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Site Evaluation and Onsite System Design Strategies for Severe Sites/Large Flows

NOWRA
National Onsite Wastewater Recycling Association
P 800.966.2942

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**Evaluate / Review Conventional Loading Rates / Boundary Design

**Design Approaches to Severe Sites, At-Grades / Modified Mounds

**Large Flow Design Considerations

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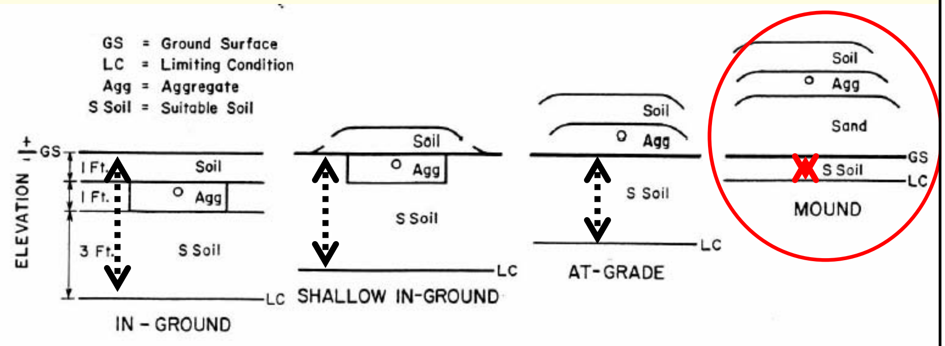

- With numerous Pretreatment and Dispersal Methodologies, separation to limitation and infiltrative surface installation depths maybe be reduced. Loading Rates maybe be increased.
- Soils utilized go from Well Drained to Moderately Well Drained even Somewhat Poorly Drained

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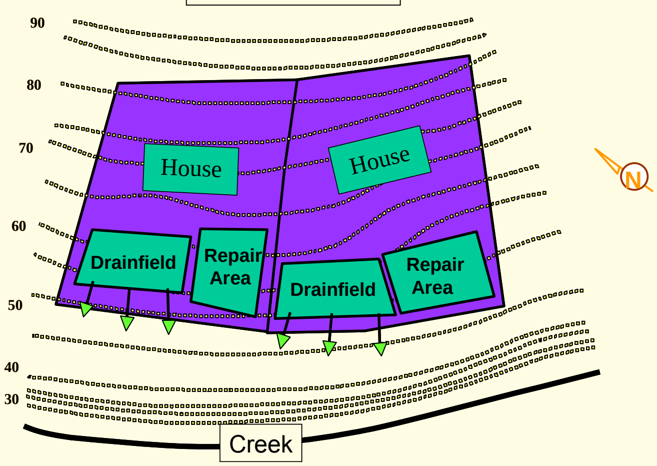
HYDROLOGY OF INDIVIDUAL SEPTIC SYSTEMS

An Aerial View



Two one acre lots, 1000 GPD

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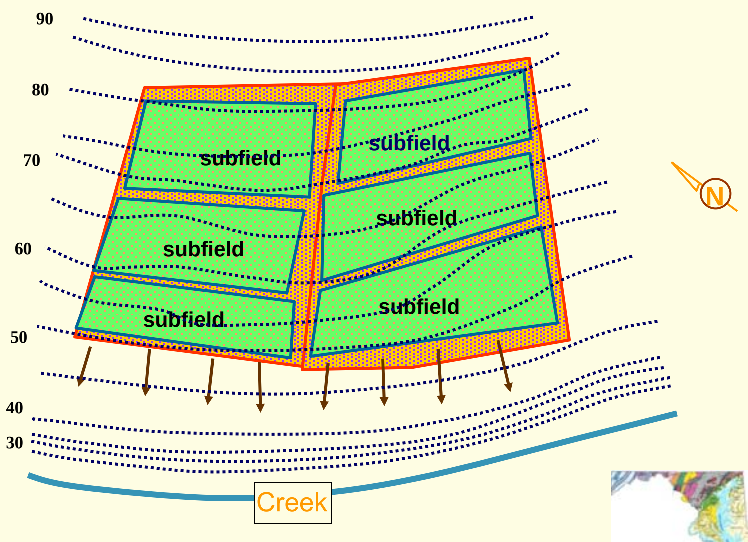
HYDROLOGY OF A LARGE SEPTIC SYSTEM

2 acres, 0.2 gal/(ft^2 d) = 114 in rain/yr or 8700 GPD 100% RESERVE



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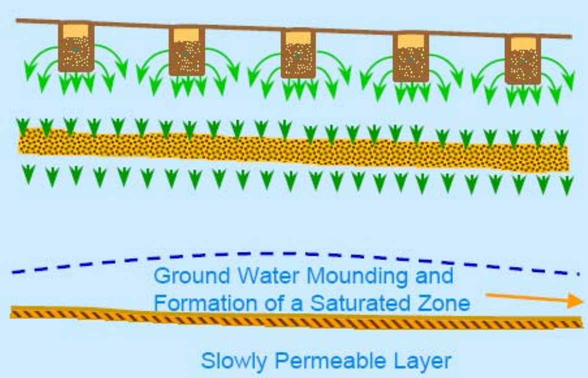
LARGE FLOW SYSTEMS

HYDROLOGY OF A SEPTIC SYSTEM

Infiltration from Trenches

Vertical Movement through the Unsaturated Zone

Lateral Movement in the Saturated Zone



Require extensive site characterization

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Mass Loadings

Table 5-1. Types of mass loadings to subsurface wastewater infiltration systems.

Mass loading type	Units	Typical loading rates
Hydraulic		
• Daily	Volume per day per unit area of boundary surface	Septic tank effluent: 0.15–1.0 gpd/ft² (0.6–4.0 cm/d) Secondary effluent: 0.15–> 2.0 gpd/ft² (0.6–>8.0 cm/d)
• Instantaneous	Volume per dose per unit area of boundary surface	1/24–1/8 of the average daily wastewater volume
• Contour (Linear)	Volume per day per unit length of boundary surface contour (which can be a critical design parameter in areas with high water tables)	Depends on soil K_{sat}*, maximum allowable thickness of saturated zone, and slope of the boundary surface (see section 5.3)
Constituent		
• Organic	Mass of BOD per day per unit area of boundary surface	0.2–5.0 lb BOD/1000 ft² (1.0–29.4 kg BOD/1000 m²)
• Other pollutants	Mass of specific wastewater pollutant of concern per unit area of boundary surface (e.g., number of fecal coliforms, mass of nitrate nitrogen, etc.)	Variable with the constituent, its fate and transport, and the considered risk it imposes

*K_{sat} is the saturated conductivity of the soil.

Source: Otis, 2001.

USEPA Onsite Wastewater Treatment Systems Manual

Hydraulic

*Daily

*Instantaneous

*Contour

On-Site Wastewater Treatment Systems Manual

<u>Chapter 5</u> Treatment Processes and Systems

(U.S. Environmental Protection Agency.

EPA/625/R-00/008 Washington, D.C.: 2002)

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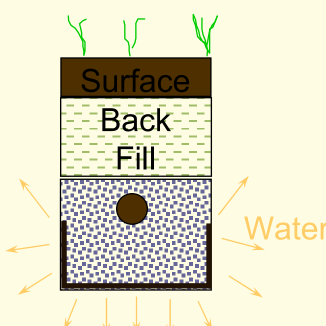
Adsorption Area Sizing

INFILTRATION SURFACE

** Where wastewater first contacts the soil.
** Traditionally (only) regulatory prescriptive loading.
** Physical, chemical, and biological filter (biomat) providing majority of treatment.
** Free water changes from saturated flow to water under tension (unsaturated flow) due to clogging layer (biomat).



Wastewater needs to enter the soil and readily move from point of application

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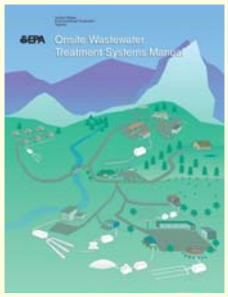
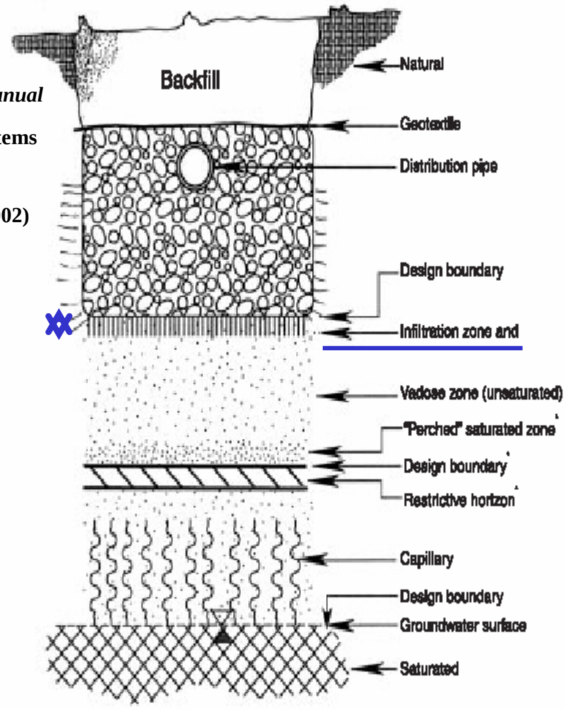
On-Site Wastewater Treatment Systems Manual

<u>Chapter 4</u> Treatment Processes and Systems

(U.S. Environmental Protection Agency.
EPA/625/R-00/008 Washington, D.C.: 2002)

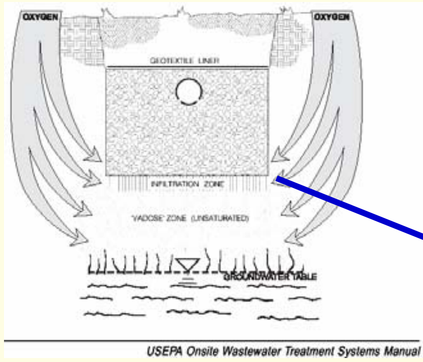




Boundary Design

Wastewater Rates over Time

Initial K_s (clean water)	Wastewater Infiltration Rate			
	1 year	2 years	3 years	4 years
in/day	in/day	in/day	in/day	in/day
453	4.3	2.0	0.8	0.3
22	1.6	0.8	0.5	0.3
7.9	0.8	0.6	0.4	0.3
1.5	0.7	0.4	0.4	0.3



1 In. per Hour= 24" of water / day.

24" X .6233 gal./in. = 14.9 g/ft²/day.

$$\frac{.461 \text{ gal./ft}^2\text{/day}}{14.9 \text{ gal./ft}^2\text{/day}} = .031 \text{ or } 3.1\%$$

Trench bottom loading rate is **3.1%** of saturated rate.

Infiltrative surfaces are loaded at a small percentage of saturated flow (tested or estimated)

7.48 Gal per Ft³ of Water / 12" = .6233 Gal. per inch

Trench Bottom Loading Rates

EPA 2002

Secondary Effluent

Soil Characteristics: Texture	Structure: Shape	Structure: Grade	Infiltration Loading Rate, gal/da/ft²: >30 mg/L	Infiltration Loading Rate, gal/da/ft²: <30 mg/L
COS, S, LCOS, LS	--	0SG	0.8	1.6
FS, VFS,LFS,LVFS	--	0SG	0.4	1.0
CSL, SL	--	0M	0.2	0.6
	PL	1	0.2	0.5
		2, 3	0.0	0.0
	PR/BK /GR	1	0.4	0.7
		2,3	0.6	1.0
FSL, VFSL	--	0M	0.2	0.5
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.2	0.6
		2,3	0.4	0.8
L	--	0M	0.2	0.5
	PL	1,2, 3	0.0	0.0
	PR/BK /GR	1	0.4	0.6
		2, 3	0.6	0.8
SIL	--	0M	0.0	0.2
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.4	0.6
		2,3	0.6	0.8
SCL,CL SICL	--	0M	0.0	0.0
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.2	0.3
		2,3	0.4	0.6
SC, C, SIC	--	0M	0.0	0.0
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.0	0.0
		2,3	0.2	0.3
A	B	C	D	E

2 / 3 Reduction

1 / 3 Reduction

1 / 3 Reduction

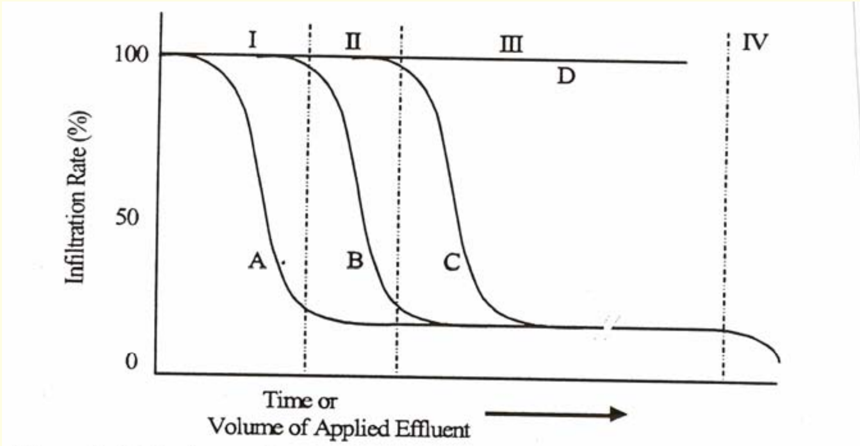
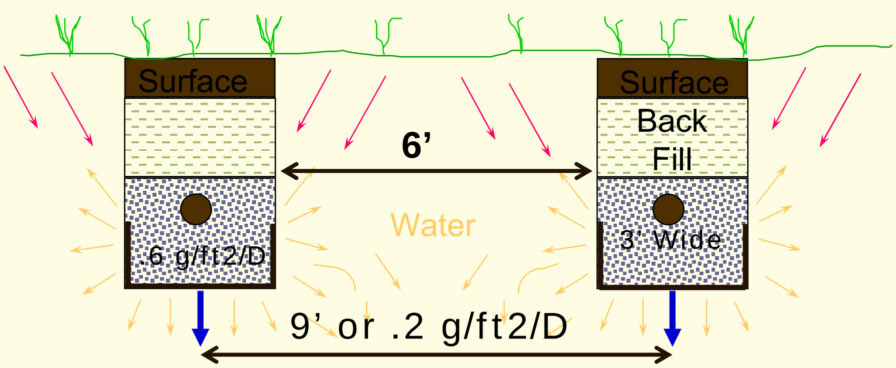


Figure 2. Infiltration vs. Time for Restaurant Effluent (A), Graywater (C), and Tap Water (D). Roman numerals refer to System B phases. (adapted from Siegrist, 1987).

