EC 1369 • Reprinted September 1994

Estimating Water Flow Rates

W.L. Trimmer

Increasing competition for water resources has made water conservation a high priority. Measuring the flow rate of water is the first step to good water management. All water right holders in the State of Oregon must be able to measure the flow rate of the water being diverted.

If a flow meter, flume, or weir isn't available, there are several methods available to estimate flow rate that you can do with available tools like stopwatches, rulers, and buckets.

The usual unit measuring flow rate for irrigation water rights is a cubic foot per second (cfs). This is water flowing through a cross-sectional area of 1 ft^2 at a velocity of 1 foot per second, and it's sometimes called a second-foot.

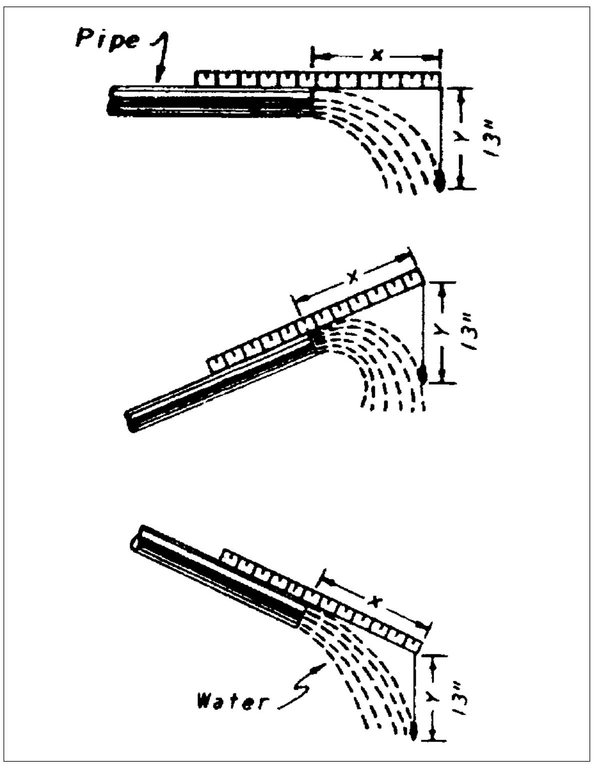

Figure 1.—Measuring horizontal distance (X) of a pipe flowing full with vertical drop Y=13".

A common diversion rate in eastern Oregon might be 1 cfs/40 acres. Here are some handy conversions (see page 4 for others): 1 cfs is about 450 gallons per minute; 1 cfs is about 1 acre-inch per hour; 1 cfs is about 2 acre-feet per day.

Propeller flow meters, weirs, and flumes provide the most accurate measures of flow rate, but in many instances you must make an estimate without them. Here are four methods to estimate irrigation diversions.

Method 1
Discharge from a pipe

If water can freely drop from a pipe, you can estimate the flow rate by measuring length with nothing more than a carpenter's rule. When the pipe is flowing full, place the rule as shown in Figure 1 and measure a horizontal distance when the vertical drop Y = 13 inches.

Find the proper pipe size in Table 1, and the discharge is in gallons per minute (gpm). If the pipe isn't level, use a plumb bob to measure the vertical drop Y.

Example 1. An 8-inch-diameter pipe is flowing full, and the horizontal distance X is measured to be 20 inches. From Table 1, the flow rate is 1,005 gpm.

If the pipe is flowing only partially full, find the ratio of the unfilled portion of pipe to the diameter of the pipe to estimate flow rate in gallons per minute, as shown in Table 2.

Example 2. A 10-inch-diameter pipe is flowing only partially full. The measured distance U is 2 inches. The ratio U ÷ D in Table 2 is 2 ÷ 10 = 0.2. The flow rate is 825 gpm.

Walter L. Trimmer, former Extension irrigation specialist, Oregon State University.

OREGON STATE UNIVERSITY EXTENSION SERVICE

Table 1.—Discharge (gallons per minute) from pipes flowing full, with vertical drop Y = 13" and variable horizontal distances X.

