



FAST DANUBE

***Technical Assistance for Revising and Complementing the Feasibility Study
Regarding the Improvement of Navigation Conditions on the Romanian-Bulgarian Common Sector of the Danube and
Complementary Studies***



**Co-financed by the Connecting Europe
Facility of the European Union**



Administrația Fluvială
a Dunării de Jos R.A. Galați

FAST DANUBE

TECHNICAL WORKSHOP

AFDJ / IAPPD / Halcrow Romania team

29 Aug 2018, Bucuresti



Technical Workshop (29 Aug'18)

- Revised options – Bechet / Corabia / Belene / Popina
- Design approach – morphological principles to option selection
- Design approach – river training structures / islands
- Design approach – bank stabilisation
- Options appraisal – modelling results
- MCA – multi-criteria (objective) analysis
- Adaptive management



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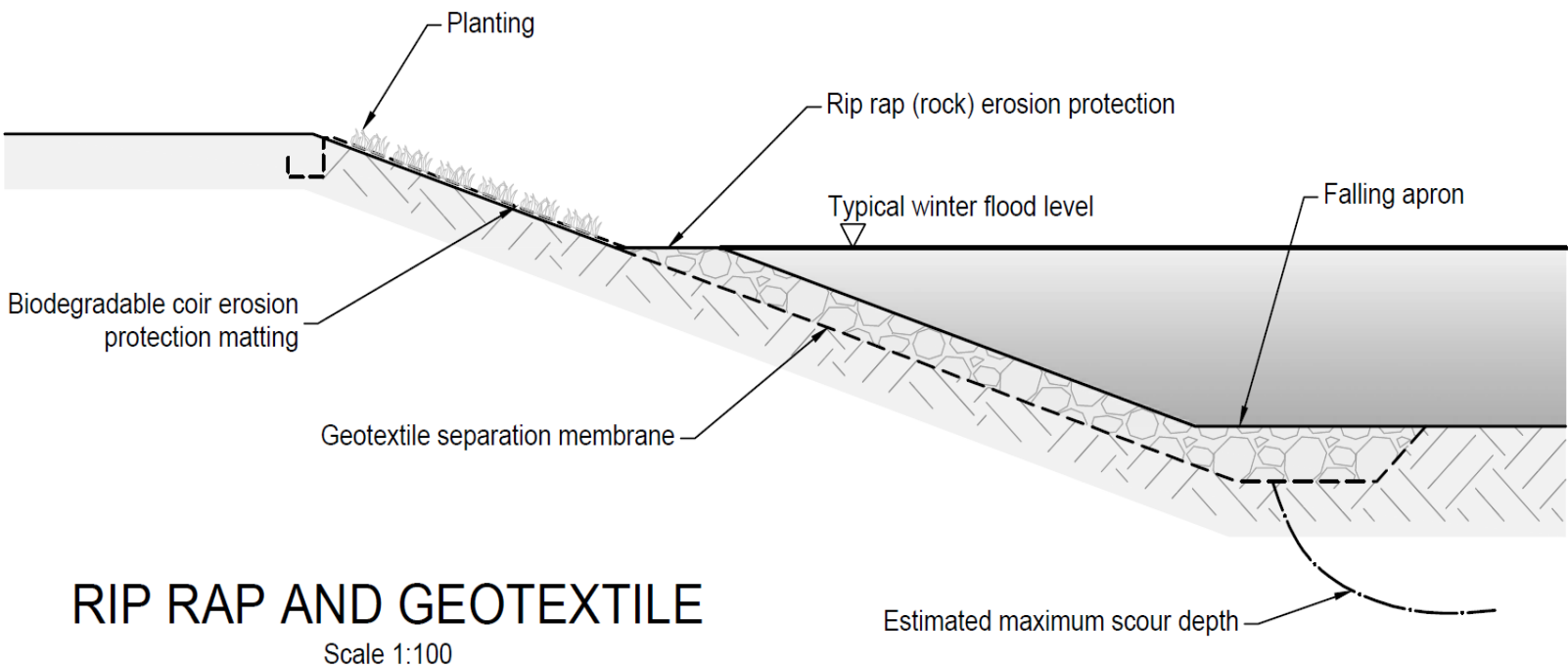
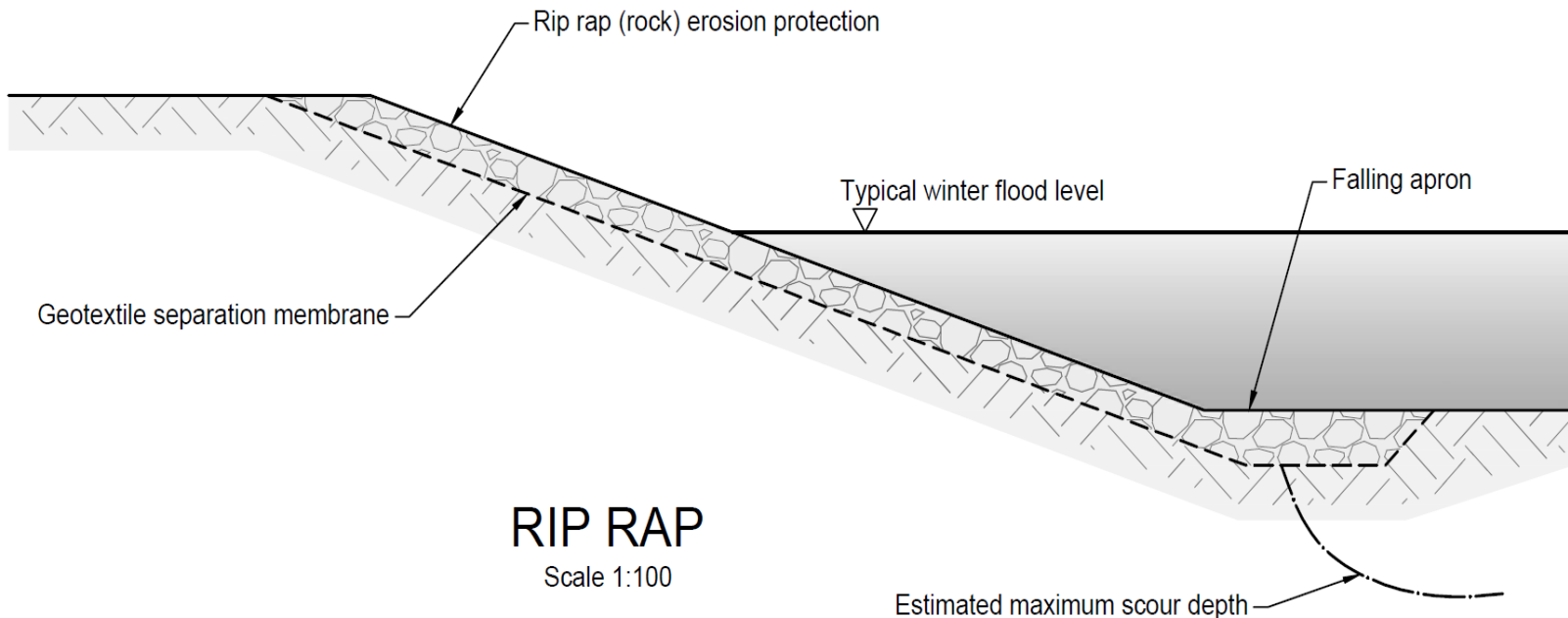


