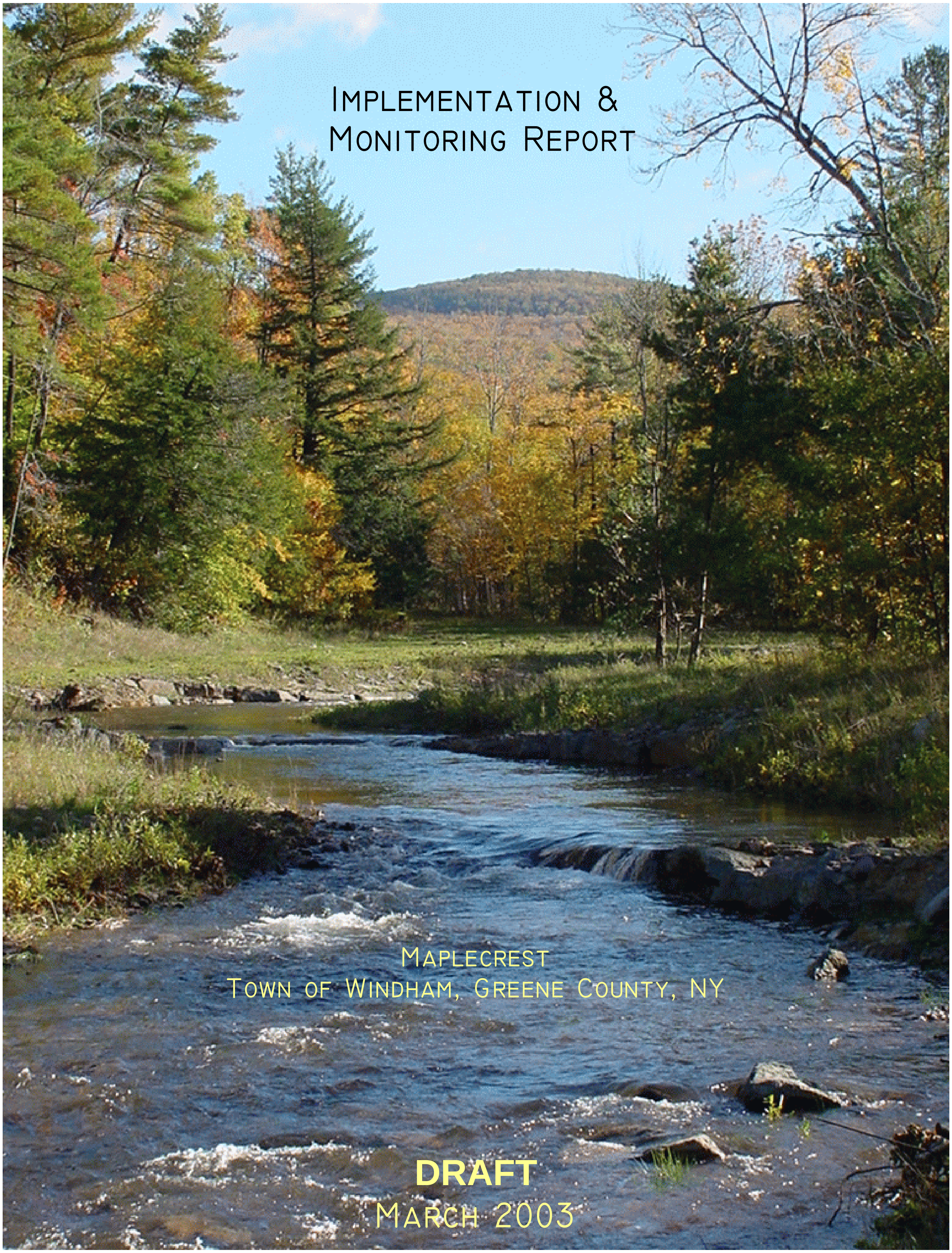
Big Hollow Restoration Project
- Batavia Kill -



Implementation & Monitoring Report

Maplecrest
Town of Windham, Greene County, NY

DRAFT
March 2003

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Big Hollow Restoration Project

Prepared for:

New York City Department of Environmental Protection,
Stream Management Program
71 Smith Avenue
Kingston, NY 12401
Phone (845) 340-7512   Fax (845) 340-7514
Contact: Beth Reichheld, Project Manager
ereichheld@dep.nyc.gov

Prepared by:

Greene County Soil & Water Conservation District
907 County Office Building
Cairo NY, 12413
Phone (518) 622-3620   Fax (518) 622-0344
www.gcswcd.com

Doug DeKoskie, Stream Program Leader doug@gcswcd.com
James Buchanan, Stream Program Technician jake@gcswcd.com

Project Partners

NYCDEP Stream Management Program
NYSDEC Division of Water
Greene County Soil & Water Conservation District
Catskill Mountain Chapter Trout Unlimited
Town of Windham
Project Landowners

For Additional Information
www.gcswcd.com/stream/bataviakill/bighollow

Big Hollow Restoration Project
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1.0 Project Background

A regional study of water quality was initiated by the New York City Department of Environmental Protection (NYCDEP) in the spring of 1993. The study focused on sub-basins in the West of Hudson (WOH) watershed and included identifying areas of concern and developing a comprehensive understanding of the sources and fate of materials contributing to turbidity and total suspended solids (TSS). The results of the study ranked the Batavia Kill sub-basin as producing the highest levels of turbidity and TSS. In 1996, a pilot project was initiated between the NYCDEP and the Greene County Soil & Water Conservation District (GCSWCD) in the Batavia Kill watershed. The Batavia Kill Stream Corridor Pilot Project focused on using fluvial geomorphic based stream classification, assessment and restoration principles in an attempt to reduce turbidity and TSS loading in the Batavia Kill.

Prior to the cooperative effort between NYCDEP and GCSWCD, geomorphic restoration principles had not been extensively tested and used in the Northeast. The NYCDEP and GCSWCD believed that stream restoration based on geomorphic and natural channel design principles would provide multiple benefits including, improved fisheries habitat, flood protection, streambank stabilization and improved aesthetics, in addition to reducing sediment loading and turbidity from in-stream sources.

