Maier Farm Restoration Project
- Batavia Kill -

Implementation & Monitoring Report

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Town of Ashland, Greene County, NY

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Maier Farm Restoration Project

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

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1.0 Project Background

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

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

1.1 Batavia Kill Pilot Project Goals and Objectives

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

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

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

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

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

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

1.2 Maier Farm Restoration Project

Three demonstration projects were initiated during the first phase of the Batavia Kill Pilot Project.

The restoration of the Maier Farm project reach is the first large scale effort implemented in the Batavia Kill stream corridor. The Maier Farm Stream Restoration Project is located in the center of the Batavia Kill mainstem, in the Town of Ashland (Appendix A). The project reach is located approximately 1,500ft. downstream of the County Route 17 bridge crossing and runs west, parallel with State Route 23, ending at the private bridge crossing located on the Maier property.

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

2.0 Watershed Setting

The Batavia Kill watershed is a 72 square mile sub-basin of the Schoharie drainage. The Maier Farm project reach has the flattest valley slope of the drainage system, at 0.3%. This reach of the Batavia Kill, having multiple river terraces positioned laterally along a broad alluvial valley, is classified as a valley type VII. Alluvial terraces and floodplains are the predominant depositional landforms occurring along this reach. The valley is very broad with extensive belt width available for stream channel migration. Historically, the stream channel alignment has been heavily manipulated, resulting in the current irregular and distorted meander pattern. Management of the watershed, including alignment modifications, have resulted in numerous channel responses including over-widened channels, rapid lateral migration and impacted habitat through the valley segment.

Field assessments, coupled with the analysis of aerial photography, were used to characterize stability and inventory historic stream response through the Maier Farm reach. An initial stream corridor inventory and assessment in 1997 included an erosion inventory to prioritize reaches for future monitoring efforts. From these assessments, It was determined that the stream segment encompassing the Maier Farm project area, had the highest level of erosion, per unit stream length, in comparison to the five other corridor segments. More than 45% of this segment's streambanks were experiencing active erosion and bank failure, averaging more than $4ft^2$ of exposure on streambanks for every foot of stream length. These soils were being lost to both hydraulic and geotechnical streambank failures, or a combination of both.

The predominant soil type found in the reaches streambanks is gravelly loam. Typically, this soil is a deep stratified soil found on the sides of terraces and convex portions of outwash plains. These soils are loose in structure with little rock content, corresponding to a high susceptibility to erosion and entrainment of the reaches streambanks. Review of the soil characteristics of the segment determined the corridor was highly susceptible to accelerated bank erosion due to the thick unconsolidated layers of glacial soils. The composition of the streambank material and soil structure, within this segment, are generally finer than the channel pavement material. Further, the assessment in 1997 inventoried lacustrine clays in the bottom of pool features in several areas. Erosion of the clays impact water quality, which is a primary concern for project partners.

Riparian buffers are crucial in maintaining stream stability within stream type and valley setting. The review of aerial photography and field investigation determined that the riparian buffer provided minimal streambank protection throughout the segment. The existing riparian vegetation primarily consisted grasses along the top of the streambank, with sparse areas of shrubs and deciduous trees. The invasive species Japanese knotweed (Polygonum cuspidatum) heavily colonized the entire segment and appeared to be actively progressing through the low lying floodplain areas. It is believed that the dominant characteristics of the knotweed severely limits the reestablishment of native plant species, essential for an effective riparian buffer.

Anthropogenic impacts have contributed to the degradation of riparian areas and flow regime in the stream channel. Historically, the land directly adjacent to the channel has been used for agriculture. Cultivation by farmers to the edge of the streambank has had the greatest impact on riparian areas. The riparian buffer has been left extremely thin and heavily fragmented through the segment. The lack of a mature riparian buffer is the primary cause of streambank instability within the segment. Further, the construction of three flood control structures within the last 30 years has modified the natural water and sediment regimes through the segment. These structures have caused increases in flow duration and available energy that impacts the streambanks and channel bottom. These structures also retain sediment which prevents sediment transport to downstream reaches and subsequently has impacted channel morphology downstream.

In summary, these watershed and corridor modifications are the likely cause for the increase of natural streambank erosion rates through the segment. Historic management, flood events and associated mitigative work had left this section of the Batavia Kill highly susceptible to increased environmental degradation from reduced stream stability.

3.0 Reach Stability Assessment

The Maier Farm reach receives flow from a 52mi^2 drainage area, which is partially regulated by three flood control structures located within the upper watershed. The Maier Farm project reach encompasses more than 1600 feet of stream channel and included approximately 640 feet of actively eroding streambank. The exposures within the project reach corresponded to 4.8 square feet of eroded streambank, for every foot of stream channel. Based on these findings, it was determined that the Maier Farm reach was a priority site for comprehensive monitoring, assessment and restoration. The following sections further summarize the state of the reach before restoration.

3.1 Existing Channel Morphology

Field assessment and monitoring of the Maier Farm reach began in 1997 and continues presently. The site has undergone Phase I-IV assessments which included several monitored cross sections, a monitored longitudinal profile, inventories of channel and point bar substrate as well as a number of stability analyses. These measures were monitored annually before construction and used in the evaluation of the reach. The location of the preconstruction monitoring cross sections and corresponding data are displayed in Appendix A. A topographic survey, covering an area of approximately 17 acres, was completed for the entire site in March of 1998.

An initial assessment of historic aerials surrounding the reach, indicated accelerated lateral migration of the lower meander bends, and a relatively stable plan form in the upper meander bend (Figure 1). In more recent aerial photography, localized channel braiding was present in the area immediately upstream of the bridge. Several relic channels were inventoried, indicating the dynamic nature of the reach historically. The meander bend along the upstream portion of the project had been stabilized in the past using riprap to protect the streambank along State Highway 23. It is surmised that the riprap influenced the accelerated migration occurring downstream, by redirecting forces to the downstream area. Further, the change in density and structure of riparian corridor along the channel, evident from the photography also influenced the instability of the

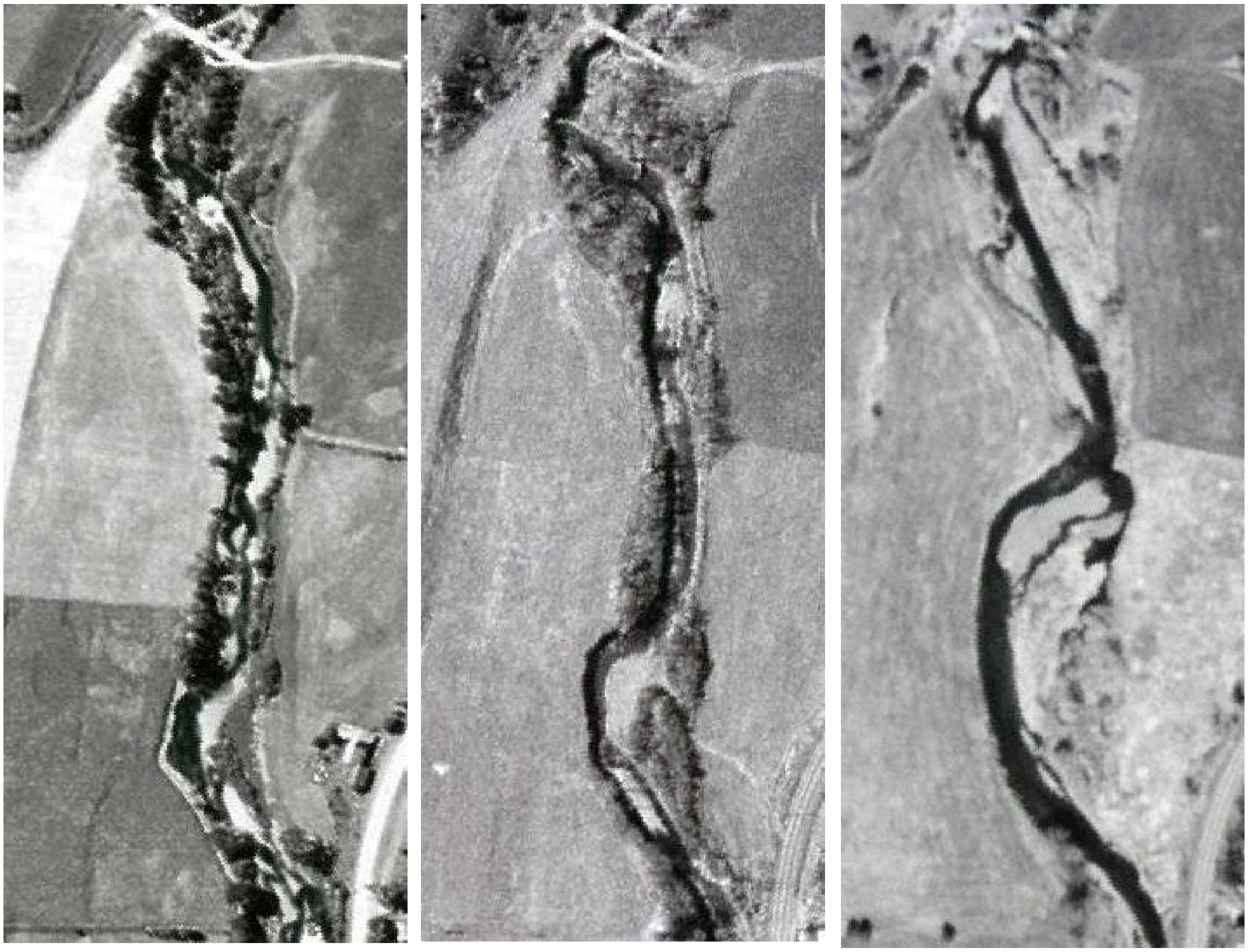


Figure 1: Aerial photograph displaying progression of Maier Farm Reach, left to right; 1959, 1980, and 1995. The direction of stream flow is from the top of the photograph to the bottom.

reach.

A private, concrete, double cell bridge, is located at the bottom of the reach. The structure had suffered extensive damages, presumably caused by debris blockages, abutment scour, channel migration and weathering. Horizontal and vertical cracks, several inches in width, were present along the abutments. A large debris blockage in the left cell and severe scour present through the right cell were noted during the initial stream assessment. The position of the structure and relatively small size of the hydraulic opening presumably compounded the instabilities of the reach.

A Phase II assessment of the reach began in 1997 with data collection concentrated in the lower half of the reach. Two monumented cross sections were installed with over 1,700 feet of longitudinal profile. The reach was classified as a C4 stream type with coarse gravel dominating the channel sediment size. The width/depth ratio increased from 17, in the upper portion of the reach, to 130 where the channel contained localized braiding upstream of the bridge. The streambanks ranged in height from 6 to 12 feet above the channel bottom.

Phase III-IV monitoring in the lower section of the Maier Farm reach continued through 1999. The first cross section documented 32ft^2 of lateral erosion between 1997 and 1999. The second cross section was located in an isolated section of braided channel, upstream of the private bridge. Channel changes monitored at the second cross section included deposition within the secondary channels and 1.7 feet of incision in the primary channel.

3.2 Soils and Geology

In the summer of 1998, a project was initiated to inventory and map clay exposures in the Batavia Kill corridor, in partnership with NYCDEP. The geologic mapping through the Maier Farm reach found glacial lacustrine clay in the bottom of several pool features. The presence of lacustrine clay denotes a thin layer of armoring sediment and susceptibility to scour and resultant water quality impairment. Additionally, the stratigraphic column of the eroding streambank was inventoried which included three distinct layers. The upper horizon consisted of 2 foot thick layer of sandy clay loam over a 1.2 foot horizon of small gravel material. The base material and channel bottom consisted of unconsolidated till.

3.3 Riparian Vegetation

The riparian vegetation through the Maier Farm reach primarily consisted of maintained hay fields through the majority of the reach, with very low density deciduous cover in the upper section of the reach. The thin riparian area was severely limited by the agricultural practices in the adjacent fields, as shown in the 1959 aerial photograph (Figure 1). By 1999, riparian buffer width had decreased, and was heavily colonized with Japanese knotweed.

4.0 Project Goals and Objectives

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

4.1 Primary Goal

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

> ***To mitigate excessive turbidity and total suspended solids impact on water quality by addressing excessive lateral erosion.***

4.2 Secondary Objectives and Benefits

- Provide long term channel stabilization, to reduce property damage and 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. The physical constraints included manmade and natural limitations which were inventoried, and incorporated into the final 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 historic bridge located at the downstream extent of the project reach presented a unique set of design considerations and constraints including:

- The bridge structure existed in extremely poor physical condition and had extensive structural damage. Horizontal and vertical cracks, several inches in width, were present along both abutments and the center pier. Extreme scour was noted through the entire right bridge opening exposing the original timbers used as the footing for the bridge. Severe scour was noted along and under both abutments as well as the center pier.

- Historical photographs of the bridge showed the wing-walls as being nearly 100 foot in length and being connected to form a baffled grade control structure which spanned the entire active channel. The existing wing-walls were severely damaged, with large sections missing. The channel was beginning to actively erode the material behind the wing-walls and migrate around the bridge structure.

- The structure appeared to limit stream flow and sediment transport through both hydraulic openings during a wide range of stream flow. The two bridge openings were less then 30 feet wide each. The center pier was more than 40 feet wide, accounting for nearly half of the width, located between the two abutments.

- The bridge openings were prone to debris jams and blockages due to their relative position and width. The stream channel upstream of the bridge structure widened considerably before the flow converged through the openings. This allowed sediment and debris to accumulate upstream of the structure.

- The hydraulic opening of the structure appeared inadequate to pass flood flow without creating extensive backwater. Sediment deposition, as well as resultant channel over-widening and braiding were present upstream of bridge. Lateral migration was prevalent through the area and was exacerbated in areas where the upstream wing-walls were damaged and/or missing.

Although the bridge was privately owned and provided a primary means of crossing the Batavia Kill, it did not provide access to the homes or ancillary structures. Several design alternatives were presented to the project partners and the project landowners regarding the bridge structure. Potential alternatives included the complete removal of the bridge structure, structural restoration, complete replacement, as well as no modification to the existing bridge.

Due to limitations on the funding applicability, alternatives for repair or replacement were not advanced. Meetings were initiated with the project landowners to discuss the alternative of complete removal of the structure. It was contended that the bridge continued to provide access to the majority of the landowners property and would need to be left intact. The existing damage as well as the potential threat was reviewed with the landowner. The final restoration design would need to adjust the stream dimensions to provide for the optimum transport of flow and sediment through the bridge based upon the existing state.

The final project design needed to incorporate additional techniques for completing the project construction through isolated areas containing lacustrine clay as well as accounting for vast areas of riparian vegetation consisting primarily of Japanese knotweed (Polygonum cuspidatum) and its potential for further dispersal.

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 using Landowner Project Agreements, which is a temporary agreement between the landowner allowing for the project construction, maintenance and monitoring.

The restoration of the Maier Farm 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).

5.0 Restoration Methodology and Strategy

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

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

- Develop a new channel plan form which will result in a meander geometry more consistent with the available valley features, while reducing the threat to the existing bridge structure.

- Reduce and/or avoid future impacts to the bridge structure.

- Create a single low flow channel through one of the existing bridge openings and use the second bridge opening during higher flow events. Create a high flow bypass channel through the adjacent field around the bridge to reduce the backwater created by the bridge.

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

- Maintain and/or increase the availability of the stream channel to utilize the active floodplain, during flow events which meet or exceed bankfull stage.

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

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

- Create a single defined channel through the braided area, capable of transporting a range a flow and provide for increased sediment transport.

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

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

In 1997, the GCSWCD initiated the development of a restoration design for the project reach. A topographic survey was conducted and supplemented with geomorphic assessments and monitoring surveys. Since a typical stable reference reach for the appropriate stream type could not be found, it was determined that the assessment and design would utilize data collected from adjacent stream reaches and aerial photography would be supplemented with typical reference values developed by other sources, regime analysis and analytical methods.

5.1 Channel Morphology

The dimensions and scale of the proposed stream channel were designed to accommodate full range of flows and to meet considerations for sediment transport and channel boundary conditions. Regime and tractive force analyses and other analytical tools were utilized in order to develop an appropriate reconfiguration. Unlike traditional channel sizing, the design channel continually transforms between channel features, which change in shape, length and spacing as the channel meanders through the one mile reach.

After reviewing the historic trends of channel migration, it was determined that the channel was expanding its available belt width and increasing overall sinuosity by laterally eroding the streambanks within the reach. The goal for the channel realignment was to develop a stable plan form, in order to accelerate the channels evolution toward a more stable form. The final design included the partial realignment of 1700 feet of stream channel. The channel alignment was created using regime and reference conditions paired with the analysis of historical aerial photography. Modifications to the proposed plan form were made to provide the best applicable alignment through the bridge structure. The plan form dimensions were carried upstream from the bridge to a point above the project where the new geometry could be matched into the existing conditions. The slight increase in channel meandering would provide for a reduction in local channel slope and allow for better local floodplain interaction near the bridge structure. The cut and fill quantities (cost) and feasibility of construction were also considered during the design for realignment.

The channel profile was created by utilizing slope characteristics of the valley, the existing channel and floodplain terraces as well as regime and reference conditions. The channel profile was constrained vertically through the reach by underlying glacial clay layers that existed in close proximity to the channel invert, requiring over-excavation in several pool areas. The channel profile was also designed to provide for bed feature variation, simulating a more natural riffle/pool complex, in order to provide for increased channel habitat and energy dissipation. These variations are common in natural riffle-pool complexes. The channel profile was enhanced using grade control devices in order to promote natural erosion and deposition characteristics through the reach.

The cross sectional dimensions of the channel were altered to promote proper sediment and flow transport through the reach during a range of flow events. A multi-staged channel was created through the reach in order to provide for a defined bankfull channel, physical habitat during low flow, and increased floodplain function for large flow events. Improving the width-depth dimensions through the over-widened sections, and creating a single channel in the braided area of the reach provide for more efficient sediment conveyance. Further, the channel dimensions of the base flow channel were enhanced by the creation of pools at the outside of meanders and behind in-stream structures throughout the entire reach.

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

Table 1: Comparison of average morphological values.

Variables	Existing Channel	Reference Section	Proposed
Stream Type (Reach)	C4/D4	C4	C4
Bankfull Width (ft.)	68.7/175.2	60.6	61.3
Bankfull Mean Depth (ft.)	4.0/1.4	3.8	3.83
Width/Depth Ratio	17/130	16	16
Bankfull Cross Sectional Area (sq. ft.)	274/236	232	235
Bankfull Maximum Depth (ft.)	6.8/3.5	6.10	6.08
Width of Flood Prone Area (ft.)	>230	>135	196.8 /201.9
Entrenchment Ratio	2.9/1.3	2.2	>2.2
Sediment D50 (mm)	29	40	35
Sediment D84 (mm)	80	230	120
Sinuosity	1.25	1.10	1.25
Average Water Surface Slope (ft./ft.)	0.002	0.002	0.002

5.2 In-stream Structures

The design incorporated four general types of in-stream structures to promote channel stabilization. A combination of rock vanes, cross vanes and root wads were used to achieve multiple benefits including channel grade control, streambank stabilization, improved physical habitat, efficiency of sediment conveyance, dissipation of excess channel energy and maintain bed form variation.

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

Root wads were incorporated into the project primarily for habitat enhancement and to provide increased bank stabilization in high stress areas. Available root wads were to be used in combination with rock vane structures. Large trees remaining from previous flood events and trees obtained during the clearing and grubbing of the project area were used to construct the root wads.

A w-weir was included in the final restoration design to provide for flow alignment through the double cell bridge at the bottom of the reach. The weir inverts were set at two separate elevations in order to concentrate the base flow through the left bridge cell and provide flow relief through the right bridge cell during higher flows. The left bridge cell was selected as the primary channel due to improved structural condition. The w-weir structure spanned the entire width of the channel between the upstream wing-walls, in order to assist in redirecting velocity away from the bridge abutments and center pier toward the center of the bridge openings. The placement of the w-weir was moved upstream of the bridge opening to prevent the scour pools generated by the structure from undermining the bridge.

5.3 Riparian Vegetation

The project design planned for the use of traditional bioengineering practices to provide increased streambank stability and to initiate riparian vegetation growth in disturbed areas. Live fascines, native sod mats, and large willow transplants were combined with the installation of live stakes, posts, and bare root transplants. The design proposed installation of more than 3,350 feet of live fascines, installed in a double row, on the outside of all meander bends and high stress areas. Locally harvested willow and alder species provided materials for the bioengineering efforts. A seed and mulch mixture were used to provide short term stabilization of disturbed areas.

The design proposed the placement of large transplanted willow clumps along significant areas of potential high stress (i.e. along bank keys where rock structures tie into the streambank). Secondary benefits of the transplants included accelerated re-vegetation and channel shading. The willow clumps were harvested from an on-site borrow area, located along the western side of the of the project.

Native sod mats were used in the design, and placed along the top of the streambanks, to accelerate streambank re-vegetation. Additionally sod mats were used to reduce sediment runoff from construction activities in the floodplain to the channel until complete ground cover was established. Upon completion of bioengineering applications a conservation seed and mulch was applied to the entire project area.

A substantial effort was put forth to mechanically remove the existing knotweed stands and to minimize the disturbance to the existing native floodplain vegetation. Areas containing knotweed were excavated below the rooting depth, collected, and disposed of in deep trenches excavated throughout the project site.

5.4 Clay Material

The project reach contained isolated exposures of glacial clay material located in existing scour areas. To mitigate the water quality impacts of the clay, 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 a minimum of three feet of clay material, below the finished grade of the project design. Excavated clay material was disposed in designated areas located in the adjacent floodplain away from the active channel.

5.5 Fill Material

Fill material was required through sections of the project reach in order to facilitate the project design and reduce the average channel width. The original estimates required approximately 4000yds^3 of fill material. The acquisition and transport of this quantity of material from off-site sources would be relatively expensive, therefore on-site sources were included within the project planning and design.

Two plans were proposed to generate additional fill material. The first plan included excavating material from an existing adjacent floodplain terrace. The material removed from the terrace would be suitable for fill within the project area and would increase the available floodplain across from the residence. The second plan included installing a pond on the upper terrace along the left floodplain. The pond situated adjoining an existing wetland would provide additional habitat. After meeting with the project landowner and discussing the options, the landowner chose the second plan. Three test pits were excavated surrounding the pond area to a depth of 9ft. The material stratification was logged and used for generating borrow material volumes.

6.0 Project Implementation

The restoration project was authorized by NYSDEC under Article 15 of ECL, and approved by the USACOE pursuant to Section 404 of the Clean Water Act, in August of 1998. A Stormwater Pollution Prevention Plan was submitted to the New York City Department of Environmental Protection and accepted in July of 1998. Due to the probability of high water and inclement weather at the time of anticipated construction, project construction was postponed until the summer of 1999. Permit extensions were granted by all reviewing agencies.

6.1 Project Bidding

A project bid package was developed to include drawings and specifications for the proposed project. The project was publically bid in July of 1999 using a competitive bid process. A mandatory site showing was attended by several contractors, and three bids were submitted for the construction. The final accepted project bid is summarized in Table 2.

6.2 Project Construction Time Line

Project construction was initiated on July 15, 1999, beginning with clearing/grubbing and dewatering. Construction of the new stream channel and in-stream structures required approximately 21 calendar days. Bioengineering components were initiated immediately following the channel reconstruction and continued until the middle of August.

Table 2: Final Project Bid

Bid Item	Estimated Quantities	Contractor - Bid Price.	
		Unit Bid Price	Total Price
Mobilization	----------	----------	$10,718.00
Clearing/ Grubbing	----------	----------	$14,250.00
De-watering	----------	----------	$26,756.00
S.C. Excavation	----------	-----------	$20,200.00
Surveys	----------	----------	$3,000.00
Rock Vanes	10	$2,295.00	$22,950.00
W-W eir	1	$2,580.75	$2,580.75
Cross vanes	3	$4,664.08	$13,992.25
Root Wads	3	$634.00	$1,902.00
Live Material Transplants - Sod Mats	733	$10.47	$7,674.51
Live Material Transplants - Trees	42	$51.42	$2,159.64
Fascines	3350	$4.99	$16,716.50
Seeding & Mulching- Permanent	----------	----------	$2,000.00
Seeding & Mulching - Temporary	----------	----------	$4,000.00
		Total	**$148,899.65**

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 C , photographs highlighting project construction are in Appendix B. A summary of project construction details is provided below.

- A temporary access road was created along the southern floodplain to provide entry to the project area. The access road utilized an existing driveway and an agricultural utility road. The areas were modified to allow for access by heavy equipment and transported material into the project area.

- Clearing and grubbing of the borrow areas and the proposed meander bends was initiated in phases prior to beginning the excavation. Cleared vegetation was buried in areas requiring fill material. Areas containing knotweed were excavated below the rooting depth, collected, and disposed of in deep trenches excavated throughout the project site.

- Prior to de-watering NYSDEC biologists installed block nets and electroshocked the reach to remove and transport any fish within the project to adjacent areas.

- An inflatable water barrier structure was installed above the project reach to dam stream flow while the active work zone was de-watered by pumping all upstream flow around the work area. Stream flow was pumped using a 12" diesel pump into a sealed pipeline. A controlled geotextile outlet was used to discharge the flow into the Batavia Kill below the bridge structure.

- Sediment control was accomplished by collecting turbid water at the bottom of the reach and pumping the turbid water to a vegetated floodplain area for natural filtration.

- Stream channel excavation of the new meander bends was initiated in the lower portion of the project reach and progressed upstream. Material generated during the excavation of the meander bends was used to fill portions of the existing channel.

- Native sod mats were obtained from the proposed pond footprint and placed along finished streambank areas.

- Approximately 260yds^3 of clay were excavated from the stream channel and replaced with adequate fill material. The excavated clay material was used in designated fill areas in the adjacent floodplain and located away from the active channel.

- The installation of rock structures was initiated at the bottom of the reach and continued upstream following the final grading of stream channel. The project included the installation of 14 rock structures, which required rock to be hauled from a local quarry in Lexington to the project site.

- As the construction progressed upstream, the pond area was prepared and utilized for additional fill material.

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

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

- Large willow transplants and sod mats were installed along with the progression of the final grading. Additional bioengineering and plantings, to include live willow fascines, live stakes and posts, and bare root seedlings, were installed in phases by the contractor, District staff and a group of local Trout Unlimited volunteers when the plant material entered dormancy.

- The planted areas were irrigated after planting in order to improve establishment and survivability.

6.4 Project Constructability

Access to the project area, through private property, was acquired through landowner agreements prior to the start of construction. Mobilization of construction equipment to the work area was achieved through the adjacent landowners driveway and a agricultural utility road. Site conditions were generally considered favorable for equipment mobilization and construction activities. Construction activities within the area of the private bridge were limited due to the poor stability of the structure.

Groundwater infiltration into the work area became a general problem during the channel excavation and rock structure installation. General stream flow up to 10cfs was diverted around the project area using a pump and pipeline system. Provisions were made to pump relatively small amounts of infiltration water to adjacent vegetated floodplain areas, but were inadequate to handle the influx of groundwater into the site. Additional pumps were added to reduce the volume of water present in the work area. However, the majority of the rock structures, especially ones located in pool areas, required installation to commence below water level. Several problems were generated by the turbid conditions limiting visibility during the installation and inspection process.

6.5 Project Construction Modifications

A grass lined emergency spillway was excavated around the bridge to reduce the backwater effect caused by the bridge during storm flows. Ultimately, the channel was designed to aid in re-connecting the streams floodplain, thereby reducing erosive energy within the primary channel and through the bridge. The spillway inlet was set at bankfull stage and incorporated subsurface rock grade control outfall protection near the re-connection with the primary channel.

Modifications that were made throughout both phases of construction and implementation of the project were included within post-construction topographic surveys of the entire project site. The as-built surveys were initiated in the fall of 1999 and 2000. Drawings of the as-built and monitoring surveys are provided in Appendix F.

6.6 Project Construction Cost

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

7.0 Project Monitoring and Performance

In order to document the stability and performance of the restoration project and to provide baseline conditions for comparison against pre-construction conditions, regular inspections and annual monitoring surveys are conducted. Project inspections include photographic documentation of the project reach and a visual inspection of the rock structures, channel stability, bioengineering and riparian vegetation. The inspections are conducted annually during the project site survey as well as during and after significant flow events. The project monitoring surveys include both physical channel and structural stability 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

Table 3: Final project construction costs.

Item #	Bid Item Description	Final Quantity	Final Cost
1	Mobilization	----------	$10,718.00
2	Clearing/ Grubbing	----------	$14,250.00
3	De-watering	----------	$26,756.00
4	S.C. Excavation	----------	$20,200.00
5	Surveys	----------	$3,000.00
6	Rock Vanes	10 vanes @ $2,295/vane	$22,925.00
7	W-Weir	1 weir @ $2,581/weir	$2,580.75
8	Cross vanes	3 vanes @ $4,664/vane	$13,992.25
9	Root Wads	3 root wads @ $634/root wad	$1,902.00
10	Live Material Transplants - Sod	733ft^2 @ $10/ft^2	$7,674.51
11	Live Material Transplants - Trees	42 transplants @ $51/transplant	$2,159.64
12	Fascines	3350 ft. @ $5/ft.	$16,716.50
13	Seeding & Mulching - Permanent	----------	$2,000.00
14	Seeding & Mulching - Temporary	---------	$4,000.00
		Total Main Contract	**$148,874.65**
	Project Change Orders		
Item #	**Description**	**Quantity**	**Final Cost**
CO1	Root Wad	- 1	($634.00)
CO2	Surveys	- 2/3	($2,000.00)
CO3	Live Material Transplants - Sod	100 ft^2	$1,047.00
CO4	Live Material Transplants - Trees	3	($153.00)
CO5	Spillway Construction (included excavation, seed & mulch)	-----------	$5,365.00
CO6	Additional Sediment Control Pump (at 24hr/day rate)	----------	$4,600.00
CO7	W-Weir (added material)	----------	$707.50
CO8	Clay Excavation	----------	$1,310.00
		Total Change Orders and Deletions	**$8,241.24**
		Total Payment Including Change Orders	**$157,115.89**

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 sets of post-construction monitoring. The physical performance of the channel is monitored using surveys which minimally include a 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 characterization of hydrologic inputs from storm events.

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

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

7.2 Habitat Assessment

The NYCDEP in cooperation with the GCSWCD, inventoried macroinvertebrate communities in the project reach prior to the commencement of the restoration. Additionally, areas upstream and downstream, as well as stable reaches located within other areas of the Batavia Kill were inventoried for use in baseline comparisons. Major objectives of the macroinvertebrate monitoring efforts were to determine:

- If macroinvertebrate populations and communities differ between neighboring, stable (reference), and unstable (project) stream reaches

- If improved stability of the restored reach is reflected by improvements in macroinvertebrate populations and communities.

Habitat assessments were completed before restoration of the unstable project commenced. Inventories were completed at project/treatment and reference reaches in the summer of 1999. Preliminary findings from these surveys are summarized in Appendix F.

8.0 Operation and Maintenance

Proper operation and maintenance is a critical element for the success of restoration projects, which use geomorphic and natural channel design techniques. Based upon experience with local conditions, 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 revegetation and adjustments/repairs to rock structures. It is critical to have a clear understanding that typically, restoration goals are not achieved the day the excavation is completed, 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.

A management plan and strategy has been developed for the Batavia Kill stream corridor by the GCSWCD. The plan provides a working document to assist with resource management in the watershed, which will also assist in the operation and maintenance of the project reach.

8.1 Rock Structures

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

8.2 Vegetation

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

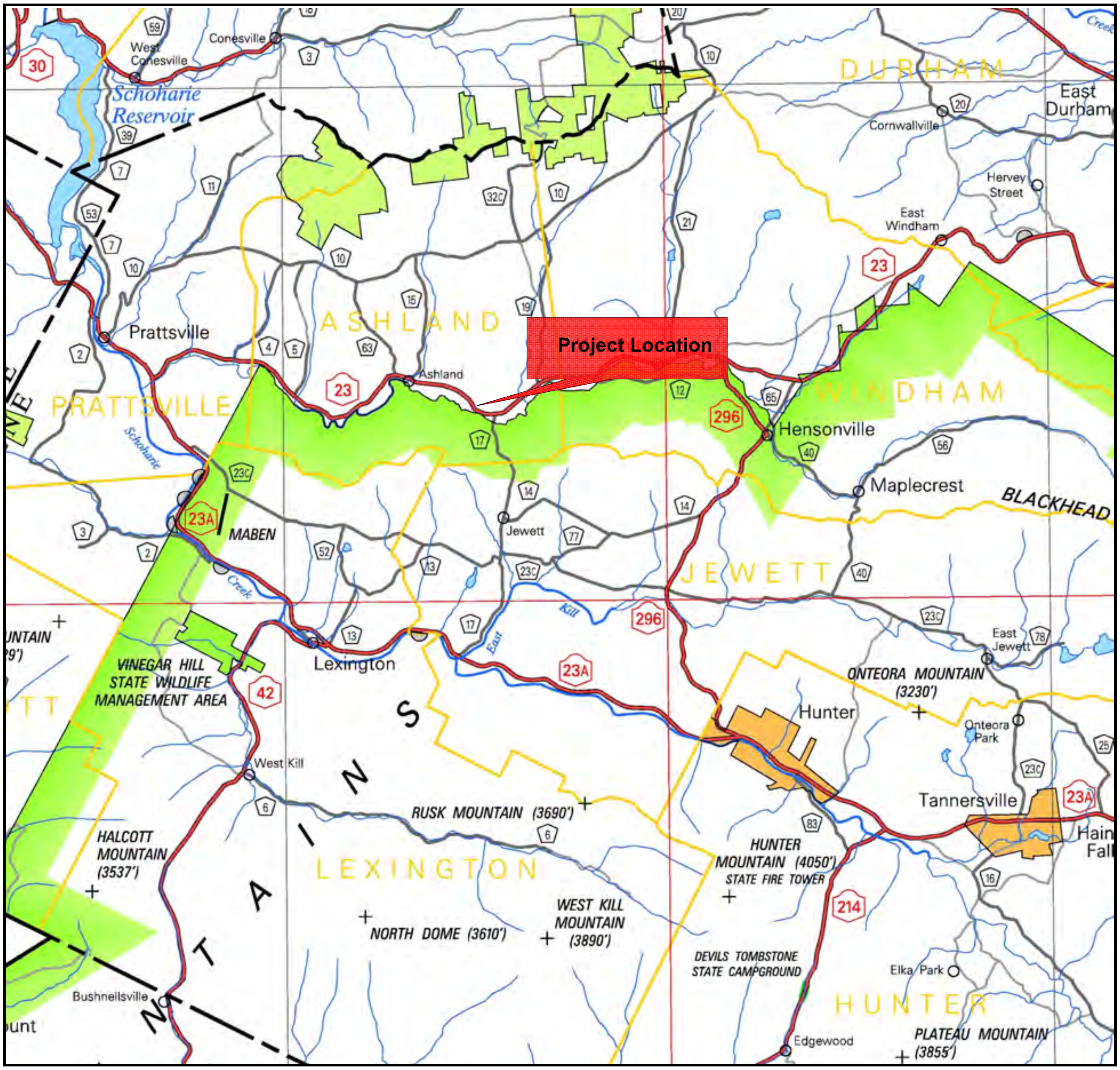
Supplemental installation of plant material, as needed, in the form of bioengineering and riparian planting will ensure effective riparian establishment. During supplemental planting, a variety of bio-engineering techniques will be used to increase woody vegetation at the site. These plantings will require maintenance to ensure proper moisture at critical times. The development of the monitoring plan for vegetation is in Appendix D.

Appendix A
Maps

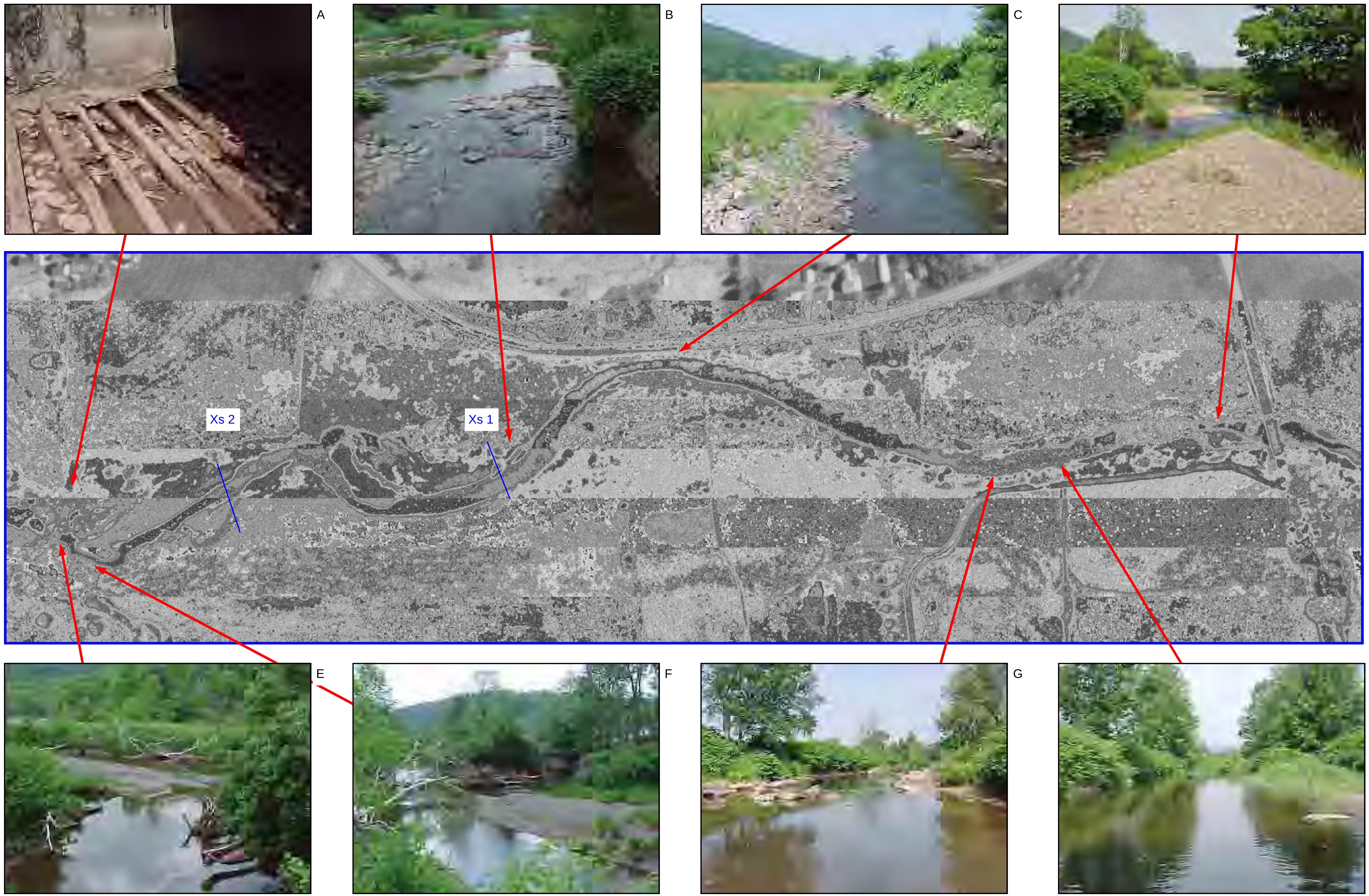
A.1 Project Location Map

A.2 Pre-Construction Monitoring

Project Location:



The Maier Farm Stream Restoration Project is located along the mainstem of the Batavia Kill, in the Town of Ashland, Greene County. The project reach is located approximately 1,500ft. downstream of the County Route 17 bridge crossing and runs west, parallel with State Route 23, ending at the private bridge crossing located on the Maier property.



A
B
C
D
Xs 2
Xs 1
E
F
G
H

Appendix B

Photographs and Descriptions

B.1 Pre-construction 1996 -1999

B.2 Project Construction 1999

B.1 Pre-construction 1996-1999

Photograph 1: A bankfull flow through the reach caused accelerated erosion. The lack of deep rooted riparian vegetation exacerbates the lateral migration and reduces bank stability.

Photograph 2: Looking downstream from the center of the proposed project area in 1998. The image shows the continual process of erosion and resultant bank slumping.

Photograph 3: The private bridge, located at the bottom of the reach, restricted stream flow and caused large debris jams to occur at the structure.

Photograph 4: The bridge structure caused backwater during stream flows which exceeded half bankfull. The backwater resulted in excessive sediment deposition and channel braiding upstream of the structure.

Photograph 5: Active erosion and slumping was present along most of the meanders within the project area. The riparian area consisted of maintained fields which did not provide sufficient rooting depth or density to provide stabilization.

Photograph 6: The existing stream channel provided minimal physical bed variation. The physical stream feature (pool, riffles, etc.) were generally lacking structure. Channel sediment was heavily imbedded with fine silts.

Photograph 7: The private bridge, located at the bottom of the reach, restricted stream flow and caused large debris jams to occur at the structure. Lateral erosion had compromised the southern wing wall and was attempting to actively migrate around the bridge structure.

Photograph 8: The northern cell of the bridge structure, had suffered severe erosion. The original timber footings, which had been covered with large rock and concrete, were exposed.

Photograph 9: The southern cell of the bridge structure was showing signs of erosion. Although the concrete along both the left abutment and center pier was scoured and weathered, the southern cell was in better structural condition than the northern cell.

Photograph 10: Multiple large, deep cracks were present along both abutments and the center pier.

Photograph 11: The northern cell of the bridge structure, had suffered severe erosion. The original timber footings, which had been covered with large rock and concrete, were exposed.

Photograph 12: Multiple cracks were present along both abutments and the center pier.

B.2 Project Construction 1999

Photograph 13: Prior to dewatering, NYS DEC biologists installed block nets and electroshocked the reach to remove and transport any fish within the project to adjacent areas. It should be noted no trout were found within the reach.

Photograph 14: The aerial image shows the site during the clearing and grubbing phase of the project. This effort was initiated as an attempt to eradicate the colony of Japanese knotweed present in the project area.

Photograph 15: An inflatable water barrier structure was installed above the project reach to dam stream flow while the active work zone was de-watered by pumping all upstream flow around the work area. Stream flow was pumped using a 12" diesel pump into a sealed pipeline.

Photograph 16: Stream flow was pumped through adjacent properties in one stage, using a sealed pipeline. A controlled geotextile outlet was used to discharge the diverted flow into the Batavia Kill downstream of the private bridge. Sediment control was accomplished by collecting turbid water at the bottom of the project reach and pumping the turbid water to a vegetated floodplain area for natural filtration.

Photograph 17: Stream channel excavation of the new meander bends was initiated in the lower portion of the project reach and progressed upstream. Bulldozers were used for the majority of the earthwork and rough grading.

