TRANSPORT AND LOSS OF NITROGEN WITHIN THE UPPER FLORIDAN AQUIFER IN THE SILVER SPRINGS SPRINGSHED

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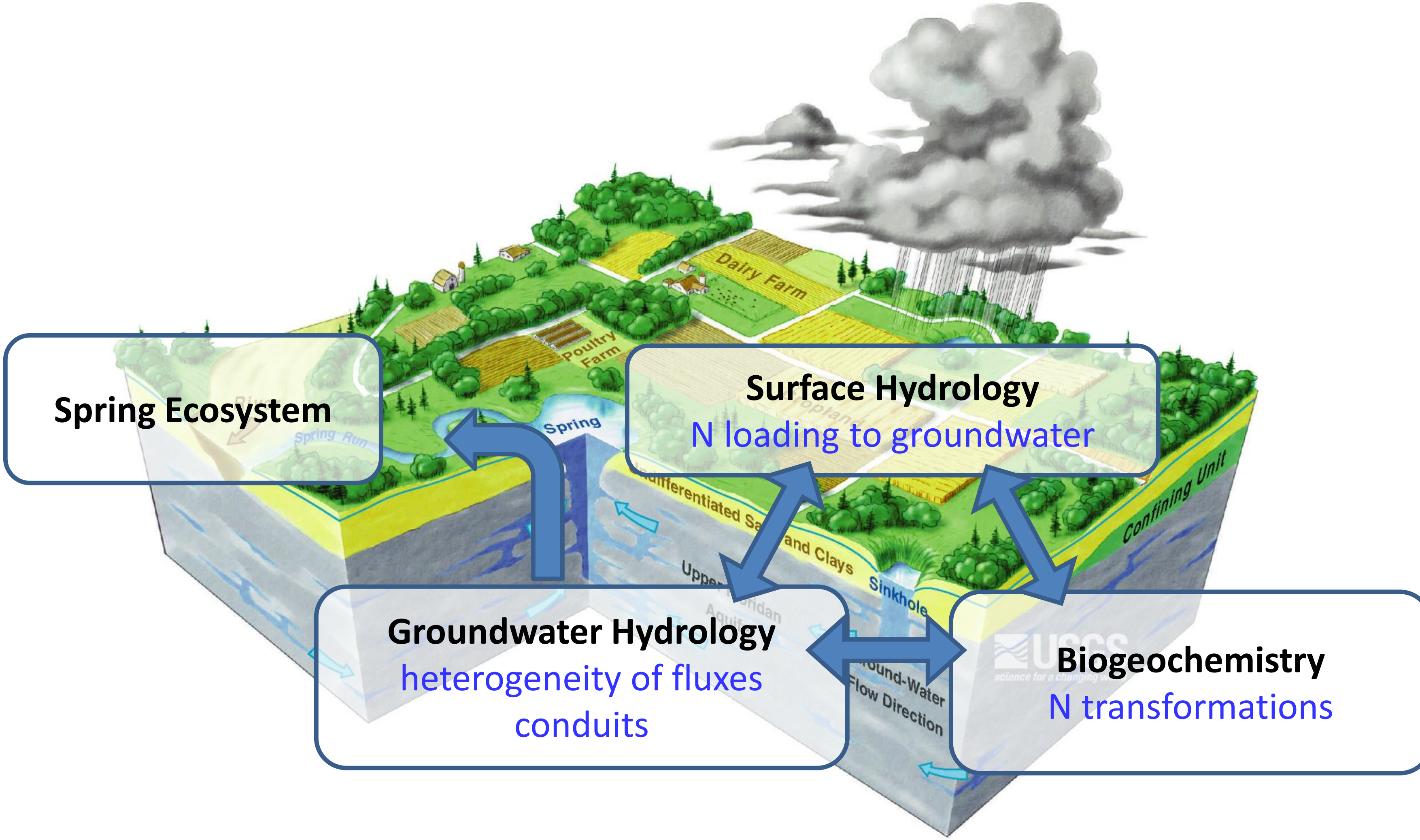
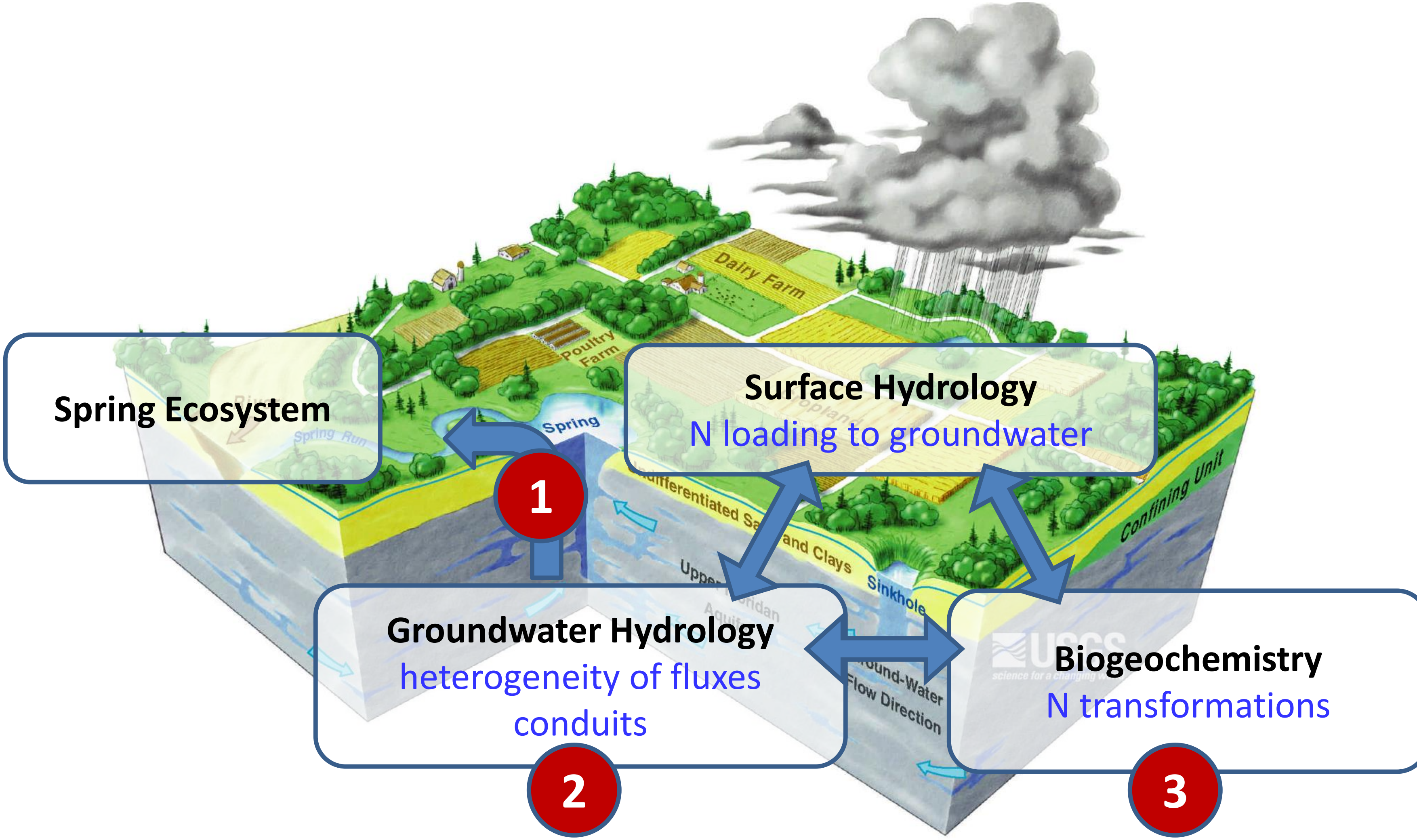

Spring Ecosystem
Surface Hydrology
N loading to groundwater
Groundwater Hydrology
heterogeneity of fluxes
conduits
Biogeochemistry
N transformations
Dairy Farm
Poultry Farm
Spring
Spring Run
Sinkhole
Confining Unit



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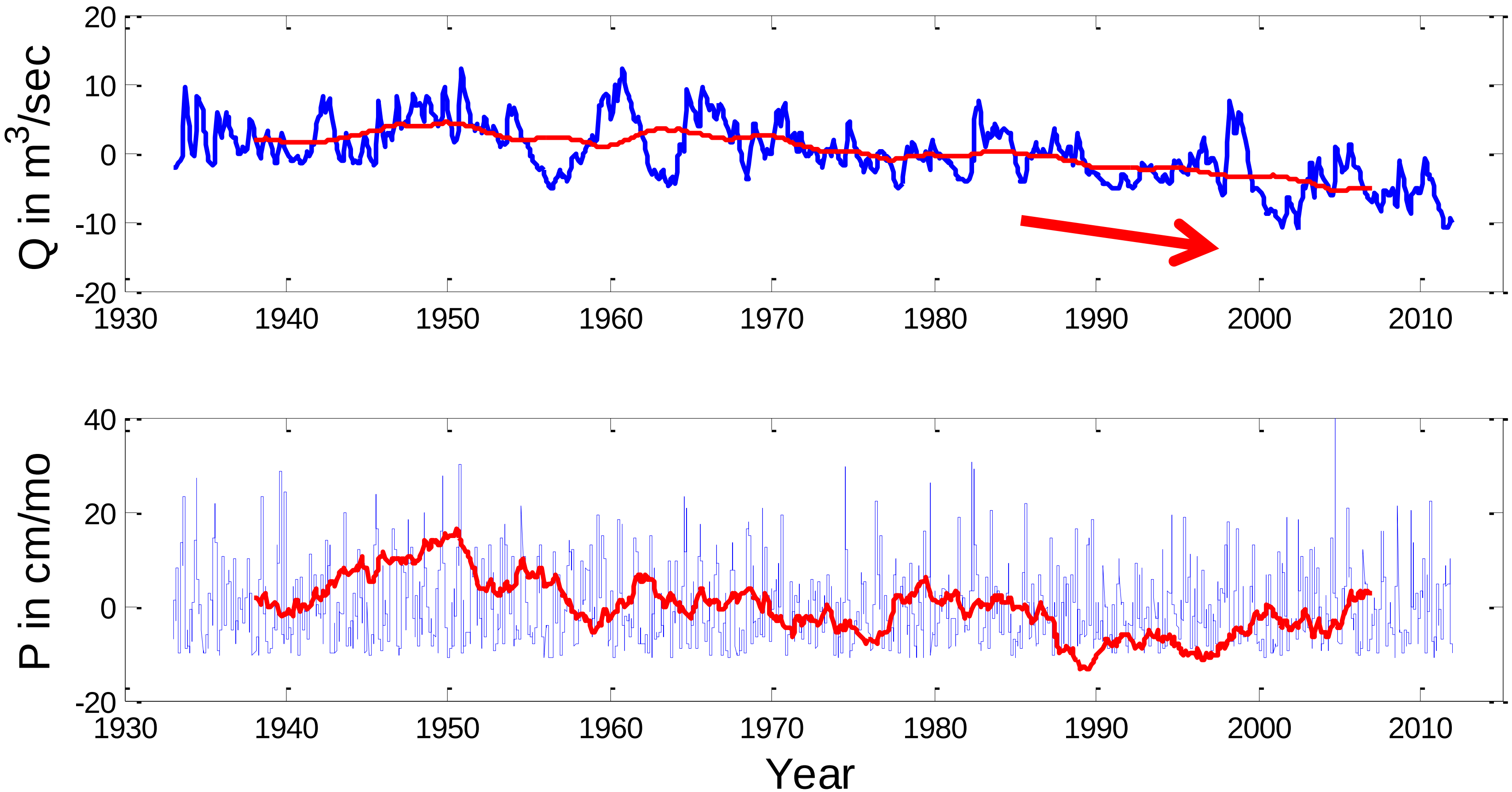
1

rainfall:discharge ratio changing?



hypotheses

groundwater pumping, vegetative damming, intra-annual rainfall shifts, land cover changes (urbanization + forest-to-agriculture), inter-connected springsheds, groundwater pumping beyond the springshed, …

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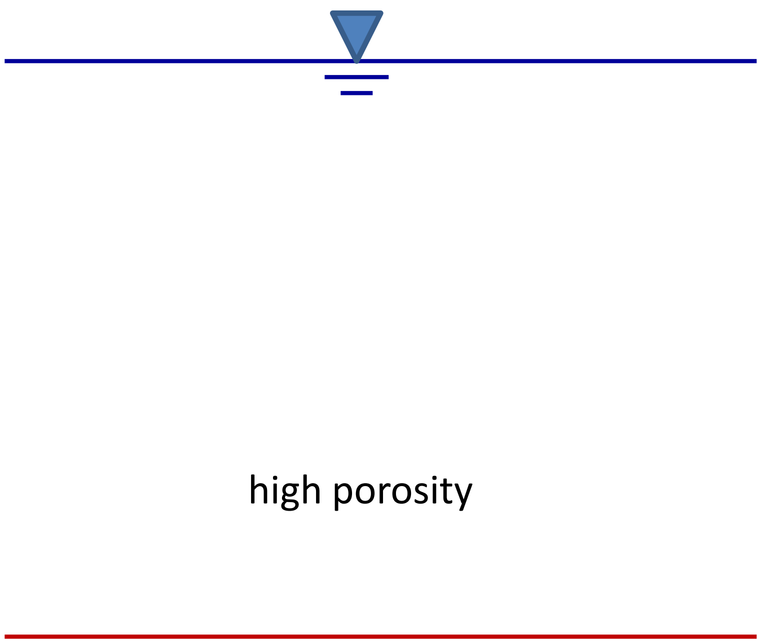
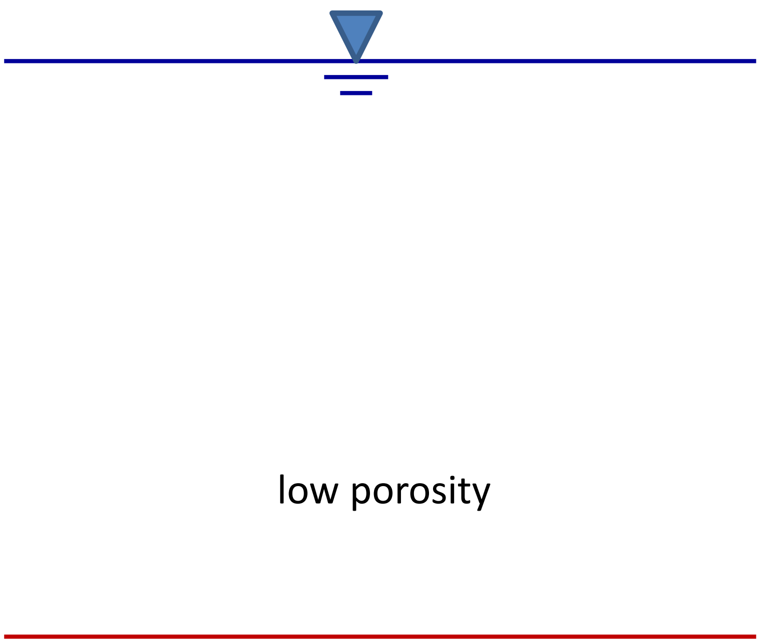
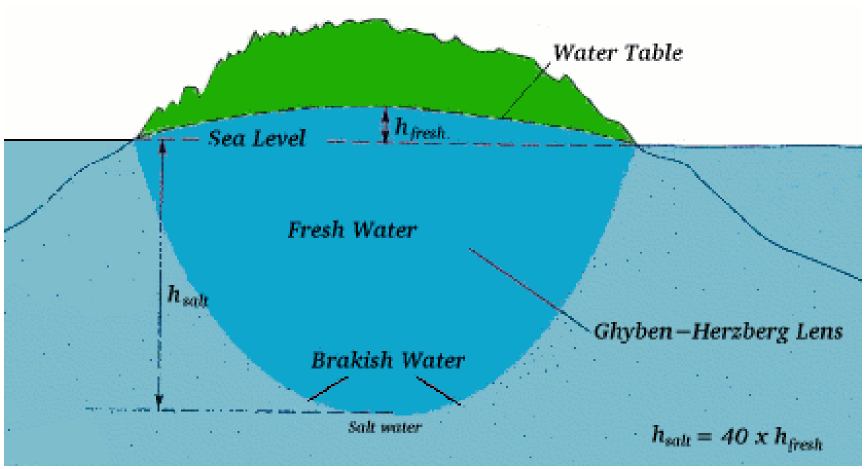
conservation of mass: mass in – mass out = ?

