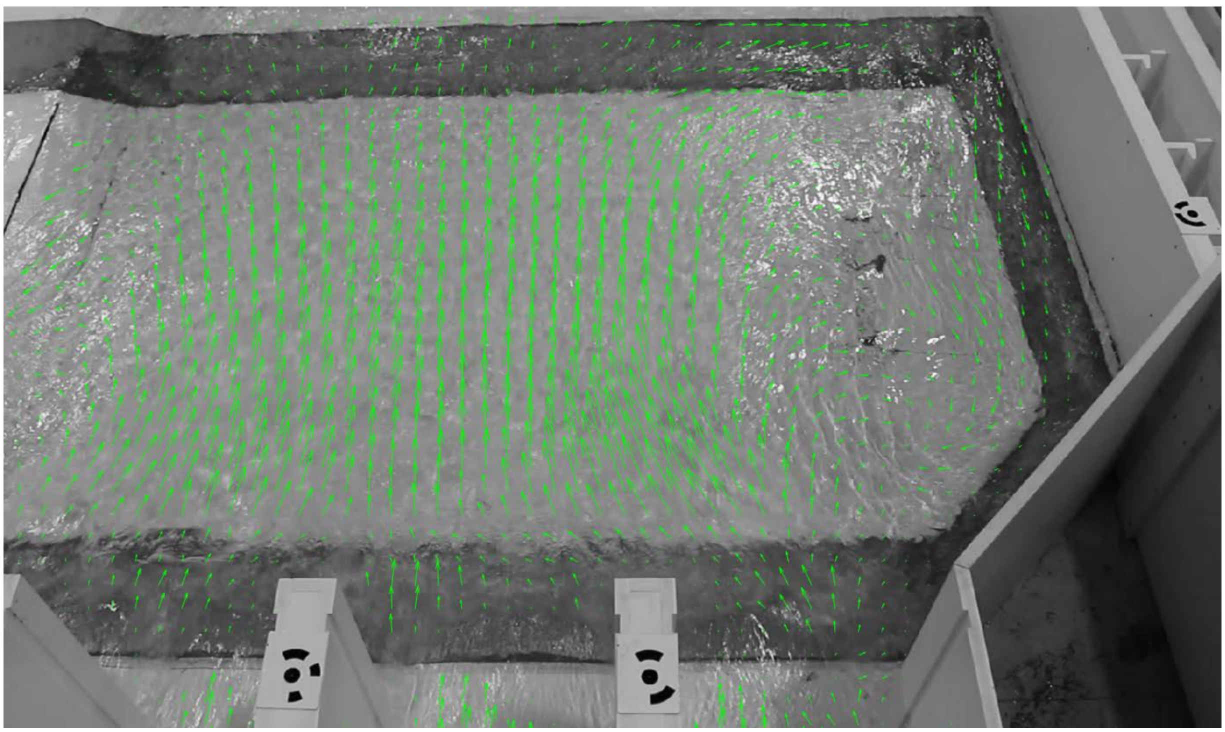
RECLAMATION

Managing Water in the West

Photogrammetric Water Surface and Velocity Mapping Near Complex Water Infrastructure

Research and Development Office
Science and Technology Program
(Final Report) ST-2017-1721-01
Hydraulic Laboratory Report HL-2017-09



U.S. Department of the Interior
Bureau of Reclamation
Research and Development Office

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Mission Statements

Protecting America's Great Outdoors and Powering Our Future

The Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

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Researchers attempted to utilize photogrammetry to determine water surface elevations and surface velocities around complex hydraulic structures. After not finding any medium that could be utilized successfully in the laboratory without negative impacts, researchers were able to determine surface velocities utilizing a technique called Large Scale Particle Image Velocimetry (LSPIV). Researchers successfully resolved surface velocities from video taken of three complex hydraulic structures. Continued development of this ability within Reclamation can help solve complex hydraulic issues found at Reclamation facilities.

