Demonstrating interconnection between a wastewater application facility and a first magnitude spring in a karstic watershed: Tracer study of the Tallahassee, Florida Treated Effluent Spray field 2006-2007

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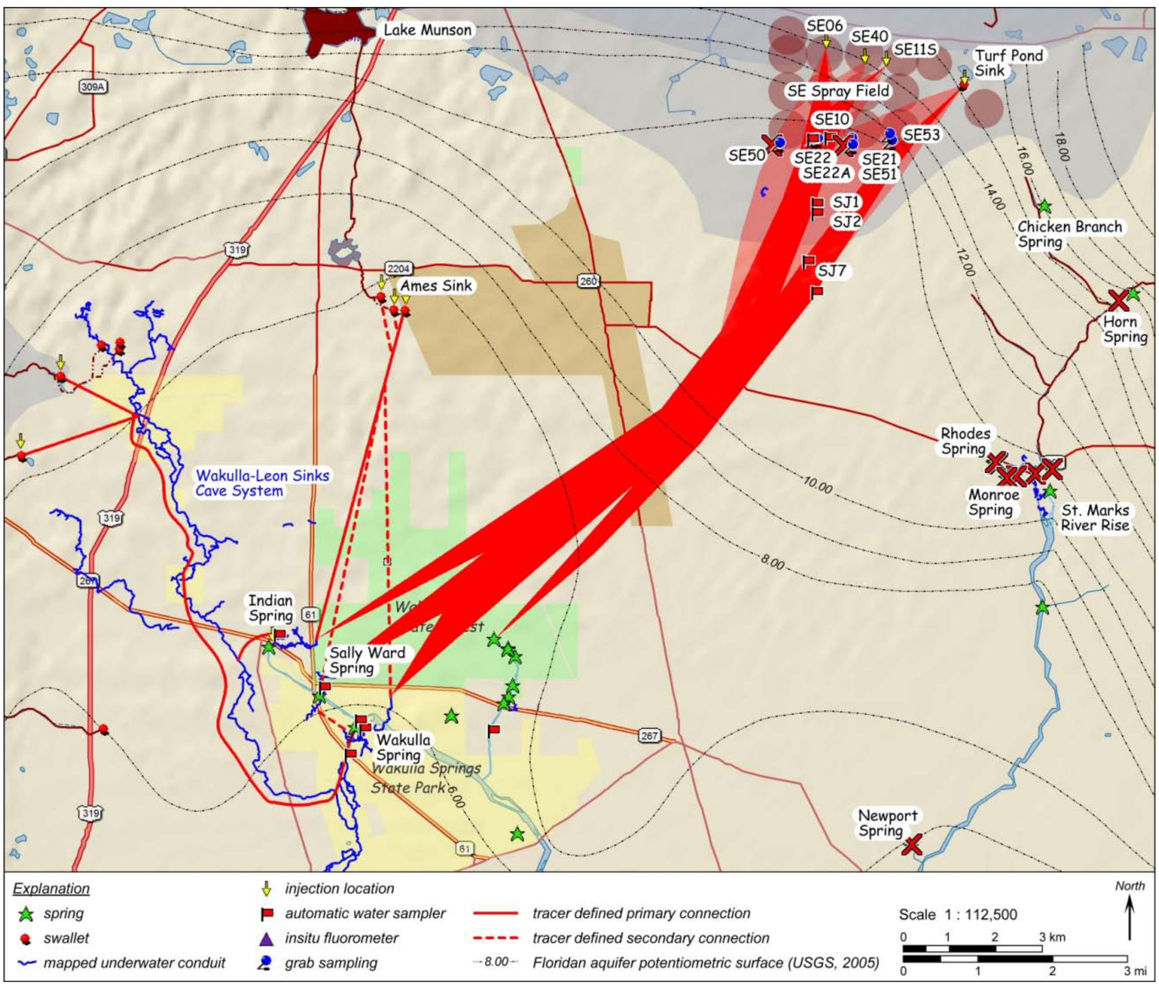

Traced groundwater flow paths from the City of Tallahassee's waste water spray field to Wakulla, Indian, Sally Ward, and McBrides springs, north Florida.

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Overview

The City of Tallahassee's SE Spray Field (SESF) receives secondarily treated wastewater and disperses it onto the land surface via center-pivot irrigators at an average rate of approximately 17 million gallons per day (City of Tallahassee, 2007). The system is intended to provide nutrient removal through plant uptake from the infiltrating water. It became operational in 1981, encompassing 1000 acres and was expanded in 1982 to 1500 acres, 1986 to 1896 acres, and 1999 to 2,159 acres (Chelette et al, 2002). Nitrate levels in groundwater monitoring wells installed in the upper Floridan aquifer beneath the SESF increased precipitously after the SESF became operational rising from ~0.5 mg/L in 1980 to as much as 10 mg/L in the 1990's and stabilizing at ~6 mg/L by 2000 (Chelette et al, 2002).

During the same period, nitrate levels measured at Wakulla Spring rose from ~0.2-0.3 mg/L between 1971 and 1976, to >1.0 mg/L in the late 1980's, to ~0.7-0.8 mg/L between 1998 and 2000 (Chelette et al, 2002). The increased nitrate levels are thought to be the primary cause of algae growth and enhanced hydrilla growth that have resulted in significant harm to the ecosystems supported by Wakulla Spring and the Wakulla River (Hand, 2005).

Given the apparent correlation between nitrate increases in Wakulla Spring and in Floridan aquifer groundwater beneath the SESF, considerable attention became focused on the SESF as the primary source of nitrate contamination to the spring by 2000. Further attention was directed toward the SESF when Chelette and others (2002) reported nutrient budget calculations for the St Marks and Wakulla River Watersheds that attributed 40% of the nitrate loading in the Wakulla Springs contributory area to the SESF.

In response to growing concerns about the fate of nitrates released to the Floridan aquifer from the SESF, the City of Tallahassee approved a 3-year study with the US Geological Survey to, in part, develop of model of nitrate transport through the upper Floridan aquifer. In concert with that effort, the Florida Department of Environmental Protection and the Florida Geological Survey commissioned Hazlett-Kincaid, Inc. to perform a groundwater tracing study to identify potential groundwater flow paths and velocities between the SESF and down-gradient springs.

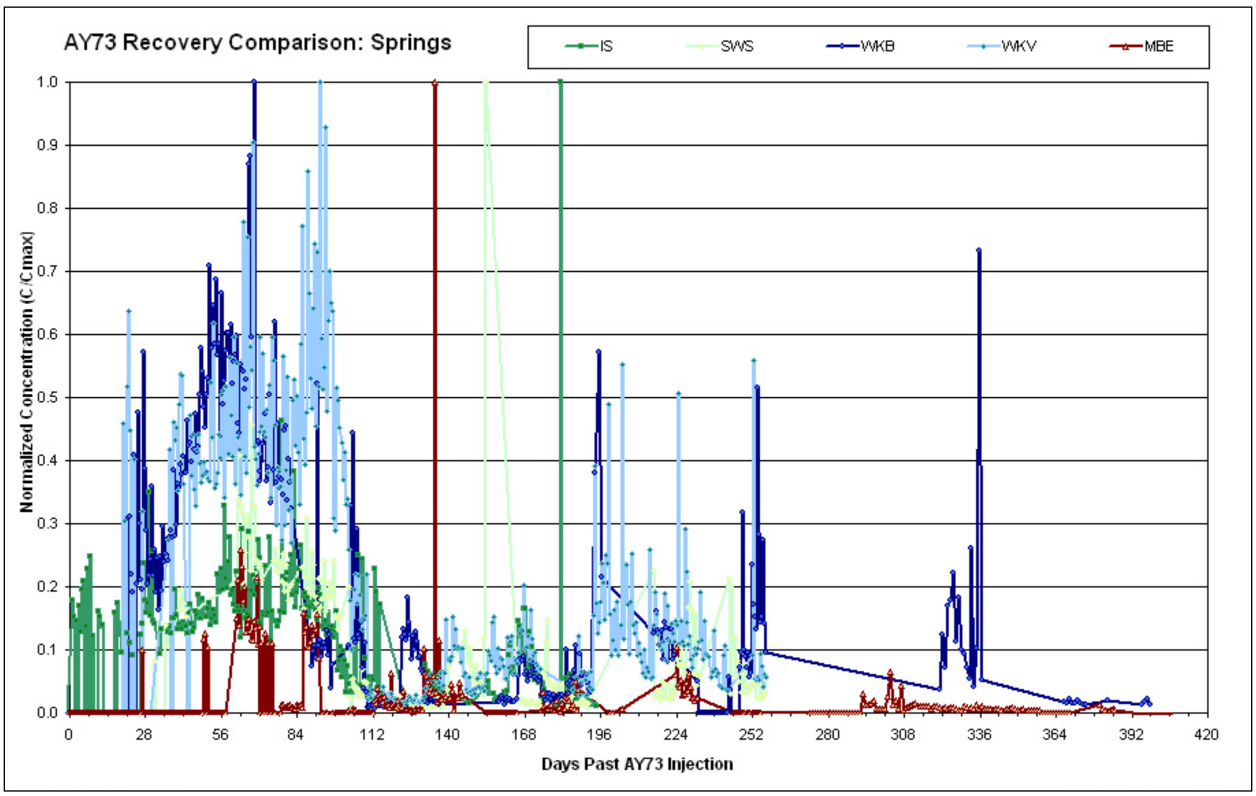
Tracer injections were performed in three wells across the northern side of the SESF and one sinking stream located on the southeastern side of the property. Water samples were subsequently collected from ten wells and eleven natural discharge points for between two and fourteen months and analyzed in a laboratory for the presence and relative amount of the injected tracers. Sampling for the fluorescent dyes was also conducted at two of the wells, Wakulla B-Tunnel, and the St. Marks River upstream of its disappearance with insitu filter fluorometers (IFF).

