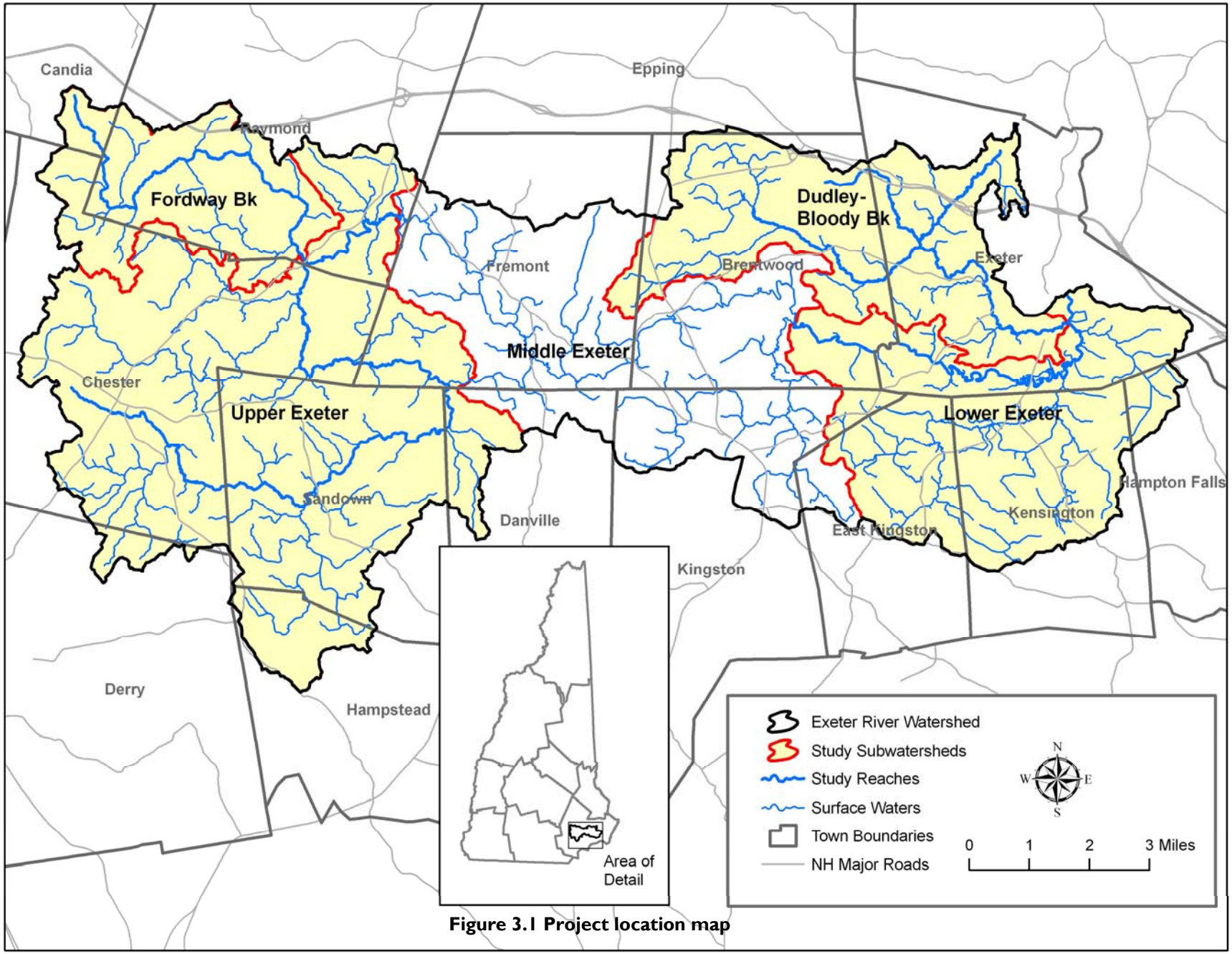

Figure 3.1 Project location map

3.2 Geologic Setting

Like much of the New Hampshire Seacoast, the underlying bedrock geology of the Exeter River watershed is comprised of a mixture of metamorphic rocks dating back to the Cambrian, Ordivician and Silurian geologic periods. The metamorphic bedrock consists primarily of schists, slates, and calcareous quartzites (Lyons et al., 1997). The surficial materials overlying the bedrock are dominated by deposits of sand, gravel, clay and silt left behind from the retreat of the most recent glaciers during the Holocene (beginning approximately 11,000 years before present).

The soil parent materials in the watershed are mixed but dominated by glacial tills (Table 3.2). Outwash materials, those transported down gradient by glacial meltwaters, are found in the vicinity of the Middle and Upper Exeter River corridor. Fine-grained marine and lacustrine deposits are abundant in the Lower Exeter River subwatershed as a result of the proximity to the estuarine and coastal deposition environments during the Holocene deglaciation. Organic deposits associated with large wetland complexes are abundant in the upper watershed. Alluvial deposits are concentrated along the Exeter River channel, and are most abundant in the lower watershed within the Town of Exeter. Small areas of unclassified soils and soils impacted by human land uses (anthropogenic) are scattered throughout the watershed, but represent a small fraction of the total area.

Table 3.2
Exeter River Parent Materials

Parent Material	Area (sqmi)	Percent
Alluvial Deposits	0.7	0.6%
Till	57.1	52.9%
Outwash	21.4	19.8%
Marine or Lacustrine	15.9	14.7%
Organic Material	10.2	9.5%
Anthropogenic	1.6	1.5%
Not Classified	1.0	0.9%
Totals:	**107.9**	**100.0%**

The differences in parent material between the study areas in the upper watershed (Upper Exeter River and Fordway Brook) and the lower watershed (Lower Exeter River and Dudley-Bloody Brook) explain many of the key differences in geomorphic stream types described in the Phase 1 and 2 assessments (Figure 3.2). The lower subwatersheds are strongly influenced by the expansive areas of marine and lacustrine deposits. Many of the stream channels in these subwatersheds are bound by cohesive clay soils that limit the rates of lateral channel migration. A majority of the channels in the lower subwatersheds have sand and silt stream beds, consistent with the mapped glaciomarine and glaciolacustrine deposits. In the upper watershed, the extensive organic deposits within the river corridor are associated with the large wetlands found along the channels in the Upper Exeter River

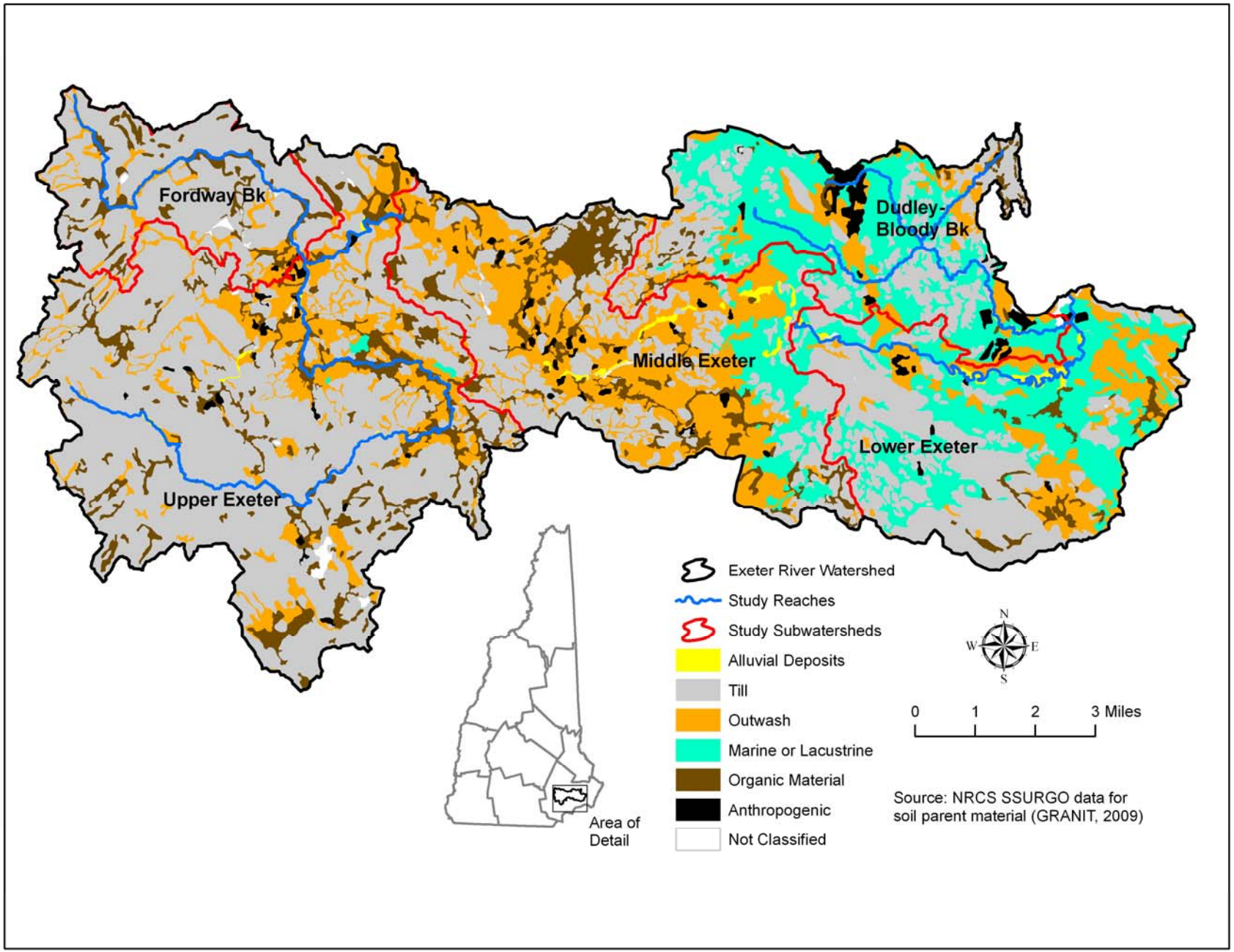

Figure 3.2 Exeter River Watershed soil parent material

and Fordway Brook. In general, the coarse-bottomed channels of the upper watershed are only found in areas where till and alluvial deposits are present. The coarser substrates associated with these parent materials have led to the formation of cobble and gravel-bottomed streams with broad or confined valley settings, depending on the local topographic relief.

3.3 Geomorphic Setting

The Exeter River Watershed was divided into 290 reaches for the Phase 1 assessment by NHGS (Table 3.3). Reach breaks were determined during Phase 1 based on changing geomorphic conditions such as valley confinement, valley slope, tributary influence and geologic materials. The four target subwatersheds: Fordway Brook, Upper Exeter River, Dudley-Bloody Brook and Lower Exeter River were selected for Phase 2 assessment. The nine non-target subwatersheds: Great Brook, Little River, Middle Exeter River, Phillips Pond, Spruce Swamp, The Cover, Towle Brook Wason Brook, and Wilson Brook were excluded from the Phase 2 assessment. Many of these subwatersheds contain a significant number of wetlands and impounded reaches. These reaches may benefit from future stream crossing and riparian buffer assessment.

Phase 2 Geomorphic Assessments were conducted on 53 of these reaches in four subwatersheds: Fordway Brook, Upper Exeter River, Dudley-Bloody Brook and Lower Exeter River. Many of these assessed reaches were further divided into segments during the Phase 2 investigation based on changes in channel conditions within a reach that were typically identified during field visits. A segment is distinct in one or more of the following parameters: degree of floodplain encroachment or channel alteration, grade control occurrence, channel dimensions, channel sinuosity and slope, riparian buffer and corridor conditions, and degree of flow regulation. The reach location and reference stream type maps included in sections 5, 6, 7 and 8 show the Phase 2 reaches and segments that were included in this study. Reach cross-reference tables have been prepared to serve as a location guide to the reader. The tables summarized reach names and locations relative to town boundaries and other landmarks (e.g. roads), and are included in Appendix A for each subwatershed.

Table 3.3
Stream Geomorphic Assessment Reach Summary for Exeter River Subwatersheds

Subwatershed	River Miles	Number of Reaches for Partial Phase 1 Assessment	Number of Reaches for Phase 2 Assessment	Number of Segments for Phase 2 Assessment
Dudley-Bloody Brook*	11.0	12	11	20
Fordway Brook*	8.6	14	14	26
Great Brook	35.3	59	0	0
Little River	21.7	32	0	0
Lower Exeter River Main Stem*	10.0	12	12	14
Middle Exeter River Tributaries	17.5	22	0	0
Middle Exeter River Main Stem	12.0	20	0	0
Phillips Pond	15.2	30	0	0

Table 3.3 Stream Geomorphic Assessment Reach Summary for Exeter River Subwatersheds				
Subwatershed	**River Miles**	**Number of Reaches for Partial Phase 1 Assessment**	**Number of Reaches for Phase 2 Assessment**	**Number of Segments for Phase 2 Assessment**
Spruce Swamp	4.2	3	0	0
The Cove	7.7	12	0	0
Towle Brook	14.4	26	0	0
Upper Exeter River Main Stem*	18.8	16	16	32
Wason Brook	7.4	10	0	0
Wilson Brook	12.0	22	0	0
Total	**195.8**	**290**	**53**	**92**
*** Exeter River Subwatersheds Included in this plan.**				

Reference stream types[2] are based on the valley type, geology and climate of a region and describe what the channel would look like in the absence of human-related changes. Reference stream typing was based on both the Rosgen (1996) and Montgomery and Buffington (1997) classification systems. Table 3.4 shows the typical characteristics used to determine reference stream types (VANR, 2007a).

Table 3.4 Reference Stream Type			
Stream Type	**Confinement**	**Valley Slope**	**Bed Form**
A	Narrowly Confined	Very steep > 6.5 %	Cascade
A	Confined	Very steep 4.0 - 6.5 %	Step-Pool
B	Confined or Semi- confined	Steep 3.0 – 4.0 %	Step-Pool
B	Confined, Semi-confined or Narrow	Moderate to Steep 2.0 – 3.0 %	Plane Bed
C or E	Unconfined (Narrow, Broad or Very Broad)	Moderate to Gentle <2.0 %	Riffle-Pool or Dune-Ripple
D	Unconfined (Narrow, Broad or Very Broad)	Moderate to Gentle <4.0 %	Braided Channel

[2] Additional information about reference stream typing can be found on the Vermont Agency of Natural Resources web page - http://www.anr.state.vt.us/dec/waterq/rivers/docs/assessmenthandbooks/rv_weblinkpgphase1.pdf

3.4 Hydrology

USGS Gaging Data

The United States Geological Survey (USGS) operates a real-time flow monitoring gage on the Exeter River at Haigh Road, near Brentwood, NH. This gage is located within the Middle Exeter Basin and has upslope drainage area of 63.5 square miles. The elevation of the gage is 60 feet above sea level and it is located in an area of coarse bottomed sediment. This gage was installed in 1996 and data collection began in June. Since then, the gage has been continuously monitoring the discharge at the site. The span of flow data records is 12 years (Figure 3.3). Provisional flow frequency and magnitude data developed by USGS employee Scott Olson (2008) was used for the return intervals observed (Table 3.5). The flow intensity predicted at each return interval (e.g. 2-year, 10-year, etc.) may be higher than what actually occurs. The discharge is likely to be skewed because the length of flow records is relatively short and because there have been three large flow events that have occurred within the last ten years. Each of these events exceeded the 100-year discharge, which could result in some error in the provisional regression used by Olson (2008).

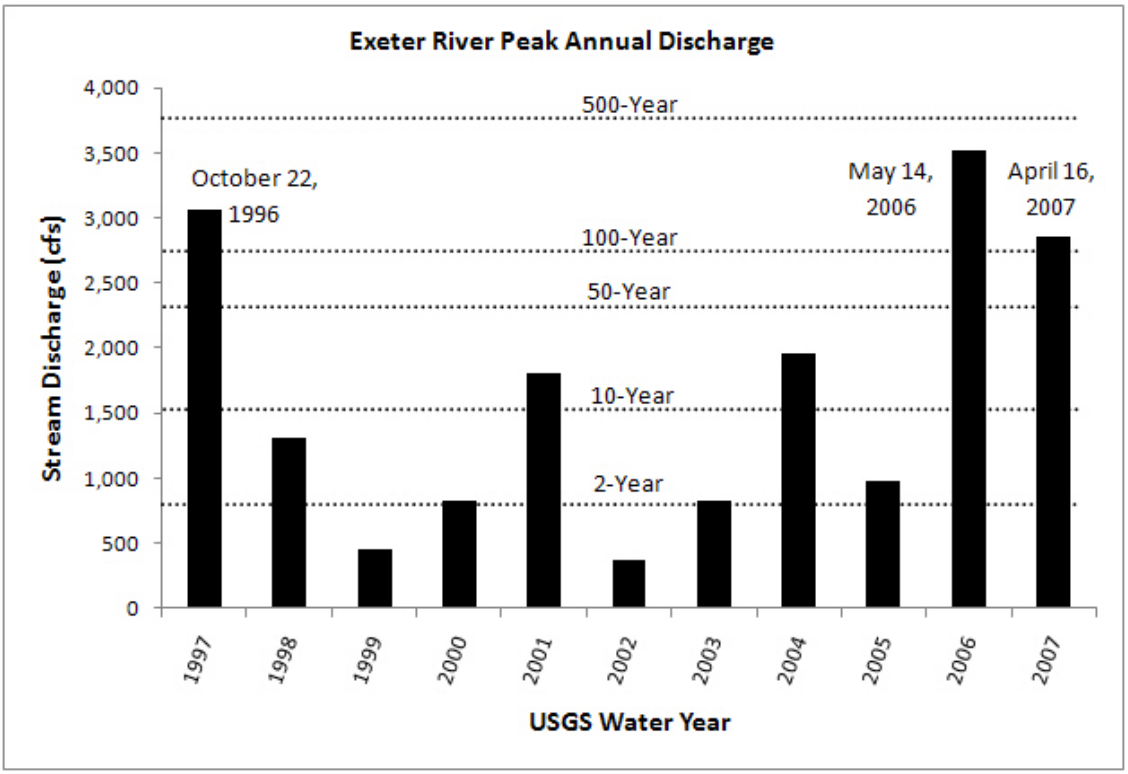

Figure 3.3 Annual peak discharges for USGS Gage # 1073587 at Exeter River, NH Estimated Flow-Frequency from Olson (2008)

Table 3.5
The frequency and magnitude for different discharge values for the Exeter River, NH

Return Frequency	Discharge (cfs)
2-Year	783
5-Year	1200
10-Year	1540
25-Year	1980
50-Year	2330
100-Year	2760
500-Year	3780

A second streamflow gage has been established on the Upper Exeter River at the Odell Road crossing in the Town of Sandown. The station started recording discharge data in September of 2008; therefore no long term flow data are available for this part of the watershed. The station is part of a 2 year streamflow monitoring network expansion project for 15 new gages across New Hampshire. The gage is being operated cooperatively by NHDES and the USGS.

Dudley Brook has also been gaged by the USGS upstream of the Route 111A crossing; however, the gage is not currently in commission. The time period of operation was from 1963 to 1985, but peak flow data was estimated during large floods in the Seacoast area in 2006 and 2007 (Figure 3.4). Since this gage operated for over 20 years, the derived frequency and magnitude data is more reliable (Table 3.6; Olson, 2007). For the Dudley Brook subwatershed, half of the annual peak flows are under the 2-year flow value of 167 cfs, and half represent flows of higher magnitude.

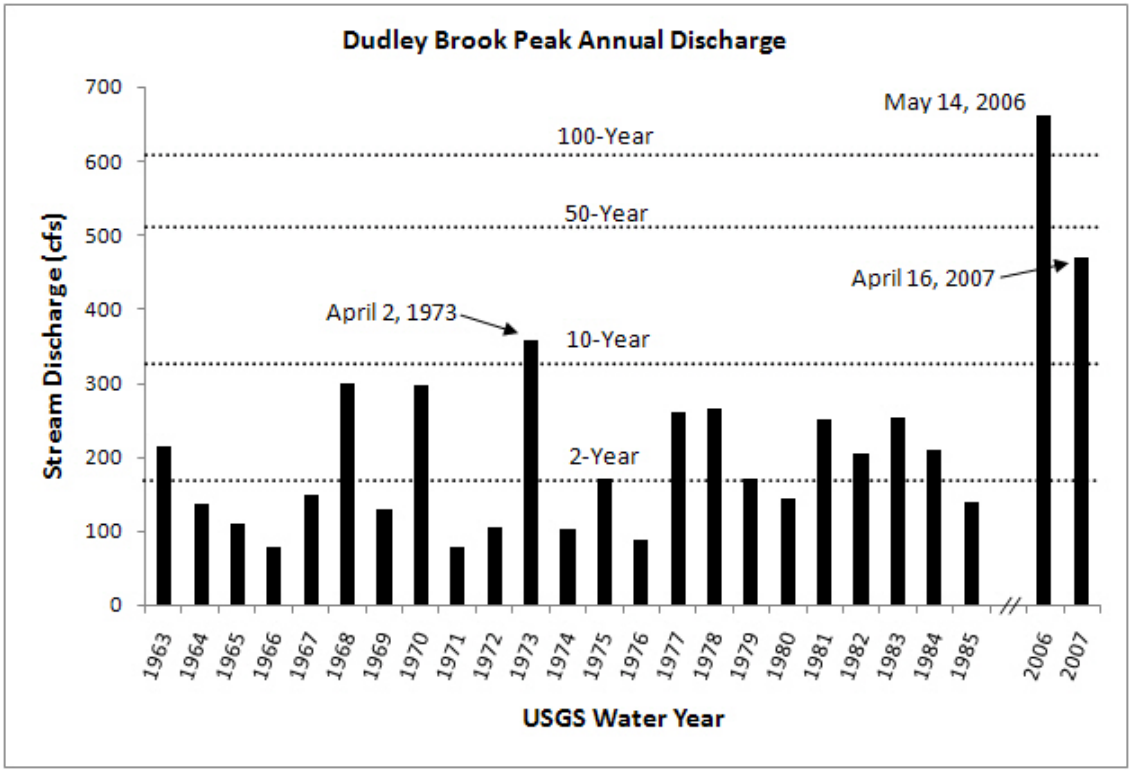

Figure 3.4 Annual peak discharges for USGS Gage # 01073600 at Dudley Brook, NH. Estimated Flow-Frequency from Olson (2007)

Table 3.6 The frequency and magnitude for different discharge values for Dudley Brook, NH	
Return Frequency	**Discharge (cfs)**
2-Year	167
5-Year	256
10-Year	326
25-Year	426
50-Year	511
100-Year	604
500-Year	859

Recent Flood Events

In October of 1996, the remnants of Hurricane Lili passed over coastal New England and produced a very large rainfall event that resulted in flooding throughout New Hampshire. A peak discharge of 3,060 cfs was measured on the Exeter River at Haigh Road, corresponding to a return interval of greater than the 100 year event. In addition, two floods of very large magnitude occurred during 2006 and 2007. Peak discharge values for the Exeter River and Dudley Brook gages were summarized by USGS in two reports (Olson, 2007; Flynn, 2008). These two events are summarized below.

The 2006 flood event occurred May 13 to 17, and resulted in severe damage to properties bordering streams and rivers. Precipitation records from that period indicate that as much as 14 inches of rainfall occurred during the storm. A federal disaster area was declared for seven counties in New Hampshire, including Rockingham County. The USGS provided a detailed review of peak discharge data at 65 stream gages within the affected area, including the Exeter River and Dudley Brook gages. The peak discharge at the Haigh Road gage was 3,450 cfs, the highest discharge recorded for the site to date. The magnitude of this discharge corresponds to a return interval of greater than the 500 year event. Similarly, the peak discharge at the Dudley Brook gage was 660 cfs, also the highest discharge recorded for the site to date. The magnitude of this discharge for Dudley Brook corresponds to a return interval of greater than the 100 year event.

The 2007 spring flooding event occurred April 16 to 18, also resulting in severe flooding and damage to properties bordering streams and rivers throughout central and southern New Hampshire. Precipitation records from the flood indicate that up to 7 inches of rainfall occurred during the storm. A federal disaster area was declared for six counties in New Hampshire, including Rockingham County. The USGS provided a detailed review of peak discharge data at 57 stream gages within the affected area, including the Exeter River and Dudley Brook gages. The peak discharge at the Haigh Road gage was 2,840 cfs, corresponding to a return interval of greater than the 100 year event. The peak discharge at the Dudley Brook gage was 470 cfs, corresponding to a flow frequency of greater than the 25 year event.

3.5 Ecological Setting

The Exeter River watershed is a protected river under the NH River Management and Protection Program (RMPP) (ERLAC, http://www.exeterriver.org/plan.html). The protection plan identifies management goals and recommends actions that may be taken to protect the valuable resources of the river. The Exeter River management plan is available through the NHDES.

The Exeter River watershed supports a variety of landscapes including wetlands, forests, ponds, streams, and farmland settings. These different environments provide habitat for many species of flora and fauna. The watershed falls within the Gulf of Maine Coastal Plain biophysical region which is dominated by hardwood and transitional forests. Large tracts of undeveloped land provide important habitat for moose, black bear, and forest dwelling birds. The watershed also provides habitat for several species of concern in New Hampshire including Blanding's turtles, New England cottontail, and the blue spotted salamander. The Exeter River is both a cold and warm water fishery that provides habitat for over 17 resident species including brook trout, small and large mouth bass, yellow perch, and chain pickerel. The river also serves as a spawning area for alewife and blueback herring (ERLAC, http://www.exeterriver.org/wildlife.html).

Beavers and their dams are common in the Lower Exeter River subwatershed in the tributary subwatersheds where low-gradient channels and clay-lined banks are found. The presence of beavers in many of the low-gradient reaches in the Dudley-Bloody Brook study

area made the assessment of physical channel conditions difficult. Some reaches were not assessed with the full RGA and RHA protocols due to beaver influences. Through dam building and tree removal, beavers dramatically influence the hydro-geomorphic characteristics of streams. However, these influences are often temporary and part of natural processes that create habitat diversity in the riparian corridor. Beavers are considered a "keystone" species by many natural scientists because of the habitat they create in riparian areas. In addition, beavers provide many benefits to humans in urban and suburban watersheds, including: decreased risk of downstream flooding, recharge of groundwater aquifers, attenuation of sediment and other pollutants, decreased bank erosion, and the addition of instream wood that is essential to healthy fish habitat.

The Great Bay Resource Compendium (The Nature Conservancy, 2006) is the result of an integrated ecosystem approach to identify multi-habitat restoration opportunities extending from upland freshwater fish habitat in the Exeter River down to the bottom of Great Bay. Restoration targets include oysters and softshell clams, salt marshes, eelgrass beds and seven diadromous fish species. The Exeter River ecosystem is not suited for the restoration of oysters, clams, salt marsh and eelgrass, however, the River does provide habitat for the restoration of diadromous fish species such as the alewife, blueback herring, American shad, rainbow smelt, Atlantic salmon, American eel, and sea lamprey.

NH Fish and Game has been stocking adult shad in the Exeter River since 1982 with the goal of restoring a self-sustaining run. The fish are released above the Pickpocket Dam in Brentwood. The Compendium finds that 111 tributary miles of the 328 total tributary miles in the Exeter/Squamscott River are blocked and preventing fish passage. The Great Dam in Exeter and Pickpocket Dam in Brentwood have fishways. A ledge located above the Pickpocket Dam below Route 125 in Brentwood serves as a natural barrier to passage of all species other than lamprey and American eel. The Compendium does not identify specific culverts blocking fish passages but notes that culverts in the watershed are contributing to a decrease in fish passage in the Exeter River. Fish ladders at Pickpocket Dam in Brentwood and Great Dam in Exeter allow for anadromous fish (saltwater fish that enter freshwater to spawn and then return to the saltwater) to reach upstream spawning and nursery habitat (ERLAC, http://www.exeterriver.org/wildlife.html).

The Land Conservation Plan for New Hampshire's Coastal Watersheds (The Nature Conservancy et. al 2006) identifies Conservation Focus Areas (see Figure 3.5). These areas are considered to be of exceptional significance for water quality and living resources. The goal of this plan is to focus conservation efforts on those lands and waters that are most important for conserving living resources – native plants, animals, and natural communities – and water quality in the coastal watersheds. Forests and wetlands, freshwater aquatic habitats and fisheries, coastal and estuarine resources, and rare species and exemplary natural communities were mapped in the Plan.

There are ten Conservation Focus Areas in the Exeter River watershed:

1. Fordway Brook Headwaters – 940 acres in Candia, Chester and Raymond
2. Lower Fordway Brook – 1,680 acres in Raymond and Chester

3. Upper Exeter River – 3,010 acres Chester, Danville, Fremont and Sandown
4. Spruce Swamp – 1,850 acres in Brentwood and Fremont
5. Exeter River – 620 acres in Brentwood and Exeter
6. Dogtown Swamp – 160 acres in Brentwood and Exeter
7. Bloody and Dudley Brooks – 550 acres in Exeter and Brentwood
8. Upper Great Brook – 540 acres in East Kingston and Kensington
9. Muddy Pond – 160 acres in Kensington
10. Great Meadows – 1,440 acres in Exeter and Kensington

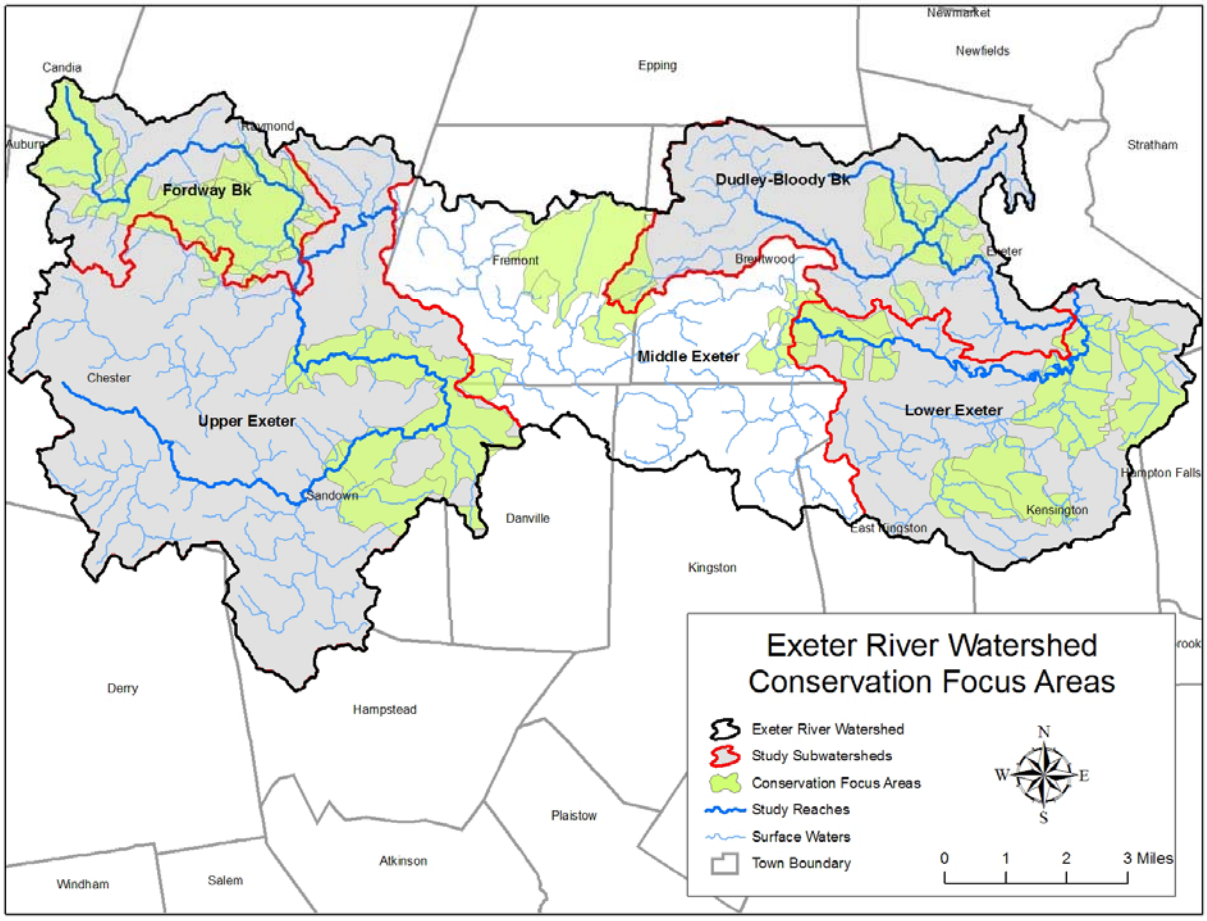

Figure 3.5 Conservation focus areas in the Exeter River Watershed

4 METHODS

This study of the Exeter River watershed utilized state-of-the-art Stream Geomorphic Assessment (SGA) protocols developed by the Vermont Department of Environmental Conservation (VTDEC). The SGA protocols are intended to be used by resource managers, community watershed groups, municipalities and others to identify how changes to land use affect hydro-geomorphic processes at the landscape and reach scale, and how these changes

alter the physical structure and biological habitat of rivers. 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.

NHGS began the Phase 1 assessment of the Exeter River watershed in late spring/early summer 2008. The fieldwork for the Phase 2 assessment was completed in summer 2008 by BCE/FEA and other project partners. These field data were used to develop river restoration and protection projects presented in this report. Phase 3 surveys for active restoration projects, included in this report, may be required at some point in the near future for project design and permitting. A summary of the Phase 1 and 2 methodologies is provided in the following sections.

4.1 Phase 1 Methodology

The Phase 1 assessment followed procedures specified in the Vermont Stream Geomorphic Assessment Handbook Phase 1 (Vermont Agency of Natural Resources 2007a), and used version 4.59 of the Stream Geomorphic Assessment Tool (SGAT) GIS extension. Phase 1, the remote sensing phase, involves the collection of data from topographic maps and aerial photographs, from existing studies, and from very limited field studies, called "windshield surveys." The Phase 1 assessment provides an overview of the general physical nature of the watershed. As part of the Phase 1 study, stream reaches are determined based on geomorphic characteristics such as: valley confinement, valley slope, geologic materials, and tributary influence.

4.2 Phase 2 Methodology

The Phase 2 assessment was conducted by BCE and FEA following procedures specified in the Vermont Stream Geomorphic Assessment (SGA) Handbook Phase 2 (Vermont Agency of Natural Resources 2007b), and used version 4.59 of the Stream Geomorphic Assessment Tool (SGAT) GIS extension to index impacts within each reach. The geomorphic condition for each Phase 2 reach is determined using the rapid geomorphic assessment (RGA) protocol, and is based on the degree of departure of the channel from its reference stream type (Vermont Agency of Natural Resources, 2007b). The study also used a new protocol developed by the Vermont Agency of Natural Resources (2008a) for conducting a rapid habitat assessment (RHA).

Reaches determined during Phase 1 were broken up further into segments for the Phase 2 geomorphic assessment as necessary. Topographic maps and orthophotos were used as a first cut in delineating segment breaks. The project team walked the entire length of the reach to confirm preliminary segment breaks determined when reviewing topographic maps and orthophotos. Attributes that were considered when determining segment breaks include: grade controls, changes in channel dimensions, changes in dominant bed material,

slope, entrenchment or sinuosity, signs of planform changes, presence of beaver dams, and evidence of aggradation and degradation. The bankfull width and depth were measured occasionally along the reach to track changes in bankfull dimensions. Once segment breaks were determined, the Phase 2 field forms were completed accordingly.

The Project Team walked the entire length of each reach to the extent that conditions were amenable for walking and landowners had granted permission. Valley walls delineated by NHGS during the Phase 1 assessment were verified in the field. Human caused changes in valley width due to permanent high embankments that serve as artificial valley walls were also mapped on field sketches with reference to topographic maps and/or orthophotographs. The field verified valley walls were used to evaluate Phase 2 confinement. Adjacent terraces and valley walls were evaluated in terms of their proximity to the channel as outlined in the most current version of the Vermont Phase 2 SGA Handbook. The location, total height and height above water surface were recorded for channel spanning grade controls, both natural and human constructed.

Channel dimensions and bed substrate composition were measured at one to three representative locations within each segment. The channel dimensions and substrate composition were recorded on the Cross-section Worksheet and summarized on the Rapid Stream Assessment Field Notes form under Step 2. Stream type was evaluated based on the channel dimension data, bed substrate composition results, and confirmed channel slope. Dominant bed forms were determined based on the criteria set forth in the most recent version of the Vermont Phase 2 SGA Handbook.

Stream banks were evaluated in terms of their typical slope and dominant texture as outlined in the Vermont Phase 2 SGA Handbook. Areas of bank erosion, mass failures, and gullies were mapped and pertinent information regarding the height and length of such features was recorded. Areas lacking adequate riparian buffers (<25 feet) were mapped and notes were made about the types of vegetation comprising existing riparian buffers. River corridor encroachments including roads, railroads, improved paths, and development were mapped according to their locations, and the height of these encroachments was recorded. Notes were also taken concerning river corridor land use activities.

The locations of springs, seeps, small tributaries, adjacent wetlands, debris jams, beaver dams and channel constrictions were recorded and evaluated in terms of how they may be affecting channel flows. Locations of stormwater inputs from urban runoff, agricultural drainage and road ditching were noted to determine the extent of increased flow status during a storm event. Similarly, locations of flow regulations and water withdrawals were mapped to evaluate potential decreases in channel flows.

Depositional features were mapped to assess the sediment transport regime and storage capacity of the segment. Channel migration features were also mapped in order to determine the amount of channel planform adjustment the segment was undergoing. Sections of the stream where the channel does not appear to be following the natural path of the river and may have been straightened were noted, along with locations where material has been removed from the channel in order to assess the extent to which stream

power and morphology have been altered. Steep riffles and headcuts were mapped and used as indicators of active geomorphic processes.

RHA and RGA field forms were completed for the Phase 2 reaches. The appropriate RHA and RGA forms were selected based on segment characteristics and scored according to the data collected from the field assessment. A segment score and corresponding condition were determined for both the RHA and the RGA. Additionally for the RGA, major geomorphic processes were identified, the stage of channel evolution was determined, and a stream sensitivity rating was assigned.

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

For segments where the Vermont SGA protocols were not applicable, such as wetlands and bedrock gorges, general notes about geomorphic stability and quality were taken. Stream channels that were highly influenced by wetlands and could not be completely assessed according to the protocols were assigned a stream type and condition based on the field team's best judgment and observed phase 2 field conditions.

To assure a high level of confidence in the Phase 2 SGA data, strict quality assurance/quality control (QA/QC) procedures were followed by BCE and FEA. These procedures involved a thorough in-house review of all data, which took place during October and November 2008. The Project Team conducted the assessment according to the approved Quality Assurance Project Plan (QAPP) and completed the Quality Assurances procedures specified in the Phase 2 handbook.

4.3 Bridge and Culvert Assessment

The Project Team conducted bridge and culvert surveys on all private and public bridges and culverts within the selected Phase 2 reaches. The Bridge and Culvert Assessment and Survey Protocols specified in Appendix G of the Vermont Stream Geomorphic Assessment Handbook (Vermont Agency of Natural Resources, 2007d) were followed. Latitude and longitude at each of the structures was determined using a Garmin Etrex Vista GPS unit. The assessment included photo documentation of the inlet, outlet, upstream, and downstream of each of the structures.

The Vermont Culvert Geomorphic Screening tool (Milone and MacBroom, Inc., 2008a) and the Vermont Culvert Aquatic Organism Passage Screening Tool (Milone and MacBroom, Inc, 2008b) were used to identify culverts within the Exeter River watershed that are highest priority for replacement/retrofit due to geomorphic incompatibility and/or for being potential barriers to movement and migration of aquatic organisms. In addition, rainfall-runoff data modeling was undertaken for bridges and culverts determined to be fully incompatible or mostly incompatible or were known to be of concern due to past flooding. For these structures, the Natural Resources Conservation Service TR20 hydrologic model and methods (NRCS, 1992) were utilized for calculating peak runoff rates and routing to the

structures for 24 hour storms with recurrence intervals of 25 and 50 years. The inclusion of rainfall-runoff modeling to determine structure capacity to accommodate large runoff events further ensures that the prioritization of structures for replacement/retrofit is based on multiple sources of scientifically-defensible data.

4.4 River Corridor Plan

The Vermont Agency of Natural Resources River Corridor Planning Guide (Vermont Agency of Natural Resources, 2007c) were followed to generate a series of stressor maps. These maps were created using indexed data from the Phase 1 and Phase 2 Stream Geomorphic Assessments along with existing data available from the New Hampshire Geographically Referenced Analysis and Information Transfer System (GRANIT).

4.4.1 Stressor Maps

Stressor, departure and sensitivity maps are presented here as a means of displaying the effects of all significant physical processes occurring within the Exeter 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 channel adjustments within the watershed. This is helpful in developing and prioritizing potential protection and restoration projects.

Successful river corridor restoration and protection projects 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 exist, long term restoration is not possible unless the increased load is accommodated within the reach or is attenuated upstream (Vermont Agency of Natural Resources, 2007c).

Within a reach, the principles of stream equilibrium dictate that stream power and sediment will tend to distribute evenly over time (Leopold, 1994). Changes or modifications to watershed inputs and hydraulic geometry create disequilibrium and lead to an uneven distribution of power and sediment. Large channel adjustments observed as dramatic erosion and deposition may be the result of this uneven distribution and may continue over the long term.

The hydrologic regime is the timing, volume, and duration of flow events throughout the year and over time and is characterized by the input and manipulation of water at the watershed scale. A Hydrologic Regime Stressors Map has been prepared for each subwatershed to summarize the land uses influencing watershed hydrology. When the hydrologic regime has been significantly changed, 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 effect of urban and cropland development is increasing peak discharges and runoff by reducing infiltration and travel time (United States Department of Agriculture 1986). Loss of significant wetland reduces the hydrologic attenuation of surface runoff at the reach and watershed scale. Wetland loss was mapped as the area where hydric soils (Natural Resources Conservation Service mapping) and National Wetland Inventory (NWI) mapped areas intersected with urban or agricultural land uses in the watershed, with the remaining areas assumed to be intact wetland.

The sediment regime is the quantity, size, transport, sorting and distribution of sediments. The sediment regime may be influenced by the proximity of sediment sources, the hydrologic regime, and the specific morphology of the valley, floodplain, and stream. A Sediment Load Indicators Map has been prepared for each subwatershed to show the distribution of sediment load indicators at the watershed scale. Bank erosion and mass failures contribute to sediment inputs along the Exeter River. Bank erosion is defined as "an area of raw and barren soil where the vegetation does not have the ability to hold the soil and/or the soil has slumped or fallen into the channel". Mass failures can occur when "a perennial stream erodes into or undercuts a high erodible landform, such as glacial lacustrine terrace" (Vermont Agency of Natural Resources, 2007b).

Many rivers throughout New England have been historically manipulated and straightened to maintain an unnaturally steep slope in a state of sediment transport, allowing for a short term sense of security from flooding and subsequent encroachment of infrastructure in the floodplain. In addition to historic alterations to channel slope in alluvial rivers, the lowering of stream beds (e.g. dredging) and the disconnection of floodplains (e.g. berming) has resulted in an increase in channel depth. Channel depths have typically been increased through the encroachment on the floodplain by roads and railroads and subsequent filling and armoring required to construct and maintain this infrastructure. Increases in impervious cover have also led to the deepening and eventual widening of channels throughout urbanized areas of New England. A channel Slope and Depth Modifiers Map has been prepared for each subwatershed to summarize human alterations to channel and floodplain geometry.

Riparian buffers provide many benefits. Some of these benefits are protecting and enhancing water quality, providing fish and wildlife habitat, providing streamside shading, and providing root structure to prevent bank erosion. Rivers which lack a high quality riparian buffer are at a significantly higher risk of experiencing high rates of lateral erosion. Many stream banks are stabilized with rip rap or hard bank armoring where they are adjacent to human constructed infrastructure. A Riparian and Boundary Condition Map has been prepared for each subwatershed to summarize human alterations to these areas.

4.4.2 Departure Analysis

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, 2007c).

Both the "D" stage and "F" stage channel evolution model (Vermont Agency of Natural Resources, 2004) are helpful for explaining the channel adjustment processes underway in the Exeter River watershed. The "F" stage channel evolution model is used to understand the process that occurs when a stream degrades (incises). The common stages of the "F" channel evolution stage, as depicted in Figure 4.1 include:

- A pre-disturbance period
- Incision – channel degradation
- Aggradation and channel widening
- The gradual formation of a stable channel with access to its floodplain at a lower elevation

The more dominant adjustment process for the "D" stage channel evolution is aggradation, widening and planform change.

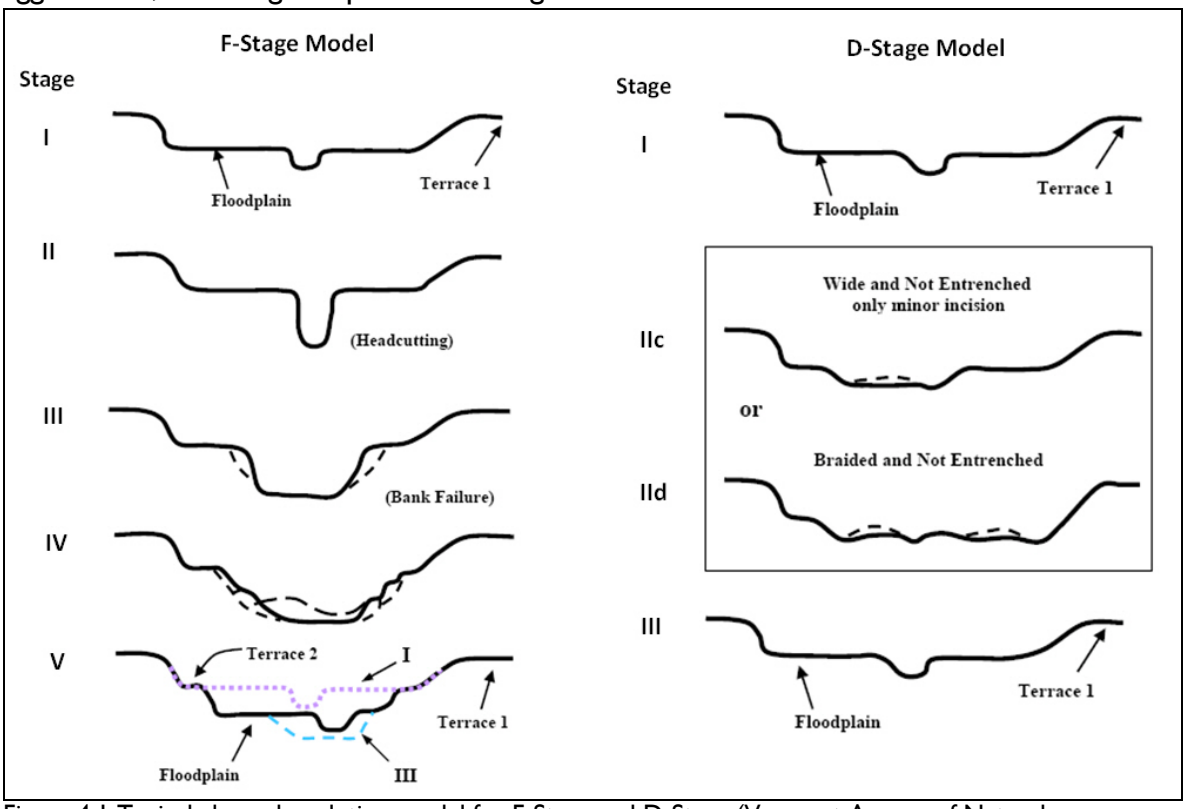

Figure 4.1 Typical channel evolution model for F-Stage and D-Stage (Vermont Agency of Natural Resources, 2007b)

The bed erosion that occurs when a meandering river is straightened in its valley is a problem that translates to other sections of the stream. Localized incision will travel upstream and into tributaries eroding sediments from otherwise stable streambeds. These bed sediments will move into and clog reaches downstream leading to lateral scour and erosion of the streambanks. Channel evolution processes may take decades to play out. Even landowners that have maintained wooded areas along their stream and riverbanks may have experienced eroding banks as stream channel slopes adjust to match the valley slopes. It is difficult for streams to attain a new equilibrium where the placement of roads and other infrastructure has resulted in little or no valley space for the stream to access or to create a floodplain.