Photograph 18: Material generated during the excavation of the meander bends was used to fill portions of the existing stream channel. General bank shaping and preparation for the structure installation was accomplished using excavators.

Photograph 19: Groundwater infiltration into the work area became a general problem during the rock structure installation. Several structures required installation to commence below the water level, limiting visibility during the installation and inspection process.

Photograph 20: Excavators equipped with hydraulic thumb attachments were used to prepare and install the rock structures.

Photograph 21: The w-weir located near the bridge approach was constructed in two stages to facilitate the size, shape, and placement of the structure near the bridge.

Photograph 22: Large quarry rock was delivered to the project site for use in the construction of the rock structures.

Photograph 23: Root wads acquired the clearing and grubbing phase were installed in the project area to provide habitat and added bank protection.

Photograph 24: Excavators were used to finish grade the stream channel around the rock structures as well as excavate scour holes.

Photograph 25: A completed rock vane structure prior to the excavation of the scour pool and finish grading.

Photograph 26: A completed j-hook structure prior to finish grading. Several rock vane structures were modified into j-hook structures in order to compare the performance between the structure types.

Photograph 27: A w-weir was installed upstream of the bridge to provide for flow alignment through the double cell bridge opening. The w-weir inverts were set at two separate elevations in order to concentrate the base flow through the southern bridge cell and provide flow relief through the northern bridge cell during higher flows.

Photograph 28: The w-weir structure spanned the entire width of the channel between the upstream wing walls, in order to assist in redirecting velocity away from the bridge abutments and center pier toward the center of the bridge openings. The placement of the w-weir was moved upstream of the bridge opening to prevent the scour pools generated by the structure from undermining the bridge.

Photograph 29: A pond was created on the upper terrace, for use as borrow material. The pond was situated adjoining a wetland drainage which would assist in maintaining the water level as well as provide additional habitat.

Photograph 30: The completed stream channel and floodplain were graded prior to the application of seed, mulch, and bioengineering. A cross vane structure is visible in the center of the photo.

Photograph 31: Native sod mats were used along the top of the streambanks, to promote accelerated re-vegetation. The sod mats would additionally reduce sediment runoff from construction activities in the floodplain until complete ground cover was established.

Photograph 32: Large transplanted willow and alder clumps were placed along significant areas of potential high stress (i.e. along bank keys where rock structures tie into the streambank). Secondary benefits of the transplants included accelerated re-vegetation and channel shading. The transplants were harvested from an on-site borrow area, located along the western side of the of the project.

Photograph 33: The photograph shows the upper portion fo the project reach prior to the installation of bioengineering. Upon completion of the finished grading, exposed areas were seeded and mulched to provide temporary stabilization.

Photograph 34: A view looking upstream toward the middle of the project reach. A cross vane structure is visible near the center of the photo.

Photograph 35: The lower meander bend, upstream of the private bridge, included three rock structures.

Photograph 36: The w-weir inverts were set at two separate elevations in order to concentrate the base flow through the southern bridge cell and provide flow relief through the northern bridge cell during higher flows.

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Maier Farm Restoration Project
Pre-construction 1996 - 1999

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Maier Farm Restoration Project
Pre-construction 1996 - 1999


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Maier Farm Restoration Project
Project Construction 1999

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Maier Farm Restoration Project
Project Construction 1999

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Maier Farm Restoration Project
Project Construction 1999

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Maier Farm Restoration Project
Project Construction 1999

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Maier Farm Restoration Project
Project Construction 1999

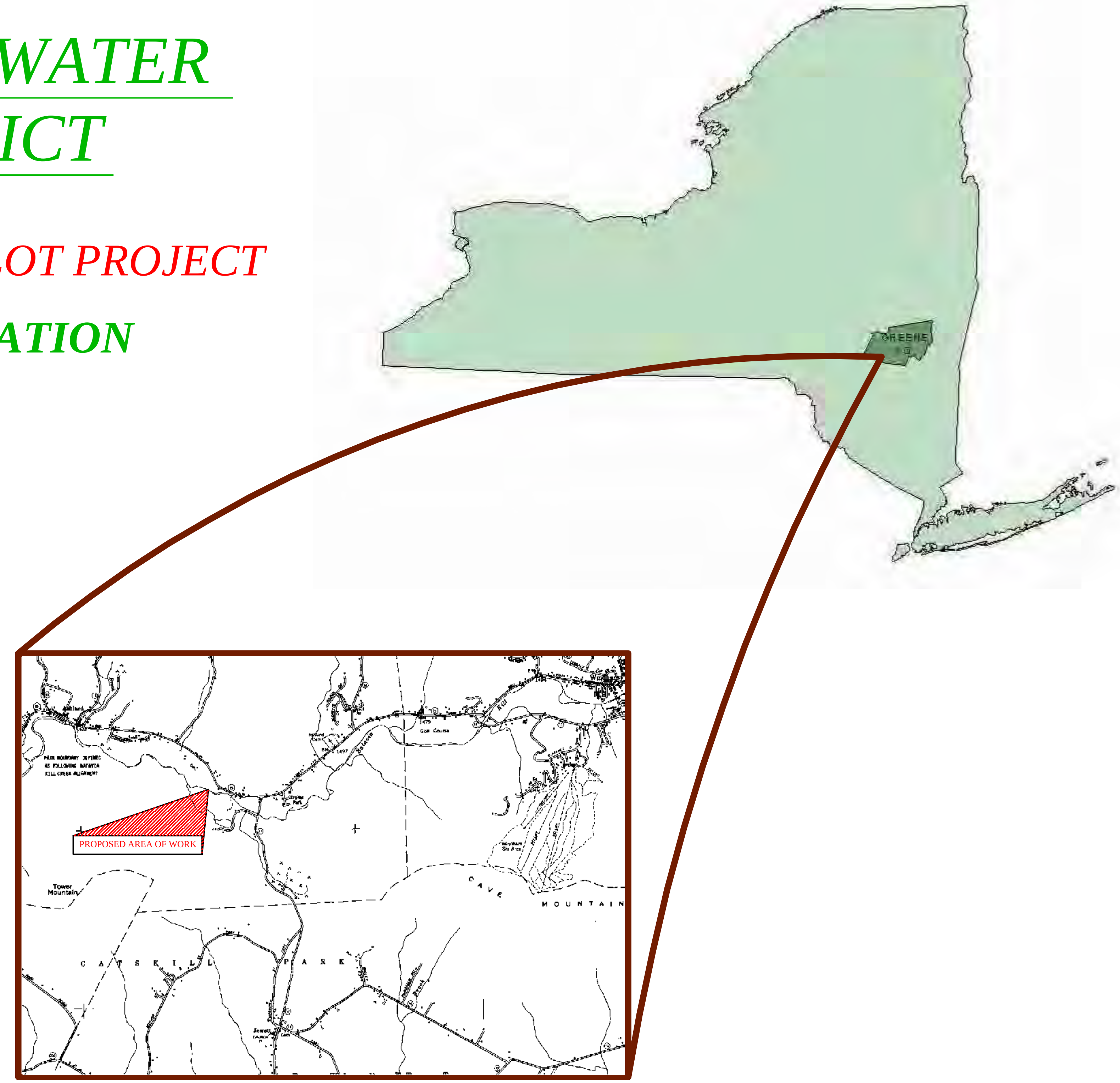
Appendix C

Project Design Drawings

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT

"MAIER FARM" STREAM RESTORATION PROJECT



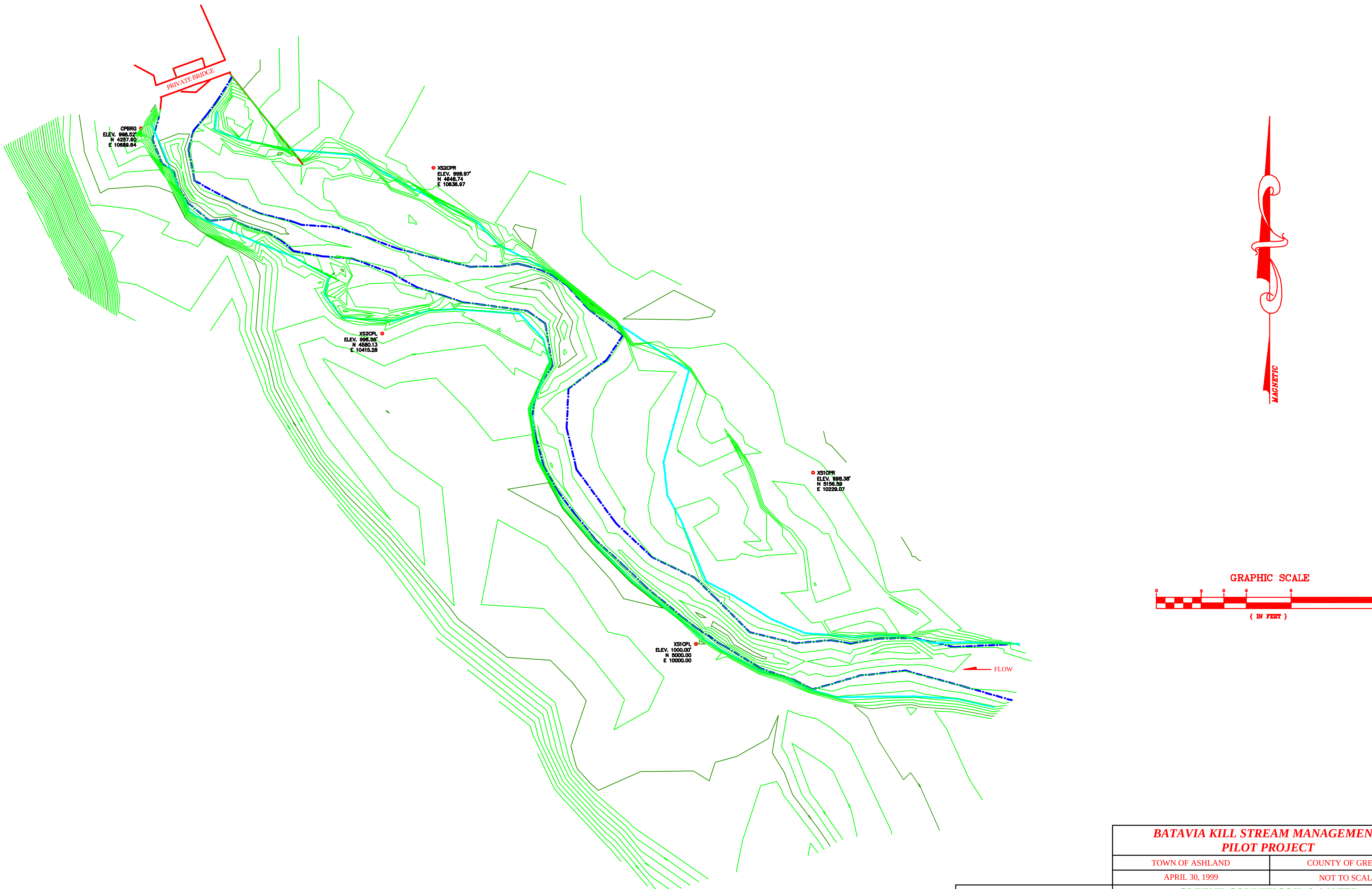
SITE LOCATION MAP
(NOT TO SCALE)

INDEX OF DRAWINGS

1. TITLE PAGE
2. EXISTING TOPOGRAPHIC MAP
3. PROPOSED PLAN VIEW (W/ EXIST. COND.)
4. PROPOSED PLAN VIEW
5. PROPOSED LONGITUDINAL PROFILE
6-8. PROPOSED CROSS SECTIONS
9. CONSTRUCTION DETAILS
10. PLANTING DETAILS
11. DEWATERING PLAN

LEGEND	
REVISIONS	

BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT	
TOWN OF ASHLAND	COUNTY OF GREENE
APRIL 30, 1999	NOT TO SCALE
GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT BOX 907 GREENE COUNTY OFFICE BUILDING, CAIRO, NY 12414 PHONE (518) 622-3620 FAX (518) 622-0344	
"MAIER FARM" STREAM RESTORATION PROJECT	
CHECKED BY:	PROJECT #: BSP-98.03
DRAWN BY: DOUG DEKOSKIE	DRAWING #: 98.03
SHEET 1 OF 11	TITLE PAGE



LEGEND

EXISTING BANKFULL CHANNEL	
WATER SURFACE	
CONTROL PIN	

NOTE

Existing topographic survey performed on March 2, 1998.

NOTE

Initial elevation, northing, and easting for XS1CPL was assumed. The entire survey is relative to these assumptions.

REVISIONS

BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT

TOWN OF ASHLAND	COUNTY OF GREENE
APRIL 30, 1999	NOT TO SCALE

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

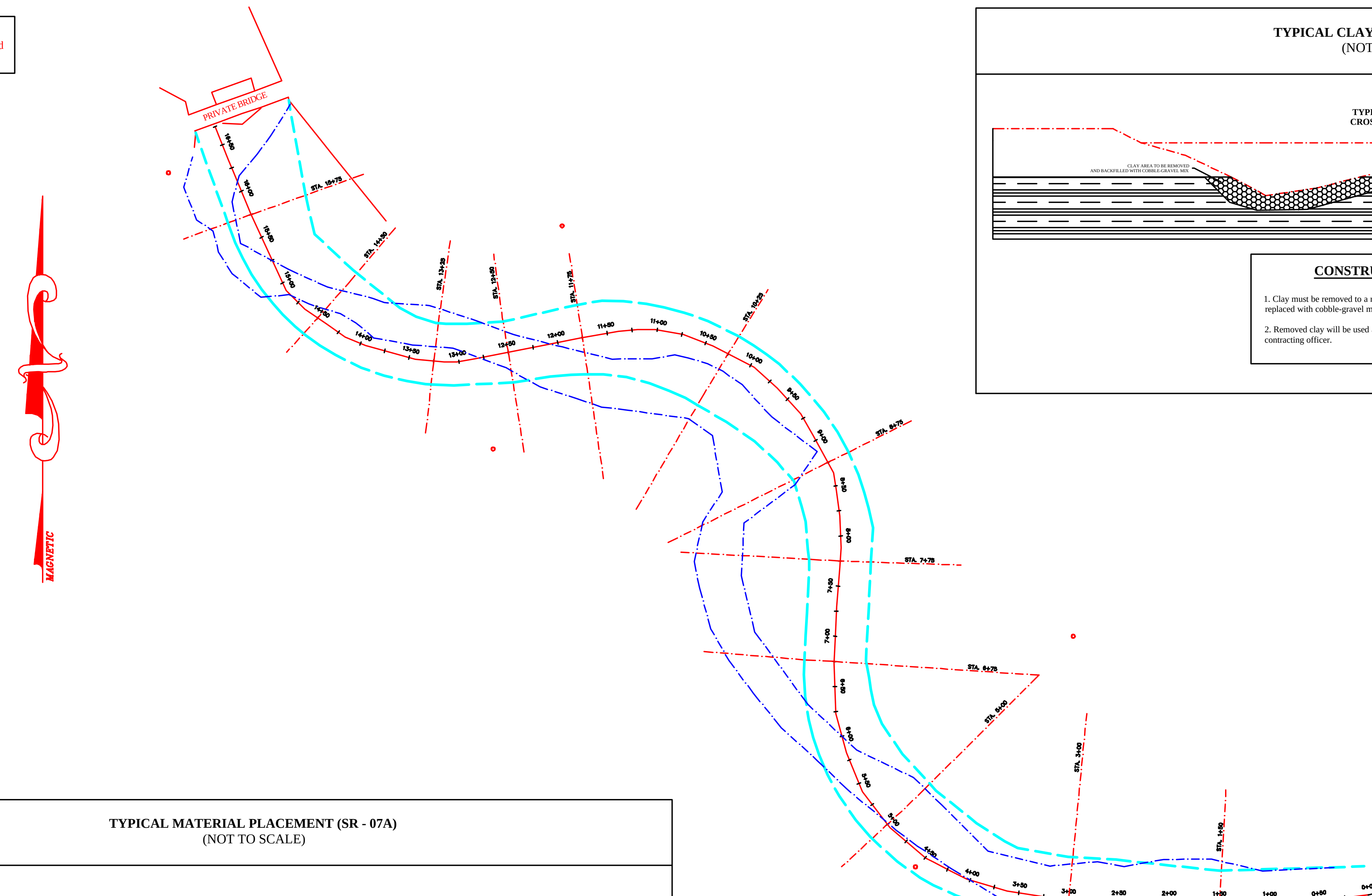
BOX 907 GREENE COUNTY OFFICE BUILDING, CAIRO, NY 12414
PHONE (518) 622-3620
FAX (518) 622-0344

"MAIER FARM" STREAM RESTORATION PROJECT

CHECKED BY:	PROJECT #: BSP-98.03
DRAWN BY: DOUG DEKOSKIE	DRAWING #: 98.03
SHEET 2 OF 11	EXISTING TOPOGRAPHIC SURVEY
1' CONTOUR INTERVAL	

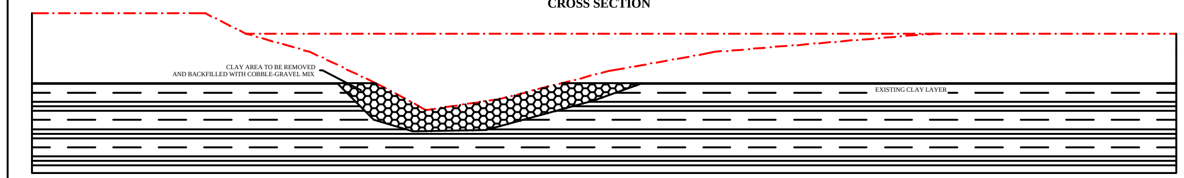
NOTE

Existing cross sections were taken from a topographic survey performed on March 2, 1998.



TYPICAL CLAY OVER-EXCAVATION
(NOT TO SCALE)

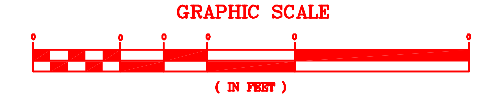
TYPICAL POOL
CROSS SECTION



CONSTRUCTION NOTES

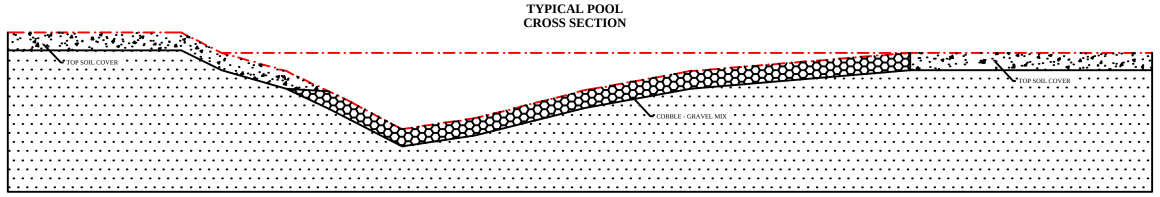
1. Clay must be removed to a minimum depth of three feet (3') and replaced with cobble-gravel mix.
2. Removed clay will be used as fill in the floodplain as directed by the contracting officer.

GRAPHIC SCALE

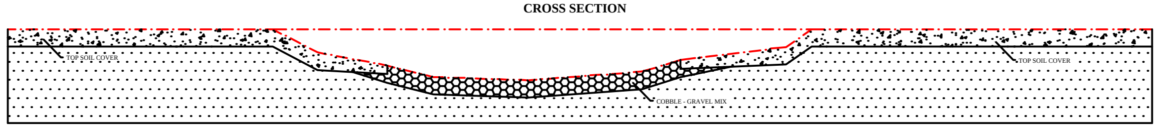


TYPICAL MATERIAL PLACEMENT (SR - 07A)
(NOT TO SCALE)

TYPICAL POOL
CROSS SECTION



TYPICAL RIFFLE
CROSS SECTION



CONSTRUCTION NOTES

1. Minimum thickness of top soil cover six inches (6")
2. Minimum thickness of cobble-gravel cover eighteen inches (18")

LEGEND

- PROPOSED BANKFULL CHANNEL
- EXISTING WATER SURFACE
- CROSS SECTION
- CONTROL PIN

REVISIONS

BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT

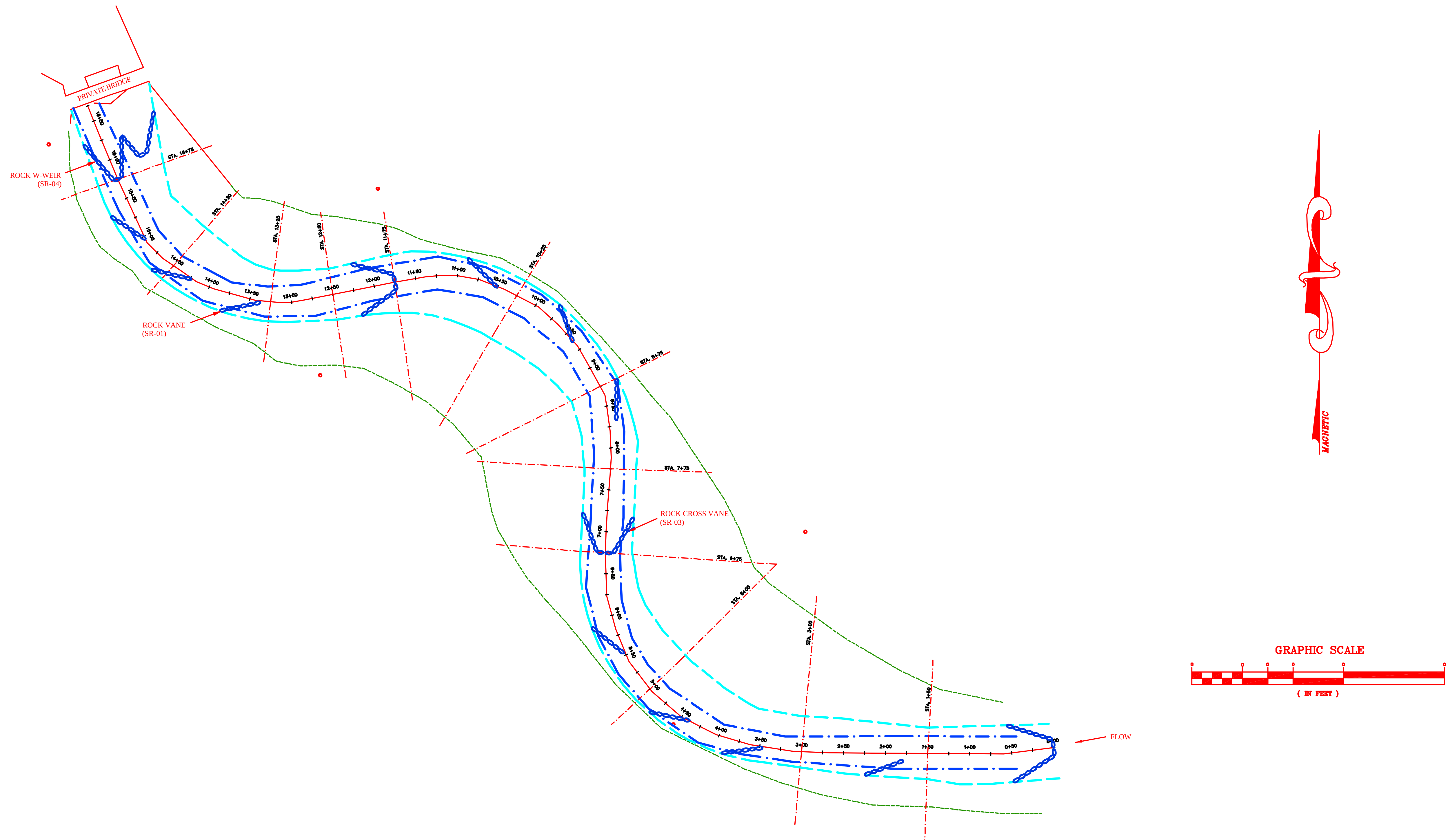
TOWN OF ASHLAND	COUNTY OF GREENE
APRIL 30, 1999	NOT TO SCALE

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

BOX 907 GREENE COUNTY OFFICE BUILDING, CAIRO, NY 12414
PHONE (518) 622-3620
FAX (518) 622-0344

"MAIER FARM" STREAM RESTORATION PROJECT

CHECKED BY:	PROJECT #: BSP-98.03
DRAWN BY: DOUG DEKOSKIE	DRAWING #: 98.03
SHEET 3 OF 11	PROPOSED PLAN VIEW (W/ EXISTING CONDITIONS)



NOTE

Existing cross sections were taken from a topographic survey performed on March 2, 1998.

NOTE

Proposed structures are shown for placement only and are not drawn to scale. See Construction Details.

LEGEND

PROPOSED BANKFULL CHANNEL	
PROPOSED WATER SURFACE	
CROSS SECTION	
STRUCTURE	
TOP OF BANK	
CONTROL PIN	

REVISIONS

BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT

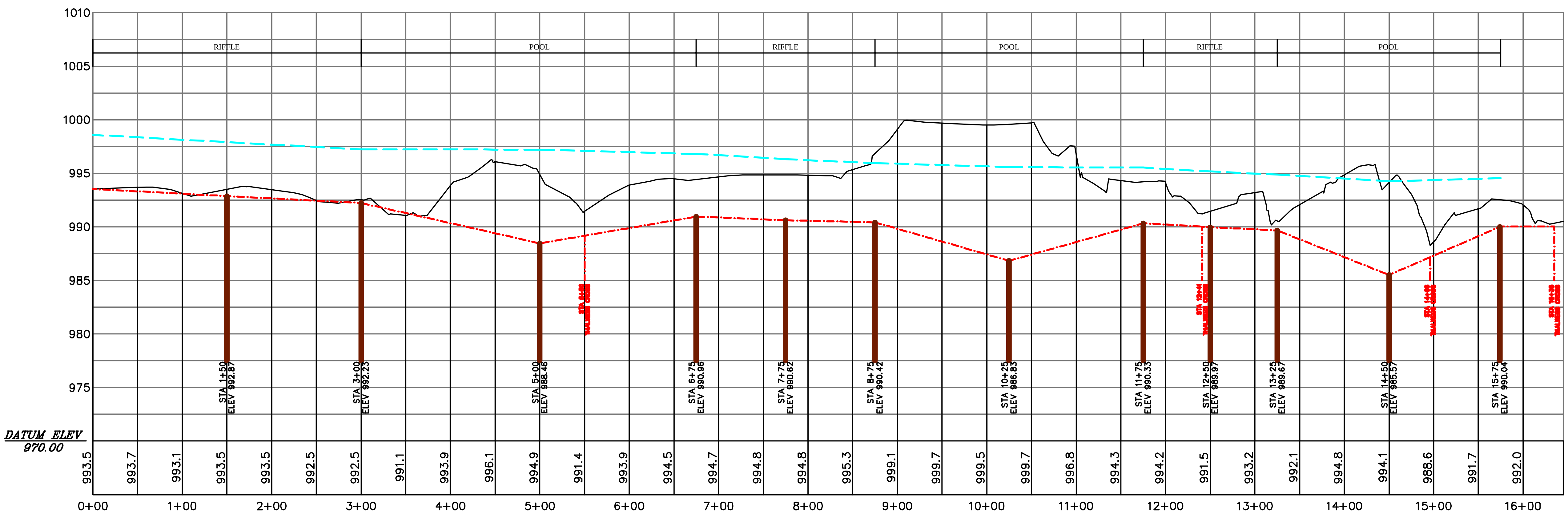
TOWN OF ASHLAND	COUNTY OF GREENE
APRIL 30, 1999	NOT TO SCALE

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

BOX 907 GREENE COUNTY OFFICE BUILDING, CAIRO, NY 12414
PHONE (518) 622-3620
FAX (518) 622-0344

"MAIER FARM" STREAM RESTORATION PROJECT

CHECKED BY:	PROJECT #: BSP-98.03
DRAWN BY: DOUG DEKOSKIE	DRAWING #: 98.03
SHEET 4 OF 11	PROPOSED PLAN VIEW



LEGEND

- EXISTING GROUND
- PROPOSED THALWEG
- BANKFULL SURFACE

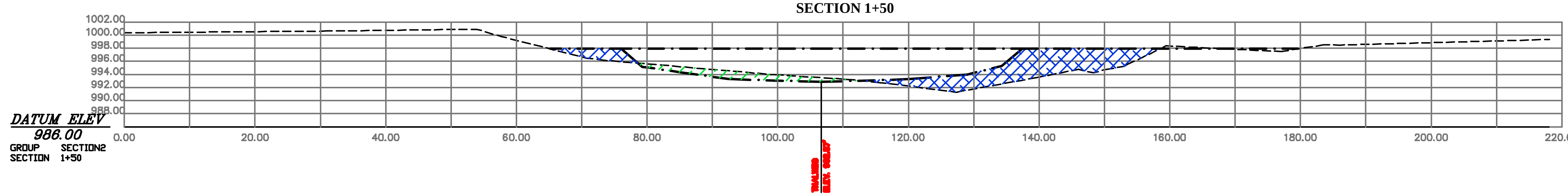
NOTE

Existing profile was taken from a topographic survey performed on March 2, 1998.

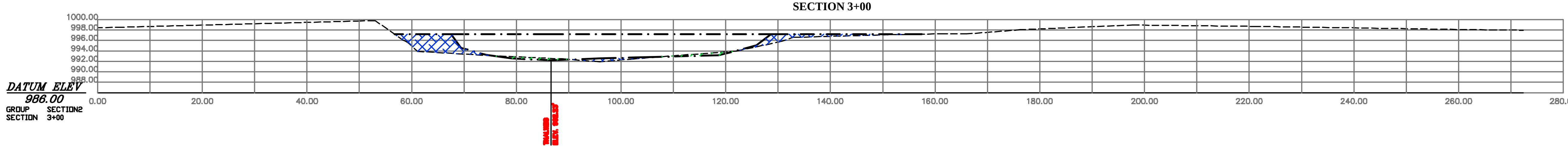
REVISIONS

BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT	
TOWN OF ASHLAND	COUNTY OF GREENE
APRIL 30, 1999	NOT TO SCALE
GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT BOX 907 GREENE COUNTY OFFICE BUILDING, CAIRO, NY 12414 PHONE (518) 622-3620 FAX (518) 622-0344	
"MAIER FARM" STREAM RESTORATION PROJECT	
CHECKED BY:	PROJECT #: BSP-98.03
DRAWN BY: DOUG DEKOSKIE	DRAWING #: 98.03
SHEET 5 OF 11	PROPOSED LONGITUDINAL PROFILE

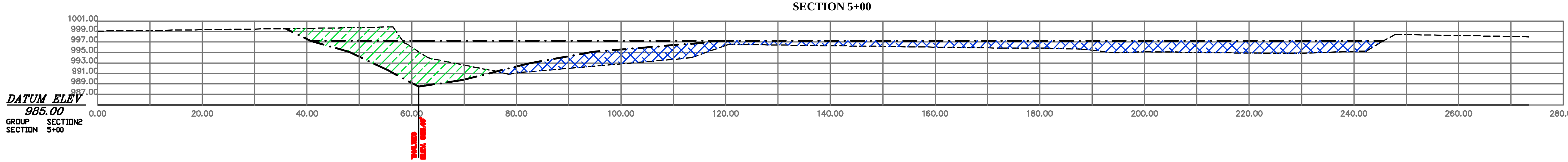
SECTION 1+50



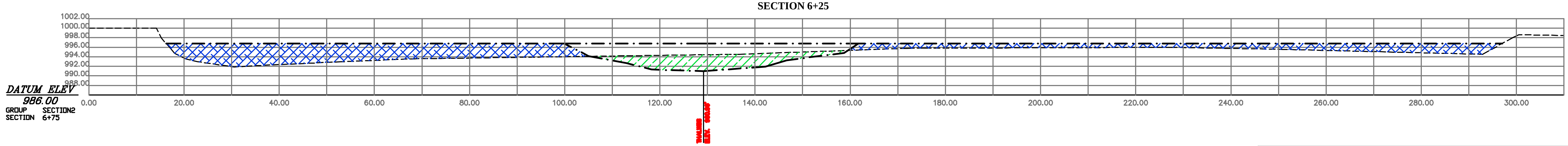
SECTION 3+00



SECTION 5+00



SECTION 6+25



NOTE

Existing cross sections were taken from a topographic survey performed on March 2, 1998.

LEGEND

EXISTING GROUND	– – – – – –
PROPOSED CUT	
PROPOSED FILL	
BANKFULL CHANNEL	– · – · –

REVISIONS

BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT	
TOWN OF ASHLAND	COUNTY OF GREENE
APRIL 30, 1999	NOT TO SCALE

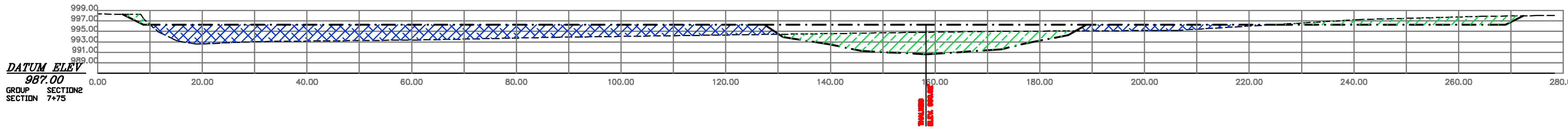
GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

BOX 907 GREENE COUNTY OFFICE BUILDING, CAIRO, NY 12414
PHONE (518) 622-3620
FAX (518) 622-0344

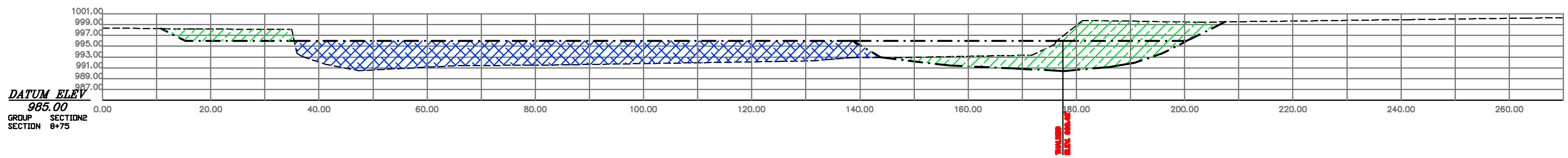
"MAIER FARM" STREAM RESTORATION PROJECT

CHECKED BY:	PROJECT #: BSP-98.03
DRAWN BY: DOUG DEKOSKIE	DRAWING #: 98.03
SHEET 6 OF 11	PROPOSED CROSS SECTIONS (1+50 - 6+75)

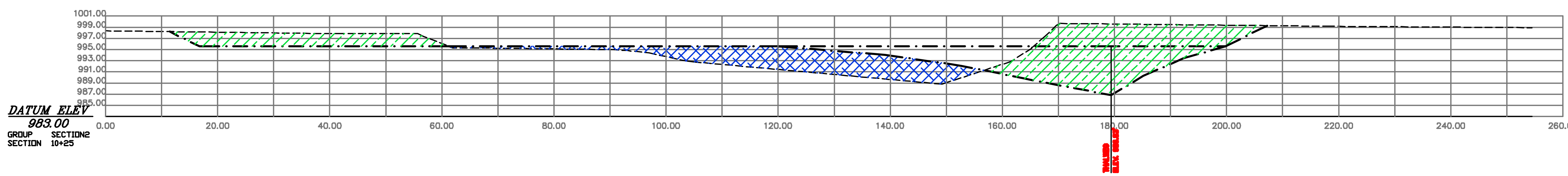
SECTION 7+75



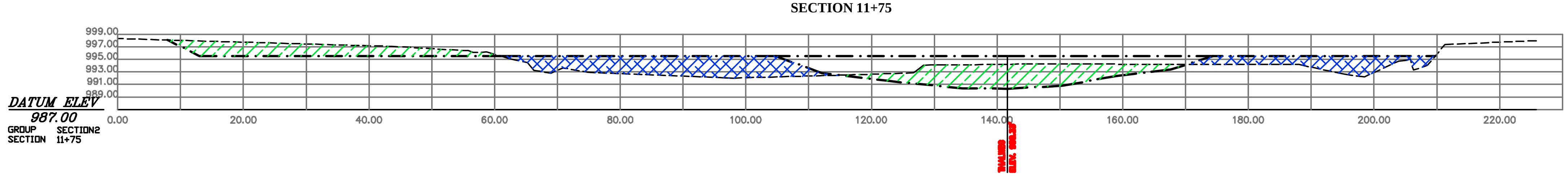
SECTION 8+75



SECTION 10+25



SECTION 11+75



NOTE
Existing cross sections were taken from a topographic survey performed on March 2, 1998.

LEGEND

- EXISTING GROUND
- PROPOSED CUT
- PROPOSED FILL
- BANKFULL CHANNEL

REVISIONS

BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT

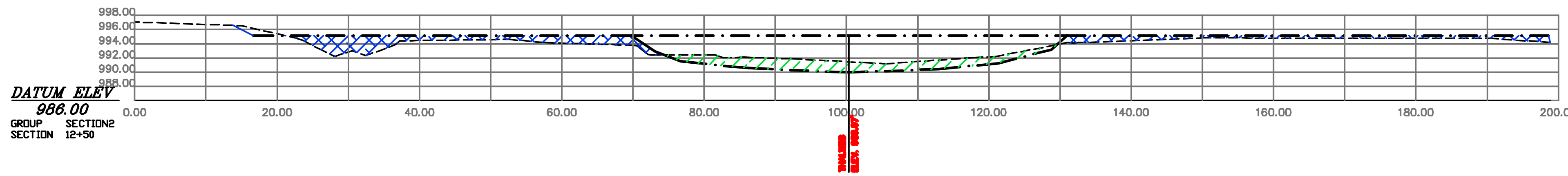
TOWN OF ASHLAND	COUNTY OF GREENE
APRIL 30, 1999	NOT TO SCALE

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT
BOX 907 GREENE COUNTY OFFICE BUILDING, CAIRO, NY 12414
PHONE (518) 622-3620
FAX (518) 622-0344

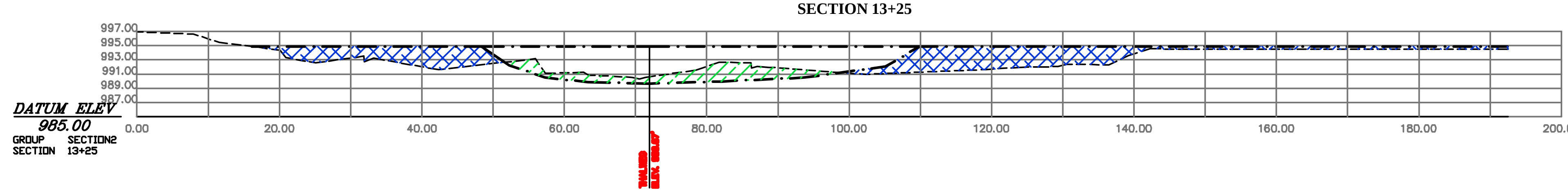
"MAIER FARM" STREAM RESTORATION PROJECT

CHECKED BY:	PROJECT #: BSP-98.03
DRAWN BY: DOUG DEKOSKIE	DRAWING #: 98.03
SHEET 7 OF 11	PROPOSED CROSS SECTIONS (7+75 - 11+75)

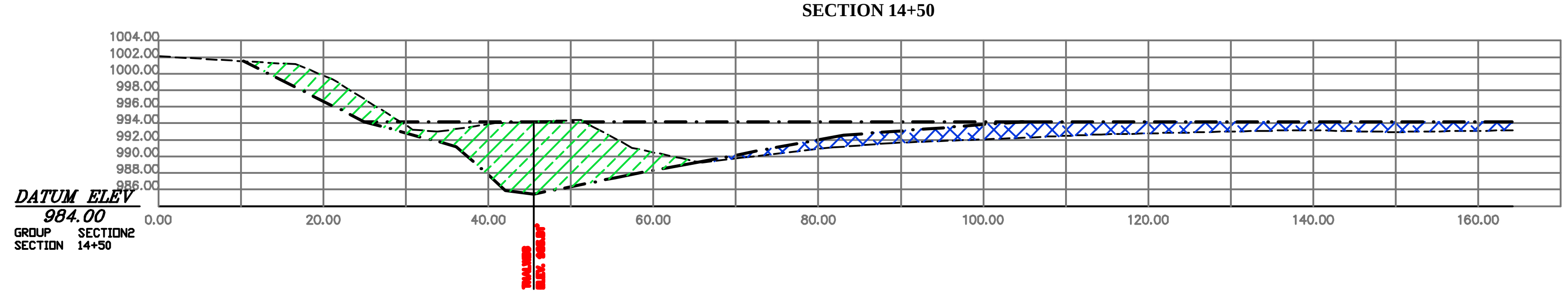
SECTION 12+50



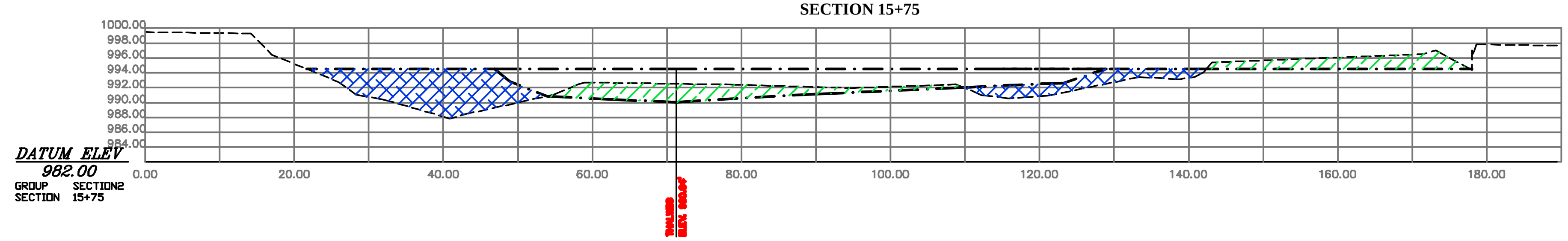
SECTION 13+25



SECTION 14+50



SECTION 15+75



NOTE
Existing cross sections were taken from a topographic survey performed on March 2, 1998.

