2024 Aquifer Storage and Recovery (ASR) Peer Review Panel Workshop

Elizabeth Caneja, Lead Project Manager

July 10, 2024

Welcome/Workshop Logistics

- Welcome/Meeting Purpose and Objectives
- Introductions
  - Panel members
  - ASR team members
- Workshop/Meeting Format
  - July 9th, 9am - 3pm (Site Visit for Panelists and Project Team)
  - July 10th, 8:30am – 4:15pm (Zoom Meeting for Panelists, Project Team, and Members of the Public)
  - Panel discussion throughout the day
  - Public comment period prior to lunch and prior to closing remarks

Workshop Agenda

2024 AQUIFER STORAGE AND RECOVERY (ASR) SCIENCE PLAN PEER REVIEW PANEL
AGENDA
July 10, 2024
8:30 AM

This meeting will be conducted via Zoom, a media technology free for the public to use

Zoom Link: https://sfwmd.link/4e9da8g

1. Welcome and Opening Remarks - Liz Caneja, Lead Project Manager, SFWMD
2. Continuous Core and Aquifer Pump Test Results - Rick Cowles, P.G., Principal Senior Hydrogeologist, Stantec
3. Geochemistry of C38s, L63N, and L63 Continuous Cores - Jamie MacDonald, Ph.D., Professor of Geology, Florida Gulf Coast University
4. Break
5. SFWMD Okeechobee 2D Seismic Program Overview - John Jansen, P.G., P.Gp., Ph.D., Principal Geophysicist/Hydrogeologist, Collier Geophysics, LLC
6. Multi-Well Assessment of Fracture Porosity of the Floridian Aquifer System in Support of Future ASR Wells in Northern Lake Okeechobee - Kevin Cunningham, Ph.D., and Victor Flores, Research Hydrogeologists, United States Geological Survey (USGS) - Caribbean - Florida Water Science Center
7. Characterization of Microbial and Geochemical Processes that Contribute to Nutrient Reduction and Potential Clogging - John Lisle, Ph.D., Microbial Ecologist, USGS - St. Petersburg Coastal and Marine Science Center
8. Panel Discussion
9. Public Comment
10. Quantitative Ecological Risk Assessment Plan - Next Steps - Joseph Allen, Senior Wildlife Biologist/Ecological Risk Assessor, Formation Environmental
11. ASR Ecological Risk Assessment Pre-Operational Ecological Monitoring Year 1 Results - Jennifer Mathia, Principal Scientist, Environmental Consulting and Technology
12. Break
13. Lake Okeechobee Watershed Restoration Project (LOWRP) ASR Treatment Technology - Treatment System Update - Heath Wintz, P.E., Project Technical Lead, Stantec
14. Engineer Research and Development Center (ERDC) and LOWRP-ASR Studies Update - Matthew Farthing, Ph.D. (Project Lead), Mandy Michalsen, Ph.D. (Task A Lead), and Martin Page, Ph.D. (Task E Lead), USACE-ERDC

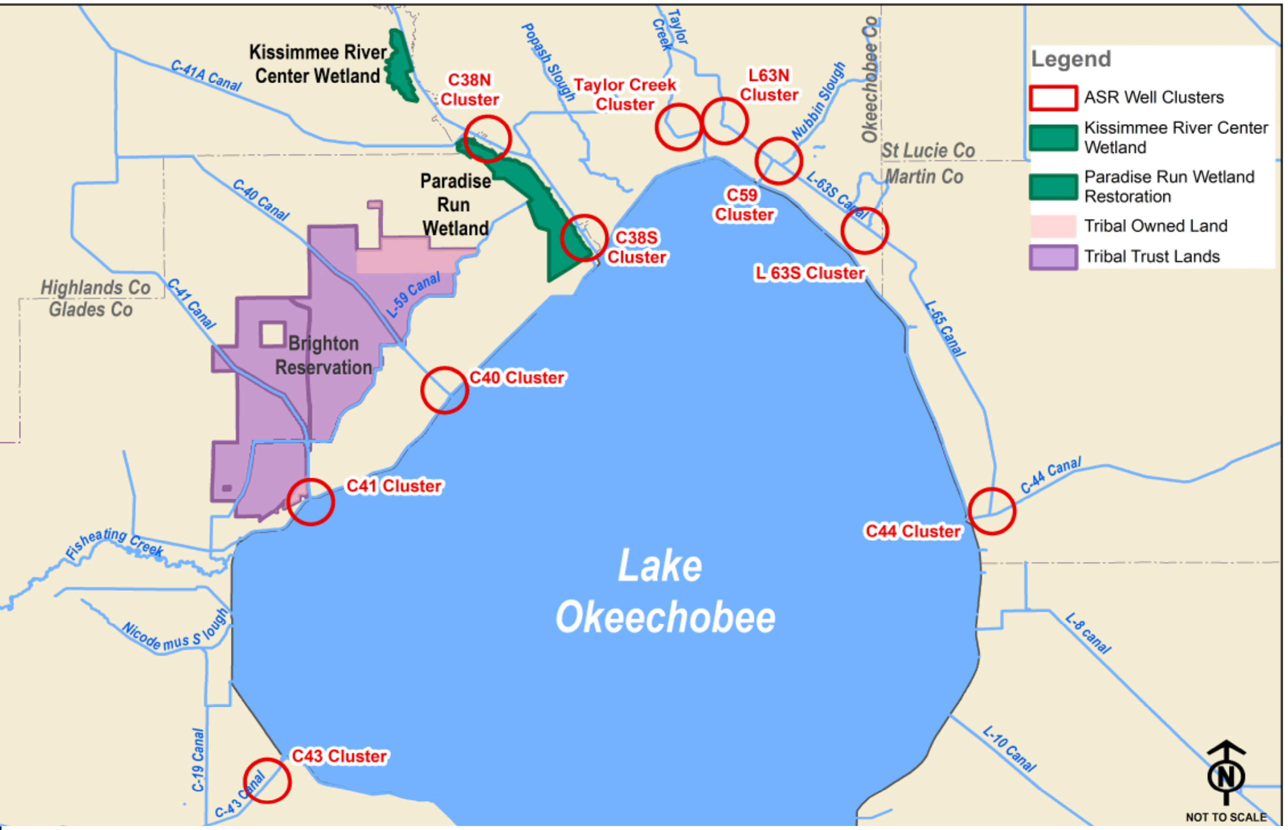
17\. Panel Discussion

16\. Public Comment

17\. Closing Remarks and Expected Progress Over the Next Two Years - Anna Wachnicka, Ph.D., Principal Scientist/ASR Science Plan Project Manager, SFWMD

18\. Adjourn

LOWRP Revised Recommended Plan (Alt ASR)

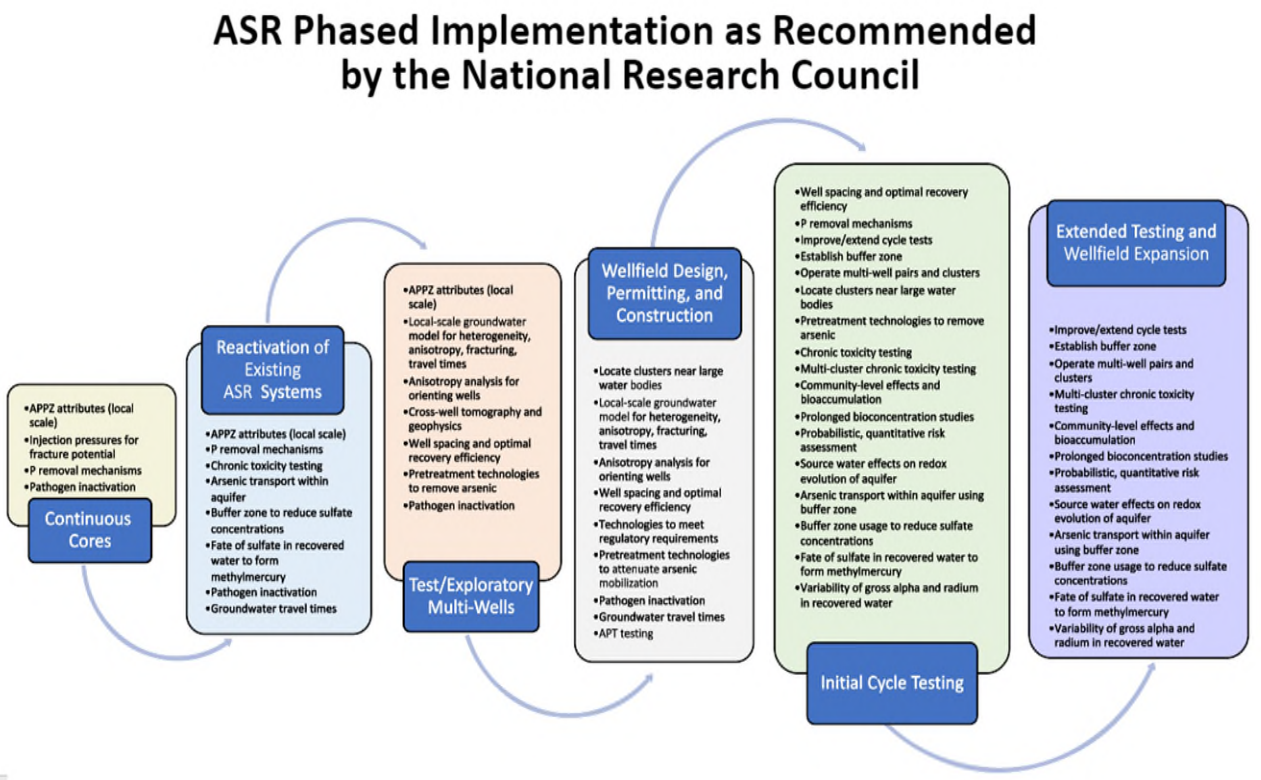


Aquifer Storage and Recovery (ASR)

- 55 ASR wells
- 308,000 acre-feet of storage per year

Wetland Restoration

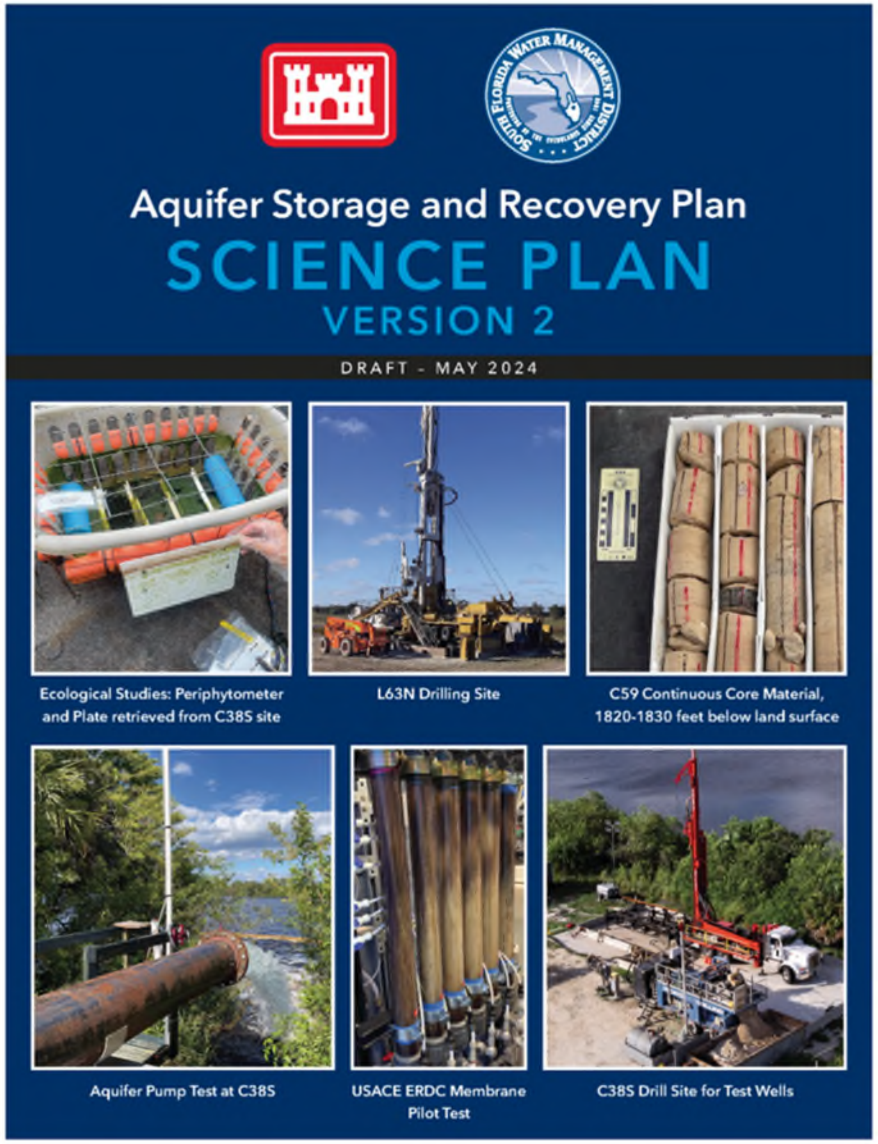
- Kissimmee River Center: ~1,200 acres
- Paradise Run: ~4,700 acres



ASR Science Plan

- **Purpose:**
  - Address the NRC uncertainties with ASR
  - Guide the ASR phased implementation with science
  - Provide annual or as needed update on the work progress
    - Workshops held annually to biannually to discuss the studies and findings
    - Update prepared with guidance from an independent peer review panel
- **Status:**
  - Draft 2022 ASR Science Plan was posted for public review in October 2022
  - The next version of the plan will be referred to as ASR Science Plan Update Version 2

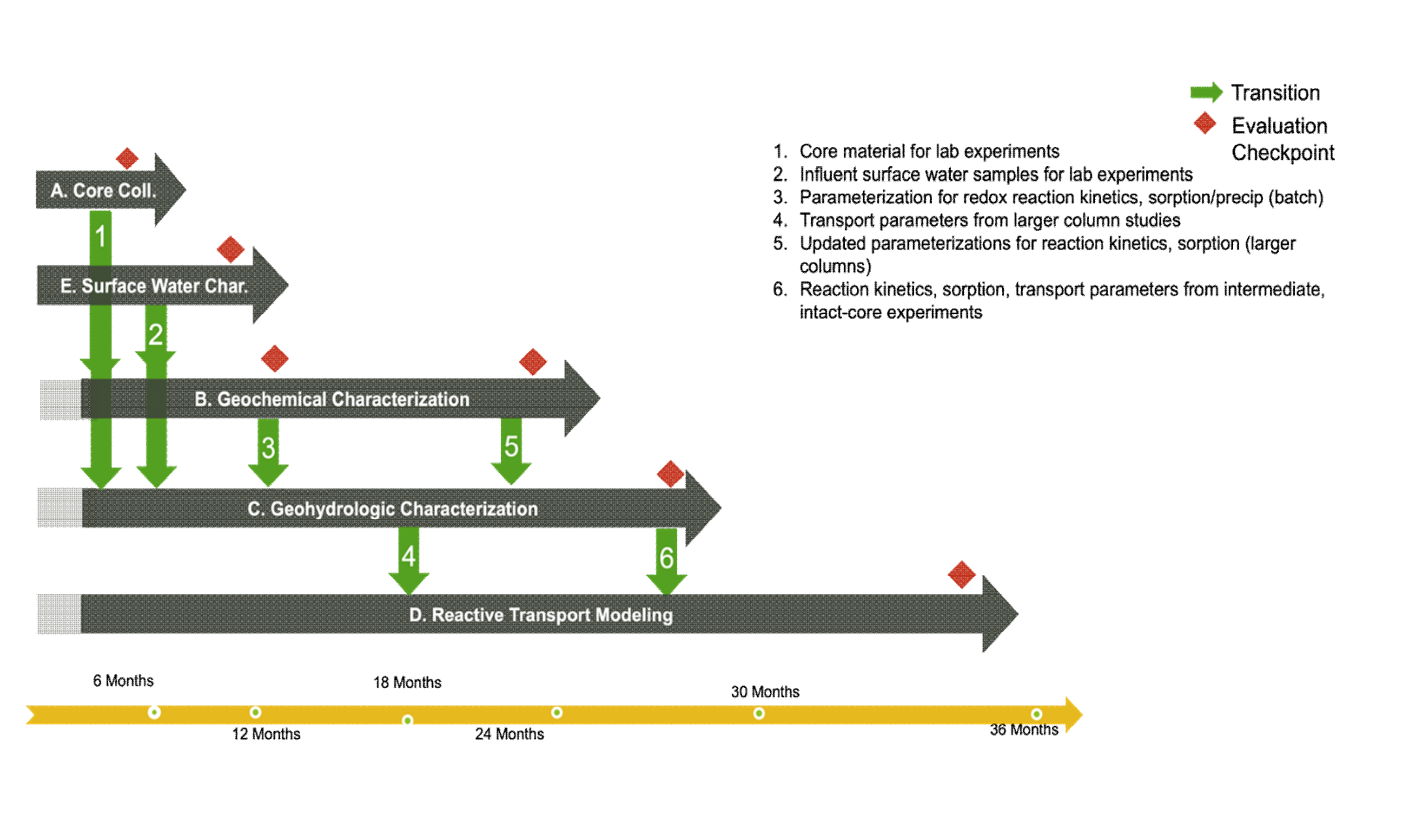
www.sfwmd.gov/asr



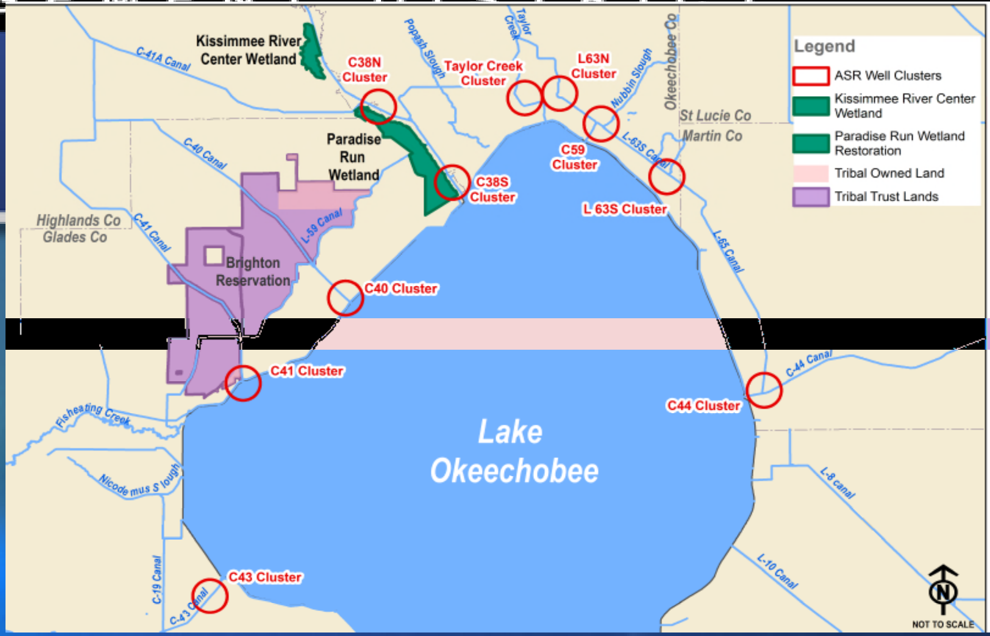
USACE Identified Uncertainties with ASR

- Water Quality Uncertainty
- Construction Cost Uncertainty
- O&M Cost Uncertainty

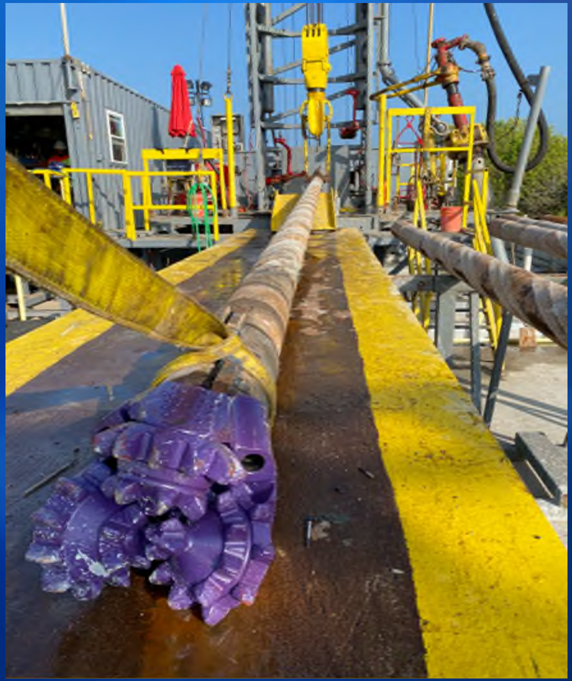
- USACE ERDC Research:
  - Executed agreement to prepare a SOW to begin addressing the identified major uncertainties
  - ERDC Staff has collected cores for water quality studies
  - Various studies will take several months to years to complete



ASR Construction Progress

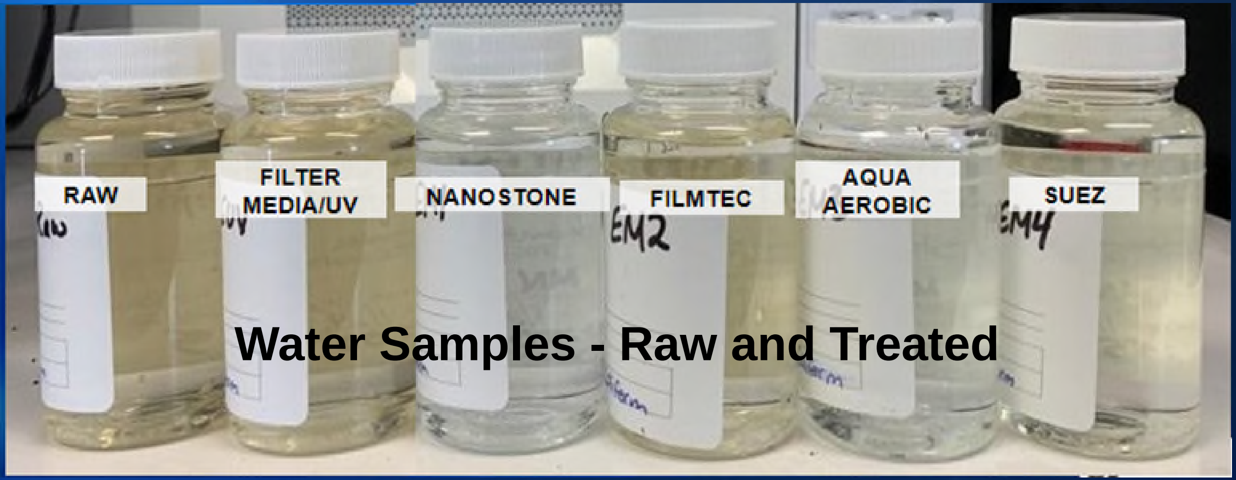


- **ASR Construction Progress from 2020-2024:**
  - Completed Continuous Cores at C38S, L63N, L63S and C59
  - Completed Test Wells 1 & 2 at C38S and C38N
  - Completed Aquifer Pump Tests for Test Wells at C38S and C38N
  - Currently Drilling Test Wells 1 & 2 at L63N
  - Design is underway for Demonstration Facility



