Appendix S
Riparian Corridor Restoration

Cayuga Lake Watershed
Very Severe Streambank Segments/Riparian Corridors

Sub Watershed Name	Location	Tributary Miles	Stream Rank (Formula)
Big Salmon Creek	E side of Stewart Corners Rd., 75'	64.29	390.9
Big Salmon Creek	W side of Rt. 34, 200'	64.29	712.4
Big Salmon Creek	W side of Rt. 34, 200'	64.29	712.4
Cayuga Inlet	W side of Dassance Rd., 25'	83.65	354.8
Cayuga Inlet	W side of Sheffield Rd., 100'	83.65	362.4
Cayuga Inlet	100' downstream from convergence of Inlet and Enfield Creek	83.65	365.7
Cayuga Inlet	NW side of Dug Rd., 300'	83.65	381.9
Cayuga Inlet	E side of Taggert Rd., 75'	83.65	393.0
Cayuga Inlet	E side of Seven Mile Dr., 10'	83.65	393.8
Cayuga Inlet	E side of Seven Mile Dr., 350'	83.65	393.8
Cayuga Inlet	S side of Smith Rd., 50'	83.65	395.4
Cayuga Inlet	W side of Brown Rd., 200'	83.65	398.8
Cayuga Inlet	E side of Rt. 96, 75'	83.65	400.0
Cayuga Inlet	W side of Barnes Hill Rd., 50'	83.65	409.6
Cayuga Inlet	W side of Culver Rd., 150'	83.65	421.8
Cayuga Inlet	N side of Vanbuskirk Gulf Rd., 50'	83.65	430.6
Cayuga Inlet	W side of Brown Rd., 50'	83.65	434.6
Cayuga Inlet	E side of Rt. 13, 300'	83.65	435.4
Cayuga Inlet	E side of Rt. 96, 75'	83.65	435.9
Cayuga Inlet	S side of Rt. 79, 100'	83.65	439.2
Cayuga Inlet	600' upstream from railroad	83.65	443.3
Cayuga Inlet	500' upstream from railroad	83.65	443.3
Cayuga Inlet	W side of Rt. 13A, 150'	83.65	449.3
Cayuga Inlet	SE side of Town Line Rd., 300'	83.65	473.5
Cayuga Inlet	W side of Rt. 96, 75'	83.65	484.7
Cayuga Inlet	W side of Rt. 96, 25'	83.65	484.7
Cayuga Inlet	W side of Shaffer Rd., 75'	83.65	486.3
Cayuga Inlet	W side of Calkins Rd., 200'	83.65	495.1
Cayuga Inlet	SE side of Rt. 79, 200'	83.65	504.8
Cayuga Inlet	W side of Rt. 13, 100'	83.65	625.6
Cayuga Inlet	S side of Rt. 79, 200'	83.65	631.6
Cayuga Inlet	W side of Bruce Hill Rd., 200'	83.65	633.6
Cayuga Inlet	E side of Sandbank Rd., 200'	83.65	747.0
Cayuga Inlet	W side of Seely Hill Rd., 150'	83.65	902.0
Cayuga Inlet	E side of Sandbank Rd., 100'	83.65	1109.5
Cayuga Inlet	N side of Blackslee Hill Rd., 75'	83.65	1130.4
Cayuga Inlet	W side of Elm St., 100'	83.65	1315.5
Fall Creek	N side of Nye Rd., 100'	150.79	375.5
Fall Creek	E side of Youngs Rd., 200'	150.79	376.6
Fall Creek	W side of Ringwood Rd., 100'	150.79	381.4
Fall Creek	E side of Pinckney Rd., 100'	150.79	384.8
Fall Creek	N side of Cemetery Rd., 50'	150.79	397.9
Fall Creek	S side of Lake St., 100'	150.79	398.5
Fall Creek	N side of Rt. 13, 100'	150.79	400.0
Fall Creek	W side of Rt. 366, 100'	150.79	587.1
Fall Creek	E side of Atwood Rd., 100'	150.79	762.7
Sixmile Creek	At confluence of trib., about 1/4 mile into woods	80.75	375.1
Sixmile Creek	Right trib at confluence	80.75	375.1
Taughannock Creek	W side of Rt. 89, 40'	62.67	385.5
Virgil Creek	N side of Ferguson Rd. Ext., 100'	79.03	386.8

Source: Cayuga Lake Watershed Streambank Inventory, 2000, Genesee/Finger Lakes Regional Planning Council

Cayuga Lake Watershed Stream Restoration

The priority water quality issue in the Cayuga Lake Watershed based on the *Cayuga Lake Watershed Restoration and Protection Plan* (RPP) is sedimentation. It creates or contributes to a number of water quality problems both in streams and ultimately in the impoundments they feed. Excessive sediment concentrations in the water column can be harmful to aquatic life and will exacerbate the toxic effects of other pollutants. Suspended sediment in the water column can increase temperature. Sediment deposits within streams degrade habitat for macroinvertebrates and fish. Finally, and perhaps most importantly, sediment carries other types of contaminants into the aquatic system: nutrients, organic compounds including pesticides, and heavy metals.

The *RPP* indicates the three main contributors to sedimentation in the watershed are streambank erosion, roadbank/road ditch erosion/maintenance and land use including agricultural and development practices.

The three critical areas of streambank erosion, and therefore streambank stabilization, based on the Cayuga Lake Watershed Streambank Inventory (2000) and the subsequent *RPP*, are segments of Salmon Creek, Cayuga Inlet, and Fall Creek. Below is the recommended methodology for streambank stabilization in the Cayuga Lake Watershed as well as examples of work already being done on the Cayuga Inlet and Six Mile Creek. The methodology includes assessment, design, restoration of riparian buffers, the implementation of best management practices, and stakeholders involvement. Due to the very severe nature of the segments indicated in the *RPP* it is recommended that this methodology be used on 3 miles of these stream segments per year for 10 years.

DESIGN PROCEDURE

The Fluvial Geomorphology remediation design procedure involves the determination of discharge-frequency through the project reach, evaluation of channel geomorphology, and determination of channel stability. Channel restoration design used the channel-forming or bankfull discharge to evaluate and design stable channel features. (FISRWG 1998). The channel-forming discharge is evaluated using a flow recurrence approach (USACE 1993,1998). The analysis of a sediment transport-rating curve, for total suspended solids, was performed for Six Mile Creek (USGS1996 to 2000).

Analysis Procedure: The analysis consists of determining the flow-frequency relationship at each location, computing the required channel geometry for the various project reaches, and the design of the project-specific features within each reach. The construction time frame required for the restoration should begin almost immediately in order to obtain a detailed design, evaluation, and restoration project alternatives in two years, after the beginning date of the project.

Design Constraints: Project design constraints included the limited space available in some areas occupied by houses, limitations on channel alignment at several locations, and channel lining material (silt or clay). Since some channel segment slopes are in the range of 2 to 3% additional lining is required to avoid degradation.

HYDROLOGIC ANALYSIS

An analysis is conducted of significant tributaries within the study reach to determine the design flow-frequency relationships at various locations through the project reach. Hydrologic analysis is conducted to determine the dominant discharge for use with design of stable channel features. Analysis is also required to determine less-frequent events to evaluate stability of critical project features. Analysis methods employ gaging station records, estimation of regional equations, and field measurements. Peak discharges are computed for the 2, 5, 10, 25, 50, and 100 year events.

EXAMPLE: SIX MILE CREEK AND CAYUGA INLET:

Gage Data Frequency Analysis: The German Cross Road USGS gage station is located downstream of the project segments at Six Mile Creek. The period of record is from 1996 to the present. The annual peak discharge records were analyzed using the procedures outlined in WRC Bulletin 17B (USWRC 1982) to determine a discharge-frequency relationship.

Regional Equations: Regional equations were estimated to provide a second method for the evaluation of discharge frequencies. The regional equations compute peak discharge from drainage area and elevation. The equation for the 2-year event is

$$Q_{2yr} = 15.4 * A^{0.69} * \left(\frac{E}{10^3} \right)^{-0.39}$$

where Q_{2yr} is the computed peak flow (cfs), A is the drainage area (sq. miles), and E is the elevation (feet msl). Similar equations were employed for the remaining flow events.

