CHAPTER 4. STREAM FLOW MEASUREMENT PROTOCOLS

Overview

Refer to the following references for further information about the Measurement & Calculation of Stream Flow:

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. Available online at: *http://pubs.usgs.gov/tm/tm3-a8/*

Rantz, S.E., and others, 1982, Measurement and computation of streamflow: Volume 1. U.S. Geological Survey Water-Supply Paper 2175, pages 1-284. Available online at: *http://pubs.usgs.gov/wsp/wsp2175/pdf/WSP2175_vol1a.pdf*

Rantz, S.E., and others, 1982, Measurement and computation of streamflow: Volume 2. Computation of Discharge. U.S. Geological Survey Water-Supply Paper 2175, pages 285-631. Available online at: *http://pubs.usgs.gov/wsp/wsp2175/pdf/WSP2175_vol2a.pdf*

Section A. Measuring Flow Using Sum of Partial Discharges Method

Most discharge measurements of stream flow are made by the **Sum of Partial Discharges Method (AKA Mid-section Method)** using a velocity-meter because it is adaptable to a wide range of velocities and is practically unlimited as to the total discharge that can be measured. The method consists of: 1) measuring the average velocity of water in each of several subsections (called a vertical) of a cross-sectional transect; 2) computing the partial discharge of each subsection as the product of the velocity and area of the subsection; and 3) summing the partial discharges to obtain the total discharge.

The usual method of making a discharge measurement is explained in ***Figure 4-1 on the next page***, which shows the cross-section of a channel.

***IMPORTANT*: All flow measurements (location, depth, velocity) should be taken in units of feet as the goal is a total discharge in cubic feet per second (cfs). Any measurement accidentally taken in inches must be converted to tenths or hundredths of feet to be compatible with the velocity measurements taken as cfs. Any accidental measurements in meters (location or depth in meters or velocity in cubic meters per second or cms) will also need to be converted to feet and cfs.**

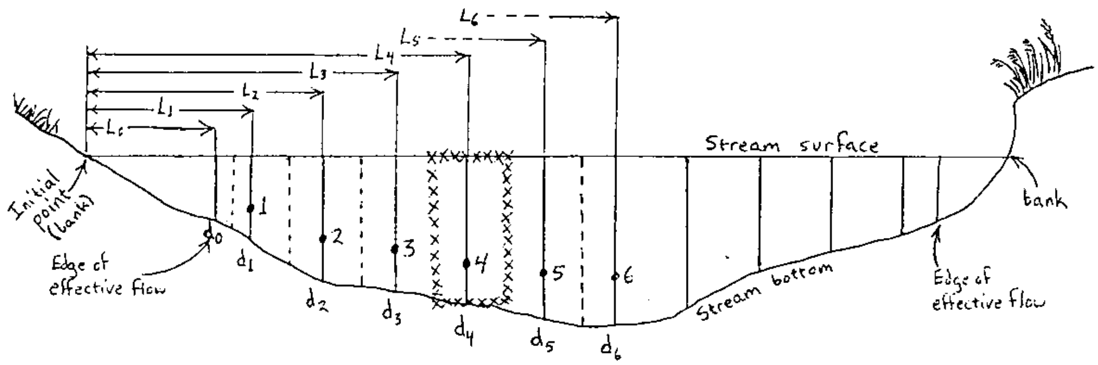


Figure 4-1. Cross-Section Transect of a Stream Channel Divided into Subsections

Where:

1, 2, 3, 4, 5, 6, - Velocity measurement points (called verticals) for each of six consecutive subsections.

L_1, L_2, L_3, L_4, L_5, L_6 – Distances in feet from the starting transect point (0) to each of six consecutive vertical locations along the transect.

d_1, d_2, d_3, d_4, d_5, d_6 – Depths of water in feet at the vertical in each of six consecutive subsections.

Dotted lines indicate the boundaries of subsections.

The depth of water is measured by wading rod or depth sensor at observation points (called verticals) 1, 2, 3, 4, and so forth. The velocity of the water is measured with a velocity meter at each of these locations at such position(s) in the vertical that the mean velocity in the vertical is obtained. The number of and depths of velocity measurements taken at a vertical is dictated by the total depth of the water at the vertical (***see Velocity Measurements at Verticals starting on page 4-7***).

The discharge of a subsection is computed using the following equation:

Equation 1. Calculation of Partial Stream Flow or Discharge

$$\mathbf{Q_4} = (\mathbf{V_4})(\mathbf{d_4})\,\frac{[\,(\mathbf{L_5} - \mathbf{L_3})\,]}{\mathbf{2}}$$

Where:

Q_4 = discharge or flow in cubic feet per second through subsection 4 (***see Figure 4-1 on previous page***)

V_4 = mean velocity in feet per second at vertical 4. The method of determining the mean velocity is dictated by the number and depths of velocity measurements taken (***see Velocity Measurements at Verticals starting on page 4-7***).

d_4 = depth of water in feet and tenths of a foot (not inches) at vertical 4.

L_3, L_5 = distances in feet and tenths of a foot (not inches) from the starting transect point to locations 3 and 5, respectively (***see Figure 4-1 on previous page***).

The subsection defined by this formula is that shown by the X-line highlight around location 4 in ***see Figure 4-1 on the previous page***.

The summation of the discharges for all the subsections equals the total discharge of the stream. It is calculated either by software within the flow meter (*e.g.,* ***OTT MF Pro***) or by data entry of manually recorded flow data in the office (*e.g.,* via database or spreadsheet calculations). ***See Table 4-1 on next page for an example of manually recorded flow data***.

Table 4-1. Example of Flow Measurement Data Recorded on a Field Form

Stream Discharge Measurement (Calculated in cubic feet per second – cfs)							
AN-Code	*PSB-25-A-5-(0.5)*	Date	*8/17/2016*	WQ ID	*98-475*		
Measurer	*John Smithee*	Recorder	*John Wick*	Time	*1300*	Meter ID	*2*
Measurement	Location Description	Distance	Depth	Velocity			Measurement Notes
				0.2	0.4	0.8	
1	*Left Bank*	*1.3*	*0*		*0*		
2	*Left EEF*	*2.4*	*0.3*		*0.01*		
3		*2.9*	*0.65*		*0.10*		
4		*3.6*	*0.9*		*0.45*		
5		*4.3*	*0.95*		*0.35*		
6		*4.9*	*0.95*		*0.51*		
7		*5.6*	*1.2*		*0.94*		
8		*6.2*	*1.6*	*0.97*		*0.84*	
9		*6.9*	*1.15*		*0.80*		
10		*7.5*	*0.9*		*0.69*		
11		*8.2*	*0.9*		*0.64*		
12		*8.9*	*0.65*		*0.35*		
13		*9.2*	*0.6*		*0.45*		
14	*Right EEF*	*9.9*	*0.4*		*0.02*		
15	*Right Bank*	*10.5*	*0*		*0*		
16							
Notes:	*Some turbulence from rocky substrate. Slightly skewed flow. Drizzling rain.*						

9.9 ← Edges of effective flow
-2.4 ←
7.5 ← Effective flow width

→ 7.5 ÷ 10 (the number of desired verticals) = 0.75 feet average increment width between each of ten measuring points (verticals).

Materials and Supplies

1. Top-Setting Wading Rod – for measuring stream depth and setting the depth of flow measuring device's sensor.
2. Marsh-McBirney Flo-Mate or OTT MF Pro – for measuring water velocity.
3. Tape Measure in feet and tenths – used as a tag line for determining the distance between velocity readings.
4. Flow Measurement Form (***see CHAPTER 2. Section C. APPENDIX #1 - Stream Discharge (Flow) on page 2-116***) – for recording data collected along the flow transect and for final computation of flow.
5. Pencils & Clipboard. If a single person is doing the measurement & recording the data, a small notebook can be used to record the data and then transcribed to the flow form later.

Part 1. Flow Measurement Procedures

A. Select a Transect Location within the Reach

1. Select a stream reach having the following characteristics:
   - ✓ A straight stretch of water with the horizontal velocity vectors running parallel to the stream bank.
   - ✓ A stable, even streambed without large rocks, weeds and protruding obstructions that create turbulence and interfere with sensor performance.
   - ✓ A level streambed configuration to reduce variation in the vertical components of velocity.
   - ✓ A water depth of 0.2 feet across most of the transect. The sensor will not work correctly unless the water depth is at least 0.2 feet.

All four of these conditions are seldom satisfied. Nevertheless, select the best possible reach using these criteria.

2. Next, select a flow transect. An ideal or optimal transect:
   - ✓ Is perpendicular to the direction of flow (velocity vectors) → It is often very hard to find an area of stream where 100% of the flow is perpendicular to the flow transect. If there is no better place to take the velocity readings, then the number of varying velocity vectors on a flow transect should be kept to a minimum.
   - ✓ Has uniform bed and stream banks.
   - ✓ Has a minimum velocity of 0.05 feet/second → Avoid transects with eddies or areas of standing/still water. **(However, you should include positive number readings of less than 0.05 feet/second on the flow sheet should you encounter them).**
   - ✓ Adequate depth for the meter to function → Typically, this means the entire velocity probe bulb should be immersed. **Please note if readings were taken with part of the bulb exposed to air.**

> ***IMPORTANT*: You may alter the channel to help meet these requirements at the selected site *before* you begin making any measurements, but *NEVER AFTER* measurement has begun. It is often possible in small streams to build dikes to cut off standing/still water and shallow flows within the transect. You can also improve the transect by removing rocks and debris within the section of water immediately upstream and downstream of the flow transect. *ALWAYS* allow the flow to stabilize after modifying the transect before starting the measurements.**

B. Set up the Transect and Width of Effective Flow Area

3. Determine the wetted width of the stream by placing a tape measure perpendicular to the stream flow to use as a tape measure/tag line. The *Distance* along the tape

measure/tag line for each bank should be recorded. Generally, the bank with the lower *Distance* is recorded under Measurement/Station 1 (AKA the Bank Reference Point) and the other bank *Distance* is recorded as the final Measurement/Station (the number of which is not certain until all the flow measurements are complete; ***see Table 4-1 on page 4-4 for an example of how the bank Distances are recorded***).

