Groundwater Monitoring of Land Application with Manure, Biosolids, and other Organic Residuals

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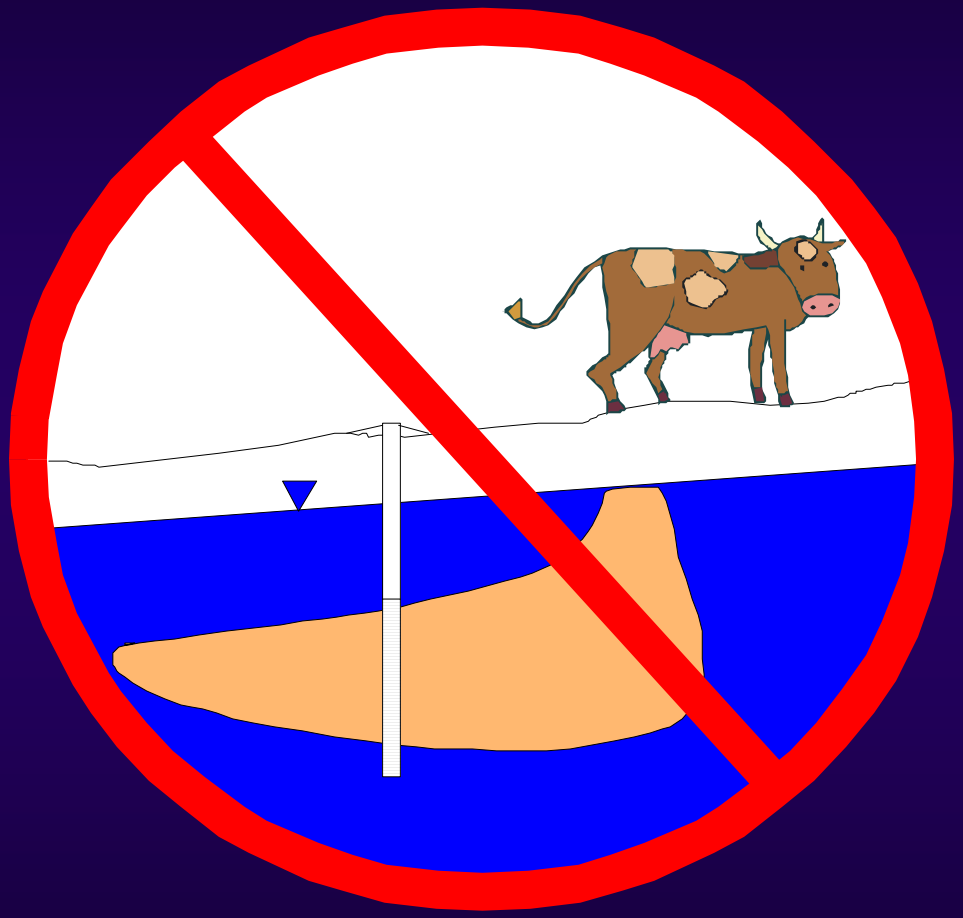
Take-Home Message



Rethinking Contaminant Hydrogeology

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Overview

- Regulatory drivers
- Land application/ag sources vs. classic point source
- Monitoring well design
- Monitoring well network design

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Regulatory Requirements: Groundwater Monitoring

- Weak federal framework for gw protection / focused on point sources
- Encouragement of BMPs
- New California dairy permit requirements
- Future California irrigated agriculture permits
- Production well monitoring
- Monitoring wells: based on "evaluation of threat to groundwater quality" beginning sometime in 2008.

  => exact requirements / approach still to be decided

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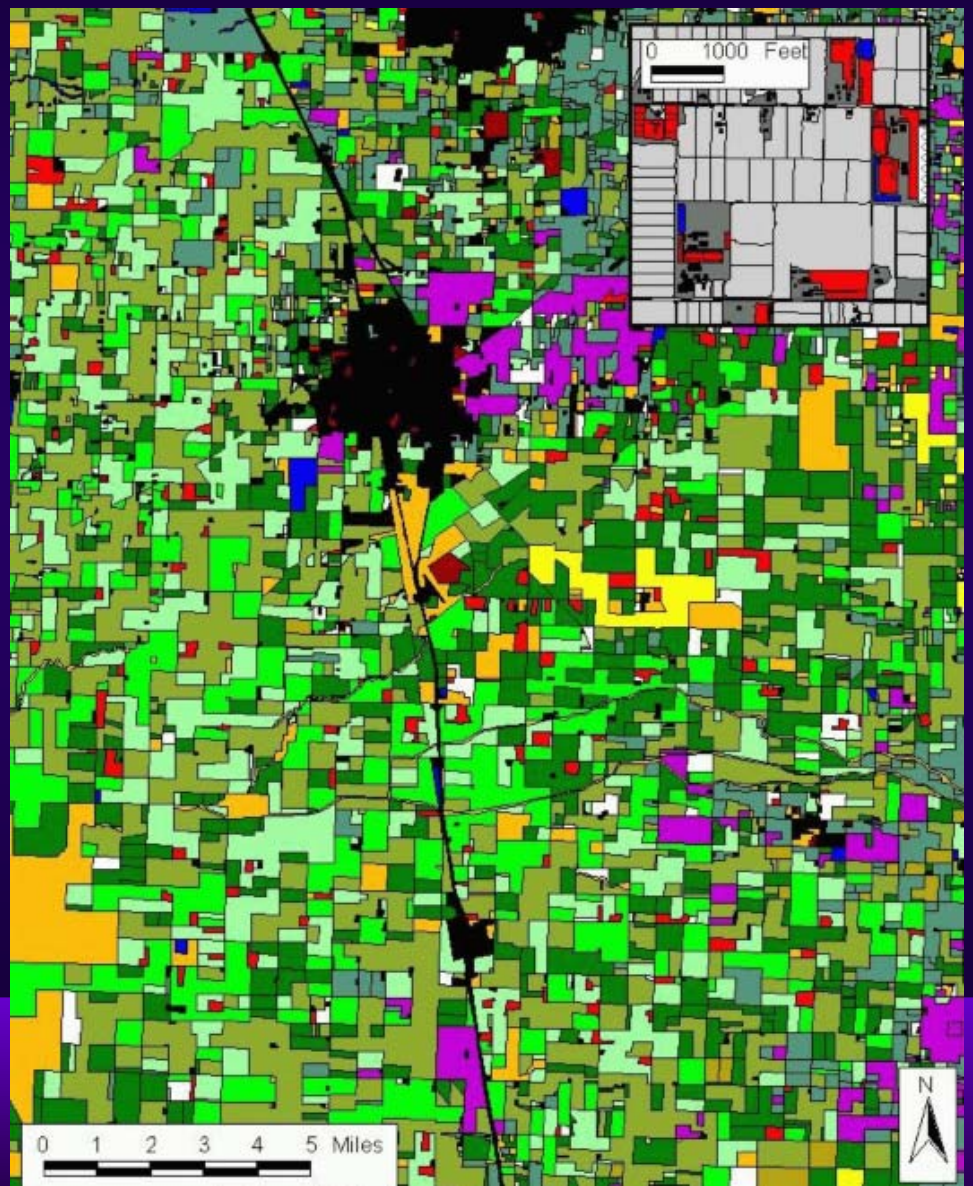
Monitoring w/ Production Wells (Domestic/Irrigation)



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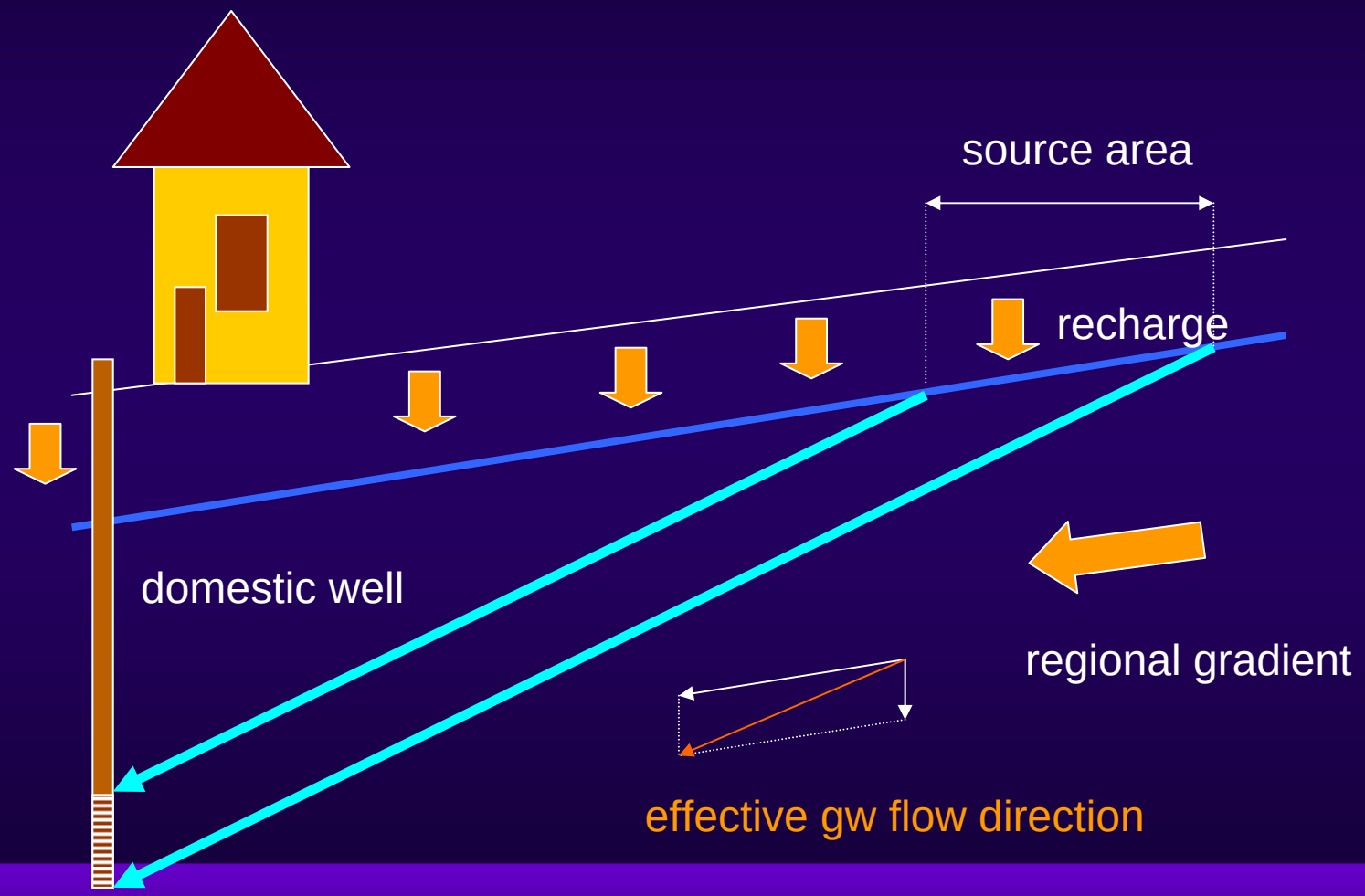
Where does Well Water Come From?
- Domestic Well-



