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Mark McCarroll, 2003

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information available from the Greene County SWCD upon request

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PROJECT REPORT

Broadstreet Hollow Stream Restoration Demonstration Project

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Greene County Soil & Water Conservation District
Catskill Mountain Chapter Trout Unlimited
Ulster County Soil & Water Conservation District
US Army Corps. of Engineers
Project Landowners

For Additional Information

http://www.gcswcd.com/stream/broadstreet

Broadstreet Hollow Stream Restoration Demonstration Project Report

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1.0 Project Background

The Broadstreet Hollow stream, located in the Catskill Mountains, is a tributary to the Esopus Creek, and a contributing sub-basin to the Ashokan Reservoir. On January 19, 1996, the Catskills experienced a heavy mid-winter rain and unseasonably warm temperatures causing rapid snowmelt, extreme runoff, and extensive flooding. During the flood event, an isolated area of the Broadstreet Hollow stream experienced severe instability, resulting in over thirty feet of lateral erosion. The erosion caused structural damage to one home and threatened several other structures in the area.

The Natural Resources Conservation Service (NRCS), in partnership with the Town of Lexington, provided assistance under the Emergency Watershed Protection Program (EWP). The emergency project rebuilt the streambank, to the pre-flood position, using stream channel sediment, and provided stabilization of 475 feet of streambank using heavy rock riprap. During the EWP project, the contractor and town highway department experienced significant difficulties with clay deposits that had become exposed in the stream channel. The final cost of the stabilization project was $45,597.

The EWP measures resulted in a straightened, over-widened stream channel and hardening of the outside meander bend. Additionally, the emergency action resulted in the loss of streambed armor, as the coarse cobble and small boulder material was used to restore the eroded streambank. Removal of the streambed armor material exposed deep deposits of glacial, lacustrine clays in the valley floor. The stream channel became more susceptible to increased levels of instability due to the combination of bank hardening, loss of streambed cover and the increased channel slope. Between early 1996 and the fall of 1999, the stream reach experienced severe degradation, leading to the de-stabilization of the high slope adjacent to the channel. The slope experienced a rotational failure, causing mass wasting and a bulging mass of lacustrine clay in the stream channel.

In the fall of 1999, flood conditions associated with Tropical Storm Floyd further degraded the stream channel. Rapid incision of the channel, paired with saturation of the adjacent hillslope, accelerated the rotational failure of the adjoining slope. This resulted in the development of an artesian formation, which created a constant upwelling of highly turbid groundwater. The turbid condition prevailed during both low and high flow conditions, with the stream remaining turbid from the project site to the confluence with the Esopus Creek.

The project area required mitigative action, which focused on reach restoration, in order to balance multi-objective project benefits with the immediate threat to water quality and erosion. The Broadstreet Hollow Stream Restoration Project was initiated, and represents a cooperative effort between the Greene County Soil and Water Conservation District (GCSWCD), the Ulster County Soil and Water Conservation District (UCSWCD) and the New York City Department of Environmental Protection Stream Management Program (NYCDEP SMP).

In the sections that follow, the coordination, design, construction and monitoring components of the Broadstreet Hollow Stream Restoration Project will be described. It is the intent of this document to be a working report displaying the status and performance of the Broadstreet Hollow project as it progresses.

2.0 Project Location

The project site is located along 1,100 feet of the Broadstreet Hollow stream channel, adjacent to Broadstreet Hollow Road in the Town of Lexington, Greene County. Broadstreet Hollow Road is located approximately 2 miles west of Phonecia and 1/4 mile East of the NYC portal exit of the Shandaken Tunnel. The project reach is located between Jay Hand Hollow Road (entrance road to Camp Timberlake) and the next county bridge upstream along Broadstreet Hollow Road.

3.0 Reach Stability Assessment

The severe conditions of the instability generated an immediate priority for the mitigation of the site's water quality impacts and assessment of the stability. Numerous assessments of the reach's physical stability were performed by various project partners prior to mitigation. The following general reach characteristics were documented and are summarized as follows:

- The reach was experiencing substantial streambank and bed erosion. In 1999, the project reach was characterized as having 600 linear feet of eroded streambank. The majority of the lower streambank and streambed contained fine clay material, amplifying turbidity of the flows through the reach.

- In addition to the lateral migration experienced during the 1996 flood event, the stream channel also experienced degradation. The degradation process was compounded by grading activities during the emergency repairs, which removed the little remaining cobble armor on the channel bottom. The channel incision further exposed deep, highly erodible lacustrine clay deposits.

