

Measuring Discharge with FlowTracker Acoustic Doppler Velocimeters

Water Survey of Canada Environment Canada, Ottawa, June 2015 Revision 4, qSOP-NA022-04-2015



Revision History

| Version | Date | Source | Description/Rational for Change |
|---------|------------|----------|--|
| 1 | 2008-05-13 | DCG/FOG | First Edition |
| 2 | 2008-05-28 | FOG | Annotation for CompuMod ingest capabilities |
| 3 | 2011-06-08 | TM/JA/PC | Various edits including adding/modifying information for under ice mmts, mounts SNR and BeamCheck |
| 4 | 2015-06 | ADC/ECJ | Various changes, including: Incorporation of <i>Performance Testing</i> (qSOP-PN002-01-2009); update of importing instructions; addition of Appendix A for Beam Check Procedures; Additional tips on QA/QC |

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This publication describes procedures required for conducting wading discharge measurements using SonTek YSI's FlowTracker acoustic Doppler velocimeter (ADV). Technologists should still refer to Water Survey of Canada (WSC) best practices of stream flow measurement found in Terzi (1981) "Hydrometric Field Manual – Measurement of Streamflow".

This document is a revision of the 2011 (3rd Revision) of the procedures and replaces the following procedure:

- SonTek Flowtracker Performance Testing, qSOP-PN002-01-2009

This publication should also be supplemented with training by experienced operators and through the completion of online training material.

Acknowledgements

Thanks to the Water Survey of Canada employees who helped complete this document by sharing their field expertise and conducting tests as required. The information in this manual also draws from the experience of the United States Geological Survey Hydroacoustic Work Group (HaWG) and from techniques documented by SonTek YSI, manufacturer of the FlowTracker.

1. Introduction

Like traditional mechanical current meters, handheld acoustic Doppler velocimeters (ADVs) provide velocity measurements at a single point and may be used to compute streamflow or river discharge using the mid-section method (Terzi, 1981). ADVs determine water velocity by measuring the change in acoustic frequency (or Doppler shift) from reflections from moving particles or scatters (such as suspended sediment) in the flow, which are assumed to be moving at the same velocity as the water. The only handheld ADV currently (2015) used by Water Survey of Canada is the SonTek FlowTracker ADV. Water Survey of Canada has been using these meters since 2006 and measurements made with the FlowTracker now represent at least a third of all discharge measurements conducted by WSC.

Extensive testing was conducted to ensure that this instrument meets WSC quality standards. Test results are published in Campbell et al (2006) (qREC-NA004-01-2006). This report concluded that no bias was detected between conventional current meters and the FlowTracker in calculated discharges and mean velocities.

This document outlines the procedures required to conduct discharge measurements with the FlowTracker. Technologist should still refer to WSC best practices of stream flow measurement found in Terzi (1981) "Hydrometric Field Manual – Measurement of Streamflow". This publication should also be supplemented with training by experienced operators and through the completion of online training material. For additional details on instrument operation and performance, refer to the SonTek FlowTracker User's Manual.

2. Instrument Description

The SonTek FlowTracker ADV is made up of the data collection and processing computer and the acoustic velocity probe (Figure 1). The FlowTracker has the following characteristics:

- The computer is protected by a water resistant case linked to the probe by a rubberized data cable. The data cable is available in standard 2.0 m or optional 5.0 m length, which is suitable for under ice measurements.
- The probe contains 3 (or 4 in the case of the FlowTracker 3D) ceramic transducers protected by an epoxy coating. The middle transmitting transducer emits sound pulses and the 2 (or 3) receiving transducers at the ends of the probes receive the echo from the pulses Although the 3D units benefit from the capacity to measure three-dimensional velocity, SNR may be lower for 3D ADVs than for the standard 2D unit in low backscatter conditions.
- The sample volume is less than 0.5 cm³ and is located 10-12 cm away from the face of the middle (transmitting) transducer (Figure 2).
- The probe includes a temperature sensor used to compute the speed of sound in water.



Figure 1: SonTek FlowTracker

2.1 Working Principles

The acoustic transmitter generates a narrow beam of sound. This pulse then travels through the sampling volume and is reflected in all directions by particles in the water. The receiver samples this reflected sound at the exact time corresponding to the return from the sample volume (based on speed of sound in water) and measures the change in frequency (Doppler shift) between the transmitted and received signals. The measured Doppler shift between the transmitted and received signals. The measured Doppler shift between the transmitted and received signal is proportional to the velocity of the moving particles (and hence the flowing water). The ADV measures velocity along the received beam and resolves the two-dimensional (2D) or three-dimensional (3D) water velocities at the location where the transmitted and received signals converge, called the sampling volume, which is typically 10-12 cm away from the transducers.





2.2 Deployment Hardware

The FlowTracker is typically deployed using conventional hydrometric field equipment (such as the top-setting wading rod) and mid-section method procedures. However, various bracket models are available for mounting the ADV to the measuring rod. Depending on the bracket used, the sampling volume may be located in a different position relative to the rod. The technologist should always be aware of the location of the sampling volume in order to properly position the instrument and avoid potential interference from nearby obstacles, for example weeds or rocks.

Mounting Options

- **SonTek wading rod attachment bracket** (supplied by the manufacturer). This bracket offsets the sensor face to the left of the rod. The resulting sampling volume is 5-9 cm to the right of the wading rod centerline (Figure 3)
- Saskatchewan wading rod attachment bracket. This bracket was designed so that the sensor face is in line with the wading rod and the location of the sampling volume is located 10-12 cm to the right (Figure 4).
- Manitoba wading rod attachment bracket. This bracket was designed so that the sensor face is in line with the wading rod and the location of the sampling volume is located 10-12 cm to the right (Figure 5)
- Saskatchewan Ice rod attachment bracket. This bracket was manufactured to minimize the overall footprint of the sensor/rod so that it would fit into a small diameter ice hole. The sampling volume is located 10-12 cm to the right (Figure 6).



Figure 3: SonTek Wading Rod Bracket



Figure 5: Manitoba Wading Rod Bracket



Figure 4: Saskatchewan Wading Rod Bracket



Figure 6: Saskatchewan Ice Rod Bracket

Orientation Bracket

Since the ADV also measures the angle of flow relative to the probe, it is important to ensure that the transmitter face is perpendicular to the tag line so that the angle of flow is measured properly (Figure 2). It is also important to hold the instrument perfectly upright so that the sensor is measuring in the horizontal or XY plane. Finally, operators should hold the rod as steady as possible to ensure that the location of the sample volume does not change during velocity sampling.

To assist with this operation, an orientation bracket is recommended (Figure 7). Such a bracket has a bubble level to help the operator keep the rod vertical and steady. The orientation bracket also has an orientation guide aligned with the tag line to keep the sensor perpendicular to the flow. To help the operator locate the sample volume, the distance of the sample volume from the centerline of the wading rod can also be indicated on the orientation guide, for example, by adjustable nuts (Figure 7). The complete FlowTracker kit, with wading rod, is shown in Figure 8.



Figure 7: Hydrological Services orientation bracket (left) and standard PNR orientation bracket (right)



Figure 8: FlowTracker kit (with top-setting wading rod)

3. Standard Field Procedures

This section describes field procedures standard for Water Survey of Canada to conduct discharge measurements using SonTek YSI FlowTracker Acoustic Doppler Velocimeter (ADV).

