Step by Step Irrigation System Design for Non-Commercial Raised Beds & Backyard Gardens

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This extension publication is intended to assist homeowners, gardeners, and educators with the basic design of non-commercial drip irrigation systems for raised beds and backyard gardens. The goal is to provide a practical, step-by-step approach to estimating water requirements, selecting irrigation components, and determining appropriate system flow rates, pressure, and run time. While the methods presented here are suitable for small-scale, non-commercial applications, commercial irrigation systems should be designed by trained specialists to account for field variability, soil conditions, crop type, and topography.

Water Source, Flow Rate, and Available Pressure

Before designing a drip irrigation system, it is essential to understand the water source and its available flow rate and pressure. Common water sources for raised bed systems include municipal water supplies, private wells, surface water (ponds or creeks), and rainwater harvesting systems such as storage totes. Each source has different pressure and flow characteristics that directly influence system design. One of the simplest methods to estimate flow rate is the bucket-and-stopwatch method, by which you measure the time required to fill a container of known volume (e.g., 1 gallon). Table 1 provides pre-calculated flow rates using this method and allows users to quickly estimate water availability.

Table 1: Pre-calculated flow rates based on the bucket and stopwatch method using a 1-gallon container.

Seconds to fill a 1-gal Container	5	6	7	8	9	10	11	12	13	14
Gallons per Hour, gph	720	600	514	450	400	360	327	300	277	257
Gallons per Minute, gpm	12	10	8.5	7.5	6.6	6	5.45	5	4.6	4.3
If filling a 5 Gallon container multiply the gph or gpm by 5										

Flow rate and pressure can also be measured using a hose-end pressure gauge and a digital flow meter connected to a hose splitter at the water source (Figure 1). Measuring both values helps determine whether the water supply can support the desired number of raised beds operating at the same time. Typical household water pressure ranges from 40 to 60 pounds per square inch (psi), while flow rates at a single faucet often range from 1 to 3 gallons per minute (gpm), depending on plumbing and supply conditions.

Figure 1: Method of measuring flowrate (right side of splitter) and pressure (left side of splitter) of a water source.

Table 2 is a list of common vegetables grown in Tennessee along with their estimated weekly and seasonal water requirements (gallons per square foot). The data in this table were developed using historical weather data from Tennessee reference grass-based weather stations and crop coefficients (Kc) from a common reference called FAO-56.

Table 2 provides estimated water requirements based on the Tennessee climate for common vegetable crops that can be planted in a raised bed, backyard garden, or even large-scale farm. The values are based on the crop evapotranspiration (ET), which represents the combined water loss from wet soil evaporation and plant transpiration.

The values approximate the amount of water that must be supplied through rainfall or irrigation to maintain healthy plant growth. This information can help you evaluate whether your water source can supply adequate water for crop irrigation throughout the growing season.

Table 2: List of crop water needs for some of the common vegetables in Tennessee.

	Average Crop Water Need			
	Inches per week [1]	Gallons/ square foot per week [2]	Inches per season [3]	Gallons/ square foot per season [4]
Spring cabbage and broccoli	0.95	0.59	10.4	6.5
Fall cabbage and broccoli	0.70	0.43	7.7	4.8
Spring tomatoes	1.16	0.72	18.5	11.5
Fall tomatoes	0.93	0.58	11.2	7.0
Spring peppers	1.08	0.67	17.3	10.8
Fall peppers	0.87	0.54	10.4	6.5
Summer squash, melons, zucchini	1.01	0.63	15.1	9.4
Winter squash and pumpkins	0.83	0.52	11.6	7.3

[1] This column shows the depth of water required by the crop each week during the growing season. One inch of water means applying enough irrigation to cover the planting area with a one-inch layer of water.

[2] Because inches of water depth can be difficult to visualize, the weekly requirement is converted into gallons per square foot. This allows gardeners to estimate how much water is to apply based on the size of their raised bed.

[3] This column represents the cumulative water requirement over the entire growing season, from planting to harvest. It helps estimate total water demand and can be useful for planning water supply or irrigation system capacity.