1.1 Batavia Kill Pilot Project Goals and Objectives

The primary goal of the Batavia Kill Pilot Project was to demonstrate the effectiveness of using fluvial geomorphic restoration techniques for reducing turbidity & TSS loading from in-stream sources. The fundamental goals of the pilot project were further developed and refined throughout the progression of the pilot project, and are summarized below:

- Evaluate and improve the effectiveness of natural channel design techniques in the Catskills, based on assessments of the physical and biological characteristics of the restoration sites paired with water quality monitoring.

- Evaluate and improve the effectiveness of geomorphic assessment indices and techniques for the identification of stability problems for use in multi-objective restoration and planning.

- Evaluate the effectiveness of using stable reference reaches and regional relationships in the development of restoration designs.

- Conduct performance evaluations of the restoration projects, through monitoring and inspection, to document the status and stability of the demonstration projects. The results of performance evaluations can then be used to improve the future use of the design techniques.

- Develop design standards, typical details, construction specifications, construction sequencing procedures, and operation and maintenance protocols for geomorphic based NCD restoration projects.

1.2 Big Hollow Restoration Project

Three demonstration projects were initiated during the first phase of the Batavia Kill Pilot Project. The restoration of the Big Hollow project reach is the third large scale effort implemented in the Batavia Kill stream corridor. The Big Hollow Stream Restoration Project is located in the upper reaches of the Batavia Kill headwaters, in the Town of Maplecrest (Appendix A). The project reach is located 2,300 feet upstream from the 26 acre CD Lane Park Flood Control Structure, between the county bridge located on Peck Road (#3-20138-0) and the county bridge (#3-30287-0) along County Route (CR) 56.

The project represents a cooperative effort between NYCDEP, GCSWCD and several other stakeholders in the Batavia Kill watershed. In the sections that follow, the planning and coordination, assessment, design, construction and monitoring components of the Big Hollow Restoration Project will be described. Further, it is our intention to make this report a working document, displaying the status and performance of the Big Hollow Restoration Project as it progresses.

2.0 Watershed Setting

The Batavia Kill watershed is a 72 square mile sub-basin of the Schoharie Creek drainage. The project reach ranges in drainage area from $5.5mi^2$ to $7.2\ mi^2$, receiving runoff from the slopes of Blackhead and Black Dome Mountains. The valley morphology transitions from a V-shaped, colluvial form into a broader U-shaped valley with multiple river terraces. The valley slopes range from greater than 6.8% in the upper sections of the headwaters, to slopes near 1.3% at the project reach. The headwaters include ten first order tributaries and three second order stream reaches, resulting in a third order stream classification for a large portion of the project's length. The Rosgen Level I stream types that are found through the headwaters include A, B, C and F type stream channels, which are consistent with the valley's natural topography and historic conditions.

In the headwaters of the Batavia Kill, sinuosity is relatively low. The channels plan form is influenced by the natural topography and narrow valley width, combined with steep valley slopes. In much of this segment, the Batavia Kill has a narrow belt width and is partially constricted by CR 56 and other infrastructure. Review of historical aerial photography suggests that portions of this segment have been repeatedly modified. These alignment modifications have caused further constriction of the stream, with a reduction in available belt width and meander potential. The overall dynamic nature of the headwaters has resulted in the loss of two town bridges since 1996 and the replacement of two or more county bridges within the last ten years.

A phase I assessment, coupled with the analysis of historic aerial photography, revealed stream instabilities located within the lower three miles of the headwaters. The majority of the instabilities were minor in nature and were observed along low banks with ample rooted vegetation. A 5,310 foot portion of the stream, located between the Peck Road crossing and county bridge #3-30287-0 on CR 56, had highly unstable, exposed streambanks with minimal vegetation and was experiencing mass wasting. Based on the Phase I assessment, it was determined that initial efforts would focus on developing a comprehensive monitoring program within the highly unstable area upstream of Peck Road (Big Hollow Project Reach).

3.0 Reach Stability Assessment

A Phase I inventory and assessment conducted in 1997, identified the Big Hollow reach as one of the most unstable reaches along the Batavia Kill stream corridor. Fifty five (55%) percent of the reach was experiencing erosion, with nearly twelve square feet ($12ft^2$) of erosion present for every linear foot of streambank. A high terrace, present along the right bank, exhibited evidence of mass wasting and contained eroding banks that exceeded fifty feet in height. Active erosion was also observed along the opposite low terrace.

The initial assessment of the reach in 1997, revealed large bank exposures comprised primarily of clay lodgement till with minor sporadic exposures of lacustrine clay in the stream channel. The reach exhibited increased signs of instability in 1998, with numerous exposures of lacustrine deposits noted in the stream channel or just below the surface of cobble/gravel armor. The predominance of fine colloidal particles present in the soils contributed to increased levels of turbidity and TSS during base flow and storm flow events.

The steeper terrace slopes were generally characterized by dense, packed lodgement till along the bottom and loose glacial till above. The floodplains were covered in a thin mantle of topsoil and organic material, underlain by unconsolidated gravel and cobble which appeared extremely dry.

3.1 Existing Channel Morphology

Field assessment and monitoring of the Big Hollow reach began in the summer of 1998 and continues presently. The site has undergone Phase I - IV assessments. Fifteen cross sections and a longitudinal profile were monitored on an annual basis along with various sediment analyses of the channel and point bar substrate. The locations of the monitoring cross sections are included in Appendix B. A topographic survey, covering an area of approximately 32.5 acres, was completed for the entire site in December 1999.

The Big Hollow reach contained predominantly B and C stream types, which changed throughout the reach based on the influence of high terraces adjoining the stream channel. The sediment of the reach is predominantly coarse gravel, with the average D50 for the entire site ranging between 45mm and 64mm.

Historical plan form adjustments were assessed using a series of aerial photographs from 1959-2000. The historical photographs were adjusted to match the topographic survey of the reach to make comparisons of the Batavia Kill's meander pattern over a period of 41 years and to analyze previously abandoned channels. An example of an aerial overlay is shown in Figure 1, which depicts the location of the channel's water surface in 1995 over the 2000 photograph.

