STANDARD OPERATING PROCEDURE FOR STREAM FLOW MEASUREMENT

State of Utah
Department of Environmental Quality
Division of Water Quality

Revision 0
Effective May 1, 2014

Utah Division of Water Quality (DWQ) Standard Operating Procedures (SOPs) are adapted from published methods, or developed by in-house technical experts. This document is intended primarily for internal DWQ use. This SOP should not replace any official published methods.

Any reference within this document to specific equipment, manufacturers, or supplies is only for descriptive purposes and does not constitute an endorsement of a particular product or service by the author or by DWQ. Additionally, any distribution of this SOP does not constitute an endorsement of a particular procedure or method.

Although DWQ will follow this SOP in most instances, there may be instances in which DWQ will use an alternative methodology, procedure, or process.[1]

[1] *Disclaimer language above adapted from Washington State Department of Ecology SOPs.*

REVISION PAGE

Date	Revision #	Summary of Changes	Sections	Other Comments
5/1/14	0	not applicable	not applicable	Put previous procedures into new standardized format, began document control/revision tracking.

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1.0 SCOPE AND APPLICABILITY

This document presents the Utah Division of Water Quality's (DWQ) Standard Operating Procedure (SOP) for performing stream flow measurements. Flow is also referred to as discharge and is measured routinely at each water quality sampling site whenever feasible. Flow measurements are performed for natural (rivers, streams) and engineered (outfalls, ditches, canals, impounded wetland outlets, etc.) surface water bodies. Flow data is used by DWQ scientists and engineers for a variety of purposes including but not limited to:

- understanding the effect of hydrologic condition on aquatic life uses
- determining pollutant loading and inputs into receiving waterbodies
- setting permit requirements for discharge of treated wastewater
- understanding groundwater/surface water interactions
- characterizing current water quality conditions and detecting long-term changes

This SOP applies to any DWQ monitor, non-DWQ cooperator, or volunteer performing flow measurements. This SOP covers taking flow measurements at both wadeable and non-wadeable sites using the following equipment/methods:

- <u>Wadeable:</u>
    - Sontek/YSI FlowTracker Handheld-ADV®
    - Hach Marsh-McBirney Flo-Mate™
    - Flow Estimate using the Neutrally Buoyant Object Method or other alternative
- <u>Non-wadeable:</u>
    - StreamPro ADCP (also referred to in this SOP as a Q-boat)

Flow estimates (fully documented and described in the field notes) can be useful data. Although not discussed in the main body of this SOP, flows can be estimated using the following methods which are attached:

- Use the neutrally buoyant object method combined with an estimate or measure of the channel cross-section.
- Locate a waterfall and time filling a bucket of known volume.
- Use a flume or V-notch weir to create a small spillway and use the timed filling method.

The preferred methods are given in **Appendix 1** – a DWQ quick reference SOP for the neutrally buoyant object method and in **Appendix 5** – select pages from EPA's NRSA Field Operations Manual.

Important Considerations:

- Flow data is critical for TMDL (total maximum daily load) monitoring. Monitors must make every effort possible to obtain flow measurements for non-gaged TMDL sampling locations, as long as conditions for obtaining the measurement are safe.

- When developing sampling portfolios for a monitoring run, the project field team leader should identify those sampling sites which are gaged by a non-DWQ entity/agency. Before a monitoring run, the project field team leader should check with the managing entity to ensure the gage is still operating and if not, make the necessary changes to the sampling portfolio. Additionally, monitors should perform a flow measurement at a gaged site if, upon arrival to the site, the gage appears to be damaged or non-functioning. *Make every effort to determine the sampling sites for which flow data is being monitored by a non-DWQ entity (e.g. wastewater treatment plant outfall or USGS gaging station) prior to beginning a sampling trip.* Monitors should also record the flow gage reading or obtain a gage height if possible (staff plate or wire weight gage) in the field, contact the wastewater treatment plant operator for discharge data during the time of sampling, or note the USGS (or other entity) gage number in the field notes/field sheet so discharge at the time of sampling may be queried at a future date.

- Some sampling sites are continuously monitored for flow by gaging stations installed and maintained by Utah DWQ (pressure transducers), although the data is not accessible in real-time. At these locations, monitors should perform the flow measurement and gage inspection and then notify the senior DWQ monitor responsible for the gaging station that a flow measurement was performed at that site (see DWQ's SOP for Pressure Transducer Installation and Maintenance).

- The information discussed in this SOP is not a substitute for the official flow meter product user manual. Consult the appropriate manual for a complete guide of the proper use, maintenance, and troubleshooting of discharge measuring equipment (see **Section 12.0 - References**).

2.0 SUMMARY OF METHOD

2.1 Wadeable Sites

2.1.1 Sontek/YSI FlowTracker Handheld-ADV®

A stream cross-section is established and the Flow Tracker is used to determine velocity at each point measured. The meter is attached to a wading rod used to measure depth and keep the meter properly positioned within the current. The monitor faces the meter upstream while standing downstream of the meter and a tagline. The Flow Tracker uses acoustic Doppler technology to measure 2D flow in a small sampling volume located at a fixed distance (10 cm or 3.9 in.) from the probe. Sound generated by the transmitter bounces off suspended particles in the water. This reflected sound returns to the receivers, is averaged together by the processor, and results in water velocity measurements that are recorded at a rate of one per second. At the end of the measurement, the FlowTracker calculates the discharge.

2.1.2 Hach Marsh-McBirney Flo-Mate™

A stream cross-section is established and the Marsh-McBirney meter is used to determine velocity at each point measured. The meter is attached to a wading rod used to measure depth and keep the meter properly positioned within the current. The monitor faces the meter upstream while standing downstream of the meter and a tagline. The Marsh-McBirney is an electromagnetic velocity meter that uses an electromagnetic sensor to measure the velocity in a conductive liquid such as water. A pair of carbon electrodes measure the voltage produced by the velocity of the passing water. The measured voltage is processed by the electronics and output as a linear measurement of velocity. The velocity is in one direction and displayed on a digital display as feet per second (ft/s) or meters per second (m/s). The user must record stream width, depth, and velocity in order to manually calculate discharge.

2.2 Non-Wadeable Sites

2.2.1 Teledyne RD Instruments StreamPro Acoustic Doppler Current Profiler (StreamPro ADCP)

A StreamPro (also called a Q-boat) is used when stream depth or velocity is such that a monitor cannot safely enter the water to take a flow measurement. However, Q-boats do not work well in very swift water such as during spring runoff, and using them in these conditions could result in equipment damage or loss. The unit is designed for operation in stream depths ranging from 15 cm to 2 m (0.5 to 6.6 ft). The instrument is pulled across the stream as the monitor walks across a bridge or the unit can be attached to a tagline or pulley system and operated from the bank if a bridge is not present. The unit uses acoustic Doppler technology and bottom tracking to measure current velocity from the top of the water column to the bottom at the same instant with a 5 cm resolution. Data is collected continuously as the unit is pulled across the stream and is sent wirelessly to a PDR (portable data recorder). Software on the PDR saves the data transmitted by the StreamPro. The complete discharge measurement is computed via a second software program on a PC.

3.0 DEFINITIONS

ADCP:	acoustic Doppler current profiler
ADV:	acoustic Doppler velocimeter
Discharge:	A term used in this SOP interchangeably with “flow”. This is the volume of water flowing past a fixed point

	per unit of time. Units are typically cubic feet/second (ft^3/s or cfs) or cubic meters/second ((m^3/s).
EPA:	Environmental Protection Agency
Flow/discharge measurement:	A manual measurement of flow/discharge performed by a DWQ monitor/cooperator/volunteer.
NRSA:	National Rivers and Streams Assessment
PC:	Personal computer
PDR:	Portable data recorder
USGS:	United States Geological Survey
Velocity:	Distance water travels per unit time. Units are typically centimeters or meters/second (cm/s or m/s) or feet/second (ft/s).

4.0 HEALTH AND SAFETY WARNINGS

Field personnel should be aware that hazardous conditions potentially exist at every waterbody. If unfavorable conditions are present at the time of flow measurement, it is recommended that the measurement be rescheduled. If hazardous conditions arise during measurement, such as lightning, high winds, rising water, or flash flood warning, personnel should cease sampling and move to a safe location.

Field personnel should take appropriate precautions when operating equipment and working on, in, or around water, as well as possibly steep and unconsolidated banks. All field crews should follow EPA, OSHA, and specific health and safety procedures and be equipped with safety equipment such as proper wading gear, personal flotation devices (PFDs), gloves, first aid kits, cellular phone, etc.

