WATER MEASUREMENT

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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

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 Inches	24 h Inches	12 h Inches	24 h Inches	12 h Inches	24 h Inches	12 h Inches	24 h Inches	12 h Inches	24 h 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

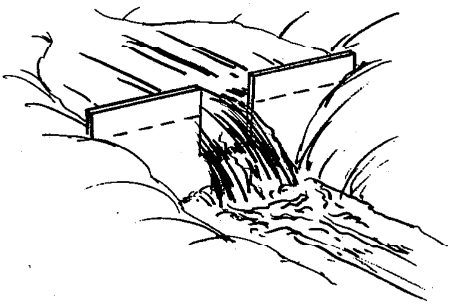
Table 2 (Continued). Depth of water applied by various flows, time and acres.

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

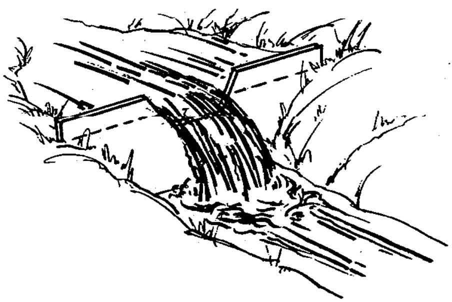
Water is conveyed in both open channels and closed conduits. This bulletin will consider some of the standard water measuring devices designed to operate under open and closed flow conditions.

OPEN FLOW

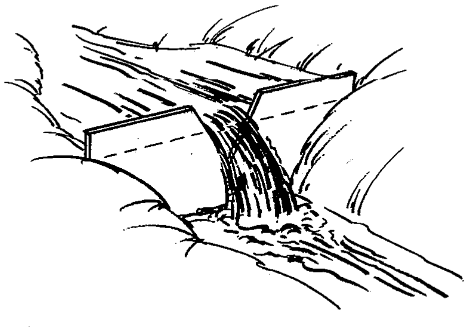
Idaho has many miles of open canals and ditches. On-farm conveyance and distribution systems equipped with measuring devices will improve water distribution and make the irrigation job much easier.



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.

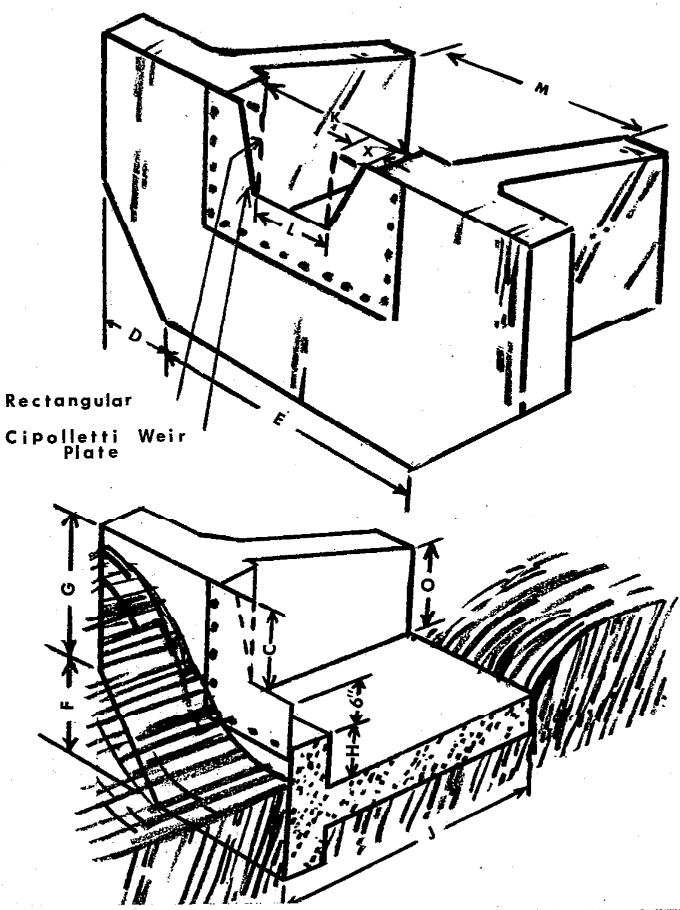
If the water is carrying silt it may settle out and fill the weir pond. This causes the approach velocity of the water to increase and the device becomes inaccurate. Grass and weeds thrive in the slow water and the weir pond requires maintenance to keep it free of silt and weeds.

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	3
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	4
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.

Rectangular Submerged Orifice

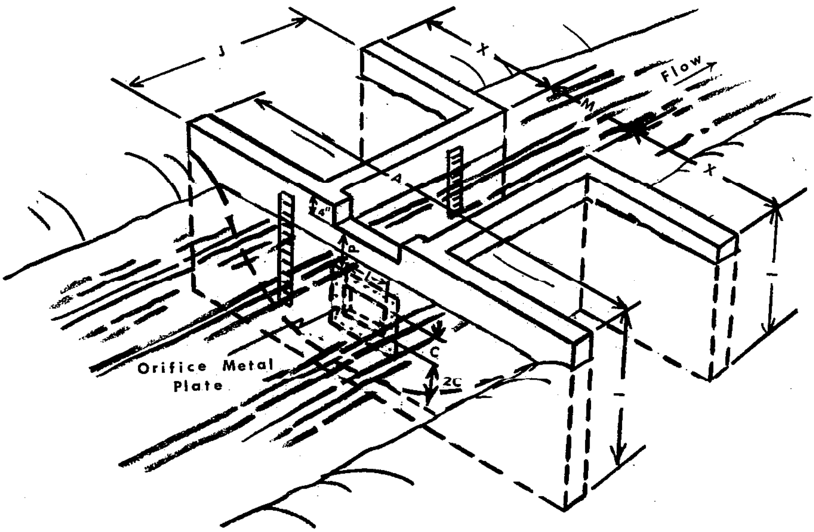
A rectangular submerged orifice is a sharp-edged rectangular opening in a vertical bulkhead placed in a stream perpendicular to the direction of flow, having the upstream and downstream water surface above the orifice as shown in Fig. 3. The cross-sectional area of the orifice is small in relation to the stream cross-section. These conditions provide complete contraction of stream flow and the approach velocity of the water becomes negligible.

This device is used on relatively flat ditches where fall is not ade-

How to Install

The following standard conditions must be met if water measurements are to be accurate:

1. The orifice opening must be submerged at all times to be accurate.
2. The orifice opening must be rectangular and have sharp edges. It should be made of metal.
3. In order to contract the flow, the distance from the edges of the opening to the channel sides and bottom must all be at least twice the least dimension of the orifice.
4. The head wall must be vertical and perpendicular to the direction of flow with the top and bottom of the orifice horizontal and the sides vertical.



Size of orifice				Symbol dimensions					
L Ft-In	C Ft-In	Area in sq.ft.	Recommended range of measurement in C.f.s.	A Ft-In	I Ft-In	J Ft-In	M Ft-In	P Ft-In	X Ft-In
1	3	.25	.4 to 1.0	8-4	4	3	2-6	1-11	2-11
1-4	3	.33	.5 to 1.4	9-8	4	3	3	1-11	3-4
2	3	.50	.8 to 2.1	9-10	4-3	3	3-6	2-2	3-2
	4	.33	.5 to 1.4	9	4-4	3	2-6	2	3-3
1-6	4	.50	.8 to 2.1	10	4-7	3	3	2-3	3-6
2-3	4	.75	1.0 to 3.2	11-3	4-10	3-6	3-6	2-6	3-10½
1	6	.50	.8 to 2.1	10-6	5-1	3	2-6	2-3	4-0
1-6	6	.75	1.0 to 3.2	11-6	5-4	3-6	3	2-6	4-3
	6	1.00	1.5 to 4.3	12	5-4	3-6	3-6	2-6	4-3
3	6	1.50	2.3 to 6.5	14	5-10	4	4-6	3	4-9
1-4	9	1.00	1.5 to 4.3	12-6	5-11	3-6	3	2-6	4-9
2	9	1.50	2.3 to 6.5	14-6	6-7	4	3-6	3	5-6
2-8	9	2.00	3.0 to 8.7	16	7	4	4	3-6	6-0

Fig. 3. Dimensions and capacities for Rectangular Submerged Orifice.

5. The cross sectional area of the channel 20 to 30 feet upstream should be at least eight times larger than the area of the orifice. Recommended orifice dimensions and capacities are shown in Fig. 3.

How to Measure

The effective head should be carefully measured. Staff gauges level with the bottom of the orifice should be installed on the upstream and downstream side far enough away from the orifice to avoid turbulence. The difference in the water depth reading on the two gauges is the effective head.

The cross-sectional area of the orifice must be measured carefully. Knowing the head and the area, the discharge can be found from 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.