[4] This is the seasonal requirement expressed in practical units for small-scale production. It helps gardeners understand the total irrigation volume needed throughout the crop cycle.

Crop Spacing and Row Spacing

To calculate the total crop water needs of each raised bed, it is necessary to know the planting density, row spacing and planting distance. Some plants are recommended to be planted with wide row spacing such as tomatoes (24-36 in) while green leafy plants like lettuce require a row spacing of 12 in. The recommended in-row plant spacing is 18-24 in tomatoes, 6-8 in for lettuce and 2-3 in for carrots.

Dimension of the Raised Bed

Sketch the plan of your irrigation system design, and include the size of the raised beds, the distance of the raised beds from one another, and the distance of the raised beds from the water source. This information is useful for designing and calculating the pressure required for operating an irrigation system, also note the length of the drip laterals and mainline.

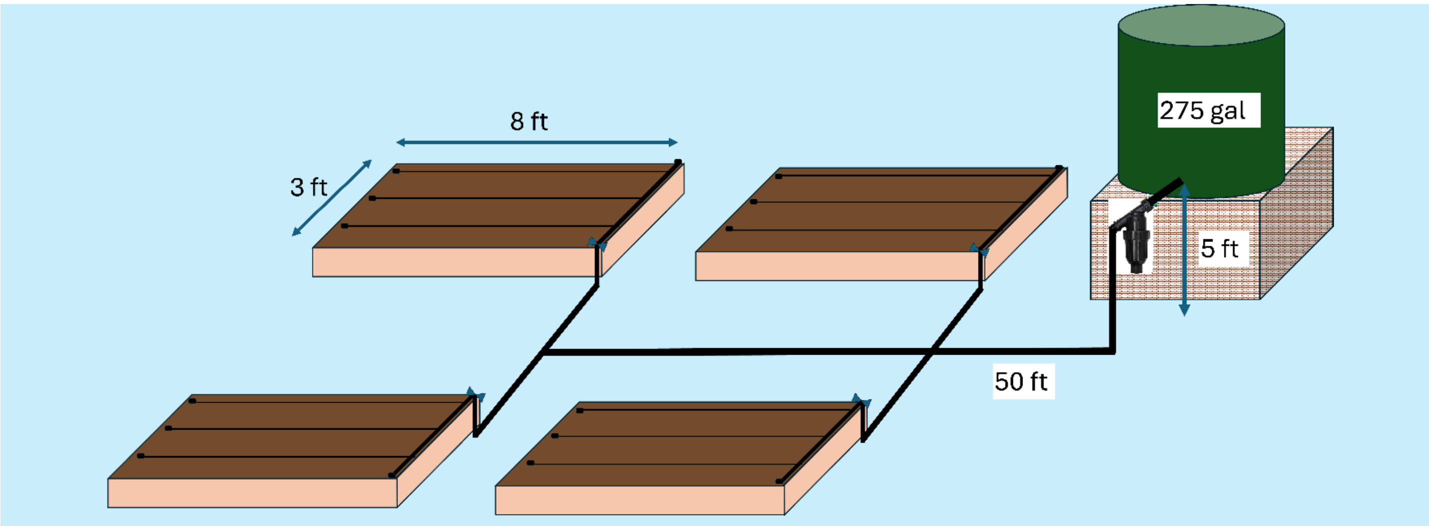
Decide on Emitter Type (Extension Fact Sheet (Molaei, et al., 2026) for More Information)

Drip Tape with inline drippers are the best choice for most annual crops, such as vegetables and cut flowers, as they are not durable for long-term use. Drip tape (Figure 2, left image) is one of the most inexpensive options that also works well with low pressure between 4-10 psi. The emitter spaces are usually around 6, 9, and 12 inches apart from each other, and flow rates are between 0.2 to 1.0 gph per emitter along the tape (Gunnel et al., 2025).