3.1 Pre-field Equipment Check

The following procedures must be performed 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 biased.
 - Inspect the battery compartment for signs of corrosion.
- 3. <u>Review the instrument maintenance records</u>
- 4. Use only the latest firmware and software approved by WSC.
 - See *"Recommended Software and Firmware for Hydroacoustic Instrumentation"* (qREC-NA058-02-2014 or later, on the WSC Library)
- 5. On the instrument:
 - o Verify and adjust the internal clock to the correct date and time,
 - o Ensure that batteries are fully charged and spares are available, and
 - Confirm that previously recorded data was retrieved and stored properly

Note: 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. It is not possible to change the batteries and continue the measurement. If the low battery error message comes up during the measurement, the technologist will have to either:

- Abort the measurement and start again with new batteries or,
- Continue the measurement attempting to finish in time (and risk to losing the measurement before it is completed)

3.2 Site Selection

Site selection is just as important when making a discharge measurement with a FlowTracker as with any other method. Always follow the site selection criteria described in the Hydrometric Field Manual – Measurement of Stream flow: General Metering Criteria (Terzi 1981; p.7). Essentially, the metering section chosen should have the following characteristics:

- Flow is perpendicular to the cross section. Angular flow should be minimized or avoided.
- Site located in a river reach where the bed and banks are straight and uniform.
- Uniform stream bed cross-section free of obstructions that create eddies and turbulences.
- Stream bed free of vegetation.
- Suspended sediments providing adequate signal echo intensity or signal-to-noise Ratio (SNR). A value of 10 dB is desirable, but under specific circumstances reasonable velocities can be obtained with lower SNR values.

Signal-to-Noise Ratio (SNR)

The SNR value (visible on the unit's display) measures the strength of the acoustic reflection from the particles in the water. If water is "too clear" the return signal to receiving transducer will be low and this will affect the quality of your data. SNR should ideally be above 10 dB, but no less than 4 dB. <u>If the SNR values are below 4 dB for any beam, the measurement requires extra scrutiny to justify acceptance of the acquired velocities.</u> Users in low SNR environments should pay particular attention to other warnings related to the number of velocity spikes and especially standard error of velocity. A combination of low SNR and velocity-related warnings indicate the FlowTracker may be generating inaccurate water velocities.

3.3 Instrument Set-up and System Check

Equipment Set-up

Ensure that the sensor is firmly attached to the wading rod and the orientation bracket is properly attached. The probe must be mounted so that the arm marked by the red tape is downstream (Figure 2). The orientation bracket must be mounted to ensure that the tagline is perpendicular to the probe face. The sample volume indicator on the orientation bracket should be adjusted to represent the actual location of the velocity measurement. This will help the technologist visually detect potential interference in the sampling zone (e.g. weeds, rock). Finally, the bubble level should be visible to assist with keeping the rod vertical and steady.

System Checks

On the FlowTracker unit, check the following parameters prior to every measurement:

- Units are Metric
- The clock date and time is correct
- The averaging time is set to 40 seconds
- The sampling method is set as "mid-section method at standard depths"
- Batteries have sufficient charge to complete the measurement
- Probe recorded temperature verified against a calibrated thermometer
- Salinity is adequate for expected conditions (0 ppm for freshwater)

Note: A secondary calibrated thermometer measurement must be collected. The temperature reported by the FlowTracker should fall within 2°C of the value measured by the secondary thermometer once allowed to acclimatize to local conditions. If a larger difference persists, the FlowTracker thermistor is suspect, the discrepancy is noted with the measurement file and the unit should be sent for servicing. If the FlowTracker temperature is more than 2°C from the calibrated thermometer, it is recommended to view the temperature time series using the DatView software (Figure 24) before leaving the site, to confirm temperature remained within acceptable limits throughout the measurement.

Conduct Automatic QC Test (SmartQC)

There are two types of diagnostic tests for the FlowTracker. One test is an **Automatic Quality Control Test (SmartQC)** done in the stream prior to each measurement. The second type of diagnostic test is a **BeamCheck (or bucket test)** that is similar to the SmartQC test but offers detailed diagnostics (See Appendix B: FlowTracker BeamCheck Procedures for more details).

The Automatic QC Test (SmartQC) must be conducted prior to the start of every measurement. The user will be prompted to start the SmartQC test at the beginning of each measurement and results will be recorded with the measurement. When prompted, the technologist places the FlowTracker probe in open, moving water (away from any underwater obstacles), and presses a key to start the test. The system collects for 30 seconds and analyzes that data to verify all major aspects of system operation. A warning is given if any test result fails the expected criteria. If this occurs, reposition the probe (in case there was interference from an underwater obstacle) and repeat the test. If the warning persists, connect the FlowTracker to a PC and run the BeamCheck software for more detailed analysis.

Check Auto QC Test results (Figure 9) for the following:

- <u>Noise level</u> Is the system noise level within expected bounds?
- <u>SNR (signal-to-noise ratio)</u>

Is SNR sufficient for reliable operation? Are all beams seeing the same SNR?

Peak location

Is the sampling volume peak in the expected range? Do all beams see the peak in the same range?

<u>Peak shape</u>

Does the sampling volume peak show the expected smooth, bell shaped curve?





3.4 Wading Measurement Procedures

Once an adequate measuring section has been found, a graduated tagline must be installed perpendicular to the flow. Standard mid-section measurement practices (Terzi 1981, Rantz 1982, and Turnipseed and Sauer 2010) should always be respected with FlowTracker measurements. A measurement of gauge height (preferably two, before and after) must be obtained in conjunction with the discharge measurement. This information should be included in the FlowTracker measurement file. The essentials of a discharge measurement are summarized below.

Spacing of Verticals

The method used to compute discharge is called the mid-section method. This method assumes that each measured velocity and depth is representative of the mean for that section (Figure 10). The number of verticals and their placement can significantly affect the measurement quality. The technologist should plan the spacing of observation verticals (stations or panels) accordingly in order to properly capture flow conditions (Figure 11). General standard rules include:

- Collect at least 20 observation verticals (stations) in any cross section (25-30 verticals is ideal). Since the total number of Stations in the FlowTracker software includes edges, the minimum number of Stations must be 22.
- Each station should account for about 5% of the total flow. Where depths and velocities are greater, verticals are closer together. Where depths and velocities are smaller, the distance between verticals increases. (Figure 11). No station must account for more than 10% of the total discharge. Insert additional stations prior to completing the measurement if necessary.
- Keep the distance between verticals greater than 5 cm. It may not be possible to obtain 20 verticals and 5% of flow per vertical on narrow streams. Adjust the total number of verticals according to this minimum criterion for distance.
- The position of the rod against the tagline corresponds to the position of the measured vertical.



Figure 10: Illustration of mid-section method, where d = depth, b = distance (adapted from Turnipseed and Sauer, 2010)



Figure 11: Example of unequally spaced observation points. Verticals should be spaced to best capture flow conditions.

Depth of Observation

The criteria defined for the selection of observation depths for current meters is maintained for FlowTrackers. Observation depths should follow these guidelines (Figure 12):

- If the depth of vertical is less than 0.75 m, observations are made at a 0.6 depth.
- If the depth is equal to or greater than 0.75 m, the twopoint method with observations at 0.2 and 0.8 depth is used to obtain the mean velocity.
- If a <u>non-standard velocity profile</u> is suspected with the two-point method, a third observation is taken at 0.6 of the depth and the three-point method is then applied.



Figure 12: Typical velocity profile with sampling location

A <u>non-standard velocity profile</u> (a profile that does not follow the 1/6th power law) is typically expected for streambeds that are very rough, irregular or covered with aquatic growth. The following observations indicate that such non-standard profile is present:

- Top velocity (at 0.2 depth) > 2 x bottom velocity (at 0.8 depth)
- Bottom velocity (at 0.8 depth) > top velocity (at 0.2 depth)
- Bottom velocity is affected by turbulence or obstruction

Time of Exposure

Under normal measurement conditions, 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. Ensure the probe remains stable during the sampling time.
- Under <u>extreme</u> conditions, such as rapidly changing stage, a shorter sample time may be used to lessen the overall
 measurement time. However, it would be advisable to conduct one or more additional measurements consecutively
 under such conditions.

Flow Angle

The orientation of the probe and wading rode is very important during a measurement. Position the probe perpendicular to the tag line while holding the wading rod vertically (Figure 13).

With the FlowTracker, it is not necessary for the operator to input a cosine correction for the flow angle since the unit measures and automatically accounts for any nonperpendicular flow. However, the accuracy of the flow angle measurement depends on the correct orientation of the probe. The pulse generated by the transmitter must be parallel to the tagline with the red-banded probe on the downstream side. A guide mounted on the wading rod should be used to help properly align and position the probe.



