

|                                       |                             |              |
|---------------------------------------|-----------------------------|--------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 1 of 10 |
|                                       | Revision 1                  |              |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |              |

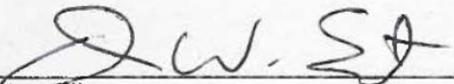
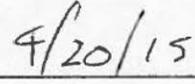
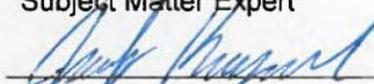
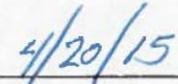
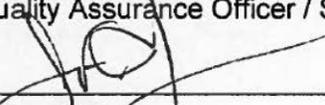
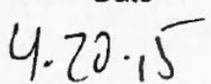
New Mexico Environment Department  
Surface Water Quality Bureau

Standard Operating Procedure

for

## STREAM FLOW MEASUREMENT

Approval Signatures

|   |   |
|---|---|
|  |  |
| Douglas Eib<br>Subject Matter Expert  | Date  |
|  |  |
| Jodey Kougioulis<br>Quality Assurance Officer / Subject Matter Expert             | Date  |
|  |  |
| James Hogan<br>Acting Program Manager   | Date  |

### 1.0 Purpose and Scope

This procedure describes the process and equipment for measuring stream flow. Flow is used by SWQB staff to validate and calibrate programs that model flow; for determining if flow-based standards criteria are in effect when chemical data was collected; for loading calculations in TMDLs; and in models such as SSTemp, used for estimating temperature load reductions.

The SWQB commonly determines flow by measuring water velocity with a current meter and cross-sectional area with a wading rod and a tagline. USGS Techniques of Water Resources Investigations Reports<sup>1</sup> refers to this as the Current-Meter Method. Flow measurement using a wading rod, tagline and current meter is based on the continuity equation,  $Q = AV$ , where  $Q$  = flow (cfs);  $A$  = cross-sectional area (ft<sup>2</sup>);  $V$  = mean velocity (ft/s).

Besides measuring flow, flow data can be obtained from gaging stations from the USGS or New Mexico Office of the State Engineer websites: <http://waterdata.usgs.gov/nm/nwis/current/?type=flow> or <http://meas.ose.state.nm.us/meas/home.jsp>. Measurements from gages will almost always be more accurate than estimates made with velocity meters, with two exceptions: a stagnant pool sometimes forms around a gage stilling well, causing a positive reading when there is actually no flow; and, after, channel altering flows, gages may need recalibration. Therefore, regularly visiting gages, both physically and on the above mentioned websites, is necessary to make sure the data they generate is accurate and suitable for use by SWQB staff.

When possible, streamflow should be measured as close as possible, in location and time, to physical and chemical water quality measurements. The accuracy of the Current-Meter Method, however, is highly

<sup>1</sup> <http://pubs.usgs.gov/twri/>. See *general procedure for gaging streams*, USGS TRWI Book 3, Chapter A6, and *Discharge measurements at gaging stations*, USGS TWRI Book 3, Chapter A8.

|                                       |                             |              |
|---------------------------------------|-----------------------------|--------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 2 of 10 |
|                                       | Revision 1                  |              |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |              |

dependent on the channel morphology where the measurement is made and finding a channel cross section that has equal flow through each window and a bottom free of obstacles is more important than locating the measurement at the site where other data is collected (see 6.1, below). Absent the presence of factors that might influence flow, such as tributaries or groundwater input, gage data can be used for long distances above and below the physical gage location. Meticulous flow measurements are not useful under unstable conditions such as during snowmelt, or during storm events, when flow changes over a short time and a single instantaneous measurement does not characterize flow over an extended period.

## 2.0 Responsibilities

All personnel who measure stream flow are responsible for implementing this procedure.

Before using equipment necessary for this procedure staff are required to sign out the equipment for the period it will be used on the Bureau's online check-out.

## 3.0 Precautions

### *Streambed Dangers and Obstacles*

Some channels have quicksand-like areas, deep holes, sharp rocks, fallen logs, etc., that can cause foot entrapment, injury, or falls. The wading rod (without the current meter attached) can be gently used for stabilization and to probe the streambed when conditions are uncertain. Use professional judgment to assess risks involved with working in the streambed.

### *Rule of 10*

Wading across a streambed can be dangerous depending on flow and substrate conditions. Do not attempt to wade into a stream if the depth (in ft) multiplied by the velocity (in ft/s) equals or exceeds 10. For example, a stream 2 ft deep and with a velocity of 5 ft/s or more should be considered too dangerous to wade. If you start to take measurements and discover that you are violating or will violate the rule of ten, return to the nearest bank and note "too fast/deep to measure" on the field form.

## 4.0 Definitions

LEW – Left Edge of Water. The left edge of the wetted stream channel, facing downstream.

REW – Right Edge of Water. The right edge of the wetted stream channel, facing downstream.

ft/s – feet per second

cfs – cubic feet per second

## 5.0 Equipment and Tools

The velocity meters that the Bureau uses are manufactured by:

Marsh-McBirney  
Flo-Mate 2000 Portable Flowmeter  
Phone: 800.368.2723 or 800.635.1230 (24/7 Technical Support)  
Email: [hachflowservice@hach.com](mailto:hachflowservice@hach.com)  
Internet: <http://www.marsh-mcBirney.com/>

Price Pygmy and AA  
Rickly Scientific  
Email: [sales@rickly.com](mailto:sales@rickly.com)

|                                       |                             |              |
|---------------------------------------|-----------------------------|--------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 3 of 10 |
|                                       | Revision 1                  |              |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |              |

Internet: <http://www.rickly.com/cgi/pygmy.htm> or <http://www.rickly.com/cgi/AA.htm>

Hach Hydromet (aka OTT MF Pro)  
5600 Lindbergh Drive  
Loveland, CO 80538  
Phone: 970.9669.3050  
Email: [sales@hachhydromet.com](mailto:sales@hachhydromet.com)  
Internet: [www.hachhydromet.com](http://www.hachhydromet.com)

The meters are used in conjunction with a top setting wading rod, available from:

Rickly Scientific  
Phone: 1-800-561-9677  
Email: [sales@rickly.com](mailto:sales@rickly.com)  
Internet: [http://www.rickly.com/cgi/wading\\_rods.htm](http://www.rickly.com/cgi/wading_rods.htm)

Additional necessary equipment includes bank pins and a tape measure (in feet) to serve as the tag line.

## **6.0 Step-by-step Process Description**

### 6.1. Standard Stream Flow Measurement

This procedure describes the process for determining stream flow by measuring stream cross-sectional area using a wading rod and tagline and measuring velocity using velocity meters. Data can be recorded on printed versions of either the Flow Sheet and Calculator or the *Flow Field Sheet* depending on staff preference. Digital recording is also an option when using advanced flow meters.

#### 1) *Select Measurement Location*

The measurement cross section should be located in a straight run or gentle riffle. Do not place a cross section through a pool. Where the length of straight run is limited, the length upstream from the cross section should be twice the downstream length.

- The channel should be as free of flow disturbances as possible. Try to avoid areas with sudden changes in stream width, contributing side streams, outgoing side streams or obstructions such as pipes, boulders, or logs. Divided channels can be used by calculating the flow in each channel and summing.
- Depths need to be at least 0.15 ft and should ideally be greater than 0.5 ft, and velocities mostly greater than 0.5 ft/s. If depths are less than 0.15 feet, use the timed-fill method described in Section 6.2.1., or just visually estimate. Enter flows judged to be less than 1 cfs simply as <1 cfs.
- The flow should be laminar (i.e., free of swirls, eddies, vortices, backward flow, or dead zones). Avoid areas immediately downstream from sharp bends or obstructions.
- The ideal streambed is "U" shaped, stable and free from large rocks, weeds and protruding obstructions that would create turbulence or interfere with the current meter. The investigator may modify the channel by removing cobbles that interrupt flow, or to temporarily make the channel deep enough to measure. Alternatively, consider using the timed-fill method, which is more accurate at very low flows.
- If necessary, build small dikes to keep water from flowing around the cross section. This is to keep all water flowing through the cross section and to prevent leaks into secondary channels (although choosing a better site is strongly recommended).

#### 2) *Set the Tagline*

|                                       |                             |              |
|---------------------------------------|-----------------------------|--------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 4 of 10 |
|                                       | Revision 1                  |              |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |              |

String a tagline (tape measure) or lay a survey rod across the stream at the chosen cross section and secure it using bank pins, a Silvey stake or vegetation. The tagline should be perpendicular to the flow (not necessarily at right angles to the whole channel) and about one foot above the water level. Make sure the tagline is tight, level and does not contact the water.

