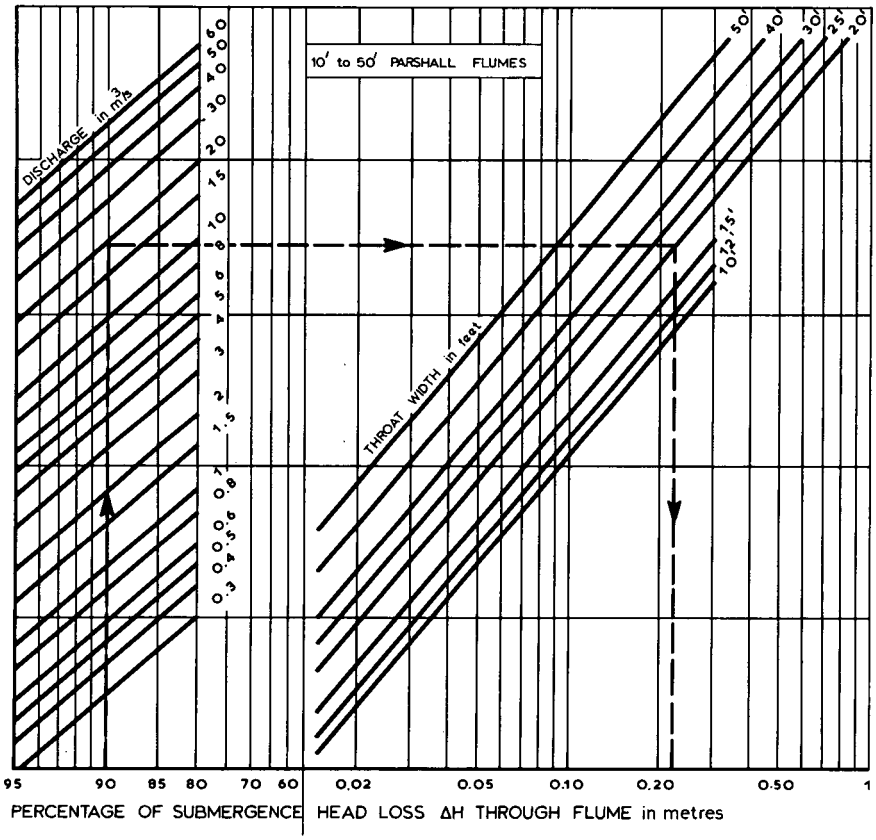

Figure 7.20 Head-loss through Parshall flumes (10-50 feet wide)

7.5 H-flumes

7.5.1 Description

On natural streams where it is necessary to measure a wide range of discharges, a structure with a V-type control has the advantage of providing a wide opening at high flows so that it causes no excessive backwater effects, whereas at low flows its opening is reduced so that the sensitivity of the structure remains acceptable. To serve this purpose the U.S. Soil Conservation Service developed the H-type flume, of which three geometrically different types are available. Their proportions are shown in Figure 7.21. They are:

HS-flumes

Of this 'small' flume, the largest size has a depth D equal to 0.305 m (1 ft) and a maximum capacity of 0.022 m^3/s.

H-flumes

Of this 'normal' flume, the largest size has a depth D equal to 1.37 m (4.5 ft) and a maximum capacity of 2.36 m^3/s.

HL-flumes

The use of this 'large' flume is only recommended if the anticipated discharge exceeds the capacity of the normal H-flume. The largest HL-flume has a depth D equal to 1.37 m (4.5 ft) and a maximum capacity of 3.32 m^3/s.

Since all three types are calibrated measuring devices, they should be constructed in strict accordance with the drawings in Figure 7.21. It is especially important that the slanting opening be bounded by straight sharp edges, that it has precisely the proportional dimensions shown, and that it lies in a plane with an inclination of the exact degree indicated in Figure 7.21. All cross sections of the flume should be symmetrical about the longitudinal axis. The flume floor should be truly level. All plates should be flat and should display no appreciable warp, dent, or other form of distortion.

All three types of flume should be located downstream of a rectangular approach channel which has the same bottom width as the entrance of the flume, i.e., 1.05D for the HS-flumes; 1.90D for the H-flumes; and 3.20D for the HL-flumes. The minimum length of this approach channel is 2D. In practice, the flume sections are frequently constructed from sheet steel or other suitable material, while the approach section is made of concrete, masonry, etc. The two parts should be given a watertight join with the use of bolts and a gasket. The bolts should be suitable for both fastening and levelling the flume. To prevent silting in the approach channel, its longitudinal slope may vary from flat to about 0.02.

The upstream head h_a is measured in the flume at a well defined location which is shown separately for each flume in Figure 7.21. The piezometric head should be measured in a separate well having a piezometer tap immediately above the flume bottom. Since the head is measured at a location of accelerating flow and where streamlines are curved it is essential that the piezometer tap be located in its precise position if accurate flow measurements are to be obtained.

To assure reliable head readings despite heavy sediment loads and the accompanying sediment deposition in the flume, an 1-to-8 sloping floor was provided for H-flumes. This false floor concentrates flows along the side wall having the stilling well intake. Low flows can scour the sediment from the little channel formed along this wall. The proportions of the sloping floor for the H-flume are given in Figure 7.22. If the H-flume is equiped with a false floor the true flow rate differs slightly from the figures given in Table 7.14. The percentage deviation in the free flow rate is shown in Figure 7.23.

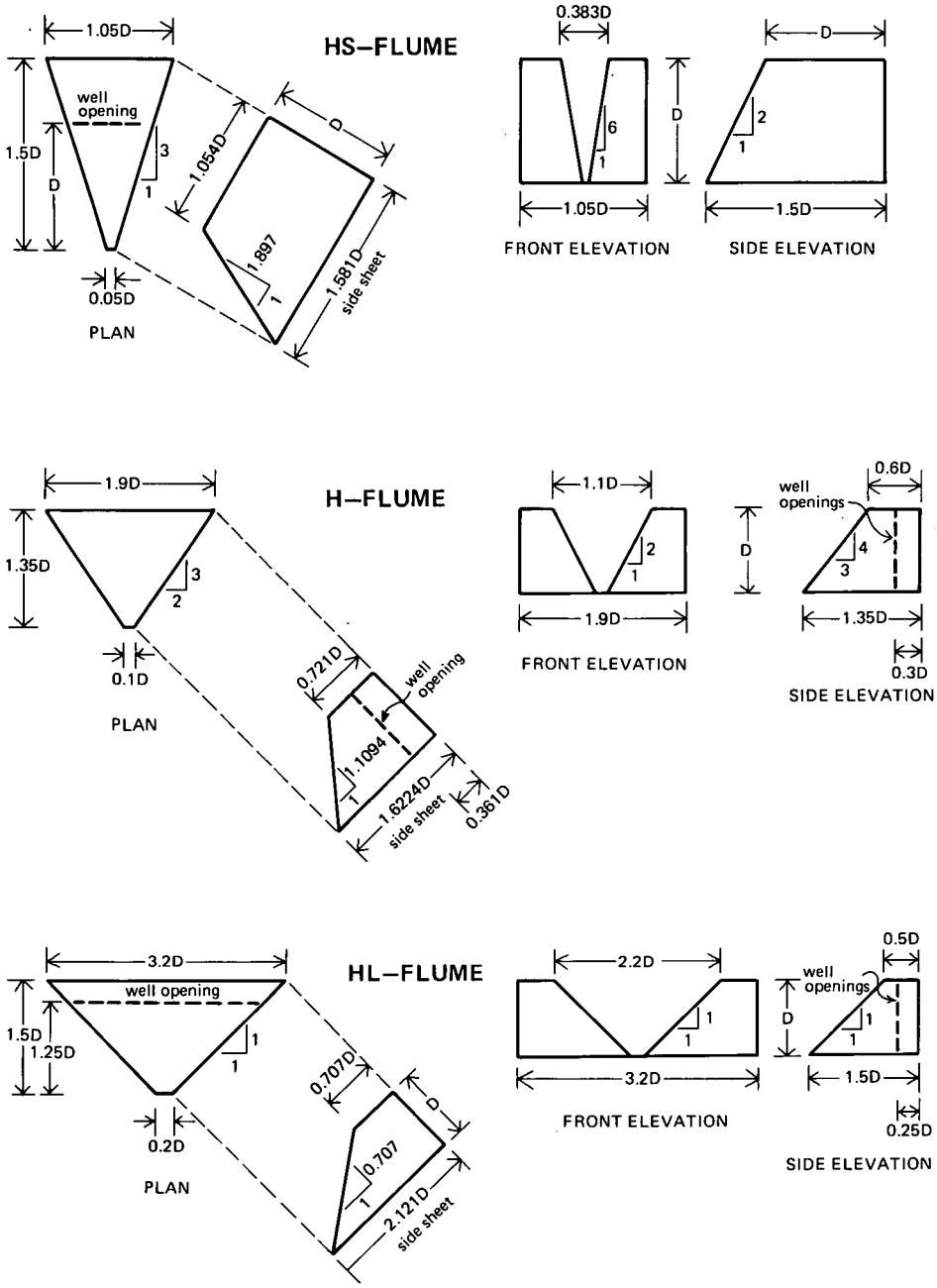

Figure 7.21 Dimensions of the types HS-, H- and HL-flume (after Holtan, Minshall & Harrold 1962)

