VII. Demonstration Restoration Projects

A primary goal of the Batavia Kill Stream Corridor Management Pilot Project was to demonstrate the effectiveness of Natural Channel Design (NCD) concepts in the Catskills. While these methods have been used successfully to restore long term stability to streams in other areas of the country for close to 30 years, NCD principles had not been tested to any significant extent in the northeast. The NYCDEP and GCSWCD believed that NCD could be used not only to reduce sediment loading and turbidity from in-stream sources, but that these methods could also provide benefits associated with improved fish and wildlife habitat, flood protection, property protection, and aesthetics.

A. DEMONSTRATION PROJECT GOALS

The demonstration projects were developed with the primary goal of demonstrating the effectiveness of geomorphology-based restoration design techniques in the reduction of turbidity from in-stream sources. The projects were also critical in the development of geomorphic-based protocols for stream classification, assessment of stream stability, and selection of restoration objectives in the NYC Watershed area. The specific goals of the Batavia Kill demonstration projects are summarized as follows:

- Evaluate the effectiveness of NCD in the Catskills using companion assessments based on physical, biological and chemical characteristics of the restoration sites.
- Evaluate the effectiveness of pre-construction geomorphic assessment indexes for identification of stability problems, and selection of restoration objectives.
- Evaluate the effectiveness of using stable reference reaches as “blueprints” for the development of restoration designs.
- Conduct performance evaluations of in-stream rock structures (angles, scour, reliability) as constructed to enhance streambank stability.
- Develop design standards, typical details, construction specifications, construction sequencing procedures, and operation and maintenance protocols for geomorphic-based NCD restoration projects.

B. DEMONSTRATION PROJECT LOCATIONS

During Phase I of the Batavia Kill Pilot Project, three separate sites were chosen as demonstration sites for the application of NCD concepts. The first two sites constructed were located in the middle of the stream corridor, in the Town of Ashland, and are referred to as the Brandywine Site and the Maier Farm Site. The third demonstration site is located in the Town of Windham, above the C.D.Lane Park facility, near Peck Road, and is referred to as the Big Hollow site **(Figure VII-1)**.

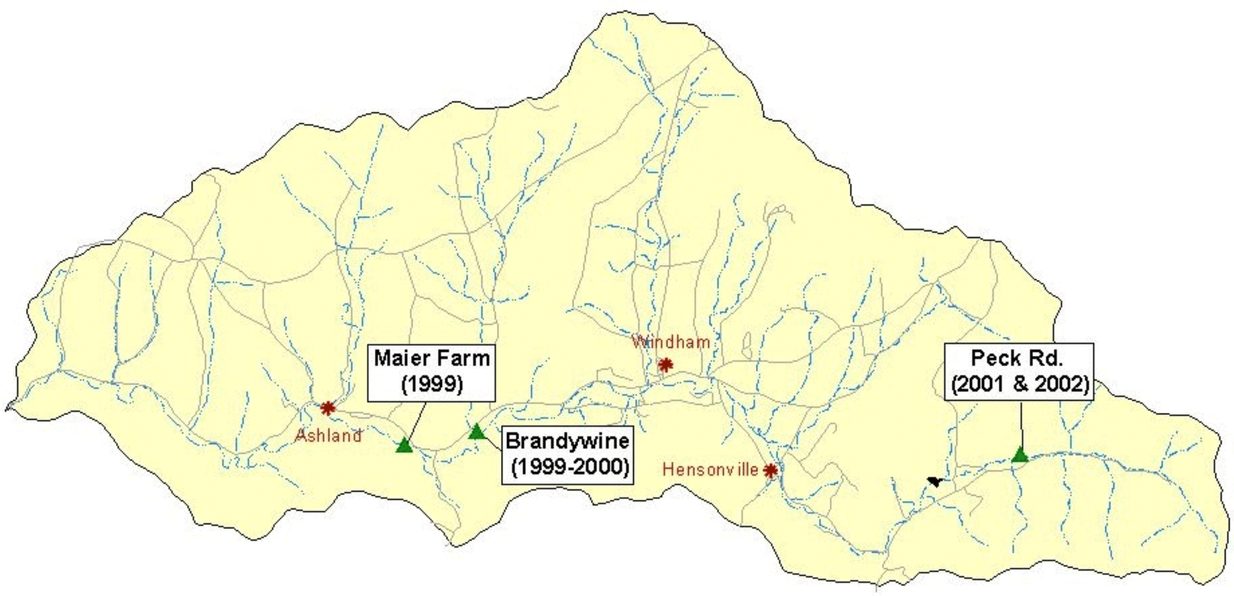

Figure VII-1: Location of Phase I demonstration projects on the Batavia Kill.

While the instability problems identified at each project site were a key factor in the selection process, a number of other factors were also considered. In addition to the current state of stability, the GCSWCD and NYCDEP evaluated factors such as predictions of the future state of stability, water quality impacts, fisheries habitat conditions, access, constructability, complexity and visibility. The following are several of the key factors that guided the site selection process.

