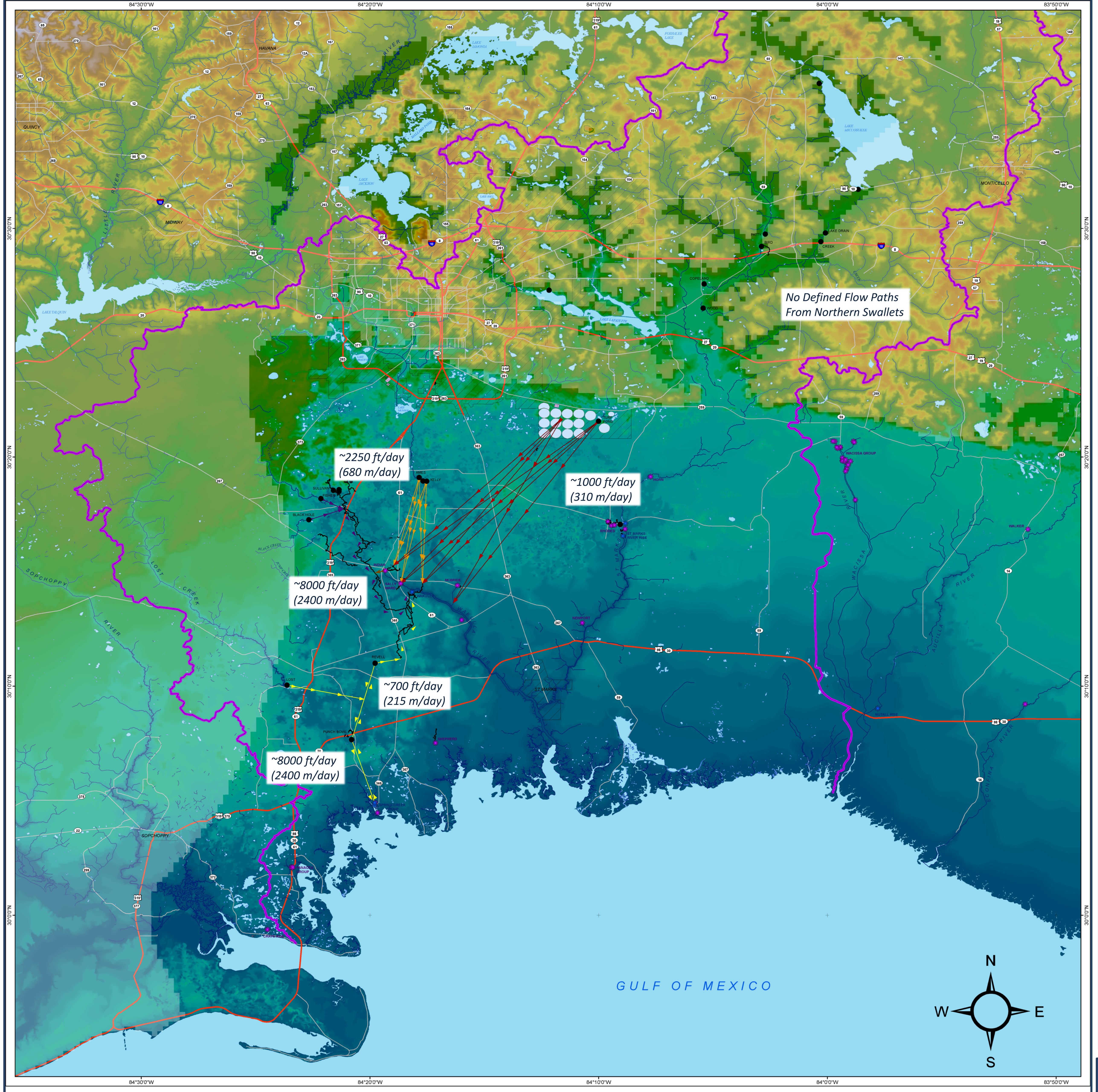

KARST & HYDROLOGIC FEATURES
- 1ST MAG SPRINGS
- 2ND - 4TH MAG SPRINGS
- SWALLETS
- SURVEYED CONDUITS
- RIVERS
- WAKULLA & ST MARKS RIVERS DRAINAGE DIVIDE
- LAKES & PONDS
- RESERVOIR