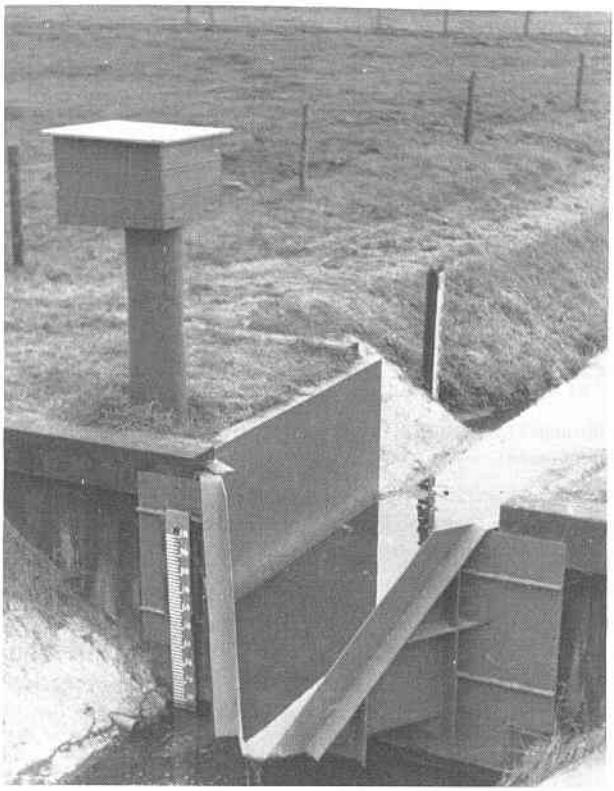

Photo 4 H-flume

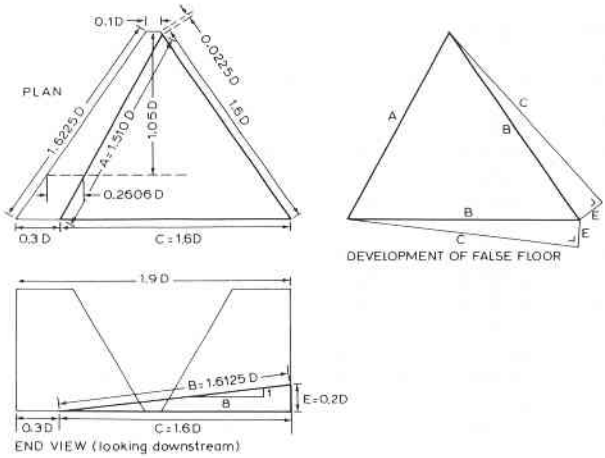

Figure 7.22 Sloping false floor for use in H-flumes (from Gwinn & Parson 1976). Original drawing prepared by L.L. De Fabritis 1938

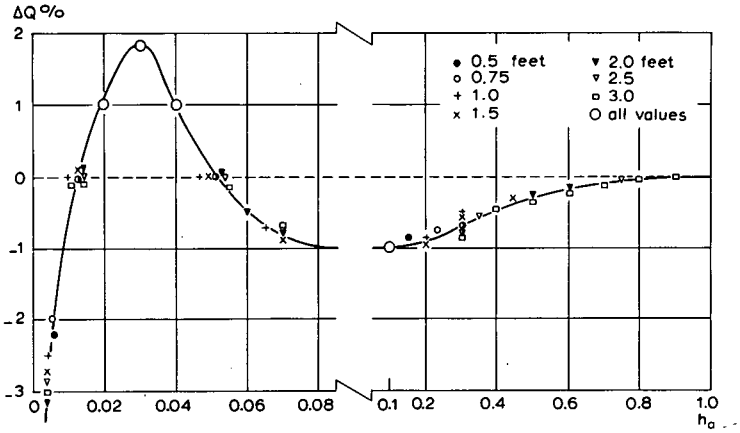

Figure 7.23 Deviation in free flow rate through H-flumes with a sloping floor from rating tables 7.14 for H-flumes with a flat floor (after Gwinn)

7.5.2 Evaluation of discharge

All three types of H-flumes have a rather arbitrary control while an upstream piezometric head h_a is measured at a station in the area of water surface drawdown. Under these circumstances, the only accurate method of finding a head-discharge relationship is by calibration in a hydraulic laboratory. Based on this calibration, an empirical formula, expressing the discharge in m^3/s as a function of the head h_a in metres, could be established of the general form

$$\log Q = A + B \log h_a + C[\log h_a]^2 \qquad (7\text{-}6)$$

Values of the numbers A, B, and C appear in Table 7.12 for each flume type. Based

Table 7.12 Data on three types of H-flumes

Flume type	Flume depth D		Maximum capacity	Number in Equation 7-6			Rating table
	ft	m	$m^3/s \times 10^{-3}$	A	B	C	
HS	0.4	.122	2.27	−0.4361	+2.5151	+0.1379	7.13.a
HS	0.6	.183	6.14	−0.4430	+2.4908	+0.1657	7.13.b
HS	0.8	.244	12.7	−0.4410	+2.4571	+0.1762	7.13.c
HS	1.0	.305	22.3	−0.4382	+2.4193	+0.1790	7.13.d
H	0.5	.152	9.17	+0.0372	+2.6629	+0.1954	7.14.a
H	0.75	.229	26.9	+0.0351	+2.6434	+0.2243	7.14.b
H	1.0	.305	53.5	+0.0206	+2.5902	+0.2281	7.14.c
H	1.5	.457	150	+0.0238	+2.5473	+0.2540	7.14.d
H	2.0	.610	309	+0.0237	+2.4918	+0.2605	7.14.e
H	2.5	.762	542	+0.0268	+2.4402	+0.2600	7.14.f
H	3.0	.914	857	+0.0329	+2.3977	+0.2588	7.14.g
H	4.5	1.37	2366	+0.0588	+2.3032	+0.2547	7.14.h
HL	3.5	1.07	2370	+0.3081	+2.3935	+0.2911	7.15.a
HL	4.0	1.22	3298	+0.3160	+2.3466	+0.2794	7.15.b

on Equation 7-6, calibration tables were prepared for each flume; see Tables 7.13 for the HS-flumes, Table 7.14 for the H-flumes and Table 7.15 for the HL-flumes.
The error in the modular discharge given in Tables 7.13, 7.14 and 7.15 may be expected to be less than 3%. The method by which this error is to be combined with other sources of error is shown in Annex 2.

7.5.3 Modular limit

The modular limit is defined as the submergence ratio h_2/h_a which produces a 1% reduction from the equivalent modular discharge as calculated by Equation 7-6. Results of various tests showed that the modular limit for HS- and H-flumes is $h_2/h_a = 0.25$, for HL-flumes this limit is 0.30. Rising tailwater levels cause an increase of the equivalent upstream head h_a at modular flow as shown in Fig.7.24. Because of the complex method of calculating submerged flow, all HS- and H-flumes should be installed with a submergence ratio of less than 0.25 (for HL-flumes 0.30).

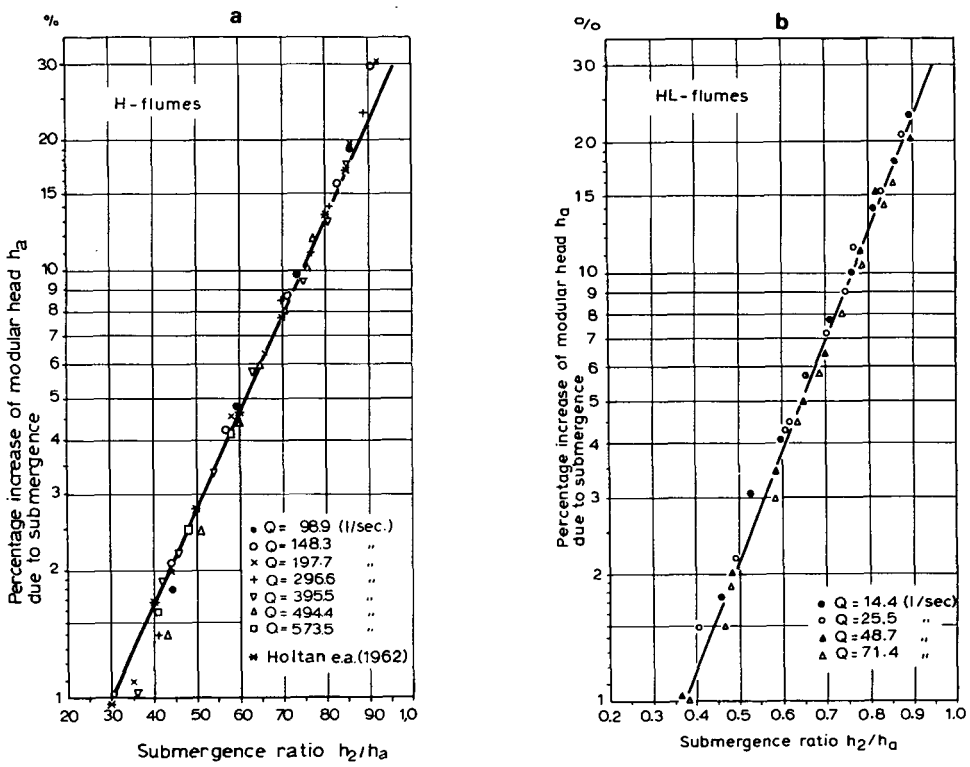

Figure 7.24a/b Influence of submergence on the modular head of HS-, H-, and HL-flumes. (Data on HL-flumes based on personal communication, Gwinn 1977)

7.5.4 Limits of application

The limits of application of all H-flumes are:

a. The inside surface of the flume should be plane and smooth while the flume dimensions should be in strict accordance with Figure 7.21.
b. The practical lower limit of h_a is mainly related to the accuracy with which h_a can be determined. For heads less than 0.06 m, point gauge readings are required to obtain a reasonably accurate measurement. The lower limit of h_a for each type of flume can be read from Tables 7.13 to 7.15.
c. To obtain modular flow the submergence ratio h_2/h_a should not exceed 0.25.
d. To prevent water surface instability in the approach channel, the Froude number $Fr_1 = v_1/(gA_1/B)^{1/2}$ should not exceed 0.5.

