Jacobs

Challenging today.
Reinventing tomorrow.

Approaching Riverbank Stabilization
Lower Coeur d’Alene River, ID

11/20/2024

Ryan Mitchell

- Typical approach for selecting riverbank treatments
- Define goals, constraints, and design criteria
- Selection of stable materials
- Stability evaluations
- Comparison of common treatment options
- Backwater design considerations
- Vegetation considerations
- Construction considerations
- Discussion

Typical Approach for Treatment Selection

1. Define Goals, Constraints, and Design Criteria
   a) This process will reduce the list of available options, and
   b) define the metrics for treatment selection
2. Alternatives Analysis at Conceptual-Level Design
   a) Identify candidate treatments that are consistent with goals and design criteria
   b) Develop conceptual level design for each alternative
   c) Evaluate performance and compare performance metrics
   d) Develop ROM construction cost estimate
   e) Identify remaining feasibility questions, if any remain
      i. i.e. more analysis needed to verify compliance with some metrics
   i. Select one or multiple treatments to advance in design process
3. *Optional:* Identify multiple treatment options for different areas
   a) Requires delineation or riverbank segments based on hydraulic conditions and other factors
   b) The various treatment options should utilize the same materials

Goals, Constraints, and Design Criteria

Goals and measures of success:

- What are the success/performance criteria?
- What constitutes failure?

Constraints:

- Physical limitations (i.e. property boundaries, infrastructure, available disposal space)
- Cost
- Available materials
- Permitting

Design criteria:

- Constraints are often adopted as design criteria
- Allowable or preferred design materials
- Habitat (aquatic and riparian), can be species-specific or broad
- Permitting requirements
- A table format is useful way to summarize all design criteria

- Avoiding adverse impacts
- Stability factor of safety

Example: Riverbank Stabilization Design Criteria

Design Criteria	Design Discharge Recurrence Interval (year)	Design Goal	Alternative 1 Vegetated Riprap	Criteria met	Alternative 2 FESL	Criteria met	Comments
Stability factor of safety	100-YR	1.5	List the result here…	(yes/no)	List the result here…	(yes/no)	add additional detail
Minimize Off-site Removal Volumes	N/A	< XX,XXX CY					
Material availability	N/A	All imported materials available within XX Miles					
No adverse impacts to WSEs at high flows	100-YR	< 0.X feet					
No increase in downstream shear stress or on opposing riverbank	2-YR	< 0.X PA increase					
" "	10-YR	< 0.X PA increase					
Provide safe access for recreational users	N/A	Slope less than 3:1					
Increase aquatic habitat value							
Permitting Compliance		Yes					
Construction complexity		Low (High, Med., Low)					
Construction cost/rivermile		Low (High, Med., Low)					

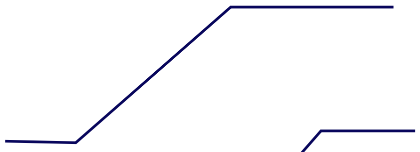
Range of Treatment Options

Materials:

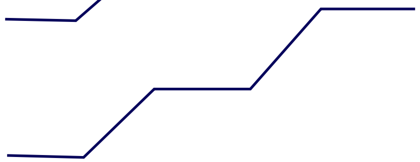
- Riprap
- Vegetated Riprap
- Rock toe with vegetated side-slope
- Fabric Encapsulated Soil Lifts
- Many other combinations of the above

Bank Geometry:

