The Evolution of the Drip Irrigation System

In April of 2015 as California entered the 4th year of a crippling drought, Governor Edmund G Brown Jr issued an executive order mandating statewide water use restrictions. This action marked the first time that Californian's were faced with mandatory water use restrictions The Governor called for a 25% reduction in urban water use and tasked the State Water Resources Control Board with implementing goals and guidelines with a continuous monitoring responsibility. The Board was charged with developing water use reduction goals for over 400 water providers in the state. In May, the Board issued final goals for each district. Among the goals for water use reduction were a variety of provisions for water use that extended to landscape irrigation. Specifically the ordinances proposed the prohibition of conventional irrigation on new homes. All landscaping for new home construction would be limited to drip-micro irrigation. Spray heads and rotors would be eliminated from all new landscapes under the new regulations.

More recently, the State Department of Water Resources updated the Water Efficient Landscape Ordinance and proposed similar significant changes in landscape irrigation. Their initial recommendations would have eliminated traditional spray type sprinklers from the landscape. Specifically, any sprinkler with an application rate in excess of one inch per hour would not have been allowed in any new or renovated landscape that exceeded 500 square feet. After much wrangling with the Industry, the Department relented and struck the provision from the ordinance and the SWRCB deferred to the State Building Standards Commission on landscape irrigation standards

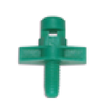
Through all of this change, one thing is clear; the shift away from traditional irrigation to drip/micro is occurring at a remarkable pace. And the trend won't be limited to California, it will likely see a parallel evolution in Texas! This dramatic shift forces a closer look at the installation and management techniques that are currently being employed for drip micro irrigation.

The heart of the drip micro irrigation system – the emission device

Point Source emitter types

2 gph pressure compensating emitter

2 gph non pressure compensating emitter



3 gph fogger

Micro sprinkler 9-27 gph stake or riser mounted

15 gph (0.25 gpm) pressure compensating bubbler

10 – 20 gph Fan jet (180 degree) with 24" stake

Much like a traditional spray or rotor irrigation system the drip/micro irrigation system is built around the sprinkler which in the case of drip is known as an emission device. Emission devices are characterized as requiring low pressure and having low flow. The working pressure ranges for drip micro irrigation systems range from 10 psi to 40 psi which is at the limit of the maximum pressure for low density polyethylene tubing and fittings. The pressure requirements for the devices varies with the type of device being used. By far the most common type of irrigation system is the point source system which utilizes individual drip emitters, bubblers, foggers, micro sprays, or mini-sprinklers fed by ½" low density polyethylene tubing .

An important distinguishing characteristic of these devices is the flow rating in gallons per hour as opposed to gallons per minute. Flow can be simply converted when planning systems by remembering that 60 gallons per hour equals 1 gallon per minute. A 480 gallon per hour system would have a flow of 8 gallons per minute (480/60 = 8).

Drip emitters and bubblers are available in a pressure compensating version. The pressure compensating feature insures that device flow will be consistent regardless of elevation changes and changes in lateral line pressures due to variations in flow. These devices are designed to regulate flow at lateral pressures as high as 50 psi though most tubing and fittings begin to reach their pressure rating limits at 40 psi. <u>It is important to always use pressure compensating emitters when constructing a drip system.</u> Often overlooked are the minimum pressure requirements for these devices which is 10 psi. At pressures below 10 psi, the emitters are in the "flush" mode which is designed to purge debris from the emitter. At these low pressures, the emitters will not regulate flow so it is important to verify that this minimum pressure exists on point source drip systems with pressure compensating drip emitters.

Turf irrigation systems project a spray or stream into the air and this water lands on the landscape. These spray and rotary type sprinklers have higher pressure requirements than drip/micro due the greater spacing intervals between individual sprinklers. The flows of each sprinkler tend to be higher than emission devices because of the physics required to project the water through the air. The higher the pressure and the greater the flow for the same spacing interval the higher the rate of application which is called the precipitation rate.

If the application rate (precipitation rate) exceeds the intake rate of the soil runoff will occur. The likelihood of irrigation runoff is higher with rotary and spray systems than with drip because the application rates tend to be higher. The rate at which the soil can take in water is known as the infiltration or intake rate.

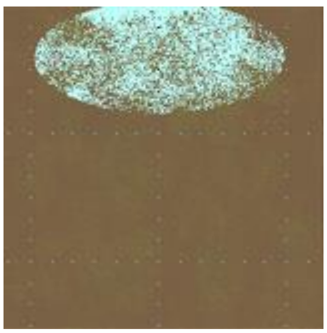
Soil Texture	**AW** Available water in/in	Infiltration in/hr
Coarse		
Sand/Fine Sand	0.05	1.50 - 3.00
Loamy Sand	0.07	1.00 - 2.00
Moderately Coarse		
Sandy Loam	0.11	0.80 - 1.20
Medium		
Loam	0.16	0.40 - 0.60
Silty Loam	0.20	0.25 - 0.40
Silt	0.20	0.30 - 0.50
Moderately Fine		
Sandy clay loam	0.15	0.10 - 0.30
Clay loam	0.16	0.07 - 0.25
Silty clay loam	0.18	0.05 - 0.12
Fine		
Sandy clay	0.12	0.08 - 0.20
Silty clay	0.15	0.05 - 0.15
Clay	0.14	0.05 - 0.10

The IR or intake rate defines how quickly irrigation water can move into the soil before runoff occurs. The AW or available water defines how much water can be stored in the soil per inch of soil depth at field capacity. A plant with a root depth of 6 inches in clay could store 0.84" of water (6 x 0.14 = 0.84). A higher AW means that a drip emitter will have a larger wetted pattern.

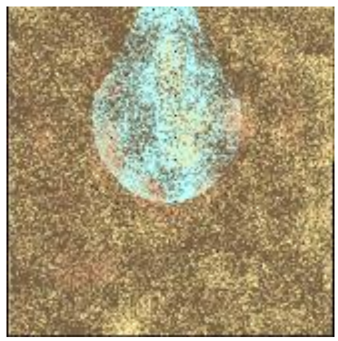
Once the water moves into the soil in the root zone profile it percolates through the soil. The rate of percolation, just like the infiltration rate varies with the type of soil. Soils that are coarse and have high sand content have high intake rates and water percolates quickly through the root zone. These coarser soils can't store water well. A soil's ability to store water is known as holding capacity. When the root zone profile is filled with water and has been allowed to drain for 24 hours it is at field capacity and the holding capacity is higher. Holding capacity can be estimated when the soil texture class (type of soil) is known.

As water percolates through the soil it moves laterally through capillary action and downward through the forces of gravity. Finer soils with more clay have greater holding capacity and consequently more capillary movement of water. A one half gallon emitter on a clay soil will have a much larger wetted pattern than the same emitter in coarse, sandy soils. A two gallon per hour emitter would be a perfect choice for sandy soils but would be more likely to create runoff and puddling on clay soils

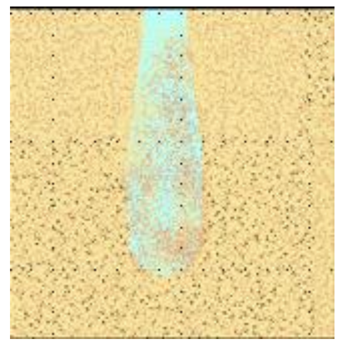
Wetted pattern of a ½ gph emitter by soil texture class



Clay 20 – 38 ft^2 wetted area



Loam 7 – 20 ft^2 wetted area



Sand 3 – 7 ft^2 wetted area

For purposes of planning and layout an average wetted pattern is used based on the emitter gph and the soil type

Average Wetted Area (square feet)

Soil Testure Class	Emitter Flow (GPH)		
	0.5	1.00	2.00
Clay	29	44	58
Clay-Loam	20.5	33	44
Loam	13.5	24	33
Sandy Loam	11.5	18	22
Sandy	5	8.5	11.5

The objective, when possible is to wet 75% of the area of the canopy. This is not a problem with a clay loam soil as a 1 gallon per hour emitter will wet 44 sq. ft. A tree that has a canopy twenty feet in diameter would be 314 sq. ft of canopy. It would be necessary to wet 235 square feet of the roots with emitters.