Hydraulic Loading for Soil Absorption Systems based on Wastewater Quality
Ayres Associates
Robert Siegrist
ASAE 1987

Trench Spacing & Area (footprint)



Assume 3' trench, with 9' center

<u>Trenches installed on centers 3X width</u>

AREA (Footprint) LOADING

Soil Characteristics			Infiltration Loading Rate, gal/da/ft²	
Texture	Structure: Shape	Structure: Grade	>30 mg/L	<30 mg/L
COS, S, LCOS, LS	--	0SG	0.8	1.6
FS, VFS,LFS,LVFS	--	0SG	0.4	1.0
CSL, SL	--	0M	0.2	0.6
	PL	1	0.2	0.5
		2, 3	0.0	0.0
	PR/BK /GR	1	0.4	0.7
		2,3	0.6	1.0
FSL, VFSL	--	0M	0.2	0.5
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.2	0.6
		2,3	0.4	0.8
L	--	0M	0.2	0.5
	PL	1,2, 3	0.0	0.0
	PR/BK /GR	1	0.4	0.6
		2, 3	0.6	0.8
SIL	--	0M	0.0	0.2
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.4	0.6
		2,3	0.6	0.8
SCL,CL SICL	--	0M	0.0	0.0
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.2	0.3
		2,3	0.4	0.6
SC, C, SIC	--	0M	0.0	0.0
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.0	0.0
		2,3	0.2	0.3
A	B	C	D	E

EPA Loading Rates

"TYLER" Chart

Soil Characteristics			Infiltration Loading Rate gal/day/ft²	
	Structure		>30 mg/l	<30 mg/l
Texture	Shape	Grade	BOD	BOD
COS, S, LCOS, LS	--	0SG	0.266	.533
FS, VFS, LFS, LVFS	--	0SG	0.133	.33
CLS, SL	--	0M	0.06	0.3
	PL	1	0.06	0.166
		2,3	0.0	0.0
	PR/BK /GR	1	0.133	0.233
		2,3	0.2	.33
FSL, VFSL	--	0M	0.06	0.166
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.06	0.2
		2,3	0.133	0.26
L	--	0M	0.06	0.166
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.133	0.2
		2,3	0.2	0.26
SIL	--	0M	0.0	0.06
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.133	0.2
		2,3	0.2	0.26
SCL, CL, SICL	--	0M	0.0	0.0
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.06	0.1
		2,3	0.133	0.2
SC, C, SIC	--	0M	0.0	0.0
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.0	0.0
		2,3	0.06	0.1

Divide by 3 to get the area or "foot print" loading rate

Soil Group	Texture	MPI	Gal./Ft2/Day Trench Bottom	Area FootPrint Gal./Ft2/Day	Inches Per WeeK
I	SD, LSd	5	0.909	0.303	3.40
II A	SdL	30	0.610	0.203	2.28
II B	L, SdCL	45	0.541	0.180	2.02
III A	SiL, CL	70	0.417	0.139	1.56
III B	CL, SiCl	90	0.352	0.117	1.32
IV	SdC, SiC, C	120	0.219	0.073	0.82
			Gal./Ft2/Day Trench	Gal./Ft2/Day Trench / 3	

Gal. per Ft^2 per day X 7 = Gal. per Ft^2 per Week

Gal. per Ft^2 per Week / .6233 Gal. per inch Ft^3 $H_2$0

7.48 Gal per Ft^3 of Water / 12" = .6233 Gal. per inch

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Loading Rate Chart Gallons per Ft^2 per Day

Soil Characteristics			AREA Loading Rate gal/day/ft^2	
	Structure		>30 mg/l	<30 mg/l
Texture	Shape	Grade	BOD	BOD
COS, S, LCOS, LS	--	0SG	0.26	.53
FS, VFS, LFS, LVFS	--	0SG	0.13	.33
CLS, SL	--	0M	.06	0.2
	PL	1	.06	.16
		2,3	0.0	0.0
	PR/BK /GR	1	.13	0.23
		2,3	.2	.33
FSL, VFSL	--	0M	.06	.16
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	.06	.2
		2,3	.13	.26
L	--	0M	.06	.166
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	.13	.2
		2,3	.2	.26
SIL	--	0M	0.0	0.2
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	.13	.2
		2,3	.2	.26
SCL, CL, SICL	--	0M	0.0	0.0
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	.06	.1
		2,3	.13	.2
SC, C, SIC	--	0M	0.0	0.0
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.0	0.0
		2,3	.06	0.1

600 Gallons per Day

.065 Gal/ Ft^2 per Day

| |

4616 Ft^2 area

Weak Structured Fine Loams

Moderate to Strong structured Clays

.73" per WEEK !!

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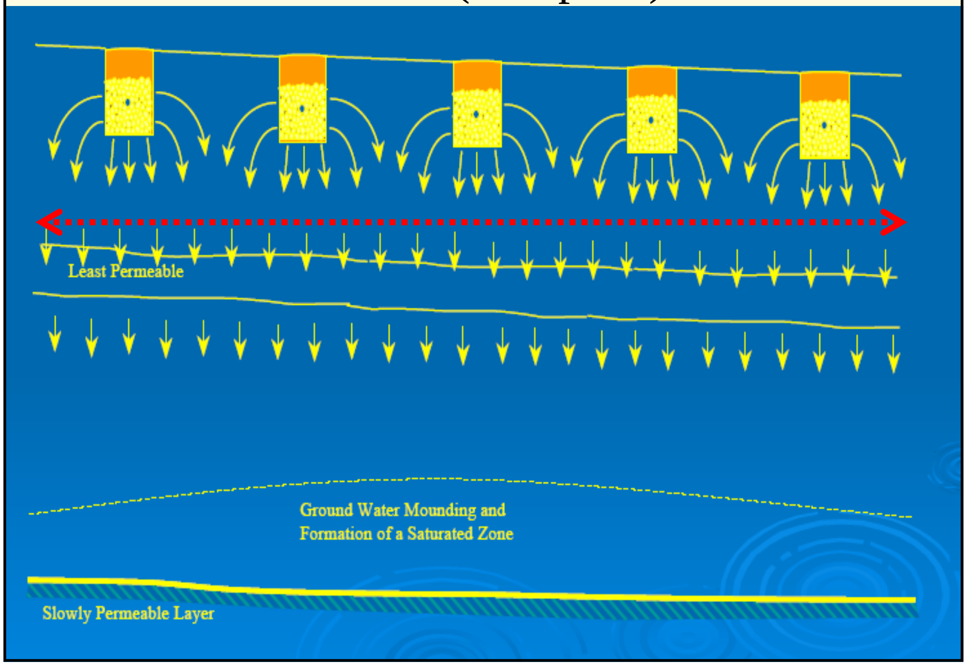
AREA (Footprint) LOADING



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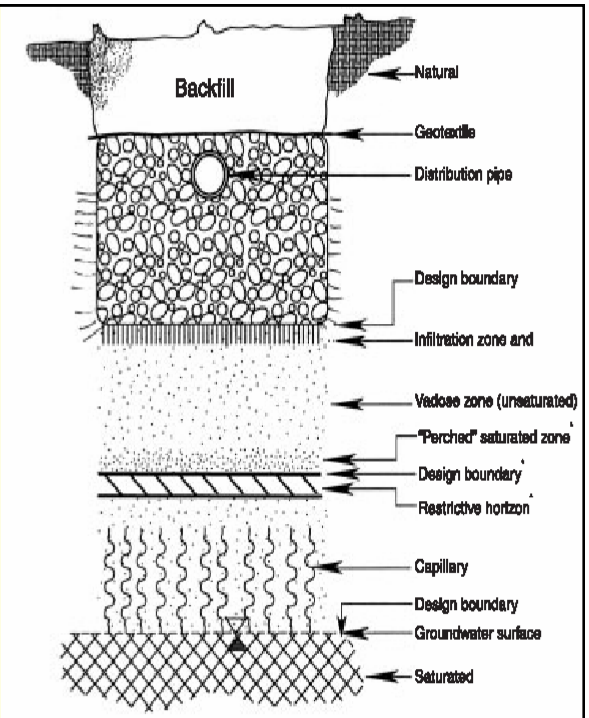
SECONDARY INFILTRATION SURFACES

** Beneath the infiltration surface layer.
** Effluent behaves as water.
** Vadose Zone, small pores filled, large pores open. Reaeration. Additional treatment.
** Additional boundaries due to texture, structure, consistence, restrictions etc. Effecting vertical flow.
** Unsaturated flow within renovative thickness (stand off).

On-Site Wastewater Treatment Systems Manual
Chapter 4 Treatment Processes and Systems
(U.S. Environmental Protection Agency.
EPA/625/R-00/008 Washington, D.C.: 2002)



Mass Loadings

Table 5-1. Types of mass loadings to subsurface wastewater infiltration systems.

Mass loading type	Units	Typical loading rates
Hydraulic		
• Daily	Volume per day per unit area of boundary surface	Septic tank effluent: 0.15–1.0 gpd/ft^2 (0.6–4.0 cm/d) Secondary effluent: 0.15–> 2.0 gpd/ft^2 (0.6–>8.0 cm/d)
• Instantaneous	Volume per dose per unit area of boundary surface	1/24–1/8 of the average daily wastewater volume
• Contour (Linear)	Volume per day per unit length of boundary surface contour (which can be a critical design parameter in areas with high water tables)	Depends on soil K_{sat}*, maximum allowable thickness of saturated zone, and slope of the boundary surface (see section 5.3)
Constituent		
• Organic	Mass of BOD per day per unit area of boundary surface	0.2–5.0 lb BOD/1000 ft^2 (1.0–29.4 kg BOD/1000 m^2)
• Other pollutants	Mass of specific wastewater pollutant of concern per unit area of boundary surface (e.g., number of fecal coliforms, mass of nitrate nitrogen, etc.)	Variable with the constituent, its fate and transport, and the considered risk it imposes

*K_{sat} is the saturated conductivity of the soil.

Source: Otis, 2001.

USEPA Onsite Wastewater Treatment Systems Manual

Hydraulic

*Daily

*Instantaneous

*Contour

Two ways to Achieve Good Treatment

1 Provide light, uniform dosing of the soil
- water infiltrates
- air follows or is there
- adsorbed water has access to air

PRESSURE DOSING and DRIP DISPERSAL

Good Treatment cont.

2 Limit Flow Rate Into Soil

- Forces unsaturated flow
- Air always in soil pores

CLOGGING MAT DOES THIS

- Pressure and soil suction moves water through the mat at a slow rate
  - The "long term acceptance rate"

Advantages of Shallow Systems

- Most biologically active soil
- More sorptive sites encountered
- Better aeration
- More permeable - in finer textured soils

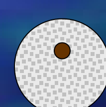
Treatment Effects of Shallow Systems

- More antagonistic to pathogens
- Nitrification
- Increased P-Removal
- More organism trapping
- More flexibility in application rates

TYPES OF SOIL WATER MOVEMENT

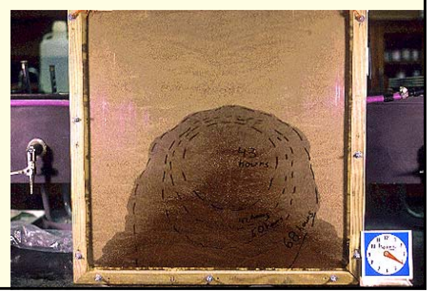
- UNSATURATED FLOW

  rate decreases as moisture content decreases and matric potential (difference in suction between wet soil areas and dry soil areas) decreases



Water Movement Through Soil

- Wet to dry
- From large pores to small pores
  - Capillary Action
- Water moves radially until saturated
- At saturation gravity moves water down



Unsaturated vs. Saturated flow

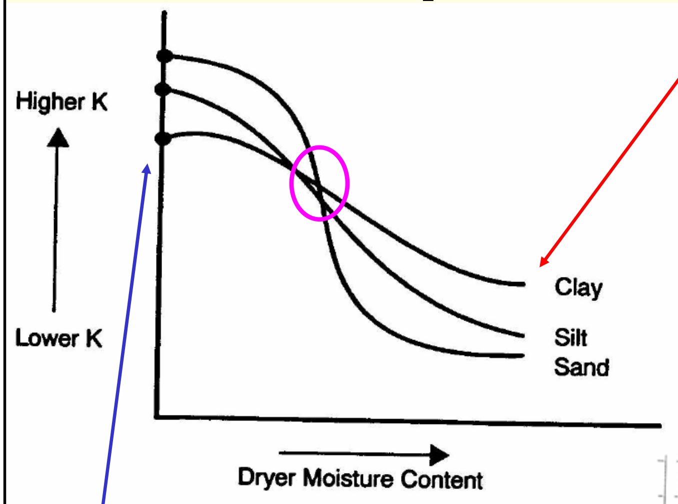
Unsaturated

- Pores: Air available
- Slower: Next to particles
- Aerobic

Saturated

- Pores: Volume filled with water
- Faster: In large pores
- Non aerobic

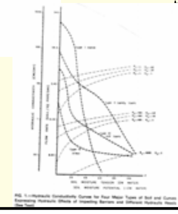
Simplified "Bouma" Curve



Clay has higher "K" at unsaturated flow compare to Sand

Sands are traditionally loaded at a smaller percentage of saturated KSAT than Clays

Clay has lower "K" at saturated flow compare to Sand



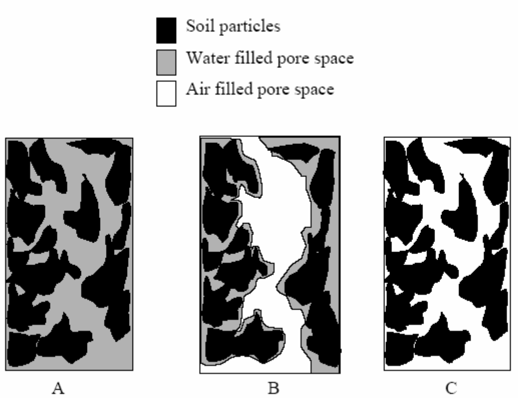


Figure 1. Image A is a soil saturated with water. In example B, the smaller pores are filled with water and the larger pores transport gases via diffusion. Image C is a completely dry soil.

