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

Time	*Topic*	*Responsible*
09:00 – 09:30	***Registration / Coffee***	***All***
WORKSHOP ON «Options Appraisal / Selection for FAST DANUBE project»		
09.30 – 9:45	**Introduction:** – Welcome – H&S moment – Project status	**Mr. Dan TARARA** **Mr. Romeo SOARE**
09.45 – 11.00	**Session 1:** – Initial option preferences, morphological (Prof Colin Thorne via skype) – Revised options, modelling engineering CBA – Environmental studies – Q&A	**Mr. Paul RAYNER** **Mr. Damian DEBSKI** **Ms. Roxana DORNEANU** **Ms. Charlotte HANDY**
11.00 – 11.30	***Coffee break***	
11.30 – 13.00	**Session 2:** – Multi-criteria analysis: introductory session	**Mr. Dan TARARA** **Mr. Paul RAYNER** **Ms. Roxana DORNEANU** **Ms. Charlotte HANDY**
13.00 – 13.45	***Lunch***	
13.45 – 15.30	**Session 3:** – Multi-criteria analysis: interactive session	**Mr. Dan TARARA** **Mr. Paul RAYNER** **Ms. Roxana DORNEANU** **Ms. Charlotte HANDY**
15.30 – 16.00	**Session 4:** – Consensus view on long term sustainable options	
16.00	**Closing statement**	**Mr. Romeo SOARE**

River training structures / islands

- Feasibility designs
- Geosynthetic tubes

<u>Best practice</u>

- Mississippi, US
- Lower Columbia River, US
- Kootenai/Lower Meander River, US
- Rhine, Holland (Rijkswaterstaat)
- mid-Danube, Austria (Bad Deutsch Altenberg/Witzeldorf Project between Vienna and Bratislava – deregulation of the river ie environmental restoration involving Prof Habersack)

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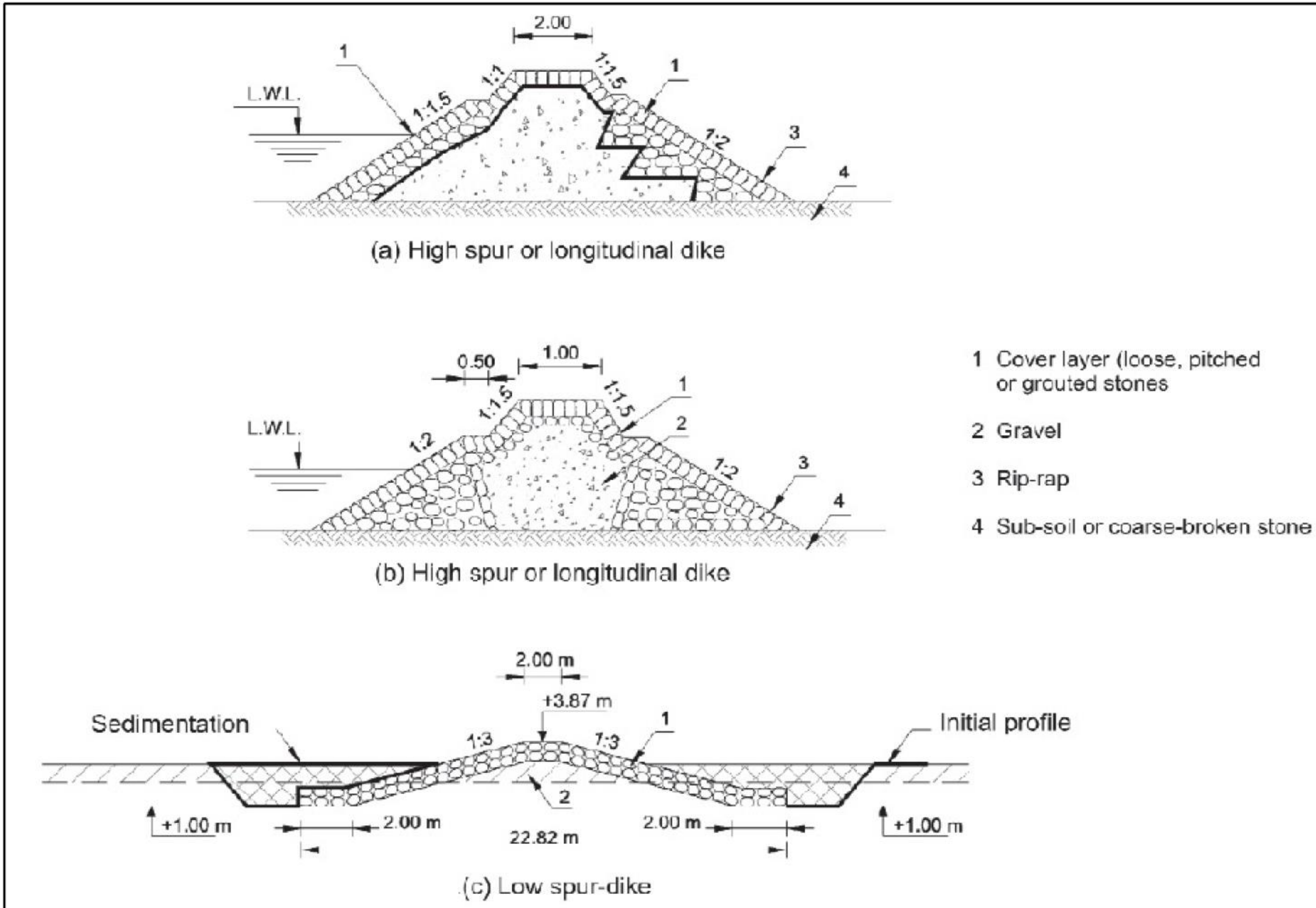


Figure 8: River training structure typical cross sections (source: CIRIA C683)

Island building, Wachau, River Danube
(source: Life Nature Wachau, 2008)

Island building, Bonners Ferry Island project
(source: Lower Meander Project Design Report, RDG 2017)

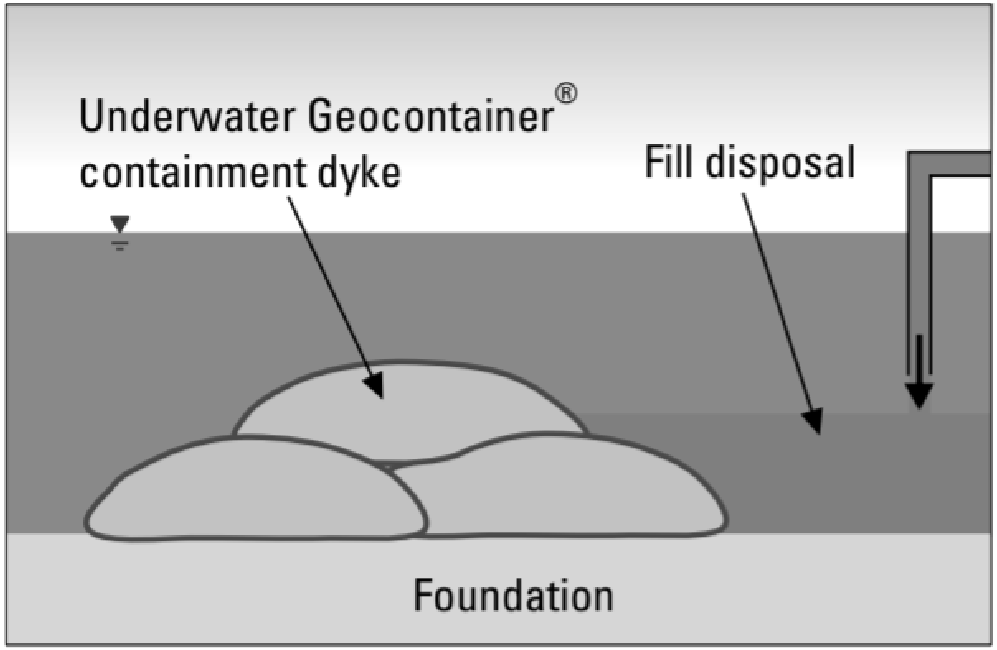
Cutter suction dredging

Causeway construction

Geosynthetic tubes (geo-tubes)

Example of construction option using sand filled geosynthetic tubes for initial building of islands, dikes, groynes and chevrons:

https://www.rhmooreassociates.com/images/pdf/Geotube-BRO_CoastalAndMarine_tcm28-43898.pdf



Underwater Geocontainer® containment dyke

- Geobag system; 2 till 10 m^3
- Geotube® system; 100 tot 750 m^3
- Geocontainer® system; 100 tot 600 m^3

Geosystems are sand filled elements made out of woven high strength textiles. The textiles used are special designed for Geosystems with the same strength in both directions.

