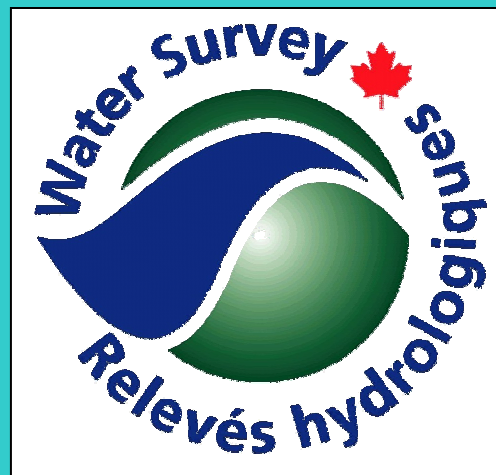Environment
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PROCEDURES FOR CONDUCTING

ADCP DISCHARGE MEASUREMENTS

First Edition

Canada

Revision History

Revision	Date	Source	Description/Rational for Change
0.0	April 2004	DCG/FOG	First Edition

Abstract

This publication describes procedures required for conducting discharge measurements using RDI ADCPs and WinRiver software version 10.06. This is one of several documents defining the standard procedures to be followed by ADCP Operators. As such, it is intended to be used by Water Survey of Canada personnel only after the completion of an introductory level ADCP training course and in conjunction with the documents called "*Policy on the Use of Hydro-Acoustic Technologies in Water Survey of Canada Operations*", "*Procedures for Review and Approval of ADCP Discharge Measurements*" and "*Procedures for the Accreditation of ADCP Operators*".

Foreword

The *Procedures for Conducting of ADCP Discharge Measurements* were prepared to assist Water Survey of Canada personnel within the Meteorological Service of Environment Canada. These procedures serve to produce hydrometric data. Since hydro-acoustic technology in general and the techniques required for deploying an ADCP are still evolving rapidly, this document is expected to require frequent updates. In addition, it should be noted that at this stage ADCP hydro-acoustic sampling equipment is expected to evolve and since many elements within these procedures remain software and product specific, it is expected that the relevance of this document will be limited to current practice.

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1.0 Introduction

This document is a reference and summary guide of the minimum requirements for conducting ADCP measurements. It is not intended as a replacement for training. It describes the procedures for obtaining data by ADCP Operators. The discharge measurement will be quality assessed partly in the field but mostly at a later stage through the application of the *Procedures for the Review and Approval of ADCP Discharge Measurements*.

There are 4 elements of ADCP operation procedures detailed in this document: Pre-field Equipment Check, Field Set-up, Field Quality Assurance, and Post-field Procedures. These measurement procedures should be used with the accepted WinRiver software version. The operator should check the WSC intranet site to ensure that approved procedures and software are current. WSC operators should be aware that while manufacturers may announce upgrades to software and procedures, only upgrades available through the WSC intranet site are approved for Canadian hydrometric operations.

2.0 Pre-field Equipment Check

Pre-field preparation is a critical element of a successful field trip. These procedures are very important in order to ensure that the computer software will be set up correctly, equipment will work properly and communication will be adequate during the deployment.

2.1 Equipment Set-up

1. Before going to the field, check that you have the equipment listed in Appendix D. Be sure that all batteries are fully charged – computer battery, ADCP battery and spare batteries.

2. Review the information captured on the ADCP Instrument History form (f001-2004) to ensure that annual maintenance, calibration and firmware are up-to-date. The instrument must use the latest approved firmware. An electronic copy should be kept archived and be routinely updated while a paper copy should be stored with the instrument. This form is outlined in Appendix F. All forms are available on WSC intranet site.

Example of ADCP Instrument History form usage.

ADCP Instrument History			
Serial #:	2676	**Model:**	WHRZ
Frequency:	1200 kHz	**Purchase Date:**	Aug/02
Log: (Description of Test or Upgrade or Maintenance, Name, Date, Comments)			
• Beam Matrix test, P-E. Bergeron, August 2002, done upon receiving equipment.			
• Firmware Upgrade to 10.14. D. Folk, Feb 13/03.			
•			

3. Check to see that the equipment is not visibly damaged, cracked, chipped, etc. This is particularly important for the ADCP transducer faces.

4. Set-up the equipment in accordance with manufacturer's instructions. There are two options which depend on the type of deployment to be performed. For remotely controlled deployments such as with the use of tethered boats, use a radio modem connection. For manned boats, use a direct connection. In addition, the use of a GPS or even a depth sounder might be desirable to position data and this will then require more than 1 serial port on the laptop to complete the set up.

Note: All power saving devices and anti-virus programs should be turned off on a laptop and the laptop connected to an external power supply (12V battery) to prevent the loss of communication during a measurement.

A. For <u>radio modem connections</u>, follow the set-up instructions below:
- Master and Slave radio modems should already be programmed and ready for deployment. If not, refer to section 2.2 Communications or the modems' technical manual.
- Connect the laptop's serial port to the radio modem labelled "*master*" using the DB-9 (i.e., 9 pins connector) serial cable. (Note: If using other peripherals e.g., GPS, depth sounder, more than one serial port will be required). Connect the battery to the pigtail on the computer end of the cable. Connect the antenna to the radio.
- Connect another antenna to the dry compartment cover top on the tethered boat. Install and connect the Slave radio modem and battery in the housing. Once closed and water tight, connect the short cable to the ADCP and then flip the power switch to the red dot on the cover to turn the power on.
- You should now have radio connection between the two modems. This is indicated by solid green "carrier detect" (CD) indicator light and flashing red clear-to-send (CTS) indicator light on the master or slave radios. If there are no lights then you do not have power or communication. Check for a blown fuse on the battery line to the radio in the boat, battery power or cables. Also check for correct polarity and secure battery connection.

B. For <u>direct connection cable</u>, connect the cable to the ADCP, making sure it is positioned properly. Connect the other end to the RS232 connection on Com port 1 on the laptop and to the battery.

5. Check your communication link between your laptop and the ADCP:
   - Open WinRiver in the *Acquire* mode.
   - Under *Settings, User Options* check that the *Terminal Program Path* lists the pathway to the BBTalk and the *Test Program Path* shows the pathway to the RGTest tool.
   - Under Acquire pick *Execute Terminal Program.* The BBTalk window will come up.
   - Under *Connect to* pick *Workhorse* on *Com 1* and pick *next.*
   - Under *Port Settings* pick *115200 baud, parity none, stop bits one, flow control none* and pick *next.*
   - Under *Options* pick *Use software break ("= = =") with Radio Modems* and *Send CK on Baud Rate Change (CB Command)* and pick *finish.*
   - You should have either a blank communication screen or a wake-up message. If the screen is blank, send the break command by entering six equal signs = = = = = =. This is the only way to send a break if you are using the radio modems. You may have to do this several times to get the wake up message. If you do not get the wake up message, then the ADCP has not been initialised or is not working at the expected baud rate. Once you get the wake-up message, you can close BBTalk.

