Water Supply FACTSHEET

British Columbia
Ministry of Agriculture and Lands

Order No. 501.400-1
January 2006

MEASURING WATER FLOW

Along Streams, From Pipes, and From Nozzles

Introduction

Probably the most important point to consider before designing or installing an irrigation or livestock watering system is to determine the amount of available water. For existing systems, it may be necessary to determine the quantity of water flowing from pipes or nozzles. Use one of the following eight methods to estimate flows. The accuracy of any method is dependent on closely following the steps.

Method 1: Stream Flow Estimate

Stream Flow Method. This method times a floating object over a set distance and a given cross-sectional area of a stream to estimate stream flow.

1. Locate a section of the stream with a uniform fall, depth, and width.
Stream Length = a minimum of 10 feet - longer for more accuracy

2. Calculate the cross-sectional area of the stream:
Area = average depth of stream flow x average width of stream flow
- average the depth by taking from 2 to 10 depths across the stream width

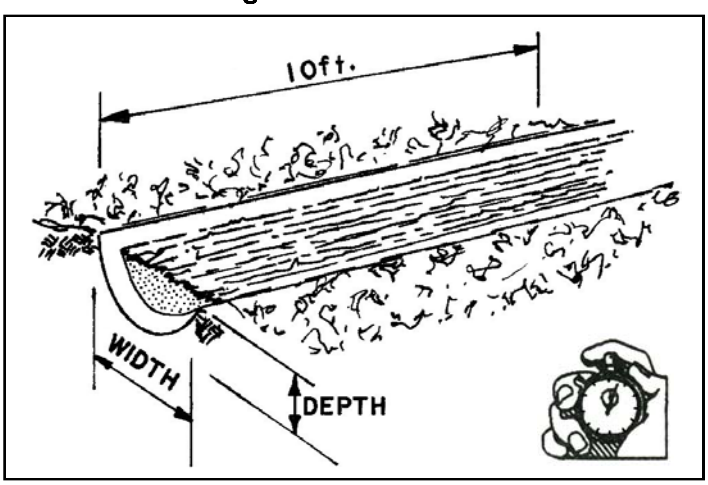
3. Calculate the average speed of flow:
- drop a wood chip into the stream
- time the interval it takes the chip to travel 10 feet
- repeat three times and average the result

$$\textbf{Average speed of flow (ft per sec)} = \frac{\textbf{test section (ft)}}{\textbf{avg. time (seconds)}} \times \textbf{roughness factor}$$

- roughness factors: 0.6 for rough, rocky stream beds: 0.85 for muddy, smooth

4. Calculate the flow in US gallons per minute (USgpm):
Flow (USgpm) = Area (#2 above) **x Avg. Speed** (#3 above) **x 448.8** (conversion)

Stream Flow Diagram



Stream Flow Example – Rough & Rocky

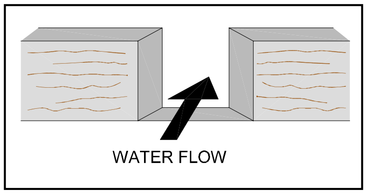
Avg. Stream Width = 1 foot
Avg. Stream Depth = $^1/_2$ foot
Speed to travel 10 ft = 5 sec

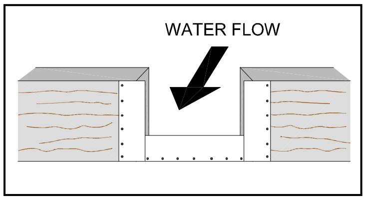
Average cross-sectional area $= 1 \text{ ft} \times {}^1/_2 \text{ ft.}$
$= {}^1/_2 \text{ ft}^2$

Average speed of flow $= \frac{0.6 \times 10 \text{ ft.}}{5 \text{ sec}}$
$= 1.2$ ft per sec

Stream Flow $= {}^1/_2 \text{ ft}^2 \times 1.2 \text{ ft/sec} \times 448.8$
= **270 USgpm**

Method 2: Stream Flow Using a Weir





Weir Method. The flow of a stream can be estimated by constructing a rectangular weir measuring device across the stream (refer to Factsheet #810.210-12 "*Changes in and About a Stream*" prior to installing). This weir is usually used where it can be left in place for numerous readings over a long period of time. The following points are important for construction and use to ensure accurate results.