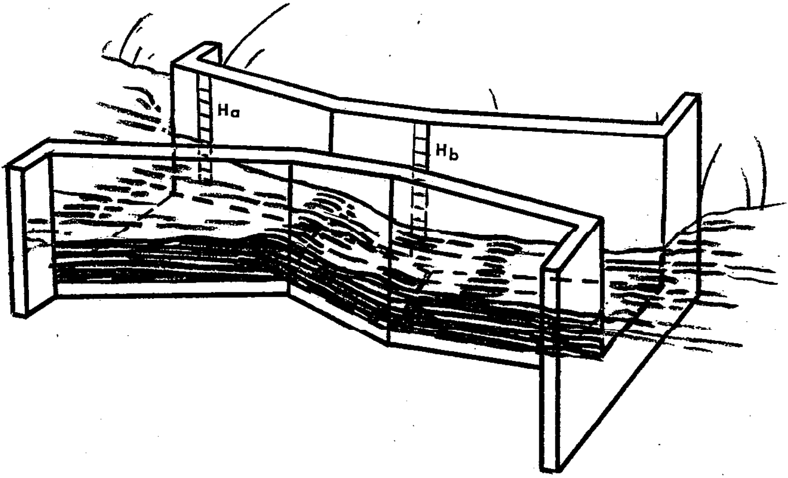


Fig. 4. Parshall measuring flume.

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.

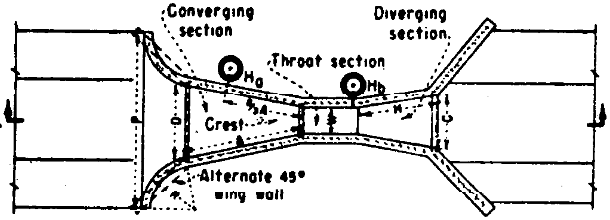
How to Measure

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/Qo 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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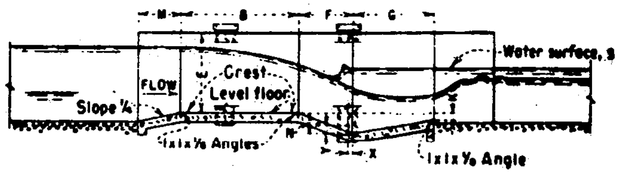

SECTION L-L

W	A	$\frac{2}{3}$A	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	0-10 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
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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.

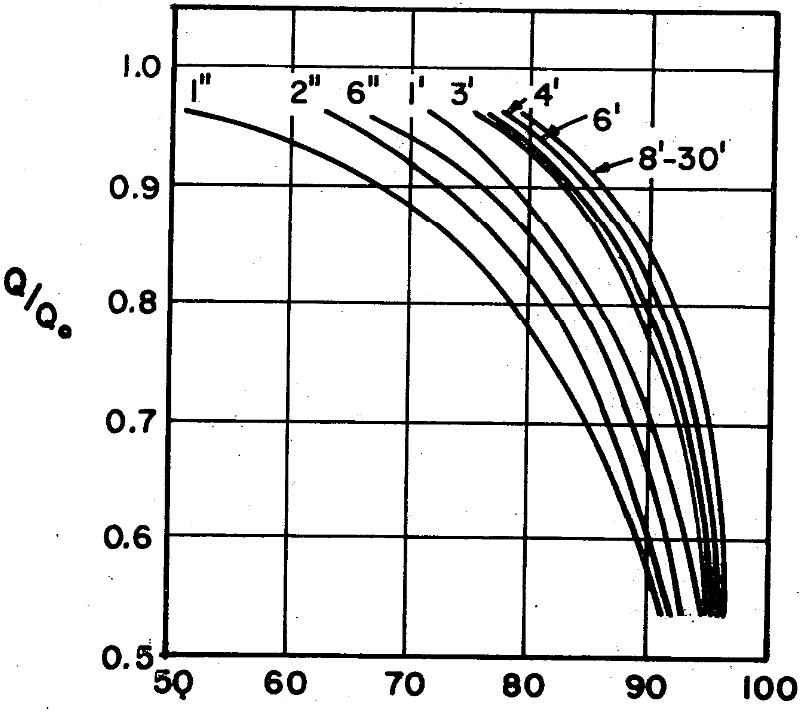


Fig. 6. Parshall measuring flume correction factors for submerged flow.

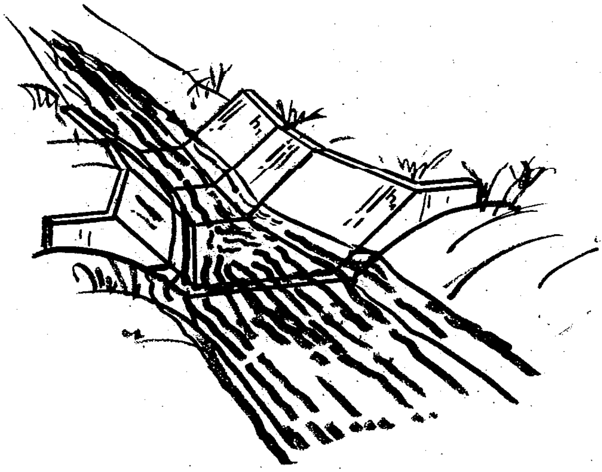


Fig. 7. Trapezoidal flume.

Trapezoidal Flume

The trapezoidal flume (Fig. 7) is relatively new. It is accurate and has the same advantages as the Parshall flume.

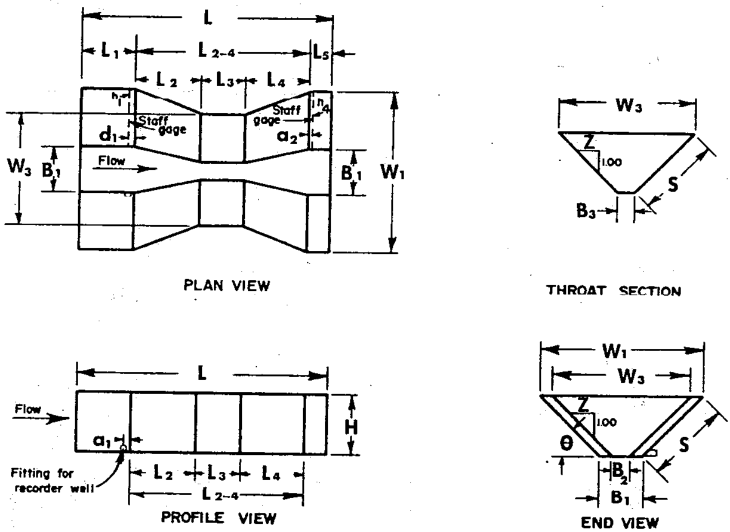
This flume is easier to build than the Parshall flume. Its cross section corresponds to the shape of many farm ditches. Procedures have been developed to cast this flume in existing concrete-lined ditches.

Because its sides diverge with depth, the trapezoidal flume of a given throat width can carry a wider range of flows than the same size Parshall flume. It can be used at a higher degree of submergence than the Parshall flume, up to 80%, with an error of less than 3% before a correction factor must be taken into account.

How to Install

Basically the trapezoidal flume is installed in the same manner as the Parshall flume. Its dimensions are shown in Fig. 8.

1. The flume should be installed level in both directions if possible, but may be installed on slopes within determined limits if cast



Flume No.	L Ft-In	L_1 Ft-In	L_2 Ft-In	L_3 Ft-In	L_4 Ft-In	L_5 Ft-In	L_{2-4} Ft-In	W_1 Ft-In	W_3 Ft-In	S Ft-In
1	5-7 1/8	1-3	1-5 1/16	1-0	1-5 1/16	6	3-10 1/8	3-8	3- 13/16	1-10 5/8
2	10-6	2-0	3-0	2-6	2-0	1-0	7-6	9-6	8-6	4- 9 5/8

Flume No.	B_1 Ft-In	B_3 Ft-In	a_2 Ft-In	d_1 Ft-In	H Ft-In	Z	θ	Free Flow Capacity Minimum cfs	Free Flow Capacity Maximum cfs
1	1-0	4 13/16	3/4	1 3/4	1-4	1.00	45°00′	0.18	7.0
2	2-0	1-0	6	6	3-0	1.25	38°40′	0.71	51.49

Fig. 8. Trapezoidal flume dimensions for two different size structures.

within concrete ditches. The maximum slope limit is about 0.0035 foot per foot or the critical slope for the given flow. If the botom slopes, the zero reference on the staff gauge (located at H1) should be the same as the elevation of the center of the throat section.

2. Only one measurement for free flow is required, at h1. The staff gauge can be attached to the sloping side wall. In this case the flume should be carefully leveled transversely so the staff gauge is on the exact slope specified. The use of a stilly well is more accurate.