- The three sites were considered unstable with little hope for self recovery in an acceptable time frame.
- The GCSWCD was successful in obtaining NYS Ag & Markets grant funding for the Maier Farm and Brandywine projects. Obtaining matching funds allowed for additional work to be completed in the watershed.
- The three sites were characterized as having a negative impact on water quality due to the presence of exposed clay deposits in the streambed and streambanks.
- The Big Hollow site also presented the opportunity to test NCD principles in a section of the stream that was not regulated by the flood control structures, and

which was characterized by a different valley morphology than the other two sites. Additionally, the site was negatively impacting the CD Lane flood control structure due to elevated sediment supply.

- The Maier Farm & Brandywine sites had excellent access and visibility, and required a relatively simple strategy to restore a stable stream form and function. Also the modification of the sites posed minimal risk to infrastructure.

C. RESTORATION STRATEGIES

Prior to the development of a final restoration design, it is critical to correctly identify the stream process causing the instability of the target reach. In previous sections of this SMP, the GCSWCD discussed the methods used in the assessment process, as well as a detailed discussion of the problems at each demonstration site. Once the stability problem has been identified, an effective restoration strategy must address the stability problems in a way that is appropriate for the watershed setting. The ultimate goal is to create a dynamically stable channel that is self sustaining, durable, and that maximizes the ecological potential of the reach.

The GCSWCD and NYCDEP selected restoration strategies that would promote a stable geomorphic form, provide for restoration of the channels natural function to move water and sediment, and to provide for long term stability of the streambanks. The final restoration strategy must find a delicate balance between sound stream science, physical site limitations, and the wishes of watershed stakeholders and the financial partners. Restoration strategies set forth the level of intervention required, an evaluation of project benefits, cost, and the potential for the projects long term success. On the Batavia Kill demonstration projects, the restoration strategies were based on several primary objectives:

- Develop a stable stream morphology, of the appropriate stream type, based on assessment of stream corridor and watershed conditions. The strategy had to provide for construction of a stable channel dimension, pattern and profile.

- Provide for short term streambank stability by using in-stream rock structures (rock vanes/cross vanes) to reduce shear stress and velocity as needed based on channel morphology.

- Establish stream channel grade control to prevent in-stream degradation into clay deposits. In-stream rock structures (cross vanes) are effective in providing this grade control.

- Use extensive woody and herbaceous planting on the streambanks and floodplain to provide for long-term stability of the project.

- Use root-wads, J-hook vanes and other design features to enhance streambank stability.

- Construct projects where there are cooperative landowners.

D. RESTORATION DESIGN PROCESS

Since the Batavia Kill demonstration projects were the first major Natural Channel Design (NCD) restoration projects in New York State, the GCSWCD had to develop protocols for collecting design related information and development of final design and bidding documents. Additionally, these were the first projects of this type presented to state and federal regulatory agencies for permitting. At the time of the projects, no data existed on stable reference reaches, and local engineers had no familiarity with the NCD methodology.

Figure VII-2: Prior to construction, the GCSWCD conducts on-site reviews with a variety of consultants.

At the beginning of the Batavia Kill project, the GCSWCD and NYCDEP elected to provide training to program staff such that they could complete the major design work on these projects, and have effective project over-sight. On each demonstration project, the design work was completed by the GCSWCD, under the supervision of E. Schwarzenegger from Kaaterskill Engineering Associates PC. Additionally, Rocky Powell of Clear Creeks Consultants was also consulted as necessary. The GCSWCD developed all necessary permit applications, bid documents and contracts. The following is a summary of the key components of the design process;

Surveys: On all NCD projects, the first task is the completion of a detailed topographical survey of the project site as well as setting survey control for implementation. The survey work was completed by GCSWCD staff and was used to produce a detailed topographical map of the project reach. Topographical maps were produced with 2' contour intervals, and were excellent for representing the complex terrain in the immediate stream corridor. The survey also includes any features such as drainage ways, roads, utilities, buildings and other structures that may need to be addressed in the final design process.

Reference Data: In the absence of a suitable C4 reference reach, GCSWCD used geomorphic data from a number of sources to develop the final project design. The GCSWCD utilized data collected from shorter reference sections within the region that exhibited stable dimensions and slopes, typical values developed by Dave Rosgen and others for C4 stream types, as well as published regional curves for the northeast, and provisional curves developed for the Catskills by the GCSWCD and

NYCDEP. Current and historical aerial photographs were used to obtain information on meander geometry while regime equations were used to validate discharge information.

Stream Channel Design: When the GCSWCD has the data from the stream assessment and reference reach in hand, it can then start the actual design process. Using computerized design tools such as AutoCAD and a detailed topographic survey, the GCSWCD designs a stream dimension, pattern, and profile appropriate for the stream type being constructed. Typically, several reiterations of the design channel are completed as the project evolves. The design channel is then analyzed to confirm it's ability to transport its sediment supply as well as the bankfull and flood flows. Low flow channel considerations are incorporated by increasing channel hydrology by improving pool sequencing, and attempting to develop a defined thalwag that will remain wetted in the dry summer months. This is a simplified description of a complex multi-discipline design process that incorporates principles of river engineering, hydrology, biology, geology, and fluvial geomorphology.

