Canal Velocity Indexing at Colorado River Indian Tribes (CRIT) Irrigation Project in Parker, Arizona using the SonTek Argonaut SL

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Abstract

An index velocity rating was developed for a SonTek/YSI Argonaut Side-Looking (SL) ultrasonic Doppler flow meter installed in the Main Canal of the Colorado River Indian Tribes (CRIT) Irrigation Project in Parker, Arizona. Velocity data collected concurrently with the ultrasonic flow meter and conventional current meter were compared using linear regression techniques. The rating equation for this installation provides a reasonably accurate means of computing discharge. This project was completed by the Irrigation Training and Research Center (ITRC), California Polytechnic State University, San Luis Obispo, working under a technical assistance contract for the Water Conservation Office, United States Bureau of Reclamation (USBR), Yuma, Arizona.

The procedure used in the evaluation included multiple measurements over a range of low, medium, and high flows. This approach verified the validity of discharge measurement through analysis of coefficients of determination and by comparison of discharges computed from the ratings to measured discharges.

Introduction

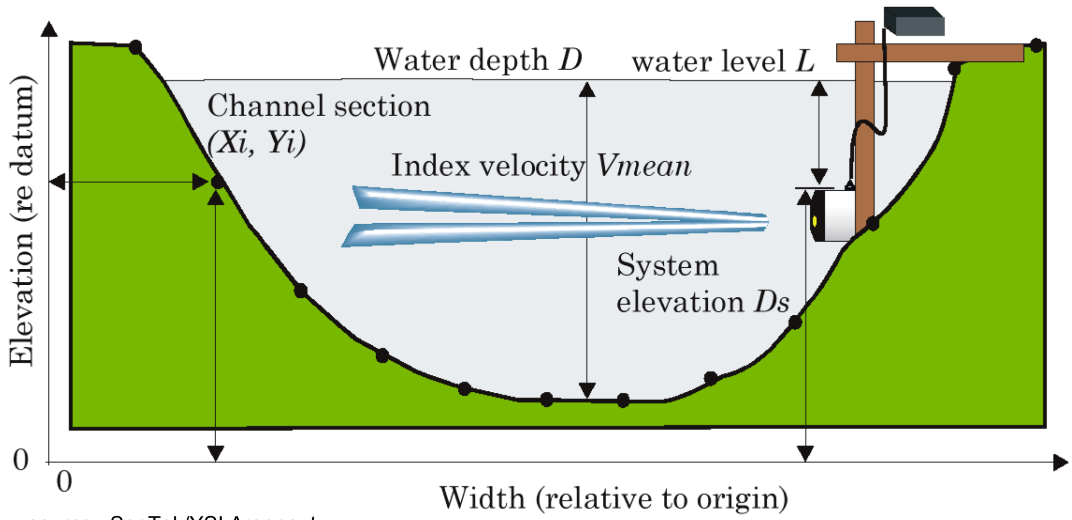
This paper is a summary of an application of the Index Velocity Rating Procedure for a SonTek/YSI Argonaut™ Side-Looking (SL) 1.5-MHz acoustic Doppler current meter. The Argonaut SL has the ability to perform internal discharge computations as the product of mean channel velocity and cross-sectional area. The index coefficients for establishing the empirical velocity relationship in a channel are determined through regression analysis. Computing flow with the internal flow algorithm requires the user to input a specific velocity equation and the channel geometry defined by up to 20 cross-sectional points (x-y pairs).

The discharge and velocity measurements presented in this paper were collected in the Colorado River Indian Tribes (CRIT) Main Canal. Current metering was done following procedures established by the USBR in their Water Measurement Manual (USBR 2001). The actual Argonaut SL measured velocity values are used to illustrate the index velocity rating technique and the development of an equation to accurately produce discharge records using hydroacoustic instruments. The process discussed in this paper is a modification of the procedure outlined by the USGS for indexing (USGS 1998).

