RECLAMATION
Managing Water in the West

Hydraulic Laboratory Technical Memorandum PAP-1052

Mace USA LLC Continuous Wave Doppler Flow Tests March 2, 2012

4' rectangular channel results

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

March 2012

Hydraulic Laboratory Technical Memorandum PAP-1052

Mace USA LLC Continuous Wave Doppler Flow Tests March 2, 2012

4' rectangular channel results

Prepared: Bryan J. Heiner
Hydraulic Engineer, Hydraulic Investigations and Laboratory Services Group, 86-68460

Technical Approval: Robert F. Einhellig, P.E.
Manager, Hydraulic Investigations and Laboratory Services Group, 86-68460

Peer Review: Tracy B. Vermeyen, P.E.
Hydraulic Engineer, Hydraulic Investigations and Laboratory Services Group, 86-68460

3/13/12
Date

Disclaimer: *The information provided in this report is believed to be appropriate and accurate for the specific purposes described herein, but users bear all responsibility for exercising sound engineering judgment in its application, especially to situations different from those studied. References to commercial products do not imply endorsement by the Bureau of Reclamation and may not be used for advertising or promotional purposes.*

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Hydraulic Investigations and Laboratory Services Group
Denver, Colorado

March 2012

Introduction

This report summarizes the testing of the Mace Agriflow3 acoustic Doppler flow meter conducted at the Bureau of Reclamation's Hydraulics Laboratory in Denver, CO. The testing was funded by Mace USA LLC. Tim Quinlan, a representative from Mace, was present during the testing to witness the test facilities, assist with the flow meter setup and troubleshoot any problems that were encountered.

Test Facility

Testing was conducted in Reclamation's Hydraulics Laboratory located in Denver, CO USA. The meter was tested in a 4-ft-wide and 8-ft-deep rectangular channel (Figure 1). The channel was operated as an open channel with discharge ranging from from 0-30 ft^3/sec. Flow was pumped into the channel using two 100-hp and one 150-hp centrifugal pumps. Reference flow rates from each pump were measured using calibrated[1] venturi meters accurate to ±0.25 percent each. Reference depth measurements were obtained using a stilling well accurate to 0.005 feet. Average reference velocities were determined by dividing the reference discharge by the channel cross sectional area calculated using the depth measurements.

Test Procedure and Results

Flows entering the channel were set at a specific rate and allowed to stabilize for 10 minutes to ensure that equilibrium conditions had been reached. Once stabilized, flow, velocity and stage were logged using the Mace Agriflo3 over a 5 to 15 minute interval at 1 minute increments. Laboratory (reference) flow rates were determined by continuously averaging the differential pressure from each venturi meter over the same 5 to15 minute testing period. Reference depths were monitored and recorded manually for each stable flow rate. Fluctuations in the water surface added a small amount of uncertainty to the depth measurements. Once flows and depths were recorded the test flow rate was changed and the process was repeated.

---

[1]Calibrations are performed every 2 years using a weight versus time relationship derived from a permanent volumetric weight tank. Historical performance of all venturis have shown little if any deviation year to year. (Hydraulic Laboratory Techniques, Denver CO 1989 available online at: http://www.usbr.gov/pmts/hydraulics_lab/pubs/manuals/HydraulicLabTech.pdf)

