Review of OSW Memo 2017.03: Policy and Guidance for Shifting and Check Measurement Practices using the Index Velocity Method

OSW Hydroacoustics Webinar - April 5, 2017

Molly Wood (OSW), Philip Habermehl (SAWSC), Travis Knight (CFWSC)

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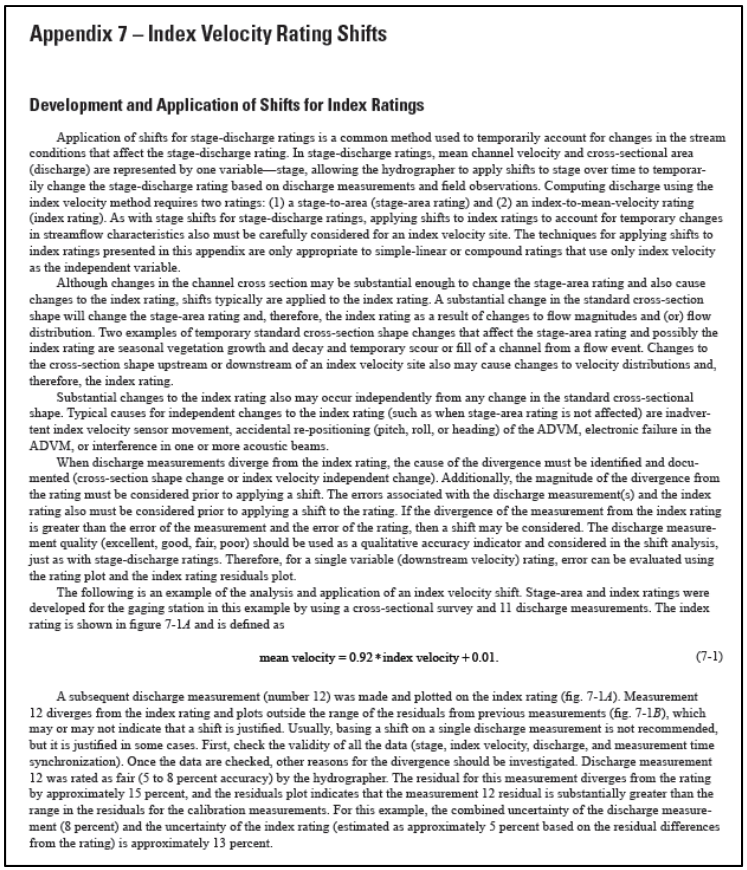
Setting the Stage….

- The Index Velocity T&M report included limited guidance on validating ratings and applying shifts (see App. 7)
- The T&M also discouraged applying shifts to MLR ratings



Appendix 7 – Index Velocity Rating Shifts

Development and Application of Shifts for Index Ratings

Application of shifts for stage-discharge ratings is a common method used to temporarily account for changes in the stream conditions that affect the stage-discharge rating. In stage-discharge ratings, mean channel velocity and cross-sectional area (discharge) are represented by one variable—stage, allowing the hydrographer to apply shifts to stage over time to temporarily change the stage-discharge rating based on discharge measurements and field observations. Computing discharge using the index velocity method requires two ratings: (1) a stage-to-area (stage-area rating) and (2) an index-to-mean-velocity rating (index rating). As with stage shifts for stage-discharge ratings, applying shifts to index ratings to account for temporary changes in streamflow characteristics also must be carefully considered for an index velocity site. The techniques for applying shifts to index ratings presented in this appendix are only appropriate to simple-linear or compound ratings that use only index velocity as the independent variable.

Although changes in the channel cross section may be substantial enough to change the stage-area rating and also cause changes to the index rating, shifts typically are applied to the index rating. A substantial change in the standard cross-section shape will change the stage-area rating and, therefore, the index rating as a result of changes to flow magnitudes and (or) flow distribution. Two examples of temporary standard cross-section shape changes that affect the stage-area rating and possibly the index rating are seasonal vegetation growth and decay and temporary scour or fill of a channel from a flow event. Changes to the cross-section shape upstream or downstream of an index velocity site also may cause changes to velocity distributions and, therefore, the index rating.

Substantial changes to the index rating also may occur independently from any change in the standard cross-sectional shape. Typical causes for independent changes to the index rating (such as when stage-area rating is not affected) are inadvertent index velocity sensor movement, accidental re-positioning (pitch, roll, or heading) of the ADVM, electronic failure in the ADVM, or interference in one or more acoustic beams.