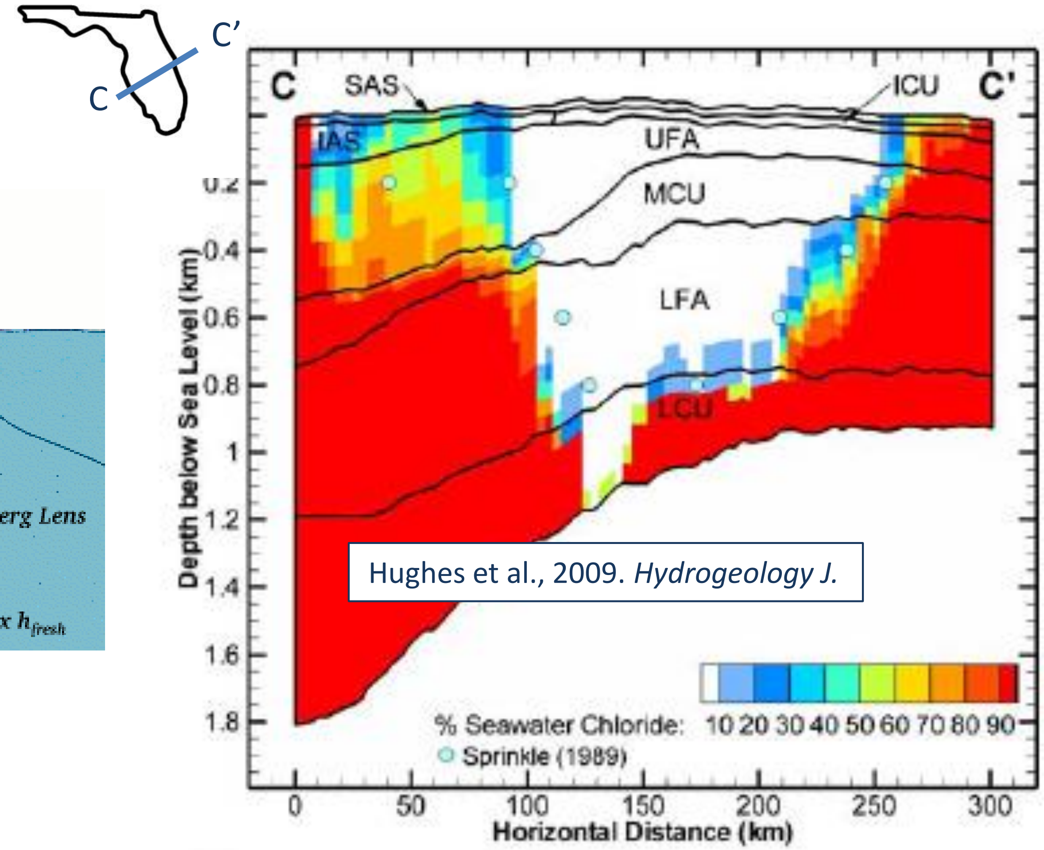
change in aquifer water storage





Floridan aquifer as freshwater lens





Hughes et al., 2009. *Hydrogeology J.*

freshwater/saltwater interface depth

Ghyben-Herzberg Principle
depth of freshwater/saltwater interface

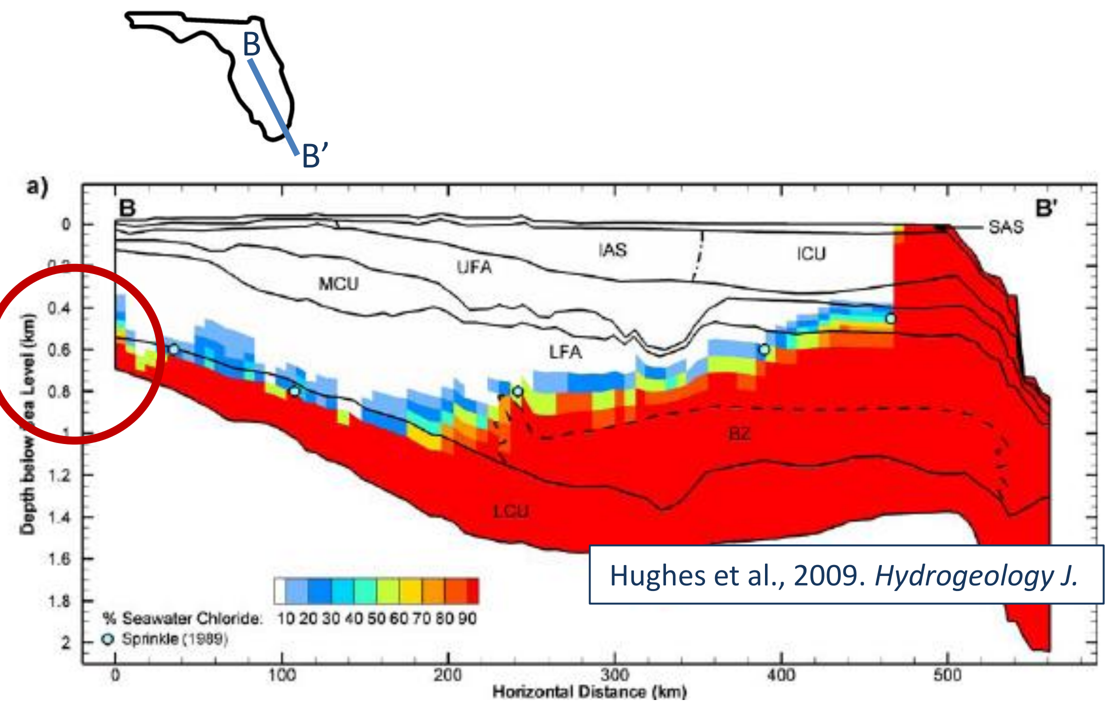
$$H = \frac{\rho_f}{(\rho_s - \rho_f)} h = 40h$$

Expected depth of salt-water interface

$$H = 40(\phi_2 + H_{spring})$$

$$H_{spring} = 11.9 \text{ m}$$

$$H \approx 500 \text{ m}$$



Hughes et al., 2009. *Hydrogeology J.*

groundwater hydraulics time scales

hydraulic response: time for output to respond to input

$t_h = L_{aq}{}^2 S_{aq} / T_{aq}$

unconfined aquifer $\boldsymbol{S_{aq}}$ **= 0.2**, L_{aq} = 27 km, T_{aq} = 2 m^2/s [Knowles et al., 2010]

t_h ~ 2 yr

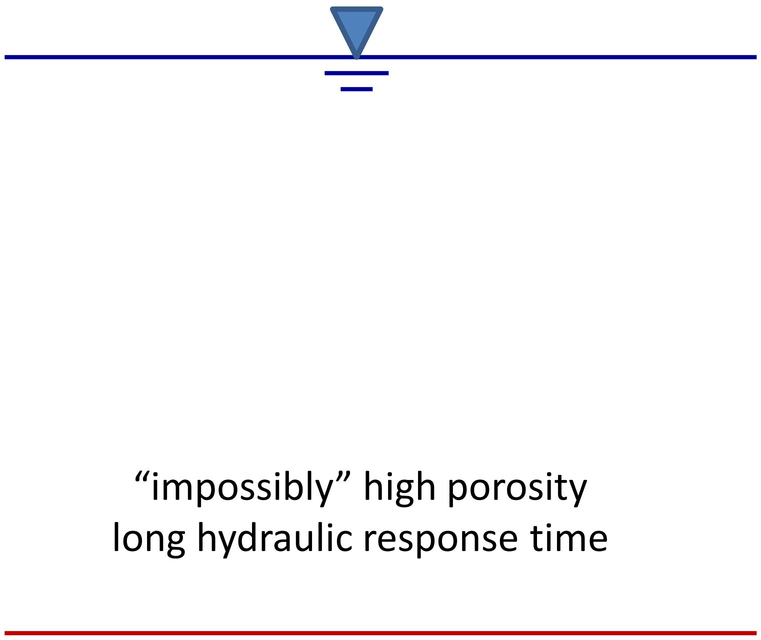
confined Floridan aquifer $\boldsymbol{S_{aq}}$ **= 0.05**

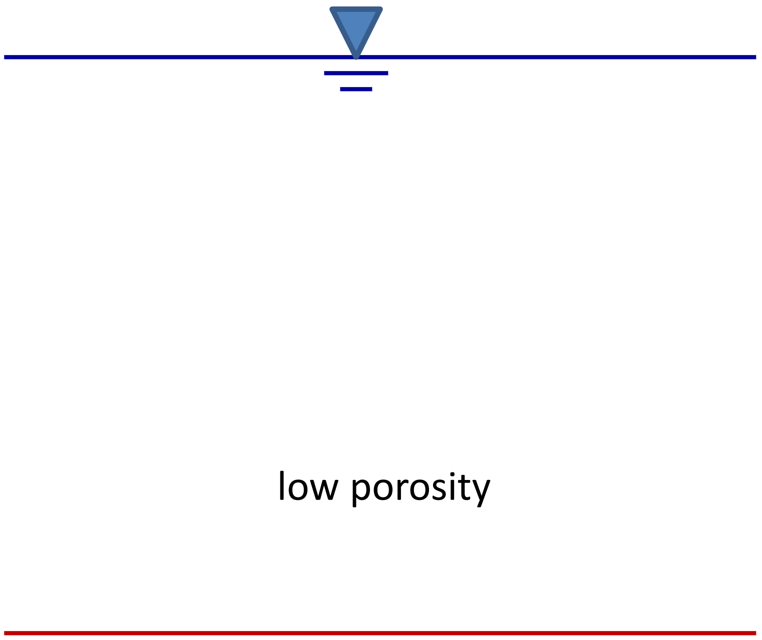
t_h ~ 0.5 yr

confined **saltwater** aquifer $\boldsymbol{S_{aq}}$ **= 40(0.05) = 2 (> 1 !)**

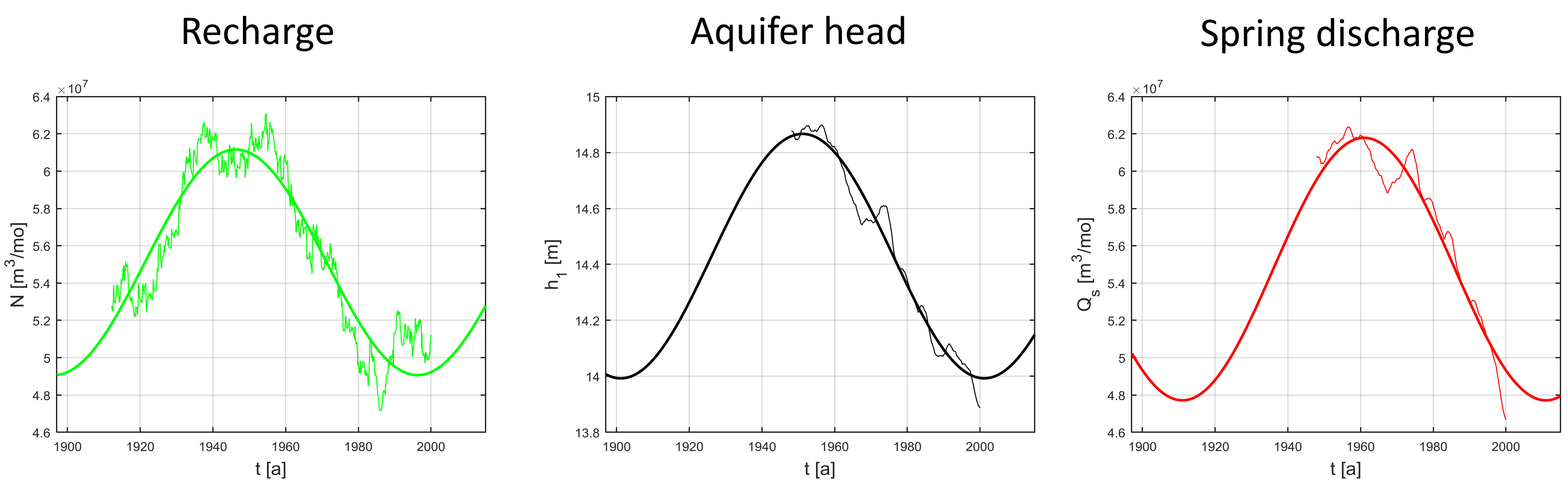
t_h ~ 20 yr

“Dynamic Saltwater Interface Hypothesis”





Silver Springs data temporal trends

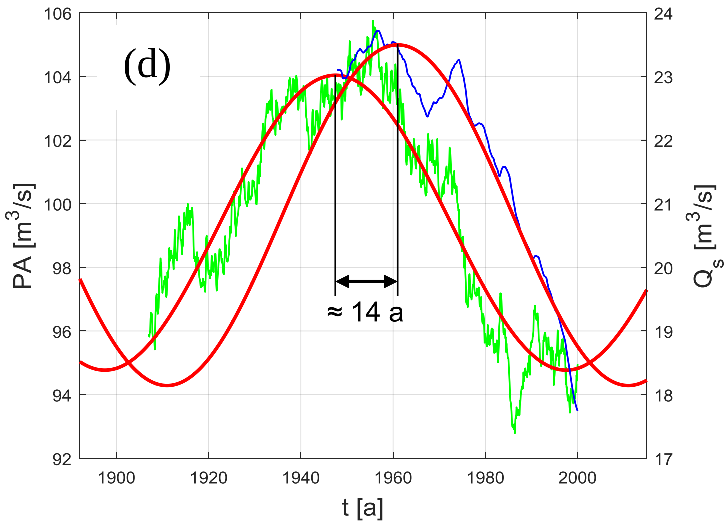


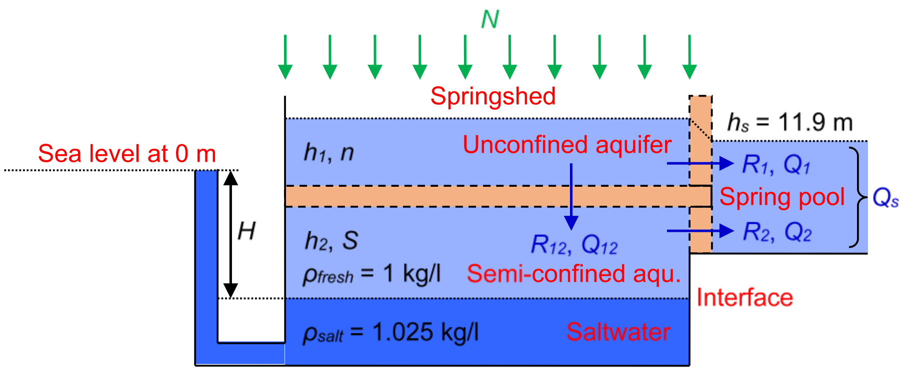
H1 Sinusoidal multi-decadal driver

100 yrs - fit using the same wavelength on all three graphs

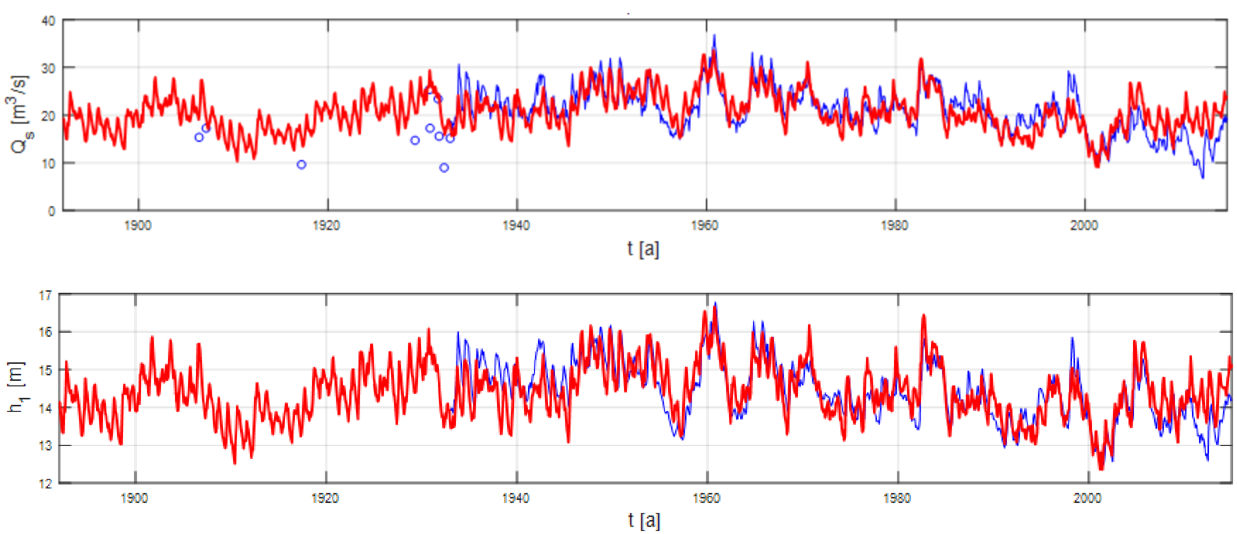
“Dynamic Saltwater Interface Hypothesis” support

long rain-discharge response time, consistent with prediction

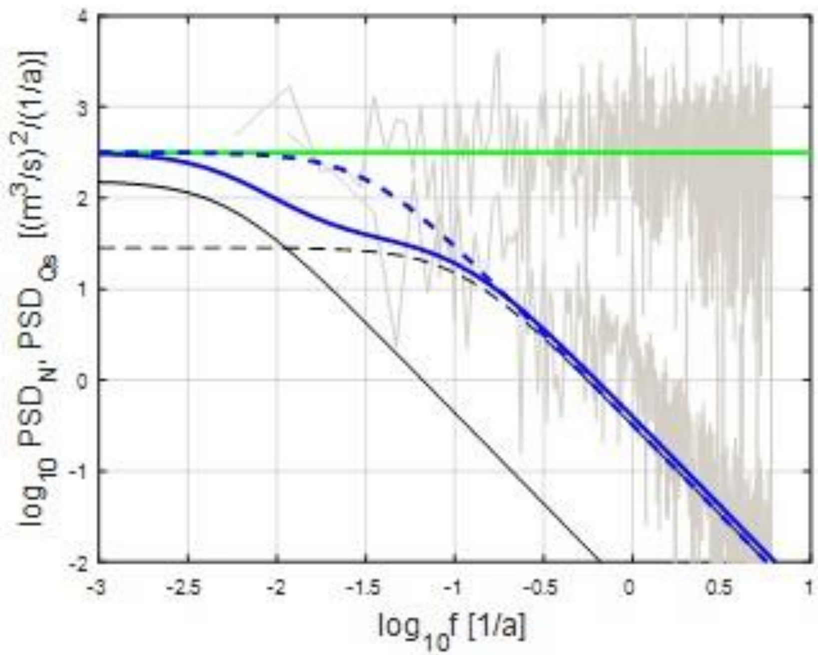


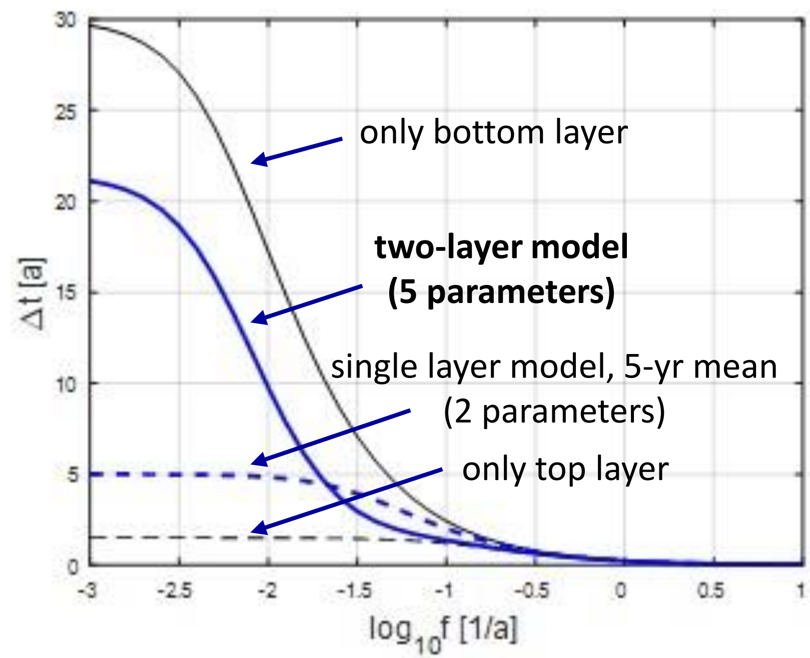


5-parameter model (n, S, R1, R2, R12)



distribution of timescales for hydraulic response

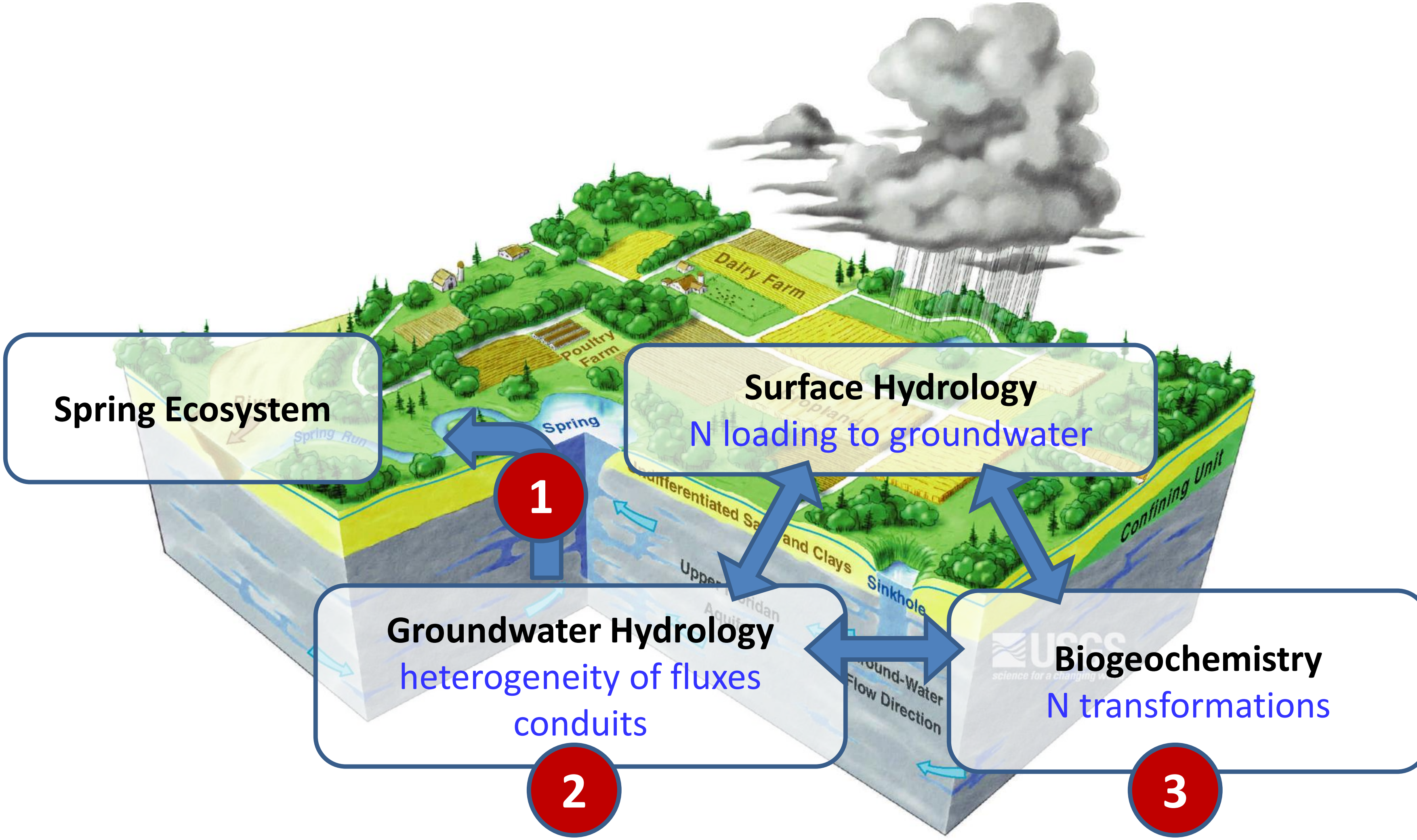




two-layer model = similar to data
single layer model = similar to data – and simpler!

single-layer model NOT able to reproduce observed long-term time lag

<u>two-layer model</u>
high frequency (daily/monthly) = FAST response
low frequency (multi-decadal) = SLOW response
in-between = in-between



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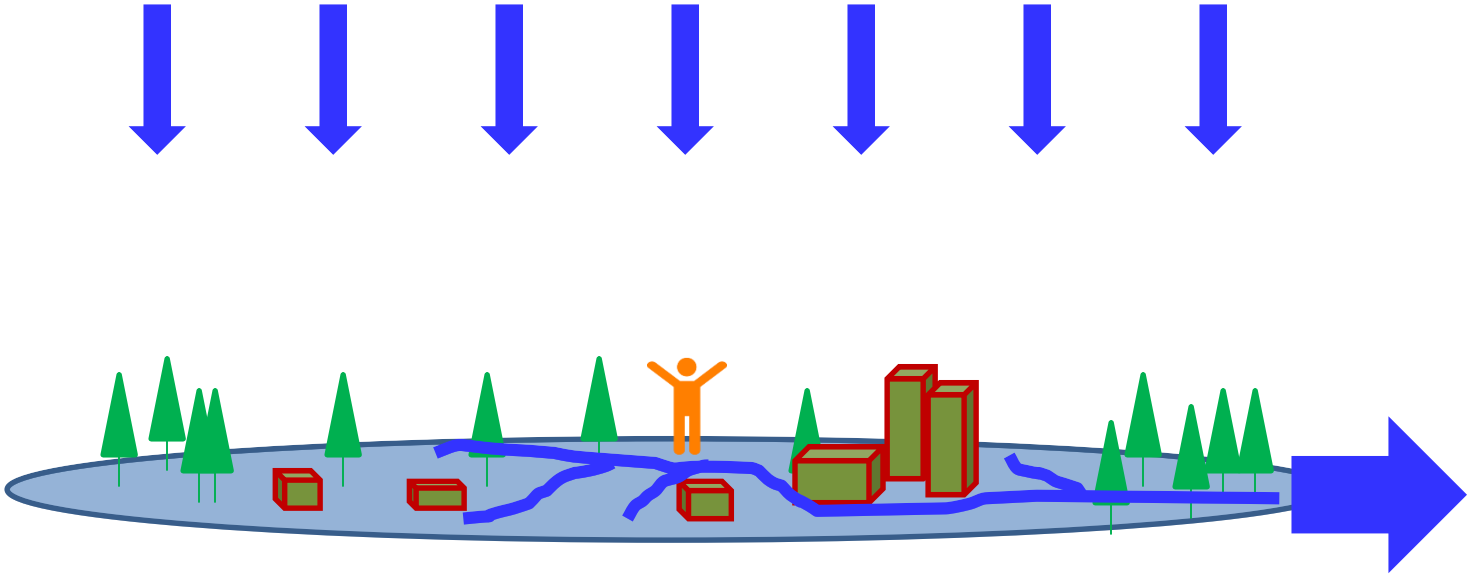
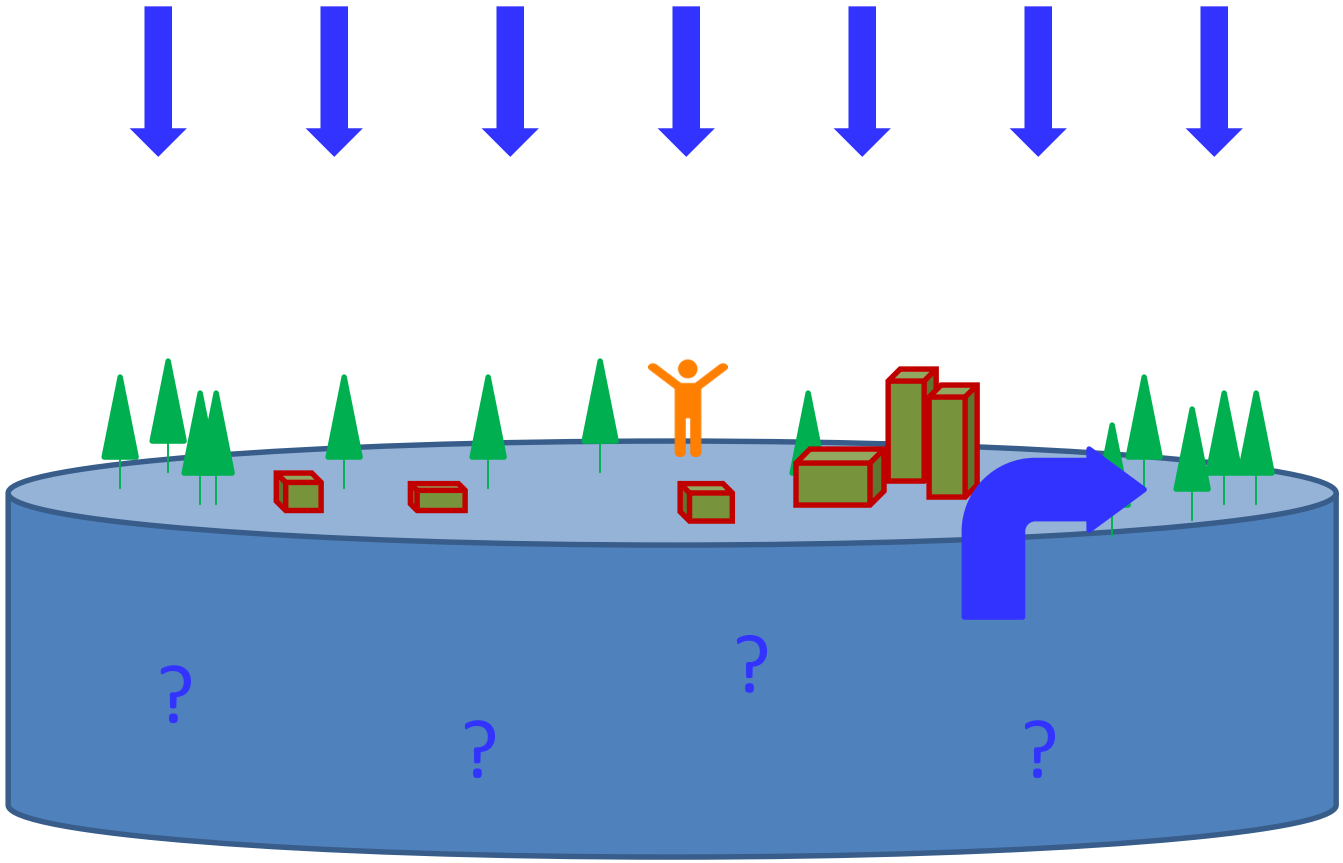


