**River Corridor Plan for the Nulhegan River:**
Stone Dam Road to Connecticut River

**Prepared By:**
**Melissa Dyer**
**For**
**Essex County Natural Resources Conservation District**

NORTHWOODS
STEWARDSHIP CENTER

Ten Mile Square Road / P.O. Box 220
East Charleston, VT 05833
(802) 723-6551
www.northwoodscenter.org

# Table of Contents


Table of Contents i
List of Tables and Figures ii
**1. Summary and Recommendations 1**
**2. Background Watershed Information 3**
2.1 Geographic Setting 3
2.1.1 Nulhegan Watershed Description 3
2.1.2 Political Jurisdictions 4
2.1.3 Land Use History 4
2.2 Geologic Setting 5
2.3 Geomorphic Setting 6
2.3.1 Description and Location of the Assessed Reaches 6
2.3.2 Longitudinal Profile, Alluvial Fans, and Natural Grade Controls 6
2.3.3 Valley and Reference Stream Data 7
2.4 Ecological Setting 8
**3. Methods 8**
3.1 Phase 1 Assessment 8
3.2 Phase 2 Assessment 10
3.3 QA/QC Summary 10
**4. Results and Discussion 11**
4.1 Hydrologic and Sediment Regime Stressors 11
4.1.1 Hydrologic Regime Stressors 11
Land Cover / Land Use
Stormwater Inputs, Road Density, and Urban Land Cover
4.1.2 Sediment Regime Stressors 15
Channel Slope Modifiers
Sediment Load Indicators
4.1.3 Channel Constrictions and Stream Crossings 17
4.2 Geomorphic Conditions
4.2.1 Geomorphic Condition Ratings and Channel Evolution Stages 19
4.2.2 Summary of Watershed-Scale and Reach-Scale Stressors 21
4.3 Results and Recommendations from Phase 2 Field Surveys
References 34
Glossary 35
Appendix A. Phase 1 Metadata 37
Appendix B. Rosgen Stream Classifications and Descriptions of Channel Bed Forms 38

## List of Tables and Figures

**List of Tables**

**Table 1.** Valley and channel characteristics for the Assessed Reaches 7
**Table 2.** Summary of land uses in the Nulhegan River Watershed 13
**Table 3.** Summary of channel constrictions or stream crossings 18
**Table 4.** Summary of watershed and in-stream stressors 22-23

**List of Figures**

**Figure 1.** Japanese Knotweed along Reach M01 2
**Figure 2.** Location and land ownerships of the Nulhegan Watershed 3
**Figure 3.** Location of numbered reaches 6
**Figure 4.** Land Uses 12
**Figure 5.** Urban land cover 14
**Figure 6.** Slope modifiers 16
**Figure 7.** Sediment load indicators 17
**Figure 8.** Railroad bridge at Reach M01 18
**Figure 9.** Description of channel evolution processes 19
**Figure 10.** Confluence of two of the three channels in Reach M02 20
**Figure 11.** Map of geomorphic conditions 21
**Figure 12.** Results for Reach M01 24
**Figure 13.** Old mill site upstream of Route 102 bridge 25
**Figure 14.** Results for Reach M02 26
**Figure 15.** Sediment deposition in Reach M02 27
**Figure 16.** Results for Reach M03 28
**Figure 17.** Representative photo of Reach M03 29
**Figure 18.** Results for Reach M04 30
**Figure 19.** Representative photo of Reach M04 31
**Figure 20.** Results for Reach M05 32
**Figure 21.** Representative photo of Reach M05 33

## 1. Summary

The Nulhegan River is an important tributary to the Upper Connecticut River and is often noted for its wild landscape and exceptional scenery. Located in remote region of northeast Vermont, this 17 mile river is an outstanding fishery and recreational resource, meandering through extensive open wetlands and coniferous forest. The river forms a portion of the 740-mile Northern Forest Canoe Trail, providing a link between the Clyde River to the west and the Connecticut and Ammonoosuc Rivers to the east. Much of it meanders through extensive coniferous and open wetlands in a basin which often exhibits a boreal character. Though it never contained significant development or agricultural activities, the watershed has had a 200 year history of intensive timber management, including the alterations of several tributaries for the purposes of transporting timber. Now, three-quarters of the watershed is owned and managed by three entities: the US Fish and Wildlife Service, Plum Creek Timber Company, and the State of Vermont.

River stability and the resulting impacts of water quality and aquatic habitat are influenced by inputs from the surrounding watershed as well as the condition of the channel itself. This study incorporates data gathered on a watershed-scale as well field-gathered data of the river in order to identify areas of instability and the factors driving that instability. The Phase 1 and 2 geomorphic assessments summarized in this document are intended to help direct management and conservation efforts for the lower 3.9 miles of the Nulhegan River which do not flow through public lands, and which contain the most agricultural and urban land uses in the watershed.

Natural land cover types total 96.3% of the watershed area; most of the remaining land cover is in the form of logging roads and other transportation infrastructure that occur throughout the watershed. The study reaches are mostly isolated from roads or other development; usually about 0.25 miles from the nearest road or house, therefore existing impacts to the stream channel are minimal. Despite the remote location of these reaches, some sections are not in a reference condition due to historic activities along the river and within the watershed. Of the 5 assessed reaches, 50% of the mileage was in reference geomorphic condition, 26% in good condition, and 24% in poor condition. The reaches that were not rated as a reference conditions tended to be the lower-gradient cobble reaches which were more likely to be affected by the log drives occurring from mid-19th through early 20th centuries.

To evaluate aquatic habitat, we assessed the condition of the riparian zone as well as conditions occurring within the channel itself. Most of the assessed river reach corridors are either currently forested or are old fields reverting to forest, though some agricultural activities occur near the reaches closer to the Connecticut River. Of the 5 assessed reaches, 50% of the assessed mileages were in reference habitat condition, and 50% were in good condition. Again, the lower-gradient cobble reaches were rated lower than the boulder-dominated reaches. The cobble streambeds tended to be very wide, shallow, and generally lacked diversity in flows and depths.

**Recommendations**

Currently, much of the river corridor discussed in this report is undeveloped. Agricultural activities appear to have been much more prevalent along the project area in the past than they are currently, though two fields are located close to the river and remain in active use today. Otherwise, much of the river's corridor is reverting to a naturally forested state on its own. Because of the remoteness of the river and the lack of human investments adjacent to it, allowing passive restoration of the few unvegetated stream banks is an appropriate approach.

The primary management approach should involve ensuring the river corridor's current undeveloped and scenic state. The river is visited by paddlers and fishermen alike for its wild character. Additionally, the corridor would serve as a valuable linkage for wildlife movement between conserved lands in northern New Hampshire and those in Essex County. While conservation easements currently exist along a portion of the East Branch and along the Nulhegan River itself, additional easements along this lower stretch of the river would ensure protection along the majority of the total length of the river.

During the Phase 2 assessments, limited populations of invasive species were noted. These plants included scattered honeysuckle *(Lonicera tatarica)* plants and a 50' patch of Japanese knotweed (*Polygonum cuspidatum*, Figure 1). All plants were located along Reaches M01 and M02 in densities that should be controlled before they spread further.

***Figure 1:*** *An isolated patch of Japanese knotweed, located along Reach M01.*

# 2. BACKGROUND WATERSHED INFORMATION

## 2.1 GEOGRAPHIC SETTING

### 2.1.1 Nulhegan River Watershed Description

The Nulhegan River Watershed is part of the Upper Connecticut Watershed in northeast Vermont. The Nulhegan River drains an area of approximately 145 mi$^2$ and flows east from its headwaters in Brighton, roughly paralleling Route 105 through the towns of Ferdinand and Brunswick (Figure 2) before emptying into the Connecticut River in Bloomfield. The river is fed by several large tributary watersheds, the largest of which are listed here in a westerly to easterly direction: the North Branch (21 mi$^2$), the Yellow Branch (12 mi$^2$), the Black Branch (27 mi$^2$), and the East Branch (37 mi$^2$). There are six ponds in the watershed: McConnell Pond (87 acres), Lewis Pond (68 acres), Nulhegan Pond (41 acres), Mile Pond (21 acres), Unknown Pond (18 acres), and Moose Pond (15 acres).

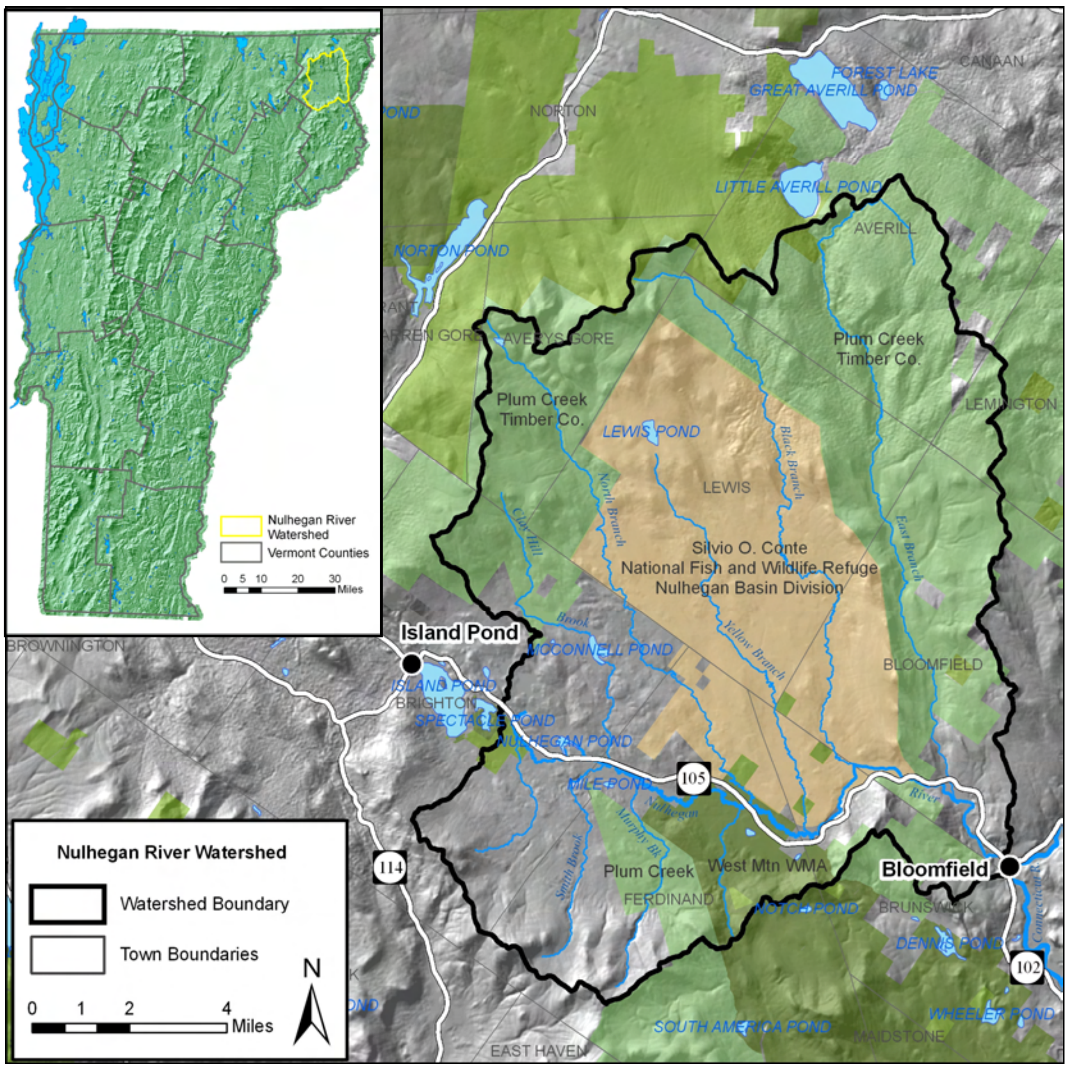



***Figure 2.*** *Location and land ownerships of the Nulhegan Watershed.*

### 2.1.2 Political Jurisdictions

The Nulhegan River Watershed lies entirely within Essex County and includes all or portions of the towns of Brighton, Ferdinand, Brunswick, Bloomfield, Averill, Avery's Gore, Lewis, and Lemington. The mainstem originates from Nulhegan Pond in Brighton; then travels in an easterly direction through Ferdinand, Brunswick, and Bloomfield until its confluence with the Connecticut River. The river also passes through Wenlock Wildlife Management Area, West Mountain WMA, and the Silvio O. Conte National Fish and Wildlife Refuge (Figure 2). The five focal reaches in this study lie within the town of Bloomfield.