Loading rate, instantaneous: quantity of effluent discharged to a unit area of the infiltrative surface during a dosing event expressed as volume per unit time, e.g., gallons per minute per square foot (gpm/ft^2).

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TABLE 4 ▶ analysis of volume per dose for various hydraulic loading rates and dosing frequencies

HLR, m/d	dosing frequency, doses/d	hydraulic application rate [a], m/dose	field capacity filled [b], percent
0.040	1	0.040	210
	2	0.020	105
	4	0.010	53
	8	0.005	26
	12	0.00333	18
	24	0.00167	9
0.081	1	0.081	426
	2	0.040	210
	4	0.020	105
	8	0.010	53
	12	0.00675	36
	24	0.00338	18
0.163	1	0.163	858
	2	0.082	432
	4	0.041	216
	8	0.020	105
	12	0.014	74
	24	0.00679	36

[a] HAR calculated with equation 1.

[b] Field capacity filled= $\dfrac{\text{HAR}}{\dfrac{\text{field capacity of filter}}{\text{surface area of filter}}}$

where field capacity is defined as (5%) x (total volume of filter) as per Bouwer, 1978, and total volume, surface area, and depth of each filter is 0.431 m^3, 1.13 m^2, and 0.38 m, respectively.

Impact of Bacteria & Dosing Frequency on the Removal of Virus within Intermittently Dosed Biological Filters

Robert Emerick, Ph.D
JaRue Manning, Ph.D
George Tchobanoglous, Ph.D
Jeannie Darby, Ph.D

The higher the loading rate, the more smaller doses per day required to maintain unsaturated conditions, lower field capacity.

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field capacity, in situ (field water capacity) The content of water, on a mass or volume basis, remaining in a soil 2 or 3 days after having been wetted with water and after free drainage is negligible. See also **available water**.

Low Pressure Distribution

Low Pressure Distribution
Dose Volumes

A	B	C	D
X	Lateral Volume Gal./Ft.	2' spacing Dose/orifice (gal.) Pump run (min.)	3' spacing Dose/orifice (gal.) Pump run (min.)
5	.32	.64 g (.88 m)	.96 g (1.31 m)
6	.384	.768 g (1.05 m)	1.152 g (1.58 m)
7	.448	.896 g (1.23 m)	1.344 g (1.84 m)
8	.512	1.024 g (1.4 m)	1.526 g (2.09 m)
9	.576	1.152 g (1.58 m)	1.728 g (2.37 m)
10	.64	1.28 g (1.75 m)	1.92 g (2.63 m)

A Represents times the volume of pipe.
B Volume of pipe does not include manifold. Assume 1.25" laterals, .064 gallons per foot.
C & D based on 7/32" orifice @ 3 foot head.

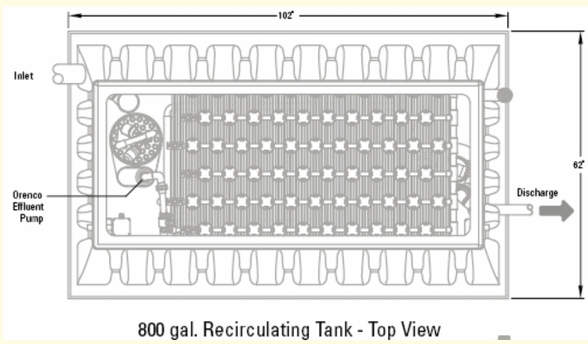
Instantaneous Dose expressed as:

- **gal / orifice per dose**
- **Gal / ft^2 per dose trench bottom**
- **Inches per dose trench bottom**
- **Note delivery time**
- **<u>Typically Less than 2 Doses per Day</u>**

Small

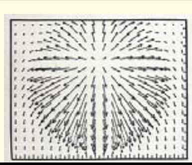
“PACKED BED”

Networks



Drip Dispersal

Volume of Dose	Volume / Emitter / Dose	Dose time in Minutes
3	.078 gal. (10 oz.)	7.7
4	.104 gal. (13 oz.)	10.2
5	.13 gal (17 oz.)	12.8
6	.156 gal. (20 oz.)	15.3
7	.182 gal. (23 oz.)	17.9
8	.208 gal. (26.6 oz.)	20.5



Instantaneous Dose expressed as:

gal / emitter per dose

gal / ft^2 per dose

gal / ft per dose tubing length

Note delivery time

Typically 4+ Doses per day, multiple fields

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DEL VAL 400 GPD .17 GPD per ft2

Reduction of Bacteriologic and Chemical Constituents of Septic Tank Effluent with Depth Using a Drip Dispersal System L.D. Hepner[1] D. Linde[2], C. Weber[3], D. Smith[4] (1 Professor Agronomy & Environ Sci Delaware Valley College, 2 Assoc. Prof Agronomy & Environ Sci Delaware Valley College, 3 Assoc. Prof Chemistry Delaware Valley College, 4 Res. Assoc. Agronomy & Environ Sci Delaware Valley College)

"Abstract. The ability of a moderately well drained soil to treat septic tank wastewater at depths of 1, 2, 3, and 4 feet beneath the surface was evaluated using drip dispersal technology. Three drip dispersal systems of 1200 lineal feet of tubing each were dosed with 400 gpd septic tank treated wastewater (loading rate of 0 .17gpd/ft2.). Zero tension lysimeters were installed at 1, 2, 3, and 4 feet beneath the surface to capture gravity water moving through the soil. Samples were analyzed for Fecal Coliform, Fecal Strep, BOD5, NH3-N, NO3-N, and Soluble P. Median value reductions of 99% for Fecal Coliform, 99% for Fecal Strep, 86% for BOD5, 85% for NH3-N+NO3-N and 90% Soluble P were obtained at the 1 foot lysimeters. ***Based on these trials 1 foot of aerobic soil appeared to provide significant treatment of septic tank wastewater*** when loaded at 0.17gpd/ft2 with a landscape linear load of approximately 6gpd/ft."

Table 2. Descriptive Statistics for Fecal Coliform (colonies/100ml).

	Tank [a]	1ft [b]	2ft [bc]	3ft [bc]	4ft [c]
Sample Num	20	108	93	90	83
Minimum	90	4	4	4	4
1st Quartile	171750	9	4	4	4
Median	2.7E+06	91	91	91	27

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WISCONSIN

SOIL TREATMENT PERFORMANCE AND COLD WEATHER OPERATIONS OF DRIP DISTRIBUTION SYSTEMS, R. M. Bohrer and J. C. Converse, Graduate Research Assistant and Professor, Biological Systems Engineering, College of Agricultural and Life Sciences, University of Wisconsin-Madison WI.

Six systems were studied, three of which were Perc Rite® systems utilizing septic effluent.

Table 4. Median Fecal Coliform Concentrations in Soil Samples in MPN/gram of Dry Soil.

Sample Interval	STE			RGF		
	Barron (Rest Area)	Fond du Lac (Home)	Wood (School)	Monroe (Camp-ground)	Jackson (Home)	Rock (Home)
Soil Surface	1[a]	11	3	1,910	3	1
10 cm (4") Above Dripline	152	1	149	1,337	1	1
Depth Below Dripline						
0-2.5 cm (0-1")	6,567	19	553	3,781	8	1
2.5-15 cm (1-6")	1,806	19	80	164	12	1
15-30 cm (6-12")	2	2	24	1	2	1
30-45 cm (12-18 ")	5	3	84	6	4	1
45-60 cm (18-24")	1	1	9	5	2	1
60-75 cm (24-30")	1	1	1	4	1	2
75-90 cm (30-36")	1	1	1	1	1	1
90-105 cm (36-42")	1	1	1	1	1	1
Effluent (col/100 ml)						
During Soil Sampling[b]	4,100,000	16,000	180,000	870,000	1,100	33
All Samples	380,000	11,000	180,000	52,000	600	37
Soil at Dripline	Coarse Sand	Coarse Sand	Silt Loam	Fine Sand	Sandy Loam	Sandy Loam
Dominant Soil Type	Coarse Sand	Clay Loam	Clay Loam	Fine Sand	Sandy Loam	Sandy Loam

[a]A value of 1 is considered to be below detection limits.
[b]During Soil Sampling: Samples taken at time of soil sampling consisting of the median value of three samples. All Samples: Median value of all samples taken before, during and after soil sampling trips.

Suggests 12" remediation thickness for secondary pretreatment

18" for STE

Column Study VPI & SU

Impact of Pre-Treatment on Domestic Wastewater Renovation as a Function of Soil Depth, C.S. Duncan, R.B. Reneau Jr., C. Hagedorn ASAE 1994

Table 2: The Effect of Influent Type and Soil Depth on Fecal Coliforms in Column Leachate.

Influent type	Soil depth (cm)	Fecal Coliforms (counts/100 mL)
Column influent		
STE	--	35800
CWE	--	3200
RSFE	--	170
Column leachate		
STE	15	910 a*
STE	30	70 b
STE	45	0 b
CWE	15	40 b
CWE	30	0 b
CWE	45	0 b
RSFE	15	0 b
RSFE	30	0 b
RSFE	45	0 b

* means followed by the same letter are not significantly different ($p<0.05$) as determined by Duncan's Multiple Range Test
STE - septic tank effluent
CWE - constructed wetland effluent
RSFE - recirculating sand filter effluent

Dosed six times per day

Columns were loaded at .5 gallons per ft^2 per day and dosed 6 times a day, mimicking dose volume / frequency only achievable as standard practice with drip dispersal.

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MASS ALTERNATIVE SEPTIC SYSTEM TEST CENTER

Emerging Substances of Concern

- Persistent, Bioaccumulative and Toxic
- Global Organic Contaminants
- Pharmaceuticals and Personal Care Products
- Endocrine Disrupting Chemicals
- Nanoparticles

Testing Beginning September 2010

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Three Replicates each

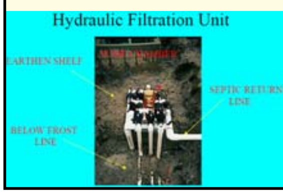
**STE

**STE w/ air

One Control

EPA Method 1694: Pharmaceuticals and Personal Care Products in Water, Soil, Sediment, and Biosolids by HPLC/MS/MS

December 2007



American Onsite

GEOMATRIX

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Buzzards Bay National Estuary Program

Each of 7 cells 5’ x 35’

C-33 Sand, 12” remediation thickness

Area Loading .74 Gal/Ft^2/Day

Linear Loading .49 Gal/Lin. Ft/Day

.06 Gallons per Emitter per Dose

Additional testing for N, P, BOD^5, Fecals

Flow equalization: system configuration that includes sufficient effluent storage capacity to allow for uniform flow to a subsequent component despite variable flow from the source; *see also* **dosing, timed.**

Decentralized Wastewater Glossary

Compiled by

The Consortium of Institutes for Decentralized Wastewater Treatment

CIDWT

2007

KEYWORDS

Variable Source (in) Flow

Sufficient Effluent Storage

Uniform (out) Flow to a Component

Tank, flow equalization: dosing tank that provides storage of effluent and uses timed-dosing to allow for uniform delivery to a subsequent component over time, usually a day or more; *also known as a* surge tank.

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CIDWT Glossary 2007

Dosing, timed: configuration in which a specific volume of effluent is delivered to a component based upon a prescribed interval, regardless of facility water use; *see also* **flow equalization**.

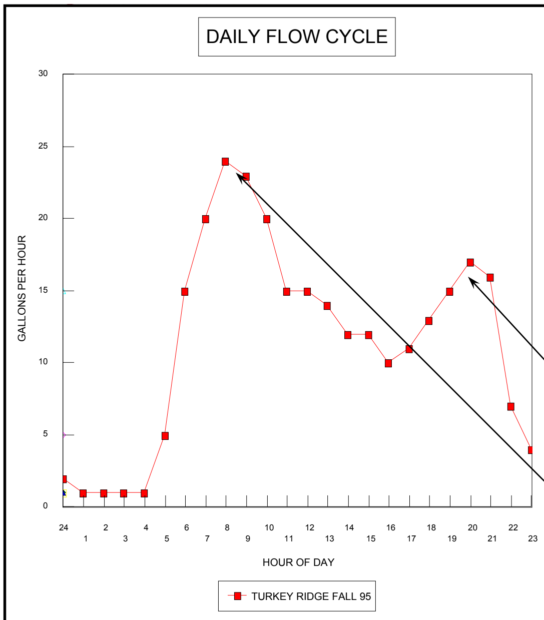
Controlled Delivery to downstream treatment component.

