Decentralized Wastewater Treatment Systems:
Processes, Design, Management, and Use

Webinar Series Sponsored by the Conservation Technology Information Center, US EPA, and Tetra Tech
Session 3

Decentralized Wastewater System Design: Part 1

Victor D’Amato, Tetra Tech
Decentralized Wastewater Design

• Part 1 – Design Fundamentals
  – Planning and Design Basis
  – Wastewater Characterization
  – Preliminary/Primary Treatment
  – Soil-Based Treatment
  – Distribution Design for Soil Dispersal
Decentralized Wastewater Design

- Part 2 – Advanced Design Topics
  - Pumping Systems
  - Clustered Collection and Treatment
  - Advanced Treatment
  - Repairs, Expansions, and Retrofits
  - Construction Management and Supervision
  - Operation and Maintenance
Planning and Design Basis
Planning Processes

• Preliminary Engineering Review (PER)
  – Requirement for USDA-RUS and other funding
  – RUS Bulletin 1780
    • Project planning area
    • Existing facilities
    • Need for project
    • Alternatives considered
    • Selection of alternative
    • Proposed project
    • Conclusions and recommendations

• Capital Improvement Plan (CIP)
  – Infrastructure/asset management planning medium-long term (1 yr, 5 yr, longer)
System Layout/Architecture

- Centralized systems
- Decentralized systems
  - Individual (onsite/onlot)
  - Cluster
- Distributed management: use and management of systems scaled to match context
System Components

• **Collection/Conveyance** (part 2)
  – Conventional (gravity/lift station)
  – STEP/STEG
  – Pressure Sewer
  – Vacuum Sewer

• **Treatment**
  – Preliminary/Primary (part 1)
  – Secondary (part 2)
  – Advanced/Tertiary (part 2)

• **Product Management**: Effluent, Residuals
  – Discharge vs. soil dispersal vs. reuse
  – Surface vs. subsurface dispersal
  – Gravity vs. pressure distribution
Key References

- State/local regulations
- 10-State Standards ([http://10statesstandards.com/waterstandards.html](http://10statesstandards.com/waterstandards.html))
- *Wastewater Engineering*, Metcalf and Eddy
- *Small and Decentralized Wastewater Management Systems*, Crites and Tchobanoglous
- Water Environment Federation Manuals of Practice (MOPs)
- EPA Manuals ([http://www.epa.gov/nrmrl/pubs/625r00008/html/625R00008.htm](http://www.epa.gov/nrmrl/pubs/625r00008/html/625R00008.htm))
- Decentralized Water Resources Collaborative/WERF project products ([http://www.ndwrcdp.org/](http://www.ndwrcdp.org/))
- Unit converter
Wastewater Characterization
Wastewater Characterization

- Flow, $Q = \text{Volume/time (gal/day)}$
- Strength expressed in concentration, $c \text{ (mg/l)}$
- Mass loading = $Qc \text{ (lbs/day)}$
  - Most meaningful measure
  - Only used to size certain pretreatment units
  - Both flow and strength should be assessed in any system design
  - Flow and strength are functions of the facilities being served

- Mass loading calculation example
  - $Q = 1,200 \text{ gpd}$
  - $c(\text{BOD}_5) = 300 \text{ mg/l}$
  - $\text{BOD}_5 \text{ loading} = 1,200 \text{ gal/day} \times 300 \text{ mg/l} \times 3.9 \text{ l/gal} \times 2.2 \times 10^{-6} \text{ lbs/kg} = 3.1 \text{ lbs/day}$
Wastewater Strength

• Domestic (from *Metcalf and Eddy*)
  – TSS = 120-400 mg/l
  – BOD5 = 110-350 mg/l
  – FOG = 50-100 mg/l
  – TN = 20-70 mg/l
  – TP = 4-12 mg/l
  – Others?

• Institutional (high N?)

• Commercial (high BOD, FOG?)

• Industrial (high metals, toxics?)