Pipe size		Horizontal distance X (in inches)												
Inside diam.	Area (sq in)	12	14	16	18	20	22	24	26	28	30	32	34	36
2.0	3.14	38	44	50	57	63	69	75	82	88	94	100	107	113
2.5	4.91	59	69	79	88	98	108	118	128	137	147	157	167	177
3.0	7.07	85	99	113	127	141	156	170	184	198	212	226	240	255
4.0	12.57	151	176	201	226	251	277	302	327	352	377	402	427	453
5.0	19.64	236	275	314	354	393	432	471	511	550	589	628	668	707
6.0	28.27	339	396	452	509	565	622	678	735	792	848	905	961	1013
7.0	38.48	462	539	616	693	770	847	924	1000	1077	1154	1231	1308	1385
8.0	50.27	603	704	804	905	1005	1106	1206	1307	1408	1508	1609	1709	1810
9.0	63.62	763	891	1018	1145	1272	1400	1527	1654	1781	1909	2036	2163	2290
10.0	78.54	942	1100	1257	1414	1471	1728	1885	2042	2199	2356	2513	2670	2827
11.0	95.03	1140	1330	1520	1711	1901	2091	2281	2471	2661	2851	3041	3231	3421
12.0	113.10	1357	1583	1809	2036	2262	2488	2714	2941	3167	3393	3619	3845	4072

$Q = \frac{3.61\,AX}{\sqrt{Y}}$, where:
A = Cross-sectional area of discharge pipe in square inches
X = Horizontal distance in inches
Y = Vertical distance in inches

Table 2.—An approximate method of estimating discharge from pipes flowing partially full.

	Inside diameter of pipe = D in inches				
$\frac{U}{D}$	4	6	8	10	12
0.1	142	334	379	912	1310
0.2	128	302	524	825	1185
0.3	112	264	457	720	1034
0.4	94	222	384	605	868
0.5	75	176	305	480	689
0.6	55	130	226	355	510
0.7	37	88	152	240	345
0.8	21	49	85	134	194
0.9	8	17	30	52	74
1.0	0	0	0	0	0

Method 2
Average cross section

The flow rate in a stream or channel can be measured as shown in Figure 2 by timing a float.

Measure off a 50- to 100-foot section of the stream. Flow rate is equal to the cross-sectional area times the velocity. Multiply the average cross-sectional area times the average stream velocity in fps to get the rate of flow in cfs.

Estimating the cross-sectional area is the hard part. A simple way to do it is to measure the bottom width of the channel and the top width, then average the two. Multiply this average times the depth of the water.

Measure the widths and depths in fractions of feet (for example, 1 foot 6 inches = 1.5 feet).

Example 3. A ditch is 10 feet wide at the top and about 6 feet across the bottom; the water is 3 feet deep. A float traveled 100 feet in 33 seconds. This is our basic formula:

Flow rate = area x velocity x roughness factor

We'll use four steps to get our answer:

Step 1—Area

= average width x average depth

$$= \frac{(10 + 6)}{2} \times 3 = 24 \text{ ft}^2$$

Step 2—Velocity

= distance divided by time

$$= \frac{100}{33} = 3 \text{ feet per second}$$

Step 3—Roughness factor

= 0.8 (because the water near the edge moves slower than the float)

Step 4—Flow rate

= area x velocity x roughness factor

= 24 ft^2 x 3 feet per second x 0.8

= 58 ft^3 per second (rounded off)

This method is the least accurate of the four we're discussing, and it can usually measure water in a natural stream only within $\pm$ 20 percent. A concrete channel can be measured to $\pm$ 10 percent accuracy.

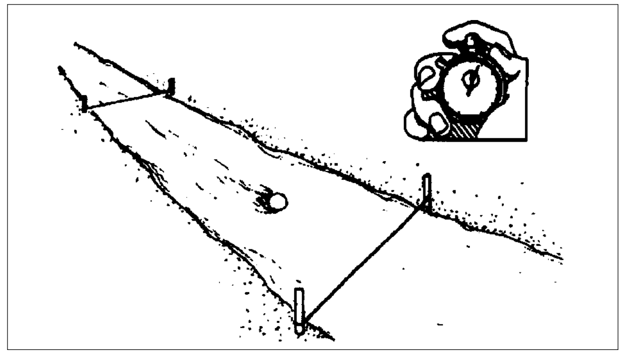

Figure 2.—Measuring the flow rate in a stream or channel by timing a float.

Method 3
Timed volume

Depending on your type of system, use a bucket and a stopwatch to measure flow. As shown in Figure 3 for a siphon tube, time a 1- to 5-gallon bucket as it's filled to get the discharge in gpm. You can use a flexible rubber hose on a sprinkler.

Example 4. A hose is placed over the nozzle of a sprinkler and water is caught in a 5-gallon bucket. A stopwatch found the time to fill the bucket was 47 seconds.

