STANDARD
FOR
SOIL BIOENGINEERING

Definition

The use of live, woody and herbaceous plants to repair slope failures and to increase slope stability. Living plant material may be used alone or in combination with structural components such as rock, wood, concrete, or geotextiles.

Purpose

To integrate structural and vegetative techniques to stabilize or protect banks of streams, lakes, shorelines, excavated channels and upland slopes; to prevent the loss of land or damage to facilities adjacent to the banks; to maintain the capacity of the channel; to reduce sediment loads causing downstream damages and/or pollution; and to protect and enhance water quality.

Conditions Where Practices Applies

Soil bioengineering techniques are generally appropriate for treatment of slopes, eroded stream banks, surface erosion, shallow mass wasting, cut and fill slope stabilization, earth embankment protection (other than dams), and small gully repair. **They are not to be considered when public safety is at risk** such as when substantial mechanical and or structural designs are required.

Descriptions of methods for installing individual Soil Bioengineering systems may be found in USDA Natural Resources Conservation Service Engineering Field Handbook (EFH), **Chapter 16** (Streambank and Shoreline Protection) and **Chapter 18** (Upland slope Protection).

Water Quality Enhancement

The use of vegetative techniques to stabilize stream banks, upland slopes and open shorelines provides long term erosion control as well as contributing to water quality through uptake of nutrients, moderation of water temperature and protection of dissolved oxygen content (in surface waters).

DESIGN CRITERIA

1. PLANNING

Flow Chart No. 26-1 (Soil Bioengineering Application Decision Chart) shall be used to determine if Soil Bioengineering Techniques alone are appropriate for correcting existing erosion problems or for preventing future erosion of shorelines, upland slopes or stream channels. Bioengineering techniques may be used singularly or in combination with one another or in combination with other erosion control techniques, such as rip rap bank protection.

The following conditions must be evaluated to help ensure a proper soil bioengineering design:

Soil type and moisture availability
Stream bed stability
Slope stability
Surface runoff (diversion may be necessary to ensure success - see Standard for Diversions, pg. 15-1)

Availability of bioengineering materials

Effects of mature vegetation on stream hydraulics, including up and downstream of the treatment area

Time of year for installation (installation of all woody vegetation shall be performed during the dormant season only)

Cause of the loss of existing vegetation (ice damage, livestock damage, fire invasive species etc.)

