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INTRODUCTION

This guide covers the basics of design for Netafim Bioline® drip dispersal applications. While secondary treated effluent will normally be used, many of the same design concepts for septic tank effluent may apply.

Because onsite wastewater designs are subject to state and local regulations, any regulatory specification must be given precedence over the recommendations included here. If local regulations allow design parameters which are more liberal than those expressed in this guide, the designer should bear in mind that the conservative recommendations herein are based on actual design experience and analysis of both properly functioning and failed onsite systems. When it comes to design, Netafim takes a conservative approach.

This guide is not meant to replace the services of a design professional. Netafim recommends that a licensed professional be consulted for proper onsite system design and operation.

Overview

Drip technology was originally developed for the agricultural industry to improve the efficient delivery of water to plants, especially in environments where water supply is limited. The technique involved delivering water that plants actually use directly into the root zone and relying on horizontal and vertical movement through the soil to disperse the water evenly. Netafim is the world leader in drip applications and its drippers, filters, valves and other products have become industry standards around the world.

Subsurface drip dispersal is the most efficient method of dispersing wastewater effluent into the soil and presents the designer with a superior solution for virtually every soil type.

The Netafim drip dispersal solution delivers effluent into the shallow subsurface and biologically-active root zone of plants, allowing plant uptake for nutrient removal, and slow effluent dispersal into the soil medium for further treatment.

The U.S. Environmental Protection Agency (EPA) has recognized that onsite treatment of domestic wastewater is a permanent rather than temporary solution for wastewater treatment when centralized collection systems are not feasible. Increasing public concern about issues related to the effective and reliable treatment and dispersal of onsite wastewater has created a climate for change beyond conventional septic tanks and drainfields. The onsite industry has responded with improved technology for wastewater treatment and regulations have become more explicit and scientifically based. These are key reasons why interest in drip dispersal in the onsite industry has increased so rapidly.

As demand increases for residential development in formerly rural areas and in less-than-optimal site conditions for older-style onsite wastewater dispersal, the importance of alternative technologies increases. Advanced onsite wastewater treatment combined with drip dispersal is the best strategy for effectively treating and dispersing the treated wastewater.

Subsurface drip dispersal has a number of benefits:

• Very even effluent distribution over large areas, including slopes
• Can be applied in almost any climate or soil conditions, as well as high wind areas, odd shaped areas, close to buildings and high water table environments
• Reduced localized loading rates
• Potential of animal and human contact is much lower than other dispersal techniques
• Installation does not require major disruption to the drain field area, taking advantage of natural or modified landscape plans
• Provides for extended contact time with soil
• Effluent can often be re-used for irrigation of lawns, shrubs, and trees - nitrate and phosphates uptake by plants is a further benefit
Beneficial wastewater nutrients are available for plant uptake and evapotranspiration is maximized.

Special consideration potential for use in a "green building" applications - the onsite treatment of the wastewater ensures no infrastructure strain on municipal treatment and the beneficial reuse of the effluent could include irrigation.

This guide focuses on Netafim Bioline® dripperline1 as the drip dispersal product. Bioline is a state-of-the-art drip dispersal tubing that is manufactured specifically for wastewater applications. While Netafim manufactures hundreds of types of dripperline, including non-pressure compensating dripperline, the features and proven performance of Bioline make any reliance on non-pressure compensating dripperlines unnecessary. Chief among the reasons that Netafim Bioline pressure compensating dripperline is the chosen standard include:

- Broadest pressure compensation range of any dripperline: 7 - 70 psi
- Broadest range of dripper flow rates to choose from: 0.4, 0.6 or 0.9 GPH
- Dripper spacings of 12", 18" or 24" (custom spacings available)
- Bioline’s continuous self-flushing design ensures drippers purge debris any time they are operating, not just at the beginning or end of a cycle
- Built-in physical root barrier protects against root intrusion without the need for chemical protection
- Large internal flow paths inside the dripper mean Bioline only requires 120 mesh/130 micron filtration
- Pressure compensating dripper design ensures even application of effluent across a broad area
- Dripperline lateral lengths are the longest in the industry
- No special storage or handling requirements ensure that outdoor storage is acceptable

**Figure 1 - The Bioline Dripper.** Capturing the effluent from the center of the flow is critical to effective dripper operation. This shows how the dripper is positioned in the center of the flow and is less likely to suffer contamination like drippers that capture water from the wall of the pipe where it is dirtiest.

---

1 At various times the following words will be used interchangeably: Bioline, drip tubing, dripperline, drip dispersal tubing.
The fast answer about only using pressure compensating dripperline is:

- Predictable
- Forgiving
- Easy to design with
- Provides a continuous self-flushing feature
- Provides a very consistent flow over time

### Table 1 - This chart shows the maximum lengths of laterals when using Netafim Bioline. The footage represents how far the dripperline can reach and how each dripper delivers equal flow under pressure compensating conditions. (These distances will decrease when designing for 2 fps flushing. See page 29 for more information on lateral length data when using 2 fps scouring).

<table>
<thead>
<tr>
<th>Dripper Spacing</th>
<th>Inlet Pressure (psi)</th>
<th>12&quot;</th>
<th>18&quot;</th>
<th>24&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dripper Flow Rate (GPH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4</td>
<td>0.6</td>
<td>0.9</td>
<td>0.4</td>
<td>0.6</td>
</tr>
<tr>
<td>15</td>
<td>25</td>
<td>35</td>
<td>45</td>
<td>292</td>
</tr>
<tr>
<td>25</td>
<td>35</td>
<td>45</td>
<td>558</td>
<td>514</td>
</tr>
<tr>
<td>35</td>
<td>45</td>
<td>55</td>
<td>656</td>
<td>594</td>
</tr>
<tr>
<td>45</td>
<td>55</td>
<td>65</td>
<td>732</td>
<td>674</td>
</tr>
</tbody>
</table>
| Lateral lengths are calculated for operation while dosing, and allow for the pressure at the end of the dripperline to be 7 psi or greater. Their data does not take scouring velocity into account.

**WHY NETAFIM ONLY USES PRESSURE COMPENSATING DRIPPERLINE**

Figure 2 – The Precision of Bioline Pressure Compensating Dripperline. Across this broad area are thousands of feet of dripperline delivering equal discharge rates from each dripper. Non-pressure compensating dripperlines cannot equal this degree of precision.
Pressure compensating (PC) dripperlines have been used in a variety of subsurface applications for decades. Whether the application is agriculture, where crop quality is largely dependant on each plant getting equal water, or landscape, where even watering yields well-balanced plantings and turf, pressure compensating dripperlines excel.

Beyond the design and maintenance ease that PC dripperline offers due to its precise and measurable rate flow, there is more. Bioline’s ability to purge debris whenever it gets into the dripper is another reason Netafim does not use non-pressure compensating dripperlines for wastewater. Using a dripper that may only clean itself at the beginning or end of a dose can lead to drippers not operating properly. This does not happen with Bioline.

Certain soils have the ability to reduce or actually cut-off the flow of non-PC drippers. Especially in tight soils, pressure created in the soil by the water can increase to the point where a non-pressure compensating dripper can actually close and stop dripping. Though these pressures dissipate by gravity after dosing - eliminating it during dosing is the object. Even on flat terrain, using non-PC dripperline can significantly and negatively affect the quality of the dose.

An excellent example of such an event is described in the Appendix section.

**Table 2** - The curved flow rate of a typical non-pressure compensating dripperline highlights why it is a poor choice for effluent dispersal. As the lateral length increases and/or the pressure decreases, the flow decreases as well. This makes designing a system difficult and reduces the effective management of effluent dispersal over the drip field.

**Table 3** - The flat flow rate line of Bioline represents the concept of pressure compensation and the resulting even discharge of water from each emitter along the full length of the dripperline lateral. This makes system design much easier and increases the effectiveness of effluent dispersal in the drip field, even if there are elevation differences.
This guide assumes the following wastewater conditions:

- Secondary-treated, domestic strength effluent
- 30/30 (ppm) BOD/TSS
- Fats, oils, and grease (FOG) less than 20 ppm
- A design flow generally less than 1,500 gallons per day (GPD)

This quality of effluent can be produced by any number of advanced onsite treatment technologies. While there are many successful drip dispersal systems on septic tank quality effluent wastewater, special care must be taken in the system design which may be beyond the scope of this publication.

Effluent typically leaves the treatment system and enters into an adequately-designed storage (dosing) tank. These tanks allow for both a working level and reserve capacity above the high water level alarm. The drip dispersal system is designed to distribute the wastewater uniformly over the drip field throughout a 24 hour day or as local regulations dictate.

The control system regulates the flow and may also provide for filter and field flushing, zone selection and alarms whenever operational conditions are exceeded.

Since Bioline® requires pressure to function, this design guide is built around commonly available 110 VAC, 60HZ, ½ HP motor pumps that operate up to about 20 GPM. System pressure is also required to operate filters (automatic or manual backflush), which remove suspended organic and inorganic particles.

Multiple zones of dripperline may be necessary or desired to keep pump size small and/or to meet local regulations, but pump capacity should allow for adequate flushing of the dripperline and piping network components during manual or automatic field flush cycles. Design considerations derived from these principles are detailed in the following chapters.

Drip tubing is frequently installed at a depth of 6”, but 8” to 12” depths may be recommended to minimize potential human or animal contact and to ensure proper effluent dispersal into the biologically-active soil layer. Cold climates may require even deeper burial, or additional cover based on local conditions. Installing dripperline below the soil’s freeze depth is generally safe, but there are numerous installations at relatively shallow depths in cold climates with appropriate design and routine dosing. See the section titled "Freezing Climate Design and Other Considerations" on page 48.

---

**Figure 3 - Typical Treatment System & Drip Dispersal System Layout.** Illustration provided by Texas Cooperative Extension.
Most critical to a proper design is matching the soil’s capacity to absorb water with the dripperline’s application rates and the demand for dispersal of the design flow. In this regard, the designer must take into account:

- Water flow over, into, and through the soil
- Soil morphology (structure, texture)
- Storage of water in the soil column
- The loss of water to the air through evaporation
- Exchange to the air through plant transpiration

This design guide shows how accurate information about daily wastewater flow, proper soil analysis and thorough site evaluation will result in a successful and cost effective drip dispersal system.

**Note:** Netafim has developed an easy-to-use computer program to do many of the quantitative design analysis steps based on gallons available per day, soil loading rates, pump size, number of doses, etc. It is available on the Netafim Wastewater Division CD and on our website at [www.netafim-usa-wastewater.com](http://www.netafim-usa-wastewater.com). The following discussions provide the context for these calculations.

A drip dispersal system must accommodate the volume of wastewater effluent being generated. The following EPA charts can be used for estimating the daily wastewater production rate for various activities. Actual water usage data or other methods of calculating wastewater usage rates must be used by the system designer if it is determined that, for whatever reason, quantities may exceed standard estimates.

**Note:** Estimates used for onsite wastewater treatment designs should always be approved by local regulatory authorities.

Residential occupancy from the 1998 U.S. Census Bureau indicated that the average occupancy per bedroom was 1.0 to 1.5 persons while the same census reported that the average household size was 2.7 people. Local census data can be used to improve the accuracy of design assumptions. The current onsite code practice is to assume that the maximum occupancy is 2 persons per bedroom. This provides an estimate that could be too conservative (meaning that wastewater flows are overstated) if additional safety factors are incorporated into the design.

### SUMMARY of Average Daily Residential Wastewater Flows*

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of Residences</th>
<th>Study Duration (months)</th>
<th>Study Average (gal/person/day)</th>
<th>Study Range (gal/person/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown &amp; Caldwell (1984)</td>
<td>210</td>
<td>-</td>
<td>66.2 (250.6)</td>
<td>57.3 - 73.0 (216.9 - 276.3)</td>
</tr>
<tr>
<td>Anderson &amp; Siegrist (1989)</td>
<td>90</td>
<td>3</td>
<td>70.8 (268.0)</td>
<td>65.9 - 76.6 (249.4 - 289.9)</td>
</tr>
<tr>
<td>Anderson et al (1993)</td>
<td>25</td>
<td>3</td>
<td>50.7 (191.9)</td>
<td>26.1 - 85.2 (98.9 - 322.5)</td>
</tr>
<tr>
<td>Mayer et al (1999)</td>
<td>1,188</td>
<td>1</td>
<td>69.3 (262.3)</td>
<td>57.1 - 83.5 (216.1 - 316.1)</td>
</tr>
<tr>
<td>Weighted Average</td>
<td>153</td>
<td>-</td>
<td>68.6 (259.7)</td>
<td>-</td>
</tr>
</tbody>
</table>

* Based on indoor water use monitoring and not wastewater flow monitoring.
* Liters/person/day in parentheses.
* Based on 2 weeks of continuous flow monitoring in each of two seasons at each home.

Table 4 - Average Daily Residential Wastewater Flows

---

2 From EPA Publication EPA 625/R-00/008-Chapter 3.
Based on the data in Table 4, estimated average daily wastewater flows of approximately 50 - 70 gallons per person per day (189 to 265 liters per person per day) would be typical for residential dwellings built before 1994.

### RESIDENTIAL WATER USE by Fixture or Appliance

<table>
<thead>
<tr>
<th>Fixture/Use</th>
<th>Gallons/Use (average range)</th>
<th>Uses/Person/Day (average range)</th>
<th>Gallons/Person/Day (average range)</th>
<th>Percent Total (average range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toilet</td>
<td>3.5 (2.9 - 3.9)</td>
<td>5.05 (4.5 - 5.6)</td>
<td>18.5 (15.7 - 22.9)</td>
<td>26.7 (22.6 - 30.6)</td>
</tr>
<tr>
<td>Shower</td>
<td>17.2^ (14.9 - 18.6)</td>
<td>0.75^ (0.6 - 0.9)</td>
<td>11.6 (8.3 - 15.1)</td>
<td>16.8 (11.8 - 20.2)</td>
</tr>
<tr>
<td>Bath</td>
<td>See Shower</td>
<td>See Shower</td>
<td>1.2 (0.5 - 1.9)</td>
<td>1.7 (0.9 - 2.7)</td>
</tr>
<tr>
<td>Clothes Washer</td>
<td>40.5</td>
<td>0.37 (0.30 - 0.42)</td>
<td>15.0 (12.0 - 17.1)</td>
<td>21.7 (17.8 - 28.0)</td>
</tr>
<tr>
<td>Dishwasher</td>
<td>10.0 (9.3 - 10.6)</td>
<td>0.10 (0.06 - 0.13)</td>
<td>1.0 (0.6 - 1.4)</td>
<td>1.4 (0.9 - 2.2)</td>
</tr>
<tr>
<td>Faucets</td>
<td>1.4e</td>
<td>8.1^ (6.7 - 9.4)</td>
<td>10.9 (8.7 - 12.3)</td>
<td>15.7 (12.4 - 18.5)</td>
</tr>
<tr>
<td>Leaks</td>
<td>n/a</td>
<td>n/a</td>
<td>9.5 (3.4 - 17.6)</td>
<td>13.7 (3.3 - 21.6)</td>
</tr>
<tr>
<td>Other Domestic</td>
<td>n/a</td>
<td>n/a</td>
<td>1.6 (0.0 - 6.0)</td>
<td>2.3 (0.0 - 8.5)</td>
</tr>
<tr>
<td>Total</td>
<td>n/a</td>
<td>n/a</td>
<td>69.3 (57.1 - 83.5)</td>
<td>100</td>
</tr>
</tbody>
</table>

---

^ Results from AWWARF REUWS at 1,188 homes in 12 metropolitan areas. Homes surveyed were served by public water supplies, which operate at higher pressure than private water sources. Leakage rates might be lower for homes on private water supplies.

^ Results are averages over range. Range is the lowest to highest average for 12 metropolitan areas.

^ Gallons/person/day might not equal gallons/use multiplied by uses/ Person/day because of differences in the number of data points used to calculate means.

^ Includes shower and bath.

^ Gallons per minute.

^ Minutes of use per person per day.

Source: Mayer et al., 1999

Table 5 - Typical Flow Rates from Residential Sources
While this guide is largely developed around residential applications, the following charts are provided for non-residential flows.

### COMMERCIAL WATER USE by Fixture or Appliance\(^a, b\)

<table>
<thead>
<tr>
<th>Facility</th>
<th>Unit</th>
<th>Flow/Gallons/Unit/Day</th>
<th>Flow/Liters/Unit/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Range</td>
<td>Typical</td>
</tr>
<tr>
<td>Airport</td>
<td>Passenger</td>
<td>2 - 4</td>
<td>3</td>
</tr>
<tr>
<td>Apartment House</td>
<td>Person</td>
<td>40 - 80</td>
<td>50</td>
</tr>
<tr>
<td>Automobile Service Station(^c)</td>
<td>Vehicle Served</td>
<td>8 - 15</td>
<td>12</td>
</tr>
<tr>
<td>Automobile Service Station(^c)</td>
<td>Employees</td>
<td>9 - 15</td>
<td>13</td>
</tr>
<tr>
<td>Bar</td>
<td>Customer</td>
<td>1 - 5</td>
<td>3</td>
</tr>
<tr>
<td>Bar</td>
<td>Employees</td>
<td>10 - 16</td>
<td>13</td>
</tr>
<tr>
<td>Boarding House</td>
<td>Person</td>
<td>25 - 60</td>
<td>40</td>
</tr>
<tr>
<td>Department Store</td>
<td>Toilet Room</td>
<td>400 - 600</td>
<td>500</td>
</tr>
<tr>
<td>Department Store</td>
<td>Employee</td>
<td>8 - 15</td>
<td>10</td>
</tr>
<tr>
<td>Hotel</td>
<td>Guest</td>
<td>40 - 60</td>
<td>50</td>
</tr>
<tr>
<td>Hotel</td>
<td>Employee</td>
<td>8 - 13</td>
<td>10</td>
</tr>
<tr>
<td>Industrial Building (sanitary waste only)</td>
<td>Employee</td>
<td>7 - 16</td>
<td>13</td>
</tr>
<tr>
<td>Laundry (self-service)</td>
<td>Machine</td>
<td>450 - 650</td>
<td>550</td>
</tr>
<tr>
<td>Laundry (self-service)</td>
<td>Wash</td>
<td>45 - 55</td>
<td>50</td>
</tr>
<tr>
<td>Office</td>
<td>Employee</td>
<td>7 - 16</td>
<td>13</td>
</tr>
<tr>
<td>Public Lavatory</td>
<td>User</td>
<td>3 - 6</td>
<td>5</td>
</tr>
<tr>
<td>Restaurant (with toilet)</td>
<td>Meal</td>
<td>2 - 4</td>
<td>3</td>
</tr>
<tr>
<td>Restaurant (conventional)</td>
<td>Customer</td>
<td>8 - 10</td>
<td>9</td>
</tr>
<tr>
<td>Restaurant (short order)</td>
<td>Customer</td>
<td>3 - 8</td>
<td>6</td>
</tr>
<tr>
<td>Restaurant (bar/cocktail lounge)</td>
<td>Customer</td>
<td>2 - 4</td>
<td>3</td>
</tr>
<tr>
<td>Shopping Center</td>
<td>Employee</td>
<td>7 - 13</td>
<td>10</td>
</tr>
<tr>
<td>Shopping Center</td>
<td>Parking Space</td>
<td>1 - 3</td>
<td>2</td>
</tr>
<tr>
<td>Theater</td>
<td>Seat</td>
<td>2 - 4</td>
<td>3</td>
</tr>
</tbody>
</table>

\(^a\) Some systems serving more than 20 people might be regulated under US EPA's Class V Underground Injection Control (UIC) Program. See [http://www.epa.gov/safewater/uic.html](http://www.epa.gov/safewater/uic.html) for more information.

\(^b\) These data incorporate the effect of fixtures complying with the U.S. Energy Policy Act (EPACT) of 1994.

\(^c\) Disposal of automotive wastes via subsurface wastewater infiltration systems is banned by Class V UIC regulations to protect ground water. See [http://www.epa.gov/safewater/uic.html](http://www.epa.gov/safewater/uic.html) for more information.

Source: Crites and Tchobanoglous, 1998.

---

Table 6 - Typical Flow Rates from Commercial Sources
### Table 7 - Typical Flow Rates from Institutional Sources

<table>
<thead>
<tr>
<th>Facility</th>
<th>Unit</th>
<th>Flow/Gallons/Unit/Day</th>
<th>Flow/Liters/Unit/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assembly Hall</td>
<td>Seat</td>
<td>2 - 4</td>
<td>8 - 15</td>
</tr>
<tr>
<td>Hospital, Medical</td>
<td>Bed</td>
<td>125 - 240</td>
<td>470 - 910</td>
</tr>
<tr>
<td>Hospital, Medical</td>
<td>Employee</td>
<td>5 - 15</td>
<td>19 - 57</td>
</tr>
<tr>
<td>Hospital, Mental</td>
<td>Bed</td>
<td>75 - 140</td>
<td>280 - 530</td>
</tr>
<tr>
<td>Hospital, Mental</td>
<td>Employee</td>
<td>5 - 15</td>
<td>19 - 57</td>
</tr>
<tr>
<td>Prison</td>
<td>Inmate</td>
<td>80 - 150</td>
<td>300 - 570</td>
</tr>
<tr>
<td>Prison</td>
<td>Employee</td>
<td>5 - 15</td>
<td>19 - 57</td>
</tr>
<tr>
<td>Rest Home</td>
<td>Resident</td>
<td>50 - 120</td>
<td>190 - 450</td>
</tr>
<tr>
<td>Rest Home</td>
<td>Employee</td>
<td>5 - 15</td>
<td>19 - 57</td>
</tr>
<tr>
<td>School (day w/cafeteria, gym, showers)</td>
<td>Student</td>
<td>15 - 30</td>
<td>57 - 110</td>
</tr>
<tr>
<td>School (day w/cafeteria)</td>
<td>Student</td>
<td>15 - 30</td>
<td>38 - 76</td>
</tr>
<tr>
<td>School (day w/o cafeteria, gym, showers)</td>
<td>Student</td>
<td>10 - 20</td>
<td>19 - 64</td>
</tr>
<tr>
<td>School (boarding)</td>
<td>Student</td>
<td>50 - 100</td>
<td>190 - 380</td>
</tr>
</tbody>
</table>

* Systems serving more than 20 people might be regulated under US EPA’s Class V UIC Program. See [http://www.epa.gov/safewater/uic.html](http://www.epa.gov/safewater/uic.html) for more information.

