Eighteenmile Creek Restoration Project
Town of Newfane
Niagara County, New York

Stream Classification Report

Prepared For:
Niagara County Department of Planning, Development and Tourism
November 20, 2003

Prepared By:

ecology and environment, inc.

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Executive Summary

The Eighteenmile Creek Aquatic Habitat Restoration project has involved a unique collaborative effort comprised of multiple stakeholders and in-kind service providers to initiate the restoration of this popular fishing destination. Niagara County is overseeing the project. Existing problems include: bank instability, unsafe trail conditions, lack of instream habitat, and excessive sediment input into the stream channel. A Rosgen classification was conducted to determine potential success of specific restoration measures, based on the stream classification of the project area. In addition, the United States Army Corps of Engineers (USACE) provided a research hydrologist, Mr. David Derrick, to conduct a site-walkover and geomorphological assessment of the existing creek channel. The assessments indicate that the channel is in a relatively stable state, which can largely be attributed to the presence of the Burt Dam, immediately upstream from the project area, and the current grade of the channel and nature of bedload material. These reviews resulted in the development of suitable restoration measures that would improve bank stability and increase in-stream habitat. Restoration measures identified for this project included a combination of rock and vegetation to stabilize the severely eroding streambank sections and increasing the structure and diversity of instream habitat. For instance, the placement of single boulders (i.e. hydraulic cover stones) in the main channel provides structures to diversify the flow regime and provides resting areas/cover for fish. The severely eroding bank will be stabilized with a stepped wall with vegetation placed along the top of the bank and interspersed within the riprap rock bank. Other sections of eroding bank will be stabilized with large rock and vegetation. The restoration techniques used included a combination of "hard" (i.e., rock/armoring) and "soft" (i.e., vegetative plantings/bioengineering) techniques to maximize the success and benefits of the project to the ecosystem. Specific aquatic habitat measures included: LUNKERS, extreme instant shade, locked limbs, rootwads, woody debris placement, and hydraulic cover stones.

1 Introduction/Study Area

Eighteenmile Creek is located in Niagara County, New York (Figure 1). It flows north from Lockport through Newfane and discharges into Lake Ontario approximately 18 miles east of the mouth of the Niagara River. Within the City of Lockport the creek passes underneath the New York Barge Canal. The Eighteenmile Creek Watershed includes two major tributaries: the East Branch of Eighteenmile (also known as Red Creek) and the Gulf tributary. The watershed encompasses a drainage area of approximately 93 square miles, most of which is relatively flat agricultural land (NYSDEC 1997). The Eighteenmile Creek watershed is part of the larger Oak Orchard-Twelvemile Creek watershed, which encompasses a drainage area of more than 1,400 square miles. The flow of the stream is influenced by the diversion of water from the Barge Canal. During dry weather most of the flow in the upper portion of the creek originates from the 50 cubic feet per second (cfs) diversion.

Review of the United States Geological Service (USGS) topographic map (Newfane Quad) indicates that approximately 16 intermittent and two perennial streams flow into Eighteenmile Creek. The largest perennial feeder stream is the East Branch of Eighteenmile Creek, which begins in Royalton and enters Eighteenmile Creek north of Route 104 in Newfane approximately 9.3 miles upstream of the confluence with Lake Ontario. The Gulf originates in the City of Lockport and flows northeasterly to its confluence with Eighteenmile Creek, approximately one mile downstream from where Eighteenmile Creek resurfaces from under the Barge Canal. The confluence of the Gulf and Eighteenmile Creek is located near Purdy Road, between Jackson St. and Old Niagara Rd in the town of Newfane.

The New York State Department of Environmental Conservation (DEC) classifies the stream in the following manner, based on water quality, the portion of Eighteenmile Creek from the mouth to 0.5 miles upstream is classified as a Class B for the protection of contact recreation. The area from 0.5 miles from the mouth to the Burt Dam is designated by the DEC as Class C (suitable for fish propagation and survival).

Burt Dam is a small (600 kW) hydroelectric facility located at the upstream end of the restoration area. The dam prohibits the movement of fish upstream from the project area, and limits the transport of bedload material to the creek below the dam. The dam is controlled as a "run-of-the-river" operation. The dam does not control ("hold back") water levels and the river flow is allowed to flow through the turbines and over the spillway, at the normal flow level of the creek.

Eighteenmile Creek is heavily used for recreational purposes including boating, fishing, and hunting. Most of the land use near the mouth in Olcott is related to boating, including marinas, a boat launch, and other commercial activities. Land use in the upper watershed includes: residential, agricultural, commercial, industrial, and forested. The creek is one of the most popular fishing destinations in Western Lake Ontario. Coldwater fish opportunities include fishing for major spawning runs of several important Lake

Ontario fish populations including: chinook salmon, coho salmon, rainbow trout, and brown trout. These fish populations originate from the DEC Lake Ontario Fish Stocking Program. In addition Olcott Harbor and a section of Eighteenmile Creek are designated as a New York state Significant Coastal Fish and Wildlife Habitat, for the warmwater fish concentration area that it provides to the Lake Ontario ecosystem. This area contains a high quality warm water fishery, as well as important habitat for a variety of local and migratory wildlife species.

