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Conveyance Systems – Performance Evaluation of Open Channels – Determination of Conveyance Loss by Inflow-Outflow Method

DEPARTMENT OF AGRICULTURE
PHILIPPINES

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Foreword

The formulation of this national standard was initiated by the Agricultural Machinery Testing and Evaluation Center (AMTEC) under the project entitled "Enhancement of Nutrient and Water Use Efficiency Through Standardization of Engineering Support Systems for Precision Farming" funded by the Philippine Council for Agriculture, Aquaculture and Forestry and Natural Resources Research and Development - Department of Science and Technology (PCAARRD - DOST).

As provided by the Republic Act 10601 also known as the Agricultural and Fisheries Mechanization Law (AFMech Law of 2013), the Bureau of Agriculture and Fisheries Standards (BAFS) is mandated to develop standard specifications and test procedures for agricultural and fisheries machinery and equipment. Consistent with its standards development process, BAFS has endorsed this standard for the approval of the DA Secretary through the Bureau of Agricultural and Fisheries Engineering (BAFE) and to the Bureau of Philippine Standards (BPS) for appropriate numbering and inclusion to the Philippine National Standard (PNS) repository.

This standard has been technically prepared in accordance with BPS Directives Part 3:2003 – Rules for the Structure and Drafting of International Standards.

The word "shall" is used to indicate mandatory requirements to conform to the standard.

The word "should" is used to indicate that among several possibilities one is recommended as particularly suitable without mentioning or excluding others.

Conveyance Systems – Performance Evaluation of Open Channels – Determination of Conveyance Loss by Inflow-Outflow Method

1 Scope

This standard specifies the method of determination of seepage and percolation in open channels by inflow-outflow.

2 References

The following normative documents contain provisions, which, through reference in this text, constitute provisions of this National Standard:

ISO 8368:1999 Flow Measurements in Open Channels Using Structures – Guidelines for Selection of Structure

3 Definitions

For the purpose of this standard, the following terms shall apply:

3.1
conveyance loss
loss of water from a channel during transport due to seepage and percolation

3.2
water balance
accounting of water inflows, such as irrigation and rainfall, and outflows, such as evaporation, seepage and percolation

4 Principle of Inflow-Outflow Method

Inflow-outflow is one of the methods used to measure the conveyance losses in open channels where a section of the selected channel shall be analyzed using the water balance approach as shown in Figure 1.

The rates of flow of water in the selected channel shall be measured using one of the flow measuring devices/structures and an appropriate flow measurement technique. The difference in the inflow and outflow rates shall be identified as the conveyance losses.

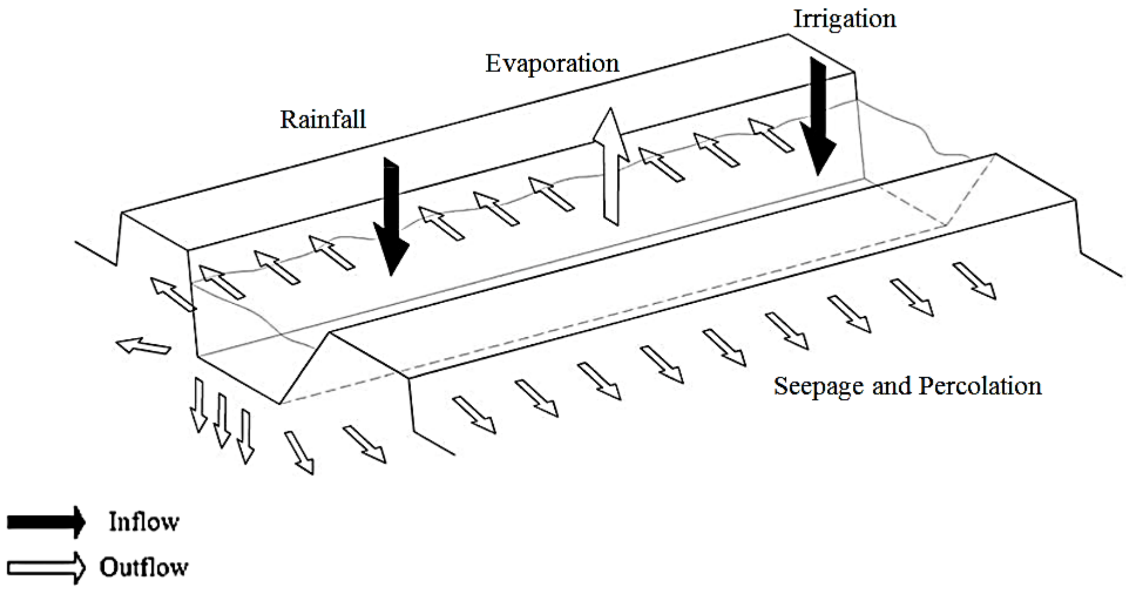


Figure 1. Water balance in an open channel

5 Site Selection

5.1 The channel section to be considered shall be accessible for measurement.

5.2 The channel section should be at least 50 m with uniform cross section and grade between the inflow and outflow measuring points.

5.3 Channels with adjoining depressions such as creeks or rivers shall be avoided.

5.4 Bends, steep slopes and segments containing turnouts, valves, gates and other structures shall be avoided.

6 Flow Measuring Structures and Devices

The appropriate flow measuring structures and devices should be selected based on ISO 8368:1999 – Flow Measurements in Open Channels Using Structures – Guidelines for Selection of Structure. Various types of flow measuring structures and devices are presented in Annex A.

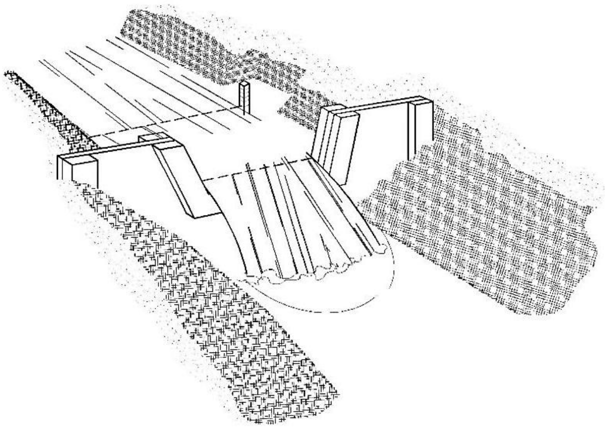
6.1.1 Weir - an overflow structure built perpendicular to an open channel axis to measure the rate of flow of water

6.1.2 Flume - in-line structure with a geometrically specified constriction built in an open channel such that the center line coincides with the center line of the channel in which the flow is to be measured

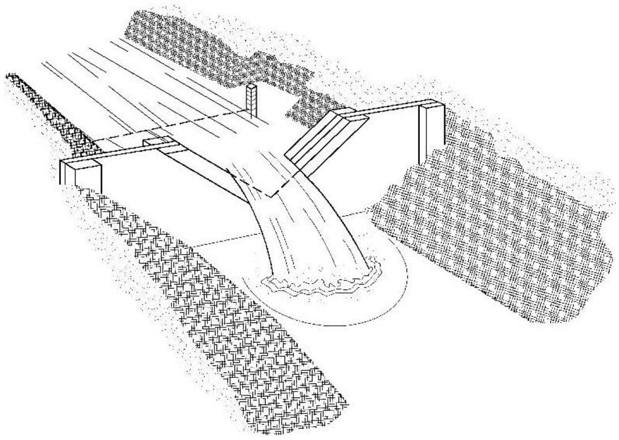
6.1.3 Orifice - measuring device with a well-defined, sharp-edged opening in a wall through which flow occurs such that the upstream water level is always well above the top of this opening

6.1.4 Current Meter - velocity measuring device used in a sample point through which partial discharge can be obtained

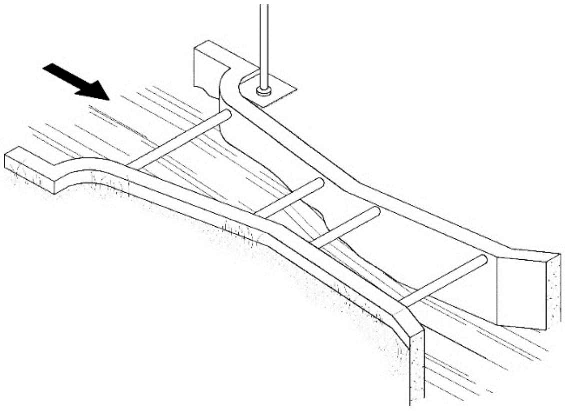
7 Flow Measuring Structure Installation



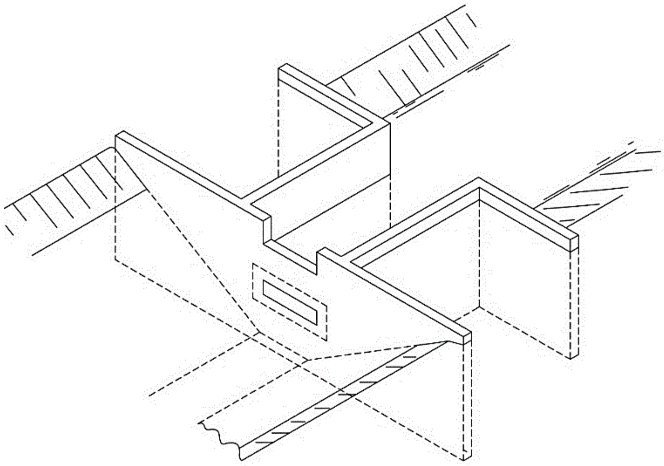
(a) Trapezoidal-notch weir



(b) Triangular-notch weir



(c) Parshall flume



(d) Submerged orifice

Figure 2. Installation of flow measuring structures
SOURCE: FAO, Irrigation and Drainage Paper 26/2: Small Hydraulic Structures, Vol. 2, 1975

7.2.1 The flow measuring structures shall be installed at the beginning and end of the channel section. The length of this section shall be recorded.

7.2.2 The outflow measuring structure shall be located at a point where backwater does not affect the flow to the extent that false intake rates are measured.

7.2.3 It is recommended that the type and size of the flow measuring structures be of the same type and size to minimize errors.

7.2.4 The beginning and end of the channel section where measurement will be taken shall be marked with stakes. The length of this section shall be recorded.

7.2.5 Current meters can be mounted on rods for stationary measurement (Figure 3) or suspended by cables (Figure 4) to allow free movement vertically and horizontally.

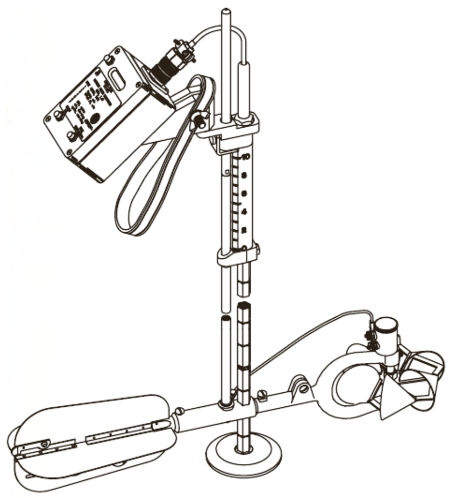


Figure 3. Current meter mounted on a rod
SOURCE: Turnipseed and Sauer, Discharge Measurements at Gaging Stations: US Geological Techniques and Methods Book 3, Chapter A8. 2010

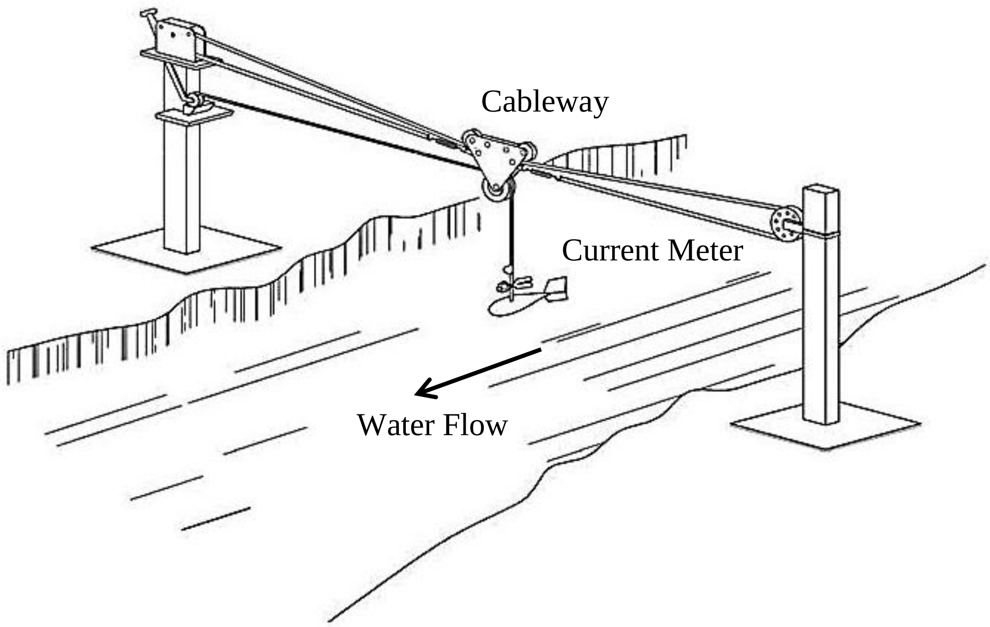


Figure 4. Current meter suspended by a cable
SOURCE: Turnipseed and Sauer, Discharge Measurements at Gaging Stations: US Geological Techniques and Methods Book 3, Chapter A8. 2010

7.3.3 Current meters mounted on rods are more suitable in gauging small sections and ditches while suspended cable are for gauging large sections.

7.3.4 When mounting a current meter in a rod, a vaned tail piece shall be used to keep the meter facing into the current. The rod shall be marked to easy determination of depth.

8 Flow Measurement

8.1 The length and width of selected channel section shall be determined and recorded. All measurements and time of readings shall be recorded.

8.2 Flow measurement and discharge evaluation using weirs, flumes and orifices are detailed in Annex B.

8.3 Flow measurements and discharge evaluation using current meters are detailed in Annex C.

9 Computation

Seepage and percolation losses shall be determined using the formula:

$$(S \,\&\, P)_{losses} = {(Q_i - Q_0)}/{L}$$

where:

$(S\&P)_{losses}$	is the seepage and percolation loss rate, $m^3/s\text{-}m$
Q_i	is the inflow rate, m^3/s
Q_o	is the outflow rate, m^3/s
L	is the length of channel reach, m

10 Bibliography

Food and Agriculture Organization. 1975. Irrigation and Drainage Paper 26/2: Small Hydraulic Structures, Vol. 2

Food and Agriculture Organization. 1993. Irrigation Water Management Training Manual No. 8 Structures for Water Control and Distribution

International Institute for Land Reclamation and Improvement. 1989. Discharge Measurement Structures, 3rd Ed.

Sarki, A., et al. 2008. Comparison of Different Methods for Computing Seepage Losses in an Earthen Watercourse. Agricultura Tropica et Subtropica, Vol. 41 (4).

Sonnichsen, R.P. 1993. Seepage Rates from Irrigation Canals. Water Resources Program: Open-File Technical Report.

United States Department of Agriculture. 1993. National Engineering Handbook

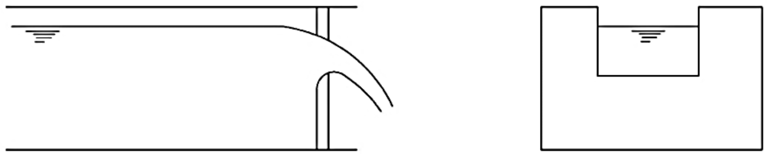
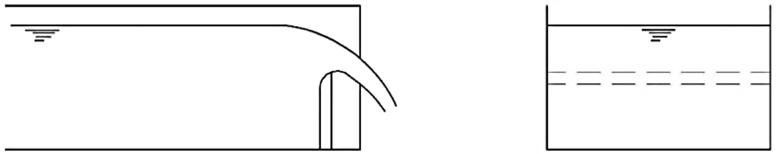
United States Department of the Interior Bureau of Reclamation. 2001. Water Measurement Manual

Turnipseed, D.P. and V.B. Sauer. 2010. Discharge Measurements at Gaging Stations: US Geological Techniques and Methods Book 3, Chapter A8.

ANNEX A
(informative)

Various Types of Commonly Used Flow Measurement Structures

Table 1. Types of Weir, Description and Discharge Evaluation

Classification	Description	Discharge Evaluation
SHARP-CRESTED/ THIN-PLATE - weir constructed with a crest of vertical thin plate		
Contracted Rectangular		$$Q = 1.84\,(L - 0.2H)H^{3/2}$$ Q = discharge, m^3/s L = length of crest, m H = head (difference between the elevation of the weir crest and the elevation of the water surface in the weir pool), m
Supressed Rectangular		$$Q = \frac{2}{3} C_d L H \sqrt{2gH}$$ $$C_d = 0.615\,\left(1 + \frac{1}{H + 1.6}\right)\left[1 + 0.5\left(\frac{H}{H + D}\right)^2\right]$$ Q = discharge, m^3/s C_d = discharge coefficient L = length of crest, m g = gravitational acceleration, m^2/s H = head, m (mm for computing μ) D = distance from the crest to the bottom of the approach channel, mm

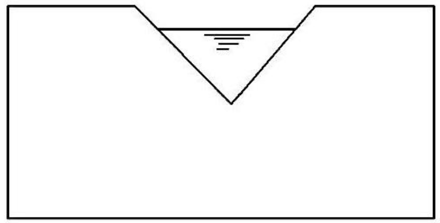
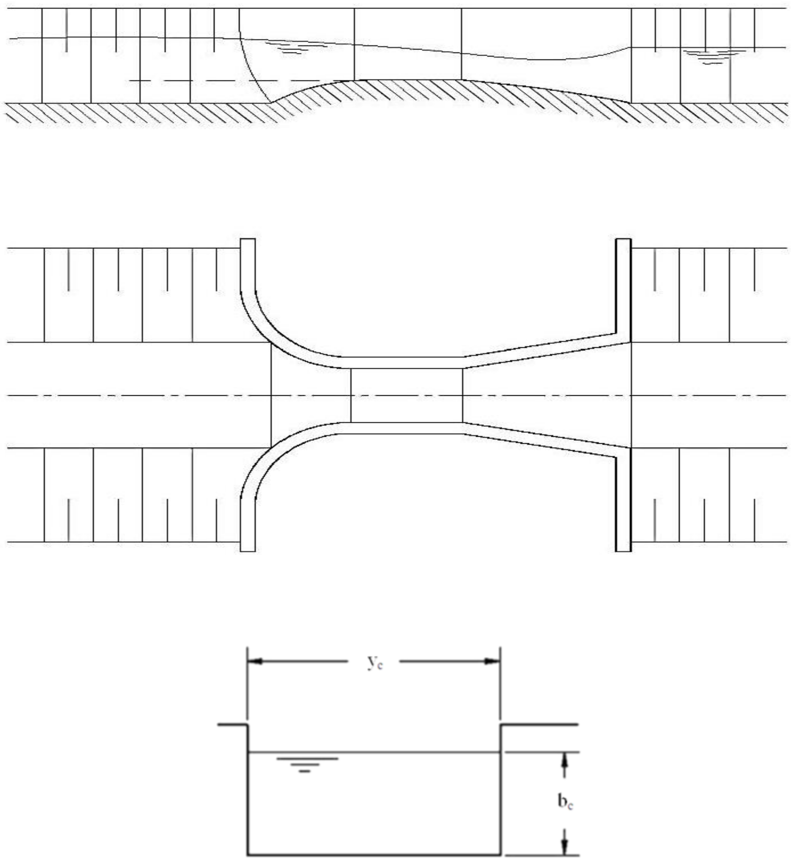
Cipoletti Contracted		$$Q = 1.86\ LH^{3/2}$$ Q = discharge, m^3/s L = length of crest, m H = head (difference between the elevation of the weir crest and the elevation of the water surface in the weir pool), m
V-notch		$$Q = \frac{8}{15}\sqrt{2gC_d}H^{5/2}$$ Q = discharge, m^3/s g = gravitational acceleration, m^2/s C_d = discharge coefficient H = head (difference between the elevation of the weir crest and the elevation of the water surface in the weir pool), m

Table 2. Types of Flumes, Description and Discharge Evaluation

Classification	Description	Discharge Evaluation
Long-throated (Rectangular control section)		$$Q = C_d C_v \frac{2}{3}\left(\frac{2}{3} g\right)^{0.50} b_c {H_1}^{1.50}$$ Q = discharge, m^3/s g = gravitational acceleration, m^2/s $H_1 = (3/2)y_c$ = total upstream energy head over the weir crest, m C_d = coefficient of discharge C_v = coefficient due to approach velocity

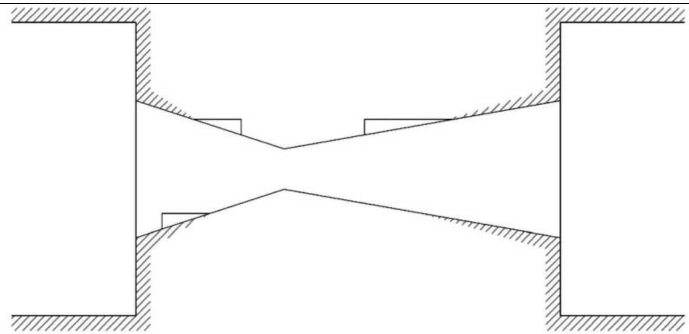
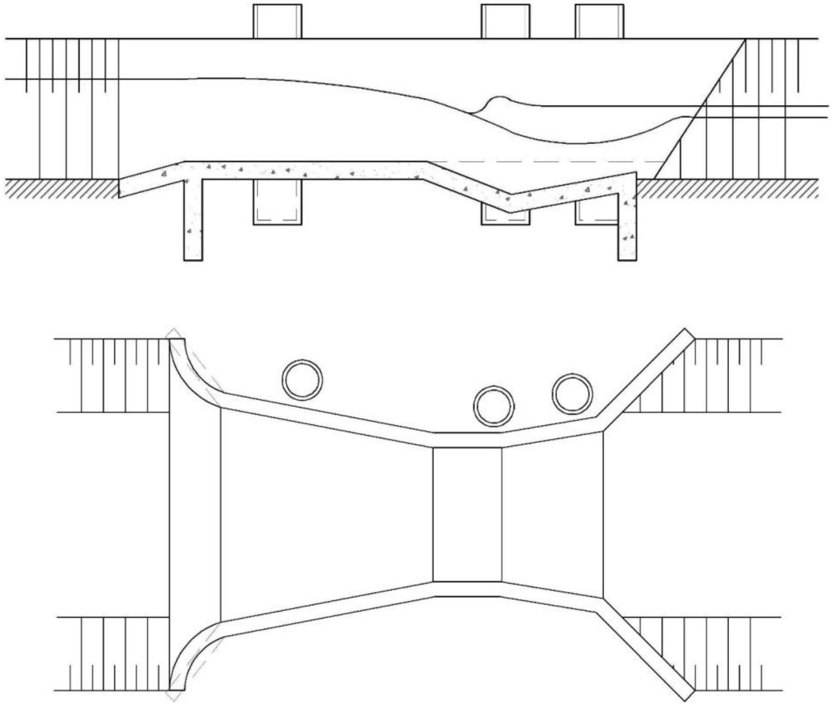
Cut-throat		$Q = CH_a^{\ n}$ $C = KW^{1.025}$ Q = discharge, m^3/s C = free flow coefficient H_a = upstream gauge reading (2L/9 from throat) K = flume length coefficient W = throat width, m
Parshall		$Q = kH_a^{\ u}$ Q = discharge, m^3/s k = dimensional factor which is a function of throat width H_a = upstream gauge reading u = 1.522 to 1.60

