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

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

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.

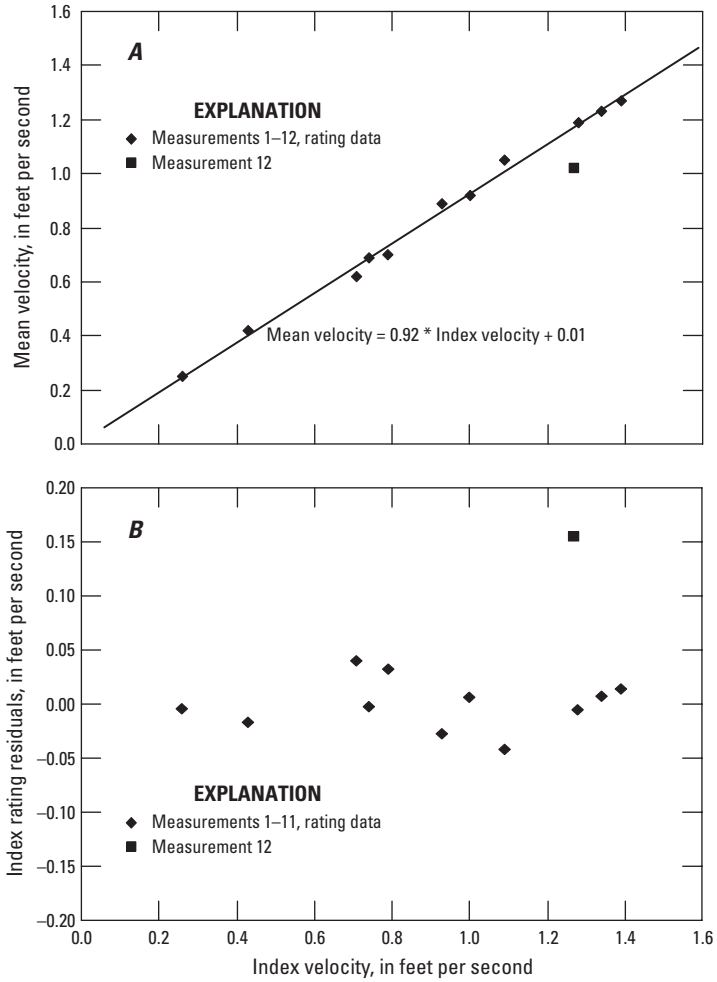


Figure 7-1. (*A*) Index rating plot and (*B*) residual plot with a divergent discharge measurement.

$$\text{Total error} = \sqrt{\sum_{1}^{n} error_1^2 + error_2^2 + error_n^2} \tag{7-2}$$

The rating should not be shifted based on this single measurement because the combined uncertainty (13 percent) is very near the combined uncertainty of the discharge measurement and the index rating (15 percent). Because the data were verified, a check measurement and cross-section re-survey should be performed. However, if additional measurements show the same divergent trend, a shift may be considered as long as there is a plausible hydraulic basis for it.

Subsequently, additional discharge measurements (numbers 13–15) were obtained and plotted on the index rating (fig. 7-2). Measurements 14 and 15 were made on the same day; measurement 15 is a check measurement that verifies measurement 14. A cross-section re-survey was performed on the same day that measurements 14 and 15 were made. The re-survey indicated a slight change in the cross-sectional area of approximately 3 to 5 percent. The results of measurements 12 through 15 combine to provide convincing evidence that the index rating has changed and that either a shift or a new rating should be developed.

An additional measurement (16) was then obtained. The rating, the data used to develop the rating, and the results of measurement 12 through 16, are shown in figure 7-3*A*. Measurement 16 suggests that the index rating has returned to the original index rating. The analysis of these measurements indicates that a rating shift can be established for a period of time ranging from near to the time of measurement 12 to a time between measurements 15 and 16. A range of measurements (12 through 15) provides a way to develop a shift that can be applied to the index velocity in order to compute a corrected mean velocity.

A shift could be computed for each measurement using the existing index rating (previously defined) and the measured-mean velocity for each measurement, solving for the index velocity.

