DP-Pro Q V4.1
User Guide

Shanghai Pan-Communication Scientific Instrumentation Co., Ltd.

2014.07

Content

Content 1

Chapter 1 Introduction 2

Chapter 2 Start Transects Measurement 4

2.1 Start a New Measurement 4

2.1.1 Communication 4

2.1.2 Configuration 4

2.1.3 Collecting Discharge Data 17

Chapter 3 Play Back Transect Data 20

3.1 Overview 20

3.2 Playback data 20

3.3 Main Interface Layout 22

3.3.1 Main Toolbar Icons 22

3.3.2 Tables to select main window 22

3.3.3 Discharge/Navigation Information 24

3.3.4 Tables to Select Data File 25

3.3.5 Additional Windows. 26

3.3.6 Summary 26

3.3.7 Attitude Display 28

Chapter 4 Data Formats and Storing 29

Appendix Calculating the River Discharge 30

Chapter 1 Introduction

Overview

DP-Pro Q is Shanghai Pan-Communication Scientific Instrumentation Co., Ltd (Pan-Comm)'s real-time discharge data collection program. This program operates Rowe Technologies' ADCP and makes accurate discharge measurements.

DP-Pro Q makes the measurement easy. Users press some buttons and short keys to complete the transect measurement. The software provides a Quick Start template for convenient reference. The "RTI ADCP/DVL User Guide" provides detailed reference. DP-Pro Q has both English version and Chinese version, see "Set Language", page 2.

System Requirements

DP-Pro Q for PC requires the following specifications,

1. Windows XP® or Windows 7® with .Net Framework 4.0
2. 1.6 GHz processor or higher recommended
3. 1 GB memory
4. 1 GB disk space
5. 1024 × 768 screen resolution or higher
6. One serial port (two or more high speed UART serial port recommended)

Note: The DP-Pro Q is developed under C# language. Make sure Microsoft .Net Framework 4.0 (or higher) is installed in the computer. Framework 4.0 can be downloaded from Microsoft website:

http://www.microsoft.com/en-us/download/details.aspx?id=17851 (English)

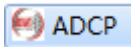
http://www.microsoft.com/zh-cn/download/details.aspx?id=17718 (Chinese)

Contact Information

Users may contact Shanghai Pan-Comm field service group for questions or suggestions. Pan-Comm provides 24/7 technical support.

Shanghai Pan-Communication Scientific Instrumentation Co., Ltd.
Suite 701, Building 11, Lane 518, Xinzhuan highway, shanghai China, 201612
Phone: +86 21 34060911
Fax: +86 21 57736883
Email: Info@pan-comm.com
Web: http://www.pan-comm.com

Starting DP-Pro Q

Double click the execute icon 

to run the DP-Pro Q. The **Landing Page** as shown below. 4 buttons are in the landing page: **Measure Discharge, View Data**, **Set Language** and **Help**.

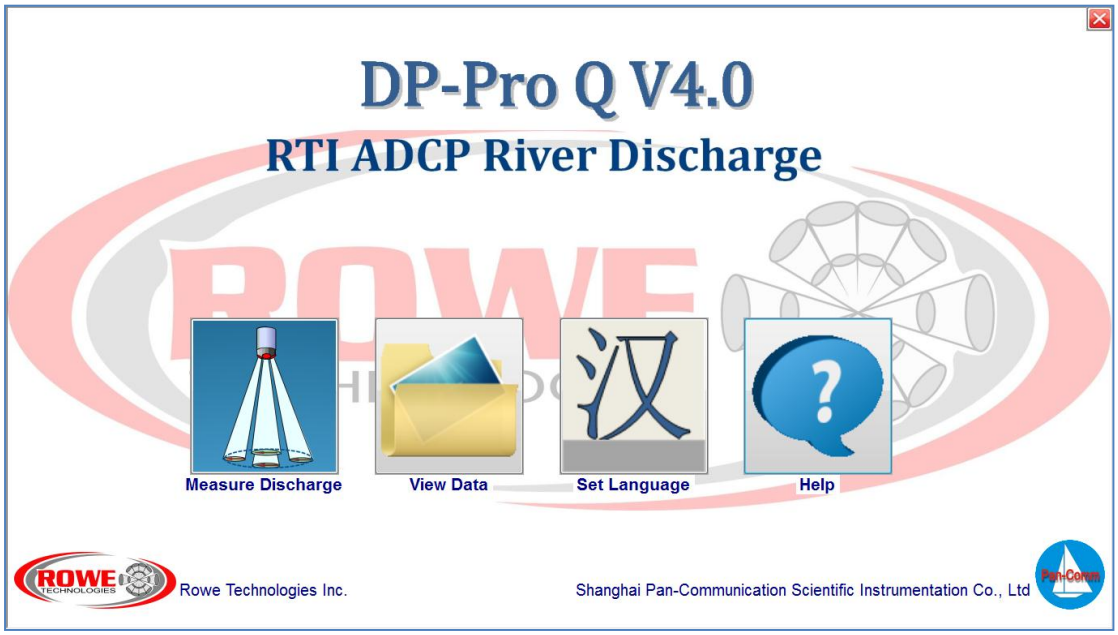


Figure 1. Landing Page

- **Measure Discharge** — Start a transect measurement.
- **View Data** — Playback transects data.
- **Set Language** — Set the program language, English or Chinese.
- **Help** — View the help document.

Chapter 2 Start Transects Measurement

DP-Pro Q has two running modes: Transects measurement and play back transects.

2.1 Start a New Measurement

Click the "**Measure Discharge**" in the **Landing Page** to start a new measurement.

2.1.1 Communication

The software can auto connect the serial port last time used. If unsuccessful, the **Setting Port** dialogue will popup. Select the correct serial port connecting to the ADCP. The default serial port baud rate of the ADCP is 115200.

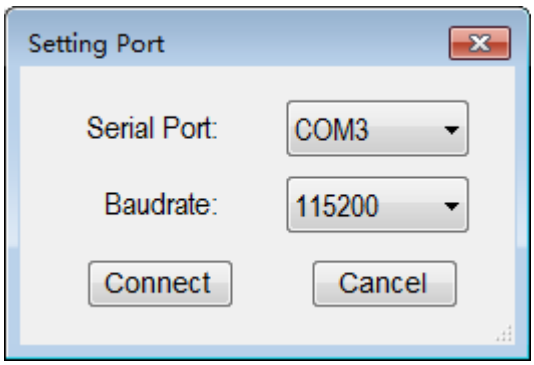


Figure 2. Setting Serial Port

Note:

1. **Make sure the system has power ON. If not, the system cannot be detected.**
2. **Select the correct serial port number and baud rate.**

2.1.2 Configuration

When connection is established, the **Smart Page** appears. The **Smart Page** allows users to configure ADCP and to set all the measurement parameters step by step.

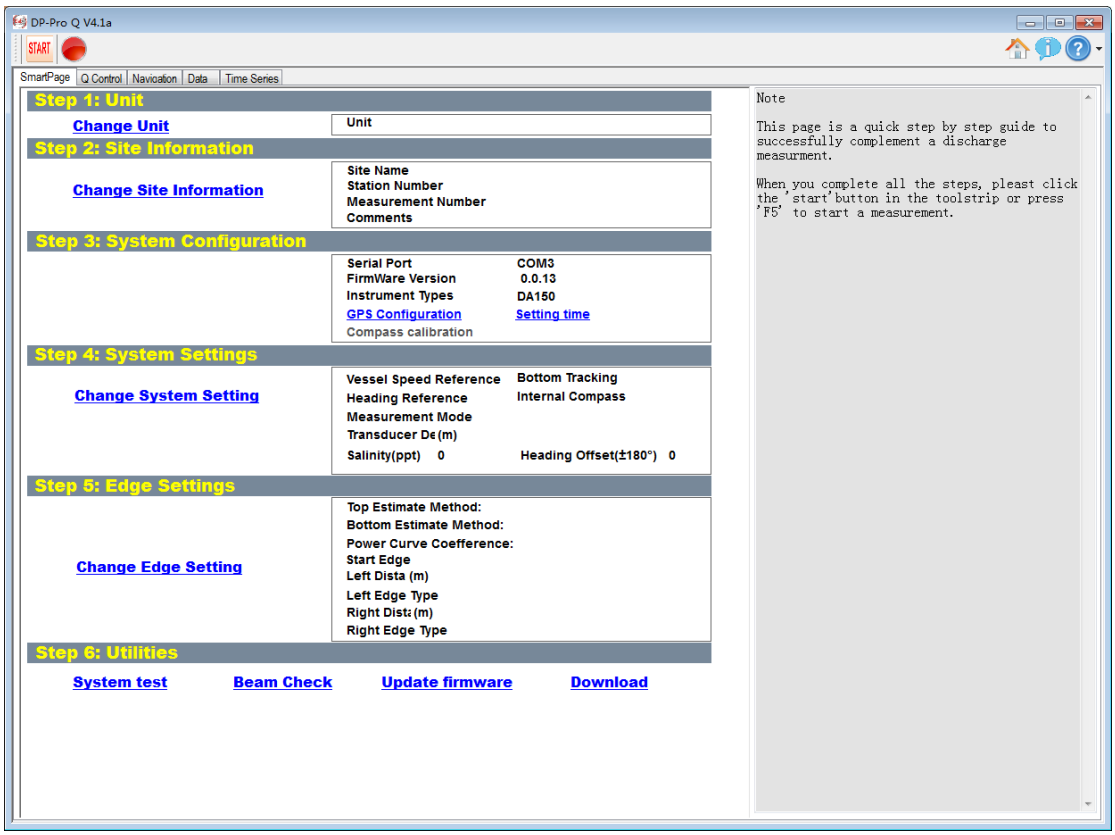


Figure 3. Smart Page

Step 1: Setting Unit

Click **Change Unit** and the **Setting Unit** dialogue will show. Users can switch the unit between Metric and English.

