Franklinton Vlaie Tributary Improvement Study

Technical Report and Recommendations
Town of Broome, Schoharie County, New York
March 2018

Milone & MacBroom
Engineering | Planning | Landscape Architecture | Environmental Science

Photo by Milone & MacBroom, 2017

Prepared for:
Schoharie County Planning and Development Agency
276 Main Street, Suite 2
Schoharie, NY 12157

MMI #6108-01-04

Prepared by:
MILONE & MACBROOM, INC.
231 Main Street, Suite 102
New Paltz, NY 12561
(845) 633-8153
www.miloneandmacbroom.com

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1.0 INTRODUCTION

1.1 Project Background

The Schoharie County Planning and Development Agency has retained Milone & MacBroom, Inc. (MMI) to assess a watercourse in the Town of Broome. This assessment is funded with a grant from the New York State Department of Environmental Conservation (NYSDEC) through the 2015 Hudson River Estuary Grants for Local Stewardship Planning. The subject watercourse is at the headwaters of Catskill Creek and is a tributary to Franklinton Vlaie. Before it discharges to the Vlaie, the watercourse crosses under Woods Road via a corrugated metal culvert that has a history of debris blockages, flooding, and channel aggradation.

The Franklinton Vlaie is part of the NYSDEC-owned Franklinton Vlaie Wildlife Management Area, which includes an 85-acre emergent and open-water wetland complex that supports fish (reportedly including American eel), waterfowl, and other wildlife. Vlaie (sometimes vly or fly) is a word used by Dutch settlers to describe areas that are "land at certain seasons and water at other times" (Gannett, 1905). The Franklinton Vlaie drains to Catskill Creek, which in turn flows to the Hudson River in Catskill, NY. Figure 1-1 is a regional project location map.

Vlaie (sometimes vly or fly) is a word used by Dutch settlers to describe areas that are "land at certain seasons and water at other times" (Gannett, 1905).

1.2 Study Purpose and Goals

The project seeks to identify mitigation projects that will:

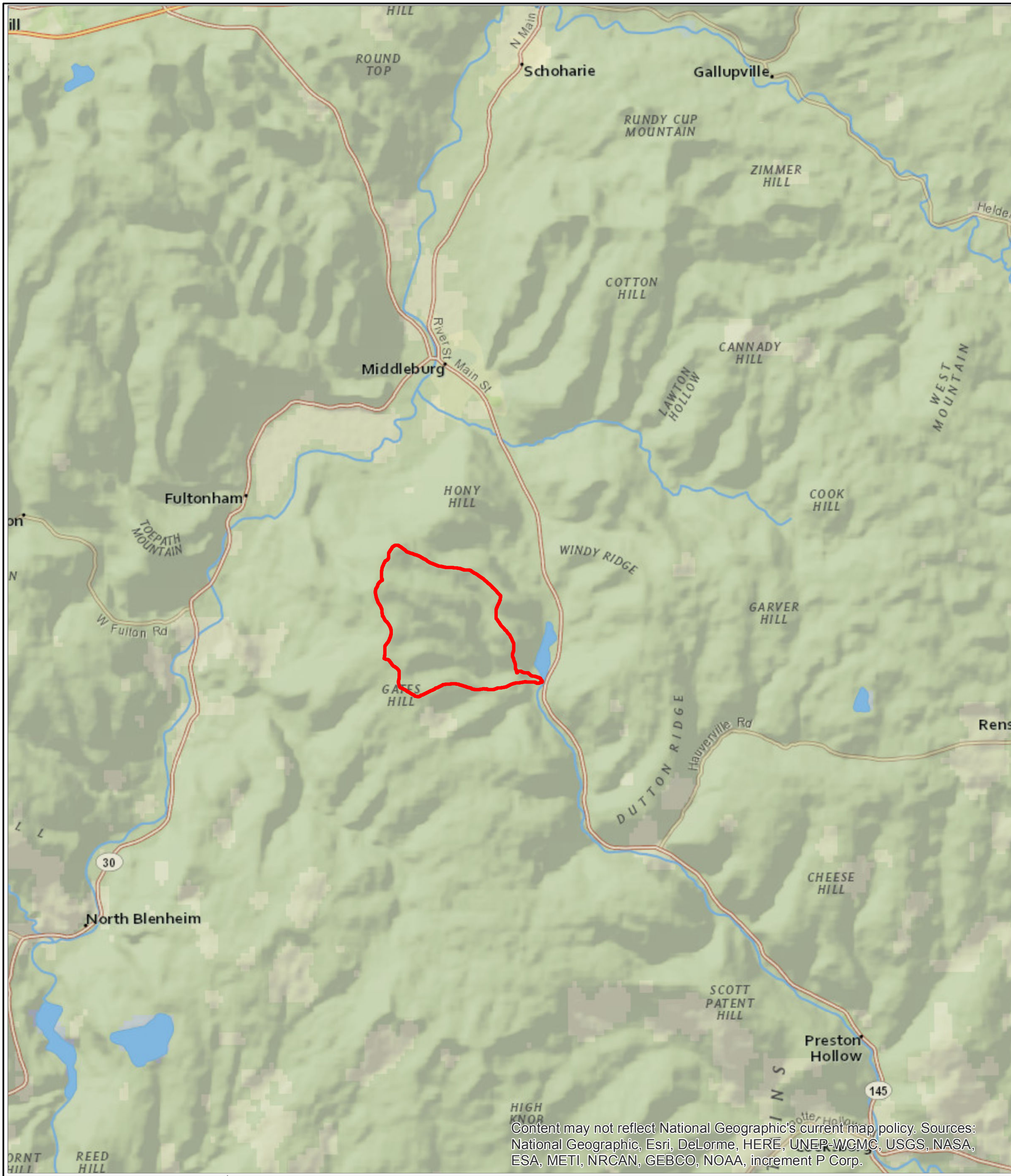
- Stabilize the stream channel.
- Restore or create new, native in-stream and riparian habitats.
- Promote best management practices to improve water quality.

One critical desired outcome of the project is to gain an understanding of how upstream erosion and sediment issues may be influencing the frequency and severity of flooding and sediment aggradation at a downstream culvert crossing at Woods Road and how these issues are influencing aquatic habitat quality and the movement of fish, amphibians, and other aquatic organisms between the watercourse and the Vlaie.

1.3 Nomenclature

The subject watercourse and its smaller tributaries are located at the headwaters of Catskill Creek. The watercourse is labeled on some maps as Catskill Creek. In other documents it is referred to as an unnamed tributary to Franklinton Vlaie. For the purpose of this report, the main stem of the watercourse will be referred to as the *main branch*, while the tributary flowing into the main branch from the north will be referred to as the *north branch*. The branches are depicted on the stream stationing map (Figure 1-2).

In this report and associated mapping, stream stationing is used as an address to identify specific points along the watercourses. Stationing is measured in feet beginning at the outlet of the main branch to the Franklinton Vlaie at Station (STA) 0+00 and continuing upstream to its headwaters at approximately STA 177+00. Stationing along the north branch begins at its confluence with the main branch at STA 0+00 and continues upstream to its headwaters at approximately STA 118+00. All references to right bank and left bank in this report refer to "river right" and "river left," meaning the orientation assumes that the reader is standing in the river looking downstream.



SOURCE(S):	Figure1-1: Regional Location Map	LOCATION: Broome, NY
Copyright:© 2013 National Geographic Society, i-cubed		

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MXD: Q:\Proposals\TNC NJ\GIS\Regional_Location_Map.mxd

Map By: EMH
MMI#: 6108-01
Original: 3/20/2017
Revision: 3/31/2017
Scale: 1 inch = 10,000 feet

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(845) 633-8153 Fax: (845) 633-8162
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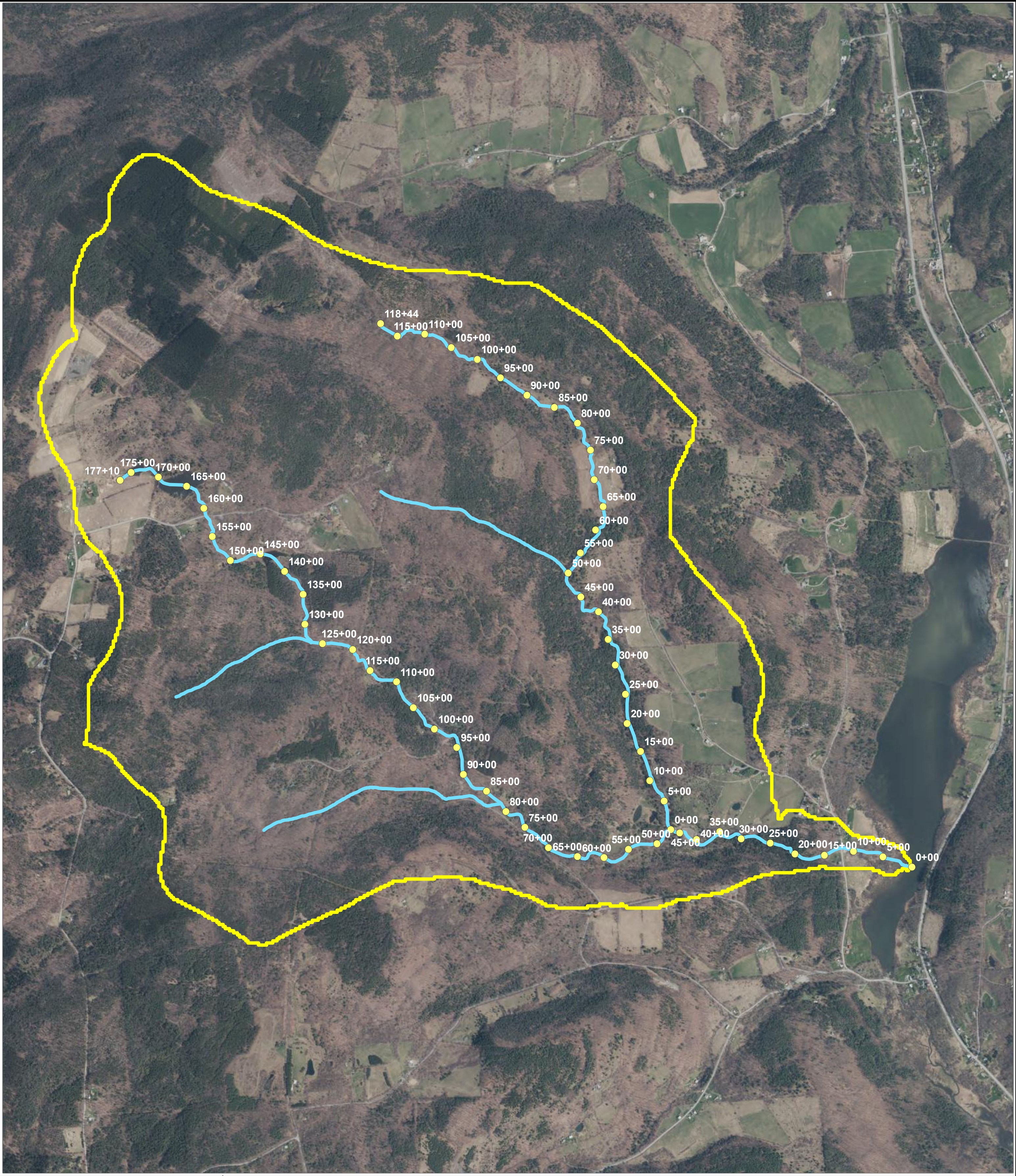

SOURCE(S):

NYState Orthos Online at
www.orthos.dhses.ny.gov (03/2017)

Figure 1-2: Stream Stationing Map

LOCATION:

Broome, NY

N

Franklinton Vlaie Tributary Improvement Study

MXD: Q:\Projects\6108-01 Franklinton Vlaie Watershed\GIS\StreamStationingMap.mxd

Map By: EMH
MMI#: 6108-01
Original: 3/31/2017
Revision: 10/10/2017
Scale: 1 inch = 2,000 feet

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(845) 633-8153 Fax: (845) 633-8162
www.miloneandmacbroom.com

2.0 WATERSHED

2.1 Overview

The following section provides a description of the watershed and its characteristics, including an assessment of watershed health. The rural, 3.7 square mile watershed includes several paved and unpaved roads, forest, and several small farms and meadows on steep hillsides (Figure 2-1). The headwaters are located along a high, broad, rounded ridgeline running west of the Franklinton Vlaie, which includes a portion of Armlin Hill State Forest at an elevation of just over 2,100 feet. This ridgeline separates that Catskill Creek watershed, which flows to the Mohawk River. The local relief is approximately 900 vertical feet from the ridgeline to the valley bottom.

> The ridgeline above Franklinton Vlaie separates the Catskill Creek watershed, which flows to the Hudson River, from the Schoharie Creek watershed, which flows to the Mohawk River.

Within the watershed, two main tributaries, or branches, join to form Catskill Creek. The north branch begins in a wetland complex near the northwest edge of the watershed and flows through forested ravines as well as several level, relatively flat areas with ponds and wetlands. The main branch begins in a wetland complex just north of Armlin Hill Road near the west edge of the watershed and flows through another wetland complex just south of the road.

2.2 Watershed Geology

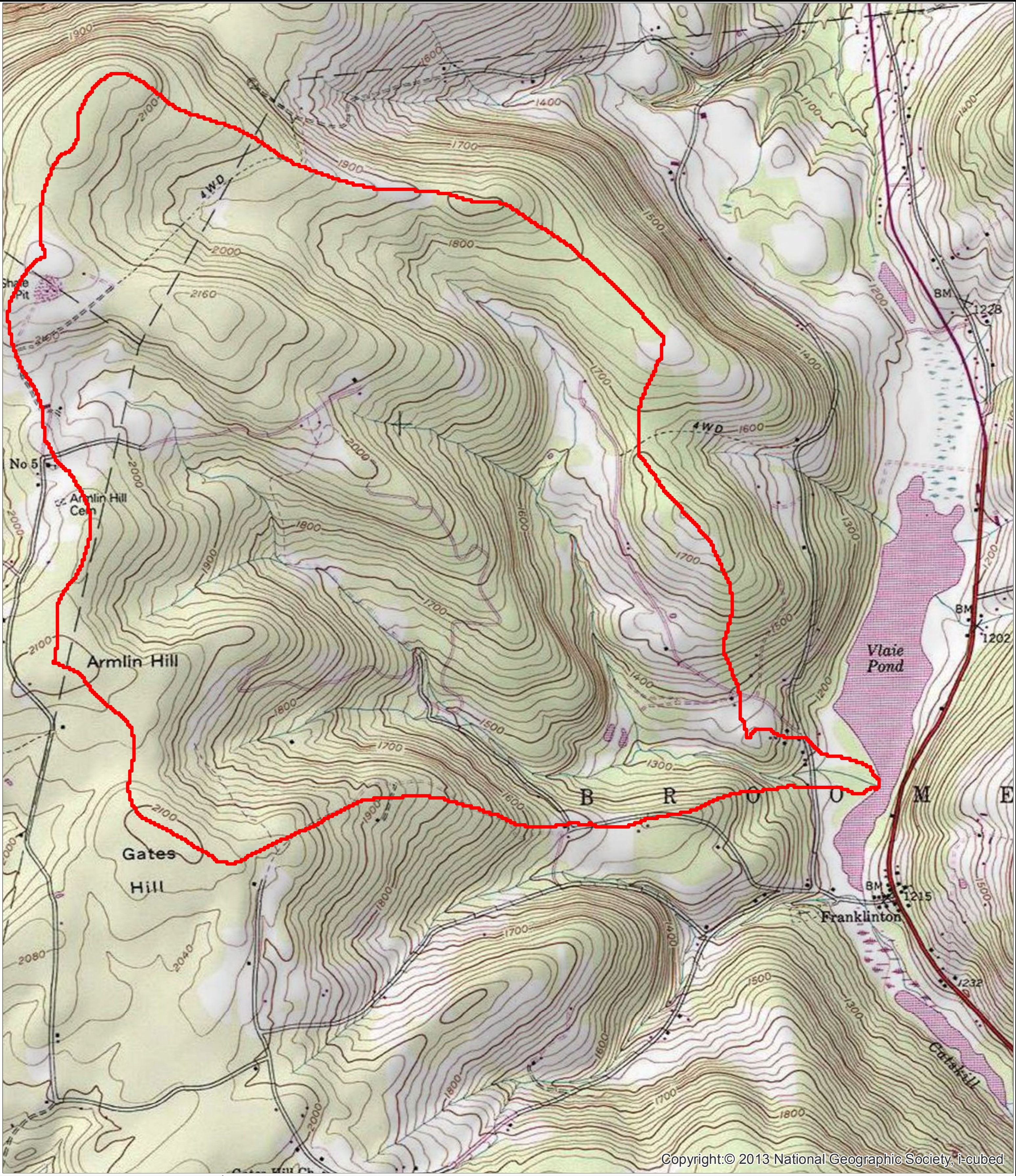
2.2.1 Bedrock Geology

The bedrock consists primarily of Panther Mountain formation, which underlies the east-facing slopes of the watershed, and Moscow formation, underlying the high ridgeline that forms the western boundary of the watershed (Figure 2-2). The primary rock type of both the Panther Mountain and Moscow formations consist of shale, with lesser amounts of sandstone. The Panther Mountain formation also includes siltstone. Both formations are categorized within the Hamilton group and formed during the Middle Devonian.

2.2.2 Surficial Geology

Most of the surficial material underlying the watershed has been mapped as glacial till (Figure 2-3). These are tills of variable texture (boulders to silt), usually poorly sorted sand-rich diamict. A small area in the southeast portion of the watershed is mapped as kame deposits consisting of coarse to fine gravel and/or sand.

The area underlying a portion of the Franklinton Vlaie, including the delta that has formed where the unnamed tributary empties to the Vlaie, has been mapped as outwash sand and gravel.