One or more of the Fluorescent dyes was detected at five of the wells and five of the springs. The springs at which the fluorescent dyes were detected include: Wakulla Spring, Sally Ward Spring, Indian Spring, and one or more of the small springs contributing to flow in McBride's Slough. The fastest travel times to those springs established by fluorescent tracer breakthrough curves ranged from approximately 28-66 days after the injections with subsequent smaller pulses of tracer-laden water arriving at Wakulla and McBride's Slough as late as approximately one year after the injections. Very minor quantities of fluorescent compounds that fluoresce in the same range as the injected tracers were detected at Monroe Spring and the St. Marks River Rise but not enough to be confident that our tracers were recovered at those locations. None of the fluorescent tracers were detected at in the St. Marks River at Natural Bridge, Rhodes Spring, or Newport Spring.

AR87 injection in Turf Pond Sink

AY73 siphon injection at well SE06

Photos of the dye injections that occurred at a swallet and monitoring wells located within the City of Tallahassee's waste water spray field.



Uranine Dye (AY73) recovery curves for Indian Spring (IS), Sally Ward Spring (SWS), Wakulla B-Tunnel (WKB), Wakulla Vent (WKV), and McBride's Slough (MBE) resulting from dye injections performed at the City of Tallahassee's waste water spray field.

References

Chelette, A., Pratt, T. R., and Katz, B. G., 2002. Nitrate loading as an indicator of nonpoint source pollution in the lower S. Marks-Wakulla Rivers watershed: Water Resources Special Report 02-1, Northwest Florida Water Management District, Havana, Florida, 138 p.

City of Tallahassee, 2007. The Southeast Farm Wastewater Reuse Facility, accessed from http://www.talgov.com/you/water/sefarm.cfm

Hand, J. 2005. Nitrate & Hydrilla at Wakulla Spring, Untitled presentation, Solving Water Pollution Problems in the Wakulla Springshed of North Florida; Hydrogeology Consortium Workshop http://www.geohydros.com/FGS/ HC_Workshops/2005_WS_Workshop/

Tracing a Connection Between the Tallahassee Treated Effluent Spray Field & Wakulla Spring: 2006-2007 Woodville Karst Plain, North Florida

Presentation for the Edwards Aquifer Authority

San Antonio, Texas

February 16, 2011

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Florida Geological Survey: RI 111, in print

FLORIDA

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Core Problem: *Public Perception & Concern*

Topic	***Internet Hits***
• global water resources:	24,800,000
• aquifer protection:	1,350,000
• water shortage:	8,130,000
• water crisis:	27,900,000
• water pollution:	34,400,000
• bottled water:	10,100,000
• Florida springs:	40,900,000
• Florida springs decline:	651,000
• Britney Spears:	49,800,000
• free porn:	188,000,000
• free sex:	366,000,000

Clean Water / Free Sex = < 10%

Clean Water / Britney Spears = 68%

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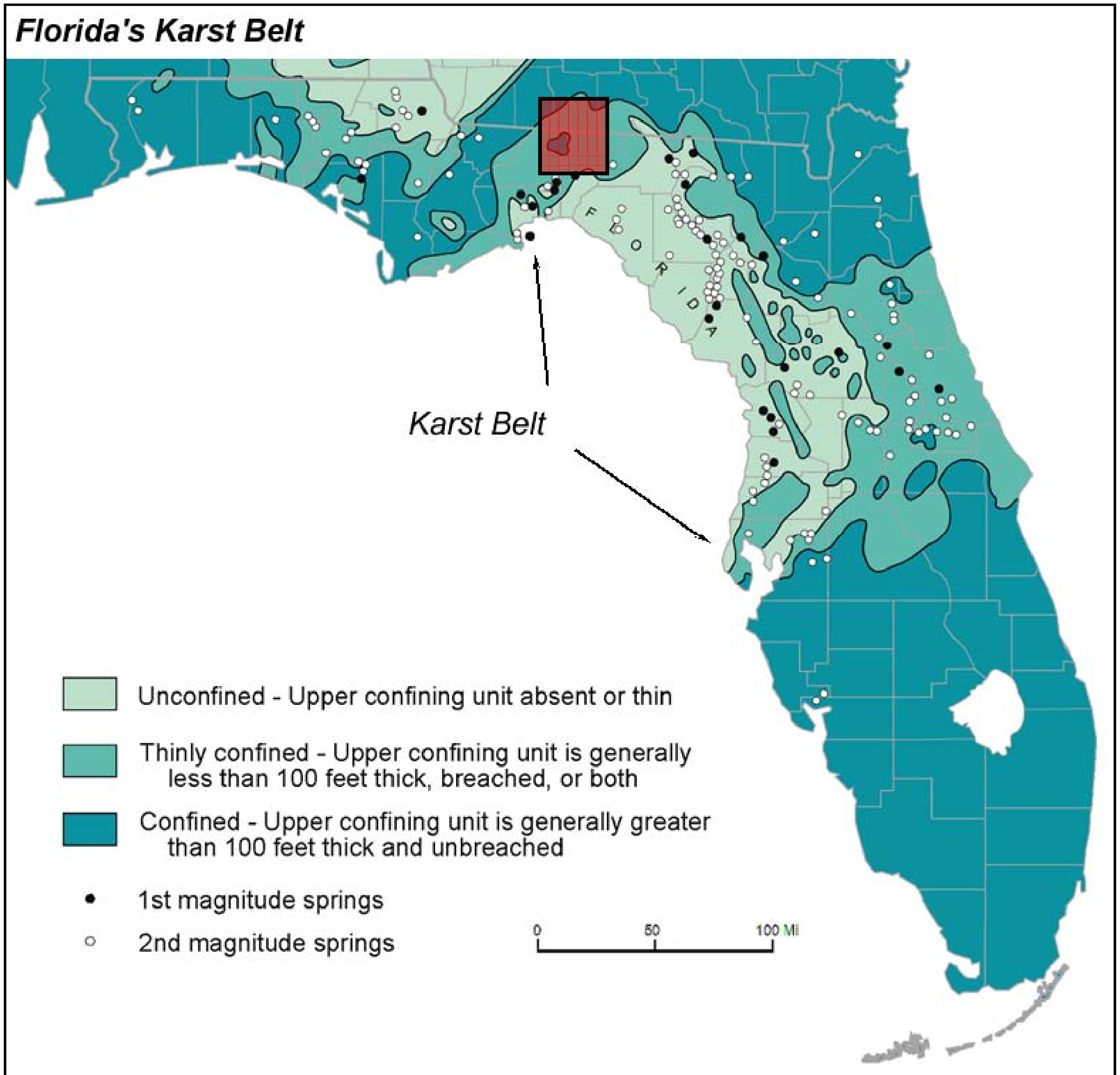
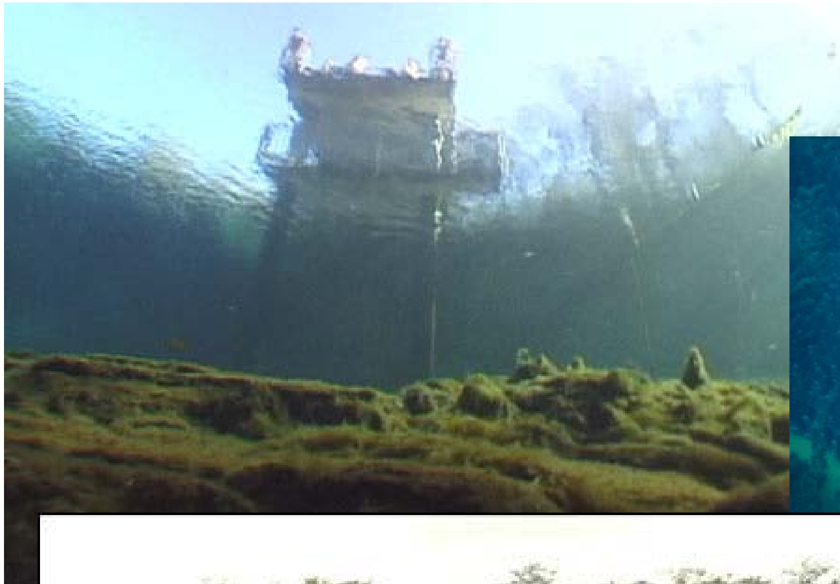
Where is Wakula? – Is it unique?



