Technical Paper
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SonTek RS5: Performance Evaluation Through Field Data

Dr. Xue Fan, Senior Application Engineer


RS5 stream gauging measurement, United Kingdom

Introduction

The SonTek RS5, released in August 2020, is the newest member of the RiverSurveyor family of acoustic Doppler current profilers (ADCPs). The RS5 builds upon the acoustic technology developed for the RiverSurveyor M9/S5 while adding expanded capability through its Broadband transducers, self-resolving Pulse-coherent pinging, and creative design to achieve the best data possible for discharge measurements. Both hardware and software for the RS5 have incorporated years of customer feedback and suggestions. Using modern electronics, SonTek has built the most compact, portable, light-weight, and user-friendly ADCP for shallow water discharge measurements available.

This Technical Note introduces certain technical aspects of the RS5 and highlights its capabilities in the field by showing data comparisons using other ADCP systems at a wide variety of different sites. The data shown in this Technical Note were used in the development of the RS5 acoustic algorithms and to optimize the performance for shallow discharge measurements.

SonTek:
Founded in 1992 and advancing environmental science in over 100 countries, manufactures affordable, reliable acoustic Doppler instrumentation for water velocity measurement in oceans, rivers, lakes, harbors, estuaries, and laboratories.

Headquarters are located in San Diego, California. SonTek is part of Xylem, Inc., a company that provides monitoring and data collection instrumentation to global water quality, water quantity, and aquaculture markets.

Additional information:
For more information about SonTek visit SonTek.com, or email SonTek directly at inquiry@SonTek.com.

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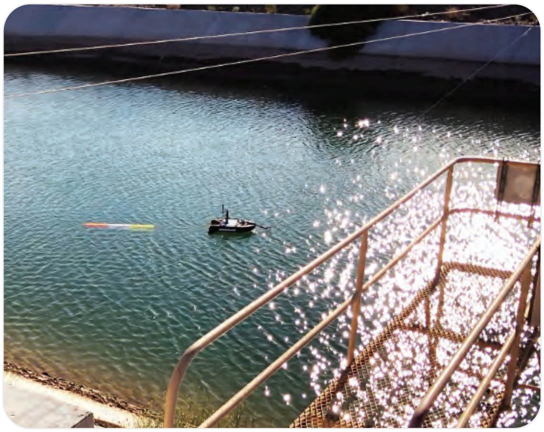
SmartPulse+

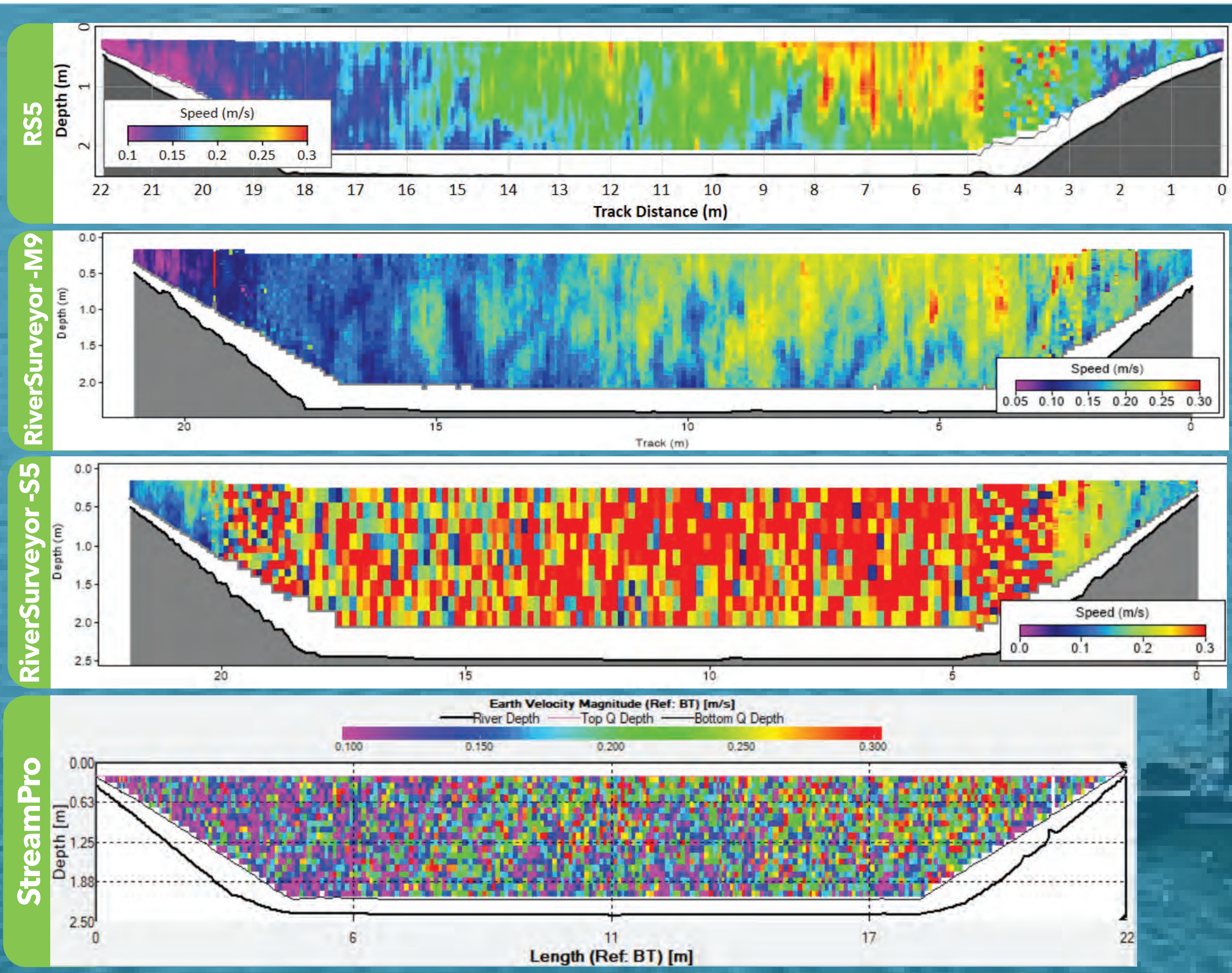
At the core of the RS5 acoustics engine is a completely new combination Broadband/Pulse-coherent pinging algorithm using new Broadband transducers. Compared to the M9/S5-style narrow-band transducers capable of Pulse-coherent and Incoherent pinging, the RS5 acoustic capability is expanded to allow complex combinations of Broadband and hybrid Pulse-coherent acoustic signals resulting in 4 different specialized ping types per sample. The SmartPulse+ algorithm uses the detected depth for each sample and automatically configures the appropriate settings for all 4 ping types. The algorithm then combines the best dataset from the different ping types based on complex algorithms to achieve the highest quality velocity profile for each sample, and changes those settings automatically throughout the measurement.