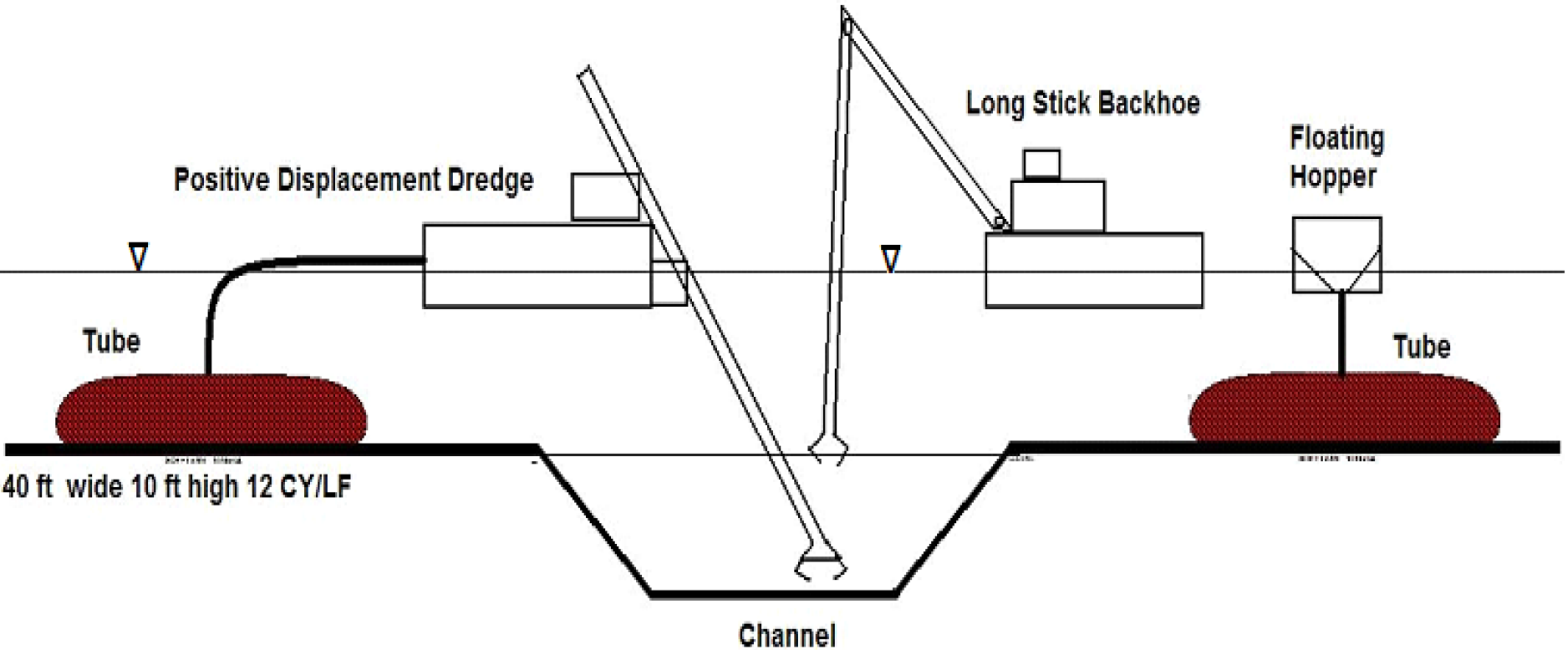
In some instances, underwater containment dykes are constructed to retain spoil and other fills in an environmentally acceptable manner.

Geotube® system

- Will be filled on position.
- Filling hydraulically with a mixture of sand and water.
- Lengths vary between 30 till 100 meter.
- Diameter vary between 1,6 till 5 meter diameter.
- In relative short period a dam can be constructed.
- Essential is fabric strength and confection, seam strength.

diameter	circum	height	fill	width max	width base	recommended high strength fabric
D	C	H	F	W	Wb	
m	m	m	m3/m1	m	m	
1,60	5,0	1,0	1,7	2,0	1,7	GT 750 M
2,50	7,9	1,5	4,1	3,2	2,7	GT 750 M
3,25	10,2	2,0	6,9	4,2	3,5	GT 1000 M
4,00	12,6	2,4	10,4	5,1	4,3	GT 1000 M
5,00	15,7	2,7	16,3	6,4	6,0	GT 1000 M

Filling Tubes Underwater



Installation/filling time

Giving: Geotube® diameter 4 meter
fillingheigth 2,4 meter, length 50 meters.

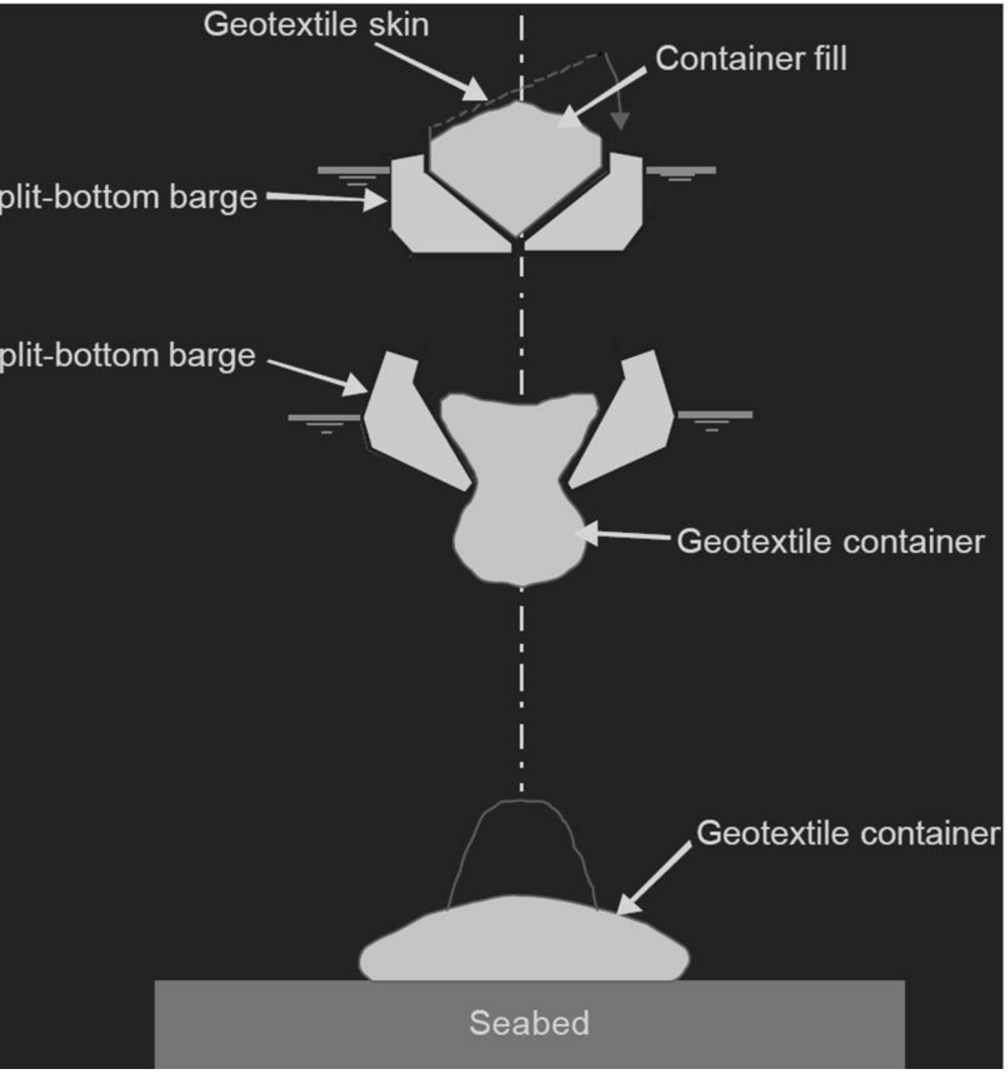
Total volume to be filled with 50 x 10,4 = 520 m3

pumpcapacity 400 m3/hour at 15 % mixture (60 m3/hour)

