APPENDIX H

Stabilization Measure Fact Sheets

Prepared for

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1. EROSION CONTROL BLANKET (BANK STABILIZATION)

Erosion Control Blankets (ECBs) are a temporary rolled erosion control product consisting of flexible nets or mats, manufactured from both natural and synthetic materials, which can be brought to a site, rolled out, and fastened down on a slope. ECBs are typically manufactured of fibers such as straw, wood, excelsior, coconut, or a combination, and then stitched to or between geosynthetic or woven natural fiber netting. Various grades of biodegradable fibers and netting can be specified depending on required durability and environmental sensitivity (Salix, 2004).

Erosion Control Blanket Placed at Boeing SSFL; Geosyntec, 2010

Erosion Control Blanket from E-SenSS; Salix, 2004

ECBs are primarily used for short-term protection of slopes and stream banks for:

- Prevention of surficial soil erosion
- Protection for new vegetation
- Reduction of flow velocities
- Stabilization of disturbed areas

Considerations related to suitability, design, construction, and operations and maintenance of ECBs are included in the sections below.

1.1 Site Suitability

ECBs are used for temporary slope and channel protection and should not be planned for long-term use. Additionally, ECBs should not be used for applications involving high stresses and scour conditions. Refer to Table II in the Restoration, Mitigation, and Monitoring Plan (RMMP) for stability thresholds for ECBs.

In addition to the stability thresholds, ECB site selection should include consideration of the following:

- ECBs are not suitable for excessively rocky sites
- ECBs are not suitable where vegetation mowing will occur
- ECBs are not suitable for areas with heavy foot traffic

1.2 Design Considerations

There are a variety of ECB material types. This fact sheet includes biodegradable materials only. Non-degradable material blankets are considered turf reinforcement mats (TRMs) and are described in the TRM fact sheet. Refer to manufacturer information to determine what material type is ideal for the application the ECB is slated for.

Organic or biodegradable materials are ideal for areas where revegetation is planned to provide permanent slope stabilization. Biodegradable materials may be suited for low-velocity or high-velocity situations, depending on the material type. Low velocity materials include looser-weave natural vegetative fibers, and typically have a one to two season lifetime. These should be used for slopes of moderate grade and length and are not designed for severe conditions. High velocity materials include high-strength and denser nettings or meshes, and have a one to five season lifetime. These ECBs may be used for steeper slopes and higher velocities. Biodegradable ECB materials include:

- Jute
- Excelsior (curled wood fiber)
- Straw
- Wood Fiber
- Coconut Fiber Blanket or Mesh
- Straw Coconut Fiber Blanket

Vegetation is recommended to stabilize the channel and to keep the ECB in place. Vegetation can be included in the ECB design as follows:

- Live pole cuttings, crimping, and seeding can be used to secure ECB in addition to manufacturer recommended staples
- Fascine bundles can be utilized to breakup long slopes
- Fiberschines can be utilized for toe of slope stabilization

1.3 Construction Considerations

ECBs should be installed as described below such that damage to channels and streambanks during installation is minimized.

Preparation of site:
- Grade and shape the area of installation
- Remove rocks, clods, vegetation and other obstructions prior to placement of ECB to ensure direct contact with soil
- Loosen top 2-3 inches of soil to promote vegetative growth
- Seed the area prior to placement of ECB for revegetation according to landscaping plans

ECBs must be anchored in place by one of the following practices:
- U-shaped wire staples, minimum 11 gauge wire steel with 8 inch legs and 2 inch crown
- Metal stake pins of 0.188 inch diameter steel with 1.5 inch steel washer at head of pin, 8 inches in length
- Triangular wooden stakes
- Staples and metal stakes should be installed flush with soil surface

1.4 Maintenance and Operations

Maintenance requirements for ECBs are included in Table VII in Section 6 of the RMMP. Also refer to manufacturer instructions for specific operations related to different ECB materials.