- part of "Karst Belt"
- probably highest concentration of very large springs in the world
- all discharge from major cave systems
- all but a few are similarly or more impacted than Wakulla

Wakulla Spring, Florida *(120-1500 cfs)*

Wakulla Spring in Decline



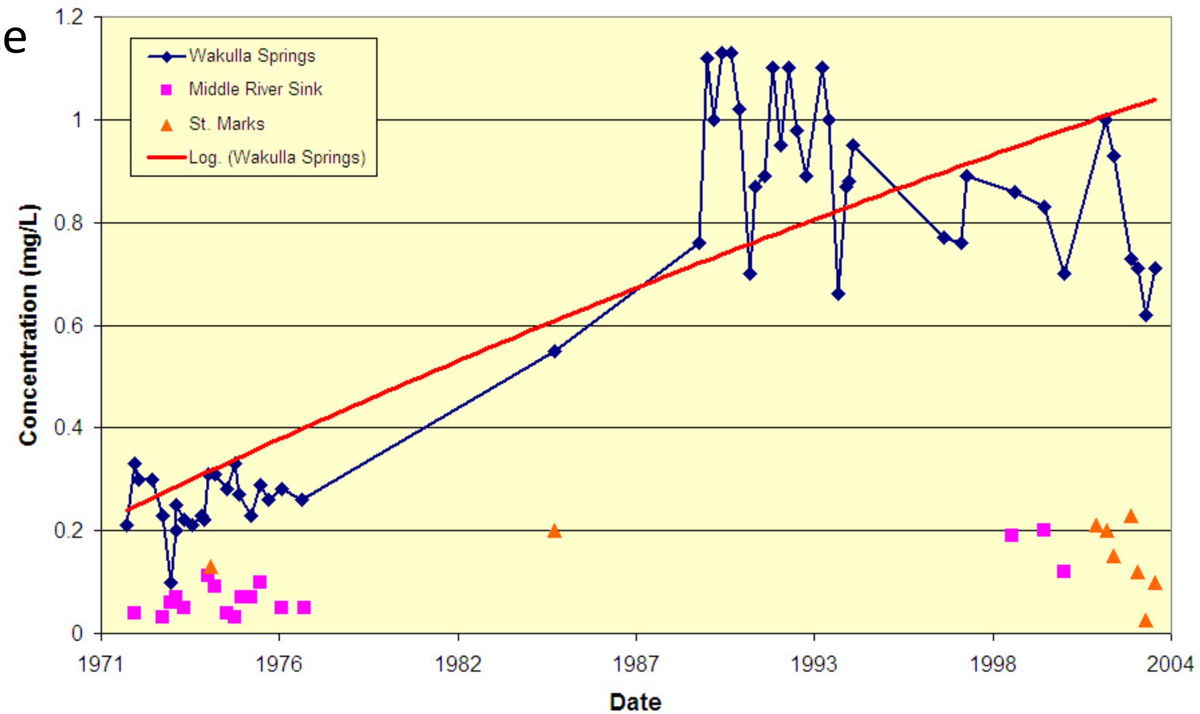
Nitrate Loading to Groundwater & Springs

Problem

- Nitrate in Florida springs: 10 – 1000 X natural levels
- Very low ecological tolerance
- Very high human tolerance
- Promotes algae and bacterial growth

Sources

- Sewage (septic systems & wastewater treatment)
- Fertilizers (lawns & agriculture)
- Industry (*CAFOs*)



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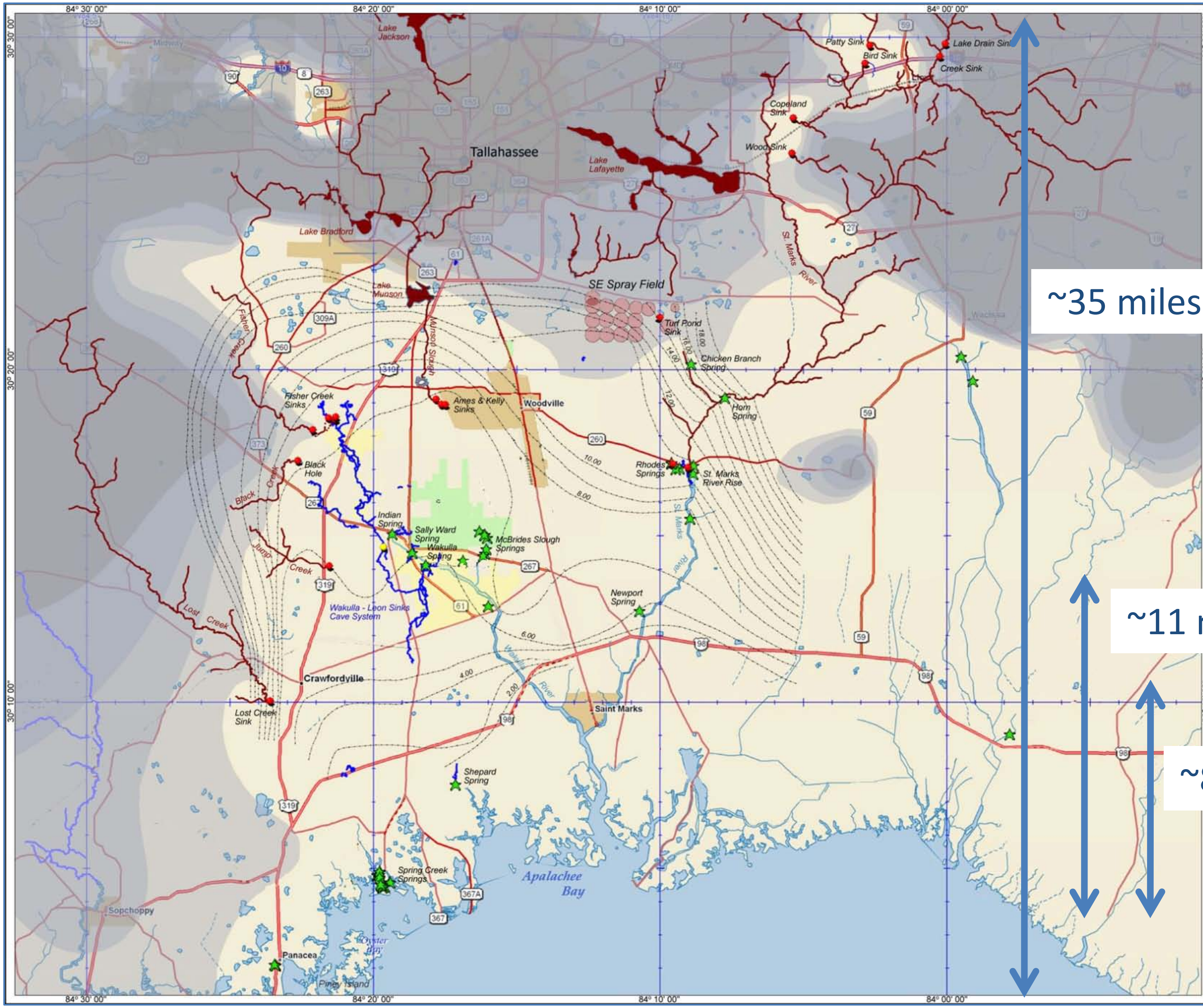
Important Hydrogeologic Features



- developments
- confining unit
- springs
- disappearing streams
- caves
- potentiometric surface

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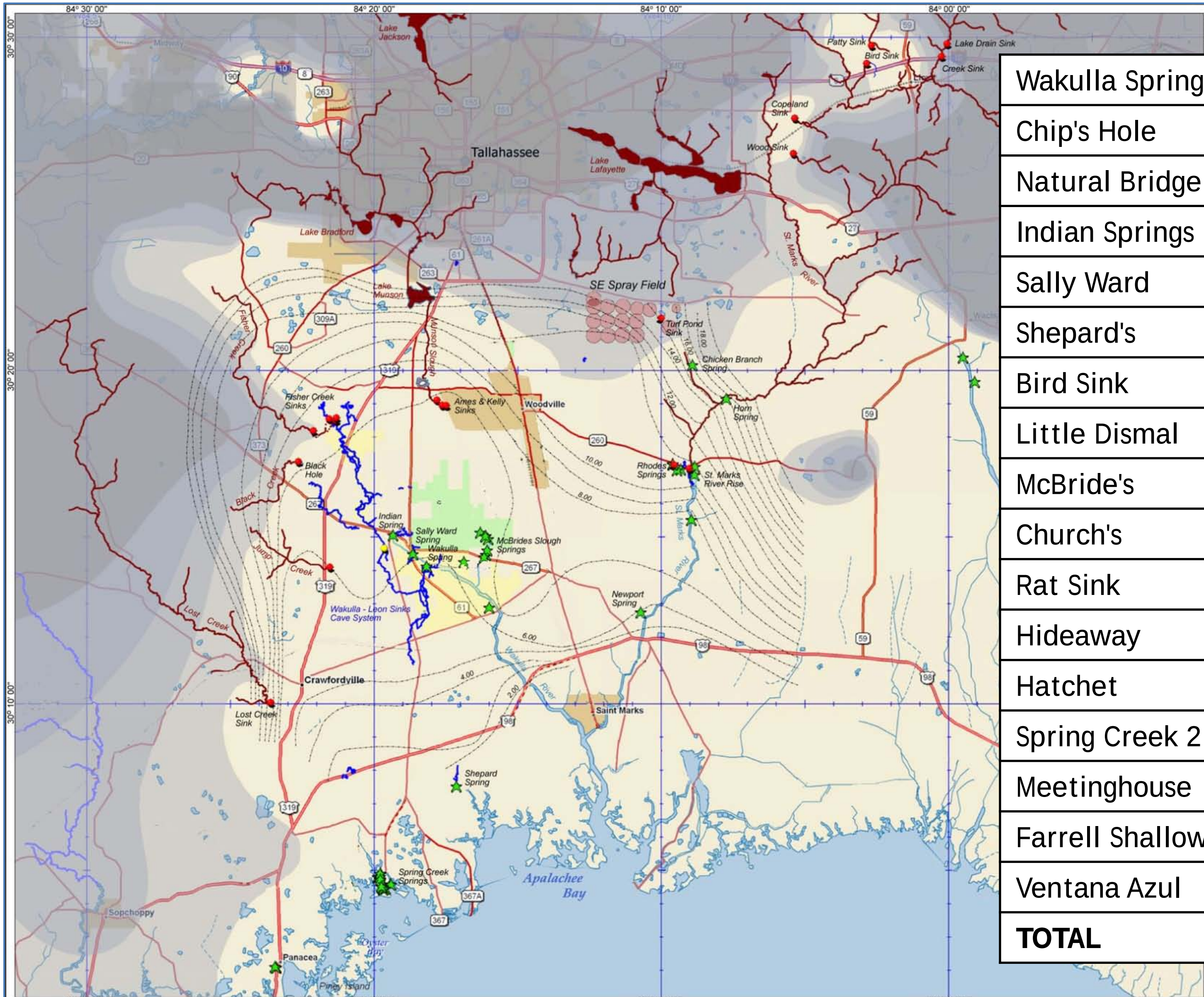
Caves in the WKP



	feet	meters
Wakulla Springs	168,900	51,484
Chip's Hole	22,292	6,795
Natural Bridge	12,108	3,691
Indian Springs	11,897	3,626
Sally Ward	6,857	2,090
Shepard's	5,689	1,734
Bird Sink	4,839	1,475
Little Dismal	2,968	905
McBride's	2,166	660
Church's	2,108	642
Rat Sink	1,463	446
Hideaway	1,228	374
Hatchet	1,120	341
Spring Creek 2	810	247
Meetinghouse	769	234
Farrell Shallow	566	173
Ventana Azul	363	111
TOTAL	**246,143**	**75,025**

