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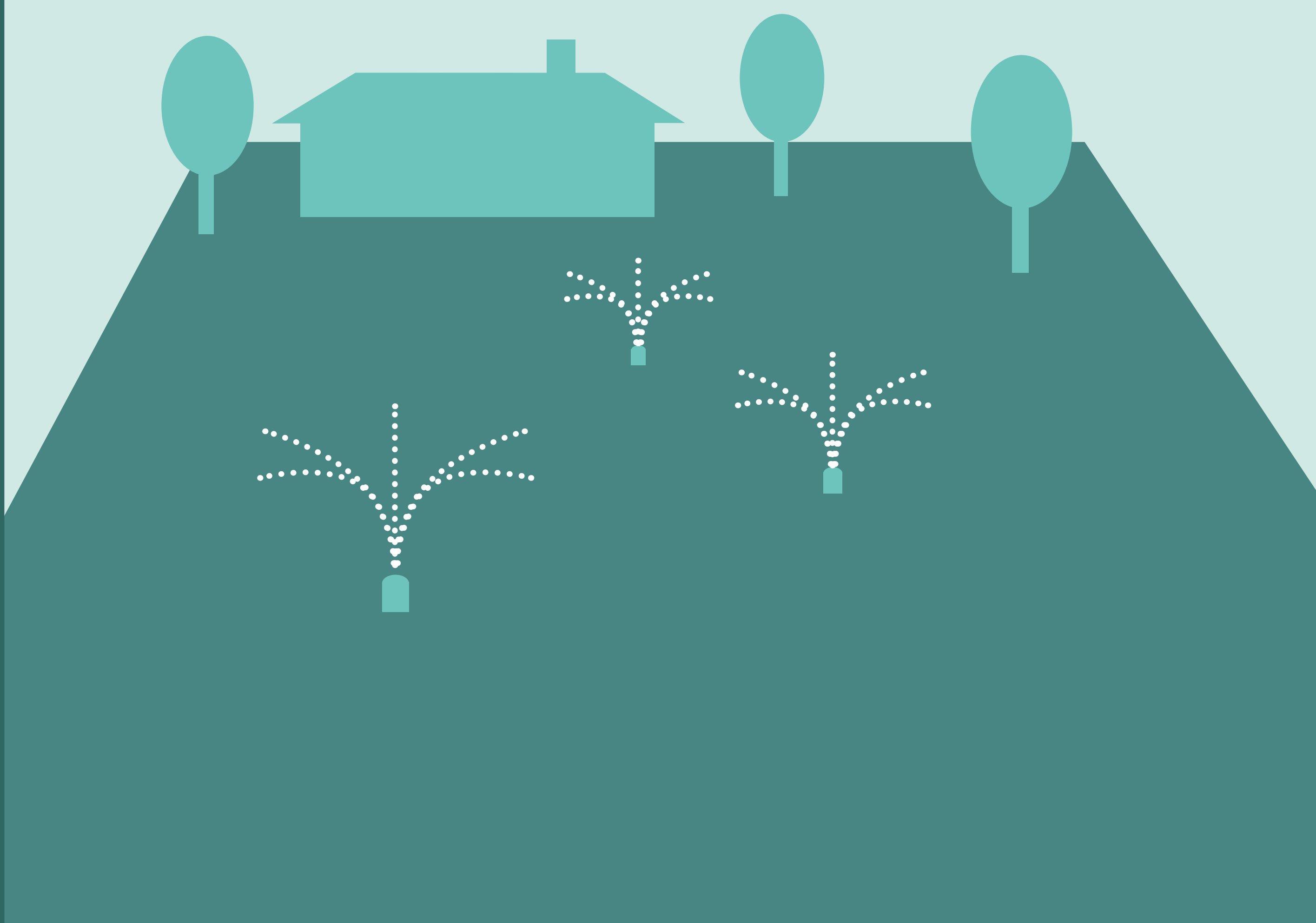
On-site Sprinkler Irrigation of Treated Wastewater in Ohio



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Introduction

Reusing the water and nutrients in treated wastewater is the goal of an on-site sprinkler irrigation system. As Ohio continues to work to eliminate the discharge of pollutants to lakes and streams, dispersing treated wastewater is one of the options to eliminate discharges. Consider an on-site sprinkler irrigation system for:

- sites where off-lot discharge is not allowed.
- wooded lots, where trenches or mounds would damage trees.
- lots with steep slopes, where trenches or mounds are dangerous to install.
- sites with shallow soils to a limiting condition—as shallow as 6 inches.
- green buildings—to reuse water and nutrients to obtain LEED credits.

Therefore, almost every rural lot in Ohio is suited for sprinkler irrigation of treated wastewater.

Wastewater Treatment

Wastewater must be treated and disinfected before sprinkler irrigation. The goal is to eliminate odors and prevent the spread of disease-causing organisms. Sand bioreactors, fixed-media bioreactors, aerobic treatment units, and wastewater stabilization ponds are all able to treat the wastewater before on-site sprinkler irrigation. For more information, see Bulletin 876, *Sand and Media Bioreactors for Wastewater Treatment for Ohio Communities*, available from local Ohio State University Extension offices or online at **extensionpubs.osu.edu/natural-resources/water/**.

People are understandably concerned about disease-causing organisms and sprinkler irrigation of treated wastewater in the yard. Currently, the Ohio Department of Health recommends that swimming beaches have water with E. coli bacteria less than $\frac{235 \text{ cfu}}{100 \text{ mL}}$. Therefore, to ensure the protection of public health, wastewater sprayed in public areas, such as lawns, should be 10 times lower than the level considered safe for swimming.

Treated wastewater can be effectively disinfected with ultraviolet light and chlorine. UV-light disinfection units require very clear wastewater; therefore, the suspended solids in the treated wastewater need to be below $10\frac{\text{mg}}{\text{L}}$ of total suspended solids (TSS). Chlorine is highly effective at killing disease-causing organisms in treated wastewater. Tablet feeders dispense calcium hypochlorite (HTH) tablets into a tank, where the tablets quickly dissolve. The treated wastewater should be held at least 30 minutes to provide adequate time for the chlorine to disinfect before discharge to the irrigation system. Fortunately, because irrigation water is stored in a large dosing tank, the contact time is easily accounted for within the system.

Research at The Ohio State University shows that a slow-release chlorine compound (sodium dichloroisocyanurate or NaDCC) usually used in spas works especially well in disinfection before irrigation. To learn more, see Bulletin 943, *Reuse of Reclaimed Wastewater—Disinfection to Protect Public Health*, available from local OSU Extension offices or online at **extensionpubs.osu.edu/natural-resources/water/**.

The treatment goals are as follows:

- $CBOD_5 < 25 \frac{\text{mg}}{\text{L}}$ (to minimize odors)
- E. coli bacteria $< \frac{23 \text{ cfu}}{100 \text{ mL}}$ (to protect public health in public access areas)

–OR–

- E. coli bacteria $< \frac{235 \text{ cfu}}{100 \text{ mL}}$ (in isolated areas)

Land Requirements

One goal of on-site sprinkler irrigation is to disperse the treated wastewater while not forming puddles. Puddles could result in odors and could create the potential for runoff. Another goal is to provide enough water and nutrients for plants, but not too much. To match Ohio's climatic conditions and plant needs, at most, 0.2 inches of water should be applied each day.

Table 1: Design Considerations

Goal	Design Considerations
Reuse water and nutrients to promote plant growth	Irrigation rate matched to Ohio's climate at less than 0.2 inches per day
No odors	$CBOD_5$ less than 25$\frac{mg}{L}$, no puddles
No disease spread	Disinfection or spray in isolated areas
No runoff	Less than 0.2 inches per day, with 10 feet of separation from the edge of the spray
No spray drift	50 feet separation from spray heads
Year-round application	Drain sprinklers, risers, and shallow pipes

To disperse the wastewater, at least 962.5 square feet per bedroom is needed to apply wastewater at full design loading of 120 gallons per bedroom. Table 2 lists the minimum area needed for houses of different sizes.

Table 2: Minimum Irrigation Area Needed in Ohio

# of Bedrooms	Volume (gallons/day)	Minimum Area (ft^2)
1	120	962.5
2	240	1925
3	360	2887.5
4	480	3850
5	600	4812.5

When considering the land area, isolation distances also must be considered. Consider isolation distances of:

- 50 feet from the sprinkler head, to account for any spray drift.

—AND—

- 10 feet from the edge of the spray field from buildings, paved surfaces (e.g., concrete sidewalks, blacktop driveways, paver patios), surface water (e.g., ponds, streams, ditches), property boundaries, and vegetable gardens.

In addition, the spray irrigation area should be 50 feet from wells. To protect delicate plants and to ensure even spray distribution, consider the spray pattern area. A tree or large shrub should be at least 10 feet away from the sprinkler within the spray pattern area.

System Design Process

Placement of spray irrigation components has a wide range of options. Designers consider the needs of the wastewater reuse and the use of the property when developing a plan. This bulletin includes example design options, but many other alternatives can also be appropriate. Use these examples as a starting point to design and site an on-site sprinkler irrigation system.