Treatment Technology Evaluation to Meet Drinking Water Standards

- Water treated to meet primary and secondary drinking water criteria
- Proof-of-Concept was conducted to determine suitable technology to meet permitting requirements
- Several technologies were tested including ceramic membranes, polymeric membranes, and mediation filtration + UV



Schedule to Update the ASR Science Plan

Studies	2023												2024											
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
USGS Fracture Porosity Analysis														[green]										
USGS Bioclogging Research																			[blue]					
FGCU Geochemistry																			[blue]					
Collier Geophysics – Seismic Surveys									[green]															
Regional Fracture Analysis (Stantec)																			[blue]					
ECO Monitoring - C-38 Canal/N Lake O.																[green]								
ERA Work Plan		[green]																						
ERDC Studies																			[blue]					
Groundwater Modeling																			[blue]					
Surface Water Mixing Zone Modeling																			[blue]					
Radium in Groundwater Survey																			[blue]					
ASR Science Plan Updates, and Internal and Inter-Agency Reviews													[yellow]	[yellow]	[yellow]	[yellow]	[yellow]	[yellow]						
Public ASR Panel Workshop																			[yellow]					
Panel Report Development																			[yellow]	[yellow]	[yellow]			
Panel Report Reviews																					[yellow]	[yellow]		
ASR Science Plan Final Revisions, Reviews & Publication																							[yellow]	[yellow]

July 9 and 10, 2024 Field Trip and Public Workshop

[green] Annual or final report incuded in ASR Science Plan
[yellow] ASR Science Plan Work in Progress
[blue] No Report/Update Only at the Public Workshop

Draft ASR Report Card ASR Science Plan V2

Status: April, 2024

2024 ASR Science Plan Report Card

National Research Council Uncertainties and ASR Peer Review Panel Recommendations	% Progress Towards Adressing the Topic								
	10	20	30	40	50	60	70	80	90
2015 National Research Council Uncertainties									
Local scale information on attributes of APPZ									
Research phosphorus removal mechanisms									
Research pathogen inactivation in the aquifer									
Couple pathogen inactivation with groundwater travel times	*								
Establish buffer zone									
Arsenic transport within aquifer using buffer zone									
Buffer zone usage to reduce sulfate concentrations									
Fate of sulftate in recovered water to form methylmercury									
Local scale model for heterogeneity/anisotropy/fracturing/travel times									
Pretreatment technologies to attenuate arsenic mobilization									
Analysis of wellfield cluster for spacing and optimal recovery efficiency									
Anisotropy analysis used for orienting wells									
Cross-well tomography and geophysics									
Locate clusters near large water bodies									
Examine technologies to meet regulatory requirements									
Variability of gross alpha and radium in recovered water									
Examine source water effects on redox evolution of aquifer									
Improve/extend cycle tests									
Operate multi-well pairs and clusters									
Continue chronic toxicity testing at multiple ASR locations									
Long-term ecological monitoring and bioconcentration studies, community-level effects									
Probabilistic, quantitative ecological risk assessment									
2021 ASR Peer Review Panel Recommendations									
Develop ASR Programmatic Quality Assurance Plan									
Data Storage, Management, and Public Access									
2022 ASR Peer Review Panel Recommendations									
Spacers in core storage									
Core geochemical analysis									
Local-scale groundwater model layers development									
Hydrologic modeling to include fracture and faulting patterns to determine optimal well spacing									
Add new Panel member with strong background in water treatment and economics of water treatment									
Revisit point-of-compliance and reduced pretreatment options with regulatory agencies									
Implement incremental approach to design, construction, and operation of the pretreatment of water to be stored									
Test other coagulants (e.g. ferrate) with media filtration as a potential pretreatment method									
Develop detailed plan of arsenic monitoring during all portions of the ASR operations									
Develop detailed water quality monitoring plan for cycle testing									
Develop recovered water monitoring including arsenic, molybdenum and other ions that may be leached from the aquifers during storage									
Expand ichthyoplankton monitoring to the early dry season; characterize ichthyoplankton risk when impingment and entrainment most possible									
Establish a system to implement and update the ERA; use Bayesian networks in a risk assessment framework; use separate but interconnected conceptual models; develop tiered assessments for focusing data collection efforts and needs from conservative to more realistic assumptions									

- NRC Uncertainties and Peer Review Panel Recommendations addressed :
  - Research of Pathogens
  - Completion of PQAP
  - Addition of ASR Peer Review Panel Member with expertise in Water Treatment
  - Testing of Coagulants for Water Treatment

*Yellow indicates progress in 2020-2022

*Green indicates progress in 2022-2024

Thank you!

www.sfwmd.gov/lowrp or www.sfwmd.gov/asr

Continuous Core and Aquifer Pump Test Results



Lake Okeechobee Watershed Restoration Project (LOWRP): Aquifer Storage and Recovery (ASR) Well Program

July 10, 2024

Generalized Hydrogeologic Section Review: Targeted Storage Zones

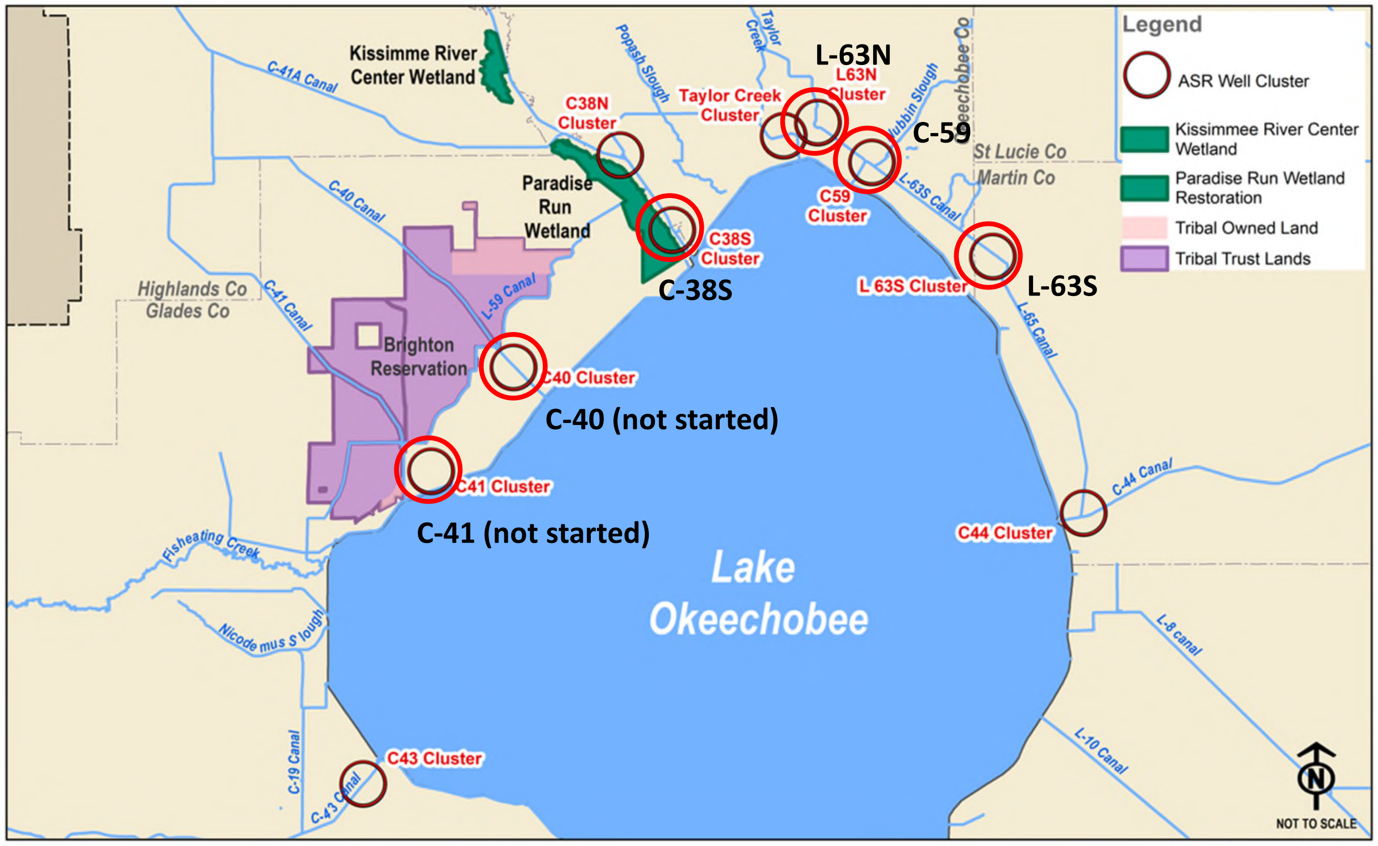
- Confinement above and below each storage zone – Hawthorn 450 to 500 feet thick.
- UFA upper flow zone is about 80 to 150 feet thick and contains the Suwannee LS and the upper most Ocala LS. The UFA flow zone can be highly productive
- Middle Confining Unit (MCU 1) approximately 500 to 600 feet thick
- Upper Avon Park Permeable Zone (APPZ) upper flow zone is approximately 80 to 120 feet thick – highly productive
- Confinement below the lower APPZ

Series			Geologic Unit		Lithology	Hydrogeologic Unit		Approximate Thickness (feet bls)
NEOGENE	HOLOCENE AND PLEISTOCENE		Undifferentiated Sedimetns		Quartz sand; silt; clay; shell; limestone; sandy shelly limestone	Surficial Aquifer System (0 ft to 150 ft bls)		0 – 150
NEOGENE	EARLY PLIOCENE AND MIOCENE		Hawthorn	Peace River Formation	Unconsolidated sand; silt; clay; carbonates; phosphatic sand	Intermediate Aquifer Confining Unit (Base of the Hawthorn varies as much as 150 feet between sites)		150 – 520
				Arcadia Formation	Limestone; sandy limestone; sand; interbedded clay; phosphate			
PALEOGENE	EARLY OLIGOCENE		Suwannee Limestone		Fossiliferous; calcarenitic; limestone; trace phosphate, abundant Oster shell **Index Fossil: Rhyncholampas gouldii, Gagaria mossomi, Dictyoconus cookei, Discorinopsis gunteri**	Upper Floridan Aquifer System	*Floridan Aquifer Upper Flow Zone (40 to 80 feet thick)*	520 – 800
	EOCENE	*LATE*	Ocala Limestone		Fossiliferous limestone; foraminiferous limestone; trace phosphate **Index Fossil: *Lepidocyclina ocalana; Amphistegina* sp., Oligopygus wetherbyi**		MCU I (800 to 900 feet thick)	800 – 1,350
		MIDDLE	Avon Park Formation		Fine grained, micritic to sucrosic limestone; dolomitic limestone; dolostone **Index Fossil: Dictyoconus americanus**		Avon Park FM	
							APPZ Upper Flow Zone (80 to 150 feet thick)	1,350 – 1,430
							Middle Semiconfining Unit (MSCU) (65 to 75 feet thick)	1,430 – 1,495
							APPZ Lower Flow Zone (50 to 155 feet thick)	1,495 – 1,650
					Dolostone with evaporites		*MCU II (250 to 350 ft thick)*	1,650 – 1,900
			Oldsmar		Evaporates with dolostone	Lower Floridan Aquifer	*Lower Floridan Aquifer (LFA) Flow Zone*	1,900 – >2,000

Continuous Coring Program

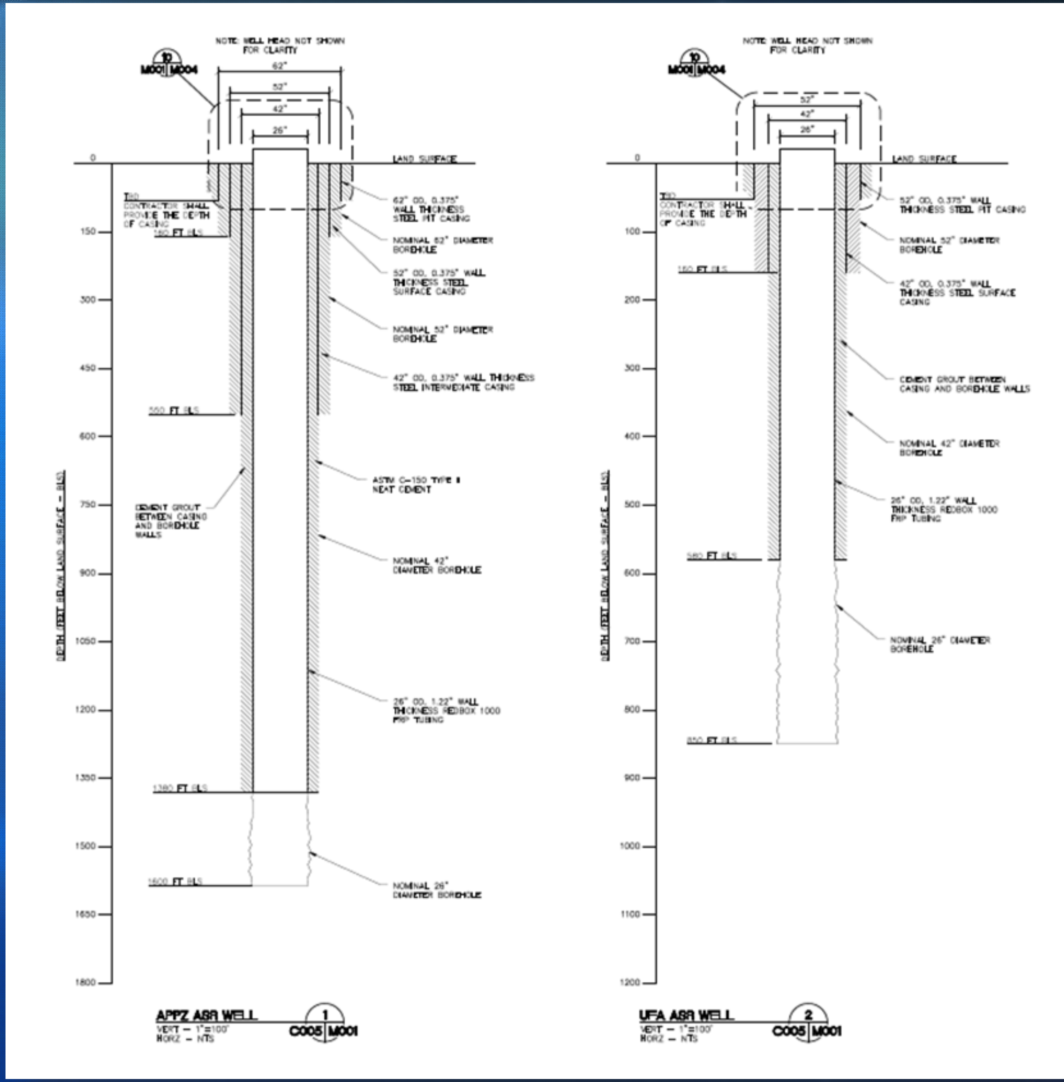
Continuous Core Program

- Advance continuous core hole to 2,000 feet bls – start coring at 500 feet bls. Approximately 6,100 feet of core collected so far.
- Conduct packer tests every 30 feet from the top of the Suwannee LS to the total depth – WQ, Isotopes, SC
- Run geophysical logs including OBI logs from the top of the Suwannee LS to total depth
- Core samples submitted for SEM, thin section, x-ray detraction analysis, and isotope analysis



Purpose of Continuous Core Program

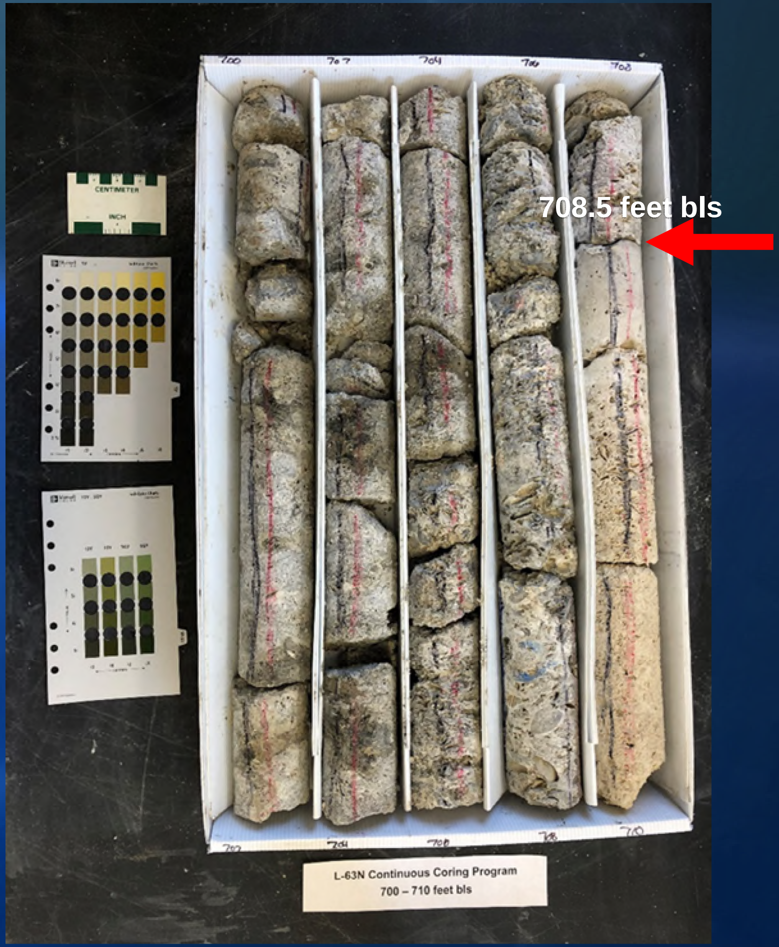
- Determine subsurface geologic and hydrogeologic conditions
- Determine water quality and specific capacity data every 30 feet
- Develop cores described in the field and detailed analysis -
  - Cores sent to Mineralogy Inc., Florida Gulf Coast University and USGS for detailed analysis
- Data used to determine if the site would support UFA and APPZ ASR wells and to develop ASR design documents



Continuous Cores

Hawthorn Group
(Confining Unit)

Top of Suwannee LS
(Upper Storage Zone)



Top of Ocala LS
(Upper Storage Zone)

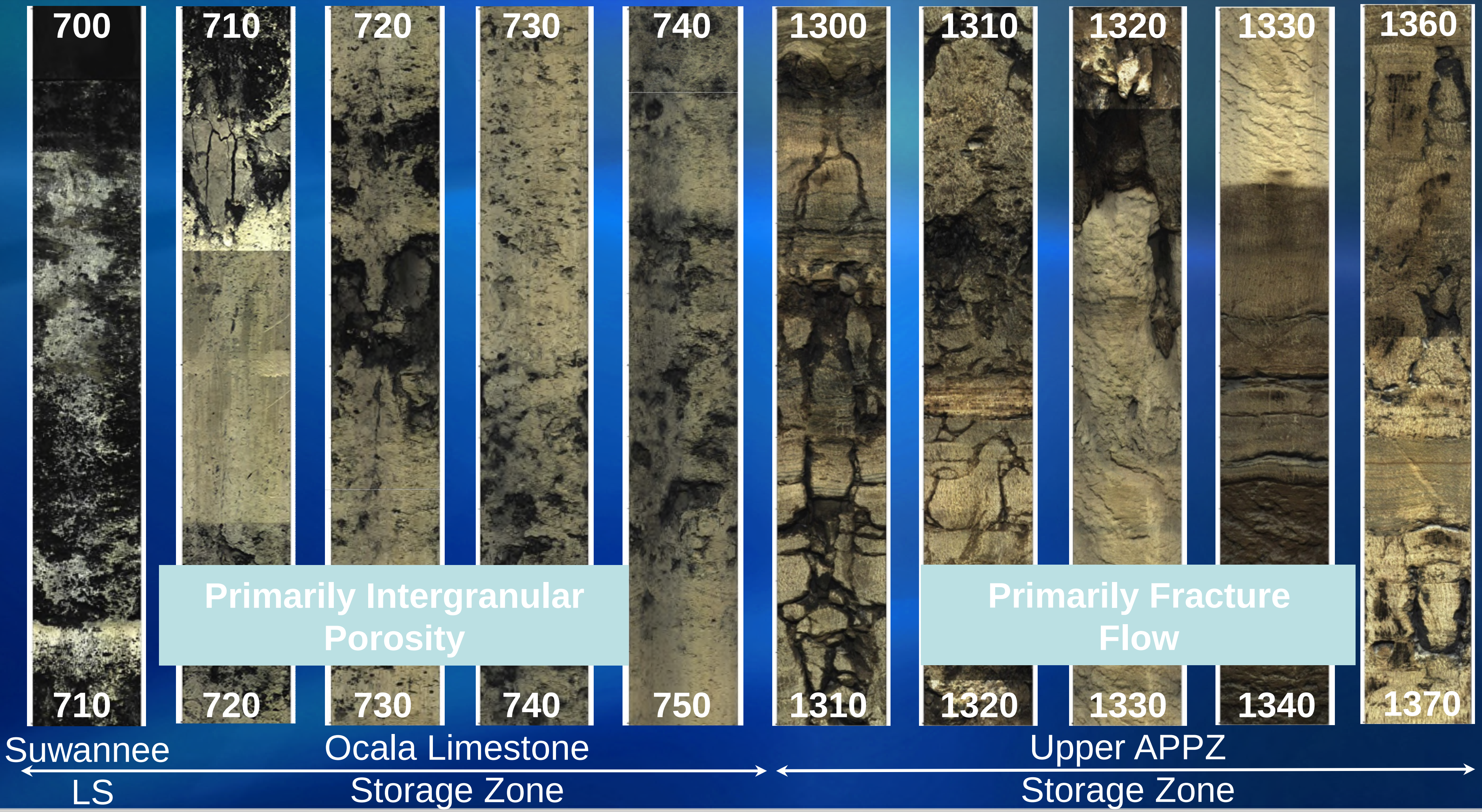
Continuous Cores

Ocala Limestone
(Middle Confining Unit 1)

Top of Upper APPZ
(Storage Zone)

Top of Oldsmar Fm
~1,750 feet

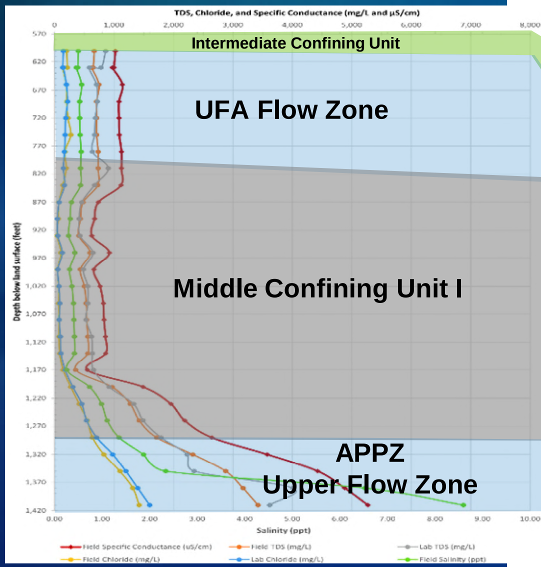
Optical Borehole Imager (OBI)



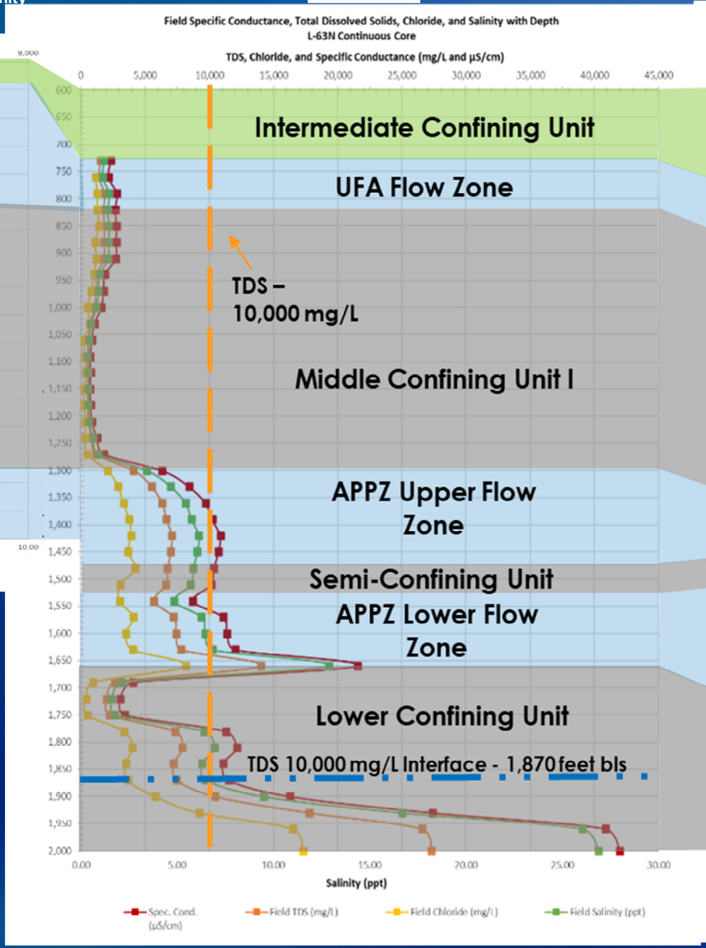
Continuous Core Field Water Quality

C-38S

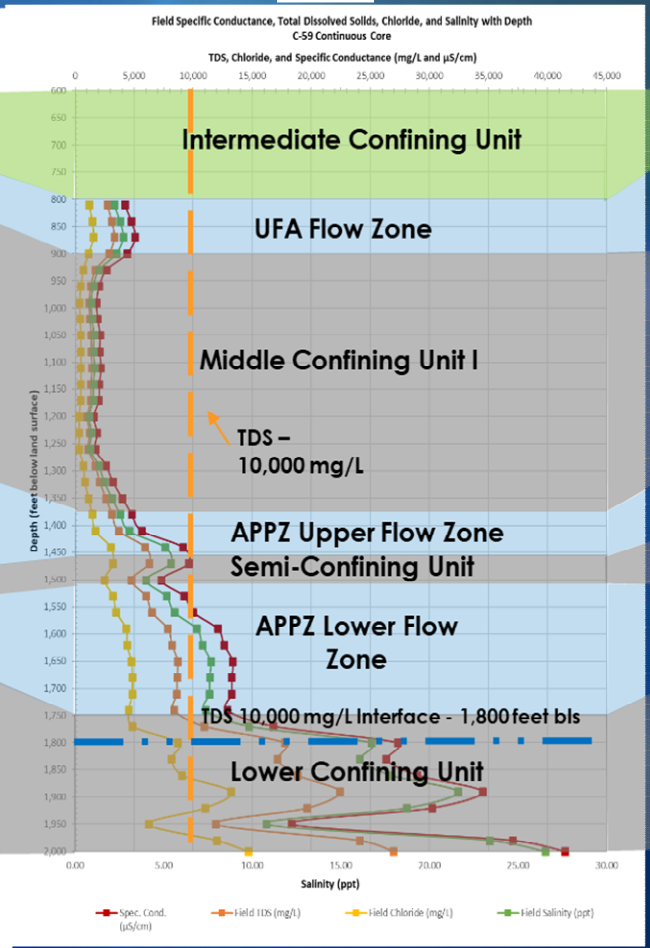
Field Specific Conductance, TDS, Chloride, and Salinity
C-38S Continuous Core



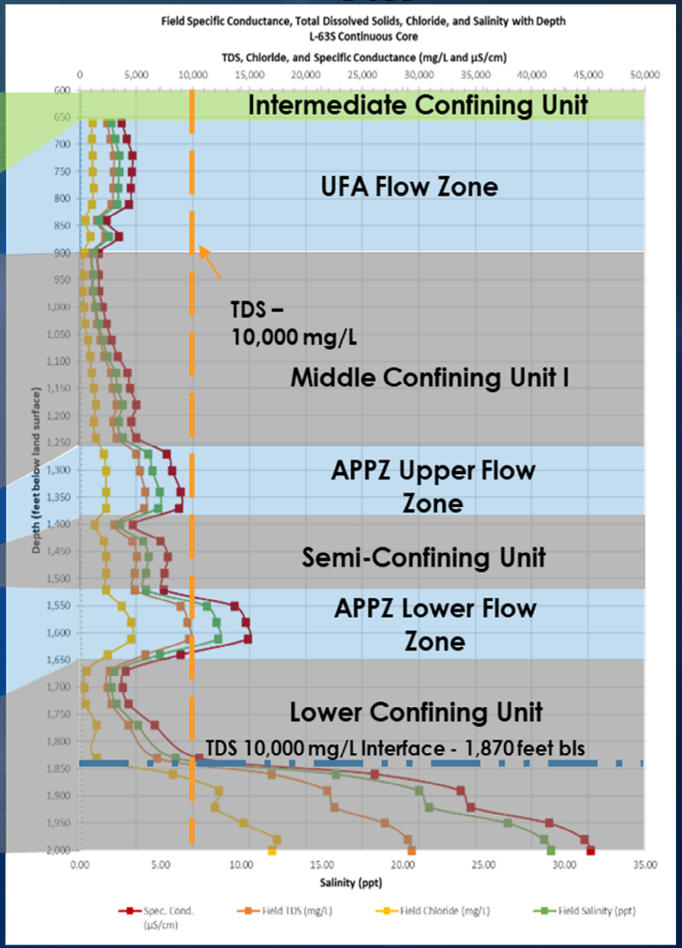
L-63N



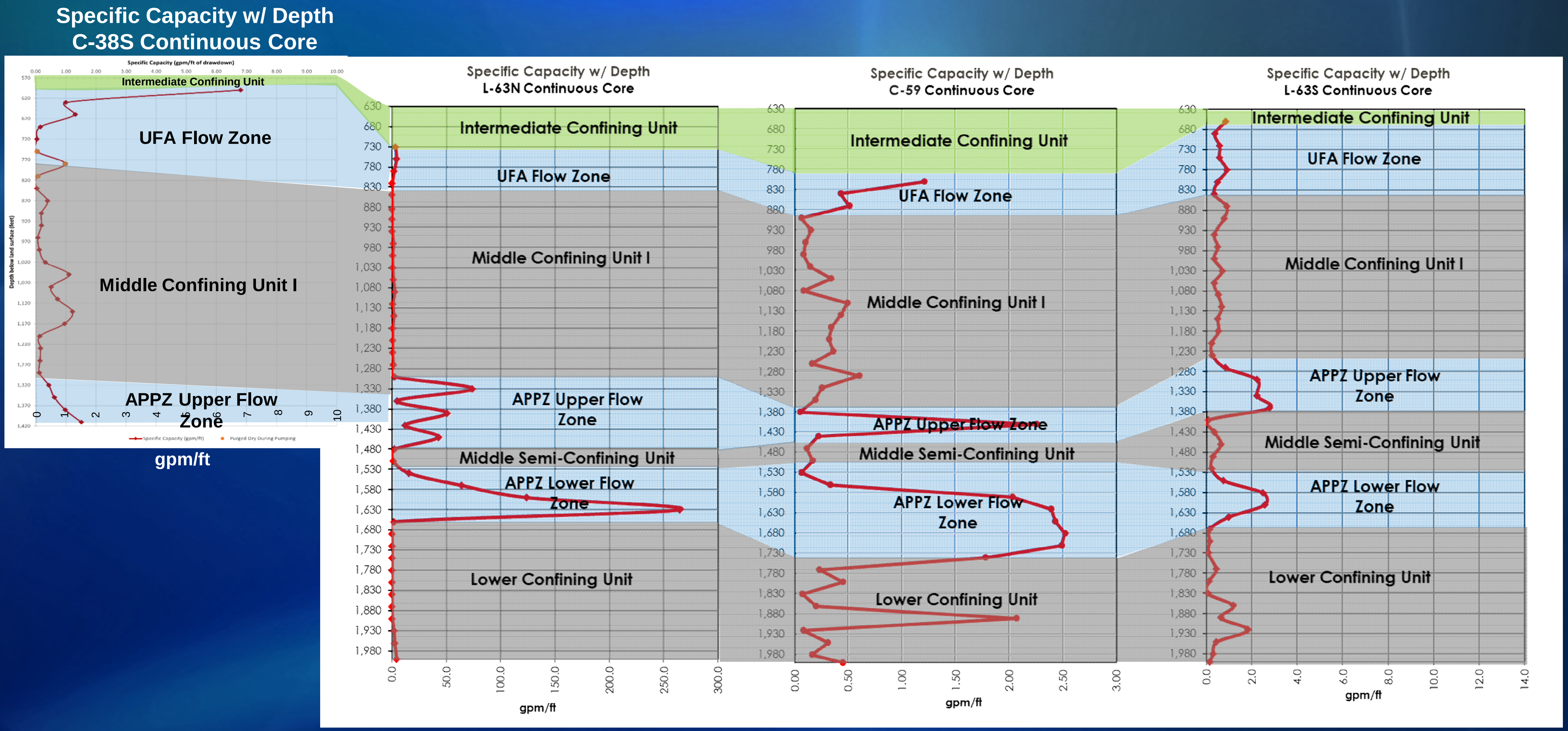
C-59



L-63S



Continuous Core Specific Capacity



USACE – Engineering Research and Development Center (ERDC)
Low Oxygen Core Extraction

Aquifer Performance Testing (APT)

ASR Test Well Construction - Casing Sizes

- stee
- stee
- stee
- fibe

- stee
- stee
- fibe

Aquifer Performance Testing (APT)

C-38S Aquifer Performance Testing

- September 18 – 23 (combined artesian)
- October 9 – 14 (APPZ pumping)
- October 16 – 21 (UFA pumping)
- October 23 – 28 (combined APPZ and UFA Pumping)
- 48-hour Recovery between tests

C-38N Aquifer Performance Testing

- November 6 – 11 (combined artesian)
- November 27 – December 2 (APPZ pumping)
- December 4 – 9 (UFA pumping)
- December 11 – 13 (combined APPZ and UFA Pumping test #1)
- December 18 – 23 (combined APPZ and UFA Pumping test #2)
- 48-hour Recovery between tests

30 Day Pre- APT Water Level Monitoring

Adding a 5-day APPZ Variable Rate Test to Evaluate Upconing in the APPZ

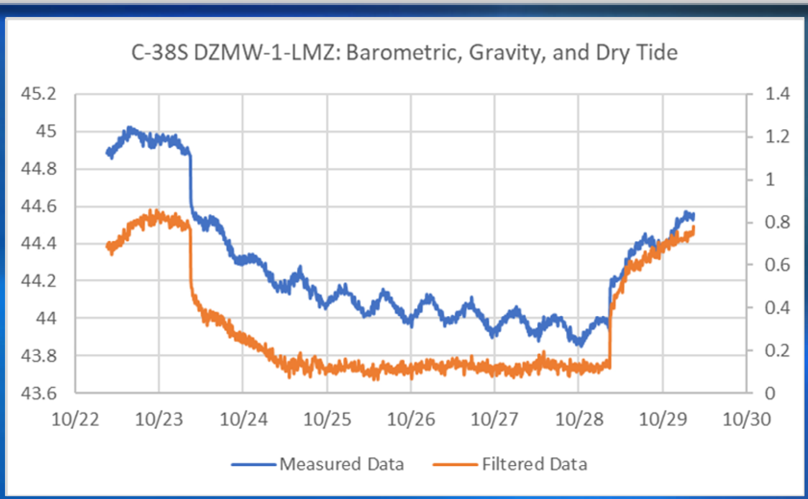
Aquifer Performance Testing (APT)

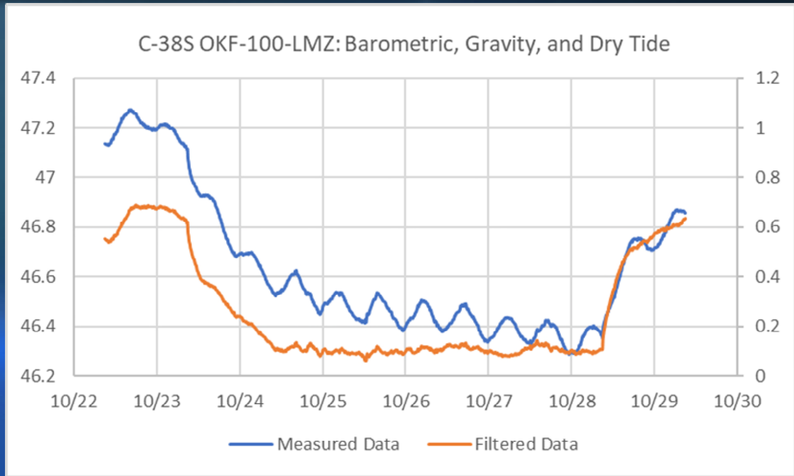
Aquifer Performance Testing - Analysis Methods

- Cooper-Jacob
  - Straight Line Solution (time and distance DD graphs)
- Theis
  - Confined, homogenous, isotropic
- Hantush-Jacob
  - Leaky confined aquifers
- Recovery – Theis
- Data correction (APPZ)
  - USGS SeriesSEE Excel Add-in

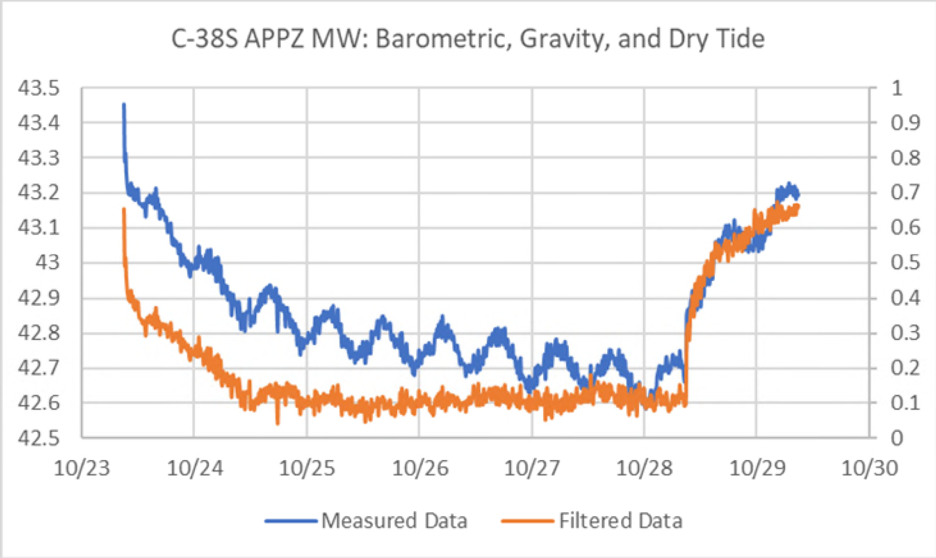
- The purpose of the APTs is to determine hydraulic characteristics of the aquifers.
- The APT results are being used in the groundwater model to aid in predicative scenarios associated with the injection bubble geometry, recovery efficiency, and to identify potential upconing between aquifers.

Aquifer Performance Testing (APT)





Examples of Corrected Data



Aquifer Performance Testing (APT)

C-38S APT Results

Aquifer Performance Testing (APT)

Test	Pipe and Orifice Diameter (inch)	Height on Manometer (inch)	Pumping Rate from Orifice (gpm)	Pumping rate from Flow Meter (gpm)
Artesian APPZ ASR	16 x 12	16	2,522	2,510
Artesian UFA ASR	16 x 10.5	12	1,528	1,510
Pumping APPZ ASR	16 x 12	67.5	5,180	5,270
Pumping UFA ASR	16 x 12	51.5	4,524	4,620
Combined Puming APPZ ASR	16 x 12	68	5,199	5,295
Combined Pumping UFA ASR	16 x 12	51.5	4,524	4,620

Orifice Calculation

16 x 12 = 630.47 √h = gpm

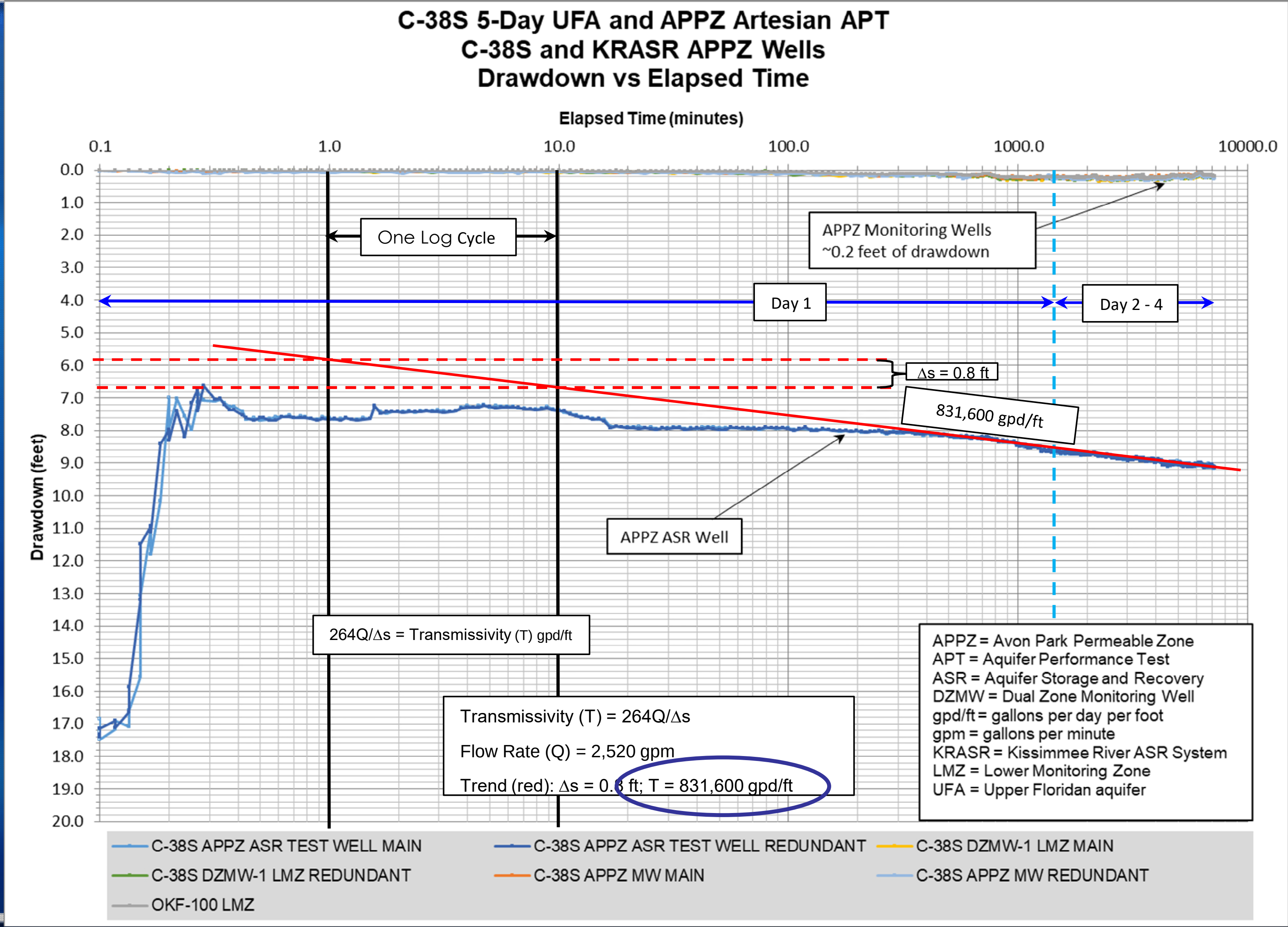
16 x 10.5 = 441.03 √h = gpm

C-38S Aquifer Performance Testing

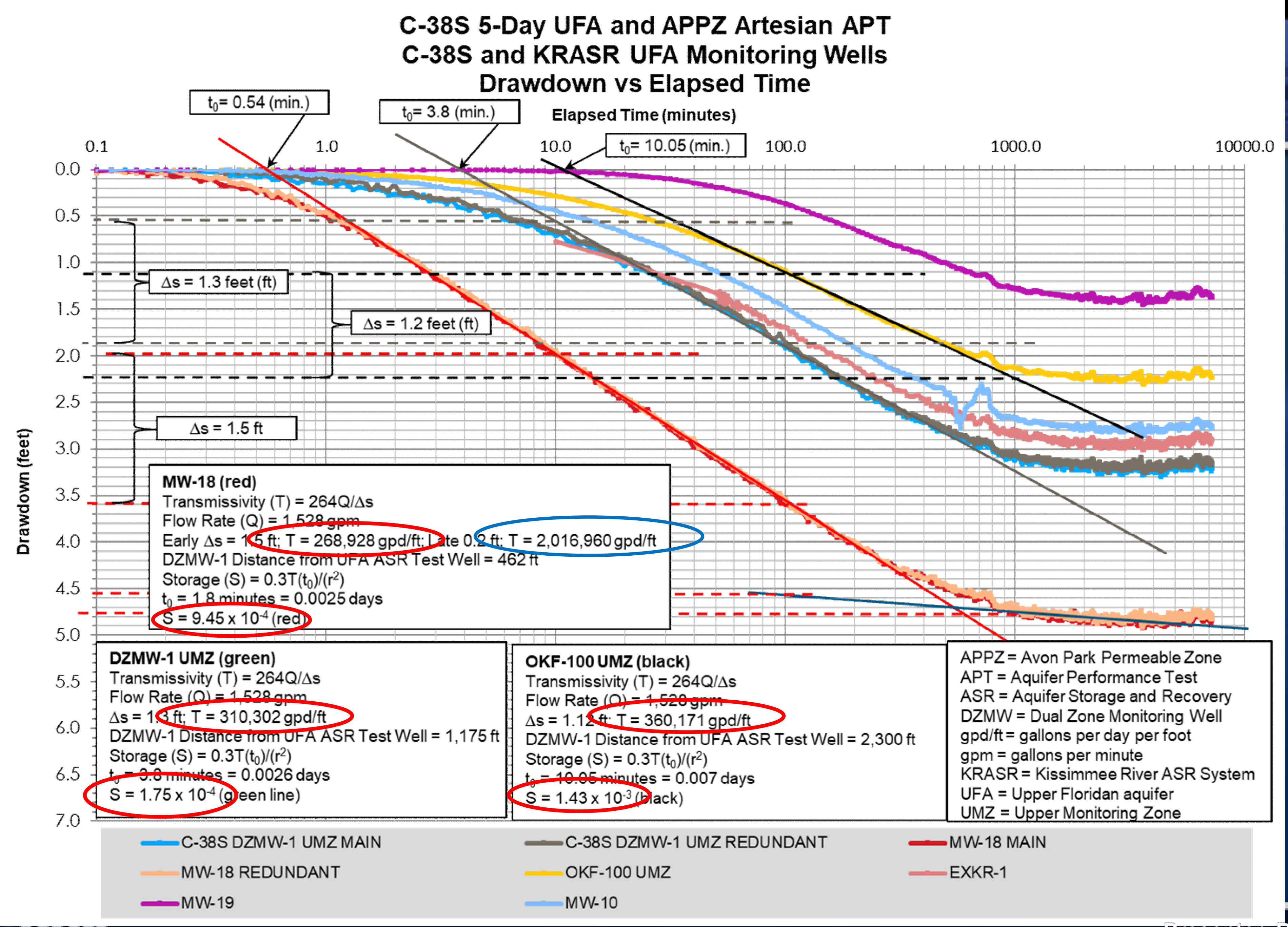
Pumping Rates

Aquifer Performance Testing (APT)