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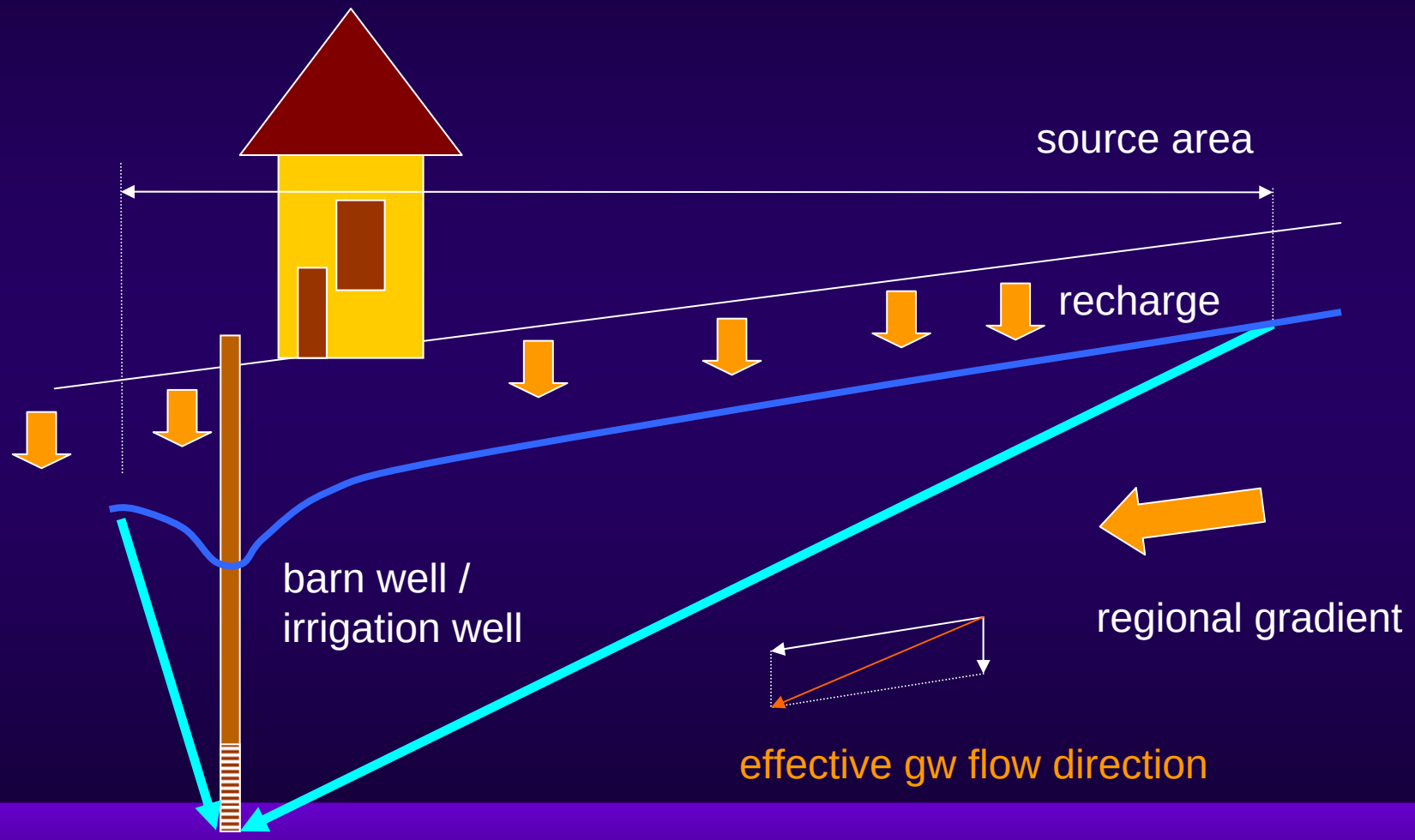
Where does Well Water Come From?
- Irrigation Well / Barn Well -



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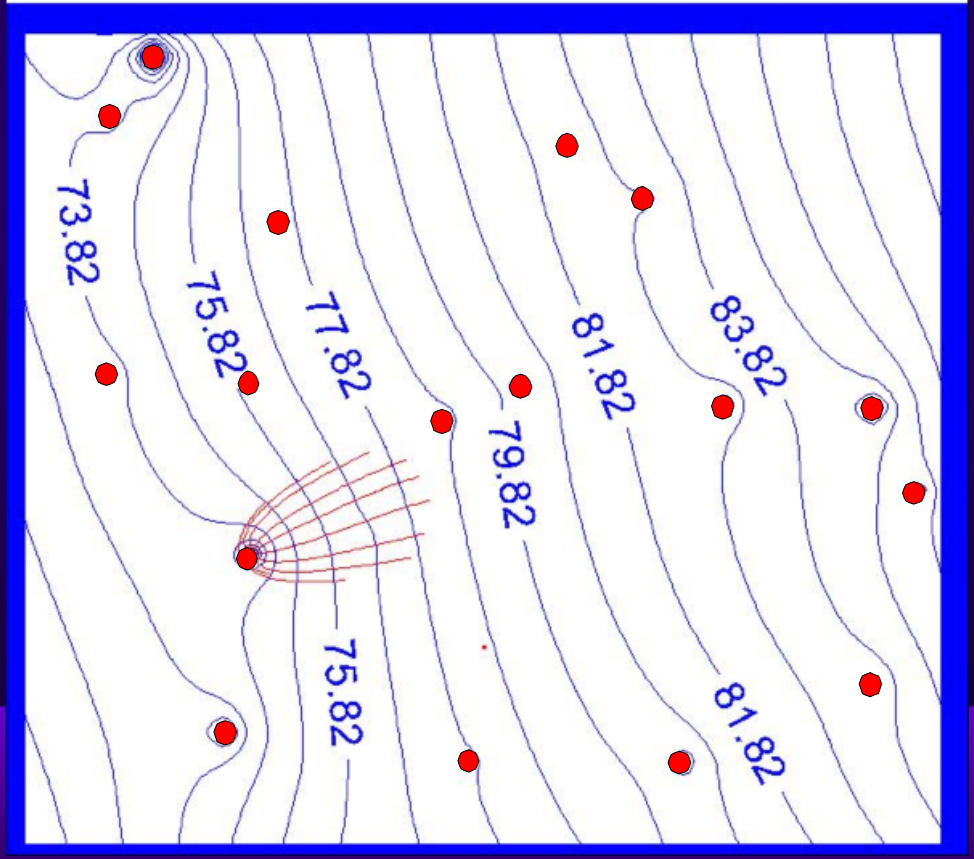
Source Area of a Barn / Irrigation Well

Cross-section

2 miles
x
200 ft

Plan-view

2 miles
x
2 miles



- Water flow is horizontal & vertical
- Horizontal travel distances are generally MUCH longer than travel vertical distances
- Different depths of the well screen capture different water!

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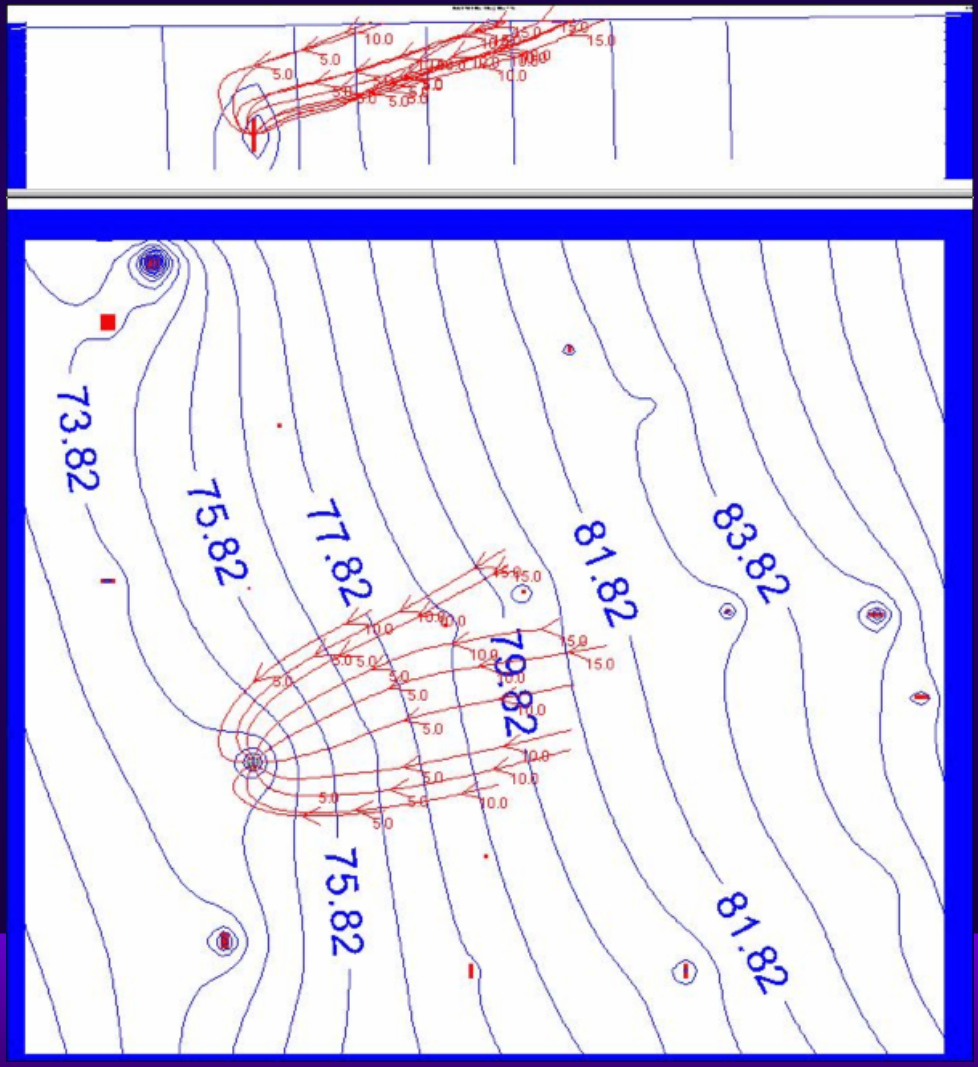
Source Area of a Barn / Irrigation Well