6. Do not set the program to 'start pinging immediately' since you would have to stop pinging in order to configure the ADCP. This setting is found under *Settings, User Options, Acquire Mode, Start Pinging Immediately.*

7. If you are using GPS to position the data, your computer must have at least a second com port available. To obtain horizontal sub-meter accuracy as is required, the deployment will require the use of either a single GPS unit or a pair of GPS depending on the signal correction methods available at the site. See the section on GPS Deployment for additional details. Note that WSC preference is for RTK correction (i.e. requires a pair of GPS).

2.2 Communications

1. ***ADCP:*** When using either a direct connection or a radio modem connection, check the communication settings in WinRiver in the Acquire Mode as follows:
    Under *Settings* go to *Communications*. You should be showing a *Broadband Device on Com Port 1*. If not, add the device. Then, click on *Properties* and check for the following:
    - Under *General* check off *Use Software Breaks*
    - Under *Comm Settings* check for *Baud Rate 115200, Parity None, Stop Bits 1*

2. ***FreeWave Modems:*** If using modems, their set up can be checked by connecting each radio to Com Port 1 at a baud rate of 19200. You will likely have to change your Port settings to accommodate this baud rate – this is done in BBTalk under *Connection Preferences* as described above. With BBTalk turned on, you can now edit the modem settings:
    - Flip the toggle switch on the radio to bring up the *Main Menu.* There will be 3 green lights on the radio – this indicates "set-up mode".
    - Go through the menu settings:
        - Item *0* is the *Operation Mode* – this will either be the *Point-to-point Master* or *Point-to-Point Slave*. The master is the laptop radio and the slave is the boat radio.
        - Item *1* is the *Baud Rate* setting – this should be set at 115200 in most cases.
        - Item *2* is the *Call Book* – the first number should be the serial number of the other radio.
    - After you have escaped back to the *Main Menu* and finished setting up the radios, the diodes should no longer be all green if you properly exited the "set up mode". You must reset the com port Baud Rate back to 115200. Again, this is done in BBtalk.

3. ***NovAtel DGPS:*** To assess communication with a GPS already configured, you must first boot up the computer. Then, connect the GPS to its battery and to your selected computer com port from its com port 1. Start BBTalk with a baud rate of 115,200.

    Data should be fed to screen right away. If not, first check the diode above the GPS com port. Data is sent from it when the diode is green. Data is received from it when the diode is red. If the diodes are not on, check the power and the line fuses.

    If problems persist, the GPS configuration might have been lost or modified. Then use the following:
    - Assess the GPS communication baud rate by typing LOG COMCONFIG. This should display com port parameters. If there is no response, set BBTalk at different baud rates, starting at 9600 which is the GPS factory default and try typing the command again.
    - Once communication is re-established, reconfigure the GPS with the script file appropriate for the type of deployment desired. BBTalk can be closed after completion of the configuration procedure. For details, refer to the GPS deployment section.

3.0 Field Set-up and Operations

3.1 Set-up and Calibration

Connect the ADCP using the procedure under section 2.1 Equipment Set-up and deploy it in the water. Under WinRiver Acquire, adjust the settings and set the clocks as follows:
   a. Under *Settings*:
       - pick *Units* and select *SI*;
       - pick *Reference* as either GPS or Bottom Track.
   b. Under Acquire:
       - pick *Set PC Clock* and enter the time. You must set the PC clock first.
       - pick *Set ADCP Clock*. WinRiver applies the PC time to the ADCP clock.

Note: the ADCP <u>must not</u> be pinging (**F4** function key) before you can change settings or set up a new configuration file.

Filing

Create an output directory on your laptop for the ADCP data files and a folder for each set of measurements according to the file naming convention described in Appendix C. This is the folder where all files associated with the measurement will be saved.

Site Selection

Ensure that you have selected the site carefully and that it is suitable with respect to standard site selection criteria (Hydrometric Field Manual – Measurement of Streamflow, Terzi 1981) and ADCP measurement considerations (Appendix A). Reference the measurement location on the ADCP Survey Notes.

ADCP Survey Notes

Start to fill in the ADCP Survey Notes (R21A-05/03). You will need to know the expected maximum depth, maximum velocity, left and right bank shapes and streambed material for entry into the survey notes and the WinRiver configuration file. This will be obtained while doing a probing transect. See table 1 as well as Figures 1a and 1b for a description of the data required on the survey notes.

Gauge Height

Remember to obtain a gauge height reading prior to and after making a measurement. *Remember to make a direct water level reading,*

Water Temperature

Measure and record the water temperature with a thermometer calibrated to read to the nearest degree Celsius. The value obtained should be comparable to the water temperature displayed by the ADCP once the instrument has acclimatised to the water. An ADCP should be checked if a difference larger than 5^oC persists between values measured with the thermometer and the ADCP.

Salinity

Measure and record the salinity of the water, if required for the site visited. This is recommended for estuaries and other marine like environments. A value of 0 is assumed for freshwater. Salinity should be measured near the surface.

ADCP Depth

Measure and record the ADCP depth in the water to the nearest centimetre. The depth, or ADCP draft, is the vertical distance from the water surface to the level of the transducers' center. See fig. 2 for information on the ADCP dimensions. An incorrect depth measurement can result in significant bias in the measured discharges.

Measure the depth while the boat pitch and roll is adjusted close to zero and is similar to what it will be during the discharge measurement.

Diagnostic Test

Run the ADCP diagnostic tests under *Acquire, Execute Test Program.* This program will run and log all diagnostic tests recommended. Watch the results to ensure that all tests 'pass'. If a test fails, refer to the Workhorse Troubleshooting Guide published by RD Instruments to determine the severity of the problem and whether it can be fixed or not. If you decide to take a measurement anyway, refer to the test failures in the survey notes. Make sure to save and archive the test log properly.

Compass Calibration

Calibrating the internal compass is always required when using a GPS. To do it, follow the *One-cycle Compass Correction Method 3* described in the WinRiver help file under "How Do I Use GPS/Compass Correction. To do so, in BBTalk start logging a file (save it with in the folder created using the file naming convention) and send the AF command (type AF and press enter). From the menu displayed, choose C and then A. Rotate the boat on a complete circle. Once back to the initial heading, the system will calculate corrections to use for the magnetic field present at the site. Complete the calibration by entering D and then hit any key. Confirm the compass calibration by sending the AX command and again rotating the boat on itself to make a complete circle. While doing this calibration:

    a. Make sure there is no ferrous material, such as a steel hull or mounting frame, in the vicinity of the ADCP which would disturb the internal magnetic compass.

    b. It is the AF command that improves and stores compass corrections. If the resulting total compass error is too high, above 4 degrees, it is this command that should be repeated in this process. Once satisfied, the AX command will further evaluate the correction accuracy.

    c. While proceeding with the test, changes in pitch and roll must be avoided. Turning the boat in steady location rather than doing large loops will reduce the likelihood of swaying in the boat's own wake.

    d. Maximum rotation velocity for best results is 5 degrees per seconds.