### 2.1.3 Land Use History

A cultural history of the Nulhegan Watershed was completed by the University of Maine in 2001, covering the post-glacial Native American populations to modern Euroamerican use of the landscape (Scharoun, et al. 2001). Since European settlement, the landscape of the watershed has been dominated by the timber industry, with the first water powered saw mills built in the area around 1800. Larger saw mills appeared during the 1850s, including the Baldwin Saw Mill (soon owned by Nulhegan Lumber Company) which was located on the Nulhegan River near the confluence with the Connecticut River. Remnants of this mill are still visible today (see Figure 13, page 23). Much of the logging was completed by the Nulhegan Lumber Co., which owned extensive portions of Bloomfield, Lewis, Brunswick, and Ferdinand, including much of the Nulhegan Watershed. Timber production was greatly facilitated by building of the Grand Trunk Railroad in 1853, which connected the forest lands between Montreal and Portland, Maine, and enabled the transport of wood products to foreign and domestic markets.

Shortly after this period, the abandonment of farming communities in New England in favor of locations west of the Appalachians began to occur. This also coincided with the migrations of working populations to manufacturing centers in urban areas. This resulted in low land values and enabled the procurement and consolidation of vast tracts of land by large-scale timber companies. In 1892, the Nulhegan Lumber Co. was purchased by George Van Dyke, owner of the Connecticut Valley Lumber company, and re-named the Lewis Lumber Co. Van Dyke then added 7,000 additional acres in Brunswick and Ferdinand to his ownership. In 1907 the Baldwin saw mill was dismantled so that logs could instead be floated down to larger mills on the Connecticut River.

By the turn of the century, the near-century's worth of logging of the Nulhegan Basin forests had its effect. In 1903, several thousand acres of forest along the river caught fire due to sparks originating from the Grand Trunk Railroad's locomotives (Pike 1967). Additionally, most of the land along the river and the lower reaches of its tributaries had been cut, and logging was confined to higher, steeper, and more remote areas. In order to transport the timber from these areas, many dams were constructed in order to provide the pulses of water necessary to float logs down the tributaries, into the Nulhegan River, and ultimately to the Connecticut River mills. Four dams had already existed along the Black Branch in 1903, Stone Dam was re-built in 1904 on the Nulhegan River, and six dams were constructed along the East Branch in 1908 (Amey 1903, Scharoun et al. 2001). The locations of these dams are viewable on the 1928 USGS topographic maps. An account of a 1908 log drive down the East Branch described a stream that was "converted into a glorified, hellroarious flume with rock sides and bottom (Pike 1967)." These drives continued well into the 20th century.

Since the times of the great log drives of the 1850's to the early 20th century, the land ownership in the basin changed hands various times. St. Regis Paper Company and then Champion International owned much of the basin through the 20th century. In 1997, Champion announced that it would sell 132,000 acres of land in Essex County, which included approximately 75% of the Nulhegan Watershed. This presented a major opportunity for conservation interests to acquire a large track of undeveloped land in Vermont. The Conservation Fund purchased the property and sold it to Essex Timber Company, the State of Vermont, and the U.S. Fish and Wildlife Service. The portion purchased by Essex Timber Co. (now owned by Plum Creek Timber Co.) contains a conservation easement requiring sustainable timber production and special protection around certain ecologically sensitive areas, such as water bodies and wetlands. The portion purchased by the State formed the West Mountain Management Area and contains an easement establishing an ecological core area where natural forest processes will dominate, as well as areas where active forest management will be conducted for the benefit of game and non-game species (State of Vermont 2002). The remaining portion was purchase by the USFWS to form the 26,000 acre Nulhegan Basin Division of the Silvio O. Conte National Fish and Wildlife Refuge for the purposes of managing fish and wildlife habitat in the Connecticut River Watershed.

## 2.2 GEOLOGIC SETTING

The Nulhegan Watershed lies within the Northeastern Highlands biophysical region, which is geologically related to the White Mountains of New Hampshire. The Northeastern Highlands are slightly higher in elevation than the adjacent Vermont Piedmont, explaining the cooler temperatures typical of the region. The Nulhegan Watershed appears as a low, circular basin surrounded by mountains which form the watershed boundary. Elevations in the watershed range from 3332' at Gore Mountain in the northwest to 890' at the confluence with the Connecticut River in the southeast.

A dominant bedrock type in the Northeastern Highlands is granite, which was formed as a result of continental plate collisions during the Acadian Orogeny over 350 million years ago. As one part of the Earth's crust was pushed beneath another, the subducted rock melted and formed magma. This magma was then pushed upward and hardened into plutons of igneous granitic rock which were surrounded by overlying metamorphic rock. Over millions of years, the metamorphic rock weathered away and exposed the harder granite beneath. These plutons form the highest mountains in the Northeast Kingdom, including Bald Mountain (Westmore), East Mountain (East Haven), and the highest point in the Nulhegan Watershed, Gore Mountain (Avery's Gore). The granite of the Nulhegan pluton, however, was softer than the metamorphic bedrock surrounding it. Over the millennia this pluton eroded so that it now forms a low flat basin in otherwise hilly and mountainous terrain.

The basin is relatively flat but contains numerous glacial deposits. The river slowly meanders through the largest kame deposits in the state (Thompson and Sorenson 2000) until it passes under the Route 105 crossing near Stone Dam Road in Bloomfield. Many of the bogs and swamps in the region formed upon the kettleholes and outwash deposits. After the final Route 105 crossing, the river passes over bedrock for a brief period before flowing through the lacustrine sediments likely deposited by the glacial Lake Coos, which filled the Connecticut Valley north of glacial Lake Hitchcock. The river's valley is bounded by these sediments, which are extremely steep and abut the river at times. The cover photo of this report was taken from the edge of the glacial lake deposit.

## 2.3 GEOMORPHIC SETTING

### 2.3.1 Description and Location of the Assessed Reaches

The river and most of its tributaries were divided into 150 reaches and sub-watersheds using topographic maps and aerial photographs. Each reach represents a section of river or stream with physical attributes that distinguish it from reaches immediately upstream and downstream. These attributes include valley width, valley slope, channel width, and channel sinuosity. The assessed Nulhegan River reaches included the five reaches (Reaches M01-M05) spanning from the Route 105 bridge crossing at Stone Dam Road to the river's confluence with the Connecticut River (Figure 3).

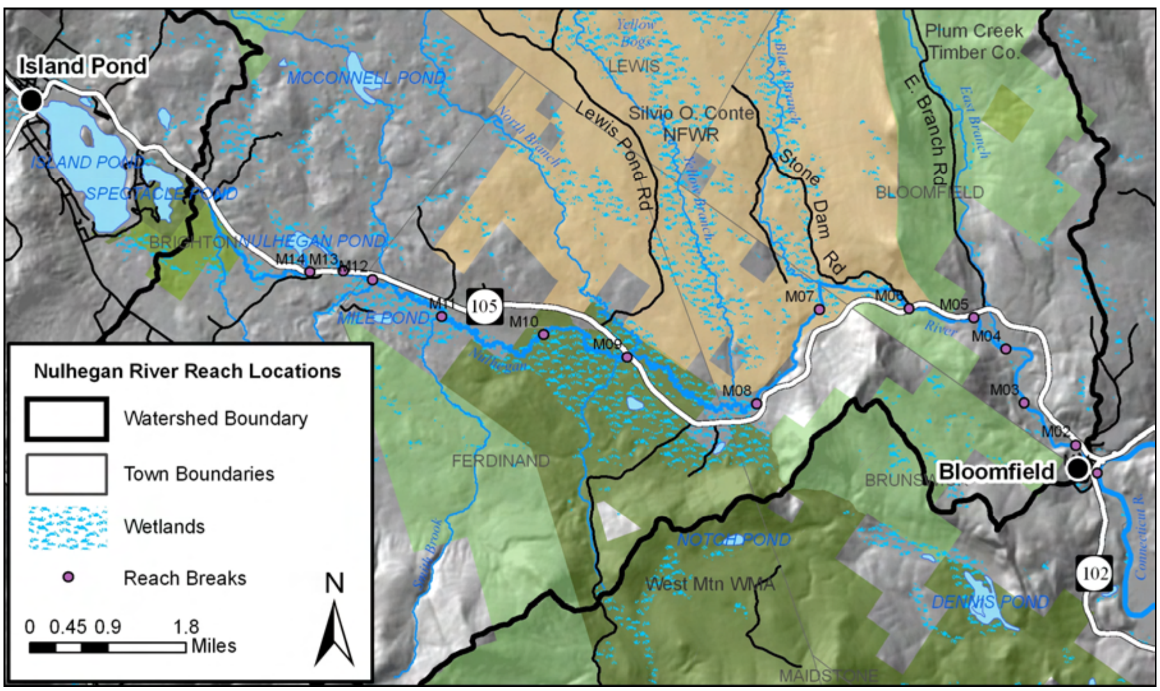



***Figure 3:*** *Location of numbered reaches along the Nulhegan River.*

### 2.3.2 Longitudinal Profile, Alluvial Fans, and Natural Grade Controls

The mainstem of the Nulhegan River originates at Nulhegan Pond in Brighton, located approximately 4.5 miles east of the village of Island Pond, and travels in an easterly course for 17 miles until its confluence with the Connecticut River in Bloomfield. Locations of the mainstem reaches are displayed in Figure 3.

After exiting from Nulhegan Pond, the river flows east for 9.5 miles (Reaches M12-M08), distantly paralleling Route 105 through a flat, wide basin containing nearly continuous wetlands. In fact, the river drops only 20 feet in elevation over this distance. Due to a combination of its gentle gradient and its broad valley setting, this portion of the river is slow flowing, very sinuous, and features many backwaters and secondary channels. The river is fed by multiple named tributaries. Listed from upstream to downstream, they are: Smith, Clay Hill, Murphy, and Stevens Brooks and, after the first Route 105 crossing, the North Branch and Yellow Branch. The North Branch is by far the largest of these tributaries and its flow inputs change the character of the Nulhegan River from that of a deep, narrow, and at times ill-defined channel to a much wider and substantial channel with well-developed gravel bars along every meander bend.

After the river passes the vicinity of Notch Pond Road, the river takes a turn in a northeasterly direction and enters a narrow and steep valley (Reach M07). The river cascades over boulders and bedrock ledges as it flows near the USFWS-Nulhegan Basin Division headquarters and descends 80 feet in elevation over 1.5 miles.

The river decreases in slope and velocity for 1.5 miles (Reach M06) prior to flowing under Route 105 at Stone Dam Road. After this bridge, the river changes dramatically again, descending 80 feet during this 0.8 mile reach and cascading over a boulder stream bed and multiple bedrock ledges (Reach M05). The final three miles (Reaches M04-M01) the river are very wide, shallow, flowing over a cobble streambed with a gentler gradient. The river flows swiftly through wide bends and long straight sections until its confluence with the Connecticut River.

### 2.3.3 Valley and Reference Stream Data

Using topographic maps and windshield surveys, data were collected to describe the valley setting and slope for each assessed reach, which determines the type of stream found there (Table 1). Stream types were assigned based on the Rosgen stream classification system (Appendix B). For example, meandering C and E stream types dominate the wider, flatter alluvial valleys throughout the upper Nulhegan River, where the river floods wide areas and deposits fine sediments on the adjacent floodplain. These stream types are typically found in river reaches with 0-2% slopes. Reaches M01-M05 flow through a valley bound by steep terraces of glacial lake sediments, thus the valley is narrower and steeper than what exists in the broad, flat basin of the upper watershed. Stream types are a mixture narrowly-confined F stream types that completely lack a floodplain, B stream types with a very narrow floodplain, and C stream-types with broad floodplains.

**Table 1.** Valley and channel characteristics for the assessed reaches on the main stem of the Nulhegan River (reaches M01-M05)

| Reach | Channel Width (ft) | Channel Slope (%) | Sinuosity | Valley Type | Reference Stream Type* | Reference Stream Bedform* |
|---|---|---|---|---|---|---|
| M01 | 121 | 0 | 1.00 | Narrowly-Confined | F | Step-Pool |
| M02 | 106 | 0.32 | 1.08 | Broad | C | Riffle-Pool |
| M03 | 129 | 0.47 | 1.25 | Broad | C | Riffle-Pool |
| M04 | 164 | 0.61 | 1.05 | Narrow | B | Plane Bed |
| M05 | 67 | 1.74 | 1.02 | Semi-Confined | F | Step-Pool |

*** See Appendix B for stream type descriptions**

## 2.4 ECOLOGICAL SETTING

The Nulhegan Watershed consists of a low, flat basin surrounded by a ring of mountains which rise to elevations of 3300'. These topographic features, in combination with its northern location and its acidic soils cause the basin to contain pockets of a boreal landscape among the northern hardwood forests typical of most of Vermont. The coniferous forests and swamps typical of these areas harbor several uncommon bird species such as gray jay, boreal chickadee, spruce grouse, rusty blackbird, black-backed woodpecker. These areas also form the largest deer wintering area in the state, and also contain extensive moose habitat in its wetlands. Many of the river's tributaries contain wild populations of brook trout.