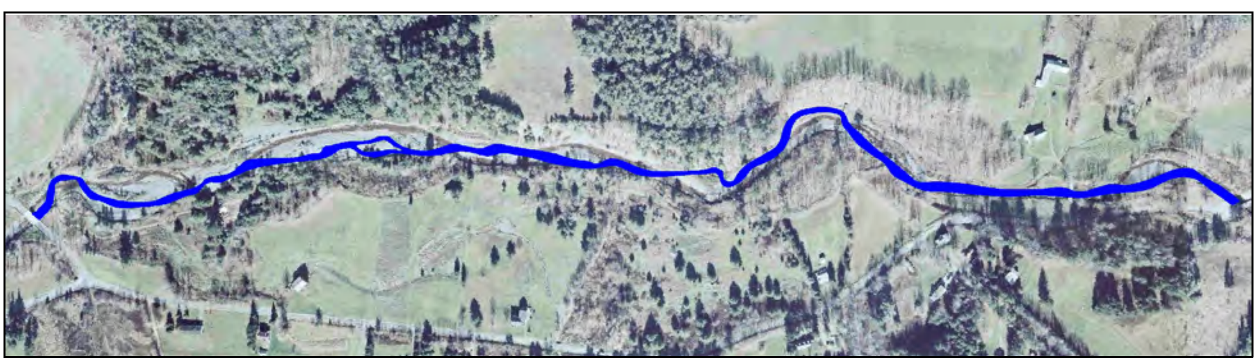

Figure 1: Overlay of the plan form changes through the Big Hollow reach. The shaded line represents the 1995 channel over a 2000 aerial photograph.

Channel migration is apparently caused by two integrated processes throughout the Big Hollow reach, rapid channel avulsion and lateral migration. Channel avulsion, which is usually associated with severe storm events, causes the rapid formation of channels. Lateral migration causes substantial channel shifts within the current channel boundaries at a slower, but measurable rate during varied flow events. The area located immediately downstream of county bridge #3-30287-0 has shown signs of minor erosion between 1959 and 1995. A healthy riparian area was present and channel migration appeared to be insignificant. Between May 1995 and December 1999, a substantial channel shift occurred in the area near cross section 1b (Appendix C, Photo D). The channel shifted approximately 80 feet to the north, which would equate to nearly 17'/year of migration. Most of the channel shift probably occurred during the September 1999 flood event.

Town bridge #2-26929, located within the reach, provides access to two private properties and remained relatively stable during the monitoring period. A stable vegetated bench was present under the structure along the right bank, and the bridge's hydraulic opening appeared sufficient to allow adequate passage of stream flows and sediment through the structure. Downstream of the town bridge, the channel has remained fairly stable between 1998 and 2001, but showed signs of past channelization and degradation (Appendix C, Photo H).

A large beaver dam was present 500 feet below the bridge, which contributed to several local instability problems (Appendix C, Photo G). The dam acted to flatten the local slope of the channel, resulting in stream channel aggradation upstream of the dam through cross section #2. The aggradation caused the stream to flow onto the adjacent floodplain, resulting in a divided channel around both sides of the beaver dam. Downstream of the beaver dam, the channel was actively down-cutting. The primary channel incised over 1 foot and the secondary channel incised over .5ft., through cross section #3. Further below the beaver dam, the channel showed signs of erosion and channel widening and had incised nearly 2.5 feet at cross section #4, figure 2.

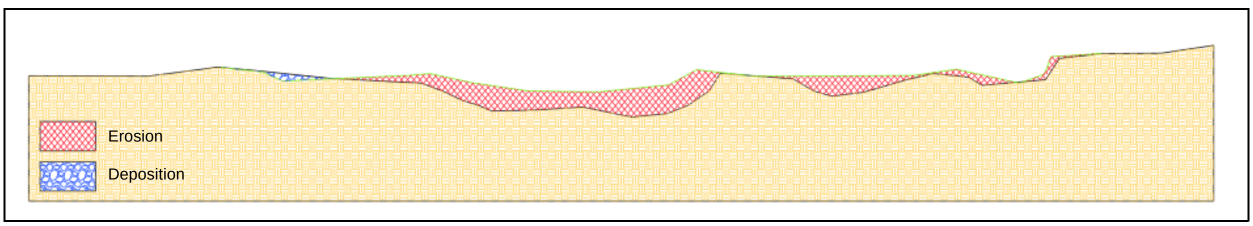

Figure 2: Overlay of monitoring cross section #4, 1998 - 2000.

The alignment of the Batavia Kill directed stream flow against a portion of the high terrace, beginning near cross section #5 (figure 3) and continuing downstream approximately 1,075 feet. The terrace is comprised primarily of unconsolidated glacial till, which is highly erodible. The height of the bank averages about 50 feet above the stream bottom and runs along nearly 2,200 feet of the channel. Mass wasting of the high bank was primarily caused by incision of the stream channel paired with erosion along the bank toe. Multiple geotechnical failures resulted from the erosion including rotational failure, shallow sliding and slab type failure. Bank failures were compounded by the relative shallow rooting depth and density of the vegetation in relation to the bank height.

The low terrace, running along the left bank of the Batavia Kill, also exhibited signs of instability. The banks along the low terrace ranged between 5ft. and 8.5ft. in height and was experiencing excessive erosion through the majority of the project reach. The low bank was actively

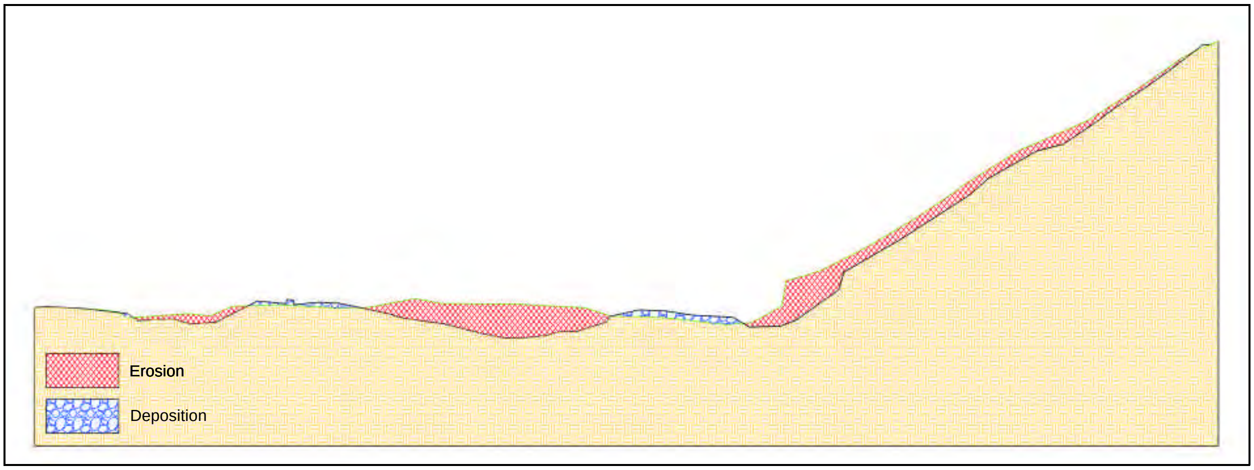

Figure 3: Overlay of monitoring cross section #5, 1998 - 2000.