Figure 2. Example of raised bed with drip tape emitter (left) and with in-line dripper (right) installed at the Middle Tennessee Research and Education Center, University of Tennesse, Spring Hill, TN.

Irrigation design examples for tomato crops with a high rate of crop water use

- Selected crop: Tomatoes
- Crop water used for tomatoes: 0.16 inch/day, or 1.16 inch/week (Table 2)
- Planting plan: 3 rows of plants, with 1 foot row spacing. Within each row, plants are 6 inches apart.
- Dimensions of the raised bed: 3 ft by 8 ft
- Number of raised beds considered for this specific example: 4 raised beds
- Selected emitter for this project: drip tape, 6-inch distance of emitters, flow rate 0.2 gph at 10 psi pressure.
- Water source: Totes with a size of 275 gallons for rainwater harvesting
- Height of totes from ground level: 5 ft
- Distance between the water source (tote) to the closest raised bed: 50 ft



Net Required Water gpm: Emitter flowrate × (1 Hour/60 minutes)

Net gpm for tomatoes using selected drip tape: 0.2 gph × (1 Hour/60 minutes) = 0.003 gpm/Tomato

Required water for each raised bed:

Number of emitters per drip line: Length of raised bed where drip tape will be installed / distances between emitters on drip tape

Number of emitters per drip tape: 8 ft / 0.5 ft = 16 emitters

Flow rate per drip tape: 16 × 0.003 gpm = 0.048 gpm

Calculated flow rate per raised bed: 0.048 gpm × 3 drip tape per raised bed = 0.144 gpm

Emitter Area (ft^2): Emitter spacing × dripline spacing on the raised bed

6 inches × 1 ft × (12 inches/1 ft) = 0.5 ft^2

Hours of irrigation: (Crop water use [in/day] × Emitter Area [ft^2]) / (96.3* Net gpm)

Hours of operation of irrigation system for each raised bed = (0.16 in/day × 0.5 ft^2) / (1.61 × 0.003 gpm) = 16.66 min/day

Gallons of water for each raised bed per irrigation: 0.192 gpm * 16.66 min/day = 3.2 gal/day

Required water for 4 raised beds: 3.2 gal * 4 = 12.8 gal/day

Number of irrigation events with 1 full tote: 275 gal/12.8 gal/day ≈ 21 irrigation events

Rule of thumb for pressure requirements for operating an irrigation system

Total Pressure (psi): Emitter Req Pressure + Filter Loss + Friction Loss + Elevation Gain/Loss

Drip Emitters' Required Pressure:

- Typical emitters operate at 10-20 psi

Friction Loss in the System:

- Measure the distances of the raised bed from the water source
- Depending on flow rate, length, and pipe size
- For a small, raised bed system with short tubing runs (~25–50 ft), the friction loss is 1–2 psi for every 50 feet of tubing

Filtration Pressure Loss:

- Typical screen or disk filter: 2–3 psi
- Use 2 psi for a clean system or more if the clogging risk is high

Adjust for Elevation Changes:

- If the raised beds are higher than the water source, add 0.43 psi per foot of elevation gain
- If the raised beds are lower, subtract the pressure
- Pressure (psi) = height of water source × 0.433
- 1 psi pressure = 2.31 ft of head water

In the above example, emitter pressure for the drip tape is 6 psi, and for the inline drip tubing is 10 psi. In this project, the drip tape can operate at a minimum of 4 psi. A filter will be installed right after the exit of the tote, so a 2-psi pressure loss will be assumed for this project. The friction loss for this raised bed will be around 2 psi.

Pressure adjustment due to elevation difference: 5 ft × 0.433 = 2.165 gain pressure

Total Pressure (psi): Emitter Pressure + Filter Loss + Friction Loss ± Elevation change
Total required pressure: 4 psi + 2 psi + 2 psi - 2.165 psi = 5.8 psi = 13.48 ft of head water

Since the total required pressure for this irrigation system is around 6 psi, if the budget is available, it would be a good choice to find a booster pump to generate this amount of pressure to guarantee proper operation and uniformity of the irrigation system. Also, the tote could be raised to higher elevation.