LEGEND

EXISTING GROUND
PROPOSED CUT
PROPOSED FILL
BANKFULL CHANNEL

REVISIONS

BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT

TOWN OF ASHLAND	COUNTY OF GREENE
APRIL 30, 1999	NOT TO SCALE

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

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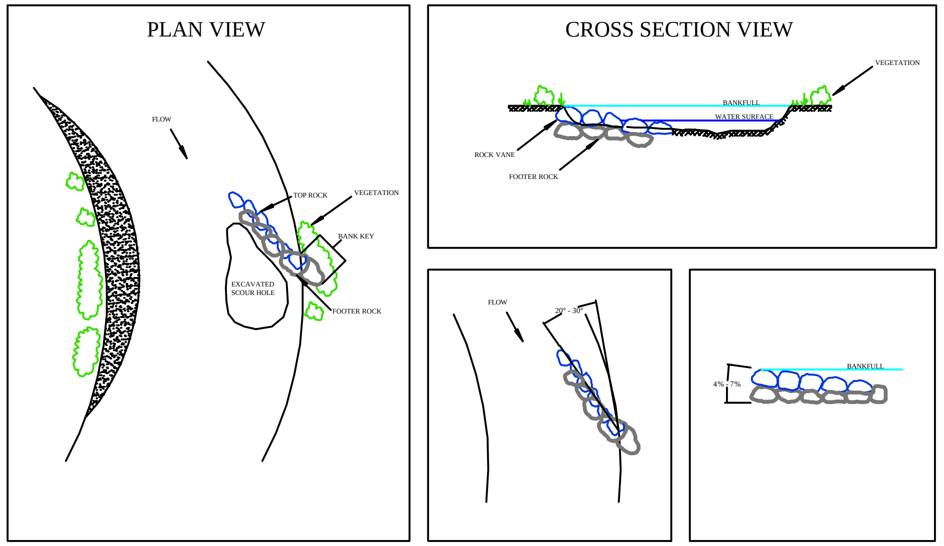
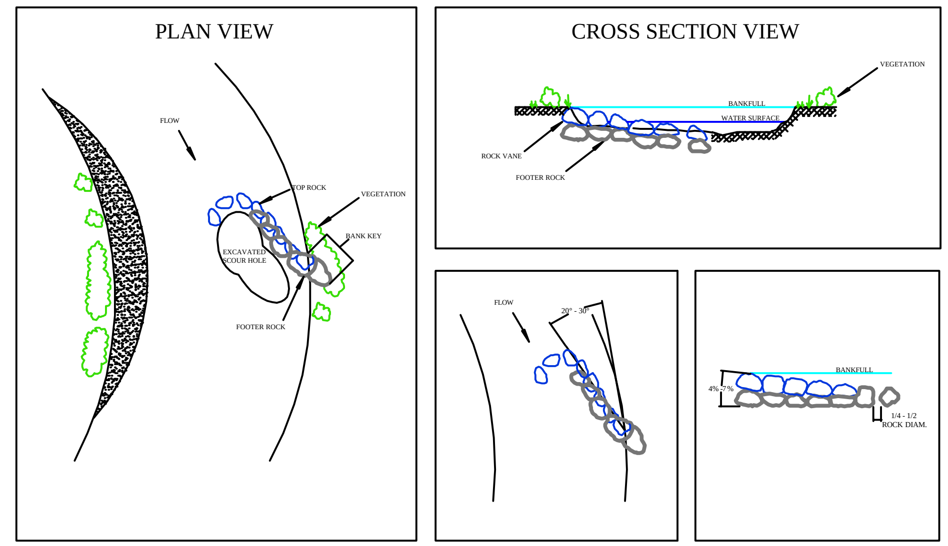
"MAIER FARM" STREAM RESTORATION PROJECT

CHECKED BY:	PROJECT #: BSP-98.03
DRAWN BY: DOUG DEKOSKIE	DRAWING #: 98.03
SHEET 8 OF 11	PROPOSED CROSS SECTIONS (12+50 - 15+75)

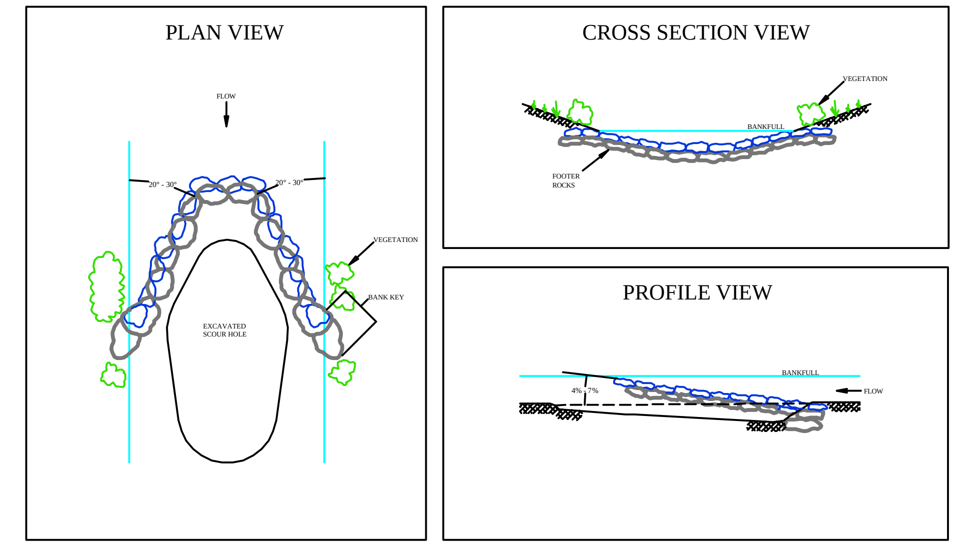
ROCK VANE (SR-01)



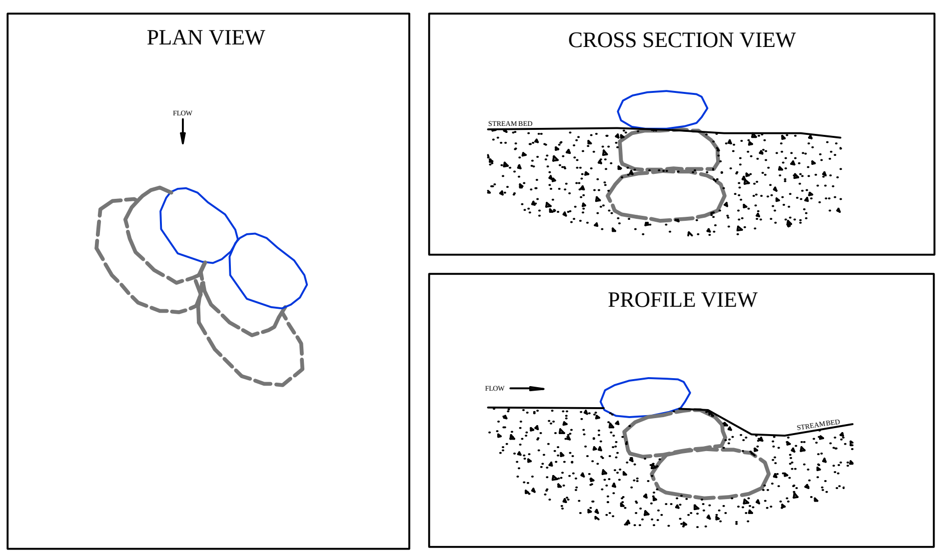
J-HOOK VANE (SR-02)



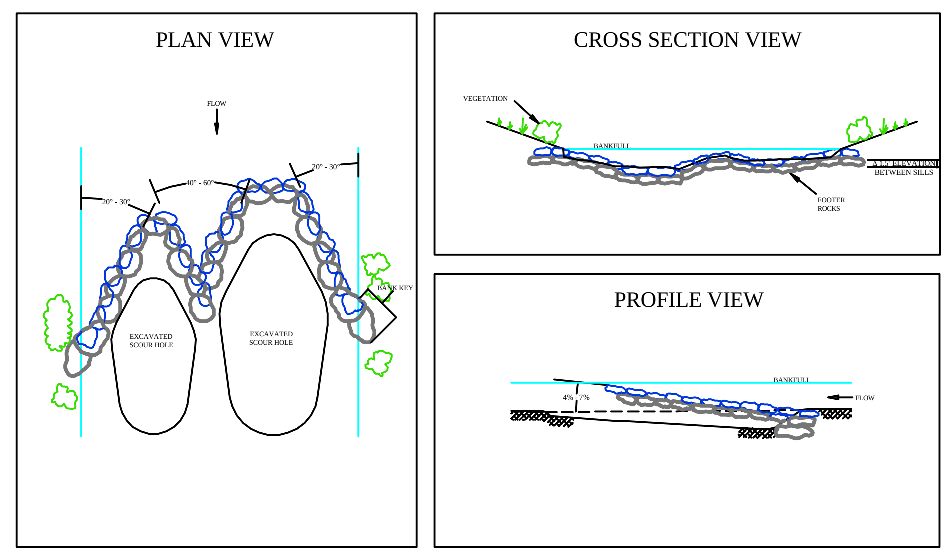
ROCK CROSS VANE (SR-03)



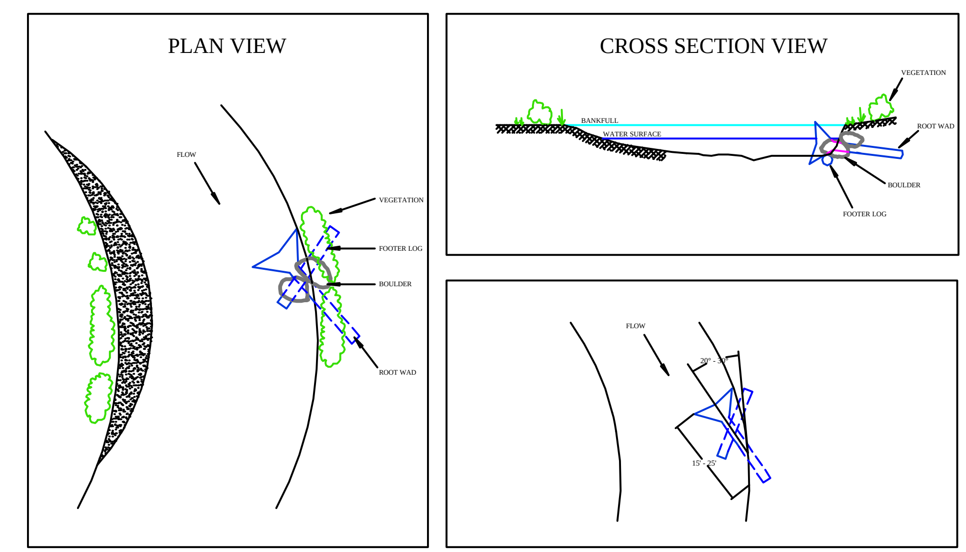
FOOTER ROCK PLACEMENT



ROCK W-WEIR (SR-04)



ROOT WAD (SR-06)



CONSTRUCTION NOTES

1. The construction of all structures will done in the presence of a designated contracting officer.

2. The size and placement of scour holes will be determined by the contracting officer. See construction specifications.

3. The bank key for all rock structures will be a minimum of eight feet (8') in length.

4. Vegetative transplants are to be placed in the immediate area upstream and downstream of the installed structure as designated by the contracting officer.

MATERIAL SPECIFICATIONS

1. Rock Size

	A-axis	B-axis	C-axis
Minimum Size	4'	3'	2'
Maximum Size	8'	6'	5'

2. Root wads and footer logs will be identified and flagged by the contracting officer.

3. Root wads should have a minimum root diameter of four feet (4') with a minimum length of fifteen feet (15') and a trunk diameter of at least eighteen inches (18").

LEGEND

REVISIONS

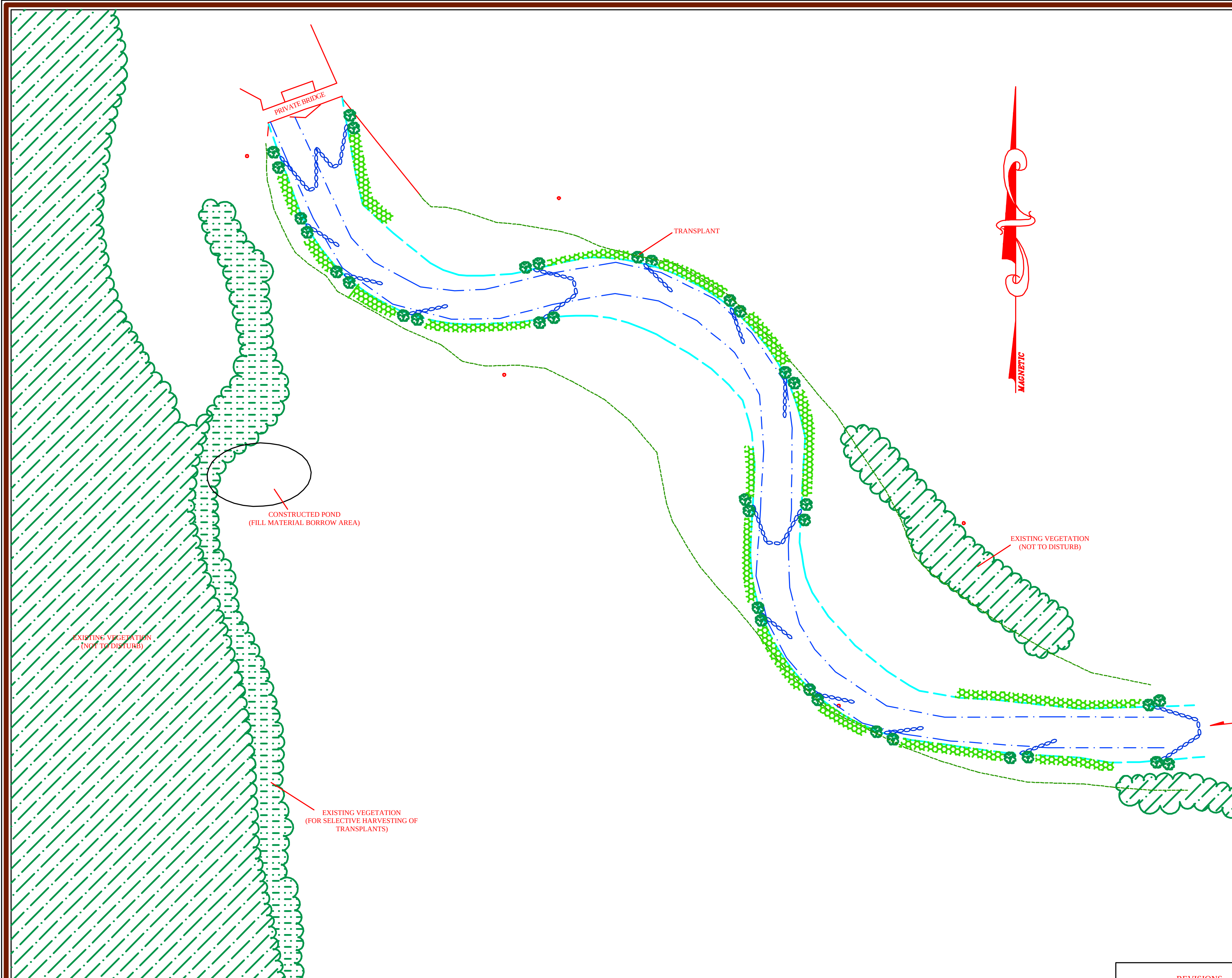
BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT

TOWN OF ASHLAND	COUNTY OF GREENE
APRIL 30, 1999	NOT TO SCALE

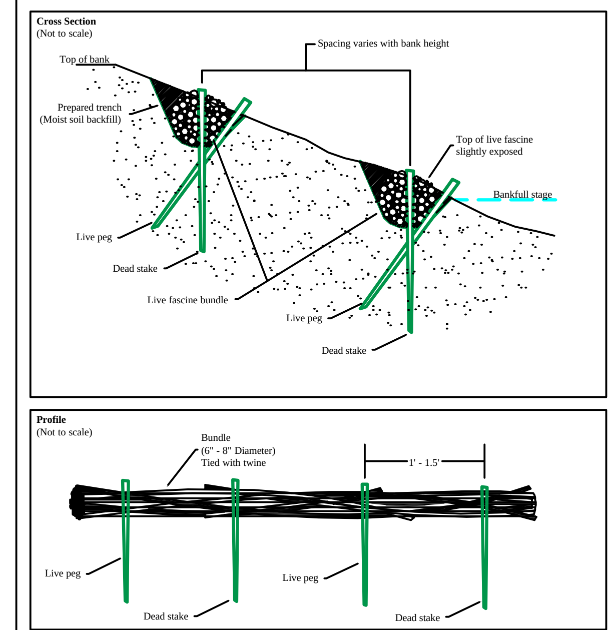
GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT
BOX 907 GREENE COUNTY OFFICE BUILDING, CAIRO, NY 12414
PHONE (518) 622-3620
FAX (518) 622-0344

"MAIER FARM" STREAM RESTORATION PROJECT

CHECKED BY:	PROJECT #: BSP-98.03
DRAWN BY: DOUG DEKOSKIE	DRAWING #: 98.03
SHEET 9 OF 11	CONSTRUCTION DETAILS



LIVE FASCINE DETAIL (VS-01)



LEGEND

- PROPOSED BANKFULL CHANNEL
- TRANSPLANTS
- LIVE FASCINE PLANTING AREA
- STRUCTURE
- TOP OF BANK
- CONTROL PIN

REVISIONS

BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT

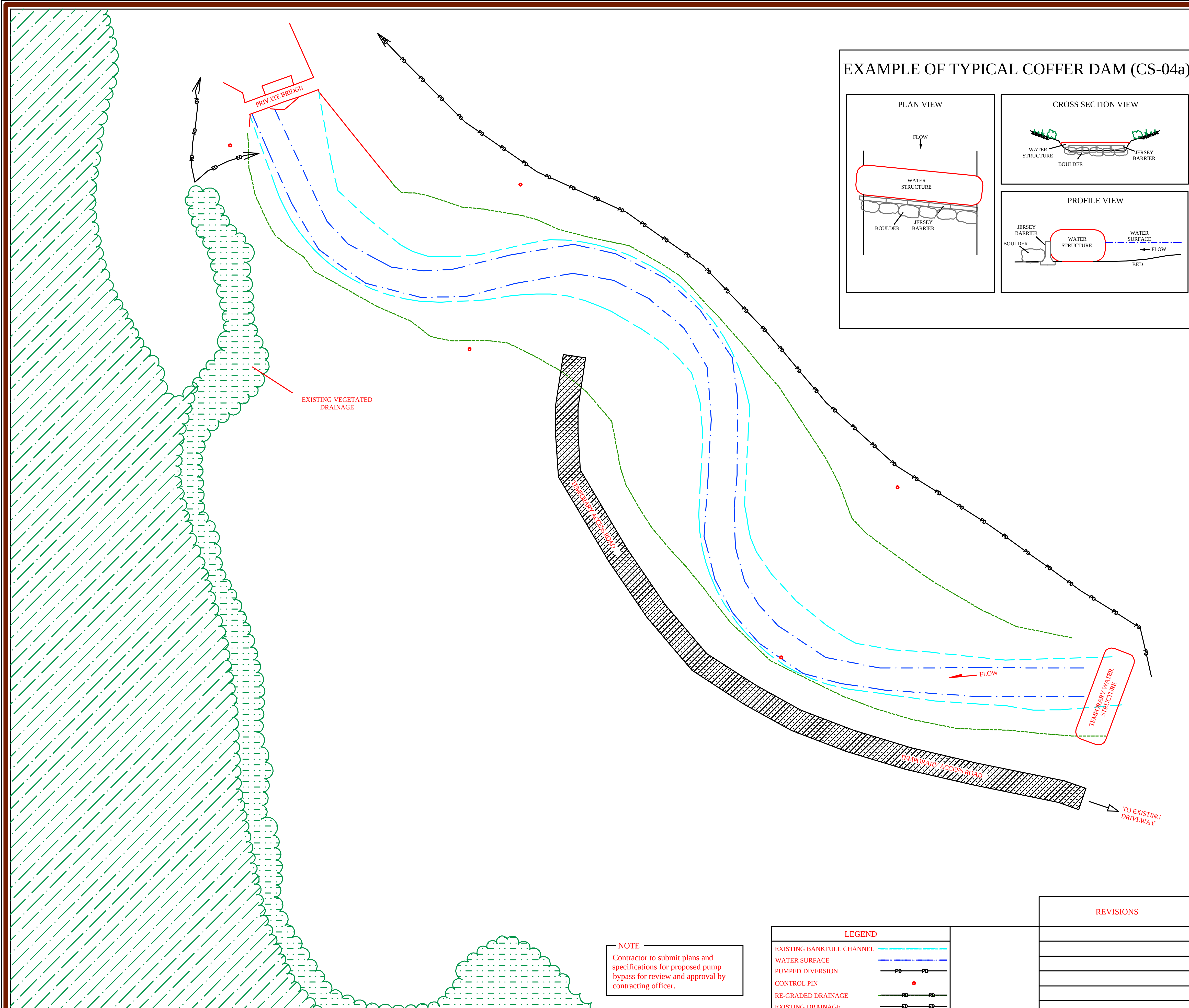
TOWN OF ASHLAND	COUNTY OF GREENE
APRIL 30, 1999	NOT TO SCALE

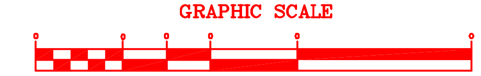
GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

BOX 907 GREENE COUNTY OFFICE BUILDING, CAIRO, NY 12414
PHONE (518) 622-3620
FAX (518) 622-0344

"MAIER FARM" STREAM RESTORATION PROJECT

CHECKED BY:	PROJECT #: BSP-98.03
DRAWN BY: DOUG DEKOSKIE	DRAWING #: 98.03
SHEET 10 OF 11	PLANTING DETAILS





NOTE

Contractor to submit plans and specifications for proposed pump bypass for review and approval by contracting officer.

LEGEND

EXISTING BANKFULL CHANNEL
WATER SURFACE
PUMPED DIVERSION
CONTROL PIN
RE-GRADED DRAINAGE
EXISTING DRAINAGE

REVISIONS

BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT

TOWN OF ASHLAND	COUNTY OF GREENE
APRIL 30, 1999	NOT TO SCALE

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT
BOX 907 GREENE COUNTY OFFICE BUILDING, CAIRO, NY 12414
PHONE (518) 622-3620
FAX (518) 622-0344

"MAIER FARM" STREAM RESTORATION PROJECT

CHECKED BY:	PROJECT #: BSP-98.03
DRAWN BY: DOUG DEKOSKIE	DRAWING #: 98.03
SHEET 11 OF 11	DEWATERING PLAN

Appendix D

Project Physical Monitoring Plan

Maier Farm Restoration Project
Project Monitoring Plan

1.0 Introduction

In recent years, there has been increasing focus on the use of fluvial geomorphic restoration techniques to provide channel stabilization while targeting a range of additional multi-objective project goals. The techniques, generally referred to as natural stream channel design, typically include the development of an appropriate channel geometry, which mimics a natural stable form of the channel. Combinations of rock and log structures and various bioengineering practices are typically used to promote increased, long term bank and channel stability, promote fisheries habitat, and facilitate flood and sediment transport.

A natural channel maintains it's stability while making continual adjustments in geometry over time as a result of changes in stream flow and sediment load. Restoration projects that are constructed to imitate the natural equilibrium of stable channels are subject to these adjustments and remain particularly vulnerable prior to the establishment of vegetation.

A critical element to the long term success of these projects is in monitoring the restoration site to provide for baseline conditions and to verify results of the restoration effort. Monitoring the restoration project can be used to meet permit requirements, measure the performance and success, and provide increased knowledge in the design and construction procedures.

The following document describes the proposed physical monitoring plan for the Maier Farm Restoration Project.

2.0 Permit Requirements - Monitoring

A condition of the permit, issued by the Army Corps of Engineers for the Maier Farm Restoration Project, requires the Greene County Soil & Water Conservation District to submit annual reports documenting the status of the project, for three years following the completion of construction. The report to the New York District of the Army Corps must include:

- the current stream type of the reach
- the condition of the planted vegetation
- the condition of upstream and downstream reaches
- color photographs taken during normal low flow, and following an annual or bankfull event to include:
    - the reconfigured channel
    - the re-vegetated areas
    - upstream and downstream reaches

3.0 General Monitoring Strategy

The physical monitoring of the project will include pre-construction, as-built, and post-construction surveys to include a complete longitudinal profile, multiple cross sections, and sediment sampling. Additionally, the project reach will be inspected on a routine basis and will have a detailed inspection after each flow event that meets or exceeds bankfull discharge. Photo documentation of the project site will be used to monitor change over time, as well as to meet the project permit requirements. A five year monitoring program will be initiated in order to fulfill the permit requirements as well as provide a longer period for data collection and comparison given the uncertainty of flow events and vegetative establishment.

4.0 Surveys and Sampling Locations

The following surveys will be performed to document physical performance:

4.1 Topographic Survey (As-built)

The completed restoration projects are surveyed immediately after construction to document the "as-built" condition of the new channel and the adjoining floodplain area. The as-built survey includes:

- topographic ground surface
- location of structures
- longitudinal profile along the thalweg
- multiple cross sections
- bankfull stage
- water surface
- locations of installed bioengineering components.

4.2 Cross Sections

At the time of the as-built survey, monumented cross sections will be installed for use in detailed monitoring efforts. Cross sections are monumented using capped rebar pins, which are located in the topographic survey and recorded using GPS.

Cross sections are placed in various locations along the completed project reach to monitor stream process. These include sections through potential high stress areas and across varying stream features (pools, riffles, etc.) in order to document stability, stream classification, and potential erosion and scour. Additional cross sections will be established across or near stabilization structures (rock vanes, cross vanes, etc.) in order to monitor performance.

4.3 Longitudinal Profile

Longitudinal profile surveys include the sampling of ground surface point at slope breaks along the thalweg of the channel to document physical channel dimensions. The profile survey also includes the daily water surface slope as well as the elevation of bankfull indicators along the channel. The sampling is tied to the project datum so future modeling efforts can be initiated. The profile survey can be used to indicate channel vertical stability and channel efficiency, as well as correlate morphological channel parameters such as feature characteristics, increase in channel storage, and riffle-pool measurements.

4.4 Sediment Samples

Sediment sampling is used to provide indicators of channel process, as well as for stream classification and monitoring. The primary sediment analysis is based on the Wolman pebble count. Pebble counts are conducted using composite methods for classification, as well as detailed sampling at designated cross sections for hydraulic analysis and to monitor shifts in particle size. Additional pebble counts may be conducted in specific features (i.e. pools) to monitor changes in the sediment stratification as the project adjusts to the natural bed load supply in the system.

The Greene County Soil & Water Conservation District also intends to conduct bar sample analyses within the project reach. Bar sample analyses are not recommended for a period of time after construction, and will not be completed until such time that the GCSWCD feels that the channel has reached a natural sediment regime. As a minimum, bar sampling analysis of the restoration reach should not be conducted until the reach has experienced at least one, preferably more, bankfull flows.

5.0 Assessment Procedures

The monitoring data will be analyzed using two general scales. Relationships will be made to annually to determine general morphological trends occurring through the project reach as well as comparisons made "at-a-station" using direct comparisons between monitored stations. Monitoring data can additionally be correlated to flow events which occur between monitoring intervals.

Surveys will be matched and analyzed in order to review the change in channel dimensions and geometry of individual surveys. This technique will assist in quantifying physical change at a station and used to review processes through the reach. The assessment can be conducted at multiple scales at various time increments in order to provide annual performance data as well as after significant flow events.

A simple comparison between surveys (annual or storm) can indicate channel progression, changes in channel efficiency, and deviation of channel morphology from the design channel parameters. Analysis of the physical data may also determine the appropriateness of a channel design technique and may show the sensitivity of certain techniques to channel processes.   In terms of management (operation and maintenance), the overlays provide indicators of the trajectory of the rebuilt channel, therefore the analysis can be used to quantify further modification of the channel. The assessment can be further developed using 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 a treatment in halting or accelerating a channel process.

6.0 Reporting

Several project status reports will be generated in order to document the specific type and timing of the project monitoring and assessment. Status reporting will include a combination of various site inspection reports, annual status reports, a post-construction report, and a final assessment report. A brief summary of each report is listed as follows:

6.1 Post-construction Report

The as-built survey report will include the following:

- Field adjustments made during the project construction
- Project construction implementation
- Location of post-construction monitoring stations (sections, profile)
- Location and placement of installed structures

- Photographs taken throughout construction and immediately following construction

6.2 Periodic Site Inspections

Periodic site inspections will include the following:

- General site inspection
- Inspection of structures
- Inspection of vegetation
- General channel stability
- Representative photographs through the reach and adjacent areas
- General notes and recommendations

6.3 Annual Status Reports

The annual status reports will include the following:

- General site inspection
- Inspection of structures
- Inspection of vegetation
- General channel stability
- Monitoring surveys and assessment
- Representative photographs through the reach and adjacent areas
- General notes and recommendations

6.4 Assessment Reports

The assessment report will include the following:

- Summary of the overall project stability
- Analysis of monitoring surveys and assessments
- Representative photographs through the reach and adjacent areas
- General notes and recommendations

Appendix E

Fish & Habitat Monitoring Plan

NOT COMPLETE

Appendix F

Project Status Reports

F.1 Project Status: Post-construction (August 1999)

The as-built survey was performed on August 16, 1999 to display modifications made to the project design during construction and to document survey benchmarks for future monitoring. The survey encompassed the as-built condition of the constructed channel and the adjoining floodplain area to include 1' contour finish grade topography, rock structures, thalweg profile, water surface, location of monumented cross section pins, and installed bioengineering components.

Cross Section Survey

At the time of the as-built survey, six monumented cross sections were installed for use in future detailed monitoring efforts. Cross sections were monumented using capped rebar pins which are located in the topographic survey as well as recorded using GPS. Cross sections were stationed at various locations along the channel profile in order to provide monitoring for stream process and stability. The cross sections were installed through various stream features (pools, riffles, etc.) and structures in order to document stream classification, potential erosion and scour, and to document the overall channel stability.

The cross section plots were sampled from a (TIN) surface, created from the post-construction topographic survey of the site. Bankfull geometry data generated from the post-construction survey is listed in Table 1.

Table 1: Maier Farm Project post-construction bankfull cross sectional geometry data

Cross Section	Station	Feature	Area (ft^2)	Width (ft)	Max. Depth (ft)	Mean Depth (ft)
1	01+15.5	Riffle	210.1	70.9	4.3	3.0
2	04+35.5	Pool	258.0	79.9	5.7	3.2
3	07+67.0	Riffle	265.5	119.2	5.8	2.2
4	10+05.5	Pool	347.3	74.8	6.8	4.7
5	12+80.0	Riffle	242.1	64.3	5.5	3.8
6	14+14.0	Pool	272.7	73.3	7.0	3.7
		Average Riffles	**239.2**	**84.8**	**5.2**	**3.0**
		Average Pools	**292.7**	**76.0**	**6.5**	**3.9**
		Total Average	**266.0**	**80.4**	**5.9**	**3.4**

The cross sections created from the TIN surface do not provide the detail necessary to perform a direct comparison between the project design and the constructed channel. The values presented in Table 2 are averages taken through multiple, feature specific cross sections. Values for as-built riffle comparisons were obtained from cross sections 1, 3, and 5 while as-built values for pool comparisons were obtained from cross sections 2, 4, and 6.

Table 2: Maier Farm Project bankfull cross sectional channel geometry for existing, proposed, and post-construction conditions.

Variables	Existing Channel	Proposed Reach	As-built
Stream Type	C4	C4	C4
Width (ft)	175.2	61.3	84.8
Mean Depth (ft)	1.4	3.9	3.0
Max. Depth (ft)	3.5	5.3	5.2
Cross Sectional Area (ft^2)	236.0	235.0	239.2
Pool Cross Sectional Area (ft^2)	273.9	288.6	292.7
Max. Pool Depth (ft)	6.8	8.8	6.5
Pool Width (ft)	68.7	79.7	76.0

Longitudinal Profile

The longitudinal profile survey included the sampling of ground, water, and bankfull surface elevations along the slope breaks of the thalweg. The profile plot was sampled from a (TIN) surface, created from the post-construction topographic survey of the site. The sampling was tied to the original pre-restoration datum and topographic survey.

TOPOGRAPHIC SURVEY

REPRESENTING THE

MAIER FARM STREAM RESTORATION PROJECT

LOCATED ON THE

MAINSTEM OF THE BATAVIAKILL

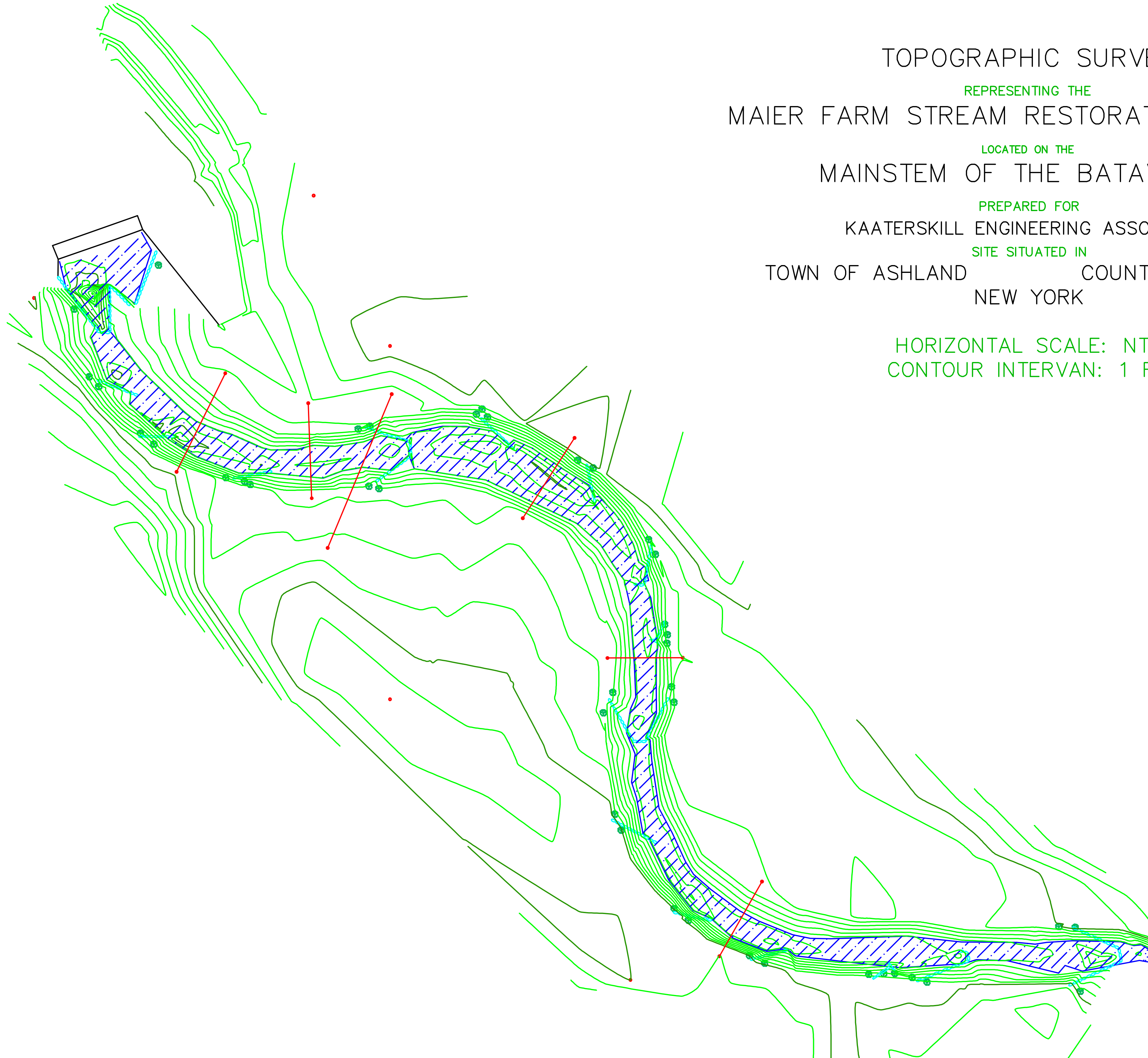
PREPARED FOR

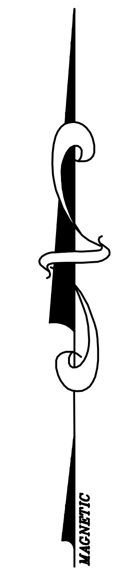
KAATERSKILL ENGINEERING ASSOCIATES

SITE SITUATED IN

TOWN OF ASHLAND COUNTY OF GREENE
NEW YORK

HORIZONTAL SCALE: NTS
CONTOUR INTERVAN: 1 FT.





LEGEND

WATER SURFACE	
STRUCTURE	
TRANSPLANT	

REVISIONS

BATAVIA KILL STREAM MANAGEMENT PILOT PROJECT

TOWN OF ASHLAND	COUNTY OF GREENE
SEPTEMBER 30, 1999	SCALE: 1" = 70'

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

BOX 907 GREENE COUNTY OFFICE BUILDING, CAIRO, NY 12414
PHONE (518) 622-3620
FAX (518) 622-0344

"MAIER FARM" STREAM RESTORATION PROJECT

CHECKED BY:	PROJECT #:
DRAWN BY: DOUG DEKOSKIE	DRAWING #:
SHEET 1 OF 1	"AS BUILT" PLAN VIEW

F.2 Project Status: Flood Event Inspection (September 16,1999)

On September 16, 1999, heavy rainfall associated with Tropical Storm Floyd, resulted in extensive flooding throughout the Batavia Kill valley. The Maier Farm Restoration project was inspected several times during and after the flood event in order to document the flow conditions and the project performance. The following report is intended to describe the magnitude of the flood event, provide a summary of the project performance, and list recommendations for repair and/or modification of the project. Please refer to Appendix F.2 for photo documentation of this inspection.

Rainfall and Stream Flow

In the Northeastern Catskills, the most significant impact of Tropical Storm Floyd was the magnitude of the flooding caused by the intensity of the rainfall and surface runoff. Rainfall totals measuring nearly 10.9 inches of rain (NYCDEP) were recorded in Windham and measurements of 12" were reported by landowners in the upper headwaters. A comparison of rainfall totals and duration from Tropical Storm Floyd to the previous hurricanes, Connie and Donna, shows that Tropical Storm Floyd produced the highest total rainfall (Table 1).

Table 1: Comparison of rainfall total and duration between hurricane related flood events in the Batavia Kill.

Storm Event	Total Rainfall	Duration
Hurricane Connie (August 1955)	7.75"	40 hours
Hurricane Donna (September 1960)	7.90"	96 hours
Tropical Storm Floyd (September 1999)	10.9" measured (12" reported)	24 hours

In addition to the total rainfall, it is also important to note the significant difference in rainfall duration. While the previous hurricanes had produced their total rainfall over an extended period of 40 to 96 hours, Tropical Storm Floyd produced the majority of the total rainfall in a much shorter period of 18-28 hours (NYSDEC).

Rainfall recurrence intervals are based on both the magnitude and the duration of the rainfall event, whereas stream flow recurrence intervals are based solely on the magnitude of the peak flow. Ten or more years of data are required for the determination of recurrence intervals. More confidence can be placed in the results of a frequency analyais based on, for example, 30 years of record than an analysis based on 10 years of record.

In a 1961 publication, the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) identifies standards for rainfall depths at specified frequencies and durations throughout the United States. Table 2 lists rainfall depths and recurrence frequencies for the 24-hour duration storm for the Batavia Kill valley, taken from the rainfall frequency atlas. A comparison between the rainfall depth listed for Tropical Storm Floyd (Table 1) and the 24-hour duration recurrence interval listed in Table 2, shows that the rainfall depth for Tropical Storm Floyd exceeded the 100 year storm by more than 3.4 inches in 24-hours.

Table 2: Recurrence intervals and rainfall depths associated with a 24-hour duration storm.

Recurrence Interval	2-year	5-year	10-year	25-year	50-year	100-year
Rainfall Depth	3.5"	4.5"	5.5"	6.25"	7.0"	7.5"

In order to evaluate and compare the magnitude of flooding of Tropical Storm Floyd on the Batavia Kill, peak flow information collected at USGS gaging stations was examined (Table 3). The real time gage near Ashland, NY (#01349900) is located approximately 1000ft. upstream of the project reach. Peak flow data from the Ashland gage indicates that the flood flow produced by Tropical Storm Floyd was greater than both the highest previous recorded events of April 1987 and January 1996, which had substantial impact in a number of drainage systems in the Catskills.

Table 3. Comparison of peak flow measurements for major historical flood events in the Batavia Kill valley.

Flood Event	USGS Gaging Station			
	Schoharie Creek at Prattsville	Batavia Kill at Red Falls	Batavia Kill near Ashland	Batavia Kill at Hensonville
October 16, 1955	25,100 cfs	No record	No record	5,000 cfs
September 12, 1960	49,900 cfs	No record	No record	5,000 cfs
April 4, 1987	47,600 cfs	No record	11,500 cfs	2,390 cfs
January 19, 1996	52,800 cfs	16,400 cfs	14,300 cfs	2,000 cfs
September 16, 1999	42,800 cfs	16,800 cfs	15,000 cfs	2,170 cfs

Data from the Hensonville gage indicates that the peak flood flow from Tropical Storm Floyd was similar in magnitude with the April 1987 and January 1996 flood events, but was relatively half of the volume recorded during previous large magnitude events. The reduced flood peaks are attributed to the construction of the C.D. Lane Park Flood Control Structure, located up-valley from the Hensonville gaging station. The flood control structure is designed to reduce the magnitude of large flood events up to a 100-year return interval flood. Flood water is detained by the structure and released at a lower volume over an extended duration. It should be noted that the C.D. Lane Park Flood Control Structure overtopped the principal spillway and utilized both emergency spillways during the September 16, 1999 flood event.

Project Inspection

The Maier Farm Restoration project was inspected several times during and after the flood event in order to document the flow conditions and the project performance. Due to the effects of the Batavia Kill Flood Control structures, the stream remained at an elevated stage for several days after the flood peak. Final project inspections and monitoring were not conducted until nearly a week following the flood event due to the elevated stage. A summary of the project damage, recorded during the post flood inspection, is included below. The features discussed are referenced by station number, starting from the top of the project and proceeding downstream. Photographs taken during the rising and falling stages of the event, as well as following the event are included in Appendix F.2.a.

Station 0+00 to 2+50

The most significant damage occurred near the top of the project reach, downstream of the first cross vane. Observations made during the flood event noted a large tree lodged on top of the cross vane, deflecting a significant portion of streamflow onto the right floodplain. The diverted stream flow resulted in significant erosion along the right bank, downstream of the cross vane.

During the storm recession, sediment was deposited along the left stream bank, covering the existing J-Hook vane, conceivably to compensate for the change in cross sectional area caused by erosion of the right bank. The erosion behind the vane, the failure of the streambank and the deposition pattern remaining after the stream stage receded were all expected responses to the influence of the debris jam.

The integrity of the cross vane remained intact and overall damage to the structure was limited. Two rocks shifted along the left vane arm, which was also attributed to the debris jam.

