River Spanning Structures Research: 2007 Update and Proposal

Research on river spanning rock structures began in 2005 and developed a conceptual model of success, failure, and performance backed by field measurements, laboratory tests, and numerical modeling. Work in progress is developing quantitative design and analysis techniques. Rock weir and ramp structures uniquely serve a necessary role in river management to meet water deliveries in an ecologically sound manner. Names for structures include: rock weirs, alphabet weirs (A, U, V, and W), rock ramps, roughened channels, and engineered riffles. Ramps and weirs lie at the extremes of the spanning structure class. Both structures extend from bank to bank and check the water surface. Uses include replacing low head diversion dams, permitting fish passage, creating habitat diversity, and stabilizing stream profiles. In addition to new construction, existing structures require maintenance to maintain function. A scientific and mechanistic based understanding of structure behavior permits making supportable planning and management decisions and adapting to new circumstances. Current design methods primarily rely on individualized professional experience and anecdotal information with mixed success. River spanning structures research provides information on sustainable construction and retrofit techniques for minimizing the lifecycle costs of building and maintaining structures to reliably meet management objectives.

Spanning structures research incorporates a multifaceted approach consisting of: field data to identify prototype conditions providing practical and applied information; laboratory physical modeling to isolate key variables and study individual processes in detail; and numerical modeling to develop tools and predictive capability for analysis and design.

Results to Date

Results to date guide the present and future courses of study. Initial field investigation and literature review identified instances of rock structures meeting design and management goals leading to a list of best practices. High levels of performance in some cases indicated merit to these structures, while a loss of function in others warrants further research to identify the distinguishing circumstances. Major failure mechanisms included: scour: undermining and collapse of structure arms, primarily for weirs; incipient motion: mobilization of constituent rocks, primarily in ramps; sedimentation: filling in and loss of pool areas required for fish passage; and interstitial flow: subsurface hydraulic connectivity resulting in depths too shallow for fish passage. Laboratory physical modeling of weirs confirmed the observed mechanisms and found scour depths exceed existing predictive equations while matching erosion and flow patterns seen in the field. Physical modeling is currently underway to determine the effects of interstitial flow through steep rock ramps on fish passage. Numerical modeling confirmed both field observations and lab results by quantifying high shear stress zones near field and lab scour areas and low shear zones near field and lab depositional areas.

Funded Work

- Rock Ramp Design Guidelines (Completed: November, 2006)
- Qualitative Synthesis of Field Evaluations (Deliverable: FY'07)
- Quantitative Synthesis of Field Evaluations (Deliverable: FY '08)
- Scour Prediction (Deliverable: FY '08)
- Interstitial Flow Quantification and Reduction (Deliverable: FY 08)
- Water Surface Profile and Hydraulic Flow Patterns (Deliverable: FY '08)
- Geometry Impacts on Flow Patterns and Scour (Deliverable: FY '08)
- Sealing of Structures (Deliverable: FY 08)
- Guidelines Synthesis Report (Deliverable: FY '08)

Proposed Improvements

Observations during the research led to hypothesis on potentially more efficient and effective design practices. The following two research options provide a path to bring concepts to a production level.

- Empirical Validation: Field, lab, and numeric work identified successful and problematic structures including specific processes and potential remedies. Initial results have guided some retrofits. Targeted field visits to retrofits, key previous sites, and newly identified locations can confirm or deny specific conclusions.
- Hybrid (H or Amphitheater) Structures: ramps and weirs lie at the extreme edge of a continuous range of structures spanning the full width of a stream. Research observations suggest a hybrid design could optimize the advantages and disadvantages between exclusively weir and exclusively ramp behaviors.
    - Initial, fixed boundary, 2D and 3D, numerical modeling to predict hydraulic performance and estimate scour.
    - Laboratory modeling to confirm hydraulic performance and develop a scour data set.
    - Mobile-boundary scour prediction methods to provide a generalized tool for testing configurations between fully weir and fully ramp behavior. The modeling code exists, but lacks sufficient test cases for confidence. Tuning and improvements can provide the necessary information.
    - Successful demonstrations would then lead to future proposal for a field application as a demonstration project.

Conclusions

The Sedimentation and River Hydraulics group performs river engineering design and analysis across the country. Our experienced and professional staff works on many different systems resulting in a broad understanding of different conditions, problems, and solutions. Structure research developed:

- A large dataset of field, lab, and computer experience resulting in a consistent understanding of structure behavior under many conditions.
- Qualitative field observations resulting in a conceptual model of performance
- Quantitative rock ramp design guidelines based on existing literature.
- Existing research will result in design tools and guidelines in 2008 to address significant failure mechanisms and performance identified in the field.
- Ideas for improved structure performance and longevity.

Development of guidelines and techniques is ongoing. We welcome hearing of new sites, experiences, conditions, and problems. The Restoration Structures web page contains additional materials including overviews, fact sheets, and guidelines: http://www.usbr.gov/pmts/sediment/kb/restructs.