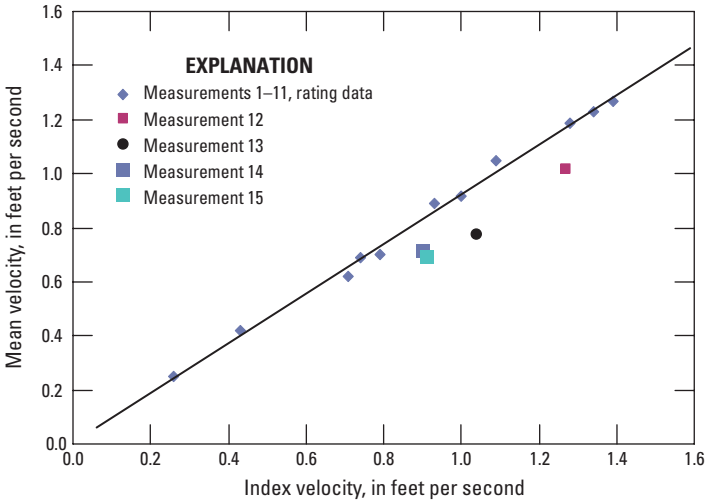


Figure 7-2. Divergent discharge measurements and the index rating.

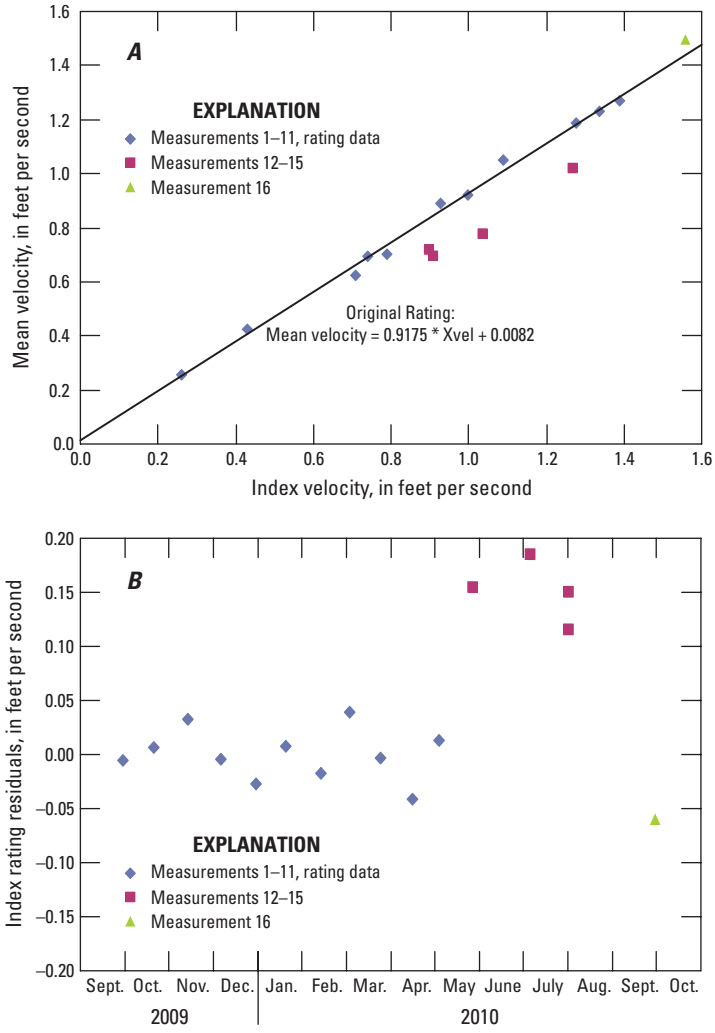


Figure 7-3. (*A*) Rating plot and (*B*) residuals plot with original rating measurements, the index rating, and five validation measurements.

$$\text{shifted index velocity} = \frac{\text{measured mean velocity} - 0.01}{0.92} \tag{7-3}$$

Shifting to each individual measurement may not be exactly valid, depending on the stream conditions, because of uncertainties in the discharge measurements and the index velocity. Computing a shift that is based on all the measurements diverging from the original index rating may be more accurate. In this example, the average value of the individual shifts (0.16) is subtracted from the index velocity values during the time that the rating required a shift. This shifted index velocity is then used to compute mean velocity in the computation of discharge. Figure 7-4 shows the results of shifting the index velocity values to match the measured-mean velocity from the discharge measurements.