experiencing slab-type and cantilever failures, caused by a combination of channel incision and rapid lateral migration. Interpretation of a 1959 aerial photograph displayed a well vegetated, relatively stable channel through the center of the project reach. Further analysis of aerial photography revealed that the channel experienced a northern lateral migration of nearly 150 feet; this occurred between 1959 and 1995. Between 1995 and 1999, the stream migrated back toward the south over 100 feet and continued to erode.

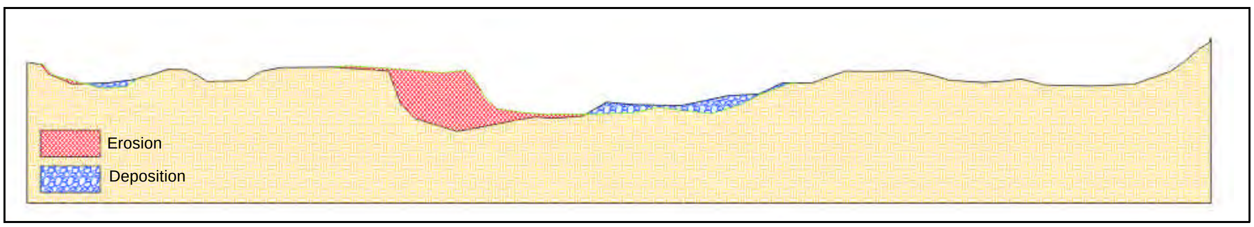

Figure 4: Overlay of monitoring cross section #8, 1998 - 2000.

Field verification of the lateral erosion was documented at cross section #8, which was first surveyed in the summer of 1998, figure 4. Minor erosion was noted during the first year of monitoring, with approximately 1 foot of stream bank lost. Between 1999 and 2000, the channel incised 2.6 feet and eroded 15 feet laterally along the left stream bank. The presence of several recently abandoned floodplain terraces, and evidence that the stream had attempted to build bankfull features at several elevations, verified that this area was continuing to actively incise. An active head-cut was observed between cross sections 8 and 9, causing the channel to incise nearly seven feet during the monitoring period.

The lower portion of the Big Hollow reach was experiencing channel aggradation, with excessive sedimentation of the stream channel and active erosion along the channel boundary (Appendix B, Photo A, E, F). The backwater effect from the Peck Road bridge and tail water from the flood control structure combined with excess sediment potentially contributed to the aggradation. The backwater created in this area induces sediment deposition upstream of the bridge causing the stream channel to develop multiple, braided channels. The condition resulted in stream flows flowing subsurface through the lower portion of the project area during base flow conditions. Evidence of gravel management and channel straightening in this area is apparent in historical aerial photographs dating back to 1959.

In 1990, the Peck Road bridge was replaced with a larger structure, which has assisted with the conveyance of bankfull and similar flow events, but potentially lacks sufficient flood plain drainage for large flood events. The stream channel above the bridge appeared to remain in constant adjustment, and was actively filling the side channels and creating a single thread channel, figure 5. Long term stability appeared to be hindered by the frequency of larger flood events in the area resulting in backwater conditions.

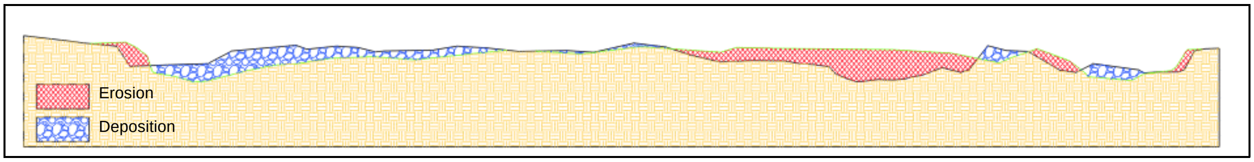

Figure 5: Overlay of monitoring cross section #14, 1998 - 2000.

3.2 Riparian Vegetation

The condition of the riparian area on the site was highly variable. The head of the reach was predominantly maintained as grass fields, which included only narrow strips of wooded riparian vegetation along the stream channel. In the lower extent of the reach, the stream was bordered by more dense, mature vegetation. The woody vegetation appeared ineffective for bank stabilization, which was compounded by the relative shallow rooting depth and density of the vegetation in relation to the bank height. The terraces through the site supported vegetation along the top of the banks, but constant erosion prevented vegetation from becoming established along the face of the banks.

4.0 Project Goals, Objectives, and Constraints

As the GCSWCD and NYCDEP reviewed the condition of the reach and its potential for restoration, a number of issues were identified. Water quality was negatively affected by streambank erosion. The partners proposed that restoration of the reach presented the opportunity to minimize erosion while meeting a wide range of objectives and providing a number of environmental benefits. The goals and objectives of the project were separated into two main categories and are outlined below.

4.1 Primary Goal

The primary goal of the restoration project can be summarized as follows:

> ***To mitigate excessive turbidity and TSS related water quality impacts associated with excessive lateral and vertical erosion in areas containing glacial lacustrine and lodgement till exposures.***

4.2 Secondary Objectives and Benefits

- Provide long term channel stabilization, to reduce property and structural damage, while maintaining the integrity and benefit of a naturally functioning channel and floodplain.

- Reduce and/or avoid further impacts on aquatic and riparian habitat within the project area and upstream and downstream reaches, while maintaining the aesthetic values of a natural stream channel.

The project design and restoration also needed to include additional parameters defined by a combination of physical assessments and input from the project partners and stakeholders. After a careful review, the following criteria were evaluated for incorporation into the project design:

- Channel Stability
- Sediment Transport
- Flood Conveyance
- Fisheries Habitat
- Riparian Functions
- Aquatic and Wildlife Habitat
- Aesthetic Value
- Stream Recreation

4.3 Project Constraints

The initial planning stages of the Big Hollow Project identified a number of potential constraints and limitations for the project design and construction. These issues include physical site constraints, landowner approval and access, project permitting, and data needs and limitations.