Source: Crites and Tchobanoglous, 1998.
### RECREATIONAL WATER USE Typical Flow Rates

<table>
<thead>
<tr>
<th>Facility</th>
<th>Unit</th>
<th>Flow/Gallons/Unit/Day</th>
<th>Flow/Liters/Unit/Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apartment, Resort</td>
<td>Person</td>
<td>50 - 70</td>
<td>190 - 280</td>
</tr>
<tr>
<td>Bowling Alley</td>
<td>Alley</td>
<td>150 - 250</td>
<td>270 - 950</td>
</tr>
<tr>
<td>Cabin, Resort</td>
<td>Person</td>
<td>8 - 50</td>
<td>80 - 190</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>Customer</td>
<td>1 - 3</td>
<td>4 - 11</td>
</tr>
<tr>
<td>Cafeteria</td>
<td>Employee</td>
<td>8 - 12</td>
<td>30 - 45</td>
</tr>
<tr>
<td>Camp (pioneer type)</td>
<td>Person</td>
<td>15 - 30</td>
<td>57 - 110</td>
</tr>
<tr>
<td>Camp (children's w/toilet, bath)</td>
<td>Person</td>
<td>35 - 50</td>
<td>130 - 190</td>
</tr>
<tr>
<td>Camp (day w/meals)</td>
<td>Person</td>
<td>10 - 20</td>
<td>38 - 76</td>
</tr>
<tr>
<td>Camp (day w/o meals)</td>
<td>Person</td>
<td>10 - 15</td>
<td>38 - 57</td>
</tr>
<tr>
<td>Camp (luxury, private bath)</td>
<td>Person</td>
<td>75 - 100</td>
<td>280 - 380</td>
</tr>
<tr>
<td>Camp (trailer camp)</td>
<td>Trailer</td>
<td>75 - 150</td>
<td>280 - 570</td>
</tr>
<tr>
<td>Campground (developed)</td>
<td>Person</td>
<td>20 - 40</td>
<td>76 - 150</td>
</tr>
<tr>
<td>Cocktail Lounge</td>
<td>Customer</td>
<td>12 - 25</td>
<td>45 - 95</td>
</tr>
<tr>
<td>Coffee Shop</td>
<td>Customer</td>
<td>4 - 8</td>
<td>15 - 30</td>
</tr>
<tr>
<td>Coffee Shop</td>
<td>Employee</td>
<td>8 - 12</td>
<td>30 - 45</td>
</tr>
<tr>
<td>Country Club</td>
<td>Guest</td>
<td>60 - 130</td>
<td>230 - 490</td>
</tr>
<tr>
<td>Country Club</td>
<td>Onsite Employee</td>
<td>10 - 15</td>
<td>38 - 57</td>
</tr>
<tr>
<td>Dining Hall</td>
<td>Meal Served</td>
<td>4 - 10</td>
<td>15 - 38</td>
</tr>
<tr>
<td>Dormatory, Bunkhouse</td>
<td>Person</td>
<td>20 - 50</td>
<td>76 - 190</td>
</tr>
<tr>
<td>Fairground</td>
<td>Visitor</td>
<td>1 - 2</td>
<td>4 - 8</td>
</tr>
<tr>
<td>Hotel, Resort</td>
<td>Person</td>
<td>40 - 60</td>
<td>150 - 230</td>
</tr>
<tr>
<td>Picnic Park (flush toilets)</td>
<td>Visitor</td>
<td>5 - 10</td>
<td>19 - 38</td>
</tr>
<tr>
<td>Store, Resort</td>
<td>Customer</td>
<td>1 - 4</td>
<td>4 - 15</td>
</tr>
<tr>
<td>Store, Resort</td>
<td>Employee</td>
<td>8 - 12</td>
<td>30 - 45</td>
</tr>
<tr>
<td>Swimming Pool</td>
<td>Customer</td>
<td>5 - 12</td>
<td>19 - 45</td>
</tr>
<tr>
<td>Swimming Pool</td>
<td>Employee</td>
<td>8 - 12</td>
<td>30 - 45</td>
</tr>
<tr>
<td>Theater</td>
<td>Seat</td>
<td>2 - 4</td>
<td>8 - 15</td>
</tr>
<tr>
<td>Visitor Center</td>
<td>Visitor</td>
<td>4 - 8</td>
<td>15 - 30</td>
</tr>
</tbody>
</table>

*Some systems serving more than 20 people might be regulated under US EPA’s Class V UIC Program.

Source: Crites and Tchobanoglous, 1998.

**Table 8 - Typical Flow Rates From Recreational Facilities**

### SITE CONSIDERATIONS

Before doing any detailed design specification, it is necessary to evaluate specific site features. This assessment should include the following:

**Site Boundaries:** Most state and local regulations will establish how close dripperlines may be placed to property lines, home foundations and other permanent property features.

**Special Features:** Community water distribution lines, property and utility easements, wells, treatment systems, water lines from wells, etc., require setbacks; 50 to 100 feet is typical. Surface waters, including ditches, ponds, lakes, streams and even intermittent water courses also require specific setbacks. Follow all local regulations.
Prior Land Use: Research should be conducted to identify any prior activities on the proposed site that may have affected soil characteristics. These effects could include compaction, foreign soils, buried materials, etc.

Future Land Use Restrictions: The drip dispersal field can be installed under a permanent lawn, among trees or other landscape features, provided that proper setbacks are followed. Any future permanent structures that will affect soil texture and water flow through the soil must be avoided over a drip dispersal field, including but not limited to the following: out-buildings, parking areas, swimming pools, tennis courts, home additions, decks, etc. The designer should consult with the property owner regarding anticipated improvements to the property and avoid these areas.

Precipitation and Landscape Position: If the site is in an area that experiences seasonal, intense, or even short duration precipitation events consider regrading the area to encourage direct runoff.

Slope: Slope or slope gradient is the inclination of the surface of the soil from horizontal and is expressed as a percentage of the distance between those points.

Examples:
1. If the difference in elevation is 1 foot over a horizontal distance of 100 feet, slope gradient is 1%.
2. A slope that drops 10 vertical feet in 100 horizontal feet is a 10% slope (vertical drop/horizontal distance times 100).
3. A slope of 45° is a slope of 100 percent, because the difference in elevation between two points 100 meters apart horizontally is 100 meters on a 45° slope.

Note: The higher the percent, the steeper the slope!

The elevation of a slope is important because it determines the rate at which water (and effluent) flows downhill. Water flows slowly over a gentle slope and rapidly over a steep one. The steepness of a slope has been evaluated by the United States Department of Agriculture’s Soil Conservation Service as follows:

- Nearly level (0 - 2%). Has no limitation on its uses. Any limitations are the result of other factors, such as drainage.
- Gently Sloping (3% - 6%). Desirable for almost any type of development; may have erosion problems; limitations are due mostly to factors other than slope.
- Moderately Sloping (6% - 12%). May have severe erosion problems and has a strong appeal for single-family development.
- Strongly Sloping (12% - 18%). Has severe limitations for all types of construction. Residential development is sometimes considered because of the scenic views associated with such terrain, or when other sites are unavailable.
- Steep Slopes (18% and over). Undesirable for most development.
The Slope Conversion chart shows equivalences between percentage of gradient and angle of slope in degrees. Drip dispersal encourages lateral (horizontal), not just vertical movement throughout the soil. This makes it an excellent choice for both level surfaces and slopes. This is especially true with the use of pressure compensating emitters and proper zoning. Additional considerations about slopes include whether:

- There is a natural or artificial barrier down-slope from the proposed site that could provide opportunities for water to surface (such as hillside cuts or walls)
- The drip tubing can be laid out along the contour of the slope
- System geometry can be used that minimizes linear loading rate
- The design can incorporate air release valves, check valves, zones and other means to equalize flow and to prevent drainback (See the design and layout discussions that follow.)

With consideration of the above issues, and any similar issues that the designer believes may affect soil absorption rates, the designer is now ready to evaluate the specific soil characteristics.

### Soil Considerations

After the drip dispersal area has been identified, the designer must undertake a thorough study of the specific soil characteristics of the proposed field. Particular attention must be given to:

- Texture
- Site uniformity
- Compaction
- Native vs. disturbed soils
- Soil depth to restrictions or water table
- Clay mineralogy

### Sample Collection

An accurate representation of the overall site condition requires that a determination of the underlying soil characteristics be done. A minimum of two samples per proposed zone is strongly recommended. The sample should be a three-dimensional soil core sample which, if possible, extends into the soil a minimum of two feet deeper than the proposed location for the drip tubing. The analysis of the soil core must establish the morphology, structure and texture, as well as the determination of the presence of ground water, seasonal high water table, restrictive layers, etc. USDA/NRCS Soils Maps or other locally available geological maps should be consulted to determine consistency between observed and referenced conditions. Any inconsistencies should result in further investigations of site particulars and history.
DETERMINING SOIL TEXTURE

Accurate analysis of the samples is critical in determining the absorptive capacity of the soil. If samples from the various locations of the proposed site are different, the design will typically be based on the most restrictive sample.

The system designer should always consult with a registered soil scientist, site evaluator or soils structure laboratory for assistance in determining an accurate soil texture classification.

The USDA Soil Texture Triangle chart serves as an outline to determine soil composition and texture, leading to suggested loading rates.

RESTRICTIVE LAYERS

Many soil environments are surrounded by other soils with less desirable characteristics. It should be recognized that water movement through multiple soil types will be determined by the characteristics of the most restrictive types. Therefore, whenever these restrictive types are encountered in a proposed drip field, they should provide the operative design criteria. In particular, soil absorptive capacities should be based on those of restrictive layers rather than those of the more absorptive soils. If restrictive layers are present within two feet below the dripperline, then the designer should use the reduced loading rates of the restrictive layer. The greater the soil depth to a restrictive layer, the better.

Considering the area two to four feet below the tubing: if there is a soil classification change of one class or more, or if a restrictive boundary layer exists (rock, tight clays, etc.), then the dispersal area should be increased. Consult local regulations for how much the area should increase.
Native, non-disturbed soils are always the most desirable medium for drip application. However, if the soils are very poor, or the site conditions (e.g., available space) are limited, and if regulations permit, the designer may consider the introduction of fill material.

If the proposed drip field employs soil fill material, artificially compacted soils, or mixed soils, special considerations apply. Although the fill material may have a greater soil absorptive capacity, the design should not rely on the better soil classification if the underlying poor soil is still present and utilized in the drip system design. Mixing or tilling of the soils may increase the soil absorptive capacity. However, adding Class II soils to a Class IV site does NOT yield a Class III absorptive capacity. A proper analysis by a soils laboratory with an engineering rather than agricultural focus is necessary to determine the new soil characteristics. In addition, at any time that a drip field is constructed with added soil, the overall field should be larger than otherwise called for in the design, and the loading rate should be determined by the restrictive layers and other site conditions rather than by the constructed soils.

The “soup bowl” graphic below demonstrates the problem. If the bowl area is scooped out and replaced with more absorptive soils, system failures may still occur because the water will be trapped in the bowl. Conversely, if the situation is reversed, such as with a “mound” configuration, water will tend to escape at the interface between the imported and native soils.

With the noted constraints used to define the overall characteristics of the proposed drip dispersal site, the designer is now prepared to establish a loading rate for the soil.

**SOUP BOWL EFFECT OF SOIL ADDITION**

Adding good quality soil fill does not relieve poor qualities of the soil that surround it.

The effluent will saturate the fill since the restrictive layer around the good soil fill does not permit proper draining.

Surfacing of effluent will eventually occur.

Figure 5 - “Soup Bowl Effect” (circles indicate dripperline laterals).
The success of a drip dispersal system is largely due to how accurately the dose rate is matched to the ability of the wastewater to be hydraulically conveyed through the soil. The soil loading rate is the estimated volume of water (expressed in gallons) that a square foot of the most restrictive soil in a horizon will accept and properly treat in one day, without creating ponding conditions. It is a rate that is determined by analyzing the soil texture and structure of the most restrictive soil horizon. For a more thorough understanding of the importance of water movement through the soil "Darcy's Law" summarizes the properties that groundwater exhibit when moving through a porous medium.

While maximum loading rates are determined by structure, slope, depth to restriction and soil texture, we will consider soil texture and structure classification as the determinant for soil hydraulic loading rate. A more thorough analysis, including depth and slope should be always incorporated into design considerations.

Different soil textures have different porosities and therefore enable different quantities of water to pass through them. In drip dispersal, the goal is shallow dispersal, not deep percolation or surfacing. Therefore, soil textures both at the surface and below the surface are important to enable wastewater to flow both horizontally and vertically, allowing the loading of the soil at an even rate in the biologically active zone near the surface. This improves treatment through better oxygenation and enhances plant uptake through evapotranspiration. Two sample loading rate charts follow.

A sample Soil Loading Rate chart has also been included as part of the Netafim computer design program.
## SAMPLE SOIL Loading Rates

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>Soil Structure</th>
<th>Max. Hydraulic Loading Rate (gallons per sq. ft., per day)</th>
<th>Area Required (sq. ft., per 100 GPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse Sand</td>
<td>n/a</td>
<td>1.5</td>
<td>67</td>
</tr>
<tr>
<td>Loamy Sand</td>
<td>n/a</td>
<td>1.5</td>
<td>67</td>
</tr>
<tr>
<td>Sand</td>
<td>n/a</td>
<td>0.8</td>
<td>125</td>
</tr>
<tr>
<td>Loamy Sand</td>
<td>Moderate to Strong</td>
<td>0.8</td>
<td>125</td>
</tr>
<tr>
<td>Fine Sand</td>
<td>Moderate to Strong</td>
<td>0.8</td>
<td>125</td>
</tr>
<tr>
<td>Fine Sand</td>
<td>Massive or Weak</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Loamy Fine Sand</td>
<td>Moderate to Strong</td>
<td>0.8</td>
<td>125</td>
</tr>
<tr>
<td>Loamy Fine Sand</td>
<td>Massive or Weak</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Very Fine Sand</td>
<td>Moderate to Strong</td>
<td>0.8</td>
<td>125</td>
</tr>
<tr>
<td>Very Fine Sand</td>
<td>Massive or Weak</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Loamy Very Fine Sand</td>
<td>Moderate to Strong</td>
<td>0.8</td>
<td>125</td>
</tr>
<tr>
<td>Loamy Very Fine Sand</td>
<td>Massive or Weak</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>Moderate to Strong</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>Massive or Weak</td>
<td>0.3</td>
<td>333</td>
</tr>
<tr>
<td>Loam</td>
<td>Moderate to Strong</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Loam</td>
<td>Weak</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Loam</td>
<td>Weak Platy</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Loam</td>
<td>Massive</td>
<td>0.2</td>
<td>500</td>
</tr>
<tr>
<td>Silt Loamy</td>
<td>Moderate to Strong</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Silt Loamy</td>
<td>Weak</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Silt Loamy</td>
<td>Weak Platy</td>
<td>0.5</td>
<td>200</td>
</tr>
<tr>
<td>Silt Loamy</td>
<td>Massive</td>
<td>0.2</td>
<td>500</td>
</tr>
<tr>
<td>Sandy Clay Loam</td>
<td>Moderate to Strong</td>
<td>0.3</td>
<td>333</td>
</tr>
<tr>
<td>Sandy Clay Loam</td>
<td>Weak</td>
<td>0.2</td>
<td>500</td>
</tr>
<tr>
<td>Sandy Clay Loam</td>
<td>Weak Platy</td>
<td>0.2</td>
<td>500</td>
</tr>
<tr>
<td>Sandy Clay Loam</td>
<td>Massive</td>
<td>0.15</td>
<td>667</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>Moderate to Strong</td>
<td>0.3</td>
<td>333</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>Weak</td>
<td>0.2</td>
<td>500</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>Weak Platy</td>
<td>0.2</td>
<td>500</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>Massive</td>
<td>0.15</td>
<td>667</td>
</tr>
<tr>
<td>Silty Clay Loam</td>
<td>Moderate to Strong</td>
<td>0.3</td>
<td>333</td>
</tr>
<tr>
<td>Silty Clay Loam</td>
<td>Weak</td>
<td>0.2</td>
<td>500</td>
</tr>
<tr>
<td>Silty Clay Loam</td>
<td>Weak Platy</td>
<td>0.2</td>
<td>500</td>
</tr>
<tr>
<td>Silty Clay Loam</td>
<td>Massive</td>
<td>0.15</td>
<td>667</td>
</tr>
<tr>
<td>Sandy Clay</td>
<td>Moderate to Strong</td>
<td>0.1</td>
<td>1,000</td>
</tr>
<tr>
<td>Sandy Clay</td>
<td>Weak to Massive</td>
<td>0.05</td>
<td>2,000</td>
</tr>
<tr>
<td>Clay</td>
<td>Moderate to Strong</td>
<td>0.1</td>
<td>1,000</td>
</tr>
<tr>
<td>Clay</td>
<td>Weak to Massive</td>
<td>0.05</td>
<td>2,000</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>Moderate to Strong</td>
<td>0.1</td>
<td>1,000</td>
</tr>
<tr>
<td>Silty Clay</td>
<td>Weak to Massive</td>
<td>0.05</td>
<td>2,000</td>
</tr>
</tbody>
</table>

Example only, please refer to local regulations.
Some states have regulations specifying loading rates that may vary from Table 10 or Figure 6. The designer must follow regulations, and whenever possible, adopt a conservative design approach.

**Calculating Drip Dispersal Area: Application Area = Daily Flow / Loading Rate**

Example: If the system will have 450 gallons per day and the soil is loam texture with weak, platy structure (0.5 gallons per square foot per day): \( 450 / 0.5 = 900 \) Square Feet of Area will be required.

Designers should take into account that proposed loading rates are for optimal soil conditions and any site-specific special circumstances including, but not limited to, the following need to be considered in the design:

- Specific features
- Precipitation
- Slopes
- Prior and adjacent land uses
- Impervious boundaries
- Depth to limitation
- Vegetation

**NOTE:** We mention again that Netafim believes that a conservative design approach is the best approach. A Netafim wastewater drip dispersal system has the ability to provide outstanding performance for many years. Taking time now to attend to the details will reward you with the performance you want and a very low total cost of ownership.
**SYSTEM COMPONENTS**

**Dripperline:** Bioline® is low volume dripperline with integral and evenly spaced pressure compensated emitters. Bioline is specifically manufactured for use with wastewater effluent and is the heart of the system. See the "Performance Specifications" section for details and performance specifications.

**Pumps:** Systems can be designed to use any type of commercially available high head pump. While many residential and commercial systems may use a 110 V, ½ HP pump that produce 12 to 20 GPM, larger systems will need to be sized accordingly.

**Dosing Tank:** A storage tank is required to provide the operating capacity for the pump, to provide flow equalization, and to allow for peak and emergency storage. The operating capacity should allow for a minimum of 24 hours of the average daily flow to provide even distribution to the drip field throughout the day. See "How to Dose" section for more information on dose tank sizing. **Note:** Follow local regulations to determine storage requirement.

**Filtration:** Every drip system must include a filter to prevent introduction of sediments and suspended organic and inorganic materials into the dripperline. Without proper filtration, sediment can accumulate and cause plugging. A 130 micron filter (120 mesh) is recommended for all Netafim Bioline dripperlines.

**Zone Valves:** When multiple zones are used, automatic solenoid valves are customarily used to turn zones on and off. Many automatic valves designed for standard irrigation may not withstand the more rigorous demands of wastewater effluent. Be certain that the valves you select are appropriate for the application.
**Air/Vacuum Relief Valves**: Air in a drip dispersal system is both good and bad. Air/Vacuum Relief Valves perform a necessary function when a zone shuts down by allowing air to replace the effluent as it drains out of the dripperline. However, air can hinder proper system performance on zone turn on by delaying when the drippers farthest from the beginning of the zone system begin operating.

On zone turn on, Air/Vacuum Relief Valves quickly expel air in the dripperlines, allowing the dripperline to fill more quickly and helping to produce a more uniform dose, especially when short dosing intervals are used.

Designs should include a minimum of two Air/Vacuum Relief Valves per zone. They should be located at the highest point(s) of both the supply and flush manifolds and are typically placed in a valve box lined with gravel for protection. It is important that they always have access to free air.

![Figure 7 - Typical Air/Vacuum Relief Valve Detail](image)

**Pressure Regulators and Pressure Regulation**: “PRV’s” ensure that a “not-to-exceed” pressure downstream of their location is achieved. They are helpful when supply pressures vary and could / do exceed the rating of fittings or tubing. They can also mitigate issues with non-PC dripperline, especially on slopes.

Pressure Regulators should be considered when severe slopes are encountered or when pressures higher than 50 psi are present. Pressure regulators are typically located at the manifold of each zone where varying topographies exist.

When using Netafim Bioline® pressure compensating dripperline and appropriately sized pumps, it is not normally necessary to regulate pressure. Normal field operating pressure should be within a recommended range of 25 to 45 psi. Netafim Bioline is designed to provide uniform drip flow rates with pressures of 7 to 70 psi at the emitter, but PRV’s should be considered if operating pressures could or will exceed 50 psi.

**Check Valves**: Check valves are designed to only allow flow in one direction. They are frequently found on slope layouts that do not take advantage of Netafim’s unique “top-feed” manifold layout. They are also used in multiple zone layouts where a common flush line is being used. This ensures that only the currently activated zone for dosing is receiving effluent. See page 47 for designing check valves in multiple zone layouts.