SonTek RS5 versus SonTek RiverSurveyor M9/S5 and TRDI StreamPro

During the development of the RS5, discharge measurements were performed at controlled sites with different systems commonly used for those sites and conditions. Here at the site pictured right, discharge measurements were performed at a concrete-lined canal at USGS gauging station 09522500 using the SonTek RS5, SonTek RiverSurveyor M9, S5, and the TRDI StreamPro.



Application Engineer RS5 testing, Yuma, AZ (USA).



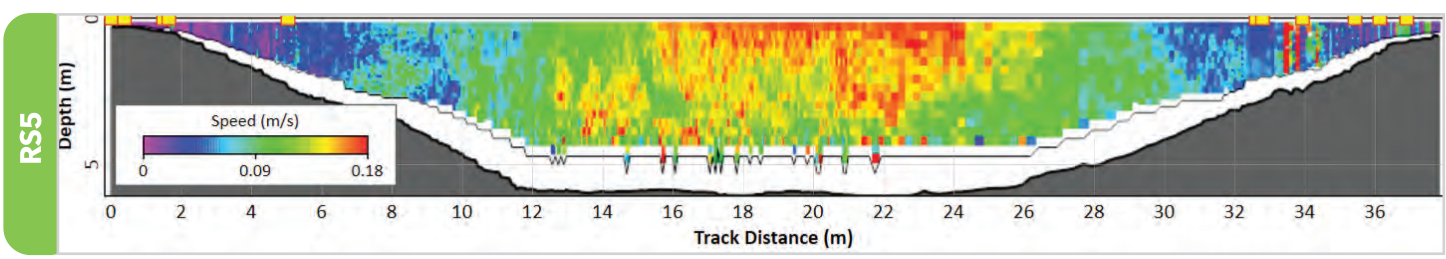
This particular site has been surveyed extensively due to the trapezoidal broad-crested weir built downstream of the measuring location. Because of remnants of a cofferdam at this location, velocities are consistently higher on the right side of the transect, which can be seen from the more red colors in the RS5 and M9 contour plots. It is clear that the velocity profiles from the RS5 and M9 provide the most detail in terms of resolution and flow structure changes across the transect compared to the S5 and the StreamPro. While the RS5's profile shows comparable definition to the M9 transect, the M9 data quality is only comparable to the RS5's thanks to its dual-frequency SmartPulseHD® capabilities. Due to its single-frequency limitations, the S5 SmartPulse algorithm was forced into Incoherent mode given the velocities at this site, resulting in a very coarse dataset compared to the RS5, which is capable of staying in Pulse-coherent mode. Finally, the StreamPro requires the user to set a fixed cell size configuration and ping type, resulting in velocity contours that do not resolve the complex velocity structure that is observed at this site, despite the seemingly simplistic type of site.

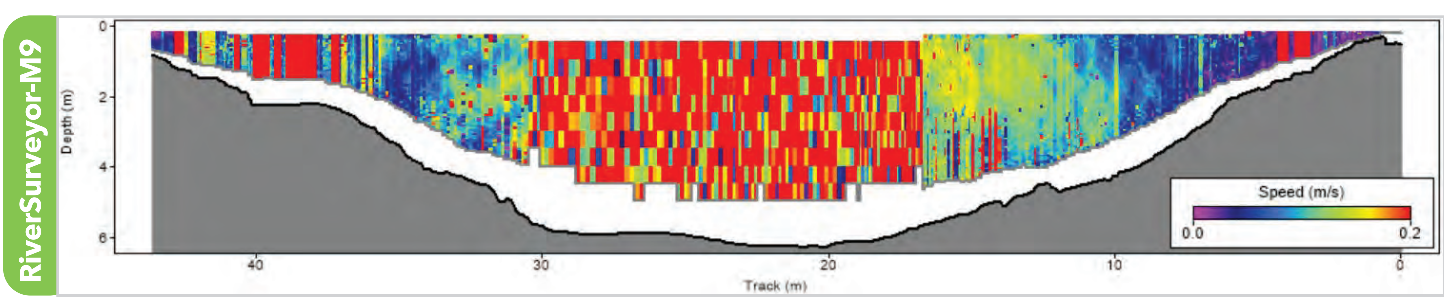
RS5 (Broadband/Pulse-coherent) versus M9 (Incoherent) Performance

Sites with certain velocity and depth features allow the RS5 SmartPulse+ algorithm to stand out even when compared to the RiverSurveyor-M9, like the following Environment Agency River Gauging Station called Skelton on the River Ouse near York in the United Kingdom (UK). In the middle of the transect, velocities were high enough and the channel was deep enough to force the M9 SmartPulseHD algorithm to use the 1MHz Incoherent ping type, resulting in much larger cells and noisier data compared to its Pulse-coherent (called "HD") pings near the edges.

While the final discharge values are comparable, it is clear from this example that the RS5 SmartPulse+ algorithm better handles such variation in flow, ranging from very slow-moving water near the edges, to deep and faster flow in the central part of the transect. In this case, the RS5 is able to resolve the detailed surface-intensified flow in the center of the channel, whereas this is not as apparent in the M9 dataset.

Skelton on the River Ouse near York, United Kingdom. Data and photo credits: Lee Pimble, SonTek Hydrometric Technical Applications Manager, Europe.