Figure 13: Orientation of probe along the tag line

Boundary Issues

A common cause of ADV measurement problems in the field is interference with a solid underwater object, such as weeds, logs or rocks (Figure 14). Solid boundaries can reduce measured water velocities and increase SNR. Solid boundaries may also produce localized regions of high shear, which could bias velocities high. Monitor data for unrealistically high or low velocity fluctuations and unusually large SNR values. All stations at one site should have approximately the same SNR value. During measurement, the unit will rate boundary issues as BEST, GOOD, FAIR or POOR. The following steps will help avoid boundary issues:

- Be careful not to position the sampling volume too close to any solid boundary
- If boundary QC is FAIR or POOR, reposition the probe.
- 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**: When rotating the probe input -1 as a correction factor for that specific sampling point.

Remember that the sampling point is offset with respect to the wading rod, and thus with respect to the location where depth is measured.

- The depth measured with the rod should be a fair representation of the depth below the sampling volume.
- Ensure that the sampling volume is more than 5 cm away from any solid boundary (Figure 14).



Figure 14: Sampling volume offset from probe should be kept at least 5 cm from a fixed boundary, shown as a rock here. (Turnipseed and Sauer, 2010)

Interference from Technologist

The technologist should stand in a position that least affects the velocity of water in the sampling volume (Figure 15).

- Hold the wading rod firmly and close to the tagline
- Stand downstream of tagline, and as far from the probe as possible (this may require standing to the side of the wading rod).
- For very small streams or near shore measurements, avoid standing in the water if feet and legs would occupy a considerable percentage of the cross-section or station.



Figure 15: Technologist conducting wading measurement

Quality Control Flags

During the measurement and after each station, the FlowTracker will warn the user if any quality assessment criteria are not met. If possible, attempt to correct the problem while in the field.

| Warning | Description | Suggested Actions |
|---|---|--|
| Low SNR | SNR < 4 dB may lead to high standard error of velocity. If standard errors of velocity are consistently below threshold values and frequent spikes are detected during the measurement, conditions are poor. | Seed water or disturb sediment upstream to increase SNR Use mechanical current meter |
| Beam SNR SNR Variation SNR Change | All stations at one site should have roughly the same SNR value. Small fluctuations (variation < ~ 5dB) 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). | Look for underwater obstacles (weeds, logs or rocks) or environmental sources (aerated water, sediment flume) and repeat measurement. |
| High ơV | High standard error of velocity may indicate interference or highly turbulent flow | Look for underwater obstacles Consider turbulence levels at location are real and repeat measurement Increase measurement time |
| Bad Boundary QC | If Boundary QC is FAIR or POOR, there may be interference from underwater obstacles | Relocate the probe/station to avoid obstruction Measure with probe rotated 180 degrees to face the other bank & apply -1 correction Proceed with measurement anyway if results are consistent. |
| High Spikes | A few spikes in the data are acceptable and the FlowTracker will automatically filter them out. A large number of spikes may indicate interference in the sampling volume. | Look for underwater obstacles Relocate the probe/station to avoid obstruction and repeat measurement |
| High Angle | Large flow angles may indicate misalignment of the probe or poor site selection. Any error in the probe orientation will impact discharge. | Confirm flow angle measured reflects actual site conditions. Reposition and repeat measurement |
| Suspect Depth Value Suspect Location Value | If depth or spacing between adjacent stations is more than expected, the user will be warned. It may indicate data entry error. | Verify station depth or station location value. |

Computation of Discharge

Once all verticals have been collected, the FlowTracker will flag all stations where issues were encountered. (For example, large flow angles, station discharge > 10% of total discharge¹, velocity spikes, high standard error of velocity etc.). Repeat or add verticals if required.

If any quality control warning has been flagged and could not be fixed during the measurement (e.g. by repositioning the probe), the technologist should review the measurements before leaving the site using DatView as described in Section 4.1 and 4.2 of this document, **Measurement Review and Approval**.

Once satisfied with the measurement, the operator must write the final discharge, gauge height and time of measurement as well as relevant meta-data on the standard Hydrometric Survey Notes. All measurement information is stored in the handheld computer and must be retrieved and copied for archiving (see Section 4, **Data Management**). The operator should document any pertinent information not collected by the handheld computer and the final results should be entered on the Hydrometric Survey Notes prior to leaving the site.

¹ In **SmartQC**, using a lower criterion for **Max Sect. Q** (i.e. less than the 10% default) helps detect where additional panels may be desired for a better distribution of panels.

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3.5 Under-Ice Measurement Considerations

Standard measurement practices for under ice conditions (Terzi, 1981) should always be respected when using a FlowTracker. In addition to the considerations discussed in the previous sections regarding the mid-section method, some special considerations apply to under-ice measurements:

Hardware Considerations

Instrument Alignment

When conducting measurements under ice, orientation of the probe must be known even when it can't be seen below the ice. Therefore the bottom bracket should be fastened in a consistent position on the rod (via a set screw or other method). Although an orientation bracket is also recommended for wading measurements, it is especially important during under-ice measurements. However, currently available alignment brackets may not be designed to be quickly repositioned along the ice rod as it is raised and lowered under ice over the range of depths. The ice rod should be marked (i.e. with a line on the face of the rod) so the alignment bracket can be easily oriented with respect to the probe position.

Rod Orientation and Stability

Users should be aware of the effect of rod flex as it affects the probe orientation and stability under ice. Increasing depth and velocity degrade the ability of the operator to ensure the sensor is oriented properly because the ice rod may bend and vibrate. Where probe orientation problems are suspected, measures need to be taken to keep the rod stable and oriented properly or another measurement system should be used.

Sensor Cable

Users must ensure that the sensor cable length is sufficient for the cross section being measured. Most FlowTrackers come with 2m long cables which are insufficient for many measurements under ice. FlowTrackers with 5m cables are more appropriate for under ice measurements. The transducer cable should be attached to the winter rod so that the effect of flow disturbance around the probe and overall resistance to flow is minimized.

Water Temperature

As mentioned earlier, the FlowTracker should be given sufficient time to acclimatize to water temperature. This may take longer for winter measurements when water temperature is low. Also avoid leaving the probe exposed to cold air for a long period of time. Before leaving the site, it is recommended to view the temperature time series using the DatView software (see Measurement Review section) to confirm that FlowTracker temperature remained within acceptable limits throughout the measurement.

Operation in Cold Temperature

Using the FlowTracker in very cold temperatures may cause the unit to shut down due to power drop. As mentioned earlier, the user will not be able to replace batteries during a measurement. To avoid losing data, the unit should be sheltered from the cold as much as possible (padded case with toe-warmer around the instrument electronics) and fully charged batteries should be used.

Software Considerations

Default Value Velocity Coefficient at 0.5 Depth

When conducting measurements under ice, WSC guidelines (Terzi, 1981) recommend measuring the velocity at 0.5 of effective depth. Moreover, because the velocity profile under ice differs from those normal in an open channel, when the 0.5 depth method is used a coefficient of 0.88 must be applied to the measured velocity.

However, the FlowTracker default value for the velocity coefficient for a measurement at 0.5 depth is 0.89. It is thus necessary to confirm and change the velocity coefficient to 0.88 prior to any station using the 0.5 depth method. (The software will not retain that setting when powered down and so must to be changed to 0.88 each time it is required).

Referencing Vertical Positions for the Sample Volume

Presently, the FlowTracker only references from the bottom of the channel when calculating the vertical position of the sample volume as opposed to the more conventional practice of providing a sample volume location with respect to the water level surface. For example, after inputting values of 1.0 m for depth of the water level surface to the bottom of the channel (total depth) and 0.4 m for the ice thickness, the FlowTracker would indicate that the probe should be placed 0.3 from the bottom of the channel. In reality, the FlowTracker should indicate the probe be placed 0.7 m from the water level surface. To derive depth location for the probe referenced from the water surface, the technician can do the following:

For verticals using the 0.5 depth method:

To derive the probe location of a 0.5 velocity measurement, SUBTRACT the probe depth referenced from bottom of channel **(C)** from the water surface to bottom of channel **(A)** (See Figure 16).



