In Reply Refer To: February 6, 2008
Mail Stop 415

OFFICE OF SURFACE WATER TECHNICAL MEMORANDUM 2008.02

SUBJECT: Upgrade for Rio Grande/Workhorse Firmware to Address Potential Bias in Discharges Measured Using Water Mode 12

The purpose of the memorandum is to request that the users of the Teledyne RD Instrument (TRDI) Workhorse acoustic Doppler current profilers (ADCPs) upgrade their firmware as soon as possible in response to a potential bias in water mode 12 velocity and discharge measurements. This memorandum provides background information on the potential problem, describes the error identified by TRDI, the fix, and provides guidelines for minimizing the impact of this potential problem. Users of Rio Grande ADCPs should immediately upgrade to firmware 10.16, available for download from the U.S. Geological Survey (USGS) Hydroacoustics Web pages, http://hydroacoustics.usgs.gov/movingboat/mbd_software.shtml. Users of Workhorse Monitor and Sentinel ADCPs should upgrade to firmware 16.30, available from TRDI's Web pages (http://www.rdinstruments.com/) for registered users.

Several other agencies, including the Norwegian Water Resources and Energy Directorate (NVE), the Environment Agency in the United Kingdom (EA), and the Water Survey of Canada (WSC) have shown that some water mode 12 measurements result in lower velocities and discharges when compared to equivalent measurements made with other water modes and/or measurement techniques. The NVE presented the results of their work at the European ADCP's in Action meeting, prompting TRDI to begin investigating the potential problem. The USGS, Office of Surface Water (OSW), collected more than 60 comparison measurements using water mode 12 and did not observe a verifiable bias in those water mode 12 measurements. See Oberg and Mueller (2007) for more information about this work (available at http://hydroacoustics.usgs.gov/). However, this work did not involve comparisons of water mode 12 measurements to measurements made using water mode 5 or water mode 11, as has been done by NVE, EA, and WSC personnel. Instead, discharges measured using water mode 12 were compared to discharges obtained from current meter measurements and rating curves. The OSW has reviewed the data collected by these agencies and the analysis of some of the data shows a definite and significant negative bias of about 3 percent.

Investigation of the problem by TRDI has uncovered an error in Rio Grande firmware 10.15 and earlier versions, and Workhorse Sentinel and Monitor firmware 16.28 and earlier versions. Under specific flow conditions and instrument configurations, this error

can lead to a negative bias at low relative velocities (< 5 ft/s) and a positive bias at high relative velocities. Relative velocity is the apparent horizontal velocity relative to the ADCP and includes both water and boat velocity. Although this error has been observed and corrected during bench testing, field data collected by TRDI and the USGS, in order to verify the error and the fix, have been inconclusive to date. The error described and fixed by TRDI resulted from a rounding error in the firmware that can cause the wrong velocity to be determined from a lookup table relating velocity to phase change. According to written communication from TRDI, this error only occurs for a single subping or even numbers of multiple subpings, small bin sizes, and high ambiguity velocities. Analysis of field data from customers, and field tests made by TRDI, using water mode 12 with 10 cm bins, 12 subpings, and ambiguity velocity of 340 cm/s (a common configuration when the Mode 12SB option is selected by a user in WinRiver version 10.06) results in a negative bias of 1.0 to 1.5 cm/s (0.0328 – 0.0492 ft/s) in the mean velocity. If the mean velocity of a discharge measurement is 0.3 m/s (1 ft/s), the expected error is about 5 percent. For velocities greater than 0.3 m/s (1 ft/s), the error would be proportionally less.

The OSW reassessed the water mode 12 comparison data (published in Oberg and Mueller, 2007) and attempted to collect additional field data to verify both the error and the fix made by TRDI. A plot of the water mode 12 comparison data with 10 cm bins, even number of subpings, and an ambiguity velocity of 340 cm/s or greater is shown in figure 1. Although a negative bias below 0.4 ft/s appears to be shown in figure 1, the measurement conditions at Elkhorn Creek in Kentucky were very challenging and the comparisons are not considered representative of other sites. Attempts by OSW to collect additional data using both the existing firmware and firmware modified to fix the error were also inconclusive as determined by OSW and TRDI.

The OSW recognizes that a potential bias in mode 12 exists and that TRDI found a bug and fixed an error in the Rio Grande and Workhorse firmware; however, field data are not sufficient to verify that the error fixed is the same error responsible for the potential bias observed by other agencies.

