Bank Protection near River Confluences

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Objectives

- Physical Processes
- Governing Equations
- Design Methods
- Conclusions

http://www.warnerimages.com/gallery/rivers/content/bin/images/large/ald3343h.jpg

Physical Processes

- Increase in discharge and sediment
- Generally:
  - Wider
  - Deeper
  - Faster velocity
- Sediment mixing
- Scour at the confluence
- Bar formation within the separation zone
- Thermal mixing
- Variability in:
  - Angle of confluence
  - Ratio of discharge between main & tributary channels

Physical Processes – Wave Propagation

- Waves can propagate across the main channel from the tributary
- Depending on the size and angle of the two streams, determining wave propagation might be critical for the design of bank protection

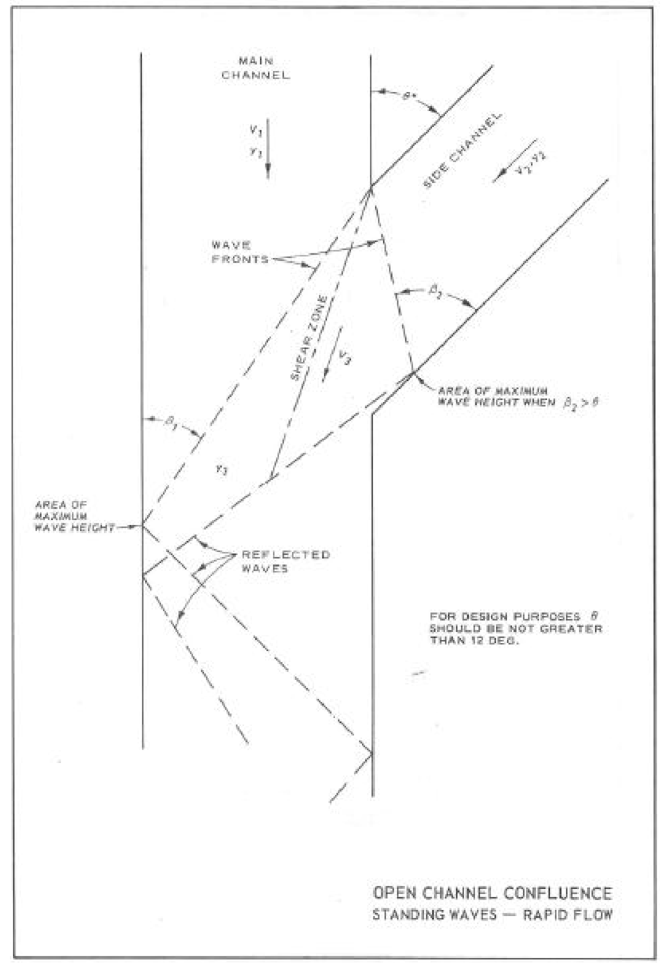


Figure 5. Plate B-53 from EM 1110-2-1601.

Stockstill, 2007

Physical Processes – Flow Dynamics

- The figure below shows flow dymanics for a confluence but also illustrates the flow seperation zone is located where bars often form

