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Tethered Acoustic Doppler Current Profiler Platforms for Measuring Streamflow

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U.S. Department of the Interior
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By Michael S. Rehmel, James A. Stewart, and Scott E. Morlock

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Conversion Factors and Abbreviations

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
square foot (ft^2)	0.09290	square meter (m^2)
pound (lb)	0.4536	kilogram (kg)

Abbreviations used:

DC	Direct Current
kHz	Kilohertz
MHz	Megahertz

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Abstract

The U.S. Geological Survey tested and refined tethered-platform designs for measuring streamflow. Platform specifications were developed, radio-modem telemetry of acoustic Doppler current profiler (ADCP) data and potential platform-hull sources were investigated, and hulls were tested and evaluated.

Different platforms, which included a variety of hull configurations, were tested for drag and stability at the U.S. Geological Survey tow tank and at a field site below a reservoir. The testing indicated that, although any of the designs could be used under certain conditions, trimaran designs provided the best all-around performance under a range of conditions. The trimaran designs housed the ADCP in the center hull; this resulted in lower drag than the catamaran designs and retained the stability advantage of catamarans over monohull designs. Waterproof radio modems that operate at 900 megahertz were used to communicate wirelessly with instruments at high baud rates.

A tethered-platform design with a trimaran hull and 900-megahertz radio modems is now commercially available. Continued field use has resulted in U.S. Geological Survey procedures for making tethered-platform discharge measurements, including methods for tethered-boat deployment, moving-bed tests, and measurement of edge distances.

Introduction

Acoustic Doppler current profilers (ADCPs) use sound transmitted in water to measure water speeds and depths. When deployed from a moving boat, ADCPs also can use these transmitted sounds to measure the speed and direction of the boat. The capability of ADCPs to measure water speed, depth, boat speed, and boat direction makes them useful in measuring streamflow (discharge). Continued developments in ADCP technologies have resulted in their use in a wide range of conditions.

Purpose and Scope

This report describes the development, evaluation, and application of an unmanned tethered ADCP platform for measuring stream discharge. The report provides a brief description of ADCP principles and describes the development of the unmanned tethered ADCP platform, including the original prototype platform built and tested by the U.S. Geological Survey (USGS) Indiana District and its refinement. The report then describes procedures specific to tethered-platform ADCP discharge measurements.

The term "ADCP" in this report refers to a generic hydroacoustic instrument that measures discharge from a moving boat and not to a specific instrument by any manufacturer. Although instruments from only one manufacturer were available during this study, the USGS uses instruments from various manufacturers.

Description of Acoustic Doppler Current Profilers

ADCPs transmit sound into the water and receive reflected sound (echoes) from particles suspended in the water. The frequency shift between the transmitted sound and echoes is used to compute the velocities of the particles and the water in which they are suspended. ADCPs measure boat speed and direction by tracking the river bottom, and they are able to compensate for the boat movement in the computation of water velocities. The ADCP beam geometry is designed for the measurement of three-dimensional velocity profiles. Because an ADCP can measure water velocities, depth, and platform path simultaneously, it can compute discharge. To make a discharge measurement with an ADCP, a portable computer loaded with the ADCP manufacturer's data-collection and processing software is interfaced with the instrument. For more detailed explanations of USGS use of ADCPs, see Morlock, 1996; Gordon, 1996; or Simpson, 2002.

Evaluations of ADCPs showed that the instruments can be used to make discharge measurements that meet USGS accuracy standards (Morlock, 1996). Subsequently, the USGS has developed procedures, published a quality-assurance plan (Lipscomb, 1995), and is providing training classes for USGS and other government ADCP users. As of 2001, the Indiana District had made more than 500 discharge measurements with ADCPs. The USGS currently uses more than 100 ADCPs for routine discharge measurements and for specialized studies.

An ADCP discharge measurement is made by moving the ADCP across the stream channel while data are being collected. A single crossing, or transect, of the stream results in one measurement of discharge. Typically, the USGS averages the discharges from at least four transects to reduce the effects of turbulence, directional bias, or other random errors. The average of the discharges from the multiple transects then is considered to be a single measure of the discharge for the stream during the time in which the transects were made.

