MICROIRRIGATION SYSTEMS
SAGA 4019

Microirrigation is a method of delivering slow, frequent applications of water to the soil near the plants through a low-pressure distribution system and special flow-control outlets.

- Outlets include emitters, orfices, bubblers, and sprayers or microsprinklers.
- Typical flow rates
  - Emitters: .5 to ~~3~~ 2 gals/hour
  - Microsprinklers: 5 to 30 gals/hour
- Microirrigation research began in the 1860s
- With the availability of plastic pipe and the development of emitters in Israel in the 1950s, it has since become an important method of irrigation worldwide.

In 2000, about 29.4 million acres of the 61.9 million total irrigated acres (about 47 percent) were irrigated by the flood irrigation process. Another 28.3 million acres were spray irrigated, with the remaining 4.2 million acres received drip irrigation. How the acres are irrigated in major irrigation states is illustrated in the following table:

State	Acres irrigated (thousands)	Acres flooded, (percent)	Acres sprayed, (percent)	Acres dripped, (percent)
California	10,100	54%	16%	30%
Nebraska	7,820	53%	47%	0%
Texas	6,490	37%	62%	1%
Arkansas	4,510	86%	14%	0%
Idaho	3,750	35%	65%	<1%
Colorado	3,400	65%	35%	<1%
Kansas	3,310	20%	80%	<1%

Oregon	2,170	47%	53%	<1%
Florida	2,060	41%	25%	34%
Montana	1,720	71%	29%	0%
Washington	1,570	16%	81%	3%
Wyoming	1,160	84%	16%	<1%
United States	61,900	47%	46%	7%

Table 1. Major Irrigation Technologies: Use in the United States, 2013

	Farms	Irrigated Acres (In Thousands)
Pressure Systems	122,000	36,200-39,800 (58%-65%)
Center Pivot	57,000	27,900
Surface Drip	41,000	2,600
Side Roll or Wheel Move	17,000	1,900
Solid Set and Permanent	21,000	1,500
Low-Flow Micro Sprinklers	15,000	1,300
Hand Move	30,000	800
Sub-Surface Drip	6,000	800
Linear Move Tower	5,000	600
Big Gun or Traveler	8,000	600
Other Sprinkler System	12,000	1,700
Other Drip, Trickle, or Low-Flow Micro Systems	4,000	300
Gravity Systems	85,000	21,500-26,200 (35%-42%)
Furrow	43,000	10,500
Controlled Flooding	37,000	8,500
Uncontrolled Flooding	12,000	1,800
Other Gravity Systems	6,000	800
Total	207,000	57,700-66,000

Source: CRS from USDA, NASS, *2013 Farm and Ranch Irrigation Survey*, Tables 29, 30, and 31, http://www.agcensus.usda.gov/Publications/2012/Online_Resources/Farm_and_Ranch_Irrigation_Survey/; Molly A. Maupin, Joan F. Kenny, and Susan S. Hutson, et al., *Estimated use of water in the United States in 2010*, U.S. Geological Survey, Circular 1405, November 5, 2014, http://pubs.usgs.gov/circ/1405/.

Notes: All numbers are rounded estimates derived from USDA or USGS data. This is not a comprehensive list of all irrigation technologies used in the United States. These are major irrigation systems used in the United States as designated by the 2013 Farm and Ranch Irrigation Survey. For definitions of each irrigation method, see **Figure 10**. USGS data is used for the estimated range of irrigated acres using pressure or gravity systems, and does not include statistics on specific irrigation system subcategories.

- Microirrigation is good for high value crops such as fruit and nut trees, grapes and other vine crops, ~~sugar cane~~, pineapples, strawberries, flowers, and vegetables.
- Microirrigation is not well suited for field crops (e.g., corn, wheat, pasture, sugarcane).
- Good for nurseries and greenhouses

1. Advantages and Disadvantages of Micro Irrigation
    - Advantages
        i. Only the root zone of the plant is supplied with water, and with proper management deep percolation is minimized.
        ii. Soil evaporation may be lower because only a portion of the surface is wetted
        iii. Greater economy of water use
        iv. Labor requirements are lower
        v. Activities such as between-row cultivations can be performed shortly after or even during irrigations.
        vi. The system can be automated
        vii. Bacteria, fungi, and other pests and diseases that depend on a moist environment are reduced
        viii. Water with higher salinity can be used than with sprinkler irrigation
        ix. Low rates of application means less runoff
        x. Yields can be higher because of the maintenance of high water content in the root zone
        xi. Some fertilizers and pesticides may be injected into the system. With proper management (i.e., small frequent applications), fertilizer and pesticide losses can be minimized, which means less groundwater pollution.

- Disadvantages
    1. high initial cost
    2. clogging of the emitters by particulate, biological, and chemical matter.
    3. Salt tends to accumulate around the fringes of the wetted area. Rainfall may move this salt into the root zone.
    4. Since only a portion of the potential root zone is wetted, roots are restricted to a smaller portion of the potential root zone.
    5. Since area between rows remains dry, dust and wind erosion may become a problem.
    6. Compared with surface irrigation, higher skilled labor is required to maintain the filtration equipment and other specialized components.

