RECLAMATION

Managing Water in the West

WATER SAVINGS VERIFICATION RESULTS FOR Florida Farmers Ditch Company Canal Lining Project (WEEG-11-141)

WaterSMART Program

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

October 2014

MISSION STATEMENTS

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

WATER SAVINGS VERIFICATION RESULTS FOR FLORIDA FARMERS DITCH COMPANY CANAL LINING PROJECT

WaterSMART Program

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

12/5/14
Date

Peer review: Mark Spears
Hydraulic Engineer
Water Resources Planning & Operations Support Group, 85-821000

12-5-14
Date

BACKGROUND

The Florida Farmers Ditch Company (FFDC) received a Reclamation WaterSmart Water and Energy Efficiency Grant in 2011 (WEEG-11-141) for funding of a canal lining project. This project was identified by Reclamation's Technical Service Center (TSC) staff as a good candidate for a water savings verification effort. The TSC has coordinated with the project Grant Officer's Technical Representative in Reclamation's Western Colorado Southern Division Area Office in Durango, Colorado and also worked with FFDC and its consultant in planning for the water savings verification activities.

CANAL LINING DESCRIPTION

The project includes installation of PVC and geotextile lining with a shotcrete cap, underdrains and earthwork within approximately 1.8 mile upper section of the Florida Farmers Ditch. The associated water savings estimate in the grant proposal of 2,300 acre-ft/yr was based on 2009 inflow/outflow measurements reported by Wright Water Engineers, Inc. (WWE, Florida Mesa Ditch Loss Study, October 2010). Figure 1 is taken from this report and shows the three sections of the Florida Farmers Ditch where measurements were taken (Reaches G, H and I). The section to be lined extends approximately 1.8 miles downstream from the canal's diversion point on the Florida River, including all of Reach G and approximately the upper 0.3 miles of Reach H. The canal lining project was started on August 27, 2012 and was completed in early May 2013. The as-built canal lining reach was shortened to about 1.35 miles because a high water table prevented lining a 900 ft reach below the 10-ft Parshall flume that measures the Florida Farmers Ditch diversion.

EVALUATION PLAN

The plan for water savings verification consisted of pre- and post-project inflow/outflow measurements to estimate pre- and post-lining seepage from the to-be-lined Florida Farmers Ditch section. Two sets of measurements were to be taken (early and late season) using two or more types of acoustic Doppler current profiler devices. Measurement locations were near the canal's diversion point and liner terminus (designated as Reach G by WWE), and at operational turnouts within the to-be-lined section.

