Spreadsheet for converting saturated hydraulic conductivity to LTAR for on-site wastewater systems

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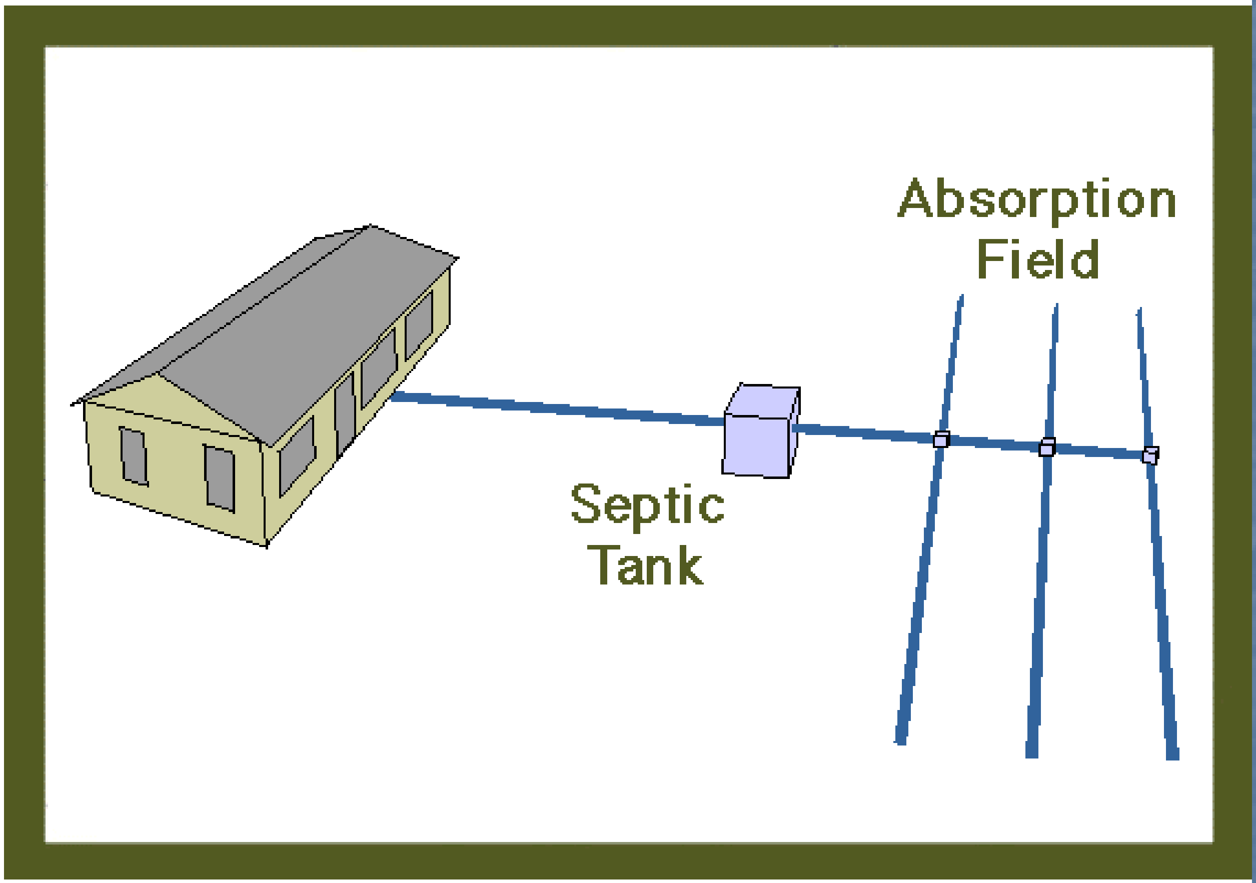
On-Site Wastewater Systems

- 60 million people in the US use on-site wastewater systems (OWS)
  - Also referred to as septic systems
- 33% of new homes use OWSs
- 75% of new homes in Georgia in 2007 used OWSs
- OWSs are often cited as potential sources of N, P, and bacteria in TMDL watersheds

Approach

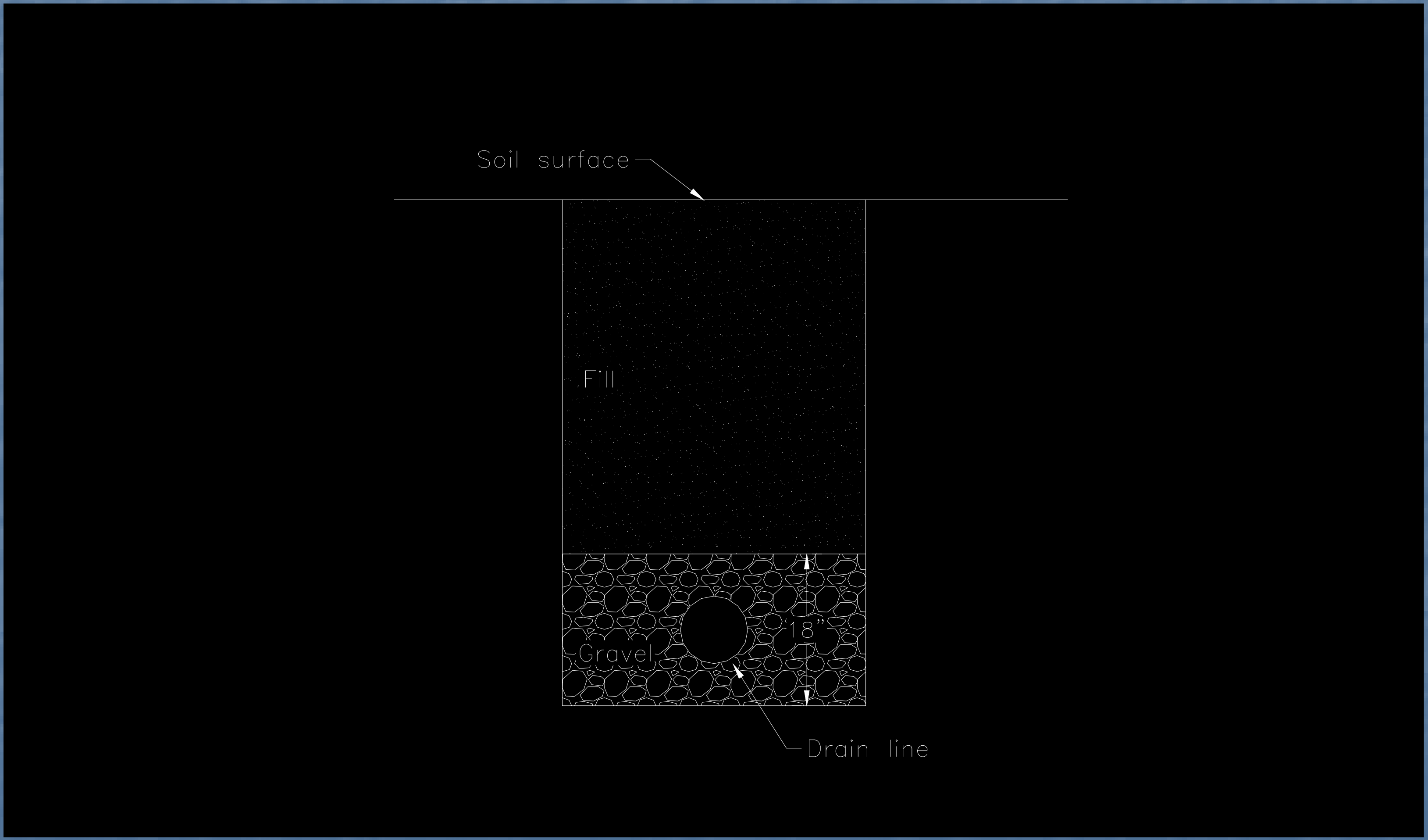
Complex numerical 2D model → Spreadsheet decision tool → Better policy