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. Sediment Regime Maps have been prepared for each subwatershed to show departure from reference conditions due to human alterations.

4.4.3 Sensitivity Analysis

Sensitivity ratings were assigned using the most current draft (September 25, 2008) of "River Corridor Protection: A Technical Guide" prepared by the Vermont River Management Program (Vermont Agency of Natural Resources, 2008c). Stream sensitivity refers to the likelihood that a stream will respond to a watershed or local disturbance or stressor, such as floodplain encroachment, channel straightening or armoring, changes in sediment or flow inputs, and/or disturbance of riparian vegetation (Vermont Agency of Natural Resources, 2007b). Assigning a sensitivity rating to a stream is done with the assumption that some streams, due to their setting and location within the watershed, are more likely to be in an episodic, rapid, and/or measurable state of change or adjustment. A stream's inherent sensitivity may be heightened when human activities alter the characteristics that influence a stream's natural adjustment rate including: boundary conditions; sediment and flow regimes; and the degree of confinement within the valley. Streams that are currently in adjustment, especially those undergoing degradation or aggradation, may become acutely sensitive (Vermont Agency of Natural Resources, 2007b).

Flow regime and floodplain constrictions affect the sensitivity of rivers and streams. 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 resulting in erosive velocities within the channel.

4.4.4 FEH Zones

Flash flooding represents the most frequent disaster type in New England and typically results in the greatest magnitude of damage suffered by private property and public infrastructure. While inundation-related flood loss is a significant component of flood disasters, the predominant mode of damage during floods is associated with the dynamic, and oftentimes catastrophic, physical adjustment of stream channel dimensions and location during storm events due to bed and bank erosion, debris and ice jams, structural failures, flow diversion, or flow modification by man-made structures. These channel adjustments and their devastating consequences have frequently been documented wherein such adjustments are related to historic channel management activities, floodplain encroachments, adjacent land use practices and/or changes to watershed hydrology associated with land use and drainage.

The purpose of defining Fluvial Erosion Hazard Zones is to prevent increases in fluvial erosion resulting from uncontrolled development in identified fluvial erosion hazard areas; minimize property loss and damage due to fluvial erosion; prohibit land uses and development in fluvial erosion hazard areas that pose a danger to health and safety; and discourage the development of property that is unsuited for the intended purposes due to fluvial erosion hazards.

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, defined through VTANR Stream Geomorphic Assessment (2007b), 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. Additional information regarding Fluvial Erosion Hazard Zones is available on the Vermont River Management website (http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_floodhazard.htm) in the Municipal Guide to Fluvial Erosion Hazard Mitigation (Vermont Agency of Natural Resources, 2008b). A model fluvial erosion hazard overlay district is provided at the end of the Municipal Guide to provide local municipalities with a tool to minimize human/river conflicts and limit losses caused by fluvial erosion.

4.5 Project Identification

Site specific projects were identified using the criteria outlined by the VTANR in Chapter 6 Preliminary Project Identification and Prioritization (Vermont Agency of Natural Resources, 2007c). This planning guide is intended to aid in the development of projects that protect and restore river equilibrium.

The departure and sensitivity analyses presented in this report provide beneficial background for selecting potential projects that will effectively help the channel return to equilibrium conditions by assessing limiting factors and identifying underlying causes of channel instability. The stream reaches evaluated in this study present a variety of planning and management strategies which can be classified under one of the following categories: Active Geomorphic Restoration, Passive Geomorphic Restoration, and Conservation.

Active Geomorphic Restoration implies the management of rivers 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.

Conservation is an option to consider when stream conditions are generally good and nearing a state of dynamic equilibrium. Typically, conservation is applied to minimally disturbed stream reaches where river structure and function and vegetation associations are relatively intact.

5.0 FORDWAY BROOK RESULTS

5.1 Fordway Brook Background Information

Fordway Brook drains from approximately 560 feet above sea level in the headwaters and flows in a southeasterly direction and meets the upper Exeter River just south of the Route 102 (Chester Road) crossing in the Town of Raymond at an elevation of approximately 160 feet above sea level. Fordway Brook generally flows through a very gentle gradient valley with numerous wetlands. Except for reaches FW03 (located adjacent to Aggregate Industries), FW07 (located below Lane Road crossing), FW09 (located upstream and downstream of the Old Bye Road crossing), and reaches FW-13 and FW14 in the headwaters, all reaches assessed for Phase 2 on Fordway Brook have a valley slope of less than 1percent as summarized in Table 5.1.

Table 5.1: Geomorphic Setting of Assessed Reaches

Reach ID	Reference Stream Type	Confinement Type	Valley Slope (%)	Bed Form
FW01	C/Wetland	Broad	0.13	Riffle-Pool

Table 5.1: Geomorphic Setting of Assessed Reaches				
Reach ID	**Reference Stream Type**	**Confinement Type**	**Valley Slope (%)**	**Bed Form**
FW02	Wetland	NA	0.20	NA
FW03	Cb	Very Broad	2.94	Riffle-Pool
FW04	Wetland	NA	0.07	NA
FW05	Wetland/Pond	NA	0.12	NA
FW06	Wetland	NA	0.17	NA
FW07	C/Cb/Bc	Broad	1.59	Riffle-Pool
FW08	Wetland	NA	0.39	NA
FW09	C	Broad	1.65	Riffle-Pool
FW10	C/Wetland/E	Very Broad	0.58	Riffle-Pool Dune-ripple
FW11	Wetland/C	Very Broad	0.54	Plane Bed
FW12	C/Wetland	Very Broad	0.98	Riffle-Pool
FW13	Wetland	NA	1.17	NA
FW14	E/Wetland/B	Narrow	4.17	Riffle-Pool

The Fordway Brook study section of 8.44 river miles was broken into fourteen reaches by the NHGS. Approximately 70 percent of the length of the Fordway Brook study section is wetland. For the remaining study section that is stream channel, the predominant reference stream type using the Rosgen (1996) classification system is C or E. A few of the reaches contained short segments that have higher slopes and were more entrenched, making these sections B stream types by reference.

5.2 Fordway Brook Phase 2 Results

As part of the Phase 2 assessment, the Fordway Brook reaches were broken into 26 segments based on field observations. The reference stream type for each segment is included in Figure 5.1. Thirteen of the 26 segments are wetland by reference. A discussion of each reach on Fordway Brook from the confluence of the Upper Exeter River to the headwaters is provided below.

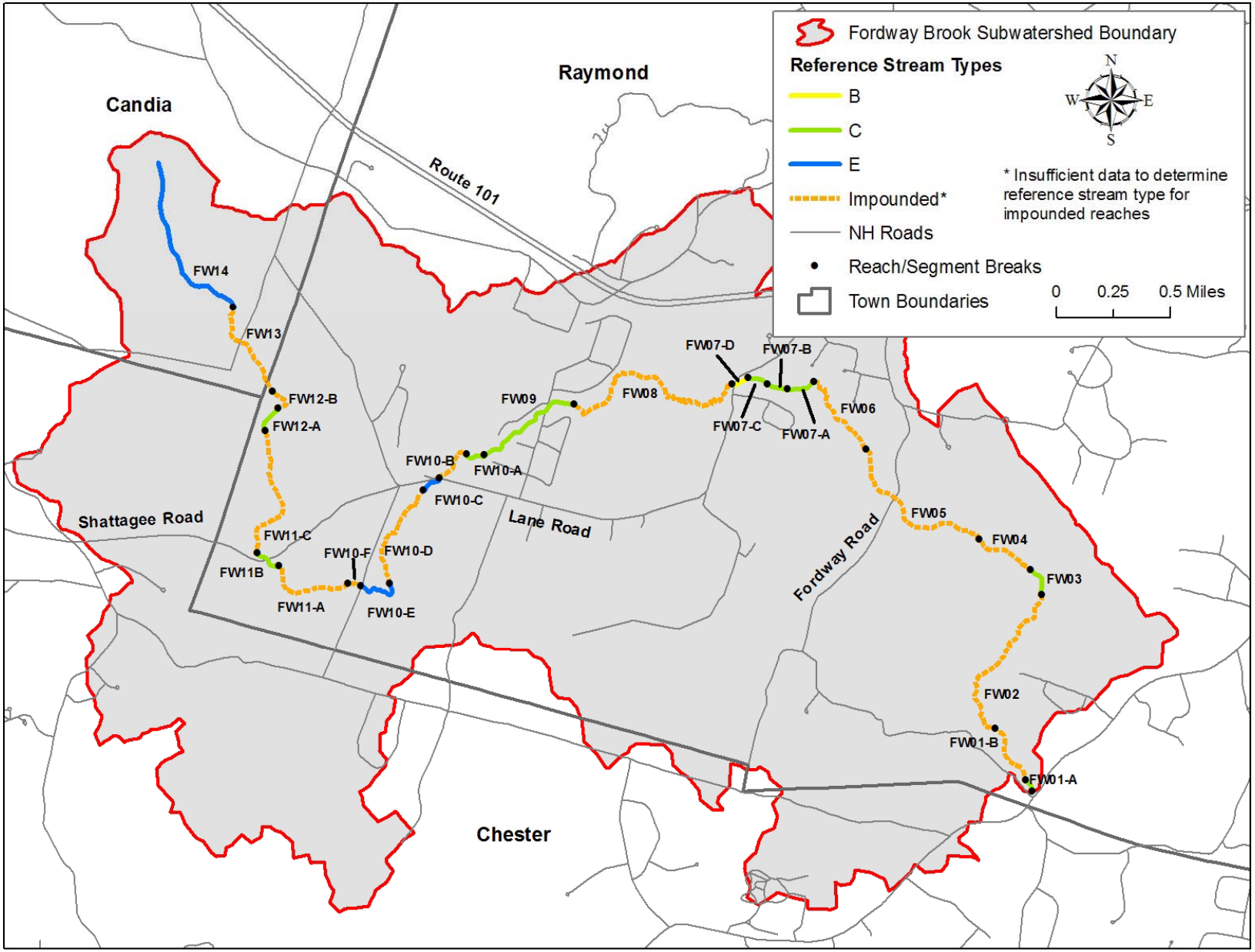

Figure 5.1 Fordway Brook reach/segment locations and reference stream types

Town of Raymond

Reach FW01

Reach FW01 begins at the confluence of the Fordway Brook and the Exeter River. The reach was split into two segments to account for the change in planform and slope and channel dimensions between the lower 305 foot segment (FW01-A) and the wetland in segment FW01-B.

Segment FW01-A is highly influenced by the Upper Exeter River and the wetland at the upper end of the segment. The dam layer from GRANIT shows a dam (Fordway Brook dam), located just upstream from the confluence. There are few remnants of the dam. The valley confinement type is narrow. There is a minor human caused change in valley width in this segment from development (a garage) on the east bank (Figure 5.2). A berm at the lower end of the segment was likely placed to protect Chester Road.

The riparian corridor on the east side is residential, while the west side is primarily forest with some residential land use. The buffer width is a reflection of the riparian corridor with little buffer (0-25 feet) on the east bank. Japanese knotweed, an invasive species, was noted on the near bank on the east side of the channel. Both springs and seeps and adjacent wetlands were present. FW01-A is a palustrine wetland that is seasonally flooded and is dominated by a broad-leaved deciduous scrub-shrub community. The aquatic habitat in segment FW01-A was difficult to assess due to the segment being very short in length. There were two short riffles in the segment and a small pool. No refuge areas or undercut banks were observed.

The bridge span at the lower end of the segment FW01-A is much narrower than the bankfull channel width with a bankfull width of only 36 percent. The Chester Road Bridge is both a channel and floodprone constriction. Deposition and scour are problems identified above the bridge.

FW01-B is 1535 feet in length. The majority of this segment is classified by the NWI as a palustrine wetland with an unconsolidated bottom that is permanently flooded (Figure 5.3). FW01-B appeared to be in reference condition with a dominant buffer width of well over 150 feet. A white pine, birch and maple forested community makes up the riparian corridor. Dogwood and arrowwood are common wetland species. Two beaver dams were noted.

Figure 5.2 River corridor encroachment near mouth of Fordway Brook

Figure 5.3 Wetland adjacent to Old County Road in Raymond

Reach FW02

Reach FW02 is 4,166 feet in length and is seasonally flooded. This second reach on Fordway Brook is a palustrine wetland with persistent emergent vegetation (Figure 5.4). The upper half of the reach is classified by the NWI as scrub-shrub that has been created or modified by beaver (Figure 5.5). Alder is the dominant vegetation in the scrub-shrub wetland. The wetland is in reference condition with buffer widths of greater than 150 feet. The upper portion of reach FW02 is within a NHDES conservation easement, which includes 74 acres. The NHDES conservation easement contains a total of 225 acres and is made up of two tracts of land. The second tract of land is within reaches FW03, FW04 and FW05.

Figure 5.4 Lower end of FW02 with beaver den

Figure 5.5 Scrub-shrub wetland in FW02

Reach FW03

The third reach on Fordway Brook is just over 700 feet in length and starts above the palustrine wetland in FW02. The upper end of the reach begins at an old dam that is the reach break between FW03 and FW04 (Figure 5.6). FW03 is a C stream type with an average channel slope of just under 3 percent. The reach is cobble dominated and generally has a riffle-pool bedform. The upper end of the reach appeared to be more plane bed and had a slightly higher gradient.

Figure 5.6 Old dam at upper end of FW03 near Aggragate Industries

Reach FW03 is located in the woods to the west of the development at Aggregate Industries. Approximately three-quarters of the river corridor of FW03 is included within a DES conservation easement. This tract of conserved land is 151 acres and extends from the lower part of FW03 up through portions of FW05.

As shown in Figure 5.7, the reach was not incised and had good floodplain access. A minor human caused change in valley width was noted on the east side due to development. The RGA resulted in a score of good with minor aggradation and widening listed as the primary channel adjustment processes. The reach is currently stable and appears to have adjusted to two old abutments and the dam at the top of the reach (Figure 5.8). For this reason, the removal of these structures is not recommended.

Figure 5.7 Section of Fordway Brook upstream of Aggragate Industries with good floodplain access

Figure 5.8 Old abutment at lower end of FW03, adjacent to Aggragate Industries

Reach FW03 had good habitat. Dense moss cover was noted on the near bank with moderate moss cover in the channel. The moss cover is an indication that Fordway Brook has a stable flow regime. Both the water color and the substrate within FW03 are dark. Dense fine particulate organic material (FPOM) was observed in the channel as well as iron and manganese staining on the substrate. The wetland upstream is the likely source of the FPOM and metals. All ten of the habitat parameters that were evaluated using the RHA resulted in a rating of "reference" or "good". Woody debris cover, channel morphology, hydrologic characteristics, connectivity, east river bank, and east riparian area were rated as "good". Bed substrate, scour and deposition features, west river bank and west riparian areas were rated "reference". Low and high flow refuge areas and undercut banks are common within FW03.

Reach FW04

FW04 is just under 1,500 feet in length. The NWI characterizes reach FW04 as a palustrine wetland with an unconsolidated bottom. The wetland is semi-permanently flooded and has dead forested vegetation around the edges (Figure 5.9). The NWI code indicates the wetland is created or modified by beaver activity. Dogwood, alder and spirea were noted to be the dominant shrub vegetation at the lower end of reach FW04, which was viewed just upstream of the old dam in FW03. White pine and other conifers dominated the forest edge. The wetland appeared to be in reference condition with greater than 150 foot buffers around the perimeter.

Figure 5.9 Palustrine wetland in reach FW04

Reach FW05

The fifth reach on Fordway Brook is made up of a number of wetland complexes. One type of wetland complex is a palustrine wetland with an unconsolidated bottom that is semi-permanently flooded and is influenced by beaver activity. The second type of wetland complex is a palustrine wetland with emergent vegetation that is seasonally flooded. FW05 was viewed from the Fordway Brook Road crossing, which is now just a trail. This location was very remote and involved a considerable hike to view the wetland. A wooden bridge (as shown in Figure 5.10) crossed the wetland with a beaver dam at the upstream end of the bridge. No bridge assessment was conducted in this location due to lack of permanence of the bridge. The buffer width in this location is extensive and is estimated to be well over 1/3 of a mile on both sides of the wetland.

Hemlock, white pine, maple, beech, red oak and white oak were in the forest surrounding the wetland. Wetland species observed in the vicinity of the bridge crossing included spirea, dogwood, arrowwood, grasses, meadow rue, Joe pyeweed and cardinal flower (Figure 5.11).

Figure 5.10 Bridge over wetland in FW05, at former Fordway Brook Road crossing

Figure 5.11Wetland vegetation in FW05

Reach FW06

Fordway Brook reach 6 is about 2,200 feet in length and is also a remote wetland in reference condition. As shown in Figure 5.12, this reach is dominated by a palustrine, scrub-shrub wetland that is seasonally flooded. There is also a small wetland in the center of the reach that is classified by NWI as a palustrine forested wetland that includes areas dominated by scrub-scrub, is seasonally flooded, and is created or modified by beaver. At the upper end of the reach, where BCE was able to access the wetland, the buffer vegetation contained thick conifers (see Figure 5.13). Some of the species observed by BCE include: dogwood, Joe pyeweed, grasses, spirea, poison ivy, and jewel weed. The water is colored brown by natural tannins produced in numerous wetlands throughout the Fordway Brook subwatershed.

Figure 5.12 Scrub-shrub wetland in FW06

Figure 5.13 Thick buffer of conifers in FW06

Reach FW07

Reach FW07 is a 2,038 foot long reach that was broken into four segments during the Phase 2 assessment. Fordway Brook is a stream channel, rather than wetland, in this entire reach. The lower end of the reach starts at the wetland/stream channel break at the upper end of reach FW06 and extends upstream to just above the Lane Road culvert where there is a change back to wetland. Numerous frogs were observed throughout this reach. All four of the segments have a broad confinement type.

The lowest segment (FW07-A) is 650 feet in length and borders the extensive wetlands complexes in FW04 through FW06 at the downstream end of the segment. This section of Fordway Brook is fairly remote and is located over 500 feet south of the southern end of Jay Court. Segment A is lower gradient than the other three segments in FW07 and is classified as a Rosgen C channel with cobble dominated substrate and a riffle-pool bedform. The substrate is dark in color and is likely stained from iron and manganese. FW07-A is very stable and rated in "good" condition based on the RGA. Floodplain access in this segment is superb and very little bank erosion was observed. There was some very minor aggradation and planform adjustment noted with one diagonal bar and some additional minor deposition features in the channel.

The habitat in FW07-A also resulted in a rating of "good". There is low embeddedness, good floodplain access and no evidence of channel alteration, resulting in reference scores for bed substrate cover and channel morphology. The riparian area for both banks also scored in reference. As noted in Figure 5.14, the ratio of wetted width to the bankfull width on the cross section was fair and the segment was estimated to have about 30 percent exposed substrate. Dense moss covered the river banks and undercut banks were present. The hydrologic characteristics, connectivity and river banks scored in the "good" category. Only two of the habitat categories (woody debris cover and scour and deposition features) scored fair. Although there was moderate woody debris recruitment, woody debris cover scored low due to the low number of large woody debris and lack of debris

jams in the segment. This lack of woody debris in the channel may be related to the extremely stable river banks (Figure 5.15).

Figure 5.14 Cross section location in FW07-A

Figure 5.15 Stable river banks in FW07-A

A segment break was made between FW07-A and FW07-B due to a change in planform and slope. Segment B is higher gradient and less sinuous than Segment A. A slope of 3 percent was measured using a clinometer in the field, making FW07-B a C channel with a subslope of b and a planebed bedform. Segment B is very stable and resulted in a RGA score in the reference range. The habitat in Segment B was noted to be good overall. The substrate had low embeddedness and the substrate was stable and well sorted. The moss on the substrate and banks in Figure 5.16 below reflect the stable flow regime. Boulders and cobbles accounted for about 70 percent of the pebble count. Segment B had good floodplain access and a relatively low width to depth ratio (16.6) with no channel straightening putting the channel morphology in the reference category. The river banks and riparian area reflect an unimpacted system with diverse plant assemblages stabilizing the banks and providing a buffer of over 150 feet on both sides of the channel. Both Segments FW07-A and FW07-B are relatively undisturbed and would be ideal for a conservation easement.

Figure 5.16 Moss cover in FW07-B

Figure 5.17 One of many green frogs in Fordway Brook below Lane Road Crossing near Hillside Drive

Segment FW07-C is just less than five hundred feet in length and begins where Fordway Brook bends away from Lane Road. A segment break was made between segment B and C due to a decrease in slope and smaller substrate size. Segment C is a Rosgen "C" gravel dominated, riffle-pool system by reference which has undergone a stream type departure to a "D" due to aggradation. The historic abutment or mill dam in segment C is impacting the channel morphology of Fordway Brook both upstream and downstream of the relict structure (Figure 5.18). A rating of fair was given based on the rapid geomorphic assessment. Extreme aggradation with major widening (width to depth ratio of 49.7) and planform adjustment was noted with braiding under low flow conditions (Figure 5.19). The channel has good floodplain access and is not incised. A ledge grade control structure with a total height of just over one foot is located immediately below the old abutment.

The aquatic habitat in Segment C was at the very low end of the "good" range based on the rapid habitat assessment scores. Several of the habitat parameters were rated in the fair category due to the impact of the relict structure. Although floodplain access is good, channel morphology was rated as "fair" due to the over-widening and the major historic channel alteration. Hydrologic characteristics were also rated as fair because of the high percentage of exposed substrate. There are a number of pools within Segment C, but the pool size rank is generally small and shallow due to the over wide stream channel. Very large depositional features were noted below the relict structure with abundant mid-channel accumulation.

The substrate in Segment C is only slightly embedded. Fine particulate organic material from the wetland upstream coats the substrate. Manganese and iron staining ("black rocks") was noted on the substrate. Numerous frogs inhabit this reach (see Figure 5.17). Some of the habitat parameters in Segment C scored in the high "good" to "reference" range. These parameters include woody debris cover, bed substrate cover, river banks and riparian area. The high quality and undisturbed riparian zone is an important aspect of this segment and is worth preserving.

Figure 5.18 Relict Structure in FW07-C

Figure 5.19 Mid- channel accumulation in FW07-C

A change in reference stream type warranted to a segment break between FW07-C and FW07-D. Segment D is a Rosgen "B" channel by reference with a slope less than two percent and substrate that is gravel dominated. Starting about 150 feet above the relict structure, Segment D is a short segment (390 feet) that ends at the Lane Road culvert. The upper end of Segment D is bordered by an extensive wetland about a mile in length in Reach 8. The wetland highly influences the water quality of Segment D as well as the hydrology. There is so much fine particulate material from the wetland above that it is difficult to see in the water column. The black rocks in Segment D from iron and manganese staining are also attributed to the extensive wetland. As shown in Figure 5.20, dense moss grows along the banks reflecting the very stable hydrologic nature of this section of stream channel.

Using the RGA, the geomorphic condition of FW07-D scored in the "good" range. Only minor aggradation and planform adjustment was noted. Some of the aggradation is due to the localized impact of the Lane Road culvert that is undersized and has a culvert diameter of 32 percent of the bankfull channel width. A large side bar is located immediately below the culvert. The side bar below the culvert contains road material including chunks of asphalt. There was also evidence of road material well downstream of Lane Road (Figure 5.21).

The habitat in Segment FW07-D was found to be on the high end of the fair category based on the RHA. There was limited woody debris in the channel, although the woody debris recruitment potential was rated as moderate due to all the trees along the bank. Riffles were noted to be short, but complete. The overall quality of the buffers and banks was good. There is very little bank erosion and the plant community within the buffer and along the banks has a diverse assemblage of plants.

Figure 5.20 Dense moss along banks of FW07-D

Figure 5.21 Stormwater runoff from Lane Rd

Reach FW08

A wetland begins just upstream of the Lane Road culvert and continues upstream for approximately one mile thereby defining Reach FW08. The upstream end of FW08 is approximately 770 feet below the Old Bye Road box culvert. The lower end of the wetland

is characterized as a palustrine, forested wetland that includes areas dominated by scrub-shrub and is seasonally flooded. The middle section of the Fordway Brook Reach 8 is scrub-shrub wetlands that are either seasonally or semi-permanently flooded. The very upper end of the reach is a palustrine wetland with an unconsolidated bottom that is permanently flooded. The NWI layer lists this upper section as diked/impounded by a man-made barrier. There are no dams listed on the NH GIS dam layer in this section.

The wetland in Reach FW08 is fairly remote. The project team was able to view the wetland in Reach 8 by hiking into the wetland from Lane Road and John Street (off of Oak Drive). Notes were taken by the project team approximately 1000 feet upstream of the Lane Road crossing. The wetland in this location has an unconsolidated bottom and is semi-permanently flooded (see Figure 5.22). The palustrine, scrub-shrub wetland accessed from John Street is shown below in Figure 5.23. The wetland in this location is semi-permanently flooded and modified/created by beaver. Some of the plant types noted in this area include: alder, dogwood, spirea, Joe pyeweed, and spatterdock. White pine and red maple are the dominant trees in the forest surrounding the wetland.

Figure 5.22 Wetland upstream of Lane Road

Figure 5.23 Wetland near John Street

Reach FW09

The ninth reach on Fordway Brook begins above the mile long wetland in FW08 and continues upstream about a half mile (2,675 feet) to where there is an increase in valley width and the confinement changes from broad to very broad at the lower end of FW10. The dominant land use within the corridor is forest, while the sub-dominant land use is residential. For the most part, the buffer width is greater than 150 feet, yet there are places where Fordway Brook is close to residential areas with buffer widths less than 100 feet.

FW09 is a very active reach in terms of geomorphic adjustment. The reach has major aggradation and planform adjustment with minor widening. Multiple diagonal bars, flood chutes and steep riffles were mapped within the reach. Extreme planform adjustment was especially evident at the lower end of the reach where there were numerous floodchutes. A channel avulsion (see Figure 5.24) was mapped about 100 feet below Old Bye Road. The

geomorphic condition using the RGA is fair. Given the planform adjustment and current aggradation in this reach, corridor protection is extremely important. FW09 appears to be an important attenuation area for sediment. The reach is not incised and floodplain access, in general, is very good. Two ledge grade controls were mapped within Reach 9 with total heights of 0.4 feet and 0.7 feet. Three channel constrictions were mapped that are leading to localized areas of geomorphic instability. These structures from downstream to upstream include: the box culvert at Old Bye Road, an old abutment, and piles of boulders placed in the channel.

Figure 5.24 Channel avulsion downstream of Old Bye Road

The lowest channel constriction is at the Old Bye Road crossing. This box culvert, which was replaced within the past few years, is causing extreme localized geomorphic instability due to poor alignment and a narrow span (see Figure 5.25). In addition to the alignment, other problems associated with the culvert are deposition above and below the structure and scour upstream of the structure. An old abutment, approximately 7 feet in height, located in the mid to upper portion of Reach FW09 (Figure 5.26), is reducing floodplain access. The width of this channel constriction is 14 feet. It would be helpful to remove this abutment on at least one side to allow provide floodplain access. A pile of boulders also creating a channel constriction was mapped just upstream of the old abutment. Restoration projects to consider in the FW09 include retrofitting the Old Bye Road culvert and removal of the old abutment. Project partners should also consider removing a relict structure (see Figure 5.27) that is in the middle of the channel upstream of the Old Bye Road culvert.

Figure 5.25 Inlet of Old Bye Road Culvert

Figure 5.26 Old Abutment upstream of Old Bye Road

The habitat rating in reach F09 was calculated to be within the high "fair" range using the RHA. Most of the habitat parameters (woody debris cover, bed substrate, channel morphology, connectivity, river banks, and riparian area) were rated as "good". Scour and deposition features and hydrologic features were given ratings of "fair" due to exposed substrate and lack of deep pools. The major deposition within this reach is responsible for filling of pools with sediment.

Figure 5.27 Relict Structure above Old Bye Road

Reach FW10

The tenth reach of Fordway Brook is just over one mile in length (6,161 feet). FW10 was broken into six segments to account for the alternating stream channel and wetland within this reach. For the most part, the change from stream channel to wetland is drastic. Segments A, C, and E are stream channel, while Segments B, D and F are palustrine wetlands. Reach 10 starts at Meadow Court and ends about 30 feet below Old Chester Road.

The lowest segment (FW10-A) is 482 feet in length and is a Rosgen "C" riffle-pool, with gravel dominated substrate. The valley type is very broad. The buffer in FW10-A is generally greater than 150 feet on both sides of the channel. There are a few isolated areas with buffer widths between 25 and 50 feet. FW10-A is similar to FW09 in term of geomorphic processes. The RGA suggests major aggradation and planform adjustment is occurring in segment A and the geomorphic condition is "fair". There are multiple diagonal bars and a large island near the top of segment A. An old washed out four foot diameter, metal culvert is sitting in the channel on one side of the island (see Figure 5.28). The culvert is not a channel constriction as flow can move on either side of the structure. However, the culvert is causing scour above and a mid channel bar below. If possible this old culvert could be removed. Floodplain access is very good in this reach, as shown in Figure 5.29.

Figure 5.28 Old washed out culvert in FW10-A, located to west of Meadow Court

Figure 5.29 Cross section location in FW10-A

The habitat in FW10-A was rated at the upper end of the "fair" range. With the exception of hydrologic characteristics, all the habitat parameters scored in the "good" or "reference" range. The hydrologic characteristics parameter was given a "poor" rating because of the low wetted width to bankfull width ratio and the high amount of exposed substrate.

Just above the island at the top of Segment A, Fordway Brook becomes a wetland for about 1,000 feet until the wetland ends at the Lane Road crossing. According to the NWI, this palustrine wetland in FW10-B has an unconsolidated bottom, is semi-permanently flooded, and is modified/created by beaver (see Figure 5.30). With the exception of the upper end of the wetland, which is near Lane Road, the wetland appears to be undisturbed. As shown in figure 5.31, twin culverts are located at the Lane Road crossing and are resulting in deposition below and scour above.

Figure 5.30 Wetland at lower end of FW10-B

Figure 5.31 Twin culverts at western most Lane Road crossing

Fordway Brook returns to a channel above the Lane Road Crossing and is heavily influenced by the wetland in Segment FW10-B and to a lesser extent by the wetland in FW10-D. FW10-C is a Rosgen "E" channel with a dune-ripple bedform by reference. The substrate is sand dominated. The entire 489 foot long segment is one large pool. A number of nice undercut banks were mapped in this segment. Segment C could not be fully assessed due to the wetland influence. The segment appeared to be geomorphically stable, but has been historically straightened. Just over 1/3 of the north bank is rock rip-rapped. The habitat is not very diverse in this section due to being historically channelized.

Segment D is 2,734 feet long and is a palustrine wetland with multiple thread channels. The downstream end of the segment is near the intersection of Lane Road and Old Colchester Road with the upper end of the segment ending about 1000 feet downstream of the twin culverts at Old Colchester Road. The wetland is remote and undisturbed. The lower portion of the reach is a forest wetland dominated by dead woody vegetation which is semi-permanently flood and modified/created by beaver (Figure 5.32). The upper part of the segment is dominated by broad-leaf vegetation and is seasonally flooded (Figure 5.33).

Figure 5.32 Wetland with dead woody vegetation at lower end of FW10-D, located east of intersection of Shattagee Road, Lane Road and Old Chester Road

Figure 5.33 Broad-leaf dominated wetland at upper end of FW10-D

Segment FW10-E begins at the twin culverts at Old Chester Road and goes downstream 1,096 feet where it meets the wetland in segment D. Segment E is a Rosgen "E" with silt as the dominant substrate and a dune-ripple bedform (Figure 5.34). The segment could not be fully assessed due to the strong influence of the large wetland downstream of Old Chester Road. The segment is in good geomorphic condition other than having undersized twin culverts that are having a localized impact due to deposition below and scour below.

Figure 5.34 Typical channel in FW10-E, downstream of Old Chester Road

White pine, hemlock and maple are the dominant trees in the buffer with sensitive fern, Christmas fern and partridge berry as important species in the understory. The riparian buffer is extensive on both banks. The segment offers important frog habitat. Numerous frogs were sighted during the field survey. Refuge areas that provide low flow and bankfull access are common. Cover in pools was noted to be good.

FW10-F begins at the upstream end of the Old Chester Road crossing and extends 333 feet upstream to the wetland complexes in FW11-A. The segment is the start of a large tract of conserved land under the name of Muriel Church # 6 that is 170 acres.

Reach FW11

Similar to Fordway Brook Reach 10, Reach 11 was broken into three segments to account for alternating sections of wetland and stream channel. The lower segment is categorized as a lacustrine wetland created by a man-made barrier or dam (see Figure 5.35). The Fordway Brook I dam is located at the lower end of Segment A. Palustrine scrub-scrub wetlands lie on the outskirts of the mapped lacustrine wetland. Segment A falls entirely with a 170 acre tract of conserved land under the name of Muriel Church #6. FW11-A offers important habitat for wildlife. A northern water snake was spotted coiled in a tree in the vicinity of the sign shown in Figure 5.36.

Figure 5.35 Wetland, west of Old Chester Road, in segment FW11-A

Figure 5.36 Conserved land in FW11-A off of Old Chester Road

FW11-B is a short section of stream channel (646 feet in length) with the downstream end near the edge of the conserved parcel and the upstream ending about 265 feet above Shattagee Road. Extensive wetlands exist both upstream and downstream of this segment. By reference, the segment is a Rosgen "C" channel with a riffle-pool bedform. The substrate is gravel dominated. There are two channel constrictions within Segment B: the culvert at Shattagee Road and an old abutment (Figure 5.37).

The RGA resulted in a score of "fair". The channel has undergone extreme historic degradation (incision ratio of 2.2) due to the old abutment. Historic straightening from the old abutment has contributed to a stream type departure from a Rosgen "C" channel to a "B" channel with a c subclass (Figure 5.38). The old abutment/structure could be removed to provide floodplain access. Major planform adjustment has occurred where there is better floodplain access at the lower end of the segment.

The RHA resulted in a score in the "fair" range. With the exception of channel morphology and hydrologic characteristics, the habitat parameters were all rated as good. Channel morphology rated in the "fair" range due to the high incision ratio and major historic channel alterations. The amount of exposed substrate within the segment placed hydrologic characteristics also in the "fair" range.

Figure 5.37 Relict structure in FW11-B above Shattagee Road

Figure 5.38 Section below relict structure

Figure 5.39 Wetland in Segment FW11-C

The upper segment on Fordway Brook Reach 11 is a 3,310 foot long wetland (Figure 5.39). The lower end of the wetland starts just upstream of the relict structure in Segment B. Segment B is consists of a number of palustrine wetlands that are either forested or scrub-shrub. Some of the scrub-shrub wetlands have emergent vegetation. The Town of Raymond and the Public Service Board of NH owns land that includes most of the wetland in FW11-C.

Reach FW12

Reach twelve on Fordway Brook was segmented because of a change in planform and slope. Segment A is a Rosgen "C" channel that is gravel dominated and has a riffle-pool bedform (Figure 5.40). Segment B is a wetland. FW12 is remote and the project team accessed the reach by hiking along a power line owned by the Public Service Company of NH. The reach is largely free of impacts with wetlands both upstream and downstream. The Town of Raymond owns a parcel that includes all of FW12. This makes this a prime reach for conservation.

FW12-A is 660 feet in length and is in good geomorphic condition (Figure 5.41). Degradation, aggradation, widening and planform adjustment were all rated in the reference categories. The habitat also rated in the good category.

Figure 5.40 Cross section in FW12-A

Figure 5.41 Reference condition stream bed

Figure 5.42 Wetland and beaver dam in FW12-B

Segment FW12-B is 650 feet in length and is primarily a forested wetland with broad-leaved deciduous vegetation and is seasonally flooded. The tree cover along the edge of the wetland is 100 percent with white pine, maple and hemlock as the dominant tree species. Figure 5.42 illustrates the wetland located upstream of the beaver dam at the top of segment FW12-A.

Town of Candia

Reach FW13

Reach FW13 is a wetland complex that extends for 2,422 feet (Figure 5.43). Most of the reach is classified by NWI as a palustrine wetland with an unconsolidated bottom that is semi-permanently flooded and has beaver activity. The upper-most portion of the reach is classified as a palustrine, forested wetland that is temporarily flooded. This reach is in good condition with buffers of greater than 150

Figure 5.43 Wetland complex in FW13

feet on both banks. There is some minor impact from the Crowley Road culvert which crosses the wetland in the middle of the reach. The culvert at Crowley Road is undersized for the wetland and it is causing deposition both above and below and creating scour below the culvert.

Reach FW14

The upper-most reach on Fordway Brook was not assessed due to its remote location, thick brush, extensive poison ivy and difficult walking conditions (Figure 5.44). The lower portion of this reach is classified by NWI as a palustrine forested wetland that is seasonally flooded and saturated with beaver activity. The upper part of the reach that was not accessible appears more confined on the topographic maps and may have a more defined stream channel. This reach is remotely located and is not impacted by human activities with buffers of greater than 150 feet on both sides. Overall, this reach is an "E" stream type in reference condition.

Figure 5.44 Thick brush and poison ivy in FW14

Fordway Brook Phase 2 Summary

Table 5.2 summarizes the channel geometry ratios, reference stream types, channel evolution states, and active adjustment process for Fordway Brook. Aggradation and planform adjustment are the dominant processes in the Fordway Brook subwatershed. Major or extreme active adjustment is occurring in segment FW07-C and is associated with the remnant structure below the eastern Lane Road crossing. Major aggradation and planform adjustment is also occurring in the vicinity of Old Bye Road and Meadow Court in segments FW09 and FW10-A. Figure 5.45 illustrates the rapid geomorphic condition (reference, good, fair or poor) of each of the Fordway Brook segments and reaches.

Table 5.2
Fordway Brook: Stream Type and Channel Evolution Stage

Segment Number	Entrench-ment Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Active Adjustment Process
FW01-A	Partial Assessment– Influenced by Upper Exeter River and wetlands upstream					
FW01-B	Wetland					
FW02	Wetland					
FW03	4.3	17.1	C3b	C3b	F1	Aggradation Planform
FW04	Wetland					

Table 5.2
Fordway Brook: Stream Type and Channel Evolution Stage

Segment Number	Entrench-ment Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Active Adjustment Process
FW05	Wetland/Pond					
FW06	Wetland					
FW07-A	6.7	20.0	C3	C3	FI	Aggradation Planform
FW07-B	2.4	16.6	C3b	C3b	FI	
FW07-C	1.9	49.7	C4	D4	DIId	**Aggradation Widening Planform**
FW07-D	1.7	16.0	B4c	B4c	FI	Aggradation Planform
FW08	Wetland					
FW09	6.0	20.3	C4	C4	DIId	**Aggradation** Widening **Planform**
FW10-A	5.2	23.7	C4	C4	DIId	**Aggradation Planform**
FW10-B	Wetland					
FW10-C	Partial Assessment– Influenced by wetlands upstream and downstream					
FW10-D	Wetland					
FW10-E	Partial Assessment– Influenced by wetlands upstream and downstream					
FW10-F	Wetland					
FW11-A	Wetland					
FW11-B	1.8	8.3	C4	B4c	FII	Aggradation **Planform**
FW11-C	Wetland					
FW12-A	13.3	13.1	C4	C4	FI	
FW12-B	Wetland					
FW13	Wetland					
FW14	Not assessed					

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

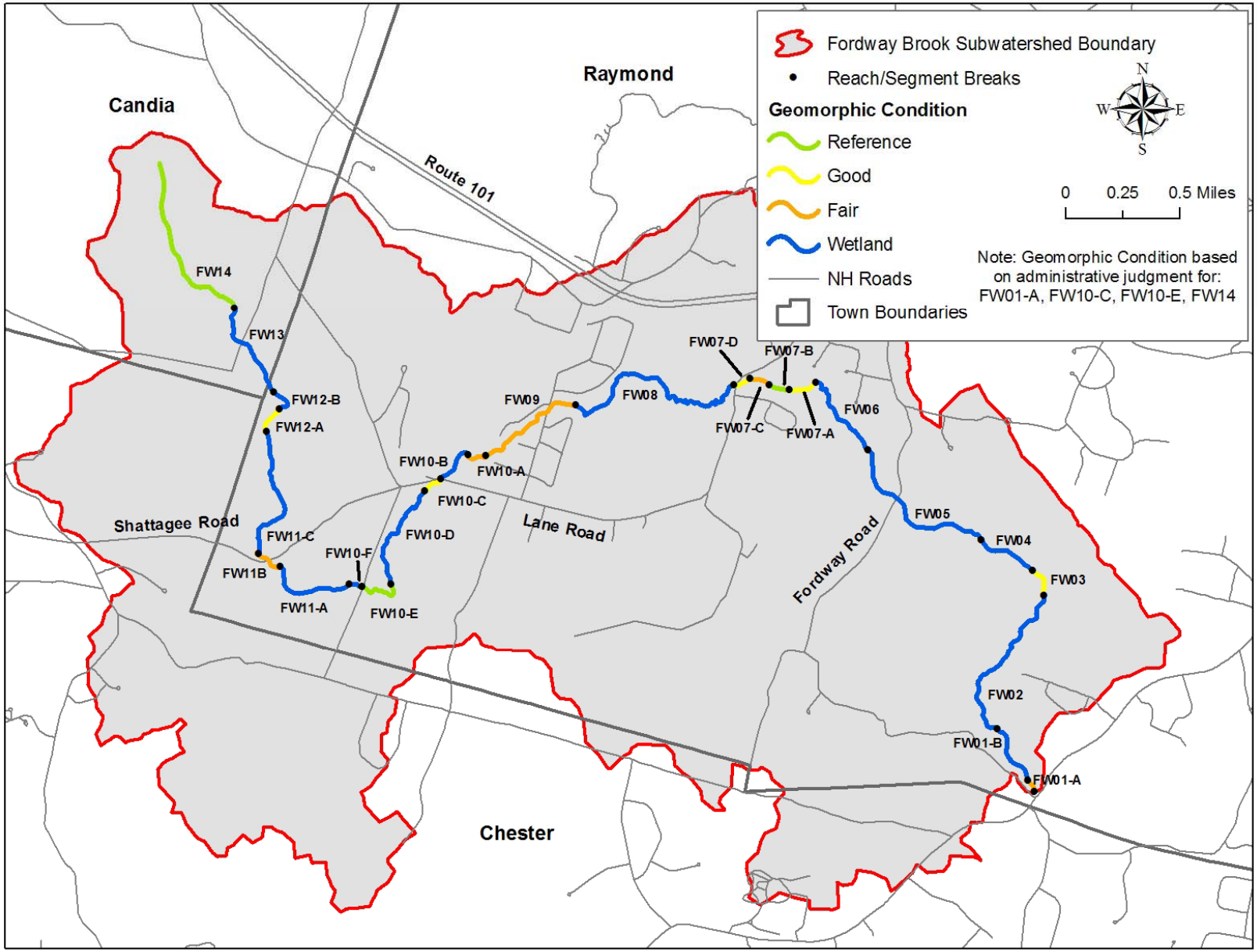

Figure 5.45 Fordway Brook reach condition map for the Phase 2 Geomorphic Assessment

Table 5.3 shows a comparison of the habitat condition based on the Rapid Habitat Assessment (RHA) and the geomorphic condition based on the Rapid Geomorphic Assessment (RGA).

Table 5.3
RHA and RGA Scores for Fully Assessed Phase 2 Segments

Segment Number	RHA Score	RHA Condition	RGA Score	RGA Condition
FW03	0.76	Good	0.75	Good
FW07-A	0.68	Good	0.79	Good
FW07-B	0.69	Good	0.94	Reference
FW07-C	0.65	Good	0.45	Fair
FW07-D	0.59	Fair	0.73	Good
FW09	0.63	Fair	0.53	Fair
FW10-A	0.64	Fair	0.64	Fair
FW11-B	0.62	Fair	0.56	Fair
FW12-A	0.69	Good	0.83	Good

5.3 Fordway Brook Bridge and Culvert Assessment

Table 5.4 summarizes the data collected for one bridge and six culverts in the Fordway Brook subwatershed. The final column of the table includes a prioritization of structures for replacement or retrofit based on a review of the following four criteria: structure width in relation to bankfull channel width; structure flood capacity; aquatic organism passage; geomorphic compatibility. Three of the Fordway Brook structures are located in wetlands and were not evaluated using the geomorphic screening tool. The culvert screening tool is not applicable to non fluvial systems. Additional summaries (including photos) for all moderate and high priority structures are provided in Appendix B. A summary of the methods and results for the watershed hydrologic modeling to determine each structure's flood capacity is included in Appendix C. Also included in Appendix C is an explanation of how structures were selected for flood capacity modeling based on the field data for geomorphic compatibility, aquatic organism passage and other local knowledge.

Figure 5.46 depicts the aquatic organism passage barriers for the Fordway Brook subwatershed, including culvert crossings and grade controls. Six culverts and four ledge grade controls were identified as reducing aquatic organism passage.