Always use caution when measuring from a bridge and take appropriate actions to make the situation as safe as possible; suspend the measurement if conditions are unsafe.

5.0 CAUTIONS

Use caution when handling flow equipment. Flow meters must be placed in a travel case or in a safe place within a vehicle to prevent damage during transport.

Submersion of the StreamPro's electronics housing is strongly discouraged by the manufacturer. The StreamPro should be kept as level as possible during the measurement.

If the electronics in the StreamPro reach a temperature of 50°C, the Bluetooth connection will likely be lost. When performing discharge measurements on very hot days, be aware of this issue; the instrument may need to cool down in the shade or in a cooler before it can be used.

Always be observant of potential debris floating from upstream that could potentially damage equipment and/or cause harm to the operator.

6.0 INTERFERENCES

The physical makeup of a stream may prevent an accurate flow measurement. If the stream is shallow and has a substrate dominated by cobble, a FlowTracker may have difficulty reading the speed of particles. When establishing the cross section, look for an area of laminar, smooth flow with minimal obstructions. Obstructions, including large rocks, can be moved out of the way of the cross section, but only before flow measurements begin, never during the measurement. The StreamPro works best with uniform straight stream reaches, stream bottoms made up of smaller substrate material with little or no aquatic vegetation or debris, little turbulence, no standing waves or “boils”, depths between 1 and 14 feet, and velocities <6-7 ft/s.

A quality control test must be performed each day prior to taking a flow measurement with the FlowTracker or StreamPro to ensure the equipment is operating properly.

For wadeable sites, be sure to place the flow meter downstream of the tape measure and be sure to stand downstream of the flow meter.

Discharge measurements performed on low-velocity streams with the StreamPro can be highly variable. Research has shown dramatic increase in variability when flow velocities are < 0.8 ft/s (Blanchard 2005). The manufacturer recommends that if water velocity is <20 cm/s (0.66 ft/s) and the depth is <1.0 m (3.3 ft), the operator should use the StreamPro software’s “Low Noise Profiling Mode” to reduce variability. For all other conditions, use the standard profiling mode.

7.0 PERSONNEL QUALIFICATIONS/RESPONSIBILITIES

Monitors performing flow measurements are required to read this SOP annually and acknowledge they have done so via a signature page (**Appendix 1**) that will be kept on-file at DWQ along with the official hard copy of this SOP.

New personnel must be trained in performing stream flow measurements by an experienced monitor. Monitors must read through the product manuals for the discharge equipment described in this SOP (see **Section 12.0 – References**) prior to their training session as well as keep these manuals on-hand in the field, as this SOP does not cover all details regarding equipment setup and use, trouble shooting, precautions, software setup and use, and downloading/reviewing of data.

Monitors have the responsibility of maintaining flow meters and flagging the equipment if it is in need of repair.

8.0 EQUIPMENT AND SUPPLIES

FlowTracker:
Meter and rod with case
Copy of this SOP
User manuals
Tape Measure (10ths of ft)
Tool box for repairs/replacement
Field sheet or notebook
Extra Batteries (8 AA)
Phillips Screwdriver
Waders and boots

Marsh-McBirney:
Meter and rod with case
Copy of this SOP
User manuals
Tape Measure (10ths of ft)
Tool box for repairs/replacement
Field sheet or notebook
Extra batteries (2 D)
Waders and boots

StreamPro:
Meter and rod with case
Copy of this SOP
User manuals
Tagline, tow ropes
Tool box for repairs/replacement
Field sheet or notebook
PDR
Extra Batteries (8 AA)

Neutrally Buoyant Object:
Tape Measure
Yardstick
Surveying flags/flagging
Float (An orange works best)
Net, if needed, to catch the float
Stopwatch
Calculator
Field sheet or notebook
Waders and boots

9.0 PROCEDURE

9.1 Preparing Site for Measurement

9.1.1 Wadeable Sites

Appendix 2 includes a flow diagram providing guidance for stream flow measurements at wadeable sites.

Use the same procedure when using either the FlowTracker or Marsh-McBirney meters. Establish a stream cross section for flow measurement to occur. Desirable characteristics for the site location include:

- A straight section of stream, away from stream bends;
- Stream flow approximately parallel to stream banks;
- A constant stream gradient;
- No obstacles protruding from water surface (i.e. stones, plants, bridge piers).

Attach a tape measure (marked in 10ths of feet) to one stream bank and string it across the stream securing onto the opposite bank. The tape should create a line perpendicular to the flow of the stream. Make sure the tape is tightly stretched across the stream and not in danger of sagging onto the water surface.

9.1.2 Non-wadeable Sites

Typically the StreamPro, also referred to by DWQ as a Q-boat, will be dragged across a transect from a bridge crossing the river/stream. If a bridge is not available, a tagline twice as long as the water body is wide can be stretched from bank to bank, with the StreamPro in the middle. As one person feeds out the tagline, another will pull the StreamPro across the water body. Although the StreamPro measures distance across the transect, initial measurements of the stream edge must be manually entered into the PDR to define starting and ending points of the transect (edge of water).

9.2 Performing the Flow Measurement

9.2.1 Sontek/YSI FlowTracker Handheld-ADV®

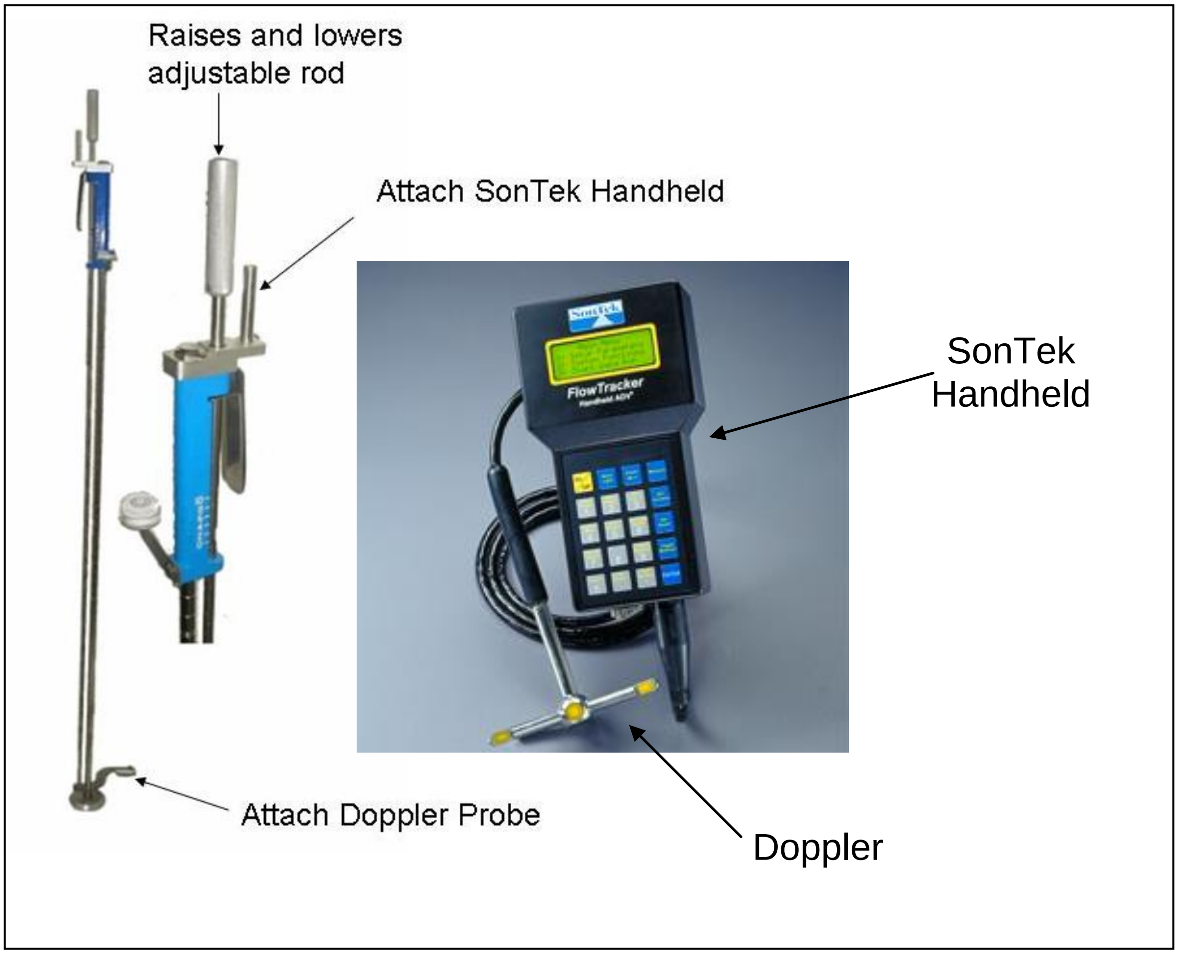
<u>Flow Tracker Assembly</u>

See **Figure 1**. Assemble the wading rod by matching up the two sections of the graduated rod (marked in 10ths of feet). Raise the adjustable rod up so that it is easier to tighten the graduated rod. Once the graduated rod is assembled and secure, lower the adjustable rod to match up with the threaded section. Twist the top of the adjustable rod to tighten.