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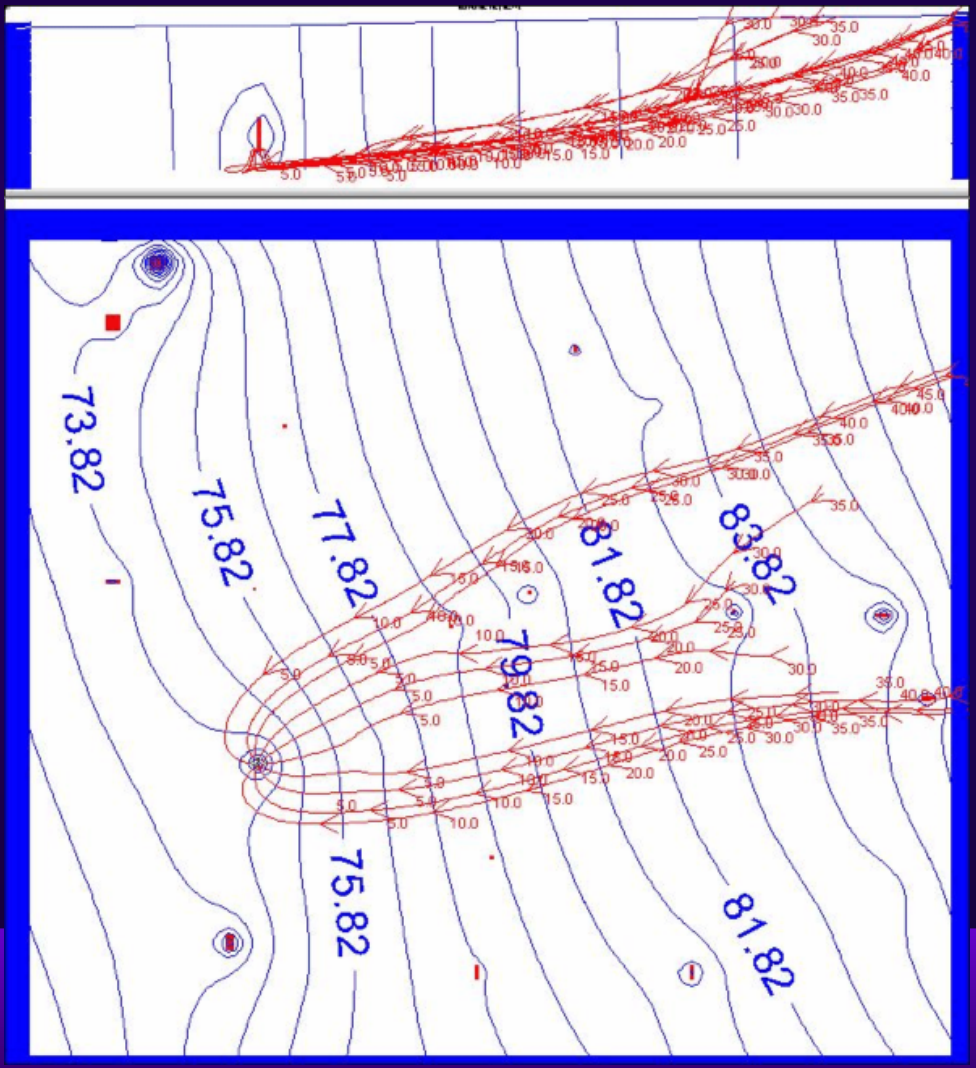

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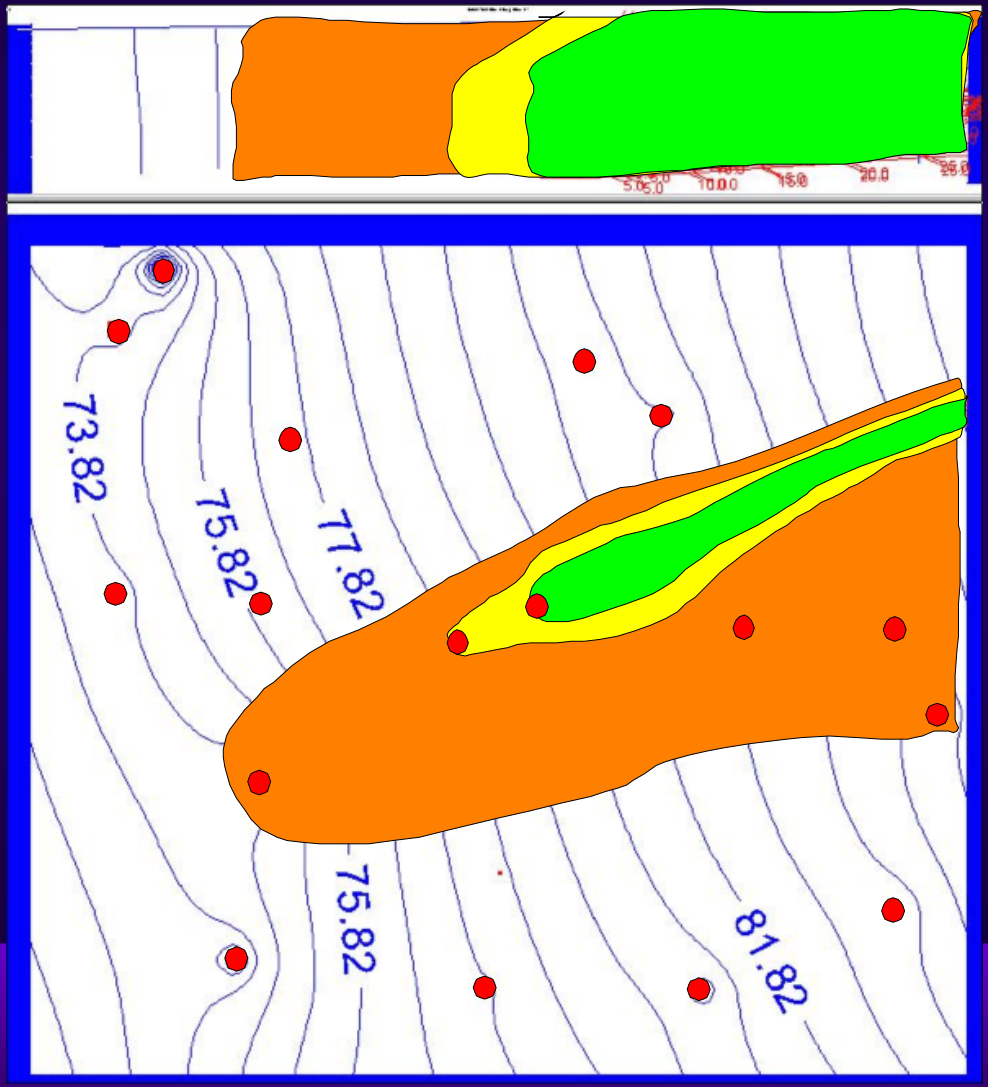

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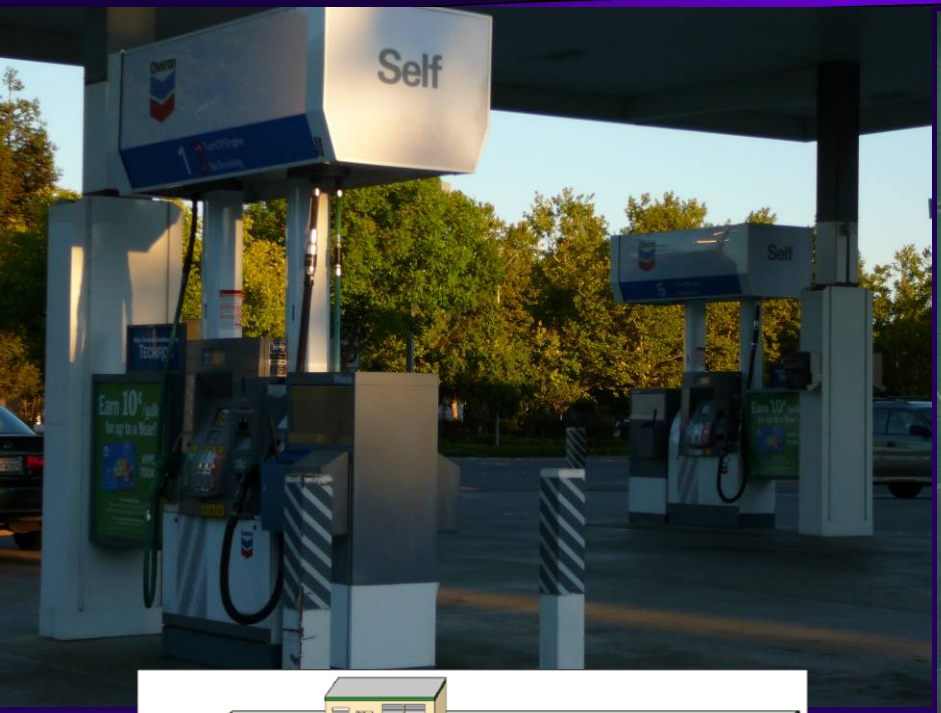
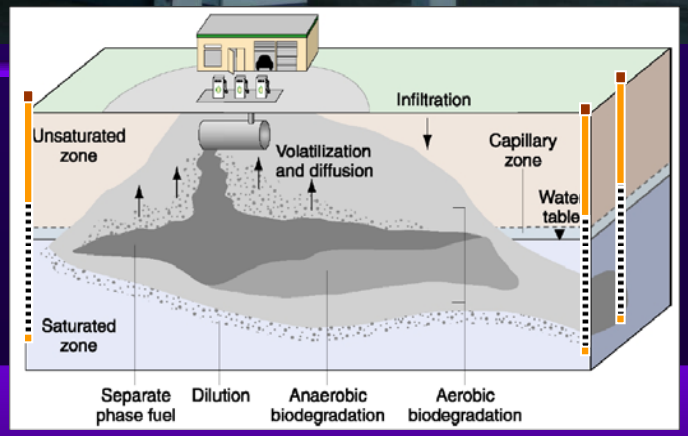
10.5 x 10^-3
21.0 x 10^-3
1.13 x 10^-3
1.13 x 10^-3
TW
21.0 x 10^-3
0.16 x 10^-3
10.5 x 10^-3
N
1 km
Unconfined Region of Principal Aquifer
0 1 2 3 4 5 Miles
N

Monitoring w/ Monitoring Wells





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Modified from: EOS, Transactions, AGU 2001

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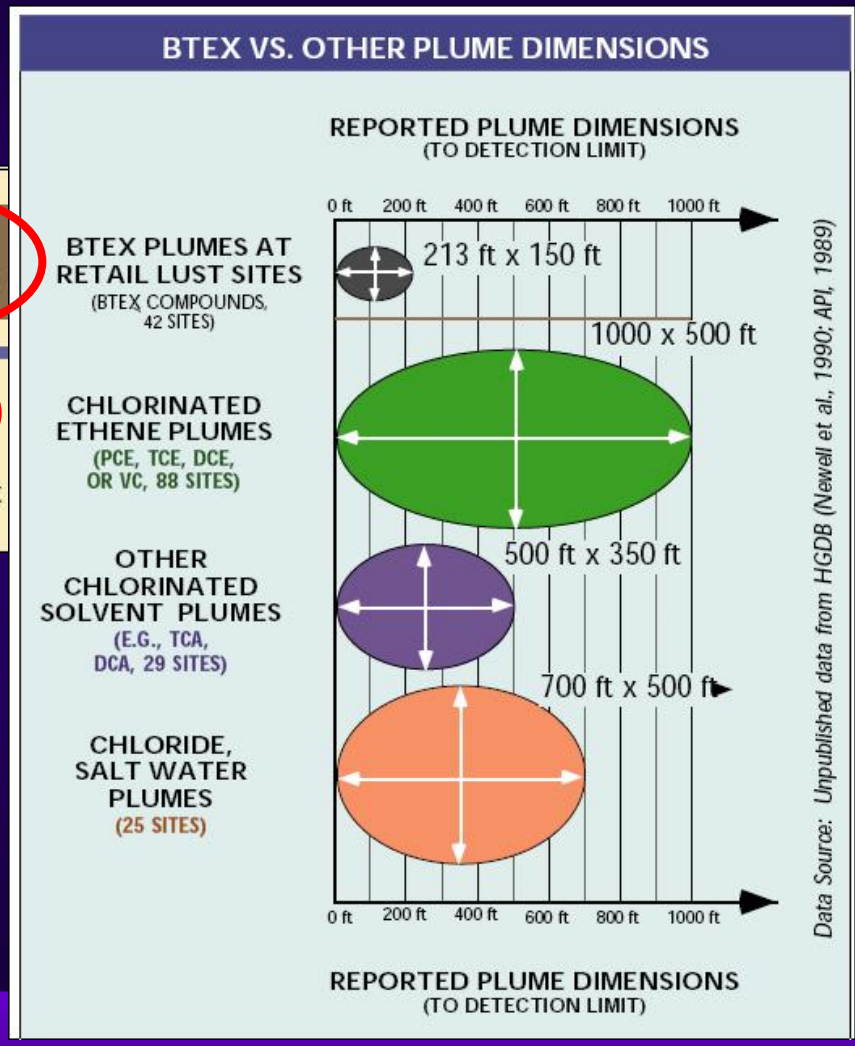
Spatial Scale
UST vs. Dairy GW Contamination