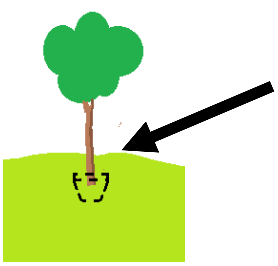
Six of the two gallon emitters would wet 256 square feet so this would be the minimum number of emitters for this tree.

The same tree in a sandy soil, if watered with emitters would best be watered with two gallon per hour emitters as they have the largest wetted pattern. Since these emitters have a wetted pattern of only 11.5 square feet, it would take 20 emitters to water this tree in sand (21 x 11.5 = 241 sq. ft).

Emitter Placement

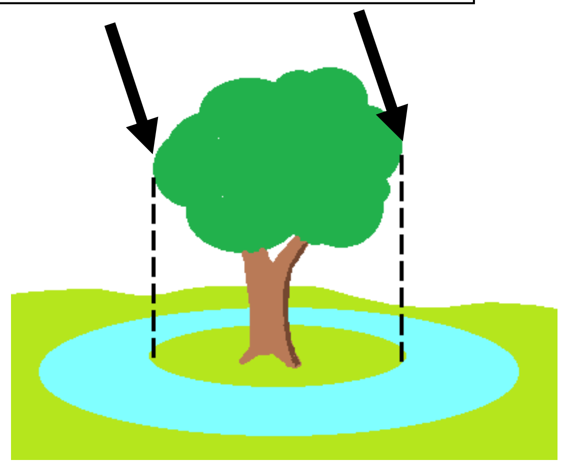
One of the most common mistakes regarding drip/micro irrigation is the placement of emitters relative to the trunk of the tree. Trees and ornamental shrubs take in most of their water from the drip line outward. Newly planted trees must have drip irrigation water delivered within the root ball. Typically, emitters are placed at the base of a new tree or shrub and never moved as the plant material gets larger.

At first planting, emitters or bubblers should be located within the root ball. At the plant matures the emitters should be moved to the drip line of the shrub or tree



Attach emitter to the root ball with a drip staple

Drip line – place emitters from this point outward

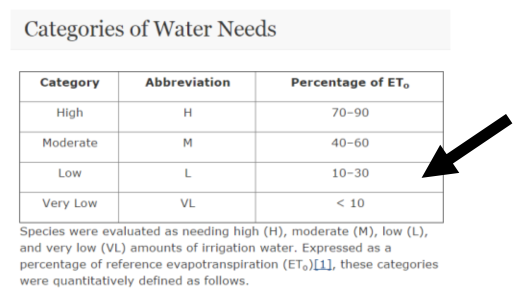


A tree or shrub takes in the majority of water beyond the drip line so emitters should be located from the drip line outward

Emitter Count - How many emitters per shrub or tree

A hydrozone is a grouping of plants based on their common water requirements. Low water use plants should be arranged on separate irrigation zones. Mixing high water use plants on the same zone would make it very difficult to irrigate. Similarly a hydrozone could be defined by exposure to excessive sun or shade. Plants may have the same water use requirement but that could vary greatly in a superheated sunny environment. Separate shady and sunny areas into hydrozones.

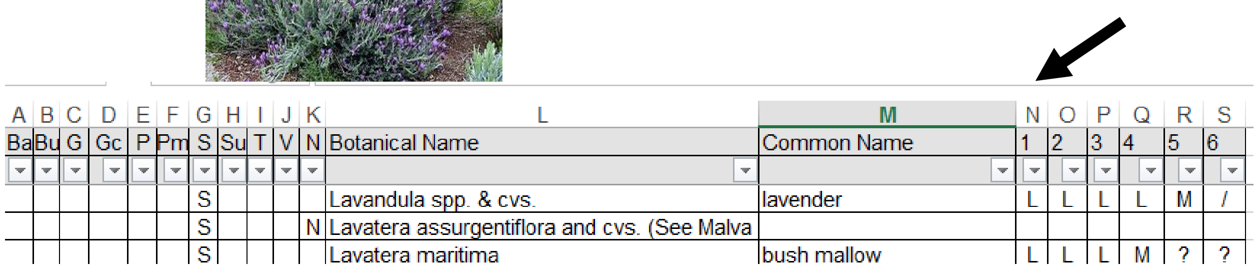
The best source to determine the plant water requirement and water use category for ornamental shrubs, trees, groundcovers, and grasses in California is WUCOLS IV. WUCOLS is an acronym for Water Use Classification of Landscape species. The latest version of WUCOLS was developed by the California Center for Urban Horticulture at UC Davis and contains over 3700 listings. A significant upgrade of this edition is the addition of a plant list in excel format. Plant lists can be developed by project and easily sorted by water use category. Plants are categorized by their landscape coefficient which range from very low to high. These landscape coefficients define the percentage of reference ET that these plant will need. These coefficients are further defined by one of six growing regions within California.



Categories of Water Needs

Category	Abbreviation	Percentage of ET_o
High	H	70–90
Moderate	M	40–60
Low	L	10–30
Very Low	VL	< 10

Species were evaluated as needing high (H), moderate (M), low (L), and very low (VL) amounts of irrigation water. Expressed as a percentage of reference evapotranspiration (ET_o)[1], these categories were quantitatively defined as follows.



A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
Ba	Bu	G	Gc	P	Pm	S	Su	T	V	N	Botanical Name	Common Name	1	2	3	4	5	6
						S					Lavandula spp. & cvs.	lavender	L	L	L	L	M	/
						S				N	Lavatera assurgentiflora and cvs. (See Malva							
						S					Lavatera maritima	bush mallow	L	L	L	M	?	?

Spanish Lavender in Concord (region 1 –North Central Coastal) has a low water use category L with a coefficient of 10-30 percent of reference ET. We have a mature Spanish lavender with a 2 foot diameter canopy so we'll uses an 20% coefficient

All of the plants in a hydrozone (drip valve circuit) should be in the same water use category. Just like a conventional turf irrigation system all plants on the circuit need to have the same precipitation rate. The problem is that there are a variety of different sizes of plants. A 20 foot tree with a low water use coefficient needs the same precipitation rate but because it is so much larger than the two foot diameter lavender it will need more emitters. The size of the canopy determines the number of emitters that will be required. A two foot diameter shrub has a 3.14 (area = 3.14×1^2) square foot canopy area. A 20 foot tree is not 20 times the size, it is 100 times the size at 314 square feet (area = 3.14×10^2).

It is important to remember that the smallest shrub on the hydrozone defines the precipitation rate of all other shrubs and trees on the hydrozone. The higher the gph on the small shrub, the higher the emitter count for the hydrozone. If the 2 foot shrub has a ½ gallon per hour emitter, the twenty foot diameter canopy tree will need 100 times that amount or 50 gallons per hour. In such cases it is probably a good idea to further define the hydrozone by canopy size.

Quick reference Chart for determining gph requirement for an ornamental shrub or tree

1. start by placing emitter around the smallest shrub. Example – 2ft shrub has a 3.14 square foot canopy at maturity. Our plan is to place the smallest emitter possible which is a ½ gallon per hour (0.5 gph). The application rate calculation formula is then applied PR (in inches/hr) = 1.605 (constant) x 0.5 (gph) / (divided by area) 3.14 = 0.255" per hour

2. Find the diameter of the next tree at maturity on the top of the quick reference table moving left to right from smallest to largest. In this example we'll use a 10 ft diameter tree at maturity. A ten foot diameter tree is 78.5 ft^2 ($3.14 \times 5^2 = 78.5$) Move down the chart until you discover a 0.255" per hour precipitation rate. Move to the far left column and find the gph. The ten foot tree will need 12 gph. If it were fairly flat the tree could be irrigated with six of the 2gph emitters. You would not do this on a slope because the 2 gph emitters are putting water down 4 times faster than the half gallon and runoff might be a problem!