The watershed almost entirely contains natural land cover, though there are logging roads which break up the forests and wetlands. Northern hardwood forests of sugar maple and yellow birch dominate the higher, well-drained soils of the basin as well as the mountain sides, where they are gradually replaced by the spruce-fir forests that occur on the higher mountain ridges. The basin lowlands are often poorly drained and contain extensive forested and shrub wetlands as well as bogs and beaver ponds. Quaking aspen is a very common species along with balsam fir, red spruce, tamarack, white pine, and black spruce. Notable natural communities include black spruce and tamarack swamps, cedar swamps, as well as extensive bogs which form in the kettlehole basins. These community types contain many plants typical of cold, acidic areas such as Labrador tea, bog rosemary, bog laurel, blueberry, etc., as well as orchids, pitcher plants, and sundew which are present in the peatlands. The Nulhegan River meanders through miles of alder swamps, sometimes interspersed with black cherry. Many oxbows, beaver dams, and backwater areas are present.

The section of river (our study area) that descends to the Connecticut River lacks the boreal characteristics seen in the broad basin which dominates the upper watershed. This portion of the watershed is narrow and steep; as a result the river flows through northern hardwood forests containing yellow birch and hemlock on the steeper slopes, and large white pine trees on the sandy glacial lake terraces which line the river valley. Much of the lands adjacent to the river are old fields reverting to forest. Speckled alder, black cherry, and tamarack are common in these young transitional forests.

# 3. METHODS

### 3.1 PHASE 1 ASSESSMENT

The Stream Geomorphic Assessments were completed using protocols established by the Vermont Agency of Natural Resources (State of Vermont 2007). The Phase 1 assessments were preliminary evaluations of selected reaches and sub-watersheds through three types of sources: remote sensing, other survey datasets, and brief "windshield" surveys. Most of the Phase 1 Assessment was completed using the following data layers (additional details about the data collected and their sources are in Appendix A):

1:24,000 USGS topographic maps (1988)
1:62,500 USGS topographic maps (1928, 1953)
1:5,000 Aerial orthophotographs (1974, 2003)
1:5,000 Vermont Hydrography Data Set
Land use – land cover maps (1990s)
Vermont Significant Wetland Inventory maps (2006)
National Wetlands Inventory maps (1975-1978)

Significant streams (generally >0.25 miles in length) within the Nulhegan River Watershed represented in the Vermont Hydrography Data Set (VHD) were divided into individual reaches and sub-watersheds. We then used the Stream Geomorphic Assessment Tool (SGAT), a GIS extension developed by the Vermont ANR, to automatically associate all existing survey data with each individual sub-watershed. The data associated with each reach and sub-watershed included the following:

| | |
|---|---|
| Reach number and length | Sub-watershed area |
| Valley length and width | Sub-watershed land cover / land use |
| Stream corridor land cover / land use | Channel slope and valley slope |
| Predicted channel width | |

Through evaluation of new and old topographic maps and aerial photographs as well as field visits, we evaluated the following features:

| | |
|---|---|
| Stream type / stream bed material | Presence of alluvial fans |
| Valley side slopes | Ground water inputs |
| Stream migration | Depositional features |
| Meander belt width and wavelength | Grade controls |

In addition, we collected data describing human-caused modifications to the streams and their corridors:

| | |
|---|---|
| Land use / land cover | Historic land use / land cover |
| Channel straightening | Riparian buffer width |
| Bridges and culverts | Floodplain encroachments |
| Dredging / gravel mining history | Development |

All data were entered and archived in the Vermont ANR Data Management System (DMS) database. The DMS integrated all of the data and assigned impact ratings to each reach based on the degree of channel and floodplain modifications, and the degree to which the streams appeared to be responding to these modifications. These ratings were summed to calculate the overall reach condition rating, predicted adjustment scores, and reach sensitivities. These data sets were reviewed by River Management staff and any needed changes were noted in the DMS. The complete DMS datasets are available to the public at https://anrnode.anr.state.vt.us/ssl/sga/security/frmLogin.cfm.

### 3.2 PHASE 2 ASSESSMENT

The Phase 2 assessments consisted of in-depth mapping and evaluation of the river and involved wading through entire reaches. The data collected included sketch maps, photographs, channel profiles, and floodplain measurements to document the condition of the stream itself and its adjacent floodplain. The following features were measured and mapped in the field:

| | |
|---|---|
| Streambank erosion | Beaver dams |
| Channel straightening | Debris jams |
| Streambank armoring | Stormwater inputs |
| Floodplain development | Stream migration |
| Bridges and culverts | Grade controls |
| Floodplain encroachments | Channel profile |
| Riparian buffer width | Pebble counts |

The river's geomorphic condition was rated based on the field measurements listed above and upon other characteristics, including sediment deposition and erosion patterns, channel evolution stage, and degree of floodplain access. Additionally, we evaluated the aquatic and riparian habitat for each reach. The conditions of the following habitat-related features were evaluated in the field:

| | |
|---|---|
| Riparian buffer width | Riffle frequency |
| Streambed substrate embeddedness | Streambank stability |
| Pool variability and depths | Channel flow status |
| Velocity/depth patterns | Epifaunal Substrate and fish cover |
| Channel Alteration | Sediment deposition |

All of the features were mapped with the SGAT extension and are presented in the following pages of this report. Like the Phase 1 data, the complete Phase 2 datasets are available to the public in the DMS database.

### 3.3 QA/QC SUMMARY

This project was completed in accordance with an approved Quality Assurance Project Plan developed in conjunction with River Management Program (RMP) staff. As part of this plan, all GIS layers and data entered into the DMS were checked through the appropriate Quality Assurance procedures specified in the Stream Geomorphic Assessment Protocol Handbook (State of Vermont 2007). In addition, DMS data were checked for blank fields and conflicting Phase 1 and Phase 2 data by NorthWoods' staff and RMP staff.

# 4. RESULTS AND DISCUSSION

## 4.1 IDENTIFICATION OF HYDROLOGIC AND SEDIMENT REGIME STRESSORS IN THE WATERSHED

### 4.1.1 Hydrologic Regime Stressors

Land Cover / Land Use

Natural land cover types such as forests and wetlands play important roles in watersheds by storing and filtering run-off, trapping sediment, reducing peak flood levels, and maintaining base flows during summer. Deforestation and urban and agricultural development increase rainwater and snowmelt runoff by decreasing the amount of natural vegetation available to naturally filter water and sediment. Urban lands also contain impervious surfaces which quickly shed stormwater into adjacent drainages rather than slowly percolating it through the soil. The result is higher peak flood levels as well as high nutrient and sediment inputs. Consistently high stormwater runoff can cause a channel to enlarge, erode, and incise to accommodate high flows.

The Nulhegan River Watershed is almost entirely covered by natural land cover (96.3%), largely due to the watershed's historic management as timber land and current ownership by public entities and private timber companies. Urban lands cover 2.8% of the watershed (Table 2) and are almost entirely in the form of roads and railroads. Agricultural lands cover 0.9% of the watershed – compared to the 20.9% of the total land in Vermont in agriculture (USDA 2007). Nearly 77% of the watershed is forested (Figure 4). The largest forest class is broadleaf forest but large tracts of coniferous and mixed forests are also present on the higher mountain ridges and poorly drained soils in the basin. Wetlands cover much of the flat interior of the watershed and make up 16.7% of the total watershed area – a much greater proportion than the total wetland cover in Vermont, which is estimated at 5% (State of Vermont 1999). The majority of these wetlands are forested and include black spruce, tamarack, and northern white cedar swamps and peatlands. The remainder of the non-forested wetlands are alluvial shrub wetlands and old beaver ponds that are associated with the tributaries.

The high proportion of forest cover and, especially, wetlands has significant implications for the Nulhegan River. The dramatic increases in stream discharge and subsequent channel enlargement that can occur after a high rain event are dampened by the absorbing effects of the wetlands and are probably not an issue. Water temperatures are kept cool by consistent streamside canopy coverage. Fresh water inputs by subsurface flows through the wetlands constantly add cool water to the tributaries. These characteristics are crucial for maintaining the brook trout populations in this watershed.

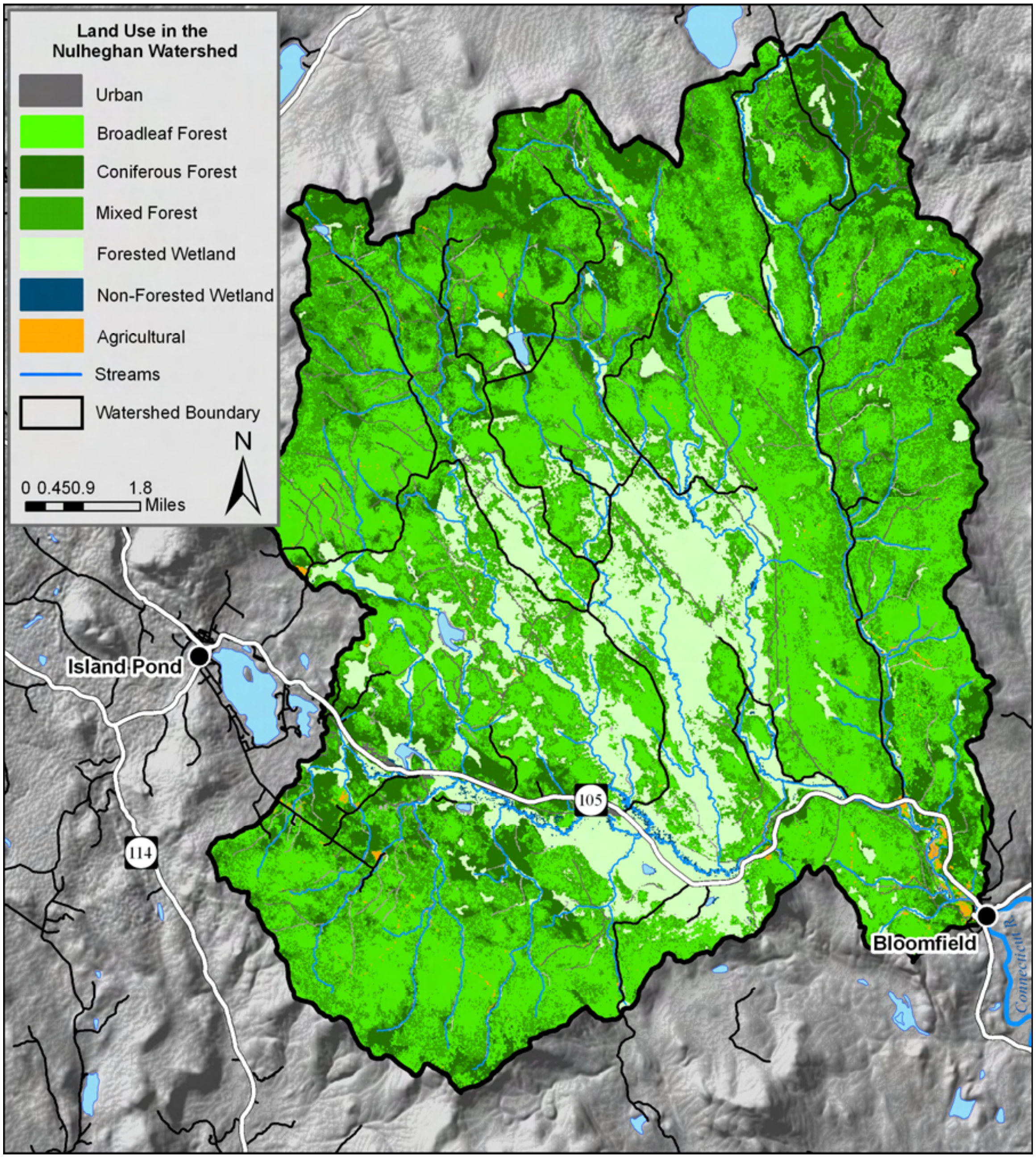


***Figure 4.*** *Land Use in the Nulhegan River Watershed. Note the contiguous natural land cover.*

**Table 2.** Summary of Land Uses in the Nulhegan River Watershed

| Land Use | Percentage of Watershed | |
|---|---|---|
| Broadleaf forest (generally deciduous) | 37.6% | Forested or brush: 76.6% |
| Mixed coniferous-broadleaf forest | 26.5% | |
| Coniferous forest (generally evergreen) | 12.5% | |
| Brush or transitional between open and forested | <0.1% | |
| Forested wetland | 16.1% | Wetland: 16.7% |
| Non-forested wetland | 0.6% | |
| Hay/rotation/permanent pasture | 0.1% | Agriculture: 0.9% |
| Row crops (not including orchards and berries) | 0.8% | |
| Other agricultural land | <0.1% | |
| Transportation, communication, and utilities | 2.7% | Urban: 2.8% |
| Residential | 0.1% | |
| Industrial | <0.1% | |
| Commercial, services, and institutional | <0.1% | |
| Outdoor and other urban and built-up land | <0.1% | |
| Water | 3.0% | Other: 3.0% |
| Barren land | <0.1% | |

Stormwater Inputs, Road Densities, and Urban Land Cover

High road and urban land densities and stormwater inputs can lead to channel enlargement due to sudden pulses of high water flows during rain events. Stormwater inputs, such as field and road ditches, tile trains, and urban stormwater inputs, were searched for during the Phase 2 assessments in order to determine whether a reach may be responding to these high flows. These features move water quickly away from land surfaces and into stream channels. For the most part, the Nulhegan River is not located near any highways, urban development, and agricultural fields. Because of its relative remoteness, stormwater inputs were not found during the Phase 2 assessments of reaches M01-M05 and have not adversely affected the river.