Project Permitting: When presented to the Army Corp of Engineers (ACOE) and NYSDEC for permits, these projects represented some of the most extensive restoration work to have been completed in NY State. The projects called for extensive realignment of the channel, as well as the placement of significant quantities of fill in the stream channel. While the projects were initially permitted by the ACOE under issuance of Individual Permits, this process required 12 to 18 months to complete and actually delayed the initial construction from 1998 to 1999. As the program has progressed, the ACOE has amended its Nationwide Permit Process, and the Big Hollow project was permitted in a few short months under a new Nationwide Permit intended for environmental restoration projects. By working in close coordination with the ACOE and NYSDEC during all phases of the project, permits were delayed, but eventually issued without any significant problems.

E. BIDDING & OVERSIGHT

Similar to the design phase of the demonstration projects, there was no prior experience in NY State with implementation of NCD restorations. As such, the GCSWCD, KEA Engineering and the NYCDEP had to develop a number of tools, including project specifications for the various techniques to be used in the restoration, as well as bidding procedures that would address the wide range of variables that can arise during implementation of the projects. The GCSWCD is bound by NY State General Municipal Law which requires projects of this size to be competitively bid, though the nature of the work made this a challenge. The following is a summary of the major components of the implementation process.

Project Bidding: As stated previously, the GCSWCD was required to select a contractor based on a competitive bidding process. While certain components of the project were fairly easy to include in a sealed bid process, other items contained significant unknowns and were not well suited to a traditional bidding process. As the projects have moved forward, the GCSWCD has continued to refine project specifications and bidding documents. The bidding process included lump sum bid items as well as items that were bid on a unit basis. To cover a wide range of contingencies, the GCSWCD developed alternate bid items that could be used to address changes in the projects scope arising after the start of construction.

Construction Management: As important as a good design, management of the project's construction is critical to the success of NCD restorations. On the Batavia Kill, all on-site project management was provided by the GCSWCD and observed by the Project Engineer (KEA). The GCSWCD provided all layout surveys and continuously monitored construction of the projects. Staff from the GCSWCD was on-site during all hours of operation. Since these projects must move rapidly to minimize the impact to the stream system, detailed management of the construction progress is essential to insure that decisions are made in a timely manner.

F. PROJECT CONSTRUCTION

By the summer of 1999, all permits, contracts, funding, easements and other items needed to complete the demonstration projects were in place, and work commenced. Construction started in early July 1999, and was essentially completed by mid-September. The bio-engineering components were postponed in order to allow for the dormant harvest and installation of the plant materials. The following is a summary of key components of the construction process;

Site Preparation: The first step on each of the projects involves the preparation of the site. This includes removal of vegetation and obstructions, creating access and staging areas, and work required to facilitate de-watering, sediment control or other project tasks. On the Maier Farm and Brandywine projects, site preparation included the removal of extensive areas of Japanese knotweed, including the removal of both the plants vegetation as well as root mass which were buried in locations where the stream would not impact them.

De-watering: A critical component of the restoration process is de-watering of the work area. As required by NYSDEC and ACOE permit conditions, the GCSWCD must divert all stream flow around the work area. In each of the three projects, a cofferdam was constructed at the top of the project reach to capture upstream flow entering the reach. Large pumps and discharge pipes are used to transport the water from the cofferdam to a downstream location beyond the project reach.

On the Maier Farm and Brandywine projects, a 12" diesel pump **(Figure VII-3)** rated at over 8,000 g.p.m. was used in conjunction with over 1,400 linear feet of 12" aluminum pipe, while the Big Hollow project was constructed under drought conditions and required much smaller pumps. De-watering on the Maier Farm and Brandywine projects represented approximately 25% of the total project costs, but was lower on the Big Hollow site. Once de-watering was started, it was maintained full-time, 24 hours a day, 7 days a week, until the channel work was completed.

Figure VII-3: A 12" diesel pump was used to intercept and pump around all upstream flow entering the project site.

Sediment Control: In regard to pollution control during construction, the GCSWCD is held to the same standards as the private sector. With the stream restoration projects, the primary consideration is erosion and sediment control, and avoidance of impacts from turbidity. Due to their very nature, these stream projects do not allow for a traditional erosion control plan. Since the streams are at the lowest point in the landscape, silt fences are generally not effective as they would have to be placed up-slope of the work. To address sediment pollutants during construction, the GCSWCD developed an effective method based on capture and treatment of sediment-laden water. A second cofferdam is placed at the project's downstream limit, and additional pumps and a pipeline system are used to move the turbid water to a well vegetated area where it typically soaks into the ground leaving the sediment on the surface **(Figure VII-4)**. This method is less effective during periods when the ground is saturated, it requires full time operation and maintenance of pumps, and inn many cases the treated water reenters the project reach via groundwater and is again cycled back for treatment. It has, however, proven to be the most effective method to insure little or no discharge of turbid water from the project reach.

Figure VII-4: Sediment-laden water is pumped to grassy fields for settlement of solids.

Construction Sequence: Once the stream channel is de-watered and the sediment treatment system is in place, construction commences on the major project components. Initially, existing on-site materials are re-graded to produce the design dimensions, pattern and stream profile. Grading also includes the reconstruction of the adjoining floodplain with remnant channels, and eroded areas are filled. In all three demonstration projects, the existing materials in the immediate stream corridor were not adequate for reconstruction of the channel, and the GCSWCD had to bring in extra materials from ponds constructed as "borrow sites" as well as re-contouring of landscape features, to make up the balance of the fill required.

