# Ouleout Creek Geomorphic Assessment, Nutrient Load Estimation, and Remediation Recommendations

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# Abstract

Nutrient loading and subsequent eutrophication are a growing concern in the Chesapeake Bay. As a result, nutrient and sediment Total Maximum Daily Loads (TMDL) were established by the United States Environmental Protection Agency (USEPA) for the Chesapeake Bay. The TMDL is far reaching, affecting the Susquehanna headwaters in Delaware County, NY. In order to help achieve the TMDL, a geomorphic assessment was conducted on Ouleout Creek, a tributary to the Susquehanna River.

The goal of this assessment was to estimate nutrient loading due to streambank erosion along the main stem of Ouleout Creek upstream of East Sidney Lake in Delaware County, New York. Eroding banks were geolocated during a Stream Feature Inventory and assessed using the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model. Annual eroded volumes were calculated for each eroding streambank using one of two methods. The first method used a combination of field measurements and GPS points superimposed on orthoimagery in ArcGIS to determine an eroded volume of sediment. The second method used a combination of field measurements and the BANCS model to determine an eroded volume of sediment.

Representative soil samples were taken from eroding streambanks and tested for total nitrogen (TN) and total phosphorus (TP) concentrations. Nutrient loading rates were then determined for each eroding streambank. In total, 5,500 $yd^3$ of sediment, 11,000 lb of TN, and 3,900 lb of TP are estimated to erode annually from streambanks along the assessed section of Ouleout Creek. Reaches were delineated and ranked by the estimated mass of TP eroded from the streambanks in each reach. Several sites of erosion accounted for a disproportionate amount of the eroded material along the Ouleout. Nineteen sites of substantial erosion were identified and ranked by their mass of TP eroded annually. Common characteristics of these sites were the lack of an adequate riparian forest buffer along the streambank and the presence of excessive depositional features within the stream channel. In addition, many of these sites were channel meanders migrating downstream. The sites of substantial erosion estimated to load the greatest amount of TP should be targeted for stream restoration projects. Included in this report are remediation recommendations for these sites of substantial erosion.

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# Introduction

*Background Information*

Ouleout Creek is a 109 mi$^2$ watershed located in the towns of Sidney, Franklin, and Meredith in Delaware County, New York (**Figure 1**). The stream flows approximately 25 miles, northeast to southwest, from its headwaters in Meredith to its confluence with the Susquehanna River in Sidney. Approximately five miles upstream of the Ouleout's confluence with the Susquehanna is the East Sidney Dam. The dam was completed in 1950 by the United States Army Corps of Engineers (USACE) for the purpose of flood mitigation and impounds water on the Ouleout to create East Sidney Lake (USACE, 2019). The impoundment increases time of concentration to reduce flood impacts of the Susquehanna in the downstream city of Binghamton, New York. East Sidney Lake is eutrophic and prone to recurring algal blooms. These issues have previously been documented in two studies by Ashby and Kennedy of the USACE (1990).

This particular assessment focuses on nutrient loading due to stream bank erosion on the approximately 20-mile long main stem of Ouleout Creek upstream of East Sidney Lake. The Ouleout Creek Watershed contains a substantial amount of agriculture, such as dairy and crop production. Many areas adjacent to Ouleout Creek are used for agriculture or are abandoned agricultural land that contain little or no riparian forest buffer. As a result, many areas along the Ouleout without an adequate riparian forest buffer are experiencing streambank erosion due to a lack of stability.

Streambank erosion is a natural process that occurs when a stream adjusts its channel position within the landscape. However, instabilities, which are often induced or exacerbated by anthropogenic activity, can increase the rate of erosion within a stream. Alteration of the stream channel, its surrounding riparian buffer, and the land cover within the stream's watershed are some common ways erosion rates can be accelerated. Streambank erosion introduces soil into the stream channel as well as the nutrients naturally therein that are adsorbed to, and bound in soil particles sand sized and smaller. Nutrient levels in the soil may be elevated due to fertilization through the use of soil amendments such as manure and fertilizers. Since streambank erosion is a nonpoint source of sediment and nutrients, it has been historically difficult to determine the extent of its impact on the nutrient budget of streams and waterbodies. Two key nutrients that predominately cause eutrophication in waterbodies are phosphorus and nitrogen. Because the aforementioned nutrients can negatively impact water quality in excessive quantity, many different agencies in recent years have focused on ways to reduce nutrient loading in waterbodies.

The Chesapeake Bay, which is primarily fed by the Susquehanna, is highly important both biologically and economically and has been negatively impacted by excessive nutrient loading. The Bay is the largest estuary within the United States and is a large contributor to the commercial shellfish industry (Chesapeake Conservancy, 2020). Because of the Bay's importance, its water quality is of great concern. In 1999, the Bay was classified as an impaired water body by the United States Environmental Protection Agency (USEPA) under the Clean Water Act (NYSDEC, 2021). As a result, the Chesapeake Bay Total Maximum Daily Load

(TMDL) was created by the EPA to address the excessive nutrient loading to the Bay. The goal of the TMDL was to create nutrient and sediment budgets for the watersheds that drain into the Bay so that sources of excessive nutrients and sediment could be identified and reduced. The three pollutants targeted by the Chesapeake Bay TMDL are nitrogen, phosphorus, and sediment.

In order to fulfill the obligations of the Chesapeake Bay TMDL, New York State developed the Watershed Implementation Plans (WIP) for the Chemung and Susquehanna watersheds within its boundaries (NYSDEC, 2021). The WIP has been updated several times since its creation, with the current iteration being the Phase III WIP. The Phase III WIP contains sediment and nutrient reduction goals to be reached by 2025. The 2025 TMDLs for the aforementioned combined watersheds, when annualized, are 0.476 million lb/year of phosphorus, 11.56 million lb/year of nitrogen, and 517.58 million lb/year of sediment. The most recent estimated loads delivered to the Chesapeake Bay from these combined watersheds were 0.548 million lb of phosphorus, 12.83 million lb of nitrogen, and 676.98 million lb of sediment delivered to the Chesapeake Bay from New York (NYSDEC, 2023). Nutrient and sediment loads clearly need to be reduced in order to meet the 2025 New York Phase III WIP goals.

Specific targets within the WIP III include implementation of conservation best management practices (BMP) within the Upper Susquehanna Watershed in order to reduce nutrient and sediment loads. These include 20,000 acres of cover crops, waste management systems for 89,012 animal units of livestock, and several other BMP practices. Another goal tracked in the WIP III is streambank restoration with a goal of 169,000 linear feet (LF) of streambank to be restored by 2025. As of 2022, only 56,585 LF of streambank restoration had been accomplished. Following this assessment, it's clear that many sites on Ouleout Creek can be restored in order to help achieve this goal.

This assessment was driven by the Upper Susquehanna Coalition's (USC) and the Delaware County Soil and Water Conservation District's (DCSWCD) overlapping goals to conserve soil and water resources within Delaware County in fulfillment of the Phase III WIP. Goals of this specific assessment included identification, prioritization, and remediation of nutrient loading due to streambank erosion along the approximately 20-mile long main stem of Ouleout Creek above East Sidney Lake. This assessment was accomplished using methods piloted by the DCSWCD which estimated nutrient and sediment loads at two sites of extensive erosion on the West Branch Delaware River (Coryat et al., 2021). This assessment mirrored the West Branch Delaware River project by following these steps along the Ouleout: field assessments to locate eroding streambanks, soil sampling of the eroding streambanks for nutrient concentrations, estimation of nutrient loading due to streambank erosion, and prioritization of sites of streambank erosion. Through these steps, this assessment prioritized sites of streambank erosion for stabilization based on the mass of total phosphorus (TP), mass of total nitrogen (TN), and volume of sediment entering Ouleout Creek from streambank erosion.

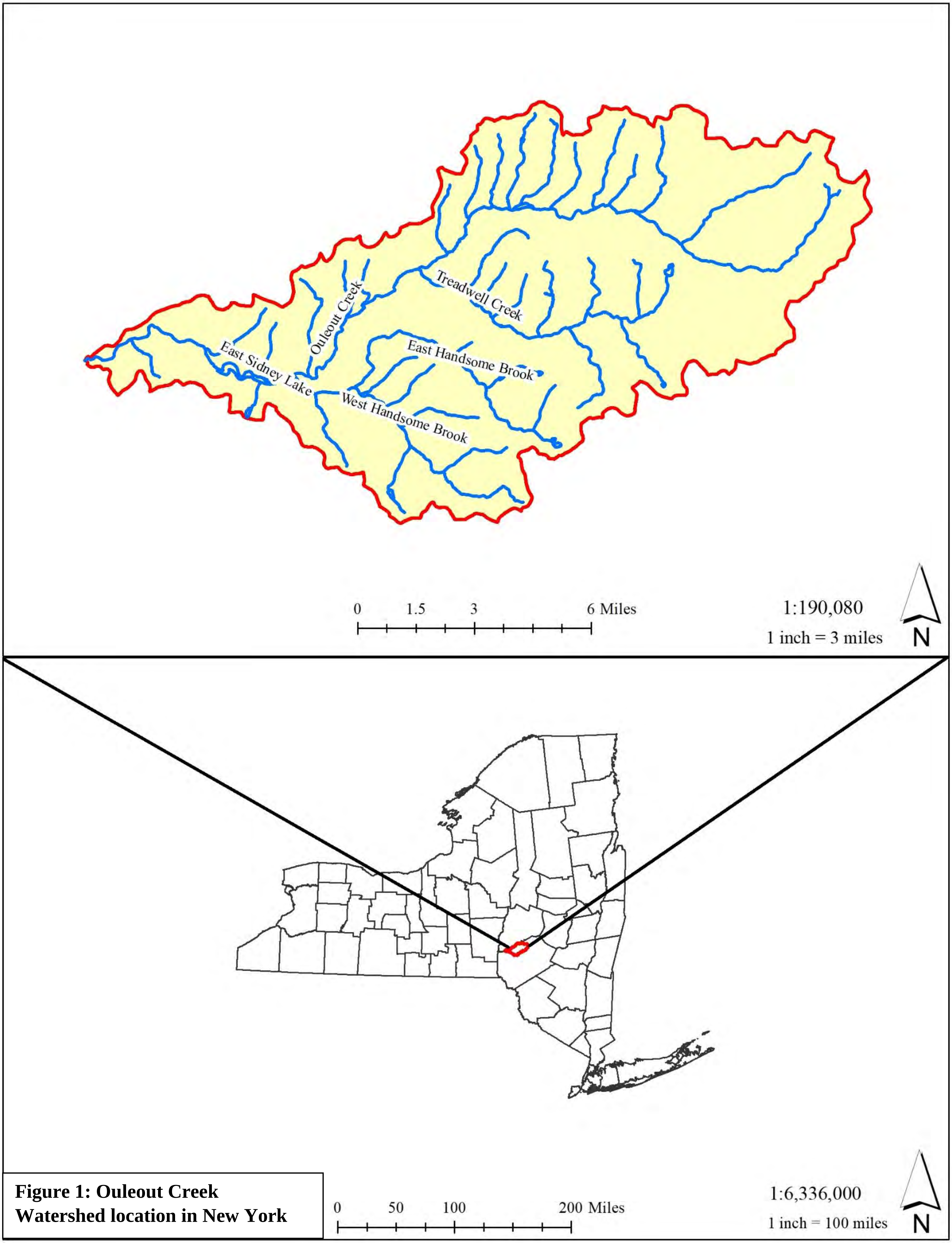


**Figure 1: Ouleout Creek Watershed location in New York**

*Nutrients and Algal Growth in Waterbodies*

The two primary nutrients that promote algal growth are nitrogen and phosphorus. Algal growth is directly related to the availability of these nutrients. Anthropogenic activities often release these nutrients into the environment and subsequently into waterbodies. Sources of these nutrients include fertilizers, wastewater treatment plants, inadequate septic systems, stormwater runoff, and runoff from agricultural activities. Excessive nutrient loads entering a waterbody often lead to eutrophication.

Excessive phosphorus and nitrogen concentrations cause algae blooms, then as bacteria breaks down the algae, oxygen in the water is consumed. This creates anoxic conditions in the waterbody which is inhospitable for aquatic organisms such as fish, macroinvertebrates, macrophytes, and other aquatic life. Cyanobacteria are a group of algae that often dominant when phosphorus is not limited due to the fact that they are capable of fixing nitrogen. Cyanobacteria, also known as blue-green algae, have been known to be harmful to human health, and are the cause of most harmful algal blooms. These blooms are responsible for bad odor, bad taste, and the release of toxins in the water. These toxins include hepatoxins and neurotoxins which can damage the liver and nervous system in humans and animals (Bláha et al., 2009). Because of the detrimental impact excessive nutrient loads can have on a waterbody, it is important to try and mitigate sources of excessive nutrients entering waterways.

*Prior Studies of East Sidney Lake and Ouleout Creek*

Water quality has been a concern at East Sidney Lake since its inception due to struggles with nutrient loading and eutrophication of the Lake. In the late 1980s and early 1990s, the USACE; produced reports that analyzed nutrient dynamics in East Sidney Lake and estimated nutrient loads entering the Lake from internal and external sources (Ashby et al., 1990). These reports shed light on many details regarding the nature of the nutrient loading and eutrophication occurring within the Lake. It was determined that nutrient concentrations within the Lake peaked during snowmelt runoff in the spring and again during stratification at the end of the summer. In the summer, when the Lake was stratified, inflow levels of phosphorus were stable while internal loading of phosphorus increased, accounting for an estimated 70% of the nutrients available for algal growth. The increase in internal loading of phosphorus was caused by mixing events and internal cycling of phosphorus within the Lake. During that same time period, internal loading of nitrogen only accounted for an estimated 20% of the nutrient load for the algal growth.

The East Sidney Lake studies by USACE also analyzed algal growth within East Sidney Lake (Kennedy et al., 1988). The study found that there was a general increase in the abundance of phytoplankton during the summer. During that time there was also a change in the ratio between TP and TN which suggested that the limiting nutrient switched from phosphorus to nitrogen. This switch of limiting nutrients would favor cyanobacteria which are able to fix nitrogen. Cyanobacteria were found to be the most abundant type of phytoplankton in East Sidney Lake during the summer. During the summer, the Lake also entered the range that is classified as eutrophic. In addition to discussing the nutrient levels of East Sidney Lake, concern was also raised regarding the impact of high nutrient level releases from the Lake into the downstream section of Ouleout Creek during low flow conditions. This nutrient laden water would flow into the Ouleout and enter the Susquehanna River.

The 1990 USACE report estimated the total external TP load for East Sidney Lake to be 7,736 lb of TP per year. The report distinguished the external nutrient load of East Sidney Lake into two sources which were Ouleout Creek and Handsome Brook. The amount of nutrients being contributed to the Ouleout in the present day may be lower than it was in 1990 due to several factors such as the installation of multiple agricultural and conservation best management practices within the Ouleout Creek Watershed, increased forested land in the watershed, and decreased agricultural land use within the watershed.

The 1990 USACE report listed several recommendations for ways to manage future nutrient loading and algal blooms in the Lake. One recommendation was to decrease the total biomass of phytoplankton during the summer by applying algicide or adding fish that would graze upon the algae. Artificial circulation of the water in the Lake to reduce internal nutrient loading was also suggested and subsequently tried from 1990 to 1992. Though the circulation decreased phosphorus concentrations in the Lake, the chlorophyll a level of the Lake was not improved and the oxygen level still decreased during summer stratification (Barbiero et al., 1996). Another recommendation was to work with landowners and other agencies to implement BMPs for activities within the Ouleout Creek Watershed to reduce the external nutrient loads from entering East Sidney Lake; this effort is still in progress.

Another important characteristic of East Sidney Lake is its pool elevation. The water level of East Sidney Lake is not static and varies throughout the year. Since the purpose of East Sidney Dam is flood mitigation, the water level of East Sidney Lake is lowered from its normal summer pool elevation of 1,150 ft National Geodetic Vertical Datum of 1929 (NVGD) in summer to its seasonally low elevation of 1,140 ft NVGD in winter. At full capacity, East Sidney Lake would reach an elevation of 1,229 ft NVGD (USACE, 2019). It is unclear the effect that the seasonal draw down of the water level has on the internal sediment and nutrient loading within East Sidney Lake.

The New York State Department of Environmental Conservation (NYSDEC) has classified Ouleout Creek as a waterbody that supports trout spawning. This indicates that maintaining a high level of water quality within Ouleout Creek is critical to trout populations. The NYSDEC previously noted several water quality issues for East Sidney Lake on its Priority Waterbodies List in 2009 (NYSDEC, 2009). Some issues noted as impairments to water quality were algal blooms, excessive nutrient concentrations, low dissolved oxygen, and low water clarity. According to the NYSDEC, the suspected source of the impairments were excess nutrients due to runoff from agricultural practices and inadequate septic systems. Streambank erosion was not mentioned as a possible source of nutrients within the fact sheet, demonstrating that streambank erosion has been overlooked as a possible source of nutrients within the Ouleout Creek Watershed. This specific assessment sought to identify and quantify sediment and nutrient loading from streambank erosion along Ouleout Creek.

## Basin Characteristics

*Climate*

The Köppen climate classification for the Ouleout Creek Watershed is the humid continental climate which is defined by a passing of four seasons with a variation in temperature between the seasons (Peel et al., 2007). The Ouleout Creek Watershed has an average high temperature of 56°F and an average low temperature of 34°F (U.S. Climate Data, 2023).

*Hydrology*

Ouleout Creek flows from northeast to the southwest where it converges with the Susquehanna River. At its confluence with the Susquehanna it is a 109 $mi^2$ watershed. The assessment area that is upstream of East Sidney Lake has a watershed size of 71.6 $mi^2$. At the Ouleout's confluence with the Lake, regional regression equations indicate that the bankfull discharge is 1,750 cubic feet per second (cfs) with an estimated 100-year recurrence interval discharge of 7,840 cfs (USGS, 2023). The mean annual precipitation for the watershed is 42.3 inches and the mean annual runoff is 23.3 inches.

The Ouleout has two notable tributaries within its watershed; Handsome Brook and Treadwell Creek. The Ouleout converges with Handsome Brook at the delta at East Sidney Lake. Handsome Brook has a drainage area of 27.1 $mi^2$. Treadwell Creek enters the Ouleout approximately 5 ½ miles upstream of the Ouleout's delta at East Sidney Lake. Treadwell Creek has a drainage area of 25 $mi^2$.

*Topography*

The Natural Resource Conservation Service (NRCS) Major Land Resource Area (MLRA) classifies the Ouleout Creek Watershed as a part of the glaciated Allegheny Plateau and Catskill Mountains. This area consists of glacially defined valleys with relatively flat bottoms and steep sided hillslopes (NRCS, 2022). The Ouleout flows through a broad valley for the majority of its extent. The Ouleout valley is at its broadest upstream of the village of Franklin.

*Geology*

The bedrock in the Ouleout Creek Watershed is primarily sedimentary and consists of three formations. The first and predominant formation is the "Oneonta Formation" which is an Upper to Middle Devonian rock unit and part of the Genesee Group. The Oneonta Formation consists of shale (red, green, dark grey), sandstone, mudstone, and conglomerates (Ver Straetan, 2013).

The Ouleout's headwaters and many of its tributaries flow through the "Lower Walton Formation" which is an Upper Devonian rock unit and part of the Sonyea Group. The Lower Walton Formation consists of shale (red, green, dark grey), sandstone, mudstone and conglomerates.

The tops of some of the mountains and hillslopes in the Ouleout Creek Watershed, chiefly along its drainage divide, are of the "Enfield and Kattel Formations" which are an Upper Devonian rock unit and belong to the Sonyea Group. These formations consist of shale, siltstone, and sandstone.

The last ice age to impact the Ouleout Creek Watershed was the Wisconsin glaciation. This glaciation left many surficial geologic features throughout the Ouleout Creek Watershed. The Ouleout's valley walls, headwaters, and many tributaries contain glacial till and colluvial deposits as their surficial geology. Bedrock exposures, kame deposits, and outwash sand and gravel are commonly found throughout the Ouleout Creek Watershed as well. The Ouleout itself flows primarily through postglacial alluvial deposits.

*Pedology*

The major soil order in the Ouleout Creek Watershed is Inceptisols with a dominant suborder being Udepts. They have a mesic soil temperature, mixed minerology, and a soil moisture regime that is usually aquic or udic (NRCS, 2022).

# Methodology

*Stream Feature Inventory*

The Stream Feature Inventory (SFI) is a method of assessing a stream's features and characteristics. With an SFI, stream issues can be identified, geolocated, and assessed (Coryat, 2018). An SFI is accomplished by walking the stream and recording streambank erosion and other notable features that could influence channel instability. Global positioning system (GPS) points are captured and recorded using a Trimble Geo7x data collector. Photos, notes, and corresponding measurements are taken when applicable for each GPS point. Each eroding streambank can also be evaluated using the Bank Assessment for Non-point source Consequences of Sediment (BANCS) model. This assessment, developed by David Rosgen, measures several features of an eroding bank and allows one to estimate the streambank's annual erosion rate (Rosgen, 2006). Once an SFI is completed on a stream, resources can then be allotted to the issues of greatest concern within the stream in a strategic, coordinated way. In order to identify these issues within Ouleout Creek, an SFI was conducted along the main stem of the Ouleout above East Sidney Lake.

For streambank erosion points and revetment points, positions are recorded at the start, end, and every break in planform and height. Once recorded, all GPS positions are post-processed with data from the nearest New York State Department of Transportation (NYSDOT) GPS base station to ensure accuracy of points. GPS points are then exported as a shape file and then loaded into ArcGIS for further analysis.

For the Ouleout Creek SFI, the documented features and the reason for their collection are as follows:

Streambank erosion

- Streambank erosion is a location along a streambank that is at least partially bare and is scoured by the action of flowing water. Erosion is an instability and a source of sediment and nutrients entering the stream channel. This is the main area of focus for this particular assessment. Streambank erosion typically takes two forms: hydraulic erosion and mass failure. Hydraulic erosion of a streambank is due to the shear stress of flowing water entraining soil particles from the bank and is the most common form of erosion along a stream. Mass failure erosion is common along hillslopes; these failures are largely due to geotechnical processes that cause the hillslope to shear in large volumes into the stream channel.

Excessive depositional feature

- A depositional feature is a location of natural sediment storage within the stream channel. Excessive sediment depositions may indicate issues such as an over widening of the stream channel or an inability to efficiently transport the amount of sediment being contributed to the channel. It could also indicate that there are substantial erosion sources upstream contributing excessive amounts of sediment to the channel. Excessive depositional features include features such as center bars, transverse bars, full channel bars, and side bars and point bars of exaggerated size or unusual characteristics. Excessive depositions can also contribute to erosion; examples include transverse bars or center bars directing flow into a bank.

Headcut

- Headcuts, also known as knickpoints, are instabilities that lower the elevation of the streambed causing widespread streambed and streambank erosion. Headcuts often cause a stream to lose access to its floodplain. Headcuts can also threaten the stability of bridges, culverts, and other structures within a stream.

Large woody debris

- Large woody debris can be a major driver of change or, conversely, a source of stability within a stream. Accumulations can cause avulsions, blockages, jams, reroutes, threaten the integrity of structures such as bridges and culverts, though they may also enhance or protect banks from erosion. In addition, large wood within a stream channel can provide stability by acting as a step to dissipate energy, acting as grade control to prevent headcuts from travelling upstream, or assisting the stream to maintain sediment transport equilibrium by storing sediment. Large woody debris can act as important habitat for aquatic life. Therefore, large woody debris within the channel and its impact is important to record.

Streambank revetment

- Revetment, is any type of material placed on the channel edge for the purpose of protecting a streambank. Revetment could provide bank protection or could cause instability in the channel if in poor condition. Examples of revetment include, concrete structures, log cribbing, riprap, sheet piling, sloped stone, stacked rock in addition to various other forms of bank armoring.

Control point

- Controls are any structures that provide grade or planform stability. Bedrock, a common natural form of control, is an indicator of stability within the stream channel as it arrests headcuts.

Tributary

- The confluence of two streams is important to note as the pattern and quantity of depositions at their convergence can provide information about the condition of the tributary. Large amounts of deposition at a confluence could indicate erosion sources within the tributary. It is also the location at which a watershed increases in drainage size.

Bridge

- The condition of bridges is important to note from a stream stability and public safety standpoint. Undersized bridges may have issues with backwater effects upstream and scour downstream. These structures may also become blocked with debris.

Culvert

- Like bridges, undersized culverts can create backwater effects upstream and scour issues downstream. They can also become blocked or cause flow to avulse if undersized. Because of this, the condition of culverts is important to record from a stream stability and public safety standpoint. Improperly sized or constructed culverts often act as a passage barrier for aquatic organisms.

Stream crossing

- Stream crossings are important for agricultural and transportation purposes. Crossings can also be a location of streambank erosion. Because of this, the condition of a crossing is important to capture.

Berm

- Berms are important to record as they restrict the stream from accessing its floodplain during high flow events. Lack of floodplain access will cause instability within the stream channel.

Fine sediment point

- Though not the main focus of this assessment, turbidity from fine sediment can cause water quality concerns within a stream and be detrimental to a stream's overall health.

Photo point

- Photo points are used for a variety of reasons, often to capture features that do not fall into a specific category. They can also be used to note the representative condition of a stream reach.

Stream feature point

- Similar to a photo point, this point is used to capture several different types of stream features that do not have their own distinct point within the data dictionary.

These recorded features are used to identify and prioritize areas of potential stream stabilization projects. It is important to note that these stream features and their related stream processes are linked in a large, complex, and open system. Thus, a feature upstream may affect a feature downstream and vice versa. The proposed solutions that follow in the "Reach Specific Assessments and Recommendations" section are based on our best analyses and interpretations of these complex problems.

*Reach Delineation*

In order to more easily prioritize issues in the Ouleout, the stream was divided into 21 different sections known as reaches (**Figure 2**). A reach is a section of stream channel with consistent geomorphology that is part of a larger stream. These smaller sections are necessary for characterization and prioritization of problems and concerns along a stream. Reaches are delineated based on channel dimensions, valley width, tributary confluence, land cover, and bedrock control. Reaches were ranked for potential projects once analysis of field data was complete. The reaches, along with a corresponding description, are listed in **Appendix 1**.

In order to reference the location of features recorded along Ouleout Creek, survey stationing was created for the main stem of the Ouleout. Station (STA) 0+00 ft starts at the Ouleout's confluence with the Susquehanna with stationing increasing in number upstream along the channel's centerline. The highest numbered station is located at the headwaters of the Ouleout.

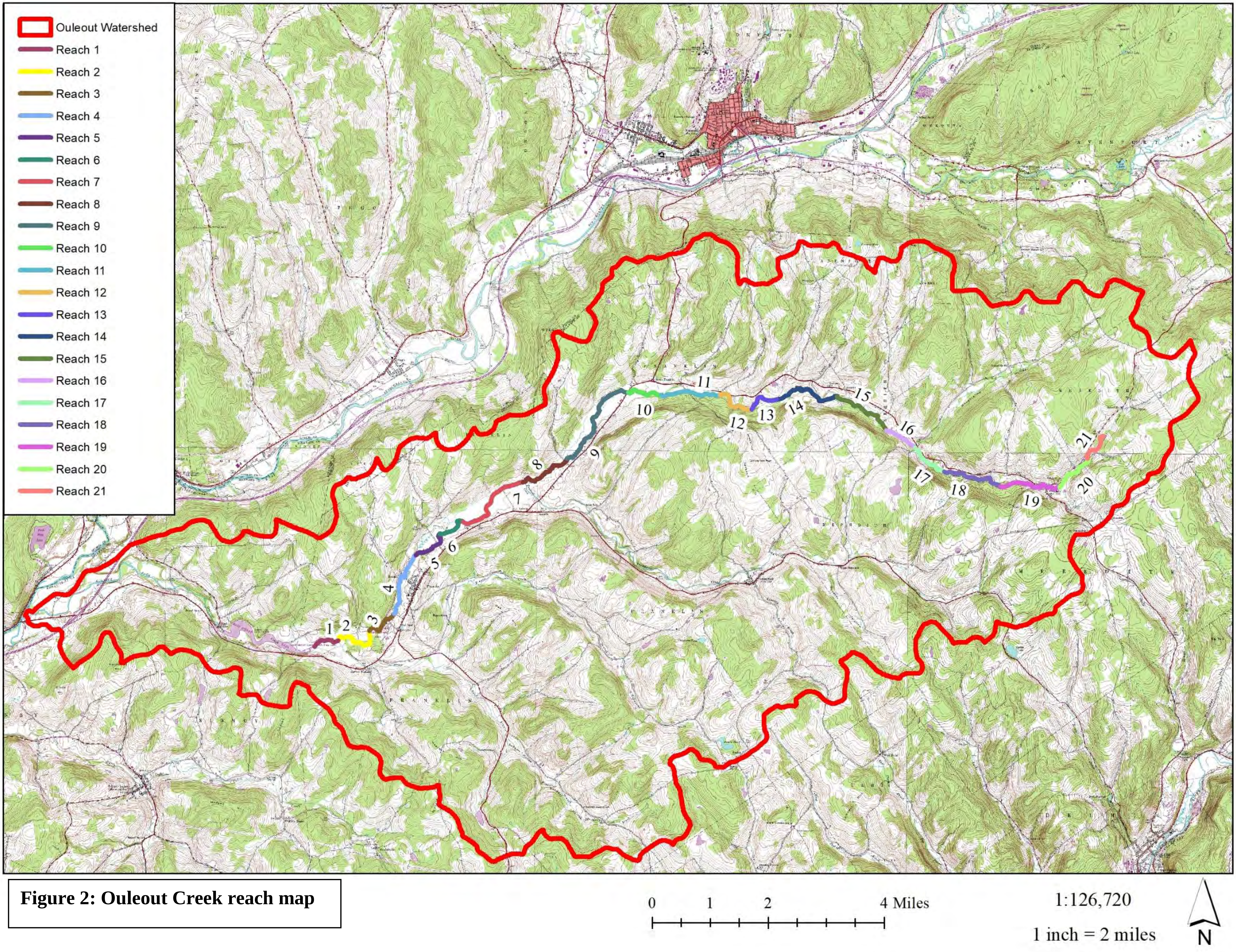


**Figure 2: Ouleout Creek reach map**

*Bank Assessment for Non-point source Consequences of Sediment*

The BANCS model is a method, developed by David Rosgen, to assess the severity of bank erosion for an eroding streambank in its current state and to predict a future erosion rate of the streambank (Rosgen, 2006). BANCS is a streamlined method intended for use by field practitioners to quickly and accurately assess long lengths of stream. The first step in this process is determining the eroding bank's Bank Erosion Hazard Index (BEHI) score. BEHI is a method used to estimate erosion potential by quantifying several eroding streambank characteristics. These measured characteristics include: study bank height, bankfull height, root depth, root density, bank angle, and surface protection (**Figure 3**). These individual characteristics are then plotted on index rating curves which give an index score out of 10 (**Figure 4**). Individual scores are summed for a total BEHI score which then corresponds to a rating category of either very low, low, moderate, high, very high, or extreme.

The second step is determining the streambank's Near-Bank Stress (NBS) score, which assesses the shear stress acting on a streambank at bankfull discharge. There are seven total methods to determine an NBS score. The two methods used in this evaluation were Method 1 and Method 5 as they were determined to be the most expedient methods to use in the field (**Figure 5**). Method 1 determines the NBS score by assigning a rating based on the presence of stream features such as transverse bars, central bars, extensive deposition, chute cutoffs, down-valley meander migration, and converging flow. Method 5 uses the ratio of the stream's near-bank max depth at bankfull, and the channels mean depth at bankfull to determine a score which then falls into a rating category. NBS rating categories are similar to BEHI ratings as they are very low, low, moderate, high, very high, and extreme. After the NBS rating is determined, it is plotted against the BEHI score (**Figure 6**) which gives an annual rate of lateral streambank erosion (**Table 1**). The rating curve used in this assessment is based on empirical data collected in Colorado.

Bank erosion and sediment loading is not a linear process in time; most erosion occurs during event-based high flows that are of bankfull size or greater. The Rosgen annual rate of lateral streambank erosion is based on bankfull discharge. Bankfull is the discharge at which the most geomorphic change and sediment transport occurs within a stream over time. It is also the incipient point of flooding when the bankfull stream channel is filled and the stream is at the point of accessing its floodplain (Rosgen, 2006).

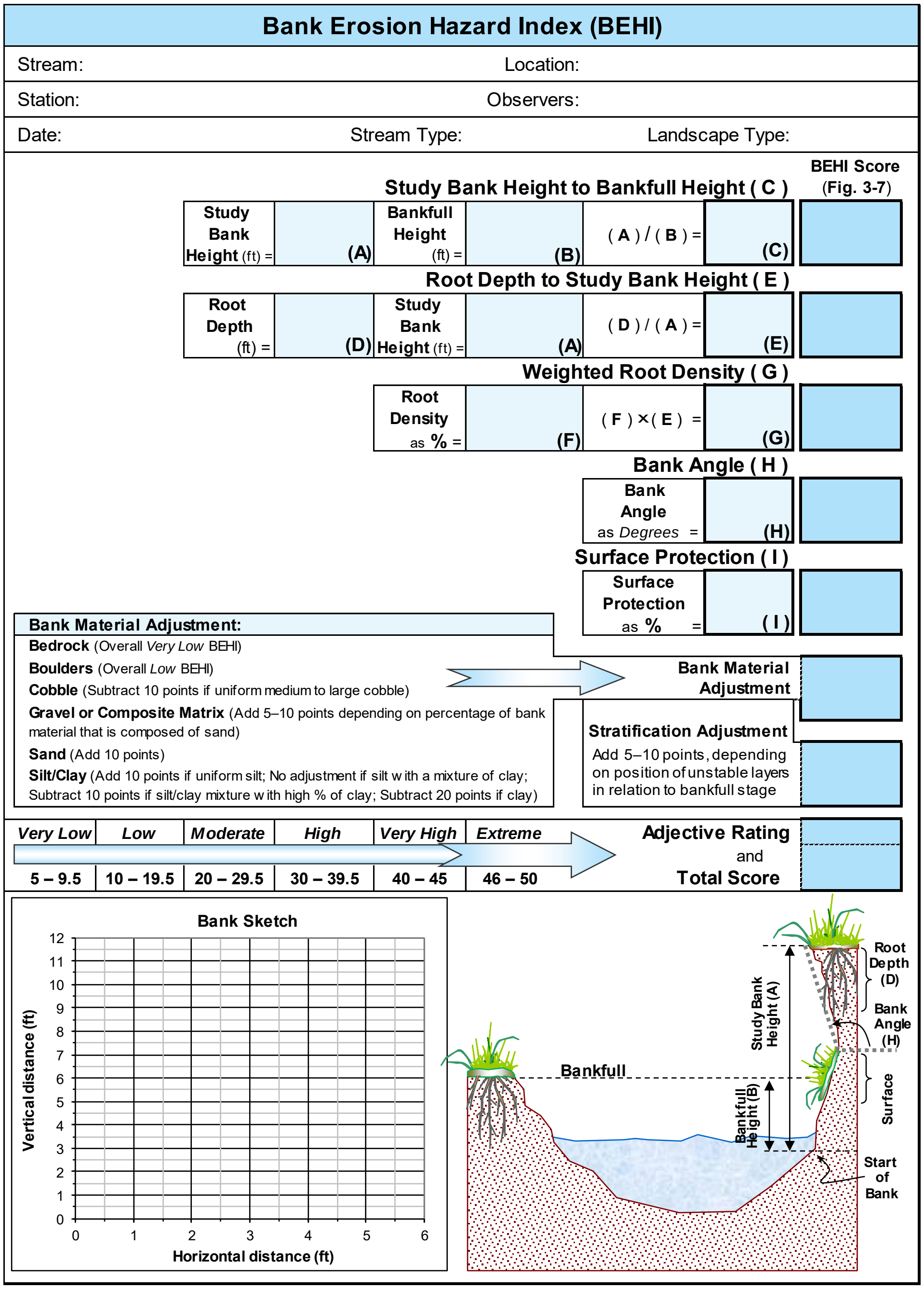


**Figure 3:** Bank erosion variables used to estimate Bank Erosion Hazard Index values and determine a Bank Erosion Hazard Index rating (Rosgen, 2006).

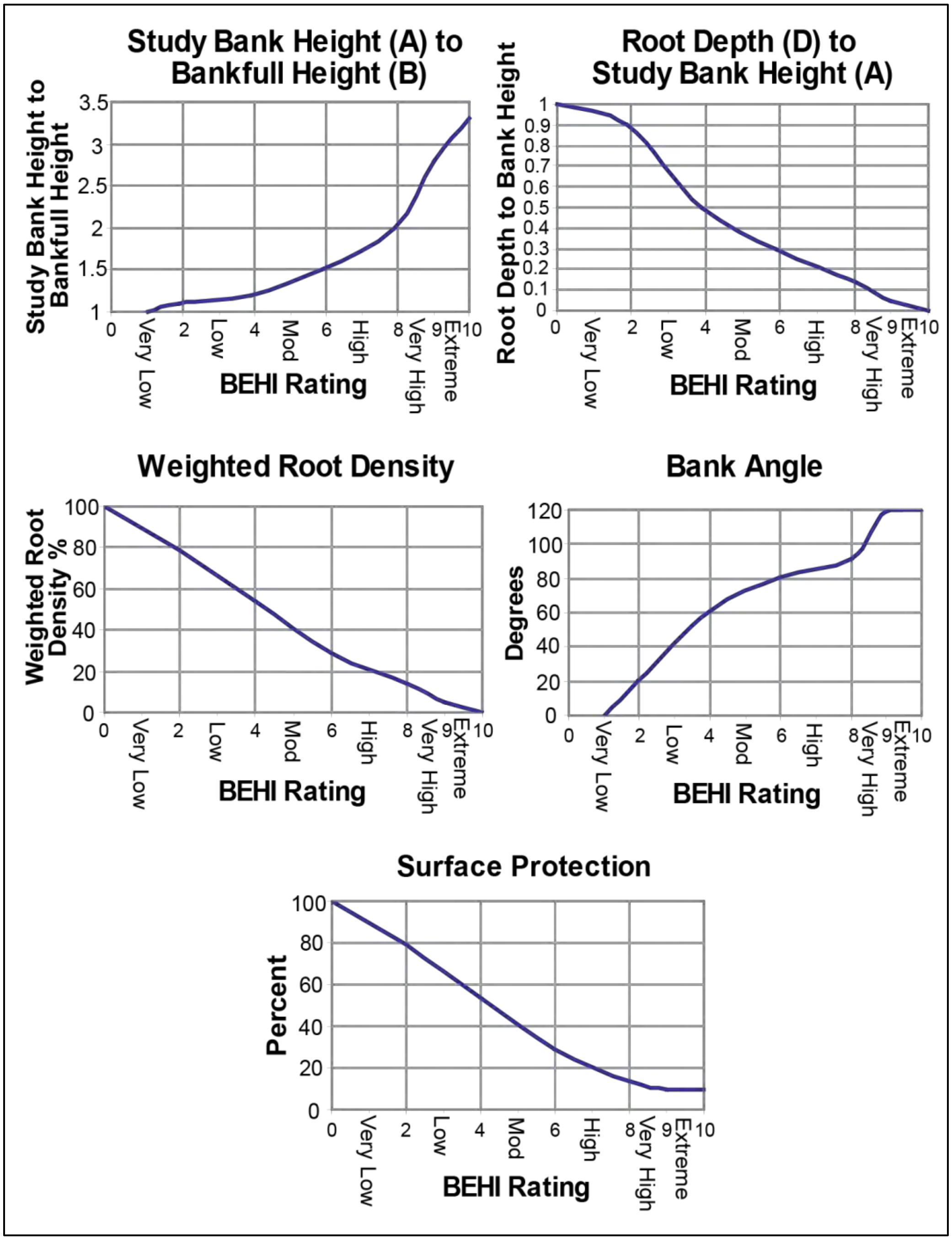


**Figure 4:** Bank Erosion Hazard Index rating conversion graphs used to determine Bank Erosion Hazard Index score for bank erosion variables (Rosgen, 2006).