Utilizing electronic flow rate measurement equipment that can cost less than 10 percent of a large concrete flume is attractive economically. However prior to the use of this indexing procedure, there was much uncertainty of the overall accuracy in the use of a flow meter such as the Argonaut SL in some irrigation canal applications.

Basic Operation Principle

The SonTek/YSI Argonaut SL measures 2-dimensional horizontal water velocity in an adjustable location and size of the sampling volume using the physical principle termed the Doppler shift. The Argonaut transducers measure the change in frequency of a narrow beam of acoustic signals in order to compute along-beam velocity data. Beam velocities are converted to XYZ (Cartesian) velocities using the known beam geometry of 25° off the instrument axis.



source: SonTek/YSI Argonaut
Operation Manual

Figure 1. SonTek/YSI Argonaut SL channel geometry for internal flow computations

Basic Deployment Instructions

To determine an index velocity rating, concurrent mean channel velocity and Argonaut SL measured velocities are required. The following steps outline the basic procedures one follows in collecting velocity and stage data for developing an index velocity rating. The result is a dataset comprised of i) a mean velocity, ii) average Argonaut SL velocity, and iii) average stage.

1. An Argonaut SL is installed with the appropriate deployment settings and mounting bracket. Site selection is an important consideration and the diagnostic guidelines provided in the manufacturer's technical documentation should be carefully observed. These diagnostic parameters include an assessment of the signal strength and standard deviation for a given set of operating conditions.

2. The channel is accurately surveyed and a stage-area rating is developed. Elevations for the cross-section points are in terms of stage referenced to the station datum.

3. Discharge measurements (Price AA current metering or comparable device) are made near the Argonaut SL site while the instrument is sampling velocity.

4. The average stage during the discharge-measurement period is recorded.

5. Mean channel velocity is derived for each individual discharge measurement by dividing the measured discharge by the channel area computed from the stage-area rating.

6. For each discharge measurement, Argonaut SL measured velocities are averaged for the discharge-measurement period. For the Argonaut SL, the velocity x-component or the computed velocity vector can be used for the measured velocity.

7. Each discharge measurement yields a computed mean channel velocity and an average Argonaut SL velocity.

8. The index velocity rating procedure recommended by the ITRC requires a wide spread in the measured discharge (a 2:1 ratio), usually at least 10 measurement values over the entire range of flows. The regression coefficient (r^2) must be better than 0.96 to assure confidence in the results.

This discussion does not attempt to provide a detailed description of all the technical issues involved with the deployment of the instrument for a desired level of accuracy. The performance of the Argonaut SL depends on considerations such as the influence of boundary interference, proper alignment with the flow, appropriate settings of the averaging and sampling intervals, and cell size. A further limitation in the operation of the Argonaut SL is the aspect ratio, which is defined as the ratio of the measurement range to height. Range is horizontal distance from the instrument and height is the vertical distance to the surface or bottom. It is strongly recommended to use the Argonaut SL for aspect ratios greater than 5:1. It is not recommended for aspect ratios less then 5:1. A bottom-mounted unit looking toward the water surface is recommended for those applications.

Measurement Results

A total of eight discharge measurements were collected in the CRIT Main Canal. The measured stage, computed mean channel velocity determined by current meter, and the Argonaut SL measured velocity are summarized in **Table 1.**

Table 1. CRIT Main Canal Current Meter and Argonaut SL Velocity Measurements

No.	Stage, feet	Current Meter Velocity, fps	Argonaut SL Velocity, fps
1	11.80	1.19	1.29
2	12.20	1.19	1.39
3	11.30	2.05	2.08
4	11.30	1.97	2.09
5	11.80	3.00	2.95
6	11.80	2.97	3.06
7	10.50	1.48	1.42
8	10.50	1.47	1.42

Index Velocity Rating Development

An index velocity rating is developed in this section to relate the mean channel velocity to the velocity measured by the Argonaut SL in the CRIT Main Canal. For some operating conditions, the index velocity relation may be linear, while in other situations the relation may be best expressed as curvilinear or a compound curve (USGS 2002). In each instance, the user should assume that stage might be a significant factor in the accurate prediction of mean channel velocity. This situation where the relationship between mean velocity and Argonaut measured velocity is affected by stage is handled by performing a multiple linear regression.

