

# Simulated Influences of Upgradient Multi-Aquifer Wells on the Movement of Contaminants to Public-Supply Wells

2011 GWPC Annual Forum

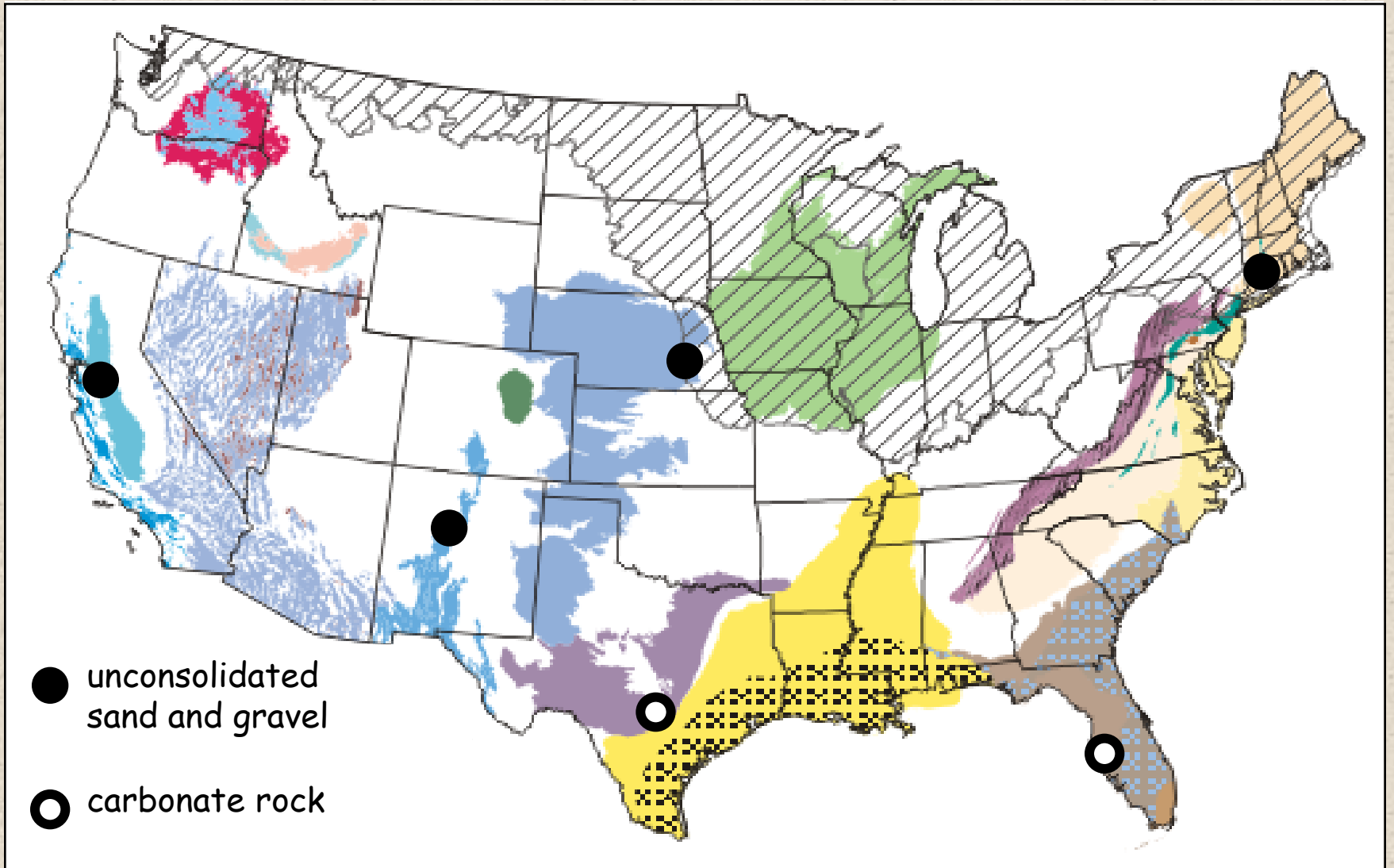
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Leon J. Kauffman  
Brian R. Clark  
Matthew K. Landon

USGS National Water  
Quality Assessment Program  
(NAWQA)