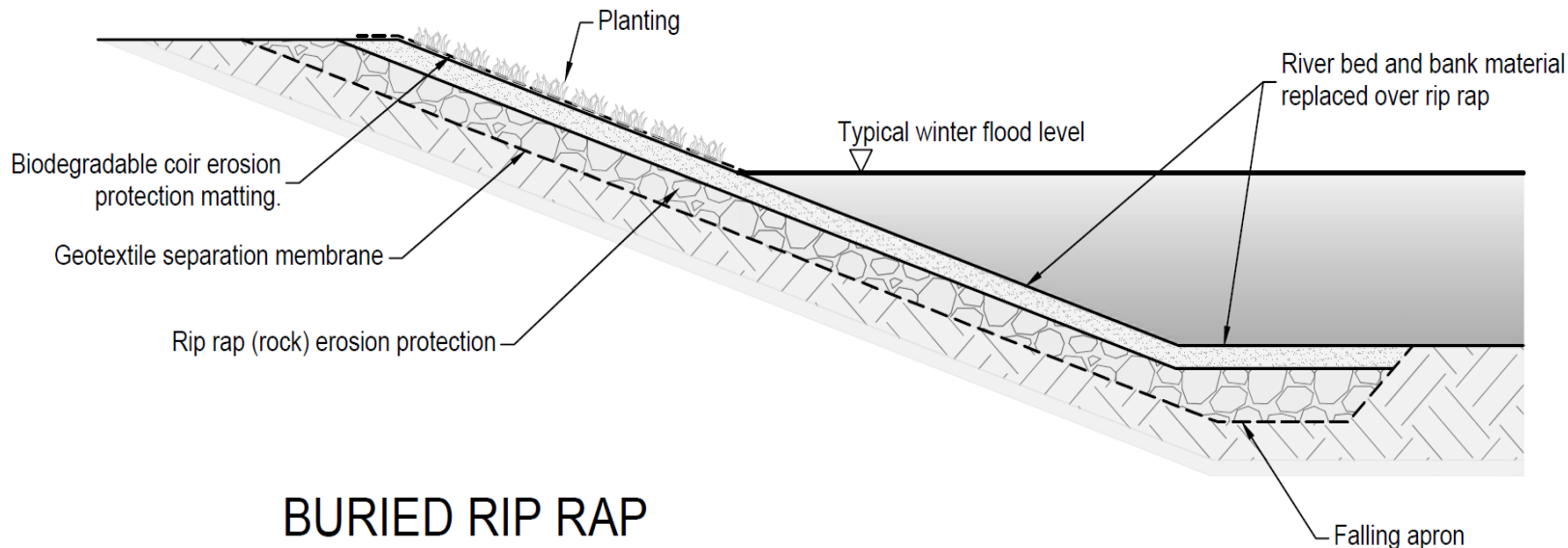
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FAST DANUBE