When discharge measurements diverge from the index rating, the cause of the divergence must be identified and documented (cross-section shape change or index velocity independent change). Additionally, the magnitude of the divergence from the rating must be considered prior to applying a shift. The errors associated with the discharge measurement(s) and the index rating also must be considered prior to applying a shift to the rating. If the divergence of the measurement from the index rating is greater than the error of the measurement and the error of the rating, then a shift may be considered. The discharge measurement quality (excellent, good, fair, poor) should be used as a qualitative accuracy indicator and considered in the shift analysis, just as with stage-discharge ratings. Therefore, for a single variable (downstream velocity) rating, error can be evaluated using the rating plot and the index rating residuals plot.

The following is an example of the analysis and application of an index velocity shift. Stage-area and index ratings were developed for the gaging station in this example by using a cross-sectional survey and 11 discharge measurements. The index rating is shown in figure 7-1*A* and is defined as

$$\text{mean velocity} = 0.92 * \text{index velocity} + 0.01. \quad (7\text{-}1)$$

A subsequent discharge measurement (number 12) was made and plotted on the index rating (fig. 7-1*A*). Measurement 12 diverges from the index rating and plots outside the range of the residuals from previous measurements (fig. 7-1*B*), which may or may not indicate that a shift is justified. Usually, basing a shift on a single discharge measurement is not recommended, but it is justified in some cases. First, check the validity of all the data (stage, index velocity, discharge, and measurement time synchronization). Once the data are checked, other reasons for the divergence should be investigated. Discharge measurement 12 was rated as fair (5 to 8 percent accuracy) by the hydrographer. The residual for this measurement diverges from the rating by approximately 15 percent, and the residuals plot indicates that the measurement 12 residual is substantially greater than the range in the residuals for the calibration measurements. For this example, the combined uncertainty of the discharge measurement (8 percent) and the uncertainty of the index rating (estimated as approximately 5 percent based on the residual differences from the rating) is approximately 13 percent.

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Setting the Stage….

- Comparison between measured and rated discharge is not always being done in the field at IV sites (required by OSW Memo 2012.01)
- Shifting and check measurement practices at IV sites are inconsistent across Centers
- SOLUTION: OSW published Tech Memo 2017.03 to provide more guidance on shifting and check measurements with a spreadsheet tool to assist with rapid field assessments

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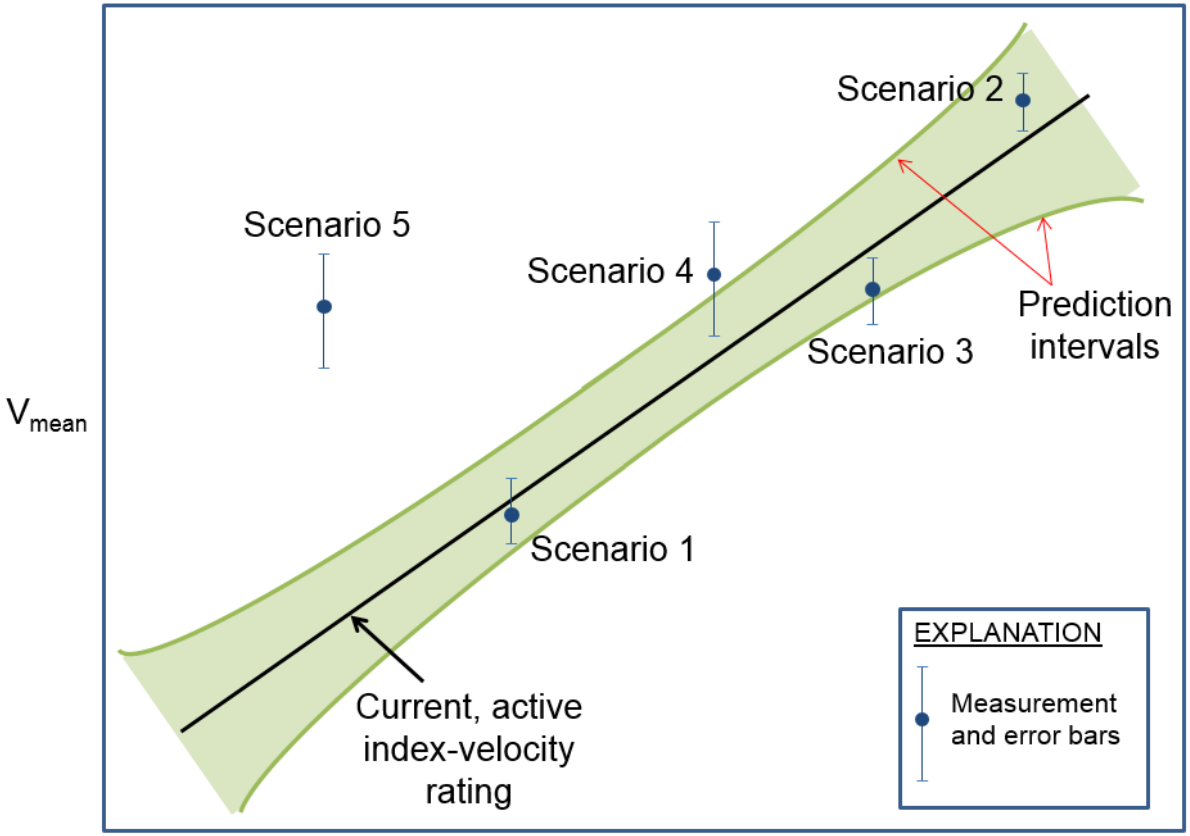
New Policy: Incorporating Measurement AND Rating Uncertainty When Deciding Whether to Shift or Make Check Qm