Figure VII-5: Extensive grading was required to create the new channel form.

Figure VII-6: Construction of rock vanes proceeds after the channel is graded .

Once the channel takes shape, a crew comes immediately behind the grading operations and starts installation of the in-stream rock structures. When the rock vanes and cross vanes are in place, the water is re-routed back into the stream channel and final grading of the upper banks and floodplain continues without the need for de-watering.

Vegetation Establishment: Upon completion of the major construction, all disturbed areas on the site are stabilized by seeding and mulching. To date, the GCSWCD has used a typical conservation seed mix consisting of fescue, rye and trefoil. This mix has proven to grow well under adverse conditions and provides short term stability until woody vegetation established. The GCSWCD has preferred hydro-seeding as the method of application due to its ability to remain in place in areas subject to strong winds. In the late fall when the leaves

Figure VII-7: Rows of willow fascines are planted on meander bends to provide vegetative protection.

Figure VII-8: Irrigation during plant establishment period is critical.

have dropped, the dormant cuttings of willow and dogwood can be effectively harvested and planted on the project sites. On the demonstration sites, the GCSWCD has used a variety of standard bio-engineering techniques to establish woody vegetation including live fascines, brush layering and live stakes **(Figure VII-7)**. These methods have generally been successful, but the GCSWCD continues to plant additional materials and to develop better methods for insuring plant establishment. Recently, the GCSWCD has provided increased focus on improving irrigation methods to insure moisture at critical times **(Figure VII-8)**.

G. INSPECTION & MONITORING

To determine if the restoration methods are successful, the GCSWCD and NYCDEP are conducting extensive post-construction inspection and monitoring of the projects. First, all work is surveyed immediately after construction to document the "as-built" condition of the new channel. At the time of the as-built survey, monitoring cross sections are also installed for use in future monitoring efforts.

Figure VIII-9: Site visits during high flow events are useful for observing how the project reach is functioning.

In addition, the projects are inspected on a routine basis, with a detailed site review after each significant flow event. Larger events, that meet or exceed the bankfull discharge, may require a re-survey of cross sections after the event if changes are noted. The GCSWCD places a high priority on routine inspections, with re-survey of the monumented cross sections completed on an annual basis. Photo documentation is also useful in monitoring change over time. The GCSWCD and NYCDEP will be using Batavia Kill demonstration sites in a long term study of restoration project stability. Project inspections and monitoring are also a requirement under the GCSWCD ACOE permit conditions.

H. MAINTENANCE & REPAIRS

As discussed in **Section III** of this document, one of the benefits of NCD projects is that they tend to become increasingly more stable as they "mature". As the vegetation becomes established and the stream completes a fine tuning of the channel, the projects become stronger and maintenance requirements are reduced. When using NCD restoration techniques, it is important to recognize that these projects will usually require some modifications or repairs after the first large storm event. Typically this may involve adjusting the alignment of a rock structure or replacing rocks that may have been displaced. As the GCSWCD continues to apply NCD principles in the Catskills, refinements to project designs and construction techniques has reduced the need for modifications or repairs after the initial construction. In the first 1-3 years after construction, rock structures may require some adjustments or repairs from time to time, and replanting of vegetation is critical when the original plantings do not achieve the desired establishment rate.

I. DEMONSTRATION PROJECT DESCRIPTION

Maier Farm Site

As noted in **Section VII-D**, the primary stability problem observed at the Maier Farm site was associated with unstable meander geometry and down valley meander migration. The Maier site was characterized by nearly 1,000 feet of actively eroding streambanks as a result of the channel's attempt to seek a stable planform. The erosion was contributing excess sediment to the stream system and presented a water quality concern.

Figure VII-10: Erosion of left streambank along the Maier Farm project site. Note eroded bank on left of photo.

While the GCSWCD had a limited period to conduct an assessment of reach stability, the primary cause of the instability was attributed to the loss of an effective riparian buffer, as well as past anthropogenic activities. While specific human activities that may have contributed to the instability are difficult to pinpoint, it was known that rip-rap had been recently installed on the meander immediately upstream of the project reach, and that gravel removal on the upstream point bar had occurred after past floods. The site's riparian buffer was dominated by active hayfields, with minimal deep rooted woody vegetation. The invasive species Japanese knotweed (*Polygonum cuspidatum*) had colonized significant portions of the streambanks and floodplain, further contributing to the lack of bank stability.

Design Stream Type:	C4
Drainage Area:	52 Square Miles
Bankfull x-section:	240 Square feet
Bankfull Mean Depth:	4 Feet
Slope:	.0021
Project Length:	1650 Feet
No. of Rock Vanes:	10
No. of Cross Vanes:	3
No. of W-weirs:	1
No. of Rootwads:	2
Construction Cost:	$187,519
Construction Period:	August 1999

Figure VII-11: Maier Farm project summary.

Based on site conditions such as a broad floodplain and low valley slope, the GCSWCD selected the C stream type (Rosgen 1995) as the appropriate basis for the restoration design **(Figure VII-11)**. The restoration design provided for the reconstruction of a riffle-pool morphological form, with four meander bends reconstructed over the 1,650 foot project reach. The design provided for the use of cross vanes to maintain a stable streambed, with rock vanes used on the new meander bends for stability. While lacustrine clay exposures had not been noted during the assessment process, during construction it was revealed that clay lenses were only 12" to 18" below the streambed.

