FINAL REPORT

UPPER MISSISSIPPI MASTER PLAN STABILIZATION, RESTORATION AND ENHANCEMENT RECOMMENDATIONS

NORTH & NORTHEAST MINNEAPOLIS, MINNESOTA

Prepared For:

Minneapolis Parks and Recreation Board
Minneapolis, Minnesota

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NORTH & NORTHEAST MINNEAPOLIS,
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UPPER MISSISSIPPI RIVER MASTER PLAN
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NORTH & NORTHEAST MINNEAPOLIS, MINNESOTA

5.0 INTRODUCTION

In the creation of a Master Plan for Park and Land Use Guidelines in the Upper Mississippi Corridor to guide long-term decision making and implementation efforts to develop a riverside park corridor connecting both the north and south existing park systems that is environmentally, aesthetically, mechanically and hydraulically sound, it was necessary to perform an inventory analysis of the existing bank conditions. The inventory performed and presented in the June 19, 1998 document for the project, is the foundation for developing and proposing appropriate alternative soil bioengineering riverbank and riparian zone stabilization and wildlife habitat restoration methods in Phase 2 of the Project. This document also addresses ranges of construction cost for each stabilization, restoration and enhancement method.

5.1 PURPOSE AND BACKGROUND

The Mississippi River represents a critical connection element in the surrounding natural landscape and city which form its watershed. This dramatic living resource offers a wide, diverse mix of healthy and damaged functions, including mechanical, environmental, recreational, aesthetic and water quality. These functions offer benefits which, among other things, enhance and support the social and economic life of the city.

In meeting the primary objective and goals, soil bioengineering offers value-added solutions with the opportunity of recovering both mechanical slope stabilization as well as the environmental, water quality, aesthetic and riparian habitat, recreational and economic values. It is used as an important protection and restoration component in rivenne management and, as such, when integrated with the other technologies, will work to connect people with this living resource.

Soil bioengineering is an applied science that develops sustainable living vegetative structures to rebuild functionality back into the Upper Mississippi River system. Living plants initially create structural stability through stems and, over time, through root systems; they also reduce surface erosion and scour by top growth. The roots serve to consolidate the soil particles and cause the soil to function as a unitary mass, thus reducing the possibility of both slumps and surface sloughs. The top growth reduces velocities, cleanses the water by collecting sediment. redirects the flow, and offers surface erosion control protection. Bioengineering contains mechanical, hydrological, geological, and ecological components in an approach which is based both on sound engineering practice and ecological principles. This living technology consists of several ecological and structural engineering components combined into an integrated solution that will offer recreational opportunities, protection, and sustainability for the entire corridor. Soil bioengineering as one important component is proposed to be used in a variety of ways to meet the desired multi-objective goals related to

the technical, ecological, aesthetic, recreational and educational aspects of the Upper Mississippi River Master Plan for North and Northeast Minneapolis.

5.2 LOCATION

In May of 1998, members of Robbin B. Sotir & Associates, Inc., performed an inventory review and analysis of the existing surface conditions on this section of the Upper Mississippi River in Minneapolis, Minnesota. The project length is approximately 4 miles (8 bank miles). This encompassed the bank area from approximately the water's edge to the top of the bank, from Plymouth Bridge on the south bank to just north of Camden Bridge in the north on the east bank, and from Plymouth Bridge on the south bank to 53rd Avenue on the west bank. Interstate 94, Washington Avenue North, and 2nd Street parallel the river reach on the west bank. The river is nearest Interstate 94 between 41st Avenue North and 53rd Avenue North. In the south, a small length of West River Parkway runs along the river from below the project area at Plymouth to just north of 22nd Avenue North. This section of river is paralleled by a railway track system, from 22nd Avenue North to 42nd Avenue North, crossing the river between Board Street N.E. and Lowry Avenue, and just south of Camden. Marshall is the main street that parallels the river on the east bank.

5.3 OVERVIEW

To maintain continuity and perform an integrated effort, the original inventory review was conducted using the reaches which were previously defined as natural and human features as follows: Natural features - Wetlands, Woodlots, Grass and scrublands, exposed water features (i.e. Shingle Creek) and slopes. Human features - Stormdram outlets, significantly disturbed and abandoned areas including automobile and railway bridges.

The work was accomplished from north to south and from upstream to downstream on each bank. The east bank is comprised of twenty two (22) reaches and the west bank of twenty three (23) reaches, including the Shingle Creek area, making the project total of forty five (45) reaches.

The work has been further connected to the overall Master Plan by incorporating the soil bioengineering stabilization, restoration and enhancement methods into selected segments where redevelopment is most likely to occur.

5.4 INVENTORY COLLECTION METHOD

In the May-June 1998 effort, each reach along this section of the river was inventoried for the following: bank length and conditions, ground cover, tree and shrub species ands erosional failure (See Tables 1 and 2 in Appendix A). This was prepared in both written text as well as in tabular form. Photographic records were made along with special notes. Special notes consist of such items as stormwater pipe outlets, concrete/construction rubble, fish, waterfowl and animal sitings/evidence, formal and informal walking paths, size and condition of vegetation, building facilities, industry and barges. Generally, the soils along this section of the river are sandy with an organic upper horizon. All tree and shrub species represent observable predominant vegetation and the percentages suggested for ground cover

are approximate and often have wide variances within a reach. The character of each reach was described.

5.5 ASSESSMENT OF FINDINGS

In assessing each of the inventoried reaches, it was found that this reach of the Upper Mississippi River illustrates a diverse landscape of healthy and damaged mechanical, environmental, aesthetic, water quality, educational and recreational functions.

The stabilization and enhancement will require a range of protection and restoration components to manage the riverine system in a way that allows for full function development and recovery within the content of the new watershed and desired river conditions.

This section of the Upper Mississippi River represents a wide range of conditions and river related functions (both natural and man-made), including (See Appendix B, for photographs):

Facilities and Structures

Sheet pile forming the edge of the river (See Photograph 1)
Riprap rock bank (See Photograph 2)
Low concrete wall treatment with rubble (See Photograph 3)
Low concrete wall along river edge (See Photograph 4)
Facility on top of slope and cleaned banks to the river edge (See Photograph 5)
Hard treatment and barge storage areas (See Photograph 6)
Large culvert (See Photograph 7)
Industrial use up to the river edge, sheet pile bank protection (See Photograph 8)

Slope Types

Flat slope - well vegetated, low banks with excellent overhanging trees providing habitat value along the shoreline (See Photographs 9 & 10)
Moderate slope - Construction debris along the shoreline with vegetation above (See Photograph 11)
Large shallow failures on bank with very little vegetation (See Photograph 12)
Steep slope - steep, well vegetated bank (See Photograph 13)
Surface Sloughs, gully and sparse vegetation on a steep bank (See Photograph 14)

Erosional Conditions

Very high sloughing, steep slopes (See Photograph 15)
Toe erosion in old construction fill bank (See Photograph 16)
Eroding, open slope face (See Photograph 17)

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Vegetated Conditions

Old growth poplars appear to be dying (See Photograph 18)
Well vegetated riparian zone (See Photograph 19)
Sparsely vegetated shoreline slope (See Photograph 20)

5.6 CRITICAL ISSUE CONSIDERATIONS

In the selection of stabilization, protection and restoration methods, several critical issues were considered as follows:

Erosion and slough/shallow mass failure control - immediate and long term
Inundation and scour
Environmental values for riparian, wildlife habitats and ecological diversity
Improved aesthetic and recreational opportunities
Hydrological/hydraulic capabilities
Risk/factor of safety
Embankment material/groundwater conditions
Type of maintenance
Economic feasibility
Constructability from the contractor's perspective

5.7 GOALS OF SOIL BIOENGINEERING FOR WATERSHED PROTECTION AND RESTORATION

Desired Technical Effects

Protection of a structure against wind, rain, and frost erosion
Protection of the soil surface against wind, rain, and frost erosion and ice gouging
Protection against erosion by flowing water
Elimination or control of soil-damaging mechanical forces so that soil stabilization and compaction (shallow or deep) may be achieved and minor slips or slumps averted
Reduction of currents and wave action near the banks or shorelines
Promotion of drainage and infiltration, thus reducing flood occurrences
Removal of silts and excess nutrients by filtration, thus improving water quality
Retention of materials with potential to move and slip, such as boulders and gravel
Creation of depositional material, thus stabilizing the toe of a bank
Direct reinforcement of soil via the development of the root (fibrous inclusion) system
Reduction in incidental floods with surface vegetation, which reduces velocity, traps rainfall, and stores water on the leaves.

Desired Ecological Effects

Improvement of water conditions through higher interception of rainfall
Improvement of water retentive capacity of the soil and improvement of water consumption through transpiration
Improvement in soil drainage
Moderation of air pollution and water temperatures in stream and lake systems

Stabilization of temperatures in the soil and in air layers near the soil surface
Improvement in provision of shade and protection from wind
Stabilization and protection of the surface soil
Improvement of soil texture by the penetration of plant roots
Improvement of soil nutrients by the addition of decaying plant matter and symbiosis (especially N-fixation), thus improving the ecosystem and promoting the soil flora and fauna
Creation of wildlife corridors and associated habitat for terrestrial wildlife
Enhancement of aquatic habitat
Creation of habitat for birds and waterfowl

Desired Aesthetic Effects

Healing of the wounds in the landscape caused either by natural disasters or by industrial activity
Blending of construction with natural landscape and softening of an urbanized landscape
Screening of constructions which may be absolutely necessary but are unsightly
Enrichment of the landscape by the addition of new shapes and colors
Reconstruction, preservation, and enhancement of wetlands, stream or river corridors, and the upland watershed

Desired Economic Effects

Reduction in cost of construction compared with hard typical conventional engineering methods
Provision of an adjunctive system to protect and enhance the function of conventional installations
Reduction in long-term maintenance costs
Enhancement of sale or rental of recreation equipment
Quality-of-life benefits to human habitat
Reduction in the number and/or size of conventional drainage systems and other structural units
Increase in property values due to aesthetic and functional improvements.

Desired Educational Effects

Provision of a framework for study of natural systems, plant succession, and ecological systems
Protection of important cultural, historical, and natural resources
Stimulus for research into nature and natural systems

5.8 SUGGESTED SOIL BIOENGINEEING METHODS

While there are numerous soil bioengineering stabilization/enhancement methods available, we selected four (4) that would be most appropriate and that would well integrate with the other Master Plan components (See Table 3). The selected methods include joint planting, live fascine, brushmattress and vegetated geogrid. most of which would also be well suited

to the incorporation of conventional revegetation. Native species would be recommended for all the riverine systems installed.

TABLE 3

APPROPRIAI E STREAMBANIC PROTECTION MEASURES
Adapted for the Upper Mississippi River

Erosion Process	Structures Provided the Greatest Environmental Benefits Ranked In Order of Benefits
Headcutting and General bed degradation	Erosion must be halted by installing grade control, runoff detention, and/or by armoring bed
Toe erosion and Upper bank failure	1. Brushmattress with rock toe 2. Vegetated Geogrid 3. Joint Planting 4. Conventional riprap
Local streambank scour	1. Vegetated Geogrid 2. Live fascine with erosion control fabric 3. Joint planting 4. Conventional vegetation 5. Conventional riprap
Local bed scour	1. Eliminate problem and armor bed scour hole
General scour of Middle and upper bank	1. Brushmattress with rock toe 2. Live fascine 3. Joint planting 4. Conventional vegetation 5. Conventional riprap
Overbank runoff	Intercept and divert ninoff and repair damage with: 1. Live fascine 2. Live fascine with erosion control fabric
Piping L	Intercept and divert nmoff. Fill existing pipes and repair damage with: 1. Branchpacking 2. Live staking

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5.9 SOIL BIOENGINEERING METHOD DESCRIPTIONS

Joint Planting

Description: Joint planting is a system that installs live stakes in between the joints of previously placed nprap rock. This method serves as a backup to the conventional installation, and is useful along riverbanks and wetland areas. It is intended to increase the effectiveness of the conventional system by forming a living root mat (which consolidates the material beneath the rock) and water filtering system in the base upon which the riprap has been placed. (See Figure 1 and Photographic Set 1).

Effectiveness: This solution will increase functionality and enable a streambank to become naturalized. Over time it will usually set in place a broad range of habitat enhancement opportunities, be aesthetically pleasing. It also provides additional protection for high-torrent, steep-gradient stream systems. This method integrates well with conventional technology and assists in dissipating energy and encouraging deposition to occur along the stream banks, thus creating a more natural look, aesthetically pleasing system with increased function. Ecologically, joint planting provides shade over the water, thus modifying the temperature as well as providing cover for habitat.

Special Concerns and Difficulties: Joint planting requires that the existing rock be loosely dumped or that it is a maximum of two feet (2') deep. Because areas where riprap has been placed are often very dry, plant survival is usually somewhat lower.

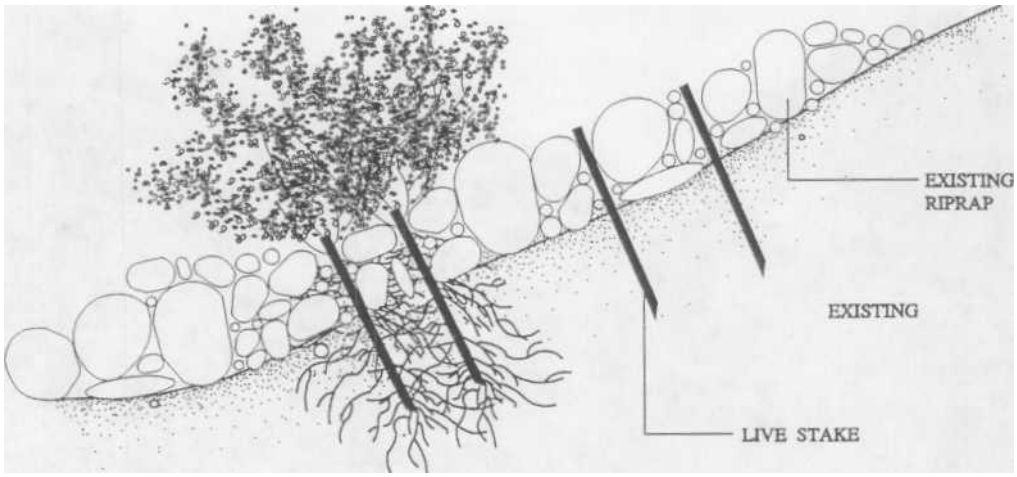
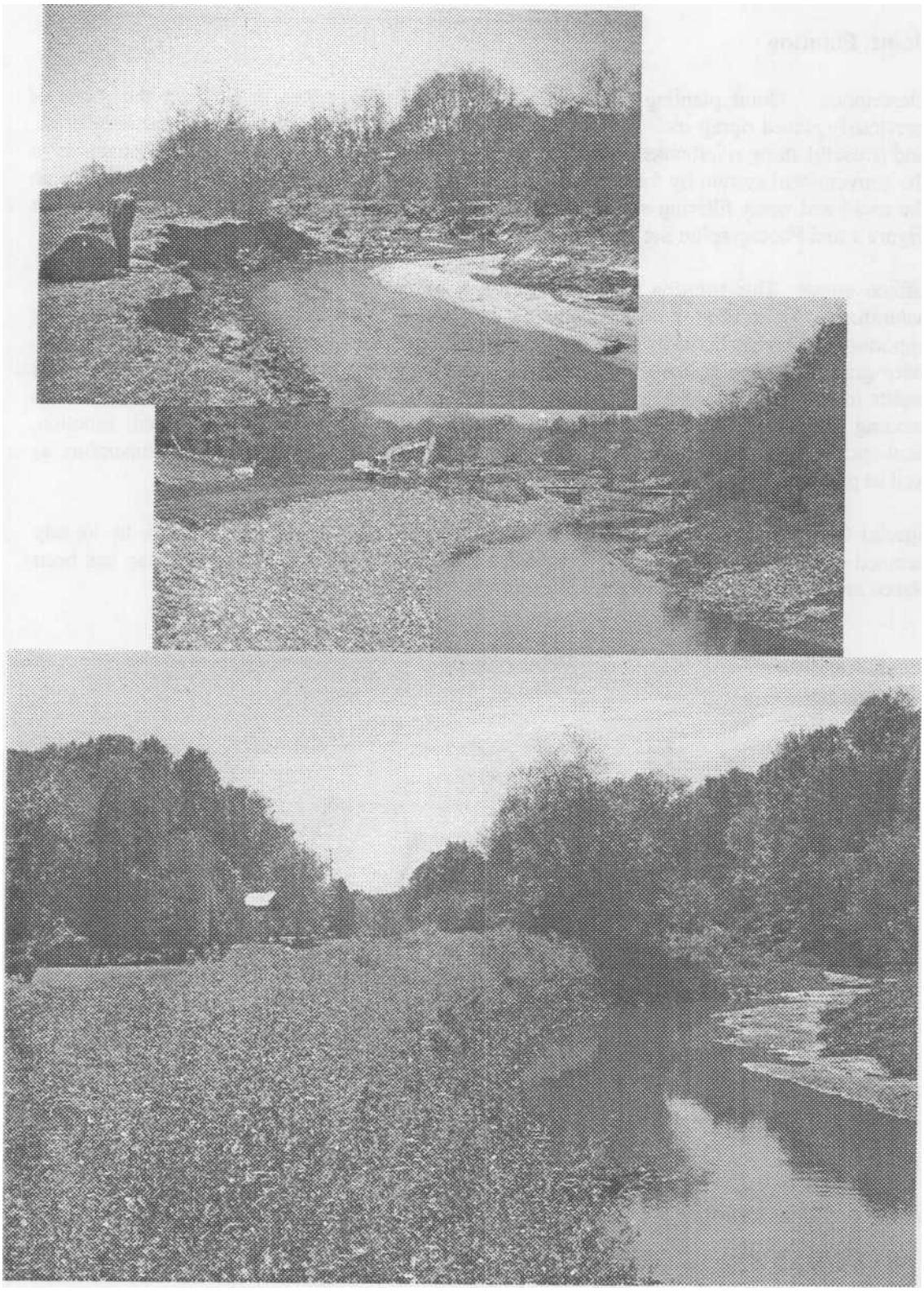


Figure 1 Joint Planting

JOINT PLANTING

PHOTOGRAPHIC SET 1



Live Fascine

Description: Live fascine structures are bound sausage-like bundles of live cut branches. They are tied together securely and placed into trenches along streambanks, upland slopes, wetlands, shorelines, or directly into gully sites. The live fascine bundles are typically installed with live stakes and dead stout stakes, and are often used in conjunction with erosion control fabrics. (See Figure 2 and Photographic Set 2).