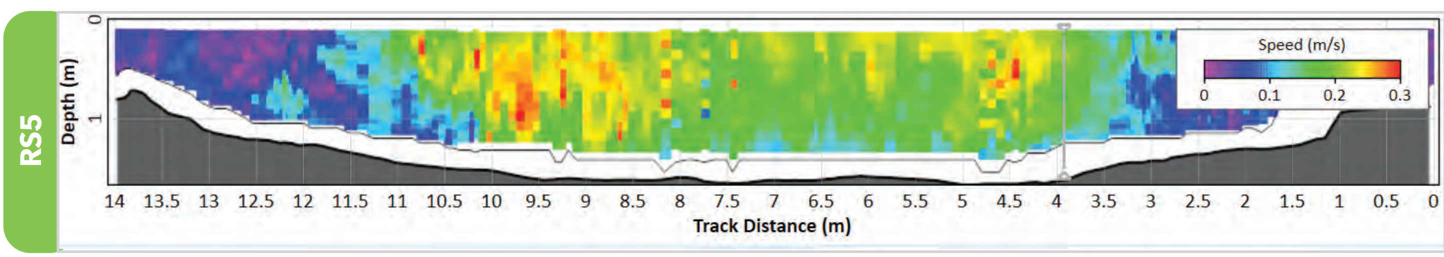


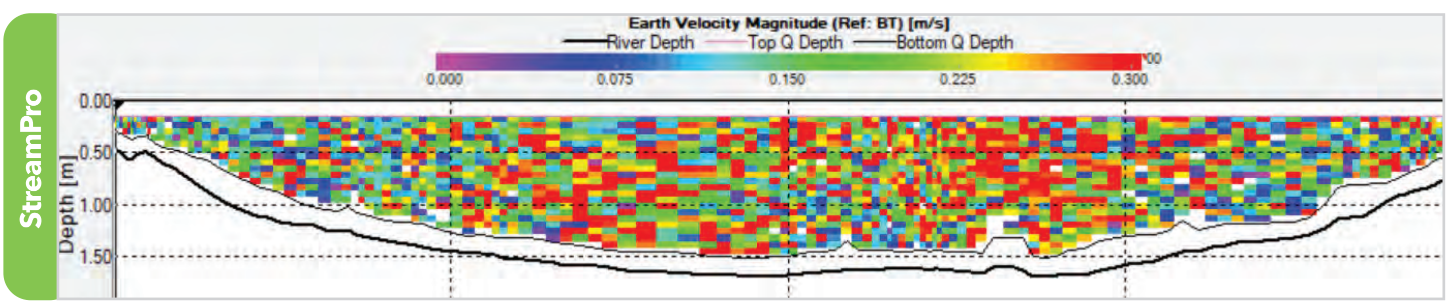
High Resolution Profiling

The RS5 is designed to produce optimal data quality in shallow, often noisy stream environments. Because shallow environments are much more susceptible to unusual flow conditions due to obstructions and variability in the flow, development focused on producing the highest resolution dataset while at the same time measuring velocities with the least uncertainty and noise.

Noise in acoustic profiling instruments often results in a "patchwork" or "harlequin" looking image with no apparent flow pattern, as can be seen at the following site using the StreamPro. This shallow stream, located at USGS Gauging Station 03302000 at Pond Creek near Louisville, KY (USA), highlights the high resolution shallow capabilities of the RS5.

Photo and data courtesy of Tim (Shawn) LeMaster, USGS.

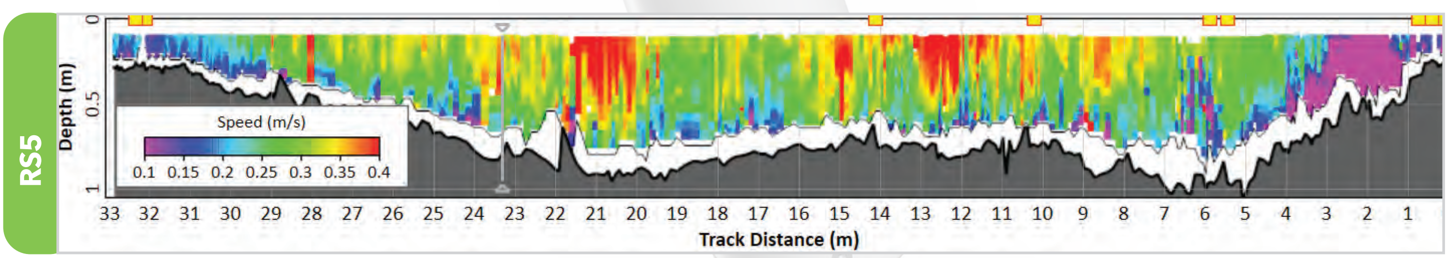


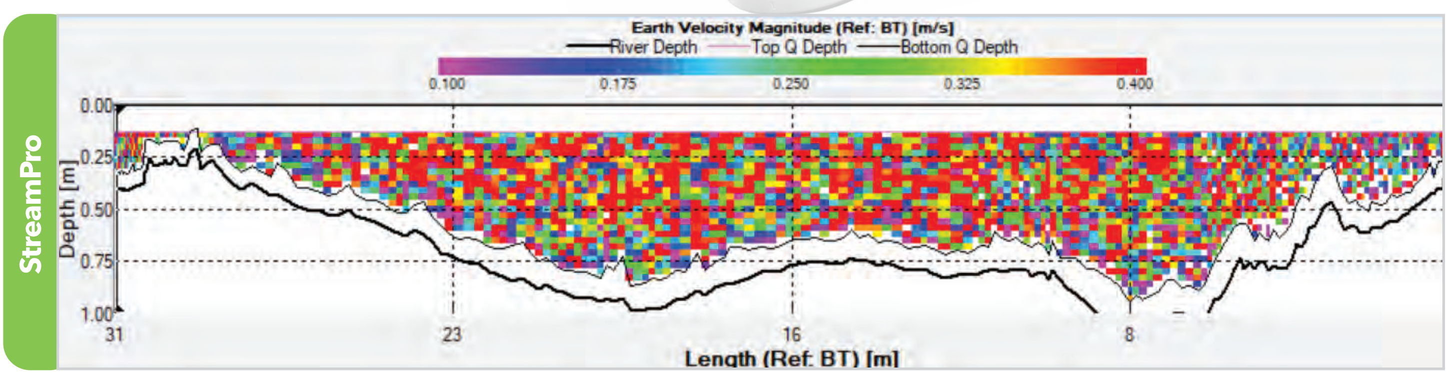


At another site near Asheville, NC (USA) at USGS gauging station 034557730, pictured to the right, shows the same effect.