### 3) *Establish Cross Sectional Windows*

Measure the stream's wetted width and divide this width into partial sections (windows). The number of windows will depend on the wetted width of the stream (Table 1). Flow measurements made with fewer windows than stipulated in Table 1 should be entered into SQUID as estimates.

Table 1. Number of stations in relation to waterway width based on EN-ISO 748 standards.

| Stream Width (ft) | Number of Windows |
|-------------------|-------------------|
| < 1.6             | 5 to 6            |
| > 1.6 and < 3.3   | 6 to 7            |
| > 3.3 and < 9.8   | 7 to 12           |
| > 9.8 and < 16.4  | 13 to 16          |
| > 16.4            | 22 or more        |

*The above serves only as a guideline for setting cross sectional windows. As necessary, adjust for changing depths and velocities, increase or decrease individual window widths. The goal is to have equal flow through each window, not equal window widths. In addition the first and last flow measurements should be made as close to the REW and LEW as possible.*

If a cross section cannot be established that is free of boulders or other debris that, these should be noted on the field form as they may influence measurements. If these obstructions create windows that have no flow they are not to be included in the tally of windows measured.

### 4) *Take Velocity and Depth Measurements*

Observe the tagline measurement at LEW. Enter measurement on first row (marked LEW) of field flow sheet. Enter depth = zero, velocity = zero.

Remove the top-setting wading rod from its carrying case and attach the sensor from the flow meter to the sensor mount and tighten the thumbscrew. Adjust the cable linking the sensor to the meter to avoid unnecessary slack and interference with the sensor and wading rod mechanism.

Move to the first point in the water – which as noted above should be the first point with sufficient depth to take a flow measurement. Enter the tagline measurement on the flow sheet. Measure water depth by reading the hexagonal portion of the top set wading rod. Enter water depth on the flow sheet. Place the current meter at the appropriate depth (see box below). Stand several inches downstream from the tagline and about 18 inches to one side of the meter to avoid disrupting the flow near the meter. For small streams, where your feet would occupy a significant portion of the wetted perimeter, stand on the bank, entirely out of the water. Ensure that the wading rod is vertical (if unsure, hold a rod level against the wading rod to check). Ensure that the current meter is facing upstream directly into the flow.

#### Marsh-McBirney Operation

Press "clear" (ON/C) and wait for the reading to stabilize. Check to make sure the meter is recording in ft/sec. If recording in m/sec change units by pressing "on" and "off" buttons at the same time.

|                                       |                             |              |
|---------------------------------------|-----------------------------|--------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 5 of 10 |
|                                       | Revision 1                  |              |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |              |

*Record the velocity after the reading has stabilized. If the reading does not stabilize, wait for the time bar to fill completely (40 seconds) and record the velocity.*

Move to the next location, press clear to reset the averaging and repeat the procedure.

See Attachment 1 for more details.

#### Price Meter Operation

Model 921 Revolution Counter: Allow a few moments (several seconds or longer in velocities less than one foot per second) for the meter to stabilize. Press “on” and start the stopwatch simultaneously. Count revolutions for 40 to 70 seconds. End the measurement at some convenient number of revolutions (generally a multiple of five, as listed across the top of the rating table included with the meter). Look up the velocity on the rating table supplied with the meter. Locate the column corresponding to the number of revolutions, and then locate the row corresponding to the number of seconds. Record the velocity. Move to the next location and repeat the procedure.

CMD 9000: Turn the meter on, select the appropriate sensor, and adjust the other settings (“English” or “metric,” etc.). Allow a few moments (several seconds or longer in velocities less than one foot per second) for the meter to stabilize. When ready, press “start/stop.” The instrument will automatically count and indicate the velocity. Record the velocity. Move to the next location and repeat the procedure.

See Attachment 2 for more details.

#### Hach Hydromet / OTT MF Pro Operation

Before leaving the lab, confirm that the battery is charged. Consult the manual for instructions on battery installation and charging. Pages 12 and 13 of the Operating Instructions (Attachment 3 should also be consulted to become familiar with the user interface.

Unlike the other flow meters described in this SOP, the MF Pro can remain attached to the top-setting wading rod. For transportation, cover the meter with a bubble-wrap sleeve. Also, the sensor on this instrument measures depth electronically so reading depth from the hexagonal portion of the wading rod is not required. Finally, once the wetted width of the channel is entered, along with the desired number of windows, the window locations will be determined automatically by the instrument.

To operate the MF Pro, push the power button while the sensor is out of the water, until an audible beep is heard. The meter will perform a self-test. When it is complete push OK and push the main menu button to go to the main menu. The meter goes into a sleep mode and automatically shuts off when not in use.

1. In the main menu, select “Profiler”.
2. Enter the Operator’s name and press OK.
3. Select “Profile” and press OK
4. Enter a stream name using a maximum of 11 characters or leave the field blank and press OK (entering a stream name before taking measurements is optional and saves progress if the complete flow measurement is interrupted).
5. Enter zero for the stage reference and press OK.
6. Enter the tagline distance at the far wetted edge and press OK.
7. Enter tagline distance at the near wetted edge and press OK.
8. Enter the number of desired equidistant windows and press OK.

|                                       |                             |              |
|---------------------------------------|-----------------------------|--------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 6 of 10 |
|                                       | Revision 1                  |              |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |              |

9. For the first and last measurement windows (and for windows that occur over mid channel islands), select "Edge/Obstruction" from the menu and press OK.
10. Select Edge (right, left, and press OK). For vertical banks, record a depth and assign a roughness factor of 0.5. The velocity will be set to zero automatically for Edge measurements.
11. Select "Next" on the menu screen.
12. Select "Edge/Obstruction" from the menu and press OK.
13. Select Open Water and press OK. (Open Water is the default option and is automatically selected if "Edge/Obstruction" is not assigned for an individual window)
14. Select "Distance to Vertical" from the menu and press OK. A diagram will appear on the sensor screen showing the position on the tagline for the current window.
15. Select "Set Depth" and move the sensor to the lowest position possible on the wading rod and look for the max depth reading on the screen. When it stabilizes, press OK (The offset from the bottom has been pre-programed into the sensor).
16. Select "Measure Velocity" from the menu and select 1 or 2 point, depending on the max depth (see Positioning the Current Meter, below) and press OK.
17. Set the sensor at the depth indicated on the sensor screen and press "Capture". When the reading has stabilized or the 20 s integration period has elapsed, press OK.
18. Press "Next" on the menu screen.
19. Repeat steps 14 to 18 until the opposite edge of water is reached and then repeat steps 9 to 11.
20. Select "Channel Summary" from the menu and record the flow for the station on the field sheet for the station and press OK.
21. Select "Save File and Exit" from the menu and press OK.
22. Name the file using a maximum of 11 characters. A date will be appended to the file so it is unnecessary to include one in the filename. Press OK.

The sensor is able to store a maximum of 10 files with up to 32 windows each.

Upon return from the field, files can be downloaded to PCs via the USB port. The files can be handled as comma delineated Excel files.

Downloaded files should be saved to the appropriate survey folder in MAS Core Documents.

#### Positioning the Current Meter

Place the current meter at the velocity measurement depth by matching the measured depth (or a multiple or fraction) with the vernier scale on the top-setting wading rod (see Attachment 4 for more details). If the stream depth is less than 2.5 ft, measure velocity at 60% depth from the surface by matching the measured depth with the vernier. If the stream depth is 2.5 ft or greater, measure velocity at 20 and 80% depth by matching twice and one-half of the measured depth with the vernier (see box below).

|                                       |                             |              |
|---------------------------------------|-----------------------------|--------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 7 of 10 |
|                                       | Revision 1                  |              |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |              |

If the depth is from 2 inches (0.15 ft) to 2.5 ft, measure velocity at 60% depth.

1. Measure the depth at each location using the scale on hexagonal (fixed) shaft of the top setting wading rod.
2. Use the measured depth to locate the current meter at 60% depth. Move the sliding (round) shaft so that the correct one foot line on the sliding rod lines up with the correct tenth foot line on the vernier scale. For example, if the stream depth is measured at 1.4 feet, move the one foot line on the sliding rod until it is adjacent to the 4 on the vernier scale.