Table 5.4
Fordway Brook Crossings

Reach/ Segment No.	Road Name, Town	Structure Type	Condition/ Observation	Percent Bankfull Channel Width[1]	Structure Capacity for Flood Events (Percent Capacity)[2]		Aquatic Organism Passage (AOP)[3]	Geomorphic Compatibility[4]	Priority for Replacement or Retrofit
					25 Year Storm	50 Year Storm			
FW01-A	Chester Road, Chester	Bridge	Channelized straight, riprap failing	36%	78%	59%	NA	Mostly incompatible	Low to Moderate
FW07-D	Lane Road, Raymond	Culvert	Bank erosion downstream on south bank; outlet slightly perched; deep pool below	32%	133%	97%	Reduced AOP	Partially compatible	Low to Moderate
FW09	Old Bye Road, Raymond	Culvert	New; poor alignment, no vegetation; riprap creating constriction	56%	368%	262%	Reduced AOP	Mostly incompatible	High (Possible retrofit)
FW10-B	Lane Road, Raymond	Twin Culverts	Flooding concern; wetland upstream and channel downstream (channel highly influenced by wetlands further downstream)	37%	69%	49%	Reduced AOP	W[5]	Moderate to high
FW10-E	Old Chester Road, Raymond	Twin Culverts	Gravel deposition below road; wetland upstream and channel downstream (channel highly influenced by large wetland)	20%	25%	17%	Reduced AOP	W	Moderate
FW11-B	Shattagee Road, Raymond	Culvert	Poor condition; deteriorating steel	22%	161%	108%	Reduced AOP	Partially compatible	Moderate to high
FW13	Crowley Road, Candia	Culvert	Wetland above and below; woody debris at outlet	18%	73%	45%	Reduced AOP	W	Moderate

[1] Shaded for bankfull width percentage less than 50% ; [2] Shaded for capacity of less than 100%; [3] Aquatic Organisms Passage ratings developed with the VTANR methodology (not applicable to bridges); [4] Scores and ratings developed with the VTANR Geomorphic Compatibility Screening Tool; [5] Screening tool not applicable for non-fluvial (wetland) reaches

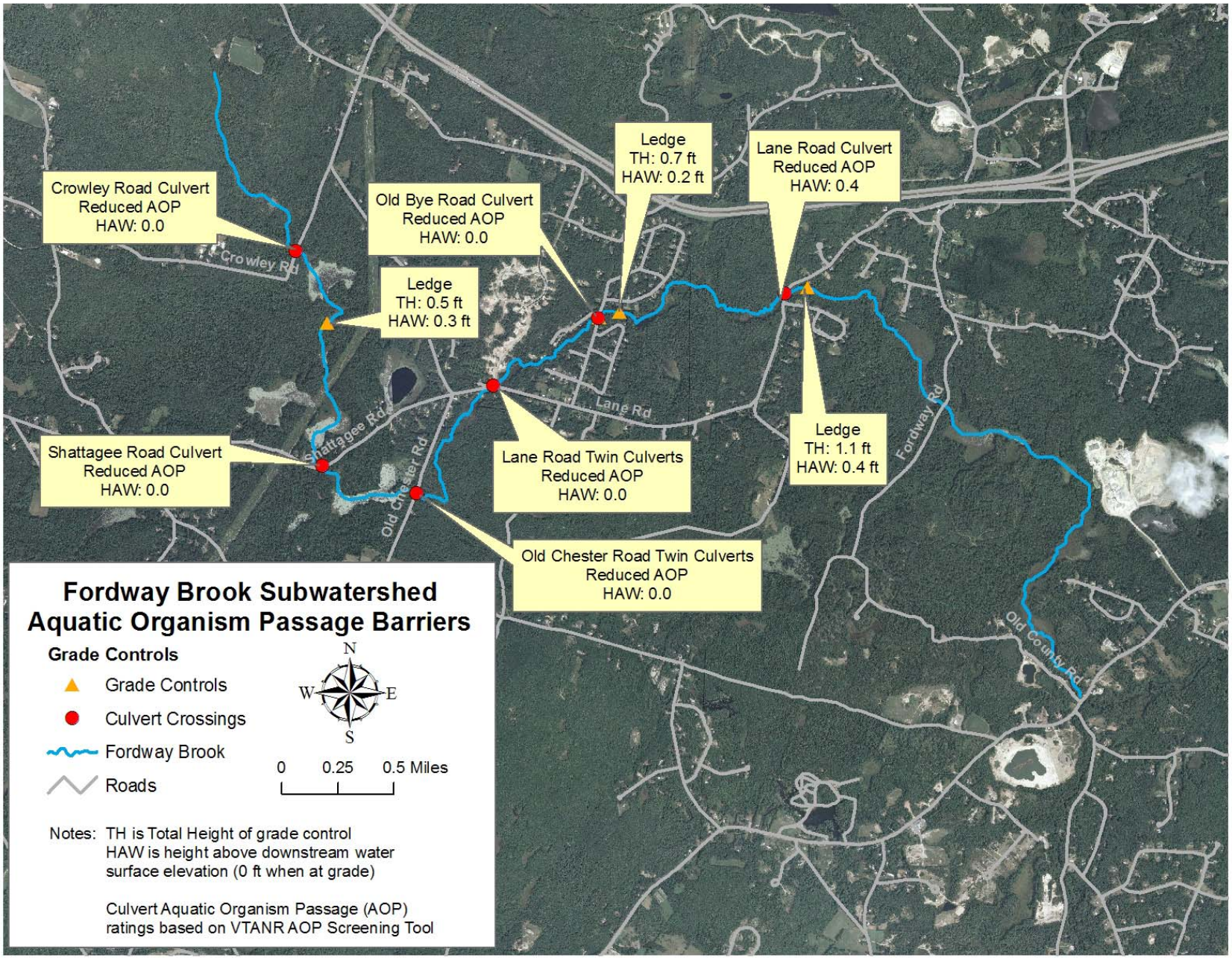

Figure 5.46 Aquatic organism passage barriers map for Fordway Brook Subwatershed

5.4 Fordway Brook Corridor Planning

5.4.1 Stressor Maps

Stressor, departure and sensitivity maps are presented here as a means of displaying the effects of all significant physical processes occurring within the Fordway Brook subwatershed that were observed during the Phase 2 Stream Geomorphic Assessment. Stressor maps are included in Appendix D. 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.

Land Cover

The Fordway Brook subwatershed has a mixture of land cover types. Much of the land adjacent to the stream channel is classified as wetland, and isolated areas of agricultural land exist throughout the subwatershed. The main areas of developed land cover found in the subwatershed are near Old Bye Road and near Aggregate Industries in Raymond. The Exeter River Vulnerability Analysis (Geosyntec, 2008) found the Fordway Brook subwatershed ranked 11 out of 13 or the third lowest for impervious cover based on 2005 land use. This impervious cover percentage of 3.5% is well below levels typically associated with degraded stream conditions at the national level (CWP, 2003).

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 and manipulation of water at the watershed scale. When the hydrologic regime has been significantly changed, 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).

Most of the wetland in the subwatershed is adjacent to Fordway Brook. Analysis of hydric soils located where current land uses are agricultural or urban indicates some minor loss of wetlands within the Fordway Brook subwatershed. The loss of wetlands decreases the attenuation of peak flows within the watershed. Based on hydric soils in areas that are urban or agricultural, the Fordway Brook subwatershed has experienced wetland loss of approximately 2 percent of the subwatershed area.

Roads contribute to localized increased flows resulting both from increased runoff and stormwater ditching. The Fordway Brook subwatershed has a modest network of

roads as illustrated in the Fordway Brook Hydrologic Regime map in Appendix D. Three areas within the Fordway Brook subwatershed have road densities greater than 5 miles per square mile (FW06, FW07 and FW08) and are associated with the Lane Road, Fordway Brook and Southside Road network. Subwatersheds FW09 (Old Bye Road) and FW13 (Crowley Road) have road densities of between 4 and 5 miles per square mile. All other subwatersheds within the study area have road densities less than 3 miles per square mile. 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 mile/ square mile account for approximately 21 percent of the entire Fordway Brook watershed.

Sediment Loads Indicators

The sediment load indicators map for Fordway Brook (see Appendix D) shows depositional features per mile and channel migration features were concentrated in segments FW07-C, FW09 and FW10-A, where both aggradation and planform adjustment are major adjustment processes. All three of these segments appear to be in stage DIId of the channel evolution model suggesting the channel has become extremely depositional and in some cases is braiding under low flow conditions. The channel adjustment process in FW07-C is due to a relict abutment or mill dam. The relict structure is impacting channel morphology both upstream and downstream of the structure resulting in a stream type departure due to aggradation. Bank erosion is minimal along Fordway Brook and only one mass failure (FW09) was observed in the subwatershed. Localized areas of depositional features and channel migration features are prevalent within the Fordway Brook subwatershed.

Channel Slope and Depth Modifiers

Corridor encroachment and development within the Fordway Brook subwatershed has been highlighted on the Slope and Depth Modifiers map (Appendix D) for areas where natural channel sinuosity may be decreased. In these areas, increased channel slopes may cause reduced floodplain function because the channel has greater capacity to hold larger flow events within the channel, rather than spilling onto the floodplain. Beaver dams are common on Fordway Brook. Although these features are ephemeral, they do temporarily control vertical channel adjustments and have been shown to help maintain floodplain function in low-gradient urban streams (Fitzgerald, 2007). Channel straightening was noted in a few locations along Fordway Brook where the channel runs adjacent to a road or where historic abutments existed.

There are no active dams on Fordway Brook that are acting as channel slope and depth modifiers. The Fordway Brook Dam, located upstream of Chester Road in Raymond (segment FW01-A) is in ruins. Also in ruins is the Fordway Brook I Dam above Old Chester Road in Raymond (segment FW11-A).

Riparian and Boundary Conditions

The Riparian and Boundary Conditions map highlights areas where human alterations to the river boundaries have increased or decreased the resistance of the banks and bed to channel adjustments. In general, Fordway Brook has healthy riparian vegetation alongside the channel and few areas of reduced riparian vegetation were observed. Isolated areas of moderate bank erosion, especially in the vicinity of Old Bye Road, have made the channel prone to lateral adjustments (e.g., further bank erosion and widening). Some channel armoring along Lane Road and Shattagee Road has reduced the potential for bank erosion. Many impacts to the channel boundaries were also noted at the lower end of Fordway Brook near the Chester Road crossing where the channel has been straightened, bermed on one side, riparian buffers have been reduced and structures have been built within the floodplain.

5.4.2 Departure Analysis

The sediment regime is the quantity, size, transport, sorting and distribution of sediments. The sediment regime may be influenced by the proximity of sediment sources, the hydrologic regime, and the specific morphology of the valley, floodplain, and stream. The sediment regime departure map (see Appendix D) shows the Phase 1 reference stream sediment conditions for each reach within the stream network. These reference type streams use available floodplain access as a means to store sediment within the watershed. In Fordway Brook, all of the reaches that are stream channel and not wetland have a reference sediment regime of an *Equilibrium Channel*.

Changes in hydrology (primarily development within the riparian corridor) and sediment storage within the subwatershed have altered the reference sediment regime type for one segment (FW11-B). Sediment regime departures were derived from the sediment regime criteria established by the Vermont Agency of Natural Resources (2007c). Segment FW11-B that was an *Equilibrium Channel* by reference has been converted to *Unconfined Source and Transport* sediment regimes due to increased transport capacity derived from bank armoring and channel straightening

5.4.3 Sensitivity Analysis

There are many variables that contribute to the sensitivity of the stream segments in the Fordway Brook subwatershed. Well established bank vegetation has helped to improve the boundary conditions between water and land and has reduced the sensitivity of many sections of Fordway Brook that are well buffered. Removal of this vegetation tends to make stream segments 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. Low gradient streams, like most segments in the Fordway Brook subwatershed, with high sediment supplies are very sensitive and may

undergo adjustment following minor changes in channel geometry or boundary conditions.

The Stream Channel Sensitivity map in Appendix D presents the stream sensitivity, generalized according to stream type and condition, and current adjustments for each reach segment in the Fordway Brook subwatershed. Major aggradation adjustment processes are displayed on the corridor where they were found to be actively occurring and not evaluated as historic. This information is helpful in prioritizing the implementation of the projects identified in section 5.5 of this report, as certain management actions may be influenced by these active adjustment processes.

5.4.4 FEH Zones

A summary of the FEH zones developed for the Fordway Brook subwatershed is included in Appendix E. Included in Appendix E is: 1) a complete summary of the methods used to develop FEH zones, 2) a summary table comparing the stream channel sensitivity assigned to each corridor with the degree of protection afforded by wetlands and conserved lands within the corridor, and 3) maps depicting the FEH corridors, sensitivity ratings, and other aspects related to corridor protection. The NHDES will work with communities who would like to adopt FEH ordinances. Some GIS corrections may need to be made to produce an ordinance ready map.

5.5 Fordway Brook Project Identification

The site level projects that were developed for Fordway Brook are provided below in Table 5.5. The project strategy, technical feasibility, and priority for each project are listed by project number and reach. A total of 19 projects were identified to promote the restoration or protection of channel stability and aquatic habitat. Photographs of the 19 Fordway Brook projects are provided in Appendix F. The table summarizes key information for each project, including the project strategy, technical feasibility, and priority based on scientific data and stakeholder input. The 19 projects are further broken down by category as follows: 12 active geomorphic restoration; 2 passive geomorphic restoration; 2 conservation; and 3 stormwater mitigation. The active geomorphic restoration projects include seven bridge and culvert retrofit/replacement locations and the removal of five relict structures or old abutments.

The project locations and categories identified for the Fordway Brook subwatershed are depicted below in Figure 5.47. Six high priority projects have been identified. All of the high priority projects are located in the Town of Raymond and are concentrated in the vicinity of the eastern Lane Road crossing and Old Bye Road in Raymond. The high priority projects include:

- **Conservation** east of eastern Lane Road crossing, adjacent to Hillside Drive (project #3);
- **Improved stormwater management** at the eastern Lane Road Crossing (project #6);
- **Active restoration** by retrofitting box culvert at Old Bye Road (project #7);
- **Stormwater management and streamside plantings** near Old Bye Road (project #8);
- **Passive Restoration** between Old Bye Road and western Lane Road (project #11); and
- **Conservation** between Shattagee Road and Raymond/Candia town line (project #18).

Table 5.5
Fordway Brook Site Level Opportunities for Restoration and Protection

Project #, Location/ Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#1 Chester Road Route 102 in Raymond 42.99060 N 71.19460 W Segment FW01-A	Active Restoration	Chester Road Bridge has a small span and modeled structure capacity is less than 100 percent. Geomorphic compatibility rated as mostly incompatible. Bridge in good condition and is allowing AOP.	Replace bridge	Moderate	Low	Improved flood capacity to protect Chester Road	High cost of design, materials and construction	Bridge is managed by the Town of Chester	Town of Chester, NHDES, ERLAC
#2 North of Chester Road Bridge in Raymond Segment FW01-A	Passive Restoration	Segment highly influenced by Upper Exeter River and wetland at upper end of segment. Riparian corridor on east side is residential, while west side is forest with some residential land use.	Corridor Easement	Low	Low	Protected floodplains allow for attenuation of fine sediment and floodwaters	Potentially high costs for easements due to private ownership		Town of Raymond, NHDES, private landowners
#3 East of most eastern Lane Road crossing in Raymond Reach FW07	Conservation	Town of Raymond already owns some land at lower end of reach FW07 and upper end of FW06. FW07 and is in an area with development pressure.	Conservation – Corridor Easement	High	High	Conserve stable river reach with good aquatic habitat and terrestrial habitat	Potentially high costs for easements due to private ownership	Research easement potential	NHDES, ERLAC, Town of Raymond, private landowners
#4 East of most eastern Lane Road crossing in Raymond 43.01707 W 71.21867 N Segment FW07-C	Active Restoration	Relict abutment or mill dam impacting channel morphology both upstream and downstream of structure; access is poor. Impact of structure on waterbody is localized.	Remove relict structure	Low	Low	Improved floodplain access for attenuation of sediment and floodwaters	High; requires funding for alternatives analysis and design and cost of removing relict structure	More research into structure origins is needed	NHDES, ERLAC, Town of Raymond
#5 Eastern Lane Road crossing in Raymond 43.01649 N 71.22034 W Segment FW07-D	Active Restoration	The Lane Road culvert is undersized and has reduced aquatic organism passage. Structure is relatively new.	Replace Lane Road culvert	Low	Moderate	Improved geomorphic stability and aquatic organism passage	Moderate	Evaluate local priorities	Town of Raymond, NHFGD, NHDES, ERLAC

Table 5.5
Fordway Brook Site Level Opportunities for Restoration and Protection

Project #, Location/ Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#6 Eastern Lane Road crossing in Raymond 43.01649 N 71.22034 W Segment FW07-D	Stormwater Management	Runoff from road contributing road material to Fordway Brook	Improve stormwater runoff along Lane Road and prevent untreated stormwater from reaching brook.	Moderate	High	Improved water quality	Low	Town may be willing to work on stormwater issues	Town of Raymond, ERLAC, NHDES
#7 Old Bye Road culvert in Raymond 43.01474 N 71.23694 W Reach FW09	Active Restoration	Old Bye Road Box culvert is causing extreme localized geomorphic instability due to poor alignment and narrow span;	Retrofit Old Bye Road culvert; vegetate where needed	High	Moderate	Improved geomorphic stability	Moderate to high cost for design and retrofit of box culvert.	Evaluate and align project with local priorities	NHFGD, NHDES, ERLAC, Town of Raymond
#8 Old Bye Road crossing in Raymond 43.01474 N 71.23694 W Reach FW09	Stormwater Management	There is no vegetation on the north bank below the old Bye Road Culvert and the north bank above the culvert is eroding. Sediment associated with urban runoff was noted above the culvert.	Vegetate north bank in vicinity of Old Bye Road culvert and investigate sources of urban runoff	Moderate	High	Improved bank stability; improved water quality	Low cost for native plant materials. Cost for improving stormwater runoff needs further investigation		NHDES, ERLAC, Town of Raymond
#9 Old Bye Road Crossing in Raymond Reach FW09	Active Restoration	Relict structure in center of channel may be deflecting flows into bank causing bank erosion	Remove relict structure in middle of channel above Old Bye Road culvert to reduce further bank erosion.	Low	Moderate	Reduced bank erosion and property damage	Relatively low cost for removal; structure could possibly be dismantled and removed in pieces.	More information is needed on origin of structure	NHDES, ERLAC, Town of Raymond
#10 West of Old Bye Road culvert in Raymond 43.01397 N 71.23872 W Reach FW09	Active Restoration	Old abutment is cutting off floodplain access near mid to upper end of reach. Boulder piles immediately above culvert are also causing a channel constriction; Access may be an issue.	Remove old abutment ; Recommend alternatives analysis	Moderate	Low	Improved attenuation of sediment	Moderate to high cost for alternatives analysis, engineering design and construction	Adjacent lot is town owned; research mitigation opportunities; may be costly to mitigate	NHDES, ERLAC, Town of Raymond

Table 5.5
Fordway Brook Site Level Opportunities for Restoration and Protection

Project #, Location/ Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#11 Between Old Bye Road and western Lane Road crossing in Raymond FW09 and FW10-A	Passive Restoration	Major aggradation and planform adjustment is occurring in this section of river. NHD stream layer is off and will need to be defined to determine easement area.	Corridor easement to allow channel to adjust and provide sediment attenuation	High	Moderate	Flood and sediment attenuation	Potentially high costs for easements due to private ownership	High costs could be a deterrent	NHDES, ERLAC, Town of Raymond
#12 Near Meadow Ct. in Raymond Segment FW10-A	Active Restoration	Old metal culvert (four feet in diameter) is sitting in channel on side of island near upper end of segment and is causing localized geomorphic instability. Need to evaluate access to determine if project is feasible	Remove old culvert from center of channel	Low	Moderate	Reduced scour and mid channel accumulation	Low costs if access is possible	Privately owned; landowner discussion/ negotiation needed; cost may be prohibitive	NHDES, ERLAC, Town of Raymond
#13 Western Lane Road crossing in Raymond 43.01089 N 71.24549 W Segment FW10-B	Active Restoration	Twin culverts at Lane Road do not appear to be causing significant geomorphic instability; however culvert is reducing AOP and brook has flooded over road.	Replace culvert	Moderate	Moderate	Reduced flooding of road; improved aquatic organism passage	Moderate cost to replace twin culverts; replacement of culverts could reduce future road repair work	Engineering study will be required to evaluate downstream impacts	Town of Raymond, NHDES, ERLAC, NHFGD
#14 Old Chester Road crossing in Raymond 43.00408 N 71.25267 W Segment FW10-E	Active Restoration	Twin culverts at Old Chester Road have narrow diameter and has reduced flood capacity and AOP	Replace culvert	Moderate	Moderate	Reduced flooding of road	Moderate cost to replace twin culverts	Class VI road not maintained by town; might be possible if funding available	Town of Raymond, NHDES, ERLAC, NHFGD

Table 5.5
Fordway Brook Site Level Opportunities for Restoration and Protection

Project #, Location/ Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#15 Old Chester Road crossing in Raymond 43.00408 N 71.25267 W Segment FW10-E	Stormwater Management	Gravel deposition noted below road; wetland below culvert is attenuating sediment	Reduce sedimentation by improving stormwater management	Moderate	Moderate	Improved water quality	Low to moderate costs for improved stormwater management		Town of Raymond, NHDES, ERLAC
#16 Shattagee Road crossing in Raymond 43.00571 N 71.26093 W Segment FW11-B	Active Restoration	Culvert at Shattagee Road is deteriorating and is narrow relative to the channel width. Structure is in poor condition.	Replace culvert with larger culvert that provides a bankfull span	Low	Moderate	Improved geomorphic stability and aquatic organism passage; improved condition of structure	Low to moderate cost for replacement of structure. Drainage area small.	Evaluate structure relative to Norton Pond outlet; conservation may also be appropriate in this reach	Town of Raymond, NHDES, ERLAC, NHFGD
#17 Northwest of Shattagee Road in Raymond 43.00603 W 71.26175 N FW11-B	Active Restoration	Relict structure (old abutment) has cut off floodplain and has caused historic incision. Town of Raymond owns land in this vicinity; impact of structure is over a short distance	Conduct alternatives analysis to evaluate removal of relict structure;	Low	Low	Improved floodplain access resulting in flood and sediment attenuation	Moderate to high cost of removing relict structure. This project could possibly be completed at some time as culvert replacement.	Research ownership; access might be difficult	Town of Raymond, NHDES, ERLAC
#18 Between Shattagee Road & Raymond/Candia town line FW11C and FW12	Conservation	This section is within conservation focus area. Town of Raymond owns land that includes this high quality section of stream channel.	Conservation easement	High	High	Wildlife and aquatic habitat, flood and sediment attenuation	Relatively low costs to acquire conservation easement given land ownership by Raymond	Work with town officials and board members to further evaluate conservation potential; would connect with Candia conservation land	Town of Raymond, ERLAC, NHDES

Table 5.5
Fordway Brook Site Level Opportunities for Restoration and Protection

Project #, Location/ Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#19 Crowley Road culvert in Candia 43.01954 N 71.26330 W FW13	Active Restoration	Crowley Road culvert is undersized in terms of bankfull width and also has reduced flood capacity and AOP	Replace culvert with larger structure that provides a bankfull span	Moderate	Moderate	Improved geomorphic stability and aquatic organism passage; possible reduction in flooding of road	Low to moderate cost for replacement of structure. Drainage area is small.	Work with Candia to further evaluate potential	Town of Candia, NHFGD

[A] Administrative judgment used for determining stream type, RGA and RHA condition for impounded segments and segments.
NE – not evaluated

Additional Notes for Reaches/Segments with No Identified Projects:

- No restoration projects have been identified for Reach FW02, FW04, FW05, FW06, and FW08 due to the existing protection offered by NWI wetlands.
- No restoration projects have been identified for Reach FW03. Much of the river corridor is within a DES conservation easement. Fordway Brook appears to have adjusted to the relict structures within this reach and removal of these old abutments is not recommended.

Project ID Table Includes Bridges and Culverts That Meet the Following Criteria:

1. Mostly incompatible or fully incompatible using VTANR Geomorphic Compatibility Screening Tool and/or
2. Modeled flood capacity or 25 year storm less than 100 percent.

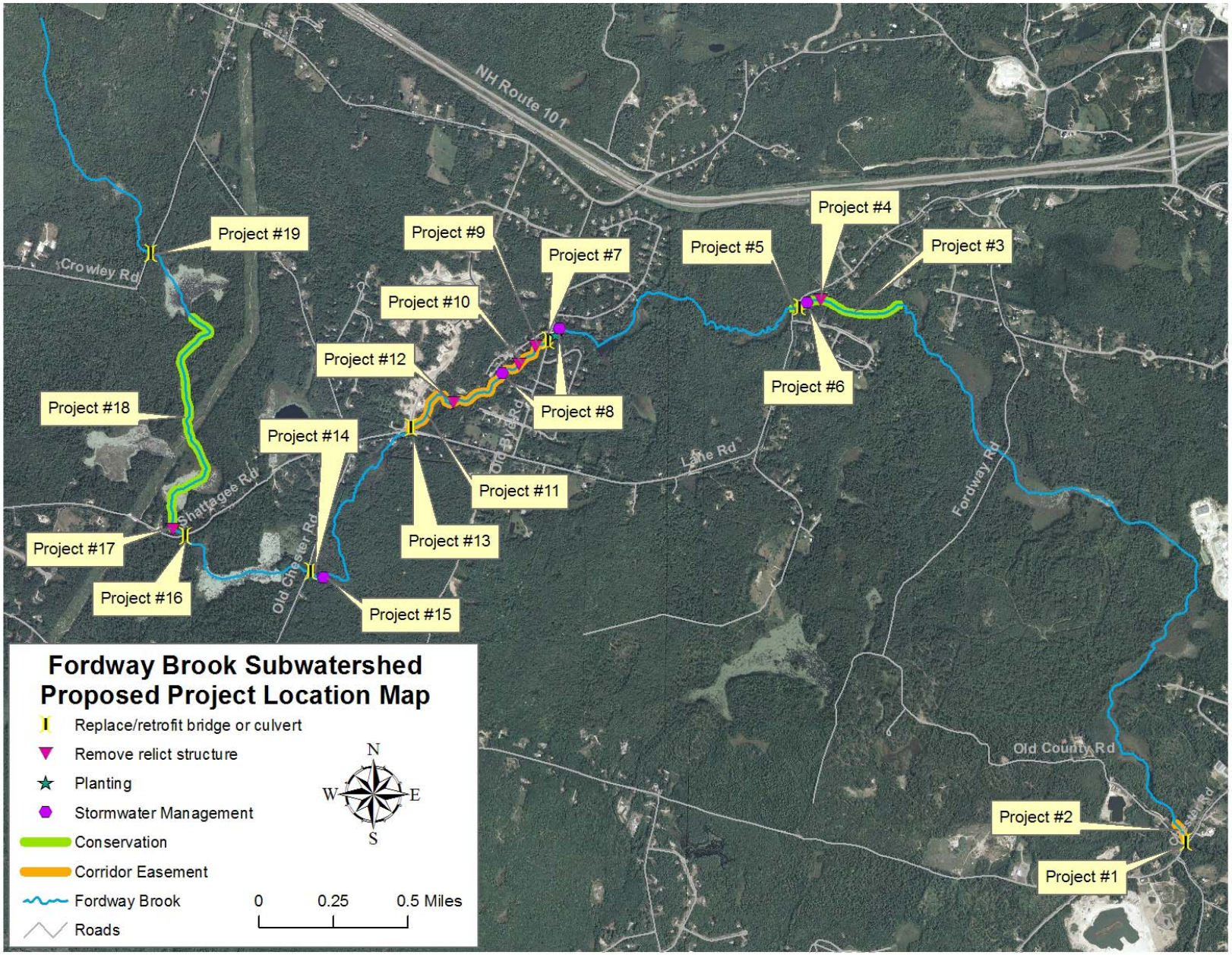

Figure 5.47 Proposed project location map for Fordway Brook Subwatershed

6.0 UPPER EXETER RIVER RESULTS

6.1 Upper Exeter River Background Information

The Upper Exeter River drains from approximately 460 feet above sea level in the headwaters of the Town of Chester and flows in an easterly direction through the Towns of Sandown, Danville, Fremont, back into Chester and then ends in Raymond at an elevation of approximately 155 feet above sea level. The Upper Exeter River generally flows through a very gentle gradient valley with numerous wetlands and ponds. With the exception of reach UE15, located at the upper end of the subwatershed, all reaches assessed for Phase 2 on the Upper Exeter River have a valley slope of less than one percent as summarized in Table 6.1.

Table 6.1
Geomorphic Setting of Assessed Reaches

Reach ID	Reference Stream Type	Confinement Type	Valley Slope (%)	Bed Form
UE01	E	Very Broad	0.07	Riffle-Pool
UE02	E	Broad	0.07	Riffle-Pool
UE03	C	Broad	0.09	Riffle-Pool
UE04	C/Wetland	Narrow	0.15	Riffle-Pool
UE05	Wetland	NA	0.04	NA
UE06	C/Wetland	Broad	0.42	Riffle-Pool
UE07	Wetland/Pond	NA	0.01	NA
UE08	C/Wetland/B	Narrow	0.43	Riffle-Pool
UE09	Wetland/Pond	NA	0.01	NA
UE10	Wetland	NA	0.21	NA
UE11	E/Wetland	Very Broad	0.17	Riffle-Pool
UE12	C/E/G	Broad	0.84	Riffle-Pool Step-Pool
UE13	Wetland/Pond	NA	0.01	NA
UE14	C/Wetland	Very Broad	0.90	Riffle-Pool
UE15	B/C/E/D	Very Broad	1.92	Step-Pool Riffle-Pool Braided
UE16	Wetland/Pond	NA	0.01	NA

The Upper Exeter River study section of 18.64 river miles was broken into sixteen reaches by the NHGS during the Phase 1 assessment. Approximately 59 percent of the length of the Upper Exeter River study section is wetland. For the remaining study section that is

stream channel, the predominant reference stream type using the Rosgen (1996) classification system is C or E. A few of the reaches contained short segments that have higher slopes or were more entrenched, making these sections B or G stream types by reference. One segment (UE15D) was a braided stream channel and was a D stream type by reference.

6.2 Upper Exeter River Phase 2 Results

As part of the Phase 2 assessment, the Upper Exeter River reaches were broken into 32 segments based on field observations. The reference stream type for each segment is included in Figure 6.1. Thirteen of the 32 segments are wetland by reference. Approximately 59 percent of the length of the Upper Exeter River study section is wetland. A discussion of each reach on the Upper Exeter River from the downstream-most reach to the headwaters is provided below.

<u>Town of Raymond</u>

Reach UE01

Reach UE01 begins in Raymond near the border with Fremont in the vicinity of a` trailer park off Brown Road. Reach UE01 is 6,356 feet in length, and the majority of this reach is classified by the NWI as a palustrine forested wetland that is seasonally flooded and saturated. The field team was unable to access the lower 2,500 feet of this reach for a visual assessment. The channel was too deep for the team to wade and extensive debris jams along the length of the channel prevented access by boat. Additionally the well established forested buffers at the lower end of the reach did not allow the field team to access this portion of the reach from the banks. There is a very minor change in valley width at the lower end of the reach due to a road, and Pennichuck Water Works has access to the stream at lower end of reach. This reach was classified as an "E" stream type and appeared to be in good condition with a dominant buffer width of over 150 feet on both banks. One beaver dam was noted and abundant refuge habitat was recorded in this reach (Figure 6.2).

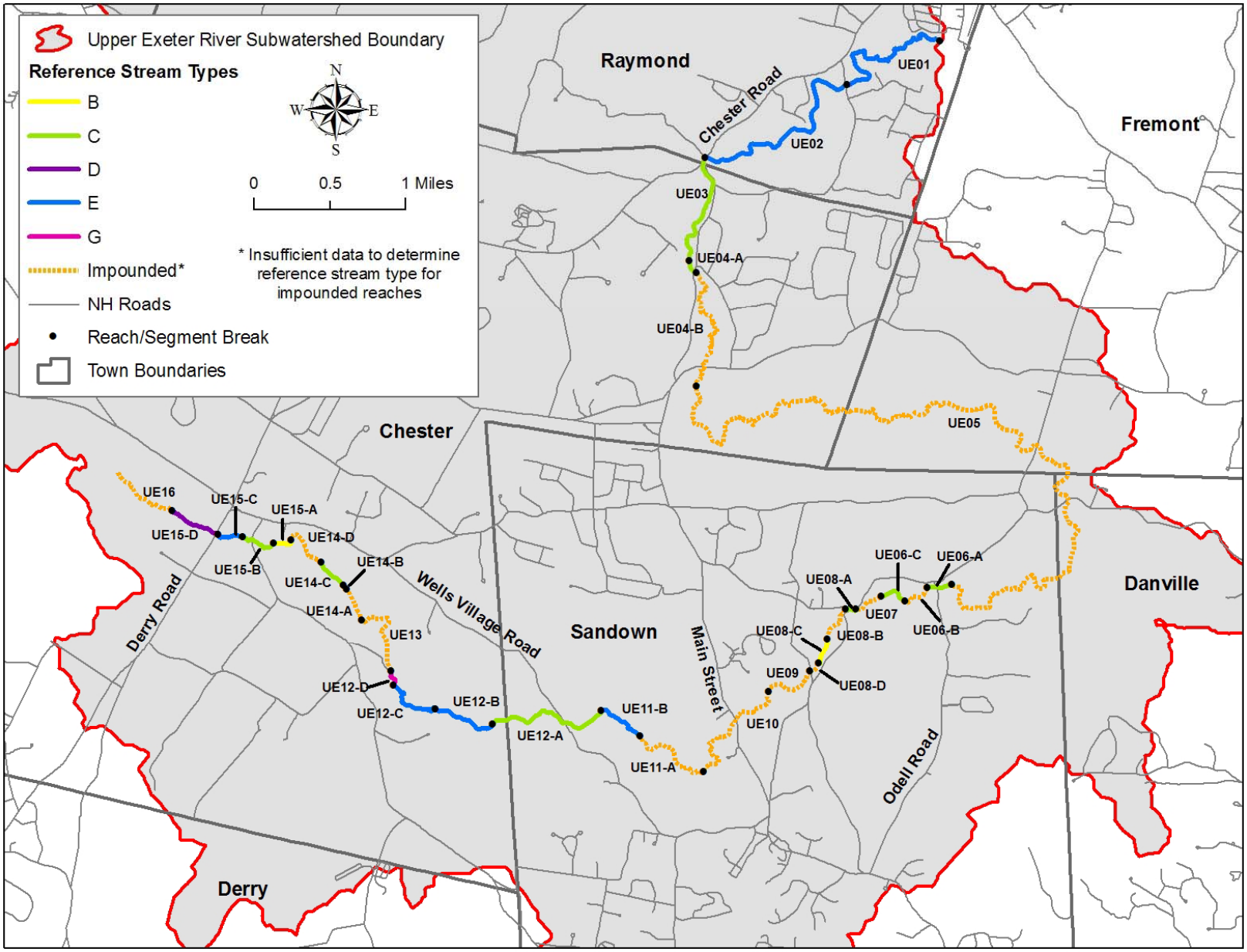

Figure 6.1 Upper Exeter River reach/segment locations and reference stream types

Figure 6.2 Debris jam in Upper Exeter River Reach, UE01, downstream of Blueberry Hill Road

Reach UE02

The second reach on the Upper Exeter River begins at the Blueberry Hill Road Bridge and continues upstream for 7,745 feet to the confluence with Fordway Brook. Portions of this reach are palustrine wetlands with persistent emergent vegetation. The upper half of the reach is classified by the NWI as scrub-shrub. UE02 is an "E" channel that is in good condition with dominant buffer widths of greater than 150 feet (Figure 6.3). Hemlock, red maple and white pine are the dominant trees in the buffer. There is some minor residential development within the buffer on the north bank along Riverside Drive (Figure 6.4).

Figure 6.3 Wetland channel in UE02, between Blueberry Hill Road and Chester Road

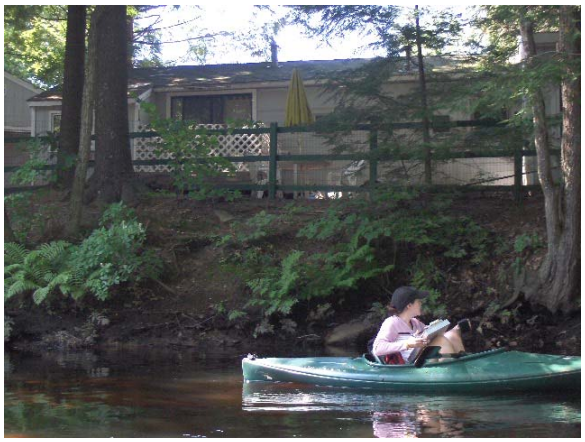

Figure 6.4 Residential development in UE02 at Riverside Drive

Town of Chester

Reach UE03

Reach UE03 begins at the confluence with Fordway Brook and continues upstream for 4,284 feet along Hanson Road and Shepard Home Road. The lower end of the reach is impacted by the abundant wetlands downstream. Hanson Road runs within the corridor for a short distance at the downstream end of the reach. This reach had limited riffle habitat so the cross section was measured near the upper end of the reach in a defined riffle (Figure 6.5). The riffles were in wider locations of the channel than was typical of the rest of the reach which resulted in a high width to depth ratio for this reach.

Figure 6.5 Typical channel adjacent to Shepard Home Road in Reach UE03

UE03 is a "C" channel in "good" geomorphic condition with dominant buffer widths of greater than 150 feet on both sides. Both banks have some small areas with limited buffers due to road encroachments within the corridor at the lower end of the reach (Figure 6.6). A portion of land along the west bank of UE03 is within a 15 acre conservation easement owned by the Town of Chester. The RHA scored in the "fair" range, mostly hindered by the lack of woody debris cover and a low channel morphology score as a result of a high width to depth ratio.

Figure 6.6 Encroachment along Shepard Home Road

Reach UE04

The fourth reach on the Upper Exeter River was broken up into two segments to account for the change in channel dimensions between the short lower segment (UE04-A) with a defined channel and the upper wetland that makes up the majority of the reach (UE04-B).

Segment UE04-A begins about 460 feet downstream of the Shepard Home Road double culverts in Chester and ends just upstream of the culverts. This short segment appeared to be stable with evidence that regular flooding occurs all the way to the valley walls. This

segment is a Rosgen "C" stream type with gravel dominated substrate and a riffle-pool bedform in good condition (Figure 6.7).

Figure 6.8 Double culverts at Shepard Home Road

Figure 6.7 Typical channel in UE04-A in Upper Exeter below twin culvert at Shepard Home Road

Both banks in segment UE04-A had a dominant buffer width of greater than 150 feet, and while there is a minor road encroachment within the river corridor, there do not appear to be any problems related to stormwater. The double culverts at Shepard Home Road are causing some scour both upstream and downstream (Figure 6.8).

Segment UE04-B is 5,680 feet in length. This segment is predominantly classified by the NWI as a palustrine forested wetland that is seasonally flooded and saturated (Figure 6.9). UE04-B appeared to be in reference condition with a dominant buffer width of well over 150 feet. A good portion of this wetland segment is contained within a conservation easement named Shepard Home Realty that includes 32.7 acres.

Figure 6.9 Wetland in UE04-B between Shepard Home Road and Fremont Road Crossings

Towns of Chester, Fremont, Danville and Sandown

Reach UE05

UE05 is nearly 5.8 miles in length. The lower end of the reach starts just above the Fremont Road crossing in the Town of Chester and extends upstream to just below the Odell Road crossing in the Town of Sandown. The NWI characterizes reach UE05 as a palustrine wetland that is seasonally flooded and saturated. The wetland varies between forested and shrub scrub vegetation (Figure 6.10). This long reach is relatively inaccessible and unimpacted by human activities except in the vicinity of the road crossings at Sandown Road in Danville and Fremont. At the time of the Phase 2 assessment, Sandown Road in Danville was closed due to an outflanked culvert and water was noted to be flowing over the road surface (Figure 6.11).

Figure 6.10 Wetland in UE05

Figure 6.11 Water rushing over Sandown Road in town of Danville

Town of Sandown

Reach UE06

The sixth reach on the Upper Exeter River was split into three segments due to a large wetland in the middle of the reach bounded by short segments of active stream channel. The reach begins just below the Odell Road culvert in Sandown where the large wetland in reach UE05 ends. The change from stream channel to wetland and back to stream channel is drastic in this reach.

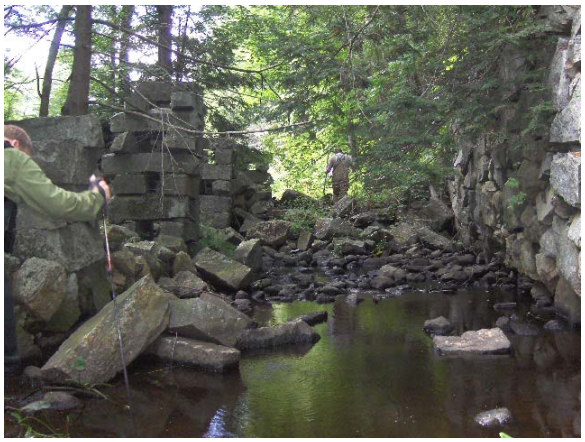

Figure 6.12 Exeter River IV Dam in UE06-A

Segment UE06-A begins downstream of the Odell Road culvert where the active stream channel begins and continues upstream beyond the culvert to the start of another wetland just upstream of an old dam. The dam layer from GRANIT includes this dam (Exeter River IV Dam) and indicates that it is in ruins (Figure 6.12). The culvert at Odell Road looks fairly new. Cobble sized rip rap was noted to be falling into channel on the downstream end.

This rip rap could be replaced with vegetation to prevent further rip rap failure (Figure 6.13).

Though it has a defined stream channel, segment UE06-A is heavily influenced from the wetland in reach UE05 and does not have any defined riffles (Figure 6.14). The confinement of the channel varies from narrowly confined at the very top of the segment to unconfined for the rest. UE06-A is a Rosgen "C" channel that is in "fair" condition due to lack of riffle features with dominant buffer widths of greater than 150 feet. Japanese knotweed and barberry (invasive species) are present along the near bank and roadside in segment UE06-A.

Figure 6.13 Failing rip rap in UE06-A at Odell Road crossing in town of Sandown

Figure 6.14 Typical channel in UE06-A

Segment UE06-B is classified as a palustrine shrub scrub wetland that is seasonally flooded and saturated according to NWI (Figure 6.15). This segment begins at the Exeter River IV Dam and continues upstream for 1034 feet. The wetland is minimally impacted and has buffer widths of greater than 150 feet on both sides.

Figure 6.15 Wetland in UE06-B upstream of former Exeter River IV Dam (west of Odell Road)

Segment UE06-C begins upstream of the wetland in UE06-B where the active stream channel begins, and continues upstream to Densen Dam. One island was noted just downstream of the dam, and a foot bridge crosses the channel just below the dam. This segment has good floodplain access and looks very stable (Figure 6.16). There was some minor lateral bank erosion and a high width to depth ratio due to a flood chute.

Segment UE06-C is a "C" channel in good condition with buffer width greater than 150 feet on both banks. The RHA also scored in the good category. A good portion of this segment and its surrounding land is conserved within the Densen Easement. The easement includes just over 35 acres including much of Densen Pond in reach UE07. An additional 138 acres of land adjacent to this conserved tract owned by the Town of Sandown was conserved in 2008 by the Southeast Land Trust. This newly conserved land extends from the large bend in the river (approximately 500 feet below Densen Pond dam) to Odell Road.

Figure 6.16 Typical channel in UE06-C below Densen Pond Dam

Reach UE07

The seventh reach on the Upper Exeter River begins at Densen Dam (constructed in 1760). The entire reach is classified by NWI as a palustrine wetland with an unconsolidated bottom that is permanently flooded due to an impoundment (Figure 6.17). Much of the land surrounding UE07 is conserved within the Densen Easement that also includes land surrounding segment UE06-C. This reach has dominant buffers of greater than 150 feet with some minor encroachment from Fremont Road at the upper end of the reach.

Figure 6.17 UE07 above Densen Dam

Reach UE08

Reach UE08 was split into four segments due to alternating stream channel and wetlands. The reach begins at the end of the wetland in UE07 and ends at the Phillips Road culvert.

UE08-A is a short segment of stream channel that extends for 365 feet from the Fremont Road crossing in Sandown to the Exeter River II Dam. The dam has been breached and may be a good candidate for removal (Figure 6.18). The dam has caused major planform alterations in the segment, including a large island and an extremely wide bankfull width. This segment has undergone extensive straightening and both banks have been extensively armored. Both Sargent Road and Fremont Road run along the banks of portions of this segment. UE08-A has undergone a stream type departure from a reference "C" to an "F" channel as a result of the encroaching roads and the breached Exeter River II Dam.

The RHA in UE08-A scored in the "fair" category for a number of reasons, including an extremely high width to depth ratio and extensive channelization. The riparian buffers were also inadequate with significant areas of buffers less than 25 feet where the channel runs along the road.

Figure 6.18 Breached Exeter River II Dam in UE08-A above the Fremont Road crossing in Sandown

Segment UE08-B was observed to be a wetland by the field team; however it has not been classified by the NWI. This segment begins above the breached Exeter River II Dam and it was found to be generally unimpacted and in good condition with buffer widths greater than 150 feet. There is a minor human caused change in valley width from Fremont Road.

UE08-C is a channel segment located between two wetlands. The segment is in a remote location with little impact from human activities. There is an old bridge abutment located at the upper end of the segment and some evidence of an old rock wall (property boundary) running along the south bank in some locations. This segment is a "B" stream type in good condition with a riffle-pool bedform (Figure 6.19). The habitat also rated in good condition in this segment, with buffer widths of greater than 150 feet on both sides.

Segment UE08-D is classified by NWI as a palustrine forested wetland that is seasonally flooded and saturated (Figure 6.20). This segment is in good condition with dominant buffer widths of greater than 150 feet on both sides, and minimal impact from Phillips Road as it crosses the wetland at the upstream end of the segment.

Figure 6.19 Typical channel in UE08-C below Phillips Road crossing in Sandown

Figure 6.20 Wetland in UE08-D, located downstream of Phillips Road in Sandown

Reach UE09

Reach UE09 (Lily Pond) is classified as a palustrine wetland with an unconsolidated bottom that is permanently flooded (Figure 6.21). This reach begins at the Phillips Road culvert and continues for approximately 1,985 feet. Lily Pond is relatively unimpacted and has dominant buffers of greater than 150 feet. A portion of land bordering Lily Pond on the south bank is contained within the Mugar-Eveillard Easement (Rockingham Land Trust), and a portion of land on the north bank in conserved within the Stoneford Parcel (Sandown). There are still large areas adjacent to both banks not currently protected by any conservation easements.

Figure 6.21 Lily Pond in UE09

Figure 6.22 Wetland in at Main Street Bridge crossing in Sandown

Reach UE10

The tenth reach on the Upper Exeter River is classified by NWI as a palustrine forested wetland that is seasonally flooded and saturated (Figure 6.22). This reach extends for 4,385 feet and is largely unimpacted with the exception of the Main Street Bridge in the Town of Sandown. UE10 has dominant buffers of greater than 150 feet. The field

team only observed the reach in the vicinity of the Main Street bridge, though a riparian landowner indicated that a beaver dam existed just downstream of the bridge.

Reach UE11

Reach UE11was split into two segments due to a change in channel dimensions. All of segment A is classified as a wetland according to NWI, whereas only a small portion of segment B is classified as a wetland and the segment has a more defined stream channel. The entire reach is remotely located, with no easy access from any nearby roads or developed areas. The lower end of UE11-A starts just north of Woodduck Circle. Segment UE11A is a palustrine wetland that is seasonally flooded and saturated according to NWI (Figure 6.23). This segment has buffers of greater than 150 feet and is in reference condition.

Figure 6.23 Wetland in UE11-A

Portions of segment UE11-B are also classified as seasonally flooded, forested, palustrine wetlands by NWI. This segment has a defined channel that is heavily influenced by the wetland in UE11-A. UE11-B is an "E" channel in reference condition with buffers of greater than 150 feet. The habitat was rated in good condition for this segment with lots of woody debris, undercut banks, and numerous refuge areas (Figure 6.24). Conversely, the stream bottom was very soft under foot and there was very little riffle coverage in the segment.

Figure 6.24 Undercut banks and woody debris in UE11-B

A small area at the extreme upstream end of UE11-B is contained within the Greenwood-Hooke conservation easement. This easement contains nearly 79 acres of land, including some of segment UE12-A.

Reach UE12

Reach UE12 was split into four segments due to changing stream types and sections of wetland. The reach begins downstream of the Wells Village Road culvert above the wetland in UE11-B and continues to the Deep Hole Pond Dam. The change from stream channel to wetland is extreme in this reach.

Segment UE12-A extends for 4,635 feet as an active stream channel. This segment is a "C" stream type with a riffle-pool bedform that is in good condition. The Exeter River I Dam once existed in this segment, but the dam is currently in ruins and few remnants were seen in the field. The culvert at Wells Village Road, though recently replaced, is undersized relative to stream channel dimensions in this segment (Figure 6.25). This undersized culvert has caused some major fine sediment aggradation above and significant scour both above and below the structure.

Figure 6.25 Undersized culvert at Wells Village Road

Figure 6.25 6.26 Typical channel in UE12-A

Aside from some aggradation due to the undersized culvert at Wells Village Road, this segment was in good geomorphic condition (Figure 6.26). The habitat in UE12-A was also good. One waterfall grade control at the downstream end of the segment is causing some problems for aquatic organism passage. The dominant buffer width in this segment is greater than 150 feet on both sides, with some minor influence from Wells Village Road on the north bank. Some of the Upper Exeter River in this segment between the downstream end of the reach and the former location of the Exeter River I Dam is contained within the Greenwood-Hooke conservation easement, which also includes a small portion of UE11-B.