2 Evaluation Methods

2.1 Rosgen Assessment

The Rosgen Stream Classification System is one of the most widely accepted methods of classifying streams (Rosgen 1996). Stream classifications serve several purposes, including integrating basin characteristics, valley types, and landforms with stream system morphology. Rosgen's stream classification provides a scheme that examines the main parameters that operate in the processes of river mechanics and maintenance. The classification depends on knowledge of processes and is useful to describe channels and evaluate how a stream will change through time.

The Rosgen classification involves four levels of classification (I, II, III, & IV) that are discussed briefly below. The Level I classification serves several primary functions: provide for initial integration of basin characteristics, valley types, and landforms with stream system morphology, provide for a consistent initial framework for organizing river information and communicating the aspects of river morphology, and assist in the setting of priorities for conducting more detailed assessments and/or companion inventories (Rosgen 1996). Level II describes the morphological conditions including: entrenchment ratio, width/depth ratio, sinuosity, channel slope, and channel materials. Level III describes the existing stream "state" or condition, includes assessments of multiple variables (riparian vegetation, deposition pattern, debris occurrence, meander pattern, channel stability rating, sediment supply, bed stability, bank erosion potential, stream size/order, flow regime, and altered channel state, dimensions, patterns, slope, and materials. The Level IV assessment represents the validation level and includes measurements of sediments, streamflow measurements, and stability.

Level I classification involves a general assessment of the stream channel including:

- Slope
- Channel shape, and
- Channel patterns.

This general information aides in furthering the classification to Level II, which involves analysis of a variety of channel characteristics to arrive at both a stream type and subclass to describe a particular reach of a stream. The following factors are all analyzed to develop the Level II stream classification:

- Channel Type
- Entrenchment Ratio

- Width to Depth Ratio
- Sinuosity
- Water Surface Slope
- Median Size of Bed Material

The analysis of Eighteenmile Creek involved a semi-quantitative approach for assessing the above-listed characteristics. The Eighteenmile Creek classification was completed to a Level II classification. A complete stream survey was not conducted as part of this analysis. However, cross-sections were measured to further examine channel characteristics, entrenchment ratio, and width to depth ratio, and survey information was collected to assist in designing the streambank restoration designs.

2.2 *Additional Geomorphological Assessment*

The Buffalo District, USACE arranged for a visit to the site by David Derrick, Research Hydrologist at the Waterways Experiment Station in Vicksburg, Mississippi. Mr. Derrick is an instructor for streambank protection courses and has been involved with numerous projects for the USACE. His visit provided guidance on the geomorphological conditions of the site, and he assisted in determining which bioengineering methods would be most suitable for the project area.

Mr. Derrick's (Derrick) analysis of numerous restoration projects has brought him to the conclusion that: much of the current design effort is channeled toward smoothed planform (constant radius bends and well-aligned crossings), with little diversity or complexity integrated into the design and construction process (Derrick 2002). Many typical bank stabilization / habitat improvement structures do not imitate natural conditions, and lock the stream into a rigid planform. Typically, the bulk of the structures designed for improved aquatic habitat are above the base-flow surface elevation, which are of limited value to aquatic biota and increases habitat for predators. Most often, there is little to no vegetation or hydraulic cover associated with these projects. Typically, projects will involve the installation of small-sized streamside vegetation that will require years to mature, reproduce, shade the stream, and contribute carbon material (dead limbs and trunks) to the stream system. These characteristics mentioned above do not make substantial contributions toward restoring lost functions and processes into disturbed stream systems.

Consequently, Derrick's approach is to evaluate reference conditions in the reach and use vegetation and natural materials to mimic and create natural conditions (Derrick 2002). According to Derrick, stream restoration projects should include the following strategies:

- Resist the tendency to over-stabilize the project and smooth stream planform (resulting in low diversity).
- Minimal or no disturbance of functioning "good" portions of the stream and riparian system.

- In areas near existing infrastructure or identified important resources, the critical bank should be hardened and the stream allowed to determine its cross-section size and opposite bank shape.
- Identify and utilize nearby available materials for stream restoration efforts.
- Utilize the "Mother Plant" theory - use of the plant stock that is mature enough to provide seed in a short period of time (self-seeding riparian areas).
- Temporary construction roads should be built on future recreational path alignments to reduce overall impacts to the riparian buffer zone.

