Low-Pressure Dosed Drainfields

Giving the Whole Drainfield a Drink of Effluent

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Low-Pressure Dosed Drainfields

Giving the Whole Drainfield a Drink of Effluent

- Fundamental definition
  - a hydraulic network that uniformly distributes primary-treated effluent across a treatment media
    - using low-pressure distribution system
- Low-Pressure Dosed Drainfields (LPDD)
  - using an LPD to deliver effluent to the drainfield

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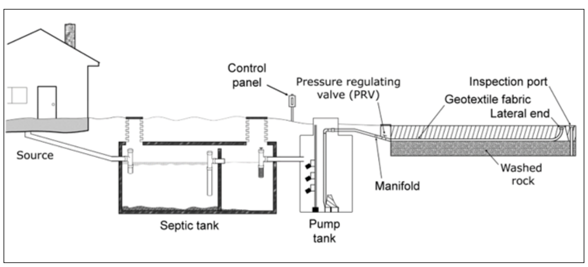
Represents the Final Treatment and Dispersal Component in this System



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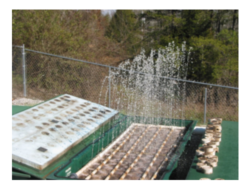
When Using Media for Treatment

- LPD is a very common application method
  - low energy consumption
  - relatively easy to maintain
    - but does require maintenance



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And, with a Low-Pressure Dosed Drainfield

- The soil is the treatment system
  - and we are going to investigate the hydraulic design of a low-pressure dosed drainfield

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Today's Session

- We will focus on
  - why use LPDD
  - the hydraulic design of an LPDD
  - operation and maintenance of an LPDD

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Why Use a Low-Pressurize Dosed Drainfield?

- Takes full advantage of the soil resource
  - especially if that resource is limited
  - the whole length of excavation receives effluent with each dose

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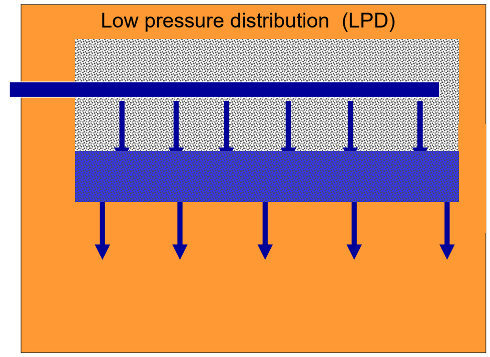

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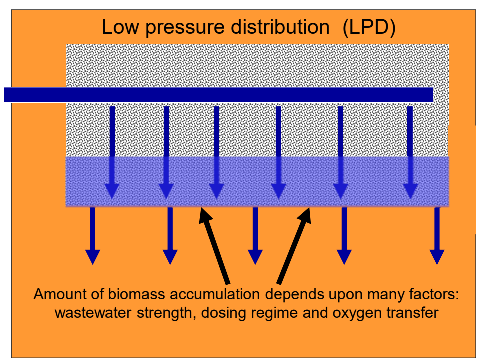

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Potential Issues with LPDD

- Pump and Controls
  - require maintenance and periodic replacement
- Pump Tank
  - would have both a septic tank and a pump tank
- Electrical requirements
  - power consumption is very low
  - but need two circuits from the breaker box

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Hydraulic Design of LPDD

- From the previous section
  - we determined the infiltrative area
  - now we need to design a system that will give that area an uniform dose of effluent
- We need
  - relatively small diameter pipe
    - quick to fill up with effluent
  - relatively small orifices
    - 1/8” to 1/4” diameters

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Low Pressure

- Typical pressure range
  - 3 to 5 feet of water head
  - 1.3 to 2.2 pounds per square inch (psi)
- Remember
  - a column of water that is 2.31 feet tall will have a pressure of 1 pound per square inch on the bottom surface

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Nomenclature

- Components of the distribution system
  - Laterals
    - pipes placed on contour with precision-bored orifices that place effluent in shallow trenches
  - Manifold
    - pipe that supplies effluent to the laterals
  - Supply Mainline
    - provides effluent to manifold

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With an LPD System

- We use that pressure to control the flow rate through an orifice
  - an orifice is a hole that is precision bored into a lateral
  - If the pressure inside the lateral is greater than the pressure outside of the lateral
    - water will flow from the pipe through the orifice