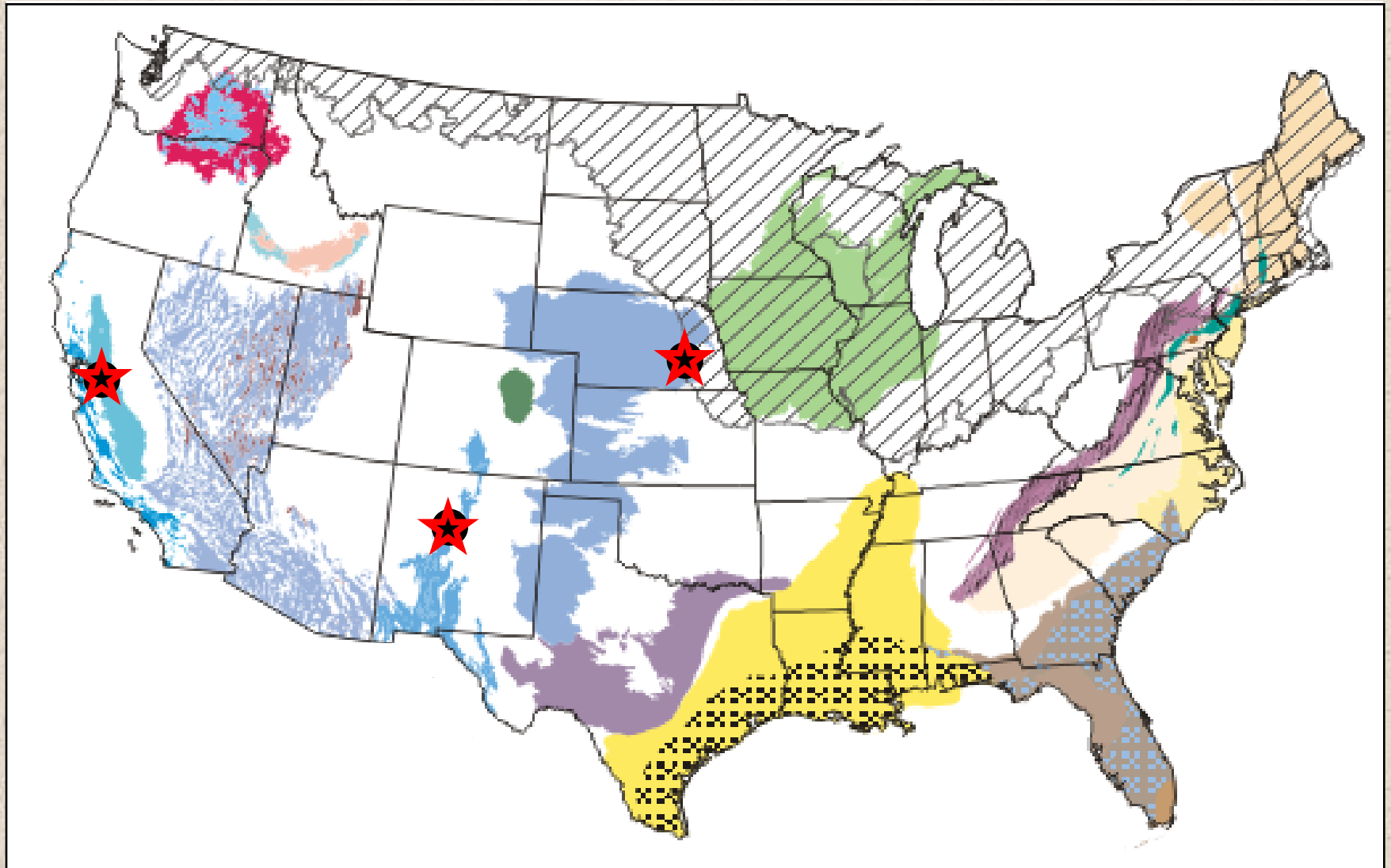


U.S. Department of the Interior  
U.S. Geological Survey

# study areas

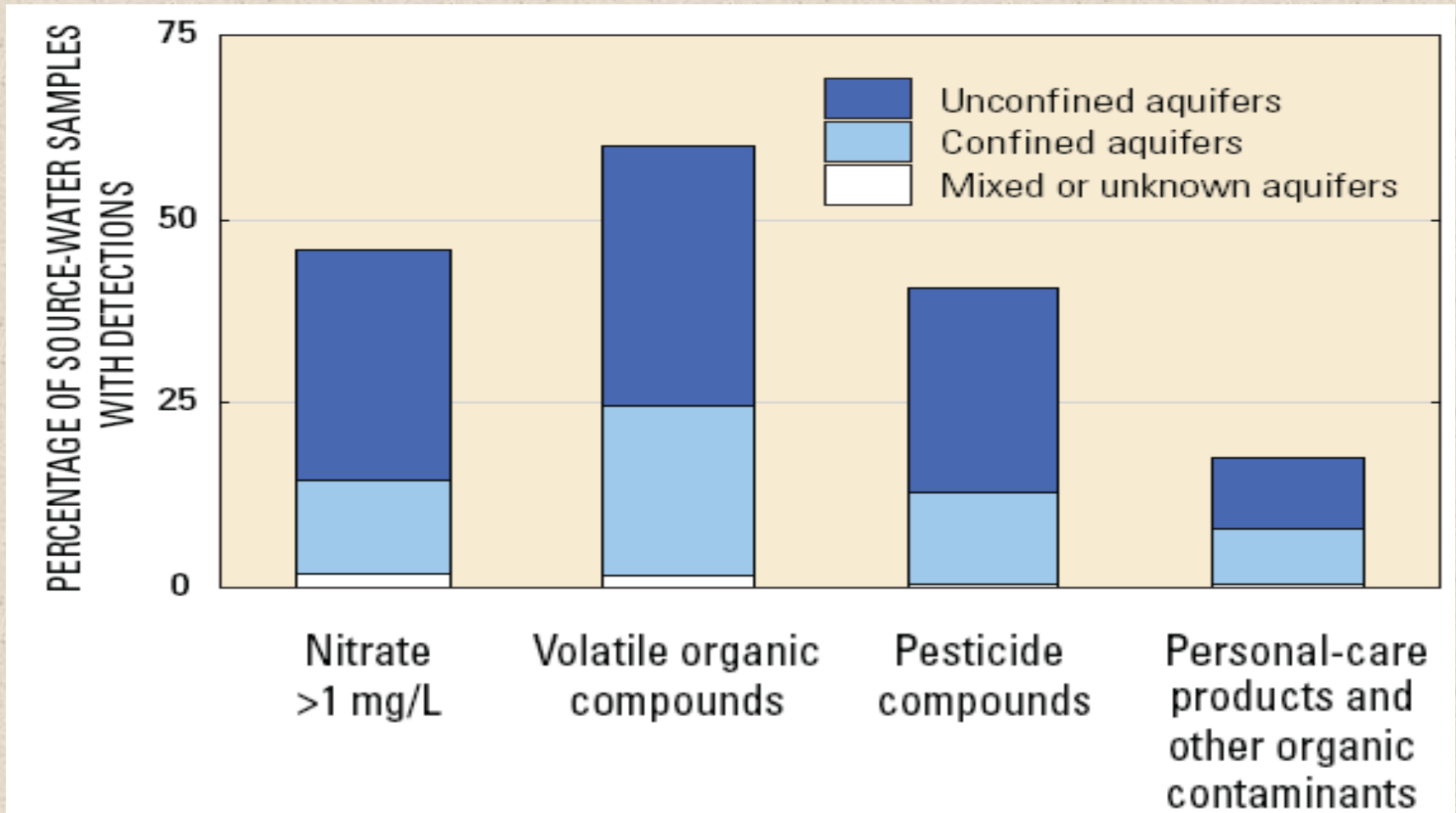


# study areas where wells served as preferential flow pathways\*



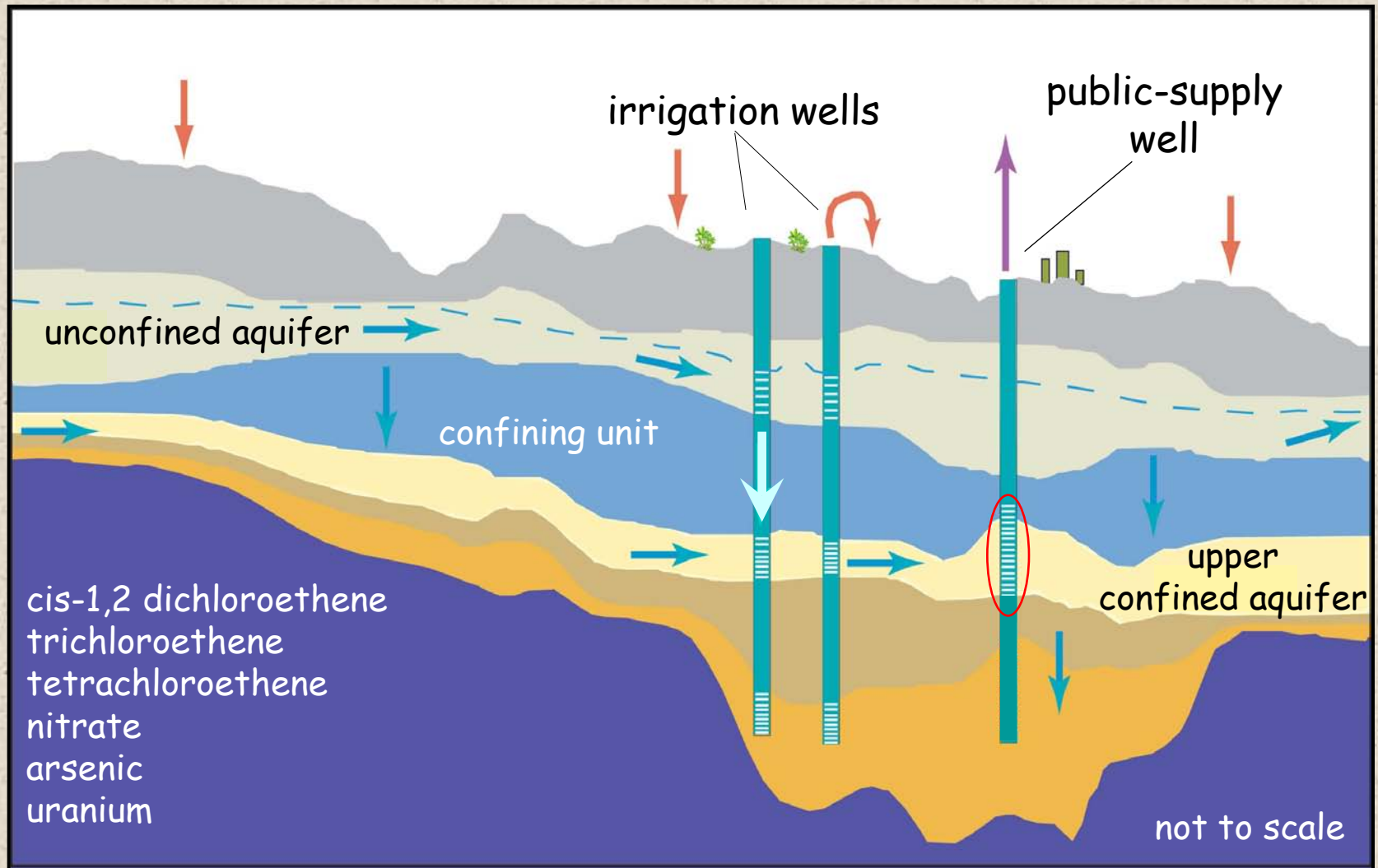
\* pathways that provide little resistance to groundwater flow

