Benthic Sources and Sinks of Nutrients and Trace Elements

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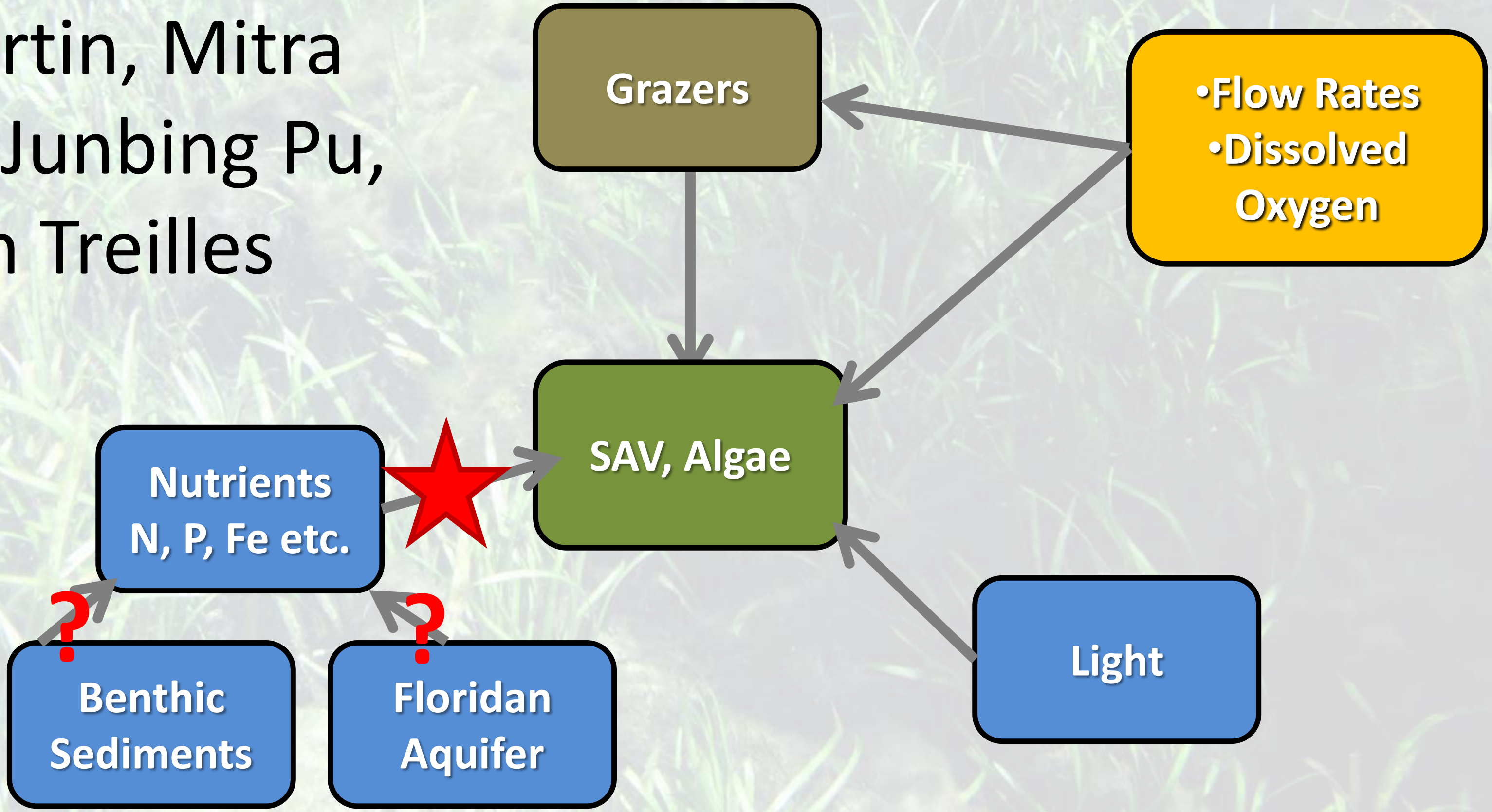
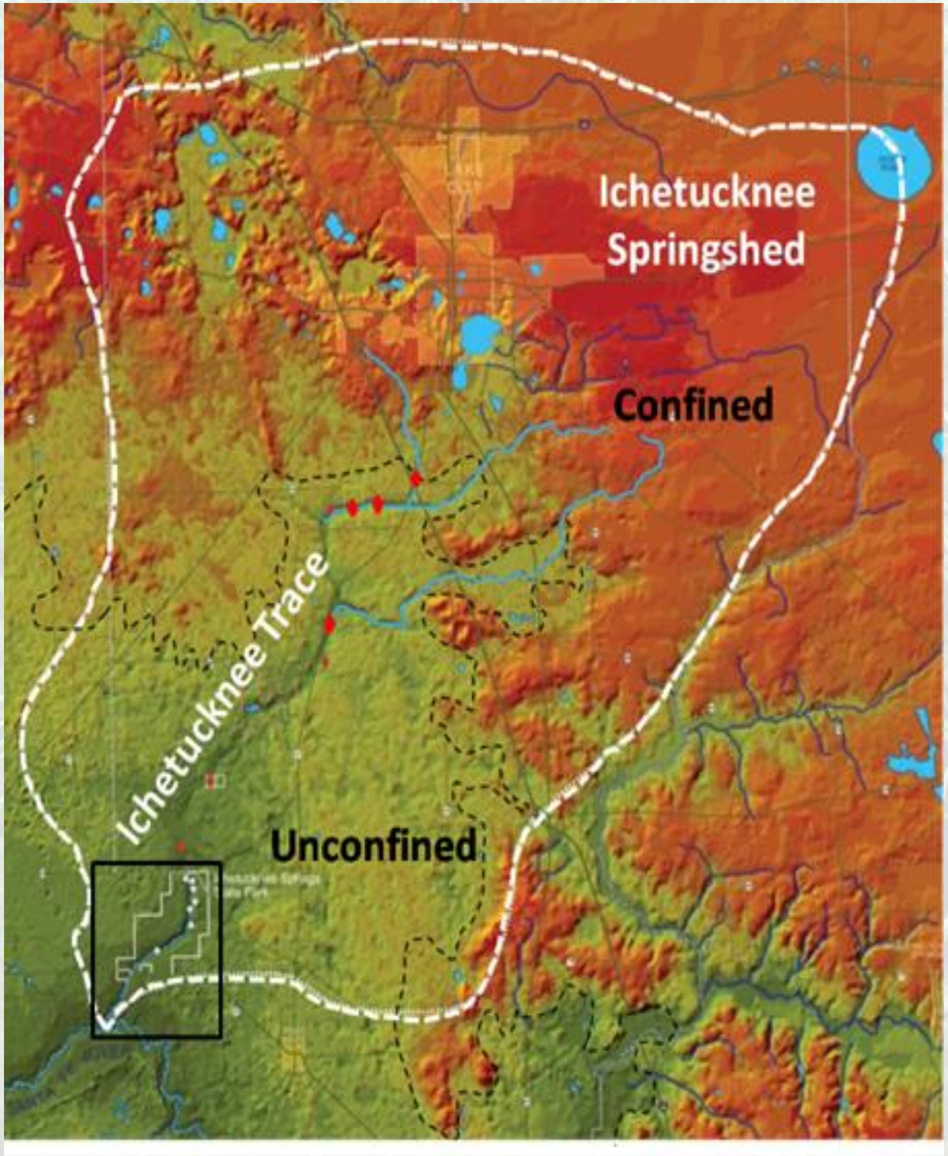


Modified from M Cohen

Ichetucknee

- Rock outcroppings of Floridan aquifer
  - Fairly typical of Florida springs
- Direct connection between river and aquifer
- Kurz et al. (2014) estimate seepage contributions:
  - Hyporheic zone ~3% of total discharge
  - Bypass hyporheic zone ~10% total discharge

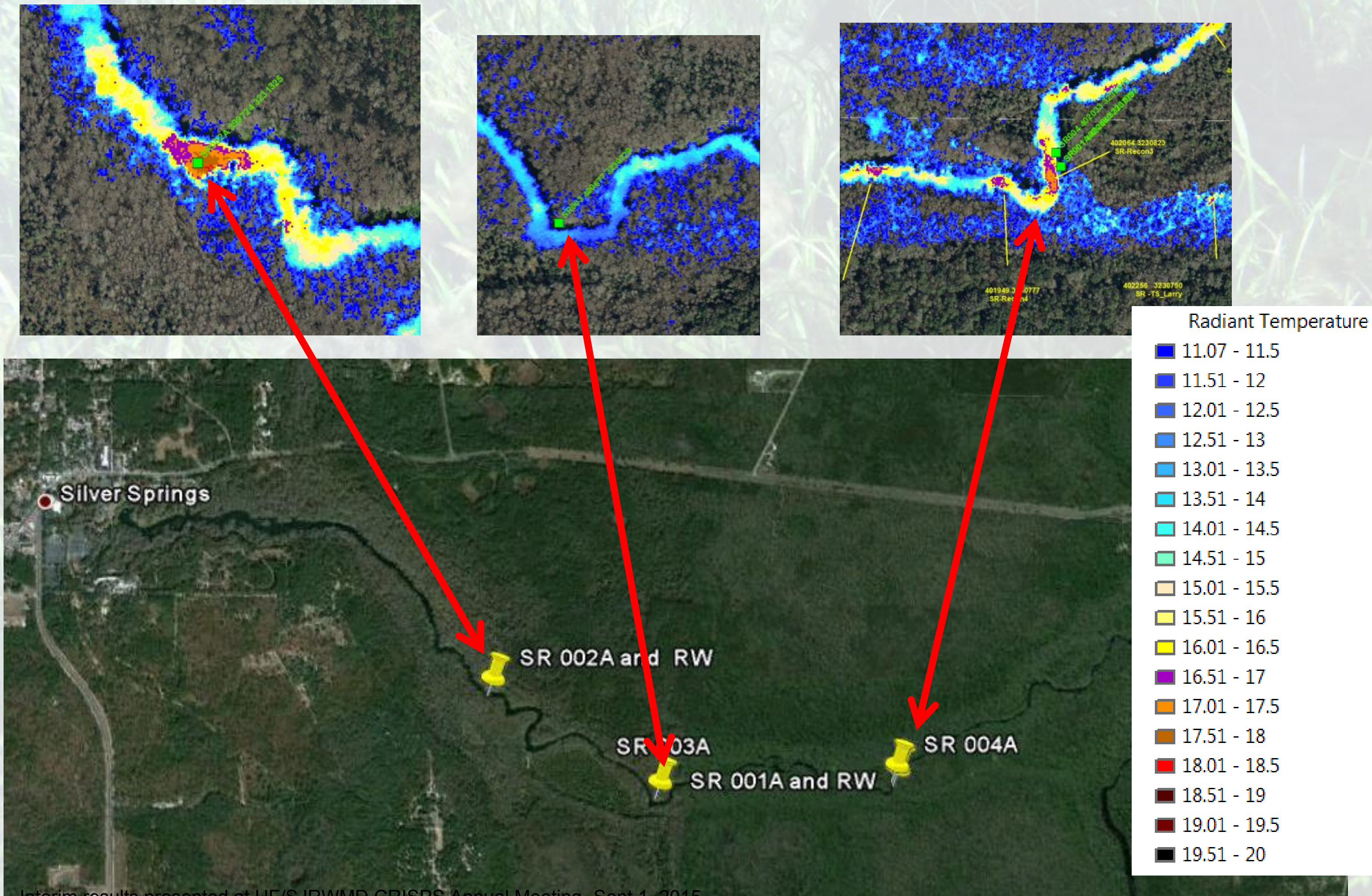
DEM Ichetucknee Springshed



- Cody scarp separates upland from springs
- Discharge from unconfined Floridan aquifer
  - Where water table intersects land surface
  - Sea level control?
- Flow across and in direct contact with Floridan aquifer

Silver River Thermography

- Appears to reflect point discharge
- Preliminary sampling indicated altered pore water compositions



Thermography images courtesy of Jeff Davis, SJRWMD

Four Project Elements

Many different hats:

1. Measure river bottom sediment thickness
2. Measure physicochemical properties of sediment
   A. C, N, P, metal (Fe) concentrations
   B. Porosity, permeability
3. Measure head gradients between pore water and river
4. Measure chemical compositions of pore waters