Figure 16: FlowTracker display during under ice measurement for 0.5 depth

For verticals using the 0.2 and 0.8 depth method (flow depth greater than 0.75m):

To derive the probe location for 0.2 velocities, SUBTRACT the 0.2 probe depth referenced from the bottom of channel **(B)** from the water surface to bottom of channel **(A)**, to produce the correct 0.2 depth (Figure 17). Similarly, the user can derive the 0.8 probe location by SUBTRACTING the 0.8 probe depth referenced from the bottom of channel **(C)** from **(A)**.



Figure 17: FlowTracker display during under ice measurement for 0.2 and 0.8 depths.

Using FlowTracker to Detect Slush Zone

The FlowTracker includes a feature which allows for the display of raw water velocities. This feature can be used to detect slush zones. At any station where slush is suspected, the raw velocity display feature must be activated. The FlowTracker probe is then slowly raised through the water column until zero velocity is displayed. This point indicates the slush horizon. Before any station, simply select QC menu (8), then choose item #5 raw velocity profile.



Figure 18: FlowTracker "raw velocity profile" display

4. Data Management

This section highlights the necessary steps to properly review a discharge measurement with SonTek FlowTracker. The steps to properly input the measurement into HWS are also discussed.

4.1 Measurement Review and Approval

To review a FlowTracker measurement, the file should be opened using the latest version of SonTek FlowTracker software. Consult the document "Recommended Software and Firmware for Hydroacoustic Instrumentation" on WSC library to confirm that you use the most up-to-date version. The software can be installed from the Run Advertised Programs.

The following items should be reviewed in the Discharge Measurement Summary:

Review Automated QC Check

Any error in the SmartQC test (Figure 9) should have been flagged during "Instrument Set-up and System Check" (Section 3.3), but the reviewer should assess the Auto QC Test results found at the bottom of the Discharge Measurement Summary page.

Review Discharge Measurement Summary Header

Review "System" and "Summary" Table (Figure 19) and make sure that it reflects the field notes.

- <u>Review Measurement Summary Information</u>
 - Mean SNR > 10dB
 - o Date and time correct
 - Width, Area and Total Q same as the field notes
- <u>Review Discharge Uncertainty Table</u>

The FlowTracker provides two estimates for the percent (%) uncertainty in the discharge at the end of the measurement: the ISO and Stats uncertainty. Although the **ISO** method is an accepted method, the **Stats** value is usually more conservative and takes into account interpolation errors when there is large variation in depths and velocities between stations. Generally, if the % Stats Discharge Uncertainty is 5% or less, the measurement is considered valid. This information can be used as guidance to assess if further work is required to improve quality prior to completing the measurement.

| Discharge № | leasure | men | t Sum | mary | Date Generate | d: Thu Sep | 18 2014 |
|--|-------------|---------------------|-----------------|--|---------------|------------|---------|
| File Information File Name Start Date and Time | De 2001/ | moData. '08/15 1 | .wad 2:58:16 | Site Details Site Name Operator(s) | | | |
| System Informatio | n | | Units | (Metric Units) | Discharge Und | ertainty | |
| Sensor Type | FlowT | racker | Distance | m | Category | I50 | Stats |
| Serial # | P | 63 | Velocity | m/s | Accuracy | 1.0% | 1.0% |
| CPU Firmware Version | 2 | .0 | Area | m^2 | Depth | 0.1% | 1.2% |
| Software Ver | 2. | 30 | Discharge | m^3/s | Velocity | 0.5% | 1.6% |
| Mounting Correction | 0. | 0% | | | Width | 0.1% | 0.1% |
| Summany | | | | | Method | 1.8% | |
| Averaging Tet | 40 | # Ctat | iona | 25 | # Stations | 2.0% | |
| Start Edge | 16W/ | # Stat | Midth | 72 762 | Overall | 2.9% | 2.3% |
| Mean SNR | 24.3 dB | Total 4 | Area | 31 111 | | | |
| Mean Temp | 27 12 % | Mean [| Denth | 0 422 | | | |
| Disch Equation | Mid-Section | Mean \ | Velocity | 0 2783 | | | |
| Dischi Equilion | ind occorr | Total | Discharge | 8.6585 | | | |

Figure 19: Discharge Measurement Summary Header Tables

Review Discharge Measurement Summary Graphics

Use the visual summary item (Figure 20) to quickly identify any potential error in the data and assess the quality of the cross-section.

- Is any station discharge > 10% of the total discharge
- Do any erroneous depths or velocity measurements stand out?
- Is the velocity distribution and cross-section as expected?
- Is there anything out of the ordinary that can be investigated in the Measurement Result Table (below)



Figure 20: Discharge Measurement Summary Graphics

Review Measurement Results Table

Review all pertinent information included in the "Measurement Result" table (Figure 21), particularly if something was flagged above.

- Depth(s) of velocity measurement(s) (Method)
 - Depth < 0.75m, Method = 0.6
 - Depth > 0.75m, Method = 0.2/0.8
 Non-Standard velocity, Method =
 - 0.2/0.6/0.8
- Spacing of Verticals
 - o At least 20 observation verticals (stations)
 - No station discharge >10% of total discharge.
 - Distance between verticals greater than 5 cm.
- <u>Time of measurement</u>
 - Start/End time corresponds to field notes
- <u>Correction Factor (CF)</u>
 - For under-ice measurement with 0.5 depth method, ensure 0.88 was used for the Correction Factor