Table 3. Types of Orifices, Description and Discharge Equation

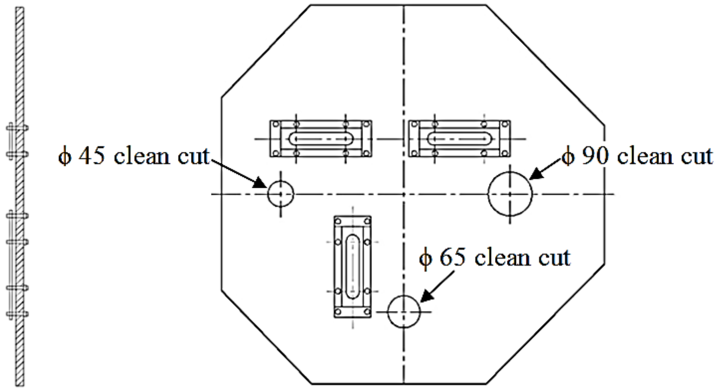
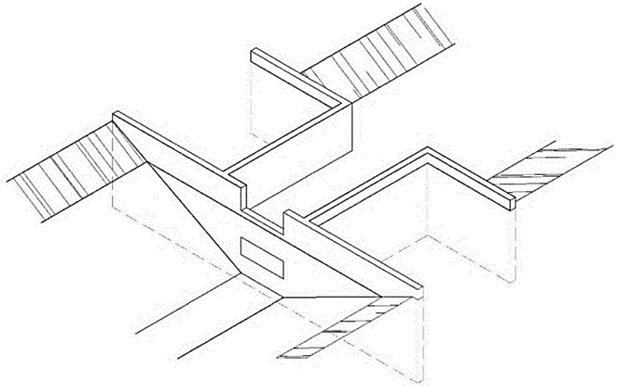
<table>
<tr><th>Classification</th><th>Description</th><th>Discharge Evaluation</th></tr>
<tr><td>Circular Sharp-Edged</td><td>
</td><td rowspan="2">$$Q = C_d C_v A\sqrt{2g(h_1 - h_2)}$$
$$Q = C_d C_v A\sqrt{2g\Delta h}$$
Q = discharge, m^3/s
C_d = discharge coefficient
C_v = velocity coefficient
A = area of the orifice, m^2
h_1-h_2 = head differential across the orifice
Δh = upstream head above the center of the orifice</td></tr>
<tr><td>Rectangular Sharp-Edged</td><td></td></tr>
</table>

Table 4. Types of Current Meters, Description and Discharge Evaluation

Classification	Description	Discharge Evaluation
Anemometer and Propeller Type	- uses anemometer cup and propellers for sensing velocity - rated by dragging through tanks of still water at known speeds - does not sense direction of velocity	Velocity-Area Method Midsection Method Moving Boat Method
Electromagnetic	- produces voltage proportional to the velocity - provides direct analog reading of velocity - provides directional measurements	
Doppler Type	- measures velocity by the change of source light or sound frequency from the frequency of reflections from moving particles - uses laser light (laser Doppler velocimeters) or sound (acoustic Doppler velocimeter)	
Optical Strobe Velocity Meter	- measures velocity using the strobe effect with mirrors mounted around a polygon drum reflecting light coming from the water surface. The rate of rotation of the mirror drum is varied until images become steady. With the rate of rotation and the distance from the mirrors to the water surface known, surface velocity can be determined	

ANNEX B
(informative)

Discharge Measurement Using Weirs, Flumes and Orifices

B.1 Discharge Measurement Using Weirs

The following measurement procedure described in this annex can be used for the following standard types of sharp-crested weirs: rectangular, Cipolleti and V-notch.

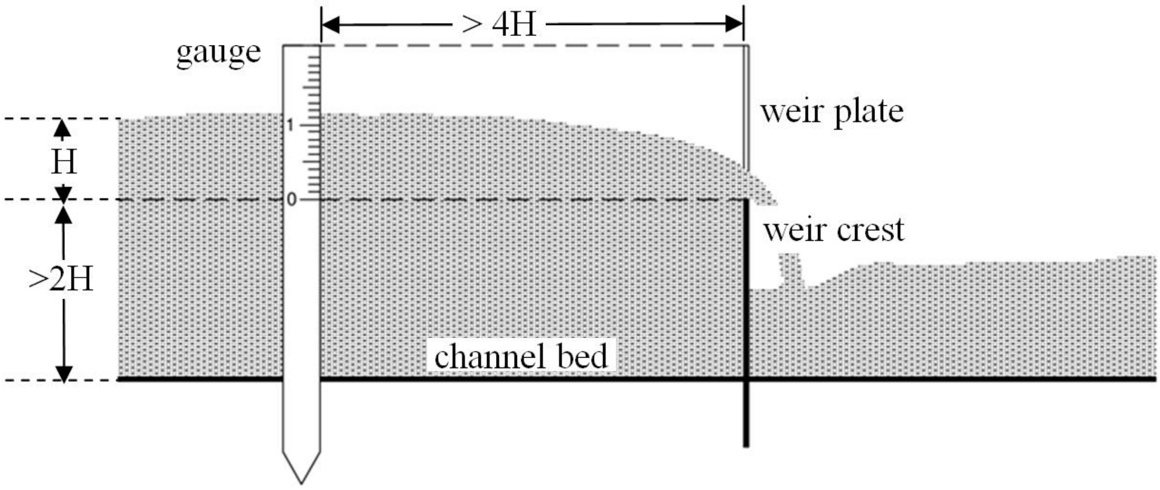


Figure B.1. Dimensions for Discharge Measurement in Sharp-Crested Weirs
SOURCE: FAO, Irrigation Water Management Training Manual No. 8 Structures for Water Control and Distribution, 1993

B.1.1 Establish the recommended dimensions shown in Figure B.1.

B.1.2 Estimate the maximum discharge to be measured which will determine the corresponding maximum head of water over the weir crest. Tables B.1 to B.3 show the corresponding head, H based on the discharge.

B.1.3 From the value of H, the level of the crest relative to the channel bed shall be at least twice higher than H.

B.1.4 The distance between the gauge and weir shall be at least four times than H.

B.1.5 The gauge’s zero mark shall be at the same elevation with the weir crest.

B.1.6 Read the water level on the gauge and record as H.

B.1.7 Compute for the discharge Q based on the type of weir using the discharge evaluation equations shown in Annex A.

Table B.1. Discharge-Head Relationship for a Rectangular Weir

Head (H), m	Discharge (Q), L/s Length of Crest (L), m					
	0.25	0.50	0.75	1.00	1.25	1.50
0.01	0	1	1	2	2	3
0.015	1	2	3	3	4	5
0.02	1	3	4	5	6	8
0.03	2	5	7	10	12	14
0.04	4	7	11	15	18	22
0.05	5	10	15	20	26	31
0.06	6	13	20	27	33	40
0.08	10	20	31	41	51	62
0.10	13	28	42	57	72	86
0.12	17	36	56	75	94	113
0.14		45	70	94	118	142
0.16		55	85	114	143	173
0.18		65	100	135	171	206
0.20		76	117	158	199	
0.25		104	161	219		
0.30			209			

SOURCE: FAO, Irrigation Water Management Training Manual No. 8 Structures for Water Control and Distribution, 1993

Table B.2. Discharge-Head Relationship for a Cipoletti Weir

Head (H), m	Discharge (Q), L/s Length of Crest (L), m					
	0.25	0.50	0.75	1.00	1.25	1.50
0.01	0	1	1	2	2	3
0.015	1	2	3	3	4	5
0.02	1	3	4	5	7	8
0.03	2	5	7	10	12	14
0.04	4	7	11	15	19	22
0.05	5	10	16	21	26	31
0.06	7	14	21	27	34	41
0.08	11	21	32	42	53	63
0.10	15	29	44	59	74	88
0.12	19	39	58	77	97	116
0.14		49	73	97	122	146
0.16		60	89	119	149	179
0.18		71	107	142	178	213
0.20		83	125	166	208	
0.25		116	174	233		
0.30			229			

SOURCE: FAO, Irrigation Water Management Training Manual No. 8 Structures for Water Control and Distribution, 1993

Table B.3. Discharge-Head Relationship for a 90^0 V-notch Weir

H, m	Q, L/s	H, m	Q, L/s	H, m	Q, L/s
0.01	0.0	0.08	2.5	0.15	12
0.02	0.1	0.09	3.3	0.16	14
0.03	0.2	0.10	4.3	0.17	16
0.04	0.4	0.11	5.5	0.18	19
0.05	0.8	0.12	6.8	0.19	22
0.06	1.2	0.13	8.3	0.20	24
0.07	1.8	0.14	10		

SOURCE: FAO, Irrigation Water Management Training Manual No. 8 Structures for Water Control and Distribution, 1993

B.2 Discharge Measurement Using Flumes

B.2.1 Determine the degree of submergence, which is the ratio of the downstream head, H_b to the upstream head, H_a.

$$\text{Degree of Submergence (\%)} = \frac{H_b}{H_a} \times 100$$

B.2.2 If the computed degree of submergence is equal to or below the free flow limit indicated in Table B.4, free flow condition exists. Read the free flow discharge ($Q_{free\ flow}$) from Table B.5 based on H_a and throat width, W.