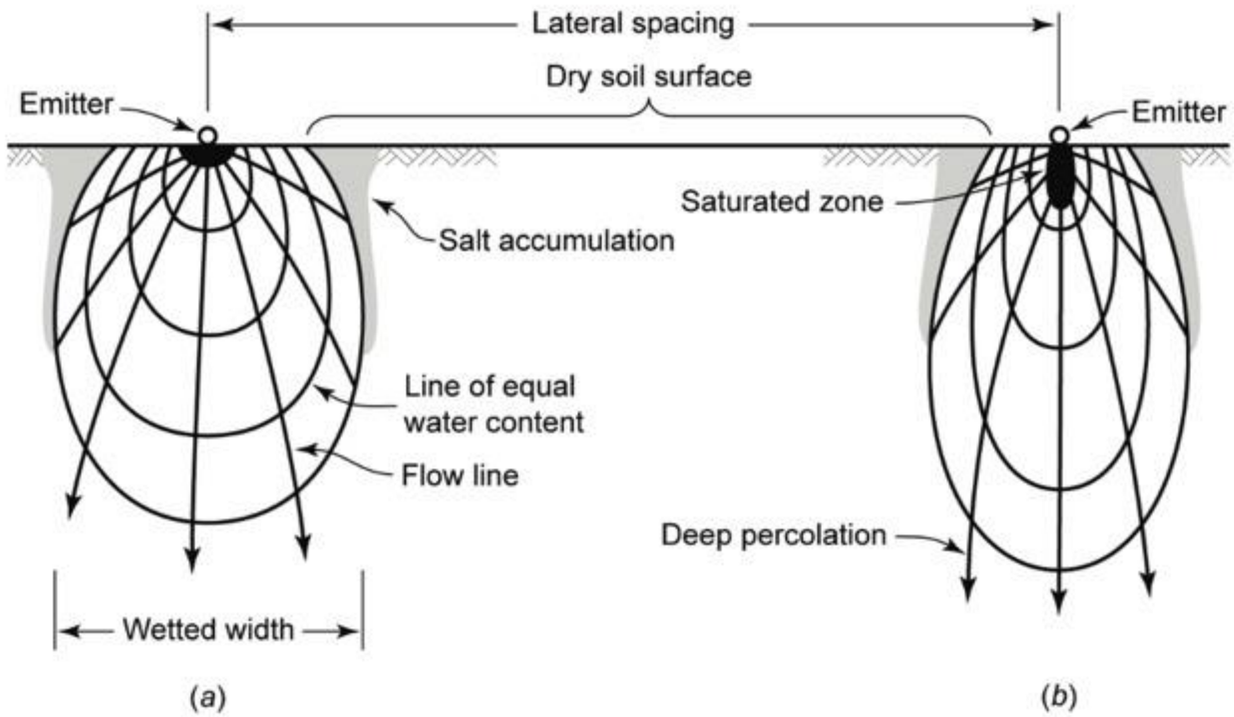

Figure 18.1–Soil wetting patter with microirrigation: (a) medium and heavy soils and (b) sandy soils. (Adapted from Karmeli and Keller, 1975.)

2. Layout and Components of Microirrigation Systems

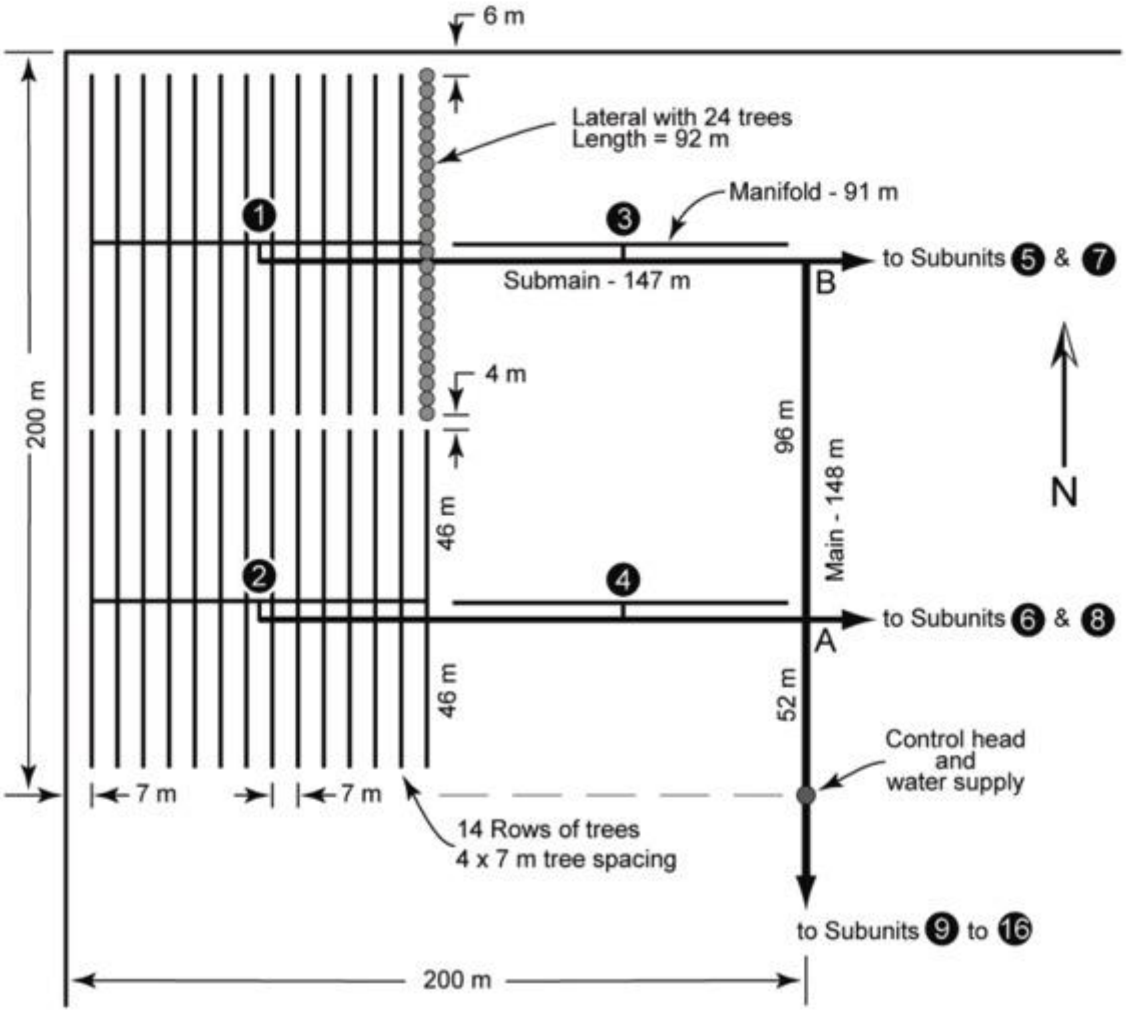

Figure 18.2–Microirrigation system layout for a 4-ha quadrant of a 16-ha orchard with the control head and water supply in the center of a square field.

