BUREAU OF RECLAMATION
Technical Service Center
Denver, Colorado

TRAVEL REPORT

Code : 86-68560 Date: August 30, 2006

To : Manager, Hydraulic Investigations and Laboratory Group

From : Tony L. Wahl

Subject : Travel to Lugert-Altus Irrigation District, Altus, Oklahoma

1. Travel period: July 3-9, 2006

2. Places or offices visited: Oklahoma City Field Office and Lugert-Altus Irrigation District

3. Purpose of trip: Collect discharge data to verify calibrations of recently installed flow measurement structures on the Lugert-Altus Irrigation District.

4. Synopsis of trip: I traveled to Oklahoma City by government vehicle, arriving on the afternoon on July 4. On the morning of July 5 I met Ben Claggett at Reclamation's Oklahoma City office. We loaded up additional field equipment and then drove to Altus, Oklahoma. We had lunch with Tom Buchanan, Manager of the Lugert-Altus Irrigation District, and then proceeded to the first of several flume and weir sites where we measured flows using the RD Instruments StreamPro acoustic Doppler flow meter that I had brought from Denver. This work was performed to verify calibration equations and rating tables for the structures, most of which were constructed during the previous two years. We were assisted at various times by district employees, including Glen Barker, Dam Tender at Altus Dam. We continued performing flume and weir measurements on July 6. On the morning of July 7 we collected survey data at several sites at which water measurement structures are still needed. We also visited several sites at which the district intends to build long-crested weir check structures in the future. We returned to Oklahoma City on Friday afternoon and I drove back to Denver on Saturday and Sunday.

Flow Measurement Data Collection and Analysis Procedure

We made StreamPro measurements of discharge at the following flow measurement sites:

- Altus Canal A11.1 flume
- Flume at head of Ozark lateral
- Ozark bench flume
- Altus Main Canal bench flume
- Flume near head of West Canal
- Zinn check
- Flume at head of A17.6 lateral

At each site we recorded upstream heads for the measurement structure from staff gages installed in the flowing canal and/or in stilling wells. We then established a measurement section upstream or downstream from the structure in a section where the channel was accessible, reasonably straight, and the flow relatively uniform. A set of stakes with pulleys was set to establish a tight tag line, and the StreamPro was attached to the tag line so that it could be ferried across the channel in both directions. At each site a mid-channel diagnostic measurement was made to determine the maximum depth and velocity and to verify that movement of the canal bed material was minimal. Following the completion of these setup tasks, velocity data were collected from 8 to 12 independent transects at each site. Preliminary discharge results were tabulated to verify that measurements were consistent with the flow rates expected at each site.

Following the completion of the trip, the data collected at each site were processed in the office. The StreamPro continuously records bottom depth and velocity from the start to the end of each transect and integrates the measurements to compute total discharge. Because a minimum flow depth is required for operation of the instrument, small segments near the right and left bank are not measured. The flow in these left and right bank areas is extrapolated from the data collected near the banks. Discharge near the surface and near the bed is also estimated, since there are small unmeasurable areas at the top and bottom of the water column. Processing consists of trimming the beginning and end of each transect to reduce the variability of the measurements made near each bank. This generally improves the consistency of the measurements but does not systematically change the average results. During processing I also eliminated transects with anomalous results, such as unusually high or low percentages of flow in any of the estimated flow areas (i.e., top, bottom, right, or left), or unusual measurements of channel width or area.

Explanation of Results

Table 1 summarizes the results for each site. The *sample standard deviation*, S_d, indicates the variability of the individual StreamPro measurements at each site, which depends on multiple factors, including the uniformity of the velocity distribution at the transect location, bed profile variability (i.e., riprap boundary vs. smooth earth or concrete), and our ability to achieve reasonably uniform motion of the instrument across the channel (i.e., not having the boat wander during the transect). For each set of measurements, a related statistic, the *standard error of the mean* is also shown. The standard error of the mean is equal to the sample standard deviation divided by the square root of the number of measurements. The standard error of the mean indicates the ability of the **multiple** StreamPro measurements to accurately define the mean value of the flow. Making multiple measurements reduces the standard error and thus improves the quality of the estimate of the mean. Finally, for each set of measurements, a 95 percent confidence interval is computed around the measured mean value. The range of this confidence interval is the uncertainty, estimated to be $\pm 2S_e$, where S_e is the standard error of the mean. The uncertainty is also shown in the table in relative terms, as a percentage of the measured mean flow rate. The confidence interval should be interpreted as the range within which the mean flow would be expected to fall 95 percent of the time, if the same procedure for measuring the mean flow were repeated multiple times.