Table B.4. Free flow limits for various sizes of Parshall Flumes

Width of throat (W)	Free flow limit of H_b/H_a
15.2 cm to 23 cm (6 in to 9 in)	60%
30.5 cm to 244 cm (1 ft to 8 ft)	70%

SOURCE: FAO, Irrigation and Drainage Paper 26/2: Small Hydraulic Structures, Vol. 2, 1975

B.2.3 If the computed degree of submergence is greater than the free flow limit indicated in Table B.4,

B.2.3.1 If W = 15.2 cm (6 in), use Figure B.2 directly

B.2.3.2 If W = 23 cm (9 in), use Figure B.3 directly

B.2.3.3 If W = 30.5 cm (1 ft), use the correction diagram shown in Figure B.4 for $Q_{correction}$

B.2.3.4 If W > 30.5 cm (1ft), use Figure B.4 and the multiplying factor shown in Table B.6 based on the size of flume for $Q_{correction}$

B.2.4 Apply the negative correction to the free flow discharge to determine the discharge from the submerged flow ($Q_{submerged\ flow}$).

$$Q_{submerged\ flow} = Q_{free\ flow} - Q_{correction}$$

Table B.5. Free Flow Discharge Values for Parshall Flumes

Head (H_a) cm	Discharge (Q), m³/s for Throat Widths (W) of-								
	15.24 cm	22.86 cm	30.48 cm	45.72 cm	60.96 cm	91.44 cm	121.92 cm	152.40 cm	182.88 cm
	0.50 ft	0.75 ft	1.00 ft	1.50 ft	2.00 ft	3.00 ft	4.00 ft	5.00 ft	6.00 ft
3.00	0.0015	0.0025	0.0033	0.0048					
3.50	0.0019	0.0032	0.0042	0.0060					
4.00	0.0024	0.0039	0.0052	0.0074					
4.50	0.0028	0.0047	0.0062	0.0089	0.0116	0.0169			
5.00	0.0034	0.0055	0.0072	0.0105	0.0137	0.0200			
5.50	0.0039	0.0063	0.0084	0.0122	0.0159	0.0232			
6.00	0.0045	0.0072	0.0096	0.0139	0.0182	0.0266	0.0348	0.0429	
6.50	0.0051	0.0082	0.0108	0.0157	0.0206	0.0302	0.0395	0.0487	
7.00	0.0057	0.0092	0.0121	0.0176	0.0231	0.0339	0.0444	0.0548	
7.50	0.0064	0.0102	0.0134	0.0196	0.0257	0.0378	0.0495	0.0611	0.0726
8.00	0.0071	0.0112	0.0148	0.0217	0.0285	0.0418	0.0549	0.0677	0.0805
8.50	0.0078	0.0123	0.0162	0.0238	0.0313	0.0459	0.0604	0.0746	0.0887
9.00	0.0085	0.0135	0.0177	0.0260	0.0342	0.0503	0.0661	0.0817	0.0971
9.50	0.0093	0.0146	0.0192	0.0282	0.0372	0.0547	0.0720	0.0890	0.1059
10.00	0.0100	0.0158	0.0208	0.0306	0.0402	0.0593	0.0780	0.0965	0.1149
10.50	0.0108	0.0170	0.0224	0.0329	0.0434	0.0640	0.0843	0.1043	0.1242
11.00	0.0117	0.0183	0.0240	0.0354	0.0466	0.0688	0.0907	0.1123	0.1338
11.50	0.0125	0.0196	0.0254	0.0379	0.0500	0.0738	0.0973	0.1205	0.1436
12.00	0.0134	0.0209	0.0274	0.0405	0.0534	0.0789	0.1040	0.1290	0.1537
12.50	0.0143	0.0222	0.0292	0.0431	0.0569	0.0841	0.1110	0.1376	0.1640
13.00	0.0152	0.0236	0.031	0.0458	0.0604	0.0894	0.1181	0.1464	0.1746
13.50	0.0161	0.0250	0.0328	0.0485	0.0641	0.0949	0.1253	0.1555	0.1854
14.00	0.0171	0.0264	0.0347	0.0513	0.0678	0.1004	0.1327	0.1647	0.1965
14.50	0.0180	0.0279	0.0360	0.0541	0.0716	0.1061	0.1403	0.1741	0.2078
15.00	0.0190	0.0294	0.0385	0.0570	0.0755	0.1119	0.1480	0.1838	0.2194
15.50	0.0200	0.0309	0.4050	0.0600	0.0794	0.1178	0.1558	0.1936	0.2351
16.00	0.0211	0.0324	0.4250	0.0630	0.0834	0.1238	0.1638	0.2036	0.2431
16.50	0.0221	0.0340	0.0445	0.0661	0.0875	0.1299	0.1720	0.2138	0.2554
17.00	0.0232	0.0356	0.0466	0.0692	0.0916	0.1361	0.1803	0.2242	0.2678
17.50	0.0243	0.0372	0.0487	0.0723	0.0958	0.1425	0.1887	0.2347	0.2805
18.00	0.0254	0.0388	0.0508	0.0755	0.1001	0.1489	0.1973	0.2455	0.2934
18.50	0.0265	0.0405	0.0530	0.0788	0.1045	0.1554	0.2060	0.2564	0.3065
19.00	0.0276	0.0422	0.0552	0.0821	0.1089	0.1620	0.2149	0.2675	0.3198
19.50	0.0288	0.0439	0.0574	0.0854	0.1133	0.1688	0.2239	0.2787	0.3333
20.00	0.0300	0.0456	0.0597	0.0888	0.1179	0.1756	0.2330	0.2901	0.3471
20.50	0.0312	0.0474	0.0619	0.0923	0.1225	0.1825	0.2423	0.3017	0.3610
21.00	0.0324	0.0492	0.0643	0.0957	0.1271	0.1896	0.2516	0.3135	0.3752
21.50	0.0336	0.0509	0.0666	0.0993	0.1319	0.1967	0.2612	0.3254	0.3895

Table B.5 (continued)