Determined Flow-Frequency: Peak discharge at each location was determined by multiplying the gage values by the ratio of the drainage areas raised to the drainage area exponent. By using the USGS regional equation exponent in the ratio, the relationship of the different frequency events was preserved. The final peak discharge value at each site was determined by

$$Q_{design} = (Q_{GageFreq}) \left[\frac{A_{site}}{A_{Gage}} \right]^{USGS\,\mathrm{Re}g.Exp}$$

where Q_{design} is the determined design flow rate (cfs), A_{site} is the total drainage area at the individual site, A_{Gage} is the gage drainage area, in square miles, and *USGS Reg.Exp* is the regional exponent applied to the drainage area in the USGS regional equation. The drainage area exponent varies from 0.69 for the 2-year event to 0.59 for the 100-year event. The gage data analysis and the USGS regional equations should produce similar results at the gage station location, with no difference at the 2-year event and an overall average difference of less than 5%.

USGS Gage Field Data Analysis: Cross sections and water surface elevations were surveyed in the vicinity of the USGS gage locations and at each project reach. The bankfull flow depth was estimated by field observations and transferred to the staff gage. From the gage frequency analysis, the estimated recurrence interval is 1.9 years. Various references often state the bankfull discharge is estimated to occur with a recurrence interval between 1.0 and 2.5 years (FISRWG, 1998). The analysis of the gage field data further supports the hydrologic frequency analysis.

Reference Reach: Within the both Six Mile Creek and the Cayuga Inlet, many stream reaches have been impacted by urban encroachment and roads runoff. Trails and access roads have also impacted existing streams. A reference reach location was selected at each sub-watershed. At the reference reach location, measured cross sections, profile, and observations were collected in order to estimate the bankfull discharge, and hydrologic analysis to determined the 2-year peak flow rate for the drainage area. If the results obtained by these two methods are similar, the estimated peak flow frequency is then considered accurate.

PROJECT DESIGN

Design Phase: The project design phase for each stream reach is based site-specific data. The hydrologic, topographic, and stream assessment data collection and analysis is indicated in detail in the enclosed data summary tables (Appendix I). Once the design channel alignment, section, slope, and location of transition features are determined, the construction phase of the restoration can then be promptly scheduled. Coordination with towns and agencies representatives, should take place form the onset of the stream assessment phase, in order to expedite as much as possible the design and construction phases of the restoration projects.

Channel Cross Section Design: The channel cross section is designed to contain a flow rate. Within some reaches, the design flow rate can be increased. Higher channel capacity may be required to provide increased reliability at critical locations.

Channel width is evaluated using reference reach data. Flow area and channel capacity is confirmed with a normal depth analysis and evaluation with SAM (USACE, 1998). The slopes are restored to a stable slope, and the flow channel is established within the designed riparian corridor. The channel section includes a minimum floodplain width between the side slope and restored channel. Established channel section width may vary. Meander wavelength is determined using available relationships (Rosgen, 1994) and constrained by the reach topography. Generally, the meander length varies from 5 to 7 times the channel bankfull width. In order to reduce bend shear stress, the radius of curvature is limited to a minimum of 3 times the channel width.

Channel Features: Not all channel features are indicated here. Channel features utilize rocks sized to provide stability for the design event. Minimum rock size is evaluated for each design reach using the radius of curvature, channel width, and flow parameters. The rock size is measured within the channel using a pebble count and sidebars sizing procedures. Rock size is also computed using steep slope riprap design guidance (USACE, 1994):

$$D_{30} = \frac{1.95 S^{0.555} q^{2/3}}{g^{1/3}}$$

where D_{30} is the riprap size of which 30 percent is finer by weight (feet), S is the bed slope (ft/ft), q is the unit discharge (cfs/ft), and g is the gravitational constant (ft/sec^2). The design methodology states many recommendations including multiplying the unit discharge by a flow concentration factor of 1.25.

Following placement of the chute rock, surface voids are filled with 2-3 inch diameter gravel and soil and vegetated to improve the aesthetic appearance of the feature, as well as to improve habitat quality. Pools are employed as energy dissipators at the base of steeper slope stream reaches under remediation. Plunge pool design follows general design guidance (USACE, 1988). The plunge pool width is approximately 2 times the channel width and the plunge pool length is approximately 3 times the channel width. Using the chute flow Froude number, plunge pool length and depth are also evaluated based on the hydraulic jump length and sequent depth.

EXISTING FLUVIAL GEOMORPHOLOGICAL STREAM RESTORATION IN CAYUGA INLET AND SIX MILE CREEK

The objective of this document is to very briefly outline the stream restoration strategy used for fluvial-geomorphology based restoration projects. Where applicable, the stream types for which the practices are appropriate are given in terms of the Rosgen classification scheme (see table The Rosgen Stream Classification Scheme). It is important to assess the causes of any instability problem prior to designing a channel restoration or stabilization project. For example, streambank stabilization involving the installation of a structure may also involve re-shaping the channel in order to provide for the stable distribution of energy (Rosgen 1996, and USDA Interagency Stream Corridor Restoration Handbook *www.usda.gov/stream_restoration*) .

Design Flows

The design of in-stream construction, stabilization, and restoration measures depends on the magnitude and frequency of stream flow. Many techniques used for streambank stabilization, including toe protection and surface armoring, are required to accommodate bankfull flow velocities and shear stresses. Bankfull velocities for design purposes can be estimated from Manning's equation as follows:

$$V = \frac{\phi}{n} R^{2/3} S^{1/2}$$

where Φ = 1.49 or 1.0 for U.S. or metric units, respectively, n is the Manning's roughness coefficient for bankfull conditions, R = the hydraulic radius associated with bankfull depth and width, and S = slope. The average boundary shear stress and cross section can be estimated from:

$$\tau_0 = \gamma RS$$

where γ = specific weight of water. R and S are the same as defined above.

Bankfull discharge is defined as the maximum discharge which can contained within the channel without over-topping the banks (Thorne et al., 1998). The bankfull depth is the flow depth associated with the bankfull discharge. In a stable channel, the bankfull discharge is thought to be the discharge which forms and maintains the present morphology of the channel. In an unstable channel, the bankfull discharge used for design purposes should reflect the bankfull discharge that would be expected if the channel were stable. Reference reaches, effective discharge studies, or bankfull indicators should be used to determine this magnitude.

Temporary measures for dewatering and diverting flow from a reach for construction purposes should have sufficient capacity to convey 2-year flows for existing development conditions. For projects where hydrologic data is not available, bankfull flows may be substituted for the 2-year storm event. Design flows for temporary structures could be reduced to a lower flow if the project will take less than 2 weeks.

Cost Information

Approximate costs are included to facilitate planning, and may vary significantly based on local conditions and constraints. The costs were derived from King, D.M., Bohien, C.C. and Kraus, M.L. (1994), "Stream Restoration: The Costs of Engineered Bioengineered Alternatives." Costs for the November 2000 revision of the guidelines were updated from the costs provided in the 1999 draft using "Engineering News Record" Construction Cost Indexes.

Cayuga Inlet and Six Mile Creek Management Plan

The streambank restoration projects at the Cayuga Lake Inlet, that includes Six Mile Creek, are part of a comprehensive watershed management plan. The restoration of riparian buffers, the implementation of best management practices, stakeholders involvement and the promotion of local ordinances are among the main components of this comprehensive management plans. The Cayuga Lake Intermunicipal Organization Restoration and Protection Plan contains these sub-watershed management plans.

The main objective of the present streambank restoration program is the reduction of silt loading and the improvement of habitat and water quality in these subwatersheds. Assessment and monitoring programs will be continued after the implementation of the streambank stabilization programs.

Performance criteria are suspended sediment load, rate of lateral channel migration, as well as water quality, sediment load, and evaluation of streambank stability.