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4 A more thorough discussion of the dangers of entrapped air is located in the Appendix section of this guide.
When supply and return headers are installed going up (with) the slope, check valves help to prevent the zone’s effluent from draining down to the lowest point or flowing back to the dose tank.

Netafim does not recommend this type of layout. Instead, Netafim recommends the “Top Feed” manifold layout which will be discussed later in this guide.

**Loops and Flexible Connections:** Bioline® dripperline or Bioline blank tubing can easily be made to turn 180 degrees in applications where the rows are 24” apart. However, for maximum long-term protection against kinking, especially in freeze-thaw conditions, it is common practice to install flex PVC pipe whenever a turn of 45 degrees or more is made. These flex connections are used to prevent the possibility of kinking the dripperline which could reduce or shut off the flow. Flexible connections are also used to connect Bioline to the supply and return manifolds. The primary purpose in this case is to ensure that any sharp objects or other debris that may be in the trenches of the supply and flush headers do not cut the dripperline. It also helps to protect against the shrinking, swelling, movement and settling of the soils.

The flex connection also prevents dripperline flow from entering the trench of the supply and flush manifolds. Because these trenches may run up and down slope, they can become drains, with the potential for effluent surfacing at the downstream end. As such, it is highly recommended that the dripperline not drip into the trench.

**Figure 8 - Loop and Flexible Connections**
Supply Line: While most systems use Schedule 40 PVC, the correct pipe should be used to match the conditions. Check local code.

Supply Manifold: Schedule 40 PVC (or as appropriate for conditions) piping is the standard of design where the effluent is distributed to the Bioline® via flex connections. Drops in system pressure should be minimized to ensure that a sufficient flushing velocity is maintained. Connections to the supply and flush manifolds (number of laterals) should be minimized for system efficiency.

Dripperlines: Effluent flows through Bioline and into the soil through its emitters (drippers). The emitters each have a specific flow rate of 0.4, 0.6, or 0.9 gallons per hour (GPH). The flow rates are designed to prevent overloading of the soil and allow the designer to match the capacity of the soil to the flow rate of the dripper. In general, the lower the dripper flow rate, the slower the infiltration rate of the soil.

Flush Manifold: The characteristics of the flush manifold are the same as the supply manifold both in terms of material, size and number of connections.

Flush Line: The flush line is typically the same size and type as the flush manifold. It either terminates at the front end of the treatment system or into the dosing tank. If it flows into the dosing tank, periodic cleaning of the tank is recommended. The destination of the flush line may be dictated by local regulations.
PIPING LAYOUT

There are many ways to lay out drip dispersal fields. It is common design practice to arrange the tubing so that dripperline lateral lengths are roughly equal and approximately 300 to 400 feet in length (refer to page 29 for actual lateral lengths for the various Bioline flow rates and dripper intervals.) Lengths greater than these may:

- Require the pump(s) to create more head and flow
- May not allow the dripperline to perform optimally
- May require too large of a dript field area to precisely manage

It is standard practice to space rows of Bioline 24" apart, however, if the soil is capable of handling higher infiltration rates, there is no reason that the rows cannot be spaced more closely. Check local codes.

It is also standard practice to use 1 ¼" PVC pipe for distribution lines, supply and flush manifolds, and the flush line. On most systems up to about 1,500 gallons per day, this size pipe optimizes flow and minimizes friction loss.

The following drawings show different layouts. Figures 10 & 11 are frequently used in flat drip field layouts, while Figures 12 & 13 are used in slope layouts.

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5 If spacing rows closer together is acceptable under local rules and if the soils permit it, the drip dispersal field may become an important part of a subsurface irrigation system. Netafim has information on its Landscape & Turf Division web page regarding dripper flow rates, dripper interval and row spacing for subsurface irrigation of plants and turfgrass. Visit http://www.netafim-usa-landscape.com for more information.
Figure 11 - Opposite Side Supply and Flush on Flat Field Layouts
This layout features one or more supply headers on one end of the drip field with the flush headers on the opposite end of the field.

Figure 12 - Same Side Supply and Flush Manifolds for Flat Field Layouts
This layout has both the supply and flush manifolds in the same trench. This method eliminates the need for two separate trenches. Flex connections or Bioline blank tubing are used at the ends of the rows to turn and return the drip line back to the appropriate header.
Figure 13 - "Top Feed" Same Side Supply and Flush Manifolds for Slope Layouts

This patented "Top Feed" layout can only be used with Netafim Bioline dripperline. Top feed layouts are popular when working on slopes because they lessen the drainage. This layout is using same side supply and flush manifolds.

Figure 14 - "Top Feed" Opposite Side Supply and Flush Manifolds for Slope Layouts

This is an opposite side supply and flush manifold version of the patented top-feed layout that can only be used with Netafim Bioline dripperline.
Flushing & Scouring of Dripperlines:
The subject of flushing, “forward field flushing” or scouring of dripperlines is an important one, in part because everyone seems to have a different approach to it.

It is generally agreed that the inside of the piping network can develop a build-up of microbial slimes that could degrade system performance. There is also the chance for inflow into the piping network from rainfall or normal on-off cycling of the system. But there are other issues as well.

The chance of the treatment system being completely sealed needs to be addressed. “The preponderance of septic tanks sold in the U.S. are structurally unsound and almost never watertight.” As such, “Because leaky tanks can exfiltrate, floatable solids, fats, soaps, oils and greases can be dosed or washed through the outlet assembly,” looking only at the type of wastewater being used only looks at part of the problem.

Protecting the system means that we are not just considering the dripperline component because we have protected the drippers with anti-microbial protection. We need to look at

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6 “Design and Performance of Septic Tanks”, T.R. Bounds, P. E.
7 “Design and Performance of Septic Tanks”, T.R. Bounds, P. E.
the entire system and consider the other components that will benefit from forward flushing:

- All other piping beside the dripperline
- Valves
- Fittings and other velocity-hinderung junctions

**Protecting the Bioline® Dripperline**

In order to lessen any adverse effects of slime build-up, Netafim incorporates an anti-microbial additive into the dripper. This additive acts to reduce the build-up of microbial slimes and has proven itself to be very effective. In addition to the anti-microbial additive, designing the drip dispersal system to flush additional effluent at an increased velocity is the norm. The speed and frequency of this action may be a topic of debate, whether it should be done is not.

**Protecting the Rest of the System**

The easiest and most common method for keeping the piping network and its allied components operating in peak condition is to design the system so that a flushing action can take place. This flushing action focuses on opening the network up so that additional flow can move through the network at an increased velocity, creating turbulence and releasing any build-up that may have occurred.

**How Fast You Should Flush**

Many people look to science to try to get that answer. In terms of the quality of effluent, there is data to suggest that secondary effluent may only need a 0.5 - 1.0 fps velocity while raw wastewater with grit and other debris should have anywhere from 2.5 - 3.5 fps, and effluent following primary settling may be in the 1.5 - 2.0 fps range. In reality, years of studying systems that have been designed with a 2 fps scouring velocity show that they continue to perform as they did when new. The 2 fps velocity requirement is also written into many regulations.

**Designing for a 2 fps Flush Velocity**

Designing for a 2 fps flush velocity often does not add any additional cost to a system. If it does, it might mean the minimal investment in an additional zone. As we have all seen in life, the adage that “an ounce of prevention is worth a pound of cure” usually wins out. The result of a well designed and maintained system is years of trouble-free operation. The cost of cutting corners can ultimately mean more money spent. When all of the costs, from installation, to the cost of the years of service performed are analyzed, what may have seemed more expensive in the beginning is really less expensive over time. That is the principle behind Total Cost of Ownership and it is why Netafim encourages conservative design approaches and active professional maintenance of an onsite system.

**Netafim’s Position on Flush Velocity**

Netafim recommends 2 fps of forward flushing velocity.

To make flushing easier from a design standpoint, Netafim has developed two sets of Bioline Maximum Length of Lateral charts. The first chart on the following page shows the maximum lateral lengths that various models of Bioline can reach, based only on pressure at the beginning and end of the line. The second chart accounts for the additional flow of water needed to increase the velocity to achieve 2 fps at the distal (far) end of the dripperline.

**Flushing Frequency**

The frequency of forward flushing is also open to debate, but a couple of factors help make the decision easier. Whether it is scheduled to be done several times a year, every 25 cycles, every 15 days, or daily is not the issue. Doing it and doing it correctly is the issue.
Table 11 - Maximum Length of a Single Lateral of Bioline

Table 12 - Maximum Length of a Single Lateral of Bioline, Allowing for 2 fps Scouring Velocity

DRAINBACK CONSIDERATIONS

When the dosing cycle ends, much of the effluent remaining in the system will drain out of the dripperline. The effluent will drain to the lowest parts of the dripperline zone, and even on a nominal (1%) slope, this could cause localized soil overloading. It is important to anticipate where the effluent will flow when the dosing event ends. There are a number of design approaches that address this issue, several of which follow. The optimal approach will be to use the “top loading” concept which is a patent-protected design approach that can only be used with Netafim Bioline. (See page 30 for more information).

One of the reasons why Bioline dripperline is a good solution on slopes is due to its pressure compensation feature. Bioline drippers deliver the same flow from 7 to 70 psi, so changes in pressure at the dripper due to elevation-created pressure variances do not affect the delivery rate of the drippers.

Other products allow additional flow anywhere higher pressures exist and as such, the soil can become saturated very quickly at the base of the slope. With Bioline, all areas of the slope are dripped at the same rate. There is no need to increase field size with Bioline. Simply use as much of the slope as possible to deliver to. (See Figures 14 & 15).

Install With the Contour: Dripperline must be installed along the contour of the slope (as level as possible), not up and down the slope. Otherwise, all the effluent in the dripperline will drain rapidly to the emitters at the base of the slope, which can overload the soil.

Feed from the Bottom of the Field: As a rule, drip fields on a slope should be fed from the bottom and flushed from the top (when not using the "Top Feed" layout). This technique will prevent the main lines and manifolds from draining to the field during rest periods. This strategy assumes that the field is uphill from the supply line. The supply manifold should “stair step” through a series of check valves, with a limited number of lines between each check valve. Check valves limit the down gradient flow of the water when the pump shuts down.
Less Frequent, Longer Doses: In more highly permeable soils with no restrictive conditions, longer dosing duration and decreased dosing frequency can help minimize the effects of drainback by reducing the number of cycles per day.

Zone Valves Location: To prevent mainline and submain drainage into the drip dispersal fields, zone valves should be installed as close as possible to the distribution field to minimize the volume of effluent subject to drainback. Local regulations often prohibit effluent from mains and sub mains draining into the drip fields during periods of rest.

Deeper Line Burial: Another way to manage potential drainback issues and the chance of surfacing is to bury the dripperline deeper.

We have seen a number of ways to minimize the effect slopes can have on the even dispersal of effluent. But there is another method that can help lessen the negative impact of draindown. It is a “Top Loading” design.

Note: This design is protected by U.S. Patent 5,984,574. If Netafim Bioline® is being used, licensing rights to this patented design may be freely applied. If any product other than Netafim Bioline is designed or installed, it is a violation of U.S. patent law.

Top Loading: Top loading refers to feeding each lateral or group of laterals individually from supply and flush manifolds mounted higher than the dripperline laterals. Each drip lateral on the contour of the slope is fed by a feed line connected to the supply manifold. At the end of the dripperline lateral, another feed line is fed upward to the flush manifold. Air/Vacuum relief valves are then located on both the supply and return manifolds.

Figure 17 - Simple Application of Tubing Across (Perpendicular) the Slope. The object is to lessen the effect of water migrating down the slope.
**Figure 18 - “Top Feed” Opposite Side Supply and Flush Manifold for Slope Layouts**

This patented “Top Feed” layout features supply and flush manifolds above the dripperline laterals. Blank tubing or flexible connections attach to individual Bioline laterals. This layout minimizes drain down because supply and flush manifolds are not running up and down the slope and acting as conduits to allow the effluent to move to the base of the slope.

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**DOSING AND CONTROLS**

The fundamental principle of drip dispersal is to take full advantage of the entire application area and to do so over the course of the entire day. Although most wastewater flows have peaks and valleys throughout the day, the goals of effective distribution are:

- Minimize soil saturation
- Encourage lateral (i.e., capillary) rather than gravitational flow of effluent
- Achieve uniform distribution
- Utilize the entire day (18-24 hours)

Historically, the cause of most drip system failures is not improperly designed drip fields, but rather an inadequate soil loading schedule. Experience has shown that even a flow as little as 200 gallons, dosed intensively, can cause a system failure in the same field that could accept 500 gallons, if dosed evenly throughout the day.

**Time vs. Demand Dosing**

The goals above are best accomplished through effective dosing controls of an integrated system. A dosing control system is especially important on tight, shrink-swell clay soils, since these soils are very sensitive to overloading.

The function and complexity of the control system is determined both by the wastewater demand and the limitations of the soil. An effective control system considers the following:

- Unusual loading conditions
- Storage capacity
- Emergency storage/malfunction

There are two ways to dose effluent - demand and time. Demand dosing means that when a tank is filled to a certain point, a switch or other device signals the pump to turn on and the effluent is dosed into the drip field. That continues until the switch shuts off the pump.

Because the system must have adequate capacity to receive the flow and distribute it evenly over the course of the day, it is difficult to balance the dose rate and the rest time between doses with a demand system. Tank sizing issues become a critical component because depending on its size, it may lead to too frequent doses or doses that operate too long.
This is the essence of time dosing - pumping the effluent out at specified intervals throughout the day rather than simply letting it flow out at the same time it is generated.

Timed dosing provides a collection system and timer that allow a specific amount of dosing to be done at prescribed times throughout the day. This system is the best way to ensure that the soil is being dosed at the proper rate and that enough time elapses between doses for the soil to manage the effluent.

RECOMMENDED DRIP DISPERSAL OPERATION CONTROLS

An electronic control system is essential to the proper operation of a drip dispersal system. The controller must be able to schedule the dosing cycles, turn the dosing pump(s) on and off, and may also schedule and control the field flushing and filter backflush operations.

While some controllers manage a very sophisticated “headwork” that doses, forward flushes the dripperline, backwashes the filters and manages one or several zones, it could also be a more simple control panel that performs the dosing cycles, turns the pump(s) on and off and is paired with a headwork unit that is a “continuous flush” unit providing forward flushing water back to the treatment system whenever dosing is occurring.

The breadth of control philosophies are only limited by the creativity of the designer, the price that the owner is willing to pay and the local regulations.

SEQUENCE OF OPERATION

Netafim does not offer control packages because many companies already offer standard and customized controls to meet any design criteria or specification. The following describes the general approach and various levels of control for a residential and small commercial system. Always consult local codes for specific control requirements.

System controls should be sophisticated enough to ensure that a sufficient volume of effluent is present in the dosing tank to allow a time dose to occur and that will stop the dose event if the level falls below a sufficient volume.

Time Dose control panels are available for use with two, three or four float combinations. In a two float system, one float in the tank is the “low level cutout” float while the other is a “high level alarm” float. The normal operating level should be between the “low level cutout” position and the “high level alarm” position.

Time Dose panels can be installed with a choice of three float systems. One choice adds a “redundant off” float which is positioned slightly below the “low level cutout” grey float, but above the pump. The normal operating level is between the “low level cutout” position and the “high level alarm” position. The other three float choice adds a “timer override” float which is positioned between the “low level cutout” and the “high level alarm” float. Normal operating level should be between the “low level cutout” float and the “timer override” float.

The four float system includes a “redundant off” float, a “low level cutout” float, a “timer override” float and a “high level alarm” float. The “timer override” float gives you the option of pumping from the basin while the timer is in the “off” cycle. It is only intended for times of abnormally high liquid level inrushes. The normal operating level should be between the “low level cutout” float and the “timer override” float. The control panel usually begins timing in the “off” sequence when the “low level cutout” float is activated. Once the timer completes the “off” sequence, the timer will start the pump and continue to run until the programmed “on” sequence is complete. At this point, the “off” sequence begins timing again and the cycle repeats.

In addition to turning the pump on and off at specified times, the control system typically enables the cleaning of filters and field flush.
HOW TO DOSE

Before we get too far into dosing, we need to agree on the volumes associated with a dose tank, what constitutes a single dose and what constitutes a flush dose, as well as some background on dose tank sizing.

Dose Tank: The dose tank acts as the storage vessel to accumulate effluent that will be dosed into the drip field. Once the effluent reaches a predetermined volume or a preset time, it is pumped to the field. The major difference between a septic tank and a dosing tank is that the dosing tank volume will be lowered on a daily basis.

Avoid oversizing the dose tank because it can be difficult to achieve adequate switch separation for the pump control.

There are different methods for sizing the dose tank. Netafim does not offer specific dose tank sizing criteria. The information provided is only a guide. Refer to local regulations for proper sizing.

Method 1:
Add the following elements together:
- The sum of the dosing volume
- The volume of the delivery pipes
- The volume needed to keep the pump submerged
- Emergency storage volume in case of pump failure. (A minimum of one-day emergency storage above the high water alarm is a frequently used value).

Method 2:

<table>
<thead>
<tr>
<th>Number of Bedrooms</th>
<th>Minimum Dosing Tank Size (gallons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>250</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
</tr>
<tr>
<td>5</td>
<td>750</td>
</tr>
</tbody>
</table>

Table 13 - Recommended Dosing Tank Size Based on Bedrooms

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8 Converse - 1978.
**Method 3:**
- Equal to what would be required for a septic tank
- Should provide 1 - 2 days average flow equalization volume
- On tough sites, increase the size to ensure that the amount of peak flow dosing is minimized
- These size systems usually work with pretreated effluent
- Engineers have guidelines on what is adequate
- The dose tank needs some emergency storage above high water and minimum equalization storage for dosing, $\frac{1}{3}$ to $\frac{1}{2}$ of the daily flow
- Equalization in the whole train should exceed one day's flow

**Volume of a Single Dose:** Many designers and regulators have established dosing times based on dosing a minimum number of drip tubing volumes through the emitters (after pressurization). This ensures that the dosing cycle is long enough to get good distribution of the wastewater into the soil. An effective minimum dose is generally regarded to be 4 to 6 times the liquid capacity (volume) of the drip laterals. Refer to local codes.

**Volume of a Forward Flush or Flush Dose:** As we discussed earlier with flushing velocities, the volume of a flush dose is subject to designer interpretation. In general, and subject to local codes, it should be at least equal to or greater than twice the void volume of all pressurized piping.

**Dosing Do's and Don'ts:**
- Do not overdose. Effective drip dispersal relies on the slow, even application of effluent to the field.
- Dosing too little could lead to unequal effluent distribution.

**Holding Volumes for Various Pipe Sizes**

<table>
<thead>
<tr>
<th>Pipe Size</th>
<th>Per Foot</th>
<th>Per 100 Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bioline</td>
<td>0.0133</td>
<td>1.33</td>
</tr>
<tr>
<td>1&quot;</td>
<td>0.04</td>
<td>4</td>
</tr>
<tr>
<td>1 ¼&quot;</td>
<td>0.07</td>
<td>7</td>
</tr>
<tr>
<td>1 ½&quot;</td>
<td>0.1</td>
<td>10</td>
</tr>
<tr>
<td>2&quot;</td>
<td>0.17</td>
<td>17</td>
</tr>
<tr>
<td>2 ½&quot;</td>
<td>0.24</td>
<td>24</td>
</tr>
<tr>
<td>3&quot;</td>
<td>0.38</td>
<td>38</td>
</tr>
<tr>
<td>4&quot;</td>
<td>0.65</td>
<td>65</td>
</tr>
</tbody>
</table>

*Table 14 - Holding Volumes for Various Pipe Sizes*

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Determining Dosing Requirements: The following provides the conceptual basis for sizing the drip field, setting up zones and designing the pump control system. A computer spreadsheet of this process is available on the Netafim Wastewater Division CD.

1. How many gallons per day (GPD) is the wastewater load?
   “Typical Wastewater Flows” on page 8 in lieu of local regulations.

2. What is the Soil Loading Rate in gallons per sq. ft. per day?
   Check local rules and “Soil Loading Rate Chart” on page 18.

3. Calculate dispersal area.
   Gallons per day (GPD) ÷ Loading Rate (GPD/sq. ft.) = Application Area (sq. ft.).

4. Calculate Total Linear Length of Tubing.
   Divide the Application Area by two to get the total linear length of drip tubing (this assumes two foot row spacing between the dripperlines. Divide by 3 for 3 foot spacing, etc.).

5. Select Dripper Flow Rate and spacing based on soil type.
   Bioline is available in flow rates of 0.4 GPH, 0.6 GPH (most common), and 0.9 GPH. Heavier soils usually indicate lower flow rate drippers, either 0.4 GPH or 0.6 GPH.

6. Calculate Total Flow Rate of all tubing.
   Use the chart “Flow Rate per Length of Tubing” on page 5, or the following formula:
   Flow Rate of Dripper x Total Linear Length of Tubing ÷ Dripper Spacing (ft.) = Total flow
   For example:
   - Bioline with 0.6 GPH drippers at 2 ft. spacing between drippers
   - For each 1,000 feet of drip tubing, the flow would be: 0.6 x 1000 ÷ 2 = 300 gallons per hour (GPH) = 5 gallons per minute (GPM) (GPH ÷ 60 = GPM).

7. Determine the Number of Zones needed by pump size consideration.
   Zones should generally not exceed half the rated volume of the pump.

8. Calculate Total Flow Rate per Zone in gallons per minute (GPM).
   Total flow rate of all tubing ÷ number of zones.

9. Calculate Number of Minutes of Total Run Time based on daily flow.
   Total Daily Load (GPD)
   Number of Zones

10. Calculate Number of Minutes per Zone.
    Total Minutes
    Number of Zones

11. Select Dosing Duration based on soil conditions (6 to 12 minutes):
    Typically, heavier soils should have shorter dosing durations.