Select Sprinkler Heads

Selecting sprinkler heads for a system requires investigating various sprinkler models to find one with the characteristics best suited for the site and watering needs. Important selection information includes the operating pressure, flow range, precipitation rate, and the radius and arc of coverage. This information is found in the product catalog provided by the sprinkler manufacturer. In addition, many sprinklers have special features such as angles of trajectory and nozzle options. All these considerations are important in the selection process. While no single sprinkler head works best in all wastewater applications, this bulletin provides a step-by-step method for selecting a sprinkler head that will provide the proper application for the site.

Sprinkler Heads

Rotary spray heads are used for small residential irrigation projects. Rotary heads provide a large spray radius (15–50 feet) and a relatively low gallon-per-minute (gpm) flow rate, which reduces the probability of puddling and runoff. Rotary heads also spray with enough force to prevent clogging of the heads with particles. The heads should be installed on stationary risers (a minimum of 18 inches) to allow for continued application through the Ohio winter season. Higher risers may be needed in the high snowfall area of northeast Ohio.

Selecting the Proper Sprinkler

Selecting the proper sprinkler for the project is a matter of analyzing the amount of water to be distributed and the area to be watered. Sprinkler selection determines the pressure requirement, pump size, and irrigation run times. This might be an iterative process requiring several attempts before the right combination of these factors merge. The following guidelines provide a general rule for sprinkler selection.

Guideline 1: Sprinkler Radius

Based on the application area geometry, how far does the sprinkler need to throw water? As a general rule, the largest radius sprinkler results in less initial system cost. However, while rotary heads have the ability to spray from 75 feet to 100 feet, a pump that can create the required pressure might be cost-prohibitive for most projects. A radius of 25–50 feet is a reasonable starting point. Most sprinklers are designed so that the throw radius can be adjusted from 75 percent to 100 percent of the manufacturer's listed full radius. Typically, the radius can be reduced by up to 25 percent and still provide acceptable uniformity of water distribution.

Guideline 2: Flow Rate

The type and number of sprinklers in an area determine the required capacity of the pump used for the system. If an area contains four sprinkler heads with 3 gallon-per-minute flow rates, the pump needs a minimum capacity of 12 gallons per minute. The flow rate of a system is controlled by selecting heads with specific flow rates. It is important to keep pump cost in mind.

Guideline 3: Pressure Requirements

Operating pressure is the pressure that provides optimum sprinkler performance. Manufacturers establish the optimal pressure for their sprinklers and publish them in catalogs and product literature. As a general rule, greater throw radius requires greater pressure, which in turn, requires a more powerful pump. Proper functioning of the sprinkler head requires that the dynamic pressure of the system meets or slightly exceeds the pressure specifications given for the sprinkler head. In addition to the pressure requirement of the sprinkler head, account for pressure losses due to elevation changes and friction in the piping system. Pressure loss calculations are discussed further in Example 1: Step 7.

Guideline 4: Sprinkler Spray Pattern

Most sprinklers distribute water in a circular pattern. The "pattern" describes the portion of the full circle that is covered by the sprinkler. The spray pattern can be adjusted from 360° (full) to 270° (⅔), 180° (½), 120° (⅓), and 90° (¼) as needed to accommodate the desired spray area.

Guideline 5: Angles of Trajectory

Sprinkler heads are available with a standard trajectory of 18°–28° or a low trajectory of 13°–15°. Standard trajectory sprinklers work well for hillsides, wooded areas, or isolated areas. Low trajectory sprinklers work well in open lawns with few trees.

Guideline 6: Non-potable Water Marking

Identify the systems as applying reclaimed water (non-potable). This can be accomplished by placing a sign within the system, installing purple sprinkler heads, or painting the sprinkler heads purple.

Example 1: Simple and Low-Cost Layout

Calculate the Minimum Land Area Requirements

Example 1: Step 1

Suppose a house has four bedrooms.

$$(4\text{ bedrooms})\left(\frac{120\text{ gallons}}{\text{bedroom}*\text{day}}\right) = 480\,\frac{\text{gallons}}{\text{day}}$$

The daily design wastewater volume is 480 gallons.

Each gallon of water requires approximately 8 square feet of area to ensure proper infiltration for one to five bedrooms. See Appendix D for the conversion of gallons to square feet.

Example 1: Step 2

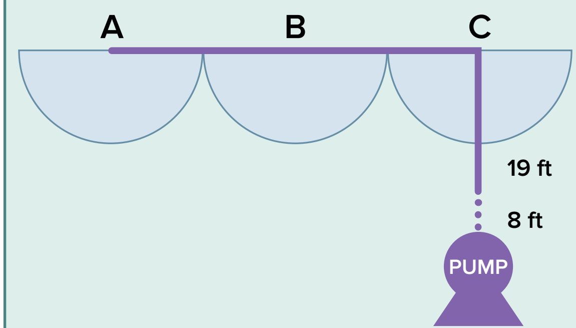
$$\left(\frac{480\text{ gallons}}{\text{day}}\right)\left(\frac{8.021\text{ ft}^2}{\text{gallon}}\right)(1\text{ day}) = 3850\text{ ft}^2$$

The land area requirement is 3850 ft^2.

Place Sprinkler Heads

Example 1: Step 3

Place three sprinkler heads in a non-overlapping line with a 32 feet radius half-circle spray pattern.



Example 1: Step 4

Using 32 feet as the spray pattern radius, find the spray area given that the design calls for three half circles.

$$3 * \frac{\pi r^2}{2} = 3 * \frac{\pi(32\text{ feet})^2}{2} = 4825.5\ ft^2$$

This design will spray a total area of 4825.5 ft^2. From Example 1: Step 2, it was determined that a four-bedroom house needed at least an area of 3850 ft^2. This design will work because it covers more than the minimum area required.

Example 1: Step 5

Select a low-angle, gear-driven rotor sprinkler from Appendix F: Nozzle Performance Table. For this design, the #3 nozzle is used.

#3 nozzle

Pressure @ 40 psi

Throw radius of 32 ft

Flow rate of 3.1 gpm

Layout and Sizing of Pipes

Selecting pipe and laying out the system depends on the sprinkler placement (Example 1: Step 3) and sprinkler selection (Example 1: Step 5).

Layout

Polyvinyl chloride (PVC) and polyethylene (Poly) pipe are commonly used for irrigation systems. Connect all sprinkler heads using the most direct route possible. Keep turns and changes in direction to a minimum. Avoid trenching lines through the middle of the spray area.

Sizing Lateral Lines

For small residential installations, it is standard practice to use the same size of pipe for all lateral lines. It is important to use the proper size. A pipe that is too small will result in unacceptable friction losses. To minimize friction loss, water velocity should not exceed 5 feet per second. Slime and bacterial growth can build up in pipes, creating clogging conditions. To prevent this, the velocity should be greater than 1 foot per second.

To size pipe based on flow rates, use the following procedure:

1. Identify the gpm requirement of the furthest head from the main line point of connection (POC).
2. On the appropriate Friction Loss Table (Appendix A) for the type of pipe selected, find the gpm amount from the first item in the far left column.
3. In that row, move right across the Friction Loss Table until a velocity of less than 5 feet per second is reached.
4. Move up that column to find the minimum pipe size necessary to carry the flow to this head.
5. Add together the gpm requirements of the last and next-to-last heads in order to size the next pipe.
6. Find the total gpm in the first column on the Friction Loss Table, and repeat the third and fourth steps in the eight-step procedure listed here.
7. Continue this process until you reach the main line POC.
8. Select the largest pipe sizes for the entire area.

Note: Do NOT size the pipe smaller than the Friction Loss Table indicates; however, a larger pipe can be used as long as the velocity is above 1 foot per second.

Sizing the Main Line

Size the main line using the appropriate Friction Loss Table (Appendix A). The main line must be large enough to handle the entire flow rate of the system without exceeding a velocity of 5 feet per second.

Example 1: Step 6

Lateral Lines

@ A

Flow rate of furthest head = 3.1 gpm (round to 4 gpm)

Look up velocity using 4 gpm on Friction Loss Table

Velocity = 4.22 ft/sec

Minimum nominal pipe size is ½ inch

@ B

Flow rate = (3.1 gpm + 3.1 gpm) = 6.2 gpm (round to 7 gpm)

Look up velocity using 7 gpm on Friction Loss Table

Velocity = 4.20 ft/sec

Minimum nominal pipe size is ¾ inch

@ C

Flow rate = (6.2 gpm + 3.1 gpm) = 9.3 gpm (round to 10 gpm)

Look up velocity using 10 gpm on Friction Loss Table

Velocity = 3.70 ft/sec

Minimum nominal pipe size is 1 inch

For this example, 1-inch PVC schedule 40 pipe will be used for all the lateral lines.

Main Line

Using the Friction Loss Table as described above, the minimum nominal size of the main line is 1 inch.

