TECHNICAL PAPER: GPS POSITIONING FOR RIVERSURVEYOR LIVE MEASUREMENTS

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I. INTRODUCTION

The traditional direct method for determining flow within a channel consists of applying the velocity area method using a current meter device. The velocity area method determines the depth and averaged velocity profile at a series of stations (verticals). The total flow is the product of the area and mean water velocity within the cross section. The flow calculation methods most commonly used for the velocity area method are the Mid-Section (Figure 1) and Mean –Section methods.

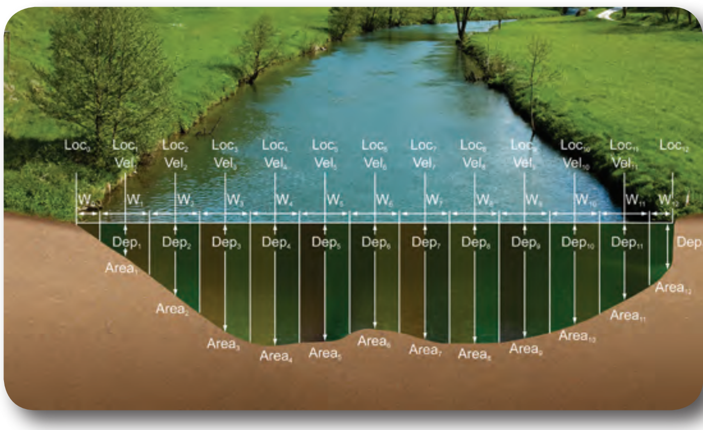

Fig. 1 Mid-Section Flow Calculation Method.

During the development of SonTek RiverSurveyor M9 / S5 instruments it was essential that the velocity area method (referred to as the "Stationary" method by SonTek) and associated flow calculations are incorporated into the operations. The Stationary method was implemented in the RiverSurveyor Stationary Live software and allows the user to perform velocity area method using either the Mid-section or Mean-Section methods.

RiverSurveyor M9/S5

The application of Acoustic Doppler Current Profiler (ADCP) instruments in area velocity method, improved key aspects in the measurement process, including the total measurement depth and the averaged velocity within the water profile.

When using ADCPs with the velocity area method, determining the station location component of the measurement process remained unchanged.

• Difficulty determining bank (edge) positions with the measuring tape or tag line,
• Deviation of the instrument from the measuring tape or tag line location due to skew flow, turbulence, or wind influences,
• Attempting to measure sections exceeding the measuring tape length.

With the release of RiverSurveyor Stationary Live 4.0 in 2017, SonTek developed a unique patent-pending method by incorporating GPS positioning with the area velocity method. This has shown significant improvement on the measurement process and also opens a wide range of applications with current instrumentation. This technical paper gives a broad overview of the methods implemented, test results, and future applications.

II. PATENT PENDING GPS POSITIONING METHOD

During the initial design, a number of key requirements were identified to ensure that the application of the GPS Positioning method enhances the measurement process and accuracy. These include:

• High accuracy of GPS position using either DGPS or RTK,
• Projected distance between stations along the measurement section,
• Flexibility to use measurement tape \ tagline, GPS or any combination for determining a station location.

A. Accuracy of GPS Position

The accuracy of GPS positioning for stationary measurements is dependent on the type of GPS solution used, the number of satellites and correction services available, and the measurement site conditions.

The method implemented in the RiverSurveyor Stationary Live (RSSL) Software consists of averaging the GPS position during a station measurement. This means that the GPS data are averaged over the same user defined averaging interval as the velocity data. In addition to improving the overall accuracy of the GPS position, the true position of the station is also determined from averaging the movement of the boat \ board during the station measurement.

The averaging of GPS position during a station measurement increases the position accuracy. From a number of field measurements performed (discussed under Results section), the measurements using DGPS and RTK compare very well.

B. Project Distance Between Stations

Due to variations in rope length and wind/flow, the ADCP system can move up or downstream throughout the stationary measurement. In order to correct for this effect, the RSSL software uses a GPS projection line. The user sets up the GPS projection line using two GPS positions along the expected transect, and all stations during the measurement will be projected along this line.

During the SmartPage configuration of RSSL, the operator is required to obtain GPS Projection Line by collecting GPS Position data at two locations within measurement section, detailed in Figure 2. The "Start Location" should be located the closest to the starting bank. The "End Location" of the projection line should be located the furthest from the starting bank.