It is evident from the photo that complex flows might be expected due to the cobbles and large boulders on the bottom. The transect from the RS5 clearly highlights the complex flow structure caused by the varying bottom shape, and shows some unexpected areas of highest flow off-center from the middle of the channel. Also evident is the more detailed channel bathymetry provided by RS5's vertical acoustic beam, whereas the StreamPro can only provide a mean depth averaged from its four slanted beams.

Photo and data courtesy of John Mazurek, USGS.





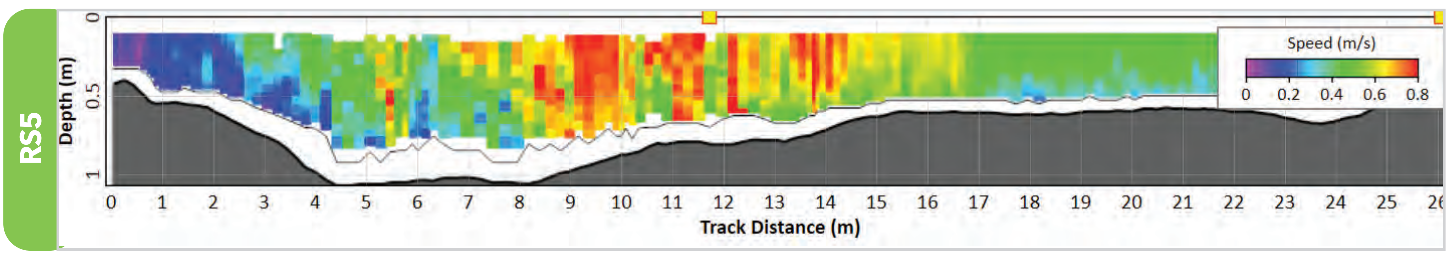
Velocity Profiles with Less Random Noise

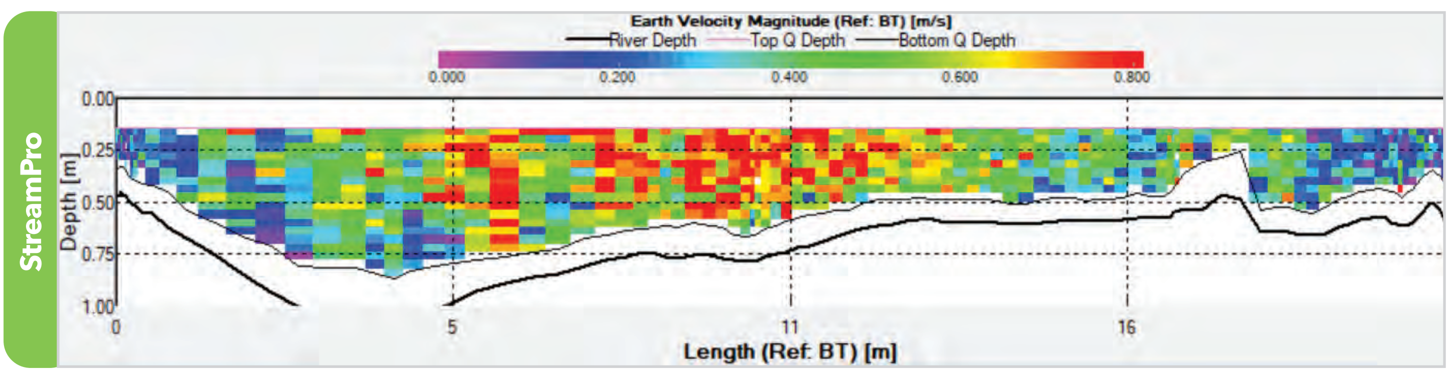
The RS5 SmartPulse+ uses many different criteria to decide on the best velocity profile for a given sample. One of the most important factors used in the decision is the velocity standard deviation. The standard deviation is a statistical value representing how noisy a certain velocity sample is; the higher the standard deviation, the higher the noise, and the more "patchy" the data will look.

Because great care has been taken to reduce measured velocity noise, data from the RS5 at many sites will have a higher resolution, whereas other instruments may produce a lower resolution image of the flow.

An example of such a site is shown here, at the USGS gauging station 07378000 on the Comite River near Comite, LA (USA).

Photo and data courtesy of James Fountain, USGS.





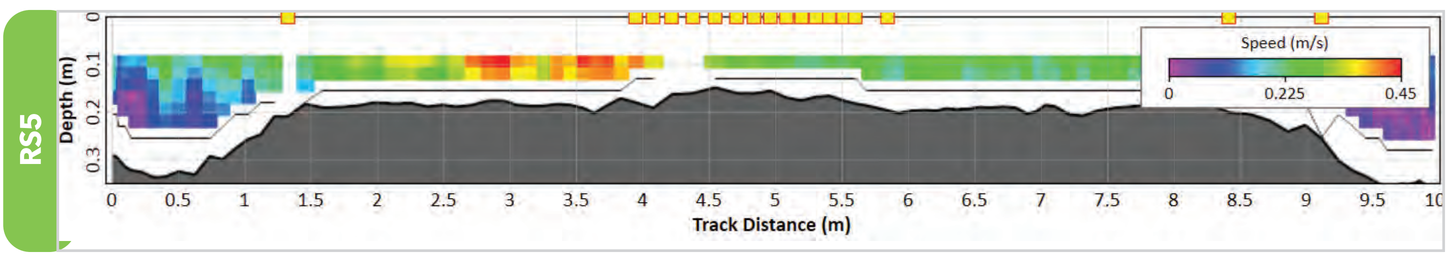
While the general structure of the flow can be observed in the StreamPro data, with more red colors near the center of the channel where highest velocities exist, the RS5 dataset produces a smooth contour plot with minimal grainy noise throughout the velocity contour plot. Noise reduction provides the most precise velocity measurements to calculate discharge and allows various fine-scale features to be visible in the transect that would otherwise be hidden in the data scatter, like the small near-bottom peak in velocity near the left bank.