Station 3+50 to 6+50

On the first meander bend, the impacts of the flood were limited to the lower 1/3 of the outside left bank. The first rock vane in the meander remained undamaged and vegetation along the streambank remained intact. Localized erosion occurred between the second and third rock vanes, but was confined to the upper third of the bank. The lower portion of the bank slope remained stable. The top layer of soil experienced the most significant level of erosional damage. In addition, on both lower rock vanes, there was evidence that the stream flow started to cut around the vane key-way. The willow transplants previously installed were not established, and therefore did not provide sufficient protection. In both cases, the transplants had slumped down the bank, but were present and intact. The opposite point bar of the meander remained intact. A thin layer of fine sand was deposited on the surface of the bar.

Station 7+00

The second cross vane remained stable with all of the top and footer rocks intact. Scour was present around the left arm, but remained shallow in a defined chute across the outer face of the point bar. Noticeable spaces were observed between the top rocks and their footer rocks which decreased the amount of predicted deposition on the upstream side of the left vane arm. The right arm remained stable, fine gravel deposition was noted along the upper bank and vane arm.

A lack of protection around the bank key was a contributing factor to the structural problem on the left arm. In this area the bank key was constructed into the streambank at an distance of 12'. The bank key, in conjunction with bioengineering, was designed 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 bank key became vulnerable to high velocities and shear stress, causing scour around the structure.

Additionally, this section of the project reach was over-excavated during construction, due to the presence of lacustrine clay in the channel bottom. The clay was removed to a depth of three feet (3') and backfilled to the final design grade with native materials. The cross vane was constructed with a controlled scour pool and functioned to provide grade control and prevent any further down cutting into the clay horizon. After several site visits following the flood event, clay was not visually present in the stream bottom or banks. Based on these observations, the structure provided sufficient protection to the channel bottom during and after the flood event. The downstream riffle remained stable, and the recently established grass remained intact along the streambank.

Station 8+00 - 11+50

The meander located between station 8+00 and 11+50 experienced similar erosion as the upper meander bend. The erosion was limited to the lower portion of the bend, occurring between the lower rock vanes. The erosion was compounded by a large tree that had been transported into the project area. The tree had become lodged on one of the rock vanes, and there was evidence that the tree deflected stream flow exacerbating the erosion. In addition, a small deposition feature resulted from the snag.

In addition to the erosion, a rock vane was severely damaged. This was the only rock structure in the project in which the structural integrity of the vane was compromised. Several top rocks had become dislodged from their footers, and prevented essential sediment deposition on the upstream portion of the structure. Excess scour downstream of the vane arm compromised the footer rocks and caused a rotational collapse along the majority of the structure. The damaged rock vane, combined with the lack of established vegetation, led to localized erosion along the streambank. Although the rock vane was damaged, it did provide limited bank protection. A loss of approximately five (5') feet was measured on the bank.

Station 11+75

The third cross vane remained in good condition and was functioning well during and after the flood event. As with several other structures, there were noticeable spaces between the top rocks and their footer rocks. This decreased the amount of predicted deposition on the upstream side of the right vane arm, but did not jeopardize its function.

Station 13+00 -15+50

The third meander, above the private bridge, functioned properly and experienced minimal levels of disturbance. The transplanted material and sod mats remained intact, and the rock vanes and w-weir functioned properly. The only concern was a small irregular shaped depositional feature, which formed behind the center rock of the w-weir. The deposition was presumably caused by the position and elevation of the center rock, and did not appear to create a problem.

Emergency Bridge Spillway

The spillway created around the North side of the private bridge experienced only minor damage. The recently established grass was stripped from the bottom of the spillway, but the elevation of the spillway remained within 2 inches of the original grade. Approximately 1 foot of bank was eroded along an isolated area along the right side of the spillway. It appeared that the spillway was effective at bypassing portions of the flood flow around the bridge structure.

Riparian Vegetation

Vegetative control is important for stabilization and erosion prevention. Much of the damage to the project site may have resulted from the lack of established vegetation. The willow transplants and sod mats provided some limited protection, but because they were installed shortly before the flood and had limited time to gain a strong root structure, they were not effective in preventing all localized scour and erosion. The installed seed and mulch was established at less than 75% cover and 2-3 inches in length.

General Stability:

The channel showed no evidence of large scale depostion (aggradation) or incision (degradation) through the reach. Stream bank erosion was present in several areas but generally remained localized. Although some damage occurred to the rock structures, all of the structures appeared to function properly during the flood flow. After thorough examination of the rock vanes, it was determined that several factors contributed to structure instability and resultant streambank erosion.

- The sediment which typically deposits along the upstream side of the rock vane arm, had not completely formed. The deposition in this area is congruent with reduced velocity along the upstream portion of the vane arm and ultimately adds to the structural stability of the vane. Several large voids were inventoried between the footer rocks and top rocks of the vane. Voids in the structures, larger than the available transported sediment, can lead to increased scour caused by the convergence of flow through areas of the structure.

- The rock vane along the second meander suffered the most damage. The primary cause of the rotational collapse is attributed to excess scour of the plunge pool immediately downstream of the structure. The scour exceeded the installation depth of the footer rocks, which may have caused the structure to partially collapse into the scour pool.

- The rock vanes were designed with an average slope of ten percent (10%). It is felt that if the slope of the structures was slightly reduced, resulting in a longer "flatter" vane arms, the vanes would provide increased stability and reduced scour.

- Significant quantities of clay were removed from the stream channel during construction. The over excavation of the clay material and saturated conditions destabilized the surface foundation for several rock structures and proved to be problematic during construction.

- The relatively short time span between the completion of the project construction and the flood event amplified the impacts noted through the reach. Minimal vegetative protection (including grass), and the intensity and magnitude of the flood event added to the destabilization. The areas that experienced the greatest damage (the lower 1/3 of the outside bank) were designed to aid in the re-direction of damaging velocities, but required the presence of strong riparian vegetation to maintain an effective system.

- Several significant debris blockages, created by floating trees from upstream areas, contributed to the damage through the project area.

Project Reach Comments and Recommendations:

- The bed substrate for the completed project consisted of a homogeneous mixture of gravel and soil material. Consideration should be given to sorting fill material in order to apply gravel and small cobble material to the channel bottom. The sorted material would provide better resistance to bed scour and assist in the natural stratification of bed materials between riffle and pool features throughout the reach.

- During construction, rock structures were inspected before they were completly backfilled to identify any large voids in the vane arms or sill. The inability to de-water the immediate area surrounding each rock structure made construction and inspection difficult. Future efforts should initiate supplemental de-watering if necessary to de-water local work areas.

- If a void is larger than the available stream sediment is detected, measures should be taken to reset the rock within the structure to minimize the voids. Alternatively large cobble (small boulder) material could be placed along the upstream face of the structure to form an obstruction over the void. In some instances all voids can not be detected or are left to remain within the structure.

- To prevent the problem of increased scour below the structures it is proposed that the top sill rocks along each of the damaged cross vanes be shifted to sit upstream, instead of being placed directly on top of the footer rock. Also the placement will reduce the rotational moment of the top sill rock and provide for a more “cascade-like“ entrance over the lip into the pool behind the structures. This modification will deviate from the sharp plunge pool that was originally built. Further this modification will assist in limiting the scour depth near the footer rocks by dissipating energy away from the foundation of the rock structures.

- Extending the rock key for critical vane structures may help prevent bank scour before vegetation becomes established. Large sills could be constructed using logs and/or rocks as suitable.

F.2 Flood Event Inspection (September 1999) - Photographs and Descriptions

Photograph 1: On September 17, 1999, flood water remained above bankfull stage. The photograph is looking downstream along the first meander bend.

Photograph 2: Stream flow remained out of bank for several days following the flood peak. High levels of turbidity and suspended sediment were present throughout the recession.

Photograph 3: The photograph is looking downstream through the right floodplain. Severla feet of water were present through the adjacent floodplain.

Photograph 4: Observations made during the flood event noted a large debris jam near the top of the project. The debris jam eventually floated onto the adjacent floodplain and became lodged against a utility pole.

Photograph 5: Looking west (left bank) along the upper meander during the recession. Stream flow is slightly above bankfull stage.

Photograph 6: Several feet of water flooded the ancillary structures on the Maier property. Note the dark line just below the small window in the photograph.

Photograph 7: The third meander bend, near the bottom of the project reach, remained stable. Gravel deposition was present to the elevation of bankfull along all of the meander bends.

Photograph 8: Flood stage nearly overtopped the bridge structure, denoted by the tree lodged against the face of the bridge. The w-weir functions to divert the majority of the stream flow during ½ bankfull stage through the left bridge opening.

Photograph 9: Erosion along the second meander bend. The erosion was compounded by a large tree that had been transported into the project area, and a single damaged rock vane.

Photograph 10: Large voids present in a rock vane along the second meander bend subsequently led to increased bank erosion and scour.

Photograph 11: Looking upstream toward the top of the project reach. Significant erosion along the streambank was attributed to the large debris jam on the floodplain. The debris on floodplain had been lodged across the channel during the flood, deflecting stream flow into the bank.

Photograph 12: Erosion along the upper meander bend was limited to the upper bank area. Rock vanes and willow transplants remained in place, despite the eorsion between the structures.

Photograph 13: Deposition of fine sand was present on streambanks where floodwater re-entered the main channel.

Photograph 14: Center Point Bar (left bank) looking east. Although scour and gravel deposition was present across the floodplain, the elevation remained consistent with the project design.

Photograph 15: Large voids present in a rock vane and excess scour downstream fo the vane arm compromised the footer rocks and caused a rotational collapse along the structure.

Photograph 16: Looking upstream along the upper cross vane arm. Noticeable spaces between the top rocks and footer rocks decreased the amount of expected deposition on the upstream side of the vane arm. The erosion behind the vane arm was caused by the large snag deflecting flow.

Photograph 17: Erosion along the second meander bend. The erosion was compounded by a large tree that had been transported into the project area, and a single damaged rock vane.

Photograph 18: Looking south toward the third cross vane. The vane functioned properly during throughout all stages of the flood flow.

F.3 Project Status: September 1999 Inspection - Survey

A monitoring survey was initiated in September of 1999 to document the project status and physical condition of the stream channel resulting from the September 16, 1999 flood event. The survey included detailed measurements of the monumented cross sections, longitudinal profile, and sediment inventories established during post-construction surveys. Data collected during the monitoring survey will be used in future analyses to compare pre-project and post-project morphological characteristics, as well as in documenting project performance and stability. Additionally, a monitored control reach located immediately adjacent to the Maier Farm project area was surveyed for use in comparative stability analyses.

The purpose of this document is to display and quantify the physical changes to project components caused by the flood event, as well as formulate recommendations for repair and/or modification as a result of erosion in the project reach. A summary of the monitoring survey, relevant data, and recommendations are provided below.

Project Site Survey

At the time of the as-built survey, six monumented cross sections were installed for use in future detailed monitoring efforts, Figure 1. Cross sections were monumented using capped rebar pins, located during the topographic survey, and recorded using GPS. Cross sections were stationed at various locations along the channel profile in order to provide monitoring for stream process and stability. The cross sections were installed through various stream features (pools, riffles, etc.) and structures in order to document stream classification, potential erosion and scour, and to document the overall channel stability. Additionally, a longitudinal profile was surveyed to include sampling of ground, water and bankfull surface elevations along the channel thalweg. Sediment inventories were conducted to document the dominant channel materials, using a modified Wolman pebble count procedure.

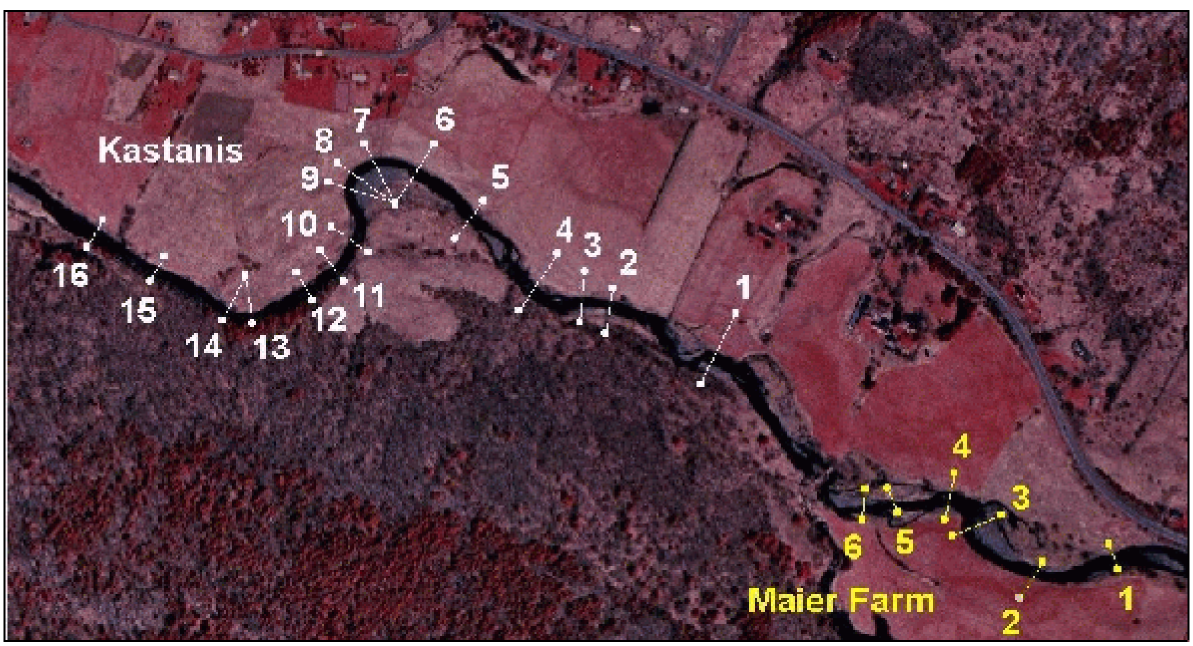


Figure 1: Approximate location of monitoring cross sections, located on a pre-restoration aerial photograph (1995).

The post-flood monitoring survey included detailed measurements of the monumented cross sections, longitudinal profile, and sediment inventories established post-construction. Pre-flood and post-flood cross sections were correlated in order to document the extent of erosion and morphological change. Additionally, pre-construction monitoring data was analyzed to provide a survey baseline. Table 1 compares selected pre-construction morphological characteristics at a single cross section.

Table 1: Selected bankfull morphological characteristics measured at cross section #1, measured pre-construction.

Date of survey	Area	Width	Max. Depth	Mean Depth
December 16, 1997	275 ft^2	68.6 ft	6.7 ft	4.0 ft
July 17, 1998	270 ft	72.9 ft	6.4 ft	3.7 ft
July 6, 1999	268 ft	77.1ft	6.6 ft	3.5ft

In addition to examining the pre-construction morphological features at the Maier Farm site, pre-flood and post-flood features were evaluated. Table 2 compared selected pre-flood and post-flood morphological characteristics at six cross sections. Changes in primary bankfull features such as area, width, and depth remained generally consistent, and within acceptable tolerances.

Table 2: Bankfull morphological characteristics measured pre-flood (post-construction) and post-flood.

Cross Section (feature)	Area		Width		Max. Depth		Mean Depth	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Section #1 - riffle	210 ft^2	215 ft^2	70.9 ft	73.3 ft	4.3 ft	5.2 ft	3.0 ft	2.9 ft
Section #2 - pool	258 ft^2	227 ft^2	79.9 ft	83.8 ft	5.7 ft	5.3 ft	3.2 ft	2.7 ft
Section #3 - riffle	265 ft^2	273 ft^2	119.2 ft	119.4 ft	5.8 ft	4.8 ft	2.2 ft	2.3 ft
Section #4 - pool	347 ft^2	277 ft^2	74.8 ft	77.4 ft	6.8 ft	5.8 ft	4.7 ft	3.6 ft
Section #5 - riffle	242 ft^2	247 ft^2	64.3 ft	72.2 ft	5.5 ft	4.8 ft	3.8 ft	3.4 ft
Section #6 - pool	272 ft^2	248 ft^2	73.3 ft	71.9 ft	7.0 ft	6.8 ft	3.7 ft	3.5 ft

Although comparisons between the pre-construction data reveal generally stable morphological parameters, continual lateral migration and erosion was present along the meander bends. Figure 2 displays correlated pre-construction cross sections. Prior to the project implementation, 35ft^2 of erosion was measured at cross section #1. During the monitoring period the largest recorded peak flow was 2,870cfs, measured at the USGS gaging station #01349900, Batavia Kill Near Ashland. In comparison, the measured erosion and morphological characteristics for six cross sections, pre-flood and post-flood are displayed in Figure 3a and Figure 3b. The post-flood survey was conducted immediately after the flood water recession and effectively related the erosion and scour directly to the flood event. Morphological characteristics remained generally consistent, although erosion was documented in varying degrees at each cross section. Comparatively the flood peaked at 15,000cfs, measured at the USGS gaging station #01349900, Batavia Kill Near Ashland.

Control Reach Survey

The "Kastanis" monitoring reach, located adjacent to the Maier Farm project, was established in July of 1998, Figure 1. The Kastanis reach includes 16 monumented cross sections, 4,300 feet of longitudinal profile, sediment inventories, and various stability indices. The reach was established as a control reach for the Maier Farm project due to similarities in valley setting, stream type, riparian vegetation, soil types, sediment characteristics, and general stream morphology.

The Kastanis reach was surveyed in July of 1998 and 1999, and again after the flood event on September 29, 1999. Pre-flood and post-flood cross sections were correlated in order to document the extent of erosion and morphological change and provide a basis for comparing the untreated reach to the Maier Farm project reach. Two cross sections, located along the meander bend used in the analysis, are displayed in Figure 4a and Figure 4b.

The comparison of pre-flood and post-flood cross sections at the Kastanis site show an evident increase in streambank erosion produced during the flood event. In most cases, the area of erosion produced by the flood event equaled or exceeded the total erosion occurring that occurred in the previous year.

Erosion Analysis

In order to draw a comparison between the erosion occurring on the project site and the control reach, pre-flood and post-flood cross sections were analyzed. Because of the variability in the location of the cross sections, a direct comparison between individual sections could not be established. Alternatively, an estimate of the total volume of soil loss along representative meander bends was made using the average end area technique for computing material volume, Table 3.

Table 3: Comparison of eroded material between the project site and the control reach.

Meander Bend Location	Total Volume Eroded	Length of Meander	Volume / Length
Maier Farm - Meander #1	7,740 ft^3	375 ft	20.6ft^3/ft
Maier Farm - Meander #2	10,080 ft^3	300 ft	33.6ft^3/ft
Maier Farm - Meander #3	225 ft^3	250 ft	0.9ft^3/ft
Kastanis Reach - Meander	54,700 ft^3	430 ft	127.2ft^3/ft

The area eroded from each cross section was applied over the length of corresponding streambank containing erosion, using field verified distances, to calculate a total volume of eroded material. In order to make comparisons independent of the meander size, the total volume of eroded material for each meander was divided by the total meander length in order to generate a volume of eroded material per length of mender.

The average volume of eroded material, per length of mender for the Maier Farm project equals 18.4ft^3/ft. A direct comparison to the Kastanis control reach of 127.2ft^3/ft, yields an overall reduction in the volume of eroded material of 81.6%. In comparing each bend independently with the meander bend on the Kastanis site, the reduction in eroded material equaled 83.8%, 73.6%, and 99.3% at each of the respective Maier Farm meander bends.

Comments & Recommendations

The comparison of pre-flood and post-flood cross sections of the project site and control reach shows that restoration significantly reduced the volume of sediment eroded from the project site. It is felt that with minor modifications to the design and construction of the rock structures, along with complete installation and establishment of the bioengineering components the resulting erosion would have been additionally reduced.

After review of the project site inspections and available site data, it was determined that repairs could be initiated to the project site without the need for re-design and complete re-construction. The following recommendations were generated to provide a basis for project repair and modification:

- All rock structures which contain voids between top rocks and/or footer rocks larger than the available channel sediment should be re-inspected before repair. During repair work, vane rocks should be adjusted as needed to reduce the size of the voids. Additional material should be used to fill any remaining voids. In general, large cobble material should be used as fill, and placed along the upstream face of the vane arm along each structure.

- Bank keys should be extended, as applicable, to a total distance of twenty feet from the top of the vane structure, perpendicular to the streambank. The extended bank keys will add bank scour protection in the event of another large flow event until rooted vegetation can become established.

- Eroded areas should be re-established to an approximate pre-flood condition. The toe of the bank should consist of large cobble material filled with bank-run gravel to establish an adequate slope.

- Gravel deposition in the area of the first rock vane should be excavated to re-establish adequate cross sectional dimension, and used as fill material as needed along the adjacent eroded streambank.

- Remove large debris from floodplain areas. Salvage material, as applicable, for use in bank keys and supplemental rootwad installations.

- Re-grade the central point bar to bankfull stage by filling in areas of surface scour. Re-grading the pont bar will maintain uniform conditions during out-of-bank flow until rooted vegetation can become established and provide adequate stability.

- Large rock material should be added to the tip of rock structures, where applicable, to lengthen the vane arm and slightly reduce the vane slope. Longer, flatter vane arms should provide increased bank protection by re-directing a larger percentage of stream flow within the active channel.

- The center rock, in the right sill, of the w-weir should be re-set to eliminate the depositional feature which formed during the flood event.

- The emergency spillway should be re-graded by filling in areas of surface scour.

- Three of the willow transplants damaged during the flood event should be replaced.
- Bioengineering installed as detailed in original design.
- Re-seed and mulch in all disturbed areas following the repair work.

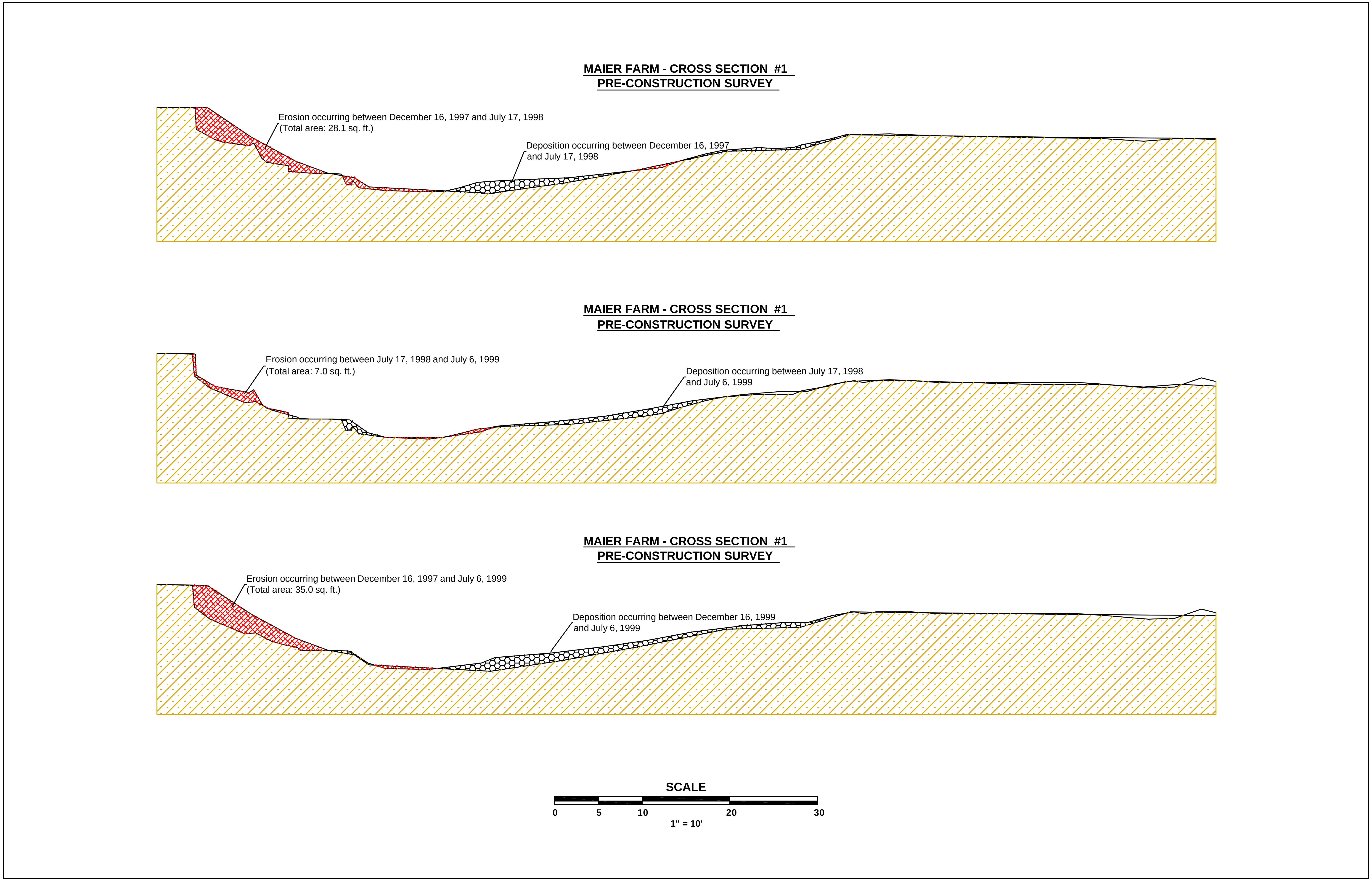


Figure 2: Monitored cross sections surveyed at the Maier Farm site pre-construction (Scale: 1" = 10').

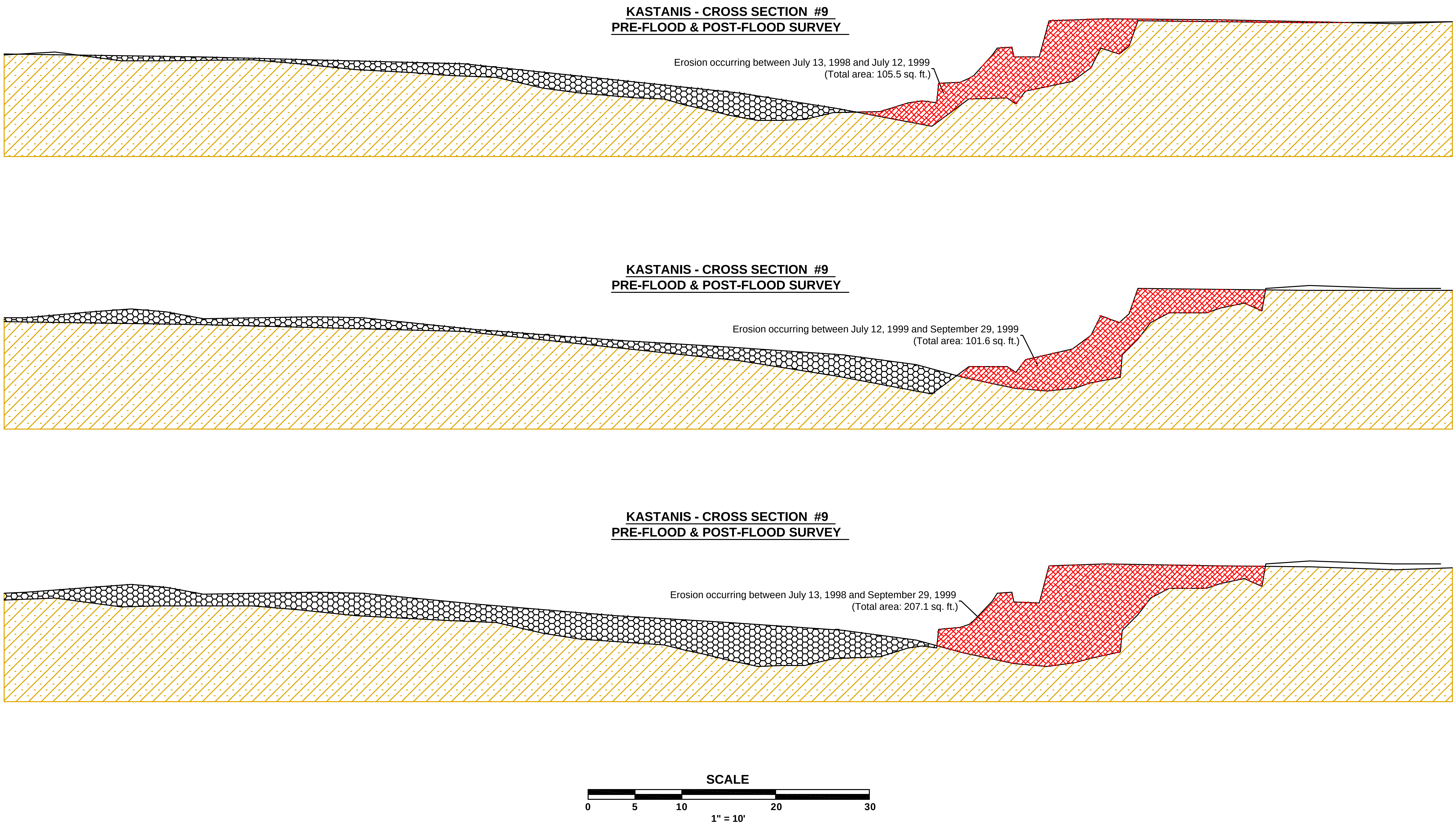


Figure 4b: Monitored cross sections surveyed at the Kastanis site (control) pre-flood and post-flood (Scale: 1" = 10').

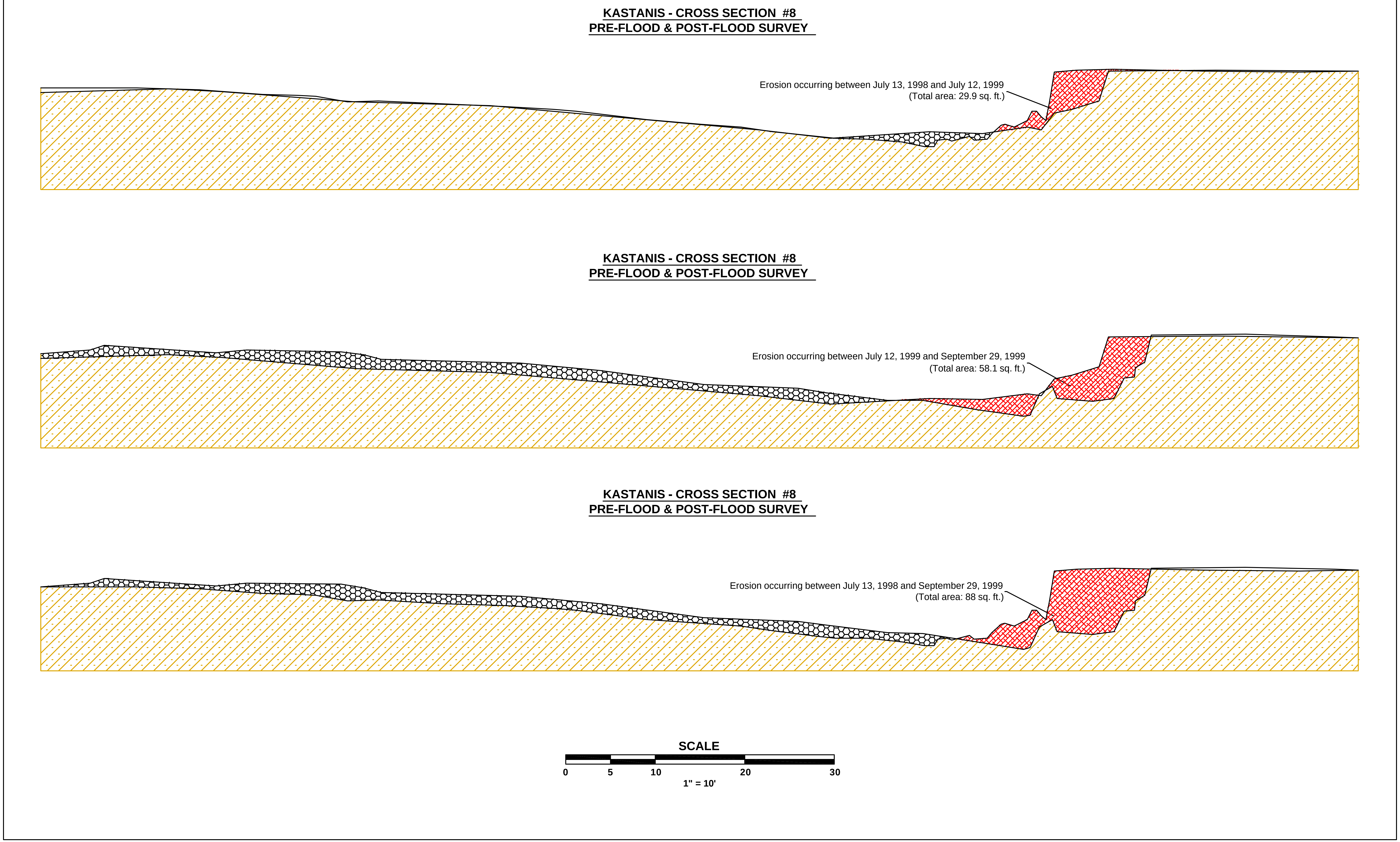


Figure 4a: Monitored cross sections surveyed at the Kastanis site (control) pre-flood and post-flood (Scale: 1" = 10').

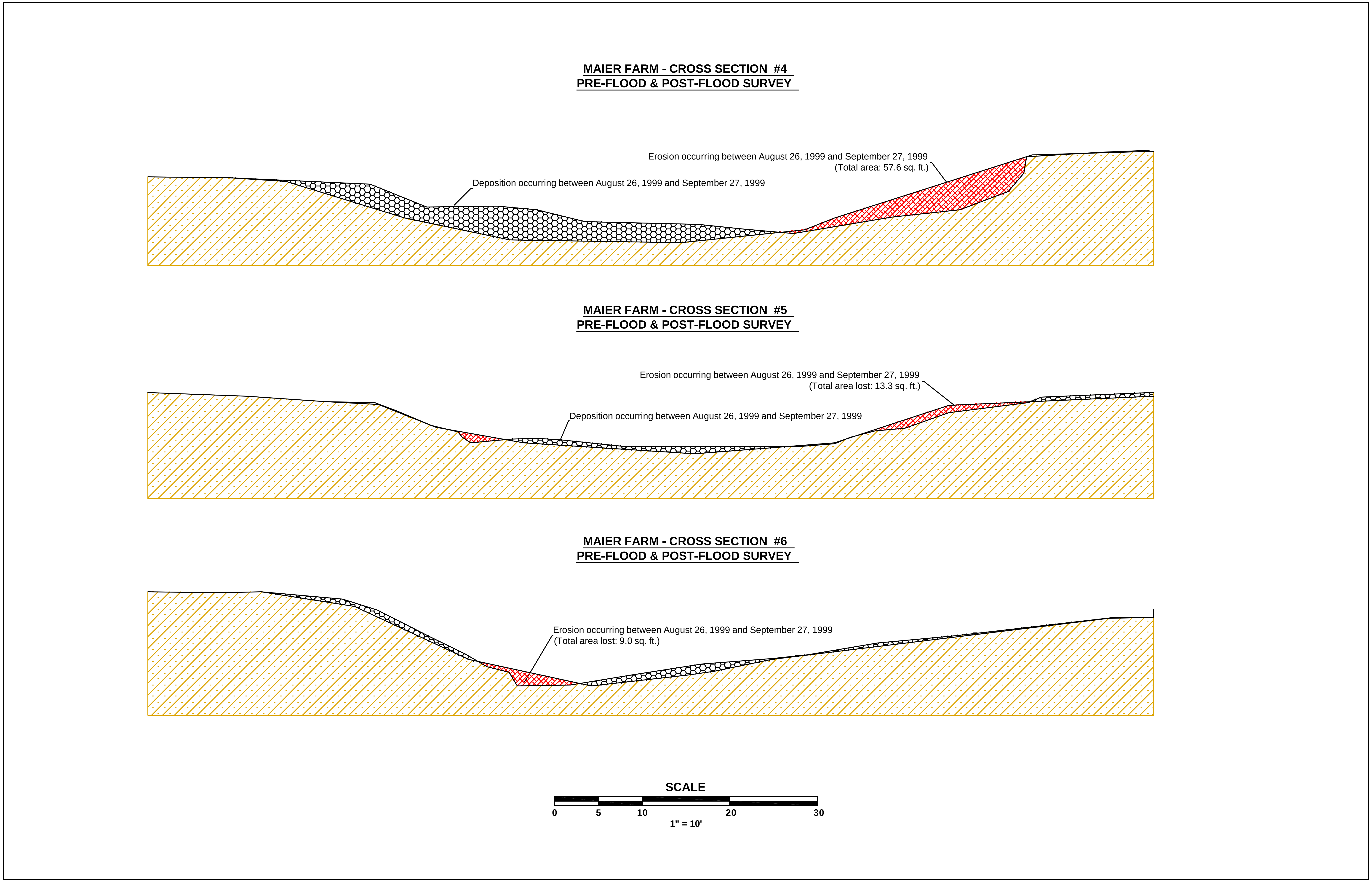


Figure 3b: Monitored cross sections surveyed at the Maier Farm site pre-flood and post-flood (Scale: 1" = 10').

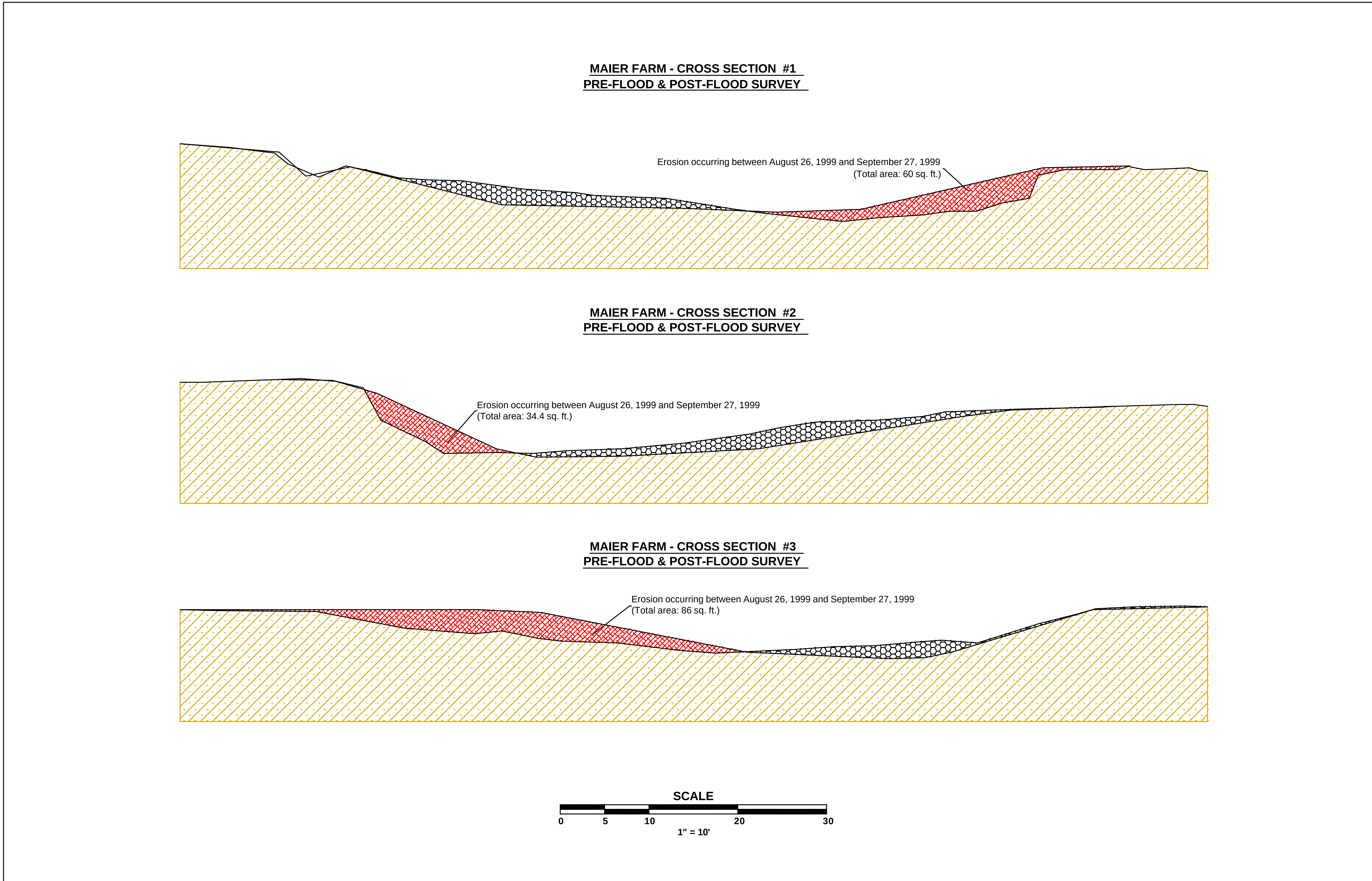


Figure 3a: Monitored cross sections surveyed at the Maier Farm site pre-flood and post-flood (Scale: 1" = 10').

F.4 Project Status: Project Modification/Repair (October 1999)

In October of 1999, following recommendations made during the post-flood project inspection, project repair work was initiated through the Maier Farm project site. Modifications were made in stages during the first two weeks of October, with supplemental vegetative plantings installed by district staff and volunteers continuing into November. The purpose of this document is to describe the specific project modifications, implementation details and costs associated with the repair and modification of the Maier Farm project. Photographs of the project repair are included in Appendix F.4.

Project Repair

The repair and modifications to the project were implemented under permit extensions of the original permits from NYSDEC, USACOE, and NYCDEP. Reviewing agencies were notified of the repair work, and required that the work be completed in accordance with the original project permits. The project repair and modifications were made without the need for extensive project de-watering, and were completed by working from the top of the streambanks. Property access was approved using a continuation of the landowner agreements and site access was established using temporary access roads used during the initial construction.

Fastracs and Van Etten Trucking were contracted to complete the repair work, with District staff providing construction management and supervision. Equipment used to complete the repair work included a large excavator with a hydraulic thumb attachment, front end loader, small bulldozer, farm tractor, and a small excavator. The repair lasted approximately seven working days.

Repair / Modification Implementation

The following provides a summary of the repair and modification activities:

- Rock structures were inspected for displaced rocks, gaps, and voids occurring in the structure. Existing rocks were adjusted, as needed, to reduce the size of any gaps. Additional material was placed within and behind the vane arms to fill remaining voids. Large cobble (6"-18") was obtained from a local gravel bank and used to fill the voids along the upstream portion of the vane arms.

- Bank keys were extended, as applicable, to a distance of approximately twenty feet from the top of the vane structure, perpendicular to the streambank. The material was completely buried below the bankfull elevation.

- Eroded areas were re-established to an approximate pre-flood condition. The bank toe was established with large cobble material, and placed using an excavator from the top of the bank. The cobble material was placed along the bank toe to isolate the work area from the active channel. Bank run gravel was added to the cobble material, to establish an adequate bank slope.

