Woodville Karst SF_6 Tracer Test

the modern N-Cycle

& Subsurface Attenuation of Nutrients

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A Global Glut of Nitrogen

Sources of Biologically Available Nitrogen

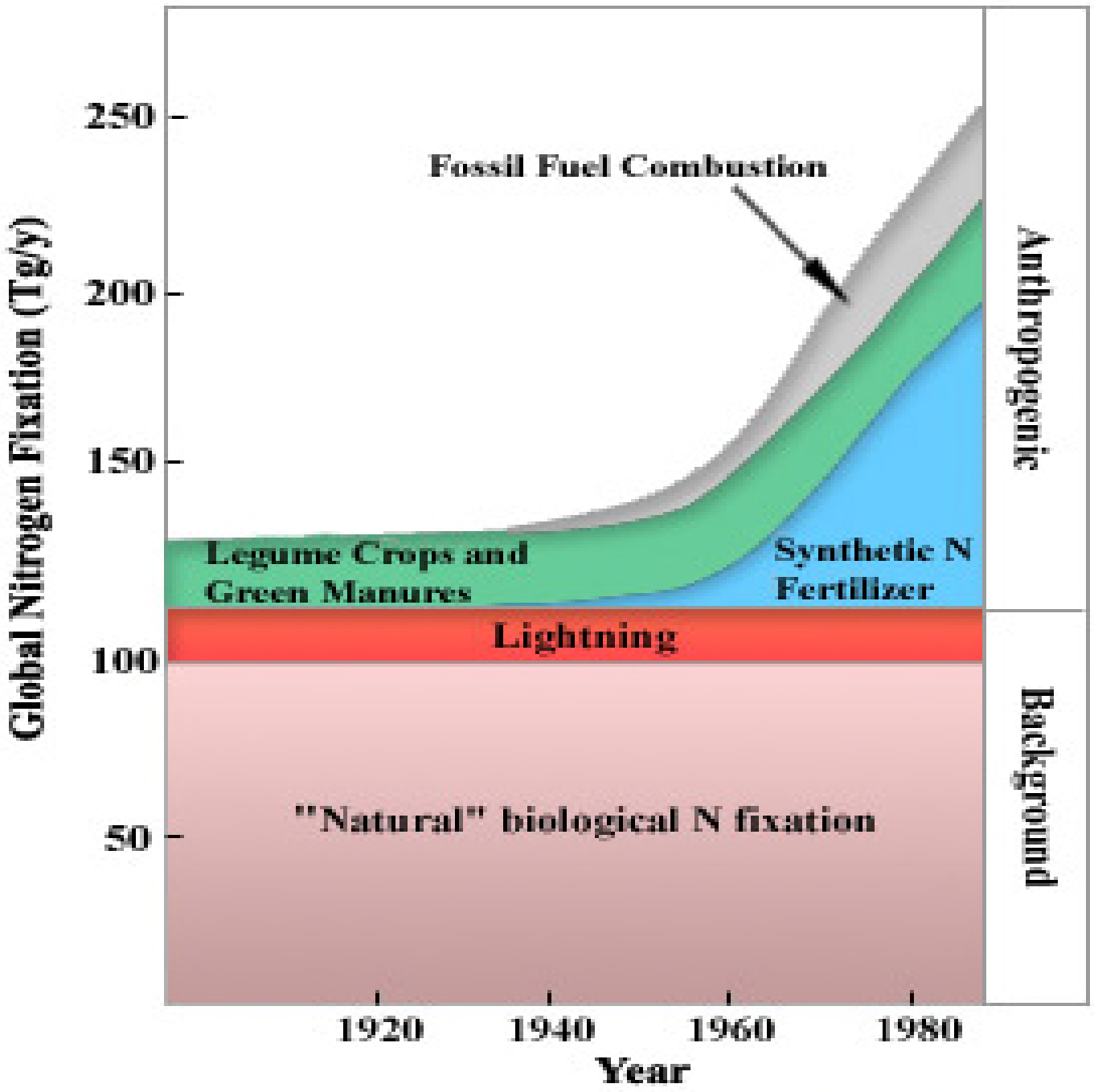
HUMAN SOURCES

ANNUAL RELEASE OF FIXED NITROGEN (teragrams)

Fertilizer 80
Legumes and other plants 40
Fossil fuels 20
Biomass burning 40
Wetland draining and clearing 20

Total from human sources 210

Natural Sources 110



Recent increases in anthropogenic N fixation in relation to "natural" N fixation. Modified from Vitousek, P. M. and P. A. Matson (1993). Agriculture, the global nitrogen cycle, and trace gas flux. The Biogeochemistry of Global Change: Radiative Trace Gases. R. S. Oremland. New York, Chapman and Hall: 193-208.

Objective 1

- Establish a connection between the surface-groundwater in the Woodville area and Wakulla Springs.