Normally, they are placed on contour in dry sections, or at an angle in wet sections on the slope face. They are shallowly installed and usually create very little site disturbance as compared with other methods.

Live fascines perform several "living systems" and mechanical "protective" functions in the erosion control process and hydrology process as follows:

- Break up the slope length into a series of shorter slopes separated by benches;
- provide surface stability for the planting or natural invasion and establishment of vegetation in the surrounding plant community, thus speed up the process of reestablishing functionality;
- trap debris, seed, and vegetation on the slope face;
- slow surface-water velocity and allow for more infiltration;
- assist in drying excessively wet sites through transpiration as they root and produce top growth;
- function as pole drains when placed at an angle on wet sites; and
- reinforce the soil mantle via the root systems.

Effectiveness: These rebuilding structures offer reasonably inexpensive and immediate surface protection from erosion when properly used and installed.

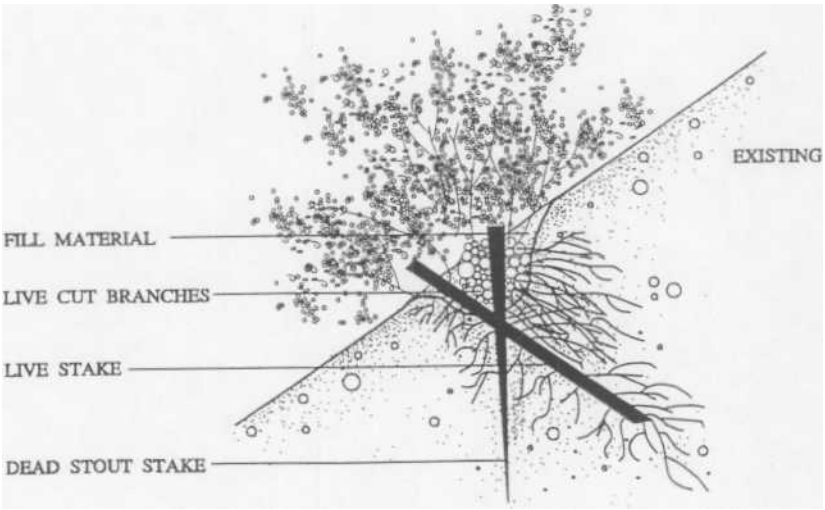
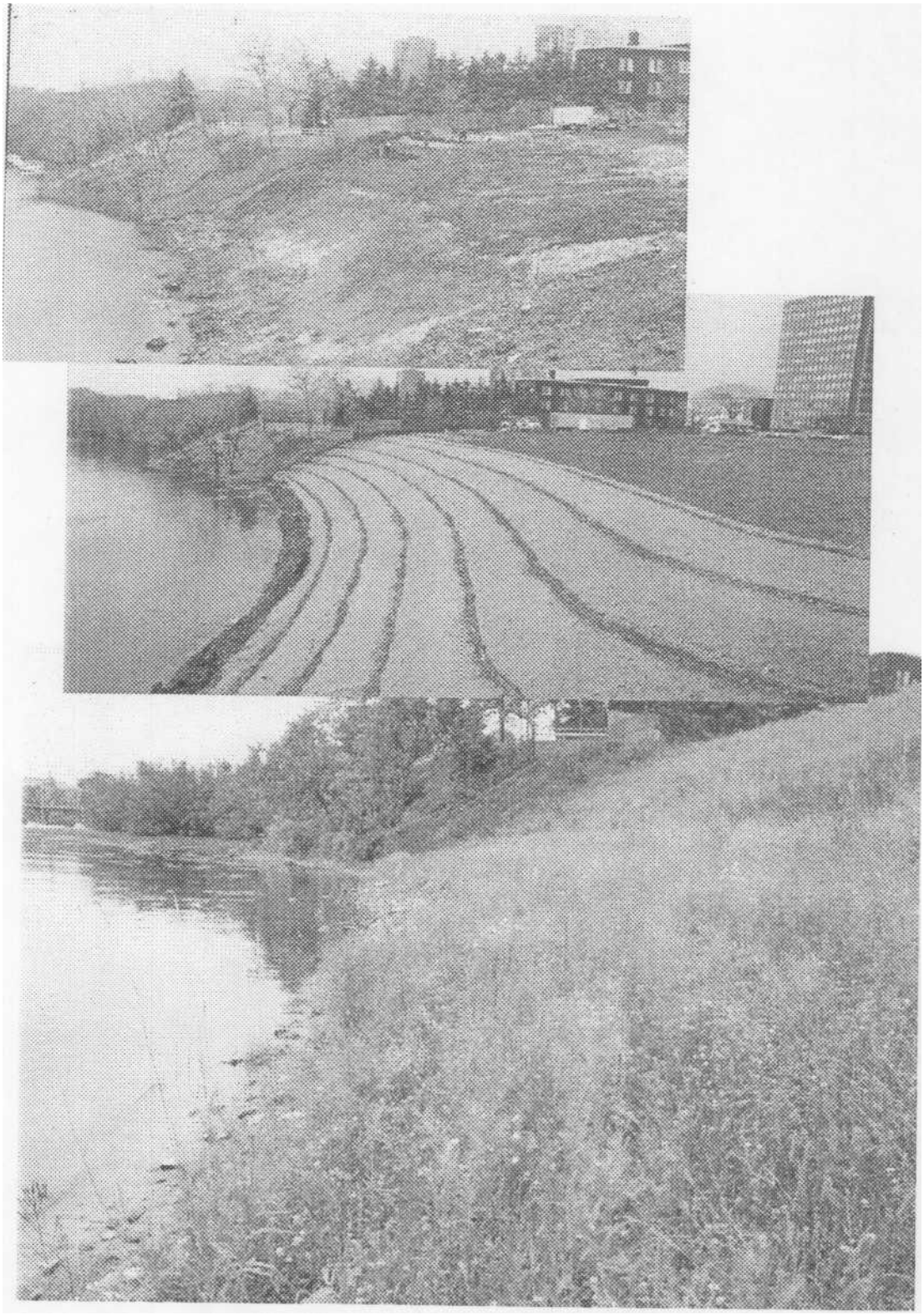


Figure 2 Live Fascine

LIVE FASCINE

PHOTOGRAPHIC SET 2



Whether they survive or not, live fascines are effective in reducing erosion on slopes and shallow gully sites. They are a very effective stabilization technique, especially once rooting is established. Live fascines are capable of holding soil on the face of a streambank or upland slope by creating mini-dam structures.

They serve as effective pole drains in seepage areas when installed at an angle on the stream bank or upland slope. They provide surface stability and connecting support for the invasion of the surrounding aquatic, riparian, or upland-slope vegetation.

Special Concerns and Difficulties: If not properly installed, these methods can gully underneath, in which case they will not root. Therefore, it is important that they be well secured in the ground. Live fascines also have a tendency to dry out as they are shallow installations.

Brushmattress

Description: The brushmattress system is a combination of living units that forms an immediate, "protective" surface cover. This method is typically useful on shorelines and streambanks. The living units used are as follows: live stakes, live fascines, and "living system" and a branch mattress cover (See Figure 3 and Photograph Set 3).

Effectiveness: This installation produces an immediate surface protection against floods. They are able to capture sediment during flood conditions, which assists in the rebuilding of the bank. They rapidly produce heavily vegetated banks that work very well to filter and to slow stormwater runoff, thus improving water quality. They rapidly produce habitat use areas and assist in enhancing the food chain. Their capabilities increase with age. They work quickly to enhance the development of a healthy riparian zone. Brushmattresses produce surface stability for the invasion of the surrounding riparian vegetation. They act as support buffers to the waterways, wetlands, and upland watershed slopes.

Special Concerns and Difficulties: Gullies can easily be started under the brushmattress installation due to the orientation of the branches. The bank must be smoothly graded before installation, and no over-the-bank drainage should occur.

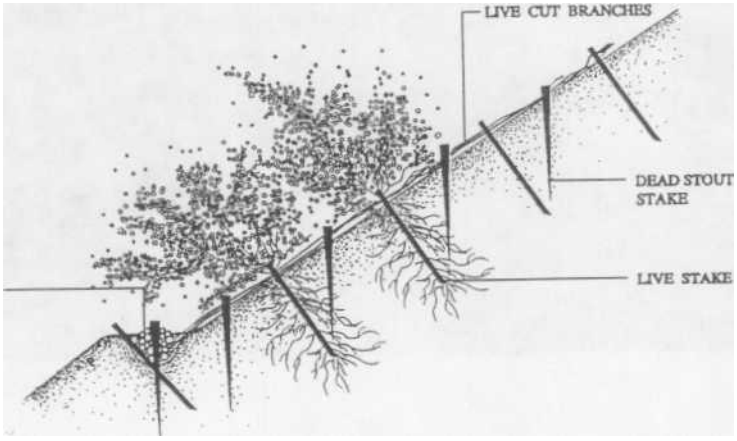
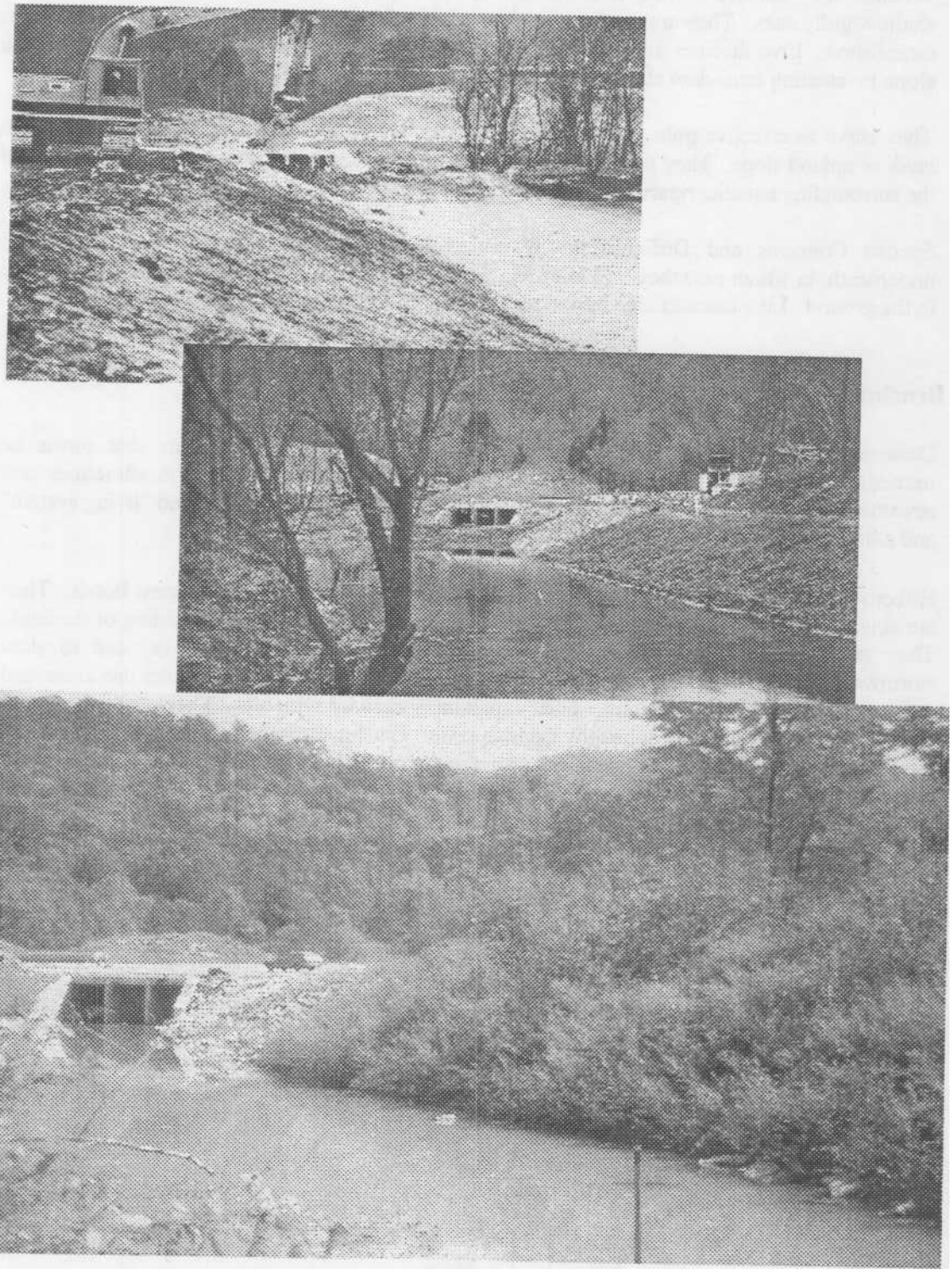


Figure 3 Brushmattress

PHOTOGRAPHIC SET 3



Vegetated Geogrid

Description: Vegetated geogrid is useful for the reconstruction of steep fill slopes. It is a complex method that requires a team with extensive knowledge and understanding of site assessment (specifically geotechnical and hydrological factors). reasons for use. and methods of installation to ensure immediate and long-term success in developing functionality. Similar to brushlaver fill, it involves the cutting and placement of live rooted plants live or branch cuttings in regular arrays in the face of a reconstructed slope. The branches or items are oriented perpendicular to the slope. This orientation- along with the addition of geogrid, offers significant reinforcement to the soil mantle. The geogrid is both used within the fill as well as wrapped around the face of each soil lift. It is a method that is useful for upland slopes, stream and riverbanks as well as shoreline areas, to solve more complex, deeper instability as well as higher velocity conditions.

Vegetated geogrid consists of placing grid and branches on prepared lifts of soil. The soil lifts between the branches are wrapped with grid.

The contribution of branches and grid offer immediate soil reinforcement to the newly constructed slope. The protecting branches assist in retarding runoff and surface erosion, as well as reducing velocities from flowing water. The installed branches are intended to grow, producing roots and leaves. (See Figure 4 and Photographic Set 4).

Vegetated geog ids perform several "protective" and "living system" functions in erosion control, earth reinforcement and mass stability of slopes as follows:

- provides surface stability for the direct planting or establishment of other vegetation;
- able to trap debris, seed and vegetation at the slope face;
- reduces surface water velocities, allowing for more infiltration on droughty sites. The slope is protected due to the overhanging installed living branches;
- assists in drying excessively wet sites through transpiration, as the stems root and grow
- effectively modifies the slope hydrologically by converting parallel flow to vertical flow. The brushlayers act like horizontal drains;
- assists in serving to promote seed germination, i.e., natural invasion of the surrounding plant community;
- immediate soil reinforcement and shallow mass stability is offered in the slope via the grid and live cut branch stems;
- further reinforce the soil mantle via the development of the root systems (or fibrous inclusions). Such secondary development is critical to the long-term success and functionality of the system. It reduces the possibility of soil displacement.
- Effectiveness: Vegetated geogrid installations produce an immediate reinforced soil slope.

Vegetated geogrids serve to create rapid revegetation on upland slope sites, and along stream systems, directly from the installed systems and through natural invasion. Habitat restoration is enhanced for wildlife corridors, food sources, nesting and protection. Useful for overhanging cover for aquatic habitat.

Special Concerns and Difficulties: These methods are excellent for stabilizing very steep slopes and are typically used when space is unavailable to cut the bank back or where soil reinforcement is desirable from a structural perspective. They are somewhat expensive and complex to construct.

