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USACE / NAVFAC / AFCEC **UFGS-31 32 39 (August 2008)**

Preparing Activity: USACE **Superseding**
UFGS-31 32 39 (April 2006)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2025
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DIVISION 31 - EARTHWORK

SECTION 31 32 39

BIOENGINEERING PRACTICES FOR STREAM BANK AND SHORELINE STABILIZATION

08/08

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SECTION 31 32 39

BIOENGINEERING PRACTICES FOR STREAM BANK AND SHORELINE STABILIZATION
08/08

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NOTE: This guide specification covers the requirements for bioengineering practices for stream bank and shoreline stabilization. This section was originally developed for USACE Civil Works projects.

Adhere to UFC 1-300-02 **Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.**

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR)**.**
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PART 1 GENERAL

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NOTE: This guide specification covers bioengineering practices as related to stabilizing stream banks and shorelines using natural vegetation by itself or in conjunction with stone, rock, dead vegetation structures, or organic erosion control matting. The methods may also be applied to small tributaries, gullies, canals, and drainage channels. The use of the term bioengineering refers to soil bioengineering in this specification. Soil bioengineering is a method of stabilizing soils using living and dead plant material and biodegradable manufactured products. Bioengineered structures should not at anytime be constructed on

embankments, levees, or flood control structures where there is a risk of failure of the project from a single event or a storm with a recurrence interval of 10 years.

This specification focuses only on stream banks and shorelines at or near the edge of water. This specification is not for coastal protection. This specification does not include requirements for hard or dead vegetation structures that are for erosion control or habitat restoration. This specification does not include the use of geosynthetic materials, metal, or requirements for traditional stone or rock hardened structures for bank protection. The designer should be cognizant that the structures described in this specification often must be augmented with the establishment or enhancement of vegetative zones on the landward portions of the banks or shores. Refer to TR-EL-97-8 <u>Bioengineering for Stream Bank Erosion Control Report 1 Guidelines</u> for guidance.

The designer should use caution in the selection of bioengineering methods for bank stabilization. Many bioengineering methods provide improved erosion resistance to stream banks or shorelines. However, bioengineering methods are not designed to repair inherently unstable stream banks or shorelines, which require engineering design, soil improvement, or extensive soil removal prior to vegetation efforts. Bioengineering methods will not prevent bank failures due to poor soil conditions, over steepened or undercut slopes, rapid draw down or drop of water levels, or where flow velocities exceed bioengineering established tolerances. Improved stability due to the development of root mats in the soil may take two or more years to be realized. Therefore, the desired bioengineering methods or bioengineered structures must be selected based on-site specific conditions, realistic expectations of performance, and consultation with soil, hydraulic, and structural engineers and environmental resource personnel.

The designer should compare bioengineered structures to more traditional stabilization methods, such as stone revetments or concrete channel lining, in terms of cost and performance before final selection of stabilization methods. Traditional stabilization methods may be better suited and more economical and provide greater protection at lower costs than bioengineered structures. The designer should review case histories on the performance and maintenance of existing bioengineered structures during selection and design. It is important to anticipate possible future failures of banks due to toppling of large mature vegetation, changes in vegetation species, and impact on the structure and vegetation by animal and human activities. Hard

structures may be preferred at locations where the risk of loss of life or property is apparent or where rapid changes in land use may pose such a risk in the future.

This specification is applicable to semiarid and temperate regions. The construction of bioengineered structures in arid regions requires special attention to the selection of appropriate plant species, water supply, irrigation, and maintenance for successful completion and performance. Other bank protection alternatives may be more cost effective than bioengineered structures in arid regions.

The construction of bioengineered structures in cold climates requires additional design efforts to reduce or prevent damage. Structures may be damaged by the impact of ice flows or ice blocks in the stream or river. The development of ice at the stream bank that incorporates the vegetation of the structure may result in vegetation loss or increased forces on the structure. Consult with a hydraulic engineer on methods to minimize damage to the structure. The percent of damage and mortality to vegetation may be higher due to frost or severe cold. Free draining soils should be used to reduce the amount of frost heave on structural components. Structures may not be suitable in climates with deep frost depths where surficial soil may be subject to flow when disturbed during the spring thaw. Bioengineering methods may not be suitable in cold regions where plant development and growth are stunned due to the climate and where root development, which is required for performance of the structure, may require more than 2 years. Consult with regional experts when planning bioengineered structures in these regions.

Planning of the bioengineered structure requires a multidisciplinary team approach. The designer should consult at a minimum with personnel in soil mechanics, structural design, hydraulic engineering, biological sciences, botany, regulatory, cost estimating, contracting, and construction during the initial development of conceptual designs, comparison of alternatives, and throughout project execution as required. Clear objectives for the selection, performance, and risk of the structure must be developed early in the planning phase. Sponsors and the public must be advised about the cost, performance, safety, benefits, and risks of the selected structure during the early stages of design. The designer should be aware of the need for construction oversight during installation to ensure quality.

The designer should include the long-term costs of maintenance in cost estimates and the amount of

maintenance required for adequate and safe performance of the structure. Monitoring or after care of the structure may be necessary for 2 to 10 years after the structure is completed to ensure the vegetation becomes established and the structure is meeting performance requirements. The impact of changes to site conditions should be evaluated during planning for safety and maintenance requirements. The effect of loss, damage, and change of vegetation species on structure performance should be discussed. The effect of disease, fire, harvesting, or removal related to plants in the structure and impact on performance must be elevated. Requirements for vegetation replenishment, pruning, selective cutting, and replacement should be included in maintenance planning. Repair to the soil, backfill, or hard materials in the structure must be addresses. The accretion of sediment on stream banks due to the trapping of sediment by vegetation should be evaluated for loss of stream conveyance and decreased slope stability due to the increased weight of accreted sediment. Damage due to wave action from storms, navigation, or boats should be determined.

Clear acceptance criteria should be defined for the project as well as warranty requirements. Acceptance and warranty requirements may be more stringent and require longer periods of time than traditional bank stabilization projects due to the need for vegetation to become established.

The following stream flow velocities are recommended for maximum limits on the selected methods of stream bank or channel stabilization.

Vegetative protection 2.5 m/s 8 feet per second (fps) Structural and bioengineering

Woody material, 2.5 m/s 8 fps

Woody material and herbaceous species, 1.5 m/s 5 fps

Herbaceous alone, 1 m/s 3 fps

(USDA TN Plant Materials No 23, Technical Notes, September 1993)

Flow velocities greater than 2.5 m/s 8 fps may require reinforced matting or hard structures.

Bioengineering methods require construction techniques and materials, which are described by other existing specifications. The following specifications should be included with this specification in the bid package depending on site conditions and design objectives.

Minor clearing and grubbing of vegetation is provided in this specification with an emphasis on salvaging cleared or grubbed material for the construction of the bioengineered structure. For

extensive clearing and grubbing of vegetation for site construction or access, refer to Section 31 11 00 CLEARING AND GRUBBING.

Minor earthworks may be required for the construction of the bioengineered structure. In addition, select fill or backfill materials may be needed. This specification only includes the requirements for the minimal earthworks necessary for key trench installation and surface roughening. For slope reduction, benching, and material specification, refer to Section 31 00 00 EARTHWORK.

The construction of bioengineered structures often results in the exposure of soils that require protection from erosion. This specification mentions the need for erosion control products but does not provide the specifications or installation methods for these products.

Bioengineering methods may incorporate stone or rock. For the requirements for hard armor, refer to Section 35 31 19.40 STONE REVETMENTS.

Seeding is an important component for many bioengineered structures. To specify the requirements for the installation procedures for seeding, refer to Section 32 92 19 SEEDING.

Fencing may be required during and after construction to protect bioengineered structures and associated vegetation from damage due to human and animal activities. For the requirements for fencing, refer to Section 32 31 13 CHAIN LINK FENCES AND GATES or 32 31 26 WIRE FENCES AND GATES.

Bioengineered structures are commonly placed in or adjacent to bodies of water. Employ Best Management Practices for storm water pollution prevention in accordance with Section 01 57 19 TEMPORARY ENVIRONMENTAL CONTROLS.

Portions of this specification may not be consistent with sections in the construction contract. The designer will delete unnecessary paragraphs of this specification or provide full requirements to portions in this specification that may conflict with or contradict other sections in the contract. These conflicts, contradictions, or lack of requirements will be resolved between this section and other specifications and the construction contract before the design package is released for review.

For additional information concerning bioengineering practices, methods, structures, construction, and performance, see the following publications:

United States Department of Agriculture, December

1996, Engineering Field Handbook, Chapter 16, Stream Bank and Shoreline Protection.

United States Department of Agriculture, October 1992, Engineering Field Handbook, Chapter 18, Soil Bioengineering for Upland Slope and Erosion Reduction.

Muhlberg, K, Gayh, A, and Moore, Nancy J., 1998, Stream Bank Revegetation and Protection, A Guide for Alaska, Alaska Department of Fish and Game, Technical Report No. 98-3, 75 p.

Schiechtl, H. M., and Stern, R., 1997, Water Bioengineering Techniques for Watercourse Bank and Shoreline Protection; Blackwell Science Ltd, London, 186 p.

TN Plant Materials No. 2, USDA, September 1993, How to Plant Willows and Cottonwoods for Riparian Rehabilitation.

The publications listed above are a small sample of the numerous publications available with related guidance for bioengineering practices. The designer is encouraged to obtain and review local and State publications that are specific to the region of project work. These publications generally contain useful information on suitable plant species, soil and stream conditions, and regulations. Insert project specific references as needed. Numerous guidance and case history publications on bioengineering by the USACE may be reviewed at http://libweb.wes.army.mil.

Publications may contain drawings of proposed structures that are of value for reference and incorporation in design documents. It is strongly recommended that the designer obtain and review drawings of the various bioengineering methods and structures during the preparation of this specification. These drawings lend considerable clarity to the descriptive text about the structures. These drawings should be included in the specification package as attachments to this specification and should be modified to reflect site-specific conditions and restraints.
****

1.1 SUMMARY

****
NOTE: Provide requirements that are specific to the work and that the Contractor will be responsible for completing.

The Contractor should submit sufficient drawings to clearly define site layout, structure, details, site conditions, extents of features, and the like to

allow adequate planning and cost estimating. The designer will delete or add drawings that are necessary to meet project needs.
****

The work by the Contractor consists of furnishing and installing bioengineered features and structures. Submit design, details, cross sections and profiles of site engineered structures to enhance [stream bank] [and] [shoreline] stability within project limits and in areas outside the project limits where the soil surface is disturbed from work under this contract [and as noted on the drawings]. Include in this work all necessary evaluation, design, materials, labor, supervision, and equipment for installation of a complete system and after construction maintenance. Submit a list of all equipment and tools that will be used for the construction of the bioengineered structure. Include information on products used in equipment such as fuel, hydraulic fluids, and the like. Coordinate this section with the requirements of Section [31 11 00 CLEARING AND GRUBBING] [and] [31 00 00 EARTHWORK] [and] [35 31 19.40 STONEREVETMENTS][and][32 31 13 CHAIN LINK FENCES AND GATES][32 31 26 WIRE FENCES AND GATES] [and] [32 92 19 SEEDING] [and all other specifications or requirements as necessary].

1.2 MEASUREMENT AND PAYMENT

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NOTE: Add or delete products and measurement and payment as require for project specific needs.
****

1.2.1 Binder

Measure the standard binder by the linear meter foot placed.

1.2.2 Live or Dead Cuttings

Measure live or dead cuttings by number and type of individual cuttings. No payment will be made for cuttings not required for use in the structure, defective, or that are trimmed from cuttings. Include all harvesting, soaking, transportation, and preparation in the measurement for payment.

1.2.3 Materials

Measure soil and rock by the [cubic meter yard] [metric 2000 pound ton].

1.3 REFERENCES

****
NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also

use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM D6765	(2012) Standard Practice for Live Staking

U.S. ARMY CORPS OF ENGINEERS (USACE)

TR-EL-97-8	(1997) Bioengineering for Streambank Erosion Control; Report 1, Guidelines

1.4 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy and Air Force projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

The designer should ensure adequate time is allowed for the review of submittals before the start of work. The designer will clearly note the time for

submittals, where required. Insert the number of copies required as needed.

The submittals listed below are for general bioengineering projects. The designer will edit this section to tailor the submittals to the project needs and requirements and include submittals not listed below as necessary.
****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submittals not having a "G" or "S" classification are for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Existing Site Conditions

Site Evaluation Plan

Permits and Regulations

Construction Work Sequence Schedule

Seed Establishment Period

Dewatering; G, [_____]

SD-02 Shop Drawings

Staging area

Structures; G, [_____]

Vegetation

Harvest Site Restoration

SD-03 Product Data

Materials

Stakes

Binders

Fertilizer

Sealing of Harvest Cuts

Painting of Stakes and Poles

Lumber

Logs, Trunks, and Brush

Equipment

Harvesting and Soaking Records

SD-04 Samples

Soil

Excavated Sediments

Surface Water

Groundwater

SD-06 Test Reports

Material Testing

SD-07 Certificates

Installer's Qualification

Personnel Qualifications

Seed

Vegetation

Binders

SD-10 Operation and Maintenance Data

Maintenance Instructions; G, [_____]

SD-11 Closeout Submittals

Maintenance Records

Final Project Report

1.5 QUALITY ASSURANCE

Ensure all Contractor and subcontractor personnel are fully qualified to perform the specified work and provide the Contracting Officer with such documentation no less than [30] [_____] days before the notice to proceed. Do not start work until the Contracting Office is satisfied that the Contractor meets or exceeds all required qualifications. All Contractor records, documents, and work may be inspected by the Contracting Officer or designated representative at any time. Replace or repair immediately items not meeting quality requirements at no cost to the Government.

1.5.1 Regulatory Compliance

Perform the specified work in accordance with all applicable Federal, State, and local regulations.

1.5.2 Pre-Installation Conference

Coordinate and conduct meetings with the USACE and all subcontractors prior to the start of any work to ensure all work requirements are fully understood and will be performed. All of these meetings must take place in the presence of the Contracting Officer.

1.5.3 Substitutions

Substitutions will not be allowed.

1.5.4 Qualifications

1.5.4.1 Installer's Qualification

Submit the installer's company name and address; training and experience and or certification. The installer must be certified by the manufacturer for any special training and/or experience required for installation.

1.5.4.2 Personnel Qualifications

Submit a list of personnel working on the project including name, title, and statements of their current positions and previous experiences. Use selected personnel that have been involved in bioengineering design and construction efforts similar to the proposed site work within the last 2 years.

1.6 DELIVERY, STORAGE, AND HANDLING

****

NOTE: Provide specific information on required delivery procedures, inspection requirements and methods, special storage needs, and specific handling methods.

Edit this section to include materials that are specific to the project work. Add or delete materials or products as required.

Sediment samples should be collected for mechanical and chemical analyses. Rock and stone should be tested for toughness, durability, chemical stability, and freeze and thaw at a minimum. Vegetation to be used in construction should be tested for health and presence of disease. All analyses must be preformed by analytical laboratories that are certified by the USACE. The designer will add or delete sample and testing requirements to this section as needed. Specify the specific tests and methods adjacent to the sample or refer to the accompanying specification in which this information is contained.

****

Submit a list of nonvegetative materials to be used in the construction of bioengineered feature or structure. Include manufacturer's literature regarding physical characteristics, limitations, and application or installation instructions. Store materials in designated areas as recommended by the manufacturer and that are protected from direct exposure to the elements, moisture, and any potential damage. Do not drop containers from trucks. Provide material free of defects that would void required performance or warranty. Deliver manufactured items in the manufacturer's original sealed containers and stored in a secure area.

Prior to delivery of materials, submit certificates of compliance attesting that materials meet the specified requirements. Include the following for items listed in this section:

a. Certification of recycled content or,
b. Statement of recycled content.
c. Certification of origin including the name, address and telephone number of manufacturer.
d. Certification for binders showing EPA registered uses, toxicity levels, and application hazards.

1.6.1 Erosion Control Blankets

Furnish erosion control blankets in rolls with suitable wrapping to protect against moisture and extended ultraviolet exposure prior to placement. Label erosion control blanket rolls to provide identification sufficient for inventory and quality control purposes.

1.6.2 Seed

Inspect seed upon arrival at the job site for conformity to species and quality. Reject seed that is wet, moldy, or bears a test date five months or older. Store seed in a cool dry area protected from moisture.

1.6.3 Lumber

Inspect lumber for straightness and defects. Reject warped, damaged, or used lumber. Do not store lumber directly on the ground and protect from moisture until the time of installation.

1.6.4 Vegetation

Inspect vegetation cuttings, herbaceous plants, and clump plantings for species, size, health, and preparation. Reject diseased, improperly sized, and incorrect species. Specific requirements for storage and handling are provided below.

1.6.5 Earth Materials

Provide select fill, top soil, stone, rock, aggregate, and sand meeting design specifications. Store excavated sediments and fill in well drained areas, separated from the ground by a non contaminating isolation barrier. Reject material not meeting specifications or with contained physical or chemical contaminates.

1.6.6 Logs, Trunks and Brush

Use logs, trunks, and brush of the size and quality specified. Place materials in organized manner in stock piles near the work site ensuring they were not damaged during delivery, storage, or installation. Do not rest materials directly on the ground or expose to precipitation if they are to remain at the storage site for longer than [4] week before installation. Use coverings for the logs, trunks, or brush that do not promote mold or rotting.

1.7 PROJECT/SITE CONDITIONS

1.7.1 Environmental Requirements

****
NOTE: Include information on the physical and environmental characteristics and limitations at the work site e.g. temperature, illumination, slope, water depth, etc.
****

[_____]

1.7.2 Existing Site Conditions

****
NOTE: Include information on site conditions, references to documents and reports about site conditions, and requirements for the Contractor to obtain all literary information available for site planning and design. This paragraph should include the need for surface mapping, subsurface exploration, hydraulic analyses of streams or lakes, and all other information necessary for successful design and construction that is not provided by the Government. Also note that lack of supply of such information by the Government does not relieve the Contractor of any such necessary research or studies.
****

Submit a detailed description of the existing site conditions prior to construction work including but not limited to literary references, site visits, public or private reports, studies (engineering, ecological, environmental, etc.) and topographic or other maps. Submit [_____] copies of this survey to the Contracting Officer [_____] days before the start of work.