In addition, to the field visit, the Channel Evolution Model (CEM) theory (Shumm et al., 1984 and Watson et al., 2002) was used to determine suitable restoration measures for Eighteenmile Creek. The CEM primary use is to determine the evolutionary state of a given channel from field observations. The evolution sequence provides an understanding that reaches of a stream may differ in appearance, but channel form in one reach is associated with other reaches by an evolving process. Form, process, and time relate dissimilar reaches of the stream. By classifying a stream based on the evolutionary-state of the channel, one can determine the suitability of conventional bank stabilization measures versus more comprehensive treatments (grade/flow control structures) to stabilize stream banks.

3 Rosgen Classification

The portion of Eighteenmile Creek in the vicinity of the project was evaluated using the Level 1 criteria. This section begins at the Burt Dam and ends approximately 1,400 ft downstream. The stream transitions from a pool at the base of the dam to a run (wide and relatively shallow) with a narrow/shallow riffle section separating them. The channel shape varies from wide and shallow to deep in the pool at the base of the dam, to narrow and shallow in the riffle downstream of the pool, to wide and shallow in the remaining portion. The channel width ranges from 50 to 185 feet. The narrowest portion of the project area forms the riffle below the spillway pool of the dam. The greatest depth is more than 10 feet in the pool at the base of the dam, with the majority of the channel varying between 0.5 and 4 feet.

The channel slope of the project area is low gradient. Shoreline elevation at the tail of the spillway pool is 93.4 feet, and the elevation is 90.3 feet at the end of the project area (just above the rail trestle), equating to a 3.1-foot change. The length of this area is approximately 1,400 feet. Defining slope as rise over run, the approximate slope in the project area is 0.2 % slope. Examining the entire lower Eighteenmile Creek (i.e. below Burt Dam to the confluence with Lake Ontario), the approximate slope is less than 0.01 % (approximately 11,000 foot length and less than 30 foot elevation change).

The channel shape is typical of an old, canyon-type river system with a wide channel and shallow depths and a well-defined floodplain. The channel shape has been modified and influenced by the construction of Burt Dam. The majority of the channel is wide and shallow, with some sections that are characteristic of deep pools in the lower section.

The area below the restoration area is influenced by water levels in Lake Ontario. The channel pattern is a single thread channel.

Entrenchment ratio is a computed index value used to describe the degree of vertical containment of a river channel (Rosgen 1996). The ratio is the width of the flood prone area at an elevation of twice the maximum bankfull depth / bankfull width. Using the floodprone width, based on field observations, and the bankfull width at several of the cross-sections, the entrenchment ratio is approximately 3.8. This ratio is indicative of different Rosgen classifications, and is discussed further below.

The four measured cross-sections indicated an average width/depth ratio of 66. Sinuosity is defined as the stream length / valley length. Through the project area, the stream length is approximately 1,400 feet, and the valley length is approximately 1,585 feet, resulting in a sinuosity of 0.8. Examining sinuosity for lower Eighteenmile Creek, the stream length is approximately, 11,220 feet, and the valley length is approximately 9,240 feet, resulting in a sinuosity of 1.2.

Based upon the channel shape, slope, form and other characteristics, Eighteenmile Creek in the project area is probably a "C" stream type. According to Rosgen (1996), C-type stream have the following characteristics: low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well-defined floodplains. Eighteenmile Creek appears to exhibit these characteristics. In addition, entrenchment ratios are greater than 2.2 (3.8 for Eighteenmile Creek), width/depth ratios are greater than 12 (66 for Eighteenmile Creek), sinuosity is greater than 1.4 (1.2 for Eighteenmile Creek), and the slope is less than 0.02 (<0.01 % for Eighteenmile Creek).

Additional characteristics of C-type streams include: broad valleys with terraces, in association with floodplains, alluvial soils. C-type streams are slightly entrenched with well-developed meandering channels, and riffle/pool bed morphology. The C-type stream type is typically located in narrow to wide valleys, constructed from alluvial deposition (Rosgen 1996). Eighteenmile Creek is a narrow valley with alluvial soils dominating the valley floor. Rosgen states that the C-type channels have a well-developed floodplain (slightly entrenched) are relatively sinuous with a channel slope of 2 % or less, and a bedform morphology indicative of a riffle/pool configuration. Eighteenmile Creek, within the project area, has a well-developed floodplain that is slightly entrenched and contains a short series of riffle/pool habitats.

Channel material is dominated by cobbles in the project area, and thus would classify Eighteenmile Creek as a C3 stream type. The number of the classification corresponds to the type of bedload material in the channel (e.g. 1 = bedrock, 2 = boulder, 3 = cobble, 4 = gravel, 5 = sand, 6 = silt-clay).