## Estimating Near-Bank Stress ( NBS )

| | | |
|---|---|---|
| Stream: | Location: | |
| Station: | Stream Type: | Landscape Type: |
| Observers: | | Date: |

### Methods for Estimating Near-Bank Stress (NBS)

| | | | |
|---|---|---|---|
| (1) | Channel pattern, transverse bar, or central bar creating NBS | Level I | Reconaissance |
| (2) | Radius of curvature to bankfull width ( $R_c$ / $W_{bkf}$ ) | Level II | General Prediction |
| (3) | Pool slope to average water surface slope ( $S_p$ / S ) | Level II | General Prediction |
| (4) | Pool slope to riffle slope ( $S_p$ / $S_{rif}$ ) | Level II | General Prediction |
| (5) | Near-bank maximum depth to bankfull mean depth ( $d_{nb}$ / $d_{bkf}$ ) | Level III | Detailed Prediction |
| (6) | Near-bank shear stress to bankfull shear stress ( $\tau_{nb}$ / $\tau_{bkf}$ ) | Level III | Detailed Prediction |
| (7) | Velocity profiles / Isovels / Velocity gradient | Level IV | Validation |

**Level I**

(1)
- Transverse or central bars - short or discontinuous……...……………….....….**NBS = *High / Very High***
- Extensive deposition (continuous, cross-channel)……………...…………... ………....**NBS = *Extreme***
- Chute cutoffs, down-valley meander migration, converging flow……………………..….**NBS = *Extreme***

**Level II**

| (2) | Radius of Curvature $R_c$ (ft) | Bankfull Width $W_{bkf}$ (ft) | *Ratio* $R_c$ / $W_{bkf}$ | **Near-Bank Stress (NBS)** |
|---|---|---|---|---|
| | | | | |

| (3) | Pool Slope $S_p$ | Average Slope S | *Ratio* $S_p$ / S | **Near-Bank Stress (NBS)** |
|---|---|---|---|---|
| | | | | |

| (4) | Pool Slope $S_p$ | Riffle Slope $S_{rif}$ | *Ratio* $S_p$ / $S_{rif}$ | **Near-Bank Stress (NBS)** |
|---|---|---|---|---|
| | | | | |

| **Dominant Near-Bank Stress** |
|---|
| |

**Level III**

| (5) | Near-Bank Max Depth $d_{nb}$ (ft) | Mean Depth $d_{bkf}$ (ft) | *Ratio* $d_{nb}$ / $d_{bkf}$ | **Near-Bank Stress (NBS)** |
|---|---|---|---|---|
| | | | | |

| (6) | Near-Bank Max Depth $d_{nb}$ (ft) | Near-Bank Slope $S_{nb}$ | Near-Bank Shear Stress $\tau_{nb}$ ( lb/ft$^2$ ) | Mean Depth $d_{bkf}$ (ft) | Average Slope S | Bankfull Shear Stress $\tau_{bkf}$ (lb/ft$^2$) | *Ratio* $\tau_{nb}$ / $\tau_{bkf}$ | **Near-Bank Stress (NBS)** |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |

**Level IV**

| (7) | Velocity Gradient ( ft / sec / ft ) | **Near-Bank Stress (NBS)** |
|---|---|---|
| | | |

### Converting Values to a Near-Bank Stress (NBS) Rating

| **Near-Bank Stress (NBS) Ratings** | **Method Number** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** |
| ***Very Low*** | N / A | > 3.00 | < 0.20 | < 0.40 | < 1.00 | < 0.80 | < 0.50 |
| ***Low*** | N / A | 2.21 – 3.00 | 0.20 – 0.40 | 0.41 – 0.60 | 1.00 – 1.50 | 0.80 – 1.05 | 0.50 – 1.00 |
| ***Moderate*** | N / A | 2.01 – 2.20 | 0.41 – 0.60 | 0.61 – 0.80 | 1.51 – 1.80 | 1.06 – 1.14 | 1.01 – 1.60 |
| ***High*** | See | 1.81 – 2.00 | 0.61 – 0.80 | 0.81 – 1.00 | 1.81 – 2.50 | 1.15 – 1.19 | 1.61 – 2.00 |
| ***Very High*** | (1) | 1.50 – 1.80 | 0.81 – 1.00 | 1.01 – 1.20 | 2.51 – 3.00 | 1.20 – 1.60 | 2.01 – 2.40 |
| ***Extreme*** | Above | < 1.50 | > 1.00 | > 1.20 | > 3.00 | > 1.60 | > 2.40 |

| **Overall Near-Bank Stress (NBS) Rating** | |
|---|---|
| | |

**Figure 5:** Methods used to estimate Near-Bank Stress ratings for Bank Assessment for Non-point source Consequences of Sediment model (Rosgen, 2006).

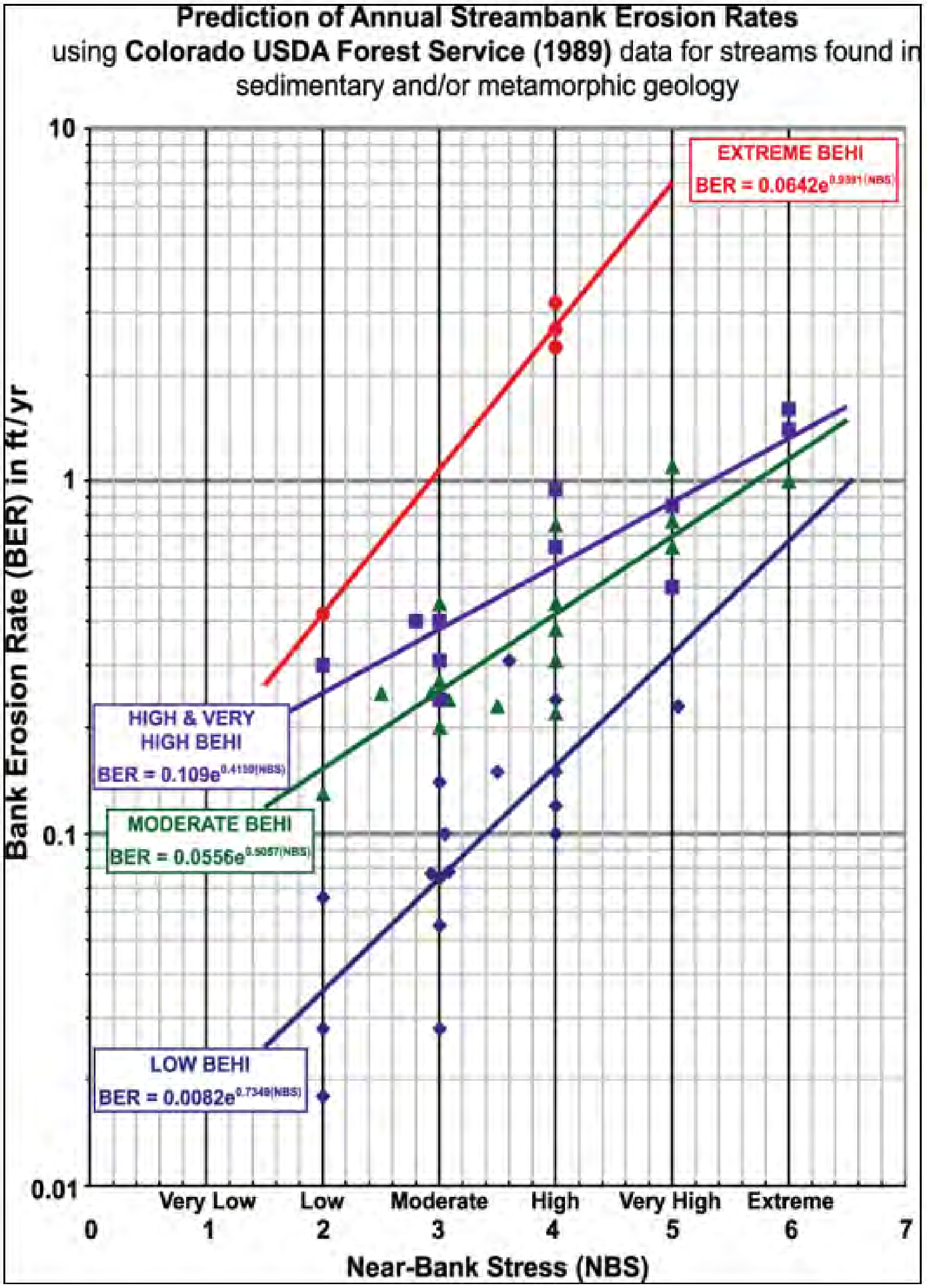


**Figure 6:** Bank Erosion Hazard Index and Near-Bank Stress relationship graph used to estimate the annual rate of lateral streambank erosion (Rosgen, 2006).

**Table 1:** Annual rates of lateral streambank erosion (ft/year) using the Bank Erosion Hazard Index and Near-Bank Stress relationship from Colorado data for streams found in sedimentary or metamorphic geology (Rosgen, 2006).

| | | NBS Rating | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Very low** | **Low** | **Moderate** | **High** | **Very high** | **Extreme** |
| **BEHI Rating** | **Low** | 0.017 | 0.036 | 0.074 | 0.16 | 0.32 | 0.67 |
| | **Moderate** | 0.09 | 0.15 | 0.25 | 0.42 | 0.70 | 1.2 |
| | **High and very high** | 0.17 | 0.25 | 0.38 | 0.58 | 0.87 | 1.3 |
| | **Extreme** | 0.16 | 0.42 | 1.1 | 2.7 | 7.0 | 18.0 |

*Sediment Volume Estimation*

Two methods were used to estimate the volume of eroded sediment for segments of streambank erosion. The first estimation method was used for larger sites of erosion and was achieved by measuring eroded area in ArcGIS. The second estimation method was accomplished by using the BANCS model to estimate erosion rate. If the eroded area could not be measured in ArcGIS due to its small size or obstructed view in the 2016 orthoimagery, the second method using the BANCS model was relied upon to determine the estimated lateral erosion rate. For the first method, once recorded in the field and postprocessed, points were brought into ArcGIS and superimposed on orthoimagery. The retreat of Ouleout Creek's eroding banks was measured in ArcGIS using 2016 orthoimagery overlain by GPS points that recorded the location of Ouleout's eroding streambank extent at the time of assessment. The area measured between the bank extent in 2016 orthoimagery and the bank erosion segments recorded by the GPS unit in the field in 2022 gave the eroded area.

Bank heights were determined in the field by measurement with a stadia rod to the nearest tenth of a foot at each location where a GPS point was taken. The average bank height was then calculated for each bank erosion segment. For a length of erosion with multiple segments, a weighted average bank height was calculated from the smaller segments. **Equation 1** was used to determine the weighted average bank height where weighted average bank height for a complete segment is $\overline{h}$, a partial segment bank height is $h_i$, and partial segment length is $l_i$.

$$\overline{h} = \sum_{i=1}^{n} \mathrm{h}_i l_i / \sum_{i=1}^{n} l_i \qquad \textbf{(Equation 1)}$$

For the larger erosion segments, where the eroded area was measured in ArcGIS, the eroded area multiplied by the weighted average bank height gave the eroded sediment volume estimate. Since the time interval between the 2016 orthoimagery and the 2022 recorded bank points is 6 years, the eroded volume was divided by 6 to reflect the annual eroded volume. The calculation for eroded volume used **Equation 2** where volume of eroded sediment is $V_S$, eroded area measured in ArcGIS is $A_S$, and weighted average bank height for an erosion segment is $\overline{h}$.

$$V_S = (A_S * \overline{h})/6 \qquad \textbf{(Equation 2)}$$

For the remaining erosion segments, the BANCS lateral erosion rate multiplied by the bank length and weighted bank height gave an estimated annual volume of eroded sediment. The BANCS lateral erosion rates were not divided by 6, due to the fact that the BANCS rate of lateral erosion is an annual rate of erosion. Therefore, eroded volume is reflective of erosion on an annual basis. This was calculated using **Equation 3** where eroded bank length is $l_s$ and BANCS lateral erosion rate is $B_S$.

$$V_S = l_S * \overline{h} * B_S \qquad \textbf{(Equation 3)}$$

*Soil Sampling and Nutrient Concentrations*

In order to determine the mass of nutrients eroded along the Ouleout, the eroding streambanks were sampled for nutrient concentrations, specifically total phosphorus (TP) and total nitrogen (TN). Because it was not feasible to sample every eroding streambank along the Ouleout, representative samples were taken. To accurately capture differences in the nutrient concentrations in the hundreds of eroding streambank segments along the Ouleout, the eroding banks were classified into different categories depending on their land cover and their soil type, with the categories being called land cover-soil categories. It was expected that nutrient concentrations would vary based on these parameters.

The National Land Cover Database (NLCD) 2019 land use/land cover data was used to determine a bank erosion segment's land cover type. The NRCS soil survey of Delaware County, New York was used to determine the soil map unit of each eroding bank. Eroding banks that fell into multiple categories were either divided into individual segments or corrected to one land cover-soil category if no noticeable differences in the soil type or land cover were determined. Banks that were clearly incorrectly classified were changed to their correct land cover-soil category based on field observations. The NLCD land cover data contains multiple different classes. In order to make the assessment more feasible, land cover was further generalized into five categories instead of the numerous categories of land cover given by the NLCD land cover data. This was possible because it was assumed there is no difference between some of the classes for the purpose of this assessment; i.e.: Mixed Forest and Deciduous Forest are both grouped as forest. The five categories used for this assessment were Forest, Field, Cropland, Herbaceous Wetland, and Developed Land. The land cover generalization and grouping can be viewed in **Appendix 2**.

In addition to sampling each distinct land cover-soil category of erosion once, several sites of substantial erosion were also sampled to obtain more precise nutrient concentrations for these larger sites. Sites of substantial erosion were locations of streambank erosion that were estimated to have eroded the greatest volume of sediment on an annual basis. When sampling a site of substantial erosion, each different land cover-soil category at the erosion site was sampled. The collected soil samples from a segment of substantial erosion, on some occasions, also served as the representative sample for their respective land cover-soil category. When a land cover-soil category was sampled more than once, an average of the nutrient values was used as the representative nutrient concentration value for BANCS assessed erosion segments.

The segments of erosion sampled along the Ouleout were chosen because they were an adequate representation of their respective land cover-soil category; length, height, exposure, accessibility, and confidence in correct classification were considered when selecting the specific sampling site. At each location, a subsample of the soil profile was collected every 50 ft along the eroding bank segment. Samples were not differentiated between topsoil and subsoil because of a prior study that showed no significant difference between topsoil and subsoil nutrient concentrations in streambank soils (Coryat et al., 2021). The bank-face was scraped clean to expose a raw bank and remove any possible weathered or recently deposited material from the bank. Subsamples of the soil were then thoroughly mixed to create a composite sample. Rocks, roots, leaf litter, and other debris were removed from the composite sample. The composite samples were then placed in a 200mL jar and analyzed by Adirondack Environmental Services Inc. (AES) in Albany, NY. TP concentrations were tested using the Standard Method 4500-P-E. TN concentrations were tested using the SW-846 method for nitrate and nitrite and Standard Method 5600-N-C for total Kjeldahl nitrogen.

*Bulk Density and Particle Size Analysis*

Bulk density and particle size for each segment of erosion was determined using the NRCS Web Soil Survey (WSS). In order to have more precise values when determining the bulk density, bulk density was distinguished by the soil type and bank height in each reach. Since bulk density often varies with depth, the median eroding bank height of the reach was used for the depth value in determining the bulk density on WSS. The median height of the eroding banks in each reach were used instead of the mean height so that the value was not skewed by the taller hillslope failures in a reach. Using bulk density, sediment volume can be converted to a mass using **Equation 4**, where mass of sediment is $M_S$, and bulk density is $\rho_B$.

$$M_S = \rho_B * V_S \qquad \textbf{(Equation 4)}$$

Particle size analysis values from WSS were used to determine the percentage of sediment that composed the fine-earth fraction, or the fraction less than 2mm in size, of each eroding bank. The fine-earth fraction is used in calculations because it is assumed that all of the nutrients in a soil are present in or adsorbed to particles of sediment 2mm in size and smaller. This ensures eroded nutrient masses are not overestimated by the inclusion of rock fragments that have little impact on nutrient loads. When retrieving particle size information off of WSS, the fine-earth fraction was distinguished by the soil type and bank height in each reach. The median bank heights of the soil types in each reach were, again, used as the depth value on WSS. In addition, the representative value of fine-earth fraction from WSS was used instead of the low or high estimate so as to have a more accurate value when calculating the mass of fine-earth fraction for each eroding bank. **Equation 5** was used for calculating the fraction of soil that is fine-earth, where mass of fine-earth fraction is $M_F$ and fine-earth fraction is $F_E$.

$$M_F = M_S * F_E \qquad \textbf{(Equation 5)}$$

*Nutrient Load Estimation*

Once the eroded masses of sediment were calculated and the nutrient concentrations were determined, the eroded TP mass and the eroded TN mass were estimated for each erosion segment. **Equation 6** was used to estimate the eroded TP mass from an erosion site with eroded TP mass being $M_{TP}$ and concentration of TP being $C_{TP}$. **Equation 7** was used to estimate the eroded TN mass from an erosion site with eroded TN mass being $M_{TN}$ and concentration of TN being $C_{TN}$.

$$M_{TP} = C_{TP} * M_F \qquad \textbf{(Equation 6)}$$

$$M_{TN} = C_{TN} * M_F \qquad \textbf{(Equation 7)}$$

*Discharge*

The BANCS model is based on bankfull discharge and is used to assess the current condition of an erosion segment in order to predict its future erosion rate. Bankfull is the stage at which the stream channel is at the incipient point of flooding and also the discharge at which the stream channel forms and maintains its dimensions (Rosgen, 2006). Geomorphic change and sediment transport occur within the stream during bankfull discharge (Leopold et al., 1964). In addition, it is thought that the greatest amount of work performed over time in the stream channel is accomplished by the bankfull discharge. Because of this, it is important to note how many bankfull discharge events occurred on the Ouleout during the study period. The sites of substantial erosion were measured as the difference between the 2016 orthoimagery bank extents and the 2022 GPS recorded bank segments. The bankfull and greater events that occurred during this time period likely caused the majority of the erosion at these sites.

Ouleout Creek does not have a USGS monitoring gage above East Sidney Lake. Therefore; there was no direct way to measure the discharge in the assessed area of the Ouleout above East Sidney Lake. Because of this, a comparable local watershed with a USGS streamflow gage was used to estimate discharge on the Ouleout. The Little Delaware River Basin was used because it contains USGS Gage 01422500, is of comparable size and orientation on the landscape, is located ~16 miles from Ouleout Creek, and is in the same hydrologic region as the Ouleout Creek Watershed. Recent evidence has shown that an area-ratio relationship can be used to model daily discharges of ungaged basins in the Catskill region (Gianfagna, 2012). As such, the Little Delaware gage discharges were scaled by the Little Delaware-Ouleout area-ratio in order to model Ouleout discharges.

Since bankfull discharge is a range and not a precise number, any flow within 10% of the given bankfull value was considered a bankfull event for this assessment. Peak instantaneous discharge on the Little Delaware was used to determine the estimated peak discharge on the Ouleout using **Equation 8** where $Q_{LD}$ is the discharge of the Little Delaware, $DA_{LD}$ is the drainage area of the Little Delaware, $Q_O$ is discharge of the Ouleout, and $DA_O$ is the drainage area of the Ouleout.

$$Q_{LD}/DA_{LD} = Q_O/DA_O \qquad \textbf{(Equation 8)}$$

The recurrence interval of flood discharges was determined for the Little Delaware using the Log Pearson type III flood frequency analysis. The estimated bankfull discharge of the Little Delaware was 1290 cfs (USGS, 2022).

In addition to discharge, other factors such as sinuosity, valley slope, bankfull discharge, bankfull area, bankfull width, bankfull depth, and the 100-year recurrence interval discharge are important characteristics to note when attempting to assess a stream and its watershed. Sinuosity and valley slope were determined for each reach using GIS analysis. Bankfull discharge, bankfull area, bankfull width, bankfull depth, and the 100-year recurrence interval discharge were determined for each reach using the USGS's online tool "Streamstats."

*Riparian Forest Buffer Analysis*

Riparian forest buffers along stream corridors are beneficial for a variety of reasons. They help protect streambanks from erosion by anchoring soil in place with roots, filter out nutrients from entering the stream channel, reduce the severity of flooding, moderate stream temperatures, and provide refuge and habitat for aquatic organisms. Riparian buffers are also ecological hotspots and wildlife corridors for terrestrial organisms. Previous studies suggest buffer width should be at least 30 meters along each bank to achieve maximum benefit (Sweeney et al., 2014). Areas of insufficient buffer width are also more susceptible to streambank erosion.

ArcGIS was used to conduct an analysis of the streamside land cover of each reach in order to determine locations of insufficient buffer width, possible sites of streambank erosion, and potential areas for future riparian forest buffer planting projects. The Chesapeake Bay Program (CBP) land use/land cover data was used as it has a higher resolution (1-meter) than the NLCD data (30-meter). This higher resolution helped increase precision when distinguishing riparian buffer width. Like the NLCD data used for determining land cover categories for soil sampling, the CBP land cover data was also generalized from its numerous categories to the five categories used for this assessment (**Appendix 3**). The five categories used for this assessment were Forest, Field, Cropland, Herbaceous Wetland, and Developed Land.

*Macroinvertebrate Sampling*

Macroinvertebrate sampling is a common method used to assess the water quality of a stream. Macroinvertebrate species vary in their tolerance of water quality conditions. Some can survive in almost any conditions while others require exceptional water quality. Ephemeroptera, Plecoptera, and Trichoptera macroinvertebrate orders are of the latter group and the Ephemeroptera, Plecoptera, and Trichoptera Index (EPT Index) is a common water quality analysis. As a result, the EPT index gives a score based on the percentage of Ephemeroptera, Plecoptera, and Trichoptera orders in a sample. The higher the percentage of these species in a sample the higher the water quality of the stream. Macroinvertebrates were sampled by DCSWCD in a riffle using a kick net near STA 452+00 ft. The order of each specimen collected was determined and an EPT index score was then calculated.

## *Limitations*

### *Accuracy and Precision*

This assessment was limited by the accuracy and precision of the tools used. Many values used in this assessment are estimates, meaning actual values and conditions in the field could differ or vary over time. When recording a point with the GPS unit, even at its highest precision, the point could plot several inches from its actual location. If a point was recorded with obstructions, such as tree cover or in close proximity to the valley wall, points occasionally plotted several feet off from their actual location. This error was mitigated by noting the location of where a point was taken in the field so if a point plotted incorrectly it could be adjusted to its correct location in ArcGIS.

### *Significant figures*

The eroded volumes and masses estimated in this study all have two significant figures. This is due to the fact that bank heights and lengths measured in the field had two significant figures. By reporting final values with two significant figures we ensure that the precisions of our estimates are no greater than that of our least precise measurements.

### *Bank Assessment for Non-point source Consequences of Sediment Model*

The BANCS model was used to estimate the annual rate of lateral streambank erosion, which gives a specific value for the rate of erosion for an eroding bank. The actual erosion rate of each bank may vary from the BANCS rate assigned to it. To mitigate this error, streambank erosional areas were measured in ArcGIS when possible. The BANCS model is based on a data set from the Colorado USDA Forest Service. Work is underway to verify that local erosion rates are comparable to the BANCS erosion rates used in this assessment.

### *Soil Survey*

Soil survey maps are only accurate to a certain degree and soils can vary spatially from what is shown on a soil map due to the scale of soil surveys in a region, microtopography within the landscape, and the fact that soil map units are heterogeneous and can vary spatially.

For the bulk density and the fraction of fine-earth sediment, the values used were the given values on WSS; the actual values of the eroding banks may have varied in the field. It was not feasible to determine the bulk density value and conduct a particle size analysis for each erosion segment in the field. However, sites where the bulk density and fine-earth fraction were clearly incorrectly classified were noted. To mitigate error based on soil depth, eroding bank heights were used when determining bulk density and fine-earth fraction on WSS.

Bulk density values may have also varied within each soil type as bulk density is not a uniform value among all soils within a map unit. Agricultural practices such as tillage often alter and compact soils at intensively farmed sites. Likewise, fine-earth fraction may have varied in the field compared to the values derived from WSS. WSS does give a high, representative, and low value of fine-earth fraction for each soil map unit. For this assessment the representative value from WSS was used for each soil map unit.

*Discharge and Hydraulic Geometry*

The Ouleout upstream of East Sidney Lake does not contain a stream gage. Because of this, peak discharge had to be estimated using the stream gage on the Little Delaware River. Peak discharge may have varied from the estimated values for the Ouleout due to localized differences during precipitation events. However, the method used to estimate peak streamflow for the Ouleout should be close to the actual peak discharge on the Ouleout and was sufficient enough for the purpose of this assessment.

The given values from Streamstats were used for the bankfull dimensions and flow statistics listed in the “Reach Specific Assessments and Recommendations” section of the report. Bankfull dimensions and conditions may vary in the field from the values given on Streamstats due to differences in land cover, runoff, the backwater effect near East Sidney Lake, and various other factors. To mitigate this error, bankfull dimensions were measured in the field and bankfull features were also periodically measured to confirm the accuracy of the given bankfull dimensions from Streamstats.

*Land Cover*

The land cover data used in this assessment can incorrectly classify different sections of land. The NLCD land cover data used to classify streambanks into land cover-soil categories had 30-meter resolution which means that large areas of land are generalized into one land cover category. Therefore, each eroding bank segment was checked to confirm the accuracy of its land cover classification and changed to the correct category when there was an obvious error. The CBP land cover, though containing superior 1-meter resolution, can incorrectly classify areas of land as well. Since it was not feasible to confirm and manually reclass the land cover for every land cover pixel in the watershed, the buffer analysis was not verified to the same level of detail as the eroding streambank segments.

## Stream Assessment Results

*Streambank Erosion*

Streambank erosion was extensive throughout Ouleout Creek. There were 1,547 eroding bank points composing 597 eroding bank segments recorded along the assessed portion of the Ouleout. In total, 19.1 miles of Ouleout Creek was assessed during the SFI, of which 10 miles out of 39.8 miles of assessed streambank was recorded as eroding. This equates to 26% of the streambank eroding along the assessed portion of Ouleout Creek.

Reach 2 had the greatest length of erosion with 4,202 ft of streambank eroding. Reach 14 had the second greatest length of erosion with 3,936 ft of streambank eroding. Reach 7 had the third greatest length of erosion with 3,747 ft of streambank eroding. Reach 1 had the lowest total length of eroding streambank at 595 ft. Reach 21 had the second lowest length of eroding streambank at 944 ft. Reach 13 had the third lowest length of eroding streambank at 1,155 ft (**Figure 7**).

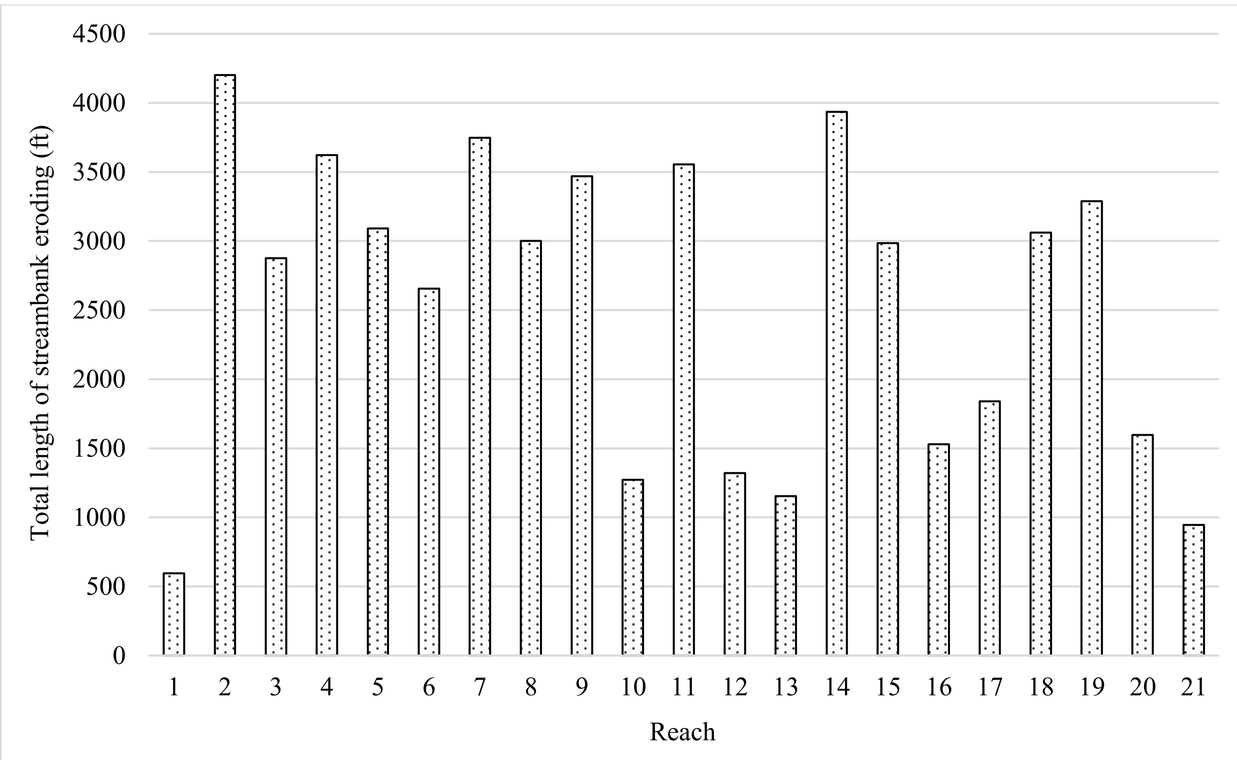


**Figure 7:** Eroding streambank length (ft) by reach along Ouleout Creek.

Reaches 1, 3, and 6 had the highest percentage of eroding streambanks. Reach 6 was the highest with 44% of streambanks eroding in the reach. Reaches 1 and 3 had the second highest with 43% of streambanks eroding in each reach. Reach 21 had the lowest percentage with 15% of the streambanks eroding in the reach. Reaches 9, 12, and 18 had the second lowest percentage with 17% of streambanks eroding in each reach (**Figure 8**).

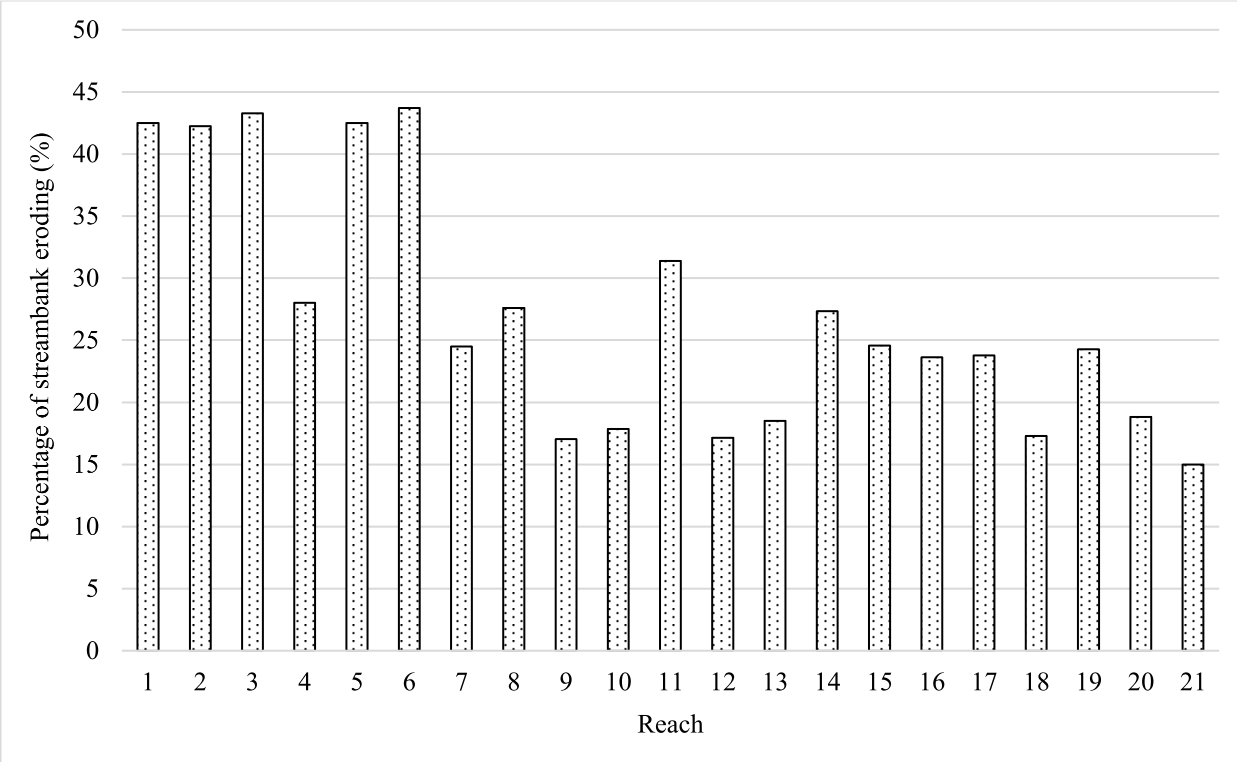


**Figure 8:** Percentage of streambank eroding by reach along Ouleout Creek.

As expected, the BANCS model ratings varied greatly amongst the eroding banks along Ouleout Creek. The majority of erosion segments scored a Low or Moderate rating in either the BEHI or NBS category but there were several segments of erosion that scored in the more severe BANCS ratings (**Table 2**).

**Table 2:** Number of erosion segments that scored in each Bank Assessment for Non-point source Consequences of Sediment model category.

| | | NBS Rating | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Very low** | **Low** | **Moderate** | **High** | **Very high** | **Extreme** |
| **BEHI Rating** | **Very low** | 0 | 0 | 1 | 2 | 0 | 0 |
| | **Low** | 14 | 101 | 10 | 19 | 0 | 0 |
| | **Moderate** | 22 | 249 | 39 | 39 | 1 | 8 |
| | **High** | 2 | 33 | 12 | 14 | 1 | 14 |
| | **Very high** | 0 | 4 | 2 | 1 | 0 | 9 |
| | **Extreme** | 0 | 0 | 0 | 0 | 0 | 0 |

In total, 5,500 $yd^3$ of sediment is estimated to erode annually from the streambanks along the assessed length of Ouleout Creek. In terms of eroded volume, reaches 2, 4, and 14 are estimated to load the greatest amount of sediment annually. Reach 4 is estimated to erode the greatest volume of sediment with 1,100 $yd^3$, annually. Reach 2 is estimated to erode the second greatest volume of sediment with 720 $yd^3$, annually. Reach 14 is estimated to erode the third greatest volume of sediment with 550 $yd^3$, annually. These reaches should be targeted for streambank restoration projects if total sediment loads are sought to be reduced. Reach 3 is estimated to erode the lowest volume of sediment with 47 $yd^3$, annually. Reach 13 is estimated to erode the second lowest volume of sediment with 52 $yd^3$, annually. Reach 17 is estimated to erode the third lowest volume of sediment with 59 $yd^3$, annually (**Figure 9**).

Several sites of substantial streambank erosion accounted for a large percentage of the total volume of eroded sediment from streambanks. Many sites of substantial erosion were along fields lacking a sufficient riparian forest buffer. These sites are discussed in detail in the "Reach Specific Assessments and Recommendations" section of the report.

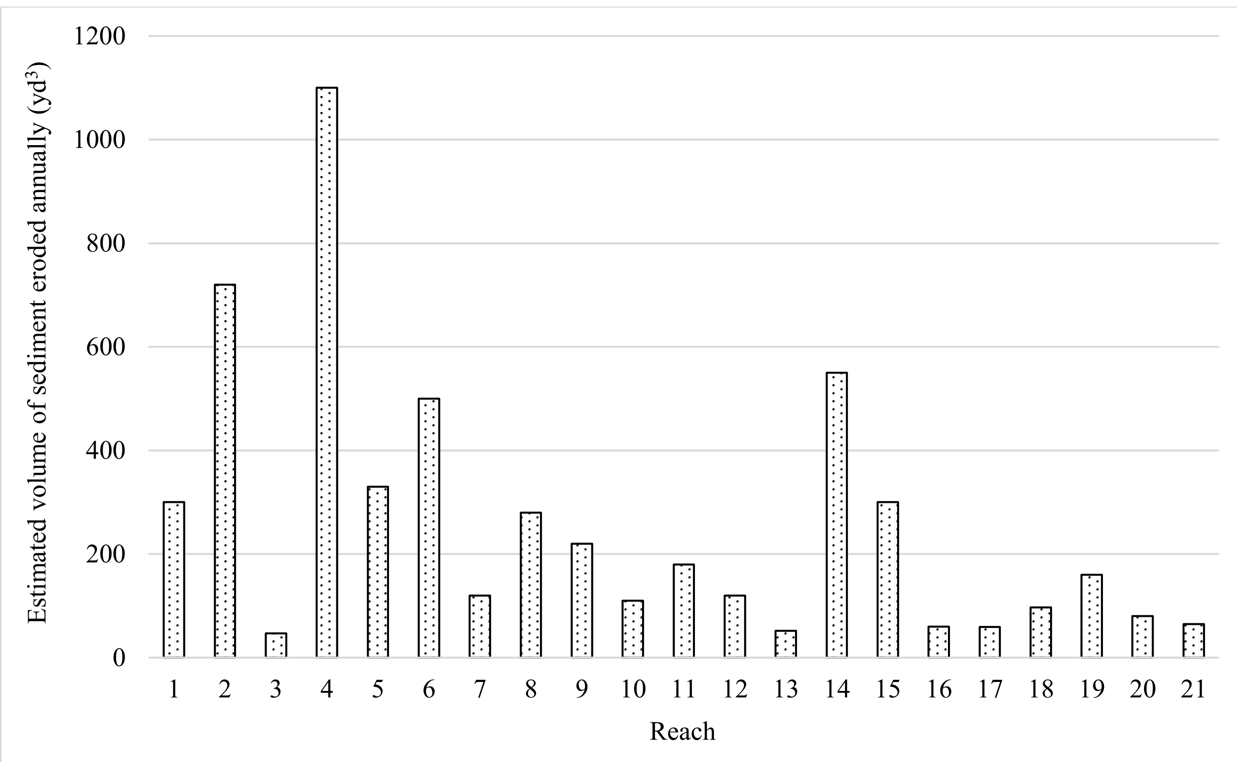


**Figure 9:** Estimated volume of sediment ($yd^3$) eroded annually by reach along Ouleout Creek due to streambank erosion.

*Soil Sampling and Nutrient Concentrations*

Five different land cover types and twelve different soil map units were present at eroding banks along the Ouleout. When combined, there were 27 distinct classes of land cover-soil categories for these eroding banks. Thirty-seven composite soil samples were collected in order to accurately represent these distinct land cover-soil categories. TN concentrations ranged from 789 mg/kg to 3,110 mg/kg and TP concentrations ranged from 86.8 mg/kg to 965 mg/kg. The average TN and TP concentrations by land cover-soil category can be viewed in **Table 3**.

**Table 3:** Average nutrient concentrations of each land cover-soil category along Ouleout Creek.

| Land cover-soil category | TN (mg/kg) | TP (mg/kg) | n |
|---|---|---|---|
| Barbour-field | 1392 | 538 | 6 |
| Barbour-forest | 1565 | 389 | 2 |
| Barbour-cropland | 2085 | 939 | 1 |
| Barbour-herbaceous wetland | 979 | 284 | 1 |
| Basher-field | 1137 | 511 | 3 |
| Basher-forest | 1520 | 639 | 1 |
| Basher-cropland | 1260 | 196 | 1 |
| Basher-herbaceous wetland | 1205 | 678 | 2 |
| Barbour-Trestle-field | 2290 | 570 | 1 |
| Barbour-Trestle-forest | 3110 | 275 | 1 |
| Barbour-Trestle-cropland | 951 | 429 | 1 |
| Barbour-Trestle-herbaceous wetland | 794 | 600 | 1 |
| Fluvaquent-Udifluvent-field | 1025 | 359 | 2 |
| Fluvaquent-Udifluvent-forest | 1340 | 246 | 1 |
| Fluvaquent-Udifluvent-herbaceous wetland | 1650 | 288 | 1 |
| Lackawanna-forest | 1340 | 112 | 1 |
| Lewbath-developed | 1510 | 544 | 1 |
| Lewbath-forest | 1270 | 263 | 1 |
| Lewbeach-Lewbath-forest | 1050 | 250 | 1 |
| Lewbeach-Lewbath-herbaceous wetland | 1300 | 304 | 1 |
| Maplecrest-field | 1190 | 86.8 | 1 |
| Maplecrest-forest | 1690 | 127 | 1 |
| Tunkhannock-forest | 1070 | 239 | 1 |
| Tunkhannock-Chenango-field | 789 | 267 | 1 |
| Tunkhannock-Chenango-forest | 1710 | 559 | 1 |
| Wellsboro-forest | 1150 | 413 | 1 |
| Willowemoc-developed | 2440 | 756 | 1 |

*Bulk Density and Fine-Earth Fraction*

The WSS bulk density values of the Ouleout soils ranged from 1.31 $g/cm^3$ in the Barbour-Trestle complex in Reach 21 to 1.54 $g/cm^3$ in the Lackawanna flaggy silt loam in Reach 18. Soils within the floodplain generally had a lower bulk density whereas soils along hillslopes had a higher bulk density. For more detailed information regarding the bulk density values in each reach see **Appendix 4**.