Both gravel and paved roads affect the watershed like urban lands. All are impervious surfaces which shed water quickly into drainages rather than allowing it to slowly percolate through the soil, resulting in higher flows during precipitation events. To determine road densities, we used the Vermont e911 roads layer, available from VCGI. Road densities were calculated based on the number of miles per area (in square miles) for each of the 150 sub-watersheds in the Nulhegan Watershed. Densities ranged from 0 miles/square mile to 4.8 miles/square mile; the average was 0.7 miles/square mile. Nearly all sub-watersheds contained densities less than 2 miles/square mile. The highest road density was located in the sub-watershed in Bloomfield.

Cumulatively, urban land uses cover 2.8% of the watershed area, the vast majority of which (97.1%) are logging and utility access roads located throughout the watershed (Figure 5). Residential areas account for a much smaller percentage of the urban land cover at 2.9% and occur at scattered locations along Route 105 and in Bloomfield.

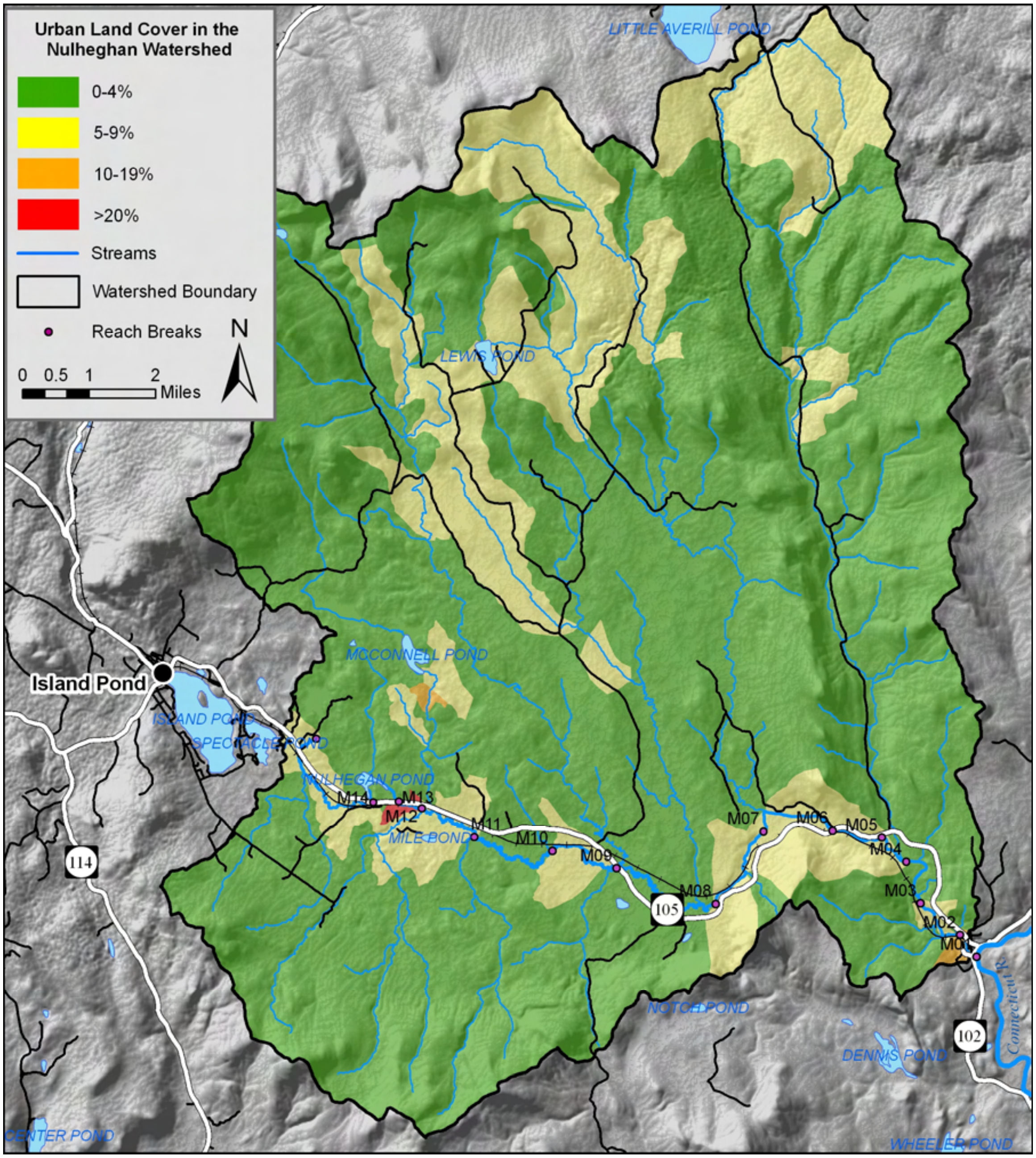


***Figure 5.*** *Urban land cover in the Nulhegan River Watershed, which almost entirely consists of roads.*

### 4.1.2 Sediment Regime Stressors

Channel Slope Modifiers

Many land uses conflict with the meandering and ever-changing nature of rivers. Rivers and streams are often straightened, dredged, and bermed to protect property investments or to make floodplains available for other land uses. Channel straightening and bank armoring remove or alter natural meanders, resulting in faster and more powerful flows. Similar results can occur when river sediments are dredged from the stream bed. These channel alterations directly affect the stream by increasing its slope and power, resulting in a higher sediment transport capacity and higher rates of erosion. Many rivers have incised (eroded the stream bed) because of these alterations, further increasing the river's power during high flows. Additionally, the sediment transported by these reaches becomes deposited into downstream reaches, which must adjust to these newly deposited sediments.

Floodplain encroachments such as roads, railroads, and berms are raised surfaces that cut off sections of floodplain that were normally utilized by the stream to migrate and deposit flood-related sediment. A stream that has access to a wide floodplain is also able to dissipate more energy when the floodwaters spread out over a large area, which decreases flood damage to downstream areas. During the Phase 2 assessments, encroachments were mapped if they fell within the stream corridor, even if they did not occur immediately adjacent to a stream. This is because streams move and meander over time; a stream that is currently near but not immediately against a floodplain encroachment could migrate closer in the future, especially if that stream is rapidly adjusting to a stressor.

Figure 6 displays the slope modifiers found along the assessed reaches of the Nulhegan River. No evidence of recent straightening or dredging were found. A portion of M05 contained a berm and had a railroad encroachment, but these small impacts are not likely to have an effect on the river because of the erosion-resistant streambed. A short distance downstream there was a 4' high waterfall and two bedrock ledges, which make it unlikely that this reach could incise. The downstream reaches were located far from any infrastructure or roads and as a result there were no channel slope modifiers observed.

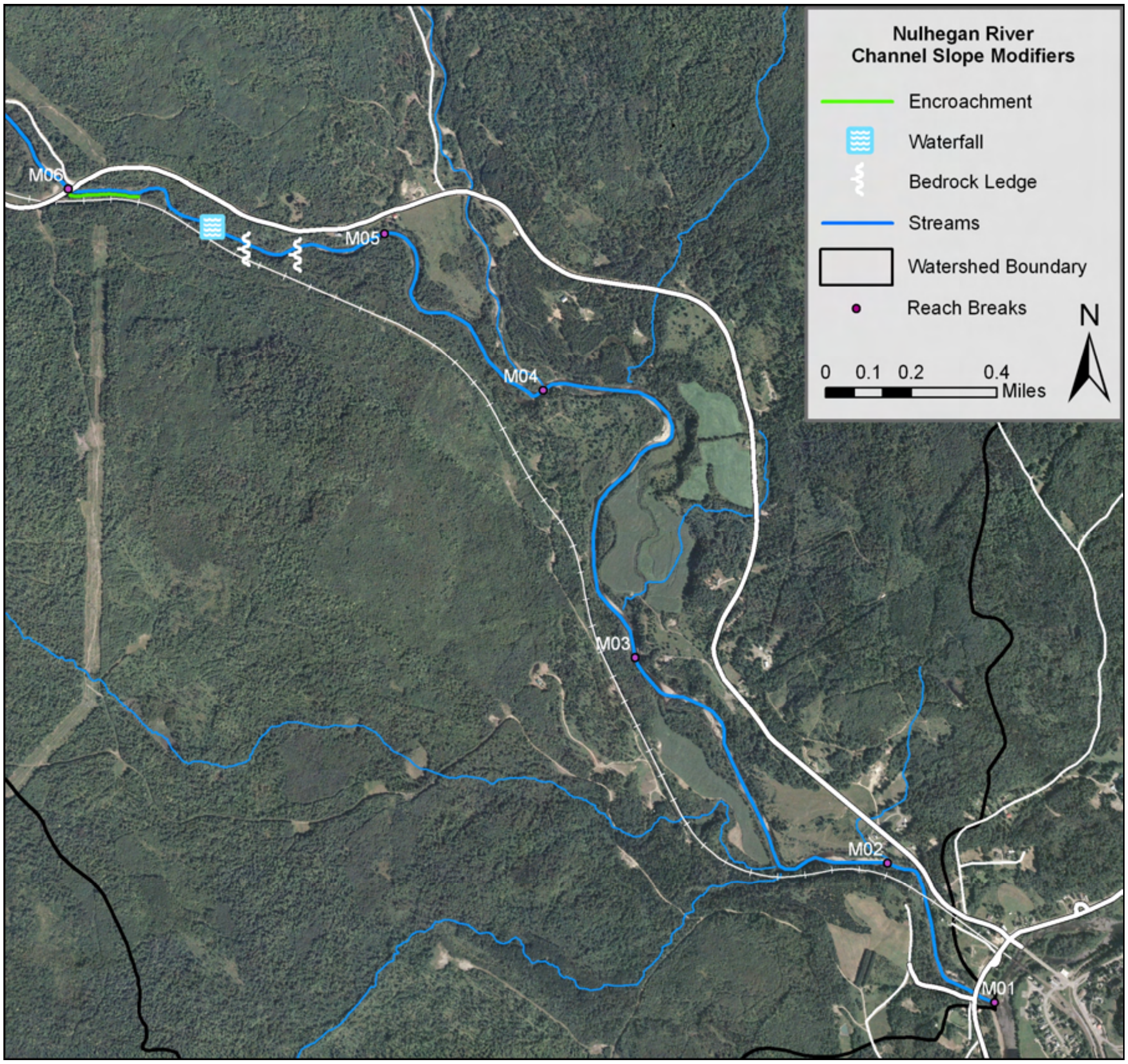



***Figure 6.*** *Slope modifiers along assessed Nulhegan River reaches, found only in Rreach M05.*

<u>Sediment Load Indicators</u>

Streams naturally erode, move, and deposit sediment. Erosion occurs on the outer bank of meander bends, where the water flows fastest and contains the most energy. The sediment is then deposited on bars along the inner bank, where the current is slowest. This process is a natural part of stream evolution as it responds to varying flow levels and sediment inputs over time.

In the absence of human influences average flow levels and sediment inputs vary little over time and the erosion process is quite slow, although some streams located on alluvial fans, at the base of very steep valleys, or are receiving large sediment inputs from mass failure sites or large tributaries are naturally more dynamic. Streams that exhibit excessive adjustments in the form of lateral and vertical migration (such as avulsions, neck cut-offs, channel widening and incision) and widespread erosion are likely to be responding to a variety of stream channel or watershed stressors disturbing the sediment regime.