| Me | asuren | nent Re | esults | | | | | | | | | |
|----|--------|---------|--------|-------|------|-------|--------|----------|--------|-------|--------|-----|
| St | Clock | Loc | Method | Depth | %Dep | MeasD | Vel | CorrFact | MeanV | Area | Flow | %Q |
| 0 | 12:58 | 3.05 | None | 0.000 | 0.0 | 0.000 | 0.0000 | 1.00 | 0.0000 | 0.000 | 0.0000 | 0.0 |
| 1 | 12:58 | 6.10 | 0.6 | 0.186 | 0.6 | 0.074 | 0.2264 | 1.00 | 0.2264 | 0.567 | 0.1283 | 1.5 |
| 2 | 12:59 | 9.14 | 0.6 | 0.305 | 0.6 | 0.122 | 0.2748 | 1.00 | 0.2748 | 0.929 | 0.2553 | 2.9 |
| 3 | 13:02 | 12.19 | 0.6 | 0.433 | 0.6 | 0.173 | 0.3781 | 1.00 | 0.3781 | 1.319 | 0.4988 | 5.8 |
| 4 | 13:03 | 15.24 | 0.6 | 0.518 | 0.6 | 0.207 | 0.4307 | 1.00 | 0.4307 | 1.579 | 0.6801 | 7.9 |
| 5 | 13:04 | 18.29 | 0.6 | 0.491 | 0.6 | 0.196 | 0.4748 | 1.00 | 0.4748 | 1.496 | 0.7101 | 8.2 |
| 6 | 13:05 | 21.34 | 0.6 | 0.515 | 0.6 | 0.206 | 0.3789 | 1.00 | 0.3789 | 1.570 | 0.5949 | 6.9 |
| 7 | 13:06 | 24.38 | 0.6 | 0.619 | 0.6 | 0.247 | 0.2571 | 1.00 | 0.2571 | 1.886 | 0.4848 | 5.6 |
| 8 | 13:08 | 27.43 | 0.6 | 0.710 | 0.6 | 0.284 | 0.2429 | 1.00 | 0.2429 | 2.164 | 0.5257 | 6.1 |
| 9 | 13:09 | 30.48 | 0.6 | 0.680 | 0.6 | 0.272 | 0.2553 | 1.00 | 0.2553 | 2.072 | 0.5289 | 6.1 |
| 10 | 13:10 | 33.53 | 0.6 | 0.671 | 0.6 | 0.268 | 0.2436 | 1.00 | 0.2436 | 2.044 | 0.4978 | 5.7 |
| 11 | 13:11 | 36.58 | 0.6 | 0.640 | 0.6 | 0.256 | 0.2644 | 1.00 | 0.2644 | 1.951 | 0.5158 | 6.0 |
| 12 | 13:12 | 39.62 | 0.6 | 0.607 | 0.6 | 0.243 | 0.3181 | 1.00 | 0.3181 | 1.849 | 0.5880 | 6.8 |
| 13 | 13:13 | 42.67 | 0.6 | 0.509 | 0.6 | 0.204 | 0.3704 | 1.00 | 0.3704 | 1.551 | 0.5747 | 6.6 |
| 14 | 13:14 | 45.72 | 0.6 | 0.451 | 0.6 | 0.180 | 0.3675 | 1.00 | 0.3675 | 1.375 | 0.5053 | 5.8 |
| 15 | 13:15 | 48.77 | 0.6 | 0.372 | 0.6 | 0.149 | 0.3421 | 1.00 | 0.3421 | 1.133 | 0.3877 | 4.5 |
| 16 | 13:16 | 51.82 | 0.6 | 0.317 | 0.6 | 0.127 | 0.2935 | 1.00 | 0.2935 | 0.966 | 0.2835 | 3.3 |
| 17 | 13:18 | 54.86 | 0.6 | 0.271 | 0.6 | 0.108 | 0.2303 | 1.00 | 0.2303 | 0.827 | 0.1904 | 2.7 |
| 18 | 13:19 | 57.91 | 0.6 | 0.256 | 0.6 | 0.102 | 0.1952 | 1.00 | 0.1952 | 0.780 | 0.1523 | 1.8 |
| 19 | 13:20 | 60.96 | 0.6 | 0.259 | 0.6 | 0.104 | 0.1314 | 1.00 | 0.1314 | 0.789 | 0.1037 | 1.2 |
| 20 | 13:21 | 64.01 | 0.6 | 0.293 | 0.6 | 0.117 | 0.1193 | 1.00 | 0.1193 | 0.892 | 0.1064 | 1.2 |
| 21 | 13:22 | 67.06 | 0.6 | 0.351 | 0.6 | 0.140 | 0.1196 | 1.00 | 0.1196 | 1.068 | 0.1278 | 1.5 |
| 22 | 13:23 | 70.10 | 0.6 | 0.421 | 0.6 | 0.168 | 0.1147 | 1.00 | 0.1147 | 1.282 | 0.1470 | 1.7 |
| 23 | 13:25 | 73.15 | 0.6 | 0.305 | 0.6 | 0.122 | 0.0696 | 1.00 | 0.0696 | 1.022 | 0.0711 | 0.8 |
| 24 | 13:25 | 76.81 | None | 0.000 | 0.0 | 0.000 | 0.0000 | 1.00 | 0.0000 | 0.000 | 0.0000 | 0.0 |

Figure 21: Measurement Results Table

Review Quality Control Table

- Interference in the sampling volume (boundary interference)
 - The Boundary variable may have one of following values:
 - 0 (Best) No adjustment necessary or minimal impact on performance
 - 1 (Good) Moderate impact on system performance
 - 2 (Fair) Notable impact on system performance
 - 3 (Poor) Major boundary adjustments necessary

If a station shows possible boundary interference with an underwater obstacle, boundary QC of FAIR or POOR will be flagged, and the operator should review the station in DatView (see next section).

Flow Angle

Any angle greater than 20° will be flagged. Flow angle should be in agreement with visual observation.

• <u>Standard Error of Velocity (σV)</u>

The standard error of velocity should typically be less than 0.01 m/s. If σV is flagged as high, the operator should review the station in DatView (see next section).

• Spikes in Velocity

The number of spikes removed from the mean velocity should be less than 10% of the total velocity data samples. Excessive spikes may be caused by an underwater obstacle or unusual conditions such as aerated water. If flagged, the operator should review the station in DatView (see next section).

| Qua | lity Contr | ol | |
|-----|------------|------|---|
| St | Loc | %Dep | Message |
| 4 | 278.00 | 0.2 | High standard error: 0.079 |
| 5 | 264.00 | 0.2 | High angle: -43 |
| | | 0.8 | High angle: -52 |
| 6 | 250.00 | 0.2 | High angle: -49 |
| | | 0.8 | High angle: -55 |
| 7 | 238.00 | 0.2 | High angle: -39 |
| | | 0.8 | High angle: -39 |
| 8 | 226.00 | 0.2 | High angle: -37 |
| | | 0.8 | High angle: -40 |
| 9 | 216.00 | 0.2 | High angle: -32 |
| | | 0.8 | High angle: -38 |
| 10 | 208.00 | 0.2 | High angle: -32 |
| | | 0.8 | High angle: -36 |
| 11 | 200.00 | 0.2 | High angle: -35 |
| | | 0.8 | High angle: -35 |
| 12 | 192.00 | 0.2 | High angle: -34 |
| | | 0.8 | High angle: -35 |
| 13 | 184.00 | 0.2 | High number of spikes: 3 |
| | | 0.2 | High angle: -33 |
| | | 0.8 | High angle: -38 |
| 14 | 176.00 | 0.2 | High angle: -34 |
| | | 0.8 | High angle: -38 |
| 15 | 168.00 | 0.2 | High angle: -30 |
| | | 0.8 | High angle: -38 |
| | | 0.8 | High standard error: 0.081 |
| 10 | 100.00 | 0.2 | High angle: -37 |
| | 152.00 | 0.8 | High angle: -57 |
| 1/ | 152.00 | 0.2 | High number of spikes: 3 |
| | | 0.2 | High angle: -34 |
| 10 | 144.00 | 0.0 | High angle: |
| 10 | 144.00 | 0.2 | High angle: -20 |
| 10 | 126.00 | 0.0 | High angle: -55 |
| 19 | 130.00 | 0.2 | High angles -20 |
| 20 | 129.00 | 0.0 | High angles -51 |
| 20 | 120.00 | 0.2 | High angle: -20 |
| 22 | 110.00 | 0.0 | High standard error: 0.107 |
| 22 | 100.00 | 0.8 | High standard error: 0.107 |
| 20 | 100.00 | 0.0 | High number of college 3 |
| 27 | 90.00 | 0.0 | High standard error: 0, 116 |
| 20 | 10.00 | 0.8 | High statuary Crivity 0,110 |
| 33 | 10.00 | 0.0 | High angle; F22 |
| | | 0.0 | Reundary OC is Eairy possible boundary interference |

Figure 22: Quality Control Table

4.2 In Depth Review Using DatView

DatView (Datview.exe) is a standalone executable software developed by the USGS for SonTek/YSI FlowTracker users to review discharge measurements. The software provides for a quick visual review of the measurement and highlights data that contains possible quality issues. DatView can be found on the Run Advertised Program List. Simply copy the program file DatView.exe onto your computer and run the executable.

How to Use DatView

DatView will use the following FlowTracker measurement ASCII file:

- Discharge (.DIS)
- Summary (.SUM)
- Data (.DAT)

To export these files, open the FlowTracker measurement (.WAD) file using SonTek FlowTracker Software. This creates the ASCII files within your measurement folder.

