Numerical Analysis of the Performance of River Spanning Rock Structures: Evaluating effects of structure geometry on local hydraulics

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Abstract. River spanning rock structures that are being constructed for water delivery also enable fish passage at barriers and provide or improve the aquatic habitat for endangered fish species. Current design methods are based upon anecdotal information applicable to a narrow range of channel conditions. As a result, scientifically supportable guidelines and methods for hydrologists and engineers are not available to estimate pool and scour-hole development, structure rock size, and scour countermeasures. Guidelines and methods are needed to design stable, cost effective, and sustainable river spanning rock structures with predictable design lives (stability), consistent performance, and minimal maintenance requirements. The complex flow patterns and performance of rock weirs is not well understood. Without accurate hydraulics, designers cannot address the failure mechanisms of these structures.

A conceptual model of success, failure, and performance backed by field measurements, laboratory tests, and numerical modeling has been developed. Flow characteristics such as jets, near bed velocities, recirculation, eddies, and plunging flow govern scour pool development. These detailed flow patterns can be replicated using a 3-Dimensional numerical model. Numerical studies inexpensively simulate a large number of cases resulting in an increased range of applicability in order to develop design tools and predictive capability for analysis and design.

The numerical model U^2RANS is used to investigate how variations in structure geometry affect local hydraulics, scour hole development, and overall structure performance. An automatic mesh generator was developed to expedite the process of generating 89 structure geometries in a simulated straight trapezoidal channel. Variations in structure geometry include arm angle, arm slope, drop height, and throat width. Various combinations of each of these parameters are modeled at 3 flow rates: 1/3 bankfull discharge, 2/3 bankfull discharge and bankfull discharge. The numerical modeling focuses on how variations in structure geometry have an effect on local flow patterns and scour development. Numerical modeling results duplicated both field observations and lab results by quantifying high shear zones near field and lab scour areas and low shear zones near field and lab depositional areas.

The analysis and results of the numerical modeling, laboratory modeling, and field data provide a process-based method for understanding how structure geometry affects flow characteristics, scour development, fish passage, water delivery, and overall structure stability. Results of the numerical modeling allow designers to reverse the analysis and determine the appropriate geometry for generating desirable flow parameters. The end product will develop tools and guidelines for more robust structure design or retrofits based upon predictable engineering and hydraulic performance criteria.

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