Water Measurement Options in Low-Head Canals and Ditches

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Measuring water in open-channel water-ways with low available head continues to challenge engineers and water managers. Over the past few years improvements and adaptability of fixed canal devices, such as the ramp flume, have become a popular tool of water measurement. However, in situations when backwater (from moss buildup or from canal operations) submerges structures or when there is not sufficient head for a standard device, an operator is left with very few options.

1. BACKGROUND

In the mid-1990s, engineers and technicians developed an ultrasonic device to determine, using profiling Doppler principles, the flow of liquid waste moving through sewers in New York City. The instrument was located on the bottom of the sewer pipe and contained a depth sensor. It combined velocity readings with the cross-sectional area of the channel (programmed into the device) to produce a flow rate. This profiling Doppler flow meter proved successful in several tests, but it carried a substantial price tag, over $20,000. It was only cost-effective to use in larger-volume canals (500 cfs and above) where a fixed structure for such data-gathering would be even more expensive or where a flow rate was desperately needed to ensure efficient canal operations.

In the late 1990s, a series of less-expensive ultrasonic Doppler measurement devices, the "StarFlow" line, was engineered by an Australian firm, Unidata. These instruments use continuous Doppler to determine average velocity and flow. The price of one model of the Unidata instruments ($1,500) suggested the device could be cost-effective in several water-measurement situations, including those for smaller canals.

The potential cost benefits of the StarFlow warranted investigation of its performance under field conditions. In 2003, the Water Conservation Center of the Bureau of Reclamation's Pacific Northwest Region conducted demonstrations of the StarFlow at two sites, one in Oregon and the other in Idaho. These sites were chosen based on canal configuration, range of flow, and the interest and cooperation of the two water districts.

2. THE INSTRUMENT

The Unidata ultrasonic Doppler instrument chosen for this demonstration was the StarFlow Model 6526C (for water less than 2 meters in depth). It is 11 inches in length, 2½ inches in width, and 1 inch in height (see Photograph 1). The instrument contains a pressure transducer and two sensors that measure velocity. It transmits an ultrasonic signal that when measured for Doppler shift and read with other data derives volume. The instrument is designed to be installed on the bottom of the canal with a signal cable leading to the surface data logger.

The StarFlow measures water velocity within a 15 degree "field of view" looking forward and upward. This velocity is then applied to a cross-sectional area determined by the measured depth and a user-specified cross-section configuration entered into the device during set-up. In wider channels, it is possible that the velocities measured within the device's field of view would not be representative of the average velocity for the entire cross-section. In theses cases, it is necessary to adjust the "measured velocity" value. This is done by making a proportional adjustment in the "speed of sound in water" parameter in the StarFlow set-up parameters.

Photograph 1. *The Unidata StarFlow ultrasonic Doppler flow meter contains a pressure transducer and two velocity sensors. The instrument is 11 inches in length, 2½ inches in width, and 1 inch in height. It can be installed facing upstream or downstream.*

3. SMALL CANAL DEMONSTRATION

The Talent Irrigation District is served by Reclamation's Rogue River Basin Project in southwestern Oregon. Its Crooked Creek Siphon on the Talent Canal (near Medford) was chosen for the first demonstration site. Flows in the Talent Canal range from 2 cfs to 15 cfs and enter the siphon just downstream from the measurement site (see Photograph 2).

The canal in this area has a flat gradient and little freeboard. The site was surveyed for the installation of a ramp flume designed to operate in all flow ranges and conditions. The ramp flume design would require that additional freeboard be established upstream of the measurement site. A bypass/overflow gate which can route canal flows to Crooked Creek is located next to the downstream siphon entrance. Because of the variability of the siphon and bypass structure, a rated section with a staff gage would not be consistent.

Photograph 2. *View is looking upstream in the Talent Canal at the Crooked River Siphon entrance. The StarFlow instrument was installed upstream of the wooden bridge. This section of canal experiences backwater when the spill to the river is not operated. The canal capacity is about 15 cfs.*

At the Talent Canal site, a data logger (Campbell Scientific Model CR10X) was used as part of the demonstration. The separate data logger allowed additional parameters to be added to the demonstration. A separate float well was installed so that the data from a float-operated depth sensor could be compared against the data from the internal pressure transducer (Photograph 1). The data logger was connected to a dial-up phone system so that the data could be downloaded by and monitored at the irrigation district's office.