Attach the SonTek handheld display to the top of the wading rod and tighten using the attached wing nut.

Secure the Doppler probe to the appropriate outlet and secure using a Phillips screwdriver or by tightening the wing nut (if available).

Figure 1. FlowTracker assembly.



Determine Measurement Interval

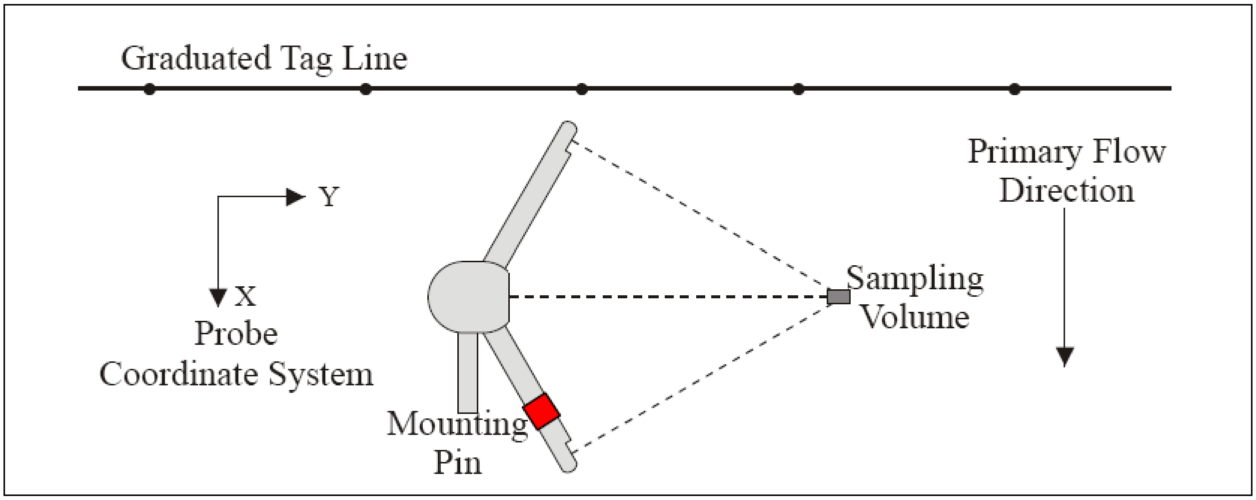
If stream width < 10 feet, collect data every 0.5 feet; and take first reading at 0.25 feet (half of interval) from edge.

If stream width > 10 feet, collect 20 evenly divided measurements across the entire stream; take the first reading at half of the determined interval from edge.

Data Collection

Figure 2 shows the proper orientation of the probe while performing discharge measurements. Be sure to take flow measurements on the *downstream* side of tape measure and to stand *downstream* of the flow meter.

Figure 2. FlowTracker orientation in stream (image from user manual).



1. On the SonTek handheld, hold on/off button down for one second.

2. Select Main Menu…Setup Parameters and System Functions will be set, refer to manual for details.

3. Press #3 Start Data Run…follow on screen instructions (use last four digits of the site code as site name). If data storage is full, erase the previous data. To do this, return to the "Main Menu" screen. Press #2 "System Functions", then press #3 "Format Recorder". The system will prompt you to press 123 to confirm your decision to erase all previously recorded data.

4. Select the option to run the QC (quality control) test once at the beginning of the day (press "skip test" the rest of the day). Instructions for performing the QC test will automatically appear on the display: go through the entire QC test.

5. After the QC test, you will be taken to the "Starting Edge" screen. Move to the water's edge of one stream bank and place the wading rod into the water to measure depth. Press "Set Location" button and enter the distance value (what the tape measure reads at waters edge). Press the "Set Depth" button and enter the depth of the water level at your starting location (measuring with graduated wading rod). If the bank is sloping, this depth will likely be zero but there will be a depth measurement if the bank is undercut. Press "Next Station" to continue to the next measurement interval.

6. Move FlowTracker to next measurement interval. This location should be at ½ the determined measurement interval. (For example, if the stream is <10 feet wide, intervals will be 0.5 feet. If the edge of water is at 0.0 feet on the tape, the first

interval will be at 0.25 feet. The next measurement should be at 0.5 feet beyond the first location, 0.25 feet + 0.5 feet = 0.75 feet.)

7. Enter in the actual depth on the handheld and move the adjustable rod to the corresponding measurement depth (60% of depth of water). Press “Measure” to record the flow at that interval. Use the bubble level on the wading rod to keep the FlowTracker parallel to the stream flow. After 20 seconds of recording, the handheld will give the velocity of the interval in feet/second. If something has caused the accuracy of the flow data to be degraded, error warnings will be displayed. Some common errors include: High Angle, Low SRM, and QC out of bounds. **Table 1** includes a summary of common errors and the corresponding solutions.

Table 1. Common error messages and solutions for the SonTek/YSI FlowTracker.

Error Message	**Potential Problem**	**Solution**
Low SNR	Lack of suspended material/ high water clarity	Introduce seeding material/ accept error
Boundary QC Error	Interference from submerged object	Move objects or relocate transect to clear channel
Spikes	Large Particles or bubbles	Move transect to location with less or no whitewater
High Angle	Improper alignment of probe to flow/ probe not level	Re-align probe directly into flow and level

8. Select “1” to accept the measured flow and the handheld will automatically move to the next measurement interval.

9. Continue to enter in the depth, move the adjustable rod, and measure the flow for each interval until you reach the last measurable interval. This may be at the opposite bank or at a point where water is no longer flowing or is flowing backward or in an eddy. At this location, press “End Section.” The FlowTracker will ask for confirmation of ending section and go through all the errors found for the entire reach. After going through the errors, the main screen will pop up again where the depth of the last interval can be entered. Press the “Set Depth” button to enter in the correct depth for the opposite edge of water and “Set Location” button if location needs to entered (i.e. last measurement was not performed at the bank).

10. Press “Calculate Discharge” to get the flow in cubic feet per second (ft^3/s) for the measured reach. The FlowTracker will ask for confirmation of calculation and then will give the flow (discharge) reading. Verify that the flow value is reasonable before recording.

9.2.2 Marsh-McBirney

Marsh-McBirney Assembly

The flow sensor must be connected into the outlet on the lower portion of the flow meter. Secure the sensor by tightening the thumbscrew. See **Figure 3**.

Determine Measurement Interval

If stream width < 10 feet, collect data every 0.5 feet; and take first reading at 0.25 feet (half of interval) from edge.