3. The bottom of the flume and the bottom of a lined channel can be the same if the slope is adequate. If the slope is not adequate, which is usually the case, the invert or flume opening will be above the channel bed level. This can be chosen arbitrarily although it must be kept in mind that the higher the invert, the higher the upstream water level, requiring higher ditch banks. The invert should always be higher than the ditch bottom on earth ditches. Invert height should be selected to provide free flow. The height generally used is the same as that used for the Parshall flume — that is, the head loss through the trapezoidal flume at 70% submergence.

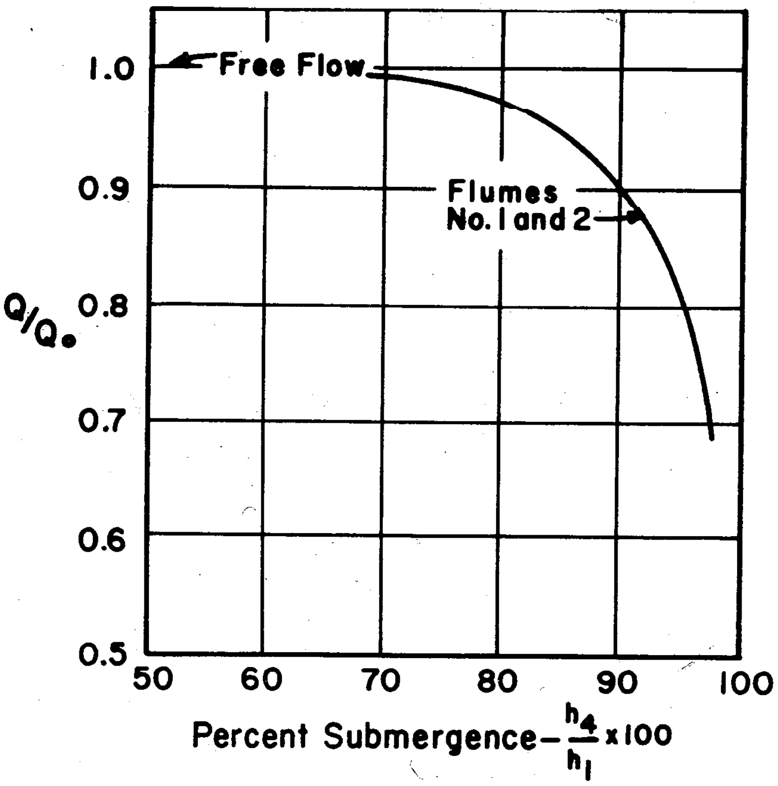


Fig. 9. Trapezoidal flume correction factors for submerged flow.

How to Measure

Under free flow conditions one reading of water depth at h1 is all that is needed. Discharges are shown in Table 8 for either sloping wall or vertical measurement of h1.

When the ratio of the depth of water at h4/h1 is 0.80 or greater, the correction factor (Q/Qo) shown in Fig. 9 must be used. The discharge found from the regular h1 measurement multiplied by the correction factor will give the correct discharge. Submergence may reduce the discharge up to 40%.

Deflection Meters

A deflection meter is a commercial meter consisting of a specially-shaped vane suspended in flowing water (see Fig. 10). An indicating device or head attached to the vane measures the deflection caused by the force of the fluid flow against the vane. The amount of flow, determined by the amount of vane deflection, is read directly on a scale opposite an air bubble within a liquid-filled tube. The vane is shaped so that the meter indicates the same flow for high velocities and shallow depths as for lower velocities and greater depths. The meter must be used in the standard channel section for which it was developed and calibrated. In addition, it must be installed and operated according to the manufacturer's recommendations. Meters are available for both rectangular and trapezoidal sections in various flow ranges.

The meter vane and indicating head are portable and may be moved from one station to another. In use, they rest on permanent brackets

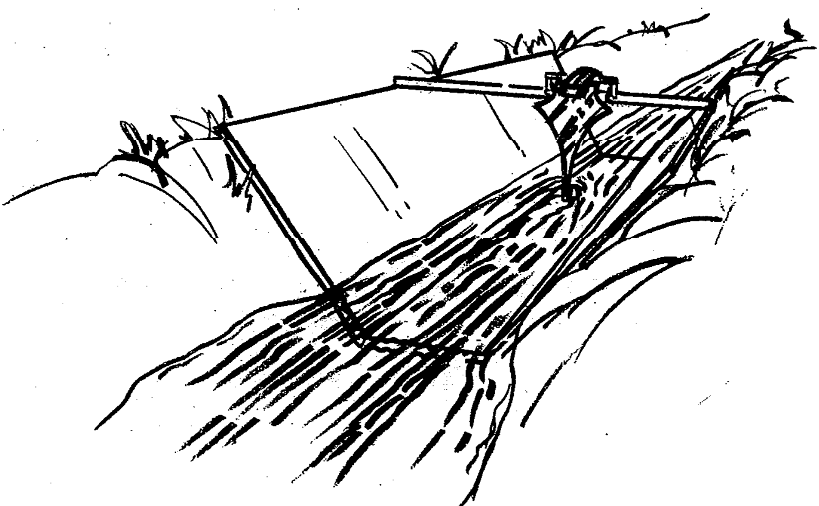


Fig. 10. Deflection meter installation.

attached to the standard channel liner. The standard section of concrete or steel is permanently installed in the ditch and may be obtained commercially or constructed according to manufacturers' specifications.

The device is simple, portable, direct reading, and operates with practically no head loss. It is less sensitive to approach and downstream conditions than most devices and unaffected by submergence. Wind will affect the deflection device and decrease accuracy. The channel must be kept free from debris. It is not adapted where continuous flow records are needed. The meter is expensive but the same unit can be used at a number of locations if a standard cross-section and brackets are mermanently located at each site.

CLOSED FLOW

Almost one-third of Idaho's irrigated acreage is served by groundwater pumping. The water is confined in a pipe in most closed flow systems until it is delivered to a head or conveyance ditch or leaves an individual sprinkler head. The following devices are some that are recommended for a closed system. These measuring devices can be used to obtain either an instantaneous reading of the flow rate, totalize the volume of flow measured, or both. Accurate measurement can reduce pumping plant and well maintenance and guard against plant failure by signaling any change in flow in a closed system.

PROPELLER METER

Propeller or displacement type meters utilize the mass of the water flowing through a confined area of known size to turn a propeller as illustrated in Fig. 11. They are made commercially by several manufacturers and sold by many Idaho firms.

The meter is accurate, easy to install in any closed system and covers a wide range of flow. Flow and pressure limits are provided by the manufacturer of the specific meter. Propeller meters can record the flow rate, accumulative volume or both. Most manufacturers

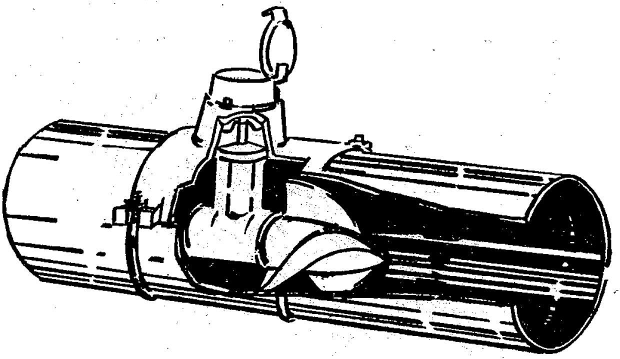


Fig. 11. Typical propeller meter. Several kinds are manufactured commercially.

feature a magnetic drive between the propeller and the counter rather than a direct drive. This reduces the drive gear and reduces maintenance costs.

Water should be free of debris. Water carrying large amounts of sand can easily cause wear on the propeller, reducing its accuracy and increasing maintenance costs.

Propeller meters have a high first cost and require an annual maintenance program as the meter has many working parts which operate continuously for about 2400 hours per year. The bearings and the propeller should be carefully checked. Good maintenance is essential. The meter should be calibrated periodically to provide accurate measurement.

How to Install

1. The water must approach the propeller at right angles.
2. Orient the propeller carefully within the pipe. The axis of propeller and pipe must be parallel.
3. Place the meter at least 6 pipe diameters downstream from the entrance to the straight pipe section it is installed in. If closer, install straightening vanes.
4. Adopt a periodic inspection and meter calibration schedule. Do seasonal maintenance work.
5. Follow the manufacturer's installation instructions and operating table.

Pitot Tube

A pitot-static tube may be used to determine the flow velocity of fluid in a closed conduit. The instrument is easy to install, accurate over a wide flow range, has a low maintenance requirement, and the pressure loss caused by it is very small.