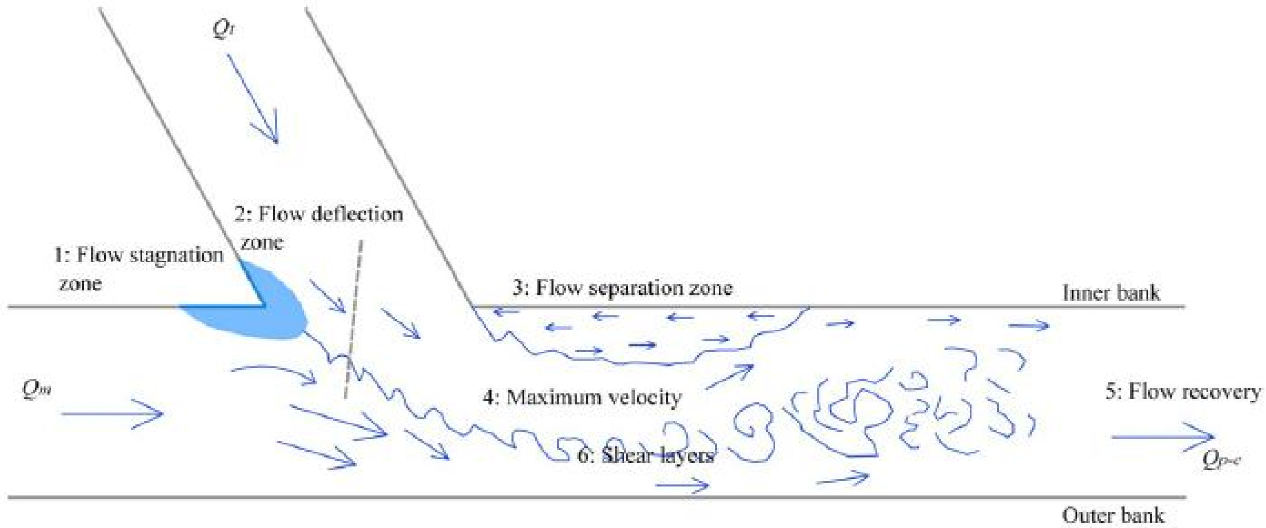


Figure 1. Descriptive model of flow dynamics at a channel confluence with horizontal concordant beds (slightly modified from *Best* [1987] with permission from Society for Sedimentary Geology).

Ribeiro, 2012

Physical Processes – Confluence Angle

- The angle at which the confluences comes together changes maximum depth of scour

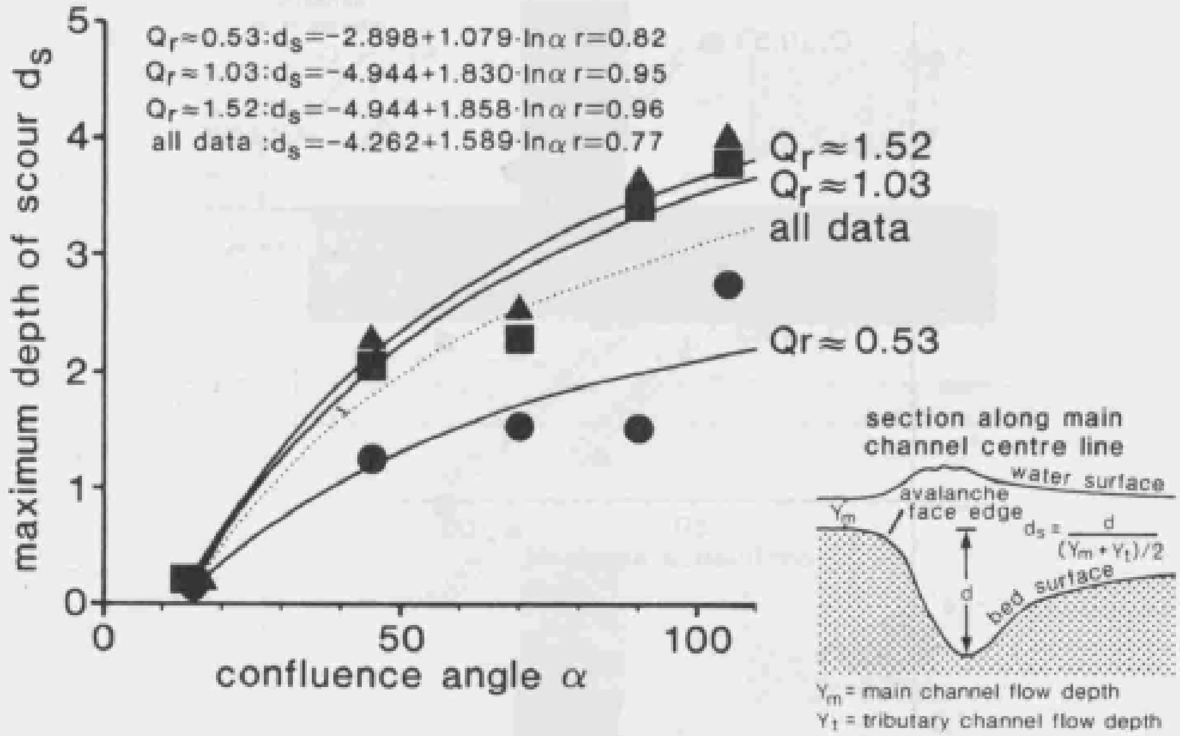


Fig. 5. Relationship between maximum scour depth, d_s, and confluence angle, α, for three values of discharge ratio, Q_r. See inset diagram for definition of terms.