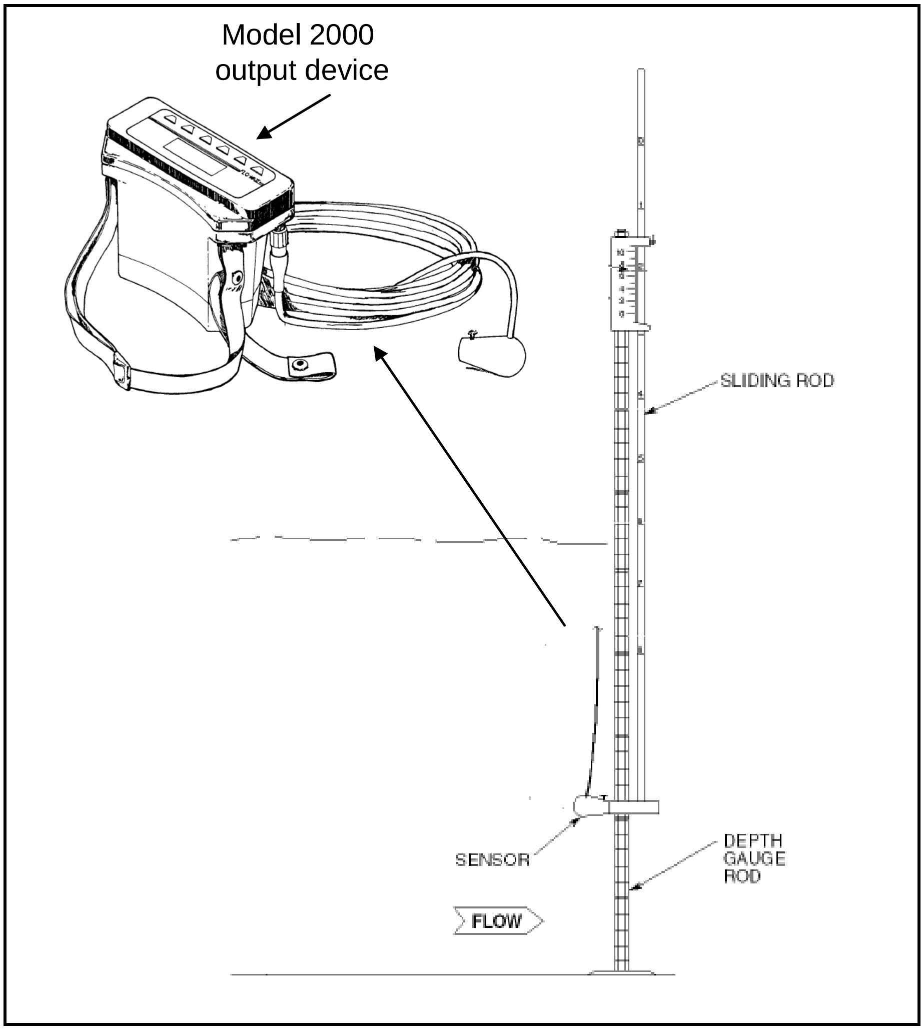
If stream width > 10 feet, collect 20 evenly divided measurements across the entire stream; take the first reading at half of the determined interval from edge.

Data Collection

Collecting flow data with the Marsh-McBirney works best with a team of two people. One person handles the flow meter while the other records water depth and the real-time stream velocity.

The operator will handle the Marsh-McBirney while the recorder writes down the stream width, depths, and velocities. The operator will stand at the starting location and turn on the Model 2000 (output device). The display will automatically give a real-time flow reading. Make sure Model 2000 is reading flow in feet per second (ft/s) and the allotted time for reading flow is set at twenty seconds (fixed point averaging). The sensor must be facing upstream. **Appendix 6** includes the instructions for changing units and measurement interval.

Figure 3. Marsh-McBirney assembly.



The operator will measure the actual water depth using the wading rod and call it out to the recorder who will record it on the field sheet. The flow meter is then adjusted to 60% of the water depth. The "On/C" button on the Model 2000 will be pushed to start the measure of velocity. After twenty seconds, the display will give an average velocity. The operator will call out the velocity to the recorder and then move on to the next reading location. Velocity can also be stored on the unit. This procedure is repeated until all readable locations are sampled.

Calculations must be performed using the recorded velocity and depth readings. The formula for flow in an even channel is: CFS = average velocity (ft/s) x average depth (ft) x width (ft).

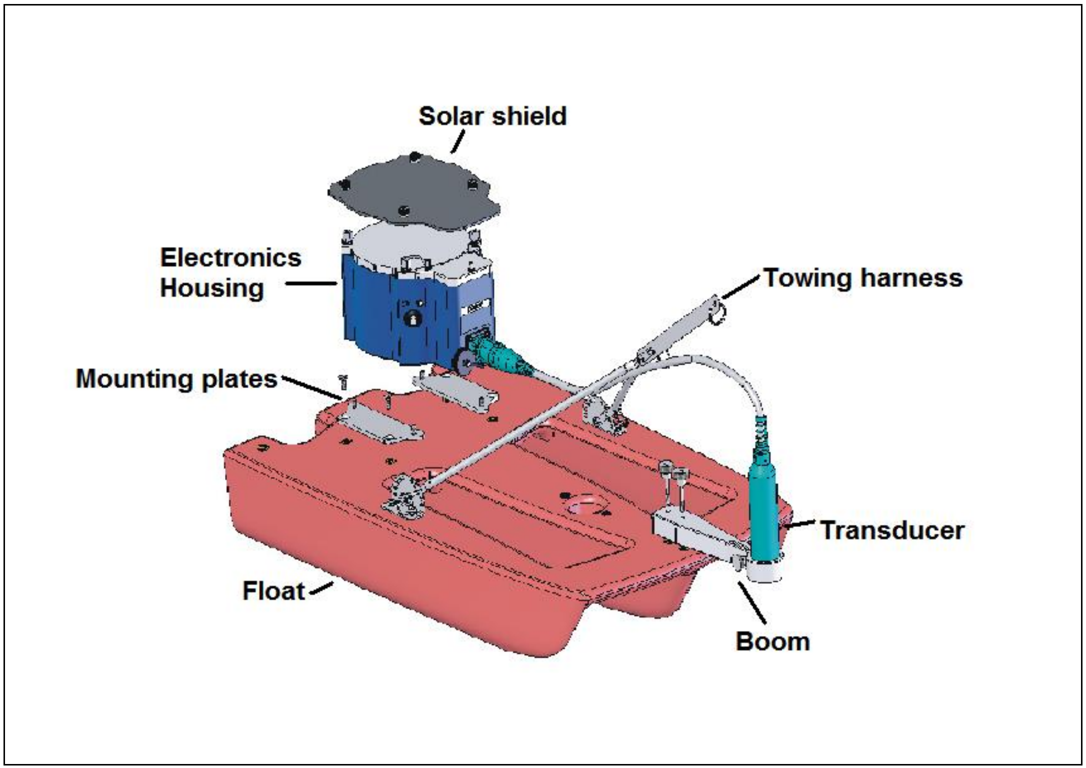
9.2.3 StreamPro ADCP

General directions are given here but the operator should follow along with the StreamPro Quick Start Guide for detailed directions incorporating easy-to-follow PDR/software screen shots.

Preparation for Deployment

The Q-boat should be assembled according to the StreamPro user manual. See **Figure 4**. Visually inspect all components for damage. Check that the transducer beams are aligned correctly and that the transducer head is set to the correct depth (3-6 cm or 1.2-2.4 in. below water surface) (see manual). A PDR is used along with the Q-boat. Before deploying the Q-boat, it must be powered on and synchronized with the Bluetooth on the PDR; a successful link is indicated by the blue light on the StreamPro electronics housing. When the StreamPro is turned on, the amber light on the electronics housing should not be blinking; if it blinks, the batteries (8 AA) should be replaced. Follow the steps in the user manual to load the default configuration file. Before the StreamPro is put into the water, run the Self-Test (see manual) to verify that the StreamPro's electronics and transducers are functioning. The test can be run with the StreamPro out of the water.

Figure 4. StreamPro assembly.



Set up the Configuration File

Once the Self-Test has been passed, the StreamPro will be used to calculate the maximum depth and maximum velocity of the cross section to be measured. Following the detailed instructions in the manual, move the StreamPro across the stream and note the maximum depth and velocity that comes up on the PDR screen. Record these on the field sheet. Edit the configuration file according to the maximum depth and velocity. If the max depth is <1.0 m (3.3 ft) and the max velocity is < 0.25 m/s (0.8 ft/s), select the "Low Noise Mode". If using Low Noise Mode, tow velocity should be half the current velocity. Once the configuration is set, save the configuration file.

Determining Edge Distances

Before collecting data, you must determine the edge locations. Edge measurements are taken as close to the bank as possible where the StreamPro can still read valid data – defined as a minimum of two good depth cells (a cell is a portion of the vertical velocity profile measured by the StreamPro – max depth cells per profile is 20).

1. With the StreamPro close to the bank, select "Start Pinging" and pay attention to the display.

2. Move the StreamPro far enough from the bank to produce a solid two-depth cell measurement (indicated by Number of Good Bins = 2 on the display).

3. Stake or otherwise mark this location and line the mark up with the center of the StreamPro transducer head. This point is the starting point for the transect.

4. Measure the distance between the edge location and the physical edge of the stream; record this distance on field sheet or as a note on the PDR. For measuring these distances, you can wade out into the stream or use a metered tape lined along the railing of the bridge. If using the bridge option, lower a weighted tape to the edge of water and note the distance on the tape running along the railing. Then lower the tape to the center of the StreamPro transducer head and note that distance; the difference between the two is the edge distance for the transect.

5. Repeat finding the edge of transect and actual physical edge for the opposite bank along the transect. The StreamPro should not be used against a vertical bank/wall even if there are an adequate number of good bins available due to interference. Position the StreamPro from a vertical wall at a distance that is equal to or greater than the depth of water at the vertical wall.