<u>A watershed</u>

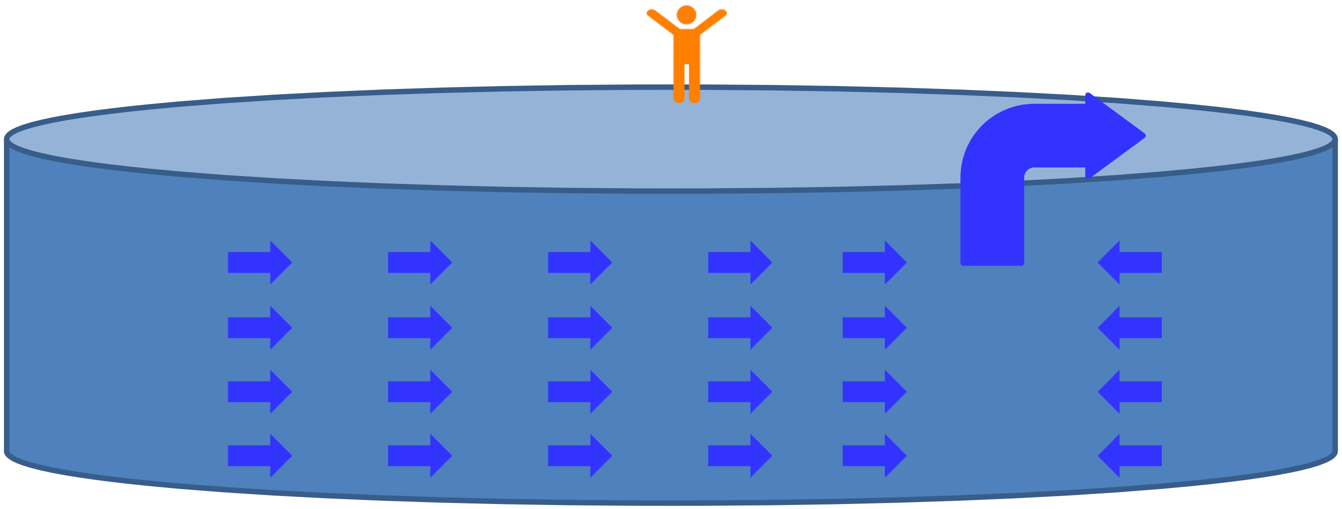
"that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community."

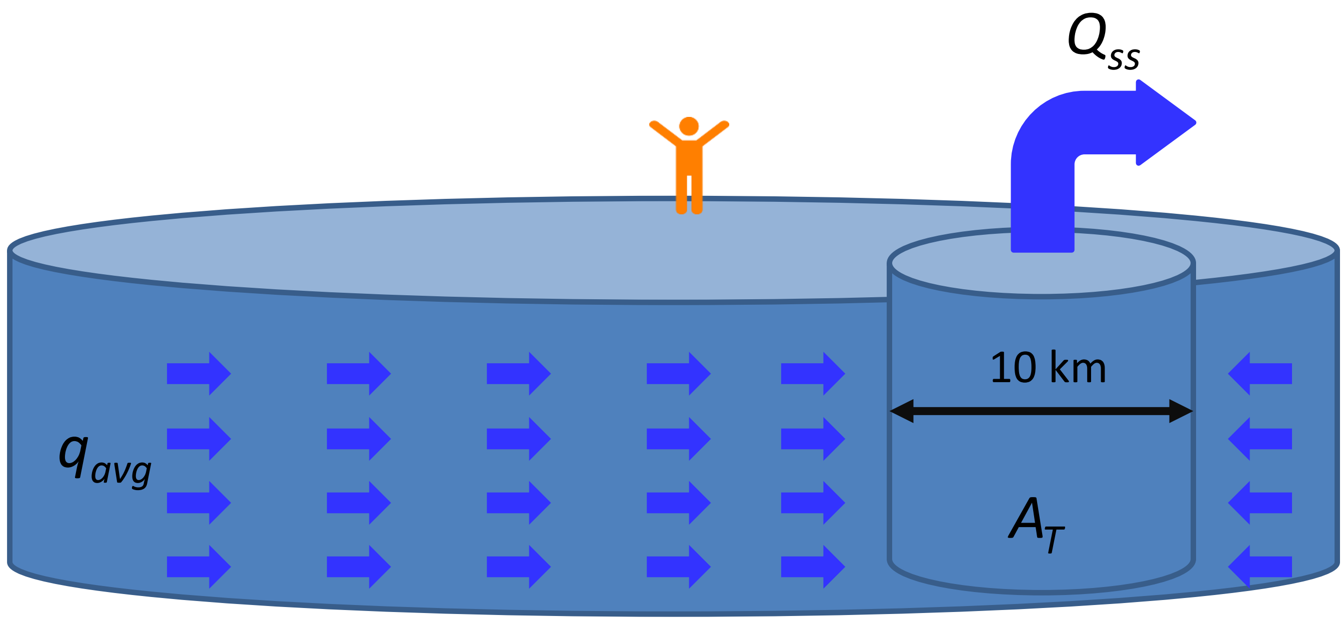
John Wesley Powell, 1890



A springshed

Flow paths??

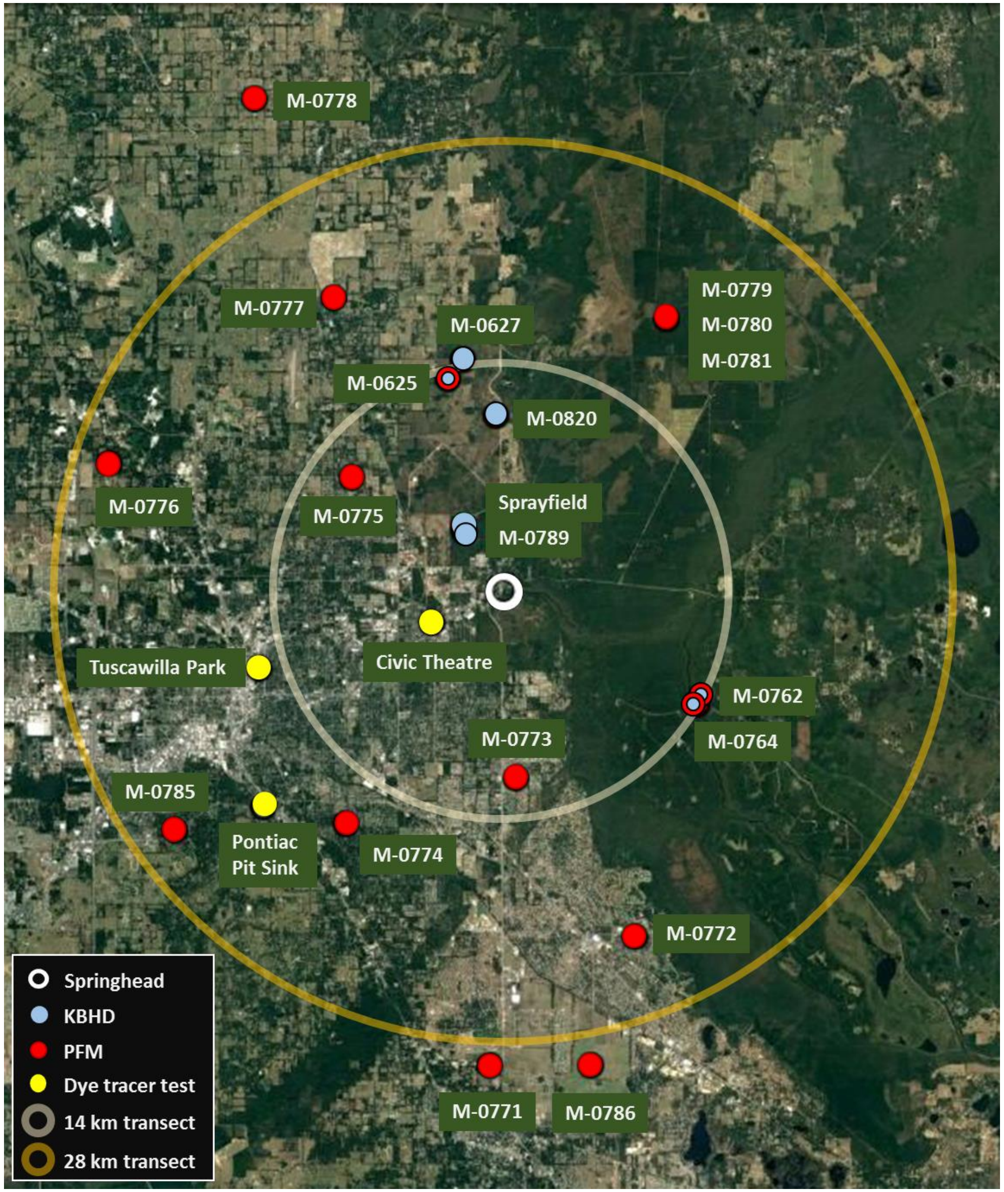


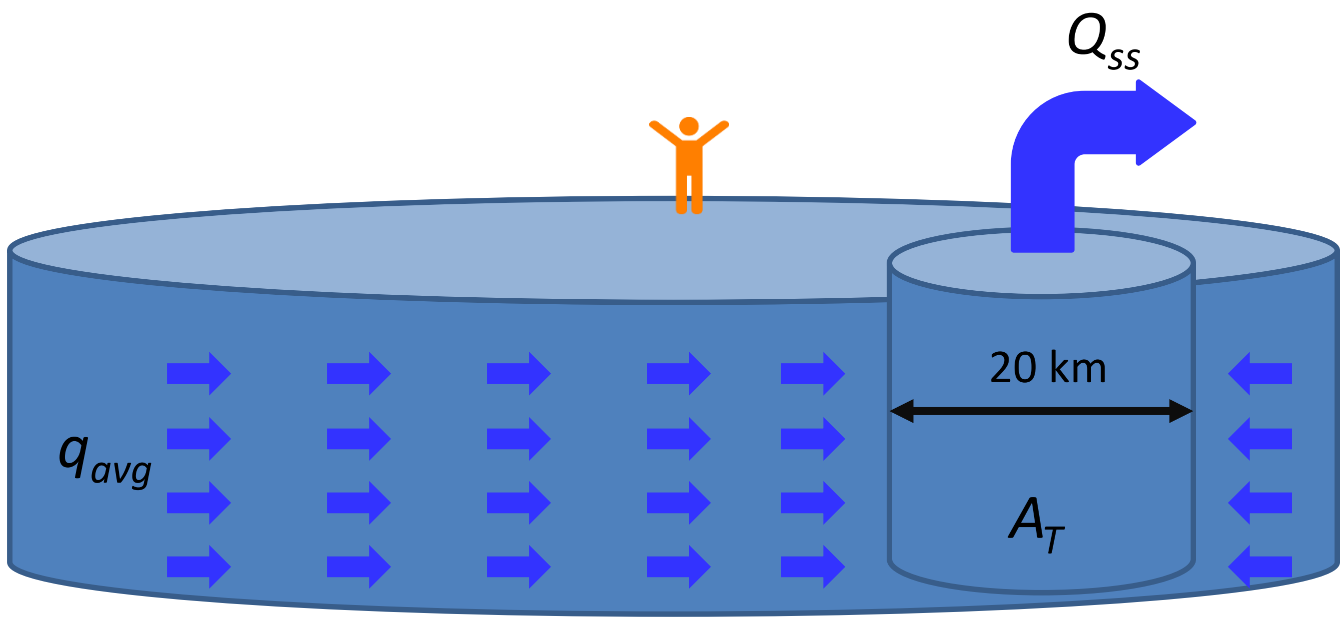


$Q_{ss} = q_{avg} A_T$
$A_T = (\pi d)h$
$q_{avg} = A_T / Q_{ss}$

	10-km transect	20-km transect
Spring flow	20 m^3/s	20 m^3/s
Depth	50 m	50 m
Perimeter	31 km	63 km
q_{avg}	**1.1 m/d**	**0.55 m/d**

Method	PFM (16 wells)	KBHD (7 wells)	DTT (3 sites) Introduction location
	M-0625 (3)	M-0625 (2)	Civic Theatre Drainage Retention Area (8)
	M-0762 (3)	M-0627 (1)	Tuscawilla Park Stormwater Drainage well (1)
	M-0764 (3)	M-0762 (2)	Pontiac Pit Sink (3)
	M-0771 (3)	M-0764 (1)	
	M-0772 (3)	M-0789 (6)	
	M-0773 (3)	M-0820 (4)	
	M-0774 (3)	Sprayfield (5)	
	M-0775 (3)		
	M-0776 (3)		
	M-0777 (3)		
	M-0778 (3)		
	M-0780 (3)		
	M-0781 (3)		
	M-0785 (3)		
	M-0786 (3)		
	M-0787 (3)		
Total	48	21	12





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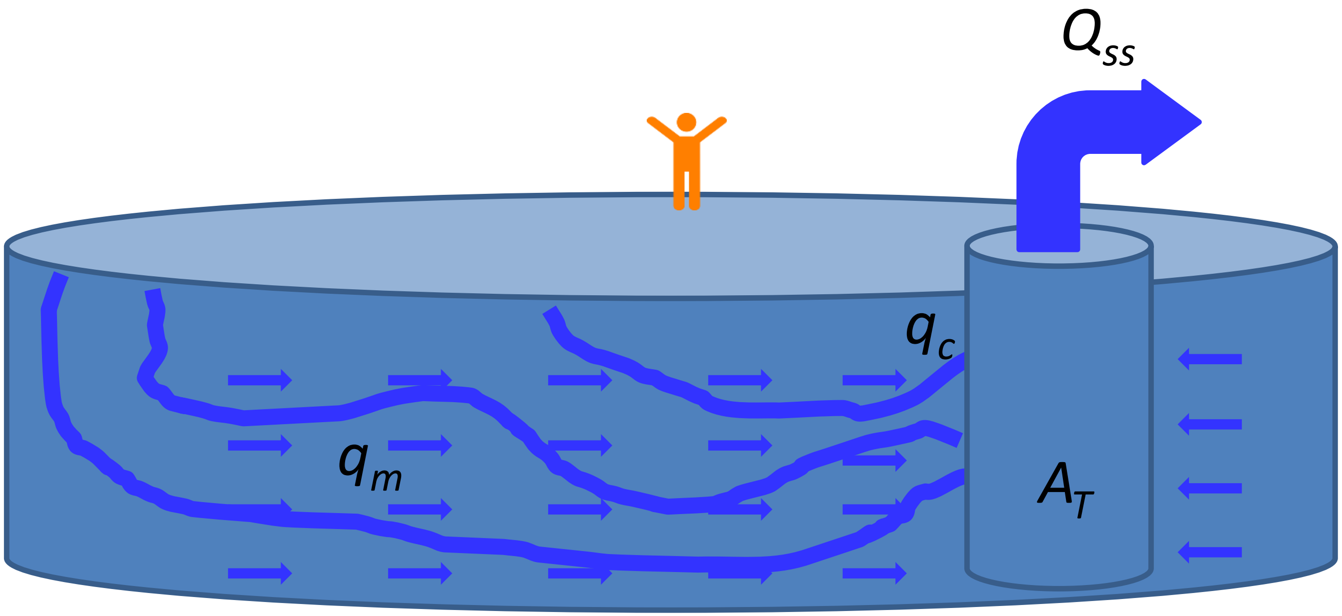
Spring flow	20 m^3/s	20 m^3/s
Depth	50 m	50 m
Perimeter	31 km	63 km
q_{avg}	**1.1 m/d**	**0.55 m/d**