• Combinations

• *Sampling raw wastewater, especially from stand-alone facilities is difficult (sample STE if possible)*
Wastewater Strength

CFD for Septic Tank Effluent $BOD_5$ Concentration – This diagram shows, for example, that ~70 percent of the STE $BOD_5$ results reported in the literature for single-source domestic systems are 200 mg/L or less.

Wastewater Flow

- **What basis?**
  - **Peak day (gpd)**
  - Peak month average (gpd)
  - Annual average (gpd)
  - Peak hour (gpm)
- **Prescriptive**: unit flow rates for different facilities
- **Data-driven**: measured flow rates from facility
  - e.g., average of three highest daily flows in peak month
- **Estimating daily design flow can be tricky** – make sure you get this right before proceeding!

### TABLE NO. 1

<table>
<thead>
<tr>
<th>TYPE OF ESTABLISHMENT</th>
<th>DAILY FLOW FOR DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airports (Also R.R. stations, bus terminals -- not including food service facilities)</td>
<td>5 gal/passenger</td>
</tr>
<tr>
<td>Barber Shops</td>
<td>50 gal/chair</td>
</tr>
<tr>
<td>Bars, Cocktail Lounges (Not including food service)</td>
<td>20 gal/seat</td>
</tr>
<tr>
<td>Beauty Shops (Style Shops)</td>
<td>125 gal/chair</td>
</tr>
<tr>
<td>Bowling Lanes</td>
<td>50 gal/lane</td>
</tr>
<tr>
<td>Businesses (other than those listed elsewhere in this table)</td>
<td>25 gal/employee</td>
</tr>
<tr>
<td>Camps</td>
<td>60 gal/person</td>
</tr>
<tr>
<td>Construction or Work Camps</td>
<td>40 gal/person</td>
</tr>
<tr>
<td>(with chemical toilets)</td>
<td>60 gal/person</td>
</tr>
<tr>
<td>Summer Camps</td>
<td>100 gal/campsite</td>
</tr>
<tr>
<td>Campgrounds -- With Comfort Station (Without water and sewer hookups)</td>
<td>120 gal/space</td>
</tr>
<tr>
<td>Travel Trailer/Recreational Vehicle Park (With water and sewer hookups)</td>
<td>3 gal/seat</td>
</tr>
<tr>
<td>Churches (Not including a Kitchen, Food Service Facility, Day Care or Camp)</td>
<td>5 gal/seat</td>
</tr>
<tr>
<td>Churches (With a Kitchen but, not including a Food Service Facility, Day Care, or Camp)</td>
<td>20 gal/member</td>
</tr>
<tr>
<td>Country Clubs</td>
<td>15 gal/person</td>
</tr>
<tr>
<td>Day Care Facilities</td>
<td>25 gal/person/shift</td>
</tr>
<tr>
<td>Factories (Exclusive of industrial waste)</td>
<td>10 gal/person/shift</td>
</tr>
<tr>
<td>Add for showers</td>
<td>40 gal/seat or</td>
</tr>
<tr>
<td>Food Service Facilities</td>
<td>40 gal/15 ft² of</td>
</tr>
<tr>
<td>Restaurants</td>
<td>dining area, whichever is greater</td>
</tr>
<tr>
<td>24-hour Restaurant</td>
<td></td>
</tr>
<tr>
<td>Food Stands</td>
<td></td>
</tr>
<tr>
<td>(1) Per 100 square feet of food stand floor space</td>
<td>50 gal</td>
</tr>
<tr>
<td>(2) Add per food employee</td>
<td>25 gal</td>
</tr>
<tr>
<td>Other Food Service Facilities</td>
<td>5 gal/meal</td>
</tr>
<tr>
<td>Hospitals</td>
<td>300 gal/bed</td>
</tr>
<tr>
<td>Marinas</td>
<td>10 gal/boat slip</td>
</tr>
<tr>
<td>With bathhouse</td>
<td>30 gal/boat slip</td>
</tr>
<tr>
<td>Meat Markets</td>
<td></td>
</tr>
<tr>
<td>(1) Per 100 square feet of market floor space</td>
<td>50 gal</td>
</tr>
<tr>
<td>(2) Add per market employee</td>
<td>25 gal</td>
</tr>
</tbody>
</table>
Wastewater Flow