- The gravel deposition in the area of the first rock vane was excavated to the elevation of the active water surface, and used as additional fill material. The material was re-graded to establish an adequate cross sectional area.

- Three (3) large snags, that were carried by the flood into the project reach, were salvaged and used as root-wads. The root-wads were placed in the high stress areas along meanders to provide additional bank protection. The root-wads were located along the lower third of the meander bends where applicable.

- The point bar near the center of the project was re-graded to the bankfull elevation by filling in areas scoured by the flood water.

- Large rocks were added to the tip of several structures to slightly lengthen the vane arms and reduce the slope.

- The center rock, in the right sill of the w-weir, was re-set to a lower elevation.

- The emergency spillway was re-graded by filling in areas scoured by the flood water.

- Damaged willow transplants were replaced in three locations.

- Live fascines and willow stakes were installed as outlined in the original project design. Bioengineering was supplemented with additional plantings by volunteers and District staff.

- Disturbed areas were seeded and mulched upon completion.

Repair / Modification Summary

Although rock and fill material used in the repair work was transported to the site using the existing access roads, handling of the material on-site was difficult. The site conditions, combined with active channel flow, required the material to be handled several times before final placement, which delayed the repair and resulted in increased repair cost.

Inspection of the rock structures was difficult without completely de-watering of the channel. Although it is felt that the majority of the structures containing voids were repaired, continued monitoring and site inspections should be conducted to monitor the structures for future scour.

Excavation within the active stream channel was prohibited by the regulatory agencies without complete de-watering. Large rocks placed at the tip of several vane arms were unable to be set on footer rocks, due to the active channel flow. Continued monitoring and site inspections should be conducted to monitor the structures for future scour.

Project Repair Cost

Project repair costs were estimated at $35,000 to include both equipment, material, and labor. Repair work was performed under a time and materials contract with Fastracs, Inc. and Van Etten Trucking. The final project repair cost was $36,723.84 which did not include construction management and labor by the District staff. Final repair costs are summarized in Table 1.

Table 1: Itemized project repair/modification cost for the Maier Farm project.

Item	Final Cost
Contractual Costs	$17,217.90
Material Cost	$11,450.94
Equipment Rental	$8,055.00
GCSWCD staff	$6,485.16
Total	**$43,209.00**

Recommendations

It is recommended that the project continue to be monitored and inspected on a regular basis in order to document changes present within the project area.

F.4.a Project Modification/Repair (October 1999) - Photographs and Descriptions

Photograph 1: Modifications and repair was made to the project in October 1999. Repairs were made from the top of the streambank during active channel flow.

Photograph 2: Bioengineering was installed to include willow fascines and stakes. The photograph shows an example of a completed fascine installation prior to backfilling.

Photograph 3: Volunteers from local Trout Unlimited chapters assist in installing supplemental bioengineering in the floodplain.

Photograph 4: The photograph shows a section of completed streambank. Cobble material used to re-establish the bank toe, and fill material to establish the bank slope, are visible above the water surface. Bioengineering components are visible along the top section of bank.

Photograph 5: All disturbed areas were seeded and mulched upon completion of the bioengineering.

Photograph 6: Volunteers from local Trout Unlimited chapters assist in installing supplemental bioengineering in the floodplain.

F.5 Project Status: 2000 Inspection - Survey

Site Inspection and Monitoring Survey

In July of 2000, the project site was inspected and surveyed by GCSWCD staff in order to review the project status and to document the physical condition and stability of the stream channel. The inspection included a review of the overall stability, rock structures, and riparian vegetation. The monitoring survey included surveying the monumented cross sections and complete longitudinal profile, performing pebble counts and a bar sample. A summary of the inspection results and recommendations are provided below. Photographs taken during various site visits in 2000 are included in Appendix B6.

Rock Structures:

Inspection of the rock structures revealed no visual damage, erosion, or problems associated with the structures. Minor voids in the vane arms and sills were noted, allowing small volumes of water to penetrate the structures during low flow periods, but do not seem to pose any significant problems to the structural integrity or function of the vane. Deposition along the upstream portion of the vane arms appears normal and the vanes all appear to be functioning properly during various flow stages. The structures appear to be effective at reducing the erosion and scour which potentially would have resulted prior to the installation of the project.

A single rock vane at station 09+75, on the meander near the center of the reach, has remained damaged since the 1999 flood event. The structure currently provides minimal protection to the streambank and minor bank erosion is present surrounding the structure. The w-weir appears to be functioning properly, no visible change to the structure was noted other than moderate sediment deposition downstream of the right invert. Sediment deposition in this area is expected during low to moderate flow events.

Riparian Vegetation:

Bioengineering was installed during the project repair in the fall 1999, and supplemented with riparian plantings by the Watershed Agricultural Program. The bioengineering included willow fascines and stakes and was supplemented with various rooted tree species. The seedlings were placed along the top of the streambanks and adjacent floodplain areas, and included the use of protective tree tubes.

In general, the bioengineering and plantings are becoming established despite heavy browsing of the bioengineering by deer. It is expected that mild browsing will result in increased generation of plant rooting and subsequent plant top growth once the plants become established. The extent of the browsing should be monitored and mitigated if necessary until the plantings become established.

Recommendations include:

- Enhancing bioengineering and riparian planting's as needed.
- Continued monitoring and inspection for signs of over browsing.

Channel Stability:

The channel showed no evidence of large-scale deposition (aggradation) or incision (degradation) through the reach. Some stream bank cutting and erosion occurring at station 09+75 (middle meander where the rock vane is in need of repair. It is felt that this erosion is minimal and localized between the two other effective rock vanes. Further, no glacial clay is visibly present in the channel bottom or stream boundary.

Visual inspection of the reaches located upstream and downstream of the project area indicates no evidence of accelerated erosion, deposition, or incision.

Recommendations include:

- Evaluate the streambank erosion located near station 09+75.
- Repair and modify the rock vane, as need, to prevent further erosion

Private Bridge:

Although the private bridge structure, located at the bottom of the project reach, remains in poor structural condition, there was no evidence of channel instability surrounding the structure. The bridge openings appear to be transporting stream flow and sediment, as staged by the w-weir. No debris had collected or was inventoried blocking the either bridge opening. The emergency spillway remained intact and vegetated, with no signs of erosion.

Project Reach Survey

A monitoring survey was initiated in July of 2000 to document the annual project status and physical condition of the stream channel. The monitoring included surveying the 6 monumented cross sections and complete longitudinal profile, performing composite pebble counts, and a summary of conditions. The dimensions presented represent changes occurring during the monitoring period as well as modifications made during the project modifications and repair in 1999.

Cross Section Survey

At the time of the as-built survey, six monumented cross sections were installed for use in future detailed monitoring efforts. Cross sections were monumented using capped rebar pins which are located in the topographic survey as well as recorded using GPS. Cross sections were stationed at various locations along the channel profile in order to provide monitoring for stream process and stability. The cross sections were installed through various stream features (pools, riffles, etc.) and structures in order to document stream classification, potential erosion and scour, and to document the overall channel stability. A summary of cross sectional data is presented in Table 1.

Caution must be made in performing direct comparisons between the post-flood survey and the 2000 monitoring survey, since no survey data was collected immediately after the project modifications were made. The values presented in Table 2 are averages taken from multiple cross sections. Values for riffle comparisons were obtained from cross sections 1, 3 and 5 while values for pool comparisons were obtained from cross sections 2, 4, and 6.

Table 1: Summary of bankfull cross section dimensions, July 2000.

Cross Section	Station	Feature	Area (ft.)	Width (ft.)	Max. Depth (ft.)	Mean Depth (ft.)
1	01+16	Riffle	209.7	79.0	4.9	2.7
2	04+36	Pool	224.5	84.0	5.3	2.7
3	07+67	Riffle	267.1	120.9	4.8	2.2
4	10+06	Pool	278.9	90.0	6.4	3.1
5	12+80	Riffle	289.1	79.0	4.8	3.7
6	14+14	Pool	234.7	71.5	7.4	3.3
Average Riffles			255.3	93.0	4.8	2.8
Average Pools			246.0	81.8	6.4	3.0
Reach Average			250.7	87.4	5.6	2.9

Table 2: Summary of bankfull cross sectional measurements.

Variable	Existing Channel	Proposed Channel	Asbuilt 1999	Post-flood 1999	Survey 2000
Stream Type	C4	C4	C4	C4	C4
Area (ft^2)	236.0	235.0	239.2	245.1	255.3
Width (ft)	175.2	61.3	84.8	88.3	93.0
Mean Depth (ft)	1.4	3.9	3.0	2.9	2.8
Max Depth (ft)	3.5	5.3	5.2	5.0	4.8
Pool Area (ft^2)	273.9	288.6	292.7	250.6	246.0
Max Pool Depth (ft)	6.8	8.8	6.5	6.0	6.4

Longitudinal Profile

The longitudinal profile survey included the sampling of ground and water surface elevations along the slope breaks of the thalweg. The 1999 and 2000 survey included a detailed profile beginning and ending at the top and bottom of the project reach. Bankfull elevations were added by reviewing cross sectional data and transposing the bankfulll elevation and station to the longitudinal profile.

The stationing along the thalweg of each channel varies between the two years resulting from the selection of features by the field staff and minor changes in thalweg plan form.

Channel Pattern

Channel alignment changes were analyzed by reviewing the cross sections and lateral alignment of the thalweg of the stream profile. Although minor erosion and deposition were noted through isolated areas of the project reach there appears to be no evidence of unstable lateral migration or plan form change of meander radius, meander length, or sinuosity.

Sediment Characteristics

Pavement samples within the bankfull channel were collected during the survey of the reach. Random sampling techniques were used through the entire reach to generate a composite sample, as well as samples obtained along independent cross sections. The inventory included the sampling at cross section #1 (riffle) and #5 (pool) feature (Table 3).

Table 3: Comparision of sediment samples taken July 2000 at selected cross sections.

Dominant Particle Size	Cross Section #1 (Riffle)	Cross Section #5 (Pool)
D_{95}	494mm	83mm
D_{85}	156mm	59mm
D_{50}	49mm	29mm
D_{35}	35mm	15mm
D_{15}	19mm	0.4mm

F.5 2000 Inspection: Photographs and Descriptions

Photograph 1: Looking upstream from cross section #2 toward cross section #1. Vegetation is becoming established along the meander bend.

Photograph 2: Looking downstream from cross section #2 toward cross section #3. Vegetation is becoming established along the meander bend.

Photograph 3: View upstream of first meander with vane in foreground and 1st point bar on left.

Photograph 4: In general, the bioengineering and plantings are becoming established despite heavy browsing of the bioengineering by deer.

Photograph 5: The w-weir appears to be functioning properly, no visible change to the structure was noted other than moderate sediment deposition downstream of the right invert. Sediment deposition in this area is expected during low to moderate flow events.

Photograph 6: Aerial image taken in the summer of 2000 showing the project reach.

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

NYCDEP STREAM MANAGEMENT PROGRAM

"MAIER FARM" STREAM RESTORATION PROJECT

2000 MONITORING SURVEY

INDEX OF DRAWINGS

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REVISIONS

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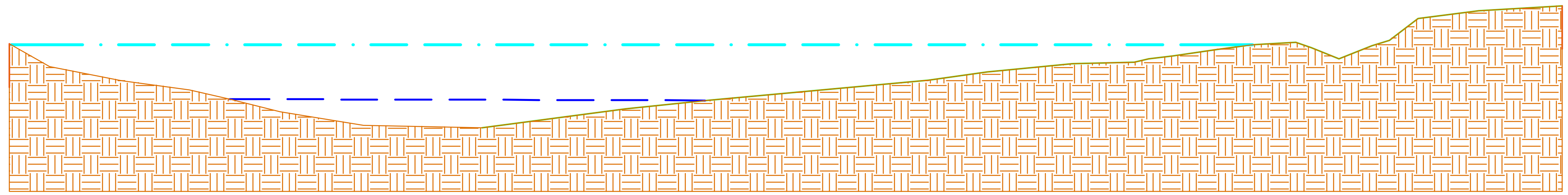
MAIER FARM
FOR
ACOE
STATE ROUTE 23A
TOWN OF ASHLAND GREENE COUNTY, NY
TITLE SHEET

PROJECT:
DATE: 3/10/06
SCALE: AS NOTED
DRAWN BY: JRB/MM
DESIGN BY:

DRAWING: MF-1

SHEET 1 OF 3



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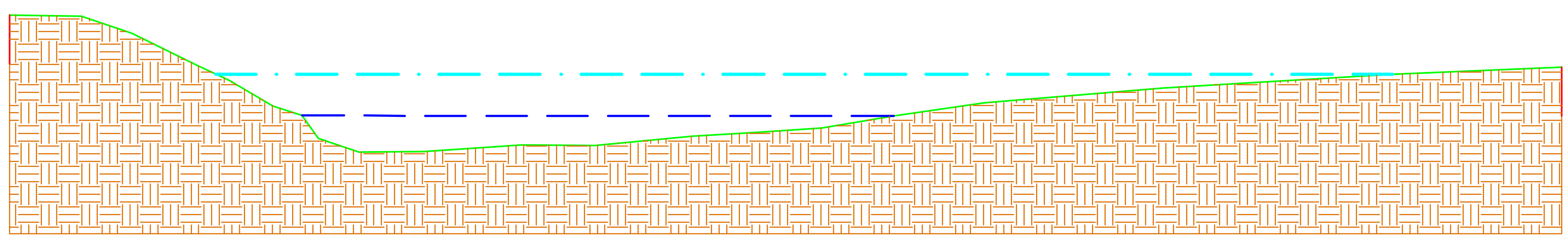

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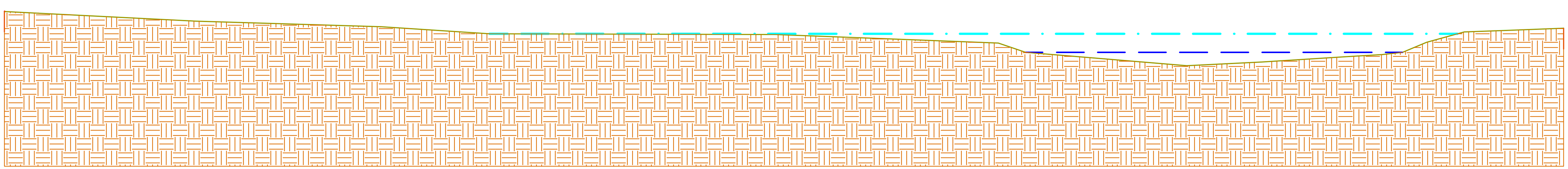

CROSS SECTION 3

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MAIER FARM

FOR

ACOE

STATE ROUTE 23A

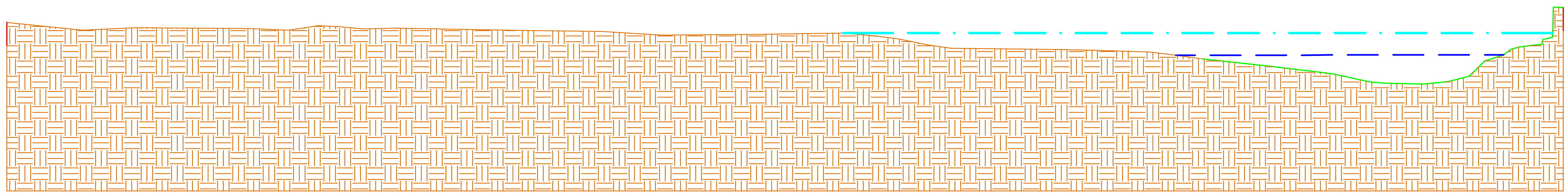
TOWN OF ASHLAND — GREENE COUNTY, NY

CROSS SECTIONS 1-3

PROJECT:
DATE: 3/10/06
SCALE: AS NOTED
DRAWN BY: JRB/MM
DESIGN BY:

DRAWING: **MF-2**

SHEET 2 OF 4



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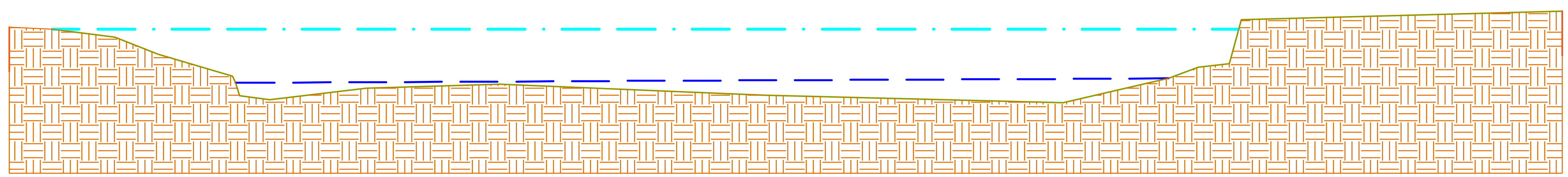

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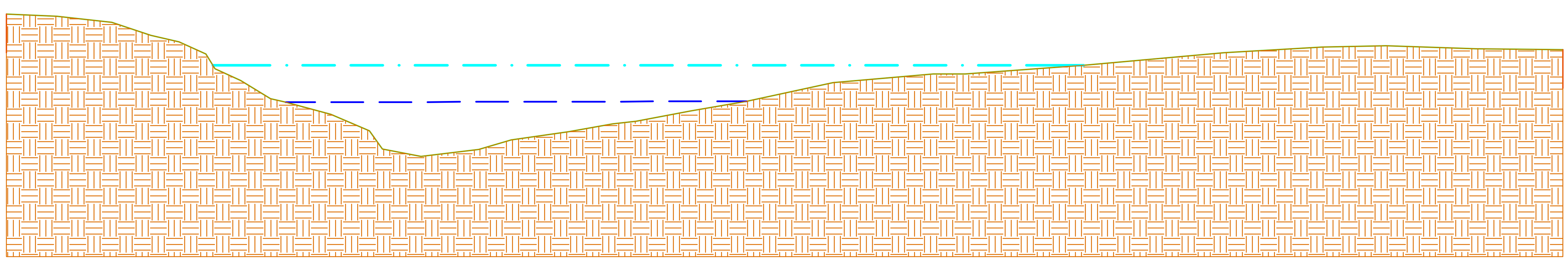

CROSS SECTION 6

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MAIER FARM
FOR
ACOE
STATE ROUTE 23A

TOWN OF ASHLAND — GREENE COUNTY, NY

CROSS SECTION 4-6

PROJECT:
DATE: 3/10/06
SCALE: AS NOTED
DRAWN BY: JRB/MM
DESIGN BY:

DRAWING:
MF-3

SHEET 3 OF 3

F.6 Project Status: 2002 Inspection - Survey

Site Inspection and Monitoring Survey

In August of 2002 the project site was inspected and surveyed by GCSWCD staff in order to review the project status and to document the physical condition and stability of the stream channel. The inspection included a review of the overall stability, rock structures, and riparian vegetation. The monitoring survey included surveying the monumented cross sections and complete longitudinal profile, performing pebble counts and a bar sample. A summary of the inspection results and recommendations is provided below. Photographs taken during various site visits in 2002 are included in Appendix F.6.

Rock Structures:

Inspection of the cross vanes revealed no visual damage, erosion, or problems associated with the structures. Minor voids in the vane arms and sills were noted, allowing small volumes of water to penetrate the structures during low flow periods but do not seem to pose any significant problems with the structural integrity or vane function. Regular deposition along the upstream portions of the vane arms appears normal and the vanes all appear to be functioning properly during various flow stages. The cross vanes appear to be effective at reducing the erosion and scour which potentially would have resulted prior to the installation of the project.

A single rock vane at station 09+75, on the meander near the center of the reach, has remained damaged since the 1999 flood event. The structure currently provides minimal protection to the streambank. Although minor erosion is still present, vegetation has increasingly become established around the structure and appears to be preventing erosion during moderate and low stream flow.

The w-weir appears to be functioning properly, no visible change to the structure was noted other than moderate sediment deposition downstream of the right invert. Sediment deposition in this area is expected during low to moderate flow events and will potentially return to its asbuilt condition following larger flows.

Riparian Vegetation:

The installed vegetation included willow fascines and willow stakes which were placed along the streambanks after the September 1999 flood event, as well as sod mats and conservation grasses which were applied along streambanks and adjacent floodplain areas prior to the flood event. The bioengineering was supplemented with additional post-flood plantings and various rooted tree species by volunteers, as well as by the Watershed Agricultural Program. The seedlings were placed along the top of the streambanks and adjacent floodplain areas, and included the use of protective tree tubes.

The bioengineering and planting appear to be establishing despite heavy browsing by deer. It is expected that mild browsing will result in increased generation of plant rooting and subsequent plant top growth once the plants become established. The extent of the browsing should be monitored and mitigated if necessary until the plantings become established.

The majority of the large transplanted willow clumps have died back, but small amounts of new growth is present near the base of the plant. The sod mat installations are vigorous and appear to be fully established.

Recommendations include:

- Enhancing bioengineering and riparian planting's as needed.
- Selective pruning of the large transplanted willow clumps to promote new growth and establishment.
- Continued monitoring and inspection for signs of willow blight and over browsing.

Channel Stability:

The channel showed no evidence of large-scale deposition (aggradation) or incision (degradation) through the reach. Some stream bank cutting and erosion was observed to be occurring at station 9+75 (middle meander where the vane failed). It is felt that this erosion is minimal and localized between the two other effective rock vanes. Further, no glacial clays are visibly present in the channel bottom or stream.

Visual inspection of the reaches located upstream and downstream of the project area indicates no evidence apparent erosion, deposition, or accelerated lateral migration. The inspections have not shown any visual indication of turbidity in the adjacent reaches.

Recommendations include:

- Evaluate erosion from stream bank at station 9+75.

Private Bridge:

Although the private bridge structure, located at the bottom of the project reach, remains in poor structural condition, there was no evidence of channel instability surrounding the structure. The bridge openings appear to be transporting stream flow and sediment, as staged by the w-weir. No debris had collected or was inventoried blocking the either bridge opening. The emergency spillway remained intact and vegetated, with no signs of erosion.

Project Reach Survey:

A monitoring survey was initiated in July of 2002 to document the annual project status and physical condition of the stream channel. The monitoring included surveying the 6 monumented cross sections and complete longitudinal profile, performing composite pebble counts, and a summary of conditions. The dimensions presented represent changes occurring during the monitoring period from July 2001 to August 2002.

Cross Section Survey

At the time of the as-built survey, six monumented cross sections were installed for use in future detailed monitoring efforts. Cross sections were monumented using capped rebar pins which are located in the topographic survey as well as recorded using GPS. Cross sections were stationed at various locations along the channel profile in order to provide monitoring for stream process and stability. The cross sections were installed through various stream features (pools, riffles, etc.) and structures in order to document stream classification, potential erosion and scour, and to document the overall channel stability. A summary of cross sectional data is presented in Table 1.

Table 1: Summary of bankfull cross section dimensions, August 2002.

Cross Section	Feature	Area (ft.)	Width (ft.)	Max. Depth (ft.)	Mean Depth (ft.)
1	Riffle	225.9	79.5	5.2	2.8
2	Pool	242.8	83.4	5.9	2.9
3	Riffle	258.7	120.5	4.6	2.2
4	Pool	313.0	92.7	6.8	3.4
5	Riffle	280.9	78.8	4.4	3.6
6	Pool	244.4	72.5	7.1	3.4
Average Riffles		255.2	93.0	4.7	2.9
Average Pools		266.7	82.8	6.6	3.2
Reach Average		261.0	87.9	5.7	3.0

The values presented in Table 2, are averages taken from multiple cross sections. Values for riffle comparisons were obtained from cross sections 1, 3 and 5 while values for pool comparisons were obtained from cross sections 2, 4, and 6.

Table 2: Summary of bankfull cross sectional measurements.

Variable	Proposed Channel	Asbuilt 1999	Post-flood 1999	Survey 2000	Survey 2002
Stream Type	C4	C4	C4	C4	C4
Area (ft^2)	235.0	239.2	245.1	255.3	255.2
Width (ft)	61.3	84.8	88.3	93.0	93.0
Mean Depth (ft)	3.9	3.0	2.9	2.8	2.9
Max Depth (ft)	5.3	5.2	5.0	4.8	4.7
Pool Area (ft^2)	288.6	292.7	250.6	246.0	266.7
Max Pool Depth (ft)	8.8	6.5	6.0	6.4	6.8

Longitudinal Profile

The longitudinal profile survey included the sampling of ground and water surface elevations along the slope breaks of the thalweg. The 2002 survey included a detailed profile beginning and ending at the top and bottom of the project reach. Bankfull elevations were added by reviewing cross sectional data and transposing the bankfulll elevation and station to the longitudinal profile.

The stationing along the thalweg of each channel varies between the years resulting from the selection of features by the field staff and minor changes in thalweg plan form.

Channel Pattern

Channel alignment changes were analyzed by reviewing the cross sections and lateral alignment of the thalweg of the stream profile. Although minor erosion and deposition were noted through isolated areas of the project reach there appears to be no evidence of unstable lateral migration or plan form change of meander radius, meander length, or sinuosity.

Sediment Characteristics

Pavement samples within the bankfull channel were collected during the survey of the reach. Random sampling techniques were used through the entire reach to generate a composite sample, as well as samples obtained along independent cross sections. The inventory included the sampling at cross section #1 (riffle) and #5 (pool) feature, Table 3.

Table 3: Comparision of sediment samples taken August 2002 at selected cross sections.

Dominant Particle Size	Cross Section #1 (Riffle)	Cross Section #5 (Pool)
D_{95}	384mm	77mm
D_{85}	88mm	51mm
D_{50}	41mm	23mm
D_{35}	28mm	15mm
D_{15}	0.9mm	6mm

F.6 2002 Inspection: Photographs and Descriptions

Photograph 1:	Upstream of the project area, looking upstream from the CR 17 bridge. The stage is approximately 3/4 bankfull.
Photograph 2:	The top of the project reach looking upstream from the first cross vane.
Photograph 3:	Looking upstream from the first meander bend toward the top of the project.
Photograph 4:	Looking downstream along the first meander bend.
Photograph 5:	Meander bend in the middle of the project reach.
Photograph 6:	Looking upstream from the bridge area along the third meander bend.

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

NYCDEP STREAM MANAGEMENT PROGRAM

"MAIER FARM" STREAM RESTORATION PROJECT

2002 MONITORING SURVEY

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REVISIONS

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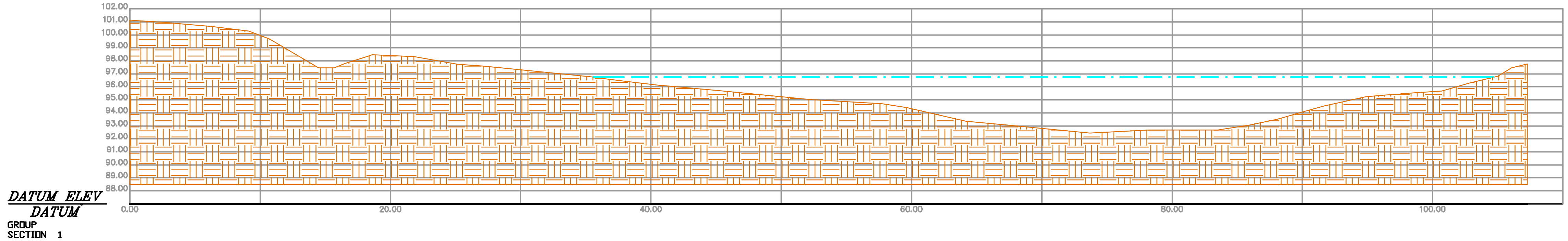
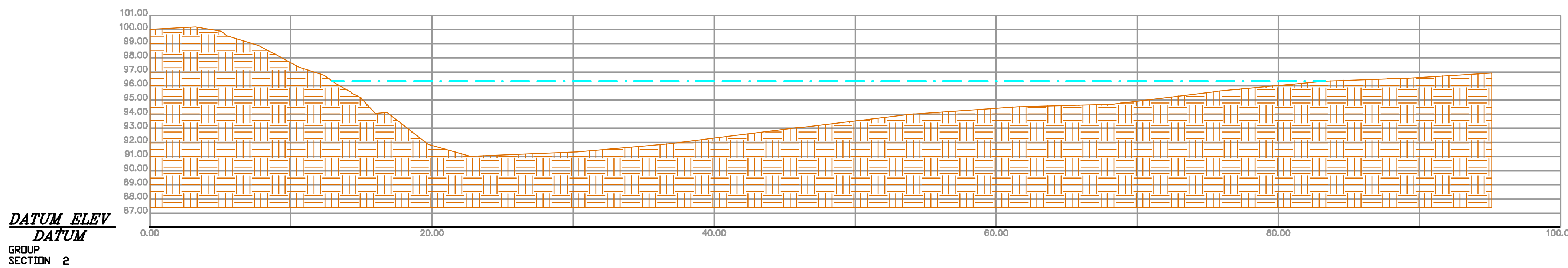
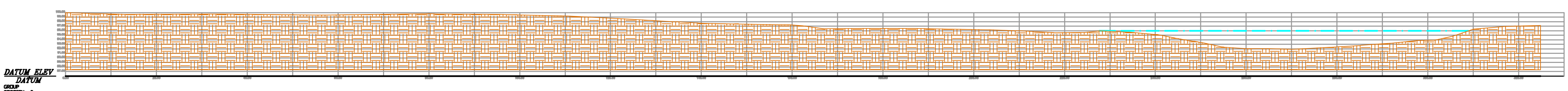
MAIER FARM
FOR
ACOE
STATE ROUTE 23A
TOWN OF ASHLAND
GREENE COUNTY, NY
TITLE SHEET

PROJECT:
DATE: 3/10/06
SCALE: AS NOTED
DRAWN BY: JRB/MM
DESIGN BY:

DRAWING:
MF-1
SHEET 1 OF 4







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MAIER FARM
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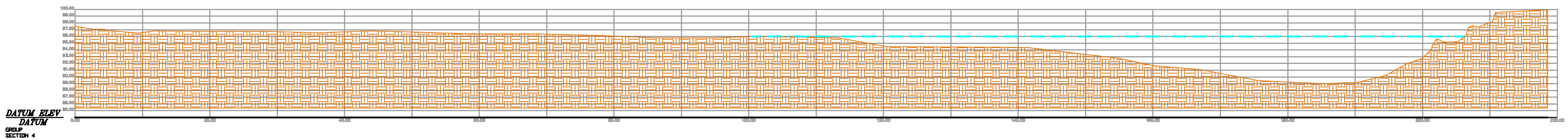
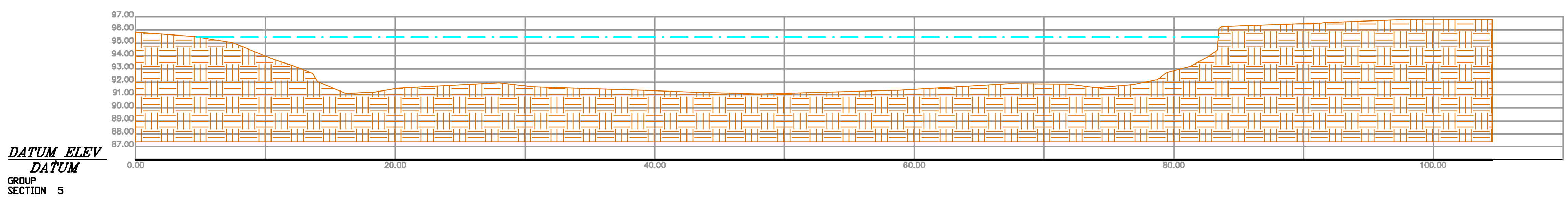
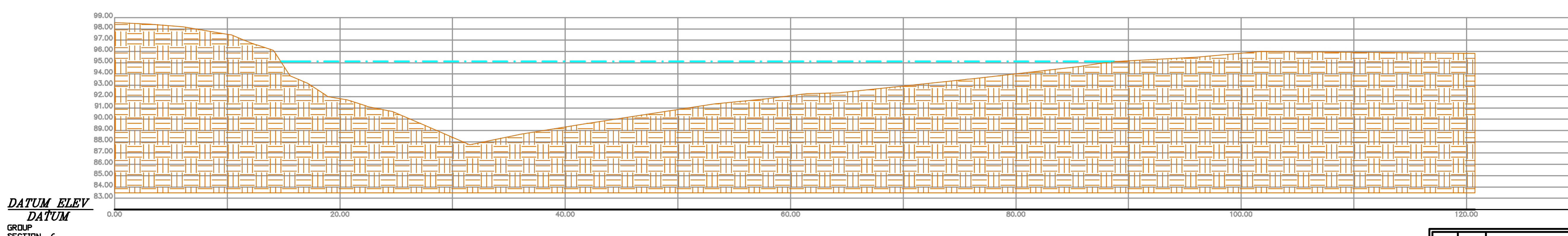
CROSS SECTIONS 1-3

PROJECT:
DATE: 3/10/06
SCALE: AS NOTED
DRAWN BY: JRB/MM
DESIGN BY:

DRAWING:
MF-2
SHEET 2 OF 4







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MAIER FARM
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STATE ROUTE 23A
TOWN OF ASHLAND GREENE COUNTY, NY

CROSS SECTIONS 4-6

PROJECT:
DATE: 3/10/06
SCALE: AS NOTED
DRAWN BY: JRB/MM
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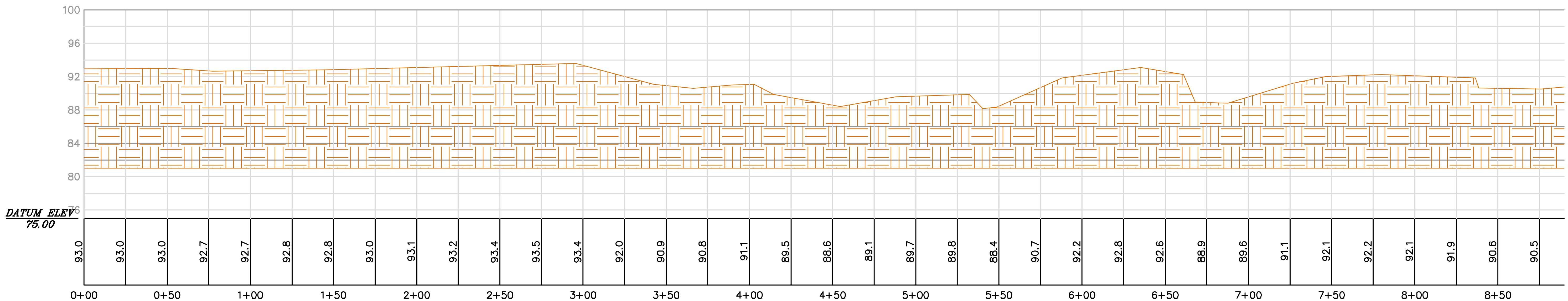
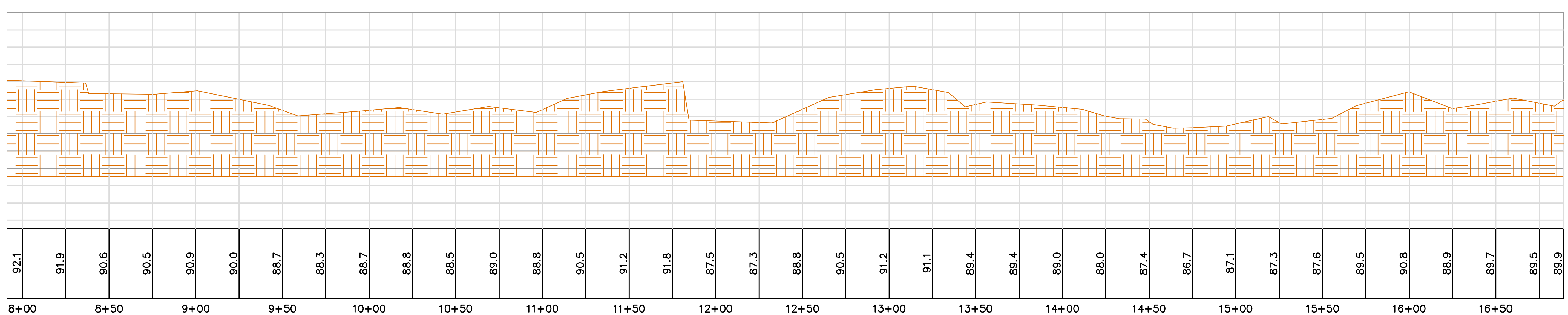
DRAWING:
MF-3
SHEET 3 OF 4





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MAIER FARM
FOR
ACOE
STATE ROUTE 23A
TOWN OF ASHLAND
GREENE COUNTY, NY

PROFILE

PROJECT:
DATE: 3/10/06
SCALE: AS NOTED
DRAWN BY: JRB/MM
DESIGN BY:

DRAWING:
MF-4

SHEET 4 OF 4

F.7 Project Status: 2003 Inspection - Survey

Site Inspection and Monitoring Survey

In June of 2003 the project site was inspected and surveyed by GCSWCD staff in order to review the project status and to document the physical condition and stability of the stream channel. The inspection included a review of the overall stability, rock structures, and riparian vegetation. The monitoring survey included surveying the monumented cross sections and complete longitudinal profile, performing pebble counts and a bar sample. A summary of the inspection results and recommendations is provided below. Photographs taken during various site visits in 2003 are included in Appendix F.7.

Rock Structures:

Inspection of the cross vanes revealed no visual damage, erosion, or problems associated with the structures. Minor voids in the vane arms and sills were noted, allowing small volumes of water to penetrate the structures during low flow periods but do not seem to pose any significant problems with the structural integrity or vane function. Regular deposition along the upstream portions of the vane arms appears normal and the vanes all appear to be functioning properly during various flow stages.

A single rock vane at station 09+75, on the meander near the center of the reach, has remained damaged since the 1999 flood event. The structure currently provides minimal protection to the streambank. Although minor erosion is still present, vegetation has increasing become established around the structure and appears to preventing erosion during moderate and low stream flow.

The w-weir appears to be functioning properly, no visible change to the structure was noted other than moderate sediment deposition downstream of the right invert. Sediment deposition in this area is expected during low to moderate flow events and may potentially return to the asbuilt condition following larger flows

Riparian Vegetation:

The installed vegetation included willow fascines and willow stakes which were placed along the streambanks after the September 1999 flood event, as well as sod mats and conservation grasses which were applied along streambanks and adjacent floodplain areas prior to the flood event. The bioengineering was supplemented with additional post-flood plantings and various rooted tree species by volunteers, as well as by the Watershed Agricultural Program. The seedlings were placed along the top of the streambanks and adjacent floodplain areas, and included the use of protective tree tubes.

The bioengineering and plantings appear to be establishing despite heavy browsing by deer. It is expected that mild browsing will result in increased generation of plant rooting and subsequent plant top growth once the plants become established. The extent of the browsing should be monitored and mitigated if necessary until the plantings become established.

The majority of the large transplanted willow clumps have died back, but small amounts of new growth is present near the base of the plant. The sod mat installations are vigorous and appear to be fully established.

Recommendations include:

- Enhancing bioengineering and riparian planting's as needed.
- Selective pruning of the large transplanted willow clumps to promote new growth and establishment.
- Continued monitoring and inspection for signs of willow blight and over browsing.

Channel Stability:

The channel showed no evidence of large-scale deposition (aggradation) or incision (degradation) through the reach. Some stream bank cutting and erosion occurring at station 9+75 (middle meander where the vane failed. It is felt that this erosion is minimal and localized between the two other effective rock vanes. Further, no glacial clays are visibly present in the channel bottom or stream.

Visual inspection of the reaches located upstream and downstream of the project area indicates no evidence of significant apparent erosion, deposition, or accelerated lateral migration. Immediately upstream of the project reach, there is evidence of the formation of a center bar. This may be attributed to increased erosion of upstream reaches including the Ashland -Connector reach. The inspections have not shown any visual indication of turbidity in the adjacent reaches.

Recommendations include:

- Evaluate erosion from stream bank at station 9+75 and determine applicability of repairs.

Private Bridge:

Although the private bridge structure, located at the bottom of the project reach, remains in poor structural condition, there was no evidence of channel instability surrounding the structure. The bridge openings appear to be transporting stream flow and sediment, as staged by the w-weir. No debris had collected or was inventoried blocking the either bridge opening. The emergency spillway remained intact and vegetated, with no signs of erosion.

Project Reach Survey:

A monitoring survey was initiated in June of 2003 to document the annual project status and physical condition of the stream channel. The monitoring included surveying the 6 monumented cross sections and complete longitudinal profile, performing composite pebble counts, bar sample, and a summary of conditions. The dimensions presented represent changes occurring during the monitoring period from August 2002 to June 2003.

Cross Section Survey

At the time of the as-built survey, six monumented cross sections were installed for use in future detailed monitoring efforts. Cross sections were monumented using capped rebar pins which are located in the topographic survey as well as recorded using GPS. Cross sections were stationed at various locations along the channel profile in order to provide monitoring for stream process and stability. The cross sections were installed through various stream features (pools, riffles, etc.) and structures in order to document stream classification, potential erosion and scour, and to document

Table 1: Summary of bankfull cross section dimensions, June 2003.

Cross Section	Feature	Area (ft.)	Width (ft.)	Max. Depth (ft.)	Mean Depth (ft.)
1	Riffle	219.5	79.7	5.1	2.8
2	Pool	239.7	83.6	6.2	2.9
3	Riffle	260.2	116.2	5.0	2.2
4	Pool	324.3	108.5	7.0	3.0
5	Riffle	280.0	79.6	4.6	3.5
6	Pool	241.9	73.3	7.3	3.3
Average Riffles		253.2	91.8	4.9	2.8
Average Pools		268.6	88.5	6.8	3.1
Reach Average		260.9	90.2	5.9	2.9

the overall channel stability. A summary of cross sectional data is presented in Table 1.

The values presented in Table 2, are averages taken from multiple cross sections. Values for riffle comparisons were obtained from cross sections 1, 3 and 5 while values for pool comparisons were obtained from cross sections 2, 4, and 6.

Table 2: Summary of bankfull cross sectional measurements.

Variable	Asbuilt 1999	Post-flood 1999	Survey 2000	Survey 2002	Survey 2003
Stream Type	C4	C4	C4	C4	C4
Area (ft^2)	239.2	245.1	255.3	255.2	253.2
Width (ft)	84.8	88.3	93.0	93.0	91.8
Mean Depth (ft)	3.0	2.9	2.8	2.9	2.8
Max Depth (ft)	5.2	5.0	4.8	4.7	4.9
Pool Area (ft^2)	292.7	250.6	246.0	266.7	268.6
Max Pool Depth (ft)	6.5	6.0	6.4	6.6	6.8

Longitudinal Profile

The longitudinal profile survey included the sampling of bankfull, ground, and water surface elevations along the slope breaks of the thalweg. The 2003 survey included a detailed profile beginning and ending at the top and bottom of the project reach. The stationing along the thalweg of each channel varies between the two years resulting from the selection of features by the field staff and minor changes in thalweg plan form.