Table 7.13a Free-flow discharge through 0.4 ft HS-flume in l/s

h_a (m)	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
0.01	0.012	0.015	0.017	0.020	0.024	0.027	0.031	0.035	0.039	0.044
0.02	0.049	0.054	0.059	0.065	0.071	0.077	0.084	0.091	0.098	0.105
0.03	0.113	0.121	0.130	0.138	0.147	0.156	0.166	0.176	0.186	0.197
0.04	0.208	0.219	0.230	0.242	0.255	0.267	0.280	0.293	0.307	0.321
0.05	0.335	0.350	0.365	0.380	0.396	0.412	0.428	0.445	0.462	0.480
0.06	0.497	0.516	0.534	0.553	0.573	0.592	0.612	0.633	0.654	0.675
0.07	0.697	0.719	0.741	0.764	0.787	0.811	0.835	0.860	0.884	0.910
0.08	0.935	0.961	0.988	1.01	1.04	1.07	1.10	1.13	1.16	1.19
0.09	1.21	1.25	1.28	1.31	1.34	1.37	1.40	1.44	1.47	1.50
0.10	1.54	1.57	1.61	1.64	1.68	1.71	1.75	1.79	1.83	1.87
0.11	1.90	1.94	1.98	2.02	2.06	2.10	2.15	2.19	2.23	2.27

Table 7.13b Free-flow discharge through 0.6 ft HS-flume in l/s

h_a (m)	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
0.02	0.064	0.070	0.076	0.083	0.091	0.098	0.106	0.114	0.123	0.131
0.03	0.141	0.150	0.160	0.170	0.181	0.191	0.202	0.214	0.226	0.238
0.04	0.251	0.263	0.277	0.290	0.304	0.318	0.333	0.348	0.363	0.379
0.05	0.395	0.412	0.429	0.446	0.463	0.481	0.500	0.518	0.537	0.557
0.06	0.577	0.597	0.618	0.639	0.660	0.682	0.704	0.727	0.750	0.773
0.07	0.797	0.821	0.846	0.871	0.896	0.922	0.948	0.975	1.00	1.03
0.08	1.06	1.09	1.11	1.14	1.17	1.20	1.23	1.26	1.30	1.33
0.09	1.36	1.39	1.43	1.46	1.49	1.53	1.56	1.60	1.63	1.67
0.10	1.71	1.74	1.78	1.82	1.86	1.90	1.93	1.97	2.01	2.06
0.11	2.10	2.14	2.18	2.22	2.27	2.31	2.35	2.40	2.44	2.49
0.12	2.53	2.58	2.63	2.68	2.72	2.77	2.82	2.87	2.92	2.97
0.13	3.02	3.07	3.12	3.18	3.23	3.28	3.34	3.39	3.45	3.50
0.14	3.56	3.61	3.67	3.73	3.78	3.84	3.90	3.96	4.02	4.08
0.15	4.14	4.20	4.27	4.33	4.39	4.46	4.52	4.58	4.65	4.72
0.16	4.78	4.85	4.92	4.98	5.05	5.12	5.19	5.26	5.33	5.40
0.17	5.47	5.55	5.62	5.69	5.77	5.84	5.92	5.99	6.07	6.14

0Table 7.13c Free-flow discharge through 0.8 ft HS-flume in l/s

h_a (m)	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
0.03						0.227	0.239	0.252	0.266	0.280
0.04	0.294	0.308	0.324	0.339	0.355	0.371	0.388	0.404	0.422	0.440
0.05	0.458	0.476	0.495	0.514	0.534	0.554	0.574	0.595	0.617	0.638
0.06	0.660	0.683	0.706	0.729	0.753	0.777	0.802	0.827	0.852	0.878
0.07	0.904	0.931	0.958	0.986	1.01	1.04	1.07	1.10	1.13	1.16
0.08	1.19	1.22	1.25	1.29	1.32	1.35	1.38	1.42	1.45	1.49
0.09	1.52	1.56	1.59	1.63	1.67	1.70	1.74	1.78	1.82	1.86
0.10	1.90	1.94	1.98	2.02	2.06	2.10	2.15	2.19	2.23	2.28
0.11	2.32	2.37	2.41	2.46	2.50	2.55	2.60	2.65	2.69	2.74
0.12	2.79	2.84	2.89	2.94	2.99	3.05	3.10	3.15	3.20	3.26
0.13	3.31	3.37	3.42	3.48	3.54	3.59	3.65	3.71	3.77	3.83
0.14	3.89	3.95	4.01	4.07	4.13	4.19	4.25	4.32	4.38	4.45
0.15	4.51	4.58	4.64	4.71	4.77	4.84	4.91	4.98	5.05	5.12
0.16	5.19	5.26	5.33	5.40	5.48	5.55	5.62	5.70	5.77	5.85
0.17	5.92	6.00	6.08	6.15	6.23	6.31	6.39	6.47	6.55	6.63
0.18	6.71	6.79	6.88	6.96	7.04	7.13	7.21	7.30	7.39	7.47
0.19	7.56	7.65	7.74	7.82	7.91	8.00	8.10	8.19	8.28	8.37
0.20	8.47	8.56	8.65	8.75	8.84	8.94	9.04	9.14	9.23	9.33
0.21	9.43	9.53	9.63	9.73	9.83	9.94	10.0	10.1	10.2	10.4
0.22	10.5	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4
0.23	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.5	12.6
0.24	12.7									

Table 7.13d Free-flow discharge through 1.0 ft HS-flume in l/s

h_a (m)	.000	.001	.002	.003	.004	.005	.006	.007	.008	.009
0.04	0.339	0.355	0.372	0.389	0.407	0.425	0.443	0.462	0.482	0.501
0.05	0.521	0.542	0.563	0.584	0.606	0.629	0.651	0.674	0.698	0.722
0.06	0.746	0.771	0.797	0.822	0.849	0.875	0.902	0.930	0.958	0.986
0.07	1.02	1.04	1.07	1.10	1.14	1.17	1.20	1.23	1.26	1.30
0.08	1.33	1.36	1.40	1.43	1.47	1.50	1.54	1.58	1.61	1.65
0.09	1.69	1.73	1.77	1.81	1.85	1.89	1.93	1.97	2.01	2.05
0.10	2.10	2.14	2.18	2.23	2.27	2.32	2.36	2.41	2.46	2.51
0.11	2.55	2.60	2.65	2.70	2.75	2.80	2.85	2.90	2.96	3.01
0.12	3.06	3.11	3.17	3.22	3.28	3.33	3.39	3.45	3.50	3.56
0.13	3.62	3.68	3.74	3.80	3.86	3.92	3.98	4.04	4.11	4.17
0.14	4.23	4.30	4.36	4.43	4.49	4.56	4.63	4.69	4.76	4.83
0.15	4.90	4.97	5.04	5.11	5.18	5.25	5.32	5.40	5.47	5.54
0.16	5.62	5.69	5.77	5.85	5.92	6.00	6.08	6.16	6.24	6.32
0.17	6.40	6.48	6.56	6.64	6.73	6.81	6.89	6.98	7.06	7.15
0.18	7.23	7.32	7.41	7.50	7.58	7.67	7.76	7.85	7.94	8.04
0.19	8.13	8.22	8.31	8.41	8.50	8.60	8.69	8.79	8.89	8.98
0.20	9.08	9.18	9.28	9.38	9.48	9.58	9.69	9.79	9.89	9.99
0.21	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	11.0	11.1
0.22	11.2	11.3	11.4	11.5	11.6	11.7	11.9	12.0	12.1	12.2
0.23	12.3	12.4	12.6	12.7	12.8	12.9	13.0	13.2	13.3	13.4
0.24	13.5	13.6	13.8	13.9	14.0	14.2	14.3	14.4	14.5	14.7
0.25	14.8	14.9	15.1	15.2	15.3	15.5	15.6	15.7	15.9	16.0
0.26	16.1	16.3	16.4	16.5	16.7	16.8	17.0	17.1	17.3	17.4
0.27	17.5	17.7	17.8	18.0	18.1	18.3	18.4	18.6	18.7	18.9
0.28	19.0	19.2	19.3	19.5	19.6	19.8	19.9	20.1	20.2	20.4
0.29	20.6	20.7	20.9	21.0	21.2	21.4	21.5	21.7	21.8	22.0
0.30	22.2	22.3								