- The degradation of the channel continued between 1996 and 1998, causing the adjacent high bank in the middle of the project reach to experience a geotechnical slope failure. Monitoring of the site showed repeated sliding, with a deep seated rotational plane resulting in mass wasting and a bulging mass of lacustrine clay in the stream channel. The exposed clay in the rotational plane, and the failing streambanks presented a persistent water quality problem, due to a large supply of highly erodible colloidal soil materials.

- In September of 1999, Tropical Storm Floyd caused severe flooding and further down-cutting into lacustrine clays. An artesian formation appeared in the streambed creating a constant upwelling of highly turbid groundwater. A detailed geotechnical investigation was initiated which revealed a sand lens, approximately 4 - 5 inches thick, located under approximately 30 feet of glacial lacustrine clay. The artesian condition developed as the pressurized water in the sand lens pushed upwards through the clay material entraining clay particles. The formation amplified year round turbidity measurements taken in the stream channel, often averaging well over 60 NTU during base flow conditions.

- The evaluation of historic aerial photographs revealed substantial floodplain fill and straightening of the channel sometime after 1968. A pre-construction topographic survey of the project site and photographs taken after the January 1996 flood event were used to document the location of the eroded meander bend after the 1996 flood event. Historical aerial photographs were matched to the survey to document historical changes in the channel plan form. The assessment revealed that the stream channel had eroded over 27ft arresting approximately five feet from its pre-development location.

- Compounding the constraints affecting the project reach is the relatively steep and narrow watershed contributing to the reach. The watershed drainage area to the project site is approximately 5 mi^2 with an average valley slope of nearly 8%. The existing roadway, multiple bridge structures and adjacent homes also provide further confinement of the floodplain.

4.0 Restoration Project Goals and Objectives

As the GCSWCD and NYCDEP reviewed the condition of the reach, and its potential for restoration, numerous additional objectives were identified. Water quality was negatively affected by the existing site conditions. The partners proposed that restoration of the reach presented the opportunity to reduce this impact 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 existing turbidity and TSS related water quality impacts associated with: lateral and vertical erosion, impacts from the artesian formation, and rotational failure in the project area.***

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.

4.3 Project Constraints

During the planning process, project partners assisted in identifying numerous project constraints. These include, physical site constraints, landowner approval and access, data needs and limitations, and project permitting.

The project design needed to address channel stability and processes, and work within the existing physical site constraints. These physical constraints were manmade and natural, and were inventoried, and incorporated into the design. The pre-construction monitoring identified several distinct instabilities and associated problems through the project reach. Ultimately, the restoration design needed to correct channel plan form, profile and cross section parameters in order to meet the goals and objectives of the project and to provide for potential long-term channel stability.
The final project design needed to incorporate techniques for completing the project construction in areas containing large volumes of saturated lacustrine clay. Additional project constraints included the close proximity of the stream channel to the adjacent homes, which limited the style of construction and increased the staging time and costs of the project. Access to the project site was limited and would required the construction of several temporary access roads.

The acceptance of the project by the landowners had substantial bearing on the success of the restoration. Landowner approval and access to the project area was identified as a critical project constraint. The need for approval by multiple primary and secondary landowners within the project area generated the need to educate the owners about 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 into the project when practical. The provision of landowner approval was set forth in Landowner Project Agreements, which is a temporary agreement between the landowner allowing for the project construction, maintenance and monitoring.

The restoration of the Broadstreet Hollow site required permits to be issued by the Army Corps of Engineers (ACOE), the New York State Department of Environmental Conservation (NYSDEC), and the New York City Department of Environmental Protection (NYCDEP). The restoration project was authorized under Article 15 of ECL by the NYSDEC and Nationwide 27 by the ACOE.

5.0 Restoration Methodology and Strategy

Alternative strategies, that best reflected the project objectives, were evaluated to reach a common consensus between stakeholders and financial partners. The reach was highly unstable and it was believed that current channel processes would continue to impact the Broadstreet Hollow resource. To meet the numerous goals, set forth by 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. Through further refinement of goals, identification of project constraints and alternative analysis, the following strategy was developed for restoration:

- Develop a channel geometry and profile that will provide stability, maintain equilibrium (form), and maximize the stream's natural potential.

- Develop a new channel plan form which will result in a meander radius and geometry more consistent with a stable stream morphology, while reducing the existing threat to the adjacent structures.