Size (in) ID (in)	½ 0.622		¾ 0.824		1 1.049		1 ¼ 1.380		1 ½ 1.610		2 2.067		2 ½ 2.469	
Flow (gpm)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)
1	1.05	0.43	0.60	0.11	0.37	0.03	0.21	0.01	0.15	0.00				
2	2.11	1.55	1.20	0.39	0.74	0.12	0.42	0.13	0.31	0.02	0.19	0.00		
3	3.16	3.28	1.80	0.84	1.11	0.26	0.64	0.07	0.47	0.03	0.28	0.01	0.20	0.00
4	4.22	5.60	2.40	1.42	1.48	0.44	0.85	0.12	0.62	0.05	0.38	0.02	0.26	0.01
5	5.27	8.46	3.00	2.15	1.85	0.66	1.07	0.18	0.78	0.08	0.47	0.02	0.33	0.01
6			3.60	3.02	2.22	0.93	1.28	0.25	0.94	0.12	0.57	0.03	0.40	0.01
7			4.20	4.01	2.59	1.24	1.49	0.33	1.10	0.15	0.66	0.05	0.46	0.02
8			4.80	5.14	2.96	1.59	1.71	0.42	1.25	0.20	0.76	0.06	0.53	0.02
9			5.40	6.39	3.33	1.97	1.92	0.52	1.41	0.25	0.85	0.07	0.60	0.03
10					3.70	2.40	2.14	0.63	1.57	0.30	0.95	0.09	0.66	0.04
11					4.07	2.86	2.35	0.75	1.73	0.36	1.05	0.11	0.73	0.04
12					4.44	3.36	2.57	0.89	1.88	0.42	1.14	0.12	0.80	0.05
14					5.19	4.47	2.99	1.18	2.20	0.56	1.33	0.17	0.93	0.07
16							3.42	1.51	2.51	0.71	1.52	0.21	1.07	0.09
18							3.85	1.88	2.83	0.89	1.71	0.26	1.20	0.11
20							4.28	2.28	3.14	1.08	1.90	0.32	1.33	0.13
22							4.71	2.72	3.46	1.29	2.10	0.38	1.47	0.16
24							5.14	3.20	3.77	1.51	2.29	0.45	1.60	0.19
26									4.09	1.75	2.48	0.52	1.74	0.22
28									4.40	2.01	2.67	0.60	1.87	0.25
30									4.72	2.28	2.86	0.68	2.00	0.29
35									5.50	3.04	3.34	0.90	2.34	0.38
40											3.81	1.15	2.67	0.49
45											4.29	1.43	3.01	0.60
50											4.77	1.74	3.34	0.73
55											5.25	2.08	3.68	0.88
60													4.01	1.03
65													4.35	1.19
70													4.68	1.37
75													5.01	1.56

For quick pipe sizing use Table 3 based on flow rates of less than 5 feet per second.

Table 3: Pipe Sizing Chart

Maximum Flow Rates in gpm		
Pipe Size (inch)	PVC Schedule 40	Polyethylene
¾	8	8
1	12	12
1 ¼	22	22

Estimate Pressure Losses

For an on-site wastewater irrigation system, water pressure is created by the distribution pump. Estimating pressure losses is necessary for determining the appropriate pump size. The total pressure loss in the system results from the combined losses due to elevation changes and friction.

Losses Due to Elevation Change

Water pressure can be expressed as either pounds of pressure per square inch (psi) or feet of head. A 1-foot-high column of water exerts 0.433 psi at the bottom; therefore, 1 psi is equivalent to 2.31 feet of head. This means that for every foot of elevation change from the pump to the sprinkler heads, the corresponding change in pressure will be 0.433 psi.

Losses Due to Friction

As water moves through the irrigation system, pressure losses occur due to water contact with pipes, valves, and fittings. Here are three factors that determine friction losses:

1. The velocity of the water. Water velocity is measured in feet per second. As velocity increases, pressure losses increase. Velocity is directly related to flow rate. An increase or decrease in flow rate will result in a corresponding increase or decrease in velocity. For irrigation systems, the velocity should never exceed 5 feet per second. At a velocity greater than 5 feet per second, the friction losses become prohibitive.

2. The size (inside diameter) of the pipe. Smaller pipe causes a greater proportion of the water to be in contact with the pipe, which creates friction. Pipe size also affects velocity. Given a constant flow rate, decreasing pipe size increases the water's velocity, which increases friction.

3. The length of the pipe. The friction losses are cumulative as the water travels through the length of pipe. The greater the distance, the greater the friction losses will be.

Friction Losses Due to Valves, Fittings, and Other Components

Friction losses for couplings, elbows, and tees are given in Appendix A-3: Pressure Loss in Valves and Fittings. Friction loss from these components must be accounted for when calculating friction losses for each section of pipe. Add the equivalent length of pipe for each fitting or valve that occurs in each section of the lateral and main lines. Consult the manufacturer's literature for friction losses through valves, regulators, filters, and other components not listed. Several formulas have been developed to calculate the friction losses in irrigation systems and, for convenience, friction loss charts based on these formulas are listed.

Friction Losses in Lateral Lines

Using the pipe layout plan with the pipe size and the gpm requirements for each sprinkler head clearly labeled, begin calculating the pressure losses as follows:

1. Determine the gpm flow rate of the furthest sprinkler head form the main line connection.

2. Locate the gpm value in the "Flow" column on the appropriate Friction Loss Table (Appendix A).

3. Across the top of the table, locate the pipe size (inside diameter) of the pipe that supplies this sprinkler head with water.

4. Move down this column and across the row for the gpm value to the corresponding "Loss (psi)," given per 100 feet of pipe. Divide this number by 100 to obtain the per-foot pressure loss.

5. Locate any fittings in this section and determine the corresponding equivalent length of pipe. Add this number to the actual length of pipe in this section to determine the effective pipe length.

6. Multiply the per-foot pressure loss value by the effective length of the pipe supplying this sprinkler head only (from this head to the next head in the system).

7. Record this information on Appendix B: Friction Loss Worksheet.

Note the gpm flow rate of the next to last head. Add this gpm to the previous head gpm to determine the total amount of water flowing through this section of pipe. Repeat steps 2–6 in the seven-step procedure listed here. Continue adding consecutive sprinkler heads and calculated friction losses using steps 2–6 in the 7-step procedure listed here until every section of the pipe is accounted for.

Friction Losses in the Main Line

Use the total gpm flow rate for the system to calculate the friction loss through the main line using the same procedure as described above. If the mainline size or pipe material is different from the laterals, be sure to use the appropriate Friction Loss Table (Appendix A).

Total Friction Losses

Add the friction losses for all lateral lines, main line, and other components in the system all the way back to the pump. Add this to the pressure loss due to the elevation change from the pump to the highest sprinkler head in the system. This total added to the operating pressure of the sprinkler heads will determine the pump requirements to ensure the proper operation of all the sprinkler heads in the system.

Example 1: Step 7

A→B

Flow Rate = 3.1 gpm (round to 4 gpm)

Look up pressure loss using 4 gpm and 1-inch pipe on Friction Loss Table

$$\text{Pressure Loss} = \frac{0.44 \text{ psi}}{100 \text{ ft}} = \frac{0.0044 \text{ psi}}{\text{ft}}$$

Look up equivalent feet on Appendix A-3: Pressure Loss in Valves and Fittings

64 ft (pipe A→B) + 0.5 ft (¾-inch gate valve @ A) + 3 ft (90° elbow @ A) = 67.5 ft

$$(67.5 \text{ ft})\left(\frac{0.0044 \text{ psi}}{\text{ft}}\right) = 0.30 \text{ psi}$$

B→C

Flow Rate = (3.1 gpm + 3.1 gpm) = 6.2 gpm (round to 7 gpm)

Look up pressure loss using 7 gpm and 1-inch pipe on Friction Loss Table

$$\text{Pressure Loss} = \frac{1.24 \text{ psi}}{100 \text{ ft}} = \frac{0.0124 \text{ psi}}{\text{ft}}$$

Look up equivalent feet on Appendix A-3: Pressure Loss in Valves and Fittings

64 ft (pipe B→C) + 2 ft (tee @ B) = 66 ft

$$(66 \text{ ft})\left(\frac{0.0124 \text{ psi}}{\text{ft}}\right) = 0.82 \text{ psi}$$

C→Pump

Flow Rate = (6.2 gpm + 3.1 gpm) = 9.3 gpm (round up to 10 gpm)

Look up pressure loss using 10 gpm and 1-inch pipe on Friction Loss Table

$$\text{Pressure Loss} = \frac{2.40 \text{ psi}}{100 \text{ ft}} = \frac{0.024 \text{ psi}}{\text{ft}}$$

Look up equivalent feet on Appendix A-3: Pressure Loss in Valves and Fittings

32 ft + 19 ft (pipe C→Pump) + 2 ft (tee @ C) + 3 ft (90° elbow) + 3 ft (90° elbow) = 59 ft

$$(59 \text{ ft})\left(\frac{0.024 \text{ psi}}{\text{ft}}\right) = 1.42 \text{ psi}$$