Town of Chester

Most of segment UE12-B begins just west of the Sandown/Chester town lines and extends upstream to the power line crossing access road. This segment is classified by NWI as a palustrine, forested wetland that is seasonally flooded and saturated (Figure 6.27). This segment is a Rosgen "E" channel with a riffle-pool bedform that is in good condition. Three old abutments and dam remnants exist within this segment causing some minor localized planform adjustment. UE12-B is remotely located with dominant buffer widths of greater

Figure 6.27 Typical channel in UE12-B in Town of Chester

than 150 feet on both banks. The habitat in this segment also rated in the good category.

Most of UE12-C is classified by NWI as a palustrine wetland that is seasonally flooded and saturated (Figure 6.28). The upstream end of the segment has the same NWI classification along with beaver activity. UE12-C is an "E" stream type in reference condition with strong wetland influence. This segment is remotely located with buffers of greater than 150 feet on both sides and little human influence aside from a power line crossing which has gullies on the access road that are contributing sediment to the waterbody (see figure 6.29). There is opportunity to work with the power company to improve stormwater runoff from the access road.

Figure 6.28 Wetland in UE12-C in vicinity of power line access road in Chester

Figure 6.29 Gully erosion in UE12-C on powerline access road

UE12-D begins above the wetland in UE12-C and continues to the Deep Hole Pond Dam. The segment is a bedrock gorge "G" stream type with a step-pool bedform in good condition (Figure 6.30). This segment is also remotely located with a buffer width of greater than 150 feet on each side. There is one old abutment in UE12-D at the very top of the segment, just downstream of the Deep Hole Pond Dam causing minor deposition above and below (Figure 6.31).

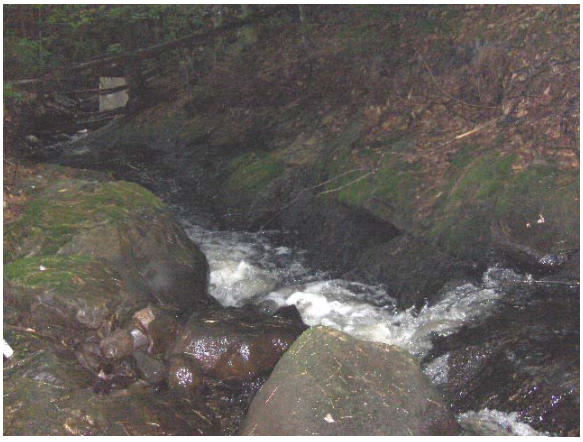

Figure 6.30 Bedrock gorge in UE12-D below Deep Hole Pond in Chester

Figure 6.31 Old abutment in UE12-D downstream of Deep Hole Dam

Reach UE13

Reach UE13 (Deep Hole Pond) begins at the Deep Hole Pond Dam, located off of Deep Hole Road in Chester, and is classified as a palustrine wetland with an unconsolidated bottom that is semi-permanently flooded and has some beaver activity (Figure 6.32). This reach was difficult to access as it is located a good distance from any roads. The pond has buffers of greater than 150 feet on both banks. Some development activities were observed by the field team at the end of Deep Hole Road, though the extent of this development is unknown.

Figure 6.32 Deep Hole Pond in UE13

Reach UE14

The fourteenth reach on the Upper Exeter River is a 4,262 foot long reach that was broken into four segments during the Phase 2 assessment. The lowest segment is a wetland, the next segment has a stream channel but is heavily influenced by the wetland downstream, the third segment is an active stream channel, and the upper-most segment is also a wetland. The change between stream channel and wetland within this reach was drastic.

Segment UE14-A begins at the upstream end of Deep Hole Pond and continues for 1235 feet to the end of the wetland. The lower end of this segment is classified by NWI as a palustrine forested wetland that is semi-permanently flooded and has beaver activity. The upper end of this wetland has a similar NWI classification but is only seasonally flooded and saturated (Figure 6.33). This wetland is also remotely located with buffers of greater than 150 feet on both sides and it is in reference condition with few anthropogenic impacts.

Segment UE14-B is a short segment above the wetland in UE14-A. This segment is a "C" stream type in reference condition that has very deep pools due to heavy influence from the wetlands downstream (Figure 6.34). This segment is also remotely located with a buffer width of greater than 150 feet on both sides.

Figure 6.33 Wetland in UE14-A, located north of Haverhill Road and south of Wells Village Road in Chester

Figure 6.34 Channel in UE14-B is influenced by wetland

UE14-C is an extremely stable stream channel segment with dense moss cover on its banks, a stable planform, and good floodplain access (Figure 6.35). This segment is a Rosgen "C" stream type with a riffle-pool bedform that is in reference geomorphic condition. The RHA in UE14-C was rated at the upper end of the good range. All of the RHA parameters were rated as "good" or "reference". There is good tree cover on both banks that have not fallen to create more woody debris cover because the banks are so stable.

Most of segment UE14-D is classified by NWI as a palustrine wetland that is seasonally flooded, with one area at the upper end of the segment that is permanently flooded with an unconsolidated bottom (Figure 6.36). This wetland segment is in reference condition with dominant buffers greater than 150 feet and minimal influence from Sandown Road at the upper end.

Figure 6.35 Stable banks in UE14-C, upstream of powerline crossing in Chester

Figure 6.36 Wetland in UE14-D

Reach UE15

UE15 is a 4,802 foot reach that was split into four segments due to different stream types. The reach starts approximately 1,650 feet below Haverhill Road and ends about 1800 feet above Derry Road. The Upper Exeter River is a stream channel, rather than wetland, in this entire reach. The lower end of the reach starts at the wetland/stream channel break at the upper end of UE14-D and extends upstream to where there is a change to a large wetland pond.

Figure 6.37 Bedrock grade control in UE15-A

The lowest segment in the reach (UE15-A) has a narrower valley than the other segments with a semi-confined valley type. This segment also has a higher gradient than the other segments in UE15 and a resulting stream type of a Rosgen "B" channel with a step-pool bedform. Segment UE15-B has multiple bedrock grade controls and very little bank erosion (Figure 6.37). The RGA scored in the "good" range with some very minor aggradation and planform adjustment noticed by the field team.

The RHA was rated in the "fair" range due to low woody debris cover, lack of deep pools, and little to no connectivity as a result of extensive channel spanning bedrock grade controls resulting in reduced aquatic organism passage through this segment. The dominant buffer width was 100-150 feet on both banks in this segment.

Figure 6.38 Undersized culvert in UE15-B at Haverhill Road crossing in the Town of Chester

UE15-B begins above the bedrock dominated section where the valley walls open up and continues upstream for about 1301 feet. This segment is a Rosgen "C" channel in "fair" geomorphic condition due to major historic degradation and major aggradation (mid channel bars, one steep riffle, and one diagonal bar) within the channel. The upper part of the segment has been historically channelized and stabilized with bank armoring. There are two undersized culverts and an old abutment structure causing problems in this segment (Figure 6.38).

The habitat in UE15-B scored in the "fair" range. Extensive woody debris cover was lacking and the pools in the segment were not much deeper than the runs. Additionally the riparian buffers could use improvement, with a dominant buffer width of 26-50 feet on the north bank and 51-100 feet on the south bank, while both banks had approximately 150 feet of residential land use with buffers less than 25 feet.

Figure 6.39 Rejuvenating tributary in UE15-C below Derry Road crossing

Segment UE15-C begins just upstream of a small culvert in the middle of an agricultural field and has been channelized along the edge of the field for 925 feet, ending about 80 feet downstream of the Derry Road culvert. This segment is classified by NWI as a palustrine, scrub-scrub and forested wetland that is seasonally flooded. It appears that the defined stream channel in this segment has been man-made to form one channel and drain the surrounding wetlands for agricultural use. The upper most part of this segment is still a wetland complex, and there is a rejuvenating tributary and head cut at the point where channelization stops (Figure 6.39). The head cut is working its way upstream and is causing the channel to incise. UE15-C is currently a Rosgen "Bc" channel which is a stream type departure from a wetland. The extensive channelization within this segment has resulted in a loss of floodplain access and a geomorphic condition of "fair". There is great opportunity at this site for restoring wetland functions as well as the stream channel.

The RHA in UE15-C ranked in the "poor" category. There was almost no woody debris cover, few deep pools or refuge areas, extensive channel alteration, and poor riparian buffers for most of the segment (Figure 6.40).

Segment UE15-D begins just below the Derry Road culvert and continues for 1,881 feet to the start of a major wetland and beaver pond. There is a palustrine, forested, seasonally flooded wetland adjacent to the channel at the lower end of the segment. UE15-D is a multi-thread Rosgen "D" channel with a braided bedform (Figure 6.41). This segment is in "good" geomorphic condition, with just some minor planform adjustment due to a high width to depth ratio. This segment is relatively unimpacted by human activities with a dominant buffer width of greater than 150 feet on both sides. A rock wall (old property boundary) runs along a portion of the upper end of the channel. The RHA was also in "good" condition, only slightly encumbered by a small wetted width.

Figure 6.40 Typical channel in UE15-C downstream of Derry Road in Chester

Figure 6.41 Typical channel in UE15-D

Reach UE16

The most upstream reach on the Upper Exeter River is classified by NWI as a palustrine wetland that is semi-permanently flooded and has been created or modified by beaver activity. UE16 begins at a large beaver dam (Figure 6.42) and was only assessed by the field team at the downstream end of the reach. The reach is remotely located and unimpacted by human activities, with buffer widths of greater than 150 feet on both sides.

Figure 6.42 Beaver dam in UE16 in headwaters of the Upper Exeter River

Upper Exeter River Phase 2 Summary

Table 6.2 summarizes the channel geometry ratios, reference and existing stream types, channel evolution stages, and active adjustment processes for the Upper Exeter River reaches. Two reaches were found to be undergoing extreme adjustment. Extreme planform adjustment and major aggradation in segment UE08-A above Fremont Road is associated with the breached Exeter River II Dam. Channel straightening is likely responsible for an active head cut (extreme degradation) in segment UE15-C. Figure 6.43 illustrates the RGA condition for reaches and segments in the Upper Exeter River subwatershed.

Table 6.2
Upper Exeter River: Stream Type and Channel Evolution Stage

Segment Number	Entrench-ment Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Active Adjustment Process
UE01	Partial assessment due to wetland influence					
UE02	Partial assessment due to wetland influence					
UE03	10.6	42	C4	C4	FI	Widening Planform
UE04-A	Partial assessment due to extremely wide bankfull width					
UE04-B	Wetland					
UE05	Wetland					
UE06-A	Partial assessment due to wetlands downstream					
UE06-B	Wetland					
UE06-C	9.4	38.4	C3	C3	DIIc	Aggradation Widening Planform
UE07	Wetland/Pond					
UE08-A	1.1	46.2	C3	F3	FIII	**Aggradation Planform**
UE08-B	Wetland					
UE08-C	1.4	28.4	B3	B3	FI	Widening Planform
UE08-D	Wetland					
UE09	Wetland/Pond					
UE10	Wetland					
UE11-A	Wetland					
UE11-B	Partial assessment due to wetlands downstream					
UE12-A	2.2	11.9	C4	C4	DIIc	**Aggradation** Planform
UE12-B	4.0	10.5	E4	E4	FI	Aggradation Planform
UE12-C	Partial assessment due to wetland influence					
UE12-D	Partial assessment due to bedrock gorge					
UE13	Wetland/Pond					
UE14-A	Wetland					
UE14-B	Partial assessment due to wetlands downstream					
UE14-C	7.5	13.7	C4	C4	FI	
UE14-D	Wetland					

Table 6.2
Upper Exeter River: Stream Type and Channel Evolution Stage

Segment Number	Entrench-ment Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Active Adjustment Process
UE15-A	1.8	10.6	B3	B3	FI	Aggradation Planform
UE15-B	29.5	15.3	C4	C4	FII	**Aggradation** Planform
UE15-C	2.0	8.9	Wetland	B5	FII	**Degradation** Aggradation
UE15-D	3.2	51.6	D4	D4	FI	Planform
UE16	Wetland/Pond					

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

Table 6.3 shows a comparison of the habitat condition based on the Rapid Habitat Assessment (RHA) and the geomorphic condition based on the Rapid Geomorphic Assessment (RGA).

Table 6.3
Comparison of RHA and RGA Scores for Phase 2 Reaches

Segment Number	RHA Score	RHA Condition	RGA Score	RGA Condition
UE03	0.61	Fair	0.75	Good
UE06-C	0.69	Good	0.74	Good
UE08-A	0.43	Fair	0.41	Fair
UE08-C	0.69	Good	0.80	Good
UE12-A	0.78	Good	0.68	Good
UE12-B	0.79	Good	0.71	Good
UE14-C	0.81	Good	0.90	Reference
UE15-A	0.59	Fair	0.81	Good
UE15-B	0.52	Fair	0.59	Fair
UE15-C	0.33	Poor	0.63	Fair
UE15-D	0.68	Good	0.79	Good

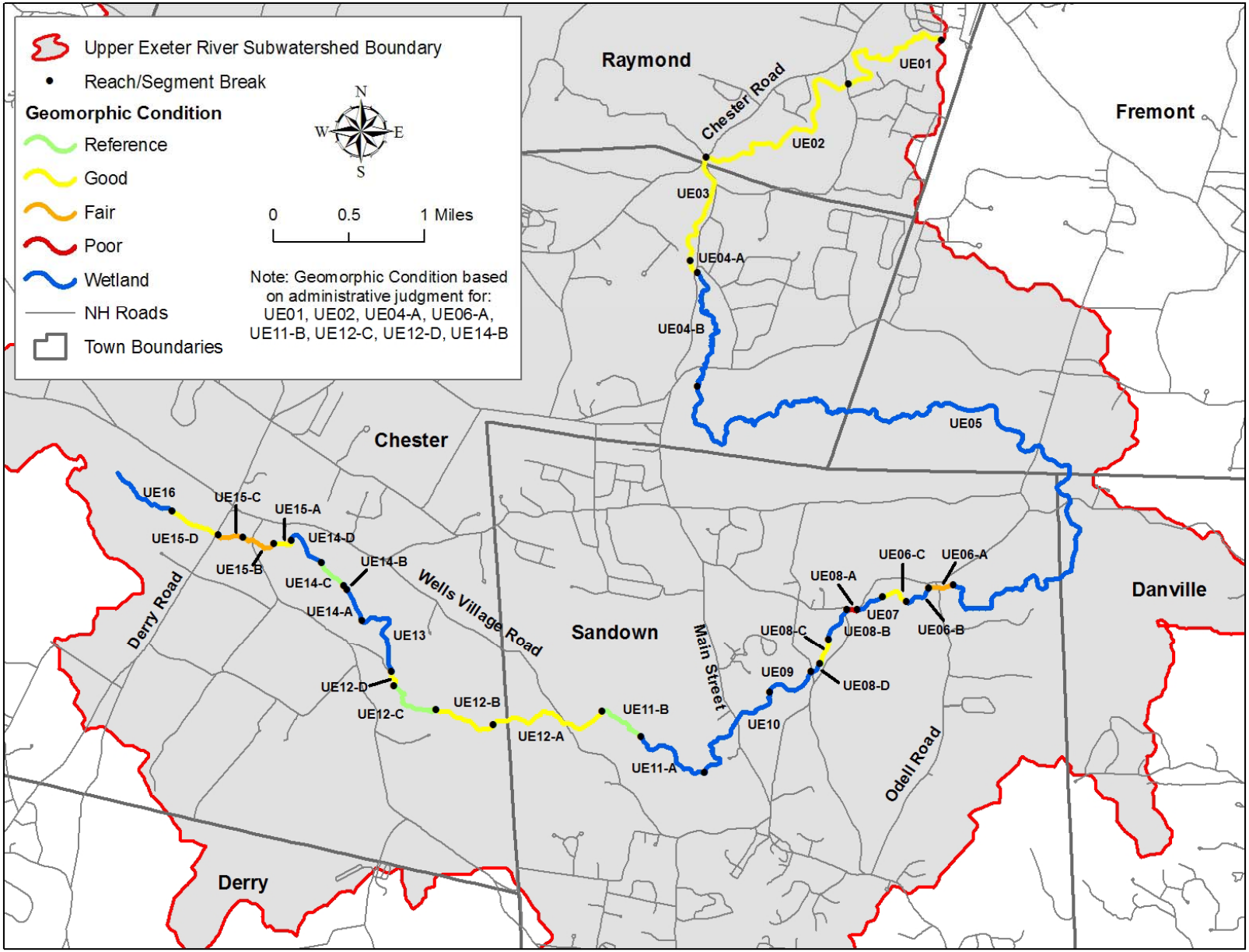

Figure 6.43 Upper Exeter River reach condition map for the Phase 2 Geomorphic Assessment

6.3 Upper Exeter River Bridge and Culvert Assessment

Table 6.4 summarizes the data collected for ten bridges and eight culverts in the Upper Exeter River subwatershed. The final column of the table includes a prioritization of structures for replacement or retrofit based on a review of the following four criteria: structure width in relation to bankfull channel width; structure flood capacity; aquatic organism passage; geomorphic compatibility. Eight of the structures are located in a non fluvial system (wetland) and were not evaluated using the geomorphic screening tool. Additional summaries (including photos) for all moderate and high priority structures are provided in Appendix B. A summary of the methods and results for the watershed hydrologic modeling to determine each structure's flood capacity is included in Appendix C. Also included in Appendix C is an explanation of how structures were selected for flood capacity modeling based on the field data for geomorphic compatibility, aquatic organism passage and other local knowledge.

Figure 6.44 depicts the aquatic organism passage barriers for the Upper Exeter River subwatershed, including culvert crossings and grade controls. Eight culverts, three locations with bedrock ledge, one waterfall, and two dams were identified as reducing aquatic organism passage.

Table 6.4
Upper Exeter River Crossings

Reach/ Segment No.	Road Name, Town	Structure Type	Condition/ Observation	Percent Bankfull Channel Width[1]	Structure Capacity for Flood Events (Percent Capacity)[2]		Aquatic Organism Passage (AOP)[3]	Geomorphic Compatibility[4]	Priority for Replacement/ Retrofit
					25 Year Storm	50 Year Storm			
UE02	Blueberry Hill Road, Raymond	Bridge	Looks good overall	58%	--------	--------	NA	Partially compatible	Low
UE03	Hanson Road, Chester	Bridge	Some scour above and below	30%	--------	--------	NA	Partially compatible	Low to Moderate
UE4-A	Shepard Home Rd., Chester	Culvert	No problems noted; wetlands upstream and downstream of culvert	37%	--------	--------	Reduced AOP	W[5]	Low
UE4-B	Fremont Road, Chester	Bridge	No major problems noted; wetlands upstream and downstream of bridge	43%	--------	--------	NA	W	Low
UE05	Sandown Road, Fremont	Bridge	Sandown Road bridges in Fremont are side by side; therefore, percent bankfull is not accurate; wetlands upstream and downstream of bridges	20%	--------	--------	NA	W	Low
UE05	Sandown Road, Fremont	Bridge		34%	--------	--------	NA	W	Low

[1] Shaded for bankfull width percentage less than 50% ; [2] Shaded for capacity of less than 100%; [3] Aquatic Organisms Passage ratings developed with the VTANR methodology (not applicable to bridges); [4] Scores and ratings developed with the VTANR Geomorphic Compatibility Screening Tool;
[5]W – Screening tool not applicable for non-fluvial (wetland) reaches.

Table 6.4
Upper Exeter River Crossings

Reach/ Segment No.	Road Name	Structure Type	Condition/ Observation	Percent Bankfull Channel Width[1]	Structure Capacity for Flood Events (Percent Capacity)[2]		Aquatic Organism Passage (AOP)[3]	Geomorphic Compatibility[4]	Priority for Replacement or Retrofit
					25 Year Storm	50 Year Storm			
UE05	Sandown Road, Danville	Culvert	Paved Road is blown out; downstream end of culvert in poor condition; wetlands upstream and downstream of culvert	12%	13%	10%	Reduced AOP	W	High
UE05	Private trail, Sandown	Bridge	In wetland just downstream of washed out culvert	106%	------	-------	NA	W	Low
UE06-A	Odell Road, Sandown	Culvert	Coarse gravel to cobble sized bank armoring washing in channel; culvert looks new	30%	------	-------	Reduced AOP	Partially Compatible	Low to Moderate
UE06-C	Pedestrian Path, Sandown	Bridge	Looks stable; minor failing of hard bank armoring	68%	------	-------	NA	Partially Compatible	Low
UE08-A	Fremont Road, Sandown	Bridge	Alignment problem	28%	170%	127%	NA	Fully Incompatible	Moderate
UE08-D	Phillips Road, Sandown	Culvert	Could not access culvert – too deep; wetlands upstream and downstream of culvert	22%	--------	--------	Reduced AOP	W	Low

[1] Shaded for bankfull width percentage less than 50% ; [2] Shaded for capacity of less than 100%; [3] Aquatic Organisms Passage ratings developed with the VTANR methodology (not applicable to bridges); [4] Scores and ratings developed with the VTANR Geomorphic Compatibility Screening Tool
[5]W – Screening tool not applicable for non-fluvial (wetland) reaches.

Table 6.4
Upper Exeter River Crossings

Reach/ Segment No.	Road Name	Structure Type	Condition/ Observation	Percent Bankfull Channel Width[1]	Structure Capacity for Flood Events (Percent Capacity)[2]		Aquatic Organism Passage (AOP)[3]	Geomorphic Compatibility[4]	Priority for Replacement or Retrofit
					25 Year Storm	50 Year Storm			
UE10	Main Street, Sandown	Bridge	Wetland upstream and downstream	39%	--------	--------	NA	W	Low
UE12-A	Wells Village Road, Sandown	Culvert	Extreme scour above and below structure; deposition above	33%	161%	114%	Reduced AOP	Mostly Compatible	Moderate[3]
UE14-C	Power Lines off Route 121, Chester	Bridge	Failing riprap obstructing inlet	41%	205%	148%	NA	Mostly Incompatible	Moderate
UE15-B	Farm crossing, Chester	Culvert	Channelized above culvert	13%	34%	24%	Reduced AOP	Mostly Incompatible	Moderate
UE15-B	Haverill Road, Chester	Culvert	Old Stone culvert; poor alignment	14%	111%	78%	Reduced AOP	Mostly Incompatible	Moderate
UE15-D	Derry Road, Chester	Culvert	Culvert is backwatered; wetland downstream of culvert	45%	--------	--------	Full	Partially Compatible	Low to moderate

[1] Shaded for bankfull width percentage less than 50% ; [2] Shaded for capacity of less than 100%; [3] Aquatic Organisms Passage ratings developed with the VTANR methodology (not applicable to bridges); [4] Scores and ratings developed with the VTANR Geomorphic Compatibility Screening Tool
[5]Screening tool not applicable for non-fluvial (wetland) reaches.

[3] Culvert at Wells Village Road did not meet minimum criteria (mostly or fully incompatible and/or structure lacks capacity to pass 25 year storm) for moderate and high priority structures, but was given a moderate rating due to extreme scour below the structure and deposition upstream.

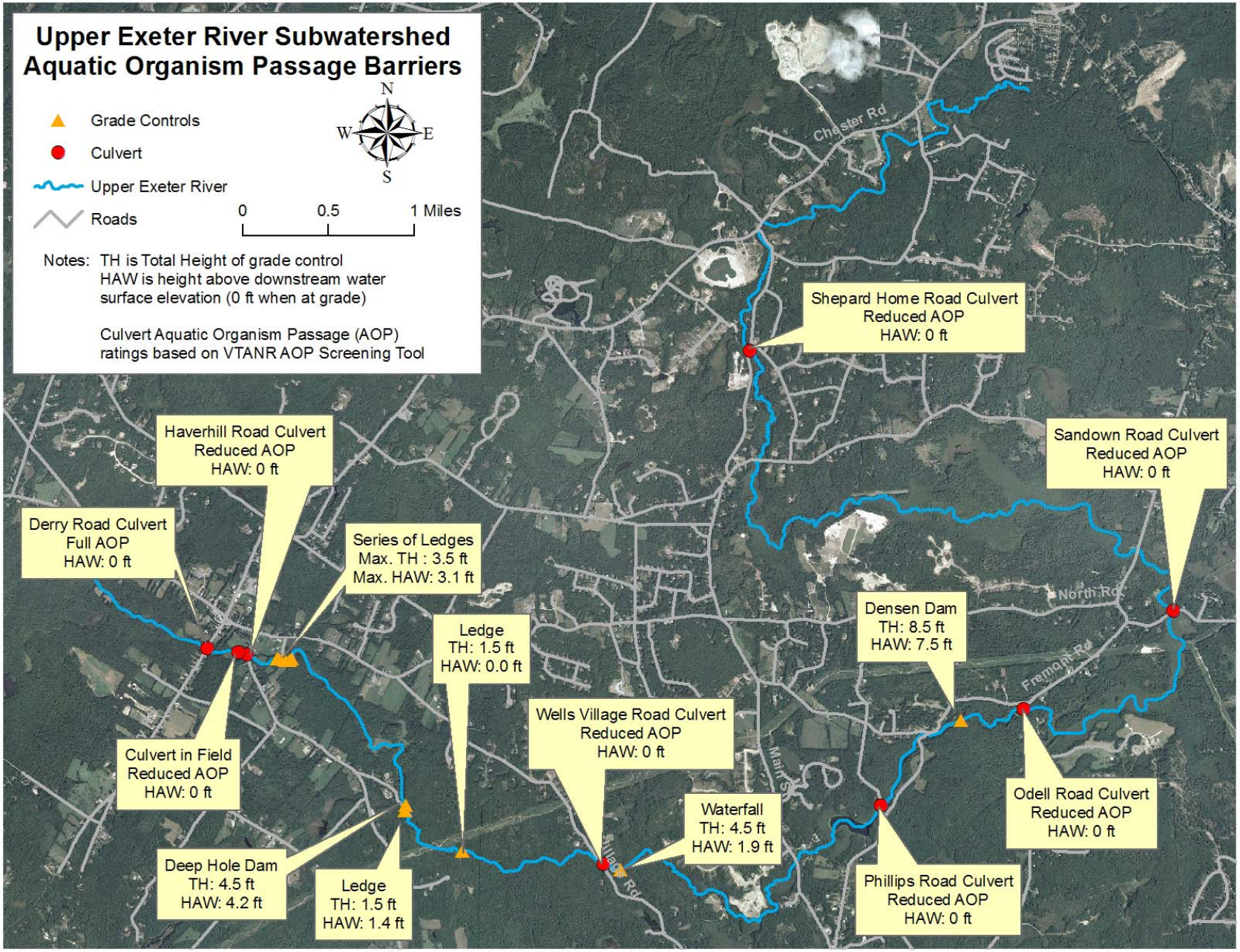

Figure 6.44 Aquatic organism passage barriers in the Upper Exeter Subwatershed

6.4 Upper Exeter River Corridor Planning

6.4.1 Stressor Maps

Stressor, departure and sensitivity maps are presented here as a means of displaying the effects of all significant physical processes occurring within the Upper Exeter River subwatershed that were observed during the Phase 2 Stream Geomorphic Assessment. Stressor maps are included in Appendix D. 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 channel adjustments within the watershed. This is helpful in developing and prioritizing potential protection and restoration projects.

Land Cover

The Upper Exeter River subwatershed has a mixture of land use types. Forest and wetland are dominant, but significant areas of agricultural land use also exist. The most significant areas of urban land use are found in the area of new development off of Main Street near UE10 an UE11-A, and in the area near the Chester Rod and Gun Club in reach UE04. The Exeter River Vulnerability Analysis (Geosyntec, 2008) found the Upper Exeter River subwatershed to rank near the middle of the range (4.9%) in the Exeter River watershed for impervious cover in 2005. This represents a low degree of impervious cover, below levels typically associated with degraded streams at the national level (CWP, 2003). However, 4% impervious cover appears to be a threshold above which Eastern brook trout have been documented to disappear from subwatersheds (Hilderbrand et al. 2008).

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 and manipulation of water at the watershed scale. When the hydrologic regime has been significantly changed, 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).

Much of the land adjacent to the Upper Exeter River is wetland. Analysis of hydric soils located where current land uses are agricultural or urban indicates some minor loss of wetlands within the Upper Exeter River subwatershed. The loss of wetlands decreases the attenuation of peak flows within the watershed. Based on hydric soils in areas that are urban or agricultural, the Upper Exeter River has experienced wetland loss of just over 3 percent of the subwatershed area.

Roads contribute to localized increased flows resulting both from increased runoff and stormwater ditching. The Upper Exeter River subwatershed has a modest network of roads as illustrated in the Upper Exeter River Hydrologic Regime map in Appendix D. Four areas within the subwatershed have road densities greater than or equal to 5 miles per square mile (UE01, UE04, UE08 and UE09). Subwatersheds UE03 (Shepard Home Road), UE10 (Main Street) and UE15 (Haverhill Road and Derry Road) have road densities of between 4 and 5 miles per square mile. All other subwatersheds within the study area have road densities less than 3 miles per square mile. 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 mile/ square mile account for approximately 44 percent of the entire Upper Exeter River subwatershed.

Sediment Load Indicators

Localized areas of depositional features and channel migration features are prevalent within the Upper Exeter River subwatershed. Planform adjustment is an extreme active adjustment process in segment UE08-A due to a breached dam (Exeter River II Dam). This structure is impacting the channel morphology downstream of the structure where the bankfull width is extremely wide due to a large island. This segment also has roads on both banks limiting floodplain access, resulting in a stream type departure. Segments UE12-A and UE15-B are undergoing major aggradation and minor planform adjustment. Segment UE15-C has undergone a stream type departure from a wetland to a "B" channel as a result of stream channel alteration. Bank erosion is minimal along the Upper Exeter River and only one mass failure (UE12-A) and two gullies (UE12-B & UE12-C) were observed in the subwatershed.

Channel Slope and Depth Modifiers

Corridor encroachment and development within the Upper Exeter River subwatershed has been highlighted on the Slope and Depth Modifiers map (Appendix D) for areas where natural channel sinuosity may be decreased. In these areas, increased channel slopes may cause reduced floodplain function because the channel has greater capacity to hold larger flow events within the channel, rather than spilling onto the floodplain. Beaver dams are common on the Upper Exeter River. Although these features are ephemeral, they do temporarily control vertical channel adjustments and have been shown to help maintain floodplain function in low-gradient urban streams (Fitzgerald, 2007). Channel straightening was noted in some locations along the Upper Exeter River where the channel runs adjacent to a road, through highly managed agricultural land, or where historic abutments existed.

Two active dams are found along the Upper Exeter River, Densen Dam and Deep Hole Dam. Densen Dam is located in the Town of Sandown off of Fremont Road. Densen Pond, located upstream of the dam, extends approximately 1060 feet upstream to the Fremont Road bridge. Densen Dam does not have a fish ladder. An overflow side

channel was mapped downstream of the dam. A small island is present just below the dam.

Three mills (Fuller's Mill, Sanborn Mill and Hook's Mill) were established in Sandown in the 1760s (Holmes 1988). Fuller's Mill was formerly located by Fremont Road and Sargent Road. Fuller's Mill became Clark's Mill in 1780 (Tardiff 2004; Holmes 1988). Clark's Mill is listed in by Tardiff (2004) as a saw and grist mill. The Exeter River II Dam located upstream of Fremont Road in segment UE8-A at the former location of Clark's Mill is breached. Sanborn Mill was located at the Densen Pond dam that is still active. The Exeter River IV Dam off of Odell Road, which is in ruins, was the home of Hook's Mill (Holmes 1988).

Based on field observations and the New Hampshire dam GIS layer, the Exeter River I Dam in Sandown below Wells Village Road and near Hazelton Mills Road in segment UE12-A is breached. This may be the former mill that Tardiff (2004) identifies as Hazelton's Mill in her book. According to Tardiff, Hazelton's Mill was established in the early 1800s and was a shingle and clapboard manufacturer.

Deep Hole Dam is the second active dam in the Upper Exeter River subwatershed. This active dam is located beyond the dead end of Deep Hole Road in the Town of Chester in reach UE-13. Some development activities were observed at the end of Deep Hole Road but the extent of this development is unknown. The wetland/pond above the dam extends approximately 0.8 miles upstream to the start of a defined stream channel near the power line crossing between Sandown Road and Haverhill Road. Deep Hole Dam does not have a fish ladder.

Riparian and Boundary Condition

The Riparian and Boundary Conditions map highlights areas where human alterations to the river boundaries have increased or decreased the resistance of the banks and bed to channel adjustments. In general, the Upper Exeter River has healthy riparian vegetation alongside the channel, but numerous isolated areas of reduced riparian vegetation were observed. Several areas of moderate bank erosion have made the channel prone to lateral adjustments (e.g., further bank erosion and widening). Some channel armoring near the Haverhill Road culvert, the Fremont Road Bridge, and where the channel runs along Shepard Home Road has reduced the potential for bank erosion.

6.4.2 Departure Analysis

The sediment regime is the quantity, size, transport, sorting and distribution of sediments. The sediment regime may be influenced by the proximity of sediment sources, the hydrologic regime, and the specific morphology of the valley, floodplain, and stream. The sediment regime departure map in Appendix D shows the Phase I reference stream sediment conditions for each reach within the stream network. These reference type streams use available floodplain access as a means to store sediment within the watershed. The majority of the stream network has a reference sediment

regime of an *Equilibrium Channel*. Some more confined and bedrock dominated reaches are *Transport* segments by reference (UE08-C, UE12-D and UE15-A).

Changes in hydrology (primarily development within the riparian corridor) and sediment storage within the subwatershed have altered the reference sediment regime types for some reach segments. The existing sediment regime for the Upper Exeter River subwatershed includes reduced floodplain access, increased stream power, minor reduced boundary resistance, and minor lateral constraints at various locations throughout the stream network. Sediment regime departures were derived from the sediment regime criteria established by the Vermont Agency of Natural Resources (2007c). One segment (UE08-A) that was an *Equilibrium Channel* by reference has been converted to a *Fine Source and Transport* sediment regime based on the Phase 2 Stream Geomorphic Assessment data. This means that most fine sediment entering the stream is either being transported through without being deposited as a result of channel incision and reduced floodplain access. Two segments (UE15-B & UE15-C) that were *Equilibrium Channels* by reference have been converted to *Unconfined Source and Transport* sediment regimes due to increased transport capacity derived from bank armoring and channel straightening

6.4.2 Sensitivity Analysis

The Upper Exeter River Stream Channel Sensitivity map in Appendix D presents the stream sensitivity, generalized according to stream type and condition, and current adjustments for each reach segment in the Upper Exeter River subwatershed. There are many variables that contribute to the sensitivity of the streams in the Upper Exeter River subwatershed. Well established bank vegetation has helped to improve the boundary conditions between water and land and has reduced the sensitivity of many sections of the Upper Exeter River that are well buffered. Removal of this vegetation tends to make stream segments more sensitive to channel adjustment. The location and slope of a stream also affects is morphology and sensitivity. Streams that are transporting sediment through the channel are less sensitive than streams that are storing and responding to sediment. Low gradient streams, like most segments in the Upper Exeter River subwatershed, with high sediment supplies are very sensitive and may undergo adjustment following minor changes in channel geometry or boundary conditions.

6.4.3 FEH Zones

A summary of the FEH zones developed for the Upper Exeter River subwatershed is included in Appendix E. Included in Appendix E is: 1) a complete summary of the methods used to develop FEH zones, 2) a summary table comparing the stream channel sensitivity assigned to each corridor with the degree of protection afforded by wetlands and conserved lands within the corridor, and 3) maps depicting the FEH corridors, sensitivity ratings, and other aspects related to corridor protection.

6.5 Upper Exeter River Project Identification

The site level projects that were developed for the Upper Exeter River are provided below in Table 6.5 with photographs of the projects included in Appendix F. The project strategy, technical feasibility, and priority for each project are listed by project number and reach. A total of 22 projects were identified to promote the restoration or protection of channel stability and aquatic habitat in the Upper Exeter River subwatershed. The table summarizes key information for each project, including the project strategy, technical feasibility, and priority based on scientific data and stakeholder input. The 22 projects are further broken down by category as follows: 13 active geomorphic restoration; 1 passive geomorphic restoration; 6 conservation, and 2 stormwater mitigation. The active restoration projects include: 7 road crossings, removal of 2 relict dams, the removal of 2 active dams, and the restoration of a channel that is actively incising.

The project locations and categories identified for the Upper Exeter River subwatershed are depicted below in Figure 5.47. Six high priority projects have been identified. The high priority projects are spaced throughout the watershed in the Towns of Danville, Sandown, and Chester. These high priority projects include:

- **Active restoration** by replacing undersized culvert at Sandown Road in Danville (project #2);
- **Conservation** between Fremont Road and Phillips Road crossings in Sandown (project #8);
- **Conservation** of river corridor from east of Wells Village Road to Deep Hole Pond (project #12);
- **Conservation** of river corridor between Sandown Road and Haverhill Road in Chester (project #15);
- **Active restoration** by arresting active incision and restoring channel and wetland (project #21);
- **Conservation** of river corridor west of Derry Road culvert to headwaters (project #22).

Table 6.5. Upper Exeter River Brook Site Level Opportunities for Restoration and Protection

Project #, Location/Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#1 West of Shepard Home Road in Chester Reach UE03	Conservation	Channel is in good condition with dominant buffer widths of greater than 150 feet. Both banks have some small areas at lower end of reach with limited buffers due to road encroachments. A 15 acre conserved tract of land owned by Town on Chester is on west side of river. Opportunity for conserving riparian corridor in areas where existing corridor is wide.	Conservation-Corridor Easement	Moderate	Moderate	Protected floodplains allow for attenuation of fine sediment and floodwaters.	Moderate costs for easement acquisition. Parcel ownership and zoning needs further investigation	Previous work may have been conducted on this situation; conduct further research	Town of Chester, ERLAC, NHDES, adjacent landowners
#2 Sandown Road culvert in Danville 42.95734 N 71.14766 W Reach UE05	Active Restoration	Culvert in wetland at Sandown Road crossing in Danville has washed out; modeling supports culvert having reduced flood capacity. High priority given road is closed; engineering work required to confirm replacement culvert is properly sized.	Replace Sandown Road culvert	High	Low	Road could be reopened	Moderate to high costs of design and replacement of culvert; road will need to be repaired		Town of Danville, NHDES, ERLAC, NHFGD
#3 Odell Road culvert in Sandown 42.94893 N 71.16480 W Segment UE06-A	Active Restoration	Culvert at Odell Road in Sandown has coarse gravel to cobble sized bank armoring that is washing into channel; culvert has reduced AOP and is undersized relative to the bankfull channel width. The culvert looks new.	Streambank restoration; consider replacing culvert at some point	Low	Moderate	Improved stability and shading	Relatively low costs for removing small sized riprap, native plant materials and labor		Town of Sandown, NHDES, ERLAC
#4 Upstream from Odell Road culvert in Sandown 42.94886 N 71.16625 W Segment UE06-A	Active Restoration	Dam (Exeter River IV) in ruins. Low priority for removal due to localized benefit and difficult access. Alternatives analysis could be completed to determine if relict dam should be removed.	Remove relict dam materials from channel	Low	Moderate	Restore natural channel dimensions	High cost for design and construction	Evaluate local historic concerns	Town of Sandown, NHDES, ERLAC

Table 6.5. Upper Exeter River Brook Site Level Opportunities for Restoration and Protection

Project #, Location/Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#5 Densen Dam off of Fremont Road in Sandown **42.94830 N 71.17224 W**	Active Restoration	Active dam forming Densen Pond; Alternatives analysis is recommended to determine trade off between pond/wetland and stream habitat and connectivity.	Remove active dam	Low	Moderate	Restore natural fluvial system and improve connectivity	High cost for alternatives analysis		Town of Sandown, landowners, NHDES, ERLAC, NHFGD
#6 Upstream of Fremont Road bridge in Sandown 42.94687 N 71.17686 W Segment UE08-A	Active Restoration	Old dam has caused extreme channel adjustment resulting in split flow and historic degradation. Alternatives analysis could be completed to determine if breached dam should be removed.	Remove relict dam	Low	High	Restore natural channel dimensions; improved habitat and geomorphic stability within the segment; improved connectivity.	High costs for design and construction	There are local historic concerns relative to this site	Town of Sandown, NHDES, ERLAC
#7 Fremont Road bridge in Sandown 42.94683 N 71.17612 W Segment UE08-A	Active Restoration	Bridge at Fremont Road found to be fully incompatible; alignment problem and span is only 28% of bankfull channel width. Bridge appears to be fairly new.	Replace bridge	Low	Moderate	Improved geomorphic stability	High	Bridge was recently replaced; may not be a local priority	Town of Sandown
#8 Between the Fremont Road bridge and the Phillips Road bridge in Sandown Reach UE08	Conservation	Conserved land is upstream and downstream of UE08; most of reach is in "good" condition with wide buffers. Makes sense to connect conserved land in UE07 with that at upstream end of UE08 to make a contiguous section of conserved land along river	Conservation Easement	High	High	Provides high quality habitat and geomorphic stability by protecting from future development	Moderate	Some land is under easements with the Southeast Land Trust (Fremont Rd. side of river); the other side of the river has a "limited cut" clause for 150' from the river's edge in the developer's subdivision approvals that will stay with the deeds as lots are sold. The town has an option to purchase the development rights of the rest of the shoreland.	NHDES, ERLAC, Town of Sandown

Table 6.5. Upper Exeter River Brook Site Level Opportunities for Restoration and Protection

Project #, Location/Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#9 Wells Village Road culvert in Sandown 42.93638 N 71.21416 W Segment UE12-A	Active Restoration	Wells Village Road culvert is causing extreme scour above structure and deposition above. Culvert width is 33% of bankfull channel width; culvert has reduced AOP. Culvert was recently replaced.	Replace culvert	Low	Moderate	Improved geomorphic stability and sediment transport	Moderate	Grant applications have been developed to seek funding for replacement	NHDES, ERLAC, Town of Sandown, NHFGD
#10 Upstream of Wells Village Road culvert in Sandown Segment UE12-A	Stormwater Management	Turbid runoff was observed coming from small tributaries/swales just upstream of Wells Village Road	Reduce sedimentation by improving stormwater management	Low	Moderate	Improved water quality	Moderate cost for design and construction of stormwater BMPs. Funding may be available from a "Better back roads program"	Evaluate source of turbidity and review local land use practices	NHDES, ERLAC, Town of Sandown, private landowners
#11 Powerline access road between Wells Village Road and Haverhill Road in Chester Segments UE12-B and UE12-C	Stormwater Management	Power line access road has severe gully erosion	Work with power company to improve stormwater management	Low	Moderate	Improved water quality	Moderate		Power company, NHDES, ERLAC, Town of Chester
#12 East of Wells Village Road to Deep Hole Pond in Chester Reach UE12	Conservation	Much of reach UE12 is remote and is in "good" condition	Conservation Easement	Moderate	High	Provides high quality habitat and geomorphic stability by protecting from future development	Moderate		NHDES, ERLAC, Town of Sandown and Town of Chester

Table 6.5. Upper Exeter River Brook Site Level Opportunities for Restoration and Protection

Project #, Location/Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#13 Beyond the dead end at Deep Hole Road in Chester **42.94117 N 71.23626 W** **Reach UE13**	Active Restoration	Active dam forming pond and wetlands. Alternatives analysis is recommended to determine trade off between pond/wetland and stream habitat and connectivity.	Remove active dam	Low	Moderate	Restore natural fluvial system and improve connectivity	High cost for alternatives analysis		NHDES, ERLAC, Town of Chester , NHFGD, landowners
#14 Beyond the dead end at Deep Hole Road in Chester Reach UE13	Conservation	Old dam in Reach UE13 causing impoundment. Development started at end of Deep Hole Road (material soft underfoot). Area that is under development pressure; some protection afforded due to NWI wetland	Conservation Easement	Low	Moderate	Provides high quality aquatic and wildlife habitat and geomorphic stability by protecting from future development	Moderate		NHDES, ERLAC, Town of Chester
#15 Between Sandown Road and Haverhill Road in Chester Reach UE14	Conservation	Much of reach is in reference condition; Segment UE14-C is extremely stable with good floodplain access (beautiful section of stream channel); According to neighbor a development was proposed adjacent to UE14-C years ago	Conservation Easement	High	High	Provides high quality habitat and geomorphic stability by protecting from future development	Property ownership needs to be researched. Potentially high costs for easements if private ownership	Conservation may be a possibility; work with town boards & town officials to research	NHDES, ERLAC, Town of Chester
#16 Power line access road bridge between Sandown Road and Haverhill Road in Chester Segment UE14-C	Active Restoration	Bridge located along power line cut found to be mostly incompatible with a span of only 41% of the measured bankfull width. Structure is also causing scour downstream. Bridge is in remote location.	Replace undersized bridge	Low	Moderate	Improved geomorphic stability	Moderate cost for design, construction and permitting.	Research status of road (Class VI?)	Power company, NHDES, ERLAC

Table 6.5. Upper Exeter River Brook Site Level Opportunities for Restoration and Protection

Project #, Location/Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#17 Downstream and upstream of Haverhill Road culvert in Chester Segment UE15-B	Passive Restoration	Segment has a few areas where buffer is less than 25 feet in a channelized (riprapped) area of stream channel. Buffer could also be planted by no longer mowing.	Streamside planting to improve buffers	Low	Moderate	Increased buffer width could provide additional streamside shading and cover for aquatic organisms; buffer also offers additional root structure in areas where there is no bank armoring	Relatively low cost for native plant materials and labor; virtually no cost for allowing buffer to grow back on its own		Private landowners, NHDES, ERLAC
#18 Haverhill Road culvert in Chester 42.95383 N 71.25441 W Segment UE15-B	Active Restoration	There is an old stone culvert at Haverill Road that is poorly aligned. Wood debris and riprap partially obstruct opening. The culvert is undersized relative to bankfull width and flood capacity for 50 year storm. Structure is creating reduced AOP and is mostly incompatible for geomorphic stability. Historic preservation investigation is warranted.	Replace undersized culvert	Low	Moderate	Improved sediment transport. Replacement structure should be designed to have improved aquatic organism passage.	Moderate cost for design, construction and permitting; possible historic preservation issue could drive up costs	Evaluate & consider local priorities	Town of Chester, NHDES, ERLAC, NHFGD
#19 Upstream of Haverhill Road culvert in Chester 42.95380 N 71.25465 W Segment UE15-B	Active Restoration	An old abutment is located just upstream of Haverhill Road and is narrow relative to bankfull channel width. Structure is located close to Haverhill Road and removal could be considered if culvert at Haverhill Road is replaced.	Remove old abutment	Low	Low	Improved sediment transport and floodplain access	Moderate cost for design and construction	Evaluate & consider local priorities	Town of Chester, NHDES, ERLAC

Table 6.5. Upper Exeter River Brook Site Level Opportunities for Restoration and Protection

Project #, Location/Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#20 Field between Haverhill Road and Derry Road in Chester in Chester 42.95412 N 71.25543 W Segment UE15-B	Active Restoration	Culvert in channelized section of field is undersized relative to bankfull width and flood capacity. Modeling also indicates flood capacity is reduced. While is undersized and has reduced flood capacity, high flows are able to overtop culvert in area with good floodplain access. Culvert is on private land.	Replace undersized culvert	Low	Moderate	Improved geomorphic stability and increased flood capacity for landowner	Moderate cost for replacement design, cost of new culvert/bridge and construction	Landowner outreach will be needed	Private landowner, NHDES, ERLAC
#21 East of Derry Road culvert in Chester Segment UE15-C	Active Restoration	A large part of this segment has been channelized. This segment seems like it was a large wetland complex that was ditched to form one channel and drain the surrounding wetland for agricultural use. There is a rejuvenating tributary and a major head cut. The clay/silt soils may be difficult to work in to arrest head cut.	Channel Restoration (arrest head cut)	High	High	Reduce siltation; improved geomorphic stability and habitat conditions	High costs for design, permitting and construction	Landowner outreach will be needed	Private landowner, NHDES, ERLAC, NHFGD
# 22 West of Derry Road culvert in Chester UE15-D	Conservation & Drinking Water Protection	"D" stream type with multiple thread channel in places and forested riparian wetlands. Segment has extreme sensitivity rating to potential stressors and is currently in "good" condition.	Conservation Easement	Moderate	High	Provides high quality habitat and geomorphic stability by protecting from future development	Property ownership needs to be researched. Potentially high costs for easements if private ownership	Conservation will may also help to protect local public water supplies	NHDES, ERLAC, Town of Chester

* Channel evolution phase not evaluated due to impoundment or wetland influence

Additional Notes for Reaches/Segments with No Identified Projects:

- No restoration projects identified for reaches UE01, UE02, UE04, UE10, and UE11 due to the existing protection offered by NWI wetlands.
- This reach is already protected by corridor easements.
- No restoration project identified in UE-9 (Lily Pond)

Project ID Table Includes Bridges and Culverts That Meet the Following Criteria:

1. Mostly incompatible or fully incompatible using VTANR Geomorphic Compatibility Screening Tool <u>and/or</u>
2. Modeled flood capacity or 25 year storm less than 100 percent.