Tracer injected into shallow wells to mimic inputs from septic tanks

Embarq Well on Woodville Hwy

6.1 miles from Wakulla Springs

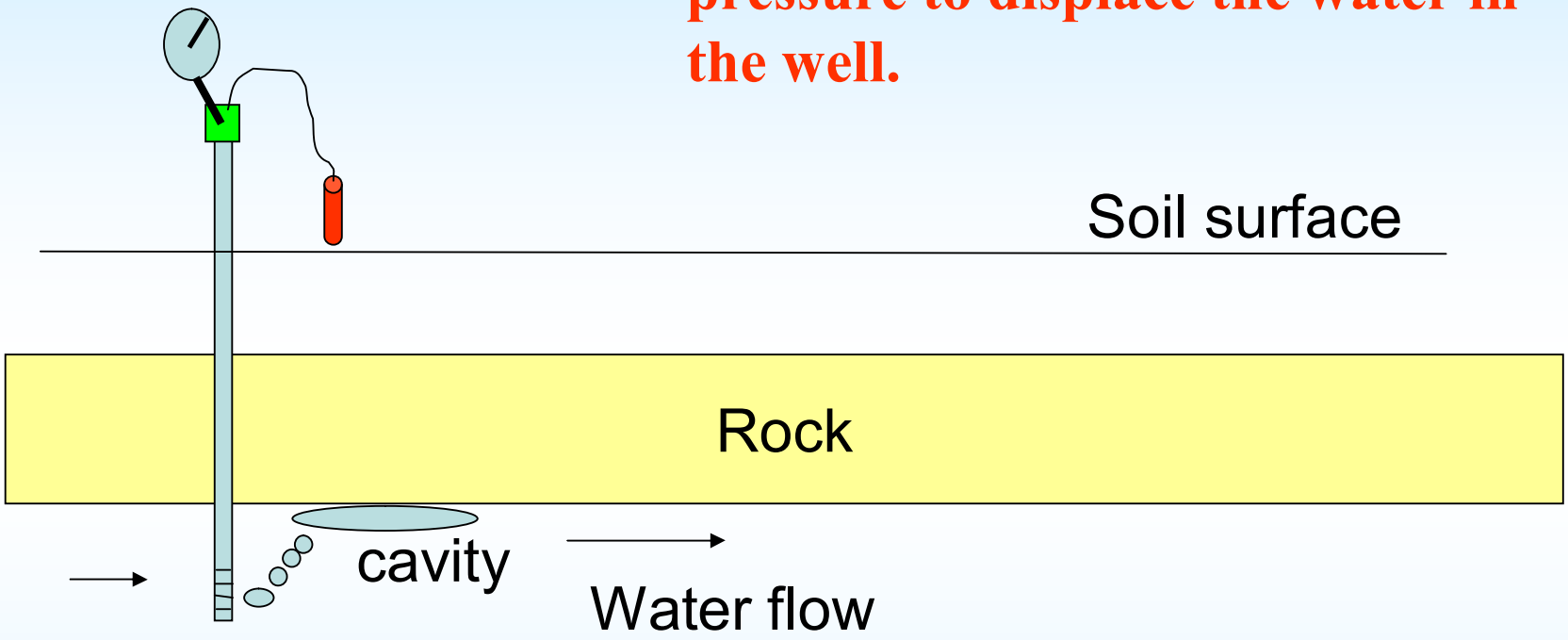
Water Depth 3.67m

Bob Miller Rd. Well

5.3 miles from Wakulla Springs

Water Depth 6.83m

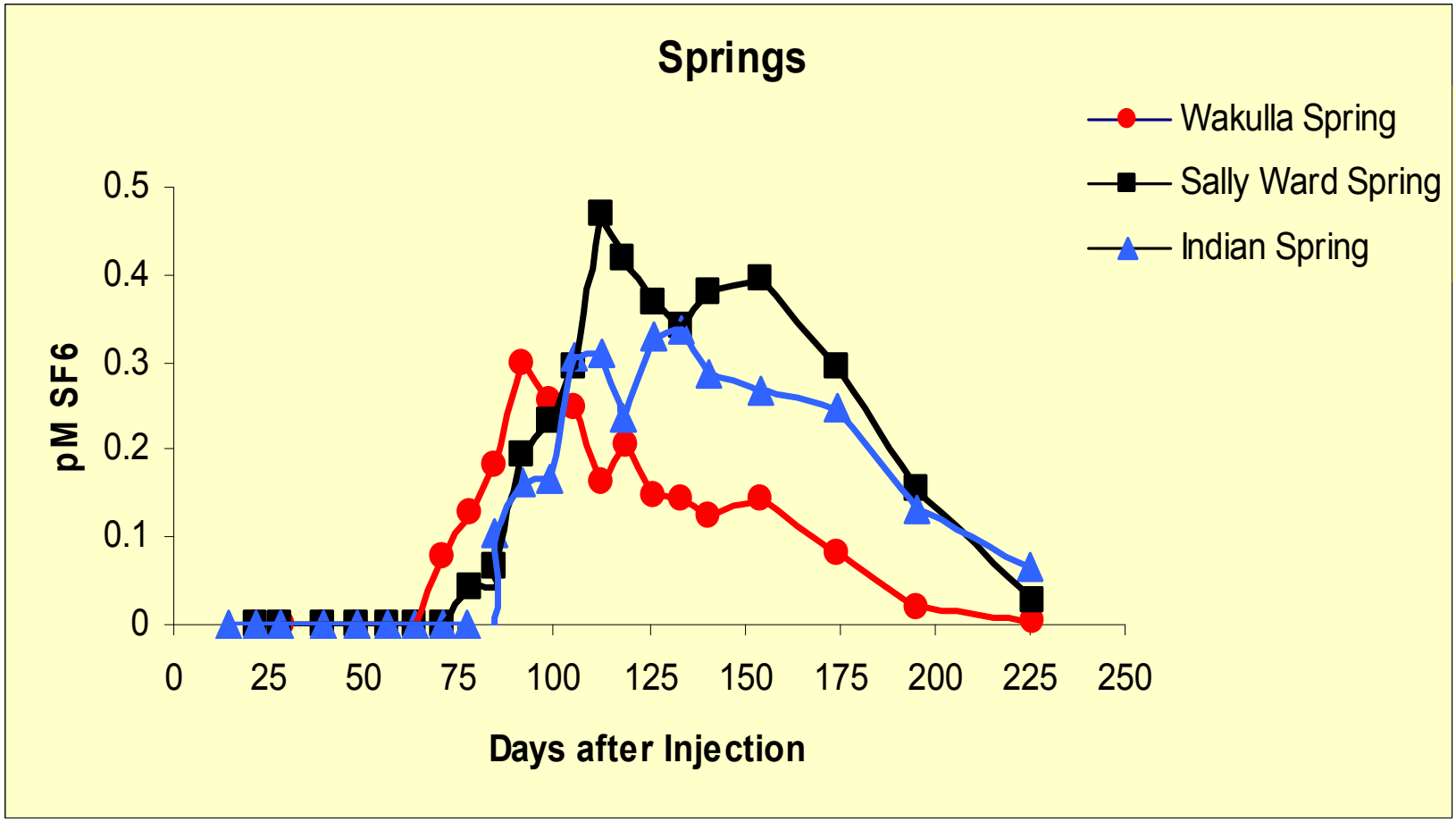
The tracer was introduced directly into the aquifer at a constant flow with enough pressure to displace the water in the well.



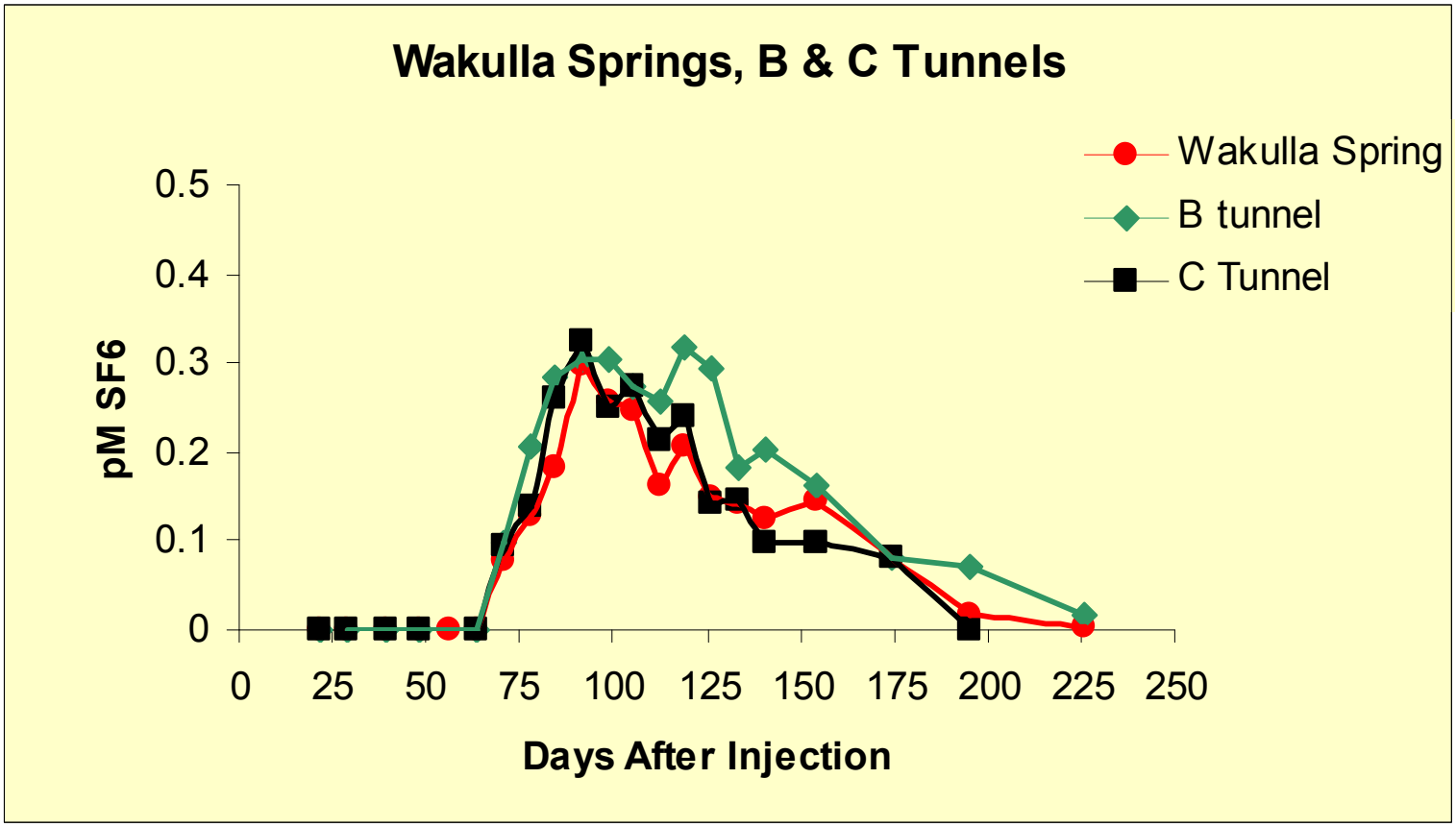
Injection wells, 4 inch open hole wells to about 25 feet in depth –
very permeable limestone
with multiple small cavities and channels.

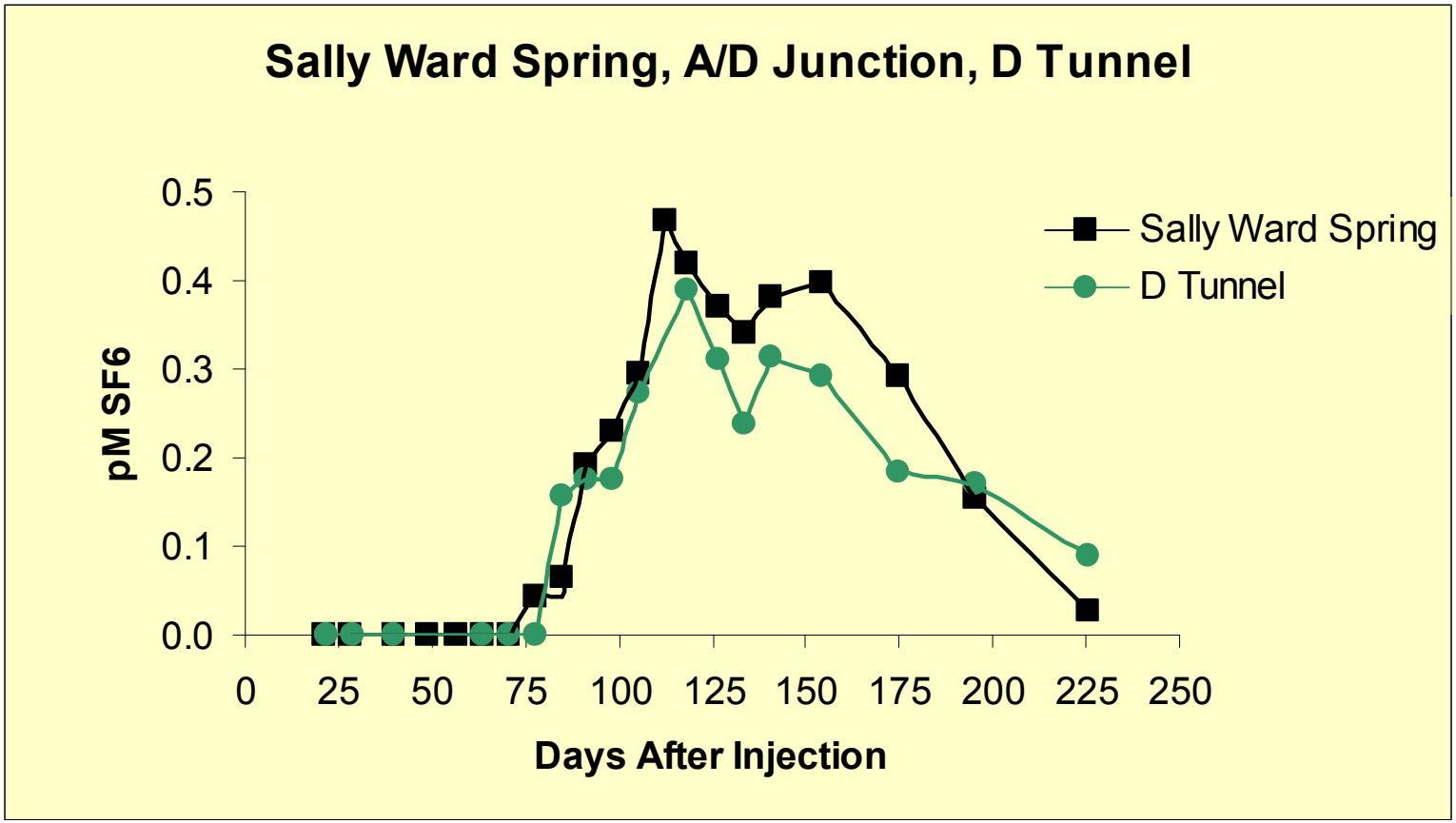
Bob Miller Rd. well: 580 liters or 23.7 moles SF_6