Use of data collected previously using water mode 12SB (in WinRiver 10.06) is left to the discretion of the hydrographer. However, if a measurement is suspect because of this water mode 12 error, the measurement quality may be downgraded and given a different weight in rating analysis and records computation. Some instances under which a measurement (made with mode 12SB) may be considered suspect include the following:

- A discharge measurement plots to the left of a well-defined, stable rating (negative shift) when there is no visible indication of a change in control.
- A discharge measurement indicates a negative or positive shift when measurements made at approximately the same range of stage or same control condition using other instruments or water modes do not show a similar shift.

It is important to note that at present only negative biases have been observed in field measurements to date (see above).

If you have any questions regarding the mode 12 bias, application of these guidelines to your sites, or would like to collect evaluation data, please contact Kevin Oberg (kaoberg@usgs.gov) or David Mueller (dmueller@usgs.gov).

Stephen F. Blanchard*/signed/*
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References

Oberg, K.A., and Mueller, D.S., 2007, Validation of Streamflow Measurements Made with Acoustic Doppler Current Profilers: Journal of Hydraulic Engineering, v. 133, No. 12, p. 1421-1432

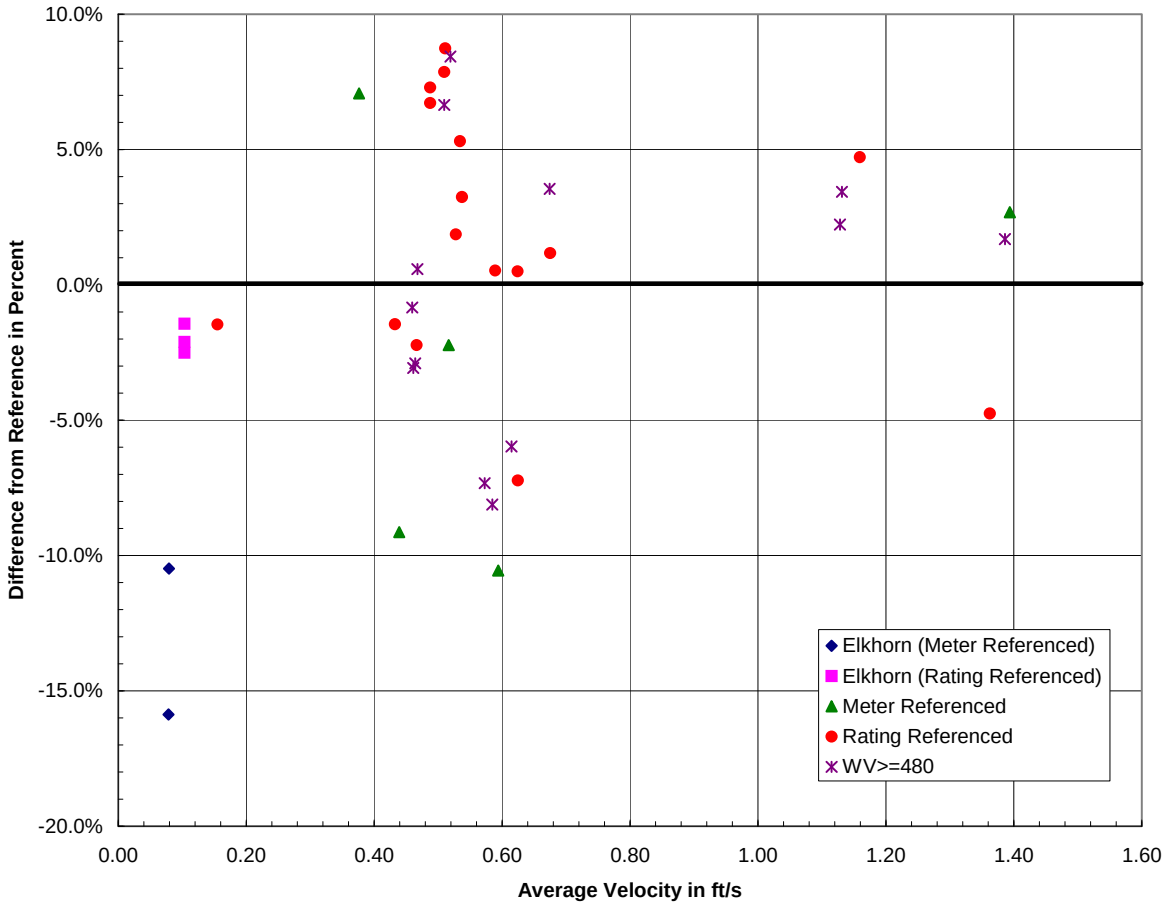

Figure 1. Percent difference from a reference for discharge measurements made using mode 12 with small bins and an ambiguity velocity greater than or equal to 340 cm/s. Comparisons made at Elkhorn Creek and the comparison reference are specified by color and symbol style. Data points with an ambiguity velocity greater than 480 cm/s are also identified by color and symbol style.