RIDING THE TREATMENT TRAIN: PRACTICAL SOIL CONCEPTS AND DESIGN STRATEGIES

Material presented represents my own opinions and does NOT reflect the opinions of NOWRA

Onsite Wastewater Mega-Conference
2024
Spokane, WA
Celebrating Tomorrow's Environment
Clean Water for the Future
NOWRA NAWT SORA O2WA WOSSA

How do ~~we~~ protect public health and drinking water?

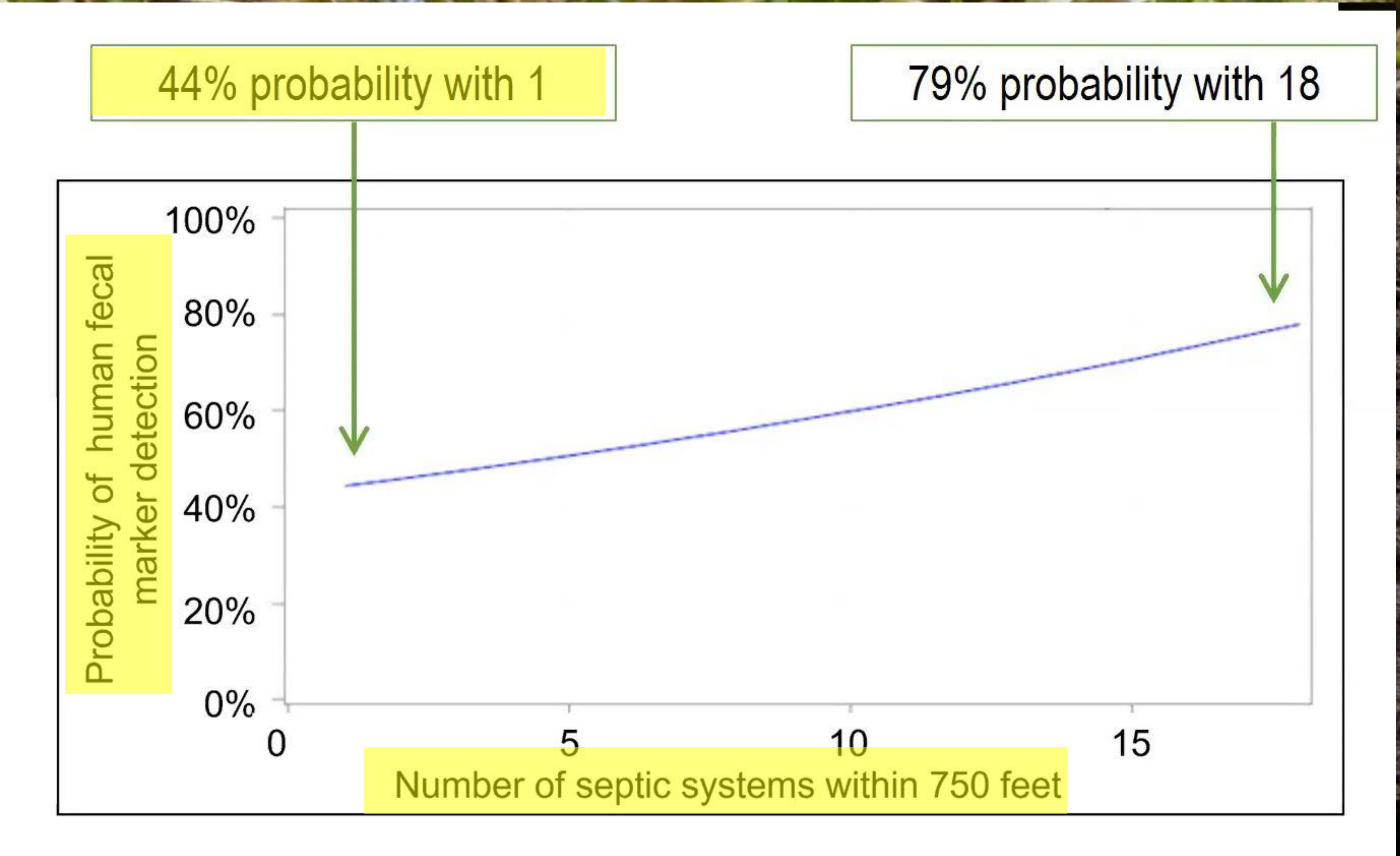

SOO LINE
SOO LINE
99085


SEPTIC TANK DIAGRAM
Plumbing Vent
Septic Line
Scum
Wastwater
Sludge
Septic Tank
Leachfield (Drain Field)
Effluent Absorption and Purification

NOTE: The complete SWIGG survey is available on the Midwest Farm Report's news feed.

A years-long study looking at well water in Southwestern Wisconsin was finally finished this week and researchers have found the majority of contamination in those wells comes from human waste, not from cows.

Midwest Farm Report May 24, 2022



Joel Stokdyk, U.S. Geological Survey – SWIGG Study Final Presentation, May 16, 2022

TABLE 3.1 Treatment Performance of Soil   Unsaturated Flows

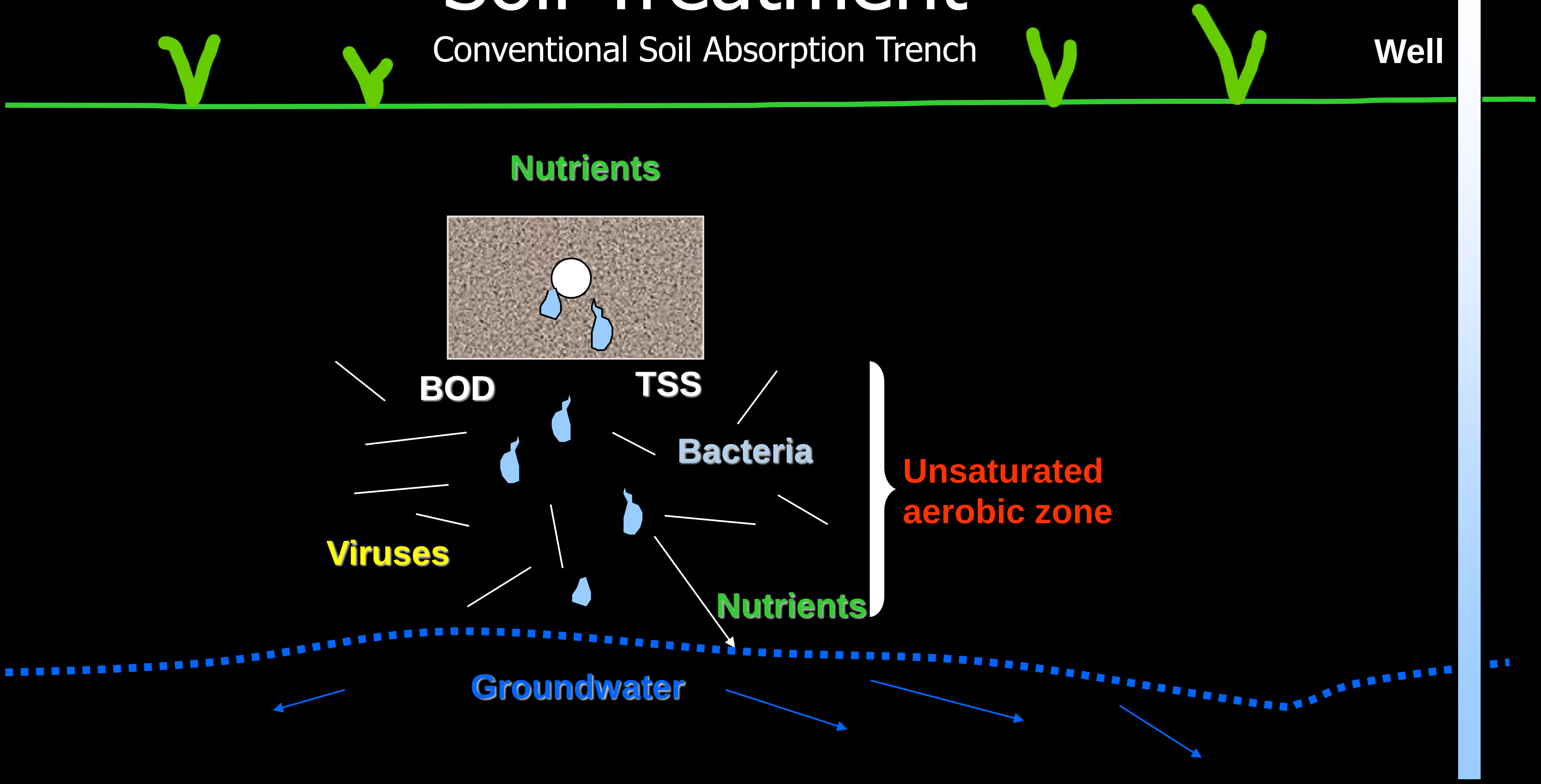
Parameter	Raw Waste	Septic Tank Effluent	One Foot Below Distribution Media	Three Feet Below Distribution Media
BOD_5 (mg/L)	30-1147***	39-861***	0**	0**
TSS (mg/L)	18-2233***	22-276***	0**	0**
Fecal Coliform (MPN/100ml)	30,000-10,000,000,000**,***	1,000-120,000,000**,***	1-100**	0**
Viruses (PFU/ml)	unknown**	100,000-10,000,000**	0-1,000**	0**
Nitrogen (mg/L)				
Total	35-189**,***	25-124**,***	—	—
NH_4	7-40**	20-60**	*B-20**	—
NO_3	<1**	<1**	*B-40**	*B-40**
Total Phosphorus (mg/L)	10-27**	3-40***	*B-10**	*B-1**

* B = background
**Tchobanoglous and Burton, 1991
***Lowe et al., 2007

Onsite Sewage Treatment Program, University of Minnesota. 2020. Manual for Septic System Professionals in Minnesota, 4th Ed. St. Paul MN

Soil Treatment

Conventional Soil Absorption Trench



Soil Treatment

Unsaturated Flow

Filtration, adsorption (nutrients and virus), predation, and retention/contact time increase treatment. Pathogens are retained on particle surfaces or in small pores.

