Higher Linear Loading Rates based on Water Table Mounding Measured during Full-Scale Multi-Day Testing

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STATEMENT

- This talk and slideshow present our own opinions only.
- We are not reflecting the opinions of NOWRA.

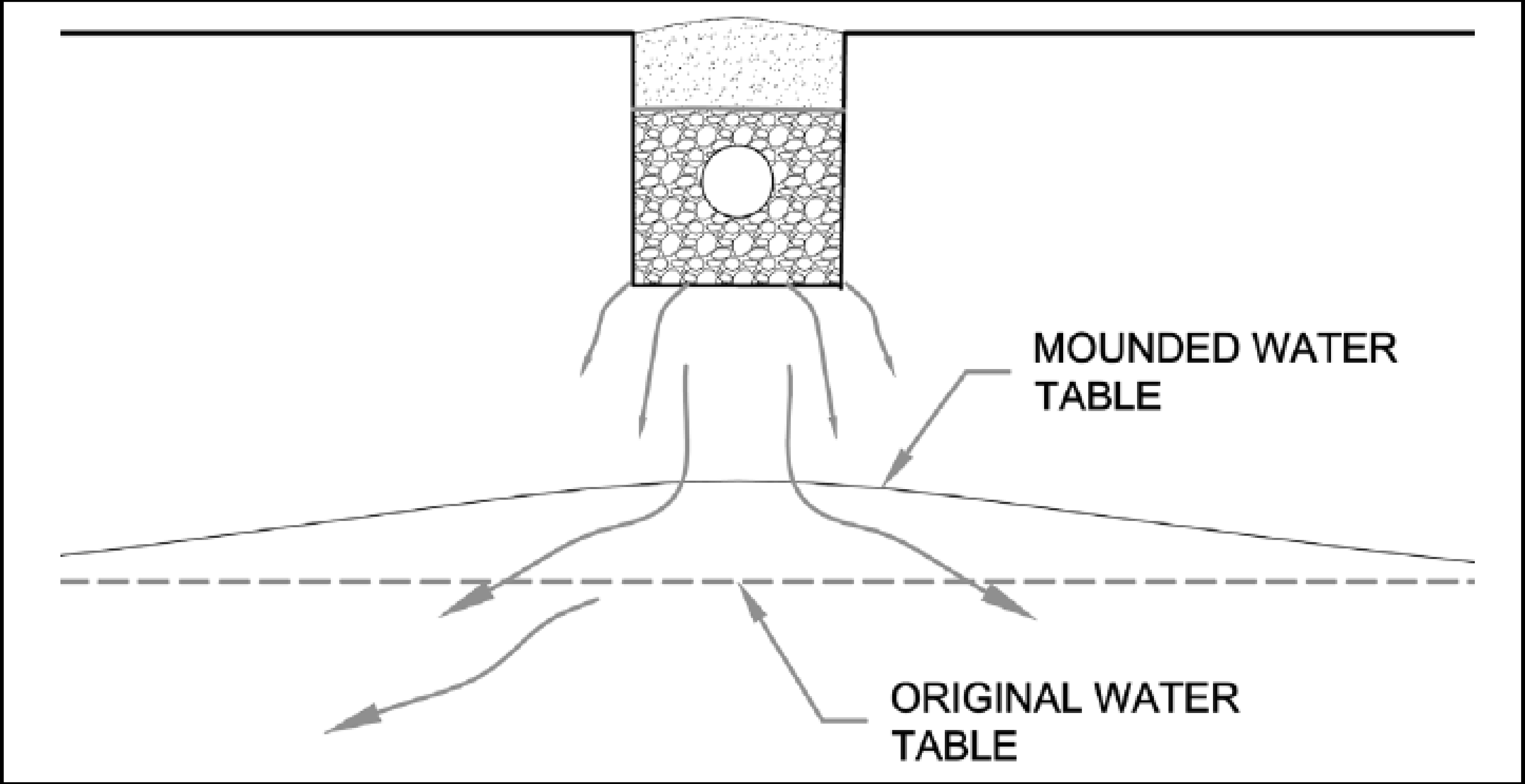