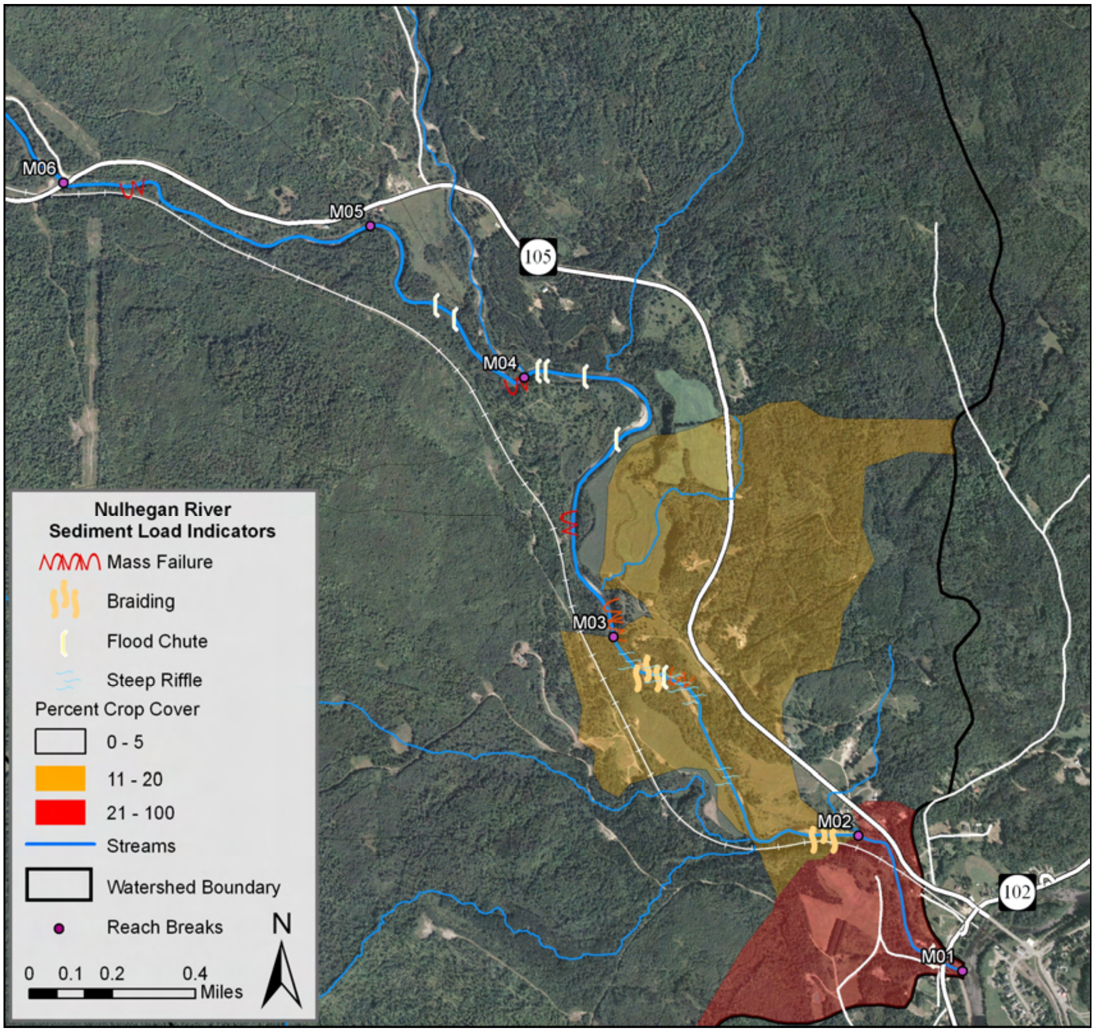


***Figure 7.*** *Sediment load indicators along Nulhegan River Reaches M01-M05.*

Indicators and sources of the sediment load within the Nulhegan River watershed are displayed in Figure 7. Agricultural land use is an important source of sediment on a watershed scale and is depicted as the percentage of land devoted to crop, hay, pasture, and other agricultural uses. Agricultural land uses were moderate (10-20%) to high (>20%) in only two sub-watersheds that drained into reaches M01 and M02; they were low (<10%) or non-existent in the remainder of the Nulhegan Watershed. Mass failure sites occurred where the river flowed against the glacial lake deposits which line the river valley, and likely contribute large amounts of sand to the river. The largest mass failure sites occurred in reaches M02 and M03.

Depositional features and channel adjustments that indicate a high sediment load are also displayed, including steep riffles, braiding, and flood chutes. Most of the depositional features were concentrated in two locations: in the vicinity of the East Branch confluence at the upstream end of reach M03 and throughout reach M02. The East Branch is a significant tributary and its watershed covers 24% of the total Nulhegan Watershed area. From viewing aerial photographs and field investigation, it appeared to carry a high load of sediment, which explains the high frequency of mid-channel bars, flood chutes, and diagonal bars located at its confluence with the Nulhegan River.

Further downstream in Reach M02, the river's flow was braided in two locations and several steep riffles were observed. These features were not present in Reach M01, which is more confined and likely transports sediment into the Connecticut River rather than depositing it within the reach.

### 4.1.3 Channel Constrictions and Stream Crossings

Bridges and culverts that are narrower than the stream channel width may decrease channel stability by causing excessive deposition upstream of the structure and increasing stream velocity and erosive energy downstream of the structure. This often results in localized areas of sediment deposition, erosion, fish passage problems, and ice and debris jams. In some cases, the stream constriction may increase the risk of flooding and property damage by forcing the river to flow around or over the bridge during high flows.

Table 3 shows the widths of the bridges measured in the Phase 2 assessments. Only three bridges were encountered during the assessments; at the Route 105 crossing near Stone Dam Road at Reach M05, the railroad bridge at Reach M01 (Figure 8), and the Route 102 crossing near the Connecticut River. All were at least as wide as the river's bankfull and floodprone widths and did not appear to affect the river.

**Table 3.** Summary of bridges found during Phase 2 assessments of the Nulhegan River.

| Reach | Road Name | Type | Bridge Span (ft) | Channel Width (ft) | % of Stream Width | Floodplain Constriction | Length of River Affected (ft) | Comments/ Problem Associated With Bridge |
|---|---|---|---|---|---|---|---|---|
| M01 | Route 102 | Bridge | 123 | 121 | 102 | No | 0 | None |
| M01 | Railroad | Bridge | 126 | 87 | 145 | No | 0 | None |
| M05 | Route 105 | Bridge | 75 | 67 | 112 | No | 0 | None |

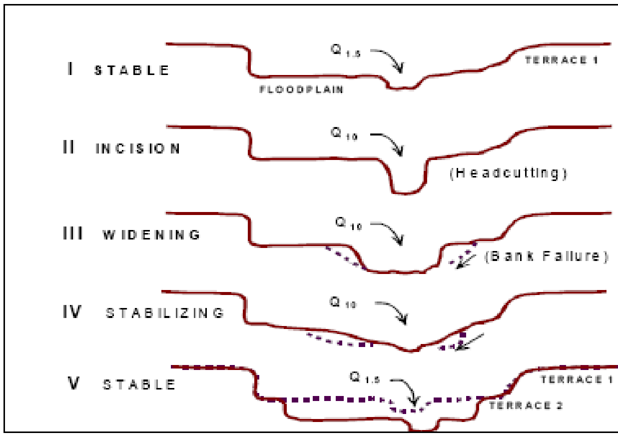
***Figure 8:*** *Railroad bridge, located in Reach M01.*

## 4.2 CURRENT GEOMORPHIC CONDITIONS

### 4.2.1 Geomorphic Condition Ratings and Channel Evolution Stage

Since European settlement, watersheds and stream channels have undergone extensive modifications such as deforestation, development, channel straightening, and bank armoring. These actions can increase peak flow levels, increase stream power, and decrease sediment storage. This has led to decreased floodplain function and increased erosion and flood damage in many rivers. When stream channels or floodplains are modified, the stream adjusts to maintain equilibrium with its flows and sediment loads, sometimes causing property damage in the process.

There are five stages in channel evolution depicted in Figure 9. Streams in stable or equilibrium condition are in Stage I. These streams are in reference or good condition and have the ability to regularly flood in order to disperse sediment and energy. Reaches in fair or poor condition are currently evolving to regain stability; these streams will be in various stages of channel evolution. Streams in Stage II have incised and may have lost the ability to access their floodplains. These reaches have increased power, increased ability to erode, and decreased ability to store sediment within the reach. Instead, much of the sediment may be sent downstream to affect downstream reaches or lakes. In Stages III and IV, the stream is widening and migrating as it re-establishes meanders and a new floodplain at a lower elevation. Erosion may be severe at these stages as the stream attempts to re-establish equilibrium. Finally, Stage V represents a new equilibrium and a re-established floodplain at a lower elevation.




In regime, reference to good condition, insignificant to minimal adjustment.

Fair to poor condition, major to extreme channel degradation.

Fair to poor condition, major to extreme widening and aggradation.

Fair to good condition, major reducing to minor aggradation, widening, and planform adjustments

In regime, reference to good condition, insignificant to minimal adjustment.

***Figure 9:*** *Channel evolution processes (State of Vermont 2007); Stages I and V represent equilibrium conditions, and Stages II, III, and IV represent the channel degradation, widening, aggradation, and planform adjustments occurring as the stream adjusts to regain equilibrium.*

Figure 11 depicts the geomorphic conditions and channel evolution stages found along the lower reaches of the Nulhegan River as found in the Phase 1 and Phase 2 Stream Geomorphic Assessments. Based on the intensity of channel and floodplain modifications, as well as the overall stream condition observed during the field assessments, reach conditions were defined as reference, good, fair, or poor. Vermont ANR Stream Geomorphic Assessment Protocols describe these conditions as follows (State of Vermont 2007):

**"In Regime: A stream reach in *reference and good* condition that** is in dynamic equilibrium which may involve localized, *insignificant to minimal change* to its shape or location while maintaining the fluvial processes and functions of its watershed over time and within the range of natural variability.

**In Adjustment: A stream reach in *fair* condition that** has experienced *major change* in channel form and fluvial processes outside the expected range of natural variability; and may be poised for additional adjustment with future flooding or changes in watershed inputs that could change the stream type.

**Active Adjustment and Stream Type Departure: A stream reach in *poor* condition that** is experiencing extreme adjustment outside the expected range of natural variability for the reference stream type; likely exhibiting a new stream type; and is expected to continue to adjust, either evolving back to the historic reference stream type or to a new stream type consistent with watershed inputs and boundary conditions."

Along the Nulhegan River, 50% of the assessed mileage was in reference condition, 26% in good condition, and 24% in poor condition. Most reaches were Stage I of channel evolution, meaning that they were in stable condition and significant channel adjustments were not evident. Reaches M03 and M04 appeared aggradational; the channels were wide and shallow and contained many gravel bars and flood chutes. Reach M02 (Figure 10) was in stage IV of channel evolution; the reach was very aggradational and the channel was braided in two areas. The reasons for such substantial sediment deposition in this area were unclear; recent man-made or natural changes in sediment and flow were not obvious. It is possible that the river was still reacting to the large-scale timber activities that had taken place over the past 200 years.

***Figure 10:*** *The confluence of two of the three channels in Reach M02.*

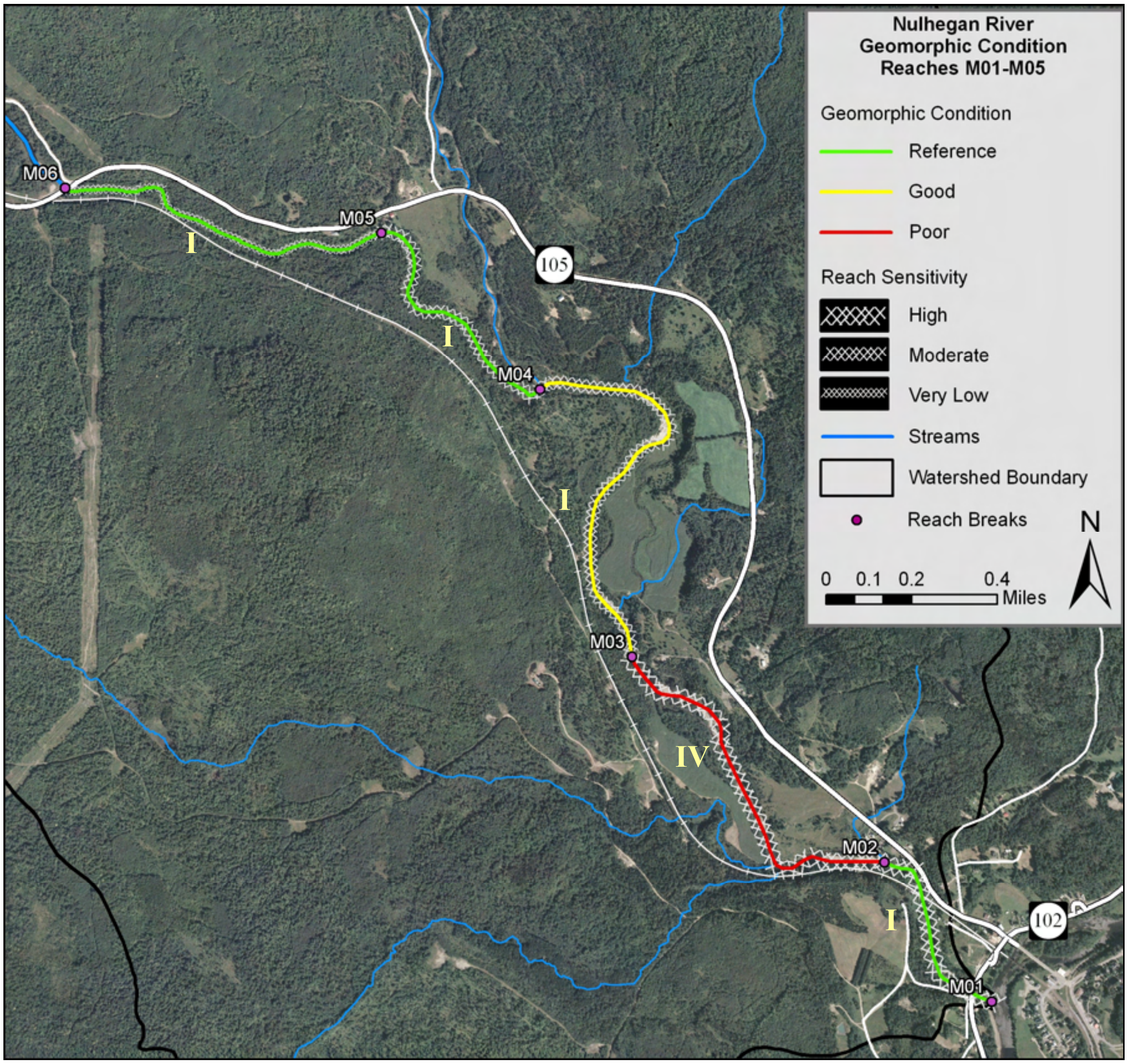



***Figure 11.*** *Map of geomorphic conditions for the five assessed Nulhegan River Reaches. Channel evolution stages are in yellow.*