• Example
  – Summer camp w/250 campers, max., full-service cafeteria, no laundry
  – State rules prescribe:
    • 30 gpd/camper
    • 60 gpd/camper with laundry and food service
    • 5 gal/meal served

• Solution
  – Prescribed unit flow = 30 gpd/camper + (5 g/meal)(3 meal/day-camper) = 45 gpd/camper
  – Design daily flow = 250 campers x 45 gpd/camper = 11,250 gpd
  – Peak month of June 2009 had three max. WW flows of 10,235, 13,794, and 9,650 gpd (average = 11,226 gpd)
  – Retrofit fixtures and monitor
Wastewater Flow

- **Variability**
  - **Hourly**
    - Generally, the fewer facilities, the higher the peaking factor
  - **Daily** – schools, churches, businesses
    - May equalize over 7 days if flow varies across a normal week
  - **Weekly** – for variable use facilities, vacation rentals, etc.
    - Ensure that treatment processes can withstand variable loading or design to address
  - **Seasonal** – for vacation areas
    - Ensure that treatment processes can withstand long periods of inactivity
Preliminary/Primary Treatment
Preliminary/Primary Treatment

• Preliminary treatment
  – Processes that remove materials and objects that may cause O&M problems (e.g., rags, grit, sticks, grease)

• Primary treatment
  – Processes that remove a portion of the suspended solids and organic material

• Typically provided by *septic tanks* and *grease traps* in decentralized systems
  – Conventional screening and grit/grease removal may be provided when extended aeration treatment plants are used for pretreatment
Septic Tank Functions

- **Treatment**
  - Solids removal (60-80%)
  - BOD removal (50-60%)
  - O&G removal (up to 80%)
  - Limited removal of nutrients, pathogens, metals, etc.

- **Storage and digestion of solids/scum**

- **Flow modulation**
- **Conditioning of wastewater for further treatment**
- **Protection of drainfield/downstream components**
- **Advanced pretreatment system component (recirc)**
- **Resource recovery (nutrients, biogas)**
Septic Tank Operational Model

• Mechanically simple, but functionally complex
• Organic molecules are converted into easily degradable sugars and acids (through hydrolysis) followed by further degradation by methane forming organisms
• Distinct layers of settled sludge, a clear zone and floating scum form
• Biogas bubbles rise from the sludge layer to seed the upper layers and disrupt settling
Septic Tank Design

- Sizing typically based on a 1-2 day HRT at design flow (max day)
- Design elements usually prescribed by state or local codes
  - Sizing requirements
  - Compartmentation (baffles)
  - Effluent screening devices
  - Usually standard designs, but engineered units may be used for larger or non-traditional applications
Septic Tank Capacity Calculation

- Use INSIDE dimensions of the tank
- Operating depth is measured from bottom to OUTLET
- Volume = length x width x depth (to the bottom of the outlet)

Example
- \(4' \times 7' \times \left(\frac{60''}{12}\right) = 4' \times 7' \times 5' = 140 \text{ ft}^3\)
- \(140 \text{ ft}^3 \times 7.5 \text{ gal/ft}^3 = 1,050 \text{ gal}\)
- \(1050 \text{ gal} / 60 \text{ inches} = 17.5 \text{ gallons per inch}\)
Septic Tank Design Factors

Septic Tank Sizing

- Size has more of an impact on pumping frequency than settling.
- Larger tanks have higher capital costs but require less frequent pumping and have lower operation and maintenance costs.
- Larger tanks with less frequent pumping may take longer to reach biological maturity but are ultimately more efficient digesters.