2. TURF REINFORCEMENT MAT (BANK STABILIZATION)

Turf Reinforcement Mats (TRMs) are similar to Erosion Control Blankets (ECBs), but they are permanent, designed to resist shear and tractive forces, and are usually specified for banks subjected to flowing water. They are designed to enhance the natural ability of vegetation to protect against erosion. The mats are composed of ultraviolet (UV) stabilized polymeric fibers, filaments, and/or nettings, integrating together to form a three-dimensional matrix.

As such, vegetated TRMs can resist higher tractive forces than either vegetation or TRMs can alone (Salix, 2004).

TRMs are largely used for long-term or permanent applications pertaining to the following:

- Prevention of channel and streambank soil erosion
- Protection of soil from scouring forces
- Enhancement of vegetative development and growth
- Reduction of flow velocities

TRMs do not lose efficacy when soil boundaries shift or subside following installation (Salix, 2004).

Photos of Turf Reinforcement Mats from E-Senss; Salix, 2004

Considerations related to suitability, design, construction, and operations and maintenance of TRMs are included in the sections below.

2.1 Site Suitability

TRMs are designed for long-term slope stability and vegetation establishment purposes. While TRMs can withstand higher velocities than ECBs, they should not be used for applications involving high stresses and scour conditions. Refer to Table II in the RMMP for TRM stability thresholds.

Note: TRMs will protect vegetation, but may delay establishment due to lower soil temperatures.

2.2 Design Considerations

TRMs typically consist of polypropylene, polyethylene, nylon, or other non-degradable synthetic materials. There are a variety of TRM types, including those listed below. Refer to manufacturer information to determine what material type is ideal for the application the TRM is slated for.

Non-biodegradable and synthetic materials used for TRM applications include:

- Plastic netting
- Plastic mesh
- Synthetic fiber with netting
- Bonded synthetic fiber
- Combination synthetic and biodegradable materials

Vegetation is recommended to be included to stabilize the channel and to keep the TRM in place. Vegetation can be incorporated into the TRM design as follows:

- Live pole cuttings, crimping, and seeding can be used to secure TRM in addition to manufacturer recommended staples
- Fascine bundles can be utilized to breakup long slopes
- Fiberschines can be utilized for toe of slope stabilization

2.3 Construction Considerations

Installation of TRMs should be conducted as described in the lists below.

Preparation of site:

- Grade and shape the area of installation
- Remove rocks, clods, vegetation and other obstructions prior to placement of TRM to ensure direct contact with soil
- TRMs can be installed after seeding the underlying soil or can be installed below soil fill, which is then seeded

TRMs must be anchored in place by one of the following practices:

- U-shaped wire staples, minimum 11 gauge wire steel with 6-12+ inch legs
- Metal stake pins of 0.188 inch diameter steel with 1.5 inch steel washer at head of pin, 8 inches in length
- Staples and metal stakes should be installed flush with soil surface
- See manufacturer guidelines for required anchor size and installation

TRMs should be installed such that damage to channels and streambanks during installation is minimized.

2.4 Maintenance and Operations

Maintenance requirements for TRMs are included in in Table VIII in Section 6 of the RMMP. Also refer to manufacturer instructions for specific operations related to different TRM materials.

3. RIPRAP CHECK STRUCTURES (IN-STREAM GRADE CONTROL)

Riprap check structures (also called check dams) are ramps or low weirs with aprons made from riprap or small boulders. Check structures allow for a smaller effective slope of the channel, reducing the velocity of flows. They are typically installed in series. The structures are built by placing rock fill within an existing channel, keying the structure into the bed and bank if the channel is erosive, and maintaining a low flow point at the center of the structure. They are constructed such that the upstream slope of the rock fill is steeper than the downstream slope. Well-constructed riprap check structures can prevent or retard channel bed erosion and upstream progression of "knickpoints" and headcuts, reduce shear stresses on potentially erosive banks located immediately upstream, as well as provide pool habitats for sedimentation and aquatic biota.