4.3.1 Physical Site Constraints

The project design needed to address channel stability while working within the existing physical constraints. Combinations of channel incision, lateral migration and aggradation needed to be addressed as well as limitations posed by the high terrace and other various landscape constraints. The restoration design needed to correct plan form, channel profile and cross sectional parameters in order to provide long term stability.

Increased channel incision had effectively detached segments of the project reach from its active floodplain area. The incision exceeded the maximum rooting depth of the adjacent vegetation, which facilitated the rapid lateral migration rates of the channel. Furthermore, the incision began to scour the channel's natural armor layer exposing glacial lacustrine clays, which pose a significant water quality threat.

A high terrace, over 50 feet in height above the channel bottom, exists along the northern floodplain boundary for a large segment of the project reach. Several areas of the terrace were in direct contact with the stream channel and were experiencing mass wasting and extreme erosion. The project design would need to provide immediate stabilization of the failing banks and provide future protection of the high terrace while remaining within a limited construction budget. The high terrace also limited site access and would pose a hazard risk during construction.

In order to provide a geomorphically stable channel through the reach, the restoration project area needed to be expanded to include over a mile of stream length. This section of stream corridor contained numerous homes, three public bridge structures and extensive landscape constraints. These attributes were initially identified by the completion of a detailed topographical survey of the project site including all features such as drainage ways, roads, utilities, bridges and buildings. These physical limitations would be incorporated into the iterated channel design and future restoration specifications and details.

4.3.2 Data Needs and Limitations

The absence of a suitable reference reach as a template for the restoration design generated a constraint on the design methodology and technique. Channel assessment and future restoration design, needed to incorporate a number of data sources, including reference reach, regime and analytical methods. These needs were documented and evaluated against the proposed restoration strategy. It was determined that the assessment and design would utilize data collected from shorter reference sections within the region, typical values developed by Dave Rosgen and others, as well as published regional curves and provisional curves developed for the Catskills by project partners.

4.3.3 Landowner Access and Approval

Landowner acceptance of the project had substantial bearing on the future success of the project. Thirteen primary landowners were located within the project reach and twelve secondary landowners were located adjacent to the project reach. This generated the need to educate the landowners about the stream instability and the apparent need for mitigative action. The planning and design process required utilizing the landowners' knowledge of the site and incorporating owner concerns when practical. The provision of landowner approval is set forth in Landowner Project Agreements, which is a temporary agreement between the landowner allowing for the project construction, maintenance and monitoring.

4.3.4 Project Permitting

The restoration project required permits to be issued by the Army Corp of Engineers (ACOE), New York State Department of Environmental Conservation (NYSDEC) and New York City Department of Environmental Protection (NYCDEP). The length and overall size and scope of the project could prolong the permitting process and delay project construction. An archeological assessment was conducted through the project site for inclusion into the permitting process in order to locate and document any historical findings.

5.0 Restoration Methodology and Strategy

Alternative strategies, that best reflected the project objectives, were evaluated to reach a common consensus between the project stakeholders and partners. The reach was highly unstable and it was believed that current channel processes would continue to impact the Big Hollow reach and the Batavia Kill resource. To meet the numerous goals, set forth by the project stakeholders, a restoration strategy focusing on the geomorphic form of the channel was chosen. This required classification of the current condition and the development of a preferred physical morphology for the restored channel.

The use of a natural channel design based restoration strategy required the development of a preferred physical morphology for the degraded reach. The plan was to develop a restoration strategy that would provide for long term stability of the stream bed and banks, while establishing a stream channel that would effectively convey both a wide range of flows and sediment from the headwater areas. The refinement of the project goals, consideration of project reach constraints and analysis of alternative restoration designs resulted in the following strategy for restoration:

- Develop a channel geometry and profile that would provide stability, maintain equilibrium (form), and maximize the stream's natural potential while appropriately conveying the sediment supply.

- Develop a new channel plan form with a meander pattern appropriate for the available belt width, channel slope and valley features.

- Install benches, at bankfull stage, against the high terrace to provide floodplain relief along the bank and to reduce shear stress.

- Utilize a combination of geomorphic structures paired with bioengineering techniques to reduce and protect against bank erosion, provide grade control, and provide for increased habitat.

- Provide streambank stability by using in-stream geomorphic style structures to reduce shear stress and velocity against the outside meander bends.

- Re-elevate portions of the incised stream channel to utilize the active floodplain in order to reduce the potential for further channel incision.

- Obtain needed fill materials from on-site sources using a combination of floodplain re-contouring, borrow areas and floodplain ponds.

- Create a single defined channel through the braided reaches, capable of transporting a range of flows and providing increased sediment transport.

- Remove the existing, exposed lacustrine clay material found within the channel boundary to a determined scour depth, below the finished grade of the project design. The over-excavation of the clay material would reduce the potential for future entrainment of clay particles.

- Re-establish an effective riparian buffer of trees, shrubs and deep rooted grasses to assist in providing long-term stability of the stream channel and floodplain.

- Provide habitat, recreation and aesthetic enhancements concurrent with the creation of a naturally functioning morphology and re-vegetated floodplain area.

In 1999, the GCSWCD and Kaaterskill Engineering Associates initiated the development of a restoration design for the project reach. Topographical surveys were completed for the entire project site and supplemented with geomorphic assessments and surveys. The project design incorporated a number of data sources including the reference data, regime analysis and analytical methods. The data was documented and evaluated against available resources for the proposed restoration strategy. It was determined that the assessment and design would utilize data collected from various reference reaches within the region, typical values developed by Rosgen and others, as well as published regional and provisional curves developed for the Catskills by the GCSWCD and NYCDEP.

5.1 Channel Morphology

The dimensions and scale of the proposed stream channel were designed to be applicable through a full range of flows and to meet considerations for sediment transport and channel boundary conditions. Regime, tractive force and analytical type analyses were utilized in order to develop an appropriate reconfiguration. Unlike traditional channel sizing, the design channel continually transforms between riffles and pools, which change in shape, length and spacing as the channel meanders through the one mile reach. The channel size was additionally adjusted through its length for the confluence of numerous drainage channels and for a twenty five percent increase in the overall drainage area.