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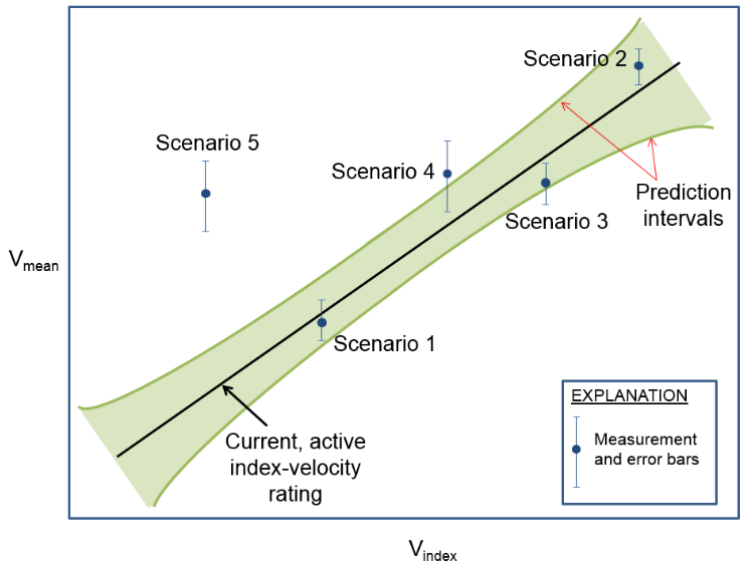
What are Prediction Intervals???

- Prediction intervals are used to convey uncertainty in the index velocity rating
- Prediction intervals provide an estimate of a “band of values” in which future observations will fall, for a given probability



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What are Prediction Intervals???

Battery Life Example

- Let's assume that the 95% prediction interval on battery life ranges from 100 - 110 hours
- That means that the life of batteries produced in the future will fall within that range 95% of the time
- That also means that there is a 5% (small) chance that the life of a battery produced in the future will be outside this range (i.e. <100 hrs or >110 hrs)

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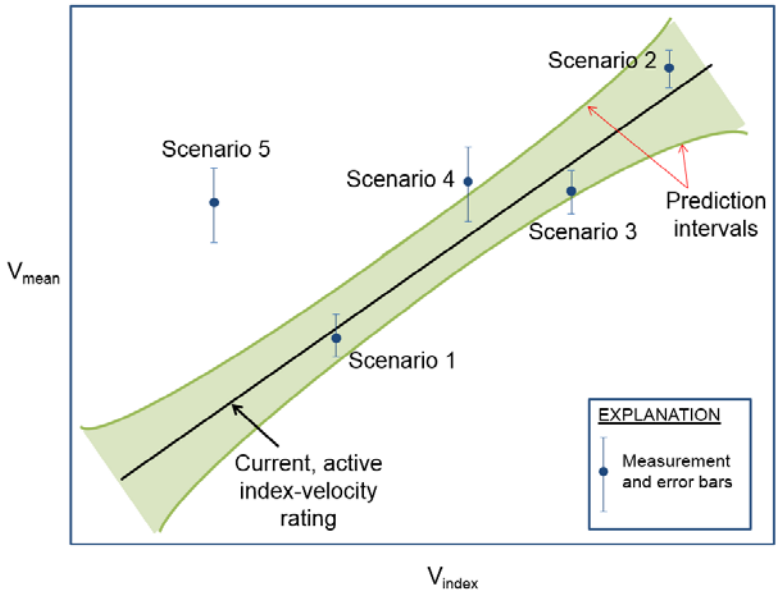
What is a Prediction Interval???