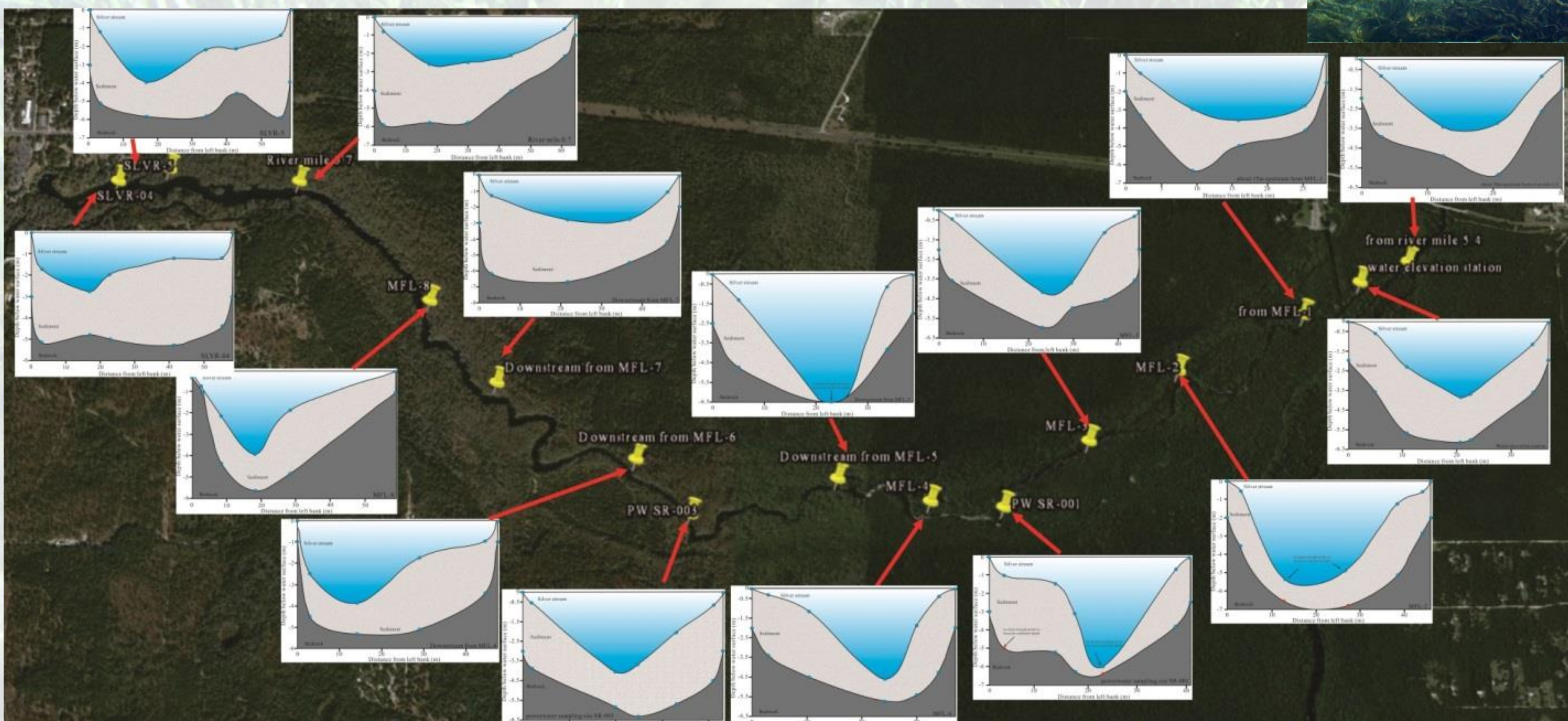
Overall Goal

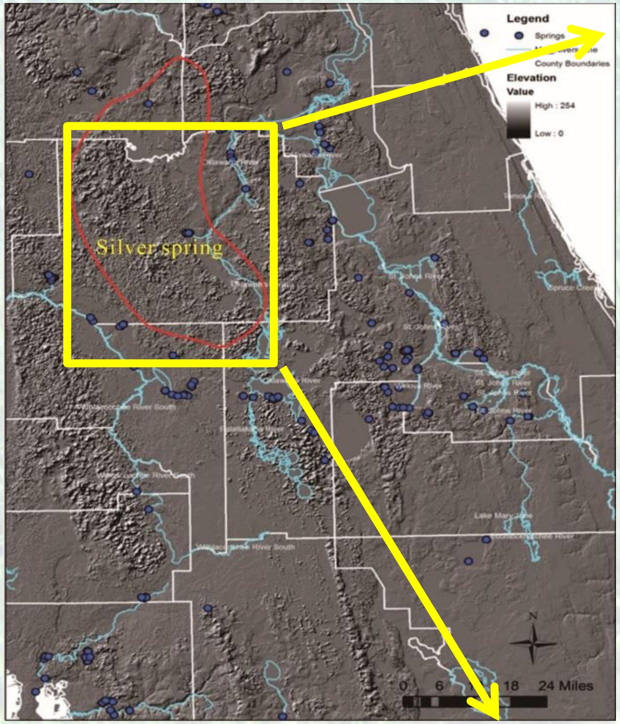
1. Measure sediment thickness
2. Measure physicochemical properties of sediment
   A. C, N, P, metal concentrations
   B. Porosity, permeability
3. Measure chemical compositions of pore waters
4. Measure head gradients between pore water and river

Estimate benthic fluxes (diffusive and advective) of nutrients (C,N,P, & Fe) to river

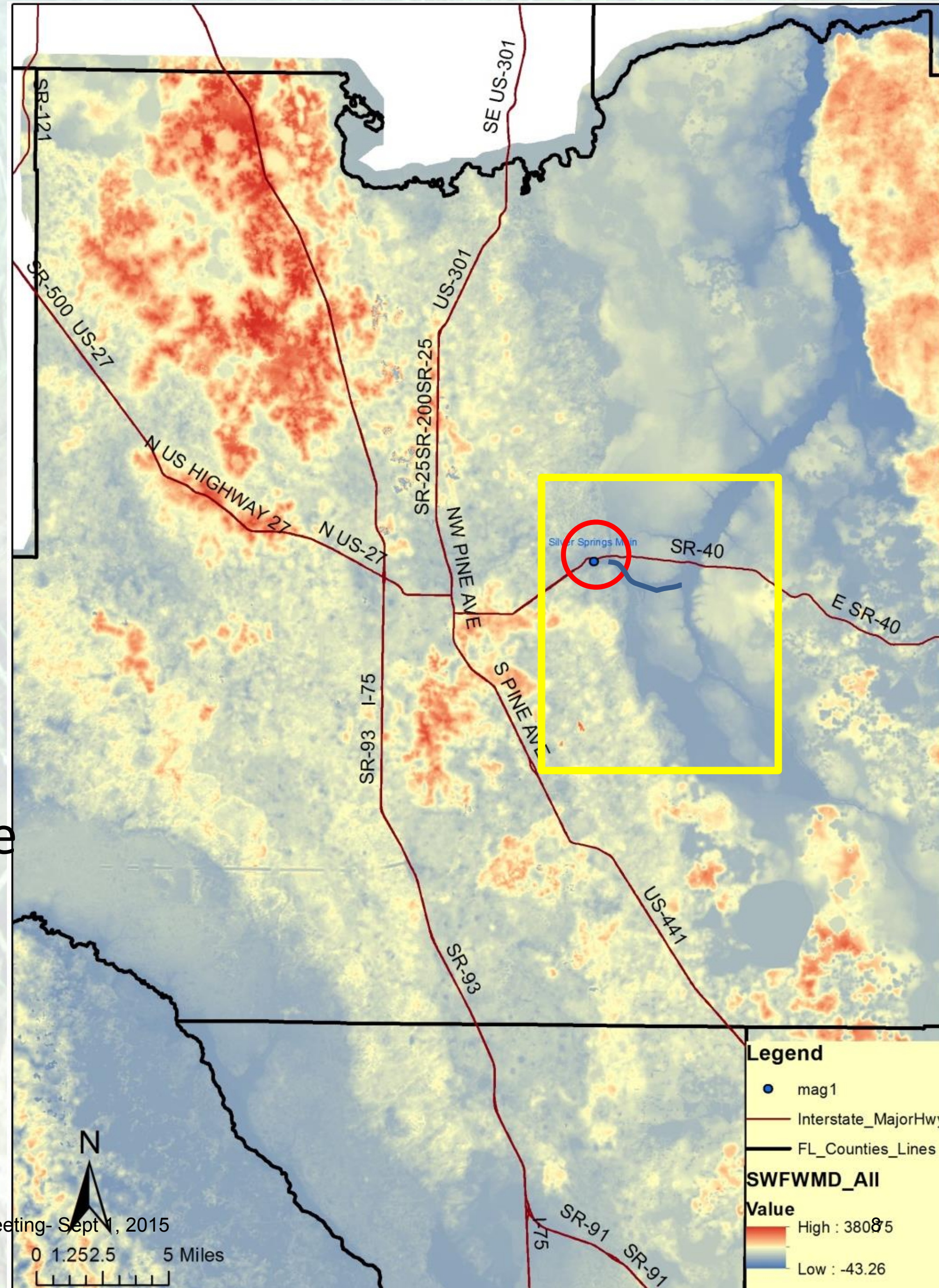
Element 1. Sediment Thickness

- 14 Transects – reoccupy MFL transect
- Sediment distributed across entire river
- Thickness 1 to > 6 m
- What is origin of sediments? Why so different from other spring systems?