Table 1. Comparison of Rosgen "C" stream-type characteristics with those observed in Eighteenmile Creek, Niagara County, NY

Measurement	**Rosgen "C" - stream type**	**Eighteenmile Creek**
Channel Shape	Meandering point-bar	Meandering point-bar
Aquatic Habitat Features	Riffle/Pool	Riffle/Pool
Floodplain Characteristic	Alluvial channels with well-defined floodplains	Alluvial channel with well-defined floodplains
Entrenchment Ratio	2.2	3.8
Width/Depth Ratio	> 12	66
Sinuosity	> 1.4	1.2
Slope	< .02 %	.01 %

4 Additional Geomorphological Assessment

The following discussion summarizes Mr. Derrick's observations, along with the Project Team, while conducting a site walkover, and reviewing preliminary design plans after the field visit.

The lower Eighteenmile Creek system is a highly manipulated stream that has been impacted by numerous anthropogenic influences including: increased impervious surfaces, channelization, dams, and decreased water quality. This has resulted in a manipulated flow regime: higher peak flows, decreased base flow, decreased sediment transport, and a manipulation of downstream grade controls. Burt Dam operates as a "run-of-the-river" operation, meaning there is not significant storage capacity in the reservoir to manage high flow events. Because of the sequestering of sediment above the project area (i.e. Burt Dam), substrate in the project area is dominated by coarse material and the channel bedload appears to be in a fairly-balanced state. Meaning, degradation and aggradation are minimal with the lack of sediment recruitment; the creek bed is relatively stable. In addition, there are no signs of channel migration in the project area; the bank and creek bed at the back of the spillway pool are well-armored and there are no signs of channel migration through the west side of the creek canyon.

However, portions of the stream banks are not stable as a result of the combination of high flows and heavy foot traffic along the banks. An examination of the existing thalweg indicates that high flows would likely not further erode the banks. Extreme high flows may have more of an impact. However, based upon disturbance patterns on the bank and the fact that over 10,000 people a year access the project area during the fall fishing season, the migration of the bank is likely a result of human disturbance.

The current thalweg is dictated by the boulder group that is on the left-bank (east-side) of the reference reach (the area immediately below the spillway pool). Thus the baseflow through the project area is not indicative of a natural flow regime (the flow is on the inside of the bend). In addition, at high flows, the bulk of the current flows away from the outside bend, causing the unstable bank area to have an eddy in front of it, and not a steady current impact.

Given what has been determined regarding the stream characteristics, restoration design should be based upon constructability and the need to control access of anglers and protect sensitive areas of the bank. The constructability will entail stabilizing the bank as necessary to prevent further erosion and migration of the existing creek bank. The control of access by anglers will be accomplished through the placement of a combination of vegetation and rocks to create stable access locations for anglers and allow for the establishment of riparian vegetation along the creek channel.

Some of the main highlights of Mr. Derrick's observations include: the use of hard structures in the channel need to be discontinuous (continuous structures will cause further damage downstream), and attack angles (angles of the structure) must not block flow and completely redirect flow in a different direction. Key structures need to be a gradual change (i.e. 30 degree angle) to tie the streambank protection devices into the bank (don't fight the flow of the water in the channel, and need to create a smooth transition of rock). Based on site observations, a stable key for the stepped wall area was estimated to be 7-feet deep and 5-feet in width. The rock used for the key should be the same rock size and gradation.

The initial restoration design had flow diverters on portions of the stepped wall area. The diverters were removed from the design for several reasons. One, an analysis of the existing flow regime indicated that the thalweg is currently in the center and the west side of the channel, which would negate the need to divert flow away from the eroding bank. Two, the use of the LUNKERs in the stepped wall area would limit the applicability of flow diverters. The diverters would adversely impact the flow through the LUNKERs. The use of hydraulic cover stones (i.e. single boulders) were added to the channel to manipulate the flow and provide additional habitat for fish.

The CEM theory was also used to define the evolutionary state of the Eighteenmile Creek channel. Mr. Derrick indicated that the project area is probably a Type I channel, but the presence of the dam confounds the classification. The channel is similar to a Type I or a Type V, which are in a relatively stable state (see Table 2), but since the trees do not appear to be perched on the banks of the stream, it is probably a Type I. A Type V channel would have some degradation of the banks, downstream from the dam, but the banks appear relatively stable, except in the areas that have been impacted by heavy foot traffic from anglers. Burt Dam limits the transport of sediments into the project area, thus impacting the aggradation and degradation of the channel within the restoration area. Immediately below the restoration area, the channel becomes influenced by Lake Ontario water levels, and is not exposed to rapid, erosive currents.

Type I reaches are generally characterized by a U-shaped cross-section with little or no sediment stored in the channel bed. Type I reaches are usually located upstream of the actively degrading reach and have not yet experienced significant bed or bank instabilities. Type V reaches represent a state of dynamic equilibrium with a balance between sediment transport capacity and sediment supply. Bank heights in the Type V channel are generally less than the critical bank height, and therefore, geotechnical bank instabilities do not exist.