OWS

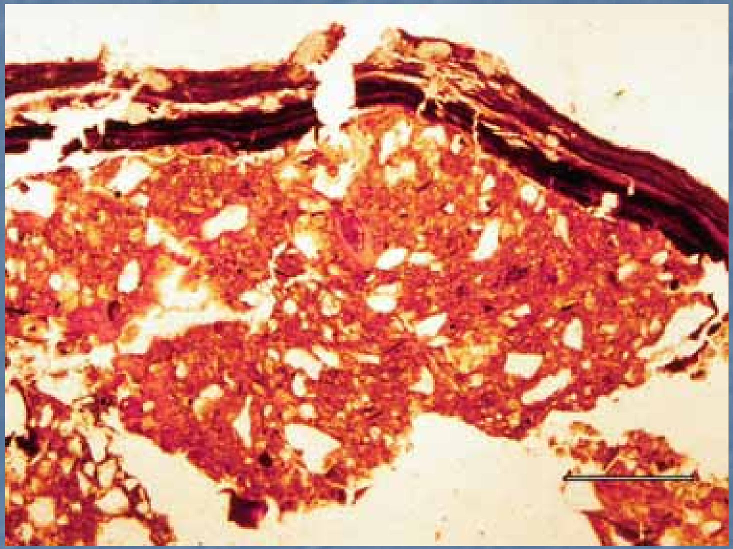


Septic tank with drainfield. Perforated pipe in the drainfield allows the soil to absorb treated effluent.

Drainfield Trench



Biomat



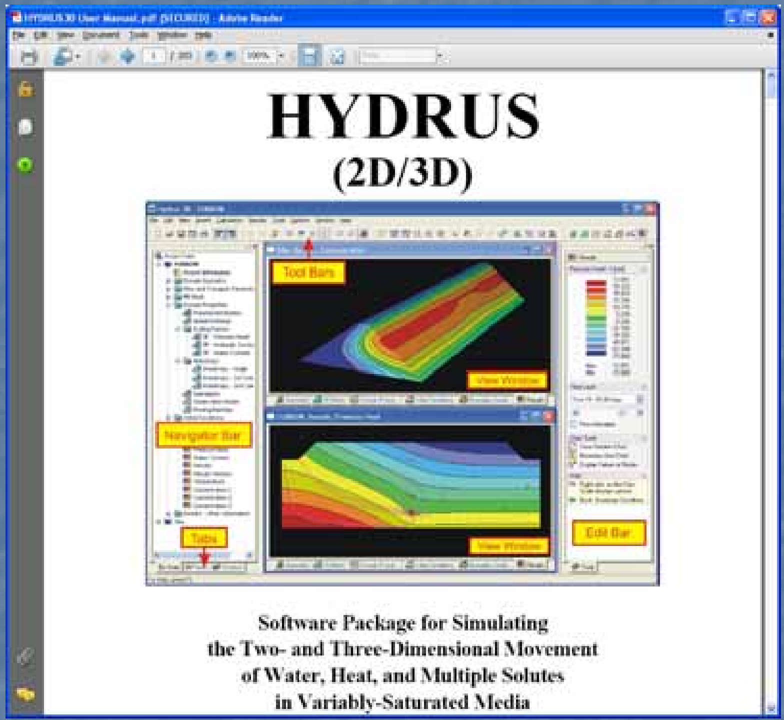
Average thickness = 0.5 cm
Average saturated hydraulic conductivity = 0.23 cm/day

Long Term Acceptance Rates (LTAR)

- Siegrist. 2007
  - LTAR is “long term acceptance rate” of wastewater by soil
  - State regulators use this rate to determine suitable sites and required trench length
  - Varies widely among states & often based on empirical evidence
  - Need more rational and uniform approach to estimate LTAR
  - Use computer models to aide design

Numerical Model

- HYDRUS
  - Simunek et al. , 2006
- Simulates water and solute flow in 2 and 3 dimensions