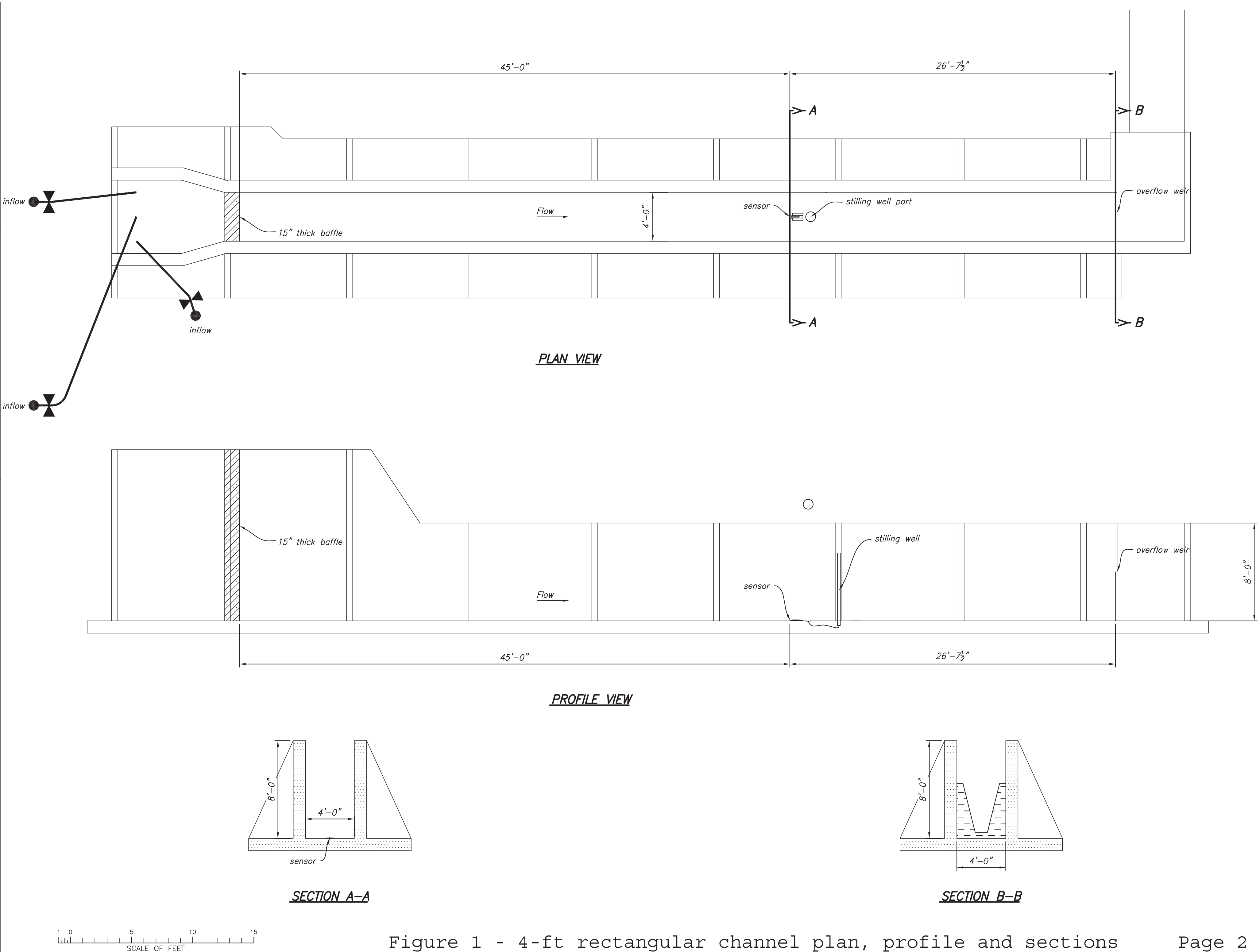

Figure 1 - 4-ft rectangular channel plan, profile and sections

Table 1 and Figure 2 provide the data for the 10 test runs completed in the 4-ft rectangular channel. Tests were conducted at flows of 1.00, 5.00, 9.84, 14.90, 20.04, 25.06 and 30.02 ft^3/sec. Data was collected for two tests at each of the 20.04, 25.06 and 30.02 ft^3/sec flows to see the effects a sluice gate would have on the Agriflo3. Percent deviations in the Agriflow3 measurements were calculated by dividing the difference of the measured and reference values by the reference. For all flows tested in the 4-ft rectangular channel the minimum deviation of flow (-14.0%) occurred at 30.02 ft^3/sec when a sluice gate was blocking 50% of the flow upstream of the meter. The maximum deviation of flow (24.1%) occurred at 1.00 ft^3/sec. During the testing the most accurate flow measurement was at 14.90 ft^3/sec with -0.4 percent deviation from the laboratory reference flow rate.

Discussion

Original testing of the Mace Agriflo3 was performed in July of 2011. After examining the setup files, Mace was concerned that the wrong method to determine the average velocity was selected and that aliasing of the velocity measurements was causing the meter-computed flow to stray from the reference flow measurements. In an effort to determine the cause of the performance issues, Mace funded re-testing of the Agriflo3 with a larger velocity range and the correct velocity method. The July 2011 testing was performed using a 3 ft/sec maximum velocity and the pump method. New data were collected with a maximum velocity of 12 ft/sec using the gravity method.