Table 7.14a Free-flow discharge through 0.5 ft H-flume in $m^3/s \times 10^{-3}$ (l/s)

h_a (m)	.000	.002	.004	.006	.008
0.01	0.031	0.044	0.059	0.077	0.097
0.02	0.119	0.145	0.172	0.203	0.236
0.03	0.272	0.311	0.353	0.398	0.446
0.04	0.497	0.551	0.609	0.669	0.733
0.05	0.801	0.871	0.946	1.02	1.10
0.06	1.19	1.28	1.37	1.47	1.57
0.07	1.67	1.78	1.89	2.00	2.12
0.08	2.25	2.37	2.51	2.64	2.78
0.09	2.93	3.07	3.23	3.38	3.55
0.10	3.71	3.88	4.06	4.24	4.42
0.11	4.61	4.81	5.01	5.21	5.42
0.12	5.63	5.85	6.08	6.31	6.54
0.13	6.78	7.02	7.27	7.53	7.79
0.14	8.05	8.32	8.60	8.88	9.17

Table 7.14b Free-flow discharge through 0.75 ft H-flume in (l/s)

h_a (m)	.000	.002	.004	.006	.008
0.01	0.044	0.061	0.080	0.103	0.128
0.02	0.155	0.186	0.220	0.256	0.296
0.03	0.339	0.384	0.433	0.486	0.541
0.04	0.600	0.662	0.728	0.797	0.869
0.05	0.945	1.03	1.11	1.20	1.29
0.06	1.38	1.48	1.58	1.69	1.80
0.07	1.91	2.03	2.15	2.28	2.41
0.08	2.54	2.68	2.83	2.97	3.13
0.09	3.28	3.44	3.61	3.78	3.95
0.10	4.13	4.31	4.50	4.70	4.89
0.11	5.10	5.30	5.52	5.73	5.96
0.12	6.18	6.42	6.65	6.90	7.14
0.13	7.40	7.65	7.92	8.19	8.46
0.14	8.74	9.03	9.32	9.61	9.91
0.15	10.2	10.5	10.9	11.2	11.5
0.16	11.8	12.2	12.5	12.9	13.2
0.17	13.6	14.0	14.4	14.7	15.1
0.18	15.5	15.9	16.3	16.7	17.2
0.19	17.6	18.0	18.5	18.9	19.4
0.20	19.8	20.3	20.8	21.2	21.7
0.21	22.2	22.7	23.2	23.7	24.2
0.22	24.8	25.3	25.8	26.4	26.9

Table 7.14c Free-flow discharge through 1.0 ft H-flume in $m^3/s \times 10^{-3}$ (l/s)

h_a (m)	.000	.002	.004	.006	.008	h_a (m)	.000	.002	.004	.006	.008
0.00						0.15	11.0	11.3	11.7	12.0	12.3
0.01				0.127	0.157	0.16	12.7	13.1	13.4	13.8	14.2
0.02	0.190	0.226	0.265	0.308	0.236	0.17	14.5	14.9	15.3	15.7	16.1
0.03	0.403	0.455	0.511	0.571	0.634	0.18	16.5	16.9	17.4	17.8	18.2
0.04	0.701	0.771	0.845	0.922	1.00	0.19	18.7	19.1	19.6	20.0	20.5
0.05	1.09	1.18	1.27	1.37	1.47	0.20	21.0	21.4	21.9	22.4	22.9
0.06	1.57	1.68	1.79	1.91	2.03	0.21	23.4	23.9	24.5	25.0	25.5
0.07	2.16	2.28	2.42	2.56	2.70	0.22	26.1	26.6	27.2	27.7	28.3
0.08	2.84	2.99	3.15	3.31	3.47	0.23	28.9	29.4	30.0	30.6	31.2
0.09	3.64	3.82	3.99	4.18	4.36	0.24	31.8	32.4	33.1	33.7	34.2
0.10	4.56	4.75	4.95	5.16	5.37	0.25	35.0	35.6	36.3	37.0	37.6
0.11	5.59	5.81	6.04	6.27	6.50	0.26	38.3	39.0	39.7	40.4	41.1
0.12	6.74	6.99	7.24	7.50	7.76	0.27	41.8	42.6	43.3	44.0	44.8
0.13	8.03	8.30	8.58	8.86	9.15	0.28	45.5	46.3	47.1	47.9	48.6
0.14	9.45	9.75	10.1	10.4	10.7	0.29	49.4	50.2	51.0	51.9	52.7
						0.30	53.5				

Table 7.14d Free-flow discharge through 1.5 ft H-flume in l/s

0.00						0.25	38.2	38.9	39.6	40.3	41.0
0.01						0.26	41.7	42.5	43.2	43.9	44.7
0.02	0.269	0.316	0.367	0.421	0.479	0.27	45.4	46.2	47.0	47.8	48.5
0.03	0.542	0.608	0.677	0.751	0.829	0.28	49.3	50.1	51.0	51.8	52.6
0.04	0.910	0.996	1.09	1.18	1.28	0.29	53.4	54.3	55.1	56.0	56.8
0.05	1.38	1.49	1.60	1.71	1.83	0.30	57.7	58.6	59.5	60.4	61.3
0.06	1.75	2.08	2.21	2.35	2.49	0.31	62.2	63.1	64.1	65.0	66.0
0.07	2.64	2.78	2.94	3.10	3.26	0.32	66.9	67.9	68.8	69.8	70.8
0.08	3.43	3.60	3.78	3.96	4.15	0.33	71.8	72.8	73.8	74.9	75.9
0.09	4.34	4.54	4.74	4.95	5.16	0.34	76.9	78.0	79.0	80.1	81.2
0.10	5.38	5.60	5.83	6.06	6.29	0.35	82.3	83.4	84.5	85.6	86.7
0.11	6.54	6.78	7.04	7.30	7.56	0.36	87.8	89.0	90.1	91.3	92.4
0.12	7.83	8.10	8.38	8.67	8.96	0.37	93.6	94.8	96.0	97.2	98.4
0.13	9.25	9.55	9.86	10.2	10.5	0.38	99.6	101	102	103	105
0.14	10.8	11.1	11.5	11.8	12.2	0.39	106	107	108	110	111
0.15	12.5	12.9	13.2	13.6	14.0	0.40	112	114	115	116	118
0.16	14.4	14.8	15.1	15.5	16.0	0.41	119	120	122	123	125
0.17	16.4	16.8	17.2	17.6	18.1	0.42	126	127	129	130	132
0.18	18.5	19.0	19.4	19.9	20.4	0.43	133	135	136	138	139
0.19	20.8	21.3	21.8	22.3	22.8	0.44	141	142	144	145	147
0.20	23.3	23.8	24.3	24.9	25.4	0.45	148	150			
0.21	25.9	26.5	27.0	27.6	28.2						
0.22	28.7	29.3	29.9	30.5	31.1						
0.23	31.7	32.3	33.0	33.6	34.2						
0.24	34.9	35.5	36.2	36.9	37.5						

Table 7.14e Free-flow discharge through 2.0 ft H-flume in $m^3/s \times 10^{-3}$ (l/s)

h_a (m)	.000	.002	.004	.006	.008	h_a (m)	.000	.002	.004	.006	.008
0.00						0.30	61.9	62.9	63.8	64.7	65.7
0.01						0.31	66.6	67.6	68.6	69.5	70.5
0.02			0.469	0.535	0.606	0.32	71.5	72.5	73.5	74.6	75.6
0.03	0.681	0.760	0.844	0.932	1.02	0.33	76.6	77.7	78.7	79.7	80.8
0.04	1.12	1.22	1.33	1.44	1.55	0.34	81.9	83.0	84.1	85.2	86.3
0.05	1.67	1.79	1.92	2.05	2.19	0.35	87.5	88.6	89.7	90.9	92.0
0.06	2.33	2.48	2.63	2.79	2.95	0.36	93.2	94.4	95.6	96.7	97.9
0.07	3.11	3.29	3.46	3.64	3.83	0.37	99.2	100	102	103	104
0.08	4.02	4.21	4.41	4.62	4.83	0.38	105	107	108	109	110
0.09	5.04	5.27	5.49	5.72	5.96	0.39	112	113	114	116	117
0.10	6.20	6.45	6.70	6.96	7.22	0.40	118	120	121	123	124
0.11	7.49	7.76	8.04	8.33	8.62	0.41	125	127	128	130	131
0.12	8.91	9.22	9.52	9.84	10.2	0.42	132	134	135	137	138
0.13	10.5	10.8	11.1	11.5	11.8	0.43	140	141	143	144	146
0.14	12.2	12.5	12.9	13.3	13.7	0.44	147	148	150	152	154
0.15	14.0	14.4	14.8	15.2	15.6	0.45	155	157	158	160	162
0.16	16.1	16.5	16.9	17.3	17.8	0.46	163	165	167	168	170
0.17	18.2	18.7	19.1	19.6	20.1	0.47	172	173	175	177	179
0.18	20.5	21.0	21.5	22.0	22.5	0.48	180	182	184	186	187
0.19	23.0	23.5	24.1	24.6	25.1	0.49	189	191	193	195	196
0.20	25.7	26.2	26.8	27.3	27.9	0.50	198	200	202	204	206
0.21	28.5	29.1	29.7	30.2	30.9	0.51	208	210	211	213	215
0.22	31.5	32.1	32.7	33.3	34.0	0.52	217	219	221	223	225
0.23	34.6	35.3	35.9	36.6	37.3	0.53	227	229	231	233	235
0.24	38.0	38.7	39.4	40.1	40.8	0.54	237	240	242	244	246
0.25	41.5	42.2	42.9	43.7	44.4	0.55	248	250	252	254	256
0.26	45.2	46.0	46.7	47.5	48.3	0.56	259	261	263	265	267
0.27	49.1	50.0	50.7	51.5	52.3	0.57	270	272	274	276	279
0.28	53.2	54.0	54.9	55.7	56.6	0.58	281	283	286	288	290
0.29	57.5	58.3	59.2	60.1	61.0	0.59	293	295	297	300	302
						0.60	305	307	309		