Total Pressure Loss

0.30 psi + 0.82 psi + 1.42 psi = 2.54 psi

Size (in) ID (in)	½ 0.022		¾ 0.824		1 1.049		1 ¼ 1.380		1 ½ 1.610		2 2.067		2 ½ 2.469	
Flow (gpm)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)
1	1.05	0.43	0.60	0.11	0.37	0.03	0.21	0.01	0.15	0.00				
2	2.11	1.55	1.20	0.39	0.74	0.12	0.42	0.13	0.31	0.02	0.19	0.00		
3	3.16	3.28	1.80	0.84	1.11	0.26	0.64	0.07	0.47	0.03	0.28	0.01	0.20	0.00
4	4.22	5.60	2.40	1.42	1.48	0.44	0.85	0.12	0.62	0.05	0.38	0.02	0.26	0.01
5	5.27	8.46	3.00	2.15	1.85	0.66	1.07	0.18	0.78	0.08	0.47	0.02	0.33	0.01
6			3.60	3.02	2.22	0.93	1.28	0.25	0.94	0.12	0.57	0.03	0.40	0.01
7			4.20	4.01	2.59	1.24	1.49	0.33	1.10	0.15	0.66	0.05	0.46	0.02
8			4.80	5.14	2.96	1.59	1.71	0.42	1.25	0.20	0.76	0.06	0.53	0.02
9			5.40	6.39	3.33	1.97	1.92	0.52	1.41	0.25	0.85	0.07	0.60	0.03
10					3.70	2.40	2.14	0.63	1.57	0.30	0.95	0.09	0.66	0.04
11					4.07	2.86	2.35	0.75	1.73	0.36	1.05	0.11	0.73	0.04
12					4.44	3.36	2.57	0.89	1.88	0.42	1.14	0.12	0.80	0.05
14					5.19	4.47	2.99	1.18	2.20	0.56	1.33	0.17	0.93	0.07
16							3.42	1.51	2.51	0.71	1.52	0.21	1.07	0.09
18							3.85	1.88	2.83	0.89	1.71	0.26	1.20	0.11
20							4.28	2.28	3.14	1.08	1.90	0.32	1.33	0.13
22							4.71	2.72	3.46	1.29	2.10	0.38	1.47	0.16
24							5.14	3.20	3.77	1.51	2.29	0.45	1.60	0.19
26									4.09	1.75	2.48	0.52	1.74	0.22
28									4.40	2.01	2.67	0.60	1.87	0.25
30									4.72	2.28	2.86	0.68	2.00	0.29
35									5.50	3.04	3.34	0.90	2.34	0.38
40											3.81	1.15	2.67	0.49
45											4.29	1.43	3.01	0.60
50											4.77	1.74	3.34	0.73
55											5.25	2.08	3.68	0.88
60													4.01	1.03
65													4.35	1.19
70													4.68	1.37
75													5.01	1.56

Nominal Pipe Size	Gate Valve	Standard Tee	Standard Elbow	45-degree Angle
½	0.4	1	2	1
¾	0.5	2	3	1
1	0.6	2	3	2
1¼	0.8	3	4	2
1½	1	3	5	2
2	1.2	4	6	3
2½	1.4	5	7	3

Example 1: Step 8

Elevation Change

$$(8 \text{ ft})\left(0.433 \frac{\text{psi}}{\text{ft}}\right) = 3.46 \text{ psi}$$

Total Pressure of Friction Loss and Elevation Change

3.46 psi + 2.54 psi = 6.00 psi

Total Feet of Head

$$(6.00 \text{ psi})\left(\frac{2.31 \text{ ft}}{\text{psi}}\right) = 13.9 \text{ ft of head}$$

$$(40 \text{ psi})\left(\frac{2.31 \text{ ft}}{\text{psi}}\right) = 92.4 \text{ ft of head}$$

13.9 ft + 92.4 ft = 106.3 ft of head

Total Flow Rate

9.3 gpm

Irrigation Area

4825.5 ft^2

Precipitation Rate

$$\frac{(9.3 \text{ gpm})(96.25)}{4825.5 \text{ ft}^2} = 0.19 \frac{\text{in}}{\text{hr}}$$

Run Time

$$\frac{480 \text{ gal}}{9.3 \text{ gpm}} = 51.6 \text{ mins}$$

Loading Rate

$$\left(51.6 \frac{\text{mins}}{\text{day}}\right)\left(\frac{0.19 \text{ in}}{\text{hr}}\right)\left(\frac{1 \text{ hr}}{60 \text{ mins}}\right) = 0.16 \frac{\text{in}}{\text{day}}$$

Select a Pump and Dosing Tank

The pumping system is submerged in a watertight dosing tank. The dosing tank should be sized to accommodate the daily volume of wastewater plus two additional days of storage.

Centrifugal pumps are typically used for residential irrigation systems. For irrigation of treated wastewater, use only pumps that have been specifically designed for use with septic tank effluent or pond water. Examine pump curves to determine an appropriate pump. Total dynamic head (TDH) and flow rate (in gpm) are used to make the selection. TDH is the sum of the total friction losses and the operating pressure of the sprinkler heads, while the flow rate is the output in gallons per minute for all of the sprinkler heads in the system. Avoid selecting too large of a pump, with the gpm versus TDH well below the pump curve. Large pumps are more expensive. The required TDH for the flow rate should be on or just below the pump curve, within the middle two-thirds of the curve, for most efficient operation.

Select a Controller

Controllers use floats and timers to determine the time and duration of each irrigation cycle. Irrigation should occur early in the morning and be limited to the amount of time needed to irrigate—at most, one day's design flow of treated wastewater. The controls should also allow for the manual override of the system to start and stop an irrigation cycle during maintenance, service, and repairs of the system. The control panel should have a visual and audible alarm for high water, pump failure, UV bulb failure, and other electrical component issues. Researchers at The Ohio State University recommend the installation of surge and lighting protection to safeguard against damage to the controller during storms and power outages.

Determine the Irrigation Schedule

Because it can be unpleasant to be sprayed with water, irrigation should be done when people and pets are not expected to be present. Early morning (between 4–5 a.m.) is a good time to run the system, because irrigating late at night might lead to the growth of fungi and might promote turf disease. Since wastewater is generated every day, the system should be able to run every day. The run duration depends on the flow rate of the sprinkler heads in the system.

Two important conditions are necessary when programming the controller:

1. The duration should allow the distribution of the design's daily flow of wastewater.
2. The duration is limited to the time it takes to apply 0.2 inches per day.

If Steps 1, 2, and 3 of Example 1 were completed properly, these two conditions will occur simultaneously.

Calculating the precipitation rate (PR) will provide the proper run time for the system. The PR for an individual sprinkler of an entire sprinkler system is the depth of water applied in a given area, expressed in inches per hour. The PR is determined by multiplying the total gpm by 96.25 and dividing by the total area: $PR = \frac{\text{total gpm} * 96.25}{\text{total area}}$. Use the PR to determine the run time. If the PR is 1 inch per hour, the run time would be 0.2 hours, or 12 minutes. Rain gauges can be used to check the system and make adjustments as needed.

Operation and Maintenance

All landscape irrigation systems require regular maintenance to protect the investment in the equipment. Wastewater irrigation systems are no different. In addition, proper operation and maintenance are essential to protecting public health and the environment. Periodic inspection and maintenance of the system ensure that the system is working as designed and will save the homeowner money by preventing premature repairs to or replacement of system components.

Every six months, do the following:

1. Check the pumps and alarms.
2. Turn on the irrigation system to check the spray head function and spray pattern. Repair, adjust, or replace the spray heads as needed. Also check for ponding and runoff.
3. Place several rain gauges in the irrigation area

to check the depth of application. The system should apply no more than 0.2 inches per day to prevent ponding or runoff.

4. Sample the quality of the irrigated water by placing a sterile container in the irrigation area and allowing the irrigated water to fill the container. Test for $CBOD_5$ and fecal coliform bacteria. Refer to the Soil Environment Technology Learning Lab website at **setll.osu.edu** for a list of qualified wastewater testing labs.

5. Check for landscaping changes that interfere with system operation. Be especially watchful for standing water, plant overgrowth, and vegetable gardens.

Irrigation in the Winter

Winter weather in Ohio presents some special concerns for irrigation of treated wastewater:

- irrigating with snow on the ground
- protecting equipment
- potential impact on plants
- preventing runoff

Irrigating Above the Snow

Spray heads should be on risers above the expected maximum snow depth. A minimum height of 18 inches to the bottom of the spray head is recommended for most of Ohio. In areas where snow accumulates, risers might need to be higher.

Protection of Equipment

Protecting a riser from breakage begins at the bottom of the riser. A swing joint or swing pipe below the ground surface connects the riser to the lateral line. The 360 flexibility in the swing joint or pipe prevents a break or crack at the connection point. The connection also allows for movement as soil settles or if the riser is hit by people or animals.

Because risers are exposed to the weather, they should be constructed with stronger pipe than is used in the rest of the system. Construct risers with Schedule 80 PVC pipe and an additional coupling to stiffen the riser. Use threaded connections so the riser can be disassembled easily for repair and replacement. If sections are glued, use the appropriate PVC primer and glue.