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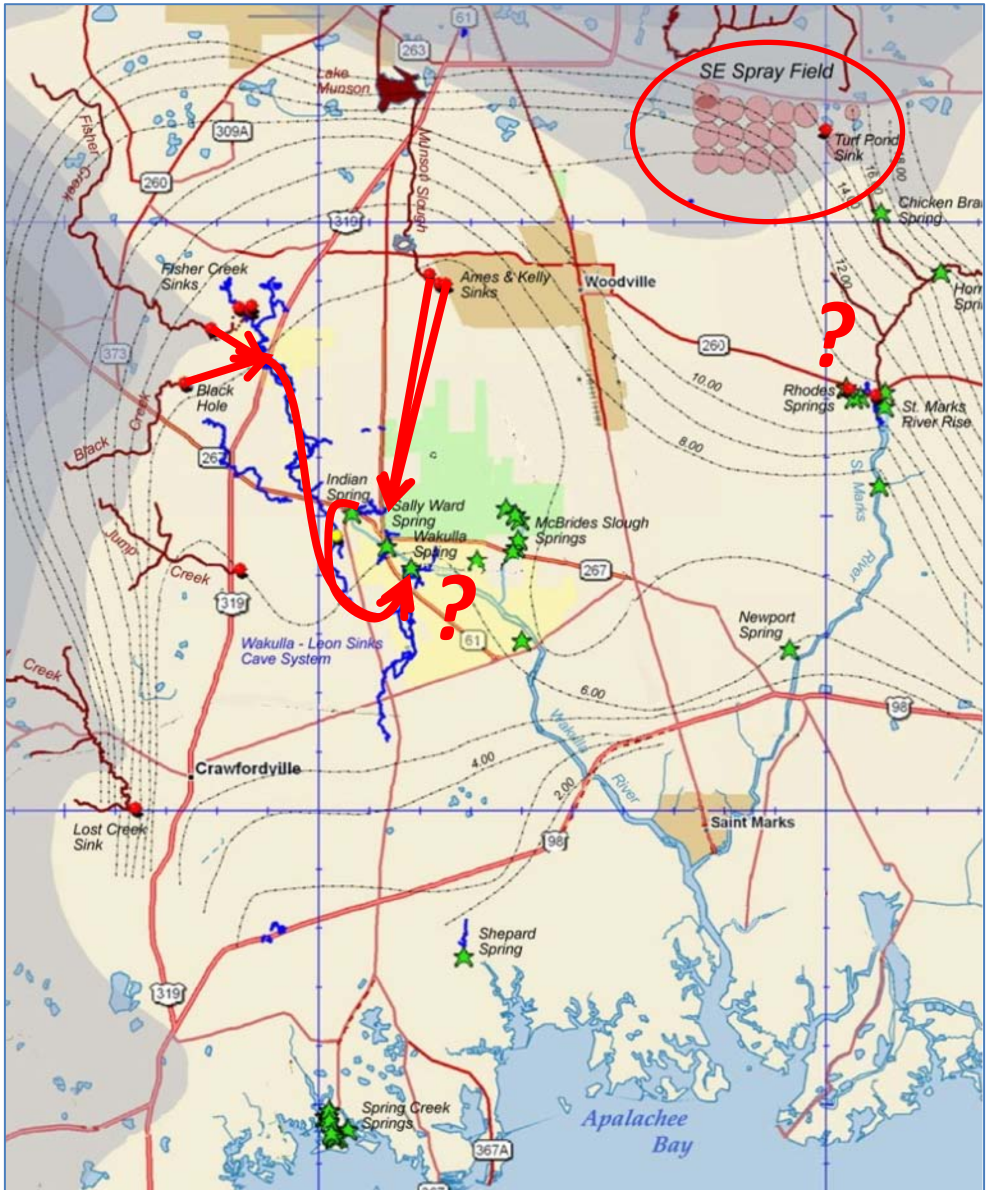
Groundwater Tracing to Wakulla Spring



2002: Fisher Creek – Emerald Sink

1.7 miles / 1.7 days (3,770 ft/day)

2003: Black Creek – Emerald Sink

1.6 miles / 1.6 days (2,670 ft/day)

2004: Emerald Sink – Wakulla Spring

10.3 miles / 7.1 days (7,650 ft/day)

2005: Kelly Sink – Indian Spring

5.2 miles / 13.5 days (2,040 ft/day)

2005: Ames Sink – Indian Spring

5.2 miles / 17.2 days (1,600 ft/day)

2005: Indian Spring – Wakulla Spring

5.5 miles / 5.9 days (4,890 ft/day)

2006: Tallahassee Spray Field

St. Marks or Wakulla?

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Tallahassee Spray Field

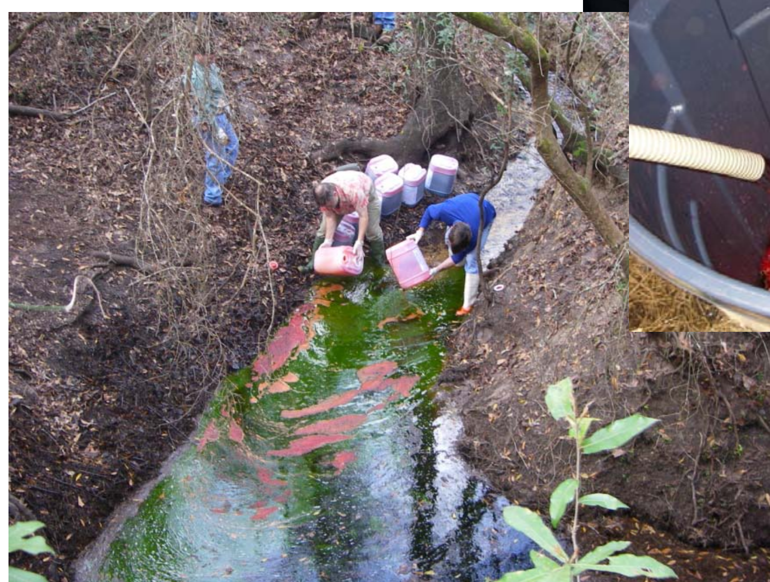
Tracer Injections

Near-field:

- 20kg phloxine-b, 3 wells

Far-field:

- 60kg uranine, 3 wells
- 60 kg eosine, 1 swallet



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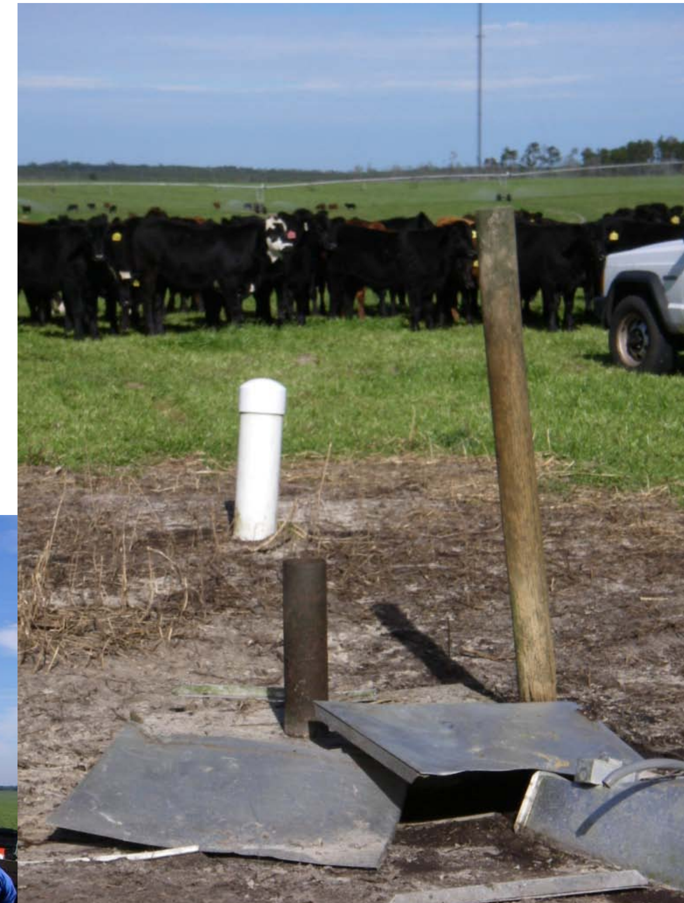
Unexpected Problems…

Cows are curious & mischievous!



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Sampling

- Collected water samples at all locations
- Varied sampling interval throughout duration of test (4 hrs – 12 hrs)
- Initial duration: 4 months – extended to 14 months
- Developed recovery curves for each station

fun stuff!