- 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 clay material would reduce the potential for the future entrainment of clay particles.

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

- Construct the appropriate "geomorphic style" structures, to provide grade control consistent with the proposed stream channel, in order to mitigate degradation of the stream channel into the clay layer, re-establish a natural step-pool bed configuration, and provide for bank stability.

- Install multiple groundwater relief wells along the rotational failure in order to provide pressure relief to the artesian formation and assist in mitigating the upwelling of turbid groundwater.

- Re-establish an effective riparian buffer of trees, shrubs and deep rooted grasses.

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

In 1998, the GCSWCD initiated the development of a restoration design for the project reach. Topographical surveys were conducted by a licensed surveyor and supplemented with geomorphic assessments and surveys performed by the GCSWCD and NYCDEP. Reference reach data, from a site located approximately 1/4 mile upstream of the project reach, was collected for use in the project design. The reference reach was a B3a stream type, with the streambed characterized by well imbricated cobbles and boulders. The moderately steep channel was typical of a stable step-pool channel morphology within this particular valley setting, and provided pertinent data for application to the project reach.

The project design incorporated a number of data sources including the reference reach data, regime analysis and analytical methods. The data was documented and evaluated against the 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 Dave Rosgen and others, as well as published regional and provisional curves developed for the Catskills by the GCSWCD and NYCDEP. Analytical methods including HEC RAS modeling for flood flow analysis as well as various geotechnical stability models were utilized in the design process.

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.

The final design incorporated a channel cross section which would partially reduce stream entrenchment. This was accomplished partially, by re-elevating the channel profile to allow for re-connection with the adjoining floodplain, and by developing a multi-stage channel. The design cross section included a lower bankfull channel and a higher flood prone channel, which provided floodplain relief. HEC-RAS analysis was used to model flood flow to ensure that the restoration project would not further impact the residential structures during large flow events. The bankfull and floodplain dimensions were iterated using the model to provide for optimal flow conditions and effective sediment transport.

The channel alignment was created using regime and reference conditions paired with the analysis of historical aerial photography. The final plan form included modifications to account for valley slope, landform constraints, adjacent homes and the two existing bridge structures. Residential structures along the left bank and steep upland slopes on the right bank presented severe limitations to the available stream belt width through the project reach. Limited alternatives were available to mitigate the previous loss of channel sinuosity and resulting increase in slope. The final plan form included shifting the upper meander toward the west and slightly changing the radius of both meanders. Extensive effort was made to minimize disturbance, to the existing vegetation, caused by the meander adjustments. Table 1 summarizes average bankfull channel variables of the pre-restoration channel, reference reach and design channel.

Variables	Existing	Proposed Reach	Reference Reach
Stream Type	F3b	B3	B3a
Drainage Area (mi^2)	4.55	4.55	4.03
Bankfull Width (ft)	39.0	28.2	26.4
Bankfull Mean Depth (ft)	1.89	1.45	1.35
Width / Depth Ratio	21.0	19.5	19.5
Bankfull Cross Sectional Area (ft^2)	72.5	41.0	35.1
Bankfull Mean Velocity (ft/sec)	-----	5.0	5.2
Bankfull Discharge (cfs)	-----	205	177
Bankfull Maximum Depth (ft)	2.58	2.60	2.42
Width of Flood Prone Area	50.8	45.1	42.3

Entrenchment Ratio	1.3	1.6	1.6
Meander Length (ft)	733	733	698
Meander Length/Bankfull Width	18.7	26.0	26.5
Radius of Curvature (ft)	419, 280	310, 280	260
Radius of Curvature / Bankfull	10.7, 7.2	11, 9.9	9.9
Belt Width (ft)	134.6	161.0	150.5
Meander Width Ratio	3.5	4.9	5.7
Sinuosity	1.10	1.10	1.10
Valley slope	0.06	0.06	0.06
Average Slope	0.03	0.03	0.05

The channel profile was created by utilizing slope characteristics of the valley, stream channel and existing floodplain terraces. The channel slope was constrained, vertically through the reach, by clay layers that would be in close proximity to the channel invert. The profile design included consideration for channel sinousity, valley slope, channel dimension, sediment characteristics and flood conveyance. The design slope also considered the volume of cut and fill material, associated cost, and feasibility for construction.

