Environment Canada Environnement Canada

PROCEDURES FOR CONDUCTING DISCHARGE MEASUREMENTS WITH SONTEK FLOWTRACKER ACOUSTIC DOPPLER VELOCIMETERS

First Edition

Water Survey of Canada
Meteorological Service of Canada
Environment Canada
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Canada

Revision History

Version	Date	Source	Description/Rational for Change
1	2008-05-13	DCG/FOG	First Edition
2	2008-05-28	FOG	Anotation for CompuMod ingest capabilities

Abstract

This publication describes procedures required for conducting discharge measurements using Sontek YSI FlowTracker Acoustic Doppler Velocimeter with firmware version 3.2 or later. It is to be used by Water Survey of Canada personnel only after the completion of all training required to safely and skillfully complete a wading measurement. This procedure must be considered in conjunction with the documents called "*Policy on the Use of Hydro-Acoustic Technologies in Water Survey of Canada Operations"*, and *"Hydrometric Field Manual – Measurement of Streamflow*".

Acknowledgement

Many thanks to the Water Survey of Canada employees who helped complete this document while sharing their field expertise and through their valuable participation in the tests required. Members of the Field Operations and Data Control Sub-committees of Water Survey of Canada were instrumental in reviewing drafts of these procedures. The information in this manual also draws heavily from the experience of the Hydro-Acoustic Working Group of the United States Geological Survey and from techniques documented by Sontek YSI, manufacturer of the FlowTracker. Special thanks to Mike Rehmel from USGS and Craig Huhta from Sontek YSI.

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INTRODUCTION

This document outlines the procedures required to conduct wading measurements with the Sontek Flowtracker Acoustic Doppler Velocimeter (ADV). Extensive testing was conducted to ensure that this instrument meets Water Survey of Canada (WSC) quality standards.[1] This report concluded that "no bias was detected between the current meter and the FlowTracker in calculated discharges and mean velocities."

This document should be used in conjunction with other references. For details on measurement technique, refer to the *Hydrometric Field Manual – Measurement of Streamflow* (Terzi 1981). For details on Instrument operation and performance, refer to the Sontek *FlowTracker User's Manual* and *FlowTracker Technical Manual.*

This document is intended to be used in conjunction with appropriate training. A proper understanding of the instrument operating principles is essential to obtain quality data.

1.1 CONSTRUCTION AND FEATURES

The Sontek FlowTracker Acoustic Doppler Velocimeter (ADV) is made up of the data collection and processing computer and the acoustic velocity probe with the following characteristics:

- The computer is protected by a water resistant case linked to the probe by a rubberized data cable.
- The probe contains 3 ceramic transducers protected by an epoxy coating. The transducer in the middle transmits sound while the two at the ends of the probes act as receivers.
- This sample volume is about ¼ cm^3 and is located approximately 10 centimeters away from the face of the middle transducer (see figure 1). Be aware that this value is unique to each probe and can vary from 10 cm to 13 cm. An attachment bracket, usually supplied by the manufacturer, offsets the sample volume so that it is approx 5 cm beside the wading rod as shown in Figure 1. Note that the FlowTracker has only been formally tested with the use of a bracket. For any type of bracket is used, it is essential to account for the offset distance between the rod and the sampling volume during the measurements. A red band (not shown here) marks the probe arm to place downstream.
- The probe includes a temperature sensor used to compute the speed of sound in water.

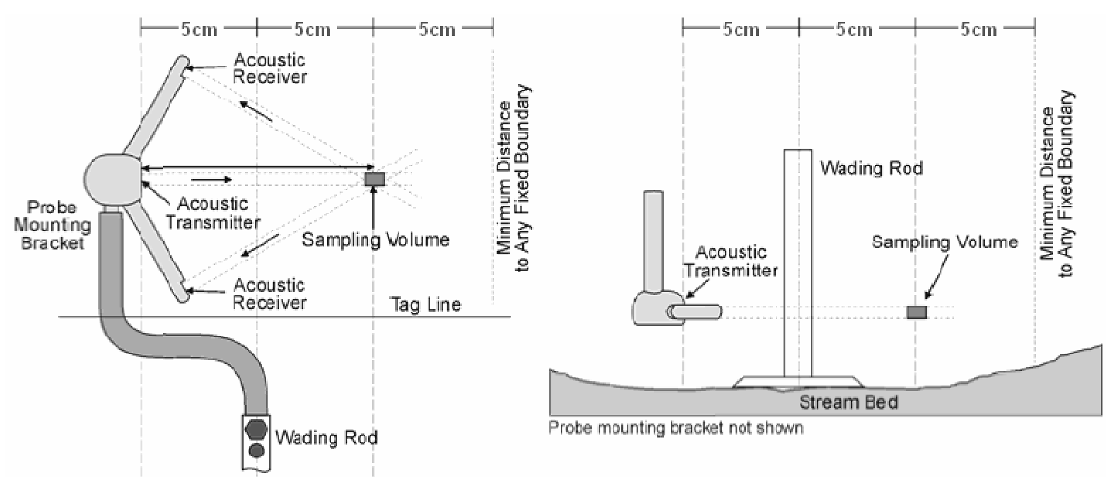


Figure 1. Schematic showing probe sampling volume from above and sideways (USGS 2005) Note that other forms of probe mounting brackets exist.