Soil Treatment Mechanisms

SOIL YOUR UNDIES CHALLENGE

Photo credit: NRCS Website

Some Things to Consider

- Loading Rates – Is the system sized appropriately for the flows AND loads? Are hydraulic loading rates assigned appropriately? What about linear loading rates?
- Disturbed Soil or Fill – Concern for preferential flow = saturated flow.
- Compaction – Has any part of the dispersal site been impacted by compaction?
- Limiting Factor – Where is it and What is it? Do we have proper separation?
- Treatment – Is there slowly or rapidly permeable soils? Gravity distribution?

What is the soil and site telling you?

The role of the soil tester is to

FIND THE STORY

<u>AND</u> REPORT IT TO OTHERS

We are not just describing the soil but also applying it and relating it to the task at hand

SOIL EVALUATION REPORT

SPS 385
Soil and Site Evaluations

Soil morphological evaluation follows USDA Soil Survey Manual

Wisconsin Department of Safety and Professional Services
Division of Industry Services

Page ____ of ____

SOIL EVALUATION REPORT

In accordance with SPS 385, Wis. Adm. Code

Attach complete site plan on paper not less than 8 1/2 x 11 inches in size. Plan must include, but not limited to: vertical and horizontal reference point (BM), direction and percent slope, scale or dimensions, north arrow, and location and distance to nearest road.

Please print all information.

Personal information you provide may be used for secondary purposes (Privacy Law, s. 15.04(1)(m)).

County	
Parcel I.D.	
Reviewed by	Date

Property Owner				Property Location Govt. Lot ¼ ¼ S T N R ☐ E (or) ☐ W		
Property Owner's Mailing Address				Lot #	Block #	Subd. Name or CSM#
City	State	Zip Code	Phone Number ( )	☐ City	☐ Village	☐ Town Nearest Road

☐ New Construction Use: ☐ Residential / Number of bedrooms ____ Code derived design flow rate ____ GPD
☐ Replacement ☐ Public or commercial – Describe: ____
Parent material ____ Flood Plan elevation if applicable ____ ft.
General comments and recommendations:

☐ Boring # ☐ Boring ☐ Pit Ground surface elev. ____ ft. Depth to limiting factor ____ in.

Horizon	Depth In.	Dominant Color Munsell	Redox Description Qu. Az. Cont. Color	Texture	Structure Gr. Sz. Sh.	Consistence	Boundary	Roots	Soil Application Rate GPD/Ft² *Eff#1	*Eff#2

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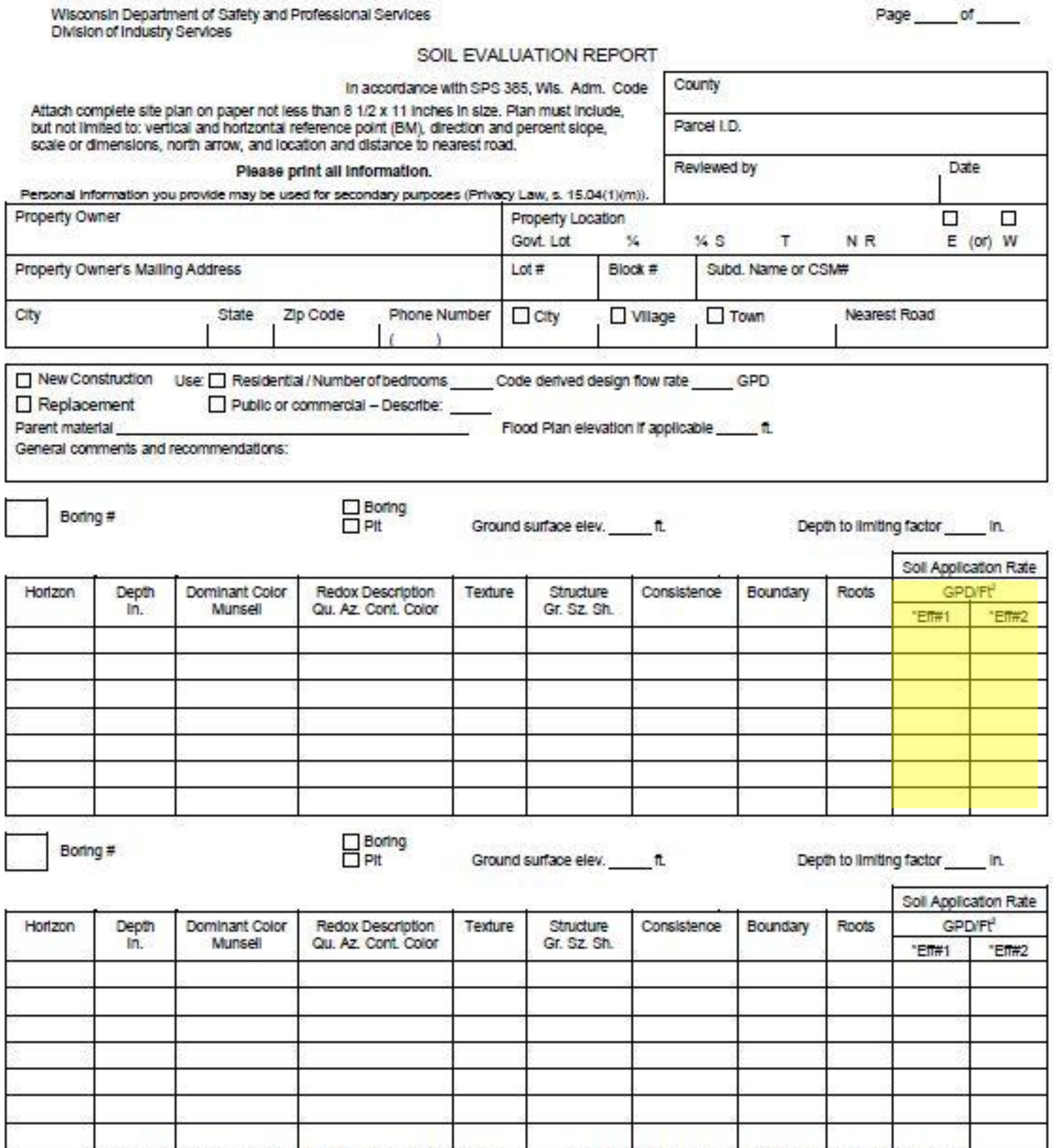
SOIL APPLICATION RATES

FROM Table SPS 383.44-2

Maximum soil application rates in gallons/sq ft/day for septic system dispersal designs



Wisconsin Department of Safety and Professional Services
Division of Industry Services

Page ____ of ____

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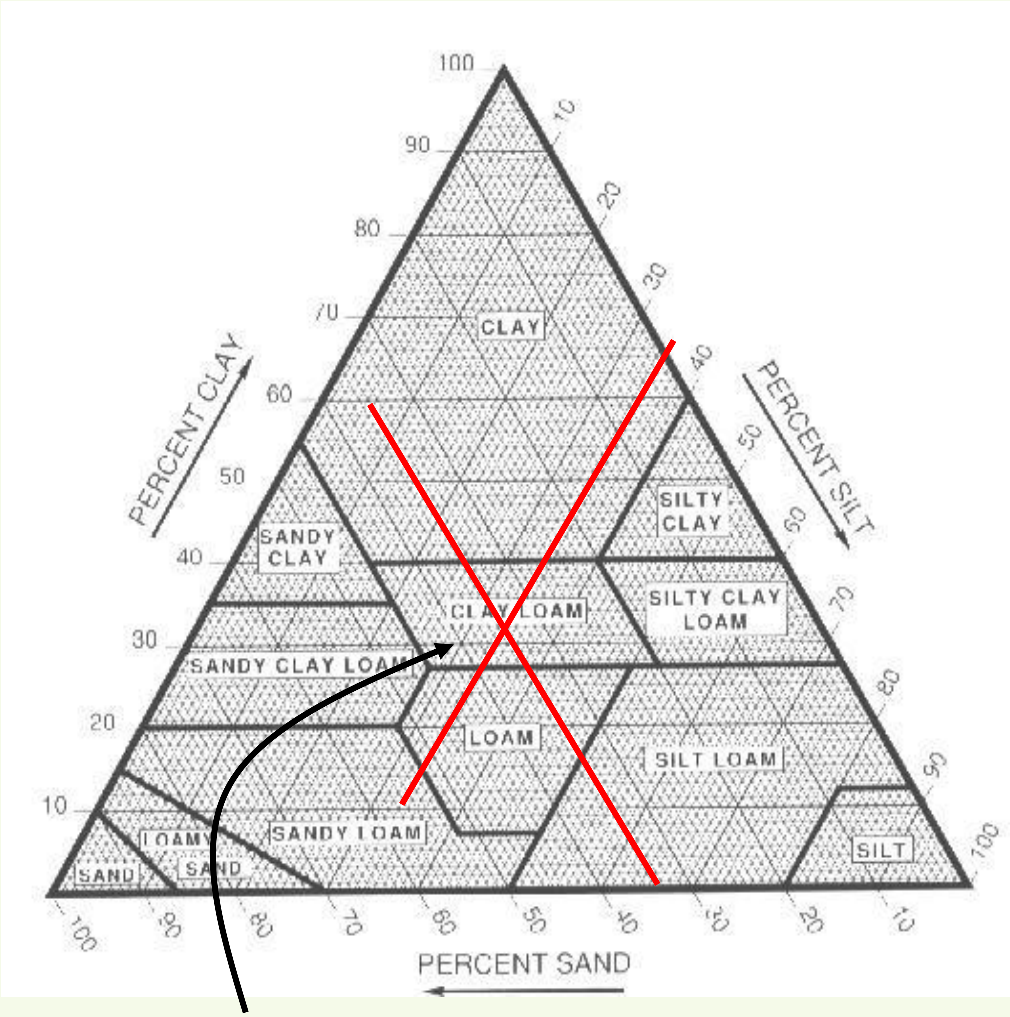
Soil Application Rates

Septic Tank Effluent and Highly Treated Effluent

Table 383.44–2
Maximum Soil Application Rates Based Upon Morphological Soil Evaluation (in gals./sq. ft./day)