1.7.3 Site Evaluation Plan

****
NOTE: Consider the following items during site evaluation and project planning to improve the success of the bioengineered structure. The items below are not all inclusive for every site. Other evaluation factors may be relevant based on site specific conditions.

Do not construct bioengineered structures:

- where soil or water is contaminated with compounds or elements that may damage live vegetation or where disturbance may result in expansion of the area of contamination,
- at locations with unstable slopes that can not be mitigated as part of construction,
- where robust stabilization structures are required for protection of navigation structures, levees, or embankments,

- where damage of the structure could pose a risk to loss of life or property,
- where long-term maintenance and after care of the structure and vegetation is not desired,
-where climate or hydraulic conditions may threaten establishment of vegetation,
- where the streambed is degrading and where such degradation can not be stopped by altering hydraulic conditions of the stream or by the use of hard armor,
- along stream banks or shorelines subjected to high wave action from storms or watercraft,
- in areas subject to shade from other plant species that may hinder growth of the selected plant species for the structure,
- in areas where the structure may not be secured from undesired animal or human traffic and subsequent damage.

Check with local, State, and Federal agencies to ensure all regulations are understood and followed. Do not alter wetland areas.

Know the mean, mean low, mean high, minimum, and maximum water elevations of the stream, river, or lake. The definitions of water levels may be defined in terms of hydrologic analyses or by observation of stream geomorphic features.

- The maximum water elevation should be the highest water possible at the site due to storm surges, waves, floods, or water storage. The elevation of debris associated with flood events or storm waves on the high bank may be used for recent high water elevations.
- The mean high water elevation is the average high water level over 19 years. This elevation is typically located where trees and brush are established on the high bank of the channel.
- The mean water elevation is the average height of water over 19 years. This elevation typically corresponds to the area where reeds and small shrubs are present on the low bank adjacent to the stream channel or shore.
- The mean low water elevation is the average height of the low water over 19 years. This water level is characterized by the upper extent of aquatic plants on the bank or swash zone at the toe of the bank or shore.
- The minimum water elevation may correspond to the minimal flow in the stream channel or lowest elevation of a lake due to drought or human activities such as irrigation or water storage. The minimal water elevation may be the bottom of the stream channel or lake if these water bodies may be completely drained.

The designer is advised to modify these definitions and water level elevations based on the growing and dormant seasons for species of vegetation used in

construction to ensure establishment, performance, and survivability. Determine the amount and rate of change of water elevations due to natural or human activities.

Determine the possible height of waves, direction, and frequency due to storms or navigation operations.

Determine the changes in current velocities and flow direction due to different stages, seasons, or storm events.

Known the sediment load, composition, size, and rates of deposition or erosion at the site.

Know the climate of the work area. Severe flooding, drought, or cold during construction or in the future may damage the structure.

Determine the requirements for regular monitoring and maintenance of the structure to ensure plant survival and structure performance.

Specify the need for and the role and responsibilities of a multidisciplinary team for design and planning, construction, and after care.

The site evaluation plan may require literary searches; subsurface and surface exploration, sampling, and testing; surface topographic, geological, biological mapping; hydraulic engineering studies; assessment of the of site in relation to residences, commercial property, and biological communities; and impact of navigation or water storage projects on the site. The report should contain sufficient information to determine if the site is viable for the proposed structure and sufficient information for structure deign and planning.

****

Furnish a site evaluation plan stating clear and concise project objectives and assessment criteria of the viability of the proposed structure based on the physical, chemical, biological, political, and social site conditions and aspects. Submit the contents of the plan developed by the Contracting Officer and the Contractor in [_____] copies of this plan to the Contracting Officer [_____] days before the start of work. The plan should contain supporting documentation and studies, which include but are not limited to climate, geological, geotechnical, hydraulic, botanical, geomorphic, project cost estimates, and regulatory and permitting requirements. Include a review of case histories of bank stabilization methods at other similar sites, reconnaissance report on site conditions and suitability for bioengineering structures or methods, design alternatives, potential problems, and recommendations for the types and methods of bioengineered structures if applicable to site conditions and uses. Include lists of all applicable permits and regulations and methods of compliance related to construction. Submit list and copies of all required and approved permits for site work and of all regulations that pertain to site work to the Contracting Officer [_____] days before the start of work. Include a report identifying the species of vegetation and plants that will be used for construction. Refer to TR-EL-97-8 for site evaluation and planning guidance. The report includes but is not limited to:

Supply of vegetation,
Harvest area and procedures,
Retention of existing vegetation,
Short and long-term interaction of selected species with existing vegetation,
Interaction of species with existing structures,
Retention or elimination of nonnative or invasive species,
Performance of selected vegetation in the proposed structure,
Maintenance and replacement.

1.8   SEQUENCING AND SCHEDULING

****
NOTE: Most bioengineered structures must be completed during the period of dormancy of plant growth unless otherwise noted. Structures completed outside of this dormant season will not be accepted by the Government unless provided with specific information on the need for such schedule and survivability of plant species used for construction. Local requirements may limit construction periods and must be fully complied with and adhered to unless granted waiver rights by the appropriate regulatory authorities. See paragraph TIME OF PLANTING in PART 3 for additional information.
****

Conduct all work [during the period of plant dormancy] [as stated below] and in accordance with all Federal, State, and local requirements for in-stream or near stream construction. The construction sequence must result in successful completion of the structure. Submit a construction work sequence schedule, detailing the work tasks and order of completion, to the Contracting Officer for approval a minimum of [90] [_____] days prior to the start of construction. Do not commence work without the approval of the schedule and construction sequence by the Contracting Officer. Construction must not occur if climatic conditions threaten the survivability of plants or worker safety. Construction sequence schedule .

1.9   WARRANTY

****
NOTE: The designer should consult with the manufacturer to ensure proper application and installation techniques for the site specific project conditions. Warranties vary with different materials and may be void if proper technical advice is not obtained. Seed germination is not covered under the warranty.
****

The structure and all manufactured materials will be under Contractor warranty for a period of [2] years including vegetation and earthworks. Stone and rock will be under warranty from decomposition for [5] years.

1.10 MAINTENANCE

****

NOTE: Bioengineered structures require observation and maintenance for up to 5 years after installation to ensure the vegetation becomes established. Observation should be done on a weekly basis for the first year and bimonthly thereafter for the second year at a minimum. A minimal level of acceptable survival of plants should be established. The Contractor should be required to replace plants that die above the allotted percentage and area of concentration that may adversely effect structure performance.

****

1.10.1 General

Include in maintenance eradicating weeds; protecting embankments and ditches from surface erosion; maintaining the performance of the erosion control materials and mulch; replacement of dead or non-viable plants; repair of soil, stone, rock, or hard structures, and protecting installed structures from human and animal activities.

1.10.2 Maintenance Instructions

Furnish written instructions containing drawings and other necessary information to the Contracting Officer, describing the care of the installed material; and including when and where maintenance should occur and the procedures for material replacement. Submit instruction for year-round care of installed products including schedule, materials, and tasks. Describe the methods for specific maintenance activities and equipment and tools required for such efforts. Include requirements on safety and regulations and permits.

PART 2 PRODUCTS

****

NOTE: Consult local codes and regulations for additional information that may effect the project before design work begins. The choice of methods and materials will be project specific and will be at the discretion of the designer. Edit the specification choices of products to best suit the needs of the project.

****

2.1 BINDERS

Submit certification for binders showing EPA registered uses, toxicity levels, and application hazards. Prior to delivery of materials, submit certificates of compliance attesting that materials meet the specified requirements and certified copies of the material certificates. Ensure all binders are biodegradable and untreated hemp or coir rope or fasteners, which are able to withstand 2 years minimum exposure to the environment of placement without significant degradation in strength or quality. Do not use steel or plastic binders or fasteners.

2.2 EROSION CONTROL ITEMS

****

NOTE: Several structures require the application or integration of erosion control products. These products include but are not limited to mulch, straw, hay, shredded bark, coir, mulch control netting, and erosion control mats. Products selected for use should be biodegradable and non-damaging to the environment in which they are placed. Sediment retention products may also be required as part of construction efforts. Mention the specific needs and types of products below.

****

Provide [erosion control products] [and] [sediment control structures or products]. Install materials and structures according to manufacturer's recommendations based on [actual site conditions] [and] [as shown in the drawings].

2.3 SEED

****

NOTE: State-certified seed is more stringently monitored than State-approved seed, and therefore, more expensive.

****

Provide seed in accordance with Section 32 92 19 SEEDING. Provide [state-certified] [state-approved] seed of the latest season's crop in original sealed packages bearing the producer's guaranteed analysis for percentages of mixture, purity, germination, hard seed, weed seed content, and inert material. Use labels in conformance with AMS Seed Act and applicable State seed laws. Provide classification, botanical name, common name, percent pure live seed, minimum percent germination and hard seed, maximum percent weed seed content, and date tested. Submit the Seed Establishment Period calendar time for seed establishment. When there is more than one seed establishment period, describe the boundaries of the seeded area specific for each period. Proportion permanent seed species and mixtures by weight as follows:

Mixture Percent by Weight	Percent Pure Live Seed	Botanical Name	Common Name
[_____]	[_____]	[_____]	[_____]

2.4 PERMANENT VEGETATION SPECIES AND MIXTURES

****

NOTE: Live or dead cuttings from locally harvested stock should be specified in this section. Nursery stock may also be used for design purposes or in areas with limited supplies of cuttings at or near the work site. Nursery stock has a higher chance of survival due to developed root systems but may add cost to the project.

The selection of the appropriate vegetation species

for the site should be made by consultation with a qualified geotechnical engineer, hydraulic engineer, biologist, and botanist based on site conditions, stability requirements, desired habitat creation, and blending ability with surrounding vegetation. The soil types, hydraulic conditions and requirements, and ability of the selected species to survive in the work area must be determined and considered in species selection. Selected species should improve or enhance slope stability and should be flexible and of low height at maturity to allow maximum conveyance of water in the channel.

At some sites, nonnative species may be more appropriate due to changed site conditions or alterations by natural or human activities. Native species may not be able to survive in such alternated settings. For restoration projects, non-native or intrusive species may need to be removed before planting native species to reduce competition for resources and to improve the survivability of the native plants. Plant species should be collected from the same watershed and near the work site to prevent the import of differing genetic stains into the project area.

Woody vegetation that matures to have trunk diameters greater than four inches should not be used. Such species when mature pose a threat of scour to the bank down stream of the trunk during high flow events. In addition, these species may develop extensive root system that may damage the structure when the tree dies and rotates into the stream or lake. In this case, the root wad typically removes a large amount of soil as it is pulled from the bank. The resulting hole may be subject to scour and result in structure damage or failure during moderate or high flow events.

Sedimentation types and depositional rates should be determined. Some streams may transport sediment that may abrade or break vegetation. Alternatively, large amounts of sediment may be deposited at the site and cover vegetation. The combined effect of the trapping of large amounts of sediment by the selected vegetation species may result in the accretion of sediment onto the bank. While this accretion of material provides additional bank protection in the short term, the long term effects may be large bank failures due to the added weight of the sediment on the bank. The structure may be damaged or destroyed if the failure plane cuts the structure. Therefore the vegetation species in such areas should allow adequate water flow through the vegetation to reduce the amount of sediment that accumulates at the site.

On banks down stream of water storage project, selected vegetation should be able to survive or

recover rapidly in the event water levels must remain at elevated levels for an extended period of time due to flood or navigation releases.

Provide specifics on quality requirements.
****

Submit classification, botanical name, common name, harvest location, plant heath, and date tested, (live or dead cuttings, nursery stock, plants). Provide permanent vegetation type and planting plan, species and mixtures for [live and dead cuttings] [and] [nursery stock] [and] [herbaceous plants] as follows:

Mixture Percent by Volume	Percent Live and Dead	Botanical Name	Common Name
[_____]	[_____]	[_____]	[_____]

Provide weed seed or noxious plants that are a maximum of 1 percent by weight of the total seed mixture. [Undesired], [non native] [and] [or] invasive vegetation species are not be allowed. Ensure all live cuttings and containerized plantings are capable of growth and rooting and free of disease or defects at the time of installation.

2.5 STAKES

Provide stakes consisting of 100 percent biodegradable materials and designed to safely and effectively secure erosion control blankets, coir logs, fascines, and other bioengineered structures for temporary or permanent applications. Ensure the biodegradable stakes are fully degradable by biological activity [within 2 years]. The stakes must exhibit ample rigidity to enable being driven into hard ground, with sufficient flexibility to resist shattering.

2.6 STAPLES

Do not use metal or plastic staples.

2.7 SYNTHETIC GRID AND SHEET SYSTEMS

Do not use synthetic grid and sheet systems.

2.8 CRUSHED ROCK, GRAVEL, SAND, STONE, RIPRAP, and BACKFILL

Provide quality of rock, gravel, sand, stone, riprap, and backfill in accordance with requirements in Section 31 00 00 EARTHWORK and Section 35 31 19.40 STONE REVETMENTS. Reject materials not meeting specified requirements and immediately replace by suitable material at no cost to the Government.

2.9 WATER

Water for irrigation, soaking of plants and cuttings, and dust control is the responsibility of the Contractor. Water must be clean, free of contaminates, and have a turbidly of less than 20 NTU. Use water from [a public source of know quality] [local surface water source] [groundwater well] near the work site. [Test water obtained from non public sources for quality in accordance with paragraph MATERIAL TESTING REQUIREMENTS.]

2.10 FENCING

****
NOTE: Permanent or temporary fencing may be required around work sites to prevent vandalism and damage to newly planted vegetation by livestock, animal, or human activities. Fencing may be temporary or permanent. Specify temporary fencing such as plastic construction fence, snow fence, or rental fence below. Use Section 32 31 26 WIRE FENCES AND GATES or 32 31 13 CHAIN LINK FENCES AND GATES to specify permanent wire and chain link fabric fences and gates if required.
****

[All fencing must be in accordance with Section [32 31 26 WIRE FENCES AND GATES][32 31 13 CHAIN LINK FENCES AND GATES].] Fencing must be temporary and consist of [_____] fence. Secure fencing to [wood] [metal T-poles] that are driven 600 mm 2 feet into the ground and extend 1.2 m 4 feet above the finish grade. Install fencing [at the start of work] [after construction]. Allow fencing to remain in place [until vegetation is established] [for 3 years].

2.11 IRRIGATION

****
NOTE: Sites may require extended periods of irrigation to ensure vegetation establishment. Irrigation systems may be on the surface or underground. Water retention in the structure in arid regions may be aided by the use of super absorbent polymers. Edit this specification for products that may be used with open trench irrigation.

Some sites may be remote and may not have electrical or water supplies available. In this case, the designer should include products for solar power, water tanks, or methods such as daily watering by water truck.
****

[All underground irrigation must conform to Section 32 84 24 IRRIGATION SPRINKLER SYSTEMS or as approved by the Government.] Provide the following products and materials for irrigation.

Product	Manufacturer	Quantity	Purpose
[_____]	[_____]	[_____]	[_____]

2.12 FERTILIZER, PESTICIDE, HERBICIDE

****
NOTE: Edit this paragraph as required. Fertilizer, pesticide, and herbicide may be required for the construction, establishment, and maintenance of

bioengineered structures. The designer will consult with a qualified botanist, biologist, landscape engineer, and regulatory agencies before selecting the use of or type of fertilizer, pesticide, or herbicide for application at the site. Products, if selected for use, should not pose a threat to water quality or the environment. Pesticides and herbicides will only be used when absolutely necessary. Use of biological methods for pest or plant control is encouraged. Provide specific product names, manufacturer, method and concentration of application, and other required product information below.

****

Provide the following products and materials.

Product	Manufacturer	Quantity/ Application	Purpose
[_____]	[_____]	[_____]	[_____]

2.13 MATERIAL TESTING

****

NOTE: Edit this section as required. Provide specific methods, procedures, sample numbers, test, and the like.

The Contractor should collect samples of select fill and site soils for physical and chemical analyses to ensure these materials are appropriate for growth of the selected plant species. Refer to specific soil requirements needed for healthy plant growth to complete this section. Imported soil or select fill must be tested to ensure the material is free of seeds or root stocks of non native or invasive species or detrimental biological organisms.

Soil samples from the surface and subsurface of the site should be collected for geotechnical and chemical analyses. Geotechnical test parameters should be at a minimum grain size with hydrometer, moisture content, density, and Atterberg limits as required. Testing of site soils and select fill for permeability, consolidation, and soil strength may also be required depending of site conditions and selected structure. Soil samples should be collected to confirm that soils at the site are not contaminated with hazardous, toxic, or radioactive compounds that would require special handling.

Samples of surface and groundwater should be collected to verify that seepage into the stream or water body at the work site is not contaminated with compounds that will endanger plant survival or pose a hazard to human health and the environment. Water that is not obtained from a public source should be

tested for biological and chemical contaminates.

Specify analytical laboratories for analyses, turn around time for samples, and holding times for chemical samples.

The soil and water samples must be collected and analyzed a minimum of 120 days before the start of construction. The analytical results must be reviewed by the Contracting Officer before work continues at the site. If hazardous compounds or chemicals are discovered, then the work will be terminated. All testing must be performed by USACE validated laboratories.

Several different types of samples and tests may be required depending on structure design, construction, and location. Soil samples should be collected for geotechnical analyses for grain size, moisture content, density, Atterberg limits, compaction, shear strength, and pH. Soil at the site and fill that may be imported should also be tested for these parameters. The chemistry of the soil should be tested to ensure the soil will support vegetation growth and is free of contaminates. Soil should be tested for deleterious microorganisms that could increase plant mortality. Surface and groundwater should be sampled for chemistry and quality.

****

Submit certified reports of inspections and laboratory tests, prepared by an independent testing agency, including analysis and interpretation of test results. Properly identify each report. Describe test methods used and compliance with recognized test standards. Collect samples of soil and water at and for use at the site, collected at the locations as shown in the drawings and at source locations for the materials or water. Collect these samples and test as specified below.