[1] *Campbell, P., Hyde, W., Woodward, J, Comparison Measurements between SonTek FlowTracker Acoustic Doppler Velocimeter and Price Current Meters*, WSC Test Plan and Report June 2005, 23pp

1.2 CARE AND MAINTENANCE

The ADV is a precision instrument that should be handled with care. The following are basic maintenance considerations:

- **Protect the probe against shock or bending**
  The FlowTracker requires no recalibration unless physically damaged. Its calibration done while at the manufacture depends on its initial geometry. Any change of this geometry will affect the system performance.
- **Keep the probe clean**
  Algae or dirt on transducer faces may increase noise in the data. Periodic cleaning of the ADV transducers will help maintain its optimal performance. Clean using a wet cloth.
- **Avoid wear and abrasion on the cable**
  The probe connection cable is a vulnerable part of the system. In particular, avoid pinching the cable when packing the instrument back into the case. Inspect the cable and all connectors on a regular basis.
- **Replace batteries in a clean and stable location**
  Whenever the field computer housing is opened, protect all seals from damage to ensure it remains water resistant. Inspect, clean and replace the o-ring if necessary.

1.3 PRE-FIELD EQUIPMENT CHECK

The following procedures must be conducted prior to each field trip to help ensure that the software, equipment and communication work properly during a deployment:

1. **Make sure that all components are firmly connected**

2. **Visually inspect equipment for damage**
   Pay extra attention to the transducer faces. If the probe arms appear to have been bent, velocity readings may be off. To check, assess the probe performance (item 5).

3. **Review the instrument maintenance**
   Verify that maintenance is up-to-date. Use only the latest firmware and software approved by WSC.

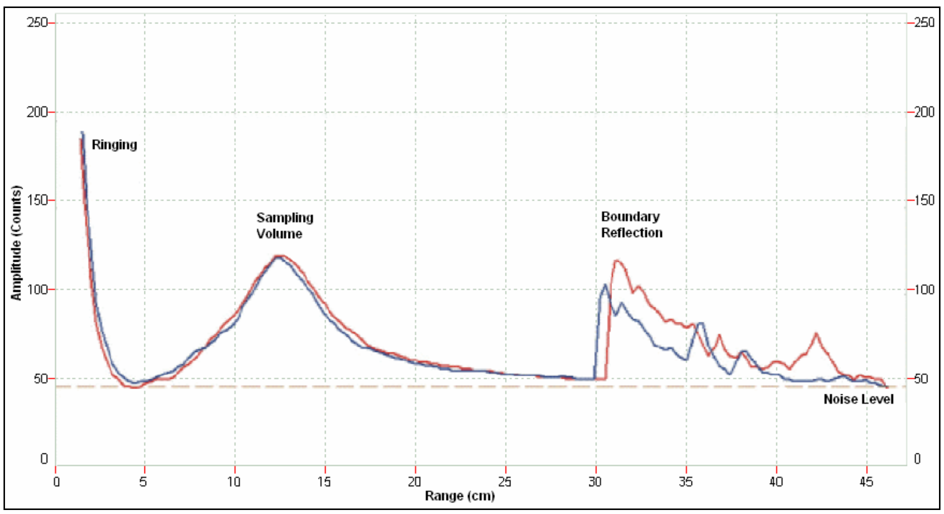
4. **Verify the probe configuration settings**
   - <u>Units</u> are SI,
   - <u>Salinity</u> is adequate for expected conditions (0 ppm for freshwater),
   - The <u>clock date and time</u> is correct,
   - The <u>averaging time</u> is set to 40 seconds,
   - The <u>sampling method</u> is set as "*mid-section method at standard depths*",
   - <u>Batteries</u> are fully charged and spares are available, and
   - Verify that previously <u>recorded data</u> was retrieved and stored properly

5. **Assess the probe performance**
   Conduct a detailed diagnostic test with BeamCheck at least once a week during field operations. Test results must be saved and archived. The date for the last test performed should be referenced in the field notes.

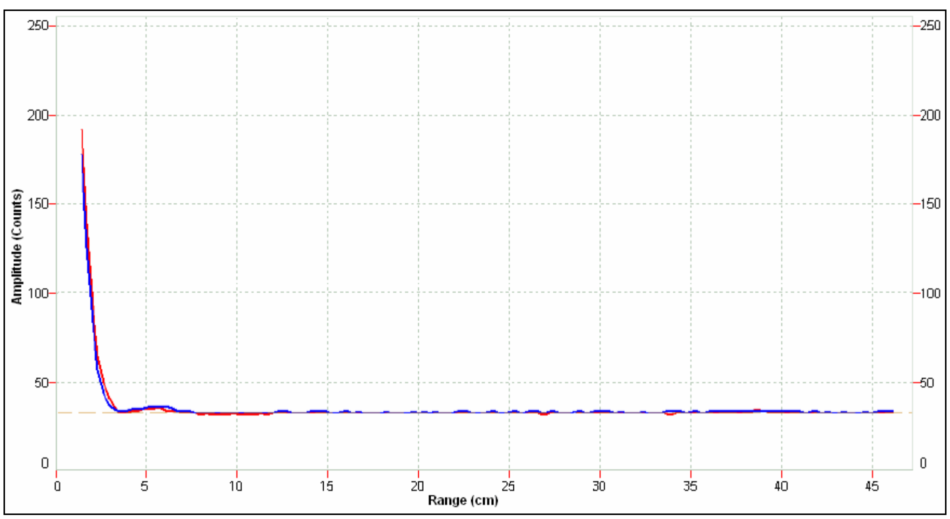
   BeamCheck assesses the health of electronics and the accuracy of the beam alignment. The test consists of transmitting a series of signals for which the echo characteristics are analyzed. BeamCheck then determines if these characteristics fall within expected values. Results may reveal problems with damaged transmitters or receivers. (Refer to Sontek manuals for details.)