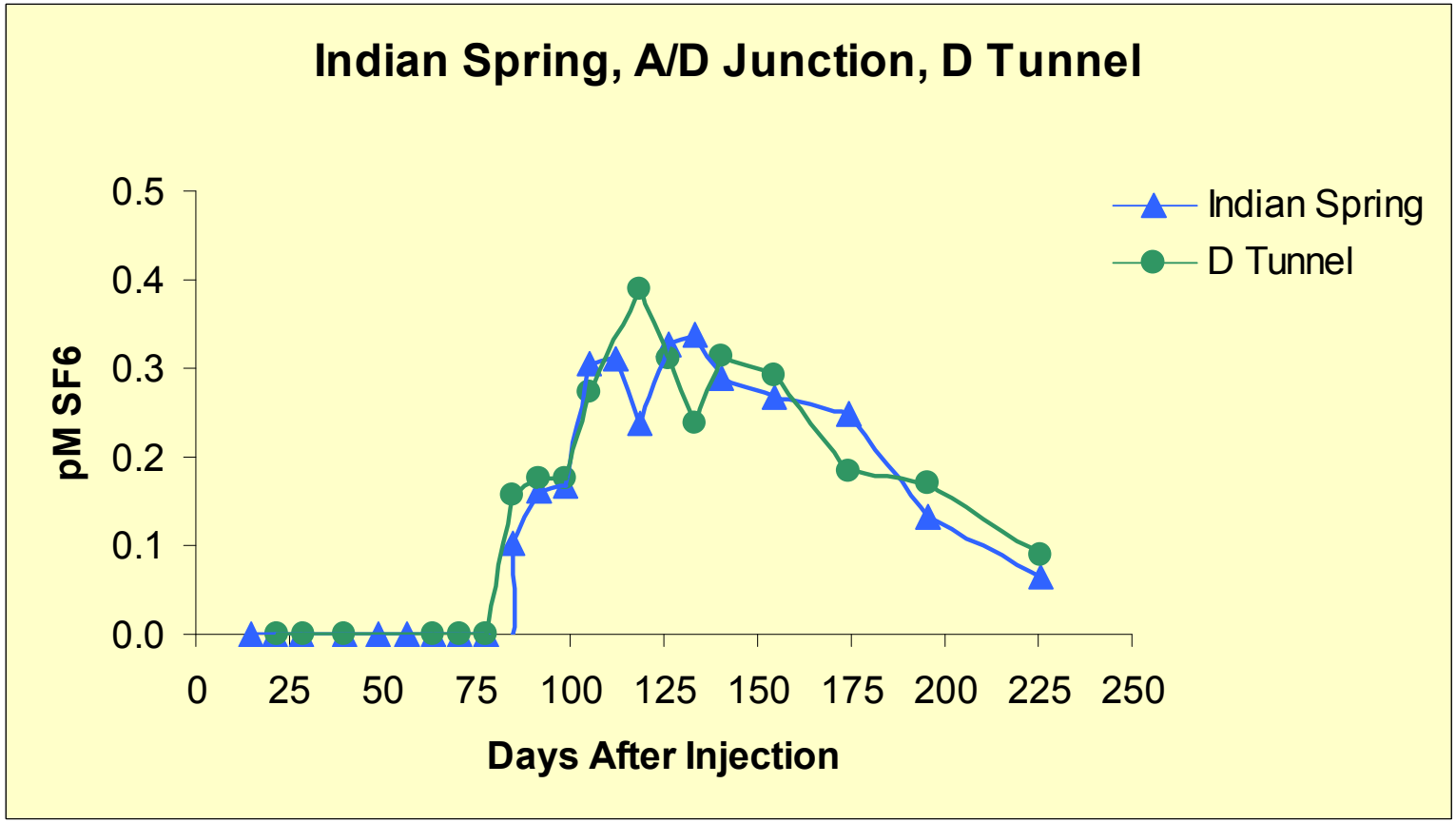
Embarq well: 360 litrers or 14.7 moles SF_6



	First Appearance	Peak
Wakulla Spring	71 Days	92 Days
Sally Ward Spring	78 Days	113 Days
Indian Spring	84 Days	126 Days


Wakulla Springs, B & C Tunnels
Wakulla Spring
B tunnel
C Tunnel
pM SF6
0.5
0.4
0.3
0.2
0.1
0
0
25
50
75
100
125
150
175
200
225
250
Days After Injection


Sally Ward Spring, A/D Junction, D Tunnel
pM SF6
0.5
0.4
0.3
0.2
0.1
0.0
0
25
50
75
100
125
150
175
200
225
250
Days After Injection
Sally Ward Spring
D Tunnel


Indian Spring, A/D Junction, D Tunnel
pM SF6
0.5
0.4
0.3
0.2
0.1
0.0
0
25
50
75
100
125
150
175
200
225
250
Days After Injection
Indian Spring
D Tunnel

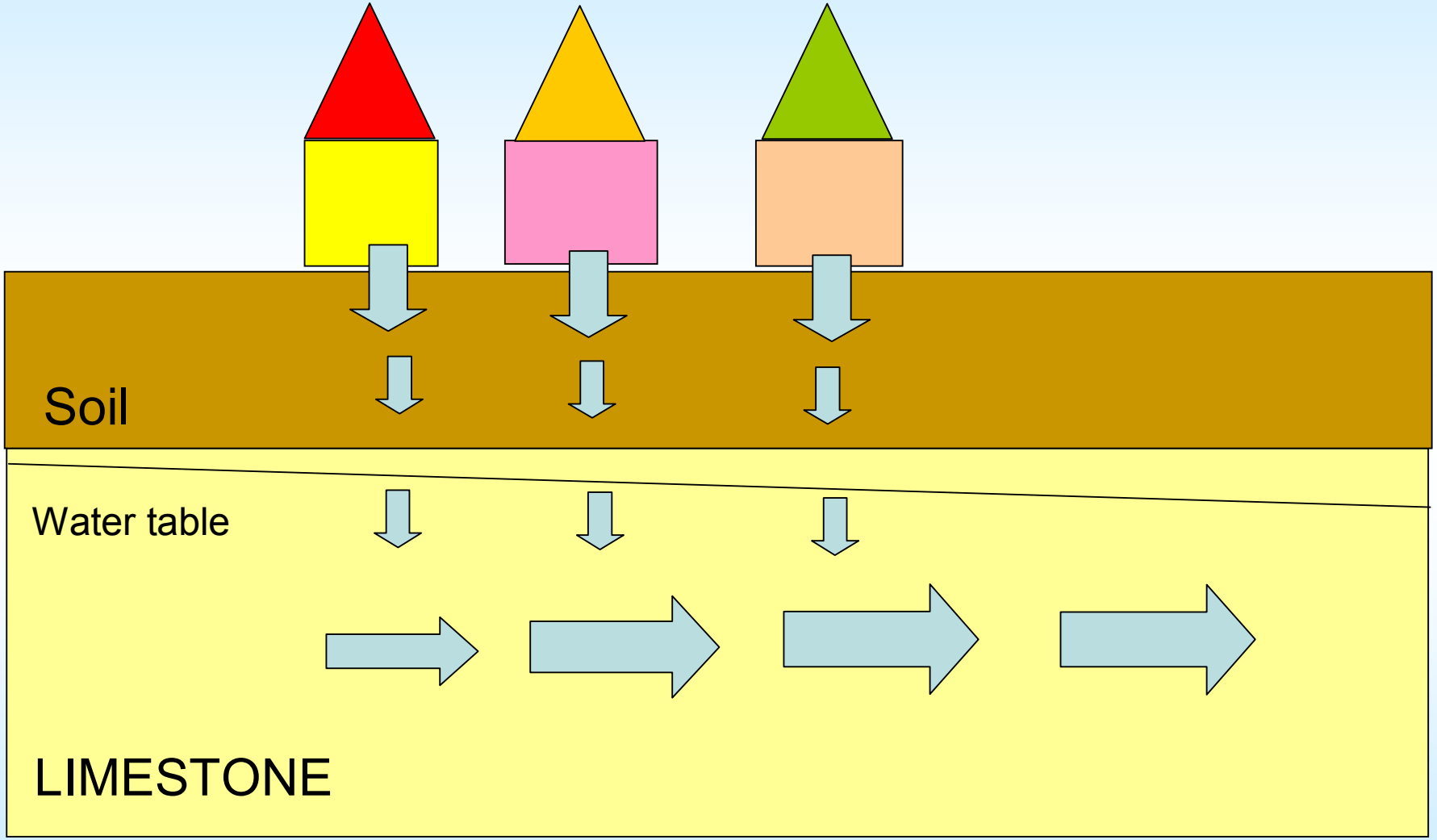
•Comparison with Spray field Dye Tracer Test