Table 7.14f Free-flow discharge through 2.0 ft H-flume in $m^3/s \times 10^{-3}$ (l/s)

h_a (m)	.000	.002	.004	.006	.008	h_a (m)	.000	.002	.004	.006	.008
0.00						0.40	125	126	128	129	131
0.01						0.41	132	134	135	136	138
0.02				0.649	0.732	0.42	139	141	142	144	145
0.03	0.820	0.912	1.01	1.11	1.22	0.43	147	149	150	152	153
0.04	1.33	1.45	1.57	1.69	1.82	0.44	155	156	158	160	161
0.05	1.96	2.10	2.25	2.40	2.55	0.45	163	165	166	168	169
0.06	2.71	2.88	3.05	3.23	3.41	0.46	171	173	175	176	178
0.07	3.59	3.78	3.98	4.18	4.39	0.47	180	181	183	185	187
0.08	4.60	4.82	5.04	5.27	5.51	0.48	189	190	192	194	196
0.09	5.75	5.99	6.24	6.50	6.76	0.49	198	199	201	203	205
0.10	7.02	7.30	7.58	7.86	8.15	0.50	207	209	211	213	215
0.11	8.44	8.75	9.05	9.36	9.68	0.51	216	218	220	222	224
0.12	10.0	10.3	10.7	11.0	11.4	0.52	226	228	230	232	234
0.13	11.7	12.1	12.4	12.8	13.2	0.53	236	239	241	243	245
0.14	13.6	14.0	14.4	14.8	15.2	0.54	247	249	251	253	255
0.15	15.6	16.0	16.4	16.9	17.3	0.55	257	260	262	264	266
0.16	17.6	18.2	18.7	19.1	19.6	0.56	268	271	273	275	277
0.17	20.1	20.6	21.1	21.6	22.1	0.57	280	282	284	286	289
0.18	22.6	23.1	23.6	24.2	24.7	0.58	291	293	296	298	301
0.19	25.2	25.8	26.4	26.9	27.5	0.59	303	305	308	310	313
0.20	28.1	28.7	29.2	29.8	30.5	0.60	315	317	320	322	325
0.21	31.1	31.7	32.3	33.0	33.6	0.61	327	330	332	335	337
0.22	34.2	34.9	35.6	36.2	36.9	0.62	340	343	345	348	350
0.23	37.6	38.4	39.0	39.7	40.4	0.63	353	355	358	361	363
0.24	41.1	41.9	42.6	43.4	44.1	0.64	366	369	371	374	377
0.25	44.9	45.6	46.4	47.2	48.0	0.65	380	382	385	388	391
0.26	48.8	49.6	50.4	51.2	52.0	0.66	393	396	399	402	405
0.27	52.9	53.7	54.6	55.4	56.3	0.67	408	410	413	416	419
0.28	57.2	58.1	59.0	59.9	60.8	0.68	422	425	428	431	434
0.29	61.7	62.7	63.5	64.5	65.4	0.69	437	440	443	446	449
0.30	66.4	67.3	68.3	69.3	70.3	0.70	452	455	458	461	464
0.31	71.3	72.3	73.3	74.3	75.3	0.71	467	470	474	477	480
0.32	76.4	77.4	78.5	79.5	80.6	0.72	483	486	489	493	496
0.33	81.7	82.8	83.9	85.0	86.1	0.73	499	502	506	509	512
0.34	87.2	88.3	89.5	90.6	91.8	0.74	515	519	522	525	529
						0.75	532	535	539	542	
0.35	93.0	94.1	95.3	96.5	97.7						
0.36	98.9	100	101	102	104						
0.37	105	106	108	109	110						
0.38	112	113	114	115	117						
0.39	118	119	121	122	124						

Table 7.14g Free-flow discharge through 3.0 ft H-flume in $m^3/s \times 10^{-3}$ (l/s)

h_a (m)	.000	.002	.004	.006	.008
0.00					
0.01					
0.03	0.959	1.06	1.18	1.29	1.41
0.04	1.54	1.67	1.81	1.95	2.09
0.05	2.25	2.40	2.57	2.74	2.91
0.06	3.09	3.27	3.46	3.66	3.86
0.07	4.06	4.28	4.49	4.72	4.95
0.08	5.18	5.42	5.66	5.92	6.17
0.09	6.43	6.70	6.98	7.26	7.54
0.10	7.83	8.13	8.44	8.75	9.06
0.11	9.38	9.71	10.0	10.4	10.7
0.12	11.1	11.4	11.8	12.2	12.5
0.13	12.9	13.3	13.7	14.1	14.5
0.14	14.9	15.4	15.8	16.2	16.7
0.15	17.1	17.6	18.0	18.5	19.0
0.16	19.4	19.9	20.4	20.9	21.4
0.17	21.9	22.4	23.0	23.5	24.0
0.18	24.6	25.1	25.7	26.3	26.8
0.19	27.4	28.0	28.6	29.2	29.8
0.20	30.4	31.1	31.7	32.3	33.0
0.21	33.6	34.3	35.0	35.6	36.3
0.22	37.0	37.7	38.4	39.1	39.8
0.23	40.5	41.3	42.0	42.8	43.5
0.24	44.3	45.1	45.8	46.6	47.4
0.25	48.2	49.0	49.8	50.7	51.5
0.26	52.3	53.2	54.0	54.9	55.8
0.27	56.6	57.5	58.4	59.3	60.2
0.28	61.2	62.1	63.0	64.0	64.9
0.29	65.9	66.8	67.8	68.8	69.8
0.30	70.8	71.8	72.8	73.8	74.9
0.31	75.9	77.8	78.0	79.1	80.2
0.32	81.2	82.3	83.4	84.5	85.7
0.33	86.8	87.9	89.1	90.2	91.4
0.34	92.5	93.7	94.9	96.1	97.3
0.35	98.5	99.7	101	102	103
0.36	105	106	107	109	110
0.37	111	112	114	115	116
0.38	118	119	120	122	123
0.39	125	126	127	129	130
0.40	132	133	135	136	138
0.41	139	141	142	144	145
0.42	147	148	150	151	153
0.43	154	156	158	159	161
0.44	163	164	166	167	169
0.45	171	173	174	176	178
0.46	179	181	183	185	186
0.47	188	190	192	194	195
0.48	197	199	201	203	205
0.49	207	208	210	212	214
0.50	216	218	220	222	224
0.51	226	228	230	232	234
0.53	246	248	251	253	255
0.54	257	259	261	263	266
0.55	268	270	272	274	277
0.56	279	281	283	286	288
0.57	290	293	295	297	300
0.58	302	304	307	309	312
0.59	314	317	319	321	324
0.60	326	329	331	334	336
0.61	339	341	344	347	349
0.62	352	354	357	360	362
0.63	365	368	370	373	376
0.64	378	381	384	387	389
0.65	392	395	398	400	403
0.66	406	409	412	415	418
0.67	420	423	426	429	432
0.68	435	438	441	444	447
0.69	450	453	456	459	462
0.70	465	468	471	475	478
0.71	481	484	487	490	494
0.72	497	500	503	506	510
0.73	513	516	519	523	526
0.74	529	533	536	539	543
0.75	546	550	553	556	560
0.76	563	567	570	574	577
0.77	581	584	588	592	595
0.78	599	602	606	610	613
0.79	617	620	624	628	632
0.80	635	639	643	647	650
0.81	654	658	662	666	669
0.82	673	677	681	685	689
0.83	693	697	701	705	709
0.84	713	717	721	725	729
0.85	733	737	741	745	749
0.86	753	757	762	766	770
0.87	774	778	783	787	791
0.88	795	800	804	808	813
0.89	817	821	826	830	835
0.90	839	843	848	852	857