Soil Characteristics			Maximum Monthly Average			
Texture[d]	Structure[e]		BOD_5 >30 ≤220mg/L TSS >30 ≤150mg/L		BOD_5 ≤30 mg/L[c] TSS ≤30 mg/L[c]	
	Shape	Grade				
COS, S, LCOS, LS	––	0	0.7[a]	0.5[b,c]	1.6[a]	0.5[b]
FS, LFS	––	0	0.5		1.0	
VFS, LVFS	––	0	0.4		0.6	
COSL, SL	––	0M	0.2		0.6	
	PL	1	0.4		0.6	
		2, 3	0.0		0.2	
	PR, BK, GR	1	0.4		0.7	
		2, 3	0.6		1.0	
FSL, VFSL	––	0M	0.2		0.5	
	PL	2, 3	0.0		0.2	
	PL, PR, BK, GR	1	0.2		0.6	
	PR, BK, GR	2, 3	0.4		0.8	
L	––	0M	0.2		0.5	
	PL	2, 3	0.0		0.2	
	PL, PR, BK, GR	1	0.4		0.6	
	PR, BK, GR	2, 3	0.6		0.8	
SIL	––	0M	0.0		0.2	
	PL	2, 3	0.0		0.2	
	PL, PR, BK, GR	1	0.4[c]		0.6	
	PR, BK, GR	2, 3	0.6		0.8	
SI	––	––	0.0		0.0	

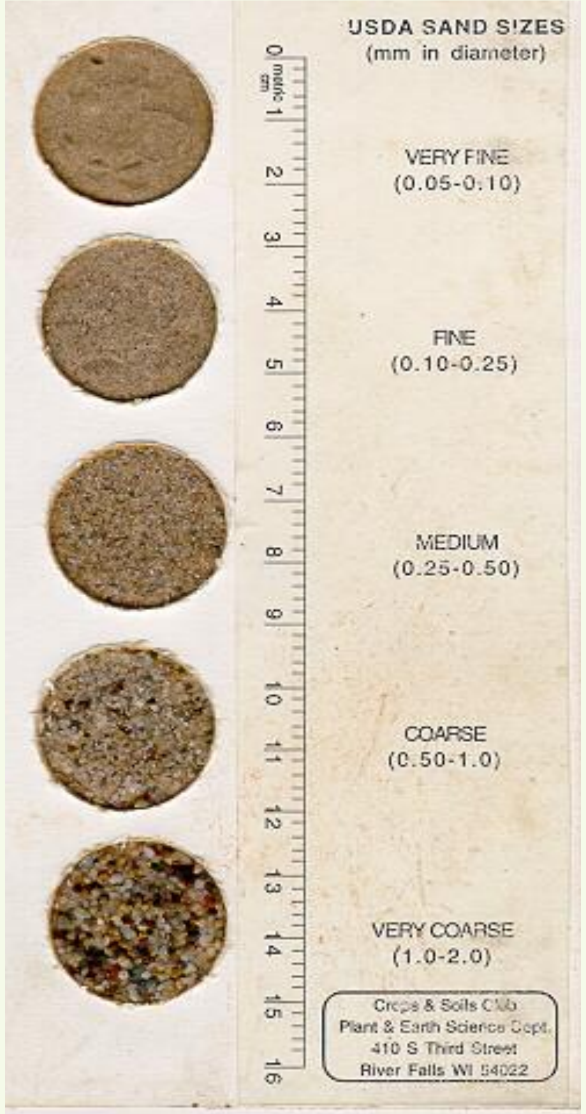
TEXTURE



clay loam = 35% sand, 35% silt, and 30 % clay

- **Defined:** Texture is the relative proportion (%) of the different soil separates in a given sample.
- Soil separates include <u>sand</u>, <u>silt</u> and <u>clay</u> size particles.
- 12 basic textural classes on the textural triangle.
  - Don't make up classes
  - Use texture modifiers
    - Very gravelly sand
    - Extremely cobbly sand
  - Use textural subclasses
    - Coarse sand
    - Coarse sandy loam

TEXTURE



Rock Fragments

- Non-soil fragments over 2mm in diameter
- Coarse fragments decrease water holding capacity (treatment)

STRUCTURE

- Soil structure is the arrangement of individual particles of sand, silt, and clay into aggregates or clusters called <u>peds</u>.
- Peds are classified based on degree of distinctness, size, and shape.
- Abbreviation: 2msbk = moderate, medium, subangular blocky
- Structure is the result of many processes
  - Freeze/thaw cycles
  - Chemical processes of organic material and clays that act as binding agents
  - Earthworms
  - Plant roots
- Compaction destroys the structure


Field Margins
(not plowed in 30+ years)
Tilled Field
(history of field corn
and currently vegetables)


Good Soil

Compact Soil

ces

SOIL EVALUATION REPORT

ance with SPS 385, Wis. Adm. Code
inches in size. Plan must include,
/), direction and percent slope,
to nearest road.
on.
urposes (Privacy Law, s. 15.04(1)(m)).

County		
Parcel I.D.		
Reviewed by		Date

	Property Location Govt. Lot ¼ ¼ S T N R		☐ E (or) ☐ W
	Lot #	Block #	Subd. Name or CSM#
one Number ( )	☐ City	☐ Village ☐ Town	Nearest Road

ooms ____ Code derived design flow rate ____ GPD
cribe: ____
____ Flood Plan elevation if applicable ____ ft.

Ground surface elev. ____ ft. Depth to limiting factor ____ in.

tion Color	Texture	Structure Gr. Sz. Sh.	Consistence	Boundary	Roots	Soil Application Rate GPD/Ft² *Eff#1	*Eff#2

Ground surface elev. ____ ft. Depth to limiting factor ____ in.

tion Color	Texture	Structure Gr. Sz. Sh.	Consistence	Boundary	Roots	Soil Application Rate GPD/Ft² *Eff#1	*Eff#2


34
35
36
37
38
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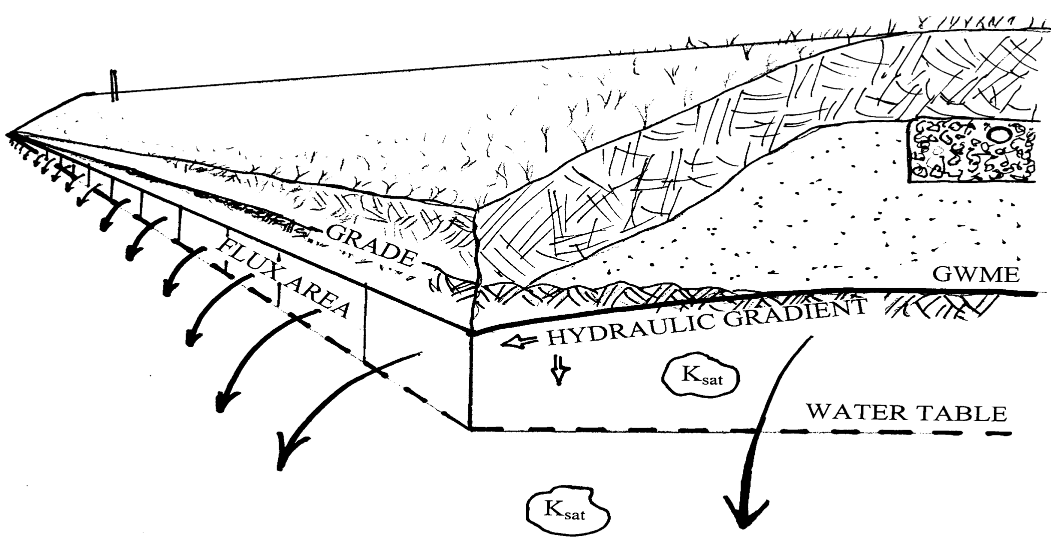
40
41
42
43

Linear Loading Rate (LLR)

100 ft

100 gpd /100 ft = 1gpd/ft

1 ft



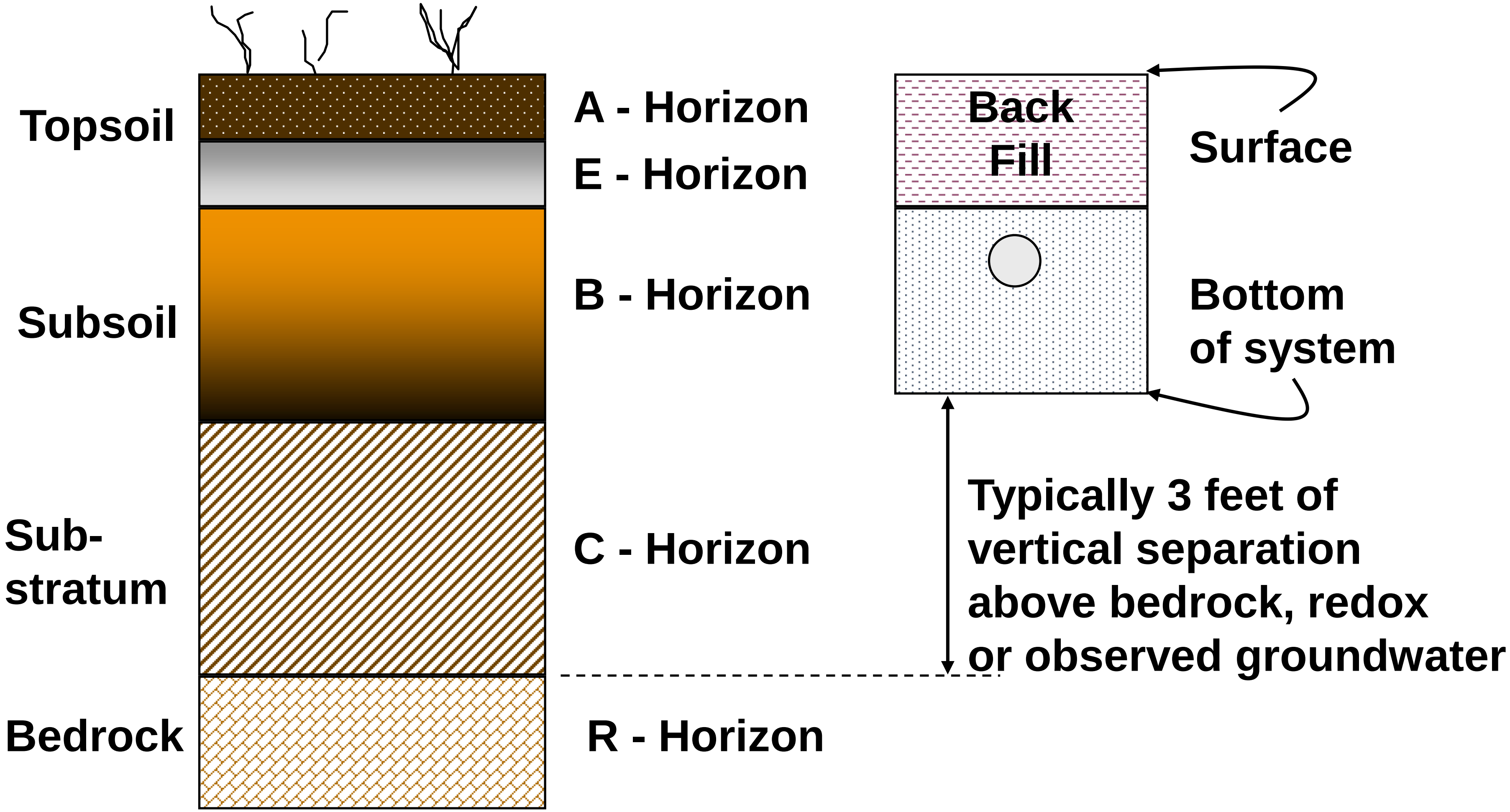
10 ft

100 gpd /10 ft = 10 gpd/ft

10 ft

What's Better?

