Standard Operating Procedure for Discharge Measurements in Wadeable Streams in California

CDFW-IFP-002

August 2013

California Department of Fish and Wildlife
Instream Flow Program
Sacramento, California

Standard Operating Procedure for Discharge Measurements in Wadeable Streams in California
CDFW-IFP-002

Approved by:

Robert Holmes, CDFW Instream Flow Program Coordinator, August 27, 2013

Beverly van Buuren, Quality Assurance Program Manager, August 27, 2013

Prepared by:

Melinda E. Woodard, Quality Assurance Research Group, Moss Landing Marine Laboratories, August 27, 2013

Table of Contents

List of Figures

Acknowledgements

This standard operating procedure represents the protocols for collecting discharge measurements in wadeable streams in California of the California Department of Fish and Wildlife Water Branch Instream Flow Program. Procedures for discharge data collection and qualitative evaluation of discharge measurements in this standard operating procedure draw from United States Geological Survey procedures (Rantz et al. 1982; Turnipseed and Sauer 2010). This standard operating procedure was developed by Melinda Woodard with the Quality Assurance Research Group at Moss Landing Marine Laboratories. Technical review of this document was provided by departmental staff.

Suggested Citation

CDFW, 2013, **Standard Operating Procedure for Discharge Measurements in Wadeable Streams in California.** California Department of Fish and Wildlife Instream Flow Program Standard Operating Procedure CDFW-IFP-002**,** 24 p. Available at: http://www.dfg.ca.gov/water/instream_flow.html.

Abbreviations and Acronyms

CDFW	California Department of Fish and Wildlife
Department	California Department of Fish and Wildlife
FPA	Fixed Point Averaging
IFP	Instream Flow Program
HP	Head Pin
LWBE	Left Wetted Bank Edge
Model 2000	Marsh-McBirney Model 2000 Flo-Mate Portable flowmeter
RWBE	Right Wetted Bank Edge
SOP	Standard Operating Procedure
TP	Tail Pin
USGS	United States Geological Survey
Wading rod	USGS Top-Setting Wading Rod

Introduction

This document is the California Department of Fish and Wildlife (CDFW) Water Branch Instream Flow Program (IFP) standard operating procedure (SOP) for collecting discharge measurements in wadeable streams using the Marsh-McBirney Flo-Mate Model 2000 Portable flowmeter (Model 2000) with the United States Geological Service (USGS) Top-Setting Wading Rod. This SOP also includes general guidelines based on those of USGS (Rantz et al., 1982; Turnipseed and Sauer 2010) necessary for collecting velocity measurements and calculating stream discharge that are not specific to use of the Model 2000, as well as USGS guidelines for evaluating and assessing the quality of the discharge measurements. This SOP is intended for use with other IFP SOPs that involve collecting discharge measurements, as relevant.

The CDFW Instream Flow Program encourages staff and contractors to contact us with any questions or for assistance with project planning. For more information, contact Diane Haas of the CDFW IFP at: Diane.Haas@Wildlife.ca.gov or (916) 445-8575.

Scope of Application

This SOP provides procedural reference for Department staff conducting discharge measurements in wadeable streams, when site conditions and research objectives indicate discharge measurement is an appropriate methodology. It is also intended as an informational resource for staff from other state and federal agencies, nongovernmental organizations, private contractors, and other organizations throughout California.

Document overview

In this document, the discharge measurement procedure covers the following topics:

- Guidelines for site selection of discharge transects
- General care and calibration of the Model 2000 and USGS Top-Setting Wading Rod
- Use of the Model 2000 in conjunction with the USGS Top-Setting Wading Rod to collect velocity measurements at predetermined depths
- Collecting Data with the Model 2000
- Qualitative evaluation of the discharge measurement
- Making discharge calculations

Section 1: Preparing for Field Work: Site Selection

Before collecting discharge data, it is important to select a site with characteristics that support accurate flow measurements. Discharge measurements may be collected at any time of year as long as the guidelines outlined below are met.