THE ROSGEN STREAM CLASSIFICATION SCHEME

	SINGLE-THREAD CHANNELS														MULTIPLE CHANNELS			
Entrenchment Ratio	ENTRENCHED (<1.4)						MODERATELY ENTRENCHED (1.4-2.2)			SLIGHTLY ENTRENCHED (>2.2)								
Width/Depth Ratio	LOW (<12)				MODERATE TO HIGH (>12)		MODERATE (>12)			VERY LOW (<12)		MODERATE TO HIGH (>12)			VERY HIGH (>40)			LOW (<40)
Sinuosity	LOW (<1.2)		MODERATE (>1.2)		MODERATE (>1.2)		MODERATE (>1.2)			VERY HIGH (>1.5)		HIGH (>1.2)			LOW (<1.2)			LO-HI (1.2-1.5)
Stream Type	**A**		**G**		**F**		**B**			**E**		**C**			**D**			**DA**
Slope	>0.10	0.04-0.099	0.02-0.039	<0.02	0.02-0.039	<0.02	0.04-0.099	0.02-0.039	<0.02	0.02-0.039	<0.02	0.02-0.039	0.001-0.02	<0.001	0.02-0.039	0.001-0.02	<0.001	<0.005
CHANNEL MATERIAL																		
Bedrock	A1a+	A1	G1	G1c	F1b	F1	B1a	B1	B1c			C1b	C1	C1c				
Boulders	A2a+	A2	G2	G2c	F2b	F2	B2a	B2	B2c			C2b	C2	C2c				
Cobbles	A3a+	A3	G3	G3c	F3b	F3	B3a	B3	B3c	E3b	E3	C3b	C3	C3c	D3b	D3		
Gravel	A4a+	A4	G4	G4c	F4b	F4	B4a	B4	B4c	E4b	E4	C4b	C4	C4c	D4b	D4	D4c	DA4
Sand	A5a+	A5	G5	G5c	F5b	F5	B5a	B5	B5c	E5b	E5	C5b	C5	C5c	D5b	D5	D5c	DA5
Silt/Clay	A6a+	A6	G6	G6c	F6b	F6	B6a	B6	B6c	E6b	E6	C6b	C6	C6c	D6b	D6	D6c	DA6

Reference

Rosgen, D. *Applied River Morphology*, Classification Key for Natural Rivers, 1996.

ROCK VANES

DESCRIPTION
The work should consist of installing rock vanes to direct normal flows away from unstable stream banks and to improve/create aquatic habitat by enhancing flow diversity through the formation of scour pools.

EFFECTIVE USES & LIMITATIONS
Rock vanes are single-arm structures, which are partially embedded in the streambed such that they are submerged even during low flows. When properly positioned, rock vanes induce secondary circulation of the flow thereby promoting the development of scour pools. Rock vanes can also be paired and positioned in a channel reach to initiate meander development or migration.

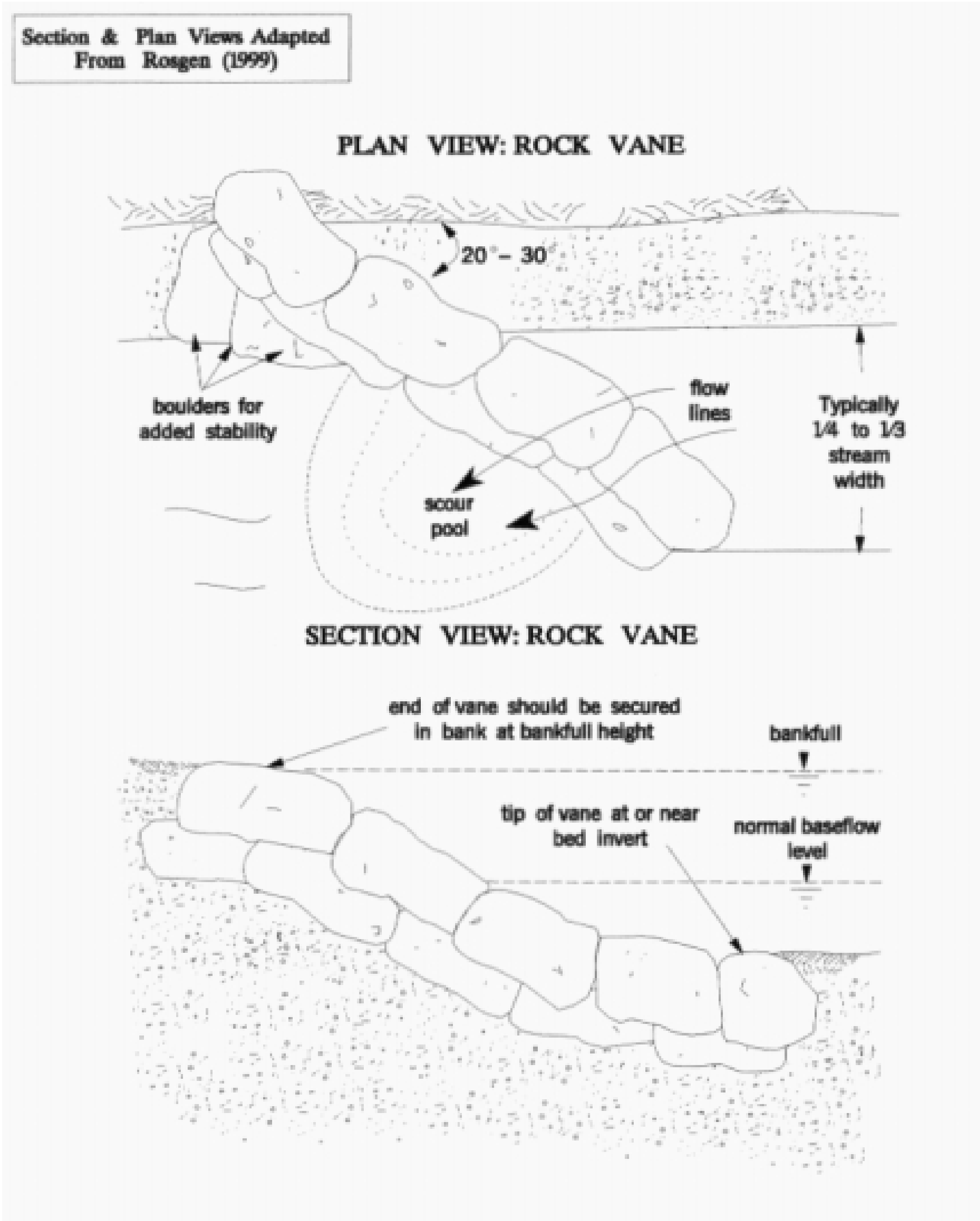
The following limitations apply to rock vanes:

- Vanes should not be used in unstable streams unless measures have been taken to promote stream stability so that it may retain a constant planform and dimension without signs of migration or incision
- Vanes are ineffective in bedrock channels since minimal bed scouring occurs. Streams with fine sand, silt, or otherwise unstable substrate should be avoided since significant undercutting can destabilize this structure. In these streams, log vanes may be considered.
- Vanes should not be used in stream reaches which exceed a 3% gradient.
- Vanes should not be used in streams with large sediment or debris loads.
- Vanes are best suited to Rosgen types B2-B5 and C2-C4.
- Banks opposite these structures should be monitored for excessive erosion.

MATERIAL SPECIFICATIONS
Materials for vanes should meet the following requirements:
Large Rocks: Rock size should be a minimum of 2.5 median diameter or weigh a minimum of 200 pounds. Additionally, large rocks and boulders can be positioned on the downstream side of straight vanes to provide further stability.

Approximate Cost ($1999):
$406 per single wing vane

INSTALLATION GUIDELINES
All erosion and sediment control devices, including dewatering basins, should be implemented as the first order of business according to a plan approved by NYS DEC. The stream should be diverted according to an approved practice, and the construction area should be dewatered. (See Rock vane diagram):


Section & Plan Views Adapted From Rosgen (1999)
PLAN VIEW: ROCK VANE
20° – 30°
boulders for added stability
flow lines
Typically 1/4 to 1/3 stream width
scour pool
SECTION VIEW: ROCK VANE
end of vane should be secured in bank at bankfull height
bankfull
tip of vane at or near bed invert
normal baseflow level

J-H00K VANES

DESCRIPTION

The work should consist of installing rock vanes to direct normal flows away from unstable stream banks and to improve/create aquatic habitat by enhancing flow diversity through the formation of scour pools.

EFFECTIVE USES AND LIMITATIONS

J-hook vanes are single-arm structures whose tip is placed in a "J" configuration and partially embedded in the streambed such that they are submerged even during low flows. When properly positioned, J-hook vanes induce secondary circulation of the flow thereby promoting the development of scour pools. J-hook vanes can also be paired and positioned in a channel reach to initiate meander development or migration.

The following limitations apply to J-hook vanes:

- J-hook vanes should not be used in unstable streams unless measures have been taken to promote stream stability so that it may retain a constant planform and dimension without signs of migration or incision
- J-hook vanes are ineffective in bedrock channels since minimal bed scouring occurs. Streams with fine sand, silt, or otherwise unstable substrate should be avoided since significant undercutting can destabilize this structure.
- J-hook vanes should not be used in stream reaches which exceed a 3% gradient.
- J-hook vanes should not be used in streams with large sediment or debris loads.
- J-hook vanes are best suited to Rosgen types B2-B5 and C2-C4.
- Banks opposite these structures should be monitored for excessive erosion.