TRACE PATHWAYS
- AMES SINK
- BLACK & FISHER CREEKS
- INDIAN SPRINGS
- LOST CREEK
- TALLAHASSEE SPRAYFIELD & TURF POND

GEOLOGY

MAP SHOWS REGIONS WHERE THE FLORIDAN AQUIFER IS CONFINED AND UNCONFINED. AREAS WHERE THE TOPOGRAPHY IS MUTED (WEST & NORTH) REPRESENT WHERE THE FLORIDAN IS COVERED BY AT LEAST A 10FT THICKNESS OF THE INTERMEDIATE CONFINING UNIT (ICU). THE ICU CONSISTS OF MIOCENE AND PLIOCENE CLAYEY SAND AND SANDY CLAY.

SITE MAP

HYDROLOGIC FEATURES OF THE WOODVILLE KARST PLAIN
WAKULLA RIVER DRAINAGE BASIN
NORTHWEST FLORIDA

SCALE 1 : 100,000

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CONTRIBUTORS

POLITICAL FEATURES
- INTERSTATE ROUTE
- US ROUTE
- STATE & COUNTY ROUTE
- TALLAHASSEE SPRAYFIELD CENTER PIVOTS
- MUNICIPAL BOUNDARY

ELEVATION
FEET
300
0

0 1.5 3 6 9 12 Miles

MAP PROJECTION: WGS 1984 MAP CREATED: SEPT 1, 2010

TRACING REVERSING GROUNDWATER FLOWS IN THE COASTAL FLORIDAN AQUIFER

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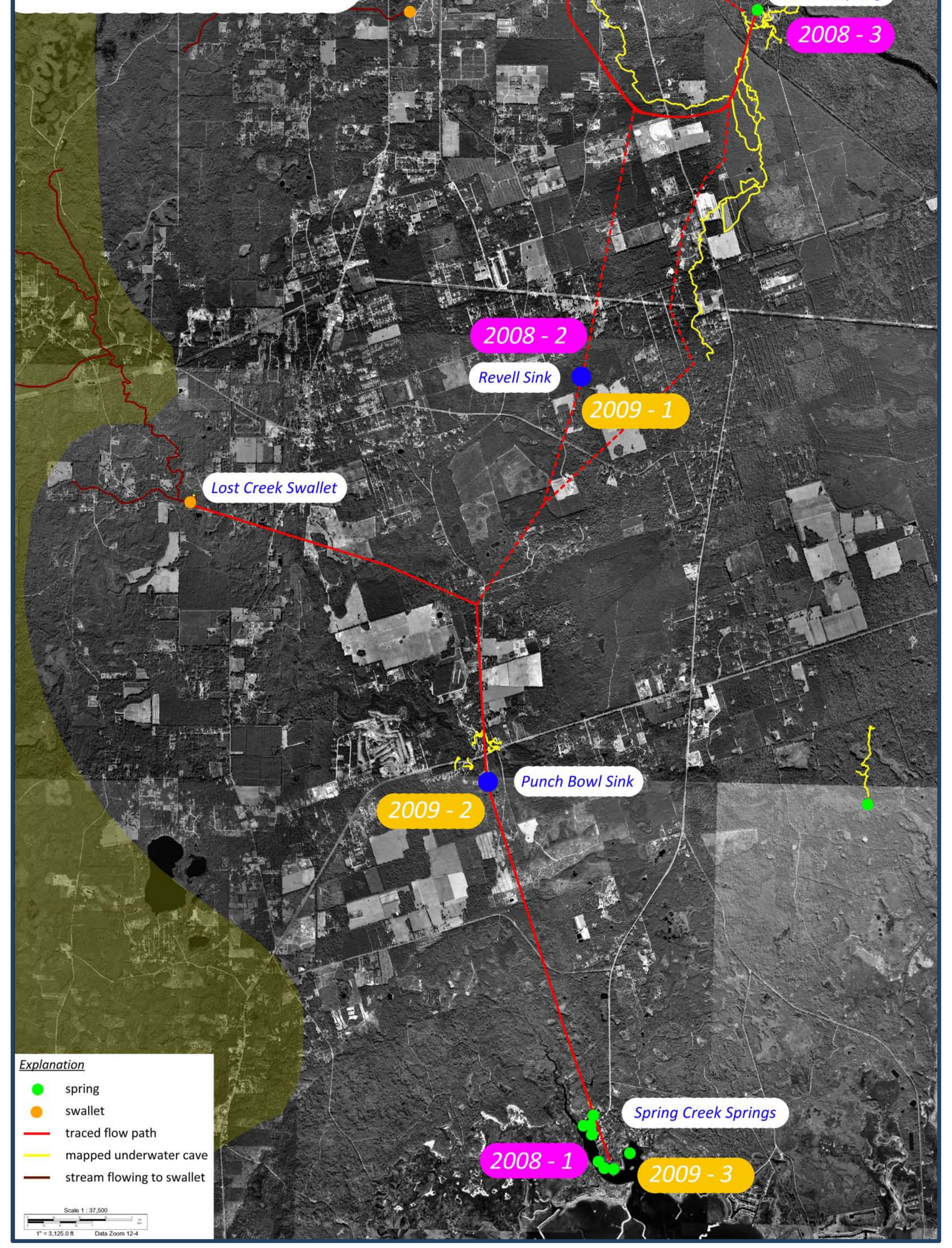
ABSTRACT NO: 182283