Chart 26-1

Soil Bioengineering Applicability

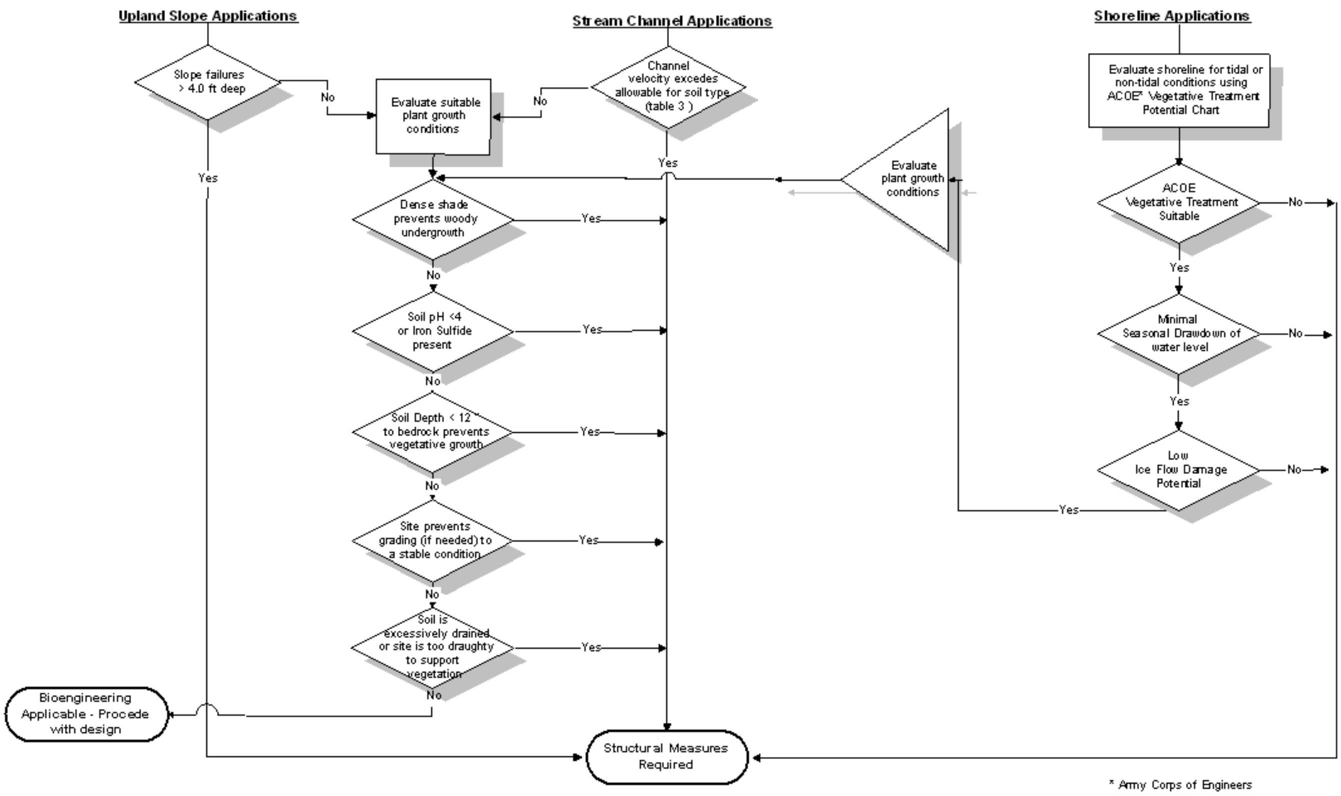
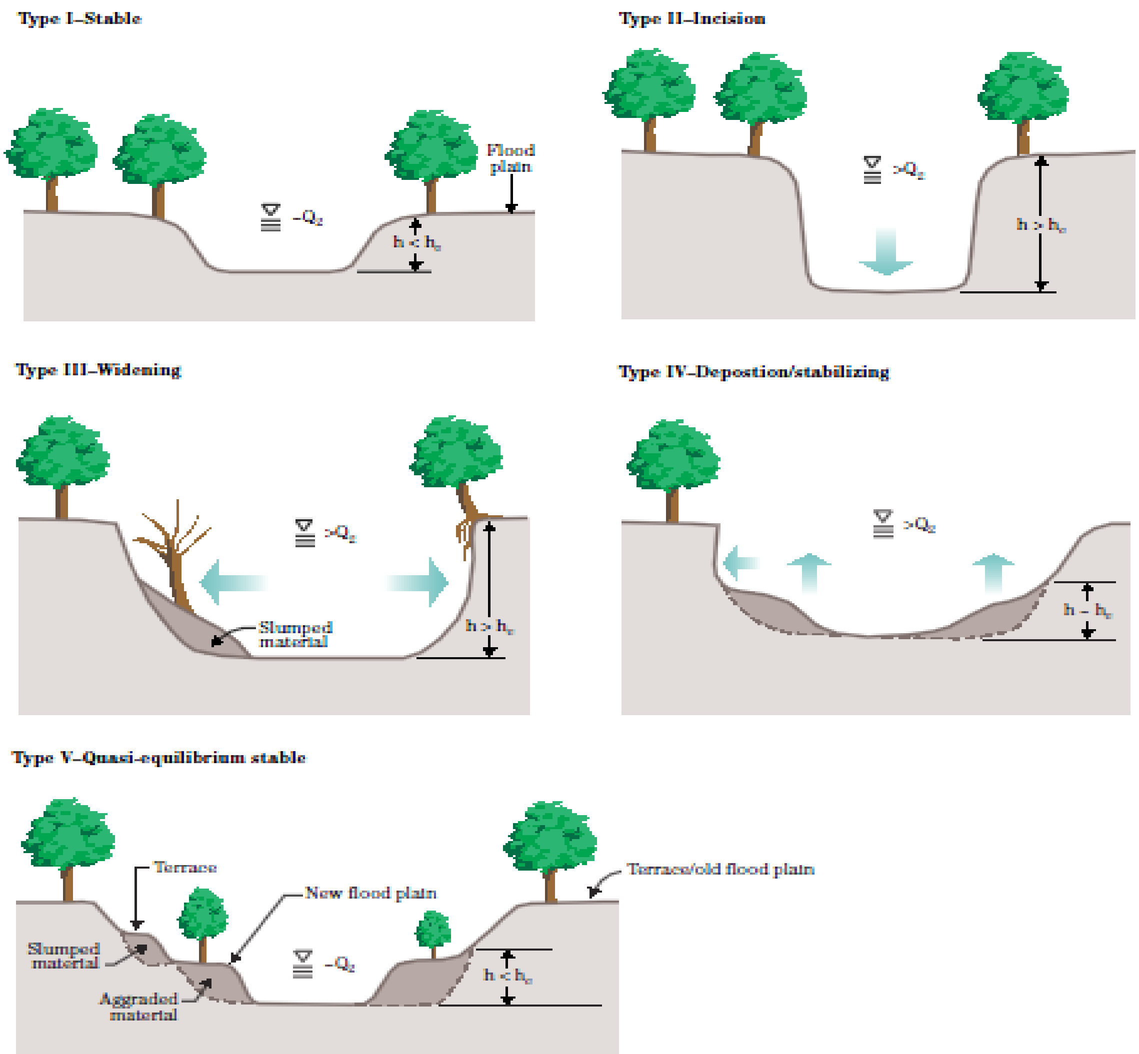


Figure 26-1 – Simplified Channel Evolution Model

Figure 3–4a Schumm, Harvey, and Watson (1981) schematic cross sections and longitudinal profile of an incised stream showing features of the five classes of the CEM



3–20 (210–VI–NEH, August 2007)

2. ENGINEERING

Grading

Steep, unstable slopes and deep undercuts in banks may require extensive grading to achieve a stable slope or will require structural measures, (such as crib walls, riprap, or wire-mesh baskets), or redirective measures within the channel (such as weirs or vanes) . For Planting purposes only, the steepest acceptable slope is 1.5 horizontal to 1.0 vertical. Slope stability analysis or design shall be subject to municipal, county and state regulations. All newly graded banks shall be protected from overbank flow in accordance with the Standard for Diversions, pg. 15-1., Grade Stabilization, pg. 17-1 or Slope Protection, pg. 27-1 as appropriate.