Best, 1988

Physical Processes – Discharge Ratio

- A higher ratio between the tributary discharge to the main discharge increase the depth of scour

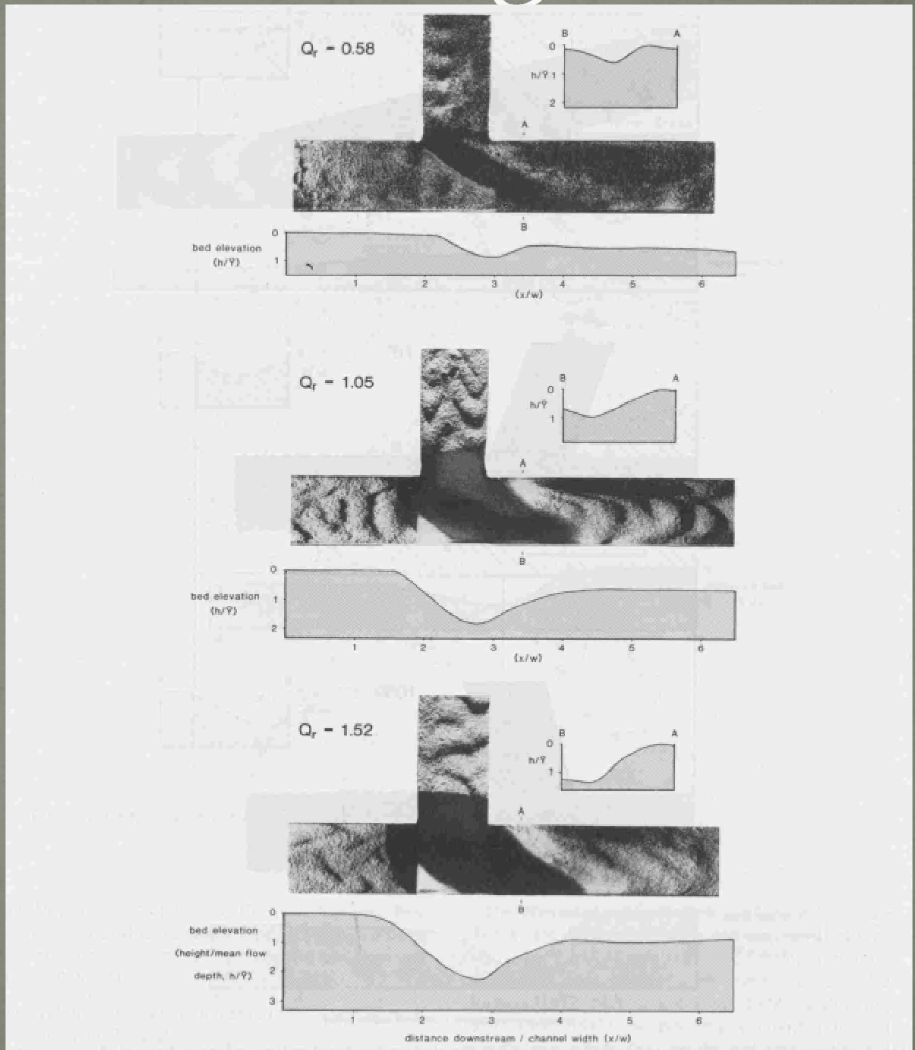
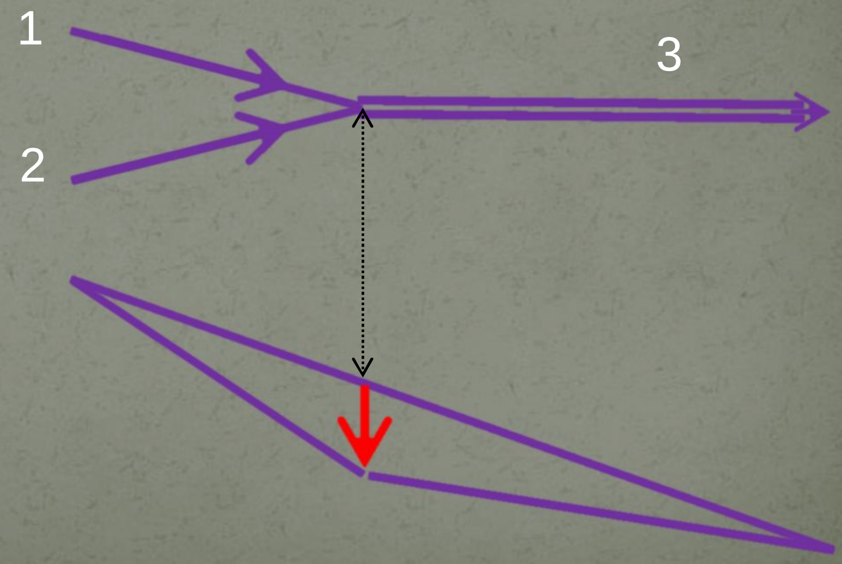