Crew safety is of paramount importance; ensure that the river can be safely sampled by crews. Contact the CDFW Instream Flow Program for project planning assistance, as needed.

Locating the Discharge Transects

The first step in making an accurate flow discharge measurement is to select a cross section with desirable properties (Turnipseed and Sauer 2010). A desirable cross section is depicted in Figure 1. The USGS recommends that cross sections with the following characteristics be chosen whenever possible:

- The channel is reasonably straight, the streambed is stable, the streambed is free of large rocks, weeds, and physical obstructions that would create eddies, slack water, or turbulence that could influence velocity measurements;
- Cross sections are roughly parabolic, trapezoidal, or rectangular in shape with even flow across the transect - no more than 5% of the total water discharge should be in any one cell on the cross section, defined as the distance between two adjacent vertical measurement points on the cross section transect;
- Ideally the water surface is smooth, mirror-like with steady, uniform, nonvarying flow conditions;
- Ideally the cross section is located relatively close to a gaging station to avoid effects of intervening drainage area inflows or diversions between the cross section and the gaging station if there will be a comparison between field and gage values;
- The wetted lengths of the transects are wide enough to make velocity measurements for at least 20 sections;
- Sites should not be immediately downstream of sharp bends or vertical drops.

Figure 1: Example of discharge transect exhibiting desirable site qualities in natural stream channel. Auburn Ravine, CA.

Section 2: Preparing for Field Work: Preparation, Calibration and Use of Field Equipment

This section describes how to prepare, calibrate, and use the Model 2000 and USGS Top-Setting Wading Rod in the field. The procedures for inspection, calibration, and set-up should be followed before continuing on to data collection in Section 3. This SOP only covers use of the Model 2000 and USGS Top-Setting Wading Rod; if using a different velocity meter, follow the guidelines for calibration and use provided by the manufacturer in the product manual.

2.1 Inspection and Calibration of the Model 2000

The Model 2000 is an electronic, battery powered device. Precautions should be taken to ensure cables are not worn, frayed, or damaged. Before each field day, the Model 2000 should be physically inspected to ensure it is not damaged and that all connections and fittings are intact, tight and secure. The Model 2000 velocity sensors are located on the front end of the meter probe. Care should be taken when handling the meter probe so as to not touch the three velocity sensors and to keep them clean of foreign substances and oils. The Model 2000 is calibrated at the beginning of each field day by performing a zero check and, as necessary, a zero adjustment. The following procedure for the Model 2000 is consistent with the manufacturer's instruction manual (Marsh-McBirney 1990). A paper copy of the manual should be kept with the field team operating the meter.

To calibrate the Model 2000, complete the following steps before each field day:

Step 1: Check to make sure that the sensors on the Model 2000 probe are clean. Oil films on the electrodes may cause noise and interfere with readings. Remove any films from the sensors by gently wiping the sensors with 1000-grit or greater wet-dry sandpaper.

Note: Avoid directly touching the sensors with fingers or sunscreen.

Step 2: Suspend the probe in a five gallon bucket of water. Ensure that the probe is at least three inches away from the sides and bottom of the bucket. Figure 2 represents an example set up for calibration.

Figure 2: Set up for calibration of the Model 2000 flow meter. This example shows the probe suspended from the rebar, and stabilized by the hammer.

Step 3. Wait five to ten minutes before continuing the calibration process. The water in the bucket and the probe must be completely still before proceeding to Step 4.

Step 4: When the water is still, power the meter on and let the meter run through one complete cycle of velocity measurements. The minimum cycle time is 40 seconds; refer to Marsh-McBirney (1990) for cycle time adjustment as needed.

Step 5: Depress the "STO" (store) and "RCL" (recall) buttons at the same time to begin the zeroing process. Make sure the probe does not move when the buttons are pressed on the Model 2000). The screen will read "3" (Figure 3).

Figure 3: Model 2000 screen when beginning the zeroing process.