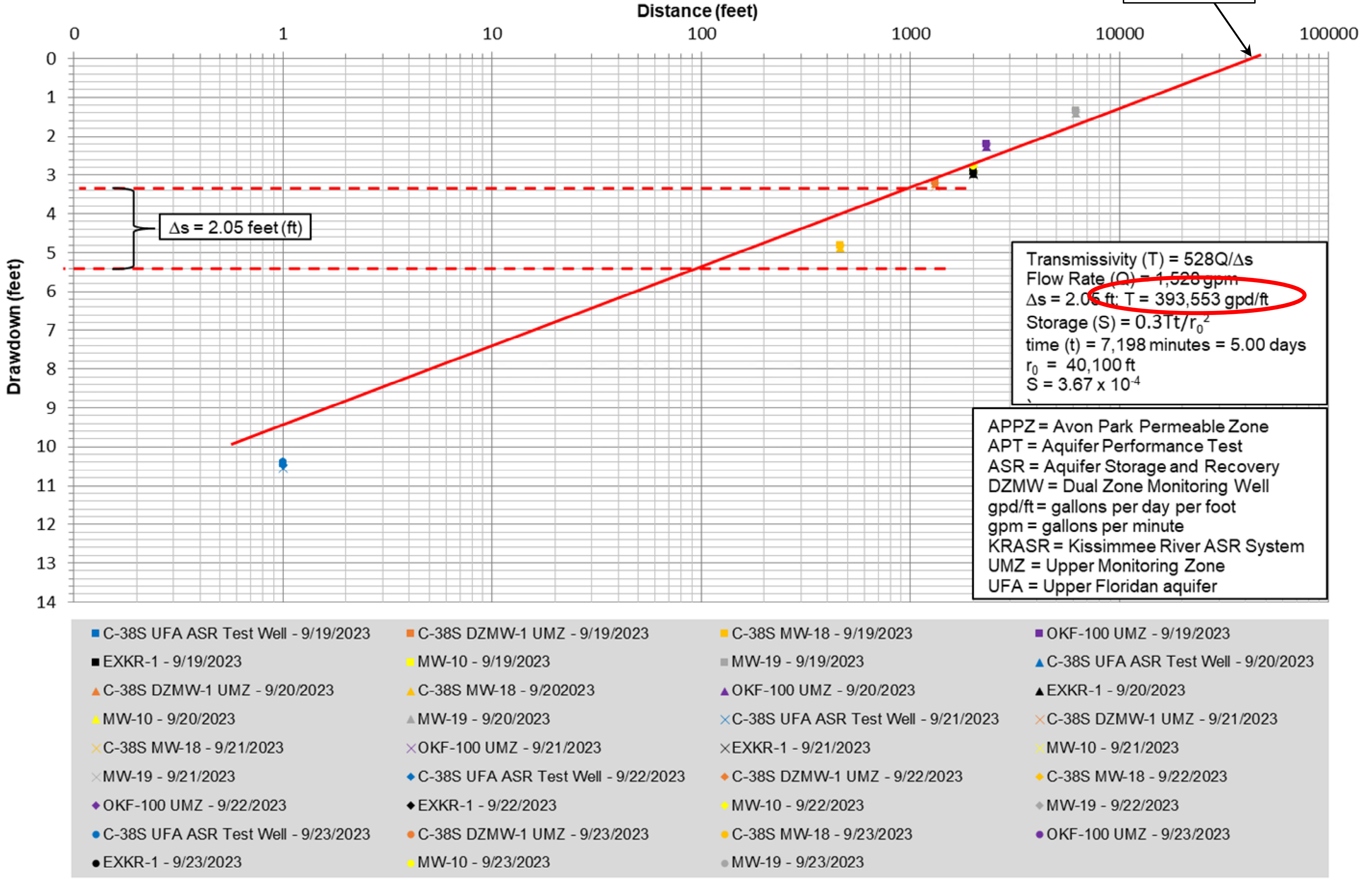
Cooper-Jacob Straight Line Method

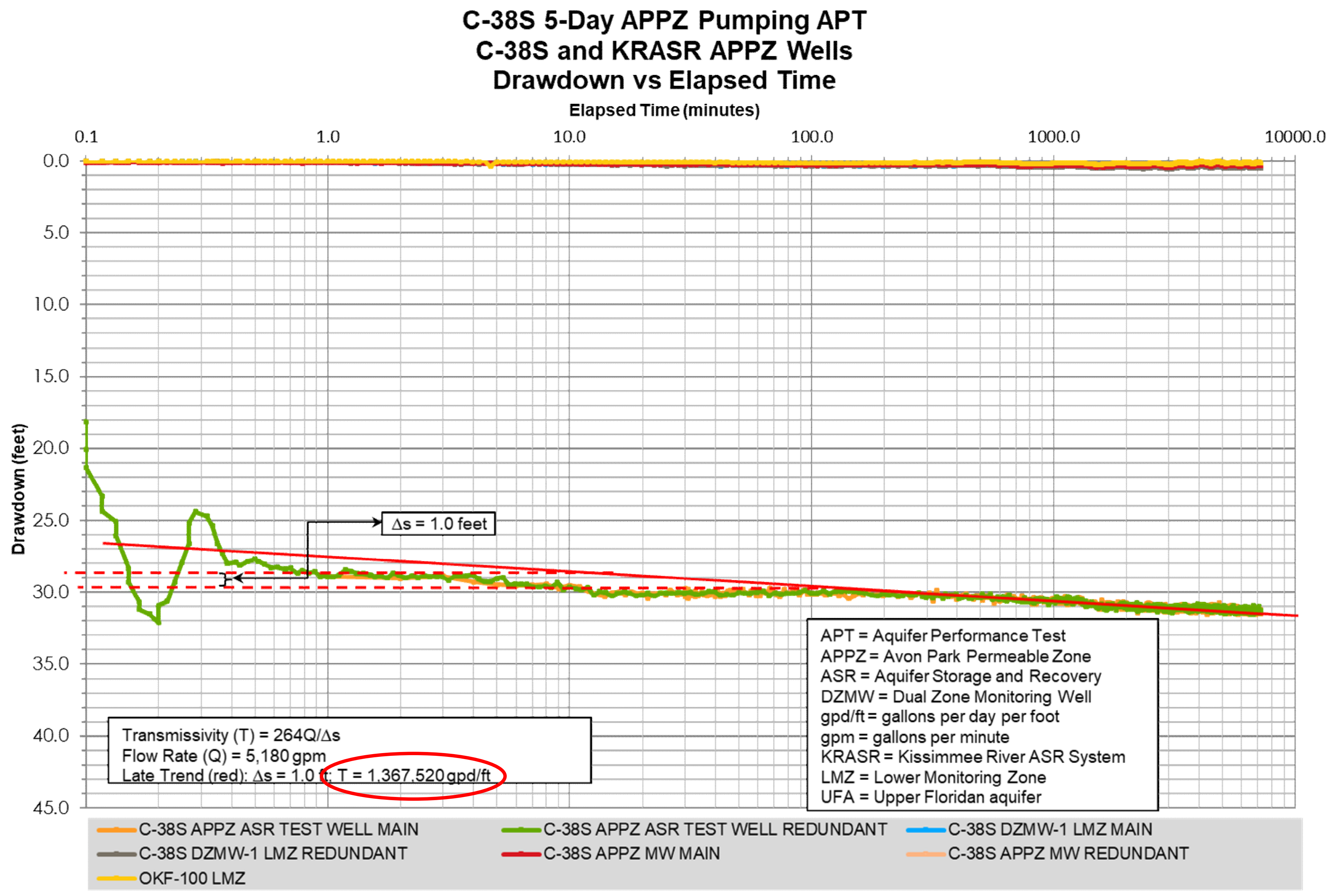


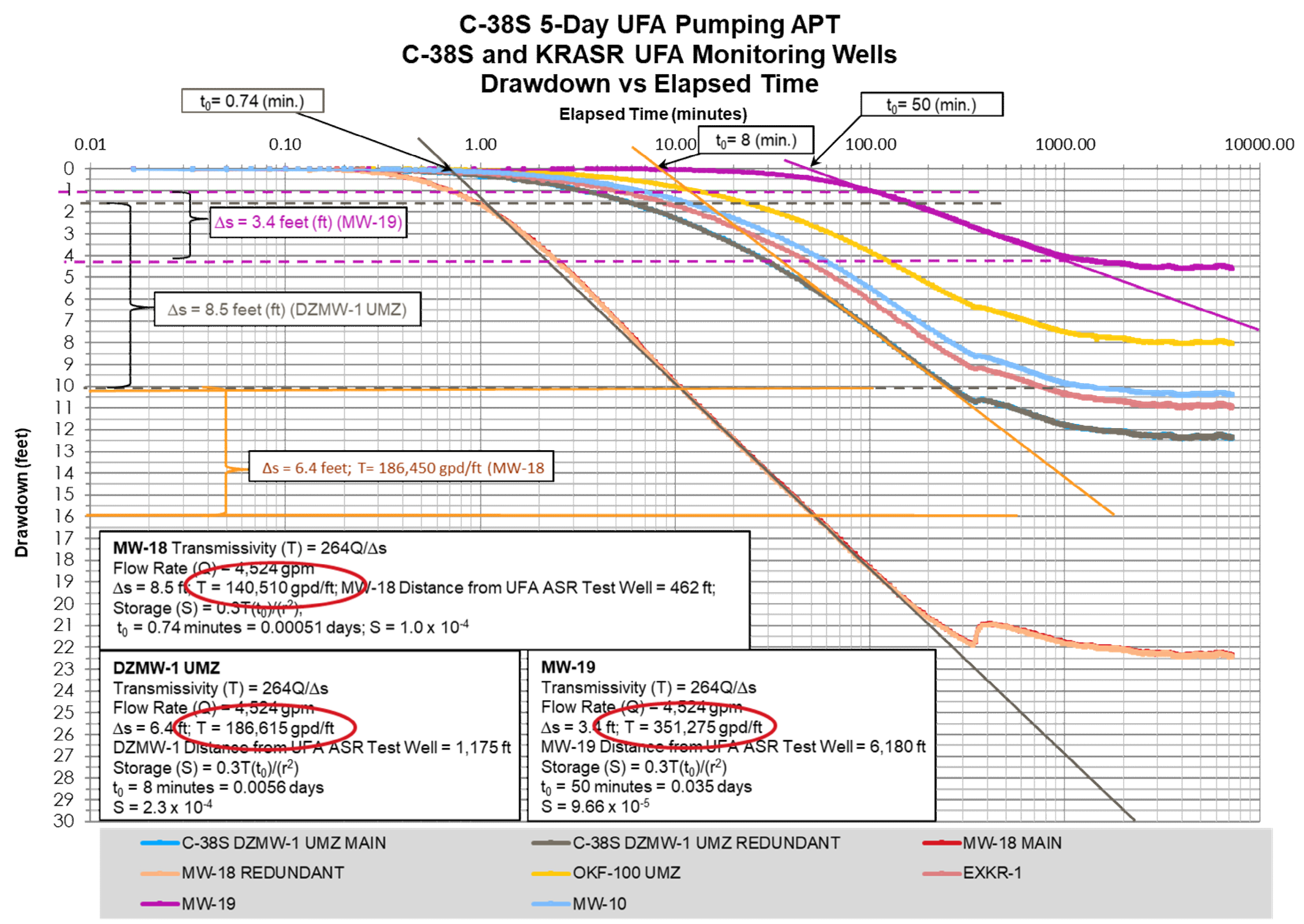
Presenter: Rick Cowles


C-38S 5-Day UFA and APPZ Artesian APT
C-38S and KRASR UFA Monitoring Wells
Drawdown vs Elapsed Time
Elapsed Time (minutes)
t_0= 0.54 (min.)
t_0= 3.8 (min.)
t_0= 10.05 (min.)
0.1
1.0
10.0
100.0
1000.0
10000.0
Drawdown (feet)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
Δs = 1.3 feet (ft)
Δs = 1.2 feet (ft)
Δs = 1.5 ft
MW-18 (red)
Transmissivity (T) = 264Q/Δs
Flow Rate (Q) = 1,528 gpm
Early Δs = 1.5 ft; T = 268,928 gpd/ft; Late 0.2 ft; T = 2,016,960 gpd/ft
DZMW-1 Distance from UFA ASR Test Well = 462 ft
Storage (S) = $0.3T(t_0)/(r^2)$
t_0 = 1.8 minutes = 0.0025 days
S = 9.45×10^{-4} (red)
DZMW-1 UMZ (green)
Transmissivity (T) = 264Q/Δs
Flow Rate (Q) = 1,528 gpm
Δs = 1.3 ft; T = 310,302 gpd/ft
DZMW-1 Distance from UFA ASR Test Well = 1,175 ft
Storage (S) = $0.3T(t_0)/(r^2)$
t_0 = 3.8 minutes = 0.0026 days
S = 1.75×10^{-4} (green line)
OKF-100 UMZ (black)
Transmissivity (T) = 264Q/Δs
Flow Rate (Q) = 1,528 gpm
Δs = 1.12 ft; T = 360,171 gpd/ft
DZMW-1 Distance from UFA ASR Test Well = 2,300 ft
Storage (S) = $0.3T(t_0)/(r^2)$
t_0 = 10.05 minutes = 0.007 days
S = 1.43×10^{-3} (black)
APPZ = Avon Park Permeable Zone
APT = Aquifer Performance Test
ASR = Aquifer Storage and Recovery
DZMW = Dual Zone Monitoring Well
gpd/ft = gallons per day per foot
gpm = gallons per minute
KRASR = Kissimmee River ASR System
UFA = Upper Floridan aquifer
UMZ = Upper Monitoring Zone
C-38S DZMW-1 UMZ MAIN
C-38S DZMW-1 UMZ REDUNDANT
MW-18 MAIN
MW-18 REDUNDANT
OKF-100 UMZ
EXKR-1
MW-19
MW-10

C-38S 5-Day UFA and APPZ Artesian APT
C-38S and KRASR UFA Wells
Drawdown vs Distance




C-38S 5-Day APPZ Pumping APT
C-38S and KRASR APPZ Wells
Drawdown vs Elapsed Time
Elapsed Time (minutes)
0.1
1.0
10.0
100.0
1000.0
10000.0
Drawdown (feet)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
Δs = 1.0 feet
Transmissivity (T) = 264Q/Δs
Flow Rate (Q) = 5,180 gpm
Late Trend (red): Δs = 1.0 ft; T = 1,367,520 gpd/ft
APT = Aquifer Performance Test
APPZ = Avon Park Permeable Zone
ASR = Aquifer Storage and Recovery
DZMW = Dual Zone Monitoring Well
gpd/ft = gallons per day per foot
gpm = gallons per minute
KRASR = Kissimmee River ASR System
LMZ = Lower Monitoring Zone
UFA = Upper Floridan aquifer
C-38S APPZ ASR TEST WELL MAIN
C-38S APPZ ASR TEST WELL REDUNDANT
C-38S DZMW-1 LMZ MAIN
C-38S DZMW-1 LMZ REDUNDANT
C-38S APPZ MW MAIN
C-38S APPZ MW REDUNDANT
OKF-100 LMZ



C-38S 5-Day UFA Pumping APT
C-38S and KRASR UFA Monitoring Wells
Drawdown vs Elapsed Time
Elapsed Time (minutes)
t0= 0.74 (min.)
t0= 8 (min.)
t0= 50 (min.)
0.01
0.10
1.00
10.00
100.00
1000.00
10000.00
Drawdown (feet)
Δs = 3.4 feet (ft) (MW-19)
Δs = 8.5 feet (ft) (DZMW-1 UMZ)
Δs = 6.4 feet; T= 186,450 gpd/ft (MW-18
MW-18 Transmissivity (T) = 264Q/Δs
Flow Rate (Q) = 4,524 gpm
Δs = 8.5 ft; T = 140,510 gpd/ft; MW-18 Distance from UFA ASR Test Well = 462 ft;
Storage (S) = 0.3T(t0)/(r2),
t0 = 0.74 minutes = 0.00051 days; S = 1.0 x 10-4
DZMW-1 UMZ
Transmissivity (T) = 264Q/Δs
Flow Rate (Q) = 4,524 gpm
Δs = 6.4 ft; T = 186,615 gpd/ft
DZMW-1 Distance from UFA ASR Test Well = 1,175 ft
Storage (S) = 0.3T(t0)/(r2)
t0 = 8 minutes = 0.0056 days
S = 2.3 x 10-4
MW-19
Transmissivity (T) = 264Q/Δs
Flow Rate (Q) = 4,524 gpm
Δs = 3.4 ft; T = 351,275 gpd/ft
MW-19 Distance from UFA ASR Test Well = 6,180 ft
Storage (S) = 0.3T(t0)/(r2)
t0 = 50 minutes = 0.035 days
S = 9.66 x 10-5
C-38S DZMW-1 UMZ MAIN
C-38S DZMW-1 UMZ REDUNDANT
MW-18 MAIN
MW-18 REDUNDANT
OKF-100 UMZ
EXKR-1
MW-19
MW-10

Aquifer Performance Testing (APT)

C-38S APT Summary Table

Aquifer Performance Test	Aquifer	Transmissivity (gpd/ft)	Transmissivity (ft^2/day)	Storage
Combined Artesian - APPZ	APPZ	831,600	111,176	*1.4 x 10^{-4}
APPZ Constant Rate APT	APPZ	1,538,760	205,717	*1.4 x 10^{-4}
Combined Constant Rate - APT	APPZ	784,306	104,854	*1.4 x 10^{-4}
	Average	1,051,555	140,582	*1.4 x 10^{-4}
Combined Artesian - UFA	UFA	302,445	40,434	1.38 x 10^{-4}
UFA Constant Rate APT	UFA	219,024	29,281	2.87 x 10^{-4}
Combined Constant Rate - UFA	UFA	227,280	30,385	6.49 x 10^{-4}
	Average	249,583	33,367	3.58 x 10^{-4}

C-38N Aquifer Performance Testing

Aquifer Performance Testing (APT)

C-38N Flow and Pumping Rates

Test	Pipe and Orifice Diameter (inch)	Height on Manometer (inch)	*Pumping Rate from Orifice (gpm)	Pumping rate from Flow Meter (gpm)
Artesian APPZ ASR	16 x 12	17.5	2,637	2,510
Artesian UFA ASR	10 x 2	7.375	40	1,510
Pumping APPZ ASR	16 x 12	71.5	5,331	5,550
Pumping UFA ASR	10 x 5	11.5	318	303
Combined Pumping APPZ ASR (1)	16 x 12	71.5	5,331	5,550
Combined Pumping UFA ASR (1)	10 x 5	11.5	318	303
**Combined Pumping APPZ ASR (2)	16 x 12	71.5	5,331	5,550
**Combined Pumping UFA ASR (2)	10 x 5	11.5	318	303