Short presentation – TECHNICAL WORKSHOP
DESIGN APPROACH – BANK STABILISATION

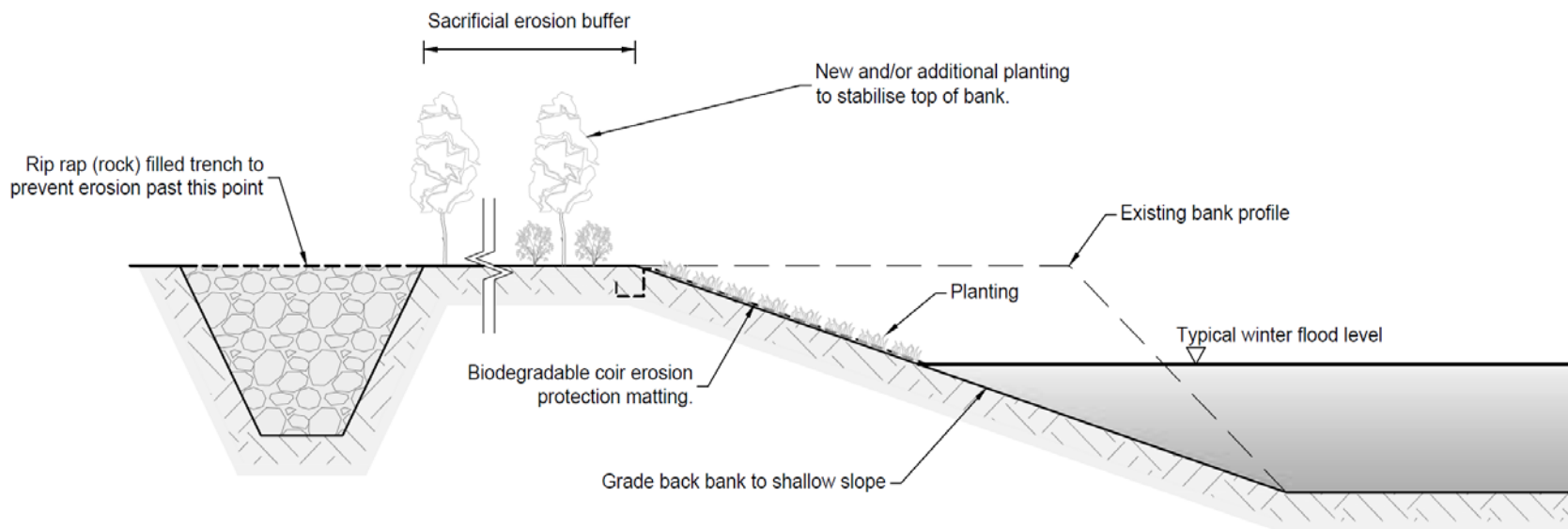
29 Aug 2018, Bucuresti





BURIED RIP RAP

Scale 1:100



GRADE BACK AND REINFORCE

Scale 1:100



NCHRP

REPORT 544

Environmentally Sensitive Channel- and Bank-Protection Measures

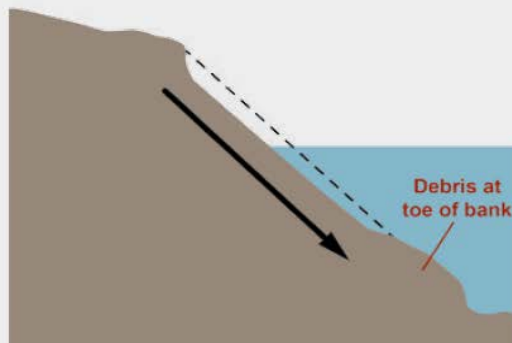
TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

NATIONAL
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HIGHWAY
RESEARCH
PROGRAM

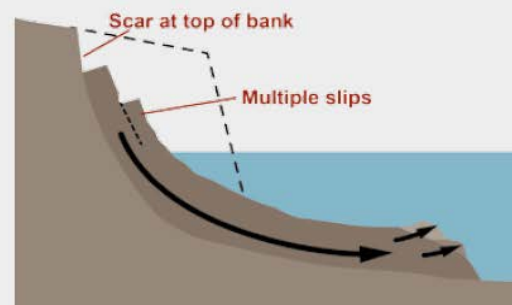


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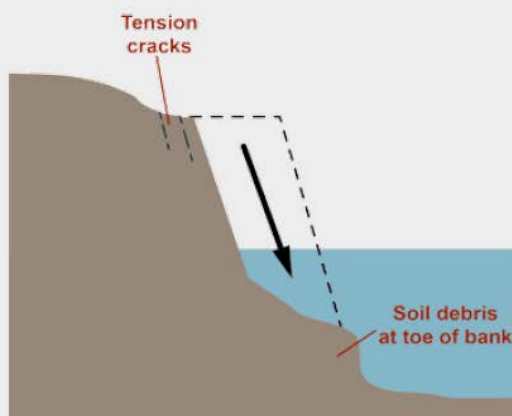




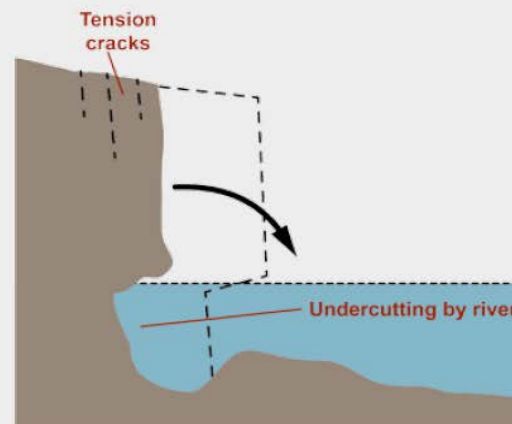
Shallow slide



Rotational slip



Slab failure



Cantilever failure

Sketch of typical bank failures. Dotted line represents original profile. Arrows indicate the direction of movement.