3. Components of Microirrigation Systems

- Components
  - Water source
  - Pump
  - Check valve
  - Fertilizer injector

- Controls
- Pressure gauges
- Preliminary filter
- Piping
  - Mainline
  - Submainlines
  - Manifold
  - Lateral lines
- Valves (ball or gate type)
- Water meter
- Submainline
- Solenoid valves
- Pressure regulators
- Secondary filter
- Emitters

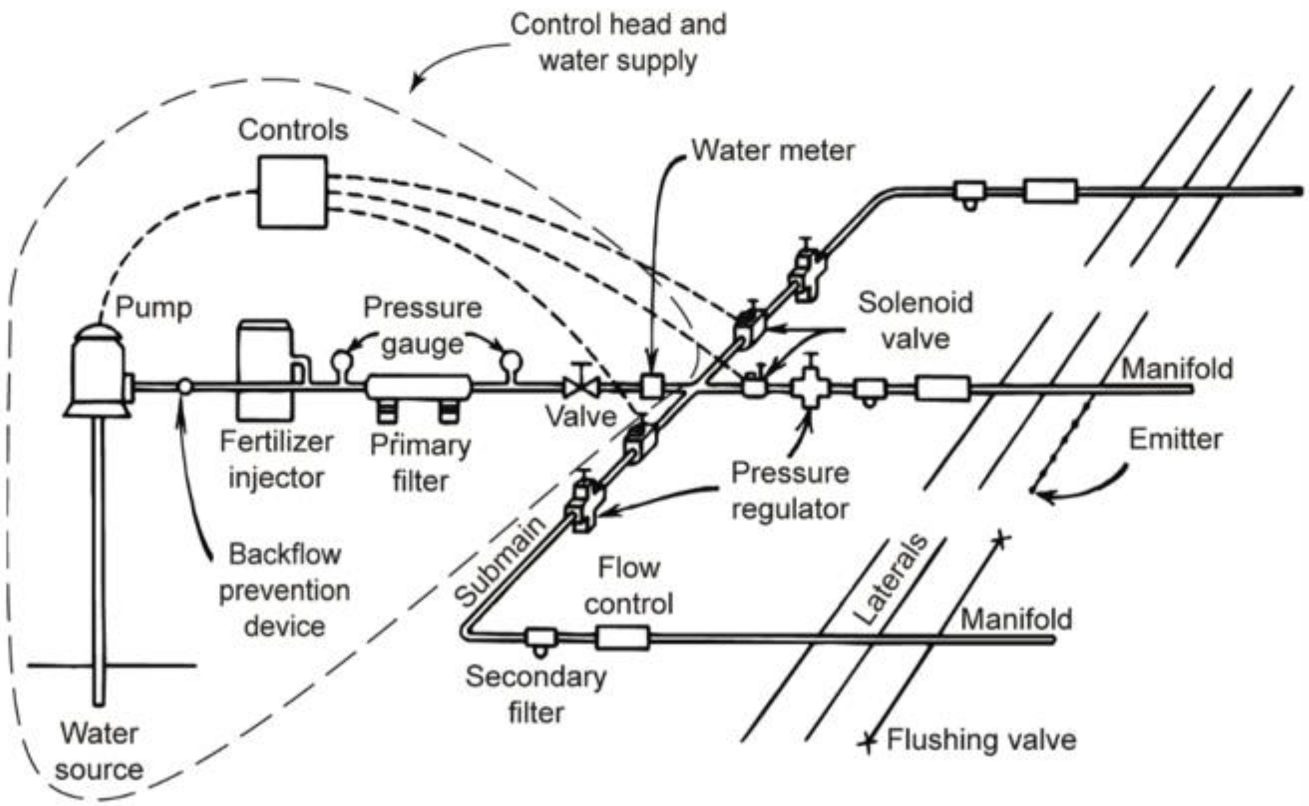

Figure 18.3–Components of a microirrigation system.

- Filters
  - One of the most important parts of a microirrigation system
  - Recommendations from emitter manufactures should be followed relative to selecting a filtration system.
  - Generally, the net opening diameters of the filter must be smaller than ¼ to 1/10 of the emitter opening diameter.
  - For clean groundwater, an 80 to 200 mesh screen filter may be adequate.
  - Screen filter should not be used with high algae water.
  - When the source of water is surface water (e.g., a pond), a sand filter must be used, since it is the only type of filter than can remove algae.
  - Secondary filters should be installed at the inlet to each manifold.

- Filter should be cleaned regularly, and pressure losses through the filters monitored.

Disk filter

CDFS

DISK FILTER BATTERY

Screen Filter

Screen filter

Automated Screen filter

 Sand Filter

Sand Filter Battery

The following table can help you select which filter or filters to use with a drip irrigation system. To use the table, determine which row to use based on the irrigation system flow rate and the concentration of organic and inorganic solids.

Example 1

A liter of water from an irrigation water supply contained 40 ppm organic concentration and 200 ppm inorganic concentration. The irrigation system flow rate is 200 gpm.

From the table footnote, the organic concentration is Medium (M) and the inorganic concentration is High (H). Therefore, use filters A+B or A+B+C. A is screen filter, B is a hydro-cyclone, and C is a sand filter.

Example 2.
A liter of water from an irrigation system water supply contains 0.06 gm of organic contamination and 0.01 gm of inorganic contamination. The irrigation system flow rate is 1,000 gpm.