Flow rate = volume/time

$$= \frac{5 \text{ gallons}}{47 \text{ seconds}} \times \frac{60 \text{ seconds}}{1 \text{ minute}}$$

= 6.4 gpm

Multiply the number of tubes or sprinklers by the flow rate of an individual tube or sprinkler to get the total. You can use the rule of thumb (450 gpm = 1 cfs) to convert to the proper units.

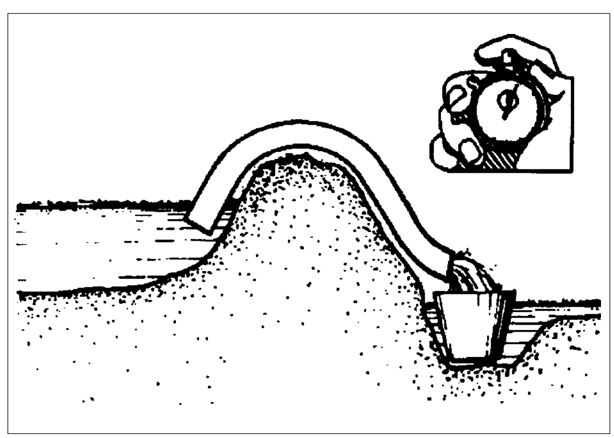

Figure 3.—Timing a bucket as it's filled to get the discharge in gpm.

Table 3.—Capacities (gallons per minute) of certain diameter nozzles.

Pressure (psi)	Nozzle size (in inches) 3/32	1/8	9/64	5/32	11/64	3/16	13/64	7/32
35	1.50	2.70	3.40	4.16	5.02	5.97	7.08	8.26
40	1.60	2.90	3.63	4.45	5.37	6.41	7.60	8.87
45	1.70	3.20	3.84	4.72	5.70	6.81	8.07	9.41
50	1.80	3.10	4.04	4.98	6.01	7.18	8.49	9.88
55	1.90	3.30	4.22	5.22	6.30	7.51	8.87	10.30

Method 4
Pressure and nozzle size

A way to estimate diversions pumped into a sprinkler system is to measure the pressure of a few sprinklers as shown in Figure 4. Find the nozzle size stamped on the side of the nozzle and use Table 3 to find the flow rate.

Example 5. The sprinkler in example 4 is marked as a $\frac{3}{16}$-inch diameter nozzle, and a Pitot pressure gauge reads 40 psi. From Table 3, the flow rate is 6.41 gpm. There are 30 sprinklers, so the total flow rate is 190 gpm.

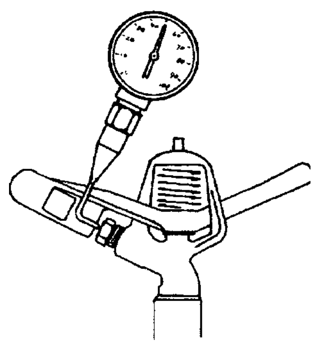

Figure 4.—Check pressure at sprinklers when they're in operation by inserting a Pitot tube into the stream spraying from the nozzle. Read the highest pressure indicated.

Try to measure several sprinklers near the center of the field. The pressure differences caused by friction loss down the laterals and around the field and elevation changes, plus nozzle wear, limit the accuracy of this method to about $\pm$ 10 percent.

Flow control nozzles and nozzles meant for low pressure with orifices that aren't round create some difficulties. Use the bucket and stopwatch method in this case. If you're using a center pivot, find out if your dealer can provide you with a chart of flow rates vs. the pivot pressure for your machine.

List of equivalents

1 acre-foot	=	325,851 gallons
1 acre-foot	=	43,560 cubic feet
0.001 acre-foot	=	325.9 gallons
1 acre-inch	=	27,154 gallons
1 acre-inch	=	3,360 cubic feet
1 cubic foot	=	7.48 gallons
1 cubic foot	=	0.0283 cubic meters
450 gallons/minute	=	1 acre-inch in 1 hour
1 gallon/minute	=	0.06309 liter/second

Extension Service, Oregon State University, Corvallis, O.E. Smith, director. This publication was produced and distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. Extension work is a cooperative program of Oregon State University, the U.S. Department of Agriculture, and Oregon counties.

Oregon State University Extension Service offers educational programs, activities, and materials—*without regard to race, color, national origin, sex, age, or disability*—as required by Title VI of the Civil Rights Act of 1964, Title IX of the Education Amendments of 1972, and Section 504 of the Rehabilitation Act of 1973. Oregon State University Extension Service is an Equal Opportunity Employer.