Since stability of the proposed C4 stream type is strongly influenced by the condition of its riparian vegetation, the demonstration project utilized a variety of plant materials and planting techniques. The project used live willow fascines, which are bundles of dormant willow shoots, planted in shallow trenches on the outside of all meander bends as well as other high stress areas in the channel. Live willow stakes were also randomly installed starting at the mean water surface and continuing into the riparian buffer on the flood plain.

A limited application of transplanted sod matts and established willow clumps was also tried. Transplanted willow clumps were placed at key stress areas (ex. top of rock structures), with sod mats placed along the top of the streambanks between the transplants to reduce sediment runoff. The floodplain was seeded with conservation grasses and mulched. The Watershed Agricultural Program assisted in the planning and implementation of substantial flood plain plantings.

The project was started in early August 1999, and required approximately ten calendar days to reconstruct the channel and install the floodplain structures. The entire project was completed within 21 days with the exception of the willow plantings, which had to be done in the fall when the source materials are dormant. The project was completed without any significant changes, though groundwater levels required additional resources to achieve effective de-watering and sediment control.

Figure VII-12: Construction of w-weir.

As discussed in **Section VII-D**, the private bridge at the bottom of the project reach presented several limitations that were addressed in the restoration design. First, to control flow in each side of the bridge opening, a W-weir was constructed just upstream of the bridge **(Figure VII-12 & VII-13)**. The weir was constructed such that it would direct base flows through the bridge opening that was in the best structural condition. As stream stage rises to one half the design bankfull, the other side of the weir becomes active, and it starts to divert flows and velocities toward the other bridge opening.

Figure VII-13: Aerial view of completed w-weir

In addition to the w-weir, the restoration design also included the construction of a bypass channel to convey higher flow events around the bridge on the floodplain. Since the bridge openings are undersized for larger floods, the bridge can act as a dam and cause water to back up upstream of the bridge. This backwater effect is characterized by lower velocities, which in turn reduce the stream's ability to transport sediment, resulting in aggradation upstream of the bridge. Constructed so as to take water when the stream reaches the bankfull stage, the high flow channel will route water around the bridge and reduce the backwater effect. Approximately 21 days after completion of the project, the Batavia Kill Watershed was hit by tropical storm Floyd. The storm hit the watershed on September 16^{th} to 17^{th}, and the impact on the demonstration projects is addressed later in this section.

Brandywine Site

The Brandywine project is located just upstream of the Maier Farm project, and is located behind the Brandywine restaurant. Similar to the Maier Farm site, the stream condition at the Brandywine project was also characterized by poor riparian vegetation, unconsolidated soils, and severe bank erosion associated with meander adjustments. The invasive species Japanese knotweed (Polygonum cuspidatum) had colonized significant portions of the streambanks and floodplain, further contributing to bank instability.

Figure VII-14: Heavy equipment working to construct the design channel at the Brandywine site.

The restoration design for this project also had to address the confluence of North Settlement Creek, which enters the Batavia Kill at the middle of the project reach. North Settlement Creek is a major tributary, and its sediment and water contributions had to be addressed during the restoration process. With little to no good reference conditions for stability at confluences with major tributaries, the GCSWCD used its best judgement to utilize traditional rock structures that would provide a stable confluence.

As with the Maier Farm site, the restoration strategy involved the construction of a stable C4 stream type, with a typical meandering riffle-pool morphology. The project length was 3,500 linear feet, and involved full reconstruction of four meander bends and the installation of rock vanes and cross vanes to provide stability to the streambank and streambed. As in the case of the Maier Farm site, the lack of suitable reference reaches in the Catskills required the development of the channel planform based on analysis of historical aerial photographs, as well as analytical and regime techniques. A summary of selected design information is presented in **Figure VII-15**.

Construction on the project was started during the third week in August, immediately after the Maier Farm site was completed. Primary construction of the new channel and rock structures took approximately 16 calendar days, and during construction the GCSWCD found extensive clay deposits that were excavated and replaced with clean gravel. The work was finished and the site seeded by early September. Approximately seven days after the project was completed, tropical storm Floyd hit the watershed, and the Batavia Kill experienced flood flows that exceeded the 1987 and 1996 events. With the absence of any vegetation on the site, and tens of thousands of yards of newly graded materials, the site experienced damage during the flood.

Drainage Area	43 Sq Miles
Bankfull X-section	230 SqFt
Design Stream Type	C4
Slope	.0005-.006
Project Length	3600 Ft
No. of Rock Vanes	14
No. of Cross Vanes	6
No. of Root-wads	1
Final Cost	$169,000

Figure VII-15: Stream channel design features for the Brandywine project.

As discussed later in this section, the GCSWCD evaluated both the Maier Farm and Brandywine sites after the flood event and decided to immediately repair the Maier site and leave the Brandywine until the following year. In late August 2000, the GCSWCD returned to the site with the original contractor, and the Brandywine project was repaired. The repairs took approximately two weeks to complete, and the GCSWCD used the opportunity to make some adjustments in the design. By 2001, the site was characterized by good coverage of grasses, and willow plantings were becoming established **(Figure VII-16)**.