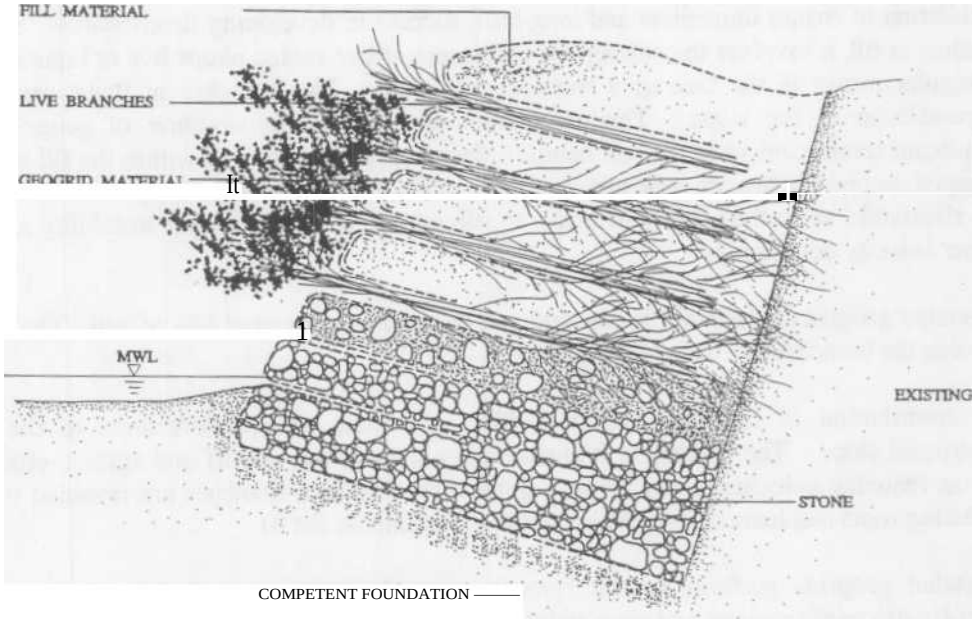


Figure 4 Vegetated Geogrid

6.0 STABILIZATION, RESTORATION AND ENHANCEMENT AREAS

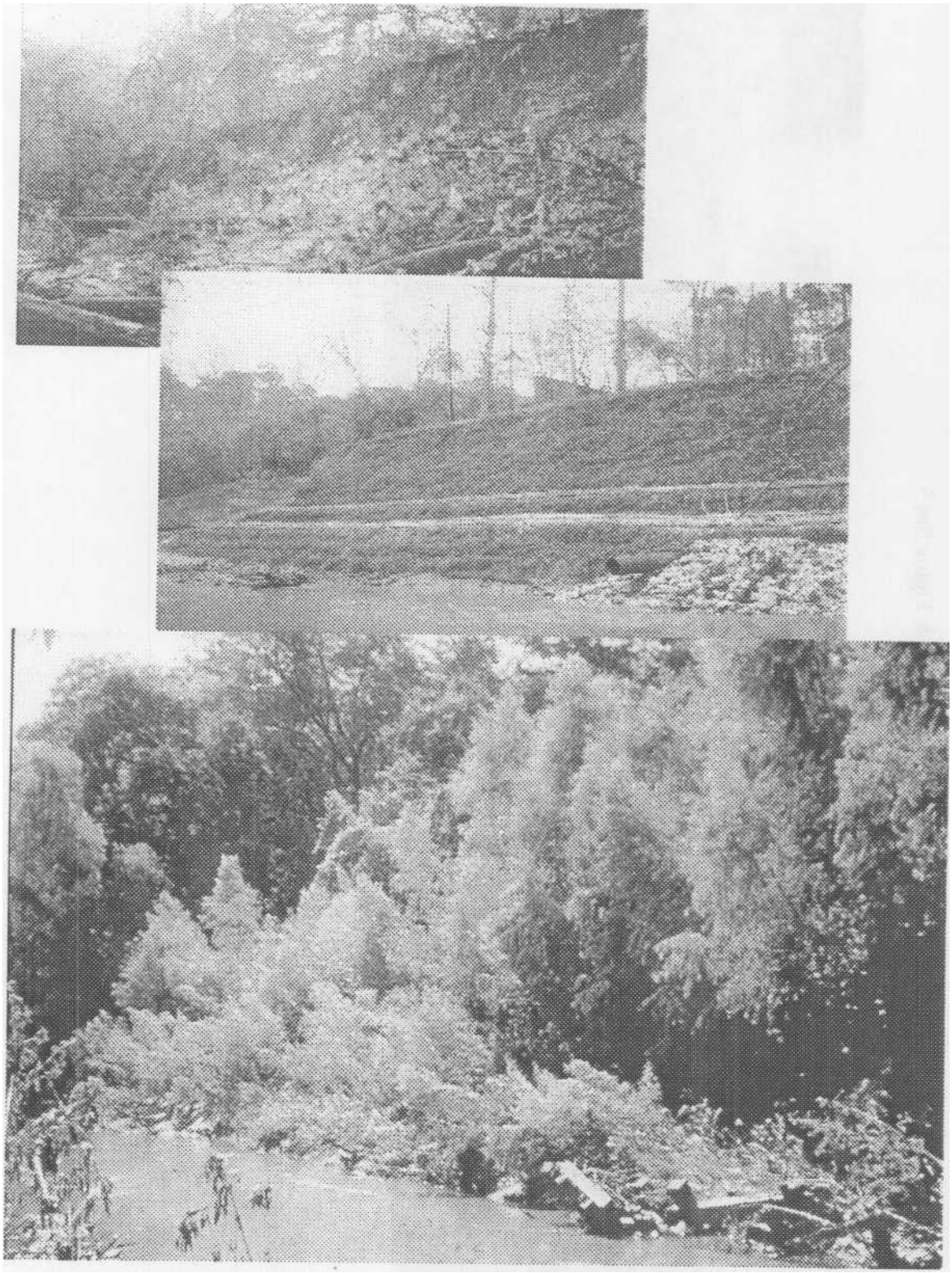
Applying the desired technical, ecological, aesthetic. economic and educated goals along this section of the Upper Mississippi River areas have been selected as soil bioengineering candidates as follows:

West Bank - Plymouth Bridge to Broadway Bridge

Length:	2,300 feet.
Bank Condition:	Landscaped and maintained grassed areas, bank elevation is low upstream.
Erosional Failure:	Toe erosion very severe in sections.
Ground Cover:	Grass above toe.
Tree/Shrub Species:	Elm, ash, spirea, russian olive, willow, silver maple and alder.
Special Notes:	Asphalt ramp to waterline, sand and gravel dump, also some sheet piling rock and mortar. A row of trees along the tip in sections.
Recommendations:	Rock toe with brushmattress and/or live fascines with erosion control fabric. Rock toe could also be joint planted at higher elevations.
Area Photographs:	See Photographic and Figure Set 5.

VEGETATED GEOGRID

PHOTOGRAPHIC SET 4



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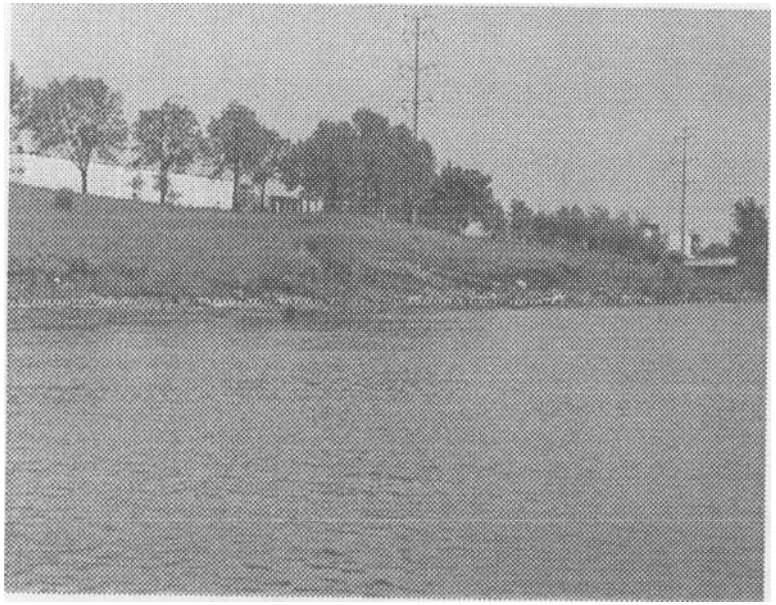
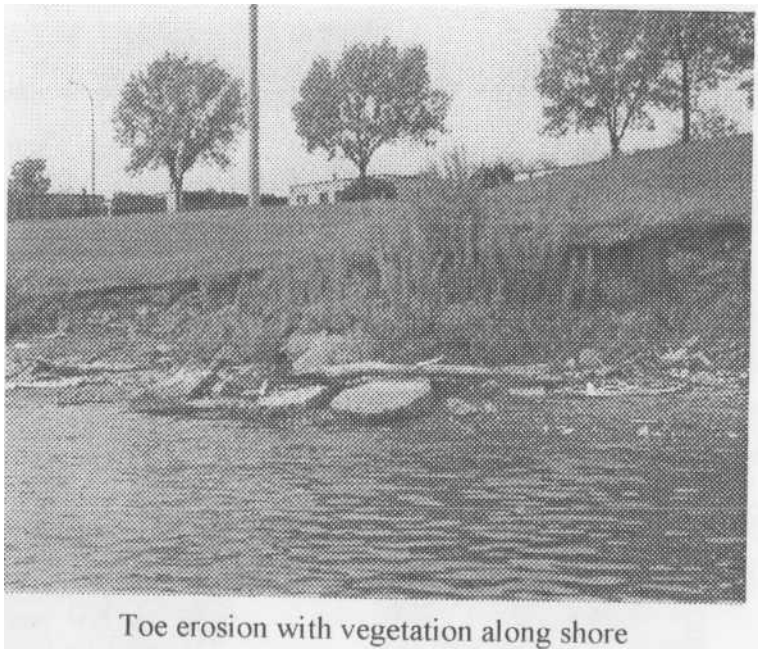
WEST BANK - PLYMOUTH BRIDGE TO BROADWAY BRIDGE

Photographic & Figure Set 5



Maintained grass area with trees on top

Brushmattress



Toe erosion with vegetation along shore

Live Fascine

West Bank - Broadway to South of Burlington Northern Bridge

Length:	1.800 feet.
Bank Condition:	Low banks with fairly gentle slopes.
Erosional Failure:	Toe erosion. ovenvash and sloughs.
Ground Cover:	Grass above toe.
Tree/Shrub Species:	Poplar, willow. elm. ash and robinia fairly sparse on bank and face
Special Notes:	Stormwater outlet with concrete wall. Walking trail and power line tower on top of the bank.
Recommendations:	Rock toe with joint plantings or live fascines and erosion control fabric and planted shrub and tree face.
Area Photographs:	See Photographic and Figure Set 6.

West Bank - North of Burlington Northern Bridge to Lowery Avenue

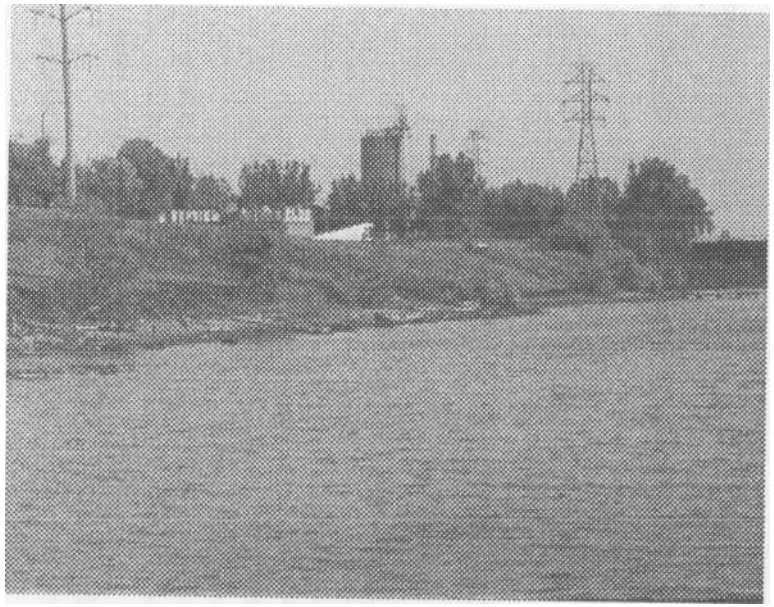
Length:	2,900 feet.
Bank Condition:	Sheet piles. steep dumped fill. concrete blocks, and new vertical banks in sections
Erosional Failure:	Upper bank shows some erosion throughout the reach with some toe erosion in the mid-northern end. No toe erosion was evident due to bank protection devices in the southern end.
Ground Cover:	20% to 80%.
Tree/Shrub Species:	Poplar, ash, silver maple, russian olive and willow. The vegetation becomes very dense in the southern end of this reach.
Special Notes:	Gravel and sand barge area, sheet pile, electric tower protectors, low failing walls, riprap rock banks.
Recommendations:	Vegetated geogrid for steeper slope sections and live fascines for Rock toe with brushmattress and/or live fascines with erosion control fabric. Rock toe could also be joint planted at higher elevations.
Area Photographs:	See Photographic and Figure Set 7.

West Bank - Lowery Avenue to Dowling Avenue

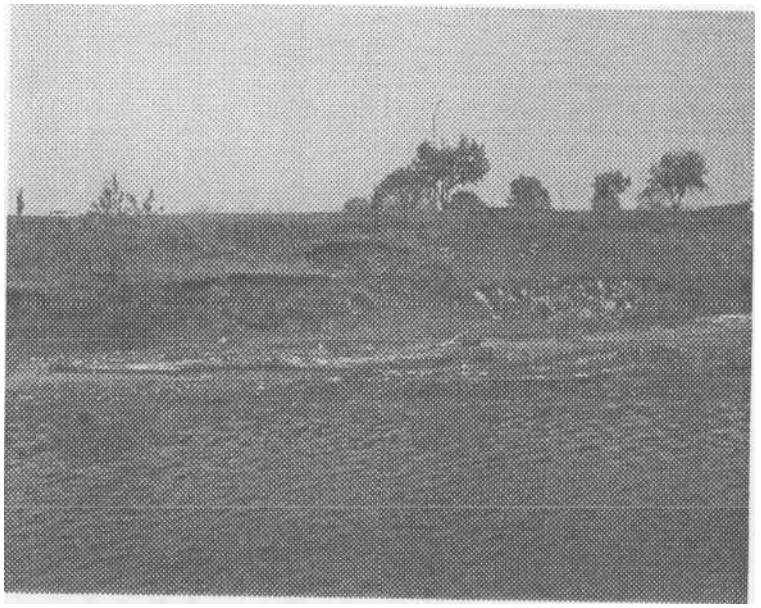
Length:	4,200 feet.
Bank Condition:	High and steep banks with rock along the toe.
Erosional Failure:	Toe erosion stopped with riprap rock protection. Southern area has evidence of surface sloughs.
Ground Cover:	Sparse, up to 40% in the central area section of this reach.
Tree/Shrub Species:	Some shrubs and a few small trees. Poplar and ash also exist in some areas along this reach.
Special Notes:	Very industrial along the river's edge with sheet pile walls in some locations and riprap rock banks in other areas. An extremely sterile area with coal and sand piles on top of the bank including asphalt treatment on the banks.
Recommendations:	Vegetated geogrid in narrow steep areas and joint plantings on flatter slopes.
Area Photographs:	See Photographic and Figure Set 8

WEST BANK - BROADWAY TO SOUTH OF BURLINGTON NORTHERN BRIDGE

Photographic and Figure Set 6



Open bank condition



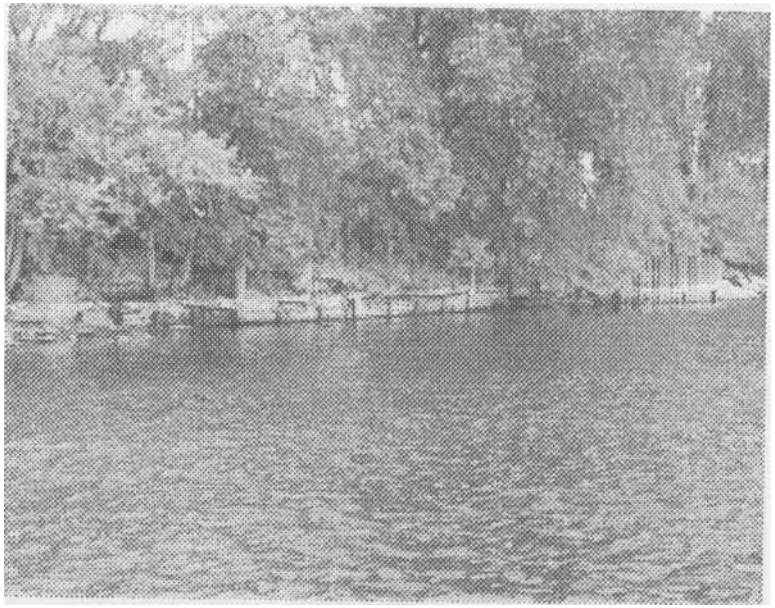
Large shallow failures, little vegetation