Table 7.14h Free-flow discharge through 4.5 ft H-flume in $m^3/s \times 10^{-3}$ (l/s)

h_a (m)	.000	.002	.004	.006	.008	h_a (m)	.000	.002	.004	.006	.008
0.00						0.40	152	154	155	157	159
0.01						0.41	160	162	164	165	167
0.02						0.42	169	170	172	174	176
0.03	1.39	1.53	1.68	1.84	2.00	0.43	177	179	181	183	184
0.04	2.17	2.35	2.53	2.72	2.91	0.44	186	188	190	192	193
0.05	3.12	3.32	3.53	3.76	3.98	0.45	195	197	199	201	203
0.06	4.22	4.46	4.70	4.95	5.21	0.46	205	207	208	210	212
0.07	5.48	5.75	6.02	6.31	6.60	0.47	214	216	218	220	222
0.08	6.90	7.20	7.52	7.83	8.16	0.48	224	226	228	230	232
0.09	8.49	8.82	9.17	9.52	9.88	0.49	234	236	238	240	243
0.10	10.2	10.6	11.0	11.4	11.8	0.50	245	247	249	251	253
0.11	12.2	12.6	13.0	13.4	13.8	0.51	255	257	260	262	264
0.12	14.3	14.7	15.1	15.6	16.1	0.52	266	268	271	273	275
0.13	16.5	17.0	17.5	18.0	18.5	0.53	277	280	282	284	287
0.14	19.0	19.5	20.0	20.5	21.0	0.54	289	291	294	296	298
0.15	21.6	22.1	22.7	23.2	23.8	0.55	301	303	305	308	310
0.16	24.4	25.0	25.6	26.2	26.8	0.56	313	315	317	320	322
0.17	27.4	28.0	28.6	29.2	30.0	0.57	325	327	330	332	335
0.18	30.5	31.2	31.9	32.5	33.2	0.58	337	340	343	345	348
0.19	33.9	34.6	35.3	36.0	36.7	0.59	350	353	355	358	361
0.20	37.4	38.2	38.9	39.7	40.4	0.60	363	366	369	371	375
0.21	41.2	42.0	42.7	43.5	44.3	0.61	377	380	382	385	388
0.22	45.1	45.9	46.8	47.6	48.4	0.62	390	393	396	399	402
0.23	49.3	50.1	51.0	51.8	52.7	0.63	405	407	410	413	416
0.24	53.6	54.5	55.4	56.3	57.2	0.64	419	422	425	427	430
0.25	58.1	59.1	60.0	61.0	61.9	0.65	433	436	439	442	445
0.26	62.9	63.9	64.8	65.8	66.8	0.66	448	451	454	457	460
0.27	67.8	68.9	69.9	70.9	72.0	0.67	463	466	470	473	476
0.28	73.0	74.1	75.1	76.2	77.3	0.68	479	482	485	488	491
0.29	78.4	79.5	80.6	81.7	82.8	0.69	495	498	501	504	507
0.30	84.0	85.1	86.3	87.4	88.6	0.70	511	514	517	520	524
0.31	89.8	91.0	92.2	93.4	94.6	0.71	527	530	534	537	540
0.32	95.8	97.0	98.3	99.5	101	0.72	544	547	551	554	557
0.33	102	103	105	106	107	0.73	561	564	568	571	575
0.34	109	110	111	113	114	0.74	578	582	585	589	592
0.35	115	117	118	119	121						
0.36	122	124	125	126	128						
0.37	129	131	132	134	135						
0.38	137	138	140	141	143						
0.39	144	146	148	149	151						

Table 7.14h Free-flow discharge through 4.5 ft H-flume in $m^3/s \times 10^{-3}$ (l/s) (cont.)

h_a (m)	.000	.002	.004	.006	.008	h_a (m)	.000	.002	.004	.006	.008
0.75	596	599	603	606	610	1.05	1281	1287	1292	1299	1304
0.76	614	617	621	625	628	1.06	1310	1316	1321	1327	1333
0.77	632	636	639	643	647	1.07	1339	1345	1350	1356	1362
0.78	650	654	658	662	666	1.08	1368	1374	1380	1386	1392
0.79	669	673	677	681	685	1.09	1398	1403	1409	1415	1421
0.80	689	693	696	700	704	1.10	1427	1434	1440	1446	1452
0.81	708	712	716	720	724	1.11	1458	1464	1470	1476	1482
0.82	728	732	736	740	744	1.12	1489	1495	1501	1507	1513
0.83	748	752	757	761	765	1.13	1520	1526	1532	1539	1545
0.84	769	773	777	781	786	1.14	1551	1558	1564	1570	1577
0.85	790	794	798	802	807	1.15	1583	1590	1596	1603	1609
0.86	811	815	820	824	828	1.16	1616	1622	1629	1635	1642
0.87	833	837	841	846	850	1.17	1648	1655	1661	1668	1675
0.88	855	859	863	868	872	1.18	1681	1688	1695	1701	1708
0.89	877	881	886	890	894	1.19	1715	1722	1728	1735	1742
0.90	899	904	909	913	918	1.20	1749	1756	1763	1769	1776
0.91	922	927	932	936	941	1.21	1783	1790	1797	1804	1811
0.92	946	950	955	960	965	1.22	1818	1825	1832	1839	1846
0.93	969	974	979	984	988	1.23	1853	1860	1867	1875	1882
0.94	993	998	1003	1008	1013	1.24	1889	1896	1903	1910	1918
0.95	1018	1023	1028	1032	1037	1.25	1925	1932	1939	1947	1954
0.96	1042	1047	1052	1057	1062	1.26	1961	1969	1976	1983	1991
0.97	1068	1073	1078	1083	1088	1.27	1998	2006	2013	2020	2028
0.98	1093	1098	1103	1108	1114	1.28	2035	2043	2050	2058	2066
0.99	1119	1124	1129	1134	1140	1.29	2073	2081	2088	2096	2104
1.00	1145	1150	1156	1161	1166	1.30	2111	2119	2127	2134	2142
1.01	1172	1177	1182	1188	1193	1.31	2150	2158	2165	2173	2181
1.02	1198	1204	1209	1215	1220	1.32	2189	2197	2205	2212	2220
1.03	1226	1231	1237	1242	1248	1.33	2228	2236	2244	2252	2260
1.04	1253	1259	1265	1270	1276	1.34	2268	2276	2284	2292	2300
						1.35	2308	2317	2325	2333	2341
						1.36	2349	2357	2366		

Table 7.15a Free-flow discharge through 3.5 ft HL-flume in l/s ($m^3/s \times 10^{-3}$)

h_a (m)	.000	.002	.004	.006	.008
0.05	4.86	5.19	5.52	5.86	6.22
0.06	6.58	6.95	7.34	7.73	8.14
0.07	8.55	8.98	9.41	9.86	10.32
0.08	10.79	11.27	11.75	12.25	12.77
0.09	13.29	13.82	14.36	14.92	15.48
0.10	16.06	16.65	17.24	17.85	18.47
0.11	19.11	19.75	20.40	21.07	21.75
0.12	22.44	23.14	23.85	24.57	25.31
0.13	26.05	26.81	27.58	28.36	29.16
0.14	29.96	30.78	31.61	32.45	33.31
0.15	34.17	35.05	35.94	36.84	37.76
0.16	38.69	39.63	40.58	41.54	42.52
0.17	43.51	44.51	45.53	46.55	47.59
0.18	48.65	49.71	50.79	51.88	52.99
0.19	54.10	55.23	56.38	57.53	58.70
0.20	59.89	61.08	62.29	63.52	64.75
0.21	66.00	67.27	68.54	69.83	71.14
0.22	72.45	73.79	75.13	76.49	77.86
0.23	79.25	80.65	82.06	83.49	84.93
0.24	86.39	87.86	89.34	90.84	92.36
0.25	93.88	95.42	96.98	98.55	100.14
0.26	101.73	103.35	104.98	106.62	108.28
0.27	109.95	111.64	113.34	115.06	116.79
0.28	118.53	120.30	122.07	123.86	125.67
0.29	127.49	129.33	131.18	133.05	134.93
0.30	136.83	138.74	140.67	142.61	144.57
0.31	146.55	148.54	150.55	152.57	154.61
0.32	156.66	158.73	160.82	162.92	165.03
0.33	167.17	169.32	171.48	173.66	175.86
0.34	178.07	180.30	182.55	184.81	187.09
0.35	189.38	191.69	194.02	196.36	198.73
0.36	201.10	203.50	205.91	208.33	210.78
0.37	213.24	215.72	218.21	220.72	223.25
0.38	225.80	228.36	230.94	233.53	236.15
0.39	238.78	241.43	244.09	246.77	249.47
0.40	252.19	254.92	257.68	260.45	263.23
0.41	266.04	268.86	271.70	274.56	277.43
0.42	280.33	283.24	286.17	289.12	292.08
0.43	295.06	298.06	301.08	304.12	307.18
0.44	310.25	313.34	316.45	319.58	322.73
0.45	325.89	329.07	332.28	335.50	338.74
0.46	341.99	345.27	348.57	351.88	355.21
0.47	358.56	361.93	365.32	368.73	372.16
0.48	375.60	379.07	382.35	386.05	389.58
0.49	393.12	396.68	400.26	403.86	407.48
0.50	411.12	414.77	418.45	422.15	425.86
0.51	429.60	433.35	437.13	440.92	444.74
0.52	448.57	452.43	456.30	460.19	464.11
0.53	468.04	472.00	475.97	479.96	483.98
0.54	488.01	492.07	496.14	500.24	504.35
0.55	508.49	512.65	516.82	521.02	525.24
0.56	529.48	533.74	538.02	542.32	546.64
0.57	550.98	555.34	559.73	564.13	568.56
0.58	573.00	577.47	581.96	586.47	591.00
0.59	595.55	600.13	604.72	609.34	613.97