BTEX Plume Volume (95%)	X	No. of LUST Sites	=	Total BTEX GW Volume
0.7 acre-ft		10,000		7000 acre-ft
0.7 acre-ft.		358,000 (U.S. EPA, 1998)		250,000 acre-ft



IN COMPARISON, ONE TYPICAL SAN JOAQUIN VALLEY DAIRY HAS:
900 milking cows
250 acres (cropland & production area)
length of 3,000 feet across the dairy
1 acre-foot of recharge per acre per year
been 40 years in operation
Potentially affected volume:

250*1*40 = 1,000 ac-ft

Newell and Connor, 1998, API Bulletin 8

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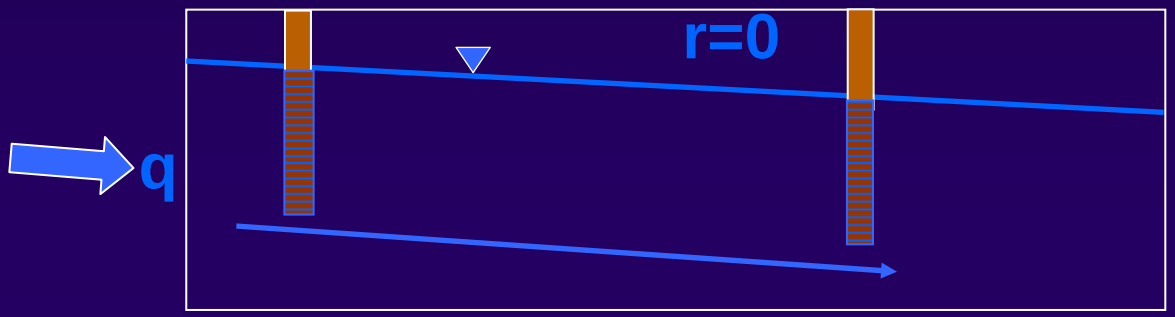
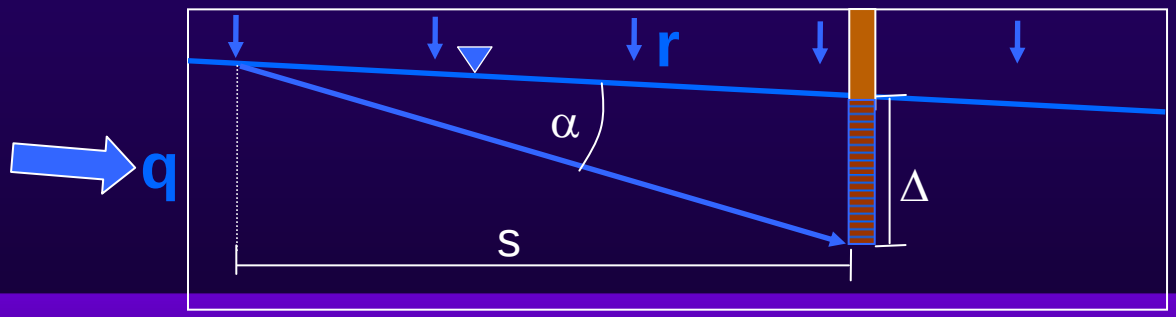
Monitoring Wells: Land Application vs. UST

Non-recharging source: incidental release



Recharging source: planned/frequent release



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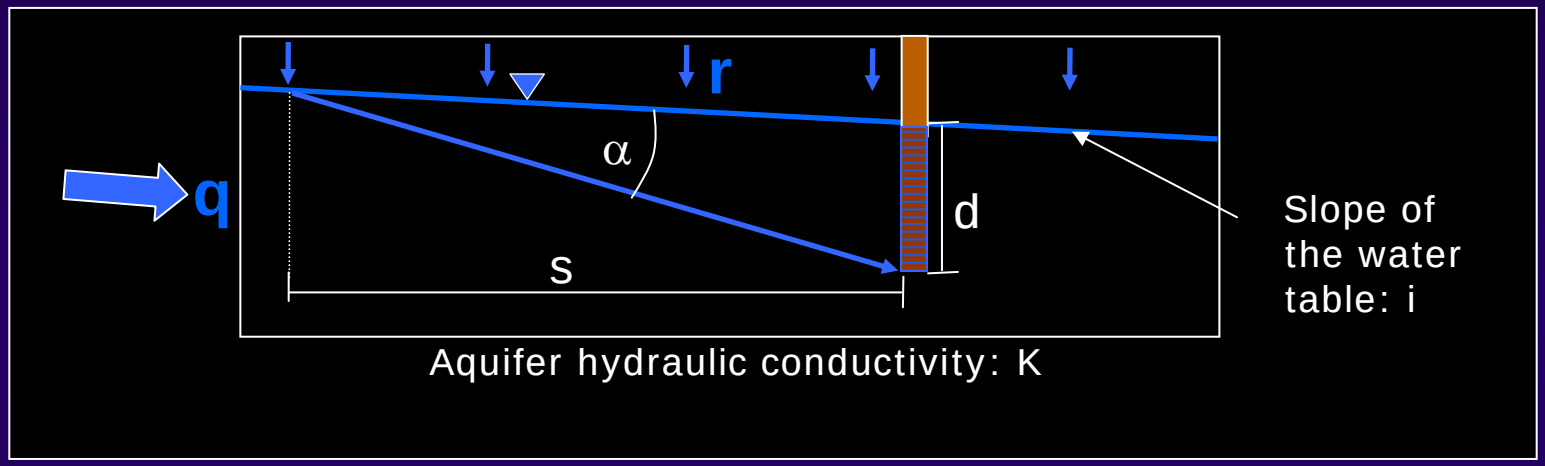
What Does a Monitoring Well Measure? Recharging Source Area



Horizontal flow: q = K * i (Darcy's law)

Vertical flow: r (recharge)

Monitored source length, s = d * q/r

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Source Area of a Monitoring Well in a Recharge Area

Horizontal flow: $q = K * i$ (Darcy's law)

Vertical flow: r (recharge)

Monitored source length, $s = d * q/r$

- Recharge rate, r: 1 ft/yr = 0.003 ft/d
- Horizontal gradient, i: 0.3% = 0.003
- Length of screen below water table, d: 20 ft
- K (ft/d) - q (ft/d) - s (ft)

K (ft/d)	q (ft/d)	s (ft)
1	0.003	20
10	0.03	200
20	0.06	400
50	0.15	1,000
100	0.3	2,000
500	1.5	10,000

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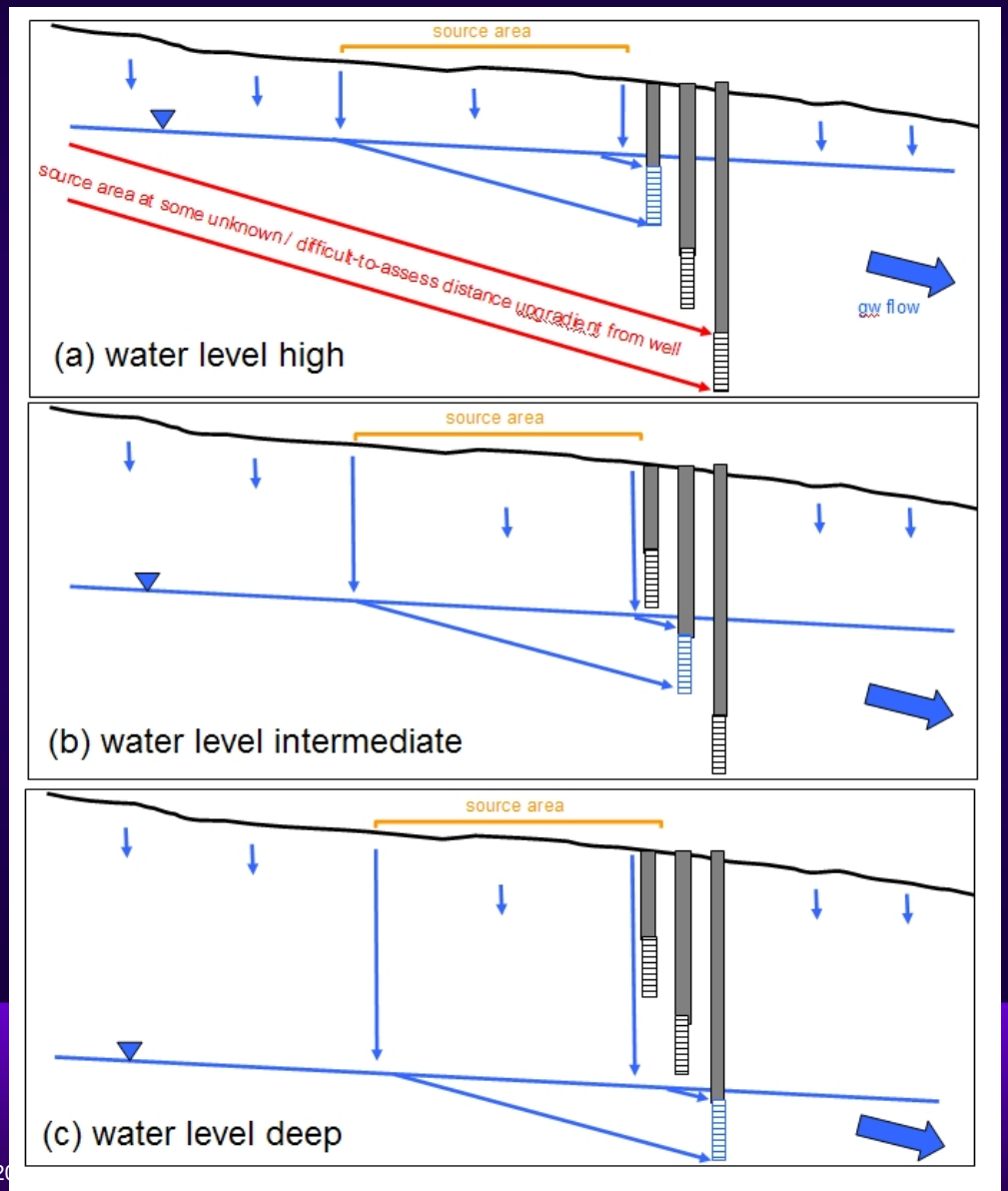
Variable Depth to Groundwater