Spray Field Dye	Woodville SF_6
Deep Wells and a Sink Hole	Shallow Wells, 8 meters deep
injected into three wells. 27m, 30m, 50m, 11.2 and 11.8 miles from Wakulla Springs	6.1 and 5.3 miles from Wakulla Springs
Peak at 92 for wells Peak at 93 Days for sink hole	Peak at 92 Days
Recovery 10-41% Well Injection 4-15% Sink hole injection	Recovery 0.1-10%

Conclusion

1. There is a direct connection between the surficial aquifer and Wakulla Springs.

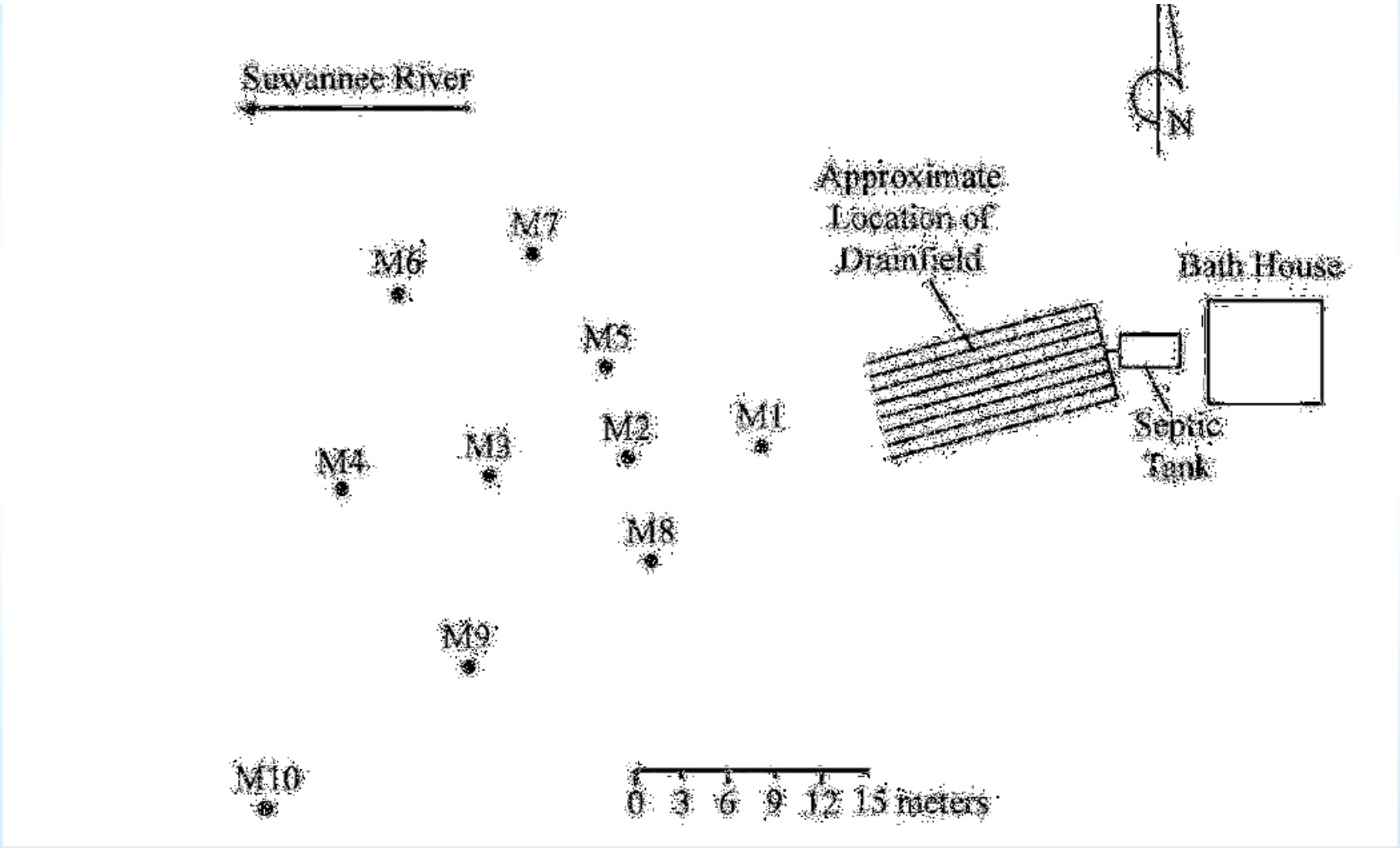
Hypothesis: Nitrogen attenuation happens in air filled soil.
Not in oxygenated limestone aquifers.



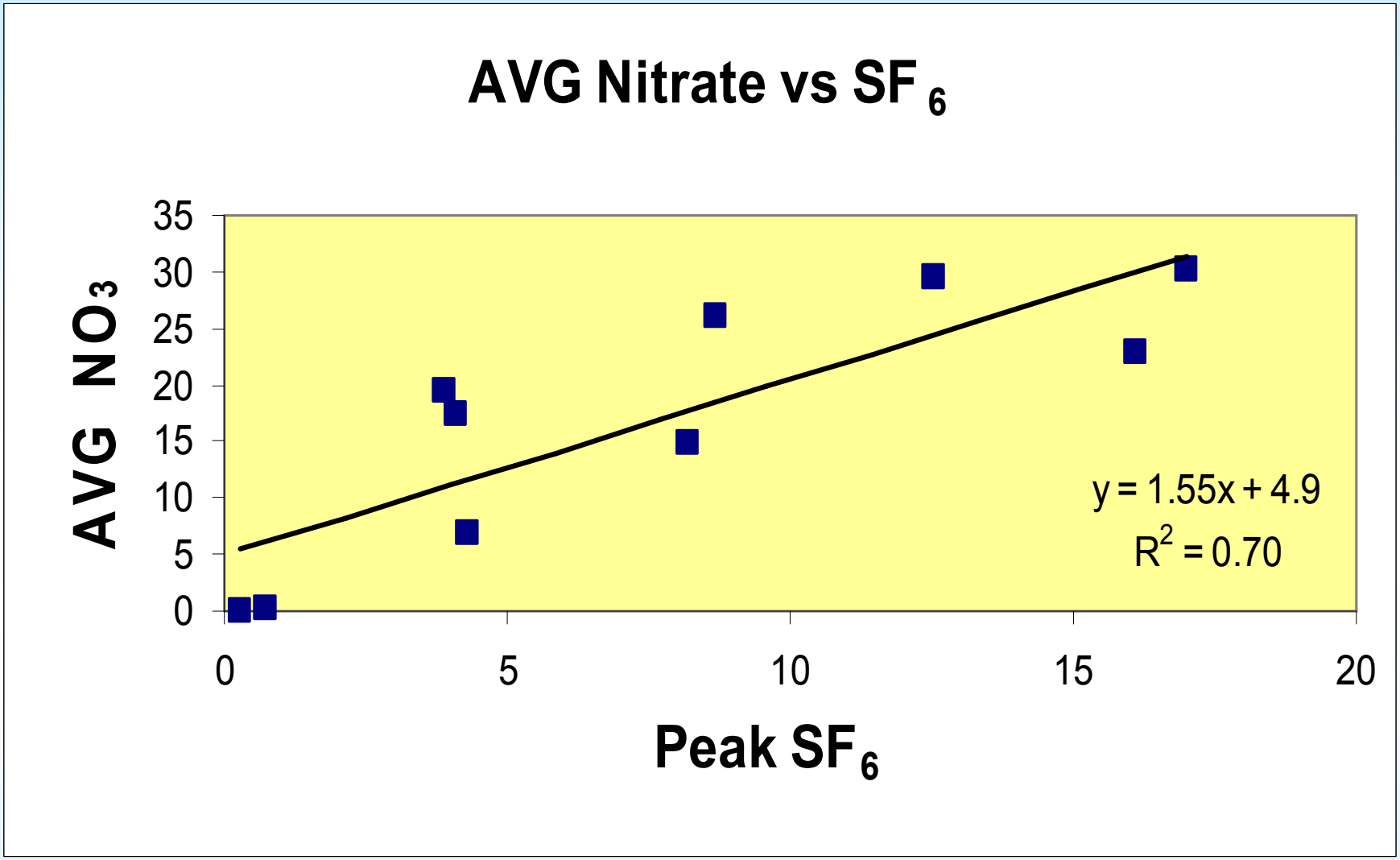
Nitrate attenuation

- Plant uptake
- Soil adsorption
- Denitrification
  - Organic matter + NO_3 → N_2 + CO_2
  - Denitrification requires organic matter and low O_2 concentrations
  - <u>The limestone aquifer is aerobic.</u>