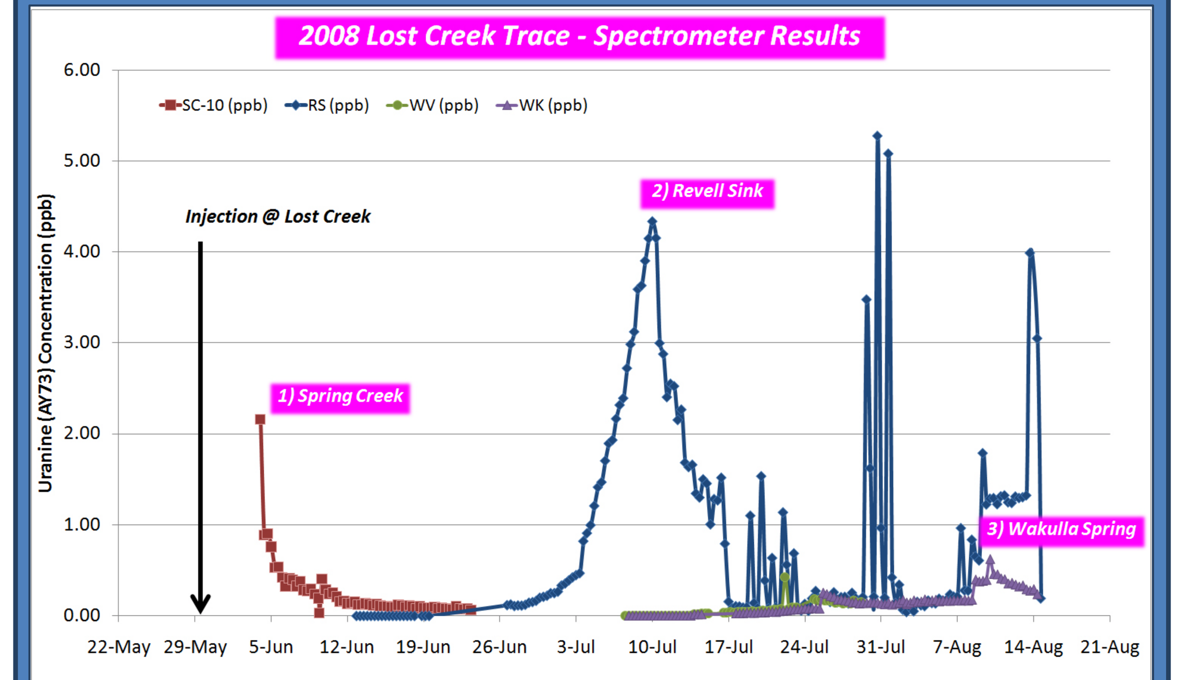
Groundwater tracing done in 2008 and 2009 reveal that Wakulla Spring and the Spring Creek Spring Group (both 1st magnitude springs) the latter approximately 16 km down-gradient from Wakulla Spring on the coast of the Gulf of Mexico, are connected via one or more conduits. Both Wakulla and Spring Creek springs display a very large range in discharge due to their connection to numerous swallet inputs whose inflows are dependent on rainfall. Prior to 2006, baseflow at both springs was thought to be composed of groundwater flow derived from distant diffuse recharge. Following 2006, the Spring Creek vents reversed flow for extended periods during low stage. This had not previously been documented. During these reversal periods, siphoning water can be observed at the surface of the Spring Creek vents and Wakulla Spring's discharge increases.