Application Rate of Emission Device in inches per hour

Area of Canopy in sq. feet			3.1	7.1	13	20	28	38	50	64	79	95	113	133	154	177	201	227	254	283	314
Canopy Diameter >			2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cubic Feet/Min.	GPM	GPH																			
		0.5	0.26	0.11	0.06	0.04	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0
		1	0.51	0.23	0.13	0.08	0.06	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		2	1.02	0.45	0.26	0.16	0.11	0.08	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
		3	1.53	0.68	0.38	0.25	0.17	0.13	0.1	0.08	0.06	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02
		4	2.04	0.91	0.51	0.33	0.23	0.17	0.13	0.1	0.08	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02
		5	2.56	1.14	0.64	0.41	0.28	0.21	0.16	0.13	0.1	0.08	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.03
		6	3.07	1.36	0.77	0.49	0.34	0.25	0.19	0.15	0.12	0.1	0.09	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.03
		7	3.58	1.59	0.89	0.57	0.4	0.29	0.22	0.18	0.14	0.12	0.1	0.08	0.07	0.06	0.06	0.05	0.04	0.04	0.04
		8	4.09	1.82	1.02	0.65	0.45	0.33	0.26	0.2	0.16	0.14	0.11	0.1	0.08	0.07	0.06	0.06	0.05	0.05	0.04
		9	4.6	2.04	1.15	0.74	0.51	0.38	0.29	0.23	0.18	0.15	0.13	0.11	0.09	0.08	0.07	0.06	0.06	0.05	0.05
0.02	0.17	10	5.11	2.27	1.28	0.82	0.57	0.42	0.32	0.25	0.2	0.17	0.14	0.12	0.1	0.09	0.08	0.07	0.06	0.06	0.05
0.02	0.18	11	5.62	2.5	1.41	0.9	0.62	0.46	0.35	0.28	0.22	0.19	0.16	0.13	0.11	0.1	0.09	0.08	0.07	0.06	0.06
0.03	0.2	12	6.13	2.73	1.53	0.98	0.68	0.5	0.38	0.3	0.25	0.2	0.17	0.15	0.13	0.11	0.1	0.08	0.08	0.07	0.06
0.03	0.22	13	6.64	2.95	1.66	1.06	0.74	0.54	0.42	0.33	0.27	0.22	0.18	0.16	0.14	0.12	0.1	0.09	0.08	0.07	0.07
0.03	0.23	14	7.16	3.18	1.79	1.14	0.8	0.58	0.45	0.35	0.29	0.24	0.2	0.17	0.15	0.13	0.11	0.1	0.09	0.08	0.07
0.03	0.25	15	7.67	3.41	1.92	1.23	0.85	0.63	0.48	0.38	0.31	0.25	0.21	0.18	0.16	0.14	0.12	0.11	0.09	0.08	0.08
0.04	0.27	16	8.18	3.63	2.04	1.31	0.91	0.67	0.51	0.4	0.33	0.27	0.23	0.19	0.17	0.15	0.13	0.11	0.1	0.09	0.08
0.04	0.28	17	8.69	3.86	2.17	1.39	0.97	0.71	0.54	0.43	0.35	0.29	0.24	0.21	0.18	0.15	0.14	0.12	0.11	0.1	0.09
0.04	0.3	18	9.2	4.09	2.3	1.47	1.02	0.75	0.58	0.45	0.37	0.3	0.26	0.22	0.19	0.16	0.14	0.13	0.11	0.1	0.09
0.04	0.32	19	9.71	4.32	2.43	1.55	1.08	0.79	0.61	0.48	0.39	0.32	0.27	0.23	0.2	0.17	0.15	0.13	0.12	0.11	0.1
0.04	0.33	20	10.2	4.54	2.56	1.64	1.14	0.83	0.64	0.5	0.41	0.34	0.28	0.24	0.21	0.18	0.16	0.14	0.13	0.11	0.1
0.05	0.35	21	10.7	4.77	2.68	1.72	1.19	0.88	0.67	0.53	0.43	0.35	0.3	0.25	0.22	0.19	0.17	0.15	0.13	0.12	0.11
0.05	0.37	22	11.2	5	2.81	1.8	1.25	0.92	0.7	0.56	0.45	0.37	0.31	0.27	0.23	0.2	0.18	0.16	0.14	0.12	0.11

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0.051	0.38	23	11.76	5.23	2.94	1.88	1.31	0.96	0.73	0.58	0.47	0.39	0.33	0.28	0.24	0.21	0.18	0.16	0.15	0.13	0.12
0.053	0.4	24	12.27	5.45	3.07	1.96	1.36	1.00	0.77	0.61	0.49	0.41	0.34	0.29	0.25	0.22	0.19	0.17	0.15	0.14	0.12
0.056	0.42	25	12.78	5.68	3.19	2.04	1.42	1.04	0.80	0.63	0.51	0.42	0.35	0.30	0.26	0.23	0.20	0.18	0.16	0.14	0.13
0.058	0.43	26	13.29	5.91	3.32	2.13	1.48	1.08	0.83	0.66	0.53	0.44	0.37	0.31	0.27	0.24	0.21	0.18	0.16	0.15	0.13
0.060	0.45	27	13.80	6.13	3.45	2.21	1.53	1.13	0.86	0.68	0.55	0.46	0.38	0.33	0.28	0.25	0.22	0.19	0.17	0.15	0.14
0.062	0.47	28	14.31	6.36	3.58	2.29	1.59	1.17	0.89	0.71	0.57	0.47	0.40	0.34	0.29	0.25	0.22	0.20	0.18	0.16	0.14
0.065	0.48	29	14.82	6.59	3.71	2.37	1.65	1.21	0.93	0.73	0.59	0.49	0.41	0.35	0.30	0.26	0.23	0.21	0.18	0.16	0.15
0.067	0.5	30	15.33	6.82	3.83	2.45	1.70	1.25	0.96	0.76	0.61	0.51	0.43	0.36	0.31	0.27	0.24	0.21	0.19	0.17	0.15
0.069	0.52	31	15.85	7.04	3.96	2.54	1.76	1.29	0.99	0.78	0.63	0.52	0.44	0.38	0.32	0.28	0.25	0.22	0.20	0.18	0.16
0.071	0.53	32	16.36	7.27	4.09	2.62	1.82	1.34	1.02	0.81	0.65	0.54	0.45	0.39	0.33	0.29	0.26	0.23	0.20	0.18	0.16
0.074	0.55	33	16.87	7.50	4.22	2.70	1.87	1.38	1.05	0.83	0.67	0.56	0.47	0.40	0.34	0.30	0.26	0.23	0.21	0.19	0.17
0.076	0.57	34	17.38	7.72	4.34	2.78	1.93	1.42	1.09	0.86	0.70	0.57	0.48	0.41	0.35	0.31	0.27	0.24	0.21	0.19	0.17
0.078	0.58	35	17.89	7.95	4.47	2.86	1.99	1.46	1.12	0.88	0.72	0.59	0.50	0.42	0.37	0.32	0.28	0.25	0.22	0.20	0.18
0.080	0.6	36	18.40	8.18	4.60	2.94	2.04	1.50	1.15	0.91	0.74	0.61	0.51	0.44	0.38	0.33	0.29	0.25	0.23	0.20	0.18
0.082	0.62	37	18.91	8.41	4.73	3.03	2.10	1.54	1.18	0.93	0.76	0.63	0.53	0.45	0.39	0.34	0.30	0.26	0.23	0.21	0.19
0.085	0.63	38	19.42	8.63	4.86	3.11	2.16	1.59	1.21	0.96	0.78	0.64	0.54	0.46	0.40	0.35	0.30	0.27	0.24	0.22	0.19
0.087	0.65	39	19.93	8.86	4.98	3.19	2.21	1.63	1.25	0.98	0.80	0.66	0.55	0.47	0.41	0.35	0.31	0.28	0.25	0.22	0.20
0.089	0.67	40	20.45	9.09	5.11	3.27	2.27	1.67	1.28	1.01	0.82	0.68	0.57	0.48	0.42	0.36	0.32	0.28	0.25	0.23	0.20
0.091	0.68	41	20.96	9.31	5.24	3.35	2.33	1.71	1.31	1.03	0.84	0.69	0.58	0.50	0.43	0.37	0.33	0.29	0.26	0.23	0.21
0.094	0.7	42	21.47	9.54	5.37	3.43	2.39	1.75	1.34	1.06	0.86	0.71	0.60	0.51	0.44	0.38	0.34	0.30	0.27	0.24	0.21
0.096	0.72	43	21.98	9.77	5.49	3.52	2.44	1.79	1.37	1.09	0.88	0.73	0.61	0.52	0.45	0.39	0.34	0.30	0.27	0.24	0.22
0.098	0.73	44	22.49	10.00	5.62	3.60	2.50	1.84	1.41	1.11	0.90	0.74	0.62	0.53	0.46	0.40	0.35	0.31	0.28	0.25	0.22
0.100	0.75	45	23.00	10.22	5.75	3.68	2.56	1.88	1.44	1.14	0.92	0.76	0.64	0.54	0.47	0.41	0.36	0.32	0.28	0.25	0.23
0.102	0.77	46	23.51	10.45	5.88	3.76	2.61	1.92	1.47	1.16	0.94	0.78	0.65	0.56	0.48	0.42	0.37	0.33	0.29	0.26	0.24
0.105	0.78	47	24.02	10.68	6.01	3.84	2.67	1.96	1.50	1.19	0.96	0.79	0.67	0.57	0.49	0.43	0.38	0.33	0.30	0.27	0.24
0.107	0.8	48	24.54	10.90	6.13	3.93	2.73	2.00	1.53	1.21	0.98	0.81	0.68	0.58	0.50	0.44	0.38	0.34	0.30	0.27	0.25