The final design profile includes bed form variations typical of a step-pool morphology. The addition of cross vane structures provides an effective method to ensure profile stability while maintaining a step-pool morphology. Scour pools were created downstream of the cross vane structures in order to provide energy dissipation and to mimic the natural bed form characteristics. In total, thirteen cross vane structures were added through the project reach to provide grade control, to assist in providing lateral stability and to maintain a natural step-pool configuration for fisheries habitat.

5.2 Slope Failure & Artesian Formation

The rotational slope failure, occurring along the wooded area on the north bank of the project reach, was documented and surveyed by NYCDEP SMP staff and subsequently analyzed by Daniel G. Loucks, P.E., for incorporation into the project design.

- Soil borings revealed an upper layer of gravel and silt that extends between seven to nine feet in depth with a layered silt and clay layer extending an additional thirteen to thirty feet.

- A thin layer of clean sand was encountered between 26 and 30 feet.

- A single observation well was installed into the sand layer to monitor the groundwater levels. The level of the groundwater increased in the well to approximately 2.1 feet below the existing ground surface. This condition would presumably cause the artesian condition in the stream.

- A computer-aided stability analysis was used to analyze the failure slope and to assist in determining possible ways of improving the stability of the failure. Existing conditions verified a factor of safety less than 1.0.

The analysis indicated that the slope failure and resulting artesian formation were likely caused by excess water pressure that existed in the sand layer below the bottom of the stream. The water pressure would cause the sloping area to move toward the stream when the pressure increased and/or the stream bottom eroded enough to cause an instability on the slope.

In order to mitigate the effects of the rotational failure and the artesian formation several techniques were incorporated into the design and construction. The final design included re-grading the riparian area, along portions of the slope failure, in order to remove excess weight from the slide and to prepare the area for the installation of three groundwater relief wells. The relief wells were to be spaced along the failure and were to be installed 35' - 40' deep in order to relieve the pressure associated with the artesian condition below the streambed.

Construction of relief wells involved drilling a 14" diameter boring with a steel casing into which a 6" slotted PVC well point was placed. The casing was filled with a coarse gravel drainage envelope and then the casing was removed leaving the PVC well. The drainage envelope was capped with bentonite to maintain the artesian condition in the relief well. Each relief well included a solid PVC connecter pipe in order to allow the clear groundwater to gravity feed from the relief well into the adjacent stream channel.

5.3 Clay Materials

The project reach was characterized by extensive exposures of glacial clay material. 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 finish grade of the project design. The over-excavation of clay material would reduce the potential for the future entrainment of clay particles. The additional weight provided by the exchange in material would also assist with providing counterbalance to the rotational failure.

5.4 Riparian Vegetation

The project design includes the use of traditional bioengineering practices to provide for increased streambank stability and to initiate riparian vegetation growth in the disturbed areas. Over 1,000 feet of live willow fascines and over 200 willow stakes were incorporated through the project reach for installation along high stress streambank areas. Short term stabilization of the disturbed areas are seeded and hydro-mulched using a conservation seed mixture. Additional planting will be accomplished in the riparian areas as needed using various native trees and shrubs.

5.5 Special Considerations

The project design included relocating the stream channel closer, from 26ft. to 13ft., toward one of the homes on the lower portion of the project reach. A retaining wall was proposed for installation behind the residence and further evaluated by project engineers. It was determined that a lateral soil pressure between 20 and 40 psf per foot could be used for the retaining wall design, depending on backfill conditions. The resulting design included a stacked and pinned rock wall for installation behind the residence. The wall included large block shaped boulders stacked nearly vertical with steel pins drilled and inserted through the rock to join the wall. The addition of the stacked rock retaining wall would provide an economical alternative while providing adequate protection to the structure during high flow events.

6.0 Project Implementation

6.1 Project Bidding

A project bid package was developed to include drawings and specifications for the proposed project. The project was publically bid using a competitive bid process to select a contractor. Due to the relatively short time between the public bid and the proposed commencement of construction, as well as the extreme site conditions, only two bids were submitted for the project. The final accepted project bid is summarized in Table 2.

