Index-Velocity Rating Development (Calibration) for H-ADCP Real-Time Discharge Monitoring in Open Channels

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Summary: ChannelMaster H-ADCP has an Index-velocity rating model built-in its firmware. As long as the Index-velocity rating model is calibrated at a site (i.e., a rating is developed for the site), an H-ADCP will turn into a “flow meter” that can directly output discharge (flow rate), channel mean velocity, and water level data in a text format through a serial port or SDI12. It then can be easily integrated with a telemetry system. Therefore, an H-ADCP with its calibrated internal Index-velocity rating model is a simple, practical solution to real-time, remote monitoring of river, stream, or any open channel flows. This technical note describes the Index-velocity method and rating development or calibration of the H-ADCP built-in Index-velocity rating model.

1.0 Introduction

ChannelMaster H-ADCP (Horizontal Acoustic Doppler Current Profiler) is an acoustic Doppler instrument manufactured by Teledyne RD Instruments for velocity measurement and discharge monitoring in rivers, streams, and open channels. It is often used in real-time mode and integrated with a telemetry system at a remote site. It can also be used in self-contained mode.

An H-ADCP measures velocity horizontal profile across a channel by its two horizontal acoustic beams (Figure 1). The H-ADCP also measures water level by its up-looking acoustic beam and by its internal pressure sensor. However, the H-ADCP does not directly measure discharge. Discharge is calculated by a mathematical model or method using the H-ADCP measured velocity profile and water level data.

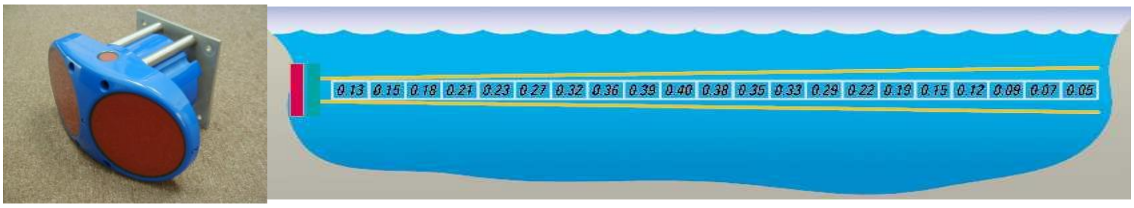


Figure 1 ChannelMaster H-ADCP and velocity profiling

The ChannelMaster H-ADCP firmware has a built-in Index-velocity rating model. As long as the model coefficients are determined for a site through calibration and entered into an H-ADCP, the H-ADCP will turn into a “flow meter” that can directly output *Q* (discharge), *V* (channel mean velocity), *H* (water level), and other parameters in a text format (PD19 or PD23 data format, referring to the ChannelMaster H-ADCP operation manual) through a serial port or SDI12. This allows an H-ADCP being easily integrated with a telemetry system for monitoring discharge at the site in real-time (Figure 2).

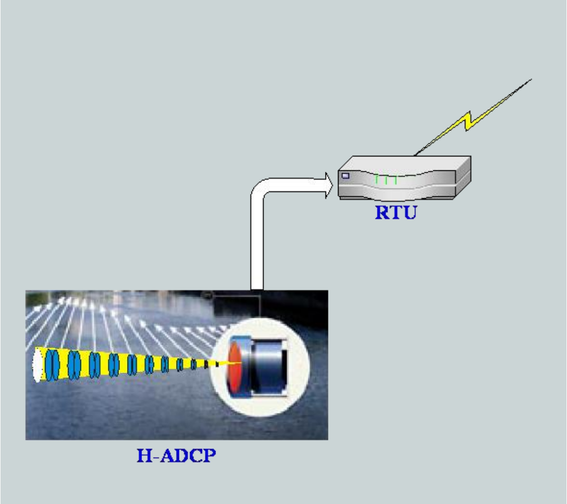


Figure 2 After calibration, a ChannelMaster H-ADCP will turn into a “flow meter” that can directly output *Q*, *V*, *H* data in a text format through a serial port. This allows an H-ADCP being easily integrated with a telemetry system.

The Index-Velocity method is especially useful at a site where a stage-discharge rating does not exist. An advantage of the Index-velocity method is that it can be used for a channel with its width much greater than the H-ADCP profiling range.

This technical note describes the Index-velocity method and rating development or calibration of the H-ADCP built-in Index-velocity rating model. The Appendix describes the site selection considerations.

2.0 Index-Velocity Method and the H-ADCP Built-in Index-Velocity Rating Model

The principle of the Index-velocity method is to establish a relation between the channel mean velocity and the Index-velocity. The Index-velocity defined here is a time and range averaged velocity measured by a ChannelMaster H-ADCP.

The channel discharge *Q* is the product of the wetted cross-section area and the channel mean velocity:

$$Q = AV \tag{1}$$

where A = wetted area of the “standard” cross-section, and V = mean velocity of the channel.

It should be pointed out that the “standard” cross-section used in the Index-velocity method does not need to be the same cross-section where an H-ADCP is mounted at.

