



Installation and Maintenance Guide




Bank Stabilization System (BSS)

Contents

- 1.0 Required tools
- 2.0 Materials
- 3.0 Installation
- 4.0 Design Considerations
 - 4.1 General
 - 4.2 Anchoring
 - 4.3 Filter blanket or Geo-textile
 - 4.4 Scour and long-term stability
 - 4.5 Vegetation & Planting
 - 4.6 BSS as a Retaining Wall
- 5.0 Inspection and Maintenance



1.0 Required Tools

Item	Typical specs
Crimp tool (or swaging tool)	 HSC-600 Combination hand swaging tool
Wire Rope cutter	 C-7 Felco wire rope cutter
Cable Tensioning tool (Cable grip) 2 required – for tensioning and securing cable around the modules	 Klein Haven Grip 1604-10





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Anchor Drive Steel with extensions as required	For Duckbill Anchor 88-DB DS-88 (Part No. 50012) Length 48" Diameter 0.75" Head Diameter 1.5" Tip Diameter 0.75"
Sledge Hammer (for manual anchor driving)	
Shovels	
Pneumatic Driver (optional – for mechanical anchor driving)	
Excavator (optional)	
Portable Water pump, 100 ft hose (optional) – for filling modules, compacting soil	


2.0 Required Materials

Item	Typical Spec	Average quantity per linear foot of bank (will vary with each project)
Anchor	Duckbill Anchor: DB-88 	1.0 / ft
Crimp sleeves	1/8" Diameter Zinc plated copper oval sleeves 	Tie Back: 2.0 / ft Horizontal: 0.25 / ft Total: 2.25 / ft

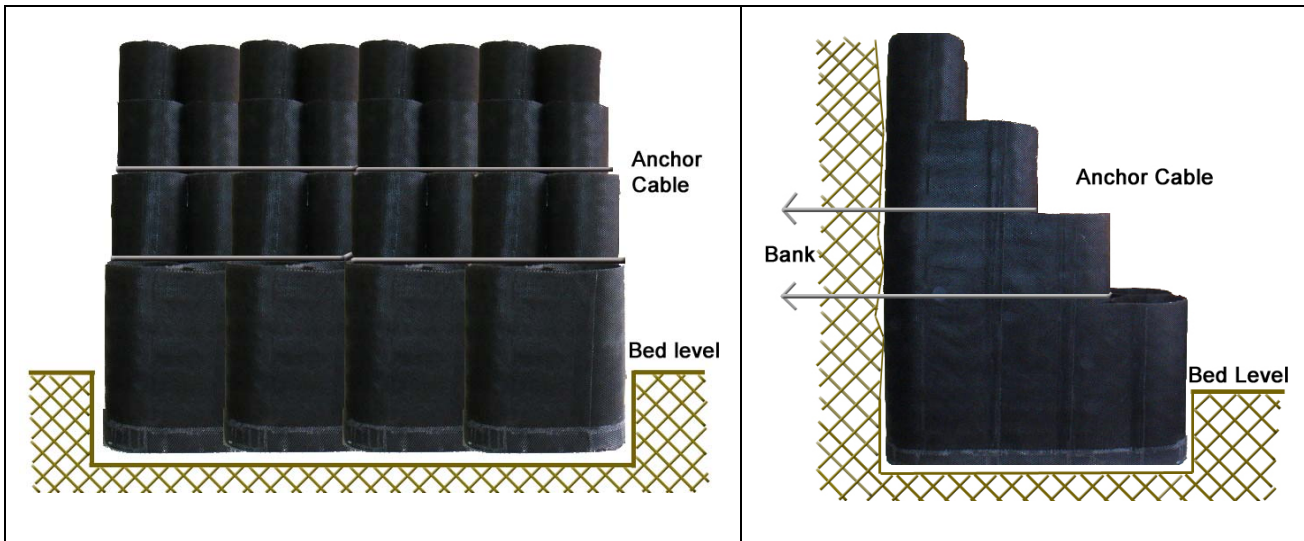


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Wire Rope	1/8" Diameter 7X19 Stainless Steel aircraft cord  Flexible	Tie Back: 11 ft / ft Horizontal: 2.75 / ft Total: 13.75 / ft
Filter Blanket, Geo-textile		10 sq ft / ft
Plantings – native grasses, willows, etc.		As required