# why preferential flow pathways are important



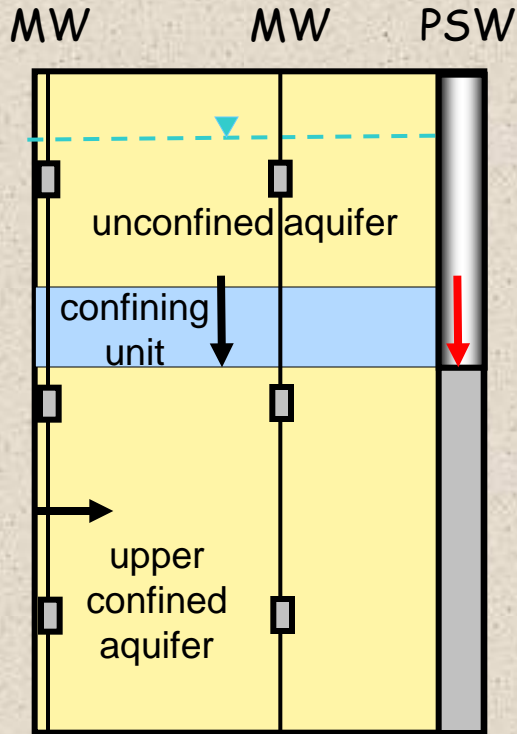



# multi-aquifer wells as preferential flow pathways example from the High Plains aquifer--York, Nebraska



# contaminant pathway hypotheses

public-supply well (PSW)  
leakage or drawdown  
induced leakage

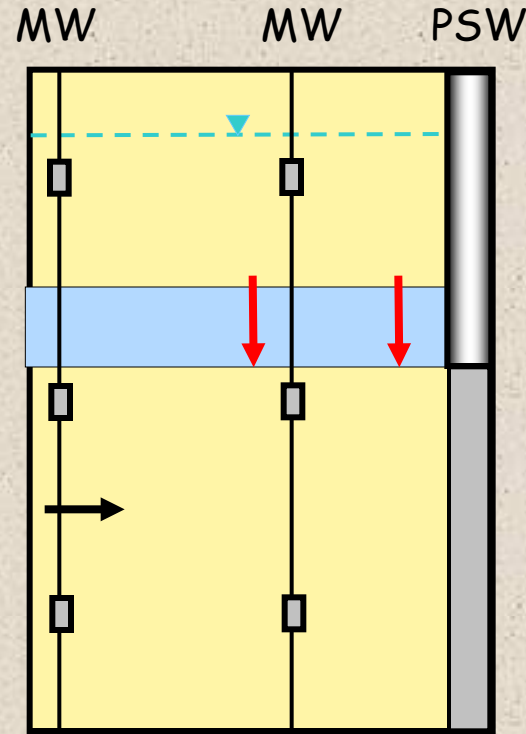
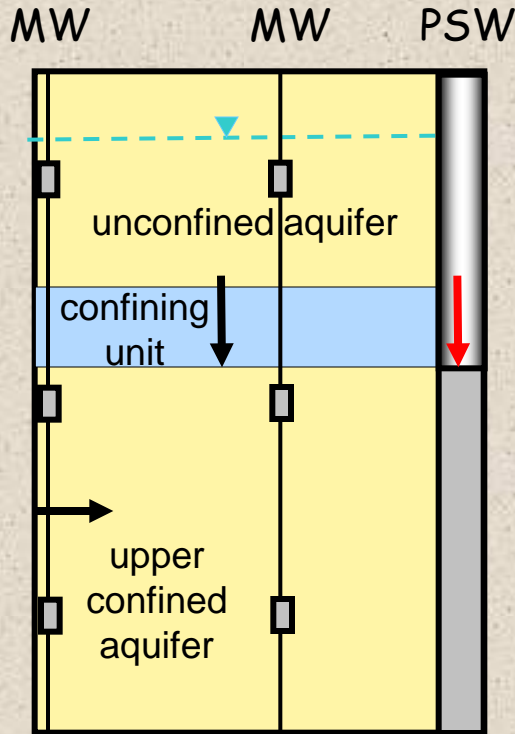


- MW Monitoring Well
- LW Leaky Well (multi-layer)
- PSW Public-Supply Well
-  Well Screen

# contaminant pathway hypotheses

public-supply well (PSW)  
leakage or drawdown  
induced leakage

areal leakage  
through  
confining unit



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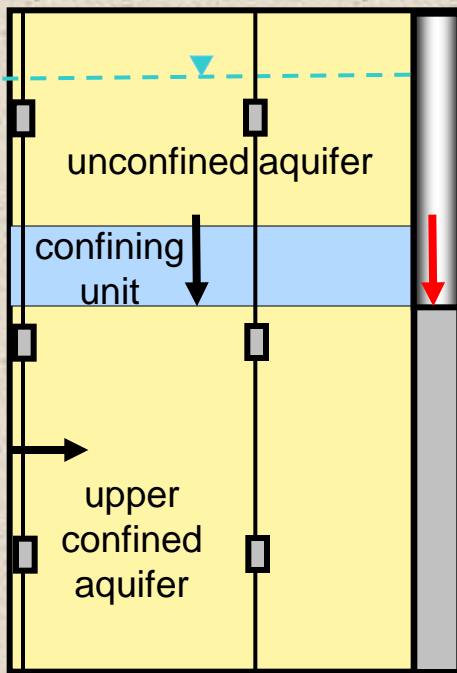
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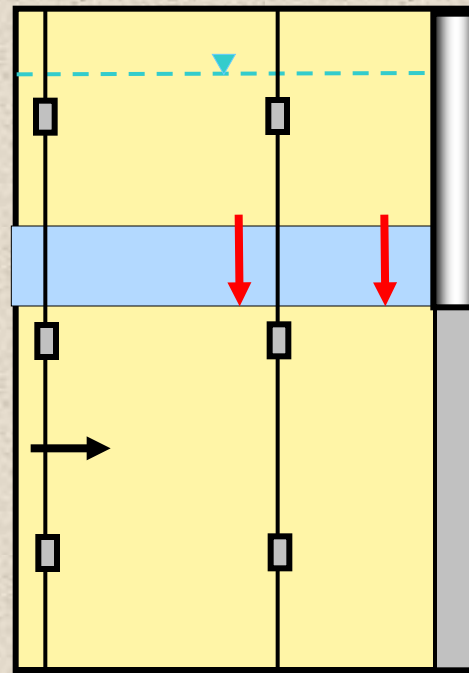
areal leakage  
through  
confining unit

upgradient  
multi-aquifer well  
leakage

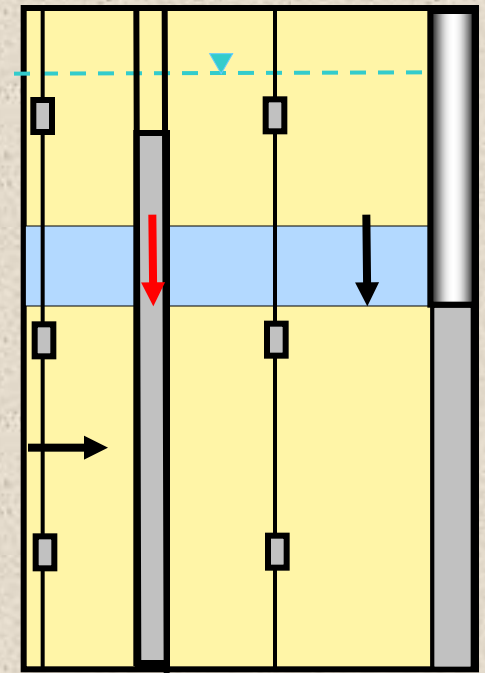
MW MW PSW



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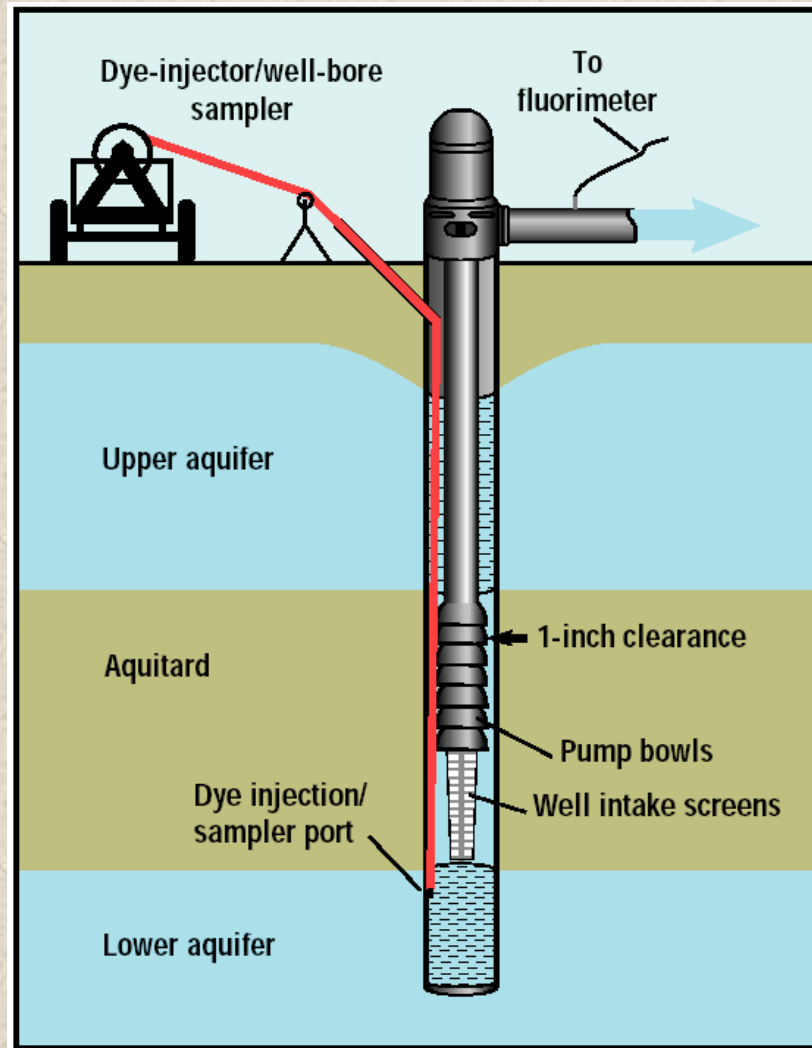
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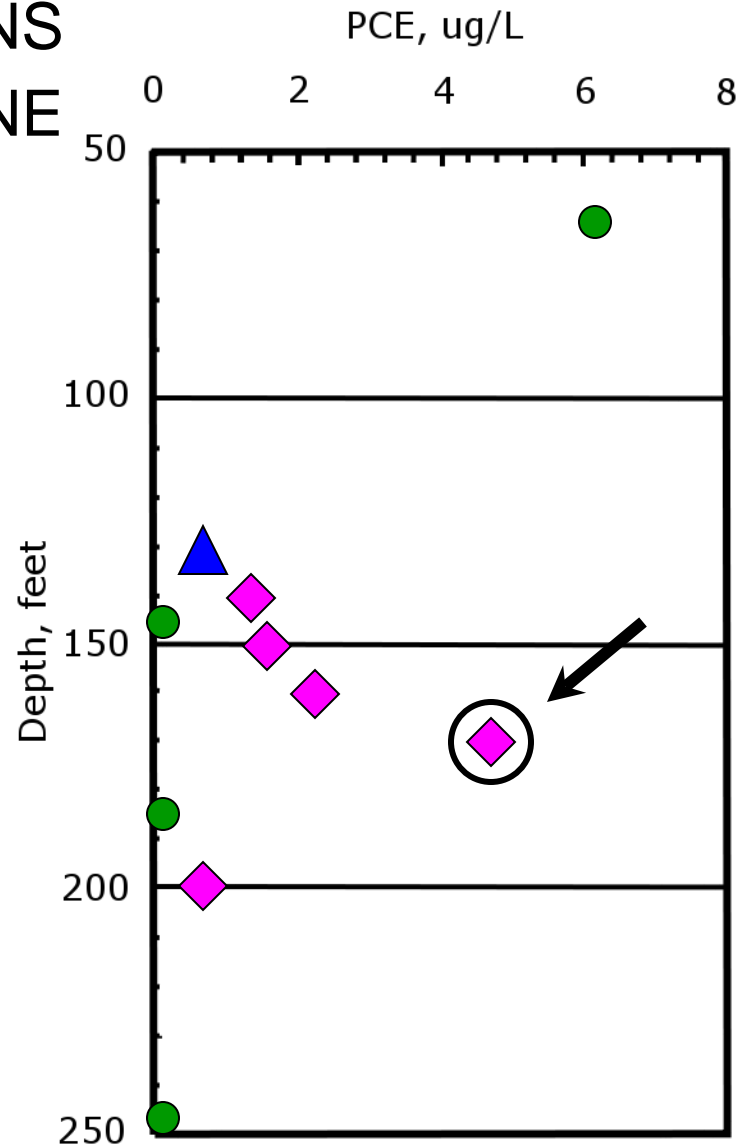
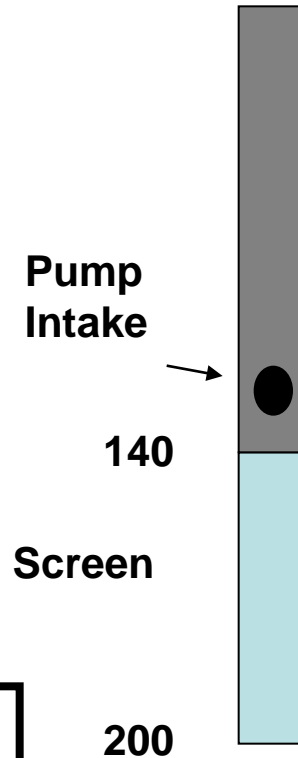


# depth-interval sampling



- Public-supply well depth samples differ from adjacent monitoring well samples
- No direct evidence of borehole leakage from the relatively contaminated unconfined layer; most PCE appears to be entering well around 170 ft

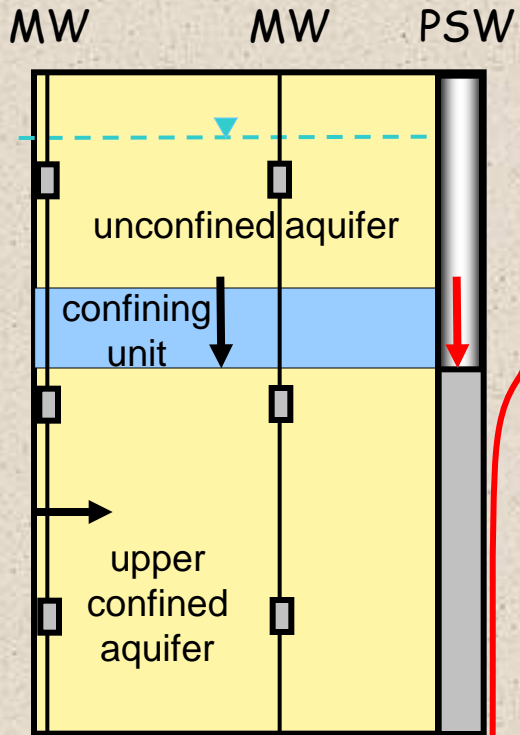
## HIGH PLAINS AQUIFER, NE



- Monitoring Wells
- ▲ Public-Supply Well Wellhead Sample
- ◆ Public-Supply Well Depth Samples

# upgradient multi-aquifer well leakage hypothesis fits data

public-supply well (PSW)  
leakage or drawdown  
induced leakage



- MW Monitoring Well
- LW Leaky Well (multi-layer)
- PSW Public-Supply Well
- Well Screen

contaminant concentration  
in public-supply well  
(increasing left to right)