First, estimate the organic and inorganic concentrations.
1000 gm of water in 1 liter of water.
(0.06 gm/1000 gm) * 1,000,000 = 60 ppm organic concentration = H
0.004 gm/1000 gm) * 1,000,000 = 4 ppm inorganic concentration = L

Use A+C type filters.

Cuadro I. Guía para la selección del Filtro[1/]

Razón de Flujo	Concentración de sólidos* Orgánicos	Inorgánicos	Recomendación**
Menor de 11.4 m^3/hr. (50 U.S. gpm)	L	L	A
	L	M	A
	L	H	A
	M	L	A
	M	M	B+ A
	M	H	B+ A
	H	L	B+ A
	H	M	B+ A
	H	H	B+ A
11.4 - 45.4 m^3/hr. (50-200 U.S. gpm)	L	L	A
	L	M	A
	L	H	A
	M	L	A+ B
	M	M	A+ B ó A+ C
	M	H	A+ B ó A+ B+ C
	H	L	A+ C
	H	M	A+ C ó A+ B+ C
	H	H	A+ B+ C
Mayor de 45.4 m^3/hr. (200 U.S. gpm)	L	L	A
	L	M	A+ C
	L	H	A+ C
	M	L	A+ C
	M	M	A+ B+ C
	M	H	A+ B+ C
	H	L	A+ C
	H	M	A+ C+ C
	H	H	A+ B+ C

* Clave de la concentración de sólidos
L= menor de 5 ppm
M= 5-50 ppm
H= mayor de 50 ppm

** Clave de Recomendación
A= Filtro de malla ó anilla screen or ring filter
B= Filtro de hidrociclónico o separador de sólidos
C= Filtro de arena sand

1/ El uso de esta guía es sólo con el propósito de ayudar en la selección apropiada del Filtro. Las necesidades específicas e individuales del área bajo diseño deben ser evaluadas.

From Goyal: Manejo de Riego por Goteo, 1990.

4. Emitters

a. Many types of emitters are available commercially (see figure)
    1. in-line long-path single exit emitter
    2. in-line long-path multiple-exit emitter
    3. flushing-type emitter
    4. orfice-type emitter
    5. Porous-tubing lateral
    6. Single-tube lateral
    7. Double-tube or double-wall lateral

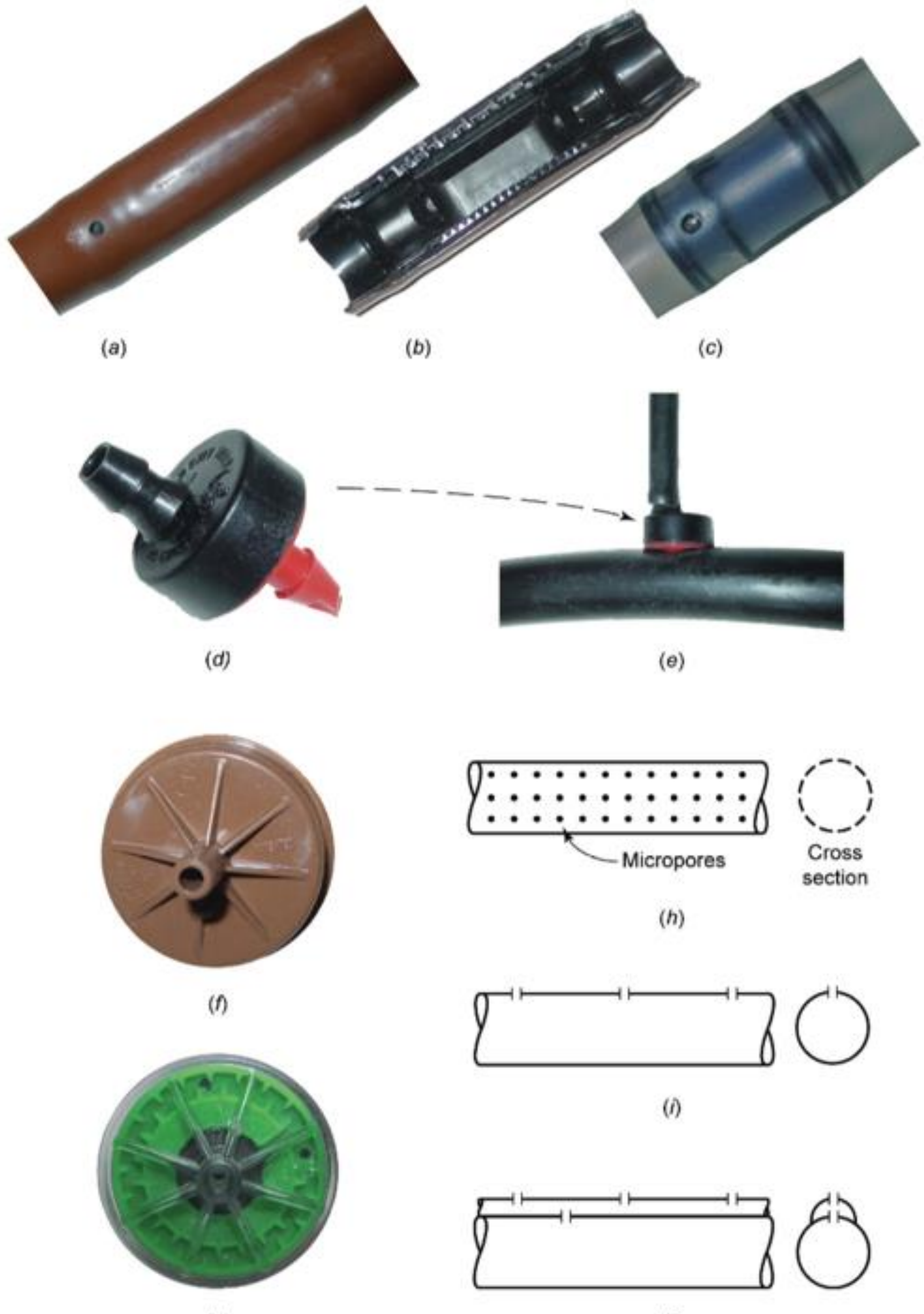

Figure 18.5–Types of microirrigation laterals and emitters: (a) in-line emitter formed in the lateral during production; (b) cross section of emitter a; (c) pre-molded in-line emitter in a transparent tube; (d) emitter with barb for attachment; (e) emitter d attached to a lateral and with a small tube attached to deliver water to the desired location; (f) pressure compensating emitter; (g) emitter f with a transparent cap to show the pressure reducing path; (h) porous tubing; (i) single-tube lateral; and (j) double-tube lateral.