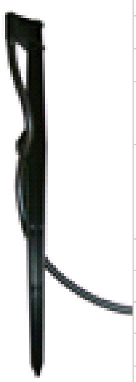
Irrigation & Landscape Supply

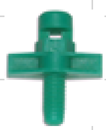
Micro Sprays and Mini Sprinklers

Micro sprays and mini sprinklers are frequently employed in the landscape for annual flowers and groundcovers. In general they have a higher minimum pressure requirement than drip emitters with an optimum pressure between 20 and 30 psi. Furthermore these sprinklers have a much higher precipitation rate than drip emitters. They will also cover a large area of up to 20 feet in diameter (314 square feet)

The most common spray type sprinkler sold is the light green fan jet mounted on a 24" drip stake. The maximum effective radius of these sprinklers is about five feet. They are available in a fixed 90 degree arc (pn 12002363) a 180 degree arc (pn 12002362) and a full or 360 degree (pn 12002361). We've conducted field tests under various layouts and pressures to determine flow and precipitation rates.

When spaced at five foot intervals, at 20 psi, the sprinklers will project out about 4 feet into a bed. Beyond that distance the precipitation rate is extremely low. The application rate in that 4 foot wide area is 1.08" per hour. The DU_{LQ}, distribution uniformity is surprisingly high at 83% (0.83). When full, halves and quarter sprays are employed the uniformity drops because the flows are not balanced. The full, half and quarter half roughly the same flow rates.



12002361	**GREEN SINGLE-PIECE FULL JET**									
12002362	**GREEN SINGLE-PIECE HALF JET**									
12002363	**GREEN SINGLE-PIECE QUARTER JET**									
							Single row - 180 degree arc			
				**Precip. Rate**	**Precip. Rate**		**Precip. Rate**		**Precip. Rate**	
PSI	**GPH**	**GPM**	**Radius**	**Square spacing @ radius**	**5 ft. - square**	**DU**	**5 ft.-single row**	**DU**	**4 ft.-single row**	**DU**
							@5 ft x 4 ft wide		**@4 ft x 3 ft wide**	
10	11	0.18	3 ft.	3.85						
15	14	0.24	3.5 ft	3.77						
20	16	0.27	4 ft.	3.25	2.56"	0.69	1.08"	0.83*	1.25"	0.8*
25	19	0.32	4.5 ft.	3.04						
30	21	0.35	5 ft.	2.70						

* while the actual DU is higher on a single row, the efficiency is lower because of the overspray beyond the 3 and 4 foot margins

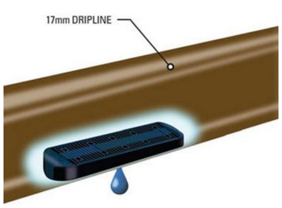
The fan jet or mini sprinkler can be an excellent option for a tree. If the rest of a zone was designed with emitters, the fan jets could be placed on large trees. Imagine a large tree that needed 48 gallons per hour. If emitters were being used it would take twenty four two gallon per hour emitters. The inclination might be to use a five gph emitter. If the small shrubs had ½ gallon per hour emitters the five gph would have 10 times the application rate and would cause runoff.

An excellent alternative is a fan jet because at 20 psi it will cover up to 48 square feet. Since each fan jet is 16 gph at 20 psi, it would take only three to irrigate the tree.

Line source drip irrigation

Line source irrigation utilizes pressure compensating drip emitters molded into the wall of 17mm drip tubing. The emitters are available at preset intervals of 12, 18, and 24". The most common gph sold over the years has been the 0.9 gph emitter. The tubing is also available with 1.0 gph, 0.6 gph, and 0.4 gph. A very low flow 0.26 gph is also available on special request.

When installed in parallel rows the line source system has a very high uniformity. More recently the tubing has become available with a check valve feature. This prevents drain down of tubing after an irrigation cycle. When check valve tubing has been installed, it cannot be mixed with other types of sprinklers such as micro sprays and traditional pressure compensating emitters as these devices do not have check valves.



6. Application Rate (Inches per Hour)

17 MM EZ-ID CV 0.4 gph Dripline

	Landscape Products EZ-ID CV Dripline Spacing								
Emitter Spacing	12"	13"	14"	15"	16"	17"	18"	20"	24"
12"	0.64	0.59	0.55	0.51	0.48	0.45	0.43	0.39	0.32
18"	0.43	0.40	0.37	0.34	0.32	0.30	0.27	0.26	0.21

17 MM EZ-ID CV 0.6 gph Dripline

	Landscape Products EZ-ID CV Dripline Spacing								
Emitter Spacing	12"	13"	14"	15"	16"	17"	18"	20"	24"
12"	0.96	0.89	0.83	0.77	0.72	0.68	0.64	0.58	0.48
18"	0.64	0.59	0.55	0.51	0.48	0.45	0.43	0.39	0.32

17 MM EZ-ID CV 1.0 gph Dripline

	Landscape Products EZ-ID CV Dripline Spacing								
Emitter Spacing	12"	13"	14"	15"	16"	17"	18"	20"	24"
12"	1.60	1.48	1.38	1.28	1.20	1.13	1.07	0.96	0.80
18"	1.07	0.98	0.92	0.85	0.80	0.75	0.71	0.64	0.53

How to calculate application rate:

$$\frac{231.1 \times \text{Emitter Flow Rate in Gallons per Hour}}{\text{Row Spacing in Inches} \times \text{Emitter Spacing in Inches}}$$

The check valve feature raises the minimum pressure requirement for this types of system of 15 psi at the most distant emitter.

Line source tubing is frequently used for trees by running a ring around the drip line of a mature tree. Once again, the goals is to insure that all plants on the same hydrozone have the same precipitation but this can be tricky with line source tubing. We've provided a chart with the precipitation rates that may be derived from various sized rings. Note the chart employs a variety of different emitters and emitter intervals. The dripline dripper plug can be used to reduce the flow on these rings.

Dripline dripper plug – pn 12051260

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Flush caps at the end of the lateral can be adapted to a pressure gauge to insure that the pressure is at least 15 psi.