If the depth is equal to or greater than 2.5 ft, measure velocity at 20% and 80% depth.

1. Measure the depth at each location using the scale on hexagonal (fixed) shaft of the top setting wading rod.
2. To place the current meter at 20% depth, double the water depth measurement, then move the sliding shaft so that the line corresponding to twice the measured depth is adjacent to the correct tenth foot line on the vernier scale. If the stream depth is 2.8 ft, position the 5 ft line on the sliding rod at the 6 on the vernier scale.
3. To place the current meter at 80% depth, halve the water depth measurement, then move the sliding shaft so that the line corresponding to half the measured depth is adjacent to the correct tenth foot line on the vernier scale. If the stream depth is 2.8 ft, move the 1 foot mark on the sliding rod to the 4 on the vernier scale.
4. Average the two values to obtain the mean velocity.

Enter in the field flow sheet velocity column either the 60% depth velocity, or the average of the 20 and 80% depth velocities.

Take last velocity measurement as close to the REW as possible. At the REW row (the last row), enter tagline measurement. Enter depth = zero, velocity = zero.

#### 5) *Calculate Total Flow*

The flow in each section equals the average water velocity multiplied by the cross-sectional area of each window. To determine the cross-sectional area of a window, use the depth as measured in the middle of the window and multiply it by the window width.

For each window, calculate the window width based on the meter locations preceding and following (except those adjoining the REW and LEW which use the tag line distance at this location. That is, if you placed the meter at 3.0, 5.0, and 8.0 ft (along the tag line), then the window width at the "5-foot" section window would be 2.5 ft, calculated as follows:

$$\text{Window width} = \left( \frac{8-5}{2} + \frac{5-3}{2} \right) = \left( \frac{8-3}{2} \right) = 2.5 \text{ feet}$$

Calculate the flow through each window by multiplying the velocity by the window width by the window depth (velocity by cross-sectional area). **Table 1** illustrates these data and results (NOTE: The non-bolded items are directly measured in the field; the bolded items are calculated).

|                                       |                             |              |
|---------------------------------------|-----------------------------|--------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 8 of 10 |
|                                       | Revision 1                  |              |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |              |

Table 21 Example of velocity by cross-sectional area calculations for determining flow. Note that revolutions and time only need to be recorded for the Price Model 921 Revolution Counter.

| Tag line location (ft) | Window width (ft) | Depth (ft) | Revolutions | Time (seconds) | Velocity (f/s) | Flow (cfs)      | Comments      |
|------------------------|-------------------|------------|-------------|----------------|----------------|-----------------|---------------|
| 3.0                    | 1.0               | 0.0        | NA          | NA             | 0.000          | 0.00            | LEW           |
| 5.0                    | <b>2.50</b>       | 0.7        | 15          | 44             | 0.361          | <b>0.63</b>     |               |
| 8.0                    | <b>2.10</b>       | 0.8        | 25          | 43             | 0.596          | <b>1.00</b>     | Rock          |
| 9.2                    | <b>1.35</b>       | 1.3        | 40          | 43             | 0.937          | <b>1.64</b>     |               |
| 10.7                   | <b>1.05</b>       | 1.9        | 60          | 41             | 1.460          | <b>2.91</b>     |               |
| 11.3                   | <b>0.85</b>       | 2.1        | 150         | 40             | 3.690          | <b>6.59</b>     | Thalweg       |
| 12.4                   | <b>1.35</b>       | 1.4        | 80          | 45             | 1.760          | <b>3.33</b>     |               |
| 14.0                   | <b>1.80</b>       | 1.0        | 20          | 47             | 0.444          | <b>0.80</b>     |               |
| 16.0                   | <b>1.00</b>       | 0.2        | NA          | NA             | 0.200          | <b>0.40</b>     | REW           |
| <b>13.0 ft</b>         |                   |            |             |                |                | <b>17.3 cfs</b> | <b>TOTALS</b> |

### *Calculating Total Flow Using the Spreadsheet*

The Excel spreadsheet associated with this SOP and also located in SWQB Public can be used to calculate total flow. Transfer data from field sheets to the spreadsheet and calculate the total flow. Enter the result into SQUID and save a copy of the completed spreadsheet for each station where flow was measured in the survey/project binder.

## **6.2 Alternate Flow Measurement Methods**

Velocity meters are the most common tool used by the SWQB to measure stream velocity in order to determine flow. At times, however, these meters may not be available or stream conditions may require additional or alternate methods. Also, in some instances there may be a staff gauge to measure depth and determine flow based on previously measured channel geometry.

The SWQB can also measure flow by making direct volumetric (timed-fill) measurements, by using surface floats, by indirect methods (such as based on the Manning equation), by developing rating curves and measuring gage height, by constructing artificial controls (weir plates and Parshall flumes), or by dye dilution methods. Details on these methods can be found in USGS Techniques of Water Resources Investigations Reports (<http://pubs.usgs.gov/twri/>) (USGS 1968 and 1969). Some of these methods are discussed below. Any measurements of flow made with these methods should be entered into SQUID as estimates.

### *6.2.1 Timed-Fill*

At low flows, the timed-fill method may be used. Collect the entire flow of the stream in a bucket; possible locations may be below a waterfall or weir. For example, use a stopwatch to measure the time it takes to fill a 5 gallon bucket. 5 gallons = 0.6684 ft<sup>3</sup>, so 0.6684 / elapsed time in seconds = cfs.

### *6.2.2 Surface Floats*

The method involves measuring the velocity with a surface float and multiplying by the cross-sectional area. Estimates by this method may be too inaccurate for use in interpretation of data or final reporting, but may be useful in preliminary planning of studies and in conducting subsequent, more precise, measurements. The velocity measurement consists of dropping a neutrally buoyant object such as an orange or a rubber ball in the current and noting the time required for it to travel a known distance.

|                                       |                             |              |
|---------------------------------------|-----------------------------|--------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 9 of 10 |
|                                       | Revision 1                  |              |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |              |

A suggested procedure for measuring the velocity using a surface float is as follows:

Measure and mark two points, one upstream and one downstream, at least two channel widths apart. Two observers are best, one upstream and one downstream. The upstream observer places the float into the channel above the marker and calls out when it crosses the upstream point, at which point the downstream observer starts a stopwatch. The downstream observer sights across the stream at the lower point. When the float passes the downstream point, the downstream observer stops the stopwatch and records the elapsed time.

Repeat the procedure 5 to 10 times. Each float should be a different distance from the bank to get a rough average of velocities across the channel. Average the values to get the mean surface velocity and then multiply it by a velocity adjustment coefficient of 0.85 (to account for friction) to calculate the mean velocity of the entire cross section.

Measure the cross-sectional area and multiply velocity by the area to calculate flow.

### 6.2.3 Manning's Equation

Velocity can be estimated based on the physical characteristics of the channel. The characteristics include streambed roughness, channel shape and slope of the water surface. Several empirical methods are available to use these characteristics to estimate stream velocity. One of these is the Manning equation:

$$V = (1.49/n)R_h^{2/3}s^{1/2}$$

where  $R_h = A/WP$

- V = average velocity in the stream cross section (ft/sec);
- $R_h$  = hydraulic radius (ft);
- A = cross-sectional area of flow (ft<sup>2</sup>);
- WP = wetted perimeter (ft);
- s = energy slope as approximated by the water surface slope (ft/ft);
- n = roughness coefficient.

To estimate velocity using the Manning equation, estimate a roughness coefficient for the stream bed from tables available in the literature. Values range from 0.026 for coarse sand to 0.070 for boulders. A common default value is 0.035.

The channel shape is described by the hydraulic radius,  $R_h$ , which is the ratio of the wetted perimeter to the area. The wetted perimeter is the perimeter of the cross sectional area that is "wet"; that is, the portion of the stream bed that is in contact with the water. In wide rectangular channels the hydraulic radius approaches the depth as the channel width increases. Generally, it is necessary to measure both the wetted perimeter and the cross-sectional area.

Measure the water surface slope or estimate the slope from the slope of the stream bed. After estimating the velocity using the Manning equation, calculate the flow by multiplying the velocity by the cross-sectional area.

Using this method, wetted perimeter and cross-sectional area may be correlated to a stage (gauge height) and flow may be estimated in the field using a staff gauge. Stream bed roughness, channel shape and slope measurements can be made in both wet and dry channels.