- The emitter equation

$$q = K h^x \qquad (18.1)$$

where q = emitter discharge (L^3/T),
K = constant for each emitter,
h = pressure head (L),
x = emitter discharge exponent.

- The emitter equation is shown graphically in the next figure.
  - The figure includes curves, K values and x values for the following types of emitters
    - Large long-path
    - Orifices
    - Pressure compensating
    - Medium long-path
    - Small long-path

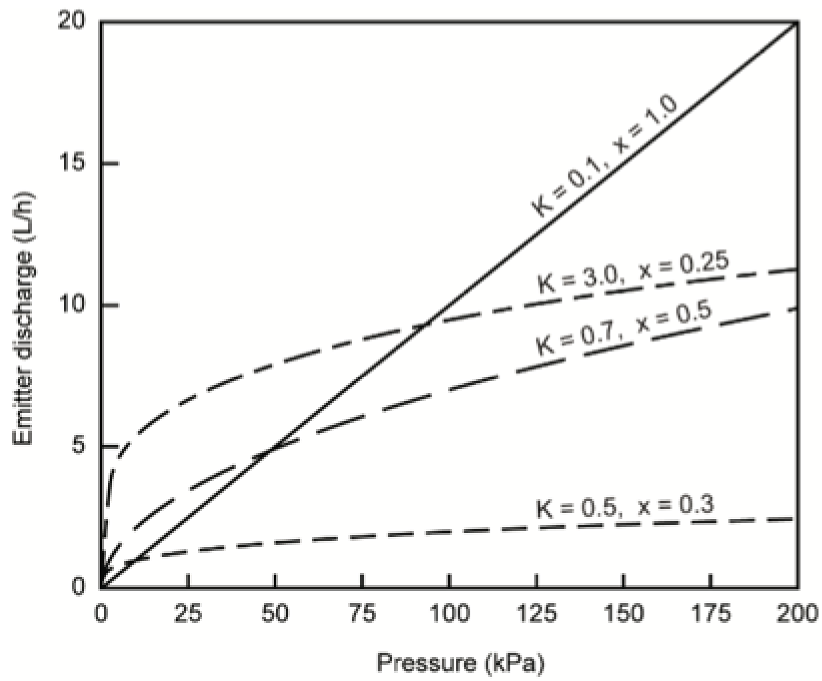

Figure 18.6–Examples of emitter discharges for various values of constant *K* and exponent *x*.

4. Water Distribution (Uniformity)

- The Emission Uniformity equation. This is also called Distribution Uniformity equation in some texts.

$$EU = 100\left[1 - 1.27\frac{C_v}{\sqrt{n}}\right]\frac{q_{\min}}{q_{avg}} \tag{18.2}$$

where EU = emission uniformity (percent),
C_v = manufacturer's coefficient of variation,
n = number of emitters per plant for trees and shrubs, or 1 for line sources,
q_{min} = minimum emitter discharge rate for the minimum pressure in the subunit (L^3/T),
q_{avg} = average or design emitter discharge rate for the subunit (L^3/T).

Recommended design values for EU are shown in Table 18.2.

Table 18.1 Recommended Classification of Manufacturer's Coefficient of Variation, C_v

Emitter Type	C_v Range	Classification
Point source	<0.05	Excellent
	0.05 to 0.07	Average
	0.07 to 0.11	Marginal
	0.11 to 0.15	Poor
	>0.15	Unacceptable
Line source	<0.10	Good
	0.10 to 0.20	Average
	>0.20	Marginal to unacceptable

Source: ASAE Standards (1988).

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Table 18.2 Recommended Ranges of Design Emission Uniformity, EU

Emitter Type	Spacing (m)	Topography	Slope (%)	*EU* Range (%)
Point source on perennial crops	>4	Uniform	<2	90 to 95
		Steep or undulating	>2	85 to 90
Point source on perennial or semi-permanent crops	<4	Uniform	<2	85 to 90
		Steep or undulating	>2	80 to 90
Line source on annual or perennial crops	All	Uniform	<2	80 to 90
		Steep or undulating	>2	70 to 85

Source: ASAE Standards (1988).

Example 18.1

Determine the emission uniformity of a system subunit that uses an emitter with $K = 0.3$, $x = 0.57$, $C_v = 0.06$, and two emitters per plant with average pressure of 100 kPa and minimum pressure of 90 kPa.