	Precipitation rate for line source tubing tree rings						
Ring	***0.42 gph***	***0.42 gph***	***0.61 gph***	***0.61 gph***	***0.61 gph***	***0.92 gph***	***0.92 gph***
(feet)	**12" spacing**	**18" spacing**	**12" spacing**	**18" spacing**	**24" Spacing**	**12" spacing**	**18" spacing**
Diameter							
2	1.35	0.90	1.96	1.31	0.98	2.95	1.97
3	0.90	0.60	1.31	0.87	0.65	1.97	1.31
4	0.67	0.45	0.98	0.65	0.49	1.48	0.98
5	0.54	0.36	0.78	0.52	0.39	1.18	0.79
6	0.45	0.30	0.65	0.44	0.33	0.98	0.66
7	0.39	0.26	0.56	0.37	0.28	0.84	0.56
8	0.34	0.22	0.49	0.33	0.24	0.74	0.49
9	0.30	0.20	0.44	0.29	0.22	0.66	0.44
10	0.27	0.18	0.39	0.26	0.20	0.59	0.39
11	0.25	0.16	0.36	0.24	0.18	0.54	0.36
12	0.22	0.15	0.33	0.22	0.16	0.49	0.33
13	0.21	0.14	0.30	0.20	0.15	0.45	0.30
14	0.19	0.13	0.28	0.19	0.14	0.42	0.28
15	0.18	0.12	0.26	0.17	0.13	0.39	0.26
16	0.17	0.11	0.24	0.16	0.12	0.37	0.25
17	0.16	0.11	0.23	0.15	0.12	0.35	0.23
18	0.15	0.10	0.22	0.15	0.11	0.33	0.22
19	0.14	0.09	0.21	0.14	0.10	0.31	0.21
20	0.13	0.09	0.20	0.13	0.10	0.30	0.20
	**** The precipitation rate may be increased by doubling or tripling the rings***						

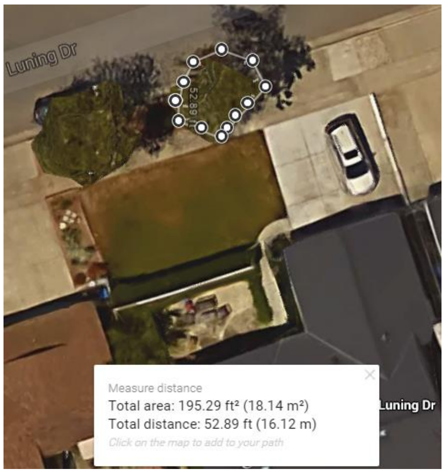
Scheduling Drip Micro Irrigation

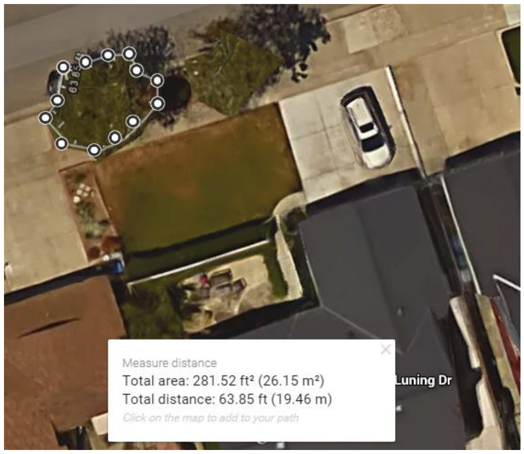
Typically, the application rate of an installed drip/micro system is not known but it can quickly be estimated in the field. Before scheduling, check the operating pressure at the last emitter. The point source system requires 10 psi and the line source 15 psi.

Start the process of calculating the precipitation rate by proceeding to the water meter. Activate the drip circuit in question and read the meter. Let the valve flow for a couple of minutes to purge out all the air from the circuit. In the example the ¾" meter had a flow of ½ revolution in one minute.

Next, measure the canopy of the drip zone, this may be done with a 100 foot tape or with Google Maps. Enter the address of the property in question. You'll have a map, but you'll notice a small window that offers a photographic option so you can observe a satellite view.

Enlarge the property until the drip zone fills the screen. Next, right click the touchpad and click the cursor around the perimeter of the zone completely. The square footage will be calculated.





The two magnolia trees are on the same circuit and have a total canopy of 477 square feet with a meter flow of one-half revolution per minute. A ¾" meter flows one cubic foot or 7.48 gallons per minute so our flow is 3.75 gallons per minute on this drip circuit irrigating the magnolia trees. The flow in gallons per hour is 225 gallons per hour (3.75 x 60 = 225). We can now use the formula to calculate the application rate. The formula is 1.605 (constant) x 225 (gph) / (divided by) area 500 sq ft = 0.76" / hr.

Quick reference charts are provided that will provide an application rate once the flow in cubic feet per minute and area of drip canopy is known.

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Application rate chart

1. Locate the meter flow on the far left column
2. Find the area in square feet on the top row and find the intersect point

Application Rate of Emission Device in inches per hour																			
Area of Drip Circuit Canopy			50	75	100	125	150	175	200	225	250	275	300	325	350	400	450	500	550	600	625
Cubic Feet/Min.	GPM	GPH																			
0.033	0.25	15	0.482	0.321	0.241	0.193	0.161	0.138	0.12	0.107	0.096	0.088	0.08	0.074	0.069	0.06	0.054	0.048	0.044	0.04	0.039
0.067	0.5	30	0.963	0.642	0.482	0.385	0.321	0.275	0.241	0.214	0.193	0.175	0.161	0.148	0.138	0.12	0.107	0.096	0.088	0.08	0.077
0.100	0.75	45	1.445	0.963	0.722	0.578	0.482	0.413	0.361	0.321	0.289	0.263	0.241	0.222	0.206	0.181	0.161	0.144	0.131	0.12	0.116
0.134	1	60	1.926	1.284	0.963	0.77	0.642	0.55	0.482	0.428	0.385	0.35	0.321	0.296	0.275	0.241	0.214	0.193	0.175	0.161	0.154
0.167	1.25	75	2.408	1.605	1.204	0.963	0.803	0.688	0.602	0.535	0.482	0.438	0.401	0.37	0.344	0.301	0.268	0.241	0.219	0.201	0.193
0.201	1.5	90	2.889	1.926	1.445	1.156	0.963	0.825	0.722	0.642	0.578	0.525	0.482	0.444	0.413	0.361	0.321	0.289	0.263	0.241	0.231
0.234	1.75	105	3.371	2.247	1.685	1.348	1.124	0.963	0.843	0.749	0.674	0.613	0.562	0.519	0.482	0.421	0.375	0.337	0.306	0.281	0.27
0.267	2	120	3.852	2.568	1.926	1.541	1.284	1.101	0.963	0.856	0.77	0.7	0.642	0.593	0.55	0.482	0.428	0.385	0.35	0.321	0.308
0.301	2.25	135	4.334	2.889	2.167	1.733	1.445	1.238	1.083	0.963	0.867	0.788	0.722	0.667	0.619	0.542	0.482	0.433	0.394	0.361	0.347
0.334	2.5	150	4.815	3.21	2.408	1.926	1.605	1.376	1.204	1.07	0.963	0.875	0.803	0.741	0.688	0.602	0.535	0.482	0.438	0.401	0.385
0.368	2.75	165	5.297	3.531	2.648	2.119	1.766	1.513	1.324	1.177	1.059	0.963	0.883	0.815	0.757	0.662	0.589	0.53	0.482	0.441	0.424
0.401	3	180	5.778	3.852	2.889	2.311	1.926	1.651	1.445	1.284	1.156	1.051	0.963	0.889	0.825	0.722	0.642	0.578	0.525	0.482	0.462
0.434	3.25	195	6.26	4.173	3.13	2.504	2.087	1.788	1.565	1.391	1.252	1.138	1.043	0.963	0.894	0.782	0.696	0.626	0.569	0.522	0.501
0.468	3.5	210	6.741	4.494	3.371	2.696	2.247	1.926	1.685	1.498	1.348	1.226	1.124	1.037	0.963	0.843	0.749	0.674	0.613	0.562	0.539
0.501	3.75	225	7.223	4.815	3.611	2.889	2.408	2.064	1.806	1.605	1.445	1.313	1.204	1.111	1.032	0.90	0.803	0.722	.657	0.602	0.578
0.535	4	240	7.704	5.136	3.852	3.082	2.568	2.201	1.926	1.712	1.541	1.401	1.284	1.185	1.101	0.963	0.856	0.77	0.7	0.642	0.616
0.568	4.25	255	8.186	5.457	4.093	3.274	2.729	2.339	2.046	1.819	1.637	1.488	1.364	1.259	1.169	1.023	0.91	0.819	0.744	0.682	0.655
0.602	4.5	270	8.667	5.778	4.334	3.467	2.889	2.476	2.167	1.926	1.733	1.576	1.445	1.333	1.238	1.083	0.963	0.867	0.788	0.722	0.693
0.635	4.75	285	9.149	6.099	4.574	3.659	3.05	2.614	2.287	2.033	1.83	1.663	1.525	1.407	1.307	1.144	1.017	0.915	0.832	0.762	0.732
0.668	5	300	9.63	6.42	4.815	3.852	3.21	2.751	2.408	2.14	1.926	1.751	1.605	1.482	1.376	1.204	1.07	0.963	0.875	0.803	0.77
0.702	5.25	315	10.11	6.741	5.056	4.045	3.371	2.889	2.528	2.247	2.022	1.838	1.685	1.556	1.445	1.264	1.124	1.011	0.919	0.843	0.809
0.735	5.5	330	10.59	7.062	5.297	4.237	3.531	3.027	2.648	2.354	2.119	1.926	1.766	1.63	1.513	1.324	1.177	1.059	0.963	0.883	0.847
0.769	5.75	345	11.07	7.383	5.537	4.43	3.692	3.164	2.769	2.461	2.215	2.014	1.846	1.704	1.582	1.384	1.231	1.107	1.007	0.923	0.886