SOURCE(S):

Figure 2-1: Watershed Topographic Map

LOCATION:

Broome, NY

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Franklinton Vlaie Tributary Improvement Study

MXD: Q:\Projects\6108-01 Franklinton Vlaie Watershed\Plots\Watershed_Location_Map.mxd

Map By: EMH
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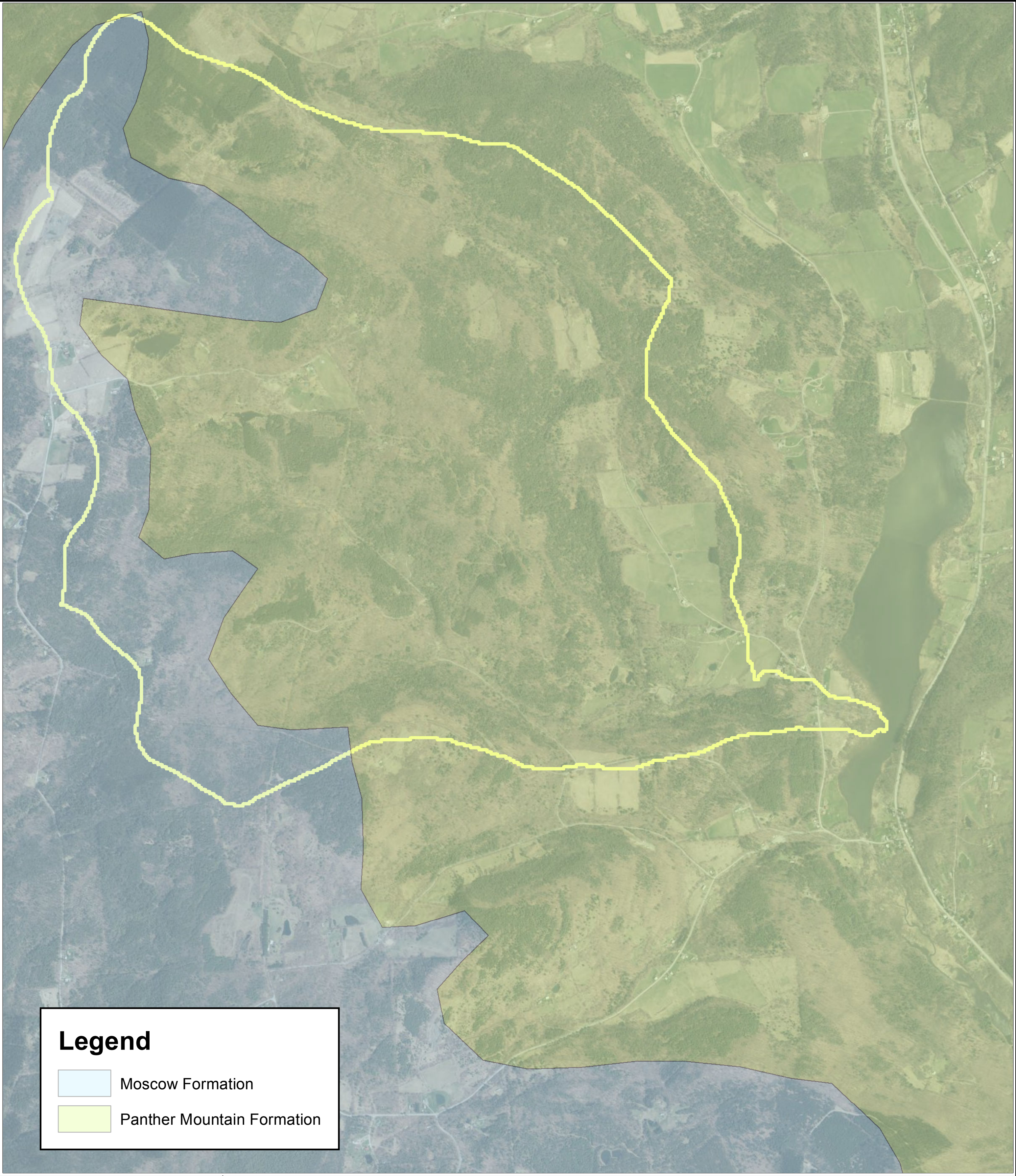

SOURCE(S):

NYS Museum Geographic Information System (accessed 03/2017)

Figure 2-2: Bedrock Geology

LOCATION:

Broome, NY

Franklinton Vlaie Tributary Improvement Study & Design

MXD: Q:\Projects\6108-01 Franklinton Vlaie Watershed\GIS\BedrockGeologyMap.mxd

Map By: EMH
MMI#: 6108-01
Original: 03/22/2017
Revision: 10/10/2017
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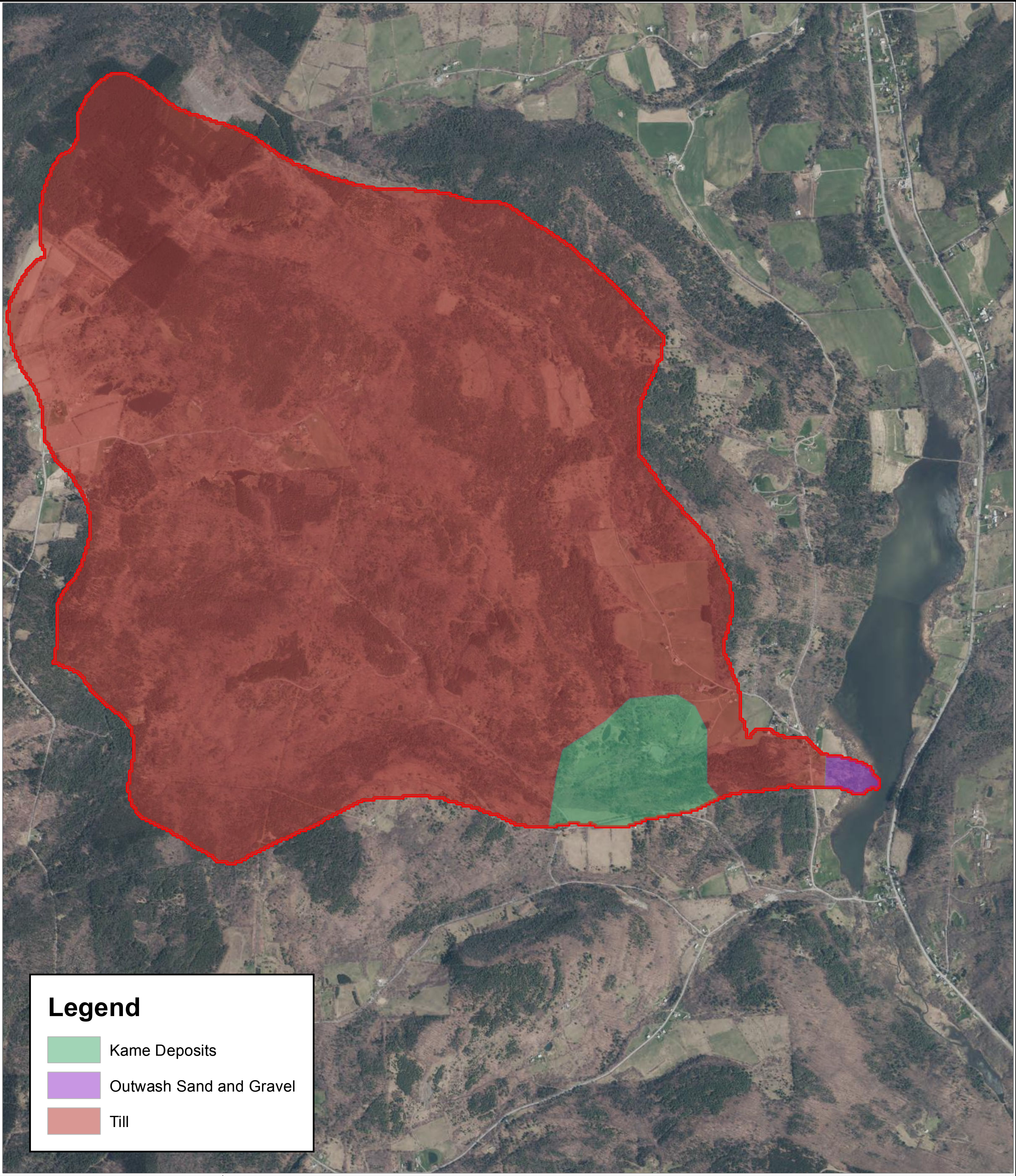

SOURCE(S):

Figure 2-3: Surficial Geology Map

LOCATION:

Broome, NY

N

Franklinton Vlaie Tributary Improvement Study

MXD: Q:\Projects\6108-01 Franklinton Vlaie Watershed\GIS\Surficial_Geology_Map.mxd

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2.2.3 *Soils*

There is a range of soil types present within the watershed. The most frequent are Lordstown channery silt loam; Lordstown and Oquaga very stony soils; and Lordstown, Oquaga, and Nassau soils. These groups together cover over 50 percent of the watershed. Arnot flaggy silt loam covers approximately 10 percent of the watershed. The delta that has formed where the unnamed tributary empties to the Vlaie is mapped as Barbour and Tioga gravelly loams. The Vlaie itself is mapped as muck and peat.

2.2.4 *Hydric Soils and Wetlands*

Wetlands are defined by specific soil, plant, and water conditions and characteristics. Soils form the foundation for habitats; they influence plant species distribution, subsequent wildlife use, drainage patterns, and wetland location. Often wetland mapping, because it is not field-verified, omits many wetlands. National Wetland Inventory maps provide valuable information, but they can miss many of the smaller wetlands that dot the landscape. The Inventory identifies only three small wetlands (farm ponds) in this watershed; the DEC identifies only the Vlaie itself. Field observations during 2017 site visits throughout this watershed noted a variety of wetland types including ponds, wet meadow, and emergent wetlands.

To help fill this gap between mapped wetlands and observed wetlands, we use hydric soils map information. Hydric soils are formed under conditions of saturation, flooding, or ponding that last long enough during the growing season to develop anaerobic conditions in the upper soil layers. These soils are generally described as very poorly drained with the water table at or near the surface. The environmental conditions that create hydric soils also favor the formation of wetlands. The plants that can grow in hydric soils, such as marsh grasses, are called "hydrophytes." Together, hydric soils and hydrophytes indicate that a wetland area is present. The amount of water present in wetlands fluctuates as a result of rainfall patterns, soil conditions, topography, snow melt, dry seasons, and droughts.

Hydric soils found within this watershed are listed in Table 2-1.

TABLE 2-1
Hydric Soil Types found in Watershed

Map Unit Symbol	Map Unit Name	Percent of Watershed
ChA, ChC	Chippewa and Norwich stony silt loam	0.8%
Ha	Holly and Papakating silt loams	1.4%
LaA, LdB	Lakemont and Madalin silty clay loams	0.4%
Mu	Muck and peat, strongly acidic	0.6%
OdA, OdB	Odessa and Rhinebeck soils	0.5%
TaB, TaC	Tuller and Allis silt loams	5.9%
VcA, VcB, VcC	Volusia channery silt loam	5.4%
VmC	Volusia, Morris, and Erie soils, very stony	3.9%

Additional hydric soils Morris stony silt loam (MoB) and Red Hook (Rh) gravelly silt loam covered less than 3 acres (less than 0.1%).

Collectively, hydric soils (and likely wetlands) occupy about 18-20% of the watershed, approximately 615 acres. These areas are generally clustered along the stream corridors, including the small streams that are tributaries of the main branch and north branch, but they are also present between the corridors and in the forested areas in the north portion of the watershed. Wetlands (and hydric soils) are often found in flat areas or shallow depressions, but they can also occupy hilltops and slopes and were observed in all of these location types within this watershed. While many of the hydric soils are found on 0-2% slopes (ChA, LaA, Mu, OdA, TaB, VcA), others are found on slightly steeper slopes at 2-8% (LdB, MoB, OdB, TaB, VcB), and some on slopes up to 15% (ChC, TaC, VcC, VmC).

Hydric soils are the best representation of probable wetland sites within this watershed, in the absence of field verified wetland delineations. Protection of these areas, and restoration of damaged habitat within them, benefit the watershed's capacity to moderate flooding and support high quality habitats.

2.3 Land Use History

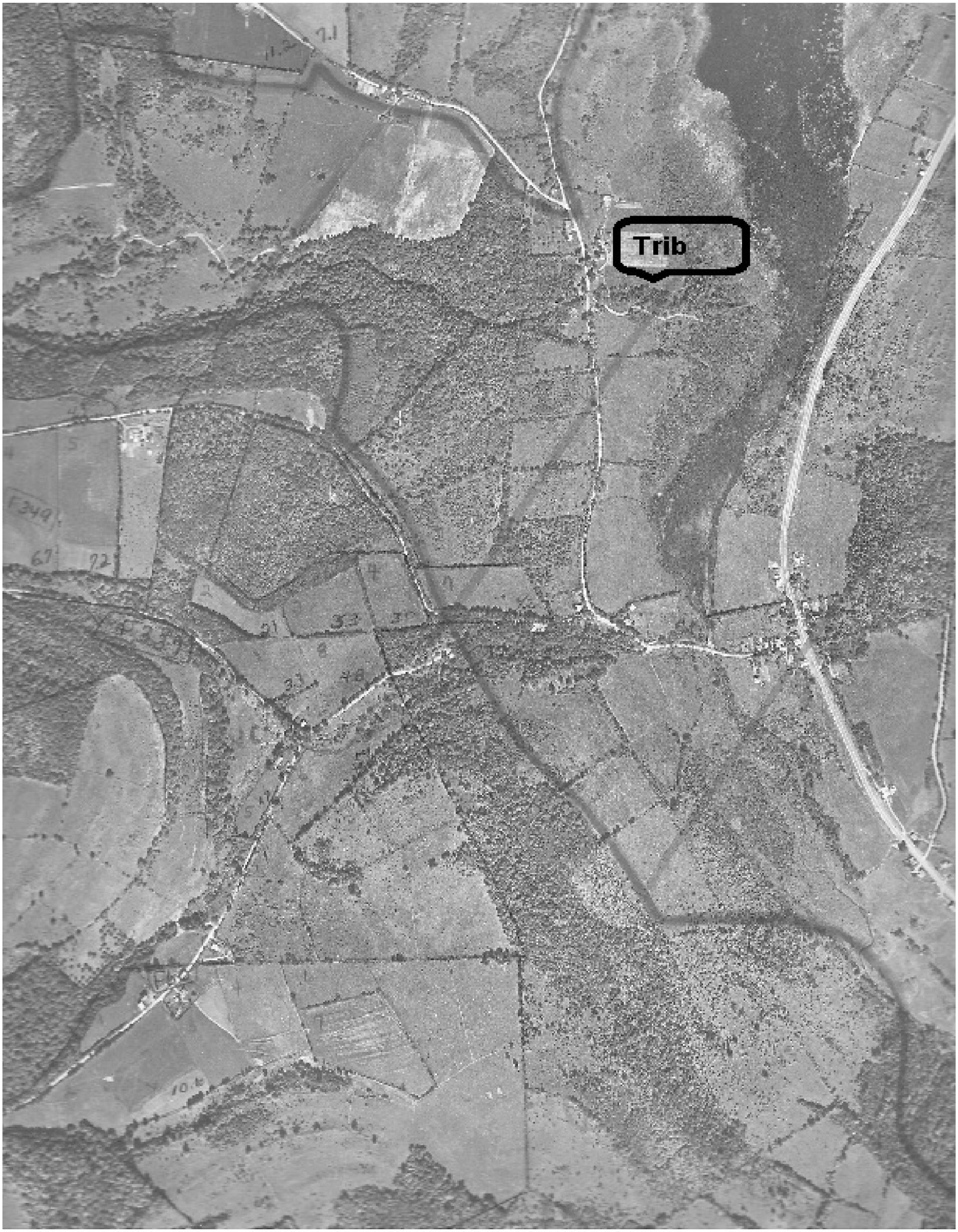
Aerial photographs of the watershed were obtained for the years of 1941, 1994, 2001, 2004, 2010, and 2014. These are included below in Figures 2-4 through 2-9.

The 1941 map shows the watershed from the Vlaie to the confluence of the two tributaries. The farm ponds at the confluence are not present. The forest appears somewhat more extensive along Woods Road and along portions of the north side of the Creek toward the western end of the ravine. Small patches of forest along Woods Road were clear in 1941 and have since grown back. The Catskill Creek channel is better defined on the 1941 map just east of the Woods Road crossing, though it is difficult to discern once it enters the delta area.

From 1994-2001, a comparison of aerial photos reveals little change in stream channel configuration, watershed land use, or stream buffers. Patterns of land clearing, roads, buildings, fields, and forests appear similar. The stream channel through the low-lying area below the confluence of the two branches has shifted, especially between 2004 and 2014, and most notably in the area between STA 40+00 and STA 45+00. The general disturbed condition of the area is evident, especially from 2010 to the present. There was a single distinct channel through this area, apparently through open land in 1994. The two farm ponds at the confluence of the tributaries were constructed prior to 1994.

The stream channel is well defined east of Woods Road in earlier maps, but by 2010 it is not as distinct. Along the north branch, changes in the configuration of some of the areas of land cleared, presumably for logging, are found from STA 95+00 to the stream's headwaters. The 2014 map shows more clearing in this area than the 1994 map.

In 2014 the delta into the Vlaie is more pronounced, and more triangular in shape; areas along the Vlaie's west edge that were probably wetland in 1941 are now open water.