### 6.2.4 Rating Curve

A rating curve is the relationship of flow to stage (or gage height). It is constructed by plotting successive measurements of flow and gage height on a graph. This relationship is then used to convert records of gage height into flow rates. Due to changing channel morphology, curves must be checked periodically to

|                                       |                             |               |
|---------------------------------------|-----------------------------|---------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 10 of 10 |
|                                       | Revision 1                  |               |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |               |

ensure that the relationship between flow and gage height has remained constant. Scouring of the stream bed or deposition of sediment can cause the rating curve to change so that the same recorded gage height produces a different flow. A constant relationship between water level and flow rate at a given site can be assured by constructing a flow control device of known dimensions in the stream, such as a sharp crested weir or flume.

## 7.0 Related Forms

Attachment 1 Marsh-McBirney Flo-Mate 2000 Portable Flow Meter Operating Instructions  
Attachment 2 Price Current Meter (Pygmy or AA) Operating Instructions  
Attachment 3 Hach Hydromet/ OTT MF pro Operating Instructions  
Attachment 4 Top Setting Wading Rod

Flow Sheet and Calculator  
Flow Field Sheet

## 8.0 Revision History

**Revision 1 (April 7, 2015)** - Added information on Hach Hydromet Flow Meter; edits to language regarding number of windows required for various stream widths.

**Revision 0 (March 21, 2011)** – Original modified from SOP 2007

|                                       |                             |              |
|---------------------------------------|-----------------------------|--------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 11 of 3 |
|                                       | Revision 1                  |              |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |              |

## Attachment 1

### Marsh-McBirney Flo-Mate 2000 Portable Flow Meter Operating Instructions

The following information is a summary of the Marsh-McBirney, Inc. Flo-Mate 2000 Portable Flowmeter instruction manual (Marsh-McBirney 1990). The Marsh-McBirney flow meter measures velocity with an electromagnetic sensor and displays results in either feet per second (f/s) or meters per second (m/s).

#### **Assembly and Calibration**

1. Remove sensor and a comfortable length of cable from the flow meter case. Attach the sensor to the top setting wading rod on the mounting shaft at the bottom and tighten the thumbscrew. Check to make sure the base of the wading rod is secure.
2. The unit should always power up in real time operating mode, as opposed to memory recall. The display should be set to Fixed Point Averaging (FPA), where the readings are stabilized by averaging velocities over a fixed period of time (the alternative is time constant filtering [rC]). Pressing the up and down arrows simultaneously will alternate between rC and FPA displays and the FPA display will show the letters FPA when you first switch over and afterwards will be indicated by the time period bar at the bottom of the display. The fixed period of time default is 40s and may be altered with the up or down arrows. SWQB uses 40s as its time period standard.
3. Calibrate the sensor at the beginning of each field season. To calibrate the sensor, first clean it with soap and water. If there are nonconductive coatings, such as oil or grease, errors may occur due to noise or conductivity loss. Do not use any hydrocarbon solvents for cleaning. Place the sensor in a 5-gallon bucket filled with water at least 3 inches away from the sides and bottom of the bucket (use the wading rod to hold it in the appropriate position). Wait 10 or 15 min to make sure that the water is not moving. Set the time period to 5s. The zero stability is  $\pm 0.05$  ft/s. In order to reset the zero, press STO and RCL at the same time while the sensor is still in the bucket (unmoved). The number 3 will display. Decrement the 3 to 0 with the down arrow. Then the number 32 will display and the unit will decrement itself to zero and turn off. It is now calibrated. Make sure you return the time period to 40s.

Note: There is a 5 second time limit between keys when zeroing. If you wait too long and ERR 3 is displayed, turn the power off and start over.

#### **Error Messages**

- Noise – Indicates that there is excessive electrical noise in the water, and the display will blank out. It is normal for this message to appear for a few seconds when the sensor is first submerged.
- Con Lost – Indicates that the electrodes are out of the water or have been coated with grease and conductivity is lost. If this continues after washing with soap and water, the electrodes can be cleaned with very fine (600 grit) sandpaper. After 5 min of this message, the unit will shut down.
- Low Bat – Replace the 2 D-cell batteries in the bottom of the unit. Usually when this flag appears the battery will have 15-30 min of life left.

|                                       |                             |              |
|---------------------------------------|-----------------------------|--------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 12 of 3 |
|                                       | Revision 1                  |              |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |              |

## Attachment 2

### Price Current Meter (Pygmy or AA) Operating Instructions

The following information is a summary of, and intended for use in conjunction with, the Scientific Instruments, Inc. Model 1205 Price Type "Mini" Current Meter user's manual. All "Price-type" current meters operate essentially the same way regardless of size, method of measurement, suspension means or data collection methods. A balanced bucket wheel is mounted on a vertical pivot and is turned by flowing water. Water velocity is determined by counting the number of revolutions of the bucket wheel over a given period of time. A "cat whisker switch" produces a signal that is either manually counted or recorded by a counting instrument. This value, or count, is then compared on a cross reference chart, or rating chart, to yield water flow velocity.

- For velocities less than 3 ft/s, use the Mini (Pygmy) current meter.
- For non-wadeable flows or velocities greater than 3 ft/s, use the Price AA current meter.
- According to the USGS, a current meter should not be used in velocities less than 0.2 ft/s, unless there is no other option.

### Assembly and Calibration

1. Inspect and assemble the meter. Remove the meter from the travel case and inspect the buckets for damage. Any visual damage, such as a bent cup, will yield an erroneous measurement. Replace the brass travel plug with the stainless steel pivot. Inspect the pivot for fractures, roughness, or other evidence of wear (use a new one as necessary). Put a drop of oil on the pivot. Insert the pivot firmly against the pivot-adjusting nut (the pivot has a flat side that should be positioned beneath the set screw that secures the pivot).
2. Ensure that the pivot is not too loose. The rotor (bucket wheel) should have a very small amount of vertical play, such that it is not impaired by the pivot while rotating. Loosen the pivot nut set screw, adjust the pivot nut out one-eighth turn and re-tighten the set screw. Loosen the pivot set screw, insert the pivot against the new adjusting-nut position and re-tighten this set screw. Check rotor play again and repeat this step as necessary.
3. Do not turn the bucket wheel clockwise. This can damage the contact wires, causing inaccurate readings. Always rotate counterclockwise as viewed from above.
4. Ensure that the pivot is not too tight. The rotor should spin freely (be sure it's right-side up, because it will not spin freely when upside down). If the rotor tends to stop abruptly, inspect the pivot and pivot bearing (on the rotor) for damage. If the pivot bearing is too tight, loosen it by turning the pivot-adjusting nut out (use one-eighth-turn increments, as described above).
5. Conduct the spin test. This procedure must be performed completely out of the wind, such as in the vehicle. After assembling the meter, attach it to the wading rod. Tighten the mounting screw and attach the sensor wire to the binding post, ensuring that the electrical connection does not short-circuit from the post to the meter housing. Attach the counter or flow computer to the plug at the top of the wading rod. While holding the wading rod so that the rotor is horizontal (as used in the water), give the rotor a brisk flip with your finger (always counterclockwise; spinning clockwise may damage the sensor) and ensure that the counter is registering the spinning rotor. Ensure that the rotor spins for at least one minute and comes slowly to a stop. If it does not, readjust the pivot or identify and fix the meter damage.