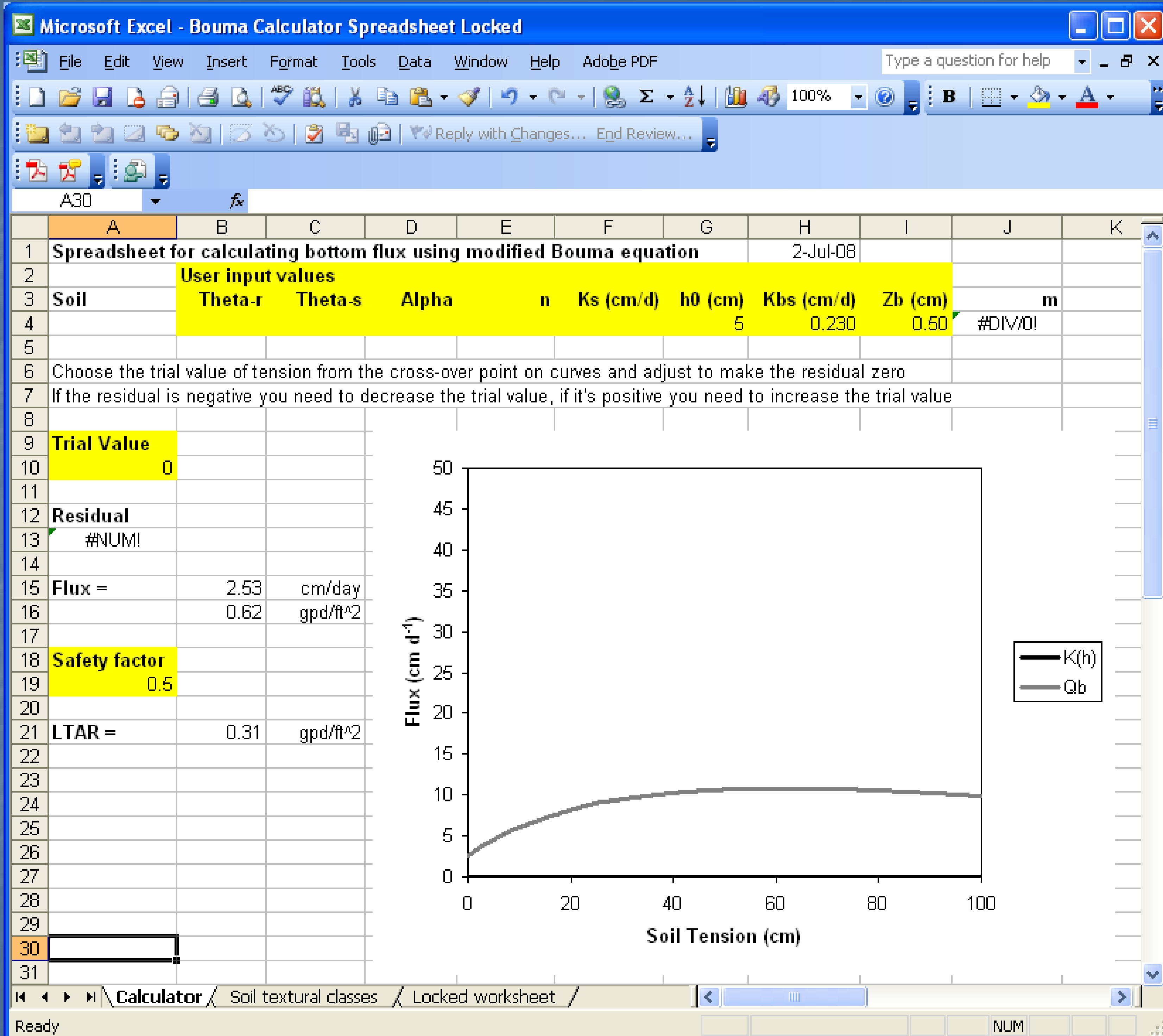


Objectives

- Develop method for estimating LTAR based on soil and biomat hydraulic properties
- Use HYDRUS to estimate steady trench bottom flow under 5-cm ponding for 12 soil textural classes
- Develop a spreadsheet method to estimate LTAR based on HYDRUS results

LTAR Spreadsheet Example

- Loamy sand
- Ksat = 80 cm/day



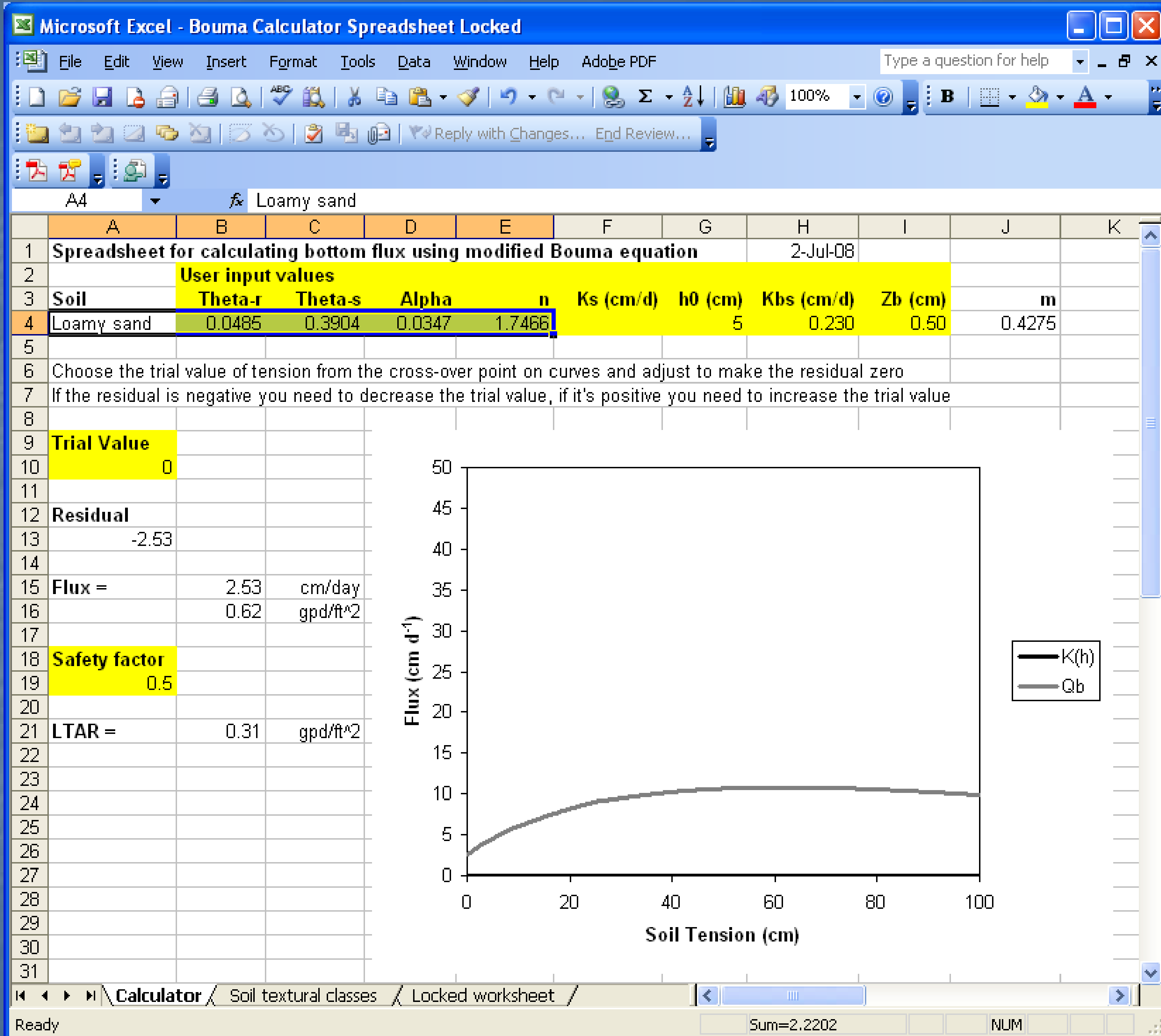
Microsoft Excel - Bouma Calculator Spreadsheet Locked
File Edit View Insert Format Tools Data Window Help Adobe PDF
Type a question for help
100%
Reply with Changes... End Review...
A30
Spreadsheet for calculating bottom flux using modified Bouma equation
2-Jul-08
User input values
Soil
Theta-r
Theta-s
Alpha
n
Ks (cm/d)
h0 (cm)
Kbs (cm/d)
Zb (cm)
m
5
0.230
0.50
#DIV/0!
Choose the trial value of tension from the cross-over point on curves and adjust to make the residual zero
If the residual is negative you need to decrease the trial value, if it's positive you need to increase the trial value
Trial Value
0
Residual
#NUM!
Flux =
2.53
cm/day
0.62
gpd/ft^2
Safety factor
0.5
LTAR =
0.31
gpd/ft^2
Flux (cm d-1)
Soil Tension (cm)
K(h)
Qb
Calculator
Soil textural classes
Locked worksheet
Ready
NUM