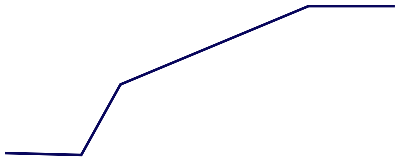
- Uniform slope



- Benched

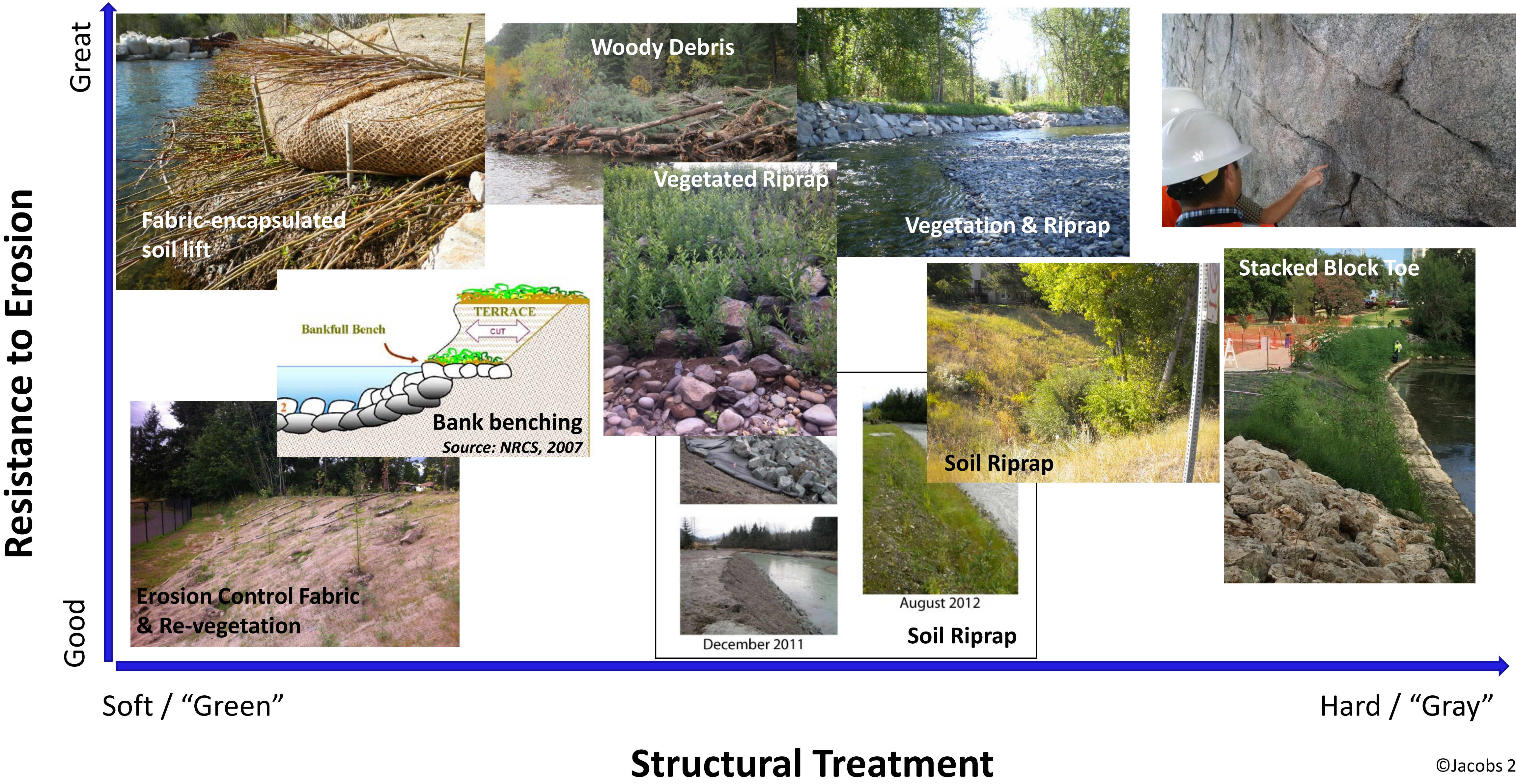


- Variable slopes

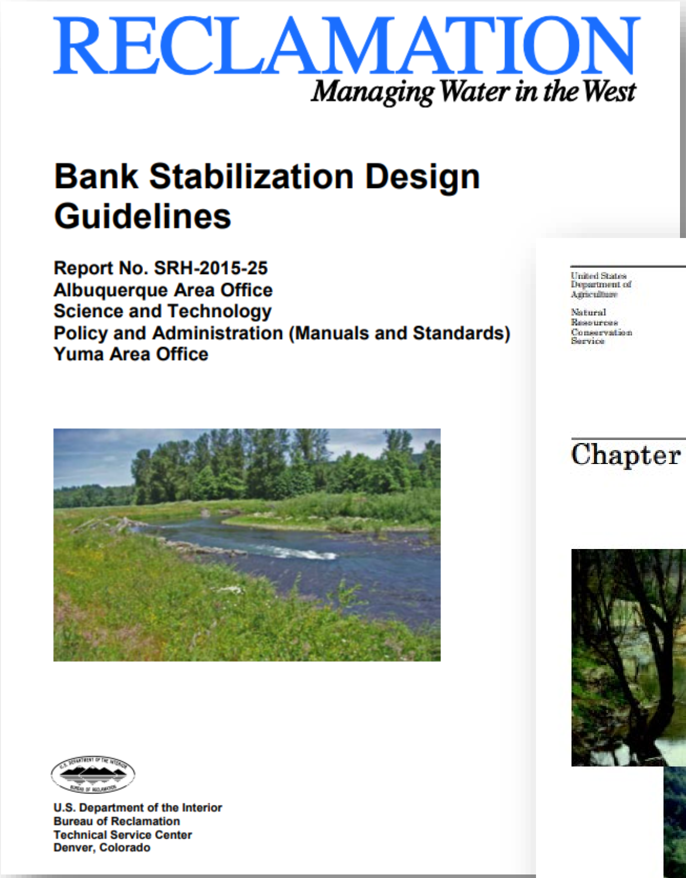


A “bank treatment” is the combined geometry and materials

Example Lateral Stability Treatments (Protective)



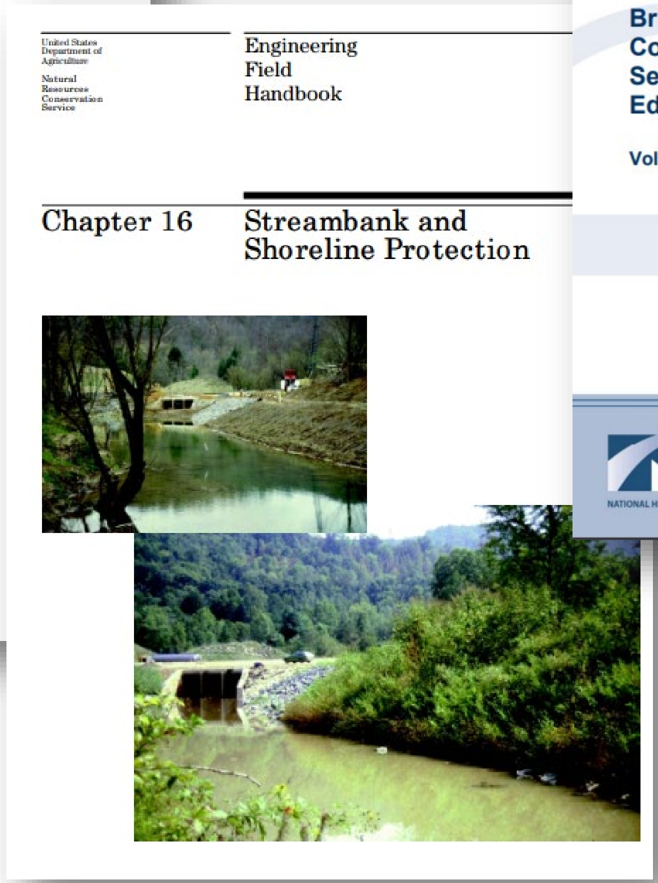
Selection of Stable Materials (Common Design Guides)