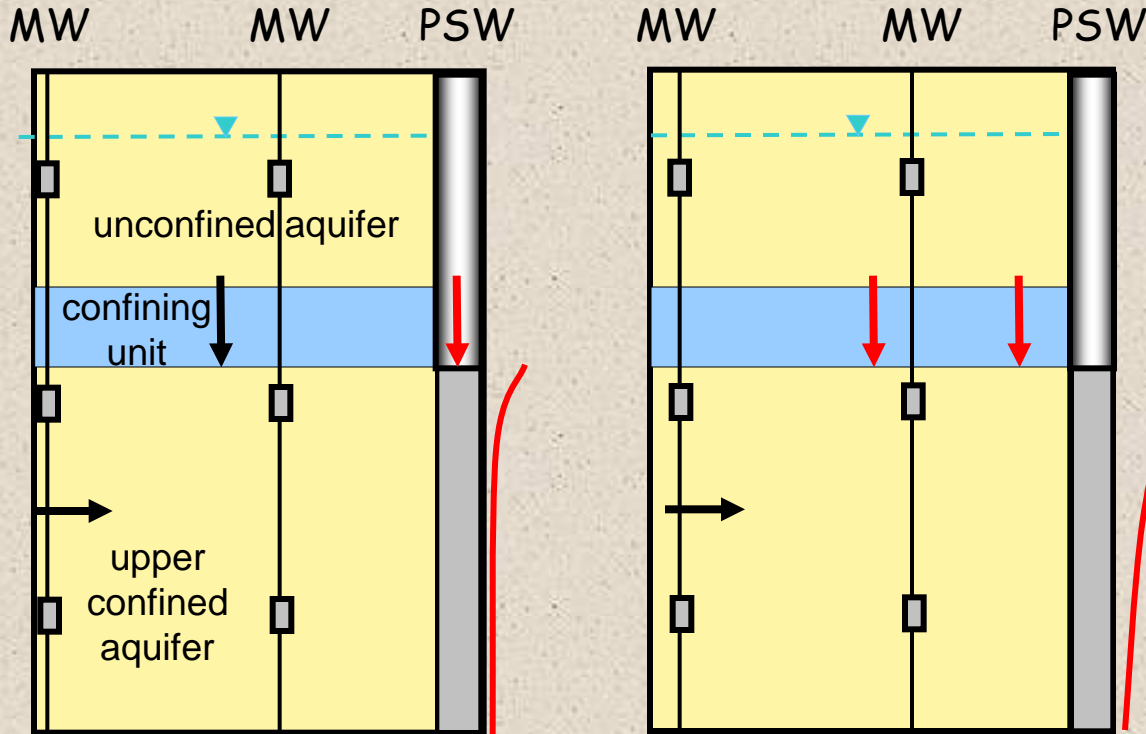


modified from Landon and others, 2008

# wellbore leakage hypothesis fits contaminant data

public-supply well (PSW)  
leakage or drawdown  
induced leakage

areal leakage  
through  
confining unit



MW Monitoring Well  
LW Leaky Well (multi-layer)  
PSW Public-Supply Well  
Well Screen

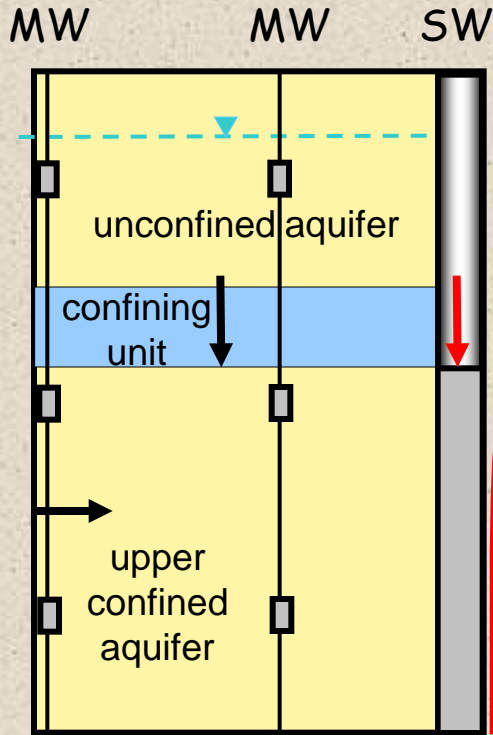
contaminant concentration  
in public-supply well  
(increasing left to right)



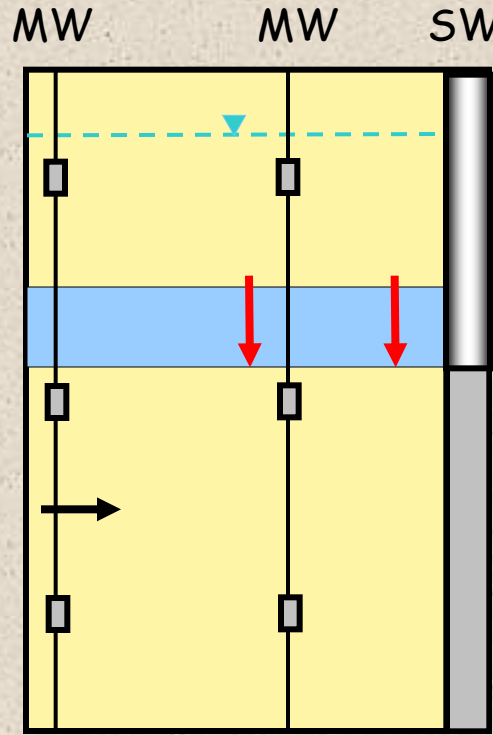


# wellbore leakage hypothesis fits contaminant data

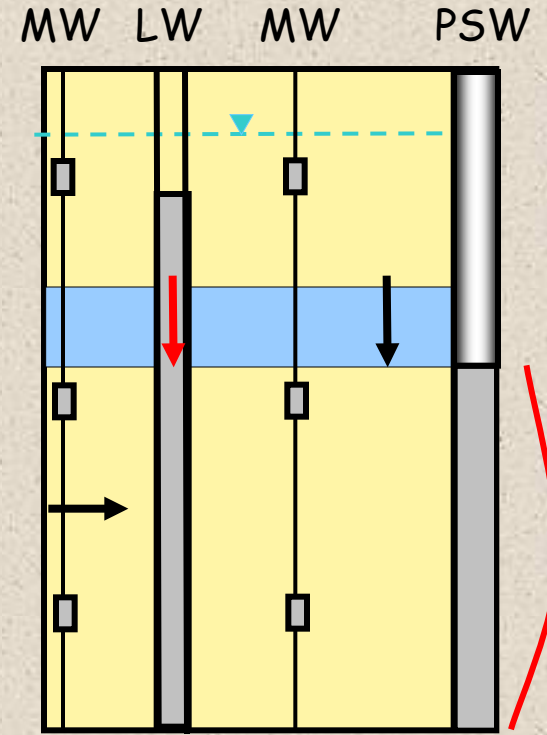
public-supply well (PSW)  
leakage or drawdown  
induced leakage



areal leakage  
through  
confining unit



upgradient  
multi-aquifer well  
leakage

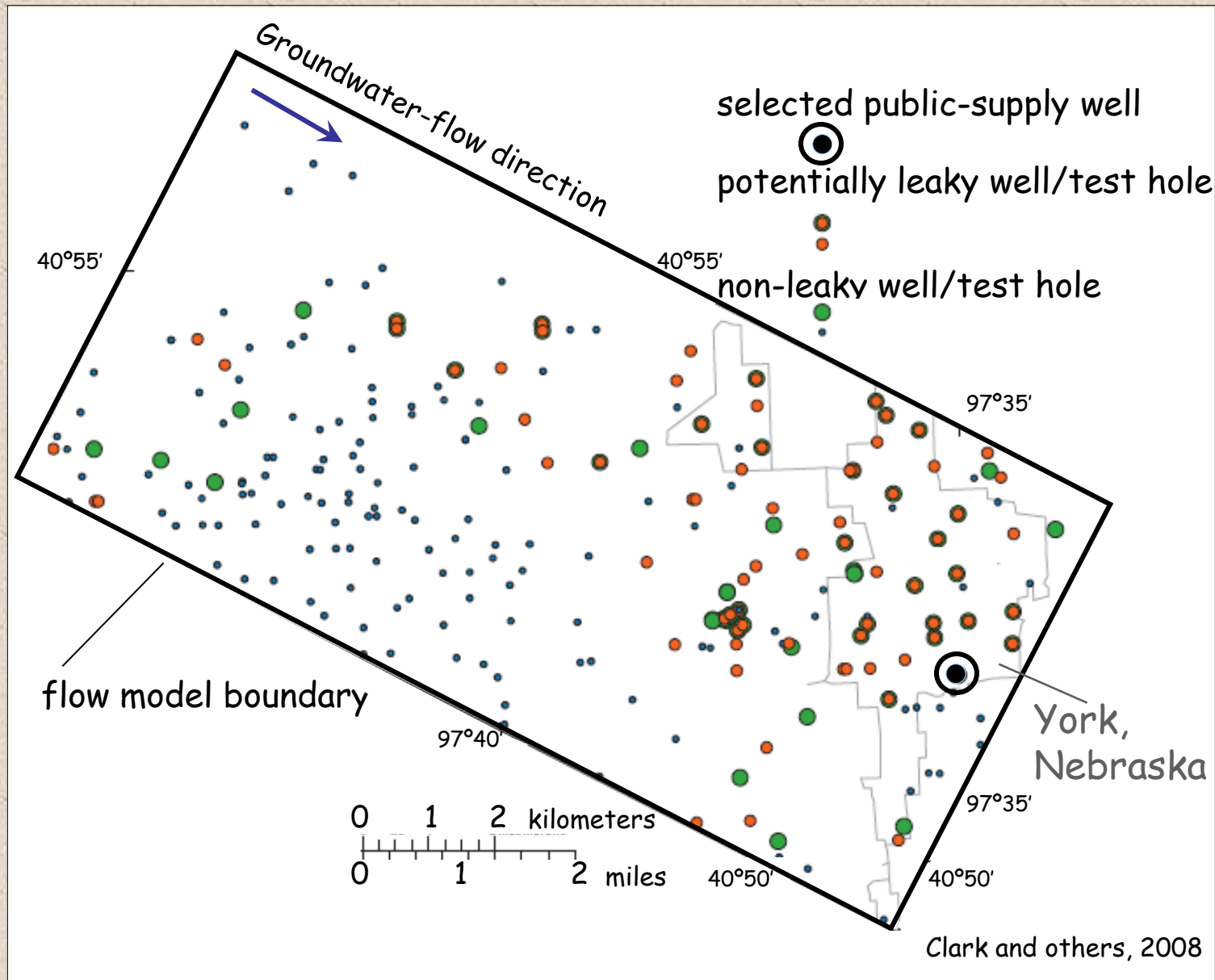


- MW Monitoring Well
- LW Leaky Well (multi-layer)
- SW Supply Well
- Well Screen

contaminant concentration  
in public-supply well  
(increasing left to right)



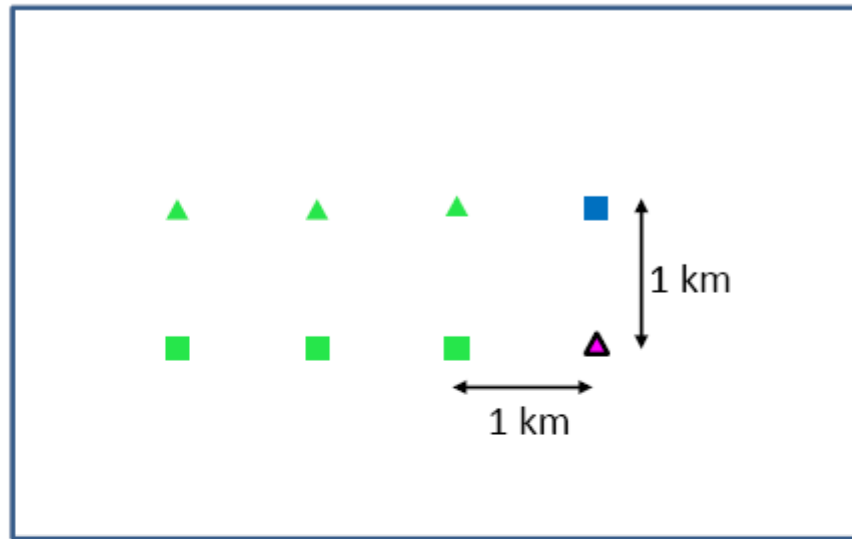
# leaky multi-aquifer wells near York, Nebraska



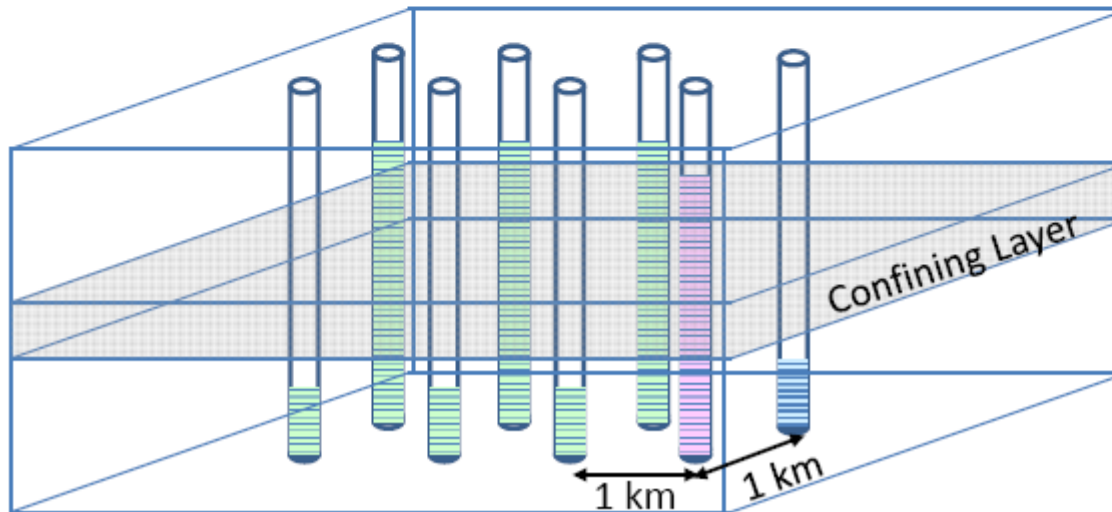
25% of water in confined aquifer from leaky multi-aquifer wells

# simple model to further explore effects of leaky multi-aquifer wells

## Simple Conceptual Model of the York Case



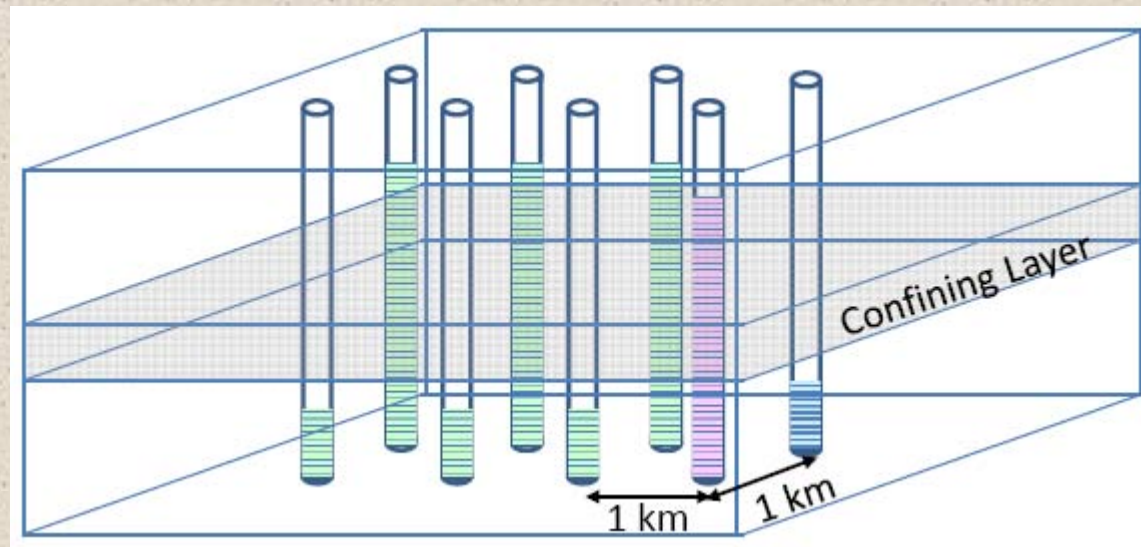
- ▲ Multi-aquifer, seasonal irrigation well, 1200 m<sup>3</sup>/day
- Confined, seasonal irrigation well, 1200 m<sup>3</sup>/day
- Confined, PSW, 400-2000 m<sup>3</sup>/day
- ▲ Multi-aquifer, abandoned well