### Troubleshooting

Some waters cause an intermittent failure of the meter. This seems to be a mechanical failure of the whisker sensor associated with high turbidity resulting from some forms of silt-clay. SWQB staff have not found a solution to this problem, except to use a different measurement method (such as the Marsh-McBirney meter). Following exposure of the Price current meters to such waters, it must be disassembled and rinsed well (it appears to begin functioning properly after about ten minutes use in clear water).

|                                       |                             |              |
|---------------------------------------|-----------------------------|--------------|
| Title: <b>Stream Flow Measurement</b> | No: SOP 7.0                 | Page 13 of 3 |
|                                       | Revision 1                  |              |
| Effective Date: 4/7/2015              | Next Revision Date 4/7/2017 |              |

**Attachment 3**

**Hach Hydromet / OTT MF Pro Operating Instructions –Selected Sections-**

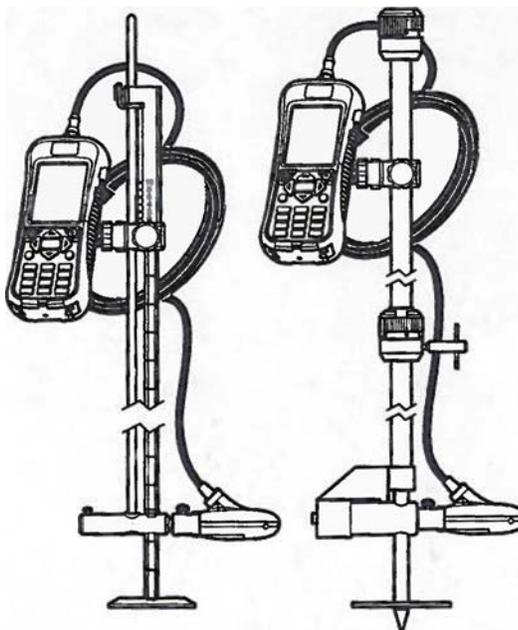


DOC026.53.80211

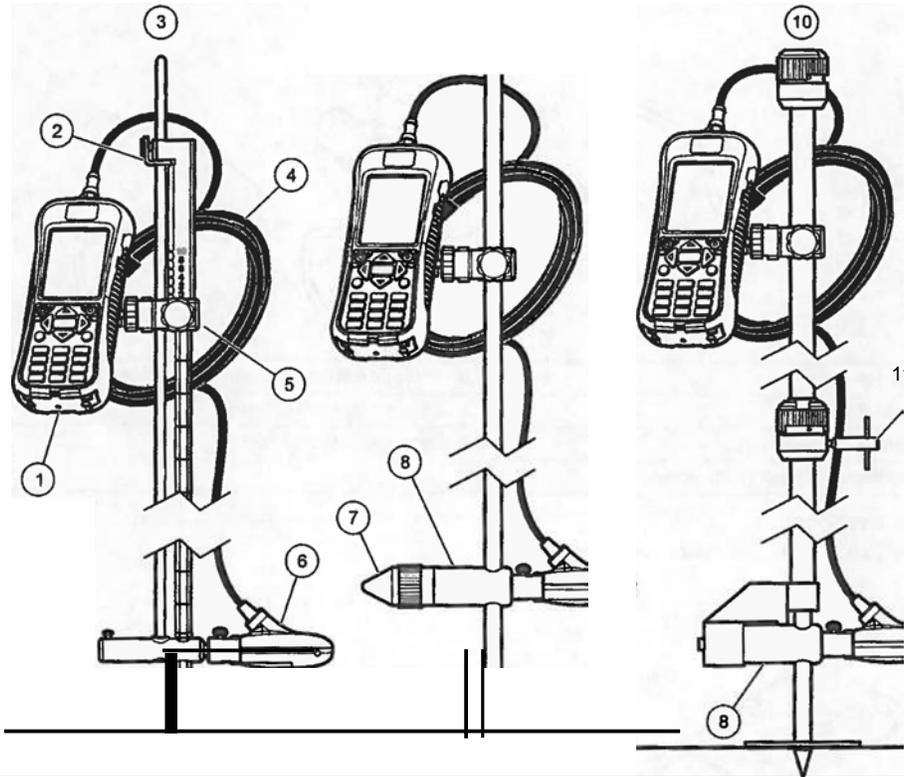
# OTT MF pro

07/2012, Edition 3

Operating Instructions



**Figure 1 Assembled components**

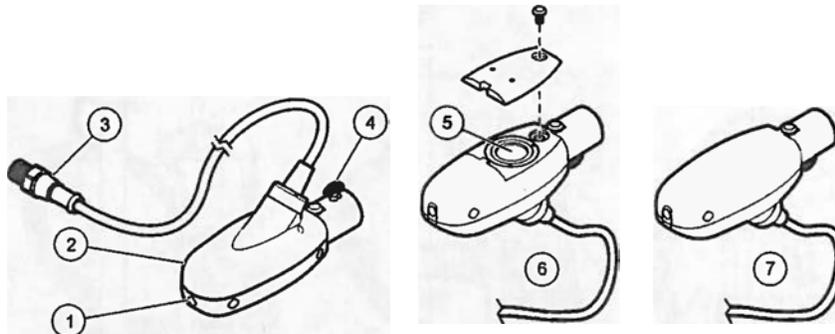


|   |   |
|---|---|
| 1 Portable meter                              | 7 Sensor height lock/release screw (optional accessory) |
| 2 Sensor height lock/release device           | 8 20 mm/HERES wading rod adapter (optional accessory)   |
| 3 Top setting wading rod (optional accessory) | 9 20 mm wading rod (optional accessory)                 |
| 4 Sensor cable                                | 10 HERES wading rod (optional accessory)                |
| 5 Adjustable mount for portable meter         | 11 Sensor height lock/release screw                     |
| 6 Sensor assembly                             |   |

*Sensor overview*

*Figure 2 shows the main sensor components. Instructions for how to attach the sensor on a standard or top-setting or HERES or 20 mm wading rod are supplied with the accessory.*

Figure 2 Sensor components

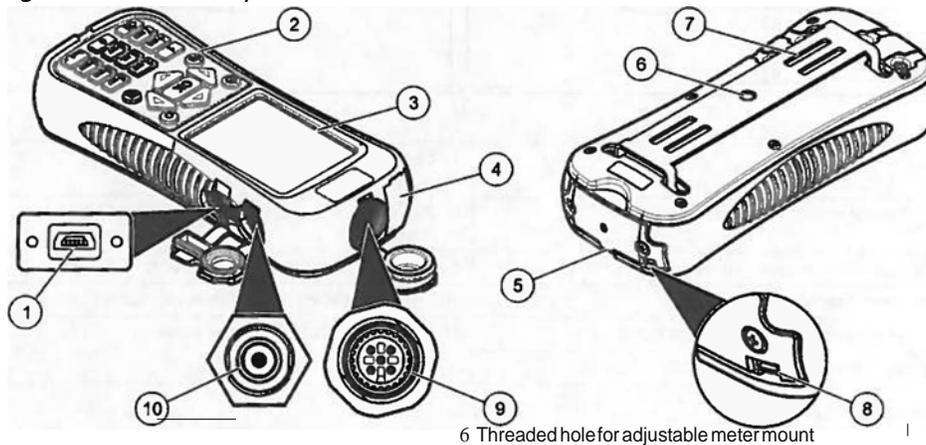


|                                 |   |
|---------------------------------|---|
| 1 Sensor electrodes             | 5 Pressure cell (sensOIS with depth option) |
| 2 Sensor body                   | 6 Sensor with depth option                  |
| 3 Sensor connection plug        | 7 Sensor without depth option               |
| 4 Sensor attachment thumb screw |   |

Meter overview

Figure 3 shows the features of the meter.

Figure 3 Meter components

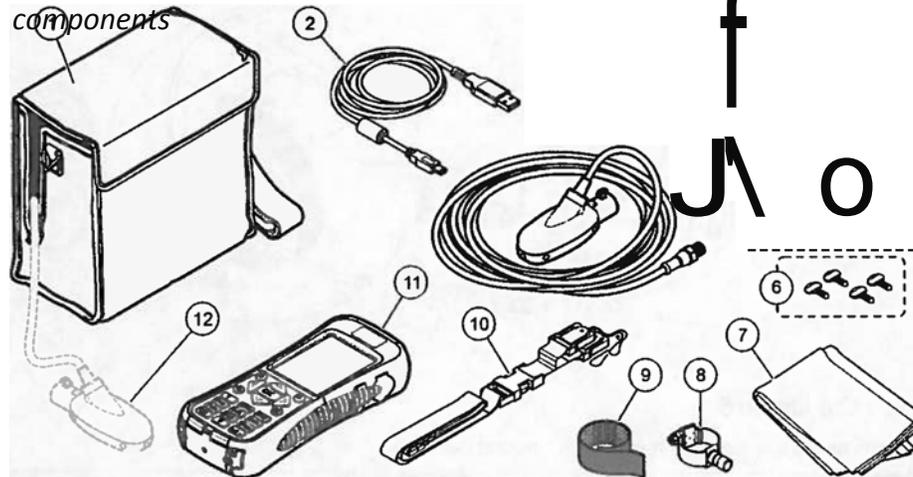


|                             |   |
|-----------------------------|---|
| 1 USB connection port       | 7 Slots for velcro or strap attachment        |
| 2 Keypad                    | 8 Slot for neck strap attachment threads (2x) |
| 3 Meter display             | 9 Sensor connection port                      |
| 4 Expansion port (not used) | 10 Wall-charger connection port               |
| 5 Battery compartment cover |   |

Product components

When purchasing a complete system, refer to Figure 4 to make sure that all components have been received. If any of these items are missing or damaged, contact the manufacturer or a sales representative immediately.