Table 2: Final Project Bid

Bid Item	Estimated Quantities	Contractor - Bid Price	
		Unit Bid Price	Total Price
Mobilization	----------	----------	$13,500.00
Clearing/Grubbing G	----------	----------	$6,500.00
De-watering	----------	----------	$25,000.00
S.C. Excavation	----------	----------	$7,500.00
Cross Vanes	1500 tons	$39.00	$58,500.00
Clay Removal	2000 yd^3	$20.00	$40,000.00
Coarse Gravel	3000 yd^3	$17.90	$53,700.00
Fine Gravel	2000 yd^3	$16.50	$33,000.00
Stacked Rip Rap (wall)	100 ft	$112.00	$11,200.00
Steel Pins	250	$30.00	$7,500.00
Live Fascines	1000 ft	$4.25	$4,250.00
Live Posts	200	$8.00	$1,600.00
Relief Wells	105 ft	$460.00	$48,300.00
		Total Bid Price	$310,550.00

6.2 Project Construction Time Line

Construction of the new stream channel and cross vane structures required approximately 45 calendar days. Project construction was initiated on September 15, 2000, beginning with channel excavation and relief well installation. Completion of the primary channel construction ended on October 31, 2000. Bioengineering components were initiated immediately following the channel reconstruction and continued into November of 2000.

6.3 Project 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 B along with photographs highlighting project construction in Appendix A.2 and A.3. A summary list of project construction details are provided below.

- A temporary access road was created along the right bank floodplain to allow for equipment to access and grade the area along the rotational failure. A temporary bridge was installed across the stream channel to allow for access by the drill rig to begin the installation of the three relief wells.

- The active work zone was de-watered by pumping all upstream flow around the work area. Due to the close proximity of homes around the project site, a two stage de-watering plan was required. Stream flow was pumped using a 10" submersible electric pump and piped through sealed pipeline through adjacent properties.

- Stream channel excavation began at the top of the project area and continued downstream. Over-excavated clay material was hauled from the project site, rock cross vanes were installed and fill material was added to re-grade the final channel bottom.
- The final project required the movement of over 8,000 cubic yards of material and the excavation and replacement of approximately 2,720 cubic yards of clay material from the streambed and streambanks. The excavated clay material was hauled to a safe, upland disposal area. The replacement material consisted of a coarse cobble/gravel material in the streambed and a finer bank-run material on the banks and flood prone areas.

- The saturated clay condition through the project area made construction extremely difficult and provided minimal stability for the equipment. Channel excavation and rock structure installation was accomplished primarily using excavators and working from construction mats made from large timbers.

- 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.

- The project included the installation of 13 rock cross vane structures utilizing approximately 940 tons of rock. Rock was obtained from a local quarry, and contained individual pieces hauled to the project site ranging from 2 -10 tons each.

- After the stream channel work was completed, a steel sheet pile wall was installed behind the residence on the lower portion of the reach. The sheet pile wall was substituted for the stacked rock wall after further investigations by the project engineer. It was determined that the structural foundation of the residence was not suitable for withstanding the necessary excavation near the home for the installation of the stacked wall.

- Final grade work was completed in the floodplain and the bioengineering was installed. The bioengineering included native willow fascines and stakes obtained from a local source. Conservation seed mix was used to provide temporary stabilization to the disturbed project areas. Live material transplants and bare root seedlings were installed in the floodplain areas.

6.4 Project Constructability

The project area encompassed two county bridges as well as several private structures in close proximity to the channel. Access to the project area through private property was necessary and permitted using landowner agreements, prior to the start of construction. The temporary access points were limited and provided minimal space for mobility and project staging, requiring the use of specific equipment for implementation.

Construction of the new channel and floodplain was performed, nearly completely, using excavators working from the upper banks. The excavators were required to have a hydraulic thumb apparatus capable of handling the boulders used for the construction of the cross vane structures. Further, the glacial clays presented a stability problem for construction equipment due to clay liquefying from the machine vibration. Timber construction matting was used to prevent the heavy equipment from sinking into the clay and rock structures were forced to be expeditiously installed in order to prevent further instability.

6.5 Project Construction Modifications

The initial project plans included the installation of a stacked rock retaining wall to protect a single residence located along the left bank of the project reach. The proposed stacked rock retaining wall was modified to a steel sheet pile wall after the determination that the house foundation was inadequate to withstand the necessary excavation. The detail was modified during construction after an initial inspection revealed the house was located on stacked block and did not rest on adequate footing.

6.6 Project Construction Cost

A summary of final project construction costs is included in Table 3.

Bid	Item Description	Final Quantity	Final Cost
1	Mobilization/Demobiliza	----------	$13,500.00
2	Clearing/Grubbing	----------	$6,500.00
3	De-watering	----------	$25,000.00
4	S.C. Excavation	----------	$7,500.00
5	Cross Vanes	938.56 tons @ $39/ton	$36,603.84
6	Clay Removal	2,718 yd^3 @ $20/$yd^3$	$54,360.00
7	Coarse Gravel	4,292 yd^3 @ $17.90/$yd^3$	$76,826.80
8	Fine Gravel	440 yd^3 @ $16.50/$yd^3$	$7,260.00
9	Sheet Pile	1998 ft^2 @ $28.50/$ft^2$	$56,943.00
10	Live Fascines	1000 ft @ $4.25/ft	$4,250.00
11	Live Posts	200 @ $8.00/post	$1,600.00
12	Relief Wells	123ft @ $460/ft	$56,580.00
		Total Contract Cost	**$346,923.64**
Change Orders (not including the substitution of steel sheet pil for stacked rock wall)			
CO1	Well Lid	replacement of well lid	$236.25
CO2	Water	provide water to shallow wells	$1,796.55
CO3	Sheet Pile Wall	excess rock drilling and bracing	$4,960.00
CO4	Waste Disposal	old fuel tank found during	$150.00
		Total Change Orders	**$7,142.80**
		Complete Project Total	**$354,066.44**

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, sheet pile wall, relief wells, 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. Specific project inspections and monitoring reports are summarized in Appendix F.

7.1 Project 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 NCD projects and treatments in the watershed. Specific project inspections and monitoring reports are summarized in Appendix F.

7.2 Fisheries Assessment

The USGS, in cooperation with the NYCDEP SMP and the GCSWCD, inventoried fish communities in stable, unstable, and control 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

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

Fishery surveys in the Broad Street Hollow Basin were completed before restoration of the unstable project (treatment) reach was done. Inventories were completed at project/treatment and reference reaches in the summer of 1999 and at all 3 reaches in 2000 and 2002. Preliminary findings from these surveys are summarized in Appendix E.

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 NCD 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 hydrological 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 the 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 Broadstreet Hollow Operation and Maintenance Plan is included, in draft form, in Appendix C.

A management plan and strategy is currently being developed for the Broadstreet Hollow watershed by the NYCDEP SMP and the Ulster County SWCD. The plan will provide a working document to assist with resource management in the watershed, which will ultimately assist in the operation and maintenance of the project reach.

A Landowner Guide for the adjacent property owners is included in Appendix D. The focus of the Landowners Guide is to support and educate the landowners around the project area regarding the physical components of the stream channel, floodplain, and project vegetation. Additionally, the Landowner Guide incorporates distinct actions the landowners will need to follow in order to maximize the benefits from the restored project reach. These actions include, defining the roles of the project stakeholders, techniques for managing riparian vegetation, accessing the stream, modification of the plan, general advice, as well as project contacts and general information.

8.1 Rock Structures

In stream rock structures may require some modification and enhancement. This is detailed in the Operation and Maintenance Plan for the site, which addresses the replacement of rocks to ensure structural integrity, intended functions of the vanes, and debris and sediment maintenance considerations. The Operation and Maintenance Plan also outlines the modification and repair, as well as monitoring schemes.

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 the Operation and Maintenance Plan and the Landowners Guide found in the attached appendices **(*See also BSH SMP Volume 2).**

Appendix A

Photographs and Descriptions (photos to be added, available from District on request)

A.1 Pre-construction 1996 - 2000

A.2 Project Construction 2000

A.3 Project Construction 2000

A.4 Completed Project Construction 2000

A.5 Flood Event: December 2000

A.6 Post Flood Inspections: 2000 - 2001

A.7 Project Repair & Maintenance - 2001

A.8 Project Inspection - October 2002

A.1 Pre-construction 1996-2000

Photograph 1: Structural and property damage at the Torregrossa residence resulting from the 1996 flood event.

Photograph 2: Structural and property damage at the Torregrossa residence resulting from the 1996 flood event. The close proximity of the residential structures along the left floodplain are prone to future threat by erosion and bank failure caused by the channel instability.

Photograph 3: Channel degradation occurring through glacial clay at the base of the adjacent rotational failure. The rotational failure is denoted by the erosion and angled vegetation along the left portion of the photograph, as well as the bulging formation of clay in the center of the stream channel. The artesian formation is present in the right portion of the image contributing high turbidity during low flow periods.

Photograph 4: The EWP stabilization utilized natural channel armor (boulder & cobble) material for fill to replace the eroded streambank which exposed the underlying glacial clay. Extreme difficulty resulted in the completion of EWP construction and the instability of the channel increased.