The cross-sectional area of the channel was measured and programmed into the data logger. Using the velocity from the demonstration instrument and the cross-sectional area for a given flow depth the flow rate is calculated by the data logger. The demonstration instrument was installed and the canal flows were turned on. Once the instrument was operating, a current meter measurement was made and an average velocity was calculated (see photograph 3).

Photograph 3. At the Talent Canal site current-meter measurements were made to provide data which were used to calibrate the velocity readings from the StarFlow instrument. Calibration was required at each demonstration site.

The average velocity calculated from the current meter measurement was approximately 25 percent lower than the velocity reading from the demonstration instrument.

To compensate for this difference, a “velocity shift” was programmed into the data logger to use in the flow-rate calculation. On later flow checks using the current meter, the flow rate indicated by the demonstration instrument were within 3 percent of the current metered flows.

The pressure transducer worked exceptionally well when compared with the depth data from the float well. Figure 1 shows the correlation of the depth versus depth plot is 99.7 percent. Figure 2 shows that 99 percent of the time the pressure transducer was within 0.01 feet of the float well reading.

***Photograph 4**. This view of the site on Talent Canal shows the equipment cabinet containing the data logger and dial-up equipment. The technicians are installing the float well equipment which was used to verify the depths obtained from the pressure transducer in the Starflow instrument.*

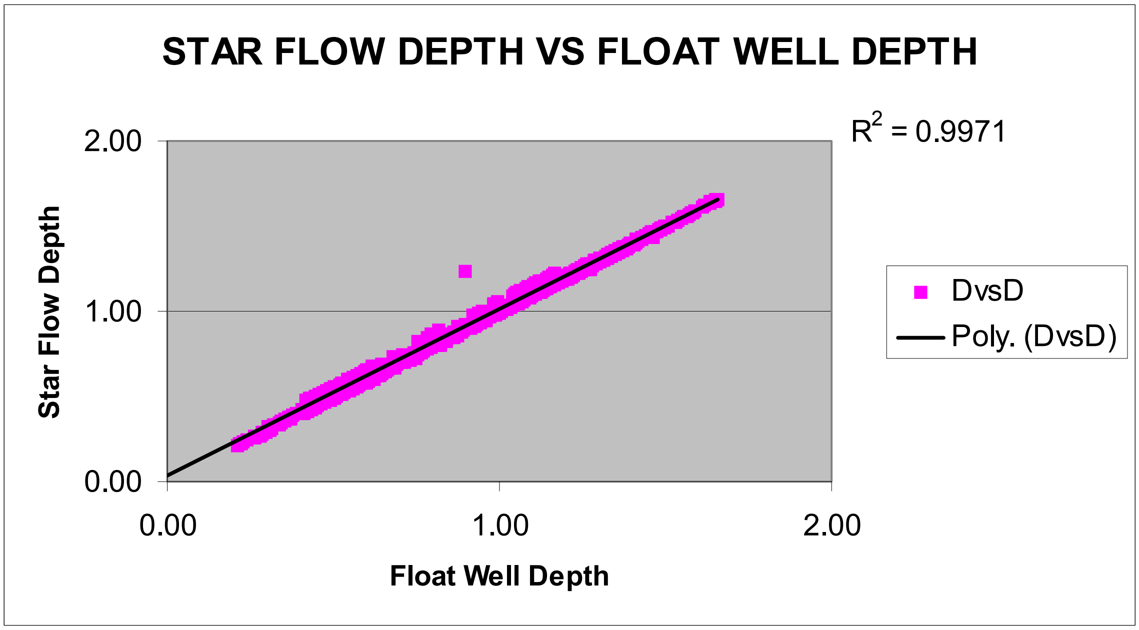

***Figure 1**. The float well data at the Talent Canal site agreed very closely with the data from the StarFlow pressure transducer.*