- We *generally* consider 95% as the acceptable probability that a future observation will lie within a range
- Prediction intervals can sometimes get slightly wider at the ends of your rating where you have less confidence and greater variability



$$\left(\hat{y} - ts\sqrt{1+\frac{1}{n}+\frac{(x_0-\bar{x})^2}{SS_x}}, \quad \hat{y} + ts\sqrt{1+\frac{1}{n}+\frac{(x_0-\bar{x})^2}{SS_x}} \right)$$

where t is the t statistic for a specified alpha, s is the standard error of estimate, n is the number of measurements used to define the index-velocity rating, Xo is the "new" index velocity obtained from the ADVM, Xbar is the mean of all the index velocities (for measurements used to define the rating), SS is the sum of squares of the index velocities used in the rating (regression analysis), and yhat is the rated mean channel velocity.

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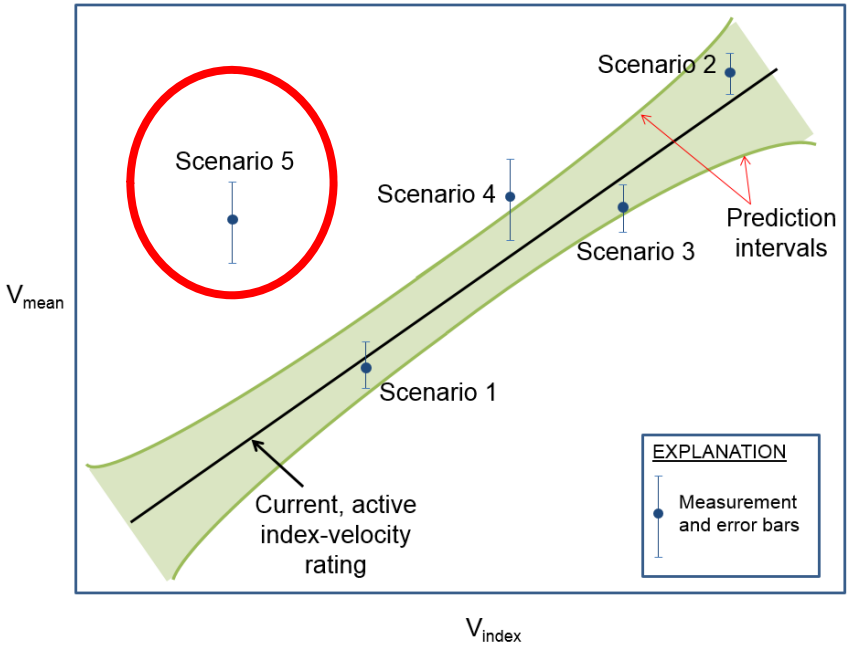
Policy: What to Do in the Field

1. You must first finalize your Q_{meas} in the field (review and process using Qrev), synchronize with IV and stage data, and calculate V_{mean_meas}
2. Compare to V_{mean_comp}!
   a. If the rated accuracy of V_{mean_meas} is within the prediction intervals for V_{mean_comp} no shift/no further action is required (scenarios 1 and 2) .
   b. If at least one of the errors bars (rated accuracy) of V_{mean_meas} is outside the prediction intervals for V_{mean_comp}, a shift *may* be indicated (scenarios 3, 4, 5)
3. Look for conditions justifying a shift and any trends in recent measurements

Policy: Check Measurements

- A check measurement MUST be made <u>regardless of observations</u> if V_{mean_meas} and both error bars are outside the rating's prediction intervals and flow is steady (scenario 5)