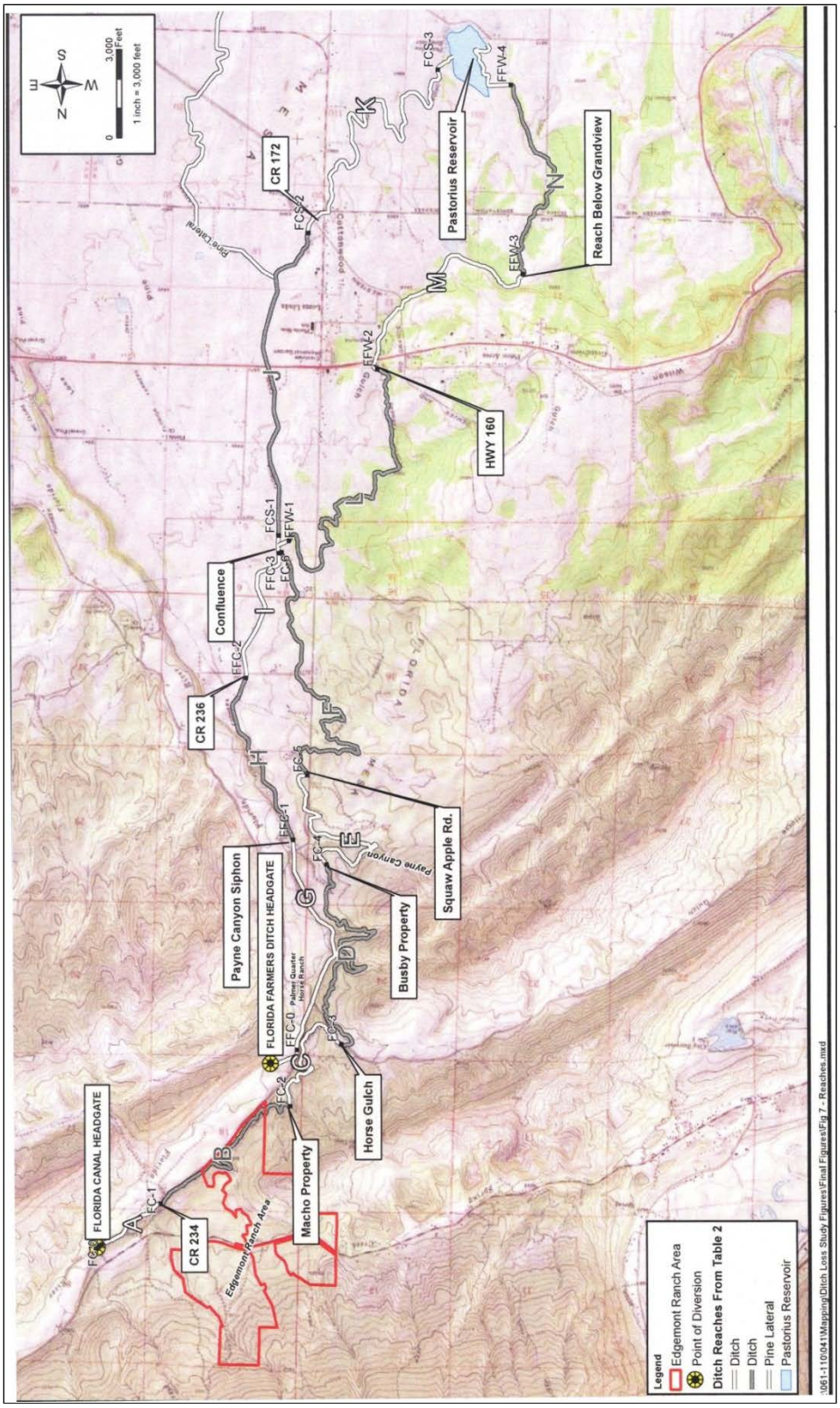

Figure 1. Map of Florida Farmers Ditch and key project locations (WWE 2010)

Following each set of measurements, the TSC analyzed the data, summarized the results, and provided this information to FFDC for review and comments. Any revisions to the data analysis and/or adjustments to procedures were mutually agreed to by TSC and FFDC. All findings were summarized by TSC and reviewed by FFDC before being submitted to Reclamation's Policy and Administration Office.

PRE-PROJECT MEASUREMENTS ON MAY 29, 2012

On May 29, 2012, Tracy Vermeyen, Hydraulic Engineer, TSC Hydraulic Investigations and Laboratory Services Group, travelled to the Florida Farmers project to perform discharge measurements at the start and end of the canal lining project. Mr. Charlie McCoy, District Manager, met Mr. Vermeyen in Durango and escorted him to the measurement sites. They were joined by Ms. Bridget Nash, Water Resources Engineer, from Wright Water Engineers.
The first flow measurement location was at the downstream end of the canal lining project, located just upstream from the Payne Canyon Siphon (Figure 2). This site was located about 180 feet upstream from the siphon entrance and 300 feet downstream from the nearest bend in the canal alignment. The site was free of aquatic vegetation and the cross section was relatively uniform with a mean depth of about 3.2 feet. A moving-bed test did not detect any bed sediment transport which could compromise the discharge measurements. Flows were measured with a portable Teledyne/RD Instruments Streampro acoustic Doppler current profiler (Figure 2). A total of 12 Streampro discharge measurement transects (passes across the channel) were made and the results are summarized in Table 1. The average flow was 172.9 cubic feet per second (ft^3/sec) with a standard deviation of ±4.2 ft^3/sec. The range of discharge measurements was 165 to 180 ft^3/sec.

Table 1. Summary of 12 Streampro discharge measurements at the downstream end of the canal lining project (near the Payne Canyon Siphon).

Transect	Start Bank	# Ens.	Start Time	Total Q ft³/s	Delta Q %	Top Q ft³/s	Meas. Q ft³/s	Bottom Q ft³/s	Left Q ft³/s	Left Dist. ft	Right Q ft³/s	Right Dist. ft	Width ft	Total Area ft²
FFDC004	Left	101	13:14:37	173.294	0.24	26.579	126.275	17.892	0.761	1.00	1.788	1.00	21.28	77.67
FFDC005	Right	81	13:16:41	176.608	2.16	26.862	129.049	17.777	1.266	1.00	1.653	1.00	20.99	76.98
FFDC006	Left	73	13:18:19	174.059	0.68	26.777	126.511	17.913	0.847	1.00	2.011	1.00	21.64	78.40
FFDC007	Right	87	13:19:41	171.405	-0.85	26.807	124.285	17.570	1.155	1.00	1.587	1.00	22.07	80.20
FFDC008	Left	93	13:28:07	169.913	-1.72	26.198	123.758	17.304	0.931	1.00	1.722	1.00	21.36	77.27
FFDC009	Right	107	13:29:51	172.666	-0.12	26.518	125.623	17.636	1.421	1.00	1.468	1.00	21.61	78.55
FFDC010	Left	93	13:31:49	169.008	-2.24	26.115	123.338	16.796	0.853	1.00	1.906	1.00	21.46	77.90
FFDC011	Right	98	13:33:29	164.647	-4.76	25.487	119.832	16.408	1.435	1.00	1.485	1.00	21.30	77.42
FFDC012	Left	91	13:40:26	179.831	4.02	27.676	131.692	17.678	0.898	1.00	1.888	1.00	21.18	76.99
FFDC013	Right	94	13:42:05	177.943	2.93	27.523	128.770	18.463	1.700	1.00	1.487	1.00	21.49	78.11
FFDC014	Left	72	13:43:45	174.803	1.11	26.814	127.743	17.432	0.877	1.00	1.937	1.00	21.99	79.75
FFDC015	Right	81	13:45:04	170.382	-1.44	26.173	124.156	17.177	1.499	1.00	1.377	1.00	22.18	80.47
Average		89		172.880	0.00	26.627	125.919	17.504	1.137	1.00	1.692	1.00	21.54	78.31
Std Dev.		11		4.190	2.42	0.604	3.152	0.541	0.317	0.00	0.214	0.00	0.37	1.22
Std./| Avg.|		0.12		0.02	0.00	0.02	0.03	0.03	0.28	0.00	0.13	0.00	0.02	0.02