Development of the Tethered Platform

In 1994, the USGS Indiana District began using a 600-kHz frequency ADCP to measure river discharges at streamflow-gaging stations from a manned 5-meter aluminum boat. Most of these measurements were made with greater accuracy, efficiency, and safety than was possible with conventional methods that relied on mechanical propeller-type current meters to measure discharges. This ADCP weighed approximately 70 pounds and could be deployed practically only from a manned boat.

In 1997, the USGS Indiana District purchased two new-model ADCPs, one with a 1200-kHz and one with a 600-kHz transducer assembly. The new-model ADCPs weighed about 12 pounds and were about one-third the length of the older model (fig. 1). The smaller size of the ADCPs led the Indiana District to develop an innovative prototype unmanned tethered platform from which to deploy ADCPs for making discharge measurements.

Figure 1. Comparison of first (left) acoustic Doppler current profiler (ADCP) used by the U.S. Geological Survey Indiana District and a newer model (right) ACDP purchased in 1997.

Tethered platforms were needed at sites where conventional methods were used in making discharge measurements from bridges and in places where lack of access prevented use of an ADCP from a manned boat. The concept was to float an ADCP on a small, light, unmanned platform that would be attached to a rope (or tether). With the tether, an operator could lower the platform from the bridge, then pull the platform back and forth across the stream to complete transects and measure discharge. Alternatively, operators on opposite streambanks, each with a tether attached to the platform, could move the platform across the stream or the operators could deploy the platform from rope and pulley arrangements (such as a cableway). The prototype tethered platforms were used in a series of verification tests and were found, in many cases, to result in safer and more-efficient discharge measurements compared to conventional methods with mechanical current meters.

Original Prototype Tethered Platform

The original prototype tethered platform was designed with the following criteria: light weight, made from readily available materials, easy to construct, sturdy, inexpensive, and stable in the water. Stability for this platform meant it must be resistant to capsizing, excessive pitch and roll, and the tendency to quickly oscillate back and forth in strong currents. A catamaran configuration was selected because it was believed to be stable yet easy to design and build.

The catamaran was constructed of polystyrene-foam floats built from a composite of several layers of 2-in.-thick standard insulation cut into a semi-V shape (fig. 2). The floats then were connected together with tubular aluminum struts. A waterproof plastic enclosure was attached to the aluminum frame, which stiffened the boat frame.

Figure 2. Original U.S. Geological Survey Indiana District prototype acoustic Doppler current profiler (ADCP) tethered platform.

The enclosure housed the radio modem necessary for communication with the ADCP and the 12-volt battery that powered the modem and ADCP. The ADCP was attached to the frame at a point centered to the boat width and slightly forward of the center of the boat length. Additional aluminum bars were used on top of the enclosure to act as skids for the boat; the skids prevented abrasion of the floats and enclosure if the boat made contact with the bridge guardrail or edge while being lowered or raised.

To measure discharge with an ADCP, data must be collected on a portable computer. When deployed from a manned boat, the ADCP is connected with a cable to the computer. For tethered-platform applications, a pair of radio modems link the ADCP to the computer. The radio modems used on the original prototype allowed two-way communication between the ADCP and the computer at a rate of 19,200 baud.

Feasibility Measurements

A series of discharge measurements were made from November 1997 through August 1998 to test the feasibility of making discharge measurements with a tethered platform. The measurements were made over a range of site and flow conditions and followed the recommended procedures outlined by Lipscomb (1995). Discharges were obtained by other USGS methods at each site for comparison to the tethered-platform measurements.

For RD Instruments systems, the USGS uses either ADCP water modes 1, 5, or 8, depending on site conditions. These modes (listed in table 1) use different acoustic water-velocity sampling schemes. Generally with the equipment used for the feasibility measurements, mode 1 is used in deep rivers; mode 5 in shallower, slow rivers; and mode 8 in shallow rivers where the current is too swift to use mode 5.

The data presented in table 1 indicate that the use of the unmanned tethered platform can result in discharge measurements that meet USGS standards. The Indiana District continued to use the original prototype tethered platform for routine discharge measurements and found the platform particularly valuable during flooding in January 1999. The platform allowed District personnel to measure a number of flood flows efficiently, safely, and within the acceptable USGS range of accuracy. Tethered platforms were needed at sites where conventional methods were used in making discharge measurements from bridges and in places where lack of access prevented use of an ADCP from a manned boat.