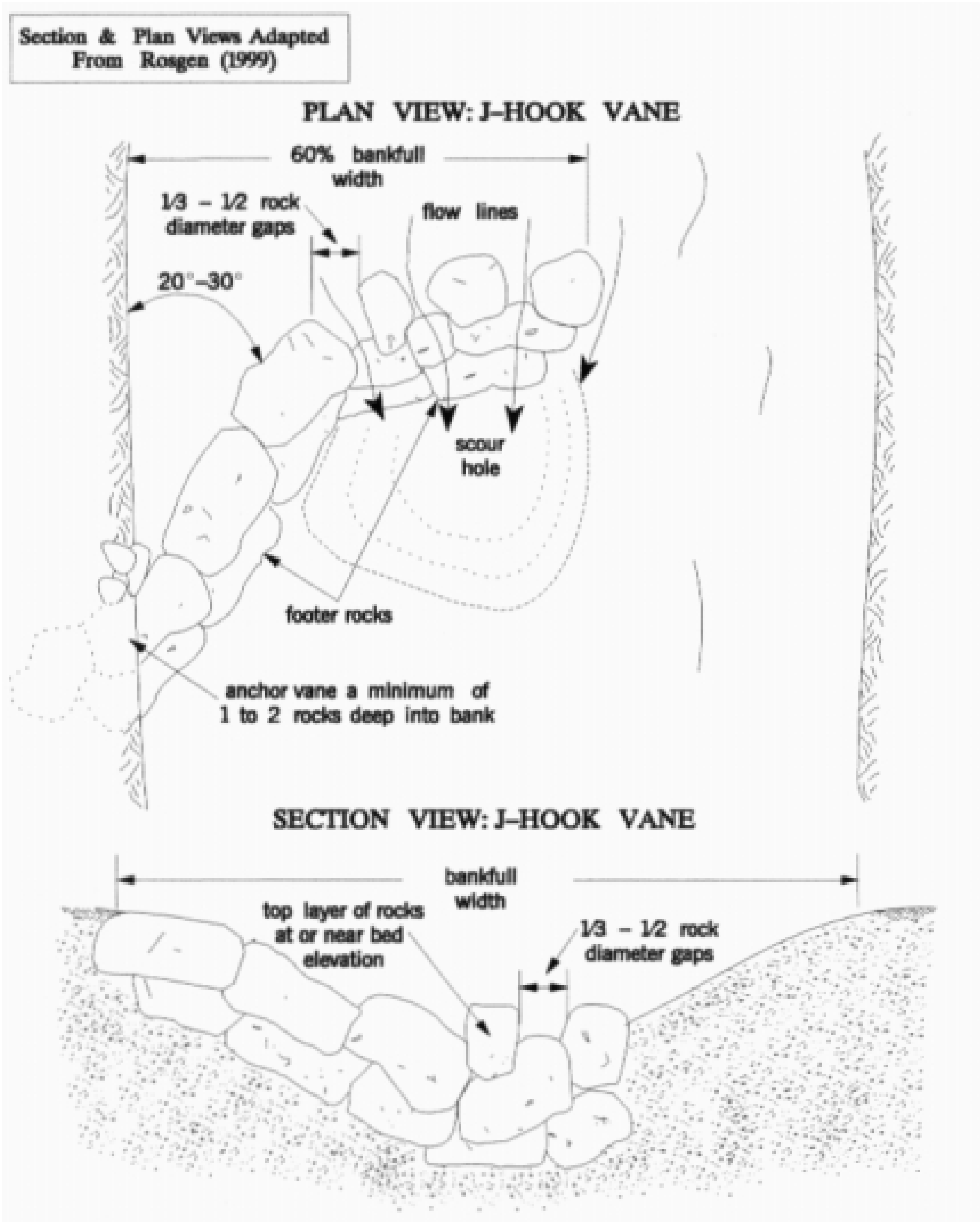
MATERIAL SPECIFICATIONS

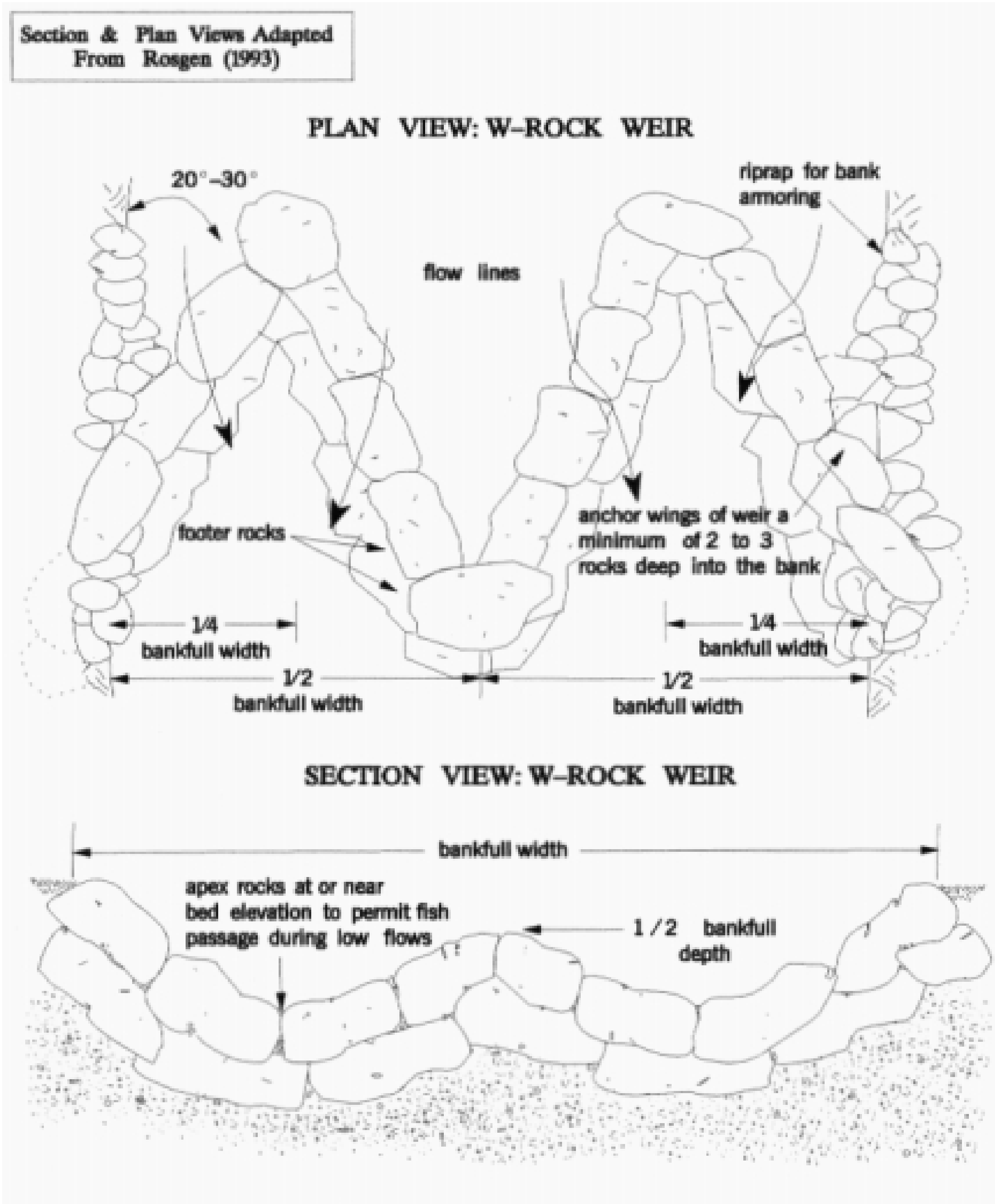
Materials for vanes should meet the following requirements:
Large Rocks Large rocks for vane construction should be sized to withstand the design flood stage. In general, rock sizes should have a minimum of *2.5* median diameter or weigh a minimum of 200 pounds. Footer rocks should be long and flat.

INSTALLATION GUIDELINES

All erosion and sediment control devices, including dewatering basins, should be implemented as the first order of business according to a plan approved by the NYS DEC. Recommended construction requirements for J-hook vanes are indicated in the J-Hook Vane illustration below.