Fig. 3. Photographs, long profiles and cross sections of bed morphology developed at the 90° confluence at three values of discharge ratio, Q_r. Explanation of terms as in Fig. 2.

Best, 1988

Governing Equations

- Conservation of Mass
  - $Q_1 + Q_2 = Q_3 = V_1 A_1 + V_2 A_2 = V_3 A_3$
- Flow Resistance
  - Manning's n, Darcy-Weisbach f, Chezy C
  - e.g. $V = \frac{\emptyset}{n} R^{2/3} S^{1/2}$
- Sediment Transport
  - Many equations available
  - e.g. $q_{bv} \approx 18\sqrt{g} d_s^{3/2} \tau_*^2$



Design Methods

- Not a lot of design is needed at confluences as there is generally little lateral migration.
- However, a few techniques for bank stabilization are presented in the following slides.

Design Methods – Vegetation

- The most natural method
- Less expensive
- Root system increases bank stability
- Two broad categories (grasses and Woody plants)
- Has its limitation (Failure to grow, wetting and drying for varied duration and flow, prone to livestock damage, etc.)

http://www.marketwallpapers.com/wallpapers/12/wallpaper-69162.jpg

Design Methods – Retaining walls

- A)Sheet-pilling walls
- B) Gravity Walls
- C)Cantilevered Walls

- Sheet-pilling walls
  - Flexible walls
  - Height restricted
  - Anchors required

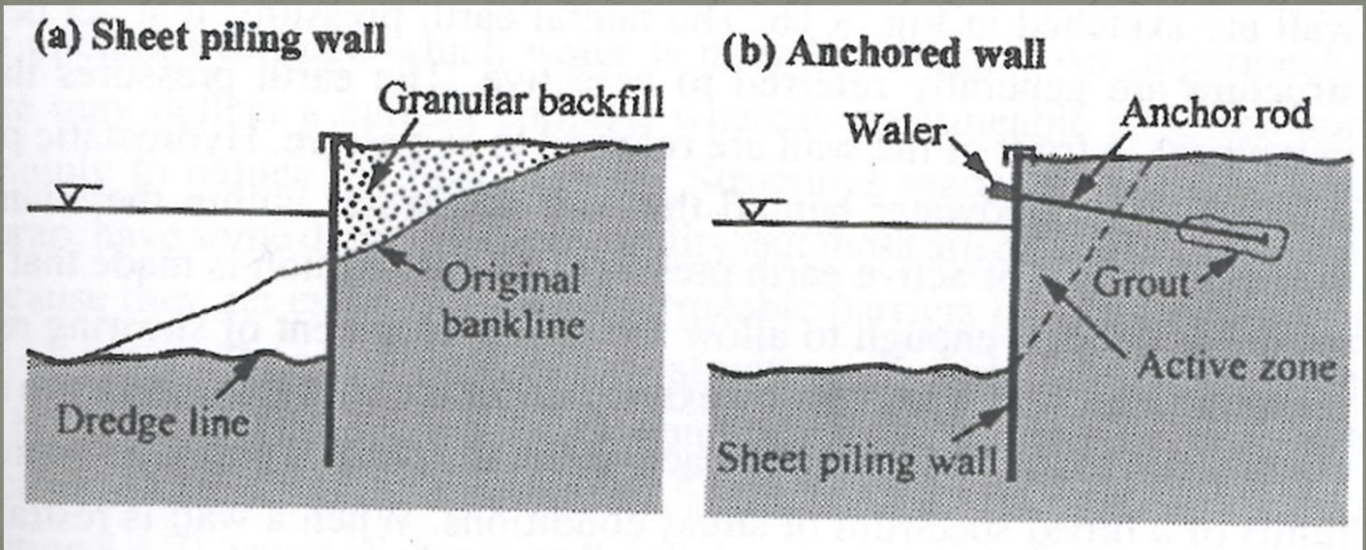


Figure 8.15. Sheet-piling walls.