This instrument consists of a tube with a right angle bend near one end which is immersed in the fluid with the bent portion parallel to the direction of flow and pointing upstream. The tube is divided into two compartments with a port or small impact opening on the tip of the tube leading into one compartment and another opening along the side of the tube leading to the other compartment. Another type uses two tubes to measure the velocity-head differential. The tubes are placed transversely through the pipe. The side of the tube against the direction of flow contains several holes which serve to average the static pressure throughout the pipe. This type is shown in Figure 12. A pitot tube will provide the flow rate but will not give accumulated volume without special instrumentation.

A manometer is used to measure the difference in head between the two pitot tube openings from which the velocity head is determined. At low flow velocities, head differentials are small and reading errors greatly affect the results. A sensitive manometer which can be used to measure small pressure changes is important in this case. If a farmer has more than one well or pump, he can install the pitot-tube device at each location and use one portable manometer to determine the discharge. The device is easily installed without dismantling the system. Depending on the type, one or two small holes tapped in the pipe are all that will be required. Clean water is impor-

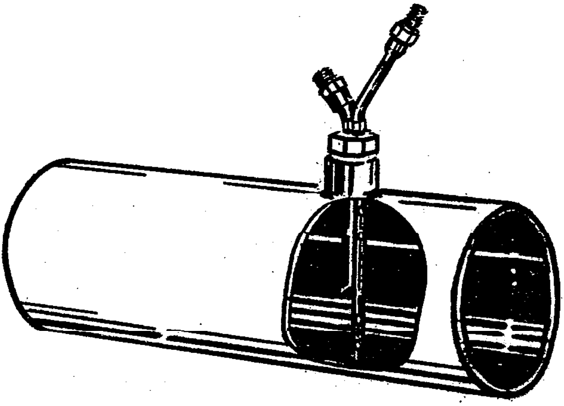


Fig. 12. Pitot tube water measuring device. Several kinds are available commercially.

tant. Most pitot tubes contain small holes which can become plugged easily with foreign materials in the water, especially if sand particles are suspended in the water. Some tubes are designed to try to minimize this hazard. Water containing large amounts of salts or unbalanced metals is hazardous. These chemicals may precipitate out, plugging the device. Consideration should be given to ease of removal of this instrument for periodic cleaning and inspection.

Installation procedures and rating tables are furnished by the manufacturer.

Pipe Orifice

Pipe orifices are used to measure discharge from the open end of a pipe or within the pipeline system.

A circular orifice plate installed on the end of a pipe can be used to measure flow within a range of 50 to 2,000 gallons per minute. The free discharge type is more commonly used in Idaho than the in-line device. It is constructed and installed as shown in Fig. 13. Ratio of the orifice diameter to the pipe diameter should be no less than 0.50 nor greater than 0.83. A ratio must be selected which will cause the pipe to flow full. The head is measured with a manometer or a glass tube and scale graduated in inches. This is placed two feet upstream from the orifice. The pipe must be level with no elbows, valves, or other fittings closer than 4 feet upstream from the manometer.

Discharge values for various combinations of orifice and pipe sizes for heads up to 70 inches are found in Table 9. The orifice is well suited to measure water flowing from a pump into a pond or ditch. It is simple to install and use. This device will provide the rate of flow only. The principal disadvantage of the pipe orifice with free discharge is its relative large head loss. For this reason other devices are normally used, as the device has to remain installed because removing it would reduce the head and the pump would provide more water than the official reading.

The inpipe type uses a thin pipe orifice inserted across the pipeline. Readings must be taken upstream and downstream with a manometer. The pipe orifice can be installed at each location where a measurement is wanted and a portable manometer can be used to measure the head at each location. It is capable of producing accurate flow measurements.

How to Install and Measure

1. There should be at least 4 feet of straight pipe from an elbow valve or other flow impairment leading into the orifice plate.
2. The pipe must be horizontal and flowing full of water to obtain an accurate measurement. Water must fall freely from the orifice.
3. An error in measurement of the diameter of the orifice will be doubled in area of discharge. Use exact diameter. The upstream side of the orifice should be relatively sharp.
4. The end of the discharge pipe should be threaded so that a coupler can be screwed on it to hold the plate against the end of the pipe.
5. A hole is tapped into the pipe 24 inches back from the end of the plate (Fig. 13). A vertical glass or plastic tube is attached by means of an elbow. The height water stands in the pipe above the *center line of the pipe* is the static head upon the orifice.
6. The tube must be free of air bubbles, which cause a higher reading. Before reading allow water to run out of tube to remove sand and air particles. A small needle or gate valve installed in the manometer tube can be used to dampen oscillations for a more precise reading.

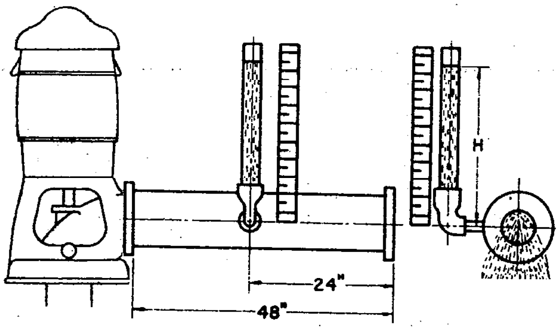


Fig. 13. Pipe orifice with free discharge.

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: $Q = 3.247\,LH^{1.48} - \frac{0.566L^{1.8}}{1+2L^{1.8}}H^{1.9}$

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	1.55
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)					For each additional foot of crest in excess of 4 ft. (approx.)
		1.0 foot	1.5 feet	2.0 feet	3.0 feet	4.0 feet	
		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	5-3/8	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	15-7/16	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. Flow through rectangular submerged orifices in cubic feet per second*

Effective Head H		Cross-sectional area, A, of orifice						
In feet	In inches	0.25 sq. ft.	0.333 sq. ft.	0.50 sq. ft.	0.75 sq. ft.	1.00 sq. ft.	1.50 sq. ft.	2.00 sq. ft.
0.01	1/8	0.122	0.163	0.245	0.367	0.489	0.73	0.98
0.02	1/4	0.173	0.230	0.346	0.518	0.691	1.04	1.38
0.03	3/8	0.212	0.282	0.424	0.635	0.847	1.27	1.69
0.04	1/2	0.245	0.326	0.489	0.734	0.978	1.47	1.96
0.05	5/8	0.273	0.364	0.546	0.820	1.09	1.64	2.19
0.06	3/4	0.300	0.399	0.599	0.899	1.20	1.80	2.40
0.07	13/16	0.324	0.431	0.647	0.971	1.29	1.94	2.59
0.08	15/16	0.346	0.461	0.691	1.04	1.38	2.07	2.77
0.09	1-1/16	0.367	0.489	0.734	1.10	1.47	2.20	2.94
0.10	1-3/16	0.387	0.518	0.773	1.16	1.56	2.32	3.09
0.11	1-5/16	0.406	0.540	0.811	1.22	1.62	2.43	3.24
0.12	1-7/16	0.424	0.564	0.847	1.27	1.69	2.54	3.39
0.13	1-9/16	0.441	0.587	0.882	1.32	1.76	2.65	3.53
0.14	1-11/16	0.458	0.609	0.915	1.37	1.83	2.75	3.66
0.15	1-13/16	0.474	0.631	0.947	1.42	1.90	2.84	3.79
0.16	1-15/16	0.489	0.651	0.978	1.47	1.96	2.93	3.91
0.17	2-1/16	0.504	0.671	1.01	1.51	2.02	3.02	4.03
0.18	2-3/16	0.519	0.691	1.04	1.56	2.08	3.11	4.15
0.19	2-1/4	0.533	0.710	1.07	1.60	2.13	3.20	4.26
0.20	2-3/8	0.547	0.729	1.09	1.64	2.19	3.28	4.38
0.21	2-1/2	0.561	0.746	1.12	1.68	2.24	3.36	4.48
0.22	2-5/8	0.574	0.765	1.15	1.72	2.30	3.46	4.59
0.23	2-3/4	0.587	0.781	1.17	1.76	2.35	3.52	4.69
0.24	2-7/8	0.600	0.798	1.20	1.80	2.40	3.60	4.79
0.25	3	0.612	0.815	1.22	1.83	2.45	3.67	4.89
0.26	3-1/8	0.624	0.831	1.25	1.87	2.49	3.74	4.99
0.27	3-1/4	0.636	0.846	1.27	1.91	2.54	3.81	5.08
0.28	3-3/8	0.646	0.862	1.29	1.94	2.59	3.88	5.18
0.29	3-1/2	0.659	0.878	1.32	1.98	2.64	3.96	5.28
0.30	3-5/8	0.670	0.892	1.34	2.01	2.68	4.02	5.36

*Computed from the formulae $Q = 0.61 A\sqrt{2gh}$.

Table 6 (Continued). Flow through rectangular submerged orifices in cubic feet per second.