Figure 2. Photograph of the flow measurement cross section upstream from the Payne Canyon Siphon (flow is from right to left). The Teledyne/RDI Streampro and tagline were temporarily installed for this flow measurement.

The second flow measurement location was upstream from the start of the canal lining project, located just downstream from a wood bridge (Figure 3). This site was located about 370 feet upstream from the 10-ft concrete Parshall Flume that measures the Florida Farmers Ditch diversion. The Colorado Division of Water Resources maintains a gaging station at this flume (see figure 4). The gaging station is about 1,000 feet below the head gate on the Florida River. The ditch upstream is straight and has a relatively uniform cross section (figure 4). The site was free from any significant aquatic vegetation and the cross section was relatively uniform with a mean depth of about 3.3 feet. A moving-bed test did not detect any bed sediment transport at the time of this flow measurement.

Discharge measurements, using a Streampro, were collected from 3:00 to 3:10 pm. A total of 8 discharge measurement transects (passes across the channel) were made and the average flow was 180.1 ft^3/sec with a standard deviation of ±2.6 ft^3/sec (Table 2). The range of Streampro discharge measurements was 176 to 184 ft^3/sec. The discharge from the Colorado Division of Water Resources gaging station (FARMERCO) was reported to be 178 ft^3/sec at 3:00 and 3:15 p.m. The difference between the measured and reported discharge is 1.1 percent which is well within the uncertainty range of both flow measurements. A review of the FARMERCO discharge records showed the flow was steady at 177 to 179 ft^3/sec for 24 hours prior to the Streampro measurements.

Figure 3. Photograph looking upstream from the wood bridge crossing the Florida Farmers Ditch above the flow measurement site.

Figure 4. Photograph of 10-ft concrete Parshall Flume and water stage recorder used to monitor Florida Farmers Ditch diversions (**DWR Site: FARMERCO**).

Table 2. Summary of 8 Streampro discharge measurements near the start of the canal lining project.

Transect	Start Bank	# Ens.	Start Time	Total Q ft³/s	Delta Q %	Top Q ft³/s	Meas. Q ft³/s	Bottom Q ft³/s	Left Q ft³/s	Left Dist. ft	Right Q ft³/s	Right Dist. ft	Width ft	Total Area ft²
FFDCUS000	Left	67	14:58:37	179.434	-0.38	30.441	128.545	19.211	1.236	1.00	0.000	0.00	18.22	62.42
FFDCUS001	Right	79	14:59:54	181.800	0.93	30.794	127.945	19.706	2.119	1.00	1.201	1.00	19.74	64.23
FFDCUS002	Left	60	15:01:19	180.140	0.01	30.794	127.027	19.282	1.271	1.00	1.730	1.00	19.05	62.28
FFDCUS003	Right	60	15:02:24	178.092	-1.13	30.406	126.532	18.399	1.519	1.00	1.307	1.00	20.58	65.69
FFDCUS004	Left	78	15:05:01	178.410	-0.95	29.982	128.263	18.116	-0.177	1.00	2.260	1.00	20.26	65.78
FFDCUS005	Right	68	15:06:24	184.166	2.24	30.547	130.664	19.282	1.942	1.00	1.730	1.00	18.91	63.11
FFDCUS006	Left	69	15:07:38	176.185	-2.19	29.205	125.226	18.681	1.271	1.00	1.801	1.00	18.45	61.46
FFDCUS007	Right	57	15:08:53	182.753	1.46	30.441	129.393	19.211	2.225	1.00	1.483	1.00	19.20	63.75
Average		67		180.122	0.00	30.326	127.949	18.986	1.426	1.00	1.439	0.88	19.30	63.59
Std Dev.		8		2.649	1.47	0.520	1.698	0.533	0.760	0.00	0.668	0.35	0.83	1.58
Std./| Avg.|		0.12		0.01	0.00	0.02	0.01	0.03	0.53	0.00	0.46	0.40	0.04	0.02