Microsoft Excel - Bouma Calculator Spreadsheet Locked

Soil textural classes and van Genuchten (1980) parameters from Rosetta Lite

Textural Class	Theta-r	Theta-s	Alpha	n	Ks (cm/d)
Sand	0.0530	0.3747	0.0353	3.1798	642.98
Loamy sand	0.0485	0.3904	0.0347	1.7466	105.12
Silt	0.0501	0.4887	0.0066	1.6769	43.74
Sandy loam	0.0387	0.3870	0.0267	1.4484	38.25
Silt loam	0.0645	0.4387	0.0051	1.6626	18.26
Clay	0.0982	0.4588	0.0150	1.2529	14.75
Sandy clay loam	0.0633	0.3837	0.0211	1.3298	13.19
Loam	0.0609	0.3991	0.0111	1.4737	12.04
Sandy clay	0.1169	0.3854	0.0334	1.2067	11.35
Silty clay loam	0.0901	0.4820	0.0084	1.5202	11.11
Silty clay	0.1108	0.4808	0.0162	1.3207	9.61
Clay loam	0.0792	0.4418	0.0158	1.4145	8.18

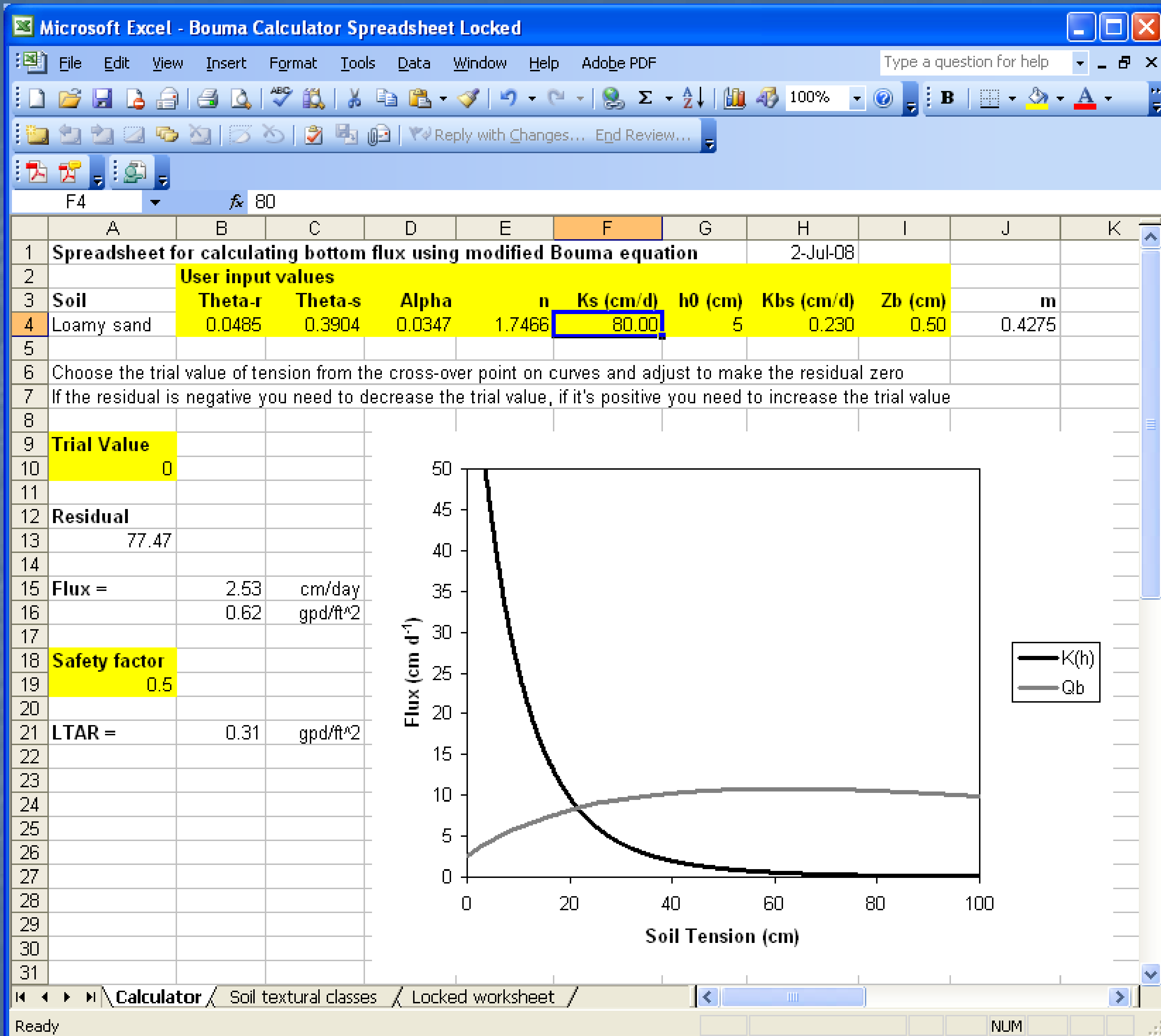
Calculator | Soil textural classes | Locked worksheet



Microsoft Excel - Bouma Calculator Spreadsheet Locked

A4 Loamy sand

	A	B	C	D	E	F	G	H	I	J
1	Spreadsheet for calculating bottom flux using modified Bouma equation							2-Jul-08		
2		User input values								
3	Soil	Theta-r	Theta-s	Alpha	n	Ks (cm/d)	h0 (cm)	Kbs (cm/d)	Zb (cm)	m
4	Loamy sand	0.0485	0.3904	0.0347	1.7466		5	0.230	0.50	0.4275
5										
6	Choose the trial value of tension from the cross-over point on curves and adjust to make the residual zero									
7	If the residual is negative you need to decrease the trial value, if it's positive you need to increase the trial value									
9	Trial Value									
10	0									
12	Residual									
13	-2.53									
15	Flux =	2.53	cm/day							
16		0.62	gpd/ft^2							
18	Safety factor									
19	0.5									
21	LTAR =	0.31	gpd/ft^2							



	A	B	C	D	E	F	G	H	I	J
1	**Spreadsheet for calculating bottom flux using modified Bouma equation**							2-Jul-08		
2		**User input values**								
3	**Soil**	**Theta-r**	**Theta-s**	**Alpha**	**n**	**Ks (cm/d)**	**h0 (cm)**	**Kbs (cm/d)**	**Zb (cm)**	**m**
4	Loamy sand	0.0485	0.3904	0.0347	1.7466	80.00	5	0.230	0.50	0.4275
5										
6	Choose the trial value of tension from the cross-over point on curves and adjust to make the residual zero									
7	If the residual is negative you need to decrease the trial value, if it's positive you need to increase the trial value									
8										
9	**Trial Value**									
10	0									
11										
12	**Residual**									
13	77.47									
14										
15	**Flux =**	2.53	cm/day							
16		0.62	gpd/ft^2							
17										
18	**Safety factor**									
19	0.5									
20										
21	**LTAR =**	0.31	gpd/ft^2							