If the relation between the mean channel velocity and the measured Argonaut SL velocity is linear, it can be represented by a linear equation as follows:

$$V_m = xV_{SL} + C$$

where,

V_m = computed mean velocity
V_{SL} = average measured Argonaut SL velocity during one measurement period
x = velocity coefficient
C = constant

The first step in determining whether a linear relation exists is to plot mean velocity (y-axis) and Argonaut SL velocity (x-axis). **Figure 2** is a graph of the velocity dataset for the CRIT Main Canal in **Table 1**.

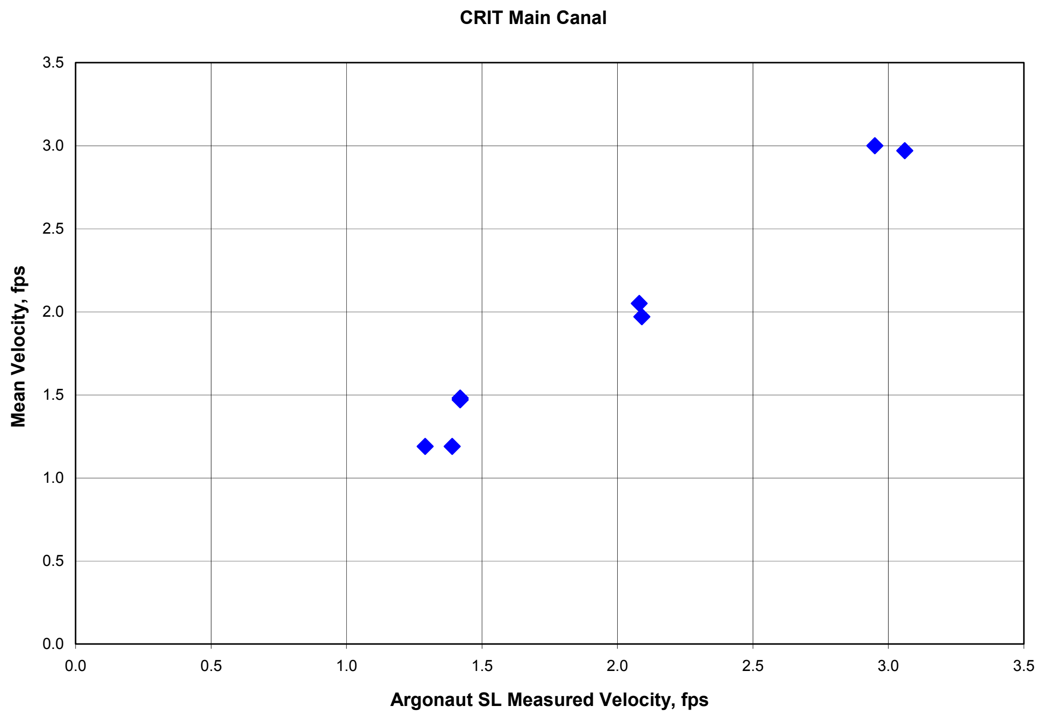


Figure 2. Mean velocity and Argonaut SL velocity from discharge measurements in the CRIT Main Canal

The next step is to derive the linear equation and compute the coefficient of determination (r^2). The r^2 value indicates what percentage of the variation in mean velocity can be explained by the variation of Argonaut SL velocity.

A simple method for determining the equation coefficient and constant along with the r^2 value is the linear regression tool in Excel® spreadsheets.

The linear index velocity rating equation determined for the CRIT Main Canal dataset in **Table 1** is shown below:

$$V_m = 1.015V_{SL} - 0.077$$

Figure 3 shows the index velocity rating from least-squares regression. The r^2 value of 0.98 indicates that 98 percent of the variation in the mean velocity can be explained by the variation in the Argonaut SL velocity.