Table 1: ADCP Survey Notes – R21A-05/03 – description of fields

Location	Field Name	Description
Page 1-A	Water Temperature	Obtained from a thermometer
Page 1-B	Measurement Start Time	Start time for first valid transect used to produce the discharge value
Page 1-C	Measurement End Time	End time for last valid transect used to produce the discharge value
Page 1-D	P.P. Discharge	Discharge value averaged from the valid transects
Page 1-E	DGPS S/N	Serial number of the differential GPS unit
Page 1-F	Depth Sounder S/N	Serial number of the depth sounder unit
Page 1-G	D.S. Freq.	Depth sounder frequency
Page 1-H	ADCP S/N	Serial number of the ADCP unit
Page 1-I	Freq.	ADCP sound frequency
Page 1-J	Firmware	Firmware version
Page 1-K	Software	Software version
Page 1-L	Water Mode	Water mode used in the transect configuration
Page 1-M	Bottom Mode	Bottom mode used in the transect configuration
Page 1-N	Blanking D.	Blanking distance used in the transect configuration
Page 1-O	Bin Size	Bin size used in the transect configuration
Page 1-P	Other	Other important commands specific to the deployment
Page 1-Q	ADCP Depth	Depth of the transducers from the water surface
Page 1-R	Diagnos. Test	Diagnostic test done
Page 1-S	ADCP Set to Clock	ADCP internal clock synchronized with the PC clock
Page 1-T	Mag Var	Magnetic variation (declination) specific to the site
Page 1-U	Method	Method used to obtain the magnetic variation value
Page 1-V	Moving Bed Test	Moving bed test done
Page 1-W	Bed Material	Type of bed material observed
Page 1-X	Boat Method	Type of deployment method
Page 1-Y	Position reference	Position of the discharge measurement relative to the gauge
Page 1–Z	Edge E. Method	Method used to measure the distance to shore from the transect ends
Page 2	Moving Bed Distance MG	Distance made good calculated during the moving bed test
Page 2	Moving Bed Elapsed Time	Time elapsed during the moving bed test, in seconds
Page 2	Estimated MB Velocity	Distance made good / Elapsed time based on moving bed test values
Page 2	MB V/Test Site Mean V	Estimated moving bed velocity / Average flow speed at the test site
Page 2	Left Bank	Shape of the left bank between the shore and the transect end
Page 2	Right Bank	Shape of the right bank between the shore and the transect end
Page 2	Latitude	Latitude of the discharge measurement
Page 2	Longitude	Longitude of the discharge measurement
Page 2	Transect Number	Transect number since the start of the measurement
Page 2	Start Bank	Bank at which the transect started (Left or Right)
Page 2	Start Time	Time at which the transect started
Page 2	Start Distance	Distance to shore at the start bank
Page 2	End Distance	Distance to shore at the end bank
Page 2	Total Discharge	Total discharge for the specific transect
Page 2	Remarks	Any comment which will help identify problems or correct transects
Page 2	Mmt End Time	Time at the end of the last valid transect
Page 2	Average	Average of the total discharge values
Page 2	Standard Dev.	Standard deviation for the average of total discharge values
Page 2	Post-Processing Remarks	Comments related to the field data review
Page 2	Post-Processed Discharge	Discharge measurement produced after data review

Figure 1a: ADCP Survey Notes – R21A-05/03 page 1

Figure 1b: ADCP Survey Notes – R21A-05/03 page 4

Figure 2: ADCP dimensions

3.2 GPS Deployment

3.2.1 GPS Quality

- To provide the required positioning accuracy, the GPS signal must be differential. There are two alternatives to obtain differential GPS signals. If a Coast Guard beacon is available in the area, a single GPS unit can be deployed as Rover to produce Pseudo-Range corrections. Otherwise, the differential correction must be obtained by using a pair of GPS working as Rover and Base to produce Real Time Kinematics (RTK) signal. Verify the kind of deployment required to obtain differentially corrected GPS in the area where the measurement will take place. It is recommended to use RTK over any other type of correction because of its higher reliability and accuracy.
- During the deployment, the Horizontal Dilution of Precision (HDOP) which is a measure of the potential accuracy of the signal should be less than 4. If the HDOP is high, wait until a better window of operation becomes available, sometimes a matter of 30 minutes while the satellites move into a better geometry. HDOP is a calculated value and it is possible to obtain a forecast of its value for a given site if high accuracy is required for your work.
- Avoid measurement sites with high canopy or bridges which may cause satellite signal reflection and frequent changes in satellites visible with your GPS antenna.

3.2.2 Rover Setup:

- Place the GPS antenna directly above the ADCP so that radial velocities do not differ between the GPS and the ADCP when the boat changes direction.
- To start a GPS configured as Rover:
  1. Boot up the computer. The GPS should not be connected yet.
  2. Connect the GPS (see product operating manual). If Coast Guard is used to produce the differential correction, a Beacon Receiver will also have to be connected to the GPS. If the Rover is used with a Base, connect the GPS with a modem and refer to the Base Setup section for additional details.
  3. Start BBTalk with a baud rate of 115,200. Data should be fed to screen right away.
     If no GPS data appears, refer to section 2.2 Communications.
  4. Close BBTalk and start WinRiver.

3.2.3 Base Setup:

To produce RTK corrections, a second GPS must be deployed on shore over a stable control point in addition to the GPS Rover. Refer to the diagram in fig. 3 for a typical set up of GPS Rover and GPS Base.

Fig. 3: Typical Deployment for GPS Base and Rover
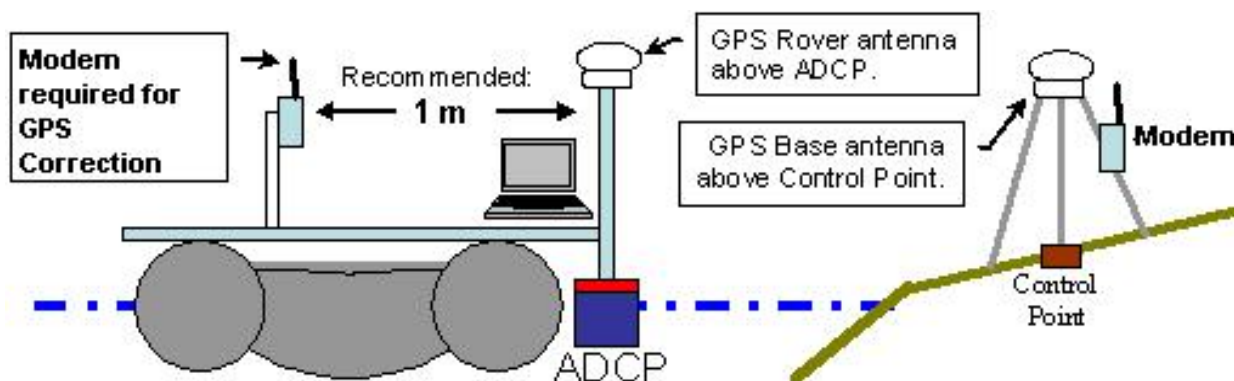
New Control Point:
- Select a Control Point at a stable site with unobstructed view of the sky.
- Install a GPS antenna on a tripod directly above the Control Point and measure its height (see fig. 4).