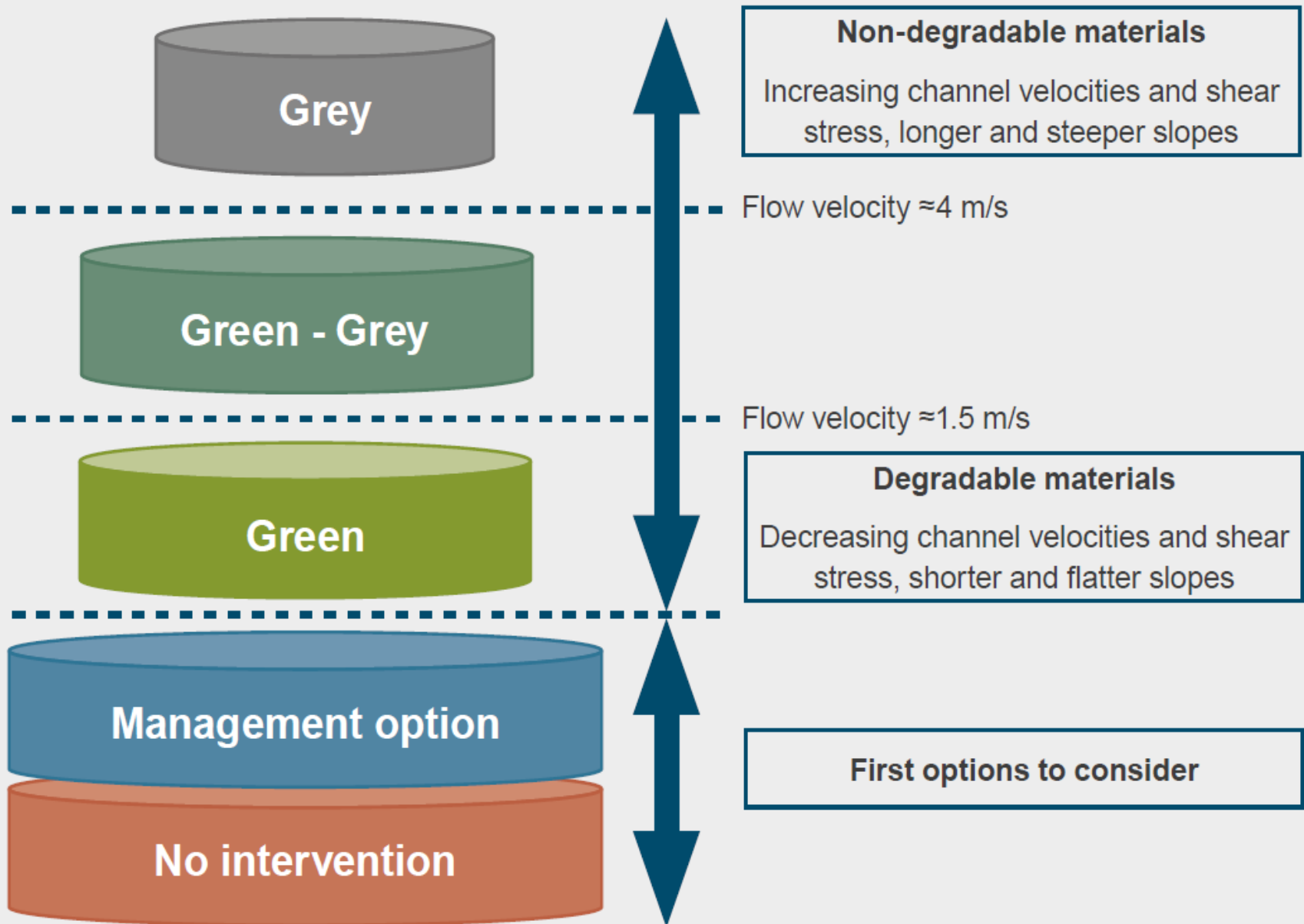


As example, the following table, adapted from USACE (2000) shows the additional environmental benefits provided by different types of measure.