Sample	Location	Number	Test Method	Collection Method
[_____]	[_____]	[_____]	[_____]	[_____]

PART 3 EXECUTION

3.1 SITE VERIFICATION OF CONDITIONS

Coordinate, through the work schedule, the timing of land disturbing activities with the provision of erosion control measures. An erosion control plan will be required in accordance with applicable Federal, State, or local requirements. Perform erosion control operations under favorable weather conditions. When excessive moisture, frozen ground, or other unsatisfactory conditions prevail, stop the work as directed. When special conditions warrant a variance to earthwork operations, submit a revised construction schedule for approval. Do not apply bioengineering materials in adverse weather conditions, which could affect their performance. Complete all tasks necessary for the required submittals.

3.2 SITE PREPARATION

3.2.1 Temporary Construction Facilities

****
NOTE: Access roads or paths may need to be permanent to allow ease in future monitoring and maintenance. If such access is required, provide requirements or references to appropriate specifications below.
****

Establish access routes to the construction site prior to the start of work and show them on the drawings. Provide all temporary construction facilities in accordance with Section 01 50 00 TEMPORARY CONSTRUCTION FACILITIES AND CONTROLS. Provide access to the work site and harvest area by [temporary] [permanent] [roads] [and] [paths] designed for [motorized vehicles] [and] [pedestrian access] if acceptable and in accordance with regulations and property owner restrictions and permission. Select access methods that have the least impact on existing site conditions and that may be easily removed and restored upon the completion of work. Provide strict access control to the work and harvesting sites to prevent access by non-authorized personnel. Install [access gates] [barricades] at the entrances of temporary [roads] [paths] to the sites. [Secure these gates with a keyed lock and keep closed at all times when personnel are not present at the gates for access. Provide duplicate keys for the lock to the Contracting Office, landowner, authorized regulatory personnel, and fire and law enforcement as required.] [Place appropriate signage on the gates that clearly specify site access is restricted.]

3.2.2 Clearing and Grubbing

Clear access route and construction site of vegetation necessary for the construction of the bioengineered structure or staging area in accordance with Section 31 11 00 CLEARING AND GRUBBING. Efforts will be made to salvage vegetation suitable for use in the bioengineered structure.

3.2.3 Erosion and Sediment Control

Install erosion and sediment control measures prior to active construction efforts to prevent erosion of soil and offsite releases of sediment.

3.2.4 Earthwork

****
NOTE: Minor or extensive earthwork may be required as part of the construction of the bioengineered structure. This specification only includes the requirements for minor earthworks for trench excavations and soil roughening. Dimensions for minor earthworks are provided in the specific bioengineering method sections below. Site grading, shaping, or trenching for drains and utilities, and material types and gradations should be included in Section 31 00 00 EARTHWORK.
****

Slope and grade the [stream bank] [shoreline] [in accordance to Section 31 00 00 EARTHWORK] [and] [as shown on the drawings].

3.2.4.1 Trenches

Unless otherwise stated, make trenches to the depth, width, and line as shown on the drawings. Make side slopes, unless otherwise indicated, at the angle of repose. [Use material removed from the trench as backfill.] [Remove material that is removed from the trench from the site.] [Backfill trenches with select fill]. [Compact the floor of the trench to 90 percent maximum dry density and smooth.] Place backfill in 150 mm 6 inch lifts compacted [to 80 to 90 percent maximum dry density] [sufficiently to improve soil density but not impede vegetation root growth]. [Key trenches into the stream bank for a distance of 3 feet]. [Install shoring [if the trench exceeds 1 m 3 feet in depth] [as required by regulations]]. [The Contractor is responsible for dewatering of trenches for construction purposes.]

3.2.4.2 Finished Grade

Provide smooth finish grade and as shown on the drawings and in accordance with Section 31 00 00 EARTHWORK.

3.2.4.3 Surface Roughening

****

NOTE: Surface roughening should be performed on all slopes with exposed earth that are greater than 3H:1V. Surface roughening reduces surface runoff velocities and provides depressions that collect sediment, seed, and water, thereby improving vegetation establishment on the slope. Roughening may be accomplished by traversing the surface with track-mounted equipment, manual efforts such as hand raking, or terracing of the slope during excavation or the placement of fill. The method of roughening may vary depending if the slope is a new cut or fill surface or an existing or graded slope. Surface roughening should not create ridges or depression that hinder the mowing of slopes that are 3H:1V or less.

****

Roughen surfaces of all barren slopes related to work efforts by [equipment] [and] [manual efforts] to reduce erosion and promote trapping of seed, water, and sediment. Compact all lifts as specified in Section 31 00 00 EARTHWORK. [Cover surfaces of the lifts with loosely compacted soil to a depth of 100 mm 4 inches.] [Use track-mounted equipment to traverse the slope from the toe to the crest to place track imprints parallel to the contours of the slope.]

a. [Roughen slopes on new cut faces greater than 3H:1V by stair-step cuts installed during construction. Ensure the faces of the steps do not exceed 600 mm 2 feet in height in soft material or 900 mm 3 feet in height in hard material. Make horizontal spacing between the vertical faces no less than the vertical height of the step.]

b. [Roughen slopes on new fill greater than 3H:1V by the installation of lifts of compacted soil that does not exceed 200 mm 8 inches in thickness.]

c. [Roughen existing slope of graded areas by tilling, disking, harrowing and seeding, or other suitable method or equipment to produce ridges and depressions in the surface of the slope, which are parallel to the contours of the slope. Ensure these ridges and depressions do not exceed 25 mm 1 inch in depth or height above the grade surface and space no more than 250 mm 10 inches apart.]

d. Do not smooth the final roughened surface by blading or scraping. Break all large soil clumps into small clumps no more than 50 mm 2 inches in diameter and disperse on the immediate surface. Cut or fill mounds or depressions of soil that are greater in height or depth than those produced by the method of roughening with suitable material to grade and roughen to match the adjacent surface. Backfill depressions of depth greater than 150 mm 6 inches with compacted suitable material until reaching the design grade of the slope and roughened. Do not compact sand or silty sand to a density that may prevent vegetation planting and growth. Seed, plant, or cover roughened areas with erosion control products [immediately after roughening] [within [_____] days after completion of roughening].

3.3 FIRE PREVENTION

Take all efforts possible to prevent fire at the work site and harvest area as a direct result of work efforts. Provide fire prevention or suppression equipment to personnel at the work and harvest sites. Provide all equipment in compliance with applicable regulations and maintain in working condition at all times and within no more than 5 m 15 feet distant from the active work areas.

3.4 SANITATION

Provide adequate portable sanitation facilities for persons at the construction and harvest sites that are in compliance with all Federal, State, and local requirements.

3.5 HARVESTING OF VEGETATION

****

NOTE: Most plants for bioengineering structures constructed near water are wetland plants except for species used for the vegetation of high bank areas. Woody plants or herbaceous plants may be used and should be somewhat flood tolerant. Harvesting may include the collection of woody plants, herbaceous plants, or single or clump plantings. Vegetation should be harvested from local sources and native plant species near the construction site. The need to obtain vegetation from distant sources should be evaluated in terms of cost and the risk of introducing foreign genetic material into the watershed in which work occurs. Vegetation should be obtained when at all possible from the same watershed in which the work will occur. Other stabilization methods may be more appropriate for the site due to high transportation and handling costs.

Site harvesting requires the cutting of existing vegetation for live and dead stakes, poles, or

cuttings, collection of roots or tubers, or excavation of plants with root mats intact. The harvest site must not be over harvested and must be restored as much as reasonably possible after harvest work is completed. Determine the number and location of the vegetation that may be harvested before construction by a qualified botanist or forest engineer.
****

3.5.1 Harvesting of Woody Plants

****
NOTE: Woody plants consist of stem cuttings that quickly sprout roots and stems from the parent stem. These plants are typically willow and perhaps some species of dogwood and alder. Nursery stock with established roots may also be used.

The length of the harvested vegetation will vary with site conditions and structure design. In general, stakes and poles should extend at least 300 mm 1-foot above the top of structure. Cuttings should extend at least 300 mm 1-foot beyond the edge of a structure or 600 mm 2 feet above the ground surface. Base the actual lengths of the stakes or poles on the depth of soil from the surface to the mid summer capillary zone or water table. For guidance, the minimum length is three feet. The diameters for the base of cuttings and stakes may range from 19 to 38 mm 3/4 to 1.5 inches and should be of sufficient diameter to resist buckling when driven into the streambed or bank. Live poles may range from 50 to 100 mm 2 to 4 inches. Live or dead logs used for crib walls should be at least 100 mm 4 inches in diameter for gullies and 200 mm 8 inches in diameter for use in streams or rivers. To improve survivability, live stakes and poles must be of sufficient length to penetrate the soil 600 mm 2 feet below the bioengineered structure or to within the capillary zone of moisture in the soil.
****

Harvest [stakes] [,] [poles] [,] [and] [cuttings] from local sources of selected species. Only import species of plants foreign to the ecosystem environment at the work site if they pose minimal threat to interfering with the native vegetation, are accepted by regulatory and environmental management, and are able to survive at the specific site. Unless otherwise stated below, provide [cuttings] [and] [stakes] that are 19 to 38 mm 0.75 to 1.5 inches in diameter and at least 1 m 3 feet in length. Use [stakes] [poles] with a diameter of 50 to 75 mm 2 to 3 inches and minimum length of 1.5 m 5 feet for insertion into armored stream bank structures. Cut [stakes] [and] [cuttings] [and] [poles] as straight as possible from healthy plants. Ensure plants for harvest are a minimum of one-year-old, preferable 2 to 5 years in age. Do not use suckers or current year growth. Ensure all cuts are clean and free of splits or excessive peeling of bark. Ensure at least two bud scars are visible on the [cutting] [stake] [pole] above the surface of the ground or structure when installed. [Stakes] [Poles] with deviations or curvatures greater than 13 mm 0.5 inch from vertical per 200 mm 1-foot of length will not be accepted. [Trim all branches emanating from the [stake] [pole] as close as possible to the surface of the stake without damage to the bark.] [Cut the bottom end of the [stake] [pole] at an angle of 60 degrees to the horizontal. Cut the top of the [stake] [pole] normal to its length.] [Harvest live cuttings from branches and include the growth tips of the branch. Cut the butt of the cutting at an angle to the vertical to aid in placing into soil.] If trunks of vegetation remain after cutting, ensure these trucks have a sufficient number of healthy branches remaining to allow survival.

3.5.2 Harvesting of Herbaceous Plants

****

NOTE: Edit this section as required. Consult a qualified botanist for harvesting, handling, growing, and transplanting requirements if herbaceous plants are to be used. Herbaceous plants may be emergent aquatic plants such as reeds, rushes, and sedges or may be non aquatic plants such as grasses or other forbs that require moisture during some portion of the year. Harvesting of these plants requires the collection of seeds, roots, or tubers. The roots or tubers may be transplanted directly to the site. Plants from the roots may be grown in a nursery and subsequently transplanted to the site. Plants or roots collected in the field must be placed in containers filled with water and kept cool until being transplanted to growing media at a nursery. Exposure of the harvested plants to wind or dry and hot conditions should be avoided. Consult a wetlands expert for methods for collecting and growing of wetland plants.

****

[______]

3.5.3 Harvesting of Reeds or Clump Plantings

****

NOTE: Edit this section as required. Consult a qualified botanist for harvesting and transplanting requirements of reed or clump plantings. Single plants or groups of plants may be harvested, which include the root mass in soil plugs. Large clump plantings require the removal of vegetation with the root mass and surrounding soil intact. These larger plantings may be extracted by hand and shovel methods or the use of light or heavy equipment.

****

[______]

3.5.4 Sealing of Harvest Cuts

Trim all harvest cuts on trunks or branches of the host vegetation of loose wood or bark and sealed with an approved sealant to prevent desiccation and disease or infestation at the end of the workday without exception.

3.5.5 Harvest Site Restoration

Restore the harvest site to preexisting conditions as best as possible after harvesting is completed. Restoration includes but is not limited to removal of aggregate or wood chip roads or access paths, access gates, and ruts or depression, or other items or features related to work activities.

3.5.6 Disposal of Excess Vegetation

Excess cut vegetation from harvesting must be [thinly distributed on site] [collected and removed from the site] [staked on-site and [burned] [left in place]] [collected and transported to the work site for incorporation in the designed structure].

3.6 TIME OF PLANTING

****

NOTE: Edit this section as needed for site specific conditions. Provide specific dates for the planting window below.

Woody plants and nursery stock should be planted in the dormant season. These plants are dormant when buds are set in the fall after the first hard freeze until the time when the buds begin to swell in the early spring. If planting can not be done during the dormant season, then the cuttings may be stored in a cold environment at -2 degrees C 28 degrees F until planting is possible.

Herbaceous plants may be planted during the dormant or non dormant seasons. If planted in the non dormant season, these plants should be placed as early as possible in the spring to allow the greatest amount of time for root development and growth. Herbaceous plants should not be planted during hot or dry weather if at all avoidable.

The time of planting is also dependent on site climatic and hydrologic conditions. The best time to plant is when the stream or lake is at mean water level. Planting should occur in the fall at sties where the water levels are expected to be low from the fall to the spring and if the plants may experience some growth and establishment before spring floods. Planting at sites where water levels fluctuate during the winter due to flooding or where frost heaving of soil occurs should be delayed until late spring. Late fall plantings may be preferable at locations subject to winter flooding and summer droughts. Fall planting is not recommended for areas where late season droughts or frost heaving occurs below the root level. The designer should consult a hydraulic engineer to determine water levels and flow velocities at the site during the planting and initial growth periods. Clump planting of shrubs or reeds should occur in the spring or early summer.

****

Start planting in the [spring] [fall] [summer] no earlier than [_____] and complete no later than [_____].

3.7 TRANSPORTATION OF HARVESTED VEGETATION

a. Submerge all freshly harvested and prepared live woody vegetation immediately in clean uncontaminated water and do not allow to dry out. Transport cut vegetation to the work staging area submerged in water. If site conditions prohibit direct access to storage bins filled with water, then wrap the freshly cut live vegetation in cloth, which is thoroughly saturated with water, and transport to a storage bin filled with water within no more than one hour from the time of cutting.

b. Transport live vegetation from the staging area to the work site in containers fully covered with clean water. Remove vegetation from the containers and immediately place in the ground. In the event that access to the installation site is limited, remove vegetation from the soaking tanks and wrap in bundles that are completely covered with at least three layers of saturated highly absorbent cloth or saturated biodegradable paper product with high saturated strength. Place cloth and bundles in plastic liners for greater ease in transportation to the work site.

c. Do not leave cut vegetation uninstalled at the work site and exposed to air or heat or excessive cold for any reason. Do not soak dead [cuttings] [stakes] [poles] unless the design requires this vegetation to be flexible. Cut live vegetation that is exposed to air for longer than 15 minutes during harvesting, transportation, installation, or which were not collected or transported as specified above are not acceptable. Do not accept damaged live vegetation and replace at no expense to the Government.

d. [Transport [herbaceous plants] [nursery stock] to the work site in covered vehicles. Do not subject plants to cold or excessive heat or drying during transport. Carefully unload plants at the staging area and place in a shaded area. Water plants and maintain in healthy condition until the time of installation. Transport plants to the work site [by hand] [push cart] [vehicles] and immediately install at the site. Do not accept damaged, wilted, diseased, or dead [plants] [nursery stock] and immediately replace at no expense to the Government.]

3.8 SOAKING AND PAINTING OF LIVE WOODY VEGETATION

****

NOTE: Make all possible efforts to prevent the harvested live vegetation from losing moisture from the time of cutting to insertion into the ground. Soaking of the live vegetation greatly improves the ability of the plants to survive transplant into the bioengineered structure.

****

a. Soak all harvested live vegetation in clean water for 3 to 5 days before installation into the ground. Place live vegetation in clean, leak proof, large plastic storage containers or similar, which are at least 300 mm 12 inches longer in length than the cut vegetation. Do not use reused or new metal drums or drums used for the containment of hazardous wastes or chemicals. Place containers in organized lines in a shaded location separated by a sufficient distance to allow access of a vehicle to the containers for the placement and removal of the vegetation. Give each container a unique identification number or series of numbers and letters that is clearly visible at the end of the container that will be approached for the placement or the removal of vegetation. Record identification numbers and reference relation to the contained vegetation for quality control and construction purposes.

b. Check water levels in the containers twice daily and add water as needed to ensure the containers are filled with sufficient water to completely cover the contained vegetation with a minimum of 50 mm 2 inches of water. Rust proof weights or clean cobbles or boulders may be used to weight down the vegetation and retain it under the water surface. Do not crush or damage the vegetation. Replace water in the containers completely with fresh and clean water every 3 days without exception. Vegetation that remains in water that has not been replaced as required will be deemed defective and will not be accepted by the Government. Water replacement schedule may be adjusted to compensate for weekends and holidays with the notification and approval of the Contracting Officer.

3.8.1 Mixing of Live Vegetation

Do not comingle vegetation of a specific species with another species during cutting, soaking, or transportation.

3.8.2 Painting of Stakes and Poles

****
NOTE: The painting of the tops of the live stakes and poles will reduce desiccation of the cuttings, potential for disease mortality, and allow ease in locating once installed. Perform all painting after soaking. Stakes or poles made of lumber may be painted at the option of the designer to improve visibility.
****

Paint the top ends of the [stakes] [and] [poles] with a latex paint diluted with water at a ratio of one part paint to one part water. The tops of the [stakes] [and] [poles] must be [dipped in the dilute paint mixture to a depth of 75 mm 3 inches after soaking] [painted immediately after planting by [brush] [spray applicator]]. The color of the paint must be [caution yellow] [safety orange]. The top ends of dead [stakes] [and] [poles] must [not] be painted.

3.8.3 Harvesting and soaking records

Prepare daily logs documenting the activities of plant harvesting, transportation, and soaking. Ensure these records contain at a minimum: name, date, weather conditions, company, location of harvest area, location of soaking area, site rehabilitation, species harvested, number of cuttings harvested, number of cuttings placed in soaking tanks, damage to cuttings, problems, and solutions to problems encountered. Clearly indicate the health of the primary vegetation from which the cuttings are obtained, diameter of cuttings and primary vegetation, length of cuttings, trimming procedures, time of cutting, time of placement in transportation bins, handling procedures, sealing of harvest cuts, time the live vegetation is delivered and transferred to soaking tanks, and identification label of the tank in which the cuttings are placed. Include the duration of soaking of the vegetation, water quality and time and amounts of water added to the tank during soaking, time of removal of the cuttings from the tanks, time of planting of the cuttings, and procedures used for removal, transportation, and planting of the vegetation at the construction site. Ensure records are signed by the lead harvest person or person in charge of soaking and planting and provide to the on-site manager at the end of each day. Provide records to the Contracting Officer within [24] [_____] hours of completion.