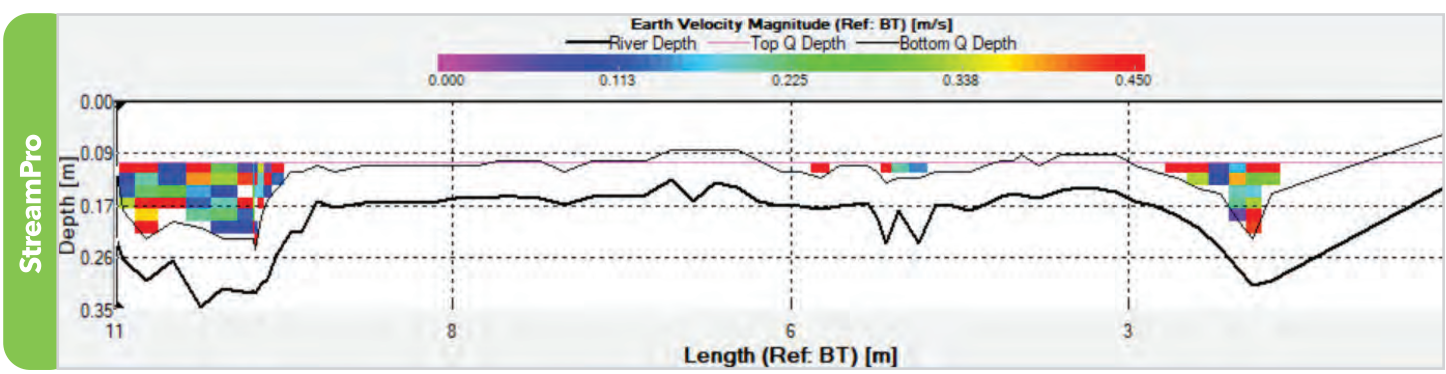
Ultra-Shallow Capabilities

The RS5's compact shape and small footprint make it ideal for shallow water discharge measurements where the user prefers not to wade (with a FlowTracker, for example) or requires a profile as opposed to a point measurement, where possible. The SmartPulse+ algorithm is optimized for fine-scale near-surface measurements, ensuring that the shallowest data possible can be collected.

The RS5 is able to achieve velocity cells at depths that are too shallow for other instruments. An example is illustrated here, again from Asheville, NC (USA) at USGS gauging station 03298150.

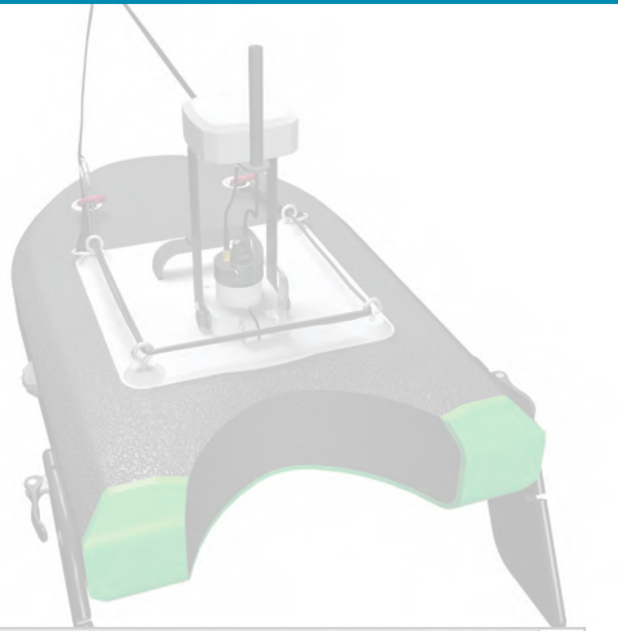
Photo and data courtesy of Tim (Shawn) LeMaster, USGS.





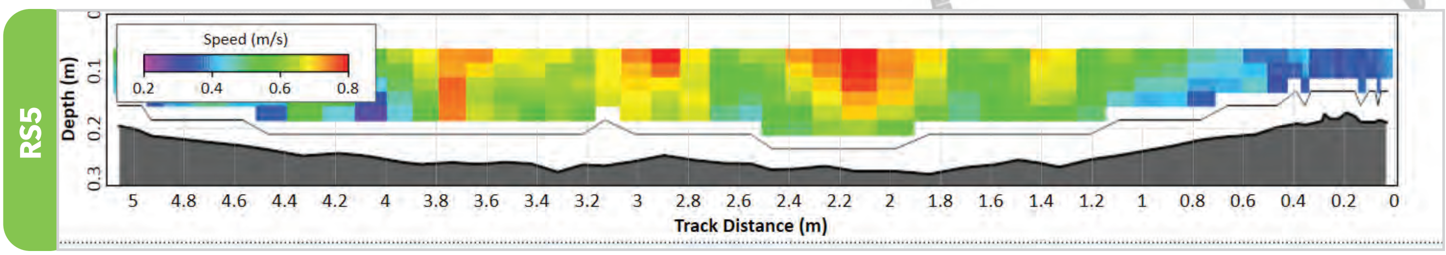
At this site, water depths get as shallow as about 13cm. While the StreamPro is unable to achieve any cells or profiles in most of the shallowest region of the cross-section, the RS5 is able to return at least one cell (and often many cells) throughout most of the transect. Sites originally too shallow to measure with an ADCP are now accessible with the RS5.