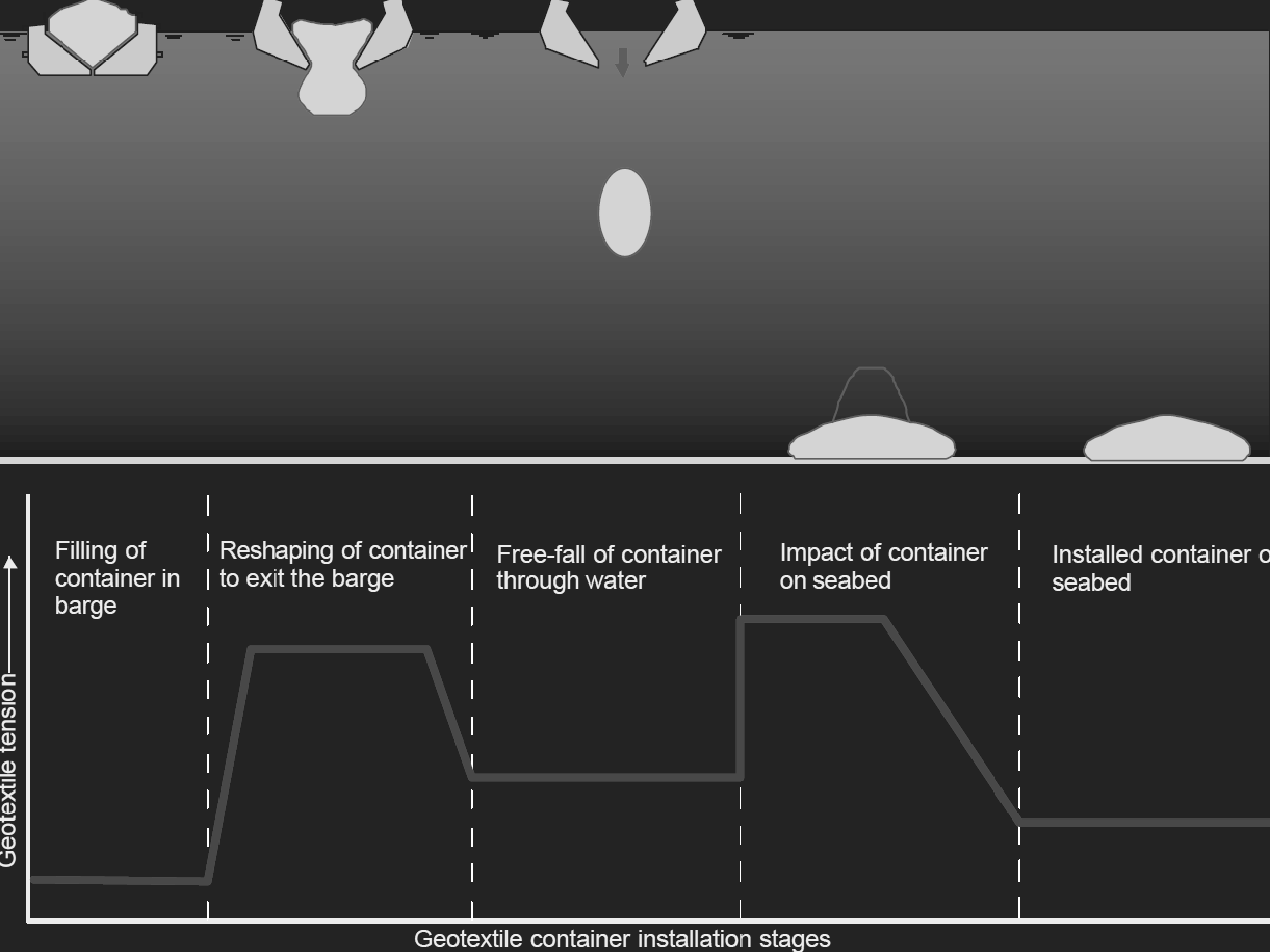
It will take around 520/60= 9 hours to fill the Geotube®.