12. Determine Number of Dosing Events:
    Number of minutes of total runtime ÷ dose duration (minutes).

13. Calculate Time Between Dosing Events:
    Based on an 18 hour day (check local regulations). Time between dosing events = 
    Number of Doses plus 1
The filter is designed to capture particles larger than can safely pass through the drip emitters. The most common filtration methods in use today in onsite systems are:

- Screen
- Disc
- Media

**Screen Filters:** Screen filters are the least sophisticated filters for use in onsite systems because they are the most likely to allow debris to pass through them. This is especially true of organics which can change shape and be squeezed through the filter during operation. Screen filters also have a much smaller surface area than other types of filters which increases the frequency of cleaning. In general, screen filters only capture about 65% of the debris at or above its stated micron size and the cleaning operation is difficult because the debris is typically wedged into the spaces of the screen. This means that the screen cannot be effectively surface flushed. It needs to be removed and physically scrubbed and it is very difficult to remove the debris jammed into the screen.

![Screen Filter with Debris Passing Through](image)

*Figure 19 - Screen Filter with Debris Passing Through*

*This picture illustrates how debris can easily pass through the single layer structure of a screen filter.*

**Disc Filters:** Disc filters fall into the category of "depth" filters because they add an additional dimension to the cleaning process. Disc filters use an overlapping series of grooves that force the effluent to move through a series of trap points. This process increases the likelihood of debris capture to 90% - 99%. Because of the increase in filtration surface area, the frequency of cleaning drops and cleaning is easier.

Netafim recommends disc filtration for standard residential and small commercial onsite wastewater drip dispersal systems.

**Media Filters:** Media filters offer the greatest protection against both organic and inorganic debris. In a media filter, raw water is introduced into a filter chamber that is filled with a media such as sand and is allowed to pass through the media bed. The media does an excellent job of capturing the debris and is superb at delivering highly filtered water. In applications where even finer filtration is required, varying types and layers of media can be
The intersection points between the grooves of adjacent discs create multi-layered depth filtration.

added to capture even very small debris. While a very effective filtration method, the typical media filter is larger and more sophisticated than residential and small commercial projects require.

**Manual Filter:** A filter is placed in the supply line after the treatment system, downstream of the pump and upstream of the Bioline®. Cleaning the filter requires that the filter cartridge be removed and the disc and housing manually flushed clean.

**Timed Backflush:** This more sophisticated filtration cleaning normally has more than one filter and valve which are used in a configuration to clean one another automatically. The frequency of the backwash is controlled using a timer clock or dosing counter to automatically flush the filter. Filtered water from one filter is sent backward through another filter dislodging captured debris between the filter’s discs. This backwash water is then returned to the treatment system and reprocessed.

**Pressure Differential Backflush:** This system is similar to Timed Backflush, but has the added component of a pressure differential switch or sensor. As debris in a filter increases, the pressure differential across the filter increases. A pre-set pressure difference across the filter triggers an automatic backflush. This can be the primary trigger for the backflush, or a back-up option for a regularly timed backflush.

If the system has a timed or pressure differential backflush, manual cleaning of the disc filter cartridge may still occasionally be required. This is especially true when a treatment and dispersal system is first started up to ensure that construction debris is removed.

**Disc Filter Cleaning:** All filters need to be taken apart, inspected and cleaned as necessary. Each disc surface has grooves that capture particles as they try to pass through the filter. It is necessary to separate the discs and clean the entire filter element using a garden hose, or other pressurized stream of water. If deposits form on the discs that cannot be easily removed by mechanical means, muriatic acid can be used (in a 10:1 ratio of water to acid, following all safety instructions on the acid container).
FIELD FLUSH

Netafim Bioline® dripperline is designed to last for many years. Although filtration is taking place, small particles (under 130 microns) therefore can still enter the tubing. Over time, these particles may accumulate. It is recommended to field flush the system. As discussed earlier, “field flushing”, “forward flushing” or “scouring” is accomplished by periodically opening the flush line from the drip field back to the pretreatment or dosing tank. In this process, the velocity of water moving through the tubing should be at least 2 feet per second at the distal (far) end of the flush manifold (to be consistent with the recommendations of most practitioners). The dirtier the water, the higher the recommended flush velocity and frequency be. To prevent an accumulation of debris in the dripperline, it is recommended that field flushing take place on a regular basis. Field flushing should be done at least several times per year, but may be as frequent as every day\(^\text{10}\). The required rate will depend on many factors. Among these are:

- Effluent quality and characteristics
- Filtration efficiency
- Length of tubing in each zone
- Local regulations for maintenance

ROOT INTRUSION

The unique design characteristics of the Bioline emitter provide an effective physical barrier against root intrusion without the addition of root inhibiting chemicals. Bioline® dripperline has a Full Ten-year Warranty against clogging due to root intrusion.

If local regulations require the addition of a root intrusion inhibiting chemical, or if the designer or system owner or operator want an extra measure of assurance, Netafim can provide the Techfilter® System. Techfilter incorporates a replaceable filter element embedded with trifluralin\(^\text{11}\), an effective root inhibiting chemical used extensively in agriculture. As water passes through the filter, a very low concentration of trifluralin (parts per billion) passes through the system. This technology provides very precise and even distribution of trifluralin throughout the piping network which is not possible when the dripper is impregnated with the chemical.

Unlike other products, Techfilter eliminates skin irritation from the chemical during handling, and does not require that tubing be stored in a dry, cool building out of the sun.

Techfilter\(^\text{®}\) is designed to provide renewable protection because the chemical is both heat and time sensitive. As it loses its effectiveness over time, it can be replaced, and as such, when prescribed maintenance of the Techfilter is performed, a limited Lifetime Warranty against root intrusion is available.

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\(^{10}\) See the earlier discussion on this topic.

\(^{11}\) Trifluralin stops cell division in any root tip that comes into an area where the chemical is present.
INSTALLATION

SITE PREPARATION
The drip field should be viewed as a wastewater dispersal field and many of the same considerations for conventional septic drain fields should apply. These limitations include:

- No future expectation of building(s), decks, or other impervious surfaces
- No long term storage of equipment or vehicles over the site
- A permanent vegetative cover
- Winter dormant grasses are over-seeded with winter grasses when possible

DRIP TUBING INSTALLATION
One of the prime benefits of Bioline® drip dispersal is its ability to deliver effluent at a prescribed rate into the biologically-active layer of the soil that supports the roots of plants, trees and turfgrass. In conjunction with the effluent-purifying capabilities of the soil, the root systems provide valuable uptake of the effluent as well.

To maximize the soil’s biological activity, the drip tubing will normally be installed 8 to 12 inches below the soil surface. Check local codes for depth of burial.

Colder climates may require deeper placement or additional cover to avoid freezing during periods of inactivity.

Where conditions allow, manifold trench depth should be the same as the dripperline depth in order for the air/vacuum relief valves to work most effectively. In freezing climates, manifolds may have to be placed below the frost line.

Dig the manifold trenches wide enough to provide sufficient working room to cut and fit tees and to insert the flex connectors between the manifolds and the tubing. Allow enough room to work. Always avoid installing drip tubing in wet soil.

Three common ways to install the Bioline drip tubing:

Plowing: Installed much the same way as TV cable, plowing refers to knifing in the dripperline through use of a vibratory plow. This method is increasingly common because the process does not disturb the soils and smearing is uncommon.

Netafim works close with Vermeer Manufacturing Company and together they have developed a vibratory plow that efficiently installs several rows of Netafim Bioline at once. The process, called Conservigation® is exclusive to Netafim and is the most sophisticated installation process on the market.
Figure 21 - The MB-40 Multi-Blade Vibratory Plow. Shown here with three 1,000’ rolls of Netafim Bioline® attached to the versatile Vermeer® LM-42 power unit. This unit has a variety of attachments and fits into narrow areas.

Figure 22 - MB-40 Minimizes Damage to Existing Landscape. Thanks to its unique design, the MB-40 quickly rake-up of this area, the rows virtually disappear.

Figure 23 - MB-40 Does Not Disturb the Grade. Even in bare dirt.

Figure 24 - MB-40 Can Be Mounted on the Vermeer® RTX-450. This ride-on unit is excellent for large installations.
**Trenching**: This method uses commonly available trenching machines to cut narrow trenches for tubing installation. The advantages of this method are that trenchers are widely available and easy to use. The disadvantages are that the trench may leave wall surfaces that are “slicked” and therefore less receptive to horizontal water flow. Trenching will damage existing vegetation; the trenches must be filled with original materials, properly compacted, and watered in from the top down.

**Fill or “Drip and Fill”**: In this method, the dripperline is laid on the ground and fill material is placed over it. If there is any vegetative cover, it should be removed and the original soil scarified (plowed or deep-raked) to minimize any variances in soil types. If soils of different textures are used, the constraints discussed in the Soils Section must apply. It is recommended that the fill material be the same as the original.

Other tips when bringing in outside soil include:

1. Use soil with a clay content not exceeding 20%
2. Harvest, ship and place the soil only under dry conditions
3. Remove all debris, roots and other coarse fragments or rocks
4. Put the soil in place in 6” - 8” increments

*Figure 25 - “Drip and Fill” Technique.*

The dripperline is laid out across the drip field and fill material is then placed over the dripperline to the prescribed depth.

*Figure 26 - Mechanized Equipment.*

May be used to spread soil over the top in larger systems. It is important to evenly spread the soil moving with the tubing direction to keep the laterals from shifting.
For all methods, it is important that the disturbed soil above the dripperline be the approximate texture and compaction as the soil around the dripperline. This will avoid creating a preferential pathway of the effluent to the surface, also known as the “Chimney Effect”. Careful, manual compaction of the soil above the dripperline may be advisable when the tube has been trenched or plowed in (local codes permitting).

NOTE: Avoid excessive mechanical stress on the tubing before, during, and after installation.

PIPING HOOK-UP
The supply and flush lines, and the supply and flush manifolds are installed using standard techniques for PVC piping. Medium body (not fast drying) PVC cement is generally preferred. Use the primer and cement as recommended by the manufacturer.

The installer should use a good quality, ratcheting type PVC cutter to prevent PVC filings from getting into the distribution lines.

OPERATION AND MAINTENANCE

START-UP
The designer should take precautions to troubleshoot the system and ensure that it is working properly over an initial startup period, typically 2 to 3 weeks.

Do not start the system with a massive dose. This can cause preferential water passages, or chimneys, that allow the effluent to surface and saturate the soil. If this happens, it may take some time to recover the drip field.

Construction debris (PVC scraps, glue remnants, soil, etc.) found in the piping network needs to be flushed. This flushing should not be done through the dripperline but rather before the dripperlines are connected to the headers. If the dripperlines are already connected to the headers, do not exceed the scheduled dosing cycle while flushing.

The pump tank or treatment system may be full of water after installation. Do not simply run it out through the drip tube. Either use the dosing schedule to empty the tank or set up a sprinkler, but always follow local codes as they apply.

If the dosing field is extremely dry, it can be advantageous to run a sprinkler on the surface to initially dampen the field.

ROUTINE MAINTENANCE
Service and maintenance of the system should be coordinated with any regulatory requirements for monitoring of the onsite system. Most states have regulations that specify a routine maintenance schedule for advanced onsite wastewater treatment systems.

When a drip dispersal system is properly sized, designed, and installed, it should operate with little maintenance and easy monitoring. In addition to the fundamental design considerations already outlined, several other installation steps will simplify maintenance. These include:

1. Provide nipples for Schrader valves (tire gauge stems for measuring pressure) on critical piping elements (pump output, supply and flush manifolds, inlet and outlet of filters, etc.) in valve boxes to provide easy measurement of system pressure.

2. Maintain access to a short length of drip tubing for inspection.

3. Keep a detailed plot plan, system diagram, and wiring diagram readily accessible in the control panel.
TYPICAL LAYOUTS FOR RESIDENTIAL AND SMALL COMMERCIAL SYSTEMS

The layout for a typical residential onsite system is comprised of several components. In the following illustrations, each design scenario will contain all or part of the following components and systems:

- Secondary treatment system - advanced treatment unit, recirculating sand filter, peat system, fixed film, or wetland system, etc.
- Pump or dosing tank with water level sensors
- Pump
- System controller for pump operations, zone control, dosing scheduling, dosing tank monitoring, filter backflushing, field flushing and alarms
- Automatic or manual disc filter (130 micron / 120 mesh) set in an access box
- Air/Vacuum Relief Valves
- Zone Control Valves - Water actuated, motor driven or solenoid activated hydraulic valve
- Underground PVC piping, typically 1¼" mainline, header and return lines
- Flexible PVC connectors and loops
- Mainline and supply header
- Flush manifold and return line
- Check valves
- Bioline® drip dispersal tubing

The following layouts illustrate some of the ways that drip dispersal fields can be laid out at a residence or small commercial complex. Use these drawings as guides only. Each system will have special circumstances that will require the designer to modify these typical layouts in order to adapt to the site. The following are basic considerations that should be taken prior to beginning any design:

- Shape of the proposed drain field
- General slope or direction of rise and fall of the site
- Location of property lines, buildings, trees, wells, water lines, gas lines, buried power lines, swimming pools, etc.
- Soil type including profiling to determine depth to most restrictive layer and or water table

4. Establish a service record chart to record:
   - **Pressure at:**
     - Pump
     - Supply line or manifold
     - Flush line or manifold
     - Other critical points
   - **Schedule:**
     - Dosing
     - Filter flushing
     - Field flushing

5. Monitor any changes in the number, activities, and water usage patterns of members of the household.

With this information framework, a system inspector can quickly and easily determine if the system is operating within specifications. If problems are identified by changes in pressure or flow, they can be located and corrected easily using information in the plans and locations of valve boxes.
• Location of treatment system
• Location of power outlets or breaker
• Location of old drain field if the new system is a retrofit

**OPPOSING MANIFOLD LAYOUT**
Rectangular field with supply and flush manifolds at opposite ends of dripperlines:
• Can be used where Bioline® lengths will be long and the drip field is narrow
• Bioline® laterals should never exceed recommended lengths
SINGLE TRENCH LAYOUT
Rectangular field with supply and flush manifolds on the same side and in the same trench:
- Locate the supply and flush manifolds in the same trench
- Dripperlines are looped at the halfway point of their run and returned to flush manifold
- Bioline® laterals should never exceed recommended lengths
IRREGULAR FIELD SHAPE LAYOUT

Triangular field with looping and varied positioning of flush manifolds:

- Used when site limitations dictate unequal dripperline length with respect to dispersal field length
- Loop the Bioline® to increase lateral length and reduce the number of connections
- Keep the Bioline laterals as close to the same length as possible to provide for an equal field flush
- The flush manifold may be located on the same or opposite side of the supply manifold
- As pictured, it may be necessary to make one or more distal end connections to the flush line on an opposing side in order to balance dripperline lateral lengths and to limit the number of connections
MULTIPLE ZONE LAYOUT
Multiple zone system with looping laterals:
- Used for a variety of reasons including when:
  - Single zone accumulated Bioline® lengths exceed recommended pump flow rate
  - Soils require additional resting time between dosings
  - There is a potential need for expansion of the system, which is common in commercial systems. Second or subsequent zone may be left out until needed
- Additional check valves are needed to isolate each zone on the flush line side. An additional air/vacuum relief valve should be installed before the check valve on each zone
- Zone changes are typically accomplished using an electric valve and controller
- Zone layouts may be parallel systems or may follow any of the scenarios discussed
- Zones should have similar flows
- Controller must be capable of operating a multi-zone system
The goal of freezing climate designs is to be able to drain the entire system as quickly as possible - preferably in 10 to 15 minutes or less. Any pipe or component that does not drain after a dose must be buried below the frost line and/or properly insulated.

Landscape and Cover:
1. Additional depth over dripperline:
   a. Dripperlines that are buried deeper in the ground are less likely to freeze than shallow.
   b. Whenever possible, add solid cover (soil) to increase the depth of the dripperline.
   c. Note: It is better to have the dripperlines in the 6” - 8” range if possible for better nutrient removal, but this should be weighed against the climate.
2. Established and undisturbed wooded sites where trees have not been removed, have been shown to allow shallow systems to perform without freezing.12
3. Landscapes with drip dispersal fields should have vegetative cover over them. This may be prairie grass, plants, bushes, shrubs, trees, turfgrass or any combination.
4. Vegetative height should be at least 4” to 6”.
5. In areas where warm season grasses go dormant:
   a. The area should be overseeded to ensure sufficient groundcover.
   b. Overseeding should begin as early as possible to allow enough growth.
   c. Cover all areas with at least 6” of straw/hay until the cover is properly established.
6. Stop mowing operations as early as possible so grasses can grow as tall as possible.
7. Managing snow cover:
   a. Because snow is an excellent insulator, provisions should be made to ensure that snow can stay in place over the drip field.
   b. Use anything that will help the snow to accumulate and stay over the field, including snow fence or other fencing, stands of trees, bushes, hedges, or decorative grasses.
8. In windy areas it may be necessary to have more than turfgrass as a cover.
9. If it is not possible to grow a cover over the field, use at least 6” of straw/hay to cover the entire system. In areas/seasons with minimum snow cover, check the depth of the straw/hay during the season. Add more cover as needed.
10. Keep foot traffic away from the drip field, especially when it has a snow cover.

Headers and Dripperline:
1. Note: Netafim Bioline® dripperline is made from low-density, linear polyethylene to weather the effects of cold weather. Due to its emitters, it will drain available effluent after dosing. Our design and operation efforts therefore are to protect the non-Bioline piping network, fittings, valves and hard/rigid components that can break or fail if frozen.
2. Manifolds and supply/return lines should be installed lower than dripperlines to provide positive drainback after the zone shuts off.

3. Manifolds and supply/return lines should be sloped back to the tank to provide positive drainback.

4. Under extreme conditions, manifolds and supply/return lines should be buried below the frost line.

5. Consider insulating all manifolds and supply/return lines with Styrofoam board if the system is in an extremely cold location.

6. Any drain valves must be able to remain open long enough for the entire field to drain. Note: Hydraulically-operated valves may close when system pressure is too low.

7. Motorized drain valves may be installed to help drain the system in lieu of hydraulic valves.

8. Dripperline should be installed level across the contour of any discernable slope.

9. On laterals with blank tubing or flex connections, they may be installed slightly above the dripperlines. This will allow them to drain into the dripperline laterals.

10. Consider using larger piping on the supply and return lines to accommodate a high pressure nozzle and tubing along with clean out ports to gain entrance into the system. There are several brands of water jets on the market that can clear ice from inside the headers. They rely on warm water and its special nozzling allows it to move forward in the pipe as the stream of water dislodges any blockages.

**Air Vents / Headworks / Valves / Valve Boxes:**

1. Install larger valve boxes than would normally be used to accommodate any service work that may be done in the winter.

2. Insulate all equipment boxes, including headworks boxes, filters, field flush valve boxes, as well as zone dosing valves and air/vacuum relief valves. Use Styrofoam panels or chips, or other closed cell insulating materials such as perlite or vermiculite in bags around the inside and the outside of valve boxes. If fiberglass is used, ensure that it cannot become waterlogged.

3. Install headworks and other components in risers over the treatment tank to capture available warmth.

4. Design the system around providing a continuous flush. This will keep water moving throughout the system during a dose and allow for fast draining on shutdown.

5. Insulate or add a heater to the headworks.

6. If using an index valve to split field zones, be sure it is capable of draining.

7. Air/Vacuum Relief Valves should be used liberally, and at least on the end of supply and flush manifolds.

8. Air/Vacuum Relief Valves should be placed below grade at any high point(s) and always above any dripperline laterals. The top of A/VRV must be no higher than the soil surface.

9. Attach and secure something metallic to the lid of valve boxes and A/VRV boxes to make them easier to find when they are covered with snow or vegetation.

10. Add a gravel sump of at least 6” under any valve box.

11. Grade away from all valve boxes to reduce groundwater incursion.

**Installation:**

1. As noted above, dripperline laterals on any discernable slope should be installed as close to contour as possible.
2. Due to potential shrinkage of the dripperline in cold weather, it should be installed so there is slack in the tubing. “Weaving” it back and forth if being installed in an open trench is an acceptable method.

3. If repairs are made to the system, keep the dripperline from becoming taut by adding sufficient tubing so the dripperline is not stretched.

4. Insulate the septic/treatment tank and pump tank to preserve whatever heat is inside.

5. All electrical components must be properly sealed to prevent condensation getting inside any controllers or panels.

6. Position and angle all filters to ensure that water does not get trapped inside.

7. Remove the check valve at the pump.

**Operation:**

1. In multi-zone systems with lower flows in the winter, reduce the number of zones being used.

2. Reduce the time between doses, but do not overload the soil.
Disclaimer: Information included in these sample specifications is made available as a convenience and is believed to be accurate. Netafim USA is not liable for any potential errors, omissions or outdated information. If any errors are noted, please notify Netafim USA toll-free at 888-Netafim (888-638-2346). For the latest information, refer to www.netafimusa.com.

BIOLINE® CONTINUOUS SELF-CLEANING, PRESSURE COMPENSATING DRIPPERLINE

Description
Bioline® is low volume dripperline designed for use with onsite wastewater drip dispersal systems. It has integral and evenly spaced pressure compensating drippers inside the tubing and is available in three discharge rates (0.4, 0.6, and 0.9 gallons per hour [GPH]) evenly spaced on 12”, 18”, or 24” centers. Bioline is available in 500’ and 1,000’ coils. Blank tubing is available in 250’ coils.