Fig. 4: Base Antenna Set Up

- Start the GPS Base as follows:
  1. Boot up the computer. The GPS should not be connected yet.
  2. Connect the GPS (see product operating manual) and a radio modem.
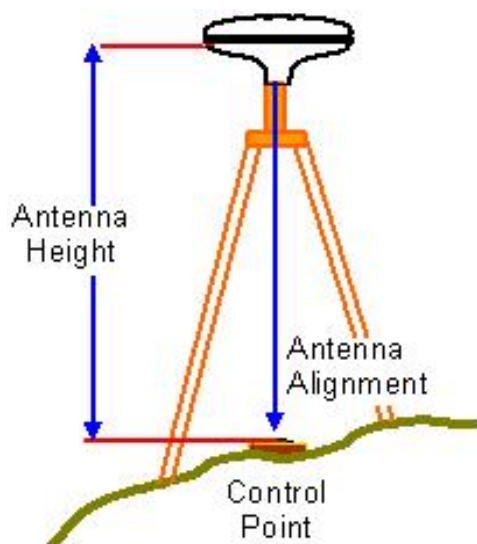 3. Start BBTalk with a baud rate of 115,200 and ensure that communication is established (see 2.2 Communications for details).
  4. Send the GPS Base Definition configuration script file appropriate for the GPS model used.
  5. Once the script file log closes in BBTalk, the Base should be emitting the desired corrections (e.g., for Novatel, the GPS diodes should be green when emitting). Check the log file to make sure that the coordinates for the Control Point were defined and recorded (e.g., FIXEDPOS precedes these coordinates in a Novatel file). If not, open a new log file until such information is captured.
  6. Turn BBTalk off and disconnect your lap top from the GPS. The GPS should now emit corrections through the modem.

- It is a good idea to use a benchmark as Control Point if it is available in the area and is adequate for the deployment of a GPS. If a Control Point will be used many times and no benchmark is available in the area, you can make the Control Point permanent by installing a brass marker at its location. Avoid possible confusion between benchmarks and control points by stamping the marker's surface with the letters "CP" and a 4 digits ID number. The number should be 2 digits for the year and 2 for the numerical sequence in which the point was established at the station for that year (e.g., "CP0502" is the 2nd Control Point for the station in 2005). Document the Control Point description for future references.
- The coordinates defined for the Control Point can be used to create a new GPS Base script file specific to this location. To do so, edit and rename the generic GPS Base Station script file called GPSBase_Station#_CP#_H#_YYYYMMDD.rds.   Enter in the script file the 3 newly defined Control Point coordinates for latitude, longitude and altitude (e.g., numbers listed right after FIXEDPOS in the log for Novatel).

Existing control point:
- Install the GPS antenna above the Control Point and measure the antenna height (Fig. 4).
- Start the GPS as follows:
  1. Boot up the computer. The GPS should not be connected yet.
  2. Connect the GPS (see product operating manual) and a modem.
  3. Start BBTalk with a baud rate of 115,200 and ensure that communication is established (see 2.2 Communications for details).
  4. Send the configuration script file created specifically for the Control Point being used. You should use the same antenna height as when the Control Point coordinates were defined. Use the log file name suggested by the script file.
  5. Once BBTalk closes the log file, the Base should be emitting the desired corrections (e.g., for Novatel, GPS diodes should be green when emitting).
  6. Turn off BBTalk and disconnect the laptop computer from the GPS.

3.3 Configuration

1. Set up the ADCP configuration through the use of the Configuration Wizard (under *Settings*, or Shift-F6. Stop pinging first). Fill in the required information:
    a. Under *Recording*, enter the filename prefix as per the naming convention (StationNo._yyyymmdd_) and pick the output directory created earlier.
    b. Under *Offsets*, fill in *Transducer depth* – Use 0 to start with, unless you know precisely what it is. Fill in the *Magnetic declination* if you know what it is – this can stay blank unless you are using a GPS. Avoid guessing. Using 0 avoids any confusion when the value is unknown.
    c. Under *Devices* – choose the ADCP model you will be using. Check on or off the *Radio Modem*, *Depth Sounder* or *GPS*, depending on the deployment.
    d. Under *Discharge method*, top and bottom methods must be *Power* using *0.1667* as *Co-efficient*. Enter the *left* and *right bank coefficients* as either *triangular* or *square*. *Shore ensembles* must remain set at *10.*
    e. Under *ADCP Configuration,* settings should be entered in accordance with field conditions, i.e. *Max Water Depth, Max Water Speed, Max Boat Speed,* and *Streambed*. If *Water Mode* remains on *Auto,* the ADCP will be configured for mode 1 or 5. If a specialized mode such as 11 or 12 is required, select it here in the Configuration Wizard with the scroll down menu.
    f. Enter any other relevant *Comments*.

    Once the information is filled in, pick *Run Wizard*. The program will look at the provided parameters to determine the most suitable commands to send the ADCP according to site conditions. If a problem is anticipated, it will give warnings. The file will be reviewed once a probing transect has been done to determine the exact site conditions.

    It is not recommended to modify the configuration provided by the Configuration Wizard with *User Commands* typed in under *Settings, Configuration Settings, Commands*. The Wizard provides the best possible configuration for the site conditions described. Any user command entered would override them and might jeopardize results. For more information on configuration and commands refer to the software user guide and the ADCP technical manuals.

2. Do a probing transect (trial run) across the river to examine the following channel characteristics:
    a. left and right bank shapes;
    b. left and right bank starting locations where the ADCP can record at least 2 good bins of data. Take note of these locations. You may want to drop buoys during the trial run to simplify starting procedures and aid in obtaining consistent edge estimates. Note: if a bank shape is vertical, the transects starting or ending points should be no closer to the edge than the depth of the channel at the bank.
    c. maximum water velocity and its location in the cross section
    d. maximum depth and the overall cross-section shape.
    e. any site particularities that may alter flow patterns – bridges, piers, debris, islands – and unusual flow conditions such as reverse flow and its location.
    Record any relevant information on the Survey Notes.

3. Go back to the Configuration Wizard and edit the original configuration based on information obtained during the probing transect. The observations will mostly affect the estimated maximum water velocity and depth. Run the Wizard again and save configuration file.