Vertical Separation Concept



Minimum Depth of Soil for Treatment

Table 383.44–3

Minimum Depth of Unsaturated Soil for Treatment Purposes[a] (in inches)

Soil Characteristics	Influent Quality[e] and Percent Coarse Fragments					
Texture[d]	Fecal Coliform >10^4 cfu/100mL			Fecal Coliform ≤10^4 cfu/100mL[b]		
	≤35%	>35 to ≤60%	>60 to ≤90%[b,c]	≤35%	>35 to ≤60%	>60 to ≤90%[c]
COS, S, LCOS, LS	36	60	60	24	36	60
FS, VFS, LFS, LVFS	36			24		
COSL, SL	36			24		
FSL, VFSL	36			24		
L	36			24		
SIL	36			24		
SI	36			24		
SCL, CL, SICL	36			24		
SC, C, SIC	36			24		

Note a: Influent quality as per s. SPS 383.44 (2)

Note b: Requires pressure distribution under sub. (5) (a)

Note c: All coarse fragment voids must be filled with fine earth

Note d:

COS – Coarse Sand	LVFS – Loamy Very Fine Sand	SI – Silt
S–Sand	COSL – Coarse Sandy Loam	SCL – Sandy Clay Loam
LCOS – Loamy Coarse Sand	SL – Sandy Loam	CL – Clay Loam
LS – Loamy Sand	FSL – Fine Sandy Loam	SICL – Silty Clay Loam
FS – Fine Sand	VFSL – Very Fine Sandy Loam	SC – Sandy Clay
LFS – Loamy Fine Sand	L – Loam	C – Clay
VFS – Very Fine Sand	SIL – Silt Loam	SIC – Silty Clay

Note e: The values for fecal coliform are reported as a monthly geometric mean. The geometric mean shall be determined on the basis of measurements taken over 30 consecutive days, with at least 6 measurements occurring on 6 separate days.

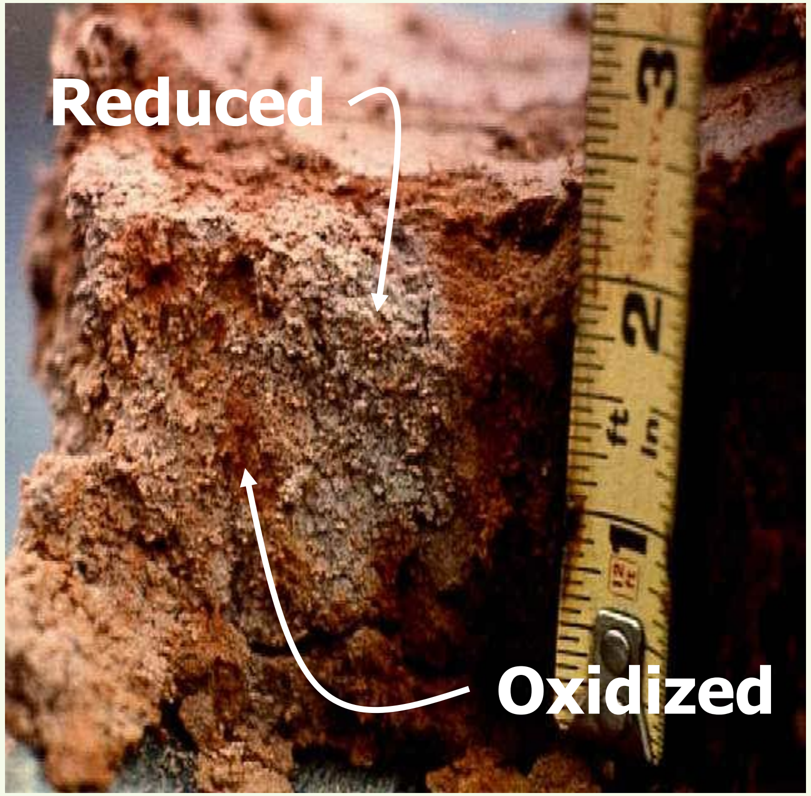
More Soils Definitions SPS 81.01

(202) **"Redoximorphic feature"** means a feature formed in the soil matrix by the processes of reduction, translocation and oxidation of iron and manganese compounds in seasonally saturated soil.

(118) **"High groundwater"** means zones of soil saturation which include perched water tables, shallow regional groundwater tables or aquifers, or zones that are seasonally, periodically or permanently saturated.

(119) **"High groundwater elevation"** means the higher of either the elevation to which the soil is saturated when observed as a free water surface, or the elevation to which the soil has been seasonally or periodically saturated as indicated by the highest elevation of redoximorphic features in the soil profile.

REDOX DESCRIPTION



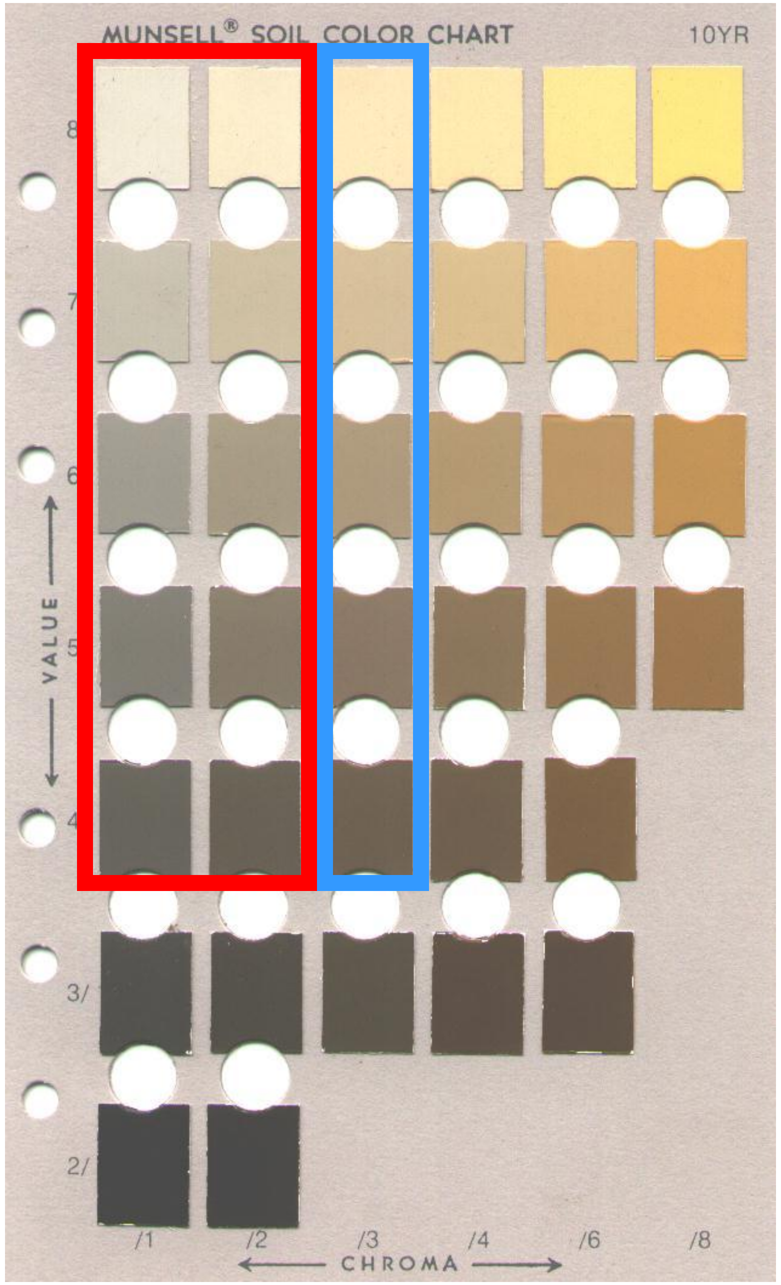
Iron Depletion and Concentration

- Redox feature formation requires:
  - Anaerobic conditions
    - Saturation
    - Near Saturation
  - Organic matter
  - Temperature
  - pH
  - Iron (Fe) and Manganese (Mn)

REDOX DESCRIPTION

Low Chroma Colors

- Value of 4 or more and a chroma of 2 or less.
  - Redox depletions
  - Reducing conditions
- Suspicious conditions with chromas of 3 or less.



REDOX DESCRIPTION

Reduced Matrices

- Soil matrices that have a low chroma color in-situ because of the presence of Fe(II)- Ferrous Iron.
- Color changes in hue or chroma when exposed to air as the Fe(II) is oxidized to Fe(III) – Ferric Iron.