Data Collection

Data collection is performed by at least 2 people – one to maneuver the StreamPro and the other to operate the PDR. The StreamPro can be towed from a bridge or from shore. Either method is acceptable as long as slow, steady control of the raft is maintained. In a bridge situation, make sure the transect is downstream of the bridge so that the StreamPro is visible to the operator at all times. Make sure to keep an eye out for debris floating from upstream.

1. Move the StreamPro to the transect starting point and press "Transect Start" to initiate data recording. The StreamPro will start the measurement by confirming the edge of the transect. Once the edge measurements have been taken, the StreamPro will prompt the user to proceed with the transect.

2. Slowly tow the StreamPro across the channel in a straight line perpendicular to the flow. Tow speed should be less than the water velocity for the most accurate and precise measurements. During the measurement, keep an eye on the Good Bins Indicator on the PDR screen. If the indicator is green, three or more cells in the profile are good. Use the indicator to help determine when you need to slow down the StreamPro at the opposite bank, trying not to overshoot the predetermined transect edge. Once again, the StreamPro will confirm the edge of the transect and then stop recording.

3. Repeat the transect measuring process in the opposite direction. Continue until you've captured at least four good transects.

Data Review

Use the "History" tab to compare the measured transects. If the "Delta Q" value (the difference (expressed as a percentage) between the measured discharge of a particular transect and the mean of all the measured transects) for any measurement file is >5%, that particular file should not be used for calculating the discharge measurement. If at least four good transects are not available, measurements should be performed for additional transects. If Delta Q is still > 5% after eight transects use best professional judgment to determine if more transects are necessary. A new cross sectional location may be needed. In this case, repeat the steps for measuring a transect above. The software allows the user to de-select transects with high error which can lower the overall error among the selected transects. Once the data is downloaded to a PC, WinRiver software is used to perform the summary discharge calculation for the measurement.

10.0 DATA AND RECORDS MANAGEMENT

Flow Tracker: All flow readings are stored in the hand held of the FlowTracker until they are deleted by the user. See the FlowTracker manual for instruction on how to recover stored flow readings. Once flow has been calculated by the FlowTracker, the user should record the reading on the trip sheet and lab sheet associated with the sample trip. Trip sheets containing flow measurements will be scanned in at the end of the sample trip and stored electronically.

Marsh-McBirney: All flow readings are recorded on the field sheet. Once total flow has been calculated, the discharge is recorded on the trip and lab sheets associated with the sample trip. Trip sheets containing flow measurements will be scanned in at the end of the sample trip and stored electronically.

StreamPro: Measurement files should be stored on the PDR's SD card. After collecting four transects, review the files in the field to ensure that each file (transect) is within 5% of the mean discharge for the set of transects. If any of the transects is outside of the tolerance, additional transects should be measured. All flow readings are stored in the PDR until they are deleted by the user. Transfer the flow reading onto the trip sheet associated with the sample trip.

If performing a flow measurement at a location that is gaged by DWQ, be sure to fill out the proper gage maintenance and inspection sheet that is kept with the portfolio folder for that site (**Appendix 3**).

Flow measurement data and associated comments should be added to the downloaded electronic Hydrolab files (field water quality readings) stored in the appropriate Monitoring Section shared folder.

If a flow measurement was not performed by DWQ monitors, the flow field in the Hydrolab file should be left blank but the "comments" field should be filled in. Use the "comments" field on the Hydrolab Surveyor (or equivalent electronic field data recording device such as a tablet/field PC) to annotate if a sampling site has a gage and to provide the gage number and the managing entity/agency. Additionally, the comment section should be used to annotate when flow data is missing (such as no gage and Q-boat malfunctioned, or no gage and stream was too deep or swift to perform flow measurement, etc.).

11.0 QUALITY ASSURANCE AND QUALITY CONTROL

Most of the quality control for flow measurements involves reviewing data in the field. Resolution of data collection and data quality problems may include selection of a different cross section, measuring additional transects (StreamPro), troubleshooting equipment issues, adjusting settings/configurations, etc.

A quality control test must be performed at the beginning of each sampling day to assure the FlowTracker is operating properly. If the QC test fails, the operator must repeat it until the test is passed and no errors are found. If FlowTracker continuously fails QC test, it must be sent in for repair.

A quality control test must be performed at the beginning of each sampling day to assure the StreamPro is operating properly and maintaining a good Bluetooth connection with the PDR. Refer to the StreamPro Quick Start Guide for instructions for performing the Self-Test; make sure the StreamPro is working properly before deployment.

If variation between measurements (transects) by the StreamPro is greater than 5%, try repeating the measurement by moving the boat more slowly across the stream (typically needs to be done for slow-moving shallow streams). Ideally measurements should take at least 3 minutes but if the velocity is <30 cm/s (about 1 ft/s) or the depth is <1 m (about 3.3 ft), measurements should take longer to increase measurement precision.

Duplicates are unable to be performed for quality control since stream conditions can change rapidly. When a sample site requires duplicate samples, one flow reading will be used for both the original and duplicate samples.

In addition, monitors should consult the United States Geological Survey's quality assurance guidance for the use of ADCPs (Oberg et al. 2005) that includes deployment and use guidance as well as guidelines for data review and rating the quality of discharge measurements.

12.0 REFERENCES

Blanchard, Stephen F. 2005. Guidance on the use of RD Instruments StreamPro Acoustic Doppler Profiler. Office of Surface Water Technical Memorandum 2005.05. U.S. Geological Survey.

Oberg, K.A., Morlock, S.E. and W.S. Caldwell. 2005. Quality-Assurance Plan for Discharge Measurements Using Acoustic Doppler Current Profilers - Scientific Investigations Report 2005-5183. U.S. Geological Survey.

Shedd, J., Springer, C., and Clishe, C. 2008. Standard operating procedure for operation of the Teledyne RD Instruments Stream-Pro Acoustic Doppler Current Profiler. Washington State Department of Ecology Environmental Assessment Program. EAP055.

USEPA. 2007. National Rivers and Streams Assessment: Field Operations Manual. EPA-841-B-07-009. U.S. Environmental Protection Agency, Washington, DC. (*Section 6.2.6.3 Stream Discharge*)

Marsh-McBirney User Manual:
http://www.marsh-mcbirney.com/manuals/Model_2000_Manual.pdf

FlowTracker User Manual:
http://www.tceq.texas.gov/assets/public/compliance/monops/water/wqm/v3.3_flow_tracker.pdf

StreamPro User Documents:
http://www.rdinstruments.com/support/documentation/cc_documents.aspx#spro

StreamPro ADCP Operational Manual -
http://www.otronix.com/kr/data/p03/StreamPro_ADCP_Operationa_Manual.pdf
StreamPro Quick Start Guide -
http://www.rdinstruments.com/support/SoftwareFirmware/x/cs/files/Manuals/SPQCKSTA.PDF
StreamPro Software User Guide -
http://www.rdinstruments.com/support/SoftwareFirmware/x/cs/files/Manuals/SPSWUSER.PDF
StreamPro Discharge Measurement Summary –
http://www.rdinstruments.com/support/SoftwareFirmware/x/cs/files/Manuals/SPDISCME.PDF

Missouri Stream Teams' *Volunteer Water Quality Monitoring Notebook* –
Chapter 3 on Stream Discharge (also at
http://www.mostreamteam.org/Documents/VWQM/Intro_Notebook/Chapter%2003%20Intro%20Stream%20Discharge.pdf)

Related DWQ SOPs:

Standard Operating Procedure for Pressure Transducer Installation and Maintenance

13.0 APPENDICES

Appendix 1 - SOP Acknowledgment and Training Form (front and back)

DWQ SOP Acknowledgement and Training Form
2/28/2011
Page 1 of 2

SOP Acknowledgement and Training Form

This SOP must be read and this form signed annually. This form must be kept with the current version of the SOP.

Document Title:	
Document Revision Number:	
Document Revision Date:	

Please sign below in accordance with the following statement: "I have read and understood the above referenced document. I agree to perform the procedures described in this SOP in accordance with the document until such time that it is superseded by a more recent approved revision."