Area of Drip Circuit Canopy			650	700	750	800	850	900	950	1,000	1,050	1,100	1,150	1,200	1,250	1,300	1,350	1,400	1,450	1,500	1,550
Cubic Feet/Min.	GPM	GPH																			
0.033	0.25	15	0.037	0.034	0.032	0.03	0.028	0.027	0.025	0.024	0.023	0.022	0.021	0.02	0.019	0.019	0.018	0.017	0.017	0.016	0.016
0.067	0.5	30	0.074	0.069	0.064	0.06	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.04	0.039	0.037	0.036	0.034	0.033	0.032	0.031
0.100	0.75	45	0.111	0.103	0.096	0.09	0.085	0.08	0.076	0.072	0.069	0.066	0.063	0.06	0.058	0.056	0.054	0.052	0.05	0.048	0.047
0.134	1	60	0.148	0.138	0.128	0.12	0.113	0.107	0.101	0.096	0.092	0.088	0.084	0.08	0.077	0.074	0.071	0.069	0.066	0.064	0.062
0.167	1.25	75	0.185	0.172	0.161	0.15	0.142	0.134	0.127	0.12	0.115	0.109	0.105	0.1	0.096	0.093	0.089	0.086	0.083	0.08	0.078
0.201	1.5	90	0.222	0.206	0.193	0.181	0.17	0.161	0.152	0.144	0.138	0.131	0.126	0.12	0.116	0.111	0.107	0.103	0.1	0.096	0.093
0.234	1.75	105	0.259	0.241	0.225	0.211	0.198	0.187	0.177	0.169	0.161	0.153	0.147	0.14	0.135	0.13	0.125	0.12	0.116	0.112	0.109
0.267	2	120	0.296	0.275	0.257	0.241	0.227	0.214	0.203	0.193	0.183	0.175	0.167	0.161	0.154	0.148	0.143	0.138	0.133	0.128	0.124
0.301	2.25	135	0.333	0.31	0.289	0.271	0.255	0.241	0.228	0.217	0.206	0.197	0.188	0.181	0.173	0.167	0.161	0.155	0.149	0.144	0.14
0.334	2.5	150	0.37	0.344	0.321	0.301	0.283	0.268	0.253	0.241	0.229	0.219	0.209	0.201	0.193	0.185	0.178	0.172	0.166	0.161	0.155
0.368	2.75	165	0.407	0.378	0.353	0.331	0.312	0.294	0.279	0.265	0.252	0.241	0.23	0.221	0.212	0.204	0.196	0.189	0.183	0.177	0.171
0.401	3	180	0.444	0.413	0.385	0.361	0.34	0.321	0.304	0.289	0.275	0.263	0.251	0.241	0.231	0.222	0.214	0.206	0.199	0.193	0.186
0.434	3.25	195	0.482	0.447	0.417	0.391	0.368	0.348	0.329	0.313	0.298	0.285	0.272	0.261	0.25	0.241	0.232	0.224	0.216	0.209	0.202
0.468	3.5	210	0.519	0.482	0.449	0.421	0.397	0.375	0.355	0.337	0.321	0.306	0.293	0.281	0.27	0.259	0.25	0.241	0.232	0.225	0.217
0.501	3.75	225	0.556	0.516	0.482	0.451	0.425	0.401	0.38	0.361	0.344	0.328	0.314	0.301	0.289	0.278	0.268	0.258	0.249	0.241	0.233
0.535	4	240	0.593	0.55	0.514	0.482	0.453	0.428	0.405	0.385	0.367	0.35	0.335	0.321	0.308	0.296	0.285	0.275	0.266	0.257	0.249
0.568	4.25	255	0.63	0.585	0.546	0.512	0.482	0.455	0.431	0.409	0.39	0.372	0.356	0.341	0.327	0.315	0.303	0.292	0.282	0.273	0.264
0.602	4.5	270	0.667	0.619	0.578	0.542	0.51	0.482	0.456	0.433	0.413	0.394	0.377	0.361	0.347	0.333	0.321	0.31	0.299	0.289	0.28
0.635	4.75	285	0.704	0.653	0.61	0.572	0.538	0.508	0.482	0.457	0.436	0.416	0.398	0.381	0.366	0.352	0.339	0.327	0.315	0.305	0.295
0.668	5	300	0.741	0.688	0.642	0.602	0.566	0.535	0.507	0.482	0.459	0.438	0.419	0.401	0.385	0.37	0.357	0.344	0.332	0.321	0.311
0.702	5.25	315	0.778	0.722	0.674	0.632	0.595	0.562	0.532	0.506	0.482	0.46	0.44	0.421	0.404	0.389	0.375	0.361	0.349	0.337	0.326
0.735	5.5	330	0.815	0.757	0.706	0.662	0.623	0.589	0.558	0.53	0.504	0.482	0.461	0.441	0.424	0.407	0.392	0.378	0.365	0.353	0.342
0.769	5.75	345	0.852	0.791	0.738	0.692	0.651	0.615	0.583	0.554	0.527	0.503	0.482	0.461	0.443	0.426	0.41	0.396	0.382	0.369	0.357