Step 6: Depress the down arrow on the meter three times to set the display to 0).

Note: The down arrow must be pressed within 5 seconds or the display will report "err" (error). Repeat the process from Step 3 if an error code appears.

Step 7: The Model 2000 will immediately count down on the display from 32 to 0. The meter will automatically turn off after the zero adjust process is complete.

Step 8: Turn the meter back on without moving the probe. Allow the meter to run through one complete velocity cycle. Zero stability of this instrument is +/- 0.05 ft/sec. If a velocity of greater than +/- 0.05 ft/second is read, repeat the zero adjust process from Step 3.

Consider cleaning the sensors or giving more time for the water to stabilize inside the bucket before repeating the process.

Note: The Model 2000 must be properly calibrated before field data collection can begin.

2.2 Inspection of the USGS Top-Setting Wading Rod

The USGS Top-Setting Wading Rod (wading rod) should be inspected carefully before each field day. The wading rod is a ½” hexagonal stainless steel rod with an aluminum threaded replaceable base plate and an anodized aluminum handle. A 3/8” aluminum suspension rod is attached to the hexagonal rod by a sliding support at the bottom and the handle. The suspension rod slides up and down the hexagonal rod with the sensor attached to the sliding support. The wading rod should be inspected each day to ensure the base plate and all parts are secure and working properly. If any part of the wading rod assembly comes loose or falls off, there is a strong risk that measurements taken will be in error because the geometry of the rod will have been altered from its factory condition.

The wading rod must be inspected and in good working condition before use in data collection.

2.3 Connection and use of the Model 2000 with the USGS Top-Setting Wading Rod

Before beginning discharge data collection, attach the Model 2000 to the wading rod as follows (Figures 4 and 5):

Step 1: Place the Model 2000 probe over the narrowed bottom end of the sliding portion of the rod.

Step 2: Turn the wing screw on the probe clockwise to secure the probe onto the rod. Do not over-tighten the thumb-screw on the probe

The fixed portion of the rod is graduated by tenths of feet. Twin graduation marks represent 0.5 foot increments and triple graduation marks represent foot increments. The sliding portion of the rod is graduated in one foot increments.

Figure 4: Attaching Probe of Model 2000 attached to the wading rod using wing screw.

Figure 5: Probe of Model 2000 attached to the wading rod.

2.4 Determining Depth for Velocity Collection Across the Transect

The Model 2000 velocity meter, which measures velocities across the transect, is used in conjunction with the wading rod, which measures stream depth, to determine site-specific discharge measurements. The depth that the Model 2000 probe is set at for each individual measurement across the discharge transect is based upon the depth of the water column at that collection point. In accordance with USGS (Turnipseed and Sauer 2010) protocol:

- <u>If the depth is at least 0.20 ft (the minimum depth the rod can measure) and less than 2.5 ft</u>, one measurement is recorded at a depth of six-tenths below the top of the water column
- <u>If the depth is 2.5 ft or greater, two measurements</u> are taken, one at two-tenths and a second at eight-tenths depth below the top of the water column.
    - If this two point method indicates a non-standard or inverted velocity profile, also obtain a velocity measurement at six-tenths depth. The velocity at six-tenths depth is then averaged with the average of the two-tenths and eight-tenths velocities to determine the velocity at that point in the transect.

<u>*Note: A minimum of 20 vertical "cell" measurements are required per discharge transect, with no more than 5% of the total flow occurring in any one cell or between any two vertical measurement points, as outlined in Section 3.2, Step 6.*</u>

2.5 Using the Model 2000 and Wading Rod to Collect Data

The vernier scale on the handle of the wading rod is graduated in tenths of feet (Figure 6). When the scale on the sliding suspension rod is aligned with the vernier scale on the handle to the water depth observed on the hexagonal rod, the Model 2000 probe is automatically set to six-tenths depth from water surface. The vernier scale can be read to the nearest 0.01 feet by visually interpolating between the 0.10 graduations. This is particularly important when measuring shallow depths.