Construction
Bioline shall consist of nominal sized one-half inch (½”) low-density linear polyethylene tubing with internal pressure compensating, continuously self-cleaning, integral drippers at a specified spacing (12”, 18”, or 24” centers), or blank tubing without drippers. The tubing shall be purple in color and shall conform to an outside diameter (O.D.) of 0.66 inches and an inside diameter (I.D.) of 0.57 inches. Individual pressure compensating drippers shall be welded to the inside wall of the tubing as an integral part of the tubing assembly and shall be chemically impregnated with an anti-microbial additive to prevent the buildup of microbial slime. Drippers shall be constructed of plastic with a hard plastic diaphragm retainer and a continuously self-flushing elastomer diaphragm capable of flushing dirt or debris that may enter the dripper at any time, and shall be capable of being flushed out during operation. Each dripper shall have an individual filter at the inlet and it shall be integral to the dripper. This filter shall have a cross-sectional area not less than five (5) times larger than the minimum cross sectional area of the dripper flow path. The dripper shall have a built-in physical root barrier whereby water/effluent shall exit the dripper from a point different than where it shall exit the tubing. This physical barrier shall create an air gap inside the exit portion of the dripper.

Operation
The dripper discharge rate shall be 0.4, 0.6, or 0.9 gallons per hour (GPH) utilizing a combination turbulent flow/reduced pressure compensation cell mechanism and diaphragm to maintain uniform discharge rates. The drippers shall be capable of continuously cleaning themselves while in operation. The dripperline shall be available with 12”, 18”, and 24” spacing between drippers unless otherwise specified. Each dripper shall have the ability to independently regulate discharge rates, with an inlet pressure between seven and seventy (7 - 70) pounds per square inch (psi), at a constant rate of flow. The dripper shall have a Cv of 3% or lower. The Kd for the dripper shall be 1.0 or less. Dripper flow shall be ±10% of the nominal flow for any single pressure within the temperature range of 70°F to 125°F (25°C to 50°C) without the use of an external pressure regulating device. At no point, from

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13 Cv - A measure of the consistency of manufacturing. It measures the deviation from the specified flow for a random sampling of drippers. In order for a waste dispersal system to operate with an EU (Emission Uniformity) in the mid 90% range, the Cv must be not more than 3%. Bioline Cv is 2.5%.
14 Kd - A measure of the friction loss within a pipe caused by the portion of the dripper which protrudes into the flow path. The higher the Kd, the higher the required pump pressure to create proper flushing.
15 This defines the flow characteristic of a pressure compensating dripper, and ensures the dripper will not have spikes in its flow curve. Flow spikes, even when present outside the designed operating pressure for the system, may require the entire system (pumps, valves, mainlines, etc) to be up-sized to the maximum flow of the dripper; thereby increasing the cost of the system without enhancing its design performance.
0 to 55 psi, will the dripper have a flow exceeding 10% of the nominal flow of the dripper. The recommended operating pressure shall be between 10-50 psi. Filtration shall be 120 mesh or finer. Bending radius shall be 7” or greater. For on-surface or under mulch installations, 6” metal wire staples (TLS6) shall be installed 3’ to 5’ on center, and two staples installed at every change of direction. Maximum system pressure shall be 50 psi.

**BIOLINE® FITTINGS (0.57”)**

**Description**

Bioline® fittings shall be constructed in one of the following end configurations:

- Barbed insert fittings only
- Male pipe threads (MPT) with barbed insert fittings
- Female pipe threads (FPT) with barbed insert fittings

**Construction**

All fittings shall be constructed of injection molded, brown plastic having a nominal outside dimension of 17mm (0.57”). Female and male threaded ends shall be capable of mating to standard PVC pipe with tapered threads.

**Operation**

Bioline fittings shall be mated with Netafim Bioline dripperline by pushing the fitting into the tubing while twisting side-to-side until the tubing abuts to either adjoining tubing or a fitting stop.

Maximum system pressure without clamps shall be 50 psi.

Bioline fittings shall be Netafim Model Numbers TLTEE, TLOUP, TL2W075MA, TLELL, TLCROS, TL050MA, TL075MA, TL075FTEE, TLIAPE and TLAPVC.

**BIOLINE® SPECIALTY FITTINGS** (Bioline® Insert Adapter for Polyethylene)

**Description**

The Bioline® Insert Adapter for Polyethylene shall be a 2-piece threaded-connection fitting designed to transition from 1” or larger polyethylene pipe to Bioline.

**Construction**

The Bioline Insert Adapter for Polyethylene shall be constructed of injection-molded plastic.

**Operation**

The fitting shall unthread to allow the inlet end of the fitting to be pressed into a pre-drilled 11mm, 15/32” or 1/2” hole created using a forstner drill bit or punch in 1” or larger medium or higher density PE pipe. The fitting shall be tightened by threading the 2 pieces together to create a watertight connection. Maximum system pressure without clamps shall be 50 psi.

The Bioline Insert Adapter for Polyethylene shall be Netafim Model Number TLIAPE-B.

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1. At various times the following words will be used interchangeably: Bioline, drip tubing, dripperline, drip dispersal tubing.
2. From EPA Publication EPA 625/R-00/008-Chapter 3.
**BIOLINE® INSERT ADAPTER** (for PVC)

**Description**
The Bioline® Insert Adapter for PVC shall be a two-piece fitting designed to transition from rigid 1½" or larger CL160, CL200 or Sch. 40 PVC pipe to Bioline.

**Construction**
The Bioline Insert Adapter for PVC shall consist of a rubber grommet and an injection molded plastic insert adapter.

**Operation**
The rubber grommet shall fit into a hole drilled with a Netafim Model Number TDBIT16.5 drill bit or other pre-drilled 16.5mm (1/1/8") hole in rigid 1½" or larger CL160 or Sch. 40 PVC pipe. The flared top of the grommet shall seat against the outside of the PVC pipe. The short end of the insert adapter is then press-fit into the seated rubber grommet. Maximum system pressure without clamps shall be 50 psi.

The Bioline Insert Adapter for PVC shall be Netafim Model Number TLIAPVC-B.

**STAINLESS STEEL CLAMPS** (for operating pressures in excess of 50 psi)

**Description**
Stainless steel clamps are used to secure Bioline to barbed insert fittings. Clamps shall be as manufactured by “Oetiker” and will be the “1-Ear Clamp with Mechanical Interlock” type. The Oetiker clamp for use with Bioline shall be Item Number 15500011 - Size Reference Number 198R.

**Construction**
Oetiker clamps shall be constructed of 304 AISI Stainless Steel. Clamps will be the “1-Ear Clamp with a formed “Dimple” in the Ear to provide for thermal expansion and contraction while maintaining a strong seal. The bottom of the clamp will have a “Mechanical Interlock” and not be spot welded.

The interior of the clamp band shall be smooth to prevent surface damage to the tubing. Band thickness of the clamp shall be 0.0236” (0.6 mm) with an overall band width of ¼” (7 mm).

**Operation**
Oetiker stainless steel clamps are used to secure Bioline over barbed insert fittings when design-operating pressures exceed 50 psi. Clamps are to be slipped over the tubing before being mated to barbed insert fittings. Place the clamp between the first and second ridge of the barbed insert fittings. Crimp (close) the “Ear” of the clamp firmly with an Oetiker Pincer Tool. Crimp the “Ear” again to ensure proper seating.

**TECHFILTER® SYSTEM WITH BIOLINE®**

**Description**
Techfilter® is the incorporation of a disc filter and a chemical root intrusion preventer (trifluralin) with a prescribed amount of Bioline® dripperline. Techfilter is available in 5 filter sizes (¾", 1", 1" Long, 1½" Long, and 2"), with dripper flow rates of 0.4, 0.6, and 0.9 GPH spaced at 12", 18", or 24" centers, and a specific amount of Bioline with each Techfilter. The mesh rating shall be 120, and maximum system pressure is 140 psi for the filter and 50 psi for the Bioline.

**Construction**
Filter: The filter shall be a multiple disc filter with trifluralin incorporated into the replaceable disc ring assembly inside the filter housing. The disc filter body shall be molded
of thermoplastics with male pipe threads for both inlet and outlet. The disc filter shall be capable of periodic servicing and replacement of the chemically treated disk ring set either by unscrewing a threaded cap or unlatching the band.

**Dripperline:** The Bioline® drippers shall have the ability to independently regulate discharge rates, with an inlet pressure of seven to seventy (7 - 70) pounds per square inch (psi), at a constant flow and with a manufacturer’s coefficient of variability (Cv) of 0.03 or less. Recommended operating pressure shall be between 10 - 50 psi. The dripper discharge rate shall be 0.4, 0.6, or 0.9 gallons per hour (GPH) utilizing a combination turbulent flow/reduced pressure compensation cell mechanism and a diaphragm to maintain uniform discharge rates. The drippers shall continuously clean themselves while in operation. The dripperline shall be available in 12”, 18” and 24” spacing between drippers unless otherwise specified. Maximum system pressure shall be 50 psi.

**Operation**
When water passes through the filter, a very low concentration of trifluralin (parts per billion) is transmitted throughout the Bioline® piping network. This provides for precise and even distribution of trifluralin throughout the piping network and effectively inhibits root growth into the dripper outlets.

The trifluralin-treated filter ring set shall be replaced every two (2) years, or two hundred (200) hours of operation, whichever occurs first.

The Techfilter system shall be Netafim Model Number TFB____ - ____.

**½" AIR/VACUUM RELIEF VENT**

**Description**
The Air/Vacuum Relief Vent serves two purposes:

- To evacuate air from the Bioline® laterals during system start-up and,
- To prevent vacuum from occurring after the remote control valve has closed, thus preventing debris intrusion into the drippers via back siphonage.

**Construction**
The Air/Vacuum Relief Vent shall be constructed of thermoplastics with ½" MPT capable of mating to a threaded fitting.

**Operation**
Air/Vacuum relief vents be installed at the highest elevation in each zone (some zones may require more than one) in order to expel air and relieve potential vacuum. In a zone where the highest elevation occurs between the supply and return manifolds (headers), such as a mound or berm, an air/vacuum relief lateral shall interconnect all the Bioline dripperlines to avoid the necessity of installing one air/vacuum relief vent on each Bioline lateral. Air/Vacuum Relief Vents can be installed below grade in valve boxes to allow for periodic inspection.

The ½" Air/Vacuum Relief Vent shall be Netafim Model Number TLAVRV.

**¾", 1", 2" & 3" GUARDIAN AIR/VACUUM RELIEF VENT**

**Description**
The Guardian Air/Vacuum Relief Vent serves two purposes:

- To evacuate air from the Bioline® laterals during system start-up and,
- To admit air into the piping network at high flow rates during drain-down to prevent a vacuum from occurring, and thus preventing debris intrusion into the drippers via back siphonage.
Construction
The Guardian Air/Vacuum Relief Vent shall allow for high flow rate air discharge, up to 8 psi differential for the 2” & 3” models and up to 5 psi for the ¾” & 1” model, preventing premature closing. It shall be constructed of UV-protected materials as shown in the chart below:

<table>
<thead>
<tr>
<th>Part</th>
<th>¾” and 1”</th>
<th>2”</th>
<th>3”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Polypropylene</td>
<td>Reinforced Nylon</td>
<td>Reinforced Nylon</td>
</tr>
<tr>
<td>Cover</td>
<td>Polypropylene</td>
<td>Polypropylene</td>
<td>Reinforced Nylon</td>
</tr>
<tr>
<td>Disc</td>
<td>-</td>
<td>Reinforced Nylon</td>
<td>Reinforced Nylon</td>
</tr>
<tr>
<td>Seal</td>
<td>BUNA-N</td>
<td>E.P.D.M.</td>
<td>E.P.D.M.</td>
</tr>
<tr>
<td>Float</td>
<td>Polypropylene</td>
<td>Reinforced Nylon</td>
<td>Polypropylene</td>
</tr>
</tbody>
</table>

Table 15 - Guardian Air/Vacuum Relief Vent Material List.

The ¾” & 1” Guardian Air/Vacuum Relief Vents shall be available with or without a Shrader valve. The Shrader valve shall allow pressure readings during system operation. The base of the ¾” and 1” Guardian shall be MPT. The base of the 2” & 3” Guardian shall be FPT. Maximum working pressure range shall be 3 - 150 psi (0.2 - 10 bar).

Operation
Air/Vacuum relief vents shall be installed at the highest elevation in each zone (some zones may require more than one) in order to expel air and relieve vacuum. In a zone where the highest elevation occurs between the supply and return manifolds (headers), such as a mound or berm, an air/vacuum relief lateral shall interconnect all the Bioline dripperlines to avoid the necessity of installing one air/vacuum relief vent on each Bioline lateral. Air/Vacuum Relief Vents can be installed below grade in vented valve boxes to allow for periodic inspection.

The Guardian Air/Vacuum Relief Vent shall be Netafim Model Number 65ARIA___________.

1” & 2” COMBINATION AIR/VACUUM RELIEF & CONTINUOUS ACTING VENTS

Description
The Combination Air/Vacuum Relief & Continuous Acting Vent serves three purposes:

- To evacuate air from the Bioline® laterals during system start-up.
- To admit air into the piping network at high flow rates during drain-down to prevent a vacuum from occurring, preventing debris intrusion into the drippers via back siphonage.
- Continue to dispel air when the system is operating under pressure.

Construction
The Combination Air/Vacuum Relief & Continuous Acting Vent shall allow for high flow rate air discharge, up to 10 psi differential, thus preventing premature closing. It shall be constructed of UV-protected materials as follows:

The body shall be made of high strength plastic and all operating parts shall be designed and manufactured from specially selected corrosion-resistant materials. Due to its light weight, the vent shall be capable of being installed on plastic piping systems, as well as other lightweight piping. A threaded drainage outlet (1½” on the 2” vent and ¾” on the ¾” & 1”) shall enable removal of excess fluids.
The base shall be MPT. Maximum working pressure range shall be as noted in Table 16. Testing pressure shall be 367 psi (25 bar) for the 230 psi valves and 235 psi (16 bar) for the 150 psi valves. Maximum working temperature shall be 203° F (95° C).

**Operation**
The vent’s orifice shall be designed to discharge large volumes of air during the filling of the system and shall admit air into the system at high flow rates during its drainage and/or at water column separation. Should internal pressure fall below atmospheric pressure at any time during operation (negative pressure), air will re-enter the system through the air valve. Admitting air in response to negative pressure shall protect the system from destructive vacuum conditions, and prevent damage caused by water column separation. The vent shall incorporate a small orifice component that shall release trapped air in the system while it is under pressure.

The Combination Air/Vacuum Relief & Continuous Acting Vent shall be Netafim Model Number 65ARIB___________.

**PRESSURE REGULATOR** (High Flow Pressure Regulator)

**Description**
The purpose of the Pressure Regulator is to maintain downstream pressure at or below the specified system operating pressure. Unregulated pressures in excess of the recommended operating ranges can cause the Bioline® fitting connections to weaken or fail.

**Construction**
The Pressure Regulator shall be a Netafim spring-operated piston-type regulator with an externally accessible regulation unit that can be serviced without removing the valve body from the piping. The body shall be molded of black plastic with a combination of male/female pipe threaded inlet and outlet.

**Operation**
The Pressure Regulator shall have a built-in indicator that indicates when it is operating. It shall be able to respond immediately to any inlet pressure variation. The regulator shall be capable of regulating downstream pressure to 15 psi, 20 psi, 25 psi, 35 psi, or 45 psi in ¾” or 1½” configurations. The Pressure Regulator shall operate in a flow range of 4.5 - 17.6 GPM in the ¾” configuration and 11 - 35 GPM in the 1½” configuration. Maximum pressure at inlet shall be 145 psi.

The Pressure Regulator shall be a Netafim Model Number PRV ______V2K.

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### Table 16 - Combination Air/Vacuum Relief & Continuous Acting Air Vent

<table>
<thead>
<tr>
<th>Model Number</th>
<th>Size</th>
<th>Body</th>
<th>Base</th>
<th>Maximum Operating Pressure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>65ARIB1</td>
<td>1”</td>
<td>Reinforced Nylon</td>
<td>Reinforced Nylon</td>
<td>150</td>
</tr>
<tr>
<td>65ARIB1-B</td>
<td>1”</td>
<td>Reinforced Nylon</td>
<td>Brass</td>
<td>150</td>
</tr>
<tr>
<td>65ARIB2</td>
<td>2”</td>
<td>Reinforced Nylon</td>
<td>Reinforced Nylon</td>
<td>230</td>
</tr>
<tr>
<td>65ARIB2-B</td>
<td>2”</td>
<td>Reinforced Nylon</td>
<td>Brass</td>
<td>230</td>
</tr>
<tr>
<td>65ARIB2PP</td>
<td>2”</td>
<td>Polypropylene</td>
<td>Polypropylene</td>
<td>150</td>
</tr>
<tr>
<td>65ARIB2BPP</td>
<td>2”</td>
<td>Polypropylene</td>
<td>Brass</td>
<td>150</td>
</tr>
</tbody>
</table>
**PRESSURE REGULATOR** (In-Line low Flow Pressure Regulator)

**Description**
The purpose of the Pressure Regulator is to control downstream pressure at or below the specified system operating pressure. Unregulated pressures in excess of the recommended operating ranges can cause the Bioline fitting connections to weaken or fail.

**Construction**
The Pressure Regulator shall be a Netafim spring-operated, in-line piston-type regulator. The body shall be molded of black plastic with ¾” female/female pipe threaded inlet and outlet. Directional arrows shall indicate flow direction of water.

**Operation**
The Pressure Regulator shall be able to respond immediately to any inlet pressure variation. The regulator shall be capable of regulating downstream pressure to 15 psi, 20 psi, 25 psi, 35 psi, or 42 psi. The Pressure Regulator shall operate in a flow range of 0.25 - 4.4 GPM. Maximum pressure at inlet shall be 145 psi.

The Pressure Regulator shall be a Netafim Model Number PRV075LF______V2K.

**DISC FILTER**

**Description**
The purpose of the Disc Filter is to capture and retain water-transported debris or sediment.

**Construction**
The filter shall be a multiple disc filter with color-coded filter elements indicating the mesh size of the element being used. The discs shall be constructed of chemical-resistant polypropylene for corrosion resistance.

The disc filter body shall be molded of black plastic with male pipe threads for both inlet and outlet. The disc filter shall be capable of periodic servicing by either unscrewing the threaded cap or unlatching the band. The ¾” DFV model shall have an integral manual shut-off valve.

Disc filter ring color-coding shall be: Yellow (80 Mesh / 200 Micron), Red (120 Mesh / 130 Micron), Black (140 Mesh / 100 Micron), or Green (200 Mesh / 70 Micron).

**Operation**
Installation of the Disc Filter shall be as detailed. Disc filters can be installed downstream of the remote control valve to allow for periodic servicing when the remote control valve is not operating. It can be installed upstream of the remote control valve if the disc filter is specified with manual shut-off valve or when a line-sized shut-off valve is also specified to allow for periodic servicing with a pressurized main line. Recommended installation of disc filters shall be as specified. It may be installed below grade, positioned in a valve box large enough to remove the disc filter cap and internal disc element, or above grade. A gravel sump in the bottom of the valve box is recommended.

The Disc Filter shall be a Netafim Model Number ______________.

**2” COMPACT** (Disc-Kleen Automatic Filter - DC Model)

**Description**
The purpose of the 2” Compact Disc Kleen Automatic Filter is to capture and retain water-transported debris or sediment in areas where no power is available.

The filter is designed to fit into small, tight locations. The automatic backflush reduces the need for frequent maintenance and is operated by a built-in controller and powered by 4 each “C” batteries.
WASTEWATER REUSE AND DRIP DISPERsal GUIDE

Construction
The filter shall be a multiple disc filter with color-coded filter elements indicating the mesh size of the element being used. The filter and spine shall be constructed of glass reinforced polyamide.

Disc filter ring color-coding shall be: Yellow (80 mesh / 200 micron), Red (120 Mesh / 130 Micron), or Black (140 Mesh / 115 Micron).

The flush valves shall be 12 VDC latch-style, of plastic construction, seals shall be Nitrilo/EPDM, filter and spine shall be glass-reinforced polyamide, and all clamps and screws shall be stainless steel.

The controller shall be capable of managing all functions of the unit, it shall be capable of time or pressure-differential backflushing control, it shall utilize a Digital Pressure Differential Switch for accurate operation, and shall have a built-in Manual Flush Button for manual filter backflushing.

The filter body inlet shall be 2” MPT, the outlet shall be 2” FPT with union assembly and the flush port shall be 2” FPT.

Minimum allowable pH shall be 5.

Operation
Installation of the Disc Filter shall be as detailed.

Standard Model - The 2” Compact standard model filter shall be designed to operate in the 1 - 80 GPM flow range (approximately 55 GPM maximum in poor water quality* and 35 GPM in very poor water quality**), with a minimum pressure for backflush of 40 psi and a minimum flow for backflush of 35 GPM. It shall have a maximum operating pressure of 140 psi.

Low Flow Model - The 2” Compact low flow model filter shall be designed to operate in the 1 - 50 GPM flow range (approximately 30 GPM maximum in poor water quality* and 20 GPM in very poor water quality**), with a minimum pressure for backflush of 40 psi and a minimum flow for backflush of 20 GPM. It shall have a maximum operating pressure of 140 psi.

The backflush cycle shall be activated by a Digital Pressure Differential Switch (PDS) without the need of an outside controller. The automated backflush operation shall operate on 4 each “C” batteries.

Dimensions
- Overall Dimensions (L x H): 30” x 25”
- Inlet to Outlet: 21 1/2”
- Inlet to Outlet Offset: 8 5/8”
- Weight: 32 lbs. net

The filter shall be Netafim Model Number DFA200-XXXDCL for flow rates of 1 - 80 GPM.

The filter shall be Netafim Model Number DFAL200-XXXDCL for flow rates of 1 - 50 GPM.

Substitute proper mesh size (080 = 80 mesh, 120 = 120 mesh, 140 = 140 mesh) for “XXX”.

2” COMPACT (Disc-Kleen Automatic Filter - AC Model)
Description
The purpose of the 2” Compact Disc Kleen Automatic Filter is to capture and retain water-

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* Poor Water Quality shall include well water from a poor quality aquifer with >2 ppm of sand or surface water in hot climates with increased biological growth and no chemical treatment which includes lakes, ponds, reservoirs and canals.