Research at The Ohio State University shows that draining water from spray heads and risers at the end of each irrigation event keeps the system from freezing. Two options are recommended to ensure that the water drains from the risers:

- **Drain-back to the dosing tank** is a common method of freeze protection. Once the pump shuts off at the end of an irrigation cycle, water drains through a weep hole or a slightly opened valve in the dosing tank. The irrigation heads themselves serve as air-release valves. The heads should have no backflow preventers or check valves. Sometimes, spray heads come equipped with screens in them. Be sure to remove the screens, as they can hold moisture and freeze in cold weather.

- **King-drains** are an option when the dosing tank is upslope or far from the irrigation system, making drain-back impractical. A king-drain is at the base of the riser and drains the 1 cup of water that it takes to fill the pipe above ground. The king-drain is a special valve that closes due to the water pressure created by the irrigation pump. When the pump shuts off and the pressure drops, the king-drain opens and the small amount of water drains into a gravel-filled sump at the base of the riser. Placing a king-drain directly in the soil is not recommended, because it will drain too slowly, allowing the risers to freeze.

Rotational delay can occur during periods of sub-freezing temperatures. Even with draining the risers between irrigation events, a small amount of moisture remains in the sprinkler head. Researchers at The Ohio State University found that it takes about five minutes of water flowing through the sprinklers to melt any frost that prevents the head from rotating. However, since the sprinklers stop in different places at the end of each irrigation cycle, wastewater is still evenly distributed over the area during long, cold spells.

Impact of Plants

Winter irrigation is used by farmers to protect plants. Fruit growers spray water on fruit and flowers during unseasonably cold weather in the spring. As ice forms on a plant, the water gives up heat to warm the plant and prevent freeze damage of the plant tissue. Farmers and landscapers irrigate plants on warm winter days to keep plants from blooming too early. In this practice, called bloom delay, the evaporating water on the unseasonably warm winter day will cool off the plant. The cold, dry winter wind can also dry out and kill delicate branches on one side of the plant, resulting in a deformed bush or tree. Spraying water on a plant in the winter creates a protective layer of ice to keep the plants from drying out.

Researchers at The Ohio State University looked at irrigation of plants year-round and compared it to summer-only and no irrigation. Of the three treatments, the year-round, irrigated plants were the healthiest. Two plants were an exception, though: hemlock and arborvitae (fine-needle evergreens) did not grow well when irrigated in the winter.

Preventing Runoff

Irrigated wastewater is treated to the level considered safe for discharge into a body of water, so most of the pollutants have been removed in the treatment process. However, nitrogen and phosphorus are in treated wastewater and are important plant nutrients. Grass and landscape plants benefit from the nitrogen and phosphorus in the wastewater. However, nitrogen—and especially, phosphorus—can pollute streams and lakes if they are discharged or allowed to drain off the lot. The potential for runoff must be considered to protect the environment.

Researchers at The Ohio State University looked at the potential for nutrient runoff from an irrigated lawn during the winter when plants are not actively growing or using nutrients. The research showed that even the soil that appears frozen still allows water to soak in. The research was done on a hillside, and any water that flowed off the lot at the bottom of the hill could be collected and tested. During an average winter, no water ran off; it all soaked into the cold soil.

The research was repeated during a severe winter. During the 2013–14 winter, the temperatures were below freezing for weeks. Over the course of the winter, irrigated wastewater did not run off. Instead it froze and became a part of the ice and snow on the lawn. Warm, rainy days at the end of the winter resulted in some runoff on 11 different days. The water that ran off the hillside during the severe winter contained 0.5 $\frac{mg}{L}$ more phosphorus than the lawns that were not irrigated. The ammonia level was 2 $\frac{mg}{L}$ well below the 4 $\frac{mg}{L}$ standard for a discharging system.

Researchers at The Ohio State University found that irrigation water soaks into cold soil. Water and nutrients do not run off except under very severe weather conditions. What does run off on these rare occasions is below the effluent level of a city or an on-site discharging wastewater treatment system.

No irrigation—OSU research looked at the impact of reclaimed wastewater irrigation. In the no irrigation area, 30 shrubs and trees were planted, but after five years, only two trees remained. The others died off.

Summer irrigation—Of the 30 shrubs and trees planted in the summer irrigation area, only three trees and three shrubs survived after five years.

Year-round irrigation—Of the 30 shrubs and trees planted, all were growing and thriving after five years. (Not all of the plants are visible in the photo.)

Example 2: Limited Space

Example 2: Step 1

Suppose a house has two bedrooms.

$$(2 \text{ bedrooms})\left(\frac{120 \text{ gallons}}{\text{bedroom} * \text{day}}\right) = 240 \text{ gallons/day}$$

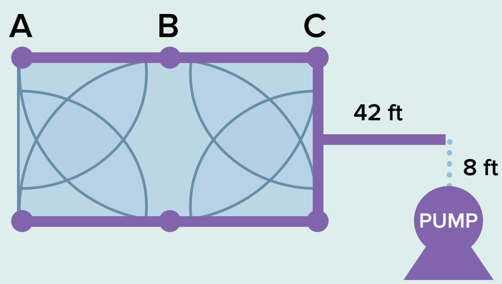
The daily design wastewater volume is 240 gallons.

Example 2: Step 2

$$\left(\frac{240 \text{ gallons}}{\text{day}}\right)\left(\frac{8.021 \text{ ft}^2}{\text{gallon}}\right)(1 \text{ day}) = 1925 \text{ ft}^2$$

The land area requirement is 1925 ft^2.

Example 2: Step 3



Example 2: Step 4

The area can be determined by multiplying the sides of the rectangle together.

(32 ft)(64 ft) = 2048 ft^2

This design will spray a total area of 2048 ft^2. From Example 2: Step 2, it was determined that a two-bedroom house requires an area of 1925 ft^2. This design will work since the spray area is more than the required area.

Example 2: Step 5

Select a low-angle, gear-driven rotor sprinkler from Appendix F: Nozzle Performance Table. For this design, both the #1 and #3 nozzle will be used.

Center Sprinklers

#3 nozzle

Pressure @ 40 psi

Throw radius of 32 feet

Flow rate of 3.1 gpm

Corner Sprinklers

#1 nozzle

Pressure @ 40 psi

Throw radius of 24 feet

Flow rate of 1.7 gpm

Example 2: Step 6

Lateral Lines

@ A

Flow rate of furthest head = 1.7 gpm (round to 2 gpm)

Look up velocity using 2 gpm on Friction Loss Table

$$\text{Velocity} = 2.11\,\frac{\text{ft}}{\text{sec}}$$

Minimum nominal pipe size is ½ inch

@ B

Flow rate = (1.7 gpm + 3.1 gpm) = 4.8 gpm (round to 5 gpm)

Look up velocity using 5 gpm on Friction Loss Table

$$\text{Velocity} = 3.00\,\frac{\text{ft}}{\text{sec}}$$

Minimum nominal pipe size is ¾ inch

@ C

Flow rate = (4.8 gpm + 1.7 gpm) = 6.5 gpm (round to 7 gpm)

Look up velocity using 7 gpm on Friction Loss Table

$$\text{Velocity} = 4.20\,\frac{\text{ft}}{\text{sec}}$$

Minimum nominal pipe size is ¾ inch

A ¾-inch pipe will be used for all of the lateral lines.

Main Line

For this design, the total flow rate is found to be 13 gpm. Using the Friction Loss Table, the minimum nominal pipe size for the main line is found to be 1¼-inch pipe.

Size (in) ID (in)	½ 0.622		¾ 0.824		1 1.049		1 ¼ 1.380		1 ½ 1.610		2 2.067		2 ½ 2.469	
Flow (gpm)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)
1	1.05	0.43	0.60	0.11	0.37	0.03	0.21	0.01	0.15	0.00				
2	2.11	1.55	1.20	0.39	0.74	0.12	0.42	0.13	0.31	0.02	0.19	0.00		
3	3.16	3.28	1.80	0.84	1.11	0.26	0.64	0.07	0.47	0.03	0.28	0.01	0.20	0.00
4	4.22	5.60	2.40	1.42	1.48	0.44	0.85	0.12	0.62	0.05	0.38	0.02	0.26	0.01
5	5.27	8.46	3.00	2.15	1.85	0.66	1.07	0.18	0.78	0.08	0.47	0.02	0.33	0.01
6			3.60	3.02	2.22	0.93	1.28	0.25	0.94	0.12	0.57	0.03	0.40	0.01
7			4.20	4.01	2.59	1.24	1.49	0.33	1.10	0.15	0.66	0.05	0.46	0.02
8			4.80	5.14	2.96	1.59	1.71	0.42	1.25	0.20	0.76	0.06	0.53	0.02
9			5.40	6.39	3.33	1.97	1.92	0.52	1.41	0.25	0.85	0.07	0.60	0.03
10					3.70	2.40	2.14	0.63	1.57	0.30	0.95	0.09	0.66	0.04
11					4.07	2.86	2.35	0.75	1.73	0.36	1.05	0.11	0.73	0.04
12					4.44	3.36	2.57	0.89	1.88	0.42	1.14	0.12	0.80	0.05
14					5.19	4.47	2.99	1.18	2.20	0.56	1.33	0.17	0.93	0.07
16							3.42	1.51	2.51	0.71	1.52	0.21	1.07	0.09
18							3.85	1.88	2.83	0.89	1.71	0.26	1.20	0.11
20							4.28	2.28	3.14	1.08	1.90	0.32	1.33	0.13
22							4.71	2.72	3.46	1.29	2.10	0.38	1.47	0.16
24							5.14	3.20	3.77	1.51	2.29	0.45	1.60	0.19
26									4.09	1.75	2.48	0.52	1.74	0.22
28									4.40	2.01	2.67	0.60	1.87	0.25
30									4.72	2.28	2.86	0.68	2.00	0.29
35									5.50	3.04	3.34	0.90	2.34	0.38
40											3.81	1.15	2.67	0.49
45											4.29	1.43	3.01	0.60
50											4.77	1.74	3.34	0.73
55											5.25	2.08	3.68	0.88
60													4.01	1.03
65													4.35	1.19
70													4.68	1.37
75													5.01	1.56