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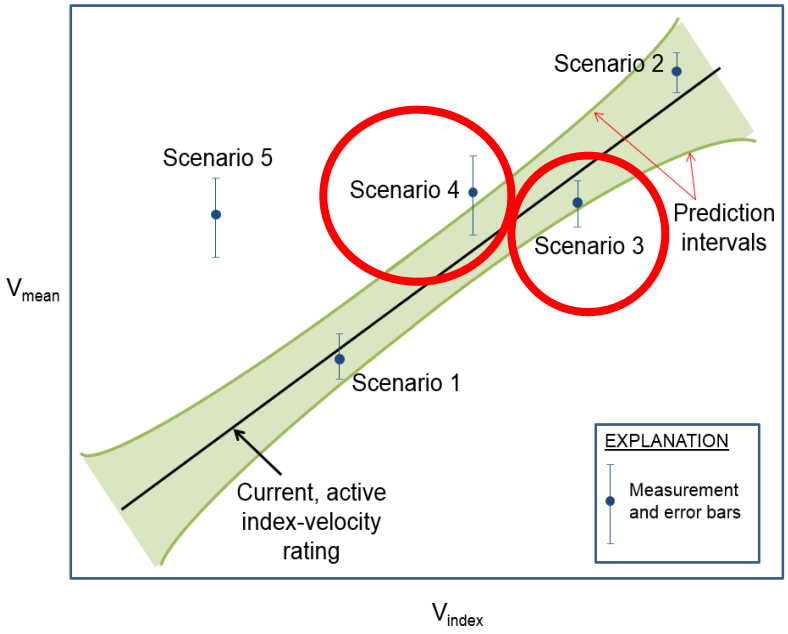
Policy: Check Measurements

- A check measurement MUST be made if:
  - at least one of the error bars for V_{mean_meas} is outside the rating's prediction intervals (scenarios 3 and 4), AND
  - a condition justifying a shift CANNOT be observed or recent measurements don't follow trend, AND
  - flow is steady



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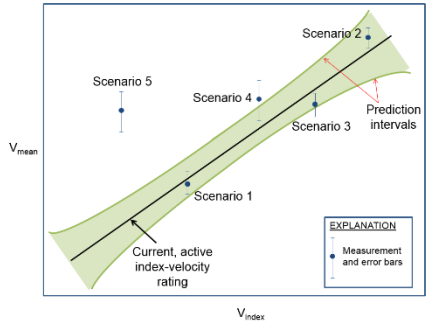
Policy: Check Measurements

- A check measurement is *recommended*, but not *required*, if it lies within a poorly defined portion of the rating and the error bars do not cross the rating.
- Check measurements often not practical in rapidly-varying discharge or stage.

Policy Flowchart



1. Process and synchronize discharge measurement

2. Calculate V_{mean_meas} and assign uncertainty

3. Compare V_{mean_meas} to V_{mean_comp}

4. Is V_{mean_comp} within the rated uncertainty of V_{mean_meas}?

YES

Scenario 1 V_{mean_meas} error bars cross rating

No shift indicated; analysis complete

NO

5., 6. Plot measurement and error bars on rating with 95% prediction intervals (PIs)

Scenario 2 V_{mean_meas} and both error bars are inside rating PIs

No shift indicated; analysis complete

Scenario 3 V_{mean_meas} is inside rating PIs but one error bar is outside rating PIs

Scenario 4 V_{mean_meas} is outside rating PIs but one error bar is inside rating PIs

Shift may be indicated; more information required

Scenario 5 V_{mean_meas} and both error bar are outside rating PIs

Shift likely indicated; more information required

7. Can you identify a condition justifying a shift or do recent measurements support a shift?

YES

Calculate and apply shift

NO

8. Is discharge steady or rapidly varying?

RAPIDLY VARYING

No check measurement required. Calculate and apply shift ONLY if a series of measurements made over event (e.g. tidal cycle, storm) supports a shift curve

STEADY

Make a check measurement

9. Does check measurement support original measurement?

YES

Calculate and apply shift

NO

Repeat flow chart for check measurement

Justifications for Shifts

- Change in velocity distribution in the ADVM-measured cross section
- Changes in area at the standard cross section
- Unforeseen changes to the ADVM (orientation change, obstruction, beam failure, biofouling, etc)