Provided By:
Schoharie County Soil &
Water Conservation District

Figure 2-4: 1941 Aerial Photograph

LOCATION:
Broome, NY

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MXD: Q:\Projects\6108-01 Franklinton Vlaie Watershed\Plots\1941_Aerial_Map.mxd

Map By: EMH
MMI#: 6108-01
Original: 3/31/2017
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SOURCE(S):

NYState Orthos Online at
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Figure 2-5: 1994 Aerial Photograph

LOCATION:

Broome, NY

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Franklinton Vlaie Tributary Improvement Study

MXD: Q:\Projects\6108-01 Franklinton Vlaie Watershed\Plots\1994AerialMaps.mxd

Map By: EMH
MMI#: 6108-01
Original: 3/31/2017
Revision: 3/31/2017
Scale: 1 inch = 2,000 feet

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SOURCE(S):

NYState Orthos Online at www.orthos.dhses.ny.gov (03/2017)

Figure 2-6: 2001 Aerial Photograph

LOCATION:

Broome, NY

N

Franklinton Vlaie Tributary Improvement Study

MXD: Q:\Projects\6108-01 Franklinton Vlaie Watershed\Plots\AerialMaps.mxd

Map By: EMH
MMI#: 6108-01
Original: 3/31/2017
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SOURCE(S):

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Figure 2-7: 2004 Aerial Photograph

LOCATION:

Broome, NY

N

Franklinton Vlaie Tributary Improvement Study

MXD: Q:\Projects\6108-01 Franklinton Vlaie Watershed\Plots\AerialMaps.mxd

Map By: EMH
MMI#: 6108-01
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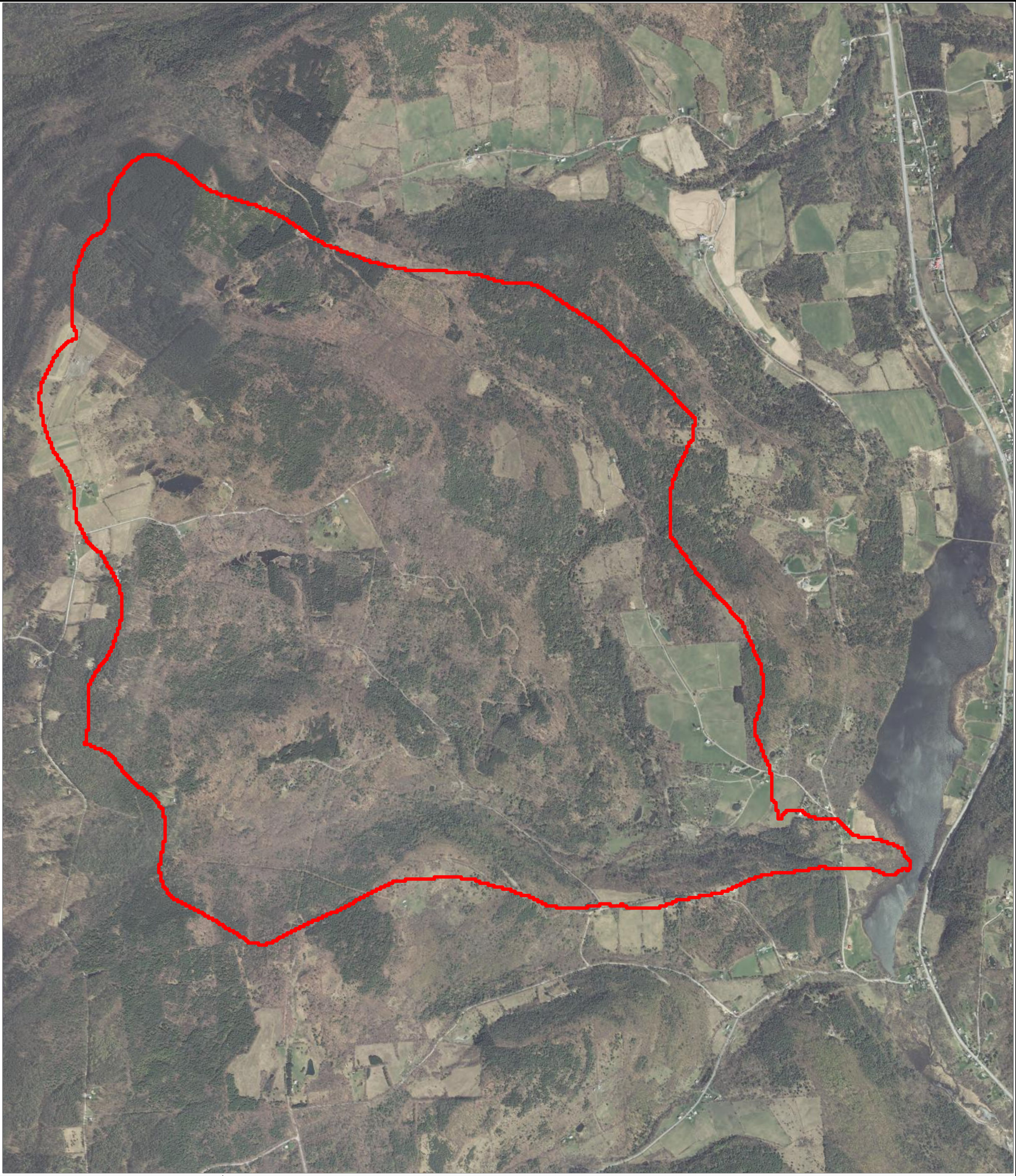

SOURCE(S):

NYState Orthos Online at
www.orthos.dhses.ny.gov (03/2017)

Figure 2-8: 2010 Aerial Photograph

LOCATION:

Broome, NY

N

Franklinton Vlaie Tributary Improvement Study

MXD: Q:\Projects\6108-01 Franklinton Vlaie Watershed\Plots\AerialMaps.mxd

Map By: EMH
MMI#: 6108-01
Original: 3/31/2017
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SOURCE(S):

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Figure 2-9: 2014 Aerial Photograph

LOCATION:

Broome, NY

N

Franklinton Vlaie Tributary Improvement Study

MXD: Q:\Projects\6108-01 Franklinton Vlaie Watershed\Plots\AerialMaps.mxd

Map By: EMH
MMI#: 6108-01
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2.4 Flood History

Weather in the region is influenced by frontal storms from the west and north and coastal storms from the south. The high, steep slopes and deep valleys that characterize the region can strongly influence local air temperature, wind velocity, and relative humidity, affecting precipitation and producing variations in storm intensity within a watershed. The greatest precipitation tends to occur on the eastern slopes. The mean annual precipitation is 40 inches in the adjacent Schoharie Creek watershed and 42 inches in Greene County (FEMA, 2012).

Flooding can occur in the region during any month of the year. The majority of the larger floods in Schoharie and Greene Counties have occurred in late winter and early spring and when snowmelt adds to heavy spring rains to produce increased runoff. Summer and fall floods also occur due to hurricane activity (FEMA, 2012; FEMA, 2015).

According to FEMA, major flooding events have occurred within the Schoharie Creek watershed in 1938, 1955, 1960, 1980, April 1987, January 1996, September 1999, and August 2011 (FEMA, 2012). Many of these same events caused flooding in the Catskill Creek watershed as well.

The FEMA Flood Insurance Study for Schoharie County does not include flood history information for the unnamed tributary to Franklinton Vlaie. However, anecdotal reports of flooding were collected as part of this study. These are summarized below:

- A landowner in the watershed reported that a 1908 flood destroyed a sawmill that had been located on the creek near Woods Road. Various buildings along the lower portion of the creek were destroyed.

- The southern (Catskill Creek) outlet from the vlaie became clogged by debris in the Irene flood and caused flows to exit the vlaie to the north (towards Schoharie Creek), causing water elevations in the vlaie to increase and causing a washout and bank collapse in the channel north of the vlaie.

- Water surface elevations in the vlaie are thought to be generally higher than in the past, and areas of lawn around the vlaie that were once dry are now saturated. Water levels are reportedly higher since roads and culverts were repaired after Irene.

- A series of beaver dams located in the upper watershed reportedly blew out during tropical storm Lee and caused a wave of water to move downstream. It was this debris that led to the clogging of the culvert at the southern outlet from the vlaie.

- A pond in the upper watershed on State Park land has gradually filled in over time. This pond used to sustain flows during dry periods.

- A landowner in the watershed shared a postcard of the falls showing a boulder that had been in place for a very long time. It disappeared during the 2011 flood (either broken up or washed downstream).

- A culvert located in the upper watershed near the confluence of two tributaries washed downstream to Woods Road during Irene.

- The property downstream of Woods Road to the left of the creek is periodically flooded. Water flows down the left side of the alluvial fan and floods the dug basement and backyard. This occurred in Irene, Lee, and one other time prior to these storms. The back yard becomes saturated and filled with cobble from the creek.

- The watershed has gradually become more forested with less open fields.

- There are many trees on the alluvial fan that are buried at their bases by sediment, indicating a very active sediment load.

2.5 Indicators of Watershed Health

Watershed health depends on the condition of its parts: streams, ponds, wetlands, groundwater, and land. The following basic watershed characteristics can be used to evaluate watershed health. Land use and the condition of the watershed's tributaries and wetlands contribute to the condition of Catskill Creek and Franklinton Vlaie.

2.5.1 Forest Cover

Forest cover along streams and rivers improves water quality, stabilizes banks, and provides valuable habitat. It is measured in terms of:

1. The percent of the total watershed that is forested, or
2. The extent and width of forested cover along the edges of lakes, streams, and rivers.

Wooded riparian corridors improve stream condition and habitat. Forested cover in headwaters and along small tributary streams maintains healthy downstream conditions, reducing stormwater runoff and flooding.

About 94% of the watershed is forested. Portions along the upper half of the northern tributary have been logged. Improper logging practices have left steep eroded paths through forest and muddy, eroded access roads through wetlands and near the stream. Some areas are severely eroded.

Catskill Creek and its tributaries support trees and other woody vegetation along banks and within at least a 100-foot riparian buffer in most places within this watershed. However, several areas that are highly degraded lack forested cover along stream edges, most notably the low-lying area between the confluence of the main and north branches and the upstream end of the gorge.

2.5.2 Impervious Surfaces

The extent of impervious surfaces (e.g., roads, buildings, and pavement) as a percent of land cover in the watershed increases runoff and its contaminant load, flooding, and water contamination. This watershed has a low percentage of impervious surfaces (developed land covers about 2% of the watershed; impervious surfaces less than 0.06%) so this is not a factor that influences local flooding.

2.5.3 Water quality

NYSDEC has classified Catskill Creek as a Class C (TS) Watercourse, indicating a best usage for fishing. The stream is designated as trout spawning (TS). The presence of trout, larval salamanders, and larval mayflies and caddis suggest good water quality conditions despite several sources of contamination and increased channel instability and sediment aggradation, especially in the area of the confluence of the main and north branches.

Cattle have free access to much of Catskill Creek and up into both branches, especially the main branch. The large pool at this confluence was turbid with fine-grained sediment deposits. Resultant erosion and wastes are likely to affect certain water quality parameters such as bacteria content and nitrates. In addition, the presence of junk cars along the top of the stream bank may contribute to water quality contamination from leaked fluids or breakdown of car body parts.

2.5.4 Buffers

Vegetated buffers along streams, wetlands, and lakes protect water from contaminants carried by stormwater runoff, reduce erosion, moderate water temperature, and provide important habitat. The characteristics of a buffer (width, slope, type of vegetation, and specific location in the watershed) affect the level of protection provided for the adjacent water resource and its aquatic life. No single size for buffers will fit all circumstances. However, research indicates a buffer of 100 feet for water quality protection and 300 feet or more for wildlife habitat depending on species. Effective buffers lie directly between the water's edge and sources of contamination on adjacent land.

To compensate for more rapid runoff, buffers need to be wider than the recommended minimums on steep slopes or rocky soils along Catskill creek and its tributaries. Woody vegetation in buffers stabilizes streambanks throughout most of this watershed. However, significant breaches in stream buffer protection are found along agricultural fields; in areas heavily used and grazed by cattle (along both branches); along the wide, low-lying disturbed area just below the branches' confluence; and in logged or cleared areas along the north branch.

2.5.5 Small Wetlands and Streams

Collectively, a network of small wetlands and streams throughout the watershed catches, stores, and distributes runoff, floodwaters, and precipitation. Small streams and wetlands throughout the watershed are generally not mapped, except for two sub-tributaries to the main branch of Catskill Creek, and one to the north branch.

The watershed contains wetlands that don't appear on National Wetland Inventory or state wetland maps (with the exception of the Vlaie, streams mapped as riverine wetlands and two constructed farm ponds by the National Wetland Inventory). About 18% of the sub basin is hydric soil, a strong indicator of the presence of wetlands. Field observations noted several ponds, wet meadow, and emergent wetland, though these were not delineated. Wetlands are also present at the headwaters of both Catskill Creek branches.

Headwaters of both branches arise in wetland/pond complexes. A series of ponds/wetlands lies along the north branch. Historically there were beaver ponds in this area though the beavers' current status is unknown. According to aerial photos, several small wetlands appear to be vernal pools surrounded by forest, so they may provide habitat for vernal pool breeding amphibians of conservation concern. This may be true for some of the larger wetlands/ponds, depending on the presence or absence of fish. The constructed ponds within agricultural lands lack buffer vegetation and may be nutrient-loaded from extensive use by cattle and from agricultural runoff.

The Franklinton Vlaie wetland is NYSDEC Class 1 wetland. Catskill Creek flows into the Vlaie, forming a delta. The Franklinton Vlaie Wildlife Management Area consists of about 195 acres of open water, wetland, and upland. At its southern end, the Vlaie drains to Catskill Creek via two 5.5-foot diameter iron pipes set under Gates Hill Road.

2.5.6 Floodplains

River and stream floodplains slow and absorb floodwaters and surface runoff and allow it to seep into the soil. Their ability to provide these services is optimal when they are well-vegetated, support minimal structures and impervious surfaces, and are connected to the stream channel.

Even very small streams with floodplains are important to overall watershed flood reduction. Meandering stream channels slow streamflow; straight channels are more conducive to high-velocity water flows.

While steep slopes with little to no floodplain border much of Catskill Creek and its tributaries in this watershed, a few areas with wide floodplains may be especially important for absorbing flood flows (e.g., the area below the tributaries' confluence from STA 40+00 to STA 50+00, along the headwaters of both tributaries, and in open areas along the middle reach of the north branch from STA 60+00 to STA 95+00).

3.0 HABITAT

3.1 Overview

This section includes a description and characterization of the habitats found within the watershed and along the main and north branches of the watercourse. Overall land cover within the watershed consists of mixed forest and open fields with agricultural and sparse residential development. Upland forested areas are primarily hardwoods, while ravines are dominated by eastern hemlocks.

The watercourse flowing to Franklinton Vlaie consists of first- and second-order streams that form in the upper watershed and flow through steep hemlock ravines and a bedrock gorge to Franklinton Vlaie. The Franklinton Vlaie Wildlife Management Area consists of about 195 acres of open water, wetland, and upland. The 85-acre Vlaie Pond is surrounded by marshes and shrub swamp, comprised of species including buttonbush, cattail, water arum, pickerel weed, and red maple. Surrounding the pond and wetland are second growth maple-beech forests and active agricultural fields. The emergent and open-water wetland complex supports fish (reportedly including American eel), waterfowl, and other wildlife.

The Franklinton Vlaie Wildlife Management Area Biodiversity Inventory (New York State Natural Heritage Program, 1994) maps ecological communities between the Vlaie and Woods Road as follows: the broad delta area adjacent to the Vlaie is shrub swamp; between the delta and Woods Road, Catskill Creek flows through a narrow band of successional northern hardwoods with field crops adjacent on both the north and south sides.

Habitats along Catskill Creek are described in detail in a publication entitled "Significant Habitats along Catskill Creek in Schoharie, Albany, and Greene Counties, New York" (Stevens, et al., 2014). While that study focused on habitats along Catskill Creek downstream of Franklinton Vlaie, some of the habitats described are also found upstream of the Vlaie, so are relevant to this study. Table 3-1 is a summary overview of habitat types in the watershed based on the information presented in that study.

TABLE 3-1
Overview of Habitat Types in the Watershed[1]

Habitat Type	Description
Upland Hardwood Forest	The habitat includes many different types of deciduous forest communities and is used by a variety of animals. Common trees include maples (sugar, red), oaks (black, red, white, chestnut), hickories (shagbark, pignut), American beech, white ash, black birch, and black cherry.
Upland Conifer Forest	Dominant species are eastern hemlock and eastern white pine. These upland conifer forests in the watershed are typical of gorges with steep slopes.
Upland Mixed Forest	Non-wetland forests with both hardwood and conifer species in the overstory; conifer cover is 25-75%. Mixed forests are less densely shaded at ground level and tend to support a higher diversity and greater abundance of understory species than pure conifer stands.
Floodplain Hardwood Forest	A few small patches are found in this watershed. Typical floodplain forests include a mixture of upland and wetland plant species and floodplain specialists such as sycamore, eastern cottonwood, and pin oak. Common trees include black locust, slippery elm, American sycamore, basswood, red maple, green ash, and American hornbeam. Japanese knotweed often forms dense stands within and at the edges of floodplain forests, especially in disturbed areas.
Upland Meadows	Upland meadows include cultivated fields, hayfields/pastures, and old fields. The ecological values of these habitats can differ widely according to the types of vegetation present and disturbance history (e.g., tilling, mowing, grazing, pesticide applications). Extensive hayfields or pastures dominated by grasses may support rare grassland-breeding birds.
Hardwood and Shrub Swamp	A "swamp" is a wetland dominated by trees or shrubs. Common species include red maple, American elm, green ash, sycamore, and swamp white oak (trees); winterberry holly, highbush blueberry, silky dogwood, alder, and willows (shrubs); skunk-cabbage, beggar-ticks, false-nettle, common jewelweed, Japanese knotweed, tussock sedge, and cinnamon, sensitive, and marsh ferns (herbaceous plants).
Marsh	A marsh is a wetland that has standing water for much or all of the growing season and is dominated by herbaceous (non-woody) vegetation. Marshes often occur at the fringes of ponds, or in close association with wet meadows or swamps. Cattails, tussock sedge, lakeside sedge, woolgrass, reed canary-grass, common reed, water-plantain, and purple loosestrife are some typical emergent marsh plants in this region. Some marshes are dominated by floating-leaved plants such as pond-lilies, water-shield, and duckweeds.