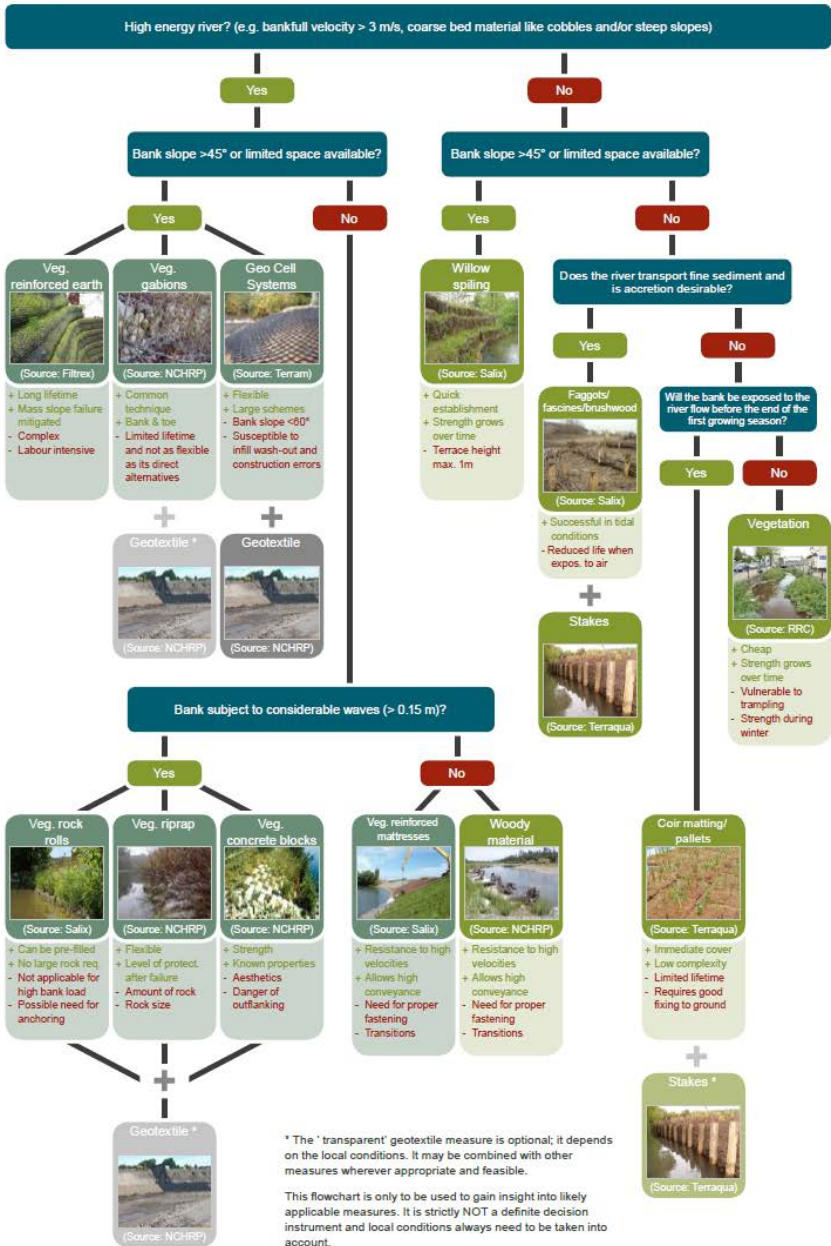
	Green	Green-Grey		Grey	
	Vegetation	Vegetated reinforced soil	Turf reinforced mattresses	Riprap	Sheet piles
Wildlife access	Beneficial	Neutral to beneficial	Neutral to beneficial	Neutral to detrimental	Detrimental
Aquatic habitat complexity	Neutral to beneficial	Neutral to beneficial	Neutral	Neutral to beneficial	Detrimental
Vegetation habitat complexity	Beneficial	Neutral to beneficial	Neutral to beneficial	Neutral to detrimental	Detrimental
Shade, temperature	Neutral to beneficial	Neutral to beneficial	Neutral	Neutral to detrimental	Detrimental
Cover, refugia	Neutral to beneficial	Neutral to beneficial	Neutral to detrimental	Neutral to beneficial	Neutral to detrimental
Pollutant removal	Beneficial	Beneficial	Beneficial	Neutral to detrimental	Neutral to detrimental
Sediment capture	Beneficial	Beneficial	Neutral to beneficial	Neutral to beneficial	Neutral to detrimental

Key

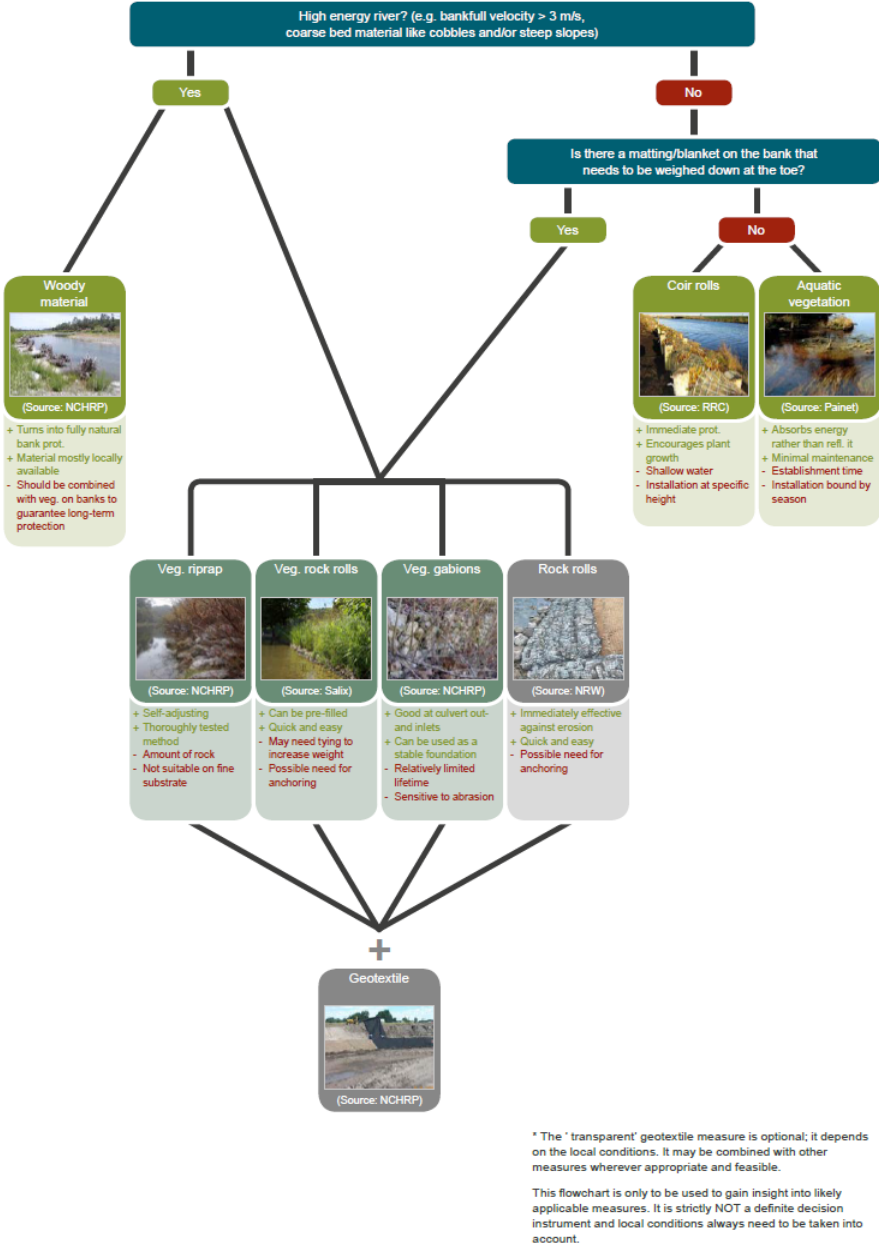
- Beneficial
- Neutral to beneficial
- Neutral
- Neutral to detrimental
- Detrimental



Bank protection



Toe protection



Toe protection

Aquatic
vegetation



(Source: Painet)

Rock rolls



(Source: NRW)

Veg. rock rolls



(Source: Salix)

Bank and toe protection

Coir rolls



(Source: RRC)

Faggots/
fascines/brushwood



(Source: Salix)

Woody material



(Source: NCHRP)

Veg. gabions



(Source: NCHRP)

Veg. riprap



(Source: NCHRP)

Geotextile



(Source: NCHRP)

Bank protection

Coir matting/
pallets



(Source: Terraqua)

Willow spiling



(Source: Salix)

Stakes



(Source: Terraqua)

Vegetation



(Source: RRC)

Veg. concrete
blocks



(Source: NCHRP)

Geo Cell
Systems



(Source: Terram)

Veg.
reinforced earth



(Source: Filtrex)

Veg. reinforced
mattresses



(Source: Salix)



Measure	Relative cost
Live stakes	Low
Live fascines	Moderate
Brush mattresses	Moderate
Vegetation	Low
Riprap	Moderate-High