In DatView, select "File" and "Load FlowTracker Data Set". Navigate to your measurement folder and select the .DAT file for your measurement. DatView will then load the measurement for review (Figure 23). There are two main tabs, "Summary" and "Cross Section" (Figure 23), allowing you to carefully review your measurement. All possible quality issues will be highlighted in yellow.

| 🍯 DatVi | iew(C:\U | sers\duo | capa\Des | ktop\ | ALAIN | ON C\AI | OCP DA | TA\FL(| OWTRA | CKER MEA | SURE | MENT\02 | MC027_ | 2013111 | 3.FQ1\02MC | 0 _ 🗆 × |
|-----------|---------------------------|----------------------------|-------------|----------|-----------------|-------------|---------------|-----------|----------|--------------|--------------------|----------------------|----------|-------------|-------------|----------------|
| File View | w Help | | | | | | | | | | | | | | | |
| Summary | Cross | Section | | | | | | | | | | | | | | |
| File: 02 | 2MC027 2 | 20131113. | WAD | | | | | | | | | | | | | |
| Start Da | ate Time: | 2013/1 | 1/13 11:05 | :28 | Mean S | NR: | | 12 | 2.3 dB | | Total | Width: | 9 | .100 m | | |
| Serial N | umber: | P2496 | | | # Statio | ns: | | 24 | L . | | Mean | Velocity: | 0 | .3214 m/s | | |
| Averadi | na Time: | 40 sec | | | Mean si | td. Error a | f Vel: | 01 | 0093 m/s | | Total | Área: | 8 | 282 m^2 | | |
| Starting | FUM | LEW. | | | Maan R | oundariu | onditon | ··· | Root | | Total | Diecha | - | 6616 m^3 | le. | |
| ordining | 2011. | | | | meanb | oundary | Jonaton | •. •. | | | TOLO | Discina | igo. 2 | | | |
| Possible | Quality Is | sues: | | | | | F . | | Ur | nit Values F | or Mea | suremen | Location | 1 | | - Vol X |
| Large and | in Angles ale at local | tion 1. | cation I | | | - | 0.06 | | <u> </u> | <u>.</u> | ~~ | | | A A | | - Vel Y |
| SNR at lo | cation 1 in | ndicates p | ossible bou | undary i | ssues. | | ≧ 0.04 | ۲Y | Y | \sim | % | \sim | κ | V | ¥ 20 ¥ | - Vel Z |
| Discharge | at locatio | n 3.8 is gi | eater than | 6% of I | total. | | 2 0.02 > 0 | LAY | ~~ | | $\langle \rangle$ | | / Y | <u>U</u> VN | 10 70 | - SNR 1 |
| Discharge | e at locatio | n 4.2 is gi n 4 6 is gi | eater than | 6% of I | total. total | | -0.02 | 1 <u></u> | ÷ | | mini | nijanijan | | | in in its o | - SNR 3 |
| | saciocado | // 4.018 gi | | 0/6 01 | lotai. | • | | 0.60.60 | 0.60.60. | 60.60.60.6 | 60.60.6 | 60.60.60 | 60.60.60 | 0.60.60.60 | .60.6 | |
| Location | Denth | MDepth | Clock | Nots | Spike | Vel | SNB | Angle | Verr | Boundary | Temp | CorrEact | MeanV | Area | Discharge | % of Total Q |
| 0.6 | 0.15 | 0 | 11:05:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.027 | 0.03 | 0.0008 | .0 |
| 1 | 0.34 | 0.6 | 11:05:00 | 40 | 0 | 0.027 | 20.6 | 23 | 0.0023 | 0 | 1.34 | 1 | 0.027 | 0.136 | 0.0037 | .1 |
| 1.4 | 0.61 | 0.6 | 11:06:00 | 40 | 0 | 0.088 | 12.9 | 0 | 0.0069 | 0 | 1.34 | 1 | 0.088 | 0.244 | 0.0215 | .8 |
| 1.8 | 0.76 | 0.6 | 11:07:00 | 40 | 0 | 0.1759 | 12.2 | 11 | 0.0055 | 0 | 1.34 | 1 | 0.1759 | 0.304 | 0.0535 | 2.0 |
| 2.2 | 0.93 | 0.6 | 11:08:00 | 40 | 0 | 0.2138 | 11.8 | 2 | 0.0046 | 0 | 1.34 | 1 | 0.2138 | 0.372 | 0.0795 | 3.0 |
| 2.6 | 1.03 | 0.6 | 11:09:00 | 40 | 0 | 0.2287 | 12 | 0 | 0.0063 | 0 | 1.35 | 1 | 0.2287 | 0.412 | 0.0942 | 3.5 |
| 3 | 1.09 | 0.6 | 11:10:00 | 40 | 1 | 0.2484 | 12.2 | 4 | 0.0059 | 0 | 1.35 | 1 | 0.2484 | 0.436 | 0.1083 | 4.1 |
| 3.4 | 1.14 | 0.6 | 11:11:00 | 40 | 1 | 0.3433 | 12.2 | 5 | 0.0081 | U | 1.36 | 1 | 0.3433 | 0.456 | 0.1565 | 5.9 |
| 3.8 | 1.16 | 0.6 | 11:12:00 | 40 | 0 | 0.4035 | 12.4 | 5 | 0.0087 | 0 | 1.38 | 1 | 0.4035 | 0.464 | 0.1872 | 7.0 |
| 4.2 | 1.12 | 0.0 | 11.13.00 | 40 | 2 | 0.4362 | 12.4 | 2 | 0.0071 | 0 | 1.30 | 1 | 0.4362 | 0.440 | 0.1304 | 6.7 |
| | 1.12 | 0.0 | 11:15:00 | 40 | 0 | 0.0000 | 11.0 | 1 | 0.0096 | 0 | 1.41 | 1 | 0.0000 | 0.440 | 0.1765 | 7.4 |
| 5.4 | 1.12 | 0.6 | 11:16:00 | 40 | 0 | 0.374 | 11.6 | 4 | 0.0113 | 0 | 1.43 | 1 | 0.374 | 0.448 | 0.1676 | 6.3 |
| 5.8 | 1.06 | 0.6 | 11:17:00 | 40 | 3 | 0.4353 | 11.8 | 0 | 0.0114 | 0 | 1.44 | 1 | 0.4353 | 0.424 | 0.1846 | 6.9 |
| 6.2 | 1.04 | 0.6 | 11:18:00 | 40 | 0 | 0.3902 | 12 | 1 | 0.0117 | 0 | 1.46 | 1 | 0.3902 | 0.416 | 0.1623 | 6.1 |
| 6.6 | 1.06 | 0.6 | 11:19:00 | 40 | 1 | 0.3609 | 11.4 | 0 | 0.013 | 0 | 1.48 | 1 | 0.3609 | 0.424 | 0.153 | 5.7 |
| 7 | 1.04 | 0.6 | 11:20:00 | 40 | 0 | 0.3609 | 11.6 | 0 | 0.0108 | 0 | 1.49 | 1 | 0.3609 | 0.416 | 0.1501 | 5.6 |
| 7.4 | 1.09 | 0.6 | 11:21:00 | 40 | 0 | 0.3304 | 11.4 | 1 | 0.012 | 0 | 1.5 | 1 | 0.3304 | 0.436 | 0.1441 | 5.4 |
| 7.8 | 1.02 | 0.6 | 11:22:00 | 40 | 0 | 0.3334 | 12 | 4 | 0.0149 | 0 | 1.51 | 1 | 0.3334 | 0.408 | 0.136 | 5.1 |
| 8.2 | 0.9 | 0.6 | 11:23:00 | 40 | 0 | 0.2828 | 11.6 | 0 | 0.0111 | 0 | 1.53 | 1 | 0.2828 | 0.36 | 0.1018 | 3.8 |
| 8.6 | 0.83 | 0.6 | 11:24:00 | 40 | 3 | 0.3467 | 11.6 | -2 | 0.0097 | 0 | 1.56 | 1 | 0.3467 | 0.332 | 0.1151 | 4.3 |
| 9 | 0.63 | 0.6 | 11:25:00 | 40 | 0 | 0.2413 | 11.4 | -1 | 0.0125 | 0 | 1.6 | 1 | 0.2413 | 0.252 | 0.0608 | 2.3 |
| 9.4 | 0.48 | 0.6 | 11:26:00 | 40 | 0 | 0.0772 | 13.3 | 4 | 0.0112 | 0 | 1.75 | 1 | 0.0772 | 0.168 | 0.013 | .5 |
| 9.7 | 0 | 0 | 11:26:00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | .0 |

Figure 23: DatView Summary Tab

Routine Measurements with no Quality Issues

For any measurement with no specific Quality Control Flags, the user may still want to quickly review the measurement in DatView and confirm that no possible quality issues are highlighted. More importantly, the reviewer should look at the "Mean Temp" time series in the Cross Section tab to confirm that thermistor functioned properly and that the unit was allowed sufficient time to acclimatize to water temperature (Figure 24).