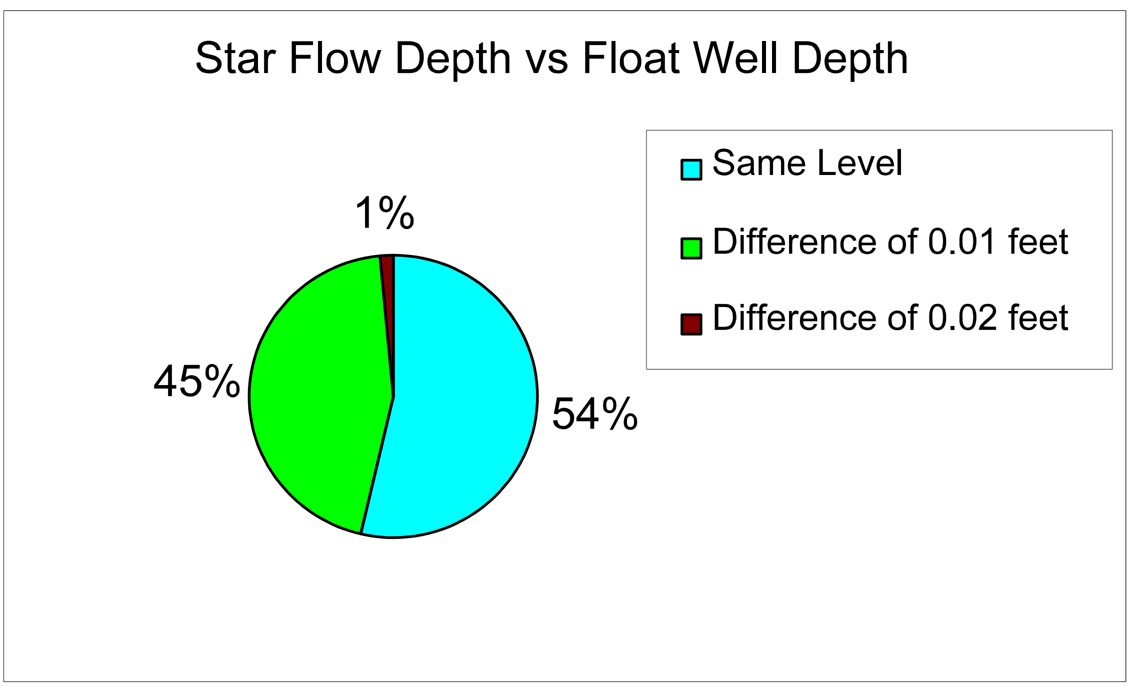

***Figure 2**. Depth readings from the two different data sources at the Talent Canal site were within 0.01 foot of each other 99 percent of the time.*

4. LARGE CANAL DEMONSTRATION

The South Board of Control in Homedale (southwest Idaho) is supplied by water delivered through the South Canal from Reclamation's Owyhee Project. The canal carries up to 500 cfs and is operated and maintained by the South Board of Control. The measurement site in the South Canal was located at the terminus of a rock tunnel; this site has been used for flow measurements for several years. The site is a trapezoidal section of concrete lining with a foot bridge to facilitate current metering for the rated section (see Photograph 5). The rated section functions well in the early months of the irrigation season; however; as aquatic growth continues into the late summer periods, water is backed into the rated section and the rating table becomes inaccurate.

***Photograph 5**. The view is looking downstream at the South Canal measurement site. The StarFlow instrument was installed in the concrete section. Canal capacity is approximately 500 cfs. This site was chosen because there is a well-defined, stage-discharge curve which could be compared with the data gathered from the demonstration instrument.*

Flows at this site are up to 5.5 feet deep (see Photograph 6). It is a long-term measurement site and there is a well established stage-discharge curve to compare against values obtained by the demonstration instrument. At this site, the data were recorded by the StarFlow data logger purchased with the demonstration instrument. The stage-discharge curve was checked using a current meter at different times during the summer. The current meter measurements correlated very well with the stage-discharge curve.

The pressure transducer depths were compared with visual staff gage readings each time the station was visited. The two readings were never more that 0.01 feet different on any of the visits.

The demonstration instrument was installed on May 22, 2003 in the center of the concrete-lined section at the measurement site. The demonstration device was operated 20 days before the first calibration was made. Figure 3 displays the flow data gathered by the data logger compared with calculated flows from the stage-discharge curves for the recorded depths. It shows that the demonstration instrument was indicating a flow about 9 percent higher than the stage-discharge curve.

After the first adjustment, the instrument was operated 9 days. A review of the data indicated that the earlier adjustment had been excessive. The data indicates that the demonstration instrument was indicating a flow about 4 percent lower than the stage-discharge curve (see Figure 4). Another calibration adjustment was made.