RECLAMATION
Managing Water in the West

Bank Stabilization Design Guidelines

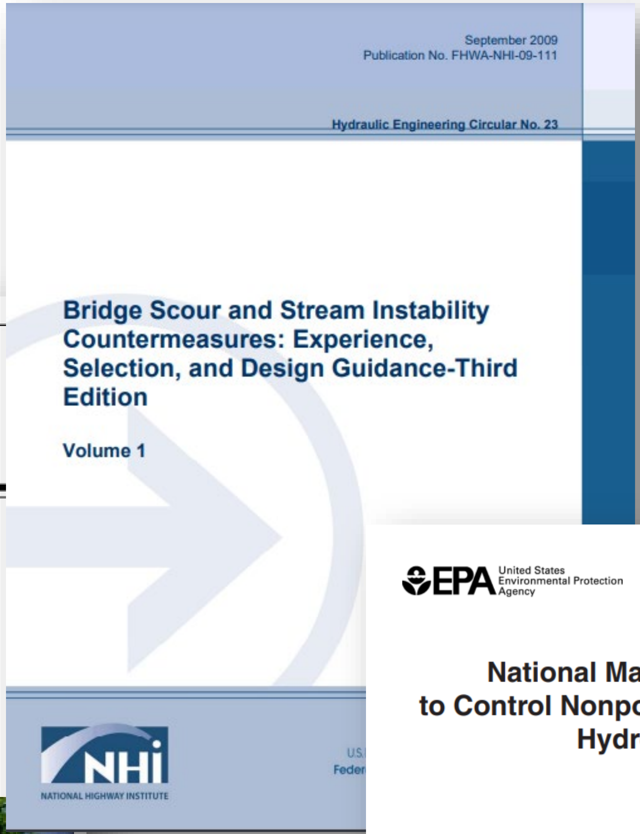
Report No. SRH-2015-25
Albuquerque Area Office
Science and Technology
Policy and Administration (Manuals and Standards)
Yuma Area Office

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado


United States Department of Agriculture
Natural Resources Conservation Service

Engineering Field Handbook

Chapter 16 Streambank and Shoreline Protection

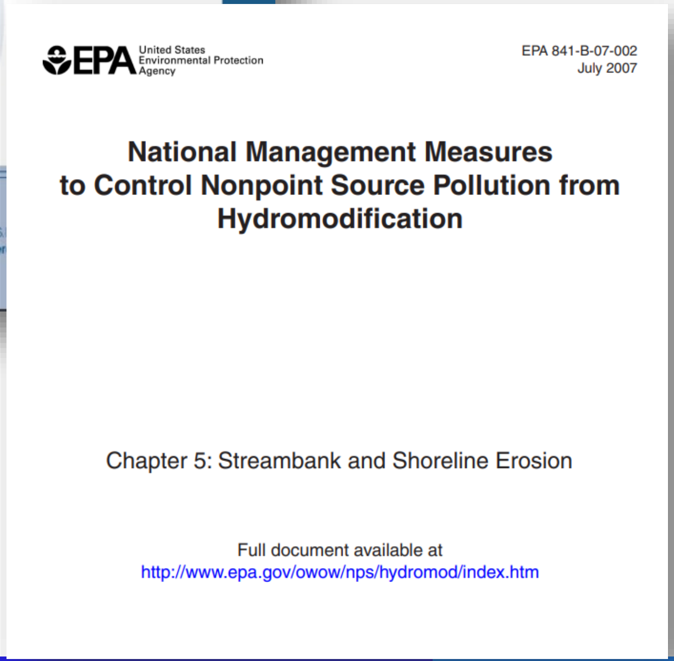

September 2009
Publication No. FHWA-NHI-09-111

Hydraulic Engineering Circular No. 23

Bridge Scour and Stream Instability Countermeasures: Experience, Selection, and Design Guidance-Third Edition

Volume 1

NHI
NATIONAL HIGHWAY INSTITUTE


EPA United States Environmental Protection Agency

EPA 841-B-07-002
July 2007

National Management Measures to Control Nonpoint Source Pollution from Hydromodification

Chapter 5: Streambank and Shoreline Erosion

Full document available at
http://www.epa.gov/owow/nps/hydromod/index.htm

Many available agency design guides.

Most redundant but some are more applicable to specific types of treatments

Selection of Stable Materials

All methods require modeling of velocities and shear stress to guide selection and sizing of materials. Requires selection of "design flood(s)"

Fischenich (2001) is a great resource for selecting stable materials (step-by-step) procedure

Factors of safety used to account for uncertainty

Table 4. Stability of Channel Linings for Given Velocity Ranges

Lining	0 – 2 fps	2 – 4 fps	4 – 6 fps	6 – 8 fps	> 8 fps
Sandy Soils	Use Caution	Not Appropriate	Not Appropriate	Not Appropriate	Not Appropriate
Firm Loam	Use Caution	Use Caution	Not Appropriate	Not Appropriate	Not Appropriate
Mixed Gravel and Cobbles	Appropriate	Use Caution	Use Caution	Not Appropriate	Not Appropriate
Average Turf	Appropriate	Use Caution	Use Caution	Not Appropriate	Not Appropriate
Degradable RECPs	Appropriate	Use Caution	Use Caution	Use Caution	Not Appropriate
Stabilizing Bioengineering	Appropriate	Use Caution	Use Caution	Use Caution	Not Appropriate
Good Turf	Appropriate	Appropriate	Use Caution	Use Caution	Use Caution
Permanent RECPs	Appropriate	Appropriate	Appropriate	Appropriate	Use Caution
Armoring Bioengineering	Appropriate	Appropriate	Appropriate	Appropriate	Use Caution
CCMs & Gabions	Appropriate	Appropriate	Appropriate	Appropriate	Use Caution
Riprap	Appropriate	Appropriate	Appropriate	Appropriate	Appropriate
Concrete	Appropriate	Appropriate	Appropriate	Appropriate	Appropriate

Key:

Green	Appropriate
Yellow	Use Caution
Red	Not Appropriate

Stability Thresholds for Stream Restoration Materials

by Craig Fischenich[1]

May 2001

Complexity	*Value as a Planning Tool*	*Cost*
Low Moderate High	Low Moderate High	Low Moderate High

