Shoreline Erosion Control Plan

Lake Thunderbird, Cleveland County, Oklahoma

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Lake Thunderbird Shoreline Erosion Control Using Bioengineering Methods

by

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INTRODUCTION

Background

Lake Thunderbird, Oklahoma, a Bureau of Reclamation reservoir, is experiencing considerable shoreline erosion with cut banks in some areas exceeding 20 feet in height. This erosion negatively impacts numerous resources including public use areas with picnic sites and camping areas being eroded in some cases; water quality from the soils eroding into the lake; fisheries and wildlife habitat being diminished from both turbidity and a lack of suitable vegetative cover. The Oklahoma Tourism and Recreation Department requested the Oklahoma Water Resources Board (OWRB) to address the erosion problem using vegetative erosion control where possible.

Purpose

The purpose of this report is to relate results of a field survey by boat of the lake, give examples of various categories of erosion that occur on the lake, and then illustrate some possible treatments of erosion using bioengineering methods that incorporate both herbaceous and woody plant materials. Cost estimates for those treatments will also be given.

Scope

Bioengineering is basically the use of vegetation either alone or in combination with engineered structures and materials to achieve erosion control of soil on slopes, shorelines, and streambanks. When vegetation is used alone, it is used in such a way that its physical attributes along with its biological attributes of stems and roots increase the shear and tensile strengths of soils. Bioengineering often incorporates hard structures into the design such as wave deflection structures or rock toes to achieve its purposes. This report will give examples of shore reaches on Lake Thunderbird where vegetation alone can be used as well as combinations of vegetation and other engineered structures and materials. Obviously, for the time allotted for the survey, every foot of shoreline cannot be addressed, but typical eroded reaches can be.

APPROACH

The approach used was a three-pronged one that included 1) an examination of literature and data sources; 2) coordination with Oklahoma Tourism and Recreation Department (OTRD) personnel; and 3) a field survey by boat to examine the lake's shoreline. Examination of literature and data sources included looking at the Cleveland County Soil Survey (USDA Natural Resources Conservation Service, 1987), climatic (NOAA, 2001) and hydrologic data (USCOE, 2001). The field reconnaissance was conducted by both land and boat on September 17 - 19. Coordination was made with OTRD personnel on September 17th and land reconnaissance of some park sites were made. On September 18 - 19, a boat survey was conducted of two major arms of the lake, Hog Creek and Little River.

FINDINGS

Soils along the shoreline, particularly where eroded escarpments occur, are variations of red sandy clay loams (USDA SCS 1987) that are underlain by red sandstone and shale. In severely eroded reaches, the topsoil has eroded away leaving only the subsoils or parent materials such as sandstone and shale exposed. In general, the soils along the shoreline are very noncohesive, nutrient deficient, and tend to be acidic (USDA SCS 1987). These characteristics together make these soils very erosive and difficult to revegetate without man's assistance.

Fetch, the distance across a body of water to produce a wind-driven wave, ranges from less than ½ mile to over 3 miles in some cases from primarily the north and west. According to NOAA climatological records, wind speed data around Oklahoma City can gust at least up to 51 miles per hour. Assuming that there are sustained wind speeds of 35 miles per hour for 5 minutes or more, waves could be produced that are between 1.5- and 2-ft high as a general rule (Fuller 1997).

The top of active conservation pool at Lake Thunderbird is 1039.0 feet msl and occasionally drops down 2-3 ft below that in the winter. In the spring, the pool level sometimes rises as much as 4 feet or so, up to 1043.66 or slightly higher. This rise in pool level can be held for a couple of weeks or longer. This has the combined effect of producing even longer fetches and thus bigger waves because the water can inundate peninsulas and islands that would otherwise normally block the wind at lower pool elevations and the prolonged flooding may kill vegetation intolerant to longer flooding durations. As a consequence of this higher flooding level, there are sites where escarpments appear shoreward of a terrace or bench and the escarpment may be at the site of a picnic table, such as that observed at South Sentinel Day Use Area.

Shoreline geometry and bathymetry play a big part in determining the degree of erosion at a particular shoreline site. Sites with straight shorelines or headlands that are exposed to long wind fetches from prevailing wind directions are particularly vulnerable to more frequent and higher waves. Conversely, sites within coves or that are behind peninsulas or islands that block the wind are more protected from waves. Thus, vegetation is often present and erosion is less severe or even minimal. Bathymetry, like geometry, also plays a big part in degree of wave action. The shallower the nearshore and the wider an underwater bench, for instance, the more drag or resistance to waves there will be. Waves will subsequently be smaller in these areas in contrast to those where the water deepens abruptly and there is less resistance or bottom roughness to influence the wave. There are places where the bathymetry is shallow because rocks have dropped from an eroded shoreline bluff or soil erosion has exposed a rock strata to form a natural rock barrier or breakwater that deflects waves

(Figure 1). This improves the chances for vegetation to colonize behind the rocks and together they minimize further erosion of the bluff.

Figure 1. Rocks forming natural wave breakwater with vegetation colonizing behind the rocks

Land use also influences the degree of erosion at a site. If the site is adjacent to a public use area where there are a lot of people going to and from the shoreline, vegetation is often mowed and/or trampled leaving very little, if any vegetation to control erosion. Subsequent paths from foot-traffic are created and then these channelize water flow creating rills and gullies from the above terrain. Examples of this type of impact was evident at several public use areas at Lake Thunderbird, such as at Clear Bay Point, Little Sandy, and South Sentinel and West Sentinel use areas.

The findings suggest that a combination of the above factors such as noncohesive soils, long fetches, and high winds produce significant wave heights. Exposed shorelines with abrupt and deep lake depths adjacent to them, and heavy human foot traffic and mowing at day use areas, all contribute to substantial shoreline erosion in certain reaches of the reservoir.

METHODOLOGY FOR USE OF BIOENGINEERING TREATMENTS

Constraints and Assumptions

The OWRB (Mr. Paul Koenig) and AllEnVironment (Mr. Hollis Allen) met with Ms. Nancy Denton of the OTRD on September 17th. As a result of that meeting, certain working constraints and assumptions became known and made respectively. The constraints are primarily related to funding that in turn relate to types of equipment, material, and labor that can be used to implement any bioengineering treatment on the shoreline. Mainly, because of a shift in state funding priorities and more emphasis being placed on security issues, funding for shoreline erosion control may be reduced or slipped. Thus, any treatment should be relatively low cost and should be able to be installed by either volunteer labor and/or prison labor.