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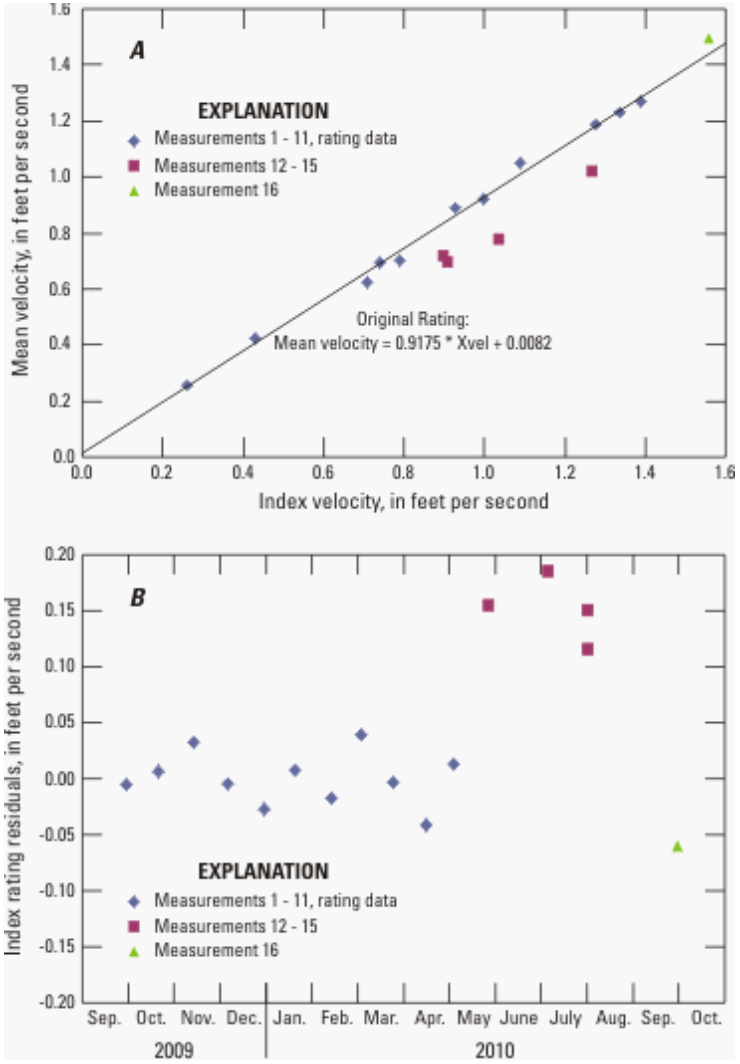
Identifying Justifications for Shifts

- Before you decide to shift or not, check for the following possibilities:
  - Synchronization (timing) errors
  - Incorrect stage-area rating calculations
  - Index-velocity data quality problems

Identifying Justifications for Shifts

- Shifts *can* be based on a single measurement but apply with CAUTION
- May need to collect several measurements and revise if needed
- Is the change abrupt or gradual?
- Can you <u>observe and document</u> a possible reason for the shift?



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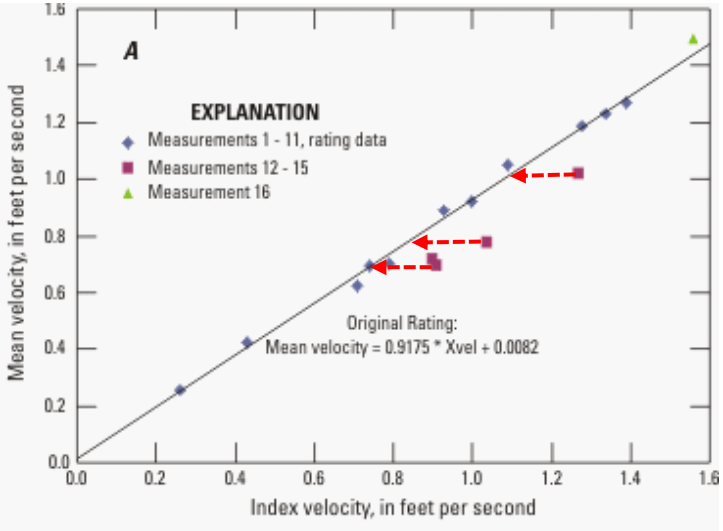
What to Shift

- Shifts are applied to the **INDEX VELOCITY**!
- Positive (+) shifts (Qms plot to left of rating when IV on x axis) indicate that index velocities are abnormally low (e.g., scour, change in velocity distribution due to upstream condition)
- Negative (-) shifts (Qms plot to right of rating when IV on x axis) indicate that index velocities are abnormally high (e.g., constriction such as sediment infilling or vegetation)



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How to Calculate Shifts

- SLR rating:

$$Optimum\ shift = \frac{(V_{mean_{meas}} - rating\ intercept)}{rating\ slope} - V_{index}$$

Where $V_{mean_{meas}}$ is the measured mean channel velocity

V_{index} is the average synchronized index velocity during the measurement

- MLR rating:

$$Optimum\ shift = \frac{(V_{mean_{meas}} - rating\ intercept)}{rating\ slope1 + (rating\ slope2 * stage)} - V_{index}$$

Where:

rating slope1 is the regression coefficient on the V_{index} term

rating slope2 is the regression coefficient on the V_{index} *stage term

stage is the average synchronized stage during the measurement

- Average shifts together where appropriate:
  - $average\ shift = \frac{\sum_1^n (shift_1, shift_2, shiftn)}{n}$