Solution. Substitute Equation 18.1 into Equation 18.2

$$EU = 100\left[1 - \frac{1.27(0.06)}{\sqrt{2}}\right]\frac{0.3(90)^{0.57}}{0.3(100)^{0.57}} = 89\%$$

5. Layout of Microirrigation Systems

- Lateral lines may be located along rows of trees, with one or more emitters required per tree. Use of spaghetti tubing or pigtail line can be used with multiple emitters.
- Alternatively, you can use two laterals with inline emitters.
- It is recommended that 1/3 of the potential root volume should be irrigated

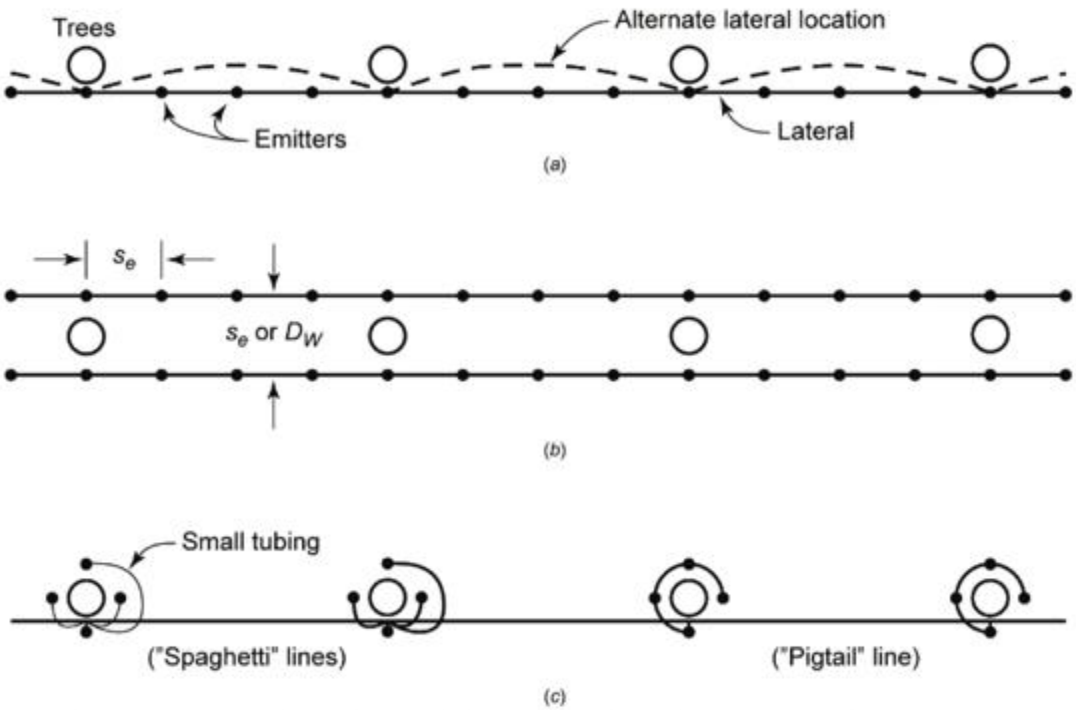


Figure 18.4–Lateral and emitter locations for an orchard or vineyard: (a) single lateral for each row of plants, (b) two laterals for each plant row, and (c) multiple outlet layouts.

- Estimated Diameter of the wetted circle formed by a single emitter

The horizontal area wetted is based on the wetted diameter 6 to 12 inches below the surface. If field measurements are not available, estimates may be obtained from the above table for the horizontal wetted diameter D_w from a single outlet. For a line source (e.g., tape), the outlet spacing S_e should be less than or equal to $0.8D_w$ to overlap the patterns of adjacent emitters along a lateral. For double laterals, a spacing of D_w between lateral will adequately wet the area. The spacing between laterals and between outlets should be reduced to $0.8D_w$ if the water is saline.

$n = (p_w\ x$ area/plant$)$ / effective area wetted by one emitter

where p_w is the percentage of the total area to be irrigated, area/plant is based on the plant spacing, and effective area wetted by one emitter depends on the wetted diameter, emitter layout, and water quality.

Table 18.3 Estimated Maximum Diameter of the Wetted Circle Formed by a Single Emission Outlet Discharging 4 L/h on Various Soils

Soil or Root Depth and Soil Texture	Homogeneous Soil (m)	Varying Layers	
		Generally Low Density (m)	Generally Medium Density (m)
Depth 0.75 m			
Coarse	0.45	0.75	1.05
Medium	0.90	1.2	1.5
Fine	1.05	1.5	1.8
Depth 1.5 m			
Coarse	0.75	1.4	1.8
Medium	1.2	2.1	2.7
Fine	1.5	2.0	2.4
Adapted from SCS (1984).			

Example 18.2

For the layout in Figure 18.2 with mature orange trees and one lateral per row, determine the number of the emission devices needed per tree if 40% of the area is to be irrigated; salt content of the irrigation water is low; soil is layered, medium density, with coarse texture to a 2-m depth; and emitters will be installed on a "pigtail" as in Figure 18.4c.

Solution. From Table 15.3 determine the effective rooting depth is 1.5 m; then from Table 18.3, $D_w = 1.8$ m. The effective wetted area is assumed to be 0.8(1.8 m) × 1.8 m, which is substituted into Equation 18.3 as:

$$n = \frac{0.40 \times 4 \times 7}{0.8(1.8) \times 1.8} = 4.3 \quad \text{Round to 5 emitters per tree}$$

Note that if the irrigation water is saline, the effective wetted area is reduced to 0.8(1.8) × 0.8(1.8), which provides overlap of the wetting patterns and reduces salt accumulations within the wetted area.

Alternatively, use the area of a circle in the denominator of the equation:

Effective wetted area by one emitter = $[3.1416*(D_w)^2]/4$

- Water use rate:

$$ET_t = ET_p \times 0.1 \times p^{0.5} \tag{18.4}$$

where ET_t = average peak transpiration of crops under microirrigation (L/T),
ET_p = average peak conventional ET rate for the crop (L/T),
p = percentage total area shaded by the crop.

For example, if a mature orchard shades 70% of the area and the average peak conventional *ET* is 7 mm/day, the net microirrigation design rate is 5.9 mm/day ($7 \times 0.1 \times 70^{0.5}$).

Another method:

ET_t= ET *(shaded area/85)

For example, if a mature orchard shades 70% of the area and the conventional ET is .25 in/day, the irrigation design rate is [0.25 in/day x (70/85)] = 0.21 in/day. The shaded area is proportional to the leaf area that contributes to ET. For P_s greater than 85 %, ET_t = ET.