Do not use the FlowTracker and report through ProbTrack if results from this test display any of the following issues (ref. FlowTracker Technical Manual, 6.5.4 BeamCheck Operation):

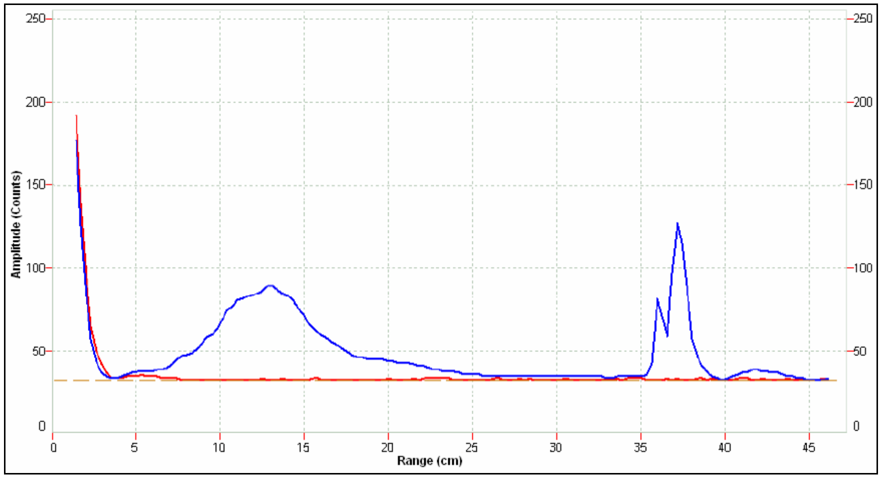
- *Malfunctioning transmitter*
  Results translate into a flat signal response (very low SNR) if the water is too clear or if the transmitter is malfunctioning. You may need to "seed" the test water to verify results.
- *Malfunctioning receiver(s)*
  Results display unequal peak amplitudes of 10 to 20 counts or more. First, make sure the transducer faces are clean and verify results.
- *Damaged/bent receiver arms*
  Results show a shift in peak positions between the two signals. If the peak positions differ by more than 1.5 cm, note the difference and do not use the FlowTracker.
- *Excessive noise or high signal strength beyond boundary*
  Noise more than 10 counts above the instrument level or a signal strength that remains high at a distance that correspond to a location outside of the tank boundary may indicate a problem with test conditions. Change/modify the testing container and retry BeamCheck to confirm that the problem is with the probe.



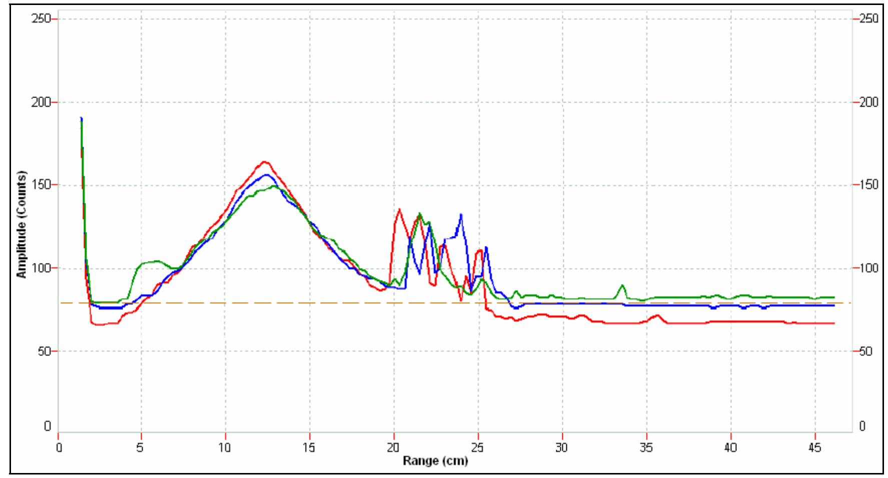
Typical BeamCheck Profile (Adapted from Sontek)



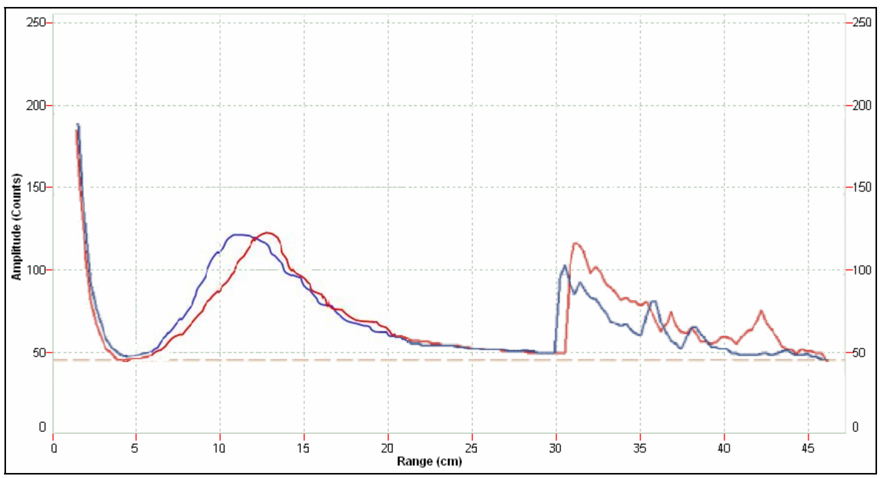
Malfunctioning Transmitter (Adapted from Sontek)