22.00	0.0349	0.0528	0.0690	0.1029	0.1366	0.2039	0.2708	0.3375	0.4040
22.50	0.0361	0.0546	0.0714	0.1065	0.1415	0.2112	0.2806	0.3498	0.4188
23.00	0.0374	0.0565	0.0738	0.1101	0.1464	0.2186	0.2905	0.3622	0.4337
23.50	0.0387	0.0584	0.0762	0.1138	0.1513	0.2261	0.3005	0.3748	0.4489
24.00	0.0400	0.0603	0.0787	0.1176	0.1564	0.2337	0.3107	0.3875	0.4642
24.50	0.0413	0.0622	0.0812	0.1214	0.1614	0.2413	0.3210	0.4004	0.4797
25.00	0.0427	0.0642	0.0838	0.1252	0.1666	0.2491	0.3314	0.4134	0.4954
25.50	0.0440	0.0661	0.0863	0.1291	0.1718	0.2569	0.3419	0.4267	0.5113
26.00	0.0454	0.0681	0.0889	0.1330	0.1770	0.2649	0.3525	0.4400	0.5274
26.50	0.0468	0.0701	0.0915	0.1370	0.1823	0.2729	0.3633	0.4535	0.5436
27.00	0.0460	0.0722	0.0942	0.1410	0.1877	0.2810	0.3741	0.4672	0.5601
27.50	0.0482	0.0742	0.0968	0.1450	0.1931	0.2892	0.3831	0.4810	0.5767
28.00	0.0496	0.0763	0.0995	0.1491	0.1986	0.2975	0.3962	0.4949	0.5935
28.50	0.0510	0.0784	0.1023	0.1532	0.2041	0.3058	0.4075	0.5090	0.6105
29.00	0.0525	0.0805	0.1050	0.1573	0.2097	0.3143	0.4188	0.5233	0.6277
29.50	0.0539	0.0826	0.1078	0.1615	0.2153	0.3228	0.4303	0.5377	0.6451
30.00	0.0554	0.0848	0.1106	0.1658	0.2210	0.3314	0.4418	0.5522	0.6626
30.50	0.0569	0.087	0.1134	0.1700	0.2267	0.3401	0.4535	0.5669	0.6803
31.00	0.0583	0.0892	0.1162	0.1743	0.2325	0.3489	0.4653	0.5817	0.6980
31.50	0.0599	0.0914	0.1191	0.1782	0.2383	0.3577	0.4772	0.5767	0.7162
32.00	0.0614	0.0936	0.1219	0.1831	0.2442	0.3667	0.4892	0.6118	0.7344
32.50	0.0629	0.0959	0.1248	0.1876	0.2502	0.3757	0.5013	0.6270	0.7528
33.00	0.0645	0.0981	0.1278	0.1919	0.2562	0.3848	0.5135	0.6424	0.7713
33.50	0.0661	0.1004	0.1307	0.1964	0.2622	0.3939	0.5259	0.6579	0.7901
34.00	0.0677	0.1027	0.1337	0.2010	0.2683	0.4052	0.5385	0.6736	0.8089
34.50	0.0693	0.105	0.1367	0.2055	0.2744	0.4125	0.5508	0.6893	0.8280
35.00	0.0709	0.1074	0.1398	0.2101	0.2806	0.4219	0.5635	0.7053	0.8472
35.50	0.0725	0.1097	0.1428	0.2145	0.2869	0.4314	0.5762	0.7213	0.8666
36.00	0.0742	0.1121	0.1459	0.2194	0.2932	0.4410	0.5891	0.7325	0.8861
36.50	0.0758	0.1145	0.149	0.2241	0.2995	0.4506	0.6021	0.7538	0.9051
37.00	0.0775	0.1169	0.1521	0.2289	0.3059	0.4603	0.6151	0.7703	0.9257
37.50	0.0792	0.1193	0.1552	0.2337	0.3123	0.4703	0.6283	0.7869	0.9457
38.00	0.0809	0.1218	0.1584	0.2385	0.3188	0.4799	0.6416	0.8036	0.9659
38.50	0.0826	0.1242	0.1616	0.2433	0.3253	0.4898	0.6549	0.8204	0.9863
39.00	0.0843	0.1267	0.1648	0.2482	0.3319	0.4998	0.6684	0.8374	1.007
39.50	0.0861	0.1292	0.168	0.2531	0.3385	0.5099	0.6820	0.8545	1.027
40.00	0.0878	0.1317	0.1713	0.2580	0.3452	0.5201	0.6957	0.8718	1.048
40.50	0.0896	0.1342	0.1745	0.2630	0.3519	0.5303	0.7094	0.8891	1.069
41.00	0.0914	0.1368	0.1778	0.2680	0.3586	0.5406	0.7233	0.9066	1.090
41.50	0.0932	0.1394	0.1811	0.2731	0.3654	0.5509	0.7373	0.9242	1.112
42.00	0.0950	0.1419	0.1845	0.2782	0.3783	0.5614	0.7513	0.9419	1.133
42.50	0.0968	0.1445	0.1878	0.2833	0.3792	0.5719	0.7655	0.9598	1.155

Table B.5 (continued)

43.00	0.0986	0.1471	0.1912	0.2884	0.3861	0.5824	0.7798	0.9778	1.176
43.50	0.1004	0.1498	0.1946	0.2936	0.3931	0.5931	0.7941	0.9959	1.198
44.00	0.1023	0.1524	0.198	0.2988	0.4001	0.6038	0.8086	1.014	1.220
44.50	0.1042	0.1551	0.2014	0.3040	0.4072	0.6140	0.8231	1.033	1.243
45.00	0.1060	0.1577	0.2049	0.3093	0.4143	0.6254	0.8377	1.051	1.265
45.50	0.1079	0.1604	0.2084	0.3146	0.4214	0.6363	0.8525	1.070	1.287
46.00		0.1631	0.2119	0.3199	0.4286	0.6473	0.8673	1.088	1.310
46.50		0.1659	0.2154	0.3253	0.4359	0.6384	0.8822	1.107	1.333
47.00		0.1686	0.2189	0.3307	0.4432	0.6695	0.8972	1.126	1.356
47.50		0.1713	0.2225	0.3361	0.4505	0.6807	0.9124	1.145	1.379
48.00		0.1741	0.2260	0.3416	0.4579	0.6919	0.9276	1.164	1.402
48.50		0.1769	0.2296	0.3471	0.4653	0.7033	0.9428	1.184	1.423
49.00		0.1797	0.2333	0.3526	0.4727	0.7147	0.9582	1.203	1.449
49.50		0.1825	0.2369	0.3581	0.4802	0.7261	0.9737	1.223	1.473
50.00		0.1853	0.2405	0.3637	0.4878	0.7376	0.9893	1.242	1.496
50.50		0.1882	0.2442	0.3693	0.4953	0.7492	1.005	1.262	1.520
51.00		0.1910	0.2479	0.3750	0.5030	0.7609	1.021	1.282	1.544
51.50		0.1939	0.2516	0.3806	0.5106	0.7726	1.037	1.302	1.569
52.00		0.1968	0.2553	0.3863	0.5183	0.7844	1.052	1.322	1.593
52.50		0.1997	0.25911	0.3921	0.5261	0.7962	1.068	1.342	1.617
53.00		0.2026	0.2629	0.3978	0.5339	0.8081	1.085	1.363	1.642
53.50		0.2056	0.2666	0.4036	0.5417	0.8201	1.101	1.383	1.667
54.00		0.2085	0.2704	0.4094	0.5495	0.8321	1.117	1.404	1.692
54.50		0.2115	0.2743	0.4153	0.5575	0.8442	1.133	1.424	1.717
55.00		0.2144	0.2781	0.4212	0.5654	0.8564	1.150	1.445	1.742
55.50		0.2174	0.2820	0.4271	0.5734	0.8686	1.166	1.466	1.767
56.00		0.2204	0.2858	0.4330	0.5814	0.8809	1.183	1.487	1.793
56.50		0.2235	0.2897	0.4390	0.5895	0.8932	1.200	1.508	1.818
57.00		0.2265	0.2936	0.4449	0.5976	0.9057	1.217	1.529	1.844
57.50		0.2295	0.2976	0.4510	0.6057	0.9181	1.233	1.551	1.870
58.00		0.2326	0.3015	0.4570	0.6139	0.9307	1.250	1.572	1.896
58.50		0.2357	0.3055	0.4631	0.6221	0.9433	1.267	1.594	1.922
59.00		0.2388	0.3095	0.4692	0.6304	0.9559	1.285	1.615	1.948
59.50		0.2419	0.3135	0.4753	0.6387	0.9686	1.302	1.637	1.975
60.00		0.245	0.3175	0.4815	0.6470	0.9814	1.319	1.659	2.001
60.50		0.2481	0.3215	0.4877	0.6554	0.9943	1.336	1.681	2.028
61.00		0.2513	0.3256	0.4939	0.6638	1.007	1.354	1.703	2.055
61.50			0.3296	0.5001	0.6723	1.020	1.371	1.725	2.082
62.00			0.3337	0.5064	0.6808	1.033	1.389	1.748	2.109
62.50			0.3378	0.5127	0.6893	1.046	1.407	1.770	2.136
63.00			0.3420	0.5190	0.6978	1.059	1.425	1.793	2.163
63.50			0.3461	0.5254	0.7064	1.073	1.443	1.815	2.191

Table B.5 (continued)

64.00			0.3503	0.5317	0.7151	1.086	1.460	1.838	2.218
64.50			0.3544	0.5381	0.7238	1.099	1.479	1.861	2.246
65.00			0.3586	0.5446	0.7325	1.113	1.497	1.884	2.274
65.50			0.3628	0.5510	0.7412	1.126	1.515	1.907	2.302
66.00			0.3671	0.5575	0.7500	1.139	1.533	1.930	2.330
66.50			0.3713	0.5640	0.7588	1.153	1.552	1.953	2.538
67.00			0.3755	0.5706	0.7677	1.167	1.570	1.977	2.386
67.50			0.3798	0.5771	0.7766	1.180	1.588	2.000	2.415
68.00			0.3841	0.5837	0.7855	1.194	1.607	2.024	2.443
68.50			0.3884	0.5903	0.7945	1.208	1.626	2.047	2.472
69.00			0.3927	0.5970	0.8035	1.222	1.645	2.071	2.501
69.50			0.971	0.6036	0.8125	1.236	1.663	2.095	2.530
70.00			0.4014	0.6103	0.8216	1.249	1.682	2.119	2.559
70.50			0.4058	0.6170	0.8307	1.263	1.701	2.143	2.588
71.00			0.4102	0.6238	0.8399	1.278	1.720	2.167	2.617
71.50			0.4146	0.6306	0.8491	1.292	1.739	2.192	2.647
72.00			0.4190	0.6373	0.8583	1.306	1.759	2.216	2.676
72.50			0.4235	0.6442	0.8675	1.320	1.778	2.240	2.706
73.00			0.4279	0.6510	0.8768	1.334	1.797	2.265	2.736
73.50			0.4324	0.6579	0.8862	1.349	1.817	2.290	2.766
74.00			0.4369	0.6648	0.8955	1.363	1.836	2.314	2.796
74.50			0.4414	0.6717	0.9049	1.378	1.856	2.339	2.826
75.00			0.4459	0.6787	0.9143	1.392	1.876	2.364	2.856