TABLE 3-1 (Continued)

Habitat Type	Description
Wet Meadow	A wet meadow is a wetland dominated by herbaceous vegetation and which has little or no standing water during most of the growing season. Some wet meadows are dominated by purple loosestrife, common reed, reed canary-grass, or tussock sedge; others by wetland grasses, sedges, forbs, and scattered shrubs. Typical native plants include manna grasses, woolgrass, reed canary-grass, soft rush, spotted joe-pye-weed, common jewelweed, sensitive fern, and marsh fern.
Open Water	Open water habitat includes naturally formed ponds and lakes, large pools lacking floating or emergent vegetation within marshes and swamps, and unvegetated ponds that may have originally been constructed by humans but have since reverted to a more natural state (e.g., surrounded by unmanaged vegetation). The largest open water habitats in the area is the Franklinton Vlaie.
Constructed Ponds	The habitat value of constructed ponds is higher when the ponds have undeveloped, unmanaged shorelines, are relatively undisturbed by human activities, and are within an area of intact habitat. In this watershed, the constructed ponds were not protected by sufficient natural vegetation and undisturbed soils, and are vulnerable to the adverse impacts of agricultural runoff and cattle. Constructed ponds that lack emergent or submerged vegetation have little habitat value, but are sometimes used as drought refuges by turtles, amphibians, and other wildlife, and as stopover resting sites for migrating waterfowl. Those with significant vegetation may have nesting waterfowl and resident turtles, frogs, and salamanders.
Streams	Perennial and intermittent streams provide essential habitats for aquatic invertebrates, fish, amphibians, and wildlife (buffers and riparian corridors). The main Catskill Creek tributaries in this watershed are characterized by mostly cobble/gravel substrate, with areas of flat shale bottom (as in the falls gorge and the upper reaches of the north tributary), and a balance of riffles and small pools. Intermittent streams provide microhabitats not present in perennial streams, supply aquatic organisms and organic drift to downstream reaches, and can be important local water sources for wildlife.

1 – Summarized from Significant Habitats along Catskill Creek in Schoharie, Albany, and Greene Counties, New York (Stevens, et al., 2014)

3.2 Stream Condition Summary

The following summary of stream conditions (Table 3-2) is based on two site visits (July 27 and August 31, 2017). The summary is organized according to the stream stationing numbers found on the stream stationing map. Observations are made traveling from downstream (STA 0+00) to upstream (STA 160+00 on the main branch and STA 95+00 on the north branch).

TABLE 3-2
Stream Conditions along Main and North Branches

Stationing	Location	Observations
Vlaie to Confluence		
0+00 to 12+50	Vlaie to Woods Road	• Creek's delta at Vlaie is wet meadow with emergent wetland, small channels • Channel interruption (temporary) between upstream edge of dense vegetation and open disturbed area with scattered trees, jewelweed, and Japanese knotweed • Channel resumes as small pool with 2-4 inch fish, including trout, crayfish, and salamander larvae • Water temperature 59 degrees F. (8-31-17) • Prolific growth of Japanese knotweed downstream side of bridge • Numerous green frogs near bridge
12+50 to 17+00	Woods Road to base of Falls	• Cobble/gravel substrate at bridge transitions to slab rock at base of falls • Base of the falls' banks are rocky, forested; some exposed tree roots along the channel • Silt deposits increase toward base of falls • Several types of fish in pool at base of falls, may include small trout (2-4") • Water temperature 62 degrees F. (7-27-17)
17+00 to 40+00	Bedrock Gorge	• Water temperature 62 degrees F. above falls to 64 degrees F. at upstream end of gorge (7-27-17) • Steep rocky banks with hemlock forest • Gravel riffles connect pools with small trout (4-8") • Crayfish, larval salamanders, caddis, mayfly throughout ravine, adult two-lined salamanders along edges • Gravel bars and stream edges support mosses, sensitive fern, jack in the pulpit, and jewelweed • West end of the gorge, "fencerow" of junk cars at top of steep bank on the north; muddy roads and cattle paths between the creek and the shrubby areas and field beyond its banks

TABLE 3-2 (continued)

Stationing	Location	Observations
40+00 to 47+00	Unstable Wandering Channel	• Highly disturbed low-lying area, braided channels through loose cobble/gravel • Poorly defined banks, erosion • Algae in slow-moving or still water • Water temperature 66-68 degrees F., 62 degrees in small spring fed rivulet and pool at confluence (7-27-17) • Eroded, disturbed banks and buffer • Significant cattle disturbance, access to stream via eroded muddy paths • Small patches of wet meadow • Pasture on both sides of stream, scattered trees • Steep eroded pile of mud and rocks at confluence
47+00	Main Branch at Confluence	• Shallow flow, 62 degrees F. (7-27-17) • Channel is about 20 feet wide but half is dry; disturbed cobble/gravel substrate • Small mayflies, few small caddis, green frogs, algae
0+00	North Branch at Confluence	• Water is slightly deeper, 4-12 inches, 62 degrees F. (7-27-17) • Channel 10 feet wide; rock/cobble, silt in small pools • Somewhat eroded banks support woody vegetation, shady • Caddis and mayfly larvae; salamander larvae and adult two-lined salamanders • Farm machinery within and along channel upstream
	Constructed farm ponds west of confluence	• Surrounded by grasses and grazed vegetation, small areas of cattail wetland • Buffers lack woody vegetation • Extensive use by cattle; muddy paths
Upper Main Branch		
75+00 to 80+00		• Channel about 10 feet wide, silt deposits, 58 degrees F. (8-31-17) • Moderately steep banks with mixed vegetation • Disturbed site: rusting culverts, junk car, cattle paths, erosion • Thick growth of Japanese knotweed
80+00 to 85+00	Laura Land crossing	• Site of former bridge • Channel is 2-4 feet wide, cobble/stone bottom • Water temperature 58 degrees F. (8-31-17) • Wooded banks • Proliferation of Japanese knotweed downstream of crossing

TABLE 3-2 (continued)

Stationing	Location	Observations
105+00 to 110+00	Armlin Road dead end	• Channel is 4-6 feet wide, cobble/stone bottom • Water temperature 58 degrees F. (8-31-17) • Woody banks, moderate slope, good condition
155+00 to 160+00	Last Armlin Hill Road crossing	• Channel is about 2 feet wide, no silt • Well vegetated banks and buffer (thick jewelweed, aster, tearthumb) • Water temperature 60 degrees F. (8-31-17) • Dropped culvert (about 15 inch drop) on downstream side of road crossing
North Branch		
0+00 to 70+00		• Mostly forested along edges, stream runs through farmland, just west of pastures with cattle throughout
70+00 to 75+00		• Stream runs through a large cleared area just west of the road; small track crosses stream via wooded bridge • Channel about 24 inches wide, 4-6 inches deep, 60 degrees F. (8-31-17) • Dense shrub buffer (including willows) at least 15 ft. wide on both sides • Adjacent to buffer-black muck, wet meadow wetlands (Joe Pye weed, sensitive fern, sedges); pasture • Upstream is a series of ponds/wetlands
80+00 to 85+00		• Evidence of logging • Open muddy staging areas with wood debris and muddy roads leading to the stream • Portions of road posted by Whortlekill Rod and Gun club, Hopewell Junction
90+00 to 95+00		• Access road muddy, eroded, evidence of logging • Logging road leads through woods and wetland to stream crossing • Channel is 6-10 feet wide with fractured pieces of slab substrate and rock • Shallow water, steady flow, 58 degrees F. (8-31-17) • Adult Dusky salamanders and two-lined salamanders; aquatic salamander larvae • From here the stream leads to its headwaters in a wetland complex beyond the last stream markers indicated on the map

3.3 Species of Conservation Concern

Habitats found within the watershed support a large variety of plant and animal species, including species of conservation concern. Conservation concern includes wildlife listed by NY State (in the state's wildlife action plan) as Species of Greatest Conservation Need. This list includes endangered, threatened, or special concern species. Based on information presented in Hudsonia's Catskill Creek habitat study, the following species of conservation concern may be found in the habitats within this watershed. NYS endangered (E), threatened (T), and special concern (SC) species are noted.

3.3.1 Wildlife

High Priority Species of Greatest Conservation Need

The status of these species is known and conservation action is needed in the next ten years. These species (Table 3-3) are experiencing a population decline, or have identified threats that may put them in jeopardy, and are in need of timely management intervention or they are likely to reach critical population levels in New York.

TABLE 3-3
High Priority Species of Greatest Conservation Need

Common Name	Scientific Name	Status
Indiana myotis	*Myotis sodalis*	E
Northern long-eared bat	*Myotis septentrionalis*	T
Spotted turtle	*Clemmys guttata*	SC
Wood turtle	*Glyptemys insculpta*	SC
Woodland box turtle	*Terrapene carolina carolina*	SC
Blue-spotted salamander	*Ambystoma laterale*	SC
Four-toed salamander	*Hemidactylium scutatum*	
American black duck	*Anas rubripes*	
Bobolink	*Dolichonyx oryzivorus*	
Canada warbler	*Cardellina canadensis*	
Eastern meadowlark	*Sturnella magna*	
Grasshopper sparrow	*Ammodramus savannarum*	SC
Olive-sided flycatcher	*Contopus borealis*	
Brown thrasher	*Toxostoma rufum*	
Prothonotary warbler	*Protonotaria citrea*	
Red-headed woodpecker	*Melanerpes erythrocephalus*	SC
Sedge wren	*Cistothorus platensis*	T
Vesper sparrow	*Pooecetes gramineus*	SC
American eel	*Anguilla rostrata*	
Gray petaltail	*Tachopteryx thoreyi*	
Tiger spiketail	*Cordulegaster erronea*	

NYS endangered (E), threatened (T), and special concern (SC) species are noted

<u>Species of Greatest Conservation Need</u>

The status of these species (Table 3-4) is known and conservation action is needed. These species are experiencing some level of population decline, have identified threats that may put them in jeopardy, and need conservation actions to maintain stable population levels or sustain recovery.

TABLE 3-4
Species of Greatest Conservation Need

Common Name	Scientific Name	Status
Hoary bat	*Lasiurus cinereus*	
Eastern red bat	*Lasiurus borealis*	
Silver-haired bat	*Lasionycteris noctivagans*	
American bittern	*Botaurus lentiginosus*	SC
American kestrel	*Falco sparverius*	
American woodcock	*Scolopax minor*	
Bald eagle	*Haliaeetus leucocephalus*	T
Blue-winged warbler	*Vermivora cyanoptera*	
Black-throated blue warbler	*Setophaga caerulescens*	
Least bittern	*Ixobrychus exilis*	T
Louisiana waterthrush	*Parkesia motacilla*	
Northern harrier	*Circus cyaneus*	T
Pied-billed grebe	*Podilymbus podiceps*	T
Red-shouldered hawk	*Buteo lineatus*	SC
Cooper's hawk	*Accipiter cooperii*	SC
Sharp-shinned hawk	*Accipiter striatus*	SC
Osprey	*Pandion haliaetus*	SC
Scarlet tanager	*Piranga olivacea*	
Wood thrush	*Hylocichla mustelina*	
Cerulean warbler	*Setophaga cerulea*	SC
Eastern rat snake	*Pantherophis alleghaniensis*	
Northern black racer	*Coluber constrictor constrictor*	
Northern copperhead	*Agkistrodon contortrix mokasen*	
Brook trout (wild)	*Salvelinus fontinalis*	

NYS endangered (E), threatened (T), and special concern (SC) species are noted

Species of Potential Conservation Need

Species of Potential Conservation Need include species whose status is poorly known, cases where there is an identified threat to the species, or cases where features of the species' life history makes it particularly vulnerable (Table 3-5). The species may be declining or begin to experience declines within the next ten years, and studies are needed to determine actual status.

TABLE 3-5
Species of Potential Conservation Need

Common Name	Scientific Name	Status
Jefferson salamander	*Ambystoma jeffersonianum*	SC
Northern red salamander	*Pseudotriton ruber ruber*	

3.3.2 Plants

Rare plants, usually associated with floodplain forests in the region, are described in Hudsonia's Catskill Creek habitat study. These include the following:

Endangered native plants in danger of extirpation throughout all or a significant portion of their ranges within the state and requiring remedial action to prevent such extinction.

- Cat-tail sedge *Carex typhina*

Threatened native plants that are likely to become endangered within the foreseeable future throughout all or a significant portion of their ranges within the state.

- Davis sedge *Carex davisii*
- Golden-seal *Hydrastis canadensis*

Rare native plants that have from 20 to 35 extant sites or 3,000 to 5,000 individuals statewide.

- Winged Monkeyflower *Mimulus alatus*

3.4 Significant Natural Communities

There are no communities designated as "Significant" by NYSDEC that are mapped within the watershed, per NYS Natural Heritage data.

3.5 Fish

The habitat quality of a stream is affected by direct disturbance to the stream channel and banks as well as land use in adjacent areas and throughout the watershed, which can erode soil, increase runoff, and contaminate water. Removal of trees or other shade-producing woody vegetation along a stream destabilizes banks and leads to increased water temperature. Even small changes in water quality and temperature can adversely affect aquatic invertebrates and fish, especially trout which require cold, well-oxygenated water. Land disturbance can create conditions that favor invasive plants like Japanese knotweed, which has invaded many parts of the Catskill Creek corridor and out-competes native species that provide important habitat.

The overall health of the Creek's aquatic ecosystem, including its two branches, appears to be good. However, in some places land use practices adversely affect water quality and habitat, especially effects from logging, agricultural practices, channel and bank disturbance, junk cars and other debris near the stream, and cattle access to the creek and its banks.

Aquatic connectivity that allows species to move throughout this stream system is generally good, but there are a few places where this movement is impeded, including:

1. A culvert drop on the downstream side of the Armlin Hill Road crossing
2. Seasonal channel interruption (during low flow), Woods Road crossing to the Vlaie
3. The highly disturbed braided stream area below the confluence of the Creek's two tributaries

Despite these conditions, Catskill Creek and its two tributaries within this watershed support aquatic life that includes a variety of small fish, trout, salamander larvae and adults, frogs, and invertebrates including crayfish, mayflies, and caddis.

Spot checks at 18 locations along the Creek and its branches during July and August 2017 found small trout in several pools throughout the forested ravine above the falls, in a pool just downstream from the confluence of the two tributaries, at the base of the falls, and in a small pool about 200 feet downstream from the Woods Road crossing. Water temperature ranged from 58-62 degrees F.; one area just upstream from the falls' ravine was 64 degrees. The stream bottom was most often cobble/ gravel with shallow riffles and pools and little or no aquatic vegetation, and in a few areas flat, smooth shale slabs (e.g., in the falls' ravine and portions of the north tributary).

Fish sampling in the Vlaie and nearby areas by the NYSDEC (personal communication) provided the following information:

> *American eel have been documented in close proximity to the Vlaie. On August 14, 2003, four American Eel were found in Broome 0.3 miles above T53 at CCC Camp Road (Survey 403018). SUNY Cobleskill found eel upstream at Stone Store Road, indicating eels are likely in close proximity to the Vlaie.*
>
> *Vlaie Pond was last surveyed by DEC in 2008. Most noticeable of the catches were large adult Brown Bullhead and Largemouth Bass (very common), sunfish species, and Yellow Perch dominated by small sizes. A total lack of juvenile bass and uncommon catches of large-sized*

panfish suggest a high population of stunted panfish and very little to no bass recruitment. This may be caused by egg predation in nests by small panfish or larval bass predation by abundant panfish.

The Franklinton Vlaie Wildlife Management Area website notes that "Anglers will find a variety of fish species in the Vlaie including largemouth bass, yellow perch, chain pickerel, sunfish, brown bullhead, and black crappie."

According to DEC fish survey data:

- July 1986 survey found Eastern Brook Trout (5 fingerling/2 yearlings) 0.2 miles above the mouth of Catskill Creek
- H-193-62 was last surveyed in September of 2007 when SY/YY Brook Trout were found.
- On September 25, 2007, as part of the Eastern Brook Trout Joint Venture Project, sampling found trout at the upstream side of Braun Hill Road (Site 1): 2 adult/30 fingerling brook trout collected 0.2 miles above the mouth; water temp was 60.5 degrees F. Approximately 50 older brook trout and numerous fingerlings were observed from the end of the sample site upstream to the waterfall pool. The threat to brook trout habitat in this location at the time of this survey was low; land use included few rural homes, and a majority of the watershed is within a reforestation area.
- This reach of Catskill Creek was last surveyed in 2009. Rainbow Trout yearling numbers were up by a factor of 5 to 10 times higher than in 2003. Brown Trout yearling numbers were down at Site 1, but up at Site 2 and Site 3. Wild trout biomass increased at all three sites in 2005 compared to 2003. CROTS analysis of yearling wild trout numbers indicate that sites 2 and 3 do not qualify for stocking. Survey Site 1 could be stocked, though it is currently outside of the stocked reach on Catskill Creek in Albany County.

Tim Portnoy, DEC, noted that on September 25, 2007, DEC personnel talked to the homeowner next to the sample site; most summers the homeowner moves numerous brook trout upstream of the waterfall. DEC did not sample above the waterfall so it is not known whether the brook trout inhabit and reproduce in that section.

The presence of trout, mayflies, and caddis are indicators of generally good water quality. However, many opportunities for habitat improvement exist within the watershed, as noted elsewhere in this report.