BEDROCK

"Bedrock" means rock that is exposed at the earth's surface or underlies soil material and includes:

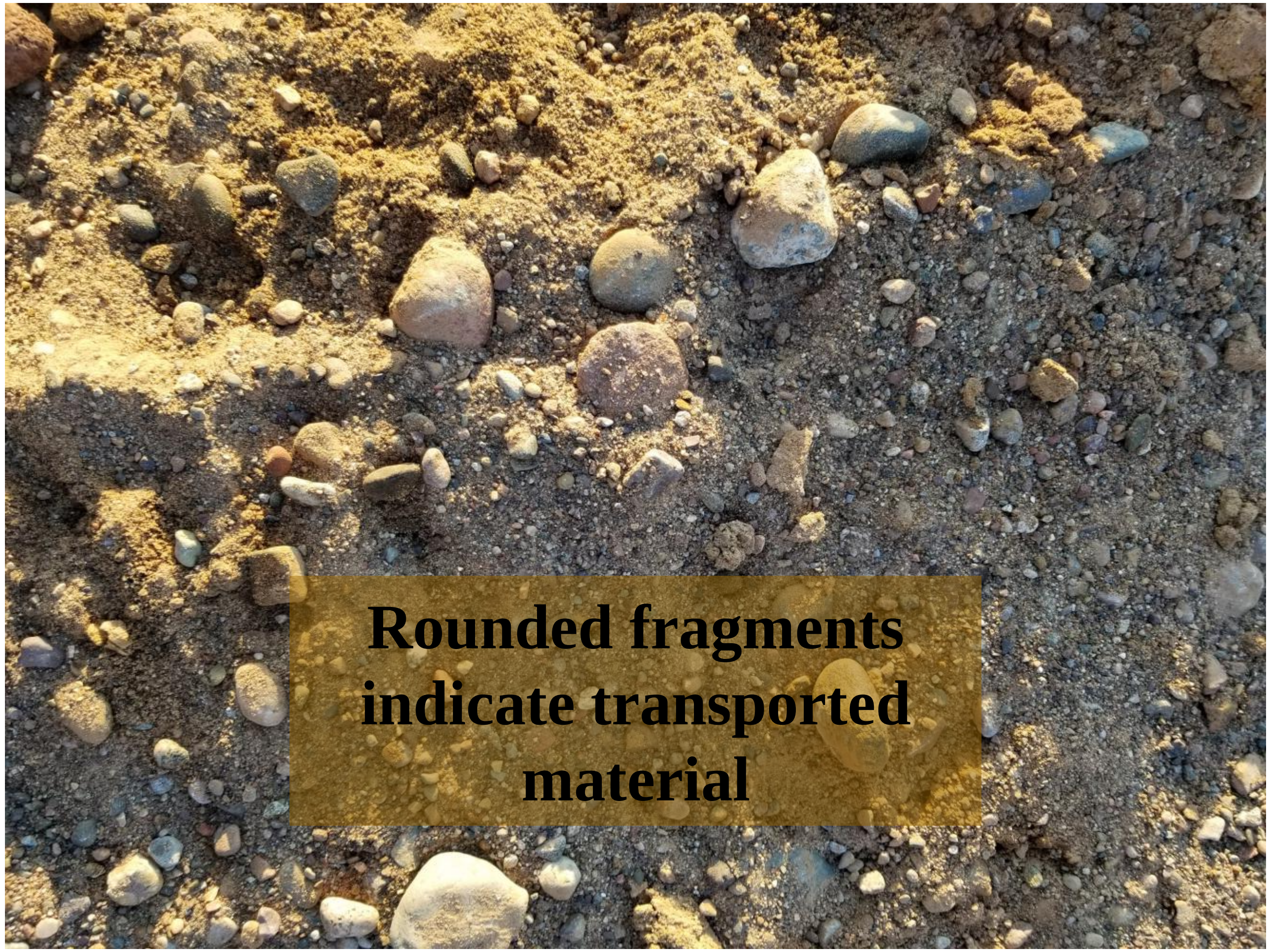
(a) Weathered in–place consolidated material, larger than 2 mm in size and greater than 50% by volume;

AND

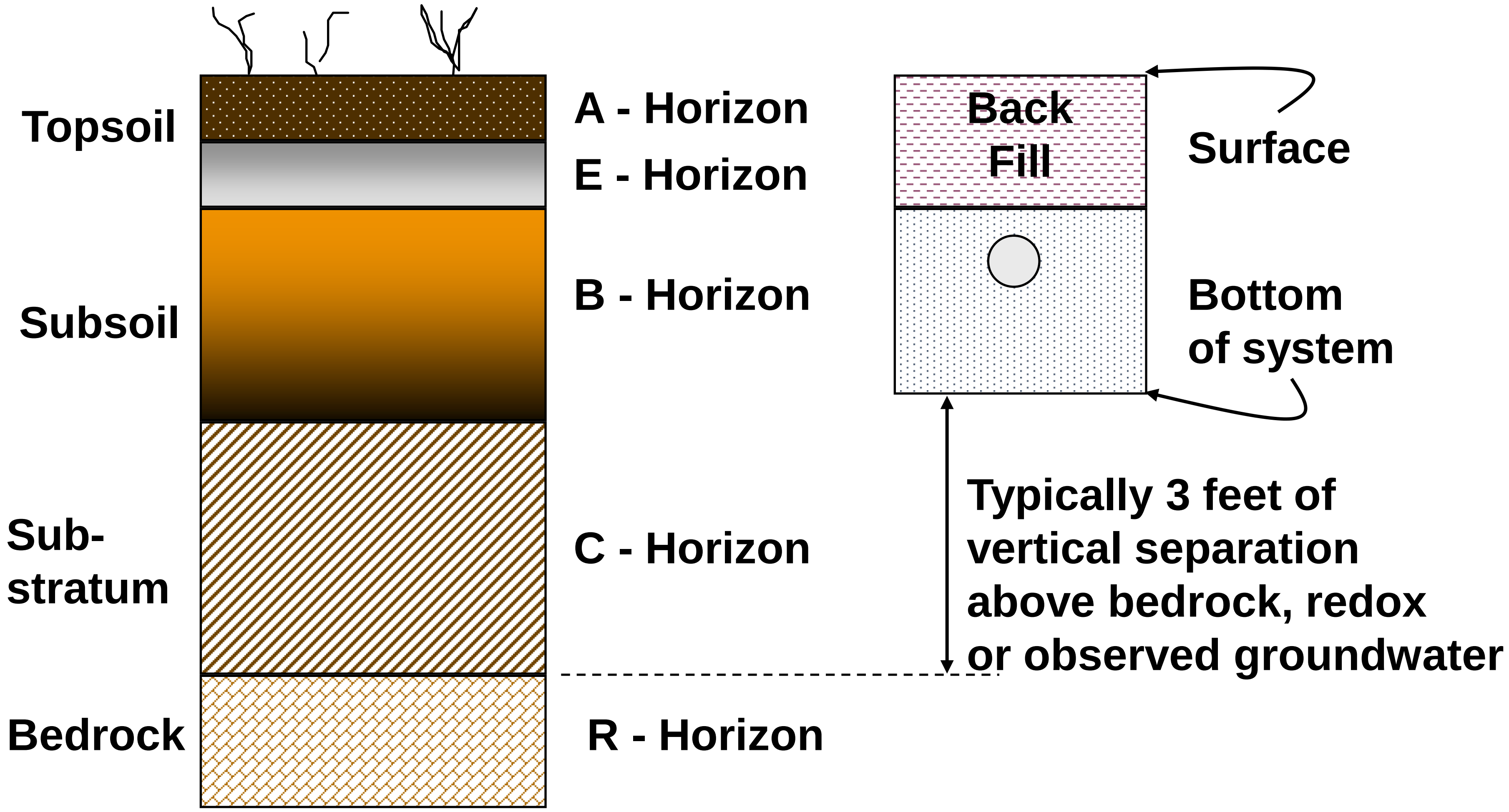
(b) Weakly consolidated sandstone at the point of increased resistance to penetration of a knife blade.