$Q_{ss} = q_{avg} A_T$
$A_T = (\pi d)h$
$q_{avg} = A_T / Q_{ss}$

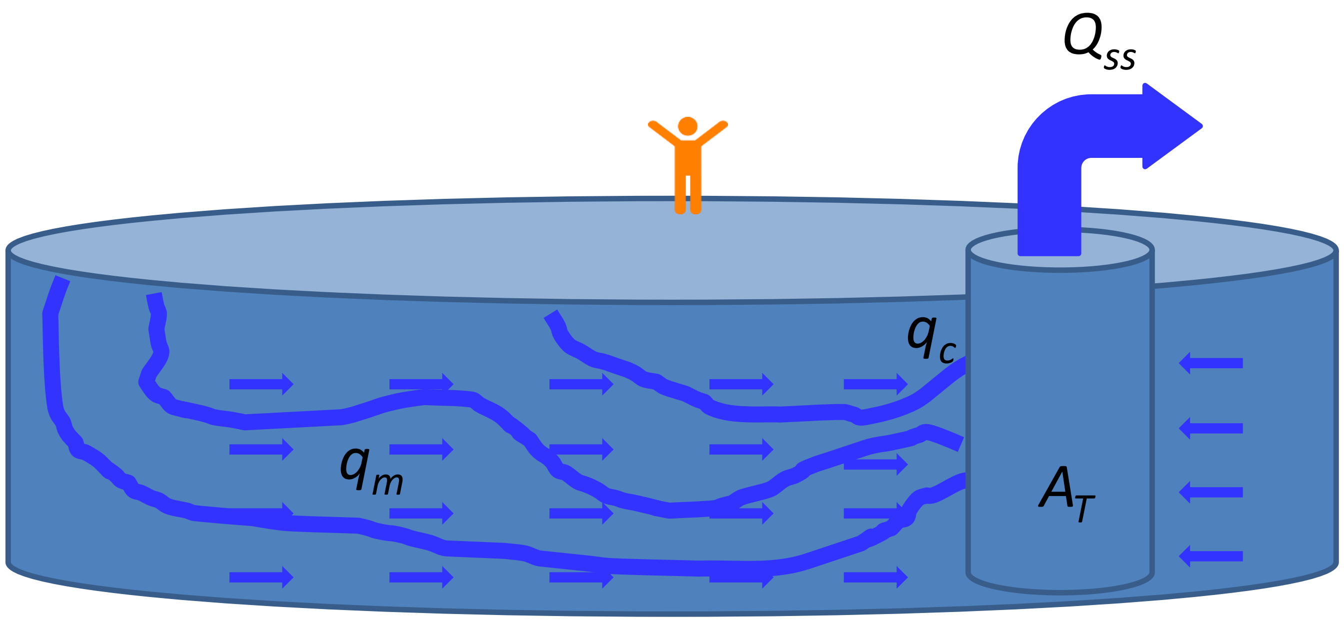
PFMs (n=16 wells)
0.06 ± 0.02 m/d



$Q_{ss} = q_{avg}A_T$
$Q_{ss} = Q_m + Q_c$
$Q_{ss} = q_mA_m + q_cA_c$
$A_T = A_m + A_c$

$A_c/A_T = (q_{avg} - q_m)/(q_c - q_m)$

	10-km transect	20-km transect
q_{avg}	1.1 m/d	0.55 m/d
q_m	??	??
q_c	??	??
A_c/A_T		
Q_c/Q_{ss}		

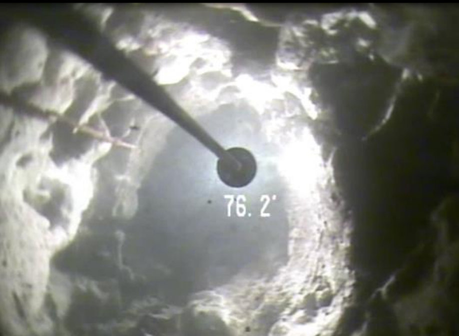


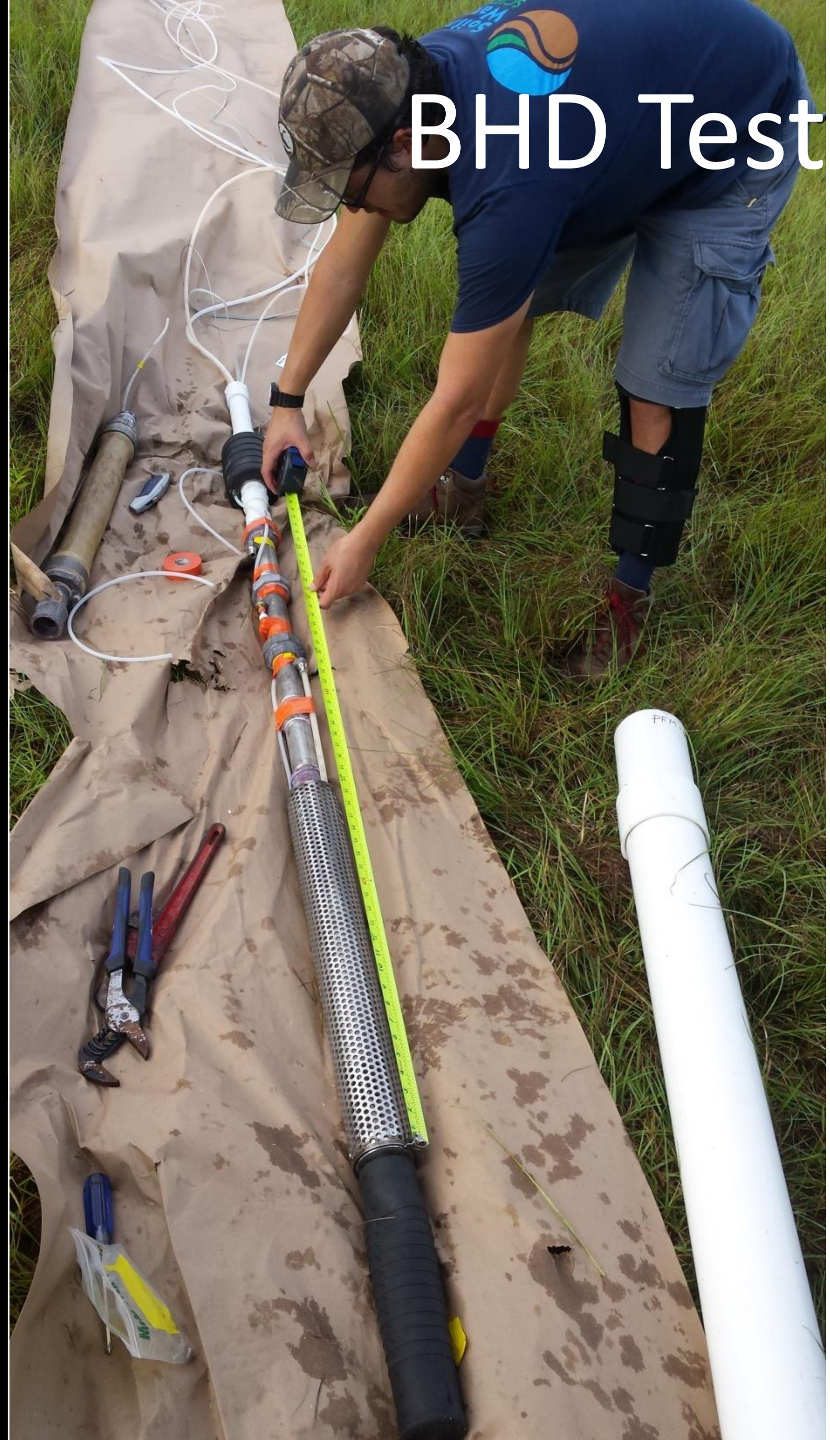
$$Q_{ss} = q_{avg} A_T$$
$$Q_{ss} = Q_m + Q_c$$
$$Q_{ss} = q_m A_m + q_c A_c$$
$$A_T = A_m + A_c$$

$$\underline{\underline{A_c/A_T = (q_{avg} - q_m)/(q_c - q_m)}}$$

	10-km transect	20-km transect
q_{avg}	1.1 m/d	0.55 m/d
q_m	0.06 m/d	0.06 m/d
q_c	??	??
A_c/A_T		
Q_c/Q_{ss}		

BHD Test Procedure





- Identify areas of interest
- Assemble KBHD device
- Deploy to target depth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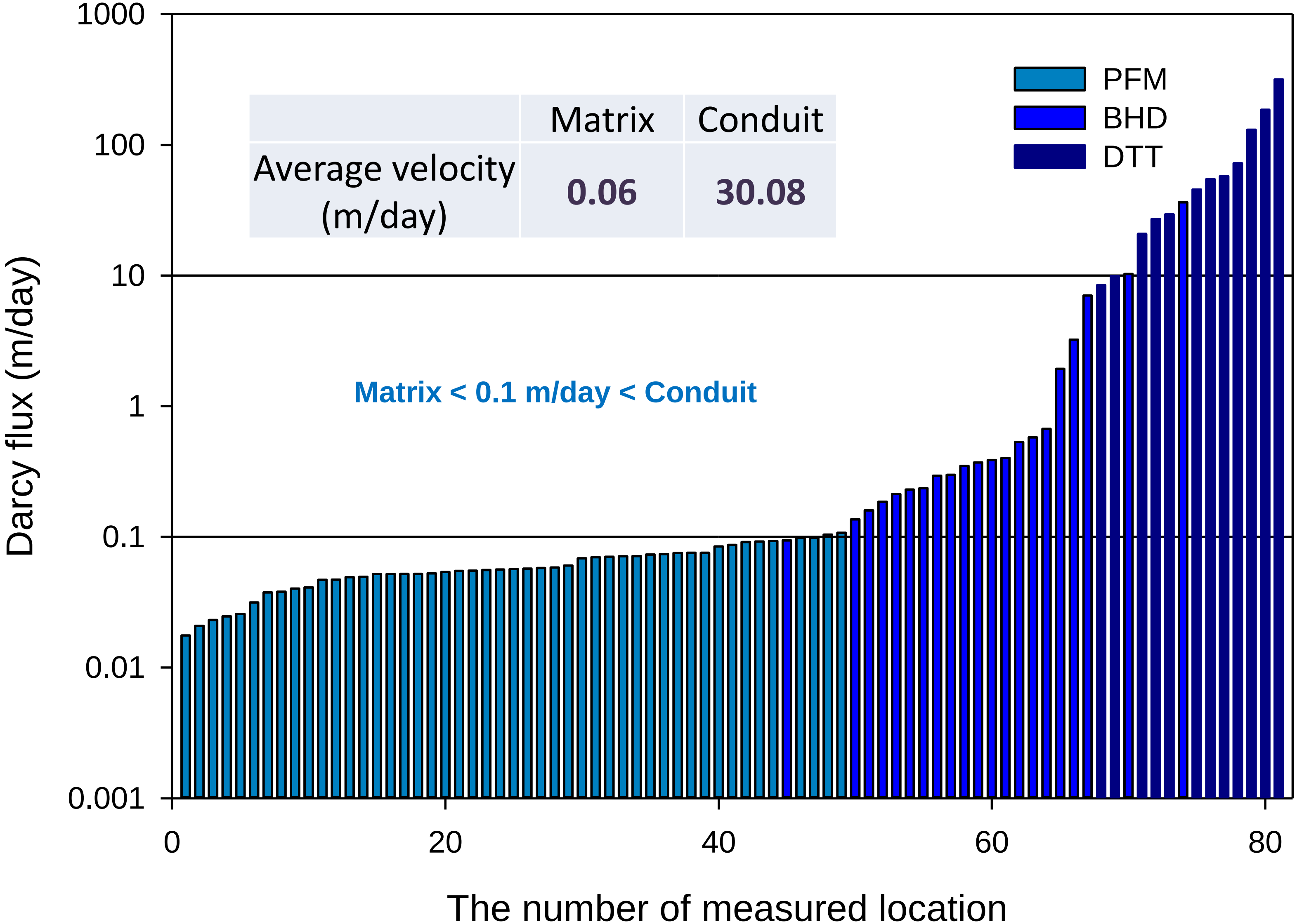
REED