The wetted cross-section area depends on the cross-section geometry and water level. For a specific site, the wetted cross-section area is a function of water level only:

$$A = f(H) \tag{2}$$

where H = water surface level (stage) above the local datum. Equation (2) is a stage-area rating that can be developed from the depth survey data. This rating is usually available at a hydrology station.

The channel mean velocity V may be a function of the Index-velocity and the water level H:

$$V = f(V_I, H) \tag{3}$$

where V_I = Index-velocity.

The Index-velocity rating model that is built in the ChannelMaster H-ADCP firmware is:

$$V = b_1 + (b_2 + b_3 H)V_I \tag{4}$$

where b_1、 b_2、 b_3、 b_4 are coefficients to be determined from field calibration tests.

However, the use of the two parameter rating model, Eq. (4), beyond the parameter calibration range must be with caution. In addition, the model requires multiple regression analysis.

In most cases, the channel mean velocity may be a function of the Index-velocity only. Thus, Eq. (4) is reduced to:

$$V = b_1 + b_2\ V_I \tag{5}$$

In some cases, the coefficient $b_1$is small and may be neglected. Thus, Eq. (5) is reduced to a simple coefficient rating:

$$V = b_2\ V_I \tag{6}$$

The user needs to make a judgment for forcing b_1=0 (i.e., forcing the rating through zero) or not during a regression analysis.

The key in using the Index-velocity method is to calibrate the rating model at a site because the model coefficients are site specific. The calibration, also called rating development, involves two steps. The first step is to conduct field calibration test. The test involves collecting H-ADCP velocity data from which the Index-velocity is obtained, and concurrently conducting discharge measurement from which the channel mean velocity is obtained. The second step is to create a relation between the channel mean velocity and the Index-velocity by regression analysis of the data obtained from the field calibration test.

It should be note that other rating models such as power law and second-order polynomial may be used. However, at the present time, only the above rating models, Eqs. (4), (5), and (6), are built in the ChannelMaster H-ADCP firmware. Therefore, other rating models are not described here.

3.0 Field Calibration Test

While an H-ADCP is sampling velocities, the calibration discharge measurements are conducted concurrently using a moving boat ADCP or a conventional current meter. It is important to note that the calibration test must cover a flow or water level range from low to high to obtain a set of data for channel mean velocity, water level (stage), and Index-velocity. This is because, like a stage-discharge rating, an index-velocity rating will have uncertainties outside the range of the calibration measurements – particularly if channel conditions (flow in the floodplain) change with stage/flow. Some sites may require a year to complete the calibration to cover the whole stage/flow range.

3.1 H-ADCP installation and configuration

Referring to Figure 3, an H-ADCP may be mounted on a bank at an elevation of Z_{adcp} above the local datum. A mounting structure must be designed and constructed based on site conditions. The H-ADCP must be mounted with its two horizontal beams in the horizontal plane. Tilt, either pitch or roll, must be zero or close to zero. The mount must be stable without changing over time.

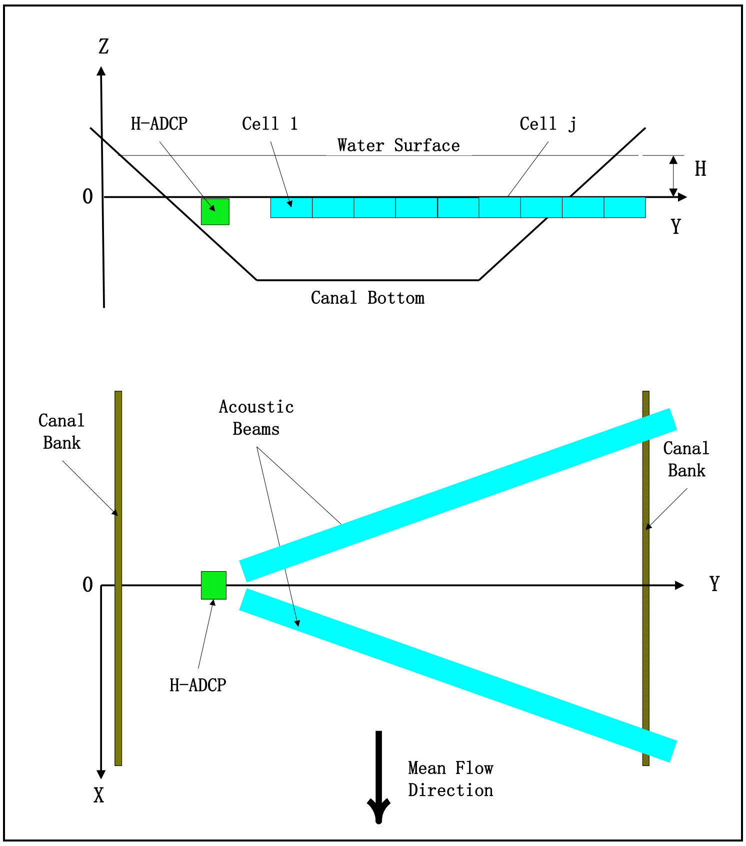


Figure 3 A sketch of H-ADCP setup

The H-ADCP's orientation should be perpendicular to the mean flow direction. That is, its instrument coordinate X should be parallel to the mean flow direction and Y is to the cross-section direction. The up-direction is defined as Z coordinate. Z = 0 is the local datum used or defined by the user or a local authority. For a channel with a flat bottom, the bottom may be set as Z = 0.