Figure 24: DatView Mean Temp Cross-Section showing acceptable temperature variation (< 1°C) during the measurement

Measurements with Quality Issues

Any measurements with Quality Control issues flagged on the FlowTracker Discharge Summary Page should be opened in DatView. The stations affected by quality control flag(s) should be reviewed to assess the validity of the discharge measurement. In particular, the Unit Value (1 second value) for raw velocity and SNR data should be reviewed if any of the following are observed:

- SNR < 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 is flagged;
- 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 viewed in DatView 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 of historical measurements made for similar discharges. It may then be advisable to do a check measurement with another instrument (for example, a current meter), or to estimate a replacement value from the best information available. The adequacy of any corrective action must be discussed among those responsible for data quality in the area, and if applied, be well documented.

4.3 Data Filing

Discharge measurements must be downloaded from the FlowTracker using the SonTek/YSI FlowTracker software. Once downloaded, the raw measurement file (.WAD) should be renamed using the standard naming convention: **Station#_YYYYMMDD.WAD**

Once the .WAD file is opened in the FlowTracker software, a number of ASCII files will be created. In order to keep all the associated files together, the .WAD file should first be copied to a measurement folder following the naming convention: **Station#_YYYYMMDD.FQ#** (FQ1 for 1st measurement of the day at the site, then FQ2).

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:

- Raw sampled data including water velocity, SNR, sampling station and user-specified station information (.DAT)
- Computed data, including discharge values for each station (.DIS)
- Summary file with mean data for measurement (.SUM)
- Follow office procedures to establish folder location.
- Field notes must also be properly completed and a printout of the discharge measurement summary (printed in FlowTracker software) should be attached to the field note.

4.4 Measurement Import into Data Computation System (AQUARIUS)

To import a FlowTracker measurement into AQUARIUS, open the Field Visit Tool (FVT) and select **New** then **Measurement** File Import then FlowTracker DIS (Figure 25).

| File Help | | | | | | |
|-----------------|-------------------------|--------------------|---|--|--|--|
| 🚽 😼 🔳 New 🛀 | XII | | | | | |
| A 2014-08-14 | Day | n | | | | |
| 1110 | Measurement File Import | HFC | 1 | | | |
| Discha M.G.H | Manual Data Entry | FlowTracker DIS | | | | |
| | | WinRiverII HydroML | | | | |
| Stage I | Cross Section Survey | SonTek ADCP | | | | |
| Stage 1 | Cross Section From File | RMR | | | | |
| 2014-07-16 | Activity Result | | | | | |

Figure 25: Example Import of FlowTracker measurement into AQUARIUS Field Visit Tool

If water level data was not entered on the FlowTracker before and after the measurement, the Mean Gauge Height (MGH) will not be populated in FVT and will have to be input manually. The end time may not always be correct if the technologist had to input extra stations at the end of the measurement. It is important to confirm that the start and end time is correct in AQUARIUS.

It is important to use the **Measurement File Import** for all discharge measurements, as the import will automatically read additional measurement information into AQUARIUS and save it for other uses. Additional information that will be imported with a FlowTracker include, a summary of the measurement under **Discharge Details** in FVT, Instrument Type and Serial Number, all of which are important for Reporting, Auditing and Review and Approval purposes.

5. Routine Maintenance and Instrument Check (QA/QC)

5.1 Instrument Care and Maintenance

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

<u>Protect the probe against shock or bending</u>

The FlowTracker requires no recalibration unless physically damaged. The FlowTracker is calibrated at the factory and the calibration is based on its initial probe geometry. Any change of this geometry will affect the system performance. The instrument should be kept in its carrying case during travel (Figure 8).

- <u>Keep the probe clean</u> Algae or dirt on the 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.
- <u>Avoid wear and abrasion on the cable</u>
 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.
- <u>Replace batteries in a clean location</u>

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.

There is a small drain on batteries even when the FlowTracker is turned off. If it is expected the FlowTracker will not be used for a month or longer, remove the batteries from the battery compartment.

5.2 Software and Firmware Procedures

The most current version of software and firmware for the FlowTracker should always be used. Consult the document titled "Recommended Hydroacoustic Software and Firmware for WSC" posted on the WSC Library for the latest list of approved software and firmware.

How to Upgrade the Software

The FlowTracker software used to download, review and print measurements from the instrument is called FlowTracker Software. The currently approved version of this software can be downloaded from the Software Center accessible from the Start/All Programs button on the computer desktop.

How to Upgrade Firmware

Before updating FlowTracker firmware:

- Review the Release Notes included with the Firmware update.
- Ensure the FlowTracker meets the system requirements listed in the release note.
- Download all data files from the FlowTracker to your computer, and then format the FlowTracker's recorder using FlowTracker software to complete this step.

If necessary, download the FlowTracker Firmware Update Package from the SonTek web site (www.sontek.com). This package contains the firmware hex file (e.g. hh039.hex) and access code file (e.g. hh039.sfc) needed to install the firmware. Extract these files and save them to a folder on your computer and follow these steps:

- If needed, install *SonUtils* version 4.20 (or later) from the Software Center.
- Connect the FlowTracker to a COM port on your computer.
- Run SonUtils and select the appropriate COM port in the upper left portion of the screen.
- Click the **Break** icon to establish communications with the system.
 You should see a wake up message from the FlowTracker.

- Click Instrument|Update Firmware.
- Use the **Browse** window to select the firmware hex file (eg. hh039.hex).
 - The access code should load automatically.
 - Use the **Binary** transfer mode, and be sure the **Verify new firmware** and **Use fast connection** boxes are selected.
 - o Click **Start** when ready.
- SonUtils will show updates as the new firmware is loaded; this takes about five minutes.

After installing the firmware update, run the Automatic QC Test.

NOTE: Since the release of Firmware version 3.7 and software version 2.3, there is an option to use a mounting correction factor to correct potential bias in the x-velocity component due to flow disturbance caused by the instrument and standard wading rod and offset mount. However, numerical modelling and laboratory tow tank tests carried out by the USGS has shown that flow disturbance in turbulent flows typical of natural streams is minimal and the use of mounting correction factor is <u>not</u> recommended (OSW Memo 2009.04).

5.3 Instrument QA/QC

This section provides detailed instructions for the type of QA/QC tests that must be performed to insure optimal performance of your ADV. This includes best practice recommendations to ensure that faulty instruments and biased measurements are identified during the data production cycle.

Routine Quality Assurance (Best Practices)

Routine QA involves local testing by the technologist to monitor and ensure instruments are functioning normally. These tests are not mandated on a specific schedule but should be conducted routinely and whenever a critical measurement is conducted with the unit.

Thermistor Testing

Temperature is required by the FlowTracker to compute the speed of sound in water. This temperature reading is obtained via a thermistor inside the probe. A difference of 5°C with the actual water temperature would translate into a 2% difference in the water velocity. Although it is mandatory to verify the accuracy of the unit's thermistor using a calibrated thermometer reading before every measurement, it is possible to experience intermittent thermistor failure (for example, the unit reads a faulty temperature only at certain times during measurement). To identify that temperature was accurate during the entire measurement, the "mean temp" cross-section can be viewed in DatView (see section 4.2 "In Depth Review using DatView")

Comparison Measurement

Scheduled comparison measurements are not mandated with the FlowTracker. However, in order to avoid collecting biased measurement with a faulty unit, technologists should attempt to collect a check measurement whenever possible. When a historical measurement is collected or when a measurement does not plot and may be used to draw a new curve, it is best practice to collect a check measurement. This is a good opportunity to collect a check measurement with an independent instrument (another FlowTracker, a mechanical current meter or an ADCP).

Periodic Instrument Checks

Testing of newly acquired instrument or post-factory repair unit

To document the baseline performance of a new FlowTracker a BeamCheck (bucket test) must be performed in a controlled environment using the BeamCheck application within the FlowTracker software. For a complete description on how to complete the BeamCheck and on guidance to evaluate the result, consult **Appendix A**.

