A. Scope

This procedure is used to measure flow in wadeable streams, irrigation ditches or drainage ways. The determination requires one to measure the velocity of water passing through a cross-sectional area of the channel. This is done by taking a series of velocity, distance, and depth measurements across the stream and summing the products of the areas and velocity. This method is appropriate for channels which have water depths between about 0.2 and 4.0 feet, or .06 to 1.2 meters. This document replaces operating procedures in WDNR Field Procedures Manual 2301 Part C, Open Channel Flow Measurement and WDNR Guidelines for Evaluating Habitat of Wadeable Streams (WDNR 2002), Station Flow (p. 14-16).

B. Instrumentation

The most common instrument used by WDNR staff is the Marsh McBirney Flo-Mate electromagnetic current meter (which is now owned by Hach). This SOP is written for in-stream field procedures and will be applicable to any electromagnetic or acoustic Doppler hand held flow meter mounted to a top setting wading rod. Always refer to manufacturer's recommendations for calibration, maintenance and usage for operating your specific model.

C. Safety

All standard WDNR field safety SOPs apply when conducting flow monitoring activities. Measurements require wading into streams. Hip boots or chest waders with a wading belt should be worn at all times for protection from in-stream hazards and hypothermia. A safety line and PFD should be worn if current is strong and water is more than 2.5 feet deep.

D. Standard QA/QC practices

Care and Maintenance

a. As with any electronic equipment, meters should be handled with care. Meters and top setting wading rods should be stored in a dry environment at room temperature.
b. Avoid crimping and stretching of the cable, and do not suspend the sensor or meter by the cable.
c. During transport meters should be stored securely and protected against excess vibrations, such as lying unprotected in a truck bed or trailer floor.
d. Keep contacting surfaces clean and bright. Occasionally wash the sensor with a mild soap and water to keep it free of nonconductive grease and oils. Never use any hydrocarbon cleaning solvents on any art of the meter or sensor.

QAQC – Daily Routine

a. Before use, make sure batteries are in good operating condition. Always carry extra batteries in your vehicle or equipment kit.
b. Check to be sure all connector pins and screws needed to assemble the unit are secured and with the equipment.
    a. It is highly recommended that an equipment kit contains extra pins/wing nuts/screws that connect the probe to the wading rod. These will need to be purchased from a hardware store.
c. The sensor should be zero calibrated at least once per week if that function is available for a given meter. Even if calibration is not possible with a given model, a zero reading should be achieved with the following procedures to verify accuracy of the sensor. For monitoring activities that require increased precision and accuracy (see Section G, subsection Advanced Collection Procedures) be sure to zero calibrate each morning.
d. This SOP is written for common zero calibration procedures. Refer to the manufacturer's manual for your particular meter for proper zero calibration procedure.
e. Clean the sensor with mild dish detergent and water, rinsing well.
f. Set the meter to the ft/second display, and use a 5 second filter value.
    a. Place the sensor in a non-metallic (plastic) 5-gallon bucket of tap water (never use distilled water), suspending the sensor in the middle of the water column, away from the bottom and sides of the bucket.
    b. Do not disturb the sensor or bump the bucket, waiting a minimum of 15 minutes before taking any readings.
    c. Initiate the zero start sequence following manufactures directions.
    d. If reading is greater than ± 0.05 ft/sec after calibration, try using a larger container for calibration, and allow the sensor to sit for a longer period of time.
    e. If the reading is constantly greater than ±0.05 ft/sec then the meter needs to be returned to the manufacturer for repairs.

Factory Recalibration Schedule

a. Meters should be returned to the factory for recalibration according to the manufacturer's recommendations. Many Marsh-McBirney models do not need to be sent in for factory calibration if a proper zero calibration can be achieved (Jim Klosiewski, personal conversation with Marsh-McBirney).

E. Site Selection

Select a sampling location in the stream in a straight channel that most closely approximates laminar flow. Ideally, stream channel will be uniform in shape with relatively similar flow along each bank. The streambed should be stable enough to easily support the weight of the top setting wading rod. The site should be free of overhanging vegetation that significantly deflects streamflow or causes turbulence. However, all of these situations are seldom found in nature, sites should be selected that best approximates these ideal channel characteristics.

Situations to Avoid

a. Avoid braided channels.
b. Avoid abrupt changes in the channel upstream from the reach to be measured.
c. Avoid ponded conditions, including a change in head on the transect caused by downstream ice damming, log jams, large boulders etc.
d. Avoid heavily vegetated or silt laden reaches.
e. Avoid sampling behind large boulders or logs that deflect streamflow. If a large boulder cannot be avoided take a reading on the left and right sides and on top of the boulder, top setting wading the depth as usual.
f. Avoid reaches containing turbulent flow or freefalling water.