Hydraulic Considerations

<table>
<thead>
<tr>
<th>Hydraulic Considerations</th>
<th>Design Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface loading rate</td>
<td>Surface area</td>
</tr>
<tr>
<td>Flow characteristics (short circuiting)</td>
<td>Compartmentation (intercompartment transfer device) Geometry Inlet design</td>
</tr>
<tr>
<td>Exit velocity</td>
<td>Outlet sizing Effluent hydraulic control</td>
</tr>
</tbody>
</table>

(Bounds, 1994)
Septic Tank Design Factors

Geometry

• Shape not as important as L:W, SA and compartmentation

• Compartmentation restricts most digestion to the first compartment and mitigates interferences in the outlet zone

• Connection between compartments likely important, but studies inconclusive

Influent/Effluent Appurtenances

• Effluent screens and baffles help to prevent resuspended and neutral buoyancy solids from entering outlet devices

• Effects of specific devices difficult to isolate in experiments

• Minimal published data on effluent screens (there is an industry testing standard, NSF 46)
Alternative Septic Tank Designs

from: Seabloom, et al. (1982)

from: Waterloo Biofilter (Jowett, 2006)
Grease Interceptors or Traps

- FOG removal from dedicated food service wastewaters
- Two types
  - Large interceptors provide relatively long HRT to cool water and float grease
  - Small undersink traps remove grease using other physical and hydraulic methods
Grease Interceptors or Traps

- Plumbed to only receive food service wastes
- Effluent from grease removal unit is directed to septic tank influent
- Little consensus on sizing and factors affecting performance
- Characteristics (including management and operating practices) of food service facilities are important
- Design elements *may be* prescribed by state or local codes
  - Sizing requirements
  - Compartmentation (baffles)
  - Effluent screening devices
  - Usually standard designs, but engineered units may be used for larger or non-traditional applications
- Need to be maintained!
Tank Materials

- Precast reinforced concrete
  - One-piece vs. two-piece
- Plastic
- Built-in-place
Precast Concrete Tanks

- Reinforcing
- Concrete compressive strength
- Honeycombing
- Uneven joint
- Reinforcing wire exposure
Tank Installation Provisions

- Traffic loading
- Anti-buoyancy
- Excavation and bed prep
- Risers
- Pipe penetrations
- Waterproofing
- Grading/landscaping
Tank Testing

- Strength/structural integrity
- Watertightness

### Hydrostatic Test

<table>
<thead>
<tr>
<th>Standard</th>
<th>Preparation</th>
<th>Pass/fail criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>C 1227, ASTM (1993)</td>
<td>Seal tank, fill with water, and let stand for 24 hours. Refill tank.</td>
<td>Approved if water level is held for 1 hour</td>
</tr>
<tr>
<td></td>
<td>Seal tank, fill with water, and let stand for 8 to 10 hours. Refill tank.</td>
<td>Approved if no further measurable water level drop occurs</td>
</tr>
</tbody>
</table>

### Vacuum Test

<table>
<thead>
<tr>
<th>Standard</th>
<th>Preparation</th>
<th>Pass/fail criterion</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPCA (1998)</td>
<td>Seal tank and apply a vacuum of 2 in. Hg.</td>
<td>Approved if 90% of vacuum is held for 2 minutes.</td>
</tr>
<tr>
<td></td>
<td>Seal tank and apply a vacuum of 4 in. Hg. Hold vacuum for 5 minutes. Bring vacuum back to 4 in. Hg.</td>
<td>Approved if vacuum can be held for 5 minutes without a loss of vacuum.</td>
</tr>
</tbody>
</table>
More Information

• Septic Tanks
  – CIDWT Practitioner Curriculum
    • http://www.onsiteconsortium.org/Ed_curriculum.html
  – D’Amato (2008) *Factors Affecting the Performance of Primary Treatment in Decentralized Wastewater Systems*
    • http://www.ndwrcdp.org/research_project_04-DEC-7.asp
• Grease Interceptors or Traps
  – International Association of Plumbing & Mechanical Officials (IAMPO) Uniform Plumbing Code (UPC)
    • www.iapmo.org
  – Ducoste (2008) *Assessment of Grease Interceptor Performance*
    • http://www.ndwrcdp.org/research_project_03-CTS-16T.asp
Soil-Based Treatment
Soil Treatment Unit