Both tracer tests were performed by injecting C.I. AY73 (uranine) dye into a large swallet (Lost Creek Sink) 8 km SW of Wakulla Spring and 8.5 km NW of Spring Creek. Sampling for both tests was conducted as continuously as possible at three Spring Creek vents (#1, #2, and #10), Wakulla Spring, and at intermediate karst windows known or suspected to connect to the conduit system. In 2008, the tracer was injected into the swallet prior to the Spring Creek reversal. The tracer was detected first at Spring Creek until initiation of the reversal and then approximately 45 days later at Revell Sink, a karst window north of the Lost Creek Sink, and then at Wakulla Spring. In 2009, the tracer was injected after Spring Creek began reversing. This time, the tracer again migrated to Revell Sink presumably on the same path toward Wakulla Spring as it did in 2008, but only until Spring Creek began flowing, when the tracer reversed direction to the south and quickly flowed to the Spring Creek vents. These results document the extent to which groundwater flow patterns in the Floridan aquifer are impacted by conduits and also demonstrate the rapidity of and inland extent to which the coastal region of the aquifer can be impacted by saltwater intrusion.

Tracer Detections

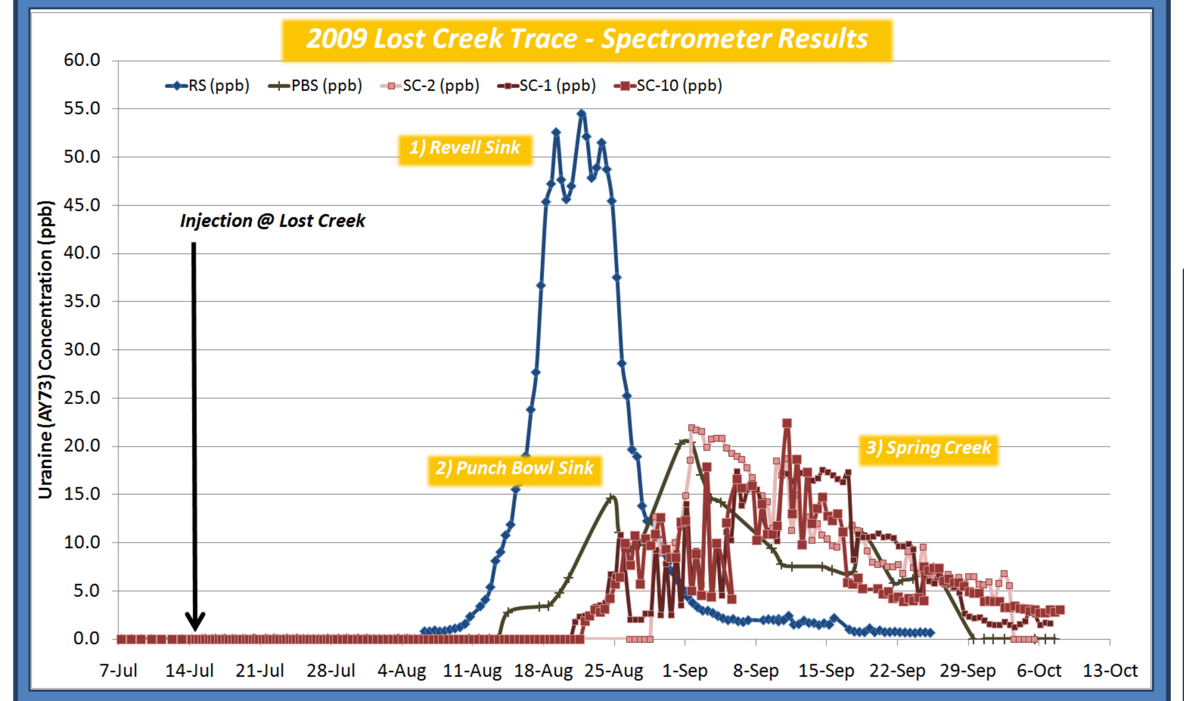


2008 RECOVERY CURVES



- May 29: Injected 10 kg Uranine (AY73) into the Lost Creek Swallet.
- May 30: Sampling at Spring Creek halted due to property owner relations.