Once the shift magnitude is determined, the beginning and ending times of the shift must be established. It may be possible to establish the time of the shifts using the stream hydrograph if the shift was due to changes in velocity distribution. If an electronics failure occurred, accurately defining the start and end times may be more difficult. The record quality during the time of the shift should be considered, unless adequate information and documentation can justify the shift based on hydraulic reasoning. A plot of the velocity residuals over time (fig. 7-3*B*) may help establish the beginning and ending times for the shift. In this example, the shift should be prorated over time at the start and at the end unless distinct changes in the stream or the data would indicate otherwise. As with stage-discharge ratings, the shift applied to an index rating is only applicable to the range of discharge, stage, and index velocity measured. Applying a shift to a range of conditions greater than those defined by measurements may result in an erroneous computation of discharge.

When a shift is applied, the justification for the shift must be documented in the station analysis. Evidence for the shift may be as simple as vegetation growing along the channel edges upstream of the index velocity sensor location that has been observed and documented (ideally with photographs). If visual observations of the channel conditions do not reveal a possible cause for the shift, then other field observations or measurements and data analysis should be made in an effort to explain the divergence of the measurements from the rating. Examples of additional useful field observations are verification of the index velocity sensor location and orientation, cross-section shape (standard cross section, upstream, and downstream cross sections), stage sensor malfunction, or change in offset. Examples of additional data analysis that can aid documentation and verification of shifts include verification of the ADVM configuration, time synchronization between in situ sensors and the discharge measurement, and quality-assurance review of internally recorded ADVM data.

When a divergence in the index rating is determined to be caused by an independent change in the index velocity sensor position, configuration, beam interference, or electronic failure, a shift analysis can be performed that uses regression analysis to determine the quantitative shift correction value. Remember that the applied shift may be limited to the range of flow conditions used to define the shift. In the case of an ADVM that has moved, calibration discharge measurements collected before and after the move are required to accurately assess the shift needed to correct the velocity data.

A shift may not be valid for any period other than that of the discharge measurement. For example, a sidelooking ADVM could have been accidentally rotated so that one beam was aligned parallel to the channel flow and the other beam was aligned nearly perpendicular to the channel flow. A shift may be difficult to determine and apply for conditions different from those at the time of the measurement, especially if the index velocity data are too noisy or not representative of the mean channel velocity. In this example, the velocity data during the time of the misaligned sensor should be considered invalid.

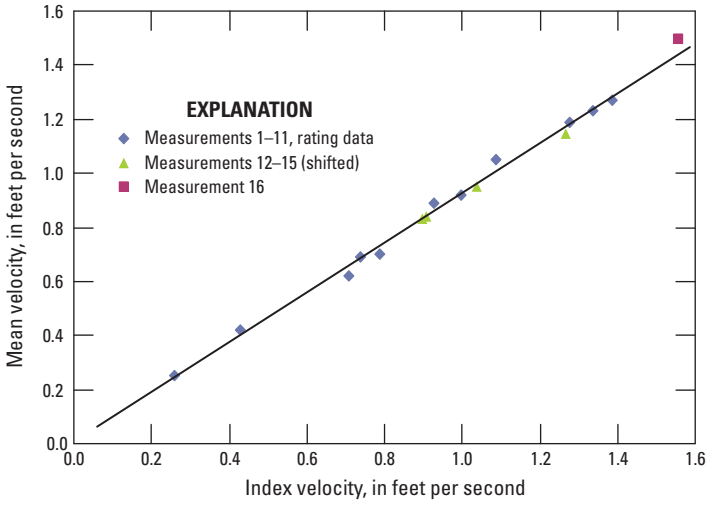
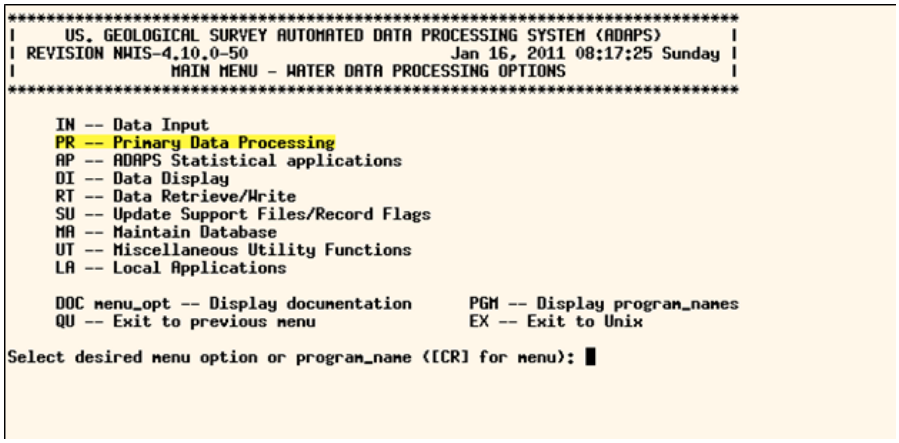