Table 1. — Summary of StreamPro measurements.

Site	StreamPro measurements								Rating in use	
	Mean flow, Q_{mean} ft^3/s	Standard deviation, S_d ft^3/s	No. of good transects N	Standard error of the mean S_e, ft^3/s	Uncertainty $\pm 2S_e$ ft^3/s	Relative uncertainty, percent	Confidence interval, ft^3/s Lower	Confidence interval, ft^3/s Upper	h_1 ft	Q_{rating} ft^3/s
[1]Altus Canal A11.1 flume	199.3	3.43	8	1.21	±2.43	±1.2%	196.9	201.7	3.50	201.3
[2]Flume at head of Ozark lateral	80.0	4.69	10	1.48	±2.97	±3.7%	77.0	83.0	1.35	**73.6**
[3]Ozark bench flume	47.0	3.82	13	1.06	±2.12	±4.5%	44.9	49.1	1.57	**42.6**
[4]Altus Main Canal bench flume	444.0	8.84	10	2.80	±5.59	±1.3%	438.4	449.6	4.10	444
[5]Flume near head of West Canal	101.0	1.39	7	0.53	±1.05	±1.0%	99.9	102.1	1.47	**103**
[6]Zinn check	279.0	10.8	5	4.83	±9.66	±3.5%	269.3	288.7	#N/A	#N/A
Flume at head of A17.6 lateral	56.4	1.32	6	0.54	±1.08	±1.9%	55.3	57.5	1.24	56.3

Notes:

[1] Actual staff gage reading was 3.60 ft, but the gage is known from prior surveys to be set 0.1 ft lower than the flume crest (gage reads too high).

[2] Staff gage reading was made in flowing canal upstream from flume. Gage was difficult to read accurately due to turbulence from a debris deflector and the post on which the gage was mounted.

[3] Staff gage reading was 1.55 ft, but survey measurements of crest and gage elevation showed gage to be set 0.02 ft high (reading is low). Measurements were made in upstream earth-lined section and were more varied (41 to 53 ft^3/s range) than usual for unknown reasons, possibly somewhat irregular channel shape. An independent measurement of channel centerline velocity using a propeller meter in the 6-ft wide rectangular concrete section yielded estimated discharge of 48.6 ft^3/s. As-built dimensions of flume and staff gage setting should be verified following the irrigation season.

[4] Rating equation in use at this site is $Q = 43.38(h_1 + 0.04824)^{1.635}$. This adjusted equation yields flows that are 3% lower than the theoretical rating curve.

[5] A small region of reverse-flow at the left bank may have affected these measurements (although instrument should account for it in theory)

[6] Foam on water surface may have affected measurements. We had difficulty maintaining bottom tracking and had many bad velocity measurements at this site. Because of these problems and the lack of a dedicated staff gage at this site, we made no attempt to determine the upstream head and rated flow.

For comparison, Table 1 also shows the measured upstream head and the rated discharge corresponding to that head, as determined from the rating equation in use for the structure at the time of the measurements. Where the rated discharge is shown in bold, it is outside of the range of the 95 percent confidence interval on the mean of the StreamPro measurements. This is an indication of a statistically significant difference between the rating in use and the average of the StreamPro measurements. When the rated discharge is within the confidence interval of the measurements, we conclude that the measurements do not give substantial evidence that the rating is inaccurate.

Discussion

The StreamPro instrument performed well at most of the sites; four of the seven sets of measurements had relative uncertainties below ±2 percent. The two sites on the Ozark lateral and the measurements made at the Zinn check exhibited greater uncertainties. The measurements at the head of the Ozark lateral were made in a relatively shallow and swift-flowing reach of the canal, which made it more difficult to obtain a uniform motion of the StreamPro. The measurements upstream from the Ozark bench flume were made in a more tranquil flow condition, but the channel was relatively small and the banks were weedy, which again made for more difficult measurement conditions. The site below the Zinn check-drop structure proved to be very difficult for reasons not fully understood, but the presence of some foam on the water surface may have been interfering with the ability of the acoustic transducer to send and receive signals. In retrospect, an option for deploying the transducer in front of the catamaran boat hull (which would have prevented foam from being trapped against the transducer face) should have been tried. This site probably will not be a part of the district's telemetry network in the future, so it is probably not worthwhile to try to repeat measurements at this site.