Channel Realignment

The realignment of channels (change in location or cross-sectional geometry) shall be kept to an absolute minimum unless realignment is part of an overall stream restoration plan and is the subject of the soil erosion and sediment control plan.

Channel Capacity

Peak discharge and/or hydrographs for capacity shall be determined by the following methods:

1. Rational Method - for peak discharge of uniform drainage areas as outlined in Technical Manual for Land Use Regulation Program, Bureau of Inland and Coastal Regulations Stream Encroachment Permits, Trenton, N.J. September 1997 or subsequent editions

2. NRCS Win TR-55 or Win TR-20

3. U.S. Army Corps of Engineers HEC HMS

4. Other methods which produce similar results to the models listed above.

.

Hydraulic Requirements

Manning's formula (where appropriate) or a water surface profile analysis shall be used to determine the velocities in the channels. Resistance (Manning's "n") values shall be estimated using Table 26-1. Site specific n values may be used if verified by USGS stream gage data or by a hydrologic and hydraulic analysis approved by the local district.

Design storm requirements for stability analysis shall be in accordance with the Standard for Channel Stabilization, pg. 11-1. Aged condition shall analyze capacity at vegetative maturity.

Table 26-1 - Estimating Manning's "n" for Soil Bioengineering practices

Bioengineering System	Manning's "n" values*	
	Installation condition (stability)	**Mature condition (capacity)**
Conventional vegetation (use of the retardance method is required for designing grass lining)	0.025	0.055
Live Staking Live Facines (wattling bundles) Branchpacking Brushmattress Live Cribwall (similar to wire-mesh baskets in hydraulic effects)	0.025	0.1
Joint Planting	see riprap standard	see riprap standard

* Does not consider channel alignment, obstructions etc. Based on non-gravel soils. See Appendix 8, supplement "A" for additional guidance for selecting "n" values

Maximum allowable velocities for bankfull and out of bank discharges (fig. 26-2) shall be based on allowable soil velocities found in Table 26-2. These velocities are based on the use of an acceptable erosion control matting in conjunction with the bioengineering system. Every reach shall be individually designed unless all reaches are designed for the worst cases for velocity and capacity (lowest allowable velocity, steepest slope). **Bioengineering designs must begin and end in a stable channel section**. Design procedures may be evaluated according to channel conditions represented in Table 26-3, below.

Table 26-2 - Maximum Allowable Velocities for Bioengineering

Soil Texture	Velocity (fps) with matting [1]
Sand	2
Silt loam, sandy loam, loamy sand, loam and muck	5
Silty clay loam, sandy clay loam	5.5
Clay, clay loam, sandy clay, silty clay	6

1. All Soil Bioengineering Application designs shall incorporate a an erosion control blanket or flexible channel liner over seeded areas and shall be integrated into the measure in accordance with USDA EFH Chapters 16 and/or 18. The flexible channel liner shall be selected based on the design requirements for the planned bioengineering application.

