United States Department of the Interior
U.S. GEOLOGICAL SURVEY
Reston, Virginia 20192

In Reply Refer To: March 6, 2015
Mail Stop 415

OFFICE OF SURFACE WATER TECHNICAL MEMORANDUM 2015.05

SUBJECT: Minimum requirements for documenting stage-area and index-velocity ratings for computation of streamflow records using the index velocity method

The purpose of this memo is to specify the documentation required for stage-area and index-velocity ratings when using the index velocity method for computing streamflow records. The index velocity method was documented and described in the Techniques and Methods (T&M) report "Computing Discharge Using the Index Velocity Method" (Levesque and Oberg, 2012). However, the T&M does not specify minimum requirements for the documentation of stage-area and index-velocity ratings. Because much of the development for stage-area and index-velocity ratings presently (2015) takes place outside of the National Water Information System (NWIS), it is therefore necessary to provide guidance for documenting the development and implementation of these ratings.

Stage-Area Rating Documentation

Methods for acquiring data for stage-area ratings are described in Levesque and Oberg (2012, p29-30). The AreaComp2 software (an updated version of the software described in that report) should be used to create stage-area ratings until equivalent or better capability is provided as a part of the NWIS software. AreaComp2 is available for download at the USGS Hydroacoustics Web pages (http://hydroacoustics.usgs.gov/). The cross-section survey data used to develop and validate the rating, the current rating information, and the rating validation must be documented. Additional details, including the suggested location for this information, are specified below.

1. Standard cross-section data. The data used to develop the stage-area rating must be available in the electronic data archive (EDA) so that the stage-area rating can be re-created readily. The data also can be summarized in a rating spreadsheet or other rating analysis tool or software. This includes any files used to create the ratings (for example, the *.mat or *.txt outputs from an acoustic Doppler current profiler (ADCP), and any level notes of the banks). An example of such data is shown on p. 31-32 of Levesque and Oberg (2012). The exact geographic location of the standard cross-

section must be clearly stated in the station description. In addition, methods used to perform the survey (level and stadia, ADCP, tagline and soundings) must also be listed in the station description to facilitate future validation surveys. If survey methods change among surveys, a description of all methods used over time must be provided in the station description. A description of the methods used to develop the stage-area rating currently in use must be provided in the station analysis.

2. Rating information and output. The station analysis must clearly state when the data were acquired, the tool used to develop the stage-area rating (e.g., AreaComp2), the NWIS rating number, and the applicable dates and stage ranges. The output of AreaComp2 (or equivalent), which consists of both the stage-area rating table and final cross-section table, must be included in the EDA. A saved copy of the AreaComp2 *.mat file also must be archived in the EDA.

3. Rating validation analysis. Analyses of the stage-area rating validation measurements must be documented in the station analysis for the site. Included in this documentation must be a brief description of the data acquisition (where, when, and how) and comparisons of computed area over the observed range of stages and cross-section shape like those shown in Appendix 5 of Levesque and Oberg (2012). Validation data (ADCP files, survey notes, AreaComp output and *.mat file) must be readily accessible from the EDA for analysis and verification. A plot of the validation cross section data with the prior cross section data for the existing rating is recommended.

Index-Velocity Rating Documentation

The required minimum documentation for index-velocity ratings, as well as suggestions for additional documentation and locations for this information, are provided in the following paragraphs. At the present time (2015), most index-velocity ratings are developed using Microsoft Excel-based rating spreadsheets and consist of simple linear, compound linear, and multiple linear regressions (Levesque and Oberg, 2012). As the USGS transitions to new time-series database software, other tools or software may be available for rating development, validation, and analysis. It is expected that the output from these tools will supply all or most of the required documentation discussed below. Therefore, in the following sections, requirements are presented "generically", that is without regard to the tool being used.

The following documentation is required for every index-velocity rating used to compute streamflow records.