Riprap Check Structure photos from E-SenSS; Salix, 2004

Check structures can be installed for temporary or permanent purposes. Applications include:

- Temporary grade control in eroding channels that will be filled or stabilized at a later date.
- Erosion prevention in temporary channels where a non-erodible lining is not practicable.
- Temporary erosion protection in vegetated channels as vegetation is getting established.
- Permanent grade control in small open channels with constructed spillway and hardened riprap apron

Considerations related to suitability, design, construction, and operations and maintenance of check structures are included in the sections below.

3.1 Site Suitability

Check structures can be used for both temporary and permanent applications for a range of slope features. Refer to Table II in the RMMP for check structure stability thresholds.

In addition to the parameters listed above, check structure site selection should include consideration of the following:

- Check structures should not be used in already-vegetated channels, as damage to plant life may occur

- Check structures should not be used in streams with extended base flows

3.2 Design Considerations

Check structures will result in a reduced effective slope, which will slow down flows but will also reduce the capacity of the system. Capacity should be calculated with the reduced slope to determine that it is sufficient. If needed, the ditch or swale into which check structures are being installed may be widened.

Generally, the toe of the upstream check structure should be constructed at the same elevation as the top of the downstream structure. The center of the check structure should be lower to direct flows to the middle of the channel. The check structures should be sized such that high flows travel safely over the check damage without upstream flooding or damage to the structure.

Small pools will form between check structures in series. Backwater from a downstream check structure should reach the toe of the check structure directly upstream.

Riprap check structures are typically constructed of 8 to 12 inch rocks.

3.3 Construction Considerations

Considerations should be taken during construction to maximize the efficiency of the check structures and reduce damage to the channel.

- Riprap or boulders should be installed mechanically or by hand.
- The check structure must span the entire width of the channel.
- If installed in series, the first check structures should be installed approximately 16 feet from culvert outlets, then at regularly spaced intervals thereafter.

For steep slopes and high flows, the following measures should be taken to reinforce the check structures:

- Non-woven geotextile fabric should be installed under and around the check dam to prevent erosion around the structure.
- Structure sections should be keyed into the channel banks and bottom.
- Extended rock aprons may need to be installed upstream or downstream of the structure.

3.4 Maintenance and Operations

Maintenance requirements for check structures are included in in Table VI in Section 6 of the RMMP.

4. ENERGY DISSIPATION RIPRAP

Energy dissipation riprap includes both loose riprap stones and hardened (grouted) riprap. These measures can be used for erosion protection at the outlets of culverts, conduits, or channels, as well as protection on channel banks.

Loose riprap outlet protection consists of an apron of placed riprap stone located at the outlet of a concentrated discharge, as described above. Riprap aprons can be used to reduce surface water velocity and dissipate energy of flow exiting a storm drain pipe before it flows into erodible receiving channels. A benefit of utilizing loose riprap, as opposed to grouted riprap or gabions, is that the material can potentially fall into scour holes that may be created from high discharge events, thus making it a more adaptive measure.

Loose riprap;
http://www.p2pays.org/ref/02/01524/urbst95.jpg

Grouted riprap consists of riprap mixed with concrete grout which fills the interstitial space between the stones. It is a hardened stabilization measure which is appropriate to use when the anticipated design velocities and shear stresses are higher than the stability thresholds associated with vegetated measures, such as ECBs and TRMs, and loose riprap. Grouted riprap is used primarily for energy dissipation at the outlets of culverts, conduits, or channels. Grouted riprap can also be used to reinforce the bed and banks of channels susceptible to erosion. When utilized for outlet energy dissipation, grouted riprap aprons should be designed with sufficient toe down so that bed scour does not undermine the structure.

Grouted riprap;
http://www.fs.fed.us/eng/pubs/html/wr_p/99771804/images/fig11.jpg

4.1 Site Suitability

Energy dissipation riprap should be used where discharge velocities are erosive and can be used for a variety of flow conditions. Stability thresholds are included in Table II in the RMMP.

