Countermeasure Calculations and Design

- Author’s experience
Selecting a Countermeasure

- depends on
  - Erosion Mechanism,
  - Stream Characteristics,
  - Construction and Maintenance Requirements,
  - Vandalism, and
  - Costs
Countermeasures for Meander Migration

- bank revetments,
- spurs,
- retardance structures,
- longitudinal dikes,
- vane dikes,
- bulkheads,
- channel relocations, and
- a carefully planned cutoff
River Out-Flanking Bridge Opening

- Some rivers continue to meander and migrate in plan view.
- River may go around (out-flank) the bridge opening, or attack abutment.
Example of River Meander

FHA (1978) “Countermeasures for Hydraulic Problems at Bridges”
Countermeasures For Channel Braiding And Anabranching

- dikes constructed from the margins of the braided zone to the channel over which the bridge is constructed,
- guide banks at bridge abutments (Design Guideline 10) in combination with revetment on highway fill slopes (Design Guideline 12),
- riprap on highway fill slopes only, and
- spurs (Design Guideline 9) arranged in the stream channels to constrict flow.
Countermeasures For Degradation

- Check-dams or drop structures,
- Combinations of bulkheads and riprap revetment,
- Deeper foundations at piers and pile bents,
- Jacketing piers with steel casings or sheet piles,
- Adequate setback of abutments from slumping banks,
- Rock-and-wire mattresses,
- Longitudinal stone dikes placed at the toe of channel banks,
- Tiebacks to the banks to prevent outflanking.
Riverbed Degradation

- Some rivers have beds that are naturally degrading due to conditions upstream or downstream.
- Any bridge piers or abutments built will need to have a deeper foundation.
Degradation Failure, Ariz.

FHA (1978) “Countermeasures for Hydraulic Problems at Bridges”
Grade-Control Structure

Before

After

FHA (1978)
“Countermeasures for Hydraulic Problems at Bridges”
Countermeasures to Control Aggradation

- Alteration or replacement of a bridge,
- Maintenance programs,
- Spurs or dikes with flexible revetment have,
- A debris basin and controlled sand and gravel mining
Riverbed Aggradation

- Some rivers have beds that are naturally aggrading due to conditions upstream or downstream.
- Higher riverbed leads to increased flow depth and bridge over-topping.
Countermeasure to Control Contraction Scour

- longer bridges,
- relief bridges on the floodplain,
- superstructures at elevations above flood stages of extreme events, and
- a crest vertical profile on approach roadways to provide for overtopping during floods exceeding the design flood event
Contraction Scour

- For some bridges the width of the river has been narrowed to reduce span length.
- This smaller flow cross-sectional area leads to higher velocity \((V=Q/A)\)
- If increased velocity is high enough, then the sediment will start to erode.
Contraction Scour Schematic

- Original riverbanks
- Reduced flow area
- Bridge Abutments
Scour Monitoring

- very important to catch problems before they get dangerous
Bendway Wiers/ Stream Barbs

- Flow goes over to redirect flow
- Made of stones, grout bags, or logs
- Must design
  - height,
  - angle,
  - length,
  - location,
  - spacing,
  - key length,
  - top width,
  - # of wiers
Rock Riprap at Piers and Abutments

- Does help, but must be monitored
- Must design
  - rock size,
  - extent of mattress, and
  - underlying Geotextile filter size
Bank-Hardening: Riprap

- Use round stones; flat ones can be lifted and washed away.
- Use well-graded stones so small ones fill void spaces. Largest size = \(2D_{50}\); smallest size is gravel.
- Use geotextile filter fabric between bank material and riprap stones to prevent winnowing of fines. Place stones carefully. Seal sides of fabric to prevent undermining.
- Riprap blanket thickness should be at least 12 in. or \(1.5D_{50}\).
- Difficult to place in flowing water. Can add additional thickness at toe to settle into place after initial settling.
Sizing Riprap

\[ D_{50} = \frac{(\tau_c)_s}{4} \; \text{in ft, } \tau_{cs} \; \text{in psf} \]

\[ (\tau_c)_b = 1.6 \gamma RS \]

\[ \theta = \text{angle of repose; } R = \text{hydraulic radius; } S = \text{bed slope} \]
Spurs

- Flow goes around to re-direct flow
- Must design
  - type of spur,
  - extent of spur field,
  - length,
  - orientation,
  - permeability,
River-Training: Groynes/Spur Dikes

- Rock structures tied into bank
- Directs flow away from bank
River-Training: Groynes/Spur Dikes

Photo courtesy of Roger Kuhnle
Additional Design Parameters for Spurs

- height,
- depth of keying into bank,
- spacing,
- shape, and
- protection with riprap
Guidebanks

- For use when embankments encroach on floodplain
- Must design
  - orientation,
  - length,
  - height,
  - shape,
  - size,
  - riprap protection, and
  - downstream extent
River-Training: Guidebanks
Guide flow through opening

Additional Countermeasures

- Soil cement (where rock not available)
- Wire-enclosed riprap mattress (Gabions)
- Articulated concrete blocks
- Grout-filled mattress
- Concrete Armor Units
- Grout-filled bags
- Check dams for grade control
- Revetments for bank stabilization
Geobags-Pervious Bags Filled with Gravel

- PLAN

- SECTION

- Vertical water seepage

- No winnowing of fines
New Version of HEC 23

- coming out this summer
- new material on biotechnology as countermeasures
NCHRP Reports Published on Bridge Scour

- Expert System for Stream Stability and Scour Evaluation
- Scour at Contracted Bridge Sites
- Complex Pier Scour and Contraction Scour in Cohesive Soils
- Abutment Scour in Cohesive Soils
- Methodology for Predicting Channel Migration
- Prediction of Scour at Bridge Abutments
- Criteria for Selecting Numeric Hydraulic Modeling Software
More NCHRP Reports

- Guidelines for Risk-Based Management of Bridges with Unknown Foundations
- Effects of Debris on Bridge-Pier Scour
- Handbook for Predicting Stream Meander Migration and Supporting Software
- Debris Forces on Highway Bridges
- Riprap Design Criteria, Recommended Specifications, and Quality Control
More NCHRP Reports

- Countermeasures to Protect Bridge Piers from Scour
- Countermeasures to Protect Bridge Abutments from Scour
- Instrumentation for measuring scour at bridge piers and abutments
- Pier And Contraction Scour in Cohesive Soils
- Portable Scour Monitoring Equipment
Bank-Hardening: Toskanes

- Kind of jacks that interlock (Tetrapods)
- Won’t wash away as easily as riprap
- Placement similar to riprap
Bank Hardening: Cable-Tied Blocks

- Large concrete block tied together with cable. Acts as a mattress

Photo courtesy of Bruce Melville
Bank-Hardening: Geobags-Pervious Bags Filled with Gravel

- SECTION
  - Vertical water seepage
  - No winnowing of fines
Flow Altering: Submerged Vanes

- Creates vortex to direct bed sediment
- Plan View
- Downstream View
- Side View
Flow Altering: Submerged Vanes

- Direct bed sediment to scour holes
Flow Altering: Delta Wings

- Creates vortex to counter pier’s horseshoe vortex
River-Training: Submerged Vanes

- Can stop bank erosion also.
- Vane vortex cancels river-bend vortex
Grade-Control Structure

Small dam to fix bed elevation

Before

After

FHA (1978) “Countermeasures for Hydraulic Problems at Bridges”