The demonstration instrument was then operated from June 20 to July 24, 2003. The flow rate data collected by the demonstration instrument was within 1 percent of the flow rate calculated from the stage-discharge curve (see Figure 5).

The flow depths at this site were up to 5.5 feet. The velocity measurements from the demonstration instrument fluctuate up and down which creates a wide plot line. The average of the data, however; correlates well with the stage-discharge curve calculations. The data seem to indicate that the deeper the flow the wider the range of fluctuation.

***Photograph 6**. At the South Canal site, flow depths varied from 3.5 feet to 5.5 feet during the 2003 irrigation season. Current meter measurements were made from the foot bridge.*

With a correlation of greater than 99 percent, no calibration adjustments were made on the July 24th visit.

On September 4, 2003 data were again downloaded as the water district was near the end of its irrigation season. The data plot (see Figure 6) indicates that for a short period in mid August the flow rate calculated from the stage-discharge curve was nearly 50 cfs higher than the flow rate recorded from the demonstration instrument. It appears that the demonstration instrument was able to adjust for a backwater situation and plot a more reliable flow rate during the backwater period.

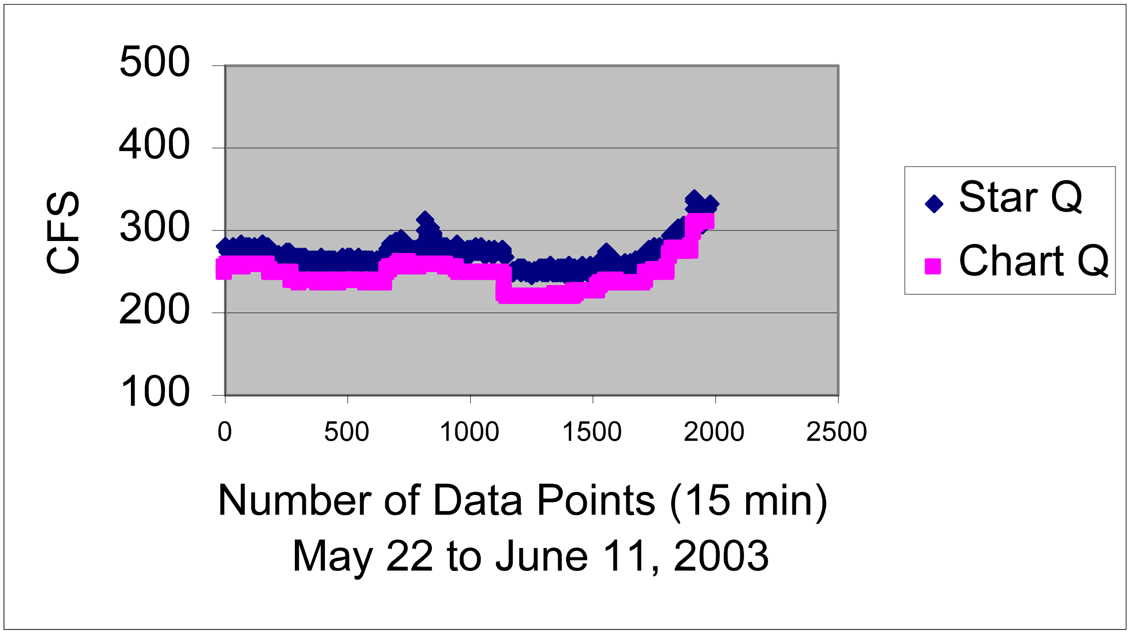

Figure 3. South Canal Site *— For the South Canal site, the plot shows that before any calibration was attempted, the StarFlow was reading approximately 9 percent higher than the stage-discharge curve.*