The WSS fine-earth fraction of sediment for the Ouleout soils ranged from 0.347 in the Tunkhannock-Chenango soils in Reach 2 to 1.00 in the Basher silt loam soils along the Ouleout. Soils within the floodplain generally contained a higher fraction of fine-earth whereas soils along hillslopes had a lower fraction of fine-earth. For more detailed information regarding the fine-earth fraction of sediment in each reach see **Appendix 5**.

*Nutrient Load Estimation*

In total, 3,900 lb of TP is estimated to erode annually from the streambanks along the assessed portion of Ouleout Creek. Reach 2 is estimated to load the greatest amount of TP with 720 lb, annually. Reach 4 is estimated to load the second greatest amount of TP with 640 lb, annually. Reach 1 is estimated to load the third greatest amount of TP with 460 lb, annually. These reaches should be targeted for restoration and stabilization projects in order to reduce TP loads. Reach 16 is estimated to load the lowest amount of TP with 16 lb, annually. Reach 13 is estimated to load the second lowest amount of TP with 19 lb, annually. Reach 12 is estimated to load the third lowest amount of TP with 22 lb, annually (**Figure 10**).

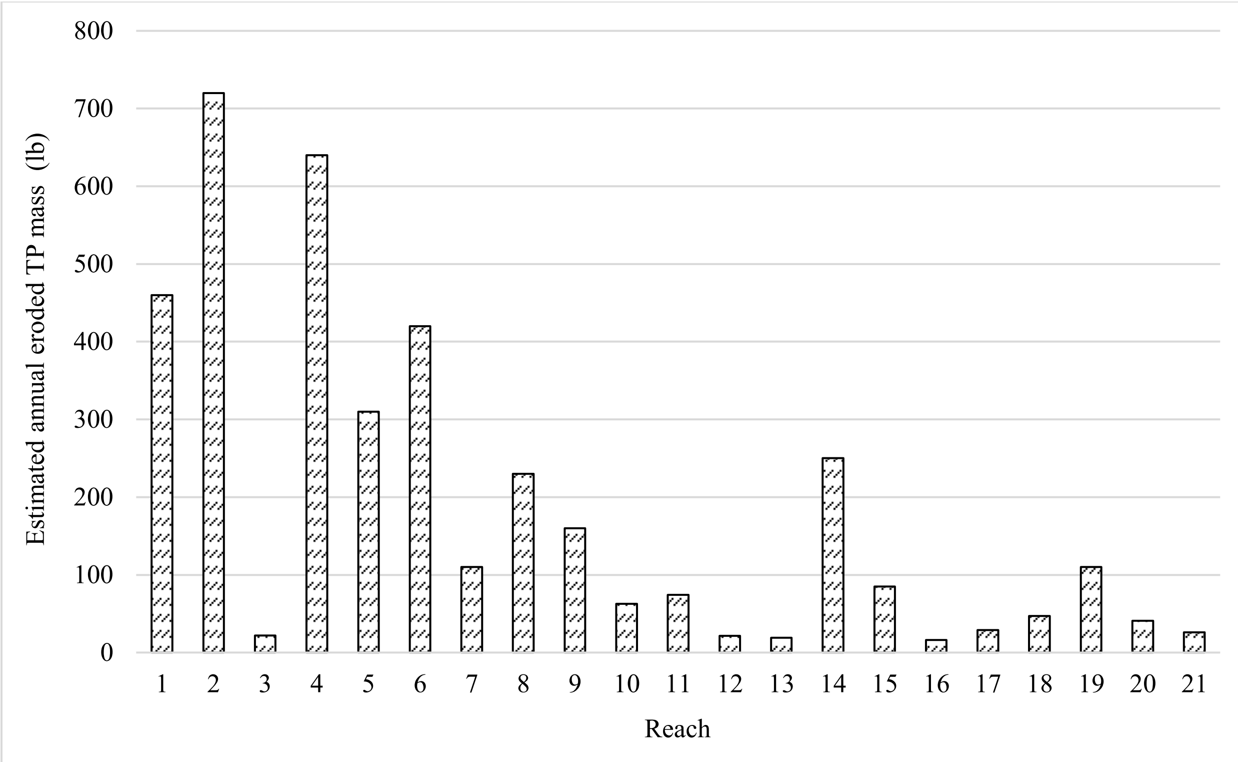


**Figure 10:** Estimated mass of TP loaded annually by reach along Ouleout Creek due to streambank erosion.

In total, 11,000 lb of TN is estimated to erode annually from the streambanks along the assessed length of Ouleout Creek. Reach 4 is estimated to load the greatest amount of TN with 1,700 lb, annually. Reach 2 is estimated to load the second greatest amount of TN with 1,400 lb, annually. Reach 14 is estimated to load the third greatest amount of TN with 1,200 lb, annually. These reaches should be targeted for restoration and stabilization projects if TN load reduction is sought. Reach 3 is estimated to load the lowest amount of TN with 99 lb, annually. Reach 13 is estimated to load the second lowest amount of TN with 110 lb, annually. Reach 17 is estimated to load the third lowest amount of TN with 120 lb, annually (**Figure 11**).

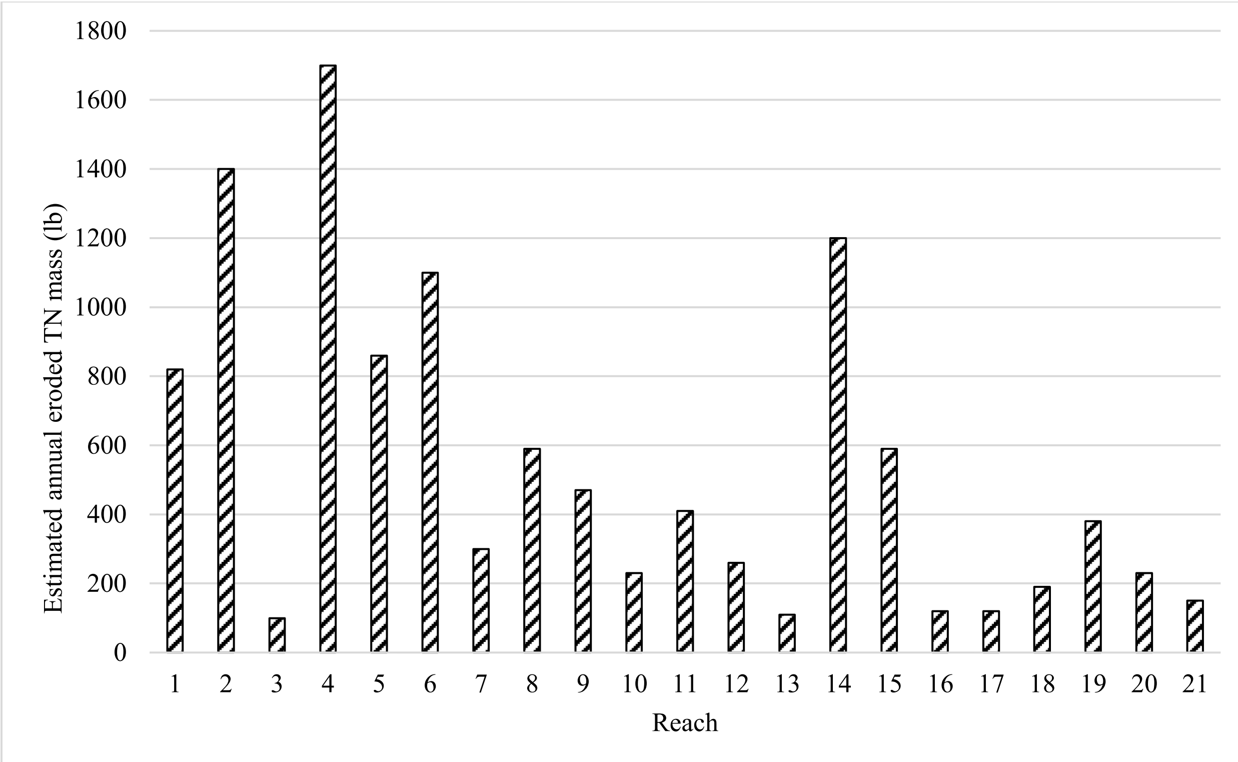


**Figure 11:** Estimated mass of TN loaded annually by reach along Ouleout Creek due to streambank erosion.

As discussed in the Methodology section of the report, calculations for the volume of eroded sediment were based on two separate estimation methods. The eroded volumes of larger sites of erosion were calculated using bank heights measured in the field and GPS points superimposed on orthoimagery in ArcGIS. Whereas the eroded volume of smaller erosion segments were calculated using bank heights measured in the field, bank erosion segments recorded in the field, and the BANCS annual rate of streambank retreat. The ArcGIS derived bank erosion segments accounted for 3,100 lb of TP loaded annually which is 81% of the TP eroded from assessed streambanks along the Ouleout main stem. The BANCS derived bank erosion segments accounted for 750 lb of TP loaded annually which is 19% of the TP eroded from assessed streambanks along the Ouleout main stem. The ArcGIS derived bank erosion segments accounted for 8,300 lb of TN loaded annually which is 73% of the TN eroded from assessed streambanks along the Ouleout main stem. The BANCS derived bank erosion segments accounted for 3,100 lb of TN loaded annually which is 27% of the TN eroded from assessed streambanks along the Ouleout main stem. The larger sites of erosion measured in ArcGIS are clearly responsible for a disproportionate amount of nutrients loaded annually to the Ouleout.

As discussed in the "Basin Characteristics" section of the report, there have been previous studies of phosphorus loading in the Ouleout Creek Watershed. The USACE study of East Sidney Lake estimated TP loading of the Lake from internal and external sources. This estimation was based upon direct measurements of TP values in water samples taken from East Sidney Lake, Ouleout Creek, and Handsome Brook from 1987 to 1988. The estimated external

TP load that was being delivered annually to East Sidney Lake during the USACE study period was approximately 7,736 lb of TP. The external TP load estimate by USACE includes the Ouleout Creek and Handsome Brook watersheds.

The Chesapeake Bay Assessment Scenario Tool (CAST) is used to model nutrient loads entering the Chesapeake Bay. The CAST estimate uses several variables based on land cover, land use practices, BMPs installed, and other factors to estimate the annual nutrient and sediment loads for a given watershed. For the Ouleout Creek Watershed upstream of East Sidney Lake, CAST estimated that approximately 18,314 lb of TP was loaded into the Ouleout Creek edge of stream in 2022 (NYSDEC, 2023). The edge of stream load is defined as the amount of TP that is estimated to enter a waterbody. The CAST estimate includes the Ouleout Creek and Handsome Brook watersheds.

This particular assessment only accounts for streambank erosion along the main stem of the Ouleout above East Sidney Lake and it is a certainty that there are other sources of erosion in the Ouleout's tributaries as well as non-bank erosion sources of nutrients and sediment that are not accounted for. Based on the Ouleout Creek assessment, it is estimated that 3,900 lb of TP is loaded annually from streambanks along the assessed portion of Ouleout Creek. If the entire estimated TP load from the Ouleout Creek assessment reaches East Sidney Lake, this eroded TP would account for 50% of the input of total TP into the Lake based on USACE estimates. The estimated TP load from the Ouleout Creek assessment would account for 20% of the CAST TP load entering East Sidney Lake. This demonstrates that the resource in direct contact with the stream, the streambank sediment, is a substantial contributor to the in-stream TP load in the Ouleout Creek Watershed.

The mass of nutrients loaded varied greatly between each reach. For example, Reach 2 is estimated to load 19% of the total eroded TP from streambanks along the assessed portion of Ouleout Creek, whereas Reach 16 is estimated to load only 0.42% of the total eroded TP. In order to more precisely determine the sources of nutrients, specific erosion sites responsible for a disproportionately high quantities of nutrients and sediment were identified. These locations were called sites of substantial erosion and 19 sites in total were identified along the main stem of Ouleout Creek. These 19 sites of substantial erosion were estimated to account for 76% of all TP eroded from streambanks along Ouleout Creek (**Figure 12**), 66% of all eroded TN (**Figure 13**), and 69% of all eroded volume of sediment (**Figure 14**). Photos of each site of substantial erosion can be viewed in **Appendix 6**.

In order to determine which sites of substantial erosion to prioritize for remediation along the Ouleout, the sites were ranked by their mass of TP eroded annually. Additionally, **Table 4** contains each site's estimated mass of TN eroded annually and estimated volume of sediment eroded annually as well as where each site ranked for the categories. The prioritization of sites for remediation and stabilization is simplified due to the fact that a relatively small number of sites account for a disproportionately large amount of the sediment and nutrients being loaded. Remediation recommendations for each site of substantial erosion identified are included in the "Reach Specific Assessments and Recommendations" section of the report. These recommendations are based on natural channel design methods found in Part 654 Stream

Restoration Design of the USDA NRCS National Engineering Handbook and DCSWCD's best knowledge of streambank stabilization techniques.

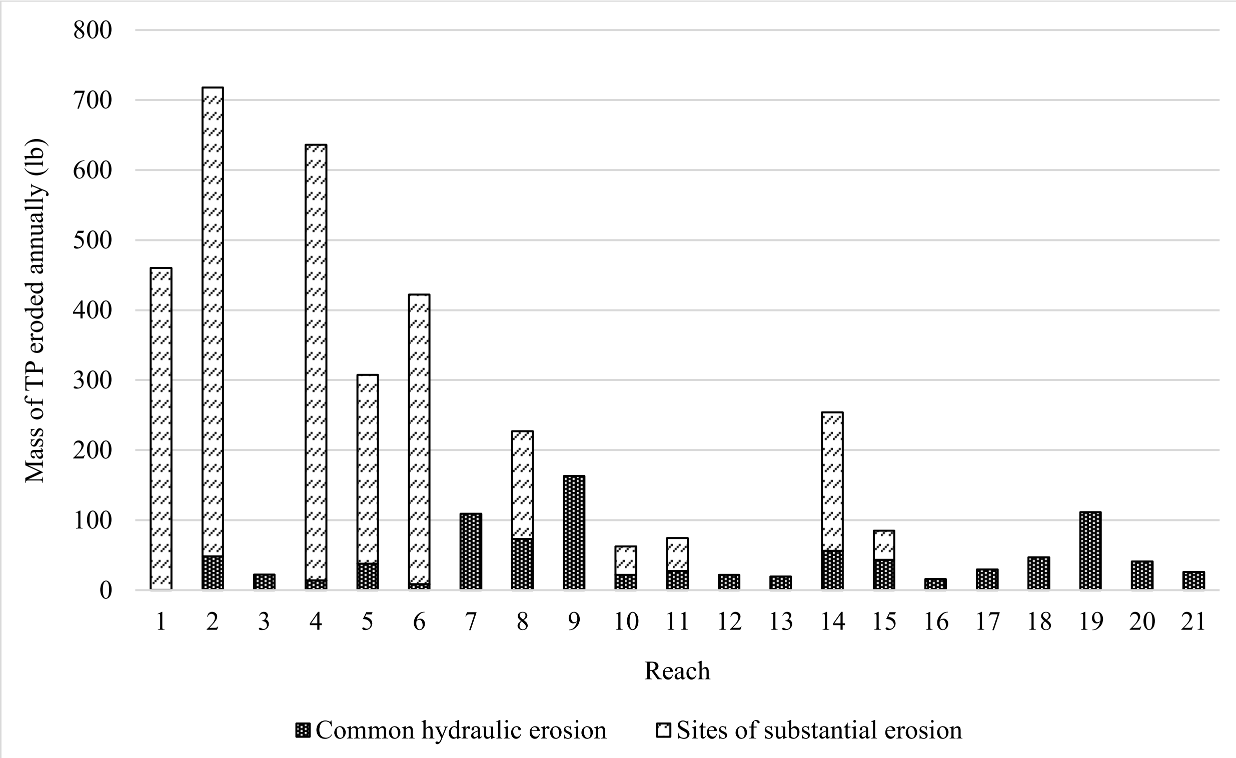


**Figure 12:** Annual eroded mass of TP by reach distinguished by sites of substantial erosion and common hydraulic erosion.

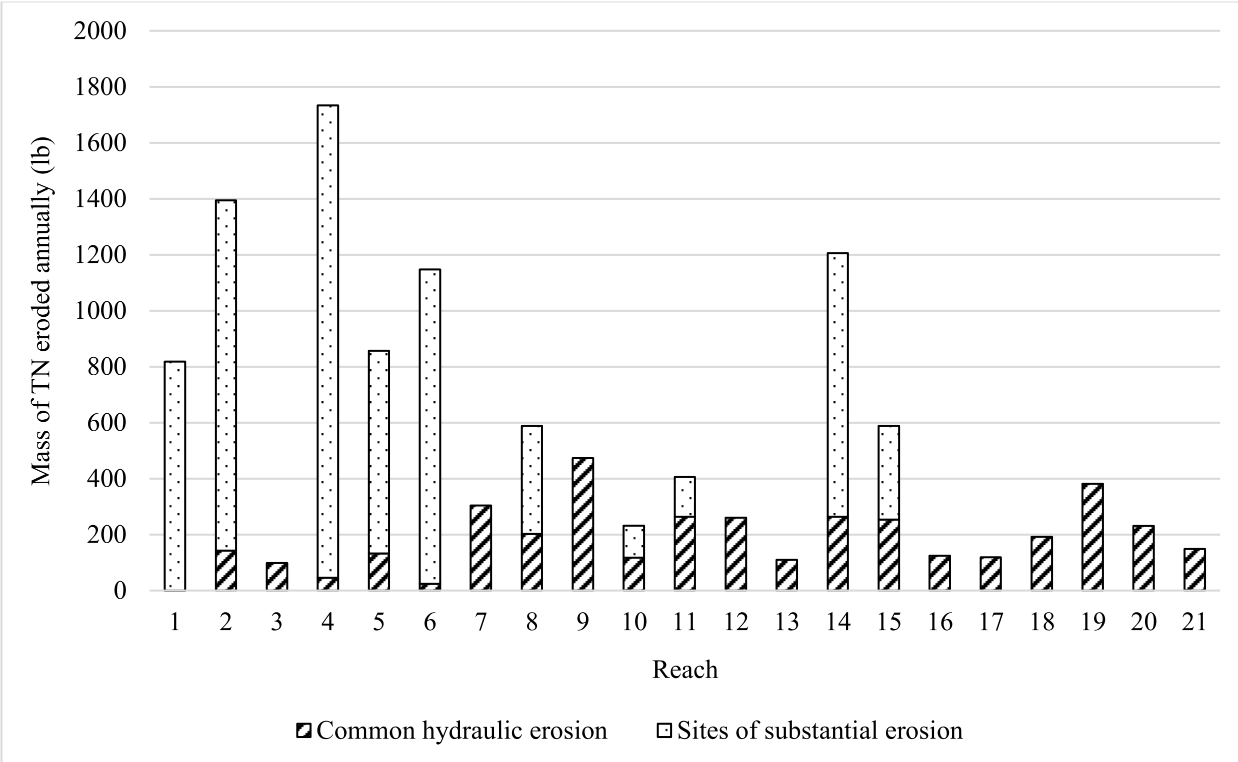


**Figure 13:** Annual eroded mass of TN by reach distinguished by sites of substantial erosion and common hydraulic erosion.

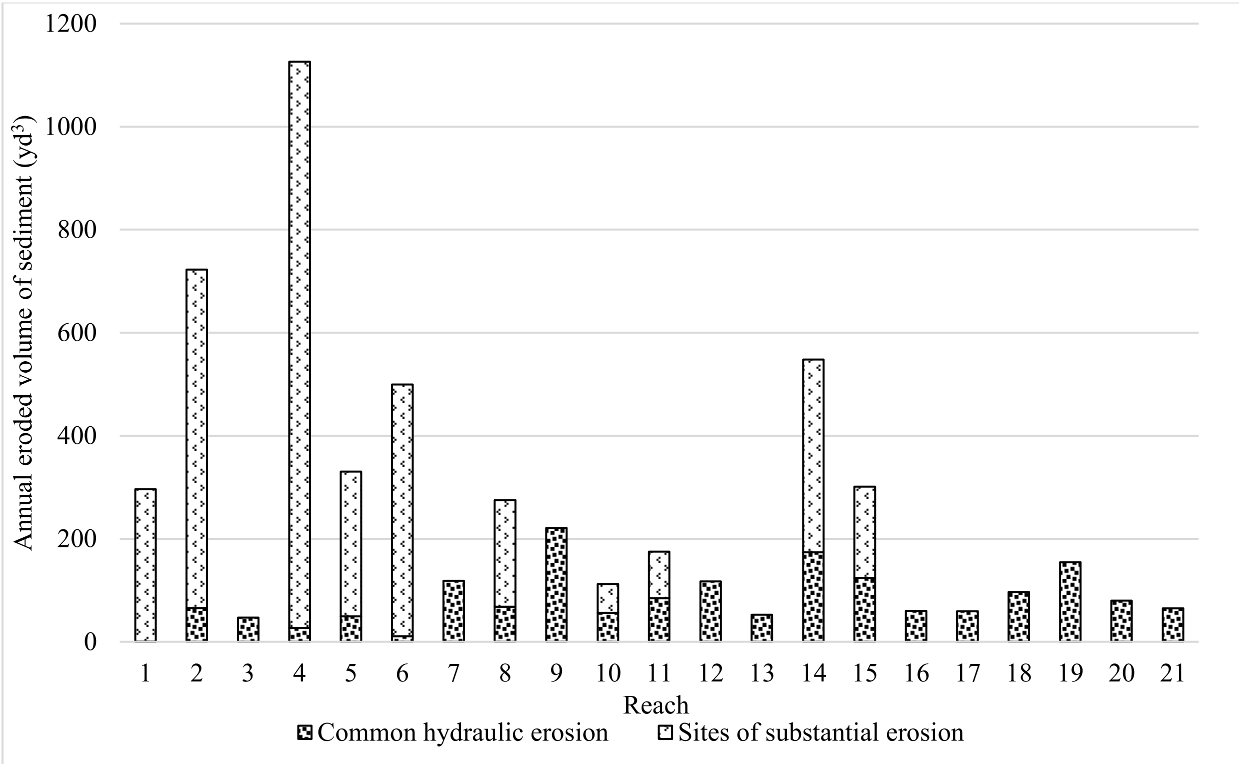


**Figure 14:** Annual eroded volume of sediment ($yd^3$) by reach distinguished by sites of substantial erosion and common hydraulic erosion.

**Table 4:** Estimated annual eroded TP mass, eroded TN mass, and eroded volume of sediment for sites of substantial erosion along Ouleout Creek prioritized by eroded TP mass.

| Prioritization | Site ID | Reach | Estimated Annual Eroded TP (lb) | Eroded TP Rank | Estimated Annual Eroded TN (lb) | Eroded TN Rank | Estimated Annual Eroded Volume ($yd^3$) | Eroded Volume Rank |
|---|---|---|---|---|---|---|---|---|
| **1** | 2-a | 2 | 480 | 1 | 900 | 2 | 430 | 2 |
| **2** | 4-b | 4 | 440 | 2 | 1200 | 1 | 860 | 1 |
| **3** | 6-b | 6 | 280 | 3 | 740 | 3 | 300 | 3 |
| **4** | 1-b | 1 | 260 | 4 | 460 | 6 | 170 | 8 |
| **5** | 1-a | 1 | 200 | 5 | 360 | 9 | 130 | 11 |
| **6** | 2-b | 2 | 190 | 6 | 350 | 10 | 220 | 6 |
| **7** | 4-a | 4 | 190 | 7 | 510 | 5 | 240 | 5 |
| **8** | 6-a | 6 | 130 | 8 | 390 | 8 | 190 | 7 |
| **9** | 14-b | 14 | 130 | 9 | 720 | 4 | 280 | 4 |
| **10** | 5-a | 5 | 120 | 10 | 220 | 13 | 80 | 15 |
| **11** | 5-b | 5 | 110 | 11 | 410 | 7 | 160 | 9 |
| **12** | 8-b | 8 | 91 | 12 | 240 | 11 | 160 | 10 |
| **13** | 14-a | 14 | 72 | 13 | 220 | 12 | 130 | 12 |
| **14** | 8-a | 8 | 63 | 14 | 150 | 16 | 52 | 18 |
| **15** | 11-a | 11 | 47 | 15 | 140 | 17 | 90 | 14 |
| **16** | 10-a | 10 | 41 | 16 | 110 | 18 | 56 | 17 |
| **17** | 5-c | 5 | 37 | 17 | 97 | 19 | 43 | 19 |
| **18** | 15-a | 15 | 31 | 18 | 180 | 14 | 70 | 16 |
| **19** | 15-b | 15 | 11 | 19 | 160 | 15 | 110 | 13 |

*Discharge*

There were 14 probable bankfull or greater events on the Ouleout between 2016 and 2022. These events likely caused a substantial amount of the erosion within the stream channel between the 2016-2022-time interval. A table of the probable bankfull or greater events on the Ouleout, along with their corresponding recurrence interval, can be viewed in **Table 5**. Peak discharge was estimated for Ouleout Creek's confluence with East Sidney Lake excluding Handsome Brook.

**Table 5:** Estimated probable bankfull or greater events on Ouleout Creek between 2016 and 2022.

| Date | Estimated peak discharge for Ouleout Creek at the confluence with East Sidney Lake (cfs) | Recurrence interval (years) |
|---|---|---|
| 4/6/17 | 2590 | 1.5 |
| 10/30/17 | 3970 | 4.1 |
| 8/17/18 | 2330 | 1.3 |
| 1/24/19 | 3260 | 2.3 |
| 4/15/19 | 2360 | 1.3 |
| 5/20/19 | 2080 | 1.2 |
| 10/17/19 | 1910 | 1.1 |
| 11/1/19 | 2950 | 1.9 |
| 8/4/20 | 1960 | 1.2 |
| 12/25/20 | 3670 | 2.9 |
| 7/12/21 | 4030 | 4.3 |
| 9/23/21 | 3770 | 3.5 |
| 10/26/21 | 1910 | 1.1 |
| 4/8/22 | 3420 | 2.6 |

*Excessive Sediment Depositions*

Excessive sediment depositions were recorded when they were features such as center bars, transverse bars, full channel bars, or side bars and point bars of excessive size or unusual characteristics. These features often indicate instability within the stream channel or a disruption in sediment equilibrium. In total, there were 159 excessive depositional features recorded along the Ouleout. This equates to 8.3 excessive depositions per mile. This density is similar to that of other densities from streams assessed by DCSWCD that are considered to have a large number of instabilities.

The reaches with the greatest number of excessive depositions recorded were reaches 14, 17, and 19. Reach 14 was the greatest with 17 excessive depositions recorded. Reach 19 was second with 15 excessive depositions recorded. Reach 17 was third with 12 excessive depositions recorded. The reaches with the lowest number of excessive depositions recorded were reaches 1, 2, 3, 5 and 6. Reach 2 was the lowest with 3 depositions recorded. Reaches 1, 3, 5, and 6 were the second lowest with 4 depositions recorded in each reach. (**Figure 15**).

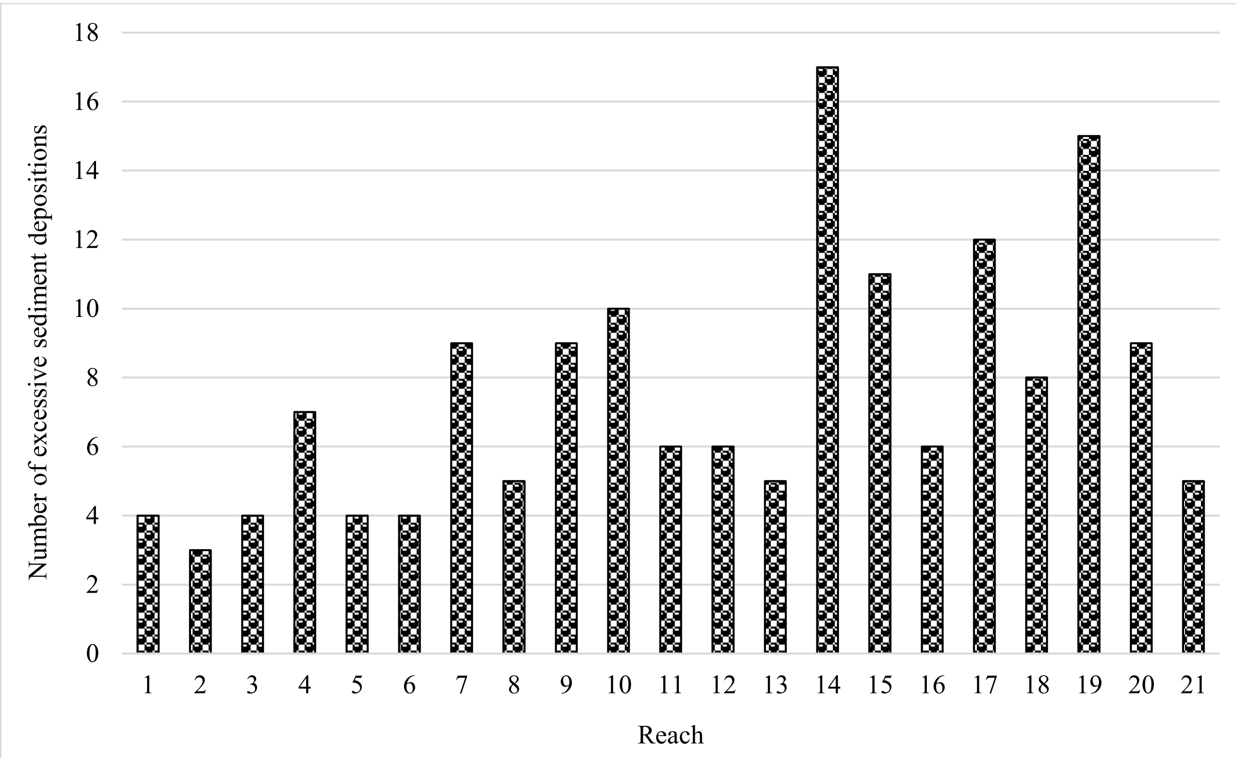


**Figure 15:** Excessive sediment depositions recorded by reach along Ouleout Creek.

Reaches 1, 10, and 17 had the greatest densities of excessive sediment depositions recorded. Reach 1 had the greatest density of excessive depositions with 30 depositions/mile. Reach 17 had the second highest density of excessive depositions with 16 depositions/mile. Reach 10 had the third highest density of excessive depositions with 15 depositions/mile. The reaches with the lowest density of excessive depositions were reaches 2, 8, and 9. Reach 2 had the lowest density with 3.2 depositions/mile. Reach 9 had the second lowest density with 4.8 depositions/mile. Reach 8 had the third lowest density with 4.9 depositions/mile (**Figure 16**). Several excessive depositions recorded were aggrading point bars opposite sites of substantial erosion. Notable areas of excessive deposition are discussed in more detail in the "Reach Specific Assessments and Recommendations" section of the report.

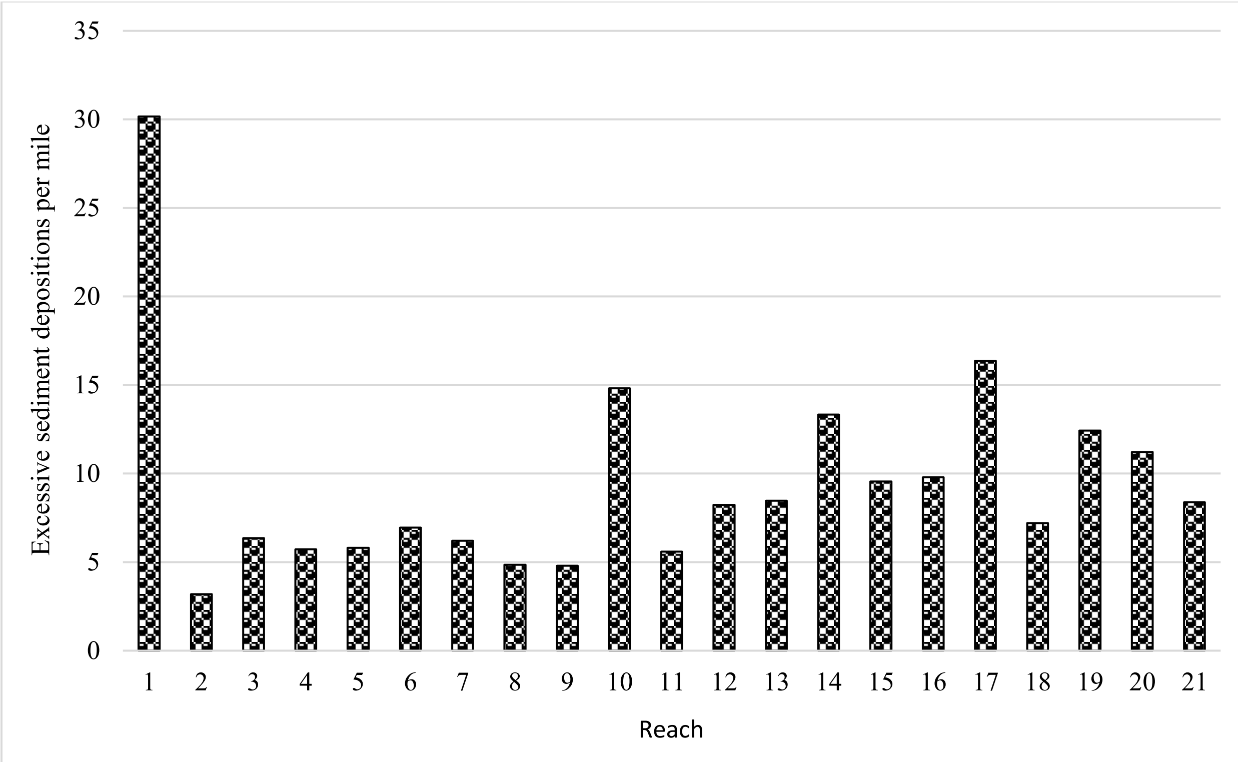


**Figure 16:** Density of excessive sediment depositions by reach along Ouleout Creek.

*Headcuts*

Headcuts are a major instability that lowers the elevation of the streambed causing streambed and streambank erosion. Since headcuts are a major instability, they are a threat to streambanks, as well as structures such as culverts, bridges, and revetments. Headcuts were present in the upper reaches of the Ouleout where there is a steeper gradient in the stream channel. In total, 11 headcuts were recorded along the Ouleout. Headcuts were present in reaches 14, 16, 18, 19, 20, and 21 (**Figure 17**). Each headcut is discussed in more detail in its corresponding "Reach Specific Assessments and Recommendations" section of the report.

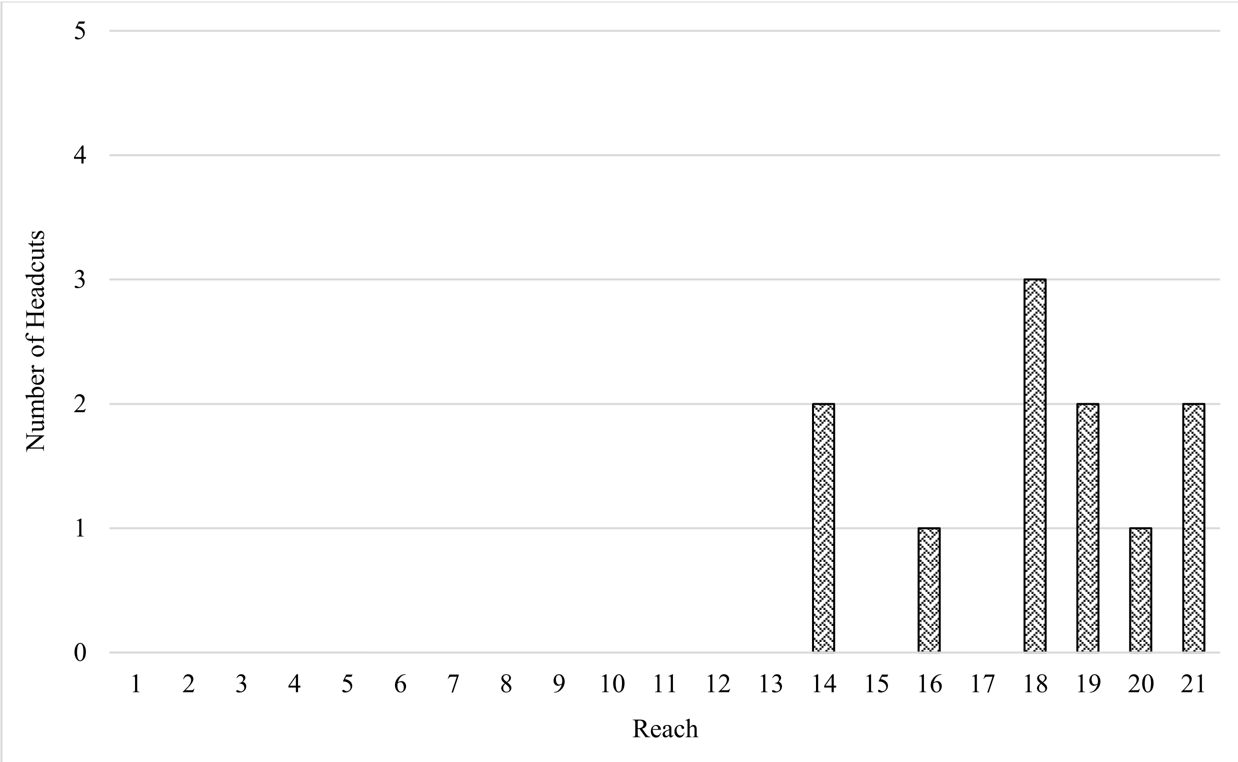


**Figure 17:** Number of headcuts recorded by reach along Ouleout Creek.

*Large Woody Debris*

Large woody debris was recorded as a point when it had a diameter at breast height greater than 0.5 ft and a length of 10 ft or greater. Large woody debris was also documented if it was an accumulation of debris that obstructed flow in over a third of the channel.

As previously noted, large woody debris can be a substantial driver of change within a fluvial system. However, not every piece of large woody debris is of concern. Only pieces that pose a threat to infrastructure or stream stability should be targeted to be cut into smaller pieces so that they can be transported downstream without causing any obstructions. Pieces of large woody debris that are causing erosion, scour, or blockages in the stream channel should also be cut into smaller sizes. Pieces of large wood that are having no impact or a positive impact on the stream channel should be left in their current state.

In total, there were 183 large woody debris points recorded along the Ouleout during the SFI. The number of large wood debris points increased heading upstream in the Ouleout. The increase in large wood in the upstream reaches can be attributed to the following reasons: there is a higher percentage of forested area along the upper half of the Ouleout and the channel is smaller in size and streamflow making it more difficult for large wood to be transported. There is also more contact of the stream with the valley margins in the upper sections of the Ouleout and therefore more hillslope failures contributing large woody debris.

The reaches with the greatest number of large woody debris points were reaches 18, 19, and 20. Reach 18 and 19 were tied for the greatest number of points with 21 large woody debris points recorded in each reach. Reach 20 was third with 17 large woody debris points recorded. The reaches with the lowest number of large woody debris points were reaches 1, 2, 5, and 21 with 2 large woody debris points recorded in each of these reaches (**Figure 18**).