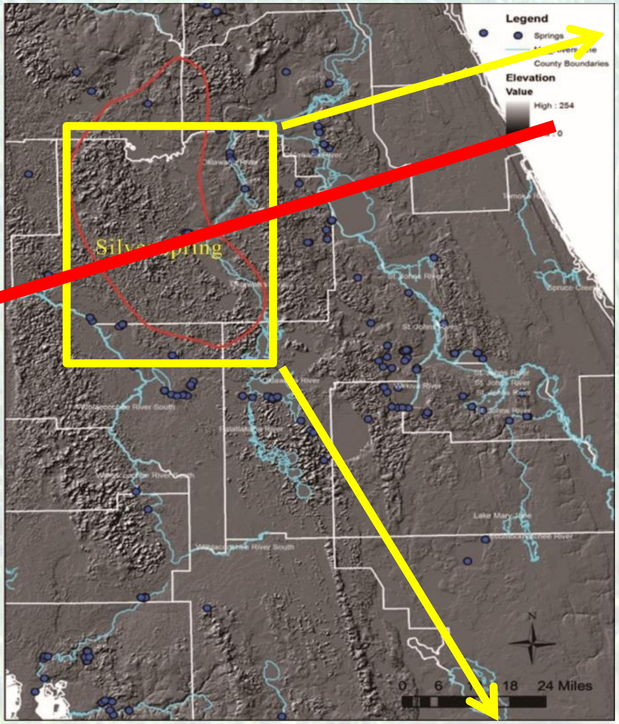
Regional DEM



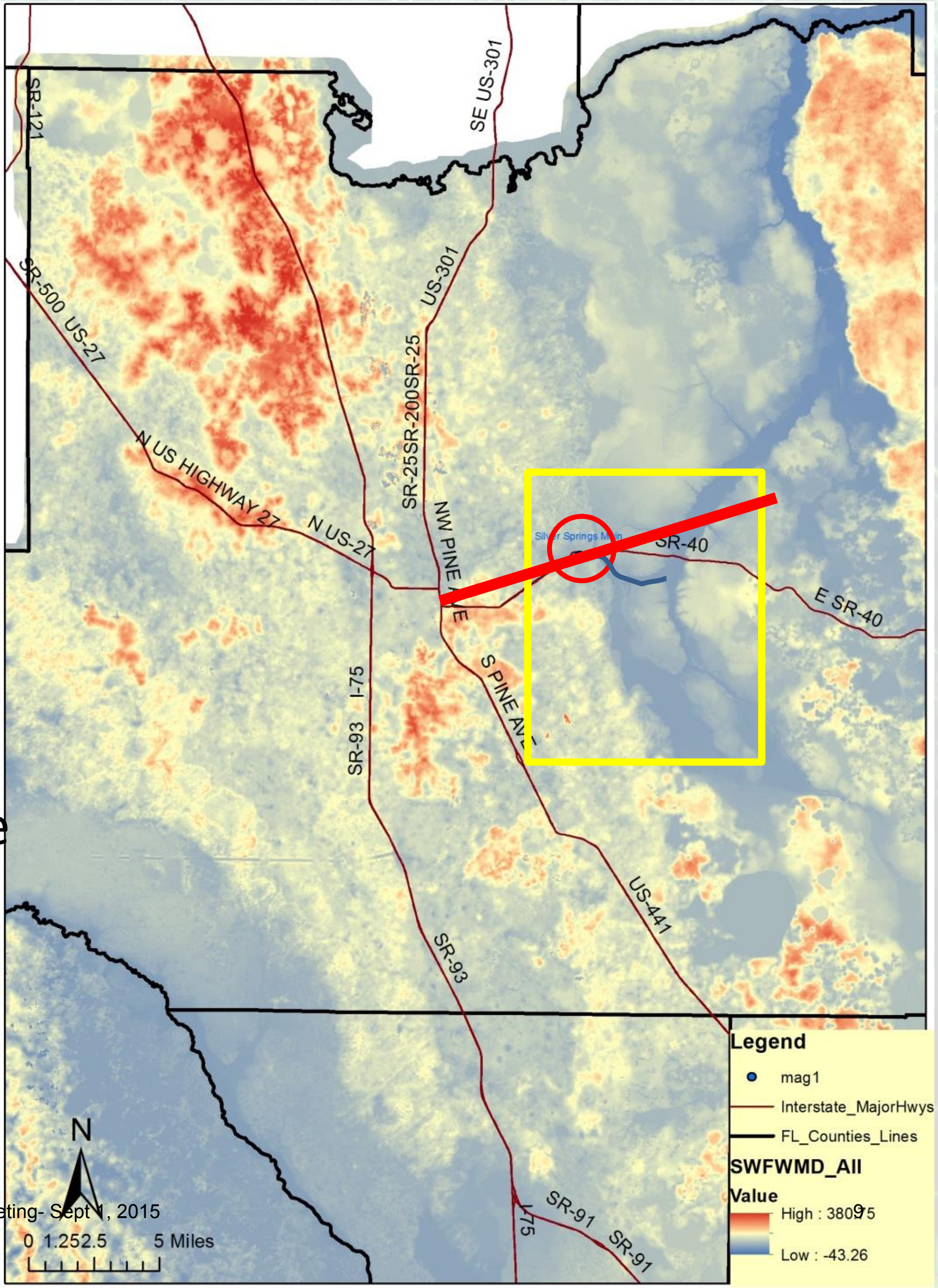
LIDAR Image

- Importance
  - Distribution of lakes and wetlands
  - Distribution and composition of highlands

Images thanks to Harley Means, FGS



Regional DEM

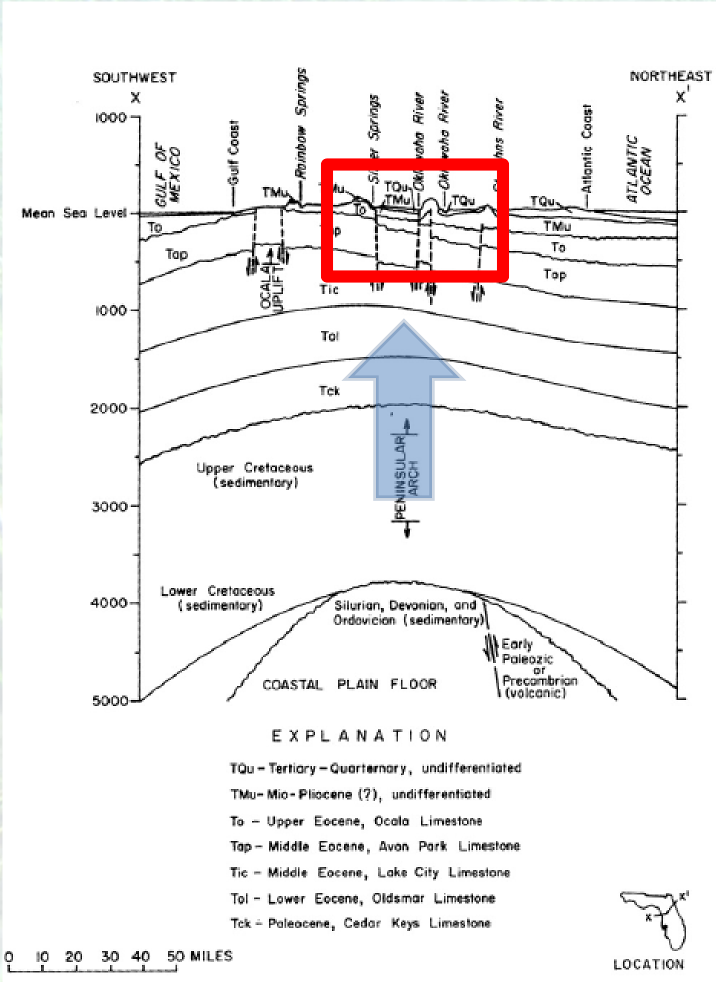


LIDAR Image

- Cross sections
  - Show stratigraphy

Images thanks to Harley Means, FGS

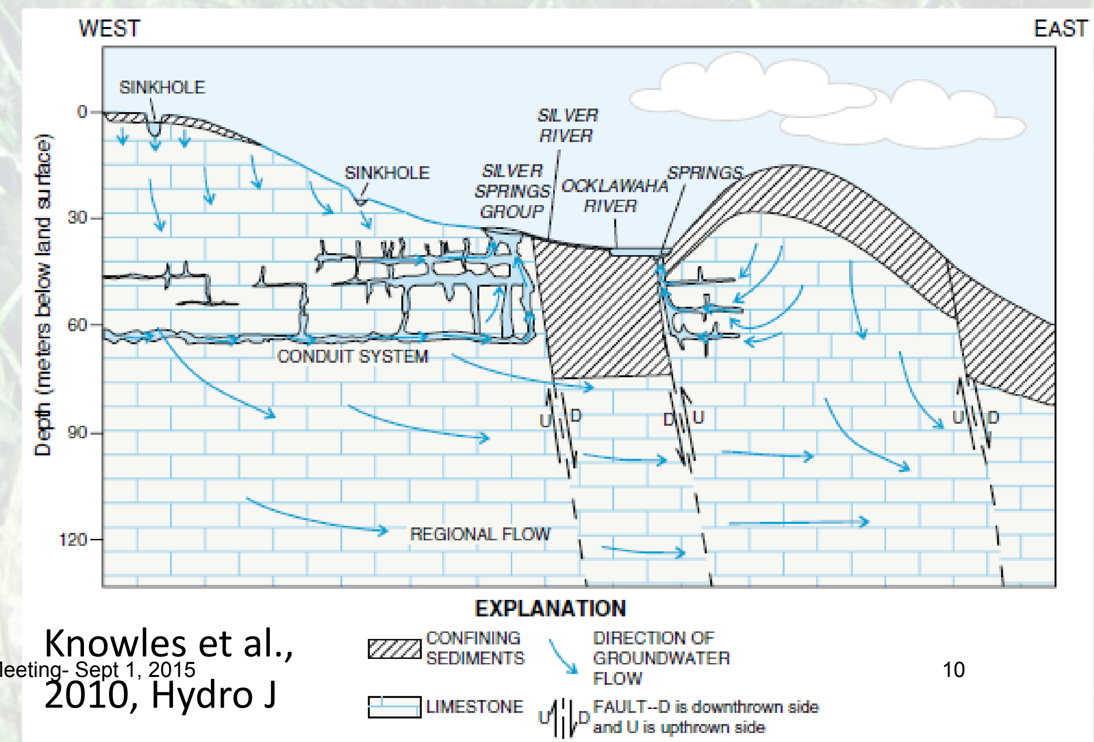
Faulkner 1973, USGS WRI 1-73



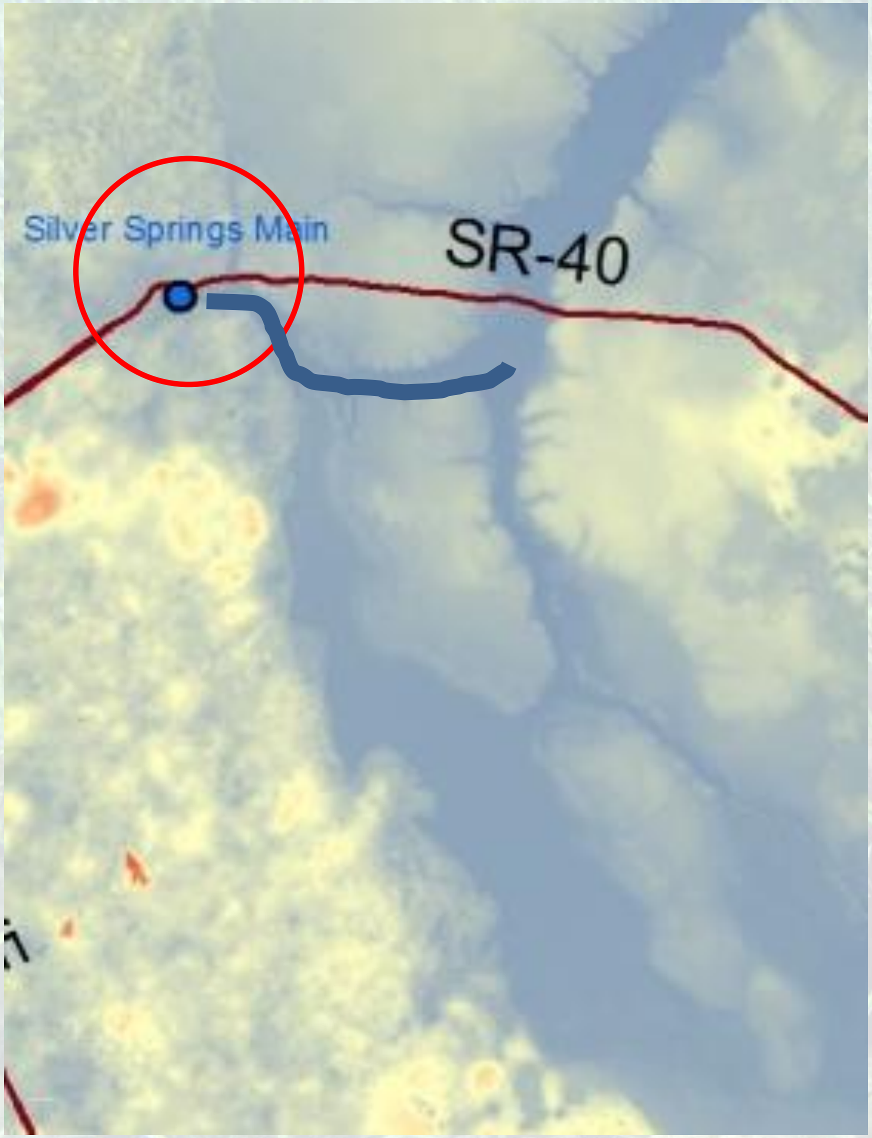
Cross Sections

- Regional uplift causes
  - Exposure of Ocala Group rocks (Floridan aquifer) west of Silver spring
  - Blocking eastward flow creates springs
  - Silver River flows across confining unit