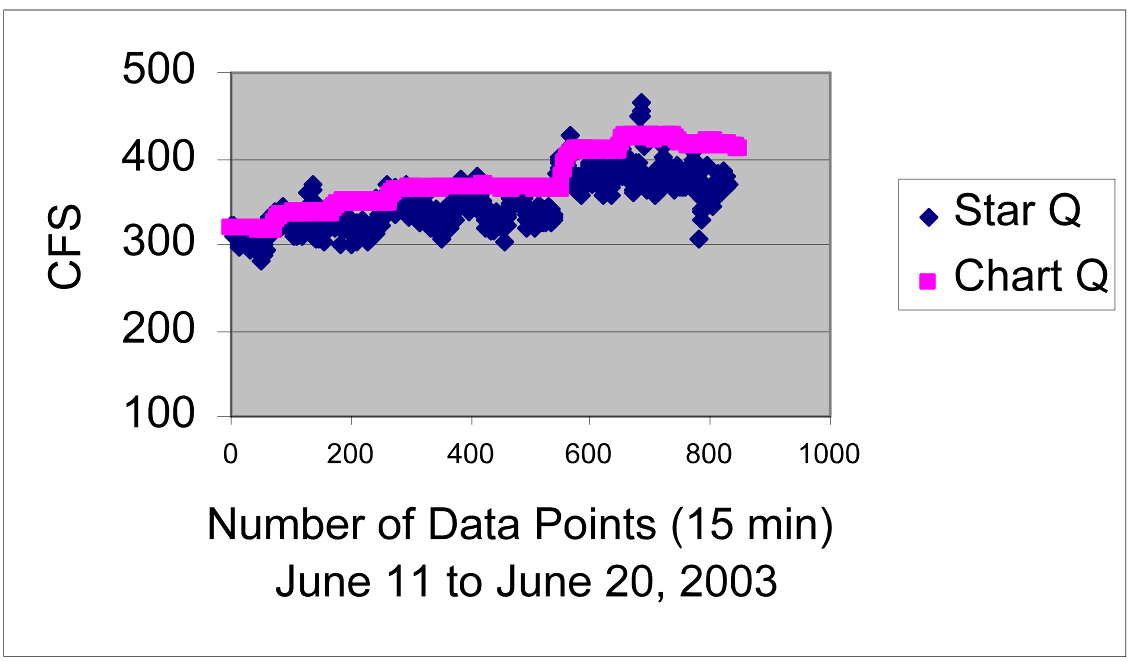

Figure 4. South Canal Site *— The plot shows that the calibration adjustment was excessive as the StarFlow readings are approximately 4 percent lower than the stage-discharge curve.*

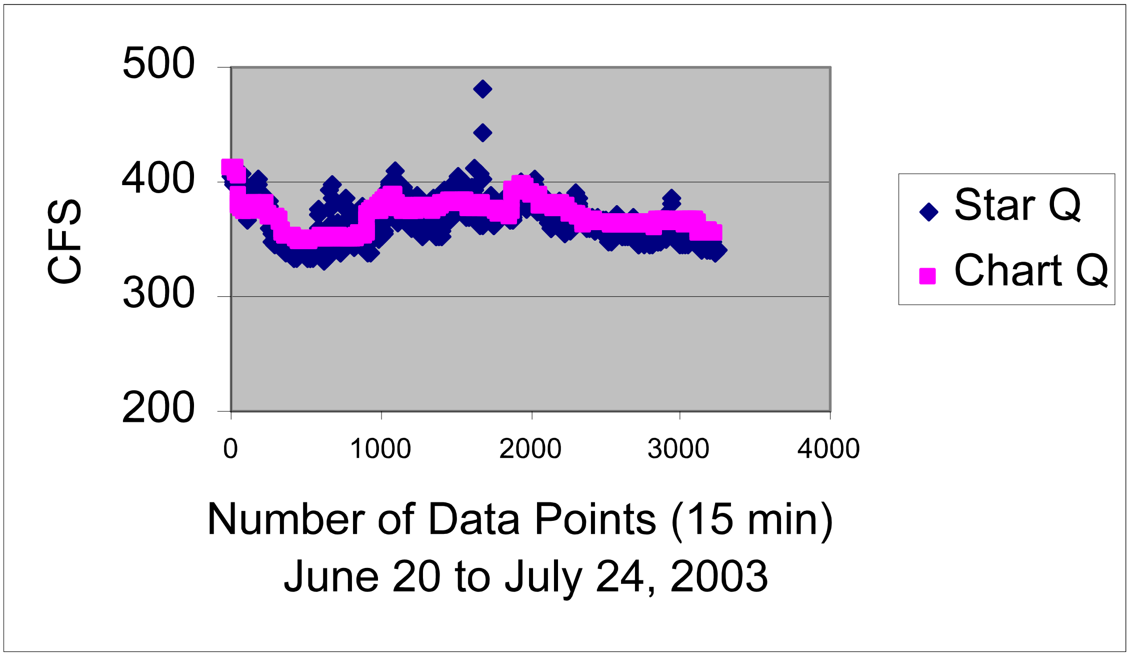

Figure 5. South Canal Site *— The second calibration adjustment brought the average of the StarFlow flow readings to within 1 percent of the stage-discharge curve tabulations.*

