Subsurface Drip Distribution System Design

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Designing a Subsurface Drip Dispersal System

- Introduction
  - drip dispersal is a means of applying effluent to the soil for final treatment
  - provides uniform distribution across the soil treatment area
  - allows for dosing and resting of the soil treatment area

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Subsurface Drip Dispersal Systems

- Often allowed at sites that have shallow soils
  - controlled application maximizes effluent contact with the soil
  - ensures that effluent receives treatment before entering the restrictive zone
  - soil matrix forces “pull” water away from the tubing

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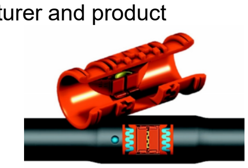
How Does it Work

- Emitters
  - this is the technology that makes these systems **work**
  - pressure compensated
  - about ½ gallon per hour per emitter
    - depending on manufacturer and product



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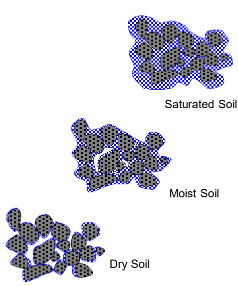
How Does it Work

- Soil moisture tension
  - slow rate of application
  - frequent, low volume doses
  - allows for re-aeration of the soil to maximize decomposition of organic matter



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This Presentation…

- Is about the hydraulic design of drip dispersal systems
  - We are going to focus on
    - determining how much land is needed
    - determining pipe diameters
    - selecting a pump

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Be it known that…

- Many regulatory agencies require that a drip dispersal system must be preceded by aerobic treatment
  - whether aerobic treatment units or packed-bed media filters
- And,
  - that the system must be approved as a package
    - treatment system, tubing, pumps and controls are pre-packaged

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Further…

- Drip systems can be customized for any size wastewater management system and with additional management can handle primary treated effluent

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However, This Presentation…

- Is given because,
  - we need to know how these systems are designed
  - one size does not fit all
- If you are going to install drip systems
  - you really need to know how they operate
  - and there are custom applications ranging from 400 gallons per day and beyond a MGD

Truth in advertising, and this hat does not fit me

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Before We Can Design a Drip System

- We need to know
  - the daily wastewater design volume
  - the strength of the wastewater
  - the hydraulic properties of the soil
- From which
  - we can determine the application rate
- These are same requirements for any other type of land application system
  - for today, we are going to assume these parameters have already been determined

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From the Loading Rate, We Determine the Size of Dispersal Area

- Soil treatment area

$$\frac{Daily\ Wastewater\ Volume\ (gpd)}{Application\ Rate\ \frac{gpd}{ft^2}} = ft^2$$

- Question
  - does your local code require a secondary area for drip dispersal?

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Distance between Laterals and Spacing between Emitters

- How many square feet per emitter?
  - many jurisdictions require one emitter per four square feet
  - tubing (laterals) would be spaced on two-foot intervals
  - emitters on tubing would be spaced every two feet

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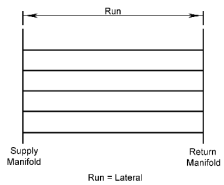
How Will You Supply Effluent to the Tubing?

- Must have a supply manifold
  - to feed effluent to the tubing
- Must have a return manifold
  - to forward flush the tubing
- Nomenclature
  - a “lateral” line carries a flow of water between the two manifolds
  - a “run” is a length of tubing that spans the field



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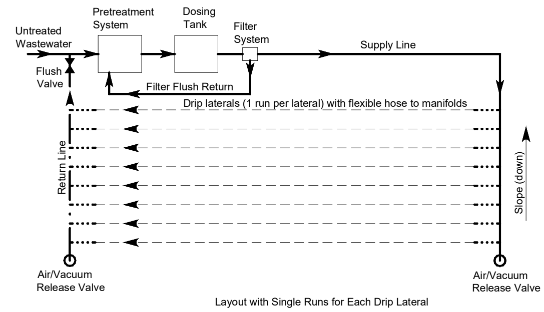
Ladder Layout



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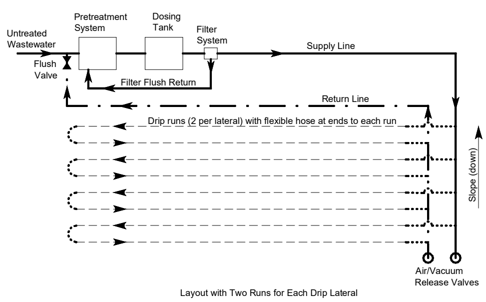
Looped-Back Layout



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Top-Feed Manifolds

- For sites with an observable slope
  - effluent will drain to the lowest point when the pump shuts off
  - a top-feed manifold limits effluent movement to within the individual lateral
  - prevents saturation due to nonsteady state water movement

Manifolds with A/V valves are placed such that water cannot flow to a different lateral

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Connecting the Tubing to the Manifolds

- Use flexible SCH40 pipe to transition from manifold to drip tubing
  - prevents kinks in tubing when the manifold is down below the frost depth and the tubing is higher in the soil profile

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Hydraulic Design of Subsurface Wastewater Drip Systems - Flow

- The hydraulics must match the objectives of the drip system
  - need a wide range of flows
    - normal operation (dosing the fields)
    - have turbulent flow velocity for forward flushing the laterals
    - back flushing the filters

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Hydraulic Design of Subsurface Wastewater Drip Systems - Pressure

- The hydraulics must match the objectives of the drip system
  - need a range of pressures
    - must have 10 – 60 psi at all emitters
      - Assuming pressure compensated emitters
    - must have enough pressure to overcome the headloss of flushing solids back to primary

Sometimes you have to pump effluent to the top of a big hill.

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Wastewater Source

- Elementary school
  - design flow for 2,200 gpd
  - plenty of extra nitrogen
- Recirculation media filter
  - high quality effluent
- UV disinfection

Can you see where the tubing is buried?

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Soil and Wastewater Source

- Initial site investigation
  - soil based application rate
    - 0.2 gpd/ft^2
  - design flow (which includes peaking factors)
    - 2,200 gpd
  - footprint area (A) required:
    - A = 2,200 gpd ÷ 0.2 gpd/ft^2 = 11,000 ft^2

Photo provided by Bruce Lesikar

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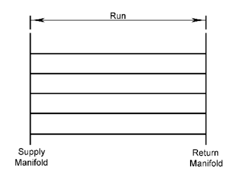
Distributing the Water

- For this example
  - placing drip tubing on 2-ft spacing
  - emitters are spaced 24” on center
  - using the ladder layout
- Selected B&W Drippy Drippers as my tubing
  - P.C. emitters rated at 0.5 gph
  - tubing internal diameter is 0.5 inch



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Tubing and Emitters

- Required length of tubing:
  - dispersal area is 11,000 ft^2
  - tubing placed on 2-ft centers
  - (11,000 ft^2) divided by (2 ft^2 per foot of tubing)
  - 5,500 feet of tubing
- Number of emitters
  - emitter spacing is 24”
  - 5,500 ft tubing ÷ 2 ft/emitter = 2,750 emitters

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Emitter Production and Operation

- Daily volume dosed per emitter:
  - 2,200 gallon per day using 2,750 emitters
    - 0.8 gpd per emitter
  - emitter flow rate is 0.50 gph
    - need emitter to operate 1.6 hours each day
- This is 0.8 gpd emitted over 4 ft^2

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Two Different Loading Rates

- Hydraulic loading rate
  - water applied to soil over time
  - average loading over duration of one day
  - 0.2 gpd/ft^2
- Instantaneous loading rate
  - rate of water application during dose
    - when the system is pressurized
  - emitter rated at 0.5 gph
  - (0.5 gph) divided (4 ft^2) multiplied by (24 hrs/day) is 3 gpd/ft^2

Number of Zones

- If the entire system was dosed at one time, the flow rate would be:

  2,750 emitters x 0.50 gph/emitter x
  1 hr/60 min = 22.9 gpm
- Many jurisdictions requires a minimum of two zones
  - could dose individually or at same time
  - let's go with four zones for this example
  - strongly encouraged to use smaller zones
    - provides some buffer if you need to take a zone out of commission

Layout of Zones

- To help balance the system hydraulically,
  - some designers will adjust pumping rates or lateral lengths to obtain an even number of zones
  - remember, you have various flow requirements
    - dosing
      - based on the number of emitters per zone
    - forward flush (higher flow than dosing one zone)
      - based on achieving 2 fps in laterals plus emitters
    - back flush filters
      - provided by the manufacturer

Layout of Zones

- Having an even number of zones
  - this allows for the same pump (or pumps) to dose two zones simultaneously during normal operation, and then allows for one zone to be flushed

Friction Controls the Lateral Length

- If we do not have site limitations as to lateral length, how far can we move water in drip tubing?
  - for PC drip tubing:
    - try to keep pressure losses less than 10 psi along the lateral length
    - for 1/2-inch diameter tubing, maximum length on contour will be about 300 ft
    - if longer laterals are needed, then use 7/8-inch diameter tubing

I made a Decision

- I want four zones
  - Now recalculate the # of laterals and emitters to match the zones
    - 5,500-ft of tubing ÷ 4 zones = 1,375 feet per zone
    - assume 6 laterals per zone
    - each lateral will be 229 feet long
    - 687 emitters per zone

I made a Decision

- Now I have a flowrate
  - If I operate one zone with 687 emitters
    - the flow rate will be 5.7 gpm (round up to 6 gpm)
  - If I operate two zones at the same time
    - will need 11.5 gpm (round up to 12 gpm)

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Forward Flush Laterals

- Solids will accumulate in the drip tubing
  - open the distal end of the tubing and allow water to flush the solids forward
  - return to primary treatment
- A rule of thumb
  - Scour velocity to be 2 fps
  - At the distal end
  - We need sufficient flow to dose and flush
- Remember
  - 2 fps at distal end means greater velocity at near end

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Flushing Flow

- Flushing flow: Q = VA
  - flushing flow per lateral = velocity x tubing cross-sectional area
    - for this example, the tubing diameter is 1/2-inch

$$2 \text{ fps} \times 60 \text{ s/min} \times (\pi \times (0.50 \text{ in})^2 \div 4) \div 144 \text{ in}^2/\text{ft}^2 \times 7.481 \text{ gal/ft}^3 = 1.22 \text{ gpm/lateral}$$

  - there are 6 laterals per zone
    - flushing flow required per zone is 7.3 gpm (round up to 8 gpm)

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Summary of System Pumping Requirements

- Forward flush per zone
  8 gpm/zone
- Dosing and flushing flow per zone:
  6 gpm + 8 gpm = 14 gpm

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Summary of System Pumping Requirements

- Dosing flow for simultaneously dosing two zones:
  6 gpm x 2 zones = 12 gpm
  - nice balance for the hydraulic system
  - can design for 14 gpm because PC emitters are self limiting
    - however, must confirm that pump will not over pressurize the emitters

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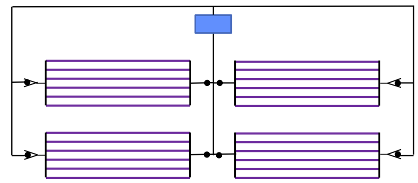
How do you Want to Feed the Zones?

- One larger diameter pipe with valves at each zone?
  - valves and wiring are out in the field



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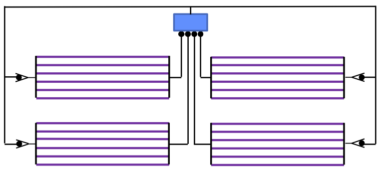
How do you Want to Feed the Zones?

- Four smaller diameter pipes with zone valves at headworks?
  - valves and wiring are protected, but requires more pipe



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Pre-Manufactured Headworks

- Will typically have individual pipes for each zone
  - more pipe
  - less wiring
- Insulate all valve boxes and vaults
- Heater or in heated building

Plug and Play: valves, meter, filters and heater

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Electrical Cautionary Note

- Please,
  - do not install electrical plug and receptacle without a sealed control panel

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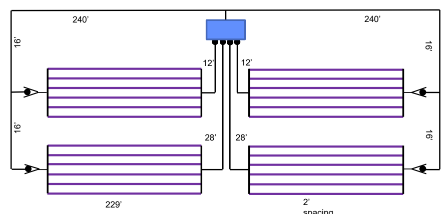
Proposed Layout



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We Need a Pump

- Must have at least two pieces of information to specify a pump
  - flow rate (gallons per minute)
  - pressure (feet of head)
    - 2.31 feet of head per pound per square inch (psi)
- We have our flows,
  - 12 gpm to dose two zones
  - 14 gpm to flush one zone (which includes dose)

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Calculations Needed for Pump Pressure

- Pump Pressure or Total Dynamic Head (TDH)
  - the sum of
    - pressure required at emitters (pressure head)
    - the elevation change (elevation head)
    - pressure drop due to friction (friction head)
  - This is how hard the pump has to work to make the system operational

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Pressure Head

- For most brands of emitters
  - the minimum pressure for PC emitters is about 10 psi
  - the maximum pressure for PC emitter is about 58 psi
  - you must confirm these numbers for the brand of emitters that you are using
- Our goal is to make sure we have a pressure that is within this range
  - along the length of the tubing
  - and in each lateral

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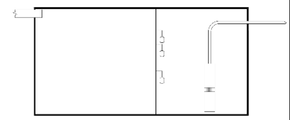
Elevation Head

- For this location,
  - the elevation change from the pump-off float to the drip tubing is 19 ft
    - the low water level in the tank
  - the pump-on float is 15 ft below the drip tubing elevation
    - the high water level



19 feet ÷ 2.31 feet of head per psi = 8 psi

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Friction Losses in Supply and Return Pipes

- The energy needed to overcome the friction of water moving within the system
  - piping system must be preliminarily sized and adjusted as needed
  - target velocity = 2 to 5 fps

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Pipe Hydraulics

- Velocity

  $Q = V \cdot A$

  solve for velocity

  $V = Q/A$

  where

  V is fps

  A is ft^2

  Q is ft^3/sec

- Friction
  - Hazen Williams Equation

$$H_f = \frac{10.44\, Q^{1.85}\, L}{C^{1.85}\, d^{4.87}}$$

where

H_f is friction in feet

Q is gpm

L is pipe length in feet

d is pipe ID in inches

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Pipe Tables Instead of Calculations
Make sure you have the correct pipe standard

Schedule 40 IPS PVC Plastic Pipe — C=150 — ASTM 1120, 1220

Nominal Size	1/2"		3/4"		1"		1-1/4"		1-1/2"		2"		2-1/2"		3"	
Pipe ID	0.622		0.824		1.049		1.380		1.610		2.067		2.469		3.068	
Pipe OD	0.840		1.050		1.315		1.660		1.900		2.375		2.875		3.500	
Wall	0.109		0.113		0.133		0.140		0.145		0.154		0.203		0.216	
Flow GPM	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss	Velocity FPS	PSI Loss
1	1.06	0.43	0.60	0.11	0.37	0.03	0.21	0.01	0.16	0.00	0.10	0.00	0.07	0.00	0.04	0.00
2	2.11	1.55	1.20	0.39	0.74	0.12	0.43	0.03	0.32	0.02	0.19	0.00	0.13	0.00	0.09	0.00
3	3.17	3.28	1.80	0.83	1.11	0.26	0.64	0.07	0.47	0.03	0.29	0.01	0.20	0.00	0.13	0.00
4	4.22	5.59	2.41	1.42	1.48	0.44	0.86	0.12	0.63	0.05	0.38	0.02	0.27	0.01	0.17	0.00
5	5.28	8.45	3.01	2.15	1.86	0.66	1.07	0.17	0.79	0.08	0.48	0.02	0.34	0.01	0.22	0.00
6	6.33	11.84	3.61	3.01	2.23	0.93	1.29	0.25	0.95	0.12	0.57	0.03	0.40	0.01	0.26	0.01
7	7.39	15.75	4.21	4.01	2.60	1.24	1.50	0.33	1.10	0.15	0.67	0.05	0.47	0.02	0.30	0.01
8	8.45	20.17	4.81	5.13	2.97	1.59	1.72	0.42	1.26	0.20	0.76	0.06	0.54	0.02	0.35	0.01
9	9.50	25.09	5.41	6.39	3.34	1.97	1.93	0.52	1.42	0.25	0.86	0.07	0.60	0.03	0.39	0.01
10	10.56	30.50	6.02	7.76	3.71	2.40	2.14	0.63	1.58	0.30	0.96	0.09	0.67	0.04	0.43	0.01
11			6.62	9.26	4.08	2.86	2.36	0.75	1.73	0.36	1.05	0.11	0.74	0.04	0.48	0.02
12			7.22	10.88	4.45	3.36	2.57	0.89	1.89	0.42	1.15	0.12	0.80	0.05	0.52	0.02
13			7.82	12.62	4.83	3.90	2.79	1.03	2.05	0.48	1.24	0.14	0.87	0.06	0.56	0.02
14			8.42	14.48	5.20	4.47	3.00	1.18	2.21	0.56	1.34	0.16	0.94	0.07	0.61	0.02
15			9.02	16.45	5.57	5.08	3.22	1.34	2.36	0.63	1.43	0.19	1.01	0.08	0.65	0.03
16			9.63	18.54	5.94	5.73	3.43	1.51	2.52	0.71	1.53	0.21	1.07	0.09	0.69	0.03
17			10.23	20.74	6.31	6.41	3.65	1.69	2.68	0.80	1.63	0.24	1.14	0.10	0.74	0.03
18			10.83	23.06	6.68	7.12	3.86	1.88	2.84	0.89	1.72	0.26	1.21	0.11	0.78	0.04
19			11.43	25.48	7.05	7.87	4.08	2.07	2.99	0.98	1.82	0.29	1.27	0.12	0.82	0.04
20			12.03	28.02	7.42	8.66	4.29	2.28	3.15	1.08	1.91	0.32	1.34	0.13	0.87	0.05
22					8.17	10.33	4.72	2.72	3.47	1.28	2.10	0.38	1.47	0.16	0.95	0.06
24					8.91	12.13	5.15	3.20	3.78	1.51	2.29	0.45	1.61	0.19	1.04	0.07
25					9.28	13.09	5.36	3.45	3.94	1.63	2.39	0.48	1.68	0.20	1.08	0.07
26							5.58	3.71	4.10	1.75	2.49	0.52	1.74	0.22	1.13	0.08
28							6.01	4.25	4.41	2.01	2.68	0.60	1.88	0.25	1.22	0.09
30							6.43	4.83	4.73	2.28	2.87	0.68	2.01	0.28	1.30	0.10
32							6.86	5.44	5.04	2.57	3.06	0.76	2.14	0.32	1.39	0.11
34							7.29	6.09	5.36	2.88	3.25	0.85	2.28	0.36	1.48	0.12
35							7.51	6.43	5.52	3.04	3.35	0.90	2.35	0.38	1.52	0.13
36							7.72	6.77	5.67	3.20	3.44	0.95	2.41	0.40	1.56	0.14
38							8.15	7.48	5.99	3.54	3.63	1.05	2.55	0.44	1.65	0.15
40							8.58	8.23	6.30	3.89	3.82	1.15	2.68	0.49	1.74	0.17

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Zone Pipe Sizing

- PVC pipes are typically either
  - Schedule 40
  - SDR 21 (Class 200)
- Using data for Sch 40 pipe, the best selection is 1" for 6 and 14 gpm
  - during dose, the velocity would be 2.2 fps, and 0.93 psi headloss per 100'
  - during flush, the velocity would be 5.2 fps, and 4.47 psi headloss per 100' of length

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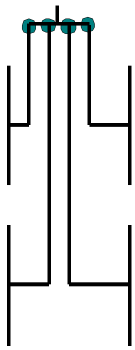
Pipes in Parallel

- Dosing two zones
  - I have parallel pipes carry flow to two zones
  - I don't add the friction in both pipes



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Return Pipe Sizing

- For the return manifold and line:
  - Flushing flow from one zone is 8 gpm
  - 272 feet long
- Using data for Sch 40 pipe,
  - Could use 3/4" diameter (velocity is 5 fps)
  - Could use 1" diameter (velocity is 3 fps)
    - friction: 1.59 psi loss/100 ft
  - Go with 1" diameter
    - already using 1" at beginning of system, less fittings to keep up with

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Friction in Drip Tubing

- Special case (same as the manifolds)
  - water is lost along length of tubing, so the flow of water is reduced along the length, and so is the friction
- And, the emitters
  - act like little bumps inside the tubing, and cause additional friction
- Best to use the manufacturers' information for friction in tubing

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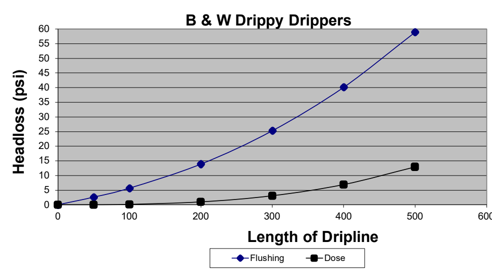
Dripperline Friction



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Friction in Tubing

- Friction losses
  - Dosing: 3 psi for a lateral length of 229 feet
  - Flushing: 17 psi for a lateral length of 229 feet and a flushing velocity of 2 fps
- Minimum pressure for PC emitters
  - 10 psi
- Maximum pressure for PC emitter
  - 58 psi

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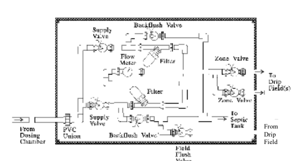
Control System Friction

- Filters, valves and fittings
  - significant source of headloss
  - manufacturer can provide information
    - at 12 gpm, 5 psi friction loss
- Assume
  - dirty filter is 5 psi



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Important Note: Filters

- The most important protection for the emitters
  - disc filters
  - screen filters
- Follow tubing manufacturer's specifications for filtering
  - typically 100-120 micron or 130 mesh

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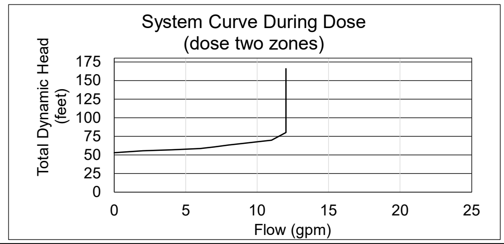
System Curves – Graphic Method

- Demonstrates how system will respond to flow and pressure
  - during dose, the flow is limited by the PC emitters



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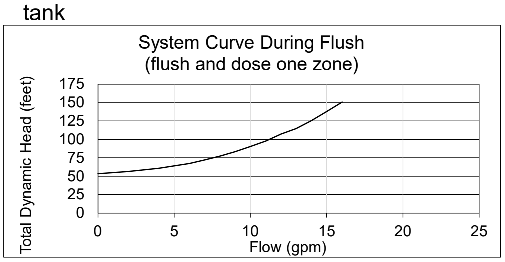
System Curve

- During flush
  - flow is not limited by emitters
  - must be enough flow to get 2 fps and enough pressure to move the solids back to the primary tank



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First Cut at Pump Selection

- Design points
  - dose two zones
    - 12 gpm
    - 81 feet of head
  - flush one zone
    - 14 gpm
    - 126 feet of head
  - Backflush filter
    - 15 gpm
    - 92 feet of head