Advantages and Limitations of Tethered Platforms

The use of tethered platforms for ADCP discharge measurements has many advantages over manned-boat ADCP discharge measurements and conventional mechanical current-meter-type discharge measurements. Tethered platforms for ADCP discharge measurements, however, have some limitations that may make them impossible to use at some sites.

Advantages

- ADCP discharge measurements can be made with tethered platforms where manned boats cannot be launched.
- The unmanned platform eliminates risks associated with personnel working from boats, particularly in swift rivers or during floods.
- ADCP discharge measurements usually can be made faster than conventional mechanical current-meter-type discharge measurements made from bridges, reducing personnel time on bridges and exposure to traffic hazards. During periods of rapidly changing stage or flow, this faster measurement can result in a more accurate stage/discharge relation.

Table 1. Comparison of discharge measured with an unmanned tethered acoustic Doppler current profiler (ADCP) platform and other acceptable U.S. Geological Survey methods at Indiana testing sites
[kHz, kilohertz; ft^3/s, cubic foot per second; --, no remark]

Tethered-platform ADCP discharge measurement: Frequency (kHz)	Water mode	Discharge (ft^3/s)	Comparison discharge measurement (ft^3/s)	Departure of platform from comparison discharge (in percent)	Remarks
Station: Indianapolis Water Supply Canal at Broad Ripple; Date: 11/04/97					
1200	5	104	108	-3.7	Flow slow and steady
Station: Indianapolis Water Supply Canal at Broad Ripple; Date: 08/14/98					
1200	5	111	110	+.9	Flow slow and steady
Station: Grand Calumet River at Industrial Highway at Gary; Date: 08/18/98					
1200	1	537	523	+2.7	Flow turbulent
Station: Wabash River at Lafayette; Date: 07/24/98					
1200	1	47,800	54,500	-12.2	Flood flow; detected moving river bed that could bias ADCP measurement low
600	1	50,100	54,500	-8.1	Flood flow; detected moving river bed that could bias ADCP measurement low
Station: Wabash River at Peru; Date: 07/23/98					
600	1	13,700	13,300	+3.0	Flood flow
Station: Wabash River at Wabash; Date: 06/18/98					
1200	1	3,400	3,290	+3.2	Flood flow
Station: Salamonie River at Warren; Date: 06/17/98					
600	1	2,550	2,680	-4.8	Flood flow
Station: St. Joseph River at Elkhart; Date: 08/18/98					
1200	1	2,270	2,350	-3.5	Some turbulence in flow
Station: St. Marys River at Decatur; Date: 04/17/98					
1200	1	1,230	1,210	+1.7	--
Station: Kankakee River at Dunns Bridge; Date: 08/17/98					
1200	1	783	866	-12.0	Flow uniform and steady
1200	8	857	866	-1.0	Flow uniform and steady
600	8	861	866	-.1	Flow uniform and steady
Station: Kankakee River at Shelby; Date: 08/17/98					
1200	1	924	1,100	-16.0	ADCP measurement poor due to platform speed and rapid oscillations
600	5	970	1,100	-11.8	ADCP measurement poor due to platform speed and rapid oscillations
600	8	978	1,100	-11.1	ADCP measurement poor due to platform speed and rapid oscillations

- ADCP discharge-measurement quality can be affected significantly by speed and control of the ADCP. The tethered platform can be moved across the river more slowly and with more control than a manned boat, improving ADCP measurement quality at some sites.

Limitations

- Measurement-site selection is limited. Use of a tethered platform usually is confined to the downstream side of bridges and to cableways. The ability to change measurement sections from these structures is limited to changes in rope length to vary the downstream distance of the platform.
- The quality of discharge measurements made on the downstream side of bridges can be degraded by turbulence from bridge piers.

Platform-Refinement Needs

The original prototype unmanned tethered platform was designed by intuition and trial and error, with no formal design process (such as estimating hydrodynamic parameters like drag). While the prototype proved that the concept was viable, experience in constructing and operating the platform resulted in refinements. Although the platform was stable, the general consensus was that the stability should be improved and drag reduced in stream currents greater than 5 ft/s. A commercially available hull that could be modified or platforms constructed by private vendors for this application were seen as a necessary component to anticipated widespread USGS use. The radio modems originally used to transmit data from the ADCP were not reliable under many of the desired operating conditions, and a better-suited replacement was needed.