- Regional uplift of Peninsular Arch



Knowles et al., 2010, Hydro J



Expanded LIDAR

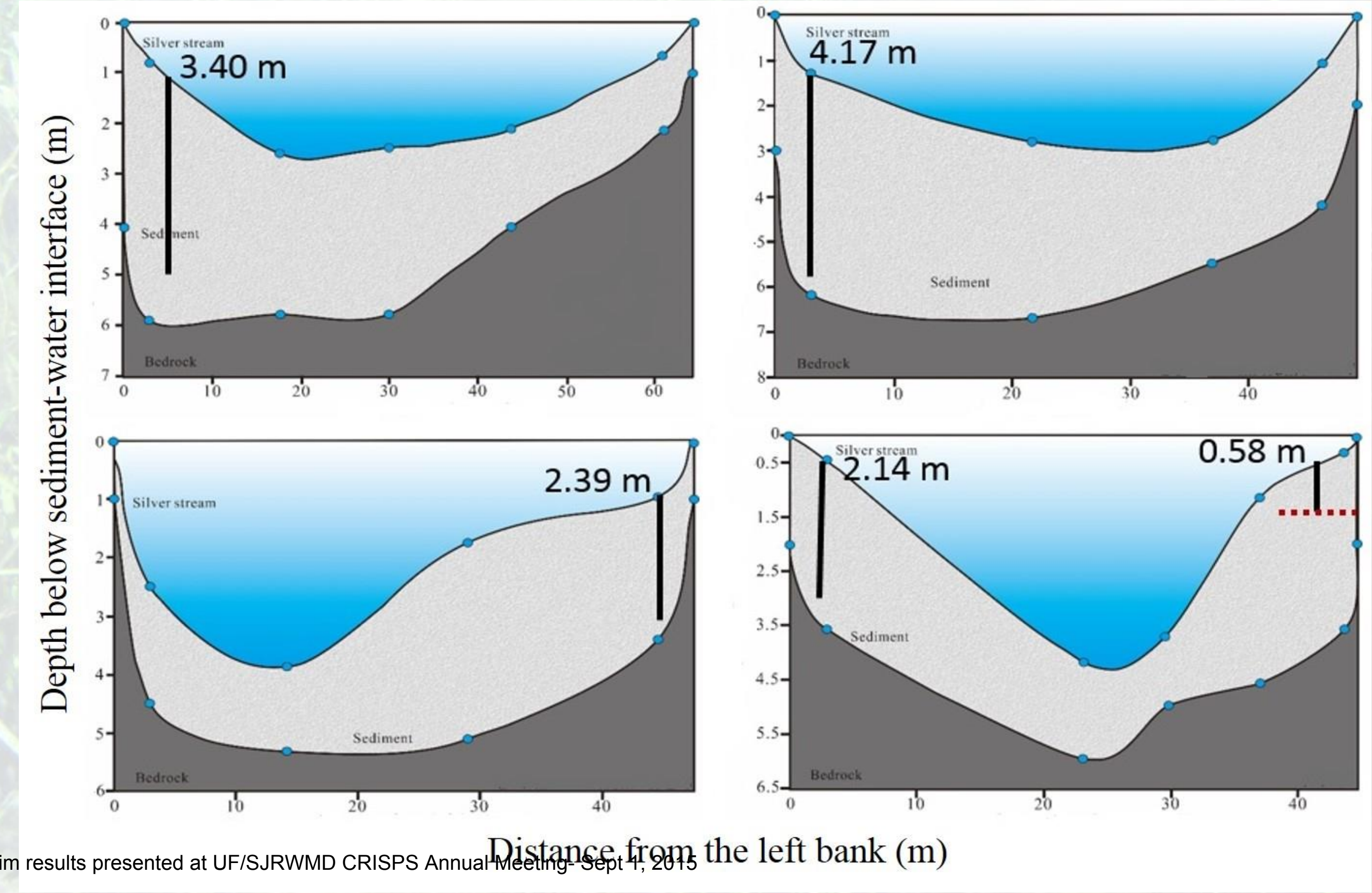
- Upland outcrops
  - Floridan aquifer
  - Silver River flows across confining sediments
- Sediment may limit flow to Silver River from Floridan
  - Possibly large fluxes of solutes from reactions in sediments
- Sediments compositions
  - Deposited in quiescent setting?
  - Lake bed?
- Drainage to river from surrounding wetlands?

Element 2A. Sediment Composition

Detailed sediment and pore water analyses – 4 transects

Coring locations and depths

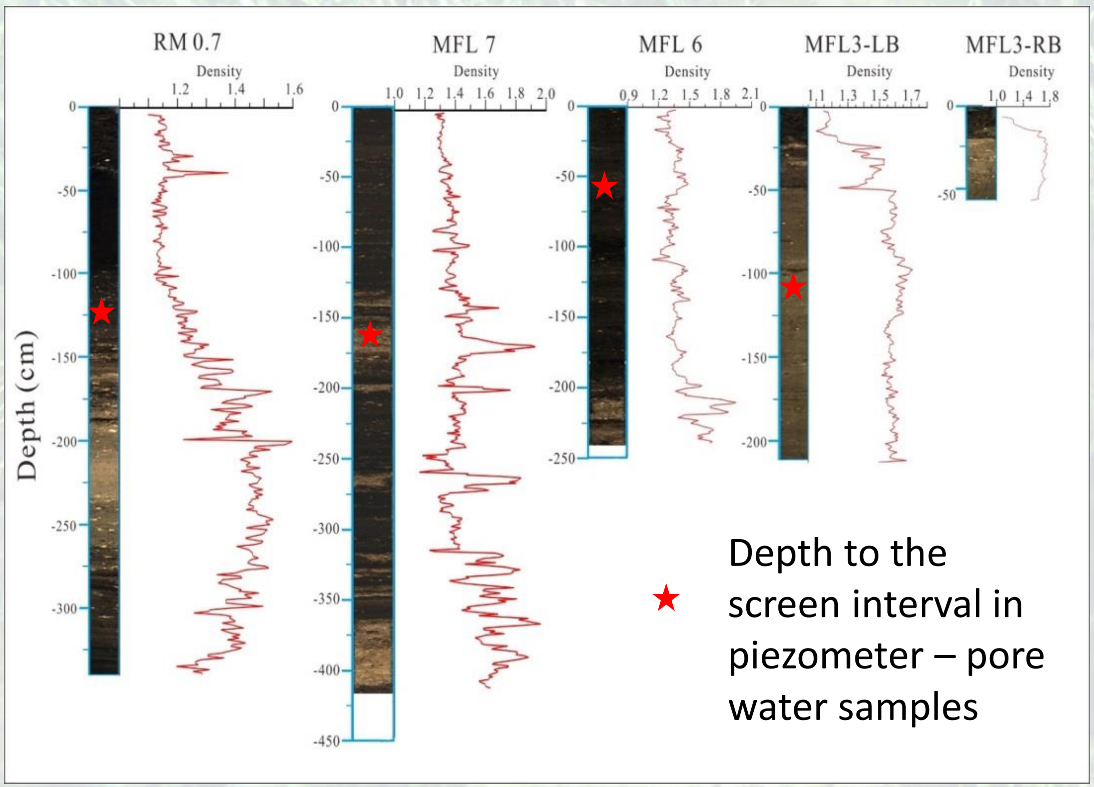
- Collect 5 cores
  - 4 with full penetration
  - 1 short, stopped by hardground



Sedimentary Material

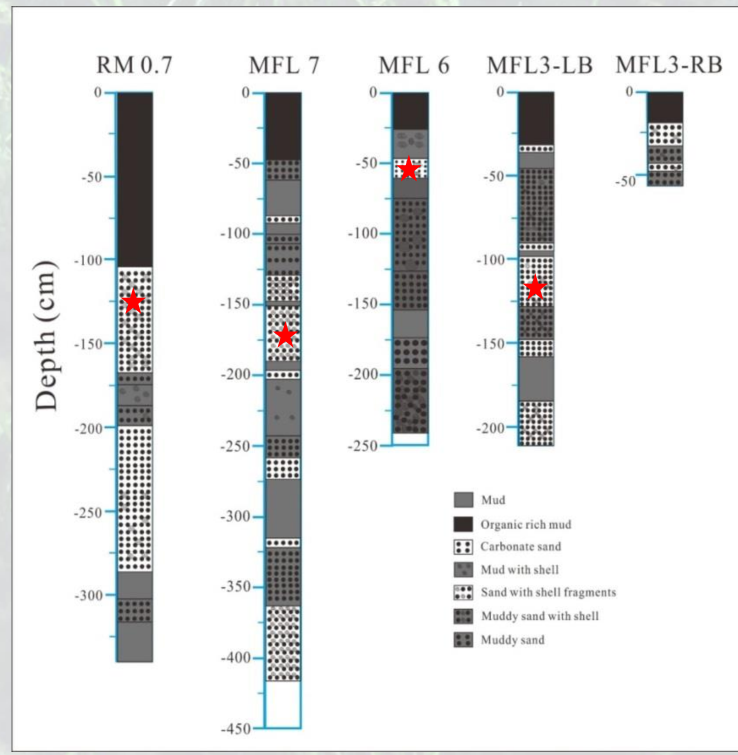
- Sediments consist of interbedded organic C-rich layers and shell-hash layers
- Lower portion higher carbonate content, lower OC contents