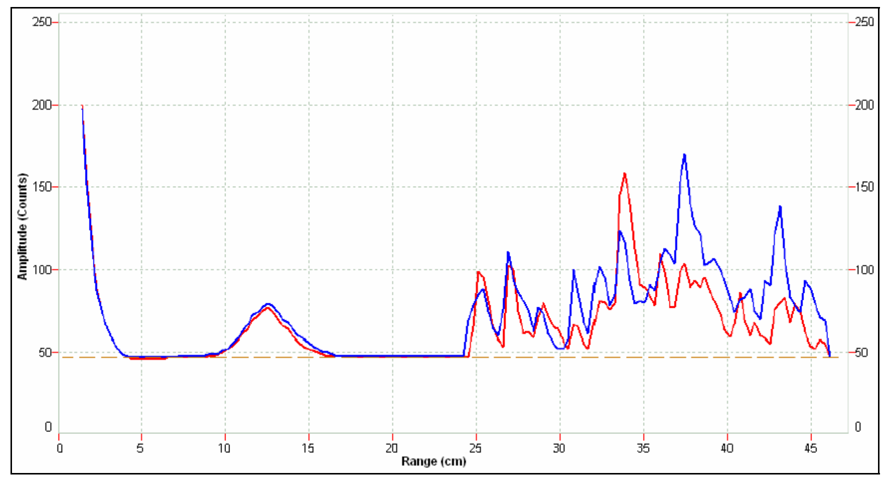
Malfunctioning Receiver (Adapted from Sontek)



Excessive Noise (Adapted from Sontek)



Bent Receiver Arm (Adapted from Sontek)



High Signal Strength beyond Boundary (Adapted from Sontek)

1.4 FIELD OPERATIONS

1.4.1 SITE SELECTION

Follow the conventional site selection criteria as described in the *Hydrometric Field Manual – Measurement of Streamflow* (Terzi 1981). In addition, the site selection for a FlowTracker must consider differences in the sampling principles. The metering section chosen should thus possess the following characteristics:

1. Flow is perpendicular to the cross section. Angular flow should be minimized or avoided.
2. Site located in a river reach where the bed and banks are straight and uniform.
3. Uniform stream bed cross-section free of obstructions that create eddies and turbulences.
4. Stream bed free of vegetation.
5. Suspended sediments providing adequate signal echo intensity. 10 dB is desirable. A minimum of 4 dB is required in the instrument measured Signal to Noise Ratio (SNR) for any beam.

1.4.2 SET-UP AND CALIBRATION

1.4.2.1 Instrument Set-up

Ensure that the system used to connect the probe to the wading rod allows for easy control of the position.

The probe must be mounted so that the arm marked by a red tape is downstream for proper reading of flow angles.

Use an attachment bracket to offset the sample volume so that it is approx 5 cm beside the wading rod (Figure 1).

It is recommended to use a fish eye bubble and alignment guide attached to the wading rod to maintain proper position (Figure 2).

1.4.2.2 Data Filing

Apply the standard naming convention to files produced during a measurement. Refer to the *File Naming Convention* standards document. No data file obtained during a measurement should be deleted.

Field Notes must also be properly completed and referenced in the electronic data. Field Notes serve as official references. Final measurement information should be transcribed onto the Field Notes.

1.4.2.3 System Checks

Check the following parameters prior to every measurement:

- Batteries capacity at sufficient levels
  Check the battery voltage once the system has acclimatized to the site temperature. The FlowTracker will not collect data unless the input voltage is at least 7.0 V. If voltage drops below 8.0 V during data collection, the FlowTracker will provide a warning message. Stop data collection and replace the batteries to prevent loss of data.
- Clock date and time adjusted to local requirements
  All data will be time stamped according to this internal clock.
- Probe recorded temperature verified against a calibrated thermometer
  The temperature reported by the FlowTracker should fall within 2^{o}C of the value measured by a calibrated thermometer. If a larger difference persists, the Flowtracker calibration is suspect and should be sent for servicing.
- Raw velocities in agreement with visual inspection

Raw velocities should respect field observation at the test point, factoring the relative angles. Rotate the probe by 90° and verify that it results in a reversal of the velocity values V_x and V_y.

- Raw SNR at required levels
  In general, all beams should show SNR values within 2-4 dB of each other. Raw values above 10 dB are desirable. Data is bad if values are below 4 dB for any beam.

1.4.2.4 Automatic QC Test

The Automatic QC Test (SmartQC) is a simplified and automated version of the BeamCheck that can be run in the field. This test does not replace the need to routinely run BeamCheck from a PC as this allows the evaluation of FlowTracker performance in more details.

The Automated QC Test must be conducted prior to the start of every measurement. Run the Automated QC Test when prompted at the beginning of each data file for your measurement, so that results are recorded and can be archived and reviewed at a later date. It is possible to run the Automated QC Test manually from the "System Function" menu prior to starting a measurement but in this case, the results are displayed to the user but not recorded.

A BeamCheck should be conducted if the Automatic QC Test identifies any warning.

1.4.3 VELOCITY SAMPLING

1.4.3.1 Time of Exposure

Each point velocity must be sampled for a minimum of 40 seconds.

- If velocities at a location appear highly variable, a longer sampling time should be used.

Maintain the probe stable during the sampling time.

- Use a fish eye bubble and alignment guide attached to the wading rod to maintain proper position during the sampling period (See figure 2). The alignment guide will help maintain the probe perpendicular to the tag line. The split bubble helps keep the rod vertical throughout the sampling period. Keeping the rod steady during data acquisition is crucial for good results.