Johnson et al., 2011

## scenarios that were simulated

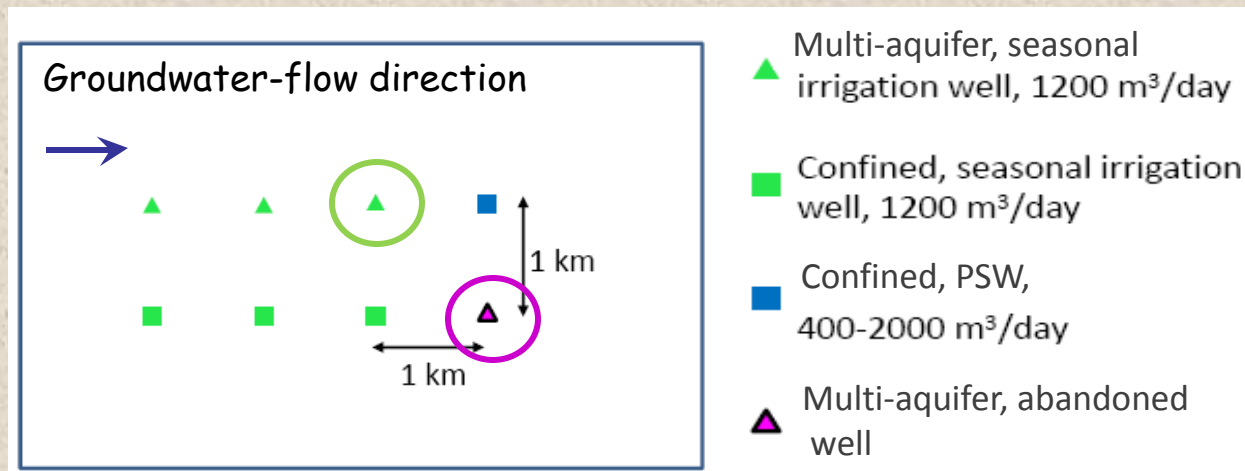
1. Public-supply well (PSW) is the only well in the model. Three different pumping rates were simulated
2. All 8 wells are in the model but only the PSW is pumping
3. All 8 wells are in the model. The PSW is pumping (year round) while the 6 irrigation wells are pumping 4 months out of the year



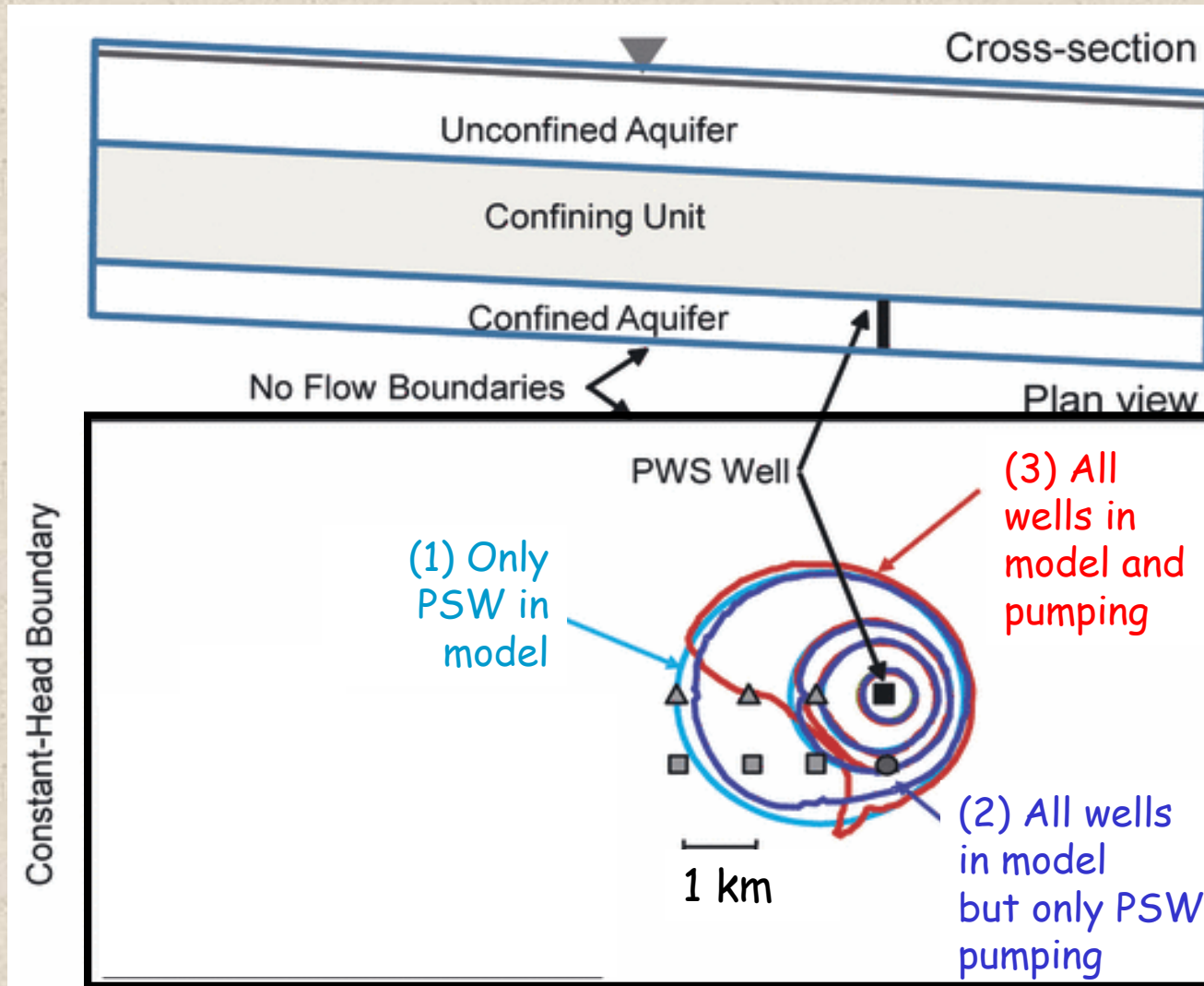


# more leaky wells affect PSW when there is no irrigation pumping

distance from supply well (km)	no irrigation						irrigation					
	irrigation well			abandoned well			irrigation well			abandoned well		
	public-supply well (PSW) pumping rate											
	high	med	low	high	med	low	high	med	low	high	med	low
percent of water at PSW from multi-aquifer well leakage after 40 years												
1	7	8	9	8	8	0	9	10	13	10	11	6
2	2	2	2				2	0	0			
3	1	0	0				0	0	0			