Channel Pattern

Channel alignment changes were analyzed by reviewing the cross sections and lateral alignment of the thalweg of the stream profile. Although minor erosion and deposition were noted through isolated areas of the project reach there appears to be no evidence of unstable lateral migration or plan form change of meander radius, meander length, or sinuosity.

Sediment Characteristics

Pavement samples within the bankfull channel were collected during the survey of the reach. Random sampling techniques were used through the entire reach to generate a composite sample, as well as samples obtained along independent cross sections (Table 3). The inventory included independent sampling at cross section #1 (riffle) and cross section #5 (pool).

Table 3: Comparision of sediment samples taken August 2003 at selected cross sections.

Dominant Particle Size	Composite	Cross Section #1 (Riffle)	Cross Section #5 (Pool)
D_{95}	330mm	312mm	65mm
D_{85}	87mm	130mm	41mm
D_{50}	36mm	39mm	17mm
D_{35}	26mm	27mm	1.7mm
D_{15}	0.3mm	13mm	0.14mm

A gravel bar sample was collected (table 4) to be used as a surrogate for stream subpavement particle size. This sample was collected according to the procedure utilized for the "bottomless bucket method." This procedure to this approach is as follows: locate the sampling site along the lower 1/3 of a meander bend at an elevation equal to the thalweg elevation plus one half the elevation difference between the thalweg and bankfull elevations, locate the two largest particles that may be mobile at bankfull flow in the vicinity and average their intermediate axis, excavate and collect all material from an area the size of the mouth of a standard five gallon pail to a depth equal to twice the average intermediate axis of the two aforementioned particles, finally, wet sieve the material to obtain the particle size distribution. This analysis produces values that are used in various classification equations and may be used in conjunction with the pebble counts to help determine particle size distributions of the stream pavement and sub-pavement.

Table 4: Gravel bar sample

Dominant Particle Size	Bar Sample
D_{95}	36.04mm
D_{85}	25.94mm
D_{50}	6.97mm
D_{35}	2.73mm
D_{15}	0.48mm

F.7 2003 Inspection: Photographs and Descriptions

Photograph 1:	A moderate flow event on March 18, 2003 cresting at approximately 3/4 bankfull stage. The photograph was taken along the first meander bend looking downstream.
Photograph 2:	The photograph was taken from the first meander bend looking downstream toward the center of the project.
Photograph 3:	The photograph was taken looking downstream from cross section #5. The cross vane appears to be functioning properly, gravel deposition in the foreground remains consistent with the bankfulll elevation.
Photograph 4:	The rock vanes along the third meander appear to be functioning properly. The photograph was taken looking downstream along the third meander.
Photograph 5:	The w-weir upstream of the bridge was assisting to split stream flow at the bridge approach.
Photograph 6:	Construction (demolition) debris was noted along the perimeter of the constructed floodplain pond.
Photograph 7:	A moderate flow event on June 03, 2003 cresting at approximately 3/4 bankfull stage. The photograph was taken from the top of the project looking downstream toward the first meander bend.
Photograph 8:	The photograph was taken looking downstream along the first meander bend.
Photograph 9:	The photograph was taken looking upstream along the first meander bend.
Photograph 10:	A single rock vane at station 09+75, on the meander near the center of the reach, has remained damaged since the 1999 flood event. The structure currently provides minimal protection to the streambank. Although minor erosion is still present, vegetation has increasing become established around the structure and appears to preventing erosion during moderate and low stream flow.
Photograph 11:	The photograph was taken looking upstream from the private bridge.
Photograph 12:	A significant amount of construction (demolition) debris was noted surrounding the perimeter of the constructed floodplain pond.

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2003 MONITORING SURVEY

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MAIER FARM
FOR
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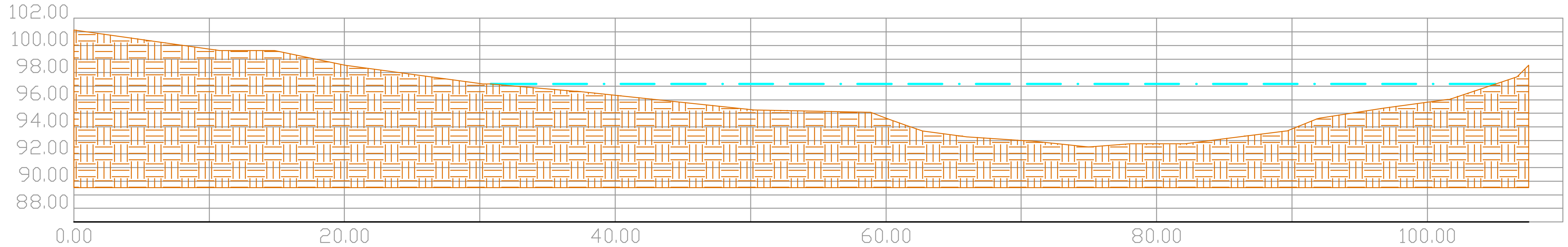
STATE ROUTE 23A
TOWN OF ASHLAND
GREENE COUNTY, NY
TITLE SHEET

PROJECT:
DATE: 3/10/06
SCALE: AS NOTED
DRAWN BY: JRB/MM
DESIGN BY:

DRAWING: MF-1

SHEET 1 OF 4



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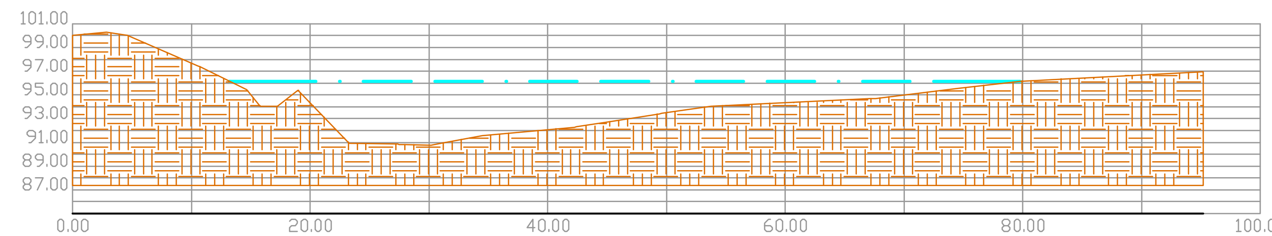

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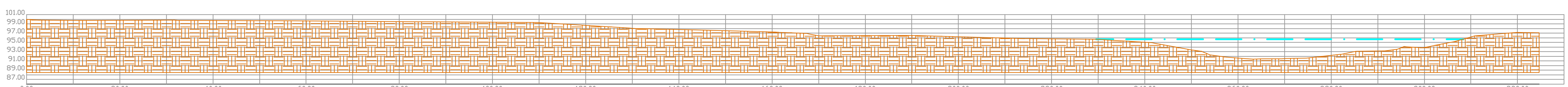

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CROSS SECTIONS 1-3

PROJECT:
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SCALE: AS NOTED
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DESIGN BY:

DRAWING:
MF-2
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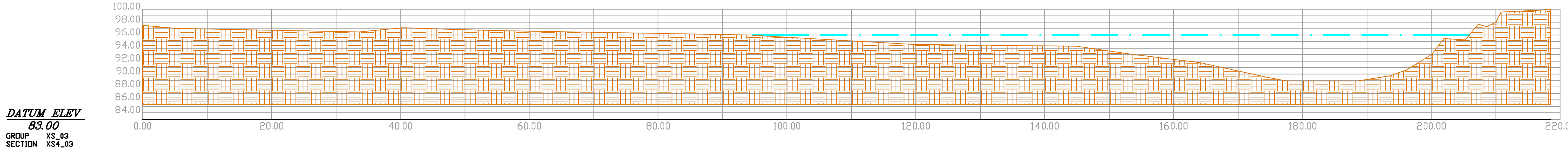

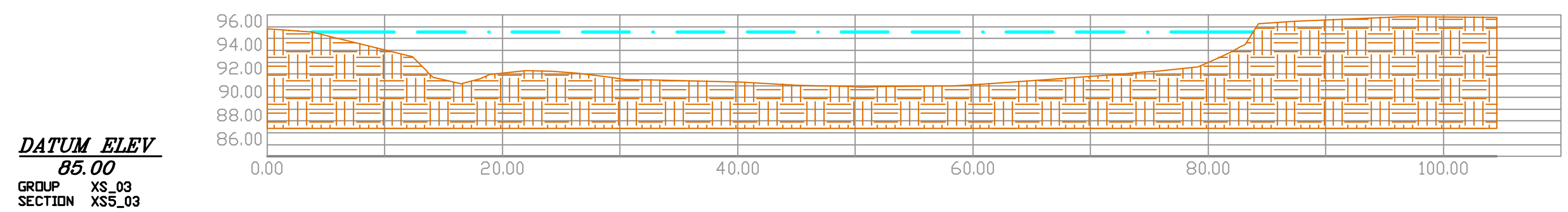

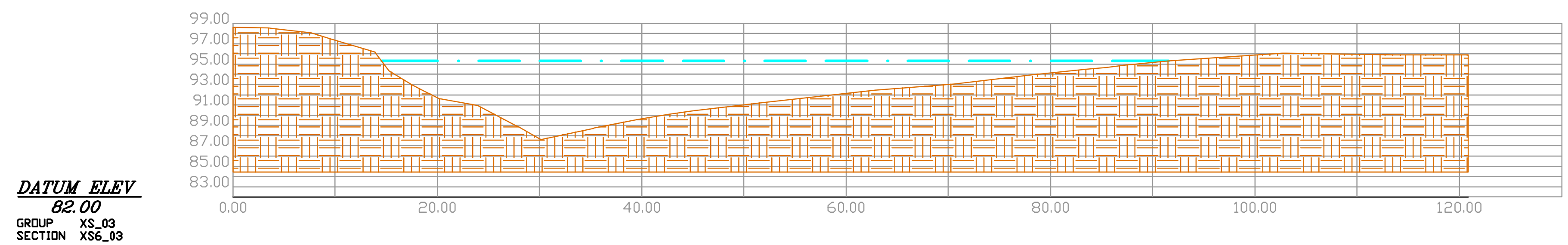

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MAIER FARM
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CROSS SECTIONS 4-6

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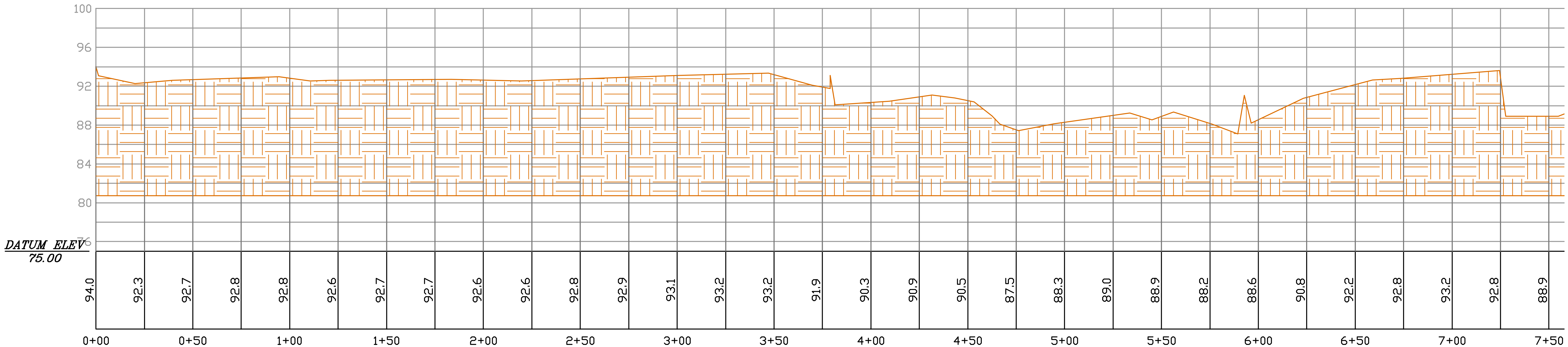

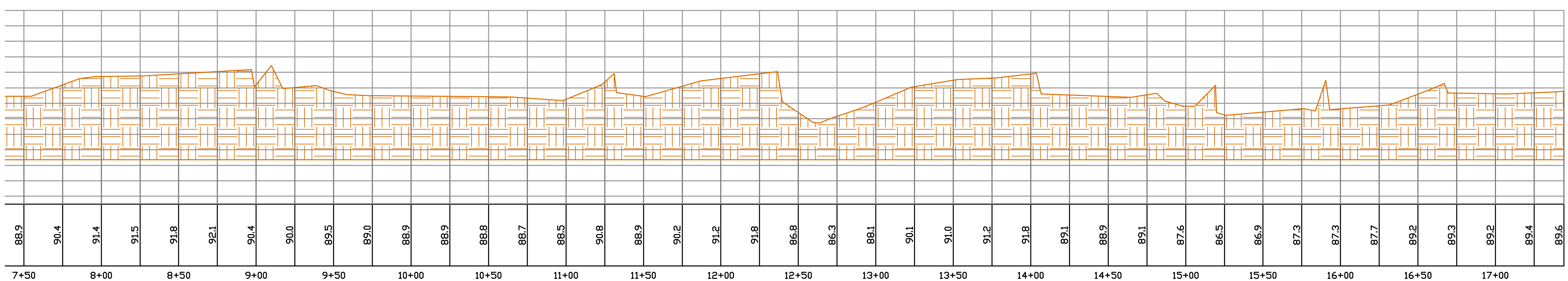

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MAIER FARM
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PROFILE

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SCALE: AS NOTED
DRAWN BY: JRB/MM
DESIGN BY:

DRAWING:
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F.8 Project Status: 2004 Inspection - Survey
Site Inspection and Monitoring Survey

In June of 2004 the project site was inspected and surveyed by GCSWCD staff in order to review the project status and to document the physical condition and stability of the stream channel. The inspection included a review of the overall stability, rock structures, and riparian vegetation. The monitoring survey included surveying the monumented cross sections and complete longitudinal profile, performing pebble counts and a bar sample. A summary of the inspection results and recommendations is provided below. Photographs taken during various site visits in *2004* are included in Appendix F.8.

Rock Structures:

Inspection of the cross vanes revealed no visual damage, erosion, or problems associated with the structures. Minor voids in the vane arms and sills were noted, allowing small volumes of water to penetrate the structures during low flow periods but do not seem to pose any significant problems with the structural integrity or vane function. Regular deposition along the upstream portions of the vane arms appears normal and the vanes all appear to be functioning properly during various flow stages.

A single rock vane at station 09+75, on the meander near the center of the reach, has remained damaged since the 1999 flood event. The structure currently provides minimal protection to the streambank. Although minor erosion is still present, vegetation has increasing become established around the structure and appears to preventing erosion during moderate and low stream flow.

The w-weir appears to be functioning properly, no visible change to the structure was noted other than moderate sediment deposition downstream of the right invert. Sediment deposition in this area is expected during low to moderate flow events. This may potentially return to the asbuilt condition following larger flows.

Riparian Vegetation:

The installed vegetation included willow fascines and willow stakes which were placed along the streambanks after the September 1999 flood event, as well as sod mats and conservation grasses which were applied along streambanks and adjacent floodplain areas prior to the flood event. The bioengineering was supplemented with additional post-flood plantings and various rooted tree species by volunteers, as well as by the Watershed Agricultural Program. The seedlings were placed along the top of the streambanks and adjacent floodplain areas, and included the use of protective tree tubes.

The bioengineering and plantings appear to be establishing despite heavy browsing by deer. It is expected that mild browsing will result in increased generation of plant rooting and subsequent plant top growth once the plants become established. The extent of the browsing should be monitored and mitigated if necessary until the plantings become established.

The majority of the large transplanted willow clumps have died back, but small amounts of new growth is present near the base of the plant. The sod mat installations are vigorous and appear to be fully established.

Recommendations include:

- Enhancing bioengineering and riparian planting's as needed.
- Selective pruning of the large transplanted willow clumps to promote new growth and establishment.
- Continued monitoring and inspection for signs of willow blight and over browsing.

Channel Stability:

The channel showed no evidence of large-scale deposition (aggradation) or incision (degradation) through the reach. Some stream bank cutting and erosion occurring at station 9+75 (middle meander where the vane failed. It is felt that this erosion is minimal and localized between the two other effective rock vanes. Further no glacial clays visibly present in the channel bottom or stream.

Visual inspection of the reaches located upstream and downstream of the project area indicates no evidence apparent erosion, deposition, or accelerated lateral migration. The inspections have not shown any visual indication of turbidity in the adjacent reaches.

Recommendations include:

- Evaluate erosion from stream bank at station 9+75.

Private Bridge:

Although the private bridge structure, located at the bottom of the project reach, remains in poor structural condition, there was no evidence of channel instability surrounding the structure. The bridge openings appear to be transporting stream flow and sediment, as staged by the w-weir. No debris had collected or was inventoried blocking the either bridge opening. The emergency spillway remained intact and vegetated, with no signs of erosion.

Project Reach Survey:

A monitoring survey was initiated in June of 2004 to document the annual project status and physical condition of the stream channel. The monitoring included surveying the 6 monumented cross sections and complete longitudinal profile, performing composite pebble counts, bar sample, and a summary of conditions. The dimensions presented represent changes occurring during the monitoring period from 2003 to 2004

Cross Section Survey

At the time of the as-built survey, six monumented cross sections were installed for use in future detailed monitoring efforts. Cross sections were monumented using capped rebar pins which are located in the topographic survey as well as recorded using GPS. Cross sections were stationed at various locations along the channel profile in order to provide monitoring for stream process and stability. The cross sections were installed through various stream features (pools, riffles, etc.) and structures in order to document stream classification, potential erosion and scour, and to document the overall channel stability. A summary of cross sectional data is presented in Table 1.

Table 1: Summary of bankfull cross section dimensions, June 2004.

Cross Section	Feature	Area (ft.)	Width (ft.)	Max. Depth (ft.)	Mean Depth (ft.)
1	Riffle	164.2	70.9	4.3	2.3
2	Pool	225.2	69.6	5.8	3.2
3	Riffle	190.6	79.4	4.5	2.4
4	Pool	308.0	89.9	6.9	3.4
5	Riffle	305.1	82.1	5.2	3.7
6	Pool	277.0	75.2	7.6	3.7
Average Riffles		220.0	77.5	4.7	2.8
Average Pools		270.1	78.3	6.8	3.4
Reach Average		245.0	77.8	5.7	3.1

The values presented in Table 2, are averages taken from multiple cross sections. Values for riffle comparisons were obtained from cross sections 1, 3 and 5 while values for pool comparisons were obtained from cross sections 2, 4, and 6.

Table 2: Summary of bankfull cross sectional measurements.

Variable	Asbuilt 1999	Post-flood 1999	Survey 2000	Survey 2002	Survey 2003	Survey 2004
Stream Type	C4	C4	C4	C4	C4	C4
Area (ft^2)	239.2	245.1	255.3	255.2	253.2	220.0
Width (ft)	84.8	88.3	93.0	93.0	91.8	77.5
Mean Depth (ft)	3.0	2.9	2.8	2.9	2.8	2.8
Max Depth (ft)	5.2	5.0	4.8	4.7	4.9	4.7
Pool Area (ft^2)	292.7	250.6	246.0	266.7	268.6	270.1
Max Pool Depth (ft)	6.5	6.0	6.4	6.6	6.8	6.8

Longitudinal Profile

The longitudinal profile survey included the sampling of bankfull, ground, and water surface elevations along the slope breaks of the thalweg. The 2004 survey included a detailed profile beginning and ending at the top and bottom of the project reach. The stationing along the thalweg of each channel varies between the two years resulting from the selection of features by the field staff and minor changes in thalweg plan form.

Channel Pattern

Channel alignment changes were analyzed by reviewing the cross sections and lateral alignment of the thalweg of the stream profile. Although minor erosion and deposition were noted through isolated areas of the project reach there appears to be no evidence of unstable lateral migration or plan form change of meander radius, meander length, or sinuosity.

Sediment Characteristics

Pavement samples within the bankfull channel were collected during the survey of the reach. Random sampling techniques were used through the entire reach to generate a composite sample, as well as samples obtained along independent cross sections (Table 3). The inventory included independent sampling at cross section #1 (riffle) and cross section #5 (pool).

Table 3: Comparision of sediment samples taken August 2002 at selected cross sections.

Dominant Particle Size	Composite	Cross Section #1 (Riffle)	Cross Section #5 (Pool)
D_{95}	330mm	312mm	65mm
D_{85}	87mm	130mm	41mm
D_{50}	36mm	39mm	17mm
D_{35}	26mm	27mm	1.7mm
D_{15}	0.3mm	13mm	0.14mm

A gravel bar sample was collected (table 4) to be used as a surrogate for stream subpavement particle size. This sample was collected according to the procedure utilized for the “bottomless bucket method.” This procedure to this approach is as follows: locate the sampling site along the lower 1/3 of a meander bend at an elevation equal to the thalweg elevation plus one half the elevation difference between the thalweg and bankfull elevations, locate the two largest particles that may be mobile at bankfull flow in the vicinity and average their intermediate axis, excavate and collect all material from an area the size of the mouth of a standard five gallon pail to a depth equal to twice the average intermediate axis of the two aforementioned particles, finally, wet sieve the material to obtain the particle size distribution. This analysis produces values that are used in various classification equations and may be used in conjunction with the pebble counts to help determine particle size distributions of the stream pavement and sub-pavement.

Table 4: Gravel bar sample

Dominant Particle Size	Bar Sample
D_{95}	24.08mm
D_{85}	15.33mm
D_{50}	5.86mm
D_{35}	3.01mm
D_{15}	0.38mm

F.8 2004 Inspection: Photographs and Descriptions

Photograph 1:	Image looking upstream of project reach displaying stability.
Photograph 2:	Looking downstream at first meander bend displaying minor erosion of left bank.
Photograph 3:	Looking downstream at second meander bend noting grass type vegetation establishment.
Photograph 4:	Looking upstream at second meander and cross vane noting knotweed establishment in foreground
Photograph 5:	Image looking upstream at W-weir and third meander bend from Maier Farm Bridge .
Photograph 6:	Image looking downstream of reach from Maier Farm Bridge.

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MAIER FARM
FOR
ACOE
STATE ROUTE 23A

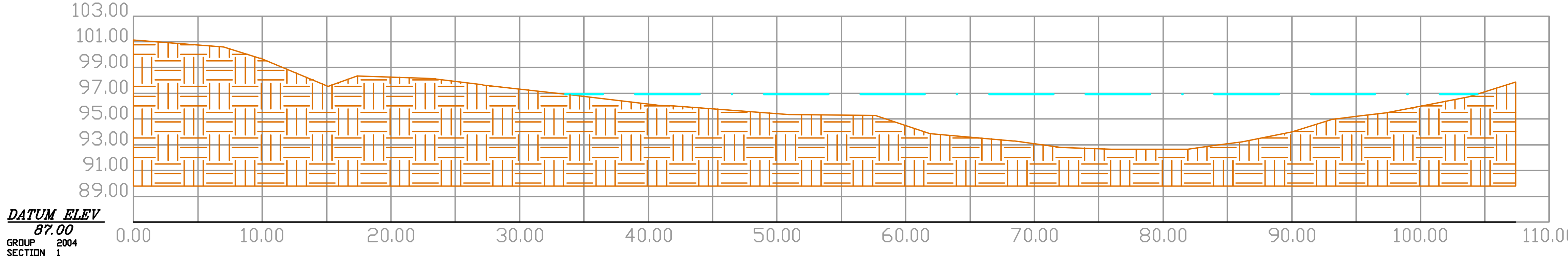
TOWN OF ASHLAND — GREENE COUNTY, NY

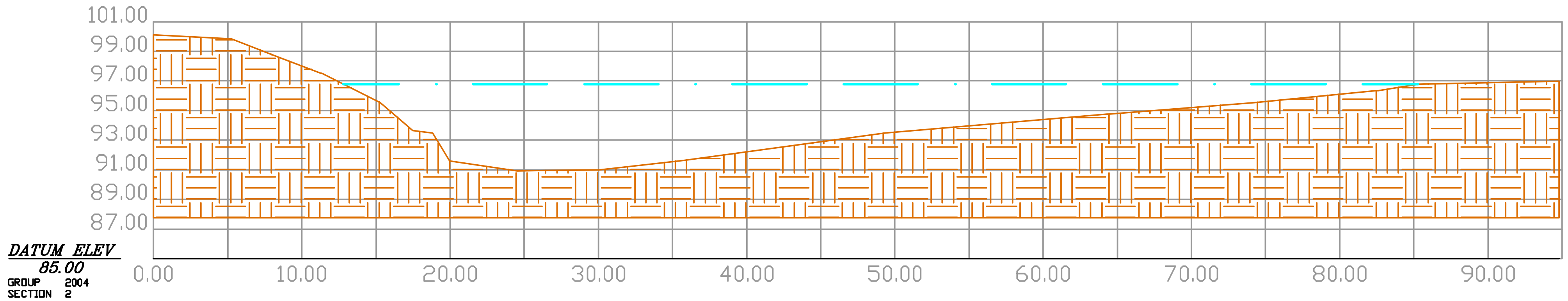
TITLE SHEET

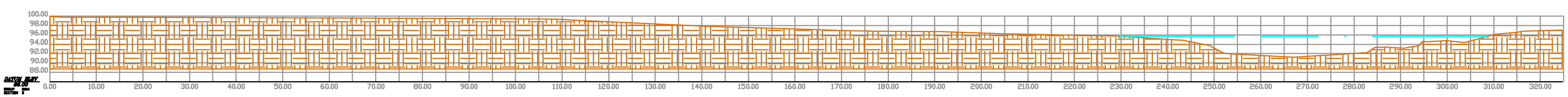
PROJECT:
DATE: 3/10/06
SCALE: AS NOTED
DRAWN BY: JRB/MM
DESIGN BY:

DRAWING: MF-1

SHEET 1 OF 4







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CROSS SECTIONS 1-3

PROJECT:
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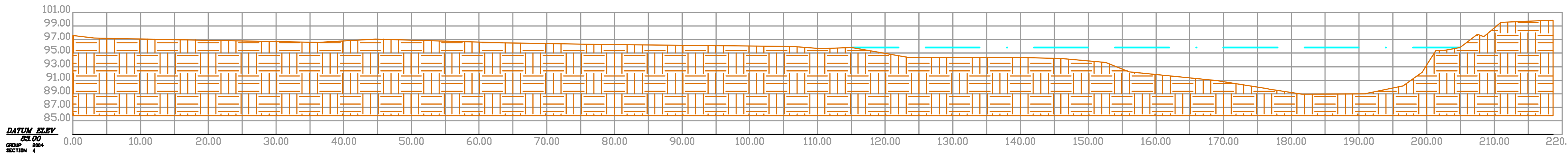

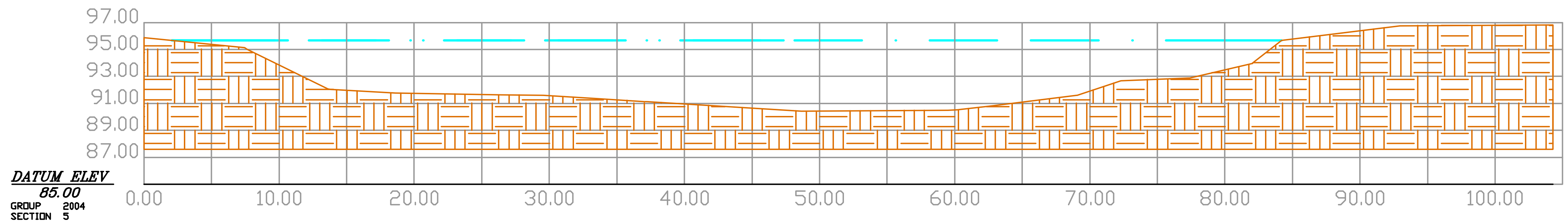

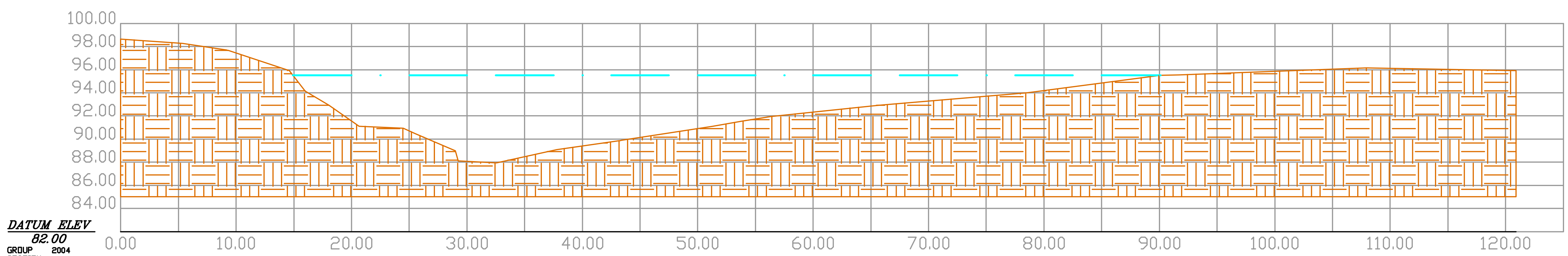

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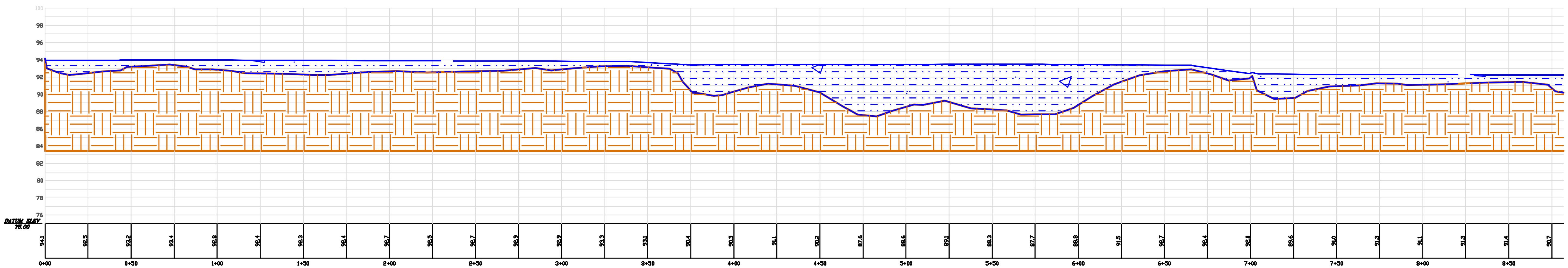

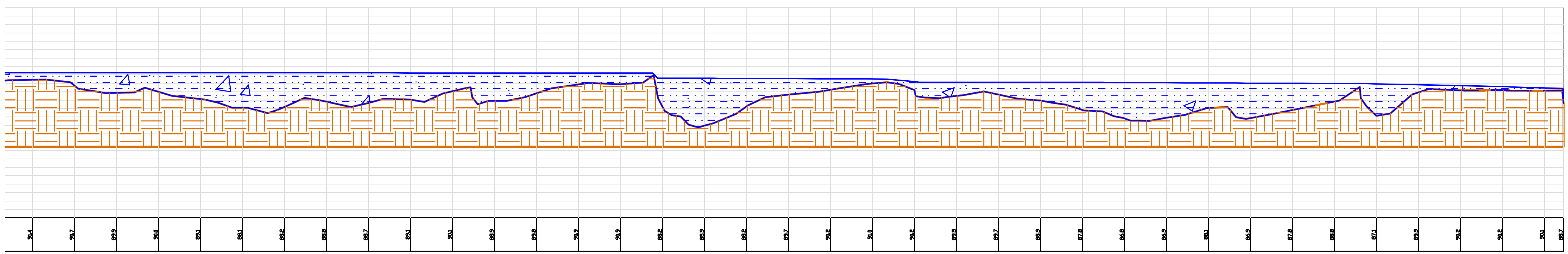

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DRAWING: **MF-4**

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F.9 Project Status: Flood Event Inspection (April 21, 2005)

On April 3, 2005, the Batavia Kill watershed experienced several inches of rain on snow resulting in a peak flow through the stream channel exceeding the bankfull flood stage. The peak flow recorded at the USGS Gage Station (#01349950) at Red Falls equaled or exceeded 14,000cfs. The Maier Farm Restoration Project was inspected several times during and after the flow event to document the flow conditions and project performance. The following written description is a summary of the inspected project components. Attached are images of the site taken after the flood event (Appendix F9).

Rock Structures:

Two of the fourteen rock structures experienced continued damage as a result of the flood flow. Both rock vane structures originally sustained damage during previous high flow events and have been scheduled for repair/modification for several years, however, due to staffing and budgetary constraints, the repairs were not completed. The damaged structures include rock vanes located at Stations 8+50 and 9+50.

Previous damage to the rock vane structures included rotational collapse and movement of top rocks along the vane arm. Problems associated with the structure included undesirable scour in areas where voids occurred between the top and footer rocks. Voids in the structures, larger that the available channel sediment, lead to increased scour caused by the convergence of flow through areas of the structure. Proper deposition of sediment, along the upstream face of the vane arm scoured as a result of the flow concentration through the voids.

Although isolated problems occurred at two of the fourteen structures, the remaining structures appeared to function properly during and after the flood flow. The cross vanes, rock vanes, and w-weir were effective at reducing the erosion and scour which potentially would have resulted prior to the installation of the project. Grass vegetation remained along the majority of the streambanks to the base water surface elevation.

Recommendations pertaining to the modifications to the existing rock structures, outlined in previous permit documents, include increasing the length of the two rock vanes (Stations 3+50 and 5+50), as well as adding a rock vane on the right bank at Station 1+50.

Channel Stability:

The channel showed no evidence of large-scale deposition (aggradation) or incision (degradation) through the reach. Bank erosion was present along the meander bend between Station 8+25 through 10+50 where the rock vanes have sustained damage. Two additional areas of isolated erosion were noted downstream of the rock vane near Station 6+00 and downstream of the cross vane near Station 12+50. It is presumed that the bank erosion would have been partially if not entirely mitigated if the vegetation had been able to establish prior to the increased stresses caused by the flood event.

Riparian Vegetation:

The installed vegetation included willow fascines, live transplants, and stakes, which were placed along the streambanks and in the adjacent floodplain areas, as well as conservation grass which was applied with hay mulch. Subsequent plantings were installed in the floodplain by the Watershed Agricultural Program as well as streambank and floodplain plantings by Trout Unlimited volunteers.

Establishment of vegetation appears poor considering the amount and density of the installed material. It is felt that the lack of established vegetation exacerbated the damage through the project site. It is presumed that if the vegetation had become established the damages would have been limited and in some areas avoided.

Large stands of Japanese knotweed have re-colonized in the floodplain and along the streambank in the project area. Maintenance and/or methods of eradication should be initiated in the project area to facilitate the success of the planted vegetation.

Private Bridge

The private bridge located at the lower extent of the project has continued to weather and deteriorate. Large woody debris has begun to accumulate at the upstream bridge opening and currently restricts flow through the left opening. The w-weir appears to be effective at redirecting flow through the bridge openings and reducing bank stress. There is evidence of moderate aggradation immediately upstream of the bridge opening, which may be attributed to the backwater affect that is potentially caused by the accumulated debris.

The bridge spillway appears to function properly and remains vegetated with grass. Several piles of construction/demolition debris were noted along the upper right bank along the spillway. Several stands of Japanese knotweed have re-colonized in the spillway.

Pond

The excavated pond, used for fill material during construction, has been partially filled with construction/demolition debris and remains full with water. The pond and the adjacent wetland area remain hydraulically connected.

Recommendations and proposed repair/modification:

- Monitoring of the entire site should be completed prior to the initiation of any modification or repair. Additionally, the control reach at the "Kastanis" site should be monitored in the same time frame to continue comparative analyses. Monitoring of the project reach should be completed again immediately after the modification/repair is completed.

- Monitoring of the site should include surveying all monumented cross sections, flood stage profile through the entire site, a composite pebble count and a longitudinal profile.

- Repair to the project site should follow recommendations outlined in the previous permit applications and include:

    a. Rebuilding the damaged rock vanes (Stations 8+50 and 9+50) to include updated design dimensions for slope and interior acute angle.

    b. Extending the rock vane length at two structures (Stations 3+50 and 5+50) to reduce the slope of the structure and increase performance.

c. Adding a rock vane along the right bank near Station 1+50. The addition of the structure may serve to reduce near bank stress and maintain the current channel alignment.

d. A bankfull bench should be constructed along the meander bend through the damaged structures. Material cut from the top of the bank (by laying the bank back to a more stable angle) can be used as fill along the bench in order to balance the material. The upstream and downstream floodplain areas should be connected with the bench, to provide floodway continuity. The bench should be evenly graded to an elevation equal to the adjoining upstream and downstream floodplains. Bankfull benches were not originally designed into the project, but have been effective at reducing stress to the streambank and rock structures in similar projects.

e. Rocks must abut one another and should contain minimal void space between the rocks. Cobble fill should be used along the upstream side of the vane arm and bank key. The vane arms should be rebuilt to ¾ bankfull elevation.

f. Re-grade banks, seed, and vegetate all exposed areas after completion of project repair/modifications. An attempt should be made to harvest native sod matting from the adjacent floodplain areas. The sod mat should be applied to critical areas surrounding the repaired vane structures, and be installed between the base water surface and bankfull elevations. Sod harvest areas should be reseeded and mulched. Bioengineering should be reinstalled along all outer bank areas and other defined high stress areas.

g. The debris blockage along the upstream face of the bridge should be removed to allow for unobstructed stream flow. Operation and maintenance of the project should include a plan for long-term inspection and removal of the material as needed.

h. Construction/demolition debris in the excavated pond and along the emergency bridge spillway should be removed and disposed of in a proper manner.

i. Japanese knotweed maintenance and/or methods of eradication should be initiated in the project area to guarantee the success of the planted vegetation.

j. Initiate repair work while equipment is nearby during the 2006 construction season for the proposed construction of the Ashland -Connector reach.

F.10 Project Status: 2005 Inspection - Survey
Site Inspection and Monitoring Survey

In June of 2005 the project site was inspected and surveyed by GCSWCD staff in order to review the project status and to document the physical condition and stability of the stream channel. The inspection included a review of the overall stability, rock structures, and riparian vegetation. The monitoring survey included surveying the monumented cross sections and complete longitudinal profile, performing pebble counts and a bar sample. A summary of the inspection results and recommendations is provided below. Please see Appendix F.9 for photographs taken during various site visits in 2005. The 2005 inspection/survey was completed one month after the April 2005 flood report (Appendix F.9). Accordingly, most criteria evaluated in April is applicable to the site inspection conducted in June.

Rock Structures:

Please see appendix F.9 for a description of the condition of the rock structures.

Riparian Vegetation:

The installed vegetation included willow fascines and willow stakes which were placed along the streambanks after the September 1999 flood event, as well as sod mats and conservation grasses which were applied along streambanks and adjacent floodplain areas prior to the flood event. The bioengineering was supplemented with additional post-flood plantings and various rooted tree species by volunteers, as well as by the Watershed Agricultural Program. The seedlings were placed along the top of the streambanks and adjacent floodplain areas, and included the use of protective tree tubes.

The bioengineering and plantings appear to be establishing despite heavy browsing by deer. It is expected that mild browsing will result in increased generation of plant rooting and subsequent plant top growth once the plants become established. The extent of the browsing should be monitored and mitigated if necessary until the plantings become established.

The majority of the large transplanted willow clumps have died back, but small amounts of new growth is present near the base of the plant. The sod mat installations are vigorous and appear to be fully established.

Recommendations include:

- Enhancing bioengineering and riparian planting's as needed.
- Selective pruning of the large transplanted willow clumps to promote new growth and establishment.
- Continued monitoring and inspection for signs of willow blight and over browsing.

Channel Stability:

Please see appendix F.9 for a description of channel stability.

Private Bridge:

Please refer to appendix F.9 for a description of the private bridge.

Project Reach Survey:

A monitoring survey was initiated in June of 2005 to document the annual project status and physical condition of the stream channel. The monitoring included surveying the 6 monumented cross sections and complete longitudinal profile, performing composite pebble counts, bar sample, and a summary of conditions. The dimensions presented represent changes occurring during the monitoring period from 2004 to 2005.

Cross Section Survey

Table 1: Summary of bankfull cross section dimensions, June 2005.

Cross Section	Feature	Area (ft.)	Width (ft.)	Max. Depth (ft.)	Mean Depth (ft.)
1	Riffle	149.8	71.3	4.3	2.1
2	Pool	196.9	69.7	5.4	2.8
3	Riffle	243.4	113.1	5.4	2.2
4	Pool	333.1	99.4	7.6	3.4
5	Riffle	290.2	82.3	5.3	3.5
6	Pool	279.1	73.6	7.8	3.8
Average Riffles		227.8	88.9	5.0	2.6
Average Pools		269.7	80.9	6.9	3.3
Reach Average		248.7	84.9	6.0	3.0

At the time of the as-built survey, six monumented cross sections were installed for use in future detailed monitoring efforts. Cross sections were monumented using capped rebar pins which are located in the topographic survey as well as recorded using GPS. Cross sections were stationed at various locations along the channel profile in order to provide monitoring for stream process and stability. The cross sections were installed through various stream features (pools, riffles, etc.) and structures in order to document stream classification, potential erosion and scour, and to document the overall channel stability. A summary of cross sectional data is presented in Table 1.

Table 2: Summary of bankfull cross sectional measurements.

Variable	Asbuilt 1999	Post-flood 1999	Survey 2000	Survey 2002	Survey 2003	Survey 2004	Survey 2005
Stream Type	C4	C4	C4	C4	C4	C4	C4
Area (ft^2)	239.2	245.1	255.3	255.2	253.2	220.0	227.8
Width (ft)	84.8	88.3	93.0	93.0	91.8	77.5	88.9
Mean Depth (ft)	3.0	2.9	2.8	2.9	2.8	2.8	2.6
Max Depth (ft)	5.2	5.0	4.8	4.7	4.9	4.7	5.0
Pool Area (ft^2)	292.7	250.6	246.0	266.7	268.6	270.1	269.7
Max Pool Depth (ft)	6.5	6.0	6.4	6.6	6.8	6.8	6.9

The values presented in Table 2, are averages taken from multiple cross sections. Values for riffle comparisons were obtained from cross sections 1, 3 and 5 while values for pool comparisons were obtained from cross sections 2, 4, and 6.

Longitudinal Profile

The longitudinal profile survey included the sampling of bankfull, ground, and water surface elevations along the slope breaks of the thalweg. The 2005 survey included a detailed profile beginning and ending at the top and bottom of the project reach. The stationing along the thalweg of each channel varies between the two years resulting from the selection of features by the field staff and minor changes in thalweg plan form.