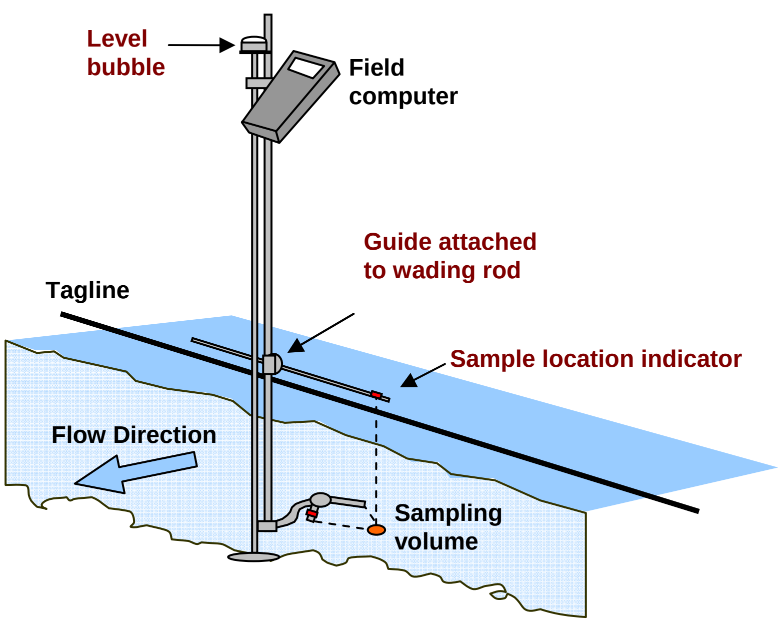


Figure 2. Recommended guides to help proper positioning

1.4.3.2 Depth in the Water Column

Select observation depths in the water column as per standard measurement practices. These criteria defined for the use of current meters are maintained for FlowTrackers.[2]

- For measurements at depths equal or greater than 75 cm, the two-point method with 0.2 and 0.8 depth is normally used for obtaining the mean velocity.
- For measurements at depths below 75 cm, observations are made at a 0.6 depth.
- If a non-standard velocity profile is detected with the two-point method, a third observation is taken at 0.6 of the depth and the three-point method is then applied. A non-standard velocity profile (profile that does not follow the 1/6 power law) is typically expected for streambeds that are very rough, irregular or covered with aquatic growth. Figure 3 illustrates the likely shape of a typical velocity profile with the location of velocity samples in the vertical.

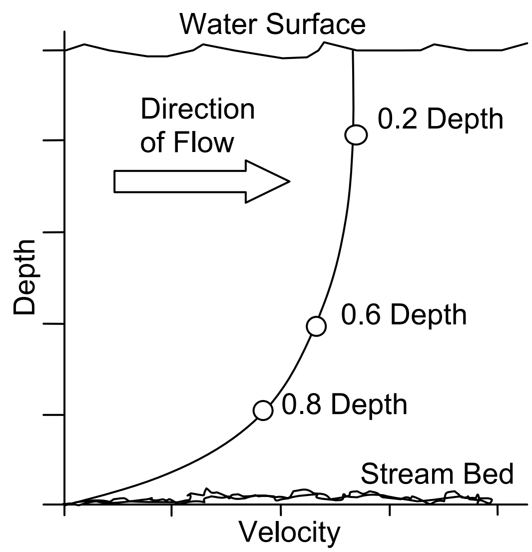


Figure 3. Typical velocity profile with sampling locations

Keep the sampling volume away from interferences.

- Do not position the probe so that the sampling volume gets too close to any solid boundary. Since the sampling volume is not visible, it may be difficult to keep it away from immersed objects such as logs or rocks. Monitor data for unrealistically high or low velocities and unusually large SNR values. Solid boundaries reduce velocities and can artificially increase SNR. All stations at one site should have roughly the same SNR value. Small fluctuations (up to about 5 dB or so) are not uncommon over a cross section, but larger fluctuations may indicate a problem (unless there is a good reason for the change, such as sediment being stirred up or the mixing of two different streams). The most common cause for problems is interference with a solid underwater object. Solid boundaries reduce water velocities and increase SNR. Alternatively, solid boundaries also produce high flow shear areas which tend to bias velocities high.
- It is possible to flip the probe around when approaching a hard surface. The measurement is then performed with the probe's red arm positioned upstream. This may help avoid boundary effects when approaching walls or rocks. Note that it then requires entering -1 as a correction factor for that specific sampling point. Review the menu options within Sontek manuals for details relative to this option.

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[2] *Hydrometric Field Manual – Measurement of Streamflow* , General Metering Criteria, p.7 and *APTP Lesson Package 10.3,* Section 5.5.

- Remember that the sampling point is offset with respect to the wading rod, and thus with respect to the location where depth is measured. Ensure that the depth measured with the rod is a fair representation of the depth below the sampling volume, and that this volume is more than 5 cm away from any solid boundary.

1.4.3.3 Spacing of Verticals

Gather data on at least 20 observation verticals (panels) in any cross section.

- This is in addition to the 2 points which define channel edges. Previous measurements statistics may help define the optimum distribution of verticals. In general, where depths and velocities are greater, space verticals more closely together. Where depths and velocities are smaller, the distance between verticals should increase. Figure 4 illustrates a typical distribution of verticals.

No panel must account to more than 10% of the total discharge.

- Each panel should account for about 5% of the total flow. Insert additional panels prior to completing the measurement if necessary.

Keep the distance between verticals greater than 5 cm.

- The 20 verticals and 5% of flow criteria may not be practical on narrow streams. Adjust the total number of verticals according to this minimum criterion for distance.

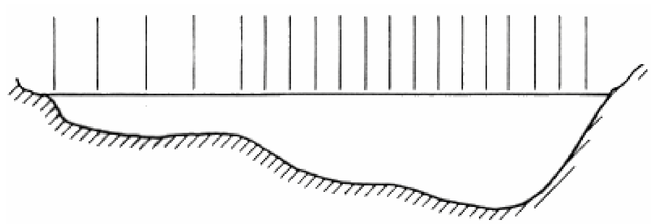

Figure 4. Unequally spaced observation points

1.4.3.4 Flow Angle

Position the probe perpendicular to the tag line while holding the wading rod vertically.