** Mechanical Pretreatment

** Soil based Infiltration

** Discharge

Loading rate, instantaneous: quantity of effluent discharged to a unit area of the infiltrative surface during a dosing event expressed as volume per unit time, e.g., gallons per minute per square foot (gpm/ft^2).

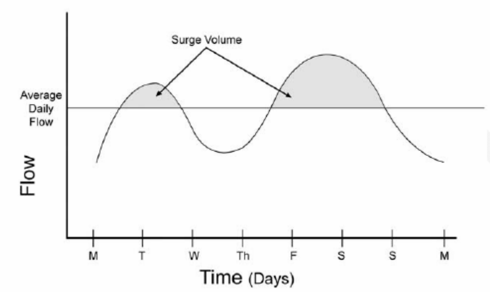


DAILY FLOW

Typical home peaks in morning and evening.

CIDWT Glossary 2007

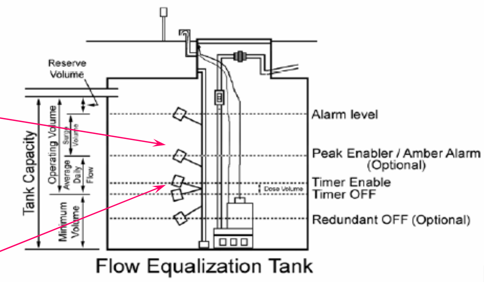
Volume, surge: 1. in a flow equalization tank, the volume above the average daily volume and below the reserve volume; **2.** volume of effluent in excess of average daily flow.



Graphic illustration of **surge volume** *compared to* **average daily flow**

Flow equalization: system configuration that includes sufficient effluent storage capacity to allow for uniform flow to a subsequent component despite variable flow from the source; *see also* **dosing, timed.**

CIDWT Glossary 2007



Surge Flow Storage

Accommodate with peak over ride and /or additional volume

Average Daily Flow

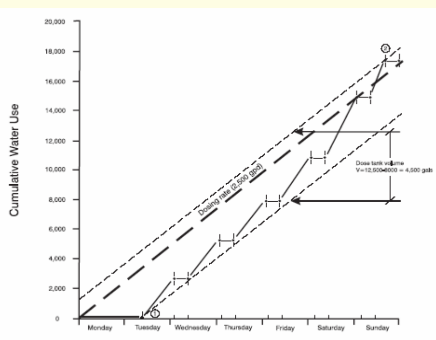
Illustration of **average daily volume, surge volume, minimum volume, operating volume** *and* **reserve volume** *within a flow equalization tank*

Characterizing "average flow" (weekly?)

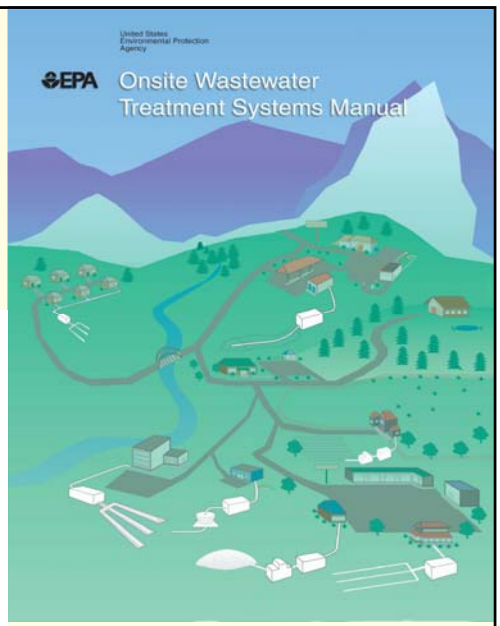
Extent / duration of "peak flow"

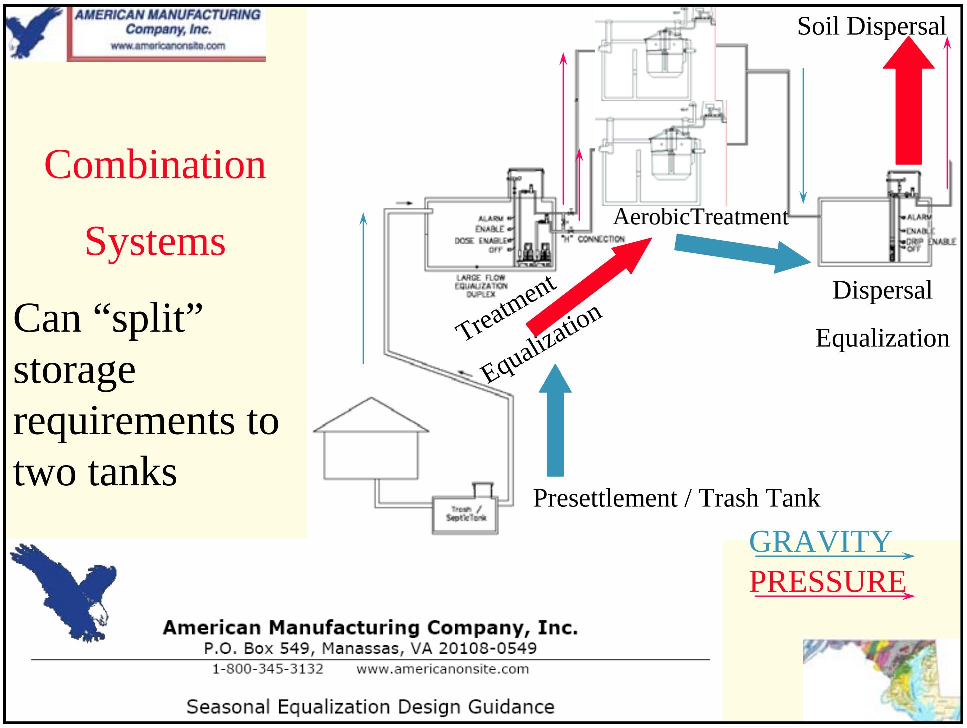
Tank, flow equalization: dosing tank that provides storage of effluent and uses timed-dosing to allow for uniform delivery to a subsequent component over time, usually a day or more; *also known as a* surge tank.

2000 EPA Design Manual has limited discussion flow equalization and a design example



Source: Ayres Associates.





Mass Loadings

Table 5-1. Types of mass loadings to subsurface wastewater infiltration systems.

Mass loading type	Units	Typical loading rates
Hydraulic		
• Daily	Volume per day per unit area of boundary surface	Septic tank effluent: 0.15–1.0 gpd/ft² (0.6–4.0 cm/d) Secondary effluent: 0.15–> 2.0 gpd/ft² (0.6–>8.0 cm/d)
• Instantaneous	Volume per dose per unit area of boundary surface	1/24–1/8 of the average daily wastewater volume
• Contour (Linear)	Volume per day per unit length of boundary surface contour (which can be a critical design parameter in areas with high water tables)	Depends on soil K_{sat}*, maximum allowable thickness of saturated zone, and slope of the boundary surface (see section 5.3)
Constituent		
• Organic	Mass of BOD per day per unit area of boundary surface	0.2–5.0 lb BOD/1000 ft² (1.0–29.4 kg BOD/1000 m²)
• Other pollutants	Mass of specific wastewater pollutant of concern per unit area of boundary surface (e.g., number of fecal coliforms, mass of nitrate nitrogen, etc.)	Variable with the constituent, its fate and transport, and the considered risk it imposes

*K_{sat} is the saturated conductivity of the soil.
Source: Otis, 2001.

Hydraulic

*Daily

*Instantaneous

*Contour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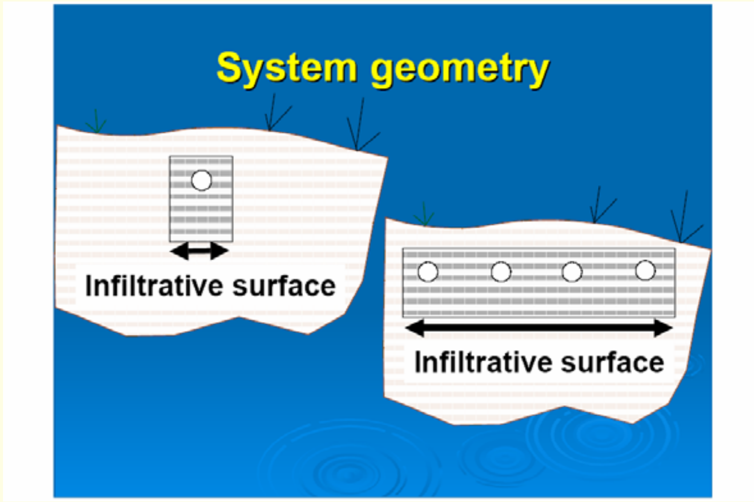

Infiltrative Surface Width

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EXAMPLE

450 GPD

100' Trench Length on Contour

50' Header Ditch

.09 Gal / Ft^2 / Day

* 6 lines, 100' long, 3' wide, 9' CENTERS = 1800 FT^2
  450 GPD / 600' trench = .75 gallon per linear foot

* 9 lines, 100' long, 2' wide, 6' CENTERS = 1800 FT^2
  450 GPD / 900' trench = .5 gallon per linear foot

* DRIP 24 lines, 2' centers
  450 GPD / 2400' tubing = .19 gallon per linear foot

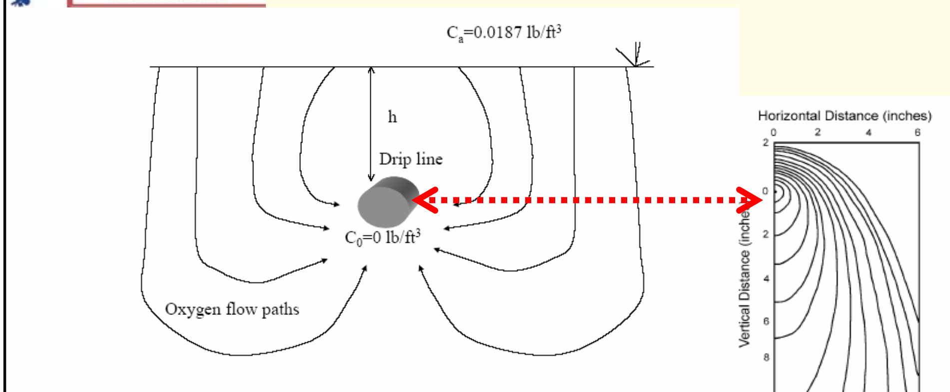


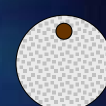
Figure 3. A schematic representation of a single drip line emphasizing the flow paths of oxygen diffusion. C_a is the concentration of oxygen in the atmosphere and h is the depth of the drip line in the soil.

Drip Dispersal places effluent *into* the soil

rather than

onto a constructed infiltrative surface

TYPES OF SOIL WATER MOVEMENT



- SATURATED FLOW

  hydraulic conductivity x gradient

  hydraulic conductivity - ease with which pores permit water movement.