Either the WinH-ADCP or Q-Monitor-H software may be used to collect H-ADCP data. The H-ADCP may be configured with the following parameters:

- Cell size
- Number of Cells
- Averaging Interval (AI)
- Sampling Interval (SI)
- ADCP mounting elevation: Z_{adcp}
- Channel cross-section data (to be used to calculate the wetted cross-section area)
- PD0 data format

For field calibration tests, we recommend SI= 30 seconds and AI=25 seconds. Cell size and the number of cells should be selected according to the channel width. Note that settings of these two parameters for field calibration tests should be the same as those to be used in the real monitoring operation.

Note that WinH-ADCP is the standard operation software that comes with ChannelMaster H-ADCP. Q-Monitor-H is an advanced software for ChannelMaster H-ADCP. It is a third party, commercial software.

3.2 Calibration discharge measurement

While the H-ADCP samples velocities (Index-velocities), the calibration discharge measurements are conducted concurrently using a moving boat ADCP or a conventional current meter. Figure 4 shows a photo during a field calibration test at an irrigation canal in the Imperial Irrigation District, California. A StreamPro ADCP was used for the calibration discharge measurements.

Figure 4 Field calibration test at an irrigation canal in the Imperial Irrigation District, California, using a StreamPro ADCP

It is important to note that the quality of a calibrated rating model depends on the accuracy of the Index-velocity measurement as well as the accuracy of the calibration discharge measurements. Special attention on the measurement accuracy must be given to low flow conditions when the water velocity is small, say, in an order of several centimeters per second. In addition, during high flow conditions such as a flood period, moving bottom may exist. In this situation, the moving bottom effect needs to be accounted for if a moving boat ADCP is used for the calibration discharge measurements.

4.0 Rating Creation: Regression Analysis

To create a rating, i.e., determine the coefficients in the rating model by the least-square method, the field data must be first organized as described below.

4.1 Index-velocity

An H-ADCP measures and outputs horizontal velocity in its instruments coordinate X-Y. The X component of the measured velocity is assumed to be parallel to the mean flow direction.

The Index-velocity is a time and range averaged velocity component in X direction at time *t*, measured by the H-ADCP. The Index-velocity is calculated from H-ADCP velocity data as follows:

$$V_I = \frac{1}{\eta - \zeta + 1} \sum_{k=\zeta}^{k=\eta} V_k \tag{7}$$

where:

V_I = Index-velocity at time t;
ξ=range averaging start cell number; ξ =1, 2, 3,……..or M;
η= range averaging end cell number; η =1, 2, 3,……..or M; $\eta \geq \xi$;
M=total number of cells of H-ADCP;
V_k= V_x at Cell k. V_x is an output velocity from H-ADCP.

It is important to determine proper time-averaging interval and range-averaging cells for the Index-velocity. Below are general considerations for determining the time-averaging interval and range-averaging cells.

The time-averaging interval

The time-averaging interval should be long enough to reduce the measurement uncertainties mainly due to the ADCP system random noise and ambient turbulence. The ambient turbulence may be a controlling factor for the time-averaging interval determination. The user may follow the time-averaging interval (i.e., sampling duration) requirement on traditional current meter velocity measurement in a national hydrology survey code or regulation. This requirement is mainly based on the consideration of ambient turbulence.

For calibration purpose, the averaging interval must match the duration of the calibration discharge measurement. For example, if a calibration discharge measurement using a moving boat ADCP takes five minutes, do 5min moving averaging for the H-ADCP data for velocity and water level.

The range-averaging cells

The range-averaging cells are site-specific. The H-ADCP provides velocity data at many range cells set by the user. The user may conduct regression analysis by trial and error of different range-averaging cells (grouping). For example, group Cell 1 through Cell 20 together or group Cell 10 to Cell 30 together. The range-averaging cells should be determined so that the corresponding Index-velocity has the best correlation with the channel mean velocity for the site.

For a small channel, simply select all cells that are not affected by the channel bank. That is, average Cell 1 to Cell N, where N is the last valid cell near the other bank. Look at the echo intensity plot that will help identify the last valid cell.

The rang-averaging (Eq. (7)) is actually conducted by the H-ADCP software during data playback. The Q-Monitor-H software is preferred because it does moving averaging. WinH-ADCP does not do moving averaging. It does box-averaging only. The data for Index-velocity V_I can be found in the text file generated by the software during data playback, *.QVH file from Q-Monitor-H or *.rpt file from WinH-ADCP

4.2 Water level

An H-ADCP also measures the water depth above the vertical transducer surface. The water surface level (i.e., the stage) is calculated as Z_{adcp} plus the H-ADCP measured water depth:

$$H = Z_{adcp} + (H\text{–}ADCP\,measured\,depth) \tag{8}$$

where H= water level (stage) above the local datum at time t; and Z_{adcp} = H-ADCP mounting elevation, measured from the local datum to the surface of the vertical transducer.