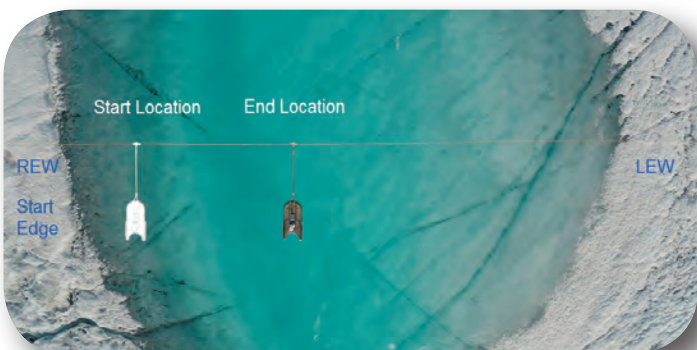

Fig. 2. Obtain GPS Projection Line.

The GPS position of the start and end locations are used to develop a projection line defined by markers A and B in Figure 3. The projection line, averaged GPS positions and measuring tape or tag line measurements of stations are converted a to single datum.

The station coordinates are projected perpendicularly onto the Projection Line. The physical station position in this illustration is defined by marker C and the marker D represents where the location will be projected in Figure 3.

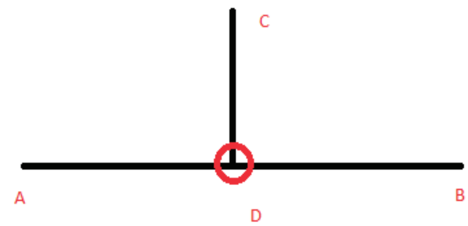

Fig.3. Projected Distance Between Stations

The distance between two stations is calculated from the two adjacent points intersection coordinates on the Projection Line (A to D, for example).

III. OPERATIONAL ASPECTS TO BE CONSIDERED DURING A MEASUREMENT

The application of GPS for station positioning in RSSL is a relatively simple process. There are a number of operational aspects that need to be taken into account to ensure efficient measurement process and reliable data set. These include, obtaining a projection line using a cable way, determining the distance between stations, and determining the station position. Each of these is discussed subsequently.

A. Obtain Projection Line Using Cable Way

The method used to traverse across the measurement section can impact the Projection Line development resulting in systematic error in the measurement.

In the case of cable ways, the cable tends to have increased slack toward the center of the cable span. This can adversely impact the calculations of distances between stations. It is recommended to set the end location of the Projection Line close to the opposite bank. This will ensure that the GPS position data for the projection line is measured outside the slack zone.

The data set illustrated in Figure 4 shows two Stationary measurements performed at a monitoring site equipped with cable way system (shown in yellow line). The stationary measurement depicted in blue markers uses a projection line created with both the start and end locations measured close to the channel banks. The stationary measurement depicted in red markers shows a measurement with a projection line using the start location at the bank and the end location in the center of the cable way.

Figure 4. Impact of Cable Way Projection Line

The slack in cable way is creating an angle in the projection line. This will result in an increase in station widths and an overestimate of the total width and area.

B. Distance Between Stations

When the instrument is moved, the RSSL software will display live non-averaged GPS data at 1 second intervals that update as the instrument travels. The data will show a small variation in position even if the instrument is not moving due to the noise present in the 1 second raw data.

It is recommended that an approximate distance (as close as possible to target distance) is selected when positioning the instrument at the next station. This will improve the overall measurement time.

C. Station Position

When a stationary measurement is performed with a measuring tape or tag line, users tend to select equal distances between stations across the measurement section.

It is recommended that an approximate position (close as possible to target position) is selected when positioning the instrument at the next station. This will improve the overall measurement time.

IV. RIVERSURVEYOR STATIONARY LIVE MEASUREMENTS USING GPS POSITIONING

The measurement results during the development phase confirmed that RSSL with GPS positioning is an accurate solution for Stationary measurements. Field measurements were performed in three different locations in North America to verify the accuracy with regard to the following aspects:

- Number of Satellites,
- Correction service,
- GPS Solution (RTK \ DGPS).

The measurement locations that were selected for the tests consisted of Yuma (Arizona), Sacramento (California), Lethbridge (Canada) and Melbourne (Australia).

A. Yuma, Arizona

The measurements were performed at an USGS monitoring site equipped with a cable way upstream of the weir. The Stationary measurements performed using RTK and DGPS is depicted in Figure 4.

Date	Method	Discharge ft^3/s	Width ft
20160831	RSL(4 transects)	1498.870	78.434
20160831	RSSL + RTK	1498.308	78.116
20160901	RSL(4 transects)	1457.299	77.247
20160901	RSSL + DGPS	1457.197	77.953

The measurements results compared against the average of four moving boat transects are very similar.

B. Sacramento, California

The measurements were performed at an USBR monitoring site equipped with a cable way. The edge measurements were measured with measuring tape. The ability to combine measuring tape or tag line measurements with GPS positioning in the same measurement makes RSSL extremely versatile.