Figure VII-16: Brandywine site one year after the project was repaired.

Big Hollow Site

The Big Hollow stream reach was restored during the 2001 and 2002 construction seasons. Approximately three quarters of the project was completed in 2001, with the remainder completed the following year. The restoration project included the entire length of management reach 1C **(Section VI-A)**, beginning at the county bridge at Peck Road and continuing upstream for approximately one mile to the newly replaced county bridge on County Route 56.

Figure VII-17: Preconstruction aerial view of Big Hollow site, note the braided channel at bottom, and lack of sinuosity at top.

As previously discussed, the Big Hollow project reach was selected due to its identification as a significant contributor to water quality impacts. The impacts on water quality were primarily the result of active incisement of the stream channel into the deep clays that underlie much of the valley floor. In addition, exposures of harder, more densely packed lodgement tills in the streambanks also contributed to water quality degradation. Between 1998 and 2000, when the GCSWCD was monitoring stream changes, the reach was shown to be highly dynamic and there was no evidence that the stream was moving toward stabilizing its form.

Drainage Area	7 Sq Miles
Bankfull X-section	83 - 98 SqFt
Bankfull Mean Depth	2.2 Ft
Design Stream Type	C4
Slope	0.016
Project Length	5,130 Ft
No. of Rock Vanes	60
No. of Cross Vanes	12
No of W-Weirs	0
No. of Root-wads	various
Construction Period	2001-2002

Figure VII-18: Stream channel design features for the Big Hollow project.

While initially slated for construction in 2000, the GCSWCD was not satisfied with the results of the bidding process that year and a decision was made to rebid the project the following spring. At that time, the restoration plans called for the creation of three additional ponds to provide the materials required for the project. The GCSWCD was concerned that the high groundwater table would not allow for the ponds to be sealed with clay as called for in the project specifications, and the use of alternate bid items based on bringing the required materials from off-site sources would have added over $500,000 to the project costs. The GCSWCD reevaluated possible borrow sources for the required materials, and the restoration design was modified prior to rebidding in the spring of 2002.

The Big Hollow project involved the reconstruction of approximately 5,130 feet of stream channel and adjacent floodplain, with the restoration design providing for the construction of 19 meander bends and over 70 rock structures **(Figure VII-18)**. The primary strategy of the restoration effort was to re-attach the stream to its adjacent floodplain as well as to relocate the stream away from the failing slopes on the adjacent high terrace. The restoration strategy selected for the project reach involved the construction of a stable C4 stream type, with a typical meandering riffle-pool morphology. Channel form and meander pattern was derived from analysis of historical aerial photographs, as well as analytical, regime and reference reach techniques. As in the other demonstration sites, rock vanes were used primarily on meander bends to protect stream banks from erosion, with cross vanes installed for grade control in critical areas.

Figure VII-19: Construction of rock structures at the Big Hollow site.

A significant feature of the Big Hollow project was the restoration of floodplain function, with over 35,000 cubic yards of additional material required to fill old remnant channels and incised areas.

Providing for an effective floodplain that is well connected to the active stream channel, will help reduce erosive forces in the channel and greatly increase the project's chance of success. This effort required large amounts of fill materials that were obtained from the excavation of two ponds, as well as upland re-contouring at several borrow areas. During the project, the GCSWCD was also able to re-contour locations along the stream corridor where glacial moraines were causing a constriction on the floodplain. This allowed for making the floodplain wider, as well as provided additional fill materials.

Figure VII-20: View of completed Big Hollow reach less than one year after construction.

While the design of the project is directed at improving water quality and reducing excess sediment inputs to the Batavia Kill, the added benefits of the restoration included enhanced fish habitat and improvements to the riparian buffer. Like the other projects constructed on the Batavia Kill, stability of the proposed C4 stream type is highly dependant on providing a good vegetative cover for protection of streambanks. Similar to the Maier Farm and Brandywine sites, the GCSWCD utilized live willow fascines and stakes, but this project also incorporated brush layering as well as extensive plantings of bareroot tree and shrub stock. In addition to the typical plantings on the streambanks, the GCSWCD also had to undertake extensive plantings on the new floodplain. While some of this work was accomplished by the contractor, GCSWCD staff and volunteers also planted significant quantities of materials. In November 2001, the GCSWCD held a very successful volunteer planting weekend, with over 70 people assisting in the planting of trees and shrubs on the floodplain. Volunteers included staff from NYSDEC, NYSDOT, NYCDEP, Trout Unlimited, and Boy Scouts, as well as citizens and others interested in stream restoration. In addition to the mile of stream reach restored, the GCSWCD had to stabilize over 14 acres of floodplain and borrow areas.

J. TROPICAL STORM FLOYD IMPACTS

On September 16, 1999 the Batavia Kill basin was hit by tropical storm Floyd just after GCSWCD completed work on the Maier Farm and Brandywine projects. The Maier Farm site had been completed approximately 21 days before the storm, and the Brandywine site only nine days prior to the event. The sites were vulnerable, with little to no vegetative cover on the streambanks. Bio-engineering components had not been installed, and grass establishment was light on the Maier Farm site and had not yet germinated on the Brandywine project. When the flood waters receded, initial observations revealed what appeared to be major damage to the projects, but when the sites were re-surveyed and compared to a control reach that had not been restored, the results were encouraging.