3.0 Installation





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<p>A. Clear debris and unwanted material from site. Excavate soil to provide level footing and squared-bank to set the modules. Prepare a trench as necessary in front of the bank, designing for expected total scour. (It is not necessary to install the modules against a smooth vertical face as shown above. However, where backfilling behind the modules is required, the modules should be filled before backfilling to prevent deformation of the modules). When trenching in tidal areas, dig enough trench to support the day's work. In most cases, it is efficient to start in the middle of the bank and work outwards.</p>	<p>See Section 4.4</p>
<p>B. Temporarily locate BSS into position, into trench and against bank along the entire bank to be protected.</p>	
<p>C. Mark the locations for anchor insertion. (for example, mark by spray paint above the modules). Anchors and cables will be inserted after every fourth cylinder, at typically two levels. Anchors should be inserted 4 to 6 feet into the bank, depending on soil conditions.</p>	
<p>D. Temporarily remove BSS structures to make room to drive anchors into bank.</p>	



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<p>E. Insert anchors. After anchor insertion, set anchors (see below – anchor installation).</p>	<p>See section 4.2</p>
<p>F. After anchors are set, install a layer of geo-textile material beneath and in the area between the BSS and the bank to provide additional soil retention. Install so that the fabric covers the outside face, to the top of the lowest cylinders, under the base, and up the back face to the top of the tallest cylinders. Perforate the geo-textile material and thread the anchor cables through.</p>	<p>See section 4.3</p>
<p>G. Prior to filling, there is an opportunity to plant willow poles, or other vegetation.</p>	<p>See section 4.5</p>
<p>H. Fill modules with local soil, sediment, sand, or gravel before backfilling behind modules and before tensioning cables around modules. This will create a rigid, but semi-permeable structure. Consolidate soil within modules by filling with water (slurry), or via vibrating compaction. If a water source is available, slurry soil into modules to provide soil compaction. After filling modules. Back-fill between bank and modules.</p>	
<p>I. After filling cylinders, tie cables tightly around every 4th cylinder. Meet the anchor cables across four modules from either direction. Swage two crimps (oval sleeves) around each pair of joining cables. Use the cable grips to tension cables tightly while sleeves are swaged (requires 3 installers).</p>	
<p>J. Tie cable around every eight adjacent modules at the highest transition point of the staircase, parallel to bank surface – offset from tie-back anchors by two modules – and cinch modules tightly together.</p>	
<p>K. After filling, plant modules (in and around) with native grasses, willows, etc.</p>	<p>See section 4.5</p>



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4.0 Design Considerations

All of the general bank stabilization considerations should be followed. The following are specific considerations for BSS structures

4.1 General Considerations

BSS walls are appropriate where:

- The vertical integrity of a soil bank needs higher strength to reduce sloughing of the bank
- There is moderate to excessive sub-surface water movements that may be creating erosion and damage other types of non-permeable structures
- Where bank must be stabilized and heavy machinery is not available to the site
- A retaining or toe wall is needed to stabilize the bank
- An excessively steep slope must be stabilized and vegetative or mechanical means of stabilization (i.e. pulling back bank) are not feasible due to site conditions and location

4.2 Anchoring

Recommended anchor – Duckbill Anchors for cable tie-back installation.

The DUCKBILL earth anchor has been developed to function in the total range of soils.

The DUCKBILL anchor works very much like a toggle bolt. The anchor body is driven into the soil with the re-useable drive steel (drive rod). Once the anchor body is placed to the proper depth the drive steel is removed. A backward pull on the cable then rotates the anchor body in the ground until it is perpendicular to the cable. This is called anchor-locking the anchor. Because the DUCKBILL is driven into the earth, it is actually compacting the soil around it, not disturbing it. As the anchor is anchor-locked it cuts through the compacted soil into undisturbed soil and further compacts the soil. One of the most important features of the DUCKBILL anchoring concept is the ability to proof-test the anchor during normal installation. The anchor locking operation can be a proof-test of the anchor. By measuring the force required to anchor-lock the anchor the installer knows the actual holding capacity of the installation.

Design must take into account forces and soil characteristics. 88-DB is suitable for most installations. Specifications as follows:

DUCKBILL MODEL #	RATED CAPACITY	DRIVE ROD DIAMETER	MINIMUM DEPTH OF INSTALLATION INTO BANK
Model 88-DB1	3,000 lbs.	3/4"	3 1/2'



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Model 138-DB1	5,000 lbs.	1'	5'
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The anchors are rated in an average soil condition. Higher capacities can be expected in harder soils and lower capacities in softer soils. The rating is mainly useful as a reference for anchor selection. Proof-loading is the only way to insure the exact capacity of each installation.

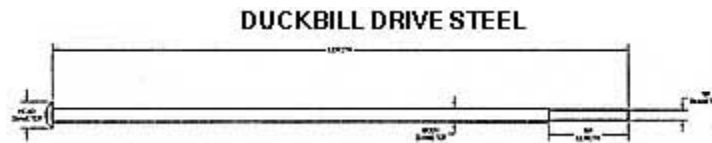
Installation

The first step in any installation is to select the proper anchor for the job. Keep in mind the maximum load expected and add a reasonable safety factor.