Effective Head H		Cross-sectional area, A, of orifice						
In feet	In inches	0.25 sq. ft.	0.333 sq. ft.	0.50 sq. ft.	0.75 sq. ft.	1.00 sq. ft.	1.50 sq. ft.	2.00 sq. ft.
0.31	3-3/4	0.681	0.908	1.36	2.05	2.73	4.09	5.45
0.32	3-13/16	0.692	0.920	1.38	2.07	2.76	4.15	5.53
0.33	3-15/16	0.703	0.936	1.41	2.11	2.81	4.22	5.62
0.34	4-1/16	0.713	0.950	1.43	2.14	2.85	4.28	5.70
0.35	4-3/16	0.724	0.963	1.45	2.17	2.89	4.34	5.78
0.36	4-5/16	0.734	0.976	1.47	2.20	2.93	4.40	5.87
0.37	4-7/16	0.745	0.991	1.49	2.23	2.98	4.46	5.95
0.38	4-9/16	0.754	1.00	1.51	2.26	3.02	4.52	6.03
0.39	4-11/16	0.764	1.02	1.53	2.29	3.05	4.58	6.11
0.40	4-13/16	0.774	1.03	1.55	2.32	3.09	4.64	6.19
0.41	4-15/16	0.783	1.04	1.57	2.35	3.13	4.70	6.27
0.42	5-1/16	0.792	1.06	1.59	2.38	3.17	4.75	6.34
0.43	5-3/16	0.802	1.07	1.60	2.41	3.21	4.81	6.42
0.44	5-1/4	0.811	1.08	1.62	2.43	3.24	4.87	6.49
0.45	5-3/8	0.820	1.09	1.64	2.46	3.28	4.92	6.56
0.46	5-1/2	0.829	1.10	1.66	2.49	3.32	4.98	6.64
0.47	5-5/8	0.839	1.12	1.68	2.52	3.36	5.04	6.71
0.48	5-3/4	0.847	1.13	1.70	2.54	3.39	5.08	6.78
0.49	5-7/8	0.856	1.14	1.71	2.57	3.42	5.14	6.85
0.50	6	0.865	1.15	1.73	2.59	3.46	5.19	6.92
0.51	6-1/8	0.873	1.16	1.75	2.62	3.49	5.24	6.99
0.52	6-1/4	0.882	1.17	1.76	2.65	3.53	5.29	7.05
0.53	6-3/8	0.890	1.19	1.78	2.67	3.56	5.34	7.12
0.54	6-1/2	0.898	1.20	1.80	2.70	3.59	5.39	7.19
0.55	6-5/8	0.907	1.21	1.81	2.72	3.63	5.44	7.25
0.56	6-3/4	0.915	1.22	1.83	2.75	3.66	5.49	7.32
0.57	6-13/16	0.923	1.23	1.85	2.77	3.69	5.54	7.38
0.58	6-15/16	0.931	1.24	1.86	2.79	3.73	5.59	7.45
0.59	7-1/16	0.939	1.25	1.88	2.82	3.76	5.64	7.51
0.60	7-3/16	0.947	1.26	1.90	2.84	3.79	5.68	7.58

Table 6 (Continued). Flow through rectangular submerged orifices in cubic feet per second.

Effective Head H		Cross-sectional area, A, of orifice						
In feet	In inches	0.25 sq. ft.	0.333 sq. ft.	0.50 sq. ft.	0.75 sq. ft.	1.00 sq. ft.	1.50 sq. ft.	2.00 sq. ft.
0.61	7-5/16	0.955	1.27	1.91	2.87	3.82	5.73	7.64
0.62	7-7/16	0.963	1.28	1.93	2.89	3.85	5.78	7.70
0.63	7-9/16	0.971	1.29	1.94	2.91	3.88	5.82	7.76
0.64	7-11/16	0.978	1.30	1.96	2.93	3.91	5.87	7.82
0.65	7-13/16	0.986	1.31	1.97	2.96	3.94	5.92	7.89
0.66	7-15/16	0.993	1.32	1.99	2.98	3.97	5.96	7.95
0.67	8-1/16	1.00	1.33	2.00	3.00	4.00	6.01	8.01
0.68	8-3/16	1.01	1.34	2.02	3.02	4.03	6.05	8.06
0.69	8-1/4	1.02	1.35	2.03	3.05	4.06	6.10	8.13
0.70	8-3/8	1.02	1.36	2.05	3.07	4.09	6.14	8.18
0.71	8-1/2	1.03	1.37	2.06	3.09	4.12	6.19	8.25
0.72	8-5/8	1.04	1.38	2.08	3.11	4.15	6.23	8.30
0.73	8-3/4	1.05	1.39	2.09	3.14	4.18	6.27	8.36
0.74	8-7/8	1.05	1.40	2.10	3.16	4.21	6.31	8.42
0.75	9	1.06	1.41	2.12	3.18	4.24	6.36	8.48
0.76	9-1/8	1.07	1.42	2.13	3.20	4.26	6.40	8.53
0.77	9-1/4	1.07	1.43	2.15	3.22	4.29	6.43	8.58
0.78	9-3/8	1.08	1.44	2.16	3.24	4.32	6.48	8.64
0.79	9-1/2	1.09	1.45	2.17	3.26	4.35	6.52	8.70
0.80	9-5/8	1.09	1.46	2.19	3.28	4.38	6.56	8.75

Table 7. 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)							
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		Throat width							
Feet	Inches (approx.)	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

Table 8. Free flow through trapezoidal measuring flumes in cubic feet per second.

		Flume No. 1 (1 foot bottom width)		Flume No. 2 (2 foot bottom width)	
Feet	Inches	Measured along sloping sidewall	Measured in vertical direction	Measured along sloping sidewall	Measured in vertical direction
0.20	2-3/8		0.16		
0.21	2-1/2		0.18		
0.22	2-5/8		0.19		
0.23	2-3/4		0.20		
0.24	2-7/8		0.22		
0.25	3		0.23		
0.26	3-1/8		0.24		
0.27	3-1/4		0.26		
0.28	3-3/8		0.28		
0.29	3-1/2		0.30		
0.30	3-5/8	0.18	0.31		0.67
0.31	3-3/4	0.19	0.33		0.70
0.32	3-13/16	0.20	0.35		0.74
0.33	3-15-16	0.21	0.37		0.77
0.34	4-1/16	0.22	0.39		0.81
0.35	4-3/16	0.23	0.42		0.84
0.36	4-5/16	0.24	0.44		0.88
0.37	4-7/16	0.25	0.46		0.92
0.38	4-9/16	0.26	0.48		0.96
0.39	4-11/16	0.27	0.51		1.00
0.40	4-13/16	0.28	0.54		1.04
0.41	4-15/16	0.29	0.56		1.09
0.42	5-1/16	0.31	0.59		1.13
0.43	5-3/16	0.32	0.62		1.18
0.44	5-1/4	0.33	0.65		1.22
0.45	5-3/8	0.35	0.68		1.27
0.46	5-1/2	0.36	0.71		1.32
0.47	5-5/8	0.38	0.74		1.37
0.48	5-3/4	0.39	0.78		1.42
0.49	5-7/8	0.41	0.81		1.48
0.50	6	0.42	0.84	0.71	1.53
0.51	6-1/8	0.44	0.88	0.73	1.59
0.52	6-1/4	0.46	0.92	0.75	1.65
0.53	6-3/8	0.47	0.95	0.77	1.70
0.54	6-1/2	0.49	0.99	0.80	1.76
0.55	6-5/8	0.51	1.03	0.82	1.83
0.56	6-3/4	0.52	1.07	0.84	1.89
0.57	6-13/16	0.54	1.11	0.86	1.95
0.58	6-15/16	0.56	1.16	0.89	2.02
0.59	7-1/16	0.58	1.20	0.91	2.09
0.60	7-3/16	0.60	1.24	0.94	2.15
0.61	7-5/16	0.62	1.29	0.96	2.22
0.62	7-7/16	0.64	1.34	0.99	2.30
0.63	7-9/16	0.66	1.38	1.01	2.37
0.64	7-11/16	0.69	1.43	1.04	2.44
0.65	7-13/16	0.71	1.48	1.07	2.52
0.66	7-15/16	0.73	1.53	1.09	2.59
0.67	8-1/16	0.76	1.58	1.12	2.67
0.68	8-3/16	0.78	1.64	1.15	2.75
0.69	8-1/4	0.80	1.69	1.18	2.83

Table 8 (Continued). Free flow through trapezoidal measuring flumes.