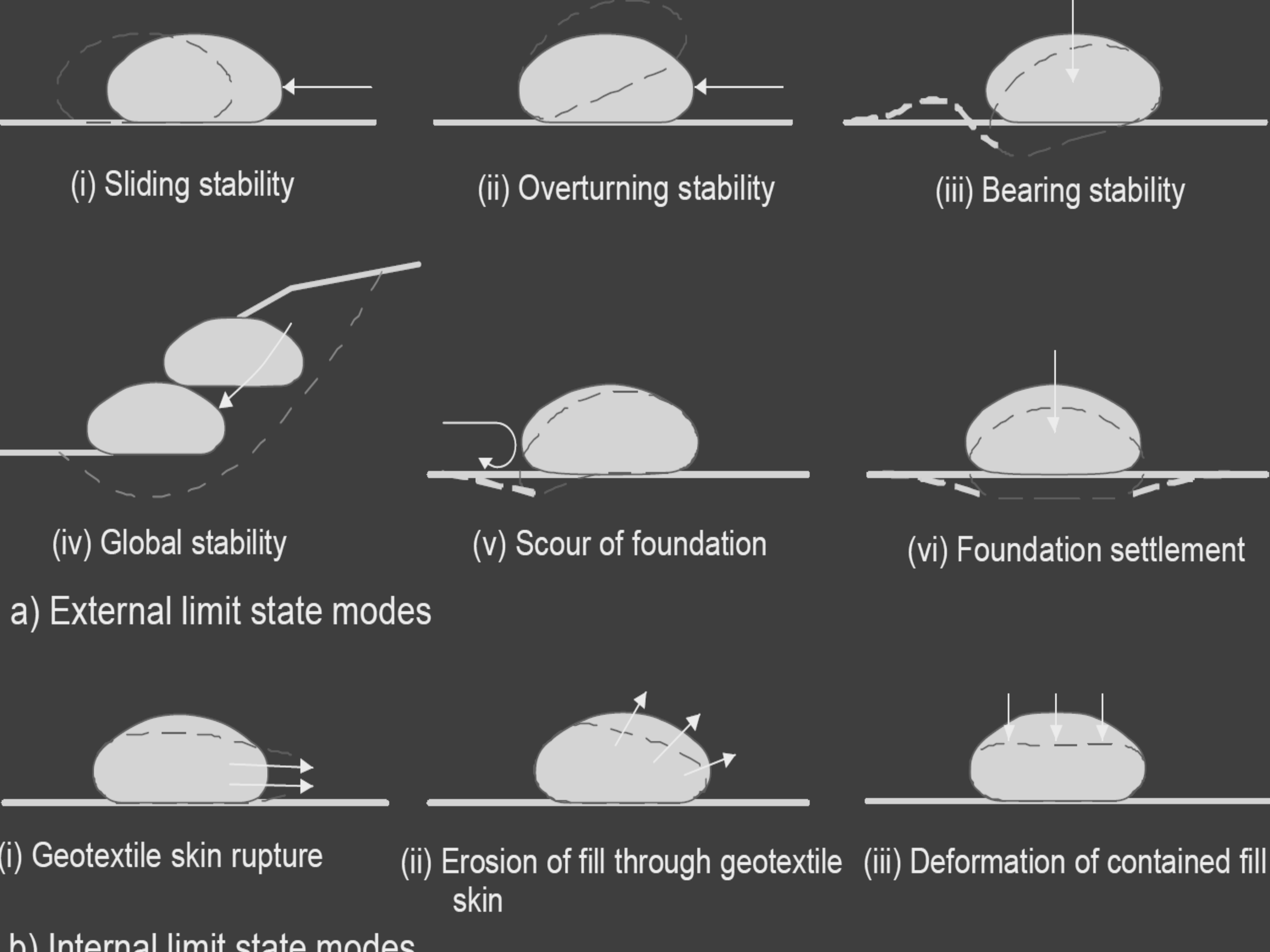
Geocontainer® system

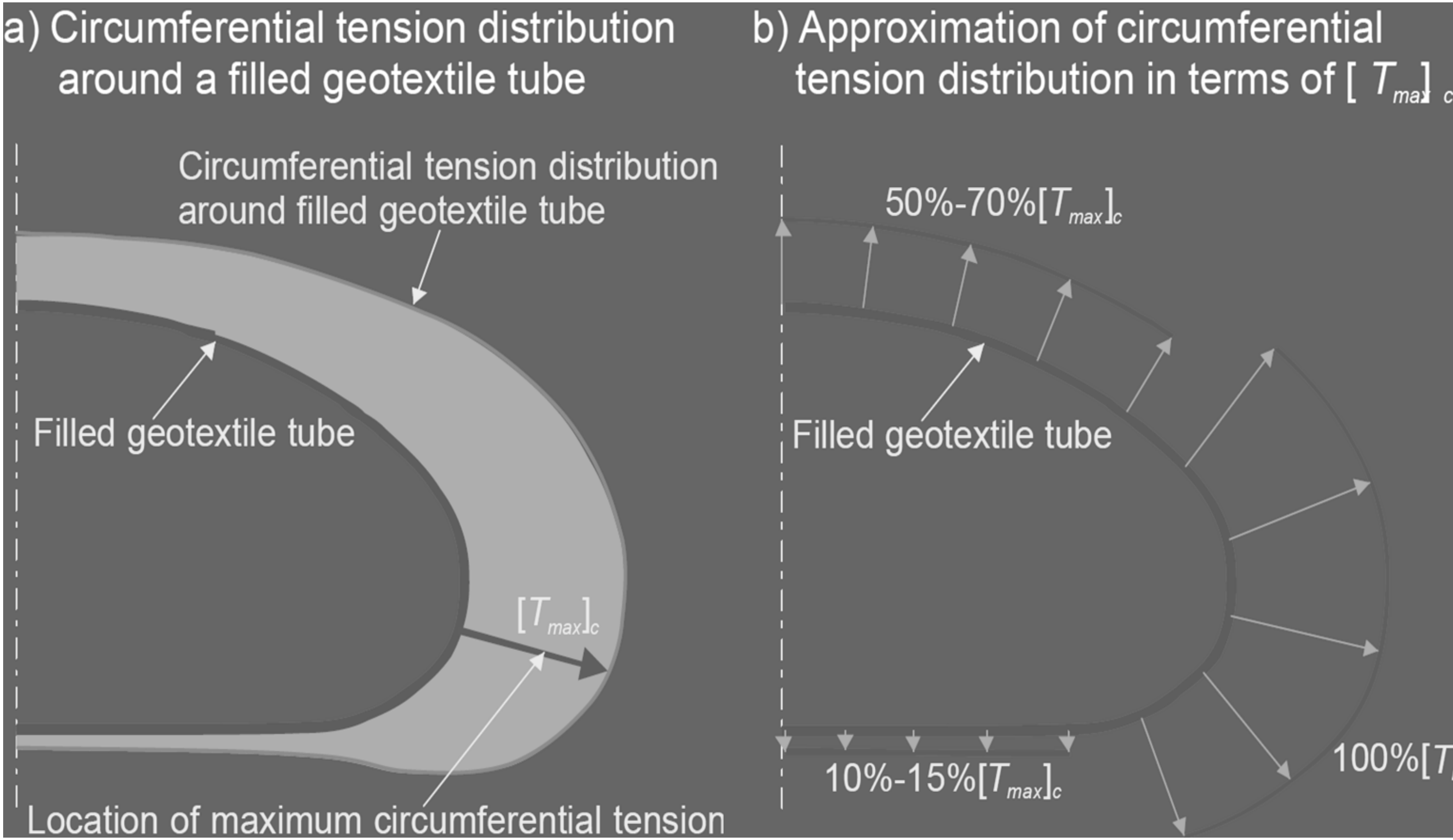


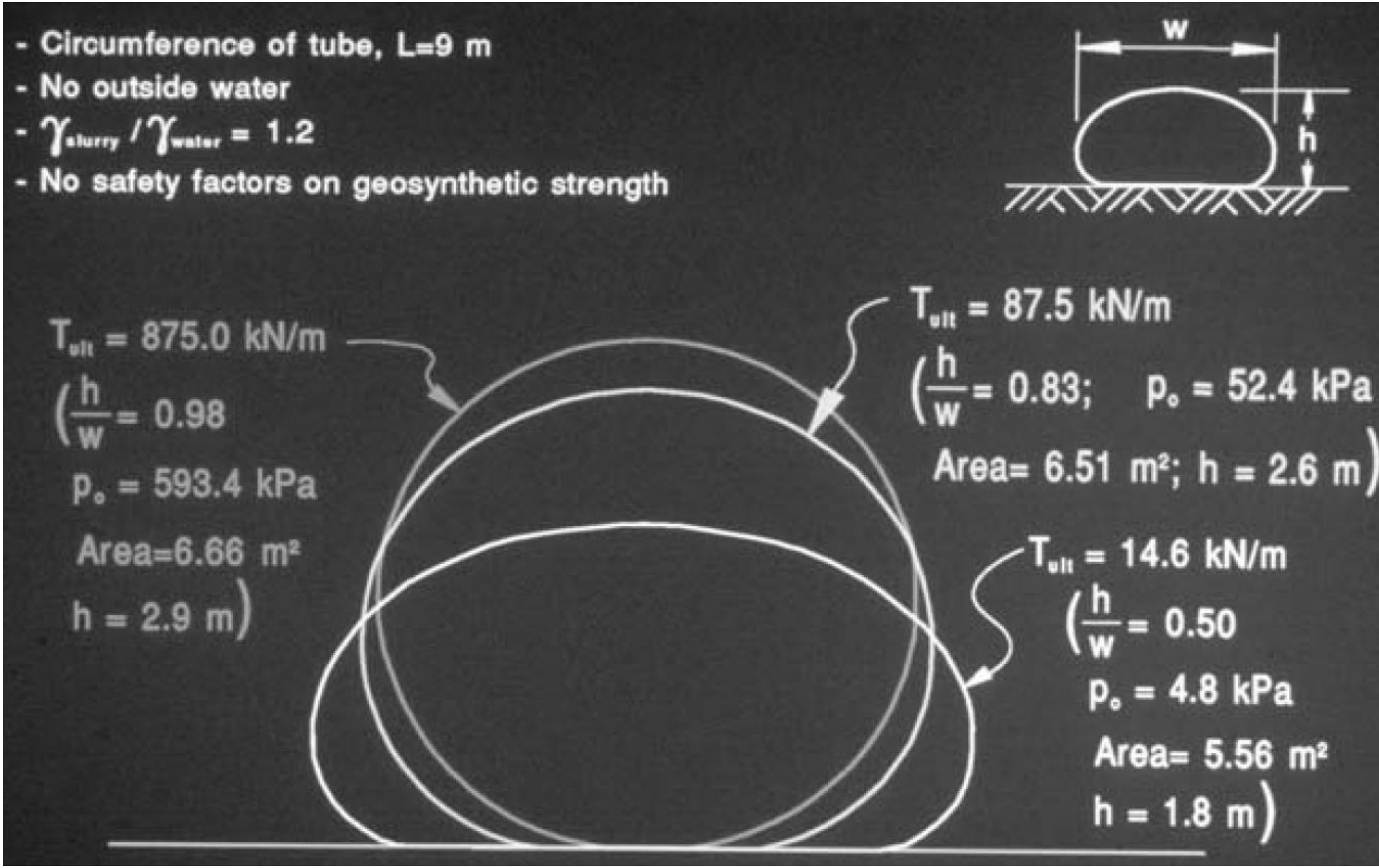
- Geocontainer® are installed by split-bottom barges
- Two types of applications:
  - Structural, submarine, mass-gravity units
  - Contained, submarine disposal of contaminated sediments
- For hydraulic applications container volumes are in range 100 to 600 m^3
  - Smaller volumes give better installed tolerances and are more easily installed but are more costly



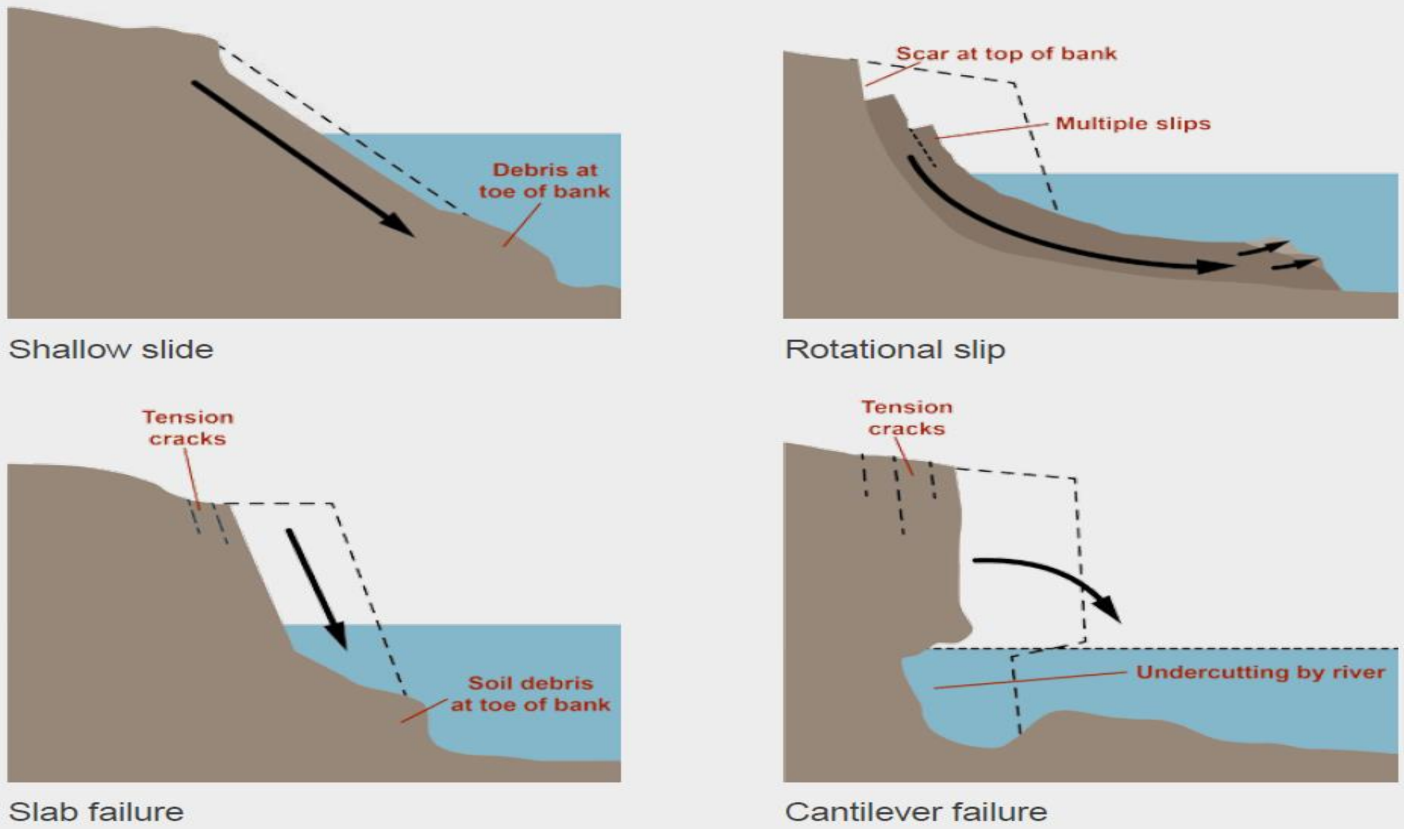
Filling of container in barge
Reshaping of container to exit the barge
Free-fall of container through water
Impact of container on seabed
Installed container o
seabed
Geotextile tension
Geotextile container installation stages


(i) Sliding stability
(ii) Overturning stability
(iii) Bearing stability
(iv) Global stability
(v) Scour of foundation
(vi) Foundation settlement
a) External limit state modes
(i) Geotextile skin rupture
(ii) Erosion of fill through geotextile skin
(iii) Deformation of contained fill
b) Internal limit state modes

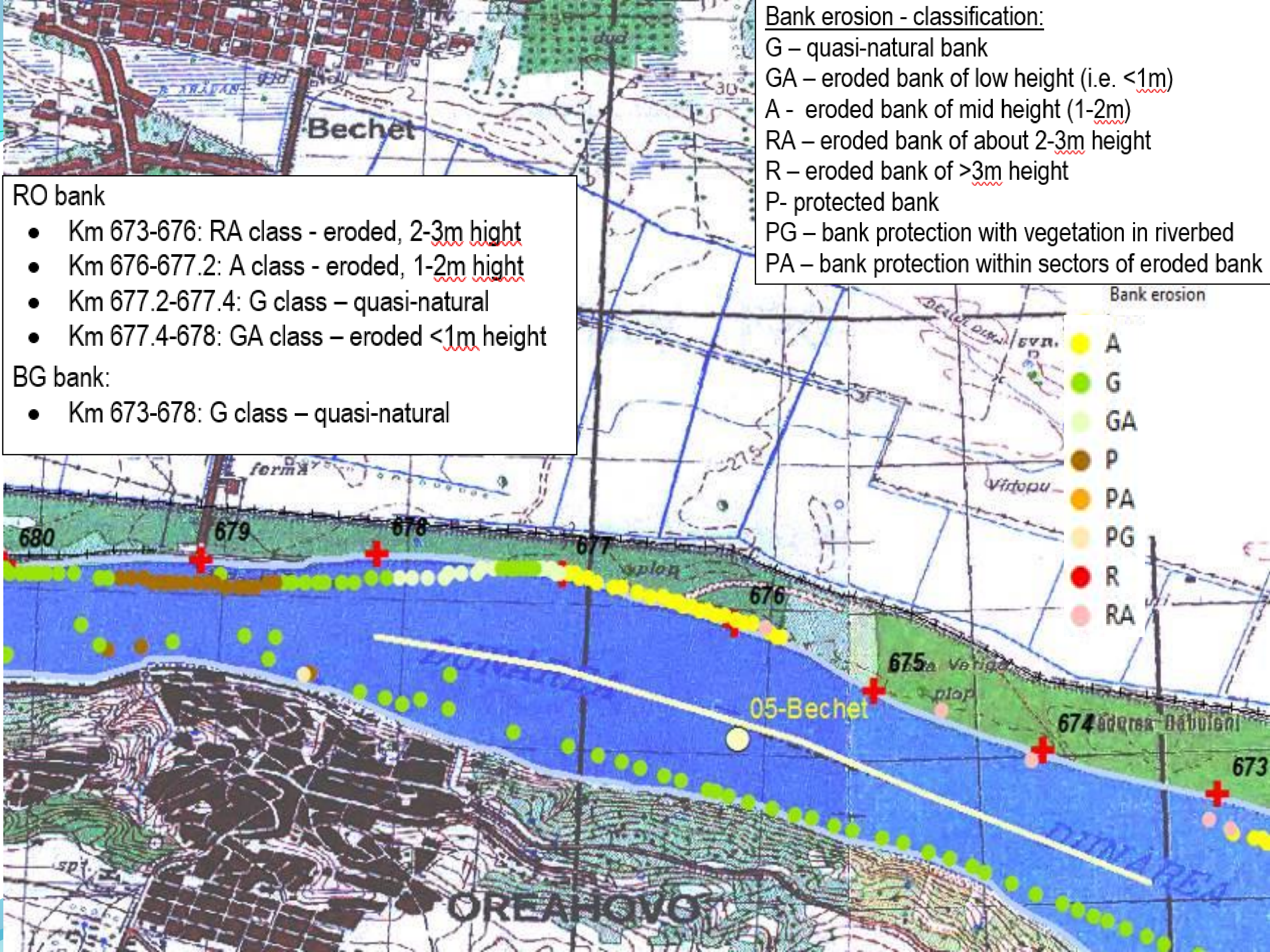

a) Circumferential tension distribution around a filled geotextile tube
b) Approximation of circumferential tension distribution in terms of [T_{max}] $_c$
Circumferential tension distribution around filled geotextile tube
Filled geotextile tube
$[T_{max}]_c$
Location of maximum circumferential tension
50%-70%$[T_{max}]_c$
Filled geotextile tube
10%-15%$[T_{max}]_c$
100%[T