Microsoft Excel - Bouma Calculator Spreadsheet Locked

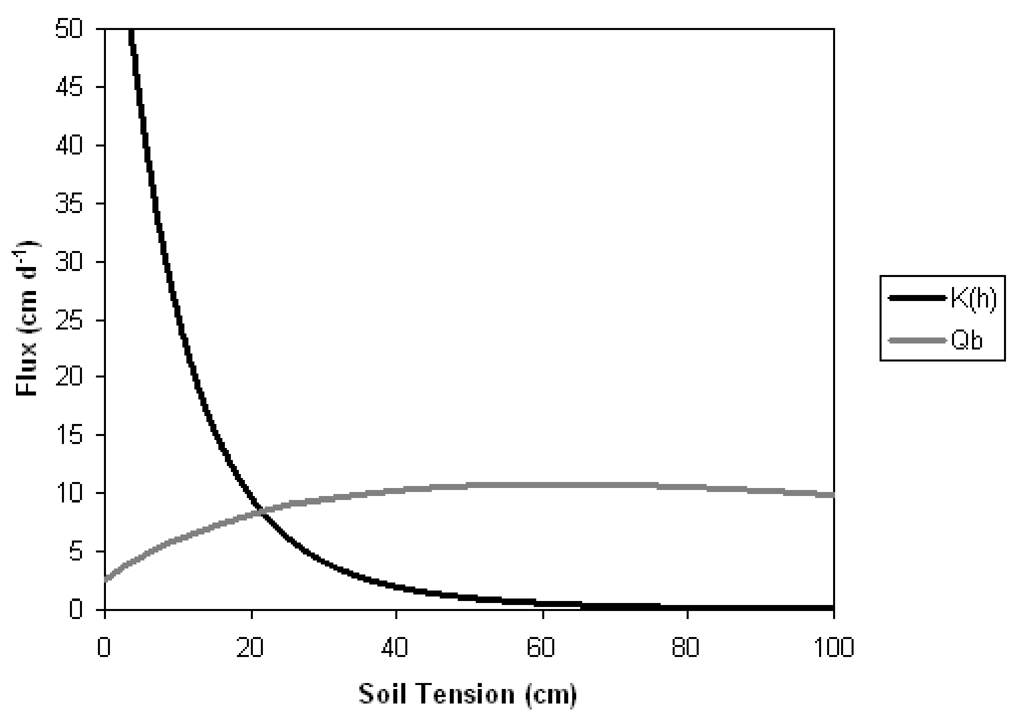
Spreadsheet for calculating bottom flux using modified Bouma equation — 2-Jul-08

	User input values								
Soil	**Theta-r**	**Theta-s**	**Alpha**	**n**	**Ks (cm/d)**	**h0 (cm)**	**Kbs (cm/d)**	**Zb (cm)**	**m**
Loamy sand	0.0485	0.3904	0.0347	1.7466	80.00	5	0.230	0.50	0.4275

Choose the trial value of tension from the cross-over point on curves and adjust to make the residual zero

If the residual is negative you need to decrease the trial value, if it's positive you need to increase the trial value

Trial Value		
21.55		
Residual		
0.00		
Flux =	8.46	cm/day
	2.07	gpd/ft^2
Safety factor		
0.5		
LTAR =	1.04	gpd/ft^2



Calculator / Soil textural classes / Locked worksheet

Soil textural class	K_s cm/day
Sand	642.98
Loamy sand	105.12
Silt	43.74
Sandy loam	38.25
Silt loam	18.26
Clay	14.75
Sandy clay loam	13.19
Loam	12.04
Sandy clay	11.35
Silty clay loam	11.11
Silty clay	9.61
Clay loam	8.18

From Rosetta database in HYDRUS

Soil texture	Deep Water Table Bottom flow	
	cm/day	% of K_s
Sand	8.74	1
Loamy sand	7.53	7
Silt	10.43	24
Sandy loam	6.06	16
Silt loam	9.68	53
Clay	4.00	27
Sandy clay loam	4.07	31
Loam	5.68	47
Sandy clay	2.92	26
Silty clay loam	6.34	57
Silty clay	3.76	39
Clay loam	4.04	49

Safety factor = 50%		LTAR	Class
Soil textural class		gpd/ft^2	
Sand	4.36	1.07	I
Silt	4.28	1.05	I
Silt loam	3.77	0.92	I
Loamy sand	3.73	0.91	I
Sandy loam	3.00	0.74	II
Silty clay loam	2.83	0.69	II
Loam	2.68	0.66	II
Sandy clay loam	2.03	0.50	III
Clay loam	1.99	0.49	III
Clay	1.99	0.49	III
Silty clay	1.87	0.46	III
Sandy clay	1.46	0.36	IV

Conclusions

- Spreadsheet
  - Provides a more scientific basis for estimating LTAR
  - Provides a method for converting measured K_s to LTAR
  - Provides a method for estimating reductions
    - Do chamber systems have higher biomat K_s?
    - If so use spreadsheet to determine reduction
- Georgia plans to adopt use of spreadsheet
- Better estimates of LTAR will hopefully lead to less OWS failures and watershed contamination