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Photogrammetric Water Surface and Velocity Mapping Near Complex Water Infrastructure

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Executive Summary

The intent of this scoping level project was to determine if 4D photogrammetry could be utilized to track the movement of water over time. Water surface elevation and surface velocities can be difficult to monitor and analyze because of the need to introduce intrusive instruments that can affect the measurements. It was thought that by using 4D photogrammetry, the water surface can be monitored and analyzed for hydrodynamic phenomena without introducing physical instruments into the flow.

Preliminary tests revealed that water is not easy to construct into photogrammetric models because it is a transparent medium. Several attempts were made to modify the properties of the water by adding nontoxic substances to make the water opaque enough to resolve points on the water surface. No medium was discovered that could be utilized in the laboratory on a large scale and not impact other systems such as pumps, piping and visualization chambers on other laboratory models.

Further testing included the evaluation of other methods to resolve water surface velocities. Recent developments in the area of Large Scale Particle Image Velocimetry (LSPIV) made this technology a candidate for investigation. Large Scale Particle Image Velocimetry (LSPIV) is the process of calculating surface flow velocities from pairs of recorded images. By tracking the movement of particles from one frame to another it is possible to obtain surface velocity vectors (magnitude and direction) for the flow field of interest.

There are several software packages available to aid in LSPIV measurements. The most comprehensive list of available software comes from the Caltrans Division of Research (2017). Software packages include, PIVlab, Fudda-LSPIV, RIVeR (Rectification of Image VElocity Results) Toolbox, PTVlab, and LSPIV App for Smartphones. The general process for conducting LSPIV measurements for surface velocities includes: illumination, seeding, image recording and image processing. In a laboratory setting efforts were focused on obtaining LSPIV measurements using the software package PIVlab (Thielicke and Stamhuis, 2014) and RIVeR. A detailed tutorial of how to use PIVlab and RIVeR are available at http://riverdischarge.blogspot.com/p/tutorial.html. These two packages were recommended by U.S. Geological Survey Office of Surface Water employees who frequently utilize LSPIV to make river discharge measurements. These software packages were utilized to obtain some sample surface velocity measurements to evaluate LSPIV performance for images obtained in a hydraulics laboratory environment and determine what imaging techniques yield the best results.

One measurement was obtained from a model of a river restoration control structure. The goal was to determine the recirculation velocity field in the energy dissipation basin at certain flow rates. One flow rate was established in the physical model and video was recorded at 30 frames per second for one minute. About 30 seconds of that video were processed to generate the velocity vectors in Figure 1. Visual comparisons between the LSPIV measurements and the video look promising.