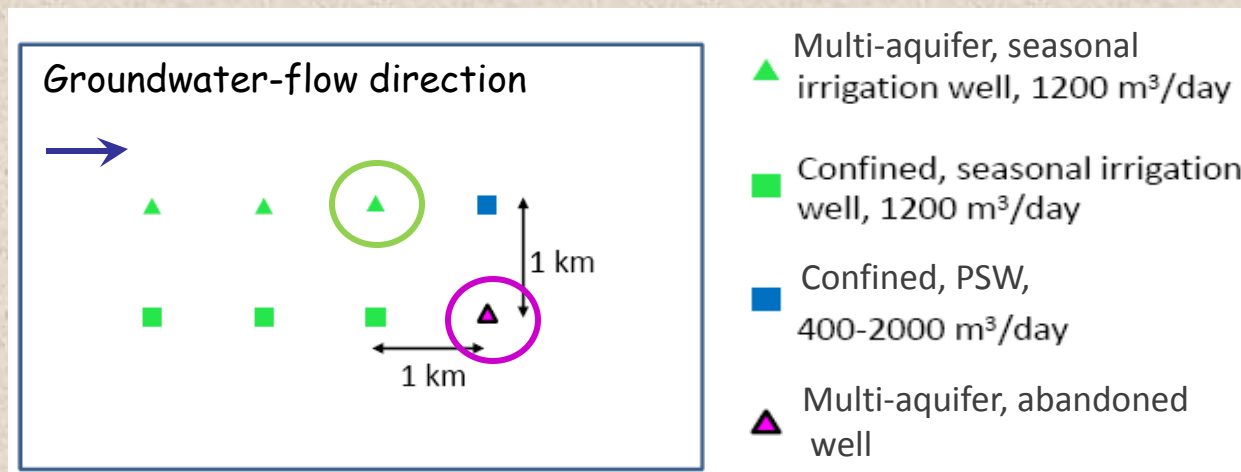


# size & shape of 40-yr zone-of-transport affected by multi-aquifer wells

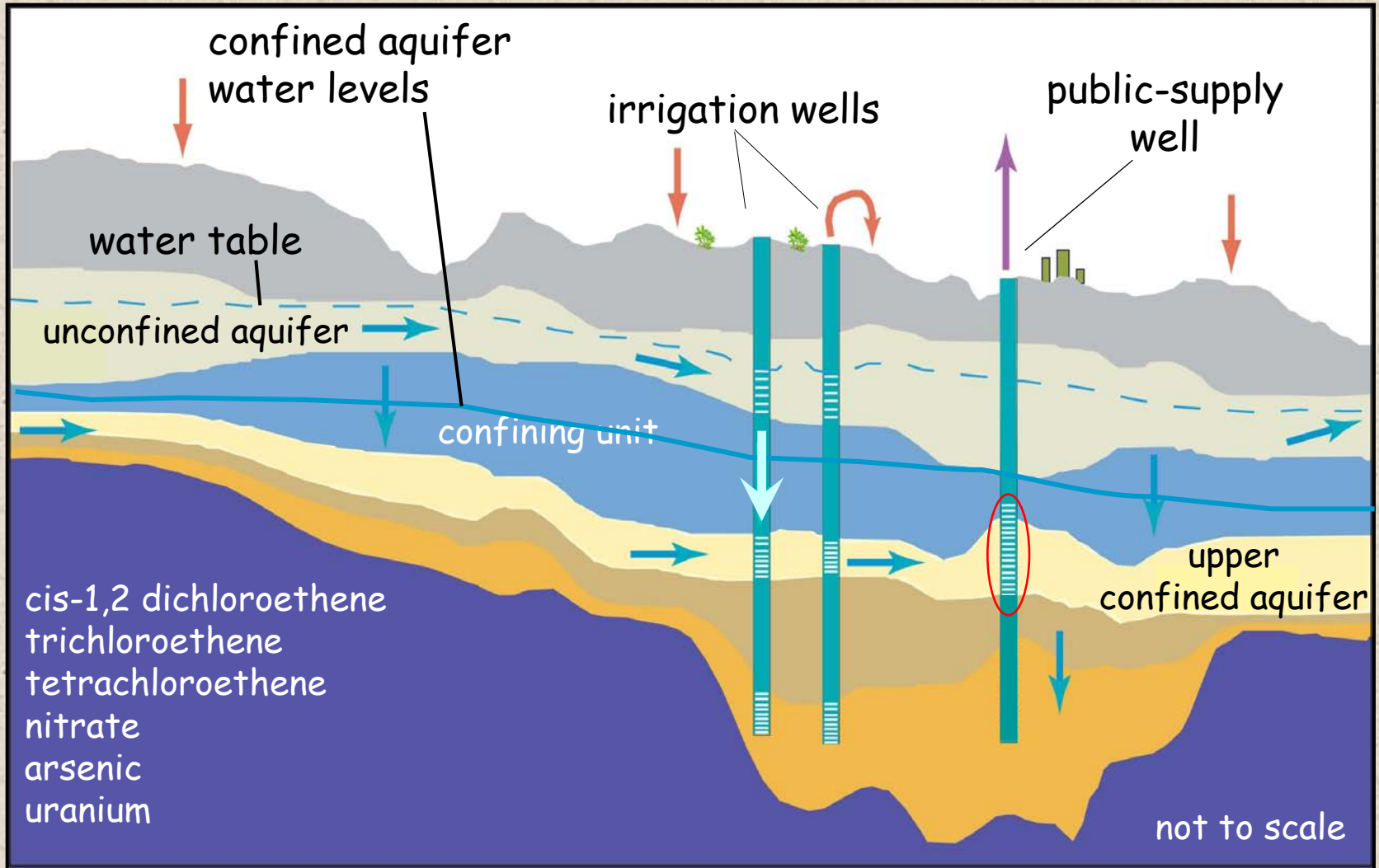


# more leaked water reaches PSW when irrigation is simulated

distance from supply well (km)	no irrigation						irrigation								
	irrigation well			abandoned well			irrigation well			abandoned well					
	public-supply well (PSW) pumping rate														
	high	med	low	high	med	low	high	med	low	high	med	low			
percent of water at PSW from multi-aquifer well leakage after 40 years															
1	7	8	9	8	8	0	9	10	13	10	11	6			
2	2	2	2	18%						2	0	0	21%		
3	1	0	0							0	0	0			

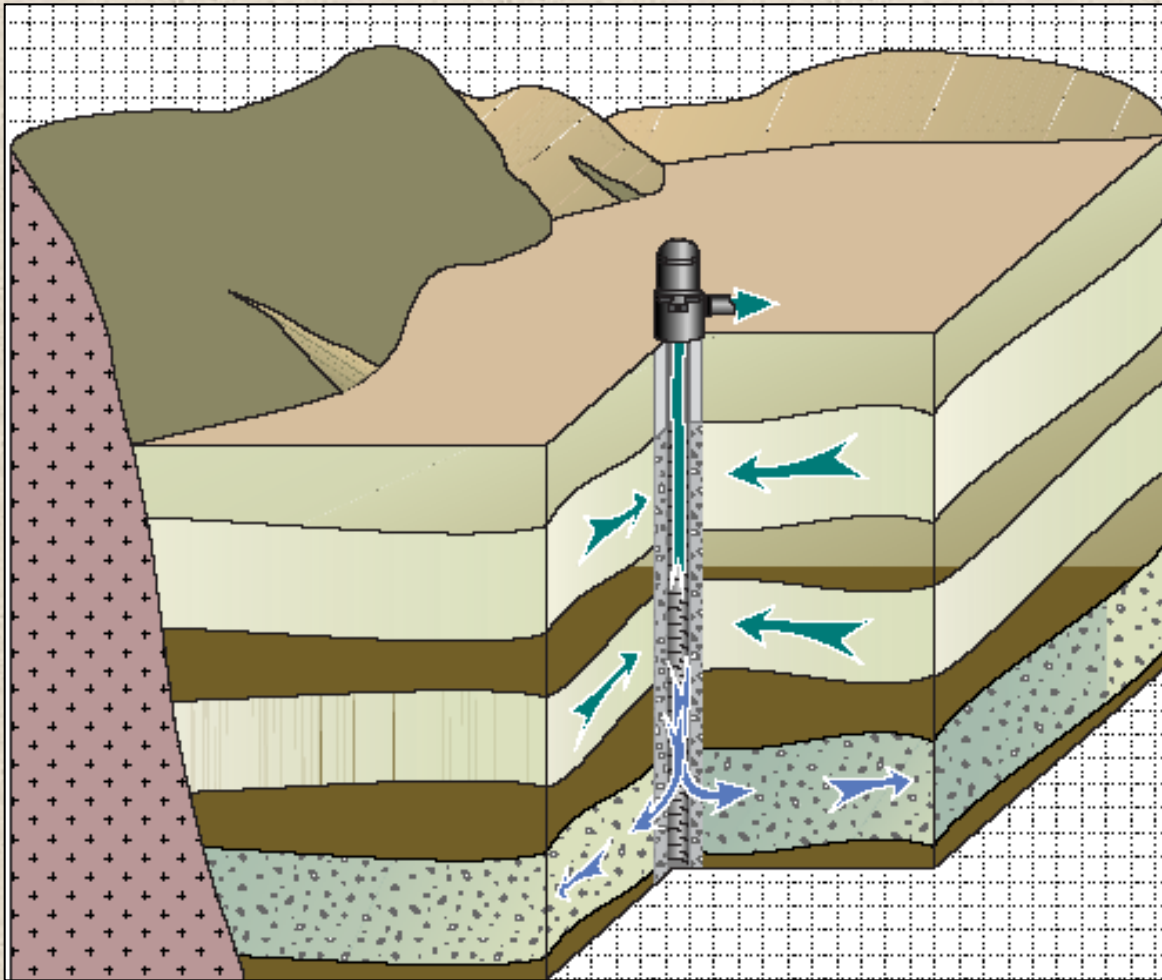


# vertical hydraulic gradients strongly affect leakage of water down multi-aquifer wells





irrigation wells can leak water even while pumping



# conclusions

- Even a single leaky multi-aquifer well may substantially compromise a confining unit's role as a hydrogeologic barrier
- Flow down a well can occur even when a long-screened interval well is being pumped (this finding is not limited to the confined aquifer scenario presented here)
- The possible presence of a small number of discrete but unknown preferential flow pathways is worth considering when establishing setback distances and designing well-head protection strategies\*