Volunteer and/or prison labor would use hand tools to install treatments, but it is assumed that at a minimum, some machinery with operators such as a backhoe with a bucket on the front and various attachments, e.g., auger, could be made available. Also, at least a dump truck and a flatbed truck could be acquired for hauling such things as rock, poles, plant materials, and geotextile materials.

Prioritization for Erosion Control

Erosion, whether its on a stream or lake, is a natural process. Its relative speed, however, can often be slowed or accelerated by human actions. We can effect erosion control plans for reservoirs that will influence selected reaches of shorelines in terms of slowing erosion in those areas. Such plans should be based on a prioritization process that has to be dependent on the objectives and values of the sponsor while taking into consideration the ecosystem functions of the reservoir or lake such as providing good water quality and fisheries and wildlife habitat. In this context, treatments that meet the objectives of the OTRD should focus primarily on public use areas. Public use areas, such as picnic areas and campgrounds, should receive high priority while non-public use areas receive lower priority even though they may be important from a water quality and habitat standpoint.

The above prioritization of public use areas and secondarily, other non-public use areas, should then be based on degree of erosion which is explained in general and then categorized below.

Categories of Treatments Based on Degree of Shoreline Erosion

Generally speaking, the higher the fetch, the higher the wave. Table 1 portrays a general relationship between fetch and wave height. The higher the wave height impacting a steep hill on the edge of the reservoir, the greater an escarpment will be. The more sand in the soils and the less the soil stratigraphy contains rock strata, the more erosion will be evident. Also, as mentioned earlier, if the reservoir reach of concern is on a point exposed to all wind directions with long fetches in any direction, it is going to have more erosion. Those sites in protected coves will have less or no erosion.

Categories of erosion are given below (from least eroded to most eroded) for Lake Thunderbird based on the boat survey. It should be noted that the categories were determined when the reservoir level was 1308.88 ft msl, close to conservation pool of 1309 ft msl.

Category 1: No noticeable erosion of bank; good swath of emergent aquatic vegetation at shoreline such as water willow (*Justicia americana)* or hardstem bulrush (*Scirpus acutus*) backed by wetland facultative species, such as other herbaceous plants and willow, buttonbush (*Cephalanthus occidentalis*), and others (Figure 2)

Average Sustained Over-Water Wind Speed (MPH)

Fetch (Miles)	10	20	35	50
1.0	0.30	0.60	1.05	1.50
2.0	0.40	0.85	1.45	2.15
5.0	0.70	1.35	2.35	3.30
10.0	0.90	1.90	3.30	4.75
15.0	1.20	2.35	4.10	5.80
20.0	1.35	2.70	4.70	6.75

Table 1: Simplified chart to estimate significant wave heights for different conditions of wind speed and fetch.

Figure 2. Category 1 of erosion; no treatment necessary; photo taken on north end of Hog Creek arm of lake

Category 2: some erosion noticeable; ≤ 1-2′ escarpment with a shallow area or bench lakeward of escarpment and covered in part with emergent aquatic plants such as water willow and/or some other wetland facultative plants like grasses and buttonbush and willow (Figures 3-4).

Figure 3. Category 2 of erosion; some erosion noticeable; photo taken on Hog Creek arm of lake

Figure 4. Category 2 erosion; ≤ 1-2' escarpment with bench; photo taken at Hog Creek Camp

Category 3: eroded 2-4’escarpment present; some toe or bench lakeward of escarpment evident, but containing no plants (Figure 5)

Figure 5. Category 3 eroded shoreline; photo taken at Little Sandy Campground on Hog Creek arm of lake

Category 4: eroded $\geq$ 4'escarpment present; some toe or bench lakeward of escarpment evident; substantial number of rocks and/or logs and dead trees on bench mixed with plants (Figure 6)

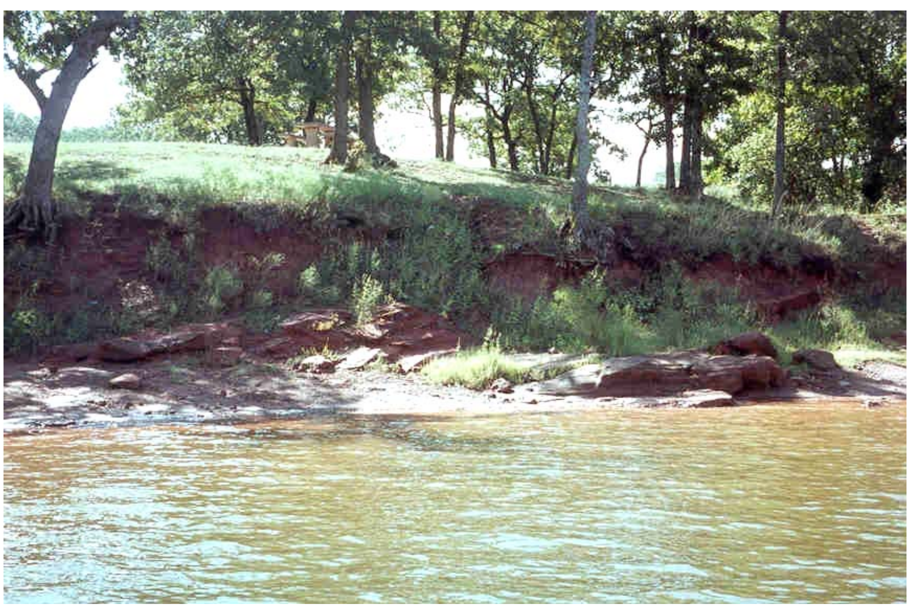


Figure 6. Category 4 eroded shoreline; photo taken on eastern end and south shore of Little River arm of lake

Category 5: eroded ≥ 4-ft escarpment present; not much, if any, toe or bench noticeable lakeward of escarpment; no vegetation noticeable in water (Figures 7 and 8)

Figure 7. Category 5 erosion; about a 4-ft escarpment without a toe or bench at Clear Bay Cafe area.

Figure 8. Category 5 erosion; > 4-ft escarpment without toe or bench; exposed to > 4-mile northern fetch; 1st point west of dam

Treatment Types and Erosion Categories
To Which They Are Suitable

Use of vegetation alone. This treatment relies solely on using sprigs of emergent aquatic plants, such as water willow, bulrush, spike-rushes, or other grass-like plants, and unrooted cuttings or poles of dormant woody plants, such as willow, that sprout roots and stems from the parent stem (adventitious). Willow or some other similar type of adventitious plant can be placed in the ground and oriented in such a way as to provide physical benefits of increasing soil strengths and/or intercepting runoff. We normally like to use combinations of both emergent aquatic plants and wetland facultative woody plants, such as willow, in zones. Emergent aquatic plants would be placed in a zone lakeward of the woody zone in water depths extending from conservation pool level to depths up to 1.5 ft normally. Woody plants would be planted from conservation pool level on up to an elevation that is affected by erosion, but has the appropriate hydrology for the species used. Other plants, such as grass mixtures, can also be used farther up the bank in park areas in combination with erosion control fabrics to control surface erosion. Treatments of using vegetation alone are appropriate for the Category 2 erosion type and when used in combinations with other treatments defined below, they are also useful for other categories of erosion.