1. The stream should be diverted according to an approved practice, and the construction area should be dewatered.
2. When placed to initiate meander development, vanes should be spaced 5 to 7 bankfull widths apart and arranged on alternating banks. Vanes used for habitat creation should be spaced by one or more channel widths apart depending upon the pattern of scour pools in natural reference reaches. Additionally, the following primary design criteria need to be satisfied: shape and orientation, height, and length.


Section & Plan Views Adapted
From Rosgen (1999)
PLAN VIEW: J–HOOK VANE
60% bankfull
width
1/3 – 1/2 rock
diameter gaps
flow lines
20°–30°
scour
hole
footer rocks
anchor vane a minimum of
1 to 2 rocks deep into bank
SECTION VIEW: J–HOOK VANE
bankfull
width
top layer of rocks
at or near bed
elevation
1/3 – 1/2 rock
diameter gaps


Section & Plan Views Adapted From Rosgen (1993)
PLAN VIEW: W-ROCK WEIR
20°–30°
riprap for bank armoring
flow lines
footer rocks
anchor wings of weir a minimum of 2 to 3 rocks deep into the bank
1/4 bankfull width
1/4 bankfull width
1/2 bankfull width
1/2 bankfull width
SECTION VIEW: W-ROCK WEIR
bankfull width
apex rocks at or near bed elevation to permit fish passage during low flows
1/2 bankfull depth

CROSS VANEs

DESCRIPTION

Low profile in-stream structures such as cross vanes are primarily used to create aquatic habitat in the form of scour pools and for grade control on incising streams and rivers. Additionally, they are well suited for channeling flow away from unstable banks.

EFFECTIVE USES & LIMITATIONS

Cross vanes are used in moderate to high gradient streams. Cross vanes are best suited to Rosgen stream types A3-A4, B3-B4, C3-C4, F3-F4, and G3-G4. When constructed and spaced properly, cross vanes can simulate the natural pattern of pools and riffles occurring in undisturbed streams while forming gravel deposits which fish use as spawning grounds. Cross vanes can also be used to stabilize banks when designed properly.

Cross vanes should be avoided in channels with bedrock beds or unstable bed substrates, and streams with naturally well developed pool-riffle sequences.

MATERIAL SPECIFICATIONS

Rock and boulder material for the construction of cross vanes should meet the following requirements:

> ***Footer Rocks****:* Vortex rocks should be large enough to achieve the desired height when partially buried in the streambed and should be sized to resist movement from shear stresses expected for the design flow. Footer rocks should be long and flat.
>
> ***Riprap:*** Riprap for added stability, bank armoring, and toe protection should be capable of withstanding bankfull flow velocities.

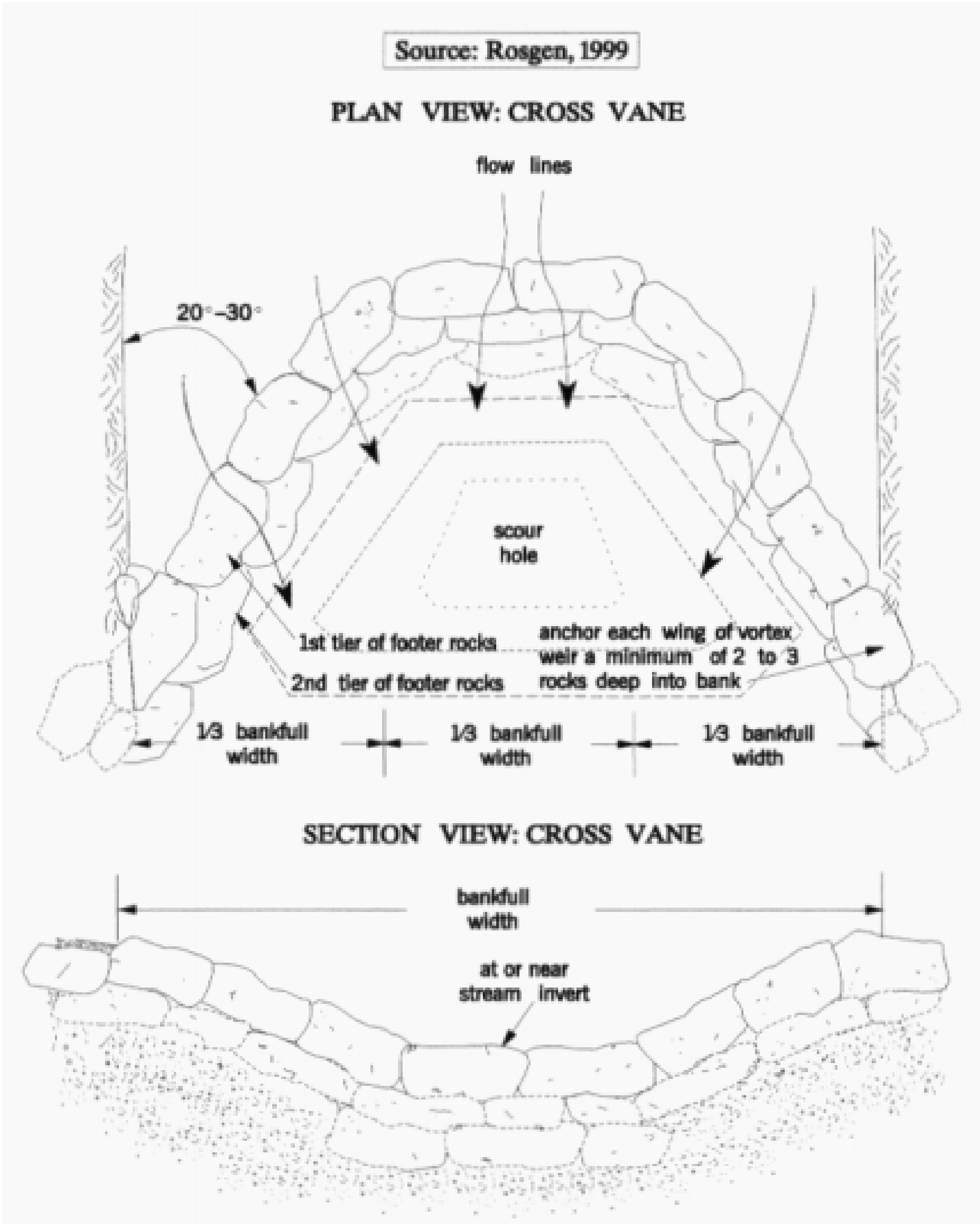
Approximate Cost ($1999):
$1,212 per structure

INSTALLATION GUIDELINES

All erosion and sediment control devices, including dewatering basins, are to be approved by the NYS DEC. The recommended construction for both cross vanes and weirs is indicated on the figure below (Cross Vanes):

I. The stream should be diverted according to a NYS DEC recommended plan, and the construction area should be dewatered.

2. Cross vanes are typically designed with a “U” shape such that the apex of the structure points upstream. The angle the arms make with the upstream bank should be approximately 20 to 30 degrees so that flows are directed away from the banks and deeper pool areas are created directly downstream of the vane or weir. All rocks should touch adjacent rocks to form a tight fit. Vane rocks shall be placed on top of footer rocks so that each vane rock rests upon two halves of each footer rock below, and so that the vane rock is offset in the upstream direction. Vane rocks shall be shingled upstream. On unstable bed substrates, two tiers of footer rocks may be required to obtain a stable structure.


Source: Rosgen, 1999
PLAN VIEW: CROSS VANE
flow lines
20°–30°
scour hole
1st tier of footer rocks
2nd tier of footer rocks
anchor each wing of vortex weir a minimum of 2 to 3 rocks deep into bank
1/3 bankfull width
1/3 bankfull width
1/3 bankfull width
SECTION VIEW: CROSS VANE
bankfull width
at or near stream invert

REFERENCES

Federal Interagency Stream Restoration Working Group (FISRWG), October 1998. Stream Corridor Restoration: Principles, Processes, and Practices, 7-10 – 7-13,7-48.

Rosgen, D.L. 1996. Applied River Morphology, Wildland Hydrology, Colorado, 3-1 – 5-189.

Thorne C R, P J Soar, R D Hey, and C C Watson (1998). Dominant Discharge Calculation. A Practical Guide. US Army Research, Development, and Standardization Group - UK, London.

USACE, March 1998, User's Manual for the SAM Hydraulic Design Package, Waterways Experiment Station, Vicksburg, MS.