- Treatment via filtration
  - Physical
  - Chemical
  - Biological

- Dispersal into environment
  - Recharge aquifer
  - Restore hydrology
Soil Treatment Unit

• Soil characterization
  – Color (wetness, parent mat'l, organics)
  – Texture (sand, silt, clay)
  – Structure
  – Mineralogy and Consistence

• Soil horizons
  – O = organic layer
  – A = topsoil
  – (E = mineral)
  – B = subsoil
  – C = substratum

• Restrictive horizons
  – Unpermeable clay
  – Bedrock
  – Groundwater table
Soil Treatment Unit

- Landscape position
- Advanced analyses
  - Pits
  - Deep borings
  - Soil wetness/monitoring
  - Saturated hydraulic conductivity measurement ($K_{sat}$)
  - Hydrogeologic evaluation (mounding, lateral flow)
- **Match system to the site!**

(S&W, 1996)
Soil Treatment Unit - Siting

- Allowable (long term) application rate: aerial vs. trench interface basis
  - Soil characteristics
  - Effluent characteristics
  - Dispersal type
- Setback distances (property lines, surface waters, wells, etc.)
  - Soil characteristics
  - Effluent characteristics
  - Dispersal type
- Dispersal depth
- Repair/replacement area allowance
- Flow rate

Example
- LTAR = 0.4 gpd/sf (aerial basis)
- Design flow = 3,000 gpd
- Required drainfield area = 3,000 gpd ÷ 0.4 gpd/sf = 7,500 sf
- Also, need to account for
  - Repair area
  - Setback distances

(a) Every sanitary sewage treatment and disposal system shall be located at least the minimum horizontal distance from the following:

1. Any private water supply source, including any well or spring 100 feet;
2. Any public water supply source 100 feet;
3. Streams classified as WS-I 100 feet;
4. Waters classified as S.A. 100 feet, from mean high water mark;
5. Other coastal waters 50 feet, from
Soil Treatment Unit

• Objectives
  – Aerobic treatment (alternating saturated/unsaturated conditions)
  – Improved treatment by dosing entire drainfield area with relatively small, frequent doses

• Dispersal system architecture
  – Conventional gravel-filled trench
  – Chamber/gravelless
  – Direct dispersal (drip, spray)
  – Bed
  – Considerations
    • Regulatory
    • Application depth
    • Footprint/size
    • Layout options
Distribution Design for Soil Treatment
Distribution System Options

- Gravity/serial distribution
- Gravity/parallel distribution (distribution box)
- Siphon or pump-dosed to gravity-flow drainfield
- Siphon or pump-dosed flow splitter (pressure manifold)
- Pressure dosing (low pressure, drip/spray irrigation)
Distribution System Design

• Orifice Equation (for flow-splitting manifold)

\[ Q = 13d^2 h^{0.5} \]

– Where
  • \( Q \) = flow per orifice (gpm)
  • \( d \) = diameter of orifice (inches)
  • \( h \) = pressure head (feet)
  • For low pressure systems, use 11.79 instead of 13

1 psi = 2.31 ft. water
Flow Splitting Manifolds

- aka, Pressure Manifold
- Used to split flow to gravity distribution lines
- Can use different orifice or tap sizes to achieve different flow rates for lines of different lengths
- Can vary operating pressure head to achieve different flow rates as desired
- Make sure manifold diameter is sufficient to handle flow (see http://www.deh.enr.state.nc.us/osww_new/new1/aidsmainten.htm for resources)