In addition, the following points should be taken into consideration:

- Energy dissipation riprap may negatively impact the channel habitat
- If subjected to freeze and thaw, grouted riprap may erode

4.2 Design Considerations

Depth of flow, roughness, gradient, side slopes, discharge rate, and velocity should be considered in the design of the energy dissipation. The sizing of the riprap structure is dependent on the forces expected at the culvert outlet. Where flows are conveyed in open channels such as ditches and swales, use the estimated discharge rate for selecting the apron length and rock size.

Design flows should be same as the culvert or channel design flow but should be at least equivalent to the 5 year flow for temporary structures planned for one rainy season, or to the 10 year peak flow for temporary structures planned for two or three rainy seasons.

Other design considerations include:

- Larger diameter stone is heavier and can resist higher shear stresses without movement. Durable, angular rock provides the best erosion control results.
- Inadequate drainage can lead to water build-up behind grouted riprap, resulting in breakage of grouted riprap.

4.3 Construction Considerations

Considerations should be taken during construction to maximize the efficiency of the check structures and reduce damage to the channel.

- Filter fabric should be installed prior to placement of loose or grouted riprap. Secure filter fabric into place by keying fabric into slope.
- Riprap or boulders should be installed mechanically or by hand; rocks should not be dumped into the energy dissipation riprap location.
- Riprap apron should be aligned with the receiving channel and should be installed straight throughout its length.

4.4 Maintenance and Operations

Typically, maintenance of energy dissipation riprap is not intensive, other than after large storms and high flows. High flows can wash away rock and leave area susceptible to erosion, and riprap should be repaired immediately after such events to ensure that the riprap is operating properly. Refer to Table X in Section 6 of the RMMP for other maintenance activities.

5. VEGETATED RIPRAP (BANK STABILIZATION)

Vegetated riprap is a layer of stone and/or boulder armoring that is vegetated using pole planting, brushlayering, and live-staking techniques. The goal of this method is to increase the stability of the bank, while simultaneously establishing riparian growth within the rock and overhanging the water, to provide shade, water quality benefits, and wildlife habitat. Vegetative riprap combines the widely accepted, resistive and continuous rock revetment techniques with deeply-planted biotechnical techniques. Vegetation has the added benefit of potentially increasing bank tensile strength due to roots, stems, and branches (Salix, 2004).

Vegetated Riprap; both from E-SenSS (Salix 2004)

Also refer to the "Energy Dissipation" fact sheet for more information about riprap systems.

5.1 Site Suitability

Vegetated riprap is appropriate for high-velocity sites, and adding vegetation allows for ecological benefits. For stability thresholds for vegetated riprap, see Table II in the RMMP.

In addition, the following points should be taken into consideration:

- Vegetation can reduce stream flow capacity, so this approach should not be used if flow capacity is of concern.

5.2 Design and Construction Considerations

There are a variety of riprap vegetation methods. Vegetation methods are summarized below (Salix, 2004):

- <u>Willow Bundles:</u> This installation method requires installing long poles and branches between riprap. While simple, the cuttings that are not in contact with soil will not become established, reducing the vegetative benefit.
- <u>Bent Poles:</u> This method may be used with filter fabric and involves planting of live willow logs or poles in riprap. Poles may vary in length from five to sixty feet.
- <u>Brushlayering and Pole Planting:</u> This method allows for the most immediate ecological benefits, but it is the most complex. This involves pole planting through riprap as well as installing brush at an opposing angle to poles to provide added structural support while poles are becoming established.

If riprap needs to be revegetated, the following method may be used:

- Joint or Live Stake Planted Riprap: This method involves planting of live wood stakes into preexisting riprap.

5.3 Maintenance and Operations

Typically, maintenance of vegetated riprap is not intensive, other than after large storms and high flows. High flows can wash away rock and leave the area susceptible to erosion, and riprap should be repaired immediately after such events to ensure that the riprap is operating properly. Refer to Table IX in Section 6 of the RMMP for other maintenance activities.

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