4. Determine the approximate width of the Effective Flow Area. The effective flow is the segment of the transect having measurable downstream velocity and exclusive of standing/still water areas or reverse flows (eddies) near the stream banks. This is not the same as a bank to bank or wetted width measurement which includes the standing/still areas along the banks (therefore, the Effective Flow Area width should always be smaller than the wetted width). This effective flow width estimate will be used in establishing the spacing of the verticals (***see Table 4-1 on page 4-4 for an example of how the width of the Effective Flow Area was calculated***).

C. Determine the Minimum Number of Verticals

5. Determine the minimum number of verticals to be taken across the transect within the effective flow area. The required minimum number depends on the width of the effective flow area:

   a. If the effective flow width is **less than 3 feet**, take **as many verticals as possible across the transect** no closer than 0.3 ft. apart using best professional judgment. Any closer, and the sensor will likely be measuring the same flow vectors as the adjacent vertical, thus wasting time for little benefit.

   b. In streams with effective flow width **between 3 and 10 feet**, take **no fewer than ten verticals** within the Effective Flow Area of the transect. For example, if the effective flow is 3.5 feet wide, the minimum number of ten verticals could be taken every 4.2 inches (this is 10% of the effective flow width, 42 inches) within the Effective Flow Area of the transect.

   c. If the effective flow is **greater than 10 feet**, a **minimum of 20 verticals** should be obtained within the Effective Flow Area of the transect.

   d. Taking more than the minimum number of verticals across the Effective Flow Area is not discouraged as the more verticals there are across the Effective Flow Area of the transect, the more accurate the Final Discharge will be.

D. Starting the Transect Measurements

6. Begin the Flow Measurement Process using one of the flow meters (***for specific operation of meters see Marsh-McBirney Flo-Mate starting on page 4-14 or OTT MF Pro starting on page 4-20***). ***Refer to Table 4-1 on page 4-4 for an idea of how the flow measurement data will look.***

a. Establish one bank as the transect starting point (Measurement/Station 1). Fit is recommended to start with the bank that has the low end (closest to 0) of the tape measure/tag line and then proceed along the tape measure in an increasing direction. Record the *Location Description* (*i.e.*, Left Bank or Right Bank) and *Distance* along the tape measure/tag line where the edge of the water lies. In most cases, the *Depth* and *Velocity* at the bank will be 0 and recorded as such. When this occurs, this is referred to as a 0-point method velocity reading (*e.g.,* when using the ***OTT MF Pro***). In some instances, there may be a near vertical bank at the edge of the water that does have a depth and/or velocity. If so, then the *Depth* should be measured, the situation documented in the *Measurement Notes*, and a vertical should be taken here to determine the *Velocity* as ***described in Velocity Measurements at Verticals on below***.

b. Determine the location of the Edge of Effective Flow (EEF) along the tape measure/tag line from the transect starting point (Measurement/Station 1). This can be determined by using the instantaneous velocity readings on the flow meter (***e.g., Marsh-McBirney Flo-Mate***) to gage where the flow changes from 0 or negative to a positive number. If instantaneous velocity readings are not readily available on the flow meter (***e.g., OTT MF Pro***) you can slightly disturb the sediments just immediately upstream of the transect and observe where the water seems to be flowing versus where there is standing/still water. Record the *Location Description* of the EEF (*e.g.*, Left EEF, Right EEF, Left Channel Left EEF, Left Channel Right EEF, *etc*.) and *Distance* along the tape measure/tag line under Measurement/Station 2. This will be the location of the first vertical (unless the bank was near vertical and had a depth).

> **NOTE:** The Bank and EEF will most likely occur at the same tag line location (i.e., there is active flow/depth right up to the water's edge) in channelized streams that have been constrained by near vertical, artificial walls. The Bank/EEF vertical and adjacent vertical should be spaced closer together to help document any changes in velocity near the combined Bank/EEF.

E. Velocity Measurements at Verticals

7. Record the water *Depth* at the vertical. For a ***Marsh-McBirney Flo-Mate*** flow meter, the water depth will be determined by observing the floating meniscus hitting the wading rod and reading/counting the scale (in tenths of a foot) on the front of the wading rod. On the wading rod scale, a single line represents 0.1 feet, a double line equals 0.5 feet and a triple line equals 1.0 feet. For a ***OTT MF Pro*** flow meter, the water depth is determined by sensor readout on the display screen and verified visually using the wading rod scale.

Number of Velocity Measurements per Vertical

The more velocity measurements taken in a vertical, the more accurate the flow measurement will be. The water depth will determine how many velocity readings need to be taken at a given vertical. There are three methods: **One-point**, **Two-point**, and **Three-point**. The following conditions dictate which method should be used:

a. If the depth is **less than or equal to 1.5 feet**, use the **One-Point** method for measuring velocity.

b. If the depth is **greater than 1.5 feet**, use the **Two-Point** method for measuring velocity.

c. The **Three-Point** method should be used only if the following conditions are met:

   1) If the depth is greater than 1.5 feet **and**
   2) The Top reading is greater than twice the Bottom velocity reading **or**
   3) The Bottom reading is greater than the Top reading **or**
   4) The Top reading is seriously affected by an obstruction (*e.g.*, ice/ slush cover or overhanging vegetation dipping into the stream channel) **or**
   5) The Bottom reading is notably affected by friction or turbulence produced by the streambed or an obstruction.

NOTE: When more than one velocity reading is taken at a vertical, the readings are combined using a specific formula (by the spreadsheet, meter software, or database programming) to calculate the final velocity measurement for the vertical.

Please note that the USGS refers to the depth locations in these methods in relative to the depth from the top of the water column while WAB refers to the depth locations in relative to the depth from the bottom of the water column. ***Table 4-2 below*** shows the relationship between these two perspectives.

Table 4-2. Relationship between USGS and WAB velocity measurement methods

Agency		USGS	WAB
Method	Reference Point	Top of Water Column	Bottom of Water Column
One-Point (i.e., One Reading)	Middle	60% (0.6) depth from Top	40% (0.4) depth from Bottom
Two-Point (i.e., Two Readings)	Top	20% (0.2) depth from Top	80% (0.8) depth from Bottom
	Bottom	80% (0.8) depth from Top	20% (0.2) depth from Bottom
Three-Point (i.e., Three Readings)	Top	20% (0.2) depth from Top	80% (0.8) depth from Bottom
	Middle	60% (0.6) depth from Top	40% (0.4) depth from Bottom
	Bottom	80% (0.8) depth from Top	20% (0.2) depth from Bottom

How to Adjust the Wading Rod to take Velocity Readings

8. The wading rod will need to be adjusted so that the sensor is at the appropriate depth for the method selected. By default, the wading rod is calibrated to set the sensor at 0.4 (or 40%; just below the Middle of the water column) from the bottom of the water column when using the Vernier scale on the handle. The ***OTT MF Pro*** has a built-in depth sensor and on-screen guidance to assist in finding the appropriate depth.

   To adjust the sliding portion of the wading rod, depress the trigger on the back side of the wading rod handle (***see Figure 4-2 on right***).

   a. To set the sensor at 0.4 from the Bottom of the Water Column line up the wading rod's numbered sliding-foot marks with the tenth scale Vernier on the wading rod handle (***see Figure 4-2 on right***). For example, if total depth is 0.9 foot, then line up the "0" line on the rod's sliding-foot scale with "9" on the Vernier on the back of the handle. If depth is 1.2 feet, then line up the "1" sliding foot scale line with the "2" Vernier on the wading rod handle.

   b. To set the sensor at 0.8 from the bottom (near the Top of the water column), multiply the water depth at the vertical by two and repeat as above. For a depth of 2.7 feet, this would be 5.4 feet. Line up the "5" on the sliding-foot scale with 4 on the Vernier.

   c. To set the sensor at 0.2 from the bottom (near the *Bottom* of the water column), divide the water depth at the vertical by two and repeat as above. For a depth of 2.7 feet, this would be 1.35 feet. Line the 1 on the foot scale with 0.35 on the Vernier (half-way between the "3" and"4").

Figure 4-2. A) Top-Setting Wading Rod and B) Close-up of handle or Top-Setting Wading Rod.
Note the tenth scale on the handle and trigger on the back side. The Slideing Foot is the rod on the back side of the handle that extends up thru the top of the handle.

Taking a Velocity Measurement

9. Once the sensor is located at the proper depth and use the following precautions before starting the observation/measurement:

a. <u>Hold the rod vertical at the measuring tape/tag line (within 1 to 3 inches downstream of the tag line) with the sensor pointing upstream</u> (into the flow perpendicular to the tape measure/tag line).

> **<u>NOTE</u>:** The bow wave produced by the wire at the top of the sensor will be symmetrical if the sensor is pointing directly into the flow. Also, a ribbon attached to the bottom of the wading rod can help visualize the flow direction.

b. <u>Stand in a position relative to the sensor that least affects the velocity of the water passing the sensor:</u>
- Downstream of the sensor for ***Marsh-McBirney Flo-Mate***
- Downstream to the side of the sensor with feet perpendicular to the sensor for ***OTT MF Pro*** (***see Figure 4-3 below***).

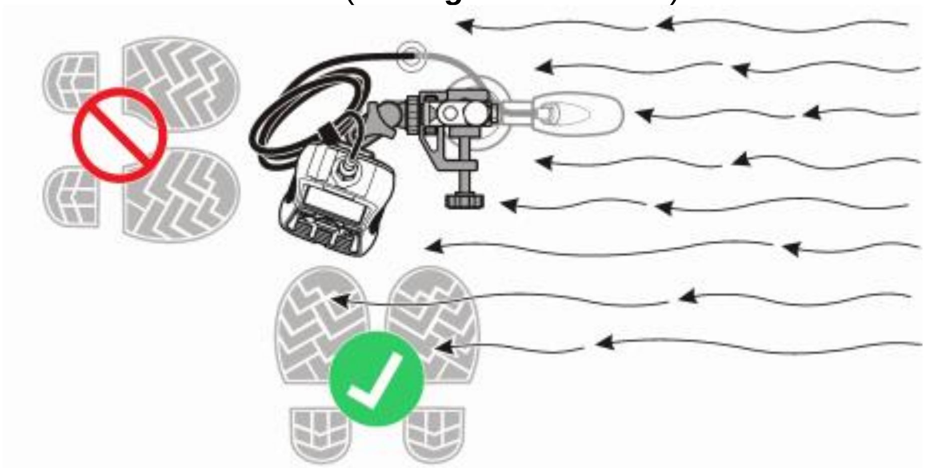


Figure 4-3. Position of User when using OTT MF Pro

c. <u>Standing at least 18 inches (1.5 feet) or more from the wading rod</u> should minimize turbulence that could impact the reading.