Turnout Flows

During the May 29, 2012 flow measurements, Mr. Vermeyen visited two small turnouts along Reach G. The turnout near the Horse Gulch siphon was delivering 0.25 ft^3/sec according to the 6-in Parshall Flume (figure 5). A field measurement was not taken because measurement of the low flow in the undefined channel would have been less accurate than the flume measurement. There was a second turnout near the Payne Canyon siphon, but it was shut-off during these flow measurements. The condition of these Florida Farmer Ditch flow measurement flumes were documented in a WWE memorandum (WWE, May 2012).

Figure 5. Photograph of 6-in. Parshall Flume on Farmers Florida Ditch diversion near the Horse Gulch siphon, N37.28947° W107.79643°.

Observed Seepage

On May 29, 2012, Mr. McCoy took Mr. Vermeyen to an area of significant seepage from the Florida Farmers Ditch. The seepage site is located about 0.4 miles downstream from the gaging station. Figure 6 is a photograph of the seepage area located between the ditch and CO Rd 234. According to Mr. McCoy, this seepage was typical for this relatively high flow in the ditch.

Figure 6. Photograph of canal seepage from the Florida Farmers Ditch near N37.28796° W107.79712°.

Previous Seepage Loss Measurements

Farmers Florida Ditch Reach G

WWE used the tracer (salt)-dilution method to measure discharge in the Florida Farmers Ditch on July 14, 2009 (WWE, October 2010). Discharge at the headgate (DWR: FARMERCO) was 157.0 cfs as measured with the 10-foot Parshall Flume. WWE measured discharge of the Florida Farmers Ditch below the Payne Canyon siphon to be 143.3 cfs, with turnout diversions of 0.5 cfs in Reach G. The seepage loss was estimated to be 13.2 cfs, and the normalized loss was 0.055 cfs/mile/cfs. WWE states that "most of the loss in Reach G probably occurs near Palmer Quarter Horse Ranch where CO Rd 234 crosses the Florida River."

May 29, 2012 Seepage Loss Estimate for Reach G of the Florida Farmers Ditch

Using the same methodology used by WWE – a normalized seepage loss was calculated in cfs (loss) per mile per cfs (flow) from (WWE, October 2010). A normalized seepage loss for Reach G was computed using a loss of 6.45 cfs over the reach length of 1.52 miles for a diversion flow rate of 180.1 ± 2.6 cfs. The normalized reach loss was computed to be 0.0235 cfs/mile/cfs. This loss is less than half what was reported by WWE in its 2010 report, 0.055 cfs/mile/cfs. However, seepage rates are highly variable and difficult to measure over such a short reach. The one likely reason for the difference is the methodology used to measure flowrates. Also, WWE did not report an uncertainty estimate for their tracer-dilution flow measurements to compare with the ±3.9 cfs standard error of the Streampro measurements made upstream from the Payne Canyon Siphon. However, a higher seepage rate for this higher flow was anticipated especially

since it was early in the irrigation season - 19 days after diversions started. Conversely, WWE seepage measurements were made on July 14, 2009 at a diversion flow of 157 ft^3/sec.

PRE-PROJECT MEASUREMENTS ON JULY 31, 2012

On July 31, 2012, Tracy Vermeyen travelled to the Florida Farmers project to perform a second set of discharge measurements at the start and end of the canal lining project. Mr. Charlie McCoy, District Manager, met Vermeyen in Durango and escorted him to the measurement sites. Flow measurements were repeated at the end of the proposed canal lining project, located just upstream from the Payne Canyon Siphon (Figure 1). The site was free of aquatic vegetation and the cross section was relatively uniform with a mean depth of depth about 2.3 ft. The water was clear enough to see the bottom which was primarily gravel and cobbles. A moving-bed test did not detect any bed sediment transport which could compromise the discharge measurements. Flows were measured with the same Teledyne/RD Instruments Streampro acoustic Doppler current profiler used on May 29, 2012. A total of 8 Streampro discharge measurement transects (passes across the channel) were made from 11:35 until 11:57 a.m. (Table 3). The average flow was 121.3 ft^3/sec with a standard deviation of ±3.4 ft^3/sec. The range of discharge measurements was 117 to 127 ft^3/sec.

The second flow measurement was at the same location measured on May 29, 2012 (Figure 2). This site was located about 370 ft upstream from the 10-ft concrete Parshall flume that measures the Florida Farmers Ditch diversion. The water was clear enough to see the bottom which was primarily sand and gravel. The site was still free from any significant aquatic vegetation and the cross section was relatively uniform with a mean depth of depth about 2.8 ft. A moving-bed test did not indicate any bed sediment transport.

Table 3. Summary of Streampro discharge measurements at the downstream end of the canal lining project. Transect FFDCDS013 data is highlighted in red because it is greater than 5% of the average discharge.

Transect	Start Bank	# Ens.	Start Time	Total Q ft^3/s	Delta Q %	Top Q ft^3/s	Meas. Q ft^3/s	Bottom Q ft^3/s	Left Q ft^3/s	Left Dist. ft	Right Q ft^3/s	Right Dist. ft	Width ft	Total Area ft^2
FFDCDS007	Right	81	11:35:39	122.477	1.00	27.961	77.769	14.369	1.021	1.50	1.357	1.50	22.65	51.28
FFDCDS008	Left	73	11:37:35	120.904	-0.29	27.036	76.726	13.886	1.569	1.50	1.688	1.50	22.79	52.23
FFDCDS010	Left	51	11:41:20	119.156	-1.74	25.446	76.256	12.884	2.526	1.50	2.044	1.50	20.95	50.25
FFDCDS011	Right	73	11:48:08	124.336	2.54	27.480	79.895	13.927	1.508	1.50	1.526	1.50	22.02	50.82
FFDCDS012	Left	71	11:50:19	118.092	-2.61	25.928	75.257	13.315	1.762	1.50	1.830	1.50	22.05	51.79
FFDCDS013	Right	72	11:52:24	127.350	5.02	28.233	81.442	14.865	1.498	1.50	1.312	1.50	22.70	52.12
FFDCDS014	Left	71	11:54:25	117.270	-3.29	25.669	74.196	13.401	1.451	1.50	2.552	1.50	21.63	50.51
FFDCDS015	Right	74	11:56:18	120.499	-0.63	27.083	76.626	13.741	1.531	1.50	1.518	1.50	21.90	50.50
Average		70		121.260	0.00	26.855	77.271	13.799	1.608	1.50	1.728	1.50	22.09	51.19
Std Dev.		9		3.362	2.77	1.059	2.384	0.623	0.425	0.00	0.412	0.00	0.63	0.78
Std./| Avg.|		0.13		0.03	0.00	0.04	0.03	0.05	0.26	0.00	0.24	0.00	0.03	0.02

Discharge measurements, using a Streampro, were collected from 12:37 to 12:49 p.m. A total of 8 discharge measurement transects (passes across the channel) were made and the average flow was 125.6 ft^3/sec with a standard deviation of ±2.0 ft^3/sec (Table 4). The range of Streampro discharge measurements was 123 to 129 ft^3/sec. The discharge from the Colorado Division of Water Resources gaging station (FARMERCO) was reported to be 125 ft^3/sec at 12:30, 12:45, and 1:00 p.m. The difference between the measured and reported discharge is 0.5 percent which is well within the uncertainty range of both flow measurements. A review of the FARMERCO discharge records showed the flow was steady at 124 to 125 ft^3/sec for 12 hours prior to the Streampro measurements.

Table 4. Summary of Streampro discharge measurements near the upstream end of the canal lining project.

Transect	Start Bank	# Ens.	Start Time	Total Q ft³/s	Delta Q %	Top Q ft³/s	Meas. Q ft³/s	Bottom Q ft³/s	Left Q ft³/s	Left Dist. ft	Right Q ft³/s	Right Dist. ft	Width ft	Total Area ft²
FFDCUS000	Left	64	12:37:25	124.667	-0.71	29.104	64.398	24.849	1.714	1.00	4.602	2.00	17.79	49.23
FFDCUS001	Right	64	12:39:17	123.861	-1.35	29.165	60.548	27.848	1.838	1.00	4.462	2.00	17.60	48.64
FFDCUS002	Left	62	12:40:55	129.552	3.19	31.728	67.334	26.816	1.823	1.00	1.851	1.00	18.15	50.25
FFDCUS003	Right	57	12:42:22	127.405	1.48	31.473	65.905	26.225	1.978	1.00	1.824	1.00	17.86	50.09
FFDCUS004	Left	60	12:44:09	124.658	-0.71	30.822	64.657	25.138	2.078	1.00	1.964	1.00	17.85	49.78
FFDCUS005	Right	56	12:45:31	124.086	-1.17	30.274	59.955	29.837	2.060	1.00	1.960	1.00	17.71	49.76
FFDCUS006	Left	54	12:46:43	124.709	-0.67	32.044	61.485	27.302	2.013	1.00	1.865	1.00	17.70	49.27
FFDCUS007	Right	63	12:48:04	125.482	-0.06	30.850	65.120	25.565	2.114	1.00	1.834	1.00	17.32	48.89
Average		60		125.553	-0.00	30.682	63.675	26.698	1.952	1.00	2.545	1.25	17.75	49.49
Std Dev.		4		1.954	1.56	1.107	2.682	1.644	0.144	0.00	1.228	0.46	0.24	0.57
Std./| Avg.|		0.07		0.02	0.00	0.04	0.04	0.06	0.07	0.00	0.48	0.37	0.01	0.01

Turnout Flows

During the July 31, 2012 flow measurements, neither of the two small turnouts in the lining project reach were delivering water during these flow measurements (pers. commun. with Mr. Charlie McCoy, July 31, 2012).

Observed Seepage

The seepage site that was observed on May 31, 2012 was observed to be dry on July 31, 2012. Figure 7 is a photograph of the dry seepage area.

Figure 7. July 31, 2012 photograph of the same canal seepage area from May 29, 2012 (shown in figure 6) that had dried up, N37.28796° W107.79712°.

July 31, 2012 Seepage Loss Estimate for Reach G of the Florida Farmers Ditch

Using the same methodology used by Wright Water Engineers, a normalized seepage loss was calculated in ft^3/sec (loss) per mile per ft^3/sec (diversion flow), WWE, October 2010. A normalized seepage loss for Reach G was computed using a loss of 4.30 ft^3/sec over the reach

length of 1.52 miles for a diversion flow rate of 125.6 ± 2.0 ft^3/sec. The normalized reach loss was computed to be 0.0225 ft^3/sec/mile/ft^3/sec. This loss is slightly less than what was measured May 31, 2012. This seepage loss is much less than what was reported by WWE in their 2010 report, 0.055 ft^3/sec/mile/ft^3/sec, even though the time of year and diversion flow were similar - WWE seepage measurements were made on July 14, 2009 at a diversion flow of 157 ft^3/sec**.**

POST-PROJECT MEASUREMENTS ON MAY 21, 2013

On May 21, 2013, Tracy Vermeyen travelled to the Florida Farmers project to perform a set of discharge measurements at the start and end of the recently completed canal lining project. Mr. Charlie McCoy, District Manager, met Mr. Vermeyen in Durango and escorted him to the measurement sites. Ms. Bridget Nash, Water Resources Engineer, with Wright Water Engineers participated in the flow measurements.

Flow measurements were repeated at the end of the canal lining project, located just upstream from the Payne Canyon Siphon (Figure 8). This canal reach was designated as "G" in previous studies by Wright Water Engineers. The site was the same as previous measurement except the canal was now lined with shotcrete. The canal cross section was very uniform with a mean and max depth of 2.8 and 3.8 ft, respectively. A moving-bed test did not detect any bed sediment transport which could compromise the discharge measurements. Flows were measured with the same Teledyne/RD Instruments Streampro acoustic Doppler current profiler used for the 2012 pre-project measurements. A total of 6 Streampro discharge measurement transects (passes across the channel) were made from 12:17 until 12:25 p.m. (Table 5). The average flow was 167.47 ft^3/sec with a standard deviation of ±2.29 ft^3/sec. The range of discharge measurements was 165 to 172 ft^3/sec and the average channel velocity was 2.79 ft/sec.

Figure 8. Photograph of the flow measurement cross section upstream from the Payne Canyon Siphon (flow is from right to left). The Teledyne/RDI Streampro and tagline were installed at the same location as pre-project measurements.

Table 5. Summary of six Streampro discharge measurements at the downstream limit of the canal lining project, May 21, 2013.

Transect	Start Bank	# Ens	Start Time	Total Q ft³/s	Delta Q %	Top Q ft³/s	Meas. Q ft³/s	Bottom Q ft³/s	Left Q ft³/s	Left Dist. ft	Right Q ft³/s	Right Dist. ft	Width ft	Total Area ft²
FFDCDS016	Right	69	12:17:22	165.379	-1.25	29.523	109.016	19.953	4.026	2.00	2.825	2.00	21.32	60.08
FFDCDS017	Left	68	12:19:04	167.780	0.19	30.371	111.630	19.423	3.072	2.00	3.284	2.00	21.18	58.90
FFDCDS018	Right	52	12:20:42	166.297	-0.70	29.135	109.864	19.035	4.803	2.00	3.496	2.00	21.17	60.85
FFDCDS019	Left	55	12:22:03	167.921	0.27	29.912	111.453	19.211	3.708	2.00	3.637	2.00	21.22	59.79
FFDCDS020	Right	50	12:24:00	165.802	-0.99	29.346	109.122	19.070	4.697	2.00	3.567	2.00	21.35	60.84
FFDCDS021	Left	61	12:25:14	171.629	2.48	30.688	113.607	20.094	3.426	2.00	3.849	2.00	21.10	59.66
Average		59		167.468	-0.00	29.829	110.782	19.464	3.955	2.00	3.443	2.00	21.22	60.02
Std Dev.		8		2.286	1.37	0.608	1.781	0.456	0.692	0.00	0.354	0.00	0.09	0.75
Std./| Avg.|		0.14		0.01	0.00	0.02	0.02	0.02	0.17	0.00	0.10	0.00	0.00	0.01

Figure 9. Photograph of Streampro measurement located 640 ft downstream from the start of canal lining. This location was selected to be an adequate distance downstream from a bend in the canal, N37°17'24.4" W107°47'46.5".

The second flow measurement site (figure 9) was setup 640 ft downstream from the start of the canal lining project. The canal lining project begins about 900 ft downstream from the 10-ft Parshall Flume. This flow measurement site was located about 1,540 feet downstream from the 10-ft concrete Parshall Flume that measures the Florida Farmers Ditch diversion. The measurement site was in a straight section of lined canal about 230 ft upstream from the Horse Gulch siphon. A moving-bed check did not detect any bed sediment transport at the time of this flow measurement.

Streampro discharge measurements were collected from 1:53 to 2:10 p.m. A total of 8 discharge measurement transects were made and the average flow was 167.79 ft^3/sec with a standard deviation of ±2.91 ft^3/sec (table 6). The range of Streampro discharge measurements was 164 to 173 ft^3/sec. The discharge from the Colorado Division of Water Resources (CDWR) gaging station (FARMERCO) website reported a flow of 169 ft^3/sec at 14:00. The difference between the Streampro measured and CDWR reported discharge is -0.7 percent which is well within the uncertainty range of both flow measurement methods. A review of the FARMERCO discharge

records showed the flow was steady at 169 to 171 ft^3/sec for 12 hours prior to making these Streampro measurements. Note: if the standard 10-ft Parshall flume discharge equation[1] in Reclamation's Water Measurement Manual -3rd Edition is used, the canal inflow was 167.3 ft^3/sec.

Table 6. Summary of eight Streampro discharge measurements near the upstream limit of the canal lining project, May 21, 2013.

Transect	Start Bank	# Ens.	Start Time	Total Q ft^3/s	Delta Q %	Top Q ft^3/s	Meas. Q ft^3/s	Bottom Q ft^3/s	Left Q ft^3/s	Left Dist. ft	Right Q ft^3/s	Right Dist. ft	Width ft	Total Area ft^2
FFCUS001	Left	67	13:53:25	168.544	0.45	34.635	108.676	17.577	3.365	2.00	4.290	2.00	20.00	48.67
FFCUS002	Right	55	13:54:48	167.459	-0.20	34.180	106.151	17.543	4.644	2.00	4.941	2.00	19.95	48.88
FFCUS003	Left	82	13:55:58	173.177	3.21	35.669	111.739	18.117	3.317	2.00	4.336	2.00	20.21	49.36
FFCUS004	Right	74	13:58:22	169.833	1.22	35.320	107.902	18.504	3.933	2.00	4.174	2.00	20.10	48.81
FFCUS005	Left	68	14:01:04	164.213	-2.13	33.860	105.474	17.078	3.149	2.00	4.652	2.00	19.98	48.58
FFCUS006	Right	89	14:02:42	164.341	-2.06	33.890	105.162	17.468	3.641	2.00	4.181	2.00	19.87	48.16
FFCUS009	Left	80	14:09:15	166.858	-0.56	34.621	105.648	17.814	3.299	2.00	5.475	2.00	20.43	49.69
FFCUS010	Right	75	14:10:48	167.917	0.07	34.849	107.286	17.886	4.290	2.00	3.606	2.00	20.44	49.24
Average		73		167.793	0.00	34.628	107.255	17.748	3.705	2.00	4.457	2.00	20.12	48.92
Std Dev.		11		2.914	1.74	0.649	2.201	0.436	0.537	0.00	0.565	0.00	0.22	0.49
Std./| Avg.|		0.15		0.02	0.00	0.02	0.02	0.02	0.15	0.00	0.13	0.00	0.01	0.01

Turnout Flows

During the May 21, 2013 flow measurements, neither of the two small turnouts in the lining project reach was diverting water during these flow measurements (pers. commun. with Mr. Charlie McCoy, May 21, 2013).

Observed Seepage

The seepage that was observed on May 31, 2012 (see figure 6) was observed to be dry on May 21, 2013. Figure 10 is a photograph of this seepage area taken on May 21, 2013.

Figure 10. May 21, 2013 photograph of the same canal seepage area observed on May 29, 2012 (see figure 6) which has remained dry since canal start-up on May 6, 2013. Photograph was taken at N37.28796° W107.79712°.