Project to Refine the Tethered Platform

The tethered platform invited interest from other USGS district offices because of the potential to reduce personnel exposure to hazards during streamflow-gaging activities. At the request of the USGS Chief Hydrologist, the Office of Surface Water Hydroacoustics Workgroup prepared a proposal for refining the design of the tethered platform in 1999; the USGS Instrumentation Committee accepted the proposal for this project.

The primary objective of the project was to develop and test designs for tethered platforms to increase safety during streamflow-gaging activities. Testing was conducted from October 1999 through September 2001. The project included the following major tasks:

- develop specifications based on a survey of user needs;
- investigate various models of radio modems for wireless data telemetry;
- investigate commercial availability of platform hulls;
- test and evaluate prototype hulls;
- make designs available to USGS district offices.

A written survey of user needs was sent to all USGS district offices and to other federal agencies known to use ADCPs. The survey asked users to specify desired features such as maximum platform length and weight. Based on the 30 responses, the following specifications were developed for a tethered platform:

- maximum weight with payload: 40 lbs;
- maximum length: 5 ft;
- maximum beam: 3 ft;
- maximum water velocity of streams where the platform would be used: 12 ft/s;
- minimum acceptable time between battery replacement or recharge: 2 hours.

To safely and efficiently acquire ADCP data from a tethered platform, wireless transmission from the ADCP to a laptop computer was needed. It had previously been determined that a 900-MHz-spread-spectrum data modem could be used for this purpose. Approval from the USGS radio liaison was obtained to use radios operating in the 900-MHz frequency range if the radios are license-free under Part 15 of the Federal Communications Commission code.

A list of desired features was developed for the radio modems. The desired features included

- reliably communicate with the ADCP, using the ADCP data-acquisition software provided by the manufacturer;
- have rugged, waterproof housing;
- operate on 12-volt DC power; and,
- have 115,200-baud data-communication capability with the ADCP to maximize data throughput.

As of April 2001, the Freewave Model DGR-115W is the only modem tested that met all of the desired specifications.

A complete list of modems tested and detailed information on using radio modems with ADCPs are available at the USGS Indiana Hydroacoustics web site

http://in.water.usgs.gov/hydroacoustics/RadioModems.shtml

The Indiana District staff completed a review of possible off-the-shelf products that could be modified to meet the specifications for the unmanned tethered-platform hull. Boat-builder literature, marine-supply catalogs, and the Internet were used to search for off-the-shelf products. The research resulted in the purchase of a small, plastic catamaran designed to float one person. The Hobie Floatcat catamaran was modified for use with an ADCP and tested (fig. 3).

Discharge measurements in the field were completed to test this platform. The field tests revealed major deficiencies: the platform exceeded the design-specification weight limit, was difficult to control in the water, and did not readily orient

Figure 3. Hobie Floatcat modified for use with an acoustic Doppler current profiler.

itself with the flow. These operational deficiencies were primarily a result of trying to apply a product designed for slow propulsion on a lake for use in faster stream velocities. Recognizing these deficiencies led to having hulls built specifically for the tethered-platform application.

Design and Testing Purpose-Built Platforms

Private vendors were commissioned to construct prototype hulls specifically designed for a tethered platform used for ADCP discharge measurements (table 2). The hulls acquired from the vendors for testing included two catamaran, two monohull, and three trimaran designs (fig. 4). The hull testing included tow-tank tests (figs. 5–12) at the USGS Hydraulics Laboratory at Stennis Space Center and field tests in which the platforms were used to make ADCP discharge measurements during varying flow conditions.

For the tow-tank tests, each platform tested was fitted with an RD Instruments Rio Grande ADCP and towed the length of the tank at varying speeds. Drag was measured for each platform with a strain-gage meter, which measured the force on the towrope (table 3). The drag each platform produced while being towed was recorded. The platforms were towed through the tank at speeds varying from 1 to 12 ft/s to simulate the flow rates in which the platform might be used. During some of the tow-tank tests, wireless 900-MHz-spread spectrum modems were used to acquire ADCP data that included the pitch and roll of the ADCP.

Field tests included using the platform below a U.S. Army Corps of Engineers (USACE) reservoir (fig. 13). The USACE increased the release of water from the reservoir during the testing to create higher flow conditions with velocities up to 7 ft/s. During these tests, each platform was fitted with an RD Instruments Rio Grande ADCP and wireless 900-MHz-spread spectrum modem. ADCP data were acquired, using RD Instruments WinRiver software.

Test Results

The results of the testing indicate that, although any of the designs could be used under certain conditions, trimaran designs provided the best all-around performance under a range of conditions.

The ADCP was mounted in the hull of the monohull platforms. The V-shaped monohull platform (Monohull #2) performed well in the drag test (table 3), but stability results were less than optimal. Both monohull platforms had more erratic motion and were more sensitive to flow disturbances or turbulence in the water than the other platform designs.

The ADCP was mounted between the two hulls of the catamaran platforms. A higher drag resulted at higher velocities when compared to the monohull designs (table 3) because of the ADCP shape. The catamaran platforms were more stable than the monohull platforms.

The ADCP was mounted in the center hull of the trimaran platforms. The trimaran platforms had lower drag while still retaining the stability of the catamaran designs (table 3). The advantage of the trimaran is realized by combining the drag efficiency gained by placing the ADCP in a hull with two outer hulls that give added stability. Placing the ADCP in a hull also has the advantage of lowering the flow disturbance around the head of the ADCP.

Tethered-Platform Production

The OceanScience Group, the manufacturer of the three trimaran platforms tested, offers a fiberglass trimaran platform. This platform is based upon the trimaran prototypes tested and specifically designed for use as a tethered platform for use with an ADCP. The center hull of the trimaran has an access port that houses a wireless modem and a 12-volt battery used for powering the ADCP and the modem.

Table 2. Descriptions of platforms tested by the U.S. Geological Survey

[USGS, U.S. Geological Survey]

Platform	Description	Manufacturer
Catamaran #1 (fig. 5)	Original prototype catamaran platform constructed of polystyrene-foam floats built from a composite of several layers of 2-inch-thick standard insulation cut into a semi-V shape.	USGS Indiana District Office
Catamaran #2 (fig. 6)	Catamaran platform constructed of molded ABS plastic; is close in size and hull shape to Catamaran #1.	Wanamaker Pontoon and Paddle Company
Catamaran #3 (fig. 7)	Catamaran platform constructed of shaped foam covered in a thin layer of fiberglass.	OceanScience Group
Trimaran #1 (fig. 8)	Trimaran design with a large center hull with small outriggers. The outriggers were constructed of molded fiberglass. The center hull was constructed of shaped foam covered in a thin layer of fiberglass. The fore and aft of this hull were symmetrical, coming to a thin edge at the ends of the hull.	OceanScience Group
Trimaran #2 (fig. 9)	Trimaran design with a large center hull with small outriggers. The outriggers were constructed of molded fiberglass.The center hull was constructed of molded fiberglass and had more of a wedge or triangle shape.	OceanScience Group
Trimaran #3 (fig. 10)	Trimaran design with a large center hull with small outriggers. The outriggers were constructed of molded fiberglass. Center hull was constructed of molded fiberglass and was longer than the center hull of Trimaran #2.	OceanScience Group
Monohull #1 (fig. 11)	Single-hull platform constructed of aluminum; had a flat-bottom-hull design with three fins on the bottom of the hull for added directional stability.	Kann Marine
Monohull #2 (fig. 12)	Single-hull platform constructed of fiberglass with a V-shaped-hull design and two fins on the bottom of the hull for added directional stability.	OceanScience Group

Figure 4. Platforms—catamaran, monohull, and trimaran designs—ready for testing at the U.S. Geological Survey Hydraulics Laboratory at Stennis Space Center.

Figure 5. Catamaran #1 in the tow tank.

Figure 6. Catamaran #2 in the tow tank.

Figure 7. Catamaran #3 in the tow tank.

Figure 8. Trimaran #1 in the tow tank.

Figure 9. Trimaran #2 in the tow tank.

Figure 10. Trimaran #3 in the tow tank.

Figures 5 through 10. Prototype hulls in the tow tank at the U.S. Geological Survey Hydraulics Laboratory at Stennis Space Center.

Figure 11. Bottom view of Monohull #1.

Figure 12. Monohull #2 in the tow tank.

Figures 11 and 12. Prototype monohulls tested at the U.S. Geological Survey Hydraulics Laboratory at Stennis Space Center.

Table 3. Results of prototype hull tow-tank tests by the U.S. Geological Survey for platform drag test, in pounds

[ft/s, foot per second; N/A, valid test data not available]

Velocity (ft/s)	Catamaran #1	Catamaran #2	Catamaran #3	Trimaran #1	Trimaran #2	Trimaran #3	Monohull #1	Monohull #2
2	1.4	2.3	1.6	0.6	0.9	0.6	0.9	0.9
4	3.8	4.9	5.9	2.7	2.6	1.5	3.5	2.1
6	14.6	11.3	14.6	7.2	8.3	3.6	12.4	5.2
8	18.0	14.8	N/A	9.3	10.9	4.5	19.5	N/A
10	24.3	24	27.3	N/A	13.5	6.6	N/A	7.3
12	33.2	29.5	N/A	N/A	16.9	8.9	29.4	9.2

Figure 13. Monohull tethered platform being field tested by the U.S. Geological Survey.

Wanamaker Pontoon and Paddle Company, the manufacturer of Catamaran #2, has manufactured a molded ABS plastic catamaran platform. The platform is based upon the design tested and specifically is designed for use with an ADCP. The two hulls have access ports where a wireless modem and a 12-volt battery used for powering the ADCP and modem can be housed. Although the catamaran design has higher drag, it could prove to be a good low-cost alternative for use in conditions with velocities below 6 ft/s.

Sontek/YSI, Inc., offers a catamaran system designed for use with their Mini-ADP. This package includes an aluminum catamaran-type platform and wireless modems. This device was not available during project testing.

Tethered-Platform Discharge-Measurement Procedures

When making discharge measurements with an ADCP and tethered platform, the operator must follow established USGS procedures, guidelines, and policies for making ADCP discharge measurements. The following procedures clarify the process of making an ADCP measurement with a tethered platform and highlight items that are specific to tethered-platform ADCP discharge measurements. These procedures are not intended as a complete list of instructions for making an ADCP discharge measurement. For information on USGS discharge-measurement procedures and policies, see Rantz and others, 1982, and Lipscomb, 1995. USGS Office of Surface Water memorandums can be accessed at

http://hydroacoustics.usgs.gov/memos/

General Procedures

To make a tethered-platform ADCP discharge measurement from a bridge, an operator first lowers the platform to the water. The operator then allows the platform to float downstream from the bridge to minimize the effects of any turbulence created by the bridge structure. Each transect consists of the operator walking across the bridge while pulling the platform across the stream; a second person operates the portable computer that stores the measurement data collected by the ADCP (fig. 14).

Figure 14. U.S. Geological Survey personnel and the personal computers used to collect data during an unmanned tethered-platform acoustic Doppler current profiler discharge measurement.

Site Selection

The use of a tethered platform for ADCP discharge measurements usually limits the cross section to cableways and the downstream side of bridges or other structures. When a measurement is made from the downstream side of a bridge, piers or other supports can cause shear and turbulent flow. This can violate a basic assumption made when using ADCPs to measure discharge—that each beam of the ADCP is measuring a homogeneous section of water (Gordon, 1996). Close attention should be paid to the ADCP quality parameters to ensure the measurement is being made at a suitable site. If parts of the cross section are of poor quality, the length of the tether may be adjusted in an attempt to find a more suitable cross section slightly farther upstream or downstream. At some sites, it may not be possible to use a tethered platform to make an ADCP discharge measurement because of the limited ability to change the measurement cross-section location.

At sites where a suitable cross section is not available on the downstream side of a bridge or cableway, it may be possible to use other methods to move the tethered ADCP platform across the river. Using a low-drag platform in slow velocities, the tether can be attached to a long pole that will extend far enough to allow the platform to be used on the upstream side of a bridge while avoiding the bridge supports. Another alternative to measuring from a bridge is to attach two long tethers, each longer than the width of the desired cross section, to the platform and place a person on each bank of the river. While one person is pulling the platform across to complete a transect, the person on the other bank keeps tension in the second tether so the platform tracks across the desired path. In high-water velocities, it may not be possible to use this method because of the drag induced if the tether cannot be kept out of the water.

Moving-Bed Test

USGS policy requires a 10-minute moving-bed test be performed at a site prior to making an ADCP discharge measurement (Lipscomb, 1995). To perform a moving-bed test with a tethered platform, the platform would be positioned in the measurement cross section where the potential for moving bed is greatest; the tether then is held in place. In most conditions, the tether will limit the upstream and downstream movement of the platform; if this is so, apparent upstream movement of the platform relative to the channel bottom can be attributed to a moving-bed condition.