> **<u>NOTE</u>:** When measuring in streams with shifting beds, the scoured depressions left by your feet can affect the velocity readings. Make sure to always keep the sensor as far as possible from the hydrographer's body and feet in such situations and record notes describing the situation that may have had an impact on the velocity readings for each such

a. <u>Create a minimal (or narrow) body profile while standing in the water</u>. This can be accomplished by either:
- Facing one of the banks while taking the velocity measurement so that the water flows against the side of the legs rather than the front of the legs (***see Figure 4-3 above versus Figure 4-4 next page***) <u>OR</u>
- Spreading your legs far apart, straddling the water's flow vector. In very small streams, you may be able to completely straddle the wetted area with a leg on each bank, effectively eliminating any alterations to the flow by your feet and legs.

Figure 4-4. Example of taking Flow Measurements at a Transect.
Note: The user is not minimizing their body profile while standing in the water.

10. Record the *Velocity* at each depth necessary according to the meter instructions (***for specific operation of flow meters see Marsh-McBirney Flo-Mate starting on page 4-14 or OTT MF Pro starting on page 4-20***)

F. Spacing of Verticals

11. Establish the next vertical (Measurement/Station 3) at an appropriate distance from the previous vertical by observing the change in depth and velocity while moving across the transect.

    While there is no set rule about how far apart to space the verticals (*e.g.,* every X distance), there are some guidelines:

    a. Verticals should be spaced to document and define:
       - ✓ *Areas of extreme turbulence*
       - ✓ *Extreme changes in velocity*
       - ✓ *Sudden changes in depth.*

       For example, if the there is a large obstacle to the flow like an unmovable boulder directly in front of or behind the flow transect, a few extra measurements should be taken on each side of the boulder (to help define the changes in velocity and depth on either side) and spaced closer together.

       Another example of spacing verticals closer than normal would be when the Bank and EEF coincide at a near vertical wall. A vertical at the bank/EEF should be followed by another vertical spaced rather closely to the adjacent vertical to help define any fluctuations in velocity near the wall.

b. Verticals may be spaced farther apart in areas where the velocity and depth are more uniform.

c. Verticals should not be placed any closer together than 0.3 feet between them. Any closer, and the sensor will likely be measuring the same flow vectors as the adjacent vertical, thus wasting time for little benefit.

d. Generally, no more than 5 to 10% of the total discharge should occur in any one subsection of the transect.
   - When using a ***OTT MF Pro*** to record the flow measurements to the device, it will calculate the Total and Partial Discharges after completion of the transect and highlight which subsections are greater than this value (***see Review Channel Summary on page 4-35***).
   - The ***Marsh-McBirney Flo-Mate*** meter does not have this ability and best professional judgement will have to be used by examining the velocity and depth readings recorded to see if an additional vertical should be added.

12. Record the *Distance* along the tape measure/tag line at the vertical, and the water *Depth* & appropriate *Velocities* per ***Steps 7 thru 11 above***.

G. Ending the Transect Measurements

13. When nearing the far bank/wetted edge, be mindful of establishing a final vertical near the EEF. If the far bank is near vertical and has a depth and/or velocity, then make the bank the last vertical. Record the *Location Description* of the EEF (*e.g.*, Left EEF, Right EEF, Left Channel Left EEF, Left Channel Right EEF, *etc*.) in addition to the *Distance* along the tape measure/tag line and the water *Depth* at the final vertical.

14. Record the *Distance* along the tape measure/tag line for the far bank as the final Measurement/Station (the number of which is not certain until all the flow measurements are complete). If there is no *Depth* or *Velocity* at the far bank, record them as 0.

15. When done, at least one velocity measurement should have been taken at all the vertical locations (except the first and last Measurement/Station locations if the banks were normal did not have a depth or flow).

H. Calculating Total Discharge from the Sum of Partial Discharges

The flow can be calculated in one of three ways:

- Via data entry into the Database
- Within the instrument (*e.g.*, ***OTT MF Pro*** meter)
- Using a Spreadsheet
  - Open Excel, and then open the file in: Q:\WATER RESOURCES\WAB\TOOLS & CALCULATORS\Flow Calculator.xlsx.
  - Type in the left and right edge-of-effective-flow values in the “no flow” rows of the “Distance” column.
  - Enter the distance, depth, and velocity in the appropriate columns.
  - The flow or discharge in CFS is automatically calculated in the upper right-hand corner of the spreadsheet.

Part 2. Operation and Maintenance of Flow Meters

<u>Marsh-McBirney Flo-Mate</u>

Manufacturer's Manual

For a more complete description of the care and operation of the Model 2000 Marsh-McBirney Flo-Mate, consult the instruction manual (***see Figure 4-5 below***) provided by the manufacturer at:

https://www.hachflow.com/pdf/Model_2000_Manual.pdf

Any information provided in this SOP is not meant to supersede the instructions or guidance provided in the manual provided by the manufacturer.

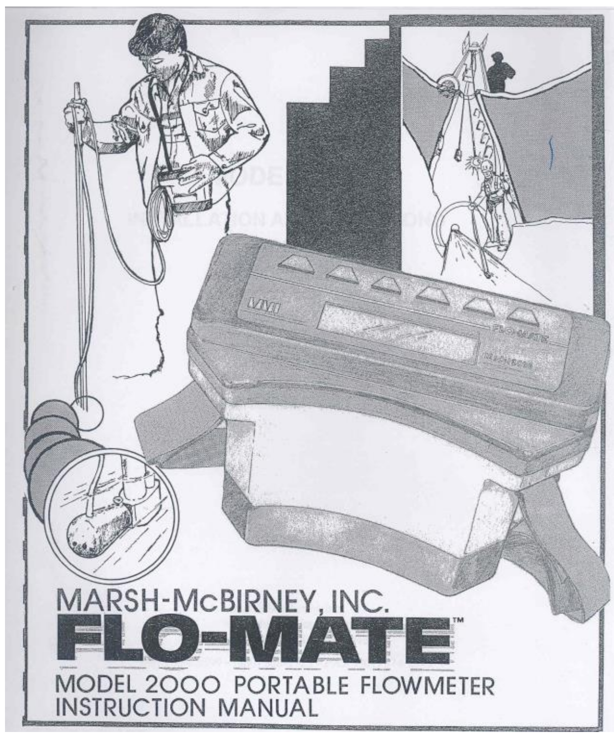


Figure 4-5. Cover of Model 2000 Marsh-McBirney Flo-Mate Instruction Manual

Theory of Operation

From the Marsh-McBirney Flo-Mate Manual, 1990-

The Flo-Mate measures velocity using the Faraday law of electromagnetic induction. This law states that as a conductor moves through a magnetic field, a voltage is produced. The magnitude of this voltage is directly proportional to the velocity at which the conductor moves through the magnetic field.

When the velocity approaches the sensor from directly in front, then the direction of the flow, the magnetic field, and the sensed voltage are mutually perpendicular to each other. Hence, the voltage output will represent the velocity of the flow at the electrodes.

The sensor is equipped with an electromagnetic coil that produces the magnetic field. A pair of carbon electrodes measure the voltage produced by the velocity of the conductor, which in this case is the flowing liquid. The measured voltage is processed by the electronics and output as a linear measurement of velocity

Maintenance

Per the Marsh-McBirney Flo-Mate manual, the only routine maintenance of the unit is confined to cleaning the sensor, changing the batteries (two alkaline D Cell batteries), and zero-adjusting the instrument. Any instrument calibration or repair must be conducted by the manufacturer.

Cleaning

Nonconductive coatings like oil and grease can cause errors or interfere with the velocity readings. This can be remedied by routinely cleaning the sensor head with soap and water. **Do not use any solvents to clean the sensor head!** If the problem persists, clean the electrodes with very fine grit (600) sandpaper. If error readings persist in the field or where you do not have immediate access to soap and water, you may try to use your fingers underwater to rub away oil and grease from the sensor electrodes. Fine clay (smaller than 600 grit) and pencil erasers may also be effective at removing oil and grease.

Zero Check and Adjust

Every month, the meter will need to undergo a zero check and possibly a zero adjust.

Zero Check Procedure

1. Clean the sensor with soap and water as stated above. Make sure the unit is set to operate in FT/S using fixed point averaging (FPA) filtering (***see Settings on page 4-16 for more information***).

2. Place the sensor in a plastic five-gallon bucket of water. Sensor should be 3 inches away from the sides and bottom of the bucket. This could possibly be achieved by attaching the senor to the wading rod during the zero check and balancing the wading rod in a hands-free standing position in the bucket. Make sure the water is not moving and wait 10 to 15 minutes. DO NOT TAKE ANY READINGS WHILE WAITING.

> **NOTE: When conducting the Zero Check or Zero Adjust procedure at the WVDEP Headquarters in Charleston, be sure that there is not a passing train during the Zero Check Procedure. It has been observed that passing trains create excessive vibrations in the laboratory end of the building to the extent that it may seriously affect the Zero Check.**

3. Using a filter value of 5 seconds (*i.e.,* change the instrument's increment reading from 20 to 5 seconds using the up and down arrows) take a reading from the unit in the still bucket. BE SURE NOT TO CAUSE ANY EXCESS

VIBRATIONS VIA THE SENSOR CORD OR FROM UNNECESSARY MOVEMENT. Zero Stability is a reading of +/- 0.05 ft. /sec. Record the unit number, the initial zero stability reading for entry into a database later. If the reading is out of this range, the unit will need to be Zero Adjusted (***see below***). If the unit is within the acceptable range, restore the increment reading back to 20.

Zero Adjust Procedure

> **<u>NOTE</u>: Each key in the zero adjust sequence must be pressed within 5 seconds of the previous key. If the time between key entries is longer than 5 seconds or if a wrong key is pressed, the unit will display an ERR 3. Turn the unit OFF then back ON and try again.**

1. Keep the position of the sensor as described above in ***Step 2 for Zero Check Procedure***. Press STO and RCL keys at the same time. The unit will display a “3”.

2. Use the “down” arrow to decrement to zero. The number “32” will be displayed.

3. Unit will decrement itself to zero and turn off. Zero adjust is complete. Return to ***Step 1 Above*** and repeat the zero check to make sure the instrument is within the acceptable range and record the final zero stability reading. If the unit is still out of range, you may attempt the zero adjust sequence again. If repeated attempts to zero adjust fail to correct the unit, it will need to be sent back to the manufacturer for recalibration and possibly repair. If the final zero check is acceptable, restore the increment reading back to 20 seconds and turn the unit off.

Accuracy

The Flow Meter accuracy is +/- 2% of reading + zero stability (which is +/- 0.05 ft. /sec). The range is -0.5 to +19.99 ft. /sec.

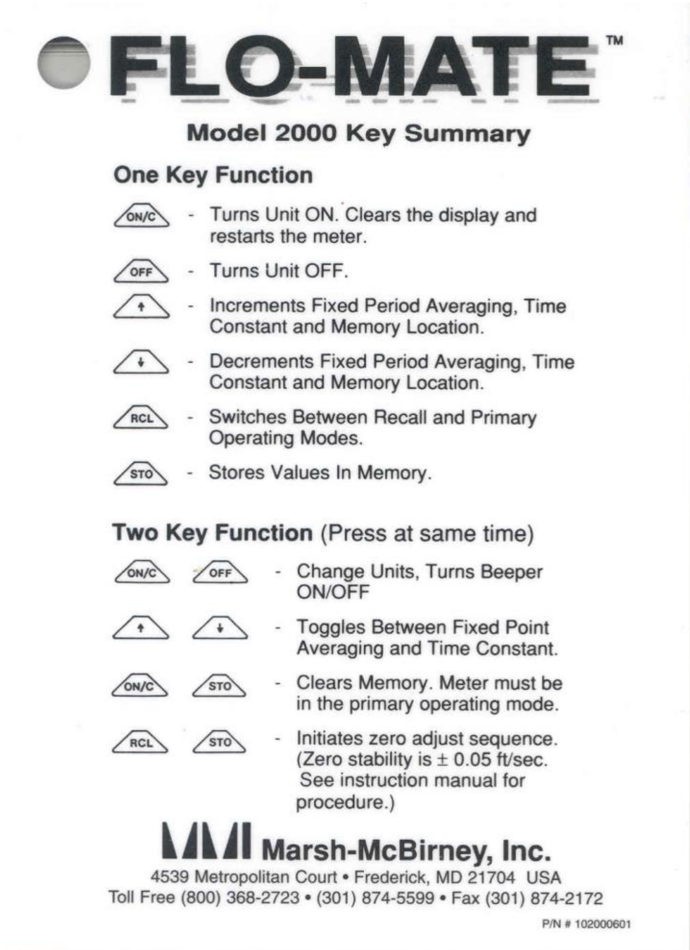
Basic Operation

<u>Settings</u>

The use of the function keys is described in Figure 4-6 on the next page.

<u>Units</u>-You can check the unit to see that it is reading in FT/S by pressing ON/C and OFF keys simultaneously. Press these two keys until FT/S is displayed. You can choose to have the beeper on or off (watch for the little speaker symbol in the lower right-hand corner) by toggling between:

- FT/S no beeper
- M/S no beeper
- FT/S with beeper
- M/S with beeper



FLO-MATE™

Model 2000 Key Summary

One Key Function

ON/C - Turns Unit ON. Clears the display and restarts the meter.

OFF - Turns Unit OFF.

↑ - Increments Fixed Period Averaging, Time Constant and Memory Location.

↓ - Decrements Fixed Period Averaging, Time Constant and Memory Location.

RCL - Switches Between Recall and Primary Operating Modes.

STO - Stores Values In Memory.

Two Key Function (Press at same time)

ON/C OFF - Change Units, Turns Beeper ON/OFF

↑ ↓ - Toggles Between Fixed Point Averaging and Time Constant.

ON/C STO - Clears Memory. Meter must be in the primary operating mode.

RCL STO - Initiates zero adjust sequence. (Zero stability is ± 0.05 ft/sec. See instruction manual for procedure.)

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Figure 4-6. Key Function descriptions for the Model 2000 Marsh-McBirney Flo-Mate

Filtering-The fluid dynamics around the sensor electrodes may cause the readings to bounce around. To stabilize the readings, the output to the display is dampened. The display can be dampened by Fixed Point Averaging (FPA) or by time constant filtering (rC). Fixed Point Averaging is an average of velocities over a fixed period. Time constant filtering is a software algorithm that mimics an RC analog circuit.

To check the unit and see what filtering method is being used, press the Up and Down arrow keys at the same time until the meter displays FPA (fixed point average). The display will show the letters rC when you first switch to the time constant mode.

Except for the first period, the display is updated at the end of each averaging period. For example, if the FPA is set to 20 seconds, the display is updated once every twenty seconds. The FPA display will have a horizontal time bar under the velocity output. The time bar provides an indication as to the amount of time left until the display is updated.

Time Increment-To set the increment, press the up arrow or down arrow to see if the unit is set to read in 20 second intervals. Note that fixed point averaging is limited to whole seconds in the range of 2-120 seconds.

The Watershed Assessment Branch (WAB) has a standard of collecting velocity measurements in feet per second using Fixed Point Averaging Filtering in 20 second intervals.

Field Operation

> **NOTE: The sensor on the flow meter has an operating temperature of 0^0C to 72^0C (32^0F to 160^0F). The electronics on the flow meter have an operating temperature of 0^0C to 50^0C (32^0F to 122^0F).**

Meter Set-up

Insert the sensor peg (on the bottom of the sliding wading rod shaft) into the opening on the back of the sensor. Position the three electrical sensors horizontal to the plane of the bottom (the foot) of the wading rod. If the sensor is properly positioned, the cord should be coming out of the top of the sensor parallel to the wading rod shaft. Tighten the thumb screw so that the sensor will not slide off the peg or rotate out of position.

Start-Up

After you have set up your flow transect (***See B. Set up the Transect and on page 4-5***) and immersed the sensor in the water, then turn the instrument on by pressing the ON/C button.

Taking In-Stream Flow Measurements

1. Record the following information on the ***APPENDIX #1 - Stream Discharge (Flow) form (see Figure 2-72 on page 2-117 or Table 4-1 on page 4-4)***:
   - ✓ The *AN-Code*, *Date*, and *WQ Sample ID*. The WQ Sample ID is used to designate measurement file names when using the ***OTT MF Pro*** meter.
   - ✓ The *Measurer*, *Recorder*, *Time* of the Flow Measurement and *Meter ID* (assigned number) of the flow meter used.
   - ✓ *Notes* about any general conditions that might affect the flow measurement (*e.g.,* wind, rain, skewed bottom configuration, ice and leaf packs in the water, overhanging vegetation, necessity of removing the probe bulb from the rod due to extremely shallow water depth).

2. Follow the procedures outlined on ***Part 1. Flow Measurement Procedures starting on page 4-5*** to establish the transect and vertical locations.

3. Record the *Location Description* and *Distance* along the tape measure/tag line and *Depth* at each vertical location starting with the Bank and EEF (Measurement/Station 1 and Measurement/Station 2; ***see D. Starting the Transect Measurements on page 4-6***).

4. The depth of the verticals will determine how many velocity readings need to be taken at each vertical (***See E. Velocity Measurements at Verticals starting on page 4-7***).

5. Adjust the wading rod so that the sensor is at the appropriate depth for the method and velocity reading (***see How to Adjust the Wading Rod to take Velocity Readings on page 4-9***).

6. Once the sensor at the proper depth, allow it to adjust to the velocity and observing precautions to prevent interfering with the velocity measurements (***described in Taking a Velocity Measurement starting on page 4-9***) before starting the observation.

> ***<u>NOTE</u>:*** **The Marsh-McBirney manufacturer says the sensor shape produces a cosine response that greatly reduces errors due to sensor positioning. For example, if the front of the sensor is pointed away from the flow at a 10° angle, the cosine of 10° is 0.98480. This is only 1.5% lower than the actual velocity. What this means is that even though you may not have the flow reading positioned 100% parallel to the flow vector, a few degrees off center will yield accurate results. You should still try to position the sensor as close to parallel to the flow vector as possible! Experience shows that slight angles away from parallel with the velocity vector, produce noticeably different velocity readings.**

7. Begin recording the velocity for each depth necessary by pressing the ON/C button.

    a. Allow the Marsh-McBirney Flo-Mate meter to go through two complete cycles. The first 20 second cycle is to allow the turbulence and eddies around the wading rod and sensor to reach equilibrium so that the final reading during the second cycle is as accurate as possible. Since the real time readings are only visible during the first cycle (***as stated in Settings on page 4-16***), it is recommended that you initialize the second cycle by pressing the ON/C button. In the rare case that the readout during the first cycle stabilizes well before the end of the 20 second cycle, you may initialize the second cycle early by clearing the display. At the end of the second cycle, record the readout. This readout is the average velocity for the second 20 second cycle only. It does not consider the velocity data gathered during the first cycle. Record the second readout on the appropriate "velocity" column on the form.

    b. Repeat for any other depths necessary at that vertical.

8. Establish the next vertical (Measurement/Station 3) at an appropriate distance from the previous one by observing the change in depth and velocity while moving across the stream (***discussed in F. Spacing of Verticals starting on page 4-11***). Move the sensor to the next vertical location in the stream and press the ON/C button to initiate a **new** cycle to begin (you don't want the 20 second cycle reading to include movement while you were moving the wading staff). Record the *Distance* along the tape measure/tag line, the water *Depth*, and appropriate velocities by repeating ***Steps 3 to 7*** at each vertical.

9. Repeat the ***Steps 3 to 7*** until the opposite bank in the flow transect is reached (***as described in G. Ending the Transect Measurements on page 4-12***).

Marsh-McBirney Flo-Mate Error Readings

The purpose of displaying errors is to alert the user of possible problems with either the unit or application. Errors can be displayed as messages or numerical codes. There are three messages and five numerical error codes. Apart from Err 2, error codes freeze the display. Turn the unit OFF then back ON to clear the display. If after corrective action the error still exists, call the manufacturer regarding repairs/calibration. Descriptions of the meanings of each error message are as follows:

Low Bat – Indicates low batteries. Replace the batteries.

Noise – Indicates excessive electrical noise is present in the velocity that will interfere with normal operation. This will cause the display to blank out.
Note: The noise flag usually comes on for a few seconds after the sensor is submerged even though there is no noise present. This is normal.

Con Lost – Indicates that either the sensor electrodes are out of the water or they have become coated with oil or grease. After 5 minutes, the unit will turn itself OFF. If the electrodes are coated, they will need to be cleaned (see *Cleaning* above).

Error#1 – There is a problem with sensor drive circuit. Check sensor disconnect.

Error#2 – Memory full error. Memory must be cleared before another reading can be stored.

Error#3 – Incorrect zero-adjust-start sequence. Reinitiate zero-adjust-start sequence.

Error#4 – Zero offset is greater than the zero adjust range. Repeat the zero-adjust procedure. If the error is still displayed, the unit needs servicing.

Error#5 – Conductivity lost, or noise detected during zero adjust. This is usually caused by the sensor being out of the water.

OTT MF Pro

Unlike the ***Marsh-McBirney Flo-Mate***, the OTT MP Pro can record all the flow reading measurements (*e.g.,* Velocity, Depth, and Distance as well as Bank Identification) electronically into a file that can be downloaded and saved. Additionally, the unit will automatically calculate the Partial and Total Discharges, QA/QC the results for irregularities (*e.g.,* too few measurements taken within the transect). The unit can also be setup to give instantaneous readings like the ***Marsh-McBirney Flo-Mate***.

Manufacturer's Manual

For a more complete description of the care and operation of the OTT MF Pro, consult the instruction manual provided by the manufacturer at:

http://www.ott.com/download/ott-mf-pro-operating-instructions/

Any information provided in this SOP is not meant to supersede the instructions or guidance provided in the manual provided by the manufacturer.

Maintenance

Cleaning the Sensor

If any unexpected increases or decreases in flow or depth are observed the sensor (***see Figure 4-7 on right***) may need to be cleaned. The sensor should also be cleaned after use in sandy or muddy streams. The sensor must be disconnected from the meter before cleaning. Acceptable cleaning solutions include dish detergent and water, window cleaner, and isopropyl alcohol. Do NOT use concentrated bleach, kerosene, gasoline, or aromatic hydrocarbons to clean the sensor. With heavier contamination, soak the sensor in clean tap water prior to using acceptable cleaning solutions. After cleaning the sensor, rinse with clean water.

Figure 4-7. Location of Depth Sensors on OTT MF Pro

Prior to use, the depth sensor ports, indicated with red arrows in ***Figure 4-7 on right***, should be checked for sand, silt, and/or mud build-up. If build-up is present, the sensor should be cleaned as described above.

Cleaning the Display

Make sure the display is NOT powered on. Clean the exterior of the display using a clean, damp cloth. A mild detergent can be used if necessary. Dry the display thoroughly before use. Paper-based cloths should NOT be used to clean the display as it could damage the screen.

Charging the Battery

The OTT MF pro uses a rechargeable, replaceable, internal, lithium-ion battery pack. With constant use, a fully charged battery will last for approximately 10 to 18 hours with typical use. Battery life is displayed as a segmented bar, with 5 segments, in the upper right corner of the display. If the battery voltage drops to 3.4 V or less a warning will be displayed, and the unit will turn off. Charge the battery using only the wall charger provided with the unit. The USB cable connection does not charge the unit. To charge the battery, insert the round end of the cable into the meter. Connect the plug end to a power outlet. While charging a blue status light will be visible. Once charging is complete the light will turn off. A discharged battery will take approximately 8 hours to recharge. Leaving the flow meter in a cold vehicle overnight will drain the battery much quicker. Additionally, use of the meter in a colder weather environment will cause the battery to drain much faster.

As the battery is a lithium-ion, it does have a limited lifetime. At some point the battery will no longer hold a charge for a sufficient amount of time. When this happens, the manufacturer should be contacted for purchase of a replacement battery pack.

Velocity Calibration

This feature can be used to account for a velocity offset and stays active until reset or the meter is turned off. This is like the zero adjust found on Marsh-McBirney flow meters (***see page 4-16***). To perform a velocity calibration, use a non-metallic bucket that is at least 8 inches deep and filled with water to a depth of at least 6 inches. Place the sensor in a plastic five-gallon bucket of water. Sensor should be 3 inches away from the sides and bottom of the bucket. This could possibly be achieved by attaching the sensor to the wading rod during the zero check and balancing the wading rod in a hands-free standing position in the bucket.

1. Make sure the water is not moving and wait 10 to 15 minutes. Do not take any readings while waiting.
2. From the **Main Menu** navigate to **Setup** and press the **<OK>** button to select.
3. Press the **<OK>** button once more to select **Velocity Calibration**.
4. Follow on-screen prompts.

> **NOTE: When conducting the Velocity Calibration at the WVDEP Headquarters in Charleston, be sure that there is not a passing train during the Procedure. It has been observed that passing trains create excessive vibrations in the laboratory end of the building to the extent that it may seriously affect the Velocity Calibration.**

Accuracy

In velocities of less than 10 ft/s, the accuracy of the measurement is ±2% of the reading, with a tolerance of ±0.05 ft/s.
For example:

Reading:	2.05 ft/s
2% of Reading:	0.041 ft/s
Tolerance:	0.05 ft/s
Minimum Flow:	(2.05 – 0.041 + 0.05) ft/s
Lower Bound:	**1.959** ft/s
Maximum Flow:	(2.05 + 0.041 + 0.05) ft/s
Upper Bound:	**2.141** ft/s

In depths of less than 10 ft, the depth measurement accuracy is the larger of ±2% of reading or ±0.504 inches.

Basic Operation

Settings

Minimum Depth Offset

This feature is used to account for the extra depth between the bottom of the sensor and the bottom of the channel/wading rod.

1. Attach the sensor to the wading rod.
2. Set the sensor at the lowest possible setting on the wading rod.
3. Measure the distance between the bottom of the sensor and the bottom of the wading rod, **in feet**. This is the minimum depth, which should be equal to approximately 0.03 ft (1 cm).
4. From the **Main Menu** navigate to Profiler and press the **<OK>** key to select.
5. Navigate to **Setup** and press the **<OK>** key to select.
6. Navigate to **Maximum depth** and press the **<OK>** key to select.
7. **Automatic** will be highlighted. Press the **<OK>** key to select.
8. Enter the minimum depth measured in ***Step 3*** and press the **<OK>** key to save the value. Press the **<OK>** key again to return to the **Profiler** menu.

Wet/Dry Threshold

The wet/dry threshold is used to determine when the sensor is in or out of the water. As a default this value is set at 20. However, in streams with low specific conductance it may be necessary to reset the Wet/Dry Threshold value.

1. From the **Main Menu** navigate to **Setup** and press the **<OK>** key to select.
2. Navigate to **Wet/dry Threshold** and press the **<OK>** key to select.
3. The present reading is displayed on the screen. Obtain a reading for out of the water and in the water. Select a point in between the two measurements. This will be the new threshold value.
4. Navigate to **Enter Threshold** and press the **<OK>** key to select.
5. Enter the new value and press the **<OK>** key to save the value. Press the **<OK>** key again to return to the **Setup** menu.

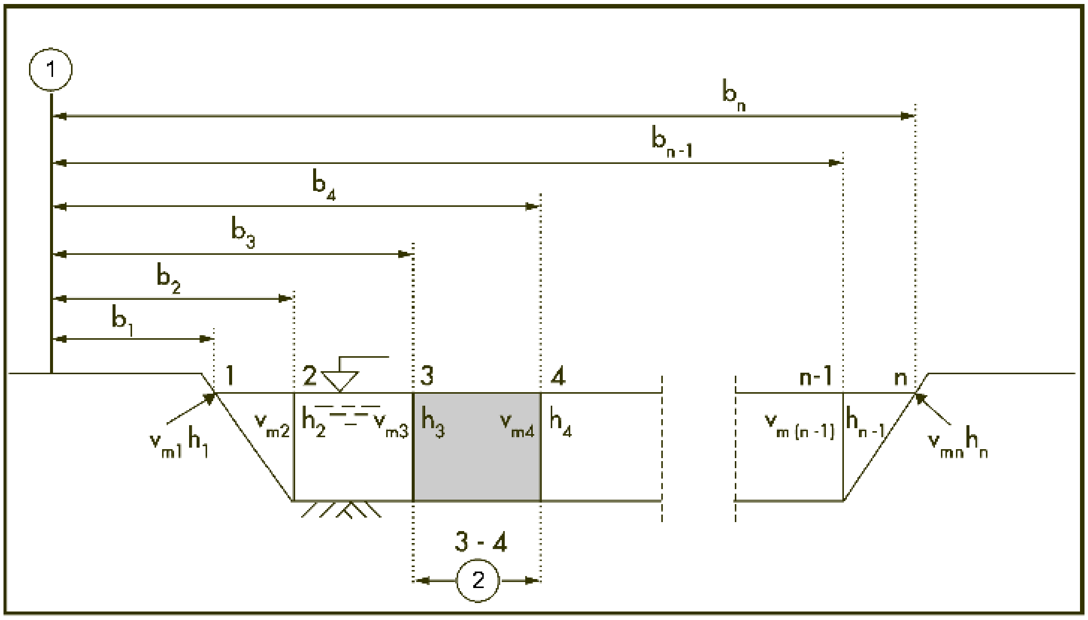
Flow Calculation Methods: Mid-section vs Mean-section

Two options exist for method of flow calculation: Mean-section and Mid-section. Ensure that Mid-section is the method used.

Mean-section Method

The following explanation and figure (***Figure 4-8 on below***) for Mean-section Method for Flow Calculation have been reproduced from the OTT MF pro manual for convenience:

> "The Mean-section method divides the cross-section into individual flow segments. Pairs of adjacent verticals are the limits of the segments. The two edges of the cross-section are given values of 0 for the velocity and depth. The total flow is the sum of the partial flows of all segments."



$$q_{3-4} = \left(\frac{V_{m3} + V_{m4}}{2}\right) \times \left(\frac{h_3 + h_4}{2}\right) \times (b_4 - b_3)$$

Where:

V = velocity at vertical

b = distance to vertical from bank

h = depth at vertical

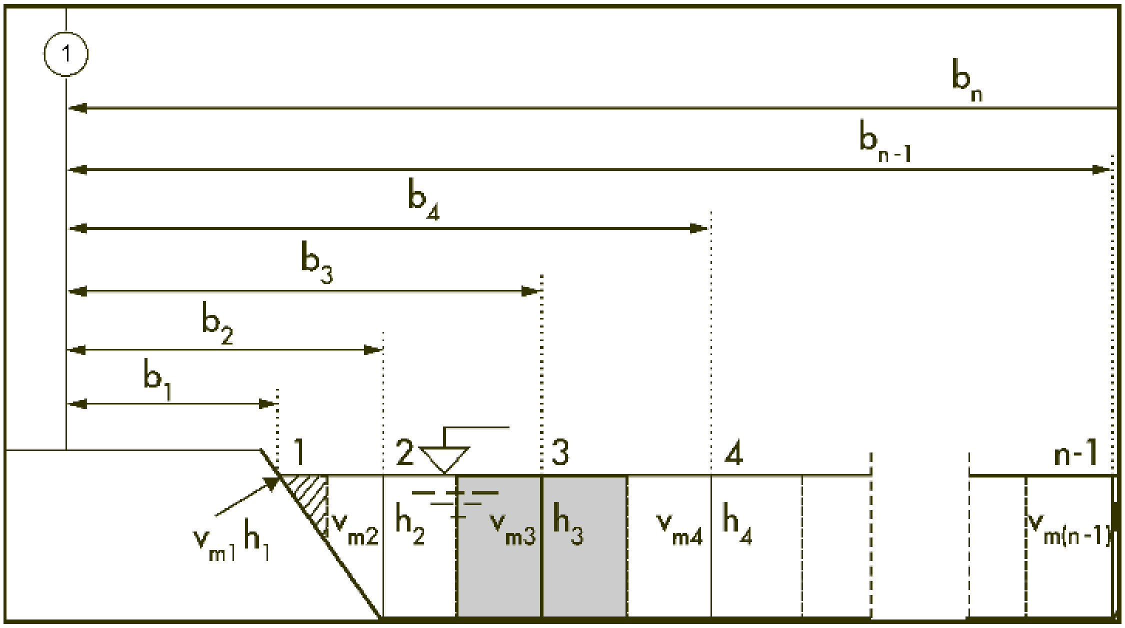
q = flow at vertical

Figure 4-8. Mean-section Method for Flow Calculation

Mid-section Method

The following explanation and figure (***Figure 4-9 on next page***) for Mid-section Method for Flow Calculation have been reproduced from the OTT MF pro manual for convenience:

> “The Mid-section method also divides the cross-section into individual flow segments. With the Midsection method, the segments are not between verticals but are defined by half of the distance to neighbor verticals in each case.”



$$q_3 = V_{m3} \times \left(\frac{(b_3 - b_2) + (b_4 - b_3)}{2} \right) \times h_3$$

Where:

m = station number

n = total number of stations

V = velocity at vertical

b = distance to vertical from bank

h = depth at vertical

q = flow at vertical

Figure 4-9. Mid-section Method for Flow Calculation

Setting the Flow Calculation Method to Mid-section

1. From the **Main Menu** navigate to **Profiler** and press the **<OK>** key to select.
2. Navigate to **Setup** and press the **<OK>** key to select.
3. Navigate to **More** at the bottom of the screen and press the **<OK>** key to select.
4. Navigate to **Flow Calculation** and press the **<OK>** key to select.
5. **Mid-section** should be highlighted. If not, navigate to **Mid-section** and press the **<OK>** key to select. Press the **<OK>** key again to return to the **Setup** menu.

Fixed Period Average

Fixed Period Averaging (FPA) is a type of filter applied to data which averages the values over a defined period (1 to 480 seconds). The default value for the OTT MF pro is 30 seconds. **<u>However, we will use a value of 20</u>.**

> **<u>NOTE</u>: A non-default value (*e.g.,* 20) is stored and used until either the value is changed, or the firmware is updated.**

To change or check the Fixed Period Average setting:

1. From the **Main Menu** navigate to **Profiler** and press the **<OK>** key to select.
2. Navigate to **Setup** and press the **<OK>** key to select.
3. Navigate to **Fixed Period Avg.** and press the **<OK>** key to select.
4. Verify that a value of **20** is entered and press the **<OK>** key to select. Press the **<OK>** key again to return to the **Profiler** menu.

Auto Zero Depth

The Auto Zero Depth feature should be set to on. This allows the meter to automatically calibrate a depth of zero when the sensor is removed from the water and is in the air. However, if the sensor has been submerged in water for 30 minutes the green status circle in the upper right corner of the display will turn red. This indicates that the sensor should be removed from the water so that the zero depth can be calibrated. When the status circle turns green it is safe to proceed with the flow measurement.

1. From the **Main Menu** navigate to **Setup** and press the **<OK>** key to select.
2. Navigate to **Auto Zero Depth** and press the **<OK>** key to select.
3. Navigate to the **On** option and press the **<OK>** key to select. Press the **<OK>** key again to return to the **Setup** menu.

Sleep Mode

If no keys are pressed within 30 seconds the screen will dim. If an additional 30 seconds pass without any key presses the screen will go to sleep. Press any key to wake from sleep mode. **After 30 minutes in sleep mode, the unit will power off and any unsaved data will be lost.**

Diagnostics Menu

Access the **Diagnostics** menu from the **Main Menu** to see information about the meter and to perform diagnostic testing in the event of an error or malfunction. The following table is reproduced from the OTT MF pro manual for convenience.

Table 4-3. OTT MF Pro Diagnostics Menu Guide

Menu Option	Description
About	Shows information about the meter and the sensor. Includes the serial number and the firmware version.
Delete files	Deletes all files from memory to make space for new measurements. Make sure that the data is downloaded to a PC before this option is selected. The system automatically reformats the memory after file deletion.
Sensor	Shows diagnostic information about the sensor.
Self-test	Makes the meter do a diagnostic self-test.
Key pad test	Does a test of any button to make sure that the button is functional.
Display test	Does a test on the display to make sure that the display is functional.
Event log	Lets the user see, delete or export the event log. Export the event log to make the contents available as an accessible file through USB mass storage. This option is used primarily by factory service.

Keypad Summary

Figure 4-10 and Table 4-4 below describe the functions of the Display Unit keys.

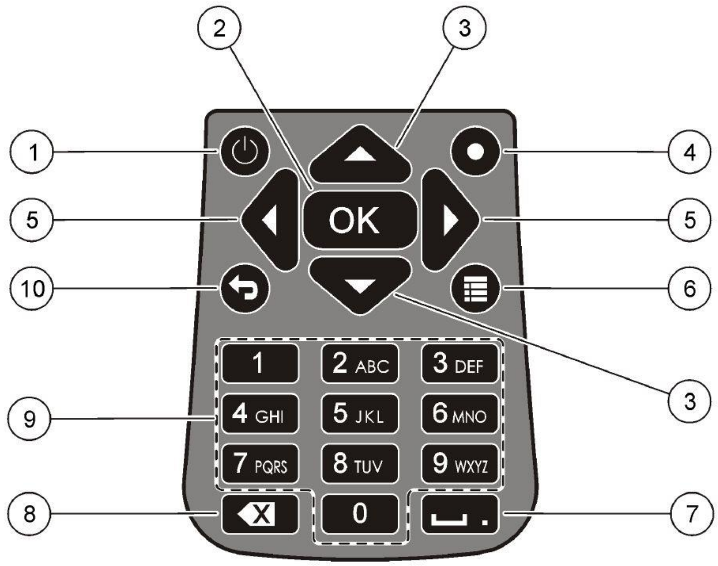


Figure 4-10. OTT MF Pro Keypad

Table 4-4. OTT MF Pro Keypad Guide

#	Key	Description
1	Power On/Off	Energizes and de-energizes the meter.
2	OK	Confirms an entry or highlighted menu option.
3	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.
4	Quick Jump	In normal operation, this key jumps to the Select conduit shape screen. If the auto-zero feature is disabled, hold this key for five seconds to do a manual zero of the depth sensor. In Real-Time mode, the Quick Jump key toggles between the digital and graph views.
5	Right and Left arrows	Moves to the right or left in the display.
6	Main Menu	Moves to the Main Menu from any submenu or screen.
7	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.
8	Backspace	Moves the cursor back one space.
9	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.
10	Previous menu	Moves to the previous screen.

<u>Field Operation</u>

> **<u>NOTE</u>: The OTT MF pro has an operating temperature of -20 °C to 55 °C (-4 °F to 131 °F). Charging temperature specifications are 0 °C to 40 °C (32 °F to 104 °F). The storage temperature specifications are -20 °C to 60 °C (-4 °F to 140 °F). Ensure that flow meters are not left in cold vehicles overnight as this can damage the meter and/or result in the battery discharging more quickly.**

Meter Set-up

1. Insert the sensor peg (on the bottom of the sliding wading rod shaft) into the opening on the back of the sensor (***see Figure 4-11 on right***). Position the three electrical sensors horizontal to the plane of the bottom (the foot) of the wading rod. Hand-tighten the thumb screw so that the sensor cannot slide off the peg or rotate out of position.

2. Connect the cable end of the sensor to the top of display unit (***see Figure 4-12 below***). Match the notch on the cable with the groove on the hand set. Twist the end of the cable by hand only. Do NOT tighten with any tools.

Figure 4-11. OTT MF Pro Sensor attached to end of wading rod.

Figure 4-12. OTT MF Pro Cable attachment to Hand Set

3. The display unit can be secured in 2 ways: attached to the wading rod with an adjustable mount for hands-free use or worn by a neck strap.
   - Adjustable Mount: Screw the mount into the back of the hand unit. Attach the mount to the wading rod using the adjustable clamp.
   - Neck Strap: ***See Figure 4-13 on next page*** for a diagram of how to secure the display unit using the neck strap.

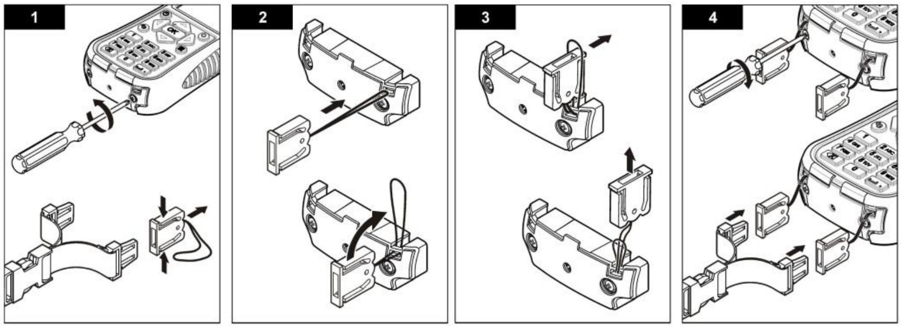


Figure 4-13. Diagram on how to Secure the Display Unit using the Neck Strap

Start-Up

1. After the flow transect has been properly set up, make sure that the sensor is out of the water and power on hand unit by holding the button down for 1-2 seconds until the unit emits a series of beeps.

2. Remain on the **Self-Test Results** screen until **Sensor Status** is **Communicating** and the Status Light in the upper right corner of the display is no longer red (***see Figure 4-14 below***). The **Sensor Status** sequence is **Unconnected**, **Establishing Communication**, followed by **Communicating** (***see Figure 4-15 below***). Once **Communicating** is displayed press the **<OK>** key.

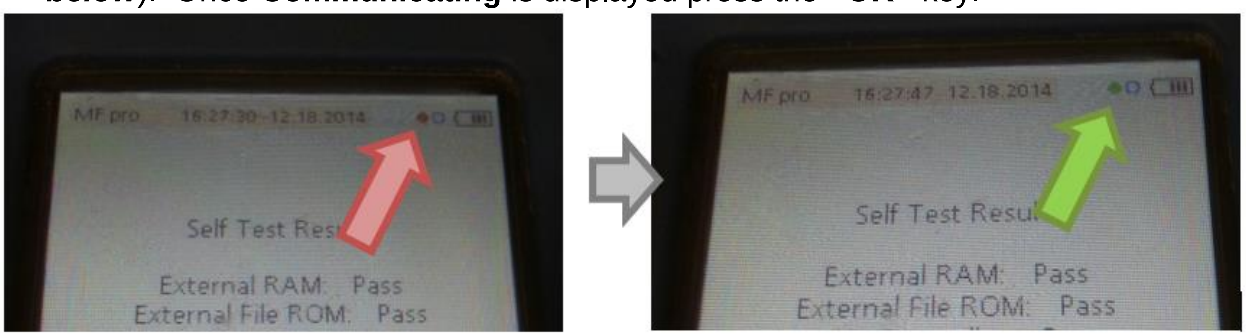


Figure 4-14. Red vs. Green Status Light on the OTT MF Pro Display Unit

Figure 4-15. Sensor Status on the Display Unit of the OTT MF Pro

File Set-Up

1. Navigate to **Profiler** using the ↓ key and press the **<OK>** key to select.

2. When prompted for **Operator Name**, enter the user's initials. Press the **<OK>** key to save and advance to the next screen.

> **<u>NOTE</u>: To skip to the next character rather than waiting for the unit to advance to the next character press the → key.**

3. Select **Stream** from the **Profiler** menu by pressing the <OK> key.

4. Enter the WQID as the **Stream profile name**. Press the <OK> key to save the name. This sets the WQID as the Profile Name within the file (***see Figure 4-16 below***).

	A	
1	Profile Name: 82926	
2	Operator Name: DES	
3	11:03:21 12.09.2014	
4		
5	Stage Reference: 0.000 ft	
6		
7	Model: MF pro	

Figure 4-16. Example of Stream Profile Name and Operator Name Embedded inside the OTT MF Pro Flow Data File

5. **Stage Reference** can be left blank as it is not needed. Press the **<OK>** key to advance to the next screen.

Taking In-Stream Flow Measurements

> **<u>NOTE</u>: For the most accurate velocity measurements, the OTT MF pro manual states that the user should stand to the side and downstream of the sensor, not directly behind it (*see Figure 4-3 on page 4-10*).**

1. Follow the procedures outlined on ***Part 1. Flow Measurement Procedures starting on page 4-5*** to establish the transect and vertical locations.

2. The meter automatically starts at Station 1; verify this at the top of the screen.

3. Set your bank by selecting **Edge/Obstruction**, using the ↑ and ↓ keys to navigate. Press the **<OK>** key to enter.

4. Select the **Edge Type** (**Left** for LDB, **Right** for RDB). Press the **<OK>** key to enter and advance to the next screen.

5. Navigate to **Dist. to Vertical** and press the **<OK>** key to select.

6. Enter the tape measure/tag line reading at the bank as Station 1 using the alphanumeric keypad. Press the **<OK>** key to save the value and advance to the next screen.

7. Depth is automatically set to 0 for bank locations. Try to avoid situations where the bank depth is not 0. However, if avoidance is not possible, which may be the case with bridge abutments, use the following procedure:

    a. Navigate to **Set Depth** and press the **<OK>** key to select.

    b. Make sure that the sensor is sitting as low as possible on the wading rod.

    c. The sensor automatically detects the depth and displays it on the screen.

    d. Check the height on the wading rod to ensure that it the displayed value is reasonable. And press the **<OK>** key to save the displayed value.

    e. The MF Pro will then prompt the user to enter the **Edge Factor**. The Edge Factor varies from 0.5 (very rough) to 1.0 (very smooth). For example, a bank that is smooth, such as concrete or steel, with no vegetation will have an Edge Factor of 0.8 or 0.9. Banks that are brick or have some vegetation will have an Edge Factor of 0.7. Banks with rough walls or heavy vegetation will have an edge factor of 0.6 or 0.5.

8. To go to the next station, navigate to **Next** at the bottom of the screen and press the **<OK>** key to select. The station number displayed at the top of the screen will advance to the next station, Station 2.

9. Select the nearest in stream location with appropriate positive flow and sufficient depth to cover the sensor (approximately 1.5” or 0.2 feet as indicated by the wading rod). Station 2 is the first actual velocity measurement point.

10. Navigate to **Dist. to Vertical** and press the **<OK>** key to select. Enter the distance on the tape using the alphanumeric keypad. Once entered, press the **<OK>** key to save the value.

11. Navigate to **Set Depth** and press the **<OK>** key to select. Make sure that the sensor is sitting as low as possible on the wading rod. The sensor automatically detects the depth and displays it on the screen (***see Figure 4-17 on next page***). Check the height on the wading rod to ensure that it the displayed value is reasonable. Press the **<OK>** key to save the displayed value.

12. Navigate to **Measure Velocity** and press the **<OK>** key to select. If the depth is less than or equal to 1.5 feet select **One point**. If the depth is greater than 1.5 feet select **Two point**. Press the **<OK>** key to select and advance to the next screen.

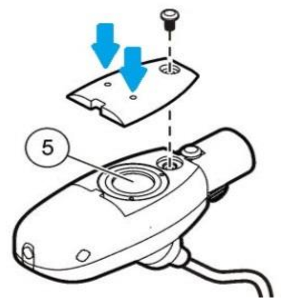


Figure 4-17. Location of the Depth Membrane on the OTT MF Pro Sensor

<u>NOTE</u>: If the displayed value varies significantly from the wading rod depth there may be an air bubble or debris trapped in/around the pressure sensor. Remove the sensor from the water and gently shake it. Return the sensor to the water and try again. If the values are still not reasonable, remove the sensor from the water and blow air through the small holes on the underside of the sensor (*indicated by blue arrows in Figure 4-17 on the left*) to dislodge the air bubble or debris. Do not insert anything, other than water or air, into the holes as the sensor membrane could become damaged.

13. The next screen will display the depth method for measuring velocity. For **One point** measurements the value displayed will be 0.6. Press the **<OK>** key to select and advance to the next screen. For **Two point** measurements 0.2 and 0.8 will be displayed. 0.2 is automatically highlighted first. Press the **<OK>** key to select and advance to the next screen.

    a. The next screen will display the current sensor depth as well as the required depth for accurate flow measurement. Adjust the depth of the sensor on the wading rod so that it equals the **Adjust Sensor to** value (0.6 for One point, 0.2 for Two point). The sliding scale on the right graphically displays proximity to the desired depth. When **Sensor Depth** is within an acceptable range the surrounding box will turn green. A yellow box surrounding **Sensor Depth** indicates that depth is close to the correct depth while red indicates that more adjustment is necessary.

    b. Press the **<OK>** key to **Capture** the depth and advance to the next screen. <u>Take caution so as not to disturb the sensor as the measurement process will begin once the **<OK>** key is pressed!</u> ***Remember to that the user should stand to the side of the meter, not behind it, for accurate measurement results!***

    c. **Progress** (%) is displayed below the **Inst. Avg. Velocity**. When **Progress** reaches 100% the flow measurement process has completed. Allow **Progress** to reach 100% even if the numbers appear stable. As the unit keeps a time-stamped record of all keystrokes, readings cut short will be recorded as such.

    d. Press the **<OK>** key to accept the value and advance to the next screen. If the flow measurement is unsatisfactory, repeat the measurement. Navigate to **Repeat** and press the **<OK>** key to select. The measurement process will begin again.

   e. If the **Two point** option was selected (for Stations with a depth greater than 1.5 feet), the screen with 0.2 and 0.8 will appear, this time with 0.8 highlighted. Press the **<OK>** key to select and advance to the next screen repeating ***Step 13 (a-d)***.

14. The next screen will once again display the depth method(s) for measuring velocity. This time the **Main** option will be highlighted. Press the **<OK>** key to return to the Profiler menu.

15. The **Next** option will automatically be highlighted. Press the **<OK>** key to advance to the next station. **Verify that the station number has changed at the top of the screen.**

16. Repeat ***Steps 10 through 15*** for remaining flow measurement locations (Stations). Remember to return the sensor to the bottom of the wading rod before recording depth at each station!

17. If an obstruction is present at a station, such as a split channel, island, dry boulder, etc., navigate to **Edge/Obstruction** and press the **<OK>** key to select.

    a. Navigate to **Open Water** to set the station as an open water obstruction. Repeat ***Steps 10 and 11*** to set the location and depth.

    b. Navigate to the **Next** option to advance to the next station.

18. Repeat ***Steps 3 to 5*** for recording the location of the opposite bank.

Review Channel Summary

Once all stations have been measured, view the **Channel Summary** by navigating to the option from the menu and pressing the **<OK>** key to select. A graphic representation of the channel flow will be displayed. A warning will display if the discharge at any given station is greater than 5% of the total discharge which indicates that additional stations may need to be added.