This CEM typing provides further evidence that the channel is in a relatively stable condition and would benefit more from bank stabilization than changes to grade or hydraulic controls in the channel.

5 Restoration Measures

The use of several stream classification techniques to assess suitable restoration measures provides assurance that the selected techniques will be appropriate for the given stream reach, as well as a greater likelihood of success. Table 2 summarizes the different classifications for the Rosgen and CEM methods, as well as suitable restoration/bank stabilization measures for the given classification. Given a classification of a Rosgen C-type stream and a CEM Type I channel, bank stabilization techniques and instream cover are deemed appropriate as opposed to grade or flow control structures.

Table 2. Summary of Stream/Channel Classification and appropriate aquatic habitat restoration measures (Rosgen Enhancement Measures adopted from Table 8-2 Rosgen 1996) and Channel Evolution Model measures based on Watson et al., (2002).

Rosgen Classification	Description	Aquatic Habitat Enhancement Measures
A	Steep, entrenched, headwater systems.	Bank placed boulder, vortex rock weir, or bank placed root wad except in bedrock or boulder dominated systems.
B	Moderate gradient and entrenchment.	Low to medium stage check dams, random boulder placement, bank-placed boulder or rootwads, wing deflectors, channel constrictor, log cover, submerged shelters, gravel traps, and weirs or spurs, depending on size of bedload material.
C	Low gradient, meandering channel, high width to depth ratio.	Bank-placed boulder or rootwads, bank cover, floating log cover, straight submerged shelter, spurs, depending upon size of bedload material.
D	Wide braided channel.	Most restoration measures are rated poor to fair.
E	Low gradient, meandering channel, low width to depth ratio.	Bank-placed boulder and rootwad, and submerged shelters.
F	Entrenched meandering channel with high width to depth ratio.	Bank-placed boulder and rootwads, submerged shelters, and vortex rock weirs.
G	Entrenched gully, moderate gradient, low width to depth ratio.	Bank-placed boulder or rootwad and vortex rock weir.
Channel Evolution Model	**Description**	**Suitable Restoration Measures**
I	U-shaped cross-section with little to no sediment stored in channel bed.	Natural treatment based on reference reach conditions. Conventional bank measures appropriate.
II	Bed degradation is dominant process, steepness causes transport capacity to exceed supply, but not to an unstable capacity.	Flow control and grade control structures may be appropriate. Conventional bank measures appropriate.
III	Bank heights have exceeded critical bank height for mass failures. Channel widening is dominant process.	Flow control and grade control structures are needed.
IV	Transition zone where incised channel is returning to a new state of dynamic equilibrium.	Flow control structures may be necessary, but grade control structures are likely not warranted. Conventional bank measures appropriate.
V	Reach is in state of dynamic equilibrium with a balance of sediment transport capacity and sediment supply. Bank heights are generally less than critical bank heights.	Natural treatment based on reference reach conditions. Conventional bank measures appropriate.

According to Rosgen, several fish habitat improvement structures area suitable to the C stream type (Rosgen 1996). The following enhancements were rated as excellent to fair for C-type streams:

- Random boulder placement
- Bank placed boulder
- Single wing deflector
- Bank cover
- Root wads

The Project Team and Derrick's observations resulted in the following recommendations for the restoration design:

- LUNKERS (Little Underwater Neighborhood Keepers Encompassing Rheotactic Salmonids) would provide additional habitat (undercut banks). These structures should not be placed near flow diverters. LUNKERS need a smooth transition of rock upstream to create necessary flow regime - (Critical Alignment);
- The end of the stepped wall needs a transition-area bringing wall back to bank.
- An ideal reference reach for the project area includes the riffle below the spillway pool. This area of the creek has stable banks and has not experienced severe bank erosion.
- "Instant Shade" technique for riparian planting in the stepped wall and other areas. This technique involves planting poles at approximately 45-degree angles to the creek, to promote growth over the stream and instant shading of the creek channel. Based on conditions in the reference reach and availability of trees, the project should incorporate "extreme instant shade". This technique places or moves trees to 90-degrees. In the project area, several trees will be pushed over to a 90-degree angle above the creek channel. Reference trees in the area were noted to be growing in this pattern, and the design intent was to mimic the reference reach conditions.
- "Locked limbs" consist of small woody debris (SWD) and branches inter-locked and secured with rock adjacent to the bank. These will provide additional structure and diversity of aquatic habitat.
- Root wads should be added to provide additional aquatic structure.
- Hydraulic cover stones (i.e. single boulders) should be added to increase cover and the diversity of flows through the project area, and additional structure in the stream channel.
- Native vegetation placed throughout the project area will improve riparian function and aesthetic qualities of the Eighteenmile Creek project area.