Emergent aquatic plants, such as bulrush or spike rushes, can be planted as single stems by hand labor using a spade or shovel. If the bank and soil conditions will allow and access is no problem, a tractor with a tobacco planter can be used to mechanize and speed up the process (Figure 9). Woody cuttings, such as willow and buttonbush cuttings, can also be pounded in by hand using a dead-blow hammer (a hammer with shot in it so it does not damage the end of the cutting).

Figure 9. Planting emergent aquatic plants using a tobacco planter and tractor

Dormant live poles of willow and cottonwood can be used along with the much shorter live cuttings. These can be several feet long and able to penetrate down into saturated soils and can also be used in between rocks or riprap. Figures 10 through 12 illustrate this technique. The treatment is installed using either a backhoe with a stinger device mounted on the hoe or the use of a jet pump and hose that can hydraulically insert the pole into the ground.

Figure 10. Cottonwood pole being inserted with aid of stinger

Figure 11. Cottonwood pole with metal cap being inserted with stinger

Figure 12. Completed installation of cottonwood pole with stinger

Woody plants such as willow can also be installed on near-vertical slopes shoreward of the emergent aquatic plants and the dormant willow cuttings/poles. They can be used in a treatment called brush layering, which is a series of trenches with live cuttings inserted into the trench perpendicular to the face of the slope as illustrated in the drawing below (Figure 13). The floor of the trench is angled down about 10 to 20°. The cuttings are criss-crossed in the trench and hang over the lip of the trench, but not to exceed about 12 inches. Figure 14 illustrates placing the branches in a trench at Lake Wister Oklahoma.

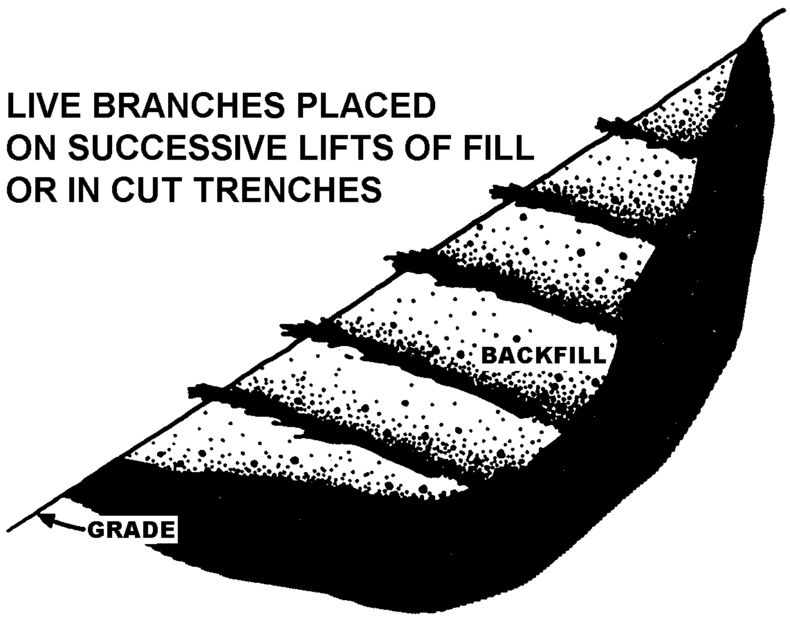


Figure 13. Brush layering

Figure 14. Brush layering; installation of willow cuttings

Vegetative Anchoring Systems. The next type of treatment focuses on using vegetation in combination with some materials such as geotextile fabrics or mats and stakes and wire to anchor plants into the ground. This anchoring is designed to hold the plant in place long enough for it to become more secure with its own roots and stems. Consistent with our zoned method of placing emergent aquatic plants lakeward of woody plants, we will show methods incorporating those plants first and then the woody methods. Vegetative anchoring systems are useful for Categories 2, 3, and in some cases, Category 4 erosion defined above. They can also be used in combination with breakwater systems described below for Category 5 erosion.

Plant roll. This method places clumps of emergent aquatic plants on about 1-1/2 ft centers inside a 10-ft long burlap strip with soil that encompasses the plants. The burlap is secured around each plant clump using hog-ring wires after the burlap is folded, much in the same way as an envelope (Figure 15). Then, the roll is buried in the substrate either with shovels or by a hydraulic jet-pump. The plant roll can be placed in a long line parallel to the shoreline with single plants installed behind it as shown in Figures 16 and 17.

Figure 15. Plant rolls ready for installation

Figure 16. Plant roll installed in line with single plants installed shoreward

Figure 17. Same plant rolls as in Figure to left after 2 years

Erosion Control Mat. Emergent aquatic plants dampen wave energy and bind the sediment. Erosion control mats aid in anchoring the plant and binding the surrounding sediment. The mats act as an instant root mat, providing the sediment with a fibrous, erosion-resistant surface and a medium in which plant roots can interlock with fibers in the mat. A type of mat found to be effective is a biodegradable fabric mat that consists of 0.1 kg/sq m of natural fibers (coconut and horse-hair, Figure 18). The mat is laid like a carpet on the shore, and single-