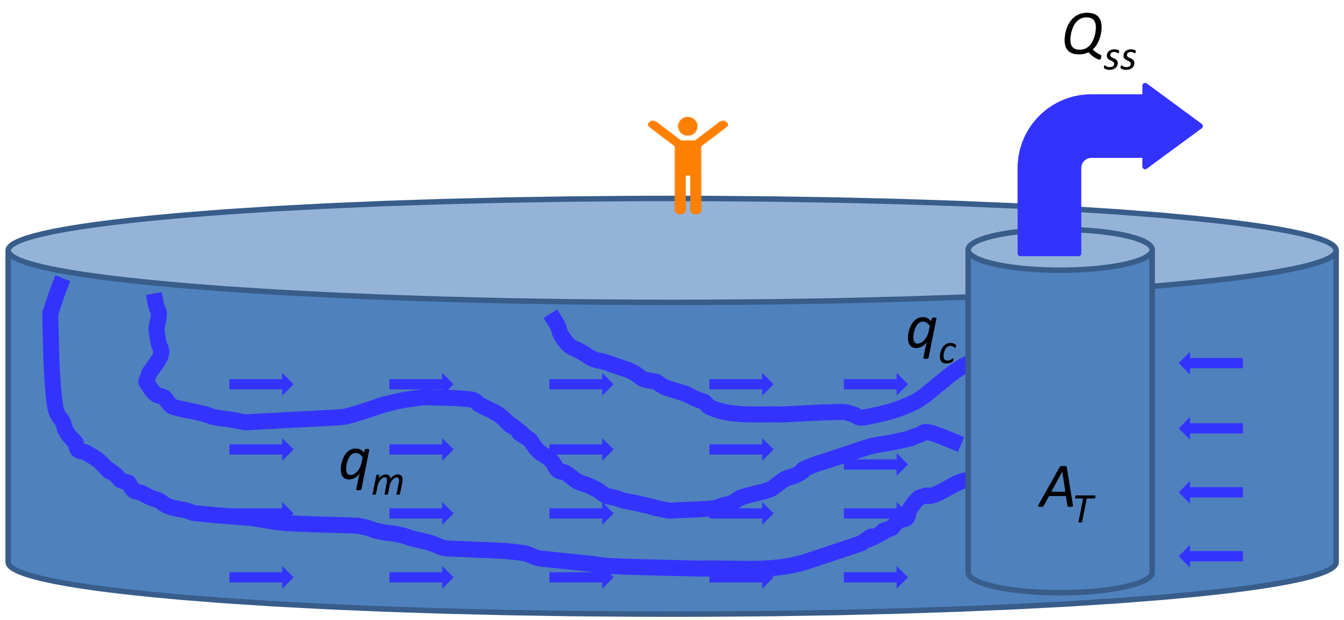
M0789

https://www.youtube.com/watch?v=eQlfhUgzJ7g

M0625



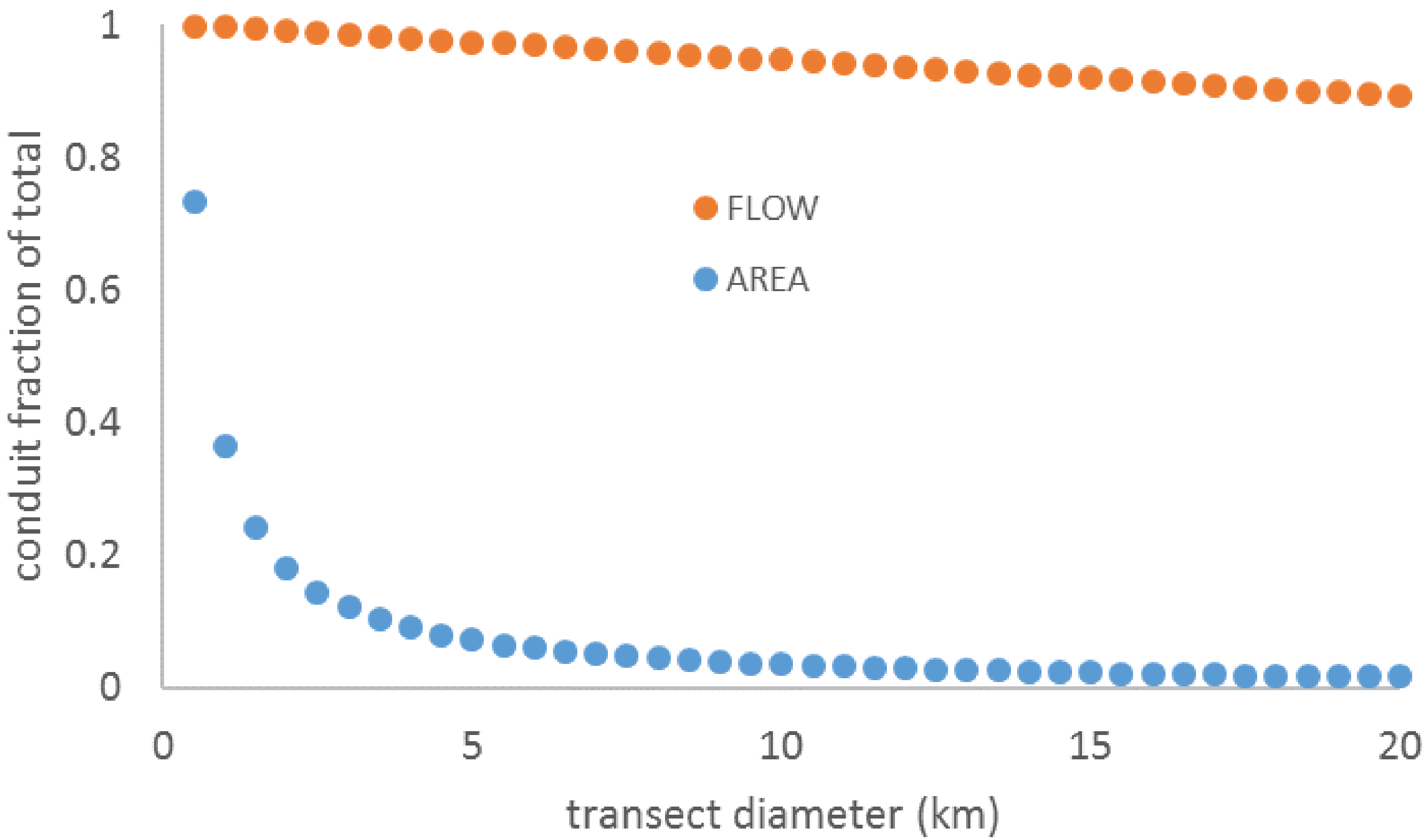
1000
100
10
1
0.1
0.01
0.001
Darcy flux (m/day)
0
20
40
60
80
The number of measured location
PFM
BHD
DTT
Matrix < 0.1 m/day < Conduit
Matrix
Conduit
Average velocity (m/day)
0.06
30.08



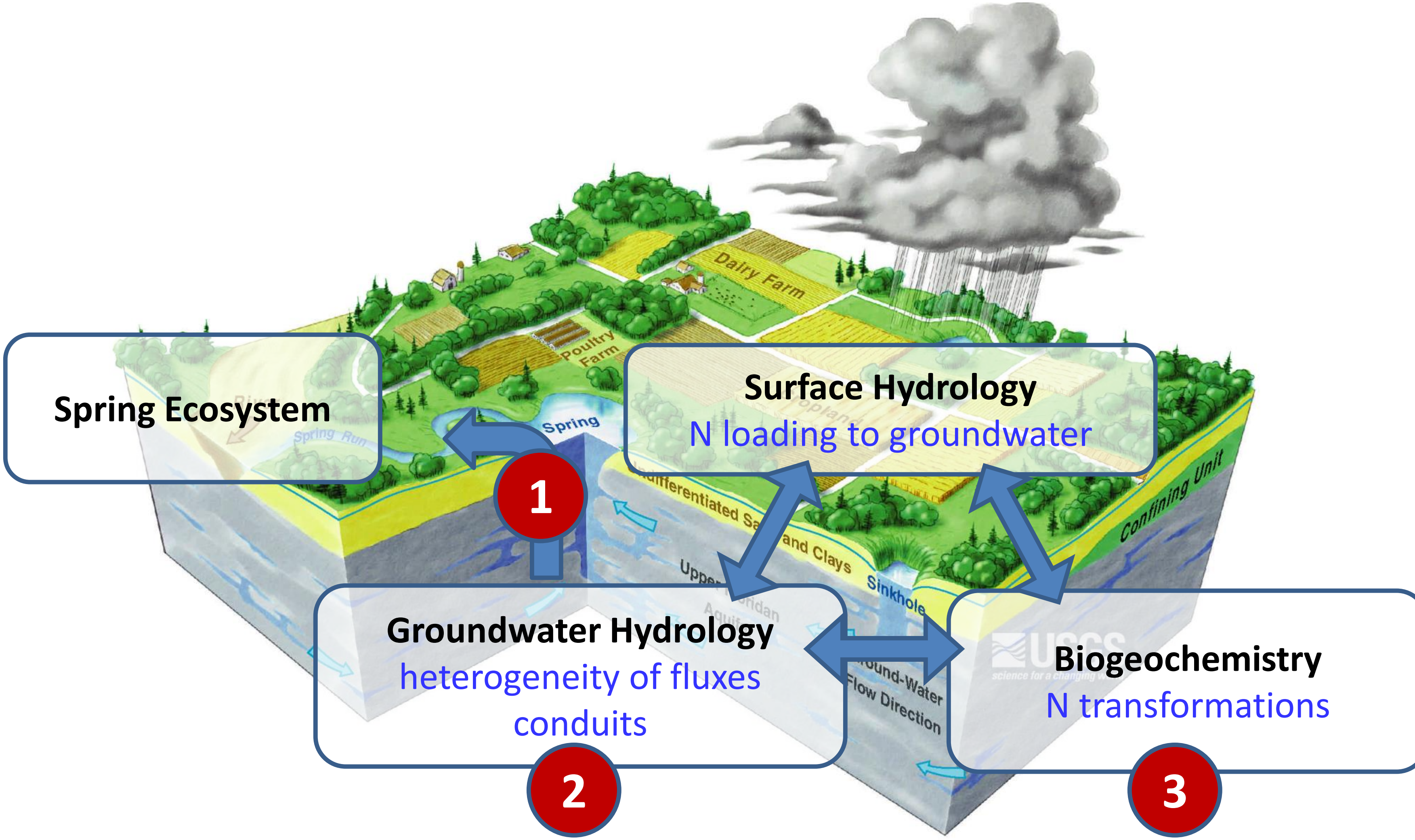
$Q_{ss} = q_{avg}A_T$
$Q_{ss} = Q_m + Q_c$
$Q_{ss} = q_mA_m + q_cA_c$
$A_T = A_m + A_c$

$$\underline{\underline{A_c/A_T = (q_{avg} - q_m)/(q_c - q_m)}}$$

	10-km transect	20-km transect
q_{avg}	1.1 m/d	0.55 m/d
q_m	0.06 m/d	0.06 m/d
q_c	30 m/d	30 m/d
A_c/A_T	0.03	0.016
Q_c/Q_{ss}	0.95	0.89



For q_m = 0.06 m/d
q_c = 30 m/d



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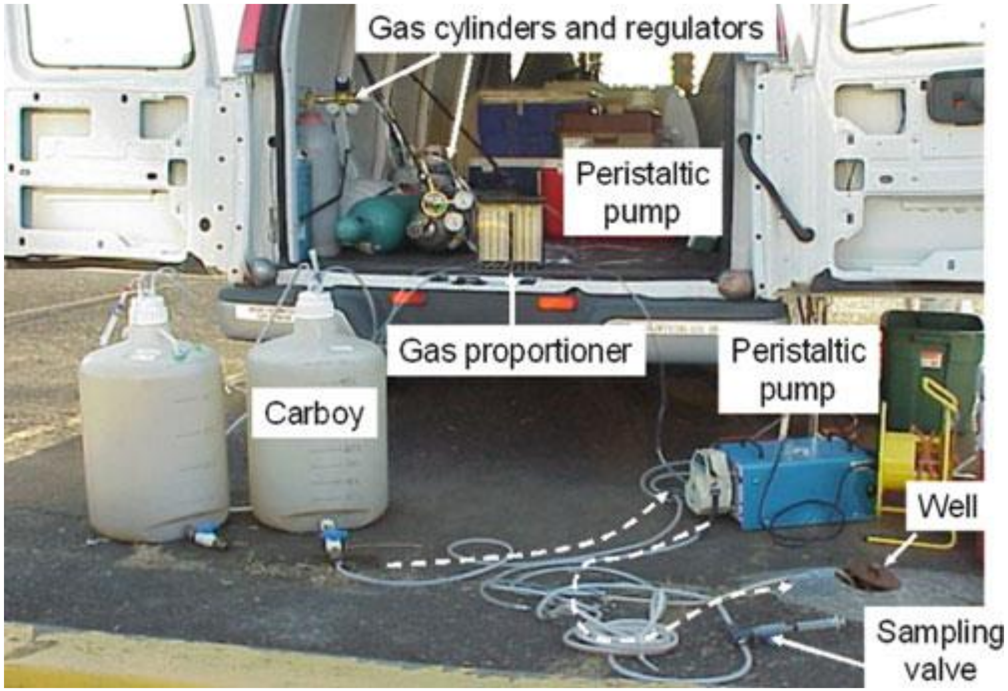
Push-Pull Test implementation

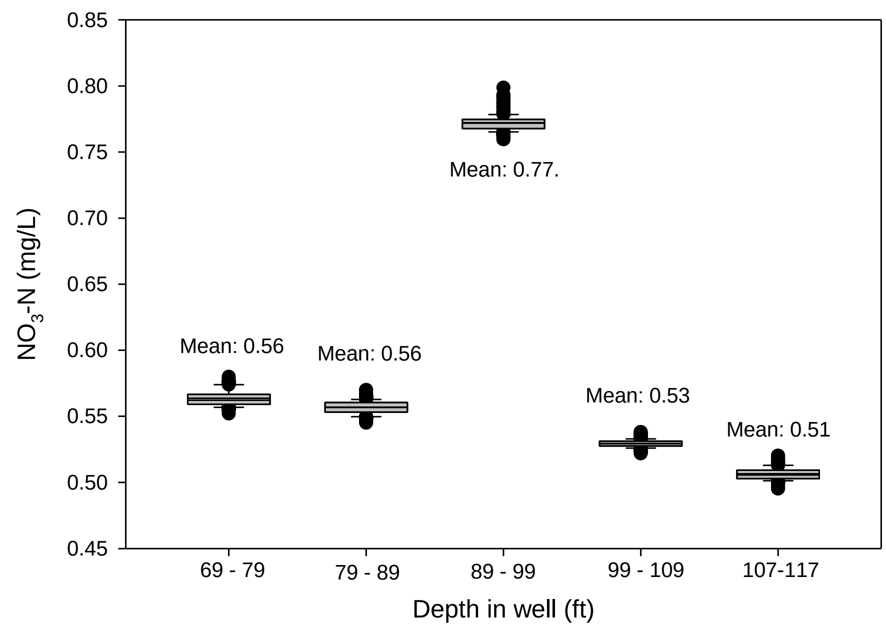


Controlled injection of a prepared test solution ("push") into an aquifer followed by the extraction of the test solution ("pull").

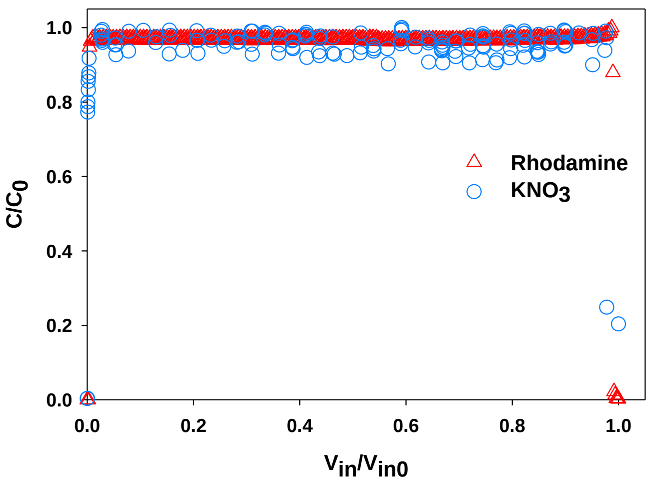
The injected test solution consists of a nonreactive tracer and NO_3^-.

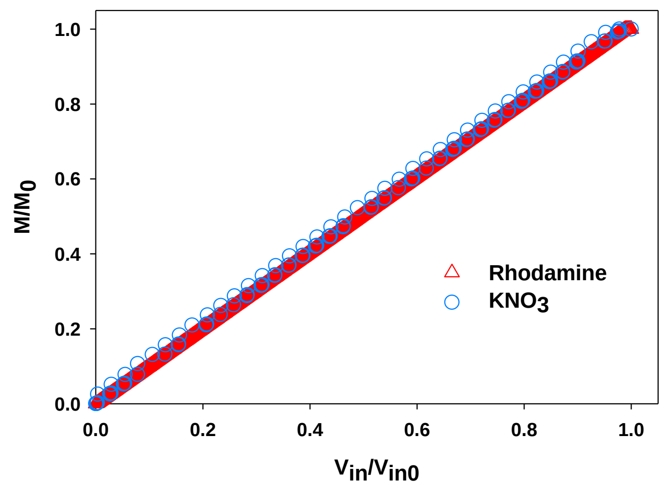
Push-Pull Test at M0789 (89-99ft)