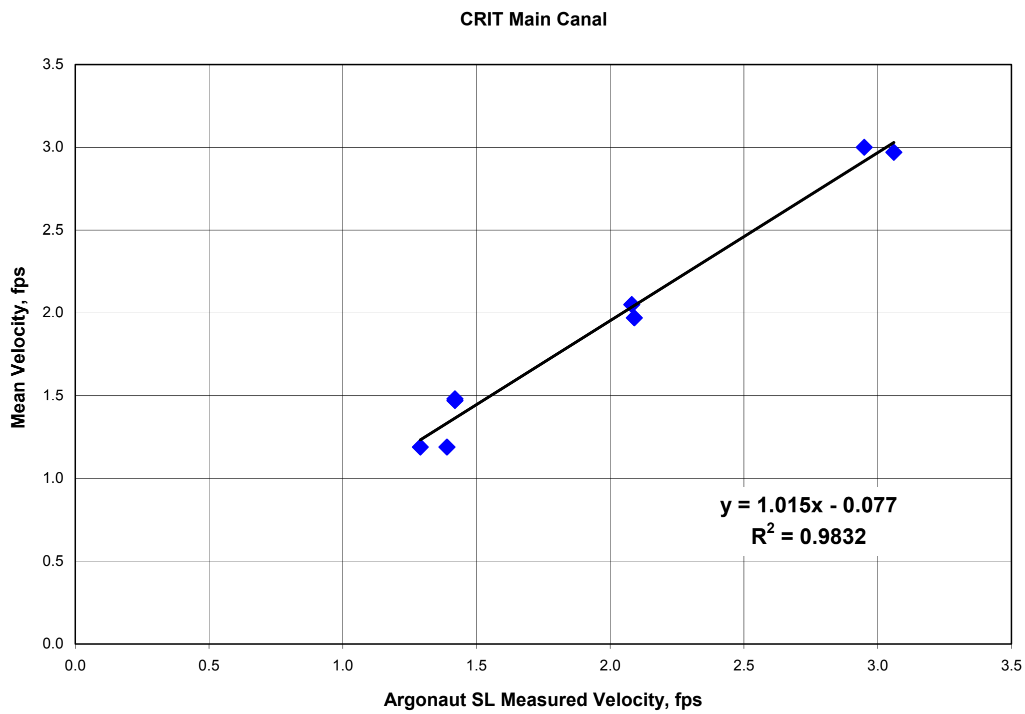


Figure 3. Index velocity rating using simple linear equation (r^2 = 0.98)

The above analysis assumed that the Argonaut SL measured velocity is the only parameter to consider when determining the index velocity rating. However depending on the site's hydraulic conditions, stage may be a significant factor in the prediction of mean channel velocity using a side-looking acoustic Doppler velocity instrument.

An equation that relates both the Argonaut SL velocity and stage to mean velocity is:

$$V_m = V_{SL}(x + yH) + C$$

where,

V_m = computed mean velocity
V_{SL} = average measured Argonaut SL velocity during one measurement period
x = velocity coefficient
y = stage coefficient
H = stage
C = constant

The values of the coefficients and constant in the index velocity equation can be determined from the multiple linear regression analysis where mean velocity is the dependent variable and the independent variables are the Argonaut SL measured velocity and the product of measured velocity and stage.

Using multiple regression analysis, the equation and r^2 value determined for the CRIT Main Canal dataset in **Table 1** assuming that stage is a factor is:

$$V_m = V_{SL}(1.995 - 0.080H) - 0.192$$
$$r^2 = 0.99$$

Figure 4 shows the relationship between the mean velocity and the computed index velocity using multiple linear regression.