Figure 26-2: Terminology in Channel Flow Descriptions

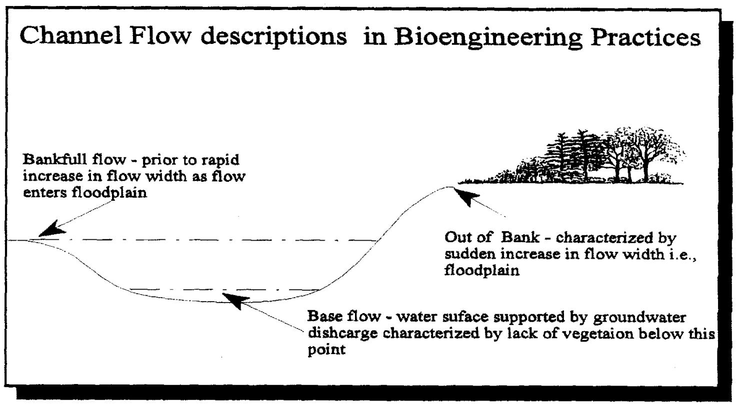
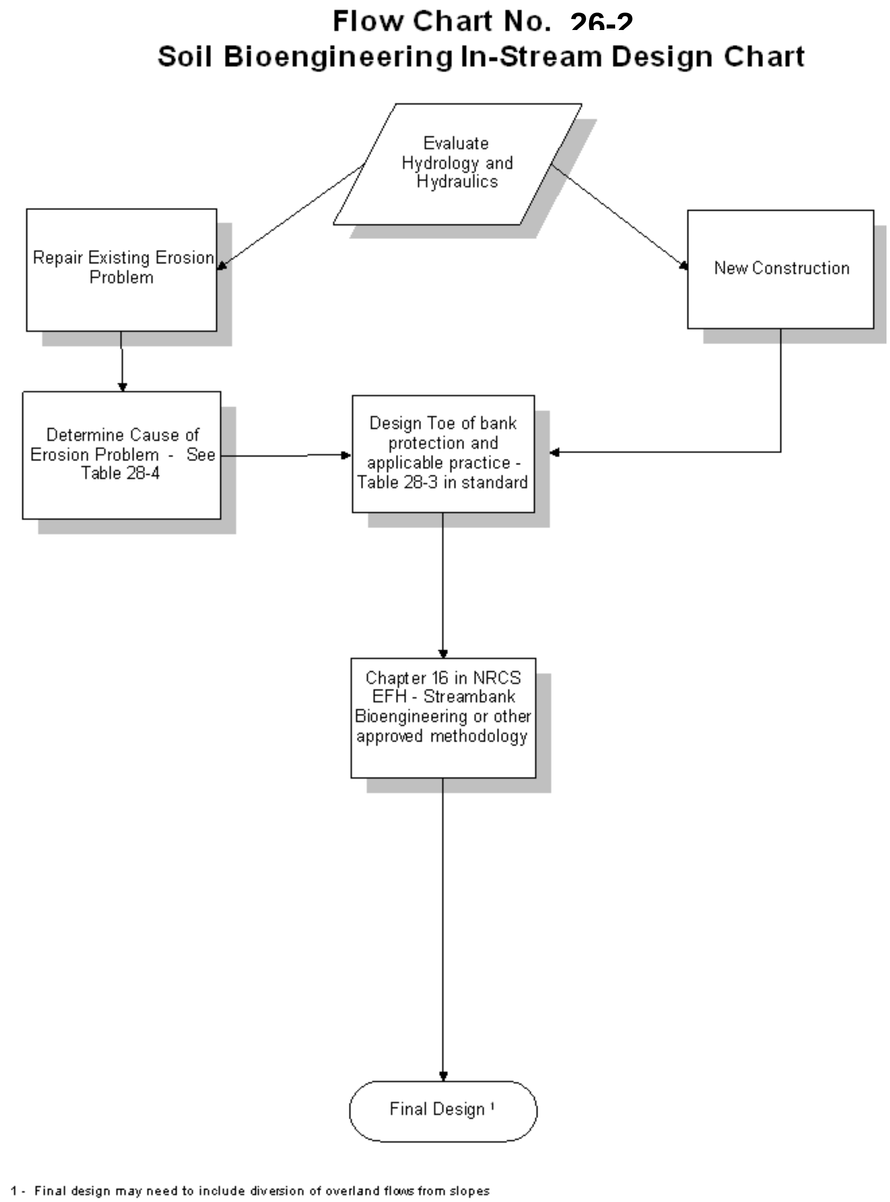


Table 26-3 – Design Approach based on Channel Boundary Conditions.

Channel Boundary Condition	Design Consideration Approach
Significant sediment load and moveable channel boundaries	Alluvial channel design techniques
Boundary material smaller than sand size	Allowable Velocity
Boundary material larger than sand size	Allowable shear stress
Boundary material does not act as discrete particles	Tractive Power
No base flow in channel. Climate can support permanent vegetation	Grass lined (retardance) / tractive stress

Toe Protection at Base Flow Elevation - Toe protection is to be provided on all streambank stabilization projects. Methods of providing toe protection may consist of a fiber roll revetment (coir log) adequately anchored or a structural revetment such as rock rip rap. Fiber roll revetments have a design life of 5 years and are suitable for sites where there is a high probability that vegetation, once established, will be adequate for stabilizing the toe zone. In general, this will be in lower velocity channels where adjacent reaches indicate vegetation alone will be adequate. Riprap for toe protection shall be designed using the bankfull or design discharge velocity using procedures in the Standard for Riprap, pg. 23-1



Flow Chart No. 26-2 (Soil Bioengineering In-Stream Design Chart) shall be followed for stream channel designs.

Table 26-3 - Summary of Streambank /Upland Slope Bioengineering Protection Measures