1. Construct a bulkhead similar to that shown in the Weir Diagram. The crest of the notch must be level, vertical (no lean) and accurate in length to within 1/8 of an inch. The crest should be above the bottom of the pool 3x the depth of water flowing over the weir crest. The sides of the pond should be a distance from the sides of the notch not less than 2x the depth of water passing over the weir crest. The centerline of the weir must be parallel to the direction of water flow.

   The corners of the notch must be square, thus making the sides truly vertical. The downstream 3 sides of the notch should be beveled to 45^0. Alternately, a sheet metal strip can be nailed and cut out to ensure sharp edges.

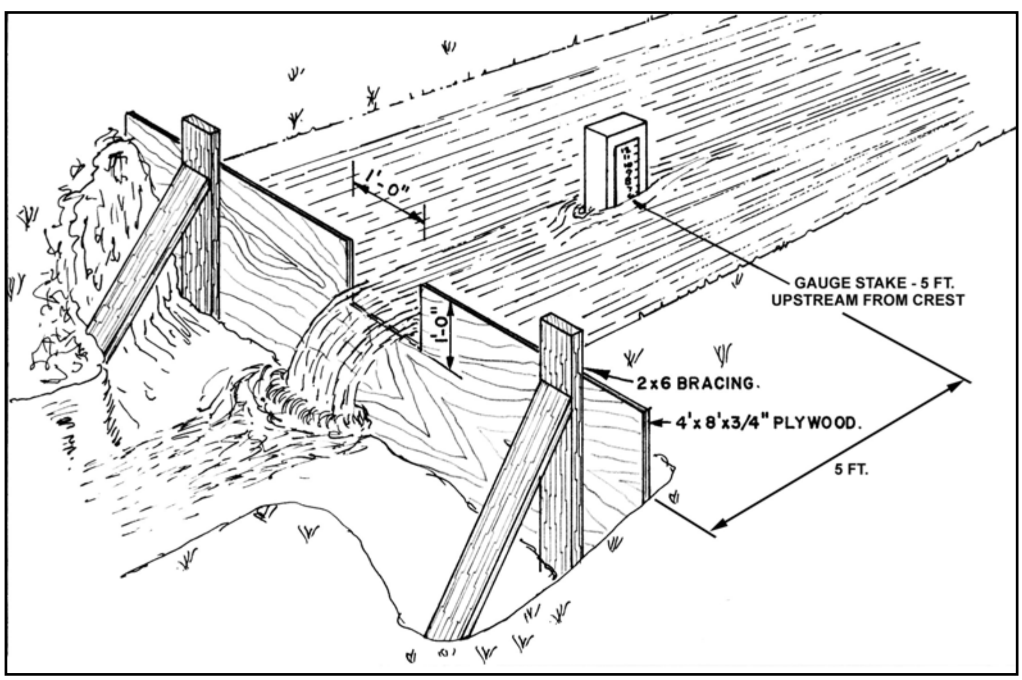
2. The velocity of the water approaching the weir should not exceed ½ foot per second, otherwise the true flow will be higher than what will be indicated by the **Weir Table**, next page.

3. The nappe (the sheet of water flowing over the weir) should free fall and not adhere to the weir.

4. The rate of water flow is found indirectly by measuring the height of the upstream water above the crest of the weir. As the water slopes down noticeably as it approaches the weir, the head must be measured several feet upstream. A permanent gauge can be made by fastening a 12-inch ruler to a post that has been driven into the stream bed five feet from the weir. The "0" reading must be at the same level as the weir crest.

For discharge rates greater than 1300 USgpm the crest length can be increased to 2 or 3 feet and the values in the tables doubled or tripled to give the approximate flow.

Weir Diagram (for flows from 50 – 1,300 USgpm)



Weir Table

DISCHARGE FROM A RECTANGULAR WEIR WITH A ONE-FOOT-WIDE CREST *			
Gauge Reading (inch)	**Discharge * (USgpm)**	**Gauge Reading (inch)**	**Discharge (USgpm)**
0.25	8	6.25	530
0.50	12	6.50	560
0.75	22	6.75	590
1.00	37	7.00	630
1.25	51	7.25	660
1.50	65	7.50	690
1.75	79	7.75	725
2.00	98	8.00	760
2.25	120	8.25	800
2.50	140	8.50	835
2.75	160	8.75	865
3.00	180	9.00	900
3.25	200	9.25	940
3.50	225	9.50	975
3.75	250	9.75	1,010
4.00	280	10.00	1,055
4.25	300	10.25	1,075
4.50	320	10.50	1,130
4.75	355	10.75	1,170
5.00	380	11.00	1,200
5.25	415	11.25	1,250
5.50	445	11.50	1,290
5.75	470	11.75	1,330
6.00	500	12.00	1,375

* Where the depth of water flowing over the weir is less than 2 3/8 inches (see dotted line), the nappe of the water may tend to adhere to the downstream face of the weir, reducing the accuracy of measurements. However, for these low flows (120 USgpm and less), the approximate discharges given by this Table can still be useful.