Introductions

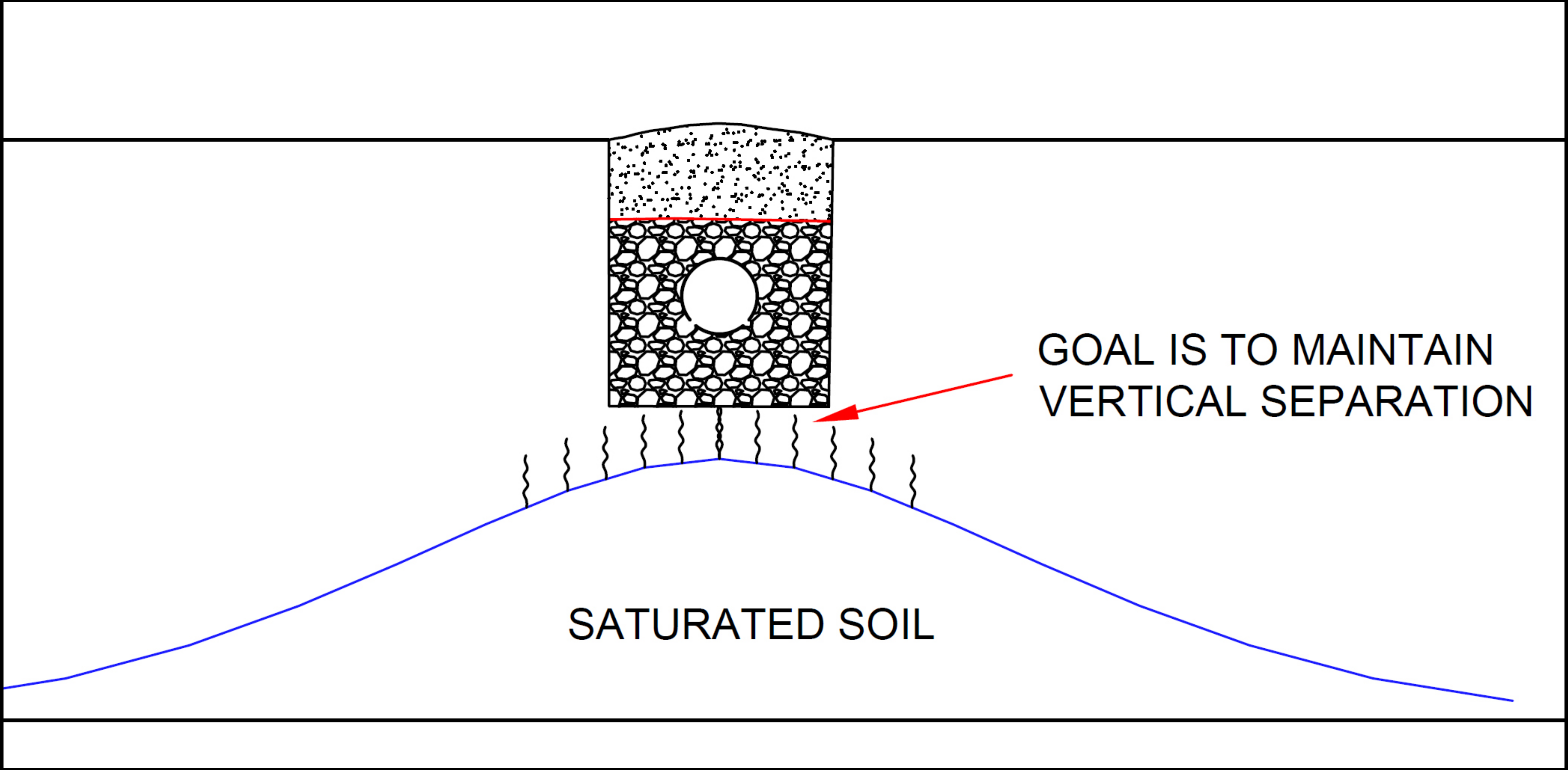
- Michael Payne
- Ian Ralston
- Engineers
- 35+ years of septic design experience
- Authors

CONTEXT – How we got here

- Just a few things we noticed over the years
- Not academic research
- See also our published paper