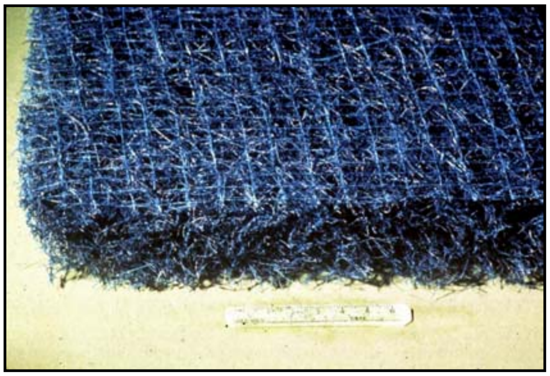


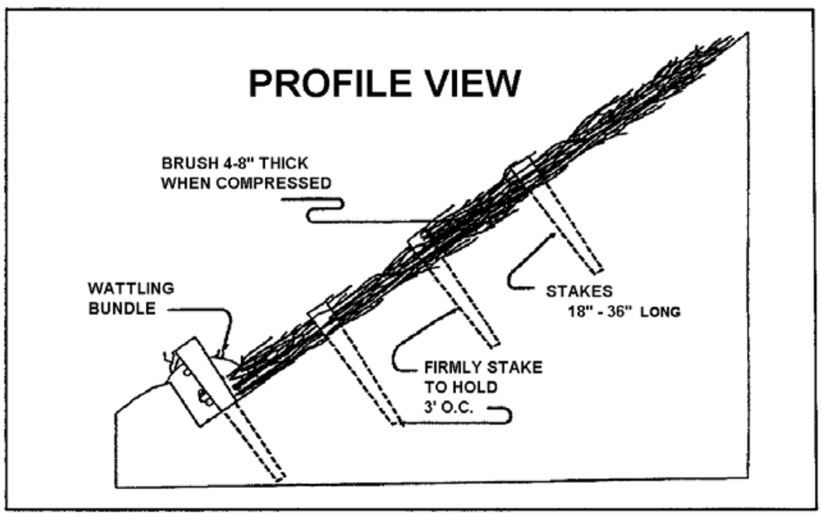
Figure 18. Erosion control mat material made of coconut and horse-hair fiber

stemmed transplants are inserted into slits cut through the material. The edges of the mat are buried in the sediment **(**Figures 19 and 20**)** between two boards (2" X 8") or just simply keyed into a trench and staked. Although not shown in Figure 19, stakes can be inserted and wire strung from stake to stake and then all stakes are hammered until the cross-wires are firmly against the mat. Plants shown in Figure 20 were exposed to wind fetches in Galveston Bay exceeding 12 miles although they were on a fairly flat and extensive beach which allowed drag effects of the beach to dampen waves.

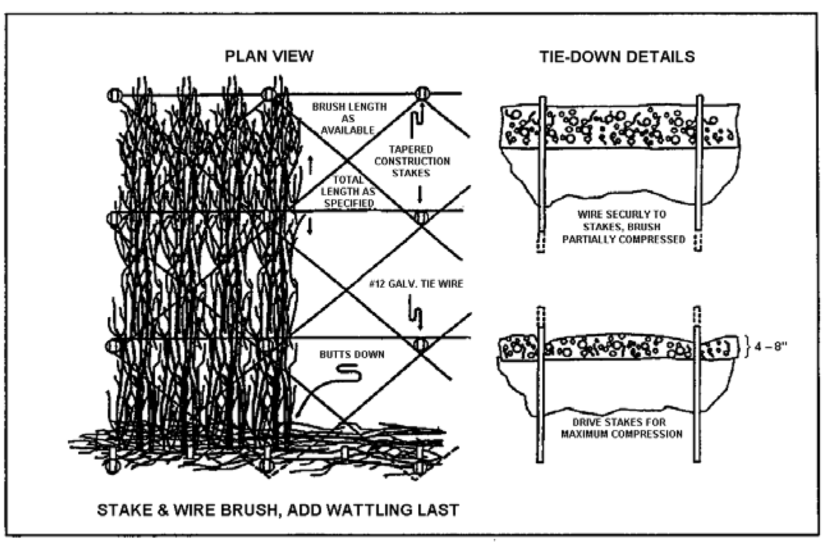
Figure 19. Erosion control mat immediately after installation

Figure 20. Same erosion control mat to left after 3 years

Brush Matting or Brush Mattress. Brush matting or brush mattresses, as they are also called, can be placed shoreward of emergent aquatic plants or used by themselves. They consist of a thick layer (mattress) of interlaced live switches or branches and often will have wattling incorporated. Wattling is a cigar-shaped bundle of live switches or branches. The live switches or branches come from any adventitiously sprouting (sprouts roots from stems) woody plant, such as willow and some species of dogwood and alder. Both are held in place by wire and stakes. A brush mattress, with wattling or rock at its toe, is used along the face of an eroding bank and acts principally to armor the bank (Figure 21). The brush mattress has the potential to immediately dampen waves along the bank and accumulate sediment. Together with the sprouting plants, the brush mattress develops a strong network of interlocking roots and plant stems.



a. Profile view



b. Plan view

Figure 21. Drawings of brush matting and wattling detail

Wattling or fascines. Wattling or fascines are bundles of sprouting willow or other woody species that sprout adventitiously. They are usually 8-10 inches in diameter in the center and can be various lengths. They are buried along slope contours in trenches upto about ¾ of their diameter and then backfilled with soil. When used successively up and down slopes, they break up slope lengths and create small check dams that slow overland flow velocities. They are often used landward and upward on slopes from such treatments as brush mattresses. Often, they have erosion control fabric, such as that made from coconut husks called coir, placed in the trenches below the wattling or fascines and in between the successive fascines on contours (Figure 22). Figure 23 shows an example of a fascine installation on