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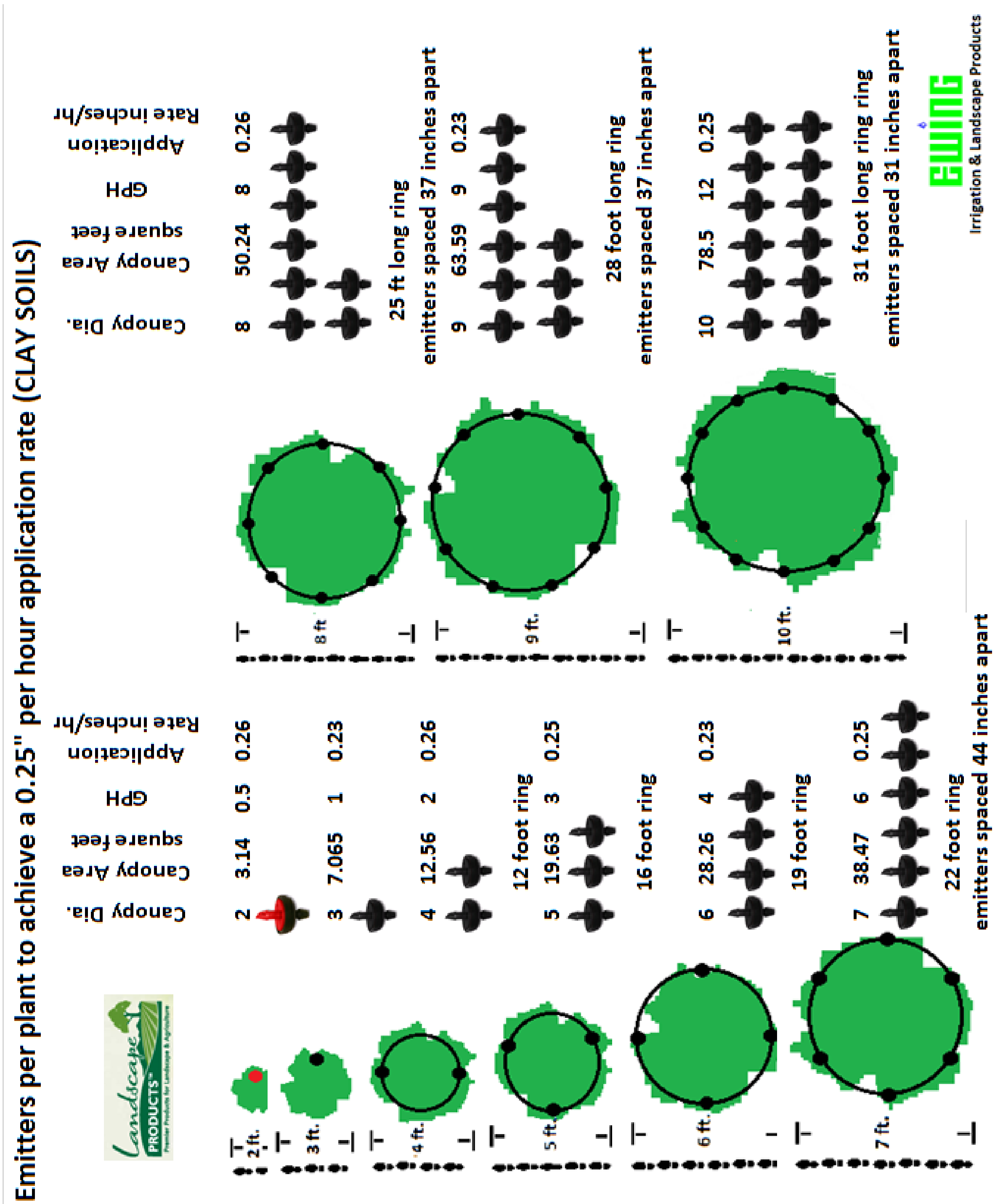
The weekly run time can be established by using the reference ET_O from Station 75 (Irvine) CIMIS station. The August reference ET from this station averages 6.17 inches of water. The magnolia's will need a percentage of this based on their WUCOLS species factor for region 3 (South Coastal.)

Ba	Bu	G	Gc	P	Pm	S	Su	T	V	N	Botanical Name	Common Name	1	2	3	4	5	6
								T			Magnolia grandiflora	southern magnolia	M	M	M	M	/	H
								T			Magnolia hybrids	hybrid magnolias	M	M	M	?	?	?
								T			Magnolia hypoleuca	whitebark magnolia	M	?	M	?	?	?

The zone 3 species factor is moderate is 40% to 60% water requirement relative to ET_O. In the example, considering the drought, we'll use a factor of 40% (0.40). The monthly requirement is 2.47" (6.17" ET_O x K_C 0.40 = 2.47") The next step is to calculate the plant water requirement per day which is 0.08" per day (2.47"/31day = 0.0796) The requirement per week would be 0.56 inches (7 x 0.08 = 0.56). Our application rate is 0.76 inches per hour. Run time is calculated as follows RT = 0.56 inches (plant requirement) /.76 inches (application rate) x 60 (constant) = 47 minutes. If this were a clay soil runoff would occur in about six minutes. (A tenth of an hour is 6 minutes, a tenth of 0.76 inches an hour is 0.076 inches) It would require 8 start times of 6 minutes each spread out over the entire evening!

Appendix


Emitters per plant to achieve a 0.25" per hour application rate (CLAY SOILS)
Canopy Dia.
Canopy Area square feet
GPH
Application Rate inches/hr
2 3.14 0.5 0.26
3 7.065 1 0.23
4 12.56 2 0.26
12 foot ring
5 19.63 3 0.25
16 foot ring
6 28.26 4 0.23
19 foot ring
7 38.47 6 0.25
22 foot ring
emitters spaced 44 inches apart
2 ft.
3 ft.
4 ft.
5 ft.
6 ft.
7 ft.
Canopy Dia.
Canopy Area square feet
GPH
Application Rate inches/hr
8 50.24 8 0.26
25 ft long ring
emitters spaced 37 inches apart
9 63.59 9 0.23
28 foot long ring
emitters spaced 37 inches apart
10 78.5 12 0.25
31 foot long ring ring
emitters spaced 31 inches apart
8 ft
9 ft.
10 ft.
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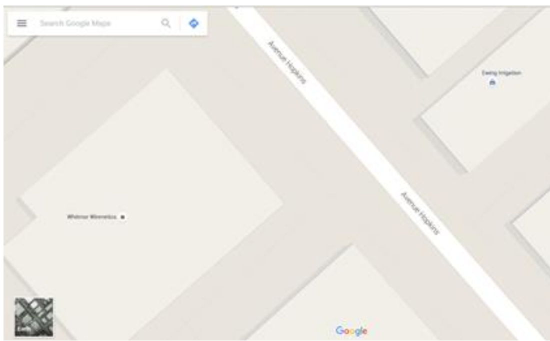
Landscape Products

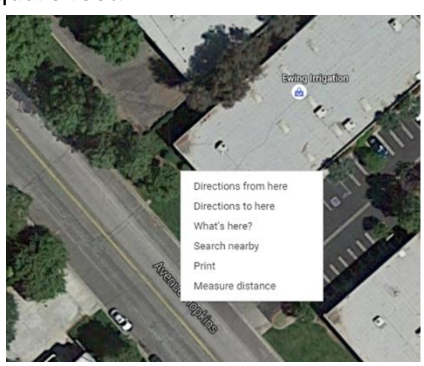
Measuring Irregularly Shaped Landscape Areas – The key to accurate Irrigation Bids

The irregular shape of a landscape is more pleasing to the eye. The curvilinear shape of turf areas in residential landscapes are more likely to be a key design element as water becomes scarce for landscaping purposes. In California, the 2015 version of the Water Efficient Landscape Ordinance (WELO) calls for turf to be limited to 25% of the landscaped area in all California landscapes.

This makes the task of estimating more difficult for the landscape professional because at first blush these areas seem more difficult to measure. The good news is that as technology advances we have more techniques to measure these landscapes quickly and accurately. If the measurement is of an existing landscape the area can be measured by accessing Google Maps. Locate the property by address and switch from the "Map" view to the "Earth" view by clicking on the box in the lower left area of the screen.



You'll now have the sight displayed as a digital photographic image. Now simply "right click" on the toolbar of your PC. You will activate the toolbar which has a "measure distance" feature. Click around the area to be measured on the perimeter at no less than 16 points in a clockwise direction. Once you arrive back at the first measure point a small box will appear displaying the area. In this case the area is 2,714 square feet.



Manually measuring the distance

Some sites are too new to have an up-to-date Google Maps Image. In other cases the image was taken in the summer where deciduous trees block the satellite image of the perimeter. These sites can be accurately measured by using some basic high school geometry. You've probably read in other publications that the irregular shape can be broken into a series of circles, squares and triangles and the areas can be calculated by using a variety of geometric formulas.

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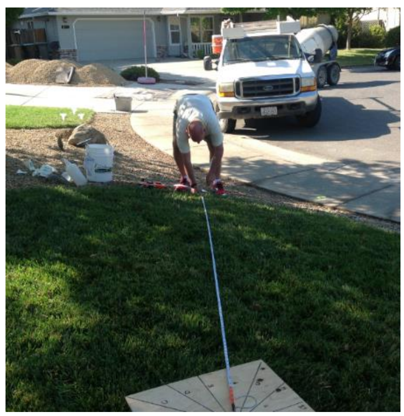
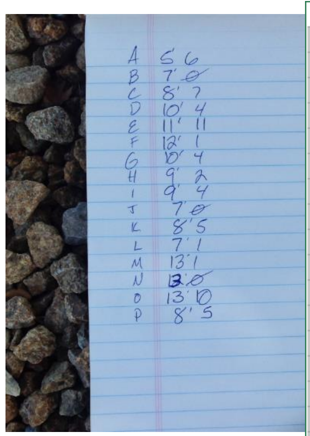
This process leads to the chance for errors and, in fact, only one formula is needed. That formula is for the area of a circle (Pi x the radius squared) where Pi is a mathematical constant of 3.1416. All we have to do is establish the average radius for any shape with a 100 ft tape from the center point. We do this with a plywood board that is 2 ft by 2 ft that has a hole in the center. The board has 16 lines drawn at 22.5 degree angles. We draw these lines at even increments because a 360 degree circle divided 16 times = 22.5 (16 x 22.5 = 360. At the job site we simply measure 16 times along the radii drawn on the board and add them together. We then reference the attached chart which incorporates the calculation.