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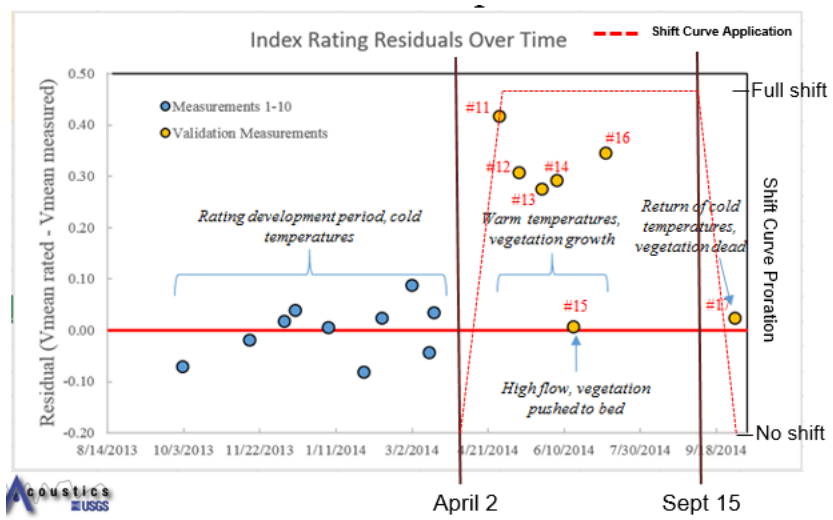
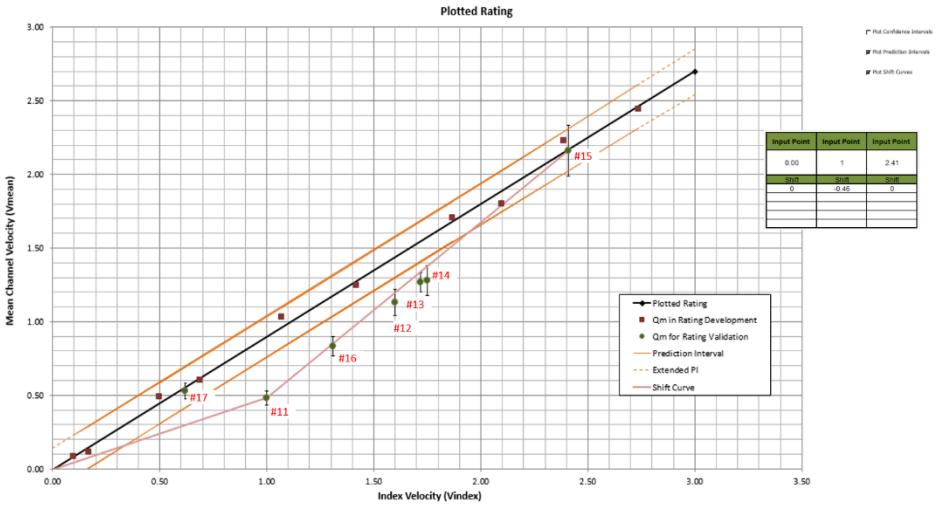
Caution – Shifts to MLR Ratings

- Shifts to MLR ratings are allowed but should be applied with extreme caution!
- Caution is needed because the shift is being applied to two terms in the rating equation.
- MLR shifts should be applied only to periods having similar stages and velocities represented by the measurement(s) used to define the shifts.

Applying the Shift

- Shift curves can be defined by as many as three points
- Determine time period to apply shift
- Document in Station Analysis





More Cautions

- Validity of shift
  - Define the range of applicable velocities
  - Identify the cause of the shift
  - Determine / document shift start and end times
  - Verify that the shift is linear (our assumption is that it is linear)
  - Most shifts should return to original index rating at upper and/or lower end (open-ended, parallel shift curves ok in some limited cases)

- More frequent than normal measurements may be needed to verify shifts

Tidal Sites

- Conditions changing rapidly
- Check measurements not usually possible
- Shifts can be applied ONLY if measurements have been made over the full range of the tidal cycle to define the shift curve

Memo Attachments

- A: Background equations for calculating prediction intervals
- B: Flowchart for determining what to do while in the field
- C: Shifting examples (3 different sites)
- D: Tip sheet for entering shifts in Aquarius
  - Note difference in shift application for SLR vs MLR ratings!
  - MLR requires creation of a “pass-through” velocity parameter