3.4 Testing for Moving Bed Bias

1. Perform a moving bed test prior to any discharge measurement. When no moving bed is detected, Bottom Track provides a higher accuracy than GPS to position data. So the test must be done even when GPS is available. Testing for moving bed can be avoided only if it is documented that this phenomena does not exist at this site for the conditions encountered. Proceed with the test as follows:
   a. In the configuration wizard, enter the filename prefix as per the file naming convention StationNo._yyyymmdd_mbed_.
   b. Move to a position on the river where moving bed can be expected. The area where the fastest velocities were observed during the probing transect is a good choice of test site.
   c. Record data for at least 10 minutes while holding the boat stationary. It is very important to avoid any drift upstream or downstream during the test. It is recommended to use an anchor or a buoy to keep track of the boat position and keep it steady. A useful but less precise method to monitor the boat upstream/downstream position is to keep two shore markers aligned as seen in fig. 5. If GPS is available, display the *Combo Ship Track* and keep the boat in position using GPS as reference.

2. Once completed, analyse the moving bed test results using the top of the last page in the ADCP Survey Notes (R21A-05/03) to keep track of the results:

   a. Play back the moving bed test.
   b. Examine the stick ship track with bottom track as reference to determine if there is any upstream movement of the boat. Take into consideration the method used to maintain the boat in steady position and possible errors influencing this method (e.g., a boat anchored at a test site cannot display any upstream motion). If GPS was available, look at the *Combo Ship Track* and determine if the bottom track trajectory ends up upstream from the GPS trajectory.
   c. Record in the ADCP Survey Notes the amount of perceived upstream displacement. Note the *Distance MG* from the *Composite Tabular*. Make sure that this value does not represent too much sideway motion in the current. If GPS is available, note the bottom track distance made good less the GPS distance made good (*BMG-GMG mag*) as shown in the *Compass Calibration Tabular*. The compass must be properly calibrated for this value to precisely represent the position bias created by the moving bed.
   d. Record in the ADCP Survey Notes the *Time* taken to complete the test from the *Composite Tabular*.
   e. Note the *Flow Speed* from the *Discharge History Tabular* (F12). This is an estimate of the average velocity in the vertical at the test site.
   f. Estimate the moving bed velocity by dividing the perceived upstream displacement by the total test time. Write the result in the ADCP Survey Notes.
   g. Estimate the bias error generated by the moving bed by dividing the moving bed velocity with the test site *Flow Speed*.   Write the result in the ADCP Survey Notes.
   h. The moving bed is considered significant if there is:
      i.) perceived upstream displacement in the ADCP position referenced by bottom track while the same displacement cannot exist in the earth reference system;
      ii.) The estimated bias error is above 1% (moving bed velocity / test site mean velocity > 0.01).

3. If you conclude that there is a significant moving bed, then you will require GPS to produce an accurate measurement. If it is not possible to use GPS, an alternative discharge measurement technology should be used. Otherwise, a correction method will have to be used to estimate the discharge bias. One such method is to collect at least 3 moving bed tests spread evenly across the river.

Figure 5: Shore marker method to control upstream/downstream movement
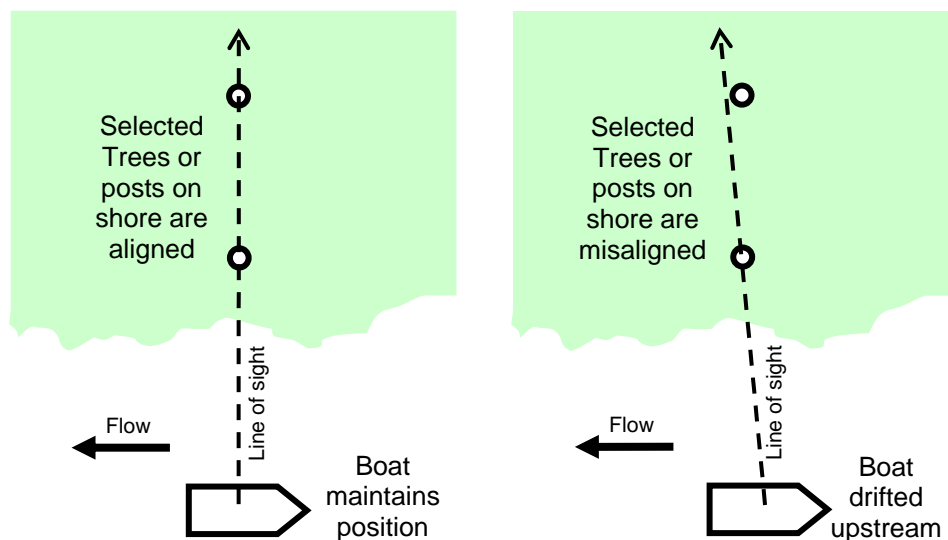
3.5 Measurement

A measurement is formed by averaging several transects together. To start a transect:
1. Bring the boat to a stop at one of the banks where you can record at least two good bins.
2. Start recording (Press **F5**). Be careful not to start/stop transects accidentally when pressing the key very fast.
3. The program will ask you for the shore distance. Enter a measured value. Do not guess. Use a range finder.
4. Begin moving across the river once 10 ensembles have been collected. Operate smoothly. Use this time to record some of the values required on the Survey Notes for each transect. In addition, to ensure the best measurement quality, watch for the following warnings during the transect:
   ▪ Excessive boat speed – The boat should move at a speed lower than the water speed.
   ▪ Excessive pitch and roll – their value should be under 5° on average.
   ▪ Twisted stick ship track – It is preferable to adopt a fairly straight path while crossing the river.
   ▪ Excessive number of lost or bad ensembles or bad bins – A good transect should have less than 10% bad ensembles, less than 10% lost ensembles and less than 25% bad bins.
   ▪ Configuration errors such as insufficient number of bins to reach the bottom.
   a. When you have reached the opposite shore at a location with at least 2 good bins, maintain position until you have collected 10 ensembles. Then, stop the recording and enter the shore distance. Again, measure the distance. Do not guess.
   b. Record the Total Discharge on the ADCP Survey Notes. If you encountered any problem during the transect, these should be noted.
   c. Take additional transects back and forth across the river until you have 4 transects in total, 2 in each direction.
   d. Prior to leaving the site, check that your data meets the quality assurance criteria listed in Section 4 <u>before</u> leaving the site.

3.6 Tethered Boat Deployment

A main principle of operating a tethered boat, especially in slow velocities, is to ferry it across the river using the current as propulsion. Be sure to allow enough time for the boat to move to the determined edge of measured flow before stopping the measurement.

Measuring distances between the shore and a tethered boat deployed from a bridge can be done if we use the bridge railing and a line of sight perpendicular to it. If the line of sight from the operator to the boat is perpendicular to the bridge, then the distance between the boat and the shore at the water level will be the same as the distance between the points where lines of sight intersect at the bridge level. A device called pentaprism is designed to determine such line of sight at 90° from a chosen object. It consists of two prisms placed so that one can see left and right while simultaneously aiming at a target. The pentaprism can thus help the ADCP Operator define the position of a line perpendicular to the bridge and going to the tethered boat. See fig. 6. The Operator moves left and right while sighting the bridge railing in the prisms until the tethered boat is seen through the visor. A mark is left on the bridge at this location. The operator then moves until the shore is seen through the visor. Another mark is left at this location. The distance between the two marks on the bridge is the distance to shore.