Table 2. Permissible Shear and Velocity for Selected Lining Materials[1]

Boundary Category	Boundary Type	Permissible Shear Stress (lb/sq ft)	Permissible Velocity (ft/sec)	Citation(s)
Soils	Fine colloidal sand	0.02 - 0.03	1.5	A
	Sandy loam (noncolloidal)	0.03 - 0.04	1.75	A
	Alluvial silt (noncolloidal)	0.045 - 0.05	2	A
	Silty loam (noncolloidal)	0.045 - 0.05	1.75 – 2.25	A
	Firm loam	0.075	2.5	A
	Fine gravels	0.075	2.5	A
	Stiff clay	0.26	3 – 4.5	A, F
	Alluvial silt (colloidal)	0.26	3.75	A
	Graded loam to cobbles	0.38	3.75	A
	Graded silts to cobbles	0.43	4	A
	Shales and hardpan	0.67	6	A
Gravel/Cobble	1-in.	0.33	2.5 – 5	A
	2-in.	0.67	3 – 6	A
	6-in.	2.0	4 – 7.5	A
	12-in.	4.0	5.5 – 12	A
Vegetation	Class A turf	3.7	6 – 8	E, N
	Class B turf	2.1	4 - 7	E, N
	Class C turf	1.0	3.5	E, N
	Long native grasses	1.2 – 1.7	4 – 6	G, H, L, N
	Short native and bunch grass	0.7 - 0.95	3 – 4	G, H, L, N
	Reed plantings	0.1-0.6	N/A	E, N
	Hardwood tree plantings	0.41-2.5	N/A	E, N
Temporary Degradable RECPs	Jute net	0.45	1 – 2.5	E, H, M
	Straw with net	1.5 – 1.65	1 – 3	E, H, M
	Coconut fiber with net	2.25	3 – 4	E, M
	Fiberglass roving	2.00	2.5 – 7	E, H, M
Non-Degradable RECPs	Unvegetated	3.00	5 – 7	E, G, M
	Partially established	4.0-6.0	7.5 – 15	E, G, M
	Fully vegetated	8.00	8 – 21	F, L, M
Riprap	6 – in. d_{50}	2.5	5 – 10	H
	9 – in. d_{50}	3.8	7 – 11	H
	12 – in. d_{50}	5.1	10 – 13	H
	18 – in. d_{50}	7.6	12 – 16	H
	24 – in. d_{50}	10.1	14 – 18	E
Soil Bioengineering	Wattles	0.2 – 1.0	3	C, I, J, N
	Reed fascine	0.6-1.25	5	E
	Coir roll	3 - 5	8	E, M, N
	Vegetated coir mat	4 - 8	9.5	E, M, N
	Live brush mattress (initial)	0.4 – 4.1	4	B, E, I
	Live brush mattress (grown)	3.90-8.2	12	B, C, E, I, N
	Brush layering (initial/grown)	0.4 – 6.25	12	E, I, N
	Live fascine	1.25-3.10	6 – 8	C, E, I, J
	Live willow stakes	2.10-3.10	3 – 10	E, N, O
Hard Surfacing	Gabions	10	14 – 19	D
	Concrete	12.5	>18	H

[1] Ranges of values generally reflect multiple sources of data or different testing conditions.

A. Chang, H.H. (1988).
F. Julien, P.Y. (1995).
K. Sprague, C.J. (1999).
B. Florineth. (1982)
G. Kouwen, N.; Li, R. M.; and Simons, D.B., (1980).
L. Temple, D.M. (1980).

Example: initial post-construction conditions and mature-vegetation

Source: Fischenich, C., 2001, Engineering Research and Development Center – U.S. Army Corps of Engineers

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F. Julien, P.Y. (1995).
G. Kouwen, N.; Li, R. M.; and Simons, D.B., (1980).
H. Norman, J. N. (1975).
I. Schiechtl, H. M. and R. Stern. (1996).
J. Schoklitsch, A. (1937).
K. Sprague, C.J. (1999).
L. Temple, D.M. (1980).
M. TXDOT (1999)
N. Data from Author (2001)
O. USACE (1997).

ERDC TN-EMRRP SR-29 5

		Permissible Shear (lbs/sf)	Permissible Velocity (ft/s)	
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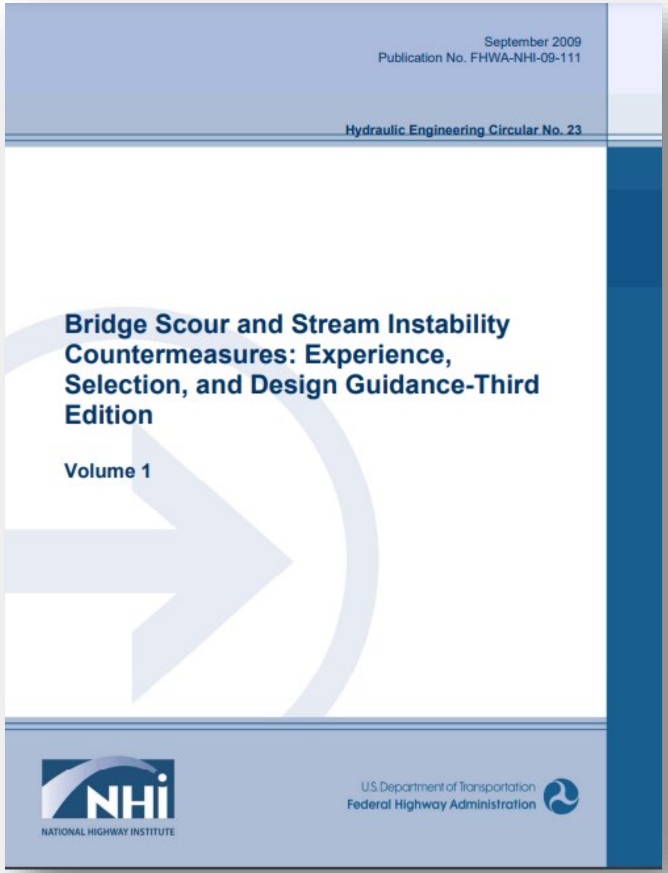
Adopted Thresholds	Permissible Shear (lbs/sf)	Permissible Velocity (lbs/sf)
Initial (immediate post construction)	2.3 lbs/sf	3-4 fps
Mature Veg. (>3 years after construction)	4 – 8 lbs/sf	12 fps