4.0 HYDROLOGY & HYDRAULICS

4.1 Hydrology

While no FEMA Flood Insurance Studies or currently active USGS stream gauges are available, peak stream flows were recorded between 1968 and 1987 by a USGS gauge at Woods Road (USGS 01361453). A HEC-SSP analysis of the peak streamflow data was conducted to determine discharges for the 2-, 10-, 50-, 100-, and 500-year return intervals. Due to the fact that data derived from this gauge is over 30 years old, critical hydrological conditions such as rainfall may have changed, which could significantly influence current return interval discharges. Therefore a comparative analysis was conducted in order to determine appropriate flow rates, and to account for changes in hydrology over the past three decades.

Peak flood flow rates have been predicted using several methods, the results of which are shown in Table 4-1. The first makes use of regional regression equations developed by the USGS, called *StreamStats*, which are based upon local gauging stations, shown in Column A. The direct statistical analysis of the 20 years of USGS gauge data at Woods Road, from 1968 until 1987, is shown in Column B. It should be noted that 18 of the 20 annual floods during this period are below 300 cubic feet per second (cfs), with a maximum flow of 1,100 cfs. Discharges shown in Column C are as reported in the USGS publication SIR 2014-5084 (Wall, et al. 2014), which makes use of weighted onsite gauge and regional regression data. The discharges shown in Column C were judged to be most reliable and were selected for use in this analysis.

TABLE 4-1
Discharges for Unnamed Tributary to Franklinton Vlaie (cfs)

Percent Chance	Return Period (years)	A *StreamStats* Regional Regression Equations	B Historic Vlaie Tributary Discharges (1968-1987)	C USGS Discharges from SIR 2014-5084
50	2	141	163	163
10	10	356	476	410
2	50	654	1,116	736
1	100	811	1,567	910
0.2	500	1,250	3,323	1,420

4.2 Woods Road Culvert

Before it discharges to the Vlaie, the watercourse crosses under Woods Road via a corrugated metal culvert that has a history of debris blockages, flooding, and filling with sediment. The existing culvert opening is 12 feet wide and effectively about 3.25 feet high, an opening area of 39 feet. The previous culvert, a 6-foot diameter round pipe, had an opening area of just under 28 feet. While the replacement culvert has a larger opening size, it has been installed with a higher invert elevation, which decreases the available head, reducing the available pressure to force water through the culvert.

The following information was gathered pertaining to the Woods Road crossing:

- The current Woods Road culvert was installed by the Town of Broome during the late 1990s or early 2000s.
- The culvert has been cleaned of sediment in the past but has quickly filled in again.
- Prior to the existing culvert, there was an approximately 6-foot diameter round pipe with a 4-foot deep pool at the outlet. There is general consensus that the old pipe was better at passing flows and less susceptible to filling with sediment, and the pool provided refuge habitat for trout during dry periods.
- Prior to the 6-foot diameter pipe, there was a wooden bridge at this location. Date or reason for its removal is unknown.
- In 2015, the bank to the right of the culvert (viewed facing downstream) was cut down in order to convey flows over the roadway and away from the house. The house has not flooded since this was done.
- When floodwaters encounter the current culvert, the water swirls around and washes out the adjacent driveway.
- The channel upstream of the Woods Road culvert filled with sediment during Irene.

The thick gravel bedding placed over the stream bed during construction of the replacement culvert (visible in Figures 4-2 and 4-3) appears to have raised the culvert and reduced its available head, leaving very little cover between the top of the culvert and the road surface.

Figure 4-1 is a photo of the culvert that preceded the current culvert. Figures 4-2 and 4-3 show the replacement culvert during construction. Figure 4-4 shows the existing culvert in 2017.

Figure 4-1
6-foot diameter round culvert that preceded existing culvert

Figure 4-2
Existing culvert during construction

Figure 4-3
Existing culvert during construction, viewed from downstream

Figure 4-4
Existing Culvert, 2017

4.3 Channel Morphology

The channel approaching Woods Road has a typical width of only 10 to 15 feet to convey the base flows, while peak flood flows overtop the banks and spreads out to hundreds of feet. The right floodplain has a low berm along the bank, then spreads out for hundreds of feet across a meadow. The narrower left floodplain has a single family home and shed on it, with a maintained yard.

Natural channels that convey high sediment loads often have low berms or levees along their banks from sediment deposition during floodplain flows. Channel cross section plots show that the right upstream berm is higher than its floodplain, so when floodwaters overtop the berm, water does not return to the channel.

Downstream of Woods Road, the channel has been dredged in the past, leaving a narrow channel width and high banks that limit hydraulic access to the low floodplains. This type of maintenance helps contain smaller floods, but causes water levels in larger floods to be higher because the water cannot spread out. The higher water levels then back up at the culvert, reducing its capacity to convey water and sediment.

4.4 Hydraulics

The term "hydraulic analysis" refers to the computational prediction of a river's water surface elevations, depths, and velocities for specified water discharges. This analysis is used to evaluate the performance and adequacy of the culvert at Woods Road.

The HEC-RAS model is used to compute water surface profiles for one-dimensional, gradually varied flow for steady (i.e., flows constant over time) flow scenarios or unsteady (i.e., flows varying over time) flow scenarios. HEC-RAS is capable of modeling water surface profiles under subcritical (i.e., tranquil, smooth, and deep), supercritical (i.e., jetting, turbulent, and shallow), and mixed-flow conditions. The basic computational procedure for HEC-RAS is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's Equation) and contraction/expansion (coefficient multiplied by the change in velocity head).

Hydraulic modeling results at the Woods Road culvert indicate that the current culvert is undersized. The culvert has adequate capacity to pass the 2-year flood event. The 5-year flood event, and any larger flood events, exceed the capacity of the culvert. When the capacity of the culvert is exceeded, flows exit the right bank of the channel upstream of the culvert and flow over Woods Road. During the 25-year flood event, floodwaters begin to approach the home located on the left bank, just upstream of the culvert. During flows larger than the 25-year flood event, the home could be flooded. When the capacity of the culvert is exceeded, water backs up behind the culvert, forming a headwater pool. In sediment-laden streams, headwater pools tend to collect depositional material that can block the waterway.

The recommended sizing of a replacement culvert will vary depending on the desired level of service and the need for the culvert to transport water, sediment, and debris. It is common practice for a minimum culvert width to be equal to or just larger than the channel's bankfull width for equilibrium conditions, with an actual width based upon the watercourse design flows. At this location, the recommended culvert width is in the range of 18 to 20 feet, well above the current width of 12 feet.

The hydraulic modeling results indicate that the channel upstream of the culvert, between Woods Road and the base of the falls, is also undersized. The base width of the channel should be enlarged slightly to 18 feet wide, and the top width should be enlarged to at least 30 feet. This can be accomplished by grading one bank, alternating the widening points to minimize the need for tree removal.

5.0 SEDIMENT TRANSPORT ANALYSIS

5.1 Overview

An analysis of sediment transport was conducted. The analysis began with a geomorphic assessment to evaluate sediment transport on a watershed scale and to identify reaches of the channel that are acting as sediment supply, transport, or depositional reaches. A more detailed sediment analysis was then undertaken in the vicinity of the Woods Road culvert.

5.2 Geomorphology

A geomorphic assessment of the watershed was conducted in order to better understand the forces and factors influencing the transport of water and sediment from the upper watershed downstream towards Franklinton Vlaie. Geomorphology is the scientific study of the earth's land surface and the processes by which it is shaped, both in the present day and in the past. Fluvial geomorphology is the study of the form and function of rivers and streams, and the interaction between these streams and the landscape around them.

> **Geomorphology** is the scientific study of the earth's land surface and the processes by which it is shaped, both in the present day and in the past. **Fluvial geomorphology** is the study of the form and function of rivers and streams and the interaction between these streams and the landscape around them.

The main branch originates in the western portion of the watershed in an area of open fields and runs roughly parallel to Armlin Hill Road, while the north branch, originating in the northern part of the watershed, runs roughly parallel to Braun Hill Road.

The upper reaches of the main branch flow through two small ponds before entering a hemlock ravine near STA 145+00. The channel is confined between steep valley walls dominated by eastern hemlock trees. The channel running through the ravine is steep with a bedrock bed, with an average slope of 5.4 percent. After flowing through a culvert under Armlin Hill Road (STA 97+00), the main branch flows to its confluence with the north branch, at STA 47+00. Before reaching the confluence, at approximately STA 70+00, the main branch begins to show signs of active incision (also called channel degradation, or lowering of the channel bed) and bank erosion. This channel incision and bank erosion extends from STA 70+00 downstream to the confluence at STA 47+00, a distance of approximately 2,300 linear feet, and becomes increasingly severe as the watercourse approaches the confluence.

The upper reaches of the north branch flow across areas of open fields. Beginning at STA 60+00, the north branch flows through a hemlock ravine, where the channel is confined between steep valley walls. Similar to the main branch, the north branch channel running through the ravine is steep, with a bedrock bed and an average slope of 4.7 percent. Before reaching its confluence with the main branch, the north branch also shows signs of active incision and bank erosion. This extends from STA 18+00 downstream to the confluence at STA 0+00, a distance of approximately 1,800 linear feet. The incision and bank erosion becomes increasingly severe as the north branch approaches the confluence with the main branch.

After exiting the hemlock ravine and being joined by the north branch at STA 47+00, the main branch flattens abruptly, from a slope of over 5.0 percent to a slope of approximately 1.9 percent. The channel between STA 47+00 and STA 40+00, a distance of 700 feet, can be characterized as unstable and wandering, with active sediment aggradation (the accumulation of sediment in the channel bed).

At STA 40+00, the main branch then enters a confined bedrock gorge valley with a slope of approximately 2.7 percent. The gorge ends at STA 17+00 at a waterfall. After flowing over the waterfall, the main branch flows through an entrenched channel with a slope of approximately 2.0 percent, across an open field for several hundred feet, then through the Woods Road culvert at STA 12+50, and continues to Franklinton Vlaie at STA 0+00. The channel downstream of Woods Road has low berms along both banks, probably formed out of dredged material that has disconnected the stream from its floodplain.

Downstream of Woods Road, the stream's sedimentary deposits over thousands of years have formed a classic delta-shaped alluvial fan that extends into and narrows the original vlaie. Aerial images show how the channel inundated its floodplain and Woods Road with debris, typical of channel aggradation on alluvial fans.

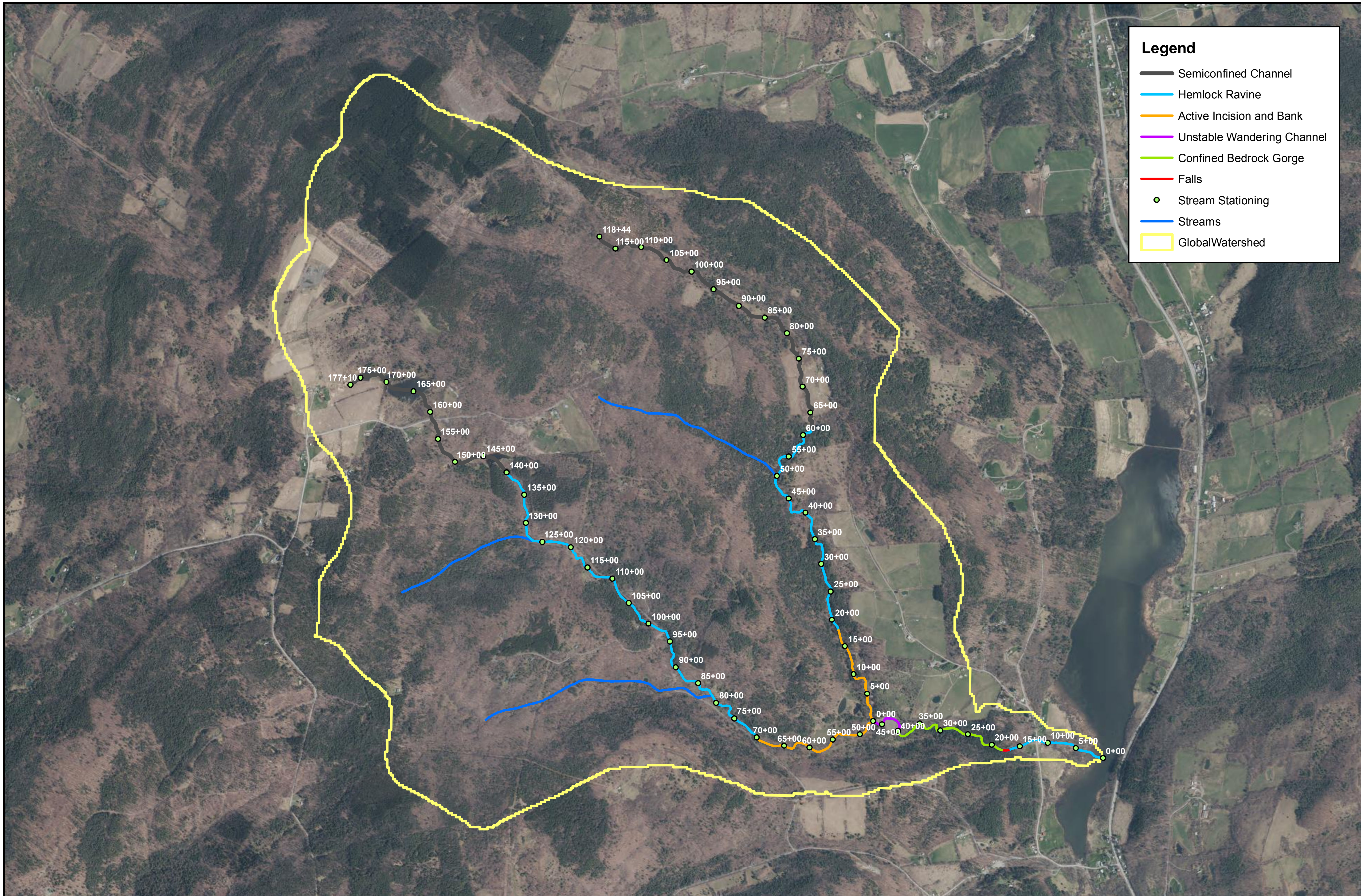
An alluvial fan is a fan-shaped deposit of sediment deposited by the running water of a stream or river. These flows come from a single point source at the apex of the fan, and over time move to occupy many positions on the fan surface. Alluvial fans are typically found where a stream or river draining from steep, mountainous terrain emerges out onto a flatter plain.

Flooding occurring on an alluvial fan is characterized by high-velocity flows; active processes of erosion, sediment transport, and deposition; and unpredictable flowpaths (FEMA). Areas where alluvial fans occur can be prone to flooding and sediment deposition when there is heavy rainfall. Building a home on or adjacent to an alluvial fan can be risky.

An **alluvial fan** is a fan-shaped deposit of sediment deposited by the running water of a stream or river. Alluvial fans are typically found where a stream or river draining from steep, mountainous terrain emerges out onto a flatter plain. Building a home on or adjacent to an alluvial fan can be risky.

Figure 5-1 is a map of the watershed showing the different reaches of the main branch and north branch, as described above.

A longitudinal profile depicts the change in elevation of a channel from its headwaters to its outlet, thereby showing the rate of change of slope over the entire length of the channel. Figure 5-2 is a longitudinal profile of the main branch, and Figure 5-3 is a longitudinal profile of the north branch.