*Pumping rate used in test analysis

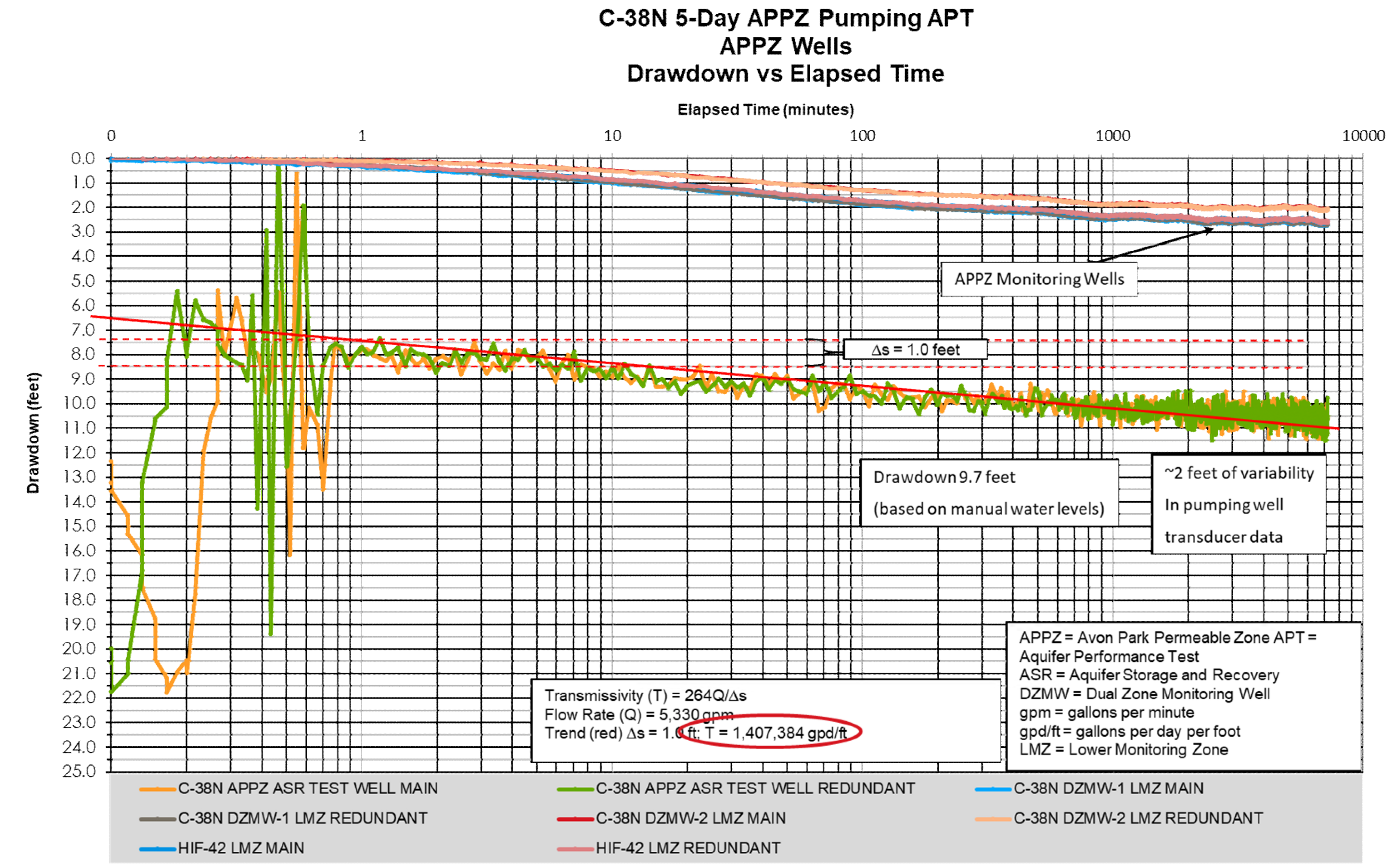
**Combined pumping test rerun because the generator failed approximately 72 hours into the test

Orifice Calculation

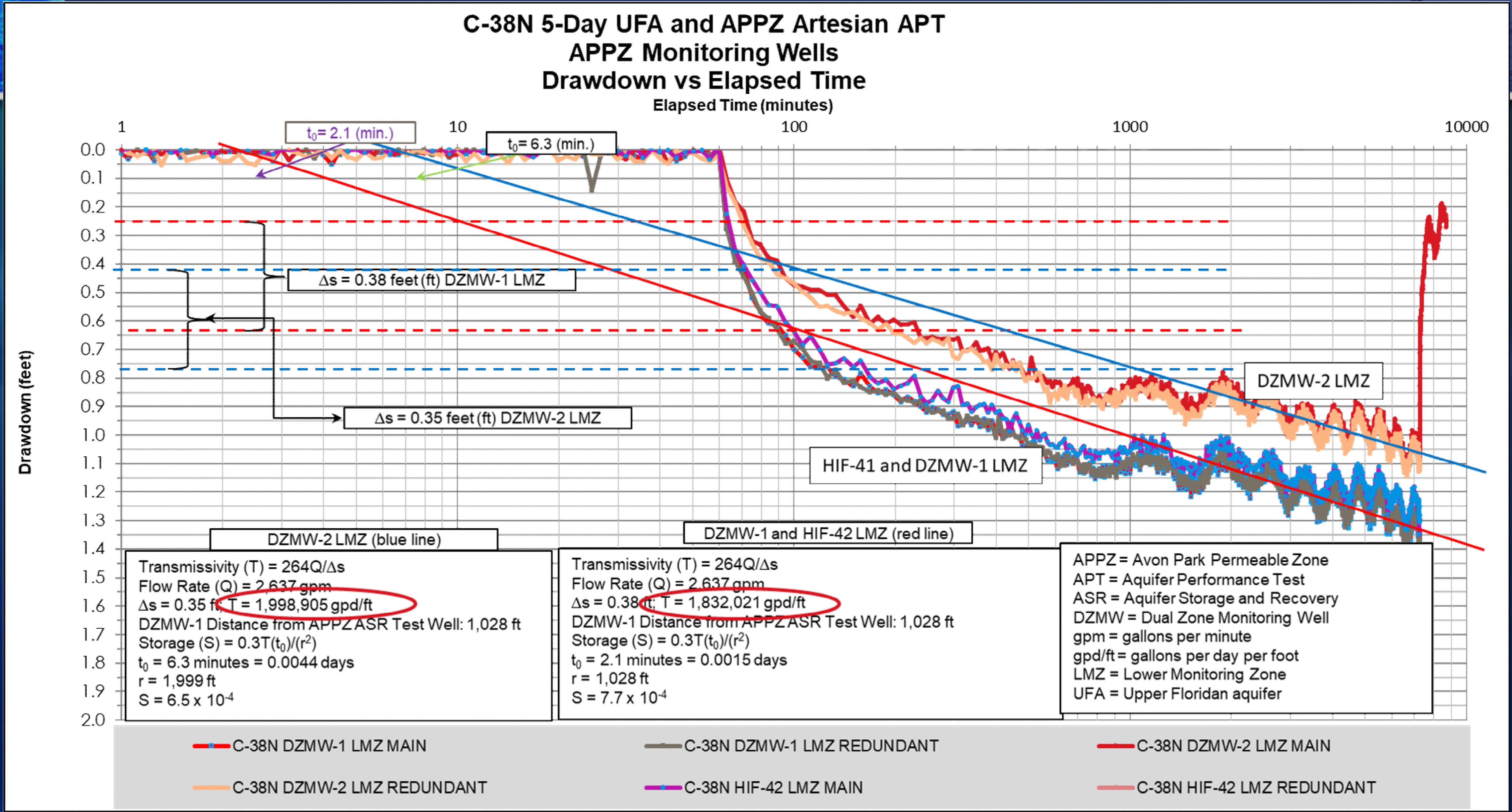
16 x 12 = 630.47 $\sqrt{h}$ = gpm

10 x 2 = 14.55 $\sqrt{h}$ = gpm

10 x 5 = 93.9 $\sqrt{h}$ = gpm



C-38N 5-Day APPZ Pumping APT
APPZ Wells
Drawdown vs Elapsed Time
Elapsed Time (minutes)
0
1
10
100
1000
10000
Drawdown (feet)
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
22.0
23.0
24.0
25.0
APPZ Monitoring Wells
Δs = 1.0 feet
Drawdown 9.7 feet
(based on manual water levels)
~2 feet of variability
In pumping well
transducer data
Transmissivity (T) = 264Q/Δs
Flow Rate (Q) = 5,330 gpm
Trend (red) Δs = 1.0 ft; T = 1,407,384 gpd/ft
APPZ = Avon Park Permeable Zone APT = Aquifer Performance Test
ASR = Aquifer Storage and Recovery
DZMW = Dual Zone Monitoring Well
gpm = gallons per minute
gpd/ft = gallons per day per foot
LMZ = Lower Monitoring Zone
C-38N APPZ ASR TEST WELL MAIN
C-38N APPZ ASR TEST WELL REDUNDANT
C-38N DZMW-1 LMZ MAIN
C-38N DZMW-1 LMZ REDUNDANT
C-38N DZMW-2 LMZ MAIN
C-38N DZMW-2 LMZ REDUNDANT
HIF-42 LMZ MAIN
HIF-42 LMZ REDUNDANT



C-38N 5-Day UFA and APPZ Artesian APT
APPZ Monitoring Wells
Drawdown vs Elapsed Time
Elapsed Time (minutes)
1
10
100
1000
10000
Drawdown (feet)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
t0 = 2.1 (min.)
t0 = 6.3 (min.)
Δs = 0.38 feet (ft) DZMW-1 LMZ
Δs = 0.35 feet (ft) DZMW-2 LMZ
DZMW-2 LMZ
HIF-41 and DZMW-1 LMZ
DZMW-2 LMZ (blue line)
DZMW-1 and HIF-42 LMZ (red line)
Transmissivity (T) = 264Q/Δs
Flow Rate (Q) = 2,637 gpm
Δs = 0.35 ft; T = 1,998,905 gpd/ft
DZMW-1 Distance from APPZ ASR Test Well: 1,028 ft
Storage (S) = 0.3T(t0)/(r2)
t0 = 6.3 minutes = 0.0044 days
r = 1,999 ft
S = 6.5 x 10-4
Transmissivity (T) = 264Q/Δs
Flow Rate (Q) = 2,637 gpm
Δs = 0.38 ft; T = 1,832,021 gpd/ft
DZMW-1 Distance from APPZ ASR Test Well: 1,028 ft
Storage (S) = 0.3T(t0)/(r2)
t0 = 2.1 minutes = 0.0015 days
r = 1,028 ft
S = 7.7 x 10-4
APPZ = Avon Park Permeable Zone
APT = Aquifer Performance Test
ASR = Aquifer Storage and Recovery
DZMW = Dual Zone Monitoring Well
gpm = gallons per minute
gpd/ft = gallons per day per foot
LMZ = Lower Monitoring Zone
UFA = Upper Floridan aquifer
C-38N DZMW-1 LMZ MAIN
C-38N DZMW-1 LMZ REDUNDANT
C-38N DZMW-2 LMZ MAIN
C-38N DZMW-2 LMZ REDUNDANT
C-38N HIF-42 LMZ MAIN
C-38N HIF-42 LMZ REDUNDANT

C-38N APT Summary Table

C-38N Preliminary APT Test Results

Well/Test		*Distance (ft)	Flow or Pumping Rate (gpm)	Pre-Test Water Level (ft als)	Drawdown (ft)	Specific Capacity (gpm/ft dd)	Transmissivity (gpd/ft)	Transmissivity (ft^2/day)	Storage	Estimated Well Efficiency (percent)
APPZ ASR Artesian	Combined APPZ and UFA Artesian	1	2,637	20.65	4.0	664.23	1,989,051	265,916	--	84
HIF-42 LMZ (APPZ)		678	2,637	20.50	1.3	--	1,832,021	244,923	7.7×10^{-4}	
DZMW-1 LMZ (APPZ)		1,028	2,637	22.50	1.4	--	1,832,021	244,923	7.7×10^{-4}	
DZMW-2 LMZ (APPZ)			2,637	22.90	0.1		1,998,905	267,233	6.5×10^{-4}	
Distance Drawdown		--	2,637	--	--		1,856,448	248,188	1.12×10^{-3}	
UFA ASR Artesian			40	21.08	9.8	4.08	25,756	3,443	--	32
HIF-42 UMZ (UFA)		678	40	23.15	1.2	--	24,558	3,283	1.28×10^{-4}	--
DZMW-1 (UMZ UFA)		1,028	40	22.33	1.1	--	14,667	1,961	5.79×10^{-4}	--
DZMW-2 (UMZ UFA)		1,999	40	23.50	0.9	--	14,667	1,961	3.06×10^{-4}	--
Distance Drawdown		--	40	--	--	--	26,400	3,529	4.4×10^{-5}	--
APPZ Pumping	APPZ Pumping	1	5,331	20.35	11.0	483.76	1,407,384	188,153	--	69
HIF-42 LMZ (APPZ)		678	5,331	20.50	2.6		1,655,745	221,356	2.34×10^{-4}	
DZMW-1 LMZ (APPZ)		1,028	5,331	22.60	2.7		1,655,745	221,356	4.43×10^{-4}	
DZMW-2 LMZ (APPZ)		678	5,331	20.50	2.1		1,759,230	235,191		
Distance Drawdown		--	5,331	--	--		1,941,219	259,521	1.81×10^{-3}	
UFA ASR Pumping	UFA Pumping	1	318	21.08	83.9	3.79	19,989	2,672	--	38
HIF-42 UMZ (UFA) Early		678	318	23.15	1.9		34,980	4,676	7.99×10^{-4}	
DZMW-1 (UMZ UFA) Early		1,028	318	22.33	4.0	--	25,831	3,453	5.73×10^{-4}	--
DZMW-2 (UMZ UFA)		1,999	318	23.50	0.0				--	
Distance Drawdown		--	318	--	--	--	16,790	2,245	7.77×10^{-3}	--
APPZ Pumping	Combined APPZ and UFA Pumping	1	5,331	20.35	11.6	459.67	2,345,640	313,588	--	39
HIF-42 LMZ (APPZ)		678	5,331	20.50	2.5		2,165,206	289,466	--	
DZMW-1 LMZ (APPZ)		1,028	5,331	22.60	2.6		2,165,206	289,466	4.67×10^{-5}	
DZMW-2 LMZ (APPZ)		678	5,331	20.50	209.0		2,069,682	276,695	1.18×10^{-4}	
Distance Drawdown		--	5,331	--	--		3,518,460	470,382	1.47×10^{-3}	
UFA ASR Pumping		1	318	21.08	86.6	3.67	27,984	3,741	--	26
HIF-42 UMZ (UFA) Early		678	318	23.15	3.7		26,235	3,507	7.53×10^{-4}	
DZMW-1 (UMZ UFA)		1,028	318	22.50	5.0	--	31,680	4,235	2.52×10^{-4}	--
DZMW-2 (UMZ UFA)		1,999	318	23.50	2.3		34,980	4,676	3.94×10^{-4}	
Distance Drawdown		--	318	--	--	--	31,093	4,157	5.18×10^{-3}	--
Average Transmissivity UFA ASR Well (Artesian)							21,210	2,836	2.64×10^{-4}	
Average Transmissivity UFA ASR Well (Pumping)							24,398	3,262	3.05×10^{-3}	
Average Transmissivity UFA ASR Well (Combined Pumping)							30,394	4,063	1.65×10^{-3}	
Average Transmissivity APPZ ASR Well (Artesian)							1,901,689	254,237	8.3×10^{-4}	
Average Transmissivity APPZ ASR Well (Pumping)							1,683,865	225,116	8.29×10^{-4}	
Average Transmissivity APPZ ASR Well (Combined Pumping)							2,452,839		5.45×10^{-4}	
Average Transmissivity UFA							25,334	3,387	1.65×10^{-3}	
Average Transmissivity APPZ							2,012,798	269,091	7.35×10^{-4}	

* = Distance for pumping wells is casing diameter approximately 1 ft.

The combined pumping APT was rerun because of generator failure after three days of pumping.

Aquifer Performance Testing (APT)

C-38S and C-38N Comparison Table

Aquifer	C-38S APT			C-38N APT		
	Transmissivity (gpd/ft)	Transmissivity (ft^2/day)	Storage	Transmissivity (gpd/ft)	Transmissivity (ft^2/day)	Storage
Average Transmissivity UFA	249,583	34,761	3.58×10^{-4}	24,334	24,327	1.65×10^{-3}
Average Transmissivity APPZ	1,051,555	146,456	*1.4×10^{-4}	2,012,798	2,012,791	7.35×10^{-4}

* Storage Values are Estimated

Questions?

GEOCHEMISTRY OF C38S, L63N, AND L63 CONTINUOUS CORES

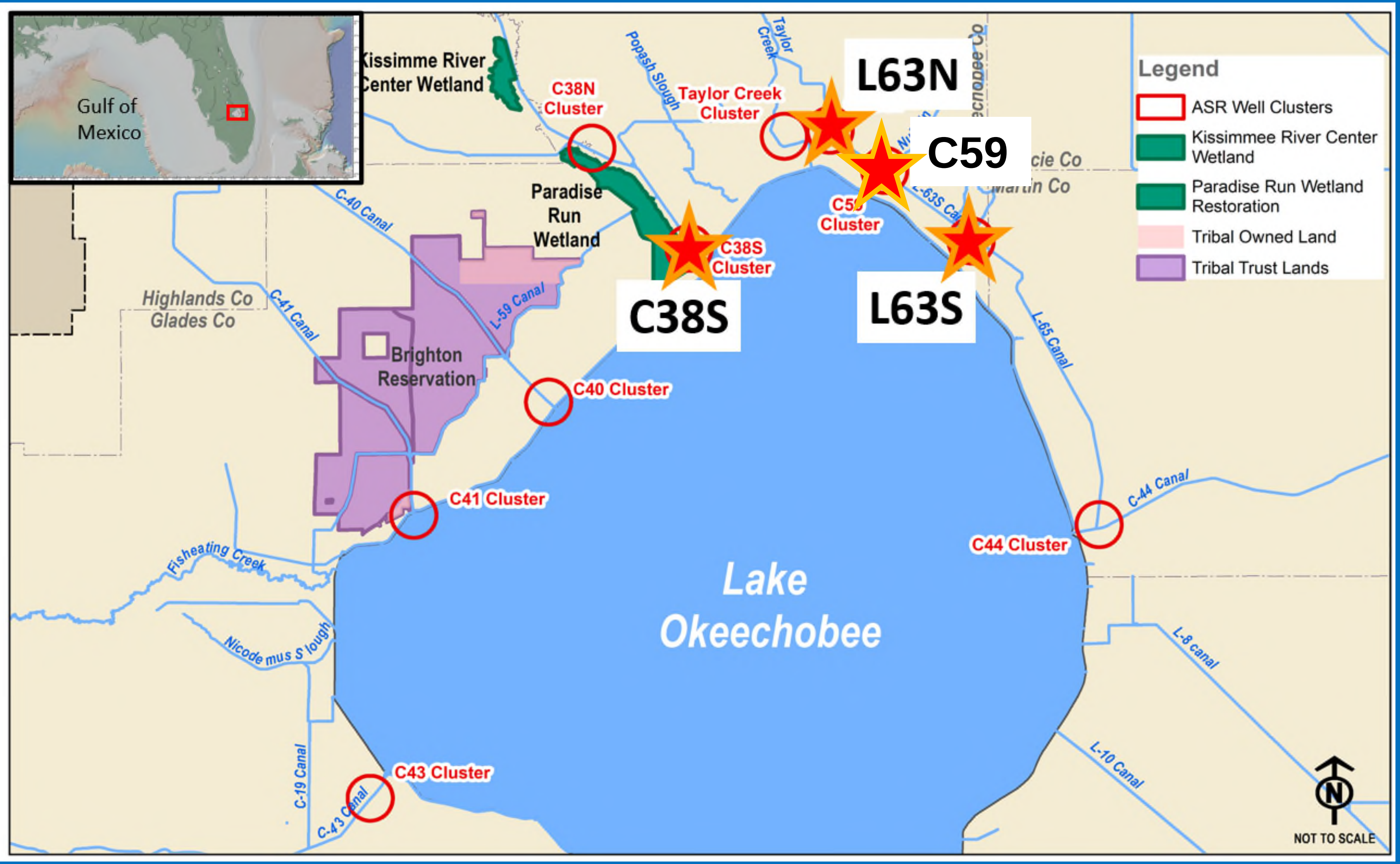
2024 ASR Science Plan Peer Review Panel
Virtual Workshop
July 10, 2024

Work completed by: Dr. Jamie MacDonald, Zoie Kassis, BeeJay Girimurugan, Ju Chou, Rachel Rotz, and 14 undergraduate students.

Presented by:
Jamie MacDonald, Ph.D.
Professor of Geology
Environmental Geology Program
Florida Gulf Coast University
jmacdona@fgcu.edu

FGCU

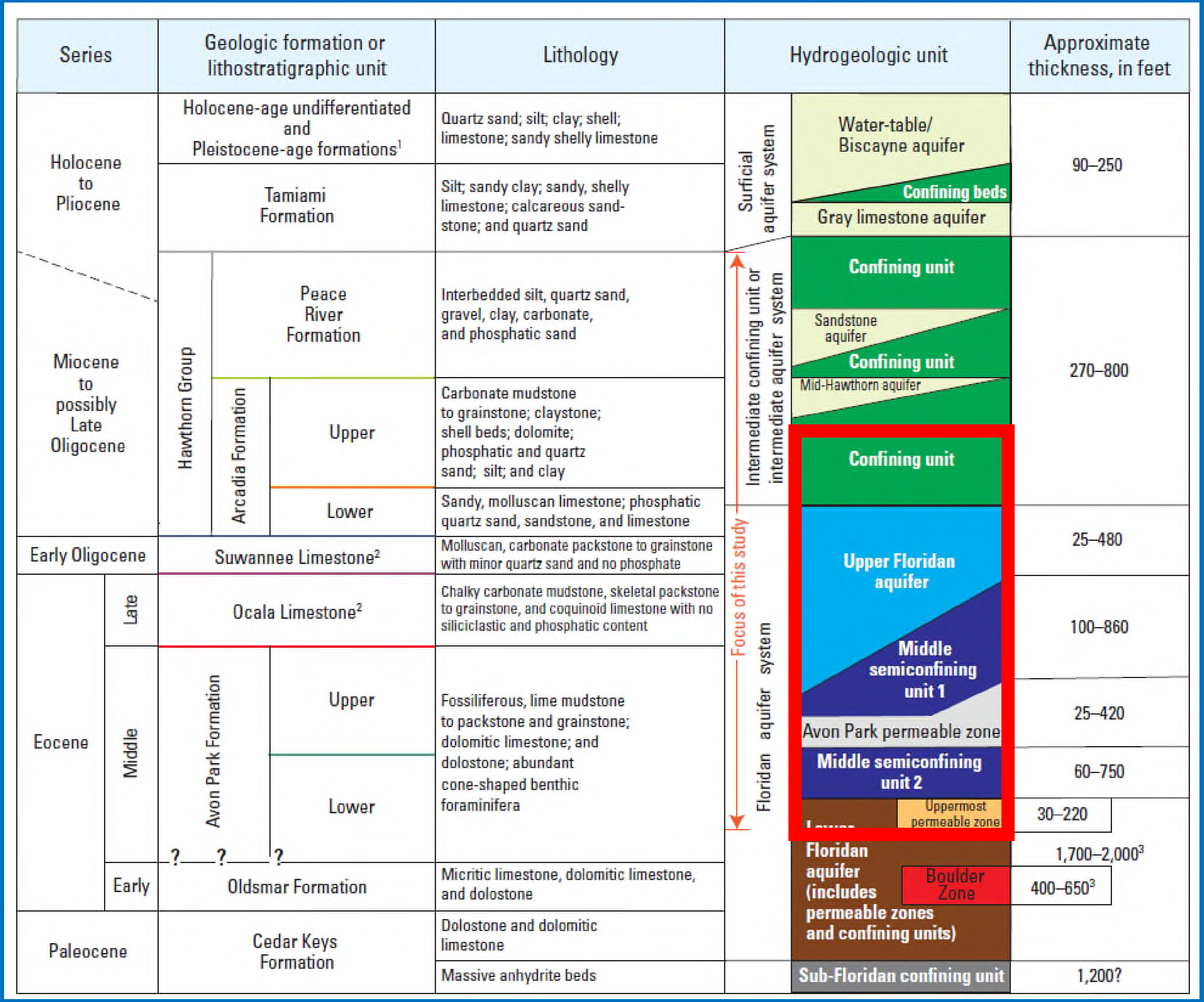
Location Of Continuous Coreholes



Continuous cores from the C38S, L63N, C59 and L63 coreholes were geochemically analyzed by FGCU.