Julien, 2002

Design Methods – Gravity walls

- Walls rely on their mass to restrain the soil movement
- Prevent lateral migration, and bank failure of channel
- Filter material required to prevent fine soil flunking behind the bulkhead

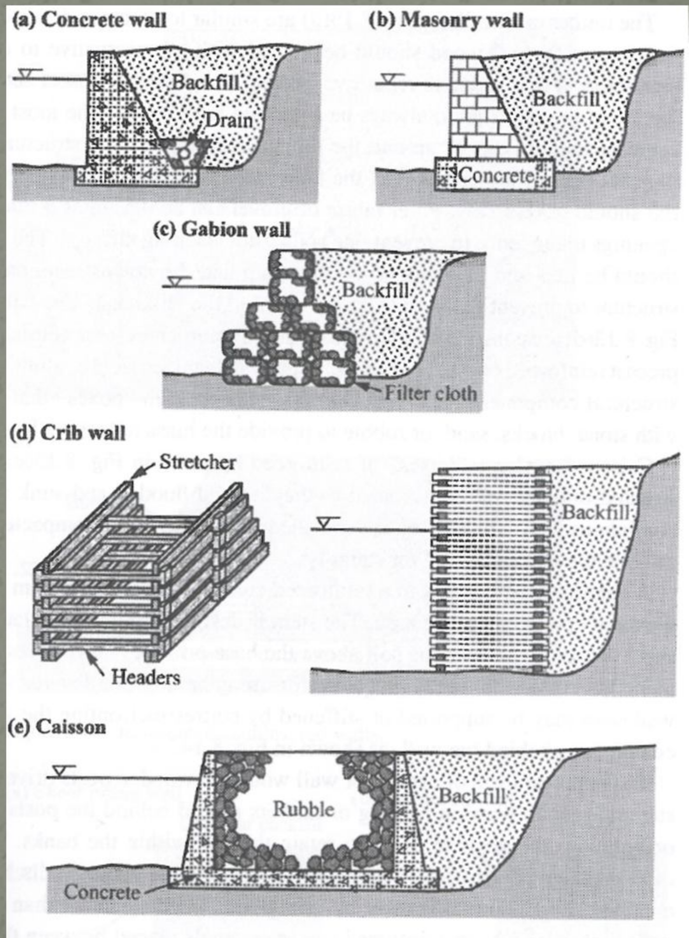


Figure 8.13. Gravity walls.

Julien, 2002

Design Methods – Cantilevered Walls

- Designed to resist the lateral and hydrostatic forces
- Soil above the base provides mass to resist movement
- Buttresses required on front or behind the wall to support the structure