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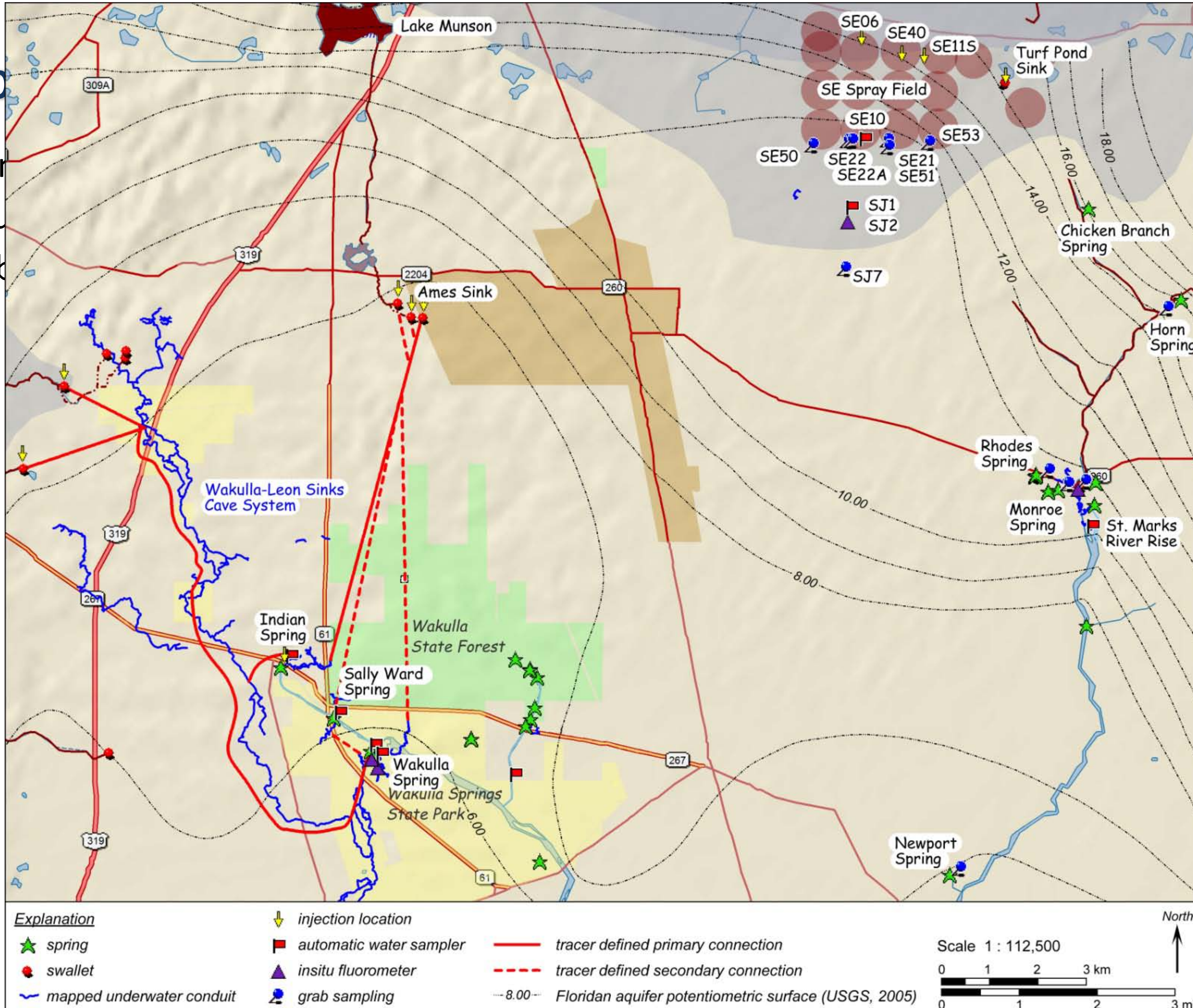
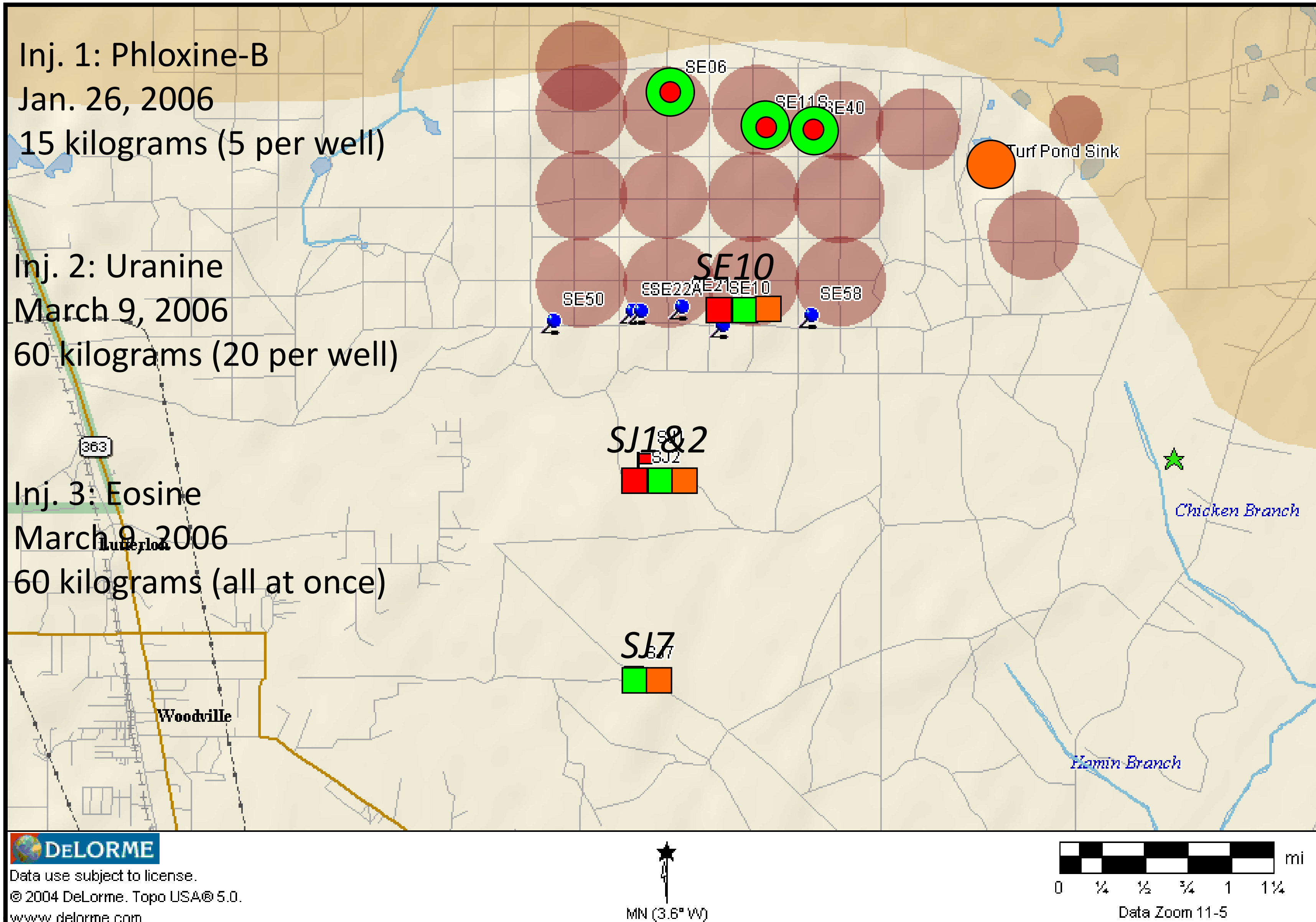
Samp

- 8 autor
- 4 insitu
- 11 grab

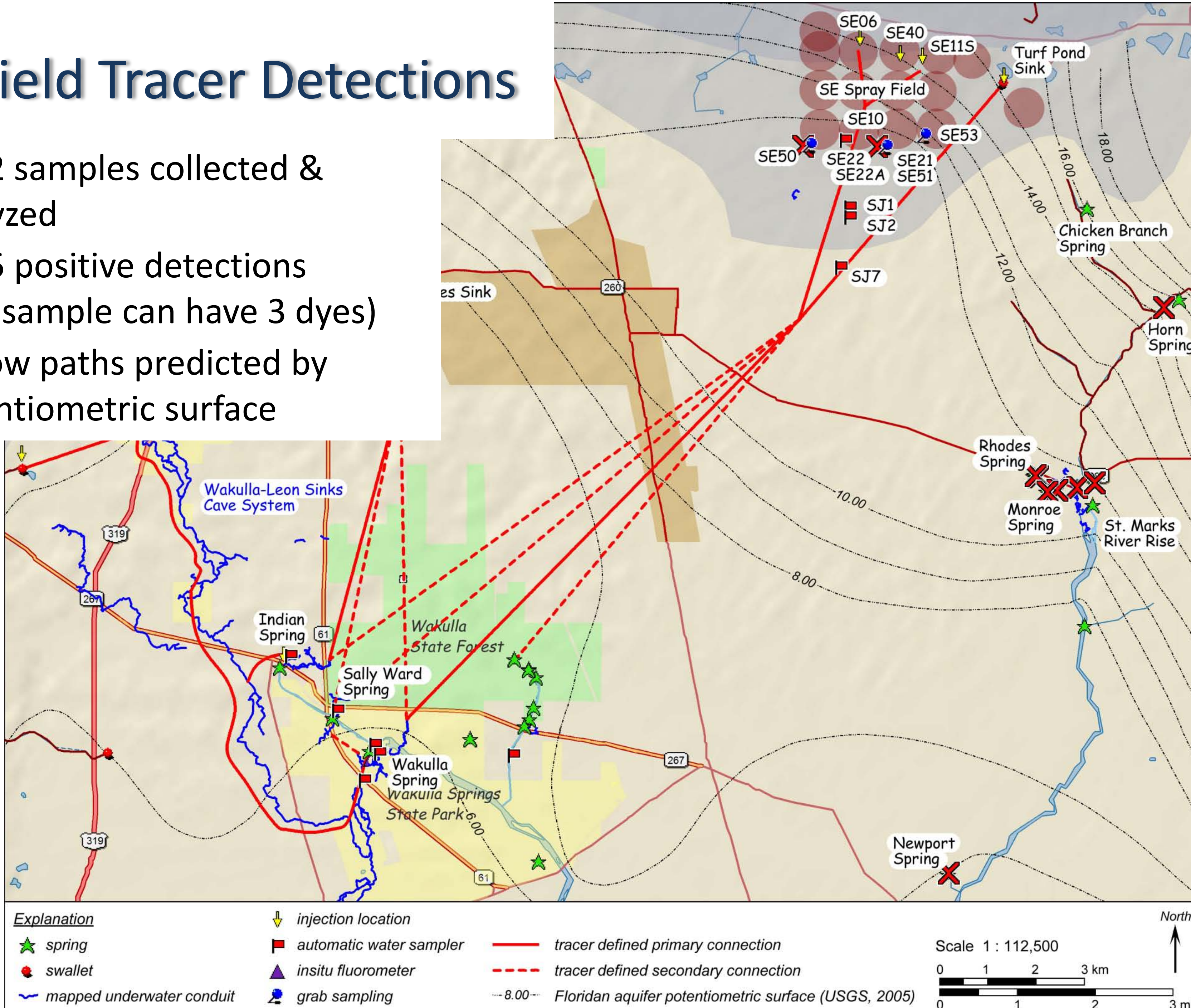


Injection & Near-Field Detections

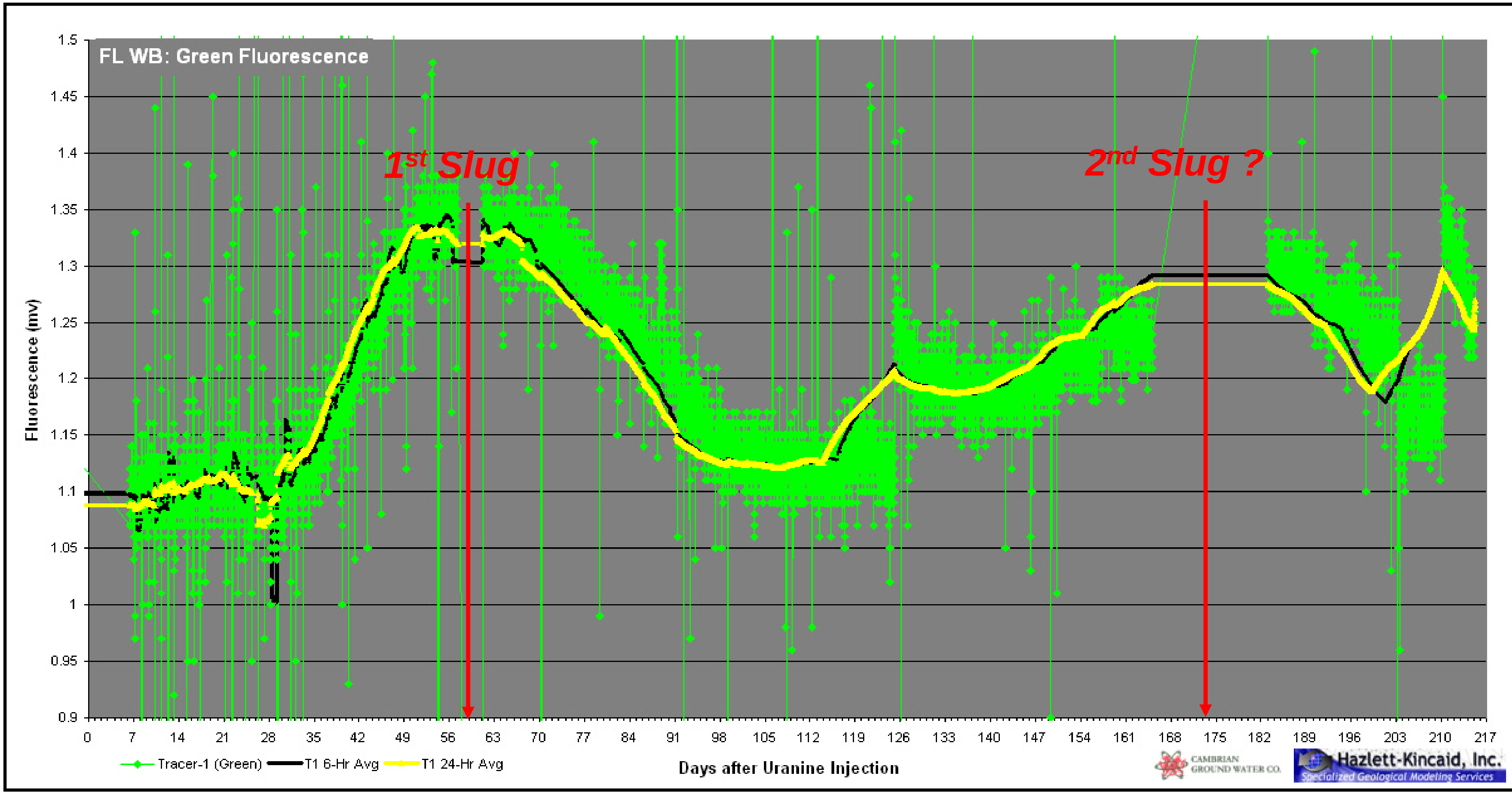


Far-Field Tracer Detections

- 5,262 samples collected & analyzed
- 6,485 positive detections (one sample can have 3 dyes)
- all flow paths predicted by potentiometric surface



Tracer Breakthrough at Wakulla B-Tunnel



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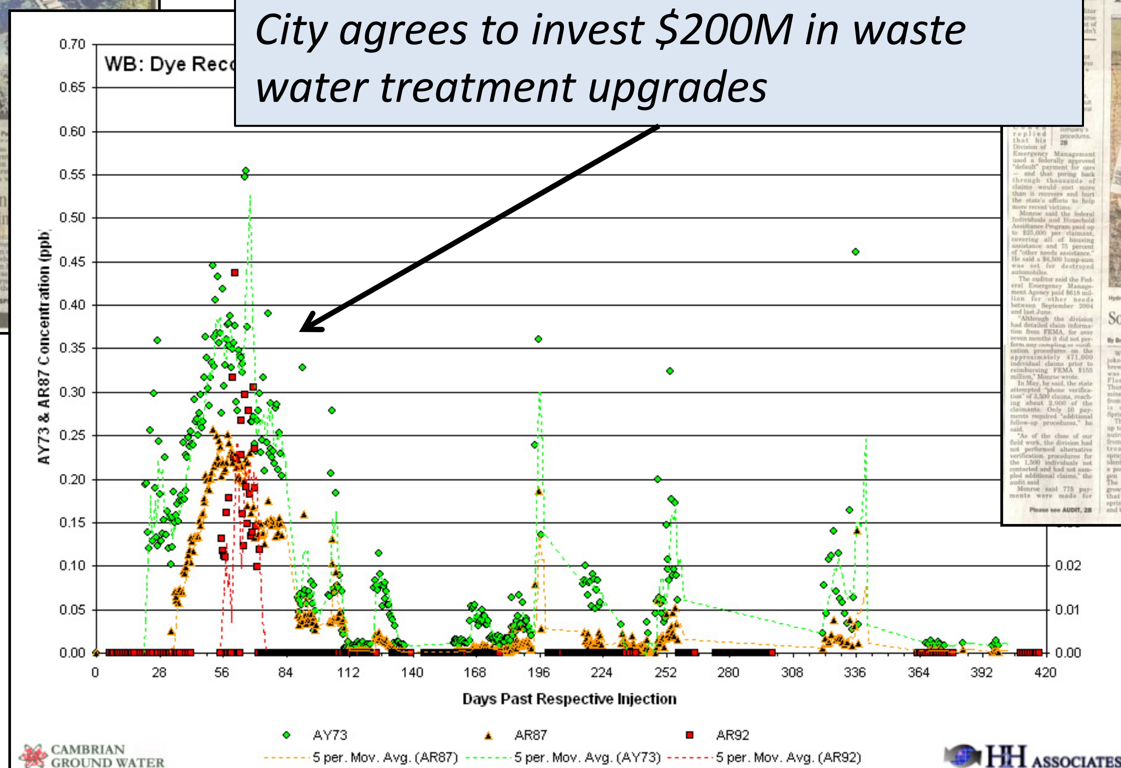
And the Bottom Line?

- $200 Million Dollar Breakthrough Curve

Education + Science + Press = Results

Tracer arrives at Wakulla: ~60 days
City agrees to invest $200M in waste water treatment upgrades



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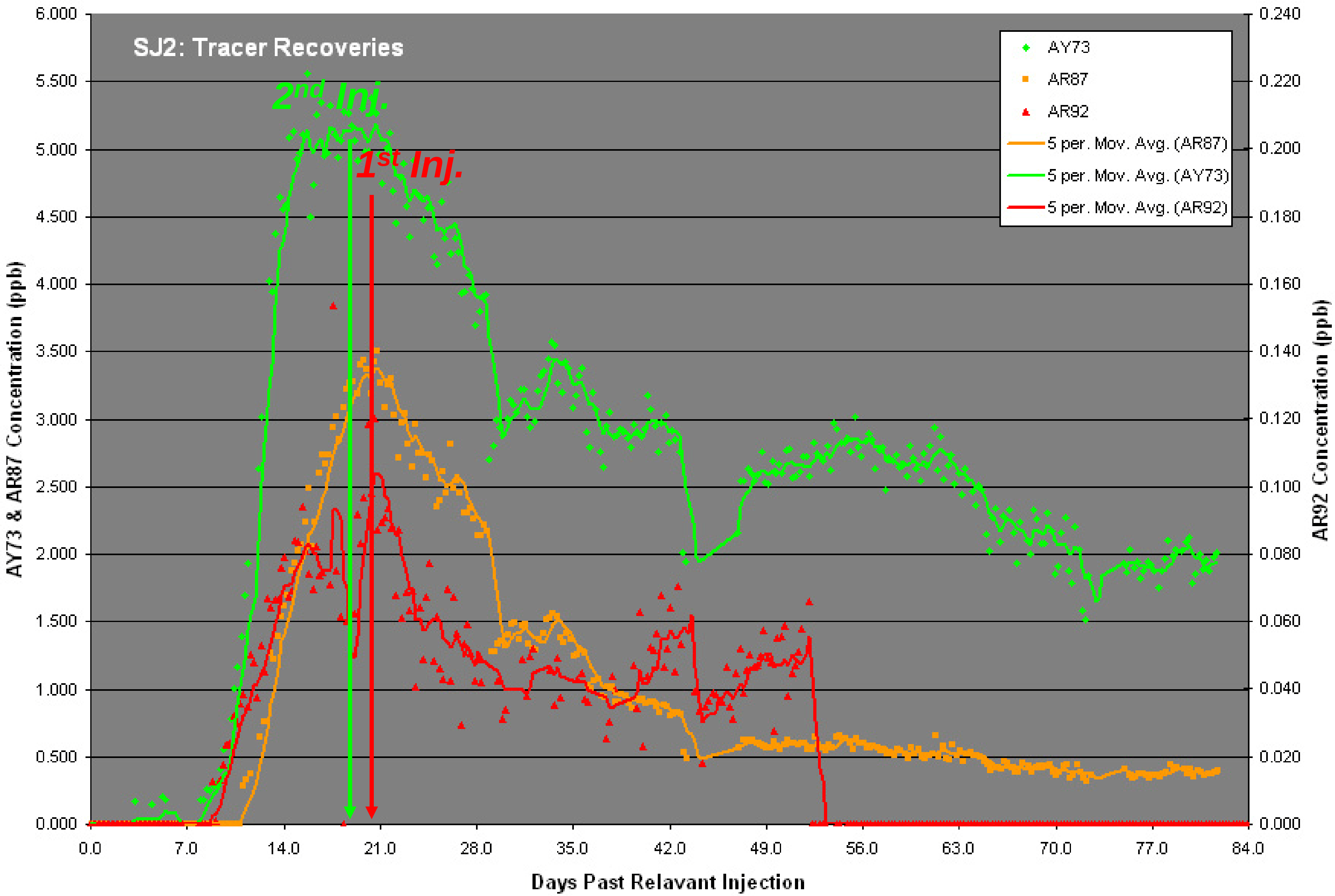
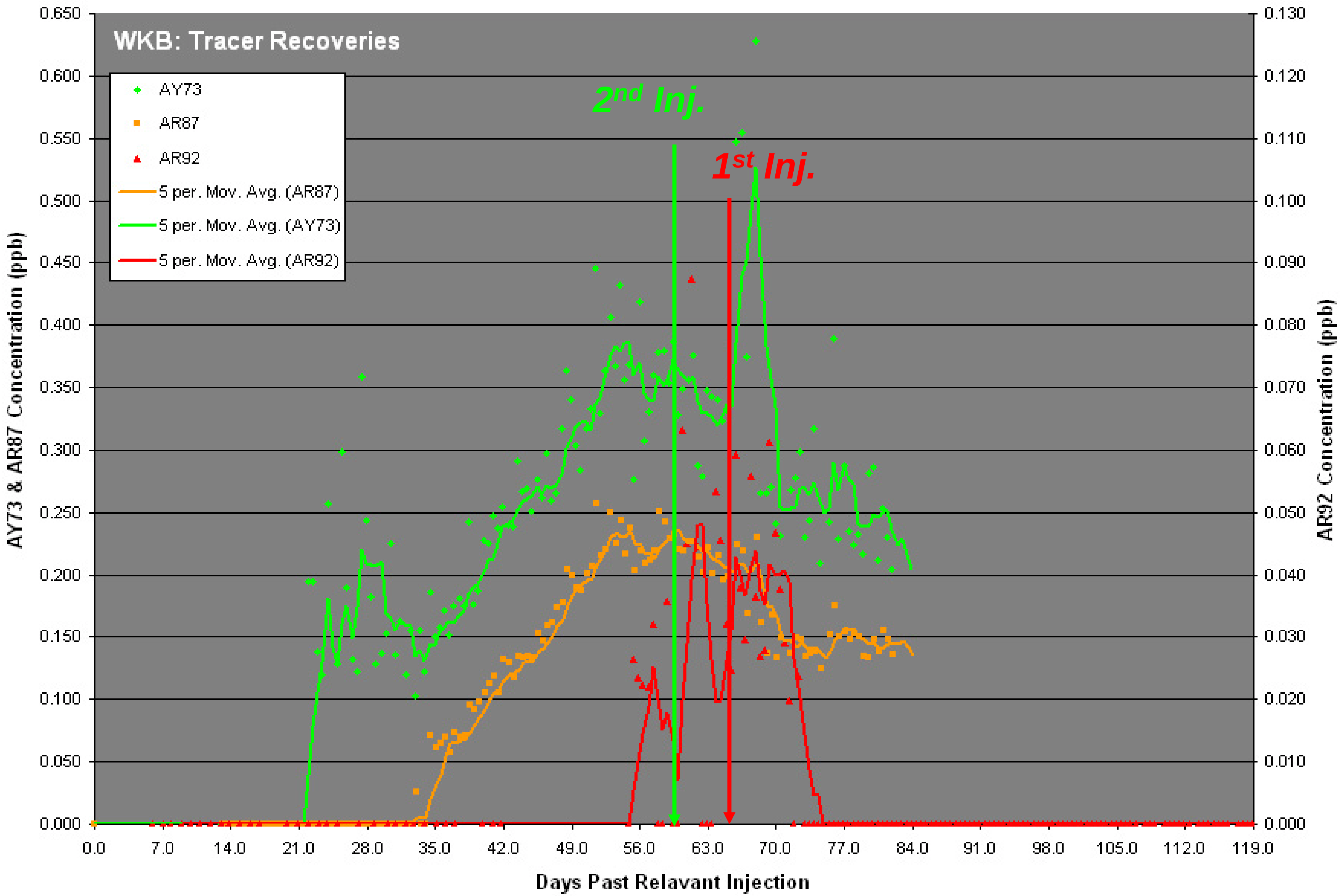
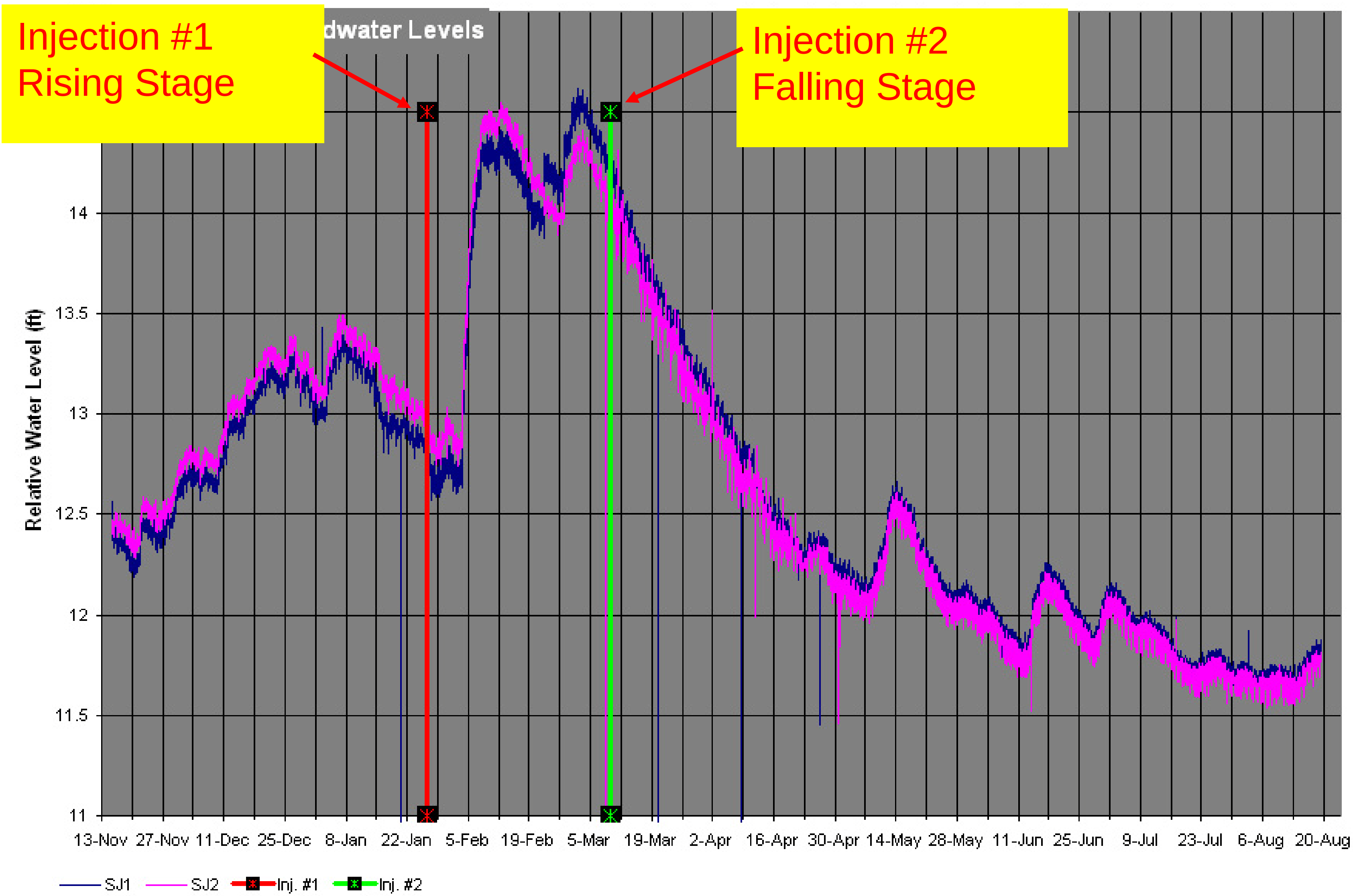
Recovery Curve Analysis – Aquifer Hydraulics