Figure 6: Determination of Shore Distances with Tethered Boat.
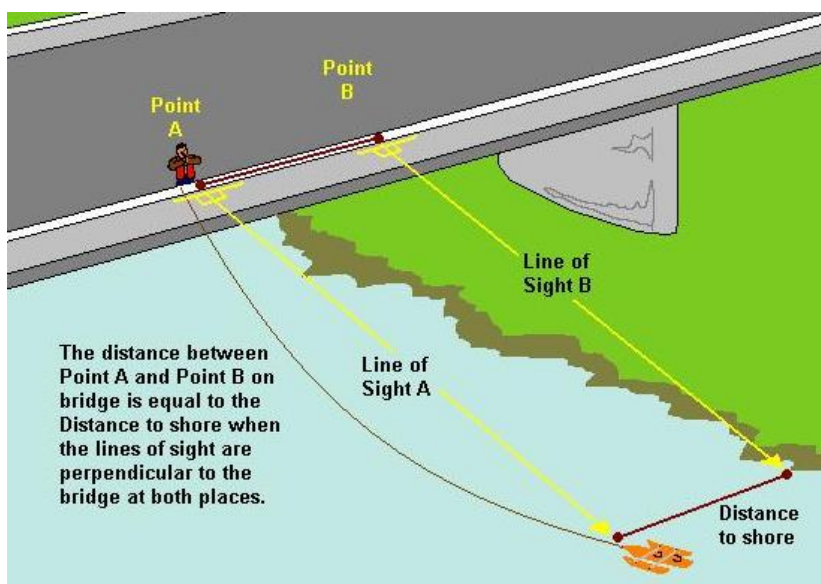
A tethered boat is harder to operate when the water velocity is either too slow or too fast. But the effect from these extremes can be mitigated as follows:

- When the current is very slow, it becomes difficult to control the tethered boat. For example, wind might then become the predominant factor in the direction the boat will take. To improve the boat handling capacity, a floating anchor can be attached at its end to increase the effect of the current and its pull on the tether. Make sure that this anchor is far enough behind the boat to not create any flow disturbance and potentially bias the readings. See fig. 7 for an example of floating anchor deployment.

Figure 7: Floating Anchor

- When the current is very fast, the tethered boat has a tendency to step up on the water, which results in an increased pitch angle. This is caused by the hull dynamics as well as the increased tension on the tether that pulls the nose up. The larger pitch angle might be a source of bias error and should be avoided if possible. Based on current experience at handling tethered boats, it appears that adding weight on the tether near the location where it is tied to the boat will help decrease the pitch angle. In addition, increasing the length of the tether helps reduce the pitch angle.

Safety Note: For security, the tether line should be visible from the water surface to avoid collision with river traffic. Orange plastic flags tied along its length can enhance its visibility. The operator should also be capable of releasing the tether at a moment's notice in case the boat gets entangled in debris or is collided by traffic on the river. DO NOT roll the tether around your hand to hold the boat. Standard OSH practices and the local highway traffic regulations for the area should be followed.

4.0 Field Data Quality Assurance

Prior to leaving the measurement site, proceed with a field review of the data quality. This review is a preliminary assessment of the data quality to determine if it appears suitable to compute a discharge value. As such, this review consists of two parts. The first involves checking the quality of each individual transect. The second involves checking the overall consistency of all transects when averaged together to produce a discharge measurement. Refer to Appendix E for a summary of this review process.

Switch WinRiver to *Playback Mode* to initiate this quality assurance exercise.

First, each transect must have been conducted in keeping with the procedures and criteria listed in Section 3.0 Field Set-up and Operations. The major points include:
1. Use of latest WinRiver software and correct file naming conventions.
2. Site selection according to standards (criteria specific to ADCP listed in Appendix A).
3. Comprehensive ADCP Survey Notes, taking particular care to record unusual stream and climatic conditions (e.g., winds).
4. WinRiver settings and ADCP configuration appropriate for site conditions.
5. Recording of ADCP transducer depth, temperature, salinity and gauge heights.
6. Diagnostic test, compass calibration and moving bed test conducted and recorded.
7. Left and right bank distances measured.
8. Appropriate boat speed and track.
9. No apparent problem with:
    - Pitch and Roll, Heading, Temperature (*Composite Tabular*). The values should reflect observations made during the measurement.
    - Boat speed and track (*Stick Ship Track* and/or *Combo Ship Track*). Should be similar to observations made during the measurement.
    - Backscatter intensity (*Intensity Profile*). Intensity should fall with increasing depth.
    - Recorded velocities (*Velocity Magnitude Contour* and *Stick Ship Track*). There should be no large gaps, banding or trends. Note: The *Velocity Magnitude Contour* plot can also be used to assess problems with bottom track caused by debris or inappropriate topography.
10. If possible, less than 10% bad ensembles, 10% lost ensembles, 25% bad bins and more than 50% of Measured Q making up the Total Q. (*Composite Tabular*)

For more details on the validation of transects, refer to the *Procedures for the Review and Approval of ADCP Measurements*.

If every transect was obtained in keeping with the procedures described in this document and appear to be of adequate quality, proceed to assess their overall homogeneity when combined to produce the discharge measurement. Playback all validated transects and view the *Discharge History Tabular* (**F12**). Be sure not to include any false start or critical problem file. Assess the following:
- As a minimum, the discharge measurement must be the average of two pairs of reciprocal transects (2 transects in each direction across the river).
- Each valid transect must be within 5% of the average. (Text in red within the Discharge History Tabular indicates a transect not within 5% of the average.)

The field QA review should reveal if additional transects are required before leaving the site.
- Take 4 additional transects if the first 4 are not within 5% of the average and no explanation can explain the difference.
- Replace a bad transect if a critical problem took place during its acquisition and the problem could be identified and documented in the Survey Notes (e.g., power surge causing a loss of ensembles while collecting a transect).

Before leaving the site, remember to obtain a gauge height, water temperature and salinity reading, ensure that the ADCP Survey Notes are completed and back up your data.

5.0 Post-field Procedures

Upon returning to the office, transfer the data from the laptop to an office file server that is routinely backed up.

Proceed with the review and packaging of the data as described in the *Procedures for the Review and Approval of ADCP Discharge Measurements*.

Inspect the equipment for damage. Leave the ADCP box cover open for drying. Recharge batteries as required.