Example 2: Step 7

A→B

Flow Rate = 1.7 gpm (round to 2 gpm)

Look up pressure loss using 2 gpm and ¾-inch pipe on Friction Loss Table

$$\text{Pressure Loss} = \frac{0.39\text{ psi}}{100\text{ ft}} = \frac{0.0039\text{ psi}}{\text{ft}}$$

Look up equivalent feet on Appendix A-3: Pressure Loss in Valves and Fittings

32 ft (pipe A→B) + 0.5 ft (¾-inch gate valve @ A) + 3 ft (90° elbow @ A) = 35.5 ft

$$(35.5\text{ ft})\left(\frac{0.0039\text{ psi}}{\text{ft}}\right) = 0.14\text{ psi}$$

B→C

Flow Rate = (1.7 gpm + 3.1 gpm) = 4.8 gpm (round to 5 gpm)

Look up pressure loss using 5 gpm and ¾-inch pipe on Friction Loss Table

$$\text{Pressure Loss} = \frac{2.15\text{ psi}}{100\text{ ft}} = \frac{0.0215\text{ psi}}{\text{ft}}$$

Look up equivalent feet on Appendix A-3: Pressure Loss in Valves and Fittings

32 ft (pipe B→C) + 2 ft (tee @ B) = 34 ft

$$(34\text{ ft})\left(\frac{0.0215\text{ psi}}{\text{ft}}\right) = 0.73\text{ psi}$$

C→Main

Flow Rate = (4.8 gpm + 1.7 gpm) = 6.5 gpm (round to 7 gpm)

Look up pressure loss using 7 gpm and ¾-inch pipe on Friction Loss Table

$$\text{Pressure Loss} = \frac{4.01\text{ psi}}{100\text{ ft}} = \frac{0.0401\text{ psi}}{\text{ft}}$$

Look up equivalent feet on Appendix A-3: Pressure Loss in Valves and Fittings

16 ft (pipe C→Main) + 2 ft (tee @ C) + 3 ft (90° elbow @ C) = 21 ft

$$(21\text{ ft})\left(\frac{0.0401\text{ psi}}{\text{ft}}\right) = 0.84\text{ psi}$$

Main→Pump

Flow Rate = (2 * 6.5 gpm) = 13 gpm (round to 14 gpm)

Look up pressure loss using 14 gpm and 1¼-inch pipe on Friction Loss Table

$$\text{Pressure Loss} = \frac{1.18\text{ psi}}{100\text{ ft}} = \frac{0.0118\text{ psi}}{\text{ft}}$$

42 ft (pipe Main→Pump) + 3 ft (tee @ Main) + 4 ft (90° elbow @ Pump) = 49 ft

$$(49\text{ ft})\left(\frac{0.0118\text{ psi}}{\text{ft}}\right) = 0.58\text{ psi}$$

Total Pressure Loss in Lateral Lines and Main Line

0.14 psi + 0.73 psi + 0.84 psi + 0.58 psi = 2.29 psi

Size (in) ID (in)	½ 0.022		¾ 0.824		1 1.049		1 ¼ 1.380		1 ½ 1.610		2 2.067		2 ½ 2.469	
Flow (gpm)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)
1	1.05	0.43	0.60	0.11	0.37	0.03	0.21	0.01	0.15	0.00				
2	2.11	1.55	1.20	0.39	0.74	0.12	0.42	0.13	0.31	0.02	0.19	0.00		
3	3.16	3.28	1.80	0.84	1.11	0.26	0.64	0.07	0.47	0.03	0.28	0.01	0.20	0.00
4	4.22	5.60	2.40	1.42	1.48	0.44	0.85	0.12	0.62	0.05	0.38	0.02	0.26	0.01
5	5.27	8.46	3.00	2.15	1.85	0.66	1.07	0.18	0.78	0.08	0.47	0.02	0.33	0.01
6			3.60	3.02	2.22	0.93	1.28	0.25	0.94	0.12	0.57	0.03	0.40	0.01
7			4.20	4.01	2.59	1.24	1.49	0.33	1.10	0.15	0.66	0.05	0.46	0.02
8			4.80	5.14	2.96	1.59	1.71	0.42	1.25	0.20	0.76	0.06	0.53	0.02
9			5.40	6.39	3.33	1.97	1.92	0.52	1.41	0.25	0.85	0.07	0.60	0.03
10					3.70	2.40	2.14	0.63	1.57	0.30	0.95	0.09	0.66	0.04
11					4.07	2.86	2.35	0.75	1.73	0.36	1.05	0.11	0.73	0.04
12					4.44	3.36	2.57	0.89	1.88	0.42	1.14	0.12	0.80	0.05
14					5.19	4.47	2.99	1.18	2.20	0.56	1.33	0.17	0.93	0.07
16							3.42	1.51	2.51	0.71	1.52	0.21	1.07	0.09
18							3.85	1.88	2.83	0.89	1.71	0.26	1.20	0.11
20							4.28	2.28	3.14	1.08	1.90	0.32	1.33	0.13
22							4.71	2.72	3.46	1.29	2.10	0.38	1.47	0.16
24							5.14	3.20	3.77	1.51	2.29	0.45	1.60	0.19
26									4.09	1.75	2.48	0.52	1.74	0.22
28									4.40	2.01	2.67	0.60	1.87	0.25
30									4.72	2.28	2.86	0.68	2.00	0.29
35									5.50	3.04	3.34	0.90	2.34	0.38
40											3.81	1.15	2.67	0.49
45											4.29	1.43	3.01	0.60
50											4.77	1.74	3.34	0.73
55											5.25	2.08	3.68	0.88
60													4.01	1.03
65													4.35	1.19
70													4.68	1.37
75													5.01	1.56

Example 2: Step 8

Elevation Change

$$(8\text{ ft})\left(0.433\ \frac{\text{psi}}{\text{ft}}\right) = 3.46\text{ psi}$$

Total Pressure of Friction Loss and Elevation Change

(2.29 psi + 3.46 psi) = 5.75 psi

Total Feet of Head

$$(5.75\text{ psi})\left(\frac{2.31\text{ ft of head}}{\text{psi}}\right) = 13.28\text{ ft of head}$$

$$(40\text{ psi})\left(\frac{2.31\text{ ft of head}}{\text{psi}}\right) = 92.4\text{ ft of head}$$

13.28 ft of head + 92.4 ft of head = 105.68 ft of head

Total Flow Rate

13 gpm

Irrigation Area

2048 ft^2

Precipitation Rate

$$\frac{(13\text{ gpm})(96.25)}{(2048\text{ ft}^2)} = 0.61\ \frac{\text{in}}{\text{hr}}$$

Run Time

$$\frac{240\text{ gal}}{13\text{ gpm}} = 18.46\text{ mins}$$

Loading Rate

$$\left(18.46\ \frac{\text{mins}}{\text{day}}\right)\left(\frac{0.61\text{ in}}{\text{hr}}\right)\left(\frac{1\text{ hr}}{60\text{ mins}}\right) = 0.19\ \frac{\text{in}}{\text{day}}$$

Example 3: Random Placement

Example 3: Step 1

Suppose a house has five bedrooms.

$$(5 \text{ bedrooms})\left(\frac{120 \text{ gallons}}{\text{bedroom}*\text{day}}\right) = 600 \text{ gallons/day}$$

The daily design wastewater volume is 600 gallons.

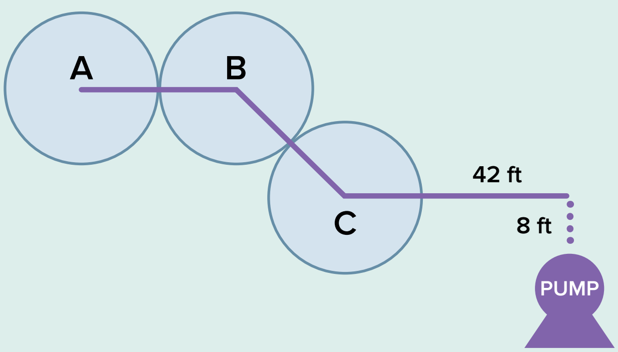
Example 3: Step 2

$$\left(\frac{600 \text{ gallons}}{\text{day}}\right)\left(\frac{8.021 \text{ ft}^2}{\text{gallon}}\right)(1 \text{ day}) = 4812.6 \text{ ft}^2$$

The land area requirement is 4812.6 ft^2.