BEDROCK


Angular fragments indicate possible weathered in place material

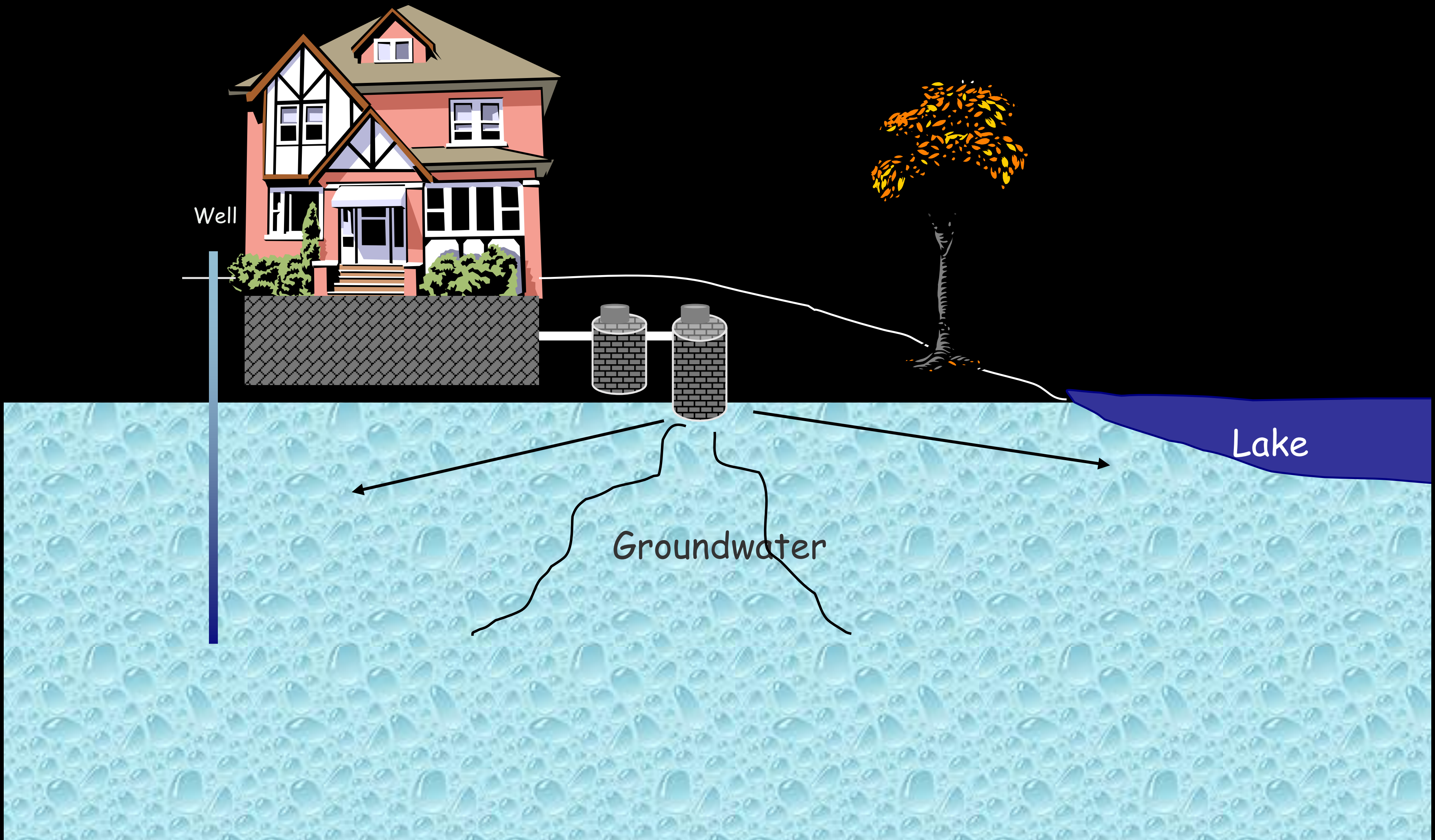

Rounded fragments indicate transported material

Vertical Separation Concept



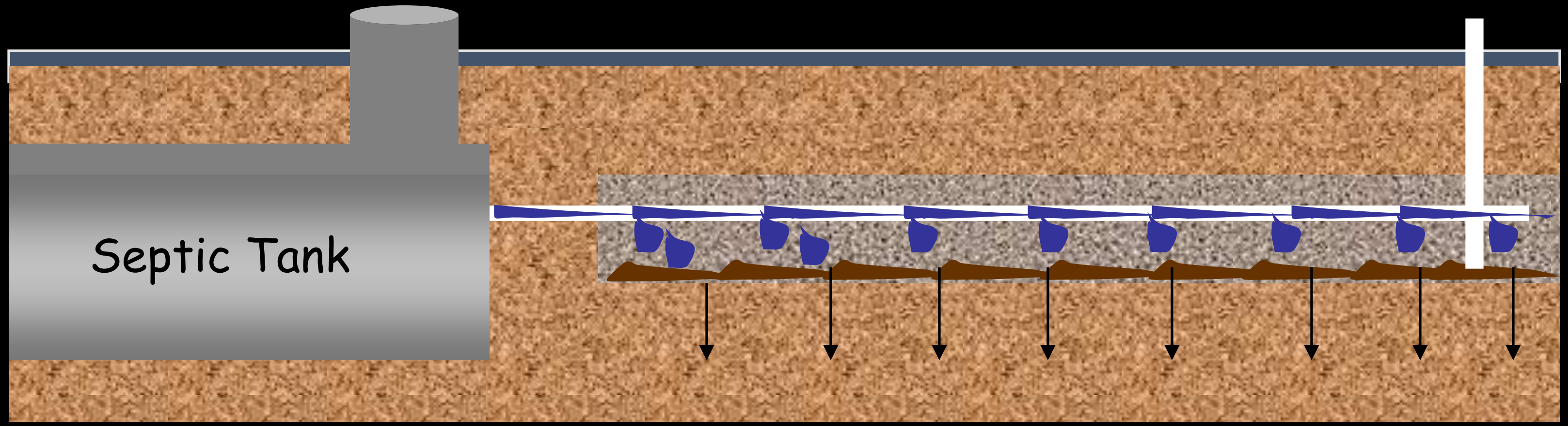
Failure Definition - § 145

- **Discharge to surface water or groundwater**
- **Discharge into seasonally saturated soils**
- **Discharge into drain tile or bedrock**
- **Discharge to the surface of the ground**
- **Back up into structure**


Well
Lake
Groundwater

Gravity Distribution

Trickle of water from septic tank results in overloading localized areas of the drainfield. This can lead to groundwater contamination in coarse granular soils because of insufficient treatment. In addition, if not properly oxygenated, the organic carbon (biomat) accumulation causes early failure.



Creeping Failure

Water Use in Dwelling

Citation: Lucas SA, Coombes PJ, Geary PM, Horn K (2017) On-Site Wastewater Systems: Investigating Dynamics and Diurnal Patterns Impacting on the Performance of Mound Systems. J Environ Anal Toxicol 7: 498. doi: 10.4172/2161-0525.1000498

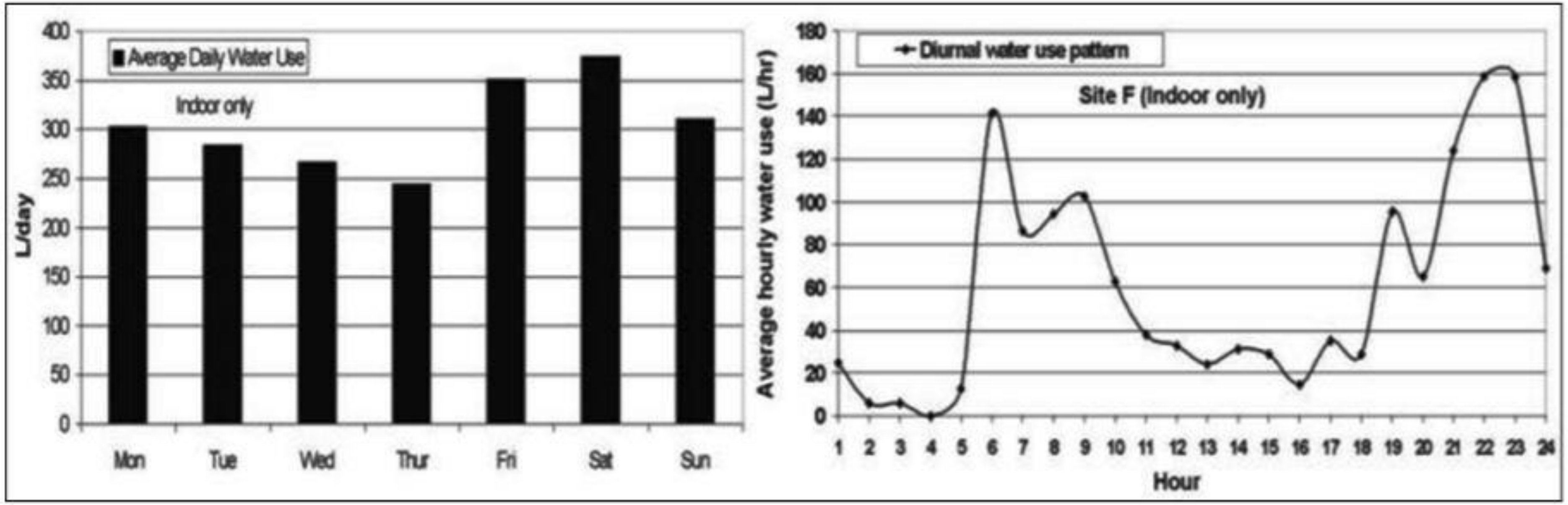
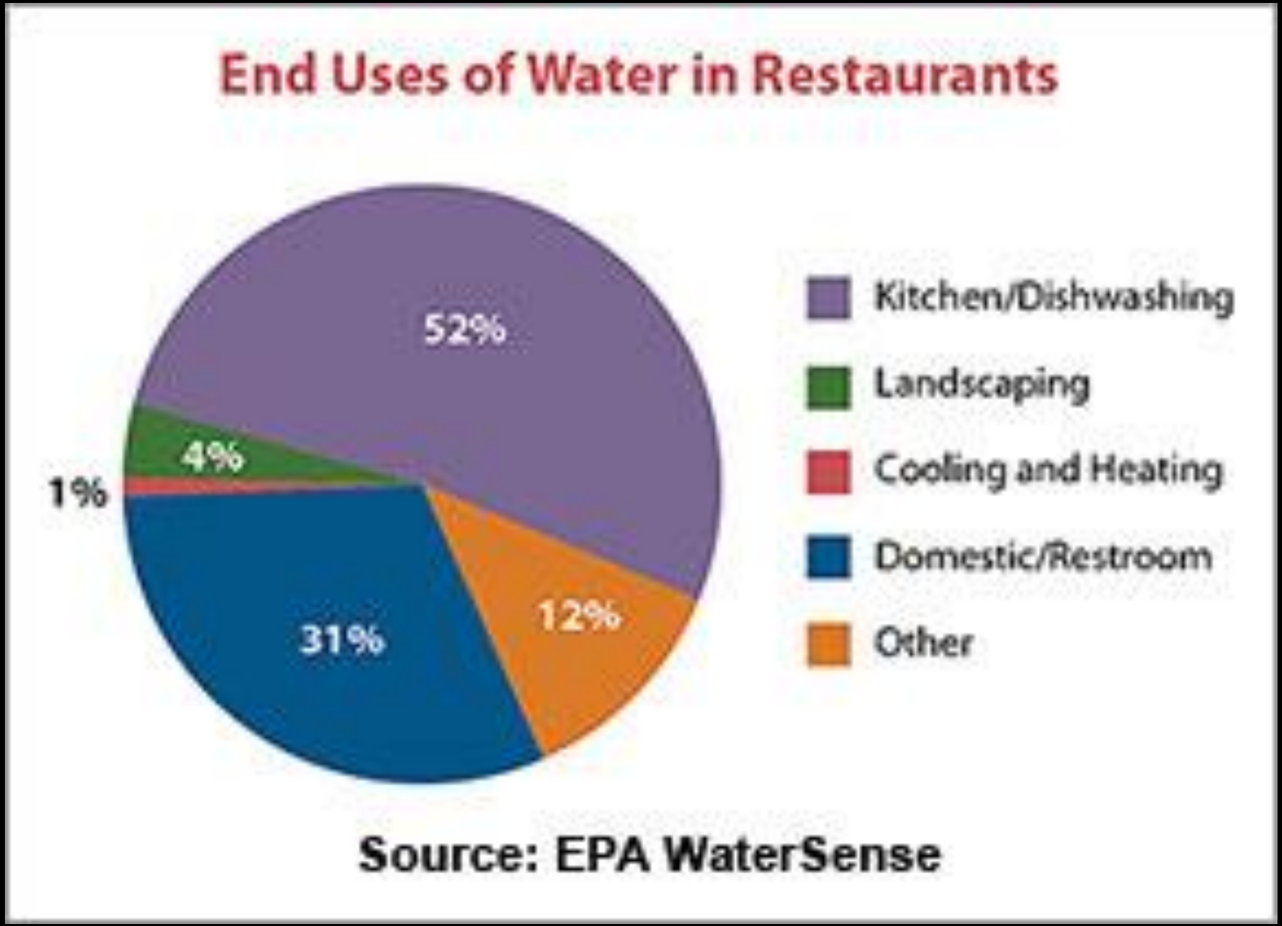


Figure 4: Daily average indoor water use and average indoor diurnal water use pattern (Site F).