USACE, 1994, EM 1110-2-1601, Hydraulic Design of Flood Control Channels, Rev. 3-1 – 3-12.

USACE 1988. Hydraulic Design Criteria, Sheet 722-4 to 722-7, Storm Drain Outlets, Riprap Energy Dissipators.

USGS, 1993, Nationwide Summary of U.S. Geological Survey Regional Regression Equations for Estimating Magnitude and Frequency of Flood for Ungaged Sites, 101-102.

USGS Water Year (1996 – 2000) Water Resources Data. Volume 3. Western New York.

U.S. Water Resources Council (USWRC). 1982. Guidelines for Determining Flood Flow Frequency. Bulletin #17B of the Hydrology Subcommittee. U.S. Interagency Advisory Committee on Water Data.

Appendix I

DATA ENTRY FORM - 1

STREAM:	
LOCATION:	
LOCATION RIGHT PIN: Latitude	
LOCATION RIGHT PIN: Longitude	
LOCATION LEFT PIN: Latitude	
LOCATION LEFT PIN: Longitude	
DRAINAGE AREA (sq. mi.):	
DATE OF FIELD OBSERVATION:	
FIELD OBSERVERS:	
DATE OF DATA ENTRY:	
DATA ENTERED BY:	
STREAM TYPE:	
VALLEY TYPE:	

CROSS SECTION DIMENSIONS

	(ft or ft^2)
Cross Section Number (Station)	
Bankfull Width	
Bankfull Cross Sectional Area	
Area of 1/3 Channel Width (right)	
Area of 1/3 Channel Width (left)	
Maximum Depth at Thalweg	
Flood Prone Area Width	

LONGITUDINAL DIMENSIONS

	(ft)
Station of Profile (begin, end)	
Thalweg Length	
Upper Thalweg Elevation	
Lower Thalweg Elevation	
Upper Water Surface Elevation	
Lower Water Surface Elevation	
Upper Bankfull Surface Elevation	
Lower Bankfull Surface Elevation	
Average Pool Length	
Average Pool Slope	
Pool Slope - Range	
Average Maximum Depth of Pools	
Maximum Depth of Pools - Range	
Average Pool Width	
Pool Width - Range	
Pool to Pool Spacing - Average	
Pool to Pool Spacing - Range	
Average Riffle Length	
Average Riffle Slope	
Riffle Slope - Range	
Riffle to Riffle Spacing - Average	
Riffle to Riffle Spacing - Range	

PLAN FORM DIMENSIONS

	(ft)
Valley Distance (of reach)	
Valley Slope	
Sinuosity (from aerial photograph)	
Date of Aerial Photograph	
Meander Length	
Meander Length-Average	
Meander Length-Range	
Average Radius of Curvature	
Radius of Curvature-Range	
Belt Width	

PEBBLE COUNT

Date:	
Location:	

Particle Size	# of Particles
<.062	
.062 - .125	
.125 - .25	
.25 - .50	
.50 - 1.0	
1.0 - 2	
2 - 4	
4.0 -6	
6 - 8	
8 - 12	
12 - 16	
16 - 24	
24 - 36	
32 -48	
48 - 64	
64 - 96	
96 - 128	
128 - 192	
192 - 256	
256 - 384	
384 - 512	
512 - 1024	
1024 - 4096	
Bedrock	

BAR SAMPLE

Location	
Sample Number	
Sample Collected by	
Date Sample Collected	
Date of Analysis	
Analysis Performed By	

*** Note:** *Enter sieve size in descending order*

Sieve Size (mm)	Total Weight (lbs.)	Tare Weight (lbs.)
Largest particles on bar (mm):		

REGIONAL FLOW DATA

Bankfull Flow (Regional Curve - Rosgen)	
Bankfull Flow (Regional Curve - Local)	

USGS Regional Regression Equation

Q_2		Q_{25}	
Q_5		Q_{50}	
Q_{10}		Q_{100}	

DATA ENTRY FORM - 2

SUMMARY OF CONDITIONS

DATE OF FIELD OBSERVATION:

Riparian Vegetation		(8a, 9b)
Flow Regime		(P;2,6)
Stream Size, Stream Order		(S-4(3)
Depositional Patterns		(B2)
Meander Pattern		(M3)
Debris/Channel Blockages		(D3)
Altered Channel State		(Straightened, Lined, Relocated, etc)

General Remarks:

Pfankuch

Channel Stability Rating

Location of analysis:		
1. Land form Slope		
2. Mass Wasting		
3. Debris Jam Potential		
4. Vegetative Bank Protection		
5. Channel Capacity		
6. Bank Rock Content		
7. Obstructions to flow		
8. Cutting		
9. Depositional Patterns		
10. Rock Angularity		
11. Brightness		
12. Consolidation of Particles		
13. Bottom Size Distribution		
14. Scouring and Deposition		
15. Aquatic Vegetation		
Sediment supply		(Extreme, Low)
Streambed (vertical) stability		(Degrading, Stable)
Width/Depth ratio condition		(Normal, High, Very High)

Bank Erosion Hazard Index (BEHI)

Location of Analysis		
Bank Height/Bankful Height		
Root Depth/Bank Height		
Root Density (%)		
Bank Angle (degrees)		
Surface Protection (%)		
Total Numerical Adjustment		
BEHI Score		
Overall Classification(Erodability)		(Extreme, High, Moderate, Low)

General Remarks:

STREAM CHANNEL CLASSIFICATION - LEVEL III

STREAM: | **Stream Type** | **Valley Type**

LOCATION:	
LOCATION RIGHT PIN: Latitude	
LOCATION RIGHT PIN: Longitude	
LOCATION LEFT PIN: Latitude	
LOCATION LEFT PIN: Longitude	
DRAINAGE AREA (sq. mi.):	
DATE OF FIELD OBSERVATION:	
FIELD OBSERVERS:	
DATE OF DATA ENTRY:	
DATA ENTERED BY:	

Cross Section Dimensions

Cross Section Number (Station)		
Bankfull Width (W)		feet
Bankfull Cross Sectional Area (A)		sq. feet
Bankfull Mean Depth (D)		feet
Width/Depth Ratio (W/D)		
Wetted Perimeter (WP)		feet
Hydraulic Radius (A/WP)		feet
Maximum Depth at Thalweg (MD)		feet
Flood Prone Area Stage (2 x MD)		feet
Flood Prone Area Width (FPW)		feet
Entrenchment Ratio (FPW/W)		

Longitudinal Reach Profiles

Thalweg Length		feet
Upper Thalweg Elevation		feet
Lower Thalweg Elevation		feet
Thalweg Elevation Difference		feet
Upper Water Surface Elevation		feet
Lower Water Surface Elevation		feet
Water Surface Elevation Difference		feet
Upper Bankfull Elevation		
Lower Bankfull Elevation		
Bankfull Elevation Difference		
Bankfull Slope		
Bankfull Slope %		%
Water Surface Slope		
Water Surface Slope %		%
Thalweg Slope		
Thalweg Slope %		%

REGIONAL FLOW DATA

USGS Regional Regression Equations

2- Year Return Flow	Q_2		cfs
5 - Year Return Flow	Q_5		cfs
10 - Year Return Flow	Q_{10}		cfs
25 - Year Return Flow	Q_{25}		cfs
50 - Year Return Flow	Q_{50}		cfs
100 - Year Return Flow	Q_{100}		cfs

Plan Form Dimensions

Valley Distance (of reach)		feet
Valley Slope		
Sinuosity (aerial photograph)		
Date of Aerial Photograph		
Sinuosity (Thalweg length / valley distance)		
Sinuosity (valley slope/stream slope)		
Meander Length (Lm)		feet
Meander length to bankfull width (Lm/W)		
Average Radius of Curvature (Rc)		feet
Radius of Curvature-Range		feet
Radius of curvature to bankfull width (Rc/W)		
Belt Width		feet
Meander width ratio (Belt Width/W)		

Feature Dimensions

Average Pool Slope		
Pool Slope - Range		
Average Maximum Depth of Pools		feet
Maximum Depth of Pools - Range		feet
Average Pool Length		
Average Pool Width		feet
Pool Width - Range		feet
Pool to Pool Spacing - Average		feet
Pool to Pool Spacing - Range		feet
Pool slope to average slope		
Pool depth to average bankfull depth		feet
Pool width to bankfull width		
Average Riffle Length		
Average Riffle Slope		
Riffle Slope - Range		
Riffle to Riffle Spacing - Average		feet
Riffle to Riffle Spacing - Range		feet
Riffle spacing to bankfull width		