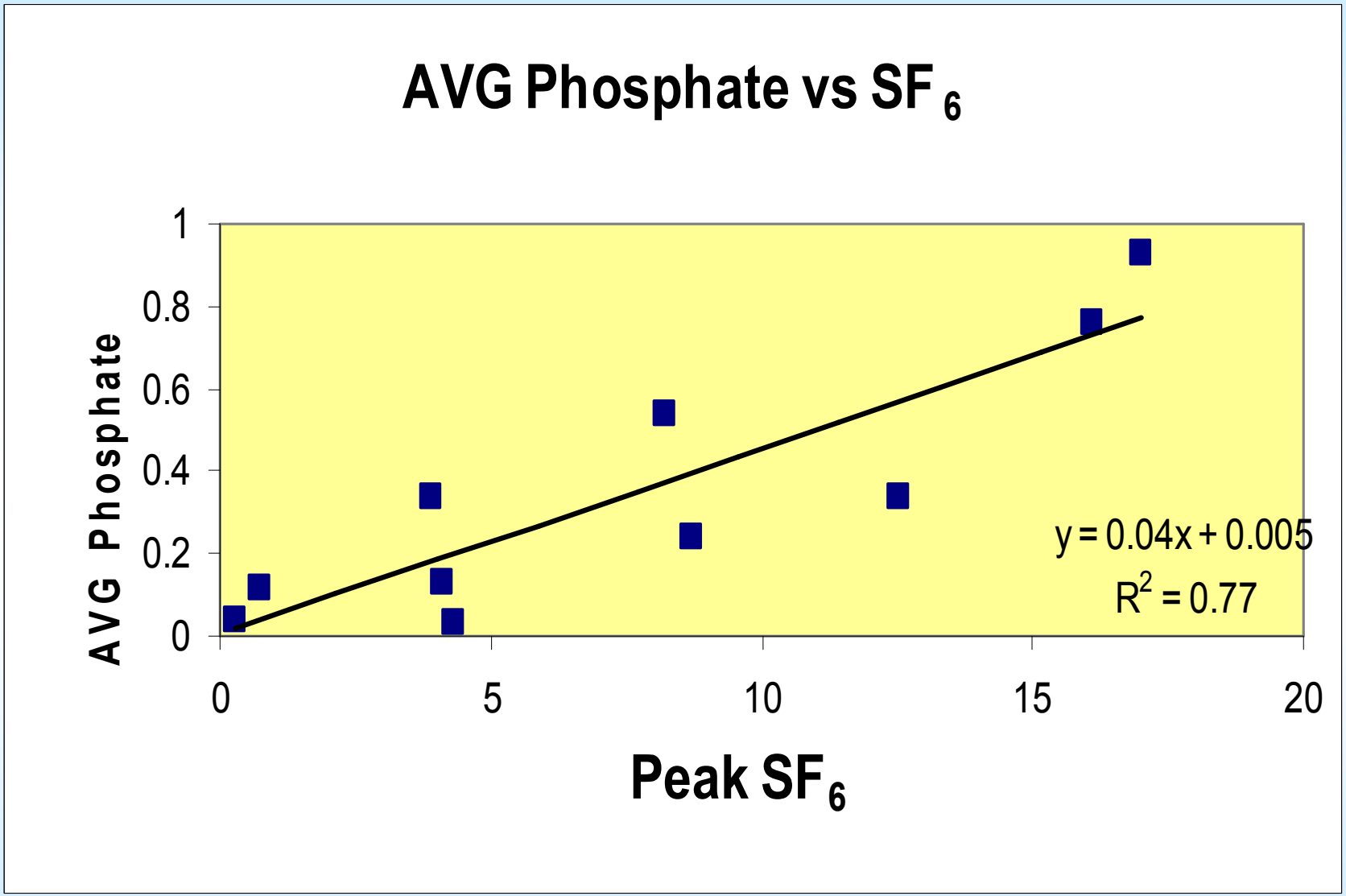
Manatee Springs State Park Septic Study. DOH funded. Added Tracer to drainfield, monitored wells downfield Drilled in the limestone.

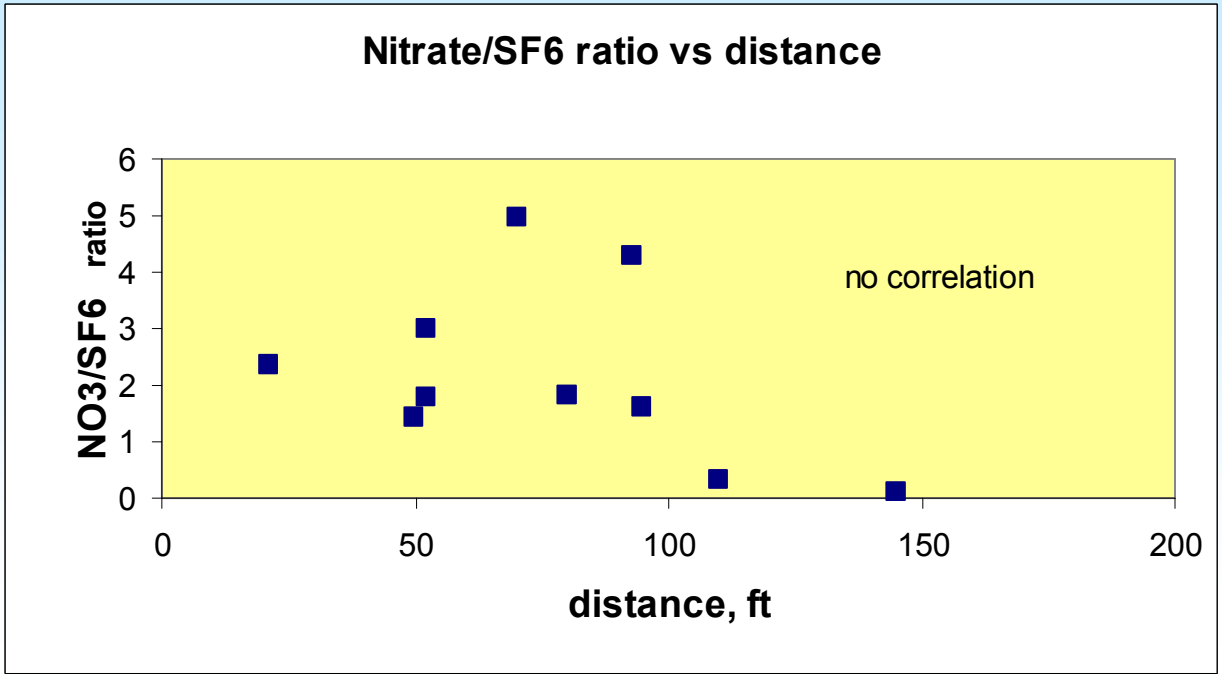


Harden, H., M. Hooks, E. Roeder, J. P. Chanton. (2008). · Evaluation of Onsite Sewage Treatment and Disposal Systems in Shallow Karst Terrain. Water Research 42 2585 – 2597