Joint Planting

Live Fascine

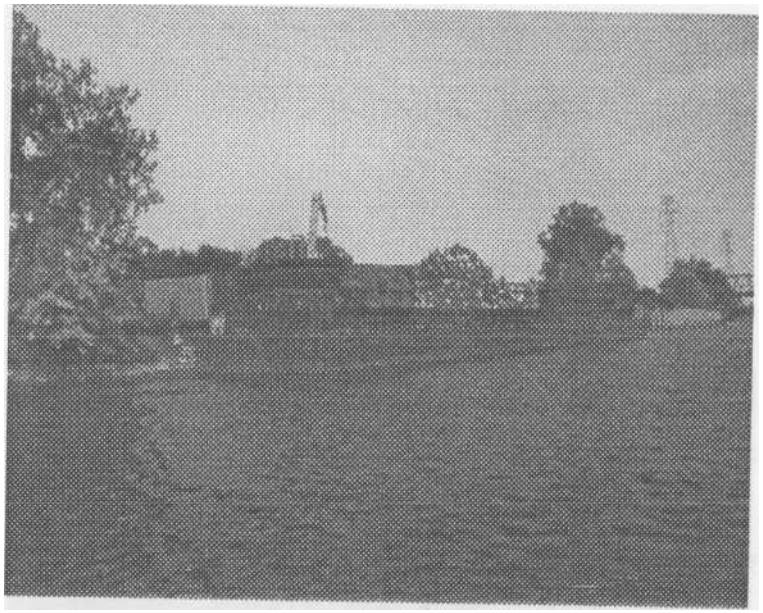
WEST BANK - NORTH OF BURLINGTON NORTHERN BRIDGE TO LOWERY AVENUE

Photographic and Figure Set 7



Low failing wall with vegetation

Vegetated Geogrid

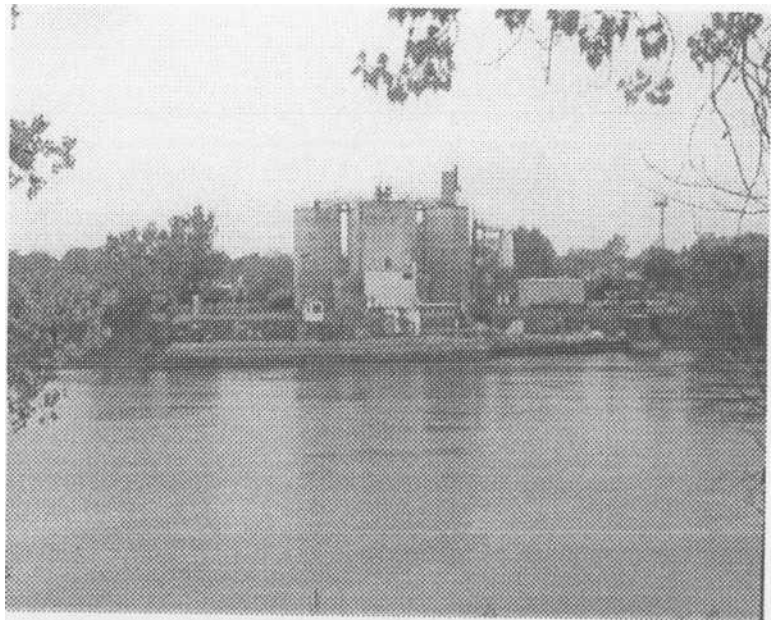


Sheet pile edge and barge area

Live Fascine

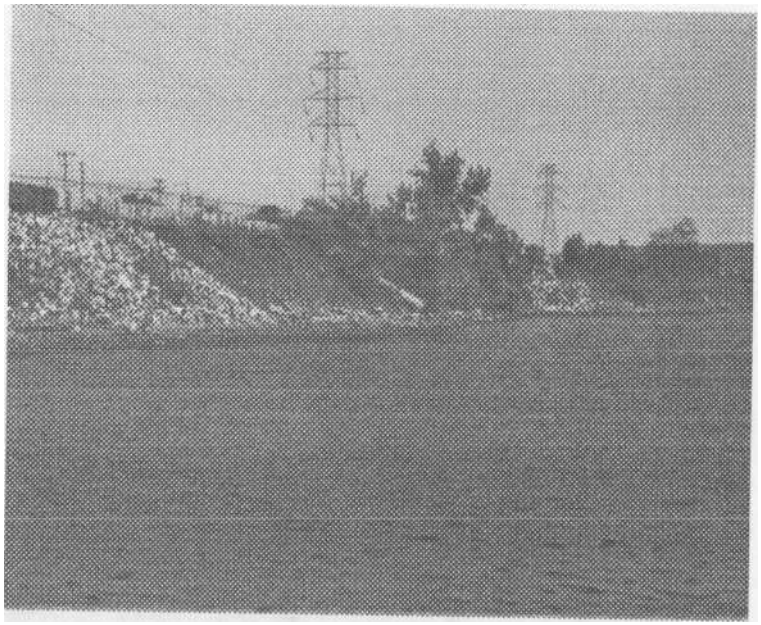
WEST BANK - LOWERY AVENUE TO DOWLING AVENUE

Photograpihc and Figure Set 8



Sheet pile at edge of river

Vegetated Geogrid



Open rock anchor area

Joint Planting

West Bank - Dowling Avenue to Soo Line Bridge (and North)

Length:	2,100 feet.
Bank Condition:	Poured concrete and also concrete rubble, low and flat bank near Soo Line.
Erosional Failure:	Some toe and surface erosion in the upstream portion.
Ground Cover:	No vegetation in front of the concrete plant. Upstream - approximately 20%.
Tree/Shrub Species:	No vegetation until halfway through the section. Upstream - small narrow band of trees - poplar and willow. Well vegetated. good ground cover on upper area. Poplar, willow, alder. ash. honeysuckle and box elder in the northern section
Special Notes:	Fairly open ground area, industrial up to river's edge. Barge storage area and a large stormwater outlet into river.
Recommendations:	Rock toe with brushmattress along the river and live fascines above.
Area Photographs:	See Photographic and Figure Set 9.

East Bank - Plymouth Avenue to Broadway

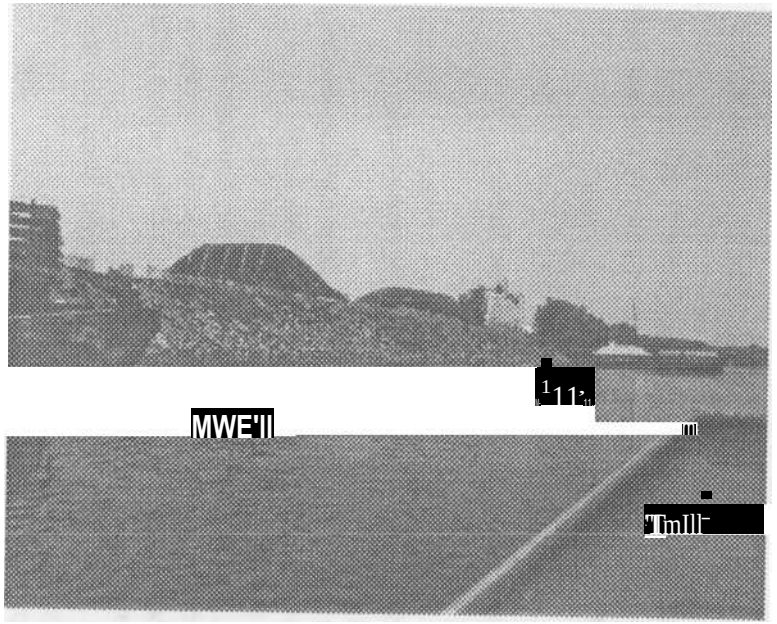
Length:	2.000 feet.
Bank Condition:	Concrete wall, rubble fill and riprap rock bank.
Erosional Failure:	Further upstream more toe erosion with some slumps evident.
Ground Cover:	10% to 20%, to none in the southern area.
Tree/Shrub Species:	Poplar, honeysuckle, elm, ash and willow - very open and canopy - essentially a line of trees. No trees are growing on the bank in the southern area.
Special Notes:	Between bridge and stormwater outlet. Concrete rubble on bank. Short failing concrete wall. lumber company with storage yard that occupies the bank up to the river's edge.
Recommendations:	Rock toe with brushmattress along the river and live fascines above.
Area Photographs:	See Photographic and Figure Set 10.

East Bank - Broadway to Burlington Northern Bridge

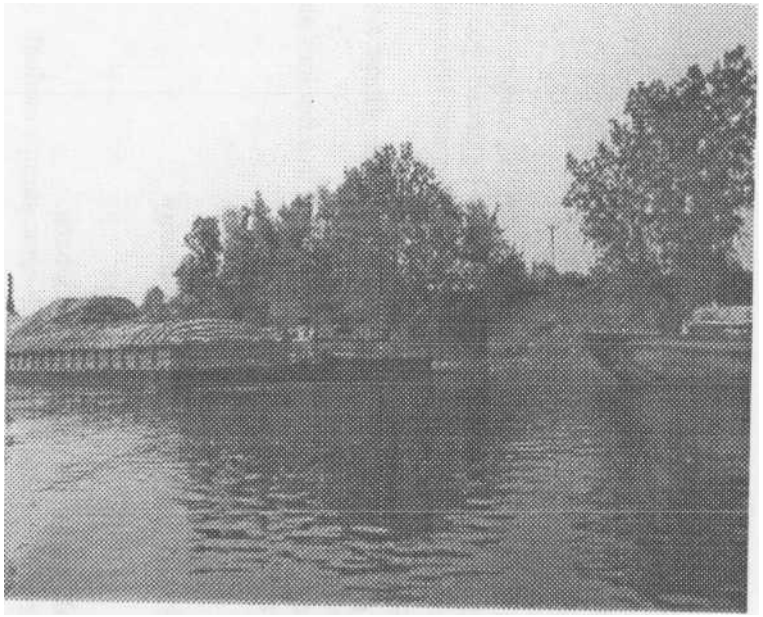
Length:	1,300 feet.
Bank Condition:	Very high and very steep, with some vertical banks in the downstream section.
Erosional Failure:	Toe erosion, runoff; mid section with long open surface sloughing. Major toe erosion exists in the mid section of this reach.
Ground Cover:	50% to 60%, grasses and open bank areas downstream.
Tree/Shrub Species:	Russian olive, box elder, sumac, ash, elm and large mature poplar.
Special Notes:	Selectively wooded with large woody and herbaceous vegetation areas. One active stormwater outlet. Major facilities on top of the bank in the downstream section.
Recommendations:	Live fascines and possibly a vegetated geogrid along the toe for additional support.
Area Photographs:	See Photographic and Figure Set 11.

WEST BANK DOWLING AVENUE TO SOO LINE BRIDGE (AND NORTH)

Photographic and Figure Set 9



Open site with concrete and rock bank



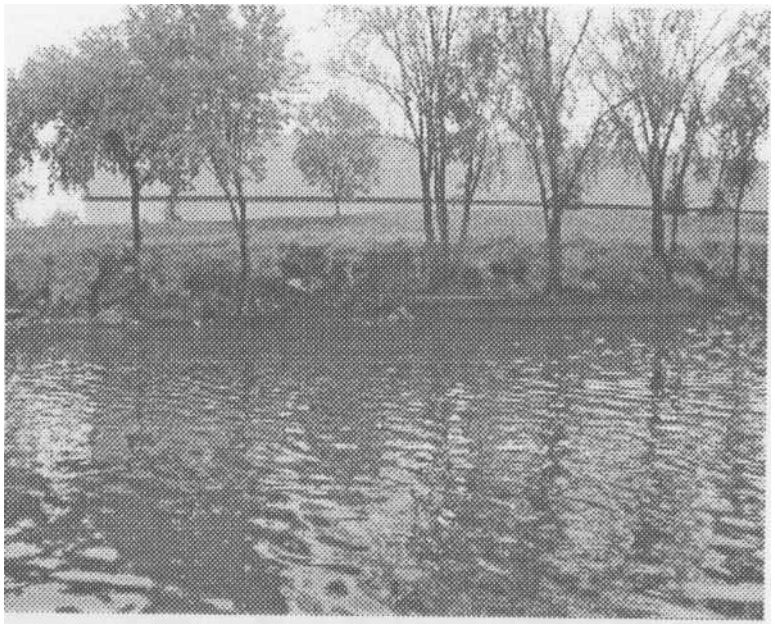
Barge activities along water's edge

Brushmattress

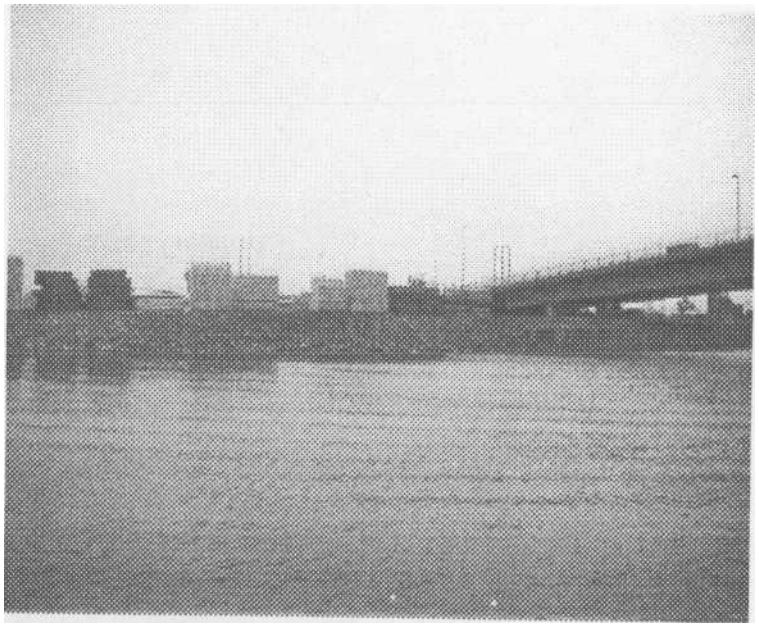
Live Fascine

EAST BANK - PLYMOUTH AVENUE TO BROADWAY

Photographic and Figure Set 10



Low concrete wall, rubble, eroding bank



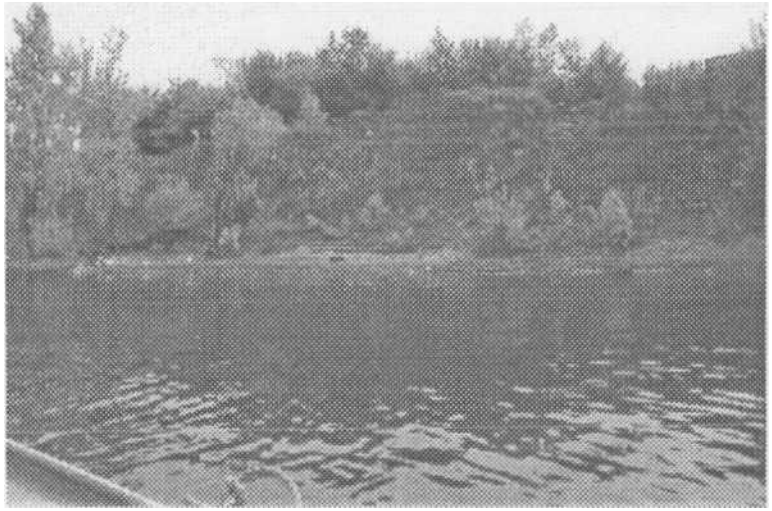
Riprap bank upstream of Plymouth Ave.

Vegetated Geogrid

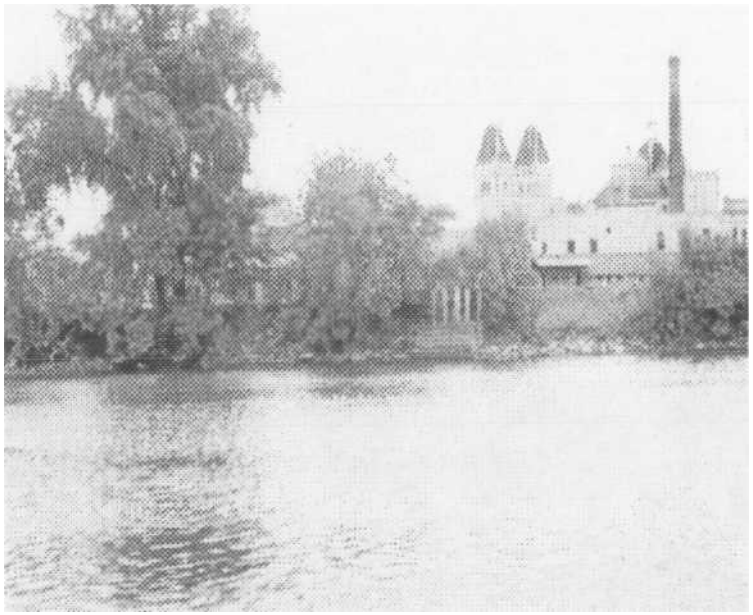
Joint Planting

EAST BANK - BROADWAY TO THE BURLINGTON NORTHERN BRIDGE

Photographic und Figure Set ! !



Very high and steep sloughing slopes



Concrete rubble batik

Live Fascitie

id

East Bank - Between Edgewater and Glueck Park

Length:	800 feet.
Bank Condition:	High bank cracking and eroding from the top.
Erosional Failure:	Mostly toe erosion with some upper bank slough.
Ground Cover:	60% to 70%.
Tree/Shrub Species:	Silver maple, elm, ash, polar, lots of robinia_ box elder and grape.
Special Notes:	Residences have cut down trees radically, large concrete blocks on shoreline, large old poplars appear to be dying along the shoreline, several informal trails to the shore from the upper bank. pipeline crossing to the north, garden debris has been dumped on the shore.
Recommendations:	Live fascines where the area is geotechnically stable and vegetated geogrids in unstable areas requiring reinforcement.
Area Photographs:	See Photographic and Figure Set 12.