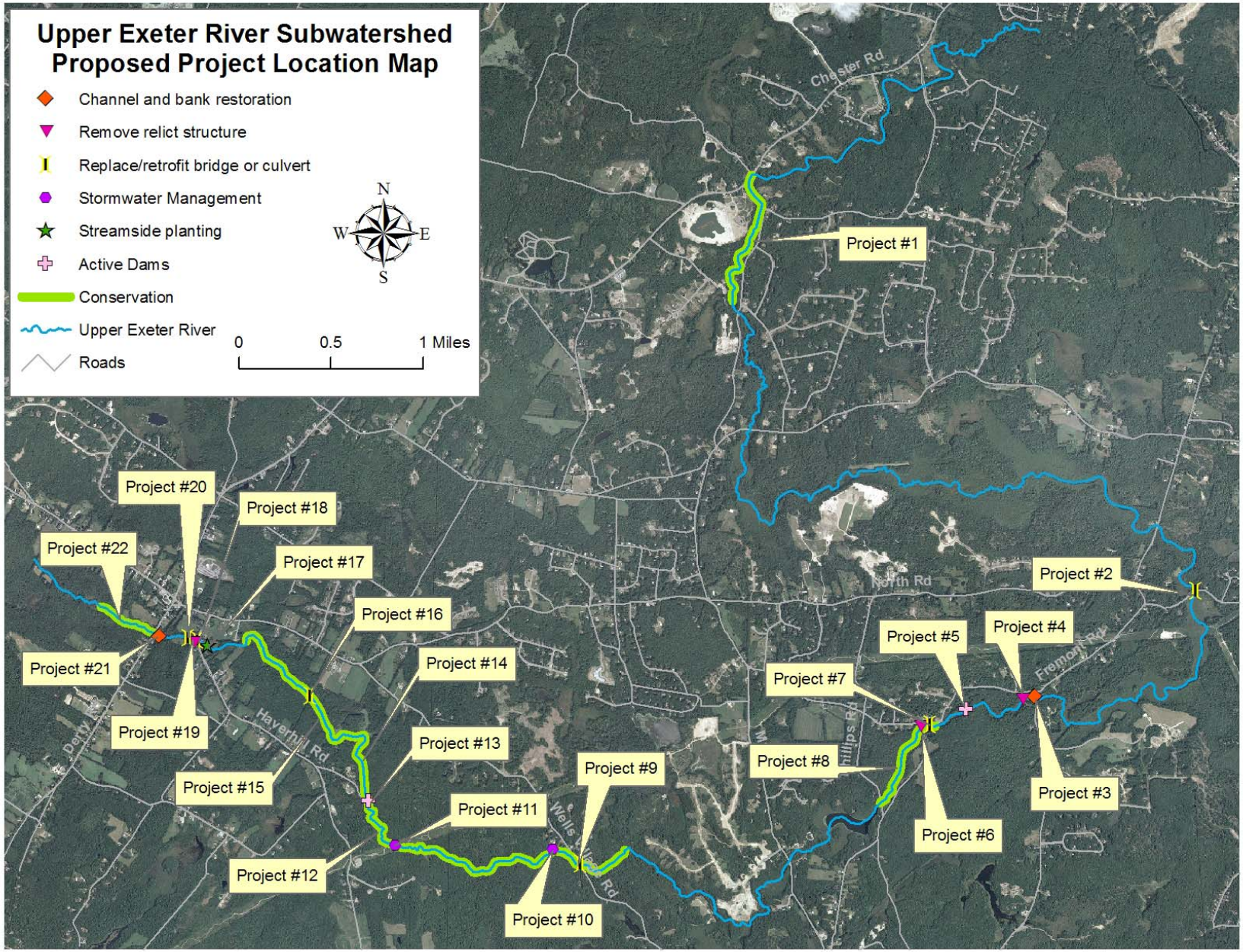

Figure 6.45 Proposed project location map for Upper Exeter River Subwatershed

7.0 Dudley-Bloody Brook Results

7.1 Dudley-Bloody Brook Background Information

This subwatershed contains the surface waters of Dudley Brook, Bloody Brook, and the Little River. Bloody Brook and Dudley Brook drain from elevations of approximately 140 feet above sea level in the western part of Exeter and the eastern part of Brentwood, and confluence with the Little River north of Route 111-A (Brentwood Road) in Exeter (Figure 7.1). The Little River flows in a southeasterly direction through the Dolloff conservation lands and areas of extensive wetlands in a rural section of Exeter. Approaching the village of Exeter, the Little River is impounded behind the Colcord Dam near the Route 111-A crossing. Following a brief section of steeper gradient channel below Colcord Pond, the Little River resumes a low-gradient form through residential lands and wetlands south of the Exeter village. The Little River crosses Linden Street and Route 108 (Court Street) prior to its confluence with the Exeter River near Gilman Park.

The Dudley-Bloody Brook subwatershed contains 13.6 miles of channel that were assessed for Phase 1 data. NHGS divided the channel into 13 reaches, 12 of which were included in the Phase 2 assessments. The following reach and segment abbreviations are used to refer to different surface waters within the subwatershed: "LR" for the Little River; "BB" for Bloody Brook; "DB" for Dudley Brook. Reach LR06 was excluded from the Phase 2 assessments, resulting in a total channel length of 10.9 stream miles. The geologic and geomorphic settings of this subwatershed have a strong influence on the reference channel morphology. As noted previously, the soil parent materials of the Dudley-Bloody Brook subwatershed have areas of extensive clays and silts originating from marine deposits. In addition, there is little topographic relief in the subwatershed. These characteristics, along with extensive areas of wetlands in the stream corridors, lead to broad valley morphology and low-gradient, sinuous channels with sand and silt bottoms (Rosgen "E" channels). With the exception of a single reach, valley slopes are all under one percent (Table 7.1).

Table 7.1
Geomorphic Setting of Assessed Reaches

Reach ID	Reference Stream Type	Confinement Type	Valley Slope (%)	Channel Bedform
LR01	E	Broad	0.18	Dune-ripple
LR02	E	Broad	0.32	Dune-ripple
LR03	Impoundment	NA	0.23	NA
LR04	E	Broad	0.42	Dune-ripple
LR05	E	Very Broad	0.11	Dune-ripple

Table 7.1
Geomorphic Setting of Assessed Reaches

Reach ID	Reference Stream Type	Confinement Type	Valley Slope (%)	Channel Bedform
LR06*	E	Very Broad	0.58	Dune-ripple
BB01	E	Very Broad	0.25	Dune-ripple
BB02	E	Very Broad	0.33	Dune-ripple
BB03	E	Very Broad	0.97	Dune-ripple
BB04	E	Very Broad	1.3	Dune-ripple
DB01	E	Very Broad	0.15	Dune-ripple
DB02	E	Very Broad	0.14	Dune-ripple
DB03	E	Very Broad	0.25	Dune-ripple

Note: LR is the Little River, BB is Bloody Brook, and DB is Dudley Brook
* Reach LR06 was not included in the scope (11 miles total) for Phase 2 assessments.

7.2 Dudley-Bloody Brook Phase 2 Results

During the Phase 2 assessments reaches were broken down into 20 segments based on more detailed field observations. The reference stream type for each assessed segment is included in Figure 7.1. A discussion of each segment in the Dudley-Bloody Brook subwatershed from the confluence with the Exeter River to the headwaters is provided below. Detailed segment summary data is provided in Appendix A.

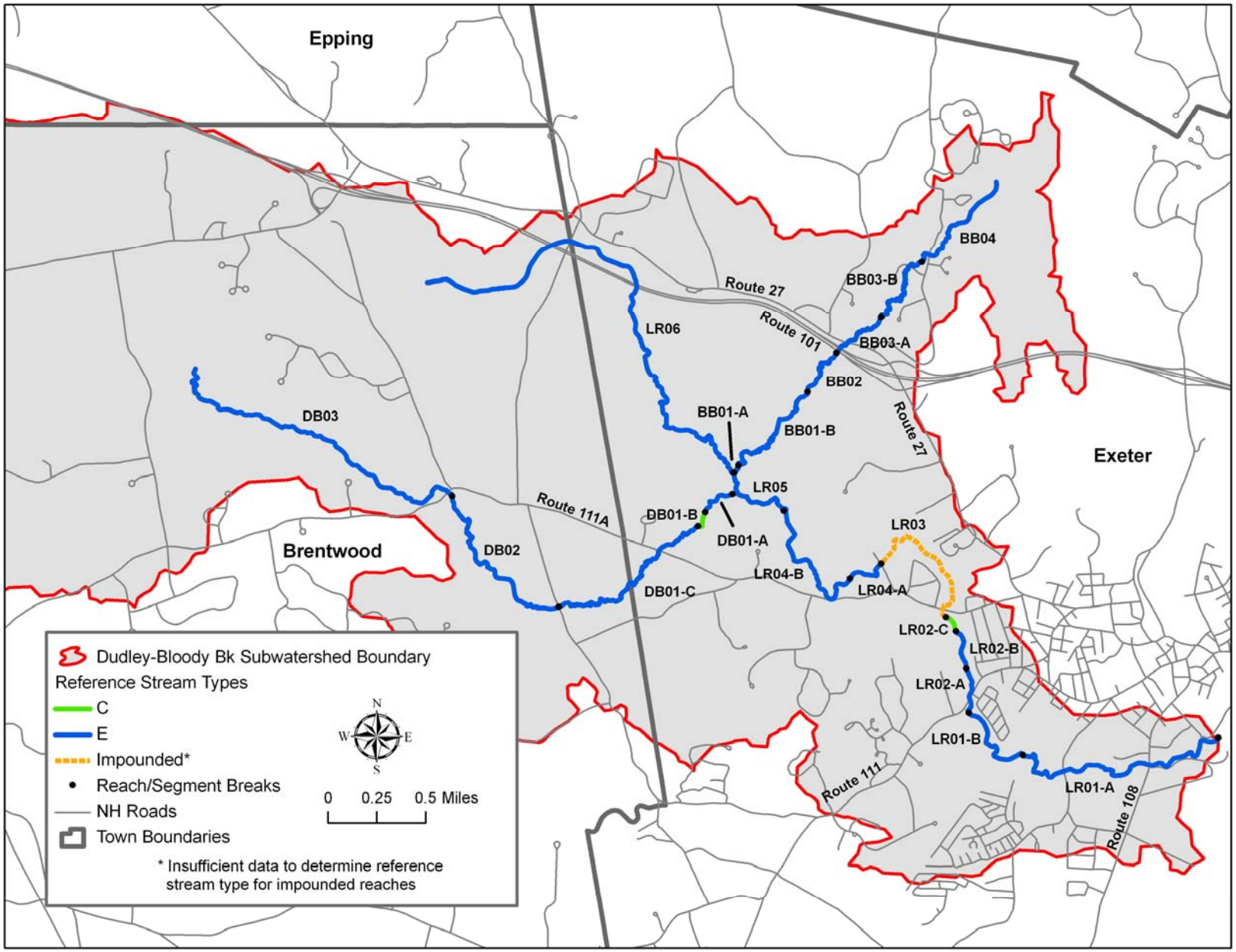

Figure 7.1 Dudley-Bloody Brook reach/segment locations and reference stream types

Town of Exeter

Little River Reaches

Segment LR01-A

The Little River is a large tributary to the Lower Exeter River with a drainage area of 15.8 square miles. The first reach, LR01 begins at the confluence with the Lower Exeter River near Gilman Park. This reach was segmented because of channel dimensions and flow patterns. Segment A extends upstream 1.2 miles and ends approximately 680 feet upstream of the crossing at Linden Street. Given the very low gradient of this reach and its location in relation to the Great Dam in downtown Exeter, much of the reach is impounded and marshy (Figure 7.2). The flow of water through this segment is slowed further by the presence of two beaver dams that impound approximately 3,900 feet of the segment. Where channelized flow exists the bedform is predominately dune-ripple in a silt substrate. The sinuosity of the segment is moderate, because the channel braids through dense mats of aquatic vegetation where the flow is often diffuse (Figure 7.3).

Figure 7.2 Open water from beaver activity

Figure 7.3 Dense vegetation and diffuse flow

The impounded nature of this segment made habitat and geomorphic surveys inapplicable. Administrative judgment was used to rate both the RHA and RGA for this reach with a "fair" rating assigned to each. Extensive corridor development and adjacent roads in the lower reach contributed to the "fair" RGA rating. Review of the national wetlands inventory (NWI) showed that this segment was composed of two major types of wetlands. The lower half of the reach is a palustrine system that is mostly forested with broad-leaved deciduous species. Extensive areas of invasive species, such as purple loosestrife and reed canary grass, were noted in the open meadow areas associated with beaver activity. The upper half of segment LR01-A is a palustrine system that is dominated by shrub and scrub species. With the exception of minor impacts around the Linden Street and Route 108 crossings, the wetlands and additional riparian vegetation adequately buffer the stream.

Figure7.4 Mass Failure on the right bank downstream of the B&M Railroad trestle

Segment LR01-B

From the segment break near Linden Street, LR01-B extends 0.5 miles upstream to the reach break located approximately 500 feet downstream of Kingston Road. Unlike the previous segment, segment B has well-defined channelized flow and many active geomorphic processes.

Figure 7.5 Bank erosion on the north bank upstream of the B&M Railroad trestle

The channel is E-type by reference with moderate sinuosity. Mid-segment the trestle crossing of the Boston and Maine Railroad (B & M) has caused some widening and bank scour downstream. The structure appears to be in good condition because it is heavily armored and robust, but the span of the bridge is only 42% of bankfull width, making it a potential constriction during large storm events. About 250 feet downstream of the structure a large build-up of sediment and woody debris associated with beaver activity has caused the channel to be directed into the south bank. The erosion caused at the toe of the bank has triggered a mass failure which may be a source of sediment downstream (Figure 7.4). Upstream of the railroad trestle poor riparian buffer width on the north bank has caused some bank erosion. Given their proximity to the channel, the properties along West Side Drive may be impacted by large flow events. One stormwater outfall originating from the West Side Drive development is causing scour and gullying along the north bank, increasing fine sediment supply to the channel.

The poor bank and buffer data negatively contributed to both the habitat and geomorphic condition of this segment (RHA score = “fair”; RGA score = “fair”; Figure 7.5). Where the cross-section was taken near West Side Drive minor channel incision was noted; however there is still accessible floodplain along the south bank. In the lower reach, the aggradation of sediment both upstream of the railroad crossing and at the beaver dam below was the

most observable change to the geomorphic condition. The mass failure and bank erosion may also be impacting fish and other aquatic organisms.

Segment LR02-A

This segment begins at the reach break downstream of Kingston Road and extends upstream 1,327 feet to a man-made grade control. The grade control was installed as a stream ford to give the land owner access to his property on both sides of the stream (Figure 7.6). However, this feature is restricting sediment from moving downstream, and causing minor channel incision in the downstream segment. The overall channel geometry was indicative of an E-type channel and the bed substrate was predominately sand (45%). However, the upstream grade control made the segment more channelized from the combination of decreased sediment supply and encroachment from the road. Two stormwater inputs were observed on this segment where runoff from the development along West Side Drive and Kingston Road drain directly into the stream channel. Stormwater inputs such as these (Figure 7.7) allow for untreated water containing pollutants and nutrients found in urban runoff to enter the channel.

Figure 7.6 Stream ford in upper segment

Figure Figure 7.7 Stormwater input downstream of Rt. 111-A

The north corridor downstream of the crossing had a buffer width that was less than 25 feet in width. This area was also rip-rapped to stabilize the banks from scour and erosion. The low buffer widths and some bank instability led to a habitat score that was "fair." The upslope sediment sink has disrupted the continuity of the sediment regime, leading to some geomorphic instability downstream (RGA score = "fair"). Channel degradation and widening were the main problems noted in the field. The degradation and widening observed in the field were typical of channels in stage II of the channel evolution model (CEM).

Segment LR02-B

Segment LR02-B is 1,156 feet in length and begins just upstream of the grade control and extends up into the stagnant backwaters created by the structure. The segment has a bed substrate consisting of sand and detritus that has accumulated behind the grade control. The water pooled by the stream ford has flooded the surrounding area, allowing for more

aquatic vegetation than the downstream and upstream segments. The NWI has this segment listed as forested, broad-leaved deciduous wetland that is seasonally flooded or saturated. Some snags and dead trees were observed on the outskirts of the impoundment, suggesting that this segment might have been forested prior to the construction of the stream ford. The north bank upstream of the stream ford had very little woody plant cover (Figure 7.8), and a pump was situated on the bank to draw water out of the stream. Since this segment was predominately still, administrative judgment was used for both the RHA and RGA, with a "fair" and "good" condition rating, respectively. If the structure were to be removed it would greatly increase the connectivity between the segments above and below, as well as potentially restore habitat for species which inhabit a swifter moving lotic environment.

Figure 7.8 Lack of riparian buffer upstream of the grade control, with a water draw pump potentially used for gardening

Segment LR02-C

This segment is located downstream of the Colcord Pond, with a length of 500 feet. It extends from the downstream segment up to the reach break at the pond. This is segment is coarse-bottomed, with predominately coarse gravel substrate (35%). It is topographically unique, because it is one of the few places within the subwatershed where there is a confined valley setting. The geometry of this segment reflects that of C-type channels, with a subclass slope of 2 to 4% (Rosgen type = C_b). The form of the channel and the features observed during the field survey reflect the position of the upstream grade control (Figure 7.9) and two overflow chutes: one that washes out over the southernmost portion of Colcord Pond and another that washes over the easternmost. The upstream end of this segment is heavily braided and the channel flows amongst boulder and cobble substrate that was placed downstream of the dam to prevent a large scour hole to develop. The channel morphology in this segment is characteristic of the D model of channel evolution in stage

IIb. This means that the channel is slightly widened (Width-to-depth-ratio = 19.6) and that sediment is aggrading within the segment. It is likely that the observed sedimentation is from the washout and erosion associated with the overflow chutes.

In the downstream portion of this segment mid-channel bars (three in total) were common and recently active floodchutes were observed. Because of the aggradation and some widening associated with the overflow chutes, the geomorphic condition rating for this reach was considered to be "fair." The habitat condition was also "fair." The scour and deposition scores were in the poor category, as was the connectivity. If the overflow chutes continue to scour out sediment the downstream deposition in this segment will continue to affect both the geomorphic stability and the integrity of the habitat.

LR03 (Colcord Pond)

This reach was canoed and assessed for bank and buffer conditions, but no geomorphic or habitat ratings could be made because of the ponding (Figure 7.10). Colcord pond, or LR03, extends approximately 0.8 miles from the dam just downstream of the Rt. 111A crossing up to the Garrison Lane Crossing. The downstream end of the pond had two prominent overflow chutes (discussed above) that acted as sources of sediment to segment LR02-C below. Upstream of the Rt. 111A crossing several areas of reduced buffer width were observed on the south and north banks, but the total impacts comprised only about 10% of the reach length. On the upstream end of the reach beaver activity raised the water elevation slightly. This has caused extensive flooding in an area that the NWI defines as palustrine, with an unconsolidated bottom that is permanently flooded.

The Route 111A crossing could be a potential problem in large flow events because it is flood constriction and the clearance is only 2.2 feet. However, the structure appears to be recently installed and no obvious erosion problems were noted around it; the discharge controls associated with Colcord dam prevent flooding problems at the crossing.

Figure 7.9 Background: the Colcord Pond dam;
Foreground: coarse substrate causing braided flow

Figure 7.10 An upstream view of Colcord Pond from the Route 111A crossing

Segment LR04-A

Segment LR04-A is 1,278 feet in length and extends from Garrison Lane up to the segment break where the channel dimensions and valley wall conditions change. This is a fast flowing segment with substrate that is predominately cobble (46%; Figure 7.11). The geometry of this segment is reflective of a C-type channel with a subclass slope of 2 to 4% (Channel type = C_b). The segment is found in a semi-confined valley and the bedform was riffle-pool. This reach has not undergone any significant channel adjustments and is in stage I of the CEM. A steep riffle was located just upstream of the Garrison Lane crossing. The sediment deposits of this feature do not seem to be caused by the current road abutments, but rather a historic bridge abutment located about 100 feet upstream of the crossing (Figure 7.12). This constriction (23 feet) has led to some scour and widening upstream of the Garrison Lane Bridge, and an active flood chute has formed where floodwaters flow around the abutment.

Figure 7.11 Coarse bottom channel with riffle-pool bedform

Figure 7.12 Steep riffle and scour pool upstream of the Garrison Ln. crossing by old bridge abutments

This segment is well buffered, with only 4% of the north bank on the downstream end of the channel having a buffer width of less than 25 feet. Woody debris was abundant in this segment (124 pieces/mile) and several deep pools were noted. The wide range of cover types found within the channel and the good bank and buffer condition made the habitat score quite high (RHA score = "good"). The segment's geomorphic condition is also "good." Apart from the minor planform changes from the floodchutes and the aggradation of sediment in the steep riffle, this segment is largely stable.

Segment LR04-B

Segment LR04-B begins at a small beaver dam, where the valley setting rapidly changes from semi-confined to broad (Figure 7.13). This segment, 0.8 miles in length, has channel geometry indicative of E-type morphology. The substrate is largely sand (68%) and the bedform is dune-ripple. The channel has not recently undergone significant adjustments and is stage I of the CEM. The first half of this segment is well buffered with herbaceous and shrubby plant species and the upstream portion is dominated by deciduous forest. The riparian buffer throughout this segment is very wide, with a dominant width greater than 200 feet for both the south and north corridors. One section of the corridor that has buffer width impacts is located on the south bank where the channel abuts Route 111A. There, the road is located on the outside edge of a meander. The edge of the road was not heavily rip-rapped and some scour was occurring at the time of the survey (Figure 7.14). Since then this area has been extensively rip-rapped, obviating the possibility for a more natural channel restoration approach.

Figure 7.13 Beaver dam at segment break

Figure 7.14 Lack of buffer with on the right bank where Rt. 111A abuts the outside of a meander bend

The large, undeveloped corridor is a critical factor in the stability and habitat conditions of this segment. The geomorphic condition of this reach is "good," with only some minor sediment aggradation problems. The available habitat within this reach was above average (RHA score = "good"). Large woody debris (LWD) was abundant at a variety of size classes and several debris jams were observed (Figure 7.15). These jams helped to create natural scour features that form deep pools and provide refuge for fish. The width of the riparian buffer also helped the overall habitat rating.

Reach LR05

LR05 is a well buffered reach that is isolated from any human developments. This reach is 2,368 feet in length and it extends up to the confluence with Bloody Brook. The channel morphology reflects E-type channel geometry and the substrate is predominately sand. The bedform is dune-ripple (Figure 7.16) and the valley is very broad. There are no areas of the reach where the buffer width is less than 200 feet. The sinuosity of this reach is high (greater than 1.5). The channel of this reach is completely within the Little River and Dolloff conservation lands.

Figure 7.15 Large woody debris jams, providing excellent habitat

The reach is very stable because it is so well buffered by the surrounding forest which is mix of coniferous and deciduous species (RGA score = "Reference"). Much of the forest, however, is not immediately adjacent to the channel in the lower half of the reach, much like LR04-B. This seemed to lower the channel's ability to accrue woody debris (LWD = 67 pieces/ mile). Historic channel adjustments were not apparent (CEM stage = I), and only minor, natural flood chutes were observed in during the survey. The overall habitat condition was "good" because of the reach's excellent riparian buffer condition and well formed dune-ripple bedform.

Figure 7.16 Reference dune-ripple bedform

Bloody Brook Reaches

Segment BB01-A

Bloody Brook is a tributary to the Little River with a total drainage area of 2.0 square miles. The confluence of Bloody Brook with the Little River marks the reach break between LR05 and LR06 (not assessed). BB01-A is a small segment 300 feet in length where channelized flow dominates before entering an area that was significantly impacted by beaver activity. This segment can be classified by E-type channel geometry with fine silt as the dominant bed material (55%). The sinuosity is high, and the bedform is dune-ripple. Two minor flood chutes were observed on this segment on the inside of meander bends, and the floodplain is easily accessible. A few areas of siltation along the adjacent floodplain indicate that recent storms (July of 2008) led to overbank flow and deposition of sediment. Robust riparian vegetation contributes to the healthy floodplain function of this segment (Figure 7.17). The condition of this segment was "good" for both the RGA and RHA because of the reach's very large riparian buffer, and healthy stream function. This high quality area of Bloody Brook is protected as part of the Dolloff conservation lands. Conservation lands, such as these, help ensure the long-term maintenance of ecosystem health.

Figure 7.17 Dense riparian vegetation that was observed throughout this segment

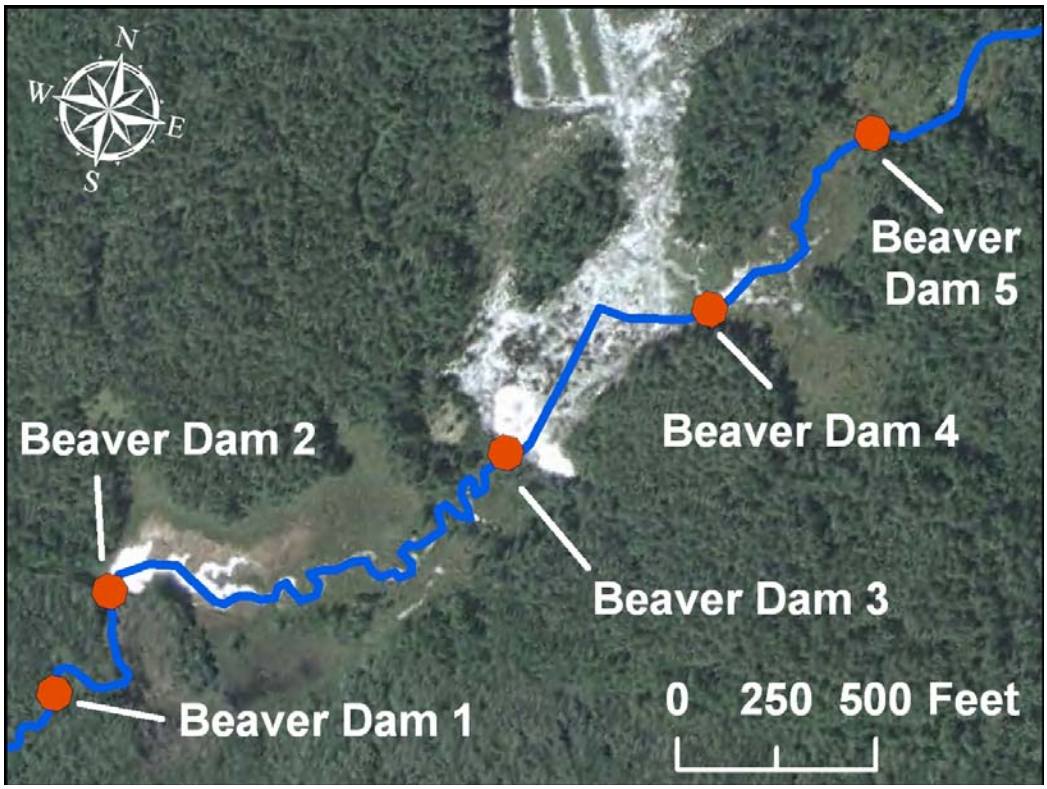

Figure 7.18 Areas of Beaver Activity in BB01

Segment BB01-B

Segment B of Reach BB01 was heavily impacted by beaver activity (Figure 7.18) and was only assessed for bank and buffer conditions. The segment begins at the first beaver dam and extends upstream for 0.7 miles to the reach break. A total of five beaver dams were noted in this segment, limiting channelized flow almost completely. The third beaver dam is the largest of the five which has been in place for several years. The bank and buffer condition of this reach was excellent with greater than 200 feet of buffer on either side of the channel. The NWI identifies eight different types of wetlands in this area that differ by the presence of beaver activity, vegetation, and the flooding regime. Administrative judgment was used to assign RHA and RGA values given the nature and extent of the wetlands in this area. The RGA was assessed as "good" and the RHA as "fair".

Reach BB02

BB02 is 1,373 feet in length and three smaller beaver dams prohibiting normal channelized flow. This reach was only assessed for banks and buffers due to beaver ponding, and administrative judgment was used to assign RHA and RGA values of "good" for both. The topography of the reach made the extent and magnitude of the beaver impoundment less severe and the vegetation remained forested and the buffer was greater than 200 feet throughout the ponded area.

Segment BB03-A

This segment begins where the channel crosses under Route 101 east bound and extends upstream 1,760 feet to the segment break where the channel is not impounded by beaver activity. This segment had a total of two beaver dams: the most downstream dam is located under the Route 27 Bridge (Figure 7.19) and the upper dam is located just south of the residential pond and clearing. The beaver activity is very recent and several freshly felled trees were observed during the survey. The bank and buffer assessment showed a large degree of rip-rap on both the west and east banks where Route 101 and 27 cross the channel. These three bridges are very large and can handle the most extreme storm events adequately. Administrative judgment was used to assign RHA and RGA values of "fair" for both.

Segment BB03-B

BB03-B is a very interesting segment with a meandering dune-ripple bedform channel (sinuosity > 1.5). The segment length is 3,120 feet and the bed substrate is comprised entirely of sand. The geometry is indicative of E-type channel morphology (Figure 7.20). The dune-ripple bedform is well spaced within the channel. Most meander bends had well formed cut-bank, point bar parings and only one mid-channel bar was noted. The canopy of the riparian vegetation completely encloses the channel and the predominant species was hemlock. The dense root mats of the tree and shrub species provided excellent bank stability and no erosion was noted. The buffer width was variable in this segment because houses have been recently built within the headwaters of this basin. The dominant buffer width on both the west and east corridors was between 51 and 75 feet. The channel crossed under Kelby Scott Way about two-thirds of the way up the segment in a culvert with a width of three feet. This culvert is undersized and accommodates only 44% of bankfull channel width, but no apparent scour or deposition was observed (Figure 7.21). Monitoring this crossing is recommended to ensure the road's integrity upstream of the crossing during large flow events.

Figure 7.19 Beaver dam underneath Rt. 27

Figure 7.20 Point bar, cut-bank complex that was common on meander bends

Figure 7.21 Upstream view of the culvert crossing at Kelby Scott Way, an undersized culvert

The habitat in segment BB03-B was excellent. The combination of dense woody debris (LWD = 158 pieces/mile), abundant pools, and frequent undercut banks rewarded this reach with a "reference" habitat condition. The floodplain connectivity was high in this reach and the overall geomorphic state was very stable (RGA score = "good").

Figure 7.22 Plunge-pool located downstream of the undersized culvert located on a private driveway

Reach BB04

This reach is the headwaters reach for Bloody Brook and extends 3,244 up into area of several different types of wetlands. The bed substrate is predominately sand (80%) and the bedform is dune-ripple. The sinuosity of this reach is moderate, and the stream geometry is characteristic of E-type channels. At the beginning of this reach two culverts occur within close proximity to one-another that are severely undersized. The first is a crossing of a private driveway (Figure 7.22). This structure is 2.0 feet in diameter and accommodates only 25% of bankfull channel width. The second structure is located at the crossing of Watson Road, and this structure's capacity is also only 25% of bankfull channel width. Upstream of the second crossing a high degree of deposition was observed. It is possible that a large volume of sediment from a development located off of Watson Road (built in 2005) washed downstream and accumulated above the constricting culvert. The bank and buffer condition in this reach are generally in good shape. The dominant buffer widths were between 51 and 75 feet on the west bank and between 101 and 150 on the east bank. Only one small stretch of the west bank had a buffer width less than 25 feet, which represented only a small section of the reach.

The bed substrate cover score was lowered because of the aggradation upstream of the Watson Road crossing, but the overall habitat condition of this reach was "good." The RHA condition was buoyed by the presence of good pools and adequate woody debris. The geomorphic stability of this reached was also affected by the culvert at Watson Road. The aggradation upstream lowered the score and was the cause of some changes in planform and widening (RGA score = "fair").

Dudley Brook Reaches

Segment DB01-A

Dudley Brook is a tributary to the Little River; its confluence is located about halfway up reach LR05. Segment DB01-A extends upstream 1,215 feet from the confluence with the Little River and ends where the channel dimensions, valley walls, and substrate change significantly. This segment is primarily sand-bottomed and has dune-ripple bedform. The channel exhibits E-type channel geometry by reference and is moderately sinuous (Figure 7.23). There is good floodplain connectivity throughout. Minor, natural flood chutes crossing meander bends were observed throughout this segment. Some aggradation in the lower reach near the confluence with the Little River may be due to backwater at the confluence during high flow events. In the upper section where the segment meets DB01-B the channel is widened significantly. There, it appears that the higher slope and transport capacity of DB01-B is able to cut down through the sand substrate of this reach.

This segment had abundant woody debris (LWD = 200 pieces/mile) and the stream banks were often undercut, providing good habitat conditions (RHA score = "good"). The channel had some areas of aggradation, especially near the confluence with the Little River, as well as changes in planform, but the overall geomorphic condition remained stable (RGA score = "good"). Because of the aggradation it is likely that channel evolution on this segment would follow the D model (currently assessed in stage IIc). This means that the channel is aggrading sediment and may begin shifting its planform in the future if channel adjustments are triggered.

Segment DB01-B

Reach DB01 was segmented because the upper section is a fast-flowing, transport-based channel type. Only 500 feet in length, the channel can be characterized by C-type morphology with a subclass slope between 2 and 4% (Channel type = C_b; Figure 7.24). In many ways this segment was similar to LR04-A. Cobble was the dominant substrate and the observed bedform was riffle-pool. The valley confinement was slightly lower than LR04-A; it is characterized as "narrow". The

Figure 7.23 Cross-section with E-type channel geometry

segment break with DB01-C is downstream of a beaver dam that was built on the larger coarse substrate. The upstream segment is heavily impounded, and the beaver dam is limiting the sediment that can enter the system.

The upstream end of this segment is constricted by the remains of an old bridge abutment or mill sluice (Figure 7.25). The large substrate found in the channel and on the banks provides natural armoring to erosion and other geomorphic stressors (RGA score = "good"). The coarse sediment size has restricted any incision and the no significant channel adjustments have occurred (CEM = stage I). Mid-segment two large pools with woody debris provide good habitat for fauna such as benthic macroinvertebrates. However, the mill sluice constriction and the scour downstream have put this segment into the lower range of "good" in terms of its overall aquatic habitat.

Figure 7.24 Fast-flowing channel with C_b-type channel geometry

Figure 7.25 Constriction on the upstream end of the segment

Towns of Exeter and Brentwood

Segment DB01-C

DB01-C is about one mile in length and is entirely impounded by a series of beaver dams. This segment begins at the beaver dam upstream of the channel constriction on DB01-B (Figure 7.26) and extends to the reach break at Pickpocket Road. The segment is well buffered, with a riparian zone that is dominantly greater than 200 feet. Because it is largely impounded, administrative judgment was used to determine the RGA and RHA scores for this segment, which were "good" and "fair" respectively. There are several different types of wetlands recognized by

Figure 7.26 Beaver dam located at the start of the segment

the NWI in this segment. Most are seasonally flooded, but some are permanently flooded and the vegetation is mostly shrub/scrub or forested.

Town of Brentwood

Reach DB02

Reach DB02 is one mile in length and is predominantly wetlands. The bank and buffer conditions are similar to that of DB01-C, with an adequate riparian buffer width on most of the channel. The upper and middle portions of this reach have experienced some human-induced channel modifications that have altered the hydrology and morphology of the reach. Figure 7.27 depicts the straightened area on the upstream end of this reach. Over half of this reach (54%) has been straightened in the past; however the straightened section mid-reach has grown in and recovered much better than the section upstream. In the upper reach, cattle graze on the field to the northeast of the channel which acts as a source of sediment and nutrients to the watershed. At this site the historic channel is still intact, but only receives flows during events of larger discharge. Administrative judgment was used to evaluate the geomorphic stability of this reach as well as the habitat condition. The geomorphic condition was considered to be "fair," because of the extensive straightening. The habitat was "fair" overall because several of the criteria for ranking habitat condition could not be met given the flow conditions and stagnant state of this reach.

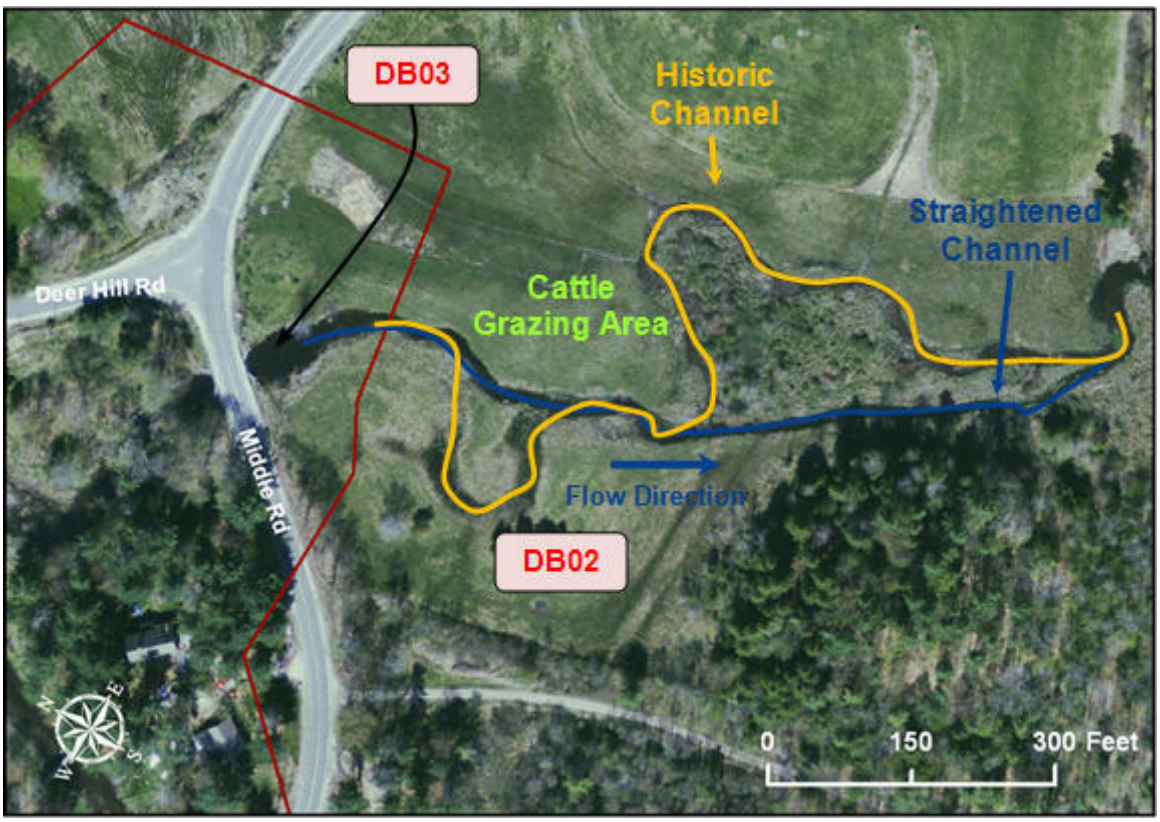

Figure 7.27 Historic channel straightening observed in the Dudley Brook Watershed

Reach DB03

The final study reach of the Dudley Brook subwatershed extends upstream 1.8 miles from the reach break at Middle Road (Route 111A). This site has some problems associated with human activity in the lower reach. The reach has two channel constrictions; one at the Route 111A crossing and one about 100 feet upstream of the crossing where an old foundation constricts the bankfull flow of the channel. The bridge at the Route 111A crossing only accommodates 54% of bankfull channel width (Figure 7.28). This may be problematic if debris or sediment ever blocks the structure. On the upstream side of the crossing some bank erosion was observed on the south bank. Downstream of the crossing the limited buffer width is also impacted by the cattle grazing area. Administrative judgment was used to rate the habitat and geomorphic condition of this reach. Because of some human-related constrictions at the lower end of this reach and the limited flow conditions this reach received a "fair" RHA score and "good" RGA score.

Figure 7.28 Bridge at Route 111A crossing in DB03

Dudley-Bloody Brook Phase 2 Summary

Table 7.2 summarizes the channel geometry ratios, streams types, channel evolution stages, and active adjustment processes for the Dudley-Bloody Brook subwatershed reaches. Table 7.3 compares the habitat condition based on the Rapid Habitat Assessment (RHA) and the geomorphic condition based on the Rapid Geomorphic Assessment (RGA) for fully assessed reaches. Figure 7.29 depicts the RGA condition for all reaches and segments.

Table 7.2
Dudley-Bloody Brook Stream Type and Channel Evolution Stage

Segment ID	Entrench-ment Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Active Adjustment Processes
LR01-A	Partially Assessed – influenced by Great Dam Impoundment					
LR01-B	9.7	11.2	E5	E5	FI	Aggradation
LR02-A	6.0	12.6	E5	E5	FII	Degradation Widening
LR02-B	Partially Assessed – influenced by Impoundment caused by stream ford					
LR02-C	3.1	19.6	C4b	C4b	DIIb	Aggradation Widening
LR03	Partially Assessed – Colcord Dam Impoundment					
LR04-A	3.9	13.2	C3b	C3b	FI	Planform

Table 7.2
Dudley-Bloody Brook Stream Type and Channel Evolution Stage

Segment ID	Entrench-ment Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Active Adjustment Processes
LR04-B	8.1	9.1	E5	E5	FI	Aggradation
LR05	19.1	9.5	E5	E5	FI	None
BB01-A	20.2	6.8	E6	E6	FI	None
BB01-B	Partially Assessed – influenced by wetlands upstream and downstream					
BB02	Partially Assessed – influenced by wetlands upstream and downstream					
BB03-A	Partially Assessed – influenced by wetlands upstream and downstream					
BB03-B	7.0	5.7	E5	E5	FI	Widening
BB04	17.9	7.5	E5	E5	DIIc	**Aggradation** Widening Planform
DB01-A	13.4	11.4	E5	E5	DIIc	Planform
DB01-B	4.8	18.2	C3b	C3b	FI	Aggradation Planform
DB01-C	Partially Assessed – influenced by wetlands upstream and downstream					
DB02	Partially Assessed – influenced by wetlands upstream and downstream					
DB03	Partially Assessed – influenced by wetlands upstream and downstream					

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

Table 7.3
RGA and RHA Scores for Fully Assessed Phase 2 Segments

Segment ID	RHA Score	RHA Condition	RGA Score	RGA Condition
LR01-B	0.53	Fair	0.63	Fair
LR02-A	0.49	Fair	0.59	Fair
LR02-C	0.56	Fair	0.63	Fair
LR04-A	0.73	Good	0.79	Good
LR04-B	0.82	Good	0.74	Good
LR05	0.79	Good	0.88	Reference
BB01-A	0.84	Good	0.80	Good
BB03-B	0.88	Reference	0.75	Good
BB04	0.73	Good	0.56	Fair
DB01-A	0.79	Good	0.69	Good
DB01-B	0.66	Good	0.73	Good

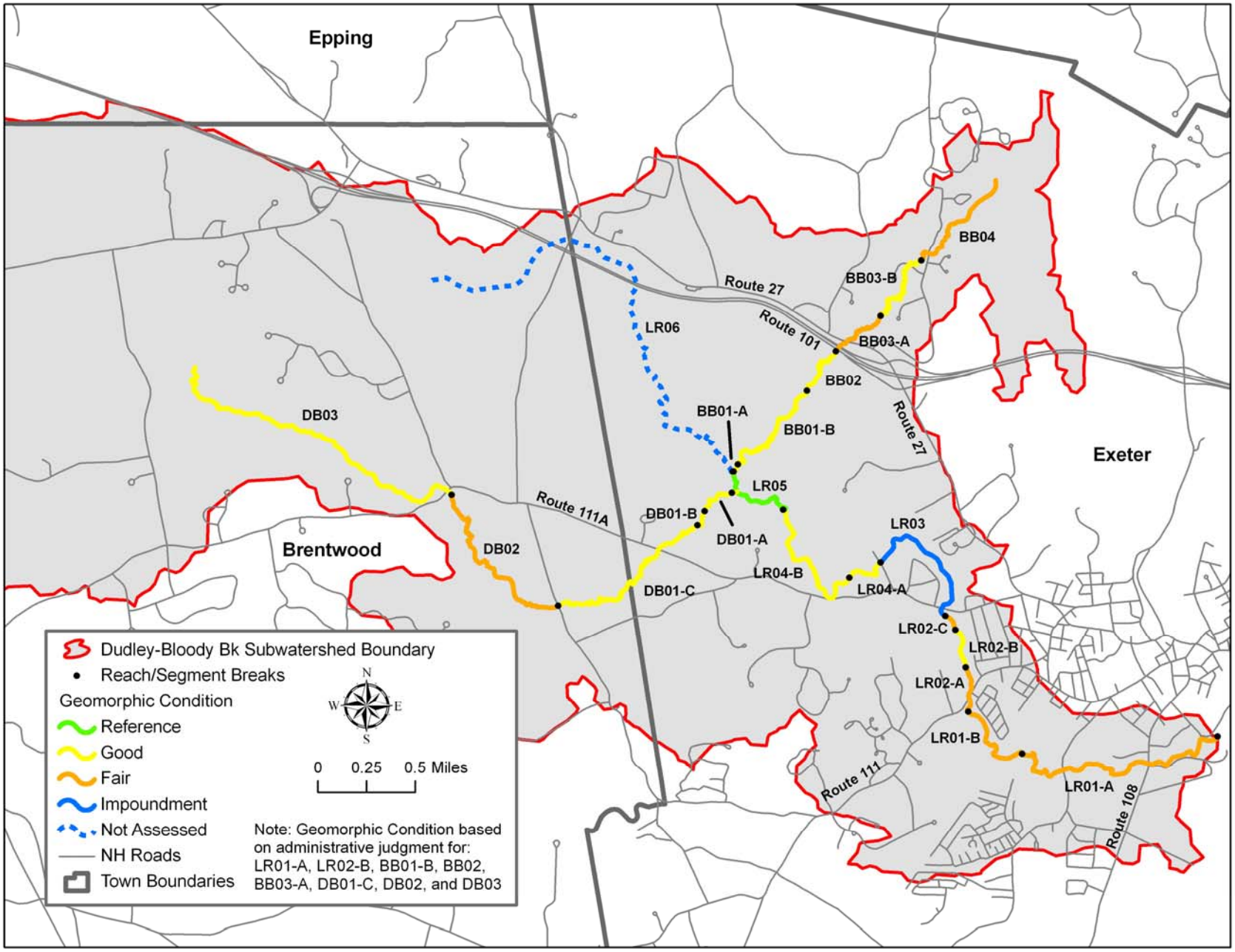

Figure 7.29 Geomorphic Condition of Assessed Reaches in the Dudley-Bloody Brook Subwatershed

7.3 Dudley-Bloody Brook Bridge and Culvert Assessment

Table 7.4 summarizes the data collected for 17 bridges and culverts in the Dudley-Bloody Brook subwatershed. The final column of the table includes a prioritization of structures for replacement or retrofit based on a review of the following four criteria: structure width in relation to bankfull channel width; structure flood capacity; aquatic organism passage; geomorphic compatibility. Five of the structures in the Dudley-Bloody Brook subwatershed are located in a non fluvial system (wetland) and were not evaluated using the geomorphic screening tool. Additional summaries (including photos) for all moderate and high priority structures are provided in Appendix B. A summary of the methods and results for the watershed hydrologic modeling to determine each structure's flood capacity is included in Appendix C. Also included in Appendix C is an explanation of how structures were selected for flood capacity modeling based on the field data for geomorphic compatibility, aquatic organism passage and other local knowledge.