WATER TABLE MOUNDING

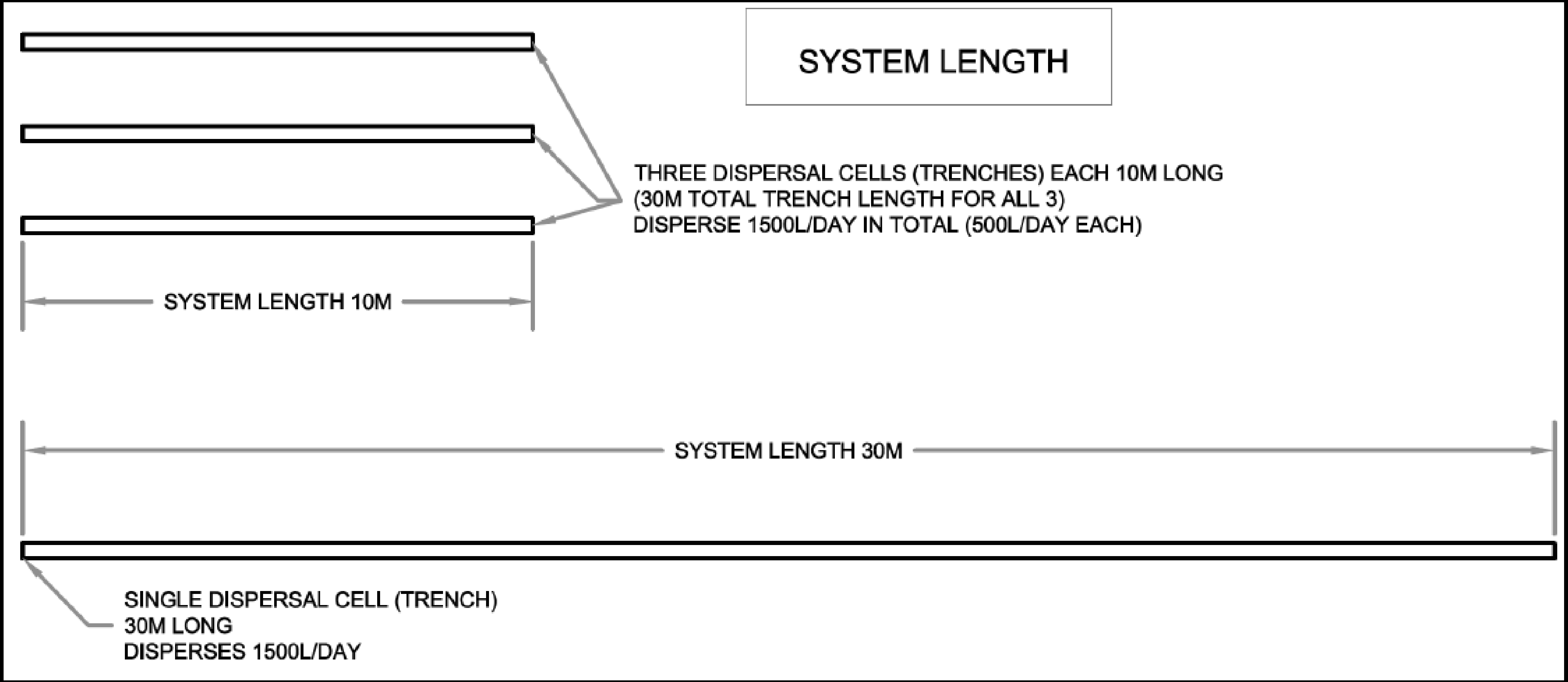


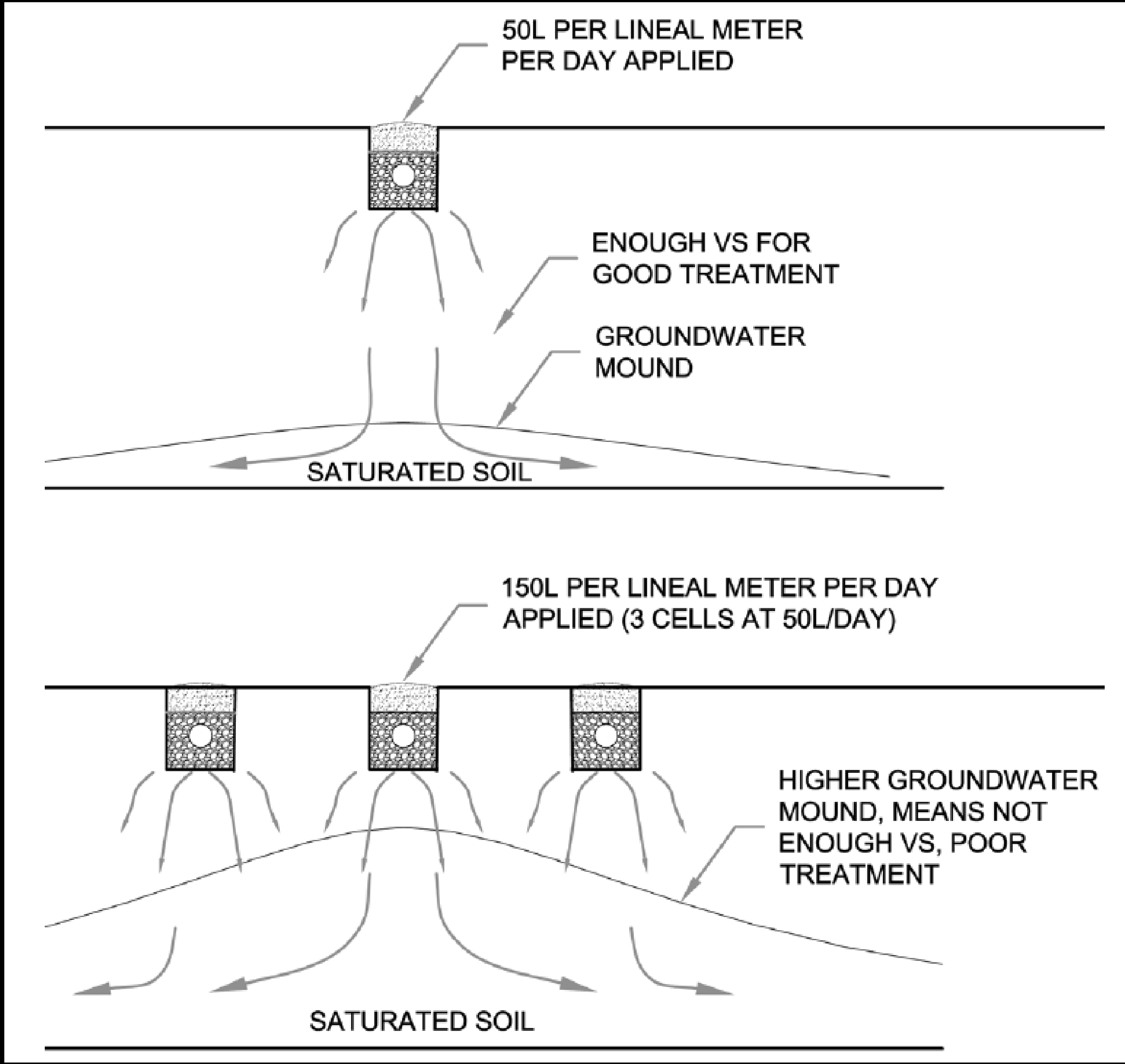

GOAL IS TO MAINTAIN
VERTICAL SEPARATION
SATURATED SOIL

MAIN RESULTS - SUMMARY

- 43 full scale tests of water table mounding
- Water table mounded up and then stabilized
- Each test took a few days to a few weeks
- Water table mound was usually much less than expected
- Tests justified using shorter drainfields