Figure 4 System components



|  |   |
|--|---|
| 1 Carrying case (with slot for sensor cable) | 7 Cloth to dry the sensor                   |
| 2 USB communication cable                    | 8 Universal sensor mount                    |
| 3 Adjustable portable meter mount            | 9 Velcro strap                              |
| 4 Wall charger and universal plug kit        | 10 Lanyard                                  |
| 5 Sensor                                     | 11 Portable meter                           |
| 6 Extra thumb screws (4x)                    | 12 Sensor as connected to meter inside case |

## Installation

### 1.1.1 Installation with optional accessories

Mount the meter on an optional wading rod for use in low-stage stream environments where the stream can be waded. Optional accessories let the user take measurements from a bridge or cable over a stream. A torpedo shaped weight attached below the sensor keeps the sensor in place when under water. For more information, refer to the documentation supplied with the accessory.

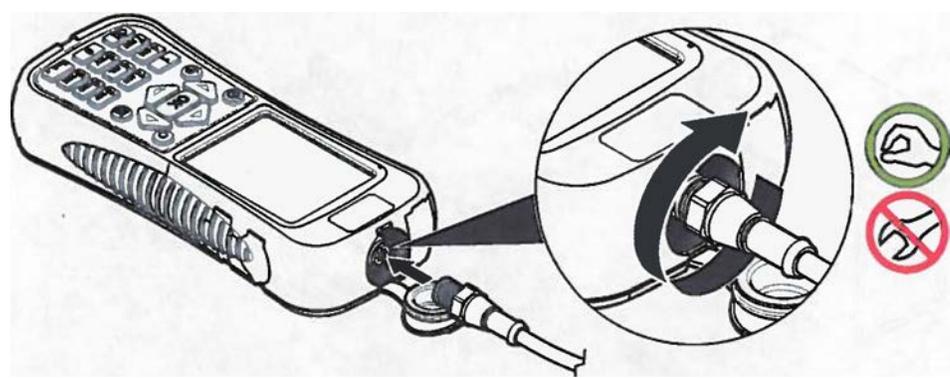
### 1.1.1 Install the sensor on the universal sensor mount

Use the universal sensor mount to attach the sensor to poles 1 inch or less in diameter. For correct operation and accurate readings, the front of the sensor must be pointed upstream with the electrodes in full contact with the flow.

*Note: Keep the sensor electrodes free from nonconductive substances such as oil and grease. To remove sensor contamination, refer to Clean the sensor on page 26*

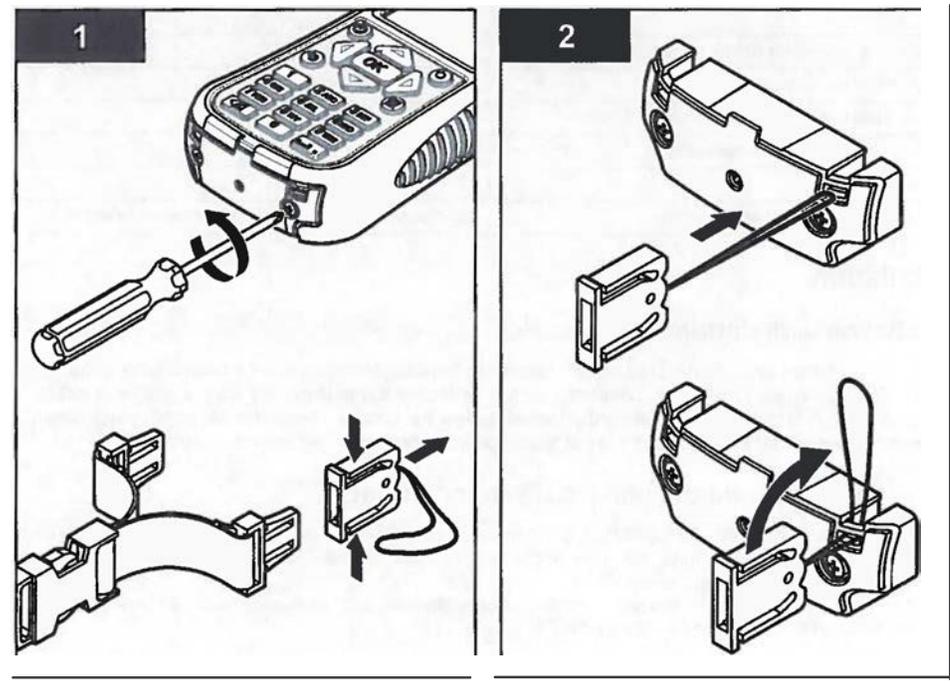
1. The front part of the sensor is round and contains three electrodes. The sensor has a mounting hole in back and a thumbscrew on top. Put the mounting shaft of the universal mount in the mounting hole at the back of the sensor. Make sure that the mounting shaft is completely engaged with the mounting hole and the thumbscrew is engaged with the groove.
2. Hand tighten the thumbscrew.
3. Move a pole 1 inch or less in diameter through the clamp of the universal sensor mount. Tighten the clamp.

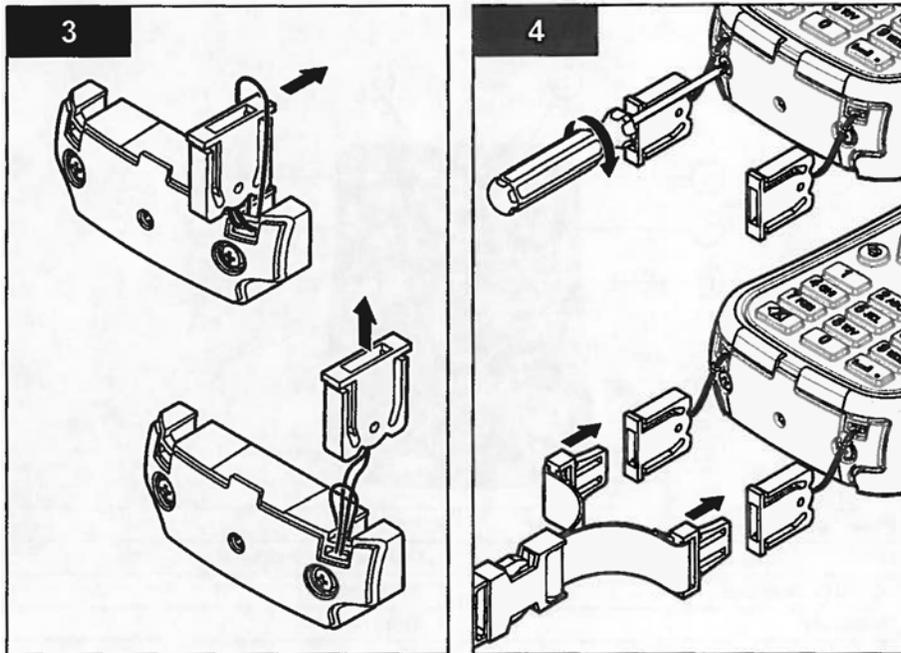
*Connect the sensor to the meter*



**Attach the lanyard**

Attach the lanyard to wear the meter safely around the neck.

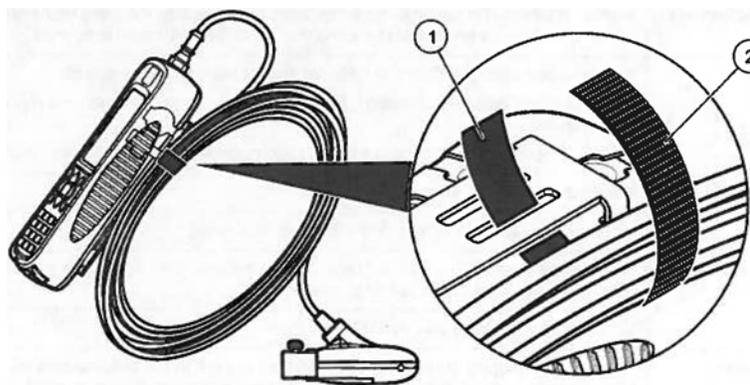




1.1.1 *Attach the velcro strap*

Use the velcro strap to hold the extra cable. Refer to Figure 5.