Background Nitrate



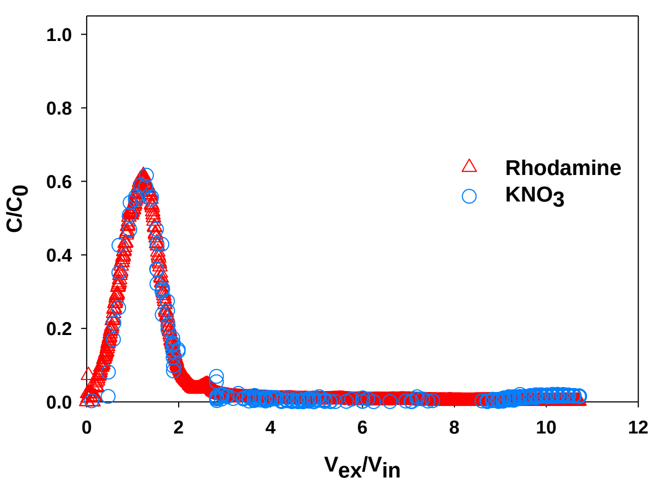
M0798 at 89-99ft

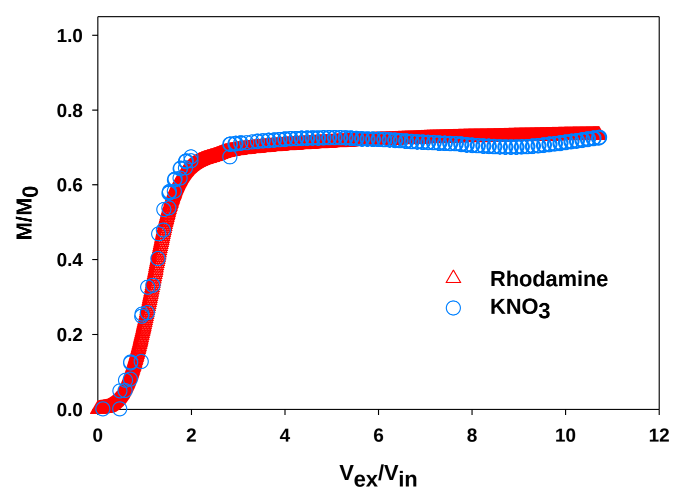




PUSH

PULL





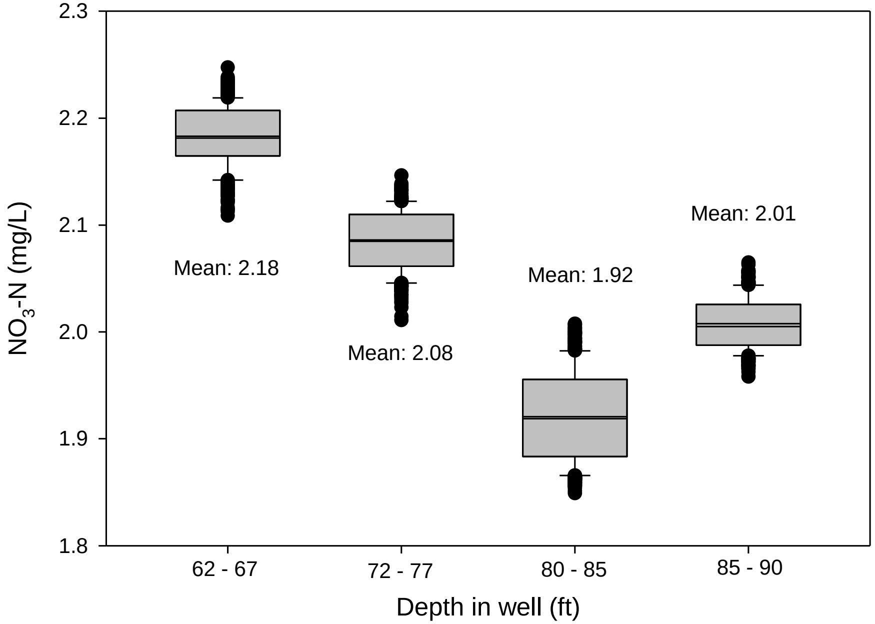
Mass Recovery

Rhodamine: **73.3%**

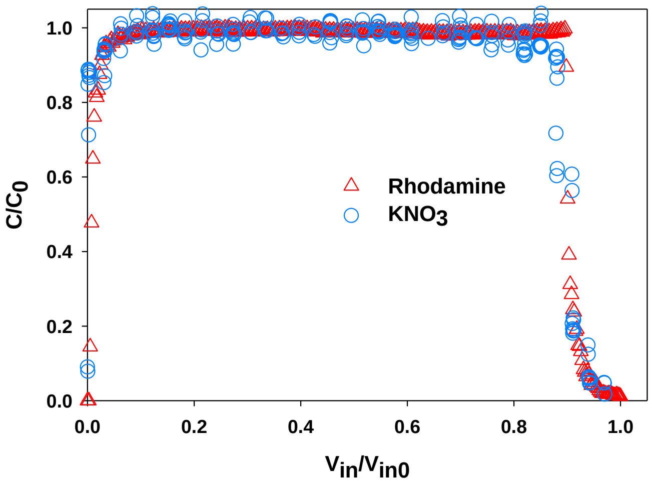
KNO_3: **73.2%**

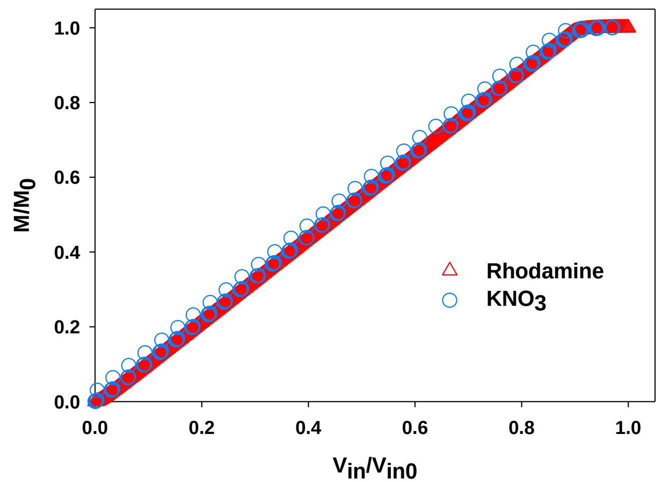
Push-Pull Test at Sprayfield (59-69ft)

Background Nitrate



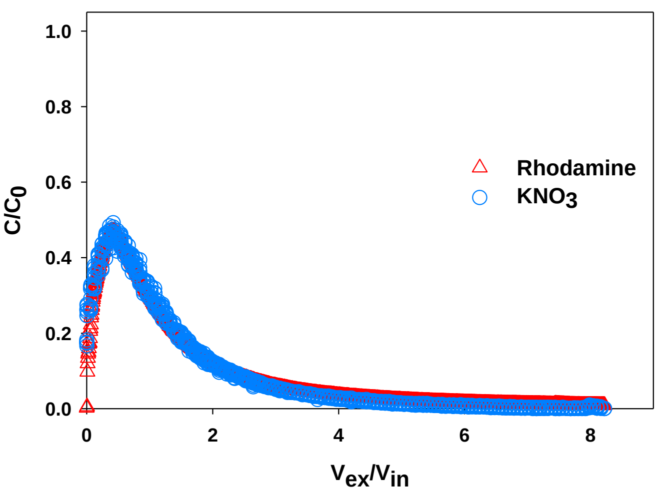
Sprayfield at 59-69ft

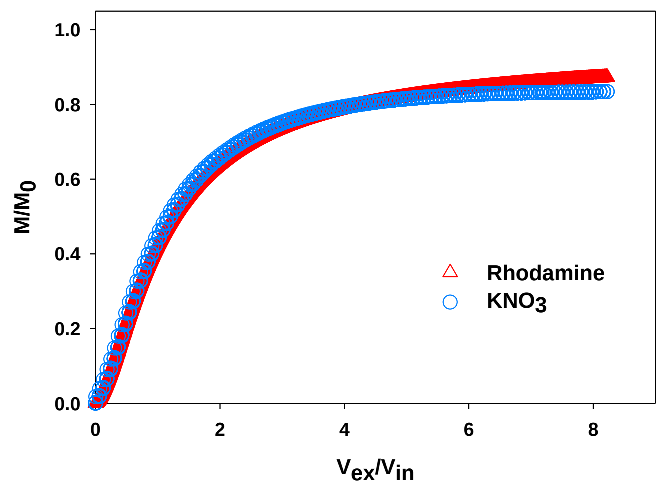




PUSH

PULL



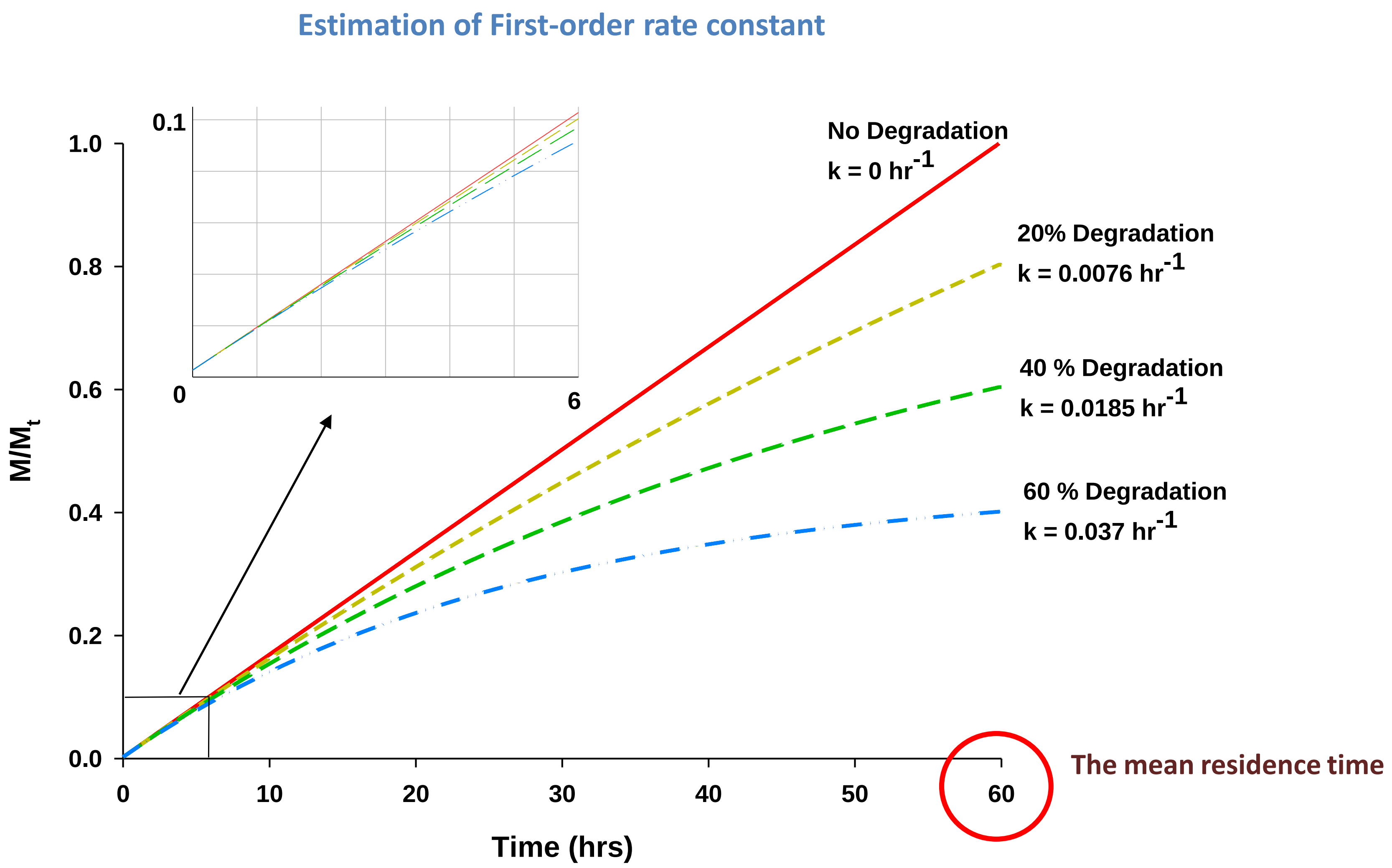


Mass Recovery

Rhodamine: **87.3%**

KNO_3: **83.4%**

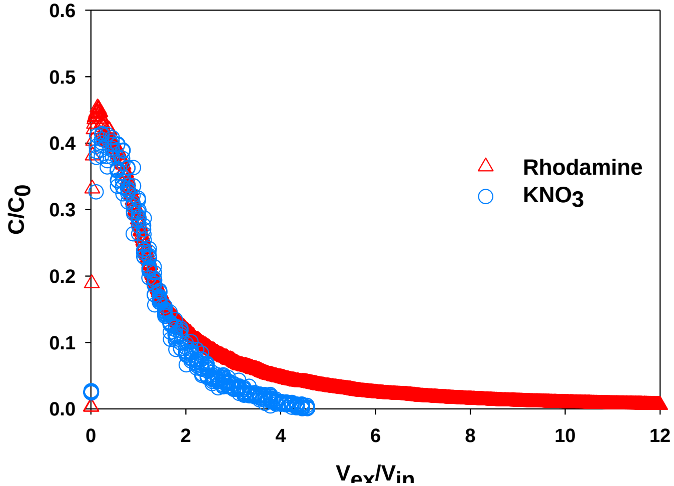
No denitrification ???