Riprap Sizing and Design

HEC-23 (FHWA 2009) is the most common guide for *sizing* riprap and establishing geometry



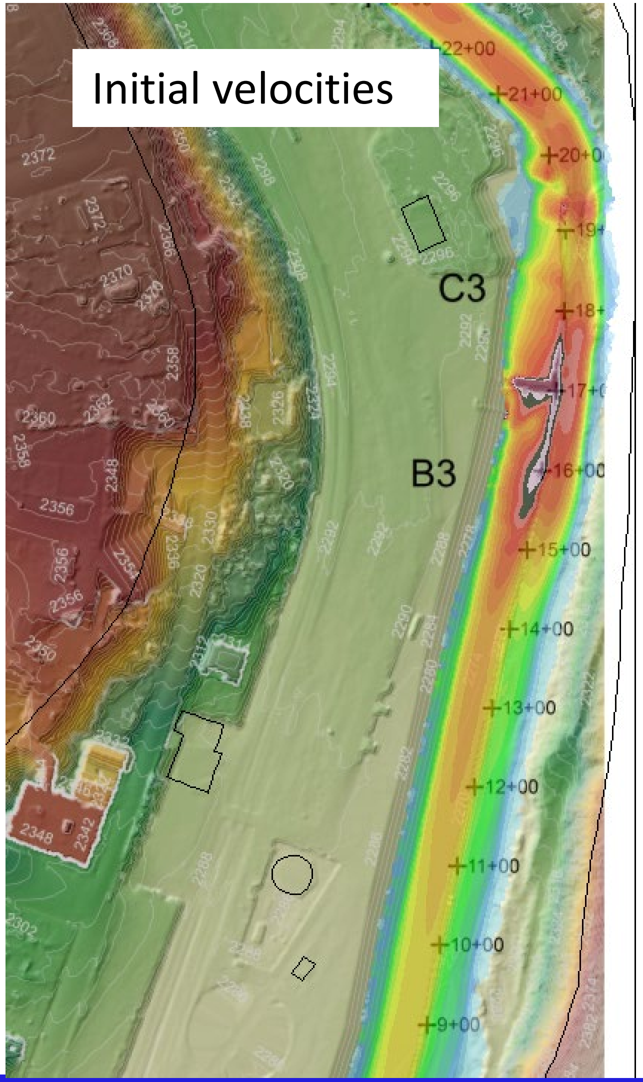
Design requires sizing and gradation of riprap
Filter requirements (based on class of riprap)
Slope (typically 2H:1V or flatter)
Thickness, height, and toe design

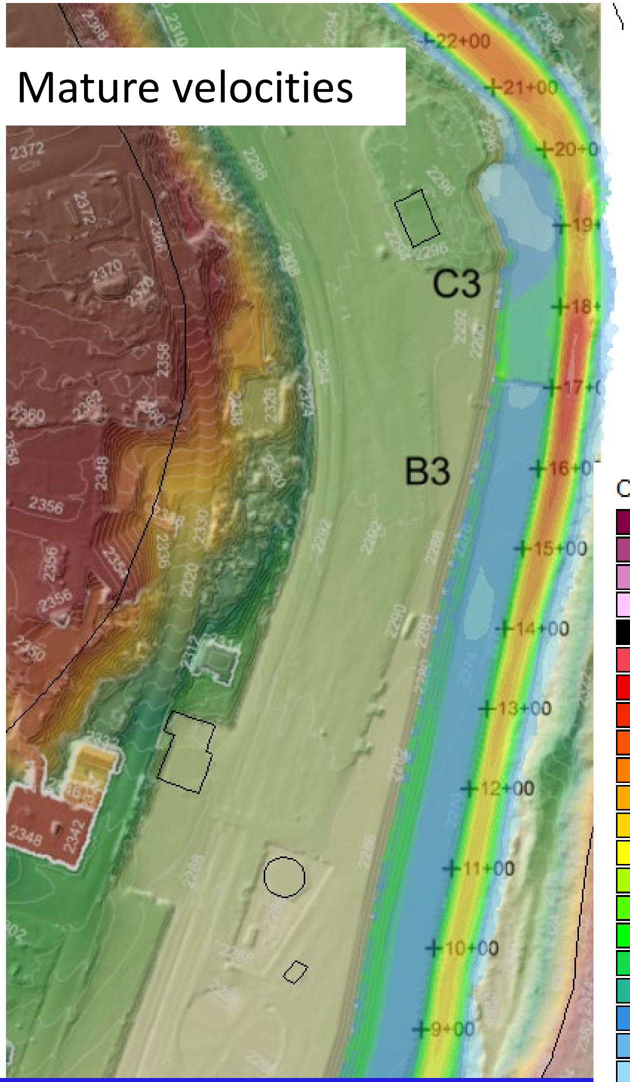
Table 5.1. Minimum and Maximum Allowable Particle Size in Inches.

Nominal Riprap Class by Median Particle Diameter		d_{15}		d_{50}		d_{85}		d_{100}
Class	Size	Min	Max	Min	Max	Min	Max	Max
I	6 in	3.7	5.2	5.7	6.9	7.8	9.2	12.0
II	9 in	5.5	7.8	8.5	10.5	11.5	14.0	18.0
III	12 in	7.3	10.5	11.5	14.0	15.5	18.5	24.0
IV	15 in	9.2	13.0	14.5	17.5	19.5	23.0	30.0
V	18 in	11.0	15.5	17.0	20.5	23.5	27.5	36.0
VI	21 in	13.0	18.5	20.0	24.0	27.5	32.5	42.0
VII	24 in	14.5	21.0	23.0	27.5	31.0	37.0	48.0
VIII	30 in	18.5	26.0	28.5	34.5	39.0	46.0	60.0
IX	36 in	22.0	31.5	34.0	41.5	47.0	55.5	72.0
X	42 in	25.5	36.5	40.0	48.5	54.5	64.5	84.0

Note: Particle size d corresponds to the intermediate ("B") axis of the particle.