LINEAR LOADING RATE – the basics




50L PER LINEAL METER
PER DAY APPLIED
ENOUGH VS FOR
GOOD TREATMENT
GROUNDWATER
MOUND
SATURATED SOIL
150L PER LINEAL METER PER DAY
APPLIED (3 CELLS AT 50L/DAY)
HIGHER GROUNDWATER
MOUND, MEANS NOT
ENOUGH VS, POOR
TREATMENT
SATURATED SOIL

Water Table Mound versus Linear Loading Rate

- Water table mound is the problem
- Linear Loading Rate is the design decision
- A low Linear Loading Rate leads to a low water table mound

LINEAR LOADING RATE STANDARDS

- E. Jerry Tyler (University of Wisconsin) and other researchers
- Tables showing maximum Linear Loading Rate
- Depends on soil type and depth, and land slope
- Many states adopted these design standards

BRITISH COLUMBIA - CANADA

- 2 hours drive north of here
- 1 million onsite systems
- Many types of systems used
- Same design challenges as elsewhere
- Standards allow Sand Mounds on shallow soils

BRITISH COLUMBIA STANDARDS

Public Health Act

↓

Sewerage System Regulation

↓

Standards (the Standard Practice Manual)

↓

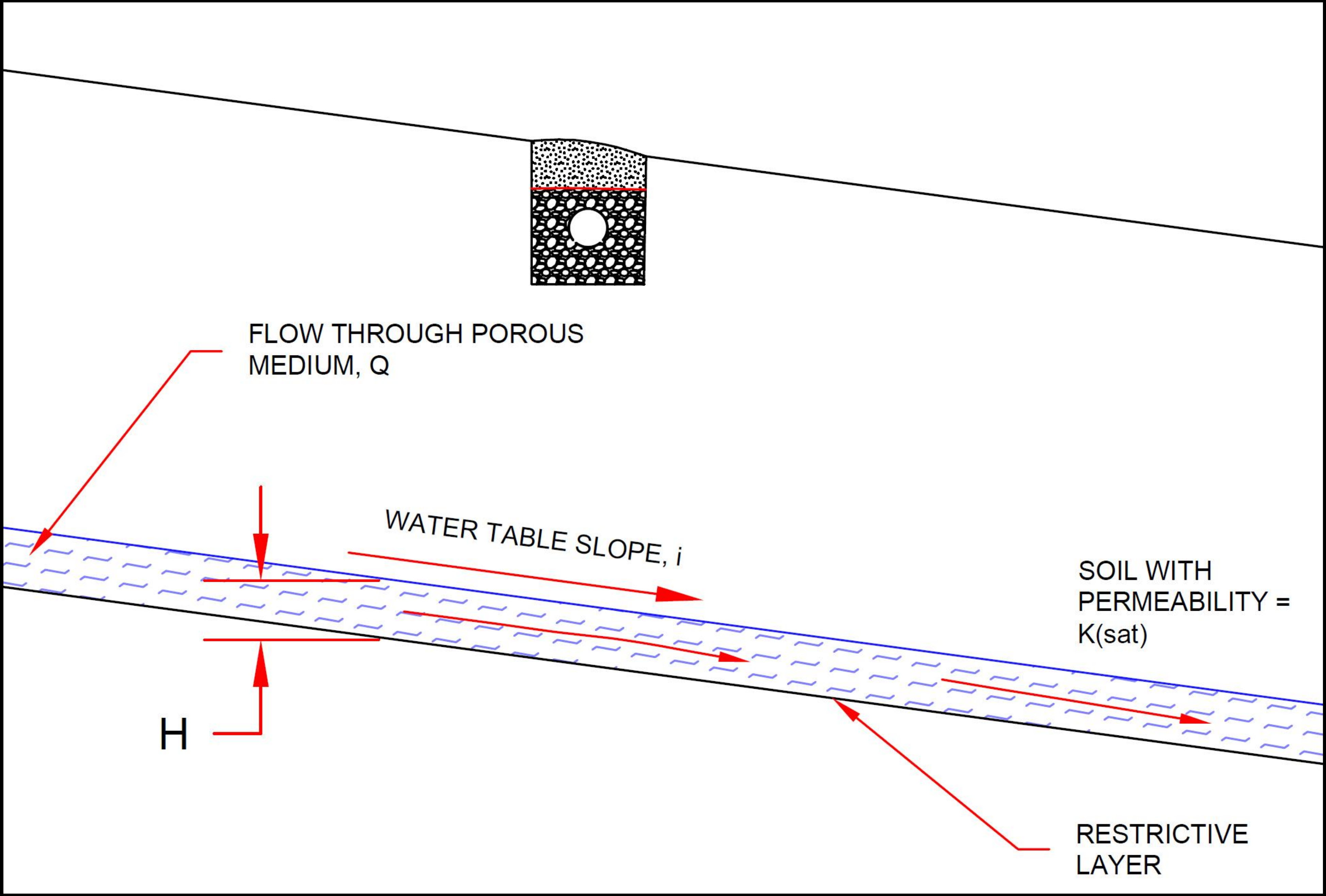
Standards include maximum hydraulic loading rates