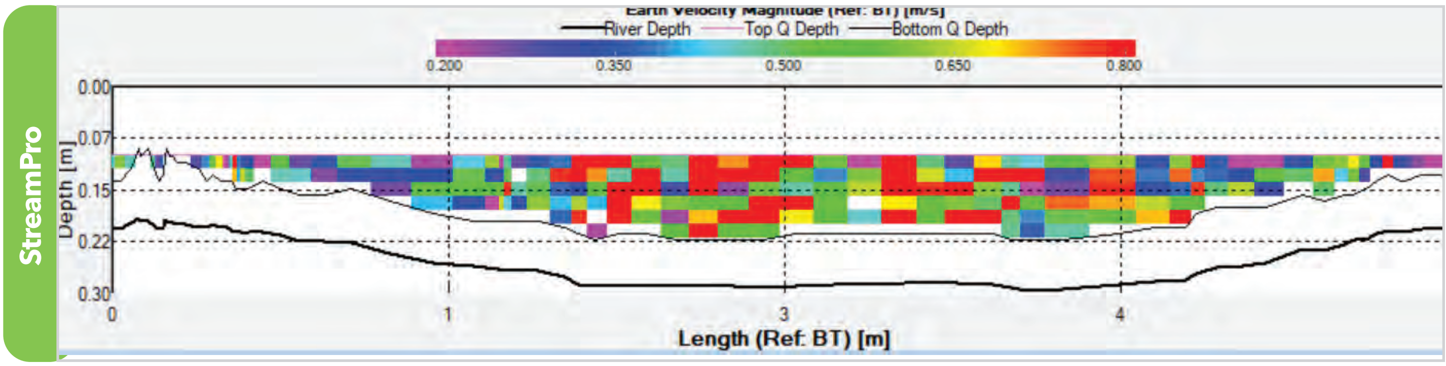
RS5 Application Engineer testing site, Yuma, AZ (USA).



A combination of the RS5's shallow capabilities and high-definition data resolution is shown in the example here, collected near Yuma, AZ (USA).

This shallow site reaches no more than 30cm at its deepest. While the Streampro is able to achieve velocity cells at these depths, the RS5's high resolution algorithm is able to highlight in smooth gradients the areas of highest and lowest flow which are lost in the noisier StreamPro data.



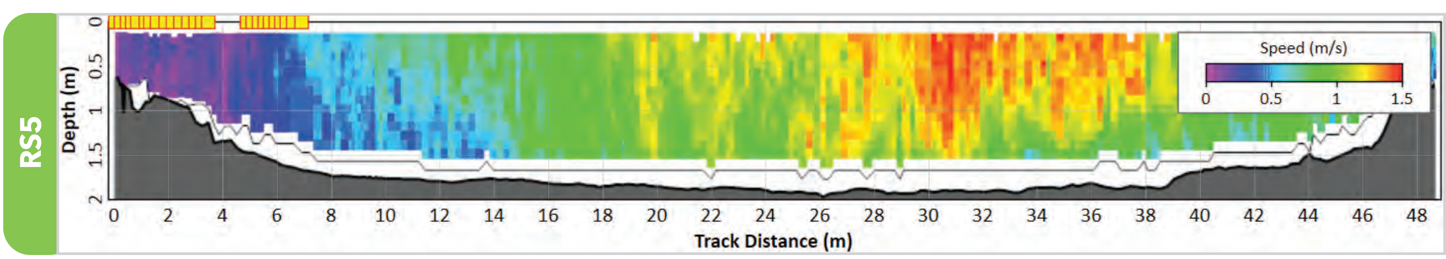


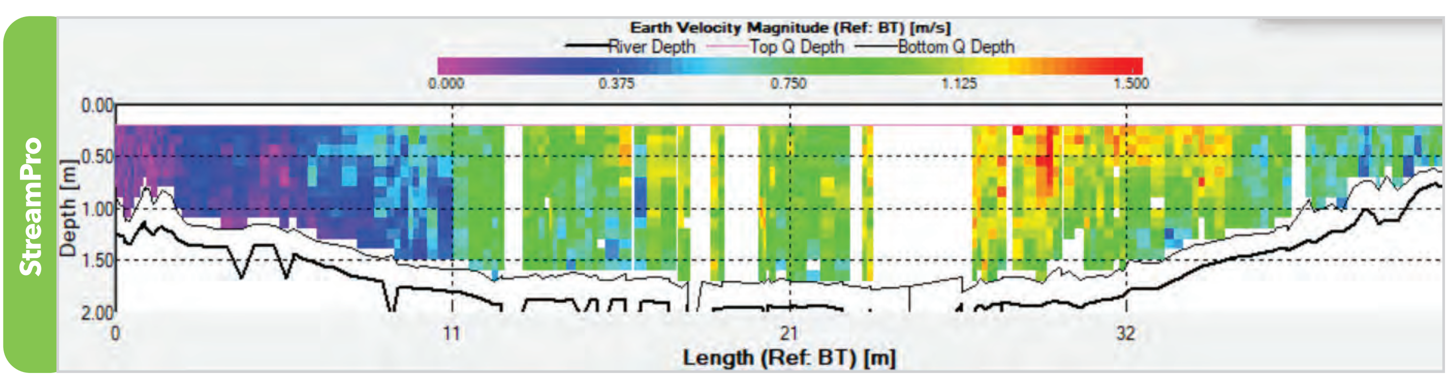
Bottom-Tracking and Bottom Detection in Difficult Substrates

The RS5 SmartPulse+ algorithms apply to all velocity calculations, which include both velocity of the water and the boat movement, called Bottom-Tracking. The Bottom-Tracking algorithm calculates with great accuracy the movement of the boat over ground, which is then used to correct the raw velocity measurements to separate out the water velocity itself. Because of the use of the combined Broadband and self-resolving Pulse-coherent techniques, the RS5 is able to achieve more stable, better quality Bottom-Tracking than comparable instruments. It provides more reliable Bottom-Track data in difficult conditions for acoustics (including highly variable rocky bottoms and some types of vegetation).