Figure 7.30 depicts the aquatic organism passage barriers for the Dudley-Bloody Brook subwatershed, including culvert crossings and grade controls. Six culverts and two human grade controls were identified as reducing aquatic organism passage.

Table 7.4
Little River, Bloody Brook, Dudley Brook Crossings

Reach/ Segment No.	Road Name, Town	Structure Type	Condition/ Observation	Percent Bankfull Channel Width[1]	Structure Capacity for Flood Events (Percent Capacity)[2]		Aquatic Organism Passage (AOP)[3]	Geomorphic Compatibility[4]	Priority for Replacement or Retrofit
					25 Year	25 Year			
LR01-A	Rt. 108, Exeter	Culvert	Minor aggradation upstream; Otherwise stable	84%	----	----	Reduced AOP	W[5]	Low
LR01-A	NA (Trail), Exeter	Bridge	No problems; Foot bridge serves trail to athletic fields	94%	----	----	NA	W	Low
LR01-A	Linden St., Exeter	Culvert	Minor constriction; Wetland upstream and downstream; Structurally stable	54%	----	----	Reduced AOP	W	Low
LR01-B	B & M Railroad, Exeter	Bridge	Sharp channel bend upstream; Large mass failure downstream; Structurally stable	42%	91%	76%	NA	Mostly incompatible	Moderate
LR02-A	Rt. 111, Exeter	Bridge	Stable structure with no noticeable problems	63%	----	----	NA	Partially compatible	Low
LR03	Rt. 111-A, Exeter	Bridge	Very low clearance due to impoundment; Structurally stable	66%	----	----	NA	Mostly compatible	Low
LR04-A	Garrison Road, Exeter	Bridge	Minor scour along footers; Otherwise stable	84%	----	----	NA	Mostly compatible	Low
BB03-A	Rt. 101, Exeter	Bridge	Large span of highway bridge; No problems noted	708%	----	----	NA	Fully compatible	Low

Table 7.4
Little River, Bloody Brook, Dudley Brook Crossings

Reach/ Segment No.	Road Name, Town	Structure Type	Condition/ Observation	Percent Bankfull Channel Width[1]	Structure Capacity for Flood Events (Percent Capacity)[2]		Aquatic Organism Passage (AOP)[3]	Geomorphic Compatibility[4]	Priority for Replacement or Retrofit
					25 Year	25 Year			
BB03-A	Rt. 27, Exeter	Bridge	Large span of highway bridge; No problems noted; Beaver dam beneath bridge	417%	----	----	NA	Fully compatible	Low
BB03-A	NA (Trail), Exeter	Culvert	Channelized upstream; Minor scour below, otherwise stable	33%	----	----	Full	Mostly compatible	Low
BB03-B	Kelby Scott Way, Exeter	Culvert	No apparent scour or deposition; Monitoring recommended due to small capacity	44%	29%	24%	Reduced AOP	Mostly incompatible	Low
BB03-B	Private Drive, Exeter	Culvert	Sharp bend upstream; minor erosion; high scour potential	25%	18%	15%	Reduced AOP	Mostly incompatible	Moderate
BB04	Watson Road, Exeter	Culvert	Sediment deposition upstream; sharp stream bend upstream	25%	29%	23%	Reduced AOP	Partially incompatible	Moderate
DB01-C	Rt. 111-A, Exeter	Bridge	Minor constriction; Wetland upstream and downstream; Stable	70%	----	----	NA	W	Low

Table 7.4
Little River, Bloody Brook, Dudley Brook Crossings

Reach/ Segment No.	Road Name, Town	Structure Type	Condition/ Observation	Percent Bankfull Channel Width[1]	Structure Capacity for Flood Events (Percent Capacity)[2]		Aquatic Organism Passage (AOP)[3]	Geomorphic Compatibility[4]	Priority for Replacement or Retrofit
					25 Year	25 Year			
DB02	Pickpocket Road, Brentwood	Culvert	Moderate constriction; Wetland upstream and downstream; Stable with large plunge pool downstream	35%	----	----	Reduced AOP	W	Low
DB03	Route 111-A, Brentwood	Bridge	New structure; Instability upstream due to grazing; Scour pool downstream	54%	132%	109%	NA	Partially compatible	Low

[1] Shaded for bankfull width percentage less than 50% ; [2] Shaded for capacity of less than 100%; [3] Aquatic Organisms Passage ratings developed with the VTANR methodology (not applicable to bridges); [4] Scores and ratings developed with the VTANR Geomorphic Compatibility Screening Tool; [5]Screening tool not applicable for non-fluvial (wetland) reaches.

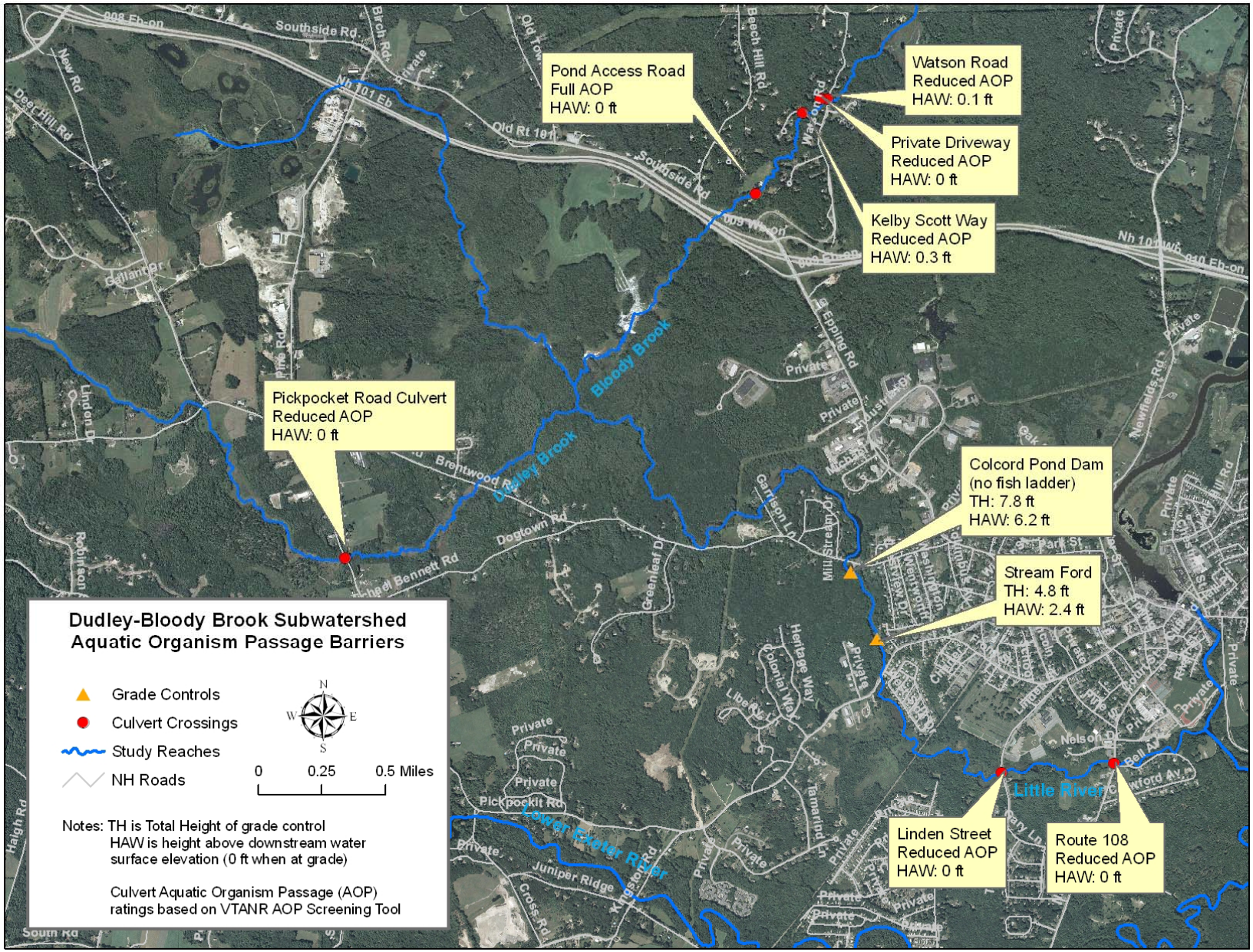

Figure 7.30 Aquatic organism passage barriers in the Dudley-Bloody Brook Subwatershed

7.4 Dudley-Bloody Brook Corridor Planning

7.4.1 Stressor Maps

Stressor, departure and sensitivity maps are presented here as a means of displaying the effects of all significant physical processes occurring within the Dudley -Bloody Brook watershed that were observed during the Phase 2 SGA. Stressor maps are included in Appendix D. 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 channel adjustments within the watershed. This is helpful in developing and prioritizing potential protection and restoration projects.

Land Cover

The Dudley-Bloody Brook subwatershed has a mixture of land cover types, with significant amounts of urban land cover found in the eastern portion around the Exeter village. The Route 101 corridor in the northern portion of the subwatershed also has commercial land use stemming from it, increasing the amount of development in the headwaters zone. The Exeter River Vulnerability Analysis (Geosyntec, 2008) found that the Dudley-Bloody Brook subwatershed had the highest degree of impervious cover of any in the watershed (8.0%). This represents a low to moderate degree of impervious cover, below levels typically associated with degraded stream conditions at the national level (CWP, 2003), but above the 5% impact threshold noted in urbanizing watersheds around Burlington, Vermont (Fitzgerald, 2007).

Hydrologic Regime Stressors

Roads networks contribute to localized increased storm flows caused by increased runoff and stormwater ditching. The Dudley-Bloody Brook subwatershed has some areas of dense road networks serving suburban development in the lower watershed and north of Route 101. Four subwatersheds associated with these areas have road densities greater than 5 miles per square mile (LR01, LR02 BB02, and BB03). Fitzgerald and Godfrey (2008) found that road densities of greater than 5 miles per square mile in a rural watershed of Vermont were associated with sensitive reaches that had degraded biological communities. Of the remaining subwatersheds, four have moderate and four have low road densities. Impacted wetlands have been quantified for the subwatershed, allowing for an interpretation of loss of hydrologic attenuation of surface runoff at the reach and watershed scales. In the Dudley-Bloody Brook subwatershed, four subwatersheds have lost at least 20 percent of the original wetland area due to agricultural or urban land uses (LR01, LR02, BB01, and DB03). This degree of wetland loss has been shown to impact water quality in the seacoast region of New Hampshire and Massachusetts (Kennedy, 1991).

Sediment Load Indicators

The Sediment Load Indicators map indicates that any potential for increased delivery of fine sediment from agricultural lands is concentrated in the upper sections of Dudley Brook and along Bloody Brook downstream of the Route 101 crossing. However, significant increases in channel sediments were not observed in these areas; the dominance of wetlands and lack of sediment bar formation made it difficult to assess upland sources. In general, E-type channels are very efficient at transporting fine sediment downstream, and bar formation is often lacking in these stream types. With the exception of two stream segments in the Dudley Brook subwatershed, all segments are E-type, and therefore very few depositional features were noted. A high degree of deposition was observed downstream of the Colcord Pond Dam (>10 features per mile) due to erosion occurring in overflow channels below the Pond outlet. Bank erosion is limited in the subwatershed, and was concentrated in the lower watershed where stormwater outfalls and urban encroachment have impacted the channel. Segment LR01-B, located downstream of the lower Route 111A crossing, had numerous erosional features. Minor bank erosion and gullying was noted along the north bank near West Side Drive, and a large mass failure was noted downstream of the B&M railroad crossing along the south bank.

Channel Slope and Depth Modifiers

Corridor encroachment and development in the lower subwatershed and along upper Bloody Brook has been highlighted on the Slope and Depth Modifiers map for areas where natural channel sinuosity may be decreased. In these areas, increased channel slopes may cause reduced floodplain function because the channel has greater capacity to hold larger flow events within the channel, rather than spilling onto the floodplain. Beaver dams are common in the upper reaches. Although these features are ephemeral, they do temporarily control vertical channel adjustments and have been shown to help maintain floodplain function in low-gradient urban streams (Fitzgerald, 2007). Channel straightening was noted in the upper reaches of Dudley Brook where agricultural impacts have resulted in a simplified planform. This was especially evident in reach DB02, located downstream of Route 111A (upper crossing), as previously described in the reach summaries.

The Colcord Pond Dam is found on the Little River immediately downstream of the Route 111A crossing in Exeter. The dam was historically used for a saw mill, but is now inactive and maintained by the Town of Exeter. There are flashboards in place to increase the dam's freeboard, which are removed during flood events. The backwater effect of the dam extends approximately 0.8 miles upstream to the Garrison Road crossing. Beaver dams are present in the western end of the impoundment, and may further raise the surface water level near Garrison Road. Colcord Dam does not have a fish ladder. No channel adjustments were observed at the upstream reach LR03 at the lentic-lotic boundary near Garrison Road. However, channel adjustments related to the dam overflow were noted downstream in segment LR02-C. Scour was noted in an overflow side channel to the northeast of the dam's main outlet. This scour is leading

to increased sediment delivery to the channel; a moderate degree of aggradation and channel widening was noted downstream. Due to the channel adjustments noted in the downstream area, sediment storage and transport to downstream reaches would need to be considered if dam removal is considered in the future for fisheries restoration.

Riparian Boundary Conditions

The Riparian and Boundary Conditions map highlights areas where human alterations to the river boundaries have increased or decreased the resistance of the banks and bed to channel adjustments. In the lower reaches of the Little River, extensive areas of reduced riparian vegetation (along West Side Drive) combined with areas of moderate bank erosion have made the channel prone to lateral adjustments (e.g., further bank erosion and widening). Some channel armoring along Route 111A has reduced the potential for bank erosion. Many impacts to the channel boundaries were also noted at the Bloody Brook crossing of Route 101. This area lacks a healthy riparian buffer; however extensive bank armoring has reduced the potential for bank erosion. Impacts to the riparian buffer were also extensive near the Dudley Brook Route 111A crossing where areas of pasture surround the channel, and in the lower Little River reaches near Linden Street and Route 108.

7.4.2 Departure Analysis

Reference Sediment Regime mapping has been prepared for the Dudley-Bloody Brook subwatershed, and indicates that most reaches would have equilibrium conditions. Under these conditions there is a balance between the sediment originating from upslope sources and the capacity of the channel to store and transport the incoming sediment. Three high-gradient reaches associated with confined valley settings (LR02-C, LR04-A, and DB01-B) would tend to have greater capacity for sediment transport. Existing Sediment Regime mapping indicates that departures have occurred in five segments: LR01-B, LR02-A, LR02-C, BB03-A, and BB04. Similar stressors are associated with the departures in LR01-B, LR02-B, BB03-A, and BB04. In these areas, a combination of increased stormwater runoff and corridor encroachments has reduced floodplain function. In LR02-C, which is located immediately downstream of Colcord Pond Dam, erosion from overflow channels below the Pond outlet have increased the supply of sediment to downstream reaches.

7.4.3 Sensitivity Analysis

In general, stream sensitivities are higher in the Dudley-Bloody Brook subwatershed due to characteristics inherent to low-gradient, E-type channels. In these geologic and topographic settings, alluvial channels that lack natural controls on channel stability (e.g., grade controls) tend to respond to watershed and reach-scale stressors more readily than coarse-bottomed, headwaters channels. The impact of human stressors on stream channel stability was quantifiable in the Little River reaches near Route 111 and in upper Bloody Brook. In these areas, stream channel sensitivity ratings are subsequently heightened to reflect the increased susceptibility of these areas to respond to human

stressors. Reaches with extreme sensitivities represent E-type channels with moderate impacts to channel stability, and include: LR01-B, LR02-B, and BB04.

7.4.4 FEH Zones

A summary of the FEH zones developed for the Dudley-Bloody Brook subwatershed is included in Appendix E. Included in Appendix E is: 1) a complete summary of the methods used to develop FEH zones, 2) a summary table comparing the stream channel sensitivity assigned to each corridor with the degree of protection afforded by wetlands and conserved lands within the corridor, and 3) maps depicting the FEH corridors, sensitivity ratings, and other aspects related to corridor protection.

7.5 Dudley-Bloody Brook Project Identification

The site level projects that were developed for the Dudley-Bloody Brook subwatershed are provided below in Table 7.5. The project strategy, technical feasibility, and priority for each project are listed by project number and reach. A total of 18 projects were identified to promote the restoration or protection of channel stability and aquatic habitat. Photographs of these projects are included in Appendix F. The table summarizes key information for each project, including the project strategy, technical feasibility, and priority based on scientific data and stakeholder input. The 18 projects are further broken down by category as follows: 8 active geomorphic restoration; 6 passive geomorphic restoration; 2 conservation; 2 stormwater mitigation. The active geomorphic restoration projects include 5 bridge and culvert retrofit/replacement locations and 2 channel restoration projects.

The project locations and categories identified for the Dudley-Bloody Brook subwatershed are depicted below in Figure 7.31. Five high priority projects have been identified. Three of the high priority projects are located in the Town of Exeter and two are within the Town of Brentwood. The high priority projects include:

- **Streamside plantings** to the west of West Side Drive (project # 3);
- **Stormwater management** for runoff originating from the West Side Drive area (project #4);
- **Active restoration** to remove stream ford west of Route 111 (project #6);
- **Streamside plantings** south of Route 111A (project #16);
- **Active restoration** to recapture abandoned meander south of Route 111A (project #17).

Table 7.5
Dudley Brook, Bloody Brook, and Little River Site Level Opportunities for Restoration and Protection

Project #, Location, Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#1 Northeast corner of Bell Avenue in Exeter 42.97315 N 70.94630 W Segment LR01-A[A]	Stormwater Management	Stormwater runoff in lower reach along south bank is causing unstable outfall, increasing sediment supply to channel	Provide small detention or infiltration structure (e.g., rain garden) upslope of outfall; stabilize outfall with rock; Investigate storm drain network upslope and location for BMP	Moderate	Low	Reduced fine sediment loading to channel and downstream areas; reduced property loss from long term bank erosion	Moderate costs to install LID BMP (Approx cost persqft: Raingarden: $10; Gravel Wetland: $10-15)	Aligns with community goals to address stormwater impacts	NHDES, ERLAC, Town of Exeter, Adjacent Landowners
#2 East of B&M railroad crossing in Exeter Segment LR01-B	Passive Restoration	Large mass failure located downstream of B&M railroad crossing on south bank; FEH corridor ends at valley toe, but erosion potential extends to south	Investigate land ownership and zoning to prevent future development conflict with slope failure; Potential conservation easement	Moderate	Low	Avoided property losses	Unknown; Potentially high if conservation easement is pursued	Evaluate local priorities & goals	Town of Exeter, Adjacent Landowner, ERLAC, Southeast Land Trust of New Hampshire (SLTNH)
#3 South of West Side Drive 42.97507 N 70.96708 W Segment LR01-B	Passive Restoration	Areas of limited woody vegetation along river edge, esp. on north bank (740 ft with buffer less than 25ft wide), contributing to degraded habitat and elevated stream temperatures	Plant stream buffer with native woody vegetation in residential areas lacking canopy cover; Coordinate with adjacent landowners to assess areas where plantings could be implemented	Moderate	High	Improved biotic habitat within reach (overhanging vegetation) and downstream (shading for lower water temp.)	Relatively low costs for native plant materials and labor	May align with local goals, but significant landowner outreach will be needed	ERLAC, Town of Exeter, NHFGD, Adjacent Landowners
#4 South of West Side Drive 42.97566 N 70.96759 W Segment LR01-B	Stormwater Management	Stormwater outfall mid reach along north bank is causing gully formation, increasing sediment supply to channel	Stabilize outfall and investigate need for stormwater BMP in upslope drainage; Investigate storm drain network upslope and potential location for BMP	High	High	Reduced fine sediment loading to channel; Reduced property loss from long term bank erosion	Moderate to high costs for design and construction of BMP, and outfall stabilization	Aligns with community goals to address stormwater & flooding impacts	NHDES, ERLAC, Town of Exeter, Adjacent Landowners

Table 7.5
Dudley Brook, Bloody Brook, and Little River Site Level Opportunities for Restoration and Protection

Project #, Location, Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#5 B&M railroad crossing in Exeter 42.97317 N 70.96628 W Segment LR01-B	Active Restoration	B&M Railroad crossing in the lower segment is 42% of bankfull width; Bridge found at sharp bend with a large slope failure downstream on south bank; Inadequate capacity for 25 year storm; Bridge appears structurally stable	Replace bridge; Engineering work required for design and permitting	Moderate	Moderate	Decreased bank erosion and improved downstream water quality	Moderate to high costs of design and replacement given potentially difficult access	Cost & landowner negotiations with the rail road might be prohibitive	Rail Company (B&M); Town of Exeter, NHDES
#6 West of Route 111 in Exeter 42.97977 N 70.96935 W Segment LR02-A	Active Restoration	Grade control (stream ford) constructed of boulders found at upstream segment break is decreasing continuity and sediment supply to lower reaches; AOP is reduced; Structure may be a wetlands violation	Remove structure and restore natural channel morphology in segment upstream to increase sediment continuity and AOP Need to further investigate land ownership, feasibility, and use of upstream impoundment	Moderate	High	Increased AOP and potential for ~1,000 ft of improved habitat upstream	High construction & permitting costs for structure removal and channel restoration	Will benefit aquatic life & mitigate flooding issues; however, cost and time to negotiate with landowners may be prohibitive	NHDES, ERLAC, NHFGD, Adjacent Landowner
#7 West of Route 111 in Exeter 42.98004 N 70.96923 W Segment LR02-B[A]	Passive Restoration	Areas of limited woody vegetation in lower segment (180 ft with buffer less than 25ft wide) contributing to degraded habitat and elevated stream temps; wide channel with open canopy has naturally high thermal loading.	Plant stream buffer with native woody vegetation along north bank of impoundment in lower segment; Assess adjacent landowner interest; Should be pursued as part of project #6	Low	Moderate	Improved biotic habitat within reach (overhanging vegetation) and downstream (shading for lower water temp.)	Relatively low costs for native plant materials and labor	Cost and time of landowner negotiations may be prohibitive	ERLAC, Town of Exeter, NHFGD, Adjacent Landowner
#8 South of Route 111A in Exeter 42.98363 N 70.97133 W Segment LR02-C	Active Restoration	Side channel to northeast of Colcord Pond outlet may be scoured during high flow events, leading to increased sediment delivery to channel	Reconfigure outlet structure to prevent overflow and scour around south side of pond; Needs further investigation to verify source of coarse sediment loading	Moderate	Moderate	Reduced sediment loading to downstream channel; reduced potential for further degradation at pond overflow	Potentially high costs to reconfigure channel outlet structure in accordance with NHDES requirements	Costs may be locally prohibitive	NHDES, Town of Exeter

Table 7.5
Dudley Brook, Bloody Brook, and Little River Site Level Opportunities for Restoration and Protection

Project #, Location, Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#9 South of Route 111A in Exeter 42.98363 N 70.97133 W Segment LR03	Active Restoration	Colcord Dam is a significant barrier to aquatic organism passage; Dam is maintained by Town of Exeter	Remove dam to restore aquatic organism passage; Channel restoration in upstream reach would also be necessary	Low	Moderate	Increased AOP and potential for ~4,000 ft of restored habitat upstream	Very high construction & permitting costs for structure removal and channel restoration		NHDES, Town of Exeter, ERLAC, NHFGD
#10 North of Route 111A in Exeter Segment LR04-B	Conservation	Portions of the south river corridor may be unprotected against development by the 100yr floodway; Land north of Brentwood Rd in lower reach may be suitable for future development	Confirm protection status of lower south corridor; If unprotected, secure conservation easements to avoid future conflicts; FEH overlay would protect area of interest	Moderate	Moderate	Protected floodplains allow for attenuation of fine sediment and floodwaters	Potentially high costs for easements due to private ownership; Needs further investigation	Would help address local flooding issues; landowner negotiations could be cost & time prohibitive	ERLAC, SLTNH
#11 Northeast of Route 101 in Exeter 43.00554 N 70.97789 W Segment BB03-A	Passive Restoration	Upper segment straightened along reservoir lacks woody vegetation along banks and buffer; contributing to degraded habitat and elevated stream temperatures; beaver activity in area	Plant stream buffer with native woody vegetation; Investigate land ownership and maintenance	Low	Moderate	Improved biotic habitat within reach (overhanging vegetation) and downstream (shading for lower water temp.)	Relatively low costs for native plant materials and labor	May align with local goals, but landowner outreach will be needed	ERLAC, Town of Exeter, NHFGD, Adjacent Landowners
#12 South of Kelby Scott Way in Exeter Segment BB03-B	Conservation	Reach has reference habitat and good channel stability; Corridor is currently undeveloped but residential area surrounds channel - approx. 8 parcels (5-10 acres in size) found in corridor	Protect river corridor through conservation easements or FEH implementation.	Moderate	Moderate	Protected floodplains allow for attenuation of fine sediment and floodwaters.	Parcel ownership and zoning needs further investigation	Conservation may protect local drinking water supplies	Town of Exeter, ERLAC, SLTNH

Table 7.5
Dudley Brook, Bloody Brook, and Little River Site Level Opportunities for Restoration and Protection

Project #, Location, Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#13 Kelby Scott Way in Exeter 43.00979 N 70.97476 W Segment BB03-B	Active Restoration	Kelby Scott Way culvert is mostly incompatible and undersized for flood events; However, culvert appears to be recently installed	Monitor stability of channel around culvert, especially upstream to assess long-term impacts; Possible future replacement	Moderate	Moderate	Improved aquatic organism passage; Potentially reduced property loss from flooding and erosion over long-term	High costs to excavate road and replace structure	The project aligns with local stormwater and flooding priorities, but costs may be prohibitive	Town of Exeter, NHDES
#14 Watson Road in Exeter 43.01065 N 70.97332 W Reach BB04	Active Restoration	Headwaters reach with limited stream power and erosion potential; Culvert is mostly incompatible and undersized for flood events; Deposition of fine sediments upstream	Monitor stability of channel around culvert, especially upstream to assess long-term impacts; Possible future replacement - culvert appears to be recently installed	Moderate	Moderate	Improved aquatic organism passage; Potentially reduced property loss from flooding and erosion over long-term	High costs to excavate road and replace structure	High costs are prohibitive	Town of Exeter, NHDES
#15 West of Watson Road in Exeter 43.01060 N 70.97277 W Reach BB04	Active Restoration	Private driveway culvert downstream of Watson Rd is mostly incompatible and undersized for flood events; some scour noted on downstream end	Monitor stability of channel around culvert; Possible future replacement - coordinate with private landowner	Moderate	Moderate	Improved aquatic organism passage; Potentially reduced property loss from flooding and erosion over long-term	Moderate to high costs to excavate driveway	Privately owned; evaluate priorities	Private Landowner; Town of Exeter, NHDES
#16 South of Route 111A in Brentwood 42.99202 N 71.02099 W Reach DB02[A]	Passive Restoration	Upper reach lacks native woody vegetation and has been historically straightened; Cattle grazing openly along stream margin; Conserved lands (south of channel) and extensive wetlands to the south	Exclude cattle from stream channel with fencing and replant buffer with native woody vegetation; CREP, WRP, and/or WHIP programs could support enhancement and conservation effort	Moderate	High	Improved biotic habitat within reach;	Relatively low costs for native plant materials, fencing and labor		ERLAC, NHDES, NRCS (WRP), USDA, NHFGD, Adjacent Landowner

Table 7.5
Dudley Brook, Bloody Brook, and Little River Site Level Opportunities for Restoration and Protection

Project #, Location, Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#17 South of Route 111A in Brentwood 42.99245 N 71.02096 W Reach DB02[A]	Active Restoration	Stream channel historically straightened and is unstable due to cattle grazing along banks	Potential channel restoration to recapture the abandoned meander to north and south; Could be implemented as part of project #15	Moderate	High	Floodplain function improved with increased sinuosity; Aesthetic improvements	Potentially moderate to high costs due to channel construction, etc.		Private landowner, NHDES, NRCS (WRP), NHFGD, ERLAC
#18 North of Route 111A in Brentwood 42.99252 N 71.02398 W Reach DB03[A]	Passive Restoration	Lower reach lacks native woody vegetation and has been historically straightened; Sheep grazing openly along stream margin; FEH corridor likely protected from future development due to extensive wetlands	Exclude sheep from stream channel and buffer with fencing; Replant buffer with native woody vegetation; CREP or WHIP programs could support enhancement and conservation effort	Moderate	Moderate	Improved biotic habitat within reach (overhanging vegetation) and downstream (shading for lower water temp.)	Relatively low costs for native plant materials, fencing and labor	Buffers are a high local priority; landowner outreach will be needed	ERLAC, NHDES, NRCS, USDA, NHFGD, Adjacent Landowner

[A] Administrative judgment used for determining stream type, RGA and RHA condition for impounded and/or wetland reaches and segments.

Additional Notes for Reaches/Segments with No Identified Projects:

- LR03: The reach associated with Colcord Pond had no RGA or RHA data collected for it because the reach is not governed by fluvial processes. Therefore no projects were identified for this reach, and no FEH corridor was developed.
- LR04-A: No restoration projects have been identified for this reach due to the existing protection afforded by the steep valley side slopes. Channel boundaries and buffers are well vegetated and stable, with only minor areas of reduced vegetation. FEH implementation would further ensure long-term protection.
- LR05, BB01, BB02, DB01: No restoration projects identified for this reach due to the existing protection afforded the FEH corridor by conserved lands and wetlands (90 - 100% of corridor). Channel boundaries and buffers are generally well vegetated and stable, with good physical stability and aquatic habitat.

Project ID Table Includes Bridges and Culverts That Meet the Following Criteria:

3. Mostly incompatible or fully incompatible using VTANR Geomorphic Compatibility Screening Tool <u>and/or</u>
4. Modeled flood capacity or 25 year storm less than 100 percent.

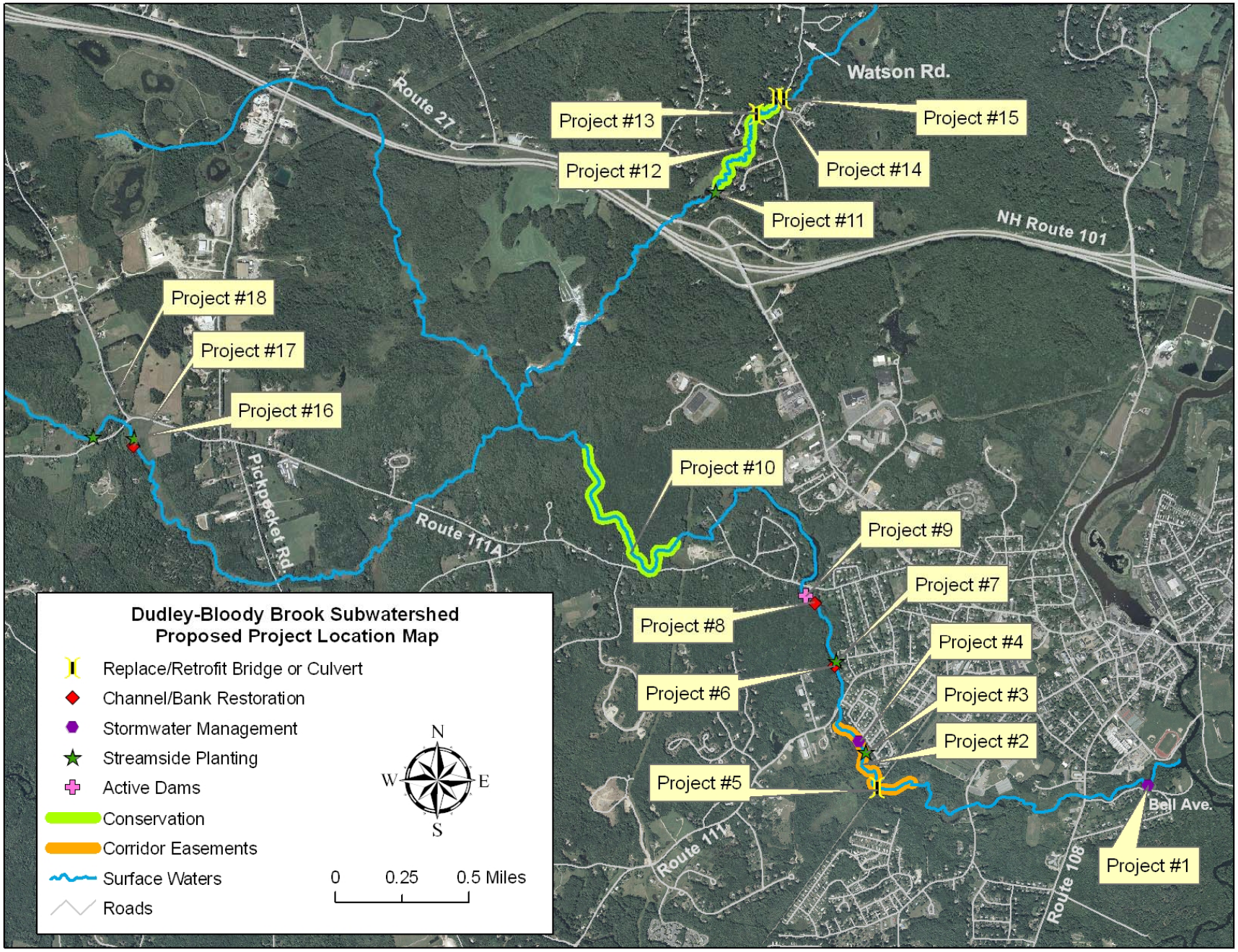

Figure 7.31 Proposed project location map for Dudley-Bloody Brook Subwatershed

8.0 Lower Exeter River Results

8.1 Lower Exeter River Background Information

The Lower Exeter River subwatershed encompasses the lowest stretch of the Exeter River prior to the Great Dam and a change to the estuarine Squamscott River. This subwatershed area is bound to the north by the east-west running drainage divide separating it from the Bloody Brook subwatershed. The subwatershed extends to the south to include Great Brook, a large tributary with a drainage area of approximately 11.5 square miles. The areas of greatest topographic relief in the subwatershed (approximately 280 feet above sea level) are found in the southeastern corner of Exeter near Great Hill Court. The Lower Exeter River flows in an easterly direction through the Towns of Brentwood and Exeter (Figure 8.1). The upstream subwatershed area begins at the river's confluence with the Little River (in Brentwood), located one mile downstream of the Haigh Road crossing. The upper two reaches (LE11 and LE12) are affected by the backwater of Pickpocket Dam, and are surrounded by extensive wetlands. Downstream of Pickpocket Dam, the river descends through a confined valley with cobble and gravel-bottomed reaches and numerous natural grade controls (e.g., ledges), as well as historical mill sites. Downstream of Route 111, the river enters a broad valley setting and is surrounded by increasing development as it approaches the village of Exeter. Following a brief section of steeper gradient channel at the Powder Mill Road crossing, the river resumes a low-gradient form through conserved lands and wetlands south of the Exeter village. After its confluence with the Little River near Gilman Park, the Exeter River enters the village of Exeter and descends over the Great Dam into the brackish waters of the Squamscott River.

The Lower Exeter River subwatershed contains 9.7 miles of channel that were assessed for Phase 1 data. NHGS and the Project Team originally identified 12 reach breaks for the Phase 1 analysis, all 12 of which were included in the Phase 2 assessments. As with the Dudley-Bloody Brook subwatershed, the geologic and geomorphic settings of this subwatershed have a strong influence on the reference channel morphology. The soil parent materials have areas of extensive clays and silts originating from marine deposits, as well as alluvial deposits in the lower reaches. These characteristics, along with extensive areas of wetlands in the stream corridors, lead to broad valley morphology and low-gradient, sinuous channels with sand and silt bottoms (Rosgen "E" channels). Outwash and till soils border both sides of the river downstream of Pickpocket Dam and to the south of the river near Powder Mill Road. The presence of these parent materials likely led to the development of coarse-bottom, riffle-pool characteristics in reaches LE05, LE08, LE09, and LE10. Despite the confined valley characteristics observed below Pickpocket Dam and at Powder Mill Road, the valley slopes of all reaches are under one percent (Table 8.1).

Table 8.1 Geomorphic Setting of Assessed Reaches				
Reach ID	**Reference Stream Type**	**Confinement Type**	**Valley Slope (%)**	**Channel Bedform**
LE01	E	Broad	0.10	Dune-ripple
LE02	E	Broad	0.02	Dune-ripple
LE03	E	Very Broad	0.06	NA
LE04	E	Very Broad	0.18	Dune-ripple
LE05	Bc	Semi-confined	0.11	Riffle-pool
LE06	C	Broad	0.05	Dune-ripple
LE07	E	Broad	0.33	Dune-ripple
LE08	C	Semi-confined	0.15	Riffle-pool
LE09	E	Narrow	0.25	Riffle-pool
LE10	C	Semi-confined	0.75	Riffle-pool
LE11	Impoundment	NA	0.04	NA
LE12	E	Very Broad	0.01	Dune-ripple

8.2 Lower Exeter River Phase 2 Results

During the Phase 2 assessments, the Lower Exeter River reaches were broken down into 14 segments based on more detailed field observations. The reference stream type for each assessed segment is included in Figure 8.1. A discussion of each segment in the Lower Exeter River subwatershed is provided below. Detailed segment summary data is provided in Appendix A.

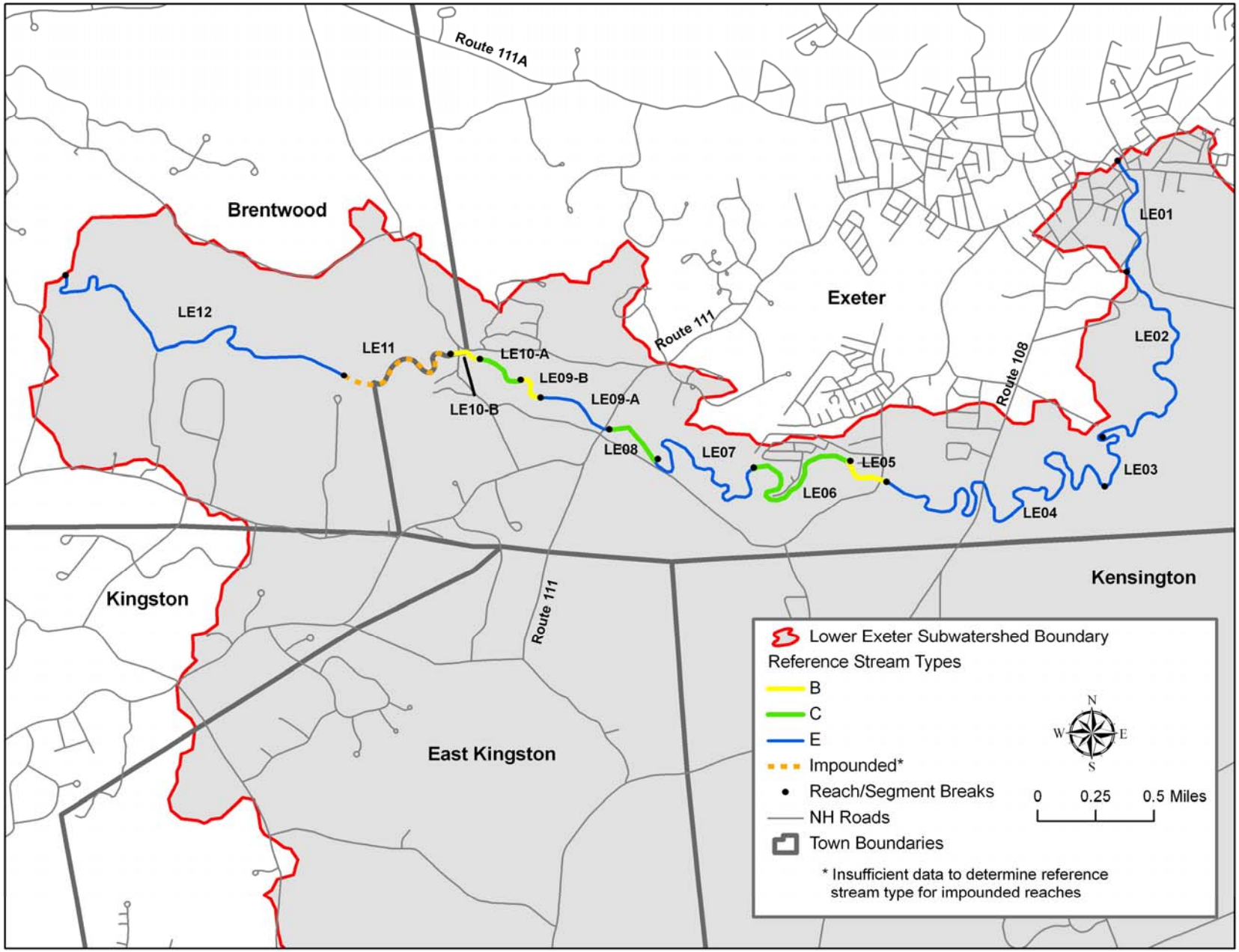

Figure 8.1 Lower Exeter River reach/segment Locations and reference stream types

Town of Exeter

Reach LE01

The downstream limit of the Lower Exeter River study area is found at the Great Dam in the Town of Exeter, immediately downstream of the High Street crossing (Figure 8.2). At this point, the drainage area to the river is 108.5 square miles. The first reach, LE01, extends 0.6 miles to the confluence with the Little River just upstream of Gilman Park. Due to the backwater effect of the Great Dam, this stretch of river is impounded and is not governed by fluvial geomorphic processes. Channel geometry data originally collected for stream typing and RGA/RHA scores were not used to develop sensitivity ratings for FEH and other corridor planning purposes, and should not be compared to non-impounded reaches upstream of LE03. Rather, an administrative judgment was used to determine RGA and RHA scores. An RGA score of "good" and an RHA score of "fair" were selected for this reach.

The NWI data indicate that this reach is composed of two major wetland types. Throughout the impounded area within the channel, the wetlands are a riverine system with an unconsolidated bottom. This wetland type extends from the Great Dam up into reach LE04 to the crossing of Route 108. Along the channel margins, the palustrine wetlands are well-forested with a mixture of evergreen and broad-leaved deciduous tree and shrub species, and are seasonally flooded during higher flow events in the river. Many areas of limited buffer (less than 25 feet width) were noted during the field surveys, especially along the west bank (Figure 8.3). These areas contribute to degraded habitat and elevated stream temperatures; however the wide channel and open canopy results in naturally high thermal loading.

Figure 8.2 High Street crossing upstream of Great Dam

Figure 8.3 Lack of healthy riparian buffer

Reach LE02

Reach LE02 begins at the confluence with the Little River entering from the west (Figure 8.4), and extends upstream for 1.2 miles to the upstream reach break just east of Lary Lane. The backwater effect of the Great Dam extends upstream through this stretch of river

(Figure 8.5), therefore this reach was considered impounded and not governed by fluvial geomorphic processes. As in LE01, channel geometry data originally collected for stream typing and RGA score were not used to develop sensitivity ratings for FEH and other corridor planning purposes. An administrative judgment was used for the overall reach scores, resulting in RGA and RHA scores of "good".

Figure 8.4 Little River confluence with Exeter River

Figure 8.5 Backwater effect of Great Dam in LE02

As in LE01, the NWI data describe two major types of wetlands for this reach. The riverine system present in LE01 is found throughout the impounded channel, extending into reaches LE03 and LE04 to the west. Palustrine wetlands outside the channel boundaries are well-forested with broad-leaved deciduous species, and are seasonally flooded during higher flow events in the river. Lands conserved by Phillips Exeter Academy (PEA) surround the entire length of this reach, and extensive wetlands provide further obstacles to development in the vicinity of the channel. The FEH corridor summary indicated that over 90 percent of the FEH corridor is protected against future development by a combination of wetlands and conserved lands.

Reach LE03

Reach LE03 begins just south of the end of Lary Lane, and extends upstream to the eastern edge of the Exeter Elms Campground. LE03 is a short reach (2,057 feet) having very similar characteristics to LE02. The backwater effect continues through this short stretch of river. Therefore, an administrative judgment was used for the overall reach scores, resulting in an RGA score of "good" and an RHA score of "fair".

The wetland complexes described in LE02 extend throughout this reach. Lands conserved by PEA are found adjacent the channel to the south, and the extensive wetlands further protect against structural development near the channel. The FEH corridor summary indicated that nearly 100 percent of the FEH corridor is protected against future development by either conserved land or wetlands.

Reach LE04

The eastern end of reach LE04 is found approximately 1.3 river miles downstream of the Route 108 crossing. LE04 is a long reach, extending upstream 2.2 miles to a river crossing at Linden Street. The lentic conditions associated with the backwater effect of the Great Dam extend through the lower section of the reach (Figure 8.6); perhaps up as far as the Route 108 crossing (Wright-Pierce, 2007). Channel geometry data was collected at two cross-sections; one downstream and one upstream of Route 108. The channel geometry values and resulting stream typing were very similar. Therefore all data collected for this reach above and below the crossing were summarized together. LE04 has a very high sinuosity value (2.0), and combined with the low width-to-depth values found at both cross-sections (<12), it has been classified as an E-type channel. The bottom substrate is fine-grained (90% silt), reflecting the depositional nature of the sediment regime.

Two areas of bank erosion were noted along the east banks. One area is found where the adjacent Exeter Elms campsites have impacted the riparian buffer (Figure 8.7), resulting in decreased resistance of the channel boundary to high flow events. Minor bank erosion was also noted upstream of the Route 108 crossing where the channel parallels the road. One neck cutoff was noted in the lower reach where the natural migration pattern of the channel, in combination with a large debris jam, has diverted moderate to high flow through a side channel to the east. This feature is not an indication of human-induced change in channel planform.

Figure 8.6 Backwater effect of Great Dam in lower LE04

Figure 8.7 Bank erosion along campsites in LE04

The wetland complexes described in downstream reaches extend throughout this reach. The riverine wetlands associated with the impounded sections of the channel end at Route 108, further indicating a hydro-ecological boundary at this point. Extensive areas of conserved lands and wetlands provide significant obstacles to development in the vicinity of the channel throughout this reach. The FEH corridor summary indicated that nearly 70 percent of the FEH corridor is protected against future development.

The channel in LE04 is physically stable (channel evolution stage is I). Minor bank erosion did not significantly lower the RGA score ("good"), and no channel incision was noted in the cross-sectional geometry, indicating good floodplain access during high flow events. Habitat was assessed as "fair" due to limited scour and depositional features, and minor buffer impacts. The formation of habitat features (e.g., pools and riffles) is likely limited by the backwater effect in the lower reach, and contributed to the marginal habitat rating.