Appendix A: Site Selection

It is important to select cross-sections appropriate for streamflow measurements. Many of the ADCP measurement problems can be solved by simply moving to a better measurement section. The guidelines provided in the Hydrometric Field Manual – Measurement of Streamflow (R.A. Terzi, 1981) for conventional measurements still apply for measurements taken with an ADCP and should be followed. However, the measurement of streamflow with an ADCP requires paying attention to other factors more specific to this technology. These are listed below:

- Desirable sections roughly are parabolic, trapezoidal, or rectangular. Asymmetric channel geometries (for example, deep on one side and shallow on the other) should be avoided if possible (Simpson, 2002), as should cross-sections with sharp channel-bottom slope changes such as rapid drop-offs. Consider the need to remain at a safe distance from vertical walls or bridge piers to avoid side lobe interferences.

- The stream bed cross-section should be as uniform as possible and free from debris and vegetal growth.

- Depth at the measurement site should allow for the measurement of two good bins. Depths below 1 m may offer challenging conditions for ADCP measurements, depending on the frequency of the instrument.

- Measurement sections with velocities less than 0.1 cm/s should be avoided if possible. While measurements can be made in such conditions, boat speeds must be kept extremely slow, which requires special techniques for boat control (Simpson, 2002).

- Highly turbulent sites should be avoided, as excessive turbulence can violate the assumption of homogenous flow required to collect reliable data.

- Measurement sections in local magnetic field disruptions caused by steel structures or transmission lines should be avoided as they can cause ADCP compass errors.

- Sections with high levels of suspended sediment and fast velocities are not recommended since "moving bed" effects are then likely to occur and might bias the data.

- When using a GPS, avoid locations where signals from the satellites might bounce off structures or be blocked from the view.

Appendix B: Standards and Guidelines

The process to deploy ADCPs and the knowledge of what constitute the good data from this technology is still evolving. For the time being, the following standards and guidelines will be used to assess the quality of Acoustic Doppler Current Profiler measurements.

Standards

ADCP Depth:
- The ADCP depth, or vertical distance between the water surface and the centre of the transducer faces, must be measured to within *1 cm*.

Correlation
- The correlation of water velocities must be done using *4* beam solutions.

Diagnostic Test:
- The instrument must be subjected to and pass the most complete instrument check routine available prior to every discharge measurement.

Discharge Computation:
- Discharge must be the average of at least two pairs of reciprocal transects (4 transects) within 5% of their average.
- Two additional pairs of reciprocal transects must be obtained when the two pairs are not within 5% of their average and no critical problem can be identified and documented for the difference. Under such conditions, once transects are validated, the discharge measurement becomes the average of up to 8 transects.
- Discarding and replacing a transect can be done only if a critical problem is identified and documented for it. (e.g., False start or loss of power to the ADCP.)

Extrapolation Method
- Top and Bottom: The discharge extrapolation method for velocities near the surface and the bed must be "power" with 1/6 as exponent. The use of any other method must be demonstrated and documented during data review.
- Edges: 10 ensembles must be used at the transect start/end points to extrapolate velocity data toward the edges.

Magnetic Variation:
- The internal ADCP compass must be calibrated when using a GPS. It is good practice to do it before each measurement.
- An accurate value for the local magnetic declination must be used when using a GPS.

Moving Bed:
- A moving bed test must be performed prior to every discharge measurement. During a moving bed test, the ADCP must record data in steady position for at least 10 minutes. Performing a moving bed test can be avoided only if it was confirmed and documented that this phenomena does not exist at the site for conditions encountered.
- The moving bed effect is considered significant when there is perceived upstream displacement of the boat and the ratio of "moving bed velocity" versus "test site mean velocity" is greater than 0.01.
- When a significant moving bed is detected, differential GPS must be used to compute boat velocities.
- If it is not possible to use a differential GPS, an alternative discharge measurement method should be used. Otherwise, at least 3 moving bed tests spread evenly across the river must be performed.
- If the quality of data produced by estimating the bias from a moving bed effect is deemed acceptable by Reviewers, a comment relative to the correction method must be documented.

Ensembles:
- Ensembles must be averaged outside of the ADCP.
- Only single water pings must be used to produce ensembles, with exception for specialized modes designed to operate differently.
- No more than 2 bottom pings can be used to produce ensembles.

Salinity:
- Water salinity can be set to 0 when working in fresh water environments. It must be measured when working in estuaries or anywhere with potential saltwater intrusions.

Software Version:
- Only an officially accepted version of WinRiver can be used to produce discharge measurements.

Temperature:
- Water temperature must be measured with a thermometer near the ADCP prior to each discharge measurement.

Time:
- The ADCP time must be set to clock prior to every discharge measurement.

Guidelines

Boat speed:
- Boat speed should not exceed water speed during a measurement. Above all, what is important is to have a smooth boat operation with as little acceleration as possible.

Edge Integrity:
- To prevent side-lobe interference and other acoustic contamination from vertical channel walls, start/stop points of transects must be no closer to a wall than the depth of water near that wall. (e.g., if the depth at the vertical wall is 4 m, the transects should start/stop no closer than 4 m to the wall).
- Ensembles closest to the edge should contain at least 2 valid bins.

Transect Quality:
- Transects should have less than *10%* bad ensembles and *10%* lost ensembles
- Transects should have less than *25%* bad bins
- Transects should have a ratio of Measured/Total Discharge greater than ½. Factors influencing the measurement such as the shape of the cross section must be considered while assessing the quality of a transect based on these guidelines.

Pitch and Roll:
- The average pitch and roll angles should be less than 5° throughout a transect.

Temperature:
- An ADCP should be checked if a difference larger than 5^oC persists between the ADCP temperature probe and the value measured by thermometer during the measurement.

GPS Quality:
- The trajectory defined by GPS should contain no large irregularities (large drifts and spikes) and, overall, be similar to the one defined by Bottom Track, within the errors caused by a potential moving bed effect.
- HDOP should be less than 4.
- Delta Altitude should remain less than 3.5 m.

Appendix C: File Naming Conventions for ADCP Measurement Data

The Acoustic Doppler Current Profiler (ADCP) is being introduced to the Water Survey of Canada as a new technology for obtaining river discharge. This instrument is capable of producing large amounts of data across numerous files. It has been agreed that as a new technology all files used and produced by the ADCP in the course of obtaining a discharge measurement will be retained. This includes calibration and configuration data as well as generated measurement data. The following proposed naming conventions would ensure that all ADCP data is stored systematically and in a manner that is nationally consistent with existing conventions.

MMM   TRANSECT number. This number starts at 000 and increments each time you stop and then start data collection. The maximum number of transects is 999.

NNN   File sequences number. This number starts at 000 and increments when the file size reaches the user-specified limit (set in Settings menu, Configuration Settings, Recording tab).

x	File type (assigned during data collection or playback)
r	Raw ADCP data.
w	Copy of the configuration file created during Acquire mode.
n	Navigation GPS data.
d	Depth Sounder data.
t	ASCII-out data (This convention is the default for ASCII-out data, but you can use other names and extensions.)
h	External heading device data file.