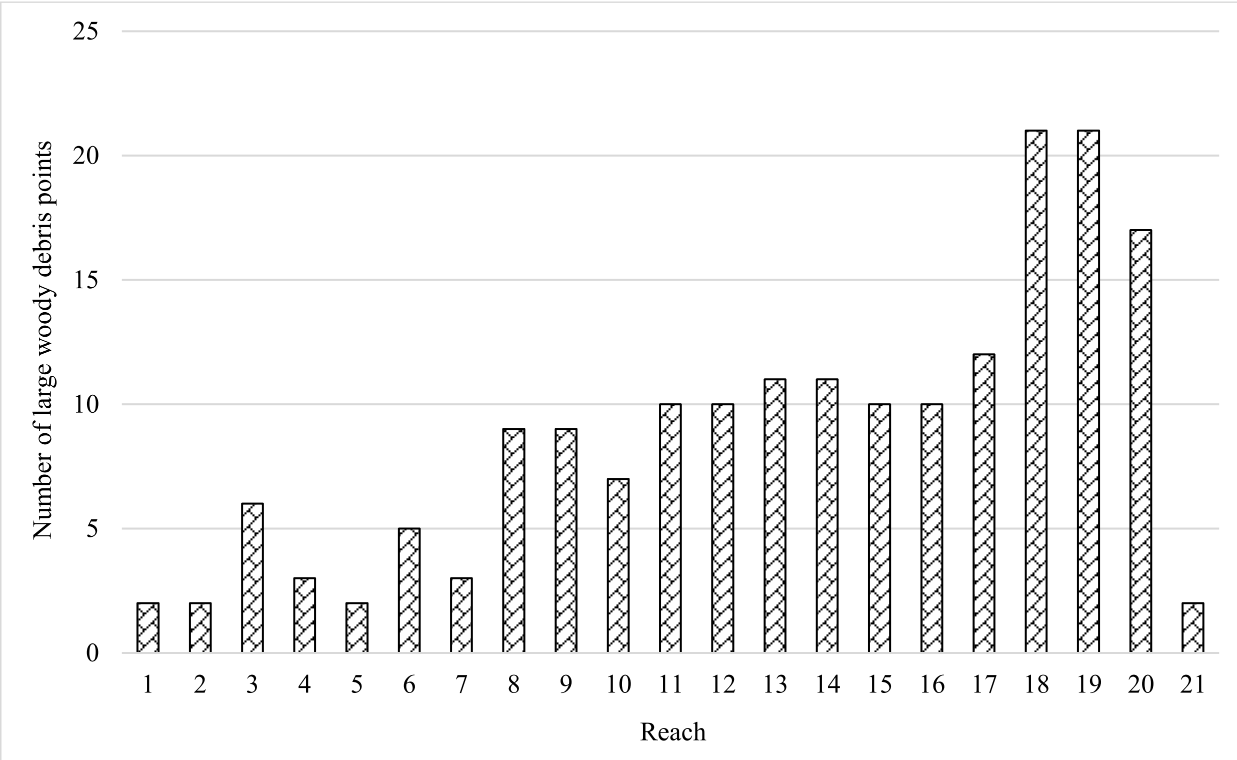


**Figure 18:** Large woody debris points recorded by reach along Ouleout Creek.

Reaches 13, 18, and 20 had the highest densities of large woody debris. Reach 20 had the highest density with 21 points per mile. Reaches 13 and 18 had the second highest densities with 19 points per mile. The reaches with the lowest densities of large woody debris points were reaches 2, 4, and 7. Reaches 2 and 7 had the lowest densities 2.1 points per mile. Reach 4 had the third lowest density with 2.5 points per mile (**Figure 19**). Not all recorded pieces of large woody debris are considered problematic. Large wood accumulations that could be of concern are further discussed in the “Reach Specific Assessments and Recommendations” section of the report.

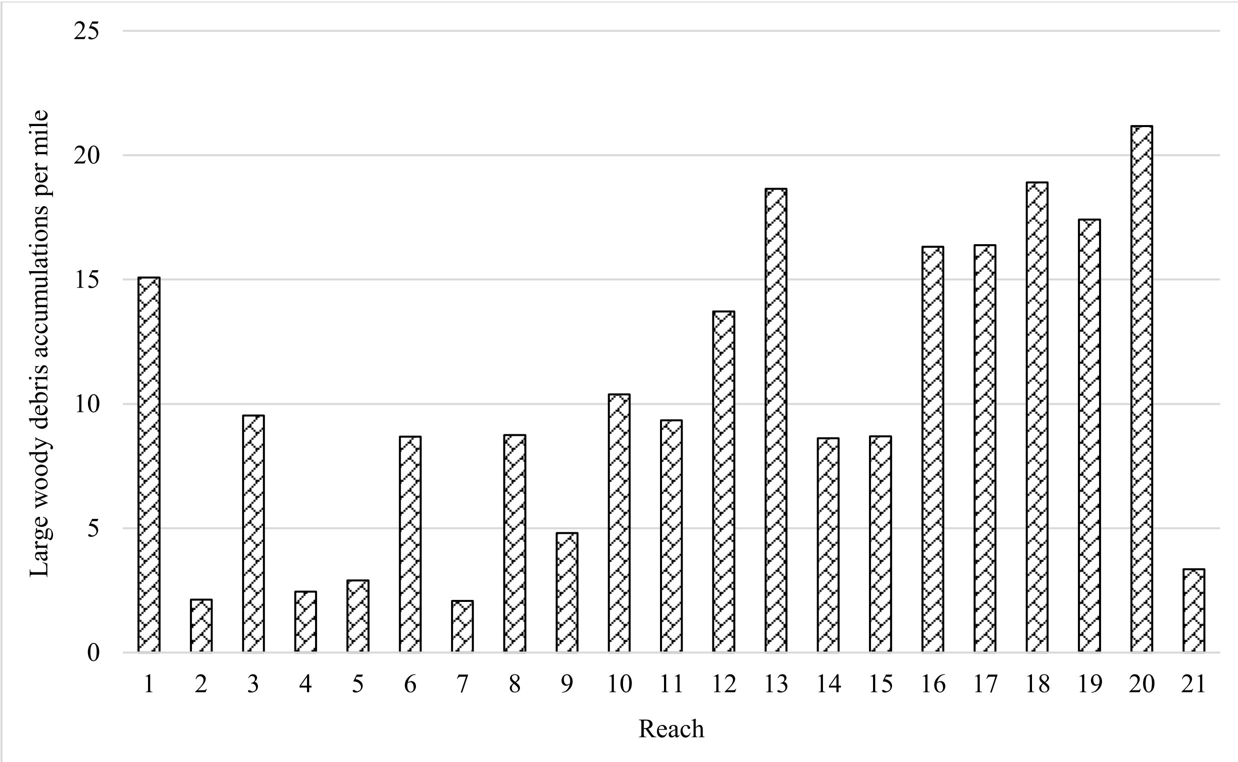


**Figure 19:** Large woody debris density by reach along Ouleout Creek.

*Revetment*

The revetments along the Ouleout exist in a variety of forms and in varying conditions. The majority of the revetments were clustered around bridges, stream crossings, previous stream stabilization projects, and agricultural fields. Unlike many of the streams within Delaware County, the majority of reaches along the Ouleout did not contain a substantial amount of revetments along the streambanks. This is likely due to the fact that the Ouleout, for the most part, does not flow in close proximity to any buildings or roads for a substantial length. Whereas for a large number of streams in Delaware County, buildings and roads are adjacent to the stream channel or on its corresponding floodplain.

In total, 3.8% of the assessed length of the Ouleout was reveted, with the revetments totaling a length of 7,895 ft. Reach 9, which contains two recent streambank stabilization projects, had by far the greatest length of revetments with 3,712 ft. Reach 8 had the second greatest length of revetments with 811 ft. Reach 7 had the third greatest length of revetment with 745 ft. Reaches that contained no revetments were reaches 1, 2, 3, 5, 12, and 16 (**Figure 20**).

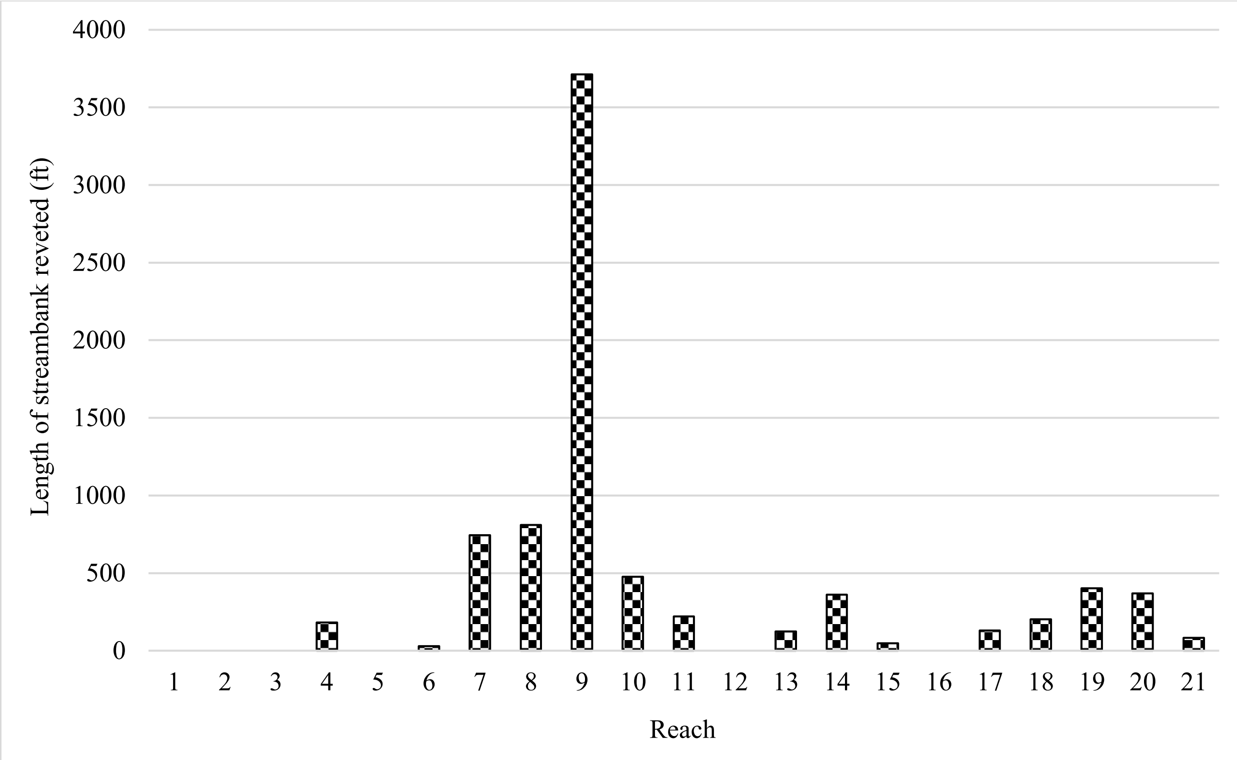


**Figure 20:** Length (ft) of streambank revetment by reach along Ouleout Creek.

Reach 9, had the highest percentage of streambank reveted with 19% reveted. Reach 8, had the second highest percentage of streambank reveted with 7.5% reveted. Reach 10, had the third highest percentage of streambank reveted with 6.7% reveted. Reaches 1, 2, 3, 5, 12 and 16 had the lowest percentage of streambank reveted with 0% of the streambank reveted (**Figure 21**).

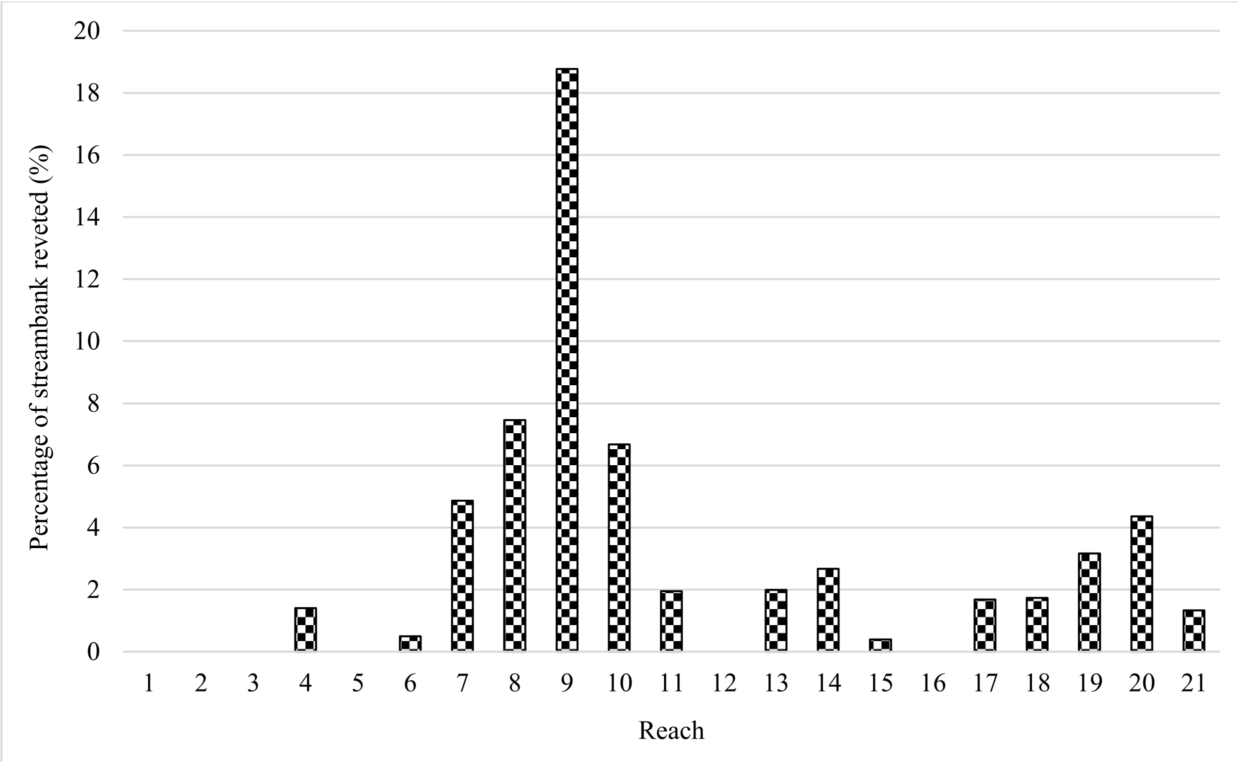


**Figure 21:** Percentage of streambank reveted by reach along Ouleout Creek.

*Riparian Forest Buffer Analysis*

Similar to many large watersheds in Delaware County, the Ouleout Creek Watershed contains a substantial amount of agriculture, and a relatively low amount of developed land. The CBP land cover analysis categorized 65% of the area in the Ouleout Creek Watershed as forest, 30% as field, 2.6% as developed land, 1.1% as cropland, 1.0% as water, and 0.39% as herbaceous wetland (**Figure 22**).

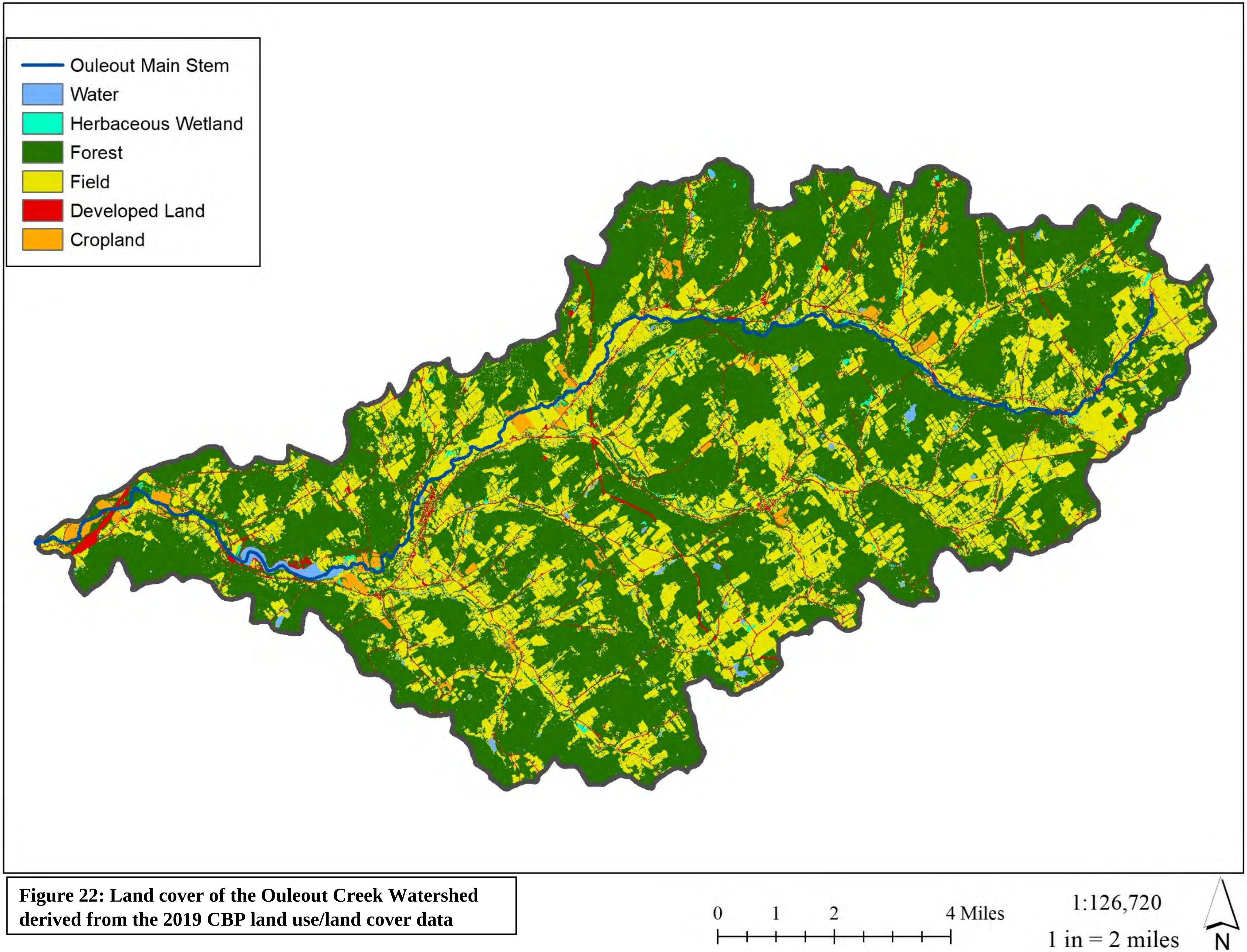


**Figure 22: Land cover of the Ouleout Creek Watershed derived from the 2019 CBP land use/land cover data**

As mentioned in the Methodology section of the report, riparian forest buffers are critical for the health and stability of streams. According to the ArcGIS buffer analysis conducted for Ouleout Creek, Reach 8 had the lowest area of tree cover adjacent to the stream with 28% of the area within 30 meters of the stream channel being forested. Reaches 6 and 21 were the second least forested with 29% of the streamside area being classified as forest in each. These reaches should be targeted for future riparian forest buffer plantings.

Reach 12 had the greatest percentage of tree cover along the stream channel with 80% of the streamside area being classified as forest. Reach 13 had the second greatest percentage of tree cover along the stream channel with 79% of the streamside area being classified as forest. Reach 11 had the third greatest percentage of tree cover along the stream channel with 73% of the streamside area being classified as forest (**Figure 23**).

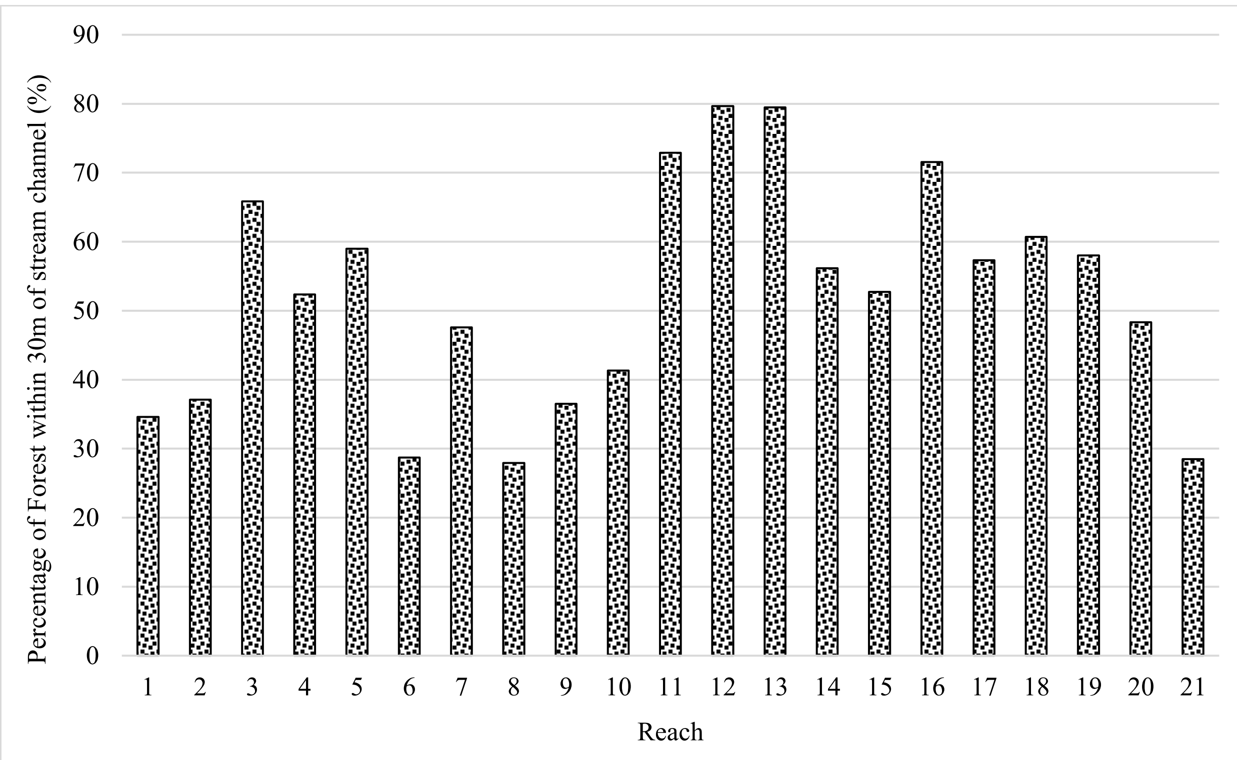


**Figure 23:** Percentage of forested area within 30m of Ouleout Creek by reach.

Reach 6 had the greatest percentage of field and cropland within the ideal riparian forest buffer area at 71%. The second highest was Reach 8 with 69% of the streamside area being categorized as field or cropland. The third highest was Reach 1 with 65% of the streamside area being categorized as field or cropland. These reaches should be targeted for future riparian forest buffer plantings.

Reach 12 had the lowest percentage of field and cropland along the stream channel at 14%. Reach 13 had the second lowest percentage of field and cropland along the stream channel at 15%. Reach 11 had the third lowest percentage of field and cropland along the stream channel at 19% (**Figure 24**).

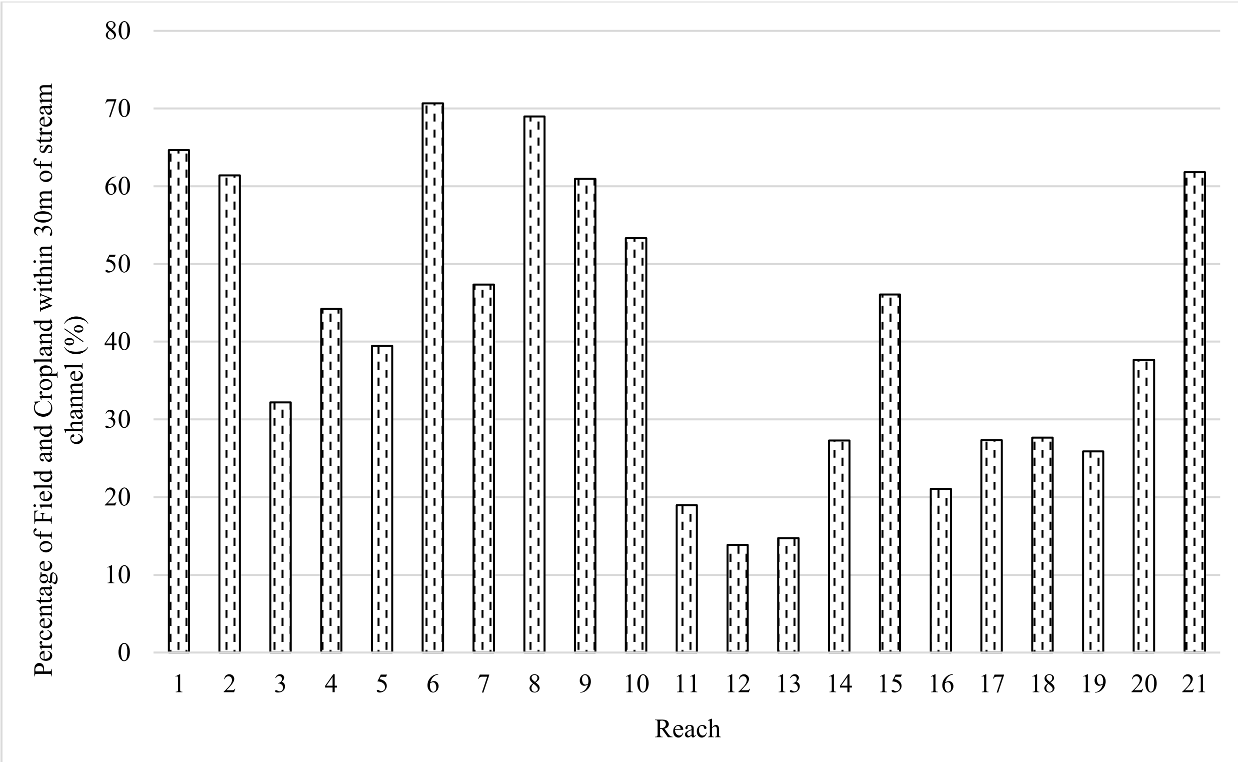


**Figure 24:** Percentage of field and cropland area within 30m of Ouleout Creek by reach.

Some of the areas that lack sufficient riparian forest buffers are in active agricultural use. However, many areas without a sufficient riparian forest buffer are abandoned agricultural fields. This indicates that there is potential for the establishment of new riparian forest buffers along the Ouleout. These areas should be targeted for future riparian forest buffer planting projects. Some areas along the Ouleout have recently had a riparian forest buffer planted along the stream, however, the establishment of a riparian forest buffer is a long process and the trees at these sites have not had time to become established and protect the streambank from erosion, as is the case in several areas within Reach 8.

*Macroinvertebrate Sampling*

Macroinvertebrate sampling was conducted by DCSWCD on Ouleout Creek in September of 2023 at STA 452+00 ft. This location was chosen as it was near the downstream end of the assessed portion of Ouleout Creek and should be representative of the water quality of the watershed. The EPT index of Ouleout Creek at STA 452+00 ft was calculated to be 77%. This percentage is similar to other EPT index percentages from samples conducted by DCSWCD in nearby watersheds and likely indicates good water quality. Results of the macroinvertebrate sampling can be viewed in **Table 6**.

**Table 6**: Ephemeroptera, Plecoptera, and Trichoptera Index sample results for Ouleout Creek.

| | | |
|---|---|---|
| **Stream:** | Ouleout Creek | |
| **Station:** | 452+00 ft | |
| **Date:** | 9/6/2023 | |
| | | |
| **Category** | **Common name** | **Count** |
| Ephemeroptera | Mayfly nymph | 27 |
| Plecoptera | Stonefly nymph | 21 |
| Trichoptera | Caddisfly nymph | 30 |
| | SUM | 78 |
| | | |
| Hydropsychidae | Common Netspinner Caddis | 1 |
| Anisoptera | Dragonflies | 0 |
| Zygoptera | Damselflies | 0 |
| Megaloptera | Hellgrammites, Alderflies, Fishflies | 0 |
| Coleoptera | Beetles | 10 |
| Diptera | True flies | 3 |
| Tipuloidea | Crane flies | 1 |
| Amphipoda | Scuds | 0 |
| Isopoda | Aquatic sowbugs | 0 |
| Decapoda | Crayfish | 0 |
| Oligochaeta | Aquatic worms | 2 |
| Hirudinea | Leeches | 0 |
| Tricladida | Flatworms | 3 |
| Gastropoda | Snails | 0 |
| Acariformes | Water mites | 0 |
| Unidentified non-EPT | | 3 |
| | SUM | 23 |
| | | |
| | Total | 101 |
| | | |
| | **EPT percentage (%)** | **77%** |

# Reach Specific Assessments and Recommendations

## *Reach 1*

### *Assessment Details*

Reach 1 begins at STA ~356+00 ft where Ouleout Creek enters East Sidney Lake at the seasonally low pool elevation of ~1,140 ft NVGD. The reach ends upstream at STA ~383+50 ft where the Ouleout enters East Sidney Lake at the normal summer pool elevation of ~1,150 ft NVGD. STA 383+50 ft is also the location where Handsome Brook converges with Ouleout Creek. To clarify, a large portion of the Reach 1 channel is inundated by East Sidney Lake for part of the year. This is because of the fact that the water level of East Sidney Lake fluctuates. The USACE, which operates East Sidney Dam, lowers East Sidney Lake's water level during the winter months for flood mitigation. During that time, East Sidney Lake's water level is dropped which results in Ouleout Creek entering East Sidney Lake at STA ~356+00 ft. In the summer months, the water level is raised and the Reach 1 channel is inundated by East Sidney Lake. During these summer months, Ouleout Creek enters East Sidney Lake at STA ~383+50 ft.

The reach is ~2,750 ft in length and has a drainage area of 99.2 $mi^2$. The sinuosity of the reach is 1.15 with a valley slope of 0.45%. Regional regression equations indicate that the bankfull area is 475 $ft^2$, the bankfull depth is 4.56 ft, and the bankfull width is 106 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 2,320 cfs and the 100-year recurrence interval discharge is estimated to be 10,600 cfs.

The general land cover of the reach is varied. The majority of the area within the stream channel is inundated for part of the year when the Lake's pool level is elevated. When that area is not inundated, it consists of depositional features such as mid-channel bars and side channel bars with sediment ranging from silt to cobble and contains little herbaceous vegetation. The area surrounding the stream channel along this section is predominately fields comprised of herbaceous plants with a shallow rooting depth. The sparse tree cover on the streambanks consists of sycamores and willows. Before East Sidney Dam was constructed, this reach consisted of agricultural fields and cropland. Within the ideal riparian buffer width area, (within 30m of the stream channel), the buffer analysis categorized 65% of the streamside area as field or cropland, 35% as forest, 0.73% as developed land, and 0.04% as herbaceous wetland.

There were 37 features recorded during the SFI for Reach 1: 25 eroding bank points composing 5 eroding bank segments, 4 excessive depositional features, 2 large woody debris points, and 1 photo point.

In the reach, there were two sites of substantial erosion and several excessive depositional features. There are several factors contributing to the instability in this reach. The backwater effect of East Sidney Lake is likely contributing to the instability within this seasonally inundated section. In addition, the stream channel is over widened in this section and historically unstable. When the water level of East Sidney Lake is lowered, the stream channel is multi-threaded from STA 359+00 ft to STA 383+00 ft and flows around several depositional bars. The aggrading depositional bars that have formed divert flow into the streambanks causing erosion. These depositional features likely formed due to the channel being over widened. This section of stream channel also acts a delta when Ouleout Creek converges with East Sidney Lake. Because of the varying water level, only ~700 ft of this reach was able to be assessed. This section of the Ouleout should be investigated further and assessed in the future when accessible.

In the assessed portion of the reach, 42.5% of the banks were actively eroding at the time of assessment and it is estimated that 300 $yd^3$ of sediment erodes annually from the streambanks in the reach. In addition, 820 lb of TN and 460 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 7th among reaches for the volume of eroded sediment, 6th for the mass of eroded TN, and 3rd for the mass of eroded TP. The two sites of substantial erosion in the reach can be viewed on the reach map in **Figure 25**.

*Areas of Concern*

*Site 1-a*

The first site of substantial erosion in the reach was along the left bank from STA 377+50 ft to STA 380+00 ft. This erosion segment measured 248 ft in length with an average height of 4.2 ft. The erosion was along a sharp bend in the channel along the left bank. This erosion affected one land cover-soil category which was Basher-field. The majority of vegetation along the left bank consisted of herbaceous plants and shrubs with a shallow rooting depth. The bank sediment was predominately composed of sand-sized and smaller soil particles making the soil highly susceptible to further erosion. At its most severe extent, the erosion at this site scored a Very High BEHI rating and an Extreme NBS rating.

It is estimated that 130 $yd^3$ of sediment has eroded annually from Site 1-a. This site accounted for 44% of the eroded volume of sediment in the reach and 2.4% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 150 tons of sediment. It is estimated that 200 lb of TP and 360 lb of TN have eroded annually from the site. This site accounted for 44% of the eroded TP in Reach 1 and 5.3% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 44% of the eroded TN in Reach 1 and 3.2% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 11th for the volume of eroded sediment, 9th for the mass of eroded TN, and 5th for the mass of eroded TP.

As previously mentioned, remediation recommendations included in the "Reach Specific Assessments and Recommendations" section of the report are based on natural channel design methods found in Part 654 Stream Restoration Design of the USDA NRCS National Engineering Handbook and DCSWCD's best knowledge of streambank stabilization techniques. Because of the effect that East Sidney Lake has on this site, any stream stabilization project would have added complexity. Stabilizing the bank with revetment may be the only way to protect it against future erosion. There are a number of ways to stabilize a bank, the most common way is to armor the bank with revetment in the form of rock. Establishing a riparian forest buffer would also help to anchor the soil in place in the future. Due to varying water level of East Sidney Lake, it may be difficult to establish a riparian forest buffer at this site. The left bank itself does not become inundated unless the water level of the Lake is raised during a flood event. Mature riparian tree species such as sycamores and willows were present at the time of assessment scattered throughout the left bank floodplain indicating that riparian tree species are capable of growing at the site. Further investigation is needed in order to determine how to remediate the erosion at this site as well as at Site 1-b.

*Site 1-b*

The second site of substantial erosion in Reach 1 was along the right bank from STA 381+00 ft to STA 383+00 ft. This erosion segment measured 347 ft in length with an average height of 4.2 ft. Just upstream of the site, Handsome Brook converges with the Ouleout along the left bank. This erosion affected one land cover-soil category which was Basher-field. The bank sediment was predominately composed of sand-sized and smaller soil particles making the soil highly susceptible to further erosion. At its most severe extent, the erosion at this site scored a High BEHI rating and an Extreme NBS rating.

It is estimated that 170 $yd^3$ of sediment has eroded annually from Site 1-b. This site accounted for 56% of the eroded volume of sediment in the reach and 3.0% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 190 tons of sediment. It is estimated that 260 lb of TP and 460 lb of TN have eroded annually from the site. This site accounted for 56% of the eroded TP in Reach 1 and 6.7% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 56% of the eroded TN in Reach 1 and 4.0% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 8th for the volume of eroded sediment, 6th for the mass of eroded TN, and 4th for the mass of eroded TP.

The channel is over widened in this section with several excessive sediment depositions in the channel. The oversized cobble bars direct the stream into the right bank further exacerbating the erosion. Similar to what was previously discussed regarding Site 1-a, this site is in the area where the stream channel is seasonally inundated by East Sidney Lake. Because of this, the same problems regarding remediation with Site 1-a are relevant to this site. The streambank would need to be stabilized with revetment. It is unlikely shifting or realigning the channel would be a feasible solution due to the effect of the Lake, the multiple excessive sediment depositions, and the natural deltaic cycle of sediment deposition and transport at the site. A riparian forest buffer could be planted on the streambank but the trees may have added difficulty becoming established due to the Lake's varying water level. A few mature sycamores and willows are scattered along the right bank floodplain indicating that these tree species could be used for a buffer at this site.

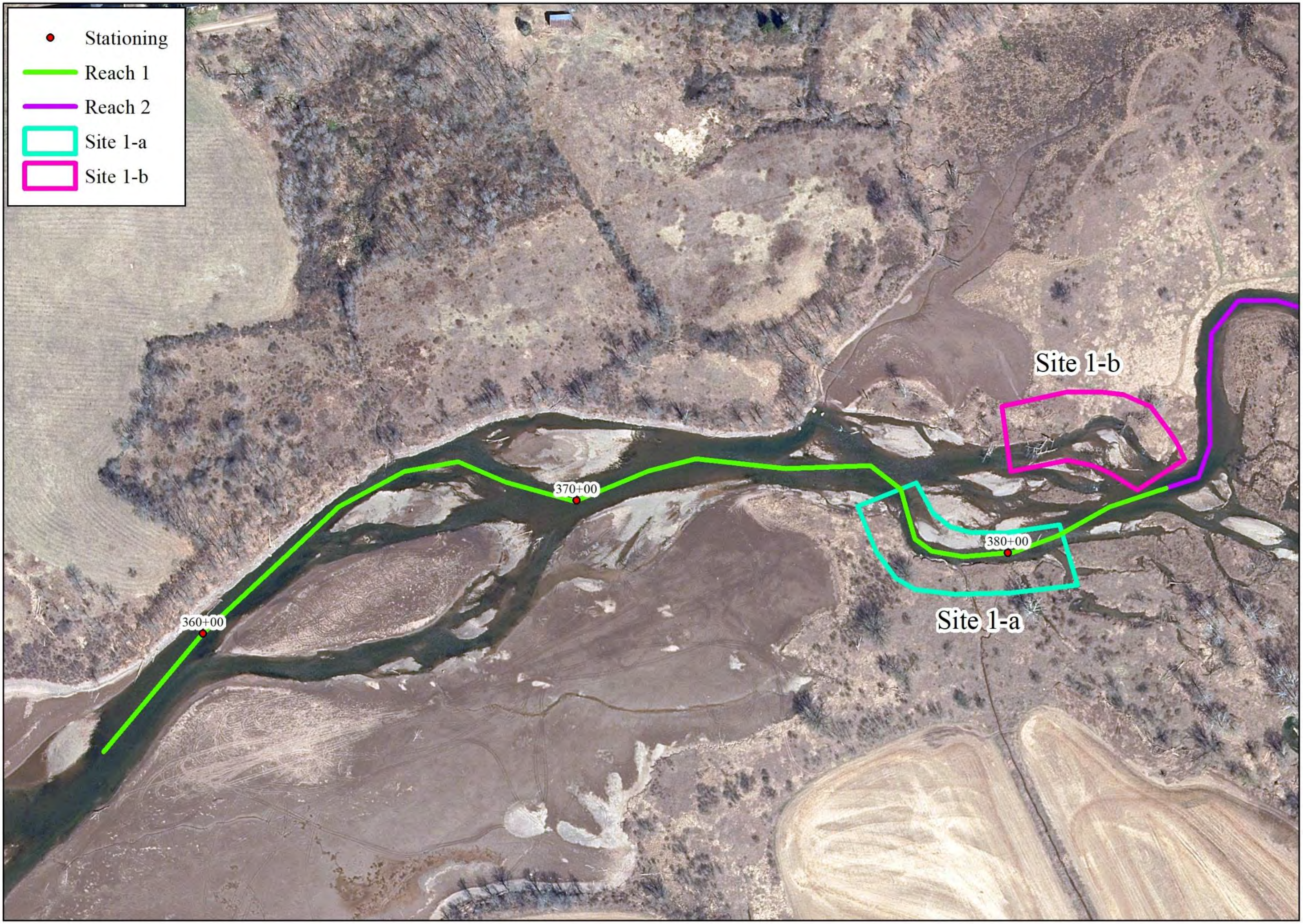


Figure 25: Reach 1 Map

## *Reach 2*

### *Assessment Details*

Reach 2 begins at STA ~383+50 ft where Handsome Brook converges with Ouleout Creek. In addition, it is also the location where the Ouleout flows into East Sidney Lake at the normal summer pool elevation of ~1,150 ft NVGD. The reach ends upstream at STA ~433+00 ft where the valley narrows. It is ~4,950 ft in length and has a drainage area of 71.6 $mi^2$. The sinuosity of the reach is 1.68 with a valley slope of 0.41%. Regional regression equations indicate that the bankfull area is 363 $ft^2$, the bankfull depth is 4.03 ft, and the bankfull width is 91.9 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 1,750 cfs and the 100-year recurrence interval discharge is estimated to be 7,840 cfs.

The general land cover in the reach can be divided into different sections. The downstream section of the reach consists of fields and an herbaceous wetland centered around Handsome Brook's confluence with the Ouleout. The middle and upstream section of the reach is primarily agricultural fields with a varying riparian buffer width. The upstream section of the reach along the left bank is a mix between forest and shrubs. Within the ideal riparian buffer width area, the buffer analysis categorized 61% of the streamside area as field or cropland, 37% as forest, 0.89% as herbaceous wetland, and 0.58% as developed land.