Reach LE05

LE05 is a very short reach (1,064 feet) found upstream of the Linden Street crossing. The elevation change at this point represents the upstream boundary of any potential backwater effect that could occur during high flows on the lower river. Channel geometry data collected at one cross-section (Figure 8.8) indicated B-type channel geometry with a subclass slope of C (< 2%). Stable riffle features were present, and no channel incision or departure in form was noted. A small increase in sand substrate was noted in the bed substrate; however this is likely due to the presence of extensive sand-bottomed channels upstream of LE05.

One large bank failure was noted along the north bank where adjacent homes have encroached upon the channel corridor and impacted the buffer (Figure 8.9). The soils associated with the failure are non-cohesive and are likely fill from the residential development in the 1970's. Armoring and encroachment along the north bank limit the ability of the channel to migrate laterally; however given the valley setting and slope, a straight channel is likely natural. Nearly 80 percent of the north bank lacks a riparian buffer greater than 25 feet, which is contributing to increased bank erosion, thermal loading, and generally degraded habitat conditions.

Figure 8.8 Channel cross section in LE05

Figure 8.9 Bank failure in upper LE05 at trailer park

Despite the bank erosion described above, the channel in LE05 exhibits equilibrium conditions (channel evolution stage is I; RGA score was "good"). No channel incision was noted in the cross-sectional geometry; however the reach lacks a well-defined floodplain due to the confined valley setting. Habitat was assessed as "fair", reflecting the lack of

woody debris and formation of scour and depositional features. In addition, bank armoring and the lack of native woody vegetation on the north bank adversely affect LWD loading and cover, and prevent the formation of undercut banks.

Reach LE06

The eastern (downstream) end of reach LE06 is found approximately 900 feet upstream of the Linden Street crossing, and extends 0.7 miles upstream to the western end of the trailer park. The channel is bordered to the north by the trailer park, with many residences found within the FEMA designated floodway. Based on a review of historic aerial photography, the trailer park was constructed throughout the 1970's and 1980's. Channel geometry data collected at one cross-section (Figure 8.10) in the lower reach indicated C-type channel geometry. Minor incision was noted (incision ratio = 1.2), likely resulting from encroachment on the floodplain and corridor over the past 30 years. Reduced floodplain access has likely led to increased stream power and minor vertical instability; however the cohesive marine clays that underlie the channel bed and banks are extremely resistant to erosion. A review of historical aerial photography suggests that the channel location has not significantly migrated since the 1960's. The surficial bed substrate is composed primarily of fine-grained sediment, indicating the depositional processes typical of this valley setting. The adjacent trailer park is the source of numerous impacts to channel stability. The lack of woody vegetation along the north bank is reducing boundary resistance (despite the cohesive clay soils) and degrading aquatic habitat, especially along the sharp bend in the upper reach (Figure 8.11). One large bank failure was noted along the north bank in less cohesive soils in the upper reach; this feature could threaten adjacent properties in the long-term if erosion continues. Although lateral channel migration is limited in much of the reach due to the cohesive soils, even minor bank erosion has the potential to strongly impact downstream aquatic habitat. Fine-grained, clay soil particles released from the banks stay in suspension for long distances and impact downstream biological habitat, as well as water quality for municipal supply.

Figure 8.10 Channel cross section in LE06

Figure 8.11 Buffer impacts from adjacent trailer park

Two stormwater outfalls originating from the trailer park on the north bank were noted and are aggravating bank erosion. One outfall is perched along the steep side slope leading down to the river, causing gully formation (Figure 8.12) and increased sediment supply to the channel.

Figure 8.12 Stormwater outfall from trailer park

The channel in LE06 has been assessed at stage II of channel evolution, indicating that some floodplain function has been lost due to incision. LE06 was one of two reaches in the Lower Exeter River subwatershed that received an RGA score of "fair". Minor channel incision, the presence of a flood chute in the lower reach (indicating the initiation of minor planform adjustments), and the bank erosion contributed to the lower rating. Habitat was also assessed as "fair" due to the lack of scour and depositional features, and impacts to the banks and buffers. LWD densities were high for this reach, as upstream reach LE07 has a healthy riparian buffer and may supply wood to the reach during channel forming events.

Reach LE07

LE07 is found from the trailer park limits up to a clearing for a gas line crossing from Powder Mill Road to the River Woods residential complex. The reach has a total length of approximately one mile, and is dissected by one crossing for the B&M railroad in the lower reach. Channel geometry data collected at one cross-section (Figure 8.13) indicated E-type channel geometry with dune-ripple bedform. Excellent formation of bed features needed for good aquatic habitat was noted, including high LWD density (Figure 8.14). Minor channel incision was observed at the cross-section; however no severe departures in form or stream type were noted. The surficial bed substrate is composed primarily of fine-grained sediment, reflecting the depositional processes typical of this setting.

Figure 8.13 Channel cross section in LE07

Figure 8.14 Large debris jam in upper LE07

Areas of extensive erosion were noted in the lower reach where approximately 500 feet of the south bank lacks a buffer greater than 25 feet (Figure 8.15). While a narrow strip of trees is still present along the channel margin, ongoing erosion could worsen in the future without buffer plantings. As in reach LE06, extensive lateral channel migration is limited in LE07 due to the cohesive soils that underlie the bed and banks. However, one minor flood chute was noted in the lower reach upstream of the B&M railroad crossing. This bridge is a floodplain constriction and may have induced the formation of the flood chute by constricting high flow events (causing temporary backwater effects).

One stormwater outfall originating from the River Woods complex to the north of the river has formed a gully adjacent the channel (Figure 8.16). This outfall is causing increased supply of fine sediment to the channel, and threatens the excellent biotic habitat observed throughout the reach. River Woods, a housing community adjacent to the river, has hired an engineer and a soil scientist to address the problem, which may lead to the design and construction of a stormwater BMP to control runoff from the extensive area of impervious cover upslope.

Figure 8.15 Lack of buffer and bank erosion in LE07

Figure 8.16 Stormwater outfall gully from River Woods

Due to the bank erosion described above, and the minor incision noted at the cross-section, the channel in LE07 has been assessed at stage II of channel evolution. However, the RGA score was calculated to be "good", and the channel had greater physical stability than downstream reach LE06. Habitat was assessed as "good", reflecting the high density of woody debris and good formation of scour and depositional features. With the exception of discrete areas of buffer and bank impacts, the healthy riparian conditions allow for numerous, well-covered undercut banks. Many schools of small mouth bass were observed in the pools and glides during the field observations under low flow conditions in July, 2008.

Reach LE08

Reach LE08 is a short reach (1,428 feet) that begins at the change in confinement just downstream of the gas line crossing that intersects Powder Mill Road and ends 90 feet downstream of the Kingston Road crossing. The lower half of this reach is widened and slow-moving (Figure 8.17). There, the bank scour can be attributed to a bedrock ledge found mid-reach. The slight change in slope increases velocity, resulting in the formation of scour pools below where the substrate becomes unconsolidated and sandy. Upstream of the grade control the substrate remains coarse, and the dominant substrate in the reach is cobble (30%). Geometry in this reach is indicative of C-type channels and the bedform is riffle-pool. Above the grade control there is a portion of the reach where the buffer has been reduced to less than 25 feet. This section of the north bank comprises approximately 25% of the reach. The south bank is well buffered and predominately between 100 and 150 feet in length. Two mid-channel bars were observed on the upper end of this reach.

Figure 8.17 The widened area downstream of the grade control

The geomorphic rating of this reach was influenced by the widening observed in the upper and lower sections of this reach as well as some aggradation in the form of mid-channel bars. However, the combined impact of stressors to the stability of the reach remained low and the RGA score was "good." The aggradational processes follow the D-type channel evolution model. The channel evolution stage was assessed at stage IIc. Downstream of the grade control a historic mill sluice or canal was observed off the south bank (Figure 8.18).

Figure 8.18 A mill sluice or canal observed off the right bank downstream of the grade control

It is likely that this site was chosen because of the change in slope associated with the grade control. The thermal loading associated with the open canopy, channel widening, and the lack of good cover in the form of undercut banks and woody debris reduced the overall habitat condition (RHA score "fair").

Segment LE09-A

This segment begins downstream of the Kingston Road (Route 111) Crossing and extends 1,819 feet upstream until the channel dimensions change significantly at the segment break. Immediately upstream of the Kingston Road crossing there was a small grade control (Figure 8.19). The first 350 feet of this segment was coarse-bottomed (Figure 8.20). However, this area was assessed as a separate segment because of its short length. The rest of the segment had channel dimensions that were indicative of E-type channel geometry and a riffle-pool bedform. The dominant substrate for this segment was sand (65%) and the sinuosity was low (<1.2). The north corridor had two areas of low buffer width. These impacts were associated with houses along Kingston Road.

Figure 8.19 Grade control upstream of Kingston Road crossing

Figure 8.20 Kingston Road crossing with coarse substrate and riffle-pool bedform

The overall geomorphic condition of this segment is "good". The segment has natural slope changes on the upstream and downstream ends that are causing only minor aggradation. The banks were stable throughout the upper segment where the corridor was largely forested. The healthy buffer in the upper segment is a source for the large amount of woody debris in the channel (LWD = 145 pieces/mile). However, the low buffer widths downstream and limited bed substrate cover reduced the overall RHA score to "fair."

Segment LE09-B

LE09-B is very similar to the lower section of LE09-A. It extends for 765 feet from the change in channel dimensions to the reach break with LE10. The substrate in this segment is mostly coarse gravel (35%), but cobble and bedrock also make up a large portion of the distribution, with 21% and 20%, respectfully. The geometry is indicative of a B-type channel, with a subclass slope that is less than 2.0% (B_c-type). The channel is experiencing minor widening, but overall had good access to adjacent floodplain along the inside of the one major meander bend to the southeast. Only minor bank erosion indicates that the high

width to depth ratio (WDR = 35) may be natural for the narrow valley setting. A small bedrock grade control was observed mid-segment (Figure 8.21). Downstream of this ledge feature there is a well formed and complete riffle. Upstream of the grade control a calm, shallow backwater was observed. Minor aggradation of fine sediment observed in this area.

Figure 8.21 An upstream view of the grade control

At the reach break with LE10 the riparian buffer is less than 25 feet (Figure 8.22). A lawn is maintained within close proximity of the channel for approximately 125 feet. Just downstream of this some erosion was observed on the south and north banks in the area where the channel meanders to the south. This is one likely source of the sediment that is trapped on the upstream end of the grade control. There was limited woody debris found in this segment (LWD = 55 pieces/mile). Since this segment is largely a transport-based system, woody debris is likely transported downstream in large storm events. The overall habitat condition of this reach was rated "fair" because of the low density of woody debris in addition to the areas where buffer and bank integrity was impacted. Some widening and associated with the bank stability caused the geomorphic condition decrease slightly, but still remain in the "good" category. The channel showed little evidence of present or historical incision (CEM stage I).

Figure 8.22 Area of low buffer observed in the upper segment

Segment LE10-A

Segment LE10-A is 1,183 feet in length, and extends from the reach break with LE09 up to approximately 700 feet downstream of the Pickpocket Dam. The channel has C-type channel geometry and the bedform is predominately riffle-pool. The dominant substrate type is cobble (43%). LE10-A is currently being influenced by the Pickpocket Dam upstream and also recovering from the presence of a historic mill that once impacted the channel. Two large abutments and a stone foundation on the north bank remain from the historic mill (Figure 8.23). When in operation, the mill likely caused a large amount of sediment to settle out upstream. Since the mill's removal (or destruction in a large flood) the sediment

has been carried downstream. Where the valley wall does not confine the channel, a small floodplain has redeveloped.

The reestablishment of a floodplain in the lower portion of this segment has been beneficial to the overall geomorphic stability of this reach. This floodplain redevelopment is indicative of stage IV of the channel evolution model. The riffles are complete and well formed (Figure 8.24) and the cross-section taken on this segment showed a defined bench and accessible floodplain. Aggradation does not appear to be a serious problem and currently only some widening has lowered the geomorphic rating (RGA score = "good"). The habitat condition in this reach is negatively influenced by some buffer impacts on the north bank as well as the armoring associated with the mill that was once located in this segment. The south bank was very stable and the south corridor was excellent (>200 feet). In summary the overall habitat was considered to be "fair." Woody debris was not as abundant as it was in the slower moving E-type reaches because the swift moving current quickly flushes out debris in large storm events (LWD = 49/mile).

Figure 8.23 Foundation of historic mill observed on the north bank mid-segment

Figure 8.24 A well formed riffle upstream of the bridge abutments

<u>Towns of Exeter and Brentwood</u>

Segment LE10-B

LE10-B is about 700 feet in length and extends from the segment break upstream to the Pickpocket dam. This segment, like LE10-A, has seen several impacts to its natural geomorphic state. Widening, aggradation and changes in planform are the dominant processes. The presence of an historic mill in downstream segment A likely led to the aggradation in this segment. Reduced channel-forming discharge due to Pickpocket Dam has caused aggraded material to remain in this segment. Some widening was observed immediately downstream of the dam along the north bank where Pickpocket Rd. has encroached upon the floodplain (Figure 8.25). The lower end of this segment has braided flows, steep riffles, and several diagonal bars (Figure 8.26). Over time the sediment aggraded in this reach should continue to move downstream, resulting in a more stable planform. The stream type is B_C with a high width-to-depth ratio (WDR = 32.0). The

subclass slope c indicates a channel slope of less than 2%. The bedform of this reach is riffle-pool and the dominant substrate is cobble (62%).

Figure 8.25 Widening downstream of Pickpocket Dam

Figure 8.26 Diagonal bar in lower portion of segment

The significant widening observed in the upper segment and the changes in planform of the lower reach influenced the geomorphic rating of this reach (RGA score = "fair"). These shifts in planform are characteristic of stage IIc of the D-type CEM. The unstable geomorphic state of this reach is a product of the past and present river uses. These impacts extend to the overall habitat condition of the segment (RHA score = "fair"). Some encroachment on the upper end of the segment and the buffer impacts on the north bank lowered the overall RHA rating.

Reach LE11

Reach LE11 begins at the Pickpocket Dam and extends 0.6 miles upstream to the reach break with LE12 just north of Stevens Road. Due to the backwater effect of Pickpocket Dam (Figures 8.27 and 8.28), this stretch of river is impounded and is not governed by fluvial geomorphic processes. Due to the severe impoundment conditions, an administrative judgment was not possible to determine RGA and RHA scores. Reference stream typing was also not possible, as the width of the impoundment made it difficult to estimate the natural, pre-dam channel and floodplain morphology. Therefore, an FEH corridor was not developed for this reach.

Figure 8.27 Impounded conditions above Pickpocket Dam

Figure 8.28 Pickpocket Dam

The NWI data indicate that this reach is dominated by one wetland type. This palustrine wetland type is "permanently flooded" due to the downstream dam, and has an unconsolidated bottom due to the shifting water levels and fine sediment deposition within the wetland body. Much of the impoundment is surrounded by a healthy buffer comprised of a mixture of evergreen and broad-leaved trees and shrubs. One area along the south bank in the upper reach lacks a healthy buffer (approximately 250 feet in length) due to residential development stemming from Stevens Road.

Town of Brentwood

Reach LE12

The upstream limit of the Lower Exeter River study area is found at the confluence with the Little River (Figure 8.29). At this point, the drainage area to the river is 74.8 square miles. This reach was accessed for Phase 2 surveys by canoeing downstream from the Haigh Road crossing, located approximately one mile upstream of the Little River. Due to the backwater effect of the Pickpocket Dam, this stretch of river is impounded and is not governed by fluvial geomorphic processes. Channel geometry data originally collected for stream typing and RGA/RHA scoring were not used to develop sensitivity ratings for FEH and other corridor planning purposes, and should not be compared to non-impounded reaches downstream of LE11. An administrative judgment was used to determine RGA and RHA scores of "good" for this reach. Habitat data collected for banks and buffers, LWD densities, debris jams, and undercut banks in upper LE12 suggest that good habitat existed in the reach prior to the flooding caused by the dam.

Figure 8.29 Confluence with Little River in LE12

Figure 8.30 Healthy riparian buffer conditions in LE12

Lower Exeter River Phase 2 Summary

The NWI data for the reach indicate multiple types of palustrine wetlands, yet dominated by "permanently flooded" wetlands due to backwater effect from the dam. Along the channel margins, the palustrine wetlands are well-forested with a mixture of evergreen and broad-leaved deciduous species, and are seasonally flooded during higher flow events in the river. Nearly the entire reach is flanked by a healthy buffer comprised of a mixture of evergreen and broad-leaved trees and shrubs (Figure 8.30).

Table 8.2
Lower Exeter River Stream Type and Channel Evolution Stage

Segment ID	Entrench-ment Ratio	Width to Depth Ratio	Reference Stream Type	Existing Stream Type	Channel Evolution Stage	Active Adjustment Processes
LE01	Partially Assessed – influenced by Great Dam Impoundment					
LE02	Partially Assessed – influenced by Great Dam Impoundment					
LE03	Partially Assessed – influenced by Great Dam Impoundment					
LE04	23.9	10.9	E6	E6	FI	Planform
LE05	1.5	13.2	Bc3	Bc3	FI	Aggradation
LE06	4.7	16.7	C5	C5	FII	Degradation Widening
LE07	9.3	11.1	E5	E5	FII	Degradation
LE08	3.0	20.6	C3	C3	DIIc	Aggradation Widening
LE09-A	4.9	12.2	E5	E5	FI	Aggradation
LE09-B	1.5	34.9	Bc4	Bc4	FI	Widening
LE10-A	3.0	19.2	C3	C3	FIV	None
LE10-B	1.9	32.0	Bc3	Bc3	DIIc	**Aggradation Widening Planform**
LE11	Partially Assessed – influenced by Pickpocket Dam Impoundment					
LE12	Partially Assessed – influenced by Pickpocket Dam Impoundment					

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

Table 8.3 RGA and RHA Scores for Fully Assessed Phase 2 Segments				
Segment ID	**RHA Score**	**RHA Condition**	**RGA Score**	**RGA Condition**
LE04	0.62	Fair	0.74	Good
LE05	0.54	Fair	0.71	Good
LE06	0.58	Fair	0.63	Fair
LE07	0.77	Good	0.65	Good
LE08	0.60	Fair	0.65	Good
LE09-A	0.59	Fair	0.68	Good
LE09-B	0.60	Fair	0.73	Good
LE10-A	0.64	Fair	0.66	Good
LE10-B	0.54	Fair	0.43	Fair

8.3 Lower Exeter River Bridge and Culvert Assessment

Table 8.4 summarizes the data collected for 7 bridges in the Lower Exeter River subwatershed. The final column of the table includes a prioritization of structures for replacement or retrofit based on a review of the following four criteria: structure width in relation to bankfull channel width; structure flood capacity; aquatic organism passage; geomorphic compatibility. Two bridges in the Lower Exeter River subwatershed were not evaluated for geomorphic compatibility because they are located in an impounded reach (LE01). The geomorphic screening tool is not applicable to non fluvial systems. None of the bridges on the Lower Exeter River were rated as incompatible with geomorphic screening tool. All of the bridges have been given a low priority rating, and none were selected for flood capacity modeling (Appendix C). Included in Appendix C is an explanation of how structures were selected for flood capacity modeling based on the field data for geomorphic compatibility, aquatic organism passage, and local knowledge.

Figure 8.32 depicts the aquatic organism passage barriers for the Lower Exeter River subwatershed, including dams and grade controls. Two human made grade controls were identified as reducing aquatic organism passage.

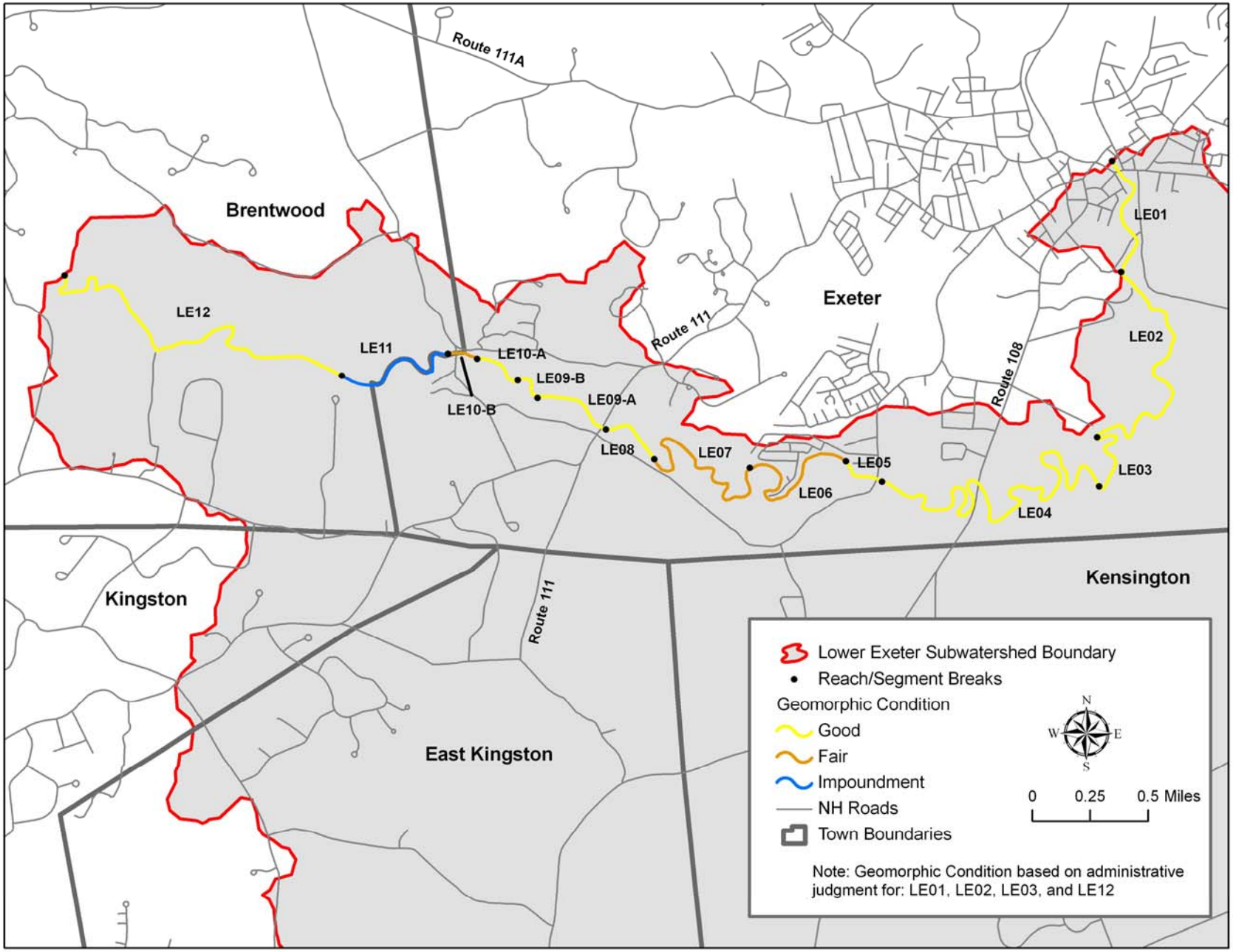

Figure 8.31 Geomorphic condition of assessed reaches in the Lower Exeter subwatershed

Table 8.4
Lower Exeter River Crossings

Reach/ Segment No.	Road Name, Town	Structure Type	Condition/ Observation	Percent Bankfull Channel Width	Structure Capacity for Flood Events (Percent Capacity)[1]		Aquatic Organism Passage (AOP)[2]	Geomorphic Compatibility[3]	Priority for Replacement or Retrofit
					25 Year	50 Year			
LE01	High Street, Exeter	Bridge	Very low clearance due to impoundment; No observable problems - bridge appears new	53%	----	----	NA	I[4]	Low
LE01	NA (Trail), Exeter	Bridge	No problems observed; Bridge serves PE Academy athletic fields	69%	----	----	NA	I	Low
LE04	Rt. 108, Exeter	Bridge	Located on sharp channel bend; moderate erosion upstream and downstream; Structurally stable	161%	----	----	NA	Partially compatible	Low
LE05	Linden Street, Exeter	Bridge	Stable crossing with minimal erosion; Large pool downstream; Very high clearance	112%	----	----	NA	Fully compatible	Low
LE07	B&M Railroad Crossing, Exeter	Bridge	High bank erosion upstream south bank; Moderate channel bend upstream	155%	----	----	NA	Mostly compatible	Low
LE09-A	Kingston Road, Exeter	Bridge	Minor channel constriction; No major scour – mostly stable	60%	----	----	NA	Mostly compatible	Low

Table 8.4
Lower Exeter River Crossings

Reach/ Segment No.	Road Name, Town	Structure Type	Condition/ Observation	Percent Bankfull Channel Width	Structure Capacity for Flood Events (Percent Capacity)[1]		Aquatic Organism Passage (AOP)[2]	Geomorphic Compatibility[3]	Priority for Replacement or Retrofit
					25 Year	50 Year			
LE10-B	Cross Road, Exeter	Bridge	Moderate constriction; Minor channel widening downstream; Bridge appears new and stable	54%	----	----	NA	Mostly compatible	Low

[1] No watershed hydrology data developed for the Lower Exeter River subwatershed as no structures were incompatible [2] Aquatic Organisms Passage ratings not applicable to bridges [3] Scores and ratings developed with the VTANR Geomorphic Compatibility Screening Tool; [4]Screening tool not applicable for non-fluvial (impounded) reaches.

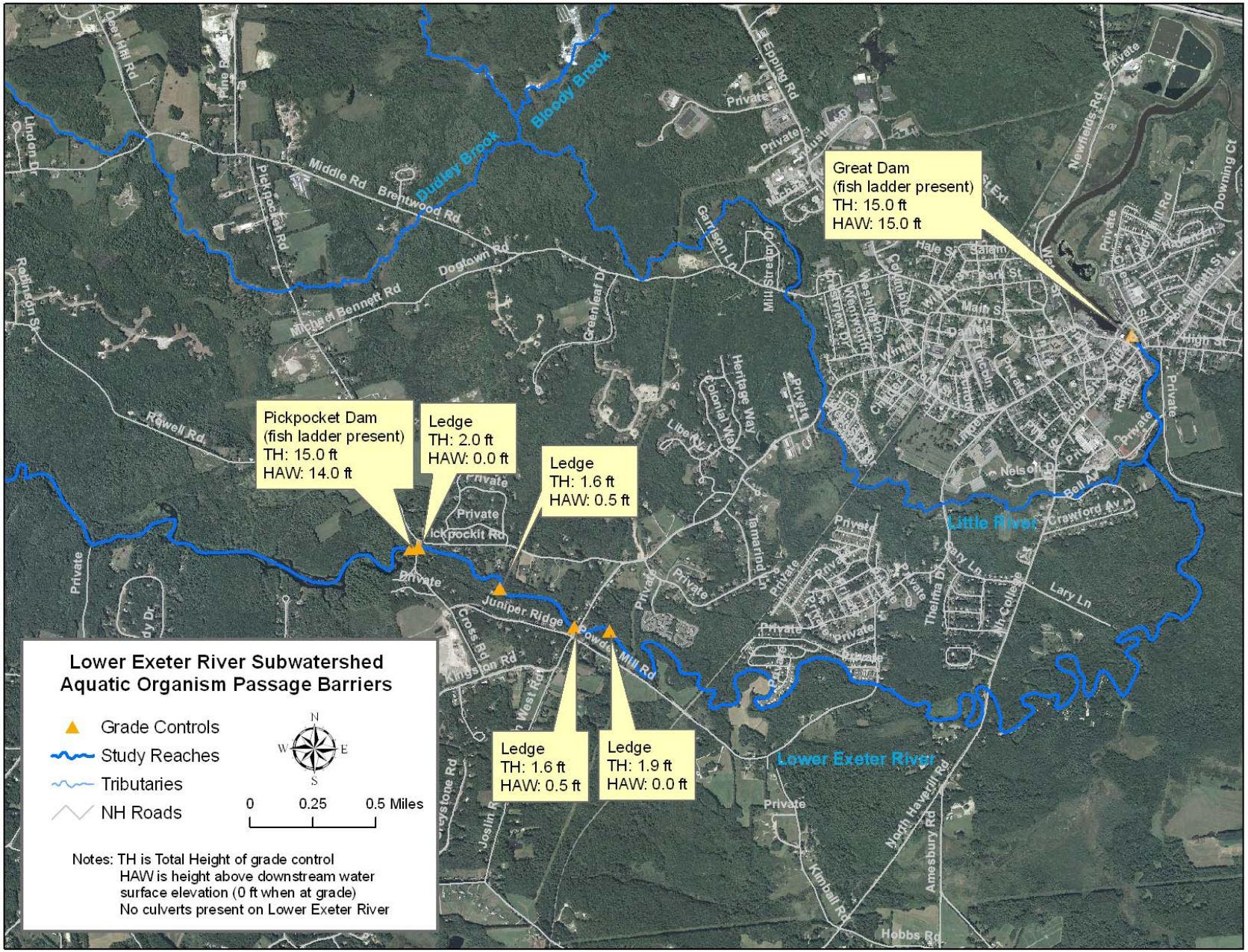

Figure 8.32 Aquatic organism passage barriers in the Lower Exeter subwatershed

8.4 Lower Exeter River Corridor Planning

8.4.1 Stressor Maps

Stressor, departure and sensitivity maps are presented here as a means of displaying the effects of all significant physical processes occurring within the Lower Exeter River subwatershed that were observed during the Phase 2 SGA. Stressor maps are included in Appendix D. 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 channel adjustments within the watershed. This is helpful in developing and prioritizing potential protection and restoration projects.

Land Cover

Similar to the Dudley-Bloody Brook subwatershed, the Lower Exeter River subwatershed has significant amounts of urban land cover in the eastern portion around the Exeter village. In addition, the trailer park west of Linden Street represents a concentrated area of suburban land cover in close proximity to the channel. The Exeter River Vulnerability Analysis (Geosyntec, 2008) found that the Lower Exeter River subwatershed had the third highest degree of impervious cover (7.1%). This represents a low to moderate degree of impervious cover, below levels typically associated with degraded stream conditions at the national level (CWP, 2003), but above the 5% impact threshold noted in urbanizing watersheds around Burlington, Vermont (Fitzgerald, 2007). In addition, a USGS study of the New Hampshire Seacoast showed a degree of impairment at the 7% impervious level (Deacon et al, 2005). Expansive areas of wetlands also exist in the subwatershed, especially to the south of the river in the subwatershed draining to Great Brook.

Hydrologic Regime Stressors

The Hydrologic Regime Stressors map summarizes the watershed scale land use changes that contribute to localized increased storm flows. The Lower Exeter River subwatershed has some areas of dense road networks serving suburban development. Five subwatersheds associated with these areas have road densities greater than 5 miles per square mile (LE01, LE05, LE05, LE08, and LE10). Of the remaining subwatersheds, three have moderate road densities (4-5 miles per square mile) and four have low road densities (<3 miles per square mile). A summary of wetland loss allows for an interpretation of loss of hydrologic attenuation of surface runoff at the reach and watershed scales. In the Lower Exeter River subwatershed, four subwatersheds have lost between 20 and 40 percent of the original wetland area due to agricultural or urban land uses (LE04, LE06, LE07, and LE10). This degree of wetland loss has been shown to impact water quality in the seacoast region of New Hampshire and Massachusetts (Kennedy, 1991). In addition, three subwatersheds have lost greater than 50 percent of

their original wetland areas (LE01, LE05, and LE08). Wetland loss at this magnitude may be contributing to the minor vertical instability observed in adjacent and downstream river reaches due to increased runoff.

Sediment Load Indicators

The Lower Exeter River Sediment Load map indicates that four subwatersheds may have increased potential for delivery of fine sediment from agricultural lands: LE04 (Great Brook), LE07, LE08, and LE10. Due to some areas of misclassification in the native data source (NOAA, 2008), the coverage of agricultural lands is likely overestimated in subwatersheds LE08 and LE10. However, significant and expansive areas of agricultural lands are indeed found to the south of the river in LE04 and LE07. The E-type channels found along the Lower Exeter River are very efficient at transporting fine sediment downstream, and bar formation was lacking for reaches LE04, LE07, LE09-A, and LE12. A high degree of sediment deposition was observed in two areas associated with current or historical in-stream structural stressors: downstream of the Pickpocket Dam (LE10-B; >10 features per mile) due to historical deposition and minor bank erosion; downstream of a historic mill site in LE09-B. Bank erosion is concentrated in the lower watershed where stormwater outfalls and urban encroachment impact the channel. Reaches LE06 and LE07 had areas of minor to moderate bank erosion, particularly on the north bank where impacts from the adjacent trailer park were greatest. Minor bank erosion was noted along the south where the river parallels Route 108, and downstream of the crossing in areas impacted by the adjacent campground.

Channel Slope and Depth Modifiers

Corridor encroachment and development has been highlighted on the Slope and Depth Modifiers map for areas where natural channel sinuosity has been impacted. In these areas, increased channel slopes may cause reduced floodplain function because the channel has greater capacity to hold larger flow events within the channel, rather than spilling onto the floodplain. Extensive channel encroachment was noted in LE01 in the village of Exeter, and in LE05 and LE06 (adjacent trailer park). Beaver dams are absent in this subwatershed. Numerous grade controls exist in the upper reaches of the subwatershed that control vertical stability. In addition to Pickpocket Dam (which is likely built on a natural grade control), four ledges were noted in the upper subwatershed that provide controls on channel slope and depth. A review of the 1962 and 1974 aerial photographs did not indicate any areas of obvious historical channel straightening.

Two dams are found along the Lower Exeter River. Given the limited topographic relief in the lower watershed, both dams have had a strong influence on the character of the river for miles upstream. A review of the each dam, with a brief discussion of dam influence on fluvial geomorphic equilibrium conditions of the river, is provided below.

- The Great Dam is located on the Great Falls in the village of Exeter immediately downstream of the Route 111 crossing. The use of the falls for water power dates back to the 1630's when the first gristmills were being constructed in the area (Tardiff, 2007). The present-day dam dates back to 1828 and has been operated by the Town of Exeter since 1981. The backwater effect of the dam extends approximately 3.5 miles upstream to the Route 108 crossing (Wright-Pierce, 2007). A fish ladder is present on the dam to encourage the passage of diadromous fishes to upstream reaches. The impacts of the upstream impoundment on aquatic life use has been well-documented (TNC, 2006; NHDES, 2008), and the dam has been implicated as a possible cause of flooding upstream. No significant impacts of the dam on fluvial geomorphic conditions were noted during the Phase 2 surveys. While the extensive impoundment has clearly degraded the natural habitat features of the Lower Exeter River, no significant channel adjustments (e.g., sediment deposition and widening) were noted near Route 108. Given the dam's long history and the agricultural legacy of the watershed, there is likely a high degree of fine sediment deposition in channel bed in the lower impoundment. The fate of sediment stored within the impoundment would need to be thoroughly examined if dam removal is considered in the future for fisheries restoration. Removal of the Great Dam for restoration of habitat connectivity in the watershed would also allow the river to redevelop a natural channel morphology (and habitat features) in response to a restored flow regime.

- Pickpocket Dam is located immediately upstream of Pickpocket Road on the Exeter-Brentwood town line. The use of Pickpocket falls for water power dates back to the 1650's when the first sawmill was constructed (Tardiff, 2007). A paper mill was operated at the site on and off for approximately 100 years during 1700 and 1800's. The backwater effect of the dam extends approximately 2.3 miles upstream. A fish ladder is present on the dam to encourage the passage of diadromous fishes to upstream reaches. As with the Great Dam, Pickpocket has clearly degraded the natural habitat features of the river for a great length upstream. No significant channel adjustments were observed in upstream reach LE12 at the lentic-lotic boundary downstream of Haigh Road. Due to the channel adjustments noted in downstream segment LE10-B, sediment storage and transport to downstream reaches would need to be considered if dam removal is considered in the future.

Riparian and Boundary Conditions

The Riparian and Boundary Conditions map highlights areas where human alterations to the river boundaries have increased or decreased the resistance of the banks and bed to channel adjustments. Many reaches in the lower subwatershed have extensive impacts to the riparian buffer due to adjacent development. These impacts were evident in LE01 in the village area; however the relative effect of this impact may be lower due to the backwater conditions associated with the Great Dam impoundment. The impacts on riparian buffer are most severe and quantifiable in LE05 and LE06 on the north bank.

Although severe lateral channel migration is limited in these locations due to the cohesive soils, even minor bank erosion has the potential to strongly impact downstream aquatic habitat. Fine-grained, clay soil particles released from the banks stay in suspension for long distances and impact downstream biological habitat, as well as water quality for municipal supply. Despite a high degree of corridor and floodplain development along the Lower Exeter River, bank armoring is very limited. This is likely due to the cohesive soil makeup of the banks; the only areas where armoring was noted was where till parent material borders the channel.

8.4.2 Departure Analysis

Reference Sediment Regime mapping for the Lower Exeter River indicates that most reaches would have equilibrium conditions. Under these conditions there is a balance between the sediment originating from upslope sources and the capacity of the channel to store and transport the incoming sediment. Three high-gradient reaches associated with confined valley settings (LE05, LE09-B, and LE10-B) would tend to have greater capacity for sediment transport. Existing Sediment Regime mapping indicates that departures have occurred in two segments: LE06 and LE10-B. In LE06, a combination of increased stormwater runoff and corridor encroachment has reduced floodplain function. In LE10-B, which is located immediately downstream of Pickpocket Dam, channel widening and planform changes are resulting an unnaturally high degree of sediment export to downstream reaches.

8.4.3 Sensitivity Analysis

Stream sensitivities are generally high in the Lower Exeter River subwatershed due to characteristics inherent to low-gradient, E-type channels. In these settings, alluvial channels that lack natural controls on channel stability (e.g., grade controls) tend to respond to watershed and reach-scale stressors more readily than coarse-bottomed, headwaters channels. Due to the impacts on channel stability noted in LE06, the stream sensitivity rating has increased to “extreme”. Three coarse-bottomed segments with limited impacts to channel stability (LE05, LE08, and LE10-A) have been classified as moderately sensitive due to their natural bed armoring. The remaining segments have been given a high sensitivity rating.

8.4.4 FEH Zones

A summary of the FEH zones developed for the Lower Exeter River subwatershed is included in Appendix E. Included in Appendix E is: 1) a complete summary of the methods used to develop FEH zones, 2) a summary table comparing the stream channel sensitivity assigned to each corridor with the degree of protection afforded by wetlands and conserved lands within the corridor, and 3) maps depicting the FEH corridors, sensitivity ratings, and other aspects related to corridor protection.

8.5 Lower Exeter River Project Identification

The site level projects that were developed for the Lower Exeter River subwatershed are provided below in Table 8.5. The project strategy, technical feasibility, and priority for each project are listed by project number and reach. A total of 16 projects were identified to promote the restoration or protection of channel stability and aquatic habitat. Photographs of these projects are included in Appendix F. The table summarizes key information for each project, including the project strategy, technical feasibility, and priority based on scientific data and stakeholder input. The 16 projects are further broken down by category as follows: 4 active geomorphic restoration; 10 passive geomorphic restoration; 2 stormwater mitigation. The active geomorphic restoration projects include 2 streambank stabilization projects in the Town of Exeter.

The project locations and categories identified for the Lower Exeter River subwatershed are depicted below in Figure 8.33. Four high priority projects have been identified. All high priority projects are located in the Town of Exeter and are associated with suburban development in the stream corridor west of Linden Street. The high priority projects include:

- **Bank stabilization** immediately west of Linden Street (project #7);
- **Stormwater management** for runoff originating from the trailer park (project #9);
- **Streamside plantings** south of the trailer park (project #10);
- **Stormwater management** for runoff originating from River Woods Development (project #13)

Table 8.5
Lower Exeter River Site Level Opportunities for Restoration and Protection

Project #, Location, Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#1 Great Dam 42.98178 N 70.94515 W Reach LE01[A]	Active Restoration	Great Dam is a significant barrier to aquatic organism passage; Dam is maintained by Town of Exeter	Remove dam to restore aquatic organism passage; Channel restoration in upstream reaches would also be necessary	Moderate	Moderate	Increased AOP and potential for ~3.5 miles of restored habitat upstream	Very high construction & permitting costs for structure removal and channel restoration		NHDES, Town of Exeter, ERLAC, NHFGD
#2 East of River St and Franklin St in Exeter 42.97639 N 70.94298 W Reach LE01[A]	Passive Restoration & Drinking Water Protection	Areas of limited woody vegetation along river edge, especially on west bank (2,740 ft with buffer less than 25ft wide), contributing to degraded habitat and elevated stream temps; wide channel with open canopy has naturally high thermal loading	Plant stream buffer with native woody vegetation in residential areas lacking canopy cover; Coordinate with adjacent landowners to assess interest and cooperation	Low	Moderate	Improved biotic habitat within reach (overhanging vegetation) and downstream (shading for lower water temp.)	Relatively low costs for native plant materials and labor	Aligns with local goals (buffers and water quality); however, landowner outreach will be needed	ERLAC, Town of Exeter, Adjacent Landowners
#3 East of Route 108 in Exeter 42.96051 N 70.95014 W Reach LE04	Passive Restoration & Drinking Water Protection	Areas of limited woody vegetation along river edge, especially on east bank along Exeter Elms Campground (2,340 ft with buffer less than 25ft wide), contributing to degraded habitat	Plant stream buffer with native woody vegetation in residential areas and camp sites lacking cover; Coordinate with adjacent landowners to assess interest and cooperation	Low	Moderate	Improved biotic habitat within reach (overhanging vegetation) and downstream (shading for lower water temp.)	Relatively low costs for native plant materials and labor	Aligns with local goals (buffers and water quality); however, landowner outreach will be needed	ERLAC, Town of Exeter, Adjacent Landowners

Table 8.5
Lower Exeter River Site Level Opportunities for Restoration and Protection

Project #, Location, Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#4 West of Route 108 in Exeter Reach LE04	Passive Restoration & Drinking Water Protection	Approx. 12 acres of corridor upstream of Rt. 108 crossing on both banks is unprotected from future development; North corridor was active agricultural land in 1960's and 70's	Protect corridor and floodplain against future development through conservation easements; FEH would protect area of interest	Moderate	Moderate	Protected floodplains allow for ongoing attenuation of fine sediment and floodwaters.	Needs further investigation; Town of Exeter may own extensive lands on north bank	Aligns with local buffer and flood protection goals; south bank is privately owned; north bank is under conservation; conservation would protect local drinking water supplies	ERLAC, Southeast Land Trust of New Hampshire (SLTNH)
#5 East of Route 108 in Exeter 42.95932 N 70.95381 W Reach LE04	Passive Restoration & Drinking Water Protection	Limited woody vegetation and high use campsites contributing to degraded habitat	Plant stream buffer with native woody vegetation along camp sites lacking cove; Need to coordinate with campsite owner to assess interest in project	Low	Moderate	Improved biotic habitat within reach (overhanging vegetation) and downstream (shading for lower water temp.)	Relatively low costs for native plant materials and labor		ERLAC, Town of Exeter, NHFGD, Adjacent Landowner
#6 East of Route 108 in Exeter 42.95923 N 70.95422 W Reach LE04	Active Restoration	Limited woody vegetation and high use campsites contributing to bank erosion along south bank in middle and lower reach	Stabilize stream banks along high use campsites in conjunction with buffer planting; combination of wood and rock to stabilize toe of slope; Coordinate with campsite owner	Moderate	Moderate	Reduced fine sediment loading to channel and downstream areas; Potentially reduced property loss from erosion	Moderate costs if machinery is needed to anchor materials; hand-building may be possible		
#7 West of Linden Street in Exeter 42.96204 N 70.96583 W Reach LE05	Active Restoration & Drinking Water Protection	North bank is developed and lacks woody vegetation; Large slope failure in upper reach supplies sediment to channel; Banks armored in lower reach	Stabilize north bank with aggressive plantings (e.g., willows); Establish native tree species in lower reach where banks are armored; Coordinate with adjacent landowners	High	High	Reduced fine sediment to channel and downstream areas; reduced property loss from erosion		Aligns with local buffer and water quality goals; landowner negations may be cost and time prohibitive	NHDES, ERLAC, Town of Exeter, Homeowners Association, Student Conserv. Association

Table 8.5
Lower Exeter River Site Level Opportunities for Restoration and Protection

Project #, Location, Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#8 North of Linden Street in Exeter Reach LE06	Passive Restoration & Drinking Water Protection	Portions of the south river corridor may be unprotected against development by the 100yr floodway; Flood chutes exist north of newly built home	Confirm protection status of lower south corridor; If unprotected, secure conservation easements to avoid future conflicts; FEH overlay would protect area of interest	Moderate	Low	Protected floodplains allow for ongoing attenuation of fine sediment and floodwaters.	Potentially high costs for easements due to private ownership; Needs further investigation	Aligns with local buffer and water quality goals; landowner negations may be cost and time prohibitive	ERLAC, SLTNH
#9 South of Friar Tuck Drive in Exeter 42.96211 N 70.97138 W Reach LE06	Stormwater Management	Stormwater outfall in lower reach along north bank is causing erosion and downstream scour; Increased sediment supply to channel	Provide small detention or infiltration structure (e.g., rain garden) upslope of outfall; Investigate storm drain network upslope and location for BMP; Determine need to stabilize gully on bank	High	High	Reduced fine sediment loading to channel and downstream areas; Reduced property loss from long term gully advance	Moderate costs to install LID BMP (Approx cost persqft: Raingarden: $10; Gravel Wetland: $10-15)	Aligns with local buffer and water quality goals; landowner negations may be cost and time prohibitive	NHDES, ERLAC, Town of Exeter, Adjacent Landowners, Homeowners Association
#10 South of Little John Drive in Exeter 42.96181 N 70.97287 W Reach LE06	Passive Restoration & Drinking Water Protection	North bank is developed and lacks woody vegetation; Bank erosion occurring along 220 feet adjacent homes due to reduced boundary resistance	Establish native tree species along north bank; Investigate need for long-term bank stabilization using bio-engineering approach	High	High	Reduced fine sediment loading to channel and downstream areas; Reduced property loss from high flow events and ongoing erosion	Relatively low costs for native plant materials and labor	Aligns with local buffer and water quality goals; landowner negations may be cost and time prohibitive	ERLAC, Town of Exeter, Adjacent Landowners, Homeowners Association, Student Conserv. Association, NHFGD
#11 Northeast of Powder Mill Road in Exeter Reach LE07	Passive Restoration	Portions of the river corridor upstream of the rail crossing may be unprotected against development by the 100yr floodway; Flood chute exists west (upstream) of crossing	Confirm protection status of lower south corridor; If unprotected, secure conservation easements to avoid future conflicts; FEH overlay would protect area of interest	Moderate	Moderate	Protected floodplains allow for ongoing attenuation of fine sediment and floodwaters.	Potentially high costs for easements due to private ownership	Aligns with local buffer and flood protection goals;	ERLAC, SLTNH

Table 8.5
Lower Exeter River Site Level Opportunities for Restoration and Protection

Project #, Location, Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#12 Northeast of Powder Mill Road in Exeter 42.96087 N 70.97580 W Reach LE07	Passive Restoration & Drinking Water Protection	Approx. 500 ft of south bank in lower reach lacks buffer >25ft. Ongoing bank erosion could worsen without increased boundary resistance in long-term; Farm ditch has formed gully at confluence with river	Plant stream buffer with native woody vegetation along field edge; Investigate need to stabilize ditch/gully to reduce sediment loading; Coordinate with adjacent landowner	Moderate	Moderate	Improved biotic habitat within reach (overhanging vegetation) and downstream (shading for lower water temp.)	Relatively low costs for native plant materials and labor	Aligns with local buffer and water quality goals; landowner outreach will be needed	NHDES, ERLAC, Town of Exeter, NHFGD, Adjacent Landowners
#13 South of Riverwoods in Exeter 42.96371 N 70.98147 W Reach LE07	Stormwater Management	Stormwater outfall in middle of reach along north bank is causing gully formation, increasing sediment supply to channel	Develop stormwater mitigation plan for River Woods impervious cover runoff; Initial investigation of site by engineer and soil scientist occurred in Nov, 2008	Moderate	High	Reduced fine sediment to channel and downstream areas; improved downstream water quality	High costs for design and construction of BMPs due to large amount of impervious cover	Aligns with local stormwater management priorities; landowner negotiations will be needed	NHDES, ERLAC, Town of Exeter, Adjacent Landowners
#14 East of Route 111 in Exeter 42.96371 N 70.98747 W Reach LE08	Passive Restoration	Approx. 400 ft of north bank in upper reach lacks buffer >25ft. Single parcel owner in area of interest.	Plant stream buffer with native woody vegetation; Coordinate with adjacent landowner	Low	Low	Improved biotic habitat within reach (overhanging vegetation) and downstream (shading)	Relatively low costs for native plant materials and labor		NHDES, ERLAC, Town of Exeter, NHFGD, Adjacent Landowner
#15 East of Pickpocket Road along Exeter-Brentwood town line Segment LE10-B	Passive Restoration	Severe aggradation and widening, with some bank erosion; River protection afforded by100yr floodway doesn't extend beyond channel boundaries; Boundaries could become more unstable in future; Only 2 landowners, one on each side	Implement FEH corridor protection to avoid future conflicts due to lateral adjustments.	Moderate	Moderate	Protected floodplains allow for attenuation of fine sediment and floodwaters; Reduced conflicts with erosion and property damage	None		NHDES, ERLAC, Town of Exeter

Table 8.5
Lower Exeter River Site Level Opportunities for Restoration and Protection

Project #, Location, Reach	Type of Project	Site Description Including Stressors and Constraints	Project or Strategy Description	Hazard Mitigation Priority	Ecological Benefits Priority	Project Benefits	Costs	Local Stakeholder Knowledge	Potential Partners
#16 Pickpocket Dam 42.96982 N 71.00117 W Segment LE10-B	Active Restoration	Pickpocket Dam is a significant barrier to aquatic organism passage; Dam is maintained by Town of Exeter	Remove dam to restore aquatic organism passage; Channel restoration in upstream reaches would also be necessary	Moderate	Moderate	Increased AOP and potential for ~2.3 miles of restored habitat upstream	Very high construction & permitting costs for structure removal and channel restoration		NHDES, Town of Exeter, ERLAC, NHFGD

[A] Administrative judgment used for determining stream type, RGA and RHA condition for impounded reaches and segments.