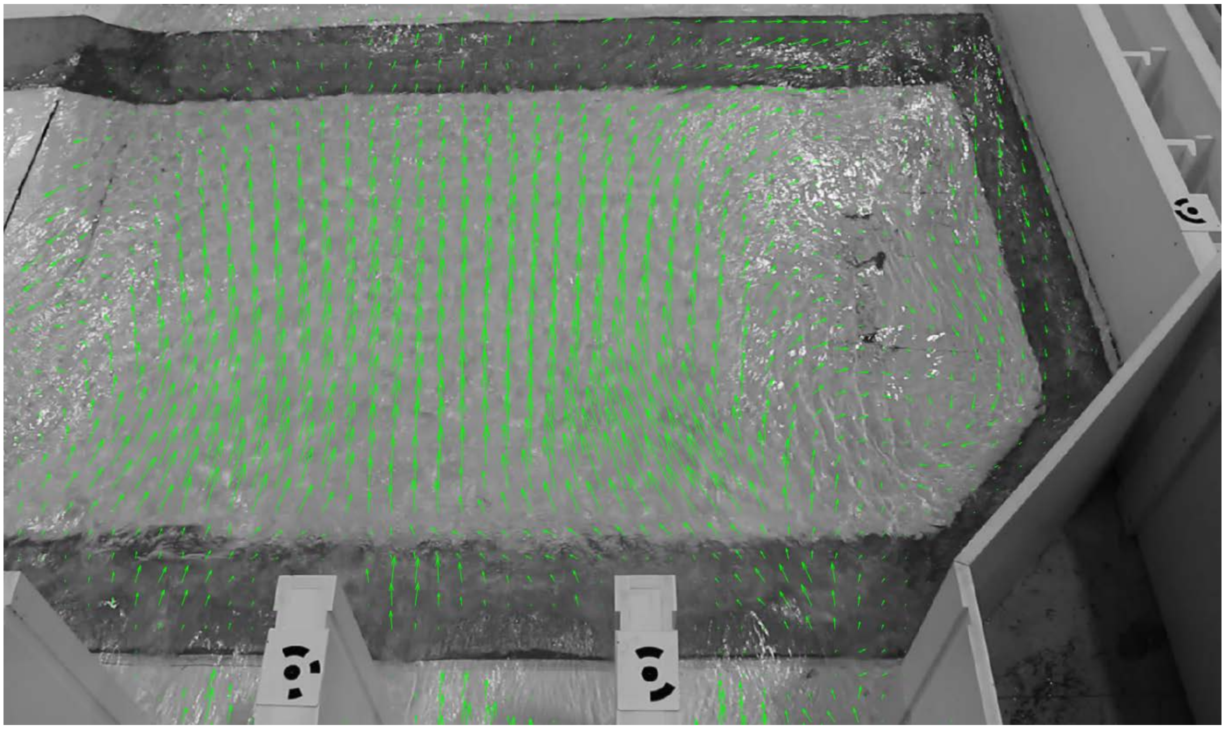

Figure 1. LSPIV-generated velocity vectors in the energy dissipation basin of the Bypass Control Structure.

Another application used old video files that were analyzed to manually digitize streamlines for the Yellowstone Intake Dam Bypass Channel hydraulic model study (Lentz, 2014) that was completed several years ago. LSPIV-generated velocity vectors are presented in Figure 2. Figure 3 shows the manually produced streamlines created during the original study. Comparing Figures 2 and 3, the PIVlab results look similar to the manually created streamlines even though the video files were of poor quality. Vectors and streamlines do not compare directly, but viewing time averaged velocity vectors can give an indication of where a streamline would trace. PIVlab has the ability to overlay streamlines onto the resultant vector field, but the poor video quality causes sink holes in the vector field that make the streamlines difficult to interpret. If PIVlab vector fields were the intended product, videos would have been shot in a different manner to reduce reflections on the water surface, and to distribute tracer particles evenly throughout the video file for LSPIV analysis.