Comparison of Rosgen and Derrick/Project Team Recommendations.

For the most part, the recommended aquatic habitat enhancement measures were similar from the Rosgen and the Derrick/Project Team Recommendations. Rosgen's recommendations for C-type streams included bank stabilization via flow deflectors and bank placed structure (boulders, rootwads, etc.). The Derrick/Project Team's recommendations included: bank placed structures (i.e. stepped wall, LUNKERs, etc.) and the use of vegetation to stabilize the bank. An additional aquatic habitat enhancement measure from both classification techniques included: random boulder placement (i.e. hydraulic cover stones). The primary difference between these two measures is that the Derrick hydraulic cover stones are placed at a strategic elevation and direction to maximize the diversity of flows at the surface of the creek, while providing an adequate amount of cover.

Figures 2 and 3 represent the streambank stabilization designs that will be carried out on the project. These bioengineering measures will primarily utilize the construction of a stable toe layer with pinned rock (minimum dimension 2 ft X 2 ft X 3 ft size), and a combination of stepped rock or flat rock. The stepped rock techniques will be used in the severely eroded and high angler-use areas. Smaller areas of unstable bank will be treated with rock, backfill, and vegetation. The tree layer will consist of dogwoods (*Cornus* sp.), willows (*Salix* sp.), buttonbush (*Cephalanthus* sp.), and other native species. The initial fall plantings of the herbaceous layer development will include erosion control grass seed mixes that are fast growing. In the spring, a combination of specialized wetland and floodplain grass seed mixes that provide wildlife food will be used as appropriate.

The stepped rock wall will provide a stable bank to resist hydraulic forces from the river, as well as the severe stress realized by the high angler volumes utilizing the project area. The stepped wall will provide a combination of stable bank toe, with backfill suitable to support riparian vegetation. Plantings will primarily be limited to the upper portions of the bank, so that anglers have ample room to fish, and are not tempted to clear (destroy) restoration vegetation. The placed rock riprap and riparian plantings will provide a improve the stability of the shoreline in the pocket areas needing stabilization.

Figure 4 displays the concept of and design for the LUNKERS. The LUNKERS will be placed in series with the toe layer of the stepped wall section to provide simulated undercut bank habitat for aquatic fauna. Undercut banks are known to provide valuable habitat for stream fishes. In addition to the LUNKERS, hydraulic cover stones will be placed in the main channel to diversify the existing aquatic habitat through the manipulation of flow and addition of cover adjacent to the stream current. These enhancements along with the riparian plantings and improvements to bank stability will significantly improve the existing aquatic habitat.