Additional Notes for Reaches/Segments with No Identified Projects:

- LE02, LE03: No restoration projects identified for these reaches due to the existing protection afforded the FEH corridor by conserved lands and wetlands (90 - 100% of corridor). Channel boundaries and buffers are well vegetated.
- LE09, LE10-A: No restoration projects have been identified for these reaches due to the existing protection afforded the corridor by wetlands and steep valley side slopes. FEH implementation would further ensure long-term protection. Channel boundaries and buffers are well vegetated, with only minor areas of reduced vegetation. Channel is stable with little to no bank erosion.
- LE11: The reach immediately upstream of Pickpocket Dam had no RGA or RHA data collected for it because the reach is not governed by fluvial processes. Therefore no projects were identified for this reach, and no FEH corridor was developed.
- LE12: No restoration projects identified for this reach due to the existing protection afforded the FEH corridor by conserved lands and wetlands (~70% of corridor). Channel boundaries and buffers are well vegetated.

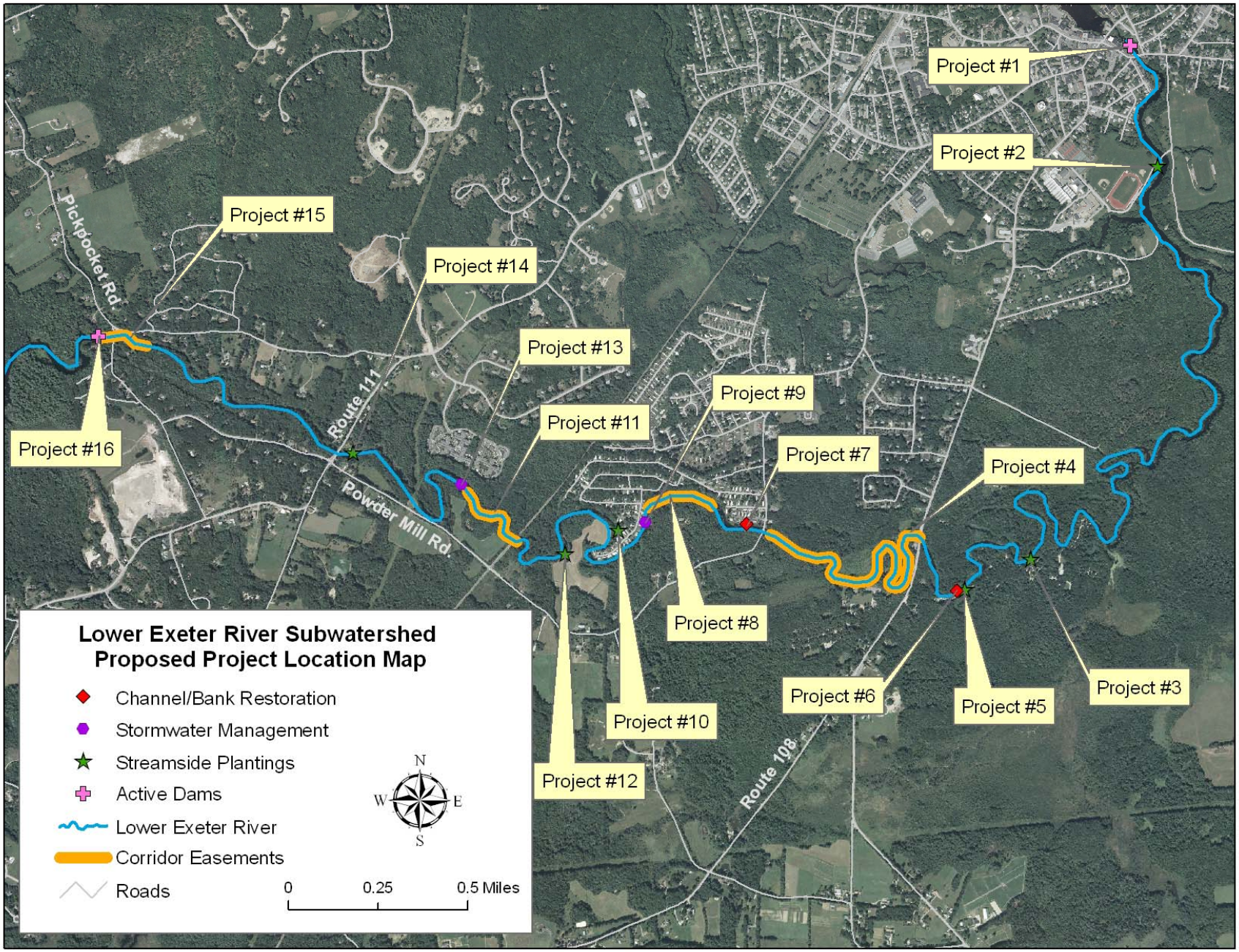

Figure 8.33 Proposed project location map for Lower Exeter River Subwatershed

9.0 PROJECT IMPLEMENTATION AND SCHEDULE

The Exeter River Geomorphic Assessment and Watershed-based Plan provides site- and watershed-specific recommendations for restoration and protection actions. The river corridor planning team has identified 70 potential protection and restoration projects that could successfully restore portions of the Exeter River Watersheds. These projects have been identified as high, moderate or low priority based on their effectiveness and feasibility.

Implementation of some of the recommended actions has already begun. For example, NHDES and RPC staff are working together to develop a Fluvial Erosion Hazards (FEH) ordinance and maps for every Exeter River watershed community. Workshops and meetings with Planning Boards, Conservation Commissions, Boards of Selectmen, Public Works and Highway Departments and Code Enforcement Officers will be conducted over the coming year to bring this information to communities and to provide technical assistance and support for development of FEH management tools. Project partners and local communities will be working together to identify priority projects that can be implemented in a feasible (socially and economically) and timely manner.

Over the next year NHDES staff will work with ERLAC, RPC, and watershed communities in the study area to develop an implementation plan and schedule to address recommended actions. Implementation projects will be selected on the basis of local capacity, funding availability and environmental benefit.

March 2009 – June 2009: NH DES, ERLAC, RPC and communities select projects and develop a one-year plan for implementation of at least one priority project in each subwatershed

July 2009 – December 2009: NH DES, RPC and communities identify funding to implement projects; project scopes are developed

January 2010: Project implementation begins for projects that are ready; other projects may take longer to develop

September 2010: NH DES, ERLAC, RPC and communities meet to discuss progress and identify next round of projects

10.0 PUBLIC OUTREACH AND EDUCATION/PROJECT MEETINGS

The process of developing a watershed plan for the Exeter River has included a number of public meetings and meetings with project partners. The following meetings have been an integral part of project coordination and outreach.

- Project Scoping Meeting with project partners in Concord, NH – June 3, 2008
- Watershed Tour with project partners to look at areas of concern (Figure 9.1) – July 11, 2008

- Public kick-off meeting for developing watershed plan in Brentwood, NH – July 22, 2008. A write up of the public meeting is found at the following link: http://www.seacoastonline.com/apps/pbcs.dll/article?AID=/20080725/NEWS/807250388/-1/TOWN0404
- Project Meeting to review Stressor and Departure Analysis in Portsmouth, NH – December 10, 2008.
- Public Meeting to present Watershed Plan – March 31, 2009

Figure 9.1 Exeter River Watershed Tour with project partners on July 13, 2008

11.0 REFERENCES

Burack, T.S., M.J. Walls, and H. Steward. 2008. New Hampshire Water Resources Primer. 2008. New Hampshire Department of Environmental Services, Concord, NH.

CWP (Center for Watershed Protection). 2003. Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph:39-49.

Deacon, J.R., S.A., Soule, and T.E. Smith. 2005. Effects of Urbanization on Stream Quality at Selected Sites in the Seacoast Region in New Hampshire, 2001-03: US Geological Survey Scientific Investigations Report 2005-5103, 18 pp.

Exeter River Local Advisory Committee. Wildlife Habitat and Natural Communities. Accessed January 20, 2009, from http://www.exeterriver.org/wildlife.html

Exeter River Local Advisory Committee. Management Plan. Accessed January 20, 2009, from http://www.exeterriver.org/plan.html

Fitzgerald, E. P. 2007. Linking urbanization to stream geomorphology and biotic integrity in the Lake Champlain Basin, Vermont [M.S. Thesis]. Burlington, Vermont. University of Vermont

Fitzgerald, E.P., and L. Godfrey. 2008. Upper Mad River Corridor Plan. Final Report to the Friends of the Mad River. Waitsfield, VT

Flynn, R.H., 2008, Flood of April 2007 in New Hampshire: U.S. Geological Survey Scientific Investigations Report 2008–5120, 53 p.

Foreman, R.T.T. and L.E. Alexander. 1998. Roads and Their Ecological Effects: Annual. Review of Ecological Systematics. Vol. 29: 207-231.

Geosyntec, Inc. 2008. Exeter River Vulnerability Analysis. Acton, MA

Hilderbrand, R.H., R. P. Morgan, M.W. Staley, A.J. Becker, A. Roseberry-Lincoln, E.S. Perry, and P.T. Jacobson. Brook trout declines with land cover and temperature changes in Maryland. North American Journal of Fisheries Management 28:1223-1232.

Holmes, R. 1988. A View form Meeting House Hill: A History of Sandown. Peter E. Randall. 451pp.

Kennedy, K. 1991. The effects of urbanization and land use on hydrology in the upper Ipswich River basin, Massachusetts, Durham, NH M.S. Thesis. University of New Hampshire.

Leopold, L.B. 1994. A View of the River. Harvard University Press. Cambridge, MA.

Lyons, J.B., Bonther, W.A., Moench, R.H., and Thompson, J.B., Jr. 1997. Bedrock geologic map of New Hampshire: U.S. Geological Survey Special Map, 2 sheets, scale 1:250,000

Milone & MacBroom, Inc. 2008a. The Vermont Culvert Geomorphic Capability Screening Tool. South Burlington, Vermont.

Milone & MacBroom, Inc. 2008b. The Vermont Culvert Aquatic Organism Passage Screening Tool, South Burlington, Vermont.

Montgomery, D., and J. Buffington. 1997. Channel-reach Morphology in Mountain Drainage Basins. Geological Society of America Bulletin; v. 109; no. 5; pp 596-611.

Natural Resources Conservation Service (NRCS). 1992. Technical Release No. 20: Computer and Project Formulation Hydrology (TR-20). Available at http://www.wsi.nrcs.usda.gov/products/w2q/H&H/Tools_Models/other/TR20.html

New Hampshire Department of Environmental Services. 2007. New Hampshire VRAP 2006 Exeter River Water Quality Report. Concord, NH

New Hampshire Department of Environmental Services. 2008. New Hampshire VRAP 2007 Exeter River Water Quality Report. Concord, NH

New Hampshire Department of Environmental Services. 2008. 2008 Section 305(b) and 303(d) Surface Water Quality Report. Concord, NH

New Hampshire Estuaries Project. 2006. State of the Estuaries. Durham, NH

New Hampshire Fish and Game Department. 2005. New Hampshire Wildlife Action Plan. Concord, NH

NOAA (National Oceanic and Atmospheric Administration). 2008. Land Cover Analysis Data for New England – Coastal Change Analysis Program. Accessed October, 2008 and available at: http://www.csc.noaa.gov/crs/lca/ccap.html

Olson, S.A., 2007, Flood of May 2006 in New Hampshire: U.S. Geological Survey Open-File Report 2007–1122, 32 p.

Olson, S.A. 2008. Personal communication with Scott Olson about new USGS regression equations to estimate flood-flow frequency.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

Tardiff, O. 2004. The Exeter-Squamscott – River of Many Uses. Peter E. Randall Publisher. Portsmouth, NH

The Nature Conservancy. 2006. Great Bay Estuary Restoration Compendium. Final report for project funded by the New Hampshire Coastal Program and the New Hampshire Estuaries Project.

United States Department of Agriculture. 1986. Urban Hydrology for Small Watersheds. Soil Conservation Service, Engineering Division, Technical Release 55. Washington, D.C.

University of New Hampshire Complex Systems. 2006. Stream Buffer Characterization Study. Final Report to the New Hampshire Estuaries Project. Durham, NH

University of New Hampshire Department of Natural Resources. 1998. Exeter River Buffer Analysis for the Towns of Fremont and Chester. Durham, NH

U.S. Geological Survey – NH/VT Water Science Center. 2007. Evaluation of Human Disturbance on Macroinvertebrate Assemblages at Selected Sites in the Exeter River Basin, New Hampshire.

Vermont Agency of Natural Resources, 2004. Appendix C, Channel Evolution Models, Waterbury, VT.

Vermont Agency of Natural Resources. 2005. Riparian Buffers and Corridors: Technical Papers. Waterbury, Vermont

Vermont Agency of Natural Resources. 2007a. Vermont Stream Geomorphic Assessment Phase 1 Handbook. Watershed Assessment Using Maps, Existing Data, and Windshield Surveys. Waterbury, Vermont.

Vermont Agency of Natural Resources. 2007b. Vermont Stream Geomorphic Assessment Phase 2 Handbook. Rapid Stream Assessment. Waterbury, Vermont.

Vermont Agency of Natural Resources. 2007c. Vermont Agency of Natural Resources River Corridor Planning Guide to Identify and Develop River Corridor Protection and Restoration Projects (Partially Drafted). Waterbury, Vermont.

Vermont Agency of Natural Resources. 2007d. Vermont Stream Geomorphic Assessment, Appendix G, Bridge and Culvert Assessment. Waterbury, Vermont

Vermont Agency of Natural Resources. 2008a. Draft Instructions for the Vermont Rapid Habitat Assessment (RHA). Vermont River Mangement Program. Waterbury, Vermont.

Vermont Agency of Natural Resources. 2008b. Municipal Guide to Fluvial Erosion Hazard Mitigation. Vermont River Management Program. Waterbury, Vermont.

Vermont Agency of Natural Resources. 2008c. River Corridor Projection: A Vermont Technical Guide. Vermont River Management Program. Waterbury, Vermont.

Wright-Pierce and Woodlot Alternatives, Inc. 2007. Phase 1 Final Report for the Town of Exeter, NH. Portsmouth, NH

12.0 LIST OF ACRONYMS AND GLOSSARY OF TERMS

List of Acronyms

ALU – Aquatic Life Use
AOP – aquatic organism passage
B & M - Boston and Maine Railroad
BB – Bloody Brook
BCE – Bear Creek Environmental, LLC
CEM – channel evolution model
cfs – cubic feet per second
CWP – Center for Watershed Protection
DB – Dudley Brook
DNR - University of New Hampshire's Department of Natural Resources
DO – dissolved oxygen
EPA - Environmental Protection Agency
ERCC – Exeter River Conservation Commission
ERLAC – Exeter River Local Advisory Committee
FEA - Fitzgerald Environmental Associates, LLC
FEH – Fluvial Erosion Hazard Zone
FEMA – Federal Emergency Management Agency
FPOM – fine particulate organic material
FW- Fordway Brook
GIS – Geographic Information System
GRANIT- New Hampshire Geographically Referenced Analysis and Information Transfer System
HUC – Hydrologic Unit Code
LE – Lower Exeter River
LR – Little River
LWD – large woody debris
NHDES - New Hampshire Department of Environmental Services
NHFGD – New Hampshire Fish and Game Department
NHGS – New Hampshire Geological Survey
NRCS – Natural Resources Conservation Service
NWI – National Wetlands Inventory
NOAA - National Oceanic and Atmospheric Administration
PREP – Piscataqua Region Estuaries Project (formerly NH Estuaries Project)
QA/QC – quality assurance/quality control
QAPP – Quality assurance project plan
RHA- Rapid Habitat Assessment
RGA-Rapid Geomorphic Assessment
RPC - Rockingham Planning Commission
SGA – Stream Geomorphic Assessment
SGAT – Stream Geomorphic Assessment Tool
TNC – The Nature Conservancy
UNH – University of New Hampshire
UE – Upper Exeter River
USGS – United States Geological Survey
VTDEC – Vermont Department of Environmental Conservation
VRAP – New Hampshire Volunteer River Assessment Program
WAP – Wildlife Action Plan

Glossary of Terms
Adapted from:
Restoration Terms, by Craig Fischenich, February, 2000, USAE Research and Development Center, Environmental Laboratory, 3909 Halls Ferry Rd., Vicksburg, MS 39180
And
Vermont Stream Geomorphic Assessment Handbook, 2007, Vermont Agency of Natural Resources, Waterbury, VT
http://www.anr.state.vt.us/dec/waterq/rivers/htm/rv_geoassesspro.htm
Acre -- A measure of area equal to 43,560 ft ^{2} (4,046.87 m^2). One square mile equals 640 acres.
Adjustment process --or type of change, that is underway due to natural causes or human activity that has or will result in a change to the valley, floodplain, and/or channel condition (e.g., vertical, lateral, or channel plan form adjustment processes)
Aggradation -- A progressive buildup or raising of the channel bed and floodplain due to sediment deposition. The geologic process by which streambeds are raised in elevation and floodplains are formed. Aggradation indicates that stream discharge and/or bed-load characteristics are changing. Opposite of degradation.
Algae -- Microscopic plants that grow in sunlit water containing phosphates, nitrates, and other nutrients. Algae, like all aquatic plants, add oxygen to the water and are important in the fish food chain.
Alluvial -- Deposited by running water.
Alluvium -- A general term for detrital deposits make by streams on riverbeds, floodplains, and alluvial fans; esp. a deposit of silt or silty clay laid down during time of flood. The term applies to stream deposits of recent time. It does not include subaqueous sediments of seas or lakes.
Anadromous -- Pertaining to fish that spend a part of their life cycle in the sea and return to freshwater streams to spawn.
Aquatic ecosystem -- Any body of water, such as a stream, lake, or estuary, and all organisms and nonliving components within it, functioning as a natural system.
Armoring -- A natural process where an erosion-resistant layer of relatively large particles is established on the surface of the streambed through removal of finer particles by stream flow. A properly armored streambed generally resists movement of bed material at discharges up to approximately 3/4 bank-full depth. Augmentation (of stream flow) – Increasing flow under normal conditions, by releasing storage water from reservoirs.
Avulsion -- A change in channel course that occurs when a stream suddenly breaks through its banks, typically bisecting an overextended meander arc.
Backwater -- (1) A small, generally shallow body of water attached to the main channel, with little or no current of its own, or (2) A condition in subcritical flow where the water surface elevation is raised by downstream flow impediments.
Backwater pool -- A pool that formed as a result of an obstruction like a large tree, weir, dam, or boulder.
Bank stability -- The ability of a streambank to counteract erosion or gravity forces.
Bankfull channel depth -- The maximum depth of a channel within a riffle segment when flowing at a bank-full discharge.
Bankfull channel width -- The top surface width of a stream channel when flowing at a bank-full discharge.
Bankfull discharge -- The stream discharge corresponding to the water stage that overtops the natural banks. This flow occurs, on average, about once every 1 to 2 years and given its frequency and magnitude is responsible for the shaping of most stream or river channels.
Bankfull width -- The width of a river or stream channel between the highest banks on either side of a stream.
Bar -- An accumulation of alluvium (usually gravel or sand) caused by a decrease in sediment transport capacity on the inside of meander bends or in the center of an overwide channel.
Barrier -- A physical block or impediment to the movement or migration of fish, such as a waterfall (natural barrier) or a dam (man-made barrier).
Base flow -- The sustained portion of stream discharge that is drawn from natural storage sources, and not affected by human activity or regulation.
Bed load -- Sediment moving on or near the streambed and transported by jumping, rolling, or sliding on the bed layer of a stream. See also suspended load.
Bed material -- The sediment mixture that a streambed is composed of.
Bed material load -- That portion of the total sediment load with sediments of a size found in the streambed.

Bed roughness -- A measure of the irregularity of the streambed as it contributes to flow resistance. Commonly expressed as a Manning "n" value.
Bed slope -- The inclination of the channel bottom, measured as the elevation drop per unit length of channel.
Bedform -- Individual patterns which streams follow that characterize the condition of the stream bed into several categories. (*See*: braided, dune-ripple, plane bed, riffle-pool, step-pool, and cascade)
Benthic invertebrates -- Aquatic animals without backbones that dwell on or in the bottom sediments of fresh or salt water. Examples: clams, crayfish, and a wide variety of worms.
Berms -- mounds of dirt, earth, gravel, or other fill built parallel to the stream banks designed to keep flood flows from entering the adjacent floodplain.
Biota -- All living organisms of a region, as in a stream or other body of water.
Boulder -- A large substrate particle that is larger than cobble, between 10 and 160 inches in diameter.
Boundary resistance -- The ability a stream bank has to withstand the erosional forces of the flowing water at varying intensities. Under natural conditions boundary resistance is increased due to stream bank vegetation (roots), cohesive clays, large boulder substrate, etc.
Braided -- A stream channel characterized by flow within several channels, which successively meet and divide. Braiding often occurs when sediment loading is too large to be carried by a single channel.
Braiding (of river channels) -- Successive division and rejoining of riverflow with accompanying islands.
Buffer strip -- A barrier of permanent vegetation, either forest or other vegetation, between waterways and land uses such as agriculture or urban development, designed to intercept and filter out pollution before it reaches the surface water resource.
Canopy -- A layer of foliage in a forest stand. This most often refers to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried stand. Leaves, branches and vegetation that are above ground and/or water that provide shade and cover for fish and wildlife.
Cascade -- A short, steep drop in streambed elevation often marked by boulders and agitated white water.
Catchment -- (1) The catching or collecting of water, especially rainfall. (2) A reservoir or other basin for catching water. (3) The water thus caught. (4) A watershed.
Channel -- An area that contains continuously or periodically flowing water that is confined by banks and a streambed.
Channelization -- The process of changing (usually straightening) the natural path of a waterway.
Channel evolution -- A series of stages used to describe the erosional or depositional processes that occur within a stream or river in order to regain a dynamic equilibrium following a disturbance.
Clay -- Substrate particles that are smaller than silt and generally less than 0.0001 inches in diameter.
Coarse gravel -- Substrate that is smaller than cobble, but larger than fine gravel. The diameter of this stream-bottom particulate is between 0.63 and 2.5 inches.
Cobble -- Substrate particles that are smaller than boulders and larger than gravels, and are generally between 2.5 and 10 inches in diameter.
Confinement -- *see* Valley confinement
Confluence -- (1) The act of flowing together; the meeting or junction of two or more streams; also, the place where these streams meet. (2) The stream or body of water formed by the junction of two or more streams; a combined flood.
Conifer -- A tree belonging to the order Gymnospermae, comprising a wide range of trees that are mostly evergreens. Conifers bear cones (hence, coniferous) and have needle-shaped or scalelike leaves.
Conservation -- The process or means of achieving recovery of viable populations.
Contiguous habitat -- Habitat suitable to support the life needs of a species that is distributed continuously or nearly continuously across the landscape.
Cover -- "cover" is the general term used to describe any structure that provides refuge for fish, reptiles or amphibians. These animals seek cover to hide from predators, to avoid warm water temperatures, and to rest, by avoiding higher velocity water. These animals come in all sizes, so even cobbles on the stream bottom that are not sedimented in with fine sands and silt can serve as cover for small fish and salamanders. Larger fish and reptiles often use large boulders, undercut banks, submerged logs, and snags for cover.
Critical shear stress -- The minimum amount of shear stress exerted by stream currents required to initiate soil particle motion. Because gravity also contributes to streambank particle movement but not on streambeds, critical shear stress along streambanks is less than for streambeds.]
Cross-section -- A series of measurements, relative to bankfull, that are taken across a stream channel that are representative of the geomorphic condition and stream type of the reach.

Crown -- The upper part of a tree or other woody plant that carries the main system of branches and the foliage.
Crown cover -- The degree to which the crowns of trees are nearing general contact with one another.
Cubic feet per second (cfs) -- A unit used to measure water flow. One cubic foot per second is equal to 449 gallons per minute.
Culvert -- A buried pipe that allows flows to pass under a road.
Debris flow -- A rapidly moving mass of rock fragments, soil, and mud, with more than half of the particles being larger than sand size.
Deciduous -- Trees and plants that shed their leaves at the end of the growing season.
Degradation -- (1) A progressive lowering of the channel bed due to scour. Degradation is an indicator that the stream's discharge and/or sediment load is changing. The opposite of aggradation. (2) A decrease in value for a designated use.
Detritus -- is organic material, such as leaves, twigs, and other dead plant matter, that collects on the stream bottom. It may occur in clumps, such as leaf packs at the bottom of a pool, or as single pieces, such as a fallen tree branch.
Dike -- (1) (Engineering) An embankment to confine or control water, especially one built along the banks of a river to prevent overflow of lowlands; a levee. (2) A low wall that can act as a barrier to prevent a spill from spreading. (3) (Geology) A tabular body of igneous (formed by volcanic action) rock that cuts across the structure of adjacent rocks or cuts massive rocks.
Dissolved oxygen (DO) -- The amount of free (not chemically combined) oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter, parts per million, or percent of saturation.
Ditch -- A long narrow trench or furrow dug in the ground, as for irrigation, drainage, or a boundary line.
Drainage area -- The total surface area upstream of a point on a stream that drains toward that point. Not to be confused with watershed. The drainage area may include one or more watersheds.
Drainage basin -- The total area of land from which water drains into a specific river.
Dredging -- Removing material (usually sediments) from wetlands or waterways, usually to make them deeper or wider.
Dune-ripple -- A bedform associated with low-gradient, sand-bed channels; the low gradient nature of the channel causes the sand to form a sequence of dunes and small ripples; significant sediment transport typically occurs at most stream stages.
Ecology -- The study of the interrelationships of living organisms to one another and to their surroundings.
Ecosystem -- Recognizable, relatively homogeneous units, including the organisms they contain, their environment, and all the interactions among them.
Embankment -- An artificial deposit of material that is raised above the natural surface of the land and used to contain, divert, or store water, support roads or railways, or for other similar purposes.
Embeddedness -- is a measure of the amount of surface area of cobbles, boulders, snags and other stream bottom structures that is covered with sand and silt. An embedded streambed may be packed hard with sand and silt such that rocks in the stream bottom are difficult or impossible to pick up. The spaces between the rocks are filled with fine sediments, leaving little room for fish, amphibians, and bugs to use the structures for cover, resting, spawning, and feeding. A streambed that is not embedded has loose rocks that are easily removed from the stream bottom, and may even "roll" on one another when you walk on them.
Entrenchment ratio --The width of the flood-prone area divided by the bankfull width.
Epifaunal – "epi" means surface, and "fauna" means animals. Thus, "epifaunal substrate" is structures in the stream (on the stream bed) that provide surfaces on which animals can live. In this case, the animals are aquatic invertebrates (such as aquatic insects and other "bugs"). These bugs live on or under cobbles, boulders, logs, and snags, and the many cracks and crevices found in these structures. In general, older decaying logs are better suited for bugs to live on/in than newly fallen "green" logs and trees.
Ephemeral streams -- Streams that flow only in direct response to precipitation and whose channel is at all times above the water table.
Equilibrium Condition -- The state of a river reach in which the upstream input of energy (flow of water) and materials (sediment and debris) is equal to its output to downstream reaches. Natural river reaches without human impacts tend towards a "stable" state where predictable channel forms are maintained over the long term under varying flow conditions.
Erosion -- Wearing away of rock or soil by the gradual detachment of soil or rock fragments by water, wind, ice, and other mechanical, chemical, or biological forces.
Eutrophic -- Usually refers to a nutrient-enriched, highly productive body of water.

Eutrophication -- The process of enrichment of water bodies by nutrients.
Fine gravel -- Is substrate which is larger than sand, but smaller than coarse gravel. It is between 0.08 and 0.63 inches in diameter.
Flash flood -- A sudden flood of great volume, usually caused by a heavy rain. Also, a flood that crests in a short length of time and is often characterized by high velocity flows.
Floodplain -- Land built of fine particulate organic matter and small substrate that is regularly covered with water as a result of the flooding of a nearby stream.
Floodplain (100-year) -- The area adjacent to a stream that is on average inundated once a century.
Floodplain Function – Flood water access of floodplain which effects the velocity, depth, and slope (stream power) of the flood flow thereby influencing the sediment transport characteristics of the flood (i.e., loss of floodplain access and function may lead to higher stream power and erosion during flood).
Flow -- The amount of water passing a particular point in a stream or river, usually expressed in cubic feet per second (cfs).
Fluvial -- Migrating between main rivers and tributaries. Of or pertaining to streams or rivers.
Fluvial Geomorphology—The study of how rivers and their landforms interact over time through different climatic conditions.
Ford -- A shallow place in a body of water, such as a river, where one can cross by walking or riding on an animal or in a vehicle.
Fry -- A recently hatched fish.
Gabion -- A wire basket or cage that is filled with gravel or cobble and generally used to stabilize streambanks.
Gaging station -- A particular site in a stream, lake, reservoir, etc., where hydrologic data are obtained.
Gallons per minute (gpm) -- A unit used to measure water flow.
Geographic information system (GIS) -- A computer system capable of storing and manipulating spatial data.
Geomorphology -- A branch of both physiography and geology that deals with the form of the earth, the general configuration of its surface, and the changes that take place due to erosion of the primary elements and the buildup of erosional debris.
Glide -- A section of stream that has little or no turbulence.
Grade control -- A fixed feature on the streambed that controls the bed elevation at that point, effectively fixing the bed elevation from potential incision; typically bedrock, dams. or culverts.
Gradient -- Vertical drop per unit of horizontal distance.
Grass/forb -- Herbaceous vegetation.
Gravel -- An unconsolidated natural accumulation of rounded rock fragments, mostly of particles larger than sand (diameter greater than 2 mm), such as boulders, cobbles, pebbles, granules, or any combination of these.
Groundwater -- Subsurface water and underground streams that can be collected with wells, or that flow naturally to the earth's surface through springs.
Groundwater basin -- A groundwater reservoir, defined by an overlying land surface and the underlying aquifers that contain water stored in the reservoir. In some cases, the boundaries of successively deeper aquifers may differ and make it difficult to define the limits of the basin.
Groundwater recharge -- Increases in groundwater storage by natural conditions or by human activity. See also artificial recharge.
Groundwater table -- The upper surface of the zone of saturation, except where the surface is formed by an impermeable body.
Habitat -- The local environment in which organisms normally live and grow.
Habitat diversity -- The number of different types of habitat within a given area.
Habitat fragmentation -- The breaking up of habitat into discrete islands through modification or conversion of habitat by management activities.
Headcut -- A sharp change in slope, almost vertical, where the streambed is being eroded from downstream to upstream.
Headwater -- Referring to the source of a stream or river.
High gradient streams -- typically appear as steep cascading streams, step/pool streams, or streams that exhibit riffle/pool sequences. Most of the streams in Vermont are high gradient streams.
Hydraulic gradient -- The slope of the water surface. See also streambed gradient.
Hydraulic radius -- The cross-sectional area of a stream divided by the wetted perimeter.
Hydric -- Wet.
Hydrograph -- A curve showing stream discharge over time.

Hydrologic balance -- An accounting of all water inflow to, water outflow from, and changes in water storage within a hydrologic unit over a specified period of time. Hydrologic region -- A study area, consisting of one or more planning subareas, that has a common hydrologic character.
Hydrologic unit Code (HUC) -- A distinct watershed or river basin defined by an 8-digit code.
Hydrology -- The scientific study of the water of the earth, its occurrence, circulation and distribution, its chemical and physical properties, and its interaction with its environment, including its relationship to living things.
Hyporheic zone -- The area under the stream channel and floodplain where groundwater and the surface waters of the stream are exchanged freely.
Impoundment -- An area where the natural flow of the river has been disrupted by the presence of human-made or natural structure (e.g. weir or beaver dam). The impoundment backwater extends upstream causing sediment to be deposited on the stream bottom.
Improved paths – Paths that are maintained and typically involve paved, gravel or macadam surfaces.
Incised river -- A river that erodes its channel by the process of degradation to a lower base level than existed previously or is consistent with the current hydrology.
Incision ratio -- The low bank height divided by the bankfull maximum depth.
Infiltration (soil) -- The movement of water through the soil surface into the soil.
Inflow -- Water that flows into a stream, lake,
Instream cover -- The layers of vegetation, like trees, shrubs, and overhanging vegetation, that are in the stream or immediately adjacent to the wetted channel.
Instream flows -- (1) Portion of a flood flow that is contained by the channel. (2) A minimum flow requirement to maintain ecological health in a stream.
Instream use -- Use of water that does not require diversion from its natural watercourse. For example, the use of water for navigation, recreation, fish and wildlife, aesthetics, and scenic enjoyment.
Intermittent stream -- Any nonpermanent flowing drainage feature having a definable channel and evidence of scour or deposition. This includes what are sometimes referred to as ephemeral streams if they meet these two criteria.
Irrigation diversion -- Generally, a ditch or channel that deflects water from a stream channel for irrigation purposes.
Islands -- mid-channel bars that are above the average water level and have established woody vegetation.
Lake -- An inland body of standing water deeper than a pond, an expanded part of a river, a reservoir behind a dam
Landslide -- A movement of earth mass down a steep slope.
Large woody debris (LWD) -- Pieces of wood at least 6 ft. long and 1 ft. in diameter (at the large end) contained, at least partially, within the bankfull area of a channel.
Levee -- An embankment constructed to prevent a river from overflowing (flooding).
Limiting factor -- A requirement such as food, cover, or another physical, chemical, or biological factor that is in shortest supply with respect to all resources necessary to sustain life and thus "limits" the size or retards production of a population.
Low gradient -- streams typically appear slow moving and winding, and have poorly defined riffles and pools.
Macroinvertebrate -- Invertebrates visible to the naked eye, such as insect larvae and crayfish.
Macrophytes -- Aquatic plants that are large enough to be seen with the naked eye.
Mainstem -- The principal channel of a drainage system into which other smaller streams or rivers flow.
Mass movement -- The downslope movement of earth caused by gravity. Includes but is not limited to landslides, rock falls, debris avalanches, and creep. It does not however, include surface erosion by running water. It may be caused by natural erosional processes, or by natural disturbances (e.g., earthquakes or fire events) or human disturbances (e.g., mining or road construction).
Mean annual discharge -- Daily mean discharge averaged over a period of years. Mean annual discharge generally fills a channel to about one-third of its bank-full depth.
Mean velocity -- The average cross-sectional velocity of water in a stream channel. Surface values typically are much higher than bottom velocities. May be approximated in the field by multiplying the surface velocity, as determined with a float, times 0.8.
Meander -- The winding of a stream channel, usually in an erodible alluvial valley. A series of sine-generated curves characterized by curved flow and alternating banks and shoals.
Meander amplitude -- The distance between points of maximum curvature of successive meanders of opposite phase in a direction normal to the general course of the meander belt, measured between center lines of channels.

Meander belt width -- the distance between lines drawn tangential to the extreme limits of fully developed meanders. Not to be confused with meander amplitude.
Meander length -- The lineal distance down valley between two corresponding points of successive meanders of the same phase.
Mid-channel Bars – bars located in the channel away from the banks, generally found in areas where the channel runs straight. Mid-channel bars caused by recent channel instability are unvegetated.
Milligrams per liter (mg/l) -- The weight in milligrams of any substance dissolved in 1 liter of liquid; nearly the same as parts per million by weight.
Natural flow -- The flow past a specified point on a natural stream that is unaffected by stream diversion, storage, import, export, return flow, or change in use caused by modifications in land use.
Neck cutoff -- A channel migration feature where the land that separates a meander bend is cut off by the lateral migration of the channel. This process may be part of the equilibrium regime or associated with channel instability.
Outfall -- The mouth or outlet of a river, stream, lake, drain or sewer.
Oxbow -- An abandoned meander in a river or stream, caused by cutoff. Used to describe the U-shaped bend in the river or the land within such a bend of a river.
Peat -- Partially decomposed plants and other organic material that build up in poorly drained wetland habitats.
Perched groundwater -- Groundwater supported by a zone of material of low permeability located above an underlying main body of groundwater with which it is not hydrostatically connected.
Perennial streams -- Streams that flow continuously.
Permeability -- The capability of soil or other geologic formations to transmit water.
pH -- The negative logarithm of the molar concentration of the hydrogen ion, or, more simply acidity.
Planform -- The channel shape as if observed from the air. Changes in planform often involve shifts in large amount of sediment, bank erosion, or the migration of the channel. A channel straightened for agricultural purposes has a highly impacted planform.
Point bar -- The convex side of a meander bend that is built up due to sediment deposition.
Pond -- A body of water smaller than a lake, often artificially formed.
Pool -- A reach of stream that is characterized by deep, low-velocity water and a smooth surface.
Potential plant height -- the height to which a plant, shrub or tree would grow if undisturbed.
Probability of exceedence -- The probability that a random flood will exceed a specified magnitude in a given period of time.
Railroads – Used or unused railroad infrastructure.
Rapids -- A reach of stream that is characterized by small falls and turbulent, high-velocity water.
Reach -- A section of stream having relatively uniform physical attributes, such as valley confinement, valley slope, sinuosity, dominant bed material, and bed form, as determined in the Phase 1 assessment.
Rearing habitat -- Areas in rivers or streams where juvenile fish find food and shelter to live and grow.
Reference stream type --Uses preliminary observations to determine the natural channel form and process that would be present in the absence of anthropogenic impacts to the channel and the surrounding watershed.
Refuge area -- An area within a stream that provides protection to aquatic species during very low and/or high flows.
Regime theory -- A theory of channel formation that applies to streams that make a part of their boundaries from their transported sediment load and a portion of their transported sediment load from their boundaries. Channels are considered in regime or equilibrium when bank erosion and bank formation are equal.
Restoration -- The return of an ecosystem to a close approximation of its condition prior to disturbance.
Riffle -- A reach of stream that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.
Riffle-pool ratio -- The ratio of surface area or length of pools to the surface area or length of riffles in a given stream reach; frequently expressed as the relative percentage of each category. Used to describe fish habitat rearing quality.
Riffle-step ratio-- ratio of the distance between riffles to the stream width.
Riparian area -- An area of land and vegetation adjacent to a stream that has a direct effect on the stream. This includes woodlands, vegetation, and floodplains. Riparian buffer is the width of naturally vegetated land adjacent to the stream between the top of the bank (or top of slope, depending on site characteristics) and the edge of other land uses. A buffer is largely undisturbed and consists of the trees, shrubs, groundcover plants, duff layer, and naturally uneven ground surface. The buffer serves to protect the water body from the impacts of adjacent land uses. Riparian corridor includes lands defined by the lateral extent of a stream's meanders necessary to maintain a

stable stream dimension, pattern, profile, and sediment regime. For instance, in stable pool-riffle streams, riparian corridors may be as wide as 10-12 times the channel's bankfull width. In addition the riparian corridor typically corresponds to the land area surrounding and including the stream that supports (or could support if unimpacted) a distinct ecosystem, generally with abundant and diverse plant and animal communities (as compared with upland communities).

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

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

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

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

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

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

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

River reach -- Any defined length of a river.

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

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

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

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

Rock -- A naturally formed mass of minerals.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Snag -- Any standing dead, partially dead, or defective (cull) tree at least 10 in. in diameter at breast height and at least 6 ft tall. Snags are important riparian habitat features.
Spawning -- The depositing and fertilizing of eggs (or roe) by fish and other aquatic life.
Spillway -- A channel for reservoir overflow.
Stable channel -- A stream channel with the right balance of slope, planform, and cross section to transport both the water and sediment load without net long-term bed or bank sediment deposition or erosion throughout the stream segment.
Stone -- Rock or rock fragments used for construction.
Straightening -- the removal of meander bends, often done in towns and along roadways, railroads, and agricultural fields.
Stream -- A general term for a body of water flowing by gravity; natural watercourse containing water at least part of the year. In hydrology, the term is generally applied to the water flowing in a natural narrow channel as distinct from a canal. Stream banks are features that define the channel sides and contain stream flow within the channel; this is the portion of the channel bank that is between the toe of the bank slope and the bankfull elevation. The banks are distinct from the streambed, which is normally wetted and provides a substrate that supports aquatic organisms. The top of bank is the point where an abrupt change in slope is evident, and where the stream is generally able to overflow the banks and enter the adjacent floodplain during flows at or exceeding the average annual high water.
Stream channel -- A long narrow depression shaped by the concentrated flow of a stream and covered continuously or periodically by water.
Stream condition -- Given the land use, channel and floodplain modifications documented at the assessment sites, the current degree of change in the channel and floodplain from the reference condition for parameters such as dimension, pattern, profile, sediment regime, and vegetation.
Stream gradient -- A general slope or rate of change in vertical elevation per unit of horizontal distance of the bed, water surface, or energy grade of a stream.
Stream morphology -- The form and structure of streams.
Stream order -- A hydrologic system of stream classification. Each small unbranched tributary is a first-order stream. Two first-order streams join to make a second-order stream. A third-order stream has only first-and second-order tributaries, and so forth.
Stream power – A measure of the erosive energy within the stream channel at different depths, typically expressed as a weight per unit stream width per second (e.g. lb/ft/sec)
Stream reach -- An individual segment of stream that has beginning and ending points defined by identifiable features such as where a tributary confluence changes the channel character or order.
Stream type -- Gives the overall physical characteristics of the channel and helps predict the reference or stable condition of the reach.
Stream type departure -- When the current stream type differs from the reference stream type as a response to anthropogenic or severe natural disturbances. These departures are often characterized by large-scale incision, deposition, or changes in planform.
Streambank armoring – The installation of concrete walls, gabions, stone riprap, and other large erosion resistant material along stream banks.
Streambank erosion -- The removal of soil from streambanks by flowing water.
Streambank stabilization -- The lining of streambanks with riprap, matting, etc., or other measures intended to control erosion.
Streambed -- (1) The unvegetated portion of a channel boundary below the baseflow level. (2) The channel through which a natural stream of water runs or used to run, as a dry streambed.
Streamflow -- The rate at which water passes a given point in a stream or river, usually expressed in cubic feet per second (cfs).
Step (in a river system) --A step is a steep, step-like feature in a high gradient stream (> 2%). Steps are composed of large boulders lines across the stream. Steps are important for providing grade-control, and for dissipating energy. As fast-shallow water flows over the steps it takes various flow paths thus dissipating energy during high flow events.
Substrate -- (1) The composition of a streambed, including either mineral or organic materials. (2) Material that forms an attachment medium for organisms.
Surface erosion -- The detachment and transport of soil particles by wind, water, or gravity. Or a group of processes whereby soil materials are removed by running water, waves and currents, moving ice, or wind.

Surface water -- All waters whose surface is naturally exposed to the atmosphere, for example, rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc., and all springs, wells, or other collectors directly influenced by surface water.
Suspended sediment -- Sediment suspended in a fluid by the upward components of turbulent currents, moving ice, or wind.
Suspended sediment load -- That portion of a stream's total sediment load that is transported within the body of water and has very little contact with the streambed.
Tailwater -- (1) The area immediately downstream of a spillway. (2) Applied irrigation water that runs off the end of a field.
Thalweg -- (1) The lowest thread along the axial part of a valley or stream channel. (2) A subsurface, groundwater stream percolating beneath and in the general direction of a surface stream course or valley. (3) The middle, chief, or deepest part of a navigable channel or waterway.
Transpiration -- An essential physiological process in which plant tissues give off water vapor to the atmosphere.
Tributary -- A stream that flows into another stream, river, or lake.
Turbidity -- A measure of the content of suspended matter that interferes with the passage of light through the water or in which visual depth is restricted. Suspended sediments are only one component of turbidity.
Urban runoff -- Storm water from city streets and gutters that usually carries a great deal of litter and organic and bacterial wastes into the sewer systems and receiving waters.
Valley confinement -- Referring to the ratio of valley width to channel width. Unconfined channels (confinement of 4 or greater) flow through broader valleys and typically have higher sinuosity and area for floodplain. Confined channels (confinement of less than 4) typically flow through narrower valleys.
Valley wall -- The side slope of a valley, which begins where the topography transitions from the gentle-sloped valley floor. The distance between valley walls is used to calculate the valley confinement.
Variable-stage stream -- Stream flows perennially but water level rises and falls significantly with storm and runoff events.
Velocity -- In this concept, the speed of water flowing in a watercourse, such as a river.
Washout -- (1) Erosion of a relatively soft surface, such as a roadbed, by a sudden gush of water, as from a downpour or floods. (2) A channel produced by such erosion.
Water quality -- A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
Waterfall -- A sudden, nearly vertical drop in a stream, as it flows over rock.
Watershed -- An area of land whose total surface drainage flows to a single point in a stream.
Watershed management -- The analysis, protection, development, operation, or maintenance of the land, vegetation, and water resources of a drainage basin for the conservation of all its resources for the benefit of its residents.
Watershed project -- A comprehensive program of structural and nonstructural measures to preserve or restore a watershed to good hydrologic condition. These measures may include detention reservoirs, dikes, channels, contour trenches, terraces, furrows, gully plugs, revegetation, and possibly other practices to reduce flood peaks and sediment production.
Watershed restoration -- Improving current conditions of watersheds to restore degraded habitat and provide long-term protection to aquatic and riparian resources.
Weir -- A structure to control water levels in a stream. Depending upon the configuration, weirs can provide a specific "rating" for discharge as a function of the upstream water level.
Wetland -- Areas adjacent to, or within the stream, with sufficient surface/groundwater influence to have present hydric soils and aquatic vegetation (e.g. cattails, sedges, rushes, willows or alders).
Width/depth ratio -- The ratio of channel bankfull width to the average bankfull depth. An indicator of channel widening or aggradation, and used for stream type classification.