SOURCE: FAO, Irrigation and Drainage Paper 26/2: Small Hydraulic Structures, Vol. 2, 1975

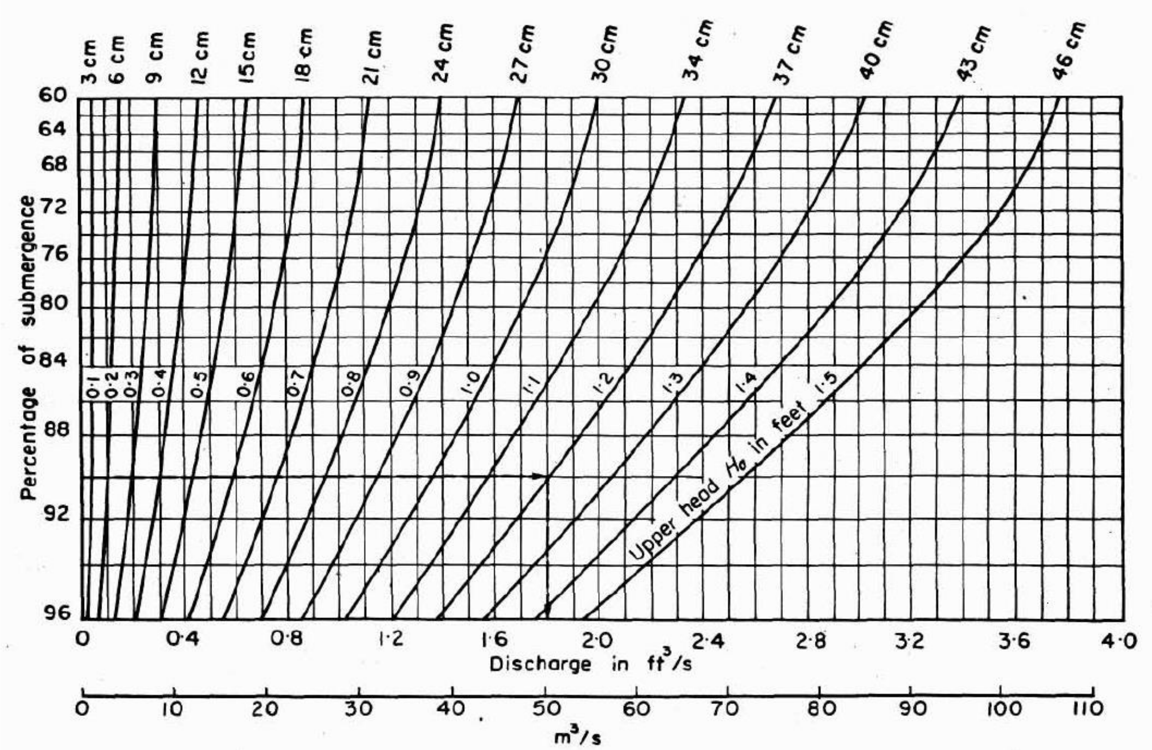


Figure B.2. Rate of Submerged Flow through a 15.2 cm (6 in) Parshall Flume

SOURCE: FAO, Irrigation and Drainage Paper 26/2: Small Hydraulic Structures, Vol. 2, 1975

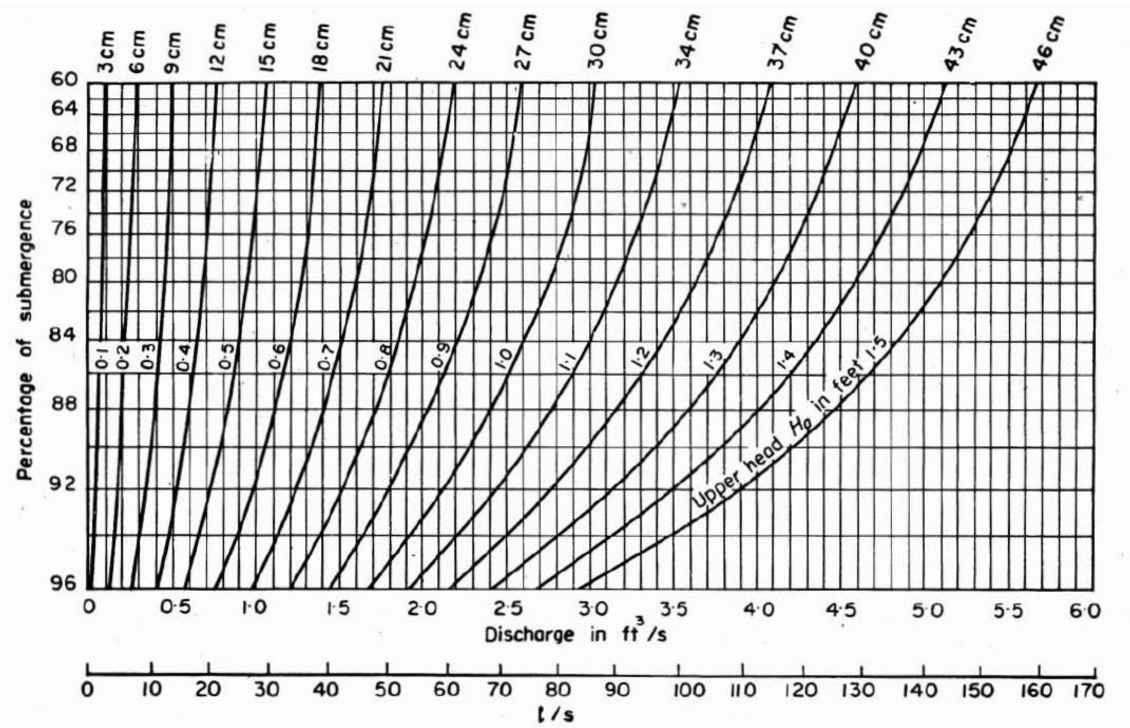


Figure B.3 – Rate of Submerged Flow through a 23 cm (9 in) Parshall Flume

SOURCE: FAO, Irrigation and Drainage Paper 26/2: Small Hydraulic Structures, Vol. 2, 1975

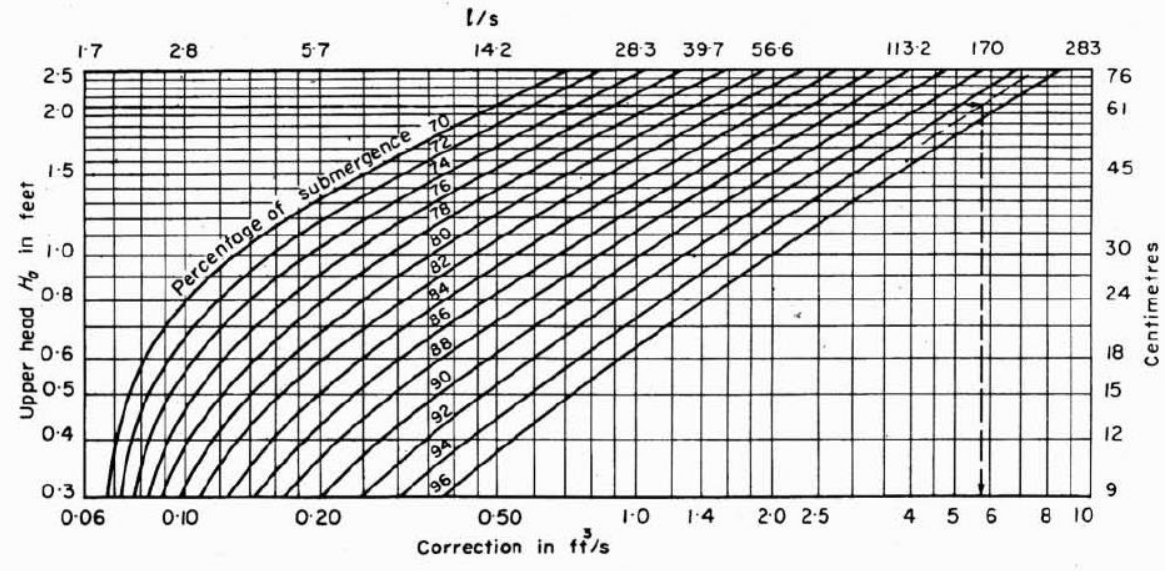


Figure B.4. Correction Diagram for a 30.5 cm (1 ft) Parshall Flume
SOURCE: FAO, Irrigation and Drainage Paper 26/2: Small Hydraulic Structures, Vol. 2, 1975