There were 98 features recorded during the SFI for Reach 2: 56 eroding bank points composing 26 eroding bank segments, 6 photo points, 3 excessive depositional features, 2 large woody debris points, 2 tributaries, 2 stream feature points, and 1 stream crossing.

In the reach, 42% of the banks were actively eroding at the time of assessment and it is estimated that 720 $yd^3$ of sediment erodes annually from the streambanks. In addition, 1,400 lb of TN and 720 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 2nd among reaches for the volume of eroded sediment, 2nd for the mass of eroded TN, and 1st for the mass of eroded TP. The two sites of substantial erosion in the reach can be viewed on the reach map in **Figure 26**.

### *Areas of Concern*

#### *Site 2-a*

The first site of substantial erosion was along the right bank from STA 385+00 ft to STA 390+00 ft and along the left bank from STA 389+50 ft to STA 393+50 ft. The erosion segment along the right bank measured 570 ft in length with an average height of 6.6 ft. The erosion segment along the left bank measured 430 ft in length with an average height of 5.3 ft. The erosion was along two sharp bends in the channel that were experiencing downstream meander migration. This erosion affected three land cover-soil categories which were Basher-herbaceous wetland, Basher-field, and Barbour-field. There was no riparian forest buffer along either bank and the bank sediment was predominately composed of sand-sized and smaller soil particles making the soil highly susceptible to further erosion. At its most severe extent, the erosion at this site scored a Very High BEHI rating and an Extreme NBS rating.

It is estimated that 430 $yd^3$ of sediment has eroded annually from Site 2-a. This site accounted for 60% of the eroded volume of sediment in the reach and 8.0% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 500 tons of sediment. It is estimated that 480 lb of TP and 900 lb of TN have eroded annually from the site. This site accounted for 67% of the eroded TP in Reach 2 and 12% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 64% of the eroded TN in Reach 2 and 7.9% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 2nd for the volume of eroded sediment, 2nd for the mass of eroded TN, and 1st for the mass of eroded TP.

The primary step in remediating the erosion at this site would be to stabilize the streambanks with revetment such as rock or root wads. The channel is also disconnected from the floodplain at this site. A floodplain bench would need to be built at a lower elevation and the channel would need to be resized to appropriate bankfull dimensions. Since the erosion along the right bank is along a sharp bend in the channel, it could also be beneficial to realign the planform of the channel so that the flow is no longer impinging against the bank. The streambank could also be graded to have a more gradual slope instead of steep vertical banks. The last step in remediating the erosion would be to establish a riparian buffer along the streambank to help anchor the soil in place and prevent future erosion.

*Site 2-b*

The second site of substantial erosion in Reach 2 was along the left bank from STA 403+00 ft to STA 408+00 ft. This erosion segment measured 660 ft in length with an average height of 4.4 ft. The erosion was along a sharp meander bend in the channel. This site has had substantial lateral adjustment recently as part of the meander bend has migrated into a cornfield after eroding away the riparian buffer. At its greatest extent, the stream has eroded approximately 100 ft laterally into the field along the left bank between 2016 and 2022, with a large aggrading point bar forming on the right bank. The increase in size of the point bar coincides with the retreat of the left bank. In addition to eroding into the cornfield, the stream was also depositing gravel and cobble sized sediment in the cornfield during high flow events. This deposition is evidence of bed aggradation. This erosion affected three land cover-soil categories which were Basher-herbaceous wetland, Barbour-Trestle-cropland, and Barbour-Trestle-herbaceous wetland. At its most severe extent, the erosion at this site scored a Very High BEHI rating and an Extreme NBS rating.

It is estimated that 220 $yd^3$ of sediment has eroded annually from Site 2-b. This site accounted for 31% of the eroded volume of sediment in Reach 2 and 4.1% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 260 tons of sediment. It is estimated that 190 lb of TP and 350 lb of TN have eroded annually from the site. This site accounted for 27% of the eroded TP in Reach 2 and 5.0% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 25% of the eroded TN in Reach 2 and 3.1% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 6th for the volume of eroded sediment, 10th for the mass of eroded TN, and 6th for mass of eroded TP.

In order to remediate the bank erosion at the site, the streambank would need to be stabilized with revetment such as rock or root wads. The channel would also have to be shifted laterally towards the right bank near its previous location so that the stream is not at a sharp angle impinging upon the left bank. In addition to the stabilization of the left bank and realignment of the channel planform, the channel has also become over widened in this section. To fix this issue, the channel would need to be resized to the appropriate bankfull dimensions. Lastly, an adequately sized riparian forest buffer would need to be established between the agricultural field and the stream channel in order to prevent future erosion.

*Other areas of note*

Handsome Brook converges with Ouleout Creek at the downstream end of the reach. Historical orthoimagery shows that Handsome Brook has shifted frequently over time, with large amounts of deposition and erosion occurring along its downstream end. It would be useful to conduct a Stream Feature Inventory along Handsome Brook to determine sources of erosion contributing the excessive amount of sediment and nutrients to East Sidney Lake.

At the time of assessment, the right bank of the Ouleout was actively eroding at several locations from STA 394+00 ft to STA 403+00 ft. The majority of this erosion was along the base of a terrace with agricultural fields at the top of the hillslope. An undersized riparian buffer separated the edge of the hillslope from the fields. Glacial till was observed intermittently throughout the toe of the hillslope. The erosion totaled to a length of 879 ft, had a maximum height of 7.8 ft, and it is estimated that 21 $yd^3$ of sediment erodes annually from the erosion segments. This erosion has the potential to increase in severity if the flow further impinges upon the base of the hillslope.

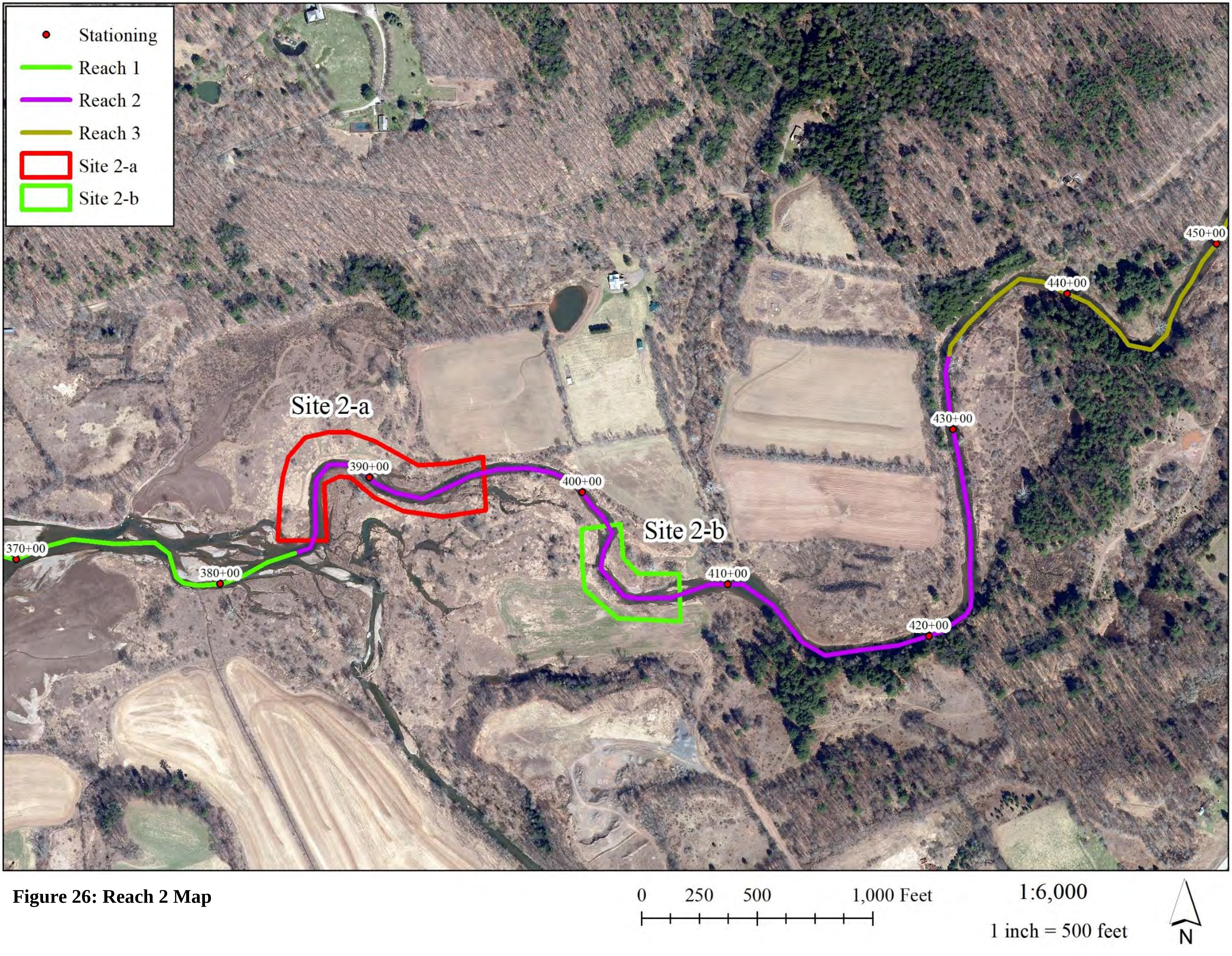


Figure 26: Reach 2 Map

## *Reach 3*

### *Assessment Details*

Reach 3 begins at STA ~433+00 ft where the valley narrows. The reach ends upstream at STA ~466+50 ft where the valley broadens. It is ~3,350 ft in length and has a drainage area of 69.2 $mi^2$. The stream has a sinuosity of 1.22 and a valley slope of 0.22%. Regional regression equations indicate that the bankfull area is 353 $ft^2$, the bankfull depth is 3.98 ft, and the bankfull width is 90.5 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 1,700 cfs and the 100-year recurrence interval discharge is estimated to be 7,650 cfs.

The general land cover of the reach is almost exclusively forest with some agricultural fields and old fields near the upstream end of the reach. The buffer analysis categorized 66% of the streamside area as forest, 32% as field or cropland, 1.6% as developed land, and 0.34% as herbaceous wetland.

There were 99 features recorded during the SFI for Reach 3: 58 eroding bank points composing 29 eroding bank segments, 6 large woody debris points, 4 excessive depositional features, and 2 photo points.

In the reach, 43% of the banks were actively eroding and it is estimated that 47 $yd^3$ of sediment erodes annually from the reach. In addition, 99 lb of TN and 22 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 21st among reaches for the volume of eroded sediment, 21st for the mass of eroded TN, and 18th for the mass of eroded TP. The reach's location can be viewed on the reach map in **Figure 27**. While a large percentage of banks were eroding in the reach, their erosion rates were low and they were not a large source of sediment or nutrients.

### *Areas of Concern*

No notable concerns were identified in Reach 3 regarding stream related issues that needed to be addressed.


**Figure 27: Reach 3 Map**

## *Reach 4*

### *Assessment Details*

Reach 4 begins at STA ~466+50 ft where the valley broadens. The reach ends upstream at STA ~531+00 ft where the valley further broadens. It is ~6,450 ft in length and has a drainage area of 68.9 $mi^2$. The stream has a sinuosity of 1.13 and a valley slope of 0.24%. Regional regression equations indicate that the bankfull area is 352 $ft^2$, the bankfull depth is 3.98 ft, and the bankfull width is 90.3 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 1,700 cfs and the 100-year recurrence interval discharge is estimated to be 7,700 cfs.

The general land cover in the reach is varied. The downstream end of the reach is a mix of agricultural fields, shrubs, and sparse tree cover. Abandoned agricultural fields make up a large section of the rest of the reach. These old fields consist primarily of herbaceous plants and shrubs. These old fields also contain backwater oxbows within them from previous channel locations. Forested areas are intermittent in small sections throughout the reach and there is no riparian buffer along the streambanks in the old fields. The buffer analysis categorized 52% of the streamside area as forest, 44% as field, 3.0% as developed land, and 0.42% as herbaceous wetland.

There were 176 features recorded during the SFI for Reach 4: 115 eroding bank points composing 40 eroding bank segments, 7 excessive depositional features, 4 revetment points composing 2 revetment segments, 3 large woody debris points, 2 photo points, 1 tributary, 1 stream crossing, and 1 bridge.

In the reach, 28% of the banks were actively eroding and it is estimated that 1,100 $yd^3$ of sediment erodes annually from the reach. In addition, 1,700 lb of TN and 640 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 1st among reaches for the volume of eroded sediment, 1st for the mass of eroded TN, and 2nd for the mass of eroded TP. The two sites of substantial erosion in the reach can be viewed on the reach map in **Figure 28**.

### *Areas of Concern*

#### *Site 4-a*

The first site of substantial erosion in the reach was along the left bank from STA 466+00 ft to STA 469+00 ft and along the right bank from STA 472+00 ft to STA 476+00 ft. The erosion segment along the left bank measured 290 ft in length with an average height of 4.5 ft. This left bank erosion was along an area that consists primarily of shrubs and herbaceous plants and affected one land cover-soil category which was Barbour-field. The erosion segment along the right bank measured 418 ft in length with an average height of 5.2 ft and was along the edge of an agricultural field. This right bank erosion affected two land cover-soil categories which were Barbour-forest and Barbour-field. There was no riparian buffer along the agricultural field. At its most severe extent, the erosion at this site scored a High BEHI rating and a High NBS rating.

It is estimated that 240 $yd^3$ of sediment has eroded annually from Site 4-a. This site accounted for 22% of the eroded volume of sediment in the reach and 4.5% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 280 tons of sediment. It is estimated that 190 lb of TP and 510 lb of TN have eroded annually from the site. This site accounted for 29% of the eroded TP in Reach 4 and 4.9% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 30% of the eroded TN in Reach 4 and 4.5% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 5th for the volume of eroded sediment, 5th for the mass of eroded TN, and 7th for the mass of eroded TP.

The erosion at this site could be remediated by stabilizing the streambanks with revetment. The channel planform would also need to be adjusted to prevent the thalweg of the stream from impinging upon the right bank of the agricultural field. It would also be important to establish a riparian buffer between the fields and the stream channel, especially along the agricultural field which was in direct contact with the stream channel. A riparian forest buffer would help stabilize the stream bank in the future when the roots of the trees become established and anchor the soil in place.

*Site 4-b*

From STA 495+00 ft to STA 520+00 ft the stream runs through a series of old fields which consist of herbaceous plants with no riparian buffer along the stream channel. The soil that the banks are composed of are predominately sand-sized and smaller soil particles making them easily erodible. Because of this fact, the banks have likely been eroding, without interruption, since being cleared of woody vegetation. As a result, this section has undergone drastic geomorphic change as evidenced by the multiple backwater oxbows at the site.

This site of substantial erosion in Reach 4 consisted of several erosion segments along both banks from STA 500+00 ft to STA 514+00 ft. The erosion totaled 1,181 ft in length with an average height of 4.7 ft. The stream at this site was eroding into fields that were once used for agriculture historically but have since been abandoned. Since abandonment, the stream has shifted dramatically in this section due to the easily erodible soil and the lack of a riparian buffer to anchor the soil in place. This shifting caused several backwater oxbows to form over time due to the stream avulsing and forming new channels. The major cause of erosion in this section was a downstream meander migrating into the left bank as well as a bend in the channel migrating into the right bank. Historically, a bridge crossed the channel at this site immediately upstream of the left bank erosion. The bridge no longer exists, however, some of the revetment from the bridge is still present in the channel at this site. The revetment, in the form of large boulders, protrudes into the channel and could be contributing to the instability along the left bank by diverting flow into the left bank.

Using historical orthoimagery, it is estimated that approximately 2 acres of the field has eroded from this site between 1997 and 2022. A large amount of this erosion occurred in the mid-2000s when the channel avulsed through the field and then continued to erode laterally. This erosion affected two land cover-soil categories which were Barbour-field and Fluvaquent-Udifluvent-forest. At its most severe extent, the erosion at this site scored a High BEHI rating and an Extreme NBS rating.

It is estimated that 860 $yd^3$ of sediment has eroded annually from Site 4-b. This site accounted for 76% of the eroded volume of sediment in the reach and 16% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 970 tons of sediment. It is estimated that 440 lb of TP and 1,200 lb of TN have eroded annually from the site. This site accounted for 68% of the eroded TP in Reach 4 and 11% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 68% of the eroded TN in Reach 4 and 10% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 1st for the volume of eroded sediment, 1st for the mass of eroded TN, and 2nd for the mass of eroded TP.

An extensive stream stabilization project would need to occur at this site in order remediate the erosion. The streambank would need to be stabilized with revetment in the form of rock or root wads to prevent further erosion along the streambanks. The channel planform would also need to be realigned so that the majority of flow does not impinge upon the streambank. The sinuosity of the channel would also need to be adjusted to a normal range. The channel is over widened in some sections as well as pinched by excessive depositions in other sections. The channel would need to be resized to appropriate bankfull dimensions to prevent future excessive depositional features from forming. The current excessive depositional features would need to be resized and graded to appropriate dimensions. The old bridge revetment would need to be removed from the channel as well. The upstream end of the backwater oxbows would need to be plugged in order to prevent the stream from avulsing back into them. The downstream end of the backwater oxbows should be left in their current state to act as a wetland habitat. The final step would be to establish a riparian forest buffer to help stabilize the streambanks.

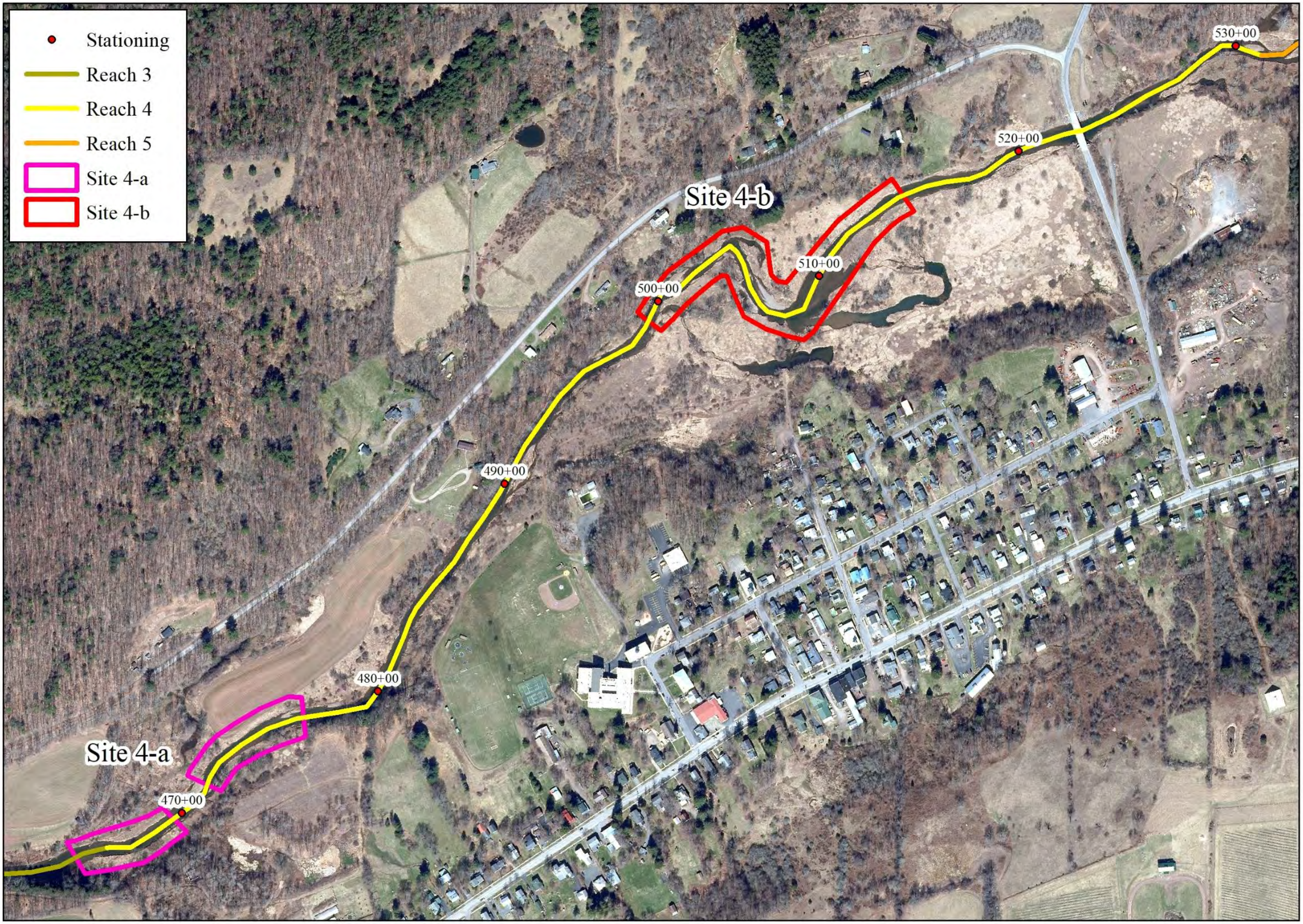


**Figure 28: Reach 4 Map**

## *Reach 5*

### *Assessment Details*

Reach 5 begins at STA ~531+00 ft where the valley broadens. The reach ends upstream at STA ~567+00 ft where the dominant land cover changes from active agricultural land to old fields. It is ~3,600 ft in length and has a drainage area of 66.4 $mi^2$. The stream has a sinuosity of 1.26 and a valley slope of 0.35%. Regional regression equations indicate that the bankfull area is 341 $ft^2$, the bankfull depth is 3.92 ft, and the bankfull width is 88.8 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 1,640 cfs and the 100-year recurrence interval discharge is estimated to be 7,540 cfs.

The general land cover in the reach is varied. The right bank contains agricultural fields with an intermittent riparian forest buffer along the stream channel. The left bank is a forested hillslope with fields at the top of the hillslope. The buffer analysis categorized 59% of the streamside area as forest, 39% as field, 1.4% as herbaceous wetland, and 0.18% as developed land.

There were 117 features recorded during the SFI for Reach 5: 79 eroding bank points composing 31 eroding bank segments, 4 excessive depositional features, 2 large woody debris points, and 1 photo point.

In the reach, 42% of the banks were actively eroding and it is estimated that 330 $yd^3$ of sediment erodes annually from the reach. In addition, it is estimated that 860 lb of TN and 310 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 5th among reaches for the volume of eroded sediment, 5th for the mass of eroded TN, and 5th for the mass of eroded TP. The three sites of substantial erosion in the reach can be viewed on the reach map in **Figure 29**.

### *Areas of Concern*

#### *Site 5-a*

The first site of substantial erosion in the reach was along the left bank from STA 530+00 ft to STA 533+00 ft. This erosion segment measured 303 ft in length with an average height of 4.9 ft. At this site, the stream was eroding into an area which consists primarily of herbaceous plants with a few mature willow trees. There are several depositional bars in the channel near the erosion segment as well as a tributary entering the Ouleout from the right bank just downstream of the erosion segment. This erosion affected one land cover-soil category which was Basher-herbaceous wetland. At its most severe extent, the erosion at this site scored a High BEHI rating and a Low NBS rating.

It is estimated that 80 $yd^3$ of sediment has eroded annually from Site 5-a. This site accounted for 24% of the eroded volume of sediment in the reach and 1.5% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 91 tons of sediment. It is estimated that 120 lb of TP and 220 lb of TN have eroded annually from the site. This site accounted for 40% of the eroded TP in Reach 5 and 3.2% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 26% of the eroded TN in Reach 5 and 1.9% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 15th for the volume of eroded sediment, 13th for the mass of eroded TN, and 10th for the mass of eroded TP.

There are a couple steps needed in order to remediate the erosion at the site. The primary step would be to stabilize the left bank with revetment in the form of rock or root wads. The excessive depositional features in the channel would also need to be resized and graded to appropriate dimensions. Establishing a riparian forest buffer along the left bank would also be beneficial in the long-term to help stabilize the streambank.

*Site 5-b*

The second site of substantial erosion in Reach 5 was along the right bank from STA 547+00 ft to STA 551+00 ft. This erosion segment measured 363 ft in length with an average height of 3.0 ft. The erosion was partially along a narrow riparian buffer between the stream and an agricultural field. The downstream section of the erosion segment is wooded and the upstream section is along the edge of a hayfield. This erosion affected two land cover-soil categories which were Barbour-forest and Barbour-field. At its most severe extent, the erosion at this site scored a Moderate BEHI rating and a High NBS rating.

It is estimated that 160 $yd^3$ of sediment has eroded annually from Site 5-b. This site accounted for 48% of the eroded volume of sediment in the reach and 2.9% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 180 tons of sediment. It is estimated that 110 lb of TP and 410 lb of TN have eroded annually from the site. This site accounted for 36% of the eroded TP in Reach 5 and 2.9% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 48% of the eroded TN in Reach 5 and 3.6% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 9th for the volume of eroded sediment, 7th for the mass of eroded TN, and 11th for the mass of eroded TP.

Immediately upstream of the site of substantial erosion is a location where the stream had previously formed a bend in the channel and eroded into an agricultural field. The bend is now a backwater oxbow and is cut off from streamflow and was not actively eroding into the field at the time of assessment. However, the backwater oxbow channel was active as recently as 2011 and has the potential to be reoccupied by the channel which would cause further erosion into the agricultural field.

In order to remediate the erosion at this site, the streambank would need to be stabilized with revetment in the form of rock or root wads. The backwater oxbow would also need to be plugged at its upstream end in order to prevent the stream from reentering it and reactivating the erosion in the agricultural field. The downstream end of the backwater oxbow should be left in its current state to serve as wetland habitat. Opposite the erosion was an oversized point bar along the left bank. This oversized point bar would need to be resized and graded to appropriate dimensions. A riparian forest buffer would also need to be established between the agricultural field and the stream channel to help stabilize the bank and protect it from future erosion.

*Site 5-c*

The third site of substantial erosion in Reach 5 was along the right bank from STA 559+50 ft to STA 561+00 ft. This erosion segment measured 184 ft in length with an average height of 3.8 ft. The erosion was near an agricultural field with a small herbaceous buffer separating the erosion and the field. This erosion affected one land cover-soil category which was Barbour-field. At its most severe extent, the erosion at this site scored a High BEHI rating and a Moderate NBS rating.

It is estimated that 43 $yd^3$ of sediment has eroded annually from Site 5-c. This site accounted for 13% of the eroded volume of sediment in the reach and 0.79% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 48 tons of sediment. It is estimated that 37 lb of TP and 97 lb of TN have eroded annually from the site. This site accounted for 12% of the eroded TP in Reach 5 and 0.97% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 11% of the eroded TN in Reach 5 and 0.85% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 19th for the volume of eroded sediment, 19th for the mass of eroded TN, and 17th for the mass of eroded TP.

The erosion at this site could be remediated by stabilizing the streambank with revetment in the form of rock or root wads along the right bank and establishing a riparian forest buffer between the agricultural field and the stream channel.

*Other features of note*

There were several lengths of erosion along the right bank from STA 533+00 ft to STA 540+50 ft. These erosion segments were not great enough in terms of the amount of eroded material to be classified as an area of substantial erosion, but are still notable. The erosion segments were along an agricultural field only being separated from the field by a small strip of herbaceous plants and shrubs. The erosion segments totaled to a length of 579 ft and had an average height of 3.5 ft. It is estimated that 20 $yd^3$ of sediment had eroded annually from the erosion segments. The erosion segments should be monitored in the future as there is potential for the erosion to increase in severity due to the lack of an adequate riparian buffer between the stream channel and the agricultural field.

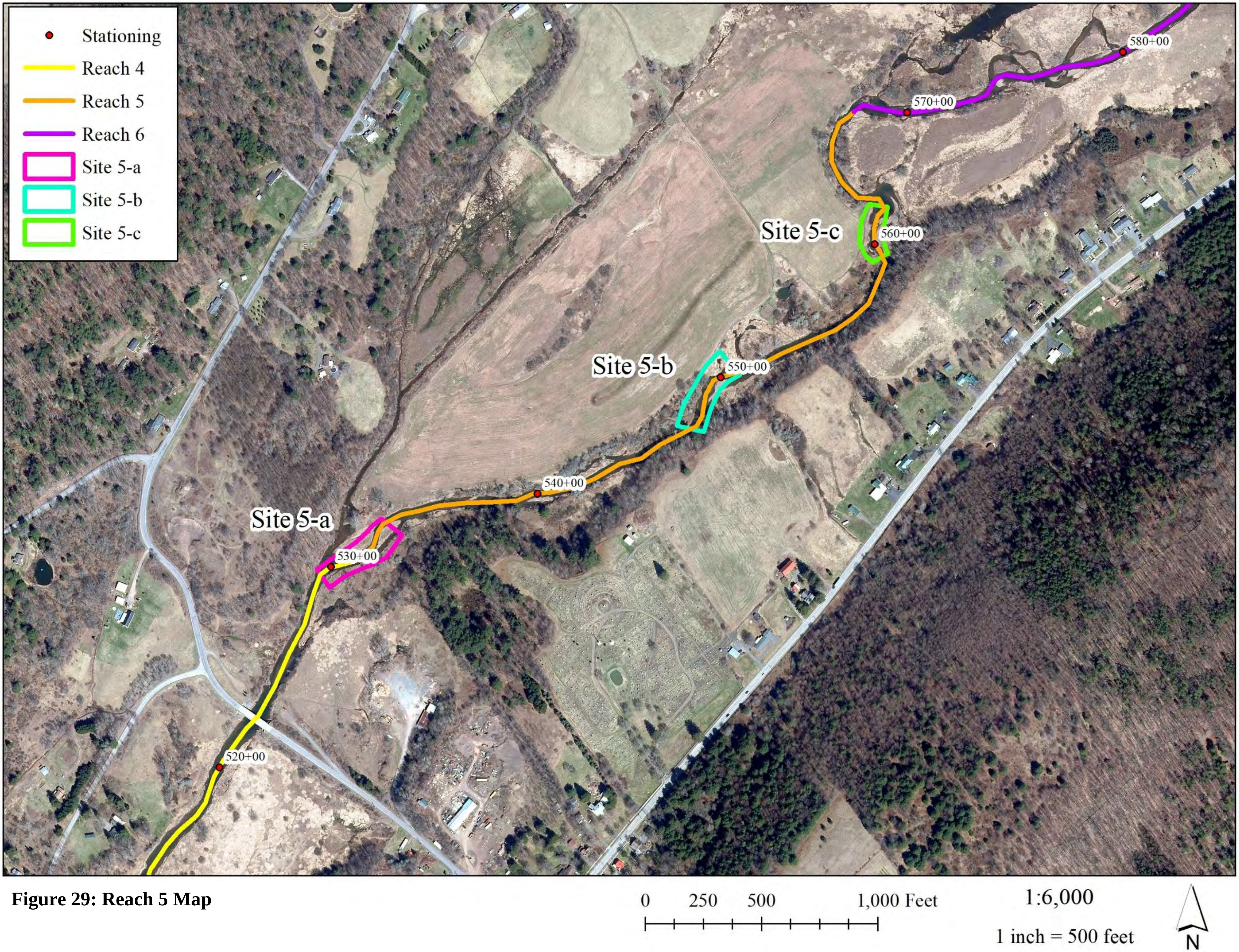


**Figure 29: Reach 5 Map**

## *Reach 6*

### *Assessment Details*

Reach 6 begins at STA ~567+00 ft where the dominant land cover changes from active agricultural land to old fields. The reach ends upstream at STA ~598+00 ft where the dominant land cover becomes active agricultural fields. It is ~3,100 ft in length and has a drainage area of 65.2 $mi^2$. The reach has a sinuosity of 1.26 and a valley slope of 0.25%. Regional regression equations indicate that the bankfull area is 336 $ft^2$, the bankfull depth is 3.9 ft, and the bankfull width is 88.1 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 1,620 cfs and the 100-year recurrence interval discharge is estimated to be 7,530 cfs.

In this section, the stream runs through the center of the valley. The general land cover of the reach is old fields with little riparian buffer along the majority of the streambanks. The buffer analysis categorized 71% of the streamside area as field, 29% as forest, 0.39% as developed land, and 0.19% as herbaceous wetland.

There were 111 features recorded during the SFI for Reach 6: 74 eroding bank points composing 24 eroding bank segments, 4 excessive depositional features, 5 large woody debris points, 1 revetment point composing 1 revetment segment, 1 stream crossing, and 1 control point.

In the reach, 44% of the banks were actively eroding and it is estimated that 500 $yd^3$ of sediment erodes annually from the reach. In addition, 1,100 lb of TN and 420 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 4th among reaches for the volume of eroded sediment, 4th for the mass of eroded TN, and 4th for the mass of eroded TP. The two sites of substantial erosion in the reach can be viewed on the reach map in **Figure 30**.

### *Areas of Concern*

#### *Site 6-a*

The first site of substantial erosion in Reach 6 was from STA 576+00 ft to STA 590+00 ft, with the erosion being almost continuous along the left bank. The erosion segments totaled to 1,272 ft in length with an average height of 4.2 ft. The majority of erosion was along an old field with little riparian buffer. The upstream section of the erosion was along an area consisting of herbaceous plants, shrubs, and a few mature willow trees. Across from the erosion, along the right bank, there are two backwater oxbows where the stream was previously eroding into the old field along the right bank. At the time of assessment, the backwater oxbows were not occupied by the stream channel. The 1,272 ft active erosion segment affected two land cover-soil categories which were Barbour-field and Barbour-forest. At its most severe extent, the erosion at this site scored a Very High BEHI rating and a High NBS rating.

It is estimated that 190 $yd^3$ of sediment has eroded annually from Site 6-a. This site accounted for 39% of the eroded volume of sediment in the reach and 3.5% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 220 tons of sediment. It is estimated that 130 lb of TP and 390 lb of TN have eroded annually from the site. This site accounted for 31% of the eroded TP in Reach 6 and 3.4% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 34% of the eroded TN in Reach 6 and 3.4% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 7th for the volume of eroded sediment, 8th for the mass of eroded TN, and 8th for the mass of eroded TP.

Several steps would be required to remediate the issues at this site. One step would be to stabilize the streambank with revetment in the form of rock or root wads, primarily along the left bank, to prevent further erosion. The backwater oxbows along the right bank would also need to be addressed to prevent the channel from avulsing into them and reactivating the erosion within those bends. That could possibly be accomplished by plugging the upstream end of the bend with large wood or revetment. The downstream end of the backwater oxbows should be left in their current state to act as a wetland habitat. A riparian forest buffer would also need to be established along the entire site as the stream is currently eroding into an old field with no riparian forest buffer.

*Site 6-b*

The second site of substantial erosion in Reach 6 was along the right bank from STA 590+00 ft to STA 595+50 ft. This erosion segment measured 597 ft in length with an average height of 5.0 ft. The erosion was along an old field with no riparian forest buffer. This erosion affected two land cover-soil categories which were Basher-field and Barbour-field. At this site, a sharp meander had formed in the channel and has been migrating downstream. At the downstream end of the erosion, there was a large boulder cross vane structure that bisects the channel. This structure is improperly sized and is likely contributing to the instability of channel as the stream could be shifting in order to try to flow at a less conflicting angle over the structure. There is also a large aggrading point bar across from the erosion. At its most severe extent, the erosion at this site scored a High BEHI rating and an Extreme NBS rating.

It is estimated that 300 $yd^3$ of sediment has eroded annually from Site 6-b. This site accounted for 59% of the eroded volume of sediment in the reach and 5.4% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 330 tons of sediment. It is estimated that 280 lb of TP and 740 lb of TN have eroded annually from the site. This site accounted for 67% of the eroded TP in Reach 6 and 7.3% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 64% of the eroded TN in Reach 6 and 6.5% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 3rd for the volume of eroded sediment, 3rd for the mass of eroded TN, and 3rd for the mass of eroded TP.

There are several issues at this site that would need to be addressed if a stream stabilization project were to occur. The streambank would need to be stabilized with root wads or revetment in order to prevent further erosion along the right bank. The channel planform would have to be realigned to adjust the sharp bend and prevent the streamflow from impinging upon the right bank. Additionally, the oversized point bar along the left bank would need to be resized and graded to appropriate dimensions. The boulder structure within the stream channel should be removed as it is likely exacerbating the problems at this site. Like other sites of substantial erosion, a riparian forest buffer would need to be established along the right bank to help stabilize the streambank long-term and protect against future erosion.

*Other features of note*

In the reach, there are two backwater oxbows that were cut off from the main flow of the channel. From historical orthoimagery, it can be seen that these backwater oxbows have historically been unstable as they have shifted frequently over time. They were previously receiving the majority of streamflow when the stream was eroding into the old field along the right bank. At the time of assessment, the backwater oxbows were not actively receiving flow from the stream channel as their upstream ends were blocked by depositional bars. However, they still have the potential to become reoccupied if the depositional bars are eroded or if the stream channel shifts.

Using historical orthoimagery, it is estimated that approximately 2 acres of field has eroded from Site 6-a and Site 6-b between 1997 and 2022, with a large amount of the erosion occurring when the two aforementioned backwater oxbows formed in the channel and eroded into the right bank. The reach also contained little riparian buffer between the old fields on the streambank and the stream channel.

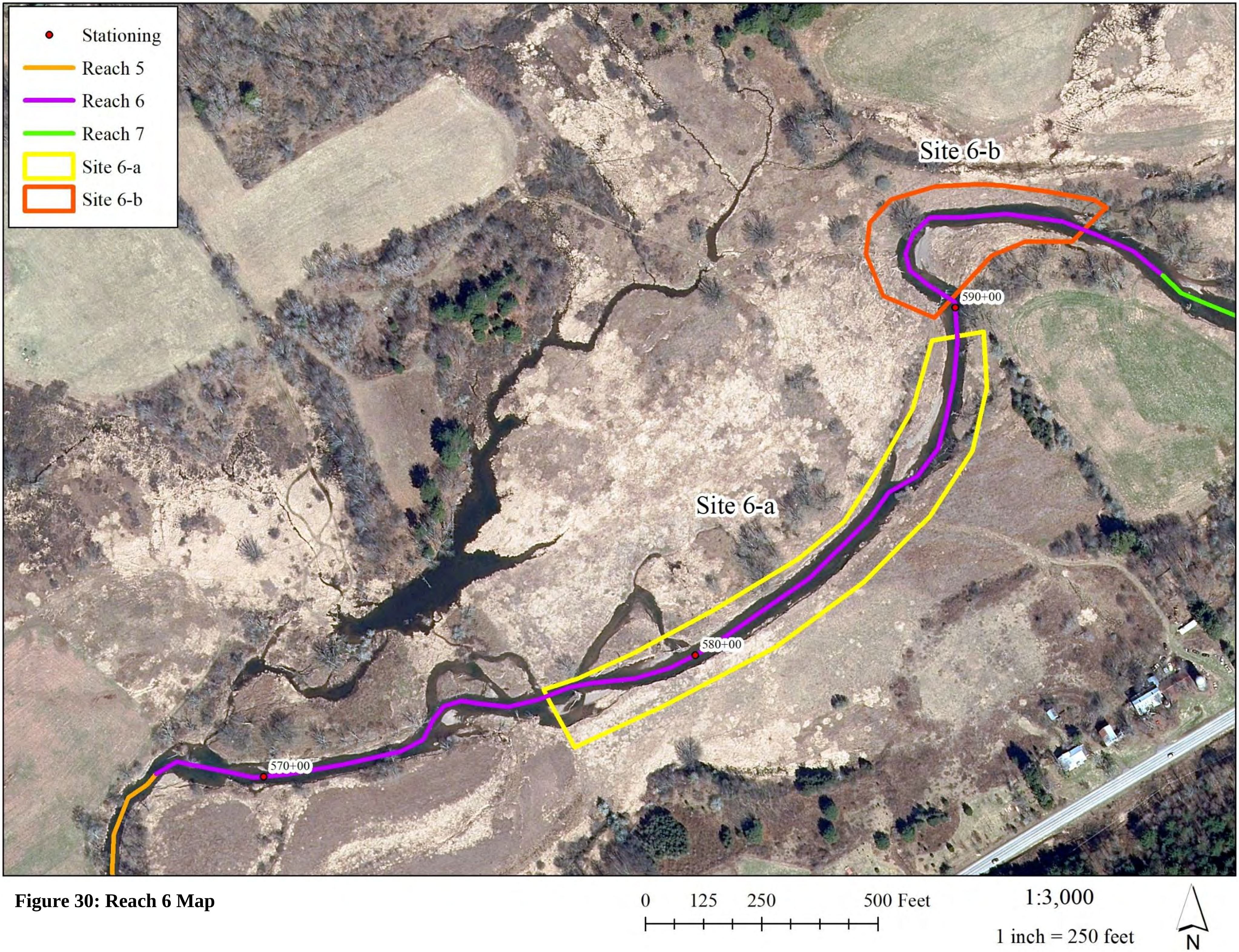


**Figure 30: Reach 6 Map**

## *Reach 7*

### *Assessment Details*

Reach 7 begins at STA ~598+00 ft where the dominant land cover changes from old fields to active agricultural fields. The reach ends upstream at STA ~674+50 ft where Treadwell Creek converges with Ouleout Creek. It is ~7,650 ft in length and has a drainage area of 65 $mi^2$. The reach has a sinuosity of 1.17 and a valley slope of 0.34%. Regional regression equations indicate that the bankfull area is 335 $ft^2$, the bankfull depth is 3.89 ft, and the bankfull width is 88 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 1,610 cfs and the 100-year recurrence interval discharge is estimated to be 7,550 cfs.

