Velocity Contour Weighting Method for Increased Accuracy of Upward Looking ADVMs in Irrigation Channels

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Project Duration: 7/1/09 – 6/30/11

Executive Summary

In California, nearly three quarters of all freshwater diversions are used for agricultural irrigation and the need for water conservation is paramount. It is currently estimated that somewhere between 20% and 40% of all farm turnouts in California have no flow measurement devices and an additional 30 to 45% utilize a rough estimation of flow (e.g. gate rating or rated section). Rough rating methods are also commonplace in irrigation districts controlling medium and small canals and drains, where accuracies of only +/-25% are possible at the time of measurement. This uncertainty is further confounded by flow rates that change throughout the day in response to changes in channel levels.

Uncertainty in flow rates is handled at the distribution level (irrigation districts) by oversupply. Districts divert more water than requested and release excess at the end of the canal through operational spill. Depending on the irrigation system, water users (farmers) may also order more water than needed to ensure sufficient supplies. Surplus either runs off the field or is applied in excess to promote deep percolate below the root zone. Accurate, cost effective flow measurement stands to improve conservation efforts by reducing the uncertainty driving the over-supply paradigm.

As unit costs continue to fall, Acoustic Doppler Velocity Meters (ADVMs) are becoming increasingly attractive for irrigation flow rate estimation. ADVMs offer improved accuracy over gate rating and rated sections, comparable to a large civil structure (e.g. broad crested weir), but at a lesser cost. However, the cost-effectiveness of ADVMs is still hampered by comprehensive calibration requirements for each installation. Essentially, a correlation must be developed between the cross-sectionally averaged velocity and the measured velocity distribution The current recommended method, the flow rate (Q) Indexing Procedure (QIP), requires 10 individual calibration points over the full range of channel flow rates and depths. *This takes an entire irrigation season to complete.* The calibration must also be conducted by personnel familiar with current metering, ADVM devices, and the QIP. The cost associated with the

calibration of the device severely limits the current ADVM applications to larger sites such as major irrigation district diversions and spills.

In this study, we aim to improve upon this situation. We introduce a new method to estimate the cross-sectional average velocity from an upward-looking ADVM, the Velocity Contour Weighting (VCW) method, and propose a combination of computational fluid dynamics (CFD) studies, laboratory flume testing, and field testing to develop and validate the method. The new method promises to improve accuracy and reduce the necessary level of calibration, compared to the QIP method which is widely used today.

Channel cross-sections are characterized by a distribution of stream-wise velocity. Water along the banks and bottom moves relatively slowly, as a result of wall friction, compared to centerline and near surface water, respectively. Indeed, the fraction of any cross-section associated with the fastest-moving water is quite small compared to the fraction of any same cross-section associated with the slowest-moving water. This is the essence of the VCW method. Given that an upward looking ADVM will measure the vertical distribution of streamwise velocity, our hypothesis is that more weight should be given to near-bed velocities and less weight should be given to near-surface velocities. The actual weights should depend on the cross-sectional distribution of stream-wise velocity; hence, the method is non-linear. The challenge is finding the correct velocity weighting as a function of channel geometry and roughness.

Our research approach will involve a combination of theoretical analysis, laboratory validation, and field testing to develop the VCW method. The theoretical analysis will be performed via a 3D computational fluid dynamics (CFD) program developed by Flow Science, Inc. called Flow 3DTM. Flow 3D allows simulations of multiple flow rates, flow depths, channel geometries, and roughnesses.

The channel scenarios will be used to develop an algorithm or equation that can be robustly applied to open channels of any shape without the need for CFD modeling prior to deployment, but with limited calibration. Preliminary analysis of the VCW indicates a high degree of accuracy (within +/-1%) in highly controlled CFD studies, although this level of control is not possible in practical applications. Laboratory measurements will involve installing an ADVM in a large rectangular flume. The VCW method will be used to compute the cross sectional velocity which will be compared to the actual velocity. In the final stage, ADVM data from irrigation district installations will be used to field test and further validate the VCW method. This will test the true applicability of the calculation procedure and determine the extent of needed calibration.

The outcome of this study will be a theoretically sound, practical tool to improve flow measurement accuracy at a reduced deployment cost (estimated savings of 20-40% of the total installation cost). We anticipate the accuracy of an ADVM using the VCW method will be better than +/-4 to 8%, in typical open channel installations, with minimal calibration (1 to 3 calibration points compared to 10 currently required). No hardware modifications to the ADVM are anticipated and existing controllers should be able to incorporate the algorithm logic so that it can be utilized in future as well as existing ADVM installations. This has the potential to impact thousands of prospective measurement sites influencing hundreds of thousands of irrigated acres in California.