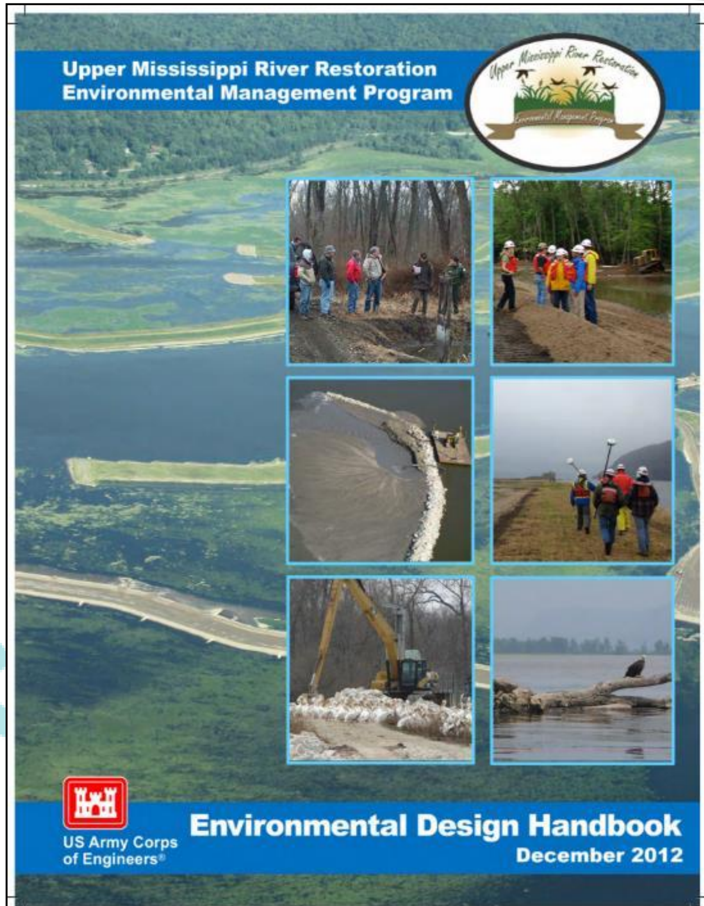

- Circumference of tube, L=9 m
- No outside water
- $\gamma_{slurry} / \gamma_{water}$ = 1.2
- No safety factors on geosynthetic strength
w
h
T_{ult} = 875.0 kN/m
($\frac{h}{w}$ = 0.98
p_o = 593.4 kPa
Area=6.66 m²
h = 2.9 m)
T_{ult} = 87.5 kN/m
($\frac{h}{w}$ = 0.83; p_o = 52.4 kPa
Area= 6.51 m²; h = 2.6 m)
T_{ult} = 14.6 kN/m
($\frac{h}{w}$ = 0.50
p_o = 4.8 kPa
Area= 5.56 m²
h = 1.8 m)

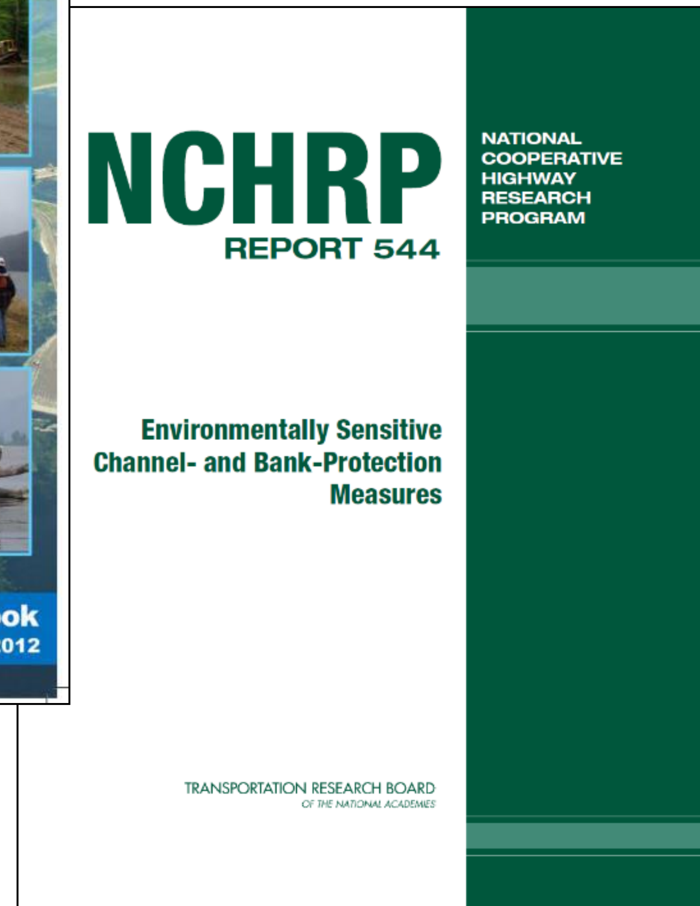
Bank protection

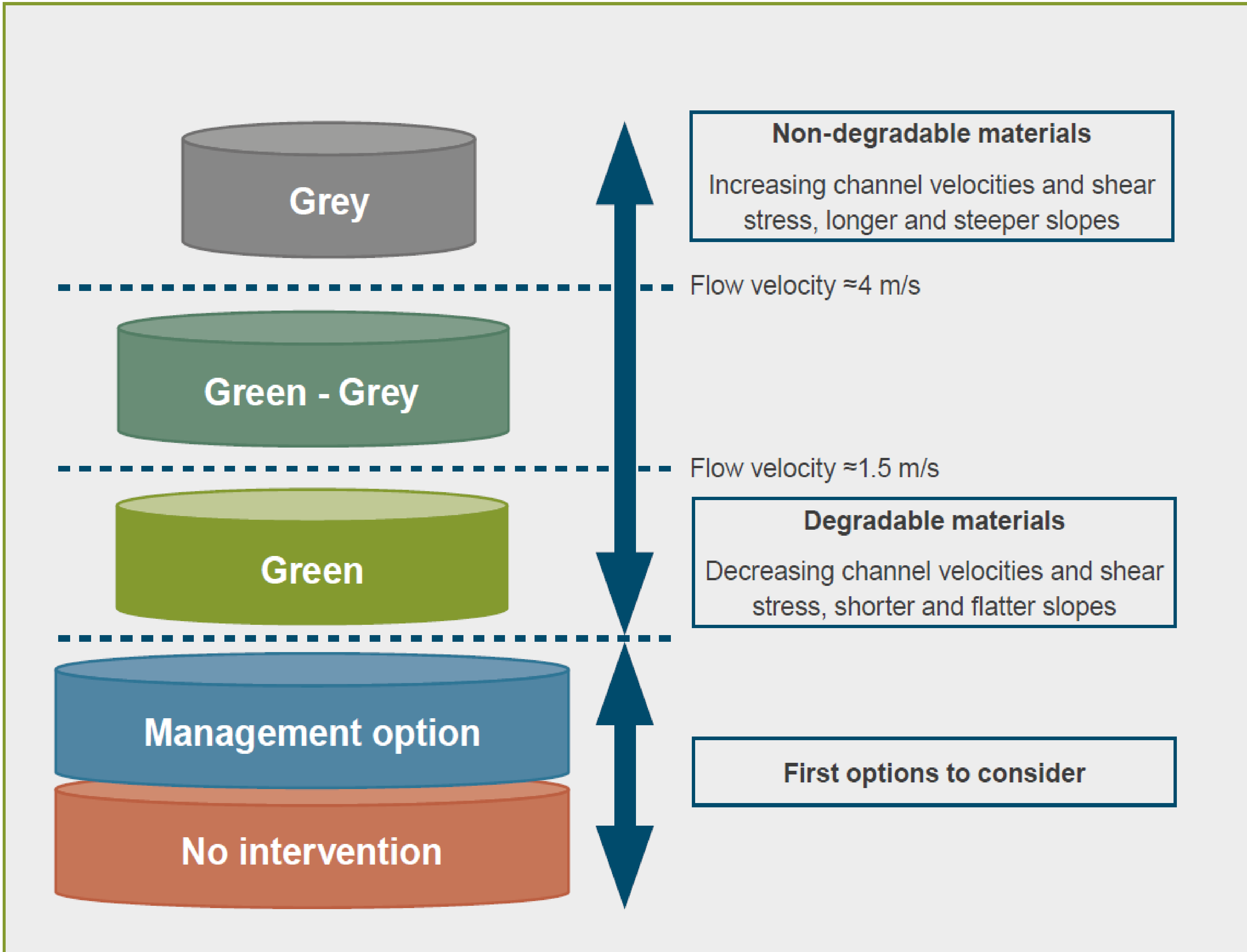


Sketch of typical bank failures. Dotted line represents original profile. Arrows indicate the direction of movement.