  gradient - height of saturated soil

DARCY'S LAW

$$Q = \frac{K\,sat \quad A \quad ♦\,P}{L}$$

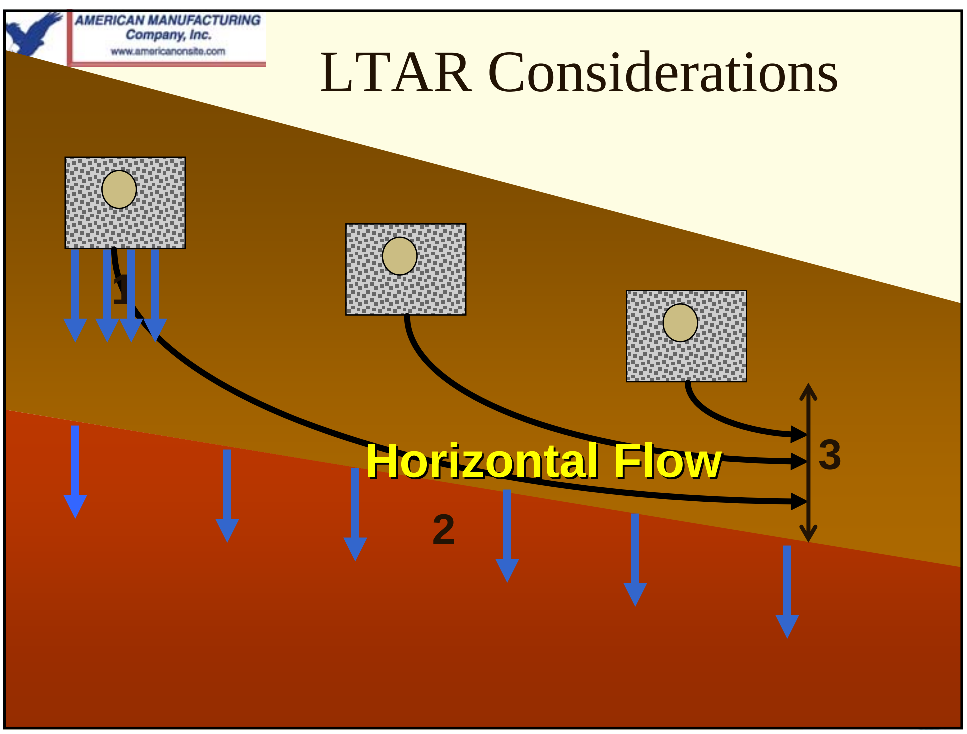
Q = quantity of flow per unit of time

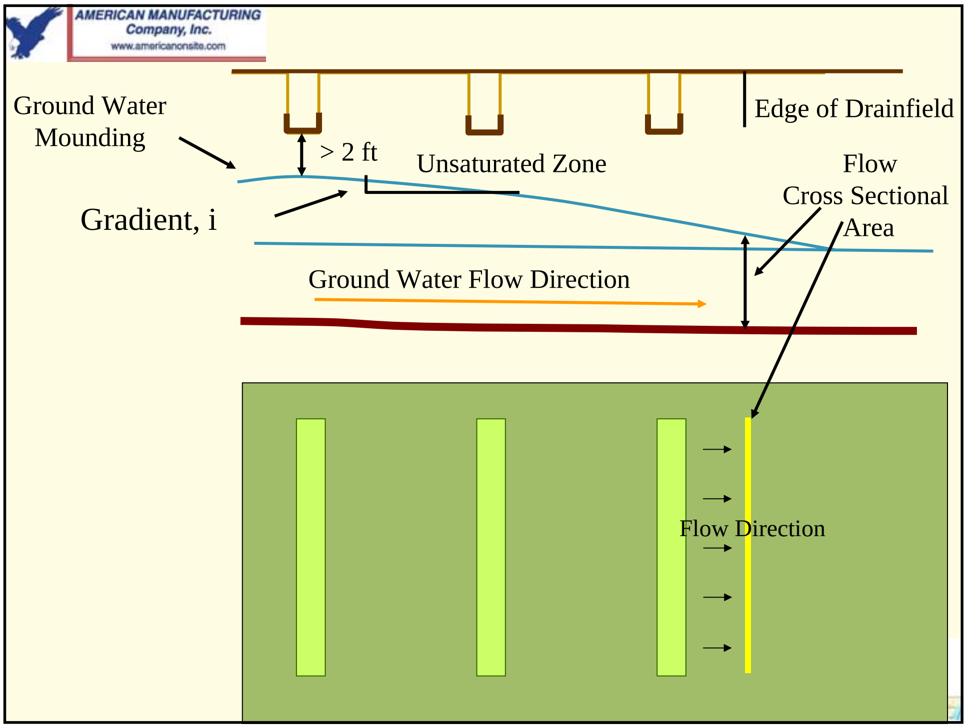
Ksat = saturated hydraulic conductivity

A = cross sectional area

♦ P = hydrostatic pressure difference between top and bottom

L = length





DARCY'S LAW	REST OF THE WORLD
■ One dimensional	■ Three dimensional
■ Steady state flow	■ Non steady flow (saturated and unsaturated flow)
■ Constant temperature	■ Variable temperature
■ Average - volume to represent all pore sizes	■ Macropores, cracks, preferential flow pathways

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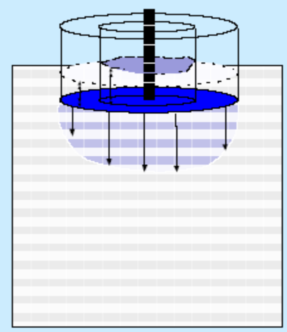
Calculating Ksat

- In lab process
- Double ring infiltrometer
- Amoozemeter reading
- Perc tests?

Double ring infiltrometer



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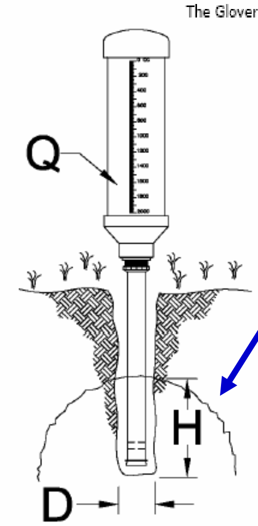
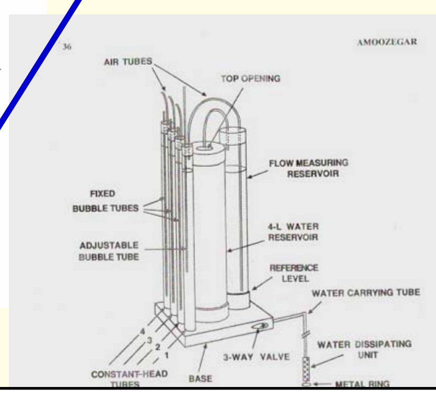
PERMEAMETER



The Glover solution: $KSAT = Q[\sinh^{-1}(H/r) - \{(r/H)^2 + 1\}^{1/2} + r/H] / 2\pi H^2$

KSAT	cm/day
H	height of water (cm) in auger hole (constant head)
r	radius of auger hole (cm)
Q	flow into auger hole (cc/day)



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Some approximate values of Saturated Hydraulic Conductivity & comments

Ksat (cm/s)	Ksat (in/h)	Comments
1×10^{-2}	14	Typical of beach sand.
5×10^{-3}	7	Typical of very sandy soil, too rapid to effectively treat pollutants in wastewater.
5×10^{-4}	0.7	Typical of moderately permeable soils.
5×10^{-5}	0.07	Typical of fine-textured, compacted or poorly structured soils.
$<1 \times 10^{-8}$	$<1.4 \times 10^{-5}$	Extremely slow; typical of compacted clay. Ksat of 10-5 may be required where nearly impermeable material is needed.

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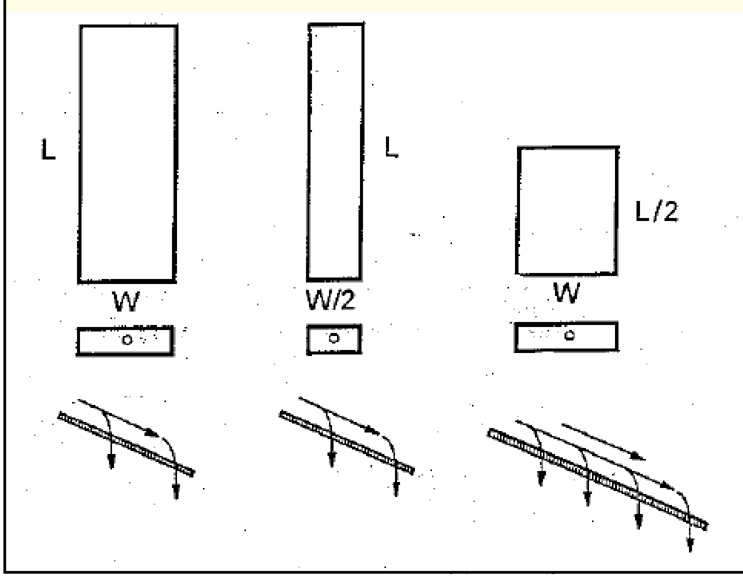
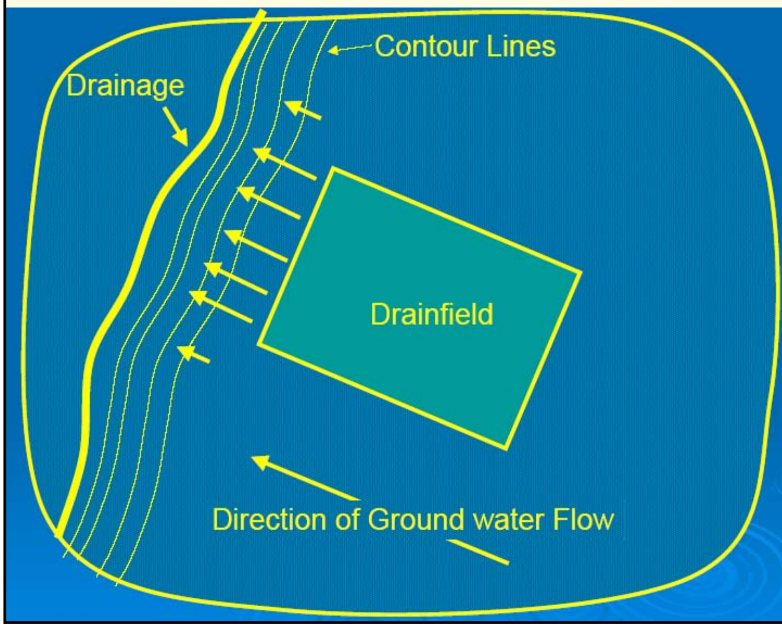
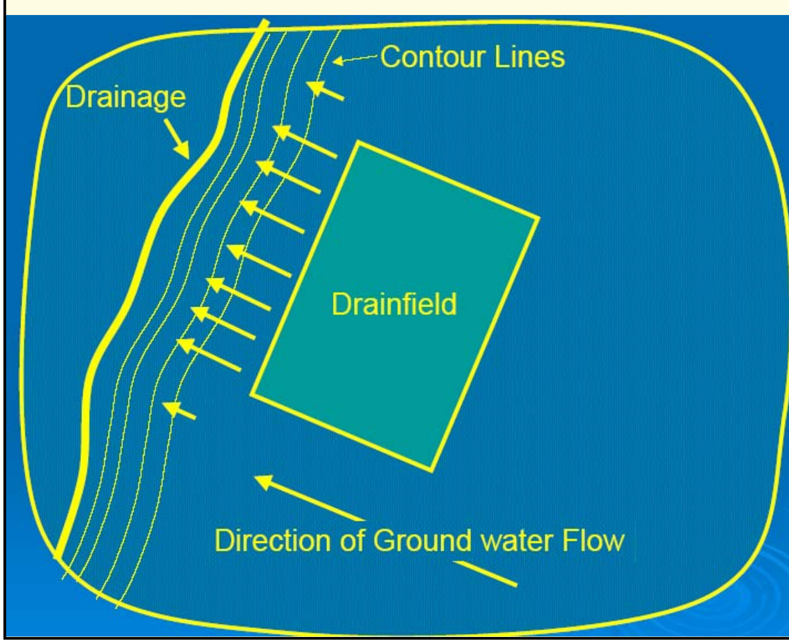
Landscape Linear (Contour) Loading



L/W Ratio .66 : 1

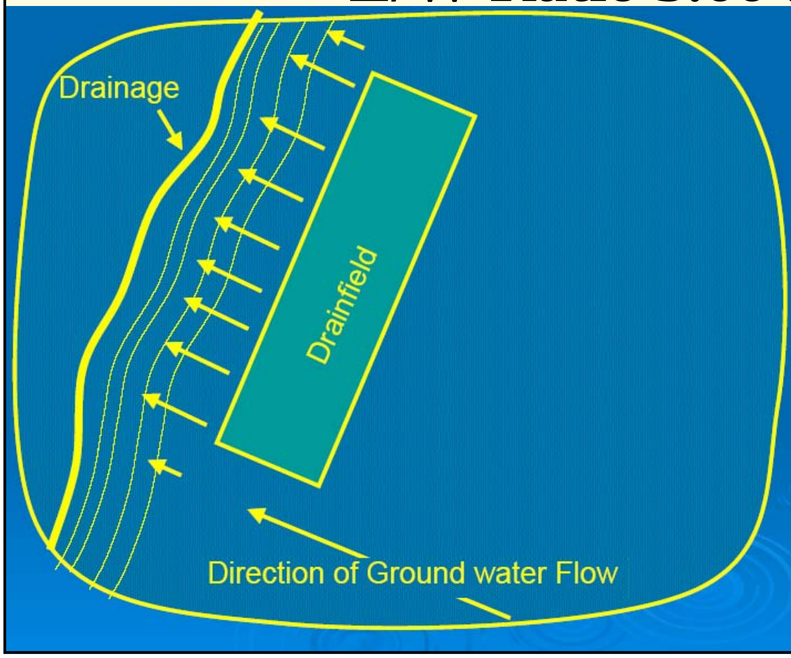


L/W Ratio 1.5 : 1

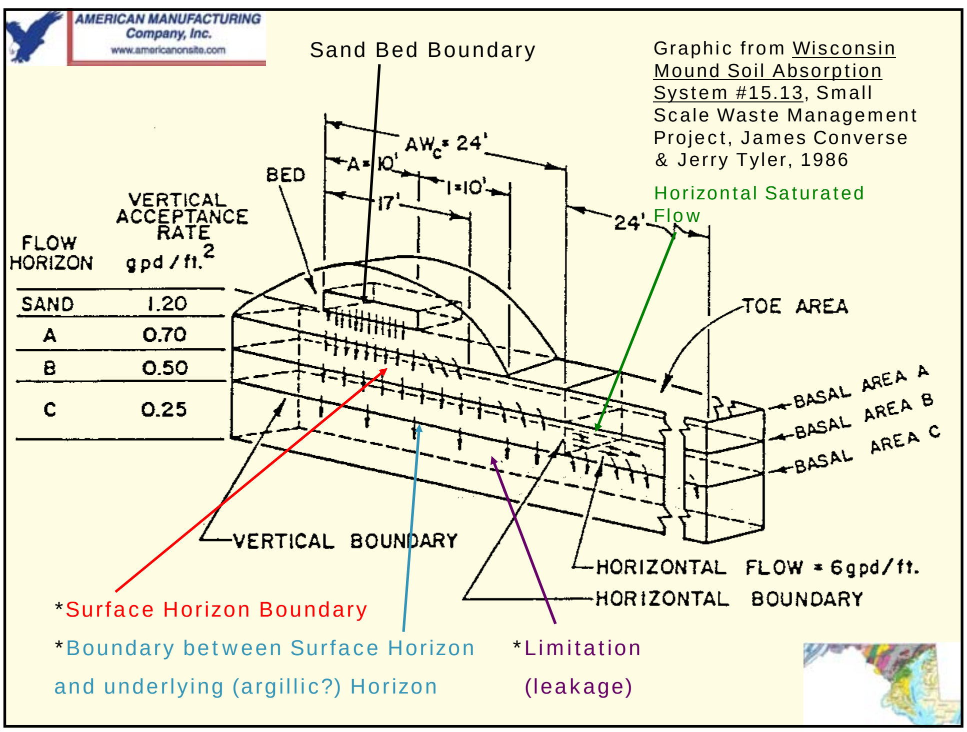


Better

L/W Ratio 3.66 : 1



Better Still!!