Channel Engineering

In some cases it may be necessary to conduct some in-stream channel modifications. These activities need to be completed and streamflow equilibrated before any measurements are made. Channel engineering will change in-stream flow paths and <u>cannot</u> be conducted during sample collection. Types of activities that may have to be done to collect a good measurement includes, but is not limited to:

a. Removing small boulders or woody debris that are deflecting flow or make sampling along a transect difficult.
b. Removing sections of in-stream macrophytes that are deflecting flow. Under dense growth conditions you may need to remove all macrophytes across the channel upstream and downstream of the transect line. Dense macrophyte beds can cause upwelling and higher velocities near the surface of the water. Clear overhanging vegetation that enters the water or makes sampling along a transect difficult.
c. Manipulate rubble/cobble and woody debris at shallow water edges in order to create a deeper channel.

Base flow vs Event Sampling

All of the general collection procedures below were developed for baseflow, or near baseflow, conditions. Sampling during these times of the year the stream flow is stable and conditions are as safe as possible for that specific site. Sampling during events is more difficult as stages may be rising or falling during the sample collection and, in general presents more hazardous conditions and less accurate results. For sampling during events the following needs to be accounted for:

Safety

a. If large objects are visibly being transported downstream (woody debris, logs, etc.) do not enter the stream. If the bottom of the stream is not visible use the top setting wading rod to determine the stream depth across the stream. Event based sampling must always be completed with two staff. If high/strong flows are suspected staff must wear a PFD.

Event-Based Sample Collection

b. During event-based sampling stage should be measured at a nearby fixed object (bridge, culvert, concrete pillar, etc.) before and after sample collection. If stage has risen/fallen during the collection timeframe the result value may need to be corrected, or a new sample collected.
    i. Typically the falling limb of discharge is more stable (i.e. changes slowly). When possible take event flow measurements soon after maximum stage height.
c. It may be necessary to set your meter to a shorter averaging period or use larger cell widths. Under a rising or falling hydrograph a more accurate result will be obtained by completing the measurement in a shorter timeframe. This will minimize the total change stage from the beginning to the end of the sample collection. This may be especially important for small/flashy streams where stage changes very quickly.

F. Meter Operation

Table from Tucker, personal communication (1995)

Averaging Period (sec)	% of True Value
6	63%
12	83%
18	95%
24	98%
30	99%

G. Collection Procedures

Equipment list

a. Flow meter and top setting wading rod
b. Bucket for zero calibration (can be done at the shop)
c. Measuring tapes (2) 100 – 300 foot lengths.
    i. Metric measuring tapes may be used, but the tape used must match the measuring system of the top setting wading rod and the preference setting in the meter.
d. Rebar, spring clamps, hammer or other methods of securing measuring tape to the bank
e. Field sheets on waterproof paper
f. Pencils
g. Extra batteries
h. Waders, PFD(s), traffic cones, and other equipment required by Field Safety Manuals

General Collection procedures

a. Enter the stream at your site and stretch a measuring tape across the width of the stream. Be sure tape is secured at both stream banks and tape is as taught as practicable.
    i. It is useful to have multiple options for attaching the measuring tape to each bank. Many staff use a spring clamp connected to a short length of rebar pounded into the bank.
b. Record the tape value at the wetted perimeter of both left and right banks. The starting (left bank) location value is often different from zero depending on where the tape is secured on the bank.
c. Determine number of cells for monitoring. A minimum of 20 cells (readings) should be used for an accurate discharge calculation.
    i. There should be no more than 10% of the discharge within a particular cell. This will have to be visually estimated before starting the measurement.
        1. In small streams this may be unavoidable due to minimum transect widths for the particular meter.
        2. Maximum 10% discharge is a goal to help determine cell width. It will not be known if this goal is violated until the entire measurement is completed and flow calculated. Small deviations from this goal are acceptable and do not require a new measurement.
    ii. Observe changes in the stream channel along the transect. Cell widths can be narrower in areas of deeper water, higher velocities or changes in flow angles caused by upstream obstructions that could not be removed. Changing cell widths requires careful record keeping and <u>should only be done in unavoidable situations</u>.
    iii. Minimum cell width is dependent on the particular sensor. 0.3 feet (~4 inches or 0.1 meters) is a common sensor width. Therefore, cells cannot be less than 0.3 feet (or 0.1 meters) otherwise there will be sensor overlap in adjoining cells.