System Type	**Zone of Application** [1] - Base Flow - Base to Top - Out of Bank	**Types of erosion problems for which the system is suitable**	**Comments and Restrictions**
Live stake	Base to Top Out of Bank	bank scour, overbank runoff	suitable for small, simple erosion problems when used in conjunction with other systems.
Live fascine	Base to Top, Out of Bank	general bank scour-, overbank runoff	useful for moderate to severe erosion-, should not be used on bank faces longer than 15 ft, after sloping.
Branchpacking	Base to Top, Out of Bank	local bank scour, gullies eroded by overbank runoff	restricted to repair of small sites(maximum depth = 4.0 ft.)
Vegetated Geogrid	All Zones	toe erosion, local bank scour	useful on steep slopes (up to 0.5H: IV) where space is limited/generally restricted to heights not exceeding 6 ft. overall
Live cribwall	All Zones	local bank scour, toe erosion (requires structural toe protection)	
Joint planting	Base to Top, Out of Bank	see riprap standard	see riprap standard
Brushmattress	Base to Top, Out of Bank	local and general bank scour; debris gouging	generally used on 3H: 1V graded slopes restricted to sites of 50 linear feet or less
Conventional vegetation	Base to Top, Out of Bank	general & local bank scour	See Table 26-2 for velocity restrictions
Tree revetment	Base to Top	general bank scour	Provides temporary protection, susceptible to damage by flooding debris and beavers
Riprap (incl. wire-mesh baskets)	All Zones	local & general bank scour, toe erosion	All headcutting and general bed degradation by erosion must have armored protection
Coir (coconut fiber) Logs	Base, Base to Top	toe erosion	Must be 2/3 submerged in water to be an effective rooting medium.

1. See Figure 26-1 for description of zones.

3. VEGETATION

Plant materials will be live, viable woody or herbaceous vegetation. The plant materials will be obtained from commercial sources or in the case of woody cuttings, may be harvested from native stands during the dormant period. (November-April).

Plant Adaptation Zones

Base Flow Zone (Toe Zone) - Too wet to grow vegetation or where side slopes meet channel bottom (intermittent streams). Select vegetation which develops an extensive root system and tolerates extended saturation. This includes Obligate and Facultative Wet herbaceous and woody plants.

Above Base flow to top of bank or 2 year storm elevation (Bank Zone) - Area between level of base flow and top of bank or 2 year storm elevation. Select vegetation which tolerates wetting and drying soils. This includes Facultative and some Facultative Wet grasses, forbs and shrubs.

Out of bank. (Terrace Zone**)** - Select vegetation which tolerates droughty conditions. This may include some Facultative and most Facultative Upland plants.

A. **Plant Material Specifications**

* Rooted seedlings - Plants shall be at least 12" long. The root system shall have approximately the mass equal to the top portion.

* Unrooted cuttings - Cuttings shall be 8"-12" in length and 1/4" - ½" in diameter.

* Live Stake - cuttings shall be 2.0' to 3.0' in length and ½" to 2.0" in diameter

* Live brush - Live brush will consist of the whole above ground portion of willow, redosier dogwood, or other hardwood species which root easily from cuttings. Plants shall be 4 to 8 feet in height and free of disease. When there is a shortage of live, dormant brush, up to 30% of nonrooting species may be mixed randomly with the rooting species. Brush will be cut by shears or saw, not by ax.

* Herbaceous plants - Grasses, sedges, and rushes shall be provided in multiple-culmed pots having a minimum of two stems per pot. Stems shall have a minimum length of 6".

B. Plant Selection - See Table 26-5 for specific species adaptations.

1. Herbaceous plant materials to be used in the coir fiber rolls shall consist of a mixture of the following:

Asclepias incarnate - Swamp milkweed
Acorns calamus/americanus - Sweet Flag
Calamagrostis spp. - Bluejoint reedgrass
Carex spp. - Sedges
Cinna arundinacea - Wood reedgrass
Distichlis spicata - Seashore saltqrass
Eupatorium purpureum - Joe-Pye weed
Glyceria spp. - Mannagrasses
Iris versicolor - Blueflag iris
Juncus spp. - Rushes
Lobelia cardinalis - Cardinal flower
Pontederia cordata - Pickerel Weed
Sagittaria latifolia - Duckpotato
Scirpus spp. - Bulrushes
Sparganium spp. - BurreedSpartina spp. -
CordgrassesTypha spp. - cattails

2. Woody plants shall consist of bareroot plants or unrooted cuttings and stems (whips) of hardwood shrub species which root easily. The plant materials may come from nursery sources or existing local stands, or a combination of the two. Plant Materials suitable for use as rooted or unrooted cuttings include:

Cephalanthus accidentalis - buttonbush
Baccharis halimifolia - groundselbus
Cornus amomum - silky dogwood
Cornus serecia - redosier dogwood
Salix purpurea - "Streamcol purpleosier willow"
Salix cottetii -"Bankers" dwarf willow
Salix exigua - sandbar willow
Salix discolor - pussy willow
Sambucus canadensis - elderberry
Viburnum dentatum - southern arrowwood
Viburnum lentago - nannyberry
Viburnum prunifolium - blackhaw viburnum

c. Plant Materials suitable for use only as bareroot or containerized plants include:

Alnus rugosa - speckled alder
Alnus serrulata - smooth alder spp.
Amorpha fruitcosa - indigobush
Aronia arbutifolia - red chokecherry
Clethra alnifolia - sweet pepperbush
Cornus racemosa - gray dogwood
Ilex verticulata - winterberry holly
Lindera benzoin - spicebush
Physocarpus opulifolius - ninebark
Prunus pumila var. depressa - dwarf sand cherry
Rhododendron viscosum - swamp azalea
Rosa palustris - swamp rose
Spirea tomantosa - steeplebush

d. Supplemental Grass Mixtures

Grass species suitable for stabilizing disturbed areas that are somewhat poorly to poorly drained are:

SPECIES	COMMON NAME	REMARKS[1]
Agrostis alba	Redtop	SP,I,CG
Agrostis palustris	Creeping bentgrass	P,I,CG
Andropogon glomeratus	Lowland broom sedge	P,N,WG
Dicanthelium clandestinum	Deertongue	P,N,WG
Echinochloa cruagaiii	Japanese millet	A,T,WG
Elymus virginicus	Wild rye	P,N,CG
Lolium perenne[2]	Perennial ryegrass	SP,I,CG
Lotus corniculatus [3,4]	Birdsfoot trefoil	P,I,CL
Pani virgatum	Switchgrass	P,N,WG
Poa trivialis	Rough bluegrass	P,I,CG
Trifolum repens [4]	White/Ladino clover	SP,I,CL

1. P - perennial
   A - annual
   I - introduced
   N - native
   CG - Cool-season grass
   WG - warm season grass
   CL - Cool-season legume
   SP - Short-lived perennial

2. Perennial ryegrass may be substituted for redtop in all mixes except Mix # 7.

3. Birdsfoot trefoil is not well adapted to the coastal plain. Use only in northern and central Jersey.

4. Need specific legume inoculant.
   Note: Warm-season grass seeding rates are based on Pure Live Seed (PLS)

Suitable seeding mixtures and recommended seeding rates for various site conditions:

<u>Seed Mix 1</u>:
Cool-season mix suitable for shady sites.

* Redtop	1/lbs./ac.
* Hard fescue	40 lbs./ac.
* Rough bluegrass	15 lbs./ac.

<u>Seed Mix 2:</u>
Warm-season mixture suitable for highly acid soils. Provides excellent wildlife value.

* Blackwell switchgrass	15 lbs./ac. PLS
* Tioga deertongue	10 lbs./ac. PLS
* Japanese millet (nurse)	8 lbs./ac. PLS

<u>Seed Mix 3</u>:
All native mixture suitable for somewhat acid soils. Provides good to excellent wildlife value.

* Blackwell switchgrass and/or	10 lbs./ac.PLS
* Broomsedge	12 lb&./ac. PLS
* Tioga deertonque	5 lbs./ac. PLS
* Wild rye	5 lbs./ac.PLS

Use a nurse crop such as oats or rye.

<u>Seed Mix 4</u>:
Turfgrass mixture suitable for moist, shady areas.

* Rough bluegrass	25 lbs./ac.
* Perennial ryegrass	15 lbs./ac.
* Creeping bentgrass	10 lbs./ac.

Optional:

*White clover or	5 lbs./ac.
*Birdsfoot trefoil	8 lbs./ac.

<u>Seed Mix 5</u>:
Mixture for providing quick, semipermanent cover in areas where natural succession is encouraged. Excellent wildlife value.

* Redtop	2 lbs./ac.
* Japanese millet	8 lbs./ac.
* White/Ladino clover	5 lbs./ac.

Seed Mix 6:
Shotgun mix (for those extremely complex sites)

*Tioga deertongue	15lbs./ac. PLS
*Redtop or	3lbs./ac.PLS
*Perennial ryegrass	5lb/./ac.PLS
*Wild rye	10lbs./ac.PLS
*Switchgrass	8lbs./ac. PLS
*Broomsedge	12lbs./ac. PLS

Wildflowers tolerant of wet conditions:

* Aqailega canadensis - Eastern Columbine
* Chrysanthemum leucanthemum - Ox-eye Daisy
* Hesperis 'matronalis - Dame's Rocket
* Lupinus perennis - Perennial Lupine
* Myostis sylvatica - Forget-Me-Not
* Rudbeckia hirta - (Golden Jubilee) Black-eyed Susan

Table 26-4: Types of Erosion And Causes of Erosion	
Type of Erosion	**Causes**
Toe erosion and upper bank failure	Removal of unconsolidated or noncohesive lower materials, especially bank failure along outside bends. Widespread toe erosion may be associated with bed lowering.
General bed degradation (Bed scour over extended channelization, reaches)	Changes in stream gradient due to factors such as lowering of stream base level due to lake or tailwater fluctuations, stream or stream relocation. Increased stream discharge due to flow diversion or watershed changes such as urbanization.
Headcutting	In streams undergoing bed degradation, headcuts often develop at locations where more resistant materials outcrop in the stream channel. Headcuts may develop at a stream mouth when base level is lowered suddenly due to dredging, erosion or draining of a lake.
Middle and upper general bank scour	Increased discharge resulting from watershed changes; increased flow velocities caused by reduction in channel roughness or increased gradients; removal or loss of bank vegetation.
Local streambank scour	Scour of local lenses or deposits of unconsolidated material, erosion by secondary currents caused by flow obstructions and channel irregularities, loss of bank vegetation.
Local bed scour	Local bed scour may be caused by channel constrictions, flow obstructions such as debris dams or flow deflectors, or trapping of sediment in reservoirs or sediment traps. Some scour generally occurs below culverts.
Piping	Piping develops when fines are removed by water flowing laterally under the surface. Extensive pipe development requires 1) rapid infiltration, 2) steep hydraulic gradients, and 3) *zones of* concentrated flow. Piping may occur in stratified soils where vertical movement is restricted by sudden reduction in hydraulic conductivity between strata or where poorly compacted soil around buried pipes provides conduits for water movement.
Overbank runoff	Failure to provide adequate means of directing concentrated flows from overbank areas into the channel.