** Very Poor Water Quality shall include well water with >10 ppm of sand including rivers, muddy canals, lakes and ponds with severe runoff deposits and raw municipal wastewater.
transported debris or sediment.

The filter is designed to fit into small, tight locations. The automatic backflush reduces the need for frequent maintenance and is operated by a built-in controller and powered 110 VAC, single phase.

**Construction**

The filter shall be a multiple disc filter with color-coded filter elements indicating the mesh size of the element being used. The filter and spine shall be constructed of glass reinforced polyamide.

Disc filter ring color-coding shall be: Yellow (80 mesh / 200 micron), Red (120 Mesh / 130 Micron), or Black (140 Mesh / 115 Micron).

The controller shall be capable of managing all functions of the filter, it shall be capable of time or pressure-differential backflushing control, it shall utilize a Digital Pressure Differential Switch for accurate operation, and shall have a built-in Manual Flush Button for manual filter backflushing. The controller shall have a transformer that reduces the voltage from 110 VAC to 24 VAC to operate the flush valves.

The flush valves shall be 24 VAC, of plastic construction, seals shall be Nitrilo/EPDM, filter and spine shall be glass-reinforced polyamide, and all clamps and screws shall be stainless steel.

The filter body inlet shall be 2” MPT, the outlet shall be 2” FPT with union assembly, and the flush port shall be 2” FPT.

Minimum allowable pH shall be 5.

**Operation**

Installation of the Disc Filter shall be as detailed.

**Standard Model**

The 2” Compact standard model filter shall be designed to operate in the 1 - 80 GPM flow range (approximately 55 GPM maximum in poor water quality* and 35 GPM in very poor water quality**), with a minimum pressure for backflush of 40 psi and a minimum flow for backflush of 35 GPM. It shall have a maximum operating pressure of 140 psi.

**Low Flow Model**

The 2” Compact low flow model filter shall be designed to operate in the 1 - 50 GPM flow range (approximately 30 GPM maximum in poor water quality* and 20 GPM in very poor water quality**), with a minimum pressure for backflush of 40 psi and a minimum flow for backflush of 20 GPM. It shall have a maximum operating pressure of 140 psi.

The backflush cycle shall be activated by a Digital Pressure Differential Switch (PDS) without the need of an outside controller.

**Dimensions**

- Overall Dimensions (L x H): 30” x 25”
- Inlet to Outlet: 21 1/2”
- Inlet to Outlet Offset: 8 3/8”
- Weight: 32 lbs. net

The filter shall be Netafim Model Number DFA200-XXXAC for flow rates of 1 - 80 GPM.

The filter shall be Netafim Model Number DFAL200-XXXAC for flow rates of 1 - 50 GPM.

Substitute proper mesh size (080 = 80 mesh, 120 = 120 mesh, 140 = 140 mesh) for “XXX”.

---

* Poor Water Quality shall include well water from a poor quality aquifer with >2 ppm of sand or surface water in hot climates with increased biological growth and no chemical treatment which includes lakes, ponds, reservoirs and canals.

** Very Poor Water Quality shall include well water with >10 ppm of sand including rivers, muddy canals, lakes and ponds with severe runoff deposits and raw municipal wastewater.
NETAFIM USA'S LIMITED WARRANTY/LIMITATION OF BUYER'S REMEDIES

(A) BASIC MANUFACTURER'S LIMITED WARRANTY:

Except as to products described in Subsections (B), (C), (D), and (E) below, products sold and/or manufactured by Netafim Irrigation, Inc. (Netafim USA) are warranted to be free from original defects in material and workmanship for a period of one (1) year from the date of delivery to the buyer unless (i) otherwise specified by and subject to the terms and conditions of any Warranty Supplements pertaining to specific products or, (ii) expressly disclaimed in writing by Netafim USA. Within the warranty period, Netafim USA at its sole discretion shall have the option to repair or replace part or all of a defective product, or refund part or all of the original purchase price, if any part proves to be defective in material or workmanship after return of such product at customer’s expense and after such return has been authorized in writing by Netafim USA. THIS BASIC MANUFACTURER’S LIMITED WARRANTY IS SUBJECT TO THE TERMS AND PROVISIONS IN SUBSECTION (F), (LIMITATION OF REMEDIES AND DISCLAIMER OF WARRANTIES) SET FORTH BELOW IN THE EVENT OF ANY INCONSISTENCY BETWEEN SUBSECTION (A) AND SUBSECTION (F) OF THIS PRODUCT WARRANTY, THE PROVISIONS OF SUBSECTION (F) SHALL PREVAIL.

(B) Dripperlines:

Bioline dripperlines are warranted to be free from original defects in materials and workmanship for a period of five (5) years and seven (7) years for environmental stress cracking. Further, the Bioline warranty against emitter clogging due to root intrusion will be for a period of ten (10) years. This warranty shall apply only to products with a wall thickness of 35 mil or greater.

(C) Filters:

Disc filters are warranted to be free from original defects in materials and workmanship for a period of five (5) years. This warranty specifically excludes gaskets, seals and o-rings, which are subject to the basic one (1) year warranty.

(D) Valves:

Valve bodies are warranted to be free from original defects in materials and workmanship for a period of five (5) years. Valve diaphragms are warranted for a period of two (2) years.

(E) Air/Vacuum Relief Vents:

Air/vacuum relief vent bodies are warranted to be free from original defects in materials and workmanship for a period of five (5) years. Polypropylene vent bodies are warranted for two (2) years. This warranty specifically excludes internal seals, gaskets or o-rings which are subject to the basic one (1) year warranty.

(F) LIMITATION OF REMEDIES AND DISCLAIMER OF WARRANTIES

EXCEPT AS EXPRESSLY PROVIDED HEREIN, ALL WARRANTIES EXPRESSED OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR USE, ARE HEREBY EXCLUDED AND DISCLAIMED.

THE REMEDIES PROVIDED HEREIN SHALL BE THE EXCLUSIVE AND SOLE REMEDY OF THE BUYER. NO OTHER EXPRESS WARRANTY IS GIVEN AND NO AFFIRMATION BY NETAFIM USA, BY WORDS OR ACTION, WILL CONSTITUTE A WARRANTY. NO OTHER EXPRESS WARRANTY NOR ANY OTHER REMEDY SHALL BE AVAILABLE TO THE BUYER AND NETAFIM USA SHALL NOT BE RESPONSIBLE OR LIABLE FOR ANY DAMAGES, INCLUDING ANY LOSS OF PROFIT, LOST SAVINGS, LOSS OF SALES, OR OTHER DIRECT, INDIRECT, INCIDENTAL, SPECIAL OR CONSEQUENTIAL DAMAGES, INJURY OR DAMAGES TO ANY PERSON OR PROPERTY ARISING OUT OF THE USE OR INABILITY TO USE THE PRODUCTS OR THE BREACH OF ANY EXPRESS WARRANTY, EVEN IF NETAFIM USA HAS BEEN ADVISED OF THE POSSIBILITY OF THOSE
DAMAGES OR CLAIMS. NETAFIM USA SHALL NOT BE RESPONSIBLE FOR THE AFORESAID DAMAGES, CLAIMS OR LOSSES DUE TO LATE DELIVERY OR DELIVERY OR NON-DELIVER, OR OTHERWISE. THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION AS SET FORTH HEREIN. IF NETAFIM USA SHALL FURNISH TECHNICAL ADVICE OR ASSISTANCE WITH RESPECT TO THE PRODUCTS SOLD HEREUNDER, IT SHALL BE GIVEN WITHOUT CHARGE TO BUYER AND SHALL BE GIVEN AND ACCEPTED AT BUYER’S SOLE RISK WITHOUT ANY EXPRESS OR IMPLIED WARRANTY AND NETAFIM USA SHALL NOT BE RESPONSIBLE OR LIABLE FOR THE ADVICE OR THE RESULTS THEREOF BUYER ASSUMES ALL RISK AND LIABILITY RESULTING FROM USE OF THE PRODUCT PURCHASED.

This warranty is expressly conditioned upon proper storage, installation, application and normal wastewater use and service as recommended by Netafim USA. Such recommendations may be updated from time to time. Any misuse, neglect, modifications, unauthorized repairs or replacement or uses of the product and/or any of its components for purposes not recommended by Netafim USA, including but not limited to the following, shall completely void this warranty:

(I) Water which has not been filtered or treated to the levels specified for individual components of the product by Netafim.

(II) Chemical concentrates, used or applied internally or externally to the product, or mechanical abuse which is harmful to the product or its components.

(III) Operating pressures greater than those specified by Netafim’s individual component specifications.

(IV) Damage or plugging caused by insects, rodents, other animals, improper installation or other mechanical damage.

THE EXPRESS WARRANTY PROVIDED HEREIN IS EFFECTIVE ONLY IF CLAIM IS MADE BY WRITTEN NOTICE WITHIN THE APPLICABLE WARRANTY PERIOD AND POSTMARKED WITHIN THIRTY (30) DAYS AFTER DISCOVERY OF THE DEFECT ON WHICH THE CLAIM IS BASED. SUCH NOTICE SHALL BE DELIVERED TO NETAFIM USA AT THE FOLLOWING ADDRESS:

NETAFIM USA
5470 EAST HOME AVENUE
FRESNO, CALIFORNIA 93727
ATTN: PRODUCT MANAGEMENT

The buyer shall, together with its notice of claim, offer Netafim USA in writing prompt opportunity to examine the defective product and correct the defect, if possible. This warranty shall be void unless buyer delivers the defective product to Netafim USA at buyer’s sole cost and in accordance with Netafim USA’s instructions.
Air entrapment in pressure pipelines is a much studied and discussed topic. Most designers are concerned about it, or should be, but many do not understand the full implications of the problem or the processes used to reduce the dangers associated with entrapped air. The problem with entrapped air is a complex issue. The behavior of air in a piping system is not easy to analyze, but the effects can be devastating.

Sources of Air in Pipelines

There are many potential sources for air in pipelines and the sources are usually multiple in any given system. The most likely source is entrapment of air during filling, either initially or when refilled after drainage. In some systems, air re-enters each time the pumps are shut off as the pipelines drain through low lying sprinklers or open valves.

Air is often introduced at the point where water enters the system. This is an especially common problem with gravity fed pipelines, but may occur with pumped systems as well. Even water pumped from deep wells may be subject to air entrance from cascading water in the well. A less obvious source of air comes from the release of dissolved air in the water, due to changes in temperature and/or pressure. The quantities may be small in this case, but accumulations over time can create problems. It is also common for air to enter through air release valves or vacuum breakers when the pressure drops below atmospheric pressure. This can occur during pump shutdown or during negative surges.

Why is Entrapped Air a Problem?

Air in a piping system tends to accumulate at high points during low flow or static conditions. As the flowrate increases, the air can be forced along the pipeline by the moving water and may become lodged at the more extreme high points where it reduces the area available for flow. Thus, these pockets of air cause flow restrictions which reduce the efficiency and performance of the system. As an air pocket grows, the velocity past that point increases until eventually the air is swept on toward an outlet. While line restrictions are problems, a more serious situation can occur when air is rapidly vented from the system under pressure. Water is about five times more dense than air at 100 psi, so when a pocket of compressed air reaches an outlet, such as a sprinkler head, it escapes very rapidly. As it escapes, water rushes in to replace the void. When water reaches the opening, the velocity suddenly decreases, since air escapes about five times faster than water at 100 psi. The result is similar to instantaneous valve closure, except that the velocity change can far exceed the normal flow velocity in the pipeline. During tests at Colorado State University, pressure surges up to 15 times the operating pressure have been recorded when entrapped air was rapidly vented under pressure. Such pressure surges can easily exceed the strength of the system components and even at lower magnitudes, repeated surges will weaken the system with time.

Dealing with Entrapped Air

Obviously, the best way to reduce problems caused by entrapped air would be to prevent it from entering the system. Precautions should be taken to eliminate air entrance. When systems are filled, either initially or after draining for winterization or repair, they should be filled slowly, at a velocity of 1.0 fps or less, and the air should be vented from the high points before the system is pressurized. Even with these precautions, some air can remain in the system. To deal with this remaining air or newly admitted air, continuous-acting air relief vents and lines should be laid to grade wherever possible. Continuous-acting air vents contain a float mechanism which allows the air to vent through a small orifice, even when the line is pressurized. The orifice diameter should be about 1 percent of the diameter of the pipe on which it is installed to allow the entrapped air to be slowly released.

Several combination air vent/vacuum relief vents are available for control of air in systems. Air and vacuum release vents are designed to exhaust large volumes of air from pipelines during the filling process and to close positively when water reaches them. These vents operate either by a buoyant float closing the vent as the water rises or by the impact of the water against a plate or other vent closure element. The vent remains closed until the pressure drops below...
atmospheric pressure, as would result from draining the line. These types of vents close rapidly and will cause a significant change in velocity at closure, thus care should be used in their sizing and placement. Combination vents are manufactured to perform the functions of both continuous acting and vent/vacuum air release vents. Upon filling, a large orifice is opened. Once water reaches the vent, the large orifice closes and allows air to escape only through the smaller orifice that is actuated by a float mechanism.
1. **SCOPE**

1.1 Drip dispersal is a method used to distribute wastewater that has received at least primary treatment over an area of land for final polishing, reuse, or recharge of groundwater. This method of dispersal is capable of uniformly distributing the wastewater effluent over large areas. It has been used in the U.S. for dispersal of pre-conditioned wastewater onto soil infiltrative surfaces since the late 1980s.

Drip dispersal is frequently, but inappropriately, referred to as drip irrigation. Drip dispersal is seldom designed to meet the agronomic water requirements of a crop. Instead, it is usually designed to maximize infiltration of water into the soil throughout the year. Some of the dispersed water will evaporate, or be transpired by vegetation during the growing season, but most will percolate into the soil and recharge the underlying groundwater. However, plant irrigation or other water reuse applications can be incorporated into the design.

1.2 This guidance describes the appropriate design, installation, operation, monitoring, and maintenance practices that are necessary to ensure the long-term performance of drip dispersal.

1.3 Site-specific engineered designs must be used. The owner may choose to specify a “pre-engineered” package that is appropriate for the site requirements; however, using a pre-engineered package does not preclude the need for proper site-specific design.

2. **REFERENCE DOCUMENTS**


2.4 American Society for Testing and Materials (ASTM), West Conshohocken, Pennsylvania.

2.4.1 ASTM D5925-96. Standard Practice for Preliminary Sizing and Delineation of Soil Absorption Field for On-Site Septic Systems. 1996

2.4.2 ASTM D5879-95. Standard Practice for Surface Characterization for On-Site Systems. 1996

2.4.3 ASTM D5921-96. Standard Practice for Subsurface Site Characterization of Test Pits for On-Site Septic Systems. 1996


3. **DEFINITIONS**

3.1 **Air/Vacuum Release Valve**: A device installed in a piping system to allow air to escape from the piping system during pressurization and air to enter during depressurization.

3.2 **Area Loading Rate**: The volume of wastewater effluent or mass of contaminants dispersed within the perimeter of the infiltration area over a 24-hour period. The area loading rate is generally described in engineering units such as gallons per day of wastewater per square foot (area hydraulic loading rate) or pounds per day of contaminant (biochemical oxygen demand, fats, oils, and greases, suspended solids, total nitrogen, etc.) per 1000 square feet (area contaminant loading rate).

3.3 **Organic Loading Rate**: The amount of BOD5 (Biochemical Oxygen Demand) delivered to a treatment component expressed as pounds per day per design unit (for example, pounds per day per square foot).

3.4 **Contour Loading Rate**: The sum of the daily volume of wastewater discharged by the dispersal system along a downslope projection parallel to the slope that intersects all dispersal zones on the slope that will or could receive wastewater on the same day. The contour loading rate is expressed in gallons per day per linear foot of contour.

3.5 **Design Flow**: The estimate of the projected maximum daily wastewater volume (gallons per day) the facility will receive during its design service life that is used to size the components of the facility.

3.6 **Dispersal Zone**: The smallest unit of a drip dispersal system, consisting of a supply manifold, return manifold, drip laterals, and associated appurtenances, which can be loaded independently of all other parts of the dispersal system.

3.7 **Dosing**: The act of intermittently discharging a measured volume or dose of wastewater to a dispersal system either on demand or on timed cycles.

3.8 **Drain-down**: The non-uniform gravity-induced redistribution of water within the piping network dripperline pre- and post-pressurization of the dripperline, which allows some emitters in the dispersal zone to discharge more wastewater than others do. This phenomenon can result in locally overloading areas of the dispersal zone.

3.9 **Dripperline (or drip tubing)**: Polyethylene tubing that has uniformly spaced drip emitters along its length, which are attached to the inside wall of the tubing.

3.10 **Drip Emitter**: An engineered flow control device that is typically attached to the inside wall of the dripperline over each orifice. The emitter discharges water at a predictable rate under a given pressure, typically stated in gallons per hour.

3.11 **Emitter, pressure compensating (PC)**: A drip emitter that discharges water out an orifice of the dripperline at a constant rate over a range of operating pressures.

3.12 **Emitter, turbulent-flow**: A non-pressure compensating (non-PC) emitter that discharges water out an orifice of the dripperline at a rate that varies directly with the operating pressure.

3.13 **Flow, pressurizing**: The portion of a dosing event during which the dispersal system is being filled to its operating pressure.

3.14 **Flow equalization**: The process of reducing the variability of the influent flow to a system component by storing peak flows and metering their release at a predetermined rate close to the average daily flow.

3.15 **Flushing**: The process by which dripperlines are hydraulically cleansed to prevent emitter clogging by increasing the velocity of water flow through the dripperlines to scour and...
transport solid materials that may have accumulated in or on the interior surfaces of the dripperlines.

3.16 **Infiltrative surface:** The soil surface that is in direct contact with free water from the dripperline through which the applied water first enters the soil and where its state changes from free water to water under tension.

3.17 **Instantaneous loading:** The volume of water discharged to a dispersal zone during a dosing event. This may be expressed as gallons per dose, gallons per dose per linear foot of dripperline, or gallons per dose per emitter.

3.18 **Lateral:** A dripperline consisting of a run or series of runs extending from the supply manifold to the return manifold of a single dispersal zone.

3.19 **Minimum dose volume:** The volume of water discharged during a dosing event that is necessary to pressurize the entire dispersal system and sustain that pressure over a sufficient period to achieve the desired uniformity of discharges between all orifices. It is commonly specified as a multiple of the total volume of the laterals in the system (for example, four times the volume of the piping network).

3.20 **Particle separator:** A device such as a filter or screen that is able to remove particulate matter from the wastewater that is larger than a predetermined size.

3.21 **Preconditioned wastewater:** Wastewater that, at a minimum, has received pretreatment in a septic tank and screening or filtration prior to discharge into the dripperline.

3.22 **Pressure regulator:** A device typically used to reduce the pressure in a dispersal system, employing turbulent flow emitters to control emitter discharges at a predetermined rate.

3.23 **Pressurization period:** The time between pump startup during a dosing event and the time when the dispersal zone is full and pressurized.

3.24 **Return flush main:** The pipe connected to the return manifold that conveys the flush water from the dispersal zone back to the preconditioning system during a flushing event.

3.25 **Return manifold:** The pipe to which the distal ends of each lateral in a dispersal zone are connected. Its purposes are to help equalize the pressure between laterals of a zone, provide an alternative pathway to a lateral that may be obstructed, and collect the wastewater from the laterals during field flushing for discharge to the return flush main.

3.26 **Run:** The portion of a looped or folded lateral that is between two loops on contour.

3.27 **Separation distance:** The vertical or horizontal distance that must be maintained between a designated design barrier, such as groundwater, bedrock, property lines, wells, or other site features, and components of the wastewater systems, which may be defined by local rules.

3.28 **Scouring:** The process to clear a conduit of particulates by hydraulic flushing at a sufficient velocity to lift and carry particulates downstream.

3.29 **Supply main:** The force main from the dose pump to the supply manifold of a dispersal zone.

3.30 **Supply manifold:** The pipe to which the proximal ends of the laterals of a dispersal zone are connected to supply water to the dripperline during dosing events.
3.31 **Timed dosing:** The dosing of an infiltration system on preset timed cycles at equal intervals that discharge equal volumes typically four or more times in a 24-hour period.

3.32 **Valve, check:** A valve that allows water to flow in only one direction.

3.33 **Valve, flush:** A valve that allows field flushing of the drip laterals.

3.34 **Valve, sequencing:** A valve used in a multiple zone dispersal system to direct flow from the supply main to the supply manifolds of the zones sequentially, one zone at a time, for each dosing event.

3.35 **Valve, zone:** A valve used to direct a dose to the supply manifold of a selected dispersal zone.

3.36 **Vacuum release valve:** A valve installed in a dispersal zone that opens to the atmosphere when a negative pressure develops within the piping to prevent water and particulate matter outside the dripperline from being aspirated into the emitters.

4. **SUMMARY OF PRACTICE**

4.1 Wastewater drip dispersal networks provide uniform distribution of preconditioned wastewater over infiltrative surfaces of land application systems, subsurface infiltration systems, media filters, or any other surfaces where water is to be infiltrated. The systems are designed to be sustainable, year-round, land application systems. Although they are not primarily irrigation systems, plant irrigation and other reuse practices may be incorporated into the design.

4.2 The unique feature of drip dispersal networks is the use of uniformly spaced drip emitters that are inserted within flexible tubing to control the rate of wastewater discharges out the tubing through small orifices. Typically, the dripperline is installed directly into the soil without aggregate or other media to expose more infiltration surface, although a drip dispersal system may be applied in other applications to achieve uniform distribution of wastewater where gravel aggregate or other media may be used to bed the distribution network. Pumps are used to fill and pressurize the dripperline sufficiently to achieve uniformity of distribution.