These four coreholes are located along the northern shore of Lake Okeechobee.

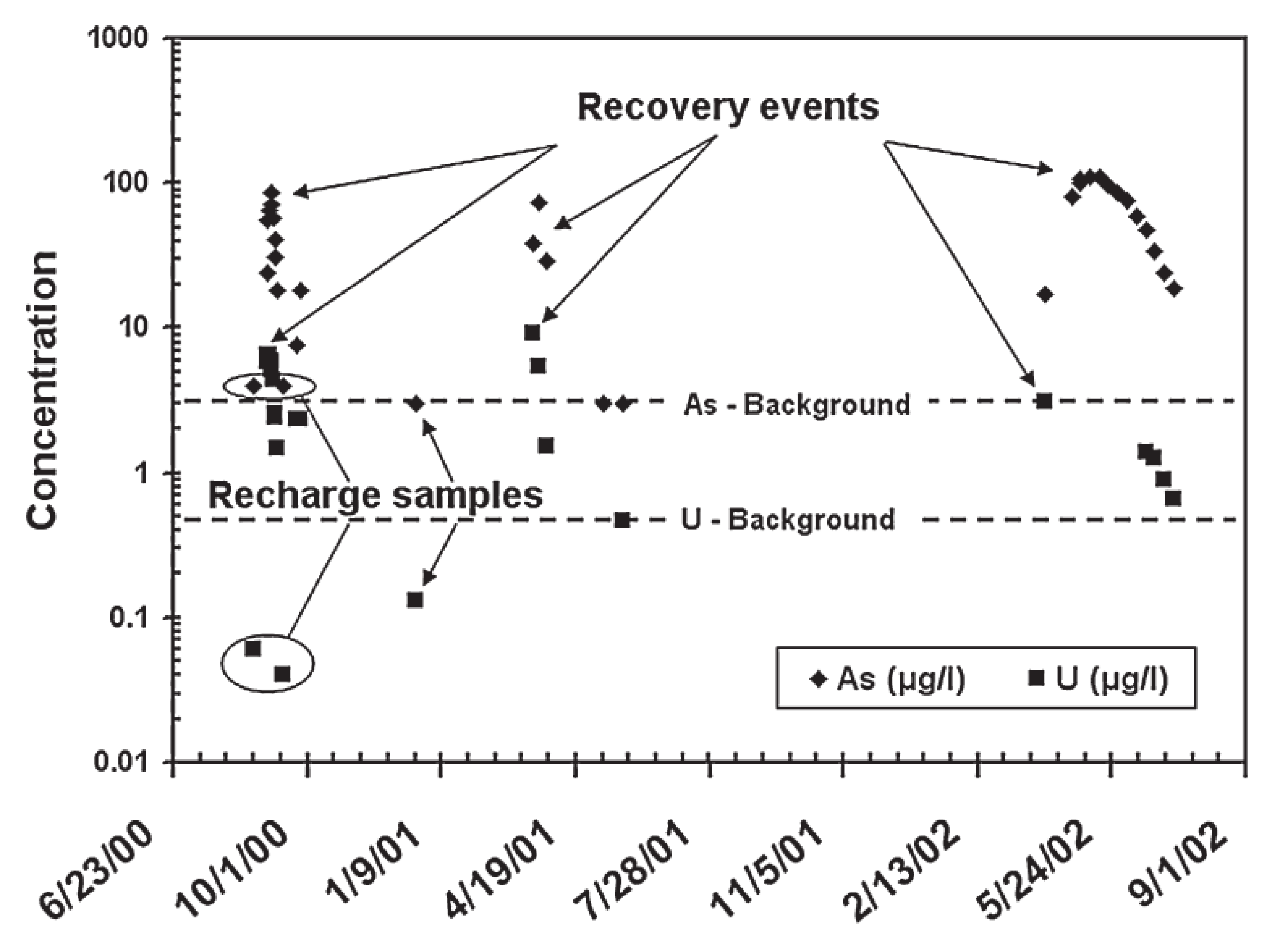
Regional Hydrostratigraphy



The analyzed cores all start within the Hawthorn Group of the Intermediate confining unit (ICU) and extend as deep as the upper part of the Lower Floridan aquifer (LFA).

Hydrostrat column from (Reese, 2014)

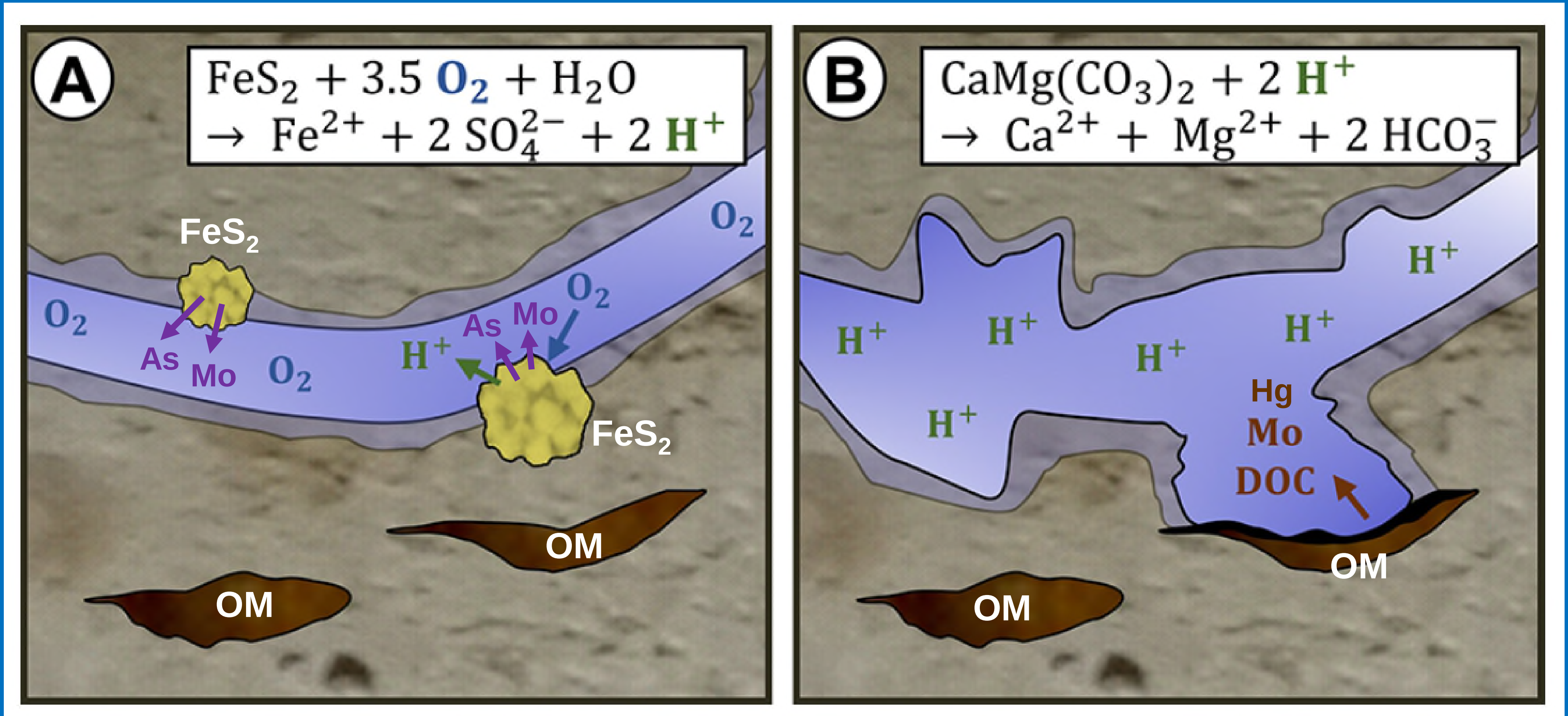
Why Perform These Geochemical Analyses?



Because ASR can cause mobilization of metals into solution from the carbonate rocks of the FAS.

Characterizing the concentrations of metals along the entire length of the recovered continuous cores provides critical information that can be used to assess the viability of specific storage zones and to assist with well design.

Mobilization Of Metals From Pyrite Dissolution



DOC = dissolved organic carbon

Dissolution of pyrite (FeS_2) is a major cause of mobilization of metals such as As into solution. Pyrite dissolution lowers the pH of groundwater. This acidic environment can then dissolve additional metals from organic matter (OM) (Koopmann et al., 2022).

Methodology

A hand-held portable X-Ray fluorescence unit (pXRF) was used to analyze the continuous cores at approximate one-foot intervals.

Additional pXRF analyses were performed in the flow zones and organic-rich intervals.

Cores from C38S, L63N, and L63S are completely analyzed and the cores from C59 are currently being analyzed.

The pXRF analyzes 31 elements including key metals (As, Hg, and Mo).

Quality Control

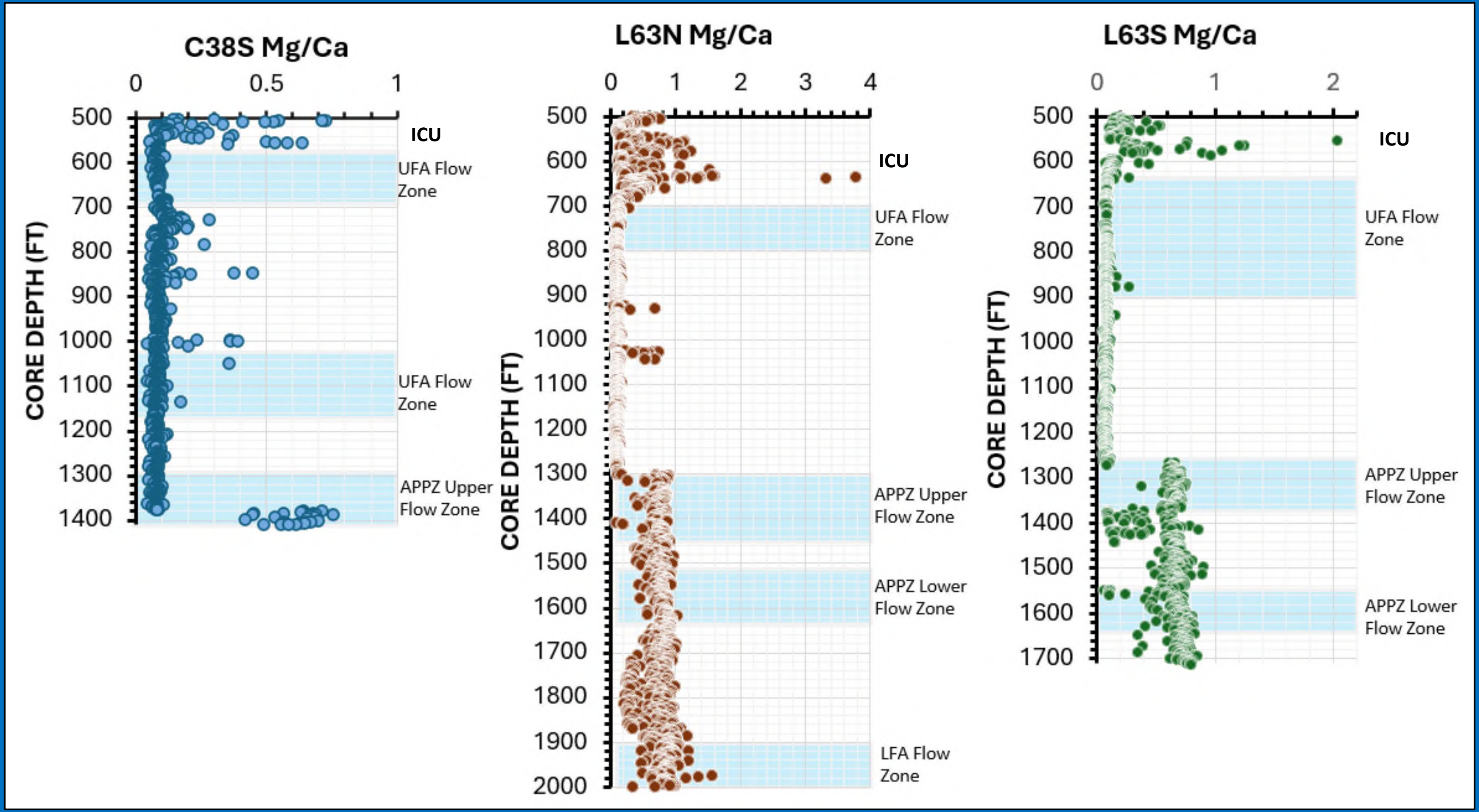
We analyzed 5 standards as knowns to test the data quality produced by the pXRF

Multiple measurements were collected at 20 depths from the C38S core to test for pXRF reproducibility.

Elemental totals were used to check for the quality of the analyses, and several results were removed due to poor totals.

Total number of analyses after quality control: 814 from C38S; 1,339 from L63N, and (currently) 1,116 from L63S.

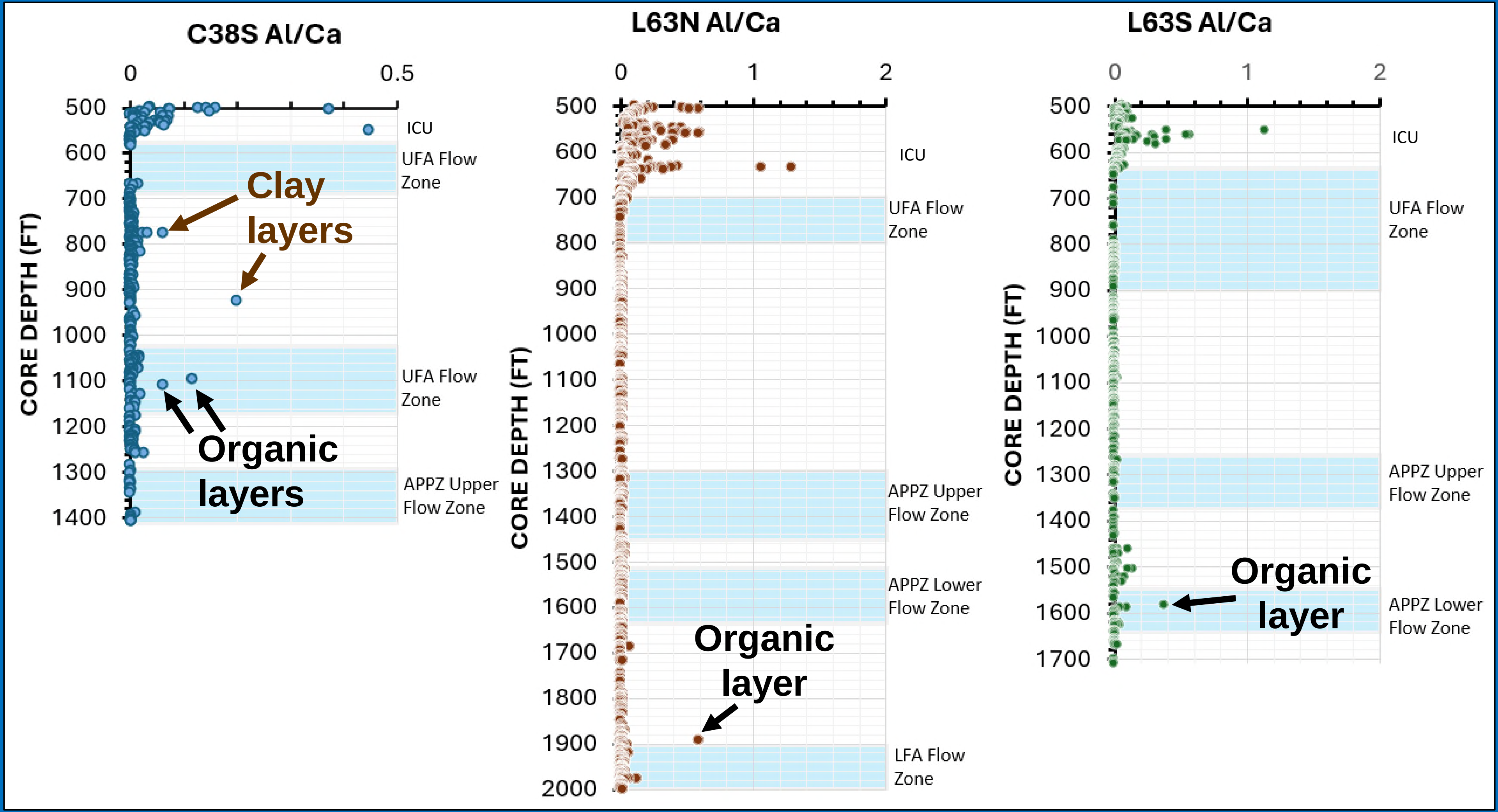
Mg/Ca ratios



Clay in the ICU causes high Mg/Ca ratios, while the underlying Ocala Limestone in the UFA has lower Mg/Ca ratios.

At about 1,300 ft bls in cores L63N and L63S the Mg/Ca ratio increases to dolostone levels of 0.8 (Prothero and Schwab, 2014) suggesting a lithologic change from limestone to dolostone.

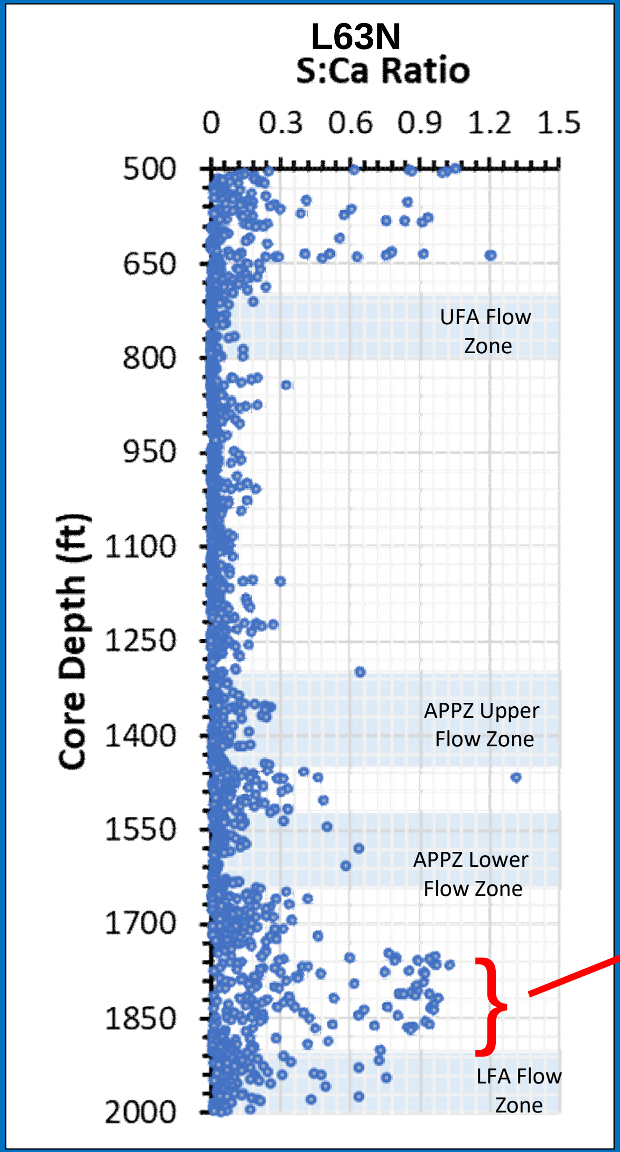
Al/Ca ratios

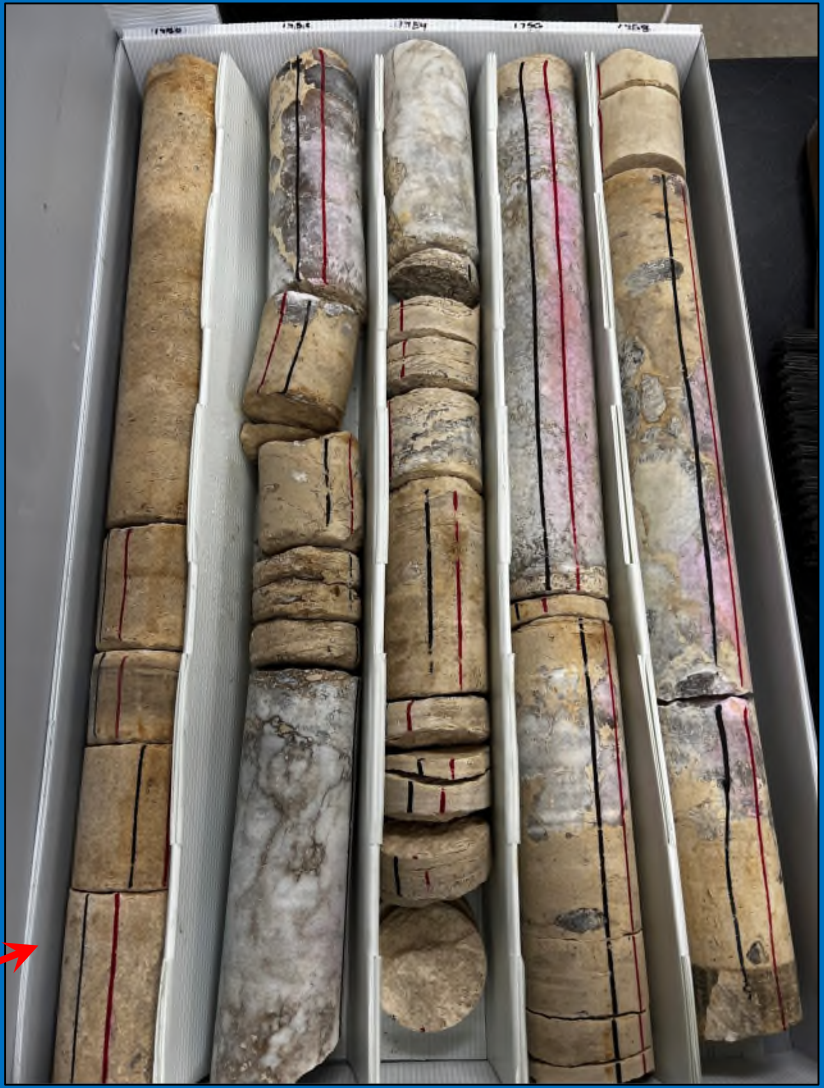


Clay in core C38S and organic-rich layers in all three cores have high Al/Ca ratios.