Printed Name	Signature	Date

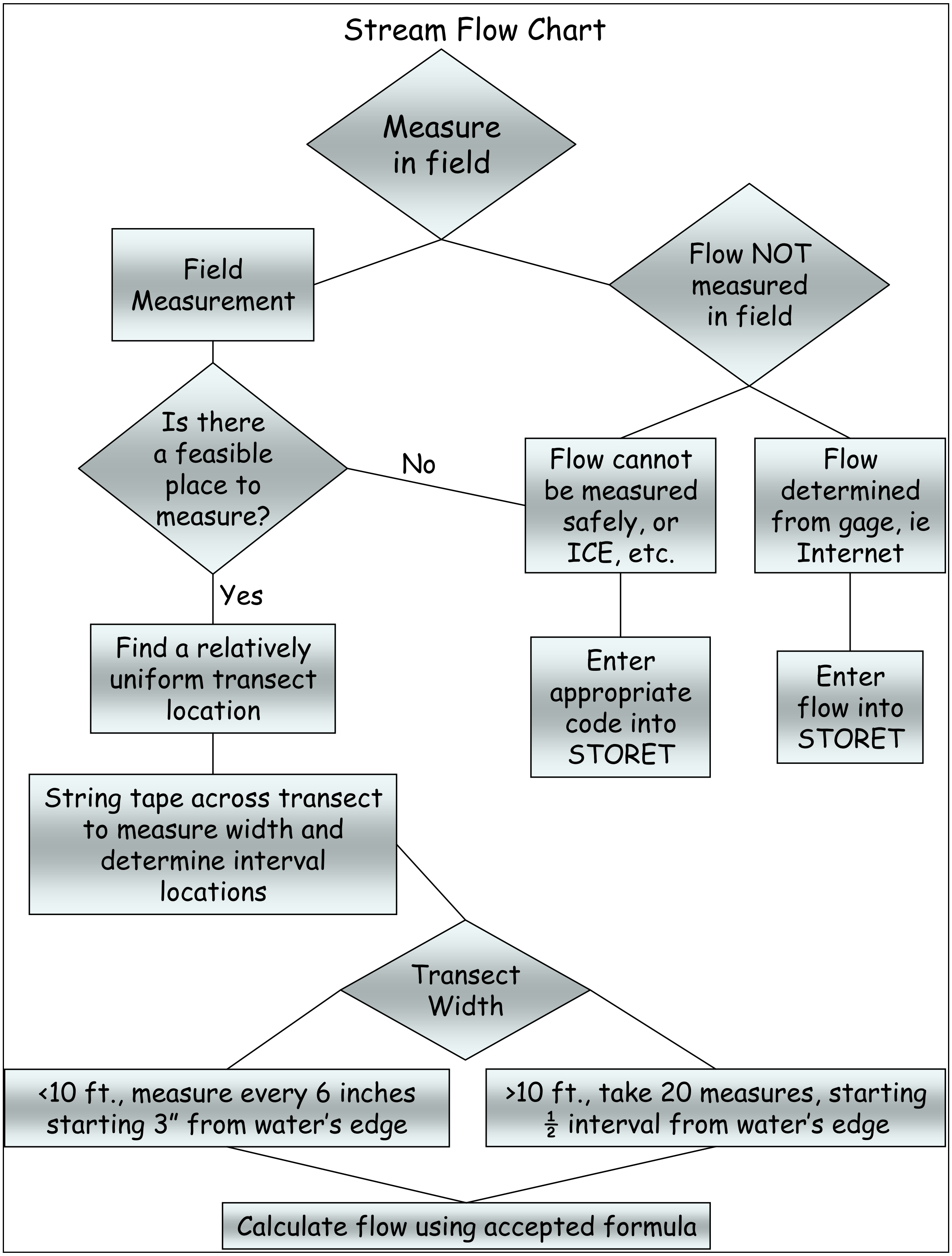
SOP Acknowledgement and Training Form (continued)

Trainee: Sign below to acknowledge that training on this SOP was received, understood, and all questions/concerns were addressed by the trainer.

Trainer: Sign below to acknowledge that training on this SOP was completed for the individual listed and that trainee is competent to perform the procedures described within.

Date of Training	Trainee Printed Name	Trainee Signature	Trainer Printed Name	Trainer Signature

Appendix 2 - Wadeable stream flow decision diagram



Appendix 3 – Pressure transducer field form
(U:\WQ\PERMITS\MONITORS\Pressure Transducers\Pressure Transducer Field Form.pdf)

Utah DWQ, May 2011

Utah DWQ Pressure Transducers
Installation, Inspection and Maintenance Form

Site Name:_______________________ STORET:_______________________
Latitude:_______________________ Longitude:_______________________
Site Description:_______________________
Pressure Transducer Make/Model/Serial Number:_______________________
Pressure Transducer Factory Calibration Date:_______________ Installation/Deployment Date:_______________
Installation Personnel:_______________________
Notes from Installation:_______________________

Date	Monitor Initials	Visual Inspection Performed (Y or N)	Visual Inspection Okay (Y or N)	Data Retrieval Performed (Y or N)	Battery Life Remaining	Memory Remaining	Maintenance Performed (Y or N)	Flow Measurement Performed (Y or N)	Equipment Condition, Comments, Describe Maintenance

U:\WQ\PERMITS\MONITORS\Pressure Transducers\Pressure Transducer Field Form.doc

Page _____ of _____

Appendix 4 - DWQ's Standard Operating Procedure for Estimating Stream Flow Using a Simple Float (non-formal SOP quick reference)

Standard Operating Procedure for Estimating Stream Flow Using a Simple Float

1. Scope and application

1.1. Stream flow, or discharge, is the volume of water moving past a cross-section of a stream over a set period of time. Stream flow affects the biology of a stream system, and coupled with the concentration of water chemistry parameters can estimate the load of substances in a stream.

2. Summary of Procedure

2.1. Stream flow is calculated by determining the average cross-sectional area (ft^2) and multiplying the area by the corrected velocity determined over an established stream segment (ft/sec). The velocity is corrected due to varying velocities in a stream throughout the water column, depending on stream substrate.

3. Definitions

3.1. Float – A neutrally buoyant object that will be mostly submerged in the stream water.

3.2. Stream segment – A section of a stream measured and marked off to determine velocity with the float.

4. Health and Safety Warnings

4.1. You will need to enter the stream channel to make measurements and calculate velocity. Be aware of stream velocity, water depth and streambed conditions at the prospective stream segment. Do not attempt to measure stream flow if conditions could knock you down or if you could become stuck in the stream substrate. Proceed with caution moving across the stream, or choose an alternate, safer point from which to measure stream flow.

5. Interferences

5.1. Choose a relatively straight, uniform stream segment where the float will not hang up on the streambed or obstructions, or enter slack-water.

6. Equipment and Supplies

6.1. Tape measure
6.2. Yardstick
6.3. Surveying flags/flagging
6.4. Float (An orange works best)
6.5. Net, if necessary, to catch the float
6.6. Stopwatch
6.7. Calculator
6.8. Data form
6.9. Waders

7. Quality Control and Quality Assurance

7.1. Average the cross-sectional area from the starting and ending points of the segment.

7.2. Measure the velocity three times and average the readings

8. Procedure

8.1. Select a stream segment that is deep enough to float the object freely, is free of obstructions, and is long enough that it will take between 10 and 30 seconds for the object to travel. Mark off the start and end and measure this distance, (**L** in the formula). Note: a round number for the length, i.e. 50 ft., is helpful for the calculations.
8.2. Determine the width of both the starting and ending transects by measuring the distance from shoreline to shoreline by stretching a tape measure (leave the tape in place for the next measure), and enter this value as total width.
8.3. Determine the average depth along the transect by marking off equal intervals along the tape. The intervals should be one-fourth, one-half, and three-fourths of the distance across the stream. Measure the water's depth at each interval point (Fig. 8.1), and enter into the data form. Average these four values to determine average depth.

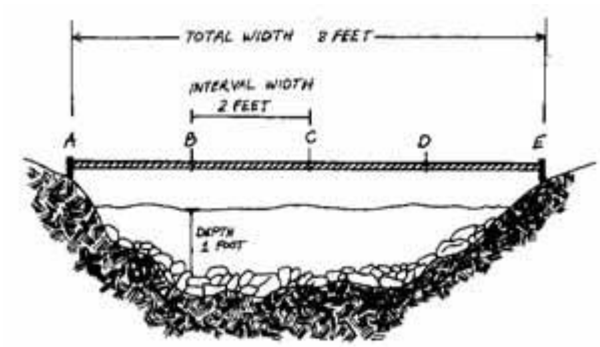


Figure 8.1 A cross-section view to measure width and depth

8.4. Calculate the cross-sectional area of each transect by multiplying width times average depth.
8.5. To determine the average cross-sectional area of the entire stream reach (**A** in the formula), add together the average cross-sectional area of each transect and then divide by 2.
8.6. Measuring velocity is easiest done with two people, but one person can measure if the current is not too swift.
  8.6.1. Gently release the float a few feet upstream of the starting transect so that it may get up to current speed when it passes the start.
  8.6.2. Start the timer as soon as it passes the start.
  8.6.3. Stop the timer and retrieve the float when it passes the ending transect. Enter the travel time on the data form as trial #1.
  8.6.4. If the float gets hung up on a log, rock or other obstruction, repeat that measurement.
  8.6.5. Repeat two more times and average the three travel times, giving **T**.
8.7. Determine the correct coefficient or correction factor based on the streambed (0.8 for rocky-bottom streams or 0.9 for muddy-bottom streams).