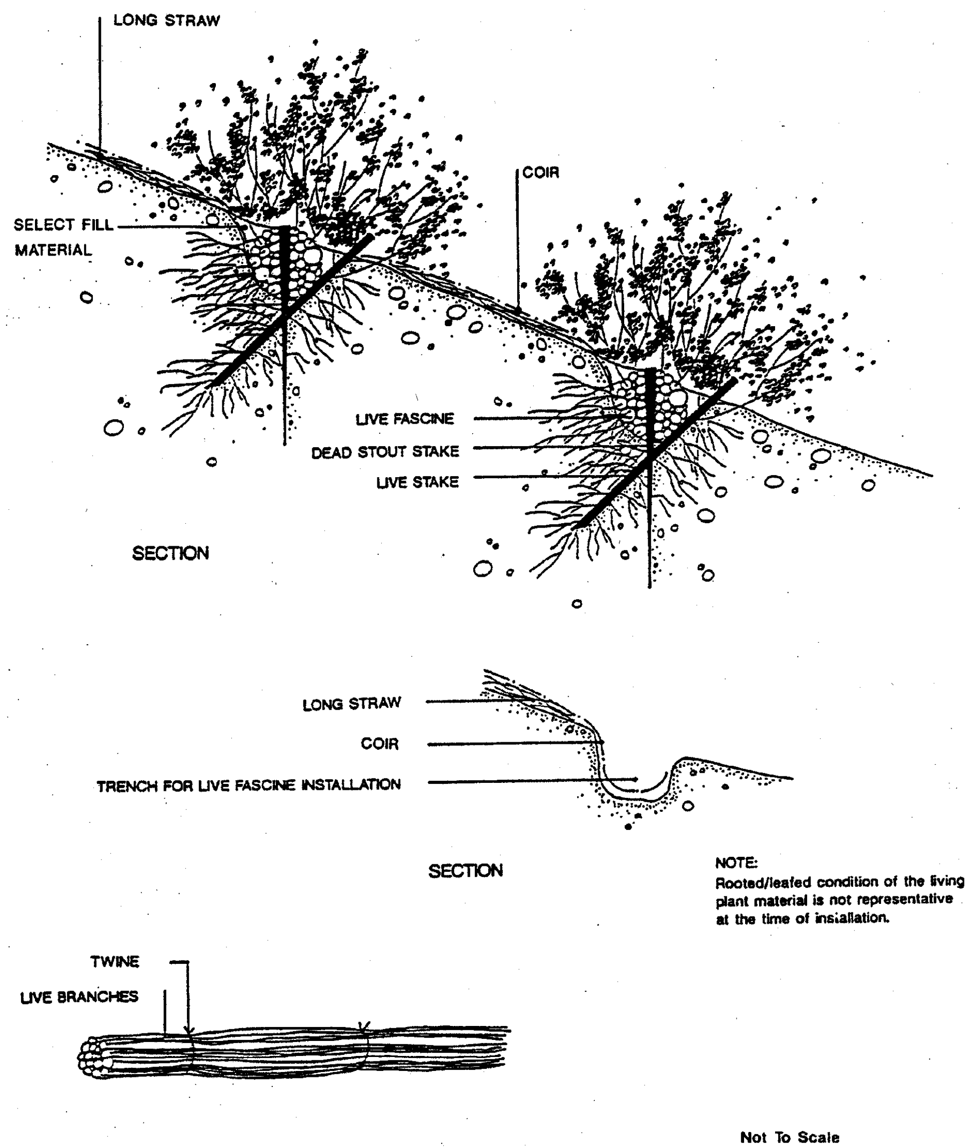


Figure 22. Drawing of fascines with erosion control fabric (coir) in between

a very sandy slope next to the Atlantic Intracoastal Waterway in South Carolina. Such an installation could be used in some of the OTRD parks landward of the lake shoreline itself where overland wash is creating rills and gullies.

Figure 23. Series of fascines installed on very sandy soil to prevent rills and gullies from overland wash

Treatments to Abut to Escarpments. Some reaches of shoreline have 2- to 4-ft high escarpments shoreward of a sandy bench or beach where wave run-up during high water events have scoured the toe creating vertical or near-vertical banks. This is categorized as Category 3 erosion and there are a couple of treatments defined below that may assist in restoring these banks with vegetative cover.

Coir Geotextile Rolls (CGRs). CGRs are biodegradable sausage-shaped rolls that are made from coconut-husk fiber (coir) that is encapsulated by a rope mesh made of coir or polyethylene. CGRs can be planted with either emergent aquatic plants or woody plants such as willow or dogwood. If the former are used, the rolls need to at least have their bottoms in contact with water (Figure 24). If the latter are used, cuttings can be planted either in the roll, between the roll, or in backfill placed behind the roll (Figure 25). In time, the CGRs will biodegrade but they will leave a mass of intertwined roots and stems of plants that will hold the bank. Figures 26 - 28 illustrate how a reservoir escarpment with an undercut tree on a Wisconsin reservoir shoreline was restored by using CGRs, backfill, and dormant willow cuttings.

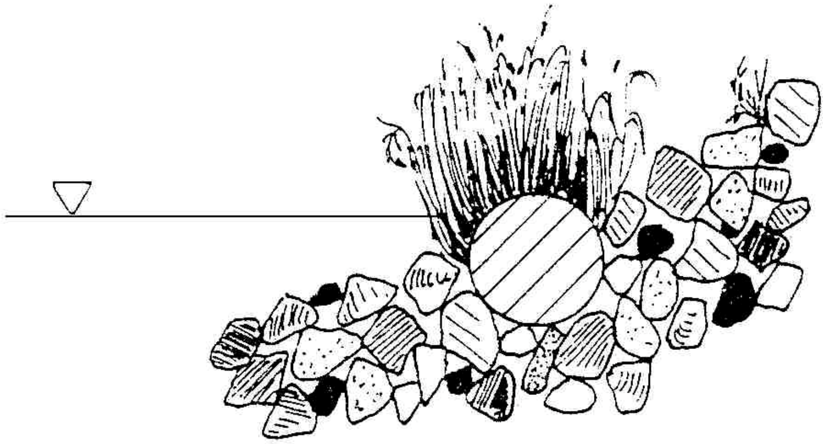


Figure 24. Profile view of CGR with emergent aquatic plants in it. Note that triangle points to surface of water. Rocks may or may not be used depending on energy conditions

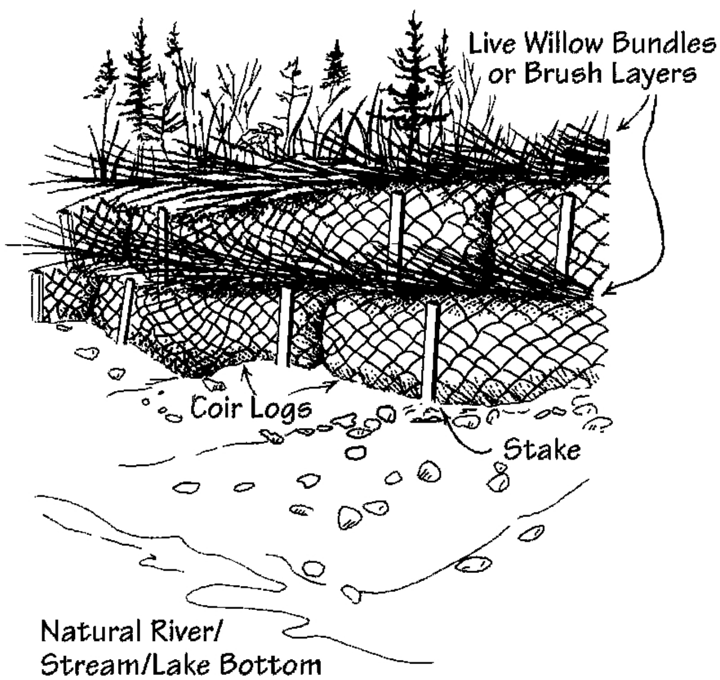


Figure 25. CGR Drawing with Willow cuttings inserted between and in backfill above the rolls

Figure 26. Undercut tree and escarpment on Rice Reservoir, Wisconsin

Figure 27. CGRs used to restore bank in figure above.