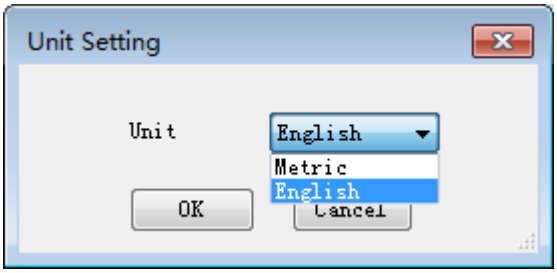


Figure 4. Unit Setting

Step 2: Site Information

Site information can be entered by clicking **Change Site Information**, Users can enter site specific details in a popup window "Site Information". This information can be changed during playing back.

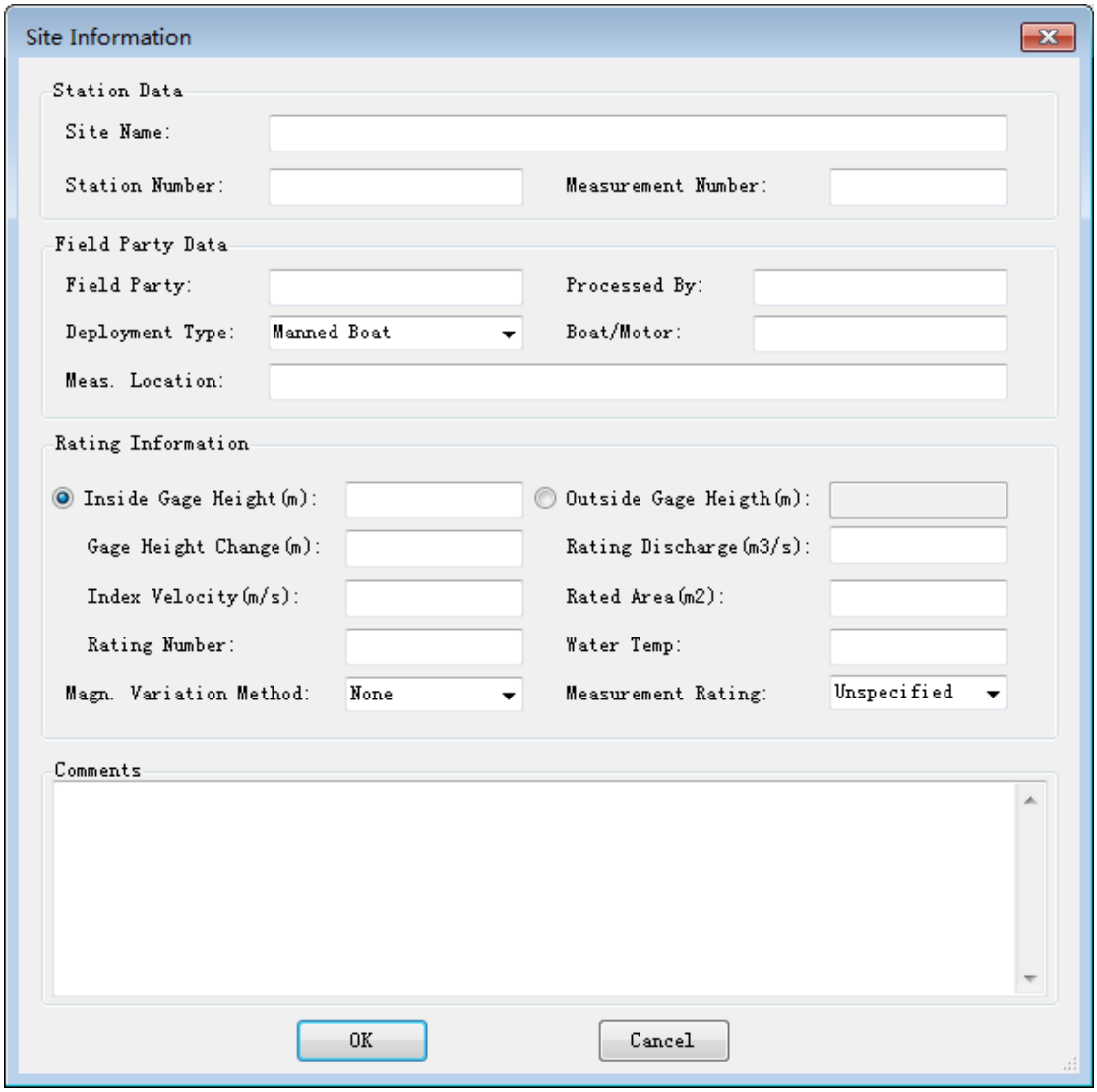


Figure 5. Site Information

Step 3: System Configuration

The System Configuration contains GPS communication, Time Setting.

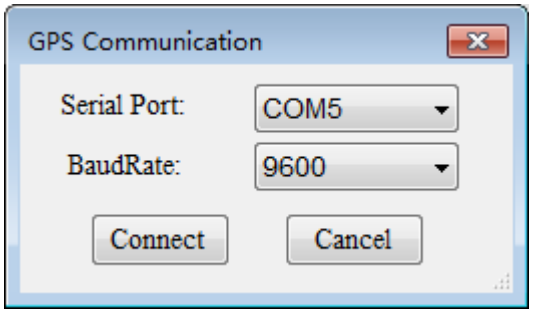


Figure 6. GPS Communication

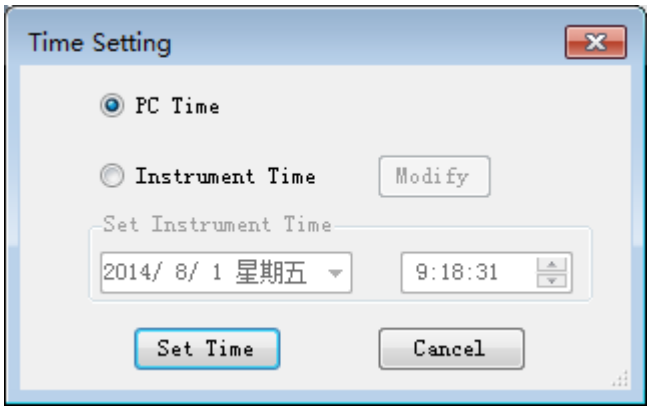


Figure 7. Time Setting

"GPS Communication" window allows the user to set the external GPS device. User can also input the GPS data to the ADCP directly through RS232 port. For more details, refer to the "RTI ADCP/DVL User Guide.pdf".

"Time Setting" window allows users to set the ADCP time used for the discharge measurement. The popup window allows users to click the check-box to use PC time or set the time manually.

Step 4: System Setting

Click the "Change System Setting" and the System Setting shows up.

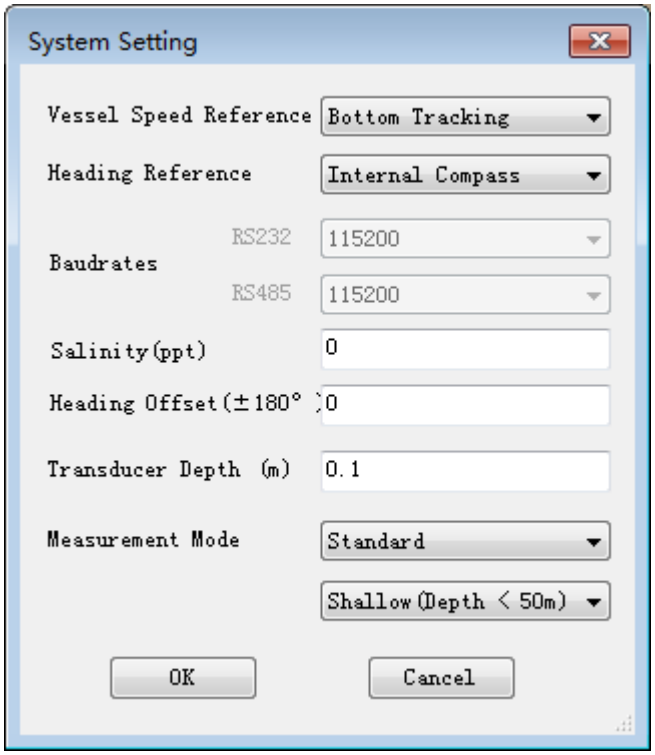


Figure 8. System Setting

Vessel Speed Reference

- **Bottom Tracking**: The ADCP uses the bottom-track feature to measure the velocity of a vessel relative to the river bottom. The vessel velocity is then subtracted from the measured water velocity to give the absolute water current profile independent of vessel motion. This is the only track reference available and standard configuration for systems without GPS.
- **GPS:** Select GPS to measure the vessel velocity other than bottom tracking. GPS will be helpful while the environment has high sediment or moving bed issues.
- **No Reference:** No reference is used.

Heading Reference

- **Internal Compass:** The ADCP compass is used. (Standard Configuration)
- **External Compass:** The external compass such as GPS heading is used instead of ADCP internal compass.

Transducer Depth

Enter the depth from the river surface to the ADCP transducer face.

Measurement Mode

Users can select measurement mode: **Standard** or **Advanced**. The default mode is Standard.

- **Standard Mode:** Users select the maximum depth to be measured. ADCP configures the rest automatically.
- **Advanced Mode:** Users can configure the ADCP in Advanced Mode manually. The advanced setting dialogue has several tables, such as Mode, Water Tracking, Ping Ensemble, etc and detailed description of each table follows.