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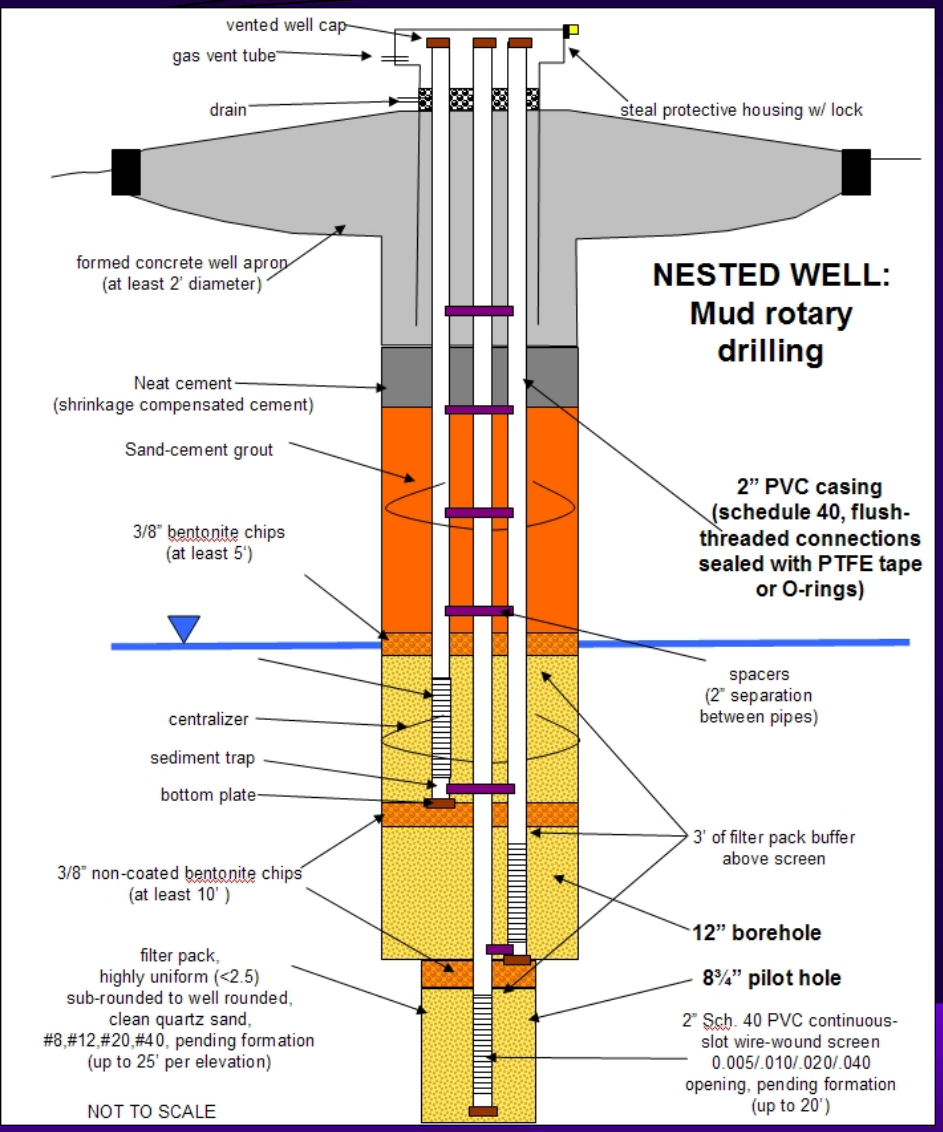
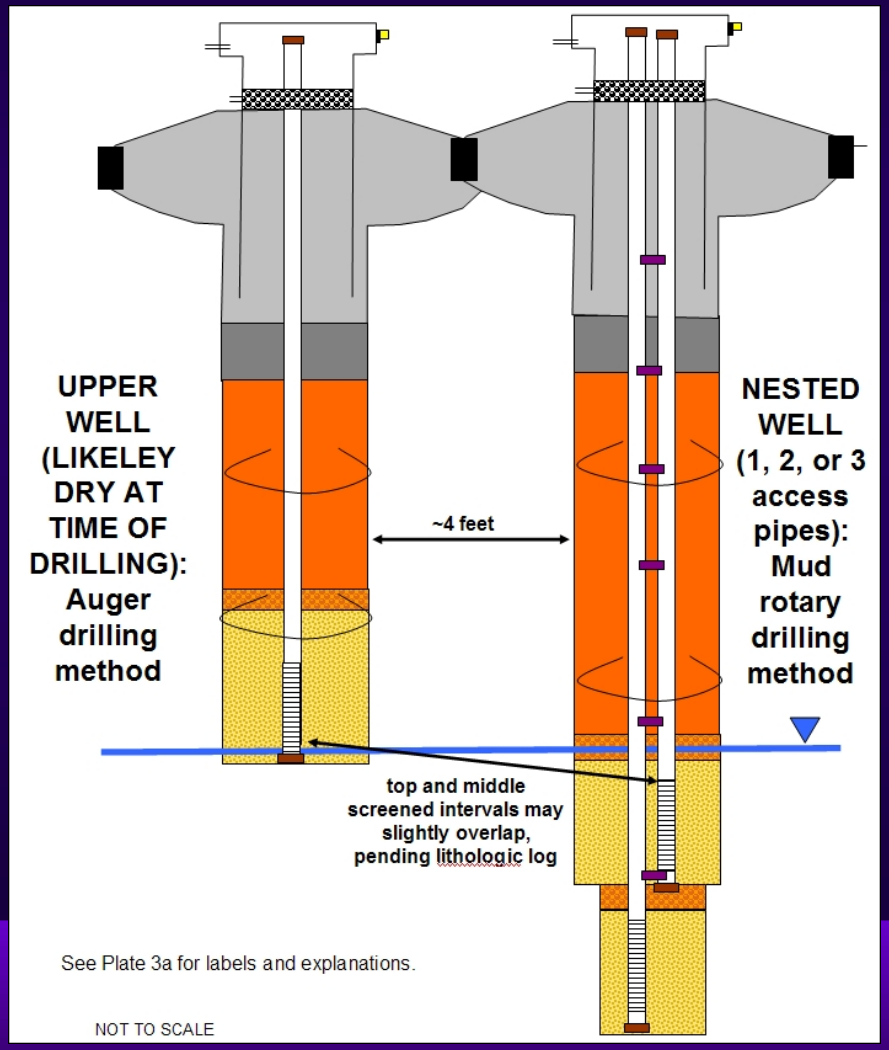
Monitoring Well Design





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Well Spacer Design

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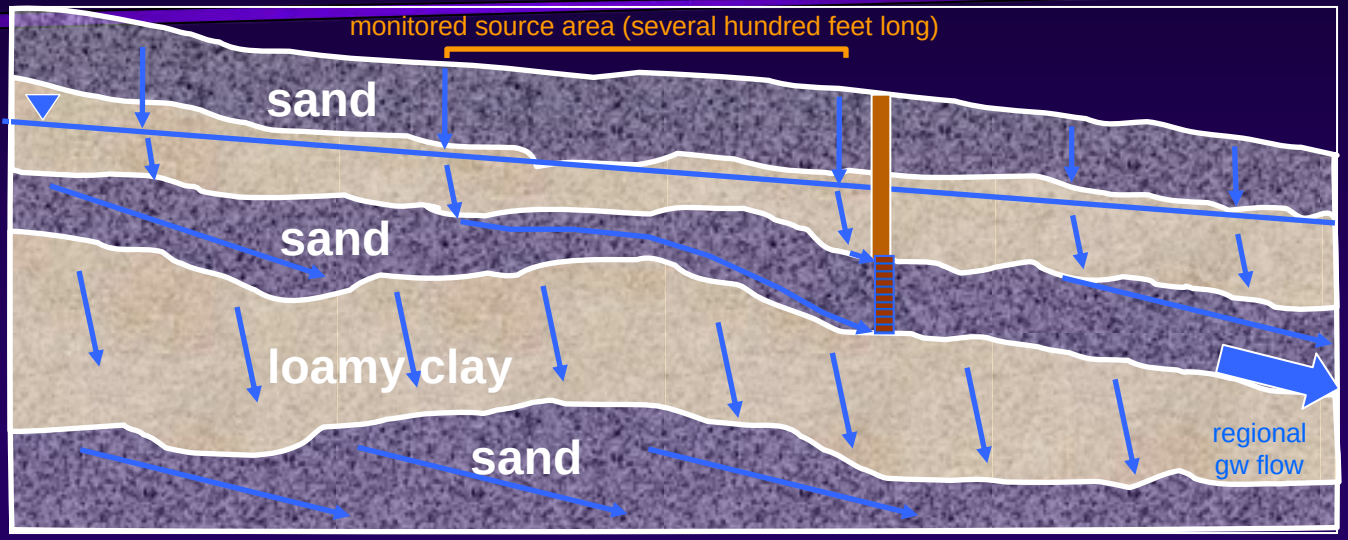
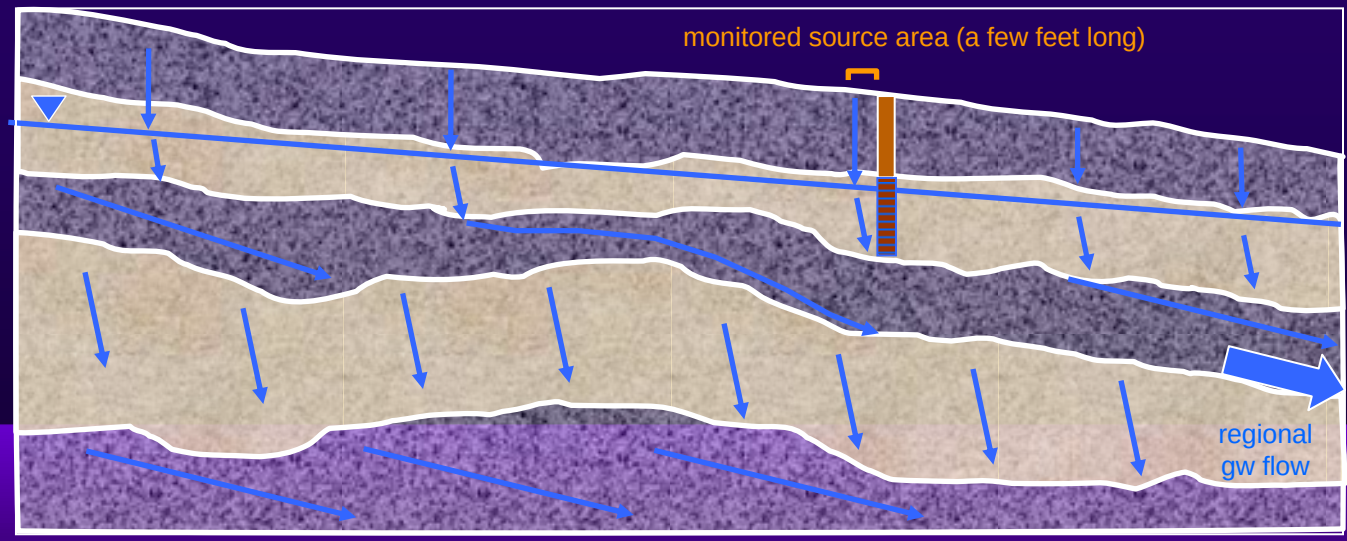
Monitoring in Heterogeneous Aquifers

- 20' – 40' screen length does not automatically guarantee that an entire source is monitored => set screen in aquifer materials only.



(a) Screen (length ~ 20') located in sand layer



(b) Screen (length ~ 20') located at water table, but not intersecting sand layer

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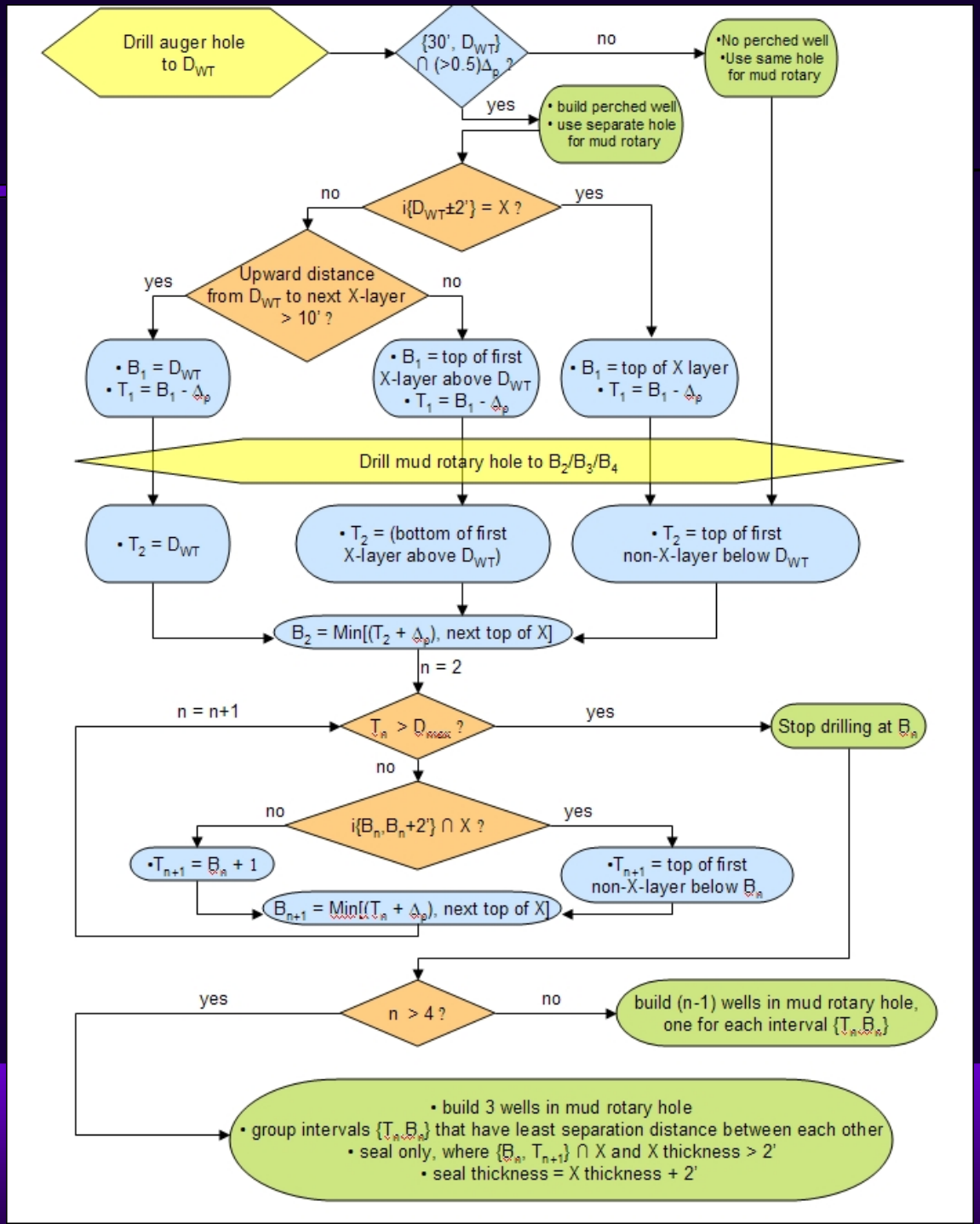
Design Flow Chart



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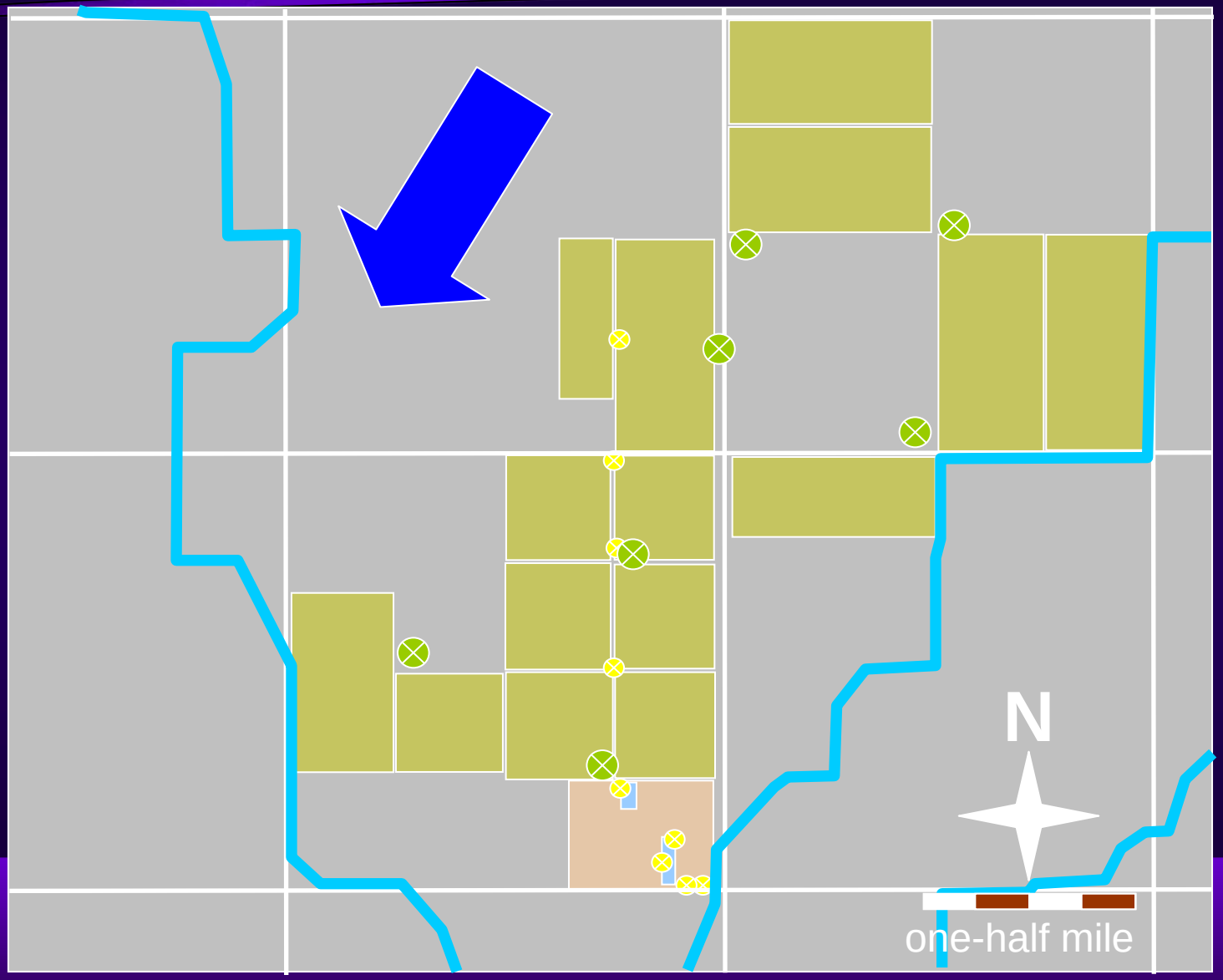
Monitoring Well Network Design

Monitoring Well Network, Example 2



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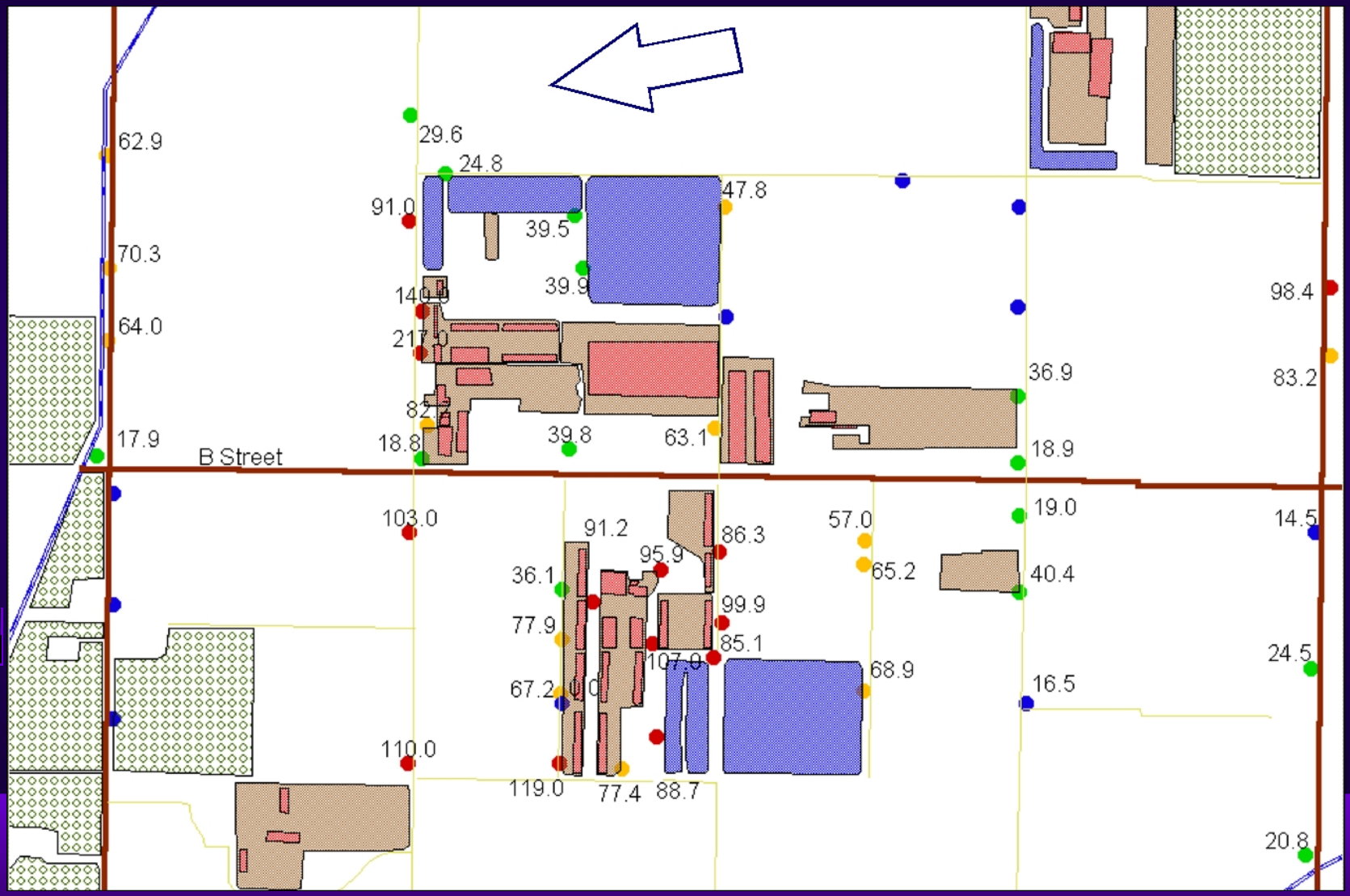
Nitrate-N: Sampling Results