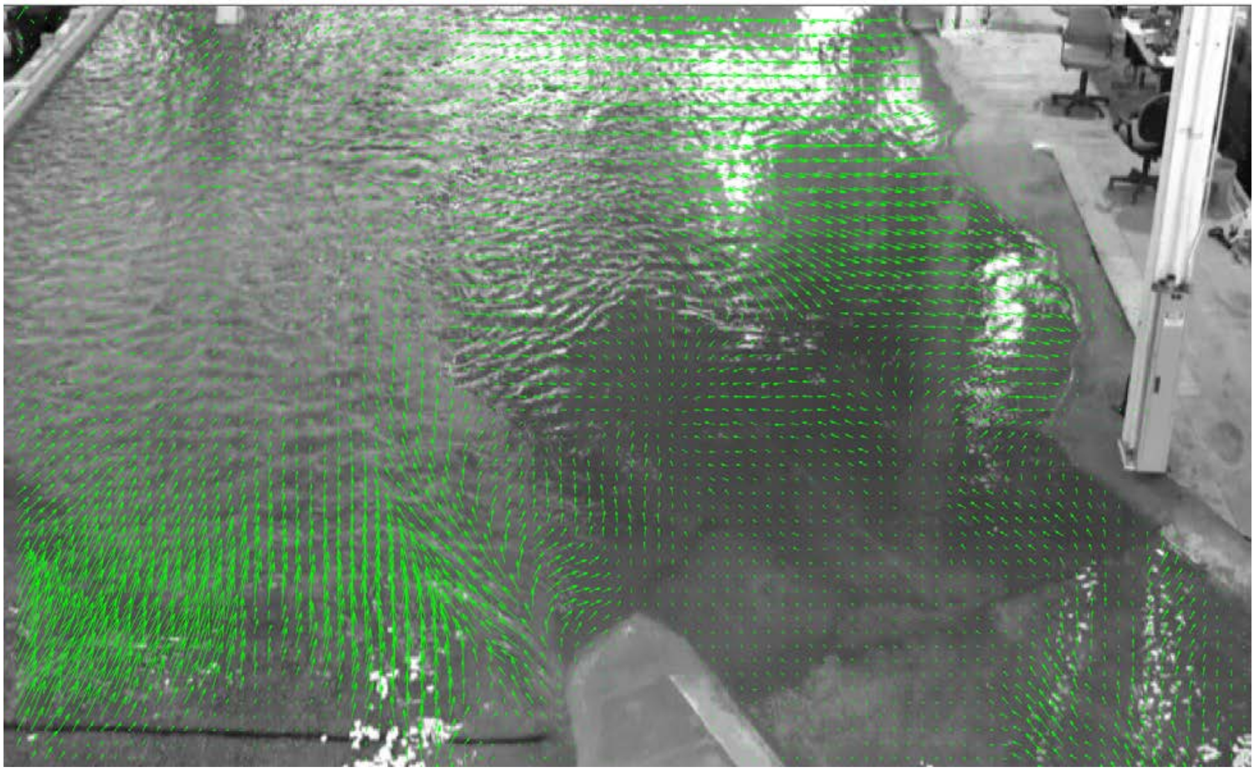

Figure 2. LSPIV velocity vectors created from a video of the Yellowstone intake hydraulic model.

Figure 3. Manual streamlines created for the Yellowstone intake model study report (Lentz, 2014).

LSPIV was successfully used to generate velocity vectors, contours and vorticity maps for a vortex that occurs in a pumping plant hydraulic model currently being studied in Reclamation's hydraulics laboratory. The surface vortex is formed at the water surface near one of the operating pump intakes. To obtain velocity vectors that have correct units, one must calibrate the images using know geometries. Once the calibration is applied, velocity vectors, contours and vorticity that are scaled to model or real world values can be obtained.   Evaluating the accuracy of LSPIV results is beyond the scope of this effort; however, the LSPIV results appear to be in the right order of magnitude. Figure 4 contains the velocity vector field, Figure 5 shows the velocity contours with vectors overlaid, and Figure 6 shows a measure of the vorticity (a measure of the tendency for fluid to circulate at a particular location).