Mode Table

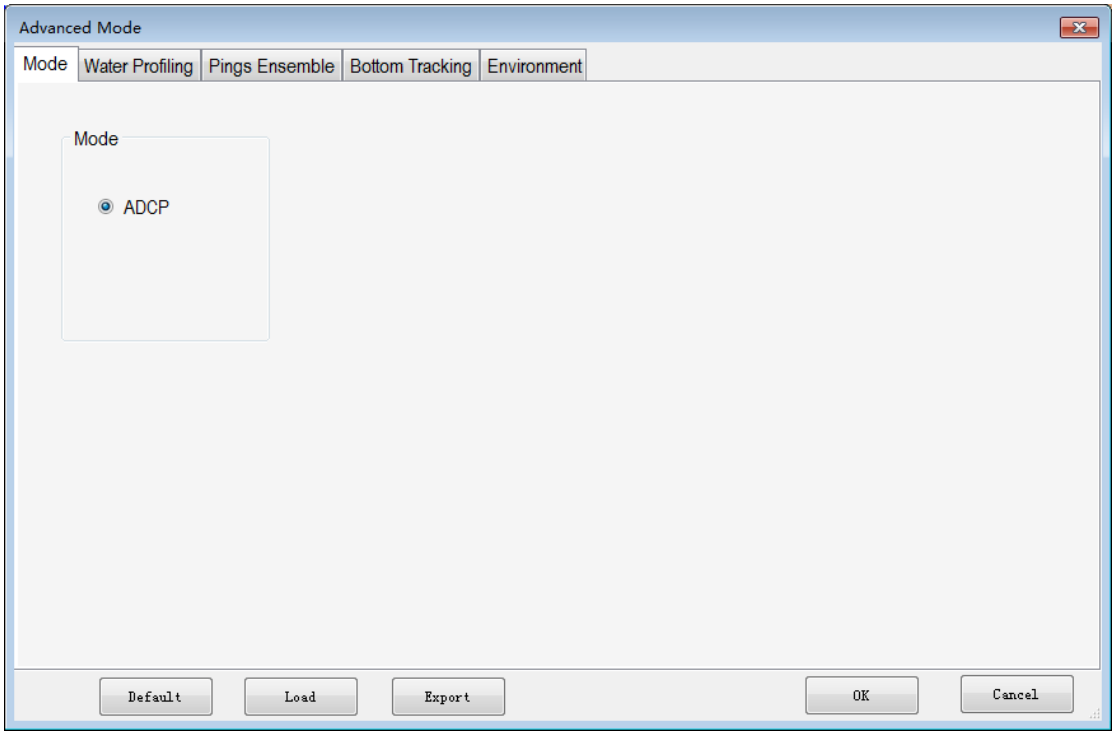


Figure 9. Mode

Mode:

- **ADCP** – The default mode for river discharge measurement. Enable Profiling mode. The system, when started, will output binary or text formatted data. Bottom track and multi cell water profiling supported in this mode.
- **DVL** – Enable DVL Mode. The system, when started, will output NMEA formatted data. Bottom track and a single water tracking cell are supported in this mode.

Water Tracking Table

Set all water profiling parameters.

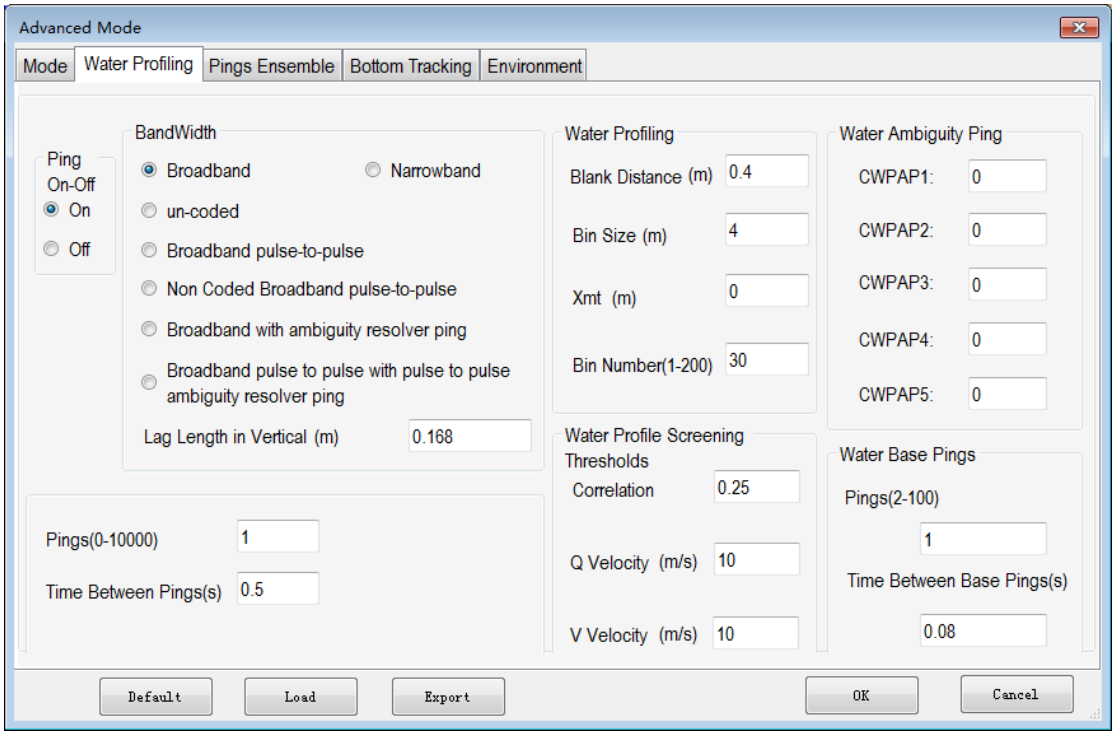


Figure 10. Water Profiling

Ping On-Off

- **On** – Enable water profiling. (Default setting for river discharge measurement.)
- **Off** – Disable water profiling

BandWidth

Set the water profiling transmit pulse type.

- **Coded** – Broadband (default setting).
- **Non-coded** – Narrow band
- **Non-coded pulse-to-pulse** – Un-coded pulse-to-pulse (no ambiguity resolver). Provide ultra low variance for small bin sizes and slow flow.
- **Broadband pulse to pulse** – Broadband pulse to pulse (no ambiguity resolver).Provide ultra low variance for small bin sizes, and has slightly lower variance than un-coded pulse to pulse mode.
- **Broadband with ambiguity resolver pings** – Used in conjunction with CWPBP averaging.
- **Broadband pulse to pulse with pulse to pulse ambiguity resolver ping** – Used in conjunction with CWPAP
- **Lag Length in Vertical** – Not used in Narrowband mode. The default lag length for DP1200, Broadband mode is 0.084m (The ambiguity velocity is 5m/s while setting lag length = 0.084, DP1200). A longer lag will have low variance.

Average

- **Pings** – Set the number of pings that will be averaged together during the ensemble. (0 to 10000).

- **Time between pings** -- Sets the time between the last ping, regardless of ping type, and the next profile ping (0.00 to 86400.00 seconds).
- **Bin Number** – Set the number bins that will be processed and output.

Water Profile Screening Thresholds

- **Correlation** – Used for screening profile beams. A beam with a correlation value less than the threshold will be flagged bad and not included in the bin average. The default value is 0.4.
  Nominal beam correlation values are dependent on the pulse coding, the number of repeated codes, and whether not the pulse-to-pulse processing is being used. For example:
  i. The pulse-to-pulse nominal correlation is 1.00. A correlation value of 0.50 occurs when the signal is equal to the noise (SNR = 1 or 0dB).
  ii. Broad band correlation is dependent on the number of repeated code sequences in the transmission. If 5 repeats are transmitted the nominal correlation will be 4/5 or 0.80. A correlation value of 0.4, in this case, indicates a signal to noise ratio is 1.
- **Q Velocity** – Used for screening transformed profile bins. A bin with a, absolute Q velocity that is higher than the Q threshold will be flagged as bad.
- **V Velocity** – Used for screening transformed profile bins. A bin with a, absolute Vertical velocity that is higher than the V threshold will be flagged as bad. Beam coordinate velocity data is not affected.

Water Profiling

- **Blank Distance** -- Water Profile Blank (0.0 to 100.0 meters). Set the vertical range from the face of the transducer to the first sample of the first bin.
- **Bin Size** – Set the water profile bin size.
- **Xmt** -- Set the water profile transmit size. A value of 0 (default) will cause the system to set transmit to the same length as the bin size.

Water Ambiguity Pings

Used when **Broadband pulse to pulse with pulse to pulse ambiguity resolver ping** is selected. Pulse to pulse ping and processing is used for the ambiguity resolver therefore (Blank + Bin Size) < Lag.

- CWPAP 1 – sets the number of pings that will be averaged together (0 to 100).
- CWPAP 2 – Lag (meters) sets the length of the lag
- CWPAP 3 – Blank (meters) sets the starting position of the bin.
- CWPAP 4 – Bin Size (meters).
- CWPAP 5 –Time between ambiguity pings (seconds).

Pings Ensemble Table

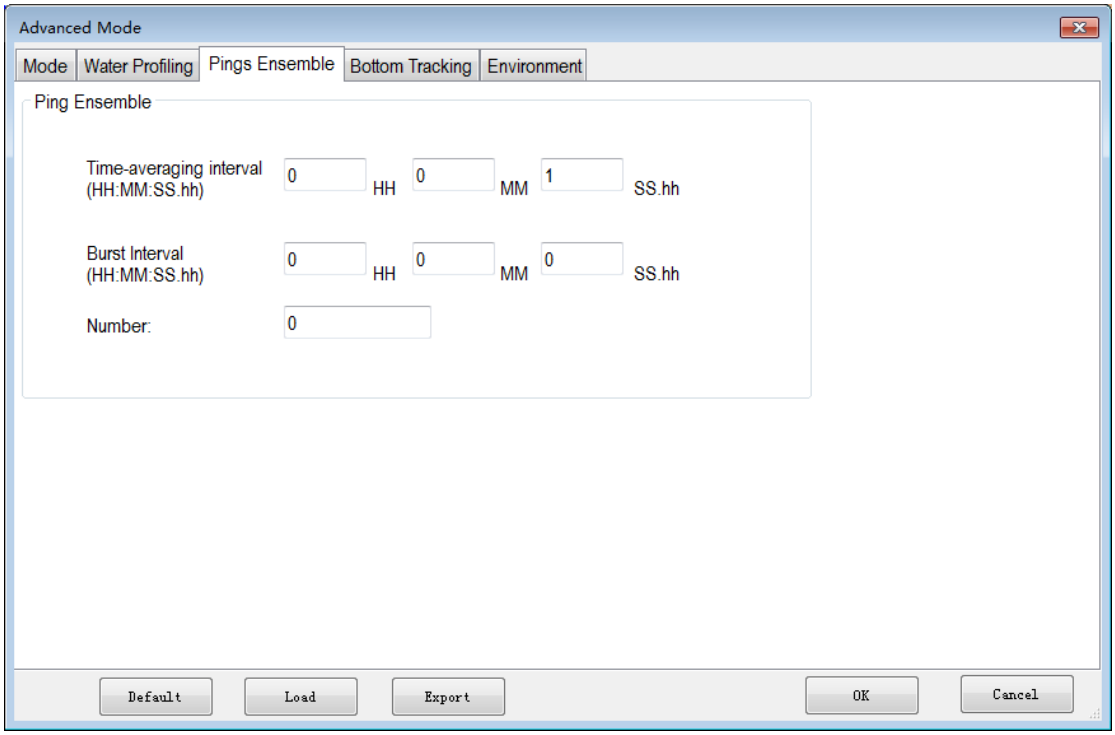


Figure 11. Pings Ensemble

Ping Ensemble

- **Time averaging interval** – Ensemble Interval. Sets the time interval that system will output the averaged profile/bottom track data.
- **Burst Interval** – Used when a precise short time interval is required between ensembles followed by a period of sleep
- **Number** – Set the number of ensembles that are output during each burst. The time between each ensemble is controlled by the Burst Interval.