Weir Example

Weir width = 1 foot

Gauge reading = 3 $^1/_2$ inch

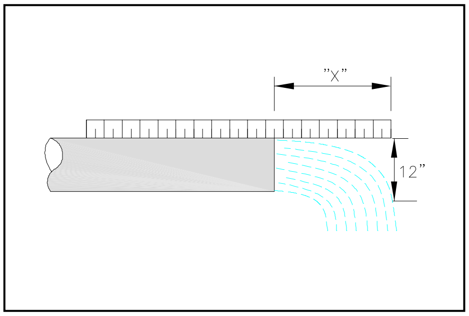
From the **Weir Table** above, the flow passing over the weir would be **225 USgpm**.

Method 3: Full Pipe

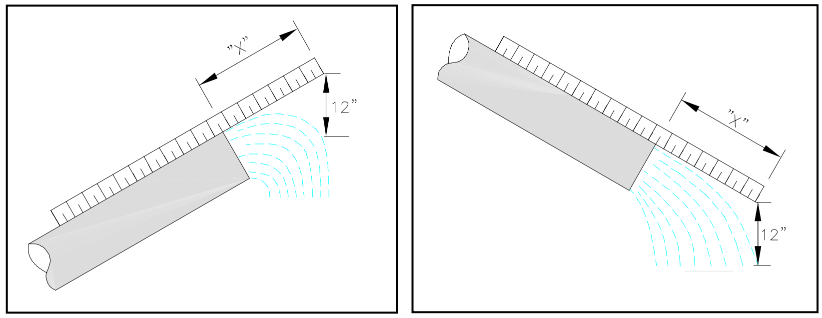
Full Pipe Method. This method is used to estimate the flow in ***pipes flowing full*** (pipe may be level or inclined).

1. For <u>level pipes</u>, place a carpenters square on top of pipe so that the water strikes the vertical scale at 12 inches and measure the horizontal distance ***X*** (in).
2. For <u>inclined pipes</u>, lay a yardstick along the pipe surface so the “plumb” distance to the water is 12 inches and measure the inclined distance ***X*** (in).
3. Using the **Full Pipe Table**, read the flow for the size of pipe used.

Full Pipe Diagram



Horizontal Pipe (Full)



Inclined Pipe (Full)

Full Pipe Table

ESTIMATE OF FULL PIPE FLOW IN USGPM

Nominal Pipe Size (inch)	Measured Distance *X* with a Vertical Drop of 12 inches *										
	4 in	**6 in**	**8 in**	**10 in**	**12 in**	**14 in**	**16 in**	**18 in**	**20 in**	**22 in**	**24 in**
1	3 1/2	5	7	8 1/2	10	12	13 1/2	15	16 1/2	18	20
1 1/2	8	11	15	19	22	26	30	34	37	40	45
2	14	20	27	34	40	47	55	60	68	74	80
2 1/2	21	32	42	53	64	75	85	95	106	116	126
3	29	45	60	72	87	100	116	130	144	160	173
4	52	78	102	128	153	180	203	230	253	280	305
5	82	120	162	200	240	280	320	355	400	440	470
6	117	177	232	290	345	400	460	520	575	640	690
7	157	235	310	390	470	550	625	705	780	850	940
8	205	305	410	510	615	710	820	920	1020	1110	1220
10	327	500	650	805	980	1120	1310	1500	1620	1770	1950
12	460	690	925	1160	1410	1620	1850	2100	2300	2500	2700

* If a 6 inch vertical drop is used, multiply the table discharge rates by 1.4

Full Pipe Example

Pipe size (nominal) = 4 inches
Vertical/plumb distance = 12 inches (set)
Measured distance ***X*** = 16 inches

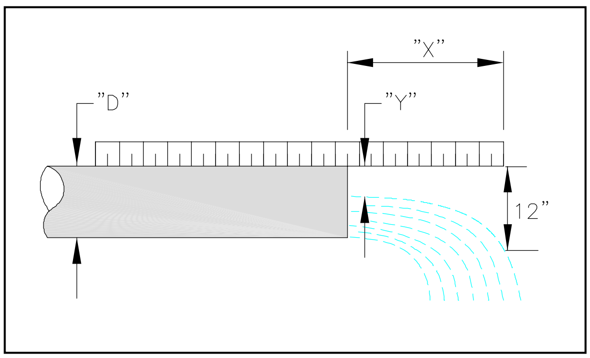
From the **Full Pipe Table** the flow in the pipe would be approximately **203 USgpm**.

Method 4: Partially Full Pipe

Partially Full Pipe Method. This method is used to estimate the flow in ***pipes flowing partially full***. Similar measurements to the **Full Pipe Method** are taken and the **Full Pipe Table** values are reduced by a factor calculated for the particular pipe situation.

1. For level pipes, place a carpenter square on top of the pipe so that the water strikes the vertical scale at 12 inches and measure the horizontal distance ***X*** (in).
2. For inclined pipes, lay a yardstick along the pipe surface so the "plumb" distance to the water is 12 inches and measure the inclined distance ***X*** (in).
3. Measure the 'empty' portion at the end of the pipe ***Y*** (in).
4. Select the ***Effective Area Factor*** from Table below using the value for the ***Y/D Ratio*** (the ratio of 'empty' portion to diameter of the pipe being measured).
5. Using **Full Pipe Table**, page 4, read the flow for ***X*** and the pipe size.
6. **Pipe Flow (USgpm) = Full Pipe Table Flow Rate x *Effective Area Factor*.**

Partially Full Pipe Diagram



Partially Full Pipe Factor Table

EFFECTIVE AREA FACTOR			
Y/D Ratio	**Factor**	**Y/D Ratio**	**Factor**
0.05	0.981	0.55	0.436
0.10	0.948	0.60	0.373
0.15	0.905	0.65	0.312
0.20	0.858	0.70	0.253
0.25	0.805	0.75	0.195
0.30	0.747	0.80	0.142
0.35	0.688	0.85	0.095
0.40	0.627	0.90	0.052
0.45	0.564	0.95	0.019
0.50	0.500	1.00	0.000

Partially Full Pipe Example (using the same pipe size as Full Pipe Example)

Pipe size = 4 inches
Vertical distance = 12 inches (set)
Measured distance ***X*** = 16 inches
The measured distance for the 'empty' portion ***Y*** = 1 inch

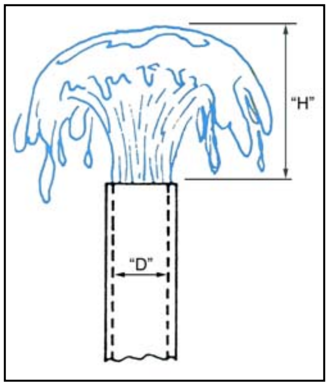
The ***Y/D Ratio*** = 1 inch / 4 inch = 0.25

From **Factor Table**, above, the ***Effective Area Factor*** for a Ratio of 0.25 = 0.805

From **Full PipeTable**, page 4, the pipe flow would be 203 USgpm ***if full***.

The Partially Full Pipe Flow Rate = 203 USgpm x 0.805
= **163 USgpm**

Method 5: Vertical Pipe



Vertical Pipe Method. This method is used to give an approximation of the flow in ***vertical pipes flowing full*** that are from 2 to 10 inches diameter.

1. Measure the height of the water above the end of the pipe, ***H*** (in).
2. Using the pipe nominal size, ***D***, select the flow rate from the Table

