Photogrammetry Applications for Physical Hydraulic Modeling

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ABSTRACT

Photogrammetry has been successfully used for moveable bed analysis, model verification, and model construction for physical models in the Bureau of Reclamation's hydraulics laboratory in Denver, Colorado. Once properly set up and calibrated, photogrammetric techniques are faster than typical model data collection techniques and provide far more data points than can be collected with traditional laboratory methods. Photographs are collected with a high resolution Nikon SLR camera and processed using ADAM Technology's 3DM CalibCam and 3DM Analyst software to identify spatial coordinates and elevations, and produce digital terrain maps.

INTRODUCTION TO PHOTOGRAMMETRY

Photogrammetry is the process of using photography to develop a three-dimensional (3D) surface of an object. In the Bureau of Reclamation's hydraulics lab in Denver, CO, a 12 megapixel Nikon D700 SLR camera with either a 20 mm or 14 mm lens was used to take photos of the area of interest. The camera and lens were calibrated using ADAM Technology's 3DM CalibCam software. To get a better vantage point the camera was either mounted on a 12-foot range pole or suspended from the ceiling of the lab by a cable trolley system. The automatic focus on the camera was turned off and tape was used to ensure that the lens settings were not unexpectedly changed. The process requires taking two photos of the same area from different vantage points. Then the images are processed using 3DM CalibCam and 3DM Analyst. The software finds common pixels and produces a 3D surface of the photographed area. The surface can then be projected into a user-defined coordinate system. More than one image pair may be required, depending on the size of the area of interest. Additional processing and analysis was completed with either ArcGIS or AutoCAD Civil 3D.

PHOTOGRAMMETRY METHODS

MOVABLE BED ANALYSIS

Photogrammetry was used to optimize the design of Blue River fish barrier by creating aggradation and degradation maps to identify the location and extent of scour downstream of the structure. The area downstream of the low head (5-foot prototype) arch dam was modeled with a sand gradation that would transport and deposit similar to the material in the prototype river. A pair of photos were taken before water was run in the model to develop a 3D surface of the initial condition (Figure 1). Testing commenced and material downstream of the dam was allowed to move. After water was drained from the model, a second pair of photos were taken and a final 3D surface was built (Figure 2). AutoCAD Civil 3D was used to compare the two digital surfaces and develop a contour map showing the differences between the initial and final surfaces. Figure 3 shows scour and deposition downstream of the fish barrier.

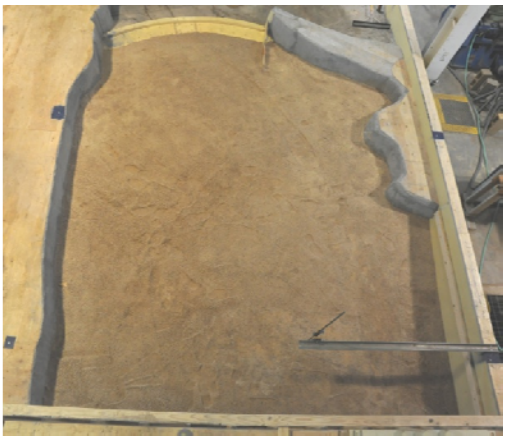

Figure 1. “Before model run" picture.

Figure 2. "After model run" picture.

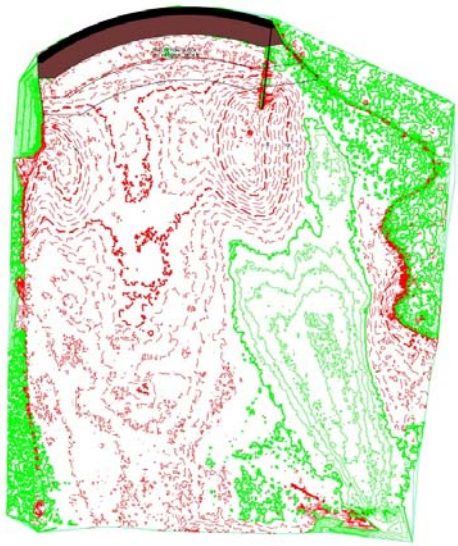

Figure 3. Difference contour map showing degradation (dashed) and aggradation (solid) downstream of the Blue River fish barrier.

Photogrammetry also was used to map scour patterns produced by various engineered large woody debris configurations in a moveable bed model. Engineered large woody debris structures are introduced into rivers due to the many realized benefits of woody debris, particularly with respect to salmonid habitat restoration and habitat complexity. “Initial” and “final” image pairs were taken and used to produce 3D surfaces of the river bed before and after model runs. Figure 4 and Figure 5 show the overlap between the two images in the pair. Post processing was completed using ArcGIS to develop scour maps relating to different engineered large woody debris configurations (Figure 6 through Figure 9).