Geomorphic Assessment Map

Franklinton Vlaie
Tributary Improvement Study

Broome, NY

MILONE & MACBROOM
231 Main St, Suite 102
New Paltz, New York 12561
(845) 633-8153
www.miloneandmacbroom.com

DESCRIPTION	DATE	BY

EMH	EMH	MC
DESIGNED	DRAWN	CHECKED

SCALE 1"=1,500 '

DATE October 10, 2017

PROJECT NO. 6108-01

SHEET NAME

Figure 5-1

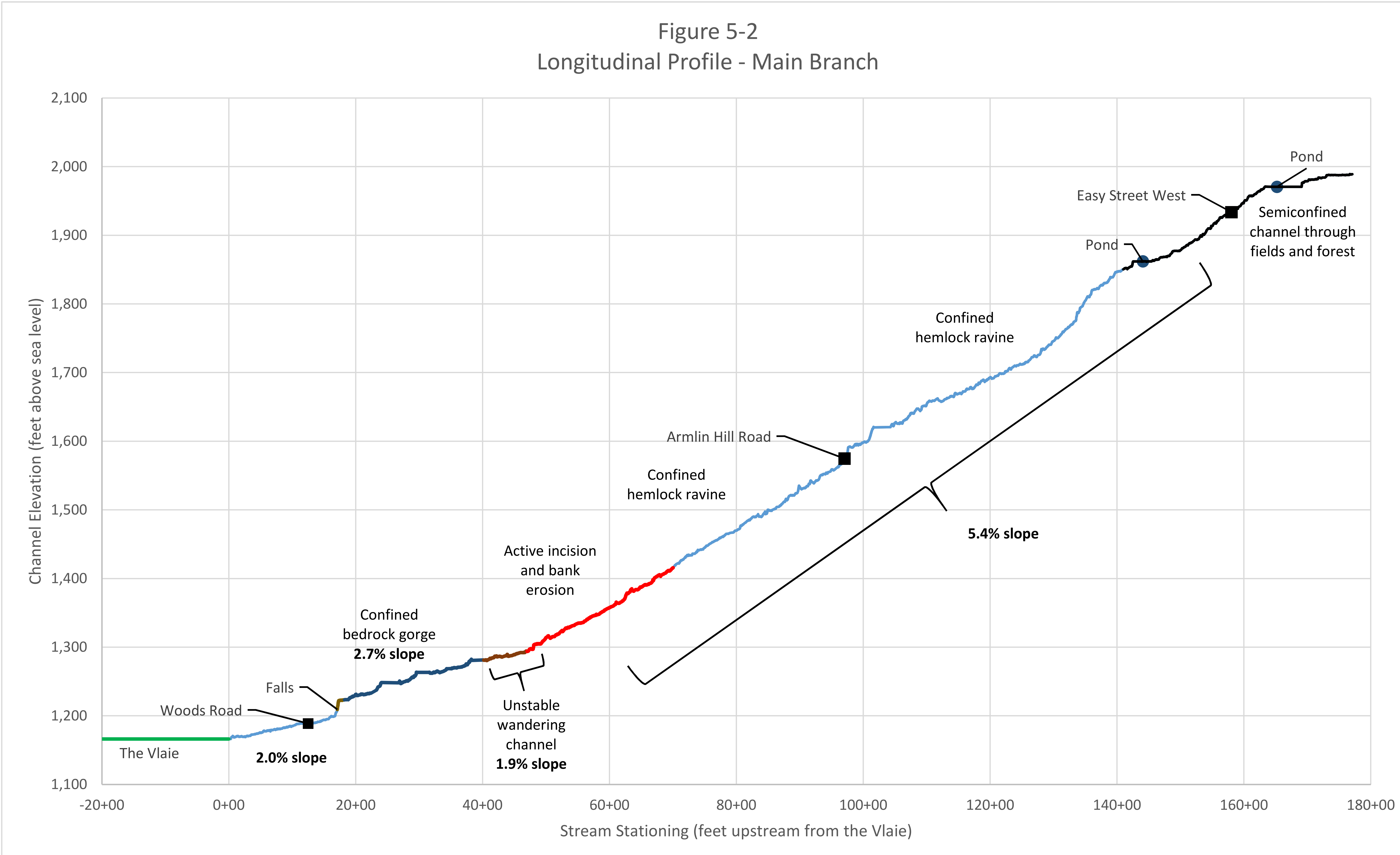


Figure 5-2
Longitudinal Profile - Main Branch
Channel Elevation (feet above sea level)
2,100
2,000
1,900
1,800
1,700
1,600
1,500
1,400
1,300
1,200
1,100
-20+00
0+00
20+00
40+00
60+00
80+00
100+00
120+00
140+00
160+00
180+00
Stream Stationing (feet upstream from the Vlaie)
The Vlaie
Woods Road
2.0% slope
Falls
Confined
bedrock gorge
2.7% slope
Unstable
wandering
channel
1.9% slope
Active incision
and bank
erosion
Confined
hemlock ravine
Armlin Hill Road
5.4% slope
Confined
hemlock ravine
Pond
Easy Street West
Pond
Semiconfined
channel through
fields and forest

Figure 5-3
Longitudinal Profile - North Branch
Channel Elevation (feet above sea level)
1,900
1,800
1,700
1,600
1,500
1,400
1,300
1,200
0+00
20+00
40+00
60+00
80+00
100+00
120+00
140+00
Stream Stationing (feet upstream from Main Branch)
Semiconfined channel through fields and forest
4.6% slope
Confined hemlock ravine
4.9% slope
Active incision and bank erosion
culvert crossing
Confluence with Main Branch

5.3 Sediment Transport Analysis

The accumulation of coarse grained sediment (primarily gravel and cobble ranging in diameter from 2 to 64 mm) at the Woods Road culvert has been an ongoing problem. This type of sediment can be characterized as bedload. Bedload is transported down the channel by rolling, bouncing, or sliding along the channel bed when the entrainment threshold is reached. The geomorphic assessment presented in Section 5.0 can be used as a starting point to assess the movement of bedload through the system.

The sections of channel identified in the geomorphic assessment can be characterized into three main types:

1. Supply reaches, which act as sources of sediment
2. Transport reaches, which transport sediment; and
3. Depositional reaches, where sediments are deposited

The confined hemlock ravines located along the upper reaches of both the main branch and the north branch are transport reaches. They are steep, narrow, have lots of energy, and erosive forces are high. However, the channel bed is primarily composed of bedrock, and the banks are generally stable, limiting erosion.

The sections of channel where there is active incision and bank erosion (extending along the main branch from STA 70+00 downstream to the confluence with the north branch at STA 47+00, a distance of approximately 2,300 feet, and along the north branch from STA 18+00 downstream to the confluence with the main branch at STA 0+00, a distance of approximately 1,800 linear feet) are sediment supply reaches, adding sediment to the channel that is then transported downstream during high flows.

The main branch between STA 47+00 and STA 40+00, a distance of 700 feet, can be characterized as a depositional reach, with active sediment aggradation occurring. However, due to the instability of the channel in this area, it also acts as a periodic sediment source during high flows, and sediment is transported through this reach from upstream and into the bedrock gorge.

The confined bedrock gorge on the main branch between STA 40+00 and STA 17+00 acts as a transport reach.

The reach of channel below the falls is a depositional reach. Further analysis of this reach is presented below.

5.4 BAGS Analysis at Woods Road

A sediment transport analysis program entitled Bedload Assessment in Gravel-bed Streams (BAGS) was used to evaluate sediment transport in the tributary to Franklinton Vlaie, in the vicinity of Woods Road. The BAGS program implements six bed load transport equations developed specifically for gravel-bed rivers. Transport capacities are calculated based on field measurements of channel geometry (determined from surveyed cross sections), reach-average slope, and bed material grain size (determined from Wolman pebble counts). In evaluating transport capacity, the BAGS program assumes an unlimited sediment supply. Results from the BAGS analysis are presented in Figure 5-4 below.

The BAGS analysis indicates strong mixed load transport by the 10-year event, with limited transport at the 2-year event. There is a decrease in sediment transport capacity moving down the channel, approaching, and through the Woods Road culvert.

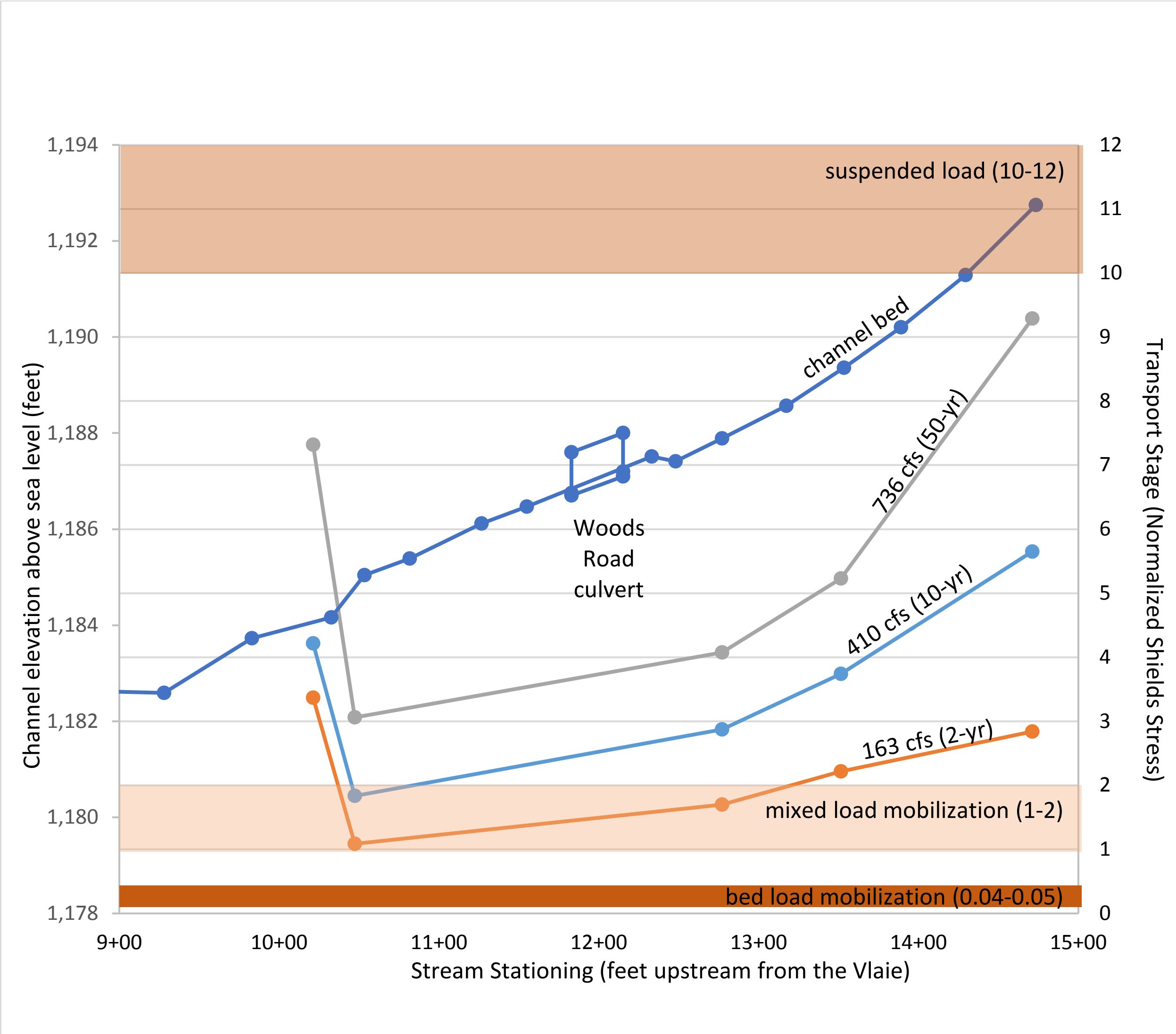


Figure 5-4
Results of BAGS Analysis

5.5 <u>Stream Power</u>

Stream power is a measure of the ability of flowing water to do work due to the loss of potential energy as water flows downhill (Bagnold, 1966). Specific stream power (stream power per unit area of channel bed) is a function of the water surface profile slope, discharge, and width. Narrow, confined river channels will thus have higher specific stream power than wider channels of the same slope and discharge. Specific stream power was calculated along the tributary in the vicinity of Woods Road using output data from the HEC-RAS hydraulic model.

Specific stream power is relatively easy to compute, but to be useful for river planning and design, it must be related to the critical threshold at which particle and general riverbed and perimeter movement begins. Relationships linking critical specific stream power thresholds (i.e., the specific stream power required to cause bedload movement) and sediment size have been established in the literature (e.g., Petit et al., 2005). Table 2-3 lists critical specific stream power thresholds for various sediment sizes.

TABLE 5-1
Critical Specific Stream Power Threshold

Dominant Sediment	Size (mm)	Critical Specific Stream Power Threshold (W/m^2)*
Sand	up to 2.0	60
Gravel	up to 32	200
Coarse gravel	up to 64	300
Cobble	up to 250	600
Small boulders	up to 1,000	1,000
Medium to large boulders	up to 2,000	2,000

* W/m^2 = Watts per Square Meter

Specific stream power for the 2-year and 10-year flow events and channel profile have been plotted against stream stationing, as presented in Figure 5-5. The plots indicate a decline in steam power as flows approach the Woods Road culvert and the alluvial fan. This decline in stream power is most pronounced during the 10-year flood event, and occurs as water exits the channel and spreads out on the alluvial fan.

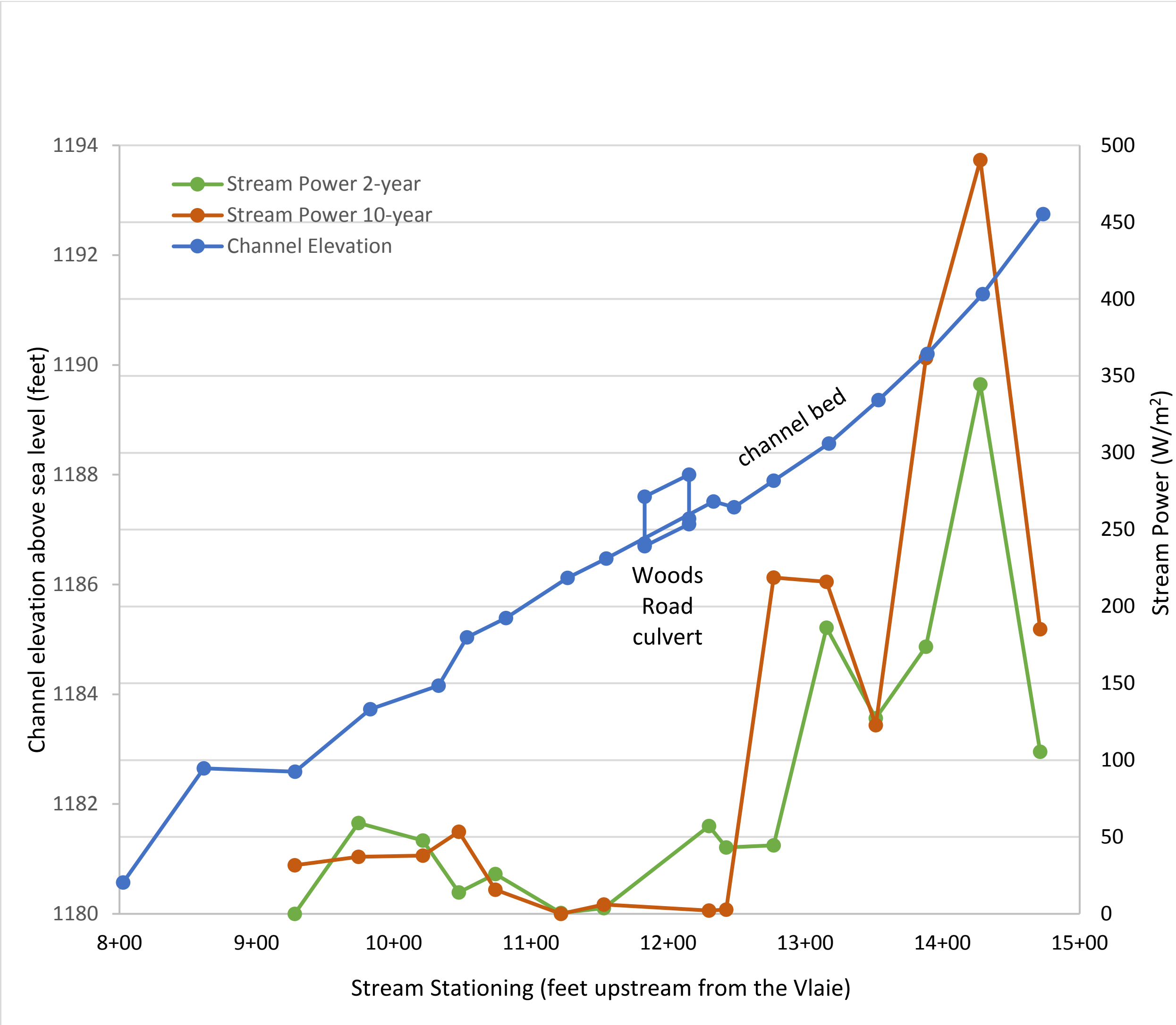


Figure 5-5
Results of Stream Power Analysis

Specific stream power upstream of Woods Road is generally higher than stream power through the area of the culvert and across the alluvial fan. This loss of stream power occurs as flows spread out across the alluvial fan. Stream power through the channel upstream of Woods Road during a 2-year flow event exceeds 200 W/m^2, which is adequate to move medium gravel, but diminishes at the culvert. During larger flow events (i.e., the 10-year flood), stream power is sufficient to transport coarse gravel, although adequate stream power is not maintained through the entirety of the reach resulting in the deposition of this material in the area of the culvert and on the alluvial fan.

Analysis of sediment transport through the project area using BAGS software, as well as calculation of critical tractive force and shear stress, was generally in agreement with the conclusions reached through the assessment of stream power and with observations made in the field, which is that the watercourse loses its ability to effectively move sediment as it approaches the culvert and spreads out across the alluvial fan.

6.0 FINDINGS AND RECOMMENDATIONS

6.1 Project Goals

The program seeks to identify mitigation projects that will:

- Stabilize the stream channel;
- Restore or create new, native in-stream and riparian habitats;
- Promote best management practices to improve water quality;
- Reduce frequency and severity of flooding at Woods Road;
- Reduce sediment aggradation at Woods Road; and
- Improve movement of fish, amphibians, and other aquatic organisms between the watercourse and the Vlaie

6.2 Discussion of Potential Strategies

A range of potential strategies is discussed below. Table 6-1 is a matrix to assess how well each of the strategies meets the project goals.

Watershed Improvement Strategies

1. Areas of land along the upper half of the northern tributary have been logged. Improper logging practices have left steep, eroded paths through forest and muddy, eroded access roads through wetlands and near the stream. Some areas are severely eroded. It is recommended that logging practices in watershed be improved.

2. Junk cars in close proximity to the stream, especially those at the top of steep banks should be relocated to protect water quality. It is not known whether these cars are leaking fluids or other contaminants into runoff or groundwater; water quality testing is needed to identify impacts.

3. The water quality and stream health of the north branch is affected by erosion and buffer/ bank disturbance from current logging practices and roads. In all areas, a wooded vegetative buffer of at least 100 feet and preferably 300 feet should be maintained along all stretches of the stream channel.

4. It is recommended that ponds and wetlands along the north branch tributary be protected from disturbance to enhance flood-absorption potential and improve habitat.

Channel Improvement Strategies

1. It is recommended that channel stabilization techniques be implemented along the main branch, in the area of unstable, wandering channel between STA 40+00 and 47+00. This will help to reduce the volume of coarse sediment being transported downstream. Schematic design concept drawings showing a range of channel stabilization techniques is included as Appendix B.

2. It is recommended that bank repairs and grade control be implemented in areas with active channel incision and bank erosion, on the main branch between STA 47+00 and 70+00, and on the north branch between STA 0+00 and 18+00. This will help to reduce the volume of coarse sediment being transported downstream. Schematic design concept drawings showing a range of bank repair and grade control techniques is included as Appendix B.

3. A key water quality issue is the use of the stream channel and banks by cattle, which has resulted in severe erosion, bank degradation, and water contamination. It is recommended that cattle be excluded from the stream channel and its banks. This is a key component of the stream restoration process.