Vertical Pipe Diagram

Vertical Pipe Table

APPROXIMATE FLOW RATE FROM VERTICAL PIPES IN USGPM *								
Height (H) (in)	**Nominal Diameter of Pipe (D)**							
	2 inch	**3 inch[2]**	**4 inch[2]**	**5 inch[2]**	**6 inch[2]**	**7 inch[2]**	**8 inch[2]**	**10 inch**
3	35	75	135	215	310	425	570	950
3.5	38	85	150	240	340	465	625	1055
4	41	90	160	250	370	505	690	1115
4.5	44	100	170	270	395	540	735	1200
5	47	105	180	285	420	575	780	1280
5.5	49	110	190	300	445	605	825	1350
6	52	115	200	315	470	640	870	1415
6.5	54	120	210	330	490	665	915	1475
7	57	125	220	345	510	700	950	1530
8	61	135	235	370	550	750	1025	1640
9	65	145	250	395	585	800	1095	1740
10	69	155	265	420	620	850	1155	1840
12	76	170	295	465	685	935	1275	2010
14	83	185	320	500	740	1020	1380	2170
16	89	195	340	540	795	1090	1480	2320
18	95	210	365	575	845	1160	1560	2460
20	101	220	385	605	890	1225	1645	2600
25	113	250	435	680	1000	1375	1840	2900
30	124	275	475	745	1095	1505	2010	3180
35	135	300	515	810	1175	1630	2160	3420

* from US Geological Survey [2] these columns rounded to the nearest 5 gallons

Vertical Pipe Example

Vertical distance, ***H*** = 10 inches
Pipe size, ***D*** = 6 inches
Approximate pipe flow = **620 USgpm**

Method 6: Corrugated Metal Pipe

Corrugated Metal Pipe Method. This method is used to estimate the flow in corrugated metal pipes ***flowing full*** by the pipe diameter and the grade (slope) of the pipe.

1. Measure the pipe diameter (in).
2. Measure the grade the pipe is on as a percentage:
   e.g., a 1 inch fall in a 20 foot pipe as a percentage is:
   $\frac{1/12 \text{ ft}}{20 \text{ ft}} \times 100 = 0.4$ percent grade
3. Use the **Corrugated Metal Pipe Table** for the flow in cubic feet per second (cfs).
   Conversions:
   1 cfs = 448.83 USgpm
   1 cfs = 373.2 Imperial gpm
   1 cfs = 28.3 litres per sec
   1 cfs = 0.0283 cubic metres per second

Corrugated Metal Pipe Table

PIPE DISCHARGE (cubic feet per second - cfs)

Pipe Dia. (in)	Pipe Grade (%)														
	0.05	0.08	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0
6	--	--	--	--	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5
8	--	0.2	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.0
10	--	0.3	0.4	0.6	0.7	0.8	0.9	1.0	1.2	1.3	1.5	1.6	1.7	1.8	1.9
12	0.4	0.6	0.7	1.0	1.3	1.5	1.7	1.9	2.1	2.3	2.4	2.5	2.6	2.6	2.6
15	0.9	1.1	1.3	2.0	2.4	2.8	3.0	3.3	3.7	4.0	4.3	4.4	4.5	4.6	4.6
18	1.4	1.8	2.1	3.1	3.9	4.4	4.9	5.4	6.1	6.5	6.8	7.0	7.1	7.1	7.1
21	2.2	2.8	3.3	4.7	5.9	6.8	7.5	8.1	9.0	9.6	10	10	10	11	11
24	3.1	4.0	4.7	6.8	8.3	9.5	10	11	13	14	14	15	15	15	15
30	5.6	7.1	8.0	12	15	17	19	21	23	24	25	25	26	26	26
36	9.0	11	12	19	25	28	31	33	37	39	40	40	40	40	40

Corrugated Metal Pipe Example

Pipe size = 18 inch
Pipe grade = 3 inch in a 50 foot length pipe
= $\frac{3/12 \text{ ft}}{50 \text{ ft}} \times 100 = 0.5$
Pipe flow rate = **4.9 cfs**
= 4.9 x 448.83
= **2200 USgpm**

For partially full pipes, an approximation of the flow can be estimated by multiplying the above Table full pipe rates by the ***Effective Area Factor***, page 5 (the ratio of 'empty' portion to full portion of the pipe).

Method 7: Timed Volume

Timed Volume Method. This method is used for estimating the flow from:

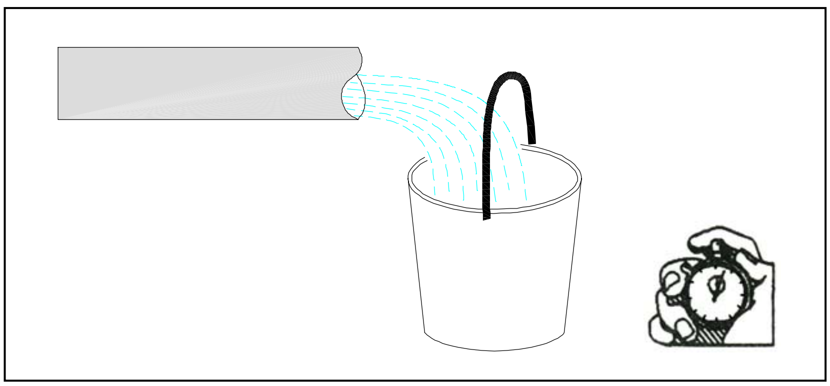
- streams, where all the flow goes over a fall
- pipes, flowing full or partially full
- nozzles

where the flow can be captured in a container.