Hardware diagnostic data file	StationNo._yyyymmdd_**tst.txt**	Multiple tests are to be appended to this file
Raw configuration data file	StationNo._yyyymmdd_MMM**w**.NNN	
Raw transect data file	StationNo._yyyymmdd_MMM**r**.NNN	
Raw navigation data file	StationNo._yyyymmdd_MMM**n**.NNN	
Raw depth sounder data file	StationNo._yyyymmdd_MMM**d**.NNN	
Output ASCII data file	StationNo._yyyymmdd_MMM**t**.NNN	
External heading device data file	StationNo._yyyymmdd_MMM**h**.NNN	
Compass calibration data file	StationNo._yyyymmdd_**ccal.txt**	Multiple tests are to be appended to this file
Magnetic declination data file	StationNo._yyyymmdd_**magd**MMM**r**.NNN	
Moving bed test data file	StationNo._yyyymmdd_**mbed**MMM**r**.NNN	
Discharge measurement data file	StationNo._yyyymmdd.dmw	Change w in .dmw to #, a sequential number starting at 1 to identify the measurement if more than one measurement was taken at the site that day.

Example: 02KB001_20020906_003r.000
Measurement taken at station 02KB001 on September 6, 2002; "003" indicates that it is the third transect; "r" indicates that it is an ADCP raw data file.

File Naming Exception:
Please note that if <u>more than one team</u> is taking <u>more than one measurement</u> at a site <u>on the same day</u>, remove the date from the filename prefix and introduce a date and time stamp with WinRiver. This date and time stamp is set in WinRiver under *Configuration Settings* (F3), *Recording* tab where you can select the option *Add Date/Time to the Filename*.

Appendix D: Equipment List

The following should used only as guidelines for the field preparation. It cannot replace the experience of ADCP Operators and the knowledge of the equipment and expected site conditions.

Basic ADCP Equipment
- ADCP with attachments bolts and nuts
- Portable computer
- Screen shade/rain protection
- Spare 12 V Battery with appropriate wiring assembly
- Power inverters and power bars
- Extension cords
- Distance measurement device
- Hand-held walkie-talkie type radios
- Extra rope and connections (karabiners)
- Battery charger
- Basic tool kit, including voltmeter

GPS Deployment:
- Rover Configuration files
- GPS Antenna and cable
- GPS and power/data cables
- 12 V DC Battery + Multi-Socket
- Spare Fuses

For Pseudo-Range (Coast Guard Beacon), Add:
- Automatic Differential Beacon Receiver and power, data and co-axial cables.

For Real Time Kinematics, Add:
- Base Configuration file generic and/or specific to the station visited
- GPS Antenna and cable
- GPS and power/data cables
- 12 V DC Battery + Multi-Socket
- Spare Fuses
- 2 Radio Modems and cables
- Tripod + Surveyor Rod
- 12 V DC Battery + Multi-Socket

Boat Deployment:
- ADCP mount
- Buoys and anchors
- Measuring stick

Tethered Boat Deployment:
- Tethered boat and harness
- Long rope to use as tether
- 2 Radio Modems and cables
- Small 12V-9A batteries and charger
- Boat repair kit
- Floating anchor (for slow velocities)
- Weight for tether (for fast velocities)
- Pentaprism

Appendix E: ADCP General Transect Review Quick Sheet

FURTHER INVESTIGATE ANY ITEM FOR WHICH THE ANSWER TO THE QUESTION IS NEGATIVE.

Open ADCP Raw Data File (Ctrl+O) to select the desired file. Start taking notes on the ADCP Data Review Progress form.

Step 1 – Computation Attributes
Review info on Ensemble Header Tabular **(F9)** to get a first idea about the transect deployment approach.
Review Configuration Settings **(F3)**. *In tabs, look at:*
- *Commands*:   User Commands field empty? (i.e. *User Commands*)
- *Offsets*:   ADCP *Depth* and *Compass Mag Variation* correct?
- *Processing*:   *Use 3 Beam Solution clicked off for WT?*
                           *Thresholds at *w.000 values?*
- *Shore Discharge:*   *Top/Bottom Discharge Methods at Power with Coefficient 1/6?*
                           Shore Left/Right Bank Edge Types consistent with Survey Notes?
- *Edge Estimates*:   *Begin/End Shore Distances consistent with Survey Notes?*
- *Moving Bed Test:*   Are test results negative?

Step 2 – General Review

File Subsection (F6), note values, then **Select All Ensembles**.
Playback entire file **(End).**
Load **Projection Angle (F2)**.

Composite Tabular **(F11 Swap)**
- % Bad Ensembles (*Bad Ens./# Ens.*)<10%?
- % Lost Ensembles (*Lost Ens./# Ens.*)<10% ?
- *% Bad Bins < 25%?*
- *Measured Q/Total Q > 0.5?*
- *Temperature within 5° of Thermometer?*

Stick Ship Track
- Trajectory relatively straight?
- Absence of potential ambiguity velocities (Use ↓)?

Combo Ship Track
- Is GPS quality adequate if it is required?

Projected Velocity Contour & Error Velocity Contour
- Absence of gaps or unusual features?
- Continuous bottom track?
- 2 valid bins near edges?

Boat Speed Time Series & Water Speed Time Series
- Boat at rest near start/end points?
- Boat slower than water?
- Boat displays little acceleration?

Pitch and Roll Time Series
- Angles remain small?

Step 3 – Trends

Under **User Options (F7)**, set the **Number of Ensembles to Average** between 10 and 20.
Play (F4) the Transect several times while assessing the following:

Discharge Profile
- top/bottom extrapolation follow the power fit curve well?

Under **User Options (F7)**, reset the **Number of Ensembles to Average** back to 1.

Step 4 – Correction

Open Next ADCP Raw File (F5) to repeat the process
Once all Transects are reviewed, proceed with corrections identified as required during previous steps.
Save and lock the Configuration File.

Step 5 – Discharge

Display the *Discharge History Tabular* **(F12)** and erase all unwanted Transects (double click name to erase or clear table).
- Are all *Total Q's* for valid transects within 5% of the average?
- Do *Start Banks* alternate to form reciprocal pairs?
- *Are Left/Right Dist., Left/Right Q, Area, Width, Boat Speed, Flow Dir. and Duration consistent?*

Packaging Data

Enter Q Measurement Wizard **(Ctrl+Q)**
- Using ADCP Survey Notes and ADCP Measurement Review Notes, complete the front page of the Q Measurement Wizard.
- Select Transects which are part of the measurement.
- Print a copy.
- Save as Station#_yyyymmdd.dmw (replace w by the measurement number if more than 1 Q value was produced at the site that day.).

Appendix F: ADCP Instrument History

ADCP Instrument History			
Serial #:		**Model:**	
Frequency:		**Purchase Date:**	
Log: (Description of Test or Upgrade or Maintenance, Name, Date, Comments)			

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