East Bank - Privately Owned Parcels Between Burlington Northern Bridge & NSP

Length:	1,200 feet.
Bank Condition:	Low construction filled bank with concrete blocks.
Erosional Failure:	Toe erosion low surface sloughs downstream, high construction filled banks with high surface sloughs and gullies.
Ground Cover:	10% to 20%.
Tree/Shrub Species:	Poplar, silver maple, oak and chinese elm - narrow but well vegetated.
Special Notes:	Marshall Block area, concrete and high wooden wall in this area, both are deteriorating, construction dump and gate area. Concrete and wooden wall structures. Sandy shoreline is in front of the wooden walls. Lumber stock piles on top further downstream.
Recommendations:	Vegetated geogrid on steep slopes and joint plantings on flatter bank sites.
Area Photographs:	See Photographic and Figure Set 13.

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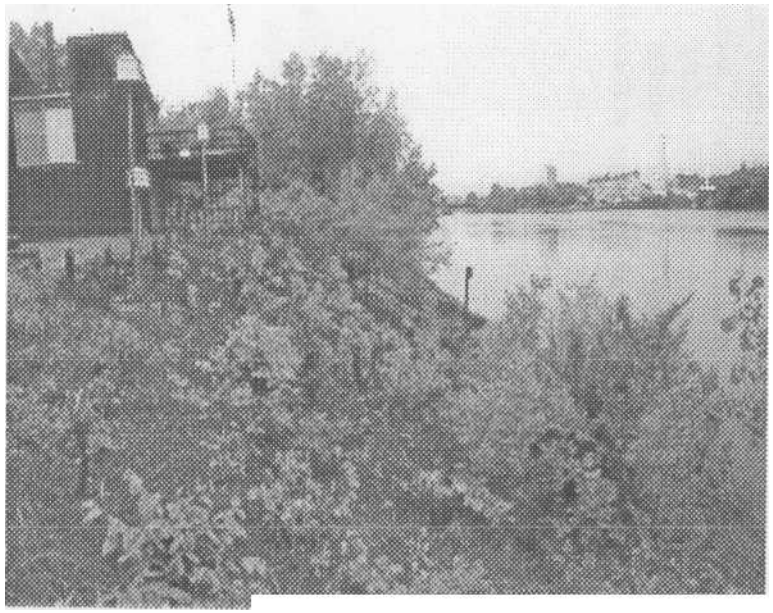
East Bank - Privately Owned Parcels Between Burlington Northern Bridge & NSP (Continued)

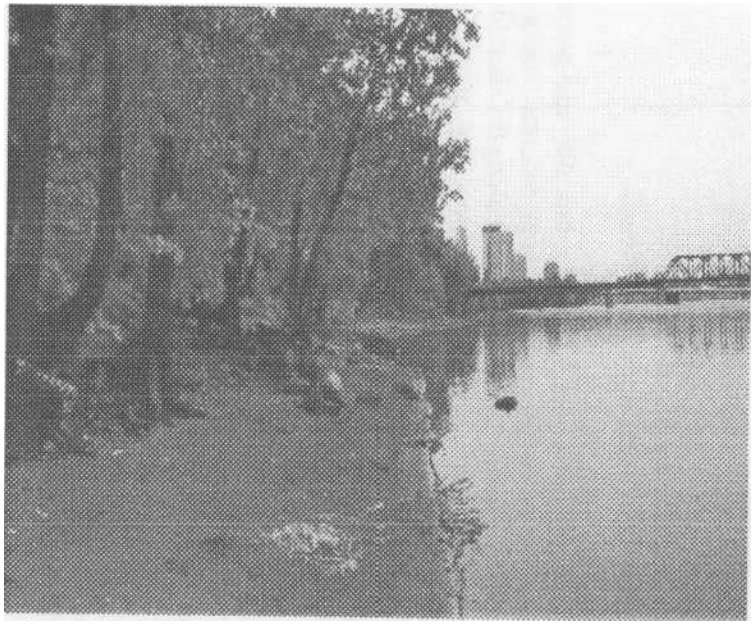
Length:	1,000 feet.
Bank Condition:	Medium banks that appear to be composed of construction debris.
Erosional Failure:	Toe erosion, bank fairly stable with some isolated upper slumps downstream.
Ground Cover:	10% to 30%.
Tree/Shrub Species:	Poplar, silver maple and box elder
Special Notes:	Well vegetated, woody and grass, private residence, some decks with erosion on both sides. Area at Garbv's restaurant. A stormwater pipe outlet is also in this section.
Recommendations:	Rock toe with joint plantings, live fascines in the upper slough areas.
Area Photographs:	See Photographic and Figure Set 14.

EAST BANK - BETWEEN EDGEWATER AND GLUECK PARK

Photographic and FigureSet 12



River view achieved by cutting vegetation



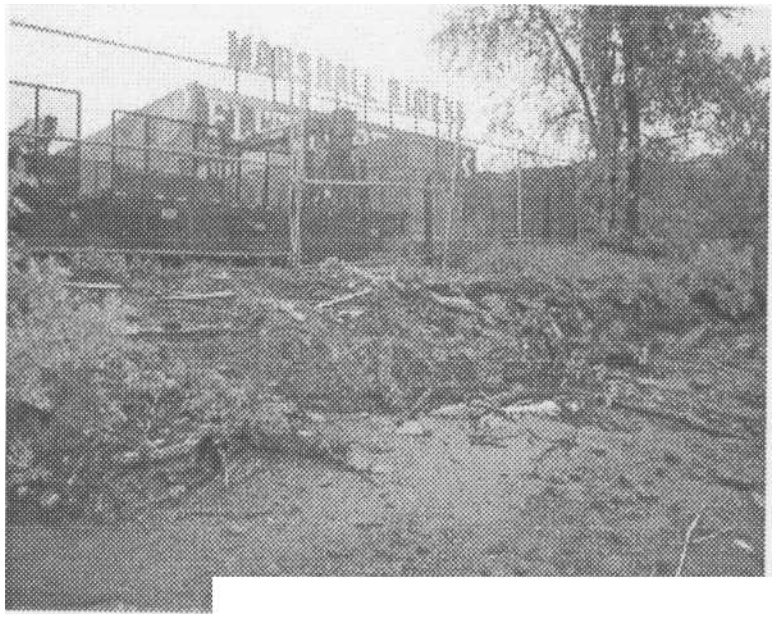
Old growth poplars appear to be dying

Live Fascine

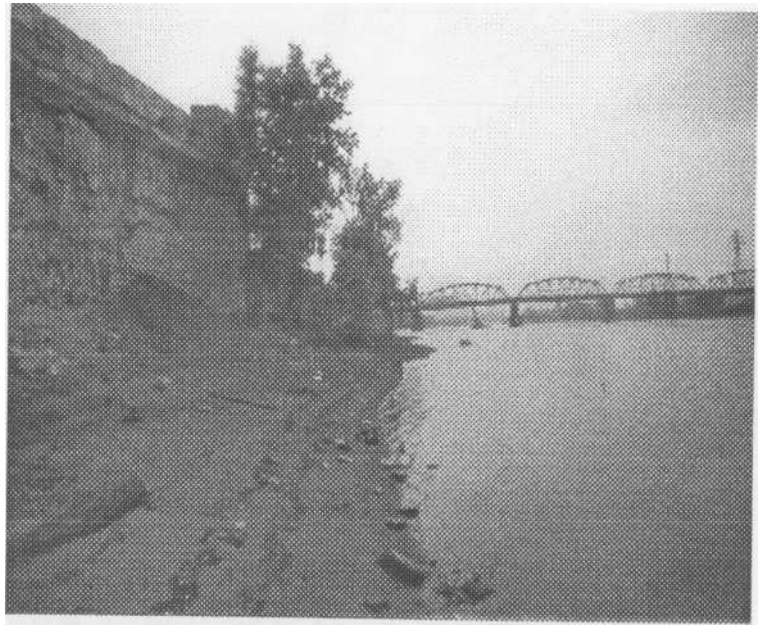
Vegetated Geogrid

EAST BANK - PRIVATELY OWNED PARCELS BETWEEN BURLINGTON NORTHERN BRIDGE AND NSP

Photographic and Figure Set 13



Toe erosion, construction fill and overwash



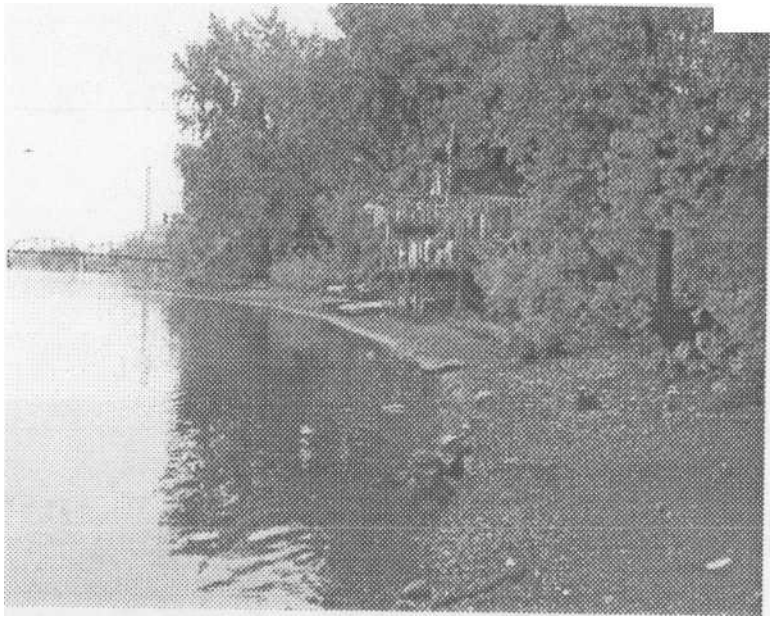
Concrete wall on river's edge

Vegetated Geogrid

Joint Planting

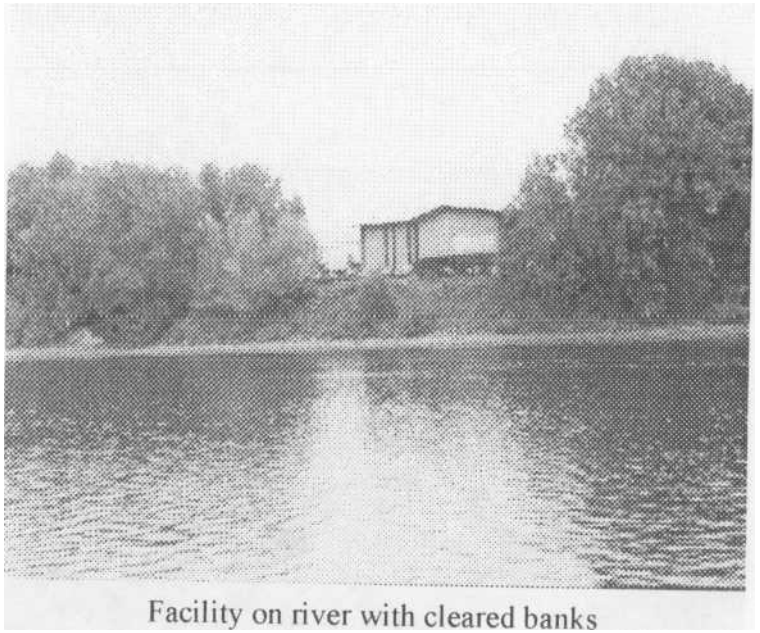
EAST BANK - PRIVATELY OWNED PARCELS BETWEEN BURLINGTON NORTHERN BRIDGE AND NSP (Continued)

Photographic and Figure Set 14



Private residence on vegetated shoreline

Joint Planting



Facility on river with cleared banks

Live Fascine

East Bank - NSP Property and North

Length:	800 feet. Downstream upper limit of this reach is the railroad bridge and ends downstream at St. Anthony Parkway.
Bank Condition:	Low vertical to rounded upper bank slope meeting the shoreline.
Erosional Failure:	Toe erosion with upper bank failure.
Ground Cover:	60% to 80%.
Tree/Shrub Species:	Lots of caranga. vetch, sedge and poplar.
Special Notes:	Evidence of beaver activity.
Recommendations:	Rock toe with joint plantings and possibly brushmattress if seepage is not evident.
Area Photographs:	See Photographic and Figure Set 15.

East Bank - NSP Property and North (Continued)

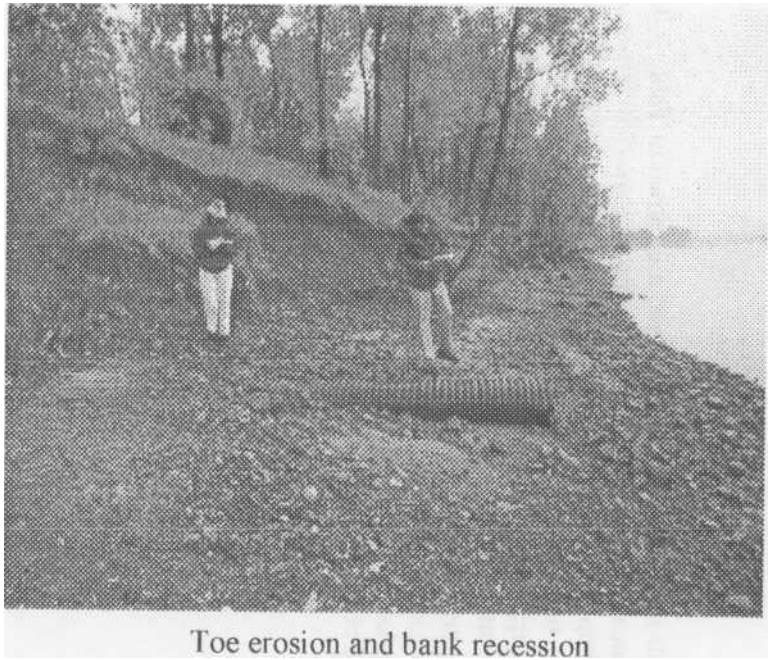
Length:	1,000 feet.
Bank Condition:	Sloping.
Erosional Failure:	Over the bank runoff, seepage and toe erosion.
Ground Cover:	Little to none, some sedges and grasses.
Tree/Shrub Species:	Poplar and silver maple are growing in this section.
Special Notes:	Northern States Power area. Building facility on shoreline. sheet pile wall.
Recommendations:	Vegetated geogrid and brushmattress.
Area Photographs:	See Photographic and Figure Set 16.

6.1 COST RANGES

Soil bioengineering ranges of construction costs for each method are shown in Table 3, Unit Cost Chart. The bank costs in lineal foot would range from fifty dollars ($50.00) to one thousand dollars ($1,000.00). A simple method such as joint planting, done in a zone of less than twenty feet (20') wide would be in the lower fifty to one hundred dollar ($50.00 to $100.00) range. This would also apply to areas that require some enhancement plantings and soft protection. While the vegetated geogrid possibly thirty feet (30') high with rock toe protection could range as high as one thousand dollars ($1,000.00 per running lineal foot. The average repair where major edging such as sheetpile and concrete do not exist, may be in the two hundred to five hundred dollar ($200.00 to $500.00) range. These would be areas that are between five and fifteen feet (5' and 15') in height and could be graded back and revegetated.