- June 3: First sample at Spring Creek. Tracer detected at vent #10 (SC-10). No detections at other vents.
- June 23: Tracer concentrations fall below detection limit at vent #10.
- June 26: First tracer detection at Revell Sink (RS).
- July 10: Peak tracer concentration measured at Revell Sink.
- July 13: First tracer detections in Wakulla Cave (WK) and Wakulla Spring (WV).

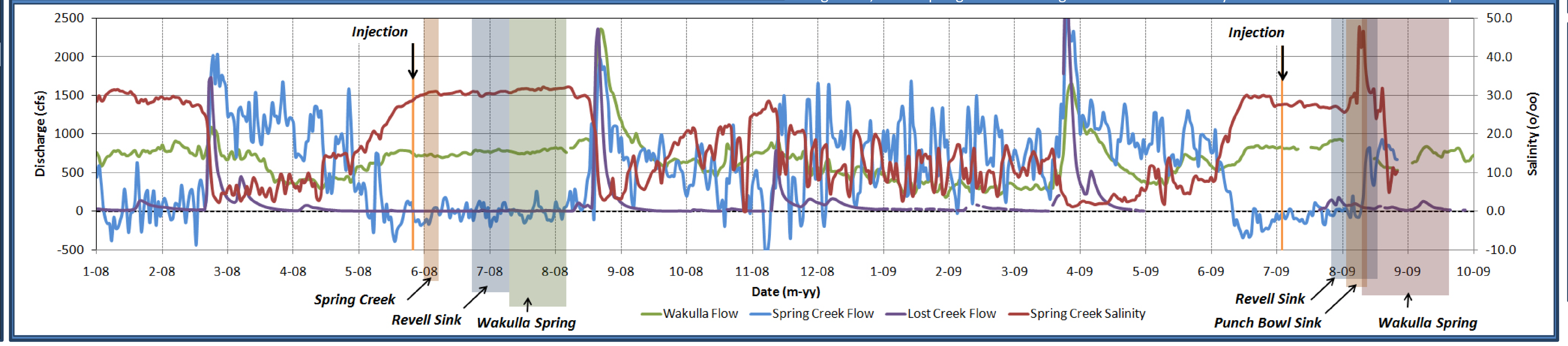
2009 RECOVERY CURVES



- July 14: Injected 15 kg Uranine (AY73) into the Lost Creek Swallet.
- August 6: First tracer detection at Revell Sink (RS).
- August 14: First tracer detection at Punch Bowl Sink (PBS).
- August 21: First tracer detection at Spring Creek (SC-1, SC-2, SC-10).

FLOW & SALINITY

- May 2008: Spring Creek & Lost Creek flow declining / Wakulla flow increasing. Spring Creek salinity increasing.
- June 3 2008: Spring Creek vents shutting down / only #10 still flowing at time of 2008 tracer injection.
- Mid June 2008: Lost Creek not flowing. Spring Creek vents siphoning. Salinity reaches sea water levels.
- June 2009: Spring Creek flow declining / Wakulla Spring flow increasing. Salinity in Spring Creek increasing.
- July 14, 2009: Spring Creek vents siphoning at time of 2009 tracer injection.
- July 31, 2009: Spring Creek vents begin to discharge sporadically.
- August 16, 2009: Spring Creek discharge increases dramatically. Water level in Punch Bowl Sink plummets.