Table 26-5: Shrubs suitable for Soil Bioengineering Systems							
Species	**Habitat** [1]	**Bank Zone** [2]	**Root Form** [3]	**Shade** [4] **Tolerance**	**Flood** [5] **Tolerance**	**pH range** [6]	**Comments**
Alnus serrulata **Smooth alder**	nontidal	toe	rooted	medium	regular	5.5-7.5	Nitrogen fixer weak wooded
Amorpha fruitcosa **False indigo**	tidal fresh moist woods	lower-mid	rooted	low	seasonal	6.0-8.5	Req. full sun Drought tolerant
Aronia arbutifolia **Red chokeberry**	nontidal	lower-mid	rooted	medium	irregular seasonal	5.1-6.5	Drought tolerant
Aronia melanocarpa **Black chokeberry**	nontidal	mid-upper	rooted	low	irregular seasonal	5.1-6.5	Drought tolerant
Baccharis halimifolia **Groundsel bush**	tidal tidal fresh	mid-upper	rooted, unrooted	high	seasonal	7.0-8.5	M/F separate plants
Cephalanthus occidentalis **Buttonbush**	nontidal tidal fresh	toe	rooted unrooted	high	permanent	6.1-8.5	Tolerates brief drought
Celthra alnifolia **Sweet pepperbush**	tidal nontidal	mid-upper	rooted	high	seasonal	4.5-6.5	
Cornus amomum **Silky dogwood**	streambankspond edges	lower-mid	rooted unrooted	medium	seasonal	5.5-8.5	Drought tolerant
Cornus racemosa **Gray dogwood**	streambanks pond edges	lower-mid	rooted unrooted	high	seasonal	5.5-8.5	Drought tolerant
Cornus serecia **Redosier dogwood**	streambanks pond edges	toe-mid	rooted unrooted	medium	seasonal	5.5-8.5	Drought tolerant
Ilex decidua **Possumhaw**	forested wetlands pond edges	lower-mid	rooted unrooted	high	irregular	4.0-6.0	M/F separate plants
Ilex glabra **Inkberry**	forested wetlands sandy woods	mid-upper	rooted	high	irregular inundation	4.5-6.0	M/F separate plants. Resists salt spray
Ilex verticulata **Winterberry holly**	tidal fresh forested wetland	lower-mid	rooted	high	seasonal	4.5-8.0	Drought tolerant
Itea virginica **Virginia sweetspire**	forested wetland streambanks	toe	rooted	high	regular	5.0-7.0	Tolerates some salt
Iva frutescens **Hightide bush**	tidal brackish	lower	rooted	low	regular	6.0-7.5	Tolerates 15ppt salt
Leucothe racemosa **Leucothe**	forested wetland moist woods	lower mid	rooted	high	regular	5.0-6.0	Tolerates some dry-down

Table 26-5: Shrubs suitable for Soil Bioengineering Systems

Species	Habitat [1]	Bank Zone [2]	Root Form [3]	Shade [4] Tolerance	Flood [5] Tolerance	pH range [6]	Comments
Lindera benzoin **Spicebush**	seasonal wetlands floodplain	lower-mid	rooted	high	seasonal	4.5-6.5	Tolerates some drought
Lyonia ligustrina **Maleberry**	open woods	lower-mid	rooted	low	seasonal	4.0-6.0	Acid tolerant
Magnolia virginiana **Sweetbay magnolia**	stream borders forested wetlands	lower-mid	rooted	high	irregular/ seasonal	4.0-6.5	Tolerates infreq. flooding by salt
Myrica cerifera **Wax myrtle**	tidal fresh brackish swales	mid-upper	rooted	high	regular	4.0-6.0	tolerates 10 ppt salt. N-fixing
Myrica pennsylvanica **Bayberry**	tidal fresh brackish nontidal	mid-upper	rooted	high	irregular-seasonal	5.0-6.5	Tolerates drought. N-fixer
Physocarpus opulifolius **Ninebark**	streamsides wood edges	low-mid	rooted	medium	seasonal		
Prunus pumila var. depressa **Dwarf sand cherry**	streamsides sandbars	mid-upper	rooted	low	irregular	6.5-8.5	Native to Del. River. Groundcover
Rhododendron viscosum **Swamp azalea**	forested wetlands	toe-low	rooted	medium	seasonal-regular	4.0-6.0	susceptible to disease
Rosa palustris **Swamp rose**	tidal fresh forested wetland streambank	toe-low	rooted	low	seasonal-regular		
Rhus typhina/glabra **Staghorn/Smooth sumac**	disturbed banks/dry sites	upper	rooted	low	irregular	6.1-7.0	tolerates some drought
Salix X cottetii **'Bankers' Dwarf willow**	streambank	toe-mid	unrooted rooted	medium	regular-permanent		introduced male hybrid. noninvasive
Salix discolor **Pussy willow**	streambank forested wetland	toe-mid	unrooted rooted	medium	regular-permanent	6.6-7.5	
Salix exigua **Sandbar willow**	streambank sandbars	toe	unrooted rooted	low	regular-permanent		
Salix purpurea **'Streamco' purpleosier** willow	streambank	toe-upper	unrooted rooted	medium	regular-permanent	6.0-7.0	introduced noninvasive shrub
Sambucus canadensis **Elderber**ry	tidal fresh nontidal wet meadow	low-mid	rooted-unrooted	high	irregular-seasonal	6.0-8.0	some salt tolerance tolerates drought