- FlowTracker readings depend on the orientation of the probe. The pulse generated by the transmitter must be parallel to the tagline with the red-banded probe downstream from it (see Figure 5). It is not necessary for the operator to input a cosine correction for the flow angle since the FlowTracker measures and automatically accounts for any non-perpendicular flow. Large variations in flow angles may indicate misalignment of the probe or poor site selection. Any error in the probe orientation will impact discharge. A guide mounted on the wading rod may help to properly align the probe (see Figure 2).

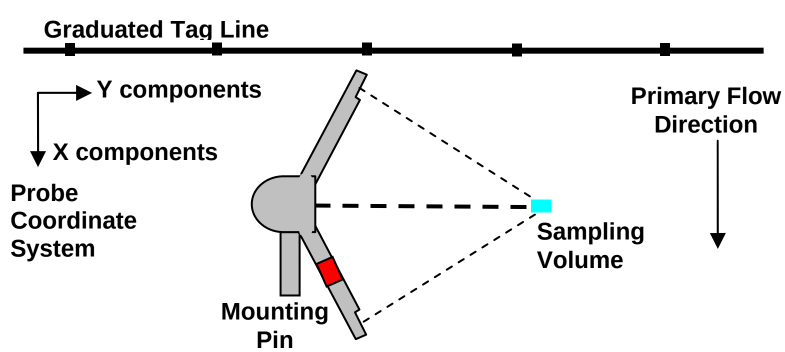

Figure 5. Orientation of probe along tag line (Sontek 2006)

1.4.4 COMPUTATION OF DISCHARGE

Use the Mid-section method for data collection and computation.

- This method is the default used in the FlowTracker system. Make sure that it is selected in the data acquisition software as the sampling method. The mid-section method is WSC standard for point measurements. Do not use any of the other methods available in the software.

1.4.5 NOTE KEEPING

Write the final discharge, gauge height and time of measurement as well as relevant meta-data on the standard Field Notes.

- The operator is not expected to capture raw values already collected by the computer on the Field Notes. However, information not covered in the electronic information and final results should be written on the Field Notes as back up prior to leaving the site.

1.5 QUALITY ASSURANCE

1.5.1 FIELD ASSESSMENT

1.5.1.1 General Criteria

During the measurement, monitor and review the quality assessment criteria listed in the table below. These factors are considered the most relevant to WSC operations. Other criteria are monitored by the FlowTracker acquisition software (*SmartQC*) and may help identify problems during a measurement. Refer to the Sontek manuals for further details on these quality flags. Always try to identify potential corrective measures while in the field when a quality factor is not met adequately.

Criteria	Description	Mitigation
Discharge % per vertical	On average 5% of total discharge per vertical. Never more than 10% in any vertical.	a) Insert additional verticals beside any above 10%
Number of panels	At least 20 verticals plus 2 for the edges in any cross-section	a) Insert additional verticals. b) Exception for streams below 1 meter in width.
Depths	As per accepted standard. For depths ≥ 75 cm: 1) Two-point method (0.2 and 0.8 depth), if the sampling volume at 0.8 depth is at least 5 cm from any boundary. 2) Three-point method (0.2, 0.6 and 0.8 depth) for non-standard velocity profiles. For depths < 75 cm: 1) Single-point method (0.6 depth)	a) The FlowTracker allows using more points in shallower depths than the current meter. Prefer the method with the largest number of points while respecting the boundary proximity limit.
Signal-to-Noise Ratio	Data not valid if obtained with any SNR ≤ 4dB. SNR > 10dB and relatively uniform (Δ<~5dB) across the section recommended.	a) Inspect, reposition and re-sample. b) Select another site nearby c) Consider seeding the water d) Select an alternative sampling technology
Boundary Interference	Sample a velocity point only when conditions are Best or Good. Note that maximum measurable water velocity is at least 3.5m/s when boundary interference QC value is listed as ‘Best’. The maximum velocity is at least 2.5m/s when the boundary interference QC value is ‘Good’.	a) Reposition and re-sample.
Flow Angle	Ideally < 20° and in agreement with visual observation	a) Reposition and re-sample. b) Select another site nearby. c) Take note of any local influence on flow angle.
Standard Error of Velocity	Typically below 0.01 m/s when flow is not highly turbulent	a) Reposition and re-sample. b) Consider the velocity profile to be non-standard. c) Select a less turbulent site. d) Document environmental conditions.
Spikes in Velocity	Number of spikes removed < 10% of total velocity data sample.	a) Identify interferences. b) Reposition and re-sample. c) Select another site nearby.

1.5.1.2 Uncertainty

The FlowTracker acquisition software provides an estimate for the % of uncertainty in the discharge value at the end of the measurement. Consider the STAT or IVE result to determine if and how data could be improved. Generally, if the % Discharge Uncertainty is 5% or less, the measurement is valid. Several parameters affecting this estimate are also monitored. The system determines and lists which is the largest individual contributor to the uncertainty. This information can be used as guidance to assess if further work is required to improve quality prior to completing the measurement.

1.5.1.3 Seeding

For sites where SNR values are too low for the FlowTracker to work reliably, consider seeding the water. The simplest way to do this is to have a second person some distance upstream (perhaps 10 or 20 meters) that is walking across and stirring up sediment. As this sediment floats downstream it will increase the SNR levels at the measurement cross section.

1.5.2 SOURCES OF ERRORS

There are limitations inherent to the design of the equipment and operating systems. Some of the most important ones are listed below. Refer to Sontek manuals for further details.

1.5.2.1 Acquisition Software

Do not turn the field computer off without first returning to the main menu. Simply powering off will cause the system to reject and delete measurements that were not properly completed via cycling through the menu.