Table 7.15a (cont.) Free-flow discharge through 3.5 ft HL-flume in l/s ($m^3/s \times 10^{-3}$)

h_a (m)	.000	.002	.004	.006	.008
0.60	618.63	623.31	628.01	632.74	637.48
0.61	642.25	647.03	651.84	656.67	661.53
0.62	666.40	671.30	676.22	681.16	686.12
0.63	691.10	696.11	701.14	706.19	711.26
0.64	716.35	721.47	726.61	731.77	736.95
0.65	742.16	747.39	752.64	757.91	763.21
0.66	768.52	773.87	779.23	784.61	790.02
0.67	795.46	800.91	806.39	811.89	817.41
0.68	822.96	828.52	834.12	839.73	845.37
0.69	851.03	856.71	862.42	868.15	873.91
0.70	879.68	885.49	891.31	897.16	903.03
0.71	908.92	914.84	920.78	926.75	932.74
0.72	938.75	944.79	950.85	956.93	963.04
0.73	969.17	975.33	981.51	987.71	993.94
0.74	1000.19	1006.47	1012.77	1019.10	1025.44
0.75	1031.82	1038.22	1044.64	1051.08	1057.56
0.76	1064.05	1070.57	1077.12	1083.69	1090.28
0.77	1096.90	1103.54	1110.21	1116.90	1123.62
0.78	1130.36	1137.13	1143.92	1150.74	1157.58
0.79	1164.45	1171.34	1178.26	1185.20	1192.17
0.80	1199.17	1206.19	1213.23	1220.30	1227.40
0.81	1234.52	1241.66	1248.83	1256.03	1263.25
0.82	1270.50	1277.78	1285.08	1292.40	1299.75
0.83	1307.13	1314.54	1321.97	1329.42	1336.90
0.84	1344.41	1351.94	1359.50	1367.09	1374.70
0.85	1382.34	1390.00	1397.69	1405.41	1413.15
0.86	1420.92	1428.72	1436.54	1444.39	1452.27
0.87	1460.17	1468.10	1476.06	1484.04	1492.05
0.88	1500.09	1508.15	1516.24	1524.36	1532.50
0.89	1540.67	1548.87	1557.10	1565.35	1573.63
0.90	1581.94	1590.27	1598.63	1607.02	1615.44
0.91	1623.88	1632.35	1640.85	1649.38	1657.93
0.92	1666.51	1675.12	1683.75	1692.42	1701.11
0.93	1709.83	1718.58	1727.35	1736.16	1744.99
0.94	1753.85	1762.73	1771.65	1780.59	1789.56
0.95	1798.56	1807.59	1816.65	1825.73	1834.85
0.96	1843.99	1853.16	1862.35	1871.58	1880.84
0.97	1890.12	1899.43	1908.77	1918.14	1927.54
0.98	1936.97	1946.42	1955.91	1965.42	1974.96
0.99	1984.53	1994.13	2003.76	2013.42	2023.11
1.00	2032.82	2042.57	2052.35	2062.15	2071.98
1.01	2081.85	2091.74	2101.66	2111.61	2121.59
1.02	2131.60	2141.64	2151.71	2161.81	2171.94
1.03	2182.10	2192.28	2202.50	2212.75	2223.03
1.04	2233.33	2243.67	2254.04	2264.44	2274.86
1.05	2285.32	2295.81	2306.33	2316.87	2327.45
1.06	2338.06	2348.70	2359.37	2370.07	

Table 7.15b Free-flow discharge through 4 ft HL-flume in l/s ($m^3/s \times 10^{-3}$)

h_a (m)	.000	.002	.004	.006	.008
0.05	5.38	5.73	6.10	6.48	6.86
0.06	7.26	7.67	8.09	8.52	8.96
0.07	9.41	9.88	10.35	10.84	11.34
0.08	11.84	12.36	12.90	13.44	13.99
0.09	14.56	15.13	15.72	16.32	16.93
0.10	17.55	18.19	18.84	19.49	20.16
0.11	20.84	21.54	22.24	22.96	23.69
0.12	24.43	25.18	25.95	26.73	27.51
0.13	28.32	29.13	29.96	30.79	31.65
0.14	32.51	33.38	34.27	35.17	36.09
0.15	37.01	37.95	38.90	39.86	40.84
0.16	41.83	42.83	43.85	44.88	45.92
0.17	46.97	48.04	49.12	50.21	51.32
0.18	52.44	53.57	54.72	55.88	57.05
0.19	58.24	59.44	60.65	61.88	63.12
0.20	64.37	65.64	66.92	68.21	69.52
0.21	70.85	72.18	73.53	74.90	76.27
0.22	77.67	79.07	80.49	81.93	83.38
0.23	84.84	86.32	87.81	89.31	90.83
0.24	92.37	93.92	95.48	97.06	98.65
0.25	100.26	101.88	103.52	105.17	106.83
0.26	108.51	110.21	111.92	113.64	115.38
0.27	117.14	118.91	120.69	122.50	124.31
0.28	126.14	127.99	129.85	131.73	133.62
0.29	135.52	137.45	139.38	141.34	143.31
0.30	145.29	147.29	149.31	151.34	153.39
0.31	155.45	157.53	159.62	161.73	163.86
0.32	166.00	168.16	170.34	172.53	174.73
0.33	176.96	179.20	181.45	183.72	186.01
0.34	188.31	190.63	192.97	195.32	197.69
0.35	200.08	202.48	204.90	207.34	209.79
0.36	212.26	214.75	217.25	219.77	222.31
0.37	224.86	227.43	230.02	232.62	235.24
0.38	237.88	240.54	243.21	245.90	248.61
0.39	251.33	254.08	256.84	259.61	262.41
0.40	265.22	268.05	270.89	273.76	276.64
0.41	279.54	282.46	285.39	288.34	291.32
0.42	294.30	297.31	300.33	303.38	306.44
0.43	309.51	312.61	315.72	318.86	322.01
0.44	325.18	328.36	331.57	334.79	338.03
0.45	341.29	344.57	347.87	351.18	354.52
0.46	357.87	361.24	364.63	368.04	371.47
0.47	374.92	379.39	381.86	385.37	388.89
0.48	392.43	395.99	399.57	403.16	406.78
0.49	410.42	414.07	417.75	421.44	425.15
0.50	428.88	432.63	436.41	440.20	440.00
0.51	447.83	451.68	455.55	459.44	463.35
0.52	467.27	471.22	475.19	479.17	483.18
0.53	487.20	491.25	495.31	499.40	503.51
0.54	507.63	511.78	515.94	520.13	524.33
0.55	528.56	532.81	537.07	541.36	545.67
0.56	550.00	554.34	558.71	563.10	567.51
0.57	571.94	576.39	580.87	585.36	589.87
0.58	594.40	598.96	603.53	608.13	612.75
0.59	617.39	622.04	626.72	631.43	636.15

Table 7.15b (cont.) Free-flow discharge through 4 ft HL-flume in l/s ($m^3/s \times 10^{-3}$)