Photograph 5: 1999 aerial photograph showing the extreme turbidity produced from the from the artesian formation during base flow conditions. The rotational bank failure is present in the left of the photograph.

Photograph 6: The artesian formation producing highly turbid flow during base flow conditions.

A.2 Project Construction 2000

Photograph 7: Drilling the first of three artesian relief wells designed to alleviate groundwater pressure. Substantial vegetation and earth was removed from the area prior to the well installation in order to provide access for the drill rig, as well as remove weight from the rotational failure.

Photograph 8: De-watering of the construction area was achieved using a 10" submersible electric pump located behind an inflatable water barrier. Stream flow was pumped through adjacent properties in two stages, using a sealed pipeline.

Photograph 9: Excavators were used as the primary equipment for completing the rough grading of the channel due the relatively narrow floodplain. Excavators worked primarily from construction mats due to the underlying clay material liquefying from the vibration of the equipment.

Photograph 10: Large quarry rock is delivered to the project site for use in the construction of the rock cross vanes. Layout of the project design was accomplished using survey equipment to stake out channel grades and rock structures.

Photograph 11: Over-excavated clay is removed from the channel bottom, while the excavator worked from construction mats. The construction of the stream channel and structures through the project reach was extremely difficult due to the limited site access, proximity of nearby homes, and clay content.

Photograph 12: Installation of a horizontal drain pipe into the adjoining relief well in order to reduce groundwater pressure. The horizontal drain pipes for each well were discharged through the arm of a nearby cross vane for aesthetic considerations and to provide cold water release into downstream scour pools.

A.3 Project Construction 2000

Photograph 13: Construction of rock cross vanes in the over-excavated channel bottom.

Photograph 14: Earthen coffer dams were used throughout the de-watered project reach to prevent turbid ground water and rain water from entering the construction areas.

Photograph 15: Wooden construction mats were used to provide a stable base for the heavy equipment to work from. Water is pumped from the excavation area while over-excavating clay material.

Photograph 16: The presence of lacustrine clay made construction extremely difficult. Clay was removed from the channel bottom and replaced with cobble/gravel mix to provide stability to the constructed channel bottom and reduce the stream contact.

Photograph 17: A steel sheet pile wall was installed along a 90 ft section of the channel to protect an adjacent home from future flood damage. The steel sheet pile wall was substituted for a stacked rock wall after the stability of the homes foundation was assessed and found to be unstable.

Photograph 18:	Completed rock cross vanes before the final channel grading and scour pools were finished.

A.4 Completed Project Construction 2000

Photograph 19:	Floodplain excavation and grading was completed using excavators after the installation of the rock structures and grading of the channel bottom.
Photograph 20:	A mixture of cobble and gravel was used to replace the over-excavated clay material and raise the streambed to final grade. Finer material was imported to re-build sections of the floodplain.
Photograph 21:	Floodplain excavation and grading was completed using excavators after the stream had been released into the constructed channel.

Photograph 22: The completed stream channel and floodplain was hydroseeded using a conservation mix and cellulose fiber mulch.

Photograph 23: Initial bioengineering was installed to include willow fascines. Fascines were placed along both streambanks and bankfull benches.

Photograph 24: The photograph represents the newly re-vegetated channel looking downstream through the lower portion of the construction area. The completed sheet pile wall can also be seen along the left streambank.

A.5 Flood Event: December 2000

Photograph 25: Cross Vane #1 actively re-directing stream flow during the December 17, 2000 flood event. This section of channel is located in the upper project area taken from the upper bridge looking downstream.

Photograph 26: The stream flow appears slightly above bankfull stage, between the second and third cross vanes. The constructed bankfull bench along the left bank is slightly underwater with stakes used in the fascine installation are noted in the center of the photograph.

Photograph 27: The extreme energy of the flood flow is displayed as well as the cross vanes effectiveness at dissipating energy and focusing flow toward the center of the channel.

Photograph 28: The image displays same cross vane in Photo 27 looking downstream through the reach.

Photograph 29: Flood flow through the area of the project reach where the erosion and damage from the January 1996 flood event occurred. Displayed is the proximity of the homes to flood flow are noted near the center of the photograph is the sheet pile wall nearly inundated.

Photograph 30: The image displays the bottom of the site looking upstream from the Timber Lake Bridge.

A.6 Post-Flood Inspections: 2000 - 2001

Photograph 31: The image displays the channel condition looking upstream through the project reach the day after the December 17th flood event. Minor erosion was noted through this portion of the reach and two cross vanes were noted with structural damage.