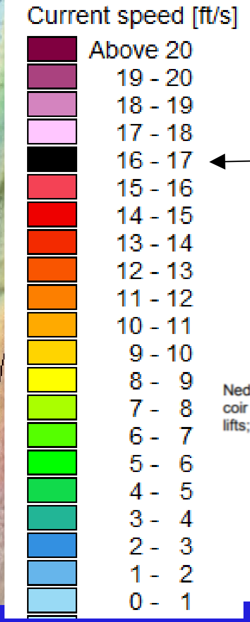
Evaluating initial post-construction conditions and mature-vegetation conditions is critical





Initial post construction surfaces are smooth leading to higher velocities compared to a surface with mature vegetation.

The strength of the surface also changes over time – stability should be checked for both conditions.



16 fps is the threshold velocity for the KoirWrap fabric (KW1200)

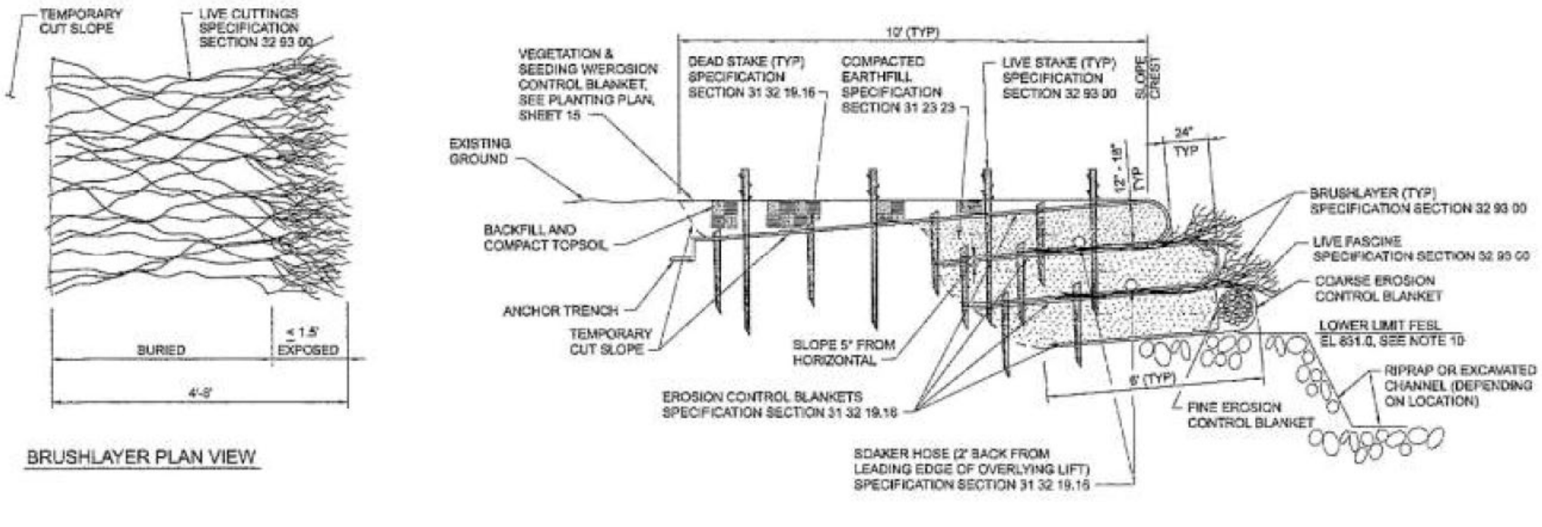
Technical Specifications for

Nedia KoirWrap™ 1200

Nedia KoirWrap™ 1200 is a double layered biodegradable erosion control fabric made up of an outer layer of high strength coir fabric and an inner layer of lightweight jute fabric tied together at regular intervals. Ideal for fabric encapsulated soil lifts; this product effectively replaces the traditional use of a coir fiber matting in combination with a non-woven coir blanket.

FESL

- High strength alternative to riprap
- Allows for steep slopes (1:1 or steeper)
- High habitat value
- Requires irrigation in first year
- Requires experienced contractor and oversite
- Check stability of immediate post-construction stability (before vegetation establishes)



(H) FABRIC-ENCAPSULATED SOIL LIFT (FESL), FASCINE, AND BRUSHLAYER DETAIL
NTS

Riverbank Stabilization with Fabric-Encapsulated Soil Lifts (Upper Sacramento River)

Lessons Learned

- *Timing of in-water fish work windows and harvesting of dormant vegetation are offset.*
- *Ensure designers are engaged in construction.*
- *Irrigation the first growing season dramatically increases survival.*