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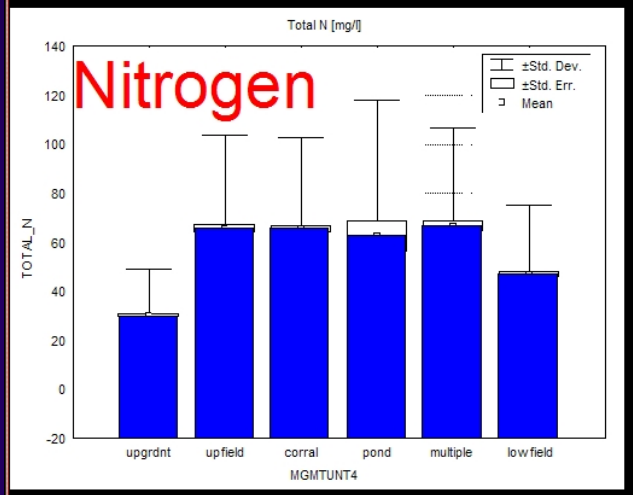
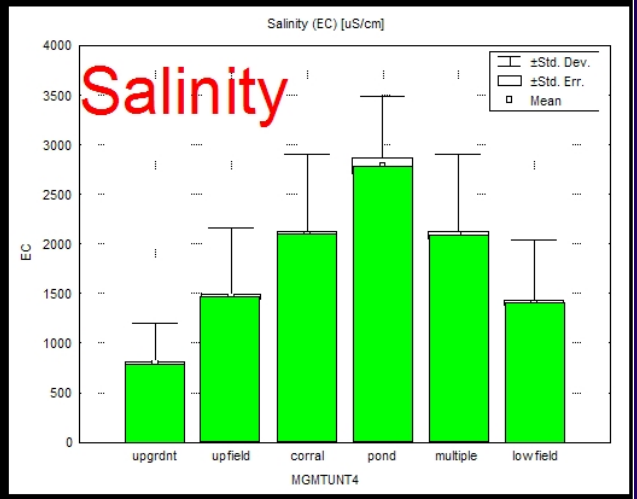
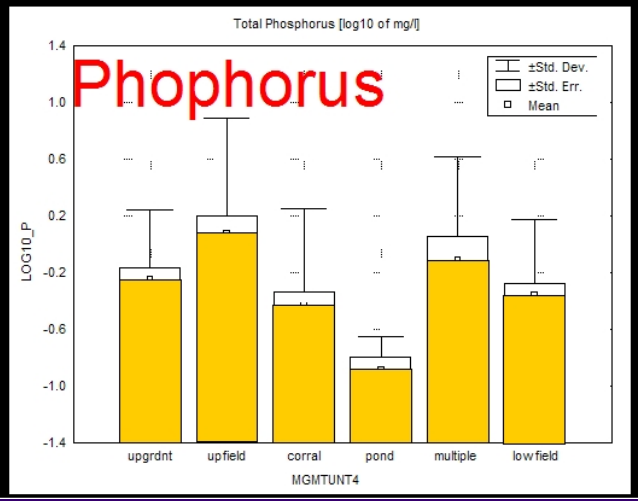
Statistical Analysis: By Management Unit

GW Flow







Harter et al.,
J. of Contam. Hydrology
April 2002

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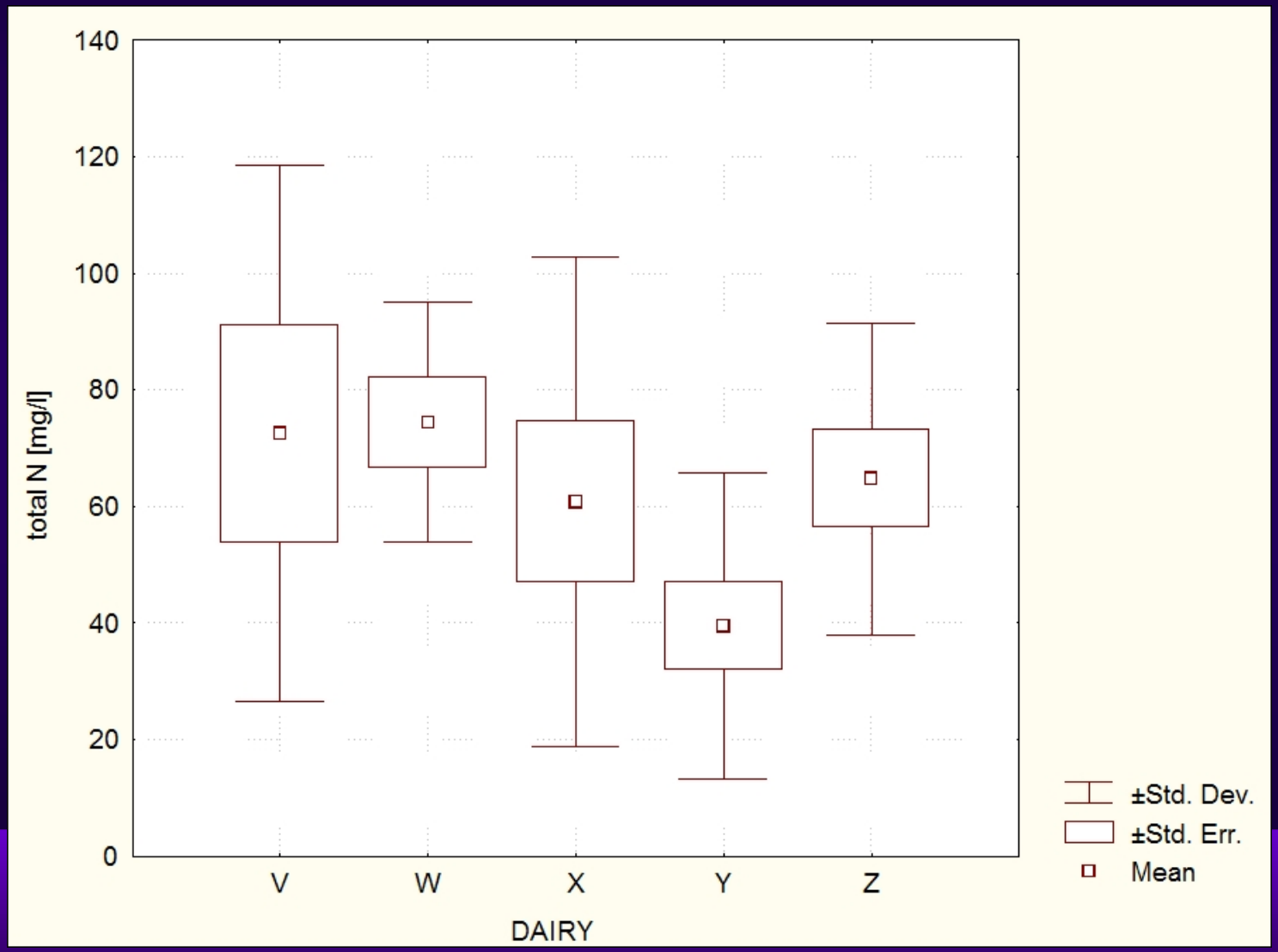
Statistical Analysis: By Farm



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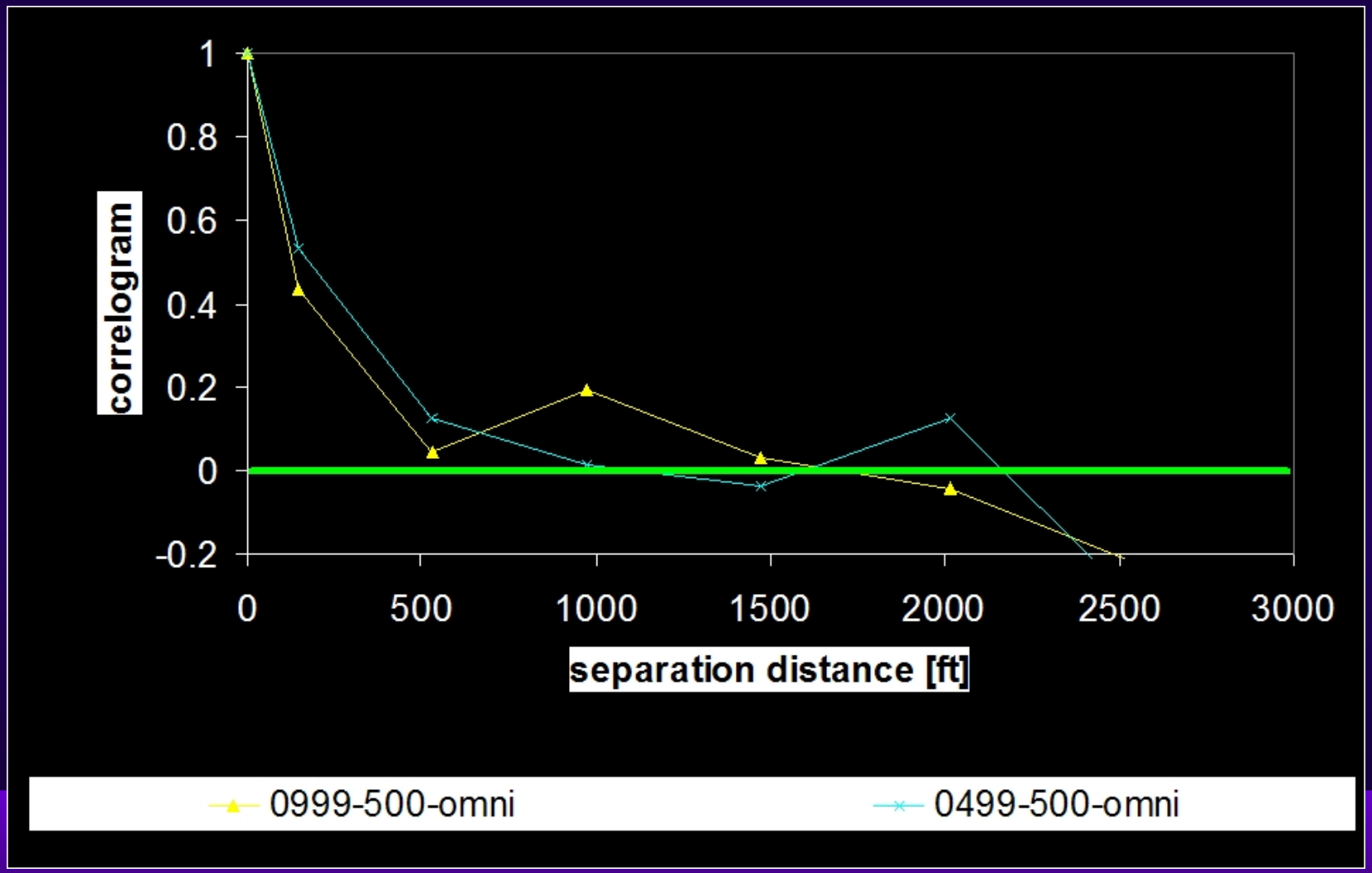
With-in Farm Variability in Space