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Summary - Validation Requirements

- Make validation measurements following the same procedures as rating calibration measurements
- Synchronize measurements with velocity and stage data while in the field!
- Plot validation data on existing rating
- Evaluate data for patterns or trends
- Make check measurements if required
- Make decisions about shifts or rating changes, based on:
  - Rating uncertainty
  - Measurement uncertainty
  - Visual observations and other supporting information
- Document in Station Analysis

Spreadsheet Tools

- OSW sponsored the development of spreadsheet tools to help you implement the requirements in Memo 2017.03

https://hydroacoustics.usgs.gov/indexvelocity/ivsynctool.shtml

IV_SYNC and EXPORT_RATING

Description

The Index Velocity Synchronization and Shifting Guidance Tool, IV_SYNC, and the accompanying Index Velocity Rating Export Tool, EXPORT_RATING, are Microsoft Excel-based spreadsheet tools developed by Philip Habermehl (SAWSC) and Travis Knight (CFWSC) through support from OSW.

The IV_SYNC tool is intended for use while in the field and allows the user to perform the following tasks:

1. Synchronize a discharge measurement at an index-velocity streamgage with stage and velocity data collected during the measurement;
2. Plot a time series of discharge measurements and accompanying stage and velocity data to assist with grouping ADCP transects into individual measurements during periods of unsteady discharge;
3. Plot the discharge measurement on the index-velocity rating;
4. Calculate possible index-velocity shifts; and
5. Obtain guidance on whether a check measurement is required and/or a shift is justified based on measurement and rating uncertainty.

The EXPORT_RATING tool allows the user to create an .XML file that is needed by the IV_SYNC tool to display the index-velocity rating and rating uncertainty (prediction intervals). The EXPORT_RATING tool is intended for use in the office, prior to going in the field. The resulting .XML file needs to be created only once when a new index-velocity rating is developed.

The IV_SYNC and EXPORT_RATING tools help users comply with requirements in OSW Technical Memoranda 2012.01 and 2017.03.

The IV_SYNC and EXPORT_RATING tools can be used on desktops, laptops, and tablets running either 32- or 64-bit versions of the Windows operating system and **Microsoft Excel version 2013 or later.**

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DEMO of Spreadsheet Tools……

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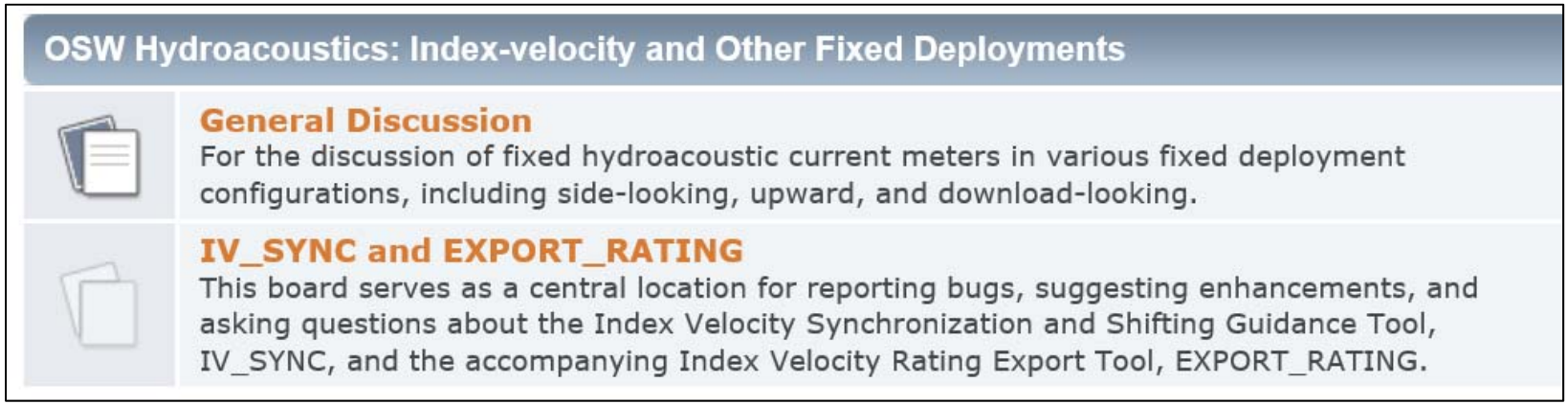
Spreadsheet Tools

- Report bugs and enhancement requests on the OSW HA Forum



Questions or Comments

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