The data for water level H can be found in the text file generated by the software during data playback, *.QVH file from Q-Monitor-H or *.rpt file from WinH-ADCP.

4.3 Wetted cross-section area

The wetted cross-section area is calculated automatically when the cross-section data are entered into either the WinH-ADCP or Q-Monitor-H software. The wetted cross-section area data can be found in the text file generated by the software during data playback, *.QVH file from Q-Monitor-H or *.rpt file from WinH-ADCP.

4.4 Channel mean velocity

The channel mean velocities are calculated by dividing the measured discharge Q by the wetted cross-section area A:

$$V = \frac{Q_{measured}}{A} \tag{9}$$

The calculation of V may be conducted using Excel.

Note again that the wetted cross-section area *A* is taken at the so-called “Standard Cross-section” that may not be the same as the cross-section where the H-ADCP is mounted at.

4.5 Example of organized data

Table 1 shows an example of the organized data from a field calibration test at the irrigation canal in California. A 600 kHz ChannelMaster H-ADCP was used for Index-velocity measurements. A StreamPro ADCP was used for the calibration discharge measurements.

Table 1 Example of organized StreamPro ADCP and ChannelMaster H-ADCP data from the field calibration test at the California irrigation canal

StreamPro ADCP Measurement			**ChannelMaster H-ADCP Measurement**			
Transect Start Time	Measured Discharge ($Q_{measured}$) [m^3/s]	Canal Mean Velocity (V) [m/s]	Sample Start Time	Water Level (H) [m]	Index-Velocity (V_I) [m/s]	Wetted Cross-Section Area (A) [m^2]
12:44:56	2.482	0.304	12:44:56	0.470	0.351	8.175
12:49:03	2.264	0.280	12:49:18	0.460	0.336	8.098
12:57:01	1.914	0.239	12:57:24	0.453	0.274	8.041
13:01:31	1.391	0.172	13:01:46	0.455	0.199	8.060
13:11:05	0.954	0.120	13:11:07	0.435	0.146	7.909
13:14:41	0.783	0.099	13:14:51	0.425	0.127	7.834
13:21:01	0.574	0.074	13:21:05	0.413	0.088	7.740
13:24:57	0.474	0.061	13:24:49	0.405	0.069	7.684
13:36:20	0.256	0.034	13:36:03	0.385	0.045	7.536
13:40:36	0.247	0.033	13:40:24	0.388	0.045	7.555
13:53:28	0.235	0.031	13:50:23	0.380	0.035	7.499
13:58:47	0.312	0.040	13:58:29	0.413	0.027	7.740
14:21:01	2.062	0.241	14:20:55	0.523	0.291	8.580
14:24:55	2.551	0.304	14:24:40	0.513	0.351	8.502
14:43:16	3.036	0.368	14:43:22	0.443	0.429	7.966
14:47:41	2.511	0.313	14:47:44	0.450	0.370	8.022
14:51:30	2.502	0.315	14:51:28	0.440	0.356	7.947
14:54:13	2.422	0.305	14:54:35	0.433	0.343	7.890
14:57:20	2.109	0.268	14:57:42	0.430	0.309	7.871
15:00:27	1.582	0.199	15:00:49	0.443	0.234	7.966
15:09:00	1.44	0.183	15:08:55	0.430	0.212	7.871
15:15:39	1.271	0.163	15:15:47	0.420	0.187	7.796
15:19:05	1.085	0.139	15:18:54	0.418	0.167	7.778
15:23:11	0.974	0.126	15:23:15	0.410	0.143	7.722
15:27:17	0.871	0.113	15:27:00	0.410	0.120	7.722
15:31:24	0.782	0.101	15:31:22	0.410	0.119	7.722
15:36:06	0.737	0.096	15:36:21	0.403	0.097	7.666
15:42:25	0.591	0.077	15:42:35	0.410	0.072	7.722
16:06:45	0.934	0.118	16:06:53	0.450	0.138	8.022
16:11:38	1.069	0.132	16:11:53	0.463	0.165	8.117
16:15:24	1.077	0.132	16:15:37	0.470	0.150	8.175

Note that the calibration discharge measurement time, i.e., the transect start time, and Index velocity measurement time, i.e., the sample start time, must match as close as possible if the flow changes rapidly with time as it was at this site.

The next step is to plot the data for channel mean velocity V vs. Index-velocity V_I. Figure 5 shows the plot of the data shown in Table 1.