Calculations

Mean Depth / D84		
u/u*		
Manning's "n"		
Average Bankfull Velocity		ft/sec
Shear Velocity (u*)		ft/sec
Bankfull Shear Stress		lbs/sq.ft
Stream Power (w)		lbs/ft/sec
Near Bank Shear Stress (right)		lbs/sq.ft
Near Bank Shear Stress (left)		lbs/sq.ft
Critical Dim. Shear Stress		

Bankfull Flow (Regional Curve - Rosgen)		cfs
Bankfull Flow (Regional Curve - Local)		cfs
Bankfull Flow (Calculated from field data)		cfs

STREAM CHANNEL CLASSIFICATION - LEVEL III

SUMMARY OF CONDITIONS

DATE OF FIELD OBSERVATION:

Riparian Vegetation
Flow Regime
Stream Size, Stream Order
Depositional Patterns
Meander Pattern
Debris/Channel Blockages
Altered Channel State

General Remarks:

Pfankuch
Channel Stability Rating

Location of analysis:
1. Land form Slope
2. Mass Wasting
3. Debris Jam Potential
4. Vegetative Bank Protection
5. Channel Capacity
6. Bank Rock Content
7. Obstructions to flow
8. Cutting
9. Depositional Patterns
10. Rock Angularity
11. Brightness
12. Consolidation of Particles
13. Bottom Size Distribution
14. Scouring and Deposition
15. Aquatic Vegetation

Channel Stability Rating (Pfankuch)

Sediment supply
Streambed (vertical) stability
Width/Depth ratio condition

Bank Erosion Hazard Index (BEHI)

Location of Analysis

Bank Height/Bankful Height
Root Depth/Bank Height
Root Density (%)
Surface Protection (%)
Adjustment(Bank Materials/Stratification)
Overall Classification(Erodability)
BEHI Score

General Remarks:

STREAM CHANNEL CLASSIFICATION - LEVEL III

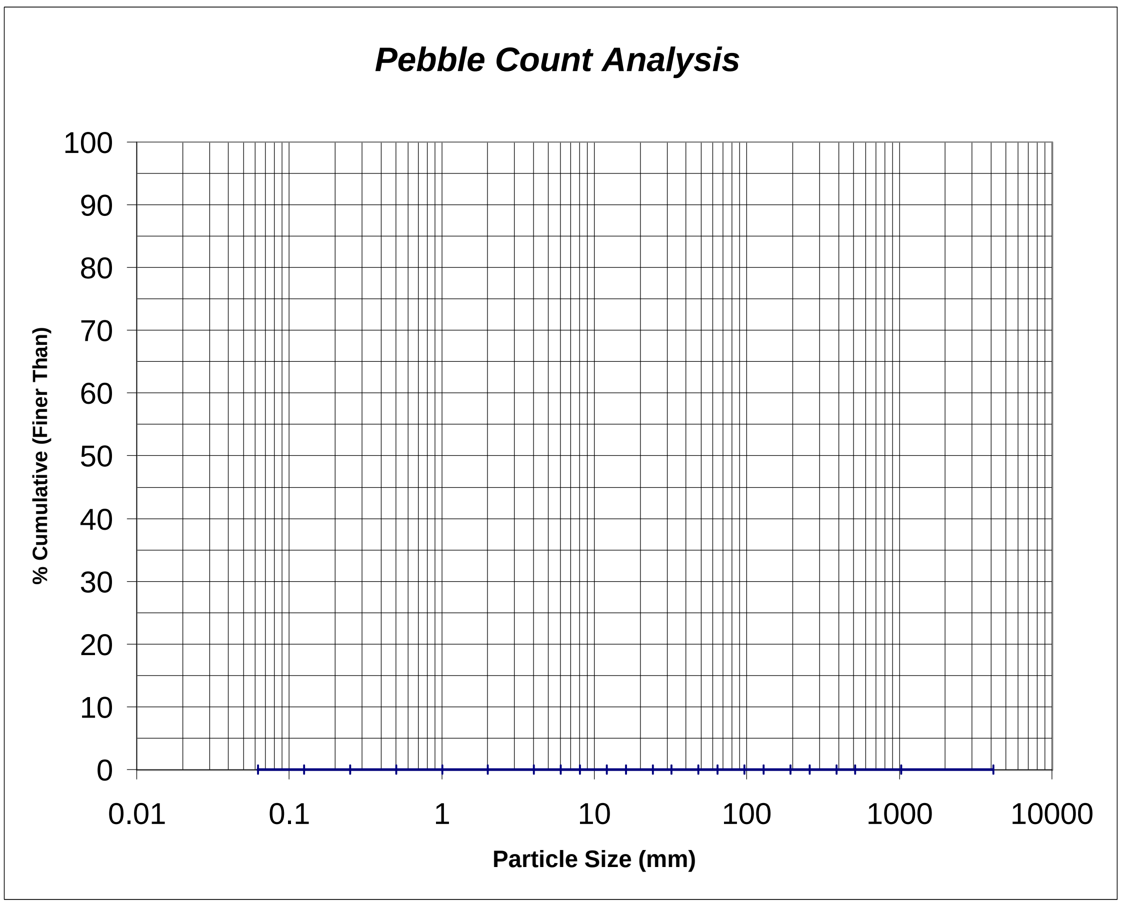
STREAM:	
LOCATION:	
DRAINAGE AREA:	
DATE OF FIELD OBSERVATION	

INTERPOLATOR		
	X	% Cum
1		
FIND		
2		

From Graph:	
D95=	
D84 =	
D50 =	
D35 =	
D15=	

Channel Material

INCHES	PARTICLE	MILLIMETERS	CLASS	TOTAL #	ITEM %	% CUM	X
	silt/clay	< .062	S/C				0.062
	Very Fine	.062 - .125	S				0.125
	Fine	.125 - .25	A				0.25
	Medium	.25 - .50	N				0.5
	Coarse	.50 - 1.0	D				1
.04 - .08	Very Coarse	1.0 - 2	S				2
.08 - .16	Very Fine	2 - 4					4
.16 - .24	Fine	4 - 6	G				6
.24 - .31	Fine	6 - 8	R				8
.31 - .47	Medium	8 - 12	A				12
.47 - .63	Medium	12 - 16	V				16
.63 - .94	Coarse	16 - 24	E				24
.94 - 1.26	Coarse	24 - 36	L				32
1.26 - 1.9	Very Coarse	32 -48	S				48
1.9 - 2.5	Very Coarse	48 - 64					64
2.5 - 3.8	Small	64 - 96	C				96
3.8 - 5.0	Small	96 - 128	O				128
5.0 - 7.6	Large	128 - 192	B				192
7.6 - 10	Large	192 - 256	L				256
10 - 15	Small	256 - 384	B				384
15 - 20	Small	384 - 512	L				512
20 - 40	Medium	512 - 1024	D				1024
40 - 160	Large	1024 - 4096	R				4096
	Bedrock						
			TOTAL				