3.9 STAGING AREA

****

NOTE: A staging area for operations may be required. This staging area should be level and of sufficient size for the positioning of numerous bins for the soaking of live vegetation before installation. The staging area should also be of sufficient size to allow parking, storage of equipment, construction of bioengineering components, work trailer, sanitation, and water tanks if necessary.

****

Construct a staging area at the work site for the storage of equipment, work trailer, portable sanitation, water tanks, parking, and all other materials and equipment required to complete the work. The site should have a level portion for the placement of soaking tubs for the live vegetation. [Secure staging area by an eight feet high chain link security fence to prevent vandalism or unauthorized access to the staging area.] Perform adequate surface preparation to prevent excessive settlement, ponding of water, or rutting. Show location and design of the staging area in the drawings.

3.10 SITE DRAINAGE

****

NOTE: The designer should specify the site specific requirements for temporary and permanent drainage in this section. Work and harvest sites should be well drained at all times to prevent the ponding of water. Runoff water may need to be stored in retention or settling ponds before release to surface water bodies or channels. Remove all temporary drainage features and structures and restore to preexisting or design conditions at the end of work. Drainage may be a requirement for structure stability and for final grade of the work site. Some structure may require internal drainage of groundwater to improve stability. The requirements for internal drainage design should be stated in the requirement paragraph of the selected structure. Employ Best Management Practices in accordance with Section 01 57 19 TEMPORARY ENVIRONMENTAL CONTROLS.

****

[_____]

3.11 DEWATERING

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NOTE: Excavations may need to be dewatered to allow construction. Failure to due necessary site investigation or characterization may result in construction delays, unsafe working conditions, and cost claims.

It is important to understand the subsurface groundwater conditions, surface drainage, and precipitation in the area of the work during the selection and design of a structure. Water in excavations may delay work efforts, interfere with proper soil placement and compaction, and damage vegetation. Structures that incorporate large amounts of woody vegetation may be damaged due to buoyant forces if these excavations fill with water before sufficient material or binders have been placed to hold the vegetation in place. Water removed from excavations may require treatment before release.

Excavations adjacent to tidally influenced water bodies offer challenges in water control and drainage of excavation in terms of construction timing. Time of construction and dewatering may need to be adjusted to match tidal events and require work during time periods other than normal working hours. Similarly, work schedule and dewatering of excavations may need special attention adjacent to rivers or streams that fluctuate seasonally or daily due to water releases from water storage or hydropower projects. In areas where water levels fluctuate, precautions should be taken to ensure the structure will not be damaged by buoyant forces or by currents.

Dewatering of excavations can be expensive due to planning, equipment, labor, and disposal efforts. Alternative designs, locations, or foundations should be considered to reduce project costs if required. Groundwater should be tested for chemical contamination before the start of work. The cost of dewatering and treatment of such water may be high.
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Submit overall plan for dewatering and any required diversion of water. Completely address in the plan installation and removal of the required systems and features. Dewater for construction, obtain and review all necessary information to ensure dewatering efforts are in compliance with regulations, and ensure the designed dewatering efforts are adequate based on site conditions and climate and other variables that may effect dewatering efforts. [Submit a technical memorandum detailing all dewatering requirements, locations, methods, and disposal procedures to the Contacting Officer at least [60] days before the start of work.] Information provided by the Government regarding dewatering requirements and site conditions in no way relieve the Contractor of full responsibility for all dewater planning, efforts, and costs. Ensure the structure will not be damaged by buoyant forces or by currents should water enter the excavation or during the removal of this water. Ensure dewatering efforts do not impact adjacent structures or property, result in instability of the excavation floor or slopes, produce unsafe working conditions, or damage to animals or the environment.

3.12 BIOENGINEERED STRUCTURES

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NOTE: The most common types of bioengineered structures are described below. These structures may be categorized as common, transverse, deflector, or longitudinal. Common structures are generic bioengineered structures applicable to gullies, stream banks, and lake shores. Transverse structures are constructed across stream channels that are less than 4.5 m 15 feet wide and 3 m 10 feet deep. Deflector structures are constructed from the bank into a stream or river to deflect flow away from the bank. Longitudinal structures are constructed parallel to stream banks or lake shores. Bioengineered structures may be used separately or in combination for bank protection and stabilization depending on the geotechnical and hydraulic site conditions, physical setting, desired habitat, and supply of construction materials. Structures not pertinent to the proposed design should be deleted from this specification. Structures described below are:

Common Structures
Permanent seeding
Live Staking
Joint planting
Pole planting
Live fascine
Siltation structures
Brush mat
Clump planting
Transverse Structures (streams less than 4.5 m 15 feet wide, gullies, small tributaries)
Palisade
Brush and stone sill
Wattle fence sill
Vegetated crib wall or wood sill
Vegetated dry stone barrier
Brush works or brush packing
Live fascine sill
Deflectors (Streams wider than 9 m 30 feet, stream bank protection)
Vegetated deflector (groins, dikes, spurs)
Live brush sill
Brush transverse
Brush grid
Longitudinal Structures

Single or clump reed planting
Live stone revetment
Brush layered revetment
Longitudinal live fascine
Longitudinal brush packing
Live crib wall

The specific names for bioengineered structures have not been standardized. The names of the structures listed above are not inclusive of all structures mentioned in literary sources and only represent a general compilation of the most commonly referenced names assigned to the structures. Therefore, individuals may have a different understanding of the function and deign of a structure when provided with only a name. A diagram of the proposed structure is recommended for inclusion in this specification to provide clarity in the description and intent of the requirements. The designer may obtain these drawings from numerous literary sources, private venders, or State resource agencies. It is recommended that the designer review these drawings during the selection of the structures for use and that the designer should provide these drawings to other personnel involved in the deign and planning of the project to reduce confusion in design objectives and requirements. These drawings may be edited for site specific conditions as needed and should be included in or attached to this specification.

The following paragraphs provide the general types of information that are required for the description of requirements for the structures. The designer must edit the selected requirements to meet project objectives and performance criteria based on actual site conditions.
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3.12.1 Common Structures

3.12.1.1 Permanent Seeding

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NOTE: Permanent seeding is a simple method of stream bank stabilization that may be used along low velocity streams or channels with peak flows less than 0.08 cubic meter per second 3 cubic feet per second. Seeding must be combined with erosion control stabilization methods to prevent or reduce soil erosion during germination and the first several years of vegetation growth. Selected species of grasses and/or plants should be native to the area, resilient, provide a dense root mat, and be able to withstand being submerged in water for extended periods. The placement of rock or woody debris may be required at the toe of the bank to reduce undercutting.
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Select seed conforming to all required regulations and requirements and perform all seeding in accordance with Section 32 92 19 SEEDING. Place seed before installation of erosion control mats or the application of other erosion control materials or products.

3.12.1.2 Live Staking

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NOTE: Live staking is the insertion of living stakes of vegetation into the ground. Live staking may be used to cover large areas of stream banks and to infill areas between other bioengineered structures. Live poles may also be used in lieu of stakes if deeper ground penetration is required. In this event, the method should be referred to as live pole staking. Combining live stakes with dead stakes may be feasible where the trapping of debris on the bank is desired or where there is a limited supply of local live vegetation.

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Drive live stakes into the ground in a row parallel to the stream bank with the stakes spaced 1 meter 3 feet apart. Install rows of stakes starting from the toe of the bank and progressing landward and space 1 meter 3 feet apart. Offset successive rows of stakes from the preceding row by one half the spacing distance between the stakes. Perform construction in accordance with ASTM D6765 Standard Practice for Live Staking.

3.12.1.3 Joint Planting

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NOTE: Joint planting is a variation of live staking in which live stakes or poles are driven between the joints of large natural stone, rip rap, or other forms of bank armor. This method may be used to add vegetation to stretches of stream bank, which are protected by barren armor to improve habitat and add areas of shade. Vegetation will improve bank stability due to the development of root mats. The vegetation will also decrease the velocity of water adjacent to the bank during high flow events. Caution is advised to check the stability and condition of the armor before using these methods on existing protected banks. The amount of sediment that may accumulate on the back as a result of the vegetation should be considered in long term design performance since the deposition of large amounts of sediment may overload the bank and result in failure.

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Install live [stakes] [poles] in rows parallel to the stream bank with the [stakes] [poles] driven into joints between the [stones] [rocks] of the bank armor. Drive [stakes] [poles] a minimum of 600 mm 2 feet into the soil behind the armor and space 1 meter 3 feet apart. Incline [stakes] [poles] at 15 to 45 degrees from horizontal. Install rows starting at the toe of the bank and progressing landward and space 1 meter 3 feet apart. Offset [stakes] [poles] in successive rows from the [stakes] [poles] in the preceding row by half the spacing distance. Extend tops of the [stakes] [poles] at least 0.5 m 1.5 feet but no more than 1 meter 3 feet above the top of the armor.

3.12.1.4 Pole Planting

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NOTE: Pole planting is the placement of vertical live or dead poles in multiple rows along the toe of a stream bank. The poles may trap debris between the poles and between the poles and the bank. The accumulation of debris should reduce the flow velocity adjacent to the bank and encourage the deposition of sediment and thus promote the aggradation of the bank over time. The structures will not provide immediate erosion protection, habitat, or bank stability. Erosion protection and habitat should develop as debris is trapped and the vegetation begins to grow. The stability of the bank should improve over time as new bank is formed and vegetation and root mats become established in the new bank material. Pole planting may be used in areas with steep or vertical banks or in areas with a limited supply of the vegetation that is necessary for the construction of other types of bioengineered structures. Pole plantings may be combined with brush mats or brush grids. Pilot holes may need to be drilled to allow the installation of the poles in coarse alluvial streambeds. Pole planting is not recommended for use in stream channels that contain large boulders or where bedrock may be within a few feet of the channel bottom. The depth to scour must be known to ensure the poles will not be lost due to degradation of the stream bottom during a flood event.

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Drive live poles vertically into the stream bed to a minimum depth of 1 m 3 feet. [Extend no more than one-half the length of the pole below grade above the ground.] [Drive poles to refusal.] [Drill pilot holes at the locations where the poles are installed using a steel rod or mechanized drilling machine. Place poles into the holes and compact loose sediment around the poles in place. Add additional sediment as needed to fill any space between the pole and the inner wall of the pilot hole until the hole is filled to the existing surface.]

a. Ensure poles are straight and at least 100 mm 4 inches in diameter. Shape driving tip to a point to aid in installation. Branches must [not] be stripped from the pole [where exposed above grade after installation]. Cut the top of each pole normal to its length.

b. Install poles in rows parallel to the stream bank at a nominal spacing of 1 m 3 feet. Install rows starting at the toe of the bank and progressing towards the stream channel to the mean low water level. Offset poles in successive rows from the poles in preceding rows by one half the spacing distance. Ensure tops of the poles are at a uniform elevation [of 1 m 3 feet] above the mean low water level along the bank.

3.12.1.5   Live Fascine

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NOTE: Live fascines are long bundles of live or dead branch cuttings tied together in tubular sections from 1 to 10 m 4 to 30 feet in length and up to 300 mm 1-foot in diameter. Smaller diameters and lengths of fascines are advantageous in areas where access by vehicles is not possible and materials must be provided to the site by manual labor. Fascines are recommended for sites close to large supplies of vegetation. Fascines are advantageous in stabilizing slopes of long length and for protecting the toes of banks. The structures are effective in reducing erosion on sloped banks that are subjected to bank scour or high surface runoff. The horizontal arrangement of fascines will reduce erosion and trap sediment and seed on the slope. The structures will deflect and insulate the bank from the stream current.

The stability of the bank will improve as the live vegetation develops root systems. Steep or undercut banks must be reduced in slope to provide a stable slope for construction and installation of the fascines. Banks that have experienced sloughing or rotational failures must be repaired by the removal of the failed material and the reconstruction of a stable surface before the installation of the fascine structures.

Fascines require large amounts of live vegetation for construction. Therefore, these structures are best suited for temperate regions where there is a significant supply of available and suitable vegetation near the work site. Staggered fascine structures are recommended in areas with limited supplies of vegetation or as a means to reduce project costs. Fascines are suitable to protect the toes of banks when used in combination with other bioengineering methods on the slopes. Fascines may be used at transition areas between different types of erosion or stabilization structures such as between erosion control mats and live siltation structures at the toe of a stream bank, or with brush mats or layered structures.

Fascines may be refereed to as horizontal or vertical structures. Horizontal fascines are placed parallel to the stream channel. These fascines will reduce bank erosion by scour and surface runoff. The recommended spacing between horizontal fascines based on bank slope are:

Slope	Slope Distance Between Trenches (m ft)	Maximum Slope Length (mft)
1H:1V to 1.5H:1V	0.9-1.23-4	4.515
1.5H:1V to 2H:1V	1.2-1.54-5	620
2H:1V to 2.5H:1V	1.5-1.85-6	930
2.5H:1V to 3H:1V	1.8-2.46-8	1240
3H:1V to 4H:1V	2.4-2.78-9	15.250
4H:1V to 5H:1V	2.7-39-10	18.360

Vertical fascines are placed normal to the stream channel. These fascines may be used to serve as drainage conduits between the key trenches of horizontal fascines and are recommended in temperate regions and banks composed of poorly drained soils. Vertical fascines may be used to protect the bank from scour. Determine the spacing of the vertical fascines by site conditions, but should be close enough to prevent scour of the bank between the vertical bundles.

The trenches for the horizontal fascines may extend the full width of the work area or may be of shorter length and staggered to reduce the amount of material and labor required for the project. Key trenches must be installed at the toes of banks for horizontal fascine structures. The key trenches may be filled with natural stone and live and/or dead fascines up to three bundles in height. The ends of all trenches should be keyed into the bank or protected with large natural stone to prevent scour.

The trenches for vertical fascines should extend from the crest to the toe of the bank if these fascines are used without other structures on the slope. The trenches for the vertical fascines may extend between the trenches of horizontal fascines if used in combination. In this case, the vertical fascine trenches should connect the lowest portions of the horizontal fascine trenches to allow drainage. Trenches for both horizontal and vertical fascines may be installed landward of the crest of the bank if additional protection is desired and sufficient room for these trenches is available.

Fascines composed of live cuttings may be placed on bank slopes to the mean high water level of the stream. Live cuttings capable of growth under saturated conditions may be placed in the stream and in key trenches to elevations below the mean water level. Dead cuttings may be used for fascines placed in saturated conditions or may be interwoven

with live cuttings to provide added resiliency to live fascines. Fascines composed of dead cuttings may also be used separately at the toe or on the bank slopes where erosion and scour protection are desired and other bioengineered or hard structures are used for bank stability. Fascines should be wrapped with erosion control matting when installed in fine-grained cohesionless soil to reduce erosion of backfill.

Fascines should not be constructed on the ground. Elevated tables or braces should be used for assembly. All fascines bundles should be constructed by laying live cuttings parallel to one another with all growth tips oriented in the same direction. The cuttings should have a minimum of 300 mm 1-foot of overlap on successive layers. The live vegetation cuttings should be secured into a bundle using biodegradable binders spaced every 450 to 600 mm 1.5 to 2 feet along the length of the bundle. The fascines should be carried to the installation site in a manner that prevents excessive bending or breakage. Fascines with broken or loose cuttings due to excessive bending or the failure of binders must be repaired or replaced at no expense to the Government.

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3.12.1.5.1 Horizontal Fascines

Install all trenches parallel to the direction of the bank contours. All trenches must be 450 mm 18 inches wide and no more than 50 mm 2 inches deeper than the diameter of the fascine bundles.

a. Excavate a key trench [at the toe of the bank] [at the mean [high] water level] [at the location shown on the drawings] [to a depth of 1 m 3 feet below the mean high water level] and extend the full length of the working area. Make trenches up slope of the key trench [the same length as the key trench] [3 m 10 feet in length and separate by a spacing of 3 m 10 feet longitudinally. The midpoints of the trenches placed up slope must coincide with the midpoints of the spaces between the down slope trenches]. Space trenches 1.2 m 4 feet apart. Install a trench at the toe and at two feet below the crest of the bank regardless of spacing interval. Extend these trenches the full length of the work site. [Place at least [2] [_____] trenches landward of the crest of the slope at a spacing of 1.2 m 4 feet.] Ensure all trenches are [keyed into the bank slope] [and] [filled for a distance of 1 m 3 feet with large natural stone at the up stream and down stream ends of the trenches].

b. Place the fascine bundle in the center of the trench with at least 50 mm 2 inches of the bundle exposed above the top of the existing grade of the stream bank. The junction between the ends of adjacent fascine bundles in the same trench must be [offset side-by-side] [interwoven with each other] for a distance of 300 mm 1-foot. Anchor fascine bundle in the trench with [live] [and] [dead] [stakes] [and] [poles] that are at least 50 mm 2 inches [square] [in diameter] at the top, 700 mm 2.5 feet in length, and taper from the top to the base. Drive [stakes] [poles] vertically through the fascine until flush with the top of the bundle starting 1-foot from the end of each fascine and space every 1 m 3 feet thereafter. Drive a terminal [stake] [pole] 300 mm one-foot from the end of the fascine regardless of spacing interval. Do not drive [stakes] [poles] through or within 150 mm 6 inches of the binders. Drive live [stakes] [poles] into the slope on the downhill side of the fascine bundle at an angle not to exceed 45 degree from vertical. Place [stakes] [poles] at the midpoint between the anchor [stakes] [poles] and contact the underside of the fascine, but do not penetrate the fascine. Extend at least 75 mm 3 inches of these downhill live [stakes] [poles] above the ground surface. Place soil and lightly tamp into place around the fascine and brush into the voids in the fascine until only the top of the bundle is partially exposed. Slope top of the backfill towards the back of the fascine trench to prevent overtopping by runoff and to retain water and sediment.

c. [Place a single fascine in the key trench.] [Stack up to [3] [_____] fascines on top of one another in the key trench.] Drive live poles vertically into the ground to a minimum depth of 600 mm 2 feet to secure the [stacked] fascine bundle(s) in the key trench. Extend these poles at least 600 mm 2 feet above the top of the upper most bundle. Backfill key trenches with compacted [removed sediment] [select fill] to match the [existing] [final grade of the] surface.