Table B.6. Multiplying Factor for Various Throat Widths

Throat Width, W		Multiplying Factor, M
ft	cm	
1	30.5	1.0
1.5	45.7	1.4
2	61.0	1.8
3	91.5	2.4
4	122.0	3.1
5	152.5	3.7
6	183.0	4.3

SOURCE: FAO, Irrigation and Drainage Paper 26/2: Small Hydraulic Structures, Vol. 2, 1975

B.3 Discharge Measurement Using Orifice

$$Q = C_d C_v A\sqrt{2g(h_1 - h_2)}$$

$$Q = C_d C_v A\sqrt{2g\Delta h}$$

where:

Q	is the discharge (m^3/s)
C_d	is the discharge coefficient
C_v	is the velocity coefficient
A	is the area of the orifice (m^2)
h_1-h_2	is the head differential across the orifice
Δh	is the upstream head above the center of the orifice

Table B.7. Average Discharge Coefficients for Circular Orifices (negligible approach velocity)

Orifice Diameter (D), m	C_d (free flow)	C_d (submerged flow)
0.020	0.61	0.57
0.025	0.62	0.58
0.035	0.64	0.61
0.045	0.63	0.61
0.050	0.62	0.61
0.065	0.61	0.60
≥ 0.075	0.60	0.60

SOURCE: ILRI, Discharge Measurement Structures, 3rd Ed. 1989

ANNEX C
(informative)

Discharge Measurement Using Current Meters

C.1 Velocity-Area Method

C.1.1 Select a measuring section and determine the overall width and depth.

C.1.2 Layout the subsection verticals such that no subsection has more than 10% of the discharge in it.

C.1.3 It is preferred that the width of the subsection lessens as depths and velocities increase.

C.1.4 The initial point can be either bank and the edge of water is the first subsection.

C.1.5 Measure and record the following for each subsection:

- distance from the initial point
- depth
- meter position
- number of revolutions
- time interval
- horizontal angle of flow

C.1.6 Measure in succession until completed to the opposite bank.

C.1.7 Compute for the discharge using the formula below.

$$Q = \sum_{i=1}^{n} a_i v_i$$

where:

Q	is the total discharge (m³/s)
a_i	is the cross-section area for the ith segment of the n segments into which the cross section is divided (m^2)
v_i	is the corresponding mean velocity of the flow normal to the ith segment or vertical (m/s)

C.2 Midsection Method

C.2.1 This method assumes that the mean velocity in each vertical represents the mean velocity in a partial rectangular area.

C.2.2 The cross-section area for a segment extends laterally from half the distance from the preceding vertical to half the distance to the next vertical, and vertically from the water surface to the channel bed.

C.2.3 Measure the velocity at one or more selected points in the vertical.

C.2.4 Compute for the partial discharge using the formula below:

$$q_i = v_i\left[\frac{(b_i - b_{(i-1)})}{2} + \frac{(b_{(i+1)} - b_i)}{2}\right]d_i = v_i\left[\frac{b_{(i+1)} - b_{(i-1)}}{2}\right]d_i$$

where:

q_i	is the discharge through partial section i (m^3/s)
v_i	is the mean velocity at location i (m/s)
b_i	is the distance from initial point to location i (m)
$b_{(i-1)}$	is the distance from initial point to preceding location (m)
$b_{(i+1)}$	is the distance from initial point to next location (m)
d_i	is the depth of water at location i (m)

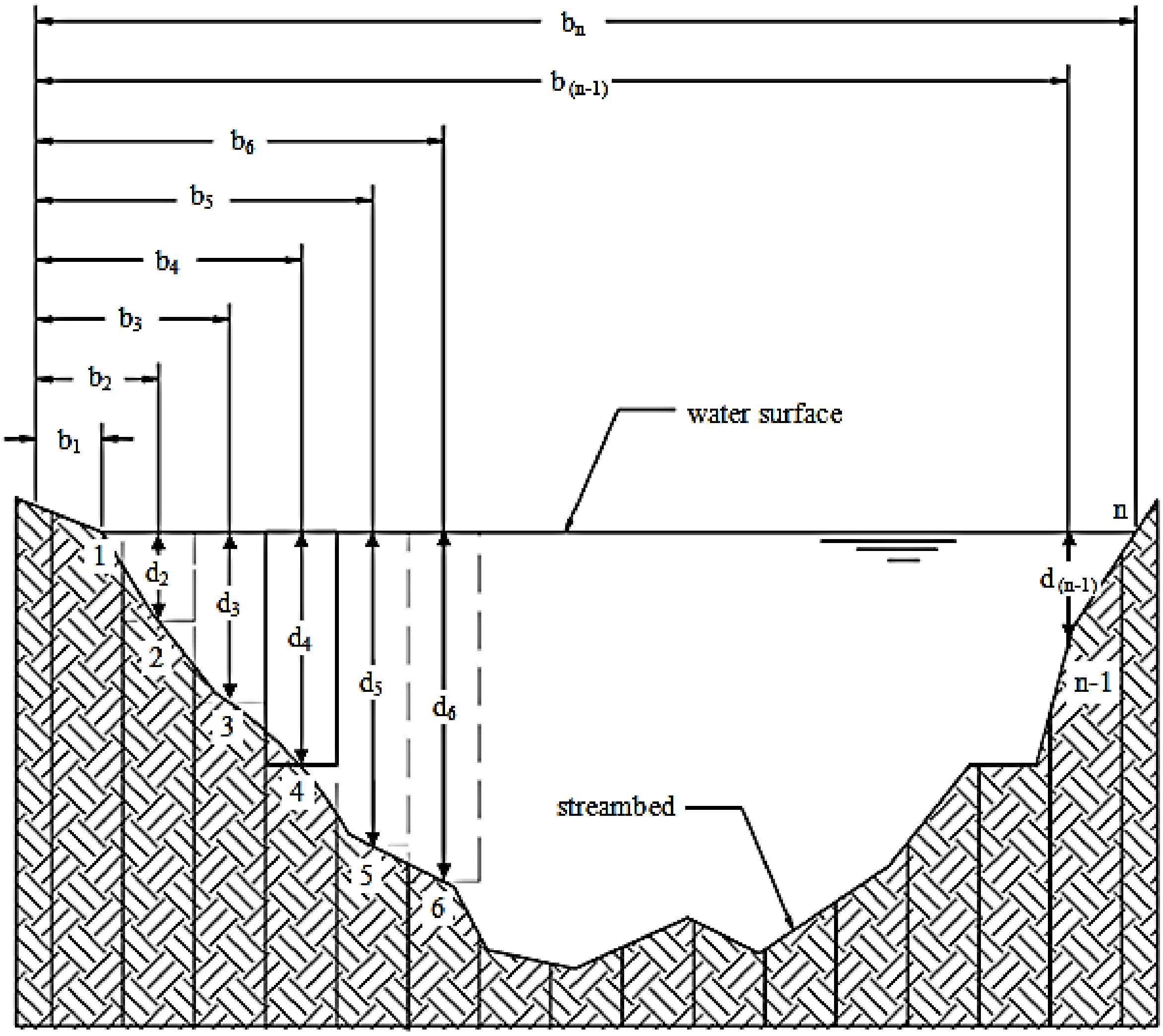


Figure C.1. Cross-section measurements for the midsection method
SOURCE: Turnipseed and Sauer, Discharge Measurements at Gaging Stations: US Geological Techniques and Methods Book 3, Chapter A8, 2010

Technical Working Group (TWG) for the Development of Philippine National Standard for Conveyance Systems – Performance Evaluation of Open Channels – Determination of Conveyance Loss by Inflow-Outflow Method

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