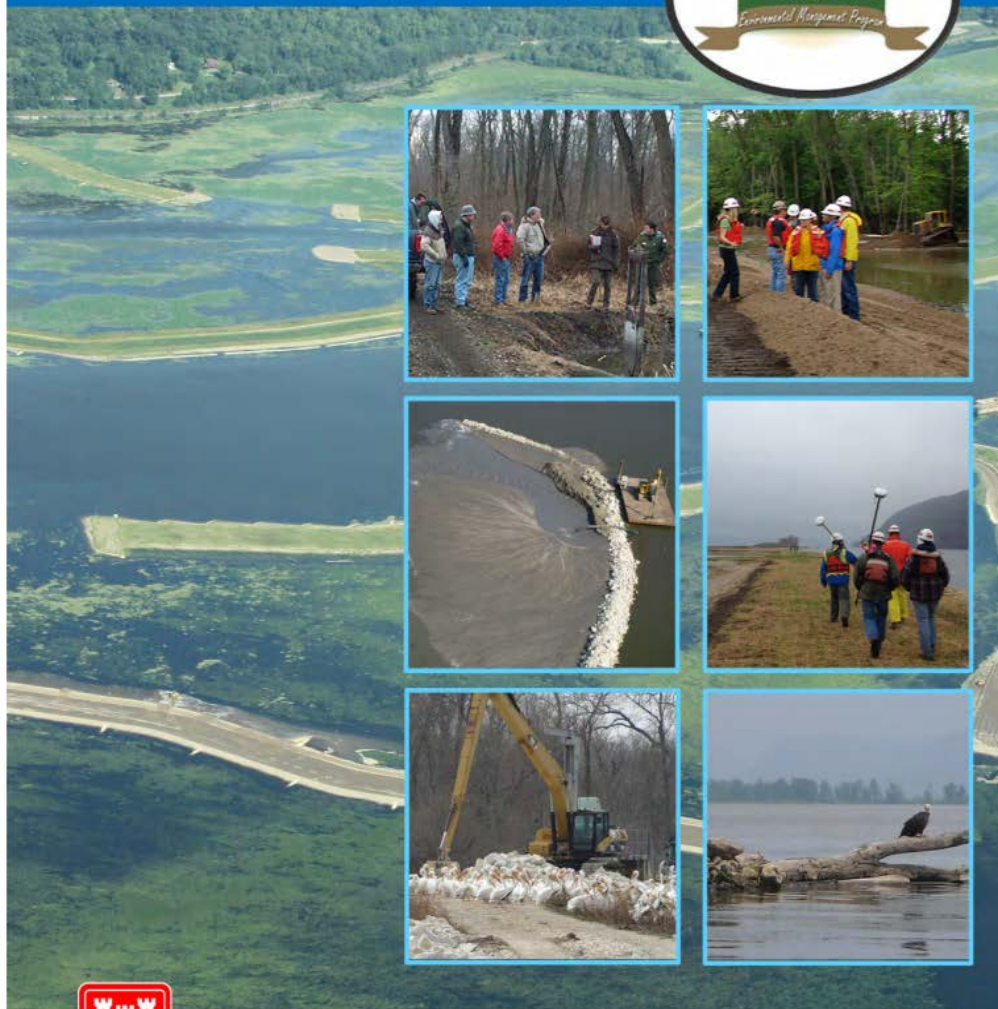


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Upper Mississippi River Restoration Environmental Management Program



US Army Corps
of Engineers®

Environmental Design Handbook December 2012



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TABLE B-1 Possible processes involved in erosion or scour by waves or currents

Region where erosion is occurring (specified by user)	Spatial extent of erosion (specified by user)	
	Local (limited to a bank segment a few channel widths long)	General (similar processes appear to be occurring for a considerable distance up- and downstream)
Bed	Local scour due to flow obstruction, constriction, or channel irregularities. Headcutting.	General bed degradation. Headcutting.
Toe	Local scour due to flow obstruction, constriction, or channel irregularities. Removal of noncohesive layers or lenses in stratified alluvium.	Toe erosion and upper bank collapse.
Middle of bank	Local scour due to flow obstruction, constriction, or channel irregularities. Removal of noncohesive layers or lenses in stratified alluvium.	Middle and upper bank scour by currents. Ice and debris gouging.
Top of bank	Local scour due to flow obstruction, constriction, or channel irregularities. Removal of noncohesive layers or lenses in stratified alluvium.	Ice and debris gouging. Navigation or wind wave wash.

Table 4-17. Other Design Considerations for Rock

Design Consideration	General Guidance for EMP Designs
Toe Protection	<p>“When designing a riprap section to stabilize a streambank, the designer accounts for scour in one of two ways: 1) by excavation to the maximum scour depth and placing the stone section to this elevation, or 2) by increasing the volume of material in the toe section to provide a launching apron that will fill and armor the scour hole. Preference should usually be given to option (2) because of ease of construction and lower cost, and because of environmental impacts associated with excavation of the streambed.” (ERDC/EL TR-03-4)</p> <ul style="list-style-type: none"> Typically, the toe extends 6 feet once the slope flattens.
Filter or Bedding	<p>Filter or bedding should be used if soil movement through the riprap is a concern. Guidance for filter design is provided in EM 1110-2-1901, Appendix D.</p> <ul style="list-style-type: none"> Filter fabric may be eliminated if thickness of riprap layer is doubled.
Side Slopes	<p>Based on guidance provided in EM 1601, riprap section side slopes should not be steeper than 1V on 1.5H.</p> <ul style="list-style-type: none"> 1V on 2 - 3H is preferred.
Shoreline Key-in	<ul style="list-style-type: none"> A key-in to the existing shoreline of 5 – 10 feet is recommended for riprap stabilization.
Field Stone	<p>When rounded stone is used instead of angular stone, the D₅₀ calculated for angular stone should be increased by 25%.</p>
Wave Action Prop Wash	<p>If the riprap section will need to withstand the forces created by the prop of a tow, riprap size should be determined by using the guidance provided in “Bottom Shear Stress from Propeller Jets” (Maynard).</p>
Ice Action	<ul style="list-style-type: none"> Rock slopes should be 1V:4H or flatter Maximum rock size should be increased to 2*ice thickness (Sodhi).
Underwater Placement	<ul style="list-style-type: none"> When riprap is placed underwater, the layer thickness should be increased by 50 percent, but the total thickness should not be increased by more than 12 – 18 inches. If the depth of water is less than 3-4 feet and good quality control can be achieved, a 25% increase in layer thickness is adequate.
Construction Accessibility	<p>Many sites requiring stone may be located in remote, shallow areas. Access to the site must be available for truck or barge. If access to the site is being achieved by land routes, consideration should be given to the viability of the existing access roads. This should include, but is not limited to, load limits, disruption of typical traffic patterns, and coordination with local officials. Additionally, sufficient water depth may require dredging before stone can be placed, and trees may need to be removed before the bankline is cut back or rock is placed.</p>
Construction Techniques	<p>Placement of smaller stone in a fast moving current could cause a significant loss of stone. Ensure that stone is sized in accordance with the conditions in which it will be placed.</p>
High Turbulence Conditions	<p>If the area being protected is subject to high turbulence, plate 29 from EM 1601 (v.1970) should be used for rock sizing and design.</p>