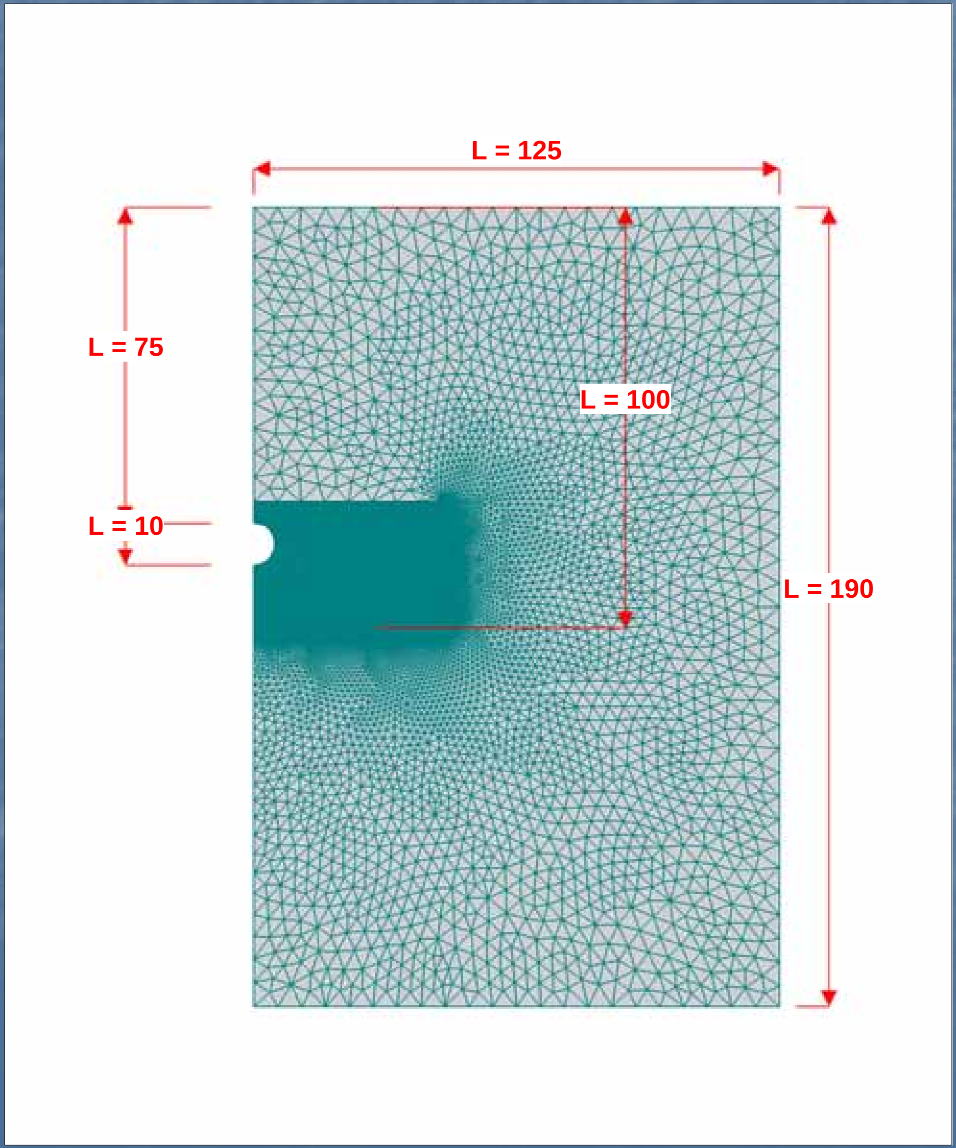
WERF Project

- Funded by Water Environmental Foundation
- Development of Quantitative Tools to Determine the Expected Performance of Unit Processes in Wastewater Soil Treatment Units
- Colorado School of Mines, University of Rhode Island, and UGA

WERF Project

- Use complex 2D numerical models to simulate N, P, and bacteria/virus transport assimilation in OWSs
- Develop simple spreadsheet tools for decision making based on model results
- Project ends 31 Dec 2009

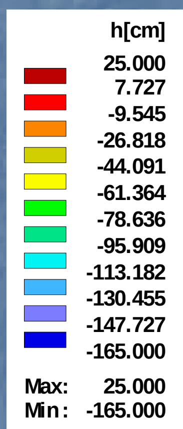
HYDRUS Model Space



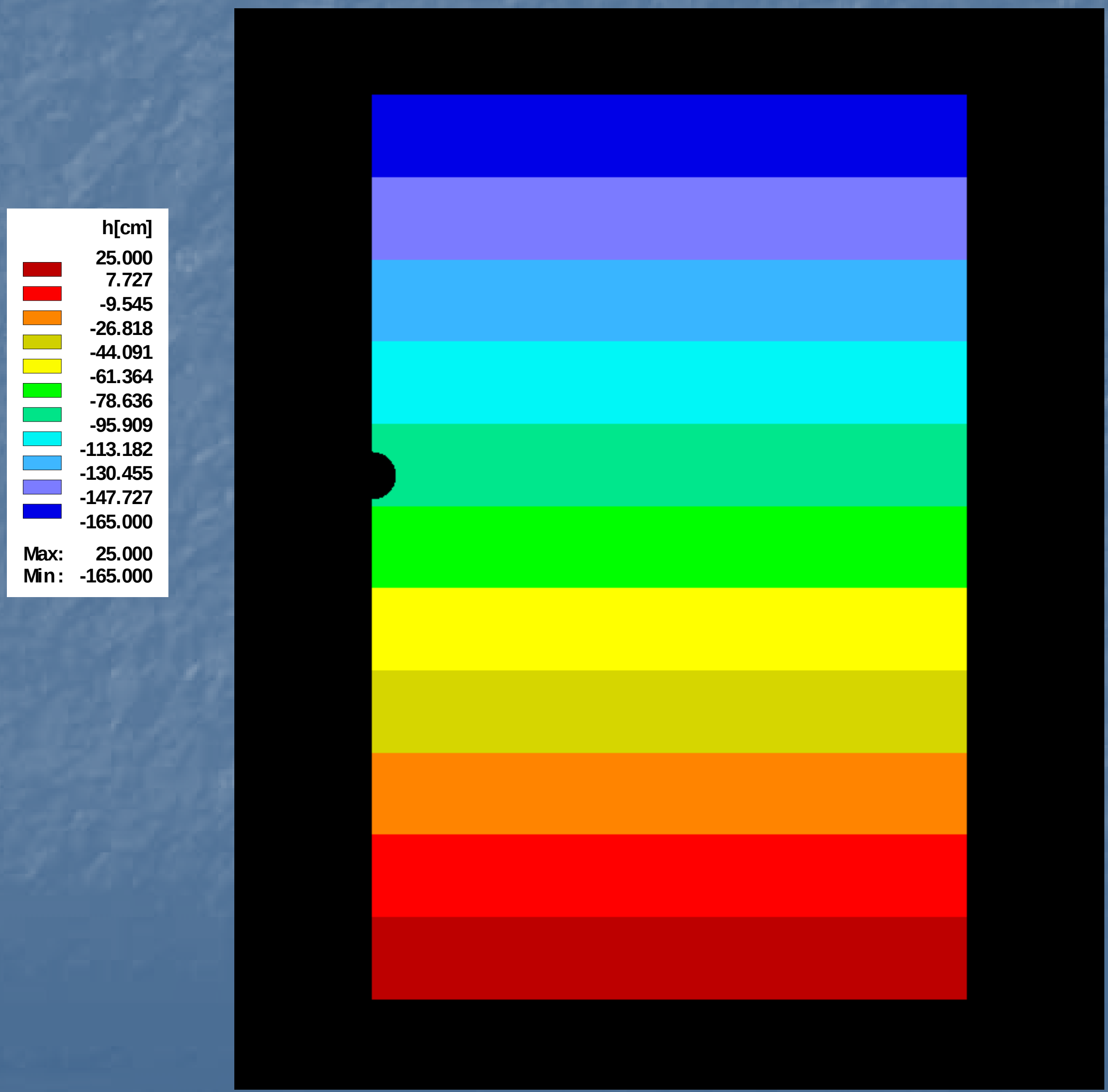
Sand

- 1,000 hours of simulation
- 4 doses per day
- Input concentrations
  - Ammonium = 60 mg/L
  - Nitrate = 0 mg/L
  - Readily biodegradable o.m. = 160 mg/L
  - Slowly biodegradable o.m. = 120 mg/L
  - Inert o.m. = 20 mg/L