Bank erosion - classification:
G – quasi-natural bank
GA – eroded bank of low height (i.e. <1m)
A - eroded bank of mid height (1-2m)
RA – eroded bank of about 2-3m height
R – eroded bank of >3m height
P- protected bank
PG – bank protection with vegetation in riverbed
PA – bank protection within sectors of eroded bank
RO bank
• Km 673-676: RA class - eroded, 2-3m hight
• Km 676-677.2: A class - eroded, 1-2m hight
• Km 677.2-677.4: G class – quasi-natural
• Km 677.4-678: GA class – eroded <1m height
BG bank:
• Km 673-678: G class – quasi-natural
Bank erosion
A
G
GA
P
PA
PG
R
RA
Bechet
680
679
678
677
676
675
674
673
05-Bechet
OREAHOVO


Upper Mississippi River Restoration
Environmental Management Program
US Army Corps
of Engineers
Environmental Design Handbook
December 2012


NCHRP
REPORT 544
NATIONAL
COOPERATIVE
HIGHWAY
RESEARCH
PROGRAM
Environmentally Sensitive
Channel- and Bank-Protection
Measures
TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES


Grey
Green - Grey
Green
Management option
No intervention
Non-degradable materials
Increasing channel velocities and shear stress, longer and steeper slopes
Flow velocity ≈4 m/s
Flow velocity ≈1.5 m/s
Degradable materials
Decreasing channel velocities and shear stress, shorter and flatter slopes
First options to consider

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

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

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

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

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

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

Photograph 4-4. Vanes

4.3. Bio-Geo Stabilization with Groins and Willows (Boomer

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

Photograph 4-5. Vegetative Stabilization (Boomerang Island)

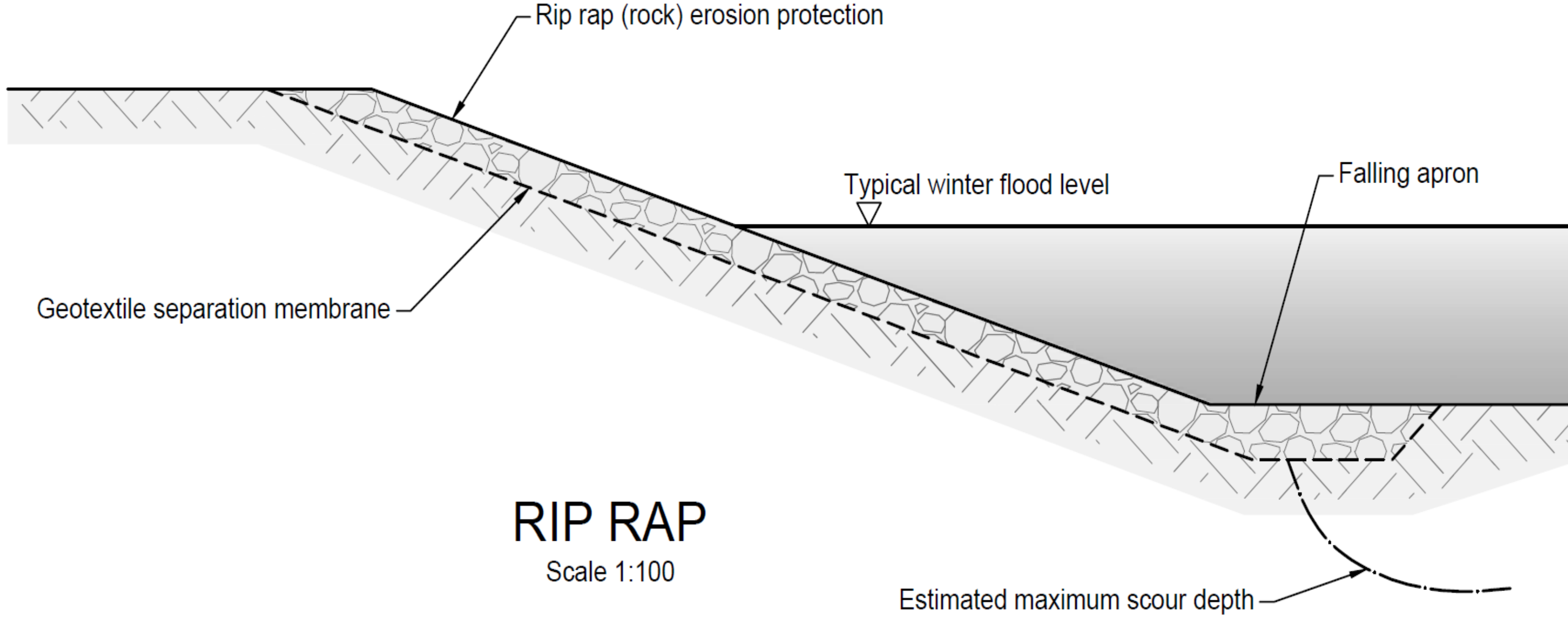
Photograph 4-15. Offshore Rock Mound at Peterson Lake in Pool 4