Differences between rating equations and measured flows were smaller than the confidence intervals at four of the seven sites. In the field we believed that the measurements on both of the Ozark canal sites and at the Altus Main Canal bench flume were significantly different from the rating equations, but after the processing of data was complete in the office, the results from the Main Canal bench flume were in essentially perfect agreement with the rating equation being used by the district. It should be noted that this rating equation is not the theoretical rating, having already been adjusted a year ago to provide consistency between the flume measurements and estimates of discharge made at the high pressure slide gates that control releases from Altus Dam. The district has reported a small ongoing discrepancy between the flows they release and changes in the volume of water stored in the reservoir, but the measurements we made do not by themselves provide justification for making further adjustments to the flume rating equation.

The measurements made at the West Canal flume were very consistent, and in the field we believed them to be in almost perfect agreement with the rating equation. However, after processing, the mean flow measured with the StreamPro was about 2% lower than the rating equation and the confidence interval was very tight (the StreamPro measurements were very consistent), so the rating equation is outside of the computed confidence interval. The accepted uncertainty of flume calibrations developed with WinFlume is about ±2 percent, so this result does not suggest any systematic problem with the flume. In this case we obtained an unusually good set of measurements with the StreamPro that suggests we could make a small adjustment to the rating of this structure. However, since the difference is only about 2 ft^3/s and the district has not had any difficulty operating the West Canal on the basis of the measurements made with this flume, the rating table will not be adjusted.

The measurements made at the two flumes on the Ozark Canal differed significantly from the theoretical ratings. In both cases, issues related to the staff gages may have contributed to this. When we arrived at the flume at the head of the Ozark lateral the staff gage used to measure the flow was located in an eddy below a trash deflector shown in figure 1. Initially the staff gage indicated a head of about 1.30 ft. While we were making the StreamPro measurements, district personnel removed the trash deflector. This improved the situation slightly, but the turbulence created by the stake that the staff gage was attached to (which was perpendicular to the flow direction) still made it difficult to accurately determine the water level. I estimated the level to be 1.35 ft, and subsequent measurements made with a folding rule in the approach section of the flume confirmed this measurement. Unfortunately, under the flow conditions on the day of our visit, we were not able to make careful and accurate survey measurements of both the crest elevation and the water level in the stilling well. Without an accurate measurement of the upstream head, we cannot confidently state that the StreamPro measurements justify adjusting the rating for the structure. The installation of an accurate staff gage and water level sensor might show that the StreamPro measurements are consistent with the real rating of the structure. However, for the remainder of this operating season (until the staff gage installation is changed), the district should adjust the flows measured at this site by increasing them 8.7 percent. We may wish to again verify the calibration of this flume (with a good staff gage installation in place) during the summer of 2007.

Figure 1. — Staff gage for flume at head of Ozark lateral.

We had some difficulty getting consistent measurements at the Ozark bench flume site. The bench flume is installed in a 6-ft wide rectangular concrete section elevated above the surrounding fields. We chose to make the StreamPro measurements a few hundred feet upstream in a wider and slower trapezoidal earthen section. Individual measurements varied about ±10 percent, with a mean flow of 47 ft^3/s, which was more than 10 percent above the rated flow for the flume. We checked the staff gage setting at the flume and did find it to be set about 0.02 ft too high, although this is only an approximate measurement because we did not have a sturdy survey pole (only a folding rule) and could measure the crest height only near the sidewalls. Adjusting for this still leaves the measured mean flow 10 percent greater than the rated flow. Tom Buchanan did note that the measured mean flow seemed consistent with the flow we measured at the head of the Ozark lateral (80 ft^3/s) and the estimated intermediate diversions and seepage losses. For the remainder of this operating season the district should adjust flows measured at the flume upward by 10 percent. Following the irrigation season, a careful check of the flume dimensions and staff gage setting should be made. The stilling well inlet port should also be checked to ensure that it is flush and perpendicular to the flume walls. Since the approach velocity in this flume is relatively large, any problems with the stilling well inlet could cause significant error in the head reading.