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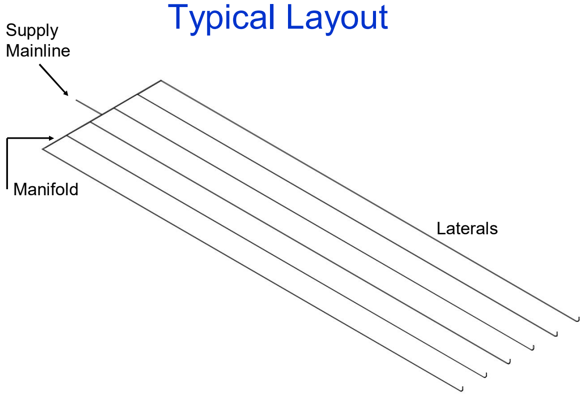
Typical Layout



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Orifice Equation

$$Q = C_d\,A\,\sqrt{2gh}$$

- Q = flow rate in cubic feet per second (ft^3/s)
- C_d = orifice coefficient (usually 0.6) for water
- A = area of orifice in square feet (ft^2)
  Area = $(d^2/4)\pi$ where d is orifice diameter (ft)
- g = gravity 32.2 feet per second squared (ft/s^2)
- h = head (pressure) in feet (ft)

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Using the Orifice Equation

- Example
  - 5/23" hole bored into PVC pipe, pressure inside of pipe is 3 feet of head
- Start with the area
  - need the units to be in ft^2
  - 5/32" diameter is 0.013 feet
  - $\{(0.013)^2\} \div 4 \times 3.14 = 0.00013\ ft^2$

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Using the Orifice Equation

$$Q = C_d\,A\,\sqrt{2gh}$$

- $Q = 0.6 \times 0.00013 \times \sqrt{2 \times 32.2 \times 3}$
- $Q = 0.0011\ ft^3/s$
  - conversions
    - 7.48 gallons per ft^3
    - 60 seconds per minute
- Q = 0.5 gallon per minute (gpm)

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So,

- At 3 feet of head, and a 5/32" diameter orifice
  - we have a flow of 0.5 gpm per orifice
- If we have 18 orifices in one lateral
  - the flow rate at the beginning of the lateral will be 9 gpm
- If we have 5 laterals in our LPD system
  - the pump flow rate will be 45 gpm

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Flow Rates for Various Diameter Orifices and Pressure

Head (ft)	Flow Rate (GPM)				
	Orifice Diameter				
	1/8"	5/32"	3/16"	7/32"	1/4"
1	0.18	0.29	0.42	0.56	0.74
2	0.26	0.41	0.59	0.80	1.04
3	0.32	0.50	0.72	0.98	1.28
4	0.36	0.58	0.83	1.13	1.47
5	0.41	0.64	0.94	1.26	1.64

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Orifice Spacing Along Lateral

- Orifice spacing
  - from 3 to 5 feet apart (5-ft is common)
- Design issue, do not want to flood trench during dose
  - if excavation is 12" wide, 100' long, and the gravel is 12" deep
    - I have approximately 225 gallons of storage per trench
      - assuming 30% porosity

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The Dose Should Last a Minimum Length of Time

- Time with steady-state conditions should be much more significant than time to fill system
  - first orifice gets more water than last
  - minimum dose volume is typically 5 times the volume in the distribution laterals
    - with 500' of 1-1/4"ø pipe, 39 gallons
    - minimum dose is 194 gallons
    - at 45 gpm: need to run for about 4 minutes

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Close Orifice Spacing

- Results in more orifices per lateral
  - greater flow rate per lateral
  - larger diameter laterals
  - bigger pump
  - and may flood the trench during a minimum dose volume
- It is better to have a lower pumping rate and small diameter laterals
  - to let more water soak into the soil between doses

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Orifices Too Close Together

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Now, How are We Going to Determine the Diameter of the Lateral?

- Issue
  - the flow from each orifice needs to be uniform
- Problem
  - due to pipe friction, the pressure changes along the length of pipe
- Consequence
  - if the pressure changes, then the orifice flow will change along the pipe length

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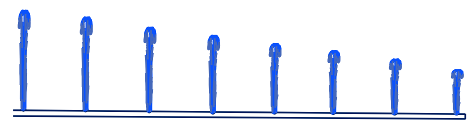
Pipe Friction Effects

- Friction reduces the available pressure
  - resulting in more water produced at pump-end of pipe and less water at distal end



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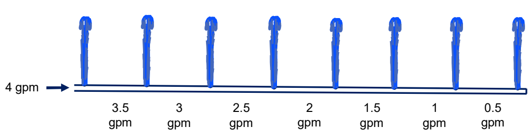
Lateral – Pipe with Orifices

- Need to select a lateral pipe diameter that will produce a very small friction along the length and the pipe must be level
- Remember
  - we are losing water flow along the length