### 4.2.2 Summary of Watershed-Scale and Reach-Scale Stressors

Both watershed-scale and reach-scale stressors are summarized and quantified in Table 4. These are the stressors that have influenced the geomorphic condition for each Phase 2 reach. This table summarizes characteristics of each reach's hydrologic regime, watershed-scale or upstream sediment inputs, stream power, and bank resistance. Urban and crop cover were summarized for each reach on the sub-watershed scale. Depositional features included mid-channel bars, steep riffles, delta bars, flood chutes, avulsions, and braiding.

**Table 4:** Summary of Watershed and In-stream Stressors

| | Watershed-Scale Stressors | | Reach-Scale Stressors | |
|---|---|---|---|---|
| **River Segment (Existing Stream Type, CES, RGA score*)** | **Hydrologic (urban land cover, stormwater inputs, wetland loss)** | **Sediment Load (depositional features, erosion, cropland, migration, mass failure)** | **Stream Power (Increase: straightening, encroachments; Decrease: deposition, migration)** | **Boundary Resistance (Increase: bank armoring, grade controls; decrease: erosion, reduced vegetation)** |
| **M01 (F3c, I, Reference)** | Increased flows:<br>• High (17%) urban land cover in sub-watershed | Increased load:<br>• Extreme (22%) cropland in sub-watershed | No significant stressors | Increased resistance:<br>• High (20%) bank armoring |
| **M02 (B4c, IV, Poor)** | Increased flows:<br>• High (12%) urban land cover in sub-watershed | Increased load:<br>• Moderate (8%) cropland in sub-watershed<br>• Abundant depositional features (>5/mile)<br>• Moderate (19%) bank erosion<br>• One mass failure site | Increased power:<br>• High (37%) straightening<br>Decreased power:<br>• Abundant depositional features (>5/mile) | Decreased resistance:<br>• Moderate (19%) bank erosion |
| **M03 (C3, I, Good)** | No significant stressors | Increased load:<br>• Abundant depositional features (>5/mile)<br>• High (40%) bank erosion<br>• Multiple mass failure sites | Increased power:<br>• Moderate (8%) bank armoring<br>Decreased power:<br>• Abundant depositional features (>5/mile) | Decreased resistance:<br>• High (40%) bank erosion<br>• Woody riparian vegetation uncommon in places<br>Increased resistance:<br>• Moderate (8%) bank armoring |

| | Watershed-Scale Stressors | | Reach-Scale Stressors | |
|---|---|---|---|---|
| **M04**<br>**(B3, I, Reference)** | Increased flows:<br>• Moderate (5%) urban land cover in sub-watershed | Increased load:<br>• Several depositional features (2-5/mile)<br>• Two mass failure sites | Increased power:<br>• Moderate (8%) bank armoring<br>Decrease:<br>• Several depositional features (2-5/mile) | Increased resistance:<br>• Moderate (8%) bank armoring |
| **M05**<br>**(F2c, I, Reference)** | Increased flows:<br>• Moderate (5%) urban land cover in sub-watershed | Increased load:<br>• One mass failure site | Increased power:<br>• High (26%) railroad/berm encroachment | Increased resistance:<br>• Multiple bedrock ledges and one waterfall |

*For Stream Type descriptions, see Appendix B. Stream type lettering is followed by the dominant stream bed material: 1 = bedrock, 2 = boulder, 3 = cobble, 4 = gravel, 5 = sand; CES = Channel Evolution Stage (Figure 8); RGA Score = Rapid Geomorphic Assessment Score

## 5.3 RESULTS AND RECOMMENDATIONS FROM PHASE 2 FIELD SURVEYS

The results of the Phase 2 field surveys are summarized in the following pages. All stream types are listed, followed by the dominant streambed material, geomorphic condition, channel evolution stage, habitat condition, and stream sensitivity. In the accompanying figures, the field measurements and locations of other features are overlaid on 2009 aerial photographs. The reach descriptions refer to left and right banks; these are determined when facing downstream (north). For stream type descriptions, see Appendix B.

<u>Nulhegan River Reach M01</u> – Connecticut River Confluence

Reference Stream Type: F plane-bed, cobble
Geomorphic Condition: Reference
Channel Evolution Stage: I (stable)
Habitat Condition: Reference
Stream Sensitivity: High

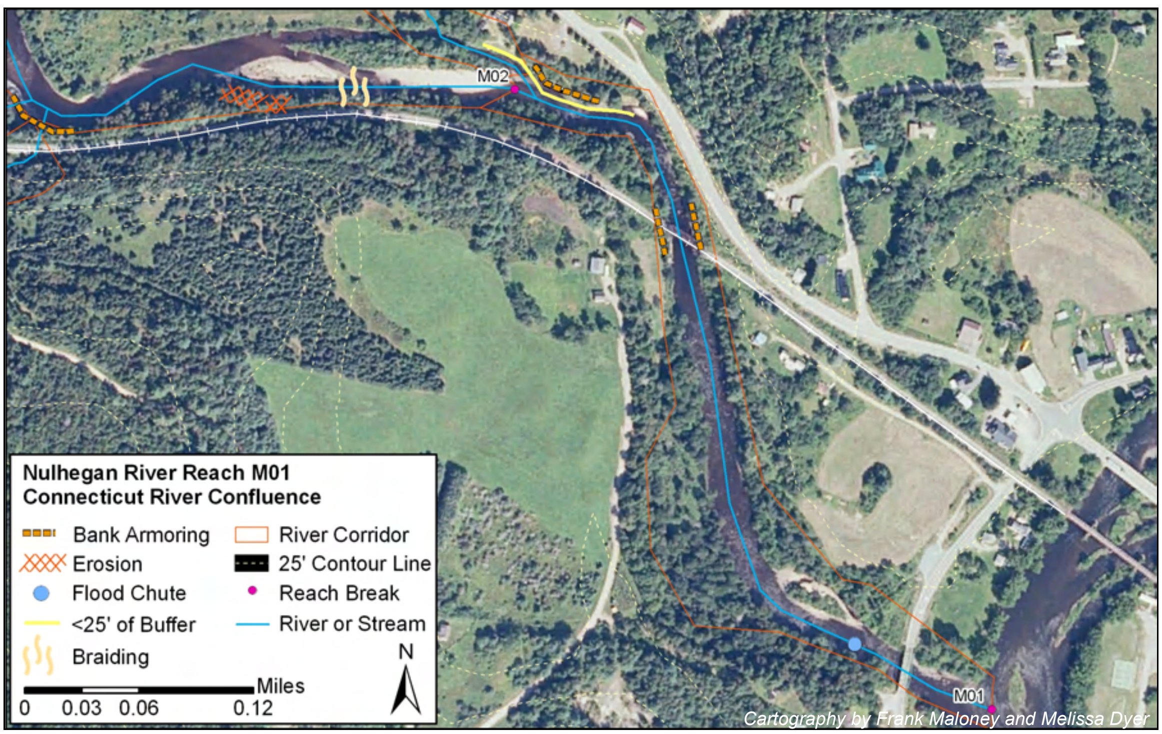


***Figure 12:** Results for Nulhegan River reach M01.*

Reach M01 (Figure 12) was a short and swiftly moving section of river that flowed along the village of Bloomfield before emptying into the Connecticut River. This reach was in reference geomorphic condition, owing to the lack of recent and significant alterations to the channel and the coarse streambed materials. It was a wide and entrenched F-type stream (the lowest top of bank measurement was 7.1 feet) without a significant slope and generally lacked bed features such as riffles and pools. Evidence of an old saw mill (Figure 13) remains just upstream of the Route 102 crossing, which may explain the flood chute located adjacent to the mill remains.

This reach contained excellent riparian habitat. While only one very large and deep pool was present at the upstream end of the reach, most of the streambed was comprised of unembedded large boulders and cobbles, completely covered by the clear, fast flowing water. The river's corridor was entirely covered by shrubs and deciduous trees, including highbush cranberry, mountain maple, yellow birch, American elm, and black cherry. The riparian buffer extended to 100' from the riverbanks along most of the reach, however there were some gaps along the left bank upstream along a mowed lawn and Route 105. There were also several scattered honeysuckle *(Lonicera tatarica)* bushes in the reach in very manageable densities; eliminating these plants should be a management priority as most of the Nulhegan River appeared free of invasive plants.


***Figure 13:*** *Old mill site upstream of the Route 102 bridge, looking upstream.*

Nulhegan River Reach M02

Current Stream Type: Bc braided, gravel. Subdominant bed form: plane bed
Reference Stream Type: C, riffle-pool, gravel
Geomorphic Condition: Poor
Channel Evolution Stage: IV (aggrading)
Habitat Condition: Good
Stream Sensitivity: High

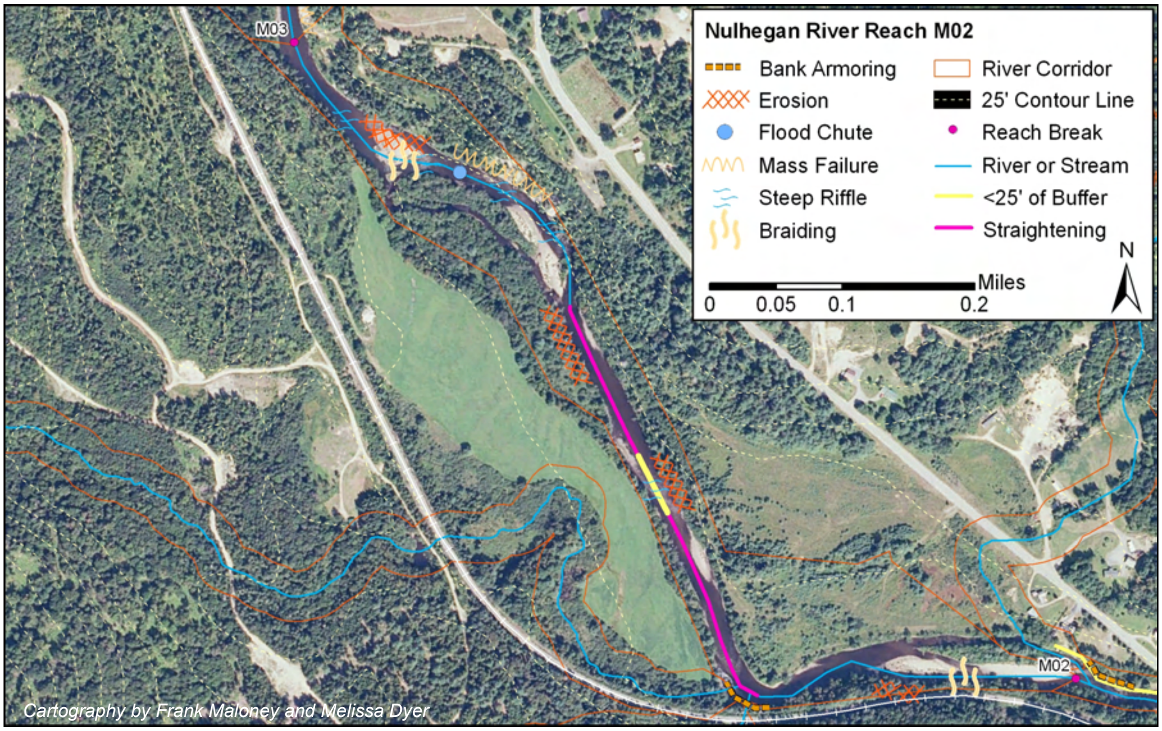



***Figure 14:*** *Phase 2 results for Nulhegan River reach M02 in Bloomfield.*

Reach M02 was an isolated section which flowed between the railroad to the southwest and Route 105 to the northeast (Figure 14). This reach was rated in poor condition because it had changed to a different stream type than should exist in this setting and appeared very aggradational. Many depositional features were observed, including four mid-channel bars, one flood chute, and five steep riffles. The channel was braided at two locations in the beginning (Figure 15) and end of the reach where the river had split into three separate channels. The cause of the braiding was not obvious; a decrease in the channel slope (and the resulting decrease in stream power) is often the cause of abundant deposition in rivers, however there was no discernable change in slope observed in this portion of the Nulhegan River. One potential cause of the upstream aggradation was that the river was flowing against the valley wall at the beginning of the reach. This was accompanied by a large mass failure site made up of sand and gravel. The river likely decreased in velocity by flowing against the valley wall. The large inputs of sediment originating from that location added to an already large sediment load that the river was not able to transport, resulting in the observed depositional features.