Survey data at future flow measurement sites

On the evening of July 6 Ben Claggett and I visited the wasteway at the tail end of the Ozark Canal. We collected some supplemental survey data here to complement information gathered on a previous trip by Bob Einhellig. The district had recently installed a 10 ft^3/s capacity EZ-Flow flume manufactured by the Nu-Way Flume Co. (fig. 2). This flume had already experienced flow beyond its capacity (as expected), but will provide the district with some measurements of spills this summer. We will provide a design for a larger-capacity replacement flume that the district can construct during this off-season.

Figure 2. — EZ-Flow flume installed in Ozark wasteway for temporary use in the summer of 2006.

On Friday morning Tom Buchanan, Ben Claggett, and I visited the A9.9 lateral near the cotton gin and measured dimensions of an existing drop structure that the district would like to use for flow measurement (fig. 3). A design utilizing a small sill and ramp with some entrance transitions will be developed and provided to the district.

Figure 3. — Drop structure in A9.9 lateral near cotton gin.

We also visited the West Canal wasteway on Friday morning. This site has undergone significant changes since my last visit. The district has added a new culvert in the wasteway that dramatically reduces the tailwater at the desired measurement site. They also added a 10 ft^3/s EZ-Flow flume to measure a portion of the wasteway flows (flow enters the wasteway through a gated overflow and also through an uncontrolled overflow section; the flume measures only the uncontrolled overflow). We collected survey data that will be used to develop a permanent flume design that will be able to measure all of the wasteway flow.

(a)

(b)

(c)

(d)

Figure 4. — Photos of the West Canal wasteway site showing (a) excavated channel, (b) new culvert [rightmost culvert], (c) EZ-Flow flume, and (d) the control structures at the end of the West Canal. Gated spill flows discharge through the concrete culvert pipe beneath the flume in (c).

We also visited the West Canal W10.6 check-drop structure, where a new long-throated flume is planned. I developed a design for this site earlier this year, but the district has not yet constructed it. We collected survey data to establish the elevations of key water levels at the site. These data show that the district is operating this canal reach in a checked up condition, so tailwater levels at this site are higher than I assumed when developing the design. A revised design based on this information will be developed and transmitted to the Oklahoma-Texas Area Office.

Potential long-crested weir sites

The district has constructed three long-crested weirs at key check structures prior to this irrigation season. Thus far they have been very satisfied with performance of the weirs and intend to build additional weirs this winter. We visited three additional potential long-crested weir sites. At the Altus 19.0 check-drop, an attempt had been made initially to develop a simple design utilizing an L-shaped layout that would funnel most of the flow through one half of a two-bay check structure. This proved to be infeasible because it would cause submergence of the downstream side of the long-crested weir. A better approach appears to be a design like that used on the three weirs that have already been built. This design is a duckbill layout that places the weir far enough upstream that the flow can pass through both bays of the original check structure. An example is shown in fig. 5.

Figure 5. Long-crested weir check structure.

The two other potential long-crested weir sites we visited were on the West Canal at mile 6.2 and mile 11.3. These sites were identified by ditchriders (who were also involved in the construction of the first three weirs) as places at which the benefits of more stable canal water surfaces would be greatest. Both sites appear to be good candidates. At the West 6.2 site there is not an existing check; the level needed to serve the turnout at mile 6.2 is maintained by a check located downstream at mile 7.4.

5. Conclusions: The trip was successful and most of the water measurement structures appear to be performing as designed. We will make minor adjustments to some of the rating tables to further increase measurement accuracy and will provide this information to the district separately.

6. Action correspondence initiated or required: Provide adjusted flume and weir ratings to Lugert-Altus Irrigation District, and complete flow measurement structure designs for the W10.6, West Canal Wasteway, and Ozark Wasteway sites.

7. Client feedback received: (Include as appropriate.)

cc: TX-Michalewicz, TX-Johnson, OK-Claggett, OK-Warren, OK-Allard

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bc:

Travelers: August 30, 2006

SIGNATURES AND SURNAMES FOR:

Travel to: Altus, Oklahoma

Date or Dates of Travel: July 3-9, 2006

Names and Codes of Travelers: Wahl, 86-68560

Traveler **Date**

Noted and Dated by: