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WATER MEASUREMENT

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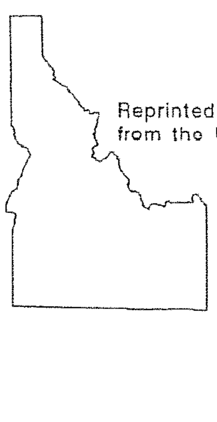

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The University of Idaho College of Agriculture Bulletin No. 552 has been reprinted to provide a general reference of water measurement devices commonly used in Idaho and to provide supplemental material for a water measurement video sponsored jointly by the US Bureau of Reclamation, the Idaho Department of Water Resources and the Idaho Water Users Association. Excerpts from other publications have been added for several measuring structures which are shown in the video but not covered in the University of Idaho Bulletin.

Copies of the video, "Let's Measure Up", may be obtained through the Idaho Water Users Association. The sponsors' directory is included in the manual.

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WATER MEASUREMENT

By D.C. LARSEN

Associate Extension Professor and Extension Irrigationist

Increasing demands from industry, recreational interests, municipal needs and agriculture are creating pressures on water, a very important and limited resource. The greater the demand, the greater the need for water users to use and share available water wisely. How can a user practice good management unless he knows the amount of water involved? Measuring water will help every user get his fair share and be treated equally.

In today's world good performance is demanded. In the quest for protection of the environment, water measurement will help reduce excessive waste and lessen drainage problems. It will establish a record of improved use and improve public relations.

Water is measured in two ways — in motion and at rest. Motion units used are Idaho miner's inches, gallons per minute and cubic feet per second. Rest units are acre-inches or acre-feet. These water measurement units are compared in Table 1. The depth of water applied in 12 or 24 hours by various stream sizes is shown in Table 2 for different acreages.

Table 1. Equivalent rates of flow.

Cubic feet per second (cfs)	Idaho Miner's inches	Gallons per minute (gpm)	Acre-inches per hour	Acre-feet per day (24 hours)
0.2	10	90	0.2	0.4
0.4	20	180	0.4	0.8
0.6	30	270	0.6	1.2
0.8	40	360	0.8	1.6
1.0	50	450	1.0	2.0
1.2	60	540	1.2	2.4
1.4	70	630	1.4	2.8
1.6	80	720	1.6	3.2
1.8	90	810	1.8	3.6
2.0	100	900	2.0	4.0
2.2	110	990	2.2	4.4
2.4	120	1080	2.4	4.8
2.6	130	1170	2.6	5.2
2.8	140	1260	2.8	5.6
3.0	150	1350	3.0	6.0
3.2	160	1440	3.2	6.4
3.4	170	1530	3.4	6.8
3.6	180	1620	3.6	7.2
3.8	190	1710	3.8	7.6
4.0	200	1800	4.0	8.0
5.0	250	2250	5.0	10.0
6.0	300	2700	6.0	12.0
7.0	350	3150	7.0	14.0
8.0	400	3600	8.0	16.0
9.0	450	4050	9.0	18.0
10.0	500	4500	10.0	20.0

Table 2. Depths of water applied by various flows, times and acres.

Water flow			Acres Applied									
			1		2		3		4		5	
Cubic ft per second	Idaho Miner's inches	gal per min	12 h	24 h	12 h	24 h	12 h	24 h	12 h	24 h	12 h	24 h
			Inches		Inches		Inches		Inches		Inches	
0.10	5	45	1.19	2.38	0.60	1.19	0.40	0.79	0.30	0.60	0.24	0.48
0.20	10	90	2.38	4.75	1.19	2.38	0.79	1.59	0.60	1.19	0.48	0.95
0.40	20	180	4.75	9.52	2.38	4.76	1.59	3.17	1.19	2.38	0.95	1.90
0.60	30	270	7.14	14.28	3.57	7.14	2.38	4.76	1.79	3.57	1.43	2.86
0.80	40	360	9.52	19.04	4.76	9.52	3.17	6.35	2.38	4.76	1.90	3.81
1.00	50	450	11.90	23.80	5.95	11.90	3.97	7.93	2.98	5.95	2.38	4.76
1.20	60	540	14.28	28.56	7.14	14.28	4.76	9.52	3.57	7.14	2.86	5.71
1.40	70	630	16.66	33.32	8.33	16.66	5.55	11.11	4.17	8.33	3.33	6.66
1.60	80	720	19.04	38.08	9.52	19.04	6.35	12.69	4.76	9.52	3.81	7.62
1.80	90	810	21.42	42.84	10.71	21.42	7.14	14.28	5.36	10.71	4.28	8.57
2.00	100	900	23.80	47.60	11.90	23.80	7.93	15.87	5.95	11.90	4.76	9.52
2.20	110	990							6.55	13.09	5.24	10.47
2.40	120	1080							7.14	14.28	5.71	11.42
2.60	130	1170							7.74	15.47	6.19	12.38
2.80	140	1260							8.33	16.66	6.66	13.33
3.00	150	1350							8.93	17.85	7.14	14.28

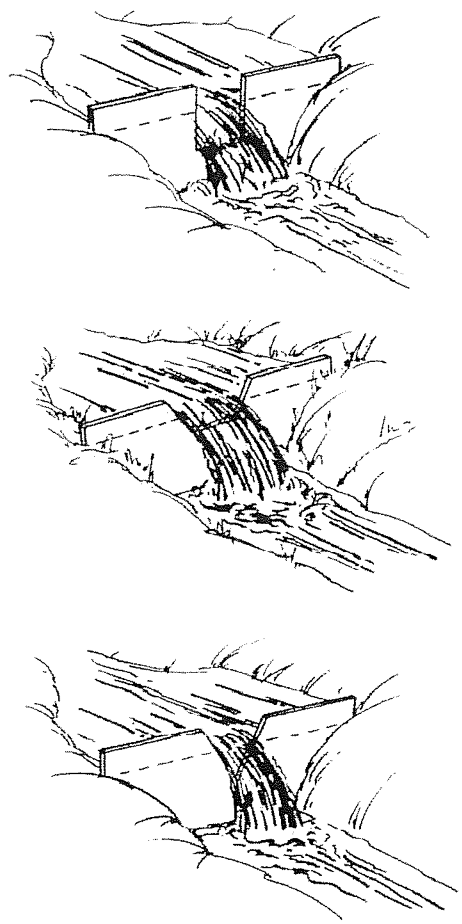
Table 2 (Continued). Depth of water applied by various flows, time and acres.

Water flow			Acres Applied									
			6		7		8		9		10	
Cubic ft per second	Idaho Miner's inches	gal per min	12 h	24 h	12 h	24 h	12 h	24 h	12 h	24 h	12 h	24 h
			Inches		Inches		Inches		Inches		Inches	
0.10	5	45	0.20	0.40	0.17	0.34	0.15	0.30	0.13	0.26	0.12	0.24
0.20	10	90	0.40	0.79	0.34	0.68	0.30	0.60	0.26	0.53	0.24	0.48
0.40	20	180	0.79	1.59	0.68	1.36	0.60	1.19	0.53	1.06	0.48	0.95
0.60	30	270	1.19	2.38	1.02	2.04	0.89	1.79	0.79	1.59	0.71	1.43
0.80	40	360	1.59	3.17	1.36	2.72	1.19	2.38	1.06	2.12	0.95	1.90
1.00	50	450	1.98	3.97	1.70	3.40	1.49	2.98	1.32	2.64	1.19	2.38
1.20	60	540	2.38	4.76	2.04	4.08	1.79	3.57	1.59	3.17	1.43	2.86
1.40	70	630	2.78	5.55	2.38	4.76	2.08	4.17	1.85	3.70	1.67	3.33
1.60	80	720	3.17	6.35	2.72	5.44	2.38	4.76	2.12	4.23	1.90	3.81
1.80	90	810	3.57	7.14	3.06	6.12	2.68	5.36	2.38	4.76	2.12	4.28
2.00	100	900	3.97	7.93	3.40	6.80	2.98	5.95	2.64	5.29	2.38	4.75
2.20	110	990	4.36	8.73	3.74	7.48	3.27	6.55	2.91	5.82	2.62	5.24
2.40	120	1080	4.76	9.52	4.08	8.16	3.57	7.14	3.17	6.35	2.86	5.71
2.60	130	1170	5.16	10.31	4.42	8.84	3.87	7.74	3.44	6.88	3.09	6.19
2.80	140	1260	5.55	11.11	4.76	9.52	4.17	8.33	3.70	7.40	3.33	6.66
3.00	150	1350	5.95	11.90	5.10	10.20	4.46	8.93	3.97	7.93	3.57	7.14

Water is conveyed in both open channels and closed conduits. This bulletin will consider some of the standard water measuring devices designed to operate under open and closed flow conditions.

OPEN FLOW

Idaho has many miles of open canals and ditches. On-farm conveyance and distribution systems equipped with measuring devices will improve water distribution and make the irrigation job much easier.



Rectangular weir

Cipolletti weir

V-notch weir

Fig. I. Three types of weirs used in Idaho.

Weirs

A weir is an over-pour notch of fixed dimensions in a vertical bulkhead or head wall through which water may flow. When properly constructed, installed and maintained, it provides a simple and accurate means of measuring water. Weirs are easy to construct and accurate if dimensions are followed carefully. They will handle floating trash and not clog easily.

Every water-measuring device has a set of standard operating conditions that must be met if it is to be accurate. If these conditions cannot be met at a given site, another measuring device should be used. A weir requires approximately a 6-inch drop between the upstream and downstream water surfaces. This loss in head is often not available in ditches with flat grades. The water must approach the weir crest very slowly. This condition is achieved by backing the water up in a weir pond with a bulkhead or head wall.

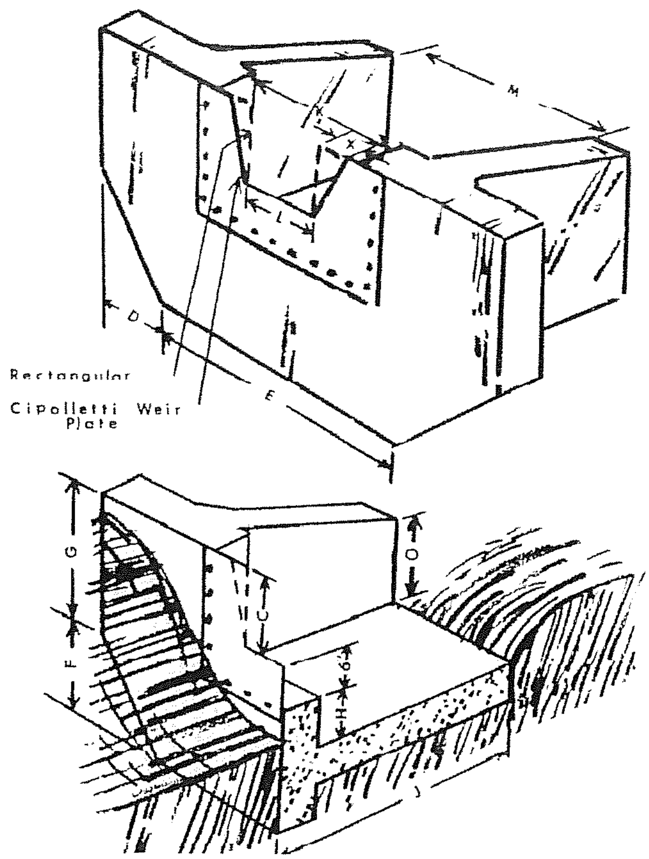
If the water is carrying silt it may settle out and fill the weir pond. This causes the approach velocity of the water to increase and the device becomes inaccurate. Grass and weeds thrive in the slow water and the weir pond requires maintenance to keep it free of silt and weeds.

Commonly used weirs, classified by the shape of the notch, are the rectangular weir, the Cipolletti weir, and the V-notch weir as illustrated in Fig. 1.

How to Install a Weir

A weir can perform accurately only if correctly constructed, installed and used. The following standard conditions must be followed:

1. Set the weir in a channel that is straight for a distance upstream from the weir of at least 10 times the weir crest length.
2. Place the weir at right angles to the direction of flow, and vertical.
3. The water approaching the weir should be free from eddies and flow slower than one-half foot per second. A weir pond can be created by the way the structure is built. The height of the crest above the bottom of the ditch should be at least twice the maximum head or depth of water flowing over the crest. The distance from the side of the weir notch to the side of the channel should be at least twice the maximum weir head. This is called a contracted weir. A bulkhead of the above proportions is used with a metal weir plate fastened to it.
4. Avoid backing the water up on the downstream side of the weir. Water must flow freely below the device, leaving an air space under the over-falling sheet of water. A concrete or rock apron should be used to prevent washing below the structure.
5. The weir plate containing the notch is usually made of steel plate no thicker than 1/8 inch. It must have exact dimensions and its edges must be rigid, straight and sharp on the upstream face. The notch should be beveled at 45 degrees on the downstream side. Avoid knife edges as they are difficult to maintain. The weir crest should be level and very accurate in length.
6. Select the crest size so the minimum head to be measured exceeds 2 inches and the maximum head is not greater than one-third the length of the weir.



Crest length L ft.	Recommended range of measurement in C.f.s. Rectangular	Cipolletti	C=H ft-in	D ft-in	E ft-in	F ft-in	G ft-in	J ft-in	K ft-in	M ft-in	N ft-in	O ft-in	X in
						For Rectangular and Cipolletti Weirs							
1.0	.2 to .6	.2 to .6	8	0	5-8	0	2-7	3	2	2-6	10	1-4	2
1.5	.3 to 1.7	.3 to 1.8	1	1-4	4-6	1-4	2	3-6	2-6	3	10	1-4	3
2.0	.4 to 3.5	.4 to 3.7	1-2	2	5	2	2	4	3	3-6	1	1-6	3½
3.0*	.6 to 9.5	.6 to 10.0	1-6	2-6	7	2-6	2-6	4-6	4-4	5	1-6	2	4½
4.0*	.8 to 19.5	.9 to 20.7	2	3-10	8-4	3-10	2-10	5	5-6	6	2	2-6	6
						For 90° V-Notch Weirs							
2.0	.02 to 1.5		1	1-6	5	1-6	2-8	3-6	2-6	3	10	1-4	
3.0*	.02 to 4.0		1-6	2-2	6-2	2-2	3-4	4	3-6	4	1	1-6	

*Use 6" x 6" No. 12 wire mesh reinforcing or equivalent.

Fig. 2. Dimensions and capacities for Rectangular, Cipolletti and 90-degree V-notch weirs.

How to Measure

The water surface as it flows over the crest is drawn down as velocity increases. For this reason any measurement at or on the crest is not as accurate as the methods described below.

Drive a 2 x 2-inch flat-topped stake in the ground in the weir pool upstream from the crest a distance of 4 times the maximum head. Place the stake to one side in still water out of the way but readily accessible for taking readings. Use a carpenter's level or an engineer's level to set the top of the stake at the same height as the crest of the weir. The depth of flow is measured from the top of the stake to the surface of the water above it. In Idaho, frost will probably heave the stake out of place so that it would have to be re-set and maintained annually to keep the top at the same level as the weir crest.

An observation well (equipped with a staff guage) next to the weir head wall and fed by a pipe from the weir pond will refine the reading.

Water depth may be measured on a bulkhead wide enough so the gauge can be attached to it in smooth water and be unaffected by the drawdown over the crest. The gauge should be at least 1 to 1½ feet away from the side of the notch. Place the zero on the staff gauge at the same height as the crest.

A rectangular weir is the simplest to construct. Its crest is horizontal and its sides perpendicular. Table 3 gives the discharges over various widths of rectangular weirs with complete contractions.

The Cipolletti weir (named after its inventor, Cesare Cipolletti, an Italian engineer) is used most in Idaho because it will measure slightly more water than a rectangular weir with the same crest length. It is more difficult to construct. The sides diverge outwardly at a 1 to 4 slope (1 inch horizontally to 4 inches vertically). The discharges for various widths of Cipolletti weirs with contractions are shown in Table 4.

The V-notch weir is designed to handle small flows accurately. A 90-degree angle or V-notch can be laid out very easily using a carpenter's square. Discharge tables for the V-notch with complete contractions are shown in Table 5. Construction details and dimensions for the weirs mentioned above are illustrated in Fig. 2.

Table 3. Flow over rectangular contracted weirs in cubic feet per second*.

Head in ft. "H"	Head in inches, approx.	Crest length (L) 1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	For each additional foot of crest in excess of 4 ft. (approx.)
		Flow in cubic feet per second					
0.10	1-3/16	0.105	0.158	0.212	0.319	0.427	0.108
0.11	1-5/16	0.121	0.182	0.244	0.367	0.491	0.124
0.12	1-7/16	0.137	0.207	0.277	0.418	0.559	0.141
0.13	1-9/16	0.155	0.233	0.312	0.470	0.629	0.159
0.14	1-11/16	0.172	0.260	0.348	0.524	0.701	0.177
0.15	1-13/16	0.191	0.288	0.385	0.581	0.776	0.196
0.16	1-15/16	0.210	0.316	0.423	0.638	0.854	0.216
0.17	2-1/16	0.229	0.346	0.463	0.698	0.934	0.236
0.18	2-3/16	0.249	0.376	0.504	0.760	1.02	0.257
0.19	2-1/4	0.270	0.407	0.546	0.823	1.10	0.278
0.20	2-3/8	0.291	0.439	0.588	0.887	1.19	0.303
0.21	2-1/2	0.312	0.472	0.632	0.954	1.28	0.326
0.22	2-5/8	0.335	0.505	0.677	1.02	1.37	0.35
0.23	2-3/4	0.358	0.539	0.723	1.09	1.46	0.37
0.24	2-7/8	0.380	0.574	0.769	1.16	1.55	0.39
0.25	3	0.404	0.609	0.817	1.23	1.65	0.42
0.26	3-1/8	0.428	0.646	0.865	1.31	1.75	0.44
0.27	3-1/4	0.452	0.682	0.914	1.38	1.85	0.47
0.28	3-3/8	0.477	0.720	0.965	1.46	1.95	0.49
0.29	3-1/2	0.502	0.758	1.02	1.53	2.05	0.52
0.30	3-5/8	0.527	0.796	1.07	1.61	2.16	0.55
0.31	3-3/4	0.553	0.836	1.12	1.69	2.26	0.57
0.32	3-13/16	0.580	0.876	1.18	1.77	2.37	0.60
0.33	3-15/16	0.606	0.916	1.23	1.86	2.48	0.62
0.34	4-1/16	0.634	0.957	1.28	1.94	2.60	0.66
0.35	4-3/16	0.661	0.999	1.34	2.02	2.71	0.69
0.36	4-5/16	0.688	1.04	1.40	2.11	2.82	0.71
0.37	4-7/16	0.717	1.08	1.45	2.20	2.94	0.74
0.38	4-9/16	0.745	1.13	1.51	2.28	3.06	0.78
0.39	4-11/16	0.774	1.17	1.57	2.37	3.18	0.81
0.40	4-13/16	0.804	1.21	1.63	2.46	3.30	0.84
0.41	4-15/16	0.833	1.26	1.69	2.55	3.42	0.87
0.42	5-1/16	0.863	1.30	1.75	2.65	3.54	0.89
0.43	5-3/16	0.893	1.35	1.81	2.74	3.67	0.93
0.44	5-1/4	0.924	1.40	1.88	2.83	3.80	0.97
0.45	5-3/8	0.955	1.44	1.94	2.93	3.93	1.00
0.46	5-1/2	0.986	1.49	2.00	3.03	4.05	1.02
0.47	5-5/8	1.02	1.54	2.07	3.12	4.18	1.06
0.48	5-3/4	1.05	1.59	2.13	3.22	4.32	1.10
0.49	5-7/8	1.08	1.64	2.20	3.32	4.45	1.13
0.50	6	1.11	1.68	2.26	3.42	4.58	1.16
0.51	6-1/8	1.15	1.73	2.33	3.52	4.72	1.20
0.52	6-1/4	1.18	1.78	2.40	3.62	4.86	1.24
0.53	6-3/8	1.21	1.84	2.46	3.73	4.99	1.26
0.54	6-1/2	1.25	1.89	2.53	3.83	5.13	1.30
0.55	6-5/8	1.28	1.94	2.60	3.94	5.27	1.33
0.56	6-3/4	1.31	1.99	2.67	4.04	5.42	1.38
0.57	6-13/16	1.35	2.04	2.74	4.15	5.56	1.41
0.58	6-15/16	1.38	2.09	2.81	4.26	5.70	1.44
0.59	7-1/16	1.42	2.15	2.88	4.36	5.85	1.49

*Computed from Cone's formula: $Q = 3.247\,LH^{1.48} \quad \frac{0.566L^{1.8}}{1+2L^{1.8}}\,H^{1.9}$

Table 3 (Continued). Flow over rectangular contracted weirs.

Head in ft. "H"	Head in inches, approx.	Crest length (L) 1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	For each additional foot of crest in excess of 4 ft. (approx.)
		Flow in cubic feet per second					
0.60	7-3/16	1.45	2.20	2.96	4.47	6.00	1.53
0.61	7-5/16	1.49	2.25	3.03	4.59	6.14	1.56
0.62	7-7/16	1.52	2.31	3.10	4.69	6.29	1.60
0.63	7-9/16	1.56	2.36	3.17	4.81	6.44	1.63
0.64	7-11/16	1.60	2.42	3.25	4.92	6.59	1.67
0.65	7-13/16	1.63	2.47	3.32	5.03	6.75	1.72
0.66	7-15/16	1.67	2.53	3.40	5.15	6.90	1.75
0.67	8-1/16	1.71	2.59	3.47	5.26	7.05	1.79
0.68	8-3/16	1.74	2.64	3.56	5.38	7.21	1.83
0.69	8-1/4	1.78	2.70	3.63	5.49	7.36	1.87
0.70	8-3/8	1.82	2.76	3.71	5.61	7.52	1.91
0.71	8-1/2	1.86	2.81	3.78	5.73	7.68	1.95
0.72	8-5/8	1.90	2.87	3.86	5.85	7.84	1.99
0.73	8-3/4	1.93	2.93	3.94	5.97	8.00	2.03
0.74	8-7/8	1.97	2.99	4.02	6.09	8.17	2.08
0.75	9	2.01	3.05	4.10	6.21	8.33	2.12
0.76	9-1/8	2.05	3.11	4.18	6.33	8.49	2.16
0.77	9-1/4	2.09	3.17	4.26	6.45	8.66	2.21
0.78	9-3/8	2.13	3.23	4.34	6.58	8.82	2.24
0.79	9-1/2	2.17	3.29	4.42	6.70	8.99	2.29
0.80	9-5/8	2.21	3.35	4.51	6.83	9.16	2.33
0.81	9-3/4	2.25	3.41	4.59	6.95	9.33	2.38
0.82	9-13/16	2.29	3.47	4.67	7.08	9.50	2.42
0.83	9-15/16	2.33	3.54	4.75	7.21	9.67	2.46
0.84	10-1/16	2.37	3.60	4.84	7.33	9.84	2.51
0.85	10-3/16	2.41	3.66	4.92	7.46	10.01	2.55
0.86	10-5/16	2.46	3.72	5.01	7.59	10.19	2.60
0.87	10-7/16	2.50	3.79	5.10	7.72	10.36	2.64
0.88	10-9/16	2.54	3.85	5.18	7.85	10.54	2.69
0.89	10-11/16	2.58	3.92	5.27	7.99	10.71	2.72
0.90	10-13/16	2.62	3.98	5.35	8.12	10.89	2.77
0.91	10-15/16	2.67	4.05	5.44	8.25	11.07	2.82
0.92	11-1/16	2.71	4.11	5.53	8.38	11.25	2.87
0.93	11-3/16	2.75	4.18	5.62	8.52	11.43	2.91
0.94	11-1/4	2.79	4.24	5.71	8.65	11.61	2.96
0.95	11-3/8	2.84	4.31	5.80	8.79	11.79	3.00
0.96	11-1/2	2.88	4.37	5.89	8.93	11.98	3.05
0.97	11-5/8	2.93	4.44	5.98	9.06	12.16	3.10
0.98	11-3/4	2.97	4.51	6.07	9.20	12.34	3.14
0.99	11-7/8	3.01	4.57	6.15	9.34	12.53	3.19
1.00	12	3.06	4.64	6.25	9.48	12.72	3.24
1.01	12-1/8		4.71	6.34	9.62	12.91	3.29
1.02	12-1/4		4.78	6.43	9.76	13.10	3.34
1.03	12-3/8		4.85	6.52	9.90	13.28	3.38
1.04	12-1/2		4.92	6.62	10.04	13.47	3.43
1.05	12-5/8		4.98	6.71	10.18	13.66	3.48
1.06	12-3/4		5.05	6.80	10.32	13.85	3.53
1.07	12-13/16		5.12	6.90	10.46	14.04	3.58
1.08	12-15/16		5.20	6.99	10.61	14.24	3.63
1.09	13-1/16		5.26	7.09	10.75	14.43	3.68

Table 3 (Continued). Flow over rectangular contracted weirs.

Head in ft. "H"	Head in inches, approx.	Crest length (L) 1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	For each additional foot of crest in excess of 4 ft. (approx.)
		Flow in cubic feet per second					
1.10	13-3/16	5.34	7.19	10.90	14.64	3.74	
1.11	13-5/16	5.41	7.28	11.04	14.83	3.79	
1.12	13-7/16	5.48	7.38	11.19	15.03	3.84	
1.13	13-9/16	5.55	7.47	11.34	15.22	3.88	
1.14	13-11/16	5.62	7.57	11.48	15.42	3.94	
1.15	13-13/16	5.69	7.66	11.64	15.62	3.98	
1.16	13-15/16	5.77	7.76	11.79	15.82	4.03	
1.17	14-1/16	5.84	7.86	11.94	16.02	4.08	
1.18	14-3/16	5.91	7.96	12.09	16.23	4.14	
1.19	14-1/4	5.98	8.06	12.24	16.43	4.19	
1.20	14-3/8	6.06	8.16	12.39	16.63	4.24	
1.21	14-1/2	6.13	8.26	12.54	16.83	4.29	
1.22	14-5/8	6.20	8.35	12.69	17.03	4.34	
1.23	14-3/4	6.28	8.46	12.85	17.25	4.40	
1.24	14-7/8	6.35	8.56	12.99	17.45	4.46	
1.25	15	6.43	8.66	13.14	17.65	4.51	
1.26	15-1/8			13.30	17.87	4.57	
1.27	15-1/4			13.45	18.07	4.62	
1.28	15-3/8			13.61	18.28	4.67	
1.29	15-1/2			13.77	18.50	4.73	
1.30	15-5/8			13.93	18.71	4.78	
1.31	15-3/4			14.09	18.92	4.82	
1.32	15-13/16			14.24	19.12	4.88	
1.33	15-15/16			14.40	19.34	4.94	
1.34	16-1/16			14.56	19.55	4.99	
1.35	16-3/16			14.72	19.77	5.05	
1.36	16-5/16			14.88	19.98	5.10	
1.37	16-7/16			15.04	20.20	5.16	
1.38	16-9/16			15.20	20.42	5.22	
1.39	16-11/16			15.36	20.64	5.28	
1.40	16-13/16			15.53	20.86	5.33	
1.41	16-15/16			15.69	21.08	5.39	
1.42	17-1/16			15.85	21.29	5.44	
1.43	17-3/16			16.02	21.52	5.50	
1.44	17-1/4			16.19	21.74	5.55	
1.45	17-3/8			16.34	21.96	5.62	
1.46	17-1/2			16.51	22.18	5.67	
1.47	17-5/8			16.68	22.41	5.73	
1.48	17-3/4			16.85	22.64	5.79	
1.49	17-7/8			17.01	22.85	5.84	
1.50	18			17.17	23.08	5.91	

Table 4. Flow over Cipolletti weirs in cubic feet per second.*

Head in ft. "H"	Head in inches, approx.	Crest length (L) 1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	For each additional foot of crest in excess of 4 ft. (approx.)
		Flow in cubic feet per second					
0.10	1-3/16	0.107	0.160	0.214	0.321	0.429	0.108
0.11	1-5/16	0.123	0.185	0.246	0.370	0.494	0.124
0.12	1-7/16	0.140	0.210	0.280	0.421	0.562	0.141
0.13	1-9/16	0.158	0.237	0.316	0.474	0.632	0.159
0.14	1-11/16	0.177	0.264	0.352	0.528	0.706	0.177
0.15	1-13/16	0.195	0.293	0.390	0.586	0.782	0.196
0.16	1-15/16	0.216	0.322	0.430	0.644	0.860	0.216
0.17	2-1/16	0.237	0.353	0.470	0.705	0.941	0.236
0.18	2-3/16	0.258	0.384	0.512	0.768	1.024	0.257
0.19	2-1/4	0.280	0.417	0.555	0.832	1.110	0.278
0.20	2-3/8	0.302	0.450	0.599	0.898	1.20	0.302
0.21	2-1/2	0.324	0.484	0.644	0.966	1.29	0.324
0.22	2-5/8	0.349	0.519	0.691	1.04	1.38	0.35
0.23	2-3/4	0.374	0.555	0.739	1.11	1.47	0.37
0.24	2-7/8	0.397	0.591	0.786	1.18	1.57	0.39
0.25	3	0.423	0.628	0.836	1.25	1.67	0.42
0.26	3-1/8	0.449	0.667	0.886	1.33	1.77	0.44
0.27	3-1/4	0.475	0.705	0.937	1.40	1.87	0.47
0.28	3-3/8	0.502	0.745	0.990	1.48	1.97	0.49
0.29	3-1/2	0.529	0.785	1.04	1.56	2.08	0.52
0.30	3-5/8	0.557	0.827	1.10	1.64	2.19	0.55
0.31	3-3/4	0.586	0.869	1.15	1.73	2.30	0.57
0.32	3-13/16	0.615	0.911	1.21	1.81	2.41	0.60
0.33	3-15/16	0.644	0.954	1.27	1.89	2.52	0.62
0.34	4-1/16	0.675	1.00	1.32	1.98	2.64	0.66
0.35	4-3/16	0.705	1.04	1.38	2.07	2.75	0.69
0.36	4-5/16	0.735	1.09	1.44	2.16	2.87	0.71
0.37	4-7/16	0.767	1.13	1.50	2.25	2.99	0.74
0.38	4-9/16	0.799	1.18	1.57	2.34	3.11	0.78
0.39	4-11/16	0.832	1.23	1.63	2.43	3.24	0.81
0.40	4-13/16	0.866	1.28	1.69	2.53	3.36	0.84
0.41	4-15/16	0.899	1.32	1.76	2.62	3.49	0.87
0.42	5-1/16	0.932	1.37	1.82	2.72	3.61	0.89
0.43	5-3/16	0.967	1.42	1.89	2.81	3.74	0.93
0.44	5-1/4	1.00	1.47	1.95	2.91	3.87	0.97
0.45	5-3/8	1.04	1.53	2.02	3.01	4.01	1.00
0.46	5-1/2	1.07	1.58	2.09	3.11	4.14	1.02
0.47	5-5/8	1.11	1.63	2.16	3.21	4.28	1.06
0.48	5-3/4	1.15	1.68	2.23	3.32	4.41	1.10
0.49	5-7/8	1.18	1.74	2.30	3.42	4.55	1.13
0.50	6	1.22	1.79	2.37	3.53	4.69	1.16
0.51	6-1/8	1.26	1.85	2.44	3.64	4.83	1.20
0.52	6-1/4	1.30	1.90	2.51	3.74	4.97	1.24
0.53	6-3/8	1.34	1.96	2.59	3.85	5.12	1.26
0.54	6-1/2	1.38	2.02	2.66	3.96	5.26	1.30
0.55	6-5/8	1.42	2.07	2.74	4.07	5.41	1.33
0.56	6-3/4	1.46	2.13	2.81	4.18	5.56	1.38
0.57	6-13/16	1.50	2.19	2.89	4.30	5.71	1.41
0.58	6-15/16	1.54	2.25	2.97	4.41	5.86	1.44
0.59	7-1/16	1.58	2.31	3.05	4.53	6.01	1.49

*Computed from Cone's formula: $Q = 3.247\,LH^{1.48} - \frac{0.566L^{1.8}}{1+2L^{1.8}}H^{1.9} + 0.609\,H^{2.5}$

Table 4 (Continued). Flow over Cipolletti weirs.

Head in ft. "H"	Head in inches, approx.	Crest length (L) 1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	For each additional foot of crest in excess of 4 ft. (approx.)
		Flow in cubic feet per second					
0.60	7-3/16	1.62	2.37	3.13	4.64	6.17	1.53
0.61	7-5/16	1.67	2.43	3.20	4.76	6.32	1.55
0.62	7-7/16	1.71	2.49	3.28	4.88	6.47	1.60
0.63	7-9/16	1.75	2.55	3.37	5.00	6.63	1.63
0.64	7-11/16	1.80	2.62	3.45	5.12	6.79	1.67
0.65	7-13/16	1.84	2.68	3.53	5.24	6.95	1.72
0.66	7-15/16	1.89	2.75	3.61	5.36	7.11	1.75
0.67	8-1/16	1.93	2.81	3.70	5.48	7.28	1.79
0.68	8-3/16	1.98	2.87	3.79	5.61	7.44	1.83
0.69	8-1/4	2.02	2.94	3.87	5.73	7.61	1.87
0.70	8-3/8	2.07	3.01	3.95	5.86	7.77	1.91
0.71	8-1/2	2.12	3.07	4.04	5.99	7.94	1.95
0.72	8-5/8	2.16	3.14	4.13	6.12	8.11	1.99
0.73	8-3/4	2.21	3.21	4.22	6.24	8.28	2.03
0.74	8-7/8	2.26	3.28	4.31	6.38	8.45	2.08
0.75	9	2.31	3.35	4.40	6.51	8.62	2.12
0.76	9-1/8	2.36	3.42	4.49	6.64	8.80	2.16
0.77	9-1/4	2.41	3.49	4.58	6.77	8.97	2.21
0.78	9-3/8	2.46	3.56	4.67	6.90	9.15	2.24
0.79	9-1/2	2.51	3.63	4.76	7.04	9.33	2.29
0.80	9-5/8	2.56	3.70	4.85	7.18	9.51	2.33
0.81	9-3/4	2.61	3.77	4.95	7.31	9.69	2.38
0.82	9-13/16	2.66	3.84	5.04	7.45	9.87	2.42
0.83	9-15/16	2.71	3.92	5.14	7.59	10.05	2.46
0.84	10-1/16	2.77	3.99	5.23	7.73	10.23	2.51
0.85	10-3/16	2.82	4.07	5.33	7.87	10.42	2.55
0.86	10-5/16	2.87	4.14	5.43	8.01	10.60	2.60
0.87	10-7/16	2.93	4.22	5.52	8.15	10.79	2.64
0.88	10-9/16	2.98	4.29	5.62	8.30	10.98	2.69
0.89	10-11/16	3.04	4.37	5.72	8.44	11.17	2.72
0.90	10-13/16	3.09	4.45	5.82	8.59	11.36	2.77
0.91	10-15/16	3.15	4.53	5.92	8.73	11.55	2.82
0.92	11-1/16	3.20	4.60	6.02	8.88	11.74	2.87
0.93	11-3/16	3.26	4.68	6.13	9.03	11.94	2.91
0.94	11-1/4	3.32	4.76	6.23	9.17	12.13	2.96
0.95	11-3/8	3.37	4.84	6.33	9.32	12.33	3.00
0.96	11-1/2	3.43	4.92	6.44	9.48	12.53	3.05
0.97	11-5/8	3.49	5.00	6.55	9.62	12.72	3.10
0.98	11-3/4	3.55	5.09	6.64	9.78	12.92	3.14
0.99	11-7/8	3.61	5.17	6.75	9.93	13.12	3.19
1.00	12	3.67	5.25	6.86	10.08	13.32	3.24
1.01	12-1/8		5.33	6.96	10.24	13.53	3.29
1.02	12-1/4		5.42	7.07	10.40	13.73	3.34
1.03	12-3/8		5.50	7.18	10.55	13.94	3.38
1.04	12-1/2		5.59	7.29	10.71	14.15	3.43
1.05	12-5/8		5.67	7.40	10.87	14.35	3.48
1.06	12-3/4		5.76	7.51	11.03	14.56	3.53
1.07	12-13/16		5.84	7.62	11.18	14.76	3.58
1.08	12-15/16		5.93	7.73	11.35	14.98	3.63
1.09	13-1/16		6.02	7.84	11.51	15.19	3.68

Table 4 (Concluded). Flow over Cipolletti weirs.

Head in ft. "H"	Head in inches, approx.	Crest length (L) 1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	For each additional foot of crest in excess of 4 ft. (approx.)
		Flow in cubic feet per second					
1.10	13-3/16		6.11	7.96	11.68	15.41	3.74
1.11	13-5/16		6.20	8.07	11.84	15.62	3.79
1.12	13-7/16		6.29	8.18	12.00	15.84	3.84
1.13	13-9/16		6.37	8.29	12.16	16.04	3.88
1.14	13-11/16		6.46	8.41	12.33	16.26	3.94
1.15	13-13/16		6.56	8.53	12.50	16.48	3.98
1.16	13-15/16		6.65	8.65	12.67	16.70	4.03
1.17	14-1/16		6.74	8.76	12.84	16.93	4.08
1.18	14-3/16		6.83	8.88	13.01	17.15	4.14
1.19	14-1/4		6.93	9.00	13.18	17.37	4.19
1.20	14-3/8		7.02	9.12	13.35	17.59	4.24
1.21	14-1/2		7.11	9.24	13.52	17.81	4.29
1.22	14-5/8		7.20	9.36	13.69	18.03	4.34
1.23	14-3/4		7.30	9.48	13.87	18.27	4.40
1.24	14-7/8		7.40	9.60	14.04	18.49	4.46
1.25	15		7.49	9.72	14.21	18.71	4.51
1.26	15-1/8				14.39	18.95	4.57
1.27	15-1/4				14.56	19.17	4.62
1.28	15-3/8				14.74	19.41	4.67
1.29	15-1/2				14.92	19.65	4.73
1.30	15-5/8				15.11	19.88	4.78
1.31	15-3/4				15.29	20.12	4.82
1.32	15-13/16				15.46	20.34	4.88
1.33	15-15/16				15.64	20.58	4.94
1.34	16-1/16				15.82	20.82	4.99
1.35	16-3/16				16.01	21.06	5.05
1.36	16-5/16				16.19	21.29	5.10
1.37	16-7/16				16.37	21.53	5.16
1.38	16-9/16				16.57	21.78	5.22
1.39	16-11/16				16.75	22.02	5.28
1.40	16-13/16				16.94	22.27	5.33
1.41	16-15/16				17.13	22.51	5.39
1.42	17-1/16				17.31	22.75	5.44
1.43	17-3/16				17.51	23.01	5.50
1.44	17-1/4				17.70	23.26	5.55
1.45	17-3/8				17.89	23.50	5.62
1.46	17-1/2				18.08	23.75	5.67
1.47	17-5/8				18.28	24.01	5.73
1.48	17-3/4				18.47	24.26	5.79
1.49	17-7/8				18.66	24.50	5.84
1.50	18				18.85	24.75	5.91

Table 5. Flow over 90° V-notch weirs in cubic feet per second.*

Head H		Discharge Q	Head H		Discharge Q	Head H		Discharge Q
Feet or Inches		Sec-feet	Feet or Inches		Sec-feet	Feet or Inches		Sec-feet
.10	1-3/16	0.008	.50	6	0.445	.90	10-13/16	1.92
.11	1-5/16	0.010	.51	6-1/8	0.468	.91	10-15/16	1.97
.12	1-7/16	0.012	.52	6-1/4	0.491	.92	11-1/16	2.02
.13	1-9/16	0.016	.53	6-3/8	0.515	.93	11-3/16	2.08
.14	1-11/16	0.019	.54	6-1/2	0.539	.94	11-1/4	2.13
.15	1-13/16	0.022	.55	6-5/8	0.564	.95	11-3/8	2.19
.16	1-15/16	0.026	.56	6-3/4	0.590	.96	11-1/2	2.25
.17	2-1/16	0.031	.57	6-13/16	0.617	.97	11-5/8	2.31
.18	2-3/16	0.035	.58	6-15/16	0.644	.98	11-3/4	2.37
.19	2-1/4	0.040	.59	7-1/16	0.672	.99	11-7/8	2.43
.20	2-3/8	0.046	.60	7-3/16	0.700	1.00	12	2.49
.21	2-1/2	0.052	.61	7-5/16	0.730	1.01	12-1/8	2.55
.22	2-5/8	0.058	.62	7-7/16	0.760	1.02	12-1/4	2.61
.23	2-3/4	0.065	.63	7-9/16	0.790	1.03	12-3/8	2.68
.24	2-7/8	0.072	.64	7-11/16	0.822	1.04	12-1/2	2.74
.25	3	0.080	.65	6-13/16	0.854	1.05	12-5/8	2.81
.26	3-1/8	0.088	.66	7-15/16	0.887	1.06	12-3/4	2.87
.27	3-1/4	0.096	.67	8-1/16	0.921	1.07	12-13/16	2.94
.28	3-3/8	0.106	.68	8-3/16	0.955	1.08	12-15/16	3.01
.29	3-1/2	0.115	.69	8-1/4	0.991	1.09	13-1/16	3.08
.30	3-5/8	0.125	.70	8-3/8	1.03	1.10	13-3/16	3.15
.31	3-3/4	0.136	.71	8-1/2	1.06	1.11	13-5/16	3.22
.32	3-13/16	0.147	.72	8-5/8	1.10	1.12	13-7/16	3.30
.33	3-15/16	0.159	.73	8-3/4	1.14	1.13	13-9/16	3.37
.34	4-1/16	0.171	.74	8-7/8	1.18	1.14	13-11/16	3.44
.35	4-3/16	0.184	.75	9	1.22	1.15	13-13/16	3.52
.36	4-5/16	0.197	.76	9-1/8	1.26	1.16	13-15/16	3.59
.37	4-7/16	0.211	.77	9-1/4	1.30	1.17	14-3/16	3.67
.38	4-9/16	0.225	.78	9-3/8	1.34	1.18	14-5/16	3.75
.39	4-11/16	0.240	.79	9-1/2	1.39	1.19	14-1/4	3.83
.40	4-13/16	0.256	.80	9-5/8	1.43	1.20	14-3/8	3.91
.41	4-15/16	0.272	.81	9-3/4	1.48	1.21	14-1/2	3.99
.42	5-1/16	0.289	.82	9-13/16	1.52	1.22	14-5/8	4.07
.43	5-3/16	0.306	.83	9-15/16	1.57	1.23	14-3/4	4.16
.44	5-1/4	0.324	.84	10-1/16	1.61	1.24	14-7/8	4.24
.45	5-3/8	0.343	.85	10-3/16	1.66	1.25	15	4.33
.46	5-1/2	0.362	.86	10-5/16	1.71			
.47	5-5/8	0.382	.87	10-7/16	1.76			
.48	5-3/4	0.403	.88	10-9/16	1.81			
.49	5-7/8	0.424	.89	10-11/16	1.86			

* Computed from Cones formula: $Q=2.49H^{2.48}$

Table 6.

Flumes

Flow measuring flumes are open-channel devices containing a specially-shaped constricted-throat section. They can be constructed from metal, concrete or fiberglass. Standard designs are available to measure water over a wide flow range. Two types are commonly used, Parshall and trapezoidal. Either can be made on the farm or purchased commercially.

Flumes can operate in a flat ditch and require a relatively small head loss. They are self-cleaning and do not require a pool upstream to reduce the approach velocity. Flumes can operate accurately over a wide range of flows. The velocity of water as it approaches the flume has little effect upon its operation. Unless submergence (water backing up in the throat) occurs, only one head measurement is required to obtain the correct flow. The pre-built flumes can easily be re-set in colder areas where the frost might heave them out each winter.

Flumes are relatively expensive when cast in place. Considerable care must be used in forming them to the correct shape and dimensions, such as throat width, drop and diverging sections and gauging wells. The size of the flume is determined by the throat width. For instance, a 6-inch flume would have a 6-inch throat width.

Parshall Flume

The Parshall flume, developed by Ralph Parshall at Colorado State University, is the oldest and most widely used flume. This flume is illustrated in Fig. 4. Dimensions and capacities for Parshall flumes ranging in size from 6 inches to 4 feet are shown in Fig. 5. Larger sizes are available.

How to Install

1. The direction of water flow must be "in line" with the structure. The flow should be reasonable smooth, free from turbulence and uniformly distributed across the channel.

2. The flume should be installed to operate under free flow conditions if possible. Free flow occurs when the elevation of the water surface near the downstream end of the throat section is not high enough to reduce flow due to water backing up in the throat.

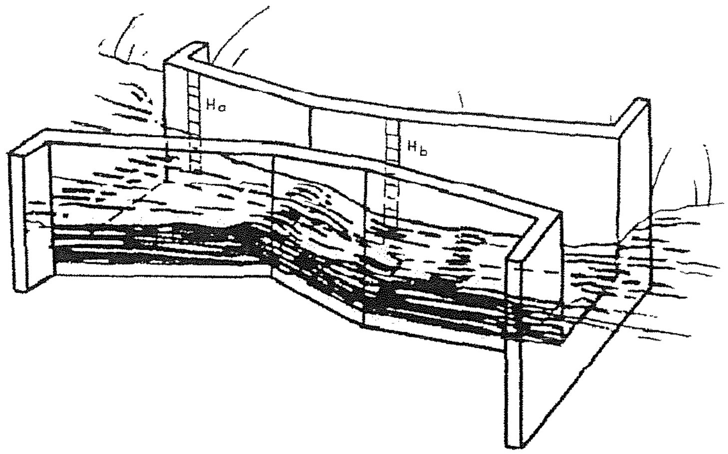


Fig. 4. Parshall measuring flume.

3. In most cases the flume is set with the floor (or crest) elevated above the ditch bottom to prevent excessive submergence. The amount to raise the flume corresponds to the head loss through the structure at about 70% submergence. The flume is set so the water elevation at H_A is higher than the normal tailwater downstream by an amount equal to the head loss. The head loss at 70-submergence is the difference between H_A and 0.7 times H_A or 0.3 H_A.
4. The floor of the converging section must be level both lengthwise and crosswise.

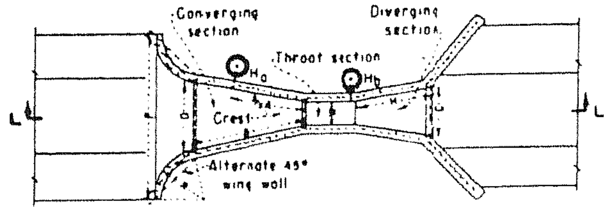
How to Measure

For free flow, one measurement of water depth at H_A is all that is required. Discharge tables are shown in Table 7.

A staff gauge attached to the inside wall at H_A will function for a depth measurement. The water surface here is often turbulent and a reading will be more accurate if a stilling well is installed with the zero of the gauge level with the crest of the flume.

The Parshall flume can be operated with a high degree of submergence — up to 70%. This means it will be accurate as long as the ratio H_B/H_A is less than 0.70. Below this figure only H_A need be measured.

When submergence or H_B/H_A is greater than 0.70 a correction must be made. To do this the discharge given by the water depth H_A is multiplied by the correction factor Q/Q_o for the degree of submergence and corresponding flume size shown in Fig. 6. This correction can reduce flow by a factor of up to 45%.



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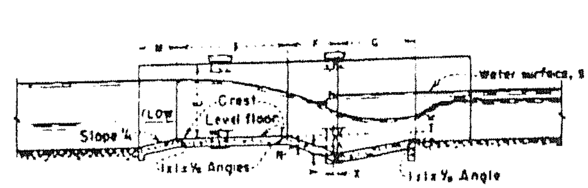


SECTION L-L

W	A	⅔A	B	C	D	E	F	G	H	K	M	N	P	R	X	Y	Free-Flow Capacity Minimum	Free-Flow Capacity Maximum
Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Ft-In	Sec Ft	Sec Ft
0-3	1-6 3/8	1-1/4	1-6	0-7	3-10 3/16	1 to 1-6	0-6	1-0	1-5/32	0-1	-	0-2¼			0-1	0-1½	0.03	1.13
0-6	2-7/16	1-4 5/16	2-0	1-3 1/2	1-3 5/8	2-0	1-0	2-0	·	0-3	1-0	0-4½	2-11 1/2	1-4	0-2	0-3	.05	3.9
0-9	2-10 5/8	1-11 1/8	2-10	1-3	1-10 5/8	2-6	1-0	1-6	·	0-3	1-0	0-4½	3-6 1/2	1-4	0-2	0-3	.09	8.9
1-0	4-6	3-0	4-4 7/8	2-0	2-9 1/4	3-0	2-0	3-0		0-3	1-3	0-9	4-10 3/4	1-8	0-2	0-3	.11	16.1
1-6	4-9	3-2	4-7 7/8	2-6	3-4 3/8	3-0	2-0	3-0		0-3	1-3	0-9	5-6	1-8	0-2	0-3	.15	24.6
2-0	5-0	3-4	4-10 7/8	3-0	3-11 1/2	3-0	2-0	3-0		0-3	1-3	0-9	6-1	1-8	0-2	0-3	.42	33.1
3-0	5-6	3-8	5-4 3/4	4-0	5-1 7/8	3-0	2-0	3-0	·	0-3	1-3	0-9	7-3 1/2	1-8	0-2	0-3	.61	50.4
4-0	6-0	4-0	5-10 5/8	5-0	6-4 1/4	3-0	2-0	3-0		0-3	1-6	0-9	8-10 3/4	2-0	0-2	0-3	1.3	67.9
5-0	6-6	4-4	6-4 1/2	6-0	7-6 5/8	3-0	2-0	3-0	·	0-3	1-6	0-9	10-1 1/4	2-0	0-2	0-3	1.6	85.6
6-0	7-0	4-8	6-10 3/8	7-0	8-9	3-0	2-0	3-0	·	0-3	1-6	0-9	11-3 1/2	2-0	0-2	0-3	2.6	103.5
7-0	7-6	5-0	7-4 1/4	8-0	9-11 3/8	3-0	2-0	3-0	·	0-3	1-6	0-9	12-6	2-0	0-2	0-3	3.0	121.4
8-0	8-0	5-4	7-10 1/8	9-0	11-1 3/4	3-0	2-0	3-0	·	0-3	1-6	0-9	13-8 1/4	2-0	0-2	0-3	3.5	139.5
10-0		6-0	14-0	12-0	15-7 1/4	4-0	3-0	6-0	·	0-6		1-1½			0-9	1-0	6	200

Fig. 5. Dimensions and capacities for Parshall measuring flume.

Table 7. Free flow through Parshall measuring flumes in cubic feet per second.

Head: Feet	Head: Inches (approx.)	Throat width: 3"	6"	9"	1'	1.5'	2'	3'	4'
		(Flow in cubic feet per second)							
0.10	1-3/16	0.028	0.05	0.09	0.11	0.15			
0.11	1-5/16	0.033	0.06	0.10	0.12	0.18			
0.12	1-7/16	0.037	0.07	0.12	0.14	0.20			
0.13	1-9/16	0.042	0.08	0.14	0.16	0.24			
0.14	1-11/16	0.047	0.09		0.18	0.27			
0.15	1-13/16	0.053	0.10	0.17	0.20	0.30			
0.16	1-15/16	0.058	0.11	0.19	0.23	0.34			
0.17	2-1/16	0.064	0.12	0.20	0.26	0.38			
0.18	2-3/16	0.070	0.14	0.22	0.29	0.42			
0.19	2-1/4	0.076	0.15	0.24	0.32	0.46			
0.20	2-3/8	0.082	0.16	0.26	0.35	0.50	0.66	0.97	1.26
0.21	2-1/2	0.089	0.18	0.28	0.37	0.54	0.71	1.04	1.36
0.22	2-5/8	0.095	0.19	0.30	0.40	0.58	0.77	1.12	1.47
0.23	2-3/4	0.102	0.20	0.32	0.43	0.63	0.82	1.20	1.58
0.24	2-7/8	0.109	0.22	0.35	0.46	0.67	0.88	1.28	1.69
0.25	3	0.117	0.23	0.37	0.49	0.71	0.93	1.37	1.80
0.26	3-1/8	0.124	0.25	0.39	0.51	0.76	0.99	1.46	1.91
0.27	3-1/4	0.131	0.26	0.41	0.54	0.80	1.05	1.55	2.03
0.28	3-3/8	0.138	0.28	0.44	0.58	0.85	1.11	1.64	2.15
0.29	3-1/2	0.146	0.29	0.46	0.61	0.90	1.18	1.73	2.27
0.30	3-5/8	0.154	0.31	0.49	0.64	0.94	1.24	1.82	2.39
0.31	3-3/4	0.162	0.32	0.51	0.68	0.99	1.30	1.92	2.52
0.32	3-13/16	0.170	0.34	0.54	0.71	1.04	1.37	2.02	2.65
0.33	3-15/16	0.179	0.36	0.56	0.74	1.09	1.44	2.12	2.78
0.34	4-1/16	0.187	0.38	0.59	0.77	1.14	1.50	2.22	2.92
0.35	4-3/16	0.196	0.39	0.62	0.80	1.19	1.57	2.32	3.06
0.36	4-5/16	0.205	0.41	0.64	0.84	1.25	1.64	2.42	3.19
0.37	4-7/16	0.213	0.43	0.67	0.88	1.30	1.72	2.53	3.34
0.38	4-9/16	0.222	0.45	0.70	0.92	1.36	1.79	2.64	3.48
0.39	4-11/16	0.231	0.47	0.73	0.95	1.41	1.86	2.75	3.62
0.40	4-13/16	0.241	0.48	0.76	0.99	1.47	1.93	2.86	3.77
0.41	4-15/16	0.250	0.50	0.78	1.03	1.53	2.01	2.97	3.92
0.42	5-1/16	0.260	0.52	0.81	1.07	1.58	2.09	3.08	4.07
0.43	5-3/16	0.269	0.54	0.84	1.11	1.64	2.16	3.20	4.22
0.44	5-1/4	0.279	0.56	0.87	1.15	1.70	2.24	3.32	4.38
0.45	5-3/8	0.289	0.58	0.90	1.19	1.76	2.32	3.44	4.54
0.46	5-1/2	0.299	0.61	0.94	1.23	1.82	2.40	3.56	4.70
0.47	5-5/8	0.309	0.63	0.97	1.27	1.88	2.48	3.68	4.86
0.48	5-3/4	0.319	0.65	1.00	1.31	1.94	2.57	3.80	5.03
0.49	5-7/8	0.329	0.67	1.03	1.35	2.00	2.65	3.92	5.20
0.50	6	0.339	0.69	1.06	1.39	2.06	2.73	4.05	5.36
0.51	6-1/8	0.350	0.71	1.10	1.44	2.13	2.82	4.18	5.53
0.52	6-1/4	0.361	0.73	1.13	1.48	2.19	2.90	4.31	5.70
0.53	6-3/8	0.371	0.76	1.16	1.52	2.25	2.99	4.44	5.88
0.54	6-1/2	0.382	0.78	1.20	1.57	2.32	3.08	4.57	6.05
0.55	6-5/8	0.393	0.80	1.23	1.62	2.39	3.17	4.70	6.23
0.56	6-3/4	0.404	0.82	1.26	1.66	2.45	3.26	4.84	6.41
0.57	6-13/16	0.415	0.85	1.30	1.70	2.52	3.35	4.98	6.59
0.58	6-15/16	0.427	0.87	1.33	1.75	2.59	3.44	5.11	6.77
0.59	7-1/16	0.438	0.89	1.37	1.80	2.66	3.53	5.25	6.96

Table 7 (Continued). Free flow through Parshall measuring flumes in cubic feet per second.

Head: Feet	Head: Inches (approx.)	Throat width: 3"	6"	9"	1'	1.5'	2'	3'	4'
		(Flow in cubic feet per second)							
0.60	7-3/16	0.450	0.92	1.40	1.84	2.73	3.62	5.39	7.15
0.61	7-5/16	0.462	0.94	1.44	1.88	2.80	3.72	5.53	7.34
0.62	7-7/16	0.474	0.97	1.48	1.93	2.87	3.81	5.68	7.53
0.63	7-9/16	0.485	0.99	1.51	1.98	2.95	3.91	5.82	7.72
0.64	7-11/16	0.497	1.02	1.55	2.03	3.02	4.01	5.97	7.91
0.65	7-13/16	0.509	1.04	1.59	2.08	3.09	4.11	6.12	8.11
0.66	7-15/16	0.522	1.07	1.63	2.13	3.17	4.20	6.26	8.31
0.67	8-1/16	0.534	1.10	1.66	2.18	3.24	4.30	6.41	8.51
0.68	8-3/16	0.546	1.12	1.70	2.23	3.31	4.40	6.56	8.71
0.69	8-1/4	0.558	1.15	1.74	2.28	3.39	4.50	6.71	8.91
0.70	8-3/8	0.571	1.17	1.78	2.33	3.46	4.60	6.86	9.11
0.71	8-1/2	0.584	1.20	1.82	2.38	3.54	4.70	7.02	9.32
0.72	8-5/8	0.597	1.23	1.86	2.43	3.62	4.81	7.17	9.53
0.73	8-3/4	0.610	1.26	1.90	2.48	3.69	4.91	7.33	9.74
0.74	8-7/8	0.623	1.28	1.94	2.53	3.77	5.02	7.49	9.95
0.75	9		1.31	1.98	2.58	3.85	5.12	7.65	10.2
0.76	9-1/8		1.34	2.02	2.63	3.93	5.23	7.81	10.4
0.77	9-1/4		1.36	2.06	2.68	4.01	5.34	7.97	10.6
0.78	9-3/8		1.39	2.10	2.74	4.09	5.44	8.13	10.8
0.79	9-1/2		1.42	2.14	2.80	4.17	5.55	8.30	11.0
0.80	9-5/8		1.45	2.18	2.85	4.26	5.66	8.46	11.3
0.81	9-3/4		1.48	2.22	2.90	4.34	5.77	8.63	11.5
0.82	9-13/16		1.50	2.27	2.96	4.42	5.88	8.79	11.7
0.83	9-15/16		1.53	2.31	3.02	4.50	6.00	8.96	11.9
0.84	10-1/16		1.56	2.35	3.07	4.59	6.11	9.13	12.2
0.85	10-3/16		1.59	2.39	3.12	4.69	6.22	9.30	12.4
0.86	10-5/16		1.62	2.44	3.18	4.76	6.33	9.48	12.6
0.87	10-7/16		1.65	2.48	3.24	4.84	6.44	9.65	12.8
0.88	10-9/16		1.68	2.52	3.29	4.93	6.56	9.82	13.1
0.89	10-11/16		1.71	2.57	3.35	5.01	6.68	10.0	13.3
0.90	10-13/16		1.74	2.61	3.41	5.10	6.80	10.2	13.6
0.91	10-15/16		1.77	2.66	3.46	5.19	6.92	10.4	13.8
0.92	11-1/16		1.81	2.70	3.52	5.28	7.03	10.5	14.0
0.93	11-3/16		1.84	2.75	3.58	5.37	7.15	10.7	14.3
0.94	11-1/4		1.87	2.79	3.64	5.46	7.27	10.9	14.5
0.95	11-3/8		1.90	2.84	3.70	5.55	7.39	11.1	14.8
0.96	11-1/2		1.93	2.88	3.76	5.64	7.51	11.3	15.0
0.97	11-5/8		1.97	2.93	3.82	5.73	7.63	11.4	15.3
0.98	11-3/4		2.00	2.98	3.88	5.82	7.75	11.6	15.5
0.99	11-7/8		2.03	3.02	3.94	5.91	7.88	11.8	15.8
1.00	12		2.06	3.07	4.00	6.00	8.00	12.0	16.0
1.01	12-1/8		2.09	3.12	4.06	6.09	8.12	12.2	16.3
1.02	12-1/4		2.12	3.17	4.12	6.19	8.25	12.4	16.5
1.03	12-3/8		2.16	3.21	4.18	6.28	8.38	12.6	16.8
1.04	12-1/2		2.19	3.26	4.25	6.37	8.50	12.8	17.0
1.05	12-5/8		2.22	3.31	4.31	6.47	8.63	13.0	17.3
1.06	12-3/4		2.26	3.36	4.37	6.56	8.76	13.2	17.5
1.07	12-13/16		2.29	3.40	4.43	6.66	8.88	13.3	17.8
1.08	12-15/16		2.32	3.45	4.50	6.75	9.01	13.5	18.1
1.09	13-1/16		2.36	3.50	4.56	6.85	9.14	13.7	18.3

Table 7 (Continued). Free flow through Parshall measuring flumes in cubic feet per second.

Head		Throat width							
Feet	Inches (approx.)	3"	6"	9"	1'	1.5'	2'	3'	4'
		(Flow in cubic feet per second)							
1.10	13-3/16		2.40	3.55	4.62	6.95	9.27	13.9	18.6
1.11	13-5/16		2.43	3.60	4.68	7.04	9.40	14.1	18.9
1.12	13-7/16		2.46	3.65	4.75	7.14	9.54	14.3	19.1
1.13	13-9/16		2.50	3.70	4.82	7.24	9.67	14.5	19.4
1.14	13-11/16		2.53	3.75	4.88	7.34	9.80	14.7	19.7
1.15	13-13/16		2.57	3.80	4.94	7.44	9.94	14.9	19.9
1.16	13-15/16		2.60	3.85	5.01	7.54	10.1	15.1	20.2
1.17	14-1/16		2.64	3.90	5.08	7.64	10.2	15.3	20.5
1.18	14-3/16		2.68	3.95	5.15	7.74	10.3	15.6	20.8
1.19	14-1/4		2.71	4.01	5.21	7.84	10.5	15.8	21.1
1.20	14-3/8		2.75	4.06	5.28	7.94	10.6	16.0	21.3
1.21	14-1/2		2.78	4.11	5.34	8.05	10.8	16.2	21.6
1.22	14-5/8		2.82	4.16	5.41	8.15	10.9	16.4	21.9
1.23	14-3/4		2.86	4.22	5.48	8.25	11.0	16.6	22.2
1.24	14-7/8		2.89	4.27	5.55	8.36	11.2	16.8	22.5
1.25	15			4.32	5.62	8.46	11.3	17.0	22.8
1.26	15-1/8			4.37	5.69	8.56	11.5	17.2	23.0
1.27	15-1/4			4.43	5.76	8.67	11.6	17.4	23.3
1.28	15-3/8			4.48	5.82	8.77	11.7	17.7	23.6
1.29	15-1/2			4.53	5.89	8.88	11.9	17.9	23.9
1.30	15-5/8			4.59	5.96	8.99	12.0	18.1	24.2
1.31	15-3/4			4.64	6.03	9.09	12.2	18.3	24.5
1.32	15-13/16			4.69	6.10	9.20	12.3	18.5	24.8
1.33	15-15/16			4.75	6.18	9.30	12.4	18.8	25.1
1.34	16-1/16			4.80	6.25	9.41	12.6	19.0	25.4
1.35	16-3/16			4.86	6.32	9.52	12.7	19.2	25.7
1.36	16-5/16			4.92	6.39	9.63	12.9	19.4	26.0
1.37	16-7/16			4.97	6.46	9.74	13.0	19.6	26.3
1.38	16-9/16			5.03	6.53	9.85	13.2	19.9	26.6
1.39	16-11/16			5.08	6.60	9.95	13.3	20.1	26.9
1.40	16-13/16				6.68	10.1	13.5	20.3	27.2
1.41	16-15/16				6.75	10.2	13.6	20.6	27.5
1.42	17-1/16				6.82	10.3	13.8	20.8	27.8
1.43	17-3/16				6.89	10.4	13.9	21.0	28.1
1.44	17-1/4				6.97	10.5	14.1	21.2	28.5
1.45	17-3/8				7.04	10.6	14.2	21.3	28.8
1.46	17-1/2				7.12	10.7	14.4	21.7	29.1
1.47	17-5/8				7.19	10.8	14.5	21.9	29.4
1.48	17-3/4				7.26	11.0	14.7	22.2	29.7
1.49	17-7/8				7.34	11.1	14.9	22.4	30.0
1.50	18				7.41	11.2	15.0	22.6	30.3

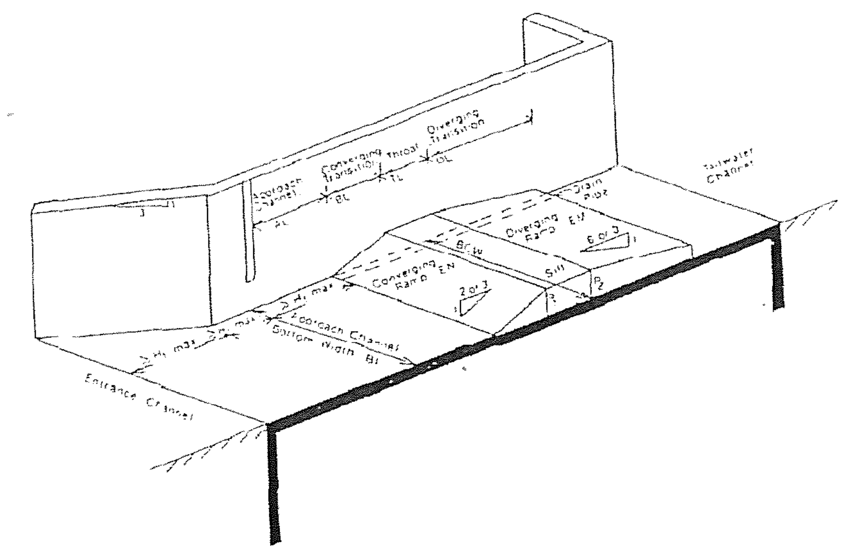
RAMPED BROAD CRESTED WEIR[1]

General Description

The ramped broad crested weir (RBCW) has been used successfully in a number of canals in Southern Idaho and is one of several types of broad crested weirs. This device requires only a single upstream depth measurement for discharge determination. The structure can not be used to regulate flow, but is capable of accurately measuring a wide range of discharges. Construction costs for this weir may be relatively lower than other measurement structures used on larger ditches or canals. The RBCW also passes floating debris and sediment well. As with other weirs and flumes, normal periodic maintenance is required.

Installation and Measurement

A computer model has been developed for use in designing the RBCW and allows the weir to be tailored to fit the channel configuration. The computer program also generates a rating table using the as-built dimensions. Discharge is then determined by reading the height of water on the staff gauge with the corresponding height listed on the computer generated rating table. Further detailed information about the weir and computer program may be obtained from the University of Idaho Kimberly Research and Extension Center or the Idaho Department of Water Resources.



Schematic view of a ramped broad crested weir.

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[1] RBCW text and figures reprinted from France, K.E. and Brockway, C.E., Flow Measurement Using Ramped Broad Crested Weirs. Idaho Water Resource Research Institute, University of Idaho, Moscow, Idaho. September, 1987.

CONSTANT HEAD ORIFICE TURNOUT (CHO)[1]

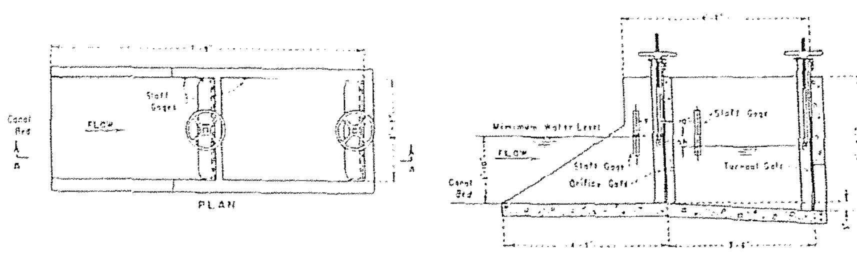
General Description

The constant head orifice turnout (CHO) is a combination regulating and measuring structure that uses an adjustable submerged orifice for the discharge measurement. The structure has been developed and widely adopted by the Bureau of Reclamation. Its operation is based upon setting and maintaining a constant head differential (usually 0.20 foot) across the orifice. Discharges are varied by changing the gate opening, that is, the area of the orifice. The rate of flow is measured by using the principle that a submerged orifice of a given size operating under a specific differential head will always pass the same known quantity of water.

The CHO turnout consists of a short entrance channel leading to a headwall containing one or more gate-controlled openings, a stilling basin section, and a downstream headwall with one or more gate-controlled openings that release the flow into the delivery channel. The turnouts are usually placed at right angles to the main canal. The upstream gate or gates constitute the orifice, the size of which can be increased or decreased by opening or closing the gates. The head across the orifice is measured at a constant value, usually 0.20 foot, by adjusting the downstream gate or gates, and is measured by staff gauges or stilling wells upstream and downstream from the orifice gate headwall.

How to Measure

The opening of the orifice for the desired discharge is obtained from discharge tables. With the upstream gates set at this opening, the downstream gates are adjusted until the differential head across the orifice as measured by the staff gauges or stilling wells is at the required constant head (usually 0.20 foot). The discharge will then be at the desired value.



Schematic view of a CHO turnout with a horizontal inlet channel

[1]CHO text, figures and tables reprinted from <u>Water Measurement Manual</u>, Department of Interior Bureau of Reclamation. Second Edition Revised Reprint: 1984 (Denver) pp. 95-99, 298-299.

Table 32.—Discharge of constant-head orifice turnout in second-feet. Capacity 20 second-feet, gate size 30 by 24 inches, $\Delta h=0.20$ foot. (See sec. 64.)

Discharge, second-feet	Gate opening in feet		Discharge, second-feet	Gate opening in feet	
	2 gates	1 gate		2 gates	1 gate
0.25	0.02	0.04	10.25	0.81	....
.50	.04	.08	10.50	.83	....
.75	.06	.12	10.75	.85	....
1.00	.08	.16	11.00	.87	....
1.25	.10	.20	11.25	.89	....
1.50	.12	.24	11.50	.91	....
1.75	.14	.28	11.75	.93	....
2.00	.16	.32	12.00	.95	....
2.25	.18	.36	12.25	.97	....
2.50	.20	.40	12.50	.99	....
2.75	.22	.44	12.75	1.01	....
3.00	.24	.48	13.00	1.03	....
3.25	.26	.52	13.25	1.05	....
3.50	.28	.56	13.50	1.07	....
3.75	.30	.60	13.75	1.085	....
4.00	.32	.64	14.00	1.10	....
4.25	.34	.68	14.25	1.12	....
4.50	.36	.72	14.50	1.14	....
4.75	.38	.755	14.75	1.16	....
5.00	.40	.79	15.00	1.18	....
5.25	.42	.83	15.25	1.20	....
5.50	.44	.87	15.50	1.22	....
5.75	.46	.91	15.75	1.24	....
6.00	.48	.95	16.00	1.26	....
6.25	.50	.99	16.25	1.28	....
6.50	.52	1.03	16.50	1.30	....
6.75	.54	1.065	16.75	1.32	....
7.00	.56	1.10	17.00	1.34	....
7.25	.58	1.14	17.25	1.355	....
7.50	.60	1.18	17.50	1.37	....
7.75	.62	1.22	17.75	1.39	....
8.00	.64	1.26	18.00	1.41	....
8.25	.66	1.30	18.25	1.43	....
8.50	.68	1.34	18.50	1.45	....
8.75	.70	1.375	18.75	1.47	....
9.00	.72	1.41	19.00	1.49	....
9.25	.74	1.45	19.25	1.51	....
9.50	.76	1.49	19.50	1.53	....
9.75	.775	1.525	19.75	1.545	....
10.00	.79	1.56	20.00	1.56	....

Table 33.—Discharge of constant-head orifice turnout in second-feet. Capacity 10 second-feet, gate size 24 by 18 inches, $\Delta h=0.20$ foot. (See sec. 64.)

Discharge, second-feet	Gate opening in feet		Discharge, second-feet	Gate opening in feet	
	2 gates	1 gate		2 gates	1 gate
0.25	0.025	0.05	5.25	0.525	....
.50	.05	.10	5.50	.55	....
.75	.075	.15	5.75	.575	....
1.00	.10	.20	6.00	.60	....
1.25	.125	.25	6.25	.625	....
1.50	.15	.30	6.50	.65	....
1.75	.175	.35	6.75	.675	....
2.00	.20	.40	7.00	.70	....
2.25	.225	.45	7.25	.722	....
2.50	.25	.50	7.50	.74	....
2.75	.275	.55	7.75	.765	....
3.00	.30	.60	8.00	.79	....
3.25	.325	.65	8.25	.815	....
3.50	.35	.70	8.50	.84	....
3.75	.375	.745	8.75	.865	....
4.00	.40	.79	9.00	.89	....
4.25	.425	.84	9.25	.915	....
4.50	.45	.89	9.50	.94	....
4.75	.475	.94	9.75	.965	....
5.00	.50	.99	10.0	.99	....