*Figure 6 Attach the velcro strap*



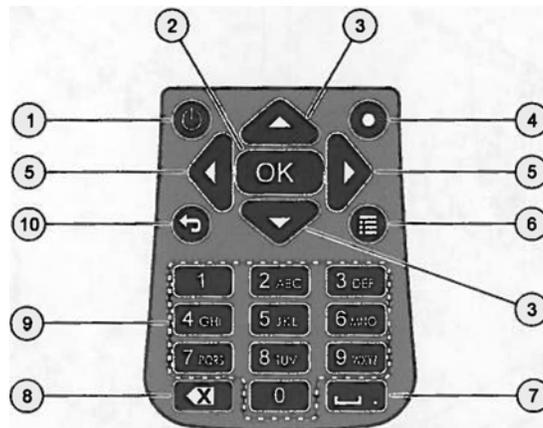
j 2 Hook side

User interface and navigation

## Keypad and key functions

Figure 6 shows the meter keypad. Table 1 gives the functions of each key or key type.

Figure 6 Keypad



|                         |                         |
|-------------------------|-------------------------|
| 1 Power On/Off          | 6 Main Menu             |
| 2 OK                    | 7 Underscore or decimal |
| 3 Up and Down arrows    | 8 Backspace             |
| 4 Quick Jump            | 9 Alpha-numeric         |
| 5 Right and Left arrows | 10 Previous menu        |

Table 1 Key description

| Key                   | Description  |
|-----------------------|--|
| Power On/Off          | Energizes and de-energizes the meter.  |
| OK                    | Confirms an entry or highlighted menu option.  |
| Up and Down arrows    | Moves up or down in the display. If the cursor is at the top or bottom of the display, the cursor wraps to the bottom or top when the UP or DOWN arrow is pushed.  |
| Quick Jump            | In normal operation, this key jumps to the Select conduit shape screen.<br>If the auto-zero feature is disabled, hold this key for five seconds to do a manual zero of the depth sensor.<br>In Real-Time mode, the Quick Jump key toggles between the digital and graph views. |
| Right and Left arrows | Moves to the right or left in the display.   |
| Main Menu             | Moves to the Main Menu from <i>any</i> submenu or screen.  |
| Underscore or decimal | Puts in an underscore or decimal character. In numeric-only fields, this key automatically puts a decimal point in the cursor position.  |
| Backspace             | Moves the cursor back one space.   |
| Alpha-numeric         | Puts in the key alpha or numeric value. Values are put in the order shown on the key. After 2 seconds, the value shown in the display is stored and the cursor advances.   |
| Previous menu         | Moves to the previous screen.  |

## Status bar

A status bar is shown in the top of the display. Descriptions of the information in the status bar are given in Table 2.

Table 2 Status bar indicators

| Indicator                 | Description  |
|---------------------------|--|
| Time and Date             | Shows the current time and date.   |
| USB                       | Shows when a USB cable is connected. If a USB cable is connected and this indicator does not show in the status bar, the USB cable is not fully engaged. Make sure that the USB cable is pushed in completely and makes full contact with the connection port. |
| Conductivity              | If the sensor is out of the water and non-conductive, a blue ring appears next to the battery icon. If the sensor is in the water and conductive, the indicator is a solid blue circle.  |
| Battery                   | A five-bar graph shows the level of charge in the battery.   |
| File access               | Shows while the meter gets access to a file.   |
| Auto zero depth indicator | If the depth sensor was zeroed in the last 30 minutes, a solid green circle shows next to the Conductivity indicator. If the depth sensor was not zeroed in the last 30 minutes, this indicator flashes red.   |

## Navigation and Main Menu

Push OK to confirm a selected menu option or a value shown in the display. Select More and push OK to see additional screens and options if available. Push the Main Menu button to go to the Main Menu from a submenu.

*Note: Some operations cannot be completed unless a sensor is connected to the meter. If these operations are tried when there is no sensor connected, the display shows an error message. Connect a sensor and try the operation again.*

1. Real time-Select this option to get real-time velocity and depth information. (A sensor with depth capability is necessary to read depth). An example of a Real Time screen for sensors with velocity only is shown in Figure 7. Real time screens for sensors with both velocity and depth is shown in Figure 8. The format of the information and options shown depends on the type of sensor used. In Real Time mode, the Quick Jump key toggles between digital and graphic views of Real Time information. The velocity is updated in FPA filter mode according to fixed period averaging time. In RC filter mode, the velocity is updated continuously on the screen every 250 ms.

| Option     | Description  |
|------------|--|
| Capture    | Stores the depth and velocity information shown in memory. The information is saved until power is cycled, the memory is saved to a non-volatile real-time file, or the user exits from real-time mode.                |
| Save       | Saves captured measurements in the volatile memory to a non-volatile real-time file. A message will show if the number of files is greater than the maximum possible. Files are stored in tab delimited (.tsv) format. |
| Done or OK | Exits the real-time mode and returns to the Main Menu. If there is unsaved data in volatile memory, a confirmation message asks the user to confirm the exit without saving the data.                                  |
| Clear      | Clears captured measurements from the volatile memory buffer. The user can choose from Clear Last, Clear All or Cancel options.  |

| Option        | Description   |
|---------------|---|
| Setup         | <p>Allows the user to modify the main filter parameters and enable and program the Maximum Depth sensor positioning feature. The Maximum depth feature allows a user to enter system parameters for depth measurement in Real Time mode. The user can choose to enter a maximum depth value taken directly with a ruler measurement (manual), or taken indirectly with the depth measurement (automatic). Both methods enable the Maximum Depth sensor positioning feature.</p> <p>In automatic mode setup, the user directly enters the distance from the bottom of the channel to the bottom of the sensor mount (offset). The setup interface will continuously show the current depth value returned by the sensor plus the offset. The meter stores this value as the Maximum Depth when the OK button is pushed. In all other cases, the depth values shown do not include the offset.</p> <p>The Maximum depth feature requires a sensor with velocity plus depth.</p> |
| Files or View | Shows a summary of each real-time file stored in non-volatile memory. Files can be individually viewed and deleted.   |

*Figure 7 Real time screen*

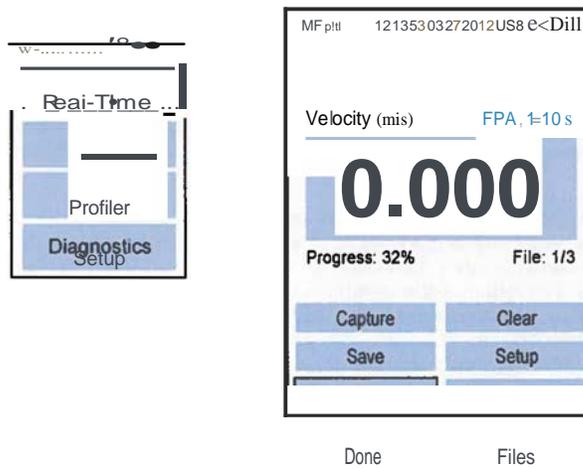
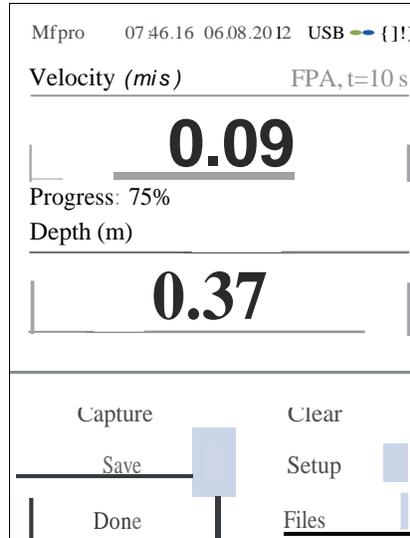


Figure 8 Real time screen for sensor with depth



2. Profiler- Select this option to do stream or conduit velocity measurements . The meter shows prompts when user input is necessary. The meter saves up to 10 profiles with up to 32 stations per profile. This number can be greater if data acquisition time is less than the maximum . A percentage of the remaining memory is given in 1% resolution. Refer to the [Appendix](#) on page 30 for more information about profiles.

| Option | Description |
|--------|-------------|
|--------|-------------|

|        |  |
|--------|--|
| Stream | This option is used to set up a profile for a stream or flowing channel. Do velocity measurements to calculate total discharge based on ISO 748 or USGS standards for Mid-section or Mean-section methods. |
|--------|--|

|         |  |
|---------|--|
| Conduit | This option is used to set up a profile for a conduit. |
|---------|--|

|       |   |
|-------|---|
| Files | This option is used to view or delete stored files. Files can be deleted all at once or individually. |
|-------|---|

|       |   |
|-------|---|
| Setup | This option is used to set up or change the settings for filter parameters and the Maximum Depth feature. |
|-------|---|