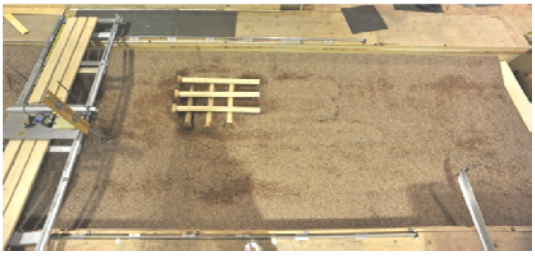

Figure 4. Left image in the pair, large woody debris model.

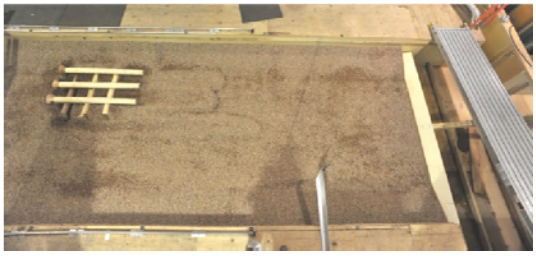

Figure 5. Right image in the pair, large woody debris model.

Figure 6. Scour pattern, configuration 1.

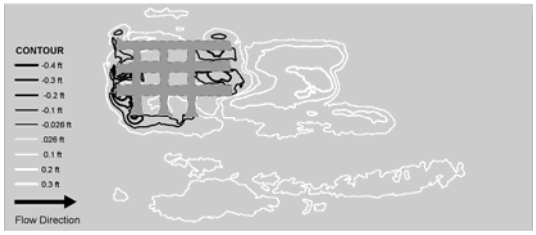

Figure 7. Scour pattern, configuration 2.

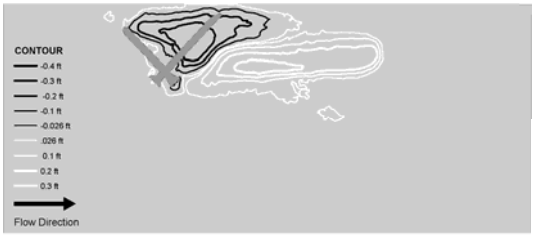

Figure 8. Scour pattern, configuration 3.

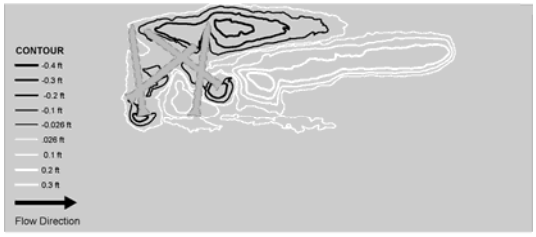

Figure 9. Scour pattern, configuration 4.

MODEL CONSTRUCTION AND VERIFICATION

The accuracy of an in-place rock fill ramp constructed in the Lower Yellowstone Intake Dam physical model was verified using photogrammetry. In the prototype the existing 10-ft-high timber crib dam diverts water for irrigation and unintentionally prevents upstream passage of pallid sturgeon. The model evaluates replacing the dam with a smooth weir and artificially raising the riverbed downstream of the dam for 1500 ft with 4-ft-minus material to create a rock ramp to facilitate

upstream passage over the dam (Figure 10). In the model 2-in-minus rock was placed by hand in templates to represent the ramp. After placement of the rock, photogrammetry was used to ensure that the elevations and slopes met design specifications. If areas of the rock were too high or low they were modified so that the rock ramp could correctly be represented.

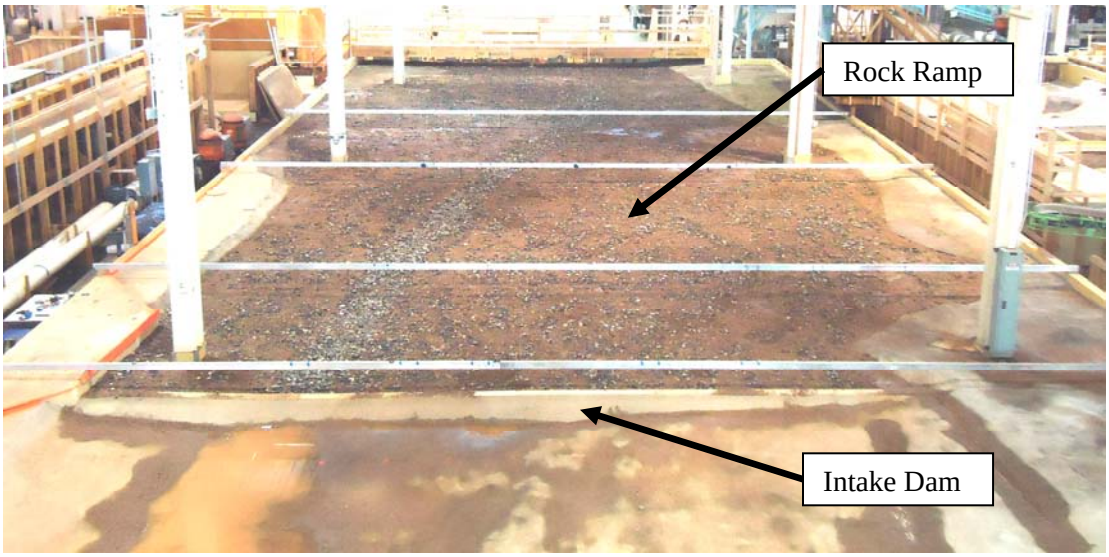

Figure 10. Lower Yellowstone Intake Dam rock ramp physical model.