The Storm Event

Typical of the Catskills, rainfall is often intense, and highly variable from location to location. The direction of storm approach, local elevation, influence from coastal weather systems, and the effects of the facing mountain slopes all contribute in the variability of rainfall distribution in the watershed. During tropical storm Floyd, 9.3 " to 12" of rain fell on the watershed area, with most of the rainfall occurring over a period of around 18 hours. As shown in Table VII-1, the rainfall associated with the tropical storm Floyd event was significantly higher than the two previous floods of record associated with hurricanes. Preliminary data indicates that the flood event associated with Floyd exceeded any of the more recent flood events.

Table VII-1: Rainfall Totals for flood events on the Batavia Kill.

Storm Event	Total Rainfall	Duration	Recurrence Interval
Hurricane Connie (Aug 1955)	7.75"	40 hours	25-year
Hurricane Donna (Sep 1960)	7.9"	96 hours	20-year
Floyd (Sep 1999)	9.36" measured lower watershed 12" reported in upper watershed	20 hours	30-year

The influence of the rainfall on the stream flow was dramatic. In the months preceding the storm, the area had been experiencing mild drought conditions and stream flow was below normal for late summer. On the morning of the storm, the Batavia Kill stream gage in Ashland between the two demonstration sites was flowing at approximately two cubic feet per second (CFS). By 10:00pm, the stream discharge rose to just over 15,300 cfs and was covering the entire floodplain in the area of the demonstration sites. Both restoration sites are located within one river mile of each other, and the Ashland gage lies directly between the sites.

Flood Impacts on Channel Morphology

Immediately after the flood event, the GCSWCD conducted detailed surveys at the Maier Farm site, as well as a monitored control site just down stream (Kastansis). The control site is characterized by the same site conditions and instability problems as the Maier Farm site, and it provided an opportunity to measure erosion rates in the project reach against rates seen on an untreated control reach. The Maier Farm as-built surveys and a survey conducted in July 1999 on the control site were used for comparison to the post-flood surveys. The control site is the same Rosgen stream type (C4) and was characterized by similar BEHI values, soil types, riparian vegetation, and a similar drainage area **(Figure VII-21).**

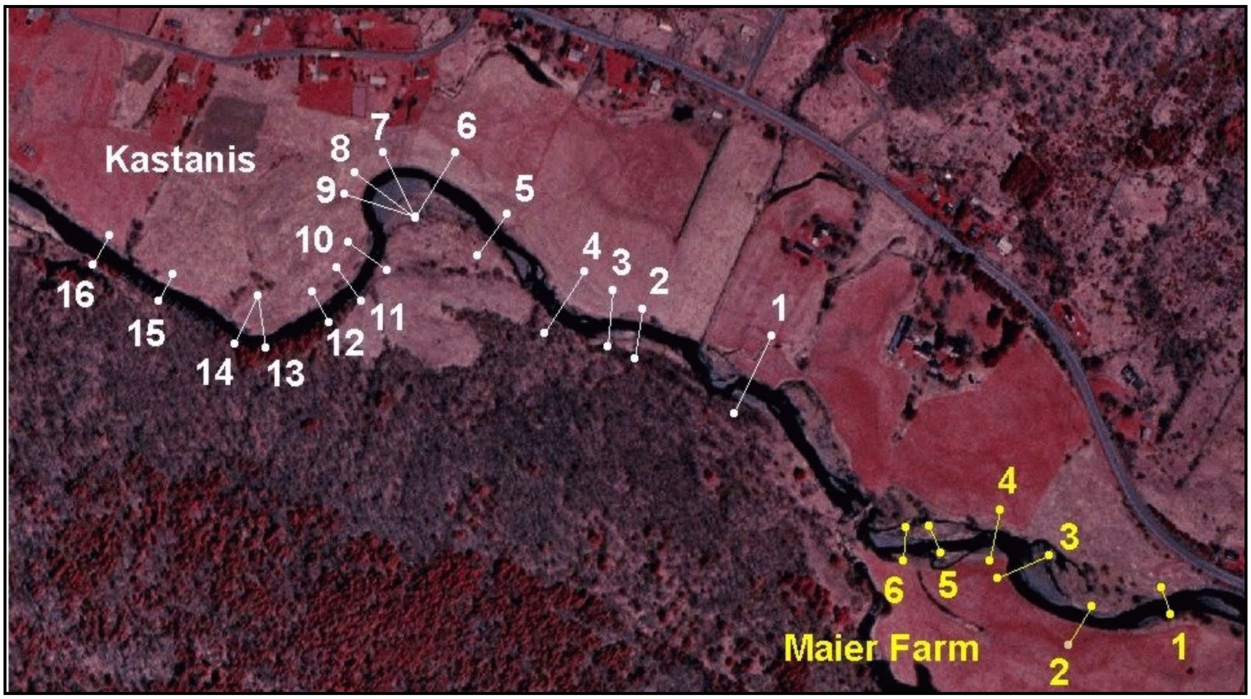

Figure VII-21: Location of monitoring cross sections on the Maier Farm project site and control reach.