Soil Characteristics			Infiltration Loading Rate gal/day/ft²		Hydraulic Linear Loading Rate, gal/day/ft — Slope								
					0-4%			5-9%			>10%		
	Structure		>30 mg/l	<30 mg/l	Infiltration distance, inch			Infiltration distance, inch			Infiltration distance, inch		
Texture	Shape	Grade	BOD	BOD	8-12	12-24	24-48	8-12	12-24	24-48	8-12	12-24	24-48
COS, S, LCOS, LS	--	0SG	0.8	1.6	4.0	5.0	6.0	5.0	6.0	7.0	6.0	7.0	8.0
FS, VFS, LFS, LVFS	--	0SG	0.4	1.0	3.5	4.5	5.5	4.0	5.0	6.0	5.0	6.0	7.0
CLS, SL	--	0M	0.2	0.6	3.0	3.5	4.0	3.6	4.1	4.6	5.0	6.0	7.0
	PL	1	0.2	0.5	3.0	3.5	4.0	3.6	4.1	4.6	4.0	5.0	6.0
		2,3	0.0	0.0	-	-	-	-	-	-	-	-	-
	PR/BK /GR	1	0.4	0.7	3.5	4.5	5.5	4.0	5.0	6.0	5.0	6.0	7.0
		2,3	0.6	1.0	3.5	4.5	5.5	4.0	5.0	6.0	5.0	6.0	7.0
FSL, VFSL	--	0M	0.2	0.5	2.0	2.3	2.6	2.4	2.7	3.0	2.7	3.2	3.7
	PL	1,2,3	0.0	0.0	-	-	-	-	-	-	-	-	-
	PR/BK /GR	1	0.2	0.6	3.0	3.5	4.0	3.3	3.8	4.3	3.6	4.1	4.6
		2,3	0.4	0.8	3.3	3.8	4.3	3.6	4.1	4.6	3.9	4.4	4.9
L	--	0M	0.2	0.5	2.0	2.3	2.6	2.4	2.7	3.0	2.7	3.2	3.7
	PL	1,2,3	0.0	0.0	-	-	-	-	-	-	-	-	-
	PR/BK /GR	1	0.4	0.6	3.0	3.5	4.0	3.3	3.8	4.3	3.6	4.1	4.6
		2,3	0.6	0.8	3.3	3.8	4.3	3.6	4.1	4.6	3.9	4.4	4.9
SIL	--	0M	0.0	0.2	2.0	2.5	3.0	2.2	2.7	3.2	2.4	2.9	3.4
	PL	1,2,3	0.0	0.0	-	-	-	-	-	-	-	-	-
	PR/BK /GR	1	0.4	0.6	2.4	2.7	3.0	2.7	3.0	3.3	3.0	3.5	4.0
		2,3	0.6	0.8	2.7	3.0	3.3	3.0	3.5	4.0	3.3	3.8	4.3
SCL, CL, SICL	--	0M	0.0	0.0	-	-	-	-	-	-	-	-	-
	PL	1,2,3	0.0	0.0	-	-	-	-	-	-	-	-	-
	PR/BK /GR	1	0.2	0.3	2.0	2.5	3.0	2.2	2.7	3.2	2.4	2.9	3.4
		2,3	0.4	0.6	2.4	2.9	3.4	2.7	3.0	3.3	3.0	3.5	4.0
SC, C, SIC	--	0M	0.0	0.0	-	-	-	-	-	-	-	-	-
	PL	1,2,3	0.0	0.0	-	-	-	-	-	-	-	-	-
	PR/BK /GR	1	0.0	0.0	-	-	-	-	-	-	-	-	-
		2,3	0.2	0.3	2.0	2.5	3.0	2.2	2.7	3.2	2.4	2.9	3.4

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Stacking

Soil Evaluation and Design Selection for Large or Cluster Wastewater Soil Adsorption Systems shows stacked beds on pg. 5.

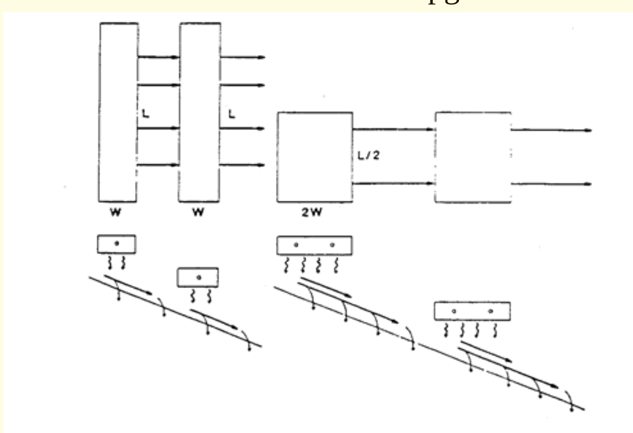


Fig. 4. Relationship of wastewater movement from equal absorption areas of with W and 2W in a landscape with horizontal flow over a leaky subsurface horizon.

5

“GRADIENT” Drains

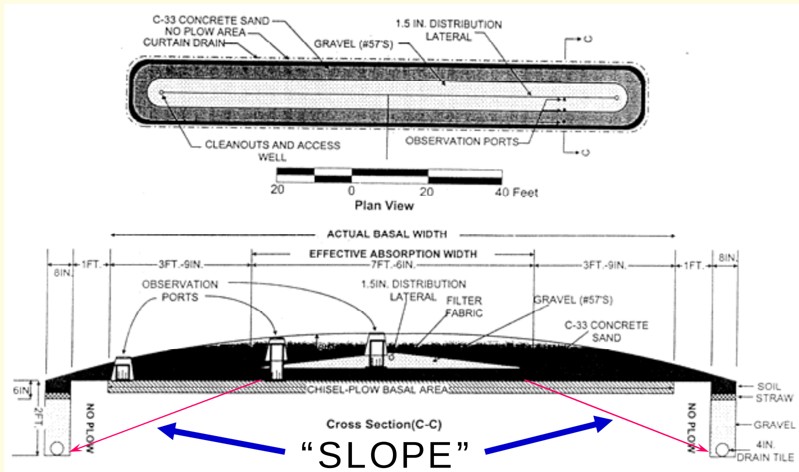
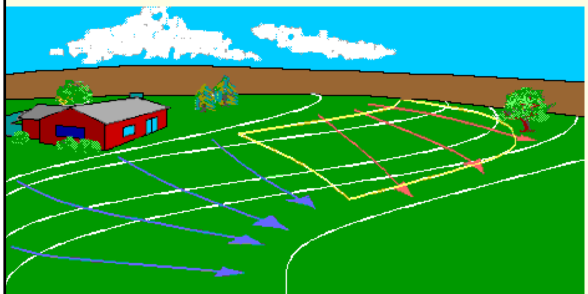


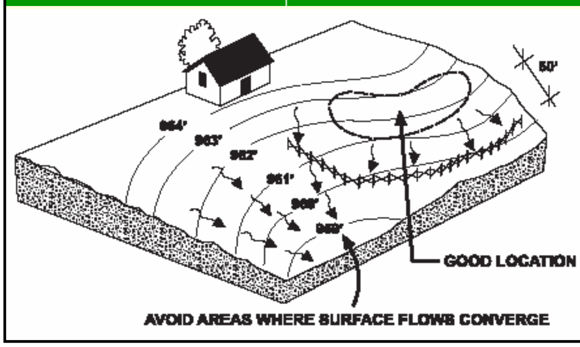
Figure 1: Modified Mound For Intermittent Sand Filters And Peat Biofilter Effluents

Soil and Site Investigation

- ***Landscape position and surroundings***
- Soil morphology
  - – horizons, color, texture, structure, mineralogy, depth, limiting layers, wetness

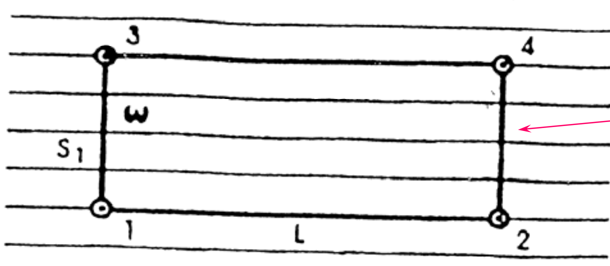
Site Delineation





The report is to communicate to the designer site-specific details of the delineated area including a preliminary design (dimensions of the area, slope of site etc.) meeting the requirements of this guidance.

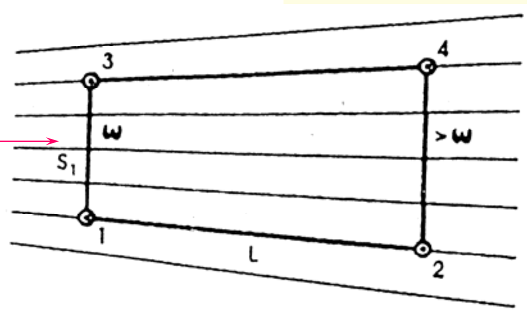
The report should identify, and offer recommendations to address, as necessary, certain site specific conditions such as slope, stoniness, vegetation, surface drainage, site preparation etc. that may, in the judgment of the evaluator, effect the design and / or field installation.



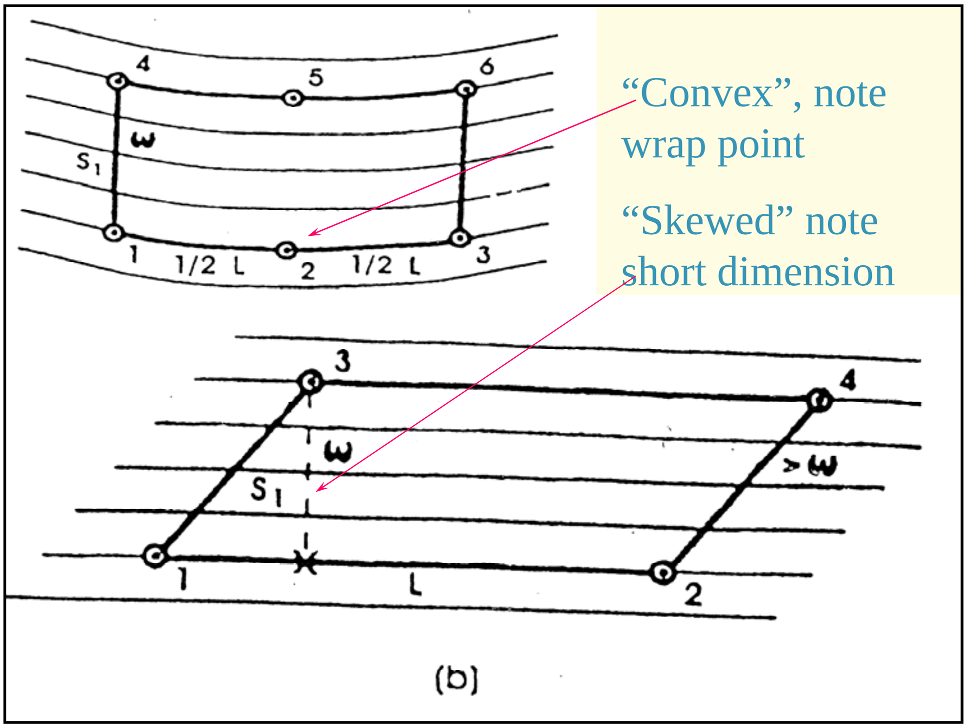
(a)

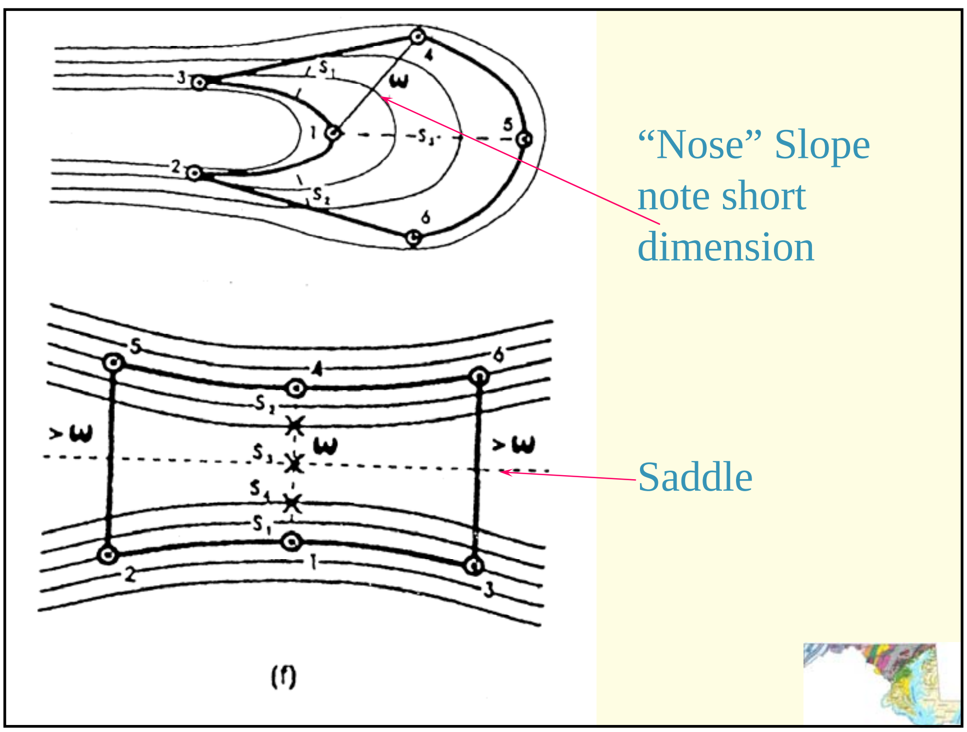
Perfect !!