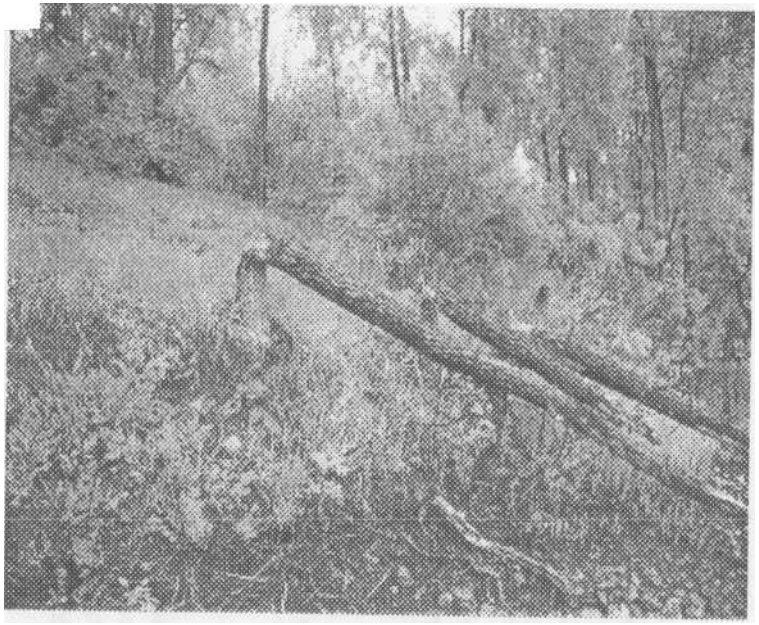
EAST BANK NSP PROPERTY (AND NORTH)

Photographic and Figure Set 15



Toe erosion and bank recession

Joint Planting

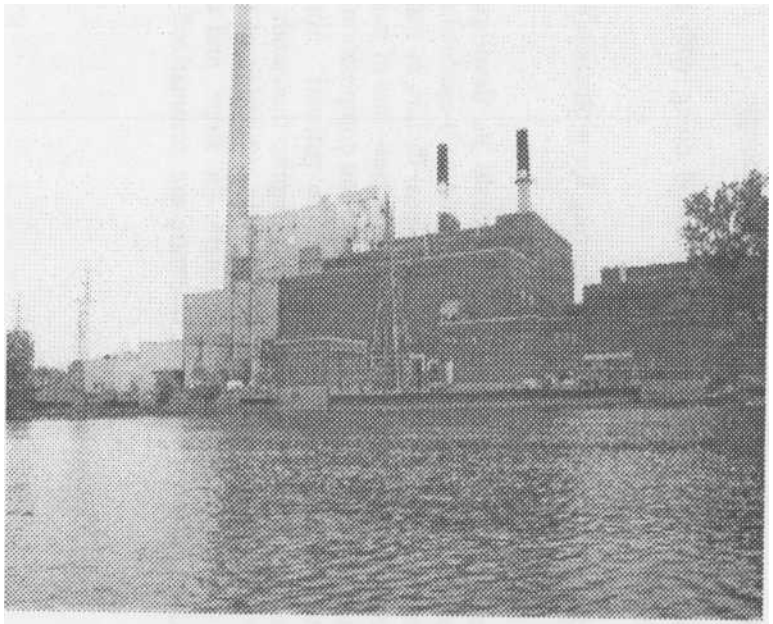


Beaver activity

Brushmattress

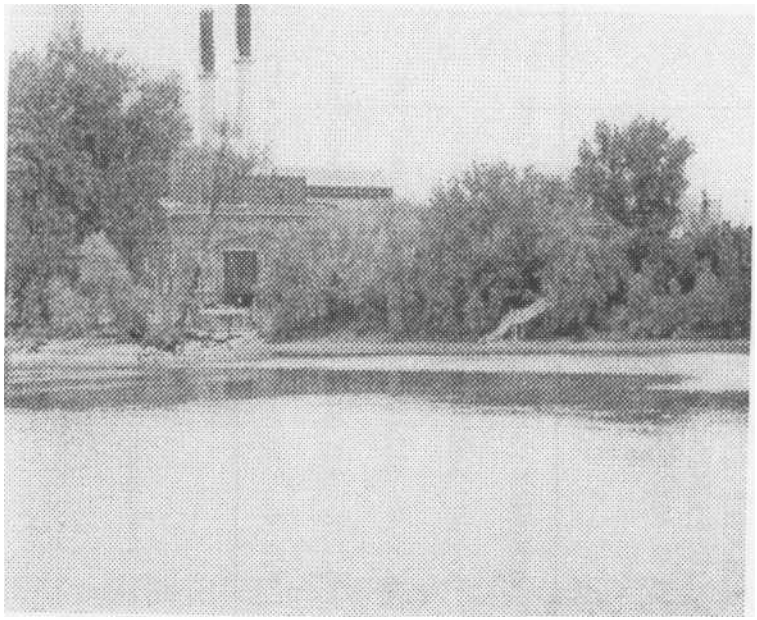
EAST BANK - NSP PROPERTY (AND NORTH), Continued

Photographic and Figure Set 16



Industrial use up to river's edge

Vegetated Geogrid



Connection area between industrial zone and Glueck Park

Brushmattress

TABLE 4
UNIT COST CHART FOR SELECTED
SOIL BIOENGINEERING METHODS
ON THE UPPER MISSISSIPPI RIVER

Method	Installed Cost	Per Unit
Joint Planting	$ 4.00 - $ 9.00	per stake
Live Fascine	$ 5.00 - $12.00	per lineal foot
Vegetated Geogrid	$12.00 - $25.00	per lineal foot
Brushmattress	$10.00 - $20.00	per square yard

Sotir 1999

* Installation includes harvesting, transportation, storage and placement in 1999 dollars

6.1 SUMMARY

As each specific area is planned for development, a number of options should be prepared. These could be lined up with the goals and objectives of the area in terms of restoring loss - i.e. habitat, aesthetics, stability, as well as desired use for recreation, as an example.

Failures, as well as erosional mechanisms would need to be considered along with the ecological, aesthetic, economic and recreation desires.

One further consideration for naturalizing areas using soil bioengineering for protection and restoration is the use of buffers.

In cases where existing riparian buffers are not adequate, buffers could be developed. Although their value is well recognized, criteria for buffer strip sizing is not well established. Economic and legal considerations have taken precedence over ecological factors in many cases, and most existing criteria address contaminant and nutrient loading, only one of many functions performed by riparian buffers. In general, the width and vegetation composition of buffer strips will dictate the extent to which the above benefits will be realized. Some benefits can be obtained for buffers as narrow as 20 feet while others require thousands of feet. In general, the ability of buffer strips to meet specific objectives is a function of the vegetation species utilized and their density. buffer width and length, the slope, and the position in the landscape. Buffer width guidelines from the literature are summarized in Table 5, below.

TABLE 5
GENERAL BUFFER WIDTH GUIDELINES
FOR THE UPPER MISSISSIPPI RIVER

Water Quality Protection	Buffers, especially dense grassy buffers on gradual slopes intercept overland runoff trap sediments. remove pollutants, and promote ground water recharge.	20 - 100 ft.
Riparian Habitat	Buffers, particularly_ diverse stands of shrubs and trees, provide food and shelter for a wide variety_ of riparian and aquatic wildlife.	30 - 300 ft.
Stream Stabilization	Riparian vegetation moderates soil moisture conditions in stream banks, and roots provide tensile strength to the soil matrix, enhancing bank stability.	30 - 50 ft.
Flood Attenuation	Riparian buffers promote floodplain storage due to backwater effects, they intercept overland flow and increase travel time, resulting in reduced flood peaks.	50 - 500 ft.
Detrital Input	Leaves, twigs and branches that fall from riparian forest canopies into the stream are an important source of nutrients and habitat.	10 - 30 ft.

1 - Synopsis of values reported in the literature, a few wildlife species require much wider riparian corridors.

A

APPENDIX A

REACH INVENTORY TABLES FOR THE EAST BANK

Table 1 Upper Mississippi River Master Plan
Reach Inventory for the East Bank

	Length in	Bank Condition					Debris	Structure	Erosional Failure			Ground Cover in Percentage
		Steep	Moderate	Flat	High	Low			Te Erosion	Slumps	Surface Sloughs	
1	1,000	*			*				*	*		40-50/20
2	1,200	*			*				*	*		20-30/50-70
3	800	*				*			*	*	*	60-80
4	1,400	*				*		*	*			90-100
5	850	*				*			*			100
6	1,000		*		*			*	*			10-20
7	600		*		*			*	*		*	40-60
8	1,050				*		*		*		*	10-20
9	200	*			*		*	*			*	0
10	580		*		*		*				*	5-10/40-60
11	800		*		*		*				*	60-70
12	500		*			*	*		*	*		30/60-70
13	400		*		*		*		*	*		10-30
14	100		*		*		*		*			70-90
15	500		*		*		*		*	*		70-90
16	100		*		*				*			10-20
17	900	*			*				*		*	50-60
18	400	*				*	*		*			0
19	400	*			*		*		*			10-20
20	250	*			*				*		*	30-40
21	1,200		*			*	*	*	*	*		10-20
22	800		*		*			*				0

A Structure: Sheetpile, Riprap Rock, Facility, Barge or Other Hard Surface Systems Along the Shoreline or in Water

Table 2 Upper Mississippi River Master Plan
Reach Inventory for the West Bank

Reach	Length in Feet	Bank Condition					Const. Debris	Structure A	Erosional Failure			Ground Cover in Percentage
		Steep	Moderate	Flat	High	Low			Toe Erosion	Slumps	Surface Sloughs	
1	1,250		*		*							60-80
2	100		*		*		*		*			20-30
3	1,600		*			*	*		*		*	60-70
4	1,200			*		*						70-80
5	800			*		*						60-8U
6	600			*		*			*			80
7	1,300			*		*			*			40-80
8	250			*								60-80
9	180		*									40-80
10	280		*		*		*					50-70
11	200			*		*			*			un_on
12	1,900				*		*	*	*			v 20
13	1,400	*			*			*				10
14	1,500	*			*							20-40
15	600	*			*				*			10-20
16	700		*		*		*	*		*	*	10-20
17	600	*			*		*	*				10-20
18	1,000		*		*			*	*			20
19	500		*		*		*	*			*	20
20	850	*			*		*	*				20-30
21	400		*			*			*			20
22	1,400		*			*		*	*		*	100
23	2,300	*				*		*	*			100

A Structure: Sheetpile, Riprap Rock, Facility, Barge or Other Hard Surface Systems Along Shorelines or in Water

APPENDIX B

CONDITIONS AND RIVER RELATED FUNCTIONS

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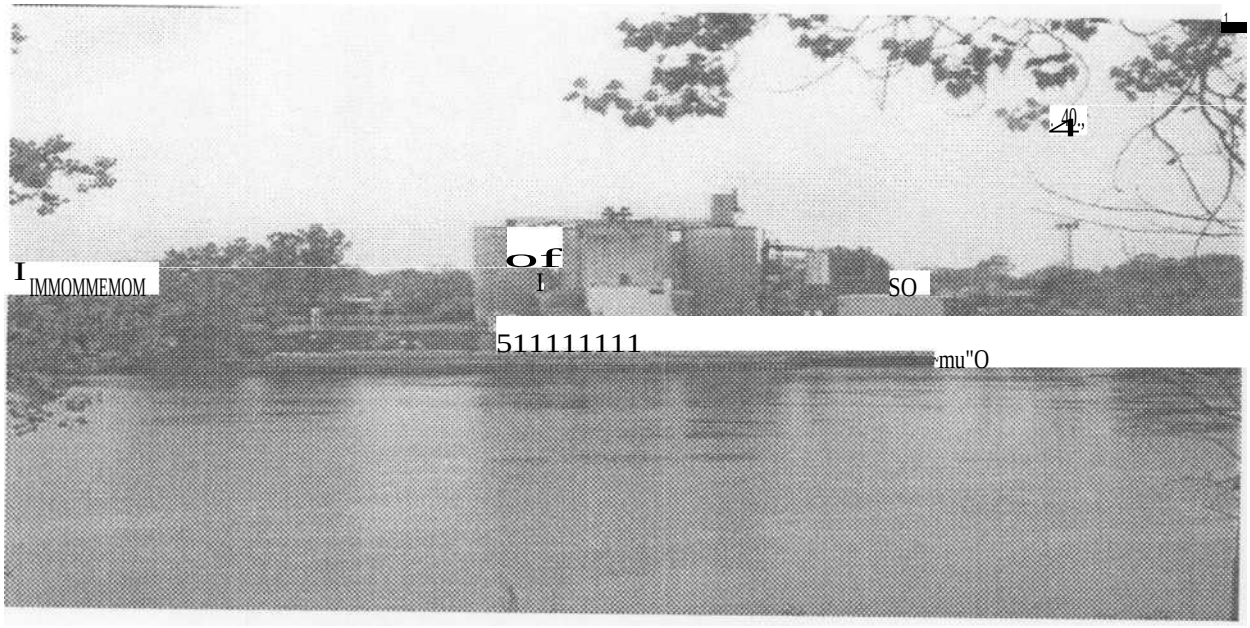
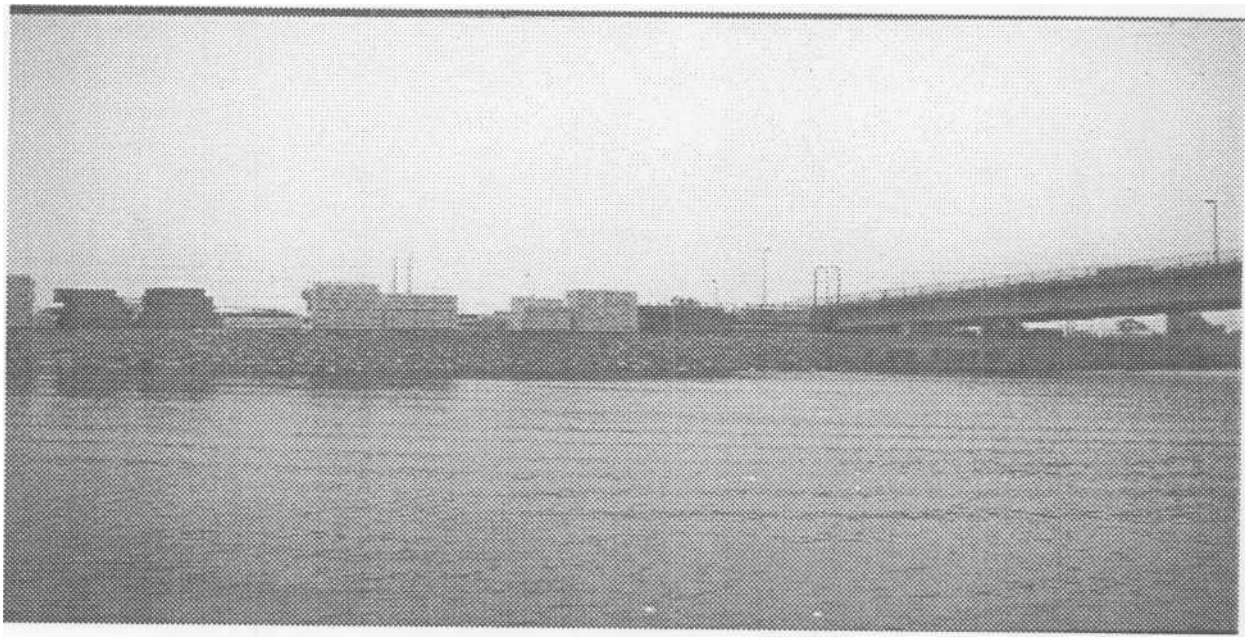
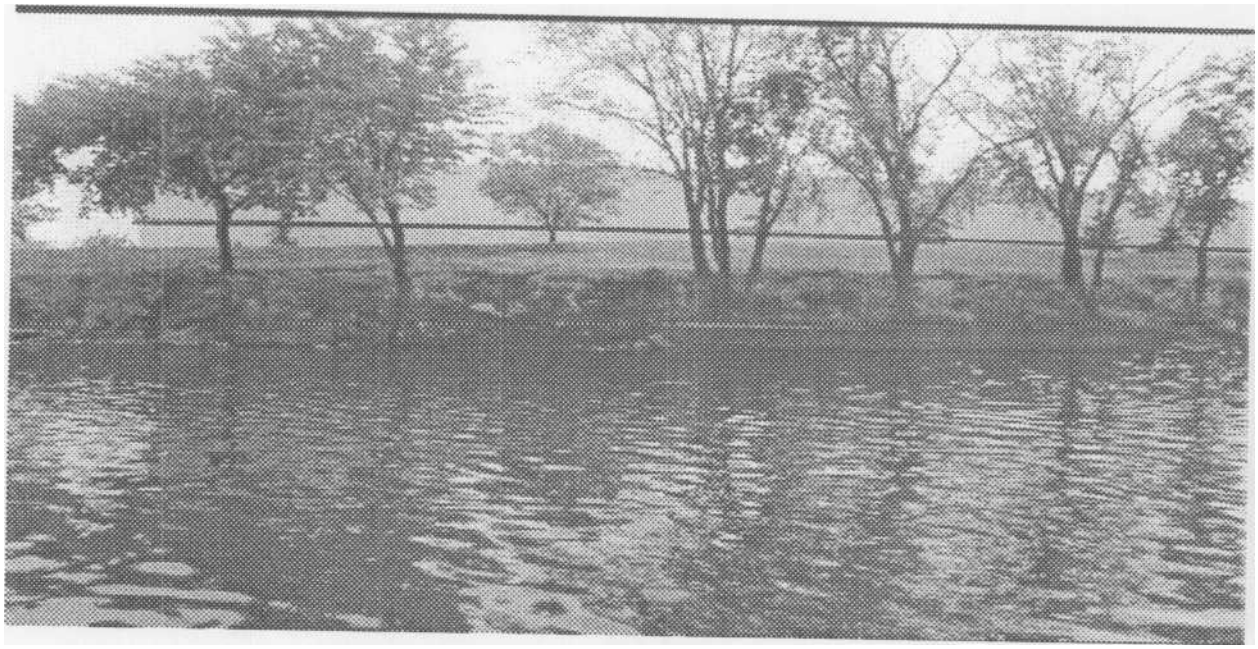