- <u>For depths measuring 0.20 ft to 2.5 ft:</u> set probe to six-tenths of the total depth from the water surface by lining up the foot scale on the suspension rod with the vernier scale on the wading rod handle. For example, if the depth is 0.9 ft, line up the 0 on the suspension rod foot scale with the 9 on the wading rod handle's vernier scale (Figure 5).

- <u>For depths equal to or greater than 2.5 ft:</u> set the probe to two-tenths and eight-tenths of the total depth. For example, if the depth is 2.8 ft, set the wading rod as follows:
  - o To measure two-tenths depth from water surface, double the depth observed on the hexagonal rod (i.e., 2.8 ft x 2 = 5.6) and set the scale to 5.6 by aligning the 5 on the suspension rod foot scale with the 6 on the vernier scale of the wading rod handle.
  - o To measure eight-tenths depth from surface, divide the depth by two (i.e., 2.8 ft / 2 = 1.4) and set the scale to 1.4 by aligning the 1 on the suspension rod foot scale with the 4 on the vernier scale of the wading rod handle.

Figure 6: USGS Top-Setting Wading Rod handle showing vernier scale set at 0.9 ft.

2.6 Checking Display Outputs on the Model 2000

After attaching the Model 2000 to the wading rod, check the display outputs of the Model 2000.

To ensure that the Model 2000 is in the correct mode, a check should be conducted at the beginning of the sampling day and at the beginning of each transect. The procedure for checking display outputs of the Model 2000 is as follows:

Step 1: Power the Model 2000 on.

Step 2: Check that the velocity units are ft/s. If unit is not ft/s, toggle between velocity units by simultaneously pressing "ON/C" and "OFF" buttons until display reads ft/s.

Step 3. Check that the display shows that the meter is using Fixed Point Averaging (FPA) with a period of at least 40 seconds. FPA averages the velocities read by the meter over a set period of time. At the end of this time, the display shows the averaged velocity. The FPA display shows a time bar underneath the velocity output that indicates the amount of time remaining in the averaging period. To toggle between FPA and time constant filtering (rC), simultaneously press the up and down arrow buttons on the meter.

Step 4: After the display indicates FPA, it will show the number of seconds used for averaging. Check that this number is 40 seconds. If it is not, press the up or down arrows until the display reads 40 seconds.

Section 3: Field Procedures

Once a site has been identified for discharge measurements as in Section 1, and the field equipment has been prepared as described in Section 2, proceed with field procedures. Establish, mark, and photograph the transects at a site before collecting data. During the initial discharge data collection event at a site, locate the discharge transect and mark it with a headpin (HP) on the left bank, a tailpin (TP) on right bank. Flag the transect with site information both above the high water mark and on the HP. The HP and TP should be marked with 2.5 to 4 ft long ½" rebar. HPs and TPs can be hammered into the stream bank at or above bankfull water surface elevation.

After the survey tape measure is installed from HP to TP, photograph the discharge transects from left bank (HP to TP) and the entire study site from downstream before collecting discharge measurements. Photographs are important for documenting and comparing transect areas between measurements. If the stream channel changes its structure between measurements due to downstream migration of woody debris or sediment, the hydraulics of the stream can change, which will affect the stage/discharge relationship of the transect. Field staff should clearly note on the data sheet any changes to the stream channel in the transect area.

Projects generally use at least one discharge transect per site, with a minimum of 20 velocity measurements collected per transect. Contact the CDFW IFP for more information or assistance with project planning.

Following data collection, a qualitative evaluation of the transect must be conducted to determine the general quality of field conditions and associated quality of data. The quality of the qualitative evaluation is directly dependent on the experience of the staff conducting the evaluation. Qualitative evaluation guidance and staff experience requirements are outlined in Section 3.3.

3.1 Equipment List

Prior to going in the field, inspect and pack the following equipment. Crews should pack enough equipment to accommodate work on multiple transects.

- Marsh-McBirney Model 2000 Flo-Mate Portable flowmeter velocity meter and manual
- USGS top-setting wading rod
- Five gallon bucket for initial flowmeter calibration
- Small plastic bucket for meter recalibration in field
- Fiberglass measuring tapes (100-300 feet)
- Extra rebar
- Hammer
- Rite in the Rain field data sheets/note book, clipboard, pencils
- Camera
- Flagging, such as survey tape, and permanent marker
- Tool kit with extra batteries, ≥ 1000 grit wet-dry sandpaper, screwdriver, knife, zip ties, duct tape, electrical tape

- Field data sheets and qualitative evaluation data sheets, as found at: http://www.dfg.ca.gov/water/instream_flow.html.

3.2 Data Collection

Step 1: Populate the top fields of the data sheet, including site information, location, Model 2000 identification number, and staff names.

Step 2: Insert a staff gage into the substrate near the stream's edge (Fig 7). This gage should be located near the discharge transect, but out of the way of foot traffic so that it is not disturbed during data collection. Record the gage water surface height and time or measurement at the beginning and end of data collection. This accounts for any changes in water surface height due to flow changes that may occur during data collection.

Figure 7: Example of staff gage.

Step 3: Record the gage water surface height in the “Gage Start” field of the data sheet and start time.

Step 4: Secure the survey tape measure to the HP, then run survey tape measure across stream and secure it to the TP with minimum slack, but not so tight to break the tape.

Step 5: Take photos in the following sequence for consistency and ease of managing large sets of photos:

A. Photograph the transect flagging showing the discharge site number and transect number.
B. Photograph the transect while standing upstream above the HP on the left bank, across the stream to the TP, including the survey tape measure.

C. Photograph the entire longitudinal profile of the transect from HP to TP (while standing downstream of the transect and facing upstream). Record the photo ID numbers on the data sheet.

Step 6: With the survey tape measure secured from the HP to the TP, record the stream wetted width from left bank wetted edge (LBWE) to right bank wetted edge (RBWE). Divide the wetted width by 20. The resulting number is the maximum interval along the survey tape measure where the velocity measurements will be taken. A minimum of 20 velocity measurement are required across the transect. For example, if the stream width is 53 feet, the maximum interval required for velocity measurements is 2.65 feet. For ease of measurement, the crew may decide to measure velocity at 2 ft or 2.5 ft cell intervals across the transect. Smaller, more narrow cell widths may also be needed in the deepest cells to ensure no cell exceeds 5% of the total flow across the transect.

Note: No more than 5% of the total flow should occur in any one cell or between any two vertical measurement points.

Step 7: Starting on the left bank (looking upstream), at each station along the survey tape measure the record the following information on the data sheet: each station number (1 – 20 or more), each station distance from the HP on the survey tape measure, and the width between vertical measurements along the transect.

Step 8: Check the display outputs on the Model 2000 as described in Section 2.6.

Step 9: Stand on the downstream side of each station to avoid interfering with velocity measurements. At each station, place the wading rod onto the stream bed, check that it is plumb, and record the stream depth from the hexagonal rod onto the data sheet. Check that the Model 2000 probe is facing directly into the flow at the station, and that there is no debris impeding or otherwise obstructing the probe sensors from detecting flow at that point.

Step 10: Adjust the suspension rod to the proper depth as described in Section 2.5.

Step 11: On the Model 2000 depress the “ON/C” button. The Model 2000 will start recording velocity for 40 seconds. When the time bar on the bottom of the Model 2000 display reaches the end of 40 seconds, it will start over and the average velocity will be displayed. Record this velocity measurement number on the data sheet.

Step 12: Repeat Steps 7 through 11 at each station along the survey tape on the transect.

Step 13: Upon completing the discharge data collection, record the end gage water surface height and the end time on the data sheet. It may be necessary to make more frequent staff readings if there is concern about changing stage during data collection.

Note: CDFW IFP recommends calculating discharge in the field for the transect as outlined in Section 4. Check for measurement and transcription errors, and re-measure as necessary.

3.3 Qualitative Evaluation of Discharge Measurements

Immediately after completing discharge measurements on a transect, it is recommended that the hydrographer conduct a qualitative assessment of the discharge measurements for the sample site per USGS protocol (Turnipseed and Sauer 2010). This evaluation is conducted for all discharge transects. The quality of this assessment is heavily influenced by the experience and training of the hydrographer, who are recommended to meet basic minimum qualifications such as:

- A Bachelor’s degree, or higher, in hydrology, stream ecology, or related field
- At least one field season of experience conducting discharge measurements
- Training on conducting qualitative evaluations by CDFW IFP

Contact the CDFW Instream Flow Program for additional information or training on conducting qualitative evaluations of discharge measurements.

Factors for Consideration in Scoring Qualitative Evaluations

The hydrographer should consider many factors when conducting the qualitative evaluation of discharge measurements. Among these important factors are:

- Measuring section: Consider the conditions in the transect that could affect the accuracy of the discharge measurement. Such conditions include: uniformity of depths, smoothness of the streambed, composition and uniformity of the streambed (silt, gravel, cobbles, detritus), presence of bridge piers or other obstructions, and the ability to accurately measure depth.
- Velocity conditions: Consider the factors present that could affect the accuracy of measuring velocity. Such conditions could include: smoothness of velocity, very slow or very high velocity, turbulence, factors that could affect the vertical distribution of velocity, and the use of the one-point method, two-point method, or three-point method with unusual velocity profiles (as outlined in Section 2.4).
- Equipment: Consider the working condition of the velocity meter being used to conduct field work.
- Spacing of observation verticals: A minimum of 20 vertical measurements should be used per discharge transect, with each subsection containing no more than 5% of total discharge. Using fewer vertical measurements may reduce the accuracy of the discharge measurement.
- Rapidly changing state: Rapidly changing stage can negatively affect the accuracy of discharge measurements, and should be avoided when determining where to conduct discharge measurements. A temporary staff gage is used to determine if flows conditions have changed during the measurement process (see Section 3.2, Steps 3 and 13).
- Ice: The presence of ice generally decreases the accuracy of velocity and depth measurements. Ice affects velocity distribution and may negatively affect equipment. The minimum operating temperature of the Model 2000 is 32 degrees F.
- Wind: Wind can affect accuracy of discharge measurements by changing the vertical distributions of velocities, and may obscure the angle of the current or produce waves that complicate depth readings. The effect of wind on the velocity profile lessens as depths and stream velocity become greater.

Qualitative Evaluation of the Discharge Measurement

When conducting the qualitative evaluation, the hydrographer should consider the impacts on velocity measurement accuracy present for all of the factors listed above, as well as the overlapping impacts of these factors. The hydrographer should also consider the ambient factors written on the data sheet (cross section, flow, weather) that impact measurement accuracy. All information on the qualitative evaluation data sheet should be considered by project managers to determine impacts of field conditions on data quality.

Section 4: Discharge Calculations

CDFW IFP recommends that, in accordance with USGS policies, discharge is calculated in the field as a check on depth measurements and velocity transcription. After field work is completed, discharge data are then checked before entering the data electronically in the office. Discharge may be calculated using the Discharge Data Input File. Discharge can also be calculated by hand. Directions for both methods are included in this section.

Discharge Calculations using the Discharge Data Input File

Discharge may be calculated for each transect by inputting data from the data sheet into the Discharge Data Input File. This Excel spreadsheet automatically calculates the average velocity for each observation vertical and the discharge at each vertical observation. The discharges at each vertical observation are then summed to calculate the total discharge of the transect.

Details of Discharge Calculations

Discharge is calculated using the width, depth, and velocity data from each point in the transect.