The final design included the complete realignment of the stream channel. The channel alignment was created using regime and reference conditions paired with the analysis of historical aerial photography. Modifications to the proposed plan form were made to provide the best applicable alignment through the three existing bridges, and to avoid residential structures, existing utilities, and the high terrace. The increased channel meandering would provide for a reduction in local channel slope in order to re-elevate sections of the base channel. Substantial effort was also made to minimize the disturbance to the existing floodplain vegetation and to utilize the existing vegetation where applicable as bank protection.

The channel profile was created by utilizing slope characteristics of the valley, the existing channel and floodplain terraces as well as regime and reference conditions. The channel profile was constrained vertically through the reach by underlying glacial clay layers that existed in close proximity to the channel invert. The profile design included re-elevating portions of the channel invert in order to properly utilize the adjacent floodplain, decrease entrenchment and to prevent future scour into the clay layers. Consideration was given to the associated cost of elevating portions of the stream channel and weighed against the potential benefits of decreased suspended sediment loading and multiple floodplain functions. The channel profile was also designed to provide for bed feature variation, simulating a more natural riffle/pool complex, in order to provide for increased channel habitat and energy dissipation. The existing grade of the floodplain was used to match the proposed bankfull elevation of the project throughout the entire channel length.

The cross sectional dimensions of the channel were altered to promote proper sediment and flow transport through the reach during a range of flow events. A multi-staged channel was created through the reach to provide increased physical habitat during low flow, a defined bankfull channel, and provide increased floodplain function for large flow events. The existing conditions of the reach, which included areas containing lateral migration, degradation and aggradation, required various modifications to the existing cross section dimensions.

In the lower portion of the reach, the existing channel ran subsurface through nearly 1000 feet of channel during base flow. The over-widened, aggrading condition was improved by creating a single defined channel and by altering the width/depth in order to promote increased sediment transport. The dimensions of the base flow channel were enhanced by the creation of pools at the outside of meanders and behind in-stream structures throughout the entire reach. Restoration in several areas included re-grading portions of the floodplain and removing several landform obstructions, which impeded flood flow and channel belt width. The central portion of the project was changed from a B stream type to a C stream type by elevating the channel as well as providing a wider flood prone area.

A summary of various average channel design parameters and general reach characteristics has been described in Table 1.

Table 1: Big Hollow Channel Morphology Features

Variables	Existing Channel			Reference	Typical Values		Proposed	
Stream Type	C3	B4c	C4	C3	C3	C4	C3	C4
Drainage Area (sq. mi.)	5.9	6.1	7.15	11.4			5.52	7.15
Bankfull Width (ft.)	61.4	43.2	41.7	35.5			41	44
Bankfull Mean Depth (ft.)	1.3	2.5	2.3	2.21			2.1	2.2
Width/Depth Ratio	47.7	17.5	18.2	16.1	12 - 25	17 - 18	20	20
Bankfull Cross Sectional Area	79.1	106.8	95.2	78.4			83	98
Bankfull Maximum Depth (ft.)	2.35	3.65	3.58	3.16			2.84	2.97
Width of Flood Prone Area (ft.)	215.6	79.9	255.3	93			variable	variable
Entrenchment Ratio	3.48	1.85	6.13	2.62			variable	variable
Meander Length (ft.)							492	528
Meander Length / Bankfull					12 - 14	11 -12	12	12
Radius of Curvature (ft.)							164	176
Radius of Curvature / Bankfull					3.5 - 4.5	3.0 - 4.0	4	4
Belt Width (ft.)							95 - 210	95 - 210
Meander Width Ratio							3.9	3.6
Sinuosity							1.2	1.2
Average Slope	0.013	0.011	0.013	0.019			0.016	0.016
Maximum Pool Depth (ft.)	3.9	4.3	3.9	4.9			4.9	4.9
Pool Width (ft.)	49.8	53.7	49.8	36.8			51.25	55

5.2 In-stream Structures

The restoration design incorporated three general types of in-stream structures to promote channel stabilization. A combination of rock vanes, cross vanes and root wads were used to provide multiple benefits by providing grade control, bank stabilization, improved physical habitat, facilitate sediment transport, dissipate excess channel energy and maintain bed form variation.

Sixty rock vanes were incorporated along nineteen meander bends in the project to assist in reducing shear stress and bank erosion, while allowing for the long term establishment of vegetation. Additionally, rock vanes would provide bed form variation by maintaining scour pools downstream of the vane arms. The design incorporated twelve cross vane structures at the top of channel cross over segments. The cross vanes would primarily provide grade control and impede future head ward erosion and reduce shear stress and bank erosion. Material for the construction of the rock structures was obtained from local quarries and transported to the project reach.

Root wads were incorporated into the project primarily for habitat enhancement and to provide increased bank stabilization in high stress areas. Available root wads were to be used in combination with rock vane structures. Material for the construction of root wads was obtained on site by the collection of large trees remaining from previous flood events as well as trees obtained during the clearing and grubbing of the project area.

5.3 Riparian Vegetation

The project design included the use of traditional bioengineering practices to provide for increased streambank stability and to initiate riparian vegetation growth in disturbed areas. Live fascines and brush layering techniques were combined with the installation of live stakes, posts and transplants. Over 5,800ft of live fascines and 5,200ft. of brush layering was designed for installation along outer meander bends. Bioengineering involved the use of local native willow species combined with various hybrid species. Short term stabilization of the site was provided by hydro-seeding the site with a conservation seed mixture.

The increased meander of the proposed design required removing large areas of riparian vegetation to facilitate construction of the new channel. Substantial effort was made to minimize the disturbance to the existing floodplain vegetation and to utilize the existing vegetation where applicable. In segments where the stream meander was created through vegetated floodplain areas, the existing riparian vegetation was preserved in order to provide increased stabilization to the streambanks and to provide overhead stream cover. Temporary access roads required for construction of the project were designated on the plans and marked in the field to provide the least disturbance.

5.4 Clay Material

The project reach was characterized by extensive exposures of glacial clay materials. To mitigate the water quality impacts of the clays, the restoration design provided specifications for removal of the clay materials by over-excavation and replacement with clean gravel/cobble material. Specifications called for the removal of 3 - 4 feet of clay material, below the finished grade of the project design. The over-excavation of clay material would reduce the potential for future entrainment of clay particles. Excavated clay material was disposed in designated fill areas in the adjacent floodplain and located away from the active channel.