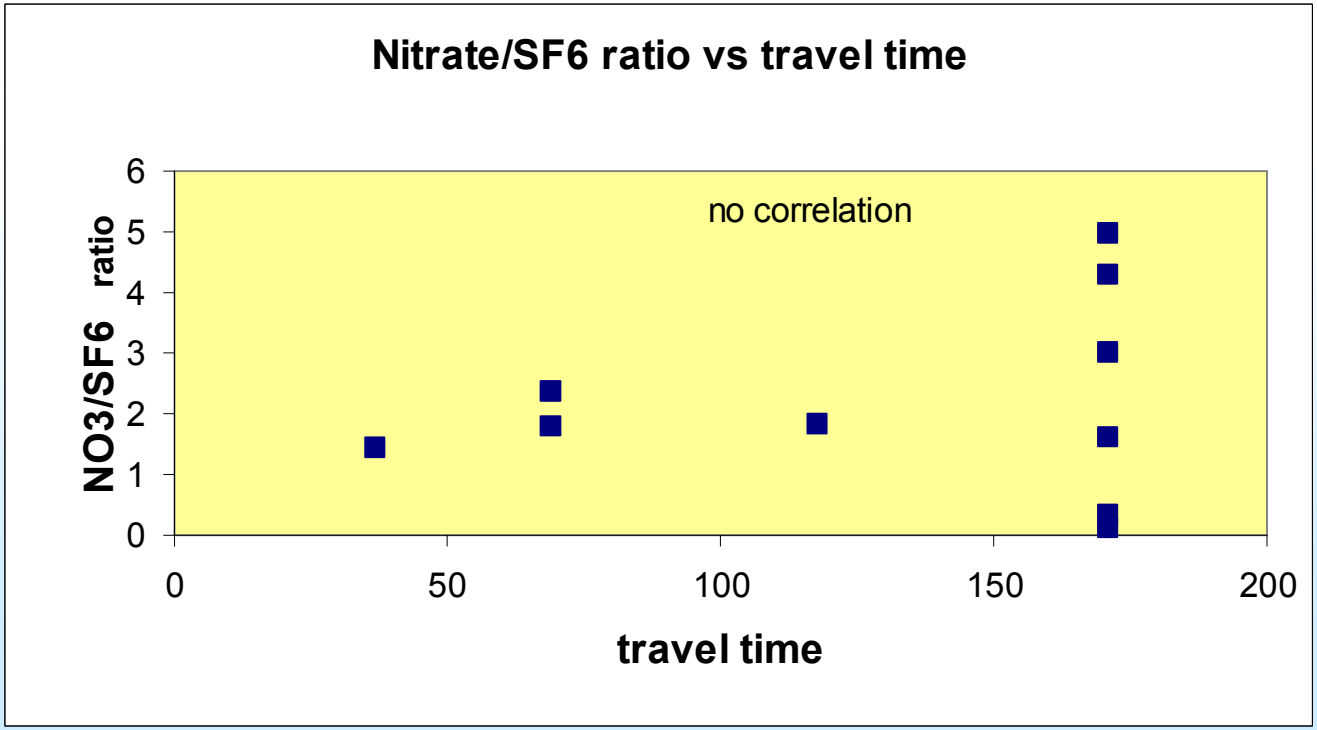


Linear relationship indicates nitrate is conservative relative to the inert tracer

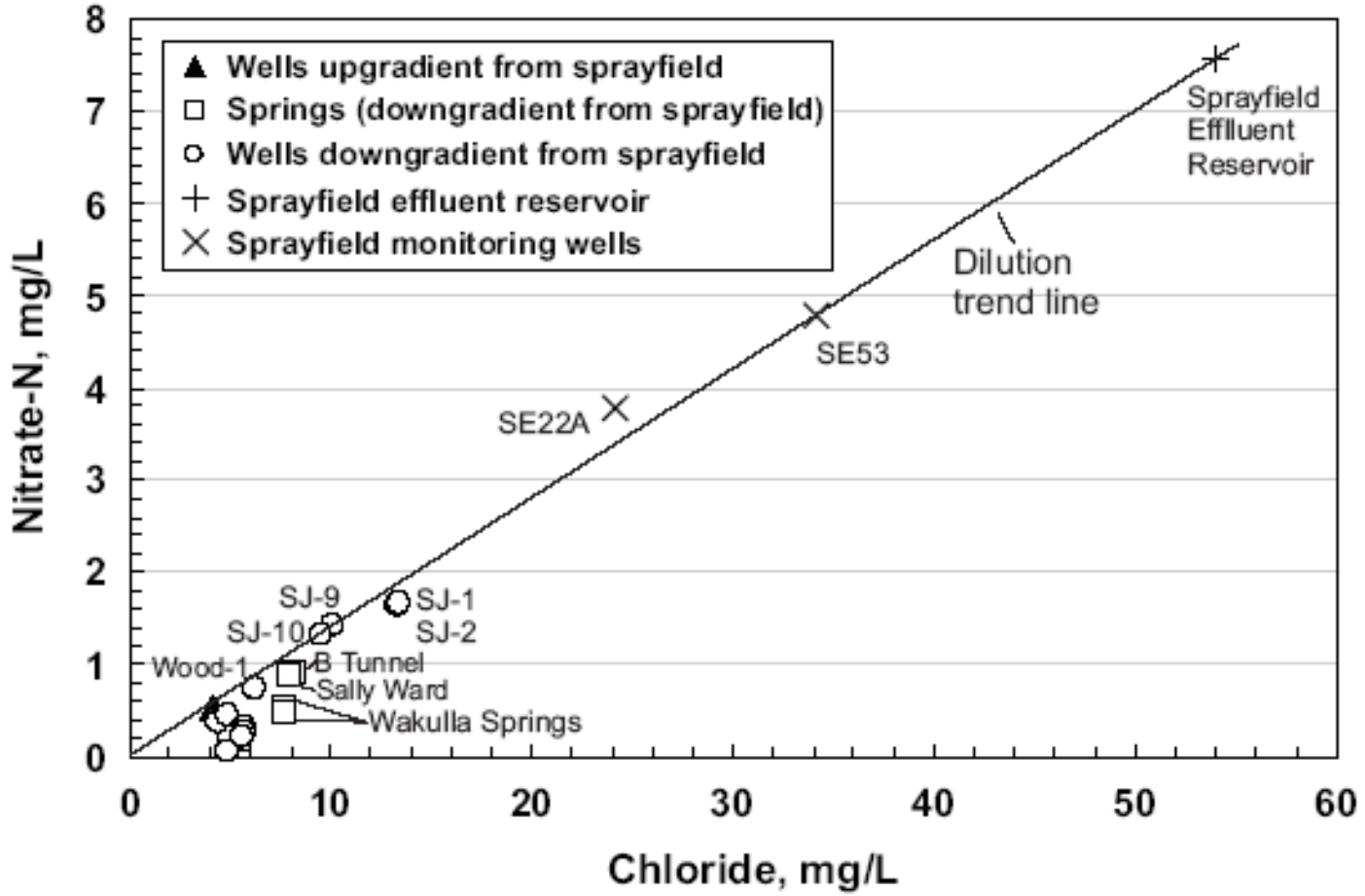

AVG Phosphate vs SF6
AVG Phosphate
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
Peak SF6
y = 0.04x + 0.005
R2 = 0.77

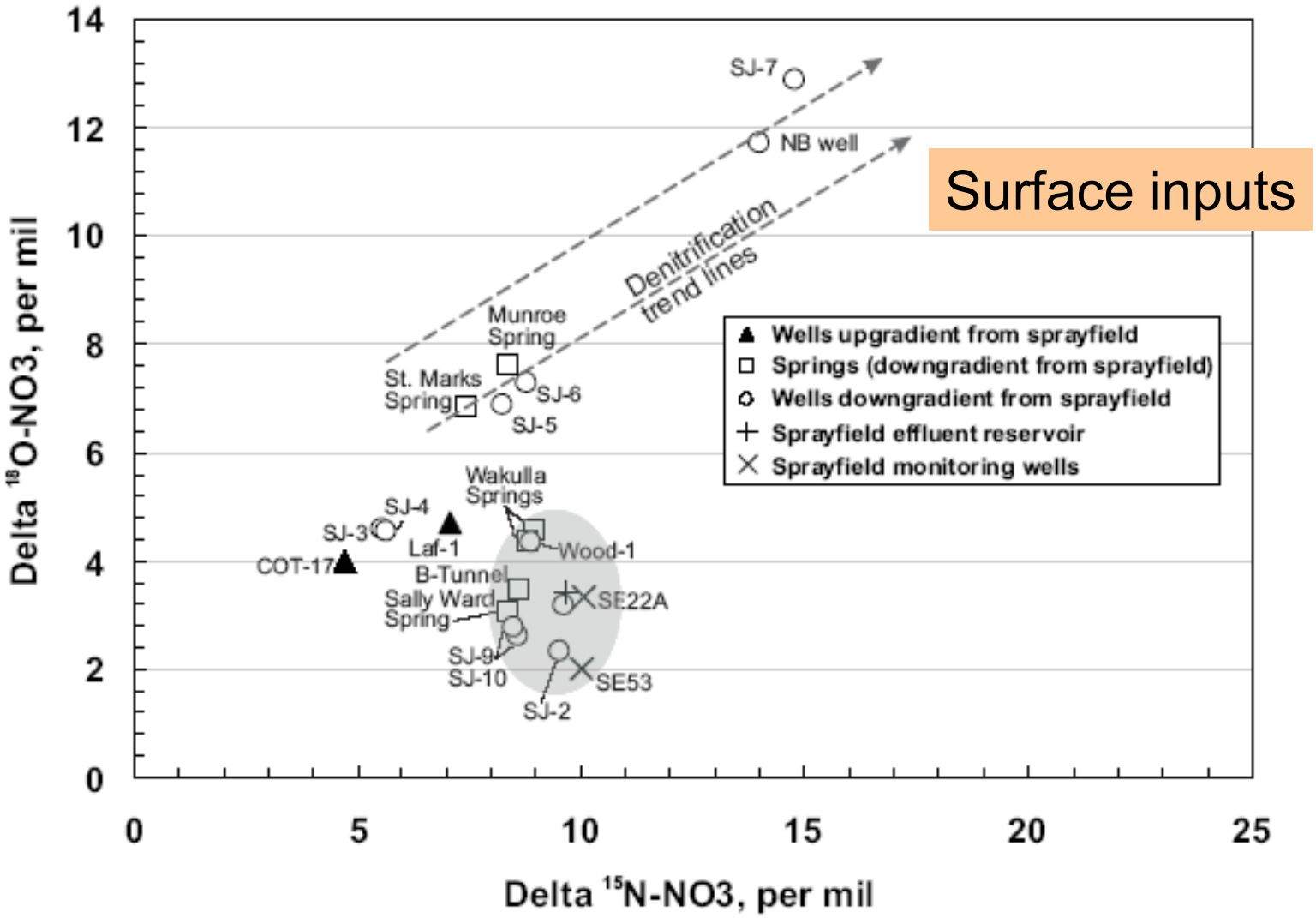


No relationship between nitrate tracer ratio and well distance or travel time



From Sprayfield to Wakulla Springs, no change in relationship Between Nitrate and Conservative Tracer, Cl.
Brian Katz, USGS data.