Figure 7-4. Shifted index velocity data and the index rating.

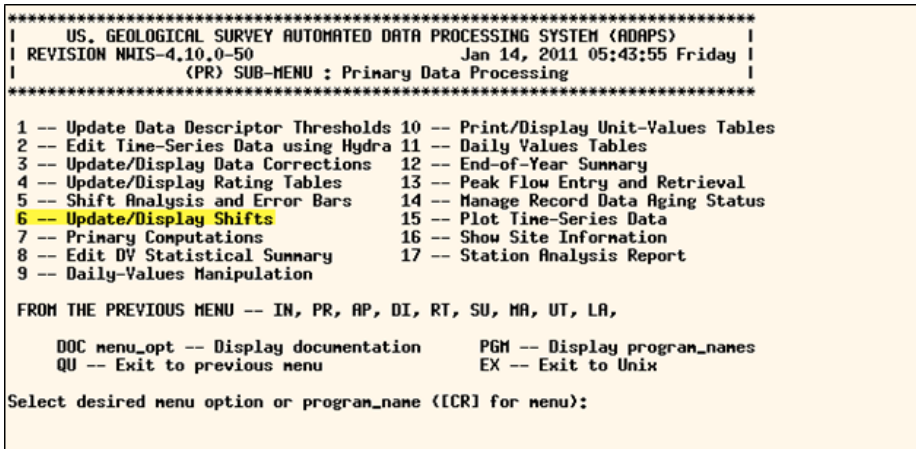
All available information should be considered in order to apply an index rating shift, and the limitations of using velocity shifts should be understood. An index rating shift can be caused by a change in cross-sectional area, a change in flow distribution, seasonal changes in channels caused by vegetative growth, or electronic failures. Discharge measurements are required to assess and determine any shift. If the computed mean velocity is a function of index velocity only, then a shift can be applied temporarily to the index velocity values. Index rating shifts may only be applicable for the specific measured condition and not for the total range of velocity. Determining appropriate times for shift application may be more difficult for index ratings than stage-discharge ratings, especially if an electronics failure occurs gradually over time. Field observations and measurements, as well as time-series data quality reviews, are critical to appropriate shift application. The same kind of hydrologic reasoning used for stage-discharge shift application (such as the hydraulics of the site, changes in channel shape or roughness, etc.) should be used for index velocity shifts.

Implementing a Shift for Index Ratings in National Water Information System (NWIS) Automated Data Processing System (ADAPS) version 4.10

1. Start ADAPS.
2. Select the Primary Data Processing (PR) option.



3. Select Update/Display Shifts (option 6).



4. Select the station and set the DD to Discharge.

```
                    SV_EDIT - UPDATE/DISPLAY SHIFTS
                          FLORIDA INSTALLATION
DATE: 01-16-2011     USER seanders                              TIME: 07:41:35
********************************************************************************
CURRENT USER INFORMATION
PA - FILE PATH     - /home/orl/ds/seanders
OT - OUTPUT TO     - Data General (TELNET) TERMINAL
--------------------------------------------------------------------------------
DB - DATA BASE     -  Main
AG - AGENCY        - USGS   US Geological Survey
ST - STATION(S)    - 02257000 FISHEATING CREEK AT LAKEPORT, FL
DD - DATA DESCR.   - Discharge (cfs)
YR - PERIOD        - WATER YEAR - 2011
********************************************************************************
Enter: PA,OT,DB,AG,ST,DD,YR  to edit field or
     [CR] to continue:
```

5. Select the rating to be shifted.

```
USGS  02257000 FISHEATING CREEK AT LAKEPORT, FL

                          TYPE AND ID MENU
                         ==================
                                                          RATING
            NUM    TYPE                                     ID
            ---    ----                                   ------

              1    velocity                               9.0
  Enter the number of the rating desired:
```

If no shift exists for the selected rating during the given water year, the following prompt will appear: RECORD NOT FOUND - WOULD YOU LIKE TO ADD IT [Y/N DEFAULT=Y]
Enter "Y" or press enter to bring up the edit screen to add shifts.