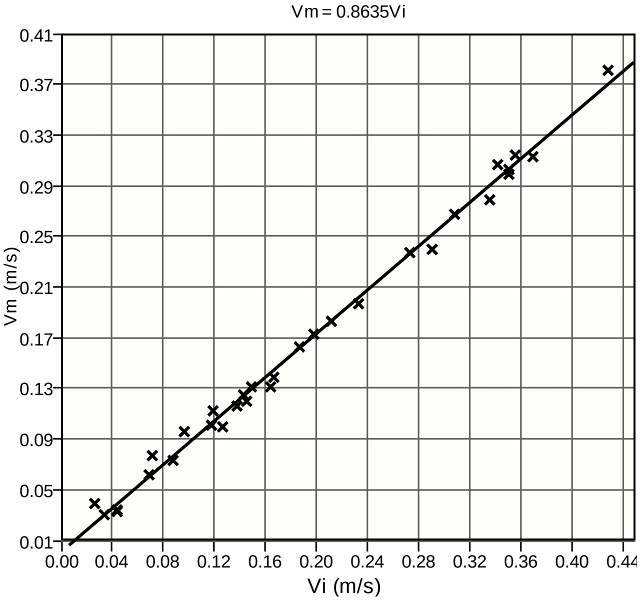


Figure 5 Plot of data for V and V_I shown in Table 1

4.6 Regression analysis to determine rating model coefficients

First, select a rating model based on the observation of the V vs. V_I plot. Apparently, the plot shown in Figure 3 indicates a leaner relation.

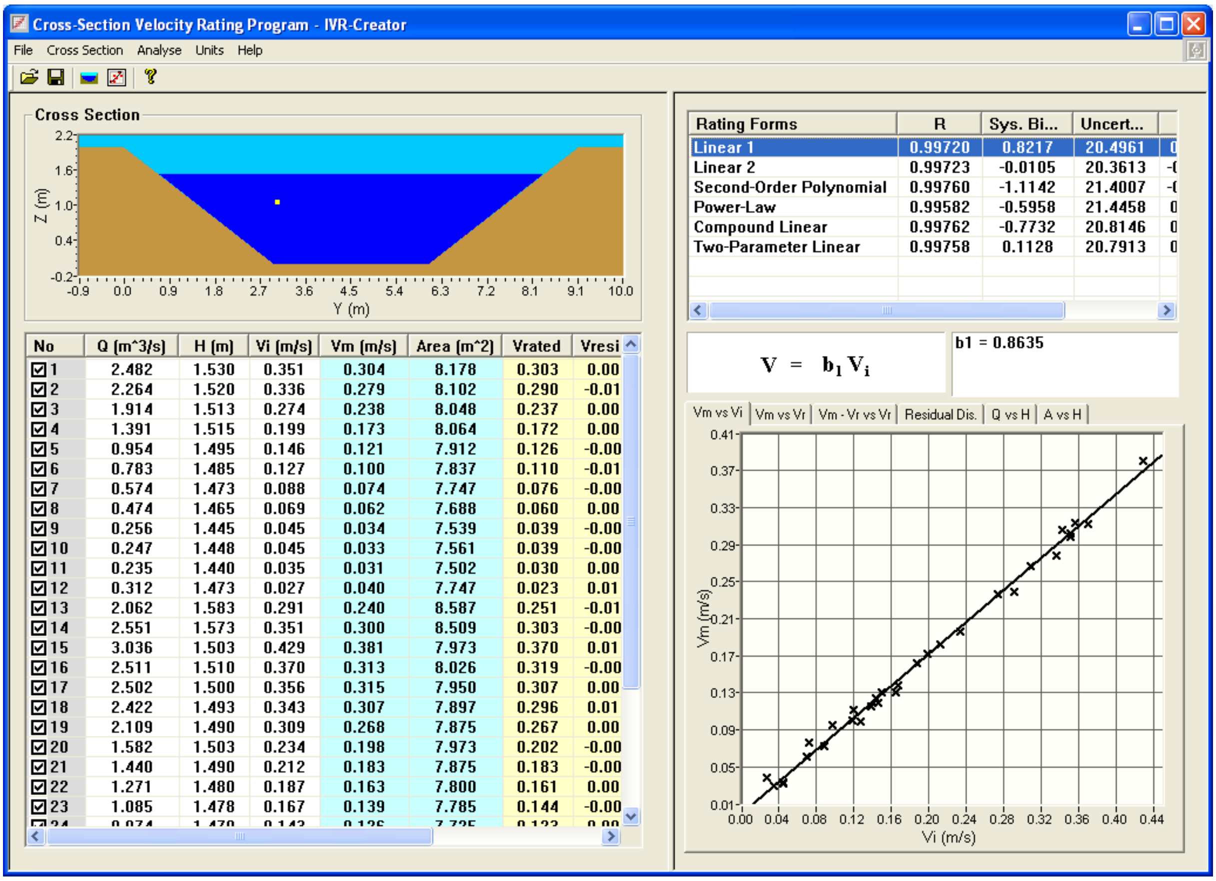
Second, conduct regression analysis for the mean velocity and index velocity using Excel or a rating creation software such as IVR-Creator. Below is the rating result obtained from the regression analysis for the data shown in Table 1:

$$V_{mean} = 0.8635 \times V_I \tag{10}$$

with a correlation coefficient of 0.9972.

Note that in this case, a judgment of forcing b_1=0 was made during the regression analysis.

Although the Excel spread sheet may be used for regression analysis to determine the rating model coefficients, its use requires knowledge of Excel and it is time consuming. IVR-Creator, the software that is specially designed for Index-velocity rating development is recommended. IVR-Creator does linear and nonlinear regression analysis using the least-square method. It accepts field data for channel cross-section geometry, discharge, water level (stage), and Index-velocity. Figure 6 shows a screen shot of the IVR-Creator software. IVR-Creator is very easy to use and saves a lot of time. It is a useful tool for Index-velocity rating development.



No	Q (m^3/s)	H (m)	Vi (m/s)	Vm (m/s)	Area (m^2)	Vrated	Vresi
☑ 1	2.482	1.530	0.351	0.304	8.178	0.303	0.00
☑ 2	2.264	1.520	0.336	0.279	8.102	0.290	-0.01
☑ 3	1.914	1.513	0.274	0.238	8.048	0.237	0.00
☑ 4	1.391	1.515	0.199	0.173	8.064	0.172	0.00
☑ 5	0.954	1.495	0.146	0.121	7.912	0.126	-0.00
☑ 6	0.783	1.485	0.127	0.100	7.837	0.110	-0.01
☑ 7	0.574	1.473	0.088	0.074	7.747	0.076	-0.00
☑ 8	0.474	1.465	0.069	0.062	7.688	0.060	0.00
☑ 9	0.256	1.445	0.045	0.034	7.539	0.039	-0.00
☑ 10	0.247	1.448	0.045	0.033	7.561	0.039	-0.00
☑ 11	0.235	1.440	0.035	0.031	7.502	0.030	0.00
☑ 12	0.312	1.473	0.027	0.040	7.747	0.023	0.01
☑ 13	2.062	1.583	0.291	0.240	8.587	0.251	-0.01
☑ 14	2.551	1.573	0.351	0.300	8.509	0.303	-0.00
☑ 15	3.036	1.503	0.429	0.381	7.973	0.370	0.01
☑ 16	2.511	1.510	0.370	0.313	8.026	0.319	-0.00
☑ 17	2.502	1.500	0.356	0.315	7.950	0.307	0.00
☑ 18	2.422	1.493	0.343	0.307	7.897	0.296	0.01
☑ 19	2.109	1.490	0.309	0.268	7.875	0.267	0.00
☑ 20	1.582	1.503	0.234	0.198	7.973	0.202	-0.00
☑ 21	1.440	1.490	0.212	0.183	7.875	0.183	-0.00
☑ 22	1.271	1.480	0.187	0.163	7.800	0.161	0.00
☑ 23	1.085	1.478	0.167	0.139	7.785	0.144	-0.00

Rating Forms	R	Sys. Bi...	Uncert...
Linear 1	0.99720	0.8217	20.4961
Linear 2	0.99723	-0.0105	20.3613
Second-Order Polynomial	0.99760	-1.1142	21.4007
Power-Law	0.99582	-0.5958	21.4458
Compound Linear	0.99762	-0.7732	20.8146
Two-Parameter Linear	0.99758	0.1128	20.7913

$$V = b_1 V_i$$

b1 = 0.8635

Figure 6 Screenshot of the IVR-Creator software

4.7 Rating quality evaluation

The quality of a calibrated rating model needs to be evaluated. Below are the parameters for rating quality evaluation.

Correlation coefficient

The correlation coefficient (r^2) indicates what proportion of variation in the dependent variable (V) can be explained by the independent variable (V_I). An r^2 of 0.97 indicates that 97% of the variation in V is explained by variation in V_I. Lower values of r^2 could indicate that other parameters (variables) may be significant and missing in the rating.

Residual plot

A residual plot shows the departures of observed samples from the regression line (i.e., the calibrated rating model). The residuals should have a random pattern, be distributed equally above and below zero line, and have reasonable magnitudes.

Attention should be given for the residual plots that reveal non-linearity and outliers. Figure 7 shows three example residual plots.

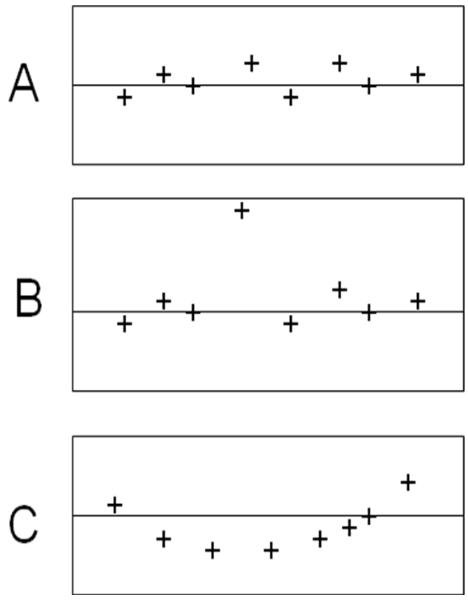


Figure 7 Examples of residual plots

It can be seen from Figure 7 that, Plot A looks good, Plot B has an outlier, and Plot C has a pattern or non-linearity. The outlier may be due to an error in the calibration discharge measurement. The pattern or non-linearity may be an indication that another independent variable (e.g., the water level) may be missing in the rating.

Figure 8 shows the residual plot for the California irrigation canal rating example. The red lines are the 95% confidence intervals. Note that the residuals are random and relative uniformly distributed between the 95% confidence intervals.

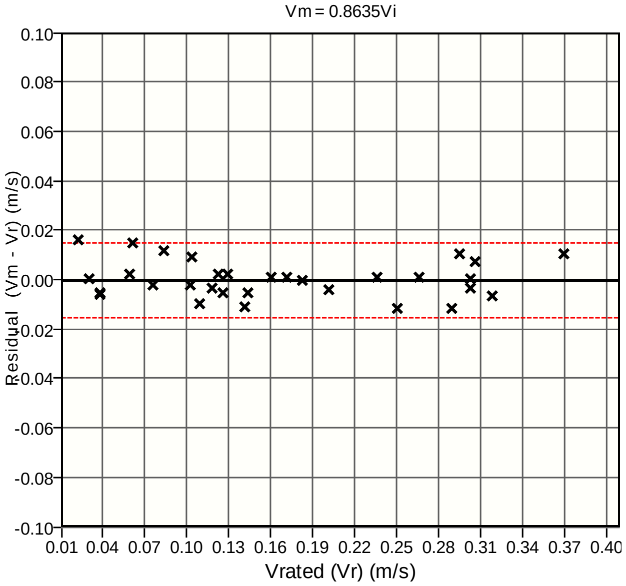


Figure 8 Residual plot for the California irrigation canal rating example

Residual distribution plot

The residuals from a good rating should have a nearly Gaussian distribution.   Figure 9 shows the residual distribution plot for the California irrigation canal rating example.

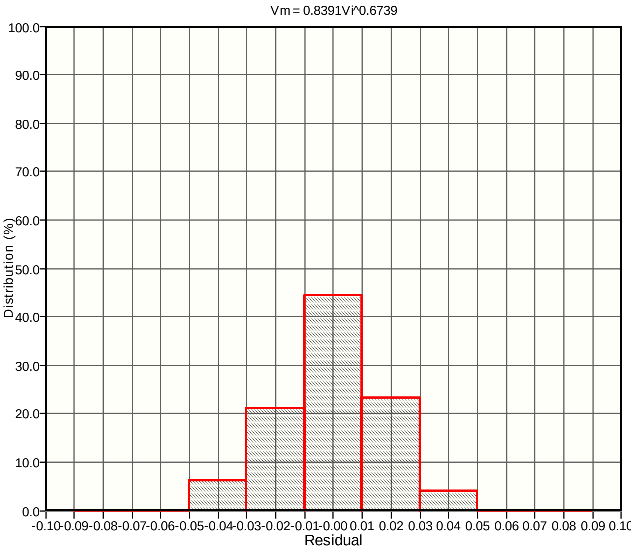


Figure 9 Residual distribution plot for the California irrigation canal rating example

Standard error

Standard error of estimate (S_e) is a measure of how nearly values of the dependant variable (V) predicted from the regression line agree with observed values. The smaller it is, the better the rating. The standard error is particular useful when comparing several rating models.

Percent difference between the rated Q and the measured Q

Regardless of the rating model used, you need to check the calibration measurement data points against your rating. That is, first calculate the rated channel mean velocity using your rating model. Secondly, calculate the rated $Q = VA$, where the wetted area A is calculated from the water level data and the cross-section geometry data. Then calculate the residual Q and the percent difference between the rated Q and the measured Q:

$$Q_{residual} = Q_{measured} - Q_{rated} \tag{11}$$

$$Percent\ difference = \frac{Q_{measured} - Q_{rated}}{Q_{measured}} \times 100\ (\%) \tag{12}$$

Table 2 shows the percent difference between the rated Q and the measured Q for the irrigation canal rating example. Note that some percent differences are greater than 14% during low flow conditions. But most of the differences are less than 5%.

Table 2 Percent difference between the rated Q and the measured Q for the California irrigation canal rating example

No.	Measured Q (m^3/s)	Rated Q (m^3/s)	Residual Q (m^3/s)	Percent difference (%)
1	2.482	2.479	0.003	0.14
2	2.264	2.35	-0.086	-3.82
3	1.914	1.904	0.01	0.51

4	1.391	1.386	0.005	0.39
5	0.954	0.997	-0.043	-4.56
6	0.783	0.859	-0.076	-9.76
7	0.574	0.589	-0.015	-2.56
8	0.474	0.458	0.016	3.37
9	0.256	0.293	-0.037	-14.43
10	0.247	0.294	-0.047	-18.95
11	0.235	0.227	0.008	3.52
12	0.312	0.181	0.131	42.11
13	2.062	2.158	-0.096	-4.64
14	2.551	2.579	-0.028	-1.09
15	3.036	2.953	0.083	2.72
16	2.511	2.564	-0.053	-2.11
17	2.502	2.444	0.058	2.33
18	2.422	2.339	0.083	3.43
19	2.109	2.101	0.008	0.38
20	1.582	1.611	-0.029	-1.83
21	1.44	1.441	-0.001	-0.1
22	1.271	1.259	0.012	0.91
23	1.085	1.123	-0.038	-3.46
24	0.974	0.954	0.02	2.07
25	0.871	0.8	0.071	8.1
26	0.782	0.794	-0.012	-1.5
27	0.737	0.643	0.094	12.8
28	0.591	0.48	0.111	18.74
29	0.934	0.956	-0.022	-2.39
30	1.069	1.158	-0.089	-8.28
31	1.077	1.059	0.018	1.65

In theory, at least 30 data sets are required to obtain a statistically sound calibration. However, field calibration tests are time consuming and costly. Therefore, less data sets, say, 10 may be fine, particularly for initial calibration. The calibration may be refined when more calibration data are available.

4.8 Rating verification

It is important to note that the created rating (i.e., the calibrated rating model) for a site may change over time in the following conditions:

- Cross-section change due to sediments deposition or bottom erosion
- H-ADCP sampling volume change due to mounting settlement, tilt, or high solids concentration

Therefore, periodically filed discharge measurements may be required to verify the rating. Recalibration may be needed if the rating has a significant change.

References

Huang, H. (2004). "Index-velocity rating development for rapidly changing flows in an irrigation canal using broadband StreamPro ADCP and ChannelMaster H-ADCP." Proceedings of Rivers'04, First International Conference on Managing Rivers in the 21st Century: Issues and Challenges, 146-154.

Appendix: Site Selection Considerations

A fundamental question for the site selection is "will we be able to index the channel mean velocity over the range of flows at the selected site?" In other words, does a unique relation between the channel mean velocity and the index-velocity exist for the selected site?

An ideal site will be at a straight reach and easy to access. It has turbulent flow (well mixed), uniform cross section, and stable bed. The turbulent flow will have long-term stable vertical velocity profiles which allow creating index-velocity ratings. A stable bed means stable cross-section; erosion or sediment deposition may cause a change in cross-section, resulting in a change in ratings.

Other questions need to be answered are:

- What are the minimum and maximum flows expected at the site?
- What are the minimum and maximum water levels at the site?
- Can the H-ADCP be easily mounted at the site?
- Can the H-ADCP be mounted to sample the maximum flow? It is best to sample in the zone of highest velocities away from the banks.

Below are the conditions or sites that should be avoided:

(1) Nearby structures such as bridges, piers, pilings and other manmade features that may cause possible backwater affects, eddies, or wake flows (Figure A-1), and interfere or reflect the acoustic signal near the acoustic beams. If an H-ADCP has to be mounted on a pier, avoid the H-ADCP sampling volume in the wake flow due to the pier.
(2) Density gradients or flow stratification. The long-term flow in these conditions will be less uniform and harder to predict. It may be difficult or impossible to gage stratified flows with horizontal systems such as an H-ADCP.
(3) Interference between the acoustic beams and boundaries. The boundary can be the water surface or the stream bed. As a rule of thumb, the Aspect Ratio, i.e., Range/Depth, should be less than 40 to avoid potential side lobe that will bias velocity measurement.
(4) Banks having point bars, big rocks, logs, weed beds, which may not only be unstable, but flow separation may set downstream recirculation zones (eddies) .
(5) Nearby upstream flow control structures such as gates or locks. Gates may not always open at same time.
(6) Bi-directional flow (Figure A-2). It may be difficult or impossible to gage bi-directional flow with horizontal systems such as an H-ADCP
(7) Vegetation. Vegetation may cause a change in flow patterns and a change in area of effective flow, and acoustic signal interference.

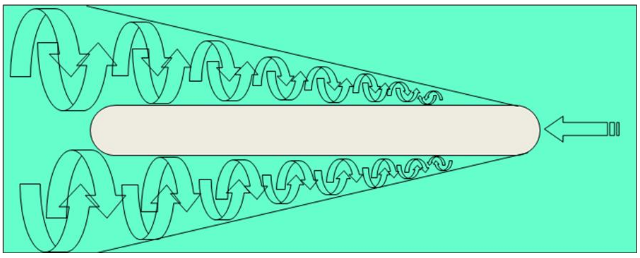


Figure A-1 Wake flow generated by a pier. If an H-ADCP has to be mounted on a pier, avoid the H-ADCP sampling volume in the wake flow.

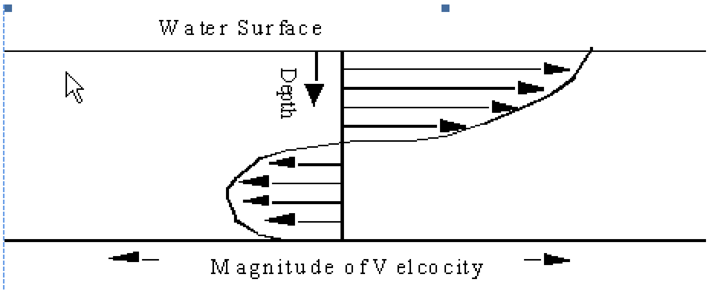


Figure A-2 Bi-directional flow. It may be difficult or impossible to gage bi-directional flow with horizontal systems such as an H-ADCP