During discharge measurements at sites where a moving-bed condition is possible, the operator should pay close attention to the path of the platform as reported by the ADCP. Because the path of the platform usually is consistent between transects when making a tethered-platform discharge measurement, apparent upstream movement may be associated with a moving-bed condition, especially at points of increased velocity. If the same beginning and ending points are used for each transect, a moving bed may be detected by watching for ADCP-reported shiptrack movement upstream during both transects of a reciprocal pair. If there is not a moving-bed problem, the sum of the upstream and downstream movement of two reciprocal transects should be close to zero.

Edge-Distance Measurements

According to USGS policy, edge distances for estimation of edge discharge must be measured with an electronic distance-measuring device, a tag line, or some other accurate measuring device (Lipscomb, 1995). When making a tethered-platform ADCP measurement close to the downstream side of a bridge that has been "marked" with distances, the markings may be used as an accurate way to measure the edge distances.

Depending on the distance of the platform downstream from the bridge, it may be difficult to accurately measure the edges with the bridge markings. An alternative is to use a laser range finder. With a laser range finder that measures horizontal distance, the tethered platform would be moved to the near shore-edge location and, while the operator stands at the shoreline in line with the tethered platform, the distance from the shore to the platform would be measured. The platform then would be moved to the far shore-edge location; the difference in the distances measured to the far shore and to the platform would equal the far-edge distance. If the operator is using a range finder with a compass and inclinometer that has a "missing-line" mode (a mode to calculate the horizontal distance between two points), the operator would measure edge distances with this mode by simply "shooting" the appropriate bank and the platform at both shore-edge locations. It generally is recommended to measure the edge distances before the start of a measurement and always to use the same beginning and ending locations for each transect. Doing so limits the amount of edge measurements needed and allows for easier comparisons between transects.

Summary and Conclusions

With the introduction of smaller ADCPs that could be used for discharge measurements, it became possible to mount the ADCP on small, unmanned floating platforms instead of large, manned boats. With the purchase of a new, smaller ADCP, the USGS Indiana District began the design of a prototype unmanned platform that could be used at sites where lack of access prevented use of an ADCP from a manned boat. The platform could be lowered with a tether from a bridge or deployed from rope and pulley arrangements (such as a cableway). A pair of 900-MHz radio modems were used for wireless ADCP communications. Using the prototype platform, the Indiana District made a series of comparison discharge measurements that indicated a tethered platform could be used to make discharge measurements that meet USGS standards. Tethered-platform ADCP discharge measurements usually can be made faster than conventional mechanical current-meter-type discharge measurements, reducing personnel time on bridges and exposure to traffic hazards. Although the prototype proved that the concept was viable, experience in constructing and operating the platform resulted in refinements.

As part of a USGS Instrumentation Committee project to further refine and test tethered-platform designs, various hull configurations were tested for drag and stability characteristics. Although all platforms tested may be adequate under certain conditions, the trimaran design with a semi-V center hull that held the ACDP proved to offer the best performance over the greatest range of water speeds. As a result of this study, tethered platforms designed for ADCP discharge measurement are commercially available.

When making discharge measurements with an ADCP and tethered platform, the operator must follow established USGS guidelines for making ADCP discharge measurements; these include selecting a good site, testing for moving-bed problems, and measuring edge distances. In most cases, site selection is limited for tethered-platform ADCP measurements to cross sections at cableways and the downstream side of bridges. When a measurement is made from the downstream side of a bridge, piers or other supports can cause shear and turbulent flow, which may result in poor measurement quality. Moving-bed problems can be tested for by positioning the platform in the measurement cross section where the potential for moving bed is greatest, holding the tether in place, and observing any apparent upstream movement reported by the ADCP. Edge distances can be measured, using distances previously measured and marked on the downstream side of a bridge if the measurement cross section is close to the downstream side of a bridge. Depending on the distance of the platform downstream from the bridge, it may be difficult to accurately measure the edges with the bridge markings. An alternative is to have the operator stand at the shoreline in line with the tethered platform and measure the edge distances with a laser range finder. When the established USGS guidelines for making ADCP discharge measurements are followed, the use of tethered platforms has proven to be accurate and efficient.

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