4.3 The drip emitter is designed to create a high headloss between the in-line pressure of the dripperline and the outlet orifice in dripperline wall. The pressure loss that is created controls the pressure at the outlet orifice so that the discharge is limited within a desired range. Each emitter in a dripperline acts as a point discharge, which releases water at a rate nearly equal to the discharge rate from other emitters in the same dripperline. Roots may intrude into the emitters. The severity of root intrusion is dependent upon the climate, soil, type of vegetation, dosing regimes, and the hydraulic loading rates. There are proprietary methods to guard against root intrusion. Follow the manufacturer’s instructions.

4.4 Two types of emitters are commonly used, “turbulent-flow” and “pressure compensating.” The turbulent-flow emitter discharges water at rates that vary directly with the in-line pressure of the dripperline. The pressure compensating emitter discharges water at a nearly constant rate over a wide range of pressures above a minimum pressure. Below the minimum pressure, the pressure compensating emitter operates similarly to a turbulent-flow emitter. Both types of emitters are used successfully in drip dispersal systems.

4.5 The preconditioned wastewater is intermittently dosed to each drip dispersal zone. Intermittent dosing provides several significant benefits. It allows time for the soil at the infiltrative surface to reaerate so the soil can maintain an aerobic environment.
for biochemical treatment of the wastewater to occur. It makes better use of the hydraulic capacity of the system to accept the wastewater by avoiding few, large doses. It prevents excessively high instantaneous hydraulic loadings that can cause surface breakouts of wastewater above the infiltration system, because the dripline typically is installed directly in the soil, and therefore little void space is provided for storage of any wastewater that is not immediately infiltrated. Also, timed dosing protects the infiltration system from receiving wastewater in excess of the daily design flow storing excessive flows in the dose tank for later dispersal.

4.6 Monitoring system function and performance is essential to proper operation. In addition, metering the volume of water dispersed is a critical monitoring item for evaluating performance.

4.7 The dispersal system is usually operated by an integrated controller, which is programmed to activate the pumps to dose the dripperline at appropriate intervals and duration, to flush the dripperline, and backflush the liquid/solid separator device. It also may be used to store operating data for later use in documenting system performance and diagnosing system malfunctions.

5. SIGNIFICANCE OF USE

5.1 Subsurface drip dispersal is an efficient method for dispersal of wastewater into the soil. It is the most precise method currently available for applying wastewater effluent over an infiltration surface in small-volume doses throughout the day. The uniformity of the dosing and equal distribution can be designed and operated to provide for unsaturated flow over the entire infiltration area.

5.2 Wastewater drip dispersal systems may be used anywhere preconditioned wastewater needs to be distributed uniformly over an infiltration surface such as is used in land application, subsurface infiltration and media filters. They are ideally suited for facilities treating large volumes of wastewater, but are also available for single-home use.

5.3 With appropriate design and operation, drip dispersal systems are sustainable year-round. In cold climates, design and operating measures should be considered to protect the dispersal system against freezing.

6. PROCESS DESCRIPTION

6.1 The drip dispersal system typically includes the following components arranged as illustrated in Figure 26.

6.2 The wastewater must be preconditioned before it is discharged to the drip dispersal system. The preconditioning criteria depend on the component equipment used, system design, and characteristics of the receiving environment. Primary settling or septic tank treatment is a minimum level of preconditioning necessary. Additional preconditioning to remove specific pollutants, which may adversely impact the soil or receiving environment, may be necessary.

6.3 The preconditioned wastewater is discharged to the dispersal system through a dosing tank that has sufficient volume to provide flow equalization. Flow equalization is frequently used to maximize the hydraulic and treatment capacity of the infiltration system by dosing each zone at pre-set timed intervals. This process is called “timed dosing.” The dose tank is sized with sufficient volume to be able to hold influent flows of wastewater that exceed the dosing rate. The wastewater that is held during peak periods is dosed to the infiltration system during periods of lower-than-average
flow conditions. If the storage volume that is used for equalization in the dose tank is exceeded, a high-water alarm is activated.

6.4 Before a dose is discharged to the dripperline, it typically undergoes particle separation by screening or filtering. The purpose of this step is to remove any particles larger than the smallest opening in the emitters to reduce the potential for emitter clogging. This is a necessary step regardless of the level of preconditioning the wastewater receives. The separation devices are usually either self-cleansing or routinely cleansed by backwashing with filtered water, which is returned to the headworks of the preconditioning system.

6.5 The manufacturers of dripperline should be consulted for recommendations regarding specifications for maximum particulate size that can pass the liquid/solid separation device to adequately protect the emitters. The screens or filters must be cleaned periodically and the residuals returned to the preconditioning device. Both manual and automatic cleaning methods are used. Access to the particle separator is important for the periodic servicing required to sustain its performance.

6.6 The drip dispersal systems are designed to provide nearly equal distribution between all emitters in a zone when applying the preconditioned wastewater. The dispersal system layout must consider the system hydraulics during the pressurization, dosing, and drain down periods that occur with each dose.

6.6.1 The density of emitters determines uniformity of wastewater application over the infiltration area. This is a function of both emitter spacing and dripperline spacing. The number of emitters and rate required is determined from the daily hydraulic design application rate over the infiltration surface. This determines the total length of dripperline needed.

6.6.2 During pressurization and drain-down of a drip zone, the in-line pressure at each emitter in a network will vary, resulting in unequal discharge rates between the emitters and localized hydraulic overloading within the zone. Minimum dose volumes must be established for each drip dispersal system to limit any hydraulic overloading. While small doses can enhance soil treatment, this advantage is lost if a significant portion of each dose is discharged by the system during
pressurization and drain-down periods of the network. Small, frequent doses should be avoided. Dose volumes should be several times the total supply and return manifolds and dripperline volumes within the zone.

6.6.3 Air/vacuum release should be provided at the highest elevation in each zone to let air out during pressurization and to let air in to prevent negative pressure within the dripline, which can result in aspiration of soil fines into the emitters and dripperline during system drain-down.

6.6.4 The drip system should also be designed to periodically flush the supply and return manifolds as well as the dripperlines. Flushing velocities must be created to achieve sufficient velocities to scour the dripperline to remove any accumulations of organic and inorganic particulates.

6.7 Flushing of the dripperlines is typically included as a routine operating practice to remove biological solids that grow within the dripperline and any other solids that may enter the lines during construction or operation. The flushing is typically a forward flush that is done during a normal dose. A return main directs the flush water to the headworks of the pretreatment system, which must be sized to accommodate the returned flush volume and characteristics to avoid impacts detrimental to the pretreatment. To activate the field flushing, the return valve on the return main is opened, which increases the flow rate. Experience indicates that necessary flushing flow velocities can vary with the characteristics of the preconditioned wastewater and the type of dripperline used. Designers should meet or exceed the recommendation of the dripperline manufacturer for necessary flushing velocity.

6.8 Automatic controls are necessary for effective operation and monitoring of drip dispersal systems. The system controller should activate a dose only when there is a sufficient volume of preconditioned wastewater for a full design dose to ensure that each dose achieves uniform distribution. It should also be programmed to provide a sufficient rest time between doses for the effluent to move into the soil away from the dripperline. It must confirm that there is a sufficient volume of effluent to proceed with a dose event. Partial doses will result in non-uniform application of wastewater and reduced performance of the dispersal system. The control provides the operator interfaces for the operational adjustments and diagnostic monitoring of the system. A means to meter and record flow volumes is essential to provide total flow processed over time, monitor flow rates during both dosing and flushing events and troubleshoot system malfunctions.

7. DESIGN

7.1 A demand analysis of water use at the building(s) to be served should be conducted to estimate the average daily flow, expected daily peak flows and diurnal and weekly variations. Local codes usually will dictate unit values to estimate the design flows for wastewater systems. The design flow estimates obtained from using these unit values typically will represent maximum peak flows. While dispersal systems must be designed to distribute the maximum expected peak flows, drip dispersal systems are usually designed to distribute the average daily flow with peak flows controlled by flow equalization.

7.2 The dose or pump tank should provide sufficient storage for equalization of peak flows. The storage volume is calculated to hold any peak flows that are expected to routinely occur over a given period, typically a day or week depending on the expected flow variations. The pump tank should provide at least one quarter of a day’s storage above the alarm level, and more storage is better. Equalization storage from one-half to one
day between the pump-enable water level and the alarm water level is necessary for small flow systems. Local regulations may require a specific storage capacity. The design may increase or decrease this storage based on available redundancy of facilities.

7.3 Drip distribution may be used with a wide range of preconditioning processes and water quality. Preconditioning, water quality and quantity should be evaluated when selecting soil loading rates and mechanical equipment.

7.4 The layout of the dispersal system piping network must provide reasonably uniform distribution over the proposed soil treatment area. The hydraulic design should achieve discharge rates and volumes that vary no more than +10% between all the emitters within a zone during a complete dosing event. Consideration should be given to the unequal distribution during flow pressurizing and flow depressurizing periods. The designer must be able to mathematically support the design for equal distribution and demonstrate it upon installation. The design of the soil treatment area (sizing, depth, geometry, and orientation), are not included in this document.

7.4.1 Manufacturers must rate all valves, pressure regulators, fittings, and piping for wastewater application. The system designer must evaluate the compatibility of these appurtenances for the specific application.

7.4.2 Drip field piping layout must provide a sufficient number and density of emitters to achieve reasonably uniform distribution and application of the preconditioned wastewater over the entire soil treatment area. The number of emitters must be sufficient to maintain an instantaneous loading rate (gallons per dose) that will maximize use of the hydraulic and treatment capacities of the soil and prevent breakout of wastewater on the treatment area surface during dosing.

7.4.3 Emitter and dripperline spacing should be based on the permeability of the soil. Horizontal movement of water in coarse-textured soils with high permeability is much less than it is in fine-textured soils, which can draw water several feet, so the horizontal spacing of the dripperline should be adjusted accordingly to avoid exceeding the instantaneous hydraulic capacity of the infiltrative surface. Standard two-foot emitter and dripperline spacing should be adequate for most applications.

7.4.4 Minimum and maximum installation depths of the dripperline may be established by local rules based on soil characteristics and separation distances. Installation depths typically range from 6 to 12 inches. Recommendations of the manufacturer should be considered. Shallow drip dispersal systems must be protected from possible physical damage.

7.4.5 Drain-down, which occurs after each dose as the dripperline depressurizes, must be managed to prevent localized overloading through the lower laterals of the network. Dripperline should be placed on contour and laid out to drain itself through the emitters as evenly as possible so as not to cause localized overloading.

7.4.6 Dispersal systems are often divided into zones that can be loaded independently. This is done to better adapt the dispersal of wastewater to the capacity of the receiving environment and to meet the hydraulic requirements for equal distribution, field flushing of the dripperline, reduce localized overloading from the drain down prior to and after pressurization of dripperline. Multiple zones also can provide standby capacity for equipment servicing and system repairs.

7.4.7 Lateral lengths within a zone should be close to equal to achieve efficient flushing of each of the laterals. To determine the suitable flushing flow and
pressure requirements at the proximal end necessary to achieve the flushing velocity at the distal end, the designer should obtain dripperline headloss information relating dripperline diameter, emitter spacing, and emitter and flushing flow rates to lateral lengths. Computer programs are available to aid in evaluating the hydraulic design of the dispersal system.

7.4.8 Drip dispersal systems should be designed to operate in the manufacturer's specific pressure range for emitter operation. The dripperline should be placed within appropriate elevation tolerance limits in each zone to maintain equal distribution within the preferred range. It may be necessary to control the inlet pressure with a pressure-regulating valve in order to control emitter flow rate. Hydraulic analyses should be performed to ensure appropriate pressure and flow is achieved for both dosing and flushing conditions.

7.4.9 Air/vacuum release valves must be installed at the high points in each zone to provide a vacuum break as the dripperline drains after a dose event. This is critical to prevent aspiration of soil particulates back into the dripperline through the emitter.

7.5 The piping layout is typically flushed. Flushing velocities should meet or exceed the recommendations of the manufacturer of the dripperline used. Flush materials should be returned to the headworks of the wastewater treatment system.

7.6 The pump must be designed to handle preconditioned wastewater and to manage all hydraulic operations required for the system. The dosing capacity must be sufficient to apply a full dose at the design rate for the largest zone in the system and meet the flushing rate requirements. If automatic particle separators are used, the pump must also be capable of achieving the backflushing or washing rate and pressure requirements of the manufacturer of the separator.

7.7 Particle separation is required to reduce the size of suspended particles in the wastewater effluent to prevent emitter plugging. Separators should follow the manufacturer's recommendations and be suitable for wastewater applications. They should be accessible for maintenance and designed to match the maintenance frequency of the system.

7.8 Monitoring Devices: A method for measuring the volume of wastewater dispersed against elapsed time should be provided. Also, means to measure flow rates and operating pressures are beneficial to diagnose hydraulic problems. Continuous data recording should be considered.

7.9 Controls: An integrated controller is necessary to manage the multifunction processes of drip dispersal systems. The control panel shall be located in an accessible location where an operator can monitor and perform diagnostics on the system. Manual override switches for all automated mechanical functions should be provided. H-O-A (Hand-Off-Auto) switches for manual operation of pump and valves should be provided for an operational interface. Visual indications of specific operations are recommended.

7.9.1 The controller must manage the dosing and resting cycles to the drip field as designed. The run times and the rest times should be adjustable to manage the instantaneous loading rates to regulate the demand with the field capacity.

7.9.2 Each major component should be located to perform properly and to be accessible for operation and maintenance.

7.10 All components of the drip arrangement must work together for the successful, long-term, reliable operation of a drip dispersal system. Each function of the system design, regarding flow rates and pressures, should be appropriately integrated and designed
to meet requirements. All components in a drip dispersal system should be rated to withstand contact with wastewater and recommended for this application by the manufacturer or supplier. Additional components may be used as deemed appropriate by the manufacturer or designer to treat and evenly disperse the wastewater to prevent emitter clogging, prevent physical damage, monitor operation, or otherwise enhance system performance.

8. INSTALLATION

8.1 Only trained and otherwise qualified contractors shall install drip dispersal systems.

8.2 The installer must pay particular attention to site protection and protection of the dripperline. Installation practices should provide site protection for shallow soil installations.

8.3 The installation of the dispersal system should reasonably follow the designer’s plans.

8.4 During installation, the dripperline should be protected against entry of construction debris and soil materials by taping or otherwise tightly covering the ends until their connections to the manifolds are made.

8.5 All aspects of the design objectives should be tested, proven, and recorded at startup to confirm that site-specific design objectives are met.

9. OPERATION, MONITORING, AND MAINTENANCE

9.1 Drip dispersal systems should be designed such that system operation can be monitored for proper usage and performance. The monitoring frequency should be based on the most limiting process in the system.

9.2 Monitoring of flow rates and pressures is necessary to diagnose possible overuse and ensuing system damage.

9.3 All aspects of the design objectives should be monitored, proven, and recorded at regular intervals to confirm that site-specific design objectives are met.

9.4 Operational monitoring should determine if wastewater has been or is surfacing as a result of the operation of the drip system and that the system is in good repair.

9.5 Only trained and otherwise qualified operators or installers should operate and service drip dispersal systems.

9.6 For more complete guidance, see reference documents 2.3 and 2.5.
Background: Subsurface irrigation has become a common method for irrigation of field crops and fruit tree plantations. Field results summarizing 5 years of fixed subsurface in cotton suggested no dripper plugging. In fact, the same results were noted on 2 years in a commercial mango plantation, and after a full season of melon production.

In a preliminary study done by the authors who recorded the above results, they did notice a phenomena unique to subsurface. The discharge rate of drippers at various zones of a subsurface mango plantation decreased by 10 to 50 percent, depending on the site. However, when the dripper laterals were carefully exposed and examined, the discharge rate increased at once to its predetermined value. No drippers were plugged by dirt or roots.

Three researchers, U. Shani, S. Xue, and R. Gordon-Katz, theorized that when the predetermined discharge rate of drippers exceeds the soil’s capacity to hold water (either because of a very high discharge rate, or low soil permeability), the soil itself limits the discharge rate. Thus, the soil and the drip system’s hydraulic properties together affect the local discharge of a subsurface dripper, rather than the characteristics of the system alone.

Hypothesis:
When the dripper discharge is larger than the soil infiltration capacity, water pressure at the dripper outlet and in the soil will, in turn, decrease the pressure gradient through the dripper, and decrease the discharge in a manner that depends on the dripper’s characteristic curve.

Test:
A method was developed to test and measure the hypothesis, which employed tubing connected to drippers which had water supplied to them from a Marriott-style water reservoir. A compressed air tank was attached to the Marriott via a pressure regulator. A water manometer was connected to the dripper outlet to measure backpressure.

The actual dripper discharge rate was measured by the rate of the falling water level in the water reservoir. A 5 mm tube was inserted into a 7 mm borehole that was augered to the desired depth. After the tube was inserted, the soil was compacted.

Discharge rates and backpressures were measured as a function of the dripper nominal discharge rate and the soil hydraulic properties.

Results & Summary:
The results of the research confirmed the hypothesis. That is, soil infiltration rate can cause positive pressure against the dripper, and will affect discharge rates. This occurrence is most likely to be noticed in tighter, more clay-like soils, and less often in sandy soils.

The researchers reported that pressure compensated drippers performed far better than non-compensating drippers. Pressure compensating drippers showed no appreciable variation from -6 m to 5 m, where non-pressure compensating drippers had discharges ranging from 132% at -6 m to 0% at 10 m. They performed nominally (100% of stated flow) at 0 m.

Results are plotted on the chart to the left.

Table 18 - Dripper discharge rate variances based on soil pressure at dripper outlet.
## METRIC CONVERSION FACTORS

Factors for the Conversion of U.S. Customary Units to the International System (SI) of Units

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**WASTEWATER REUSE AND Drip Dispersal Guide**

### Friction Loss Characteristics

**PVC Schedule 40 IPS Plastic Pipe**

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**PSI Loss of 100 Feet of Pipe (psi per 100 feet)**

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**Note:** Shaded areas of the chart indicate velocities over 5 Fps. Use with Caution.

### Velocities are calculated using the Hazen-Williams Equation:

\[ V = 0.4085 \times \left( \frac{Q}{d^2} \right) \]

**Friction Losses are calculated using the Hazen-Williams Equation:**

\[ Hf = 0.2083 \times \left( \frac{100}{C} \right) \times 1.852 \times \left( \frac{Q^1.852}{d^4.866} \right) \]

**C = 150**

**Q = GPM (gallons per minute)**

**d = ID (inside diameter)**

**Flows 1 to 900 GPM**

**Sizes ½" to 6"**
### FRICITION LOSS CHARACTERISTICS

**PVC SCHEDULE 80 IPS PLASTIC PIPE**

\( C = 150 \)

Sizes \( \frac{1}{2}" \) to \( 6" \)

**Flows 1 to 900 GPM**

**Note:** Shaded areas of the chart indicate velocities over 5 ft/sec. Use with caution.

Velocities are calculated using the general equation:

\[ V = (0.4085 \times \frac{Q}{d^2}) \]

Friction Losses are calculated using the Hazen-Williams Equation:

\[ Hf = \frac{0.2083}{C} \times (\frac{100}{C})^{1.852} \times (\frac{Q}{d})^{1.852} \]

\( Q \) is the GPM (gallons per minute)

\( d \) is ID (inside diameter)
Friction Loss Characteristics
PVS Class 315
IPS Plastic Pipe
(1120, 1220)
SDR 13.5
C = 150
Sizes ½" to 6"
Flows 1 to 900 GPM

Friction Loss is calculated using the Hazen-Williams Equation:

\[ Hf = \frac{1}{C^4} \left( \frac{V^2}{2g} \right) \]

where:
- \( Hf \) is the head loss (psi/100 feet)
- \( C \) is the Hazen-Williams coefficient
- \( V \) is the velocity (fps)
- \( g \) is the acceleration due to gravity (32.2 fps²)

Note: Shaded areas of the chart indicate velocities over 5 fps. Use with caution.

Friction Losses are calculated using the general equation:

\[ Hf = 0.2083 \left( \frac{100}{C} \right)^{1.852} \]

with Caution.

Note:
- Shaded areas of the chart indicate velocities over 5 Ft/Sec. Use with caution.
FRICITION LOSS CHARACTERISTICS

PVC CLASS 200

IPS PLASTIC PIPE

(1120, 1220)

SDR 21

C=150

Sizes ¾" to 6"

Flows 1 to 900 GPM

Note: Shaded areas of the chart indicate velocities over 5 Fpsec. Use with Caution.

Velocities are calculated using the general equation:

\[ V = \frac{0.4085 \times Q}{d^2} \]

Friction Losses are calculated using the Hazen-Williams Equation:

\[ Hf = \frac{0.0283 \times 100}{C^1.852 \times d^4.866} \]

\[ \text{Flow} \] \[ \text{GPM} \] \[ \text{Flow} \] \[ \text{GPH} \] \[ \text{Velocity FPS} \] \[ \text{PSI Loss} \] \[ \text{PSI} \] \[ \text{Velocity FPS} \] \[ \text{PSI Loss} \] \[ \text{PSI Loss} \] \[ \text{PSI Loss} \] \[ \text{PSI Loss} \]

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**Flow GPM**

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**PSI Loss**

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**Note:** 30 1,800 8.67 9.97 5.43 3.20 4.14 1.65 2.65 0.56 1.81 0.22 1.22 0.08 0.74 0.02 0.34 0.00 0.22 0.00 0.07 0.00
**WASTEWATER REUSE AND Drip Dispersal Guide**

---

**Friction Loss Characteristics**

**PVC Class 160 IPS Plastic Pipe**

(1120, 1220)

SDR 26

C = 150

**Sizes 1” to 6” Flows 1 to 600 GPM**

---

**Table:**

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**Friction Loss of 100 Feet of Pipe (psi per 100 feet)**

- **Velocity (FPS):**
- **PSI Loss:**
- **Note:** Shaded areas of the chart indicate velocities over 5 Fpsec. Use with caution.