FESL examples

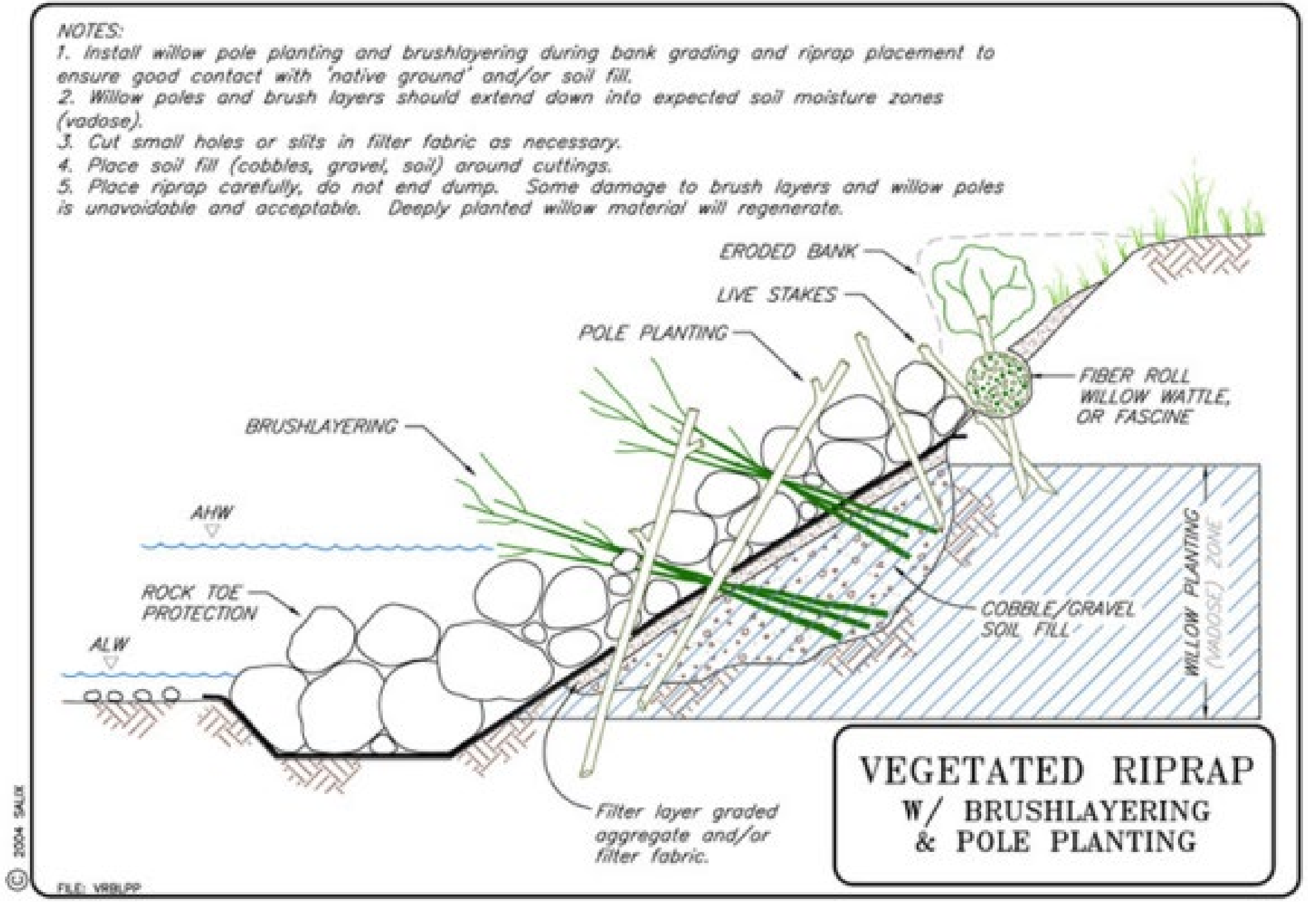
June 2010

Central Washington (Chumstick Creek – bridge replacement bank stabilization)

September 2012

Vegetated Riprap Options

1. Vegetated riprap with willow bundles
2. Vegetated riprap with bent poles
3. Vegetated riprap with brush layering and pole planting
4. Vegetated riprap with soil cover, grass and ground cover (aka Buried Riprap)
5. Joint or Live Stake Planted Riprap

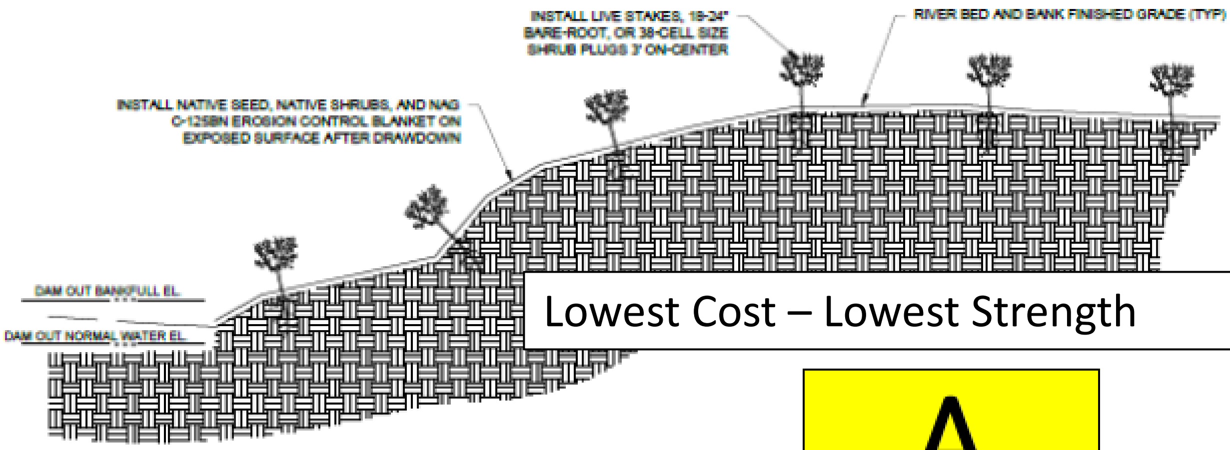


Source: HEC-23 / NCHRP Report 544 (McCullah and Gray 2005)

Vegetated Riprap examples

- High strength
- Provide moderate habitat value
- Max slope 1.5:1 - Typical slope is 2:1
- Irrigation required
- Unnatural riverbank
- Maintenance may be needed