Date	Method	Discharge ft^3/s	Width ft
20160919	RSSL + DGPS	531.061	95.000
20160920	RSSL + DGPS	545.399	95.000
20160928	RSSL + DGPS	543.739	91.519
20160928	RSSL + DGPS	542.998	94.000

The third measurement performed on the 28 September showed reduction in width. The reduction can probably be contributed to error in the edge measurements.

Figure 5. Sacramento Stationary Measurements

The measurement section in Figure 5 depicts one of the Stationary measurements performed in Sacramento.

C. Lethbridge, Canada

The measurements were performed during the Water Monitoring Workshop in Lethbridge, Alberta.

Date	Method	Discharge ft^3/s	Width ft
20160913	RSL (12 transects)	759.371	106.873
20160913	RSSL + DGPS	741.572	104.625

The measurement results compared well against the average of twelve moving boat transects.

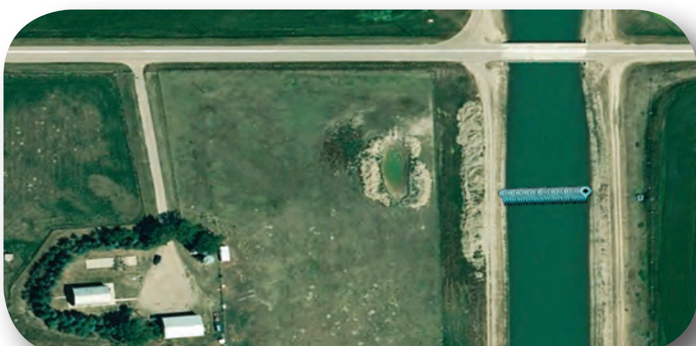

Figure 6. Lethbridge Stationary Measurements

The measurement section in Figure 6 depicts the Stationary measurements performed in Lethbridge.

D. Nagambie, Australia

The measurements were performed in the Stuart Murray Channel near Nagambie, north of Melbourne.

Date	Method	Discharge ft^3/s	Width ft
20170328	RSL (2 transects)	605.575	125.282
20170328	RSSL + RTK Hemisphere S321	610.414	115.846

The measurement results between the moving boat and stationary shows almost 8% difference in total width. The difference can be attributed to the accuracy of edge measurements during the measurement exercise. The discharge results compare very well between the moving boat and stationary measurements.

Figure 7. Nagambie Stationary Measurements

The measurement section in Figure 7 depicts the Stationary measurements performed in Nagambie.

V. ADVANCED APPLICATIONS

The ability to associate GPS positions with stationary measurements opens up a wide range of applications. The collection of velocity and backscatter information within a water profile at a single or series of locations can be applied to a range of study areas such as suspended sediment, hydraulic modeling, etc.

Scouring around hydraulic structures can result in significant damage to water, road or harbor infrastructure. The amount of scouring over a period can be determined by collecting depth and velocity information near hydraulic structures.

Mapping velocity profiles at various locations within and around hydraulic structures allows designers to determine the optimal design and best model calibrations. For these specialized applications, it is recommended that the raw data from the RSSL matlab export are used. The discharge, area and width calculated during the individual point measurements is not applicable and should be discarded.

VI. CONCLUSIONS

RiverSurveyor Stationary Live 4.0 with GPS Positioning is an accurate solution for stationary measurements. The method improves the overall measurement process, efficiency and accuracy.

The accuracy of the method is however dependent on the quality of GPS data and the measurement results have shown that the same level of accuracy can be obtained with both DGPS and RTK. A sufficient number of satellites and or correction services (SBAS or L-Band) is required to achieve the required accuracy level for Stationary measurements.

ABOUT OUR AUTHORS:

DANIEL WAGENAAR - Senior Hydrologist
Daniel started his hydrographic career in South Africa with experience in surface water and ground water monitoring. He continued with his career progression as Technical Manager of hydrographic operations overseeing all computations including stage-discharge development and data processing. He expanded his 25 years' experience in hydrographic operations by accepting Manager of Water Monitoring Systems position in Australia, responsible for the design of business process frame works and the development of operational standards, quality assurance systems and training programs. His current focus at SonTek is the improvement in the application of methodology, quality assurance and data management principles used in collecting Acoustic Doppler data with respect to International Standards and Organizational requirements. Daniel holds a B.Sc. in Water Engineering from Central University Technology and B.Sc. in Geohydrology from Free State University.

XUE FAN - Application Engineer
While you may already know her from SonTek's stellar Technical Support group, Xue recently joined the Product Management team as Application Engineer. She has a Doctorate in Physical Oceanography from Scripps Institution of Oceanography, and Bachelors in Physics and Atmospheric/Oceanic Sciences from McGill University (Canada), She speaks English, Chinese and French.

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