Bottom Tracking

Set all bottom tracking parameters.

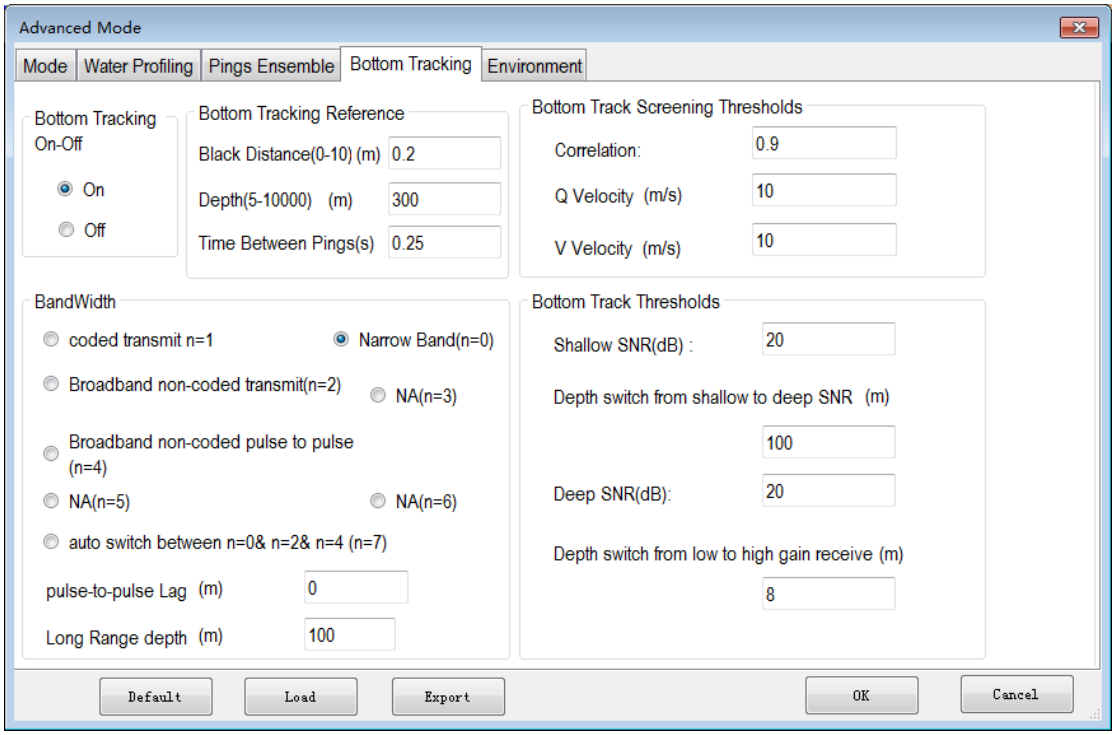


Figure 12. Bottom Tracking

Ping On-Off

- **On** – Enable bottom tracking. (Default setting for river discharge measurement).
- **Off** – Disable bottom tracking

BandWidth

Set the bottom tracking transmit pulse type.

- **Coded transmit** – Broadband (default setting).
- **Narrow Band** – Narrow band long range.
- **Broadband Non-coded transmit** – Broad band transmit pulse without coded.
- **Broadband Non-coded pulse to pulse** – Broadband pulse to pulse. Provide ultra low variance for shallow water.
- **pulse to pulse Lag** – Lag length in vertical meters. When enabled bottom track will use pulse-to-pulse transmit and processing at depths less than ½ the lag length. Allows for near bottom ultra low variance velocity measurements.
- **Long Range depth** –The range in meters beyond which the bottom track will switch to narrowband long range processing

Bottom Track Screening Thresholds

- **Correlation** – Correlation Threshold (0.00 to 1.00) The default value is 0.9. Used for screening beam data. A beam with a correlation value less than the threshold will be flagged bad and not included in the average. Nominal correlation for bottom tracking is 1.
- **Q Velocity** – Used for screening transformed bottom track velocities. An absolute Q velocity that is higher than the Q threshold will be flagged as bad. Beam

coordinate velocity data is not affected.

- **V Velocity** –Used for screening transformed bottom track velocities. An absolute Vertical velocity that is higher than the V threshold will be flagged as bad. Beam coordinate velocity data is not affected.

Bottom Track Thresholds

- **Shallow SNR** –SNR(dB) shallow detection threshold.
- **Depth switch from shallow to deep SNR** –Depth(m) at which the bottom track switches from using the shallow to the deep SNR.
- **Deep SNR** –SNR(dB) deep detection threshold.
- **Depth switch from low to high gain receive** –Depth(m) at which the bottom track switches from low to high gain receive.

Environment Table

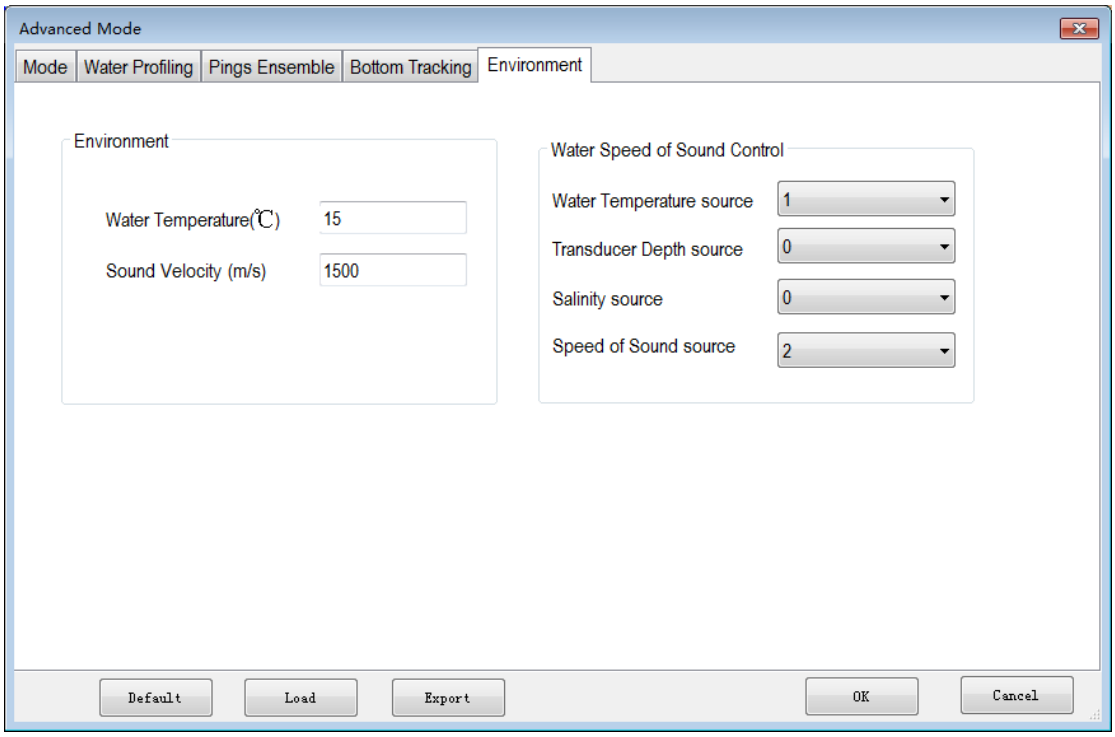


Figure 13. Environment Table

Environment

- **Salinity** – Water Salinity (ppt). Used in the water speed of sound calculation.
- **Water Temperature** – Used in the water speed of sound calculation if the temperature sensor is not available.
- **Transducer Depth** – Used in the water speed of sound calculation.
- **Sound Velocity** – Water Speed of Sound (meters per second). **Not used.**
- **Heading Offsets** -- Added to the compass output prior to heading being used within the system.

Water Speed of Sound Control

All of these source have three options. 0 = input by the Environment settings, 1 = sensor, 2 = internal calculation.

Note: For more detail Advanced Setting information, refer to the "RTI ADCP/DVL User Guide".

Step 5. Edge Setting

Edge Settings can be entered by clicking Change Edge Setting. Users set discharge estimation method and edge parameters for unmeasured area. All the parameters in this dialogue can be changed in play back.