Add/Delete Stations

To add a station between existing stations, navigate to the Profiler Menu using the  key. Use the **Prev.** and **Next** options to navigate to the station preceding the one to be added. Navigate to the **Ins.** option at the bottom of the screen and press the **<OK>** key to insert a new station. Subsequent stations will automatically be renumbered to account for the additional station. Repeat ***Steps 10 through 14***.

<u>IMPORTANT</u>: If adding a Station between two existing Stations, be sure to read and enter the Distance measurement along the tape measure/tag line when keying in the Dist. to Vertical value. The OTT MF Pro will insert the new Station readings between the existing readings according to the distance value keyed in (e.g., a reading taken at 12.5 will be inserted between readings at 12 and 13. If you input the distance incorrectly (e.g.,13.5 when it should have been 12.5), then it will insert the station in the wrong location (e.g., between readings at 13 and 14) and the total discharge calculation will be incorrect.

To remove a station, navigate to the desired station using the **Prev.** and **Next** options at the bottom of the screen. Navigate to the **Del.** options and press the **<OK>** key to select the delete option. Navigate to **Yes** to delete and press the **<OK>** key to confirm. Navigate to **No** to cancel the deletion. The  key can also be used to return to the previous screen, cancelling the deletion. Subsequent stations will automatically be renumbered to account for the deleted station.

Saving the File

1. Once the flow has been completed satisfactorily, save the flow measurement data by navigating to **Save Data and Exit** and pressing the **<OK>** key.

2. Enter the WQID as the name of the file using the alphanumeric keypad. Press the **<OK>** key to save the file name.

<u>NOTE</u>: Some files take longer to save than others; you may not see the file access icon at all if the file is saved quickly. The MF Pro will warn you if you are about to exit without saving.

3. Wait for the file access icon, below the battery status bar, to disappear before selecting Done and pressing the **<OK>** key (***see Figure 4-18 below***).

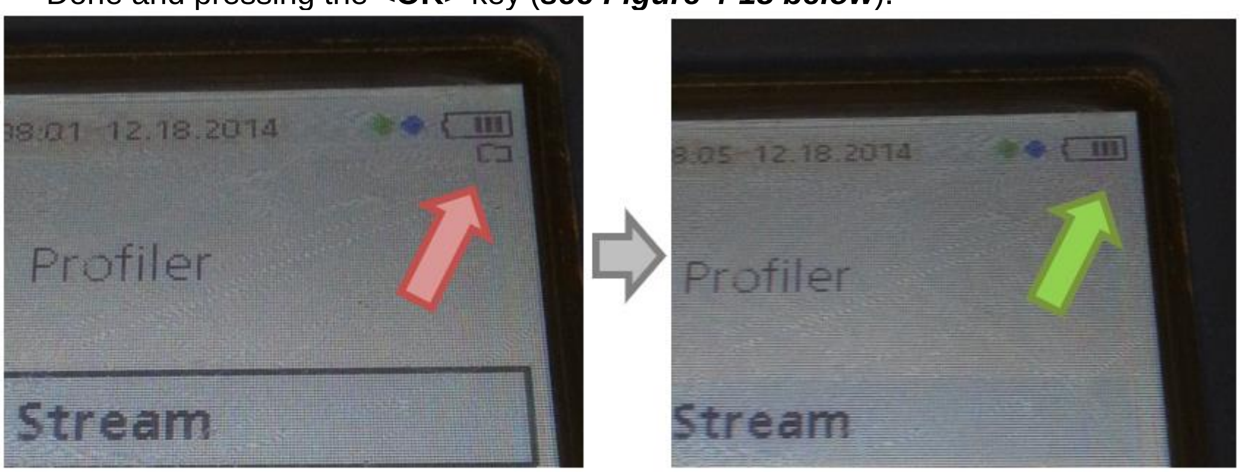


Figure 4-18. Example of File Access (Saving) Icon on OTT MF Pro Display Unit

Power Down

To power off the OTT MF Pro press and **Confirm power off** by navigating to **Yes** and pressing the **<OK>** key. The unit will power off.

Real-Time Mode

This is like doing a flow measurement with a ***Marsh-McBirney Flo-Mate*** meter.

1. From the **Main Menu** navigate to **Real-Time** and press the **<OK>** key to select.

2. Once the wading rod has been properly adjusted for depth (***see How to Adjust the Wading Rod to take Velocity Readings on page 4-9***), navigate to **Capture** and press the **<OK>** key to select. Take caution so as not to disturb the sensor as the measurement process will begin once the **<OK>** key is pressed! ***Flow velocity will not be displayed until 20 seconds have passed.***

3. After 20 seconds the average flow will be displayed, record this number.

4. Navigate to **Clear** and press the **<OK>** key to select.

5. Navigate to **Clear All** and press the **<OK>** key to select.

6. Move to the next station/flow location and adjust the wading rod for the proper depth.

7. Repeat ***Steps 2 through 6*** for all remaining stations.

8. Once all stations have been measured navigate to **Done** and press the **<OK>** key.

9. To power off the OTT MF Pro press and Confirm power off by navigating to **Yes** and pressing the **<OK>** key. The unit will power off.

Downloading Data

1. Connect the OTT MF Pro to the computer using a mini-USB cord and power the flow meter on.

2. The computer may take a minute to recognize the connection. Locate the drive that the OTT MF Pro has been connected to using the file browser (click on Computer or My PC on the Start Menu). The meter will be displayed as ‘PVM’.

3. Open the drive by double clicking. Navigate to the Profile folder and select the flow measurements you wish to download. You can select multiple files by holding the Ctrl key while clicking the individual file names.

4. Once the desired files are selected, right click and select ‘copy.’

5. Navigate to the following folder:
   Q:\WATER RESOURCES\WAB\FLOW\Recent downloads Not Printed

6. Right click in the 'Recent downloads Not Printed' folder and select 'paste.' The selected files will be copied to the folder

OTT MF Pro Troubleshooting

The following table is reproduced from the OTT MF pro manual for convenience.

Table 4-5. OTT MF Pro Troubleshooting Guide

Message or Problem	Solution
Sensor is not connected	Connect a sensor and try the action again.
Value is out of range	Change the measurement parameters or put in a different value, then try the action again.
Sensor data is known to be not correct or not accurate	Clean the sensor and test.
Sensor is not recognized	Check the sensor connection. Make sure that the lock nut on the connection port is tight (finger-tighten only).
Display is dim or is not visible	Push a key on the keypad to exit dim/sleep mode.
Data is not available or access to the data is not possible	Make sure that the USB option (Main Menu) is set to Mass Storage.
Meter is unresponsive	Push and hold the power button for at least 3 seconds. This de-energizes the meter. Energize the meter again. **Note:** Do not use this method to power off while in normal operation or if the file access icon is visible in the display.

Section B. Measuring Flow Using a Bucket and Stop Watch

On some rare occasions, it may be possible or more practical to measure flow using a bucket of known volume and a stop watch. Such instances include measuring flows coming out of a pipe where there is adequate room to place the bucket underneath the pipe. The procedure to measure flow in this manner is to measure the seconds it takes to fill up the bucket. It is recommended that you repeat this measure at least three times and take the average time as the final reading. Converting this measurement into cubic feet per second (CFS) units may require some research into conversion units (*e.g.,* gallons or liters into cubic feet). However, the flow template sheet (***mentioned in H. Calculating Total Discharge from the Sum of Partial Discharges on page 4-13***) contains a worksheet already calibrated to convert measurements using gallons per second into cubic feet per second. Simply enter the seconds it took the fill up the bucket, the volume of the bucket in gallons and the resultant CFS will be calculated at the end of the row. Document on the field sheet the flow method and the individual and final average CFS.

Section C. Measuring Flow Using a USGS Gauging Station

In some instances, a sampling station on a larger stream may coincide or be very near a USGS Gauging Station. If this is the case, then flow readings could be read from the USGS gage. USGS maintains a website to access current and historical stream discharge and stream stage data from the gages. The web addresses for West Virginia daily stream gage data are:

http://waterdata.usgs.gov/wv/nwis/current?type=dailystagedischarge
http://wv.usgs.gov/
http://waterwatch.usgs.gov/?m=real&r=wv

See Figure 11-3 and Figure 11-4 in CHAPTER 11. Section A. Part 4. Measuring Stream Flow starting on page 11-9 for examples of USGS website data displays.

Once you have accessed a specific gage, you will need to use the real time and table options to view hourly gage data. Record the USGS gage number, discharge and/or stage readings, for the date and time sampled, onto the analysis request form. Hourly data are available for up to 60 days, from the date a site is visited. Daily averages are available up to two years.

Flow Measurement Quality Assurance/Quality Control

Before use, each Flo-mate velocity-meter should be examined for wear and fouling, and adjustments should be made as required.

Zero check and adjust logbooks are maintained for each instrument and entered into a database. Any instrument failing to meet zero check requirements is zero adjusted or shipped to the manufacturer for diagnosis and repair. Flow meters are checked monthly and may be zero checked and adjusted in the field if necessary.

Each flow meter has an identification number, which is recorded on the habitat assessment sheet each time it is used. If any instrument fails a zero check, readings taken prior to the failed zero check will be examined for reliability and accuracy. Documentation of the instrument used at each site will help to keep data loss to a minimum. All repair logs to flow meters are documented and maintained by the manufacturer and noted in a repair log.

All measurements calculated within the instrument (*i.e.*, ***OTT MF Pro*** meter) are downloaded to a .csv file and stored permanently on the network drive. During data entry, the raw measurement values (distance, depth, velocities at different depths, *etc*.) are copied from the .csv to the database. The copied data is in turn run thru a separate calculation (identical to the spreadsheet calculation) within the database and the results are compared between the two for discrepancies (beyond differences in rounding). Any discrepancies are resolved and documented.

Once a year, all field participants in the WAB attend mandatory training sessions. The purpose of these sessions is to ensure that all field personnel are familiar with sampling protocols and calibrated to sampling standards. A hands-on session concerning the measurement and collection of flow data is included. Individual training will occur simultaneously on the same stream, so the results can be compared to the group average. Readings that deviate exceptionally from the norm will be examined for errors. Individuals who are more experienced in determining flows will be teamed up with the less experienced to ensure reinforcement of training and accurate results before they can measure flows. This document is also provided to all program personnel for review and use in the field.