If a shift exists for the given rating in the given water year, a "shift correction" menu will appear.

```
                      SHIFT CORRECTION MENU
                     =======================

          "AD"  -  ADD correction values
          "ED"  -  EDIT/update correction values
          "DL"  -  DELETE entire selected record
          "VI"  -  VIEW correction values
          "LI"  -  LIST selection on screen/printer

          "ID"  -  Return to set ID screen
          "US"  -  Return to USer information screen

         "QUIT"  -  QUIT  and return to previous menu
         ENTER THE CODE OF THE FUNCTION DESIRED:
```

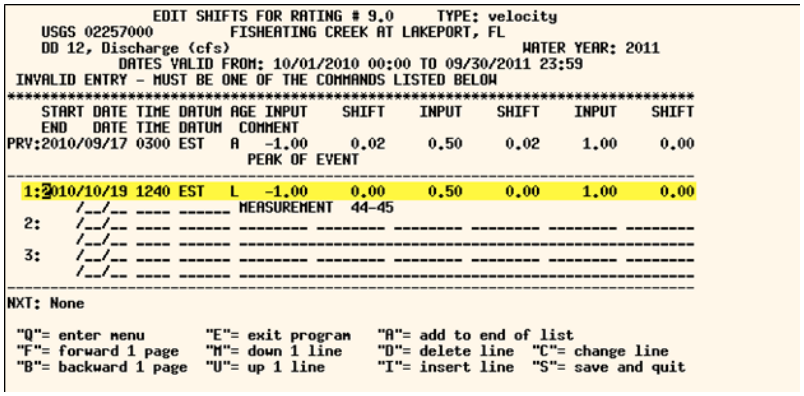
Selecting AD will bring up the edit screen with the cursor at a new line below the existing shifts. Selecting ED will bring up the edit screen with the cursor on an existing shift line.

6. The shift input table will be displayed after the rating is selected.

The station number, station name, and water year are listed at the top of the table. Listed next, with the line heading PRV, is the last shift for that rating from a previous water year.

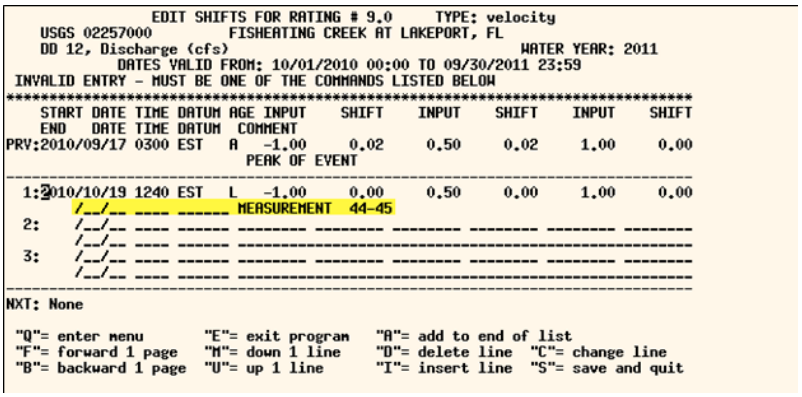
```
                EDIT SHIFTS FOR RATING # 9.0     TYPE: velocity
    USGS 02257000         FISHEATING CREEK AT LAKEPORT, FL
    DD 12, Discharge (cfs)                                  WATER YEAR: 2011
              DATES VALID FROM: 10/01/2010 00:00 TO 09/30/2011 23:59
 INVALID ENTRY - MUST BE ONE OF THE COMMANDS LISTED BELOW
********************************************************************************
    START DATE TIME DATUM AGE INPUT    SHIFT    INPUT    SHIFT    INPUT    SHIFT
    END   DATE TIME DATUM  COMMENT
PRV:2010/09/17 0300 EST   A   -1.00     0.02     0.50     0.02     1.00     0.00
                          PEAK OF EVENT
--------------------------------------------------------------------------------
  1:2010/10/19 1240 EST   L   -1.00     0.00     0.50     0.00     1.00     0.00
       /__/__ ____ ______ MEASUREMENT  44-45
  2:   /__/__ ____ ______ -------- -------- -------- -------- -------- --------
       /__/__ ____ ______ --------------------------------------------------------
  3:   /__/__ ____ ______ -------- -------- -------- -------- -------- --------
       /__/__ ____ ______ --------------------------------------------------------
--------------------------------------------------------------------------------
NXT: None

 "Q"= enter menu       "E"= exit program   "A"= add to end of list
 "F"= forward 1 page   "M"= down 1 line    "D"= delete line  "C"= change line
 "B"= backward 1 page  "U"= up 1 line      "I"= insert line  "S"= save and quit
```