We had determined that the existing stream type did not represent the reference state of this reach, which was likely a ‘C’ stream type. The existing ‘B’ stream type would typically be found in a confined valley setting, however the valley of Reach M02 was relatively flat and unconfined. This reach was entrenched and had a well developed but limited floodplain. This change in stream type likely had occurred over a century ago when the Nulhegan River and its tributaries had been dammed and used to transport timber. About 37% of Reach M02 appeared to have been straightened long ago, likely for this purpose. Additionally, the pulses of water released from the dams to float logs likely resulted in enlargement of the river channel that were observed as old, forested terraces along the river.

The aquatic habitat was in good condition; the monotony of the stream bed, sediment deposition, and lack of woody debris kept this from being a reference reach. The riparian corridor contained a mixture of old pasture, mixed forest, and hay field where mowing occurred within 25’ of the river. Where present, the riparian buffer consisted of a mixture of large white pines, eastern hemlock, and aspen; however a large portion of the left buffer was an old field with shrubs and young tamarack trees. Invasive plants, including a 50’ long patch of Japanese knotweed *(Polygonum cuspidatum)* and several honeysuckle bushes *(Lonicera tatarica)* were observed near the downstream reach break and should be removed while they are still in manageable densities.

***Figure 15:*** *Abundant sediment deposition in Reach M02.*

Nulhegan River Reach M03 – Downstream of the East Branch Confluence

Reference Stream Type: C riffle-pool, cobble. Subdominant bed form: plane bed
Geomorphic Condition: Good
Channel Evolution Stage: I (stable)
Habitat Condition: Good
Stream Sensitivity: Moderate

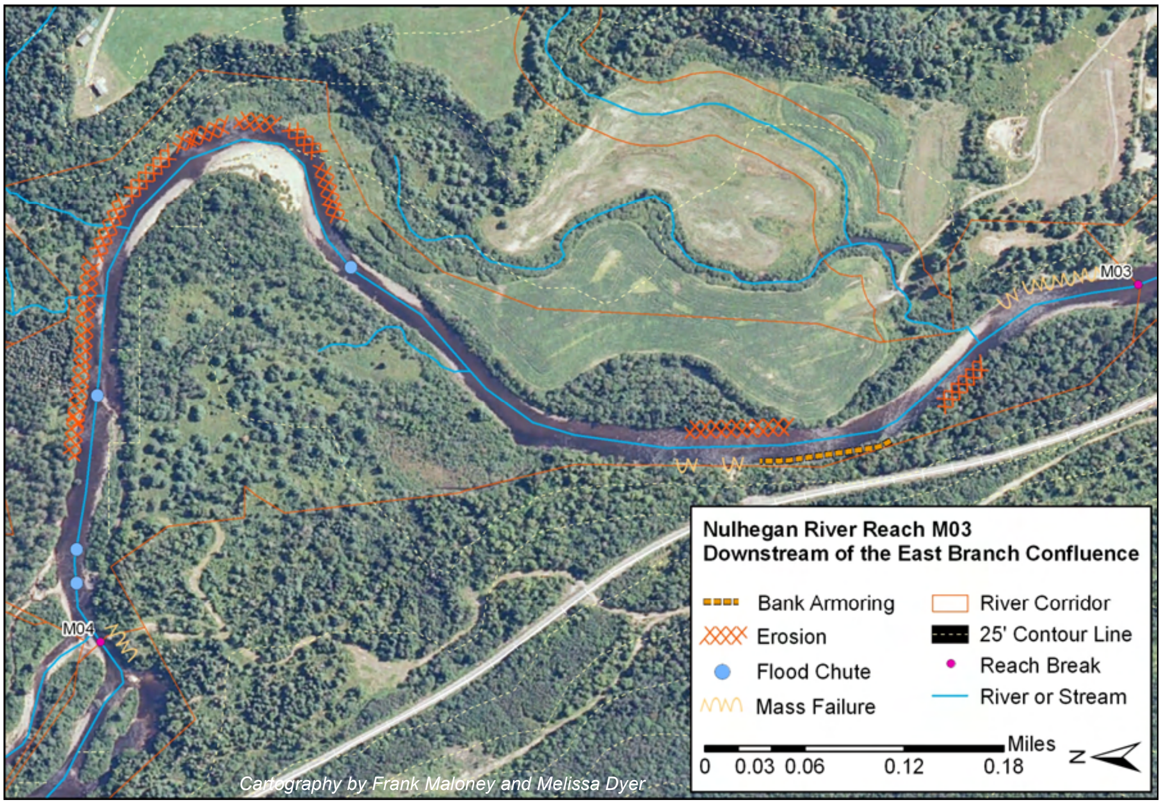


***Figure 16:*** *Results for Nulhegan River Reach M03.*

Reach M03 began at the East Branch confluence and flowed from one mile beyond this junction (Figure 16). This reach was in good geomorphic condition. Initially the reach was impacted by sediment deposition from the East Branch, which is a major tributary that comprises about 24% of the total Nulhegan Watershed area. This tributary had been used intensively for timber operations and at one time had six dams controlling its flows in order to transport timber downstream. The influences from the East Branch included several diagonal bars, flood chutes, two small mid-channel bars, and extensive scouring along the left bank opposite of a large and growing point bar. These depositional features disappeared 0.5 miles downstream of the confluence, about mid-way through the reach. The remainder of the reach was characteristic of much of the lower Nulhegan River: swift, wide, and shallow (Figure 17).

Though Reach M03 exhibited a riffle-pool bedform, pools were actually infrequent, resulting in a fairly homogenous stream bed characterized by nearly continuous riffles. This, in combination with some bank instability, was the main reason the reach was rated in ‘good’ habitat condition rather than ‘reference’. Most of the bank instability occurred near the immediate influence of the East Branch and continued along an old field that lacked woody vegetation along the riverbanks. Because of the lack of human investments in the area, the riverbank vegetation could be allowed to grow naturally. A short distance downstream, the river flowed along a corn field (a rare sight in the Nulhegan Watershed) that was located approximately 25’ from the riverbank; however the majority of the remaining landscape was forested. Much of the forest was young, consisting of black cherry, speckled alder, and balsam fir that had colonized several old fields.

***Figure 17:*** *A typical section of Reach M03, with forested riverbanks and a wide, shallow channel.*

Nulhegan River Reach M04 – Upstream of the East Branch Confluence

Reference Stream Type: Bc plane bed, cobble
Geomorphic Condition: Reference
Channel Evolution Stage: I (stable)
Habitat Condition: Reference
Stream Sensitivity: Moderate

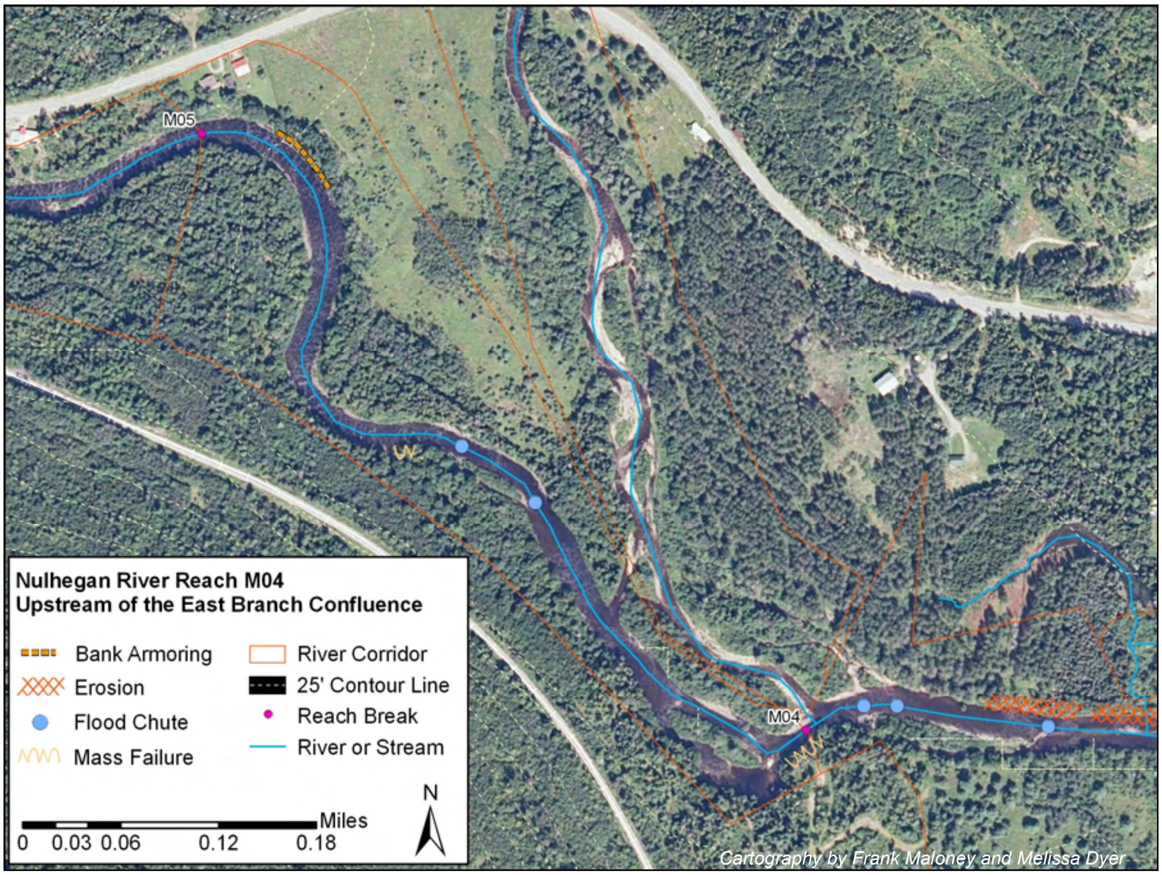



***Figure 18:*** *Results for Nulhegan River Reach M04.*

Reach M04 (Figure 18) was a transition between the bedrock and boulder-dominated cascades upstream and the cobble streambeds that dominate the remainder of the Nulhegan River. The riverbed was uniformly flat and very wide (Figure 19) until it approached the East Branch confluence where several flood chutes and depositional features occurred. Though the reach was set in an unconfined and gently sloped valley, the broad valley seen from the topographic maps was actually an old floodplain. The consistent and well-defined bankfull level was located approximately 5' below the abandoned floodplain along the left riverbank and at least 25' below the narrow old floodplain on the right. The reach was quite entrenched – its floodplain was only 1.5 times the width of the river. It was determined that the reach had not incised recently, despite the unconfined valley setting. The presence of large trees on the current floodplain and the complete lack of streambank erosion associated with the downcutting of river channel was evidence against recent incision. Whether the river's entrenchment was a result of historic timber activities or a post-glacial feature was not clear. Regardless, the reach appeared to be in a reference state in its current condition.

The reach's habitat was rated in reference condition. Though this was predominantly a plane-bed channel that lacked woody debris, there was enough variability in the channel bed to provide a diversity of habitats. Large boulders created scour pools and several portions of the reach varied in their flows and depths, including one large pool near the East Branch confluence. The riparian corridor was completely forested with deciduous trees along the right side and contained a mixture of forest and regenerating forest along left side.