The time for a known volume of water to be captured in a container such as a bucket is recorded and converted into a flow rate. The larger the container the more accurate the result, but a "5 gallon" bucket may work well for low flow rates. Mark the level on the bucket indicating the volume which will be captured (use a container of known volume to do this). If available use a stop watch for timing. Take the average of three readings.

1. At the water discharge point or stream fall, move the bucket under the flow and at the same time start the stop watch.
2. Stop the watch when the water reaches the marked level on the bucket and note the time.
3. Repeat two more times and average the three readings of time to fill the container.
4. Convert the readings into a flow rate: **Flow rate = volume / time**

Timed Volume Diagram



Timed Volume Example

A bucket marked at 4 Imperial gallons is used.

Three readings of water flow averaged 10 seconds to fill the bucket to the mark.

Imperial gpm Flow Rate = 4 Igal / 10 sec x 60 sec / min
= **24 Igpm**

If needed, convert to USgpm by multiplying the Imperial rate by 1.2 :

USgpm Flow Rate conversion = 24 Igpm x 1.2
= **28.8 USgpm**

Method 8: Nozzle Volume

Nozzle Method. This method can be used for flow from small nozzles knowing the nozzle size and the pressure ***at the nozzle***. Use the stem-end of a steel drill bit to confirm the nozzle size. Measure the pressure as shown in the **Nozzle Photo** then determine the nozzle flow rate using the **Nozzle Table**.

Nozzle Photo

Nozzle Table

FLOW RATE OF SELECTED NOZZLES IN USGPM *

Nozzle Size (in)	Pressure at Nozzle								
	20 psi	25 psi	30 psi	35 psi	40 psi	45 psi	50 psi	55 psi	60 psi
1/16	--	0.55	0.60	0.65	0.70	0.74	0.78	0.82	0.86
5/64	--	0.80	0.87	0.95	1.03	1.10	1.16	1.21	1.26
3/32	1.07	1.21	1.34	1.45	1.56	1.66	1.76	1.85	1.94
7/64	1.54	1.73	1.91	2.07	2.22	2.36	2.50	2.62	2.75
1/8	2.03	2.25	2.47	2.68	2.87	3.05	3.22	3.38	3.53
9/64	2.53	2.88	3.15	3.40	3.64	3.86	4.07	4.27	4.46
5/32	3.08	3.52	3.85	4.16	4.45	4.72	4.98	5.22	5.45
11/64	3.62	4.24	4.64	5.02	5.37	5.70	6.01	6.30	6.57
3/16	--	5.00	5.50	5.96	6.38	6.78	7.16	7.52	7.85
13/64	--	5.90	6.50	7.05	7.55	8.00	8.45	8.85	9.25
7/32	--	6.85	7.55	8.20	8.80	9.35	9.90	10.40	10.75
15/64	--	7.8	8.5	9.2	9.8	10.4	11.0	11.5	12.0
1/4	--	8.8	9.6	10.4	11.1	11.8	12.4	13.1	13.6
17/64	--	9.9	10.8	11.7	12.5	13.3	14.0	14.7	15.3
9/32	--	11.2	12.2	13.2	14.1	15.0	15.8	16.5	17.3
19/64	--	12.4	13.6	14.7	15.7	16.6	17.5	18.4	19.2
5/16	--	13.8	15.1	16.3	17.4	18.4	19.4	20.4	21.3

* from Nelson Irrigation Co. for L20W sprinkler (1/16 to 7/64 nozzles); F32 (1/8 to 7/32 nozzles) and F43 (15/64 to 5/16 nozzles) allow for up to +/- 2% variation from these table values for the effect of other sprinkler types, etc, on nozzle flow

Nozzle Example

A nozzle that is identified as 11/64 inch was confirmed with a 11/64 inch drill bit.
The pressure at the nozzle was measured to be 50 psi.
From the Nozzle Table, the flow rate is 6.01 USgpm – round off and use **6 USgpm**.

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