Driving the anchor

The DUCKBILL® can be driven to almost any depth at any angle. Start by inserting the drive-steel into the anchor body. Use a sledge hammer, fence post driver or a power driven jack-hammer to drive the anchor to the proper depth.

Drive Steel



FOR USE ON ANCHOR	PART NUMBER	DESCRIPTION	LENGTH INCHES	BODY DIAMETER INCHES	HEAD DIAMETER INCHES	TIP LENGTH INCHES	TIP DIAMETER INCHES
88-DB	50012	DS-88	48	.75	1.50	N/A	.75



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Locking the Anchor

After the anchor has been driven to depth, the drive steel is retracted from the anchor. Pull back on the anchor cable to toggle the anchor into the perpendicular position. In average soils a rule of thumb is that the length of pull should equate to the length of the anchor. For example: Model 88 anchor body measures 6" inches. A pull of 5-6" will rotate the anchor into a completely perpendicular position. Several methods are used to anchor lock the anchors.

Anchor locking by hand

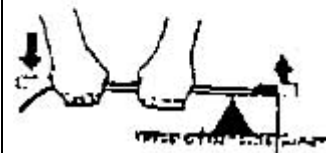
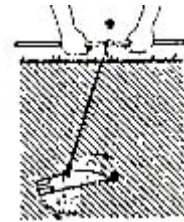
The smaller DUCKBILL models may be locked by hand. Insert the drive steel through the cable loop or wrap the cable around the drive steel to fashion a "T" handle. Pull on the drive steel to anchor-lock the anchor. A fulcrum is also very useful in locking anchors by hand.

Come-alongs and fence stretchers

These tools work very well providing that there is a substantial counter anchor nearby. A truck bumper for example.

No matter what method is used, it is critical that the anchor be properly locked before tying off the object to be anchored.

An anchor not properly locked prior to attaching will result in significant pull out before the anchor self locks. Obviously this is not desired. Failure to install and lock the anchor at the correct angle will result in the anchor cable cutting through the soil until the angles equalize. This will cause slack.



Special Soil Considerations

Soft soils

In areas where the soil proves to be softer than normal, steps should be taken to assure the capacity of the anchor. Proof-loading is especially useful in soft soils. Guesswork as to the capacity is eliminated. The installer will know immediately if the anchor point is adequate or if further steps are necessary. Backfilling and tamping the hole behind the anchor will yield somewhat higher capacity in most soft soils. Fill and tamp the hole in 3" lifts prior to anchor locking the anchor. Another option is to drive the anchor deeper in an effort to penetrate a harder layer of soil. Larger anchors may need to be placed to achieve the required load. As a last resort a number of anchors may be placed in a cluster and bridled together to form one point.



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Hard soils and rock

If excessive resistance to driving occurs it may be necessary to drill a hole. If the anchor stops moving and is subjected to excessive pounding (especially from power equipment) metal fatigue can occur and the anchor body can fracture. The DUCKBILL® anchor may be placed in a pre-drilled hole in hard dirt or rocky material, and achieve very good results. Hand augers and gasoline or hydraulic powered earth drills can be used to form the hole. A PIONJAR 120 gasoline powered breaker/drill is very useful due to the fact that it performs both drilling and driving operations.

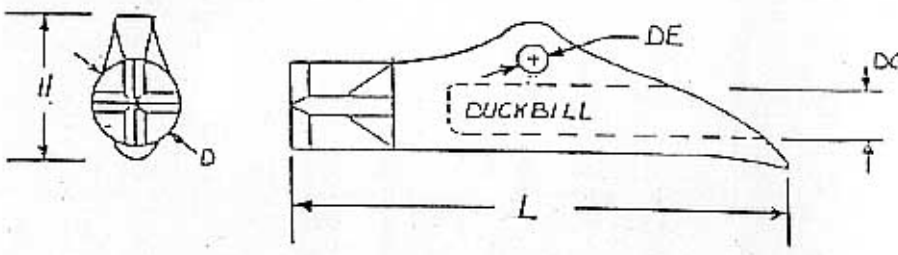
Clearance hole diameters and hard soil pilot hole diameters

Installation of anchors in hard soils can be greatly helped by the use of a pilot hole. Typically, the pilot hole has no significant affect on the holding power of the anchor. There are many acceptable methods of drilling pilot holes and many manufactures of equipment to do so. Recommended hard soil pilot hole diameters and clearance hole diameters are charted below.