Channel Pattern

Channel alignment changes were analyzed by reviewing the cross sections and lateral alignment of the thalweg of the stream profile. Although minor erosion and deposition were noted through isolated areas of the project reach there appears to be no evidence of unstable lateral migration or plan form change of meander radius, meander length, or sinuosity.

Sediment Characteristics

Pavement samples within the bankfull channel were collected during the survey of the reach. Random sampling techniques were used through the entire reach to generate a composite sample, as well as samples obtained along independent cross sections (Table 3). The inventory included independent sampling at cross section #1 (riffle) and cross section #5 (pool).

Table 3: Comparision of sediment samples taken August 2005 at selected cross sections.

Dominant Particle Size	Composite	Cross Section #1 (Riffle)	Cross Section #5 (Pool)
D_{95}	347.20mm	405.33mm	62.60mm
D_{85}	70.27mm	108.80mm	47.00mm
D_{50}	33.03mm	49.68mm	17.33mm
D_{35}	21.74mm	37.60mm	1.61mm
D_{15}	0.66mm	21.00mm	0.33mm

A gravel bar sample was collected (table 4) to be used as a surrogate for stream subpavement particle size. This sample was collected according to the procedure utilized for the “bottomless bucket method.” This procedure to this approach is as follows: locate the sampling site along the lower 1/3 of a meander bend at an elevation equal to the thalweg elevation plus one half the elevation difference between the thalweg and bankfull elevations, locate the two largest particles that may be mobile at bankfull flow in the vicinity and average their intermediate axis, excavate and collect all material from an area the size of the mouth of a standard five gallon pail to a depth equal to twice the average intermediate axis of the two aforementioned particles, finally, wet sieve the material to obtain the particle size distribution. This analysis produces values that are used in various classification equations and may be used in conjunction with the pebble counts to help determine particle size distributions of the stream pavement and sub-pavement.

Table 4: Gravel bar sample

Dominant Particle Size	Bar Sample
D_{95}	34.46mm
D_{85}	19.72mm
D_{50}	5.69mm
D_{35}	4.42mm
D_{15}	0.32mm

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

NYCDEP STREAM MANAGEMENT PROGRAM

"MAIER FARM" STREAM RESTORATION PROJECT

2005 MONITORING SURVEY

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REVISIONS

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT
BOX 907 GREENE COUNTY OFFICE BUILDING, CAIRO, NY 12413
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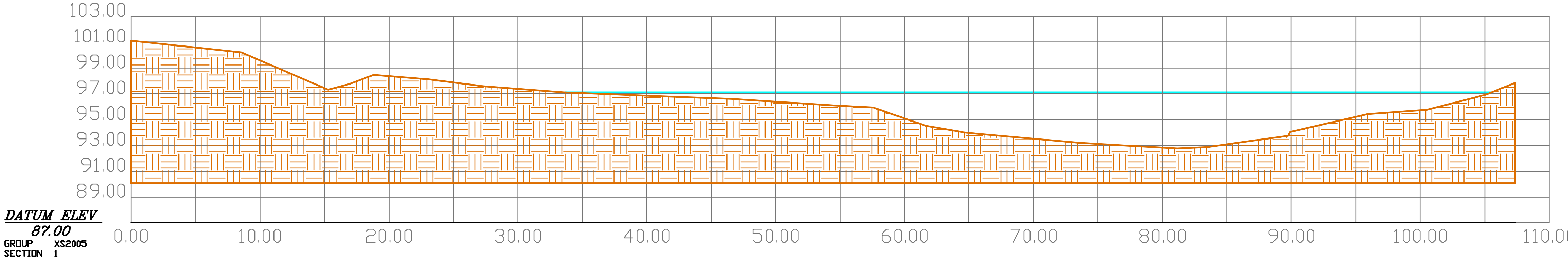
FAX (518) 622-0344

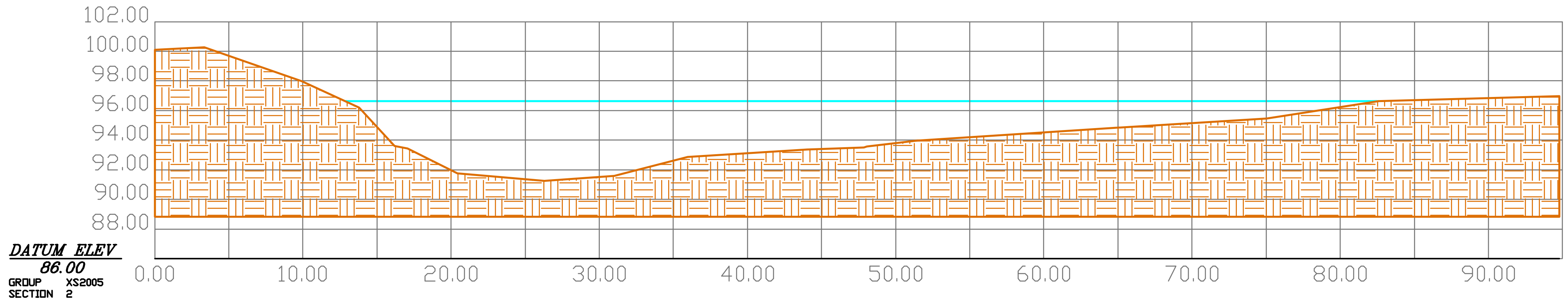
MAIER FARM
FOR
ACOE
STATE ROUTE 23A
TOWN OF ASHLAND
GREENE COUNTY, NY
TITLE SHEET

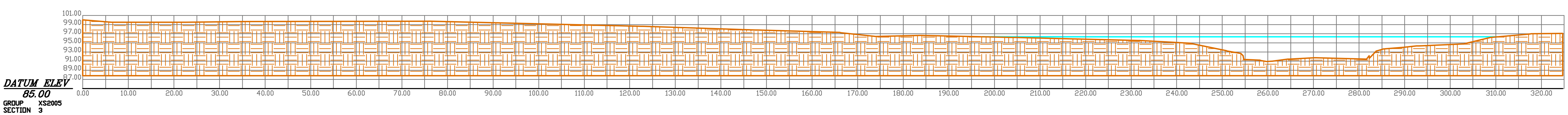
PROJECT:
DATE: 3/10/06
SCALE: AS NOTED
DRAWN BY: JRB/MM
DESIGN BY:

DRAWING: MF-1

SHEET 1 OF 4







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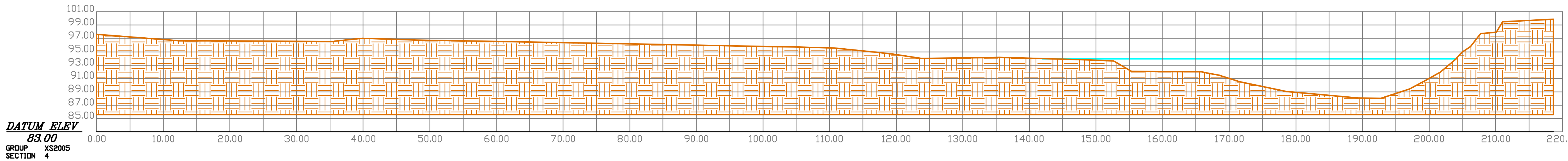
MAIER FARM
FOR
ACOE
STATE ROUTE 23A

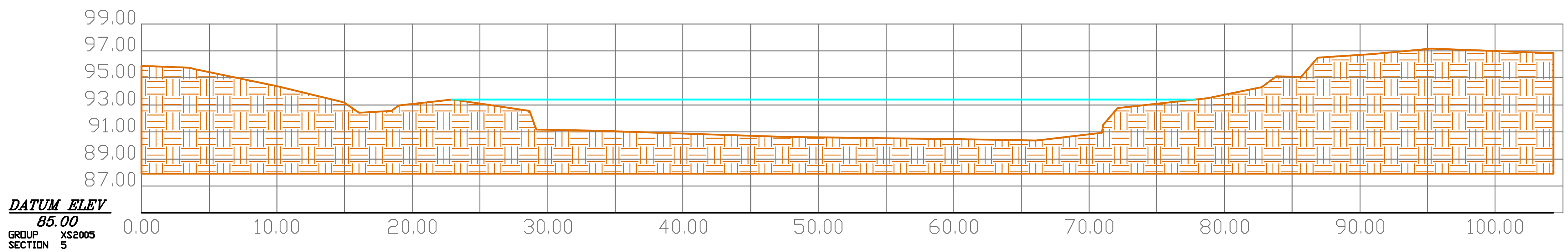
TOWN OF ASHLAND — GREENE COUNTY, NY

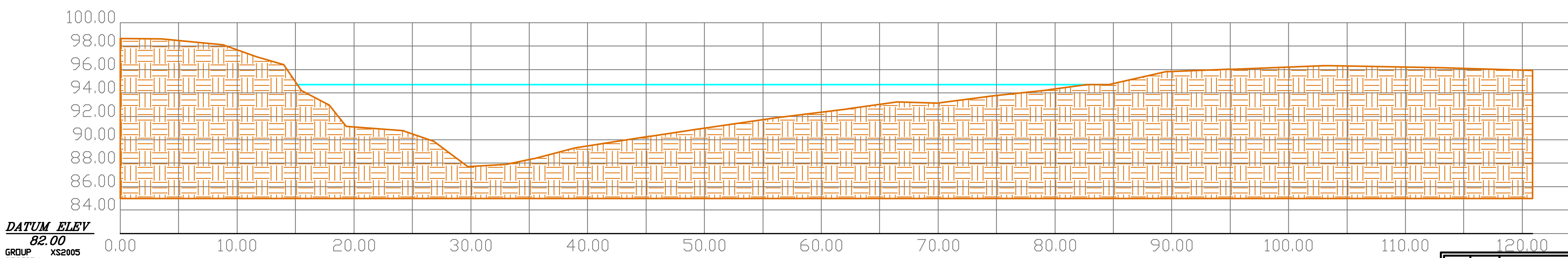
SECTIONS 1-3

PROJECT:	
DATE:	3/10/06
SCALE:	AS NOTED
DRAWN BY:	JRB/MM
DESIGN BY:	

DRAWING:
MF-2
SHEET 2 OF 4







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MAIER FARM

FOR

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STATE ROUTE 23A

TOWN OF ASHLAND

GREENE COUNTY, NY

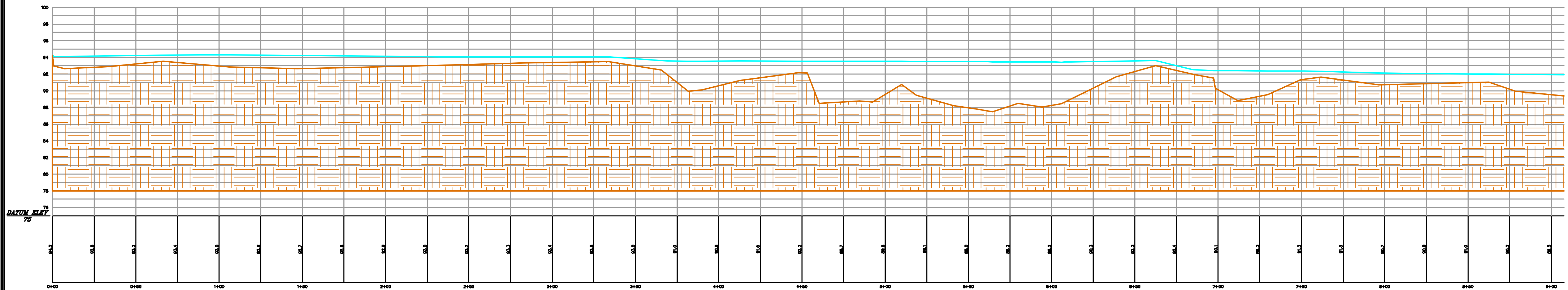
SECTIONS 4-6

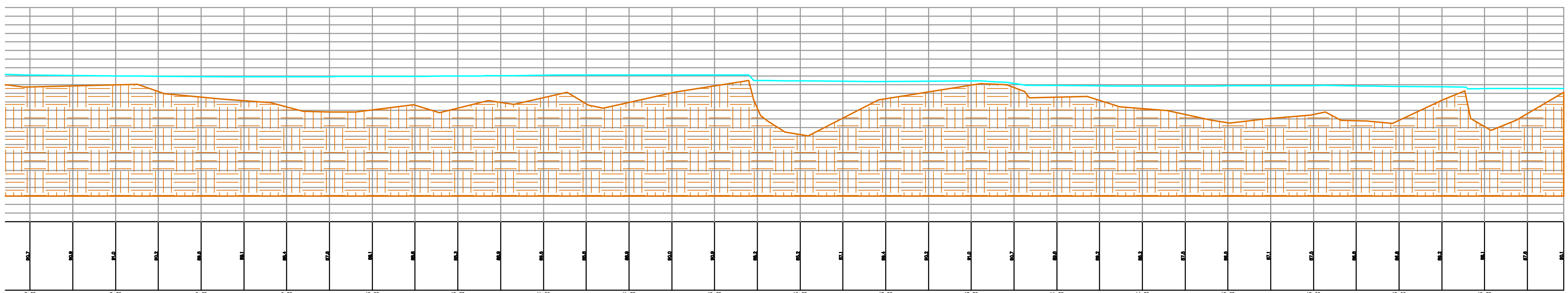
PROJECT:
DATE: 3/10/06
SCALE: AS NOTED
DRAWN BY: JRB/MM
DESIGN BY:

DRAWING:

MF-3

SHEET 3 OF 4





REV	DATE	DESCRIPTION	APP.

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MAIER FARM
FOR
ACOE
STATE ROUTE 23A

TOWN OF ASHLAND — GREENE COUNTY, NY

PROFILE

PROJECT:
DATE: 3/10/06
SCALE: AS NOTED
DRAWN BY: JRB/MM
DESIGN BY:

DRAWING: **MF-4**

SHEET 4 OF 4

F.11 Project Status: 2007 Inspection - Survey

Site Inspection and Monitoring Survey

In November of 2007 the project site was inspected and surveyed by GCSWCD staff in order to review the project status and to document the physical condition and stability of the stream channel. The inspection included a review of the overall stability, rock structures, and riparian vegetation. The monitoring survey included surveying the six monumented cross sections and the complete longitudinal profile, performing pebble counts and a bar sample. A summary of the inspection results and recommendations is provided below.

Rock Structures:

Inspection of the cross vanes revealed no visual damage, erosion, or problems associated with the structures. Minor voids in the vane arms and sills were noted, allowing small volumes of water to penetrate the structures during low flow periods but do not seem to pose any significant problems with the structural integrity or vane function. Regular deposition along the upstream portions of the vane arms appears normal and the vanes all appear to be functioning properly during various flow stages.

A single rock vane at station 09+75, on the meander near the center of the reach, has remained damaged since the 1999 flood event. The structure currently provides minimal protection to the streambank. Although minor erosion is still present, vegetation has increasing become established around the structure and appears to preventing erosion during moderate and low stream flow.

The w-weir appears to be functioning properly, no visible change to the structure was noted other than moderate sediment deposition downstream of the right invert. Sediment deposition in this area is expected during low to moderate flow events. This may potentially return to the asbuilt condition following larger flows.

Riparian Vegetation:

The installed vegetation included willow fascines and willow stakes which were placed along the streambanks after the September 1999 flood event, as well as sod mats and conservation grasses which were applied along streambanks and adjacent floodplain areas prior to the flood event. The bioengineering was supplemented with additional post-flood plantings and various rooted tree species by volunteers, as well as by the Watershed Agricultural Program. The seedlings were placed along the top of the streambanks and adjacent floodplain areas, and included the use of protective tree tubes.

The bioengineering and plantings adjacent to the stream appear to be well established. Many clumps of willow are established on the tops of the stream banks. Additionally numerous locust trees are thriving in the riparian area. Areas where sod mats were installed appear as naturally vegetated. Herbaceous vegetation in the riparian area is also well established.

Substantial amounts of Japanese Knotweed are present in the riparian areas of the project reach. Knotweed is an invasive species which can have negative impacts on the native riparian vegetation. The New York City Department of Environmental Protection is attempting to determine a method for controlling the growth and spread of knotweed. However, at present there is no simple way to eliminate knotweed from the site. The extent to which the knotweed spreads should be monitored to ensure it does not overwhelm existing native vegetation.

Recommendations include:

- Enhancing biodiversity of native plant species through follow up shrub and tree plantings
- Continued monitoring of Japanese knotweed
- Remediation of Japanese knotweed if a feasible method is discovered

Channel Stability:

The channel showed no evidence of large-scale deposition (aggradation) or incision (degradation) through the reach. Some stream bank cutting and erosion occurred at station 9+75 (middle meander where the vane failed). It is felt that this erosion is minimal and localized between the two other effective rock vanes. Additionally, erosion and bank cutting is noted at station 6+75 (upstream side of cross vane). Despite minor erosion no glacial clays were visibly present in the channel bottom or stream.

Visual inspection of the reaches located upstream and downstream of the project area indicates no apparent evidence of erosion, deposition, or accelerated lateral migration. The inspections have not shown any visual indication of turbidity in the adjacent reaches.

Recommendations include:

- Evaluate erosion from stream bank at station 9+75
- Evaluate erosion from stream bank near station 6+75

Private Bridge:

Although the private bridge structure, located at the bottom of the project reach, remains in poor structural condition, there was no evidence of channel instability surrounding the structure. The bridge openings appear to be transporting stream flow and sediment, as staged by the w-weir. Large woody debris has collected downstream of the weir, but at present no debris is blocking either bridge opening. The emergency spillway remained intact and vegetated, with no signs of erosion.

Project Reach Survey:

A monitoring survey was initiated in November of 2007 to document the annual project status and physical condition of the stream channel. The monitoring included surveying the six monumented cross sections and the complete longitudinal profile, performing composite pebble counts, bar sample, and a summary of conditions.

Cross Section Survey

At the time of the as-built survey, six monumented cross sections were installed for use in future detailed monitoring efforts. Cross sections were monumented using capped rebar pins which are located in the topographic survey as well as recorded using GPS. Cross sections were stationed at various locations along the channel profile in order to provide monitoring for stream process and stability. The cross sections were installed through various stream features (pools, riffles, etc.) and structures in order to document stream classification, potential erosion and scour, and to document the overall channel stability. A summary of cross sectional data is presented in Table 1.

Table 1: Summary of bankfull cross section dimensions, November 2007.

Cross Section	Feature	Area (ft.)	Width (ft.)	Max. Depth (ft.)	Mean Depth (ft.)
1	Riffle	188.0	72.1	5.0	2.6
2	Pool	218.2	69.7	5.7	3.1
3	Riffle	153.0	52.6	4.4	2.9
4	Pool	234.4	89.3	5.6	2.6
5	Riffle	141.8	60.1	4.0	2.4
6	Pool	257.2	68.9	7.5	3.7
Average Riffles		160.9	61.6	4.5	2.6
Average Pools		236.6	76.0	6.3	3.1
Reach Average		198.8	68.8	5.4	2.9

The values presented in Table 2 are averages taken from multiple cross sections. Values for riffle comparisons were obtained from cross sections 1, 3 and 5 while values for pool comparisons were obtained from cross sections 2, 4, and 6.

Table 2: Summary of bankfull cross sectional measurements.

Variable	Asbuilt	Post-flood 1999	Survey 2000	Survey 2002	Survey 2003	Survey 2004	Survey 2005	Survey 2007
Stream Type	C4	C4	C4	C4	C4	C4	C4	C4
Area (ft^2)	239.2	245.1	255.3	255.2	253.2	220.0	227.8	160.9
Width (ft)	84.8	88.3	93.0	93.0	91.8	77.5	88.9	61.6
Mean Depth (ft)	3.0	2.9	2.8	2.9	2.8	2.8	2.6	2.6
Max Depth (ft)	5.2	5.0	4.8	4.7	4.9	4.7	5.0	4.5
Pool Area (ft)	292.7	250.6	246.0	266.7	268.6	270.1	269.7	236.6
Max Pool Depth (ft)	6.5	6.0	6.4	6.6	6.8	6.8	6.9	6.3

Longitudinal Profile

The longitudinal profile survey included the sampling of bankfull, ground, and water surface elevations along the slope breaks of the thalweg. The 2007 survey included a detailed profile beginning and ending at the top and bottom of the project reach. The stationing along the thalweg of the channel varies between years as a result of the selection of features by field staff and minor changes in thalweg plan form.

Channel Pattern

Channel alignment changes were analyzed by reviewing the cross sections and lateral alignment of the thalweg of the stream profile. Although minor erosion and deposition were noted through isolated areas of the project reach there appears to be no evidence of unstable lateral migration or plan form change of meander radius, meander length, or sinuosity.

Sediment Characteristics

Pavement samples within the bankfull channel were collected during the survey of the reach. Random sampling techniques were used through the entire reach to generate a composite sample, as well as samples obtained along independent cross sections (Table 3). The inventory included independent sampling at cross section #1 (riffle) and cross section #5 (pool).

Table 3: Sediment sample sizes taken November 2007 at selected cross sections.

Dominant Particle Size	Composite	Cross Section #1 (Riffle)	Cross Section #5 (Pool)
D_{95}	341.11	418.21	63.10
D_{85}	72.38	106.78	48.72
D_{50}	31.84	48.98	16.99
D_{35}	20.46	34.57	1.53
D_{15}	0.73	20.17	0.41

A gravel bar sample was collected (Table 4) to be used as a surrogate for stream subpavement particle size. This sample was collected according to the procedure utilized for the “bottomless bucket method.” The procedure to this approach is as follows: locate the sampling site along the lower 1/3 of a meander bend at an elevation equal to the thalweg elevation plus one half the elevation difference between the thalweg and bankfull elevations, locate the two largest particles that may be mobile at bankfull flow in the vicinity and average their intermediate axis, excavate and collect all material from an area the size of the mouth of a standard five gallon pail to a depth equal to twice the average intermediate axis of the two aforementioned particles, finally, wet sieve the material to obtain the particle size distribution. This analysis produces values that are used in various classification equations and may be used in conjunction with the pebble counts to help determine particle size distributions of the stream pavement and sub-pavement.

Table 4: Gravel bar sample

Dominant Particle Size	Bar Sample
D_{95}	
D_{85}	
D_{50}	
D_{35}	
D_{15}	

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2007 MONITORING SURVEY

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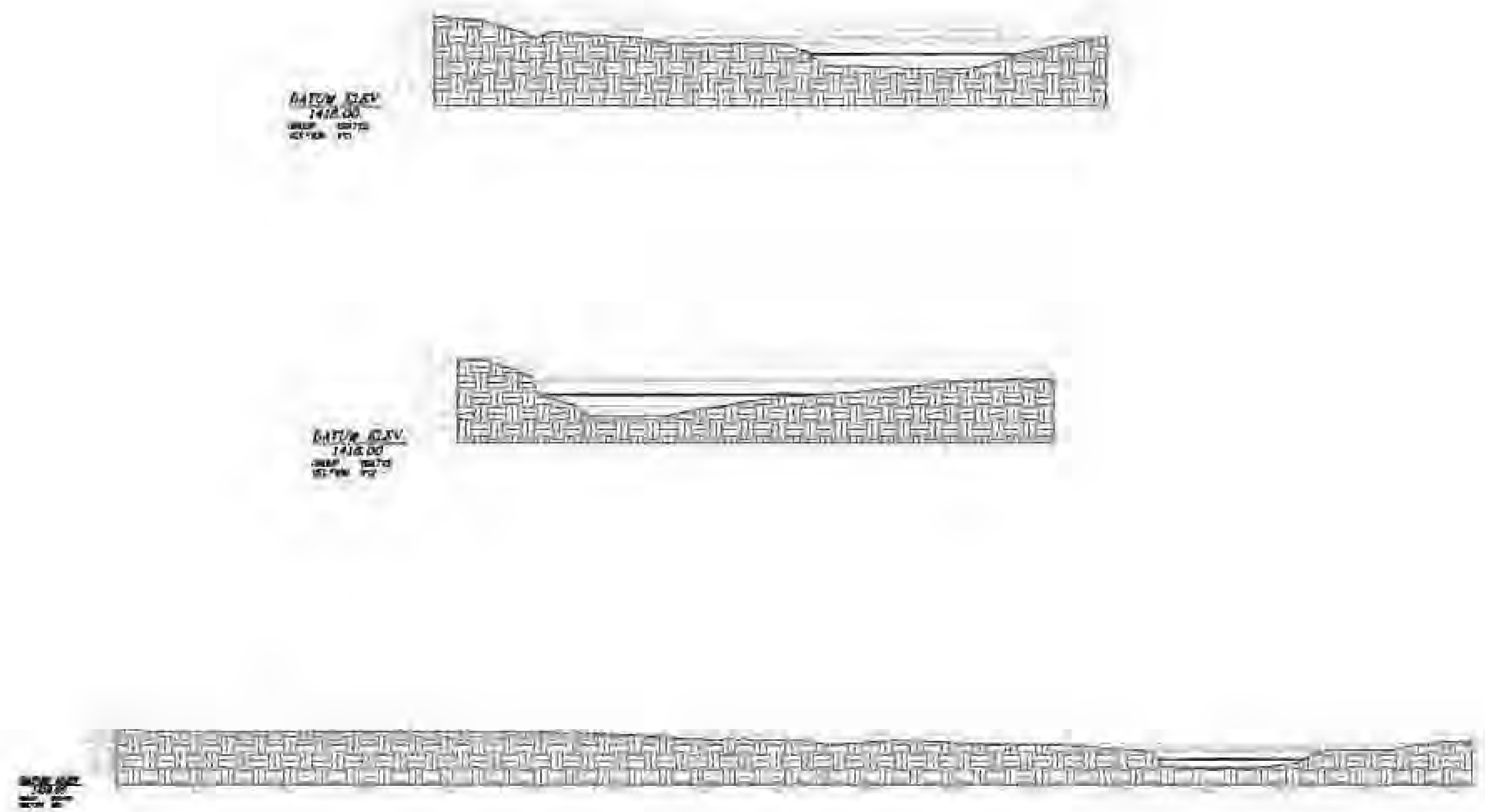
REVISIONS

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

MAIER FARM
FOR
ACOE

TITLE SHEET

MF-1



REVISIONS

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

MAIER FARM

for

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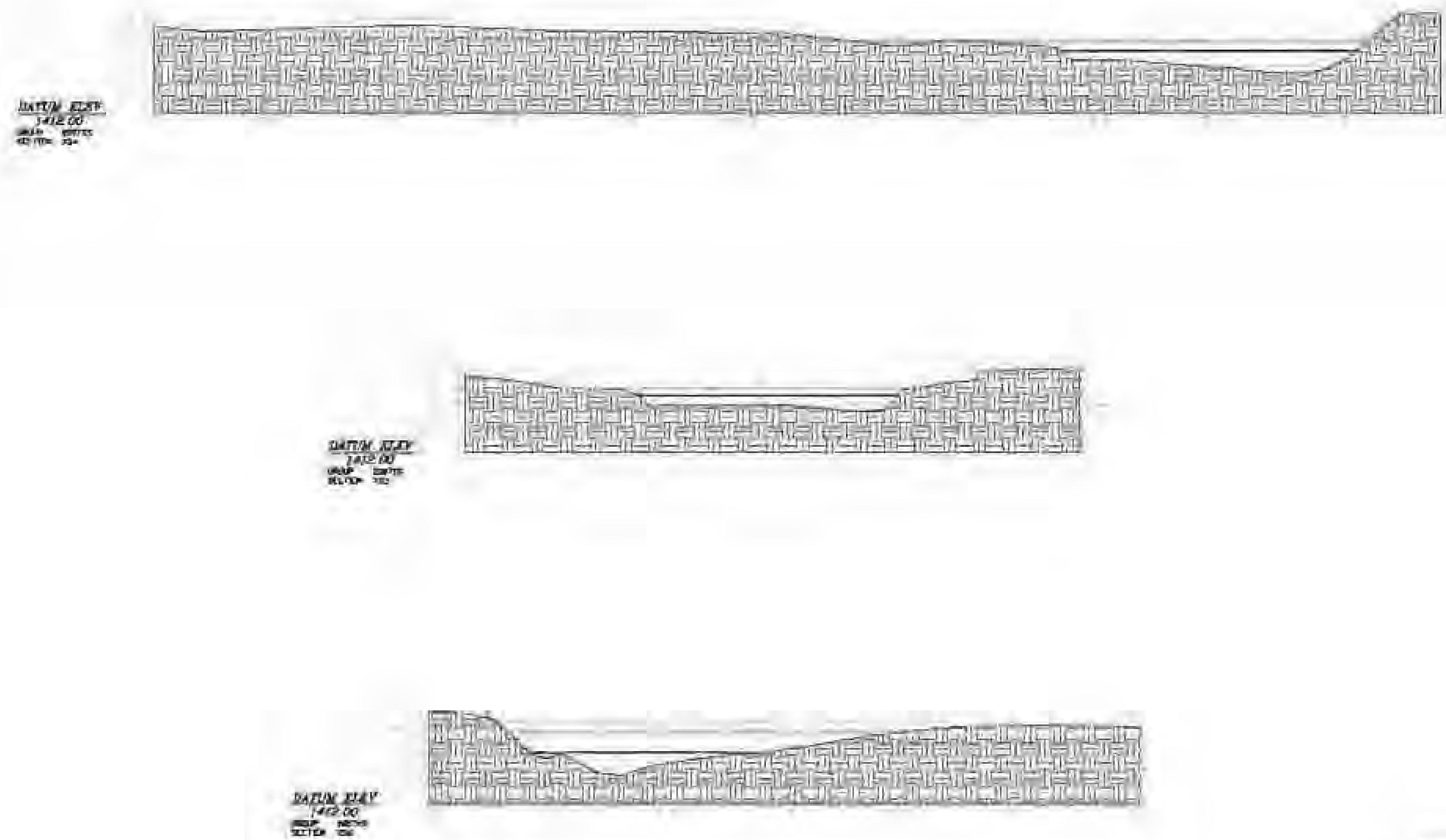
STATE ROUTE 23A

TOWN OF ASHLAND — GREENE COUNTY, NY

2007 - CROSS SECTIONS 1-3

MF-2



REVISIONS

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

MAIER FARM
for
ACOE
STATE ROUTE 23A

TOWN OF ASHLAND — GREENE COUNTY, NY

2007 - CROSS SECTIONS 4-6

DATE: 12/11/08
SCALE: 1:20

MF-3

Legend	
Bedrock	
Thalweg	
Water Surface	

REVISIONS

GREENE COUNTY SOIL & WATER CONSERVATION DISTRICT

MAIER FARM

for

ACOE

2007 - PROFILE

MF-4

Appendix G

Other Project Reports

G.1 Evaluation of the Effectiveness of Stream Restoration in Batavia Kill Watershed

G.2 Effectiveness of Stream Restoration in Reducing Stream Bank Erosion: The Case of Batavia Kill Stream Restoration Projects, New York

Evaluation of the Effectiveness of Stream Restoration in Batavia Kill Watershed

By Yanwei Chen[1], S. K. Bhatia[2], James Buchanan[3], Doug DeKoskie[4]

ABSTRACT

The number of stream restoration projects has increased dramatically during the last decade, especially in the New York City watershed region, where stream management to improve water quality is a high priority, and where NYC Department of Environmental Protection and the Greene County Soil and Water Conservation District have partnered to develop a set of restoration demonstration projects. In this paper, post-project evaluation is conducted on the Maier Farm project, the first demonstration project in the Batavia Kill watershed (Greene County, New York). This evaluation focuses on the changes of morphological characteristics and erosion rates. The pre-project and post-project morphological characteristics such as width/depth ratio, bankfull width, bankfull area, bankfull mean depth, and bankfull maximum depth at the Maier Farm project reach are compared, and the trends in these characteristics are then analyzed. The post-project erosion rates at the Maier Farm reach are compared to the pre-project values as well as to those of other untreated reaches. It is found that the morphological characteristics tend to be stable three years after the completion of the project, and the restoration project contributed to the improvement of the bank stability and the reduction of the stream erosion rates.

Key Words: Stream restoration, Stream management, Post-project evaluation, Morphological characteristics, Erosion rates, Bank stability, Greene County SWCD, New York City Watershed, NYC Department of Environmental Protection

INTRODUCTION

With increasingly awareness of the negative impact of human activities on the watershed system, growing numbers of stream restoration projects are being carried out to improve water quality, stabilize the stream banks, and enhance the integrity of aquatic ecosystems (FISRWG, 1998). Stream restoration means to return an ecosystem to a close approximation of its condition prior to disturbance (Kondolf 1995, FISRWG 1998). However, the uncertainties in certain aspects of stream channel restoration, such as the bankfull elevation, meander dimensions, bankfull discharge, slope, and cross-sectional shape make the accurate prediction of the consequence of stream restoration projects extremely intricate (Johnson and Rinaldi 1998). Thus the post-project evaluation becomes critical to assess the performance of any restoration project.

In 1995, Kondolf and Micheli proposed an approach to evaluating stream restoration projects by emphasizing the measurement of the geomorphic characteristics of the restoration reach. Their emphasis of the geomorphic characteristics is based on the understanding that interactions between the stream channel, floodplain, and stream flows provide the framework supporting aquatic and riparian structures and functions (Kondolf and Micheli 1995). Since then, growing studies have been undertaken to evaluate the stream restoration projects by comparing the pre-project and post-project geomorphic characteristics.

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[2] Prof., Dept. of Civil and Environmental Engineering, Syracuse University, Syracuse, NY, 13244
[3] Stream Restoration Specialist, Greene County Soil & Water Conservation District, Cairo, NY, 12413
[4] Stream Program Leader, Greene County Soil & Water Conservation District, Cairo, NY, 12413

Smith (1997) conducted a post-project evaluation on a 300-meter reach of Deep Run (Maryland) with a goal of assessing the change in stability over a two-year period. The Deep Run project was reconstructed into a meandering channel in August 1995 as mitigation for highway construction. Smith found that the cross-section dimensions increased over the monitoring period, and the absence of floodplain vegetation allowed high flow velocities which encouraged scour on the floodplain. He concluded that the reconfiguration was ineffective at enhancing channel stability.

In another study, Kurz and Rosgen (2002) compared the pre-project and post-project morphological characteristics of an 1800-meter demonstration project reach on the Lower Rio Blanco River (Colorado), which was restored in fall 1999. They found that even with 33% less flow, the maximum depths and the mean depth of the 2001 cross-sections were greater than the average values of 5 wildlife pre-restoration cross-sections. From the post-project monitoring data, they also noticed that there was an increasing trend in bankfull mean depth and bankfull maximum depth as well as a decreasing trend in width/depth ratio. Their analysis showed that the restoration was successful in improving the channel stability.

Although many studies have been conducted to evaluate stream restoration projects, little or no quantitative analyses were carried out on the change of the erosion rates. One possible reason for the absence of such studies might be the unavailability of pre-project erosion rates data. This paper evaluates the effectiveness of the first major stream restoration project in New York State – the Maier Farm Project in Batavia Kill watershed. This evaluation is based on the changes of morphological characteristics and erosion rates.

BATAVIA KILL WATERSHED STREAM RESTORATION

The Batavia Kill watershed is located in the Catskill Mountains in southeastern New York State (Figure 1). The watershed has an area of 186 km^2 and its mainstream, the Batavia Kill, runs for a distance of 34 km to its confluence with the Schoharie Creek, which is a major water resource for New York City's daily water supply.

The Batavia Kill watershed is characterized by steep slopes with unconsolidated glacial till, glacial lacustrine clays, and fine silts. The New York City Department of Environmental Protection (NYCDEP) had identified the watershed as having one of the highest turbidity conditions of all the NYC water supply systems. In 1997, the United States Environmental Protection Agency (USEPA) required NYCDEP to either improve the surface water quality to a certain level or to spend $8 billion to build a filtration plant. The NYCDEP has responded by developing a watershed protection program instead of the filtration plant. As part of the watershed protection program, the Greene County Soil & Water Conservation District (GCSWCD) has initiated the use of a geomorphic-based classification, assessment, and restoration strategy for addressing degraded stream reaches in the Batavia Kill Watershed.

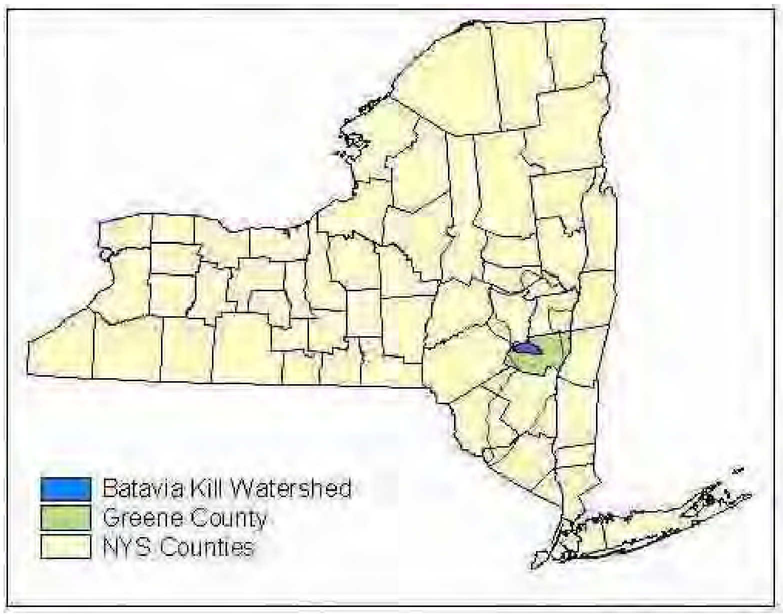


Figure 1: Batavia Kill Watershed Location Map

Three separate reaches were chosen as demonstration projects based on the consideration of the instabilities, funding, water quality, accessibility, and other factors. The first two projects were located in the middle of the stream corridor and are referred to as the Maier Farm project and the Brandywine project. The third demonstration project is located at the top of the watershed and is referred to as the Big Hollow project. Figure 2 shows the locations and the restoration periods of demonstration projects. Table 1 gives the design features of the demonstration projects.

Figure 2: Locations and Construction Periods of Demonstration Projects in Batavia Kill Watershed

The Primary objective of the restoration projects is to mitigate excessive turbidity and total suspended solids impact on water quality by addressing excessive stream bank erosion (GCSWCD Management Plan, 2003). To achieve this goal, a stable Rosgen C4 stream type (Rosgen 1996) with typical meandering riffle-pool morphology was selected as the restoration strategy for the demonstration projects. Channel form and meander pattern was derived from historical aerial photographs, regime equations, and reference reach analyses.

Table 1: The Design Features of the Demonstration Projects

Projects	Maier Farm	Brandywine	Big Hollow
Drainage Area (km^2)	134	111	23
Bankfull X-section Area (m^2)	22	21	9
Bankfull Mean Depth (m)	1.2	2	0.67
Design Stream Type	C4	C4	C4
Slope	.0021	.0005-.0006	0.016
Project Length (m)	500	1100	> 490
No. of Rock Vanes	10	14	60
No. of Cross Vanes	3	6	10
No. of W-Weirs	1	-	-
No. of Root-wads	2	1	-

To date, the monitoring data at Maier Farm reach from 1997 to 2002 were provided by GCSWCD, and monitoring data at other project sites are under organization. It is for this reason that this paper will focus on the Maier Farm project, the first restoration project in the Batavia Kill watershed. The annual mean flow at the Maier Farm reach is about 2.8 m^3/s (USGS 01349900). During the monitoring period from 1997 to 2002, the biggest storm event was the tropical storm Floyd, estimated to be a 30-year storm event, which hit the watershed in September 1999 with the peak flow at 420 m^3/s. Other big storm events were the May 1998 flood which peaked at 65 m^3/s, the June 2000 flood with a peak flow of 136 m^3/s, and the December 2000 flow which peaked at 70 m^3/s.

MORPHOLOGICAL ANALYSIS

Morphological characteristics can be categorized into cross-section dimension, longitudinal profile, and bed material (Rosgen 1996). The cross-section survey, longitudinal profile measurement, and pebble count at the Maier Farm reach started in 1997. Two monitoring cross-sections (Refer to Harrelson et al. 1994) were installed in that year to serve as the pre-project survey baseline. The pre-project monitoring survey was conducted in 1997, 1998, and 1999. After the completion of the projects in August 1999, six permanent cross-sections were established on the Maier Farm project reach and as-built survey was conducted. Three weeks later, on September 16, 1999, the Batavia Kill basin was hit by tropical storm Floyd. After the flood event, six cross-sections were surveyed again. The monitoring survey was then conducted in 2000 and 2002.

Table 2 compares the post-project and pre-project morphological characteristics. The post-project value is the mean of post-project monitoring data, and the pre-project value is the mean of pre-project monitoring data. The proposed value is the average of the riffle and pool suggested in the design (GCSWCD, 2002).

Table 2: Changes in Morphological Characteristics at Maier Farm Project Reach

	W/D Ratio	BKF Mean Depth (m)	BKF Max. Depth (m)	BKF Width (m)	BKF Area (m^2)
Post-project	24.89	1	1.77	24.62	24.87
Pre-project	75.44	0.56	1.58	42	23.65
Proposed	19.1	1.13	2.10	21.5	24.2

The restored reach has much lower width/depth ratio and higher depth than the pre-restoration reach. The width/depth ratio is a very sensitive indicator in channel instability (Rosgen 1996). High width/depth ratio indicates a sharp reduction in the channel's capacity to transport sediment. The average post-project width/depth ratio (24.89) at the Maier Farm project reach is close to the average value (29.28) provided by Rosgen (1996) for the stable C4 stream type.

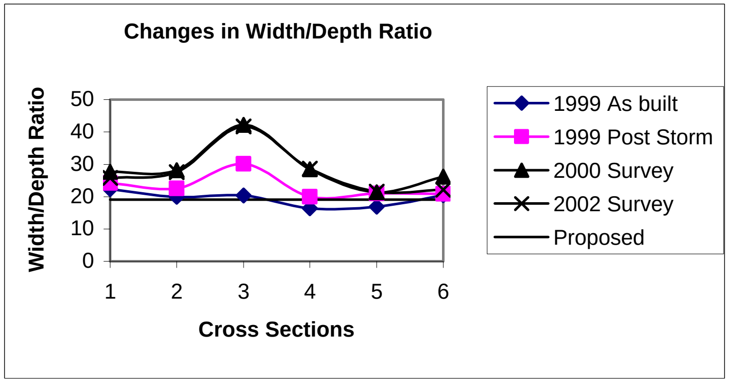
The changes of morphological characters from 1999 to 2002 at six cross-sections are given in Figure 3. The width/depth ratio has an increasing trend in 1999 and 2000 and then tends to be stable. The bankfull mean depth has a decreasing trend in 1999 and 2000 and then tends to be stable. No clear pattern was captured in the bankfull area and bankfull width changes. Notice that the changes in morphological characters between 1999 as-built survey and 1999 post-storm survey are obvious. These obvious changes were mainly due to the 1999 flood event. The Maier Farm site's construction was completed only three weeks before the storm hit. The site was vulnerable, with little to no vegetative cover, which is very essential in providing the bank stability, especially for the C4 type reach, on the stream bank. Although there were some damages on individual structures, the whole project still held its constructed planform and profile (GCSWCD, 2003). The project survived well compared to other untreated reaches (GCSWCD, 2003). Although the time period covered in this study is not long enough to assess a stable condition, Figure 3 shows that the project reach tends to be stable especially over 2000-2002 seasons.