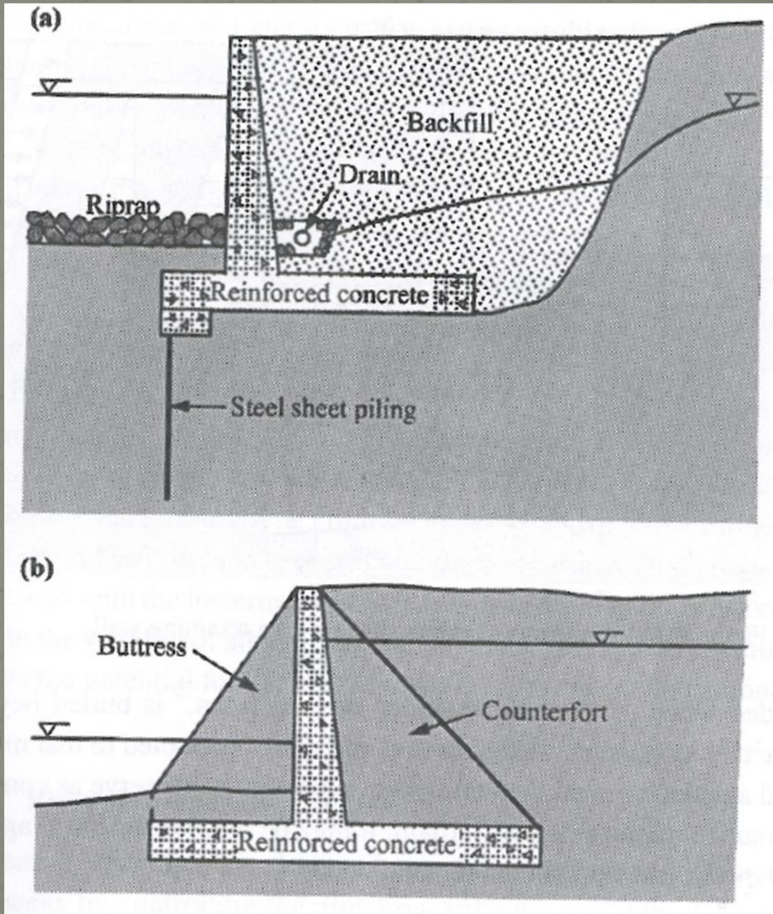


Figure 8.14. Reinforced cantilevered walls.

Julien, 2002

Design Methods – Sacks and blocks

- Filled with Soil or Sand –Cement mixture

- Advantages
  - Possible Placement on steep slopes
  - Locally Available
  - Smooth boundary for Channel conveyance
  - More aesthetic
- Disadvantages
  - Labor intensive
  - More susceptible to excess hydrostatic pressure
  - Vulnerable to environmental hazard

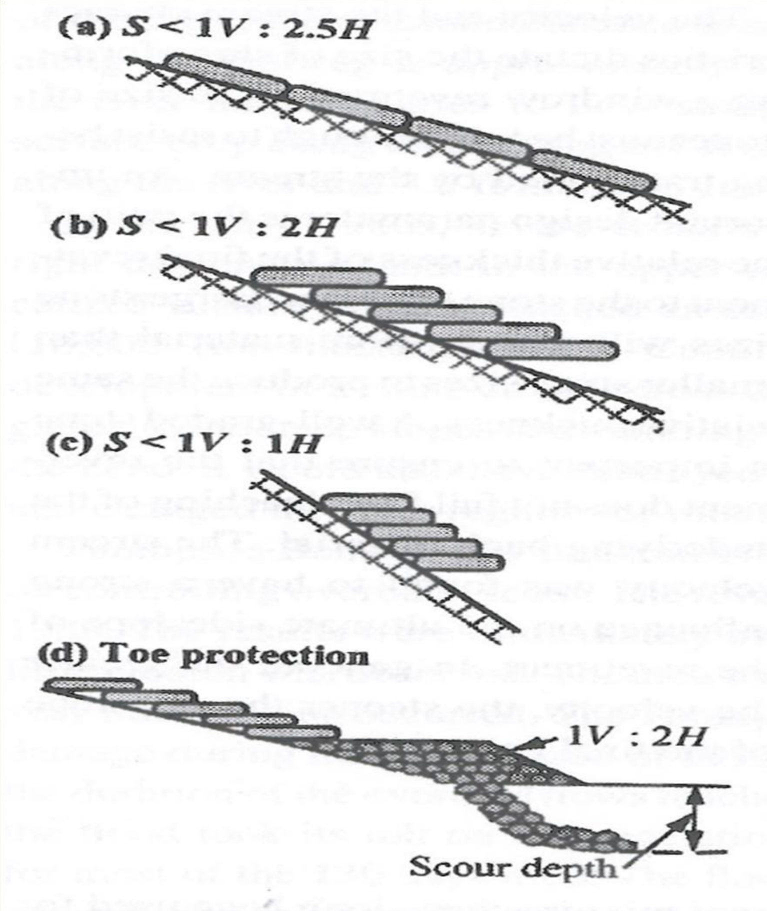


Figure 8.9. Sacks and blocks.