Example 3: Step 3

Place three sprinkler heads in a random pattern with 24 foot radius circles.



Example 3: Step 4

Using 24 feet as the spray pattern radius, find the spray area given that the design calls for three full circles.

$$3\pi r^2 = 3\pi(24)^2 = 5428.67 \text{ ft}^2$$

This design will spray a total area of 5428.67 ft^2. From Example 3: Step 2, it was determined that a five-bedroom house needed at least an area of 4812.6 ft^2. This design will work since it covers more than the minimum area required.

Example 3: Step 5

Select a low-angle, gear-driven rotor sprinkler from Appendix F: Nozzle Performance Table. For this design, the #1 nozzle is used.

#1 nozzle

Pressure @ 40 psi

Throw radius of 24 ft

Flow rate of 1.7 gpm

Example 3: Step 6

Lateral Lines

@ A

Flow rate of furthest head = 1.7 gpm (round to 2 gpm)

Look up velocity using 2 gpm on Friction Loss Table

Velocity = 2.11 $\frac{ft}{sec}$

Minimum nominal pipe size is ½ inch

@ B

Flow rate = (1.7 gpm + 1.7 gpm) = 3.4 gpm (round to 4 gpm)

Look up velocity using 4 gpm on Friction Loss Table

Velocity = 4.22 $\frac{ft}{sec}$

Minimum nominal pipe size is ½ inch

@ C

Flow rate = (3.4 gpm + 1.7 gpm) = 5.1 gpm (round to 6 gpm)

Look up velocity using 6 gpm on Friction Loss Table

Velocity = 3.60 $\frac{ft}{sec}$

Minimum nominal pipe size is ¾ inch

A ¾-inch pipe will be used for all of the lateral lines.

Main Line

For this design, the total flow rate is found to be 5.1 gpm. Using the Friction Loss Table, the minimum nominal pipe size for the main line is found to be ¾-inch pipe.

Example 3: Step 7

A→B

Flow Rate = 1.7 gpm (round to 2 gpm)

Look up pressure loss using 2 gpm and ¾-inch pipe on Friction Loss Table

$$\text{Pressure Loss} = \frac{0.39 \text{ psi}}{100 \text{ ft}} = \frac{0.0039 \text{ psi}}{\text{ft}}$$

Look up equivalent feet on Appendix A-3: Pressure Loss in Valves and Fittings

48 ft (pipe A→B) + 0.5 ft (¾-inch gate valve @ A) + 3 ft (90° elbow @ A) = 51.5 ft

$$(51.5 \text{ ft}) \left(\frac{0.0039 \text{ psi}}{\text{ft}}\right) = 0.20 \text{ psi}$$

B→C

Flow Rate = (1.7 gpm + 1.7 gpm) = 3.4 gpm (round to 4 gpm)

Look up pressure loss using 4 gpm and ¾-inch pipe on Friction Loss Table

$$\text{Pressure Loss} = \frac{1.42 \text{ psi}}{100 \text{ ft}} = \frac{0.0142 \text{ psi}}{\text{ft}}$$

Look up equivalent feet on Appendix A-3: Presure Loss in Valves and Fittings

48 ft (pipe B→C) + 2 ft (tee @ B) + 1 ft (45° elbow @ B) = 51 ft

$$(51 \text{ ft}) \left(\frac{0.0142 \text{ psi}}{\text{ft}}\right) = 0.72 \text{ psi}$$

C→Pump

Flow Rate = (3.4 gpm + 1.7 gpm) = 5.1 gpm (round to 6 gpm)

Look up pressure loss using 6 gpm and ¾-inch pipe on Friction Loss Table

$$\text{Pressure Loss} = \frac{3.02 \text{ psi}}{100 \text{ ft}} = \frac{0.0302 \text{ psi}}{\text{ft}}$$

Look up equivalent feet on Appendix A-3: Pressure Loss in Valves and Fittings

24 ft + 42 ft (pipe C→Pump) + 2 ft (tee @ C) + 1 ft (45° elbow @ C) + 3 ft (90° elbow @ Pump) = 72 ft

$$(72 \text{ ft}) \left(\frac{0.0302 \text{ psi}}{\text{ft}}\right) = 2.17 \text{ psi}$$

Total Pressure Loss in Lateral Lines and Main Line

0.20 psi + 0.72 psi + 2.17 psi = 3.10 psi

Example 3: Step 8

Elevation Change

$$(8\text{ ft})\left(0.433\,\frac{\text{psi}}{\text{ft}}\right) = 3.46\text{ psi}$$

Total Pressure of Friction Loss and Elevation Change

(3.10 psi + 3.46 psi) = 6.56 psi

Total Feet of Head

$$(6.56\text{ psi})\left(\frac{2.31\text{ ft of head}}{\text{psi}}\right) = 15.15\text{ ft of head}$$

$$(40\text{ psi})\left(\frac{2.31\text{ ft of head}}{\text{psi}}\right) = 92.4\text{ ft of head}$$

15.15 ft of head + 92.4 ft of head = 107.55 ft of head

Total Flow Rate

5.1 gpm

Irrigation Area

5428.67 ft^2

Precipitation Rate

$$\frac{(5.1\text{ gpm})(96.25)}{5428.67\text{ ft}^2} = 0.09\ \frac{\text{in}}{\text{hr}}$$

Run Time

$$\frac{600\text{ gal}}{5.1\text{ gpm}} = 117.65\text{ mins}$$

Loading Rate

$$\left(\frac{117.65\text{ mins}}{\text{day}}\right)\left(\frac{0.09\text{ in}}{\text{hr}}\right)\left(\frac{1\text{ hr}}{60\text{ mins}}\right) = 0.18\ \frac{\text{in}}{\text{day}}$$

Appendix A: Friction Loss Tables

Appendix A-1: PVC Schedule 40 IPS Plastic Pipe

PSI loss per 100 feet of pipe.

Shading indicates that the $5\frac{ft}{sec}$ maximum velocity has been exceeded.

Size (in) ID (in)	½ 0.022		¾ 0.824		1 1.049		1 ¼ 1.380		1 ½ 1.610		2 2.067		2 ½ 2.469	
Flow (gpm)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)
1	1.05	0.43	0.60	0.11	0.37	0.03	0.21	0.01	0.15	0.00				
2	2.11	1.55	1.20	0.39	0.74	0.12	0.42	0.13	0.31	0.02	0.19	0.00		
3	3.16	3.28	1.80	0.84	1.11	0.26	0.64	0.07	0.47	0.03	0.28	0.01	0.20	0.00
4	4.22	5.60	2.40	1.42	1.48	0.44	0.85	0.12	0.62	0.05	0.38	0.02	0.26	0.01
5	5.27	8.46	3.00	2.15	1.85	0.66	1.07	0.18	0.78	0.08	0.47	0.02	0.33	0.01
6			3.60	3.02	2.22	0.93	1.28	0.25	0.94	0.12	0.57	0.03	0.40	0.01
7			4.20	4.01	2.59	1.24	1.49	0.33	1.10	0.15	0.66	0.05	0.46	0.02
8			4.80	5.14	2.96	1.59	1.71	0.42	1.25	0.20	0.76	0.06	0.53	0.02
9			5.40	6.39	3.33	1.97	1.92	0.52	1.41	0.25	0.85	0.07	0.60	0.03
10					3.70	2.40	2.14	0.63	1.57	0.30	0.95	0.09	0.66	0.04
11					4.07	2.86	2.35	0.75	1.73	0.36	1.05	0.11	0.73	0.04
12					4.44	3.36	2.57	0.89	1.88	0.42	1.14	0.12	0.80	0.05
14					5.19	4.47	2.99	1.18	2.20	0.56	1.33	0.17	0.93	0.07
16							3.42	1.51	2.51	0.71	1.52	0.21	1.07	0.09
18							3.85	1.88	2.83	0.89	1.71	0.26	1.20	0.11
20							4.28	2.28	3.14	1.08	1.90	0.32	1.33	0.13
22							4.71	2.72	3.46	1.29	2.10	0.38	1.47	0.16
24							5.14	3.20	3.77	1.51	2.29	0.45	1.60	0.19
26									4.09	1.75	2.48	0.52	1.74	0.22
28									4.40	2.01	2.67	0.60	1.87	0.25
30									4.72	2.28	2.86	0.68	2.00	0.29
35									5.50	3.04	3.34	0.90	2.34	0.38
40											3.81	1.15	2.67	0.49
45											4.29	1.43	3.01	0.60
50											4.77	1.74	3.34	0.73
55											5.25	2.08	3.68	0.88
60													4.01	1.03
65													4.35	1.19
70													4.68	1.37
75													5.01	1.56

Appendix A-2: Polyethylene SDR—Pressure-Rated Tube

PSI loss per 100 feet of pipe.

Shading indicates that the $5\frac{ft}{sec}$ maximum velocity has been exceeded.