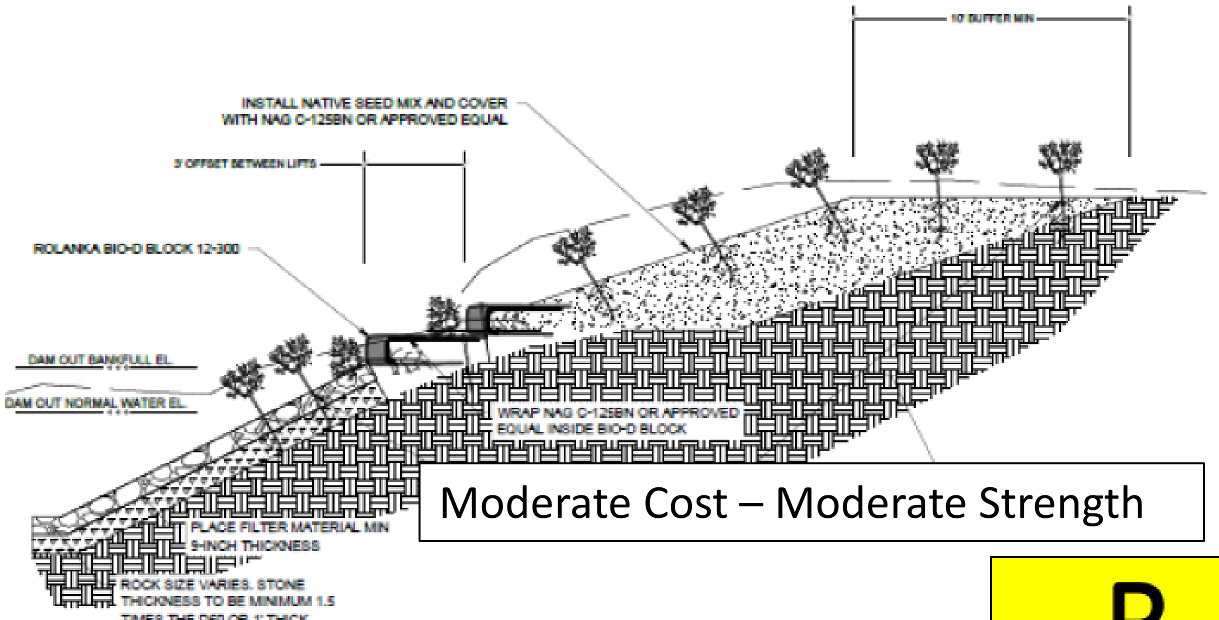
Multiple Treatment Types within a Project Reach (example)



Lowest Cost – Lowest Strength

A

EROSION CONTROL BLANKET TYPICAL SECTION (TREATMENT A)
NOT TO SCALE

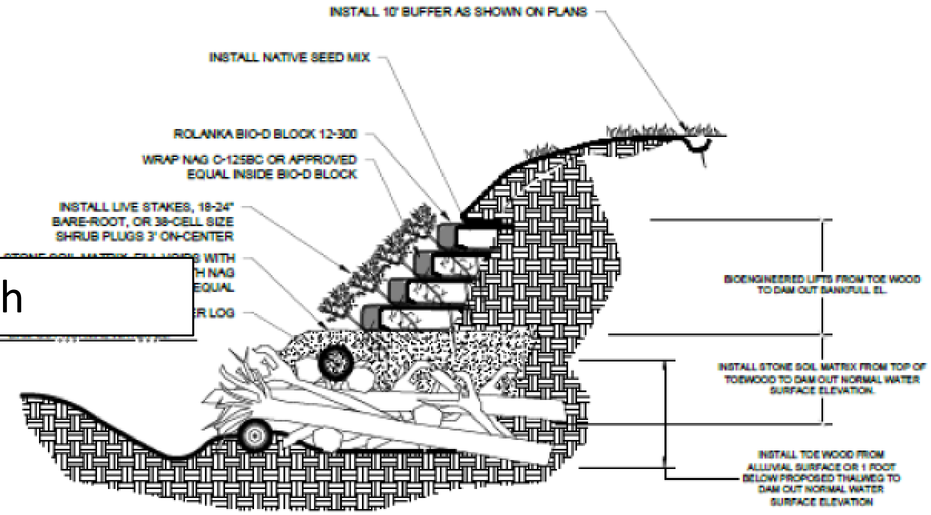


Moderate Cost – Moderate Strength

ROCK TOE/BIOENGINEERED LIFT TYPICAL SECTION (TREATMENT B)
NOT TO SCALE

B

Using multiple treatment options within a project reach can reduce cost



Higher Cost – Highest Strength

C

TOEWOOD BANK STABILIZATION TYPICAL SECTION (TREATMENT C)
NOT TO SCALE

Backwater Design Considerations

- Full-pool elevations will determine lower limit of vegetation
- Boat wake energy dissipation over a range of lake levels
- Design flood scenarios need to consider flashy flows with a low-pool elevations where velocities are often the highest
  - Peak velocities may occur during smaller, flashier floods compared to larger and longer duration floods with higher backwater conditions
- Water management can be challenging because of high water levels during the summer construction season

Vegetation Considerations

- Riparian vegetation provides high quality habitat value
- Vegetation reduces water velocities which reduces erosive forces
- Reduced velocities can lead to increases in water levels if conveyance isn't also increased as part of the design
- Requires irrigation for the first two growing seasons to ensure survivability
  - Contractor is typically responsible for irrigation and survivability via performance specifications
- Live-stake Willows establish rapidly and perform well but require a near-by source for harvest
- Consider partnering with non-profits or other community stakeholders to help with vegetation to lower project costs and increase community engagement

Construction considerations

- **Access and workspace:**
  - Access roads, staging areas, and consolidation areas – can be a logistical challenge depending on the site constraints
- **Care and management of water specifications:**
  - coffer-dam design and sequencing, dewatering, possible effluent treatment, seasonal considerations, etc.
  - Often one of the most challenging aspects of in-water work
- **Management of contaminated sediments:**
  - Off-site disposal volumes and near-by access to disposal facilities
  - On-site handling of contaminated materials – consolidation areas, wash-stations and possible water treatment requirements

Discussion


AES10 – Task Order 49
Architect and Engineering Services Contract
CONTRACT NO. 68-S7-04-01