The following measurements were collected at the USGS gauging station 07048600 on the White River near Fayetteville, AR (USA). The site photo shows a semi-turbid flow with a transect containing large cobbles and vegetation near the edges. The main streambed is mainly gravel. The combination of high sediment load and variations in bottom substrate (cobbles to gravel) make this site a challenge for both bottom detection and Bottom-Tracking. With the benefit of having a vertical beam, the RS5 is able to maintain a depth measurement throughout the transect and reliably reports Bottom-Tracking velocity compared to the StreamPro.

Photo and data courtesy of Neil Holaway, USGS.





During the RS5 development, sites that have historically caused Bottom-Tracking issues for ADCPs were targeted. The example below shows a site, operated by Canals and River Trust, with a highly-variable stone bed under fast-flowing (up to 1 m/s or 3 ft/s), silty water. It is located on the Bywash channel at the Toddbrook Reservoir at Whaley Bridge near Manchester, UK.

The combination of these conditions proves to be very difficult for the RiverSurveyor M9 to maintain bottom-track lock during the transect, as shown below. Because the bottom-tracking algorithm has the help of the self-resolving Pulse-coherent pinging and tuning specifically for these difficult shallow sites, the RS5 successfully collects a full dataset across the cross section.

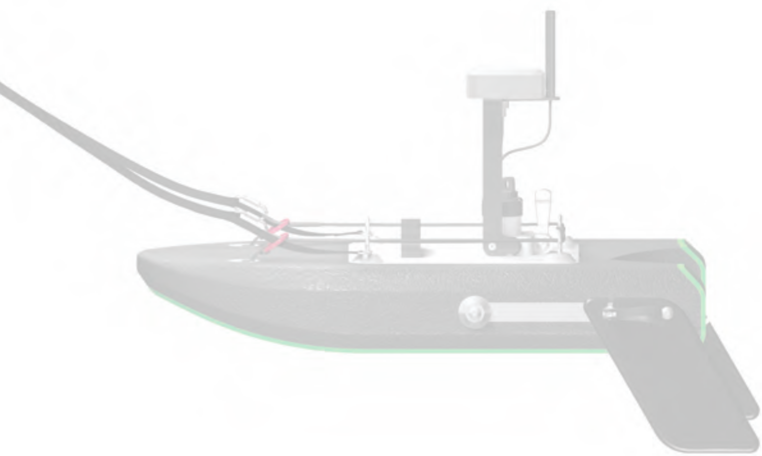
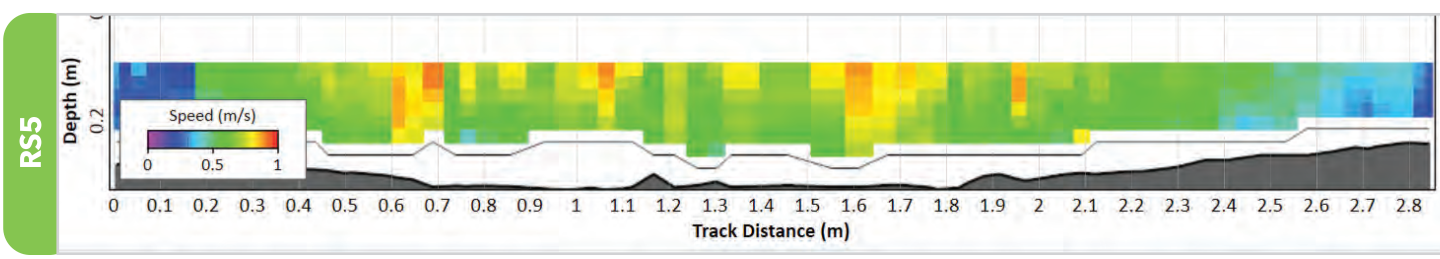
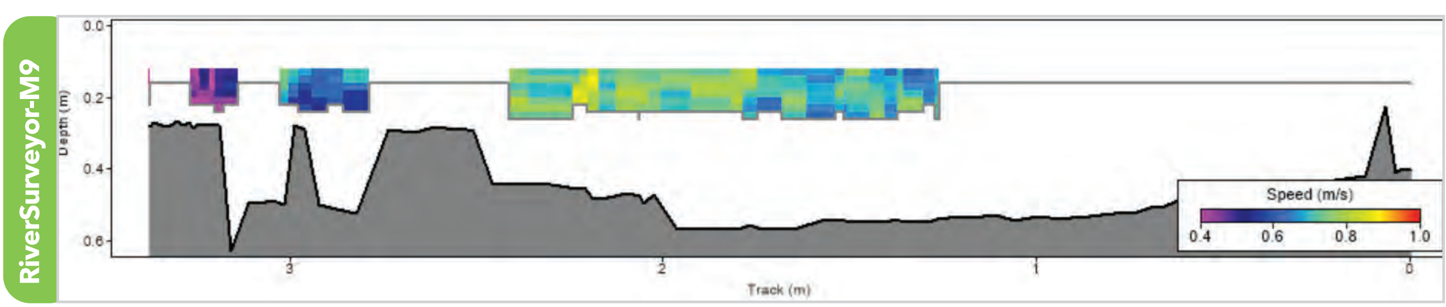


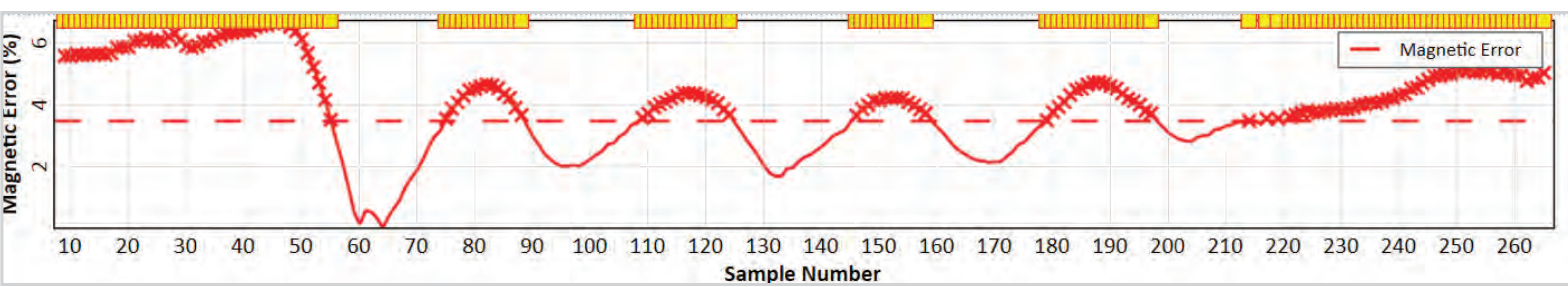
Photo and data courtesy of Nick Martin, Xylem UK, and the Canals & Rivers Trust