In this reach, the stream runs along the right hillslope at the upstream end, cuts through the valley at the center of the reach, and then runs along the left hillslope at the downstream end of the reach. The general land cover in the reach is primarily agricultural fields. As with previous reaches, the riparian buffer along several agricultural fields in Reach 7 is undersized and nonexistent in certain sections. The buffer analysis categorized 48% of the streamside area as forest, 47% of the area as field or cropland, 5.0% as herbaceous wetland, and 0.06% as developed land.

There were 182 features recorded during the SFI for Reach 7: 106 eroding bank points composing 41 eroding bank segments, 14 revetment points composing 4 revetment segments, 9 excessive depositional features, 3 large woody debris points, 2 tributaries, 2 stream crossings, and 1 photo point.

In the reach, 24% of the banks were actively eroding and it is estimated that 120 $yd^3$ of sediment erodes annually from the reach. In addition, it is estimated that 300 lb of TN and 110 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 12th among reaches for the volume of eroded sediment, 12th for the mass of eroded TN, and 10th for the mass of eroded TP.

There were no sites of substantial erosion in the reach, however, there were some notable erosion segments that have the potential to increase in severity. There were other noteworthy features in the reach as well. The reach's location can be viewed on the reach map in **Figure 31**.

### *Areas of Concern*

### *Other features of note*

One notable segment of bank erosion was along the left bank from STA 598+00 ft to STA 600+50 ft. This erosion segment measured 255 ft in length and had an average height of 4.4 ft. It is estimated that 15 $yd^3$ of sediment has eroded annually from the erosion segment. At the time of assessment, there was no riparian buffer separating the stream channel from the agricultural field on the left bank. This was also the case for the erosion along the right bank from STA 615+50 ft to STA 620+00 ft. This erosion segment measured 411 ft in length and had an average height of 3.0 ft. It is estimated that 12 $yd^3$ of sediment has eroded annually from the erosion segment. It would be useful to monitor the erosion segments as they have the potential to increase in severity because the riparian buffer is no longer present and the stream is eroding adjacent to the agricultural fields.

There was a hillslope failure along the left bank from STA 621+00 ft to STA 623+00 ft. The failure measured 211 ft in length and had a maximum height of 22 ft. The hillslope failure had little toe protection along the majority of its extent, though a cantilevered block of soil with trees had slid down the hillslope near the upstream end of the erosion partially providing some toe protection for the upstream section of the failure. The failure was recently active at the time of assessment indicated by the fact that the bank face was bare and contained little vegetation growth. This failure should be monitored in the future to make sure that the erosion does not increase in severity or cause further instability within the stream channel.

Another area of note in the reach was Treadwell Creek's confluence with the Ouleout at STA 674+00 ft. The confluence of two streams is naturally a dynamic area where fluctuating sediment depositions are common. From recent orthoimagery it can be seen that Treadwell Creek has shifted frequently over the past 25 years. Additionally, it has previously eroded into the banks of the agricultural fields near its confluence with the Ouleout. Treadwell Creek also deposits large amounts of sediment at its confluence with the Ouleout. At the time of assessment, there were several excessive depositional features in the form of side channel bars and transverse bars upstream and downstream of the confluence. During times of low flow, Treadwell Creek sometimes flows subsurface along its downstream extent, indicating an excessive amount of gravel and cobble sized sediment at Treadwell's confluence with the Ouleout. The stream flowing subsurface is detrimental to aquatic organisms as they are unable to inhabit or pass through this section of Treadwell Creek. It would be useful to assess Treadwell Creek upstream of its confluence to determine possible instabilities causing the excess of sediment being delivered to the Ouleout.

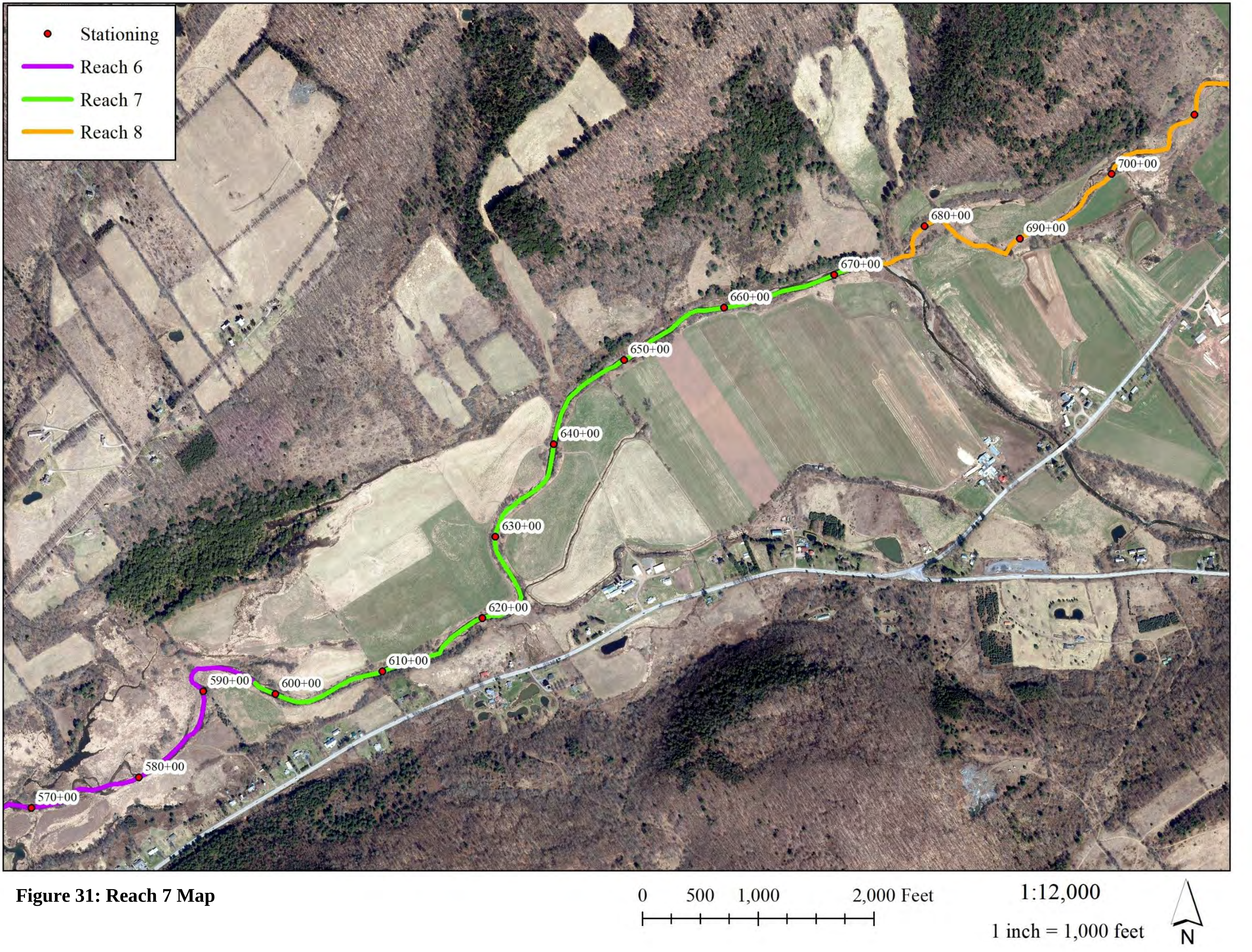


**Figure 31: Reach 7 Map**

## Reach 8

### *Assessment Details*

Reach 8 begins at STA ~674+50 ft where Treadwell Creek converges with Ouleout Creek. The reach ends upstream at STA ~729+00 ft where the valley broadens. It is ~5,450 ft in length and has a drainage area of 37.9 $mi^2$. The reach has a sinuosity of 1.20 and a valley slope of 0.44%. Regional regression equations indicate that the bankfull area is 215 $ft^2$, the bankfull depth is 3.18 ft, and the bankfull width is 69 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 1,020 cfs and the 100-year recurrence interval discharge is estimated to be 4,400 cfs.

The general land cover of the reach is primarily agricultural fields and old fields. At the time of assessment, a sizeable riparian forest buffer had recently been planted along some of the streamside area that was old fields. The buffer analysis categorized 69% of the streamside area as field or cropland, 28% as forest, 1.7% as herbaceous wetland, and 1.4% as developed land.

There were 200 features recorded during the SFI for Reach 8: 100 eroding bank points composing 38 eroding bank segments, 23 revetment points composing 10 revetment segments, 9 large woody debris points, 7 control points, 5 excessive depositional features, 3 tributaries, 2 stream crossings, 2 photo points, and 1 bridge.

In the reach, 28% of the banks were actively eroding and it is estimated that 280 $yd^3$ of sediment erodes annually from the reach. In addition, 590 lb of TN and 230 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 8th among reaches for the volume of eroded sediment, 7th for the mass of eroded TN, and 7th for the mass of eroded TP. The two sites of substantial erosion in the reach can be viewed on the reach map in **Figure 32**.

### *Areas of Concern*

#### *Site 8-a*

The first site of substantial erosion in the reach consisted of several erosion segments along both banks from STA 686+00 ft to STA 690+00 ft. The erosion segments totaled to 322 ft in length with an average height of 3.6 ft. The erosion along the left bank was along agricultural fields with no riparian forest buffer. The right bank consisted of recently planted trees as part of a riparian forest buffer planting project. The buffer was recently planted at the time of assessment so it had not had time to become established and protect the bank from erosion. This erosion affected two land cover-soil categories which were Basher-cropland and Basher-field. At its most severe extent, the erosion at this site scored a High BEHI rating and a Low NBS rating.

It is estimated that 52 $yd^3$ of sediment has eroded annually from Site 8-a. This site accounted for 19% of the eroded volume of sediment in the reach and 0.96% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 59 tons of sediment. It is estimated that 63 lb of TP and 150 lb of TN have eroded annually from the site. This site accounted for 28% of the eroded TP in Reach 8 and 1.6% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 25% of the eroded TN in Reach 8 and 1.3% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 18th for the volume of eroded sediment, 16th for the mass of eroded TN, and 14th for the mass of eroded TP.

In order to remediate the erosion at this site, the streambank would need to be stabilized with revetment in the form of rock or root wads. Revetment from a previous bank armoring project was present along the left bank just downstream of the erosion. Future revetment should be tied into the existing revetment along the left bank. At the time of assessment, a riparian forest buffer had recently been planted along the right bank, but the left bank would also benefit from the establishment of a riparian buffer as the stream was eroding into an agricultural field with no riparian buffer.

*Site 8-b*

The second site of substantial erosion in Reach 8 consisted of two erosion segments along both banks from STA 706+00 ft to STA 711+00 ft. The erosion segment along the right bank measured 246 ft in length with an average height of 4.3 ft and the erosion segment along the left bank measured 228 ft in length with an average height of 3.8 ft. Opposite the left bank erosion was an oversized point bar. The erosion segments were along old fields that were planted with trees as part of a riparian forest buffer planting project a few years before the assessment. This erosion affected one land cover-soil category which was Barbour-field. At its most severe extent, the erosion at this site scored a Very High BEHI rating and a Moderate NBS rating.

It is estimated that 160 $yd^3$ of sediment has eroded annually from Site 8-b. This site accounted for 57% of the eroded volume of sediment in the reach and 2.9% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 180 tons of sediment. It is estimated that 91 lb of TP and 240 lb of TN have eroded annually from the site. This site accounted for 40% of the eroded TP in Reach 8 and 2.4% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 40% of the eroded TN in Reach 8 and 2.1% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 10th for the volume of eroded sediment, 11th for the mass of eroded TN, and 12th for the mass of eroded TP.

Like Site 8-a, a riparian forest buffer planting project had recently occurred at the site but had not become established enough to anchor the bank in place to protect it from erosion. The erosion at this site could be remediated by stabilizing the streambank with revetment in the form of rock or root wads. The point bar opposite the left bank should also be resized and graded to appropriate dimensions.

*Other features of note*

In the reach, there were several areas of erosion that were not large enough in the amount of eroded material to be ranked as an area of substantial erosion but are still notable.

The first erosion segment of note was along the left bank from STA 698+00 ft to STA 700+00 ft. This erosion segment measured 188 ft in length, had an average height of 4.4 ft, and it is estimated that 8 $yd^3$ of sediment has eroded annually. The riparian buffer had previously been eroded away and there was no buffer separating the erosion from an agricultural field. Across from this erosion segment, along the right bank, the stream had previously eroded extensively into a pasture. This right bank erosion occurred primarily when the right channel was receiving the majority of streamflow. Both segments of erosion occurred due to the fact that the channel is over widened and there is a large center bar splitting the streamflow and directing the flow into the left bank and right bank causing the stream to erode into the agricultural fields. At the time of assessment, only the left channel was receiving flow as the right channel was partially filled with sediment. The erosion along the left bank has the potential to increase in severity due to the lack of a riparian buffer. The erosion along the right bank has the potential to be reactivated if the stream switches channels. The erosion could be remediated by removing the center bar, grading the channel to create a single channel, reestablishing appropriate bankfull channel dimensions, armoring the streambanks along the agricultural fields, and establishing a riparian forest buffer between the agricultural fields and the stream channel.

Another area of note was from STA 714+00 ft to STA 717+00 ft. In this area, the stream was eroding into both banks. The erosion segments totaled to 489 ft in length and had an average height of 3.6 ft. It is estimated that 19 $yd^3$ of sediment has eroded annually from the erosion segments. In addition to the erosion, the stream channel in this section contained several excessive depositional features including transverse bars. Several mature willow trees had also cantilevered into the channel at this location. The majority of the land cover in the surrounding area is old fields with herbaceous plants and shrubs covering the majority of the fields. At the time of assessment, the fields had recently been planted as part of a riparian forest buffer planting project. The erosion could be remediated naturally if the riparian forest buffer becomes established and protects the streambank from future erosion.

Another erosion segment of note was along the left bank from STA 726+50 ft to STA 727+50 ft. This erosion segment measured 101 ft in length, had an average height of 3.5 ft, and it is estimated that 3 $yd^3$ of sediment has eroded annually. Like the previous erosion segments mentioned above, this erosion segment was not substantial enough in the amount of eroded material to be ranked as a site of substantial erosion, but is still a cause for concern since it was along an agricultural field with no riparian buffer. The riparian buffer had previously been eroded away and all that remained between the agricultural field and the stream channel was a small strip of herbaceous plants. The erosion was more active in the mid-2010s when the riparian buffer was eroded away. Directly across the channel from the erosion is where an unnamed tributary enters the Ouleout from the right bank. At the tributary's confluence with the Ouleout was an aggrading bar along the right bank. This depositional bar is likely contributing to the erosion along the left bank by directing flow to the left side of the channel and into the streambank. This erosion could be remediated by armoring the left bank, grading and resizing the oversized bar to appropriate dimensions, and establishing a riparian forest buffer along the left bank.


**Figure 32: Reach 8 Map**

## *Reach 9*

### *Assessment Details*

Reach 9 begins at STA ~729+00 ft where the valley broadens. The reach ends upstream at STA ~828+00 ft where the valley narrows. It is ~9,900 ft in length and has a drainage area of 36.1 $mi^2$. The reach has a sinuosity of 1.20 and a valley slope of 0.51%. Regional regression equations indicate that the bankfull area is 207 $ft^2$, the bankfull depth is 3.12 ft, and the bankfull width is 67.6 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 976 cfs and the 100-year recurrence interval discharge is estimated to be 4,270 cfs.

In this reach, the Ouleout runs along the right hillslope at the upstream end, cuts through the center of the valley at the middle of the reach, and runs along the left side of the valley at the downstream end of the reach. Like the previous few reaches, the general land cover of the reach is primarily agricultural fields. The upstream section of the reach is forested along the right hillslope. When analyzing the streamside area, the buffer analysis categorized 61% of the area as field, 37% as forest, 1.7% as developed land, and 0.87% as herbaceous wetland.

There were 378 features recorded during the SFI for Reach 9: 145 eroding bank points composing 58 eroding bank segments, 96 revetment points composing 27 revetment segments, 16 photo points, 9 excessive depositional features, 10 control points, 9 large woody debris points, 4 tributaries, 2 stream crossings, and 2 bridges.

In the reach, 17% of the banks were actively eroding and it is estimated that 220 $yd^3$ of sediment erodes annually from the reach. In addition, 470 lb of TN and 160 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 9th among reaches for the volume of eroded sediment, 9th for the mass of eroded TN, and 8th for the mass of eroded TP. The reach's location can be viewed on the reach map in **Figure 33**.

### *Areas of Concern*

#### *Site 9-a*

At the time of assessment, Site 9-a was actively eroding. Since assessment, a stream stabilization project occurred at the site. The erosion at this site was along both banks from STA 768+50 ft to STA 776+00 ft. The erosion segment along the right bank measured 189 ft in length with an average height of 4.1 ft and the erosion segment along the left bank measured 554 ft in length with an average height of 3.6 ft. The erosion was occurring due to the downstream migration of a sharp meander bend in the channel that was eroding into an agricultural field. At its greatest extent, the stream had eroded approximately 120 ft laterally into the left bank between 2016 and 2022. There was also a large aggrading point bar on the right bank that increased in size as the left bank eroded. This erosion affected two land cover-soil categories which were Barbour-cropland and Barbour-field. At its most severe extent, the erosion at the site scored a Very High BEHI rating and an Extreme NBS rating.

Since the assessment, a stream stabilization project occurred at the site that shifted the stream laterally away from the agricultural field, stabilized the streambank and streambed with the installation of revetment and grade control structures, and resized the oversized point bar to appropriate dimensions. A riparian forest buffer planting occurred as well.

It is estimated that 480 $yd^3$ of sediment was eroding annually from Site 9-a. This eroded volume equated to 540 tons of sediment. It is estimated that 630 lb of TP and 1,400 lb of TN had eroded annually from the site. Due to the stabilization project remediating the erosion, this site was not included in sediment and nutrient calculations. It would be useful however, to continue to monitor this site and the condition of the stabilization project.

*Other features of note*

One erosion segment of note in the reach was along the right bank from STA 792+00 ft to STA 794+00 ft. This erosion was not large enough in the amount of eroded material to be ranked as a site of substantial erosion but it is still noteworthy and should be monitored. This erosion segment measured 170 ft in length with an average height of 4.1 ft. It is estimated that 38 $yd^3$ of sediment has eroded annually from the erosion segment. The erosion was along an area comprised primarily of shrubs between the stream channel and an agricultural field. The erosion was along the outside of a long, gradual bend in the channel. Within the erosion segment, an unnamed tributary enters the Ouleout from the right bank. The erosion could be remediated by establishing a riparian forest buffer by planting trees along the right bank which would help to stabilize the bank and protect against future erosion.

The Ouleout is a split channel from STA 729+50 ft to STA 733+00 ft. There were several erosion segments within the right channel. The right channel flows through an old field with no riparian buffer. The erosion segments within the right channel totaled to a length of 298 ft, had an average height of 3.0 ft, and it is estimated that 19 $yd^3$ of sediment erodes annually. In order to remediate the erosion, the right bank should be stabilized and a riparian forest buffer should be planted within the old field.

Another notable area in the reach was a hillslope failure along the left bank from STA 733+50 ft to STA 735+00 ft. This erosion segment measured 167 ft in length with a maximum height of 23 ft. Unlike the other hillslope failures along the Ouleout, that are composed primarily of glacial till, this failure was composed primarily of unconsolidated material. This unconsolidated sediment is much more susceptible to erosion due to its natural instability. The face of the hillslope was bare and contained little vegetation. There was also little toe protection at the foot of the bank and stream flow was impinging upon the base of the hillslope making the hillslope susceptible to further erosion. The hillslope was at a near vertical angle in some sections and will likely continue to contribute large amounts of sediment into the stream before it reaches an angle of repose.

In 2019, there was a stream stabilization project from STA 783+00 ft to STA 791+50 ft. Similar to the project that occurred at Site 9-a, the stream was eroding into an agricultural field along the left bank. The streambank was stabilized, grade control and revetment structures were installed, and a riparian forest buffer was planted along the streambank.

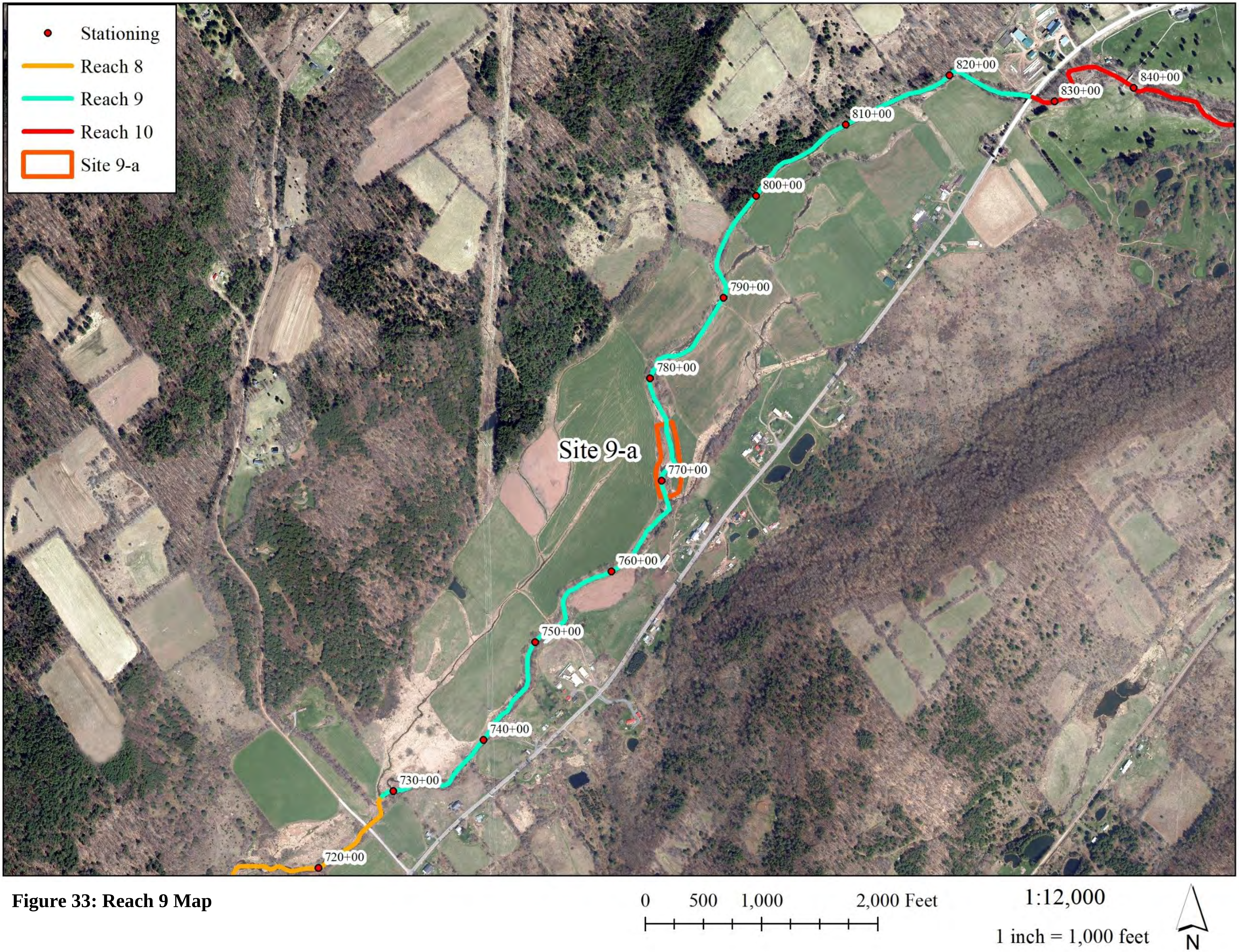


Figure 33: Reach 9 Map

## *Reach 10*

### *Assessment Details*

Reach 10 begins at STA ~828+00 ft where the valley narrows. The reach ends upstream at STA ~863+50 ft where the valley further narrows. It is ~3,550 ft in length and has a drainage area of 33.7 $mi^2$. The reach has a sinuosity of 1.19 and a valley slope of 0.74%. Regional regression equations indicate that the bankfull area is 195 $ft^2$, the bankfull depth is 3.05 ft, and the bankfull width is 65.5 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 920 cfs and the 100-year recurrence interval discharge is estimated to be 4,120 cfs.

The general land cover in the reach consists of agricultural fields and a golf course with a varying riparian buffer width throughout the reach. The buffer analysis categorized 53% of the streamside area as field, 41% as forest, 3.2% as herbaceous wetland, and 2.1% as developed land.

There were 103 features recorded during the SFI for Reach 10: 43 eroding bank points composing 15 eroding bank segments, 17 revetment points composing 6 revetment segments, 10 excessive depositional features, 7 large woody debris points, 3 tributaries, 1 bridge, and 1 photo point.

In the reach, 18% of the banks were actively eroding and it is estimated that 110 $yd^3$ of sediment erodes annually from the reach. In addition, 230 lb of TN and 63 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 14th among reaches for the volume of eroded sediment, 14th for the mass of eroded TN, and 13th for the mass of eroded TP.

Throughout this reach there were several natural and excessive depositional features indicating that this is primarily a reach where sediment is stored by the Ouleout system. During times of low flow, the stream flows subsurface in some sections of the reach as well. The one site of substantial erosion in the reach can be viewed on the reach map in **Figure 34**.

### *Areas of Concern*

#### *Site 10-a*

The one site of substantial erosion in the reach was along the right bank from STA 832+50 ft to STA 838+00 ft. This erosion segment measured 536 ft in length with an average height of 4.0 ft. The erosion was occurring along a meander that was migrating downstream through a forested section of land. Across from the erosion was a large aggrading point bar. This erosion affected two land cover-soil categories which were Barbour-forest and Tunkhannock-Chenango-forest. At its most severe extent, the erosion at this site scored a Moderate BEHI rating and an Extreme NBS rating.

It is estimated that 56 $yd^3$ of sediment has eroded annually from Site 10-a. This site accounted for 50% of the eroded volume of sediment in the reach and 1.0% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 64 tons of sediment. It is estimated that 41 lb of TP and 110 lb of TN have eroded annually from the site. This site accounted for 65% of the eroded TP in Reach 10 and 1.1% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 49% of the eroded TN in Reach 10 and 1.0% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 17th for the volume of eroded sediment, 18th for the mass of eroded TN, and 16th for the mass of eroded TP.

Though still active at the time of assessment, this site was eroding at a higher rate in the early 2010s. In addition to the eroding bank and the oversized point bar, there were several channel bridging trees that had cantilevered off the right bank and were causing an accumulation of debris in the channel and partially disrupting flow. These trees could potentially cause further blockages in the channel.

Near the apex of the meander bend is an old stream channel that runs alongside State Highway 357. This old channel used to be part of the unnamed tributary that enters the Ouleout from the right bank at STA 835+00 ft. This old channel was historically occupied by the tributary and would enter the Ouleout at STA 828+00 ft. In the early 2010s, the downstream meander on the Ouleout eroded into the right bank far enough to reach the tributary channel and capture it at STA 835+00 ft. There is a possibility that the old tributary channel could become occupied by the Ouleout if the Ouleout's current channel becomes further blocked by the cantilevered trees or if the stream erodes further into the right bank. If the Ouleout avulses into the old tributary channel, it could threaten the road and the bridge downstream at STA 828+00 ft.

The first step in addressing this site would be to cut up the trees that have cantilevered into the channel. Cutting the trees into smaller pieces would allow the debris to be transported downstream and prevent future blockages of the channel. The channel would also need to be realigned at this site to prevent future erosion and prevent the Ouleout from avulsing into the unoccupied tributary channel and potentially threatening the road. The unoccupied tributary channel should also be plugged at the upstream end to prevent the Ouleout from avulsing into it. The oversized point bar would also need to be adjusted and graded to appropriate dimensions when the channel is realigned. It would be important to maintain curvature in the newly realigned channel as the stream is naturally sinuous in this reach. Finally, the banks would need to be stabilized with revetment in the form of rock or root wads to prevent further erosion.

*Other features of note*

One erosion segment of note in the reach was along the left bank from STA 847+00 ft to STA 851+00 ft. This erosion was not great enough in terms of eroded material to be ranked as a site of substantial erosion but is still noteworthy and should be monitored. This erosion segment measured 404 ft in length, had an average height of 3.4 ft, and it is estimated that 53 $yd^3$ of sediment has eroded annually from the erosion segment. The erosion was along an area comprised of shrubs between the stream channel and a golf course. There was a large aggrading cobble bar opposite the erosion. The erosion could be remediated by stabilizing the left bank with revetment and establishing a riparian forest buffer along the left bank.

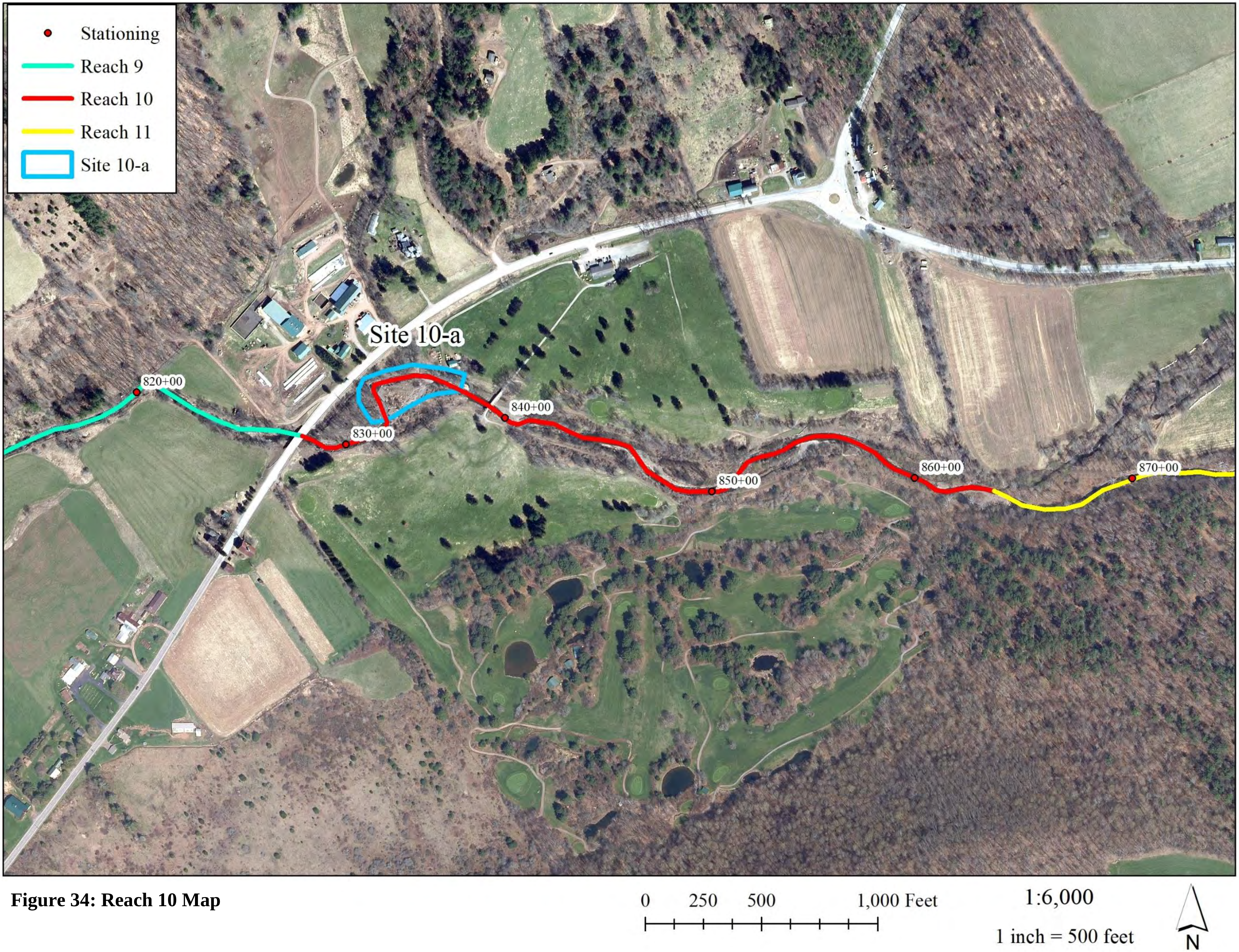


**Figure 34: Reach 10 Map**

## *Reach 11*

### *Assessment Details*

Reach 11 begins at STA ~863+50 ft where the valley narrows. The reach ends upstream at STA ~920+00 ft where Gay Creek enters the Ouleout and the valley narrows further. It is ~5,650 ft in length and has a drainage area of 30.5 $mi^2$. The reach has a sinuosity of 1.06 and a valley slope of 0.90%. Regional regression equations indicate that the bankfull area is 180 $ft^2$, the bankfull depth is 2.93 ft, and the bankfull width is 62.6 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 845 cfs and the 100-year recurrence interval discharge is estimated to be 3,970 cfs.

The stream flows along the left hillslope for the majority of the reach. In the reach, the general land cover along the left bank hillslope is forest. The land cover along the right hillslope is a mix of forest and fields. The buffer analysis categorized 73% of the streamside area as forest, 19% as field, 5.0% as herbaceous wetland, and 3.2% as developed land.

There were 152 features recorded during the SFI for Reach 11: 89 eroding bank points composing 28 eroding bank segments, 10 large woody debris points, 7 revetment points composing 2 revetment segments, 6 excessive depositional features, 4 tributaries, 4 control points, 1 bridge, and 1 photo point.

In the reach, 31% of the banks were actively eroding and it is estimated that 180 $yd^3$ of sediment erodes annually from the reach. In addition, 410 lb of TN and 74 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 10th among reaches for the volume of eroded sediment, 10th for the mass of eroded TN, and 12th for the mass of eroded TP. The one site of substantial erosion in the reach can be viewed on the reach map in **Figure 35**.

### *Areas of Concern*

#### *Site 11-a*

The one site of substantial erosion in the reach was from STA 906+00 ft to STA 908+00 ft along the right bank. This erosion segment measured 200 ft in length with an average height of 3.4 ft. The erosion was along an old field and affected one land cover-soil category which was Fluvaquent-Udifluvent-field. In this section of stream, the channel has become over widened and several excessive depositional features were located in the channel. At its most severe extent, the erosion at this site scored a Very High BEHI rating and a Low NBS rating.

It is estimated that 90 $yd^3$ of sediment has eroded annually from Site 11-a. This site accounted for 52% of the eroded volume of sediment in the reach and 1.7% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 110 tons of sediment. It is estimated that 47 lb of TP and 140 lb of TN have eroded annually from the site. This site accounted for 63% of the eroded TP in Reach 11 and 1.2% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 35% of the eroded TN in Reach 11 and 1.3% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 14th for the volume of eroded sediment, 17th for the mass of eroded TN, and 15th for the mass of eroded TP.

The erosion at this site could be remediated by stabilizing the right bank with revetment and establishing a riparian forest buffer along the right bank between the stream channel and the field. The channel would also need to be resized to appropriate bankfull dimensions. The excessive depositional features in this section would also need to be resized and graded to appropriate dimensions.

*Other features of note*

One notable erosion segment in the reach was the hillslope failure along the left bank from STA 872+50 ft to STA 874+50 ft. This erosion segment measured 201 ft in length and had a maximum height of 28 ft. The hillslope failure contained some toe protection consisting of cantilevered soil blocks and trees resting along the base of the hillslope. Some sections of the failure were actively eroding and contained little vegetation at the time of assessment.

A second hillslope failure in the reach was located along the left bank from STA 919+50 ft to STA 921+00 ft. The failure measured 135 ft in length and had a maximum height of 22 ft. The hillslope failure had little toe protection though some boulders were resting intermittingly along the base of the hillslope. The hillslope was composed primarily of glacial till which can be more resistant to erosion than a bank composed of unconsolidated sediment but can also be a source of fine sediment. The majority of the hillslope was bare, with a small amount of coltsfoot and other herbaceous vegetation growing on it. Across from this shallow slide, there was an oversized side channel bar with large woody debris deposited on it. This bar was centered around Gay Brook's confluence with the Ouleout. This bar is contributing to the erosion by causing flow to be directed towards the left hillslope. Like the previous hillslope failures, it would be wise to monitor this failure to make sure it does not increase in severity or cause instability within the stream channel.

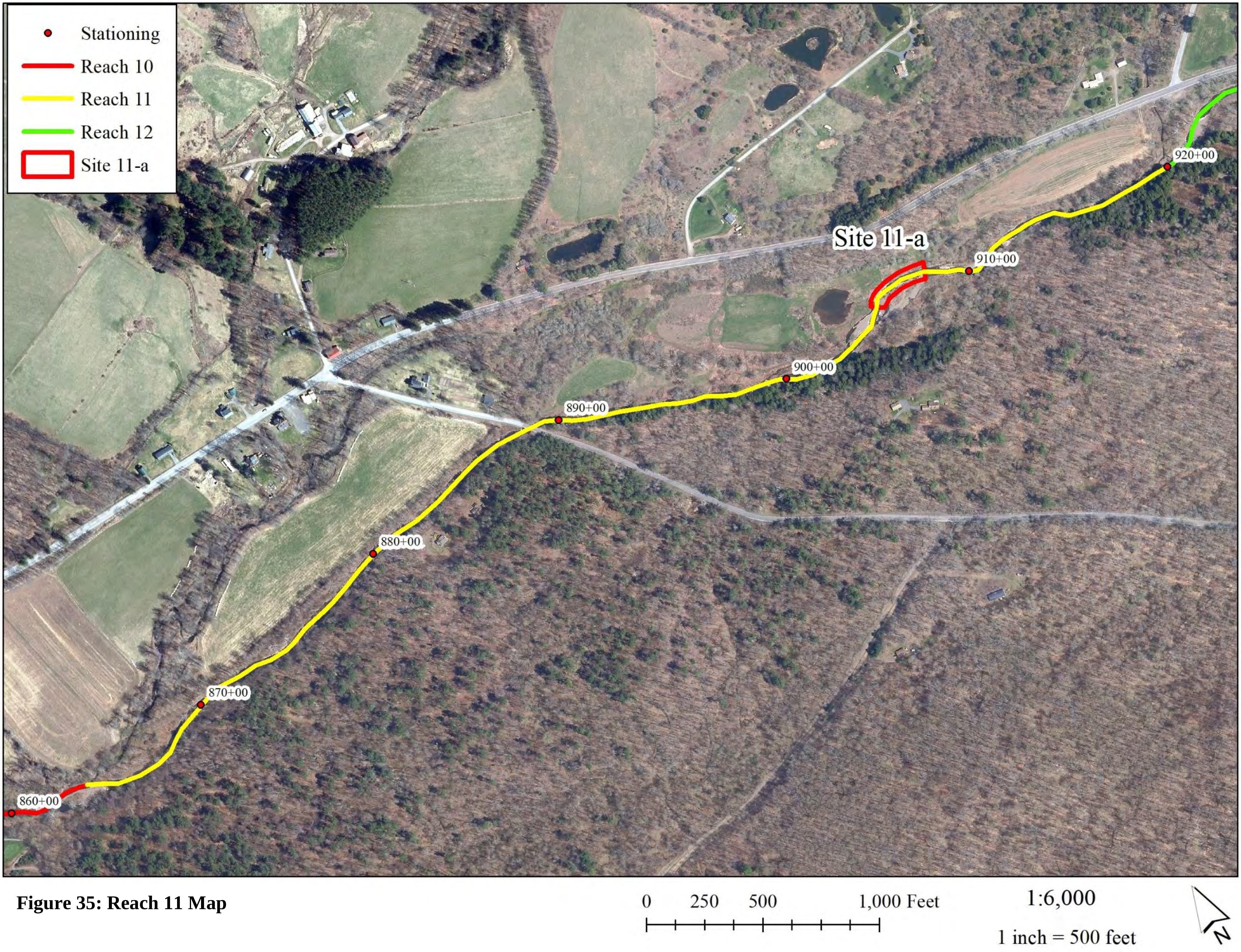


**Figure 35: Reach 11 Map**

## *Reach 12*

### *Assessment Details*

Reach 12 begins at STA ~920+00 ft where Gay Creek enters the Ouleout and the valley narrows. The reach ends upstream at STA ~959+00 ft where the valley further narrows and bedrock control ends. It is ~3,900 ft in length and has a drainage area of 27 $mi^2$. The reach has a sinuosity of 1.23 and a valley slope of 1.02%. Regional regression equations indicate that the bankfull area is 163 $ft^2$, the bankfull depth is 2.8 ft, and the bankfull width is 59.3 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 761 cfs and the 100-year recurrence interval discharge is estimated to be 3,800 cfs.