Julien, 2002

Design Methods – Gabions and Mattresses

- Rectangular wire boxes filled with relatively small sized stones
- Resistant to both river flows and unsuitable bank material
- Expensive method but satisfactory performance
- Periodic inspection and maintenance required

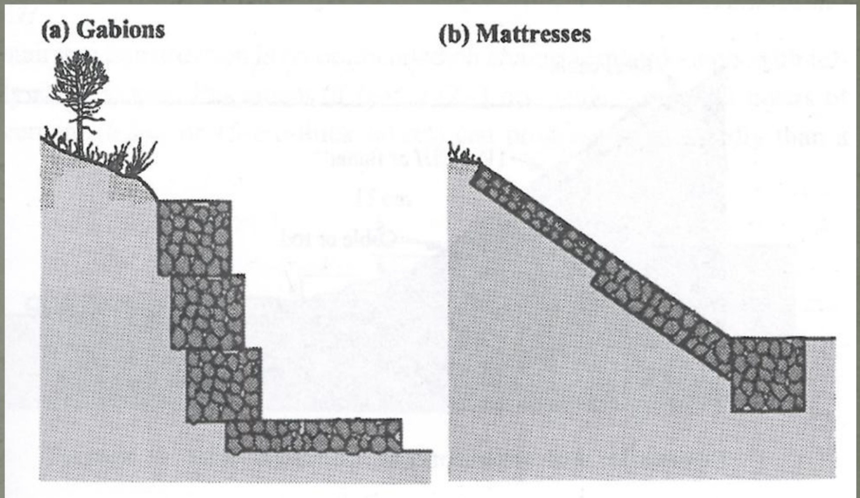


Figure 8.10. Gabions and mattresses.

Julien, 2002

Design Methods – Concrete mattresses

- Concrete blocks held together by steel rods or cables
- Prevent bank erosion and lateral migration of channel
- Flexible, strong and durable
- Low maintenance but high initial cost

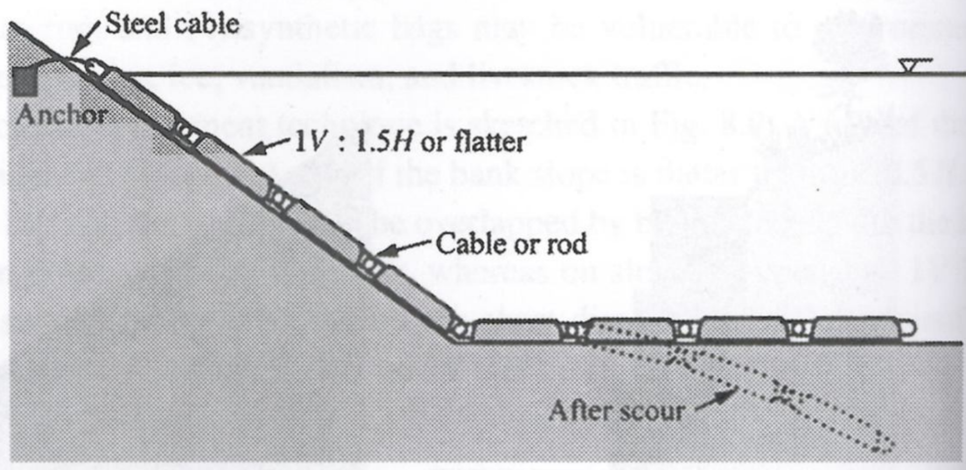


Figure 8.11. Articulated concrete mattresses.

Julien, 2002

Design Methods – Soil cement

- Used where riprap is scarce
- Sensitive to soil silt and clay ratio
- No steeper slope than 1V: 3h
- When velocity exceed 6-8 ft/s the aggregates should contain 30% gravel