The first shift for the selected water year (the 2011 water year in this example) is displayed with the line heading "1." The start date and time (24-hour time) and time zone are listed on the first line, followed by the input points and corresponding shift values (the ± correction to index velocity). The first shift has three input points and corresponding shift values.



If it is a one-point shift, the shift will be applied as a constant across the entire range of index velocities regardless of the index velocity entered. If it is a two- or three-point shift, the shift will be prorated between the input index velocities and will be carried as a flat shift for values less than or greater than the least and greatest specified input index velocities, respectively.

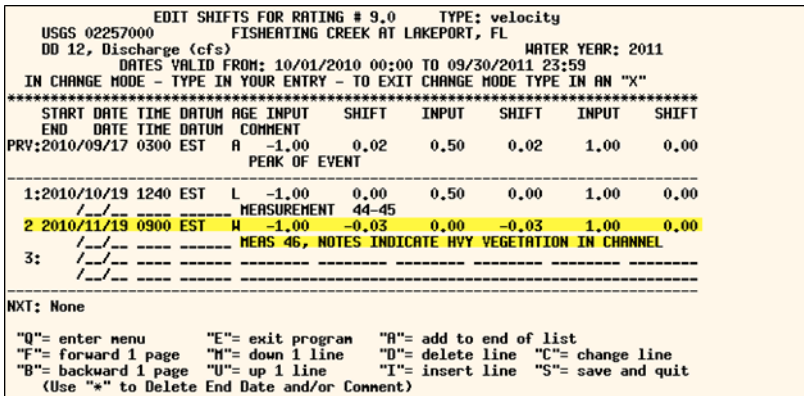
On the next line, the end date and time are followed by any comments pertaining to this shift. This shift is applied to the period between the start time and the end time. If no end time is entered (as in this example), the shift is prorated to the next shift, or held constant if there is no next shift.



The variable shift input form displays up to three shift values per page. To move the cursor from one shift value to another shift value, enter "M" to move to the next one or "U" to move to the previous one. To see the next page of shift values, enter "F." As many as 333 pages of shift information can be entered for a water year. To move back to a previous page, enter "B," which returns you to the page immediately preceding the current one.

7. Add a new variable shift value to the end of the list by entering "A." This automatically places the cursor at the end of the list after which the entry is then made.

   Enter the month, day, time, time zone, input value (index velocity), and corresponding shift values in the spaces provided. The time zone can be skipped by pressing enter after the time. The default time zone for that station at that date and time will be automatically entered, and the entry will skip to the first shift index velocity input point. Up to three pairs of index velocity shifts may be entered on a line after the time data. These three points are entered with the first point being the lowest index-velocity shift. After entry of the first line of shift information, press enter to get to the second line. On the second line, the date and time can be left blank, and the shift will prorate linearly through time to the next available shift. If a date and time is entered on the second line, the shift will be held constant through time and ended at the date and time specified.



Note: When inputting shifts (whether inserting, adding, or changing), the input points and the corresponding shift are separated by spaces. The values will not be lined up perfectly under the headers as they are entered. After entering all data on a line, a carriage return will center the data in their respective columns. Any comments on the end date line should be lined up under the comment header.

The comment line should be filled out for every shift entered. The comment should provide information about why the shift was applied and about the events or measurements upon which the shift is based.

8. To discontinue entries and exit from the Add mode, enter “X.”
9. To save entries and exit, enter “S.”

Note: The record must be recomputed for the shift adjustments to be applied correctly.