What about a restaurant?



How is water being used in the structure?

Many different people in and out = higher risk of infectious disease

TABLE 3.1 Treatment Performance of Soil

Unsaturated Flows

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Nitrogen (mg/L)				
Total	35-189**,***	25-124**,***	—	—
NH_4	7-40**	20-60**	*B-20**	—
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Total Phosphorus (mg/L)	10-27**	3-40***	*B-10**	*B-1**

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**Tchobanoglous and Burton, 1991
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Onsite Sewage Treatment Program, University of Minnesota. 2020. Manual for Septic System Professionals in Minnesota, 4th Ed. St. Paul MN

Passage of microorganisms in septic tank effluents through mound sand in a controlled laboratory environment. [DNR-164] [2001]

Standridge, Jon H.; Olstadt, Jeremy; Sonzogni, William C.
Madison, Wisconsin: Wisconsin State Laboratory of Hygiene, [2001]

About the Study

Used varying heights of columns of C33 sand loaded at variable dose volumes at 2.0 g/ft^2/day for highly treated effluent and 1.0 g/ft^2/day for residential strength effluent

About the Study

- Conclusions:
- Organisms in reasonably clean effluents do not pass through mound sand in columns 12 inches or longer <u>**when dosed evenly throughout the day**</u> at the rate of 2.0 g/ft^2/day.

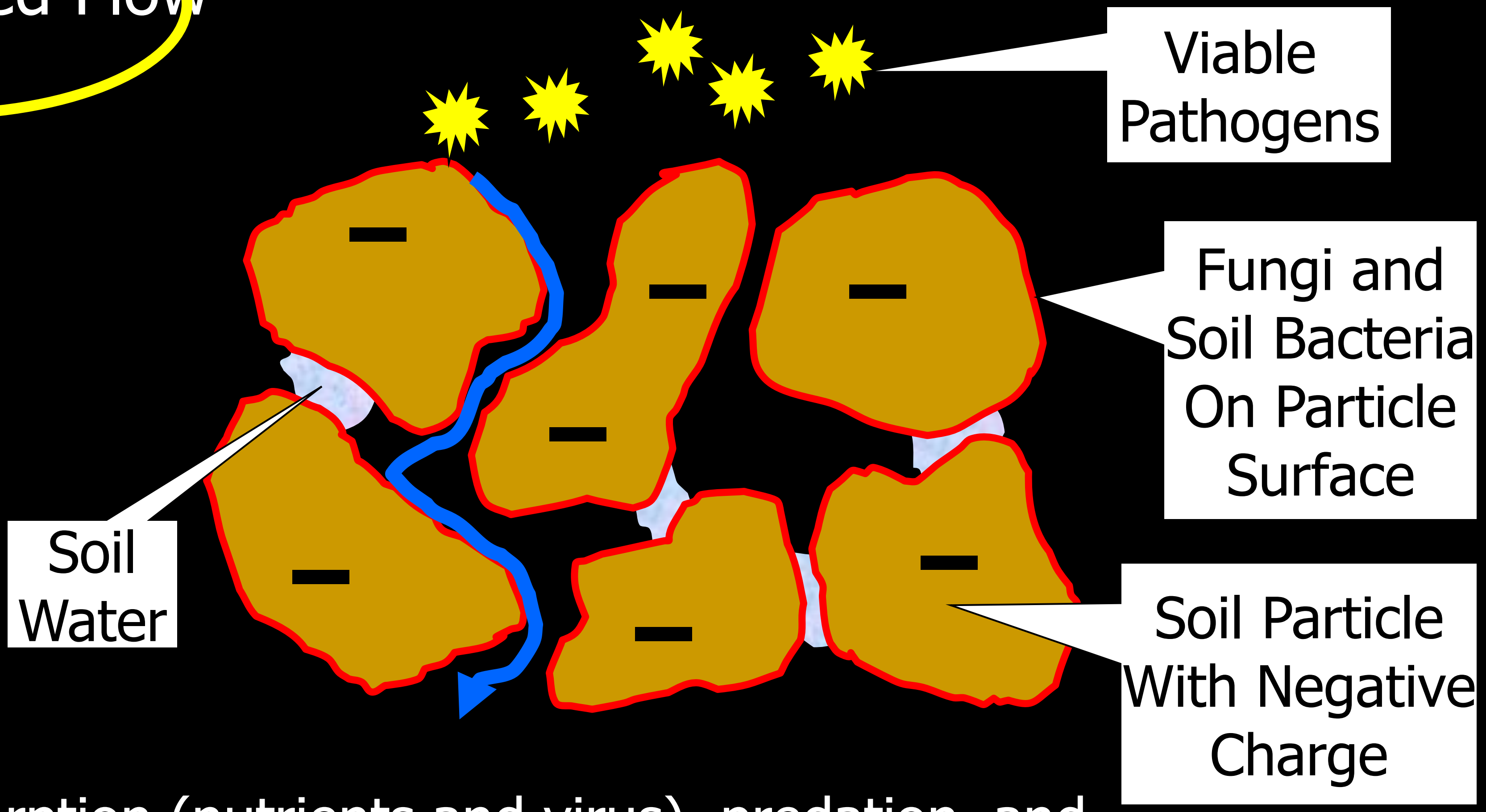
- Organisms in low quality septic tank effluents do no pass through mound sand in columns 24 inches or longer <u>**when dosed evenly throughout the day**</u> at the rate of 1.0 g/ft^2/day

About the Study

If mound sand columns are loaded with either <u>poorly spaced dosing or excessive flows, organisms will pass through the sand, even when the column length is 60 inches.</u>