To select a pump, it is important to know the pressure required to generate the pressure and the flow rate of water in the system. As 4 raised beds exist for this project, and you want to irrigate all the raised beds at the same time. If we had 12 raised beds, we could divide them into 3 zones, 4 raised beds per zone. The required flow rate per zone can be calculated as follows:

(4 raised beds × 3.2 gal for each raised bed) / 60 minutes = 0.21 gpm per zone
Flow rate for the pump when all 12 raised beds irrigated at once:
(12 raised beds × 3.2 gal for each raised bed) / 60 minutes = 0.64 gpm

Nominal vs. Actual Drip Tape Flow

Table 3 presents the nominal drip tape flow rate at the standard design pressure of 8 psi and the corresponding calculated actual flow rates at different operating pressures, providing a practical reference for field irrigation management. Although drip tape is typically rated at 8 psi, actual system pressure often varies due to elevation changes, friction losses along laterals, pump performance, and system configuration. These pressure differences directly affect emitter discharge and, therefore, the irrigation application rate. By using the pressure-adjusted flow values in this table, growers can more accurately estimate the amount of water being applied and determine the correct irrigation run time needed to achieve a target irrigation depth. This approach improves irrigation scheduling accuracy, helps prevent under- or over-irrigation, and supports more uniform water distribution and efficient use of water and energy.

$$\text{Actual Drip Tape Flow} = \text{Nominal Drip Tape Flow at 8 psi} \times \left(\frac{\text{Operating Pressure (psi)}}{\text{8 psi}}\right)^{0.5}$$

For example, suppose we select a drip tape with a nominal flow of 0.5 gpm per 100 ft at 8 psi, and we want to estimate the flow rate at 15 psi.

Actual Drip Tape Flow (gpm per 100 ft) at 15 psi = 0.5 × $[15 \div 8]^{0.5}$ = 0.685 gpm per 100 ft

Table 3. Pre-calculated Actual Drip Tape Flow at Variable Pressure:

		Nominal Drip Tape Flow at 8 psi (gpm per 100 feet)							
		0.1	0.2	0.3	0.4	0.5*	0.6	0.7	0.8
Common Pressure Regulator Ratings	10 psi	0.11	0.22	0.34	0.45	0.56	0.67	0.78	0.89
	12 psi	0.12	0.24	0.37	0.49	0.61	0.73	0.86	0.98
	15 psi	0.14	0.27	0.41	0.55	0.68	0.82	0.96	1.09
	20 psi	0.16	0.32	0.47	0.63	0.79	0.95	1.11	1.26

* The red color fonts represent the values used in the previous calculation example

Run Time of Drip Tape Irrigation Systems

Run time of irrigation systems is a critical management factor in drip tape irrigation systems because it directly controls the amount of water applied to the soil profile. Drip tape systems operate at relatively low application rates, and this effect is more pronounced in finer-textured soils where water meets crop demand and adequately wets the active root zone. If the run time is too short, irrigation may fail to deliver the intended depth of water, leading to shallow wetting, uneven moisture distribution, and crop water stress. Conversely, properly calculated run times ensure that the desired irrigation depth is achieved without excessive runoff or deep percolation. Table 4 and Table 5 shows the run time for pre-calculated drip tape and in-line dripper.

Drip Tape Run Time to Apply X inches of Water (hours)

In-line Drip Emitter Run Time to Apply X inches of Water (hours) can be calculated from the equation below.

$$Run\,Time\ (hr) = \frac{X\ inches\ of\ Water}{((96.3 \times (Flow/60)/(Emitter\ Distance\ in\ /12) \times (Lateral\ Distance\ in/12)))}$$

Example 1: Suppose we have in-line drip emitters with a flow rate of 0.53 gph, emitter spacing of 12 inches, and lateral spacing of 15 inches, and we want to apply 0.5 inches of water using this system. How long should we run the irrigation system to apply the required 0.5 inches of water?