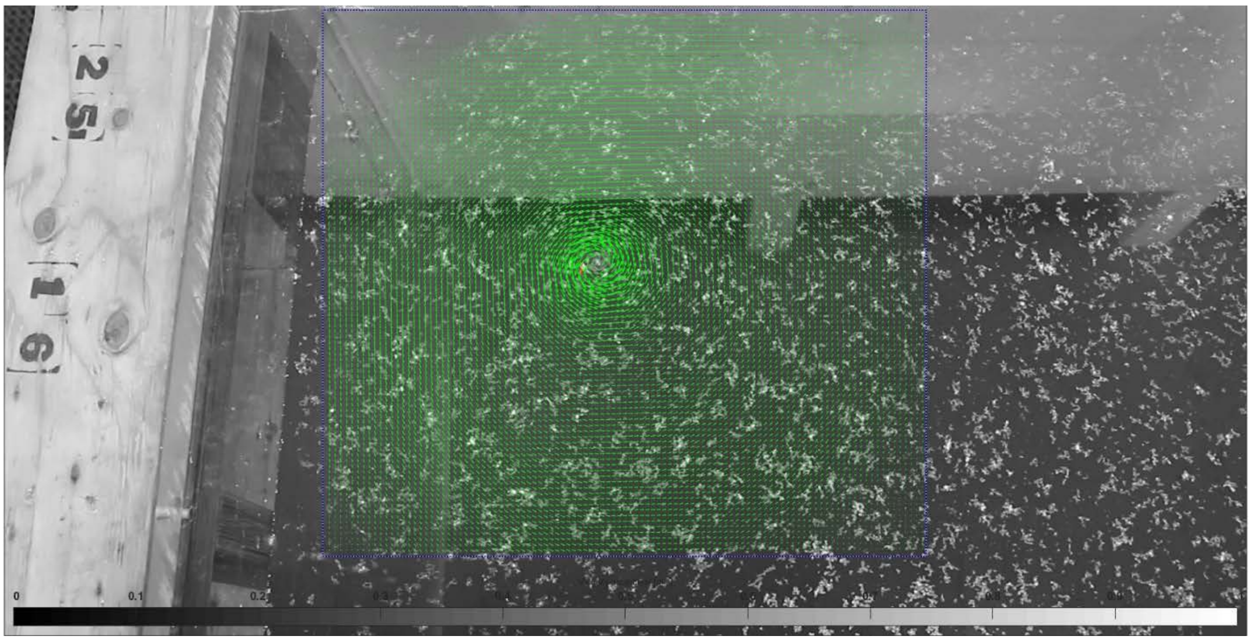

Figure 4. LSPIV-generated velocity vectors for a vortex created in a hydraulic model of a pump intake.

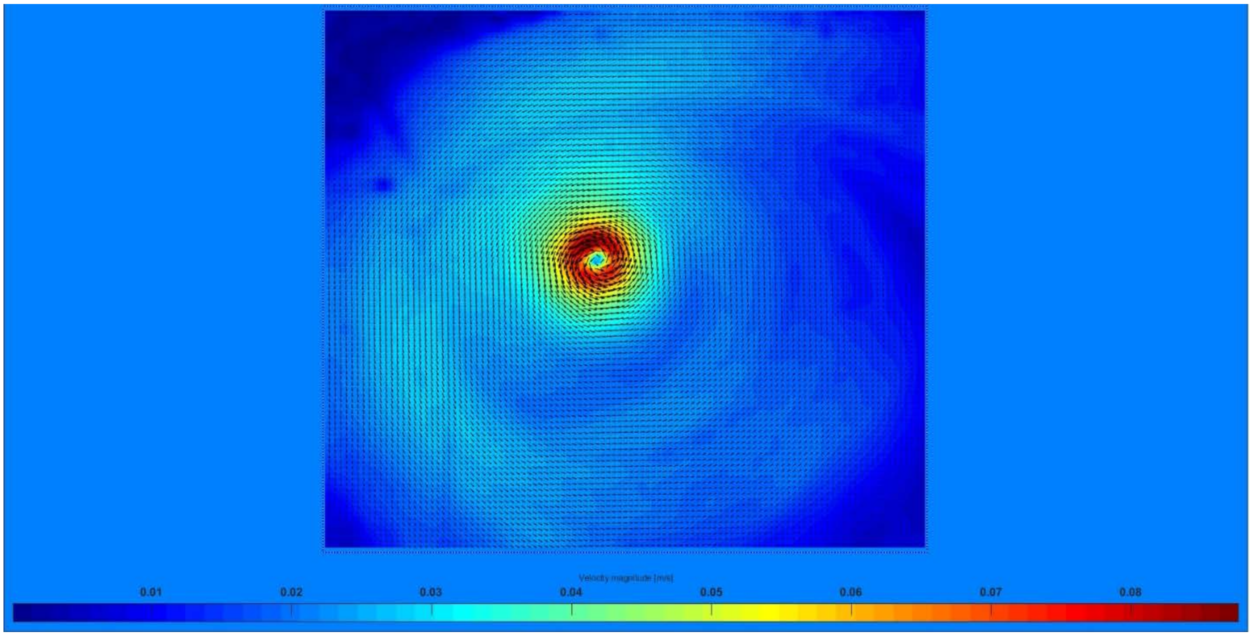

Figure 5. LSPIV-generated velocity contours and velocity vectors for a vortex created in a laboratory environment.