Each flow rate tested was analyzed to determine if aliasing would have occurred with the maximum velocity of 3 ft^3/sec. Aliasing occurs when the velocity range of the Agriflo3 is set lower than the maximum measured velocity in the channel, causing the calculated average velocity to be unreliable. During the review of real-time velocity histograms measured by the Agriflo3 it appears that only the 30.02 ft^3/sec discharge could have been aliasing during the original testing.

At the end of testing the 20.04, 25.06 and 30.02 ft^3/sec flow rates, a sluice gate was lowered into the channel about 30 feet upstream from the meter and data was collected for an additional 5 minutes. At the 20.04 and 25.06 ft^3/sec tests discharge output from the Agriflo3 improved with the sluice gate lowered. However, for the 30.02 ft^3/sec flow a larger error was observed. Tim Quinlan expected that introducing the sluice gate should decrease accuracy because minimum unobstructed channel length requirements would no longer be met.

After comparing the previous test data to the new test data the only significant improvement observed with the adjusted setup parameters was for the 30.02 ft^3/sec flow. Original 30.02 ft^3/sec data deviated -27 percent, the new data improved to -7 percent. All other flow rates tested were similar or worse than the original data when comparing discharge accuracy.

Table 1- 4-ft rectangular channel data from March 02, 2012

Stage (ft)			Velocity (ft/sec)			Discharge (ft^3/sec)		
Reference	Measured ±SD	% Deviation	Reference	Measured ±SD	% Deviation	Reference	Measured ±SD	% Deviation
1.27	1.28 ± 0.005	1.4%	0.20	0.24 ± 0.011	22.0%	1.00	1.24 ± 0.053	24.1%
2.24	2.26 ± 0	0.7%	0.56	0.64 ± 0.005	15.8%	5.00	5.83 ± 0.058	16.8%
2.84	2.86 ± 0.003	0.7%	0.87	0.89 ± 0.019	2.1%	9.84	10.12 ± 0.209	2.8%
3.34	3.35 ± 0.004	0.4%	1.12	1.11 ± 0.015	-0.6%	14.90	14.84 ± 0.169	-0.4%
3.76	3.77 ± 0.005	0.4%	1.33	1.44 ± 0.018	8.1%	20.04	21.75 ± 0.278	8.5%
3.76*	3.76* ± 0.004	0.2%*	1.33*	1.32* ± 0.09	-1.3%*	20.04*	19.83* ± 1.332	-1.1%*
4.13	4.13 ± 0.006	0.2%	1.52	1.67 ± 0.038	10.2%	25.06	27.65 ± 0.646	10.3%
4.13*	4.13* ± 0.005	0.2%*	1.52*	1.42* ± 0.153	-6.5%*	25.06*	23.47* ± 2.558	-6.4%*
4.42	4.44 ± 0.005	0.4%	1.70	1.57 ± 0.034	-7.4%	30.02	27.92 ± 0.625	-7.0%
4.42*	4.42* ± 0.007	0%*	1.7*	1.46* ± 0.232	-14.0%*	30.02*	25.82* ± 4.091	-14.0%*

*A sluice gate was lowered about 50 percent into the approach flow 30 feet upstream of the meter

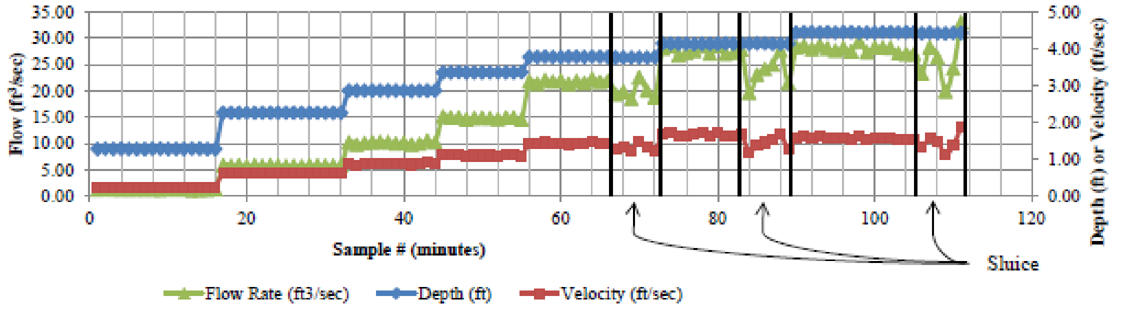

Figure 2- 4-ft rectangular channel data from March 02, 2012