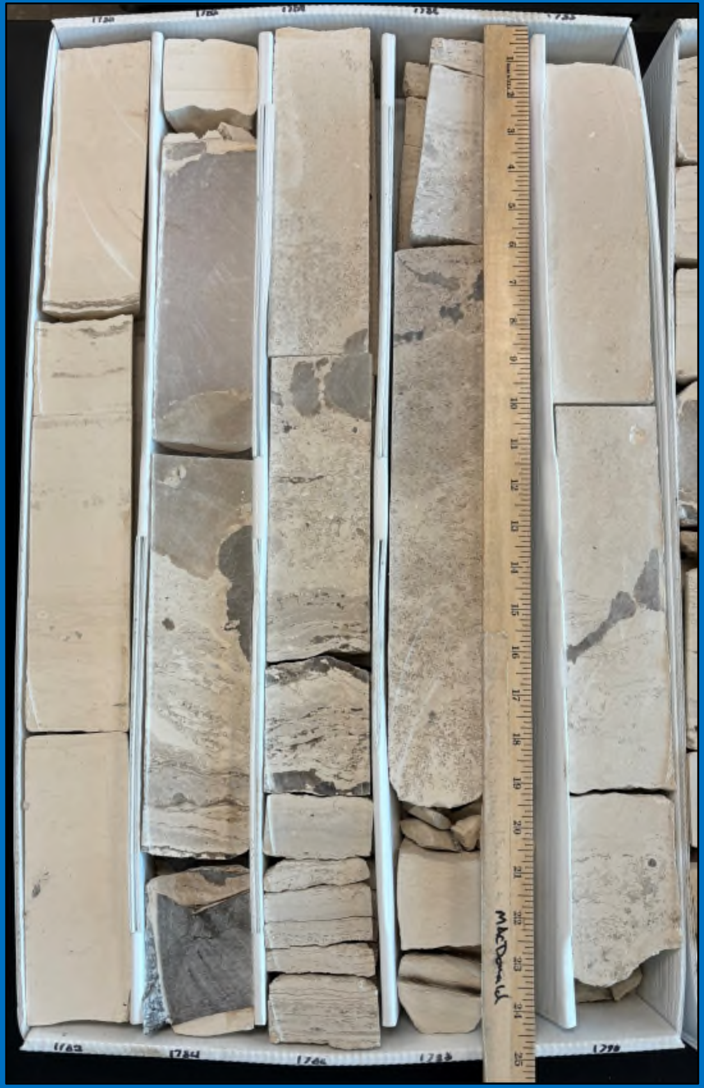
This supports a terrestrial (dry land) origin for these layers – which will be supported by other geochemical data.

Massive and Nodular Gypsum in MCU_II



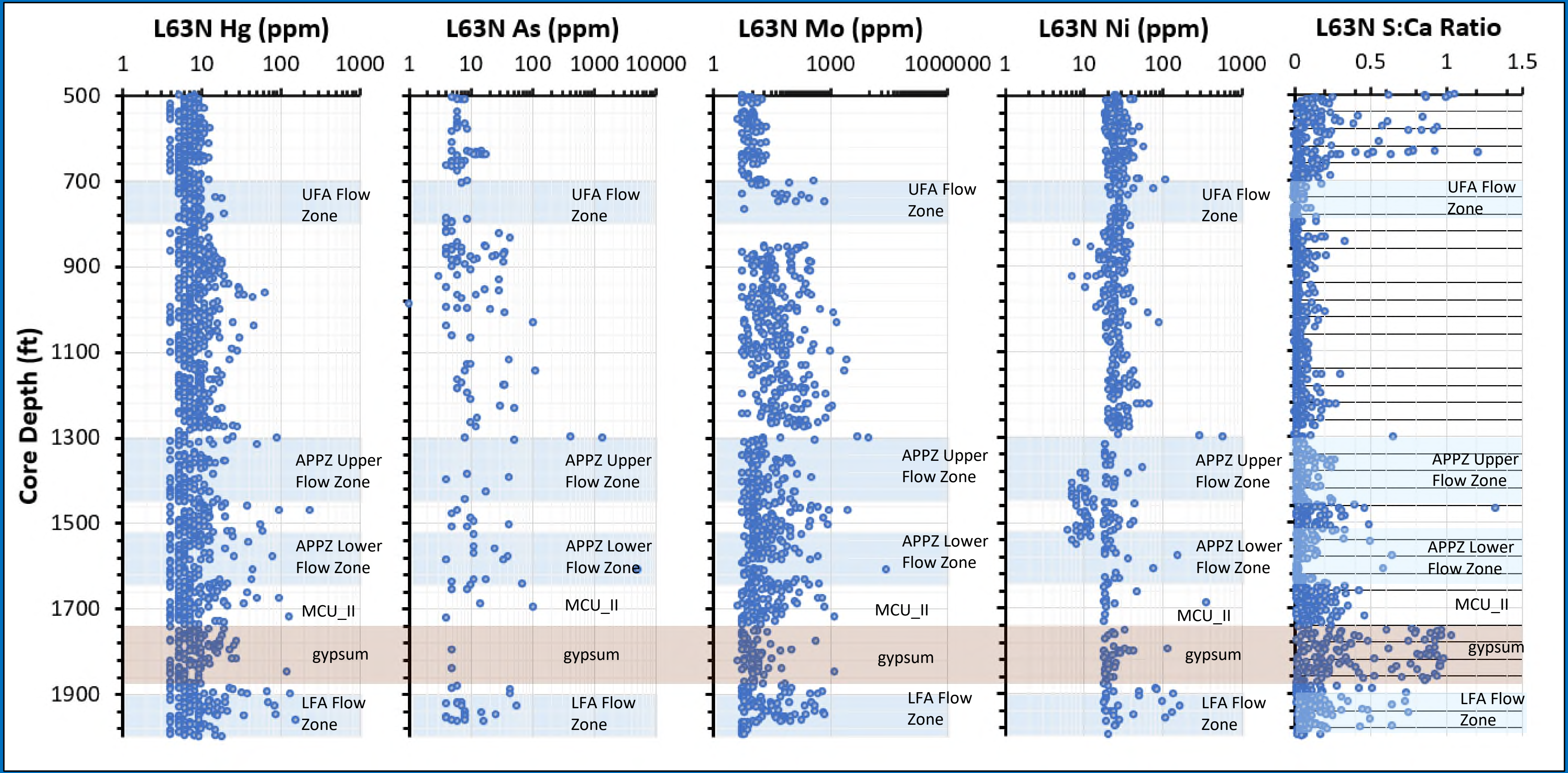


L63N 1,750-1,760 ft bls.



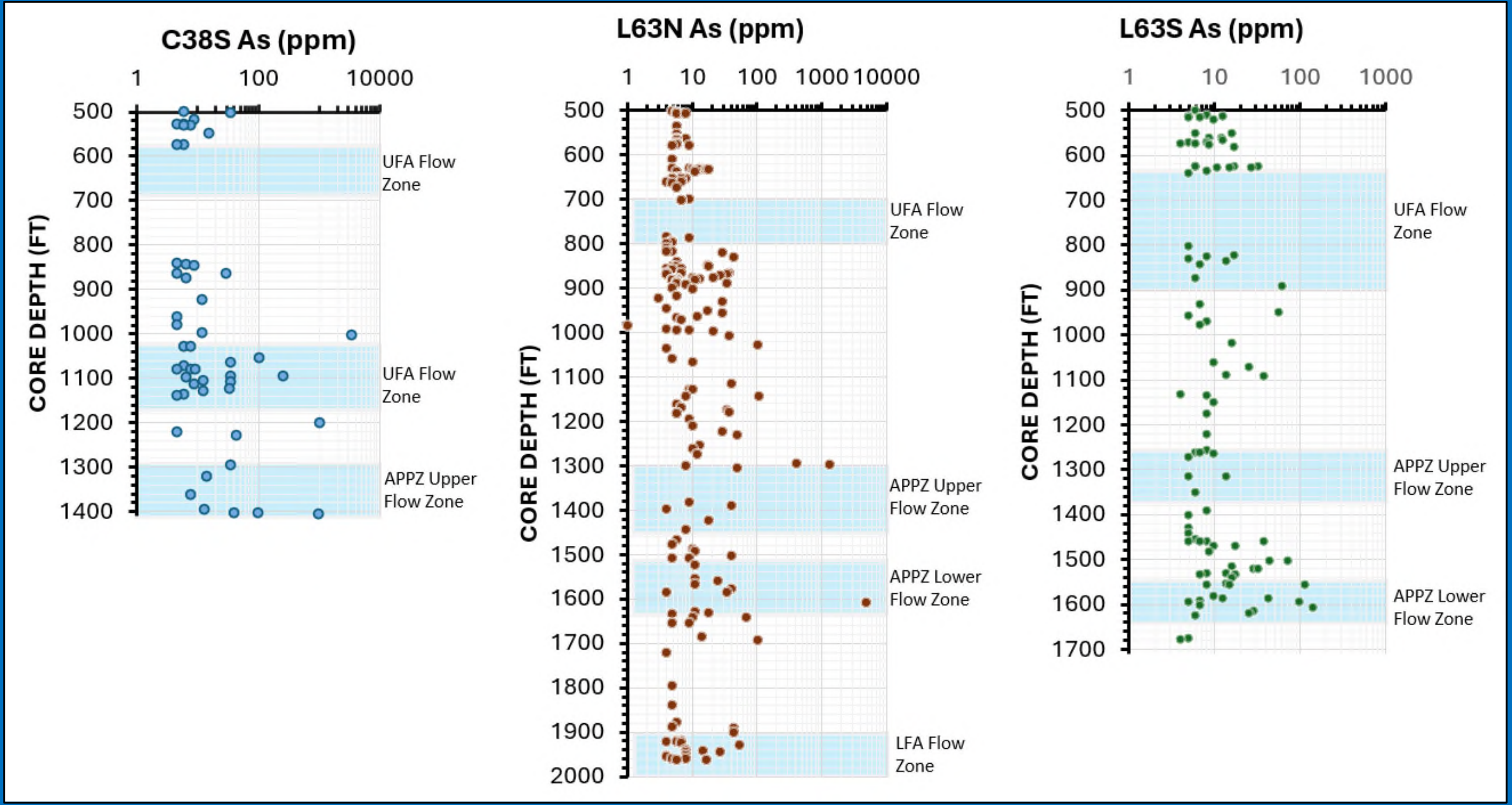
L63S 1,730-1,740 ft bls.

Chemistry of Massive and Nodular Gypsum in MCU_II at L63N



The gypsum in the Middle Confining Unit II at L63N. Metal concentrations in MCU_II tend to be lower than the in the rock directly above and below the gypsum and have elevated S:Ca ratios.

Arsenic Concentrations



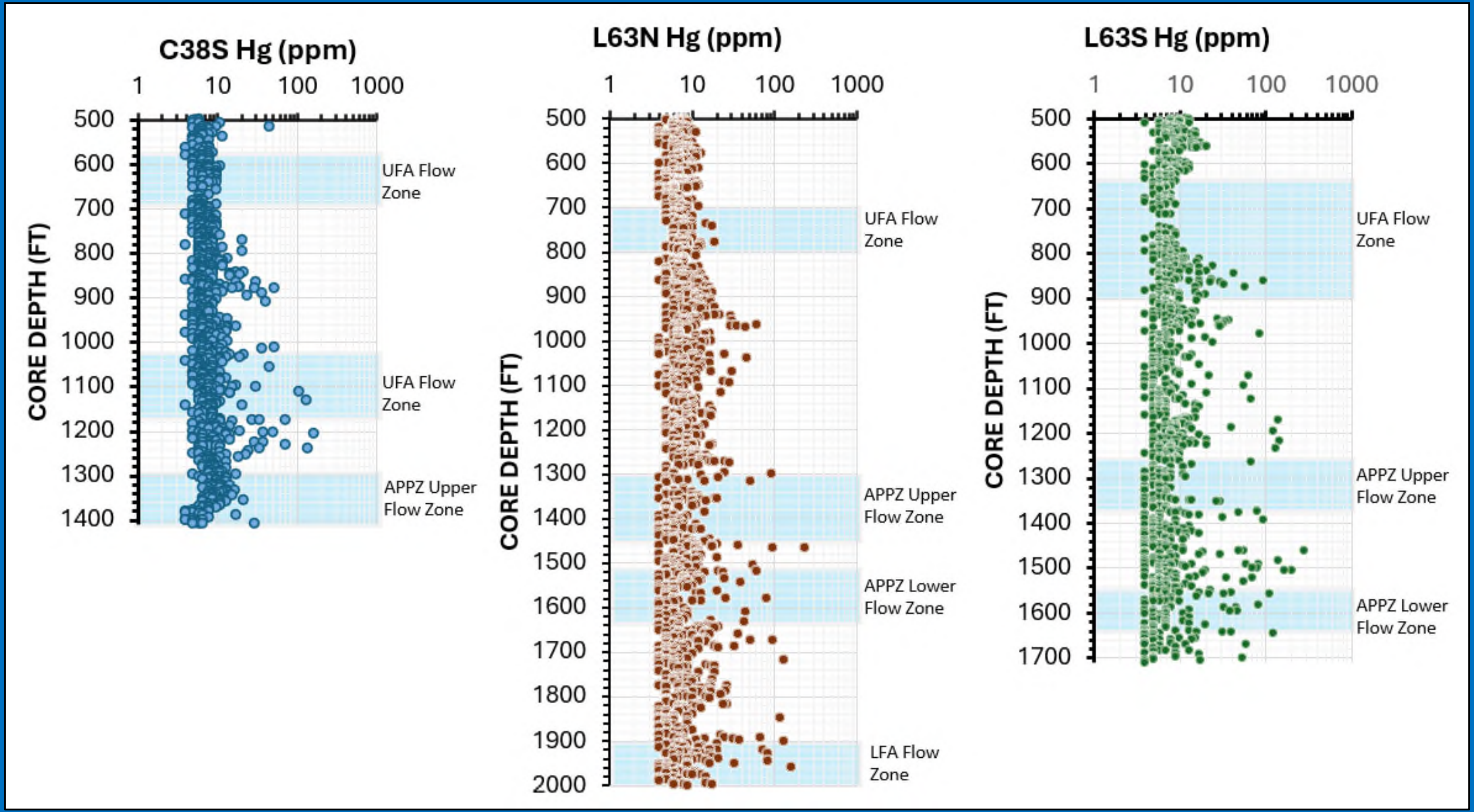
Arsenic (As) is elevated in the lower UFA flow zone and in the APPZ upper flow zone at C38S.

As is elevated at the top of the upper APPZ flow zone, the bottom of the lower APPZ flow zone, and in approximately the upper 100 ft of the underlying confining unit in L63N. Arsenic becomes elevated in the upper portion of the LFA flow zone.

As is elevated in the UFA flow zone, in the confining units, and in the lower APPZ flow zone in L63S.

The gaps in data on the plots are areas where As was below the pXRF detection limit of 1 ppm (1 mg/kg).

Mercury Concentrations

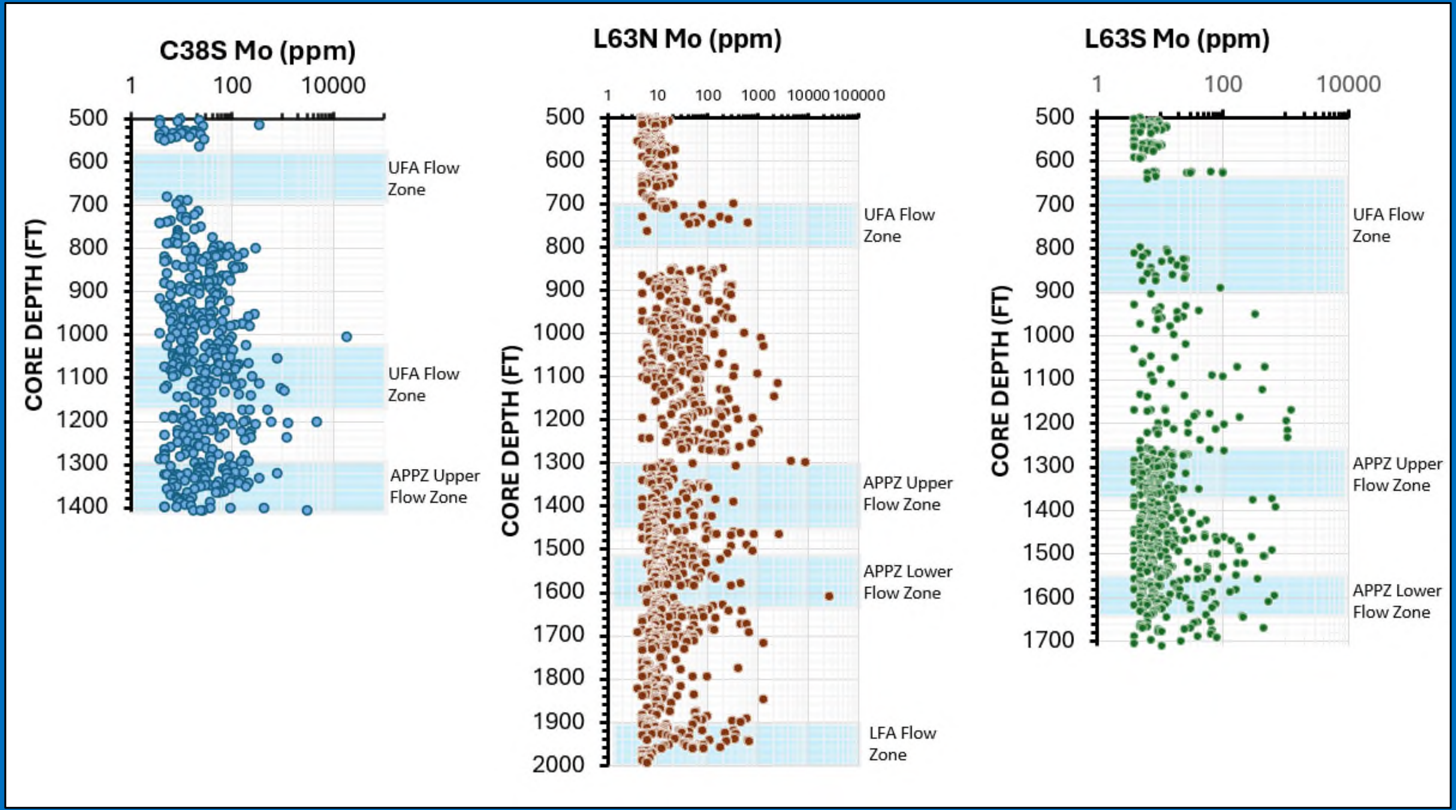


Hg is elevated at the bottom part of the UFA flow zone, within the confining units, and the lower APPZ flow zone in L63S.

Mercury (Hg) concentrations are elevated in the confining unit between the two UFA flow zones, within the lower UFA flow zone, and in the underlying confining unit in C38S.

Hg concentrations are elevated at the top and bottom contacts of the upper APPZ flow zone , within the lower APPZ flow zone, and the upper part of the LFA flow zone in L63N.

Molybdenum Concentrations

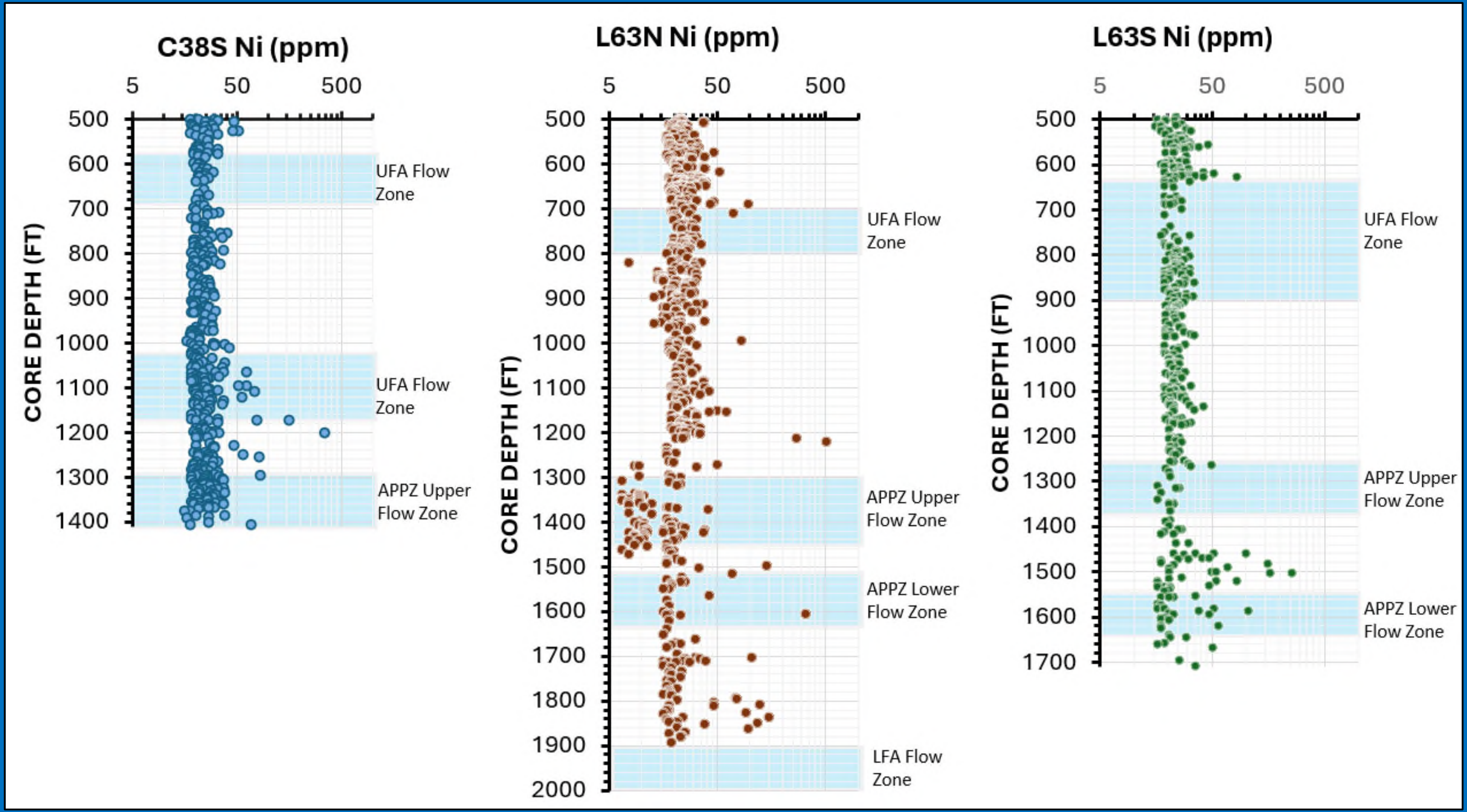


Molybdenum (Mo) concentrations were generally highest in the L63N cores.

Although Mo shows a range of several orders of magnitude, it was measured at slightly lower concentrations in the upper APPZ flow zone in L63N and L63S. Relatively elevated Mo concentrations were measured in the lower APPZ flow zone in L63S

The gaps in data are areas where Mo was below the pXRF detection limit of 1 ppm (mg/kg).

