Project Completion Report

Project 2597: — Flow Calibration of Submerged Sluice Gates

Principal Investigator: Tony L. Wahl, Hydraulic Investigations and Laboratory Services (86-68460)
Collaborators: Dr. Albert J. Clemmens, WEST Consultants (retired USDA-ARS)
Dr. Gilles Belaud, Montpellier SupAgro

Radial (tainter) gates and vertical sluice gates are commonly used in headworks and check structures of Reclamation canals. The objective of this project was to develop algorithms and software tools that would enable accurate measurement of flow rates at these sluice gates. Using gates as flow measurement devices eliminates the need for other dedicated flow measurement devices and puts the point of measurement exactly at the point of flow control, eliminating lag in measurements and delay in making flow changes.

Final Research Office funding for this project ended September 30, 2012, but work is continuing, both at Reclamation and among the collaborators. The principal product of this research is the WinGate computer program that can be used to determine the rating relationship (discharge as a function of head and gate opening) for canal gates, either radial (tainter) gates or vertical sluice gates. This computer program was developed during the project to implement the energy-momentum (E-M) method for gate calibration, first proposed by **Henderson (1966)** and developed in more detail by **Clemmens et al. (2003)**. Compared to simpler energy-based methods, the E-M method has better ability to simulate the transition from free to fully submerged flow, especially for gates discharging into downstream channels that are significantly wider than the gates themselves.

The WinGate program has been written in the Visual Basic.NET language. During the course of the project, the user interface for the program was created and the software was initially developed to implement the algorithms in **Clemmens et al. (2003)** for canal radial gates. The software was gradually modified to incorporate continuing improvements in the E-M algorithms, notably those developed by **Wahl (2005)** and **Clemmens et al. (2012)**. These improvements have been based on analysis of new and old data sets from laboratory testing of radial gates (**Buyalski 1983** tests performed at Reclamation; **Tel 2000** tests performed at USDA; **Clemmens and Wahl 2012** tests performed at USDA) and potential-flow analysis of vertical sluice gates (**Belaud et al. 2009**). To enable analysis of large laboratory data sets and testing of new algorithms, a batch analysis capability was added to the program, and this has proven useful in recent applications of the software to Reclamation facilities.

A valuable collaboration with Dr. Gilles Belaud, a researcher at Montpellier SupAgro (France), began following the 2012 EWRI World Environmental and Water Resources Congress in Albuquerque, NM, where the principal investigator and Dr. Clemmens met Dr. Belaud for the

first time and found many common interests. A significant improvement in the accuracy of the flow calculation algorithms was made when the concepts developed by **Belaud et al. (2009)** for vertical sluice gates were adapted to radial gates, as documented in **Clemmens et al. (2012)**. These improvements made parts of the **Clemmens et al. (2003)** and **Wahl (2005)** methods obsolete, and the improvements were incorporated into WinGate during 2012. WinGate was also improved to enable analysis of either radial gates or vertical sluice gates.

A pair of journal papers were drafted during the project and first submitted for possible publication during 2011. The papers were temporarily withdrawn when it became apparent that the gate-flow calculation algorithms could still be significantly improved. During 2013 and early 2014 Dr. Clemmens made several improvements to the calculation algorithms (primarily related to the momentum analysis of the submerged jet on the downstream side of a gate). These have produced further reductions in flow calculation errors, especially for submerged flow conditions. These improvements to the algorithms have been incorporated into new revisions of the two journal papers, which we plan to resubmit soon, probably to the ASCE *Journal of Hydraulic Engineering*. Although the most recent algorithm improvements have been tested in Dr. Clemmens' working copy of WinGate, they have not yet been incorporated into the end-user version of the program with the complete user interface, which is being programmed at Reclamation.

Applications

WinGate has been successfully applied to a pair of Reclamation facilities (Yellowtail Afterbay Dam and Helena Valley Dam) for the purpose of developing rating curves for vertical sluice gates at the head of large canals. These studies are documented in Hydraulics Laboratory technical memorandums (Wahl 2013; Wahl 2014).

References

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End Product

WinGate software, http://www.usbr.gov/pmts/hydraulics_lab/wingate/