3.12.1.5.2 Vertical Fascines

Install trenches normal to the bank contours and space 3 m 10 feet apart starting from the up stream end of the work site. Place a trench at the down stream end of the work site regardless of spacing interval. Extend trenches [from the [toe of the bank] [key trench]] to [[the crest of the bank] [3 m 10 feet landward of the crest of the bank]] [between the horizontal fascine trenches. Offset vertical trenches by 1.5 m 5 feet between horizontal trenches to prevent through flow of drainage]. Make all trenches 450 mm 18 inches wide and no more than 50 mm 2 inches deeper than the diameter of the fascine bundles. [Excavate a key trench parallel to the bank contours at the [toe of the bank] [mean high water level] and extend the full length of the working area. Fill key trench with horizontal fascine bundles as specified above in paragraph HORIZONTAL FASCINES].

a. Place fascine bundle in the center of the trench with at least 50 mm 2 inches of the bundle exposed above the top of the existing grade of the stream bank. The junction between the ends of adjacent fascine bundles in the same trench must be [offset side-by-side] [interwoven with each other] for a distance of 300 mm 1-foot. Anchor fascine bundle in the trench with [live] [and] [dead] [stakes] [and] [poles] that are least 50 mm 2 inches [square] [in diameter] at the top, 700 mm 2.5 feet in length, and taper from the top to the base.

b. Drive [stakes] [poles] vertically through the fascine until flush with the top of the bundle starting 300 mm 1-foot from the end of each fascine and space every 1 m 3 feet thereafter. Drove a terminal [stake] [pole] 300 mm one-foot from the end of the fascine regardless of spacing interval. Do not drive [stakes] [poles] through or within 150 mm 6 inches of the binders. Drive live [stakes] [poles] into the slope on the up stream and down stream sides of the fascine bundle at an angle not to exceed 45 degree from vertical. Place [stakes] [poles] at the midpoint between the anchor [stakes] [poles] and contact the underside of the fascine, but do not penetrate the fascine. Extend at least 75 mm 3 inches of the up stream and down stream live [stakes] [poles] above the ground surface.

c. Place soil and compact into place around the fascine and brush into the voids in the fascine until only the top of the bundle is partially exposed. Roughen, seed, and cover the top of the backfill with erosion control matting to prevent the loss of soil.

3.12.1.6 Siltation structures

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NOTE: Siltation structures are composed of live or dead cuttings that are placed parallel to the toe of a stream bank at or below the mean high water elevation of the stream. These structures provide immediate erosion protection, fish habitat during high flow events, and trap sediment that results in bank aggradation. The structures deflect the current in the stream away from the toe of the bank to prevent scour and undercutting. The stability of the bank is improved as root systems develop.

Siltation structures are recommended for sites with low flow velocities such as the insides of meander bends, side channels, and in areas of bank scour behind obstructions. The structures are well suited for locations where the development of new bank is desired. Siltation structures should be combined with large natural stone, coir logs, root wads, or other hard structures if used in areas subject to high flow velocities and scour.

The structures may be constructed of live or dead cuttings. Live cuttings should be 1 to 2 m 3 to 6 feet in length, flexible, and from species of plants with do not mature to heights greater than 3 m 10 feet. Side branches may remain on the cuttings. Live cutting structures should be placed at the mean high water elevation of the stream to allow growth of vegetation unless the selected species is capable of root generation under saturated conditions.

Dead cuttings may be incorporated into a live structure to improve its resiliency and resistance to abrasion by sediment and debris. The dead cuttings may be from any locally available species of vegetation. Structures composed completely of dead cuttings are suitable for areas were temporary bank aggradation and erosion protection are desired. Dead cutting structures may be placed above or below the mean high water level of the stream. If the dead structure is placed below the mean high water level, it is recommended that large natural stone be placed on the cuttings to reduce floating of the cuttings. More than one row of live or dead siltation structures may be placed along a stream bank to increase the width of coverage.

Siltation structures may be placed on the stream

bank normal to the toe of the bank and oriented up to 15 degrees down stream from the perpendicular to the toe. Theses structures are recommended for low slope banks to reduce erosion of low banks, improve bank stability due to root development, and for areas where sedimentation is desired. The spacing between these structures should be determined based on actual field conditions and flow velocities to prevent scour between the structures. Live stakes or poles may be placed between the siltation structures.

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a. The siltation structure must [be [parallel] [normal]] [consist of segments parallel and normal] to the contours of the bank. Compose the structure of [live] [dead] [live and dead cuttings, comprising [80 percent] [and] [20 percent] of the structure, respectively]. Provide cuttings that are 1 to 2 m 3 to 6 feet in length [and flexible] with side branches attached.

b. Place cuttings in a trench that is excavated [at the toe of the bank] [1 m 3 feet from the toe of the bank towards the stream channel] [as shown on the drawings]. The trench must [be parallel to the bank contours and at the mean high water elevation.] [extend the entire length of the work site.] [[normal] [inclined at 15 degrees down stream to the bank contours.]] [Extend the trench from the toe of the bank to the mean water elevation of the stream.] Ensure all trenches are 600 mm 2 feet deep with a 'V' shaped cross section. [Space trenches 1 m 3 feet apart.] [Key all trenches 1 m 3 feet into the stream bank.]

c. Push ends of the cuttings vertically into the bottom of the trench along the centerline with the growth tips extending 450 mm 1.5 feet above the top of the trench. Place cuttings to form a layer that is 150 mm 6 inches thick with at least [15] [_____] cuttings per 300 mm linear foot of trench. Place large natural stone on either side of the bases of the cuttings and place backfill to infill between the stones to the top of the existing [design] grade. [Protect the stream side portion of the structure and the toe of the bank with [coir logs] [exposed dead fascines] [large natural stone with joint plantings of [live] [and] [dead] [poles] [stakes] [root wads]]]. Protect the ends of the structure with large natural stone placed on the up stream side of structure where it ties into the stream bank.

3.12.1.7 Brush Mat

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NOTE: A brush mat is composed of live or dead cuttings that are placed on the stream bank to form a densely packed layer of cuttings. These structures provide immediate erosion protection, habitat for fish during high flow events, and the rapid establishment of extensive root systems in the bank. Brush mats are well suited for erosion protection of banks damaged by flooding. The growth of the vegetation composing the mat structure may be improved by placing an initial lift of brush and covering it with soil and then placing a second lift of brush to the design surface. The mat is held in

place by anchor stakes or poles and further secured to the slope by rope or binding products that are laced between the anchor poles. Erosion control matting may be installed beneath the brush mat to reduce erosion of slope soil, especially if this soil is poorly compacted or easily eroded.

Brush mats require large quantities of vegetation and labor for construction. If an insufficient supply of live cuttings is available, then dead cuttings may be intermixed with the live cuttings in approximately equal portions. Dead cuttings should be flexible to allow construction and interweaving with the live cuttings. The base of the mat at the toe of the bank should be secured with rock or longitudinal bioengineered structures to prevent erosion or damage of the mat. The cuttings for the mat may be placed in small trenches cut into the face of the bank or pushed directly into the slope without the excavation of trenches.
****

a. Provide [live] [and] [dead] cuttings that are generally straight, supple, 1.5 m 5 feet long, and with lateral branches still attached. Shape cut ends of the cuttings to sharp tips for penetration into the stream bank. Place cuttings in rows parallel to the contours of the bank starting 1 m 3 feet below the bank crest. Space rows every 600 mm 2 feet thereafter down slope to the toe of the bank. Extend all rows the full length of the work site.

b. Push cut ends of the cuttings into the bank at the same contour elevation for each row with the growth tips toward the top of the bank. Orient the cuttings [normal] [at an angle of 15 degrees down stream from normal] to the bank toe. Place at least 15 cuttings per 300 mm liner foot in each row. Use a light roller and foot pressure to push the cuttings of subsequent rows against the bank over the cuttings of preceding rows to achieve a mat thickness of 100 mm 4 inches. [Place up to 15 percent of the cuttings parallel to the slope of the bank and interwoven with the cuttings that are placed with the growth tips toward the top of the bank. Use these parallel cuttings to reinforce the brush mat. Orient the growth tips of the parallel cuttings down stream.] Continue process of placing and compressing cuttings down slope until the toe of the bank is reached. Place a row of cuttings along the toe of the bank regardless of spacing interval.

c. Protect toe of the bank by [large natural stones] [[live] [dead] fascines] [coir logs] that overlie the base of the cuttings of the row at the toe of the bank. [Install an erosion control mat on the prepared grade of the bank slope before the placement of the cuttings.] [Extend ends of the mat 1.2 m 4 feet over unprepared bank.]

d. Drive [live] [dead] anchor stakes that are 50 mm 2 inches in diameter through the mat and 600 mm 2 feet into the stream bank. Do not extend the tops of these stakes more than 300 mm 1-foot above the top of the mat. Place stakes in rows parallel to the bank contours starting at the crest of the bank with the stakes spaced 1 m 3 feet apart. Space subsequent down slope rows every 1 m 3 feet to the toe of the bank. Install a row of stakes along the toe of the bank regardless of spacing interval to anchor the base of the mat. Notch the top of each anchor stake with a 13 mm 1/2-inch deep triangular cut that is normal to the length of the stake and 25 mm 1 inch below the top of the mat when compressed by foot pressure adjacent to the stake.

e. Secure the up stream and down stream ends of the mat with anchor stakes that are placed with a spacing interval equal to one half the above specified spacing distance of stakes in the rows. Extend the one half distance spacing of stakes for 1 m 3 feet towards the center of the structure from the up stream and down stream ends of the mat and extend from the base to the top of the mat at these locations.

f. Secure mat to the slope using binding ropes. Lace ropes across the mat in a diagonal. Secure a single length of rope to a stake in the row of stakes at the toe of the bank. Secure rope to each stake that is oriented diagonally to this stake in a single direction from the toe of the bank to the crest of the bank. Tie together ropes that cross between stakes . Secure ropes parallel and normal to the slope along the rows of stakes and to the stakes that lie in a line from the crest to the toe of the bank. Tie these ropes together where they meet between stakes. Secure all ropes to the stakes with non raveling knots. Allow no more than 150 mm 6 inches of rope to remain at the ends of the rope lengths after they are installed.

g. Brush [removed soil] [select fill] into the mat to within 50 mm 2 inches of the top of the structure.

3.12.1.8 Clump Planting

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NOTE: Clump planting requires the excavation, transport, and placement of live vegetation with root wads and attached soil. This planting method is recommended for establishing vegetation on steep banks of limited height and on the upper banks or floodplains of a stream where the plants will not be subjected to long periods of inundation by water and where adequate moisture is available. Plantings should not be subjected to erosion, flooding, animal traffic or grazing, dry conditions, or high winds during the first several years after installation. Minor earthwork is recommended to reduce vertical faces or remove undercut slopes from the bank to limit the loss of plant clumps due to scour or flooding. Selected woody vegetation should not grow to large mature trees, which could induce scour and loss of the bank due to obstruction of the stream flow or the rotation of the tree into the stream channel and creation of a large hole as the root wad is pulled from the bank. Heavy equipment may be required if plant clumps or root wads are too large to be easily moved by manual efforts. The toe of the stream bank should be protected from erosion by the placement of large natural stone, erosion control matting, or construction of longitudinal bioengineered structures. Irrigation and fencing may be required to ensure the survivability of the plants.

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a. Prepare stream bank for clump planting by excavating 600 mm 2 feet deep holes with floors that slope into the bank and that are at least 150 mm 6 inches longer and wider than the same dimensions of the removed clumps. Ensure the floors of these holes are not within 150 mm 6 inches of the groundwater table. The excavations must be [spaced at 2 m 6 feet and separated by 1 m 3 feet of existing bank] [1 m 3 feet in width, continuous, and separated by 1 m 3 feet of existing bank] along the extent of the work site. Use removed soil as backfill. [Remove excess soil from the excavations from the site.] [Thinly spread excess soil from the excavations on the upper bank landward of the clump plantings.] Roughen and seed exposed surface of the backfill [and cover with erosion control products].

b. Locate suitable species for transplant in the vicinity of the work site. Do not allow plant species to mature to heights greater than 4.5 m 15 feet or trunk diameters exceeding 100 mm 4 inches. Ensure clumps of plants do not exceed the width of the removal equipment. If clumps are removed by hand, ensure these clumps do not exceed 1 m 3 feet in any dimension. Remove clumps with existing soil and as many shallow roots as possible to aid in growth and survival, and transport immediately to the work site and place.

c. Prior to placement, flood the excavation with water to moisten the soil and aid in plant survival. Place plant clumps with vegetation [standing vertically] [slightly inclined towards the stream] and firmly push into the soil at the base of the excavation to prevent rafting. Drive at least [[3] [_____]] [dead stakes] [or] [live poles] driven through each clump to secure it to the bank. Place biodegradable coir net with a minimal life of 2 years on top of the soil of the clump and extend 1 m 3 feet onto the bank beyond the limits of the excavation.

3.12.2 Transverse Structures

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NOTE: Transverse structures consist of live vegetation or a combination of live vegetation and hard material (dead vegetation, logs, rock, and natural stone) that are constructed normal to and across small stream or river channels or narrow gullies. These structures are recommended for streams with low flow, intermittent streams, or dry gullies subject to flow after precipitation events. The harder structures may be used in narrow channels that experience infrequent or seasonally torrential flows.

The transverse structures function as weirs and drop structures, which reduce the velocity of stream flow, bed degradation, and may result in the transformation of the channel profile to a stepped profile due to the retention of sediment and debris. The reduction in flow velocity aids in reducing bank erosion. In addition, these structures may be placed at the toe and parallel to the stream bank, thus directly improving bank stability and reducing undercutting and erosion especially in areas with banks composed of low cohesive materials. Structures should be placed

with key trenches into the banks to improve stability and to prevent the by pass of the structure due to lateral erosion of the bank.

Advantages of transverse structures are ease of construction at remote sites using locally available materials and the establishment of habitat with time. A primary disadvantage of these structures is that they may obstruct fish passage and may reduce the conveyance of the channel resulting in local flooding. Therefore, the structures should be designed to allow fish passage and constructed of supple vegetation that matures to minimal height. Some transverse structures require significant amounts of manual labor and may not be economical in areas of limited vegetation supply. Periodic maintenance may be required to remove excessive amounts of trapped debris to prevent possible flooding, fire dangers, build up of decomposing plant material, or heath hazards caused by habitation of the debris by insects or vermin or trapping of dead fish or animals. These structures may be combined with other forms of live and dead bioengineered structures and hard structures such as gabions, or riprap.

Stagnant water may become present behind transverse structures depending on site conditions. These areas of stagnate water may become breeding grounds for mosquitoes or other insects and undesirable aquatic plants and animals. The designer will include adequate drainage features in the design to remove water from behind the structure, such as open channels, drainage pipes, or passive subsurface drains.
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3.12.2.1 Palisade

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NOTE: A live palisade is a weir composed of live poles, which develops into a transverse zone of vegetation that crosses the stream channel. These structures may be installed rapidly, are easy to construct, and provide shade to the stream channel as the vegetation matures. Palisades are best suited for small gullies or streams in low-lying areas that are less than 10 m 30 feet wide and 4 m 12 feet deep. The streambed should consist of loose sand, silt, or soft clay to allow easy installation of the poles used in the construction of the palisade. A steel rod may be required to install pilot holes for the driving of the poles in medium to hard clay, dense sand, sand with fine gravel, and medium dense silt. Palisades may be installed in coarse alluvial streams if placed in a trench excavated in the streambed. These structures in coarse alluvial systems should be viewed as temporary and expendable since they may be damaged

by bed load and large debris transported during periods of high flow.

A palisade may be constructed entirely of dead poles if the project objective is the temporary stabilization of the stream channel. These structures will not become reinforced with time by root structures and will deteriorate. However, depending on the site conditions, these structures may be adequate for the retention of sediment on which native grasses and vegetation may take root, thus resulting in the evolution of the dead structure to a live transverse brush sill. Dead palisades may be used in coarse alluvial streams since the establishment of a vegetated structure is not expected and may not be desired.

The live or dead poles should be driven a minimum of 600 mm 2 feet into the streambed for poles under 1.5 m 5 feet in length. Poles over 1.5 m 5 feet in length should be driven a minimum of 1 m 3 feet into the streambed. The poles should be harvested from local vegetation and should be a minimum of 38 mm 1.5 inches in diameter. The bottoms of the poles should be formed to sharp points to aid in the driving of the poles into the streambed.

The strength of the palisade may be increase by attaching a cross beam to the structure. A cross beam is recommended for palisades with widely spaced or thin poles and that have a height greater than one-foot above the streambed. The cross beams should be at the same height and inclination on both sides of the palisade. The beams are attached to the palisade with binders composed of untreated coir or hemp rope that is capable of withstanding several years of exposure. The binder must be looped and tied around the cross beams and the adjacent poles in a manner that tightly secures the members together. The binders should not unravel if a portion of the binder or structure is lost or damaged. Cross beams may be composed of untreated dimensional lumber or straight poles of similar diameter as the palisade poles.
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a. Provide live poles that are 1 m 3 feet long, 38 to 100 mm 1.5 to 4 inches in diameter, and cut the bottom ends of the poles to form sharp drive points. Drive poles vertically into the streambed to a minimum depth of 600 mm 2 feet and place across the channel in a [straight row] [row that is deflected down stream by 15 degrees] ['V'-shaped row pointing down stream with the apex at the center of the channel]. Space poles no less than 50 mm 2 inches but no greater than 150 mm 6 inches. [Extend center poles of the structure a maximum of [300] [600] mm [1] [2]-foot above the existing grade of the streambed.] [Use dead poles for center poles and place for a distance of 1 m 3 feet about the centerline of the structure.] [Compose central span of the structure of large natural stone keyed 600 mm 2 feet into the streambed with a top elevation 300 mm 1 foot above the existing streambed. Extend the stone 600 mm 2 feet on each side of the centerline of the structure and tightly butt with [live] [dead] poles of the palisade structure.] [The tops of the poles must increase in height outward from the center of the structure by no more than 15 mm 0.05-foot for each adjacent pole to form a notch at the center of the structure.] [The tops of the poles must be at the same elevation.] Place ends of the structure in key trenches that extend 1 m 3 feet into the stream bank.

b. Attach cross beam members of untreated [straight 25 by 100 mm 1 by 4 inch dimensional lumber] [long straight poles at least 50 mm 2 inches in diameter] to the palisade with binding products; wrap at least two times around the cross beam and adjacent pole. Install binding products to prevent raveling of the binder in the event of the loss of a portion of the binder or structure. Place [horizontal] [inclined] cross beam members at the same elevation on each side of the palisade and extend the entire width of the structure. Use beams that are 600 mm 2 feet greater in length than the structure and place the ends of the beams in key trenches in the bank. Excavate key trenches to the depth and width necessary for the placement of the ends of the cross beams and backfill with soil removed by excavation.

c. Compact sediment in the streambed around each pole using a tamping bar. [Place sediment removed from the streambed for the installation of the poles as compacted backfill around the poles.] Place dead cuttings and excess live cuttings in a criss-cross pattern on the up stream and down stream sides of the structure for a distance of 600 mm 2 feet and pack tightly against the stream bank at the ends of the structure to a thickness of 150 mm 0.5-foot for 600 mm 2 feet beyond the limits of backfill exposed at the key trenches.