h_a (m)	.000	.002	.004	.006	.008
0.60	640.89	645.66	650.44	655.25	660.08
0.61	664.92	669.80	674.69	679.60	684.54
0.62	689.49	694.47	699.47	704.49	709.53
0.63	714.60	719.68	724.79	729.92	735.07
0.64	740.24	745.44	750.65	755.89	761.15
0.65	766.44	771.74	777.07	782.41	787.79
0.66	793.18	798.59	804.03	809.49	814.97
0.67	820.48	826.00	831.55	837.13	842.72
0.68	848.34	853.98	859.64	865.32	871.03
0.69	876.76	882.51	888.29	894.09	899.91
0.70	905.75	911.62	917.51	923.42	929.36
0.71	935.31	941.30	947.30	953.33	959.38
0.72	965.46	971.55	977.67	983.82	989.99
0.73	996.18	1002.39	1008.63	1014.89	1021.18
0.74	1027.49	1033.82	1040.18	1046.56	1052.96
0.75	1059.39	1065.84	1072.31	1078.81	1085.34
0.76	1091.88	1098.45	1105.05	1111.67	1118.31
0.77	1124.98	1131.67	1138.38	1145.12	1151.89
0.78	1158.68	1165.49	1172.32	1179.19	1186.07
0.79	1192.98	1199.92	1206.88	1213.86	1220.87
0.80	1227.90	1234.96	1242.04	1249.15	1256.28
0.81	1263.44	1270.62	1277.82	1285.05	1292.31
0.82	1299.59	1306.90	1314.23	1321.59	1328.97
0.83	1336.37	1343.81	1351.26	1358.74	1366.25
0.84	1373.79	1381.34	1388.93	1396.54	1404.17
0.85	1411.83	1419.52	1427.23	1434.96	1442.73
0.86	1450.52	1458.33	1466.17	1474.04	1481.93
0.87	1489.84	1497.79	1505.76	1513.75	1521.77
0.88	1529.82	1537.89	1545.99	1554.12	1562.27
0.89	1570.44	1578.65	1586.88	1595.13	1603.42
0.90	1611.73	1620.06	1628.42	1636.81	1645.23
0.91	1653.67	1662.14	1670.63	1679.15	1687.70
0.92	1696.28	1704.88	1713.51	1722.16	1730.84
0.93	1739.55	1748.29	1757.05	1765.84	1774.66
0.94	1783.50	1792.37	1801.27	1810.20	1819.15
0.95	1828.13	1837.14	1846.17	1855.23	1864.32
0.96	1873.44	1882.58	1891.75	1900.75	1910.18
0.97	1919.43	1928.71	1938.02	1947.36	1956.73
0.98	1966.12	1975.54	1984.99	1994.46	2003.97
0.99	2013.50	2023.06	2032.65	2042.26	2051.91
1.00	2061.58	2071.28	2081.01	2090.76	2100.55
1.01	2110.36	2120.20	2130.07	2139.97	2149.90
1.02	2159.85	2169.84	2179.85	2189.89	2199.96
1.03	2210.06	2220.18	2230.34	2240.52	2250.73
1.04	2260.97	2271.24	2281.54	2291.87	2302.23
1.05	2312.61	2323.03	2333.47	2343.95	2354.45
1.06	2364.98	2375.54	2386.13	2396.75	2407.40
1.07	2418.07	2428.78	2439.52	2450.28	2461.08
1.08	2471.90	2482.76	2493.64	2504.55	2515.49
1.09	2526.47	2537.47	2548.50	2559.56	2570.65
1.10	2581.77	2592.93	2604.11	2615.32	2626.56
1.11	2637.83	2649.13	2660.46	2671.82	2683.21
1.12	2694.63	2706.09	2717.57	2729.08	2740.62
1.13	2752.19	2763.80	2775.43	2787.09	2798.79
1.14	2810.51	2822.27	2834.05	2845.87	2857.72
1.15	2869.60	2881.50	2893.44	2905.41	2917.41
1.16	2929.45	2941.51	2953.60	2965.73	2977.88
1.17	2990.07	3002.29	3014.54	3026.81	3039.13
1.18	3051.47	3063.84	3076.25	3088.68	3101.15
1.19	3113.65	3126.18	3138.74	3151.33	3163.96
1.20	3176.61	3189.30	3202.02	3214.77	3227.55
1.21	3240.37	3253.21	3266.09	3279.00	3291.94

7.6 Selected list of references

Ackers, P. and A.J.M. Harrison 1963. Critical-depth flumes for flow measurement in open channels. Dept. of Sci. & Industrial Research. Hydraulic Res. Sta., Hydr. Research Paper No. 5. London.

Balloffet, A. 1951. Critical flow meters (Venturi flumes). Proc. ASCE. 81, Paper 743.

Bennett, R.S. 1972. Cutthroat flume discharge relations. Thesis presented to Colorado State University, Fort Collins, Col., in partial fulfillment of requirements for the degree of Master of Science.

Bos, M.G. 1985. Long-throated flumes and broad-crested weirs. Martinus Nijhoff Publishers, Dordrecht. p 141.

Bos, M.G. and Y. Reinink 1981. Head loss over long-throated flumes. Journal of the Irrigation and Drainage Division, ASCE, Vol. 107, IRI, pp.87-102.

Blau, E. 1960. Die modelmässige Untersuchung von Venturikanälen verschiedener Grösse und Form. Veröffentlichungen der Forschungsanstalt für Schiffahrt, Wasser- und Grundbau 8. Akademie Verlag, Berlin.

British Standards Institution 1965. Methods of measurement of liquid flow in open channels. BS3680. Part 4. Weirs and flumes. 4A: Thin plate weirs and venturi flumes.

Caplan, F. 1963. Nomograph for Free Flow Discharge through a Parshall Flume. Water & Sewage Works.

Clemmens, A.J., J.A. Replogle & M.G. Bos 1987. Flume: a computer model for estimating flow rates through long-throated measuring flumes, U.S. Dept. of Agriculture, ARS-57, p.64.

Eggleston, K.O. 1967. Effects of boundary geometry on critical and subcritical flow through measuring flumes. Utah Water Research Laboratory. College of Engineering, Utah State University. Logan, Utah.

Engel, F.V.A.E. 1934. The venturi flume. The Engineer. London. Vol. 158. Aug. 3, pp. 104-107. Aug. 10, pp. 131-133.

Fane, A.C. 1927. Report on flume experiments on Sirhind Canal. Punjab Irrigation Branch. Paper 110, Punjab Eng. Congress.

Gwinn, Wendell R. and Donald A. Parsons. 1976. Discharge equations for HS, H, and HL flumes. J. of the Hydraulics Div. ASCE, Vol. 102. No. HY1., pp. 73-88.

Harvey, W.B. 1912. Harvey's Irrigation Outlet. Punjab Irrigation Branch.

Holtan, H.N., N.E. Minchal and L.L. Harrold. 1962. Field manual for research in agricultural hydrology. Soils & Water Conservation Research Div., Agricultural Research Service, Agricultural Handbook No.224. Washington D.C.

Idelcik, I.E. 1969. Memento des pertes de charge. Collection du Centre de recherche et d'essais de Chatou. Eyrolles. Paris.

Inglis, C.C. 1929. Notes on standing wave flumes and flume meter falls. Public Works Dept. Technical Paper No. 15. Bombay.

Jameson, A.H. 1930. The development of the venturi flume. Water & Water Engineering. March 20, pp. 105-107.

Khafagi, A. 1942. Der Venturikanal. Theorie und Anwendung. Diss. Drückerei AG. Gebr. Leemann & Co., Zurich.

Parshall, R.L. 1945. Improving the Distribution of Water to Farmers by Use of the Parshall Measuring Flume. Soil Conservation Service. Bull. 488. U.S. Dept. of Agriculture and Colorado Agricultural Experiment Station. Colorado A and M College. Fort Collins, Colorado.

Parshall, R.L. 1950. Measuring Water in Irrigation Channels with Parshall Flumes and Small Weirs. Soil Conservation Circular No. 843. U.S. Dept. of Agriculture.

Parshall, R.L. 1953. Parshall Flumes of Large Size. Bull. 426-A (Reprint of Bull. 386). Colorado Agric. Experiment Sta., Colorado State University, Fort Collins, Colorado.

Peterka, A.J. 1965. Water Measurement Procedures. Irrigation Operators' Workshop. Hydraulics Laboratory Report No. Hyd.-552. Bureau of Reclamation, November 15 (unpublished).

Robinson, A.R. 1957. Parshall Measuring Flumes of Small Sizes. Technical Bulletin No. 61. Agricultural Experiment Station. Colorado State University. Fort Collins, Colorado.

Robinson, A.R., and A.R. Chamberlain. 1960. Trapezoïdal flumes for open channel flow measurement. Trans. Amer. Soc. Agri. Engnrs. Nr. 2, pp. 120-128.

Robinson, A.R. 1965. Simplified Flow Corrections for Parshall Flumes under Submerged Conditions. Civil Engineering ASCE.

Robinson, A.R. 1968. Trapezoïdal flumes for measuring flow in irrigation channels. Agr. Res. Service ARS 41-140. U.S. Dept. of Agriculture. 15 pp.

Schuster, J.C.(Ed.). 1970. Water measurement procedures. Irrigation operators' workshop. Report on REC-OCE-70 pp.49.

Skogerboe, G.V., M.L. Hyatt, R.K. Anderson, and K.O. Eggleston 1967. Design and calibration of submerged open channel flow measurement structures. Part 3: Cutthroat flumes. Report WG31-4. Utah Water Res. Laboratory. College of Engineering. Utah State University. Logan, Utah.

Skogerboe, G.V. and M.L. Hyatt 1967. Analysis of submergence in flow measuring flumes. J. of the Hydraulics Div., ASCE . Vol. 93, No. HY4, Proc. Paper 5348. pp. 183-200.

Skogerboe G.V., M.L. Hyatt, J.D. England and J.R. Johnson 1967. Design and Calibration of submerged open channel flow measurement structures. Part 2. Parshall flumes. Report WG 3/-3. Utah Water Research Laboratory. College of Eng. Utah St. University. Logan, Utah.

Skogerboe, G.V., and M.L. Hyatt 1967. Rectangular cutthroat flow measuring flumes. J. of the Irrigation and Drainage Div. ASCE, Vol. 93, No. IR4. pp. 1-33.

Skogerboe, G.V., R.S. Bennett, and W.R. Walker 1972. Generalized discharge relations for cutthroat flumes. J. of the Irrig. and Drainage Div. ASCE, Vol. 98. No. IR4. pp. 569-583.

U.S. Department of the Interior 1967. U.S. Bureau of Reclamation: Water measurement manual. Second Ed. Denver, Colorado, 327 pp.

Ven Te Chow 1959. Open channel hydraulics. McGraw-Hill Book Comp., New York. pp. 680.

Wells, E.A., and H.B. Gotaas 1956. Design of Venturi flumes in circular conduits. J. Sanit. Engng. Div., ASCE. Paper No. 2937. pp.749-771.