9. Data Analysis and Calculations

9.1. Complete the formula: **Flow = ALC/T**, to determine ft^3/sec.

10. References

10.1. United States Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds, *Volunteer Stream Monitoring: A Methods Manual.* EPA 841-B-97-003
November 1997

10.2. Missouri Stream Teams. *Volunteer Water Quality Monitoring.* Missouri Department of Natural Resources, P.O. Box 176, Jefferson City, MO 65102.

Appendix 5

Select pages from EPA's NRSA Field Operations Manual to be used for performing flow estimates. [Reference: USEPA. 2007. National Rivers and Streams Assessment: Field Operations Manual. EPA-841-B-07-009. U.S. Environmental Protection Agency, Washington, DC. (*Section 6.2.6.3 Stream Discharge*)]

else they were transporting. Upstream, the *torrent track* is severely scoured, often reduced in channel complexity and devoid of near-bank riparian vegetation. As with floods, the massive disruption of the stream channel and its biota are transient, and these intense, infrequent events will often lead to a high-quality complex habitat within years or decades, as long as natural delivery of large wood and sediment from riparian and upland areas remains intact.

In arid areas with high runoff potential, debris torrents can occur in conjunction with flash flooding from extremely high-intensity rainfall. They may be nearly annual events in some steep ephemeral channels where drainage area is sufficient to guarantee isolated thunderstorms somewhere within their boundaries, but small enough that the effect of such storms is not dampened out by the portion of the watershed not receiving rainfall during a given storm.

Because they may alter habitat and biota substantially, infrequent major floods and torrents can confuse the interpretation of measurements of stream biota and habitat in regional surveys and monitoring programs. Therefore, it is important to determine if a debris torrent or major flood has occurred within the recent past. After completing the thalweg profile and channel/riparian measurements and observations, examine the stream channel along the entire sample reach, including its substrate, banks, and riparian corridor, checking the presence of features described on the Torrent Evidence Assessment Form (Figure 6.2-18). It may be advantageous to look at the channel upstream and downstream of the actual sample reach to look for areas of torrent scour and massive deposition to answer some of the questions on the field form. For example, you may more clearly recognize the sample reach as a torrent deposition area if you find extensive channel scouring upstream. Conversely, you may more clearly recognize the sample reach as a torrent scour reach if you see massive deposits of sediment, logs, and other debris downstream.

6.2.6.3 Stream Discharge

Stream discharge is equal to the product of the mean current velocity and vertical cross-sectional area of flowing water. Discharge measurements are critical for assessing trends in streamwater acidity and other characteristics that are very sensitive to streamflow differences. Discharge should be measured at a suitable location within the sample reach that is as close as possible to the location where chemical samples are collected, so that these data correspond. Discharge is usually determined after collecting water chemistry samples.

No single method for measuring discharge is applicable to all types of stream channels. The preferred procedure for obtaining discharge data is based on “velocity-area” methods (e.g., Rantz and others, 1982; Linsley et al., 1982). For streams that are too small or too shallow to use the equipment required for the velocity-area procedure, two alternative procedures are presented. One procedure is based on timing the filling of a volume of water in a calibrated bucket. The second procedure is based on timing the movement of a neutrally buoyant object (e.g., an orange or a small rubber ball) through a measured length of the channel, after measuring one or more cross-sectional depth profiles within that length.

DISCHARGE FORM - WADEABLE

Reviewed by (Initials): JD

SITE ID: FW08 XX000 DATE: 07/01/2008

● Velocity Area

Distance Units	Depth Units	Velocity Units
○ ft ● cm	○ ft ● cm	○ ft/s XX.X ● m/s X.XX

	Dist. from Bank	Depth	Velocity	Flag
1	0	0	0	F1
2	20	6	- 0.10	
3	40	6	0.30	
4	60	12	0.59	
5	80	15	0.37	
6	100	15	0.34	
7	120	24	0.43	
8	140	27	0.37	
9	160	40	0.43	
10	180	40	0.37	
11	200	46	0.30	
12	220	37	0.27	
13	240	30	0.25	
14	260	24	0.15	
15	280	15	0.10	
16	300	0	0	
17				
18				
19				
20				

● Timed Filling

Repeat	Volume (L)	Time (s)	Flag
1	4.0	10.5	F1
2	4.0	11.2	
3	4.0	10.8	
4	4.0	11.0	
5	4.0	10.7	

● Neutral Bouyant Object

	Float 1	Float 2	Float 3
Float Dist. ○ ft ● m	5	5	5
Float Time (s)	10	10	12
Flag	F1		

Cross Sections on Float Reach

	Upper Section	Middle Section	Lower Section
Width ○ ft ● m	2.5	1.8	3.0
Depth 1 ○ ft ● cm	10	5	12
Depth 2	9	15	20
Depth 3	9	20	15
Depth 4	8	7	6
Depth 5	5	2	5

● Q Value If discharge is determined directly in field, record value here: Q = 0.24 ○ cfs ● m³/s FLAG F1

Flag	Comments
F1	DATA FOR ALL FOUR METHODS ARE SHOWN.

Flag Codes: K = No measurement or observation made; U = Suspect measurement or observation; Q = Unacceptable QC check associated with measurement; Z = Last station measured (if not Station 20); F1, F2, etc. = Miscellaneous flags assigned by each field crew. Explain all flags in comments section.

Draft

03/18/2008 NRSA Stream Discharge

Figure 6.2-20. Discharge Form, showing data recorded for all discharge measurement procedures.

6.2.6.5 Timed Filling Procedure

In channels too “small” for the velocity-area method, discharge can sometimes be measured by filling a container of known volume and timing the duration to fill the container.

“Small” is defined as a channel so shallow that the current velocity probe cannot be placed in the water, or where the channel is broken up and irregular due to rocks and debris, and a suitable cross-section for using the velocity area procedure is not available. This can be an extremely precise and accurate method, but requires a natural or constructed spillway of freefalling water. If obtaining data by this procedure will result in a lot of channel disturbance or stir up a lot of sediment, wait until after all biological and chemical measurements and sampling activities have been completed.

Choose a cross-section of the stream that contains one or more natural spillways or plunges that collectively include the entire stream flow. A temporary spillway can also be constructed using a portable V-notch weir, plastic sheeting, or other materials that are available onsite. Choose a location within the sampling reach that is narrow and easy to block when using a portable weir. Position the weir in the channel so that the entire flow of the stream is completely rerouted through its notch (Figure 6-3). Impound the flow with the weir, making sure that water is not flowing beneath or around the side of the weir. Use mud or stones and plastic sheeting to get a good waterproof seal. The notch must be high enough to create a small spillway as water flows over its sharp crest.

The timed filling procedure is presented in Table 6.2-16. Make sure that the entire flow of the spillway is going into the bucket. Record the time it takes to fill a measured volume on the Discharge Measurement Form as shown in Figure 6-2. Repeat the procedure 5 times. If the cross-section contains multiple spillways, you will need to do separate determinations for each spillway. If so, clearly indicate which time and volume data replicates should be averaged together for each spillway; use additional Stream Discharge Form if necessary.

Table 6.2-16. Timed filling procedure for determining stream discharge

NOTE: If measuring discharge by this procedure will result in significant channel disturbance or will stir up sediment, delay determining discharge until all biological and chemical measurement and sampling activities have been completed.

1. Choose a cross-section that contains one or more natural spillways or plunges, or construct a temporary one using on-site materials, or install a portable weir using a plastic sheet and on-site materials.
2. Fill in the “TIMED FILLING” circle in the stream discharge section of the Stream Discharge Form.
3. Position a calibrated bucket or other container beneath the spillway to capture the entire flow. Use a stopwatch to determine the time required to collect a known volume of water. Record the volume collected (in liters) and the time required (in seconds) on the Stream Discharge Form.
4. Repeat Step 3 a total of 5 times for each spillway that occurs in the cross-section. If there is more than one spillway in a cross-section, you must use the timed-filling approach on all of them. Additional spillways may require additional data forms

6.2.6.6 Neutrally-Buoyant Object Procedure

In very small, shallow streams with no waterfalls, where the standard velocity-area or timed-filling methods cannot be applied, the neutrally buoyant object method may be the only way to obtain an estimate of discharge. The required pieces of information are the mean flow velocity in the channel and the cross-sectional area of the flow. The mean velocity is estimated by measuring the time it takes for a neutrally buoyant object to flow through a measured length of the channel. The channel cross-sectional area is determined from a series of depth measurements along one or more channel cross-sections. Since the discharge is the product of mean velocity and channel cross-sectional area, this method is conceptually very similar to the standard velocity-area method.