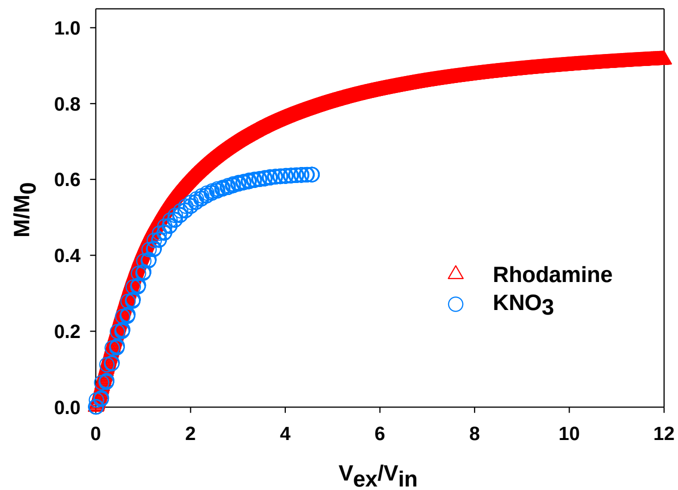


Push-Pull Test M779 at 135-145ft

NO nitrate at three wells

M779 at 135-145ft

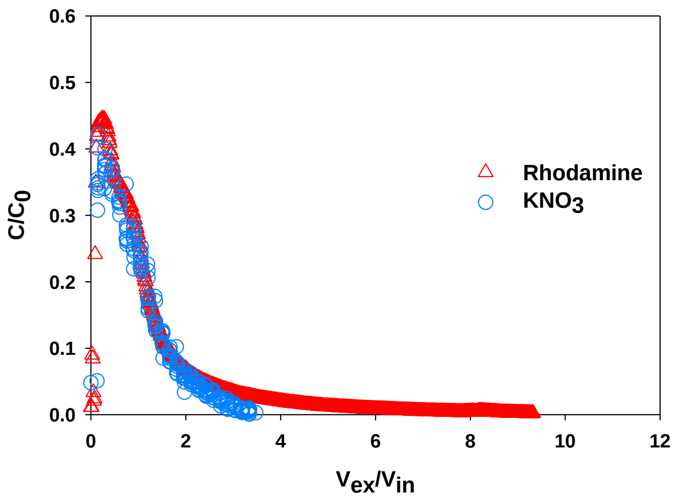


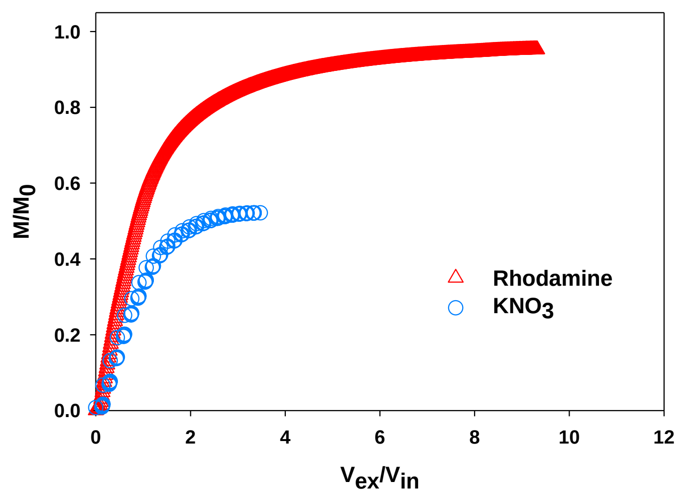


Mass Recovery

Rhodamine: **93.9%**

KNO_3: **61.2%**



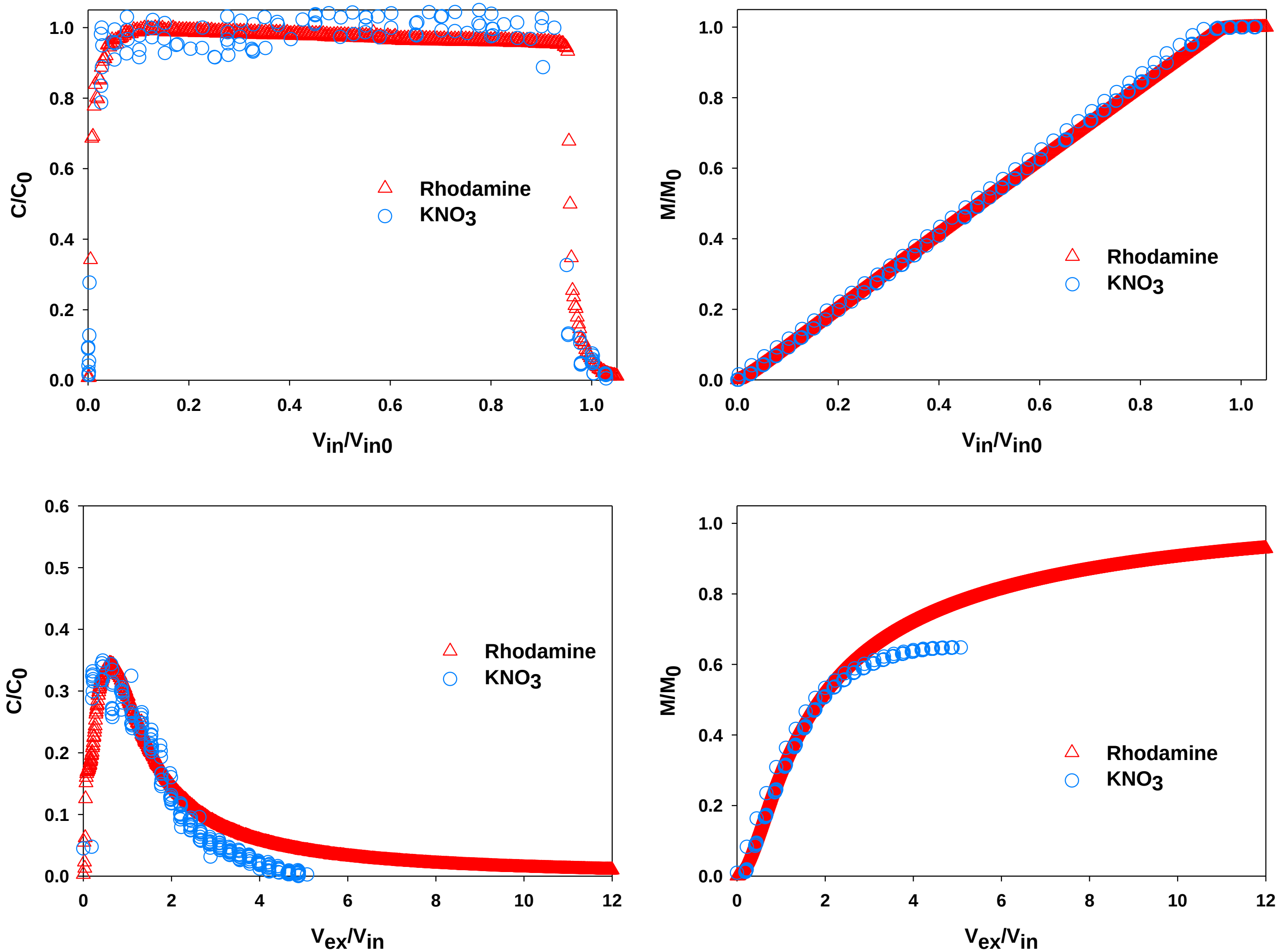


Mass Recovery

Rhodamine: **95.3%**

KNO_3: **52.1%**

M780 at 59-69ft

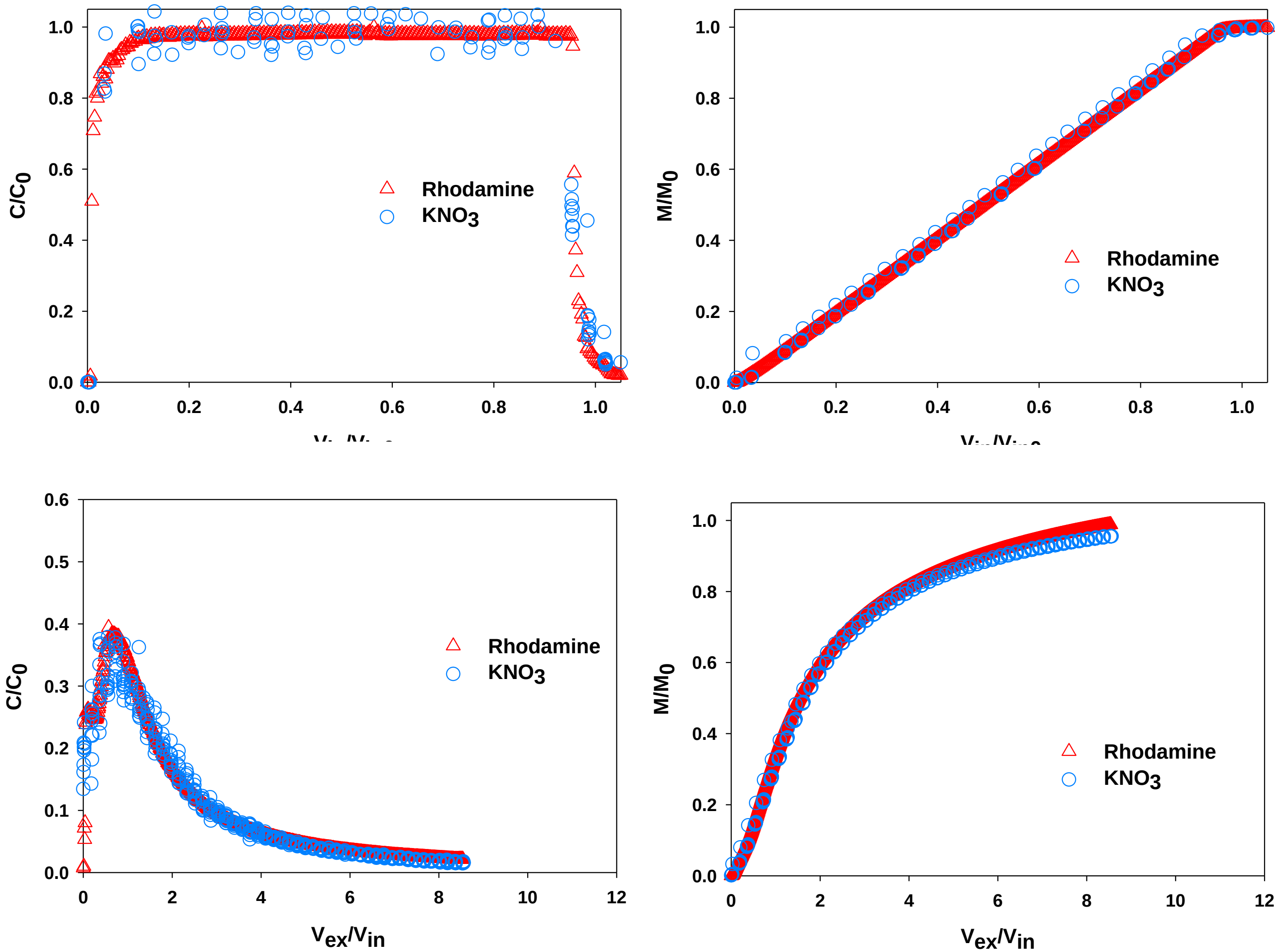


Mass Recovery

Rhodamine: **97.1%**

KNO_3: **64.8%**

M781 at 25-35 ft



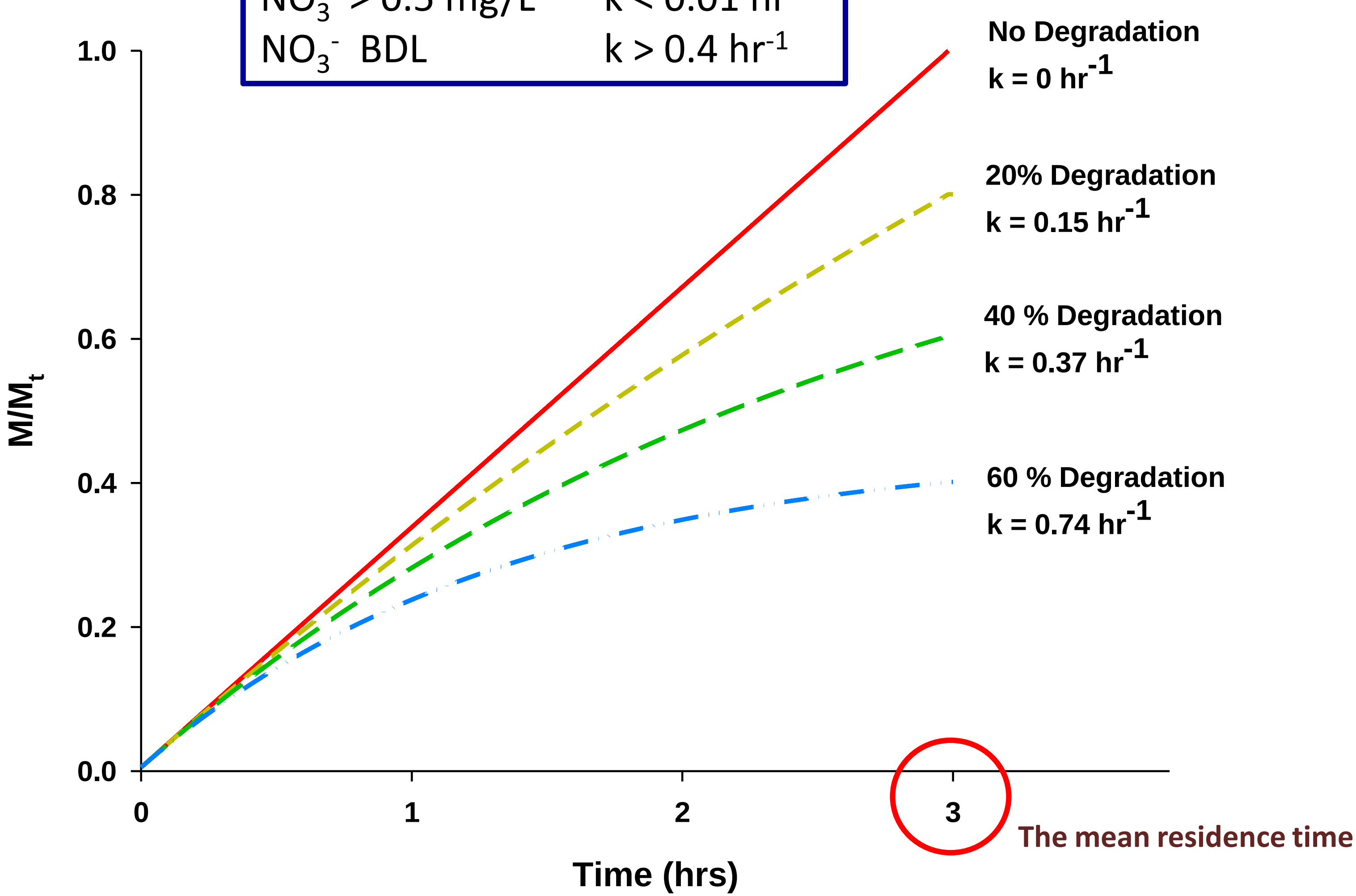
Mass Recovery

Rhodamine: **98.8%**

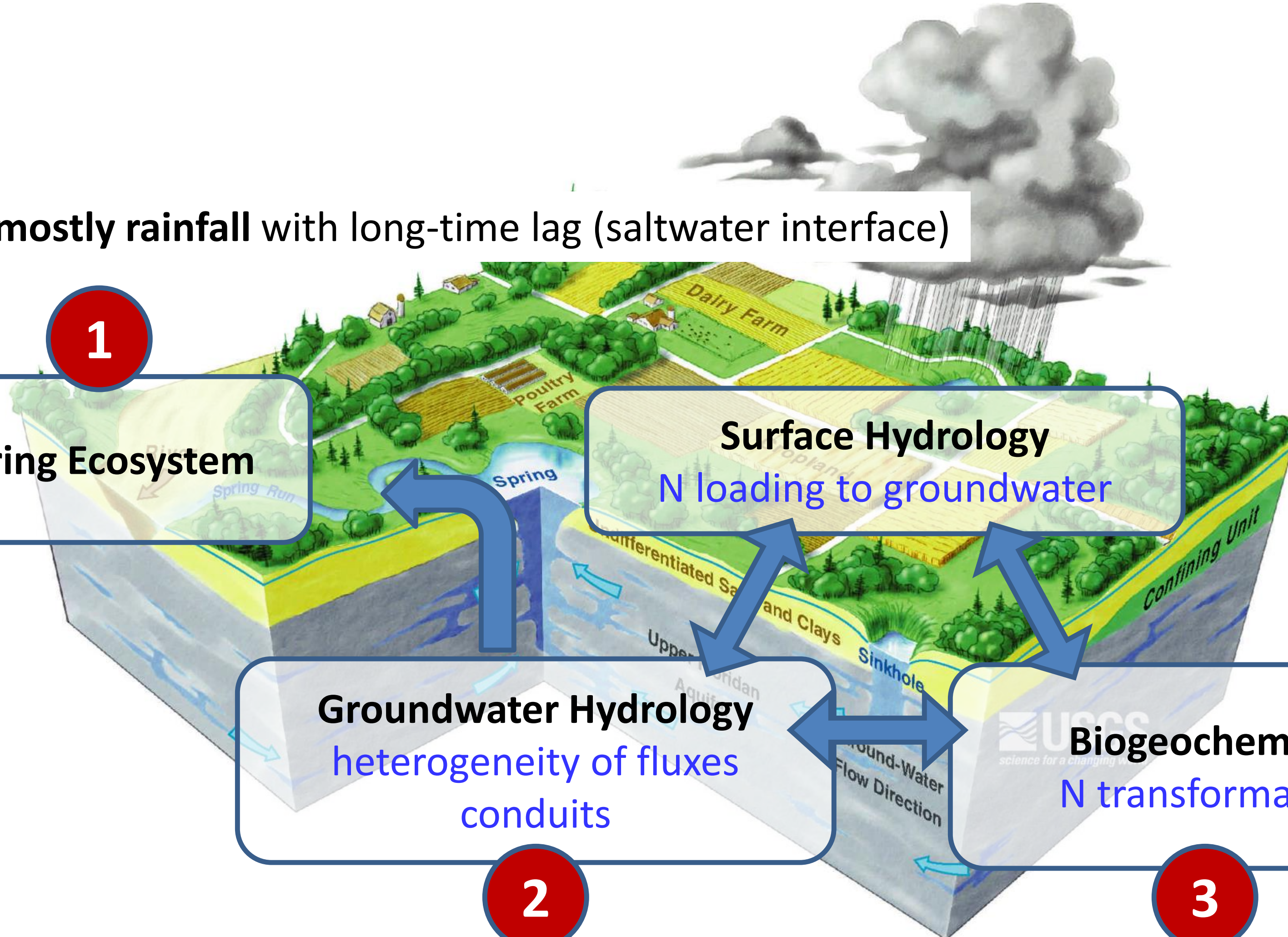
KNO_3: **95.6%**

Estimation of First-order rate constant

$NO_3^- > 0.5$ mg/L	$k < 0.01$ hr^{-1}
NO_3^- BDL	$k > 0.4$ hr^{-1}



mostly rainfall with long-time lag (saltwater interface)



1

Spring Ecosystem

Surface Hydrology
N loading to groundwater

Groundwater Hydrology
heterogeneity of fluxes
conduits

2

mostly conduits (flow)
mostly matrix (area)

Biogeochemistry
N transformations

3

mostly inert
H_2S smell = not inert

</end>