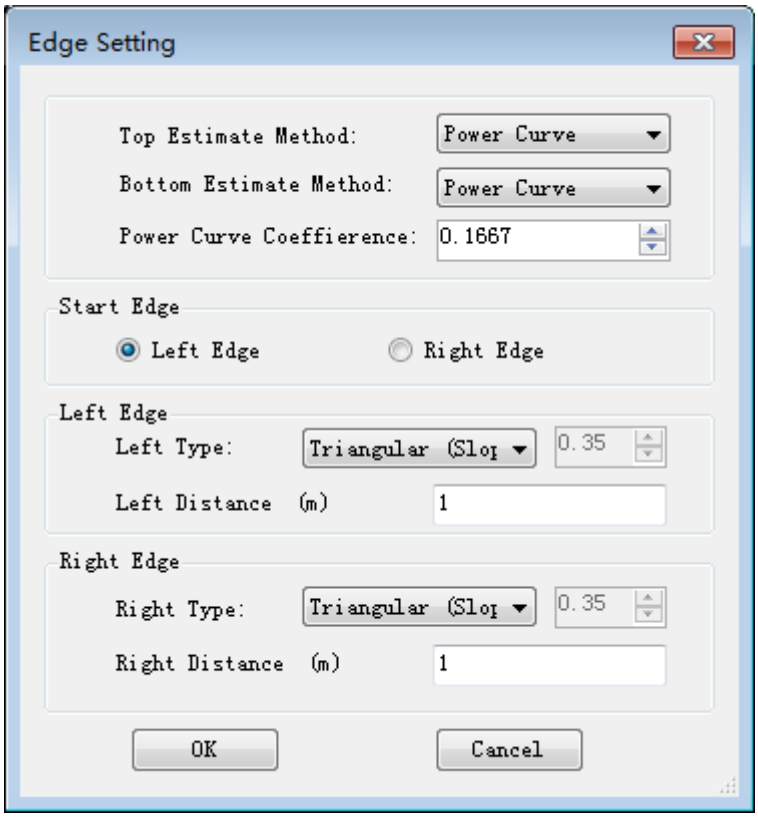


Figure 14. Edge Setting

Discharge method

- **Top discharge method**: The estimation methods of the top discharge are power curve, constant and 3-Point Slope.
- **Bottom discharge method**: The estimation methods of the bottom discharge are power curve and constant.
- **Power curve coefficient**: The power curve coefficient can be changed when the

power curve method is used, the default is 0.1667(1/6).

- **Strat Edge**: The begin edge when surveying.
- **Edge Type**: The edge type is used in estimating the shore discharges according to the shape as triangular or square which you selected. Users can set a coefficient to estimate the shore discharge.
- **Shore distance:** The distance from the shore to the vessel.

Note: When facing the downstream, the left bank is on your left hand.

2.1.3 Collecting Discharge Data

After completing the Smart Page setting, DP-Pro Q sends all the configuration commands to ADCP and starts acquiring transect data. DP-Pro Q calculates discharge in real-time and displays in Q Control window.

If necessary, perform a pre-run test before actually collecting data to ensure that the ADCP is working well as expected.

The program provides a step by step procedure to take the transect discharge measurement. Below is the procedure in detail.

- **Step 1: Start Pinging**

Click START or press the short-key **F5** to start pinging. The program will not record any data during this time, but the data will be displayed and users may view it and make sure the ADCP is operating correctly.

Figure 15. Start Pings

Note: Move away from the shore until ADCP can measure 2 good bins at least.

- **Step 2: Start Edge**

Mark the start edge position, and determine the edge distannce to shore, and then click **EDGE1** or press the short-key **F5** to measure the start edge. Collect at least 10 samples(default setting) before you cross the river.

Figure 16. Start Edge

The Begin Transect Setting dialogue will appear after click the EDGE1 button.

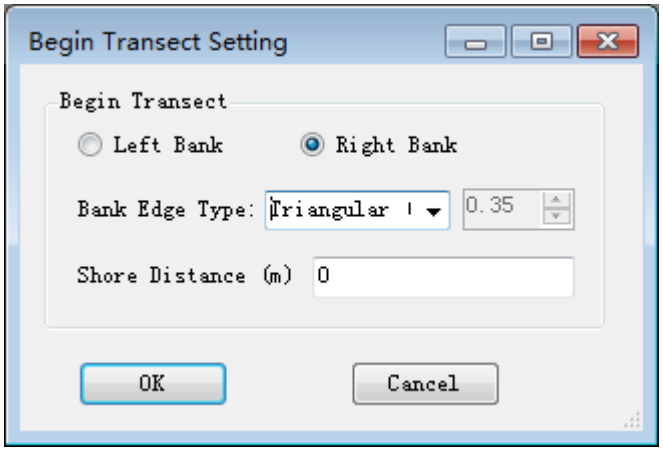


Figure 17. Begin Transect Setting

Note:

1. **Keep the vessel as stationary as possible during this time.**
2. **Make sure that at least two good cells are taken.**

- **Step 3: Cross the River**

After collecting 10 shore samples (default setting), the **Move** button will blink. Click **Move** or press the short key **F5** and move the vessel crossing the river.

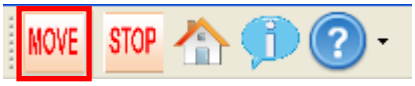


Figure 18. Move

Note: Keep the vessel movement stable, be sure the vessel speed equals or less than water flow speed.

- **Step 4: End Edge**

When the vessel reached the other edge, click the EDGE2 button or press the short-key F5 to set the end transect. Holding the vessel at the ending edge and collect at least 10 shore ensembles (default setting).

Figure 19. End Edge

The End Transect Setting dialogue will appear after click EDGE2 button.

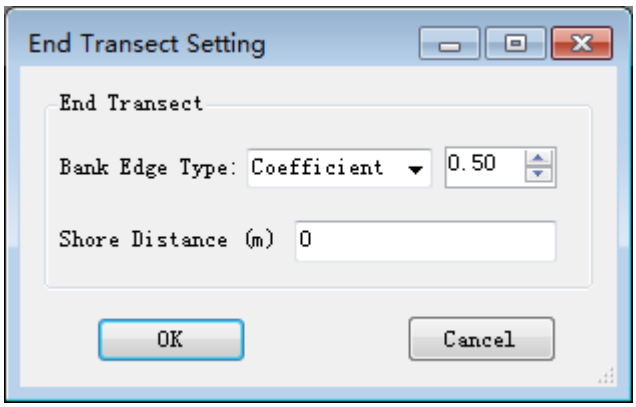


Figure 20. End Transect Setting

- **Step 5: Compelet Transect Measurement**

Finally, click the STOP button or press the short-key F6 to stop pings and finish the transect measurements.

Figure 21. Stop

The first discharge measurement is completed. Repeat the measurement procedure to make additional measurements. The ADCP configuration can be changed by clicking the Smart Page and typically use short key F5 to start additional transect and F6 to complete.

Chapter 3 Play Back Transect Data

3.1 Overview

DP-Pro Q is also used for post-processing transect data to view the discharge value and output summary report. Click **View Data** button in the Landing Page to start the playback.

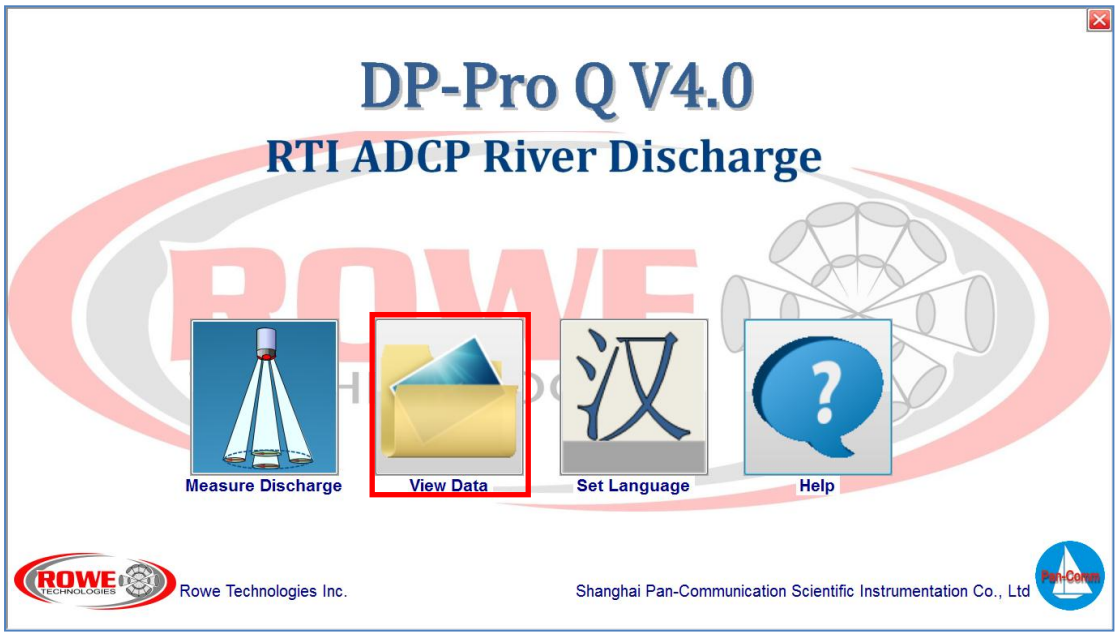


Figure 22. Start Play Back

3.2 Playback data

After Clicking the View Data button, the Playback main interface along with Browse Folder dialogue will appear.

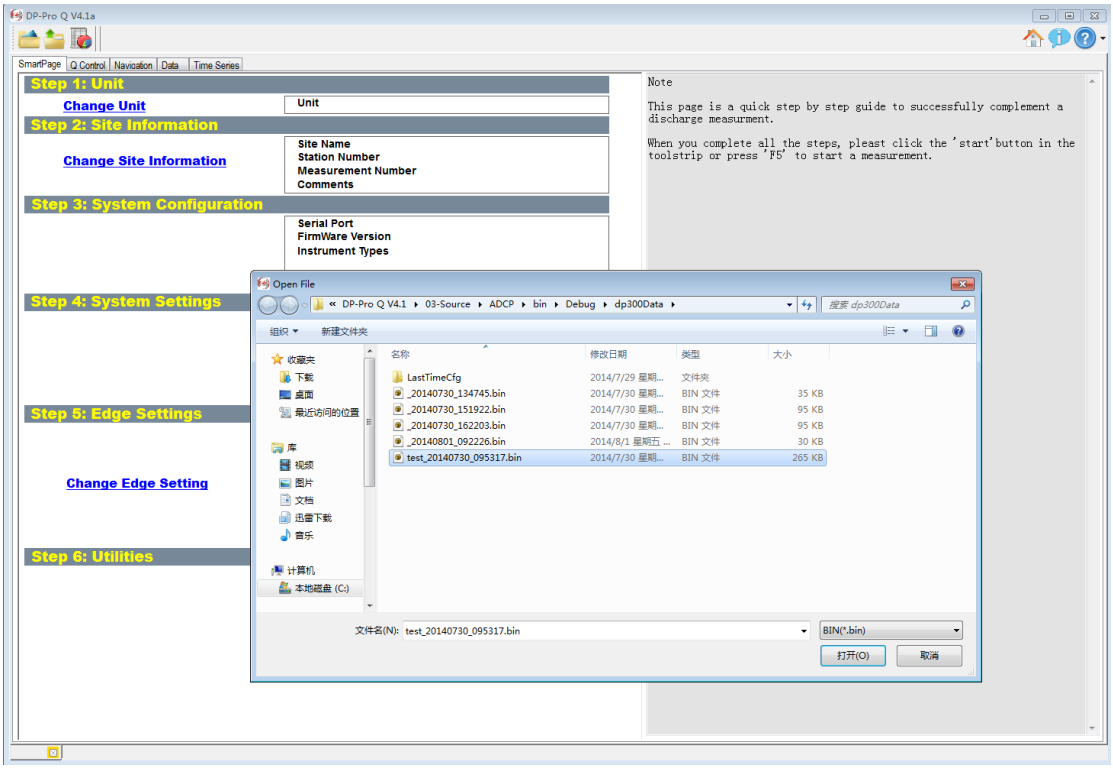


Figure 23. Playback Main Interface

Select the bin data and click OK to load the transect data. The program will play back it automatically from first sample to last.

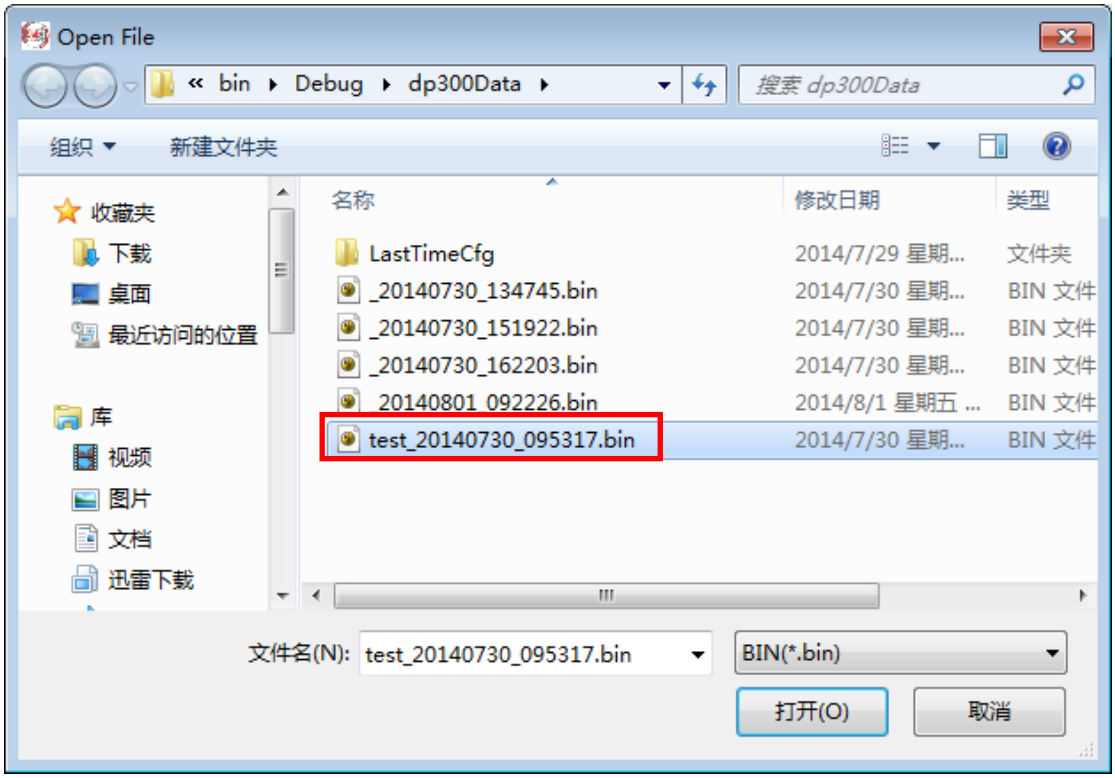


Figure 24. Load Data Dialogue

3.3 Main Interface Layout

The main interface layout shows below. A detailed description of each section will follow.

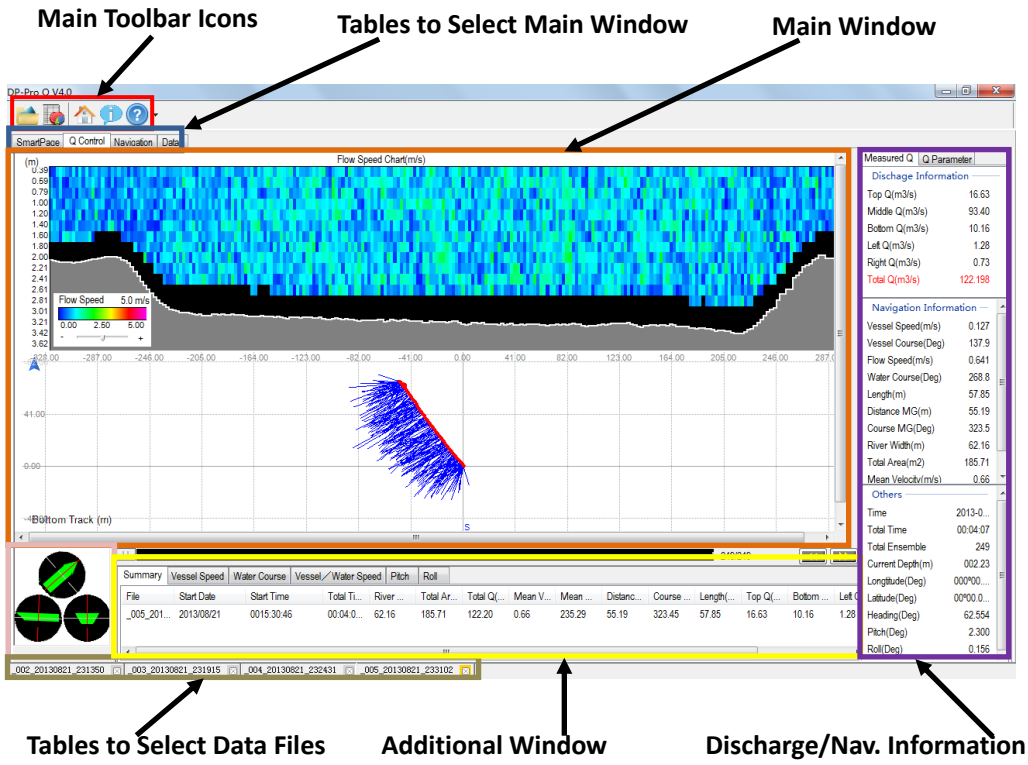


Figure 25. Main Interface Layout

3.3.1 Main Toolbar Icons

Open File: Open a Browser Folder dialogue to select additional transect data for viewing and post processing.

Show Summary: Show discharge summary.

Home: Back to the Landing Page.

About: Show the program copyright and other relevant information.

Help: Present help document.

3.3.2 Tables to select main window

- **Smart Page**

Users can change the unit, site information and bank edge (Change Unit, page 5, Site Information, page 5, Change Edge Bank, page 7) during the post processing.

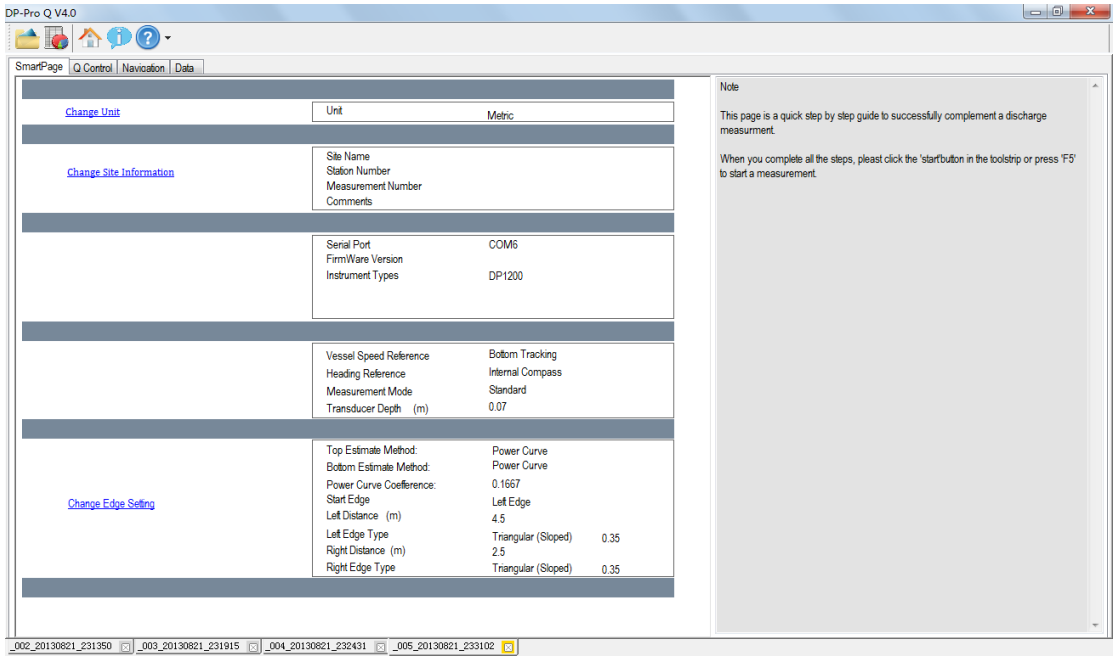


Figure 26. Smart Page

- **Navigation**

Click “Track” page to check the navigation chart. The navigation chart shows the ship tracking recorded by bottom tracking or GPS.

Geographical system projection

Geographical system: This is the data track in GPS system (when choosing the GPS, the geo-system is active).

UTM grid system: The track chart of the GPS system changing to project system.

Bottom tracking: The track chart of the instrument’s bottom tracking data.

Auto size: The function of the auto size the tracking chart.