1.5.2.2 Temperature

Temperature is required by a FlowTracker to compute the speed of sound in water. This temperature reading is obtained via a thermistor inside the probe. If this temperature is wrong, the water velocity will be inaccurate. A difference of 5°C with the actual water temperature would translate into a 2% difference in the water velocity.

1.5.2.3 Salinity

Salinity affects the speed of sound in water and thus on the determination of velocity. A 12 ppt salinity error would translate into a 2% velocity error. For most cases, fresh water can be assumed to have 0 ppt while seawater is generally at 35 ppt. When in doubt (e.g. in estuaries), salinity must be measured near the surface and the value entered in the software for speed of sound calculations.[3]

1.5.2.4 Rod Alignment

Holding the FlowTracker probe in a wrong position relative to the measurement tagline and the vertical will result in a velocity biased low. An error of about 8 degrees from the tagline may result in a velocity in error by as much as 1% (assuming that flow was perpendicular to the tagline). Learn to interpret angles reported by the system (see figure 6 below).

- [3] In-Field Salinity Measurements for ADCP Deployments, Jeff Woodward, Vida Ramin, 2003, Water Survey of Canada.

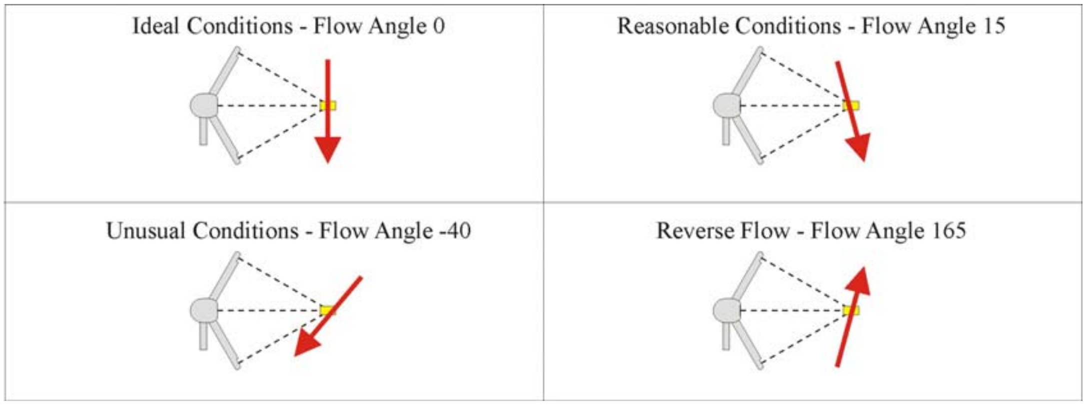

Figure 6. Angles reported by the FlowTracker
(*Craig Huhta, Sontek 2007*)

1.5.2.5 Sampling Interference

If the FlowTracker sample volume includes or is too close to a solid boundary, it will be corrupted by the velocity of that object.

- When the object is at rest, the velocity is biased low. The low bias is caused by the instrument measuring a zero velocity from the stationary object for at least part of the exposure time. See Figure 7.
- When the object is moving, the velocity is biased by the velocity of that object which may differ from that of the backscattering particles. For example, a small fish, air bubbles or algae may cause such velocity errors. See Figure 8.

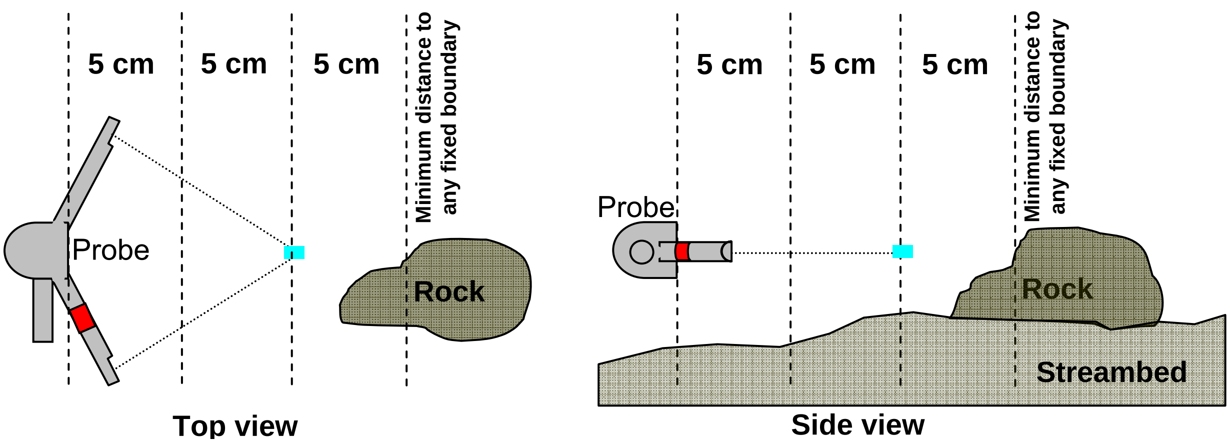

Figure 7 Proximity to large stationary object in stream

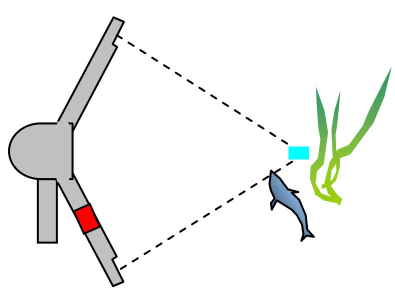

Figure 8. Contamination by large floating object in stream

1.6 DATA REVIEW AND APPROVAL

1.6.1 DATA MANAGEMENT

While in the field, periodically download your data to your laptop computer. See Sontek user manual for details on downloads.