Upstream → Downstream



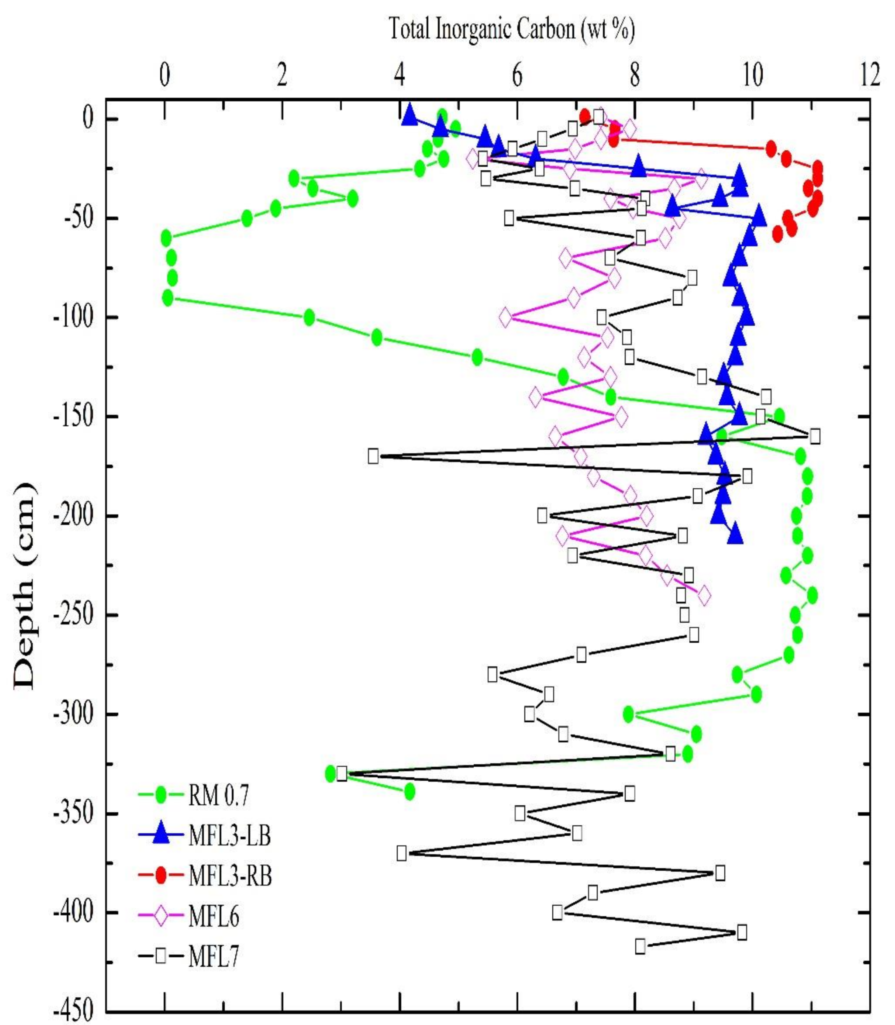
Core log images & gamma density

Upstream → Downstream



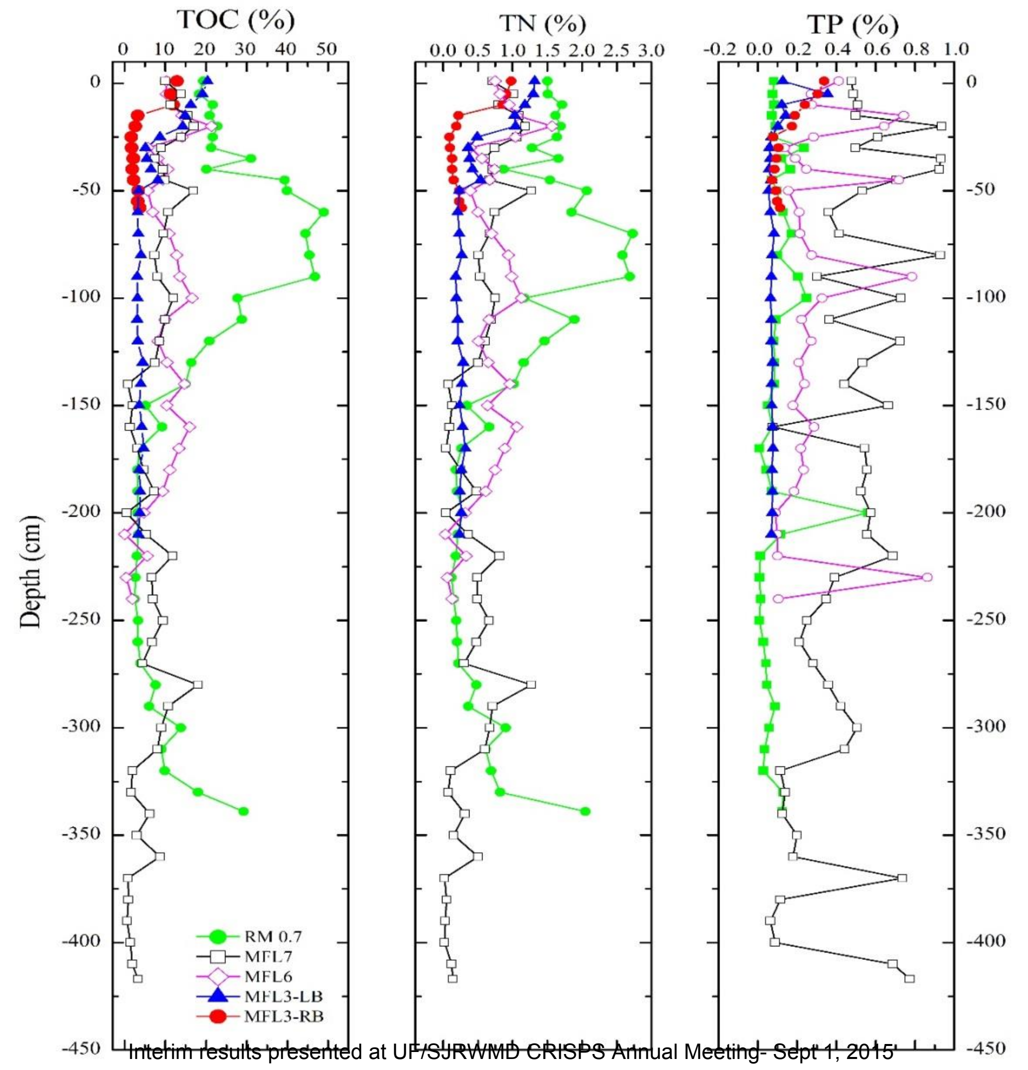
Stratigraphic Descriptions

Carbonate Mineral Contents



- Carbonate minerals major mineral content
  - Largely calcite
  - Many macrofossils
- Contents range up to ~11% TIC (~100% carbonate)
- Little carbonate = high OC

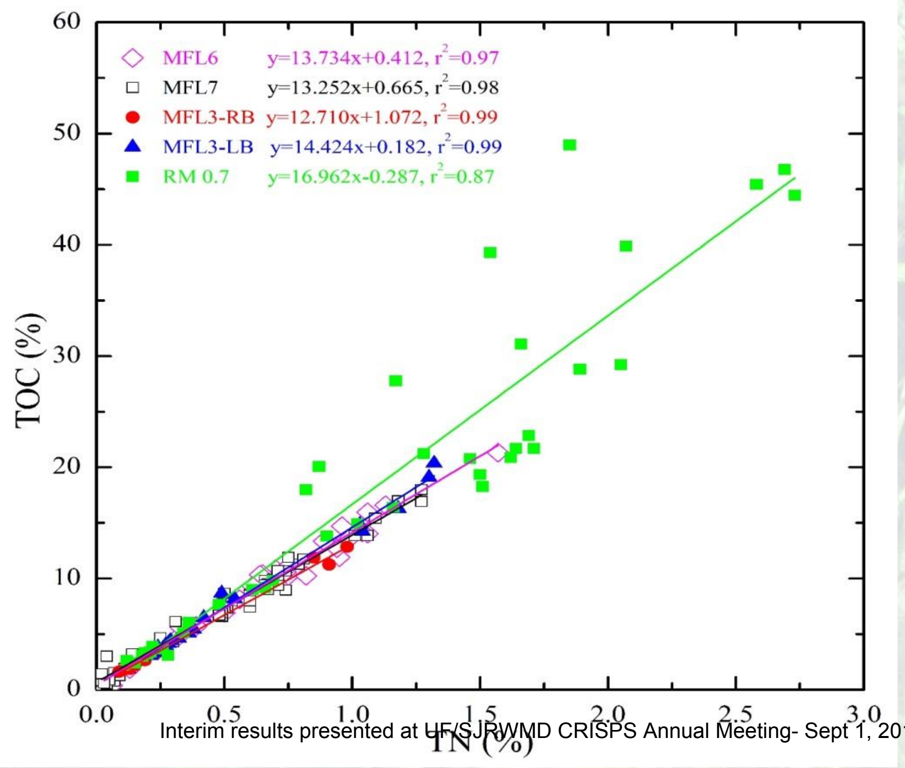
Sediment Composition: OC, TN, TP

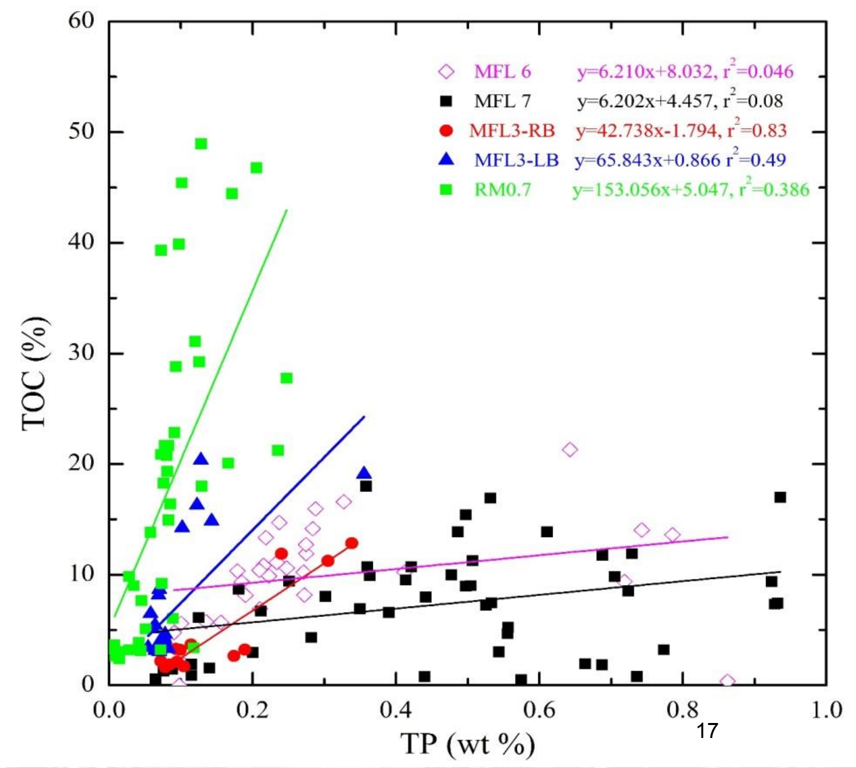


- OC in cores vary:
  - Nearly 50% OC upstream shallow depths
  - Decrease to ~5 to 20% downstream
- TN contents vary similarly to OC
- C/N ratios ~ constant
- C/P and P/N ratios variable
- See also Mitra's poster
  - discussion of possible OC sources
  - $\delta^{13}C$, $\delta^{15}N$, C/N ratios

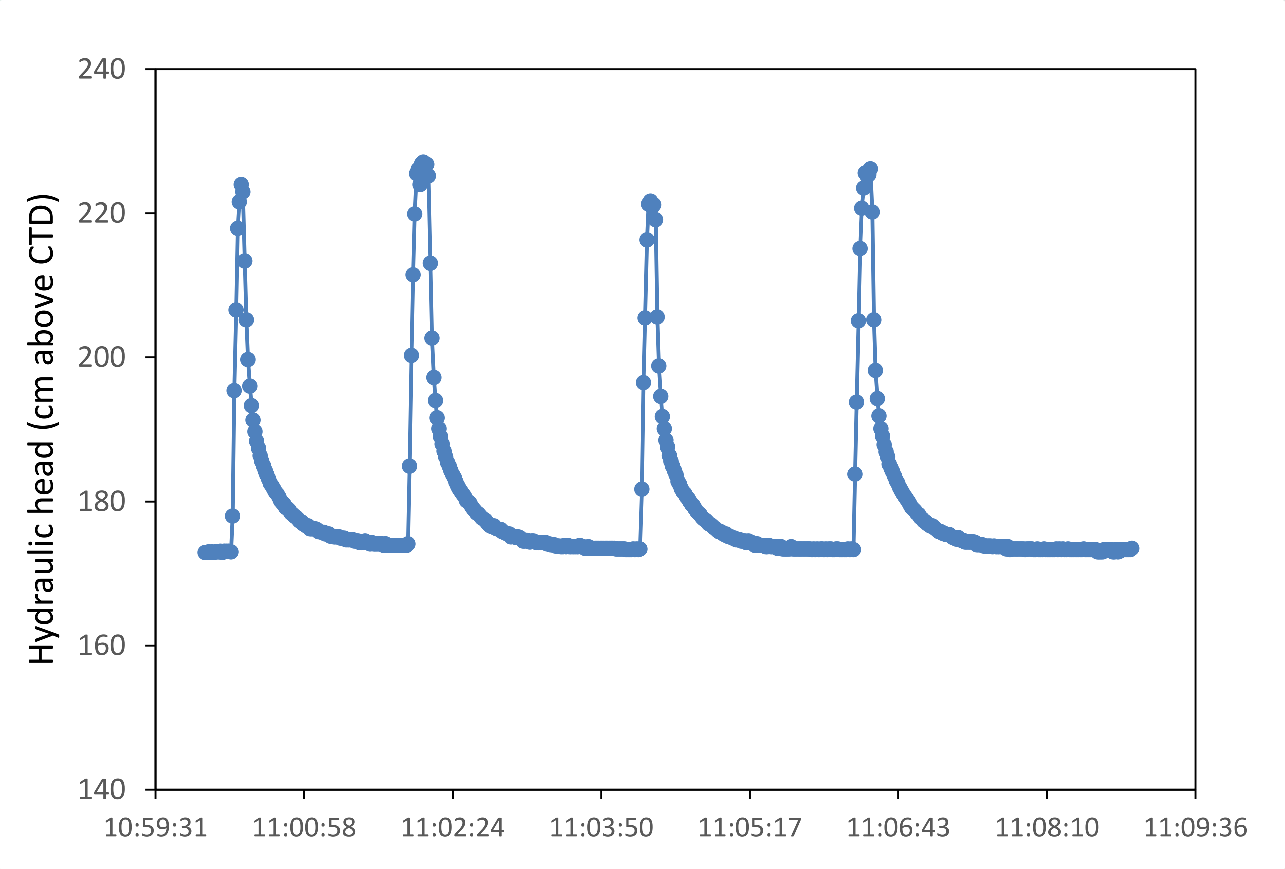
Cross Plot TOC and N, P

- C/N wt. ratios
  - Downstream constant at 12.7 to 14.4
  - RM0.7 = ~17
  - Reflects immobilization pathways downstream?
- C/P ratios scattered
  - Highest ratio at RM0.7
  - Decrease downstream
  - Scatter reflects mineral P
  - More organic P upstream





Element 2B. Sediment hydraulic characteristics



- Slug tests:
  - Falling head method
- Suggests highly permeable sediments
- Plan to redo with rising head method