Photograph I Sheet pile forming the edge of the river

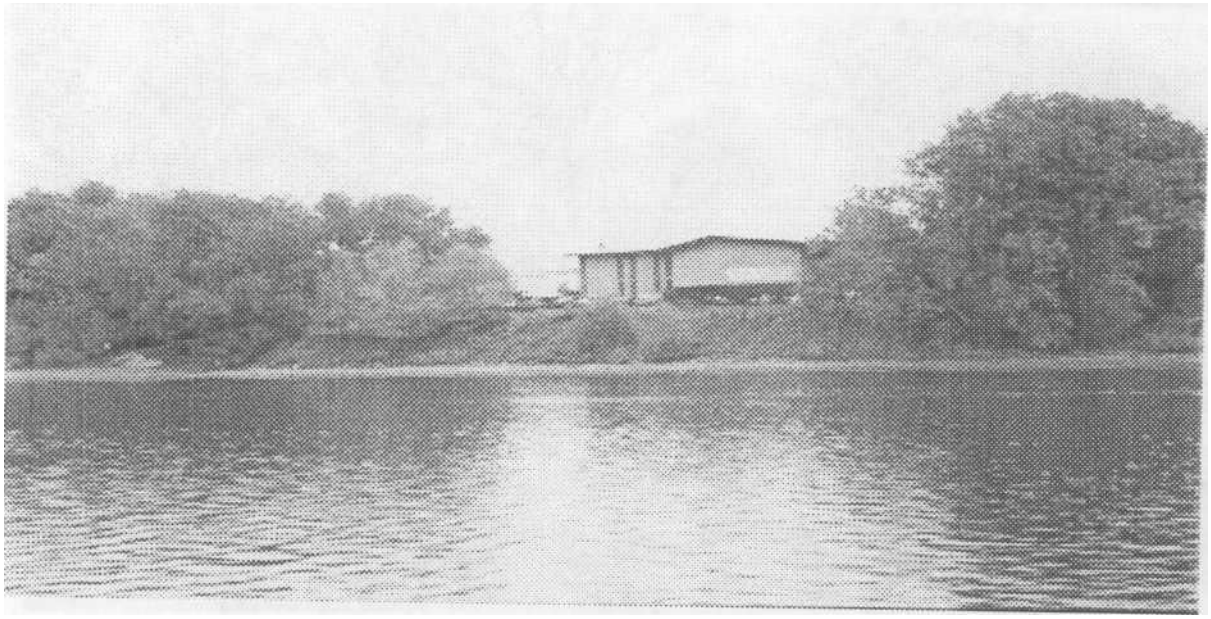


Photograph 2 Riprap rock bank

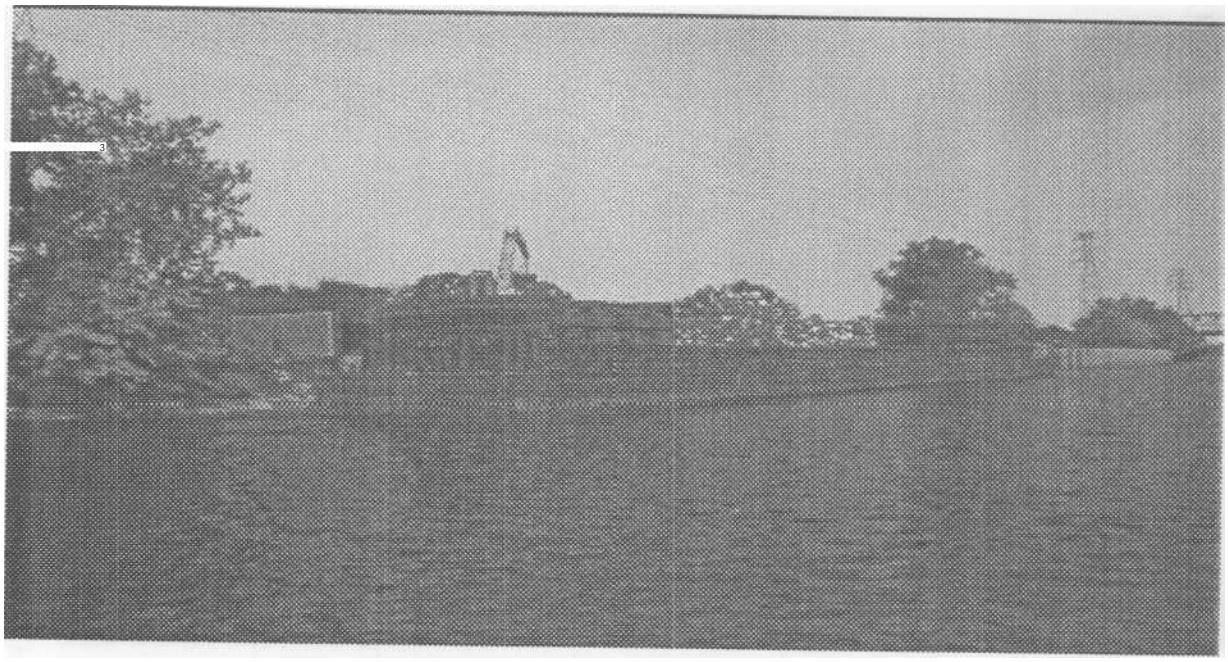


Photograph 3 Low concrete wall with rubble

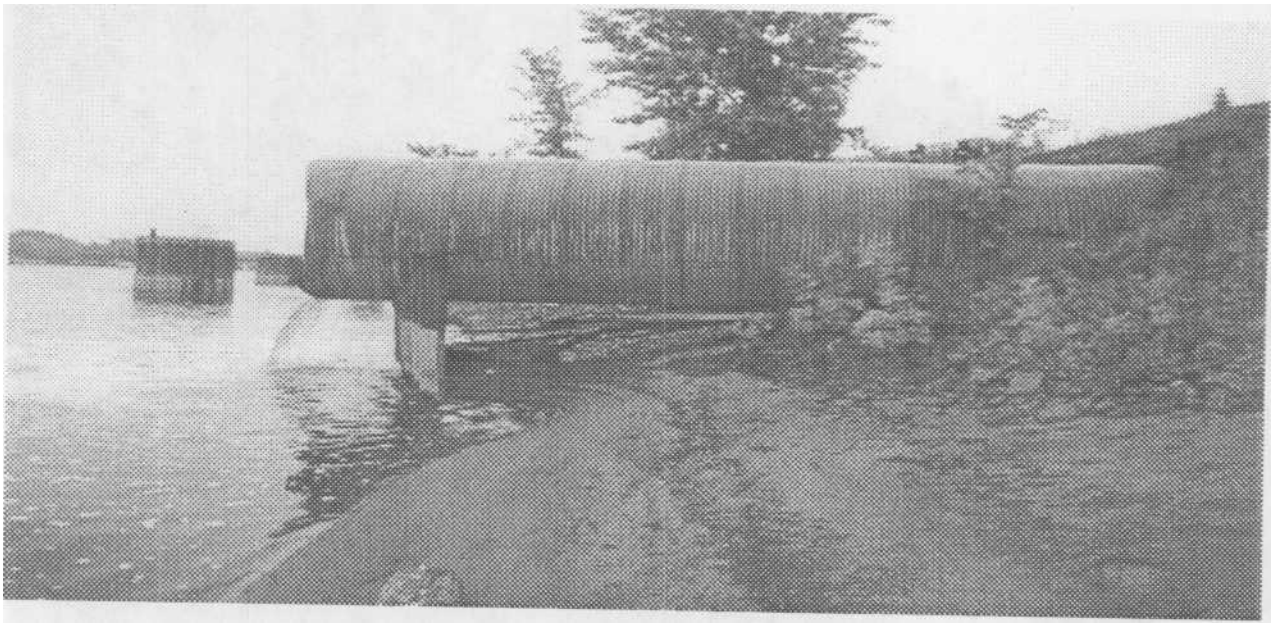
Photograph 4 Concrete wall treatment along river edge



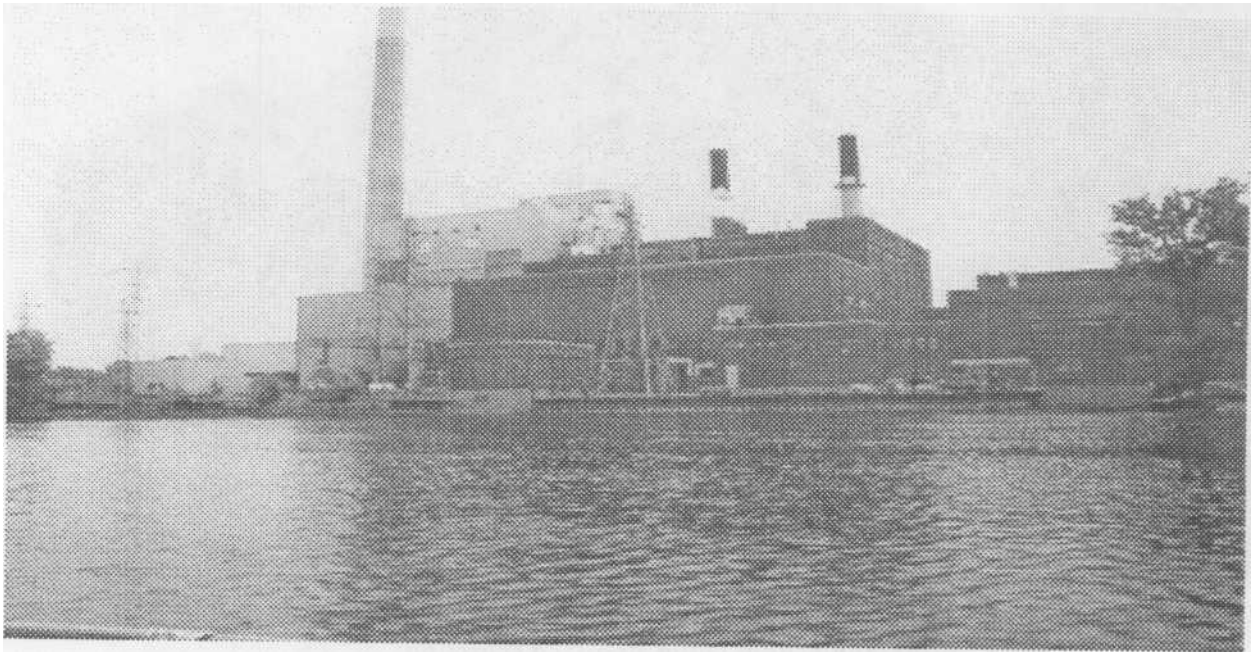
Photograph 5 Facility on top of slope and cleared banks