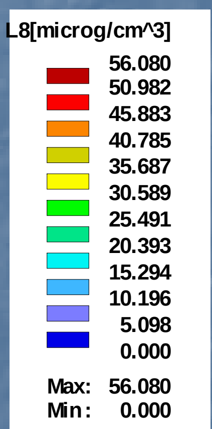
Sand: Water Content



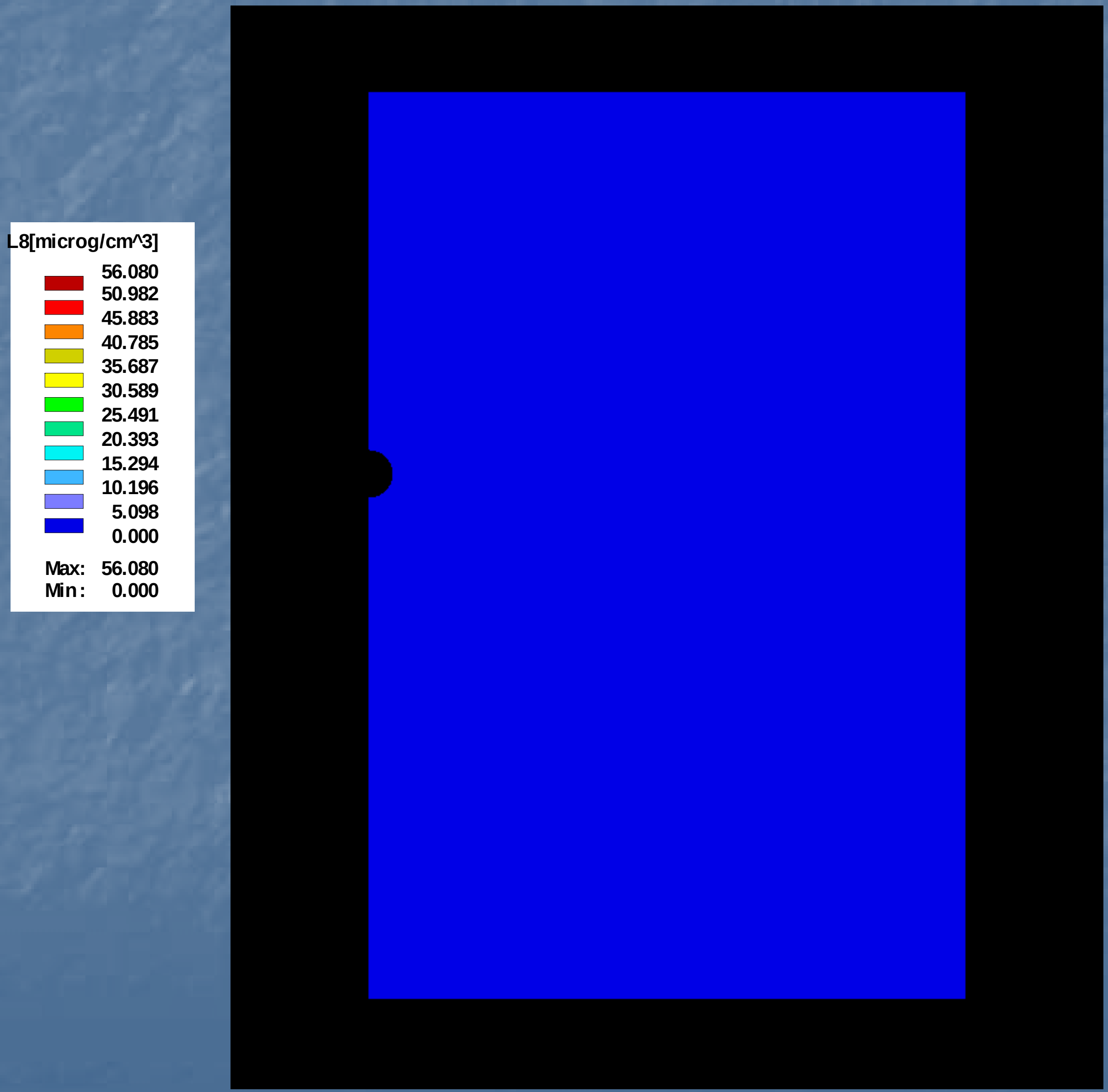
Sand: Water Content



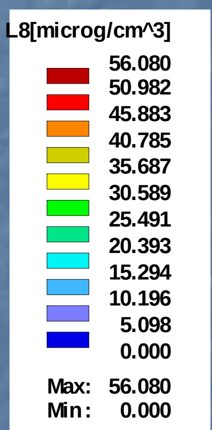
Sand: Ammonium



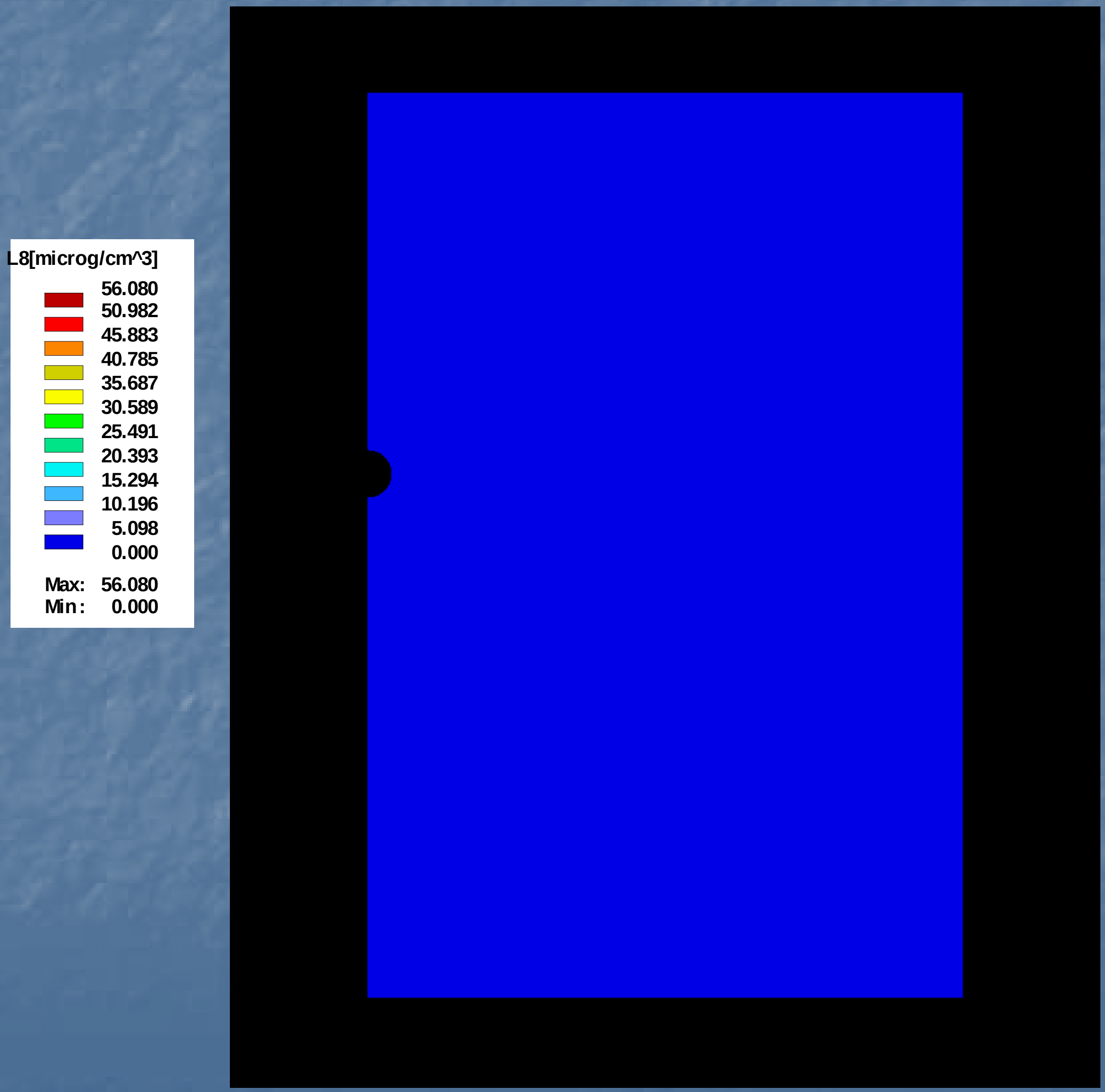
Sand: Ammonium



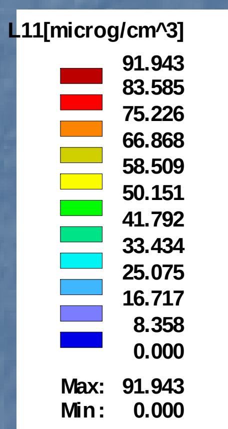
Sand: Nitrate



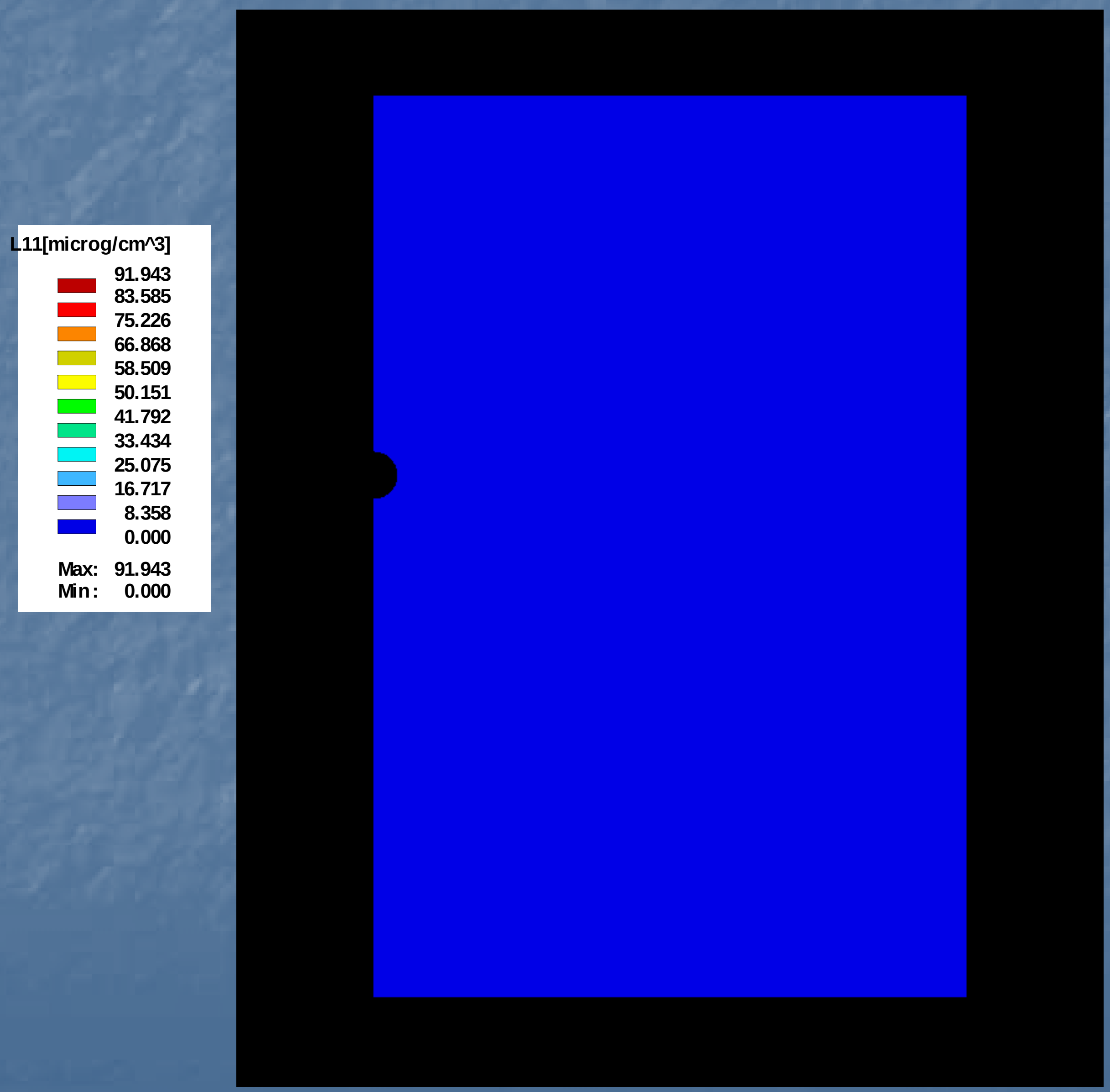
Sand: Nitrate



Sand: N_2 Gas


L11[microg/cm^3]
91.943
83.585
75.226
66.868
58.509
50.151
41.792
33.434
25.075
16.717
8.358
0.000
Max: 91.943
Min: 0.000

Sand: N_2 Gas


L11[microg/cm^3]
91.943
83.585
75.226
66.868
58.509
50.151
41.792
33.434
25.075
16.717
8.358
0.000
Max: 91.943
Min: 0.000

UGA Field Experiment

Poster: Ken Bradshaw, Development of a field-scale protocol to measure LTAR of mature wastewater drainfields: Preliminary results