**Friction Losses are calculated using the Hazen-Williams Equation:**

- **H = 0.2083 * (100 / C)**
- **H = 1.852 / d^4.886**
- **V = FPS (feet per second)**
- **Hf = PSI per 100 feet**
- **C = 150**
- **Q = GPM (gallons per minute)**
- **d = ID (inside diameter)**

---

**Note:**

- **Flow:**
- **GPM:**
- **GPH:**
- **Velocity (FPS):**
- **PSI Loss:**

---

**Table:**

| Flow (GPM) | 0.33 | 0.67 | 1.00 | 1.33 | 1.67 | 2.00 | 2.33 | 2.67 | 3.00 | 3.33 | 3.67 | 4.00 | 4.33 | 4.67 | 5.00 | 5.33 | 5.67 | 6.00 | 6.33 | 6.67 | 7.00 |
|------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Velocity (FPS) | 0.00 | 0.04 | 0.09 | 0.14 | 0.19 | 0.24 | 0.29 | 0.34 | 0.39 | 0.44 | 0.49 | 0.54 | 0.59 | 0.64 | 0.69 | 0.74 | 0.79 | 0.84 | 0.89 | 0.94 | 0.99 |
| PSI Loss | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

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**Note:**
WASTEWTATER REUSE AND DRIIP DISPERAL GUIDE

FRICITION LOSS CHARACTERISTICS

PVC CLASS 125 IPS PLASTIC PIPE (1120, 1220) SDR 32.5 C=150

Sizes 1" to 6"

Note: Shaded areas of the chart indicate velocities over 5 fps. Use Caution.

Friction Losses are calculated using the Hazen-Williams Equation:

\[
Hf = 0.2083 \times \left( \frac{100}{C} \right)^{1.852} \times V^2
\]

where:

- \( Hf \) = PSI/100 Ft. (pounds per square inch per 100 feet)
- \( V \) = FPS (feet per second)
- \( C \) = 150

Velocities are calculated using the general equation:

\[
V = \left( \frac{0.4085 \times (Q / d^2)}{1220} \right)^{1/2}
\]

Friction Losses are calculated using the Hazen-Williams Equation:

\[
Friction Loss = \frac{Hf \times L}{100} \times \frac{d^4}{V^4}
\]

where:

- \( Hf \) = PSI/100 Ft. (pounds per square inch per 100 feet)
- \( V \) = FPS (feet per second)
- \( L \) = Length of pipe in feet
- \( d \) = ID (inside diameter)

Note: Flows 1 to 600 GPM

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<td>3.60</td>
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<td>1.23</td>
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<td>1.29</td>
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<td>900</td>
<td>4.12</td>
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<td>16</td>
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<td>0.88</td>
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<td>4.65</td>
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<td>2.50</td>
<td>1.73</td>
<td>1.47</td>
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<td>0.90</td>
<td>0.75</td>
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<td>4.91</td>
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<td>4.00</td>
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<td>1.90</td>
<td>1.66</td>
<td>1.15</td>
<td>0.94</td>
<td>0.80</td>
</tr>
</tbody>
</table>

WATER USE AND DRAINAGE GUIDE

Note: Shaded areas of the chart indicate velocities over 5 fps. Use Caution.

Friction Losses are calculated using the Hazen-Williams Equation:

\[
Hf = 0.2083 \times \left( \frac{100}{C} \right)^{1.852} \times V^2
\]

where:

- \( Hf \) = PSI/100 Ft. (pounds per square inch per 100 feet)
- \( V \) = FPS (feet per second)
- \( C \) = 150

Velocities are calculated using the general equation:

\[
V = \left( \frac{0.4085 \times (Q / d^2)}{1220} \right)^{1/2}
\]

Friction Losses are calculated using the Hazen-Williams Equation:

\[
Friction Loss = \frac{Hf \times L}{100} \times \frac{d^4}{V^4}
\]

where:

- \( Hf \) = PSI/100 Ft. (pounds per square inch per 100 feet)
- \( V \) = FPS (feet per second)
- \( L \) = Length of pipe in feet
- \( d \) = ID (inside diameter)
### Friction Loss Characteristics

**Polyethylene (PE) SDR Pressure Rated Pipe**

- SDR 7, 9, 11.5, 15
- Sizes ½" to 6"
- Flows 1 to 900 GPM
- RATED PIPE

#### General Equation

The Hazen-Williams Equation:

\[
V = \frac{Q^{1.852}}{d^{4.866}}
\]

### PSI Loss of 100 Feet of Pipe (psi per 100 feet)

<table>
<thead>
<tr>
<th>Size</th>
<th>½&quot;</th>
<th>⅜&quot;</th>
<th>¾&quot;</th>
<th>1&quot;</th>
<th>1¼&quot;</th>
<th>1½&quot;</th>
<th>2&quot;</th>
<th>2½&quot;</th>
<th>3&quot;</th>
<th>4&quot;</th>
<th>6&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.D.</td>
<td>0.622&quot;</td>
<td>0.824&quot;</td>
<td>1.049&quot;</td>
<td>1.380&quot;</td>
<td>1.610&quot;</td>
<td>2.067&quot;</td>
<td>2.469&quot;</td>
<td>2.907&quot;</td>
<td>3.408&quot;</td>
<td>4.025&quot;</td>
<td>6.065&quot;</td>
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<tr>
<td>Flow</td>
<td>PSI</td>
<td>PSI</td>
<td>PSI</td>
<td>PSI</td>
<td>PSI</td>
<td>PSI</td>
<td>PSI</td>
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<tr>
<td>Flow</td>
<td>GPM</td>
<td>GPM</td>
<td>GPM</td>
<td>GPM</td>
<td>GPM</td>
<td>GPM</td>
<td>GPM</td>
<td>GPM</td>
<td>GPM</td>
<td>GPM</td>
<td>GPM</td>
</tr>
<tr>
<td>Flow</td>
<td>Velocity FPS</td>
<td>Velocity FPS</td>
<td>Velocity FPS</td>
<td>Velocity FPS</td>
<td>Velocity FPS</td>
<td>Velocity FPS</td>
<td>Velocity FPS</td>
<td>Velocity FPS</td>
<td>Velocity FPS</td>
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<tr>
<td>Flow</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
</tr>
<tr>
<td>Flow</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
<td>PSI Loss</td>
</tr>
</tbody>
</table>

**Note:** Shaded areas of the chart indicate velocities over 5 Ft/sec. Use with Caution.

Velocities are calculated using the general equation:

\[ V = \frac{Q}{d} \]

### Friction Losses are calculated using the Hazen-Williams Equation:

\[ Hf = 0.2083 \left( \frac{100}{C} \right)^{1.852} \]

### Properties

- **Flow**
- **GPM**
- **Velocity FPS**
- **PSI Loss**

**Table Values:**

- **Flow GPM:** 2306, 3206, 3306
- **Flow Velocity FPS:** 13.47, 10.02, 8.04
- **PSI Loss:** 2.36, 2.39, 2.49

**Units:**

- **Flow:** GPM
- **Velocity:** FPS
- **PSI Loss:** psi per 100 feet

**Dimensions:**

- **I.D. (inside diameter):** 0.622" to 6.065"
### Friction Loss Characteristics

#### Schedule 40 Standard Steel

<table>
<thead>
<tr>
<th>PSI Loss of 100 Feet of Pipe (psi per 100 feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SIZE</strong></td>
</tr>
<tr>
<td>I.D.</td>
</tr>
<tr>
<td>O.D.</td>
</tr>
</tbody>
</table>

#### Velocities

- **GPM**: gallons per minute
- **FPS**: feet per second

#### Note:

- Shaded areas of the chart indicate velocities over 5 fps. Use with caution.

#### Velocities are calculated using the general equation:

\[ V = \frac{0.04085 \times Q \times d^2}{C} \]

#### Friction Losses are calculated using the Hazen-Williams Equation:

\[ Hf = 0.2083 \times \left( \frac{100}{C} \right) \times 1.852 \times \left( \frac{Q^2}{1.852} \right) \]

#### Wastewater Reuse and Drip Dispersal Guide

- **d**: inside diameter
- **C**: 100
- **Q**: GPM (gallons per minute)

#### Chart:

- **Note**: shaded areas indicate velocities over 5 fps. Use with caution.

#### Schedule 40:

- **SIZES**: ½" to 6" Flows 1 to 900 GPM
### FRICTION LOSS CHARACTERISTICS

**TYPE K COPPER**

**C = 140**

Sizes ½" to 3"

Flows 1 to 450 GPM

<table>
<thead>
<tr>
<th>SIZE</th>
<th>½&quot;</th>
<th>¾&quot;</th>
<th>1&quot;</th>
<th>1¼&quot;</th>
<th>1½&quot;</th>
<th>2&quot;</th>
<th>2½&quot;</th>
<th>3&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>L.D.</td>
<td>0.527&quot;</td>
<td>0.652&quot;</td>
<td>0.745&quot;</td>
<td>0.995&quot;</td>
<td>1.245&quot;</td>
<td>1.481&quot;</td>
<td>1.959&quot;</td>
<td>2.435&quot;</td>
</tr>
<tr>
<td>O.D.</td>
<td>0.625&quot;</td>
<td>0.750&quot;</td>
<td>0.875&quot;</td>
<td>1.125&quot;</td>
<td>1.375&quot;</td>
<td>1.625&quot;</td>
<td>2.125&quot;</td>
<td>2.625&quot;</td>
</tr>
<tr>
<td>Wall Thk</td>
<td>0.040&quot;</td>
<td>0.049&quot;</td>
<td>0.065&quot;</td>
<td>0.065&quot;</td>
<td>0.072&quot;</td>
<td>0.083&quot;</td>
<td>0.095&quot;</td>
<td>0.109&quot;</td>
</tr>
</tbody>
</table>

---

**Note:** Shaded areas of the chart indicate velocities over 5 ft/Sec. Use with Caution.

Velocities are calculated using the general equation:

\[ V = \sqrt{\frac{Q}{d^4}} \]

Friction Losses are calculated using the Hazen-Williams Equation:

\[ Hf = 0.0283 \times \left( \frac{100}{C} \right) \times 1.852 \times \left( \frac{Q^2}{144 \times d^4} \right) \]

\[ V = \text{FPS (feet per second)} \]

\[ Hf = \text{PSI per 100 Feet} \]

\[ C = \text{140} \]

\[ Q = \text{GPM (gallons per minute)} \]

\[ d = \text{ID (inside diameter)} \]
### Conversion Charts

Multiply Units In Left Column By Conversion Number

#### Length

<table>
<thead>
<tr>
<th>Units</th>
<th>inches</th>
<th>feet</th>
<th>yard</th>
<th>mile</th>
<th>mm</th>
<th>cm</th>
<th>m</th>
<th>km</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Inch</td>
<td>1</td>
<td>0.033</td>
<td>0.027</td>
<td>1</td>
<td></td>
<td>25.4</td>
<td>2.540</td>
<td></td>
</tr>
<tr>
<td>1 Foot</td>
<td>12</td>
<td>1</td>
<td>0.333</td>
<td>1</td>
<td></td>
<td>304.8</td>
<td>30.48</td>
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<tr>
<td>1 Yard</td>
<td>36</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>914.4</td>
<td>91.44</td>
<td>91.44</td>
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<tr>
<td>1 Mile</td>
<td>5280</td>
<td>5.28</td>
<td>1760</td>
<td>1</td>
<td></td>
<td>1609.3</td>
<td>1.609</td>
<td></td>
</tr>
<tr>
<td>1 Millimeter</td>
<td>0.0001</td>
<td>0.0033</td>
<td>0.0109</td>
<td>1</td>
<td>0.100</td>
<td>0.001</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>1 Centimeter</td>
<td>0.3937</td>
<td>0.0328</td>
<td>0.0109</td>
<td>1</td>
<td></td>
<td>0.01</td>
<td>0.01</td>
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</tr>
<tr>
<td>1 Meter</td>
<td>39.37</td>
<td>3.281</td>
<td>1.094</td>
<td>-</td>
<td>1000</td>
<td>100</td>
<td>1</td>
<td>0.001</td>
</tr>
<tr>
<td>1 Kilometer</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1000</td>
<td>1</td>
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#### Weight

<table>
<thead>
<tr>
<th>Units</th>
<th>grain</th>
<th>ounce</th>
<th>pound</th>
<th>ton</th>
<th>gram</th>
<th>kg</th>
<th>metric ton</th>
</tr>
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<tbody>
<tr>
<td>1 Ounce</td>
<td>437.5</td>
<td>1</td>
<td>0.0625</td>
<td>1</td>
<td>28.35</td>
<td>0.0283</td>
<td>-</td>
</tr>
<tr>
<td>1 Pound</td>
<td>7000</td>
<td>16</td>
<td>1</td>
<td>0.0005</td>
<td>453.6</td>
<td>0.4536</td>
<td>-</td>
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<tr>
<td>1 Ton</td>
<td>15,433</td>
<td>32,000</td>
<td>2000</td>
<td>1</td>
<td>907.2</td>
<td>0.9072</td>
<td>-</td>
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<tr>
<td>1 Gram</td>
<td>15.43</td>
<td>0.0328</td>
<td>0.0109</td>
<td>1</td>
<td>0.001</td>
<td>0.001</td>
<td>-</td>
</tr>
<tr>
<td>1 Kilogram</td>
<td>1.00</td>
<td>35.27</td>
<td>2.205</td>
<td>-</td>
<td>1000</td>
<td>1</td>
<td>0.001</td>
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<tr>
<td>1 Metric Ton</td>
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<td>35.274</td>
<td>2.205</td>
<td>1.1023</td>
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#### Density

<table>
<thead>
<tr>
<th>Units</th>
<th>lb/in³</th>
<th>lb/ft³</th>
<th>lb/gal</th>
<th>g/cm³</th>
<th>g/liter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Pound/in³</td>
<td>-</td>
<td>1728</td>
<td>231.0</td>
<td>27.68</td>
<td>27.680</td>
</tr>
<tr>
<td>1 Pound/ft³</td>
<td>-</td>
<td>1</td>
<td>0.1337</td>
<td>0.0160</td>
<td>16.019</td>
</tr>
<tr>
<td>1 Pound/gal</td>
<td>0.00433</td>
<td>7.481</td>
<td>1</td>
<td>0.1198</td>
<td>119.83</td>
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<tr>
<td>1 Gram/cm³</td>
<td>0.0061</td>
<td>62.43</td>
<td>8.345</td>
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<tr>
<td>1 Gram/liter</td>
<td>-</td>
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<td>0.0085</td>
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#### Area

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<thead>
<tr>
<th>Units</th>
<th>inches²</th>
<th>feet²</th>
<th>acre</th>
<th>mile²</th>
<th>cm²</th>
<th>m²</th>
<th>hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Inch²</td>
<td>1</td>
<td>0.0069</td>
<td>-</td>
<td>-</td>
<td>6.452</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1 Foot²</td>
<td>144</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>929.0</td>
<td>0.0929</td>
<td>-</td>
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<tr>
<td>1 Acre</td>
<td>-</td>
<td>-</td>
<td>640</td>
<td>1</td>
<td>4047</td>
<td>0.4047</td>
<td>-</td>
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<tr>
<td>1 Mile²</td>
<td>-</td>
<td>-</td>
<td>640</td>
<td>1</td>
<td>-</td>
<td>259.0</td>
<td>-</td>
</tr>
<tr>
<td>1 Centimeter²</td>
<td>0.1550</td>
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<td>-</td>
<td>-</td>
<td>0.0001</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1 Meter²</td>
<td>1550</td>
<td>10.76</td>
<td>-</td>
<td>1</td>
<td>10000</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1 Hectare</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10,000</td>
<td>-</td>
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</tbody>
</table>

#### Volume

<table>
<thead>
<tr>
<th>Units</th>
<th>inches³</th>
<th>feet³</th>
<th>yards³</th>
<th>cm³</th>
<th>meter³</th>
<th>liter</th>
<th>U.S. Gallon</th>
<th>Imp. Gallon</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Inch³</td>
<td>1</td>
<td>0.0069</td>
<td>-</td>
<td>-</td>
<td>6.452</td>
<td>0.0016</td>
<td>7.481</td>
<td>6.229</td>
</tr>
<tr>
<td>1 Foot³</td>
<td>1728</td>
<td>1</td>
<td>0.0370</td>
<td>28.317</td>
<td>0.0283</td>
<td>28.32</td>
<td>7.481</td>
<td>6.229</td>
</tr>
<tr>
<td>1 Yard³</td>
<td>46.656</td>
<td>1</td>
<td>0.0027</td>
<td>0.7646</td>
<td>0.0016</td>
<td>764.5</td>
<td>202.0</td>
<td>168.2</td>
</tr>
<tr>
<td>1 Centimeter³</td>
<td>0.0610</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.0001</td>
<td>0.001</td>
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<td>0.001</td>
</tr>
<tr>
<td>1 Meter³</td>
<td>1002</td>
<td>1.03</td>
<td>1.308</td>
<td>1000</td>
<td>1.000</td>
<td>999.97</td>
<td>264.2</td>
<td>220.0</td>
</tr>
<tr>
<td>1 Liter</td>
<td>1002</td>
<td>1.03</td>
<td>1.308</td>
<td>1000</td>
<td>1.000</td>
<td>999.97</td>
<td>264.2</td>
<td>220.0</td>
</tr>
<tr>
<td>1 U.S. Gallon</td>
<td>231</td>
<td>0.1337</td>
<td>1.380</td>
<td>178.54</td>
<td>1.000</td>
<td>178.54</td>
<td>1.380</td>
<td>1.380</td>
</tr>
<tr>
<td>1 Imp. Gallon</td>
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<td>0.1605</td>
<td>-</td>
<td>4546.1</td>
<td>-</td>
<td>4546.1</td>
<td>1.201</td>
<td>1.201</td>
</tr>
</tbody>
</table>
**Friction Loss Through Fittings**

| Item          | 1/8" | 1/4" | 1/2" | 3/4" | 1"   | 1 1/4" | 1 1/2" | 2"   | 3"   | 4"   | 6"   | 8"   | 10"  | 12"  | 14"  | 16"  | 18"  | 20"  | 24"  |
|---------------|------|------|------|------|------|--------|--------|------|------|------|------|------|------|------|------|------|------|------|
| Tee Run       | 1.0  | 1.4  | 1.7  | 2.3  | 2.7  | 4.0    | 4.9    | 6.1  | 7.9  | 12.3 | 14.0 | 17.5 | 20.0 | 23.0 | 27.0 | 32.0 | 35.0 | 42.0 |
| Tee Branch    | 3.8  | 4.9  | 6.0  | 7.3  | 8.4  | 12.0   | 14.7   | 16.4 | 22.0 | 32.7 | 49.0 | 57.0 | 67.0 | 78.0 | 88.0 | 107.0 | 118.0 | 137.0 |
| 90˚ Elbow     | 1.5  | 2.0  | 2.5  | 3.8  | 4.0  | 5.7    | 6.9    | 7.9  | 11.4 | 16.7 | 21.0 | 26.0 | 32.0 | 37.0 | 43.0 | 53.0 | 58.0 | 67.0 |
| 45˚ Elbow     | 1.1  | 1.4  | 1.8  | 2.1  | 2.6  | 3.1    | 4.0    | 5.1  | 8.0  | 10.6 | 13.5 | 15.5 | 18.0 | 20.0 | 23.0 | 25.0 | 30.0 |

* Friction loss through fittings is expressed in equivalent feet of the same pipe schedule and size for the system flow rate. Sch40 head loss per 100 feet values are commonly used for other wall thicknesses and standard iron pipe size O.D.s.

**Thermal Expansion**

<table>
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Thermal Expansion (ΔL) of PE Pipe (inches) = 0.3”/100’ per each 1˚C change.

**Contents of a Pipe**

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<tr>
<th>Diameter (inches)</th>
<th>Diameter (feet)</th>
<th>Cubic Feet (231 inches³)</th>
<th>U.S. Gallons (231 inches³)</th>
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CONTENTS OF A PIPE
### Volume of a Pipe

Where

- \( V \) = volume (cubic inches)
- \( \text{ID} \) = inside diameter (inches)
- \( \pi \) = 3.14159
- \( L \) = length of pipe (feet)

\[
V = \pi \times \text{ID}^2 \times L \times 3
\]

### Weight

- 1 U.S. gallon @ 50º F = 8.33 lbs. x specific gravity
- 1 cubic foot = 62.35 lbs. x specific gravity
- 1 cu. ft. of water @ 39.2º F = 62.43 lbs. (39.2º F is water temp. at its greatest density)
- 1 kilogram = 2.2 lbs.
- 1 imperial gallon of water = 10.0 lbs.
- 1 pound = 12 U.S. gal. x by specific gravity
- 1 pound = .016 cu. ft. x by specific gravity

### Velocity

\[
V_{\text{ft./sec.}} = \frac{0.4085 \times \text{Flow (GPM)}}{\text{Pipe I.D. (in)}^2}
\]

\[
V_{\text{m./sec.}} = \frac{1273.24 \times \text{Flow (L/sec)}}{\text{Pipe I.D. (mm)}^2}
\]

### Capacity or Flow

- 1 cu. ft. minute (cfm) = 449 GPM
- 1 cu. ft. second (cfs) = 449 GPM
- 1 acre foot per day = 227 GPM
- 1 acre inch per hour = 454 GPM
- 1 cubic meter per minute = 264.2 GPM
- 1,000,000 gal. per day = 595 GPM

### Slope

\[
S = \frac{\text{Rise}}{\text{Run}}
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### Pressure Loss Through Water Meters (AWWA Standard)

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## Temperature Conversion

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### Temperature Conversion Formulas

- Degrees Centigrade (°C) = \( \frac{5}{9} \times (°F - 32) \)
- Degrees Fahrenheit (°F) = \( \frac{9}{5} \times (°C + 32) \)