The GCSWCD examined both riffle and pool cross sections, as well as the stream profile to determine the impact of the flood on the channel's morphology. Comparison of the pre- and post-flood cross sections at the Kastanis site, indicated that there was significant streambank erosion during the flood event. In most cases the area of erosional loss during the flood event equaled or exceeded the erosion occurring in the entire previous year under all runoff and flow conditions combined. In one location, lateral meander migration of 40 feet was measured on the Kastansis site.

Figure VII-22: Erosion on upper streambanks after tropical storm Floyd. The lower toe of bank remained unchanged.

When the Maier Farm project was examined, it was evident that the flood produced some erosion, but the measured rate was significantly less than the erosion rates measured at the Maier Farm site between 1997 and 1999. The flood event erosion rate was also significantly lower than the erosion at the Kastansis control reach. The highest lateral erosion rate measured post-flood was six feet, and this occurred primarily on the very uppermost streambank. While the outer meanders appeared to have significant erosion, the toe of the slope remained essentially unchanged, with no impact on channel planform.

In addition to examining erosional losses on cross sections, the GCSWCD also evaluated as-built and post-flood measurements of morphological features at the Maier Farm site and control reach. Changes in primary features such as bankfull area, width, and depth remained fairly consistent. The minor changes in these features did not appear to exceed change expected in a stable stream system. During Phase II of the Batavia Kill project, the GCSWCD and NYCDEP will be continuing performance monitoring to determine the rates of change in stable channel morphology. In the case of the Brandywine reach, the project exhibited a greater level of damage than the Maier Farm site but can be attributed to generally the same causes. A detailed analysis of the Brandywine site was not completed.

Impacts on Rock Structures

On both the Maier Farm and the Brandywine projects, a number of rock vanes and cross vanes were also damaged during the flood event. After the storm, it was noted that the depositional wedge upstream of the structures was lost due to voids between the top rocks and footer rocks that allowed sediment to pass through the structure. The absence of deposition was primarily noted in the middle of the vane, with the structure generally still keyed in on the upper end, and buried in sediment on the lowest area. The lack of large

Figure VII-23: Scour behind Cross Vane arm due to loss of depositional feature attributed to voids between vane rocks enough bed load material to plug the holes, combined with the excessive erosional forces experienced during the flood, resulted in the loss of the depositional feature and the inability of the vanes to effectively reduce shear stress against the streambank.

The second major contributing factor in rock structure damage was related to the lack of protection where the rock structures were keyed into the streambank. The rock vane and cross vane bank keys were constructed into the streambanks at an average linear distance of 12'. This key was designed in conjunction with the bioengineering to reduce scour and velocity around the back of the structure during over-bank flow. Without the protection of the bioengineering (live fascines, transplants, willow stakes and posts, sod mats, and conservation grasses), the 12' bank key became vulnerable to high velocities and shear stresses, causing scour around the structure.

Site Repairs

Immediately after the flood, the GCSWCD and NYCDEP evaluated each project and determined that the Maier Farm site could be immediately repaired. On that site, the damage to the rock structures was minimal, and the work could be done without de-watering the stream channel. In the case of the Brandywine project, repairs would require full de-watering of the channel.

[1] On damaged structures, additional rock was placed to strengthen the vanes and to chink the voids. Larger cobble (6"-18") was obtained from a local gravel bank and used to fill the voids and as fill in the upstream depositional area on each structure.

[2] On most structures, an extended floodplain sill was constructed for a distance of approximately twenty feet from the top of the vane. The sills were completely buried below the bankfull or flood plain level to eliminate future erosion around the head of the vanes.

[3] The top of the streambanks between the rock vanes was repaired using medium size stone as a toe for replacement fill, and by slightly lowering the slope on the upper bank, The material was compacted with an excavator bucket and prepared for planting of live fascines.

[4] Three large snags carried into the project reach were salvaged and used as root-wads. The root-wads were placed to provide additional protection in the high stress areas on the meanders, with new installations placed between the lowest rock vanes on the upper and middle meanders.

The repairs took approximately seven days and were limited by additional rain as well as the slower pace due to working under conditions where the channel was not de-watered. Repairs were limited to some extent by the need to use two excavators to “pass” rock and materials from one side of the stream to another. Total repair costs were approximately $35,000, including both equipment and materials.

Flood Damage Summary

While the previous section of this report addressed the negative impacts of the flood, it must be noted that there were also several positive observations. In summary:

[1] Even though the rock structures suffered from the lack of an adequate depositional wedge on the upstream slope, in the vast majority of cases the structures themselves weathered the flood intact even after facing the full force of the stream.

[2] On both sites, while some shifts in the channel alignment did occur, they were relatively minor and the overall meander geometry was maintained. The stream profile saw an insignificant change and for the most part the sites maintained their meander radius. This is significant considering that the sites had been subjected to extensive cuts and fills and there was for all practical purpose no vegetation present.

[3] On both sites, new depositional features provided a very strong validation that the bankfull elevation had been properly designed and constructed. When not influenced by a channel shift or debris, the deposition patterns were shallow or thin in nature and generally provided a very fine tuning of the flood plain or point bar surface. One interesting observation that was consistent on the Maier project was the stream's slight adjustment to steepen the lower 1/3 of the point bars where they transition to riffles.