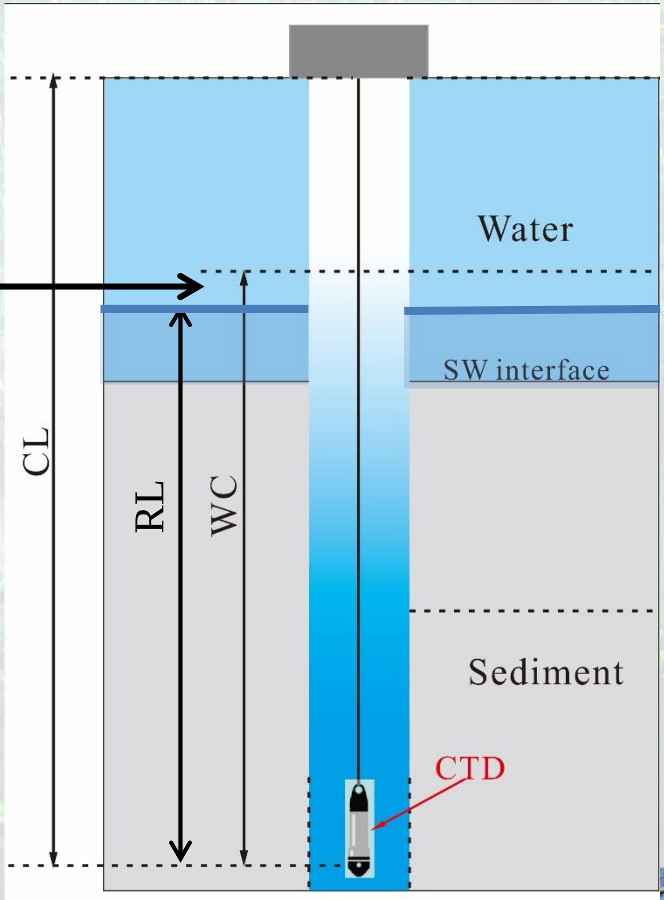
Hydraulic Conductivity (m/s)

- Analytical quality
  - Red = $r^2 < 0.7$; Yellow $0.7 < r^2 > 0.8$
  - All other $r^2 > 0.8$
- Range: ~10^{-4} to 10^{-3} m/s

Site	Eq. 1	Eq. 7, scenario 1	Eq. 7, scenario 2	Eq. 7, scenario 3
RM 0,7	9.82E-05	3.08E-04	8.70E-05	2.60E-04
MFL7	6.82E-05	3.08E-04	8.70E-05	2.60E-04
MFL3	5.23E-05	-1.46E-04	7.10E-05	2.82E-04
MFL6	6.65E-04	1.00E-03	7.09E-04	5.06E-04

Element 3. Head Gradients

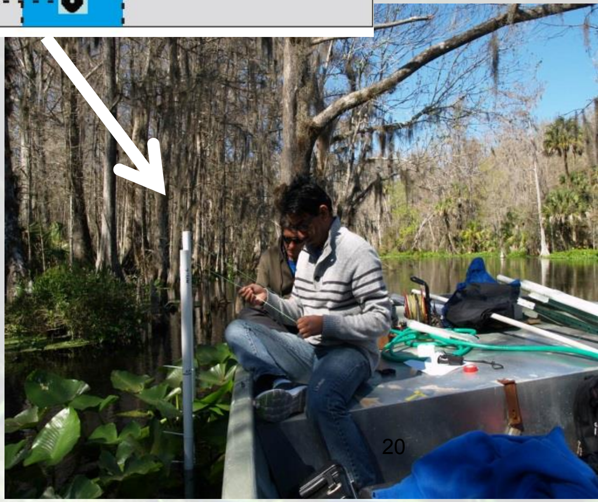
Head Gradient



- CTD installation
  - CL – cable length, benchmark
  - WC – water column, pore water
  - RL – river level
- Plan was use river levels measured by District
- Altered – now installed our own river level CTDs

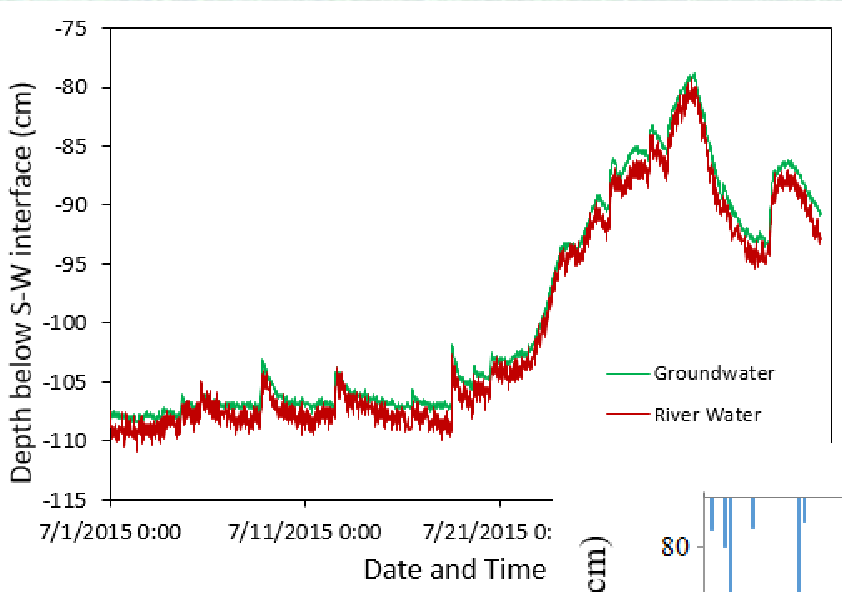
Two wells:

- Piezometer in sediments
- Stilling well in river

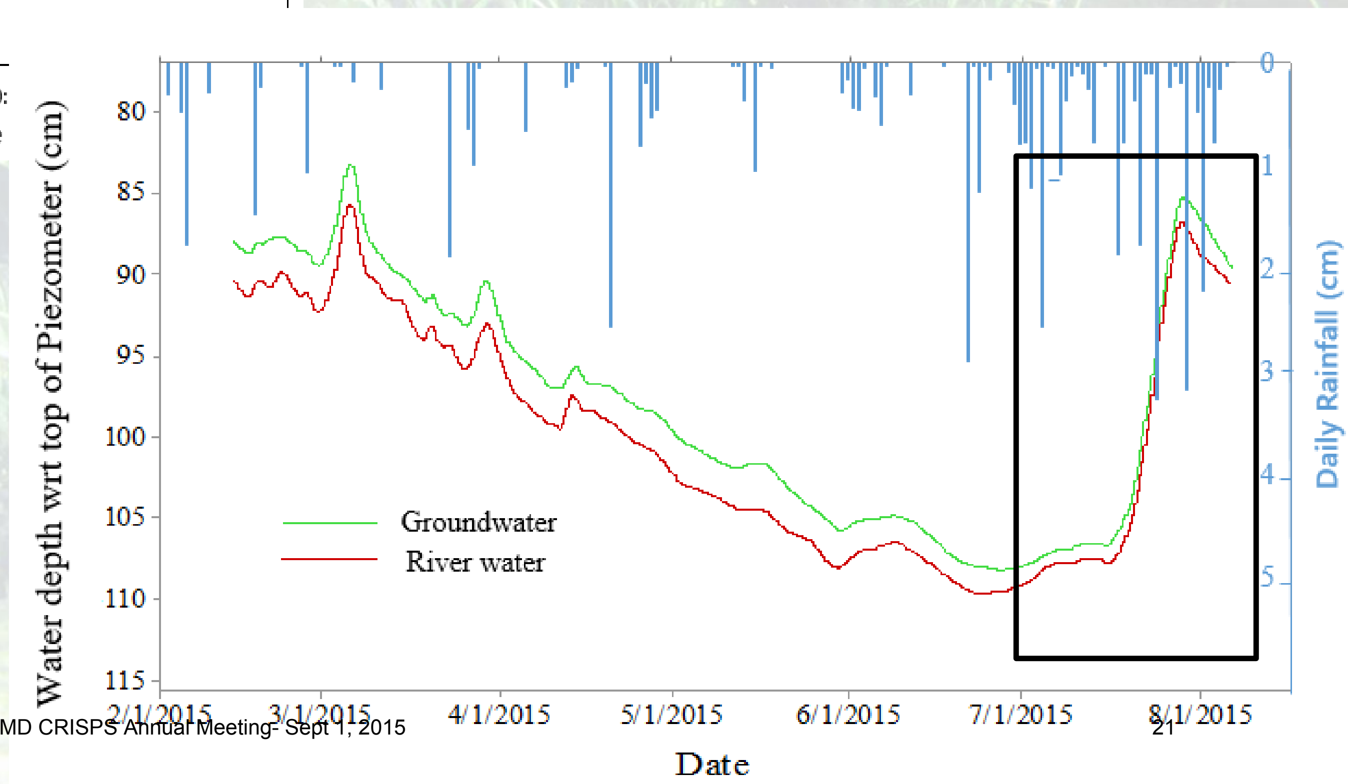


MFL6 – Hydraulic Heads

- GW elevation > RW
  - Smoothed using LOWESS

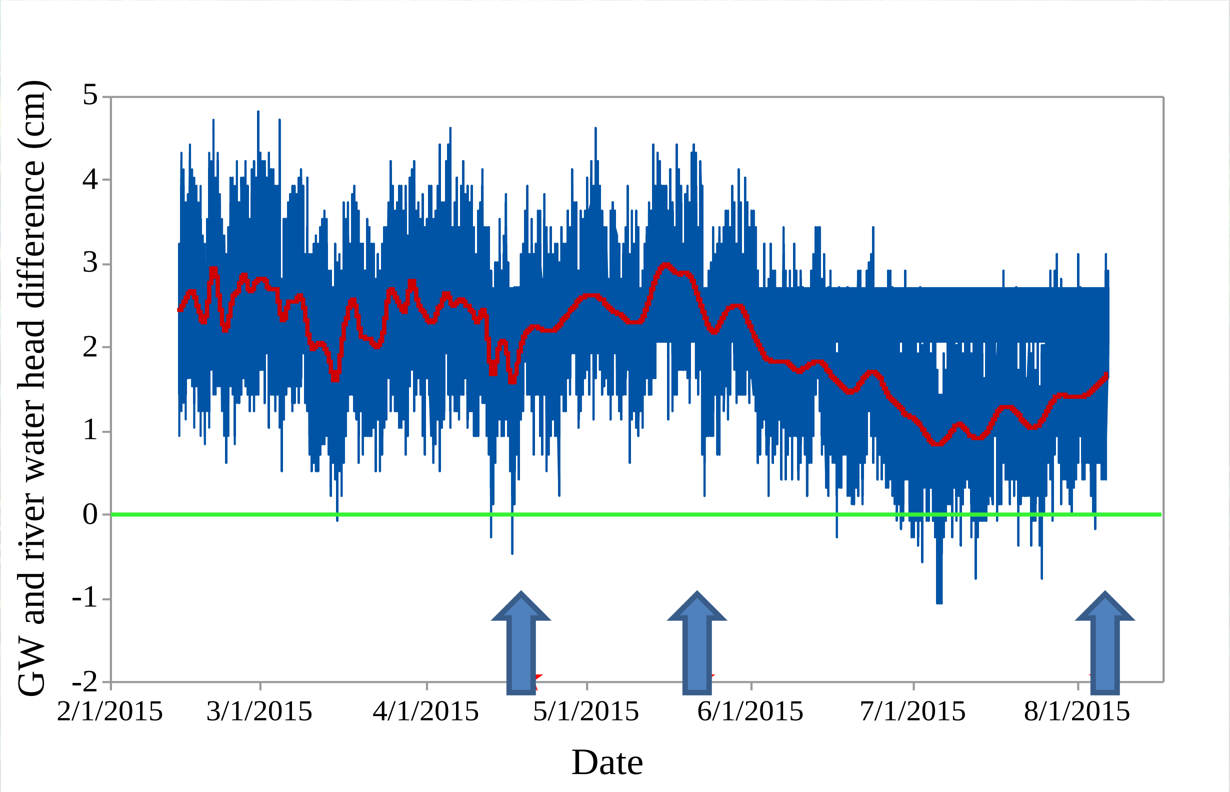


Raw data



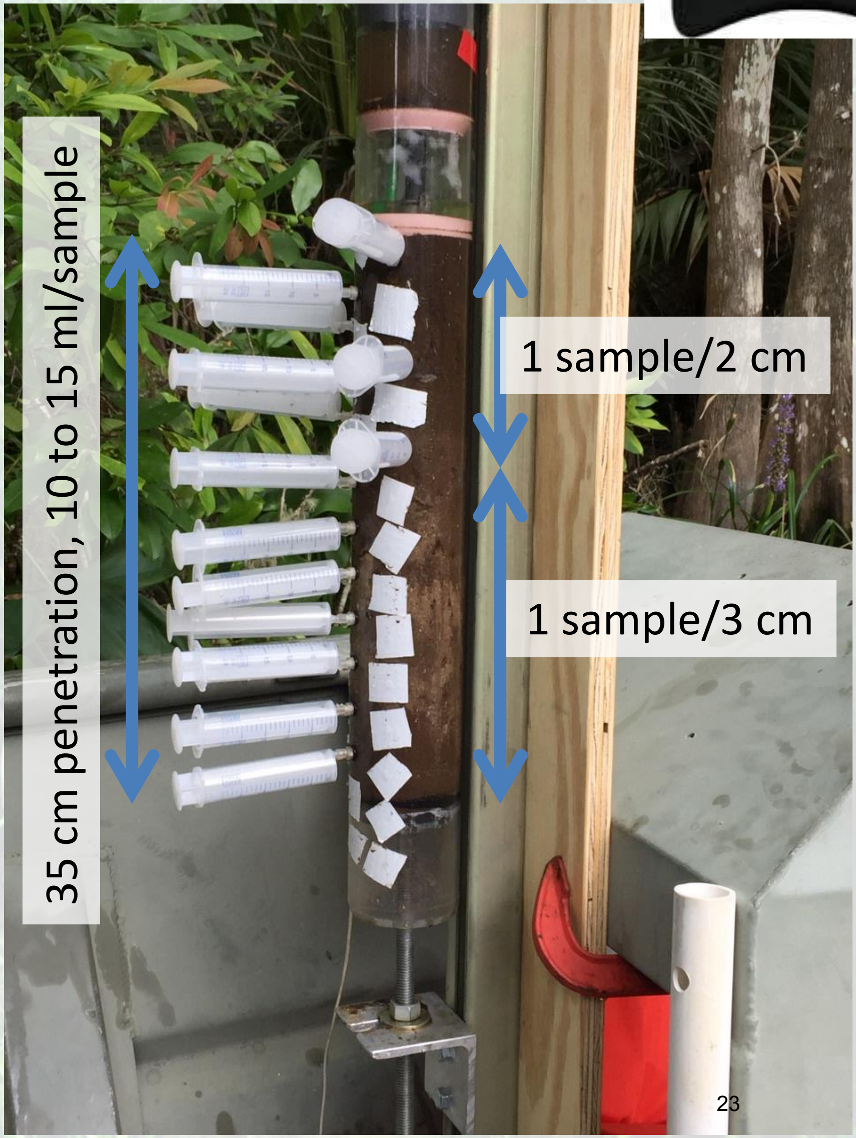
Smoothed data

Head gradients



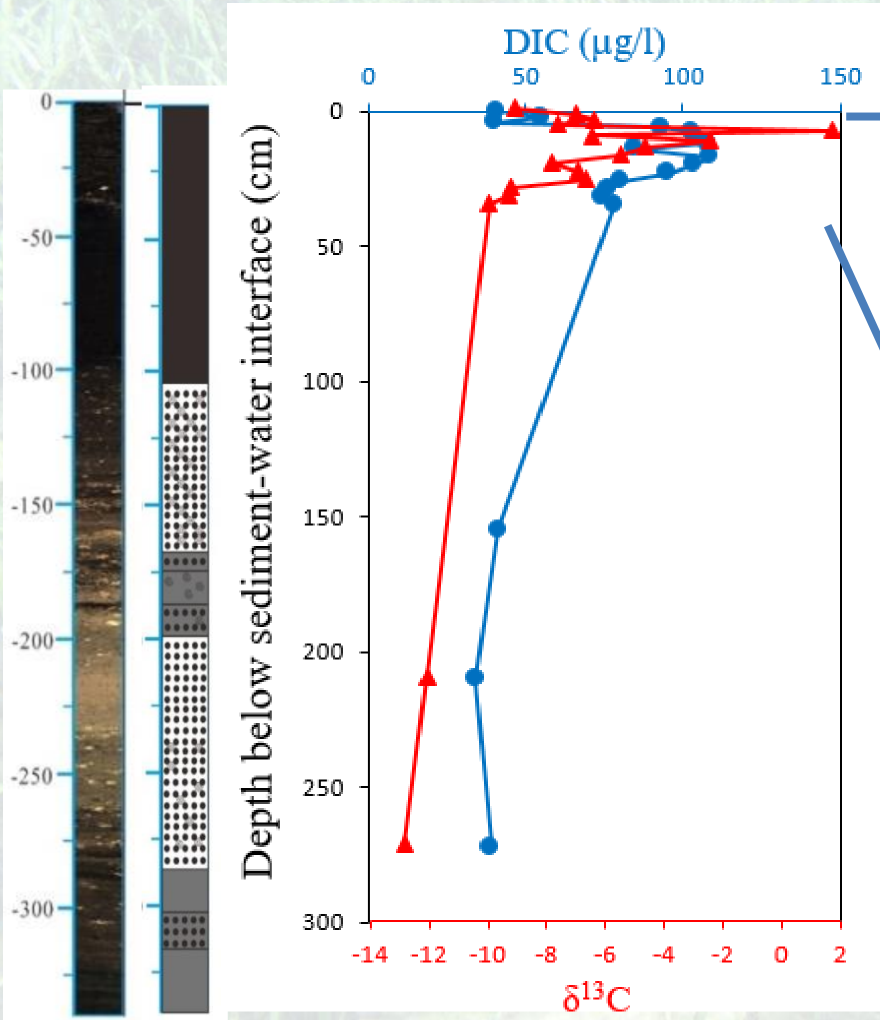
- Gradients:
  - Range from -1.1 to 4.8 cm
  - Average 2.2 cm
  - CTD difference ~1 to 1.5 cm > than measured difference
  - Mostly oriented toward river
- Still to do:
  - Combine head gradients with K

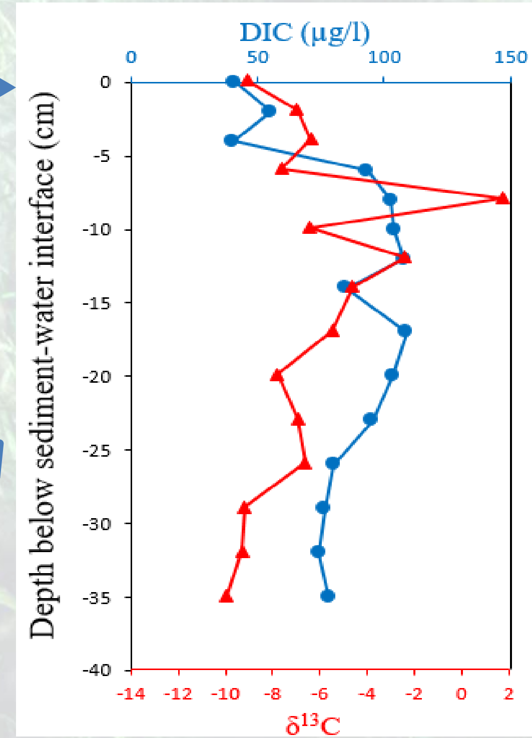
Element 4. Pore water chemistry



- Two techniques used:
  - Vapor probe: Deep pore waters > 40 cm
  - Whole core squeezers: Shallow high resolution pore water

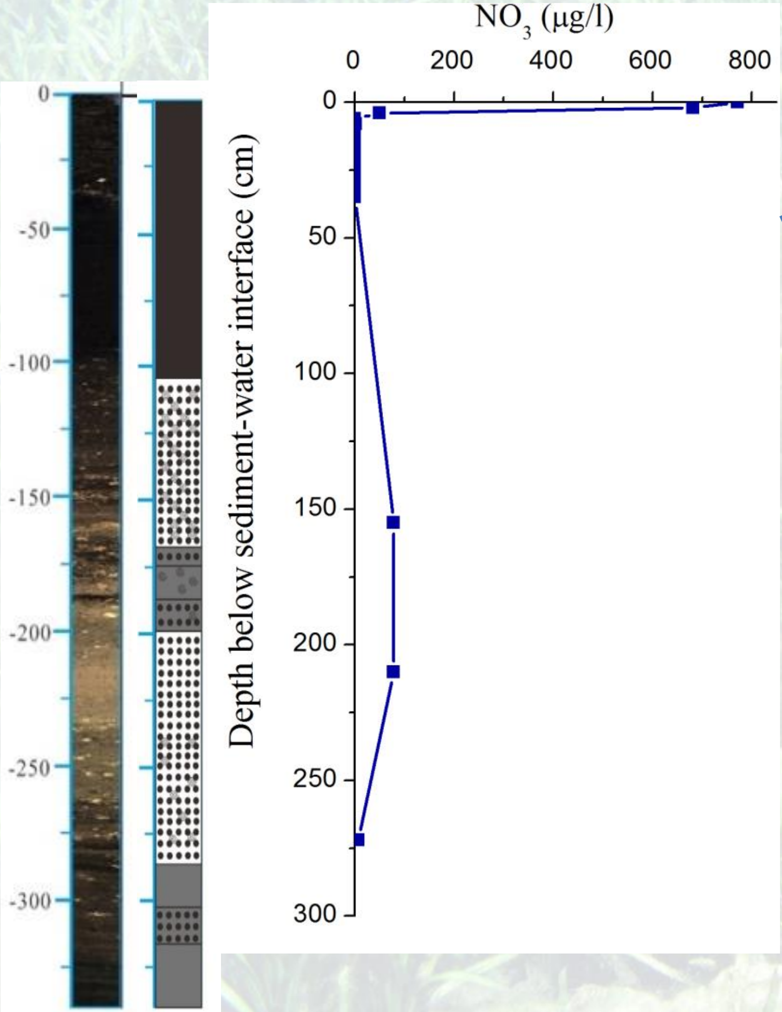
RMO.7 –Upstream Site: DIC & $\delta^{13}C$