Table 26-5: Shrubs suitable for Soil Bioengineering Systems							
Species	**Habitat** [1]	**Bank Zone** [2]	**Root Form** [3]	**Shade** [4] **Tolerance**	**Flood** [5] **Tolerance**	**pH range** [6]	**Comments**
Spirea alba/tomentosa **Meadowsweet**	forested wetland	mid-upper	rooted	low	irregular	5.1-6.0	
Viburnum dentatum **Southern arrowwood**	tidal fresh nontidal forested wetland	mid-upper	rooted unrooted	medium	seasonal	5.1-7.0	tolerates drought
Viburnum lentago **Nannyberry**	forested wetland	mid-upper	rooted unrooted	medium	seasonal		
Viburnum prunifolium **Blackhaw viburnum**	forested wetland	upper	rooted unrooted	medium	irregular	6.5-7.0	
Viburnum trilobum **Am. cranberrybush**	forested wetlands	lower-mid	rooted unrooted	low	irregular-seasonal	6.0-7.5	tolerates drought

Footnotes:

1. Habitat:
   Native habitat of the plant.
2. Bank zone:
   toe - elevation of baseflow
   lower to mid - from base to two year flood elevation
   upper - above two year elevation to flood plain
3. Root form:
   rooted - use bare-root plants
   unrooted - use dormant cuttings/brush
4. Shade Tolerance:
   low -requires full sun
   medium - tolerates partial shade and full sun
   high - tolerates full shade and full sun
5. Flood tolerance:
   permanent - tolerates inundation or saturation 76-100% of the growing season.
   regular - tolerates inundation or saturation 26-75% of growing season.
   seasonal - tolerates inundation or saturation 13-25% of the growing season.
   irregular - tolerates inundation or saturation 5-12% of the growing season.
6. pH range:
   Preferred range for successful plant establishment.

Table 26-6: Soil Bioengineering Vegetative Treatment Potential (VTP) for Ponds and Lake Shores

Shoreline Variables	**Directions For Use**: Enter the applicable VTP rating (bold number) in the last column. Add the total of the VTP ratings and compare with the Treatment Potential (TP) scale below					VTP
1. **Fetch**: Average distance in miles of open water measured perpendicular to the shore and 45 degrees either side of perpendicular to shore.	Less than 0.5 miles 8	0.5 to 1.4 miles 7	1.5 to 3.4 miles 4	3.5 to 4.9 miles 2	over 5.0 miles 0	
2. **General shape of shoreline** for distance of 200 yards on each side of planting site.	Coves 8	Irregular shoreline 3		Headland or straight shoreline 0		
3. **Shoreline orientation**: General geographic direction the shoreline faces.	Any less than ½ mile fetch 5	West to North 3	South to West 2	South to East 1	North to East 0	
4. **Boat traffic**: Proximity of site to recreational and commercial boat traffic.	None 5	1-10 per week withing ½ mile of shore 3	More than 10 per week within ½ mile of shore 2	1-10 per week within 100 yards of shore. 1	More than 10 per week within 100 yards of shore. 0	

_________________________ Cumulation of VTP for variables 1,2,3, and 4

Treatment Potential (TP) Scale : if TP is:

Between	And	Potential of site to be successfully stabilized with soil bioengineering
23	26	Excellent
20	22	Very Good
16	19	Good
13	15	Fair
below 13		Poor

Shoreline Stabilization

The Vegetative Treatment Potential (VTP) as shown in Table 26-6 shall be evaluated for all shoreline protection measures. Bioengineering treatments involving vegetation may only be considered where the Treatment Potential Scale indicates excellent to very good site conditions. Vegetative measures alone are not suited to sites where wave heights are greater than 1.5 feet and beach slopes are steeper than 12H to 1V. Fiber roll revetments or structural stabilization measures such as rock riprap, and off-shore wave dissipater berms shall be considered for use in combination with vegetation where site conditions are not suited to vegetation alone. Fiber roll revetments have a design life of 5 years and are suitable for sites where there is a high probability that vegetation, once established, will be adequate for stabilizing the shoreline. In general, this will be in lower energy situations where adjacent reaches indicate vegetation alone will be adequate. Riprap for shoreline stabilization shall be designed using procedures in the Standard for Riprap, pg. 23-1.