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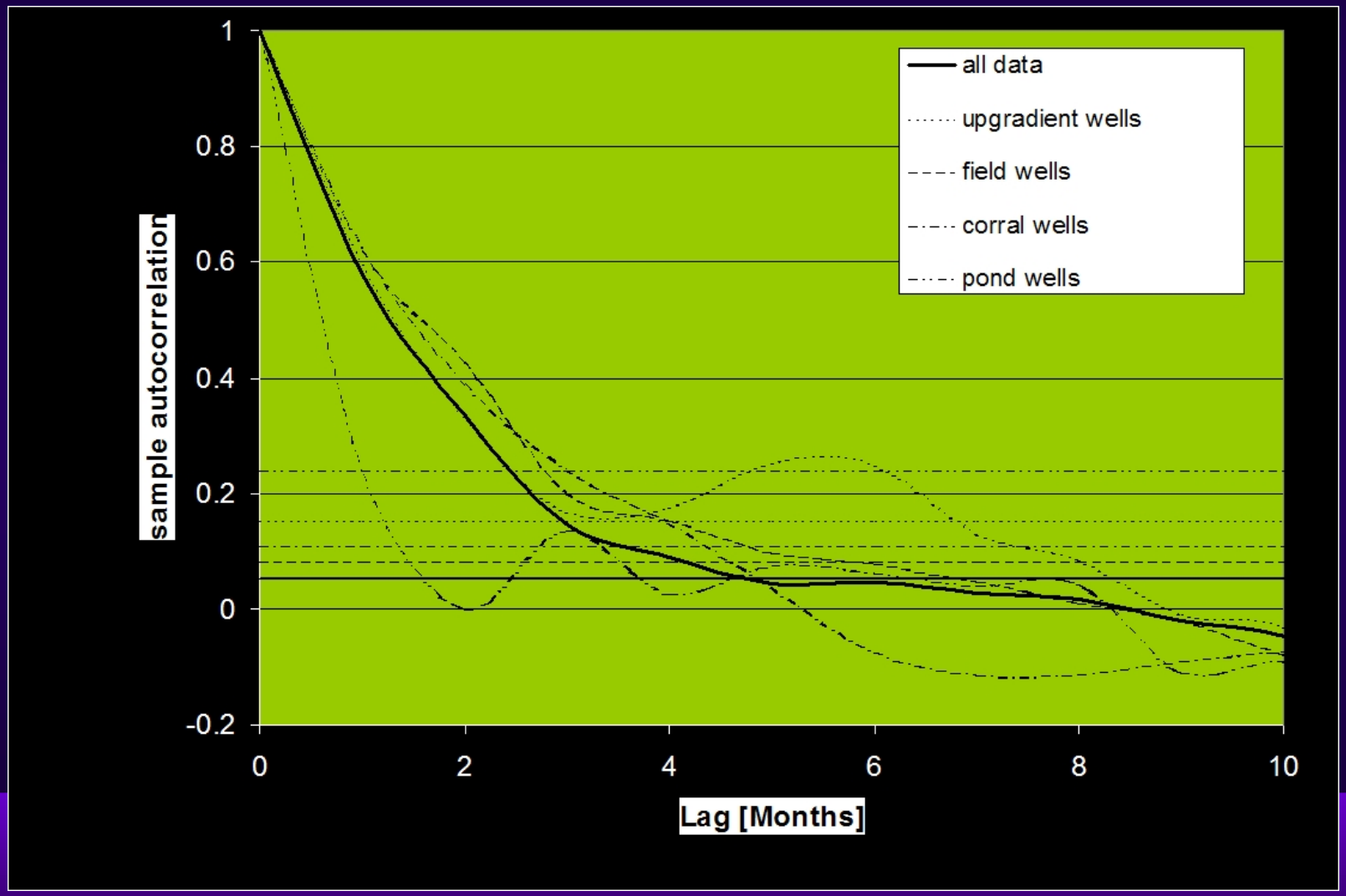
With-in Farm Variability in Time



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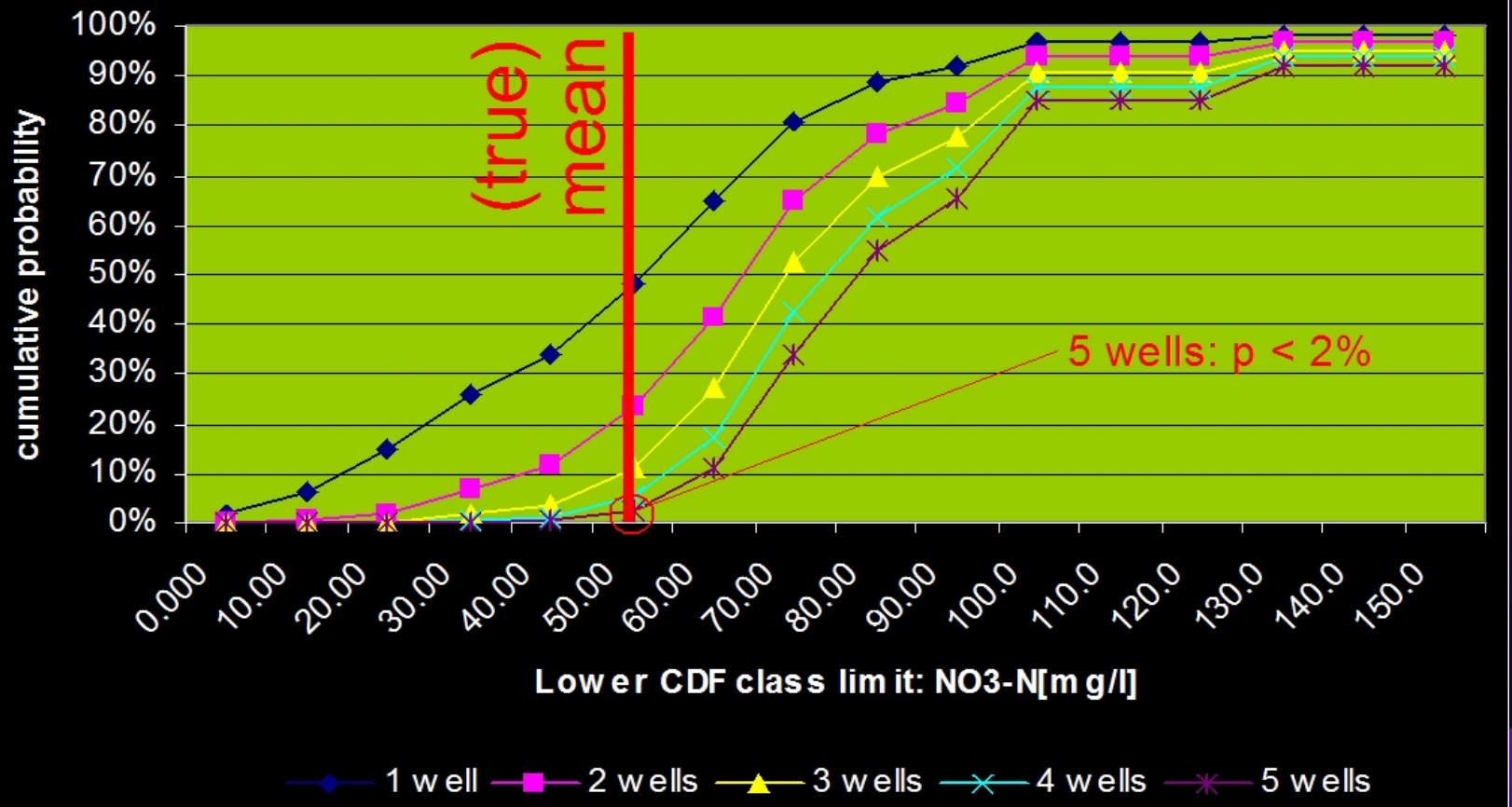
Probability that *ALL* of *n* wells have a long-term median nitrate-N concentration that is less than indicated on x-axis



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Questions?

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Monitoring Well Completion

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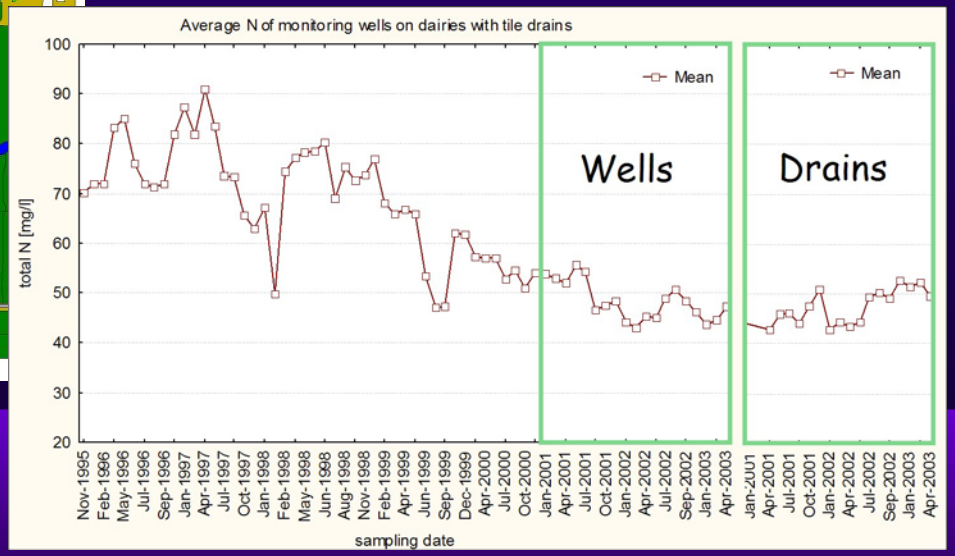
Tile Drains as Monitoring Tools?



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