Save the files (binary and ASCII) from your laptop and to an office server as soon as possible. All FlowTracker files must be archived together according to standard *File Naming Conventions* and the *Discharge Measurement Data Filing Procedures*. The raw FlowTracker binary files (*.WAD) include detailed QC and diagnostic data not available elsewhere. The files modified into ASCII format by the instrument software are human readable. In particular, make sure that saved data files include:

- Configuration details (.ctl)
- Raw Sampled Data including water velocity, SNR, sampling location and user-specified station information. (.dat)
- Computed Data, including discharge values for each location. (.dis)

1.6.2 REVIEW AND APPROVAL

Open the FlowTracker data file with a WSC approved software to review individual stations in detail.

First look at the distribution graphs for depth and velocity to see if any data looks visually suspect.

Next, review the SmartQC warnings listed at the end of the data report. Errors in velocities may not be apparent in averaged sub-section results. Take note of the quantity of warnings listed and their severity. Specifically review the raw velocity and SNR data if any of the following is observed:

- SNR recorded < 10 dB;
- SNR flagged < 4 dB for any beam at any time during a measurement;
- SNR inconsistent across the section;
- Velocities inconsistent across the section or unrealistic for the site conditions;
- Velocity spikes unrealistic at any time during a measurement;
- Potential boundary interference flagged for recorded velocities;
- Mean standard error for velocity exceeds 5% of the mean velocity; or,
- Any reason to suspect the data (e.g., irregular bed forms or solid boundaries that could interfere with the sampling volume).

If the raw data strengthens doubts about the validity of any velocity sampled, there is no method to correct that data during post-processing. Assess the relative importance of the problem data against the entire measurement result. Look at results in historical measurements done for similar discharge. It may then be advisable to estimate a replacement value from the best information available. <u>The adequacy of any corrective action must be discussed among those responsible for data quality in the area.</u>

1.6.3 COMPUMOD INGEST

Upload the information in WSC databases with CompuMod via one of two methods:

- *Automated Data Ingest*

> **NOTE:** The automated data ingest is available in CompuMod versions 1.7.4 and greater. The use of any previous version will require the manual ingest of FlowTracker data.

Select ***Import*** in the CompuMod main window. Then, in the ***DataImportExport*** window (Figure 9), select ***Flow Tracker (ADV)*** from the ***Field Q Meas*** section and press ***Go***. The system will walk you through the steps required to select and annotate the file and info to upload. Compumod will only recognize Sontek's software version 2.02 or later (2.20 was used for testing). Any file processed on previous versions should be rerun through a more recent and WSC approved software version. The .dis files are the output format that CompuMod will read in.

- *Manual Data Ingest*
  From the CompuMod main window, select the station and then press ***Enter Data*** to access the ***Front Sheet***. Type the measurement results and its metadata as per routine procedures.

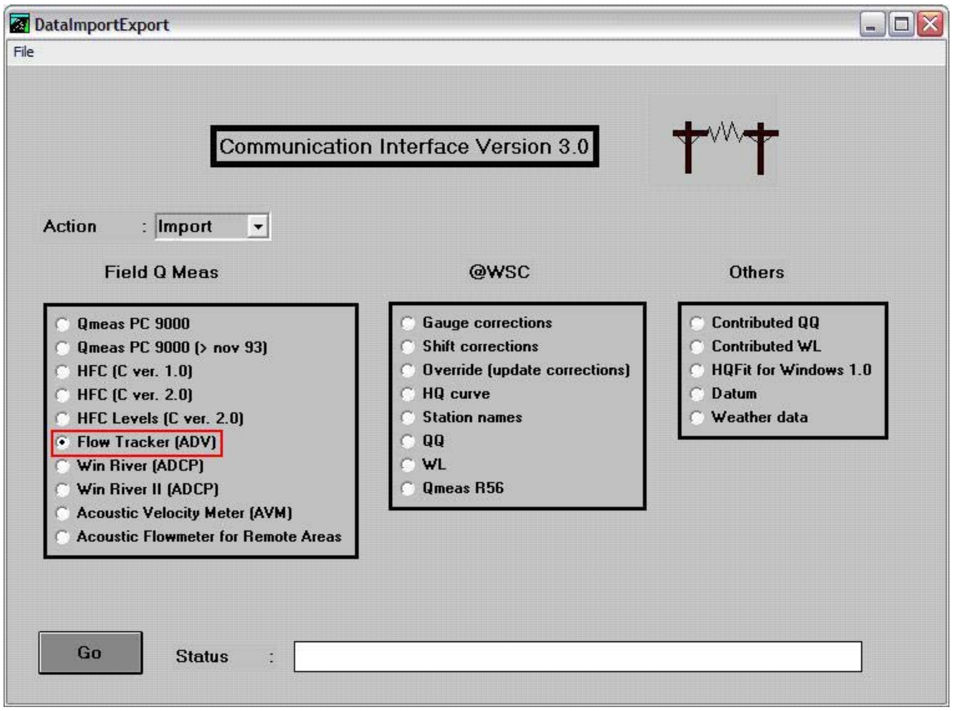

Figure 9. DataImportExport window to select Flow Tracker for automated imports

1.7 REFERENCES

- *Apprenticeship and Professional Training Program,* Water Survey of Canada, Environment Canada, 2001 *(http://www.wsc.ec.gc.ca/CDP/index_ie_e.htm)*
- *Comparison Measurements between SonTek FlowTracker Acoustic Doppler Velocimeter and Price Current Meters*, WSC Test Plan and Report, *Campbell, P., Hyde, W., Woodward, J., qREC-NA004-01-2006*
- *Discharge Measurement Data Filing Procedures*, Water Survey of Canada, qSOP-NA006-01-2004
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