Figure 28. Restored bank at same location as shown in figure above.

A-jacks® and willow cuttings. A-Jacks® are concrete structures that look like playing jacks and are installed in rows in combination with willow cuttings or similar woody species (Figure 29). Each A-Jacks® unit, when installed, has three 60-cm (24-in.) axes forming six 30-cm (12-in.) legs. The lowest rows of A-Jacks® are trenched in close to the base of the bank. Fibredam®, a synthetic geotextile, is placed between the rows and in the crevices to reduce soil movement and encourage root growth through the A-Jacks®. Live native willow and dogwood cuttings are hydraulically jetted into the structures. The A-Jacks® are then backfilled with a soil/rock mixture. Figure 30 shows a photograph just after installation at a Wisconsin reservoir and Figure 31 shows the same treated area almost 3 years after installation. As can be seen, the A-jacks® are almost masked by the willow and will be completely hidden as time progresses. The treatment is effective in reducing toe scour and undercutting and will allow the bank to become vegetated and heal. It is most effective where there is some bench on which to work right below the escarpment.

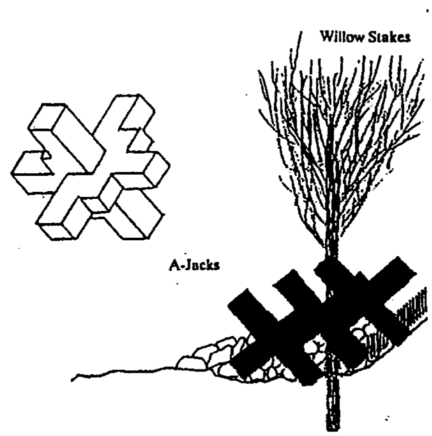


Figure 29. Schematic of A-jack and A-jacks with willow cutting

Figure 30. A-jacks immediately after installation

Figure 31. A-jacks and willow treatment during 3rd growing season

Vegetation with breakwater systems. When fetches in combination with wind produce waves greater than 1 foot in height, it is advisable to consider the use of some type of breakwater system, either floating or fixed and attached to the lake bottom. For Lake Thunderbird, breakwaters with vegetation shoreward of them should be used in most cases for Categories 4 and 5 erosion situations. Since water levels only exceed conservation pool by about 4 feet every few years, fixed breakwaters in contrast to floating breakwaters would suffice. The idea is to have breakwaters only in place long enough to obtain a sufficient vegetation community that will control erosion and heal the bank. The breakwaters mentioned below, for the most part, can be installed using hand labor and a backhoe with auger, hoe with shovel, and front-end bucket attachments. A hydraulic jet pump could be used in lieu of an auger if the soil conditions permit.

CGR breakwater with emergent aquatics. CGRs can also be used as a breakwater in addition to its use described above. They can be planted with sprigs of emergent aquatic plants, such as water willow, bulrushes, sedges, and rushes. Shoreward of the breakwater and in the area encompassed by it, emergent aquatics can be planted as single sprigs (Figure 32). Alternatively and as described earlier, the emergent aquatics can be planted in erosion control mats for even greater assurance of survival and development (Figures 33). Figure 33 shows plants in mats that were planted in the nursery and allowed to grow before the mats were transferred to the field site.

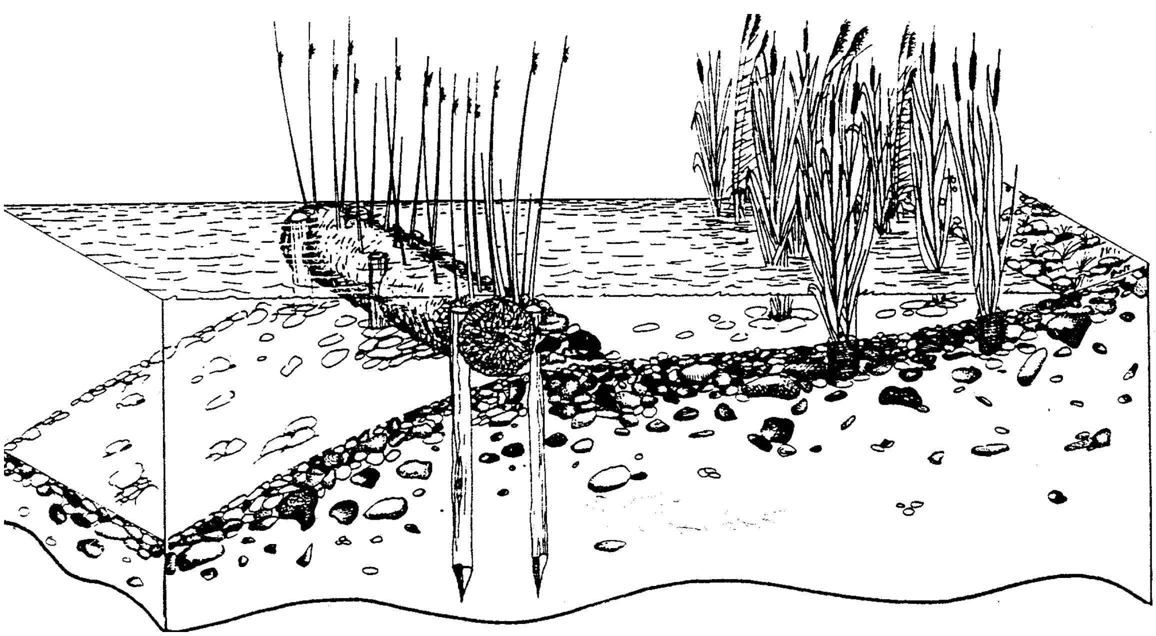


Figure 32. Drawing of CGR with single emergent aquatic plants installed shoreward of it

Figure 33. Reservoir in northern Germany with a CGR breakwater and emergent aquatic plants in erosion control mats

Branchbox breakwater. Another type of fixed breakwater is one that was developed in Europe and employed with marsh grasses shoreward of it to control erosion and develop fast land along the North Sea coast (Figure 34). A system of 100- by 100-m squares of branchbox breakwaters were used in conjunction with stone groins to protect a dike at the town of Heidi, Germany, along the North Sea coast (Figure 35).