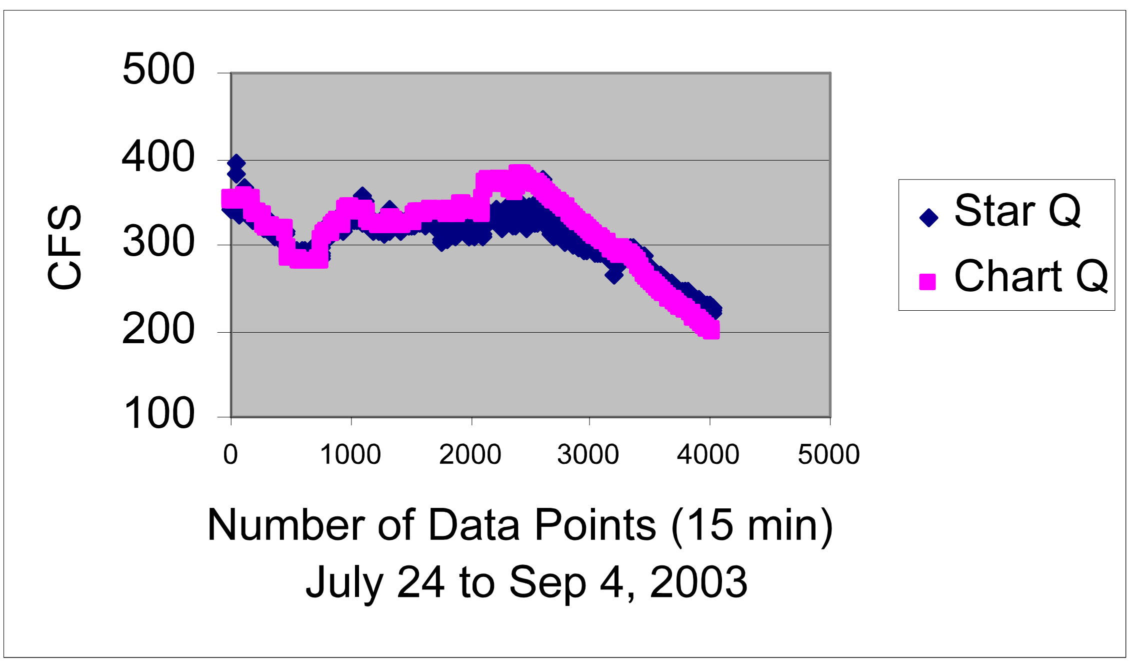

Figure 6 – South Canal Site *– The StarFlow data tracked the stage-discharge until mid August when aquatic growth backed water into the measurement site. The StarFlow instrument senses the slower velocities in a backwater situation and calculates accordingly. In contrast, a stage-discharge curve inaccurately shows more flow in a backwater situation.*

5. OBSERVATIONS AND CONCLUSIONS

- The water depths indicated from the pressure transducer of both demonstration units proved to be reliable when compared with staff gage readings and float well data.

- The demonstration instruments had to be calibrated after installation. Whether or not additional calibrations are needed at different flow ranges was not determined.

- The equipment stayed up and functioned during the entire demonstration period. The data loggers recorded properly with no malfunction or missing data.

- The irrigation district operating the Talent Canal used the telephone dial-up to obtain instantaneous data on the canal status. The district operators then used the flow data and canal-depth data to make operating decisions. The water district is pleased with the demonstration results and is looking for other locations to install additional instruments.

- In the Talent Canal, with a maximum flow rate of 15 cfs, the real-time data was very useful to the irrigation district in making daily water management decisions.

- At the South Canal site, with larger flows and a larger cross-section, there was too much variability in the instantaneous flow measurements to be of real-time use to system operators, particularly at higher flows. Over longer periods, however, the accumulated flow totals were generally within 1 percent of total calculated using the stage-discharge curve.

- The demonstration instrument may prove to be very useful in small canals with limited head. More demonstrations need to be made in larger canals and in canals with significant turbulence.