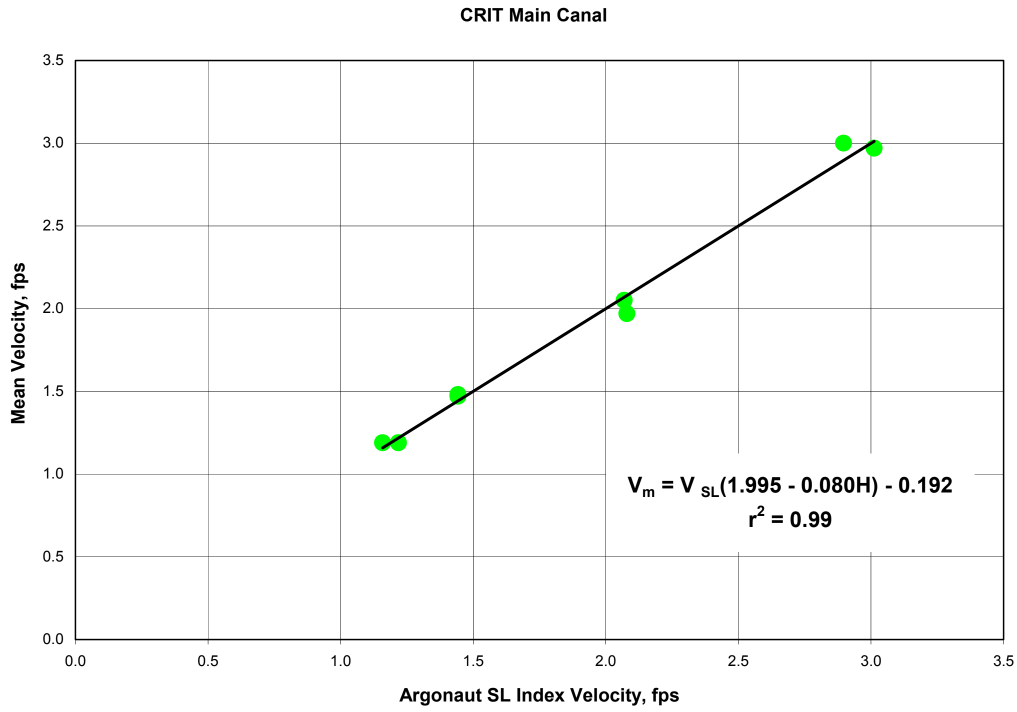


Figure 4. Index velocity rating using multiple regression equation

Results

Table 2 summarizes the computed discharge using both index velocity equations and the percent error relative to the current meter measurements. The flow rate (Q = VA) was computed using the index velocity and channel area based on the measured stage and a bottom width of 25 ft and side slope of 1:1.

Table 2. Discharge (cfs) and percent error using simple linear regression and multiple regression with stage

No.	Current meter discharge, cfs	Simple linear equation no stage		Multiple regression with stage	
		cfs	% error	cfs	% error
1	514	535	4.1%	503	-2.1%
2	540	605	12.1%	553	2.4%
3	841	834	-0.8%	849	0.9%
4	805	839	4.2%	853	6.0%
5	1318	1267	-3.9%	1258	-4.6%
6	1304	1315	0.9%	1308	0.3%
7	562	509	-9.5%	538	-4.3%
8	547	509	-7.0%	538	-1.7%

Conclusion

The index velocity rating determined using the multiple linear regression analysis with stage is generally closer to the discharge measured with a current meter. The percent error of the index velocity for the simple linear equation and the multiple linear regression equation is approximately ±10% and ±6%, respectively. In other words, the inclusion of stage as a factor in determining the index velocity rating for this particular dataset improved the accuracy by about ±4%. It is recommended to always include stage in the development of an Index Velocity Rating Procedure. The final equation can be readily programmed into the instrument for use with the internal flow computations option.

Figure 4. SonTek/YSI Argonaut SL installed in a canal

Due to the inherent problems in using current metering as the reference flow rate, future evaluations will be done using other rapid measurement techniques. The issues with current meters include; poorly defined cross-sections, fluctuating flow rates, moss hanging on meter, etc. Potential technologies include using the portable Doppler meters that can be mounted to boats and rapidly determine the flow rate in a canal.

References

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