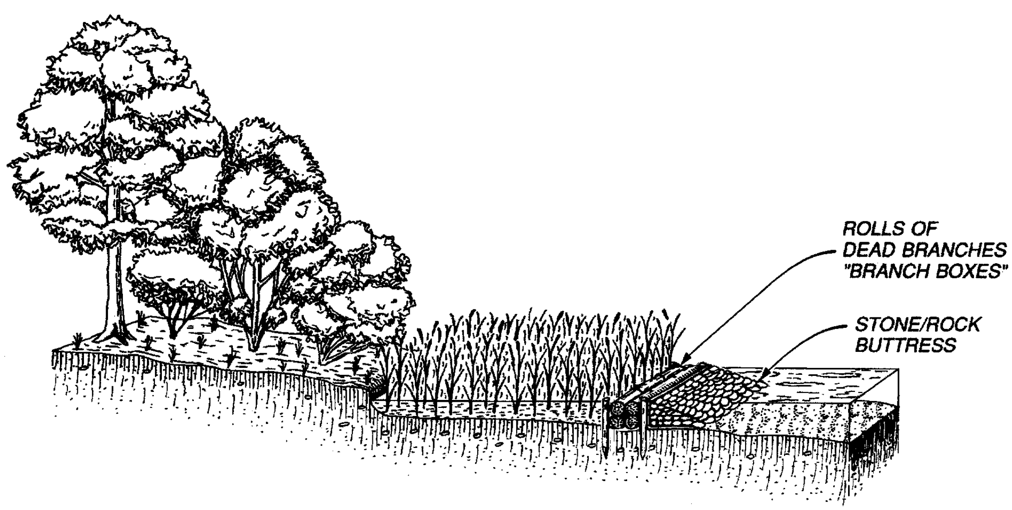


Figure 34. Schematic drawing of branchbox breakwater with emergent aquatics shoreward of it

Figure 35. Branchbox breakwaters with marsh grass employed on North Sea coast, Heidi, Germany

Lothar Bestmann, a German bioengineer, later employed similar types of breakwaters along the shoreline of Lake Havel, Berlin, Germany to control erosion (Figures 36 - 37) and clean up the water through the contaminant uptake of emergent aquatic plants. He used a series of these with gaps in them to allow access to the shore by boats and ingress and egress of aquatic organisms.

Figure 36. Branchbox breakwater at Lake Havel, Berlin, Germany.

Figure 37. Branchbox breakwater system at Lake Havel, Berlin, Germany

A branchbox breakwater with vegetation behind it has been used successfully at several different lakes by the author in the United States. One was used at Lake Wister, Oklahoma as part of a workshop and demonstration in April 2000. The breakwater was installed on a reach of shoreline that is exposed to greater than a 2-mile fetch from the southwest (Figure 38). The area shoreward of the breakwater was planted with both emergent aquatics, e.g., water willow, bulrush, sedges, and willow cuttings farther up on shore. The area was examined in September 2001 and was found to be functioning very well in terms of controlling erosion and providing habitat benefits (Figure 39).

Figure 38. Branchbox breakwater being installed at a workshop/demonstration, Lake Wister, Oklahoma, April 2000

Figure 39. Branchbox breakwater at Lake Wister as viewed from a boat on September 11, 2001

Log/tree breakwater. A log/tree breakwater with planted vegetation shoreward of it offers possibilities as a treatment, particularly if the shoreline has dead trees and logs in the water as Lake Thunderbird does. These can be oriented parallel to the shore and cabled together. Then, they are anchored to the bottom with other cables and soil anchors as shown in Figures 40 - 41. Such a breakwater was used at Lake Sharpe, South Dakota, to control shoreline erosion on a reach that had 2- to 4-ft escarpments as a result of wind-driven waves from a 2- to 3-mile westerly wind (Figure 42). Figure 43 shows personnel cabling the logs together that were floated over to the site. Emergent aquatic plants, such as bulrush and cattail were planted shoreward of the breakwater. Within a growing season, the area was covered with marsh vegetation. The breakwater withstood several years of ice action and the vegetation healed the bank (Figure 44).

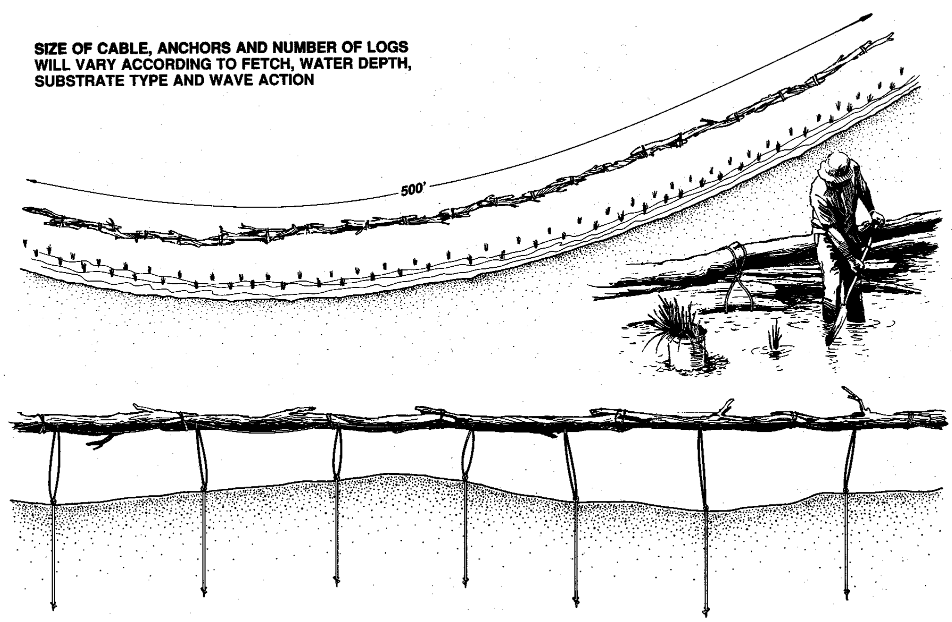


Figure 40. Plan and profile view of log breakwater used at Lake Sharpe, South Dakota