Photograph 6 Hard treatment and barge storage area

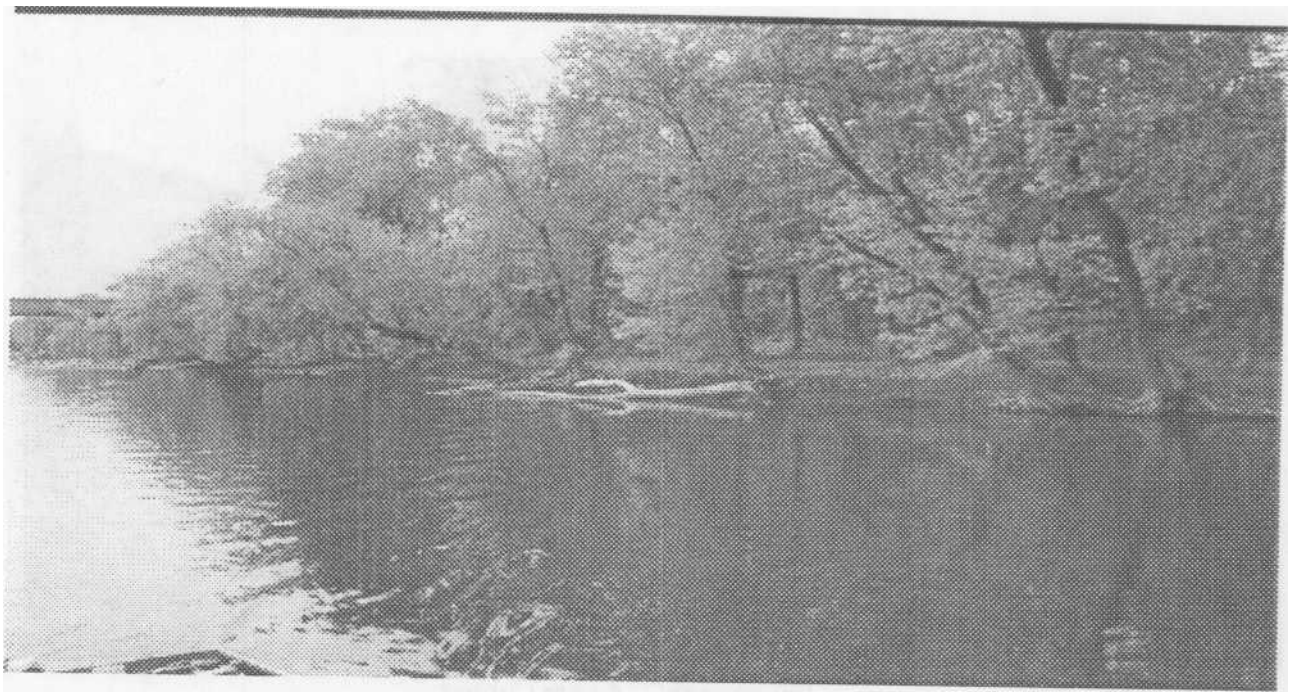


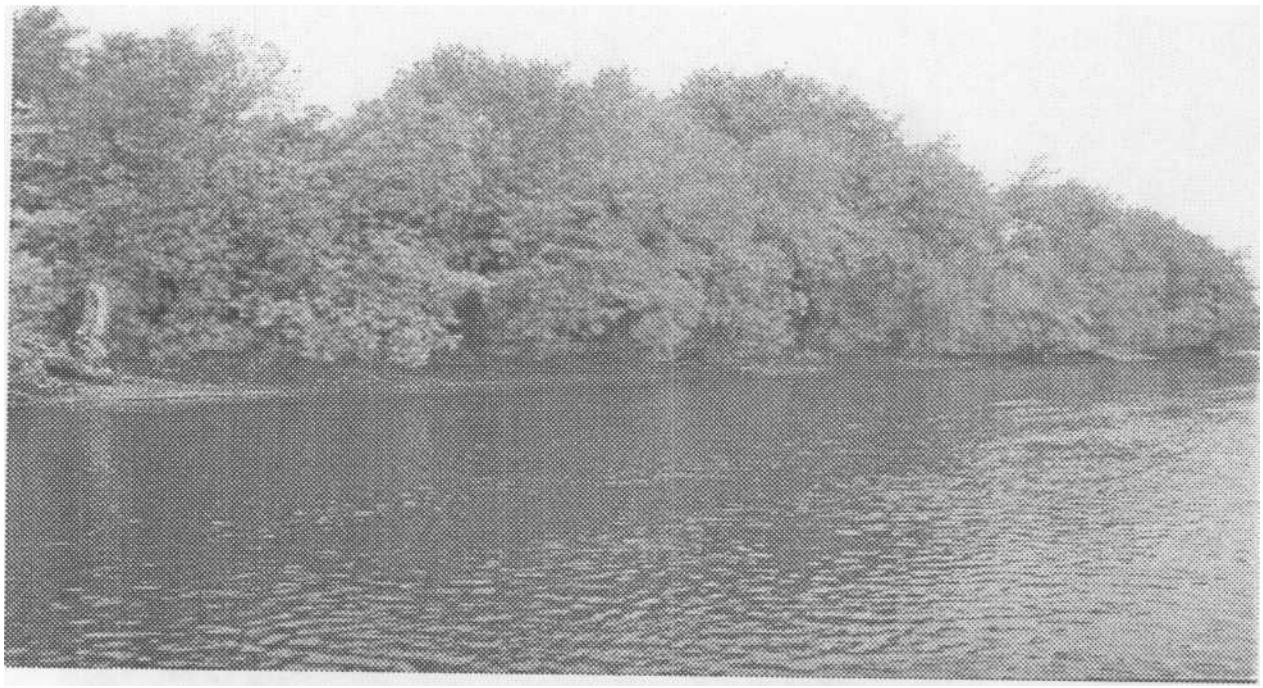
Photograph 7 Large Culvert



Photograph 8 Industrial use up to river edge, sheet pile bank protection

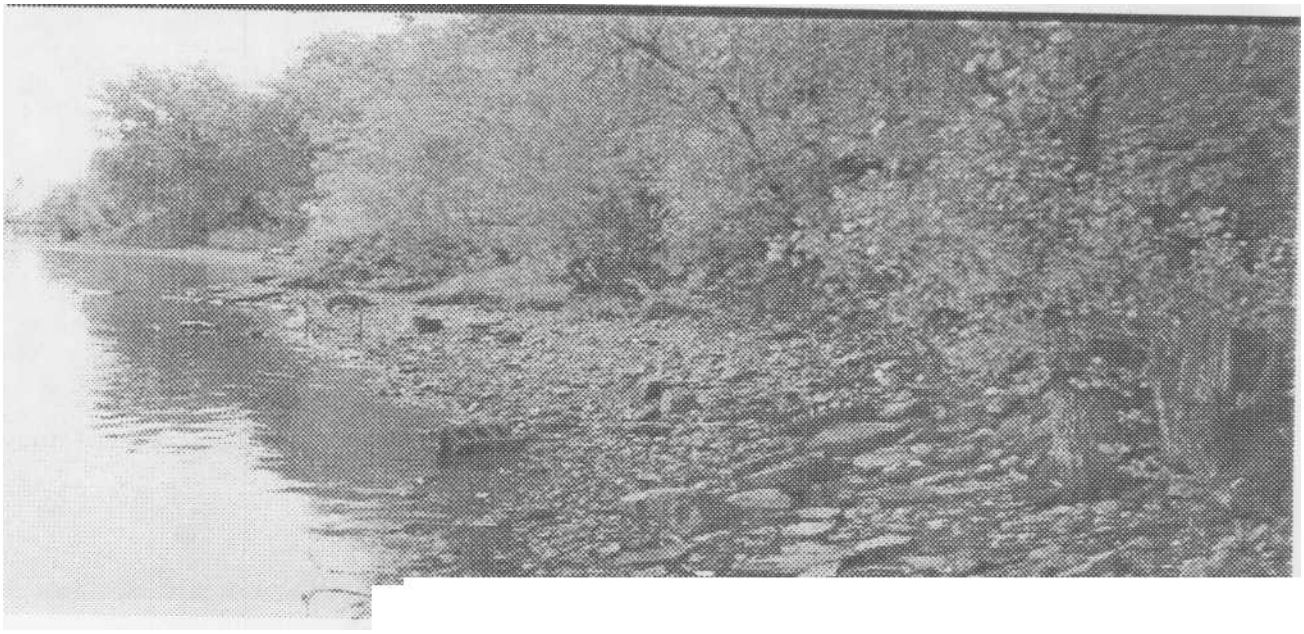
FLAT' SLOPE



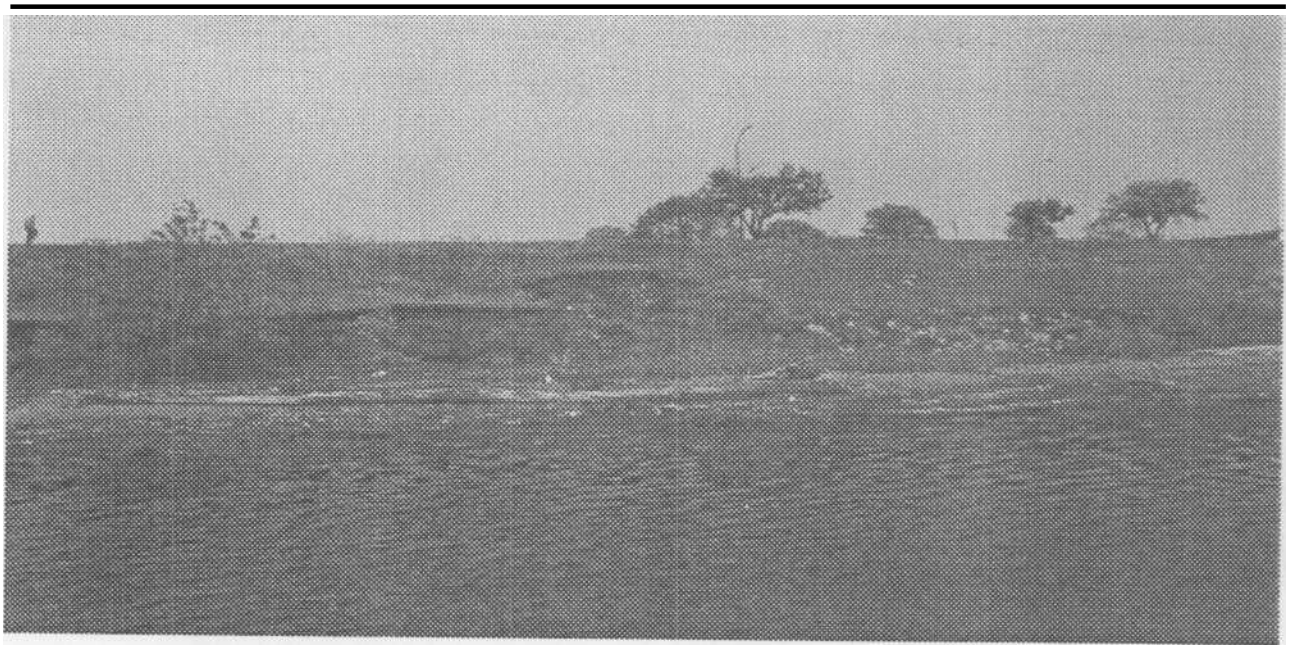


Photographs 10 and 11 Well vegetated low banks with excellent overhanging trees providing habitat value along the shoreline

MODERATE SLOPE



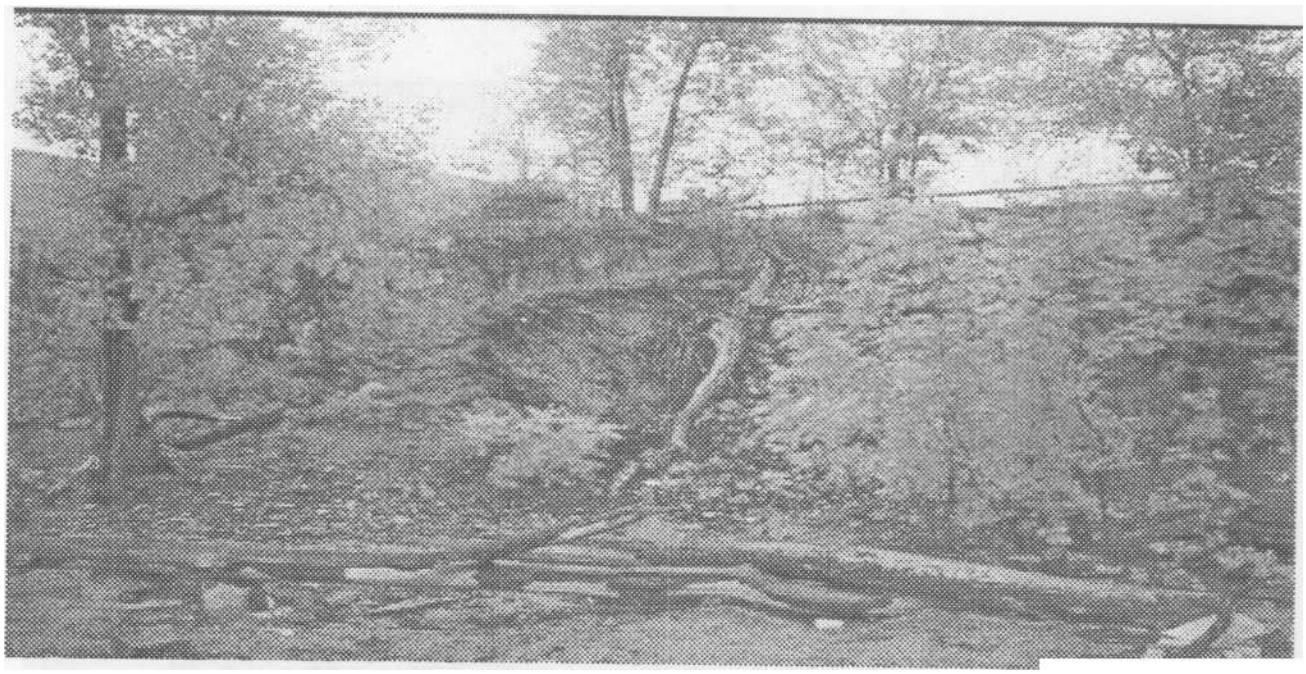
Photograph 11 Construction debris along the shoreline with vegetation above



Photograph 12 Large shallow failures on bank with very little vegetation

STEEP SLOPE

Photograph 13 Steep well vegetated bank



Photograph 14 Surface sloughs, gully and sparse vegetation on a steep bank

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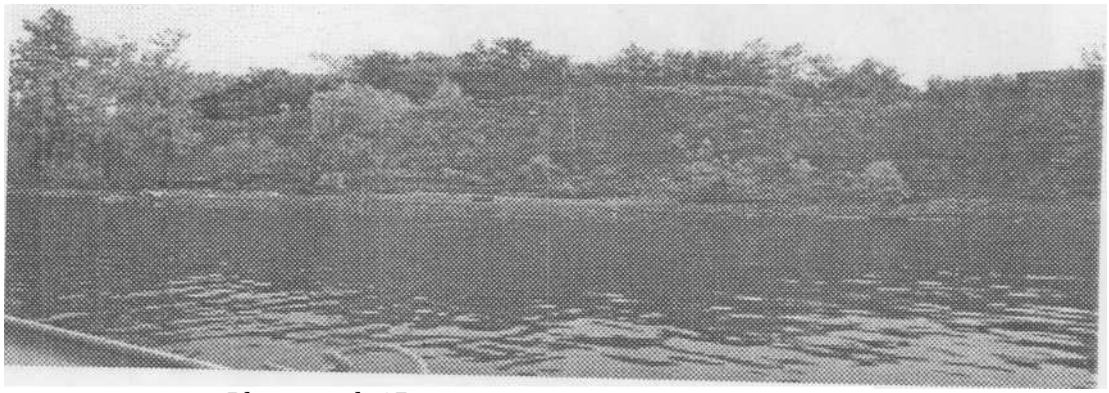
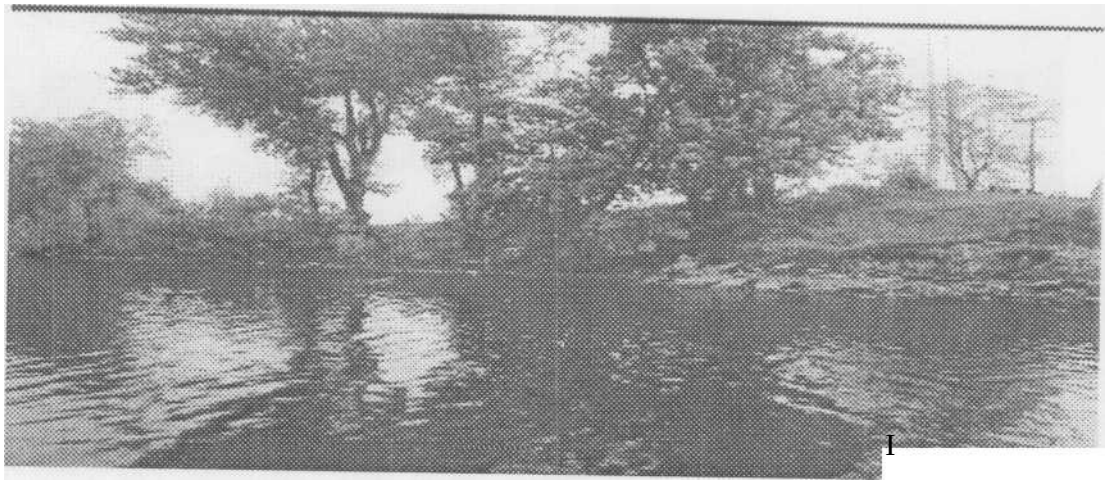
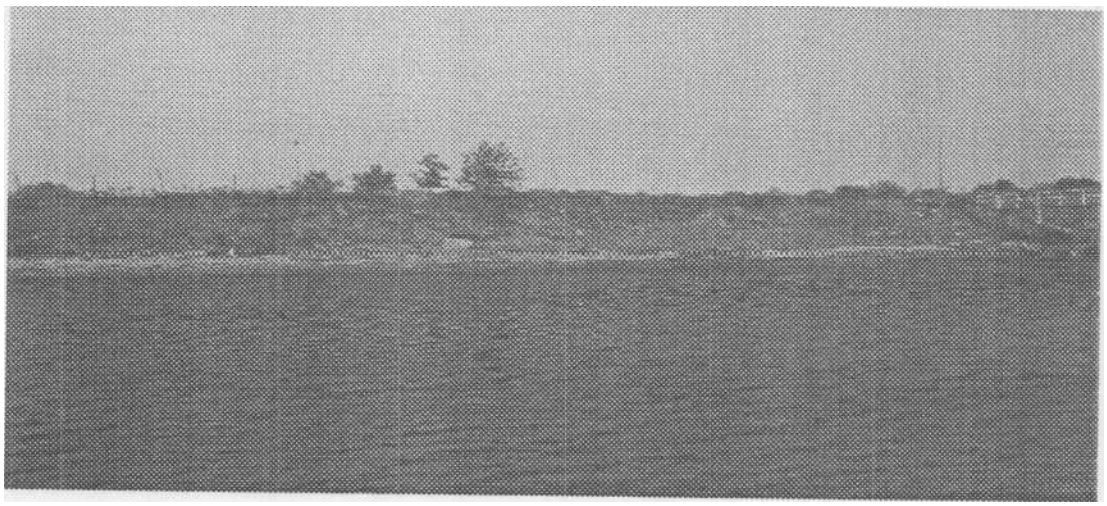


Photograph 15 Very high, sloughing steep slopes

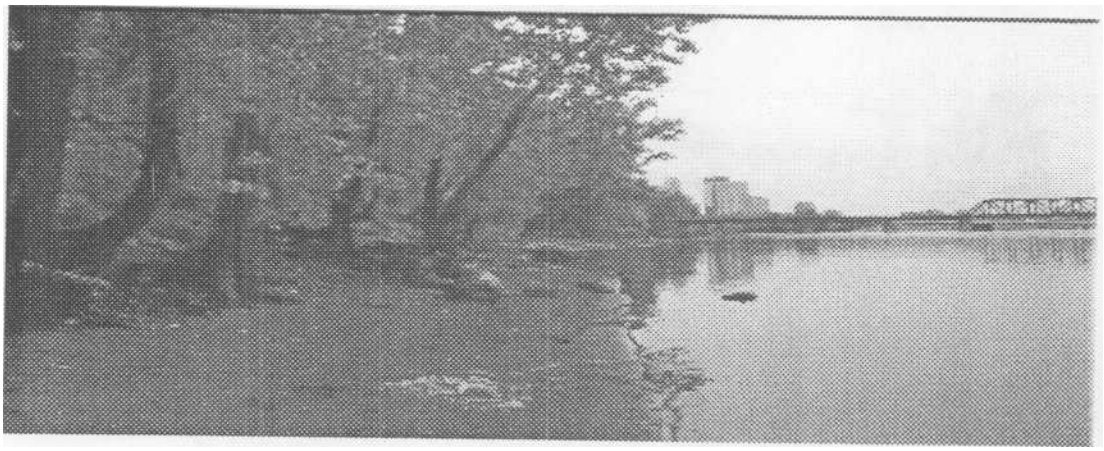


Photograph 16 Toe erosion in old construction fill bank

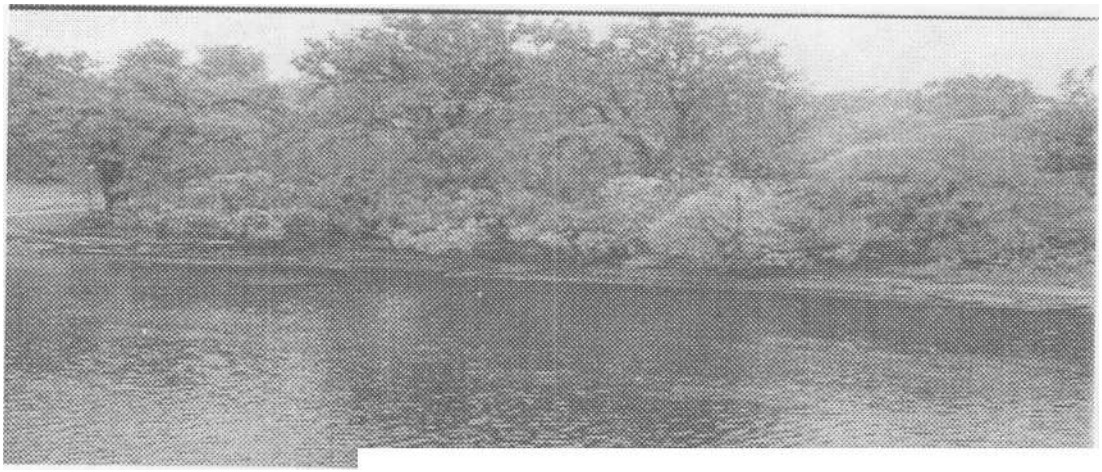


Photograph 17 Eroding open slope face

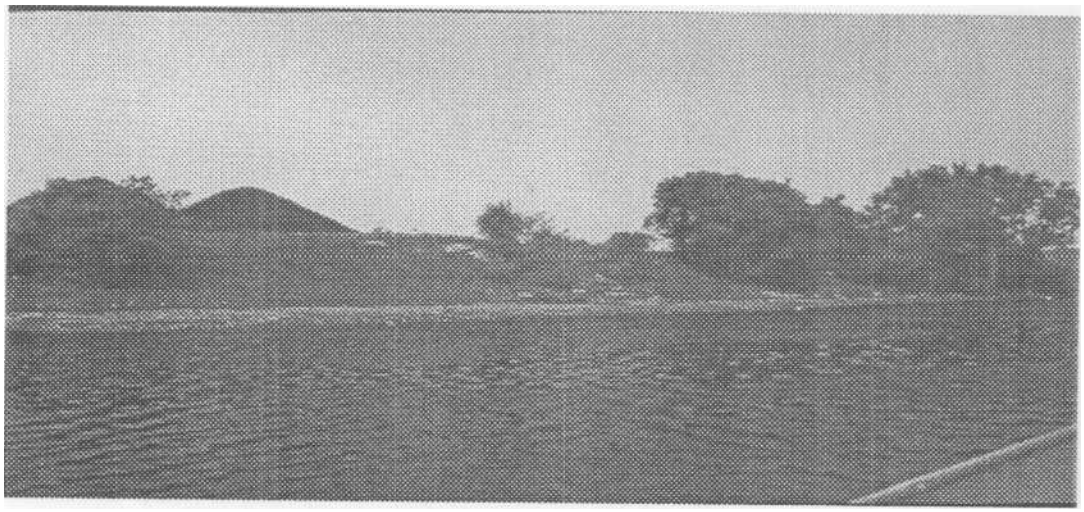
VEGETATED CONDITIONS



Photograph 18 Old growth poplars appear to be dying



Photograph 19 Well vegetated riparian zone



Photograph 20 Sparsely vegetated shoreline slope