- **Pipe Sizes**

- Diameter of lateral or manifold should be selected so that the difference in discharges between emitters operating simultaneously will not exceed 10%. (This is the same recommendation for sprinkler irrigation)
- To achieve the above requirement, pressure head (pressure) differences between emitters should not exceed 10 to15% of the average operating head for long-path emitters, or 20% for in-line flow emitters.
- Maximum difference in pressure is the head loss between the control point at the inlet and the pressure at the emitter farthest from the inlet.
  - As an example, in Figure 18.2, the maximum difference in head loss to the farthest emitter occurs over ½ the length of the lateral and ½ the length of the manifold.
- For small systems, 50% of the head loss should occur in the lateral and 50% in the manifold.

- **Friction losses** can be estimated using Hazen Williams equation:

English units

$$H_f = 10.46 \left(\frac{Q}{C}\right)^{1.85} \frac{L}{D^{4.87}} \qquad (17.1)$$

where H_f = friction loss in feet
Q = flow rate in the pipe in gpm
L = pipe length in feet
D = actual inside pipe diameter (not nominal diameter) in inches
C = Hazen-Williams coefficient from Table 17.2.

Metric units

$$H_f = 1.21 \times 10^{10} \frac{L}{D^{4.87}} \left(\frac{q}{C}\right)^{1.852} \qquad (18.5)$$

where H_f = head loss in the pipe (m),
L = pipe length (m),
D = actual i.d. of the pipe (mm),
q = volume flow rate in the pipe (L/s),
C = Hazen-Williams roughness coefficient.

C values for microirrigation tubing (e.g., polyethylene tubing) can be obtained from the following graph. **For smooth plastic pipe C = 150. For PVC pipe, use C=150.**

C values for drip tubing (0.4 to 1.1 inch diameter), for three barb sizes.

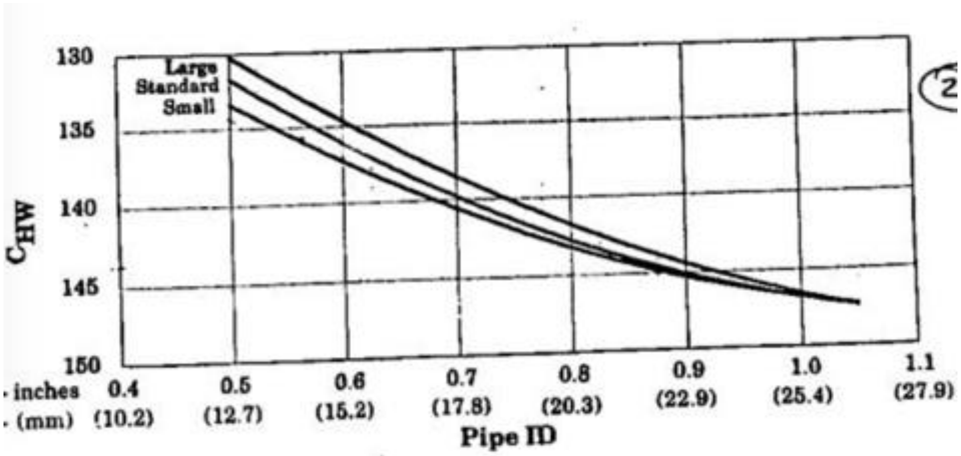


Figure 13. Hazen-Williams "C" values for three emitter barb geometries. Conditions give a single hose DU (excluding cv) of about 92%. 70°F (21.1°C) temperature, x= 0.5, various flows @ 14 psi (55 kPa), 6' (1.8m) hole spacing (excluding cv consideration).

- **<u>Very important!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!</u>** If your pipe has multiple holes in it, as for example a drip lateral with emitters or manifolds with multiple outlets, you must multiply the head lose from the Hazen Williams formula by the multiple outlet factor (see following table):

Multiple outlet factor "F" for the Hazen-Williams equation.

Number of Outlets	F
1	1.00
6	0.44
10	0.40
20	0.38
40	0.37
100	0.36

The following table can also be used for drip irrigation.

Table 17.5 Correction Factor F for Friction Losses in Pipes with Multiple Outlets for Use with Equation 17.4 and Exponent of 1.852

First Sprinkler One Sprinkler Interval from Main		First Sprinkler One-Half Sprinkler Interval from Main	
Number of Sprinklers	F	Number of Sprinklers	F
2	0.64	2	0.52
3	0.53	3	0.44
4	0.49	4	0.41
5	0.46	5	0.40
6	0.44	6	0.39
7	0.43	7, 8	0.38
8	0.42	9 to 13	0.37
9	0.41	14 to 41	0.36
10, 11	0.40	≥ 42	0.35
12 to 14	0.39		
15 to 20	0.38		
21 to 35	0.37		
36 to 114	0.36		
≥115	0.35		

For Center Pivots:
$F = 0.56$ with an end gun operating
$F = 0.54$ without an end gun

Adapted from Martin et al. (2007a).