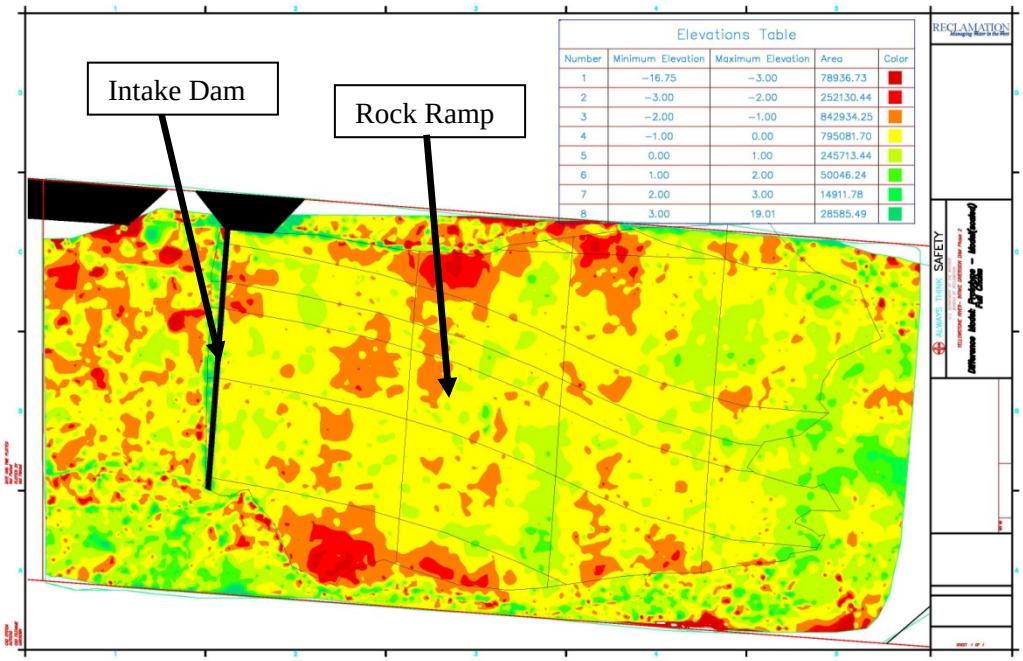

Figure 11. Map developed with photogrammetry to verify elevations of the rock ramp in the Lower Yellowstone physical model. Darker areas show elevations that needed to be modified to correctly represent the rock ramp.

The 1:48 scale Folsom Dam confluence model was built to analyze and evaluate the design of the new auxiliary spillway. During the model study a change in the concrete topography of the model was required. The proposed spillway and access haul road needed to be removed in order to model the original river channel (Figure 12). Photogrammetry was used to develop an as-built digital terrain map of the existing model. AutoCAD Civil 3D was used to create a difference map between the current topography and the desired modification to identify changes required in the model. Plywood templates were cut and placed directly on the existing model, and new wire mesh and concrete were then placed (Figure 13). Traditionally this modification would have required removal of the concrete topography and construction of the new topography. By using photogrammetry valuable time and money were saved during this modification (Figure 14).

Figure 12. Folsom model showing the auxiliary spillway and haul road before modification for future testing.

Figure 13. Templates were cut to be placed on top of the old topography.

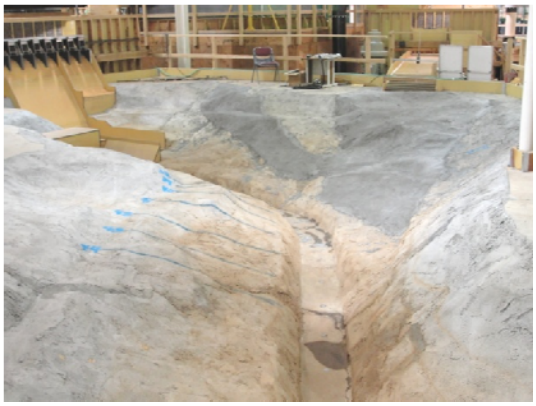

Figure 14. Finished model modification.

CONCLUSIONS

Photogrammetry has been successfully used for moveable bed analysis, model verification, and model construction for physical models in the Bureau of Reclamation's hydraulics laboratory. Once properly set up and calibrated, photogrammetric techniques are faster than typical model data collection techniques and provide far more data points than can be collected with traditional laboratory methods. Future techniques and capabilities of photogrammetry in the laboratory may include defining edges of solid objects, mapping water surface elevations with floating objects, using polarized lenses to enhance data quality, and exploring data processing options for engineering analysis including area measurement and differential volumes.

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