Note: Bedrock samples are not included into graph

STREAM CHANNEL CLASSIFICATION - LEVEL III

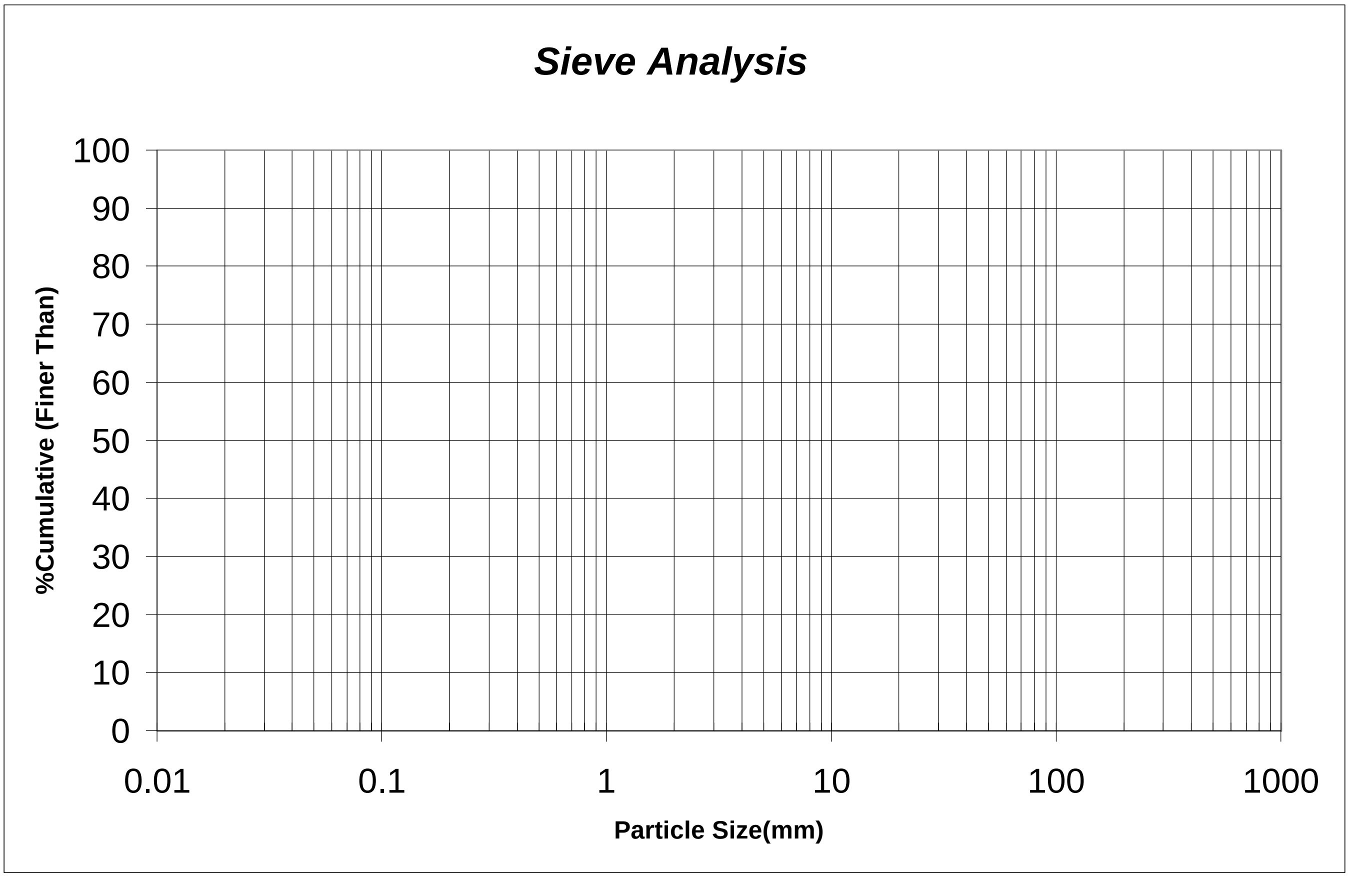
STREAM:	
LOCATION:	
SAMPLE NUMBER:	
DRAINAGE AREA:	
DATE OF COLLECTION:	
SAMPLE COLLECTED BY:	
DATE OF ANALYSIS:	
ANALYSIS PERFORMED BY:	
DATE OF DATA ENTRY:	

INTERPOLATOR		
	X	% Cum
1		
Find		
2		

From Graph:	
D95 =	
D84 =	
D50 =	
D35 =	
D15 =	

Bar Material - Sieve Analysis

Largest Particles on Bar:



Municipal Regulatory Controls for Wetlands, Shoreline & Riparian Corridors

	Comprehensive Plan	Zoning	Subdivision	Site Plan
City of Ithaca		Wetlands, floodplains, steep slopes or other areas not normally appropriate for building		
Town of Caroline			Establish buffers along streams and water courses, any disturbance shall be mitigated	
Town of Catherine			>100 ft. from normal high W line of any stream	
Town of Cortlandville			No development approval on uninhabitable land subject to flood	
Town of Covert			No development approval on uninhabitable land subject to flood	
Town of Danby			Wetland preservation	
Town of Dryden			Planning Board may require bank stabilization. No development approval on uninhabitable land subject to flood	
Town of Fayette			No development approval on uninhabitable land subject to flood. Wherever possible retain large trees, groves, water courses, water falls	

Town of Groton			No development approval on uninhabitable land subject to flood	
Town of Homer	Encourage to preserve	Establishment of Aquifer Protection District, including Wellhead Protection Area (Area I), Primary Aquifer Area (including Environmental Conservation Law wetlands)(Area II), and Principal Aquifer Area (including Environmental Conservation Law wetlands (area III), Tributary Watershed Area) (Area IV). Prohibited uses include pavement/impervious parking with area >12,000 sq feet in Areas I and II.	No development approval on uninhabitable land subject to flood	
Town of Ithaca		Six Mile Creek Valley Conservation District: Planning Board requires adequacy --protection of wetlands, water courses. Six Mile Creek Valley Conservation District: no construction within 100yr flood area (200 ft distance) and 50ft away from centerline of area that carries water 6months a year		
Town of Lansing		Construction and development shall be adequate and in accordance with NYS Environmental Conservation Law, Article 24, Clean Water Act and US Army Corps of Engineers and EPA requirements	Planning Board decides if construction and realignment of wetland	
Town of Romulus	Least possible development on wetlands			
Town of Seneca Falls		Permitted uses on wetlands: deposit or removal of natural products by recreation or sport fishing, hunting etc., ag practice (crops, livestock), selective cutting timber. Development in accordance with PUD provisions, preserving it as open space. Special	No development approval on uninhabitable land subject to flood	

		uses on wetlands: drainage, dredging, excavation, construction and reconstruction of structures, obstructions for any purpose. No permanent structure w/in 50ft of the edge of the bank of any water course		
Town of Spencer			Leave wetlands unaltered and protect by easements, etc.	
Town of Summer Hill				Shoreline standards: on-site sewage tile system >100 feet and septic systems >50feet away from shore line (high water mark). Boat service facility including oil tanks within 100 feet of shoreline must prevent leaks, spills (raised earthen or paved berm or dike)
Town of Varick		No development approval on uninhabitable land subject to flood		
Village of Aurora		Subdivision: where vegetation has been removed or damaged		
Village of Cayuga		Lake Residential District: build 10 feet away from high water line		
Village of Dryden		All water courses adjacent to the subdivision must have erosion control. Maximum retention		
Village of Trumansburg	Protection of wetlands		No development approval on	

	from destructive development		uninhabitable land subject to flood	

Return Frequency of Flood Events in Cayuga Lake Tributaries

Increased impervious cover in a subwatershed has the potential to affect both quantity and quality of the surface drainage network. Structural practices to control urban runoff rely on three basic mechanisms to treat runoff: infiltration, filtration, and detention. Practices are sized based on treating runoff from a storm of a specified probability of occurrence. As part of the watershed planning process, the magnitude of streamflow of defined recurrence intervals has been calculated. These discharges are tabulated below.

Return frequency of flood events in Cayuga Lake tributaries. Calculated using the Log Pearson Type 3 distribution from historical annual maximum flows in Cayuga Inlet (1937 -1999) and Fall Creek (1925 - 1999) (Bedient and Huber 1992). Data in cfs.						
Tributary	1 year	2 year	5 year	10 year	25 year	100 year
Fall Creek	934	2185	3201	3976	5073	6973
Salmon	671	1569	2299	2856	3643	5008
Unmonitored	593	1386	2030	2522	3218	4423
Taughannock	306	1062	1666	2108	2709	3684
Inlet	160	556	872	1103	1417	1928
Paines	114	267	391	486	620	852
Great Gully	72	251	393	497	639	869
Yawger	65	226	354	448	576	784
Trumansburg	63	220	345	437	562	764
Sheldrake	62	145	213	264	337	463
Yawger Trib	50	173	272	344	442	601
Gulf	47	109	160	198	253	348
Mack	41	96	141	176	224	308
Hicks	39	91	134	166	212	292

Ledyard (Levanna)	27	95	149	188	242	329
Willow	15	53	83	105	136	184
68 (Interlaken)	15	35	51	63	80	110
Glenwood	9.0	31	49	62	79	108
Renwick	9.4	22	32	40	51	70
Williams	5.6	19	30	38	49	67
103 (south Willow)	4.9	17	27	34	43	59
106 (north Glenwood)	5.1	12	17	22	28	38
Paines Trib	1.4	3.3	4.9	6.0	7.7	11
Indian	2.0	7.0	11	14	18	24

Discharge from the category of unmonitored tributaries would not enter Cayuga Lake at a single location, so it is not appropriate to use these estimated flows for sizing practices to control nonpoint source pollution from the drainage areas around the lake shoreline.