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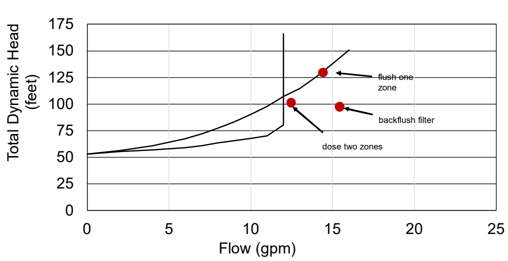
System Curve



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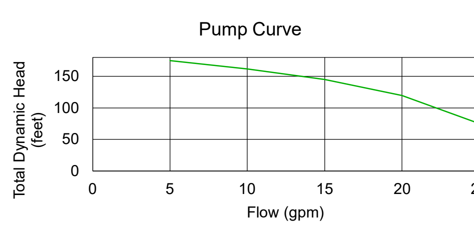
I Found a Potential Pump

- Need to overlay pump curve onto System Curve



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Overlay the Pump and System Curves

- With this pump
  - the system will operate at
    - dose two zones - 12 gpm at 145 feet of head
    - flush one zone at - 16 gpm at 120 feet of head
  - Are these points acceptable?

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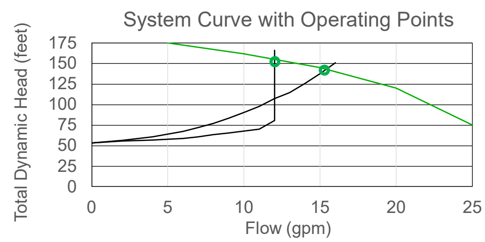
System and Pump Curve



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Pump Provides the Required Pressure and Flow

- Dose two zones
  - 12 gpm at 145 feet of head (63 psi)
  - remember, the upper limit on PC tubing is 58 psi
  - however, the 63 psi is at the pump
- With elevation change and pipe friction
  - the pressure on the first emitters will be about 45 psi with a dirty filter and about 50 psi with a clean filter

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Dosing the System

- Dose duration and volume
  - dose volume must be matched to the soil characteristics
    - prevent excessive saturation and structural damage (favors small doses at a higher number per day)
    - provide sufficient time between doses to disperse the wastewater (favors larger doses at a smaller number per day)
    - minimize drain-back potential (favors larger doses at a smaller number per day)

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Guidelines

- Dose duration and volume
    - clay soils: 6 to 12 minute dose with emitter rates of 0.4 to 0.6 gph. (0.04 to 0.12 gal/emitter/dose)
    - loams and silty soils without significant clay: up to 20 minute dose (up to 0.20 gal/emitter/dose)
    - sandy soils: can be greater than 20 minutes/dose if needed except for coarse sands which should be dosed similar to clays but using closer spacing of emitters and laterals (12" x 12")

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Example Dosing Calculations

- Clay loam:
  - use 10 min/dose
- Volume dosed/cycle
  - pump rate x dosing time
  - 12 gpm x 10 min/dose = 120 gal/dose (two zones dosed per pump cycle)

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Number of Doses

- Doses/day (design flow)
  - design daily flow ÷ gallons per dose = doses per day
  - 2,200 gpd ÷ 120 gallons per dose = 18.33 doses per day (round up to 20)
  - each zone will receive water 20 times per day for 10 minutes
  - the pump will cycle every 72 minutes

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Design, Installation, & Management

- A successful system also depends on:
  - Installation procedures
  - Startup procedures
  - Routine operation and maintenance
  - Troubleshooting
- Professional management is critical for the life of the system
  - Performance depends on the quality of O&M

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Tasks for the Service Provider

- Elapsed time meter readings
  - determine the pump run time
- Pump counter
  - does the water usage correspond to the number of pump cycles
- Check for wet spots and dry spots
  - are we getting uniform distribution
- Measure head during system operation

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Thank You For Attending This Presentation

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