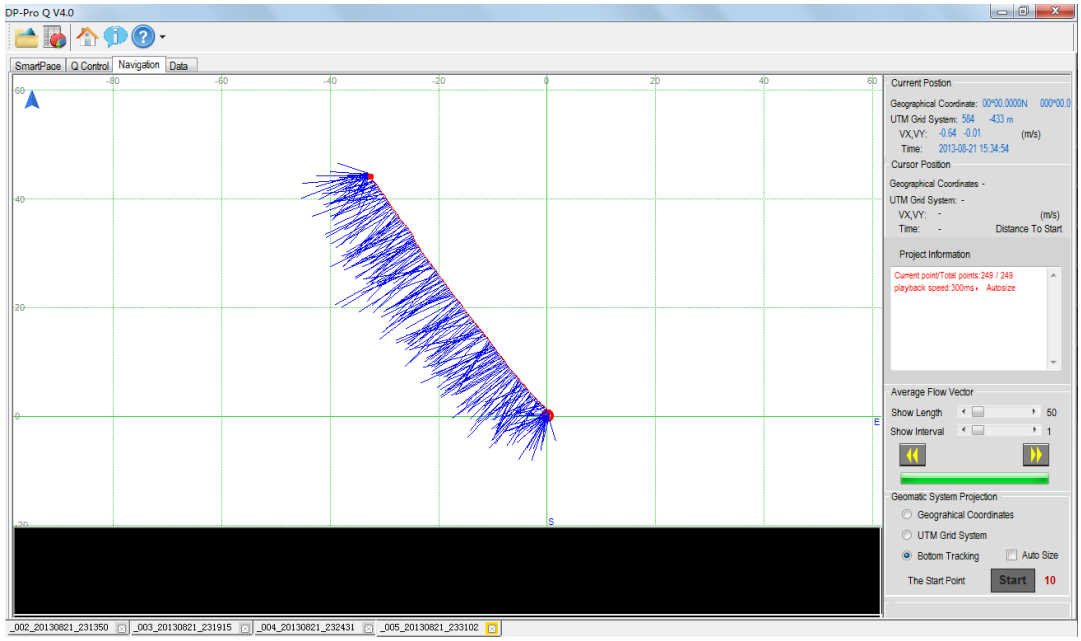


Figure 27. Ship Track

Tips: Users can zoom in/out the ship track by scroll the mouse wheel.

- **Data**

Click the **Data** table to check out the ADCP raw data. This page shows the raw data of each ensemble including but not limited to the profiling data, bottom tracking, echo intensity, correlation, etc. For more raw data explanation, see "RTI ADCP/DVL User Guide.pdf".

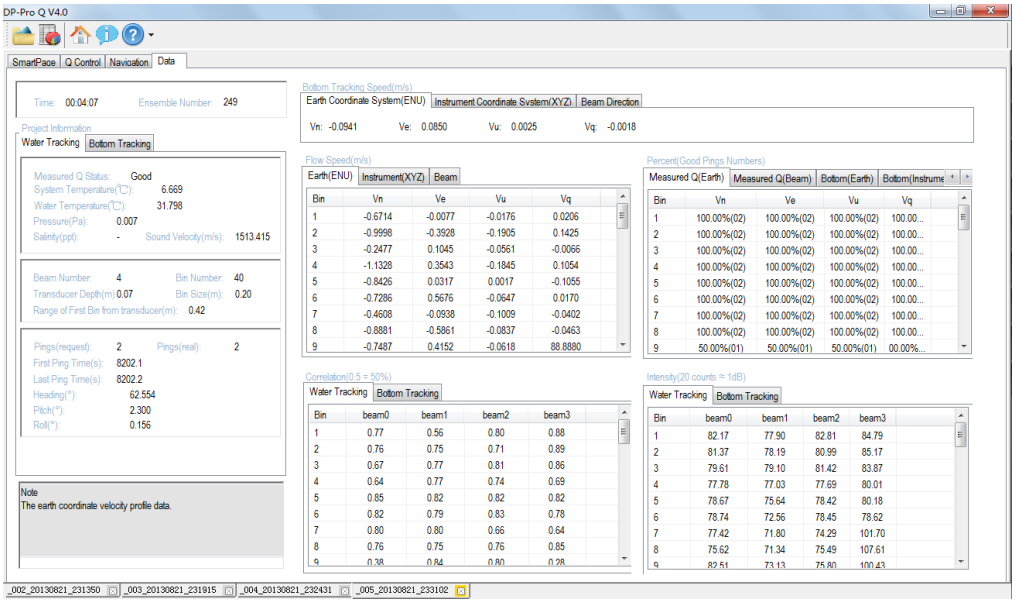


Figure 28. Raw Data

3.3.3 Discharge/Navigation Information

The discharge/Navigation tabular shows three tabular: **Discharge Information**, **Navigation information** and **Other Information**.

Discharge Information tabular shows the transect measurement discharge including total Q (shows in red highlight), measured area discharge (Middle Q) and unmeasured area (Top/Bottom/Left/Right Q). Navigation Information tabular shows the ship track information. Users also can find attitude and GPS information in the Other Information tabular.

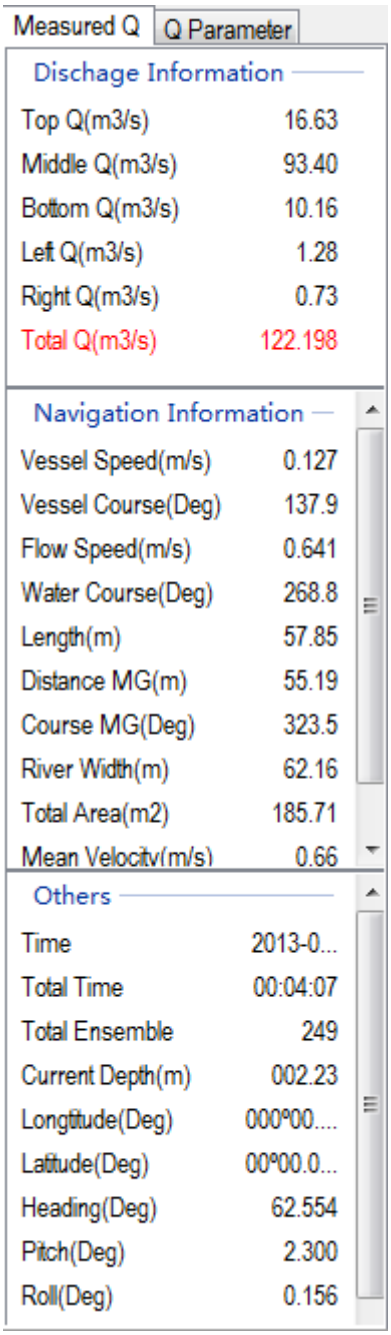


Figure 29. Discharge/Navigation Information

3.3.4 Tables to Select Data File

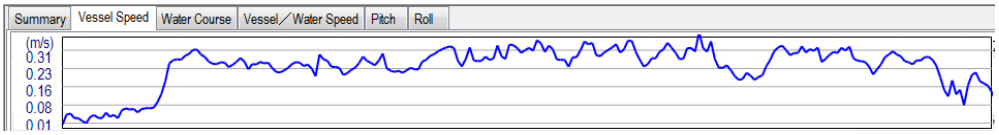
Users can see the Tables to Select Data File at the bottom of the main interface. Each table is an open transect file with file name. The tables are used to toggle between open transect files. DP-Pro Q can open multiple files simultaneously. Users should switch the transect file by clicking the transect file tables.

Figure 30. Tables to Select Data File

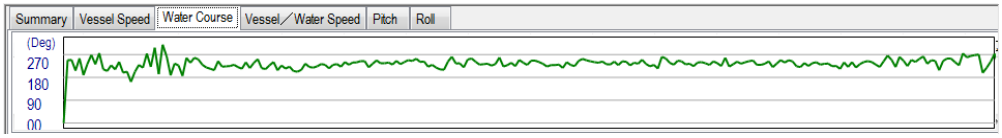
3.3.5 Additional Windows.

Users can review the time series graphs of ADCP attitude and vessel/water speed ratio in the additional windows.

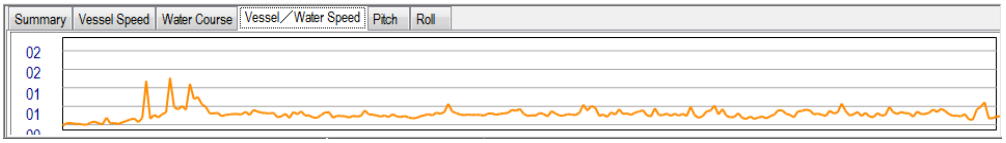
- **Vessel Speed** – The time series graph of boat speed.



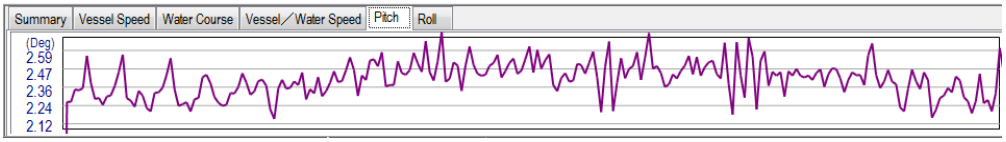
- **Water Course** – Average water course for the water column. Only the valid bins will be averaged.



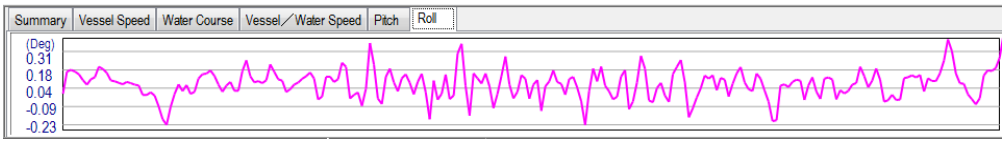
- **Vessel/Water Speed ratio** – Users can check this time series graph to ensure that the vessel is moved slowly and steady as they desired.