The valley narrows considerably in this reach causing the stream to be confined in many areas throughout the reach. The reach is primarily forested with a few hay fields on the right bank upslope of the stream channel. The buffer analysis categorized 80% of the streamside area as forest, 14% as field, 3.8% as developed land, and 2.7% as herbaceous wetland.

There were 84 features recorded during the SFI for Reach 12: 35 eroding bank points composing 16 eroding bank segments, 11 control points, 10 large woody debris points, 6 excessive depositional features, 2 tributaries, 2 stream crossings, and 2 photo points.

In the reach, 17% of the banks were actively eroding and it is estimated that 120 $yd^3$ of sediment erodes annually. In addition, 260 lb of TN and 22 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 13th for the volume of eroded sediment, 13th for the mass of eroded TN, and 19th for the mass of eroded TP. There were no sites of substantial erosion in the reach. The reach's location can be viewed on the reach map in **Figure 36**.

### *Areas of Concern*

### *Other features of note*

As common with a more forested section of stream, the notable features identified in this reach were large woody debris accumulations. There were three notable sites of large wood accumulations in the reach.

One location of note was the inactive left hillslope failure from STA 935+00 ft to STA 936+00 ft. This failure was stable and contained young woody trees repopulating the hillslope. However, at the base of the hillslope there were two trees that had fallen across the channel. These trees were causing deposition along the right side of the channel forming a large side channel bar. This bar was causing the stream to flow along the left side of the channel near the base of the hillslope. The trees that were causing the deposition could cause a blockage if they collect other debris. These trees should be cut into sections to allow debris to pass downstream.

The second feature of note in the reach was from STA 946+00 ft to STA 948+50 ft. In this section there was a recently active hillslope failure and a dormant hillslope failure along the right bank. Both failures were composed primarily of glacial till. These failures had previously contributed large wood into the channel. Several trees, along with a few soil blocks, had slid down the active hillslope and into the channel. In addition, several trees were bridging the channel at this location. The channel bridging trees could cause a blockage and prevent other debris from passing downstream. The hillslope where the majority of the large wood loading was occurring, was still unstable at the time of assessment and has the potential to contribute more large wood and sediment into the channel in the future. The hillslope was predominately bare at the time of assessment but did contain some toe protection, primarily being the aforementioned woody debris and soil blocks at the base of the hillslope. The channel bridging trees should be cut into sections to prevent blockages in the channel.

The most egregious site of large woody debris was from STA 955+00 ft to STA 957+00 ft. At this site there was a large accumulation of woody debris blocking the channel. There were approximately two dozen pieces of large woody debris that had accumulated in the channel. Some of the trees were hemlocks that had fallen off the left hillslope, others were pieces of large wood that had floated downstream and become stuck in the accumulation. The accumulation was also causing large amounts of deposition upstream and along the right side of the channel. At the time of assessment, streamflow was severely obstructed by the accumulation. During a high flow event, it is likely the channel becomes further blocked and the stream could avulse. The stream was also eroding the toe of the left hillslope adjacent to the large wood accumulation. This accumulation is in a forested area and is not located near any structures or roadways, as such, it does not pose a threat to any infrastructure but is a concern for channel stability and sediment transport. The trees in the accumulation should be cut into smaller pieces so that they do not obstruct flow and can be transported downstream.

The reach also contained bedrock control along certain sections. Notably, the right hillslope from STA 927+00 ft to STA 929+00 ft, the left hillslope from STA 939+00 ft to STA 941+00 ft, the streambed of the channel from STA 944+50 ft to STA 945+50 ft, the streambed from STA 952+50 ft to STA 956+00 ft, and the left hillslope and streambed from STA 957+00 ft to STA 959+00 ft were all composed of bedrock providing these sections of channel with stability as well as grade and planform control.


**Figure 36: Reach 12 Map**

### *Reach 13*

#### *Assessment Details*

Reach 13 begins at STA ~959+00 ft where the valley narrows and bedrock control ends. The reach ends upstream at STA ~990+00 ft where an unnamed tributary from Swart Hollow enters the Ouleout. It is ~3,100 ft in length and has a drainage area of 26.1 $mi^2$. The reach has a sinuosity of 1.26 and a valley slope of 1.05%. Regional regression equations indicate that the bankfull area is 158 $ft^2$, the bankfull depth is 2.77 ft, and the bankfull width is 58.4 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 739 cfs and the 100-year recurrence interval discharge is estimated to be 3,690 cfs.

The general land cover in the reach is forest along both banks. There are also a few agricultural fields further upslope on the right bank. The buffer analysis categorized 79% of the streamside area as forest, 15% as field, 5.8% as herbaceous wetland, and 0.04% as developed land.

There were 62 features recorded during the SFI for Reach 13: 26 eroding bank points composing 11 eroding bank segments, 11 large woody debris points, 5 excessive depositional features, 3 revetment points composing 2 revetment segments, 3 tributaries, and 1 bridge.

In the reach, 19% of the banks were actively eroding and it is estimated that 52 $yd^3$ of sediment erodes annually from the reach. In addition, 110 lb of TN and 19 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 20th among reaches for the volume of eroded sediment, 20th for the mass of eroded TN, and 20th for the mass of eroded TP. There were no sites of substantial erosion in the reach. The reach's location can be viewed on the reach map in **Figure 37**.

#### *Areas of Concern*

#### *Other features of note*

Similar to Reach 12, the noteworthy feature in this predominately forested reach was large woody debris. There were several channel bridging trees throughout the reach that were causing small accumulations of debris. Channel bridging trees were located at STA 962+50 ft, STA 963+50 ft, STA 969+50 ft, and STA 986+50 ft. These channel bridging trees should be cut into smaller pieces to allow debris to pass downstream.


**Figure 37: Reach 13 Map**

## *Reach 14*

### *Assessment Details*

Reach 14 begins at STA ~990+00 ft where an unnamed tributary from Swart Hollow enters the Ouleout. The reach ends upstream at STA ~1057+50 ft where an unnamed tributary from Coe Hill enters the Ouleout. It is ~6,750 ft in length and has a drainage area of 24.8 $mi^2$. The reach has a sinuosity of 1.23 and a valley slope of 1.09%. Regional regression equations indicate that the bankfull area is 152 $ft^2$, the bankfull depth is 2.72 ft, and the bankfull width is 57.1 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 708 cfs and the 100-year recurrence interval discharge is estimated to be 3,600 cfs.

The general land cover in the reach is a mix between forest and agricultural fields in the lower two-thirds of the reach, while the upstream third of the reach is an herbaceous wetland. The buffer analysis categorized 56% of the streamside area as forest, 27% as field, 15% as herbaceous wetland, and 1.4% as developed land.

There were 186 features recorded during the SFI for Reach 14: 95 eroding bank points composing 34 eroding bank segments, 17 excessive depositional features, 11 large woody debris points, 8 revetment points composing 3 revetment segments, 6 control points, 4 stream crossings, 3 photo points, 3 tributaries, and 2 headcuts.

In the reach, 27% of the banks were actively eroding and it is estimated that 550 $yd^3$ of sediment erodes annually from the reach. In addition, 1,200 lb of TN and 250 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 3rd among reaches for the volume of eroded sediment, 3rd for the mass of eroded TN, and 6th for the mass of eroded TP. The two sites of substantial erosion in the reach can be viewed on the reach map in **Figure 38**.

### *Areas of Concern*

#### *Site 14-a*

From STA 1010+50 ft to STA 1020+50 ft, the stream had avulsed into what was previously an overflow channel. Prior to assessment, the stream had eroded through the edge of a hay field along the left bank and occupied the avulsion channel between the forested floodplain and an agricultural field. The stream used to flow in a channel along a bend between a forested floodplain and the right hillslope. At the time of assessment, the beginning of the old channel was plugged with sediment and a large depositional bar had formed where the old channel once was. The old channel still contained a moderate amount of flow at the time of assessment due to the fact that the stream partially flowed subsurface through the cobble bar. It is roughly estimated that the avulsion channel contained 75% of the streamflow and the old channel contained 25% of the streamflow.

The site of substantial erosion was along the left bank from STA 1016+50 ft to STA 1020+50 ft just upstream of the avulsion. At this site, the stream was actively eroding into a hay field along the left bank with no riparian forest buffer. This erosion segment measured 465 ft in length with an average height of 2.8 ft. This erosion affected two land cover-soil categories which were Fluvaquent-Udifluvent-field and Fluvaquent-Udifluvent-forest. At its most severe extent, the erosion at this site scored a High BEHI rating and a High NBS rating.

It is estimated that 130 $yd^3$ of sediment has eroded annually from Site 14-a. This site accounted for 24% of the eroded volume of sediment in the reach and 2.4% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 150 tons of sediment. It is estimated that 72 lb of TP and 220 lb of TN have eroded annually from the site. This erosion accounted for 28% of the eroded TP in Reach 14 and 1.9% of the eroded TP along the main stem of the Ouleout. Additionally, this erosion accounted for 18% of the eroded TN in Reach 14 and 1.9% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 12th for the volume of eroded sediment, 12th for the mass of eroded TN, and 13th for the mass of eroded TP.

At STA ~1015+00 ft in the avulsion channel, there was a headcut that had been migrating upstream. The headcut had a depth of 2 ft. This headcut will likely further exacerbate the substantial erosion site when it reaches the eroding streambank at STA 1016+50 ft.

There was also a hillslope failure within the old channel from STA 1012+00 ft to STA 1012+50 ft. The failure measured 84 ft in length and had a maximum height of 21.4 ft. The hillslope was primarily bare and composed of glacial till. There is potential for more trees to cantilever off the hillslope and into the right channel as many trees at the top of the hillslope were severely undercut. The hillslope did contain toe protection in the form of boulders and will likely not continue to erode if the majority of streamflow remains in the avulsion channel and the old channel remains predominately inactive.

There are several options that could be pursued to remediate the issues at this site. Grade control structures would need to be installed in the streambed of the channel in order to prevent the downstream headcut from further destabilizing the channel. The left bank would need to be stabilized with revetment in the form of rock or root wads to prevent further erosion and a riparian buffer would also need to be established between the agricultural field and the stream channel. If the goal is to move the channel back into the old channel, the large depositional feature currently plugging the old channel would need to be resized to appropriate bankfull dimensions and the avulsion channel would need to be plugged to prevent the channel from occupying it. The right bank hillslope failure within the old channel would also need to be stabilized at the toe so further erosion does not occur along the hillslope.

*Site 14-b*

The reach from STA 1044+00 ft to STA 1059+00 ft is a flat area of aggradation. The stream regularly shifts its channel position, and erodes and deposits large amounts of sediment.

The second site of substantial erosion in Reach 14 falls within this area of aggradation and was along both banks from STA 1044+00 ft to STA 1056+00 ft. This area of the stream was previously a split channel in 2016. Between 2016 and 2022, the stream filled in both channels with sediment and a new channel formed which cut through a large center bar that was previously in between the two channels. In addition, the stream eroded into the left and right banks just upstream of where the center bar was located. This erosion affected one land cover-soil category which was Fluvaquent-Udifluvent-herbaceous wetland. At its most severe extent, the erosion at this site scored a Moderate BEHI rating and a Low NBS rating.

The erosion totaled to 555 ft in length with an average height of 3.3 ft. It is estimated that 280 $yd^3$ of sediment has eroded annually from Site 14-b. This site accounted for 52% of the eroded volume of sediment in the reach and 5.2% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 330 tons of sediment. It is estimated that 130 lb of TP and 720 lb of TN have eroded annually from the site. This site accounted for 50% of the eroded TP in Reach 14 and 3.3% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 60% of the eroded TN in Reach 14 and 6.3% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 4th for the volume of eroded sediment, 4th for the mass of eroded TN, and 9th for the mass of eroded TP.

This section of the Ouleout is naturally unstable and would be complex to stabilize. Because of this, attempting to stabilize the channel in this section of stream would not be recommended. However, the right bank at the upstream end of the site along an agricultural field could potentially be armored with revetment such as large rock or root wads. A riparian forest buffer could also be established along that section of the right bank in order to protect the bank from future erosion.

*Other features of note*

There were several other features of note throughout the reach. As recently as 2021, the Ouleout was a split channel from STA 990+00 ft to STA 999+00 ft. At the time of assessment, the beginning of the right channel at STA 999+00 ft was blocked by sediment and large woody debris and was not receiving any flow. The right channel could become reoccupied in the future if the sediment and debris is cleared from the upstream end of the right channel.

Bedrock was present along the left bank and intermittently throughout the streambed of the Ouleout from STA 1036+00 ft to STA 1045+00 ft. This bedrock acts as grade and planform control providing stability for this section of stream.

At STA 1044+00 ft there were remnants of an old mill dam. The remnants of this dam do not affect sediment transport nor act as a barrier for aquatic organisms.

There was a headcut present at STA 1056+00 ft, which had lowered the stream bed approximately 2 ft. This headcut likely contributed to the erosion at Site 14-b. At the time of assessment, the headcut only threatened bed and bank stability. If the headcut continues to migrate upstream, it could threaten the integrity of a private bridge located ~1,350 ft upstream of the headcut.

The upstream section of the reach will likely experience further erosion in the future as just upstream of this reach is a meander eroding downstream located between STA 1057+50 ft and STA 1060+00 ft. This meander previously migrated through an agricultural field in Reach 15 but has since moved downstream and, at the time of assessment, was eroding into alluvial deposits in the depositional area at the downstream end of Reach 15. In addition to this meander, there was an avulsion channel forming at STA 1059+00 ft which cuts through the left bank floodplain. This section of channel is further discussed in the Reach 15 section of the report.

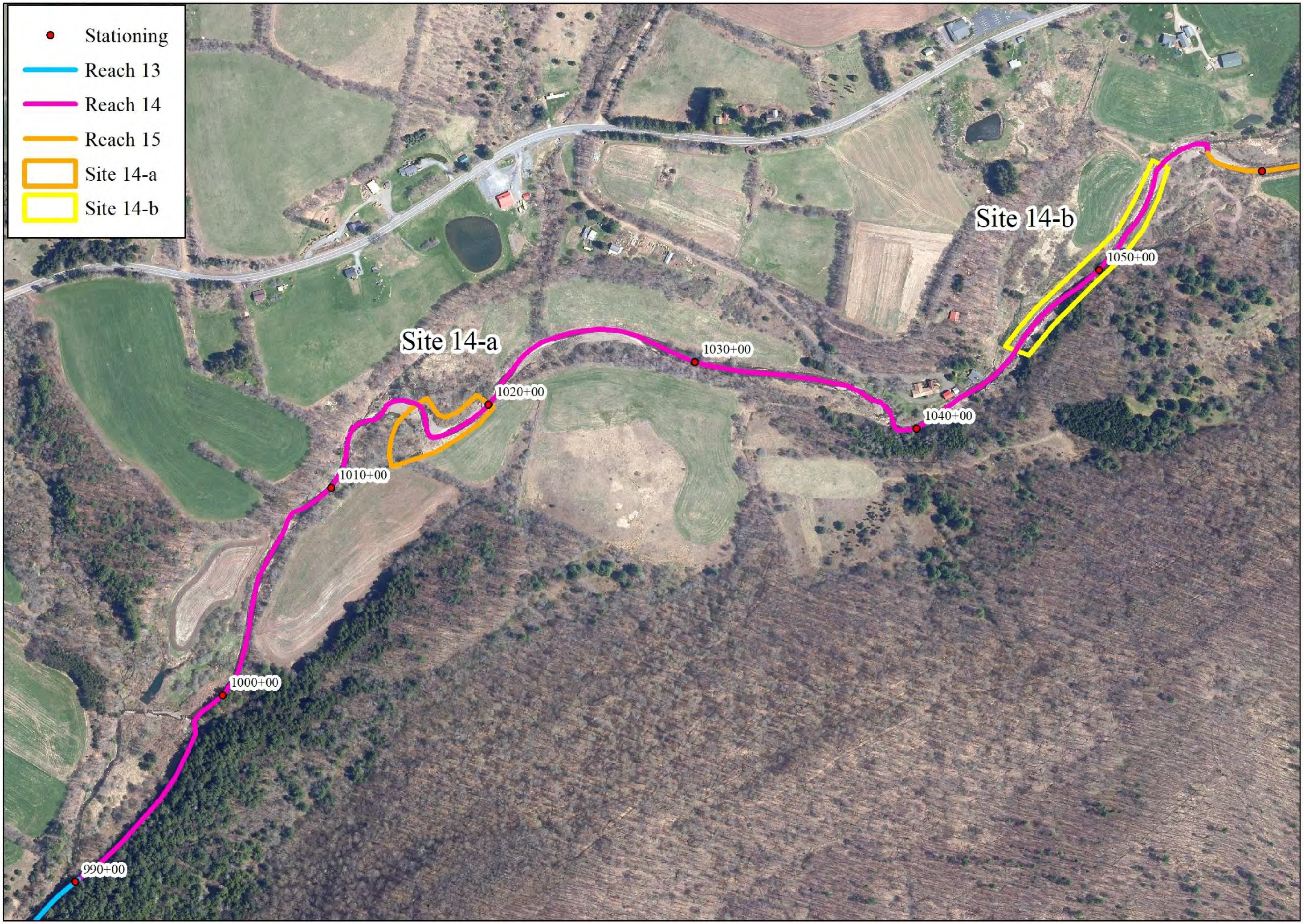


**Figure 38: Reach 14 Map**

## *Reach 15*

### *Assessment Details*

Reach 15 begins at STA ~1057+50 ft where an unnamed tributary from Coe Hill enters the Ouleout. The reach ends upstream at STA ~1118+00 ft where the valley narrows. It is ~6,050 ft in length and has a drainage area of 21 $mi^2$. The reach has a sinuosity of 1.12 and a valley slope of 1.11%. Regional regression equations indicate that the bankfull area is 132 $ft^2$, the bankfull depth is 2.55 ft, and the bankfull width is 53 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 614 cfs and the 100-year recurrence interval discharge is estimated to be 3,210 cfs.

The general land cover of the reach is predominately forest along the left hillslope and predominately fields along the right bank. The buffer analysis categorized 53% of the streamside area as forest, 46% as field or cropland, and 1.2% as herbaceous wetland.

There were 142 features recorded during the SFI for Reach 15: 79 eroding bank points composing 28 eroding bank segments, 11 excessive depositional features, 10 large woody debris points, 4 revetment points composing 2 revetment segments, 4 photo points, 2 tributaries, 1 stream crossing, and 1 bridge.

In the reach, 25% of the banks were actively eroding and it is estimated that 300 $yd^3$ of sediment erodes annually from the reach. In addition, 590 lb of TN and 85 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 6th among reaches for the volume of eroded sediment, 8th for the mass of eroded TN, and 11th for the mass of eroded TP. The two sites of substantial erosion in the reach can be viewed on the reach map in **Figure 39**.

### *Areas of Concern*

### *Site 15-a*

As mentioned in the Reach 14 section of the report, a meander in the channel has been actively eroding downstream into the left bank in Reach 15. The meander previously eroded into an agricultural field in the mid-2000s but has since moved downstream. No riparian buffer exists between the agricultural field and the stream channel. From historical orthoimagery it is estimated that the meander has migrated ~250 ft downstream between 2006 and 2022. At the time of assessment in 2022, the bend was located from STA 1057+50 ft to STA 1060+00 ft. As previously mentioned, there is an avulsion channel that has formed at STA 1059+00 ft on the left bank which cuts through the left bank floodplain and rejoins the Ouleout at STA 1051+00 ft. At the time of assessment, the avulsion channel appeared to only receive flow during high flow events. This erosion affected one land cover-soil category which was Fluvaquent-Udifluvent-herbaceous wetland. At its most severe extent, the erosion at this site scored a Moderate BEHI rating and a High NBS rating.

The erosion segment along this bend measured 245 ft in length with an average height of 2.7 ft. It is estimated that 70 $yd^3$ of sediment has eroded annually from Site 15-a. This site accounted for 23% of the eroded volume of sediment in the reach and 1.3% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 82 tons of sediment. It is estimated that 31 lb of TP and 180 lb of TN have eroded annually from the site. This site accounted for 36% of the eroded TP in Reach 15 and 0.80% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 30% of the eroded TN in Reach 15 and 1.6% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 16th for the volume of eroded sediment, 14th for the mass of eroded TN, and 18th for the mass of eroded TP.

In order to prevent further erosion at this site, the stream would need to be realigned and the sharp meander bend within the channel would also need to be adjusted in order to reestablish appropriate channel dimensions. Grade control structures would also need to be implemented in order to prevent the downstream headcut from traveling upstream and further exacerbating the erosion. A riparian forest buffer would also need to be planted along the agricultural field. As mentioned before, a project would be difficult in this section of stream because of the fact that the stream appears to be naturally unstable in this section, shifting regularly over time. Another option is to wait and see if the avulsion channel captures the majority of flow in this section of stream. If that were to occur, it could potentially alleviate some of the erosion issues downstream.

*Site 15-b*

The second site of substantial erosion in Reach 15 was along the right bank from STA 1100+00 ft to STA 1102+00 ft. This erosion segment measured 251 ft in length with an average height of 6.6 ft. The erosion was along an old field comprised of herbaceous plants. The bank was at a near vertical angle along some sections of the erosion. This erosion affected one land cover-soil category which was Maplecrest-field. At its most severe extent, the erosion at this site scored a Very High BEHI rating and a Moderate NBS rating.

It is estimated that 110 $yd^3$ of sediment has eroded annually from Site 15-b. This site accounted for 36% of the eroded volume of sediment in the reach and 2.0% of the eroded volume of sediment along the main stem of the Ouleout. This eroded volume equates to 120 tons of sediment. It is estimated that 11 lb of TP and 160 lb of TN have eroded annually from the site. This site accounted for 6.1% of the eroded TP in Reach 15 and 0.30% of the eroded TP along the main stem of the Ouleout. Additionally, this site accounted for 27% of the eroded TN in Reach 15 and 1.4% of the eroded TN along the main stem of the Ouleout. Of the sites of substantial erosion along the main stem of the Ouleout, this site ranked 13th for the volume of eroded sediment, 15th for the mass of eroded TN, and 19th for the mass of eroded TP.

In order to remediate the erosion at this site, the streambank would need to be stabilized with revetment such as rock or root wads. The bank would also need to be graded to have a more gradual angle of repose. A riparian forest buffer would also need to be established along the right bank between the field and the stream channel to help anchor the streambank and prevent future erosion.

*Other features of note*

One area of note in the reach was a left hillslope failure from STA 1075+50 ft to STA 1077+50 ft. The failure measured 111 ft in length and had a maximum height of 35 ft. The hillslope was primarily composed of glacial till and was sparsely vegetated with herbaceous plants such as coltsfoot. The base of the hillslope contained toe protection in the form of boulders. At the time of assessment, the downstream section of the failure appeared to be at an angle of repose and the erosion could likely become dormant in the future.

One notable location of large woody debris in the channel was at STA 1106+00 ft. At this location, a large pine tree that had cantilevered off the left bank and into the channel. This tree was bridging the entire active channel and has the potential to capture debris and cause a blockage in the channel at higher flow.

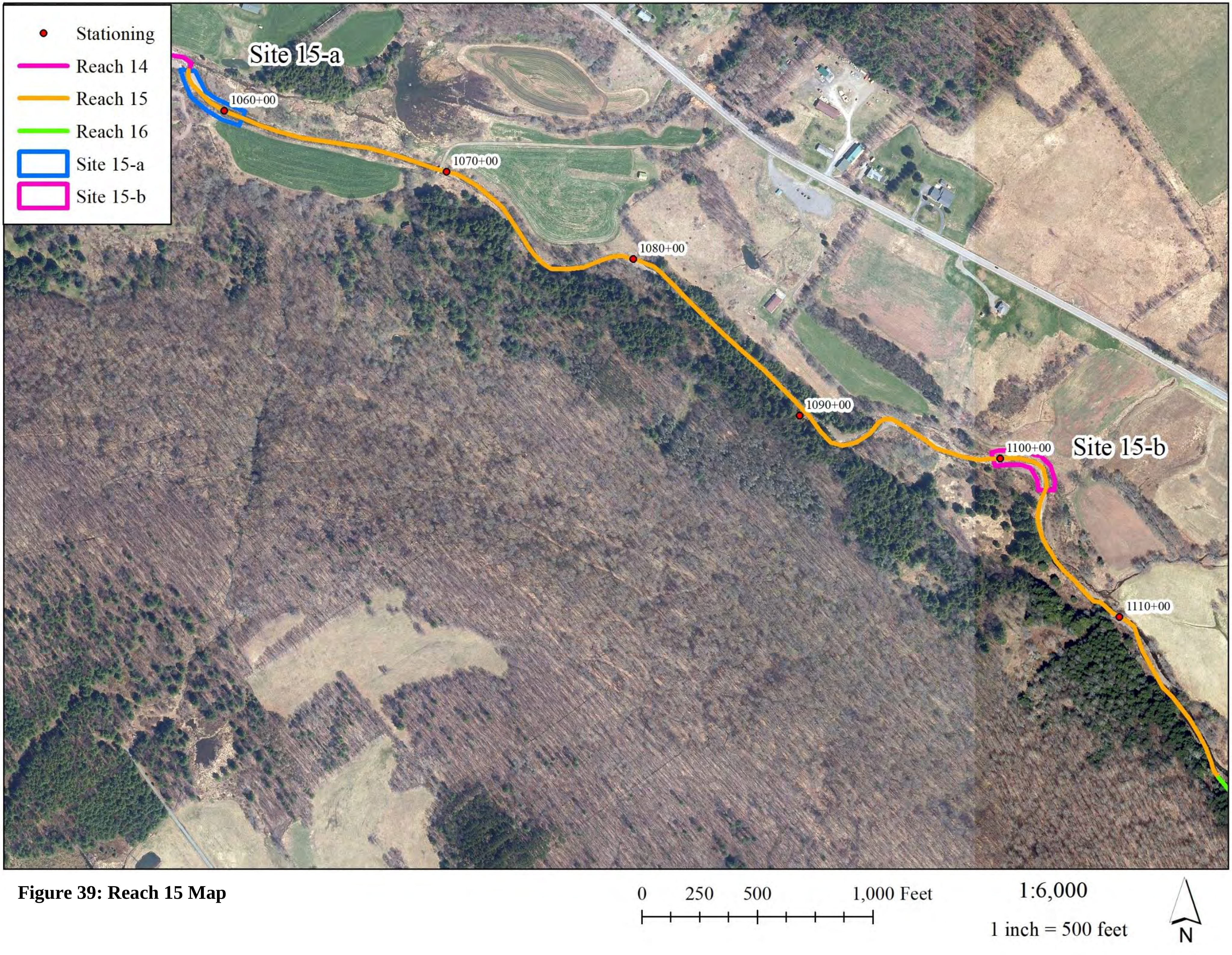


**Figure 39: Reach 15 Map**

## *Reach 16*

### *Assessment Details*

Reach 16 begins at STA ~1118+00 ft where the valley narrows. The reach ends upstream at STA ~1150+50 ft where an unnamed tributary from Houghtaling Hollow enters the Ouleout. It is ~3,250 ft in length and has a drainage area of 16.3 $mi^2$. The reach has a sinuosity of 1.06 and a valley slope of 1.18%. Regional regression equations indicate that the bankfull area is 107 $ft^2$, the bankfull depth is 2.32 ft, and the bankfull width is 47.3 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 494 cfs and the 100-year recurrence interval discharge is estimated to be 2,630 cfs.

The general land cover of the reach along the left hillslope is forest. The right hillslope contains some forest cover while the top of the hillslope consists primarily of fields. The buffer analysis classified 72% of the streamside area as forest, 21% as field, and 7.4% as herbaceous wetland.

There were 85 features recorded during the SFI for Reach 16: 47 eroding bank points composing 17 eroding bank segments, 10 large woody debris points, 6 excessive depositional features, 2 photo points, 2 tributaries, and 1 headcut.

In the reach, 24% of the banks were actively eroding and it is estimated that 60 $yd^3$ of sediment erodes annually from the reach. In addition, 120 lb of TN and 16 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 18th among reaches for the volume of eroded sediment, 18th for the mass of eroded TN, and 21st for the mass of eroded TP. The reach's location can be viewed on the reach map in **Figure 40**.

### *Areas of Concern*

### *Other features of note*

There were no substantial sites of erosion in the reach, however, there were still several notable features in the reach. There was a split channel at STA 1119+00 ft, with a mid-channel bar in between the channels. The right channel was receiving a majority of the flow at the time of assessment. Within the right channel, there was a headcut with a depth of 1.2 ft. The threat this headcut posed was to bed and bank stability as there was no infrastructure located in close proximity to the stream channel.

At STA 1124+00 ft there was a beaver impoundment that spanned the full channel creating a large pool upstream. The beaver dam rose ~4 ft above the streambed and created an ~150 ft long pool upstream of the impoundment. Of the numerous sites of beaver activity along the Ouleout, this site was notable due to the damming of the entire channel.

There were also several notable sites of large woody debris in the reach. There was a channel bridging tree that cantilevered off the right bank at STA 1126+50 ft. This tree could cause an accumulation within the channel during higher flow. Between STA 1131+00 ft and STA 1133+50 ft there were several trees that had cantilevered off the right hillslope and into the channel capturing debris within the channel. The right hillslope that the trees slid off of, was composed primarily of glacial till and had previously eroded but appeared dormant at the time of assessment.

There was a right hillslope failure from STA 1138+50 ft to STA 1139+50 ft. The failure measured 136 ft in length and had a maximum height of 18 ft. The hillslope was composed primarily of glacial till. Cantilevered blocks of soil, root wads, and large woody debris had fallen into the channel at this site and blocked a large portion of the channel obstructing flow and causing an accumulation of debris. Just upstream of the failure was a transverse bar causing streamflow to impinge upon the base of the right hillslope. Across from the hillslope was a large floodplain along the left bank that the stream was eroding into at the time of assessment due to the channel being blocked by the aforementioned debris.

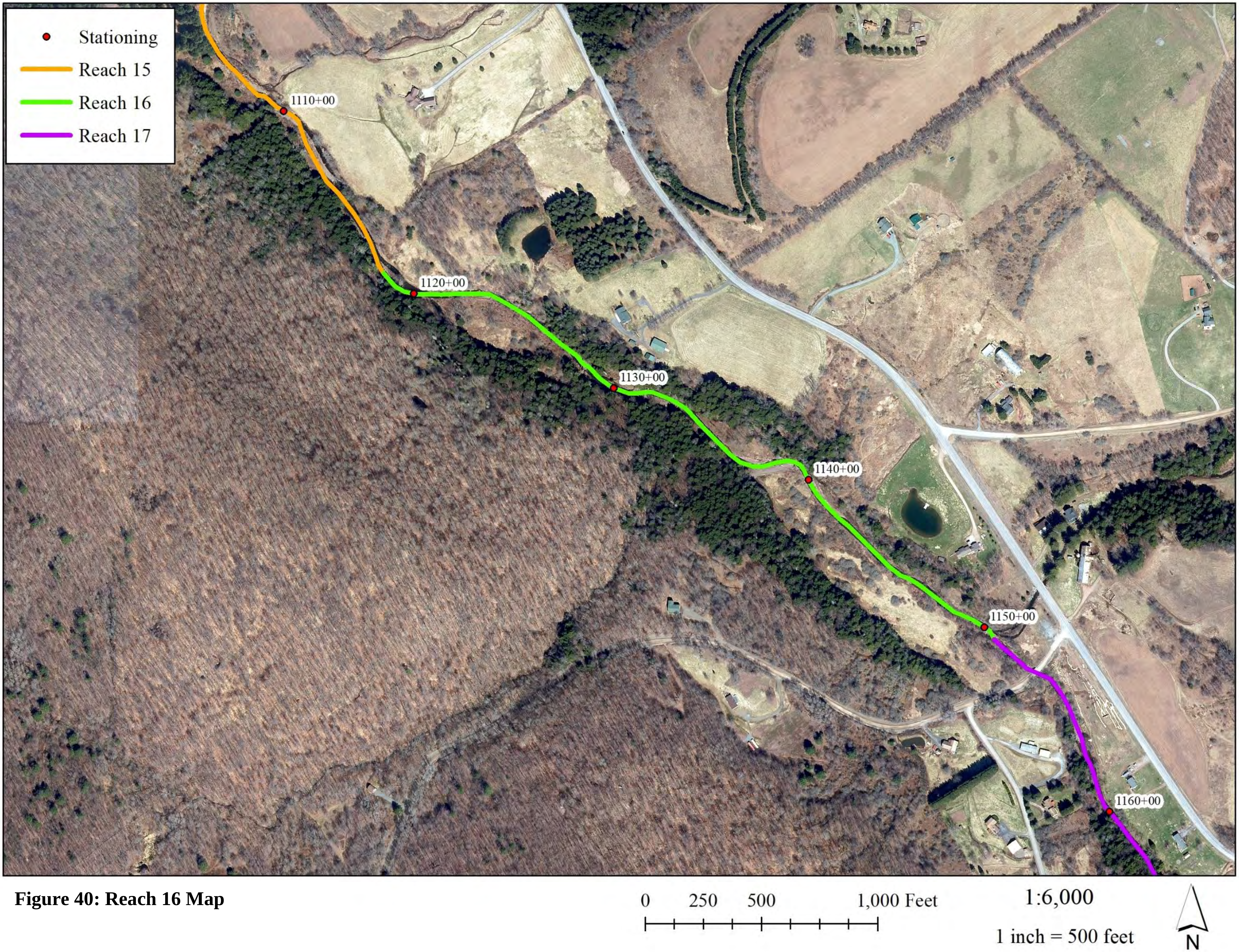


Figure 40: Reach 16 Map

## *Reach 17*

### *Assessment Details*

Reach 17 begins at STA ~1150+50 ft where an unnamed tributary from Houghtaling Hollow enters the Ouleout. The reach ends upstream at STA ~1189+50 ft where the valley narrows. It is ~3,900 ft in length and has a drainage area of 9.03 $mi^2$. The reach has a sinuosity of 1.11 and a valley slope of 1.44%. Regional regression equations indicate that the bankfull area is 66.1 $ft^2$, the bankfull depth is 1.86 ft, and the bankfull width is 36.3 ft (USGS,2023). In addition, the bankfull discharge is estimated to be 298 cfs and the 100-year recurrence interval discharge is estimated to be 1,720 cfs.

The general land cover of the reach is forest with some developed land near Warner Hill Road. The buffer analysis categorized 57% of the streamside area as forest, 27% as field, 9.4% as herbaceous wetland, and 6.0% as developed land.

There were 123 features recorded during the SFI for Reach 17: 60 eroding bank points composing 25 eroding bank segments, 12 large woody debris points, 12 excessive depositional features, 4 revetment points composing 2 segments of revetment, 3 photo points, 2 tributaries, 1 stream crossing, 1 bridge, and 1 fine sediment point.

In the reach, 24% of the banks were actively eroding and it is estimated that 59 $yd^3$ of sediment erodes annually from the reach. In addition, 120 lb of TN and 29 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 19th among reaches for the volume of eroded sediment, 19th for the mass of eroded TN, and 16th for the mass of eroded TP. There were no sites of substantial erosion in the reach. The reach's location can be viewed on the reach map in **Figure 41**.

### *Areas of Concern*

### *Other features of note*

One location of large woody debris in the channel was at STA 1173+50 ft where several large willows had cantilevered off the right bank and into the channel. These willows were causing an accumulation of debris upstream and scour within the bed of the channel. The willows could cause a blockage if further debris accumulates at the site.

The most concerning accumulation of large woody debris was from STA 1171+00 ft to STA 1171+50 ft. At this location, there were multiple trees that slid off a previously eroding left bank hillslope failure. The hillslope, for the most part, had recovered and was revegetated with young birch trees and other vegetation. However, there were approximately two dozen pieces of large woody debris that accumulated in the channel at the site. This accumulation nearly blocks the whole channel, obstructs flow, and prevents debris from passing downstream. There was also a large depositional bar upstream of the accumulation indicating that the accumulation is affecting sediment transport. Further accumulation of debris at the site would likely block the channel and could cause the stream to avulse.

Between 2016 and 2021, the Ouleout avulsed from a channel that ran through a wetland and into a channel that runs along the base of the left hillslope. The channels diverge at STA

1177+00 ft and converge at STA 1168+00 ft. At the time of assessment, only the channel along the left hillslope was receiving flow. Between STA 1166+00 ft and STA 1168+00 ft, there is an old berm along the right bank. This berm prevents the stream from accessing its floodplain during high flow events.

One erosion segment of note in the reach was along the left bank from STA 1180+00 ft to STA 1183+00 ft. This erosion was not large enough in terms of eroded material to be ranked as a site of substantial erosion but is still noteworthy and should be monitored. This erosion segment measured 210 ft in length and had an average height of 2.2 ft. It is estimated that 28 $yd^3$ of sediment has eroded annually from the erosion segment. The erosion was along a large bend in the stream channel opposite an aggrading point bar on the right bank. From 2016 to 2022, the stream had eroded approximately 30 ft laterally into a field along the left bank. To the southwest of the eroding bank, there is a tributary channel that runs along the base of the left hillslope. A field along the left bank of the Ouleout separates the Ouleout channel from the tributary channel. Within this field, there is an avulsion channel from the Ouleout to the tributary channel near STA 1182+00 ft. The avulsion channel contains a headcut which was approximately 30 ft from the main channel of the Ouleout at the time of assessment. When the headcut reaches the Ouleout, it will likely direct the flow of the Ouleout into the tributary channel that runs along the base of the left hillslope. The tributary channel converges with the Ouleout at STA 1173+50 ft.


**Figure 41: Reach 17 Map**

## *Reach 18*

### *Assessment Details*

Reach 18 begins at STA ~1189+50 ft where the valley narrows. The reach ends upstream at STA ~1248+00 ft where the valley further narrows. It is ~5,850 ft in length and has a drainage area of 8.52 $mi^2$. The reach has a sinuosity of 1.11 and a valley slope of 1.78%. Regional regression equations indicate that the bankfull area is 63 $ft^2$, the bankfull depth is 1.82 ft, and the bankfull width is 35.3 ft (USGS, 2023). The bankfull discharge is estimated to be 284 cfs and the 100-year recurrence interval discharge is estimated to be 1,680 cfs.

The general land cover of the reach is primarily forest. The buffer analysis categorized 61% of the streamside area as forest, 28% as field, 8.7% as herbaceous wetland, and 2.9% as developed land.

There were 213 features recorded during the SFI for Reach 18: 106 eroding bank points composing 41 eroding bank segments, 21 large woody debris points, 14 photo points, 8 revetment points composing 2 segments of revetment, 8 excessive depositional features, 5 tributaries, 3 headcuts, 2 stream crossings, 2 control points, and 1 bridge.

In the reach, 17% of the banks were actively eroding and it is estimated that 97 $yd^3$ of sediment erodes annually from the reach. In addition, 190 lb of TN and 47 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 15th among reaches for the volume of eroded sediment, 16th for the mass of eroded TN, and 14th for the mass of eroded TP. The reach's location can be viewed on the reach map in **Figure 42**.

### *Areas of Concern*

### *Other features of note*

There were no sites of substantial erosion in Reach 18, however, there were still several notable features in the reach. At STA ~1207+00 ft the stream flows into a wetland with a beaver impoundment. The stream exits the wetland at STA ~1203+00 ft in 4 separate channels that intertwine throughout the floodplain and eventually converge at STA 1191+00 ft. Before 2016, the stream previously flowed along the right hillslope past the wetland. Between 2016 and 2021 the old channel became blocked with debris and the stream avulsed into the wetland.