<table>
<thead>
<tr>
<th>Head (ft)</th>
<th>½-inch (6.22)</th>
<th>3/4-inch (8.24)</th>
<th>1-inch (1.049)</th>
<th>1-1/4 inch (1.38)</th>
<th>1-1/2 inch (1.61)</th>
<th>2-inch (2.067)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>6.16</td>
<td>10.8</td>
<td>17.5</td>
<td>30.3</td>
<td>41.3</td>
<td>68.0</td>
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<tr>
<td>2</td>
<td>7.11</td>
<td>12.5</td>
<td>20.2</td>
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<td>2.5</td>
<td>7.95</td>
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<td>22.6</td>
<td>39.1</td>
<td>53.3</td>
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<td>3</td>
<td>8.71</td>
<td>15.3</td>
<td>24.8</td>
<td>42.9</td>
<td>58.4</td>
<td>96.2</td>
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<tr>
<td>3.5</td>
<td>9.41</td>
<td>16.5</td>
<td>26.8</td>
<td>46.3</td>
<td>63.0</td>
<td>104</td>
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<tr>
<td>4</td>
<td>10.1</td>
<td>17.7</td>
<td>28.6</td>
<td>49.5</td>
<td>67.4</td>
<td>111</td>
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</table>

A. Sch 40 taps.

<table>
<thead>
<tr>
<th>Head (ft)</th>
<th>½-inch (5.46)</th>
<th>3/4-inch (7.42)</th>
<th>1-inch (9.57)</th>
<th>1-1/4 inch (1.278)</th>
<th>1-1/2 inch (1.50)</th>
<th>2-inch (1.939)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>4.75</td>
<td>8.77</td>
<td>14.6</td>
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<td>5.48</td>
<td>10.1</td>
<td>16.8</td>
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<td>69.1</td>
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<td>2.5</td>
<td>6.13</td>
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<td>77.3</td>
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<tr>
<td>3</td>
<td>6.71</td>
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<td>23.8</td>
<td>42.5</td>
<td>58.5</td>
<td>97.8</td>
</tr>
</tbody>
</table>

B. Sch 80 taps.
Manifolds for Sloping Site

Plan View

Profile View
Manifolds for Sloping Site

PLAN VIEW

PRESSURE HEAD CHECK
CLEANOUT PLUG
TRUE UNION BALL VALVE
MANIFOLD SCH 80 4"
REDUCER
2" PVC GATE VALVE
IN 2" SCH 40
3" SCH 40 PVC PIPE
PROTECTIVE BOX
INTERNAL VALVE DRAIN
THREADED 1 1/2" SCH 80 TYP. OF 9

OBSERVATION PORT

MONITORING PORT W/ AT-GRADE ACCESS

GRAVITY DRAINLINES ON CONTOUR 9" CENTERS

3" SCH 40 DWV PVC SOLID PIPE TO FIELD LINES 1% SLOPE MIN.

CROSS SECTION

TRUE UNION BALL VALVE

ALUMINUM OR STEEL LOCKABLE HATCH W/ HANDLES 150 LBS MAX.

LOCK CONCRETE BOX

DEAD LEVEL MANIFOLD FROM DOSING TANK

CONCRETE PAD, LEVEL GRAVEL DRAIN DISCHARGE UNDERNEATH

SUPPORT STRAPS AND BLOCKS

NOTE: BOX AND LIDS MUST BE PRE-APPROVED BY THE ENGINEER
Pressure Manifold Design

Example
- Drainfield has three 80’ lines and three 60’ lines
- Design a pressure manifold to load each line equally

Solution
- Flow to 60’ lines will need to be ~ (60/80, or 75%) the flow to 80’ lines
- Select a 2’ pressure head to start and look for appropriate tap sizes
  - ¾” SCH 40 = 12.5 gpm
  - 1” SCH 80 = 16.8 gpm
  - 12.5/16.8 = 74.4%
- Pumping rate = 3(12.5) + 3(16.8) = 88 gpm
Low Pressure Distribution

- aka, Low Pressure Pipe (LPP)
- Used to distribute effluent evenly over an area
- Vary orifice size and spacing, and operating pressure head to achieve different short term loading rates
  - Orifice size = 1/8 – 3/16” typ.
  - Orifice spacing = 1-15’, depending on the application
  - Pressure head = 2-5’ typ.
  - Line spacing = 2-10’
- On sloping sites, may need to compensate for varying pressure head and “drainback” to lower laterals
- Individual trenches and lines need to be installed level to prevent localized overloading
Low Pressure Distribution
# Low Pressure Design