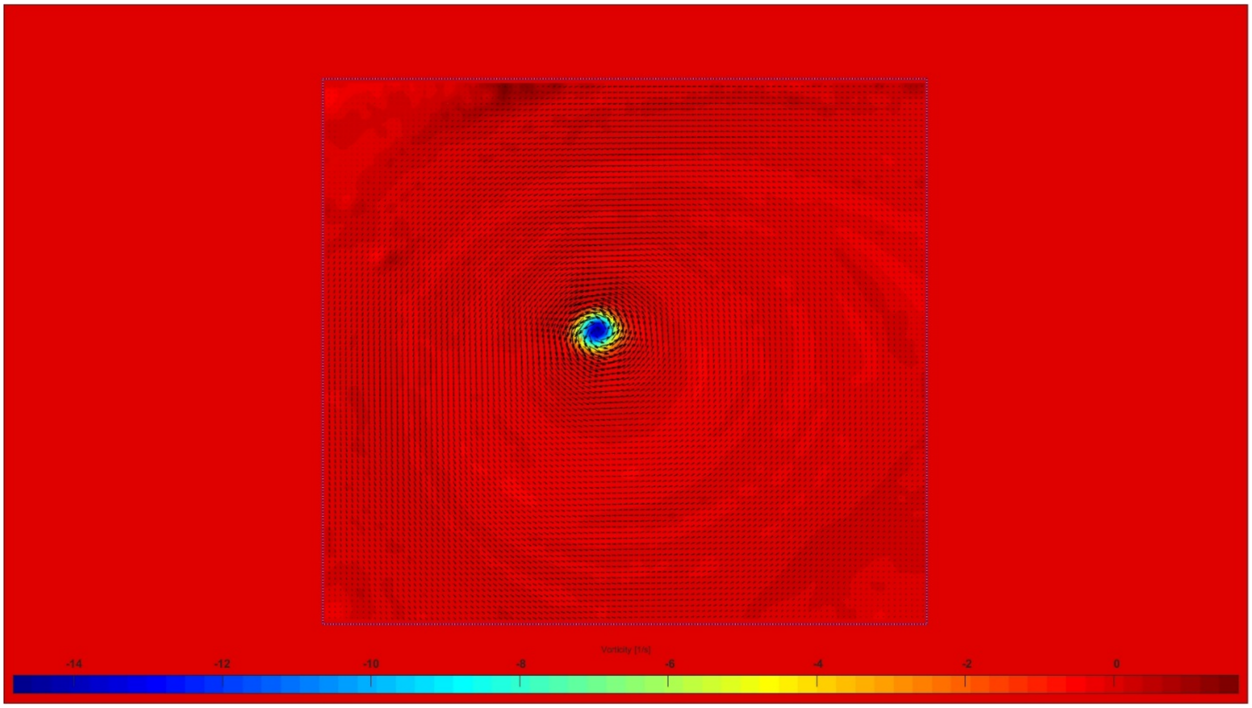

Figure 6. LSPIV-generated vorticity contours with velocity vectors for a vortex created in a laboratory environment.

While utilizing traditional photogrammetry techniques to map the water surface elevation and surface velocities was unsuccessful, a technique called LSPIV was successfully employed to resolve surface velocities for three different test cases. Funding limitations of a scoping level study did not allow evaluation of LSPIV velocity vector calculations with physical measurements. Literature indicates that accuracies are typically ±5 percent. LSPIV appears to be an efficient technique that can be successfully utilized to determine surface velocity vector fields in and around complex hydraulic structures without disturbing the water surface with a physical instrument. The next step in the evaluation process is to perform a complete literature review of LSPIV and conduct sensitivity tests to verify the accuracy of laboratory applications of this promising technique.

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