- Sizing the mainline, submains and manifolds.
  - The following table can be used to select the pipe diameters:

FLOW RATES WHICH WILL GIVE 5 FT/SEC VELOCITY FOR DIFFERENT DIAMETER PIPE

CLASS 160 PSI. SDR 26

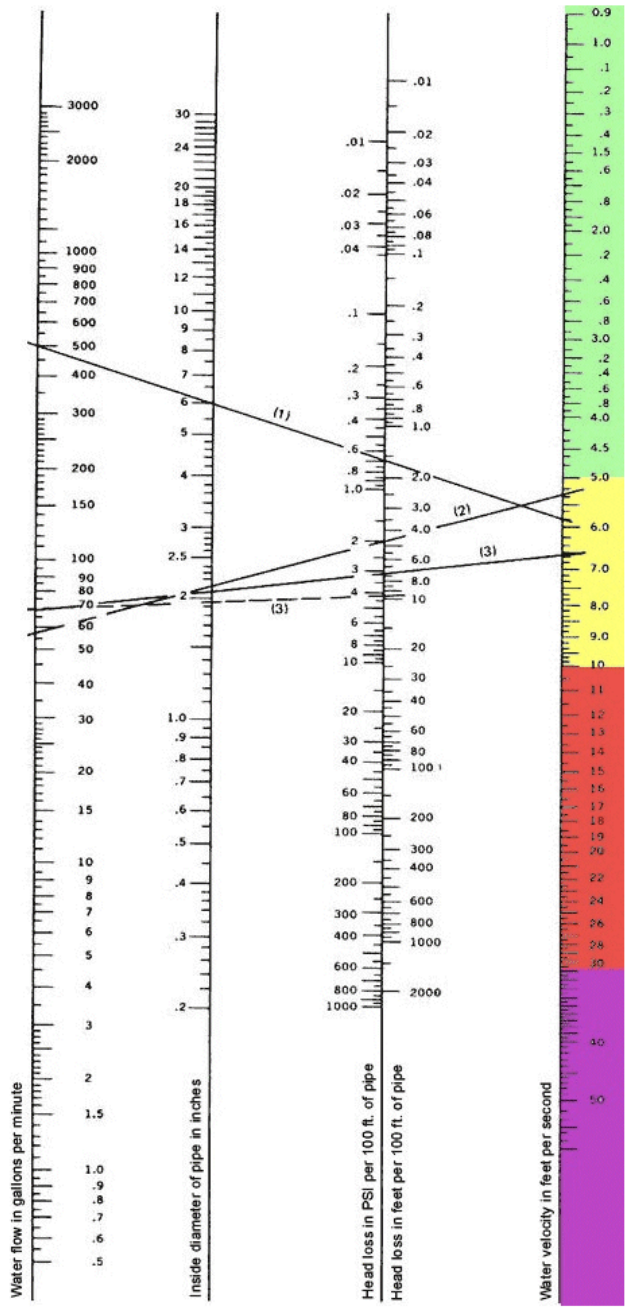
Q(gpm)	Nominal Dia. (in)	ID (in)	V ft/sec)
29	1.25	1.532	5.0
38	1.5	1.754	5.0
59	2	2.193	5.0
86	2.5	2.655	5.0
128	3	3.23	5.0
210	4	4.154	5.0
320	5	5.135	5.0
460	6	6.115	5.0
770	8	7.961	5.0
1200	10	9.924	5.0
1700	12	11.77	5.0

200 CLASS PSI. SDR 21

Q(gpm)	Nominal Dia. (in)	ID (in)	V (ft/sec)
10.5	0.75	0.93	5.0
17.2	1	1.189	5.0
27.5	1.25	1.502	5.0
36	1.5	1.72	5.0
57	2	2.149	5.0
83	2.5	2.601	5.0
122	3	3.166	5.0
202	4	4.072	5.0
310	5	5.022	5.0
440	6	5.993	5.0
750	8	7.803	5.0
1160	10	9.726	5.0

NOTE: Class 160 PSI will be fine for drip irrigation systems. Class 200 PSI is appropriate for high pressure systems (e.g., traveling big gun, which requires pressures in excess of 100 psi).

- The following graph can be used to estimate friction losses from mains, submains and manifolds.



Nemograph courtesy of Plastics Pipe Institute,
a divison of The Society of the Plastics Industry.
Color coding added by FlexPVC®

- **ELEVATION LOSSES**: Allowable head loss should take into account elevation differences.
  - For example, if a field to be irrigated is 50 ft above the water supply, the elevation head loss is 50 ft, or 50 ft x 1psi/2.31 ft = 21.65 psi.

- To size your pump you need to estimate the total losses (H_{total}):

$$H_{total} = H_{friction} + H_{elevation} + H_{minor} + H_{emitter}$$

where H_{total} = total head loss, $H_{friction}$ = friction head loss, $H_{elevation}$ = elevation head loss and H_{minor} = minor losses. Minor losses can be obtained for each filter, elbow, valve, etc., from the manufactuer.

- Your pump will have to produce H_{total} at the design flow rate.

6. Maintenance
- Biggest problem is plugging caused by physical, chemical, or biological materials.
  - Main filter and screens should be clean periodically
  - Sulfiric and hydrochloric acid are routinely used to reduce the chemical precipitation associated with high pH water and water with high concentrations of magnesium carbonates.
  - Monthly flushing is recommended
  - Chlorine or copper sulfate are common chemicals to kill bacteria and algae.

7. Chemical Applications through Microirrigation Systems

- Application of chemicals with the water reduces labor, energy and equipment costs compared to conventional systems.
- Less chemicals are required since they are applied near the plant only.
- Chemical injection can result in precipitation and clogging.
- N, P, K, micro nutrients, and herbicides can be injected into microirrigation systems.
- Chemicals should be injected into system upstream of the filter.
- Some chemicals are very corrosive and suction of the chemical through the pump may damage the pump.
- Backflow prevention is important to prevent the chemical from entering the water supply.

8. Management and Evaluation
    - Frequent inspection of the system is necessary to assure the proper amount of water is being applied and to fix any leaks.
    - The consultant should ascertain the frequency and amount of irrigation water being applied. This should be compared with estimated water requirements of the crop using a program like CROPWAT or an irrigation scheduling spreadsheet.
    - Distribution uniformity should be check in the field.
    - The wetting pattern can be determined using a soil probe.
    - Filters should be checked for excessive pressure drops across them. Inlet and outlet pressure differences should not be greater than 10 to 15 psi.
    - Pressure losses between the inlet and the last emitter on the farthest lateral should not exceed around 15% of the average pressure.