5.5 Fill Material

Extensive fill material would be required through most of the project reach in order to re-elevate the existing channel and fill the adjacent floodplain areas. The original estimates required approximately 45,000yds^3 of fill material but was modified prior to construction to nearly 35,000yds^3. The acquisition and transport of this quantity of material from off-site sources would be prohibitively expensive, therefore, on-site sources of material were included within the project planning and design.

Two ponds were designed and located in the adjacent right floodplain near the lower portion of the project. The ponds were designed in series along an existing ephemeral drainageway which would provide nearly 9,000yds^3 of material and allow for moderate flood retention and provide multiple habitat benefits. The remainder of the fill material would be generated by a combination of floodplain grading and upland re-contouring.

The grading plan was modified to reduce the amount of fill needed and to include re-grading a large floodplain terrace located in the left bank floodplain near proposed station 14+00. The removal of the existing terrace would increase the available belt width and provide more uniform flood flow throughout the floodplain during large events. Additionally, two large borrow areas were allocated for fill acquisition. The first borrow area was located in an overgrown field on top of the high terrace. A temporary access road would be constructed up the face of the high bank in the eroding area in order to minimize the disturbance to the adjacent vegetation and provide a more direct transport route for the material. Several feet of material would be removed from the surface of the field, graded and seeded. The second borrow area was located near the top of the project and would involve removing the remainder of the needed fill material from a large remnant floodplain terrace before final grading and seeding.

6.0 Project Implementation

The restoration project was authorized by NYSDEC under Article 15 of ECL, and approved by the USACOE under the Nationwide 27 guidelines. The project was approved for construction in two phases, if needed, to account for the length and overall scope of the proposed activities.

6.1 Bidding and Costs

A project bid package was developed to include drawings and specifications for the proposed project. The project was publically bid in August of 2000 using a competitive bid process. After reviewing the associated costs with obtaining the required fill material, the project bids were rejected to allow for modifications to be made to the specifications. The project was re-bid in August of 2001 and a final contractor was selected from four submitted bids. The final accepted project bid is summarized in Table 2 as well as the final construction costs associated with the primary bid items.

6.2 Time Line

Pre-construction assessment and monitoring, project design and restoration implementation occurred over a period of five years due to the scale of the project. Preliminary assessment and monitoring activities were conducted over a three year period from 1997 to 2000. Restoration designs were initiated in 1999 with a topographical survey, which had to be repeated after significant channel changes occurred as a result of Tropical Storm Floyd in September of 1999. The entire reach was re-surveyed during the winter of 1999-2000 and a permitted design was generated for construction by late summer in 2000.

Construction of the Big Hollow project commenced in August of 2001. Approximately 3,400 feet of the project was completed between August and October of 2001, before being halted in anticipation of winter weather. The remainder of the primary channel construction was completed in August of 2002. The bioengineering components and floodplain vegetation was installed during both phases in late October and early November, once the source material for cuttings became dormant.

6.3 Construction Details

Construction details and specifications were created within the project bid package and can be obtained from the GCSWCD. Detailed construction drawings can be found in Appendix D and photographs of project construction are included in Appendix B. A summary list of project construction details is provided below.

- Temporary access roads were created along floodplain areas to provide entry to the project area. Existing access areas were modified to allow for access by heavy equipment and transported material into the project area. Clearing and grubbing of the borrow areas and the proposed meander bends was initiated in phases prior to beginning the excavation. Cleared vegetation was buried in areas requiring fill material.

- The active work zone was de-watered by pumping all upstream flow around the work area in phases. Stream flow was pumped using a 10" submersible electric pump through a sealed pipeline and discharged into an existing floodplain drainageway.

- Stream channel excavation of the new meander bends was initiated in the lower portion of the project reach and progressed upstream. Material generated during the excavation of the meander bends was used to fill portions of the existing channel. Borrow material was excavated from the two pond locations and used as fill in the project area.

- Approximately 7,350yds^3 of clay material was excavated from the stream channel and replaced with adequate fill material. The excavated clay material was disposed in designated fill areas in the adjacent floodplain and located away from the active channel.

- The installation of rock structures was initiated at the bottom of the reach and continued upstream following the rough grading of stream channel. The project included the installation of 72 rock structures, which required approximately 12,000 tons of rock to be hauled from two local quarries to the project site.

- As the construction progressed upstream, designated borrow areas were prepared and utilized for additional fill material. The largest quantity of fill material was obtained from a large field located on top of the high terrace in the center of the project reach. A temporary construction road was established up the face of the terrace in order to more efficiently transport the material to fill areas and create less disturbance to the surrounding forested areas.

- Root wads were acquired during the clearing and grubbing of the project site and borrow areas. Approximately nine root wads were installed in the project area to provide added bank protection and provide habitat in high stress areas.

- Sediment and erosion control was accomplished by collecting turbid water at the bottom of the reach, prohibiting its release to downstream reaches and pumping the turbid water to grassy areas for natural filtration.

- Final grading was completed in the stream channel after the installation of the rock structures and continued in the floodplain areas as fill material was generated. Upon completion of the finished grading, exposed areas were hydro-seeded to provide temporary stabilization.

- The bioengineering was installed once the native borrow material became dormant. A combination of techniques were employed, which included live willow fascines, brush layering, live stakes and posts, live material transplants, bare root seedlings, and sod mats. Planting was completed by the contractor, GCSWCD staff and a wide range of volunteers. Disturbed areas were re-seeded and mulched following the bioengineering installation.

- The planted areas were irrigated as needed in order to improve establishment and survivability.

6.4 Constructability

Access to the project area, through private property, was acquired through landowner agreements prior to the start of construction. Mobilization of construction equipment to the work area was achieved by use of a landowners driveway and several existing earthen access roads. Site conditions were generally considered favorable for equipment mobilization and construction activities.

6.5 Construction Modifications

Several modifications were made to the original design during the project construction. A summary of modifications are listed below.

- The existing top soil was stripped from the borrow areas prior to excavating the fill material. The top soil was re-graded over each borrow area and seeded and mulched immediately after excavation was complete.

- The location of several rock structures was changed to account for existing site conditions during the implementation. Additionally, several structures were removed from the plans after making modifications to the structures' dimensions during construction.