“Flared”



(d)


“Convex”, note wrap point
“Skewed” note short dimension
(b)


“Nose” Slope note short dimension
Saddle
(f)

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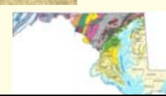

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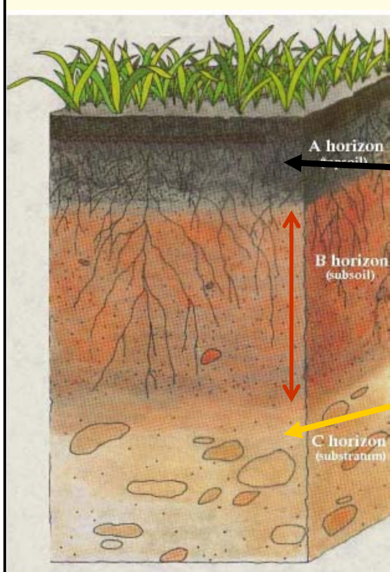


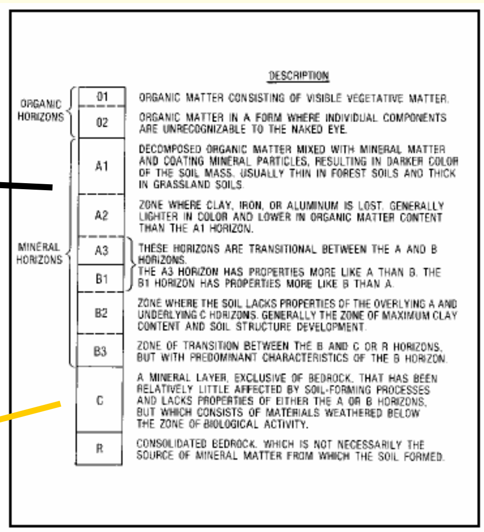
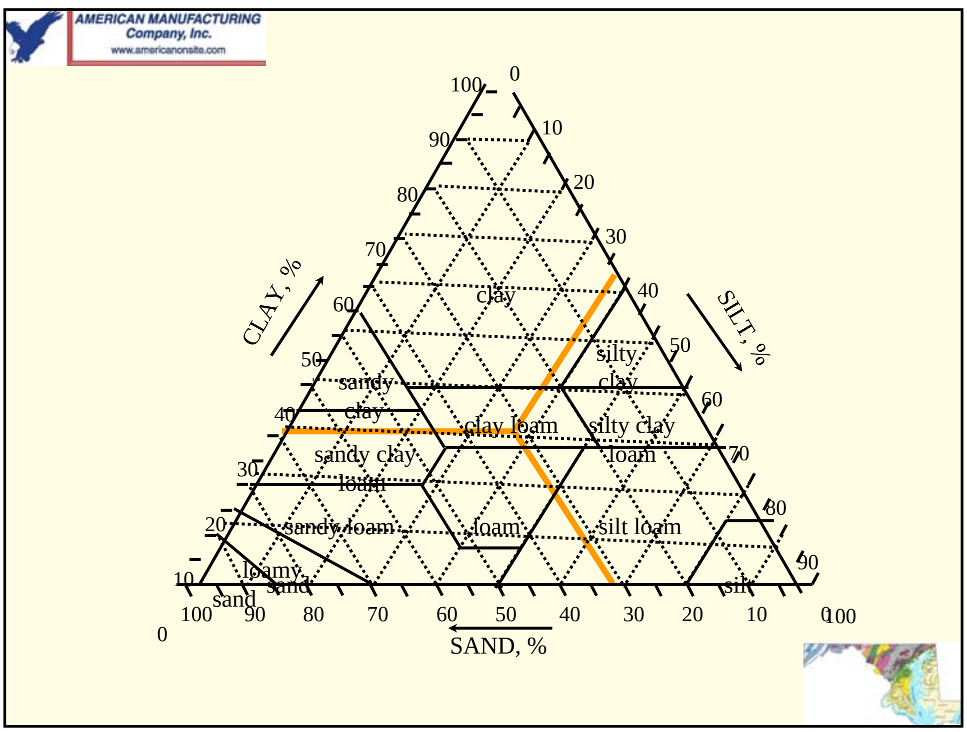


Figure 2. Generalized soil profile


Soil Texture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CLAY, %
SILT, %
SAND, %
clay
silty clay
sandy clay
clay loam
silty clay loam
sandy clay loam
sandy loam
loam
silt loam
loamy sand
sand
silt
0
10
20
30
40
50
60
70
80
90
100

STRUCTURE

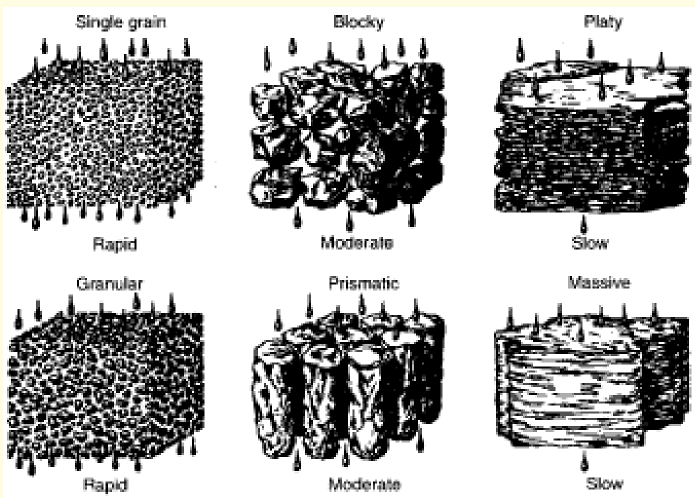
Structure is the arrangement of sand, silt, and clay particles into aggregates held together by mineral and organic colloids acting as a glue. These structural units form a secondary network of macro and micro pores for air and water movement in soil.

GRANULAR

PRISMATIC

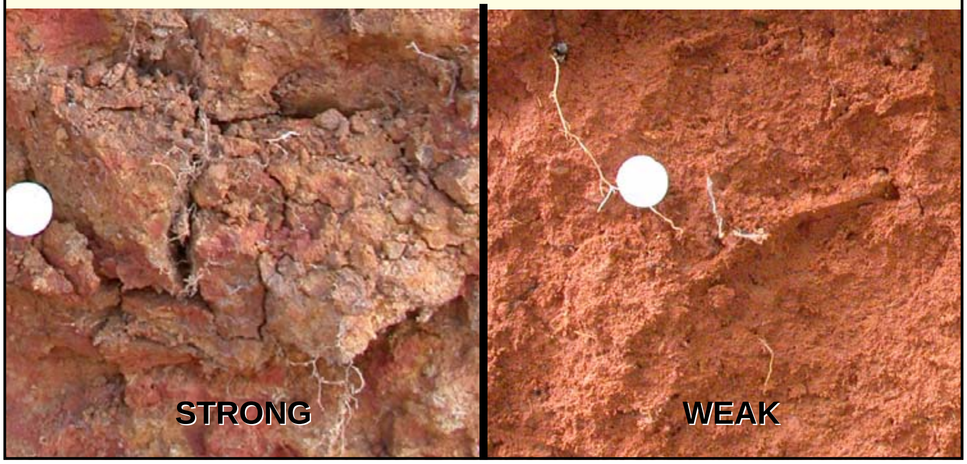
BLOCKY

Soil Structure and Water Movement



Structural Grade Adjustments

- Increase LTAR for strong
- Decrease LTAR for weak



Trench Bottom Loading Rates

Soil Characteristics			Infiltration Loading Rate, gal/da/ft²	
Texture	Structure Shape	Structure Grade	>30 mg/L	<30 mg/L
COS, S, LCOS, LS	--	0SG	0.8	1.6
FS, VFS,LFS,LVFS	--	0SG	0.4	1.0
CSL, SL	--	0M	0.2	0.6
	PL	1	0.2	0.5
		2, 3	0.0	0.0
	PR/BK /GR	1	0.4	0.7
		2,3	0.6	1.0
FSL, VFSL	--	0M	0.2	0.5
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.2	0.6
		2,3	0.4	0.8
L	--	0M	0.2	0.5
	PL	1,2, 3	0.0	0.0
	PR/BK /GR	1	0.4	0.6
		2, 3	0.6	0.8
SIL	--	0M	0.0	0.2
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.4	0.6
		2,3	0.6	0.8
SCL,CL SICL	--	0M	0.0	0.0
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.2	0.3
		2,3	0.4	0.6
SC, C, SIC	--	0M	0.0	0.0
	PL	1,2,3	0.0	0.0
	PR/BK /GR	1	0.0	0.0
		2,3	0.2	0.3
A	B	C	D	E

EPA 2002

Loading Rate

Structural Adjustment

1 / 3 Reduction For Strong Structure

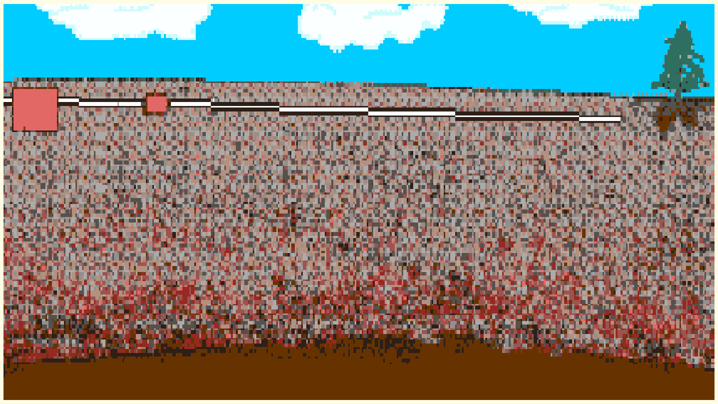
COARSE PLATEY

PLOW PAN

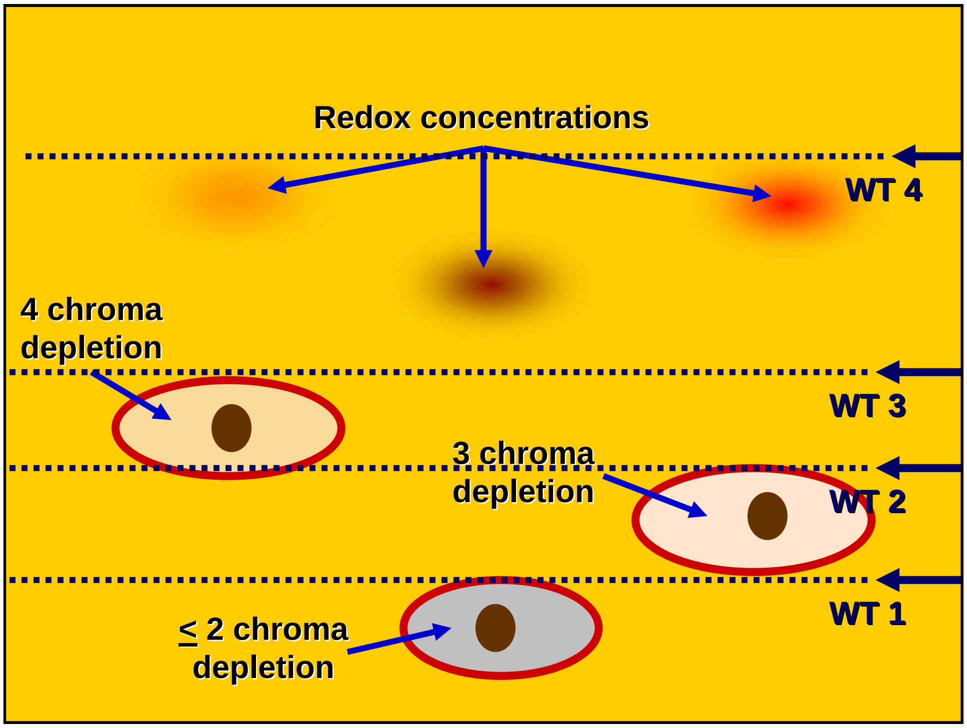
Soil Considerations

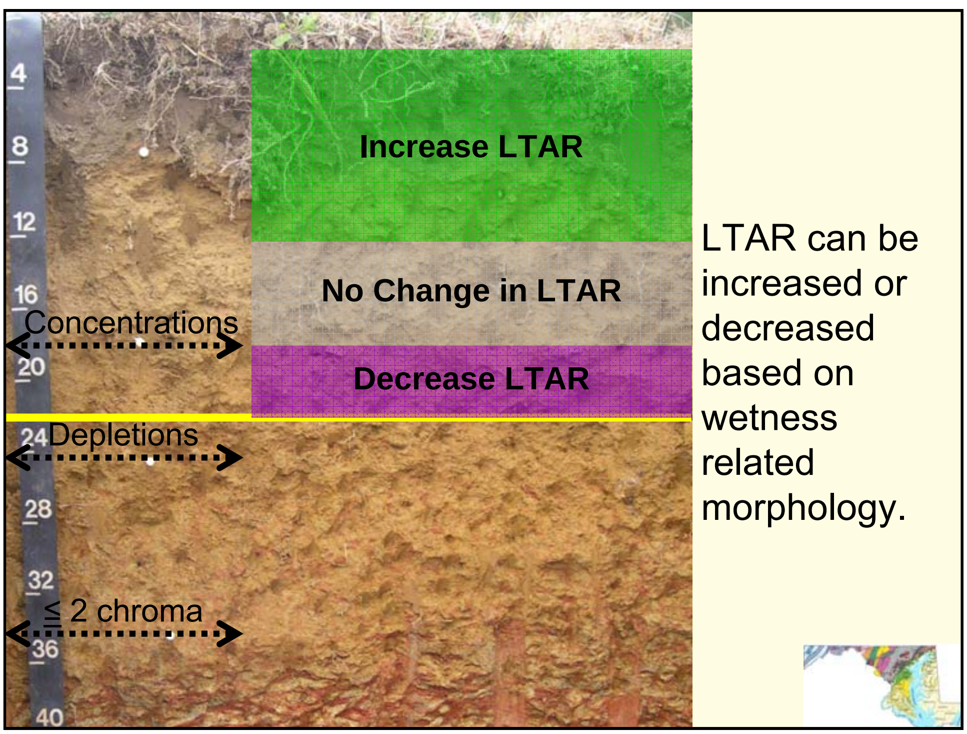
- **Soils are classified as well drained, moderately well drained, somewhat poorly drained, or poorly drained. Well drained soils are usually red or brown in color.**

Soil Considerations



- Poorly drained soils are usually gray in color.