4. A new culvert configuration would be required to restore aquatic connectivity at the culvert at Armlin Hill Road, which is currently a drop culvert. While not recommended as a priority at this time, connectivity for aquatic organisms should be considered if the culvert is slated for replacement.

5. The invasive species Japanese knotweed has taken over portions of the disturbed stream channel area downstream of Woods Road. It is recommended that the knotweed be removed and replaced with native shrubs.

6. It is recommended that debris be periodically removed from the culverts at the outlet of Franklinton Vlaie, especially following flood events.

Woods Road Strategies

1. The construction of a sediment trap upstream of Woods Road was considered as a way to reduce sediment at the culvert. This approach would require the construction of a dam across the channel, the acquisition of an easement from property owners for access and maintenance, and regular cleaning out and maintenance. It is not recommended.

2. As a short term measure, it is recommended that the Woods Road culvert be periodically cleared of sediment and other debris. If it is determined that sediment excavation is necessary, a methodology should be developed that would allow for proper channel sizing and slope. The following guidelines are recommended:

    - Maintain the original channel slope and do not overly deepen or widen the channel. Excavation should not extend beyond the channel's estimated bankfull width unless it is to match an even wider natural channel.

    - Sediment excavation requires regulatory permits. Prior to initiation of any in-stream activities, NYSDEC should be contacted, and appropriate permitting should be obtained.

    - Disposal of excavated sediments should always occur outside of the floodplain.

    - No sediment excavation should be undertaken in areas where aquatic-based rare or endangered species are located.

3. The Woods Road culvert is too small and backs up water and sediment. It is recommended that the culvert be replaced with a larger structure. The recommended sizing of a replacement culvert will vary depending on the desired level of service and the need for the culvert to transport water, sediment, and debris. The recommended culvert width is in the range of 18 to 20 feet.

4. Modeling results indicate that the channel upstream of the culvert, between Woods Road and the base of the falls, is undersized. The base width of the channel should be enlarged slightly to 18 feet wide, and the top width should be enlarged to at least 30 feet by grading one bank, alternating the widening points to minimize the need for tree removal.

5. Dredging of the channel downstream of Woods Road may help contain smaller floods but cause water levels in larger floods to be higher because the water cannot spread out. The higher water levels then back up at the culvert, reducing its capacity to convey water and sediment.

6. It is recommended that spoil piles of dredged materials be removed from the site or relocated further back from the channel to avoid trapping the water.

6.3 Cost Opinions for Select Strategies

Certain strategies discussed above will have a quantifiable cost range for design, permitting, and construction. For the Woods Road culvert replacement, cost would vary depending on the type of structure selected, the required load rating, and the specific design criteria. A preliminary opinion of the construction cost is estimated in the range of $450,000 to $550,000. This reflects structural and roadway items as well as channel improvements immediately upstream and downstream of the culvert and does not include any property easements or utility relocations or the cost of oversight during the construction process. The cost assumes a detour plan would be implemented during construction.

The cost for survey, engineering design, easement mapping, and regulatory permitting for the culvert replacement would vary depending on specific design criteria but would likely be in the range of $60,000 to $75,000.

For other strategies such as the exclusion of cattle from the stream, improvement of logging practices, or protection of headwater wetlands, the cost of implementation will vary. For these types of strategies, the likelihood of implementation can often depend less on cost and more on the willingness of landowners and other stakeholders to work cooperatively towards the common goal.

Table 6-1
Strategy Matrix

	Strategies	Project Goals							
		Stabilize stream channel	Restore in-stream/riparian habitats	Practices to improve water quality	Reduce flooding at Woods Road	Reduce sediment at Woods Road	Improve aquatic organisms passage	Cost Effective? (Yes/No/Maybe)	Recommended? (Yes/No/Maybe)
Watershed Improvement Strategies									
1	Improve logging practices	✓		✓				Y	Y
2	Relocate cars away from creek			✓				Y	Y
3	Increase wooded vegetated buffers	✓		✓				Y	Y
4	Protect ponds and wetlands along North Branch		✓	✓				Y	Y
Channel Improvement Strategies									
1	Implement channel stabilization techniques on Main Branch between STA 40+00 and 47+00	✓	✓	✓	✓	✓	✓	Y	Y
2	Implement bank repairs and grade control on Main Branch and North Branch	✓	✓	✓	✓	✓	✓	Y	Y
3	Prevent cattle from entering watercourse	✓	✓	✓		✓		Y	Y
4	Restore connectivity at drop culvert at Armlin Hill Road						✓	M	M
5	Control invasive species downstream of Woods Road crossing		✓					Y	Y
6	Maintain culverts at outlets of vlaie							Y	Y
Woods Road Strategies									
1	Construct sediment trap upstream of Woods Road				✓	✓		N	N
2	Periodically clear culvert of debris				✓	✓		Y	Y
3	Replace culvert with larger structure				✓	✓	✓	Y	Y
4	Enlarge channel upstream of culvert				✓			Y	Y
5	Deepen channel between culvert and vlaie							N	N
6	Remove spoil piles from along channel downstream of culvert				✓			Y	Y

6.4 Prioritization of Strategies

Many of the strategies recommended above can be implemented as soon as approvals are in place, stakeholders are in agreement, and project funding allows. There is no need to wait until other strategies have been implemented. For example, preventing cattle from entering the watercourse, relocating junk cars away from the creek, or increasing wooded vegetated buffers can be implemented as soon as circumstances allow.

However, for certain strategies it is important that implementation be properly sequenced in order to maximize the benefits. For example, efforts should be made to implement the recommended channel stabilization projects prior to making improvements further downstream at the Woods Road culvert. By stabilizing excess sediment at its source, the volume of sediment being transported downstream will be reduced, leading to less sediment deposition and increasingly stable conditions in the vicinity of the Woods Road culvert.

The following sequence is recommended for implementation of the strategies:

Step 1:

- Implement channel stabilization techniques along the main branch in the area of unstable channel between STA 40+00 and 47+00.

- Implement bank repairs and grade control where there is active channel incision and bank erosion, on the main branch between STA 47+00 and 70+00, and on the north branch between STA 0+00 and 18+00.

Step 2:

- Replace the culvert at Woods Road with a larger structure.

- Enlarge the base width of the channel slightly to 18 feet wide and the top width to at least 30 feet by grading one bank, alternating the widening points to minimize the need for tree removal.

- Remove spoil piles of dredged materials from along the channel downstream of Woods Road or relocated further back from the channel.

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APPENDIX A

PHOTO LOG

Franklinton Vlaie Tributary, Town of Broome, Schoharie County, New York
MMI #6108-01

Franklinton Vlaie
November 22, 2016

Outlet to Vlaie STA 0+00

Main Branch at STA 9+00
On alluvial fan near outlet to Vlaie
March 7, 2017

Main Branch at STA 9+00
On alluvial fan near outlet to Vlaie
March 7, 2017

Main Branch at STA 12+00
Looking downstream from Woods Road Culvert
February 24, 2017

Main Branch at STA 10+00
Downstream of Woods Road Culvert

Main Branch at STA 12+00
Looking upstream from Woods Road Culvert
February 24, 2017

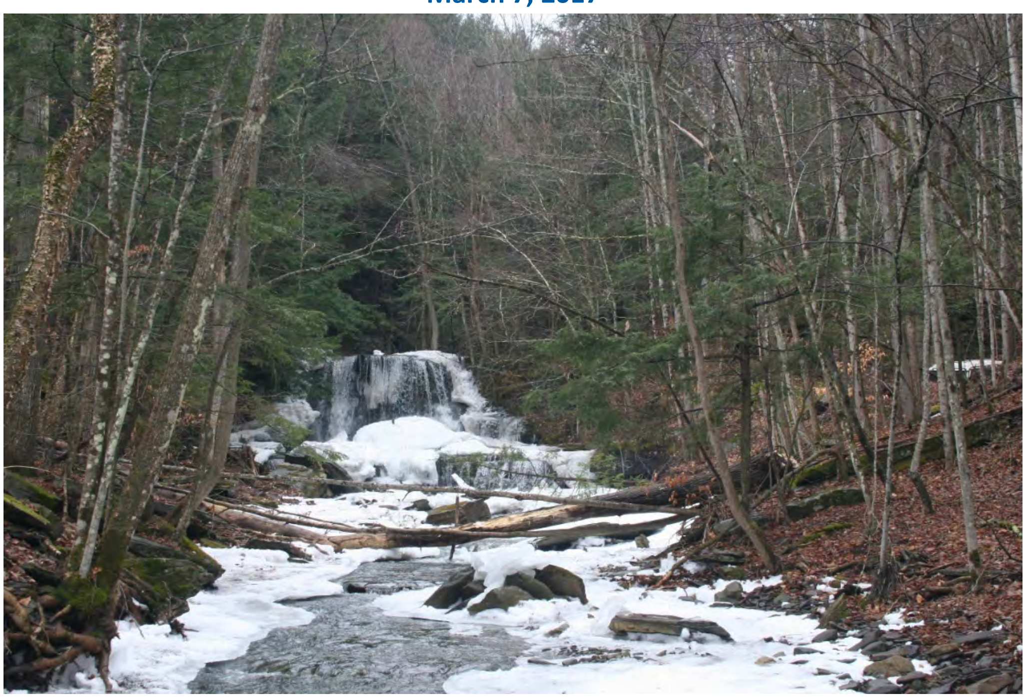
Main Branch at STA 12+00
Woods Road Culvert viewed from upstream
March 7, 2017

Main Branch at STA 15+00
View looking downstream towards Woods Road culvert

Main Branch at STA 15+00
View looking downstream towards culvert from below falls
March 7, 2017

Main Branch at STA 15+00
View looking downstream towards culvert from below falls
March 7, 2017

Main Branch at STA 17+00
Falls viewed from downstream
March 7, 2017



Main Branch at STA 17+00
Top of Falls

Main Branch at STA 25+00
Confined bedrock gorge
March 7, 2017

Main Branch in Gorge
Trout in Pool

Main Branch in Gorge

Main Branch in Gorge
Trout in Pool

Main Branch at STA 40+00
Failing hillslope with farm debris
March 7, 2017

Fencerows constructed from junked cars
March 7, 2017

Fencerows constructed from junked cars
March 7, 2017

Main Branch at STA 42+00
Unstable wandering channel
March 7, 2017

Main Branch at STA 42+00
Unstable wandering channel
March 7, 2017

Main Branch at STA 46+00
Unstable wandering channel
March 7, 2017

Main Branch at STA 46+00
Eroding bank
March 7, 2017

Main Branch near STA 46+00
Cows in Stream

Main Branch
Disturbed Area near Confluence

Main Branch at STA 46+50
Eroding bank
March 7, 2017

Logging Road crossing Main Branch

Main Branch at STA 46+50
Eroding bank
March 7, 2017

Main Branch at confluence with North Branch at STA 47+00
March 7, 2017

North Branch at STA 3+00
Channel incision
March 7, 2017

North Branch at STA 5+10
Channel crossing
March 7, 2017

North Branch at STA 10+00
Channel incision
March 7, 2017

North Branch at STA 10+00
Channel incision
March 7, 2017

Junked cars and engine blocks near North Branch
March 7, 2017

Main Branch at STA 90+00
Confined hemlock ravine
November 22, 2016

Main Branch at STA 97+00
Culvert crossing at Armlin Hill Road, viewed from downstream
November 22, 2016

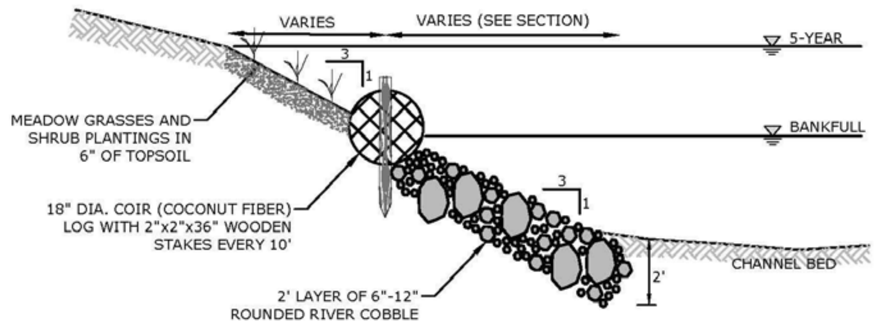
Logging Road along North Branch

North Branch looking Upstream from Confluence

South Branch looking upstream from Laura Lane

APPENDIX B

SCHEMATIC DESIGN CONCEPT DRAWINGS

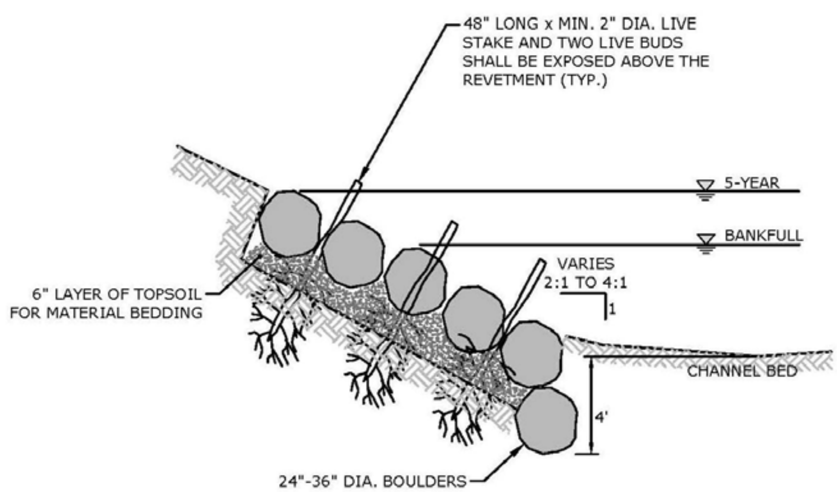


COIR LOG WITH COBBLE TOE

(NOT TO SCALE)

NOTES:

1. 6"-12" RIVER COBBLES SHALL EXTEND UP TO BANKFULL FLOOD ELEVATION. COIR (COCONUT FIBER) LOGS SHALL BE PLACED AT THE BANKFULL FLOOD ELEVATION. ABOVE BANKFULL FLOOD ELEVATION TO THE 5-YEAR FLOOD ELEVATION SHALL BE MEADOW GRASSES AND SHRUB PLANTINGS.
2. 6" OF TOPSOIL IS TO BE PLACED ABOVE COIR LOGS UP TO THE 5-YEAR FLOOD ELEVATION.
3. COIR LOGS ARE TO BE BURIED TO 1/2 OF LOG DIAMETER.
4. DRIVE STAKES DOWN ALONG THE CENTER OF THE LOG. DRIVE STAKES FLUSH WITH THE TOP OF THE COIR LOG.
5. WEAVE COIR OR NYLON TWINE BETWEEN AND AROUND THE STAKES.
6. DRIVE STAKED IN FIRMLY, SECURING THE LOG TO THE STREAMBANK.

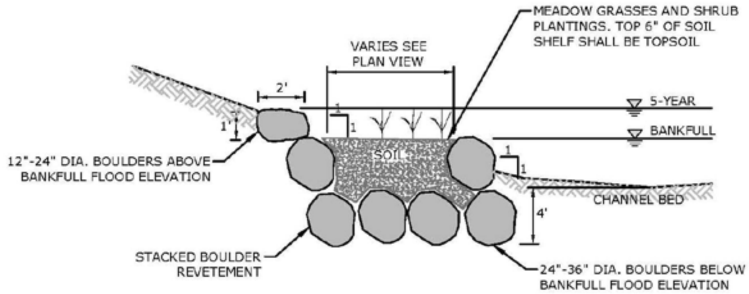


JOINT PLANTED BOULDER REVETMENT

(NOT TO SCALE)

NOTES:

1. BOULDER REVETMENT SLOPE VARIES, SEE GRADING PLAN FOR SLOPES.

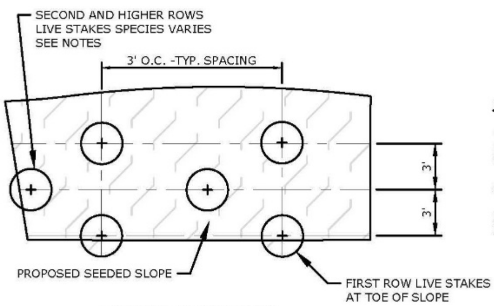


STACKED BOULDER REVETMENT WITH RIPARIAN SHELF

(NOT TO SCALE)

NOTES:

1. ALL BOULDERS BELOW BANKFULL FLOOD ELEVATION SHALL BE 36" DIA. ALL BOULDERS ABOVE BANKFULL FLOOD ELEVATION UP TO THE 5-YEAR FLOOD ELEVATION SHALL BE 24" DIAMETER.
2. WHERE GRADING DICTATES ADDITIONAL ROWS OF 24" DIA. BOULDERS MAY BE NEEDED ABOVE BANKFULL ELEVATION
3. 6" OF TOPSOIL IS TO BE PLACED ALONG THE RIPARIAN SHELF ABOVE NATIVE MATERIAL.

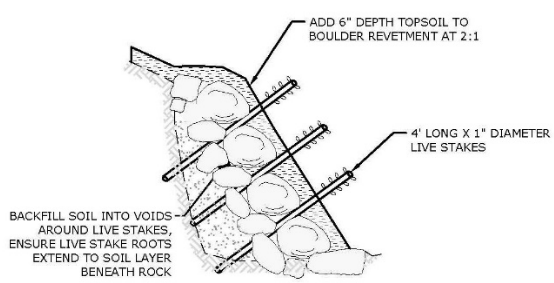


TYPICAL PLAN VIEW

EST. QUANTITY OF STAKES:

Salix lucida: ---
Sambucus canadensis: ---
Viburnum dentatum var. lucidum: ---
Cornus racemosa: ---

FOR PLACEMENT ON SLOPE, SEE PLANTING NOTES #3 AND #4.