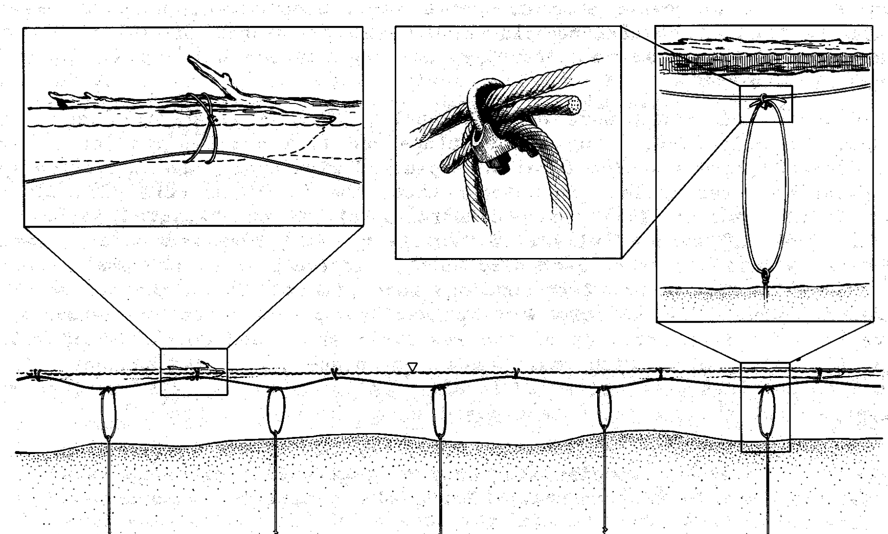


Figure 41. Cabling and clamping methods used for log breakwater at Lake Sharpe, South Dakota

Figure 42. Shoreline erosion control site at Lake Sharpe, South Dakota, 1988

Figure 43. Log breakwater installation, Lake Sharpe, South Dakota, Summer, 1989

Figure 44. Log breakwater site 6 years after construction (August 1995)

Costs of treatments. Costs of treatments (Tables 2 - 5) are estimates in terms of labor required and includes time to harvest plant materials, such as aquatic plants, unrooted willow cuttings, and poles. Some material costs are also given where possible. Dollar amounts will vary depending on local labor rates and material costs. Equipment costs are not included because of the wide cost variation, depending on a user's access to equipment or choice of equipment to do the job; however, most of the treatments can be done with hand labor and tools. In most cases, material costs assume that plants are collected or harvested from the wild and do not cost anything. Labor, however, includes collecting such plants.

Table 2. Costs of Utilized Shoreline Stabilization Treatments
Use of Vegetation Alone

Method of Stabilization	**Material Cost**	**Labor required**
Sprigging emergent aquatic plants (assumes $0.5m^2$ center spacing)	\$0.00 if harvested from wild; \$.25 - \$.50/plant if purchased from nursery	4.0 - $20m^2$/hr
Live cuttings (willow, etc) (spacing will vary- usually placed on 0.5 - 1.0 m centers)	\$0.00 if harvested from wild	45 - 50 cuttings/hr
Dormant live poles (willow, etc) (spacing will vary - usually placed on 1.0 - 3.0 m centers)	\$0.00 if harvested from wild	10 - 20 poles/hr
Brush layering	\$0.00 if harvested from wild	2 -5 m/hr

Table 3. Costs of Utilized Shoreline Stabilization Treatments
Vegetative Anchoring Systems

Method of Stabilization	Material Cost	Labor required (in manhours)
Plant roll	ca $3.00/m (assumes plant clumps harvested from wild)	6 m/hr
Erosion control mat with sprigs inserted into mat (not pre-grown)	$6.65/m^2 (assumes plants harvested from wild)	3 - 5 m^2/hr
Wattling or fascine with erosion control fabric	$.50/m for stakes, twine, and $3.00/m^2 for erosion control fabric	2 - 5 m/hr
Brush matting	$3.00 - $5.00/m^2 for construction materials (stakes, wire, etc.)	2 - 6 m^2/hr

Table 4. Costs of Utilized Shoreline Stabilization Treatments
Treatments to Abut to Escarpments

Method of Stabilization	Material Cost	Labor required (in manhours)
Coir Geotextile Roll (CGR)	ca $30.00 - $60.00 per meter depending on diameter of roll, i.e., 12", 16", 20"	1.5 m/hr
A-jacks®	$82.00/linear m (assumes plants harvested from wild)	2.5 - 3 m/hr

Table 5. Costs of Utilized Shoreline Stabilization Treatments Vegetation and Breakwater Systems		
Method of Stabilization	**Material Cost**	**Labor required (in manhours)**
Coir Geotextile Roll (CGR) Breakwater with emergent aquatic plants (sprigs) shoreward of breakwater on 0.5m^2 centers	ca $30.00 - $60.00 per meter depending on diameter of roll, i.e., 12", 16", 20"	1.5 m/hr of CGR 4.0 - 20 m^2/hr of sprigs
CGR Breakwater with sprigs on 0.5m^2 centers in erosion control mats installed shoreward of breakwater	CGR costs as above; add $6.65/m^2 for erosion control mats	1.5 m/hr for CGR 3 - 5 m^2/hr for mats
Branchbox Breakwater (bw) with emergent aquatic plants shoreward	$23.00/m	1.3 m/hr for bw 4.0 - 20 m^2/hr for sprigs
Log/tree Breakwater with emergent aquatic plants shoreward	$30.00/m	0.5 m/hr for bw 4.0 - 20 m^2/hr for sprigs

RECOMMENDATIONS AND CONCLUSIONS

Lake Thunderbird has several reaches of shoreline with five categories of erosion that have been characterized above. As one can see, there is a fairly wide array of treatments or treatment combinations that can be used in a cost-effective manner to address the shoreline erosion problem.

It is recommended that since erosion is so extensive, sites be prioritized for erosion control as mentioned above. Higher priority should go to sites where structures or facilities, such as picnic tables and grounds, are threatened. Most of the treatments presented above are also fairly easily applied by volunteer labor assuming they can be trained through a 1- to 2-day workshop. To keep costs minimal, it is recommended that cooperation be sought from such groups as yacht, fishing, and wildlife clubs or organizations, who could probably volunteer some labor.

Since bioengineering is relatively a new field for most, some education and convincing may need to be done through a workshop and demonstration in order to garner needed support and monies for future work. It is suggested that one start with less severe sites first for illustrating success and then proceed to more difficult reaches of shoreline.

References

Fuller, Douglas R., 1997. "Understanding, Living with, and Controlling Shoreline Erosion, a Guidebook for Shoreline Property Owners (2nd Edition)," Tip of the Mitt Watershed Council, Conway, Michigan 49722.

US Army Corps of Engineers, 2001. "Monthly Charts for Lake Thunderbird," http://www. http://ww.swt-wc.usace.army.mil/THUNcharts.html

USDA Soil Conservation Service, 1987. "Soil Survey of Cleveland County, Oklahoma," April, 1987.

National Oceanic and Atmospheric Administration (NOAA), 2001. "CLIMATOLOGICAL SUMMARY FOR THE MONTH, National Weather Service, Oklahoma City," http://www.srh.noaa.gov/data/OKC/CLM/OKCCLMOKC.8.txt