RS5's Other Unique Features

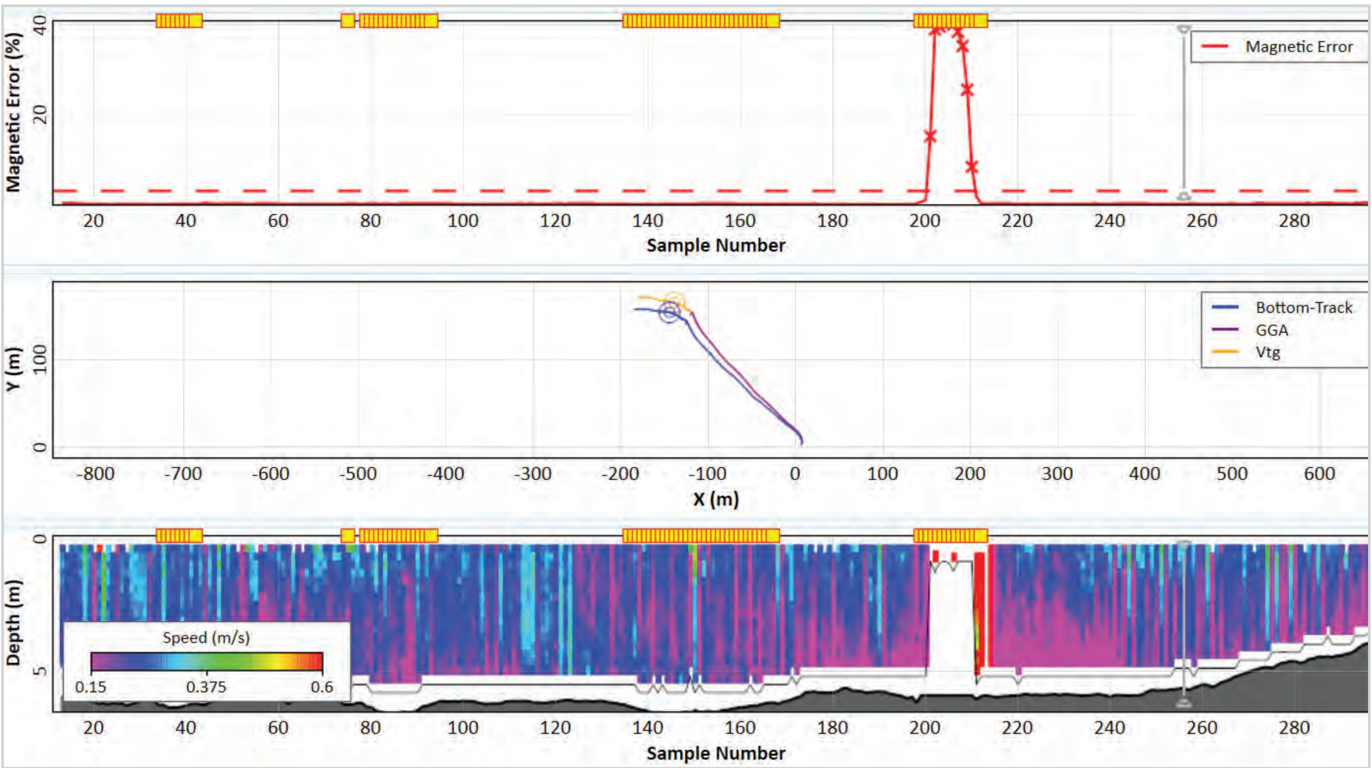
Unlike the StreamPro, the RS5 comes standard with a magnetic compass, whether it be the Standard (no GPS/GNSS) or Max (GPS/GNSS-enabled) model. This enables the user to collect Loop Moving Bed Tests and stationary discharge measurements (coming soon). The RS5 magnetic compass is the same high-quality SonTek-built compass used in the M9/S5 systems (often referred to as the "G3" compass) and provides real-time magnetic error feedback. In the example below, the RS5 performed a transect upstream of the bridge pictured.



The magnetic error is reported along with warnings (red hashes) when the system goes near each bridge piling, indicating that the magnetic error exceeds the calibration limit for accurate discharge.

Automatic Reconnection and Data Buffering for 5 Minutes

The RS5 comes with a robust automatic reconnection feature that will re-establish Bluetooth connection if lost. Unexpected things always happen in the field, including losing direct line of site, mishaps with the radio antenna or USB radio, losing power, or as in the following case, accidentally flipping the boat entirely, resulting in lost communications. The RS5 and boat were underwater for about 10 seconds (during the period outlined in the figure) before they were righted, and the connection through the RSQ software was picked up immediately without any user interventions.



When data connection is lost, the RS5 stores backup data internally for up to 5 minutes. When communications are restored, the data are transferred back to the computer and sorted accordingly so no data are lost within the 5-minute communications gap. This data buffer offers a way to preserve samples if communications are lost so the transect does not need to be repeated.

Final Notes

The SonTek RS5 incorporates both innovations in acoustic technology as well as years of customer feedback on acoustics and software interfacing to provide the highest quality data and smoothest user experience available. The SmartPulse+ algorithm and new acoustic developments allow the RS5 to meet and exceed data quality and resolution capabilities compared to other discharge measurement systems. The data examples shown in this Technical Note span a wide range of site conditions and applications and display the power of a complex acoustics engine in a small physical form.

SonTek, a Xylem brand
9940 Summers Ridge Rd.
San Diego, CA 92121

+1.858.546.8327
inquiry@sontek.com
SonTek.com

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