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Hydraulics of Laterals

- Rule of thumb
  - the pressure required to force the water through the orifice should be 10 times greater than the friction in the lateral
    - using 3 feet of head for the operating pressure
    - friction in pipe should be approximately 0.3 feet
  - Goal
    - limit flow variation among orifices to ±10%

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Lateral Design

- Calculating friction in a lateral (or manifold)
  - could use friction headloss equation for each section between orifices and sum the headloss
    - Hazen-Williams equation
    - Darcy-Weisbach equation
    - Scobey equation

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Lateral Design

- Example
  - 90-ft lateral with eighteen, 5/32” dia. orifices on 60” spacing, 1” sch. 40 PVC pipe
    - 1st 5-ft section, 9.0 gpm, 0.23 ft headloss
    - 2nd 5-ft section, 8.5 gpm 0.20 ft
    - 3rd 5-ft section, 8.0 gpm 0.18 ft

⬇

    - 17th 5-ft section, 1.0 gpm 0.00 ft
    - 18th 5-ft section, 0.5 gpm 0.00 ft

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Sum the Headloss in Each Pipe Section

Headloss in this lateral will be 1.55 feet

Orifice #1 will be 0.49 gpm
Orifice #18 will be 0.34 gpm

Variation is greater than 10%

Remember the rule of thumb headloss should be about 0.3 feet

Section	Q	L	Hf (feet)
1	9.0	5	0.23
2	8.5	5	0.20
3	8.0	5	0.18
4	7.5	5	0.16
5	7.0	5	0.14
6	6.5	5	0.12
7	6.0	5	0.11
8	5.5	5	0.09
9	5.0	5	0.08
10	4.5	5	0.06
11	4.0	5	0.05
12	3.5	5	0.04
13	3.0	5	0.03
14	2.5	5	0.02
15	2.0	5	0.01
16	1.5	5	0.01
17	1.0	5	0.00
18	0.5	5	0.00
			1.55

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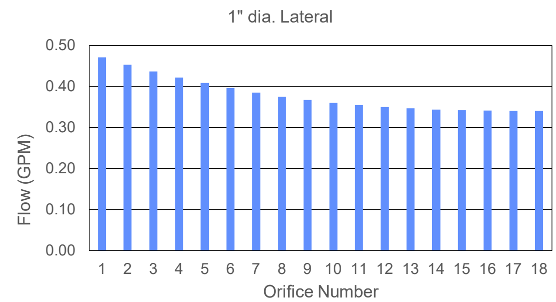
Flow per Orifice along Lateral



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Let's Try a 1-1/4" Diameter Pipe

Headloss will be 0.41 foot in this lateral – much closer to the 0.30 target

Orifice #1 will flow at 0.49 gpm
Orifice #18 will flow at 0.46 gpm

Variation within ±10%

Section	Q	L	Hf (feet)
1	9.0	5	0.06
2	8.5	5	0.05
3	8.0	5	0.05
4	7.5	5	0.04
5	7.0	5	0.04
6	6.5	5	0.03
7	6.0	5	0.03
8	5.5	5	0.02
9	5.0	5	0.02
10	4.5	5	0.02
11	4.0	5	0.01
12	3.5	5	0.01
13	3.0	5	0.01
14	2.5	5	0.01
15	2.0	5	0.00
16	1.5	5	0.00
17	1.0	5	0.00
18	0.5	5	0.00
		sum	0.41

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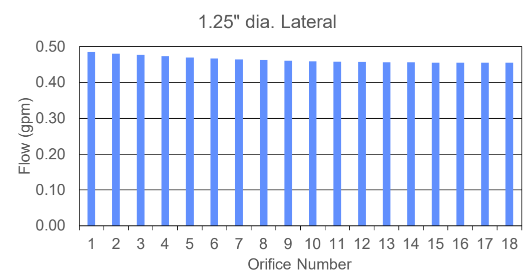
Flow per Orifice along Lateral



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Finally, Try 1-1/2" Diameter Pipe

Headloss will be 0.19 foot in this lateral – much closer to the 0.30 target

Orifice #1 will flow at 0.49 gpm
Orifice #18 will flow at 0.47 gpm

Section	Q	L	Hf (feet)
1	9.0	5	0.03
2	8.5	5	0.03
3	8.0	5	0.02
4	7.5	5	0.02
5	7.0	5	0.02
6	6.5	5	0.02
7	6.0	5	0.01
8	5.5	5	0.01
9	5.0	5	0.01
10	4.5	5	0.01
11	4.0	5	0.01
12	3.5	5	0.00
13	3.0	5	0.00
14	2.5	5	0.00
15	2.0	5	0.00
16	1.5	5	0.00
17	1.0	5	0.00
18	0.5	5	0.00
			0.19

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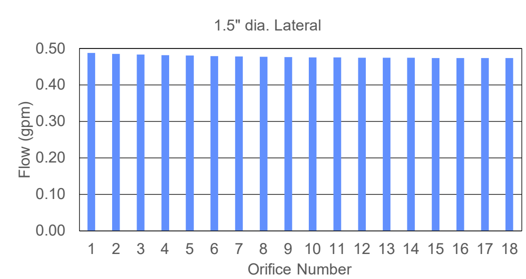
Flow per Orifice along Lateral



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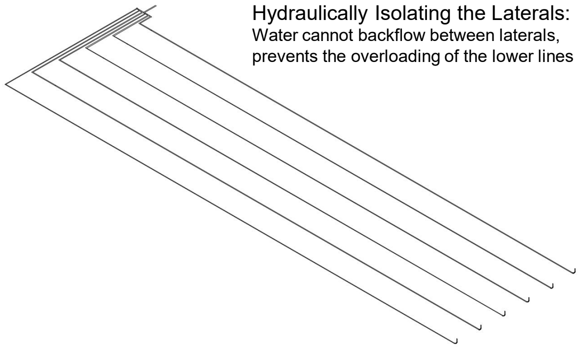
A Better Layout

Hydraulically Isolating the Laterals:
Water cannot backflow between laterals, prevents the overloading of the lower lines



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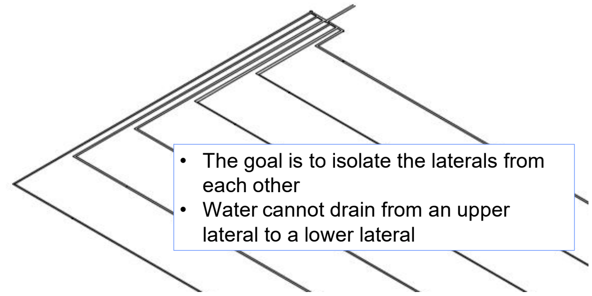
Focus on the Manifold



- The goal is to isolate the laterals from each other
- Water cannot drain from an upper lateral to a lower lateral

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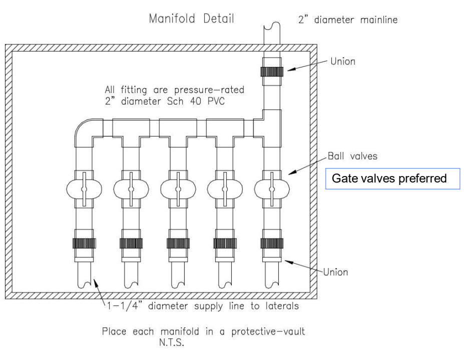
Manifold for Equal Distribution
Accounting for Drainage to Lower Laterals



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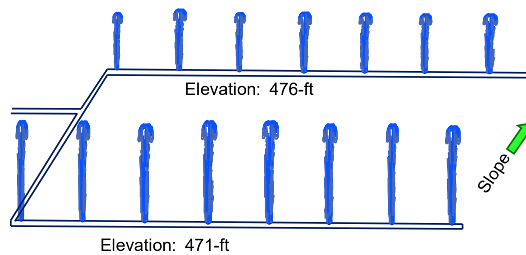
Laterals on Different Elevations

- Elevation affects pressure
  - lower lateral will have greater pressure
  - will produce more water



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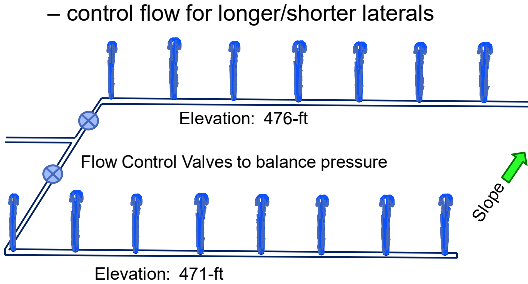
Flow Control Valves

- Valves add resistance
  - reduce pressure on lower laterals
  - control flow for longer/shorter laterals



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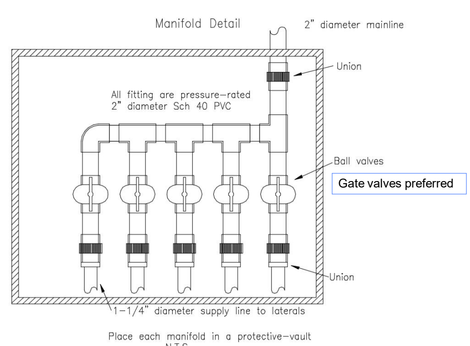
Again, Manifold for Equal Distribution
Accounting for Elevation Change



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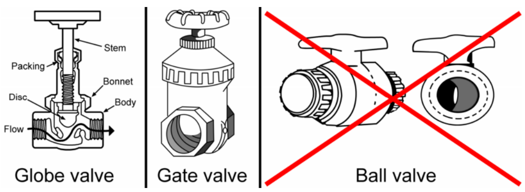
Flow Regulating Valves

- Each one added increases friction loss
- Globe valve is best but most expensive
- Gate valve is better



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Yes, I have used Ball Valves for Flow and Pressure Control

And I regretted it

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Manifold and Mainline Design Example

- If we have six laterals with 18 orifices each
  - and each lateral needs 9 gpm
  - the manifold and mainline will flow 54 gpm
- Pipe sizes
  - try 2”ø sch. 40 PVC
    - at 54 gpm, water velocity is 5.2 fps
  - try 2-1/2”ø sch. 40 PVC
    - at 54 gpm, water velocity is 3.6 fps

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As a Reminder, Water Velocity in Pipes

- Is calculated by
  - Flow (ft^3/s) equals Velocity (fps) time Area (ft^2)

Q = V x A

remember 7.48 gallons per ft^3
60 seconds per minute

- At 54 gpm

2”ø sch. 40 PVC V = 5.16 fps
2-1/2”ø sch. 40 PVC V = 3.6 fps

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Water Velocity in Pipes

- Pipe Tables
  - material
    - PVC Sch. 40
  - diameter
    - nominal and actual
  - flow rate
    - gallons per minute
  - friction loss
    - psi per 100 feet

Schedule 40 IPS PVC Plastic Pipe

Nominal Size	1/2"		3/4"		1"		1-1/4"		1-1/2"	
Pipe ID	0.622		0.824		1.049		1.380		1.610	
Pipe OD	0.840		1.050		1.315		1.660		1.900	
Wall	0.109		0.113		0.133		0.140		0.145	
Flow GPM	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
2	2.11	1.55	1.20	0.39	0.74	0.12	0.43	0.03	0.32	0.02
3	3.17	3.28	1.80	0.83	1.11	0.26	0.64	0.07	0.47	0.03
4	4.22	5.59	2.41	1.42	1.48	0.44	0.86	0.12	0.63	0.05
5	5.28	8.45	3.01	2.15	1.86	0.66	1.07	0.17	0.79	0.08
6	6.33	11.84	3.61	3.01	2.23	0.93	1.29	0.25	0.95	0.12
7	7.39	15.75	4.21	4.01	2.60	1.24	1.50	0.33	1.10	0.15
8	8.45	20.17	4.81	5.13	2.97	1.59	1.72	0.42	1.26	0.20
9	9.50	25.09	5.41	6.39	3.34	1.97	1.93	0.52	1.42	0.25
10	10.56	30.50	6.02	7.76	3.71	2.40	2.14	0.63	1.58	0.30
11			6.62	9.26	4.08	2.86	2.36	0.75	1.73	0.36
12			7.22	10.88	4.45	3.36	2.57	0.89	1.89	0.42
13			7.82	12.62	4.83	3.90	2.79	1.03	2.05	0.48
14			8.42	14.48	5.20	4.47	3.00	1.18	2.21	0.56
15			9.02	16.45	5.57	5.08	3.22	1.34	2.36	0.63
16			9.63	18.54	5.94	5.73	3.43	1.51	2.52	0.71
17			10.23	20.74	6.31	6.41	3.65	1.69	2.68	0.80
18			10.83	23.06	6.68	7.12	3.86	1.88	2.84	0.89
19			11.43	25.48	7.05	7.87	4.08	2.07	2.99	0.98
20			12.03	28.02	7.42	8.66	4.29	2.28	3.15	1.08
22					8.17	10.33	4.72	2.72	3.47	1.28

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Three Pieces of Information

- Determine a pipe diameter
- Determine the friction
- Determine that velocity is greater than the scour velocity

Schedule 40 IPS PVC Plastic Pipe

Nominal Size	1/2"		3/4"		1"		1-1/4"		1-1/2"	
Pipe ID	0.622		0.824		1.049		1.380		1.610	
Pipe OD	0.840		1.050		1.315		1.660		1.900	
Wall	0.109		0.113		0.133		0.140		0.145	
Flow GPM	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
2	2.11	1.55	1.20	0.39	0.74	0.12	0.43	0.03	0.32	0.02
3	3.17	3.28	1.80	0.83	1.11	0.26	0.64	0.07	0.47	0.03
4	4.22	5.59	2.41	1.42	1.48	0.44	0.86	0.12	0.63	0.05
5	5.28	8.45	3.01	2.15	1.86	0.66	1.07	0.17	0.79	0.08
6	6.33	11.84	3.61	3.01	2.23	0.93	1.29	0.25	0.95	0.12
7	7.39	15.75	4.21	4.01	2.60	1.24	1.50	0.33	1.10	0.15
8	8.45	20.17	4.81	5.13	2.97	1.59	1.72	0.42	1.26	0.20
9	9.50	25.09	5.41	6.39	3.34	1.97	1.93	0.52	1.42	0.25
10	10.56	30.50	6.02	7.76	3.71	2.40	2.14	0.63	1.58	0.30
11			6.62	9.26	4.08	2.86	2.36	0.75	1.73	0.36
12			7.22	10.88	4.45	3.36	2.57	0.89	1.89	0.42
13			7.82	12.62	4.83	3.90	2.79	1.03	2.05	0.48
14			8.42	14.48	5.20	4.47	3.00	1.18	2.21	0.56
15			9.02	16.45	5.57	5.08	3.22	1.34	2.36	0.63
16			9.63	18.54	5.94	5.73	3.43	1.51	2.52	0.71
17			10.23	20.74	6.31	6.41	3.65	1.69	2.68	0.80
18			10.83	23.06	6.68	7.12	3.86	1.88	2.84	0.89
19			11.43	25.48	7.05	7.87	4.08	2.07	2.99	0.98
20			12.03	28.02	7.42	8.66	4.29	2.28	3.15	1.08
22					8.17	10.33	4.72	2.72	3.47	1.28

All this information without doing any calculations

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We Still Need to Select

- A pump tank
  - two days of design flow preferred
- A pump
  - low head & high flow
- and Controls
  - timed dosing preferred
  - counters, timers, and elapsed time meters

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Pump Tanks

- Sizing
  - Buchanan’s Rules for pump tank sizing
    - shall contain a full day’s flow between the high-water alarm float and the inlet to the pump tank

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Pump Tank and Floats

- Pump tank should have more than two day’s flow as active volume
  - from top of pump to inlet invert
- If design flow is 300 gpd – then use 1,000 gallon tank
  - 300 gallons of alarm storage
  - 300 gallons of storage for dosing
  - plus enough volume to prevent tank from floating and for keeping pump motor submerged

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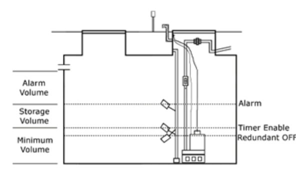
Required Volumes

- Alarm Volume and Storage Volume
  - based on the flow pattern
- Minimum Volume
  - dependent on tank characteristics
  - pump
  - pump discharge assembly



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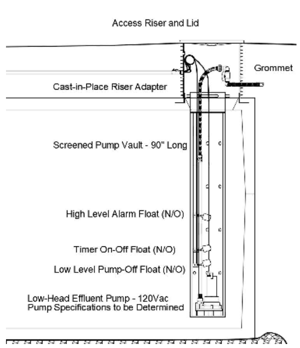
Remember, this is Septic Tank Effluent

- The intake of the pump needs to be off the bottom of the tank
- Recommend
  - a filter vault rather than a concrete block



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Selecting a Pump

- Selecting a pump is the next to last task
  - the last task is the pump controls
- Four design issues for pump selection
  - location
  - pressure
  - flow
  - solids

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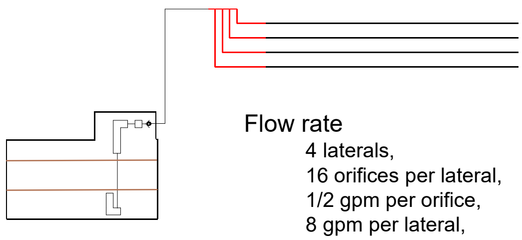
Remember How Flow Rate is Determined



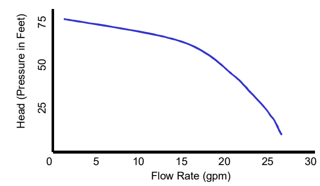
Flow rate

4 laterals,
16 orifices per lateral,
1/2 gpm per orifice,
8 gpm per lateral,
32 gpm total

55

Pump Curve

- All pumps have a curve
  - water pumps
  - air pumps
  - blowers
- Relates the flow rate that can be generated against a known pressure



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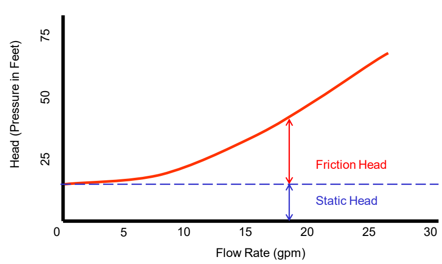
System Curve



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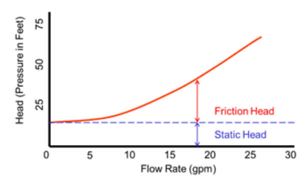
Static Head – Part 1

- Elevation Change
  - from low water level to highest elevation
  - not really static because water level elevation changes
    - must be able to pump water to the greatest difference in elevation



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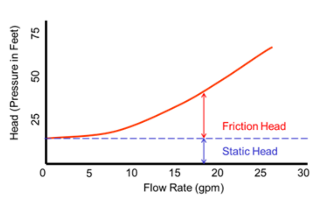
Static Head – Part 2

- Pressure requirement for operation
  - may need 3 to 5 feet of head for orifice flow



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Friction Head

- Friction Components
  - pipe friction
    - related to fluid velocity
    - related to material roughness
  - fittings
    - how much turbulence is created in transition
    - directional changes
  - filters
    - clean filter eventually becomes a dirty filter
- The higher the flow the greater the friction

60

Total Dynamic Head

- Is the combination of…
  - static head
  - friction head
  - this is the pressure that can be measured at the discharge of the pump

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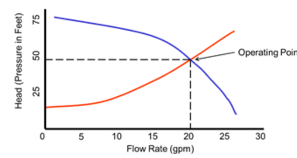
Operating Point

- Point where the
  - Flow and pressure of pump matches the flow and pressure of the system.



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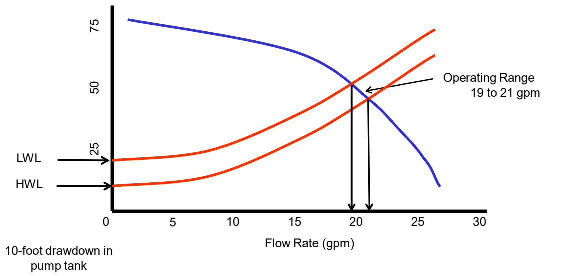
We Really have an Operating Range



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Decision Time

- We need to decide how the LPDD will be operated
  - demand dosed
    - simplest control system
    - be careful not to flood the trenches
  - timed dosed
    - best choice for limited soil conditions
    - limits the volume applied per dose

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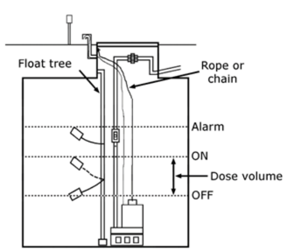
Demand Dosing

- A float turns pump on when volume reaches a predetermined level
- A float turns pump off when liquid level in the tank drops to another predetermined level



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A Piggyback Switch is not a Proper Control

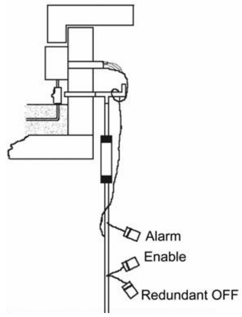
- Most basic form of demand dosing controls
  - Pump plugged into a float-operated, motor-rated switch.
- Upgrade to a control panel
  - strongly recommended

Piggyback switch is okay for a basement sump pump, not an septic system

66

Timed Dosing

- Pump operates for set amount of time at prescribed intervals
- Tank must have adequate storage volume
- If not enough liquid in the tank for a complete dose
  - timer will not activate the pump



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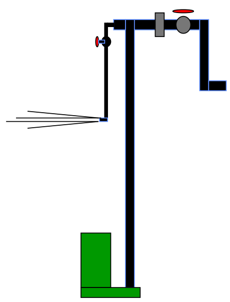
Question

- What the elevation change between the low water level (LWL) and the drainfield?
  - if the drainfield is lower than the LWL
    - need an anti-siphon device
    - siphon affect will pull the tank empty
  - If the drainfield is higher than the LWL
    - need a check valve to prevent backflow
      - by Texas rule, but make sure it will not freeze

68

Anti-Siphon Device

- Use a “tee” at top of standpipe and use smaller diameter pipe and valve to create a controlled leak
- Or
  - just drill a hole in the standpipe
    - hard to fix afterwards



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Installation Considerations

- Use markers to layout the system for the excavator

70

Line up the Orifices along Lateral

- Use a chalk line along the pipe length to mark location of orifices
- Install with orifices facing down
  - by Texas rule

71

Use a Sharp Drill Bit

(and the correct size)

Remove any burrs

But don’t drill all the way through the pipe!!

72

Orifice Shields are Recommended in LPD Systems

- Keep media away from orifice
- Helps to spread effluent
- Follow manufacturer recommendations

73

Excavation

- Understand the moisture content of the soil
  - too wet
    - it will smear the clay
  - too dry
    - it could be too hard to work

The old saying, "dry enough to plow."

74

Lateral Placement

- Typical rule
  - place lateral on at least six inches of media
  - place geotextile fabric on top of media

75

Provide Access to Lateral Clean-Outs

- Use sweep elbows or 2 – 45 degree elbows for lateral turn-ups
  - Allows insertion of plumber' s snake or pressure washer line for cleaning

76

Threaded-End Cap

For pressure measurement and for cleanout

77

Provide Access to all Controls

- Indexing valves
  - this needs service
  - needs to have easy access
- Remember to consider freezing conditions
  - insulate the pit and the cover

78

Additional Access Notes

- Size
  - room enough in riser to manually operate floats
  - don't violate "confined space entry" rules
- Backfill by hand to avoid damage
  - a rock can do a lot of damage to plastic
- Keep relatively plumb
  - certain valves must be level
  - indexing valve must be able to drain between cycles
- Place component in the center and reachable

79

Flow Regulating Valves

- Use PVC pipe sections to allow access to deeper installations

80

Bed Mainline Pipe Beneath the Frost Depth

- Reinforce the mainline where it crosses the pump-tank excavation

81

Upon Start-Up

- Fill the pump tank with Clean Water
  - trust me on this one
- Operate the pumps with the threaded end-caps removed from the laterals
  - flush out soil and debris

82

Balancing the Flow

- Pressure Head
  - use clear PVC or acrylic pipe to build a standpipe that can thread into the turn-up
  - mark the design head on the standpipe with a piece of tape
  - adjust the valves until equal pressure is gained across all laterals

Note: Squirt Height is not the same as Pressure Head

83

Tools to Clean Laterals

Bottle brush w/ plumber or electrician's snake

84

Tools to Clean Laterals

- Pressure washer w/ high pressure nozzle
- Use caution

85

Question

- Do we really want these solids going back into the excavation?
- Or in the yard?
- Could use a poly-hose to pump solids back to septic tank

86

Consider Designing a Solids Return System

- For the most part
  - we are content with flushing the laterals onto the yard
  - but it is certainly not an idea situation
- We could have a return system
  - forward flush the solids to the septic tank

Use Lime to disinfect this material

87

Control Panels for System Management

- Minimum recommendation
  - a start/stop switch or timer must be included in the system to control the dosing pump
  - an audible and visual high water alarm
    - on an electric circuit separate from the pump must be provided

88

Beyond the Alarm

- A control panel should include
  - pump clock
  - elapse time meter
  - event counter

89

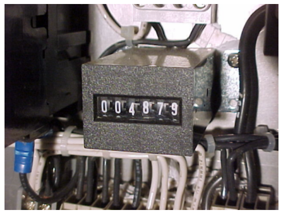
Elapsed Time Meter

- The elapsed time meter reveals the total amount of time that the pump has been running.
  - pump's flow rate multiplied by the elapsed time to determine the total effluent discharged

90

Event Counter

- Event counters will increment each time the pump is turned on
  - determine number of dose between service visits



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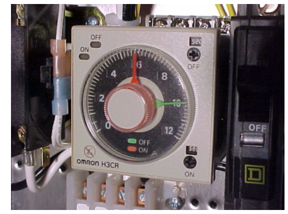
Analogue Programmable Timer

- Mechanical timers and schedulers to control an onsite system.



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Digital Programmable Timer

- Programmable controller
  - can enter parameters on the screen
  - or with laptop computer with appropriate software

93

Why Does My Control Panel Look Scorched?

- Even if the splice box is watertight, it may not be gastight
  - septic tanks can generate corrosive gases
  - corrosive gases can move though the splice box, up the conduit and into the control panel
  - a simple conduit seal can prevent this problem

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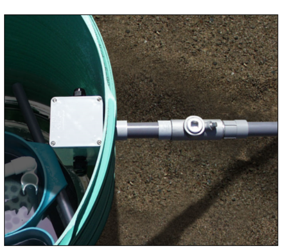
Conduit Seals



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Electrical Connections

96

Not Like This

97

Or Even Like This

- No splices should be open to atmosphere of tank
  - this is not acceptable
  - as a matter of fact
    - it just plain dumb

98

Could Electrocute the Owner

- And yourself

99

Questions

THE UNIVERSITY of TENNESSEE UT
Agricultural Experiment Station

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