3.12.2.2 Brush [and Stone] Sill

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NOTE: Brush sills are transverse structures similar to palisades, but composed of live or dead cuttings. These structures reduce stream channel degradation, are easy to construct, and may be combined with natural stone to improve performance. Selected vegetation should mature to low height, remain supple with time, and be capable of good root mat development. Live or dead cuttings may be used for the structure and the cuttings may retain small branches and do not need to be straight. Sills may also be placed along the toes of stream banks separately or adjacent to the transverse brush sills. Sills do not trap large amounts of sediment or debris since the vegetation used in construction is pushed against the stream channel during high flow events and does not form an obstruction to flow. Therefore, these structures are suitable for channels where minimal changes to the stream profile are desired. Sills may be constructed in most types of alluvial material and will function in coarse alluvial streams. Backfill and the buried portions of cuttings should be wrapped in several layers of coir mat if the sill is constructed in a stream channel subject to infrequent torrential flows. The width of the construction trench may be increased up

stream of the vegetation and filled with large natural stone to reduce damage to the structure by bed load in high flow channels. Live stakes may be planted between the joints of the stone.
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Excavate a 600 mm 2 feet deep trench normal to and across the entire width of the stream channel. Place live cuttings in a criss cross manner with 20 cuttings per 1 meter 3 linear feet of trench on the down stream face of the trench. [Place cuttings in the same pattern and concentration as in the trench for the sill on the stream side faces of trenches excavated at the toes of the banks for a distance of 4.5 meters 15 feet up stream and down stream of the ends of the sill structure]. Push cut ends of the cuttings into the bottom of the trench to [refusal] [150 mm 6 inches] and extend the growth tips 600 mm 2 feet above the top of the existing streambed. Place large natural stone on top of the cut ends of the cuttings [to the top of the existing streambed to fill the entire trench] and tamp into the streambed to secure the stones in place. Place removed sediment in the voids between the natural stone [and place over the lower stone work to fill the entire trench]. Thinly spread excess sediment up stream of the structure. Place large natural stone at the ends of the structure against the bank [and at the upstream and down stream ends of the trenches excavated parallel to the banks]. Drive [live stakes] [and] [dead cuttings] up to 600 mm 2 feet in length into the [sediment backfill on 150 mm 6 inch centers] [between the joints in the natural stone] across the entire width of the trench and 1 m 3 feet up each bank from the toe of the bank. Space sills [15 m 50 feet apart] [as shown on the drawings].

3.12.2.3 Wattle fence sill

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NOTE: Wattle fence sills are recommended for narrow and slow flowing streams, small gullies, agricultural drainage ditches, or open channel drains. These sills are best suited for streams or drainage systems with coarse-grained bed load, which will be trapped by the weaves of the fence. The sills may not trap fine-grained sediment or reduce erosion in fine-grained alluvial streams since the fine sediment may pass through the structure. These fence structures may be constructed of live or dead vegetation. The use of live poles and cuttings should result in the establishment of a row of vegetation across the stream channel with time. Cross beams are recommended for structures over two feet in height. These sills may be combined with brush sills and brush layer structures.
****

a. Excavate a trench 600 mm 2 feet deep and 300 mm 1 foot wide normal to and extend across the entire width of the stream channel. [Live] [Dead] poles must be 1 m 3 feet long with a minimum and maximum nominal diameters of 38 and 100 mm 1.5 and 4 inches, respectively. Cut bottom ends of the poles to form sharp drive points. Drive poles vertically into the streambed to a minimum depth of 600 mm 2 feet and place across the channel in a [straight row] ['V'-shaped row pointing down stream with the apex at the center of the channel with the poles] at a spacing of 600 mm 2 feet. Extend poles a maximum of [300] [600] mm [1] [2]-foot above the existing grade of the streambed. [Use dead poles for center poles and place for a distance of 1 m 3 feet about the centerline of the structure.]

b. Extend wattle fence from the bottom of the trench to the tops of the poles. The top of the fence must be [at the same elevation] [sloped to the center of the channel]. Construct fence of flexible [live] [and] [dead] cuttings that are 2 meters 6 feet in length and from 19 to 38 mm 3/4 to 1.5 inches in diameter. Ensure cuttings are [laced horizontally between the poles in an alternating woven pattern with the cuttings being placed on the up stream and down stream sides of adjacent poles across the structure starting from the steam bank] [placed on the up stream side of the poles and tightly packed and interwoven to form a braided vertical structure]. Overlap ends of the cuttings 300 mm 1-foot with adjacent cuttings. Secure cuttings of the fence to the poles with binding products. Install binders to prevent raveling of the binders in the event of the loss of a portion of the binders or structure.

c. [Place sediment removed from the trench in the excavation as compacted backfill around the poles and lower fence.] [Place live stakes at 300 mm 1-foot spacings in the backfill.] [Place large natural stone at the bottom of the trench along the up stream and down stream toes of the fence [and extend to the top of the existing streambed]. [Tamp stones into place and use sediment to fill voids between the stones.] [Place live stakes in the joints between the stones.]] Thinly spread excess sediment up stream of the structure.

d. Place [cross beam members of untreated [straight 25 by 100 mm 1 by 4 inch dimensional lumber] [long straight poles at least 50 mm 2 inches in diameter] on the down stream side of the poles and overlie the fence on the up stream side of the structure. Attach beams to the structure with binding products wrapped at least two times around the cross beam and adjacent pole and lace through the wattle fence cuttings.] [Place cross beams horizontal and at the same elevation on each side of the structure and extend the entire width of the structure.] [Extend both ends of the structure into a key trench that is excavated 600 mm 2 feet in the banks.] [Extend both ends of the structure to the existing stream banks and cover on both sides with large natural stone placed from the channel bottom to the top of the structure. Rest stone on the stream bank, at least 600 mm 2 feet thick, and extend 1.5 m 5 feet away from the structure in the up stream and down stream directions.]

3.12.2.4 Vegetated Crib Wall or Wood sill

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NOTE: A vegetated crib wall consists of a hollow box-like structure of timber or logs filled with earth and live cuttings. A wood sill is a vertical open wall composed of timber or logs that forms the front header, which is not tied to a similar structure, or rear header, up stream by stretchers as is the case with the crib wall. The crib wall is more stable than the wood sill. These structures may last 20 to 30 years depending on the type of timber used, are quick to construct, and may use locally available materials. The live cuttings take over the function of the crib wall as the cuttings grow and mature and the timber decays. These

structures should not exceed 1.5 m 5 feet in height and are well suited for gullies with fine-grained sediment bed load and narrow streams less than 4.5 m 15 feet wide with steep gradients.

Crib walls or wood sills may be combined with brush sills, brush mats, or large natural stone on the up stream or down stream sides of the structure to reduce erosion. Stability of the structure may be improved using a double crib design composed of front and back rails. Backfill should be free draining material with less than 10 percent fines. However, if such backfill material is not readily available, removed sediment may be placed as compacted backfill. Timber used for the crib wall may be untreated manufactured 100 mm 4-inch square posts, locally harvested vegetation with trunk diameters greater than 100 mm 4-inch, or a combination of these materials. Treated lumber will not be used.

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a. Excavate a trench that is 1.5 m 5 feet wide and 600 mm 2 feet deep and extends normal to and across the entire width of the stream channel. Slope the floor of the trench at 15 degrees up stream and [manually compact using a tamping bar weighing at least 18 kg 40 pounds] [compact using a small motorized tamping machine] until the bottom of the trench is dense and provides a solid base for the crib wall [wood sill]. The floor of the trench must be [as shown in the drawings] [of uniform grade across the trench width]. Fill depressions in the trench floor with compacted material to raise these areas to grade and reduce positive areas above the floor design elevation to grade. Key trench into the stream banks for a distance of 1 m 3 feet. Use material removed from the key trenches as compacted backfill in the key trenches. [Remove sediment removed from the trench in the stream channel from site and replace with select fill.] [Use sediment removed from the trench in the stream channel as compacted backfill].

b. Frame [crib wall] [wood sill] with [untreated, straight 100 mm 4-inch square by 2.5 m 8 feet long posts] [100 to 150 mm 4 to 6 inch diameter by 2.5 m 8 feet long straight logs harvested from local sources. Cut logs normal to the trunks with all branches stripped from the trucks]. Place down stream header [parallel to the bottom of the trench and extend the full width of the trench] [along the alignment shown in the drawings]. [Place up stream header parallel and 1.5 m 5 feet up stream of the down stream header.] Place splices between members end-to-end and in line. Drive wood posts that are at least 100 mm 4 inches in diameter vertically 150 mm 6 inches from the splices on the up stream and down stream sides of the headers. Drive wood post on both sides of the headers at the midpoints between the splices. Place members at the ends of the structure firmly against the faces of the key trenches. Drive wood posts on both sides of the headers at the toes of the banks and the toes of the key trenches.

c. Stretchers [for wood sills must be 1.2 m 4 feet] [for live crib walls must be 2 m 6 feet] in length. Place stretcher between the vertical splice poles and normal to the down stream header. Space stretchers every 1.2 m 4 feet between the poles and have a minimum of 100 mm 4 inches extending down stream of the header face. Place rear butt of the stretcher [firmly against the upstream face of the trench] [on top of the up stream header]. Attach stretcher to the header(s) with binding products wrapped three times around the stretcher and header in a criss cross pattern and secure with a non-raveling knot. Drill a 13 mm 1/2-inch diameter hole vertically through the stretcher and header. Drive a 16 mm diameter by 300 mm 5/8 inch diameter by 12 inch long [non-galvanized steel spike] [steel rebar] [hard wood dowel] into the hole and set flush to the top of the stretcher.

d. Backfill the open area between the down stream header and the upstream [trench face] [header and the portion of the trench upstream of the upstream header] with compacted [sediment removed from the trench excavation] [select fill] to an elevation that is at the middle of the stretchers. Place live cuttings that are 19 to 38 mm 3/4 to 1.5 inch in diameter and 2.4 m 8 feet long in a criss cross manner on top of the compacted backfill with the cut ends pushed into the up stream face of the trench. Ensure at least 600 mm 2 feet of growth tips of the cuttings extend beyond the face of the down stream header. Place backfill and lightly compact on top of the cuttings to the top of the stretchers. Place additional lifts of headers, stretchers, backfill, and cuttings until only the final lift remains. Offset centerlines of the down stream headers 50 mm 2 inches upstream of the lower headers to provide an incline to the down stream face of the structure.

e. The top down stream header must be 100 mm 4 inches larger in diameter than the headers used for wall construction to reduce sediment loss due to scour. Cut vertical poles on both sides of the headers flush with the top of the final down stream header [and the top rear header]. Place a header at the midpoint between the top down stream and up stream headers and secure with binders and [spikes] [rebar] [dowels] to the underlying stretchers. Fill the lift of backfill immediately below the completion headers with a tightly packed brush mat composed of live [and dead] cuttings that are placed in an alternating pattern perpendicular and parallel to the wall. Ensure each layer of cuttings is 100 mm 4 inches thick and cover with a thin layer of lightly compacted backfill. Place [rounded clean natural stone from 200 to 300 mm 8 to 12 inches in diameter] [excavated sediment] from the top of the packed brush to the top of the down stream header and grade up stream to match the existing slope of the stream channel up gradient of the work site. [Drive live stakes vertically on 600 mm 2 feet centers into the backfill at the top of the structure.] [Place large natural stone armor 600 mm 2 feet thick at the ends of the structure and on the slopes of the banks for a distance of 2 m 6 feet upstream and down stream from the structure. Plant live stakes in the joints between the stones.] Fill trench down stream of the structure with [large natural stone] [a brush [and stone] sill] [a brush mat].

3.12.2.5 Vegetated Dry Stone Barriers

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NOTE: Vegetated dry stone barriers are constructed of large natural stone with interlayered live cuttings. These structures may be built to heights of 4.5 m 15 feet and serve as weirs or drop structures in high gradient streams with torrential flows and heavy coarse bed load. Stone barriers may also be constructed to slightly above the existing elevation of the stream channel to prevent bed

degradation. The largest stones that may be moved by manual efforts should be used. Construction of barriers adjacent to existing large boulders may reduce the amount of work required.
****

Excavate a trench that is 1.2 m 4 feet wide and 1 m 3 feet deep normal to and across the entire width of the stream channel and key 1 m 3 feet into the stream banks. Slope the bottom of the trench at 15 percent in the up stream direction and compact using a manual tamping bar weighing at least 18 kg 40 pounds. Place large stone of similar size on the entire floor of the trench with a minimum of voids between the stones. Cover stones by [fine sediment] [select fill] and work into the voids between the stones until only the tops of the stones are visible. Place live cuttings that are 2 m 6 feet long and up to 38 mm 1.5 inches in diameter on top of the stones in a criss cross pattern with the butts of the cuttings in contact with the up stream face of the trench. Orient growth tips of the cuttings down stream and extend 0.5 m 1.5 feet beyond the farthest down stream placed stones. Place additional lifts of stone, fill, and cuttings on the lower lifts until the design height of the structure is reached. Place stones of each successive lift to interlock with the tops of the stones of the lower lift. Place live cuttings at the top of the structure in between the stones and incline slightly down stream. [Drive live stakes that are 600 mm 2 feet long between the joints of the stones at the top of the structure on 600 mm 2 feet centers and for a distance of 1 m 3 feet up the stream banks.] Cover top stones with a 100 mm 4 inch thick layer of [fine sediment] [select fill].

3.12.2.6 Brush Work or Brush Packing

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NOTE: Brush work or brush packing uses live and dead cuttings to fill a section of a gully or stream channel to reduce erosion of stream banks. These structures provide erosion protection to the channel by covering the channel with a mat of brush and are recommended for intermittent streams with fine-grained sediment. Brush works refers to brush mats placed across the stream channel with growth tips pointing up stream and which extend up the stream banks. Construction of brush work starts at the upstream limit of the work site and progresses down stream with each new layer of cuttings overlying the immediately up stream layer of cuttings. Brush packing refers to thickly packed layers of brush placed with the growth tips inclined slightly down stream that fill a gully or small stream channel. Brush packing starts at the down stream limit of the work site and progresses upstream with each new layer of cuttings overlying the immediately down stream layer of cuttings. Bank stability is improved as the vegetation grows and develops root systems in the lower bank. The cuttings may be anchored in the channel by cross logs secured to vertical poles driven into the streambed.
****

a. [Start brush work construction at the upstream end of the work site and progress down stream with each down stream layer of cuttings overlying the layer of cuttings immediately upstream.] [Start brush packing construction at the down stream end of the work site and progress upstream with each upstream layer of cuttings overlying the layer of cuttings immediately down stream.]

b. Excavate trenches that are 300 mm 1-foot deep normal to and across the entire stream channel [and extend 1.5 m 5 feet up the stream banks]. Space trenches 1.5 m 5 feet apart. Place live cuttings that are 2 m 6 feet in length in the trench in a herringbone pattern at an angle of 30 degrees from the centerline of the channel with the growth tips pointing [upstream] [inclined down stream at an angle of 45 degrees from vertical]. The cuttings must [not] extend up the stream banks. Push cut ends of the cuttings firmly into the streambed. Place [removed sediment] [select fill] and compact over the cut ends of the cuttings to the elevation of the existing channel. Repeat this procedure for the specified length of channel at the work site.

c. Place cross logs normal to the channel and on top of the cuttings every 1 meter 3 feet. Ensure logs are 100 mm 4 inches in diameter and extend the full width of the channel. [Place cross logs parallel to the slope of the bank on top of the brush [work] [pack] layers that extend up the stream banks. Shape ends of the cross logs at the toes of the banks to sharp tips and drive the logs 500 mm 1.5 feet into the streambed at the angle of the slope of the stream bank.] Drive [live] [dead] poles vertically into the streambed on the down stream sides of the cross logs. Space poles at 600 mm 2 feet intervals and ensure the tops of the poles are not greater than 150 mm 6 inches above the tops of the cross logs. Drive poles at the toes of the stream banks regardless of spacing interval. Tie poles and cross logs together using binders that are wrapped around the logs and poles in a manner to prevent raveling.