		Flume No. 1 (1 foot bottom width)		Flume No. 2 (2 foot bottom width)	
Feet	Inches	Measured along sloping sidewall	Measured in vertical direction	Measured along sloping sidewall	Measured in vertical direction
0.70	8-3/8	0.83	1.74	1.21	2.92
0.71	8-1/2	0.85	1.80	1.24	3.00
0.72	8-5/8	0.88	1.86	1.27	3.09
0.73	8-3/4	0.90	1.92	1.30	3.17
0.74	8-7/8	0.93	1.97	1.33	3.26
0.75	9	0.96	2.03	1.36	3.35
0.76	9-1/8	0.98	2.10	1.40	3.44
0.77	9-1/4	1.01	2.16	1.43	3.54
0.78	9-3/8	1.04	2.22	1.46	3.63
0.79	9-1/2	1.07	2.29	1.50	3.73
0.80	9-5/8	1.10	2.35	1.53	3.82
0.81	9-3/4	1.13	2.42	1.56	3.92
0.82	9-13/16	1.16	2.49	1.60	4.03
0.83	9-15/16	1.19	2.56	1.64	4.13
0.84	10-1/16	1.22	2.63	1.67	4.23
0.85	10-3/16	1.25	2.70	1.71	4.34
0.86	10-5/16	1.28	2.77	1.75	4.45
0.87	10-7/16	1.31	2.84	1.78	4.56
0.88	10-9/16	1.35	2.92	1.82	4.67
0.89	10-11/16	1.38	3.00	1.86	4.78
0.90	10-13/16	1.41	3.07	1.90	4.89
0.91	10-15/16	1.45	3.15	1.94	5.01
0.92	11-1/16	1.48	3.23	1.98	5.12
0.93	11-3/16	1.52	3.31	2.02	5.24
0.94	11-1/4	1.56	3.39	2.06	5.36
0.95	11-3/8	1.59	3.48	2.11	5.49
0.96	11-1/2	1.63	3.56	2.15	5.61
0.97	11-5/8	1.67	3.65	2.19	5.74
0.98	11-3/4	1.71	3.74	2.24	5.86
0.99	11-7/8	1.74	3.82	2.28	5.99
1.00	12	1.78	3.91	2.33	6.12
1.01	12-1/8	1.82	4.00	2.37	6.26
1.02	12-1/4	1.86	4.10	2.42	6.39
1.03	12-3/8	1.91	4.19	2.46	6.53
1.04	12-1/2	1.95	4.28	2.51	6.66
1.05	12-5/8	1.99	4.38	2.56	6.80
1.06	12-3/4	2.03	4.48	2.61	6.95
1.07	12-13/16	2.08	4.58	2.66	7.09
1.08	12-15/16	2.12	4.68	2.71	7.23
1.09	13-1/16	2.16	4.78	2.76	7.38
1.10	13-3/16	2.21	4.88	2.81	7.53
1.11	13-5/16	2.25	4.98	2.86	7.68
1.12	13-7/16	2.30	5.09	2.91	7.83
1.13	13-9/16	2.35	5.20	2.96	7.98
1.14	13-11/16	2.40	5.30	3.02	8.14
1.15	13-13/16	2.44	5.41	3.07	8.30
1.16	13-15/16	2.49	5.52	3.12	8.46
1.17	14-1/16	2.54	5.63	3.18	8.62
1.18	14-3/16	2.59	5.75	3.23	8.78
1.19	14-1/4	2.64	5.86	3.29	8.95

Table 8 (Continued). Free flow through trapezoidal measuring flumes.

		Flume No. 1 (1 foot bottom width)		Flume No. 2 (2 foot bottom width)	
Feet	Inches	Measured along sloping sidewall	Measured in vertical direction	Measured along sloping sidewall	Measured in vertical direction
1.20	14-3/8	2.69	5.98	3.34	9.11
1.21	14-1/2	2.74	6.10	3.40	9.28
1.22	14-5/8	2.79	6.21	3.46	9.45
1.23	14-3/4	2.84	6.33	3.52	9.62
1.24	14-7/8	2.90	6.46	3.58	9.80
1.25	15	2.95	6.58	3.64	9.98
1.26	15-1/8	3.00	6.70	3.70	10.15
1.27	15-1/4	3.06	6.83	3.76	10.33
1.28	15-3/8	3.11	6.96	3.82	10.52
1.29	15-1/2	3.17	7.08	3.88	10.70
1.30	15-5/8	3.23		3.94	10.88
1.31	15-3/4	3.28		4.00	11.07
1.32	15-13/16	3.34		4.07	11.26
1.33	15-15/16	3.40		4.13	11.45
1.34	16-1/16	3.46		4.20	11.65
1.35	16-3/16	3.52		4.26	11.84
1.36	16-5/16	3.58		4.33	12.04
1.37	16-7/16	3.64		4.40	12.24
1.38	16-9/16	3.70		4.46	12.44
1.39	16-11/16	3.76		4.53	12.64
1.40	16-13/16	3.82		4.60	12.85
1.41	16-15/16	3.89		4.67	13.06
1.42	17-1/16	3.95		4.74	13.26
1.43	17-3/16	4.02		4.81	13.48
1.44	17-1/4	4.08		4.88	13.69
1.45	17-3/8	4.15		4.96	13.90
1.46	17-1/2	4.22		5.03	14.12
1.47	17-5/8	4.28		5.10	14.34
1.48	17-3/4	4.35		5.18	14.56
1.49	17-7/8	4.42		5.25	14.79
1.50	18	4.49		5.32	15.01
1.51	18-1/8	4.56		5.40	15.24
1.52	18-1/4	4.63		5.48	15.47
1.53	18-3/8	4.70		5.55	15.70
1.54	18-1/2	4.77		5.63	15.94
1.55	18-5/8	4.84		5.71	16.17
1.56	18-3/4	4.92		5.79	16.41
1.57	18-13/16	4.99		5.87	16.65
1.58	18-15/16	5.06		5.95	16.89
1.59	19-1/16	5.14		6.03	17.14
1.60	19-3/16	5.21		6.11	17.38
1.61	19-5/16	5.29		6.20	17.63
1.62	19-7/16	5.37		6.28	17.88
1.63	19-9/16	5.44		6.36	18.13
1.64	19-11/16	5.52		6.45	18.39
1.65	19-13/16	5.60		6.53	18.65
1.66	19-15/16	5.68		6.62	18.91
1.67	20-1/16	5.76		6.70	19.17
1.68	20-3/16	5.84		6.79	19.43
1.69	20-1/4	5.92		6.88	19.70

Table 8 (Continued). Free flow through trapezoidal measuring flumes.

		Flume No. 1 (1 foot bottom width)		Flume No. 2 (2 foot bottom width)	
Feet	Inches	Measured along sloping sidewall	Measured in vertical direction	Measured along sloping sidewall	Measured in vertical direction
1.70	20-3/8	6.01		6.97	19.96
1.71	20-1/2	6.09		7.06	20.24
1.72	20-5/8	6.17		7.15	20.51
1.73	20-3/4	6.26		7.24	20.78
1.74	20-7/8	6.34		7.33	21.06
1.75	21	6.43		7.42	21.34
1.76	21-1/8	6.52		7.52	21.62
1.77	21-1/4	6.60		7.61	21.90
1.78	21-3/8	6.69		7.70	22.19
1.79	21-1/2	6.78		7.80	22.48
1.80	21-5/8	6.87		7.89	22.76
1.81	21-3/4	6.96		7.99	23.06
1.82	21-13/16	7.05		8.09	23.35
1.83	21-15/16	7.14		8.18	23.65
1.84	22-1/16	7.23		8.28	23.95
1.85	22-3/16	7.33		8.38	24.25
1.86	22-5/16	7.42		8.48	24.55
1.87	22-7/16	7.51		8.58	24.86
1.88	22-9/16	7.61		8.68	25.17
1.89	22-11/16	7.70		8.79	25.48
1.90	22-13/16			8.89	25.79
1.91	22-15/16			8.99	26.10
1.92	23-1/16			9.10	26.42
1.93	23-3/16			9.20	26.74
1.94	23-1/4			9.31	27.06
1.95	23-3/8			9.41	27.39
1.96	23-1/2			9.52	27.71
1.97	23-5/8			9.63	28.04
1.98	23-3/4			9.74	28.37
1.99	23-7/8			9.85	28.71
2.00	24			9.96	29.04
2.01	24-1/8			10.07	29.38
2.02	24-1/4			10.18	29.72
2.03	24-3/8			10.29	30.07
2.04	24-1/2			10.40	30.41
2.05	24-5/8			10.52	30.76
2.06	24-3/4			10.63	31.11
2.07	24-13/16			10.75	31.46
2.08	24-15/16			10.86	31.82
2.09	25-1/16			10.98	32.17
2.10	25-3/16			11.10	32.53
2.11	25-5/16			11.22	32.90
2.12	25-7/16			11.34	33.26
2.13	25-9/16			11.46	33.63
2.14	25-11/16			11.58	34.00
2.15	25-13/16			11.70	34.37
2.16	25-15/16			11.82	34.74
2.17	26-1/16			11.94	35.12
2.18	26-3/16			12.07	35.50
2.19	26-1/4			12.19	35.88

Table 8 (Continued). Free flow through trapezoidal measuring flumes.