<table>
<thead>
<tr>
<th>Pressure Head (feet)</th>
<th>Drilled Hole Diameter (inches)</th>
<th>Flow Rate (gallons per minute)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3/32*</td>
<td>1/8**</td>
</tr>
<tr>
<td>1</td>
<td>0.10</td>
<td>0.18</td>
</tr>
<tr>
<td>2</td>
<td>0.15</td>
<td>0.26</td>
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<tr>
<td>3</td>
<td>0.18</td>
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<td>0.23</td>
<td>0.41</td>
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<td>6</td>
<td>0.25</td>
<td>0.45</td>
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\[ Q = 11.79d^2h^{0.5} \]
Low Pressure System Design

Example
• Drainfield has four 60’ lines on a sloping site
• Design an LPD system to load each line equally

Solution
• Top line will have lowest pressure, design for min. 2’ PH
• Line 2 = 3’, Line 3 = 4’, Line 4 = 5’ PH
• Use a 5’ spacing of 5/32” holes on Line 1
• Line 1 will have 12 holes (60’/5’) and be loaded at 0.41/hole = 4.92 gpm
• Using 5/32” holes, Line 2 will have an orifice flow of 0.50 gpm
• 4.92 gpm/0.5 gpm = 10 holes
• 60’ line/10 holes = 6’ hole spacing
• And so on for the other lines…
• Can also vary hole size or add separately-valved subfields or zones
• Also need to consider manifold pipe size, lateral size, and dose volume

<table>
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<tr>
<th>Line</th>
<th>Elev.</th>
<th>PH</th>
<th>Q/hole</th>
<th># holes</th>
<th>Hole space</th>
<th>Q/line</th>
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<tbody>
<tr>
<td>1</td>
<td>105’</td>
<td>2’</td>
<td>0.41</td>
<td>12</td>
<td>5.0’</td>
<td>4.92</td>
</tr>
<tr>
<td>2</td>
<td>104’</td>
<td>3’</td>
<td>0.50</td>
<td>10</td>
<td>6.0’</td>
<td>5.00</td>
</tr>
<tr>
<td>3</td>
<td>103’</td>
<td>4’</td>
<td>0.58</td>
<td>8</td>
<td>7.5’</td>
<td>4.64</td>
</tr>
<tr>
<td>4</td>
<td>102’</td>
<td>5’</td>
<td>0.64</td>
<td>7</td>
<td>8.5’</td>
<td>4.48</td>
</tr>
</tbody>
</table>

• Line 1 (top) = 105’ elev
• Line 2 = 104’
• Line 3 = 103’
• Line 4 (bottom) = 102’
Drip/Spray Irrigation

- Used to distribute effluent evenly over an area, at surface or shallow burial depths that intercept root zone.
- Variety of emitter types (or spray patterns), flowrates, spacing to accommodate different applications.
- Many systems have distribution devices (emitters, spray heads) that provide consistent flowrates across a range of operating pressures.
- Dead level placement not as critical.
- Simplified and flexible installation methods.
- Typically requires pretreated effluent.
Spray Irrigation
Drip Irrigation
Drip Irrigation
## Upcoming Webinar Sessions

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<td>Overview of Centralized and Decentralized Treatment</td>
<td>Barry Tonning</td>
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<td>November 15</td>
<td>Decentralized Treatment: Processes &amp; Technologies</td>
<td>Jim Kreissl</td>
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<td>November 22</td>
<td>Focus on Wastewater System Design: Part 1</td>
<td>Vic D’Amato</td>
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<td>November 29</td>
<td>Focus on Wastewater System Design: Part 2</td>
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<td>Management Approaches for Wastewater Systems</td>
<td>Juli Beth Hinds &amp; Khalid Alvi</td>
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<td>December 14</td>
<td>Integrated Water Resource Management</td>
<td>Vic D’Amato</td>
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