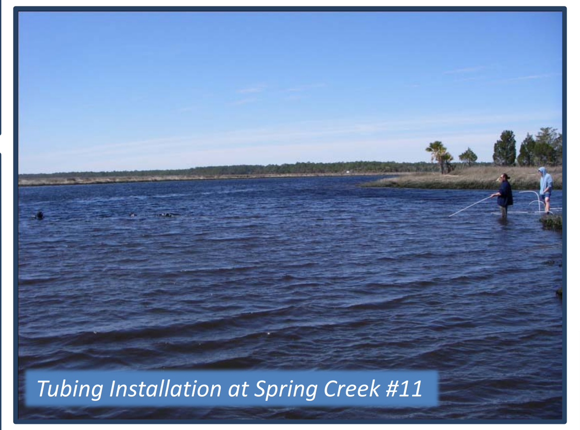


FLOW DIRECTIONS & TRAVEL TIMES

2008 Test
- Spring Creek beginning to siphon at time of injection but vent #10 still discharging.
- Tracer traveled rapidly south to Spring Creek.
  - minimum distance: 7.5 miles (12 km)
  - approximate travel time: 5 days
  - 1.5 miles/day (2.4 km/day)
- Spring Creek #10 reverses – majority of tracer cloud had not reached Spring Creek.
- Tracer changed direction and traveled north to Revell Sink.
  - minimum distance (~probable conduit junction to Revell Sink): 4 miles (6.4 km)
  - approximate travel time: 30 days
  - 700 ft/day (215 m/day)
- Tracer continues north to Wakulla Spring.
  - minimum distance (~probable conduit junction to Wakulla Spring): 7.75 miles (12.4 km)
  - approximate travel time: 47 days
  - 870 ft/day (265 m/day)

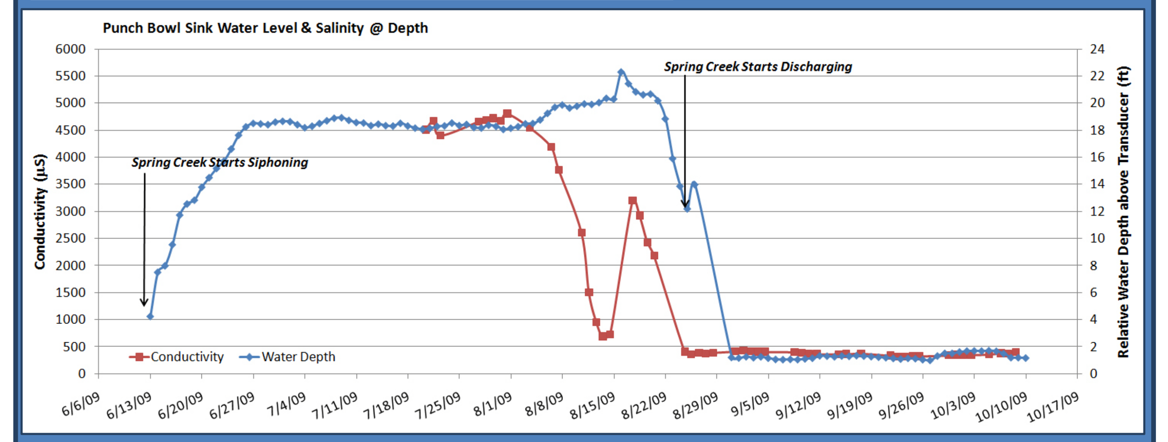
2009 Test
- All Spring Creek vents siphoning at injection.
- Tracer traveled slowly north to Revell Sink.
  - minimum distance: 5.25 miles (8.4 km)
  - approximate travel time: 39 days
  - 710 ft/day (215 m/day)
- Spring Creek starts flowing again before tracer cloud passes Revell Sink to reach Wakulla Spring.
- Flow in conduit at Revell Sink changes direction to the south.
- Tracer leaves Revell Sink and travels south to Punch Bowl Sink.
  - minimum distance: 3.5 miles (5.6 km)
  - approximate travel time: 8 days
  - 2300 ft/day (700 m/day)
- Tracer continues south to Spring Creek and is detected at all major spring vents.
  - minimum distance: 7.5 miles (5.6 km)
  - approximate travel time: 10 days
  - 3950 ft/day (1200 m/day)