Feet	Inches	Flume No. 1 (1 foot bottom width) Measured along sloping sidewall	Flume No. 1 (1 foot bottom width) Measured in vertical direction	Flume No. 2 (2 foot bottom width) Measured along sloping sidewall	Flume No. 2 (2 foot bottom width) Measured in vertical direction
2.20	26-3/8			12.32	36.26
2.21	26-1/2			12.44	36.65
2.22	26-5/8			12.57	37.04
2.23	26-3/4			12.70	37.43
2.24	26-7/8			12.82	37.82
2.25	27			12.95	38.22
2.26	27-1/8			13.08	38.62
2.27	27-1/4			13.21	39.02
2.28	27-3/8			13.35	39.42
2.29	27-1/2			13.48	39.83
2.30	27-5/8			13.61	40.24
2.31	27-3/4			13.74	40.65
2.32	27-13/16			13.88	41.06
2.33	27-15/16			14.01	41.48
2.34	28-1/16			14.15	41.90
2.35	28-3/16			14.29	42.32
2.36	28-5/16			14.43	42.74
2.37	28-7/16			14.56	43.17
2.38	28-9/16			14.70	43.60
2.39	28-11/16			14.84	44.03
2.40	28-13/16			14.98	44.46
2.41	28-15/16			15.13	44.90
2.42	29-1/16			15.27	45.34
2.43	29-3/16			15.41	45.78
2.44	29-1/4			15.56	46.23
2.45	29-3/8			15.70	46.67
2.46	29-1/2			15.85	47.12
2.47	29-5/8			15.99	47.58
2.48	29-3/4			16.14	48.03
2.49	29-7/8			16.29	48.49
2.50	30			16.44	48.95

Table 9. Flow through pipe orifices with free discharge in gallons per minute.*

Head in inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	8" Orifice	9" Orifice	10" Orifice	Head in inches
	4 in. pipe	6 in. pipe	6 in. pipe	8 in. pipe	6 in. pipe	8 in. pipe	8 in. pipe	10 in. pipe	10 in. pipe	10 in. pipe	12 in. pipe	12 in. pipe	
5	100	76	145	140	280	220	380	320			825	1100	5
5.5	104	79	153	145	293	230	394	333			860	1150	5.5
6	108	82	160	150	305	240	408	345			895	1200	6
6.5	111	85	167	155	316	250	421	358			930	1250	6.5
7	115	88	172	160	328	260	433	370			965	1300	7
7.5	119	91	179	165	339	270	446	383			1000	1350	7.5
8	122	94	185	170	350	280	458	395	600	935	1032	1400	8
8.5	125	96	190	175	361	289	471	408	617	963	1065	1440	8.5
9	128	99	195	180	372	298	483	420	633	992	1093	1480	9
9.5	130	102	200	185	383	307	495	433	650	1016	1120	1520	9.5
10	133	104	205	190	393	316	508	445	666	1040	1148	1560	10
10.5	137	107	210	195	402	324	521	458	682	1060	1172	1600	10.5
11	140	109	215	200	412	330	533	470	698	1080	1200	1635	11
11.5	143	111	220	204	421	338	545	480	713	1100	1225	1670	11.5
12	146	114	225	208	430	346	556	490	728	1120	1250	1705	12
12.5	149	116	230	212	439	354	567	500	743	1139	1277	1740	12.5
13	151	118	234	216	448	362	578	510	757	1158	1303	1775	13
13.5	154	121	239	219	457	369	589	520	771	1176	1328	1810	13.5
14	157	123	243	224	465	376	599	530	785	1194	1352	1845	14
14.5	159	126	247	227	473	383	609	540	799	1212	1376	1875	14.5
15	162	128	250	231	480	390	618	550	812	1230	1400	1905	15
15.5	164	130	254	234	488	396	627	559	825	1248	1421	1940	15.5
16	167	132	257	238	495	402	636	568	838	1266	1441	1970	16
16.5	170	134	261	241	503	408	645	577	851	1284	1460	2000	16.5
17	172	136	264	245	510	414	654	586	863	1302	1480	2030	17
17.5	175	138	268	249	517	420	663	595	875	1319	1500	2060	17.5
18	178	140	271	252	524	426	672	604	887	1336	1520	2089	18
18.5	180	142	275	256	530	432	681	612	899	1353	1540	2118	18.5
19	183	144	278	259	536	438	690	620	910	1370	1560	2146	19
19.5	185	146	282	263	542	444	699	628	922	1387	1580	2175	19.5

*Courtesy of Layne and Bowler, Inc., Memphis, Tennessee, from original calibration by Purdue University.

Not[illegible]pacities are given in nearest whole numbers.

Table 9 (Continued). Flow through pipe orifices with free discharge in gallons per minute.

Head in inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	8" Orifice	9" Orifice	10" Orifice	Head in inches
	4 in. pipe	6 in. pipe	6 in. pipe	8 in. pipe	6 in. pipe	8 in. pipe	8 in. pipe	10 in. pipe	10 in. pipe	10 in. pipe	12 in. pipe	12 in. pipe	
20	187	148	285	266	548	449	708	636	933	1404	1600	2204	20
20.5	190	150	289	270	554	455	717	643	945	1421	1620	2232	20.5
21	192	152	292	273	560	460	726	650	956	1438	1640	2260	21
21.5	195	154	295	275	566	465	735	657	968	1455	1659	2288	21.5
22	197	156	299	279	572	470	744	664	979	1471	1677	2316	22
22.5	199	158	302	282	578	475	752	671	990	1486	1695	2343	22.5
23	201	160	305	285	584	479	760	678	1001	1500	1714	2360	23
23.5	203	162	307	288	590	484	768	685	1012	1515	1732	2382	23.5
24	205	164	310	291	596	488	776	692	1022	1529	1750	2409	24
24.5	207	165	314	294	602	492	784	699	1033	1543	1767	2435	24.5
25	210	167	317	297	608	496	791	706	1043	1557	1783	2461	25
25.5	212	169	320	300	614	500	798	713	1059	1571	1799	2487	25.5
26	214	171	323	303	620	504	805	720	1064	1585	1815	2513	26
26.5	216	173	326	305	626	508	812	727	1074	1599	1830	2539	26.5
27	219	174	329	308	632	512	818	734	1084	1613	1845	2565	27
27.5	221	176	332	311	638	516	825	741	1094	1627	1860	2590	27.5
28	222	177	335	314	644	520	831	747	1104	1641	1875	2610	28
28.5	224	179	337	317	650	524	838	754	1114	1655	1890	2630	28.5
29	226	180	340	320	656	528	844	760	1124	1669	1905	2650	29
29.5	228	182	343	323	662	532	851	767	1134	1683	1920	2670	29.5
30	230	183	346	325	668	536	857	773	1143	1697	1935	2690	30
30.5	232	185	348	328	674	540	863	780	1153	1711	1950	2713	30.5
31	235	186	351	330	680	544	869	786	1162	1725	1965	2736	31
31.5	236	188	354	333	686	548	876	793	1172	1739	1980	2759	31.5
32	239	189	357	335	692	552	882	799	1181	1753	2005	2782	32
32.5	240	191	360	338	697	556	889	806	1191	1767	2020	2805	32.5
33	242	192	363	340	703	560	895	812	1200	1791	2040	2828	33
33.5	244	194	366	342	709	564	901	818	1209	1795	2050	2850	33.5
34	246	195	369	345	715	568	907	824	1218	1809	2060	2873	34
34.5	248	196	372	347	720	572	913	830	1227	1823	2075	2896	34.5
35	250	197	375	349	726	576	919	836	1235	1837	2090	2919	35
35.5	252	198	377	351	732	580	925	842	1243	1851	2100	2941	35.5

Table 9 (Continued). Flow through pipe orifices with free discharge in gallons per minute.