- The initial project was designed to account for the existing placement of three bridges located within the project limits. The original plan form of the channel was designed, in part, to establish a better alignment through the bridge openings. During construction, the Town bridge located in the project was severely damaged by an oil truck delivering fuel oil to a nearby home. The weight of the oil truck caused structural failure to the bridge decking and support beams. The entire bridge structure required replacement allowing for modifications to the alignment of the new bridge structure. Prior to the installation of the new bridge, placement and dimensions of rock structures were changed to account for the location and dimensions of the proposed bridge.

- The county bridge located at the top of the project reach was replaced with a larger structure during the first phase of the restoration project. Originally the bridge was not scheduled for modification or replacement for several years following the restoration. The replacement with a larger structure will assist the function of the project but required last minute modification to channel alignment and structure placement.

Modifications that were made throughout both phases of construction and implementation of the project were included within post-construction topographic surveys of the entire project site. The as-built surveys were initiated during the first phase of construction in the fall of 2001 and completed after the second phase of construction in the fall of 2002. The final drawings will be provided in future appendices of this report as they are completed.

7.0 Project Monitoring and Performance

In order to document the stability and performance of the restoration project and to provide baseline conditions for comparison against pre-construction conditions, regular inspections and annual monitoring surveys are conducted. Project inspections include photographic documentation of the project reach and a visual inspection of the rock structures, channel stability, bioengineering and riparian vegetation. The inspections are conducted annually during the project site survey as well as during and after significant flow events. The project monitoring surveys include both physical channel and structural stability as well as fisheries assessments. Long term monitoring of water quality is being performed by NYCDEP, which includes measurements of total suspended solids (TSS) and turbidity.

7.1 Physical Performance

Restoration projects, using geomorphic and natural channel design techniques, incorporate principles that seek to re-establish the dynamic equilibrium of the stream channel. This includes the channel's ability to make minor adjustments over time as the project experiences a range of flow events. A channel in dynamic equilibrium typically experiences minor variations in channel shape and form, which are necessary for the maintenance of a stable morphology. In order to document the changes in morphology and project stability, monitoring surveys have been initiated in the project reach.

The monitoring of the project includes pre-construction surveys, an as-built survey, and multiple post-construction monitoring. The physical performance of the channel is monitored using surveys to minimally include longitudinal profile, multiple monumented cross sections and sediment analysis. The relationship of channel morphology "at-a-station", and general morphology trends through the reach will be analyzed using the collected data. These physical measures will be further refined by stream feature specific quantities. The comparison of time intervals and change in physical parameters will be determined, as well as the association to hydrologic inputs associated with storm events and sediment transport.

These quantities can be further developed by comparisons within the reach, against regional values, stream channel classification indexes, and reference reach data. The channel parameters can be applied to channel evolution models to review the effectiveness of treatment in halting or accelerating a channel process.

In the case of long term monitoring data, the individual treatments can be compared, quantified and delineated. As the project monitoring progresses, future analyses will be used to determine the effectiveness, in terms of worth of the project at multiple scales, in comparison to other natural channel design projects and treatments in the watershed. Specific project inspections and monitoring reports are summarized in Appendix F.

7.2 Fisheries Assessment

The U.S. Geological Survey (USGS), in cooperation with the NYCDEP and the GCSWCD, inventoried fish communities in stable and unstable reaches from several streams in southeastern

New York State as part of a stream restoration demonstration program. Major objectives of the fishery monitoring effort are to determine if:

- fish populations and communities differ between stable (reference) and unstable (control and project) stream reaches

- improved stability of restored reaches is reflected by improvements in affected fish populations and communities.

Fishery surveys were completed in the summer of 2000 and 2001 at three reaches in the upper Batavia Kill basin before restoration (treatment) of the unstable project reach was completed. Annual surveys of fisheries and habitat at the three reaches in the upper Batavia Kill basin, and at comparable reaches in two to five additional streams, are planned after restoration to address the second objective. The findings are summarized in Appendix F.

8.0 Operation and Maintenance

Proper operation and maintenance is a critical element for the success of restoration projects, which use geomorphic and natural channel design techniques. Based on experience with local conditions, and the five natural channel design projects completed to date, the GCSWCD and NYCDEP SMP believe that attaining acceptable channel stability requires an extended period for the project to become "established". While site conditions and hydrologic conditions strongly influence the amount of time a project needs to become established, it appears that at least a two-year establishment period must be considered. This "establishment" period must include allowances for reestablishment of vegetation and adjustments/repairs to rock structures. It is critical to have a clear understanding that typically, restoration goals are not achieved the day the contractor leaves the project area, and the evaluation of project success must be based on performance over a longer period of time.

During the initial years after establishment, as the restoration site experiences a range of flows and the sediment regime becomes "naturalized", projects usually require modifications and design enhancements. Project sponsors must be prepared to undertake adjustments in channel form and /or rock structures as indicated by the project monitoring. It is believed that as project vegetation becomes established the overall operation and maintenance of the project will decrease. The creation of a project operation and maintenance plan and a landowners guide is currently in progress and will utilize data from the project monitoring. The Batavia Kill Stream Corridor Management Plan will provide additional assistance in the management, operation and maintenance of the project reach.

8.1 Rock Structures

In-stream rock structures may require some modification and enhancement. The monitoring and inspections performed by project partners will assist in prescribing the modification of rocks to ensure structural integrity, and debris and sediment maintenance considerations. The annual project status reports will document these needs and modifications.

8.2 Vegetation

Vegetative establishment in the project area is a critical component to the project's long term stability. General site constraints and gravelly soil conditions limit the success and establishment of the designated vegetative element of the project. Careful planning, monitoring and maintenance is required for all of the installed vegetation. Increased browsing pressure from mammals, potential for disease and extreme weather conditions can reduce the success of the plant materials. Inspection and monitoring of the plant materials throughout the initial stage of development will assist in ensuring plant viability.

Supplemental installation of plant material, as needed, in the form of bioengineering and riparian planting will ensure effective riparian establishment. During supplemental planting, a variety of bio-engineering techniques will be used to increase woody vegetation at the site. These plantings will require maintenance to ensure proper moisture at critical times. The development of the monitoring plan for vegetation is addressed in the monitoring component of this document as well as the landowners guide that is currently being developed.