- **Pitch**

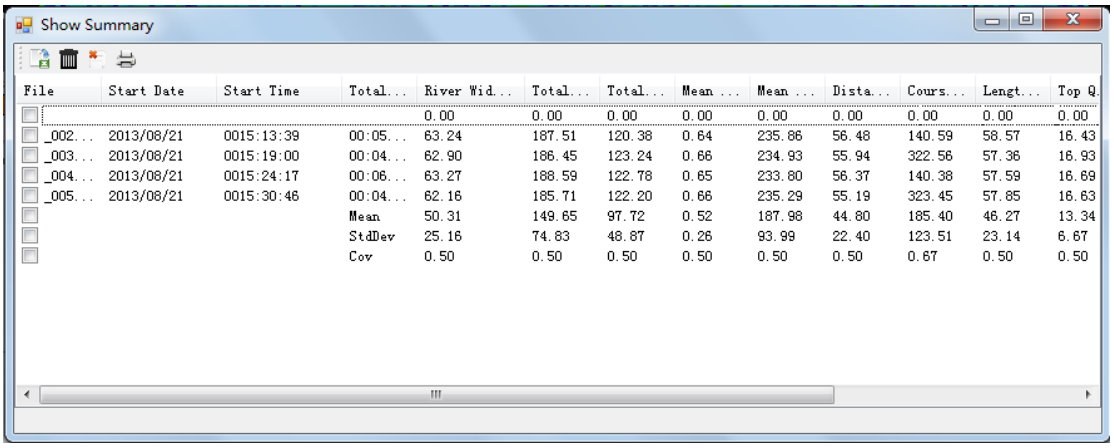


- **Roll**



3.3.6 Summary

Click the **Summary** icon ("Show Summary, Page 13) in the main toolbar and the **Show Summary** tabular will appear. This window shows the detailed transect data in tabular format. Users can resize the window by using the slider arrow when the mouse pointer is over the window border.



File	Start Date	Start Time	Total...	River Wid...	Total...	Total...	Mean ...	Mean ...	Dista...	Cours...	Lengt...	Top Q
				0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
_002...	2013/08/21	0015:13:39	00:05...	63.24	187.51	120.38	0.64	235.86	56.48	140.59	58.57	16.43
_003...	2013/08/21	0015:19:00	00:04...	62.90	186.45	123.24	0.66	234.93	55.94	322.56	57.36	16.93
_004...	2013/08/21	0015:24:17	00:06...	63.27	188.59	122.78	0.65	233.80	56.37	140.38	57.59	16.69
_005...	2013/08/21	0015:30:46	00:04...	62.16	185.71	122.20	0.66	235.29	55.19	323.45	57.85	16.63
			Mean	50.31	149.65	97.72	0.52	187.98	44.80	185.40	46.27	13.34
			StdDev	25.16	74.83	48.87	0.26	93.99	22.40	123.51	23.14	6.67
			Cov	0.50	0.50	0.50	0.50	0.50	0.50	0.67	0.50	0.50

Figure 31. Transect Discharge Summary

The transect data can be selected or deleted by clicking the mouse. It will affects the statistics presented and users can easily understand what transect data effect has on the overall average of the measurements.

Following is the detailed description of the main toolbar icons in Show Summary window.

Export Summary Report: Outputs the discharge summary report. (Deleted records are not calculated in the report)

Delete All: Deletes all transect data, remove all transects for discharge calculation.

Delete Selected: Deletes the selected transect data (with the blue check). .

Print: Print the Show Summary tabular directly.

3.3.7 Attitude Display

Display the vessel's three-dimensional attitude (Roll, Pitch and Heading) in real-time measurement and playback mode

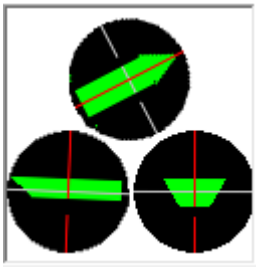


Figure32. Attitude Display

Chapter 4 Data Formats and Storing

The collected data by DP-Pro Q is saved in the dp300Data folder, the default path is "**../dp300Data**". The project name is site name plus survey date plus survey time .

1. **Raw Data**: is used to save the raw data. The file format is binary. The file name is "project name.bin".
2. **GPS**: is used to save the GPS data, the file name is "project name.gps".
3. **Configuration**: is the configuration file collected by the system, the file name is "project name.cfg".

Appendix Calculating the River Discharge

The total discharge (Total Q) is the summation of the discharge in the top (Top Q), middle (Middle Q), bottom (Bottom Q), left (Left Q) and right layers (Right Q). The middle discharge is calculated by the measured water layer, but other layers are estimated.

Calculating the Measured Discharge

Christensen and Herrick(1982) , Simpson and Oltmann (1993) give the formula of calculating the discharge.

$$Q = \iint_S u \cdot \xi ds$$

Where: Q is the total discharge

u is the water velocity vector.

ξ is the unit vector normal at a general point.

ds is the differential area.

The formula of calculating ds is:

$$\mathrm{ds} = |V_b| \cdot \mathrm{dz} \cdot \mathrm{dt}$$

Where: dz is differential depth

dt is differential time

V_b is mean vessel velocity vector

And

$$|V_b| = \sqrt{V_{bx}^2 + V_{by}^2}$$

Then

$$\mathrm{Q} = \int_0^T [\int_0^H u \cdot dz] \cdot \xi |V_b| \cdot dt = \int_0^T \int_0^H (u \times V_b) \cdot k \cdot dz\, dt$$

$$f = (u \times V_b) \cdot k = u_x V_{by} - u_y V_{bx}$$

$$\mathrm{Q} = \sum_{i=1}^{m} [\int_0^{H_i} f_i \cdot dz] \Delta t = \sum_{i=1}^{m} [\,(V \times V_b) \cdot k]_i \cdot H_i \Delta t = \sum_{i=1}^{m} [\,V_x V_{by} - V_y V_{bx}]_i \cdot H_i \Delta t$$

Where: V_x is cross-component of the mean water velocity vector.

V_y is fore/aft component of the mean water velocity vector.

V_{bx} is cross-component of the mean vessel velocity vector.

V_{by} is fore/aft component of the mean vessel velocity vector.

H_i is water depth in i segment.

The V_{xM} is: (same as V_{yM})

$$V_{xM} = \frac{1}{n}\sum_{j=1}^{n} u_{xj}$$

Where: u_{xj} is cross-component of the water velocity vector in j cell.
The formula of calculating the middle Q is:

$$\mathrm{Q}_M = \sum_{i=1}^{m}\sum_{j=1}^{n} f_j\, D_c \Delta t = \sum_{i=1}^{m}[(V_{xM}V_{by} - V_{yM}V_{bx})]_i \cdot (Z_2 - Z_1)_i \Delta t$$

Estimating Near-shore Discharge

The formula for determining a near shore discharge is:

$$Q_{NB} = \alpha A_a V_m$$

Where: Q_{NB} is near-shore discharge.

A_a is area of the near-shore segment

α is coefficient (triangular/sloped -0.35, rectangle/vertical -0.91).

V_m is mean water velocity in the near-shore segment.

Estimating Top/Bottom Layer Discharge

There are two methods to estimate discharge in the top/bottom layer. The two methods are constant and power.

Power Method:

Chen (1991) discusses the theory of power laws for flow resistance.

$$\frac{u}{u_*} = 9.5 \cdot (\frac{Z}{Z_0})^b$$

Where: u is the velocity at distance z form bed.

u_* is shear velocity.

Z is the distance to the channel bed.

z_0 is the bottom roughness height.

b is exponent（with b=1/6）

$$\mathrm{f} = a'' z^b$$
$$u_x V_{by} - u_y V_{bx} = a'' z^b$$
$$u_x = a_x z^b$$

$$\int_{Z_1}^{Z_2} u_x dz = \int_{Z_1}^{Z_2} a_x z^b dz = a_z \frac{(Z_2^{b+1} - Z_1^{b+1})}{b+1} = \frac{(Z_2 - Z_1)}{n} \sum_{j=1}^{n} u_{xj} = D_c \sum_{j=1}^{n} u_{xj}$$

$$a_x = \frac{D_c(b+1)}{Z_2^{b+1} - Z_1^{b+1}} \sum_{j=1}^{n} u_{xj}$$

$$a'' = a_x V_{by} - a_y V_{bx} = \frac{D_c(b+1)}{Z_2^{b+1} - Z_1^{b+1}} \sum_{j=1}^{n} f_j$$

$$V_{xT} = \frac{D_c(H^{b+1} - Z_2^{b+1})}{(H - Z_2)(Z_2^{b+1} - Z_1^{b+1})} \sum_{j=1}^{n} u_{xj}$$

$$V_{xB} = \frac{D_c Z_1^{b+1}}{Z_1(Z_2^{b+1} - Z_1^{b+1})} \sum_{j=1}^{n} u_{xj}$$

The formula for estimating the top discharge is:

$$Q_T = \sum_{i=1}^{m} [\frac{\Delta t D_c(H^{b+1} - Z_2^{b+1})}{Z_2^{b+1} - Z_1^{b+1}} \sum_{j=1}^{n} f_j]_i = \sum_{i=1}^{m} [\left(V_{xT} V_{by} - V_{yT} V_{bx}\right)]_i \cdot (H - Z_2)_i \Delta t$$

The bottom Q is estimated by:

$$Q_B = \sum_{i=1}^{m} [\frac{\Delta t D_c Z_1^{b+1}}{Z_2^{b+1} - Z_1^{b+1}} \sum_{j=1}^{n} f_j]_i = \sum_{i=1}^{m} [\left(V_{xB} V_{by} - V_{yB} V_{bx}\right)]_i \cdot (Z_1)_i \Delta t$$

Constant Method:

The constant method support the top velocity is constant, and the data equals the velocity of first cell.

$$V_{xT} = u_{x,first}$$

$$V_{xB} = u_{x,last}$$

Top Discharge is:

$$Q_T = \sum_{i=1}^{m} [\left(u_{x,first} V_{by} - u_{y,first} V_{bx}\right)]_i \cdot (H - Z_2)_i \Delta t$$

Bottom Discharge is

$$Q_B = \sum_{i=1}^{m} [\left(u_{x,last} V_{by} - u_{y,last} V_{bx}\right)]_i \cdot (Z_1)_i \Delta t$$