Table 4-1. Description of Shoreline Stabilization Techniques

Stabilization Technique	When To Use	Description	Advantages	Disadvantages
Rock Fill (no filter)	Remote site where erosive action is severe. If off-shore depths are greater than 5 ft deep, or if feature being protected has a convex shape in plan, rockfill should be considered. If ice action will occur, rock fill may be the best choice because of self-healing properties.	Rock fill increases the shear strength of the shoreline so that erosive forces do not displace shoreline substrate. The thickness and size of the riprap varies depending on the magnitude of the erosive force. Rock fill thickness is increased over the thickness of riprap so the layer is self-filtering. A 24" layer is used in most situations.	Rock fill can be designed and placed so that a continuous thick layer of rock results. Its performance and cost can be predicted more reliably than some other methods, and because of the greater thickness, it has self healing properties in the event of ice action or toe scour.	Cost is relatively high (see figure 4-4) because stabilization relies on continuous coverage of the shoreline with rock. Creates an unnatural aquatic/terrestrial transition which may not be beneficial to some species.
Riprap w/ Filter	Easily accessible site with severe erosive action. If off-shore depths are greater than 5 ft, or if feature being protected has a convex shape in plan, rockfill should be considered.	Riprap increases the shear strength of the shoreline so that erosive forces do not displace shoreline substrate. The thickness and size of the riprap varies depending on the magnitude of the erosive force. Because riprap layer thickness is less than rock fill, a granular or geotextile filter is required to prevent loss of su4-grade material	Less volume of rock used so if cost per linear foot of filter is less than additional rock in a rock fill layer it is less expensive than rock fill with no filter.	Creates an unnatural aquatic/terrestrial transition which may not be beneficial to some species. If site is remote, transporting the filter material to the site may be difficult which adds to the cost.
Groins	Where erosive action is mainly due to wave action and off-shore depths are less than 3 ft at the end of the groin. Shoreline material type should consist primarily of sand-size material.	Long, narrow rock structures placed perpendicular to shorelines to contain littoral drift (i.e. the transport of sand along a shoreline due to wave action). This results in a scalloped shoreline shape (requiring a sacrificial berm), which is the shoreline adjustment to the prevailing winds. Used in conjunction with planted shoreline vegetation.	One of the lowest cost stabilization techniques. Does have a beach between groins, which is beneficial to some species. More natural looking	Vulnerable to ice action. Needs room for a sacrificial berm consisting of granular fill.
Vanes	Where erosive action is mainly due to river currents. Shoreline material type should consist primarily of sand-size material.	Long, narrow rock structures placed at an upstream angle to shorelines to redirect river currents away from the shoreline. Erosive secondary currents are moved away from the toe of the bank. Used in conjunction with planted shoreline vegetation.	One of the lowest cost stabilization techniques. More effective than groins if there are river currents. Retains a beach which is beneficial to some species. More natural looking	Vulnerable to ice action rock displacement by large woody debris. Needs room for a sacrificial berm consisting of granular fill.
Off-Shore Mounds	When off-shore water depths prevent equipment access to the shoreline being protected.	Long, narrow rock structures placed parallel to shorelines some distance off-shore to reduce erosive forces due to wave action, river currents, or ice action	Creates sheltered aquatic area between mound and shoreline.	High cost Cost effective only in shallow water.
Vegetative Stabilization	Vegetative stabilization can be used along shorelines where offshore velocities are less than 3 ft/sec, wind fetch is less than 1/2 mile, ice action and boat wakes are minimal, or where offshore conditions (depth or vegetation) reduce erosive forces.	Vegetative stabilization consists of plantings of woody tree species or seeding herbaceous vegetation. Other types of stabilization structures, such as groins or vanes, are not used.	Lowest cost stabilization technique In addition to stabilization, it creates habitat.	Limited to shorelines where erosive forces are minimal. Requires the vegetation to flourish. If vegetation is attacked by some type of pest and does not thrive, it will not be effective erosion control.



Photograph 4-2. Riprap and Geotextile Filter Placed on Sand (Lake Onalaska)





Photograph 4-4. Vanes



Bio-Geo Stabilization with Groins and Willows (Boomerang)



Photograph 4-13. Rock Vanes at Lost Island Chute, Pool 5



Photograph 4-5. Vegetative Stabilization (Boomerang Island)



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Photograph 4-7. Bankline Erosion on Long Island Division, Pool 20



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Photograph 4-8. Long Island Bankline Prior to Rock Placement



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Photograph 4-9. Placement of Rock Revetment at Long Island





Photograph 4-10. Area of Rock Placement at Long Island 8 Years Post Construction



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Photograph 4-15. Offshore Rock Mound at Peterson Lake in Pool 4



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