Surface inputs

Conclusions

1. There is a direct connection between the surficial aquifer and Wakulla Springs.

2. There is little evidence for nitrate attenuation in the limestone aquifer along that pathway.

Tracer injected into shallow wells to mimic inputs from septic tanks

Embarq Well on Woodville Hwy

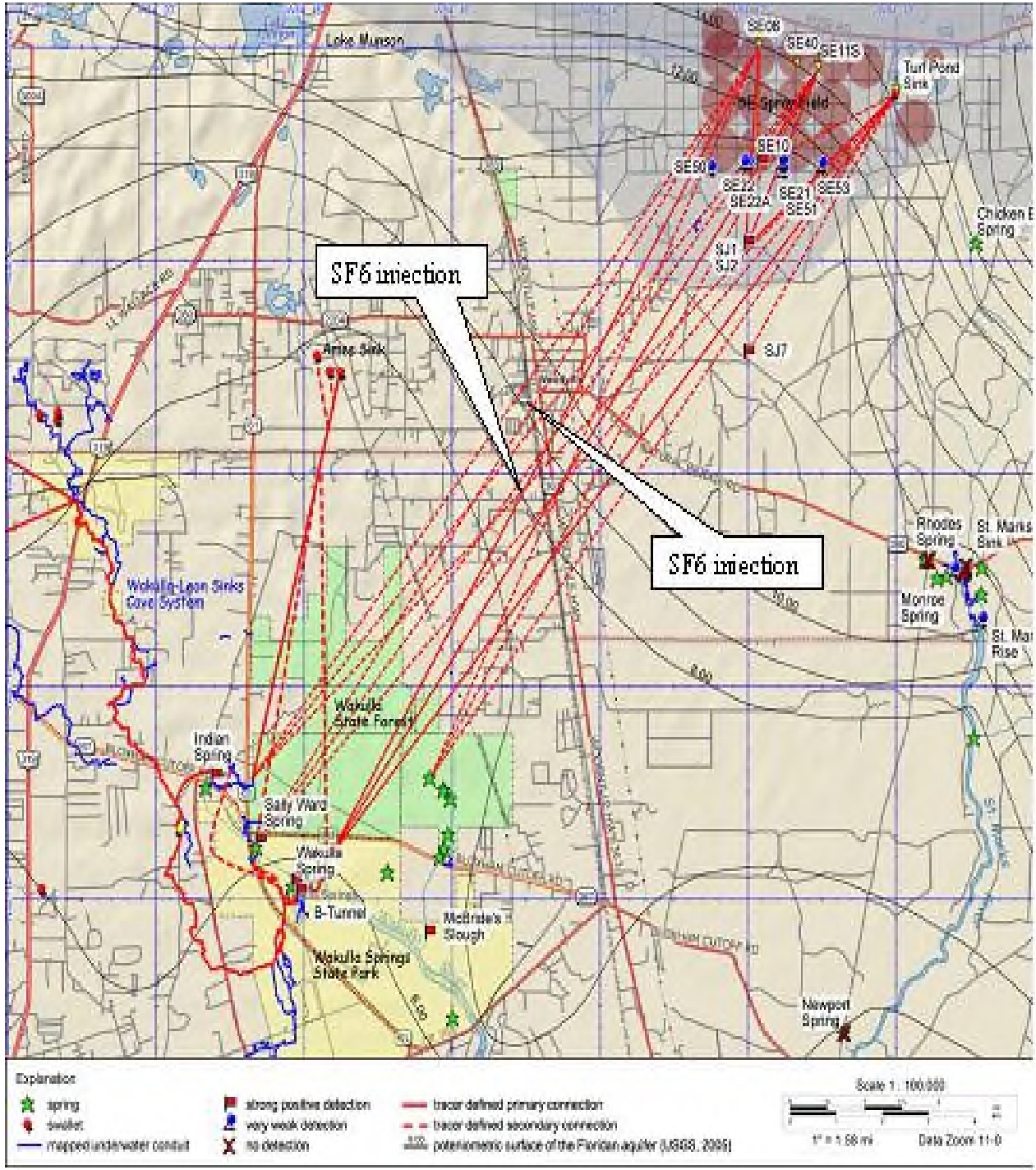
6.1 miles from Wakulla Springs

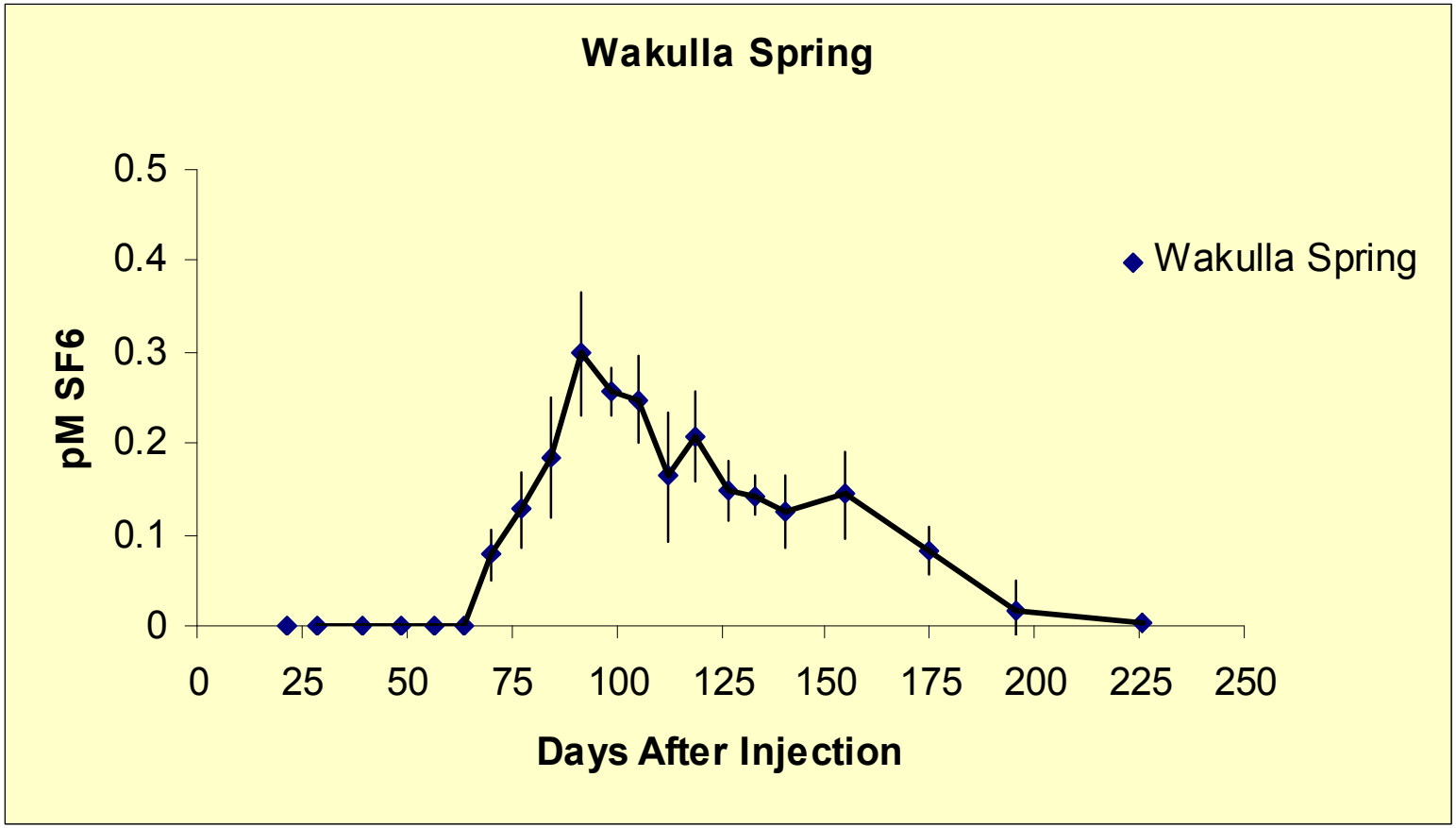
Water Depth 3.67m

Bob Miller Rd. Well

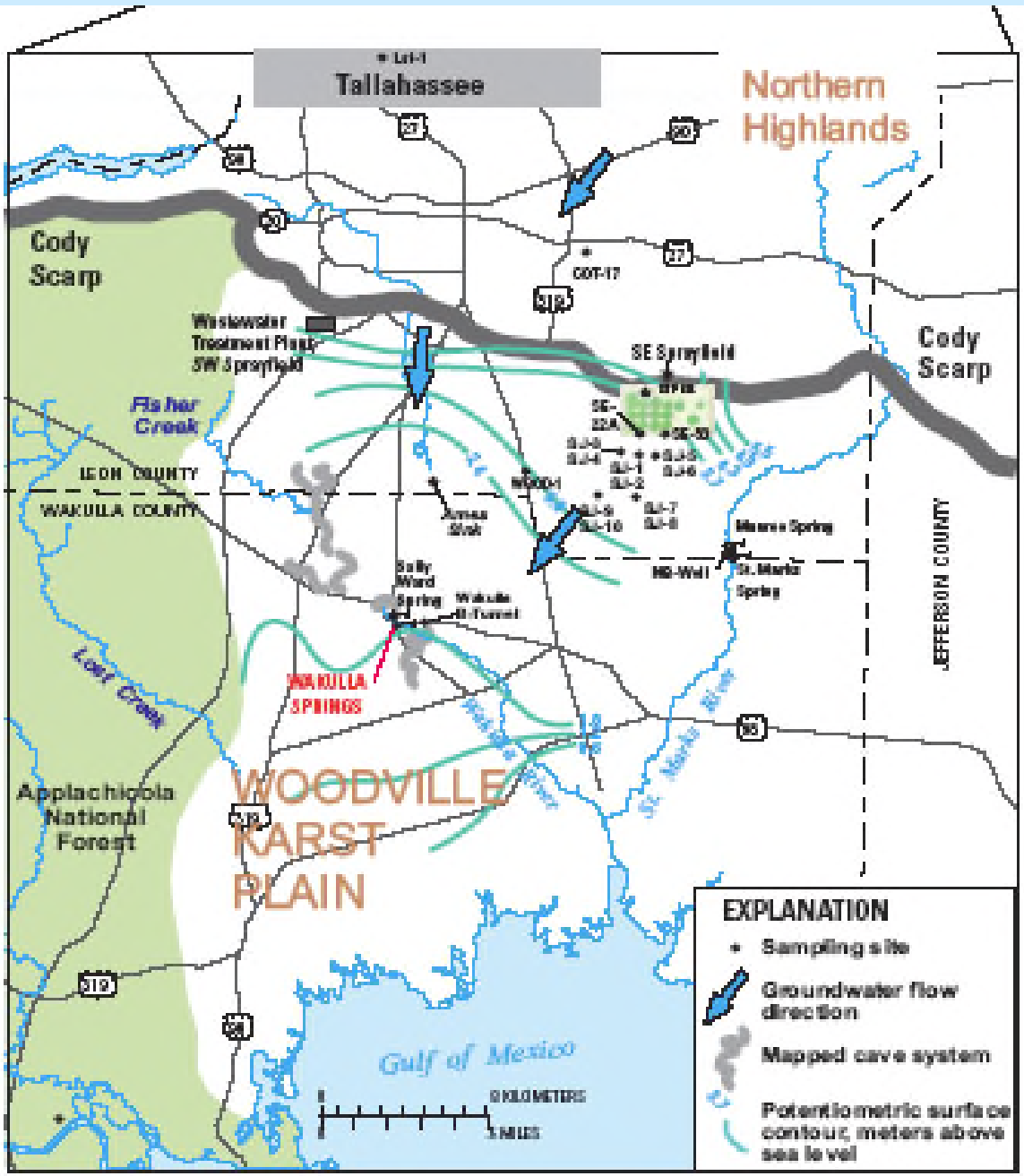
5.3 miles from Wakulla Springs

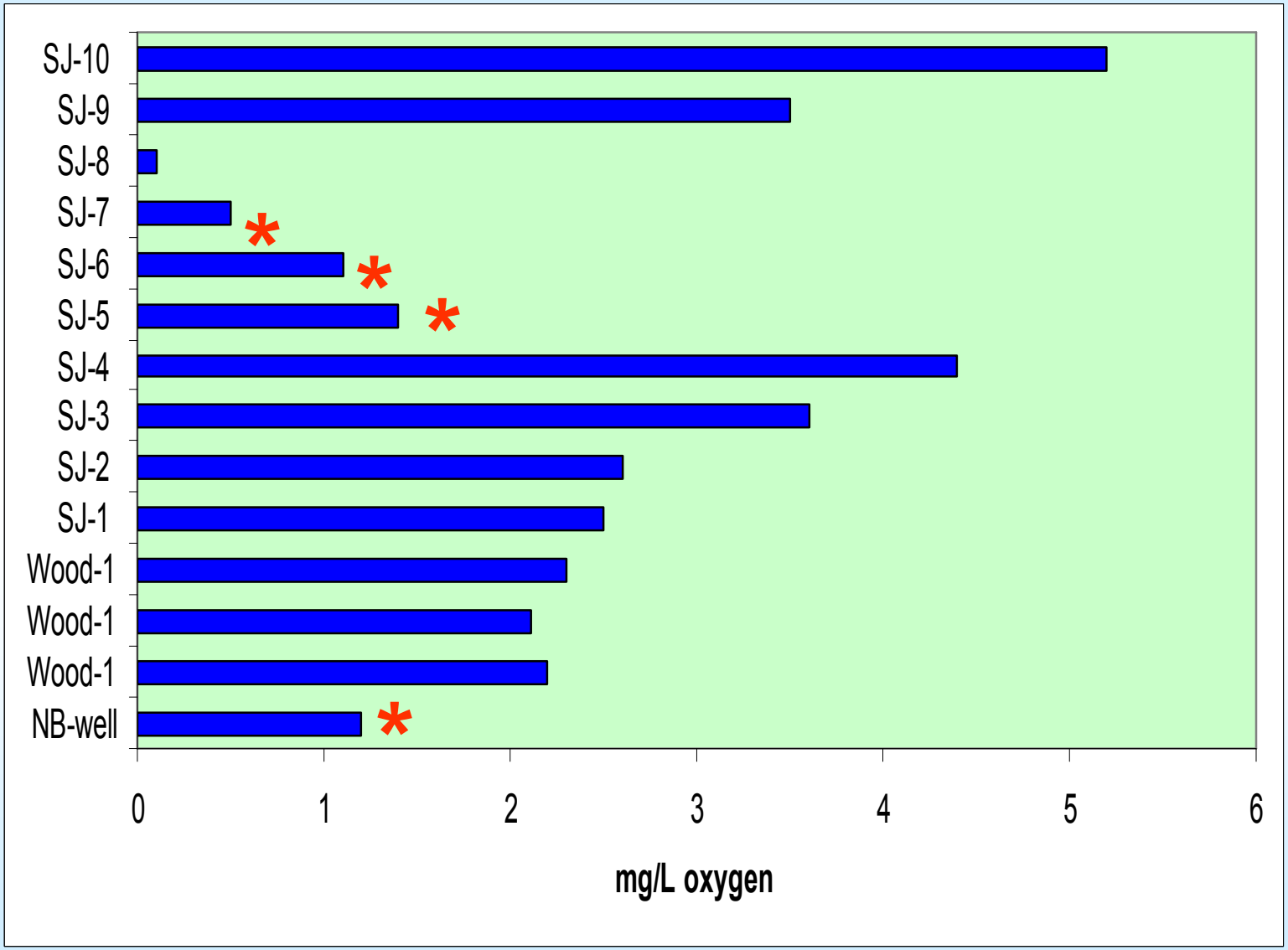
Water Depth 6.83m





First detected at 71 days after injection with a peak at 92 days.


Tallahassee
Northern Highlands
Cody Scarp
Cody Scarp
Wastewater Treatment Plant SW Springfield
SE Springfield
Fisher Creek
LEON COUNTY
WAKULLA COUNTY
JEFFERSON COUNTY
Sally Ward Spring
Wakulla Springs
Lost Creek
Apalachicola National Forest
WOODVILLE KARST PLAIN
Gulf of Mexico
Munroe Spring
St. Marks Spring
St. Marks River
Wakulla River
Ochlockonee River
EXPLANATION
Sampling site
Groundwater flow direction
Mapped cave system
Potentiometric surface contour, meters above sea level
KILOMETERS
MILES


SJ-10
SJ-9
SJ-8
SJ-7
SJ-6
SJ-5
SJ-4
SJ-3
SJ-2
SJ-1
Wood-1
Wood-1
Wood-1
NB-well
*
*
*
*
0
1
2
3
4
5
6
mg/L oxygen