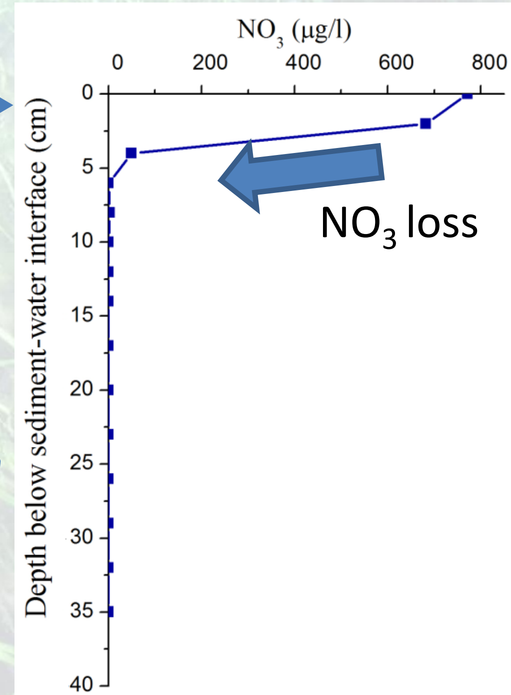




- Pore water DIC and $\delta^{13}C$ compositions
- Reflect OC remineralization

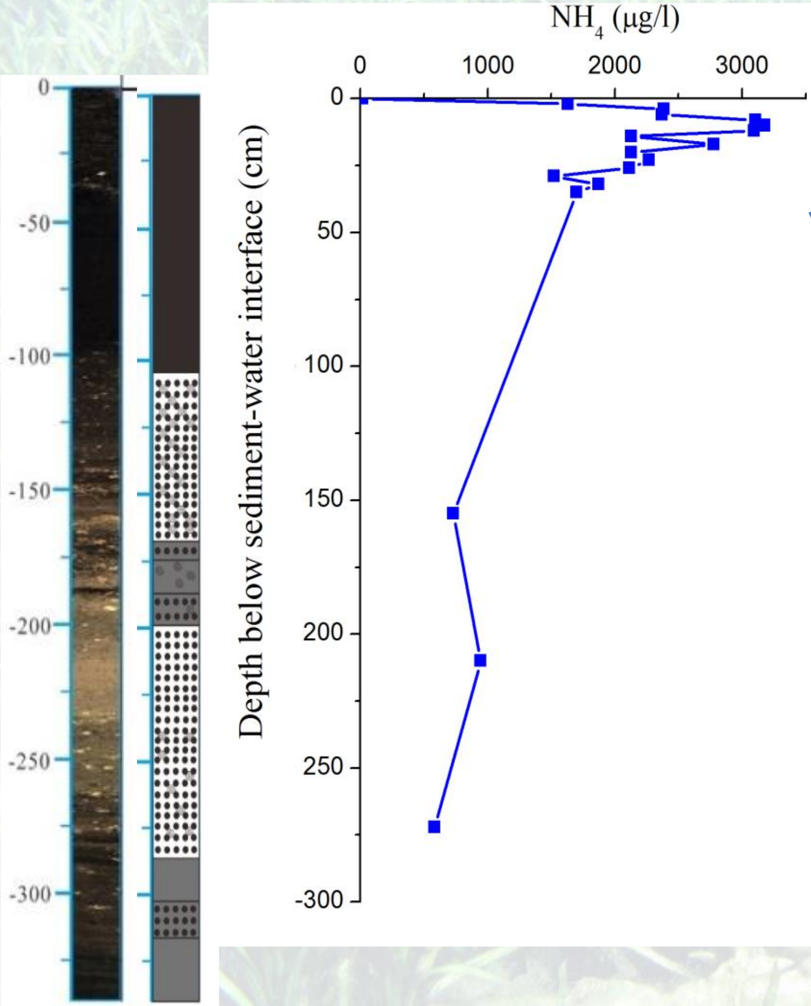
RMO.7 –Upstream Site: NO_3

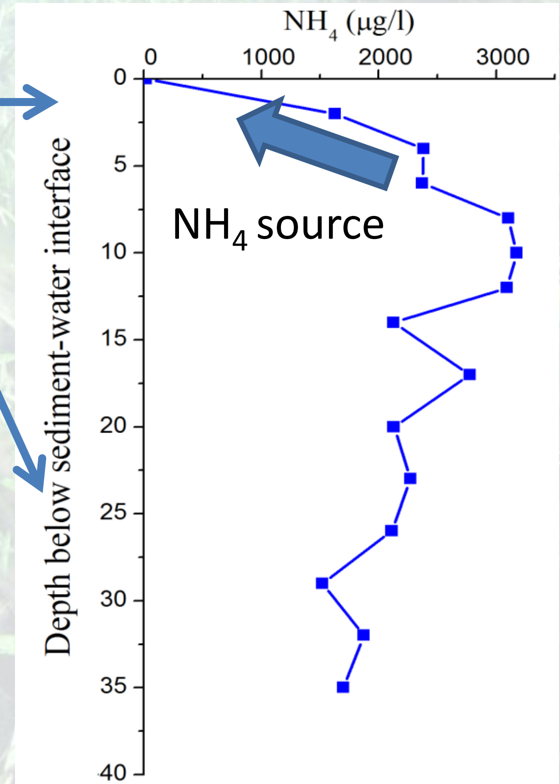




- NO_3 concentrations
- Loss of NO_3 to sediment
- Source in course sediments?
  - Flow from river?

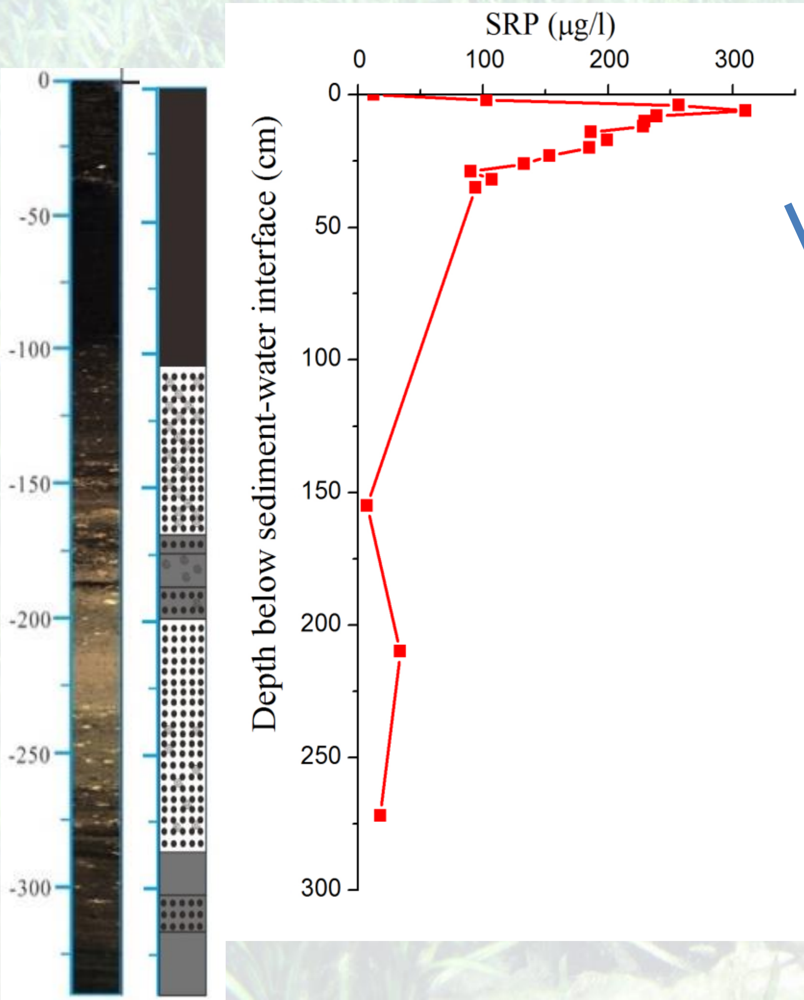
RMO.7 –Upstream Site: NH_4

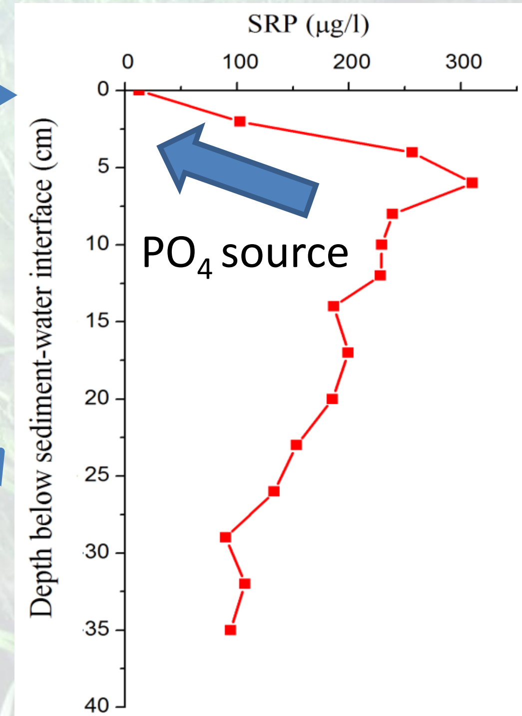




- NH_4 production
  - OC remineralization
  - Dilution from inflow?
  - Lack of source in carbonates?

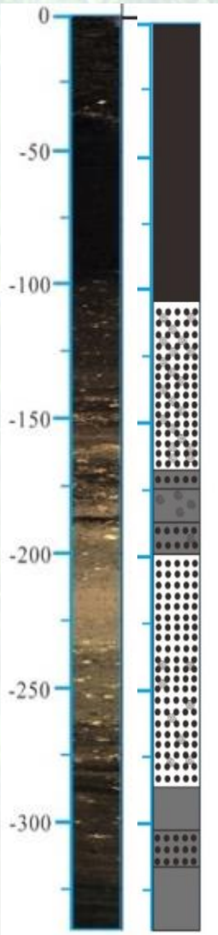
RMO.7 –Upstream Site: PO_4

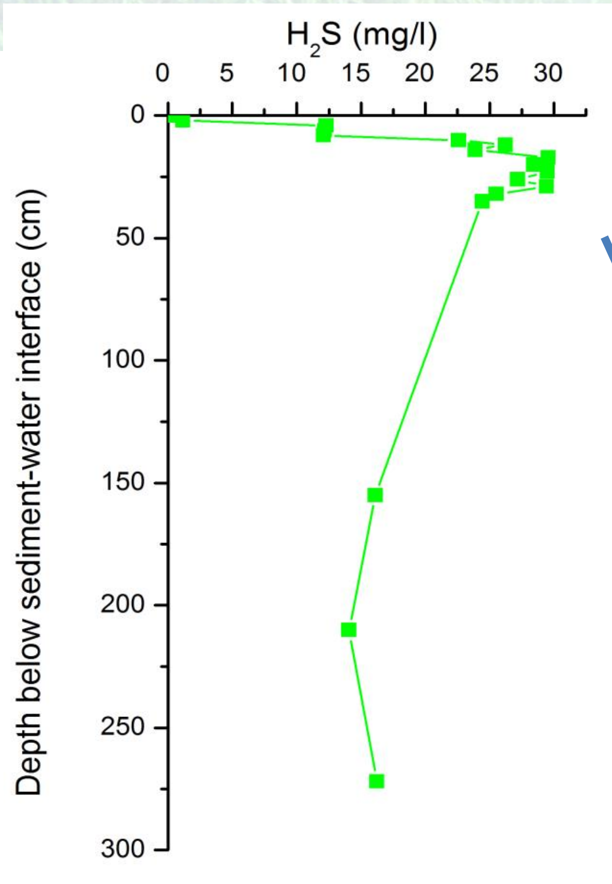


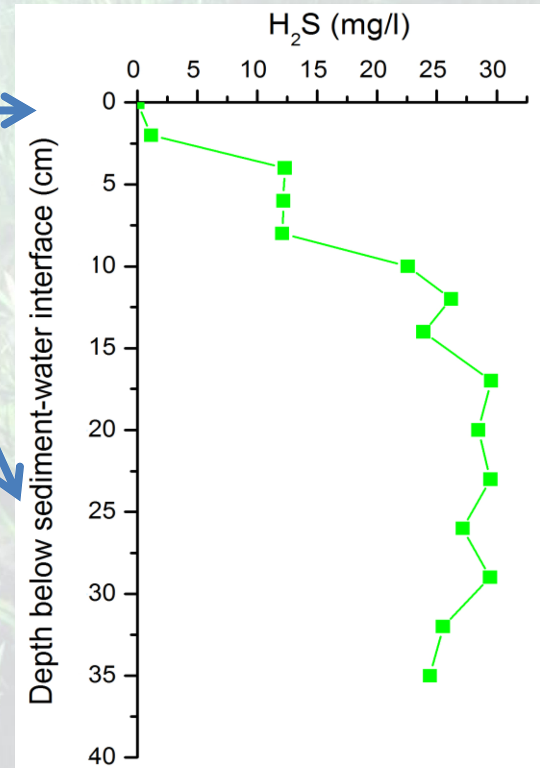


- SRP production
  - OC remineralization
  - Dilution from inflow?
  - Limited source from carbonate?

RMO.7 –Upstream Site: H_2S







- H_2S production
  - SO_4 reduction?
    - Source of sulfate – gypsum?
  - Pyrite dissolution?
  - Toxic to seagrass?

Summary

- Thick benthic sediment layer
  - Isolates river from Floridan Aquifer
  - Generates large amount of pore water nutrients
- Advective fluxes possible
  - High hydraulic conductivity
  - Head gradients oriented in the same direction
- Certainly diffusive fluxes between pore water and river
  - NO_3 sink
  - NH_4 and PO_4 source - nutrients
  - H_2S source - toxin

Looking forward

- Continue pore water sampling/composition and head gradients
- Work on data analyses
  - Fluxes
    - Diffusive from Fick's Law
    - Advective from Darcy's Law
  - Reaction rates?
    - Berner's (1980) 1-D General Diagenetic Equation

$$D_s \frac{d^2C}{dz^2} - \omega \frac{dC}{dz} + kC = 0$$

    - First estimate done at steady state, constant D_s
    - Improve constraints on sources of nutrients and rates of production

Questions?
Discussion?