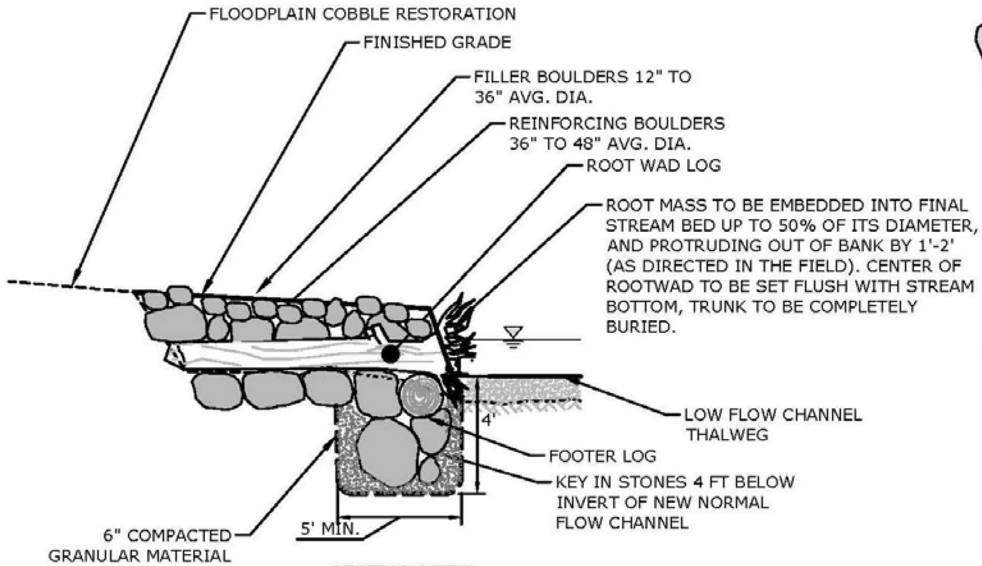
JOINT PLANTING SECTION VIEW

PLANTING NOTES:

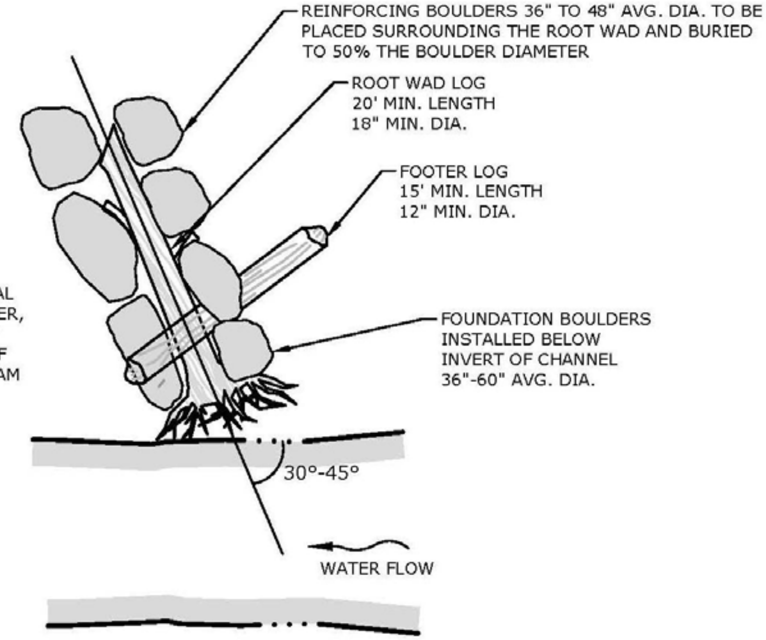
1. INSTALL RIPRAP REVETMENT PER PLAN, AND PLACE 6 INCHES OF TOPSOIL AS SHOWN IN DETAIL.
2. ALONG THE TOE OF THE SLOPE (FIRST ROW), INSTALL 4' LONG X 1" DIAMETER LIVE WILLOW STAKES (*SALIX LUCIDA* OR SIMILAR NATIVE WILLOW SPECIES) SPACED 3' ON CENTER. THESE ARE TO BE INSERTED INTO PREDRILLED PILOT HOLES SLIGHTLY LARGER THAN THE STAKE DIAMETER AND BACKFILLED. STAKES SHOULD BE INSERTED TO 36" DEPTH.
3. HIGHER ON SLOPE (SECOND AND THIRD ROW), INSTALL 4' LONG X 1" DIAMETER LIVE STAKES OF WILLOW SPECIES (*SALIX LUCIDA* OR SIMILAR NATIVE WILLOW SPECIES), ELDERBERRY (*SAMBUCUS CANADENSIS*), ARROWWOOD (*VIBURNUM DENTATUM VAR. LUCIDUM*) AND GRAY DOGWOOD (*CORNUS RACEMOSA*) SPACED 3' ON CENTER. THESE ARE TO BE INSERTED INTO PREDRILLED PILOT HOLES SLIGHTLY LARGER THAN THE STAKE DIAMETER AND BACKFILLED. STAKES SHOULD BE INSERTED TO 36" DEPTH.
4. LIGHTLY TAMP TOPSOIL AROUND EACH STAKE AND SATURATE WITH WATER.
5. SEED BANK WITH A MIX CONSISTING OF NATIVE SPECIES THAT ARE AT LEAST MODERATELY DROUGHT TOLERANT, DO WELL ON POOR SOILS AND DEVELOP SUBSTANTIAL BELOW-GROUND BIOMASS. THE SLOPE SHOULD BE HAND RAKED TO SCARIFY THE SOIL SURFACE, THEN HAND SEEDED, HYDROMULCHED OR HAND SPREAD WITH A STRAW MULCH, AND RAKED LIGHTLY TO ENSURE SEED TO SOIL CONTACT. SEE SEEDING NOTES BELOW FOR SEED MIX COMPOSITION.
6. PLANT MATERIALS SHOULD BE PLANTED THE DAY THEY ARRIVE ON SITE. PLANTS AND CUTTINGS THAT CANNOT BE PLANTED THE DAY THEY ARRIVE SHALL BE STORED ON SITE UNDER A WET TARP TO PROTECT THEM FROM WIND, DIRECT SUNLIGHT, DRYING OR OTHER DAMAGE. CUTTINGS OR UNROOTED STOCK THAT IS NOT PLANTED WITHIN TWO DAYS AFTER ARRIVAL ON THE SITE SHALL BE DISCARDED UNLESS REFRIGERATED AT 40 TO 50 DEGREES FAHRENHEIT.
7. WILLOW SPECIES AND SOURCES SHALL BE APPROVED BY THE ENGINEER PRIOR TO INSTALLATION.

JOINT PLANTING

(NOT TO SCALE)



SECTION VIEW



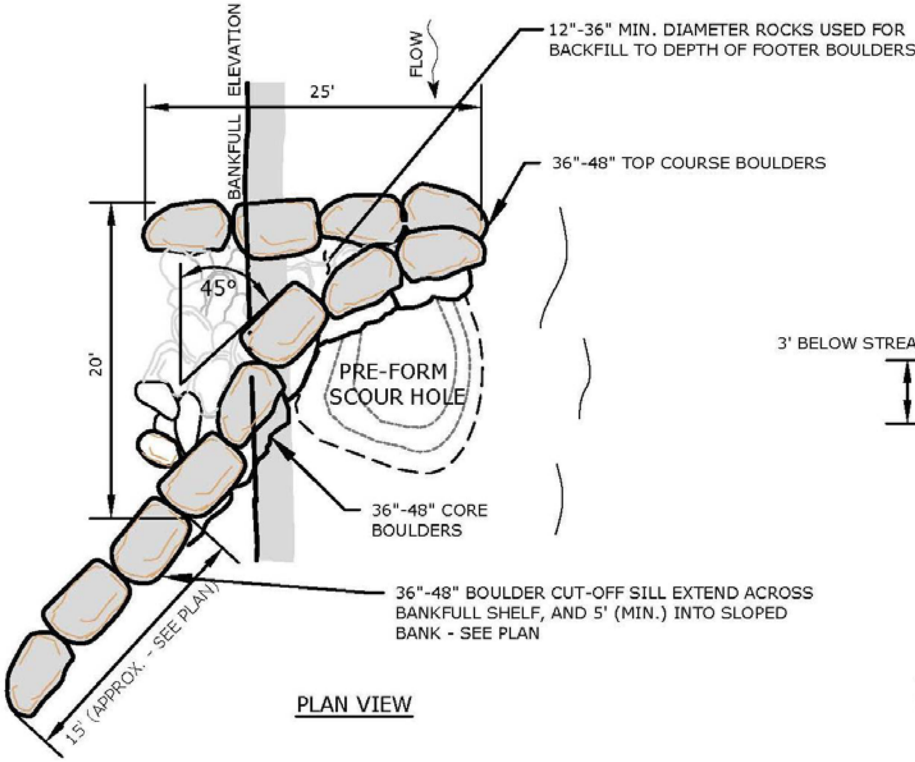
PLAN VIEW

BOULDER ROOT WAD STRUCTURE

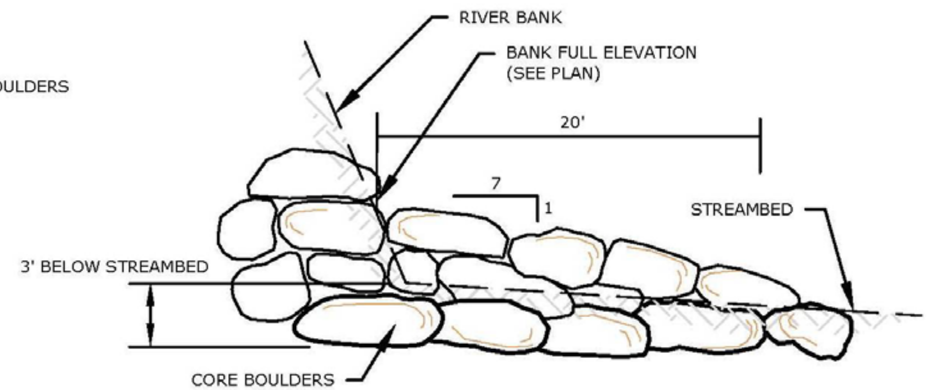
(NOT TO SCALE)

NOTES:

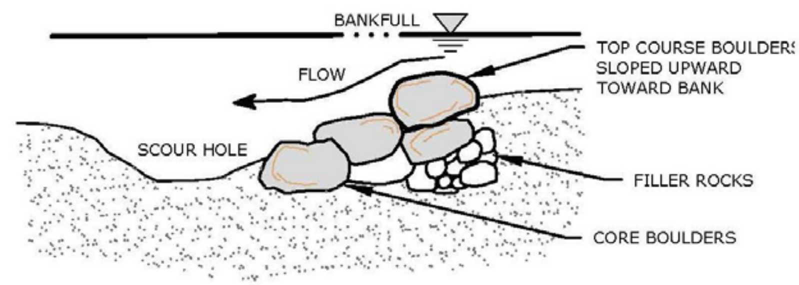
1. TOP OF FOOTER LOG SHALL BE ONE FOOT BELOW LOWEST STREAMBED ELEVATION.
2. THE FINAL ELEVATION OF THE ROOT WAD WILL BE SUBJECT TO ADJUSTMENT BASED UPON CHANGING FIELD CONDITIONS.



PLAN VIEW



SECTION VIEW (FACING UPSTREAM)



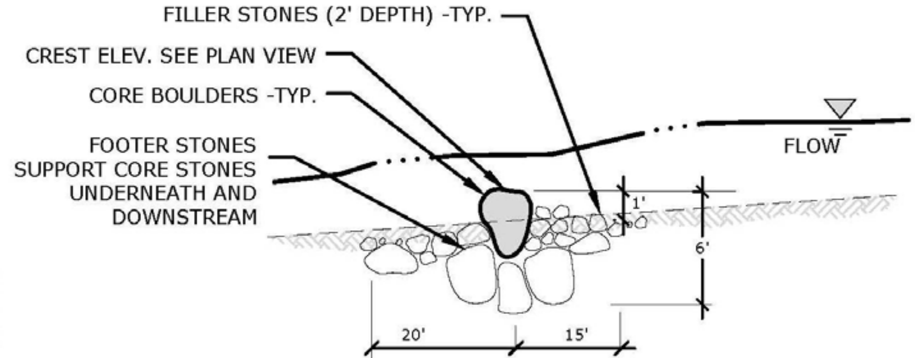
PROFILE VIEW

NOTES:

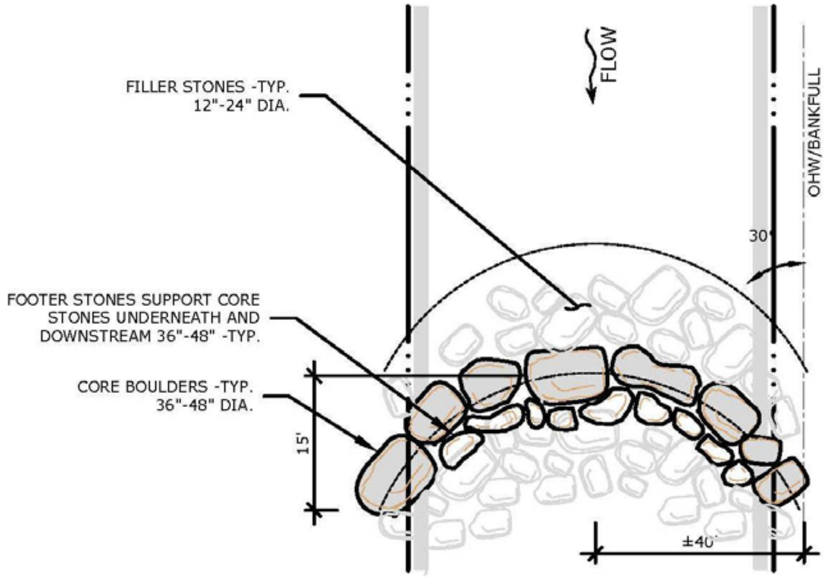
1. TOP COURSE OF ROCK TO BE IMBRICATED (PLACED IN VERTICAL AND HORIZONTAL COMPRESSION).
2. FINISHED ELEVATION OF TOP COURSE OF ROCK TO BE AT OR NEAR FINISHED BED ELEVATION.
3. ANCHOR ALL LAYERS OF ROCK A MINIMUM OF 6'-8' DEEP INTO BANK.
4. USE 12" TO 36" MINIMUM DIAMETER ROCKS TO CHINK BEHIND VANE TO PREVENT EXCESSIVE SCOUR UPSTREAM OF THE STRUCTURE.

BOULDER DEFLECTOR VANE

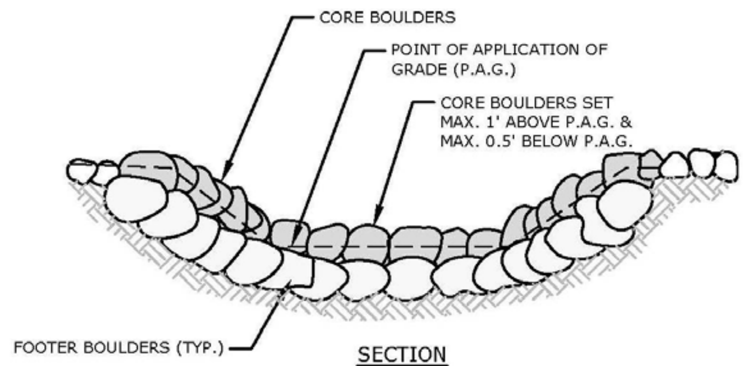
NOT TO SCALE



PROFILE VIEW



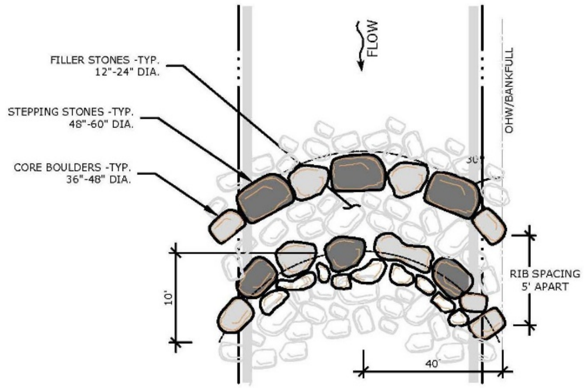
PLAN



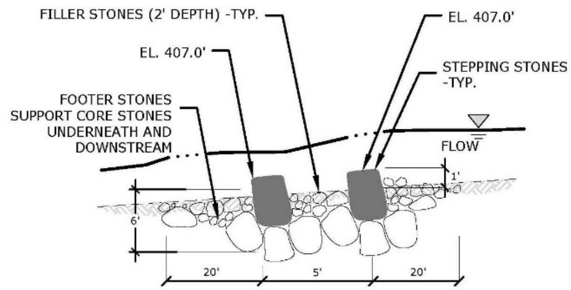
SECTION

SINGLE BOULDER RIFFLE STRUCTURE

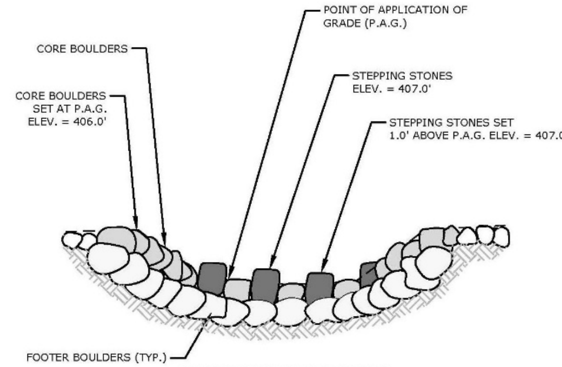
NOT TO SCALE



PLAN



PROFILE VIEW



STEPPING STONE RIB SECTION

DOUBLE BOULDER RIFFLE STRUCTURE