WATERWAY TRANSITIONS AND RESTORATION AT BRIDGES

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Stream stabilization, naturalization, restoration projects are frequently implemented in the vicinity of bridges.

– Processes occur at bridges that do not occur elsewhere in channel
  • High shear stresses and scour
  • 3D flow and vortices
  • Sediment and debris deposition
  • Backwater
• Scour is the #1 cause of bridge failure in the U.S.
We need improved methods for creating transitions from the channel through the bridge opening.

- convey flood flows up to the design flood for the bridge
- convey sediment flow without producing scour at bridge piers and abutments
- convey sediment and debris without producing deposition
Local scour frequently occurs at bridge piers and abutments.

- Caused by obstruction to flow
  - Pier or abutment
  - Deceleration of flow at boundary, pressure gradient
  - Downflow + vortex main scouring agent
  - Considerable research efforts
Contraction scour can occur beneath the bridge in the waterway opening.

- Bed erosion caused by contraction of flow area
  - Channel (piers, abutments)
  - Floodplain (embankments)
- Reduced flow area results in increased velocity and shear stress
- Causes bed erosion in the vicinity of the bridge across the bed
Channel instability, on the other hand, is not usually caused by the bridge but can have significant detrimental impacts on the bridge.

• Unstable channel definition (Thorne et al., 1996)
  – A channel in which degradation, aggradation, width adjustment, or planform changes are actively occurring in time and space
  – Net morphological change over engineering time scales
Channel instability includes bank widening,
Channel degradation,
Lateral migration, and
sediment and debris deposition.
Bridge scour is assessed using FHWA HEC-18 (google FHWA hec 18)

\[
\frac{y_s}{y_1} = 2.0 K_1 K_2 K_3 \left( \frac{a}{y_1} \right)^{0.65} F_1^{0.43}
\]

\(K_1\) = pier shape factor  \(K_3\) = bed forms factor  
\(K_2\) = angle of attack factor
Assessing channel instability and the impacts on bridges is far more difficult.
There is a wide variety of methods to protect bridges.

• The type of protection at the bridge depends on the type of problem (local, degradation,...)
  – armor channel bed and banks
  – alter flow alignment

• Span the entire floodplain

• Measures that break up vortices for local, contraction
  – sheet piles and cylindrical piles placed upstream of pier (sacrificial piles)
  – Circular shield around pier

• Measures that redirect flow lines for local, contraction, widening, lateral migration
  – Vanes and similar structures
    • Submerged (Iowa) vanes upstream of bridge (U. Auckland)
    • Bendway weirs (US Corp of Engineers; FHWA)
    • Vanes, cross vanes, w-weirs (widely used in stream projects)
Submerged (Iowa) Vanes

- Isolated, submerged vanes
  - Traditionally used for controlling erosion at banks
  - Effective in depths 2-8 times the vane height
Submerged (Iowa) Vanes

- At bridges
  - re-centering of flow
  - protection of abutments

- West Fork Cedar River Bridge
  - aligned at 20 degrees to 1984 mean flow direction
  - 3.7 m long, 0.6 m high

A. Jacob Odgaard, 2009. ASCE
Vanes, Cross vanes, W-weirs

- Widely used in stream restoration projects
- Improve lateral stability and flow alignment
- Provide bed control (cross vanes and w-weirs)
- Effective for high flow events
- Ability to reduce scour at bridges
Vanes, Cross vanes, W-weirs have been shown in lab studies to be highly effective at reducing scour at bridge foundations.

- scour reduced by 65-90%
- effective up to 100-year or overtopping flood
- Design criteria developed
  - Location of structure upstream from bridge
  - Angles, pitch, height of vanes, cross vanes, w-weirs

![Graph showing scour depth vs. distance from left bank with and without vanes.](image-url)
Applicability of vanes and weirs

• Vanes, cross vanes, w-weirs have potential to be very effective scour countermeasures
  – Also effective in moving sediment locally
• Careful placement of angle key to effectiveness
• Field testing needed
• Not effective for high bed-load streams to move sediment through bridge openings
  – Could be used in design of sediment trap upstream of bridge
Annual or bi-annual bridge inspections include scour and channel instability close to bridge.

- Bridge owner “owns” liability, conservative
- Bridge owner has right of way in vicinity of bridge
- Communication between engineers, stream practitioners, watershed groups, funding agencies, permitting agencies
- High degree of uncertainty
Bridge right-of-ways are typically very narrow, often only 15m (50 feet) upstream and downstream from a bridge. Thus, it is a difficult task to control channel stability locally within a bridge right-of-way.

- FHWA project to develop rapid stability assessment method for bridge-stream intersections
  - google “FHWA physiographic”
Field Observations

57 sites, 15 states, 13 physiographic regions
Stability Indicators

- Based on literature review, prior research, field observations
  - watershed and floodplain
    - activities and characteristics, flow habit, channel pattern, and entrenchment
  - channel bed
    - material, consolidation and armoring, bar development, and obstructions
  - banks
    - material, angle, bank and riparian vegetation, bank (fluvial) cutting, and mass wasting (geotechnical failure)
  - position relative to the channel
    - indicated by meander impact point and alignment of the bridge opening with the stream channel
Common Issues

• greatest damage to stream channels resulted from the combination of:
  – cattle activity
  – vegetation removal
  – channel straightening
Common Issues

• distinct change in channel stability upstream and downstream of bridge
• caused in every case by a change in property management
  – common for a road/bridge to divide property ownership
Common Issues

• lateral migration of meander bend
  – forces channel against the left abutment; causes additional local scour at the abutment and undermining of the abutments;
  – could result in an unstable bridge foundation
Common Issues

• narrow single-span bridges
• cannot accommodate lateral or vertical adjustments of the channel
A set of recommendations for addressing and improving channel stability at bridges was suggested.

- Control water and sediment discharges at the catchment level;
• Revegetate channel banks with diverse woody vegetation;
• Remove disturbances, such as cattle, from the stream channel;
• Reshape the channel cross-section to a more stable, natural configuration; and
• Use in-stream structures to control flow near the channel bed and banks
Use of in-stream structures at bridges to control scour, stability, sediment, and debris subject to considerable uncertainty

– Lack of systematic field testing and documentation
– Estimation of hydraulic parameters
– Construction experience and implementation
– Design guidelines
– Detection of failure
– Maintenance
The Institute for Sustainable Infrastructure (ISI) is not a for-profit organization, structured to develop and maintain a sustainability rating system for civil infrastructure in the United States. Founded by the American Council of Engineering Companies (ACEC), the American Public Works Association (APWA), and the American Society of Civil Engineers (ASCE).
• Rating system: Envision
  – holistic framework for evaluating and rating the community, environmental, and economic benefits of all types and sizes of infrastructure projects.
  – evaluates, grades, and gives recognition to infrastructure projects that use transformational, collaborative approaches to assess the sustainability indicators over the course of the project's life cycle.

• Every infrastructure project has an important impact on all five Envision™ categories:
  – Quality of Life
  – Leadership
  – Resource Allocation
  – Natural World
  – Climate and Risk
Horsetail Falls trail
Attention hikers

The steel bridge on Horsetail Falls trail #438 is open but limited to one person at a time crossing. There is some damage to the bridge, but engineers have determined one person crossing at a time is safe.

(Questions: call 541-308-1700)