The stream is also a split channel beginning at STA 1236+00 ft where it diverges into two channels. The two channels converge just upstream of the Smith Hill Road bridge at STA 1223+00 ft.

There were three headcuts in the reach. The first headcut was located at STA 1190+00 ft and had a depth of 1.5 ft. Immediately downstream of the headcut, the left bank was actively eroding at the time of assessment. In addition, several trees had cantilevered off the left bank and into the channel. The second headcut was located in the right channel at STA 1199+00 ft and had a depth of 1.2 ft. The third headcut was located at STA 1232+00 ft and had a depth of 0.5 ft. The threat these headcuts posed was to bed and bank stability as they were located in forested areas and not in close proximity to any infrastructure.

As with the previous reaches that were heavily forested, this reach contained large woody debris within the stream channel. Trees that had fallen across the channel were located at STA 1190+00 ft and STA 1191+00 ft. These trees were retaining debris and could further disrupt flow. Within the left channel at STA 1193+00 ft and STA 1194+00 ft there were two pine trees that had cantilevered off the left bank and into the channel. These trees were partially obstructing flow and causing scour within the streambed. The pine trees also have the potential of further blocking the channel in a high flow event. At STA 1246+50 ft, a tree had cantilevered off the eroding left bank and into the channel and was capturing debris. The eroding bank that this tree cantilevered off of measured 206 ft in length, had an average height of 2.7 ft, and it is estimated that 29 $yd^3$ of sediment erodes annually from the erosion segment. The erosion was along an old field that was primarily comprised of herbaceous plants and shrubs. The erosion at this location could be remediated by establishing an adequate riparian forest buffer.


Figure 42: Reach 18 Map

## *Reach 19*

### *Assessment Details*

Reach 19 begins at STA ~1248+00 ft where the valley narrows. The reach ends upstream at STA ~1312+00 ft where the valley broadens. It is ~6,400 ft in length and has a drainage area of 6.90 $mi^2$. The reach has a sinuosity of 1.18 and a valley slope of 1.81%. Regional regression equations indicate that the bankfull area is 58.7 $ft^2$, the bankfull depth is 1.77 ft, and the bankfull width is 34 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 263 cfs and the 100-year recurrence interval discharge is estimated to be 1,550 cfs.

The general land cover of the reach is a mix of different land cover types, with the lower part of the reach being predominately forest with some agricultural fields along the right bank. Part of the upstream section of the reach is developed land as the stream flows through the hamlet of Meridale. The upstream end of the reach flows through several agricultural fields with an undersized riparian forest buffer. The buffer analysis categorized 58% of the streamside area as forest, 26% as field, 9.3% as herbaceous wetland, and 6.8% as developed land.

There were 232 features recorded during the SFI for Reach 19: 112 eroding bank points composing 47 eroding bank segments, 21 large woody debris points, 15 excessive depositional features, 13 revetment points composing 5 segments of revetment, 8 photo points, 7 tributaries, 2 headcuts, 1 control point, and 1 bridge.

In the reach, 24% of the banks were actively eroding and it is estimated that 160 $yd^3$ of sediment erodes annually from the reach. In addition, 380 lb of TN and 110 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 11th among reaches for the volume of eroded sediment, 11th for the mass of eroded TN, and 9th for the mass of eroded TP. There were no sites of substantial erosion in the reach, however, there were still several notable features recorded. The reach's location can be viewed on the reach map in **Figure 43**.

### *Areas of Concern*

#### *Other features of note*

Throughout the reach, there were accumulations of large woody debris in the stream channel that could be of concern. There were several trees from STA 1282+00 ft to STA 1285+50 ft that had fallen into the channel and were causing accumulations of debris. There was also an accumulation of large woody debris at STA 1289+00 ft. Large woody debris was accumulating at this site due to a sharp bend in the channel caused by an old stacked rock revetment wall which redirects flow. The revetment also narrowed the channel and prevented the aforementioned large woody debris from passing downstream. At STA 1293+00 ft, several willows had cantilevered into the channel causing scour within the bed of the channel and constricting streamflow.

There were several sites of erosion in the reach that were not large enough in terms of eroded material but are still a concern and should be monitored. One site of erosion was along the right bank from STA 1261+00 ft to STA 1262+00 ft. This erosion segment measured 83 ft in length, had an average height of 5.4 ft, and it is estimated that 18 $yd^3$ of sediment has eroded annually. At this site, there was no riparian buffer between the stream channel and a pasture on the right bank. The bank material also consisted of unconsolidated sediment making the bank highly erodible and further exacerbating the erosion at the site. The erosion at this site can be remediated by stabilizing the bank and establishing a riparian forest buffer between the stream channel and the pasture.

The second erosion segment of note was along the right bank from STA 1273+00 ft to STA 1274+50 ft. This erosion segment measured 165 ft in length, had an average height of 3.0 ft, and it is estimated that 24 $yd^3$ of sediment has eroded annually. Like the previously described erosion segment, the bank material was also unconsolidated which makes the bank highly susceptible to further erosion. The erosion at this site can be remediated by stabilizing the bank and establishing a riparian forest buffer

The stream splits into 2 channels at STA 1277+00 ft which converge again at STA 1274+00 ft. At the time of assessment, the left channel contained the majority of the flow. Within the left channel, there were 2 headcuts located at STA 1275+00 ft and STA 1277+00 ft. The headcut at STA 1275+00 ft had a depth of 1.3 ft and the headcut at STA 1277+00 ft had a depth of 2.0 ft. The threat these headcuts posed was to bed and bank stability.

Another site of erosion was along the right bank from STA 1299+00 ft to STA 1300+00 ft. At this site, the stream was eroding into the edge of a parking lot. This erosion segment measured 120 ft in length, had an average height of 6.6 ft, and it is estimated that 17 $yd^3$ of sediment has eroded annually. The eroding bank contained no riparian buffer and the vegetation on the bank consisted of Japanese Knotweed. The bank material was primarily composed of gravel and fill which was unconsolidated and easily erodible. This site had previously been investigated by DCSWCD as a site for a potential stream stabilization project.

There was ample beaver activity within Reach 19. At the time of assessment, the channel was dammed at STA 1304+50 ft. The beaver dam rose approximately 3.5 ft from the streambed causing an impoundment of water upstream.

The stream was previously eroding into the left bank from STA 1304+50 ft to STA 1307+00 ft. Between 2006 and 2022, the stream eroded approximately 150 ft laterally into the left bank. However, at the time of assessment, the left bank was not actively eroding and was partially inundated by the pool caused by the large beaver impoundment immediately downstream.

In the upstream section of Reach 19, the stream flows along a pasture with an intermittent riparian buffer. At the time of assessment, the stream was eroding into the pasture along the left bank from STA 1311+00 ft to STA 1312+00 ft. This erosion segment measured 95 ft in length, had an average height of 2.4 ft, and it is estimated that 10 $yd^3$ of sediment has eroded annually.


Figure 43: Reach 19 Map

## *Reach 20*

### *Assessment Details*

Reach 20 begins at STA ~1312+00 ft where the valley broadens. The reach ends upstream at STA ~1354+00 ft where the valley narrows. It is ~4,200 ft in length and has a drainage area of 4.52 $mi^2$. The reach has a sinuosity of 1.18 and a valley slope of 1.66%. Regional regression equations indicate that the bankfull area is 37.4 $ft^2$, the bankfull depth is 1.44 ft, and the bankfull width is 26.6 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 165 cfs and the 100-year recurrence interval discharge is estimated to be 1,050 cfs.

The general land cover of the reach consists of agriculture fields with some forested areas and developed land as well. The buffer analysis categorized 48% of the streamside area as forest, 38% as field, 8.4% as developed land, and 5.6% as herbaceous wetland.

There were 138 features recorded during the SFI for Reach 20: 61 eroding bank points composing 27 eroding bank segments, 17 large woody debris points, 12 revetment points composing 4 segments of revetment, 9 excessive depositional features, 2 control points, 2 photo points, 1 headcut, 1 bridge, 1 tributary, and 1 stream crossing.

In the reach, 19% of the banks were actively eroding and it is estimated that 80 $yd^3$ of sediment erodes annually from the reach. In addition, 230 lb of TN and 41 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 16th among reaches for the volume of eroded sediment, 15th for the mass of eroded TN, and 15th for the mass of eroded TP. There were no substantial sites of erosion in Reach 20, however, there were other noteworthy features in the reach. The reach's location can be viewed on the reach map in **Figure 44**.

### *Areas of Concern*

#### *Other features of note*

One site of erosion to monitor was from STA 1329+00 ft to STA 1331+00 ft along the left bank. This erosion was not great enough in terms of eroded material to be ranked as a site of substantial erosion but it is still noteworthy and should be monitored. The stream was eroding into an agricultural field at this site. This erosion segment measured 255 ft in length, had an average height of 3.0 ft, and it is estimated that 42 $yd^3$ of sediment has eroded annually. Opposite the erosion was a large aggrading point bar. At the time of assessment, there was ample beaver activity within this area This erosion should continue to be monitored as it has the potential to increase in severity due to the lack of a riparian buffer between the agricultural field and the stream channel.

There was one headcut present in Reach 20 which was located at STA 1318+00 ft. The headcut had a depth of 2.3 ft and was held in place by a log step. The threat this headcut posed was to bed and bank stability. At the time of assessment, the left bank downstream of the headcut was actively eroding. The right bank downstream of the headcut was armored with boulders and not eroding.

Similar to several of the previously discussed reaches, there were several locations of large woody debris within the channel in the reach. Some of these sites of large woody debris could be of concern. At approximately STA 1328+00 ft, there were several trees that had cantilevered off the eroding right bank and had fallen into the channel. These trees were retaining large amounts of debris and preventing the debris from passing downstream. The large woody debris was also causing scour in the channel downstream of the accumulation.

A private bridge is located at STA 1334+50 ft. This bridge is approximately 30 ft in length and has 1 pier in the middle. At the time of assessment, the bridge and its corresponding revetment were in poor condition. The stream approached the sheet piling revetment at a near perpendicular angle causing streamflow to impinge upon the left bank revetment and also scour behind the revetment. The bridge itself was structurally unsound as the wood boards it is composed of were in various stages of disrepair and decay. The wood supports of the bridge along the left bank had been undercut by the stream causing the bridge to lean at an angle. If the bridge were to fail, it could partially block the stream channel and disrupt streamflow.


Figure 44: Reach 20 Map

## *Reach 21*

### *Assessment Details*

Reach 21 begins at STA ~1354+00 ft where the valley narrows. The reach ends upstream at STA ~1385+50 ft where the valley further narrows and the Ouleout exits a large beaver impoundment. It is ~3,150 ft in length and has a drainage area of 2.68 $mi^2$. The reach has a sinuosity of 1.23 and a valley slope of 1.90%. Regional regression equations indicate that the bankfull area is 24.2 $ft^2$, the bankfull depth is 1.18 ft, and the bankfull width is 20.9 ft (USGS, 2023). In addition, the bankfull discharge is estimated to be 105 cfs and the 100-year recurrence interval discharge is estimated to be 702 cfs.

The general land cover of the reach is a mix of forest and agriculture with some developed areas of land as well. The buffer analysis categorized 62% of the streamside area as field, 29% as forest, 6.1% as developed land, and 3.6% as herbaceous wetland.

There were 83 features recorded during the SFI for Reach 21: 36 eroding bank points composing 16 eroding bank segments, 7 revetment points composing 4 segments of revetment, 5 excessive depositional features, 4 photo points, 3 tributaries, 2 headcuts, 2 large woody debris points, 2 bridges, 1 berm, and 1 stream crossing.

In the reach, 15% of the banks were actively eroding and it is estimated that 65 $yd^3$ of sediment erodes annually from the reach. In addition, 150 lb of TN and 26 lb of TP are estimated to erode annually from the streambanks in the reach. This reach ranked 17th among reaches for the volume of eroded sediment, 17th for the mass of eroded TN, and 17th for the mass of eroded TP. There were no sites of substantial erosion identified in the reach, however, there were still several noteworthy features recorded. The reach's location can be viewed on the reach map in **Figure 45**.

### *Areas of Concern*

#### *Other features of note*

One noteworthy feature was an erosion segment along the left bank from STA 1356+50 ft to STA 1357+50 ft. This erosion was not large enough in terms of eroded material to be ranked as a site of substantial erosion but it is still a concern. At this site, the stream was eroding into a hay field with no riparian buffer. Across from the erosion was a large aggrading point bar. At its most severe extent, it is estimated that the stream has migrated laterally 40 ft into the left bank between 2016 and 2022. This erosion segment measured 109 ft in length, had an average height of 2.4 ft, and it is estimated that 34 $yd^3$ of sediment erodes annually from the erosion segment. The erosion at this site can be remediated by stabilizing the bank and establishing a riparian forest buffer.

Another feature of note was an eroding hillslope along the right bank from STA 1358+00 ft to STA 1360+00 ft. This erosion segment measured 220 ft in length, had a maximum height of 17 ft, and it is estimated that 16 $yd^3$ of sediment erodes annually from the hillslope. Another right hillslope failure was located from STA 1362+50 ft to STA 1363+50 ft. This erosion segment measured 105 ft in length, with a maximum height of 20 ft, and it is estimated that 7.0 $yd^3$ of sediment erodes annually from the right hillslope. Across from the upstream end of the hillslope failures was an old berm along the left bank. This berm prevents the stream from accessing its floodplain and likely causes the flow to be directed into the right hillslope contributing to the hillslope failures. At the top of the hillslope is County Highway 10. Drainage from the road may be contributing to the instability of this particular hillslope.

There were two headcuts located in the reach. The first headcut was located at STA 1368+00 ft. The headcut had a depth of 0.5 ft and was along a bend in the stream channel. Downstream of the headcut, there was erosion along both banks. The threat this headcut posed was to bed and bank stability as it was not located near any infrastructure. The second headcut was located at STA 1381+50 ft. This headcut had a depth of 2.0 ft and, at the time of assessment was, held in place by several large boulders within the stream channel. The threat this headcut posed was to bed and bank stability as it was not located near any infrastructure.

At the upstream end of the reach is an area with several large beaver impoundments between STA 1383+00 ft and STA 1400+00 ft. The SFI was concluded at this location.

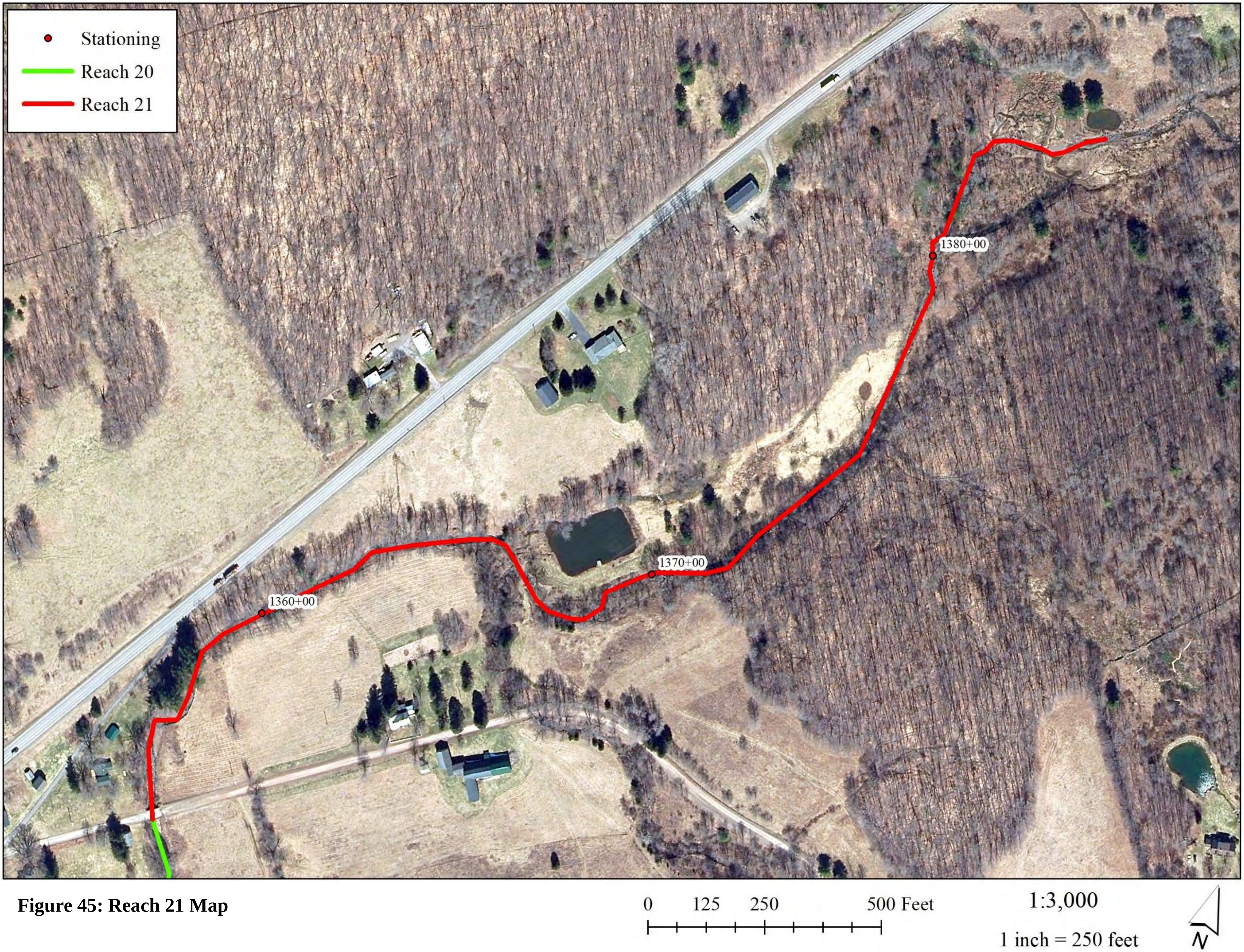


**Figure 45: Reach 21 Map**

## Prioritization and Conclusion

As evidenced by this assessment, a major water quality issue in Ouleout Creek is the excessive amount of nutrients and sediment entering the stream channel via streambank erosion. A relatively small number of sites accounted for a disproportionately large amount of eroded material along the Ouleout. Many of the sites of substantial erosion along the Ouleout were meanders in the channel that were migrating downstream. Meander migration is a natural fluvial process; however, meanders can easily become an area of instability if they erode into a field with no riparian forest buffer. Once an overly sinuous planform establishes itself, much time must pass and erosion must occur before the stream rights itself. For the sake of water quality, it is best to expedite this process and limit nutrient loading by stabilizing the affected areas. Since phosphorus is the limiting nutrient in East Sidney Lake and the Chesapeake Bay, and phosphorus reduction is a goal of the New York State Phase III WIP, sites of substantial erosion contributing the greatest mass of TP should be prioritized for remediation.

In order to prioritize the sites of substantial erosion described in the “Reach Specific Assessments and Recommendations” section, sites were ranked by their mass of TP eroded annually. Site 2-a ranked the highest with 480 lb of TP loaded annually. Second was Site 4-b with 440 lb of TP loaded annually. The third highest ranked site was Site 6-b with 280 lb of TP loaded annually. The list of substantial erosion sites, ranked by their mass of TP eroded annually, can be viewed in **Table 7**. The top three sites of substantial erosion accounted for 31% of all TP eroded from streambanks in the assessed length of the Ouleout. Remediating the erosion at the top three sites with a stream stabilization project would have a substantial positive impact on reducing the sediment and nutrient loading due to streambank erosion along Ouleout Creek.

Were stream stabilization projects to be implemented in a specific reach, several sites of substantial erosion could be combined to have an even greater impact on reducing nutrient loads. For example, if a project were to occur at Site 6-b, the erosion at Site 6-a could be addressed at the same time due to their close proximity. These sites of substantial erosion can generally be remediated by stabilizing the eroding streambanks, resizing the channel and excessive depositional features to appropriate bankfull dimensions, and establishing an adequately sized riparian forest buffer. The cost to implement such a project is substantial, but the water quality impact is commensurate due to the effort of prioritization. It is clear that the areas in **Table 7** should be addressed in order to have the greatest impact on TP loading in Ouleout Creek.

Two factors that are driving substantial erosion along Ouleout Creek are the excessive depositional features in the stream channel and the lack of an adequately sized riparian forest buffer on the streambank. Prioritizing these two issues now will go a long way toward preventing excessive erosion in the future. The lack of a riparian forest buffer, and the stability their woody roots provide, leaves streambank soil unprotected from the erosive forces of the stream. Establishing adequately sized riparian forest buffers along the least forested reaches would help prevent future unstable meander migration. Reaches with the lowest percentages of riparian forest buffer include Reaches 6, 8, and 21; these should be targeted first for riparian forest buffer plantings in order to prevent future excessive meander migration (**Figure 23**). The excessive depositions throughout the Ouleout contribute to existing erosion by forcing streamflow into the streambanks, exacerbating erosion and subsequent sediment and nutrient loading. Sediment depositions and sediment contributing areas such as bank erosion and headcuts, should also be monitored to determine if they are contributing excessive sediment loads to the stream channel. Instabilities can be monitored by comparing previous orthoimagery and SFI data with new orthoimagery as it becomes available. Following the recommendations described in this report will help reduce the excessive sediment and nutrient loading occurring along Ouleout Creek.

It is important to note that the environmental hazards associated with streambank erosion encountered in this assessment are not unique to Ouleout Creek. If other streams throughout the region are similar in erosion characteristics, this would mean streambank erosion is a substantial contributor of nutrients and sediment throughout the Upper Susquehanna Watershed. Therefore, targeting the sites of substantial erosion contributing the greatest amount of TP for remediation would have the greatest impact on improving the water quality of Ouleout Creek, the health of the stream's ecosystem, and the overall health of East Sidney Lake. It would also, in turn, benefit the Ouleout Creek Watershed, the Upper Susquehanna Watershed, and the Chesapeake Bay.

**Table 7:** Sites of substantial erosion along Ouleout Creek ranked by their corresponding estimated mass of TP eroded annually.

| Prioritization | Site ID | Reach | Estimated Mass of TP Eroded Annually (lb) |
|---|---|---|---|
| **1** | 2-a | 2 | 480 |
| **2** | 4-b | 4 | 440 |
| **3** | 6-b | 6 | 280 |
| **4** | 1-b | 1 | 260 |
| **5** | 1-a | 1 | 200 |
| **6** | 2-b | 2 | 190 |
| **7** | 4-a | 4 | 190 |
| **8** | 6-a | 6 | 130 |
| **9** | 14-b | 14 | 130 |
| **10** | 5-a | 5 | 120 |
| **11** | 5-b | 5 | 110 |
| **12** | 8-b | 8 | 91 |
| **13** | 14-a | 14 | 72 |
| **14** | 8-a | 8 | 63 |
| **15** | 11-a | 11 | 47 |
| **16** | 10-a | 10 | 41 |
| **17** | 5-c | 5 | 37 |
| **18** | 15-a | 15 | 31 |
| **19** | 15-b | 15 | 11 |

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# Appendix

**Appendix 1:** Description of each reach

1. Reach 1
   a. Reach 1 begins at STA ~356+00 ft where Ouleout Creek enters East Sidney Lake at the seasonally low pool elevation of ~1,140 ft NVGD. It ends upstream at STA ~383+50 ft where the Ouleout enters East Sidney Lake at the normal summer pool elevation of ~1,150 ft NVGD. This is also the location where Handsome Brook converges with Ouleout Creek.
   b. Reach 1 is ~2,750 ft in length.
2. Reach 2
   a. Reach 2 begins at STA ~383+50 ft where the Ouleout enters East Sidney Lake at the normal summer pool elevation of ~1,150 ft NVGD. This is also the location where Handsome Brook converges with Ouleout Creek. It ends upstream at STA ~433+00 ft where the valley narrows.
   b. Reach 2 is ~4,950 ft in length.
3. Reach 3
   a. Reach 3 begins at STA ~433+00 ft where the valley narrows. It ends upstream at STA ~466+50 ft where the valley broadens.
   b. Reach 3 is ~3,350 ft in length.
4. Reach 4
   a. Reach 4 begins at STA ~466+50 ft where the valley broadens. It ends upstream at STA ~531+00 ft where the valley further broadens.
   b. Reach 4 is ~6,450 ft in length.
5. Reach 5
   a. Reach 5 begins at STA ~531+00 ft where the valley broadens. It ends upstream at STA ~567+00 ft where the dominant land cover changes from active agricultural land to old fields.
   b. Reach 5 is ~3,600 ft in length.
6. Reach 6
   a. Reach 6 begins at STA ~567+00 ft where the dominant land cover changes from active agricultural land to old fields. It ends upstream at STA ~598+00 ft where the dominant land cover changes to active agricultural fields again.
   b. Reach 6 is ~3,100 ft in length.
7. Reach 7

a. Reach 7 begins at STA ~598+00 ft where the dominant land cover changes to agricultural fields. It ends upstream at STA ~674+50 ft where Treadwell Creek converges with Ouleout Creek.
b. Reach 7 is ~7,650 ft in length.

8. Reach 8

a. Reach 8 begins at STA ~674+50 ft where Treadwell Creek converges with Ouleout Creek. It ends upstream at STA ~729+00 ft where the valley broadens.
b. Reach 8 is ~5,450 ft in length.

9. Reach 9

a. Reach 9 begins at STA ~729+00 ft where the valley broadens. It ends upstream at STA ~828+00 ft where the valley narrows.
b. Reach 9 is ~9,900 ft in length.

10. Reach 10

a. Reach 10 begins at STA ~828+00 ft where the valley narrows. It ends upstream at STA ~863+50 ft where the valley further narrows.
b. Reach 10 is ~3,550 ft in length.

11. Reach 11

a. Reach 11 begins at STA ~863+50 ft where the valley narrows. It ends upstream at STA ~920+00 ft where Gay Creek enters the Ouleout and the valley further narrows.
b. Reach 11 is ~5,650 ft in length.

12. Reach 12

a. Reach 12 begins at STA ~920+00 ft where Gay Creek enters the Ouleout and the valley narrows. It ends upstream at STA ~959+00 ft where the valley further narrows and bedrock control ends.
b. Reach 12 is ~3,900 ft in length.

13. Reach 13

a. Reach 13 begins at STA ~959+00 ft where the valley narrows and bedrock control ends. It ends upstream at STA ~990+00 ft where an unnamed tributary from Swart Hollow enters the Ouleout.
b. Reach 13 is ~3,100 ft in length.

14. Reach 14

a. Reach 14 begins at STA ~990+00 ft where an unnamed tributary from Swart Hollow enters the Ouleout. It ends upstream at STA ~1057+50 ft where an unnamed tributary from Coe Hill enters the Ouleout.
b. Reach 14 is ~6,750 ft in length.

15. Reach 15

    a. Reach 15 begins at STA ~1057+50 ft where an unnamed tributary from Coe Hill enters the Ouleout. It ends upstream at STA ~1118+00 ft where the valley narrows.
    b. Reach 15 is ~6,050 ft in length.

16. Reach 16

    a. Reach 16 begins at STA ~1118+00 ft where the valley narrows. It ends upstream at STA ~1150+50 ft where an unnamed tributary from Houghtaling Hollow enters the Ouleout.
    b. Reach 16 is ~3,250 ft in length.

17. Reach 17

    a. Reach 17 begins at STA ~1150+50 ft where an unnamed tributary from Houghtaling Hollow enters the Ouleout. It ends upstream at STA ~1189+50 ft where the valley narrows.
    b. Reach 17 is ~3,900 ft in length.

18. Reach 18

    a. Reach 18 begins at STA ~1189+50 ft where the valley narrows. It ends upstream at STA ~1248+00 ft where the valley further narrows.
    b. Reach 18 is ~5,850 ft in length.

19. Reach 19

    a. Reach 19 begins at STA ~1248+00 ft where the valley narrows. It ends upstream at STA ~1312+00 ft where the valley broadens.
    b. Reach 19 is ~6,400 ft in length.

20. Reach 20

    a. Reach 20 begins at STA ~1312+00 ft where the valley broadens. It ends upstream at STA ~1354+00 ft where the valley narrows.
    b. Reach 20 is ~4,200 ft in length.

21. Reach 21

    a. Reach 21 begins at STA ~1354+00 ft where the valley narrows. It ends upstream at STA ~1385+50 ft where the valley further narrows.
    b. Reach 21 is ~3,150 ft in length.

22. Headwaters

Upstream of Reach 21, the Ouleout flows through a series of beaver impoundments from STA ~1385+50 ft to STA ~1400+00 ft. Above these impoundments, the Ouleout flows through a marsh and a pasture until STA ~1420+00 ft. STA ~1420+00 ft is where the Ouleout headwaters begin as several small tributaries converge into one main channel at this location.

**Appendix 2:** National Land Cover Database land cover categories and their generalization for land cover-soil categories.

| NLCD category | Land cover category reclassification |
|---|---|
| Deciduous Forest | Forest |
| Evergreen Forest | Forest |
| Mixed Forest | Forest |
| Shrub/Scrub | Forest |
| Woody Wetlands | Forest |
| Grasslands/Herbaceous | Field |
| Pasture/Hay | Field |
| Cultivated Crops | Cropland |
| Emergent Herbaceous Wetland | Herbaceous Wetland |
| Developed, Open Space | Developed Land |
| Developed, Low Intensity | Developed Land |
| Developed, Medium Intensity | Developed Land |
| Developed, High Intensity | Developed Land |
| Barren Land | Developed Land |

**Appendix 3:** Chesapeake Bay Program land cover categories and their generalization for riparian forest buffer analysis.

| CBP land cover category | Land cover category reclassification |
|---|---|
| Forest | Forest |
| Riverine Wetlands Forest | Forest |
| Riverine Wetlands Tree Canopy | Forest |
| Tree Canopy Over Turf Grass | Forest |
| Other Tree Canopy | Forest |
| Natural Succession Herbaceous | Field |
| Pasture/Hay Herbaceous | Field |
| Pasture/Hay Barren | Field |
| Turf Grass | Field |
| Cropland Barren | Cropland |
| Cropland Herbaceous | Cropland |
| Bare Shore | Herbaceous Wetland |
| Riverine Wetlands Barren | Herbaceous Wetland |
| Riverine Wetlands Herbaceous | Herbaceous Wetland |
| Structures | Developed Land |
| Roads | Developed Land |
| Suspended Succession Herbaceous, Pervious Developed | Developed Land |
| Tree Canopy Over Structures | Developed Land |
| Tree Canopy Over Roads | Developed Land |
| Tree Canopy Over Other Impervious | Developed Land |
| Other Impervious | Developed Land |

**Appendix 4:** Bulk density values of Ouleout Creek soils derived from Web Soil Survey

| Reach | Soil | Bulk Density (g/cm$^3$) |
|---|---|---|
| 1 | Basher | 1.36 |
| 2 | Barbour | 1.36 |
| 2 | Barbour-Trestle | 1.36 |
| 2 | Basher | 1.36 |
| 2 | Tunkhannock-Chenango | 1.48 |
| 3 | Barbour | 1.33 |
| 3 | Barbour-Trestle | 1.33 |
| 3 | Tunkhannock | 1.47 |
| 4 | Barbour | 1.34 |
| 4 | Basher | 1.35 |
| 4 | Fluvaquent-Udifluvent | 1.38 |
| 4 | Tunkhannock | 1.48 |
| 5 | Barbour | 1.33 |
| 5 | Basher | 1.34 |
| 6 | Barbour | 1.33 |
| 6 | Basher | 1.34 |
| 7 | Barbour | 1.33 |
| 7 | Basher | 1.33 |
| 7 | Wellsboro | 1.46 |
| 8 | Barbour | 1.34 |
| 8 | Barbour-Trestle | 1.34 |
| 8 | Basher | 1.34 |
| 9 | Barbour | 1.34 |
| 9 | Basher | 1.34 |
| 9 | Tunkhannock | 1.47 |
| 9 | Tunkhannock-Chenango | 1.47 |
| 10 | Barbour | 1.33 |

| | | |
|---|---|---|
| 10 | Fluvaquent-Udifluvent | 1.38 |
| 10 | Tunkhannock-Chenango | 1.47 |
| 11 | Barbour | 1.33 |
| 11 | Barbour-Trestle | 1.33 |
| 11 | Fluvaquent-Udifluvent | 1.38 |
| 11 | Lackawanna | 1.53 |
| 12 | Barbour-Trestle | 1.34 |
| 12 | Fluvaquent-Udifluvent | 1.38 |
| 12 | Maplecrest | 1.35 |
| 13 | Fluvaquent-Udifluvent | 1.38 |
| 13 | Maplecrest | 1.34 |
| 13 | Tunkhannock | 1.47 |
| 14 | Fluvaquent-Udifluvent | 1.38 |
| 14 | Tunkhannock | 1.46 |
| 15 | Fluvaquent-Udifluvent | 1.38 |
| 15 | Maplecrest | 1.34 |
| 16 | Fluvaquent-Udifluvent | 1.38 |
| 16 | Maplecrest | 1.34 |
| 17 | Barbour-Trestle | 1.32 |
| 17 | Fluvaquent-Udifluvent | 1.38 |
| 17 | Lewbeach-Lewbath | 1.48 |
| 18 | Fluvaquent-Udifluvent | 1.38 |
| 18 | Lackawanna | 1.54 |
| 18 | Maplecrest | 1.36 |
| 18 | Wellsboro | 1.49 |
| 19 | Fluvaquent-Udifluvent | 1.38 |
| 19 | Lewbath | 1.51 |
| 19 | Willowemoc | 1.48 |
| 20 | Barbour-Trestle | 1.32 |

| | | |
|---|---|---|
| 20 | Fluvaquent-Udifluvent | 1.38 |
| 21 | Barbour-Trestle | 1.31 |
| 21 | Fluvaquent-Udifluvent | 1.37 |
| 21 | Tunkhannock-Chenango | 1.46 |

**Appendix 5:** Fine-earth fractions of Ouleout Creek soils derived from Web Soil Survey

| Reach | Soil | Fine-earth fraction |
|---|---|---|
| 1 | Basher | 1.00 |
| 2 | Barbour | 0.529 |
| 2 | Barbour-Trestle | 0.500 |
| 2 | Basher | 1.00 |
| 2 | Tunkhannock-Chenango | 0.347 |
| 3 | Barbour | 0.688 |
| 3 | Barbour-Trestle | 0.547 |
| 3 | Tunkhannock | 0.404 |
| 4 | Barbour | 0.657 |
| 4 | Basher | 1.00 |
| 4 | Fluvaquent-Udifluvent | 0.659 |
| 4 | Tunkhannock | 0.381 |
| 5 | Barbour | 0.720 |
| 5 | Basher | 1.00 |
| 6 | Barbour | 0.693 |
| 6 | Basher | 1.00 |
| 7 | Barbour | 0.768 |
| 7 | Basher | 1.00 |
| 7 | Wellsboro | 0.751 |
| 8 | Barbour | 0.764 |
| 8 | Barbour-Trestle | 0.521 |
| 8 | Basher | 1.00 |
| 9 | Barbour | 0.623 |
| 9 | Basher | 1.00 |
| 9 | Tunkhannock | 0.371 |
| 9 | Tunkhannock-Chenango | 0.489 |
| 10 | Barbour | 0.693 |

| | | |
|---|---|---|
| 10 | Fluvaquent-Udifluvent | 0.664 |
| 10 | Tunkhannock-Chenango | 0.434 |
| 11 | Barbour | 0.655 |
| 11 | Barbour-Trestle | 0.498 |
| 11 | Fluvaquent-Udifluvent | 0.666 |
| 11 | Lackawanna | 0.876 |
| 12 | Barbour-Trestle | 0.464 |
| 12 | Fluvaquent-Udifluvent | 0.662 |
| 12 | Maplecrest | 0.519 |
| 13 | Fluvaquent-Udifluvent | 0.666 |
| 13 | Maplecrest | 0.655 |
| 13 | Tunkhannock | 0.451 |
| 14 | Fluvaquent-Udifluvent | 0.663 |
| 14 | Tunkhannock | 0.363 |
| 15 | Fluvaquent-Udifluvent | 0.662 |
| 15 | Maplecrest | 0.544 |
| 16 | Fluvaquent-Udifluvent | 0.661 |
| 16 | Maplecrest | 0.535 |
| 17 | Barbour-Trestle | 0.491 |
| 17 | Fluvaquent-Udifluvent | 0.665 |
| 17 | Lewbeach-Lewbath | 0.827 |
| 18 | Fluvaquent-Udifluvent | 0.665 |
| 18 | Lackawanna | 0.820 |
| 18 | Maplecrest | 0.631 |
| 18 | Wellsboro | 0.818 |
| 19 | Fluvaquent-Udifluvent | 0.663 |
| 19 | Lewbath | 0.813 |
| 19 | Willowemoc | 0.785 |
| 20 | Barbour-Trestle | 0.508 |

| | | |
|---|---|---|
| 20 | Fluvaquent-Udifluvent | 0.672 |
| 21 | Barbour-Trestle | 0.405 |
| 21 | Fluvaquent-Udifluvent | 0.669 |
| 21 | Tunkhannock-Chenango | 0.479 |

**Appendix 6:**

**Site 1-a: Erosion along the left bank. Note that the bank vegetation is comprised predominately of herbaceous plants and shrubs. Photo taken looking downstream at STA ~379+00.**

**Site 1-b: Erosion along the right bank with an aggrading mid-channel bar along the left bank. Photo taken looking downstream at STA ~383+00.**

**Site 2-a: Erosion along the right bank on a sharp bend. Note the shallow rooting depth and lack of riparian forest buffer. Photo taken looking downstream at STA ~389+00.**

**Site 2-a: Erosion along the left bank in the foreground and erosion along the right bank in the background. Photo taken looking downstream at STA ~392+00.**

**Site 2-b: Erosion along the left bank with an aggrading point bar on the right bank. Photo taken looking downstream at STA ~406+00.**

**Site 2-b: Erosion along an agricultural field on the left bank. Note the lack of established vegetation on the streambank. Photo taken looking downstream at STA ~406+00.**

**Site 2-b: Deposit of cobble material in an agricultural field on the left bank. Photo taken looking upstream at STA ~405+50.**

**Site 4-a: Erosion along the left bank. Note the shallow rooting depth and lack of riparian forest buffer on the bank. Photo taken looking upstream at STA ~466+00.**

**Site 4-a: Transverse bar directing streamflow into the eroding right bank along an agricultural field. Photo taken looking downstream at STA ~475+00.**

**Site 4-b: Erosion along the left bank. Note the lack of riparian forest buffer in the old field. Photo taken looking across the channel at STA ~507+00.**

**Site 4-b: Excessive depositional feature in the channel with erosion along the right bank. Photo taken looking downstream at STA ~511+00.**

**Site 5-a: Erosion along the left bank. Photo taken looking upstream at STA ~530+00.**

**Site 5-b: Erosion along the right bank. Photo taken looking across the channel at STA ~549+50.**

**Site 5-c: Erosion along the right bank of an agricultural field. Note the lack of riparian forest buffer on the bank. Photo taken looking upstream at STA ~560+00.**

**Site 6-a: Erosion along the left bank of an inactive agricultural field. Note the lack of riparian forest buffer on the right bank. Photo taken looking upstream at STA ~580+00.**

**Site 6-b: Erosion along the right bank of an old field. Note the sharp bend in the channel with flow to impinging on the right bank. Photo taken looking upstream at STA ~591+00.**

**Site 8-a: Erosion along the left bank of an agricultural field. Photo taken looking upstream at STA ~687+00.**

**Site 8-b: Erosion along the right bank. Note the shallow rooting depth of the herbaceous vegetation on the bank. Photo taken looking upstream at STA ~706+50.**

**Site 9-a: Erosion along an agricultural field on the left bank. Photo taken before stabilization project was completed. Photo taken looking downstream at STA ~774+00.**

**Site 10-a: Erosion along the right bank with trees cantilevered across the channel and an aggrading point bar on left bank. Photo taken looking upstream at STA ~833+00.**

**Site 11-a: Erosion along the right bank of an old field. Note the unconsolidated material that the bank is comprised of. Photo taken looking downstream at STA ~907+50.**

**Site 14-a: Erosion along the left bank of a hay field with an aggrading point bar on the right bank. Photo taken looking downstream at STA ~1020+00.**

**Site 14-b: Erosion along the right bank. Photo taken looking upstream at STA ~1046+00.**

**Site 15-a: Transverse bar directing flow into eroding left bank. Photo taken looking downstream at STA ~1060+00.**

**Site 15-b: Erosion along the right bank. Note the shallow rooting depth of the vegetation on the bank. Photo taken looking downstream at STA ~1102+00.**