Equation 1: Discharge of a Cell

Discharge (ft^3/s) = width of cell (ft) x depth of cell (ft) x velocity (ft/s)

For example, if the width of a cell (distance between two points measured on a transect) is 1 ft, depth is 1.2 ft, and velocity is 1.3 ft/s, discharge would be calculated as:

Discharge (ft^3/s) = 1 ft x 1.2 ft x 1.3 ft/s = 1.56 ft^3/s

Total discharge across a transect may then be found by summing together each cell's discharge rate:

<u>Equation 2: Discharge of a Transect</u>

$$\textbf{Total discharge for transect } (ft^3/s) = (D_1 + D_2 + D_3 + \ldots D_n)$$

Where:

- D1 = discharge for cell 1
- D2 = discharge for cell 2
- D3 = discharge for cell 3
- n = total number of cells in transect

To check what percent of the total transect discharge was found in the cell with the largest discharge value, use the following equation. This is an optional calculation that may be used to check for exceedence of 5% of the total transect flow in any one cell.

<u>Equation 3: Check for Exceedence of 5% Total Discharge</u>

$$\textbf{Maximum \% of cell discharge } (ft^3/s) = (Q_{Largest} / Q_{Total}) \times 100$$

Where:

- $Q_{Largest}$ = largest discharge value (ft^3/s) found in any one cell
- Q_{Total} = total discharge of transect (ft^3/s)

Section 5: Care and Maintenance of Model 2000

The Model 2000 is an electromagnetic current meter. Water moving across the probe sensors creates a current distorting a magnetic field produced by the meter. The meter converts the distortions into flow velocity. Foreign substances like oils, such as sunscreen, change the conductivity of the sensors and affects velocity measurement. General practice is to not touch the front end of the Model 2000 probe with fingertips. The back and sides of the probe can be handled. If staff believe the probe sensors have been covered by a foreign substance or if the meter is displaying error (err) messages, gently rub the surface of the sensors with fine (1000 grit or greater) wet-dry sand paper.

The Model 2000 is an electronic device powered by two D size batteries. Battery life with alkaline batteries is 25 to 30 hours (Marsh-McBirney 1990). Staff should always have an extra set of batteries accessible in the field in case the Model 2000 stops operating. Replacement of the batteries requires either a standard flathead or Phillips head screw driver. If the batteries must be replaced while measurements are underway the meter should be recalibrated in accordance to Section 2.1, and noted prominently on the data sheet. If there is no physical way to recalibrate the meter in the field then staff should note this on their field data sheet for the measurements taken after the batteries were replaced. Staff are encouraged to bring a small plastic bucket with them into the field for calibration purposes.

Glossary

Bankfull discharge	The maximum discharge that the channel can convey without overflowing onto the floodplain
Cell	The distance between two adjacent vertical measurements along the transect
Vernier scale	A small moveable scale that slides along a main scale; the small scale is calibrated to indicate fractional divisions of the main scale
Vertical measurements	Measurements for depth and velocity taken along the discharge transect. Also called observation verticals.

References

Annear, T., I. Chisholm, H. Beecher, A. Locke, and 12 other authors. 2004. Instream flows for riverine resource stewardship, revised edition. Instream Flow Council, Cheyenne, WY.

Marsh-McBirney, Inc. 1990. Flo-Mate Model 2000 Portable Flowmeter Instruction Manual. P105 0003 01, Rev. D, 11/00. Accessed 10/19/2011 at: http://www.hachflow.com/pdf/Model_2000_Manual.pdf

Rantz, S.E. and others. 1982. Measurement and Computation of Streamflow. Volume 1. Measurement of Stage and Discharge. U.S. Geological Survey, Water Supply Paper 2175. Accessed online at: http://pubs.usgs.gov/wsp/wsp2175/html/WSP2175_vol1_pdf.html 313 pp.

Turnipseed, D.P., and Sauer, V.B. 2010. Discharge measurements at gaging stations: U.S. Geological Survey Techniques and Methods book 3, chap. A8. 87 p.