3.12.2.7 Live Fascine Sill

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NOTE: Live fascine sills are more resilient and less prone to damage by scour than brush sills. However, heavy coarse bed load and large woody debris transported during high flow events may damage the fascines. Fascine sills may be used to form low drop structures to prevent streambed degradation in narrow streams with low flow velocities and minimal coarse bed load. Sills may be combined with other bioengineering methods for channel stabilization of high gradient or torrential flow streams. Fascines have the advantage of being flexible and therefore may be placed to conform to the existing profiles of the stream channel and may be easily extended up the banks of the channel. The diameter and strength of the fascine may be increased by adding dead branches and gravel or cobbles to the fascine. Fascines should be placed in trenches that are normal to the stream channel and that are at least 50 to 75 percent the diameter of the fascine in depth. Live fascines may be placed on top of one another to form step sills. Step sills are constructed by placing a down stream fascine in a trench and positioning a fascine

directly up stream of the down stream fascine. The up stream fascine should rest on the upper one quarter of the exposed down stream fascine.
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Each fascine must be 300 mm 12 inches in diameter and 3 m 10 feet in length and constructed of live cuttings that are from 19 to 38 mm 3/4 to 1.5 inches in diameter. Up to 35 percent dead branches [and 15 percent rounded gravel or cobbles] must be interwoven with the live cuttings. Excavate a 200 mm 8-inch deep by 0.5 m 1.5 feet wide trench normal to and across the entire width of the stream channel [and at least 1.5 m 5 feet up the faces of the stream banks]. Place fascine in the trench. The junction between fascine bundles in the same trench must be [offset side-by-side] [interwoven] for a distance of 300 mm 1-foot. Anchor fascine in the trench with 700 mm 2.5 feet long [live] [dead] stakes that are at least 50 mm 2 inches [in diameter] [square] at the top and taper from the top to the base. Drive stakes vertically through the fascine until flush with the top of the bundle starting 300 mm 1-foot from the end of the fascine and space every 1 meter 3 feet thereafter. Drive a terminal stake 300 mm one-foot from the end of the fascine regardless of spacing interval. Drive [live] [dead] stakes at a 45-degree angle on the down stream side of the fascine but do not penetrate the bundle. Secure fascine to the stakes with binders wrapped around the fascine and secure to the stakes. Tie binders to prevent ravel in the event of damage. Use removed sediment as backfill and place and compact on the up stream and down stream sides of the fascine and brush into the fascine structure until only the top of the fascine is visible. [Space fascine sills 8 m 25 feet apart starting from the down stream end of the work site.] [Place fascine sills at the locations shown on the drawings.]

3.12.2.8 Vegetated Deflector

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NOTE: Vegetated deflectors are traditional hard structures composed of rock (groins, dikes, spurs) or timber (log or pile revetments) that incorporate live vegetation and which provide excellent long-term bank protection with the added benefits of shade and habitat enhancement. These structures protect the banks of large streams and rivers, which are subjected to high velocity flows, by deflecting the energy of the current away from the banks. The incorporated vegetation improves the strength of the structure and the quality of habitat over time. A key component for the establishment of vegetation on these structures is the retention of fine-grained material and the exposure of the hardened structure above the mean water level of the stream or river. Only vegetation that matures to trees or brush of less than 2 m 6 feet in height and which remains flexible should be used. Species that may mature to tall tress with extensive root systems may not be used, since these trees may damage the hard structures.

For existing structures, fine-grained material may be placed in open voids and live posts driven into these voids in the structure. For new construction, the interior of the structure may be composed of

fine-grained material capable of supporting root growth. This core should be covered with rock of suitable size to resist transport by the stream or river. The cover armor must be anchored along the perimeter of the structure in a key trench below the scour depth of the high flow events. Additional stability of the armor may be gained by inserting dead stakes between stones in areas below the mean water level. Live poles may be driven into the joints of the armor above the mean water level.

Retention of fine-grained material in the core of the structure may be improved by placing this material in untreated sand bags composed of natural fibers. The lifetime of the sand bags should be sufficient to prevent the loss of fines until the roots of the live poles lock this material in place. The surface of the sand bag core may be covered with a coir erosion mat prior to the placement of armor. To reduce the number of sand bags, the core may be constructed of compacted material overlain by a three-bag thick layer of sand bags, which is in turn overlain by the stone armor. A layer of well-graded fine gravel and coarse sand may be placed beneath the stone armor to form a filter layer and thus further reduce the loss of fines from the core. Other deflector alternatives include the use of logs or wood structures as cores surrounded by fine-grained material with exterior stone armor. These structures may be used to assist in trapping sediment behind rock groins or dikes to in fill large scour areas in a stream or river banks.

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a. Excavate a trench [4.5 m 15 feet wide, 1 m 3 feet in depth below the lowest elevation of expected scour, that extends from the toe of the high bank to 3 m 10 feet into the stream below the mean low water elevation. The trench must be [keyed 1.5 m 5 feet into the bank.] [as shown on the drawings]. [Place live cuttings against the face of the trench from the mean water level to the high bank. Extend these cuttings at least 450 mm 1.5 feet above grade and push the cut ends of the cuttings firmly into the bottom of the trench and cover with a thin layer of [sediment] [select fill]]. Place [natural stone] [quarry rock] at least 1 m 3 feet in the minimal dimension against the outer perimeter face of the trench and maintain as much contact with adjacent stones as possible. [Place [stone] [rock] to a height of 600 mm 2 feet above the high mean water level of the stream]. Slope the outer face of the [stone] [rock] at [2H:1V] while the face towards the center of the trench is at the angle of repose. Brush [sediment removed from the trench] [select fill] into the voids between the [stones] [rocks] until the soil is even with the tops of the [stones] [rocks]. Place live cuttingson top of the outer [stones] [rocks] with the cut ends of the cuttings firmly pushed into the bottom of the inside trench. Cover the ends of the cuttings with a thin layer of sediment that is overlain by [backfill] [sandbags]. [Drive live poles between the [stones] [rocks] to a depth of at least 1.2 m 4 feet.] Fill the core of the structure lying inside the larger outer [stones] [rocks] with [removed sediment] [select fill] [in untreated biodegradable sand bags that are placed tightly end to end and in vertical overlapping pattern] [compacted cohesive sediment removed from the trench separated from the outer [stones] [rocks] by a 600 mm 2 feet thick layer of select fill contained in untreated biodegradable sand bags].

b. Place successive lifts of armor [stone] [rock] on top of the completed lifts to the design slopes and grades of the structure. Place live cuttings on the top of each lift. Raise the core of the structure concurrently with the lifts of armor material. The final lift must consist of interlocked [stone] [rock] that extends across the entire top of the structure. Brush [removed sediment][select fill] into the voids between the [stones] rocks]. Plant live stakes in the joints between the [stones] [rocks] with a spacing of 1 m 3 feet. The top of the rock structure must be 300 mm 1 foot above the top of the original elevation of the high bank.

3.12.2.9 Live Brush Sill

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NOTE: Live brush sills are structures composed of live vegetation that extend perpendicular from the toe of the bank into the stream channel. These structures may extend landward to the high bank. The sills trap sediment and debris, reduce scour, and are useful in establishing vegetation on point bars of barren flat expanses of low bank. These structures are inexpensive, easy to construct, and may reduce the amount of rock or stone armor required for bank protection. The development of root systems and the growth of vegetation improve bank stability and develop riparian habitat. Dead cuttings may be used in these structures to improve their resistance to erosion and damage due to currents or debris. Sills composed entirely of dead cutting may be placed below the mean high water elevation separately or between harden transverse structures. These dead brush sills trap debris, sediment, and result in bank aggradation. Live sills, or other live bioengineered structures, may be placed on the new bank created by the dead sills at a future date to promote improved stability and habitat development.

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Excavate a 600 mm 2 feet deep trench with a 'V' shaped cross section normal to the toe of the stream bank from [the mean high water level] for a distance of [3 m 10 feet into the stream channel [from the mean high water level]] [and] [6 m 20 feet landward of the toe of the bank.] [to the edge of existing vegetation] [as shown on the drawings]. Place live cuttings in the trench with the cut ends pushed firmly into the bottom of the trench with the growth tips extending at least 600 mm 2 feet above the top of the existing grade. Place at least 20 cuttings per 300 mm linear foot of trench and rest all cuttings against the down stream side of the trench. Place large stone up to 150 mm 6 inches in diameter on the bottom of the trench against the cut ends of the cuttings and cover with loosely compacted [sediment] [soil] [select fill] to the existing surface. [Mound excess material removed from the trench that is to remain on site around the base of the sill at the surface.] Space sills 1.5 m 5 feet apart.

3.12.2.10   Brush Transverse

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NOTE: Brush transverses are stone structures augmented with live or dead brush cuttings that are easy to construct and inexpensive. These structures are useful in deflecting high velocity flows away from stream banks to prevent scour and erosion and may be used to aid in the repair of scoured or failing areas of stream banks. The live vegetation will develop root systems that will strengthen the structure and provide shade and habit. The stone structure deflects and dissipates the stream velocity away for the bank thereby creating areas of still water down stream of the structures in which sediment may be deposited. The brush cuttings assist in sediment trapping during periods of high flow. This vegetation matures with time and will eventually completely cover the scour area. Brush transverses may be combined with brush grids to repair areas of bank scour in high flowing rivers.

Brush transverse structures are not suitable for use in streams with torrential flows and heavy clastic bed load. Installation trench depth and width must be based on hydraulic analyses of stream velocities and bed load transport. The structure may be normal to the stream bank or inclined at an acute angle to the stream bank in the down stream direction. The use of subrounded large natural stone from the immediate area of work is preferred for construction. If such material is in limited supply, then the available natural stone may be used as cover stone and the core of the structure may be constructed of angular to subangular quarry rock. In areas that lack natural stone, local durable quarry rock may be used for the entire structure.

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a. Excavate a trench 600 mm 2 feet deep by 1.5 m 5 feet wide from [the face of the high bank] [edge of the stream bank] to [3 m 10 feet beyond the low mean water elevation of the stream] [the new bank alignment as shown on the drawings]. [Key trench into the stream bank for a distance of 1 m 3 feet.] Firmly compact the base of the trench. Place live [and] [dead] cuttings that are at least 1.5 m 5 feet in length and that have side branches attached on the down stream side of the trench. Place the cuttings with a concentration of at least 20 cuttings per 300 mm linear foot of trench to form a layer with a thickness of 100 mm 4 inches. Push cut ends of the cuttings firmly into the streambed with a minimum of 1 m 3 feet of the growth tips extending above grade and incline in the down stream direction. Cover cut ends of the cuttings with a 75 mm 3 inch layer of moderately compacted [fine-grained sediment] [select fill] and extend from surface grade to the base of the trench at the angle of repose.

b. Place durable [large natural stone] [quarry rock] that is 450 mm 1.5 feet in minimal dimension along the up stream side of the trench, against the fill covering the cut ends of the cuttings, and completely fill the key trench. Place [natural stone] [quarry rock] ranging from

150 to 450 mm 0.5 to 1.5 feet in minimal diameter to cover the floor of the trench and firmly tamp into place to provide the greatest contact with adjacent [stones] [rocks]. [Brush] [Wash][fine sediment] [select fill] into the voids between the [stones] [rocks] until only the tops of the [stones] [rocks] remain exposed. Place successive layers of [stone] [rock] on lower lifts in a pattern that allows the greatest amount of interlocking of [stones] [rocks] and fill the voids between the [stones] [rocks] with [fine sediment] [select fill] to the top of the structure. Construct the end of the structure that projects into the stream of [large stone] [rock] that is 1 m 3 feet in minimal dimension for a distance of 2 m 6 feet. [Place excess sediment removed from the trench along the up stream and down stream toes of the structure.] Place the farthest up stream structure in the work area at an angle of 30 degrees to the direction of stream flow to deflect the current towards the center of the channel. Construct subsequent down stream structures at right angles to the stream bank with a spacing of the average length of the structure.

3.12.2.11 Brush Grid

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NOTE: A brush grid consists of layers of brush laid out in a rectilinear pattern with each successive lift being placed normal to the lower lift. The structures are well suited for the repair of severely scoured or sloughing areas on banks in streams with high flow velocities and large range or frequent changes in water level. These structures may be used on portions of the streambed from the toe of the high bank to the edge of the mean low water level of the stream. For large scour areas, a brush grid may be constructed at the up stream end of the scour hole between the stream bank and a brush traverse or vegetated groin or dike. The remaining portion of the scour area may be filled with widely spaced brush transverse structures. The areas between the transverses may be filled with brush sills. A brush grid requires significant manual labor and a large supply of brush. The amount of labor and materials may be reduced by combining the grid with brush sills, vegetated dikes, gabions, or by constructing a widely spaced grid work of brush instead of a complete cover of brush.

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a. [Extend an excavation that is 4.5 m 15 feet wide and 1 m 3 feet deep from the edge of the high bank 6 m 20 feet into the stream channel. Slope the floor of the excavation towards the bank at 2H:1V and make smooth and compact. Extend the side slopes beyond the above specified dimensions and at the angle of repose. Key trench 1.5 m 5 feet into the stream bank.] [Excavate sediment to form a level floor at the installation area to the grades and dimensions shown on the drawings.][Drive live] [dead] poles composed of [untreated manufactured lumber] [straight sections cut from local trees] vertically 1 m 3 feet into the streambed [along the alignment of the proposed bank] [as shown on the drawings] [in a straight row that is 4.5 m 15 feet from the edge of the high bank]. Place additional poles between the new alignment of poles and the stream bank on 1.5 m 5 feet centers. The poles must be 100 mm 4 inches in diameter. The length of the poles must be such to allow 600 mm 2 feet of pole to extend above the mean water level. Shape bottoms of the poles to sharp tips to facilitate driving them into the streambed. Cut tops of the poles normal to the lengths of the poles. The top elevations of the poles must be the same for all poles. [Drill pilot holes, slightly larger in diameter than the poles, into the streambed using a [steel punch rod] [mechanical drill] in coarse alluvial sediment]. Stand the poles erect without support after installation in the streambed. Install loose or nonvertical poles. Replace poles damaged during installation at no expense to the Government.

b. Provide base layer of the structure consisting of 150 mm 6 inch diameter by 6 m 20 feet long trunks of trees with their branches still attached. Do not attach root wads to the trunk. Pack these trunks tightly between the poles with the growth tips extending 600 mm 2 feet into the stream beyond the new bank alignment. Place trunks horizontally in the excavation with the cut ends placed [in the key trench] [firmly butted against] the stream bank.

c. Place [removed sediment] [select fill] over the trunks until only to tops of the trunks are exposed. Place live cuttings up to 50 mm 2 inches in diameter vertically in rows spaced 1 m 3 feet apart parallel to the base layer of trees with a minimum of 5 cuttings per 300 mm linear foot of row. Push cut ends of the cuttings through gaps between the base logs and into the streambed. The top of the growth tips of the cuttings must be at the same elevation as the top of the vertical poles and inclined at a slight angle down stream. Place a layer of live cuttings consisting of 1 m 3 feet wide rows that are up to 300 mm 12 inches thick horizontal on top of the first lift of trunks and pull around the upright live cuttings and poles. Extend the growth tips 600 mm 2 feet beyond the new alignment into the stream. Separate the rows from the vertical posts by a distance of 300 mm one-foot. Place sediment n top of the cuttings to fill all voids until only the top of the rows are exposed. Place a lift of cuttings normal to the first lift of cuttings with the growth tips extending 600 mm 2 feet beyond the down stream edge of the structure. Place sediment on top of this lift of cuttings the same as the lower lift. Place lifts of rows of cuttings in this alternating manner until the structure reaches a minimal height of 1 m 3 feet above the mean low water level. Place large natural stone along the outer perimeter of the structure to protect it from scour. Secure top of the structure with [a layer of natural stone] [sand bags filled with select fill] placed on top of the horizontal cuttings and around the vertical live cuttings and poles.

3.12.3 Longitudinal structures

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NOTE: Longitudinal structures or plantings are placed parallel to stream banks or lake shores and may be used in conjunction with hard engineered structures to provide habitat, shade, and to obscure the hard structures from view thus allowing a more natural appearance to the protected bank.

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3.12.3.1   [Single] [Clump] Reed Planting

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NOTE: Reed planting involves the planting of singe reeds or clumps of reeds along a stream bank or lake shore. This method is well suited for low flowing streams, lakes, canals, and stagnate areas of water that are protected from wave action or strong currents. Such sites may include exposed banks at or slightly below the mean low water level, tidal flats, or areas of low relief shoreline that extends some distance into a water body. The reeds dissipate energy of the water acting on the shore area and reduce erosion while root structures improve the strength of the bank. Planting should begin at the wet shoreline and progress landward. This planting method is simple to implement and complete, but must be accomplished during the first months of summer to allow the plants to become established.

The method does not provide immediate erosion protection to the bank nor will the plants tolerate shade. The effect of the plantings may not be realized until two to three years after planting. Reed planting will not reduce failure of unstable banks or shorelines. Clump planting refers to the planting of a large group of reeds contained in a large soil and root mat in a hole excavated at the site.
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Plant reeds during the active growing period. Deliver reeds to the site in bundles in saturated cloth. Plant [single reeds] [reed clumps] on a grid with a spacing of 600 mm 2 feet starting at the shoreline and progressing landward [for a distance of 16 m 50 feet] [to the existing reed line]. The stems of the reeds must be slightly above grade and vertical. Protect shoreline edge of the planting area by [a line of natural stone] [coir log] [log] [_____]. [Ensure placed between stone armor at the water line are placed between the stones in narrow trenches backfilled with fine-grained sediment.]

3.12.3.2   Live stone revetment

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NOTE: Live stone revetments are traditional stone or rock armor revetments placed on banks for stabilization and erosion protection with the addition of live cuttings placed in the joints between the armor stones. These structures are well suited for sites where extensive areas of bank must be protected along high flowing streams with heavy bed load or lake shore subject to wave action. Saplings may be placed between the rock joints if topsoil is placed to fill the interstitial voids between the armor stones. Construction must occur in the dormant season for live cutting revetments and in the spring or autumn for transplanted saplings. Expect 30 to 50 percent mortality rate

with cuttings, particularly in drier climates. Driving cuttings or live poles deeper into the stream bank and irrigation of the site may improve plant survivability.

The designer is encouraged to review existing references on stone revetment function, performance, and construction. Also, the designer should consider the impact the construction of a hard structure may have to the surrounding banks and channel such as the shifting of erosion to adjacent or cross stream locations that are not protected.