Redox concentrations
WT 4
4 chroma
depletion
WT 3
3 chroma
depletion
WT 2
WT 1
≤ 2 chroma
depletion


Increase LTAR
No Change in LTAR
Decrease LTAR
Concentrations
Depletions
≤ 2 chroma
4
8
12
16
20
24
28
32
36
40
LTAR can be increased or decreased based on wetness related morphology.

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Model Decentralized Wastewater Practitioner Curriculum
Water Movement and Soil Treatment
Anderson, Gustafson and Amoozegar,

Additional Materials for Inclusion with Water Movement and Soil Treatment Module:

1. Designing Wastewater Disposal Systems

2. Designing Large Septic Systems

and

3. Examples of Three-Step Hydrologic Analysis

By Aziz Amoozegar, PhD

North Carolina State University

Soil Science Department

(1) Infiltrative Surface Waste Water applied must readily leave trench

(2) Water must move vertically through least permeable soil layer

(3) Water reaching a impermeable / slowly permeable layer or Ground water must move laterally away

Groundwater Mounding increases volume of water moving laterally

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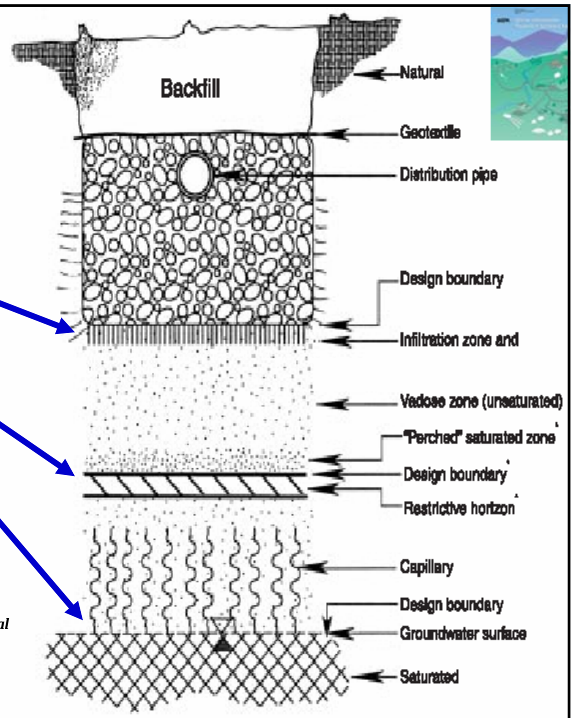
Design Boundaries

NOTE: "Infiltration Zone"

"Design Boundary"

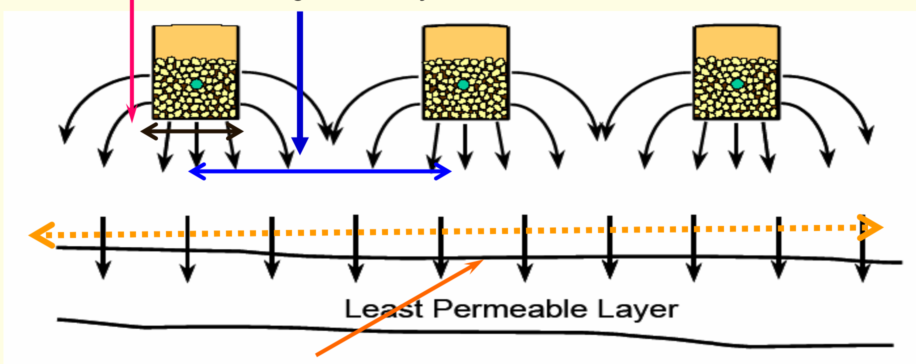


On-Site Wastewater Treatment Systems Manual
Chapter 4 Treatment Processes and Systems
(U.S. Environmental Protection Agency.
EPA/625/R-00/008 Washington, D.C.: 2002)

Large Flow Systems

Load infiltrative surface according to regs at low % of Hydraulic Conductivity, for example .6 gal/ft^2/day

Loading below trench is an area "footprint" loading rate ie. The infiltrative loading rate / 3 or .2 gal/ft^2/day or 2.25" per week

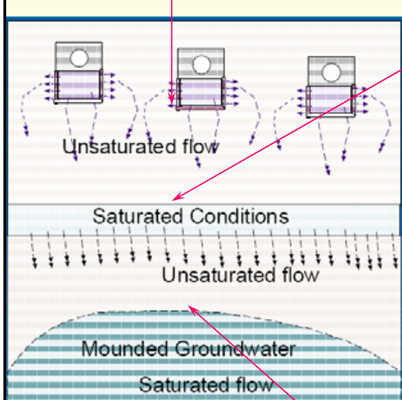


Test and evaluate (judgment!!) Hydraulic Conductivity of restrictive SOIL horizon as a percentage of Area "Footprint" Conductivity

Approach

Large Flow

Infiltrative Surface Typical loadings <10 (3-6)% of saturated Hydraulic Conductivity. May be as much as 20% with justification and managed instantaneous dosing, *if other subsurface characteristics allow.*



Water must move vertically through Least Permeable soil layer. Area, "Foot Print" Loading. Several Options for analysis.

(A)** Must be <100% of lowest Hydraulic Conductivity test (80%?)

(B)** Evaluate (judgment!!) Geometric Mean of Hydraulic Conductivity of restrictive SOIL horizon as a percentage of Area, "Footprint". Adjusts for extremes of data set.

(C)** Look at the Standard Deviation. Calculate upper SD (slowest of 66% of data) as percentage of Area, "Footprint"). May need to eliminate highest and lowest value.

Water reaching a impermeable / slowly permeable layer or Ground water must move laterally away from site. Groundwater Mounding increases volume of water moving laterally

Mass Loadings

Table 5-1. Types of mass loadings to subsurface wastewater infiltration systems.

Mass loading type	Units	Typical loading rates
Hydraulic		
• Daily	Volume per day per unit area of boundary surface	Septic tank effluent: 0.15–1.0 gpd/ft² (0.6–4.0 cm/d) Secondary effluent: 0.15–> 2.0 gpd/ft² (0.6–>8.0 cm/d)
• Instantaneous	Volume per dose per unit area of boundary surface	1/24–1/8 of the average daily wastewater volume
• Contour (Linear)	Volume per day per unit length of boundary surface contour (which can be a critical design parameter in areas with high water tables)	Depends on soil K_{sat}*, maximum allowable thickness of saturated zone, and slope of the boundary surface (see section 5.6)
Constituent		
• Organic	Mass of BOD per day per unit area of boundary surface	0.2–5.0 lb BOD/1000 ft² (1.0–28.4 kg BOD/1000 m²)
• Other pollutants	Mass of specific wastewater pollutant of concern per unit area of boundary surface (e.g., number of fecal coliforms, mass of nitrate nitrogen, etc.)	Variable with the constituent, its fate and transport, and the considered risk it imposes

*K_{sat} is the saturated conductivity of the soil.
Source: Otis, 2001.

USEPA Onsite Wastewater Treatment Systems Manual

Constituent

*Organic

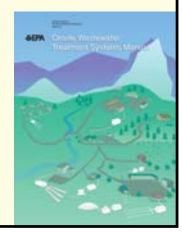
*Other Pollutants

Nitrogen

Phosphorus

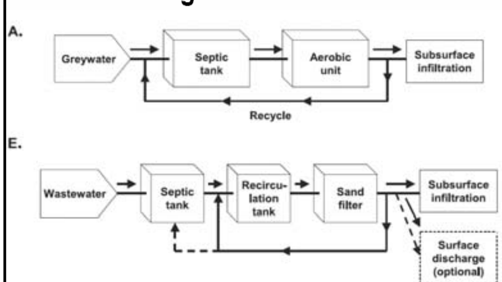
Fecals

Emerging Contaminants



EPA Onsite Wastewater Treatment Systems Technology Fact Sheet 9

Enhanced Nutrient Removal—Nitrogen



•Efficient, closed system, small footprint. Employs fast-growing bacteria, short Mean Cell Residence Time (MCRT)

•Growth Media is often suspended (water)

•Basis is in surface water resource discharge

*Nitrify to protect aquatic organisms

*Denitrify to reduce the nutrient load on the water resource

"CLASSIC" Nitrification and Denitrification Theory is no longer valid as a general ecological model

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Emerging Models for Nitrogen Removal in Treatment Wetlands

Scott Wallace, P.E., M.S.
David Austin, P.E., M.S.

Wetlands, Soils, and Sediments have many alternative pathways for NITROGEN transformation

•Slow Growing Bacteria

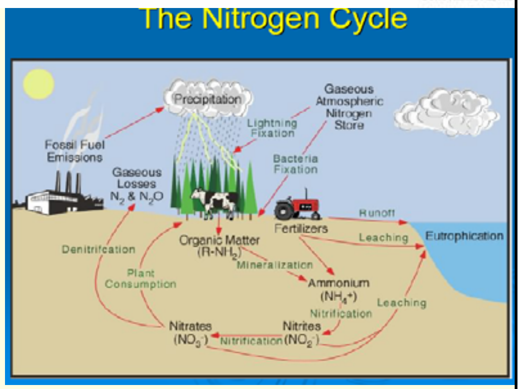
•Extended MCRT

•"Low fluid shear" environment resulting in stable biofilms

•Time

•Size

•Diversity

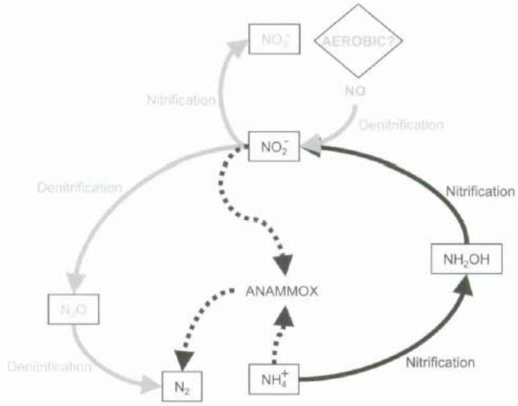


Emerging Models for Nitrogen Removal in Treatment Wetlands

Scott Wallace, P.E., M.S.
David Austin, P.E., M.S.

FIGURE 2

Anammox Pathway in Context of Classic Model



ANAMMOX

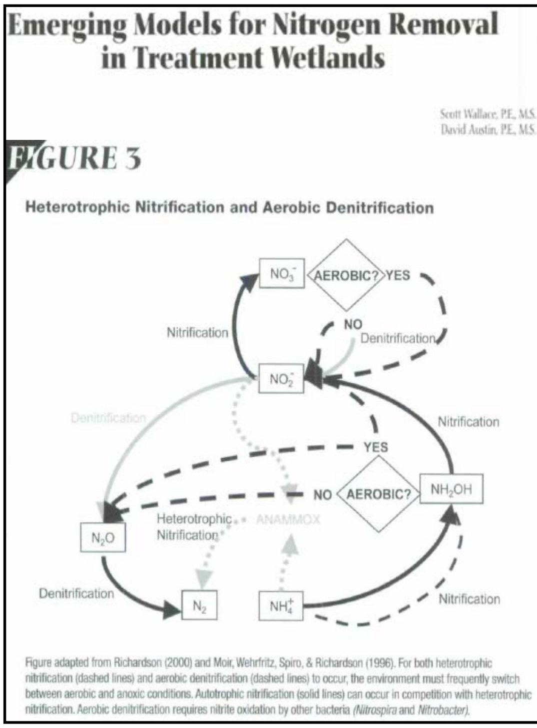
•Nitrite to atmospheric Nitrogen

•Does not require organic Carbon to remove Nitrogen from Wastewater

•Removal high once biomass is established

•20% of Oxygen compared to classic Nitrification / denitrification

Being developed into commercial application



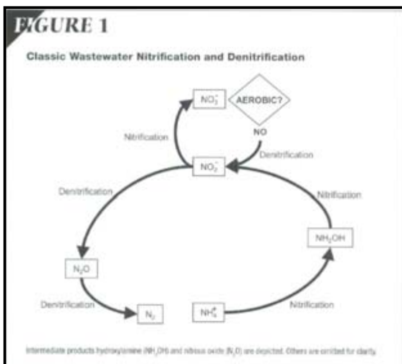
HETEROTROPHIC NITRIFICATION MODEL

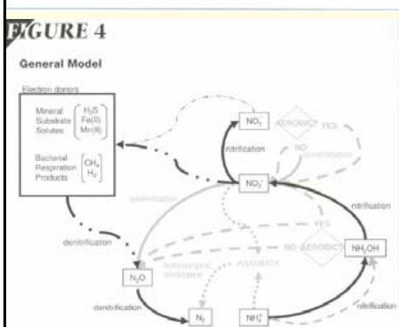
•Complex

•Uses Oxygen and Nitrate simultaneously as terminal electron acceptors favoring aerobic denitrification

“Dumps” excess ammonia to prevent interference with bacterium energy balance

Biofilms and “flood and drain” an important element





The classical process Nitrification / Denitrification Model coupled with the understanding ANAMOX and HETEROPHIC pathways presents an emerging model of nitrogen fate in large complex ecologies such as soils, wetlands, and sediments.

Other nitrogen-cycle microbes whose pathways are yet unknown likely play an important role.

The recent need for the understanding and analysis of of the global nitrogen cycle due to mans effects will increase the understanding of Nitrogen dynamics and soil based on site sewage treatment and dispersal