LINEAR LOADING RATES IN BC

- Contour length Standards for maintaining vertical separation
- “two-pronged” approach for loading rates
- Standards based closely on Dr. Tyler’s table

WATER TABLE MOUNDING CALCULATIONS

- There are models (calculations) we can use
- One popular model is Hantush (1967)
- Can also use Darcy's law with average hydraulic conductivity (K)



Darcy Equation for Flow in a Porous Medium

$Q = K A i$

Or

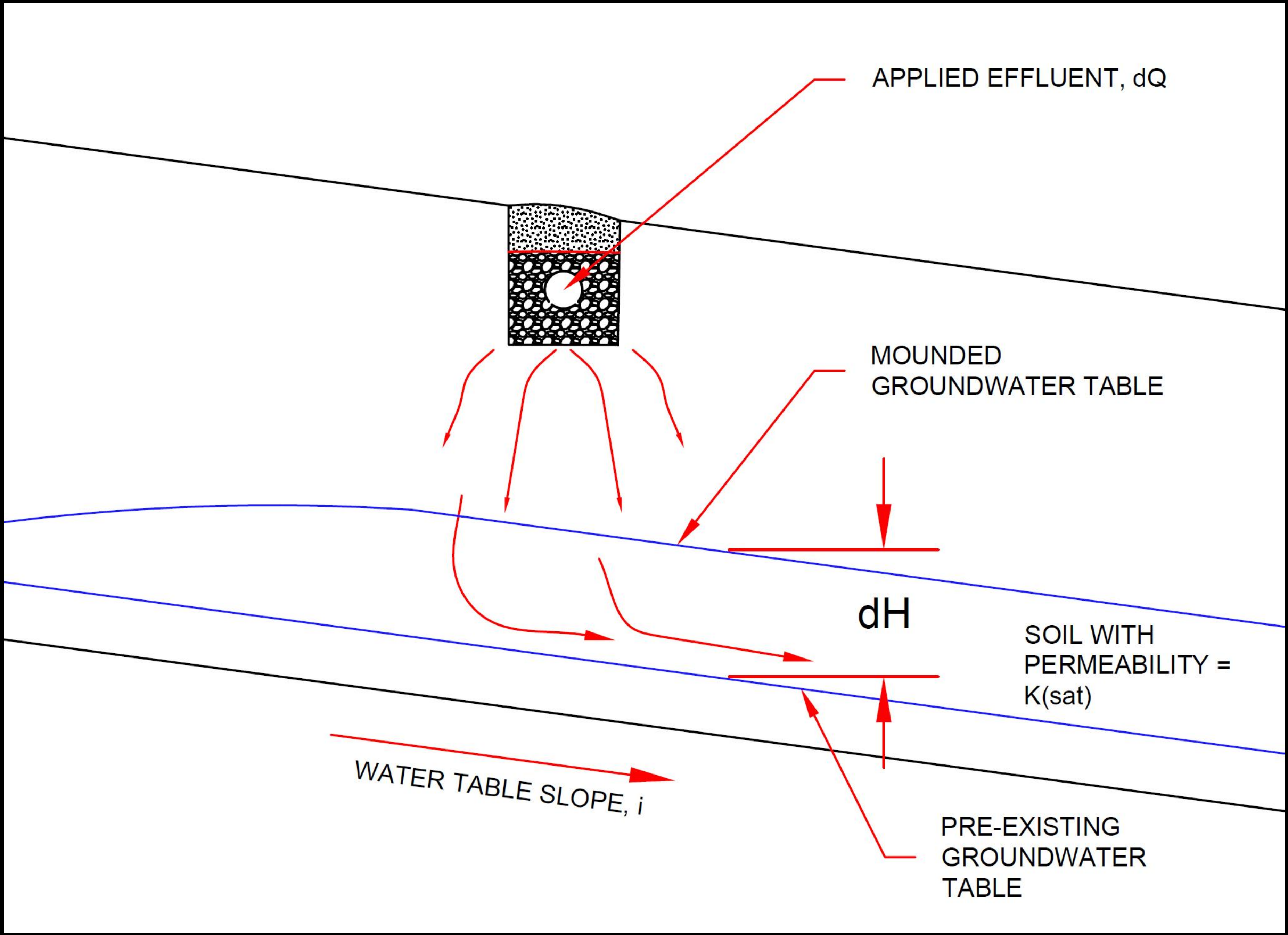
$Q = K A \, dh/dl$

For flow away from a sewage system dispersal area:

A = cross sectional flow area

= L x H = contour length x height (saturated thickness)

- We can rewrite Darcy as Q = K x L x H x i



Now consider an INCREASE in groundwater flow under a drainfield

The equation for INCREASE in flow becomes:

$\Delta Q = K \times L \times \Delta H \times i$

ΔQ is the increase in flow rate from infiltrating effluent

ΔH is the height of the water table mound

K and L are assumed constant for simplicity

Hydraulic gradient (i) is close to pre-existing hydraulic gradient

(hydraulic gradient will increase slightly and we can estimate this)

Rewriting the equation above, we have:

$\Delta H = \Delta Q / (K \times L \times i)$

We can write the equation in terms of linear loading rate (LLR) as:

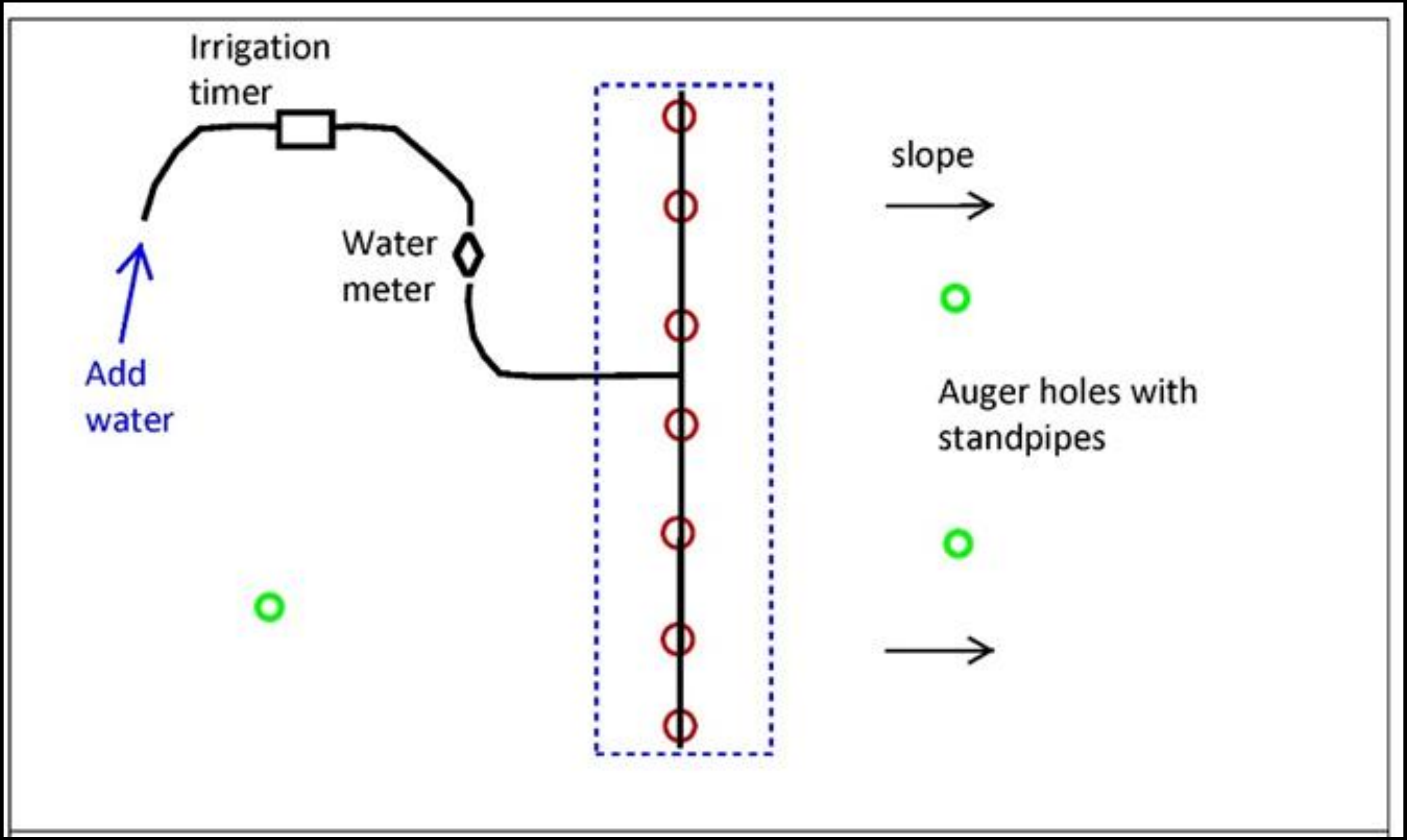
LLR = flow rate per unit length

$= \Delta Q/L = K \times \Delta H \times i$

Equation works for small systems with a downslope drain or breakout point.