Size (in) ID (in)	½ 0.022		¾ 0.824		1 1.049		1 ¼ 1.380		1 ½ 1.610		2 2.067		2 ½ 2.469	
Flow (gpm)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)	Velocity (ft/sec)	Loss (psi)
1	1.05	0.43	0.60	0.11	0.37	0.03	0.21	0.01	0.15	0.00				
2	2.11	1.55	1.20	0.39	0.74	0.12	0.42	0.13	0.31	0.02	0.19	0.00		
3	3.16	3.28	1.80	0.84	1.11	0.26	0.64	0.07	0.47	0.03	0.28	0.01	0.20	0.00
4	4.22	5.60	2.40	1.42	1.48	0.44	0.85	0.12	0.62	0.05	0.38	0.02	0.26	0.01
5	5.27	8.46	3.00	2.15	1.85	0.66	1.07	0.18	0.78	0.08	0.47	0.02	0.33	0.01
6			3.60	3.02	2.22	0.93	1.28	0.25	0.94	0.12	0.57	0.03	0.40	0.01
7			4.20	4.01	2.59	1.24	1.49	0.33	1.10	0.15	0.66	0.05	0.46	0.02
8			4.80	5.14	2.96	1.59	1.71	0.42	1.25	0.20	0.76	0.06	0.53	0.02
9			5.40	6.39	3.33	1.97	1.92	0.52	1.41	0.25	0.85	0.07	0.60	0.03
10					3.70	2.40	2.14	0.63	1.57	0.30	0.95	0.09	0.66	0.04
11					4.07	2.86	2.35	0.75	1.73	0.36	1.05	0.11	0.73	0.04
12					4.44	3.36	2.57	0.89	1.88	0.42	1.14	0.12	0.80	0.05
14					5.19	4.47	2.99	1.18	2.20	0.56	1.33	0.17	0.93	0.07
16							3.42	1.51	2.51	0.71	1.52	0.21	1.07	0.09
18							3.85	1.88	2.83	0.89	1.71	0.26	1.20	0.11
20							4.28	2.28	3.14	1.08	1.90	0.32	1.33	0.13
22							4.71	2.72	3.46	1.29	2.10	0.38	1.47	0.16
24							5.14	3.20	3.77	1.51	2.29	0.45	1.60	0.19
26									4.09	1.75	2.48	0.52	1.74	0.22
28									4.40	2.01	2.67	0.60	1.87	0.25
30									4.72	2.28	2.86	0.68	2.00	0.29
35									5.50	3.04	3.34	0.90	2.34	0.38
40											3.81	1.15	2.67	0.49
45											4.29	1.43	3.01	0.60
50											4.77	1.74	3.34	0.73
55											5.25	2.08	3.68	0.88
60													4.01	1.03
65													4.35	1.19
70													4.68	1.37
75													5.01	1.56

Appendix A-3: Pressure Loss in Valves and Fittings

Equivalent length in feet of pipe.

Nominal Pipe Size	Gate Valve	Standard Tee	Standard Elbow	45-degree Angle
½	0.4	1	2	1
¾	0.5	2	3	1
1	0.6	2	3	2
1¼	0.8	3	4	2
1½	1	3	5	2
2	1.2	4	6	3
2½	1.4	5	7	3

Appendix B: Friction Loss Worksheet

Type of pipe: ______________________________________

	Flow (gpm)	Pipe Size	Loss Per 100 Feet	Loss Per Foot	Length of Pipe	Equivalent Length of Fittings	Effective Length	Loss of Length
Lateral Line								
Lateral Line								
Lateral Line								
Lateral Line								
Lateral Line								
Main Line								
Main Line								
							Subtotal	

	Flow (gpm)	Pipe Size	Loss (psi)
Valve			
Miscellaneous Components			
Miscellaneous Components			
Loss or Gain Due to Elevation Changes			

Total Pressure Loss ____________________

Pressure Required at the Sprinkler Head + ____________________

Minimum Pressure Required for Optimal System Operation (required pump pressure) = ____________________

Appendix C: Plants for Wastewater Irrigation

Appendix C-1: Appropriate Plants for Wastewater Irrigation Sites in Ohio

Botanical Name	Common Name
Acer nigrum	Black Maple
Acer rubrum	Red Maple
Aronia arborea brilliantissima	Red Chokeberry
Aronia melanocarpa	Black Chokeberry
Aronia x prunifolia	Purple-fruited Chokeberry
Chaenomeles speciose	Common Quince
Clethra alnifolia	Summer Sweet
Cornus mas	Cornealian Cherry Dogwood
Cornus sanguinea	Bloodtwig Dogwood
Deutzia gracillis	Slender Deutzia
Diervilla sessilifolia	Summer Stars Honeysuckle
Deutzia x lemoinei	Lemoine Deutzia
Euonymus alatus	Winged Euonymus
Euonymus americanus	American Euonymus
Forsythia x intermedia	Border Forsythia
Fraxinus americana	White Ash
Fraxius pennslyvanica	Patmore Ash
Hamamelis vernalis	Vernal Witch Hazel
Hamamelis virginiana	Witch Hazel
Ilex verticulata	Winter Red Holly
Itea virginiana	Virginia Sweetspire
Juniperus scopulorum	Virginia Red Cedar
Magnolia virginiana	Sweetbay Magnolia
Myrica pennsylvania	Northern Bayberry
Rhus aromatic	Fragrant Sumac
Salix caprea	Pussywillow
Salix melanostachys	Black Pussywillow
Salix purpurea	Artic Willow
Spiraea x bumalda	Bumald Spirea
Syringa patula	Manchurian Lilac
Tilia americana	American Linden
Tsuga caroliniana	Carolina Hemlock
Viburnum acerifolium	European Viburnum
Viburnum dentatum	Chicago Luster Viburnum
Viburnum lentago	Nannyberry
Viburnum opulus	Cranberrybush Viburnum
Wigela florida	Old Fashioned Weigela

Appendix C-2: Plants Not Appropriate for Wastewater Irrigation Sites in Ohio

Botanical Name	Common Name
Chamaecyparis obtusa	False Cypress
Chamaecyparis pisifera ‘Boulevard’	Sawara Cypress
Chamaecyparis pisifera ‘Filifera Aurea’	Sawara Cypress
Thuja occidentalis	Emerald Arborvitae
Tsuga canadensis	Canadian Hemlock

Appendix D: Conversions

$$1 \text{ gallon} * 231 \frac{\text{in}^3}{\text{gallon}} = 231 \text{ in}^3$$

$$\frac{231 \text{ in}^3}{0.2 \text{ in}} = 1155 \text{ in}^2$$

$$1155 \text{ in}^2 * \left(\frac{1 \text{ ft}}{12 \text{ in}}\right)^2 = 8.021 \text{ ft}^2$$

$$96.25 \frac{\text{min} * \text{in} * \text{ft}^2}{\text{hr} * \text{gal}} = \left(\frac{60 \text{ min}}{1 \text{ hr}}\right) * \left(\frac{231 \text{ in}^3}{\text{gal}}\right) * \left(\frac{1 \text{ ft}}{12 \text{ in}}\right)^2$$

Appendix E: Spray Field Operation and Maintenance Checklist

Operational Checklist

Service provided on: Date: _________/_________/_________ Time: ________________________

Service provided by: Company: _________________________ Employee: ___________________

1. Condition at the Spray Distribution Field
   a. Evaluate the presence of odor within a 10-foot perimeter of the system:

      None ______ Mild ______ Strong ______ Chemical ______ Sour _______

   b. Source of odor, if present: ____
   c. Indication of leaks around/above the system: Yes ___ No ___
   d. Appropriate vegetation: Yes ___ No ___
   e. Excessive vegetative growth: Yes ___ No ___
   f. Adequately maintained vegetation: Yes ___ No ___
   g. Prevention of accessibility for maintenance: Yes ___ No ___

2. Site Conditions
   a. Color-coding: Yes ___ No ___
   b. Signage: Yes ___ No ___
   c. Fencing: Yes ___ No ___

3. System Operating Pressure PSI ___________
   a. Location of pressure reading: ____

4. Control Panel
   a. Timer operating properly: Yes ___ No ___
   b. Timer settings: ON ____________ mins OFF _____________ mins

5. Distribution Head Operation
   a. Low-pressure shutoff valve: Yes ___ No ___
   b. Heads in proper adjustment: Yes ___ No ___
   c. Pop-up heads retracting: Yes ___ No ___
   d. Distribution head operation summary:

Low-Angle Nozzle	Pattern		Operation (impact, rotor, spray)	Low-Pressure Drain	Riser Intact
	Current	Designed			

Appendix F: Nozzle Performance Table

Nozzle	Pressure (psi)	Throw Radius (ft)	Flow Rate (gpm)
#1	30	22	1.2
	40	24	1.7
	50	26	1.8
	60	28	2.0
#3	30	29	3.0
	40	32	3.1
	50	35	3.5
	60	37	3.8
#4	30	31	3.4
	40	34	3.9
	50	37	4.4
	60	38	4.7
#6	30	38	6.5
	40	40	7.3
	50	42	8.0
	60	44	8.6