3. Set up-Select this option to change general system settings and preferences.

| Option | Description |
|--------|-------------|
|--------|-------------|

|                      |   |
|----------------------|---|
| Velocity calibration | Calibrates the sensor. Adds a field offset to the factory calibration. Refer to the <a href="#">Appendix</a> on page 30 for more information. |
|----------------------|---|

| Option               | Description   |
|----------------------|---|
| Filter parameters    | <p>Applies a data acquisition filter (Main filter or Pre-filter). The user can select the filter parameters.</p> <p><b>Main filter</b></p> <ul style="list-style-type: none"> <li>FixedPeriodAveraging (FPA)-FixedPeriodAveraging averages data over a user selectable fixed period of time (1 to 480 seconds). The default is 30 seconds. If the FPA value is 5, the velocity value shown in the display is updated once every 5 seconds.</li> <li>RCA time constant-The RC filter helps smooth out turbulence through the use of a selected time constant in the filter algorithm. This mode is useful when searching for a maximum velocity, for example in the common 0.9 x Vmax profile method. High RC filter time constants give higher degrees of smoothing. The time constant can be set from 2 to 20 seconds, with a default value of 6. At 1 time constant, the filter settles to approximately 60% of the final value. At 5 time constants, the filter settles to 99.9% of the final value. Thus, if the RC value is set to 2, the final value shows after 10 seconds.</li> </ul> <p><b>Pre-filter</b></p> <ul style="list-style-type: none"> <li>Median filter-The filtering process is done in the sensor. The feature can be disabled. However, the recommended (default) value is 5. Enable the feature to enter or change this value.</li> </ul> |
| Wet/dry threshold    | Sets the sensor submersion threshold for wet and dry conditions. The default value is 20%. Refer to WeUDry threshold on page 33 for more information.   |
| Auto zero depth      | <p>Sets the Auto Zero feature to On or Off.</p> <p>If set to On, the instrument does an air calibration when the sensor is removed from the water and is in the air. To do the air calibration, the instrument automatically zeroes the sensor.</p> <p>If set to Off, the user can manually zero the sensor. To do this, remove the sensor from the now, then push and hold the Quick Jump key for five seconds.</p> <p>When the sensor has been in the flow for 30 minutes, the green circle in the upper right corner goes from green to red. This is a prompt to the user to remove and zero the sensor again.</p>   |
| EMI                  | Sets the local line frequency for ambient noise rejection to 50 Hz (default) or 60 Hz.  |
| Clock                | Sets the date and time of the portable meter in 24-hour format. Daylight savings time is not supported.   |
| USE                  | <p>Sets the USE mode.</p> <ul style="list-style-type: none"> <li>Mass Storage (default)-This mode operates like a memory stick or hard drive. Files are read-only.</li> <li>CDC-This mode is used to update firmware.</li> </ul>  |
| Language             | Selects the language used in the menus.   |
| Units                | Sets the units for velocity, flow and depth measurements. Options are Metric (default) or English.  |
| Beeper               | On (default) or Off. If set to On, the meter makes an audible tone when the sensor is at the correct depth for applicable profile methods. The meter also makes an audible tone when an inactive button is pushed in any menu. This feature is available only with the optional depth sensor.   |
| Flow calculation     | <p>Selects the method of flow calculation for open water segment (stream profiles only). Options are Mean-section or Mid-section Refer to the Appendix on page 30 for more information.</p> <p><b>Description</b></p> <ul style="list-style-type: none"> <li>Fixed-The operator puts in the width of the stream and the number of stations for measurements. The meter divides the cross-section into evenly spaced distances between the station verticals.</li> <li>Non-fixed (default)-The operator selects the spacing between station verticals. This is the more commonly used option as it lets the operator include obstructions and other restrictions in the cross section.</li> </ul>  |
| Option Station entry |   |

Sets all meter options to the factory default values.

4. Diagnostics- Select this option to troubleshoot problems with the meter or an attached sensor. For more information about the Diagnostics options, refer to [Diagnostics](#) on page 28.

## Attachment 4

### Top Setting Wading Rod Operating Instructions

The top setting wading rod is used both to measure depth and to position the current meter. The hexagonal rod is graduated at intervals of 0.1 ft with shallow machined lines. A single groove is used at the 0.1-ft graduations, double grooves at the 0.5-ft intervals, and triple grooves at the foot marks. The sliding or suspension rod moves up or down on the hexagonal rod and is held by a spring-actuated lock that uses a lever for release. The sliding rod is marked with grooves that are labeled 0 through 8. The current meter attaches to the sliding rod.

To position the current meter at the appropriate water depth, proceed as follows:

Attach the current meter to the sliding rod, and place the reader so that it can be seen comfortably in front of you.

Place the base of the wading rod at the stream bottom and read the stream depth to the nearest 0.1 foot on the graduated hexagonal rod.

The current meter can be set at 20, 60 or 80 percent of depth (depth from the surface) by aligning the appropriate line on the sliding rod with the appropriate line on the vernier scale.

Considering a depth of **X.x**, with **X** the units value and **x** the decimal fraction,

For 60% - At a depth of **X.x** feet align number **X** on the aluminum rod with the **x** number on the vernier,

For 20% - multiply the depth by 2 then use the resulting value with the rule as for 60% depth,

For 80% - divide the depth by 2 then use the resulting value with the rule as for 60% depth.

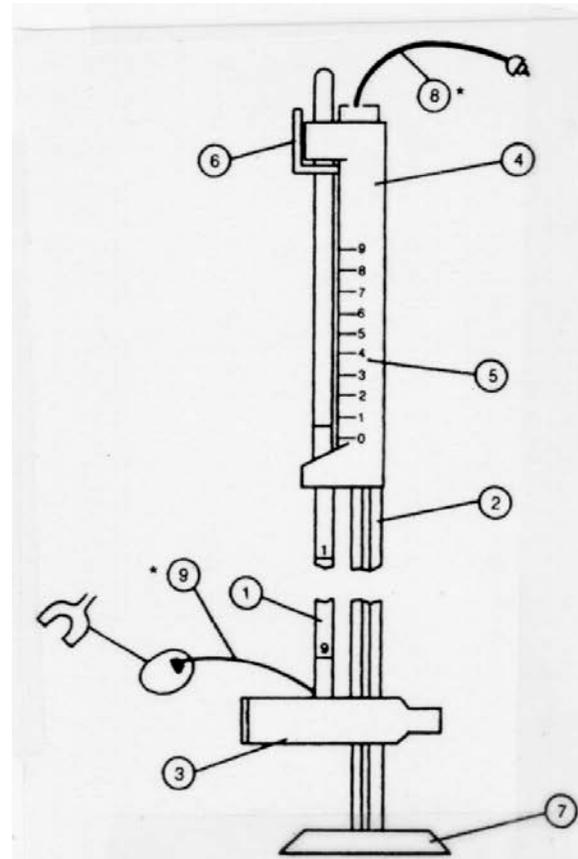
**Example 1.** Depth is measured to be 2.0 ft using the lines on the hexagonal rod. One reading at 60% depth (1.2 ft from the water surface).

Based on the depth measurement of 2.0, move the sliding rod so that the line numbered 2 on the sliding rod is aligned with 0 on the vernier. The meter will be 1.2 ft from the surface.

**Example 2.** Depth is measured to be 2.5 ft. The objective is to take two readings at 20 and 80% depth (0.5 and 2 ft from the water surface).

For the first reading at 20% depth, multiply the depth by 2 to get 5.0. Move the sliding rod so that the line numbered 5 is aligned with 0 on the vernier. The current meter will be 0.5 ft from the surface.

For the second reading at 80% depth, multiply the depth by 0.5 to get 1.25. Move the sliding rod so that the line numbered 1 is aligned with 2.5 on the vernier. The current meter will be 2.0 ft from the surface.



- (1) The 3/8" diameter Aluminum rod.
- (2) The 1/2" Hexagon Stainless Steel rod.
- (3) The Sliding Support.
- (4) The Handle.
- (5) The Vernier.
- (6) The Trigger.
- (7) The Base.
- (8) The Wire Assy. - Handle.\*
- (9) The Wire Assy. - Meter.\*

English 20