Figure 1
Eighteenmile Creek Restoration Project Area,
Niagara County, New York

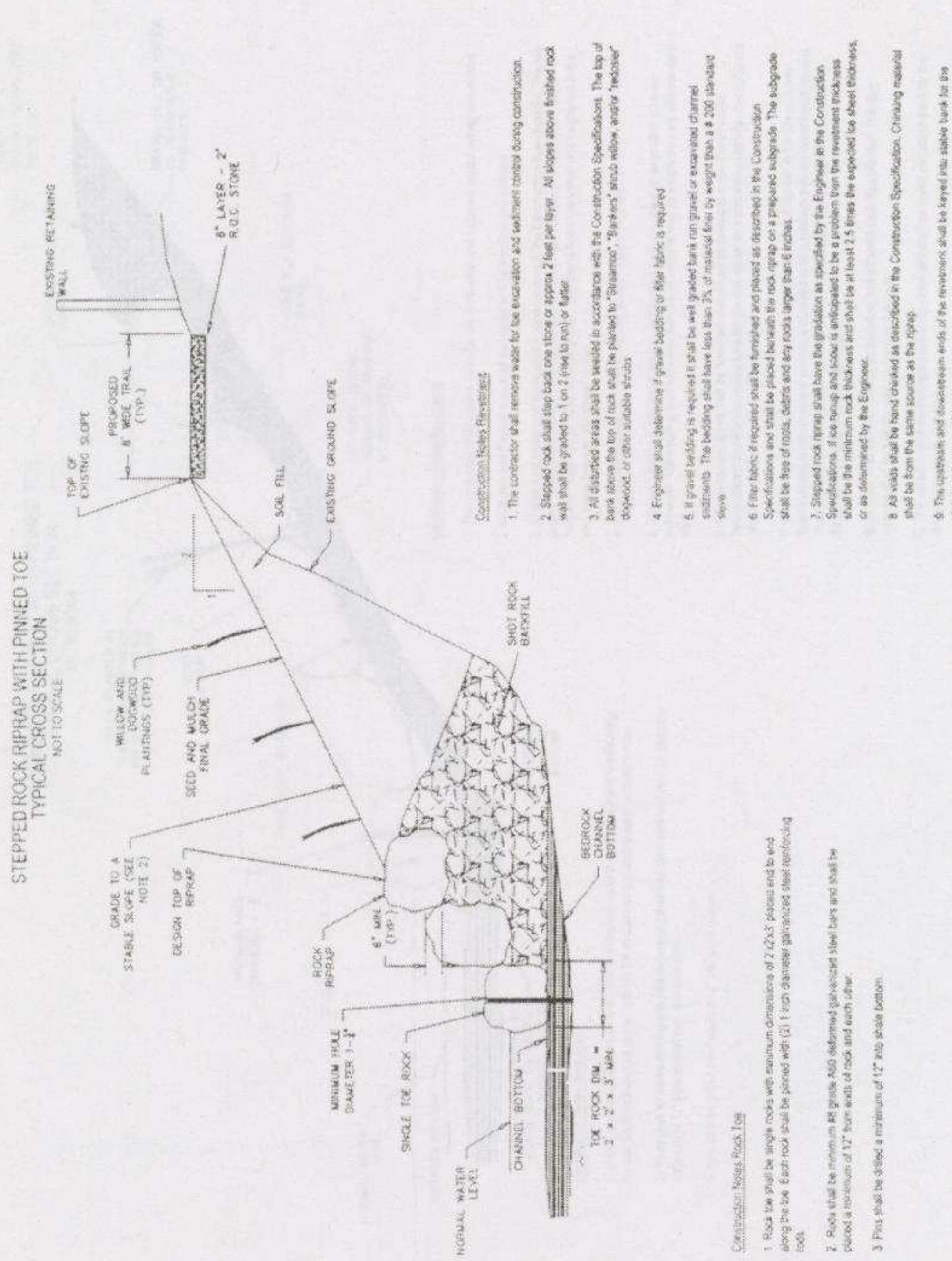


Figure 2

Cross-section of Stepped Rock Riprap Bank Treatment for Bank Stabilization on Eighteenmile Creek, Niagara County, NY