Wakulla Cave Looking Back at the Spring Entrance


Tubing Installation at Spring Creek #11


Preparing to Dive at Spring Creek #10

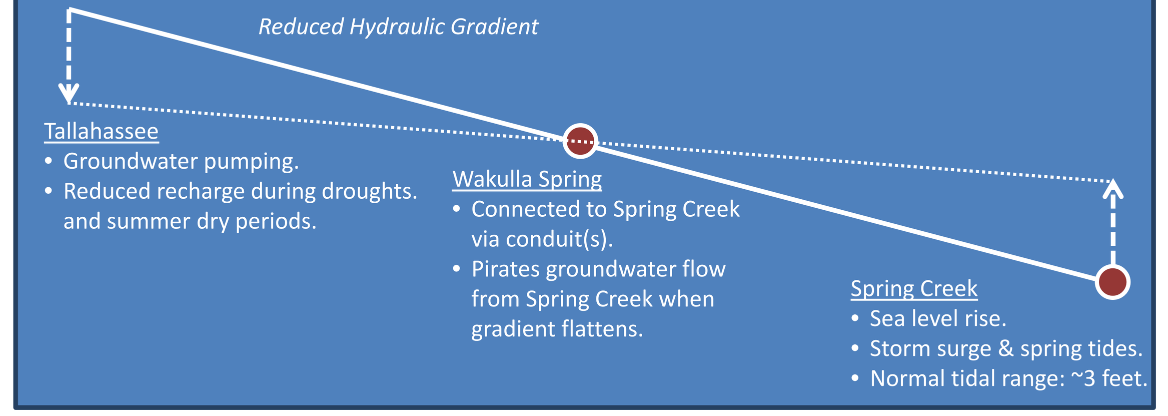
IMPACTS ON STORAGE & GROUNDWATER QUALITY



When Spring Creek stops flowing or reverses …
- Water level in sinkhole rises precipitously.
- Salinity below 200 feet rises.
- Salinity in shallow water does not change.

When Spring Creek starts flowing again …
- Water level in sinkhole falls precipitously.
- Salinity below 200 feet decreases.

MECHANISMS DRIVING FLOW REVERSALS



CONCLUSIONS & IMPLICATIONS

- Prolonged reversals of the Spring Creek spring vents were first observed in the summer of 2006 and have occurred every summer since that time.
- Tracer-defined flow paths reveal that Wakulla Spring and Spring Creek Springs are connected by one or more large conduits.
- Spring Creek reverses when water levels in the southern part of the Floridan aquifer fall below a critical level that allows tidal fluctuations in Spring Creek to reverse the hydraulic gradient near the coast.
- When Spring Creek reverses, salt water flows into the conduits that connect to the spring vents far enough north to impact salinity levels in Punch Bowl Sink (~4 miles 6.4 km inland from the coast) and Wakulla Spring flow rises significantly.
- The denser salt water creates a hydraulic dam that prevents fresh ground water discharge from the Spring Creek vents.
- A larger than normal head gradient is required to flush the salt water out of the conduits following water levels (storage) in the coastal part of the aquifer (at least as far inland as Punch Bowl Sink) to rise.
- Diminished water clarity conditions at Wakulla Spring that have been observed during the summer months since 2006 are likely due to the quality of the water that Wakulla Spring pirates from the Spring Creek springshed during the Spring Creek reversals.
- The return of flow to Lost Creek provides sufficient head in the conduits to flush out the salt water.
- When Spring Creek vents begin discharging, water levels (storage) in the coastal part of the aquifer fall precipitously and Wakulla Spring flow declines.
- Increases in groundwater withdrawals in the northern part of the region (Tallahassee) will likely exacerbate this problem because they will reduce the hydraulic gradient to the coastal springs.
- Minimum flows and levels (MFLs) should be established for Wakulla and Spring Creek springs collectively and should be protective of sufficient groundwater flow to Spring Creek to prevent prolonged reversals.
- The Wakulla / Spring Creek flow system is larger but similar to several other inland/coastal spring cave systems in Florida's Karst Belt that extends from Tallahassee to Tampa.
- Groundwater flow models that are used to manage groundwater resources in these regions must account for spring / cave systems in order to accurately simulate and thus predict potential salt water intrusion associated with inland groundwater pumping.

ACKNOWLEDGEMENTS

This work was funded by the Florida Geological Survey and Florida Department of Environmental Protection Springs Initiative Program and a grant from the National Oceanographic and Atmospheric Administration. Flow and salinity data for Spring Creek was provided by the U.S. Geological Survey. Data collection at Spring Creek, Revell Sink, and Punch Bowl Sink was made possible by the generous support and cooperation of the Spears, Trickie, Revell, and Weeks families.


Boil at Spring Creek #1


Siphon Swirl at Spring Creek #1

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