Soil Treatment

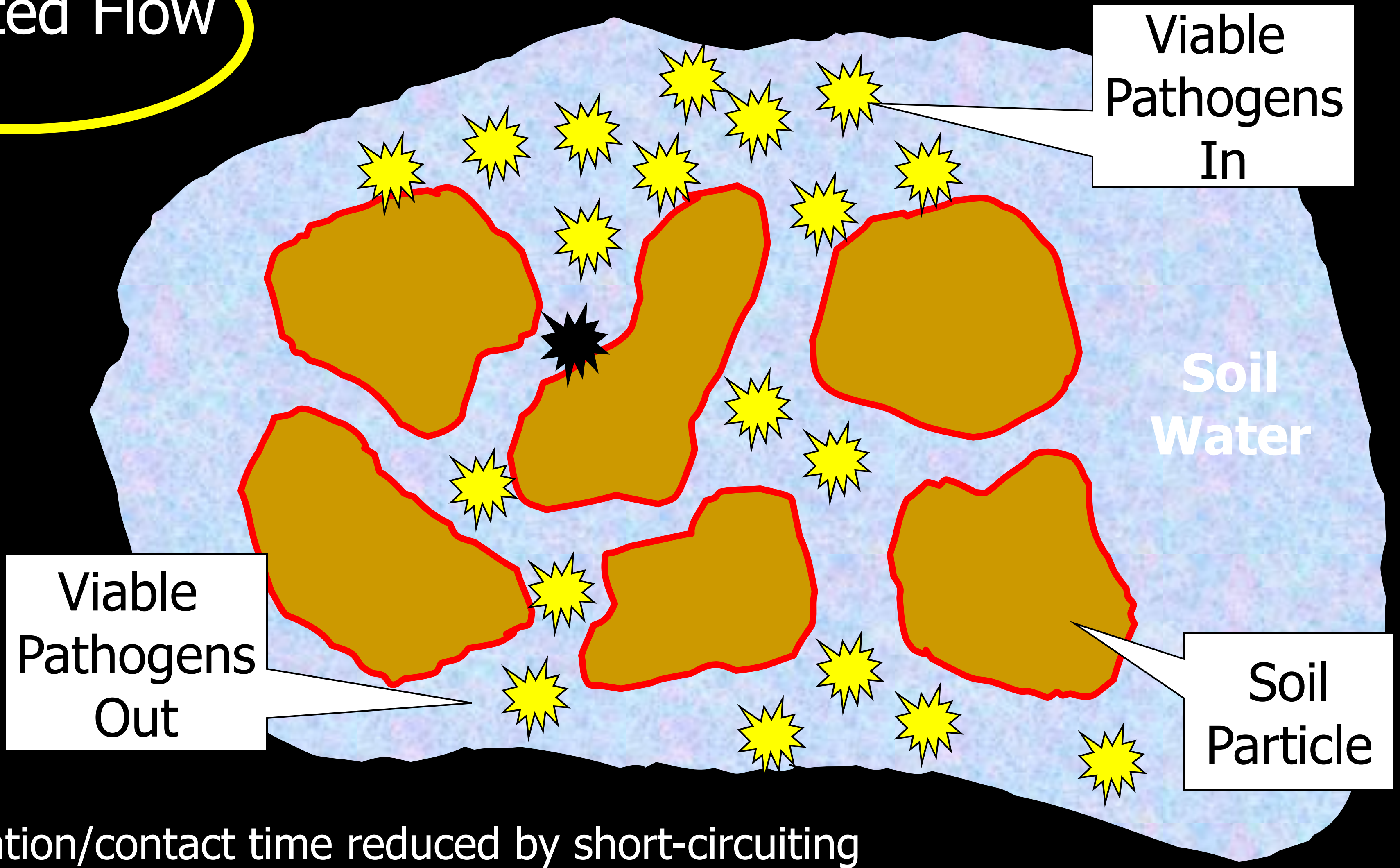
Unsaturated Flow



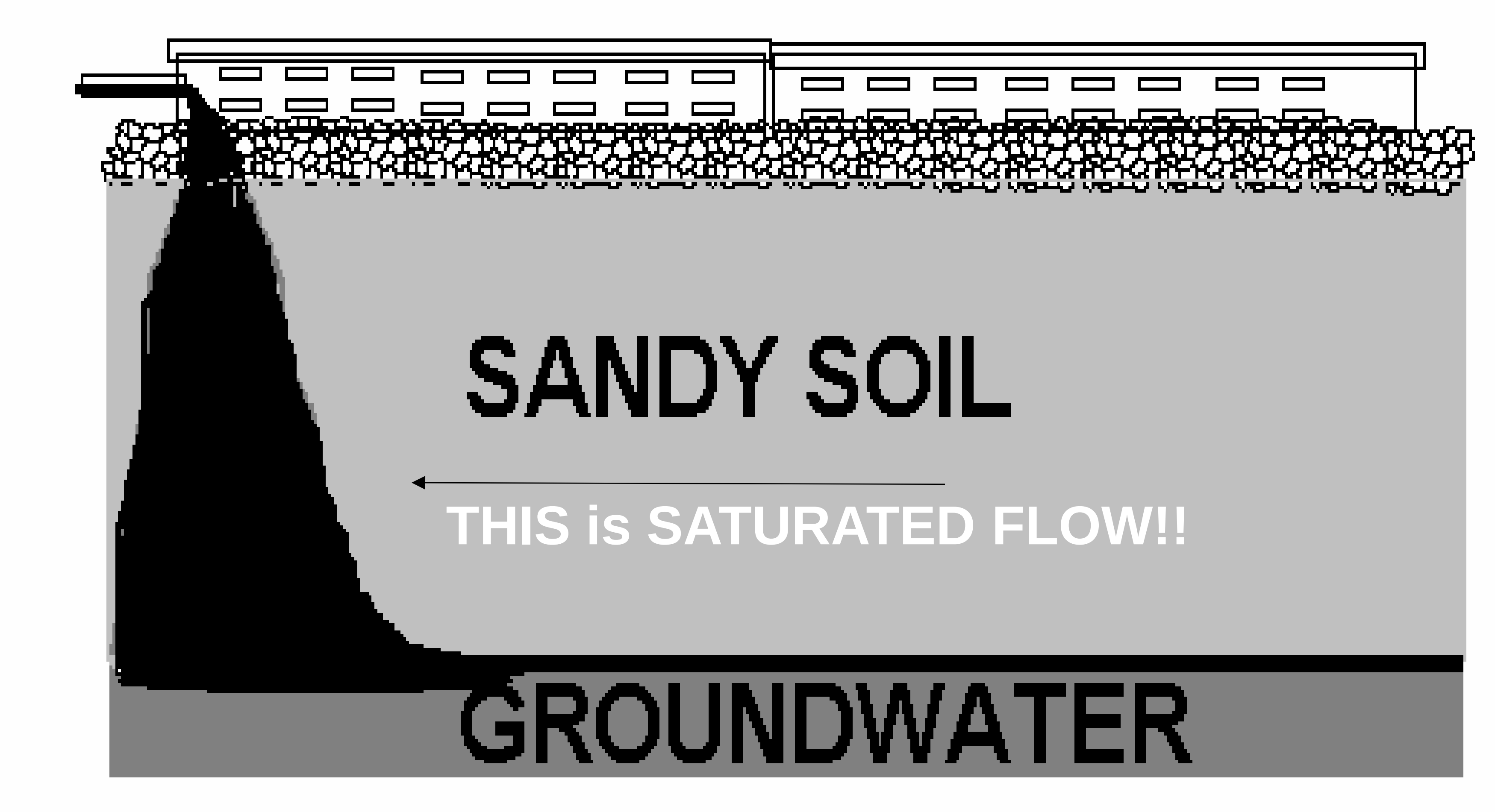
Filtration, adsorption (nutrients and virus), predation, and retention/contact time increase treatment. Pathogens are retained on particle surfaces or in small pores.

Soil Treatment

Saturated Flow

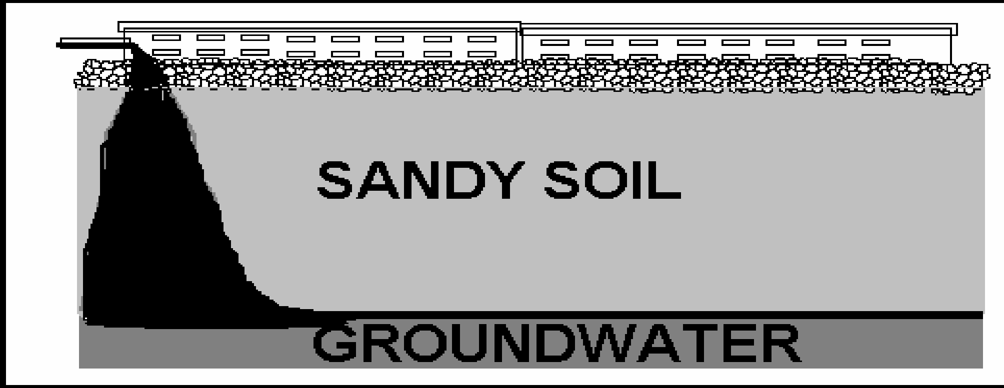


Retention/contact time reduced by short-circuiting past particle surfaces.

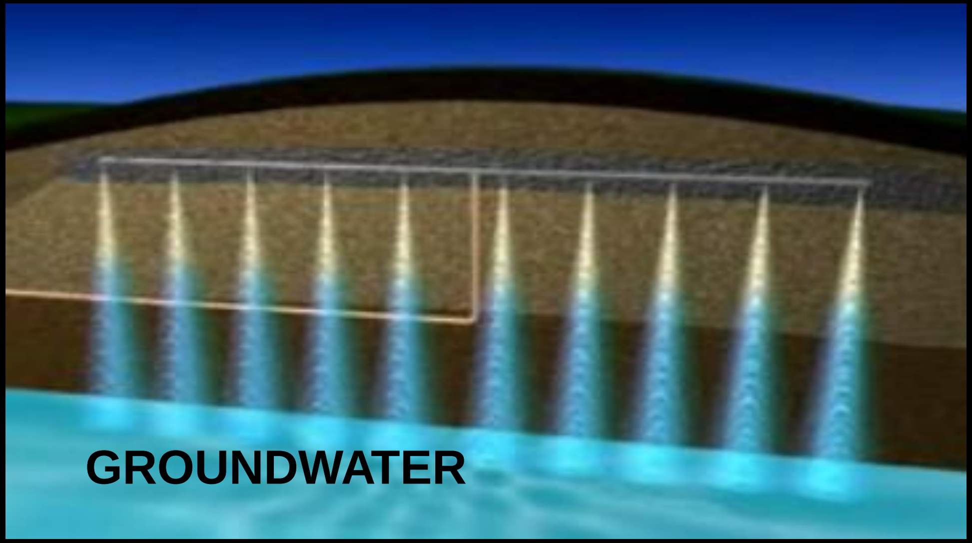


Gravity Flow – Just because the system isn't ponding or wastewater isn't breaking out does NOT mean the system is working properly!

Gravity vs. Uniform Distribution



Gravity Flow



Uniform Distribution

- Uniform distribution
  - Pressure and drip distribution
  - Spreads wastewater over a larger surface area resulting in contact with a greater volume of soil
  - Better overall treatment
    - More soil volume used
    - Unsaturated flow maintained
      - Slow moving effluent increases retention/contact time
  - Reaeration between doses
    - Reduced biomat formation

- Gravity distribution
  - Always unequal
  - Uneven cell to cell loading
    - Through headers or D-box
  - Overloads soil within cell
  - Saturated flow may occur in large interconnected pores
    - Reduced treatment
  - Quicker biomat formation

Distribution Network

"Uniform distribution by gravity or dosing <u>does not occur</u>. As the effluent is pumped in or flows by gravity, it is concentrated within one small area of the bed or trench. This results in saturated flow thru the fill material. (Converse 1974, Otis et al. 1972) This area becomes overloaded thus resulting in surface seepage with the remaining portion of the mound unused."

"*Mound for the Treatment and Disposal of Septic Tank Effluent*" Publication 15.6, 1977 - J.C. Converse, B.L. Carlile, G.W. Peterson

Distribution Network

"The only way to obtain uniform distribution is to use a pressure system consisting of a manifold with small diameter laterals and holes (Converse 1974, Converse et al. 1975, Otis et al, 1974 and 1978)."

"*Mound for the Treatment and Disposal of Septic Tank Effluent*" Publication 15.6, 1977 - J.C. Converse, B.L. Carlile, G.W. Peterson

Why Equal Distribution Matters

Equal distribution of effluent spreads wastewater out over the entire surface of the distribution cell thus ensuring more total volume of soil is used for treatment.

- Coarse soils offer less total particle surface area for treatment reactions to occur and have reduced retention time for pathogen die-off
- Under low ($\leq$ 30mg/L) BOD_5 and TSS loads, a biomat does not form to ensure a high level of wastewater treatment and groundwater protection
- Improves the performance and increases the life span of a dispersal cell
- Reduces the chance of breakout or seepage on slopes

Pressure Distribution Systems

- Basic concepts of distribution system:
  - Equal Distribution - using proper manifold size and length, proper lateral size and length, proper orifice size and spacing.
  - Accurate Total Dynamic Head (TDH) calculations
  - Dose volumes
  - Pump/siphon selection
  - Testing

Some Things to Consider

- Loading Rates – Is the system sized appropriately for the flows AND loads? Are hydraulic loading rates assigned appropriately? What about linear loading rates?
- Disturbed Soil or Fill – Concern for preferential flow = saturated flow.
- Compaction – Has any part of the dispersal site been impacted by compaction?
- Limiting Factor – Where is it and What is it? Do we have proper separation?
- Treatment – Is there slowly or rapidly permeable soils? Gravity distribution?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THANK YOU!

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