****

a. Prepare bank by reducing the slope to [2H:1V] [as shown in the drawings]. Smooth and compact the surface of the bank. Excavate a key trench at the toe of the stream bank and extend [1 m 3 feet below the mean low water level] [600 mm 2 feet below the lowest elevation of estimated scour]. Overlay bank by a 100 mm 4 inch thick layer of 75 mm 3-inch minus compacted fill that contains less than 5 percent fines to serve as a filter blanket between the outer armor stone and the bank soil.

b. Place large stone with a nominal diameter of 1 m 3 feet in the key trench. Place armor stone up bank from the key stones to the bank crest [and extend 1.5 m 5 feet landward of the bank crest]. Place each stone to interlock with down slope stones to form a rock mass that covers 100 percent of the exposed bank. Place the stones by [hand] [heavy equipment with placing bucket]. Do not dump stones in mass from the top of the bank. Push the stones into the bank once the stone is placed. Place [top soil] [excavated bank material] on top of the stone and brush over the surface of the stone to fill the voids between the stones. Drive live [cuttings] [stakes] [poles] between the joints of the rock at least 600 mm 2 feet into the bank soil below the base of the armor stone. Place up to 10 live poles per square yard of area. Place cuttings on the entire structure from the mean low water level to the landward end of the revetment.

c. Key ends of the structure into the stream bank. Excavate key trenches 1.5 m 5 feet into the stream bank at the up stream and down stream ends of the structure. These trenches must be 1.5 mm 5 feet deep and the faces of these trenches must be the same slope as the face of the prepared bank. Fill trenches with large [stone] [rock] that is pushed into the bottom and sides of the trench. Fill voids between the [stones] [rocks] with soil removed from the trench. Extend the [stone] [rock] to the surface and wrap in a continuous mass into the armor [stone] [rock] on the face of the bank.

3.12.3.3 Brush Layered Revetment

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NOTE: Brush layer revetments are constructed of alternating layers of live brush cuttings and rock. These structures are easier to construct and of lower cost than live revetments and are suitable for protecting long stretches of stream banks or lake shores. The live brush will cover the armor rock with time and obscure it from view. Angular quarry stone or rip rap may be used with this method.

****

a. Prepare bank by reducing the slope to [2H:1V] [as shown in the drawings]. The surface of the bank must be smoothed and compacted. Excavate a key trench at the toe of the stream bank and extend [600 mm 2 feet below the mean low water level] [600 mm 2 feet below the lowest elevation of estimated scour]. Overlay the bank by a 100 mm 4 inch thick layer of 75 mm 3-inch minus compacted fill that contains less than 5 percent fines to serve as a filter blanket between the outer armor stone and the bank soil.

b. Place live cuttings in the trench against the stream side wall of the trench. Push the cuttings into the streambed and cover the cut ends with a thin layer of [sediment] [select fill]. Place large stone with a nominal diameter of 1 m 3 feet in the key trench. Rest the large stone on the ends of the cuttings and anchor them in place. Place armor stone up the bank from the key stones to the bank crest [and extend 1.5 m 5 feet landward of the bank crest]. Place each stone to interlock with down slope stones to form a rock mass the covers 100 percent of the exposed bank. Place the stones by [hand] [heavy equipment with a placing bucket]. Do not dump stones in mass from the top of the bank. Push stones into the bank using suitable heavy equipment once the stone is placed. [Brush] [Wash] [sediment] [select fill] into the voids between the rocks as the rocks are placed.

c. Place stone in lifts not to exceed 1 m 3 feet in height. The top of the lift must be within 150 mm 0.5-foot of the same elevation across the surface of the lift [and parallel to the water surface of the stream]. Place a layer of loosely compacted topsoil at least 150 mm 6 inches thick on the top of the rock lift. Place live cuttings in a criss cross manner with 20 cuttings per 1 m 3 linear feet on top of the topsoil layer with the cut ends pushed at least 300 mm 1-foot into the bank beneath the filter layer and with growth tips extending 150 mm 1.5 feet beyond the face of the armor rock. Cover cuttings with 100 mm 4 inches of moderately compacted topsoil. Place the next lift of rock on top of the compacted top soil and push these rocks into the topsoil until refusal due to contact with the rocks of the underlying lift. Continue process of alternating layers of rocks, cuttings, and topsoil to the [design height] [top of bank].

d. Key ends of the structure into the stream bank. Excavate key trenches 1.5 m 5 feet into the stream bank at the up stream and down stream ends of the structure. These trenches must be 1.5 m 5 feet deep and the faces of these trenches must be the same slope as the face of the prepared bank. Fill trenches with large [stone] [rock] that is pushed into the bottom and sides of the trench. Fill voids between the [stones] [rocks] with soil removed from the trench. Extend [stone] [rock] to the surface and wrap in a continuous mass into the armor [stone] [rock] on the face of the bank.

3.12.3.4 Longitudinal Live Fascine

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NOTE: Longitudinal live fascines consist of live fascines combined with brush layers and possible bank toe armor stone along the length of a stream bank or lake shore. These structures provide immediate protection of the toe of the bank from current or wave erosion. These structures are

inexpensive and easy to construct and suitable for low banks. The method may be used as toe protection for stable high banks if the upper portions of the banks are protected by other bioengineered or hard structures.

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Compose fascines of live cuttings and construct in accordance with paragraph "Live Fascines" in PART 3. [Excavate a trench at the mean low water level of the stream with a floor that slopes at 15 degrees towards the bank.] [Excavate a key trench between the fascine trench and the mean low water line. This trench must be 600 mm 2 feet deep and 1 m 3 feet wide. Terminate the face of the key trench at the lip of the trench for the fascine. Fill trench with [quarry rock] [large natural stone] [rock and brush fascines anchored with dead stakes].] Place a layer of live cuttings in the bottom of the fascine trench in a criss cross manner with the cut ends of the cuttings in contact with the face of the trench and the growth tips extending 150 mm 1.5 feet beyond the lip of the trench. Place a minimum of 20 cuttings per linear foot. Cover cuttings with a layer of compacted soil. Place fascine the trench and anchor in place by live poles. The poles must be 1.2 m 4 feet in length and drive 10 mm 2.5 feet into the bottom of the trench through the fascine. Space the poles every 1 m 3 feet along the length of the fascine. Place backfill around the fascine to the [grade of the original bank] [design grade].

3.12.3.5 Longitudinal Brush Packing

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NOTE: Longitudinal brush packing is a method suited for the repair or protection of near vertical or under cut banks subject to erosion. These structures provide immediate protection to the bank from erosion or wave action. The stability of the bank should improve over time as vegetation becomes established dependent on the properties of the soils that compose the bank. The structures are suited for low to fast flowing streams or active lake shores. They are simple and easy to construct but may require large amounts of fill and vegetation. The structure consists of lifts of soil and brush that are wrapped by erosion control products. Do not use geosynthetic or plastic netting unless absolutely necessary and in this case only for the lower lifts of the structure.

****

a. The slope of the bank must be reduced to [2H:1V] [steps that are 300 mm 12 inches high and 600 mm 24 inches deep from the toe to the crest of the bank] [as shown on the drawings]. Excavate a key trench at the toe of the design slope. This slope must be of the same grade as the adjacent undamaged stream bank. The key trench must be 1.2 m 4 feet wide and 600 mm 2 feet deep and extend the length of the work site. Fill trench with [large natural stone] [quarry rock] that has a nominal diameter of 600 mm 2 feet and that is well graded with 100 percent greater than 100 mm 4 inches. Place [stone] [rock] to form a triangular topped dike with side slopes of 2H:1V. The [stone] [rock] must be tamped into place.

b. Place a 100 mm 4 inch layer of [select fill] [removed sediment] on top of the landward face of the rock dike and compact. Cover [fill] [sediment] layer with erosion control fabric composed of [coir netting] [_____]. Extend fabric from the face of the bank to at least 1.2 m 4 feet beyond the top of the rock dike. Secure netting to the soil layer with [staples] [stones] [stakes]. Ensure fabric is free of wrinkles and extend the full length of the rock dike.

c. Place live cuttings [with 25 percent dead branches] on top of the fabric layer in a herringbone pattern. Push cut ends of the cuttings into the streambed to refusal. Place cuttings at a density of 20 cuttings per 300 mm linear foot to a thickness of 100 mm 4 inches. The growth tips of the cuttings must extend 150 mm 1.5 feet beyond the top of the crest of the rock dike into the stream channel. Brush [select fill] [removed sediment] into the voids between the cuttings. Place a 100 mm 4 inch layer of [select fill] [removed sediment] on top of the cuttings and compact. The fabric that extends over the rock dike must be [cut and removed] [tightly rolled and anchored at the base of the cuttings on top of the rock dike].

d. Cover the top of the [fill] [sediment] layer placed on top of the first layer of cuttings with a layer of erosion control fabric composed of [coir netting] [_____]. The fabric must cover the top of the lower lift. At least 1.5 m 5 feet of fabric must remain above the contact of the lower lift and the slope of the bank. Stake this portion of fabric temporarily to the bank slope. At least 2 m 6 feet of fabric must extend beyond the top of the design slope. Place a 300 mm 12 inch layer of [select fill] [removed sediment] on top of the fabric and compact to 90 percent dry density. Place the ends of the fabric on top of the compacted material. Place the fabric near the face of the bank on top of the compacted material and pull free of wrinkles. Place the portion of fabric towards the stream channel across the face of the compacted material and pull tight and secure to the top of compacted material with staples. Install staples flush with the top of the lift.

e. Place live on top of the lift of compacted material in the same manner as the cuttings on the first lift. Cover these cuttings by a 100 mm 4 inch layer of compacted [select fill] [removed sediment]. Continue process of wrapping lifts of compacted soil with erosion control fabric and the placement of layers of cuttings to the [design height of the structure] [top of the bank]. Adjust the height of the soil lift nearest to the top of the structure in thickness to meet the design grade. Do not cover the top of the structure with cuttings. [Place live cuttings across the top of the structure on 600 mm 2 feet centers for a distance of 2 m 6 feet landward of the top of the bank and for 2 m 6 feet upstream and down stream of the ends of the structure on the original stream bank.]

f. Key the structure into the bank on the up stream and down stream sides of the structure. The key trenches must be 1.2 m 4 feet deep. Wrap lifts of the structure into the trenches and butt the ends of the lifts against the face of the key trench.

3.12.3.6 Live Crib Wall

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NOTE: Live Crib walls are robust structures suited for stabilization and protection of banks or shores subjected to high flow or moderate wave action.

These structures provide immediate erosion protection and possible habitat during high flow events dependent upon design. The structure provides a hard frame that dissipates current or wave energy. Bank stability and habitat improve as the vegetation matures and develops extensive root systems and shade along the bank. These structures typically require earthworks and large equipment for bank preparation and backfilling. Large amounts of vegetation and labor are required. Crib walls may be used to increase the width of a stream by replacing the natural sloped banks with the near vertical walls of the structure. Crib walls may be used to repair severely scoured banks by placing the structure in the stream at the new bank alignment and backfilling the void between the structure and the existing bank.

The structure may be combined with brush sills, brush mats, or large natural stone on the up stream or down stream sides of the structure to reduce erosion. Stability of the structure may be improved using a double crib design composed of front and back headers. Backfill should be free draining material. Timber used for the crib wall may be untreated manufactured 300 mm 12-inch square posts, locally harvested vegetation with truck diameters greater than 300 mm 12 inches, or combination of these materials.

****

a. Reduce stream bank to the required slope and design grade. Excavate a trench that is 600 mm 2 feet deep and extends parallel to the toe of the slope. This trench must extend the full length of the work site and must extend [for a distance of 4.5 m 15 feet into the stream channel from the toe of the slope] [in the stream channel to the distance and dimensions shown on the drawings]. Slope the floor of the trench at 15 degrees towards the bank and [manually compact using a tamping bar weighing at least 18 kg 40 pounds] [compact using a small motorized tamping machine] until the bottom of the trench is dense and provides a solid base for the crib wall. Ensure the floor of the trench is [as shown in the drawings] [of uniform grade across the trench width]. Key trench into the stream bank for a distance of 2 m 6 feet. Use material removed from the key trenches as compacted backfill in the key trenches. Sediment excavated from the trench must be [removed from the site and replaced with select fill] [used as compacted backfill]. Fill depressions in the trench floor with compacted material to raise these areas to design grade and reduce areas above grade to the design grade.

b. Frame crib wall with [untreated straight 300 mm 12-inch square by 2.5 m 8 feet long beams] [200 to 300 mm 8 to 12 inch diameter by 2.5 m 8 feet long straight logs harvested from local sources. Cut these logs normal to the trunk and strip all branches from the trucks]. Place the header adjacent to the stream parallel to the toe of the slope at the design alignment of the wall and extend the full width of the trench. Place tje header adjacent to the bank parallel to and 2 m 6 feet from the stream side header in the direction of the bank. Place headers end-to-end and in line at splices between the members. Drive wood posts vertically into the streambed 150 mm 6 inches from the splices on both sides of the header.

c. Provide stretchers that are 2 m 6 feet in length. Place each stretcher normal to the headers and between the vertical poles at the splices between the headers. Space stretchers [every 1.2 m 4 feet] [mid distance] between the vertical poles and extend a minimum of 100 mm 4 inches beyond the outer edge of the stream side header face. Place rear butt of the stretcher on top of the header near the bank and [extend 100 mm 4 inches beyond the outer face of the header] [firmly place against the exposed bank]. Attach stretcher to the header with binding products wrapped three times in a criss cross pattern and secure with a non-raveling knot. Drill a 13 mm 1/2-inch diameter hole vertically through the stretcher and header. Drive a 600 mm 24 inch long, 16 mm 5/8-inch diameter [non-galvanized steel spike] [steel rebar] [hard wood dowel] into the hole and set flush to the top of the stretcher. Backfill the open area between the inner face of the stream side header and the inner face of the landward header with compacted [sediment removed from the trench excavation] [select fill] to the middle of the stretchers. Place live cuttings 19 to 38 mm 3/4 to 1.5 inches in diameter in a criss cross manner on the top of the compacted backfill with the cut ends pushed into the backfill near the landward header. The growth tips of the cuttings must extend 600 mm 2 feet beyond the face of the stream side header. Place backfill and lightly compact on top of the cuttings to the top of the stretchers. Place additional headers, stretchers, backfill, and cuttings until only the final lift remains. The centerlines of stream side headers must be off set 50 mm 2 inches towards the bank relative to the lower headers to provide an incline to the face of the structure. Place select fill in the area between the face of the landward header and the slope of the bank. Place the fill in lifts of the same thickness as the lifts on backfill in the interior of the structure. Compact each fill to at least 90 percent dry density.

d. The top stream side headers must be 100 mm 4 inches larger in diameter than the headers used for wall construction. Cut vertical poles flush with the top of the final headers. Place a header at the midpoint between the outer headers and secured with binders and [spikes] [rebar] [dowels] to the underlying stretchers. Fill the lift of backfill immediately below the completion headers with a tightly packed brush mat composed of live [and dead] cuttings that are placed in an alternating rectilinear grid pattern. Cover each layer of brush with a thin layer of lightly compacted backfill. [Rounded clean natural stone from 300 to 600 mm 12 to 24 inches in diameter] Place [excavated sediment] from the top of the packed brush to the top of the final headers [to the grade shown in the drawings]. [Drive live stakes vertically on 600 mm 2 feet centers into the backfill at the top of the structure.] [Place large natural stone armor 600 mm 2 feet thick on the banks and against the ends of the structure for a distance of 3 m 10 feet upstream and down stream from the structure. Plant live stakes in the joints between the stones.] Fill key trenches with [large natural stone] [quarry rock] to the design grade.

3.13 IRRIGATION

Start irrigation of the structure immediately after installing erosion control products and vegetation. Apply water to supplement rainfall at a sufficient rate to ensure moist soil conditions to a minimum 300 mm 12-inch depth. Prevent run-off and puddling. Do not drive watering trucks over turf areas, unless otherwise directed. Watering of other adjacent areas or plant material not related to work efforts must be [prevented] [as specified by the Contracting Officer]. Apply water to trenches immediately before placement of live vegetation. Place water on the completed structure at the end of each day, as needed to control dust and to prevent excessive drying of vegetation, and at the completion of the structure. [Irrigate the structure after installation for 3 months until the end of the first year growing season.] [Irrigate structures in arid climates for a period of 3 years.] [Daily irrigation of the structure and work site must not exceed 20 minutes [each day] [twice a day] [3 times per week] and must be sufficient to support the survival and growth of planted vegetation. Do not exceed limits of irrigation that could impair the stability of the structure and adjust irrigation to compensate for additions or deficits to soil moisture caused by precipitation or evaporation.]

3.14 FERTILIZER, PESTICIDE, HERBICIDE

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NOTE: Edit this section as required. Fertilizer, pesticide, and herbicide may be required for the construction, establishment, and maintenance of bioengineered structures. Provide methods for application, frequency of use, safety precautions for humans and the environment in the section below.

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3.15 FIELD QUALITY CONTROL

The Contracting Officer will inspect the work site prior to final acceptance of work. A punch list noting deficiencies will be compiled by the Contracting Officer and provided to the Contractor. Perform, repair, adjust, align, or otherwise comply with the specified work on the punch list to the satisfaction of the Contracting Officer. Notify the Contracting Officer at least 14 days prior to the inspection that work is ready for inspection. Work will not be accepted until all punch list items are resolved and all work meets or exceeds contract requirements. Final acceptance of work will not be provided by the Contracting Officer until all defects or deficiencies are corrected. Final Acceptance will occur only after all corrective actions and supplemental viable plantings are complete and the structure meets performance standards and all contract requirements. Comply with necessary repairs to the structure and vegetation as stated in the warranty.

3.16 CLEAN-UP

Dispose of excess material, debris, and waste materials offsite at an approved landfill or recycling center. Clear adjacent paved areas. Restore the site to preexisting conditions to the extent reasonably possible and to the satisfaction of the Contracting Officer.

3.17 PROTECTION

Immediately upon the start of the installation in an area, protect the area against traffic or other use by erecting barricades and providing signage as required, or as directed. Provide signage [in accordance with Section 10 14 00.10 EXTERIOR SIGNAGE] [as shown on the drawings]. Protect the work site and vegetation from damage and vandalism and free of trash and debris until final acceptance by the Contracting Officer.

3.18 DOCUMENTATION

Establish and maintain documentation for bioengineering practices to record the desired information and to assure compliance with contract requirements, including, but not limited to, the following:

3.18.1 Maintenance Records

Visit, inspect, and document site conditions after the completion of construction every week for the first year and every two weeks thereafter until the end of the second year. Include written reports on site structure and vegetation conditions, damage, plant loss, and the like, to fully describe site conditions at the time of the visits and changes observed since previous visits. Obtain photographs of the site and areas of growth, defects, or damage and include with the records. Submit records to the Contracting Officer within [48] [_____] hours after the completion of the site visit.

3.18.2 Final Project Report

Specify and summarize all construction activities and problems plus information included in the construction and maintenance records as submitted throughout the project. Summarize the work rather than repeat the items in the individual reports.

-- End of Section --