Recovery Curve Analysis – Aquifer Hydraulics

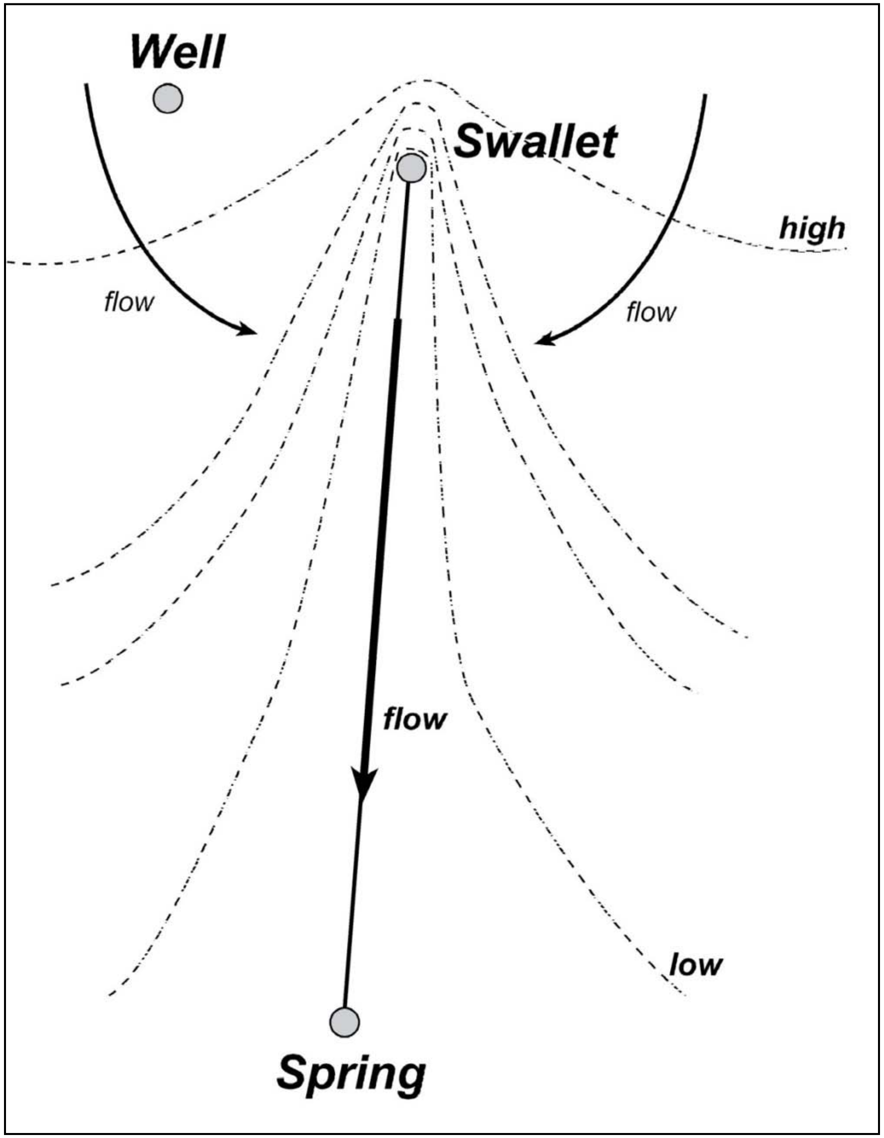


Aquifer Hydraulics – Aquifer / Matrix Interactions

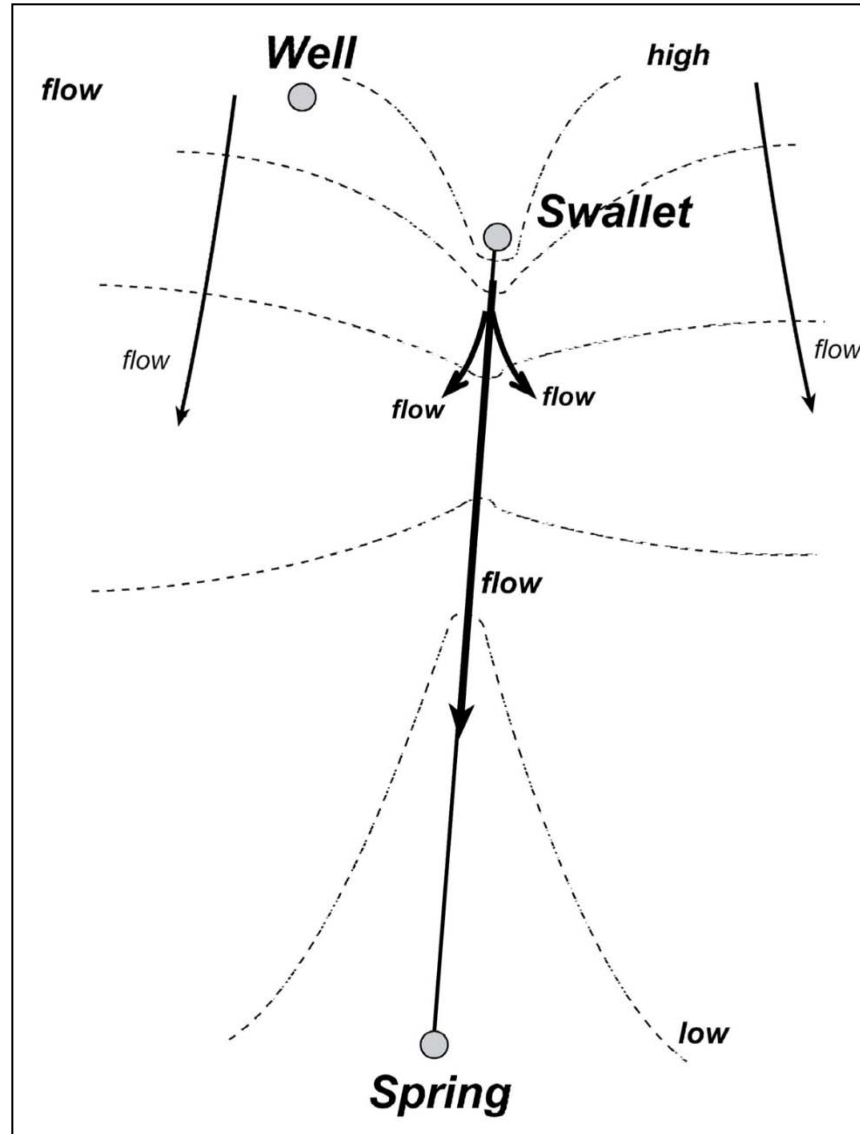


Aquifer Hydraulics

Low Flow



High Flow



Comparison of Calculated Groundwater Velocities

Method	Velocity (m/day)	Assumptions	Source
Tracing	252-2,337 m/day	none	…
Pumping Test Transmissivities	0.03-0.23 m/day	Calculated Gradient Aquifer b = 100m	Bush & Johnston, 1988
Model Derived Transmissivities	0.03 – 1.17 m/day	Calculated Gradient Aquifer b = 100m	Davis, 1996
Geochemical age dates	7.5 – 15 m/day	Age ~20-40 years 100% of Recharge derived from top of basin (~110 km to north)	Chanton, 2002 Katz et al, 2004

Summary

- Three injections performed
  - Near-field: 15 kg phloxine-b in 3 wells at middle of open interval
  - Far-field wells: 60 kg uranine in same 3 wells
  - Far-field swallet: 60 kg eosine in Turf Pond Sink of spray field property
- Sampled at 10 wells & 11 springs
  - Dye detected at 3 wells and 5 springs
  - Detected at all Wakulla area springs
  - Not detected at any St. Marks area springs
- Both phloxine-b and uranine detected at Wakulla B-Tunnel (64 & 60 days after injection respectively)
- Wakulla detections convinced City to invest in advanced wastewater treatment.
- Timing of detections at SJ-1, SJ-2, and Wakulla B-Tunnel reveal how conduits and the matrix interact and respond to changing water levels.
  - Under high-water conditions, swallets are full and pressurize the conduits resulting in slow travel-time through the matrix.
  - Under low-water conditions, swallets are empty, conduits are low pressure zones resulting in fast travel-times through the matrix directed toward the conduits
- We can get much more from tracer tests than pathways and velocities.
- The shape and timing of tracer recovery curves reflect the operative aquifer hydraulics (conduit/matrix exchange, groundwater/ surface water interactions, etc) at the time of the test.

Questions?