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Firoozfar, Ali Reza; Weber, Larry J.; Craig, Andrew J.; Lyons, Troy C.

Priest Rapids Dam Rock Scouring Simulation Using Hydraulic Modeling

PRIEST RAPIDS DAM ROCK SCOURING SIMULATION USING HYDRAULIC MODELING

Ali Reza Firoozfar[1], Larry J. Weber[2], Andrew J. Craig[3], and Troy C. Lyons[4]

Rock scouring is a significant concern in hydraulic structure safety (e.g. dams). It occurs when the energy of flowing water exceeds the resistance ability of rock (Annandale, 2006). Rock scouring process is a highly dynamic process governed by the interaction of water, air and rock.

Hydraulic modeling has shown to be a reliable approach to investigate hydraulic structures, however, rock scour studies in laboratory models pose many challenges. The prototype makeup of rock formations cannot be utilized in scaled laboratory models, since the flowing water in the model contains much less energy. Moreover, the use of non-cohesive materials in models overestimates the scour extent, underestimates the scour rate, and cannot accurately simulate the shape and steep side slopes of scour holes observed in the field (Henderson *et al.*, 2000). There is limited information available to assist in laboratory scale modeling of bed rock formation. Adding binders to non-cohesive materials is one approach that has been used to simulate rock scour formations (Johnson, 1977). The amount of added binder is important to accurately simulate the strength of the rock formation in the field.

To evaluate scour behavior in the tailrace of Priest Rapids Dam, located on the Columbia River in Washington, USA, a 1:64 Froude scaled model was utilized at IIHR-Hydroscience & Engineering, The University of Iowa. The dam consists of a ten unit powerhouse and twenty-two spillway bays. The bed rock was modeled with nominally 0.45 inch washed angular gravel (range approximately 1/16 to 1 inch). Cohesive bentonite clay was added to gravel as a binder in a series of experiments in order to find the optimum mixture of gravel, bentonite and water to accurately replicate an existing scour hole observed in the prototype tailrace in front of spillbay 22.

The existing field scour hole was resulted by the full open gate release of 63.5 Kcfs from spillbay 22 that occurred at the Priest Rapids Project between May 6 and June 5, 2003. The goal of the model scour test, then, was create a scour hole of equal depth and similar shape to that existing in the field. Several gravel:bentonite:water ratios were tested. The final erodible bed mixture was 9 parts gravel to 1 part bentonite to 1 part water by volume. Mixtures tested with larger fractions of bentonite failed to reach the target scour depth in a reasonable time frame while mixtures with smaller fractions of bentonite reached the target scour depth unrealistically quickly. The optimum erodible mixture was utilized for scour studies in the model.

The second test in the series was conducted to assess the scour potential downstream of the Priest Rapids Fish Bypass (PRFB). To achieve a conservative results the test was conducted for the 90% exceedance tailwater elevation of 405.2 ft and the 50% exceedance headwater elevation of 486.6

[1] Research Assistant, IIHR - Hydroscience & Engineering, Department of Civil and Environmental Engineering, The University of Iowa, Iowa City, IA 52242, USA (alireza-firoozfar@uiowa.edu)
[2] Professor, IIHR - Hydroscience & Engineering, Department of Civil and Environmental Engineering, The University of Iowa, Iowa City, IA 52242, USA (larry-weber@uiowa.edu)
[3] Research Engineer, IIHR - Hydroscience & Engineering, Department of Civil and Environmental Engineering, The University of Iowa, Iowa City, IA 52242, USA (andy-craig@uiowa.edu)
[4] Research Engineer, IIHR - Hydroscience & Engineering, Department of Civil and Environmental Engineering, The University of Iowa, Iowa City, IA 52242, USA (troy-lyons@uiowa.edu)

ft. The three fish bypass units were operating at 27.1 Kcfs. The results of this scour test represent an estimate of the erosion that could occur at the project over an extended period of time. The model was operated until erosion in the tailrace stabilized. Stabilization occurred after approximately 43 model hours (344 prototype hours). A plunging jet was observed in the bay 20 bypass which caused a significant amount of erosion. There was a tendency for the pier extensions to be undermined during the test, particularly pier 20. In general, the existing scour hole migrated upstream and towards the right bank. The largest amount of erosion was observed 70 feet downstream of bypass bay 20 where 17 feet of scour occurred.

In the third series, scour potential downstream of the Priest Rapids Dam spillway for the Probable Maximum Flood (PMF) condition with the PRFB in operation was assessed in the tailrace model. The total spillway flow in the model was set at the PMF of 1.33 million cubic feet per second. The scour progression was stabilized after 158.5 model hours (1268 prototype hours). Fig. 1 shows the initial and final bathymetry of the PMF scour test. Large areas of scour were observed downstream of the spillway and near the fish bypass downstream of bays 18 and 19. The greatest erosion took place approximately 350 feet downstream of spillbays 12 and 13 where 54 feet of scour was observed. Two areas of significant undermining were observed under the pier 20 training wall and to the right of the existing endsill along the right bank fish facilities. There was no tendency to undermine the main spillway apron except near spillbays 1, 19 and 20.

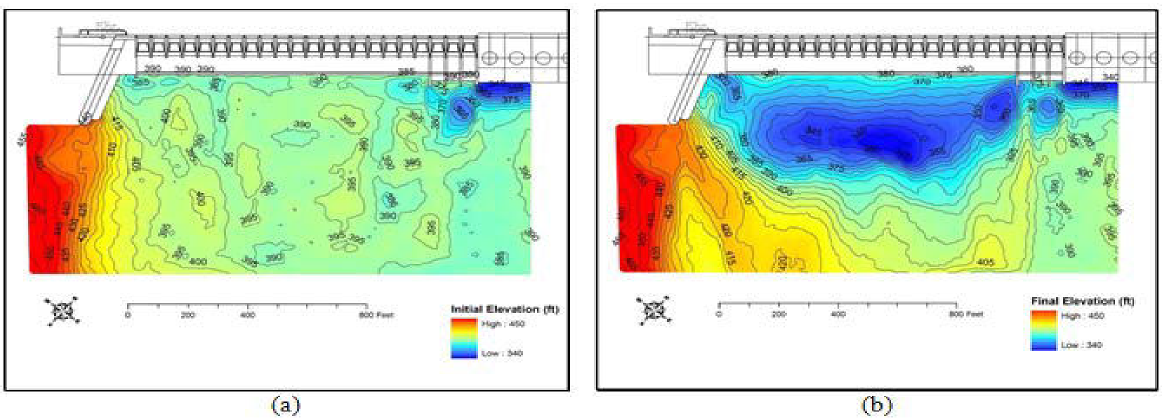

Figure 1 PMF scour test a) initial bathymetry, b) resultant bathymetry.

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