Anchor model	Clearance hole diameter	Minimum pilot hole diameter for hard soil
88-DB	2.25"	2.00"
138-DB	2.75"	2.50"

Anchor specifications

ANCHOR MODEL	D (in)	L (in)	H (in)	DE (in)	DG (in)	NORMAL DEPTH (in)	HOLDING CAPACITY (lbs)
88	1.25	6.25	2.25	0.31	0.75	42	3000
138	1.90	11.50	2.75	0.38	1.13	60	5000





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4.3 Filter blanket, Geo-textile:

A synthetic filter fabric should be used under and behind the BSS structure. The following particle size relationships should exist:

Filter fabric covering a base with granular particles containing 50% or less (by weight) of fine particles (less than U.S. Standard Sieve no. 200 (74 microns))

$$D_{85} \text{ base (mm)} / \text{EOS of filter fabric} \geq 1$$

EOS = Equivalent Opening Size compared to a U.S. Standard sieve size

D_{85} = The particle size at which 85% of the constituent particles are smaller

No filter fabric should have less than 4% open area or an EOS less than U.S. Standard Sieve No. 100 (15 microns). The permeability of the fabric must be greater than that of the soil. The fabric may be made of woven or non-woven monofilament materials and should meet the following minimum requirements:

- Thickness 0.5 to 1.5 mm (20 to 60 mils)
- Grab strength 41 to 54 kg (90 to 120 lbs)
- Conform to ASTM D-1682 or ASTM D-177

Filter blankets should always be provided where seepage is significant or where flow velocity and duration of flow or turbulence may cause the underlying soil particles to move out of the bank. Most geo-textile suppliers can offer assistance, and in some cases, fabric selection software to enable proper selection of the fabric.

4.4 Scour and long-term stability

- BSS should be securely keyed into the bank and ground (bed) to assure that flows do not erode the soils beneath or around it. Start structure where it is stable, and end structure where it is stable. The upstream and downstream keys of a longitudinal structure should never be keyed in at right angles; 20 to 30 degrees relative to the structure is best. Employ smooth expansions and contractions.
- Starting at the lowest point of the slope, excavate the loose material below the bed (ground) elevation until a stable foundation is reached. The designer must take Total Scour (additive effects of Long term, General and Local Scour) into account when determining the depth of excavation below the bed.



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4.5 Vegetation – Planting considerations

- It is possible to plant BSS structures prior to filling. Vegetation can be integrated into the design and installed during construction in order to receive the maximum geotechnical and habitat benefits e.g., better soil reinforcement, more roots, faster growth, etc. The more stem length in contact with the soil, the more roots will grow; therefore, more cover will result in greater soil reinforcement, and greater habitat enhancement.
- Woody type vegetation that can withstand periods of inundation, such as willow, have been successfully planted, in conjunction with the structural elements, in the upper areas of the toe protection zone. The most important criterion for success is the type of biotechnical technique (i.e. pole planting).
- For un-rooted stock, plant 80% in soil, 20% out.
- Good stem to soil contact is critical, so tamp and water-in material
- Use a variety of techniques, plant materials and material sizes
- Determine what type and where historical vegetation was found in the system
- Consider herbaceous plants (sedges, reeds, emergent aquatics, grasses, etc.)
- Harvested cuttings should be kept moist and out of direct sunlight.
- Some cuttings benefit from soaking (up to 31 days for Black Willow). Water for soaking plants should be fresh.
- It is very important to have good soil-to-stem contact.

Most vegetative stabilization projects are carried out on banks or slopes that are devoid of topsoil and which have relatively inert subsoil. Only well adapted pioneer plants will survive and establish under these conditions. The design team should also be aware that the rooting habits of plants are extremely dependent on environmental controls. Even though certain plants are known to have tough active root systems, drought, soil compaction and poor nutrition take their tolls on any root system establishment. The designer should always take precautions to create the best possible soil medium for best possible rooting response. Unless special harvesting and refrigerated storage provisions are employed, biotechnical measures must be installed during dormancy.

Biotechnical bank stabilization offers benefits such as relatively simple installation, visual appearance, filtering of sediment, uptake of nutrients, and environmental compatibility to make it an attractive and cost effective approach.

4.6 Retaining wall and shear force considerations

The main forces acting on BSS walls are the vertical forces from the weight of the BSS and fill materials, the lateral earth pressure acting on the back face and shear forces acting on the front face. If other forces are encountered, such as vehicular loads, they must also be included in the analysis.



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The lateral earth pressure is usually calculated by the Coulomb equation. Although based on granular material, it is conservative for cohesive material. The active soil pressure force tends to overturn the wall, and this must be properly balanced by the resisting moment developed by the structure's weight and anchoring forces into the wall of the bank.

The tendency of the active earth pressure and active shear forces to cause the wall to slide horizontally must also be opposed by frictional and structural resistance.

5.0 Inspection and Maintenance

Properly designed and installed Bank Stabilization Systems require very little maintenance. BSS should be inspected periodically for scour or damage. Structural damage caused by storm events should be repaired as soon as possible to prevent further damage to the structure or erosion of the bank.

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