Measure 16 points and write down each measurements as points A through P. We refer to these measuring points as letters rather than numbers to avoid confusion in the field. If you call out to your co-worker a measurement of 16 ft for measurement number 16 it could be confusing and lead to errors so we refer to that data point as measurement "P".





	FEET	INCHES
A	5	6
B	7	
C	8	7
D	10	4
E	11	11
F	12	1
G	10	4
H	9	2
I	9	4
J	7	
K	8	5
L	7	1
M	13	1
N	12	
O	13	10
P	8	5
	154	**1**

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Now we simply access the table and derive the area with an accuracy that is + or – 2%! The area of this small site is 295 square feet. If we manually calculated this with the formula and arrived at a total of 154 feet the answer would be 291 square feet!. We are good using 295 square feet!

Area (square feet)	Sum of 16 perimeter measurements	Area (square feet)	Sum of 16 perimeter measurements	Area (square feet)	Sum of 16 perimeter measurements	Area (square feet)	Sum of 16 perimeter measurements	Area (square feet)	Sum of 16 perimeter measurements	Area (square feet)	Sum of 16 perimeter measurements
295	**155**										
314	160	1,142	305	2,485	450	4,345	595	6,811	745	9,721	890
334	165	1,179	310	2,541	455	4,418	600	6,903	750	9,830	895
355	170	1,218	315	2,597	460	4,492	605	6,995	755	9,940	900
376	175	1,257	320	2,653	465	4,566	610	7,088	760	10,051	905
398	180	1,296	325	2,711	470	4,642	615	7,182	765	10,162	910
420	185	1,336	330	2,769	475	4,717	620	7,276	770	10,274	915
443	190	1,377	335	2,827	480	4,794	625	7,371	775	10,387	920
467	195	1,419	340	2,887	485	4,871	630	7,466	780	10,500	925
491	200	1,461	345	2,946	490	4,948	635	7,562	785	10,614	930
516	205	1,503	350	3,007	495	5,027	640	7,659	790	10,728	935
541	210	1,547	355	3,068	500	5,105	645	7,756	795	10,843	940
567	215	1,590	360	3,130	505	5,185	650	7,854	800	10,959	945
594	220	1,635	365	3,192	510	5,265	655	7,952	805	11,075	950
621	225	1,680	370	3,255	515	5,346	660	8,052	810	11,192	955
649	230	1,726	375	3,318	520	5,427	665	8,151	815	11,310	960
678	235	1,772	380	3,382	525	5,509	670	8,252	820	11,428	965
707	240	1,819	385	3,447	530	5,591	675	8,353	825	11,547	970
737	245	1,867	390	3,513	535	5,675	680	8,454	830	11,666	975
767	250	1,915	395	3,578	540	5,758	685	8,556	835	11,786	980
798	255	1,964	400	3,645	545	5,843	690	8,659	840	11,906	985
830	260	2,013	405	3,712	550	5,928	695	8,762	845	12,028	990
862	265	2,063	410	3,780	555	6,013	700	8,866	850	12,149	995
895	270	2,114	415	3,848	560	6,099	705	8,971	855	12,272	1,000
928	275	2,165	420	3,917	565	6,186	710	9,076	860	12,395	1,005
962	280	2,217	425	3,987	570	6,274	715	9,182	865	12,519	1,010
997	285	2,269	430	4,057	575	6,362	720	9,289	870	12,643	1,015
1,032	290	2,322	435	4,128	580	6,450	725	9,396	875	12,768	1,020
1,068	295	2,376	440	4,200	585	6,540	730	9,503	880	12,893	1,025
1,104	300	2,430	445	4,272	590	6,720	740	9,612	885	13,019	1,030

Area (square feet)	Sum of 16 perimeter measurements	Area (square feet)	Sum of 16 perimeter measurements	Area (square feet)	Sum of 16 perimeter measurements	Area (square feet)	Sum of 16 perimeter measurements	Area (square feet)	Sum of 16 perimeter measurements	Area (square feet)	Sum of 16 perimeter measurements
13146	1035	17,087	1180	21,545	1325	26,518	1470	32,008	1615	38,447	1770
13273	1040	17,232	1185	21,708	1330	26,699	1475	32,206	1620	38,664	1775
13401	1045	17,378	1190	21,871	1335	26,880	1480	32,405	1625	38,882	1780
13530	1050	17,525	1195	22,035	1340	27,062	1485	32,605	1630	39,101	1785
13659	1055	17,672	1200	22,200	1345	27,245	1490	32,805	1635	39,320	1790
13789	1060	17,819	1205	22,365	1350	27,428	1495	33,006	1640	39,540	1795
13919	1065	17,967	1210	22,531	1355	27,612	1500	33,208	1645	39,761	1800
14050	1070	18,116	1215	22,698	1360	27,796	1505	33,410	1650	39,982	1805
14182	1075	18,265	1220	22,865	1365	27,981	1510	33,613	1655	40,204	1810
14314	1080	18,415	1225	23,033	1370	28,167	1515	34,225	1670	40,426	1815
14447	1085	18,566	1230	23,202	1375	28,353	1520	34,430	1675	40,649	1820
14580	1090	18,717	1235	23,371	1380	28,540	1525	34,636	1680	40,873	1825
14714	1095	18,869	1240	23,540	1385	28,727	1530	34,843	1685	41,097	1830
14849	1100	19,022	1245	23,710	1390	28,915	1535	35,050	1690	41,322	1835
14984	1105	19,175	1250	23,881	1395	29,104	1540	35,257	1695	41,548	1840
15120	1110	19,329	1255	24,053	1400	29,293	1545	35,466	1700	41,774	1845
15257	1115	19,483	1260	24,225	1405	29,483	1550	35,675	1705	42,000	1850
15394	1120	19,638	1265	24,398	1410	29,674	1555	35,884	1710	42,228	1855
15532	1125	19,793	1270	24,571	1415	29,865	1560	36,094	1715	42,456	1860
15670	1130	19,949	1275	24,745	1420	30,057	1565	36,305	1720	42,684	1865
15809	1135	20,106	1280	24,920	1425	30,249	1570	36,516	1725	42,914	1870
15949	1140	20,264	1285	25,095	1430	30,442	1575	36,728	1730	43,143	1875
16089	1145	20,422	1290	25,271	1435	30,636	1580	36,941	1735	43,374	1,880
16230	1150	20,580	1295	25,447	1440	30,830	1585	37,154	1740	43,605	1,885
16371	1155	20,739	1300	25,624	1445	31,025	1590	37,368	1745	43,836	1,890
16513	1160	20,899	1305	25,802	1450	31,220	1595	37,583	1750	44,069	1,895
16,656	1165	21,060	1310	25,980	1455	31,416	1600	37,798	1755	44,301	1,900
16,799	1170	21,221	1315	26,159	1460	31,613	1605	38,013	1760	44,535	1,905
16,943	1175	21,383	1320	26,338	1465	31,810	1610	38,230	1765	44,769	1,910

Calculating Flow of an individual emitter utilizing a Sch. 40 PVC 2" Slip Cap

Estimating Irregularly shaped Areas

Measurement	
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	
K	
L	
M	
N	
O	
P	
TOTAL	
AVG/16	
SQ. FT	
METER FLOW	
CFM	
PR Rate	

EMITTER FLOW (TIME TO FILL 2" CAP)

EMITTER TYPE	GPH	FILL TIME
POINT SOURCE	2.00	56 SECONDS
POINT SOURCE	1.00	1 MIN 52 SECONDS
LINE SOURCE	0.92	2 MIN 2 SECONDS
LINE SOURCE	0.61	3 MIN 4 SECONDS
POINT SOURCE	0.50	3 MIN 45 SECONDS
LINE SOURCE	0.42	4 MIN 26 SECONDS