Figure prepared by Niagara County Soil & Water Conservation District

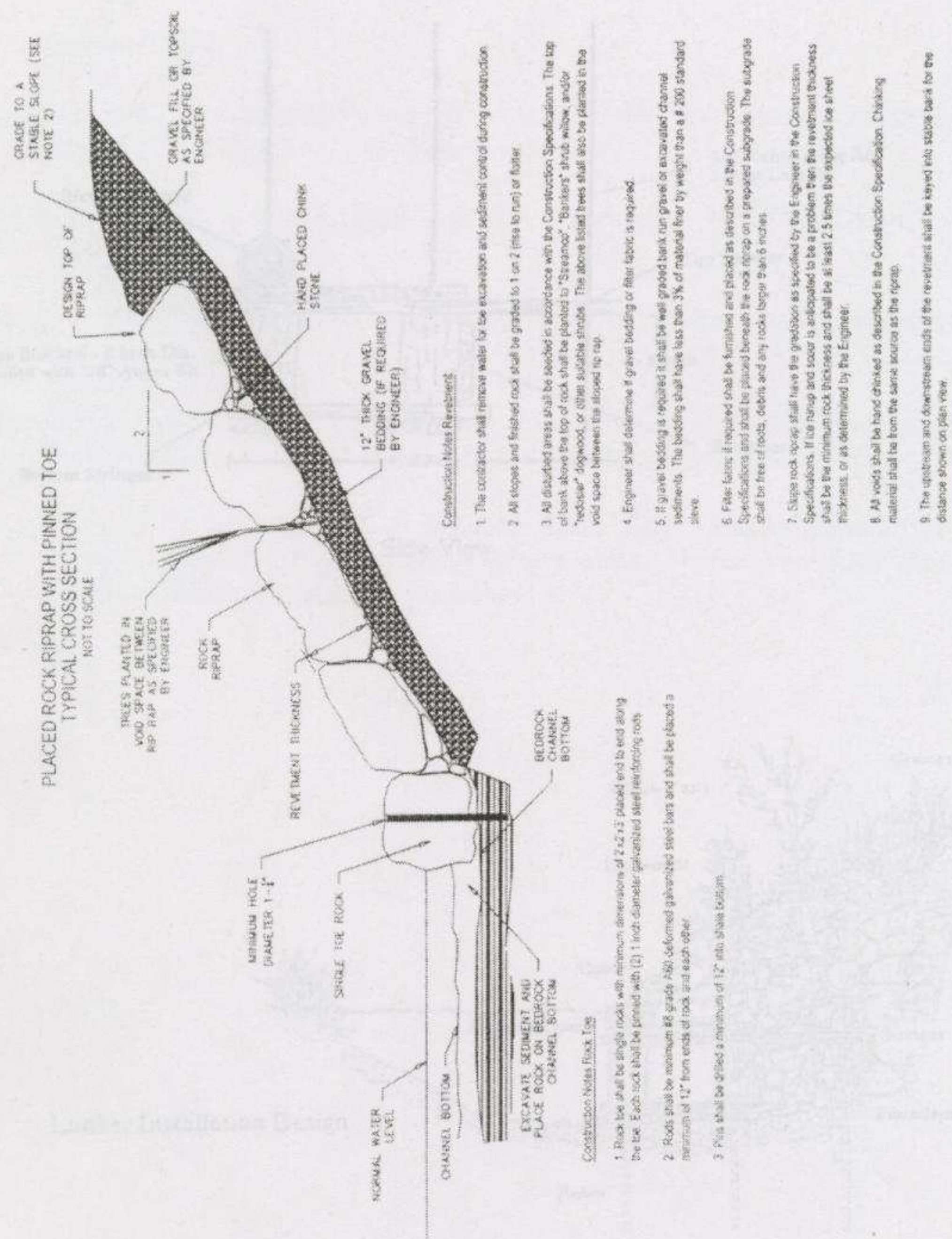
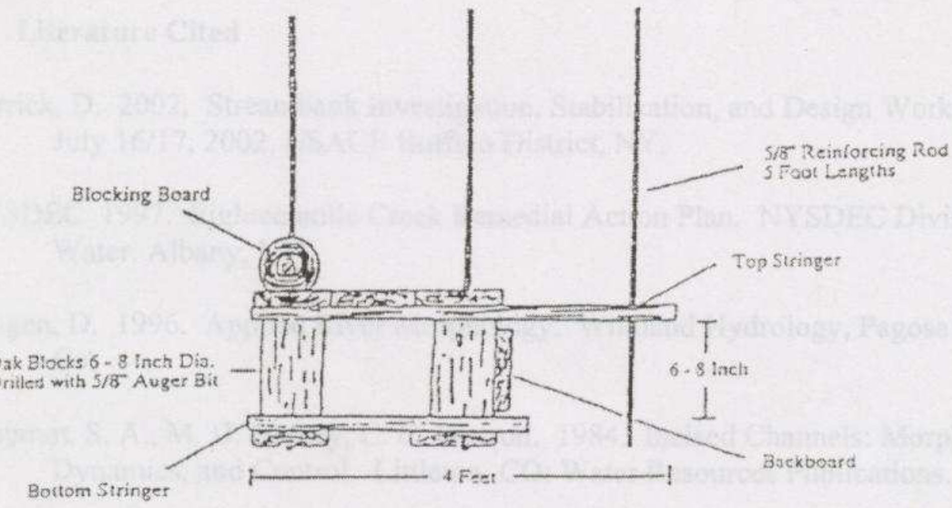


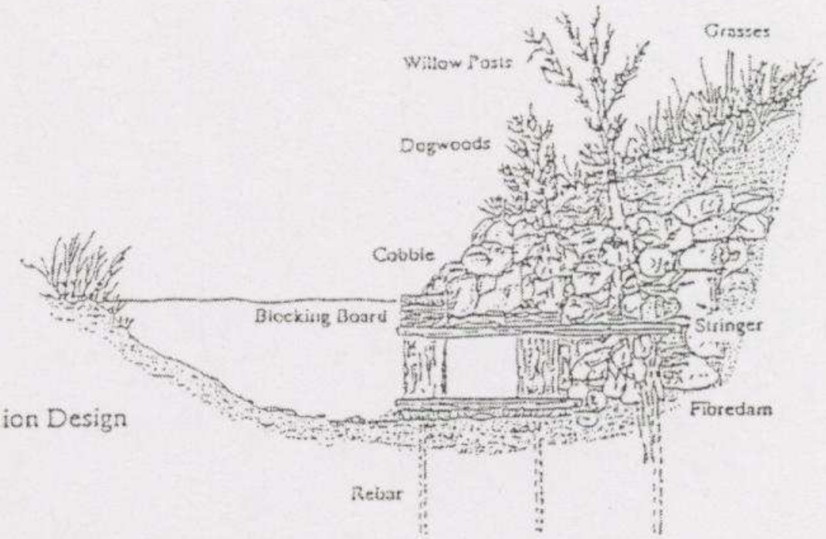
Figure 3

Cross-section of Placed Rock Riprap and Vegetation Treatment for Bank Stabilization on Eighteenmile Creek, Niagara County, NY

Figure prepared by Niagara County Soil & Water Conservation District



Side View



Lunker Installation Design

Figure 4

Designs for LUNKER Treatments for Bank Stabilization and
Aquatic Habitat Enhancement on Eighteenmile Creek, Niagara County, NY

Figure prepared by Niagara County Soil & Water Conservation District

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