***Figure 19:*** *Photo taken in the middle of Reach M04, depicting a very wide and shallow channel.*

Nulhegan River Reach M05 – Downstream of Route 105 Crossing

Reference Stream Type: Fc step-pool, boulder
Geomorphic Condition: Reference
Channel Evolution Stage: I (stable)
Habitat Condition: Reference
Stream Sensitivity: Very Low

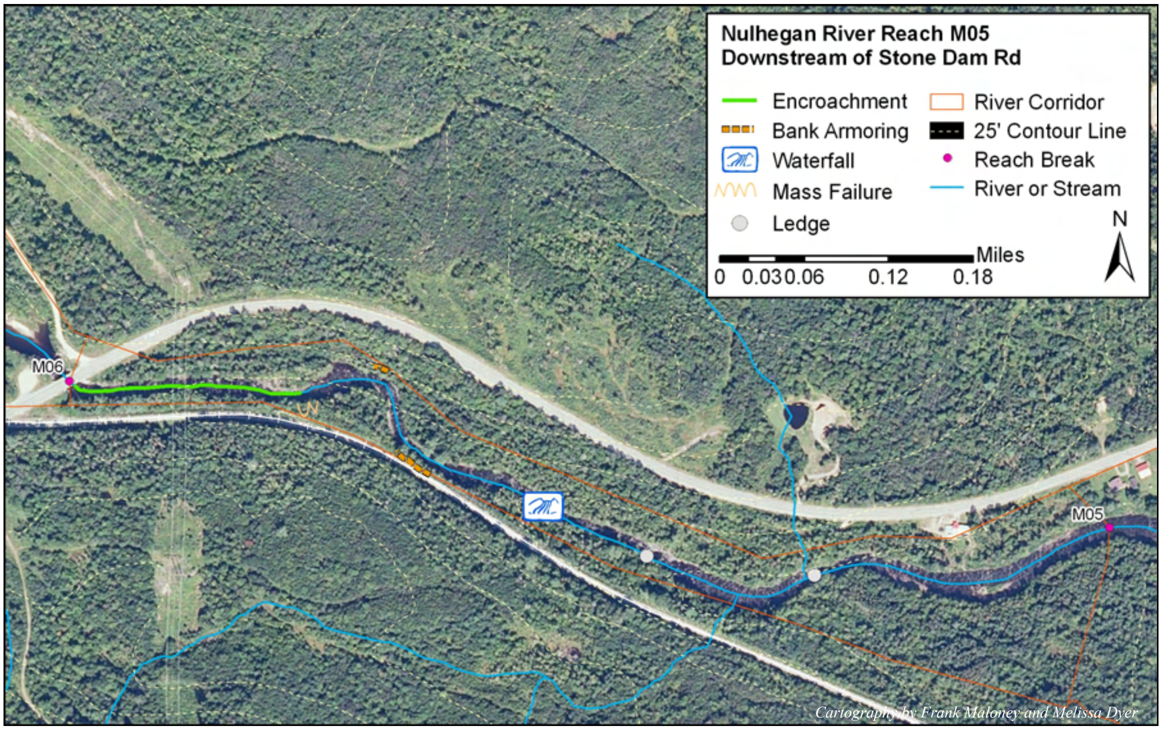



***Figure 20****. Results for Nulhegan River Reach M05.*

Reach M05 began near the remnants of an old stone dam at the Route 105 crossing and descended 75 feet during the 0.82 mile length of the reach (Figure 20). The river flowed closely between the railroad and Route 105. It swiftly cascaded over large boulders, two bedrock ledges, and one waterfall, making walking treacherous at times. Though flowing in a semi-confined valley, the channel was very entrenched along most of its length. Because of this, alterations to the channel were minimal and included a berm near the upstream end and two stone walls located a short distance downstream. The reach was in reference condition and due to the boulder-dominated streambed and streambanks is not likely to change from this condition (Figure 21).

Habitat was also in reference condition, owing to the unimpacted channel and riparian corridor and characteristics of the channel itself. The corridor was entirely forested with a mix of deciduous trees, northern white cedar, and balsam fir; these trees provided a dense canopy to shade the stream banks. Large boulders and areas of bedrock provided deep scour pools and interrupted the swift and deep flow. Additionally, steps and pools were frequent enough to provide a diversity of habitats.


***Figure 21.*** *Photo of Reach M05, showing the large boulders and cascades typical of the reach.*

**Recommendations**

As seen in this report, most of the Nulhegan River corridor is in an undeveloped state. This is further reflected by the prevalence of natural land cover in the region, which is responsible for the river's reputation as a scenic and wild waterway. Thus, management efforts should concentrate on conserving these scenic conditions along private lands bordering the river. These lands mainly occur downstream of Stone Dam Road and from Nulhegan Pond to one mile downstream of McConnell Pond Road. The remainder of the river flows through public land. Other management efforts should include invasive species control in the lower reaches, where low but easily controllable populations of invasive plants were found. Additionally, establishing a wider buffer on the two fields along reaches M02 and M03 would enhance wildlife habitat, better facilitate wildlife movement, and decrease the likelihood of any runoff from these fields. Otherwise, passive restoration of the river corridor is recommended, as much of it consists of old fields that are becoming forested on their own.

There is instability along some reaches of the river. These reaches are likely still reacting to the large-scale logging practices that occurred historically as well as sediment inputs from the East Branch. This tributary had been altered and used intensively for driving logs, and it clearly is moving large amounts of sediment. Further assessments in the basin should focus on the East Branch, as it appears to have the largest influence on the geomorphic processes of the Nulhegan River.

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## Glossary

Aggradation – Accumulation of sediment on the channel bed.

Alluvial – Refers to sediment materials deposited by a river or stream.

Avulsion – A change in a stream's course caused by the stream breaking through the banks and forming a new channel.

Basin – see Watershed

Degradation –Process of scouring of the channel bed due to changes in flow rates or sediment loads.

Entrenched – Having little space to flood. A stream's entrenchment is represented by its entrenchment ratio (the width of the floodprone area divided by the width of the channel).

Erosion – The loosening and transport of soil and other particles. Erosion is a natural process but can be accelerated by human activities, such as vegetation removal and stream channel alteration.

Flood chute – An area outside the main channel that a stream accesses during high flows. These areas may become the future location of the channel as the stream migrates.

Floodplain – The area adjacent to a stream that becomes inundated with water during high flows. This land is built of sediment originating from flooding of the stream. Floodplains have important roles in reducing sediment transport and stream power during floods.

Incision – The process by which a river erodes its channel bed to a lower level than existed previously.

Incision ratio – The lower floodplain height divided by the depth of the channel at bankfull. A stable stream in reference condition would have an incision ratio of 1, meaning that degradation of the channel bed has not occurred. A stream which has undergone degradation of the channel bed would have an incision ratio greater than 1. The higher the ratio, the less likely a stream can access its floodplain.

Neck Cutoff – The narrow strip of land that exists between two meanders migrating closer to one another; eventually, the channel may break through this strip of land and the old channel will form an oxbow.

Planform – The shape and pattern that a stream forms on a landscape.

Riffle – A section of stream characterized by fast, shallow water flowing over coarser bed materials, such as cobbles and boulders

Riparian buffer – A strip of natural vegetation growing along a waterbody which serves to reduce erosion, filter sediment and pollutants, and enhance aquatic biodiversity.

Sensitivity – A measure of how likely a reach would react to human or natural stressors to the watershed or the reach itself. This takes into account the current geomorphic condition of the reach and the composition and erodibility of its bed and bank materials.

Sinuosity – A measure of how meandering a stream is. Sinuosity is displayed as a ratio of the length of the river divided by the length of its valley.

Stream corridor – The area of land adjacent to a stream that influences and is influenced by that stream. During the Phase 1 and Phase 2 assessments, this corridor is at least 100 feet on either side of the stream.

Tributary – A body of water, such as a stream, that flows into another body of water.

Watershed (or basin) – A region drained by all of the rivers and streams flowing into a lake, river, or ocean. The relative size of a watershed and the human alterations to that watershed greatly affect the quality of the water in the waterbody into which it drains.

**Appendix A.** Phase 1 Project Metadata.

| **Parameter** | **Source** |
|---|---|
| Alluvial fan | 1:24K topos |
| Bank armoring and revetments | Not Evaluated |
| Bank erosion - relative magnitude | Field observation |
| Dominant bed form and material | Field observation |
| Belt width | 1:5K NHD, 1:5K orthos |
| Berms and roads | 1:24K topos, 1:5K orthos |
| Bridges and culverts | 1:24K topos, 1:5K NHD & orthos |
| Channel length | SGAT automated |
| Channel straightening | 1:24K topos, 1:5K NHD & orthos |
| Confinement type | 1:24K topos |
| Corridor land use - land cover data | Land use - land cover (1990s statewide) |
| Debris and ice jam potential | Field obs. at access point along reach |
| Depositional features | 1:5K orthos |
| Dredging and gravel mining history | Interviews - DEC, NRCS |
| Downstream and upstream elevations | 1:24K topos |
| Flow regulations and water withdrawals | 1:24K topos, 1:5K NHD & orthos |
| Grade controls | 1:24K topos, field observation |
| Latitude and Longitude | SGAT automated |
| Meander centerline | 1:24K topos, 1:5K NHD |
| Meander migration and channel avulsion | 1:5K orthos (1990s & 1970s), other aerial photographs |
| Historic corridor land use - land cover | Not Evaluated |
| Historic watershed land use - land cover | Not Evaluated |
| Reach breaks | 1:24K topos, 1:5K NHD |
| Riparian buffer width | 1:5K orthos |
| River corridor development | 1:24K topos, 1:5K orthos |
| Stream type | 1:24K topos |
| Towns that reaches are in | 1:24K topos |
| Valley length | SGAT automated |
| Valley side slopes | 1:24K topos |
| Valley walls | 1:24K topos |
| Valley width | SGAT automated |
| Groundwater and small tributary inputs | 1:24K topos, 1:5K NHD, NWI maps |
| Wavelength | 1:5K NHD, 1:5K orthos |
| Watershed delineations | 1:24K topos, 1:5K NHD |
| Watershed land use - land cover data | Land use - land cover (1990s statewide) |

## Appendix B: Summary of Rosgen Stream Classifications and Descriptions of Channel Bed Forms

**Rosgen Stream Classifications (Rosgen 1994)**

| Stream Type | Sinuosity | Slope (%) | Features |
|---|---|---|---|
| A | Low | >10 | Steep, entrenched, high energy/debris transport stream. Contain vertical steps, deep scour pools, waterfalls |
| B | Low to moderate | 4-10 | Moderately entrenched, dominated by riffles, pools infrequent. Stable bed and banks |
| C | High | <2 | Low gradient, meandering, alluvial channels with broad and well defined floodplains. Exhibit point bars and riffle-pool characteristics |
| D | Variable | <4 | Braided, very wide channels with eroding banks, in broad valleys with abundant sediment supply |
| E | Very high | <2 | Low gradient, highly sinuous channel with very broad and alluvial floodplain |
| F | High | <2 | Entrenched stream in highly weathered, low gradient material. Laterally unstable, high bank erosion. Riffle-pool characteristics |
| G | Low to moderate | 2-4 | Entrenched stream in narrow valley or deeply incised in alluvial or colluvial materials. Unstable, high bank erosion rates |

**Descriptions of Channel Bed Forms (State of Vermont 2007b)**

| Bed Forms | Description |
|---|---|
| Cascade | Generally occur in very steep channels, narrowly confined by valley walls. Characterized by longitudinally and laterally disorganized bed materials, typically bedrock, boulders, and cobbles. Small, partial channel-spanning pools spaced < 1 channel width apart common. |
| Step-Pool | Often associated with steep channels, low width/depth ratios and confining valleys. Characterized by longitudinal steps formed by large particles (boulder/cobbles) organized into discrete channel-spanning accumulations that separate pools, which contain smaller sized materials. |
| Plane Bed | Occur in moderate to high gradient and relatively straight channels, have low width/depth ratios, and may be either unconfined or confined by valley walls. Composed of sand to small boulder-sized particles, but dominated by gravel and cobble substrates. Channel lacks discrete bed features (such as pools, riffles, and point bars) and may have long stretches of featureless bed. |
| Riffle-Pool | Occur in moderate to low gradient and moderately sinuous channels, generally in unconfined valleys, and has well-established floodplain. Channel has undulating bed that defines a sequence of bars, pools, and riffles. Pools spaced every 5 to 7 channel widths in a self-formed (alluvial) riffle-pool channel. |
| Dune-Ripple | Usually associated with low gradient and highly sinuous channels. Dominated by sand-sized substrates. Channel may exhibit point bars or other bedforms forced by channel geometry. Typically undulating bed does not establish distinct pools and riffles. |
| Bedrock | Lack a continuous alluvial bed. Some alluvial material may be temporarily stored in scour holes, or behind obstructions. Often confined by valley walls. |
| Braided | Multiple channel system found on steep depositional fans and deltas. Channel gradient is generally the same as the valley slope. Ongoing deposition leads to high bank erosion rates. Bed features result from the convergence/divergence process of local bed scour and sediment deposition. Unvegetated islands may shift position frequently during runoff events. High bankfull widths and very low meander (belt) widths. |

NorthWoods
Stewardship Center

*fostering stewardship of human and natural communities*

Ten Mile Square Road / P.O. Box 220
East Charleston, VT 05833
(802) 723-6551
www.northwoodscenter.org