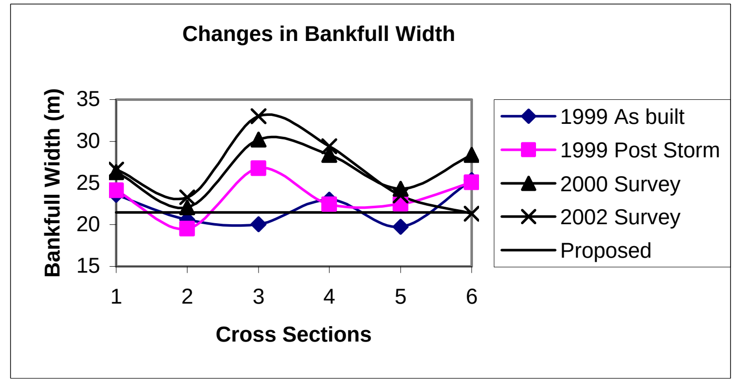
Figure 3 demonstrates that cross-section 3 has higher bankfull width and width/depth ratio than those of the other cross-sections. The field investigation showed that some in-stream structures nearby cross-section 3 were damaged during the 1999 storm event. This damage might be the reason why cross-section 3 has different morphological characteristics from the other cross-sections.

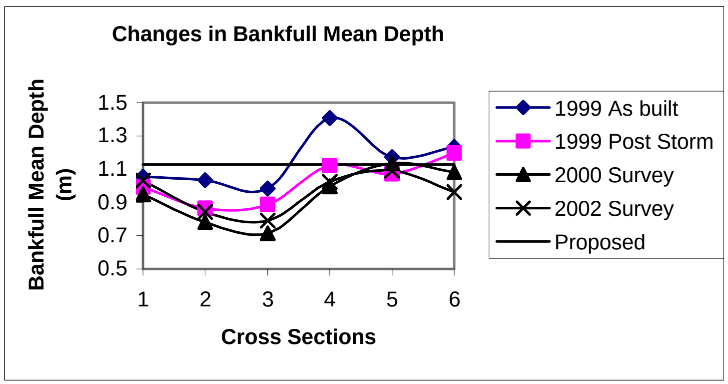
EROSION RATES ANALYSIS

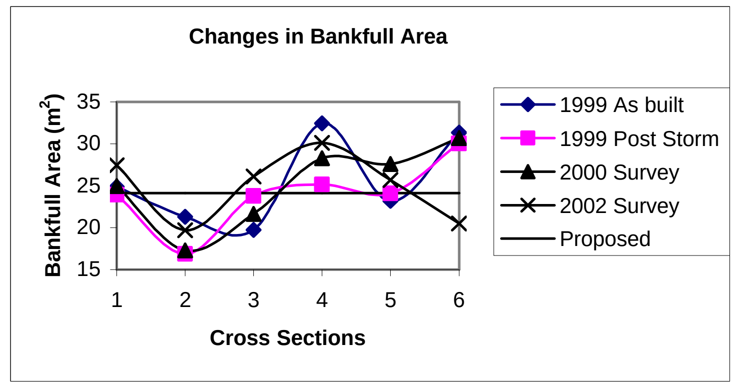
The primary stability problems observed at the pre-restoration reach were associated with meander migration and stream bank erosion, which were mainly due to poor riparian buffers and the unconsolidated layers of glacial soils. Since the primary objective of the stream restoration is to improve the water quality by reducing stream bank erosion, it is essential to evaluate the effectiveness of stream restoration on erosion rates.

Harrelson et al., (1994) suggested two ways to measure the bank erosion: the first method is the repeated cross-section survey; the second method is to insert erosion pins at regular intervals into a stream bank and to measure the exposure of the erosion pins over a certain period. Rosgen used erosion pins to measure the erosion rates in the Colorado fluvial sites study and the Yellowstone study (Rosgen 1996). The erosion rates ranged from 0.006 to 0.92 m/yr in the Colorado study and from 0.005 to 0.76 m/yr in the Yellowstone study. Most measured stream reaches in the Colorado study are A and B types.









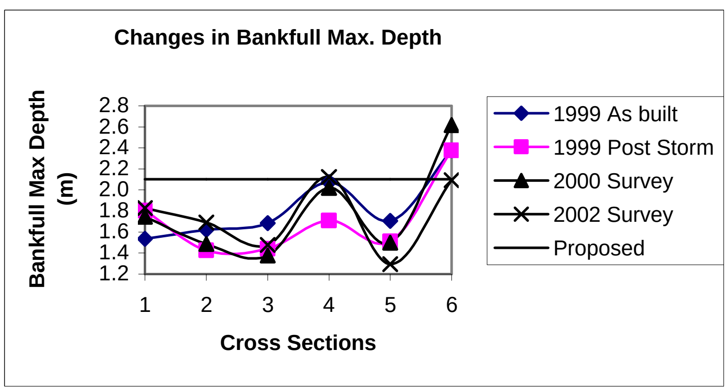


Figure 3: Changes of Post-project Morphological Characteristics from 1999 to 2002 at 6 Cross Sections on the Maier Farm Project Reach in the Batavia Kill watershed

The classification of the Yellowstone study reaches was not given. In another study, Harmel et al., (1999) measured the bank erosion rates on the Upper Illinois River in northeast Oklahoma using erosion pins. Most reaches they chose were the C4 type. The range of bank erosion measured in their study was quite different from Rosgen's results. The erosion ranged from –0.009 m to 8 m during the period from September 1996 to July 1997.

In this study, the erosion rate is measured by repeated cross-section surveys. For example, the pre-project erosion rate was determined by overlaying two different cross-sections surveyed on April 27, 1999 and on July 17, 1998. From this data, the mean erosion rates were calculated. The post-project erosion rate was obtained by surveying 6 different cross sections and overlaying that data surveyed at different times: on June 21, 2000 and the as-built cross-section on August 26, 1999. The eroded area of the six cross-sections was then averaged to determine the mean erosion rate. In this way, the eroded area at the whole cross-section was calculated, including the stream bank erosion and the channel bed erosion.

Table 3 summarizes the post-restoration erosion rate and pre-restoration erosion rate on the Maier Farm site. The first look at Table 3 shows that the difference between post-project and pre-project erosion rate is negligible. From these data, one might draw a conclusion that the restoration technique at this project site was not effective in reducing stream erosion. However, we should also take the hydrological aspect into consideration when comparing the erosion rate during different periods, because the stream flow is a very important factor that affects the erosion rate.

Table 3: Comparison of Post-project and Pre-project erosion rates

Monitoring Season	Mean Eroded Area (m^2/year)
Post-project (99-00)	4.7
Pre-project (98-99)	4.6

For the hydrological consideration, the daily mean stream flow data (Figure 4) is obtained from USGS gage 01349900 (Near Ashland), which is located upstream of the Maier Farm reach. From August 26, 1999 to June 21, 2000 (post-project period), eight storm events with the daily mean discharge higher than the mean peak flow (mean value of the flood events) were recorded. The highest daily mean stream flow, which occurred on September 17, 1999, exceeded 65 m^3/s (Notice that this is the daily mean flow, not the peak flow; the peak flow exceeded 420 m^3/s). It was followed by another major flood event on June 7, 2000, with a daily mean stream flow higher than 56 m^3/s. However, during the pre-project monitoring season (from July 17, 1998 to April 27, 1999) only three storm events exceeded the mean peak flow, while the highest daily mean stream flow is 30 m^3/s. Apparently, the post-project monitoring season experienced more storm events and higher flow than the pre-project monitoring season, but the erosion is almost the same (Table 3) during these two monitoring seasons. Therefore, one can conclude that the stream restoration project did contribute to the stream stability.

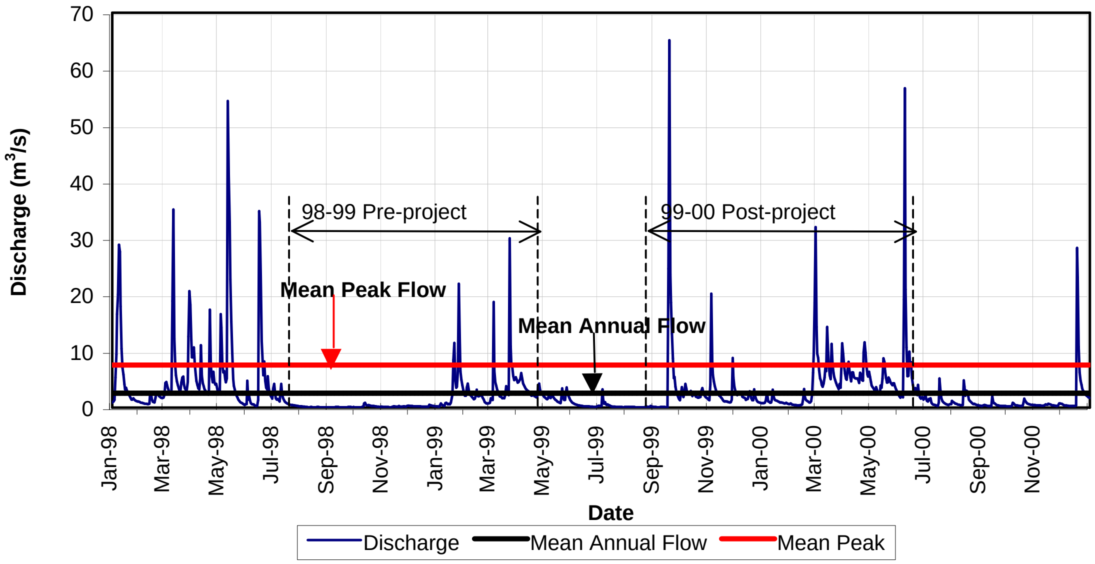


Figure 4: Daily Mean Stream Flow at Batavia Kill Near Ashland NY (USGS 01349900)

Another way to evaluate the effectiveness of the restoration project on stabilizing the stream bank is to compare the erosion rate at project reach to that of untreated stream reaches (unstable reaches). Since the project reach is a C4 type, it is interesting to compare the erosion rate between it and the untreated C-type stream reaches. There are 95 monitoring cross-sections on the Batavia Kill stream. Among them, 25 are set up on untreated C-type stream reaches. The erosion rate during 1999-2000 monitoring season can be determined by overlaying surveyed cross-sections in 1999 and 2000 to measure the eroded area. The 25 untreated C-type reaches are located from the headwaters to the mouth of the watershed, and the drainage area ranges from 13 km^2 to 182 km^2. The results are summarized in Figure 5. The mean erosion rate of 25 cross-sections on untreated C-type reaches is 7.58 m^2/year, and the mean erosion rate of 6 project cross-sections on the Maier Farm site is 4.7 m^2/year. The average erosion rate at untreated reaches is 61% higher than that of the project reach.

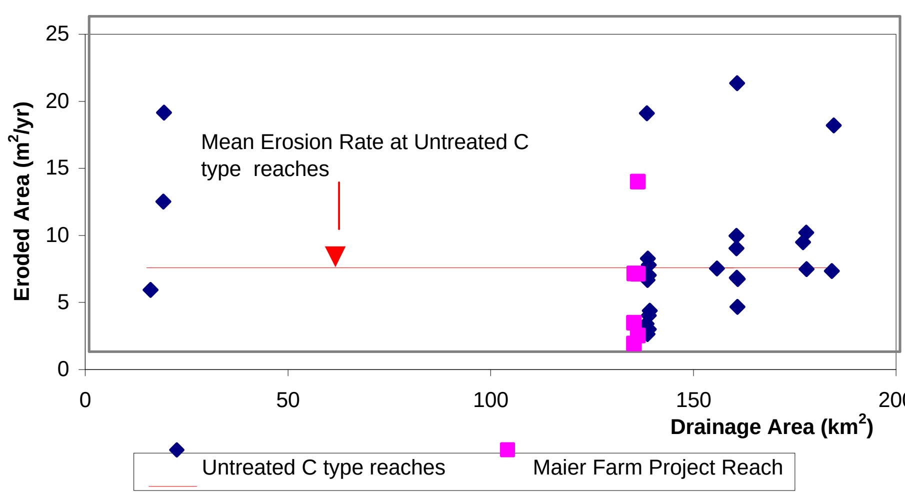


Figure 5: Comparison Erosion Rate between the Project Reach and Untreated C type Reaches in the Batavia Kill watershed

The project reach has different drainage area from other untreated reaches. To compare the erosion rate among reaches with different drainage areas, the eroded area/drainage area ratio is also calculated to normalize the erosion rate. The mean erosion area/drainage area ratio is 3.2 for untreated C-type reaches, and it is 0.97 for the project reach. The average eroded area/drainage area ratio at untreated reaches is 230% higher than that of the project reach.

It is important to note that the post-project erosion rate is calculated by using the monitoring data measured only one year after construction. At that time, the vegetative cover was not established and there was no root network on the stream bank. Since riparian vegetation can significantly improve bank stability and prevent bank erosion (Rosgen 1996), it is reasonable to assume that the post-project erosion rate would be even smaller if the vegetation cover were established on the project reach.

Stream bank erosion is the major source of the total sediment supply (Rosgen 2001). From the above analysis, one can reasonably assume that the effective reduction of erosion by the restoration project will lower the total sediment supply and thus improve the water quality, which is the primary objective of the stream restoration. However, there is no water quality data such as total suspended solids and turbidity available at the Maier Farm project reach to test that assumption. The water-quality monitoring plan should be integrated into future stream restoration projects to quantify the effect on the improvement of water quality.

CONCLUSION

The comparison of post-project and pre-project morphological characteristics shows that the restoration significantly reduced the width/depth ratio and increased the mean depth of the Maier Farm reach. The analysis of the post-project morphological data demonstrates that the width/depth ratio increased and that the mean depth decreased during 1999-2000 survey period due to the 1999 storm event, but, there are clear signs that those morphological characteristics tend to be stable during the 2000-2002 monitoring season.

Although experiencing more storm events and much higher stream flow during the post-project period (1999-2000), the Maier Farm project reach had almost the same erosion rate as that of the pre-project monitoring season (1998-1999). This fact provided excellent evidence of the restoration stability of the Maier Farm project. Moreover, compared to the project reach, the average untreated C-type reach has a 61% higher erosion rate and a 230% higher eroded area/drainage area ratio.

Overall, the Maier Farm project in the Batavia Kill watershed is successful in improving the stream channel stability and reducing the erosion rate.

ACKNOWLEDGMENT

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Effectiveness of Stream Restoration in Reducing Stream Bank Erosion: The Case of Batavia Kill Stream Restoration Projects, New York

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ABSTRACT: The number of stream restoration projects has increased dramatically during the last decade, especially in the New York City watershed region, where stream management to improve water quality is a high priority, and where the NYC Department of Environmental Protection and the Greene County Soil and Water Conservation District have partnered to develop a set of restoration demonstration projects. In this paper, the effectiveness of stream restoration projects in reducing stream bank erosion in the Batavia Kill watershed (Greene County, New York) is evaluated. This evaluation is based on a multivariate regression model to relate stream bank erosion rates to various explanatory variables including instruments representing geomorphological characteristics, flow conditions, rainfall conditions, temperature, the vegetation index, soil erodibility, and sediment characteristics. The general to specific approach is used to specify the regression model. A range of statistical tests is applied to check the model accuracy and the validity of the regression model. The results of these tests show that the stepwise regression model accurately predicts stream bank erosion rates on the Batavia Kill stream. The regression model is then applied on the project reaches, assuming there was no stream restoration to predict the stream bank erosion. It is found that the measured erosion on the restored reaches is much smaller than predicted erosion in the "without restoration" case, which means that the effectiveness of stream restoration in reducing bank erosion in the Batavia Kill watershed is significant.

Key Words: Stream restoration, Stream bank erosion, Erosion rates, Multivariate regression model, Model specification, Bank stability, Greene County SWCD, New York City Watershed, NYC Department of Environmental Protection

INTRODUCTION

Stream bank erosion and its associated sediment yield have tremendous negative impacts on water quality. Studies have shown, for instance, that stream bank erosion accounts for the majority of sediment load in some urban watersheds in the United States (Rosgen 1996; Trimble 1997). Sediment loads increase turbidity, alter aquatic habitats, and introduce pollutants, such as trace metals, in surface water. It is reported that an estimated 220,000 kilometers of stream bank are in need of erosion protection in the United States (U.S. Army Corps of Engineers 1983). Therefore, it is important to find out effective ways to minimize bank erosion and improve water quality.

In the 1960's, stream restoration was recognized for the first time as important – an occurrence that resulted from the negative impact of human activities on the watershed system. One can define stream restoration as "returning an ecosystem to a close approximation of its condition prior to disturbance" (Kondolf and Micheli 1995, FISRWG 1998). One primary purpose of the stream restoration is to stabilize stream banks and thus mitigate stream bank erosion. Therefore, the effectiveness of stream restoration in reducing stream bank erosion is critical in evaluating the success of a stream restoration project.

Extensive research has been carried out to analyze and predict stream bank erosion (Hooke 1979; Lawler 1986; Rosgen 1996; Simon and Darby 2002). Most of these studies estimate stream bank erosion rates based on the factors which are likely to control erosion. However, none of these approaches focuses on evaluating the effectiveness of stream restoration in reducing stream bank erosion. This scarcity is partially due to the relative short history of stream restoration projects and the lack of consistent monitoring of pre-project and post-project morphological and hydraulic characteristics, which are considered to be major elements controlling stream erosion. Therefore, a procedure based on stream monitoring data for the purpose of evaluating the effectiveness of stream restoration in reducing stream bank erosion needs to be developed. In this study, pre-project and post-project monitoring data in the Batavia Kill Watershed stream restoration projects have served as the basis of performance evaluation.

BATAVIA KILL WATERSHED STREAM RESTORATION PROJECTS

The Batavia Kill watershed is located in the Catskill Mountains in southeastern New York State (Figure 1). The watershed has an area of 186 km^2 and its mainstream, the Batavia Kill, runs for a distance of 34 km to its confluence with the Schoharie Creek, which is a major water resource for New York City's daily water supply. The New York City Department of Environmental Protection (NYCDEP) had identified the Batavia Kill watershed as having one of the highest turbidity conditions of all the NYC water supply systems. In 1997, the United States Environmental Protection Agency (USEPA) required NYCDEP to either improve the surface water quality to a certain level or to spend $8 billion to build a filtration plant. The NYCDEP has responded by developing a watershed protection program instead of the filtration plant. As part of the watershed protection program, the Greene County Soil & Water Conservation District (GCSWCD) has initiated the use of a geomorphic-based classification, assessment, and restoration strategy for addressing degraded stream reaches in the Batavia Kill watershed.

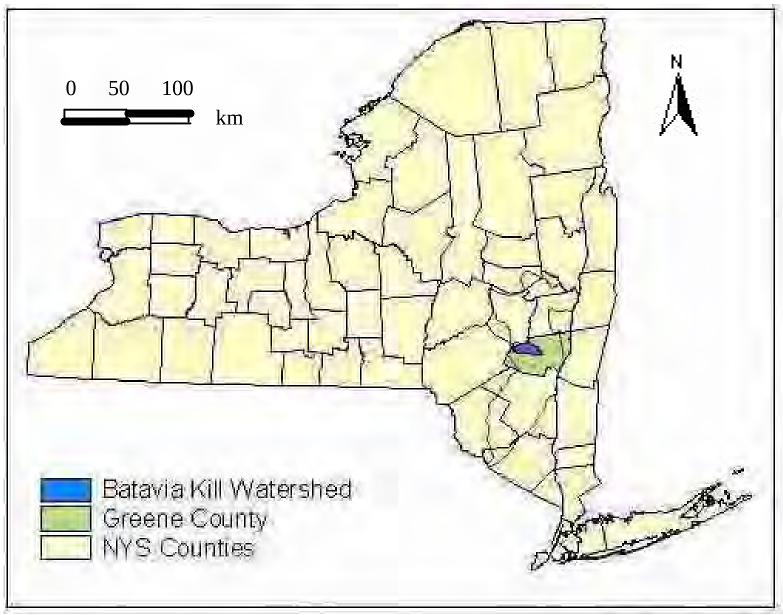

Figure 1: Batavia Kill Watershed Location Map

To date, three stream restoration projects have been accomplished in the Batavia Kill watershed. The first two projects were located in the middle of the stream corridor and are referred to as the Maier Farm project and the Brandywine project. The third project is located at the top of the watershed and is referred to as the Big Hollow project. Figure 2 shows the locations and the restoration periods of each restoration project. The Primary objective of the restoration projects was to mitigate excessive turbidity and the impact of Total Suspended Solids (TSS) on water quality by addressing excessive stream bank erosion (GCSWCD 2003). To achieve this goal, a stable Rosgen C4 stream type (Rosgen 1996) with typical meandering riffle-pool morphology was selected as the restoration strategy for the projects. Channel form and meander pattern was derived from historical aerial photographs, regime equations, and reference reach analyses.

The Batavia Kill watershed monitoring activities have been conducted annually since 1997. The monitoring activities include cross-section and profile survey, pebble counts, and the Bank Erosion Hazard Index (BEHI) measurement. To date, more than 100 cross sections have been established on the Batavia Kill stream. The channel geometry, channel bed materials distribution, and the vegetation information can be derived from the monitoring data.

STREAM BANK EROSION MONITORING AND MEASUREMENT

Sites with apparent erosion on stream banks are selected to conduct erosion monitoring since these sites are likely to show the erosion process more frequently and clearly. These sites are also important from the stream management point of view because they produce considerable amount of sediments, which are the major source of TSS and cause high turbidity. The description of erosion monitoring sites is given in Table 1. In total, eight erosion-monitoring sites were chosen on the Batavia Kill stream: these sites are Head Water, Big Hollow (pre-restoration), Brandywine (pre-restoration), Maier Farm (pre-restoration), Kastanis, Holdens, Red Falls, and Conine. The relative locations of erosion-monitoring sites are given in Figure 2. The drainage area at these sites ranges from 2.8 km^2 to 182.3 km^2. Each site was further divided into several sections based on the morphological characteristics such as sinuosity and the radius of curvature as well as soil erodibility. The subdivision of each monitoring site enables the investigation of the erosion variation under similar climatic and hydrological conditions. Altogether 33 separate sections were obtained by this approach (Table 1).

Figure 2: Demonstration Projects and Erosion Monitoring Sites in the Batavia Kill Watershed

The stream bank erosion is determined by overlaying cross-sections surveyed annually over the period from 1997 to 2003 on the Batavia Kill stream, and then measuring the eroded bank area or distance over a monitoring season. This method is believed to have the advantage of minimal disturbance on the stream bank, while covering the erosion measurement on the whole stream cross-section under investigation.

STREAM BANK EROSION PREDICTION

As one of major modeling techniques, multivariate regression is frequently used in the stream bank erosion prediction to establish the relationship between the bank erosion rates and various explanatory variables (Lawler 1986; Rosgen 1996). In this study, the stream bank erosion on the erosion monitoring sections determined from the cross-section surveys is regressed on a set of explanatory variables, and the erosion prediction model derived from the regression has been employed on out of sample data to predict stream bank erosion.

Table 1: Bank Erosion Monitoring Sites

Site	Section	No. of Cross-sections	No. of Observations	Average Drainage Area (km^2)	Description
Head Water	A	2	1	2.8	Upper portion of the reach is relatively stable, but lower portion of the reach exhibits severe erosion. Land cover is dominated by forest. Steep valley slope, narrow channel
	B	2	2	9.3	
	C	1	3	13.8	
Big Hollow	A	2	1	14.1	The reach was restored in 2001 and 2002. Prior to the restoration, the reach was highly unstable with extreme bank erosion. Very little vegetation coverage on the bank. Land use is open space with limited residential usage. Gravel bed channel. Bank materials consist of the mixture of clay/silt, sand and gravel.
	B	1	2	15.0	
	C	5	2	15.1	
	D	1	2	15.5	
	E	2	2	15.5	
	F	2	2	17.0	
	G	1	1	18.2	
	H	1	2	18.3	
Brandywine	A	1	2	108.2	The reach was restored in 1999 and 2000. The reach exhibited extreme bank erosion prior to the restoration.
	B	1	2	108.2	
Maier Farm	A	1	2	133.3	The reach was restored in 1999. The reach was extremely unstable prior to the restoration.
	B	1	2	133.4	
Kastanis	A	1	3	135.2	Experiencing large amount of bank erosion. Some portion of the stream bank has no vegetation cover. Forest and pasture land coverage, low density of residential housing. Gravel bed channel. Bank materials consist of the mixture of clay/silt, sand and gravel.
	B	3	3	136.5	
	C	1	3	136.7	
	D	4	3	136.8	
	E	3	3	137.0	
	F	2	3	137.2	
	G	2	3	137.6	
Holdens	A	2	1	158.5	Average valley slope is 0.3%, broad floodplain. Unstable reach and severe channel migration. Stream bank consists of non-cohesive materials. Farm and pasture land use.
	B	2	1	158.6	
	C	4	1	158.7	
Red Falls	A	2	2	174.7	Average valley slope is 1.2%, steep bank slope. Forest land coverage. Extremely unstable reach and highly negative impacts on water quality. High eroding banks, large clay exposure, active channel lateral migration.
	B	3	2	175.2	
	C	2	2	175.5	
	D	2	2	175.5	
Conine	E	2	2	175.5	Average valley slope is 1.2%, narrow flood plain. Extremely instable, accelerated bank erosion. Poor riparian vegetation.
	A	2	1	181.8	
	B	4	2	182.1	
	C	2	1	182.3	
Sum	33 sections	67	66		

Choices of Explanatory Variables

A number of factors have been identified as having influences on the stream bank erosion rates (Wolman 1959; Knighton 1998). These factors can be categorized into several groups: (1) cross-sectional and longitudinal characteristics; (2) parameters of flow conditions; (3) rainfall conditions; (4) temperature conditions, primarily the influence of frost; (5) vegetation and soil erodibility; and (6) sediment characteristics. Each group of influencing factors contains variables that may affect stream bank erosion rates. These variables have been considered in the regression to test their relationships with the steam bank erosion rates. Table 2 lists the explanatory variables examined in this study.

Table 2: Independent Variables used in the Bank Erosion Prediction

Factor	Variables	Source and method of measurement
(1) Cross-sectional and longitudinal characteristics	Drainage Area	USGS topographic maps measurements
	Cross-section area	Field survey of cross-sections
	Bankfull width	Field survey of cross-sections
	Cross-section maximum depth	Field survey of cross-sections
	Cross-section mean depth	Field survey of cross-sections
	Width/depth ratio	Field survey of cross-sections
	Bank height and Bank angle	Field survey of cross-sections
	Radius of curvature	GIS map measurement
	Radius of curvature/Bankfull depth	GIS map and field survey of cross-sections
	Sinuosity	GIS map measurement
	Channel slope	Field survey of longitudinal profile
(2) Flow conditions	Product of real time stream discharge and flow duration during a monitoring season	United States Geological Survey (USGS) gage stations nearby the bank erosion monitoring sites
(3) Rainfall Condition	Amount of rainfull per season Duration of rainfull per season	National Climatic Data Center (NCDC) station nearby the erosion monitoring sites
(4) Temperature	Froze-thaw circles per season Frozen days per season	NCDC station nearby the bank erosion monitoring sites
(5) Vegetation	Vegetation coverage index	GIS vegetation coverage, field pictures, field surveys, aerial photos, and BEHI.
(6) Bank and Bed Materials	Soil erodibility k, Bed materials size distribution D_{50}	GIS soil coverage, soil survey of Greene County, pebble counts, and bar samples

To quantify the influence of storm events on the stream bank erosion, the hydrograph method (McCuen 1998) is employed to account for the magnitude and duration of stream flows. In this method, volume of flow during a storm event is calculated by integrating the stream discharge with its duration. Since it is the medium to large events that contribute the most to stream bank erosion (Knighton 1998), events with flows higher than the mean peak flow, which is the average of all discharges above the mean annual flow, are taken into consideration. The volume of flows with discharge above the mean peak flow during an erosion-monitoring season at a particular site is selected as an explanatory variable to account for the impact of flows on stream bank erosion. Real time discharge data (recorded every 15 minutes) at each erosion-monitoring site are obtained from the nearby USGS gages in the Batavia Kill watershed to retrieve the flow magnitude and duration. Most erosion-monitoring sties are within several kilometers distance from the nearest USGS gage.

To investigate the influences of vegetation on bank erosion on the Batavia Kill stream, the historical vegetation information on each bank erosion-monitoring site are gathered from BEHI data, field surveys, field pictures, aerial photos as well as the GIS map. The vegetation conditions vary largely from site to site. Some sites have been fully covered by various vegetation, however others are exposed by barren soils. Meanwhile, there are also some banks partially covered by the vegetation. The vegetation condition on each site is categorized into one of these three groups, and is indexed as an explanatory variable in the bank erosion prediction model (full coverage =1, partial coverage =0.5, and barren soil =0).

Multivariate Regression Modeling

The average bank erosion area on cross-sections on an erosion-monitoring section over a monitoring season is selected as the dependent variable. Since the erosion measurement is made only on sections showing apparent bank erosion, whereas restored reaches generally exhibit little or no erosion, the project sites after stream restoration are excluded from the regression model. This strategy results in 66 observations on 33 erosion-monitoring sections. The bank erosion area – the dependent variable – has a mean value of 2.8 m^2 and a standard deviation of 3.3 m^2. There are 20 explanatory variables being considered in the regression analysis. These explanatory variables and their statistics are provided in Table 3.

Table 3: The Statistics of Explanatory Variables

Number	Variables	Abbreviation	Mean	Standard Deviation
1	Drainage area (km^2)	drain.area	107.19	64.65
2	Cross-section area (m^2)	xs.area	19.347	8.815
3	Bankfull width (m)	bkf.width	23.187	8.88
4	Cross-section maximum depth (m)	xs.maxdep	1.443	0.444
5	Cross-section mean depth (m)	xs.meandep	0.824	0.294
6	Width depth ratio	width.dep	32.335	18.837
7	Bank height (m)	bk.ht	3.916	3.248
8	Bank angle (°)	bk.angl	33.913	13.077
9	Radius of curvature	radius.curv	147.462	87.526
10	Radius of curvature/Bankfull width	rc.bkf	2.302	1.912
11	Sinuosity	sinu	1.192	0.288
12	Channel slope	chnl.slop	0.00829	0.00863
13	Erodibility K	erod	0.261	0.045
14	Stream flow ($10^6 m^3$)	streamflow	33.9	33.294
15	Precipitation days	precp.day	129.602	74.967
16	Precipitation (mm)	precp	1252.1	653.7
17	Froze-thaw circles	froze.thaw	134.136	74.300
18	Frozen days	froze.day	175.000	101.091
19	Bed material size (mm)	bed.mat	59.364	26.919
20	Vegetation index	veg	0.379	0.430

An analysis of multicollinearity among explanatory variables shows that a high degree of multicollinearity exists among regressors. The high multicollinearity makes it very difficult to interpret the effect of each independent variable on the response. Therefore, a specified model should be derived to best predict the stream bank erosion. The general to specific approach is used to specify the model. This algorithm starts with the full model, which incorporates all explanatory variables, and then deletes one variable from the model at a time. The variable to be removed from the model is the one that makes the smallest contribution. To determine a variable's contribution, the absolute value of that variable's t-ratio is considered. To be removed, the t-value must be less than a critical t-value in absolute value. This algorithm takes into account the joint effect of independent variables. In this study, the t-value corresponding to 95% significance level is used as the critical t-value.

After one variable is removed, the dependent variable is regressed on the rest of the explanatory variables to determine the next variable to be eliminated from the regression model until all variables are statistically significant. The final model selected by this approach has 7 explanatory variables: they are cross-section area, cross-section mean depth, width/depth ratio, bank angle, sinuosity, stream flow, and the vegetation index.

The final model has a R^2 of 0.7553, indicating that more than 75% bank erosion can be explained by the erosion prediction model. The F-statistic is 25.57, which is much higher than the critical F value of 2.172. The explanatory variables are therefore statistically significant in explaining the stream bank erosion. The t-statistic shows that all explanatory variables are statistically significant at a 90% confidence level, except for the bank angle (Table 4). Actually, the bank angle is statistically significant at a 77% confidence level. A variable at this significance level should be retained in the model to avoid screening out variables that may be important (Frees 1996). This choice is motivated by an algebraic result that when a variable enters a model, the standard error of the estimates will decrease if the t-ratio of that variable exceeds one in absolute value (Frees 1996). In addition, from the geotechnical point of view, the bank angle is an important variable contributing to stream bank erosion (Simon 2002). The level of multicollinearity among the explanatory variables in the final model is checked, and the results show that the degree of multicollinearity is not severe. The stream bank erosion estimated by the final model is plotted against the measured bank erosion in Figure 3.

The final model indicates that bank angle, sinuosity, and stream flow are directly related to stream bank erosion, while the vegetation index has an inverse relationship to bank erosion. Actually, field observations in the Batavia Kill watershed support the above model's interpretation. A large amount of bank erosion is observed at reaches where the banks are steep and the channels are sinuous, such as Kastanis and Red Falls. High flow events generally produce more bank erosion, and this is consistent with observations made by many researchers (Hooke 1979; Knighton 1998). At bank-erosion monitoring sections on the Batavia Kill stream, banks with high vegetation coverage in general have much less erosion than banks with little or no vegetation coverage. Table 4 also shows that bank erosion is directly related to the cross-section area while inversely related to the cross-section mean depth and width depth ratio. However, since width depth ratio can be computed as the cross-section area divided by the square of the cross-section mean depth, the relationship between the bank erosion and the cross-section area, mean depth and width depth ratio becomes intricate. The first order derivative analysis revealed that for most reaches on the Batavia Kill stream, bank erosion is indeed directly related to the cross-section area and inversely related to the cross-section mean depth, which means that wide and shallow reaches have the potential to incur more bank erosion.

Table 4: Summary of the Final Model

	Coefficients	Standard Error	t value	Pr(>|t|)	Significant codes
(Intercept)	-35.029	24.1438	-1.451	0.15221	
xs.area	0.131	0.0693	1.891	0.06367	.
xs.meandep	-18.654	7.672	-2.431	0.01815	*
width.depth	-0.43	0.251	-1.714	0.09185	.
bk.angl	0.241	0.198	1.214	0.22969	
sinu	75.814	9.045	8.382	1.41E-11	***
streamflow	0.00897	0.00265	3.391	0.00126	**
veg	-18.364	6.875	-2.671	0.00979	**

Significant codes: 0 `***' 0.001 `**' 0.01 `*' 0.05 `.' 0.1 ` ' 1

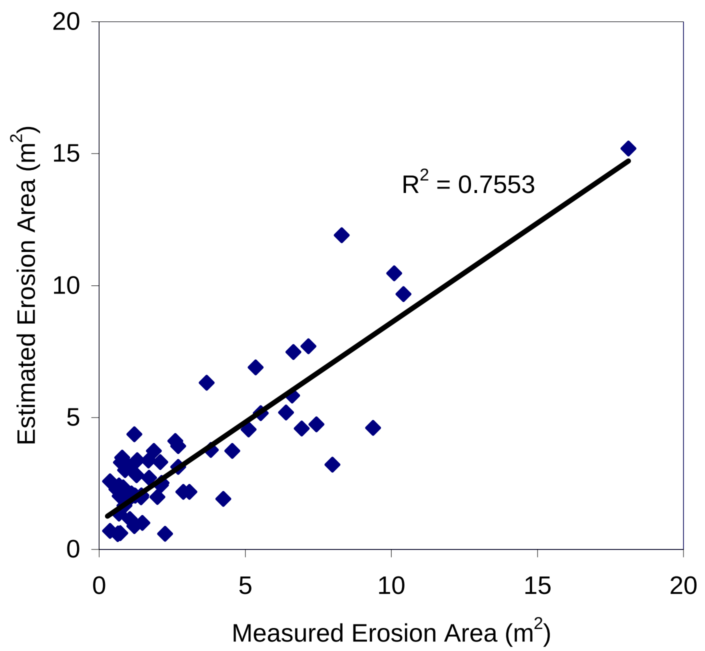

Figure 3: Estimated Bank Erosion by the Final Model vs. Measured Erosion

Model Validation

To validate the methodology being applied to the model specification, the 66 observations are split into two data sets. Each data set consists of 33 observations.

One data set is used to develop a prediction model, and the other data set containing out of sample data is used to validate the prediction model. The same general to specific method is used to specify the prediction model, and the predicted values are compared with the measured erosions (Figure 4). The R^2 between the predicted erosions and the measured erosions is 0.7084, which means that more than 70% of the measured bank erosions could be explained by the regression model. The methodology used in the model specification well predicts the characteristics of stream bank erosion. Notice that the relevant explanatory variables in the regression model generated from the validation process are not necessary the same as those in the final model specified using all observations because those two models are specified using a different number of observations.

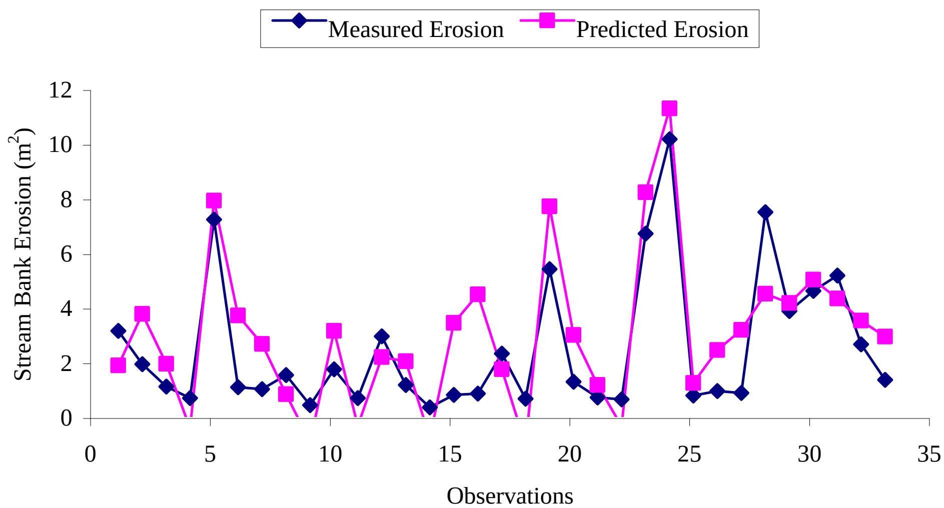

Figure 4: Comparison between the Predicted Erosion and Measured Erosion

Model Comparison

To further evaluate its predictability, the regression model developed in this study is compared with two existing bank erosion prediction models: Rosgen's Streambank Erosion Prediction Model (1996) and the Bank Stability and Toe Erosion Model developed by the United States Department of Agriculture, Agriculture Research Service (http://msa.ars.usda.gov/ms/oxford/nsl/cwp_unit/bank.html). The accuracy of prediction is measured by using three statistics: Mean Square Error (MSE), Mean Error (ME), and Mean Absolute Error (MAE) (Frees 1996). The results show that the regression model predicts the stream bank erosion in the Batavia Kill watershed more accurately than the other two models (Chen 2005). The MSE, ME, and MAE computed from the regression model are always smaller than those calculated from the other two models in absolute value.

EVALUATE STREAM RESTORATION IN REDUCING BANK EROSION

The stream bank erosion prediction model specified using all observations is applied on the Batavia Kill stream to evaluate the effectiveness of stream restoration projects in reducing bank erosion. Suppose there were no stream restoration, the bank erosion at project sites can be estimated using the prediction model given the pre-restoration conditions. The hypothetical bank erosion ("without restoration" case) is compared with the measured bank erosion at restored reaches ("with restoration" case). If the bank erosion estimated in the "without restoration" case is much greater than the erosion measured in the "with restoration" case, the stream restoration is said to be effective in reducing bank erosion. Otherwise, the stream restoration is ineffective in reducing bank erosion.

Table 5 compares the stream bank erosion measured at the restored reaches on the Batavia Kill stream from the completion of each project to the summer of 2003 with the erosion estimated by the prediction model over the same time period assuming no stream restoration. The total volume of measured stream bank erosion at the project sites is 2,685 m^3, and the total volume of bank erosion estimated by the prediction model in the "without restoration" scenario is 10,145 m^3. The "without restoration" case would produce 3.8 times more bank erosion than the "with restoration" case. The volume of reduced bank erosion by stream restoration is 7,460 m^3, which could fill about 1,000 dump trucks. The effectiveness of stream restoration in reducing stream bank erosion is significant.

Table 5: Comparison of Measured Erosion and Predicted Erosion

Project Reaches	Time Period	Reach Length (m)	Measured Erosion Volume at Restored Project Reaches (m^3)	Predicted Erosion Volume Assuming No Stream Restoration (m^3)
Maier Farm	09/99 -06/03	500	1,743	2,465
Brandywine	07/00 -06/03	1,100	226	5,048
Big Hollow	06/02-07/03	1,430	716	2,632
Sum		3,030	**2,685**	**10,145**

CONCLUSION

In this study, multivariate regression is used to relate stream bank erosion to various explanatory variables. These variables include instruments representing geomorphological characteristics, flow conditions, rainfall conditions, temperature, the vegetation index, soil erodibility, and sediment characteristics. The general to specific approach is used to derive a best-fit model to predict the stream bank erosion. The final model selected by this specification procedure shows that the higher the bank angle, sinuosity, and stream flow, the greater the amount of stream bank erosion; contrarily, the higher the vegetation coverage on the stream bank, the less the amount of bank erosion. The first order derivative analysis shows that for most reaches on the Batavia Kill stream, bank erosion is directly related to the cross-section area and inversely related to the cross-section mean depth, which means that wide and shallow reaches on the Batavia Kill stream have the potential to incur more bank erosion.

A set of tests has been applied on the bank erosion prediction model to test the model precision and to validate the methodology used to specify the model. These tests show that the stepwise regression model well predicts the stream bank erosions on the Batavia Kill stream. The regression model is then employed to predict stream bank erosion on the project reaches, assuming there was no stream restoration. The results show that from the completion of each project to the summer of 2003, the restoration projects reduced the stream bank erosion by 7,460 m^3. The effectiveness of stream restoration in reducing stream bank erosion in the Batavia Kill watershed is significant.

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