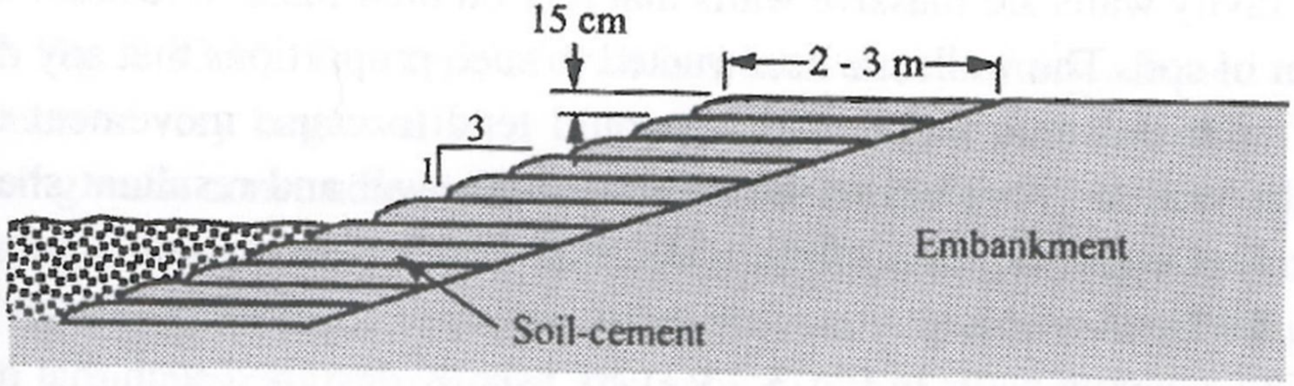


Figure 8.12. Soil–cement.

Julien, 2002

Design Methods – Windrows and trenches

- Permits natural erosion of the bank
- When rock supply undercuts, it naturally falls into the river bank to form riprap
- Velocity and stream characteristics dictate the size of stones
- Well graded stones are important
- A greater stream velocity leads to a steeper final revetment

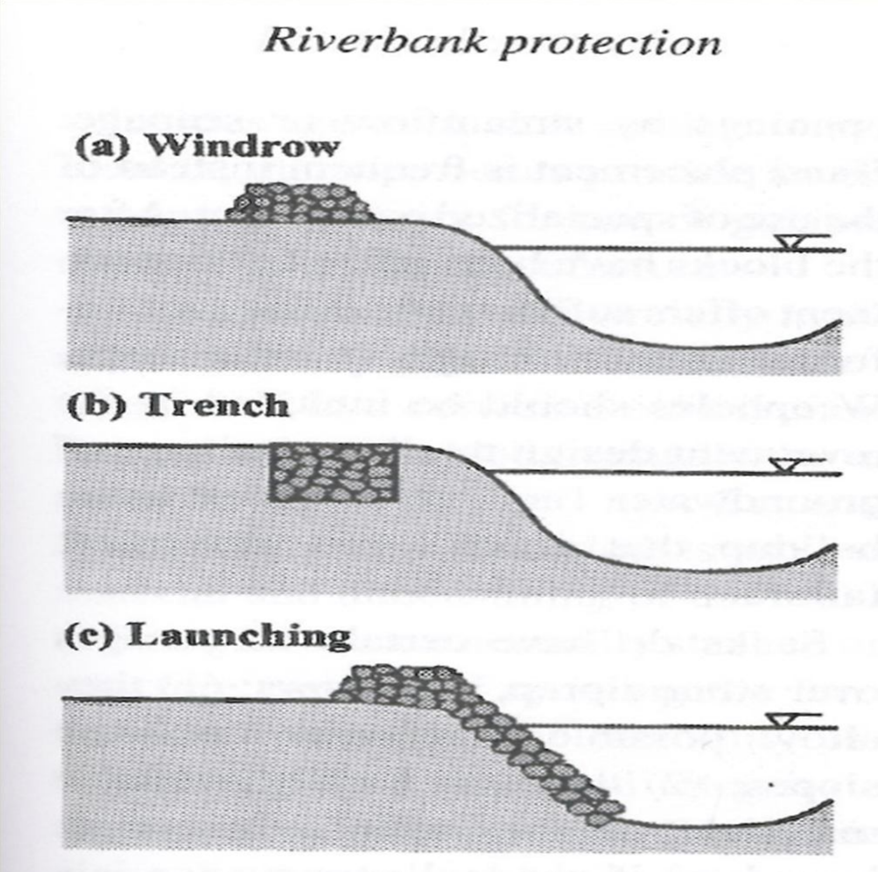


Figure 8.8. Windrows and trenches.

Julien, 2002

Design Methods – Riprap revetment

- Rock riprap is most widely used material for bank protection
- Construction is not complicated
- Often locally available
- More natural appearance than concrete
- Less wave run-up
- Easley maintained

- $d_m = \frac{\tau_0}{\tau_{*c}(\gamma_s - \gamma)\left[\cos\theta_1 \sqrt{1 - \frac{\tan^2\theta_1}{\tan^2\emptyset}}\right]}$

Conclusions

- Bank protection near river confluences are generally not necessary as they tend to be stable.
- However, in certain circumstances where bank erosion is likely, there are many methods to stabilize the banks.

References

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