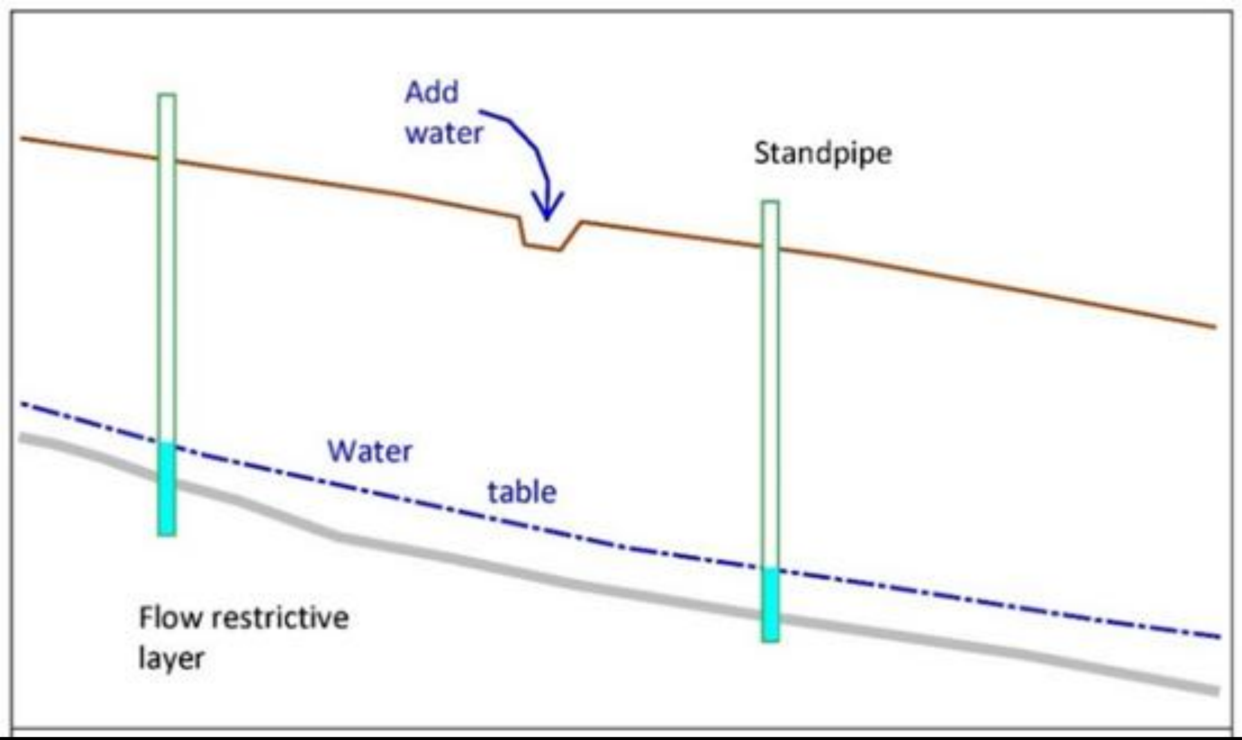
Can use this equation with flat sites also

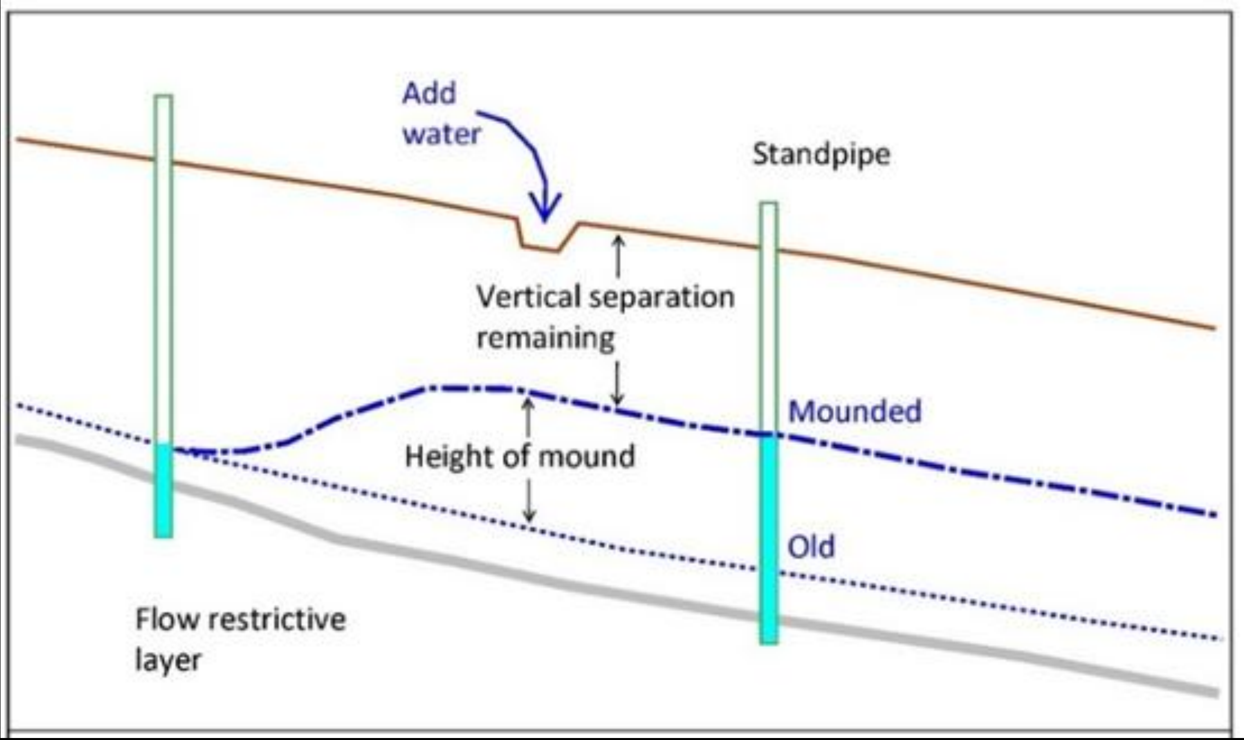
WATER TABLE MOUNDING TEST



Water Table Mounding Test

Water Table Mounding Test – Before and After





Example Form for Water Table Mounding

Test Setup:

Location of discharge:

Discharge area dimensions: Length: ______ Width: ______ Area: ______ Depth: ______

DOSING PLAN Water source: ______ Transport method (hose, pipe, truck): ______

Flow rate (range): ______ Hose needed: ______ Pipe needed: ______

Dose frequency: ______ Dose volume: ______ LLR: ______

Tracer test: Yes / No Tracer: XXX Locations: 1-2 down-slope wells and 1-2 up-slope wells

Depth and Elevation of Observation Wells:

	Length	Stickup	Depth	Top elev	WL @ start of test		Dist from	
MW #	*m*	*m*	*m BGS*	*m*	Depth	Elev	discharge	Note

Water level reference point: *Ground surface / Top of casing*

Flow Rate and Rise of Water Table in Observation Wells:

		Time	Time	Flow	Total	Average	Depth to water in wells *(metres)*				
	Time	elapsed	elapsed	meter	flow	flow	1	2	3	4	
Date	of day	*mins*	*days*	*litres*	*litres*	*Lpd*					Remarks

INTERPRETING THE TEST

We can calculate:

- Height of water table mound
- Linear Loading Rate - as tested
- Allowable Linear Loading Rate – for design purposes
- Effective K(sat) from the test

SUMMARY OF 43 TESTS – Data for One Test

Ave. Test Q	Soil Texture	K(fs)	K(sat)	i	L	Water Table Mound, "H" (m)		Ratio	Test LLR	Max LLR (Tyler 2001)
m3/d	*USDA*	*m/day*	*m/day*		*m*	*Predicted H(p)*	*Measured H(m)*	*Measured / Predicted*	*Lpd/m*	*Lpd/m*
18.4	Loamy Sand	6.0	12.0	2%	50	1.54	0.24	0.16	369	75

Summary of the 43 Tests

TYPICAL TEST (median of all tests):

- Flow rate during the test: 3,400 litres/day (900 US gallons/day)
- K(sat) from permeameter tests: 1.6 metres/day (5.2 feet/day)
- Land slope: 5%
- Contour length of the test: 15 metres (50 feet)

Summary - Continued

MEDIANS:

- Linear Loading Rate for Test: 257 Litres/day/m (21 US gals/day/ft)
- Maximum allowable rate (Tyler 2001): 75 Litres/day/m (6 US gals/day/ft)
- Water table mound predicted by Darcy's Law: 2.3 m (7.5 ft)
- Water table mound as measured: 0.18 m (7 inches)
- Ratio of predicted mound to measured mound: 26

Conservative Analysis of the 43 Tests

- 50% Percentile RATIO predicted mound to measured mound is 26
- Suggests that Linear Loading Rates can be increase by that factor
- But this is not conservative
- More conservative RATIO?
- 10^{th} Percentile of RATIO of Predicted to Measured is 2.1
- Means RATIO is higher than this for 9 out of 10 tests

Breakdown by Soil Texture

- See our paper for details

WE SEPARATED RESULTS FOR:

- Sands
- Sandy loam
- Silt loam and loam

IMPLICATIONS OF THE 43 TESTS

- Measured water table mound usually much lower than predicted (compared with linear loading rate standards)
- Suggests that linear loading rates can be higher than the Tyler table
- Drainfield contour lengths can be shorter
- Can cut drainfield lengths by half or more
- Especially helpful for sand mounds

LIMITATIONS

- Tests were at rates of less than 23,000 Lpd (6,000 US gpd).
- All tests were in British Columbia.
- Designers used similar methods but there is no standard method.
- See our submitted paper for more discussion.

FLOW RATE PEAKING FACTORS

- Peaking factor = peak-day flow ÷ average flow
- When working with Linear Loading Rate standards
- AND
- Results of water table mounding tests
- Remember which flow rate you are using

DISCUSSION

- The Water Table Mounding Test is helpful on narrow lots
- Helpful for design of sand mounds
- Test results reflect scale effects on K(sat)
- Results of similar tests across USA and Canada?
- Maybe this is a subject for university research?
- Protocol for Water Table Mounding Tests

SUMMARY

43 full scale tests of water table mounding under drainfields

The water table rose and then stabilized at a new height

Water table mound was usually much less than expected

We used the results to design drainfields with a short contour length

Are linear loading rate standards overly conservative? (Tyler, 2001; USEPA, 2002; British Columbia Standards, 2014).

Thanks for your attention

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