The neutrally buoyant object procedure is described in Table 6.2-17. Examples of suitable objects include plastic golf balls (with holes), small sponge rubber balls, or small sticks. The object must float, but very low in the water. It should also be small enough that it does not "run aground" or drag bottom. Choose a stream segment that is roughly uniform in cross-section, and that is long enough to require 10 to 30 seconds for an object to float through it. Select one to three cross-sections to represent the channel dimensions within the segment, depending on the variability of width and/or depth. Determine the stream depth at 5 equally spaced points at each cross-section. Three separate times, measure the time required for the object to pass through the segment that includes all of the selected cross-sections. Record data on the Stream Discharge Form as shown in Figure 6.2-20.

Table 6.2-17. Neutrally buoyant object procedure for determining stream discharge

1. Fill in the "NEUTRALLY BUOYANT OBJECT" circle on the Stream Discharge Form.
2. Select a segment of the sampling reach that is deep enough to float the object freely, and long enough that it will take between 10 and 30 seconds for the object to travel. Mark the units used and record the length of the segment in the "FLOAT DIST." field of the Stream Discharge Form.
3. If the channel width and/or depth change substantially within the segment, measure widths and depths at three cross-sections, one near the upstream end of the segment, a second near the middle of the segment, and a third near the downstream end of the segment.

   If there is little change in channel width and/or depth, obtain depths from a single "typical" cross-section within the segment.
4. At each cross-section, measure the wetted width using a surveyor's rod or tape measure, and record both the units and the measured width on the Stream Discharge Form. Measure the stream depth using a wading rod or meter stick at points approximately equal to the following proportions of the total width: 0.1, 0.3, 0.5, 0.7, and 0.9. Record the units and the depth values (not the distances) on the Stream Discharge Form.
5. Repeat Step 4 for the remaining cross-sections.
6. Use a stopwatch to determine the time required for the object to travel through the segment. Record the time in the "FLOAT TIME" field of the Stream Discharge Form.
7. Repeat Step 6 two more times. The float time may differ somewhat for the three trials.

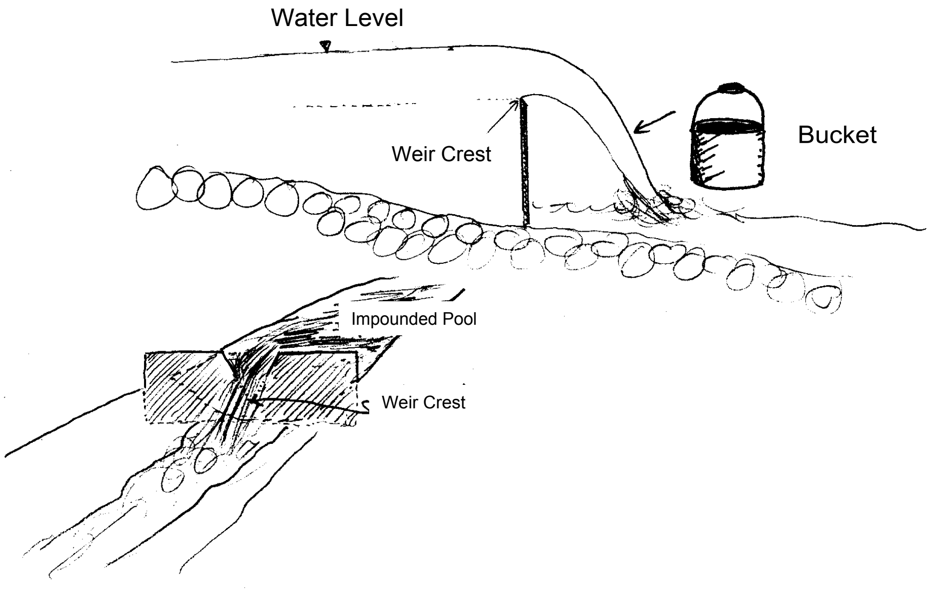


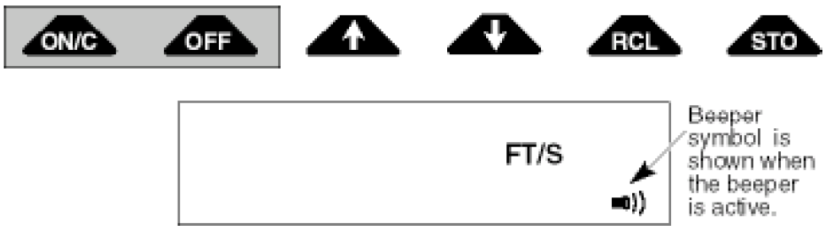
Figure 6.2-21. Use of a portable weir in conjunction with a calibrated bucket to obtain an estimate of stream discharge.

Appendix 6 - Instructions for changing units and measurement interval (from Marsh-McBirney Model 2000 Flo-Mate instrument manual)

Units of Measurement/Beeper

The Model 2000 can output velocity in ft/s or m/s. When the beeper symbol is shown, the beeper is active. Press down on the ON/C and OFF keys simultaneously to cycle between:

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



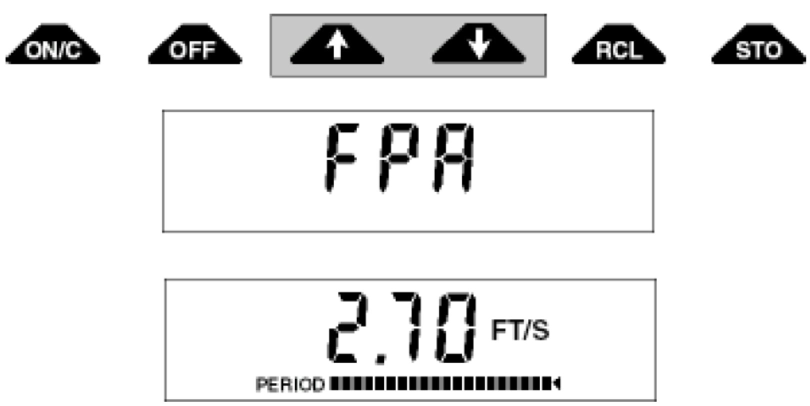
Fixed Point Average/Time Constant Filtering

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 of time. Time constant filtering is a software algorithm that mimics an RC analog circuit. Press the ↑ and ↓ keys simultaneously to alternate between the FPA and rC displays.

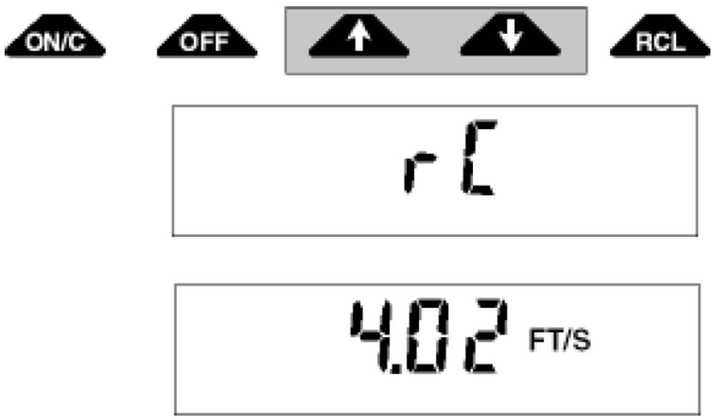
FPA

The display will show the letters FPA when you first switch to the FPA display. Except for the first period, the display is updated at the end of each averaging period. For example, if the FPA is set to 10 seconds, the display is updated once every ten 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.



rC

The display will show the letters rC when you first switch to the time constant mode. The display will start with unfiltered full scale velocities. These readings are accurate but may bounce around slightly. As the filtering takes effect, the readings will settle out. It takes five time constants to get to maximum filtering. There is no time bar on the rC display because the display is continually up-
dated.



FPA/rC Time

The FPA and rC time is specified in seconds. The ↑ key increments time and the ↓ key decrements time. The display will show the FPA/rC length in seconds. After you have reached the desired setting, wait and the display will automatically switch to velocity.

Comment:

Limits are 2-120 seconds for FPA and 2-30 seconds for rC.Changing FPA and rC time restarts the filtering.