Head in inches	3" Orifice		4" Orifice		5" Orifice		6" Orifice		7" Orifice	8" Orifice	9" Orifice	10" Orifice	Head in inches
	4 in. pipe	6 in. pipe	6 in. pipe	8 in. pipe	6 in. pipe	8 in. pipe	8 in. pipe	10 in. pipe	10 in. pipe	10 in. pipe	12 in. pipe	12 in. pipe	
36	254	200	380	354	737	584	931	847	1251	1865	2112	2964	36
36.5	256	201	383	356	743	588	937	852	1259	1879	2124	2980	36.5
37	257	203	385	358	748	592	943	857	1266	1893	2136	3002	37
37.5	259	204	388	360	754	596	949	862	1274		2148	3024	37.5
38	260	205	390	363	759	600	955	867	1281		2160	3046	38
38.5	262	206	393	365	765	604	961	872	1289		2173	3068	38.5
39	263	208	396	367	770	608	967	877	1295		2185	3088	39
39.5	265	209	398	369	776	612	974	882	1304		2197	3110	39.5
40	266	210	401	371	781	616	979	887	1311		2210	3130	40
40.5	267	211	403	373	786	620	985	891	1319		2225	3146	40.5
41	269	212	406	375	790	624	990	896	1326		2233	3160	41
41.5	271	213	408	378	795	628	996	901	1334		2245	3179	41.5
42	272	214	411	380	800	631	1001	906	1341		2257	3199	42
42.5	274	216	413	382	805	635	1007	910	1349		2273	3219	42.5
43	275	217	415	384	810	638	1012	915	1356		2285	3230	43
43.5	277	218	418	386	815	642	1018	920	1364		2397	3250	43.5
44	278	219	420	388	820	645	1023	925	1371		2309	3263	44
44.5	280	220	422	390	924	649	1029	929	1379		2326	3280	44.5
45	281	222	425	392	828	652	1034	934	1387		2338	3298	45
45.5	283	223	427	394	832	656	1040	939	1394		2350	3316	45.5
46	284	224	429	396	837	659	1045	944	1401		2363	3334	46
46.5	285	225	432	399	842	663	1051	948	1409		2375	3351	46.5
47	287	227	434	401	847	666	1056	953	1416		2387	3368	47
47.5	289	228	437	403	851	669	1062	958	1424		2399	3389	47.5
48	290	229	440	405	855	672	1067	963	1431		2411	3405	48
48.5	292	230	442	407	859	676	1073	967	1439		2423	3426	48.5
49.5	293	231	444	409	863	679	1078	972	1446		2434	3443	49
49.5	294	232	446	411	868	683	1084	977	1454		2444	3460	49.5
50	296	234	448	413	872	686	1089	982	1461		2454	3477	50
50.5	298	235	450	415	876	690	1095	986	1469		2564	3494	50.5
51	300	236	453	417	880	693	1100	991	1476		2474	3511	51
51.5	301	237	455	419	884	697	1105	996	1484		2486	3527	51.5
52	302	238	457	421	888	700	1110	1000	1491		2498	3544	52
52.5	303	239	459	423	892	704	1115	1005	1499		2510	3560	52.5
	304	240	461	425	896	707	1120	[illegible]	1506		2522	3575	53

Table 9 (Continued). Flow through pipe orifices with free discharge in gallons per minute.

Head in inches	3" Orifice 4 in. pipe	3" Orifice 6 in. pipe	4" Orifice 6 in. pipe	4" Orifice 8 in. pipe	5" Orifice 6 in. pipe	5" Orifice 8 in. pipe	6" Orifice 8 in. pipe	6" Orifice 10 in. pipe	7" Orifice 10 in. pipe	8" Orifice 10 in. pipe	9" Orifice 12 in. pipe	10" Orifice 12 in. pipe	Head in inches
53.5	205	241	463	427	900	711	1125	1014	1513		2534	3591	53.5
54	307	243	465	429	904	714	1130	1018	1520		2545	3602	54
54.5	309	244	467	431	908	718	1135	1023	1527		2555	3618	54.5
55	310	246	469	433	912	721	1140	1027	1534		2565	3634	55
55.5	311	247	471	435	915	725	1145	1032	1541		2575	3650	55.5
56	313	248	472	437	919	727	1150	1036	1548		2586	3667	56
56.5	314	249	474	439	923	730	1155	1040	1554		2597	3684	56.5
57	315	250	476	441	927	733	1160	1044	1560		2608	3702	57
57.5	316	251	478	443	930	736	1165	1046	1567		2619	3719	57.5
58	317	252	480	445	934	739	1170	1052	1574		2630	3736	58
58.5	319	253	482	447	938	742	1175	1056	1580		2641	3752	58.5
59	320	254	485	449	942	745	1180	1060	1586		2653	3768	59
59.5	321	256	487	451	945	748	1185	1064	1592		2665	3784	59.5
60	323	257	489	453	948	751	1190	1068	1598		2676	3800	60
60.5	324	258	491	455	951	754	1195	1072					60.5
61	325	259	492	457	955	757	1200	1076					61
61.5	326	261	494	459	958	760	1205	1080					61.5
62	328	262	496	461	961	763	1209	1084					62
62.5	329	263	498	463	964	766	1214	1088					62.5
63	330	264	500	465	968	769	1218	1092					63
63.5	331	265	502	467	971	772	1223	1096					63.5
64	333	266	504	469	974	775	1227	1099					64
64.5	334	267	507	471	977	778	1232	1103					64.5
65	335	268	509	472	981	781	1236	1106					65
65.5	336	269	511	474	984	784	1241	1110					65.5
66	338	271	513	475	988	787	1245	1113					66
66.5	339	272	515	477	991	790	1250	1117					66.5
67	340	273	517	479	995	793	1254	1120					67
67.5	341	274	518	481	998	796	1259	1124					67.5
68	343	275	520	483	1002	799	1263	1127					68
68.5	344	276	521	485	1005	802	1268	1131					68.5
69	346	277	523	487	1009	805	1272	1134					69
69.5	347	278	524	489	1012	808	1276	1137					69.5
70	349	280	525	491	1016	811	1280	1140					70

Equivalent Units of Water Measurement

1 Cubic Foot = 7.48 gallons
= 62.4 pounds
= 1728 cubic inches

1 Gallon = 231 cubic inches
= 8.33 pounds

1 Million Gallons (mg) = 3.0689 acre-feet

1 Acre-inch = amount of water required to cover one acre one inch deep.
= 3,630 cubic feet
= 27,154 gallons
= 226,512 pounds

1 Acre-foot = amount of water required to cover one acre one foot deep.
= 43,560 cubic feet
= 325,850 gallons
= 12 acre-inches

1 Cubic Foot per Second (cfs) = 7.48 gallons per second
= 448.8 gallons per minute
= 50 Idaho Miner's inches

1 Idaho Miner's Inch = 9 gallons per minute

1 Gallon per Minute (gpm) = 0.00223 cubic feet per second
= 1440 gallons per day (24 hours)

1 Million Gallons per 24 hours (mgd) = 1.547 cubic feet per second.
= 695 gallons per minute

1 Cubic Foot per Second flowing for:

(a) One hour = .9917 acre-inches or approximately 1 acre-inch.
(b) 12 hours = .9917 acre-foot or approximately 1 acre-foot.
(c) 24 hours = 1.9835 acre-feet or approximately 2 acre-feet.

1 Pound per Square Inch (psi) = 2.31 feet head of water (column).

1 Foot Head of Water = 0.4335 pounds per square inch.

$$HP = \frac{Q \times H}{3960 \times E}$$

HP = Horse-power required to pump or lift water.
Q = Water to be moved in gallons per minute.
H = Head or difference in elevation water is to be lifted in feet.
E = Pumping plant efficiency (rule of thumb - 70%)

The State is truly our campus. We desire to work for all citizens of the State striving to provide the best possible educational and research information and its application through Cooperative Extension in order to provide a high quality food supply, a strong economy for the State and a quality of life desired by all.

Auttis M. Mullins
Dean, College of Agriculture
University of Idaho

TEACHING RESEARCH SERVICE

SERVING THE STATE

This is the three-fold charge of the College of Agriculture at your state Land-Grant institution, the University of Idaho. To fulfill this charge, the College extends its faculty and resources to all parts of the state.

Service ... The Cooperative Extension Service has active programs in 42 of Idaho's 44 counties. Current organizaton places major emphasis on county office contact and multi-county specialists to better serve all the people. These College of Agriculture faculty members are supported cooperatively by federal, state and county funding to work with agriculture, home economics, youth and community development.

Research ... Agricultural Research scientists are located at the campus in Moscow, at Research and Extension Centers near Aberdeen, Caldwell, Parma, Sandpoint, Tetonia, Twin Falls and at the U.S. Sheep Experiment Station, Dubois and the USDA/ARS Soil and Water Laboratory at Kimberly. Their work includes research on every major agricultural program in Idaho and on economic and community development activities that apply to the state as a whole.

Teaching ... Centers of College of Agriculture teaching are the University classrooms and laboratories where agriculture students can earn bachelor of science degrees in any of 20 major fields, or work for master's and Ph.D. degrees in their specialties. And beyond these are the variety of workshops and training sessions developed throughout the state for adults and youth by College of Agriculture faculty.