The BeamCheck test can be used to locate the sampling volume and can then be saved in the unit's instrument history as a record of baseline performance.

Failed QC test or damaged equipment

If anomalies or failures are noticed in the Auto QC test done prior to every measurement or if the instrument was damaged or dropped, a BeamCheck should also be conducted to confirm that the unit probes have not been damaged.

Calibration at USGS Hydrological Instrumentation Facility (HIF)

Every FlowTracker in the WSC Inventory should be routinely tested in a controlled environment. An agreement with USGS allows WSC sub-offices to send their FlowTrackers to the USGG-HIF for evaluation (and recalibration if necessary) using their specialized tow tank facilities. All FlowTrackers should be sent for evaluation once every 3 years. The guidelines and schedule for shipping ADV for evaluation is detailed in Appendix B.

Instrument Exchange

In order to detect specific unit biases, it is recommended that all FlowTrackers be rotated between technologists (or between field areas). This will increase the likelihood that an instrument giving biased results will be identified and sent for evaluation. FlowTracker should be exchanged at least once every 2 years.

References

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Appendix A: FlowTracker BeamCheck Procedures

To document the baseline performance of the FlowTracker, a BeamCheck (bucket test) must be performed in a controlled environment using the BeamCheck application within the FlowTracker software. For an alternative description of BeamCheck see section 6.5 in the FlowTracker technical manual.

When to Run a BeamCheck

The BeamCheck is to be performed in a controlled environment on all FlowTracker units when:

- A unit is new and received from the manufacturer
- After a firmware upgrade or repair of the unit
- Anomalies or failures are noticed in the Auto QC test (done prior to every measurement)
- After any physical damage (drop, etc.)

How to Run BeamCheck

- 1. Establish a controlled environment using the following criteria (Figure B1):
 - **Container Type:** Plastic or non-ferrous metal.
 - Container Dimensions: Large enough to allow 0.2 to 0.3 meters from central sensor face to opposite container wall.
 - Water Depth: Minimum depth of water in container, 0.2 meters.
 - Test duration: Minimum 20 pings.
 - Note: It may be necessary to seed the water in the container with some neutrally buoyant fine-grained material to provide sufficient return signals
- 2. Hold the FlowTracker probe in the pail of water with the boundary within 20-30 cm of probe (Figure B1)
- 3. Connect the FlowTracker to your computer and run FlowTracker software
- 4. After establishing communication with the FlowTracker, a diagnostic menu will appear
- 5. Select "BeamCheck", then select "Start" and the unit will start pinging
- 6. Select "Record" and the test will start recording pings
- 7. Record a minimum of 20 pings, which is shown in the top right of window, and then click Stop.
- 8. The naming convention for the test file is: "YYYYMMDD_FlowTracker Serial Number.bmc"
- 9. The file should be kept with the instrument history for this instrument for future reference.



Figure B1: Typical Bucket Test Deployment

Review and Archive Test Records:

BeamCheck Test record results can be viewed using the BeamCheck application in the FlowTracker software.

- 1. Select 'Open file', select the required file and then select 'Replay'.
- 2. Use the menu and control items to alter the display of data as desired. (See the technical manual, accessible from the FlowTracker software, for more explanation of the BeamCheck results).



Figure B2: Example of BeamCheck screen capture (SonTek FlowTracker Manual)

Archive Test Records:

BeamCheck Results can only be viewed with the FlowTracker software. For this reason, the test results page generated from each FlowTracker must be saved as a screen capture (Figure B2).

The BeamCheck screen capture contains all the baseline information for the individual FlowTracker and both hard copy (printed screen capture) and electronic versions should be archived with the instrument history for this instrument for future reference.

- The screen capture is saved as a Word document with the naming convention: "YYYYMMDD_FlowTracker Serial Number.bmc.doc"
- The BeamCheck electronic file is saved with the naming convention: "YYYYMMDD_FlowTracker Serial Number.bmc."

Determining Sampling Volume Location:

To determine the FlowTracker sampling volume location, click on the "averaging" button and replay the recorded BeamCheck with averaging on. The location is graphically indicated by the peak in the bell-shaped curve 10-15 cm from the transmitter (Figure B2) and numerically in the **Peak Pos (cm)** table for each beam.

The distance to peak should be similar for the two beams, but if not, average them together to get the distance of the measuring volume from the transmitter face. This distance is used to set the sampling volume locator on the alignment tool and will be unique for each FlowTracker. This distance will be rounded to the nearest half centimeter.

Review Test Results:

A typical BeamCheck screen capture is shown in Figure B2 above. If results from this test display any of the following issues (also see FlowTracker Technical Manual, 6.5.4 BeamCheck Operation), do not use the FlowTracker and send the instrument back for factory evaluation.

Malfunctioning Transmitter (Figure B3)

BeamCheck 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. In general, all beams should show SNR values within 2 to 4 dB of each other. Raw values above 10 dB are desirable and the recommended minimum SNR value is 4dB.



Figure B3: Malfunctioning Transmitter (SonTek FlowTracker Manual)

Malfunctioning Receiver(s) (Figure B4, Left)

A receiver may be malfunctioning if results display unequal peak amplitudes of 10 to 20 counts or more. First, make sure the transducer faces are clean and verify results.

Excessive Noise (Figure B4, Right)

Noise greater than 10 counts above the instrument level may indicate a problem with the test conditions. Change/modify the testing container and retry BeamCheck to confirm that the problem is with the probe.



Figure B4: Malfunctioning receiver (Left) and excessive noise (Right) (SonTek FlowTracker Manual)

Damaged/bent Receiver Arms (Figure B5, Left)

A receiver arm may be damaged or bent if BeamCheck 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.

High Signal Strength Beyond Boundary (Figure B5, Right)

A signal strength that remains high at a distance that corresponds 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.



Figure B5: Damaged/bent receiver arms (Left) and High signal strength beyond boundary (Right) (Credit: SonTek FlowTracker Manual)

Appendix B: FlowTracker Evaluation at the USGS HIF

Summary:

The USGS Hydrological Instrumentation Facility (HIF) have built a small acoustic tow tank (1m x 1m x 3m) devoted to the calibration and testing of their FlowTrackers. Since the implementation of the USGS Quality Assurance Program for FlowTrackers (OSW Memo 2010.02), from 2009 until 2012, 9% of the FlowTrackers tested by the HIF have failed at least one of the QA checks performed.

Description of the Evaluation Performed:

When a FlowTracker arrives at the HIF Hydraulics Lab it will be inspected for physical damage. A beam check will then be conducted and recorded to verify the meter is working correctly. (Beam peak position alignment and peak SNR difference are checked). The FlowTracker will then be towed at 2 speeds in the HIF small acoustic towing tank. The towing speeds are 18 cm/s (0.59 ft/s) (which is the same speed used by SonTek/YSI to generate the beam transformation matrix), and 33.5 cm/s (1.1 ft/s). The 18 cm/s speed is used to verify that the transformation matrix is still valid at the speed for which it was generated, and the second speed is used to verify that the transformation matrix is valid at a speed other that the one used to generate it. The HIF will also measure the temperature within ± 2 ° Celsius of a National Institute of Standards and Technology (NIST) traceable reference thermometer.

If the existing transformation matrix is found to be invalid, the meter will be recalibrated using the SonTek/YSI routines and a new matrix loaded into the unit. (Copies of the old and new matrices will be kept on file). A report describing a summary of the meter's performance during the QA check will be emailed to the contacts in the HIF database. An electronic copy of the QA report, as well as the meter's QA check data files, will be accessible from the database once the meter has been checked.

If electronic or physical problems are found with the meter, the office will be contacted and advised to send the meter to the manufacturer for repair.

Shipping guideline to send Flowtracker to USGS-HIF:

A standardized process and schedule for shipping WSC Flowtracker to USGS-HIF is being developed. Contact Water Survey of Canada headquarters for the most current details.