iv. If minimum cell width is 0.3 feet then the stream will have to be at least six feet wide in order to fit 20 measurements. For streams less than six feet wide, use as many 0.3 feet wide cells as possible.

d. For the first cell, start at the water's edge (may or may not be "0" on the tape) and move across the stream 1/2 the distance of the cell width.
   i. This will place the sensor in the middle of the cell. For each subsequent cell move across the tape a distance equal to your cell width.

e. At each cell record the stream depth (in meters or feet depending on your specific instrument) using the top setting wading rod.
   i. The English setting rod is divided into increments of 0.10 feet. Readings should be taken at the 0.05 precision level.
   ii. The metric setting rod is divided into increments of 0.02 meters. Readings be taken at the 0.01 precision level.

f. Setting the sensor depth
   i. For cells less than 2.5 feet in depth set the sensor at 60% depth. Line up the foot scale on the sliding rod with the tenth scale on the top of the depth gauge rod. For example, if the water depth is 1.5 feet, line up the 1 on the foot scale with the 5 on the tenth scale.
   ii. For cells greater than 2.5 feet deep velocities at 20 and 80% need to be taken.
      1. Using a depth of 2.6 feet as an example, to set the sensor at 20% of the depth multiply the measured cell depth by two and repeat the above procedure. For this example the value would be 5.2 feet (2.6 feet cell depth x 2). Line up the 5 on the foot scale with the 2 on the tenth scale.
      2. To set the sensor at 80% of the depth, divide the measured cell depth by two and repeat the above procedure. For this example, this would be 1.3 feet (2.6 feet cell depth / 2). Line up the 1 on the foot scale with the 3 on the tenth scale.

g. For each cell use an averaging period of 20 seconds per reading.

h. For very small streams it is recommended that two complete measurements are made and averaged to calculate stream flow.
   i. Use this method when stream width is fewer than 10 transects (3 feet wide if minimum cell width is 0.3 feet).

Advanced Collection Procedures

When very high precision/accuracy data is necessary, staff can choose to use the Advanced Collection Procedures listed below. All of the above steps in the General Collection Procedures apply to the Advanced Collection Procedures except for number of cells and averaging period. Under most circumstances using the Advanced Collection Procedures will double the amount of time needed to collect a discharge measurement. The Advanced Collection Procedure recommends that no more than 5% of flow in any given cell. This will have to be calculated after the measurement is taken and adjustments can be made to cell size in subsequent site visits. Small deviations from maximum 5% flow are acceptable for most sampling activities.

i. Data needs that may require using the Advanced Collection Procedures include, but not limited to:
    i. TMDL, Waste Load Allocation or other model development
    ii. Partial record regression monitoring for fish occurrence curves
    iii. Developing flow rating curves

Collection Procedure Comparison

	General Collection Procedure	Advanced Collection Procedure
Number of Cells	20	30
Averaging Period (seconds)	20	40
Max. flow in any cell	10%	5%
Average two transects when	#cells <10	#cells <15

H. Calculation

a. The discharge of the cross section (Q) is the sum of the discharge of each cell

$$Q = \sum q_{1,}\ q_{2,\ldots} q_n$$

Where: q = discharge at any one cell = cell width * cell depth * velocity

b. Double check units of measurement are the same among measuring tape, top setting wading rod and velocity meter.
c. This calculation is easily computed by multiplying across cells 2-4 in the Field Form 3600-288 (R 6/07) and then summing all values in the “Product” column.

I. Documentation

a. The flow data sheet is located in the Wadeable Stream Quantitative Habitat Evaluation Form 3600-228 (R 6/07), page 2. Be sure to fill out all fields on the data sheet, including a note if the Advanced Collection Procedures were used. Be especially careful if variables sized cell widths were used as these need to be accurately recorded to calculated stream flow. (http://intranet.dnr.state.wi.us/formscatalog/ffDispFormImage.aspx?FormID=910

b. When entering data into the FH database use the comments section to enter a quality rating for the sample collection. If collection conditions were difficult such as, soft bottom, lots of macrophytes, unusually turbulent flow, etc., record comments that reflect these conditions and your opinion on the quality of the measurement. Be concise, but these comments are important to record.

J. References

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. (Also available at *http://pubs.usgs.gov/tm/tm3-a8/*.)

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K. SOP updates tracking

Version Number	Date	Sections	Name	Approval
1.0	07/27/16	All	Klosiewski, Hazuga, Shupryt	Shupryt, 07/28/16

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