[1] Free flow discharge equation for a standard 10-ft Parshall flume: $Q=39.38*h_a^{1.6}$

May 21, 2013 Seepage Loss Estimate for Reach G of the Florida Farmers Ditch

Using the same methodology used by Wright Water Engineers, a normalized seepage loss was calculated in ft^3/sec (loss) per mile per ft^3/sec (diversion flow). A normalized seepage loss for Reach G was computed using a loss of 0.32 ft^3/sec over the reach length of 1.35 miles (lined canal length) for a diversion flow rate of 167.79 ± 2.91 ft^3/sec. The normalized reach loss was computed to be 0.0014 ft^3/sec/mile/ft^3/sec. This computed seepage loss for the lined canal is statistically insignificant because the seepage loss (0.32 ft^3/sec) is an order of magnitude less than the uncertainty of the discharge measurements (± 2.9 ft^3/sec). However, the post-project computed seepage loss will be used to make comparison with pre-project seepage losses.

SEASONAL SEEPAGE ESTIMATES

Using the two seepage measurements from 2012, a simple linear relationship was developed to estimate the seasonal variation in seepage from Reach G of the Florida Farmers ditch. The best-fit relationship for canal seepage loss versus canal inflow to the project reach is:

$Y=0.035*X$, where Y is the seepage loss in ft^3/sec and X is the inflow in ft^3/sec

Using this relationship and the average daily value of Parshall flume measured discharge for X (obtained from the Colorado Division of Water Resources website) a daily seepage loss (Y) was estimated for each day of the 2012 irrigation season (May 10 through August 19, 2012). The daily seepage losses were converted to acre-ft/day using the conversion:

Seepage Loss (ft^3/sec) *86,400 sec/day * 1 acre/43,560 ft^2.

The daily seepage losses were summed over the irrigation season to estimate the total seepage loss in acre-ft. This same analysis was done for the 2009, 2010, and 2011 irrigation seasons for comparison. It is important to note that these seepage estimates are computed from a simple relationship for seasonal variation in canal seepage because only two seepage measurements were made in 2012. If more seepage measurements were made throughout the irrigation season a more accurate seepage vs. canal inflow relationship could be developed taking into account possible seepage variations related to changes in water table elevation.

Table 5 contains the estimated seasonal seepage from Reach G of the Florida Farmers Ditch for pre- and post-project seepage rates. These data show that seasonal seepage losses in the project reach vary from 950 to 1,380 acre-ft depending on the number of days and average daily diversion flowrate. The average estimated seepage loss for 2009 through 2012 is 1,169 acre-ft.

To compute a comparable seepage estimate for the lined-canal reach, a constant seepage rate and the canal operations for the 2012 irrigation season were assumed. The comparable estimate of seepage loss for the lined section of Reach G was 51.0 acre-ft. Similarly, average estimated lined canal seepage loss for 2009 through 2012 is 63 acre-ft.

Table 5. Summary of irrigation season characteristics and estimated seasonal seepage losses.

Irrigation Season (Year)	Length of Irrigation Season (days)	Average Daily Diversion (ft^3/sec)	Total Seepage Loss for Irrigation Season (acre-ft)	Estimated Lined Canal Seepage Loss for Irrigation Season (acre-ft)
2009	137	144	1,380	74
2010	129	115	1,039	56
2011	129	144	1,305	70
2012	101	135	953	51
Average	**124**	**134.5**	**1,169**	**63**

CONCLUSIONS

The Reach G canal lining project reduced the normalized reach loss to 0.0014 ft^3/sec/mile/ft^3/sec which is a 95% reduction from the normalized reach loss of 0.0235 cfs/mile/cfs measured in May 2012. For the 2012 irrigation season an estimate of 902 acre-ft/year of water savings could be attributed to the 2013 canal lining project on Reach G of the Florida Farmers Ditch. This estimate was based on a very simple relationship of seepage loss versus canal inflow based on two seepage measurements taken in 2012 (pre-project).

Using four years of water diversion data (2009-2012) an estimated average water savings of 1,103 acre-ft per year could be attributed to the Reach G canal lining project.

The 2009 water saving estimate bases on the pre- and post-project seepage measurements was about 1,000 acre-ft less than the water savings estimate of 2,300 acre-ft/yr reported by Wright Water Engineers, Inc. The difference in the two estimates is like attributed to the uncertainty in the discharge measurement techniques used for the inflow and outflow measurements.

The close agreement between Streampro measurements and the flow measured using the 10-ft Parshall flume (FARMERCO) created confidence in both the flume's calibration and the Streampro's performance.

REFERENCES

Wright Water Engineers, Inc., Florida Mesa Ditch Loss Study, October 2010 (061-100.041)

Wright Water Engineers, Inc. Memorandum, Florida Farmers Ditch - Flume Measurements and Water Saving Verification, May 4, 2012.