1. Measurement summary. A measurement summary must be available that includes every discharge measurement made for that particular acoustic Doppler velocity meter (ADVM) configuration. The ADVM's configuration settings currently in use must be documented in the station description, including the ADVM's frequency, location in the water column, mounting information, measurement volume beginning and ending distance, multi-cell data (number and size of cells, blanking distance), averaging period,

and measurement interval. For coastal sites, the salinity used in the ADVM configuration should also be documented in the station description. If the ADVM is deployed in a different location (e.g., moved to a different bridge piling), orientation (e.g., rotated 20 degrees) or reconfigured (e.g., sample volume is extended or shortened), either (a) a new measurement summary must be created and those measurements pertaining to the previous configuration should not be included or (b) the measurements made after the ADVM configuration change must be clearly distinguished from past measurements. Measurements that are marked as not used for rating development in Site Visit (the NWIS database for site visit data) must be clearly identified on the summary. A brief justification (in the form of a comment) should be provided in the measurement summary which indicates why any measurements were excluded from rating development.

Minimally, the measurement summary must contain the following: measurement number, date of the measurement, measurement start and stop time, synchronized stage, measured discharge, rated area (A_{rated}) corresponding to the synchronized stage, synchronized index velocity for the time of the discharge measurement, and measured mean velocity ($V_m=Q/A_{rated}$). If shifting is performed at this site, the optimal shift, applied shift, shifted velocity, shifted discharge, and % difference of the shifted discharge from the rating must be also included. Other data that may be included are: the rated discharge, percent difference of measured discharge from the rating, multi-cell velocity data, measurement rating (good, fair, poor, etc.), and measurement comments.

2. <u>Graphical data analysis results.</u> The first step in developing an index rating is a graphical data analysis of the measurements and index velocity data used to develop the rating. The documentation for this analysis should include the following plots.

Documentation for Graphical Data Analysis	Requirements
1. Plot of index velocity (x-axis) and measured mean velocity (y-axis)	Required
2. Plot(s) of multi-cell index velocity data (x-axis) and measured mean velocity (y-axis)	Strongly encouraged
3. Plot of Y-velocity (sidelooker ADVMs) or Z-velocity (uplooker ADVMs) component (x-axis) and measured mean velocity (y-axis)	Strongly encouraged
4. Plots of other explanatory variables such as stage (x-axis) and measured mean velocity (y-axis)	Required for multiple linear ratings

See example in Figure 28 in Levesque and Oberg (2012, p. 47). Hydrographers should ensure that plots and plot axes are accurately labeled for such things as index velocity, measured mean velocity, stage, Y-velocity, etc.

3. <u>Regression analysis results.</u> The results of the regression analysis performed to develop the rating must be summarized and maintained with other rating information (e.g., in the EDA). If more than one regression analysis was performed, the results of the regression analyses must be kept for documentation purposes, and the regression analysis used for the final rating must be clearly identified. The regression analysis documentation must contain the regression software output with regression statistics, the regression residuals, residual plots, and line fit plots. The regression statistics must include the number of measurements, the coefficient of determination (R^2), the standard error of the estimate, and the coefficients for the equation and their associated p-values. The plots listed below may be stored separately or in the same file with the regression statistics and results. See Levesque and Oberg (2012, p. 42-59) for examples of the regression results and plots.

Graphical Documentation for Regression Analysis	Requirements
1. Line fit plot of index velocity (x-axis) and measured mean velocity (y-axis), showing measurements and rating line. The hydrographer may create either an entirely new line fit plot or augment Plot 1 from the graphical data analysis to show the same information.	Required
2. Plot of rated mean velocity (x-axis) and measured mean velocity (y-axis)	Required for multiple linear ratings; strongly encouraged for all ratings
3. Plots of index velocity (x-axis) and regression residuals (y-axis)	Required
4. Plots of other explanatory variables such as index velocity * stage (x-axis) and regression residuals (y-axis)	Required for multiple linear ratings
5. Plots of measurement date (x-axis) and regression residuals (y-axis)	Required

4. <u>Rating information and analysis.</u> The rating number (in NWIS), measurement numbers and range in discharge of measurements used to develop the rating, justification for any measurements excluded from rating development, rating equation(s) or points used to define the rating, and the applicable dates and velocity ranges must be clearly stated in the station analysis. The rationale for using the current rating must be documented in the station analysis (and also elsewhere if desired). The rating analysis also must include information on any multi-cell data options that were evaluated and the rationale for selecting a particular rating type (simple linear rating, compound linear rating, or multiple linear rating). If use of a previously-developed rating is continued for a record period, the station analysis must include a statement such as "Use of simple linear rating no. 1, implemented on MM/DD/YY based on measurements x through y covering a range in discharge a through b, was continued through this period". Justification for any

applied shifts to the rating also must be documented in the station analysis.

5. <u>Validation results.</u> The plots generated during Step 3 (including residuals plots) must be augmented with rating validation measurements as they are made. Measurements used to develop the initial rating may be plotted on these graphs using a unique symbol at the discretion of the hydrographer. The plots can be used to evaluate rating bias, inherent noise, or spread in the rating, and assist in determining whether more complex ratings may be needed. The validation results also must be summarized in the station analysis.

Additional Documentation

Suggestions for useful additions to rating documentation include the following:

1. Photographs of the site including the measurement section(s) and the standard cross section used for the stage-area rating.
2. Ancillary data, such as multi-cell velocity data or any other information that were used in rating development or validation.
3. Hydrograph comparisons or plots with discharge from nearby or similar streamgages, if applicable.

Summary and Examples

A table summarizing the minimum requirements for documenting stage-area and index-velocity ratings is included below. In addition, examples of stage-area rating documentation and index-velocity rating documentation may be found on the OSW Hydroacoustics Web pages at http://hydroacoustics.usgs.gov/indexvelocity/IVRatingDocumentation.shtml.

Questions about this memo or other questions about the index velocity method should be addressed to Kevin Oberg, OSW (kaoberg@usgs.gov).

References

Levesque, V.A., and Oberg, K.A., 2012, Computing discharge using the index velocity method:
U.S. Geological Survey Techniques and Methods 3–A23, 148 p.
(Available online at http://pubs.usgs.gov/tm/3a23/)

//signed//

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Distribution: GS-W All

Summary of Minimum Requirements for Documenting Stage-Area Ratings

Stage-Area Rating Documentation	Electronic Data Archive (EDA) or Rating Spreadsheet/Analysis Tool	Station Analysis	Station Description
Standard cross-section field survey data: survey notes, ADCP files, etc.	**Required**		
Geographic location of standard cross-section	Possible[1]	Possible	**Required**
Methods and equipment used to survey standard cross-section	Possible	Possible	**Required**
Methods and equipment used to survey standard cross-section for current stage-area rating in use (if methods vary among surveys)	Possible	**Required**	
Field survey date and time	Possible	**Required**	Possible
Software used to develop rating (should be AreaComp2)	Possible	**Required**	
NWIS rating number, applicable dates, and applicable range of stage	Possible	**Required**	
AreaComp2 output: stage-area rating table and final cross-section table	**Required**		
AreaComp2 *.mat file	**Required**		
Rating validation analysis: description of survey, comparison of areas, and comparison of cross-section shape	Possible	**Required**	
Rating validation survey field data: survey notes, ADCP files, etc.	**Required**		
Rating validation survey AreaComp output and .act files	**Required**		

[1] The term "Possible" indicates that it is possible for the specified information to be documented in that location, however it also must be documented in the location listed as "**Required**".

Summary of Minimum Requirements for Documenting Index-Velocity Ratings

Index-Velocity Rating Documentation	Electronic Data Archive (EDA) or Rating Spreadsheet/Analysis Tool	Station Analysis	Station Description
ADVM configuration information currently in use: frequency, location in the water column, mounting information, salinity used (only required for coastal sites) measurement volume beginning and ending distance, multi-cell (number and size of cells, blanking distance), averaging period, and measurement interval			**Required**
Measurement summary: Required fields: measurement number, date, start and stop times, stage, discharge, rated area, index velocity, measured mean velocity, brief justification (comment) for any measurements excluded from rating development, shift calculation and information if applicable; Optional fields: rated discharge, percent difference from rating, multi-cell velocity data, measurement rating, comments	**Required**		
Documentation for graphical data analysis	**Required**		
Regression analysis software output: regression statistics, regression residuals	**Required**		
Graphical documentation for regression analysis: line fit and residuals plots	**Required**		
NWIS Rating #, summary of measurements used to develop rating (numbers and range of discharge measured), justification for any measurements excluded from rating development, rating equation, applicable dates, and applicable velocity ranges	Possible[1]	**Required**	
Rationale for selected rating, such as multi-cell analysis and rating type (simple linear, compound, multi-linear), and any applied shifts	**Required**	**Required**	
Plots of validation measurements overlain on current line fit (rating) and residuals plots	**Required**		
Discussion of validation measurements	Possible	**Required**	

[1]The term "Possible" indicates that it is possible for the specified information to be documented in the rating spreadsheet; however it also must be documented in the location listed as "**Required**".