Photograph 32: The photograph shows the channel condition looking downstream from the same point as photo 31. Vegetation had not been established through the project reach before the flood event.

Photograph 33: Spring photograph taken prior to the development of vegetation. Note the comparison in water clarity to the pre-construction photographs.

Photograph 34: The image displays the channel from the uppermost bridge looking downstream in April of 2001. Cross vane structures appear to be functioning properly despite several problems caused by the December 2000 flood event.

Photograph 35: The image displays some minor bank scour near station 3+50 resulting from the flood event. The erosion is attributed to large voids which were located between the top rocks and footer rocks of the cross vane prohibiting deposition which should occur in this area.

Photograph 36: The image displays the void created at cross vane #1 from the undermining of the structures footer rock during the flood event. The depth of the scour hole behind the structure exceeded the placement depth of the footer rocks, causing rocks within the structure to shift.

A.7 Project Repair & Maintenance: 2001

Photograph 37: Repair and maintenance was made to the project in October 2002. The stream channel was de-watered and repairs were made to the structures show in the photograph.

Photograph 38: Excavators were used from the top of the streambank to make repairs and modifications. The area receiving the most damage during the flood event is shown in the photograph.

Photograph 39: Repair work to cross vane was completed by resetting several of the top rocks and filling the voids between the top rocks and footers. Additionally, coarser boulder material was placed below the scour pool to roughen the stream bed and provide additional stability.

Photograph 40: Cross vane #1 after the completion of repair and modifications.

Photograph 41: Cross vane #5 prior to the repair and modifications. Noted on the right of the photograph is a large boulder dislodged from the upstream cross vane and transported during the flood event.

Photograph 42: De-watering for project repair and modification was accomplished using a 10" submersible pump and sealed pipeline.

A.8 Project Inspection October 2002

Photograph 43: Cross vane #1, taken from the upper bridge during a storm event in October, 2002. Note the change in water clarity from the pre-construction photographs.

Photograph 44: Repaired cross vanes structures functioning during a moderate flow event on October 12, 2002. This area received the most damage in the December 2000 event and a majority repair work in 2001. Apparent is the continued vegetative growth and properly functioning structures.

Photograph 45: The image shows the middle and lower portion of the project reach through the area where the artesian formation existed.

Photograph 46: After the recession of the October 12, 2002 flow, cross section #1 appears to be functioning properly during normal flow. (Reference image #43)

Photograph 47: After the recession of the October 12, 2002 flow, the middle and lower portion of the project appears to be functioning properly during normal flow. (Reference image #45)

Photograph 48: The lower portion of the project appears to be functioning properly under normal flow conditions.

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Broadstreet Hollow Stream Restoration Project
Pre-Construction 1996 - 2000

Broadstreet Hollow Stream Restoration Project
Project Construction 2000


Broadstreet Hollow Stream Restoration Project
Project Construction 2000

Broadstreet Hollow Stream Restoration Project
Completed Project Construction 2000

Broadstreet Hollow Stream Restoration Project
Flood Event: December 2000

December 18, 2000

December 18, 2000

April 12, 2001

April 12, 2001

Broadstreet Hollow Stream Restoration Project
Post Flood Inspections: 2000 - 2001



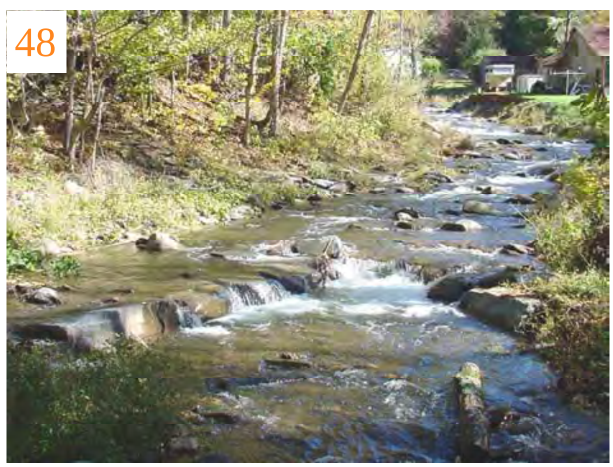



Broadstreet Hollow Stream Restoration Project
Project Repair & Maintenance 2001

October 12, 2002

October 12, 2002





October 14, 2002

October 14, 2002

Broadstreet Hollow Stream Restoration Project
Project Inspection—October 2002