Galati Lower Danube River Administration

River Danube Navigation Improvements

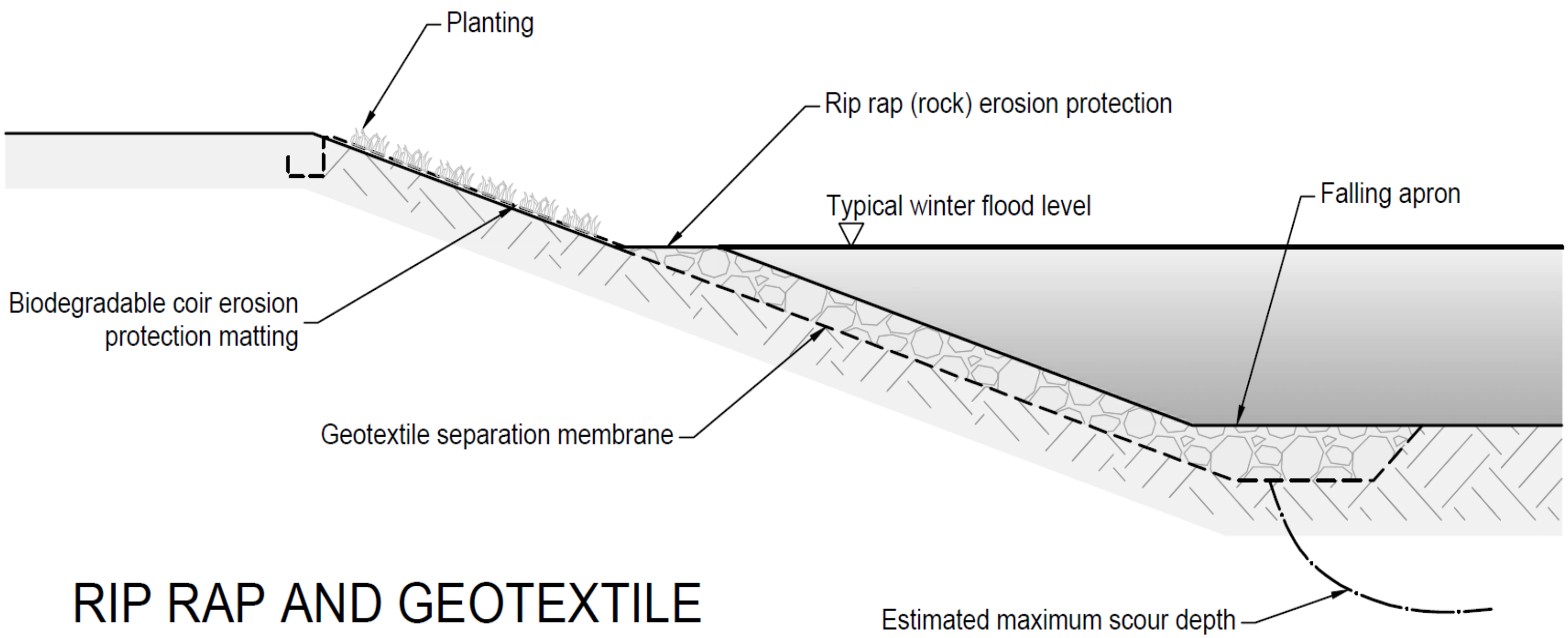
Romania-Bulgaria

RIVER BANK EROSION PROTECTION OPTIONS



RIP RAP

Scale 1:100



RIP RAP AND GEOTEXTILE

Scale 1:100

Galati Lower Danube River Administration

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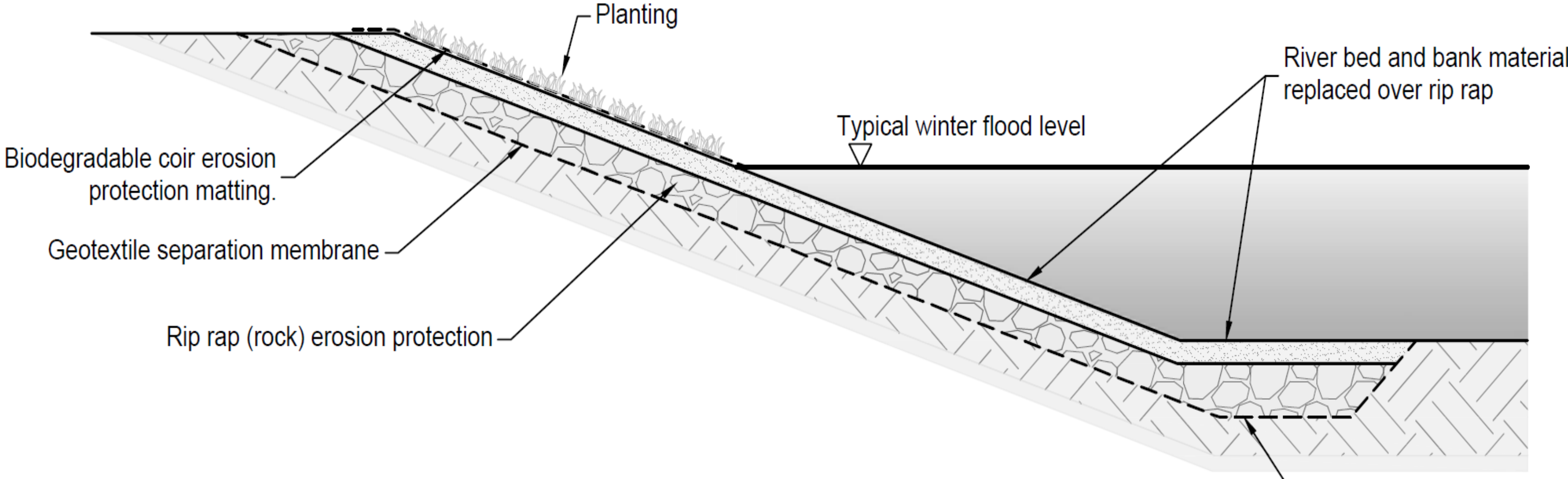
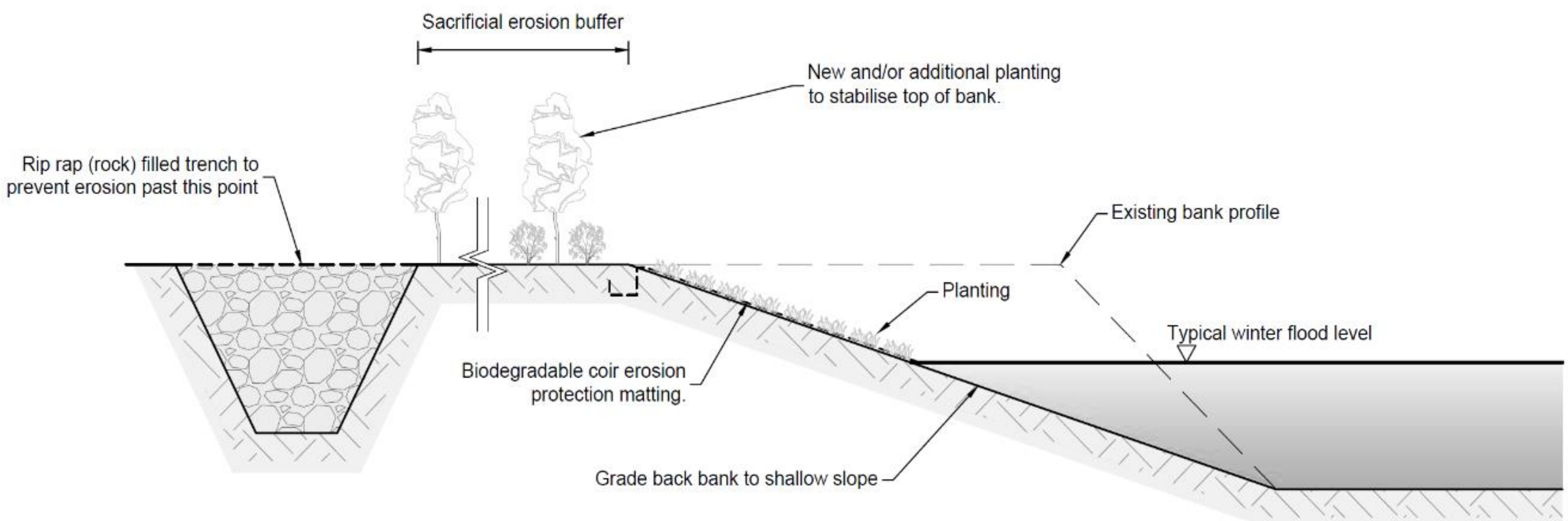


BURIED RIP RAP

Scale 1:100



GRADE BACK AND REINFORCE

Scale 1:100

Infrastructure

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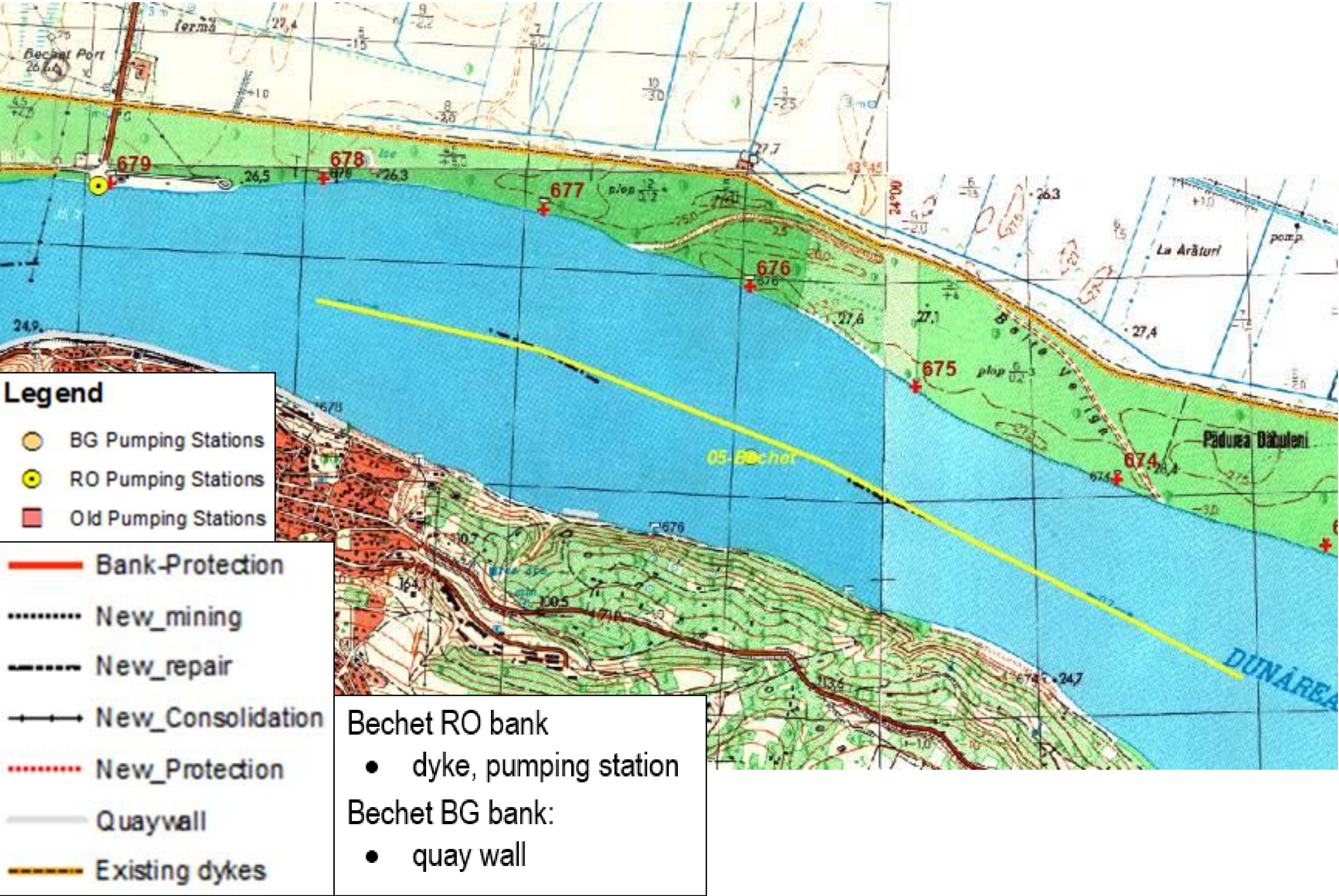

Bechet RO bank
- dyke, pumping station

Bechet BG bank:
- quay wall

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