$$Run\,Time\ (hr) = \frac{0.5\ inches\ of\ Water}{((96.3 \times (0.53/60)/(12/12) \times (15/12)))} = 0.73\ hr$$

Table 5. Pre-calculated In-line Drip Emitter Run Time to Apply X inches of Water (hours)

		Flow per Emitter (gph/100 feet)					
Distance Between Emitters	Distance Between Laterals	0.42	0.5	0.53	0.92	1	2
12 in	12 in	0.74	0.62	0.59	0.34	0.31	0.16
	15 in	0.93	0.78	0.73	0.42	0.39	0.19
	18 in	1.11	0.93	0.88	0.51	0.47	0.23
	24 in	1.48	1.25	1.18	0.68	0.62	0.31
	30 in	1.85	1.56	1.47	0.85	0.78	0.39
18 in	12 in	1.11	0.93	0.88	0.51	0.47	0.23
	15 in	1.39	1.17	1.10	0.63	0.58	0.29
	18 in	1.67	1.40	1.32	0.76	0.70	0.35
	24 in	2.23	1.87	1.76	1.02	0.93	0.47
	30 in	2.78	2.34	2.20	1.27	1.17	0.58
24 in	12 in	1.48	1.25	1.18	0.68	0.62	0.31
	15 in	1.85	1.56	1.47	0.85	0.78	0.39
	18 in	2.23	1.87	1.76	1.02	0.93	0.47
	24 in	2.97	2.49	2.35	1.35	1.25	0.62
	30 in	3.71	3.12	2.94	1.69	1.56	0.78
30 in	12 in	1.85	1.56	1.47	0.85	0.78	0.39
	15 in	2.32	1.95	1.84	1.06	0.97	0.49
	18 in	2.78	2.34	2.20	1.27	1.17	0.58
	24 in	3.71	3.12	2.94	1.69	1.56	0.78
	30 in	4.64	3.89	3.67	2.12	1.95	0.97

* The red color fonts represent the values used in the previous calculating example

$$Drip\ Tape\ Run\ Time\ (hours) = \frac{X\ inches\ of\ Water}{((96.3 \times Drip\ Flow)/(Inches\ Distance/12) \times 100))}$$

Example 2: Suppose we have drip tape with a flow rate of 0.65 gpm per 100 ft, the spacing between drip tape laterals is 15 inches, and we want to apply 0.5 inches of water using this system. How long do we need to run the system to apply 0.5 inches of water?

$$Drip\ Tape\ Run\ Time\ (hours) = \frac{0.5\ inches\ of\ Water}{((96.3 \times 0.65)/(15/12) \times 100))} = 1\ hr$$

Table 4. Pre-calculated Drip Tape Run Time to Apply 0.5 inches of Water (Hours)

		Drip Tape Flow (gpm/100 feet)								
		0.15	0.25	0.35	0.45	0.55	0.65*	0.75	1.00	1.50
Distance Between Drip Tape Laterals	12 in	3.5	2.1	1.5	1.2	0.9	0.8	0.7	0.5	0.3
	15 in	4.3	2.6	1.9	1.4	1.2	1.0	0.9	0.6	0.4
	18 in	5.2	3.1	2.2	1.7	1.4	1.2	1.0	0.8	0.5
	24 in	6.9	4.2	3.0	2.3	1.9	1.6	1.4	1.0	0.7
	30 in	8.7	5.2	3.7	2.9	2.4	2.0	1.7	1.3	0.9

* The red color fonts represent the values used in the previous calculation example

Conclusion

Designing an efficient drip irrigation system for raised beds requires a clear understanding of water availability, crop water needs, system components, and operating conditions. By following a step-by-step approach—estimating flow rate and pressure, selecting appropriate emitters, and calculating system capacity and run time—gardeners can apply water more accurately and consistently. This not only supports healthy plant growth but also improves water use efficiency and reduces waste. While these guidelines are well-suited for small-scale and non-commercial applications, they also provide a strong foundation for understanding the key principles of irrigation system design.

References and Further Reading

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