Nickel Concentrations



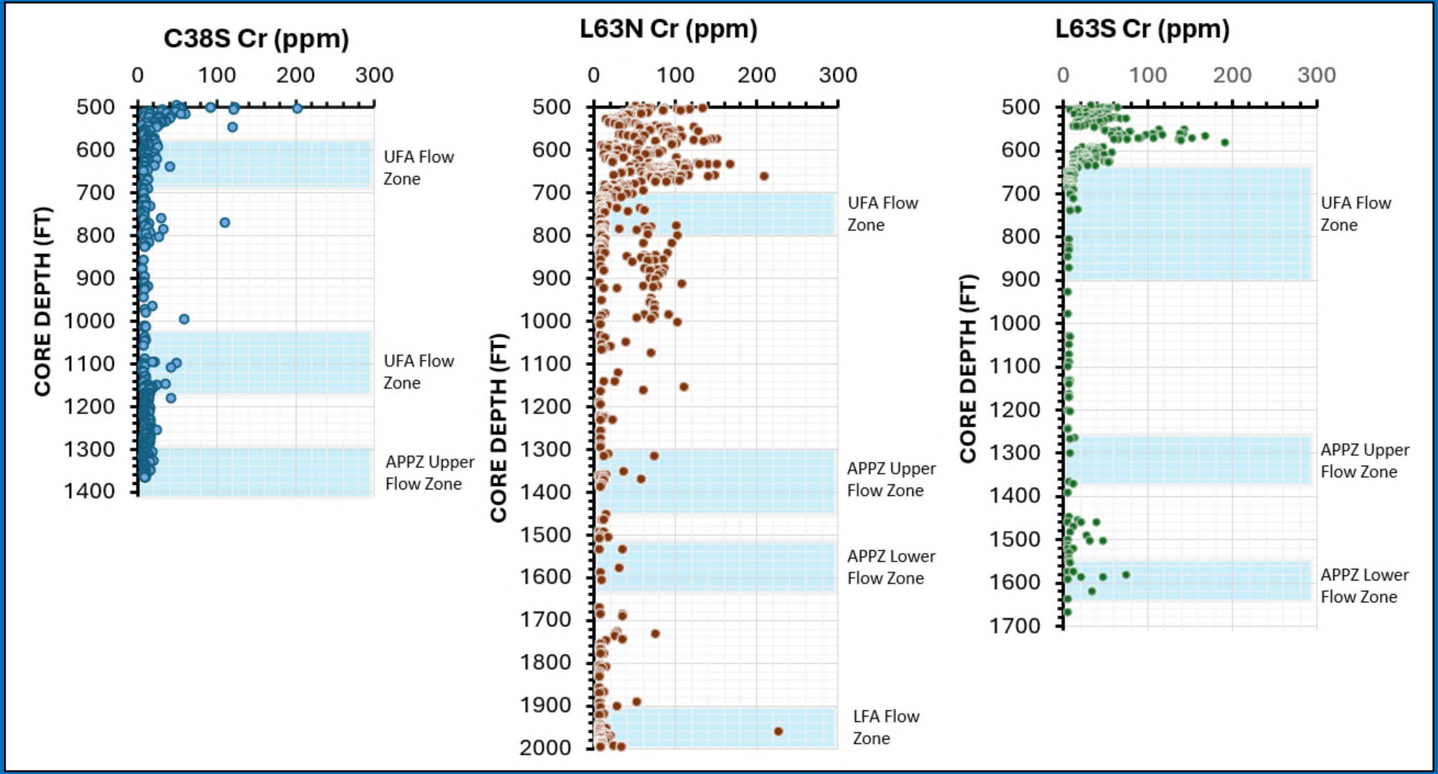
The gaps in data are areas where Ni was below the pXRF detection limit of 5 ppm (mg/kg).

Nickel (Ni) is elevated in the lower UFA Flow Zone and the confining unit beneath the UFA flow zone in C38S.

In L63N and L63S, elevated Ni concentrations were measured at the upper contact of the UFA flow zone.

At L63N, elevated Ni concentrations were measured in the confining unit between the upper and lower APPZ flow zones, sporadically in the APPZ lower flow zone, and within MCU_II above the LFA flow zone.

Chromium Concentrations

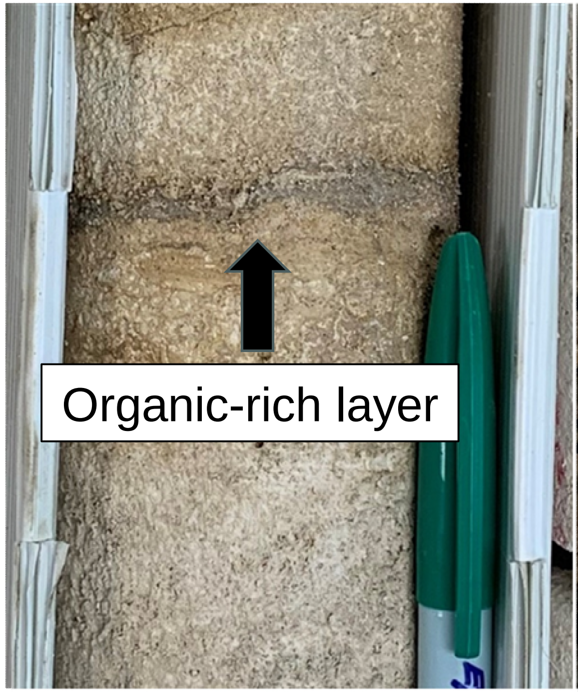


The gaps in data are areas where Cr was below the pXRF detection limit of 2 ppm (mg/kg).

Chromium (Cr) concentrations are relatively low throughout the FAS in C38S and L63S, except for a few elevated concentrations within the UFA flow zone at C38, the confining unit between the APPZ flow zones and the APPZ lower flow zone in L63S.

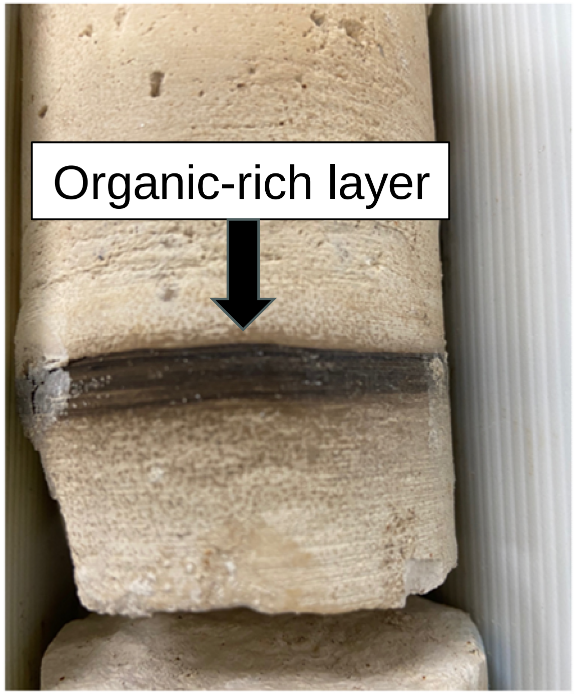
Cr concentrations in L63S are highest in the ICU, the bottom half of the UFA flow zone and upper half of MCU_I and sporadically in the APPZ upper flow zone and LFA flow zone. Is is also elevated in the UFA flow zones at L63N, and within the middle semiconfining unit and APPZ lower flow zone at L63S.

Organic-rich Layers

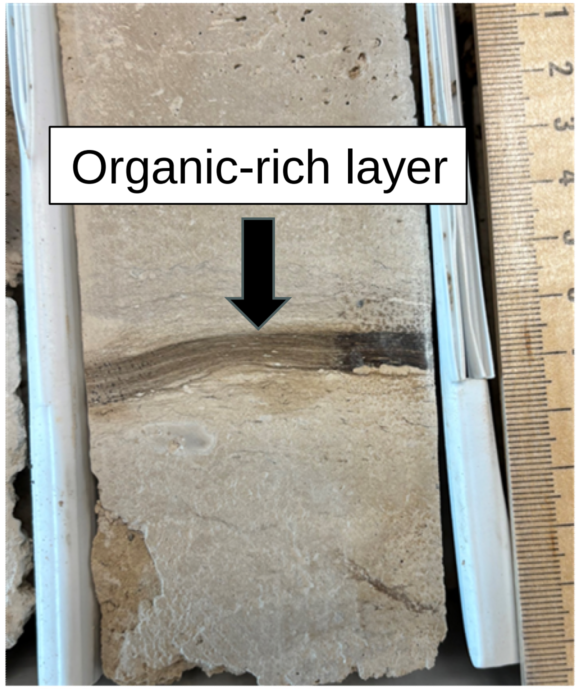


Organics at 1007 ft. depth in core C38S

Organics at 1607 ft. depth in core L63N



Organics at 1795.5 ft. depth in core L63N



Organics at 1619.7 ft. depth in core L63S

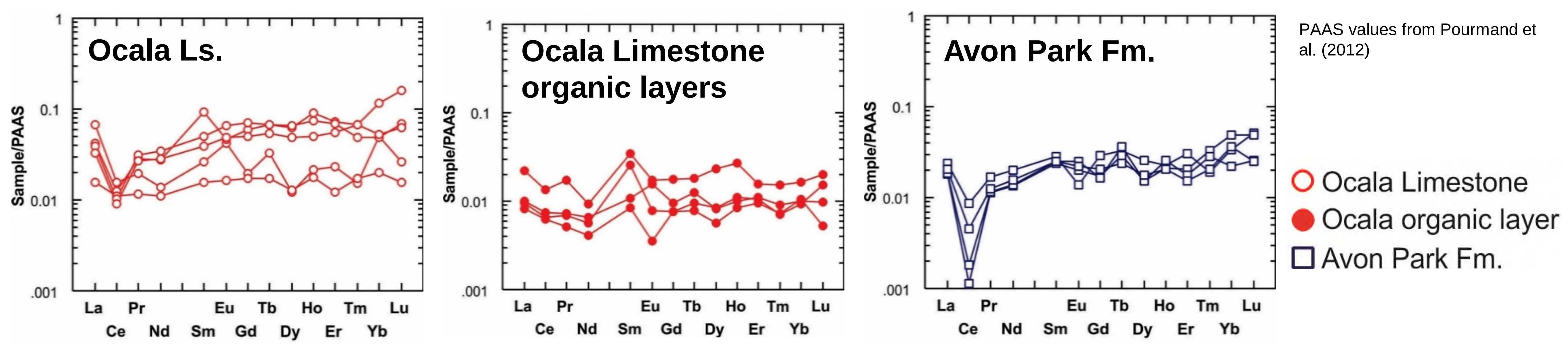
Summary of Organic-rich Layers

Core	C38S	L63N	L63S
Number of organic layers in UFA Flow Zone	UFA Flow Zone 1 = 0 UFA Flow Zone 2 = 6	0	1
Number of organic layers in APPZ Upper Flow Zone	2	1	0
Number of organic layers in APPZ Lower Flow Zone	Core not recovered	4	6
Number of organic layers in LFA Flow Zone	Core not recovered	7	28

Effects Of Organic Layers On Metals Concentrations

		As (ppm)	Hg (ppm)	Mo (ppm)	Ni (ppm)
C38S	Average Metal Concentration in Non-Organic Sections of Core	63	9	81	26
	Average Metal Concentration in Organic Layers	741	46	2209	101
L63N	Average Metal Concentration in Non-Organic Sections of Core	16	9	65	26
	Average Metal Concentration in Organic Layers	605	48	1666	102
L63S	Average Metal Concentration in Non-Organic Sections of Core	15	10	31	25
	Average Metal Concentration in Organic Layers	25	49	142	57

ICP-MS Analysis

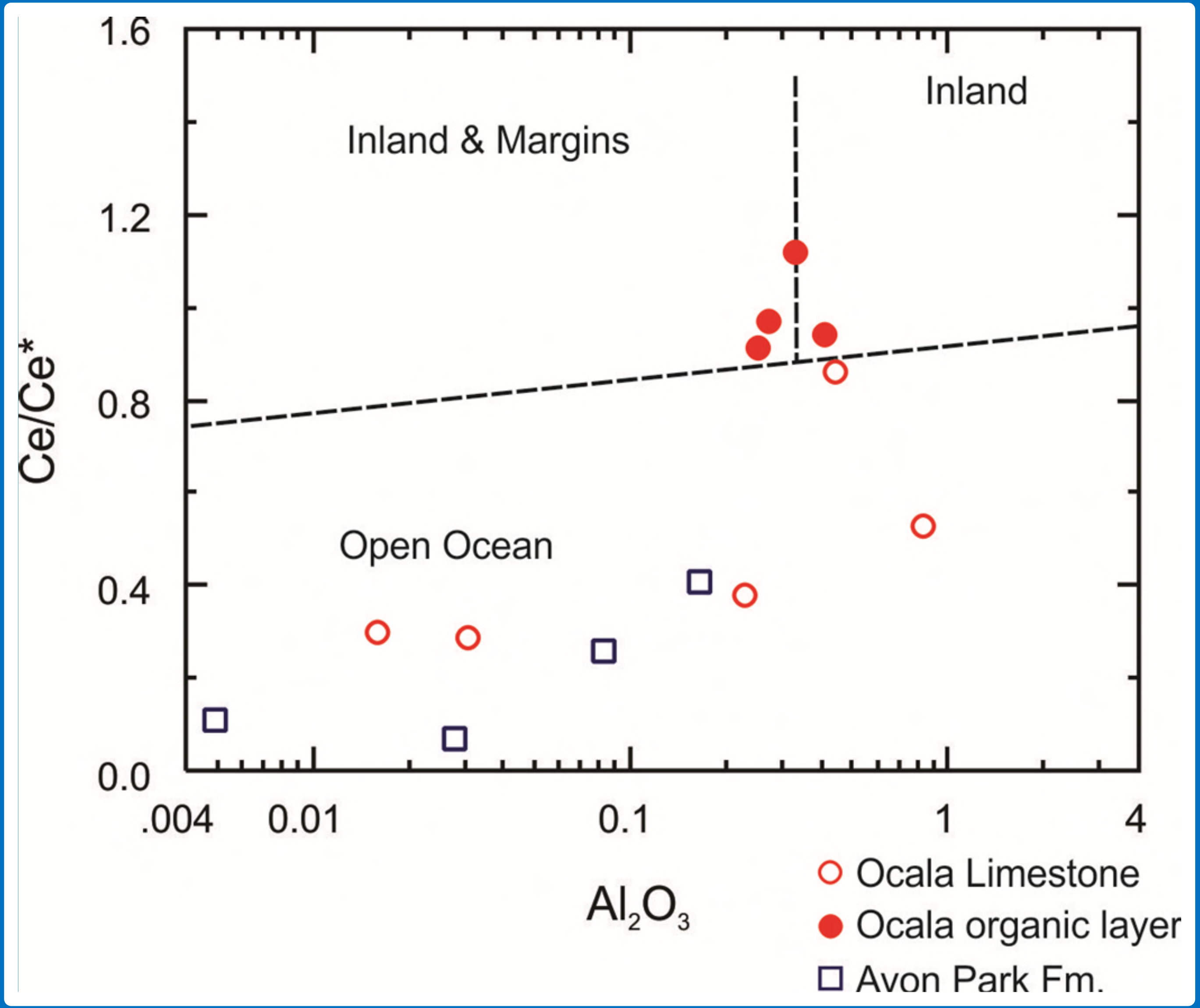


Portions of the cores, like zones of broken rock, were sampled and sent out for external ICP-MS analysis at Hamilton Analytical Laboratory, Hamilton College.

Post-Archean average sediment (PAAS)-normalized diagrams for samples from C38S and L63N shown here.

<u>Note that the cerium (Ce) anomaly is not pronounced in the organic-rich layers.</u>

Origins Of Organic-rich Layers

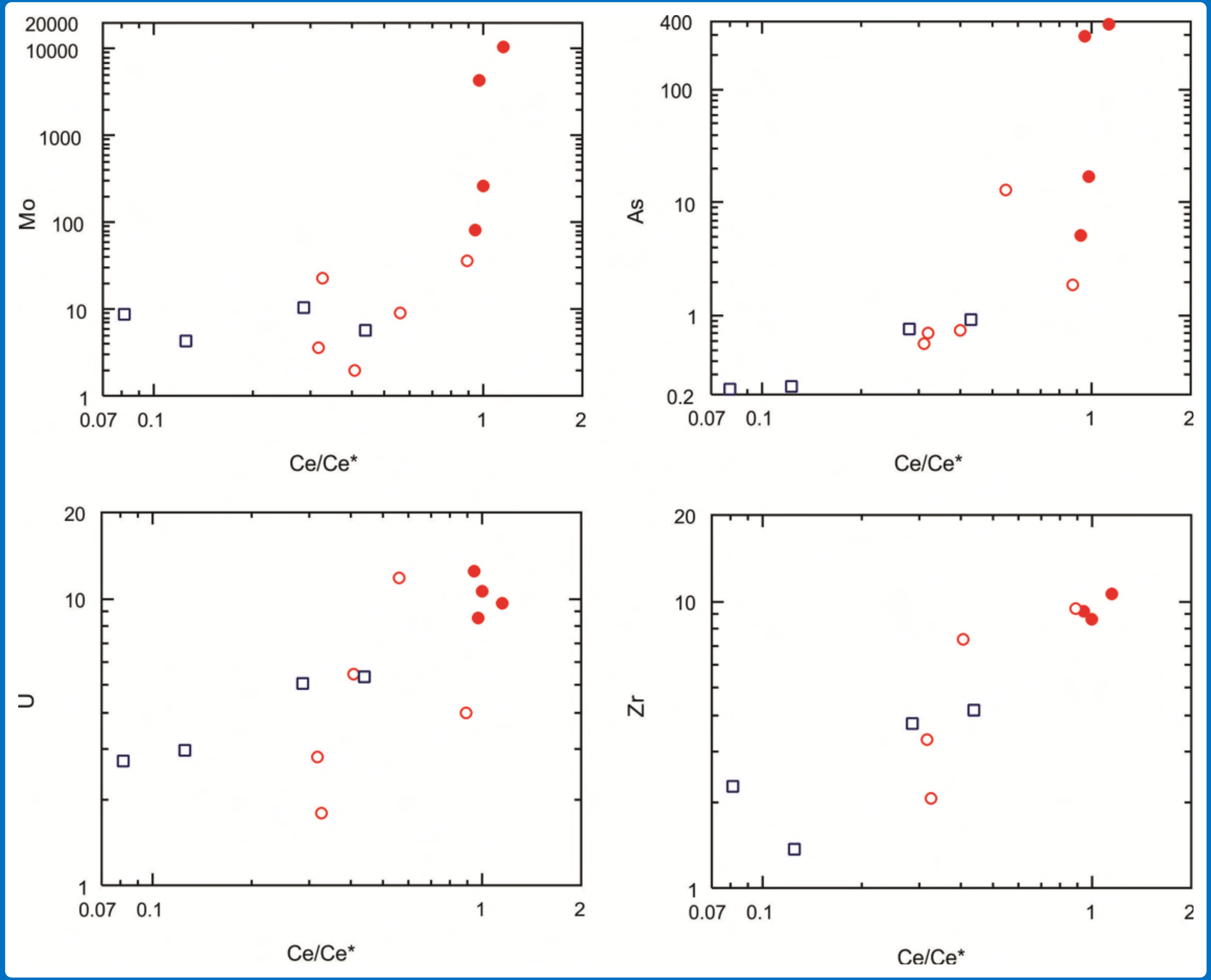


This cerium anomaly can be represented by normalizing Ce to post-Archean average sediment compositions from Australia to create a Ce/Ce*.

This suggests the organic-layers have a stronger terrestrial component than the limestones and dolostones from the Ocala Limestone and Avon Park Formation.

Ce/Ce* vs. Al_2O_3 diagram from Zhang et al. (2017).

Origins Of Organic-rich Layers



Mo, As, U, and Zr correlate to a higher Ce/Ce*.

Generally, the higher Mo, As, U, and other metal values are in the organic layers.

The correlation between the elevated metals concentrations and the high Ce/Ce* suggests terrestrial origin for these metals in the organic-rich layers is possible.

Conclusions

The limestones of the UFA flow zones have relatively lower As, Hg, Ni, and Cr concentrations than the deeper flow zones in the dolostone-dominated APPZ and LFA-upper. Mo, however, can be elevated in the UFA Flow Zone.

Metals in the analyzed cores are elevated in organic-rich layers, clay layers, and, locally, along unit boundaries and disconformities.

Organic-rich layers have a terrestrial source and contain very high metal concentrations, high Al concentrations, and high Ce/Ce*. These organic layers are found within flow zones and should be considered when selecting injection and recovery zones and during well design. Of the 3 continuous cores analyzed so far, L63S had the lowest As and Mo concentrations in the organic layers and the lowest overall concentrations of As, Hg, and Mo.

Rock, mineral, and elemental solubility as well as aquifer parameters from aquifer testing should be combined with the metal concentrations obtained from this study when considering future ASR well design and planning/modeling efforts.

Break (15 min)

LAKE OKEECHOBEE WATERSHED RESTORATION PROJECT (LOWRP)

AQUIFER STORAGE AND RECOVERY (ASR) TREATMENT TECHNOLOGY

TREATMENT SYSTEM UPDATE

District Project Manager: Jennifer Gent, PE

Stantec Project Technical Lead: Heath Wintz, PE

sfwmd.gov

Stantec

DRAFT: June 26, 2024

OVERVIEW

- Summary of Work to Date
- Technology Selection & Testing
- Treatment Systems
  - Process Overview
  - Membrane Filtration Systems
  - Treatment Facility Site Plan & Phasing
  - Recovered Water Considerations
    - DO reduction & Arsenic sequestration
  - Backwash Thickening & Dewatering
- Schedule
- Next Steps

SUMMARY OF WORK TO DATE

- Treatment Alternatives Evaluation (2020)
- Proof of Concept (POC) Testing (2021-2022)
- Conceptual Discipline Design (2022)
- Preliminary Design (2023-2024)
- Membrane Filtration System RFP (2023-2024)
- DO Reduction Bench-Scale Testing (2024)*
- DO Reduction Process Alternative Evaluation (2024)
- Backwash Thickening Bench-Scale Testing (2024)*

*in coordination with USACE Engineering Research & Development Center (ERDC)

TECHNOLOGY SELECTION & TESTING

POC Testing (Stantec, 2021-2022) demonstrated:

MEDIA FILTRATION + UV:

- Low filtration rate for media filters translates to a large facility footprint. Backwash ponds require significant land.
- Even at low filtration rate, media filters minimally reduce turbidity/solids, resulting in high UV dose requirement.
- UV can reliably disinfect but requires up to a 30 mJ dose during poor water quality events (as opposed to 21 mJ dosed at KRASR previously)
- Clean water source strongly recommended for backwashing, but utility water may not be available from OUA.

MEMBRANE FILTRATION:

- Coliform was reliably removed by size exclusion without additional disinfection technology.
- Excellent removal of solids and turbidity results in greater solids content in backwash.
- Operations vary significantly by vendor:
  - Coagulant dose (color removal)
  - Cleaning chemical requirements
  - Membrane life
- Settleability and dewaterability of backwash waste differs significantly

TREATMENT SYSTEMS

How do we produce water suitable
for aquifer recharge?

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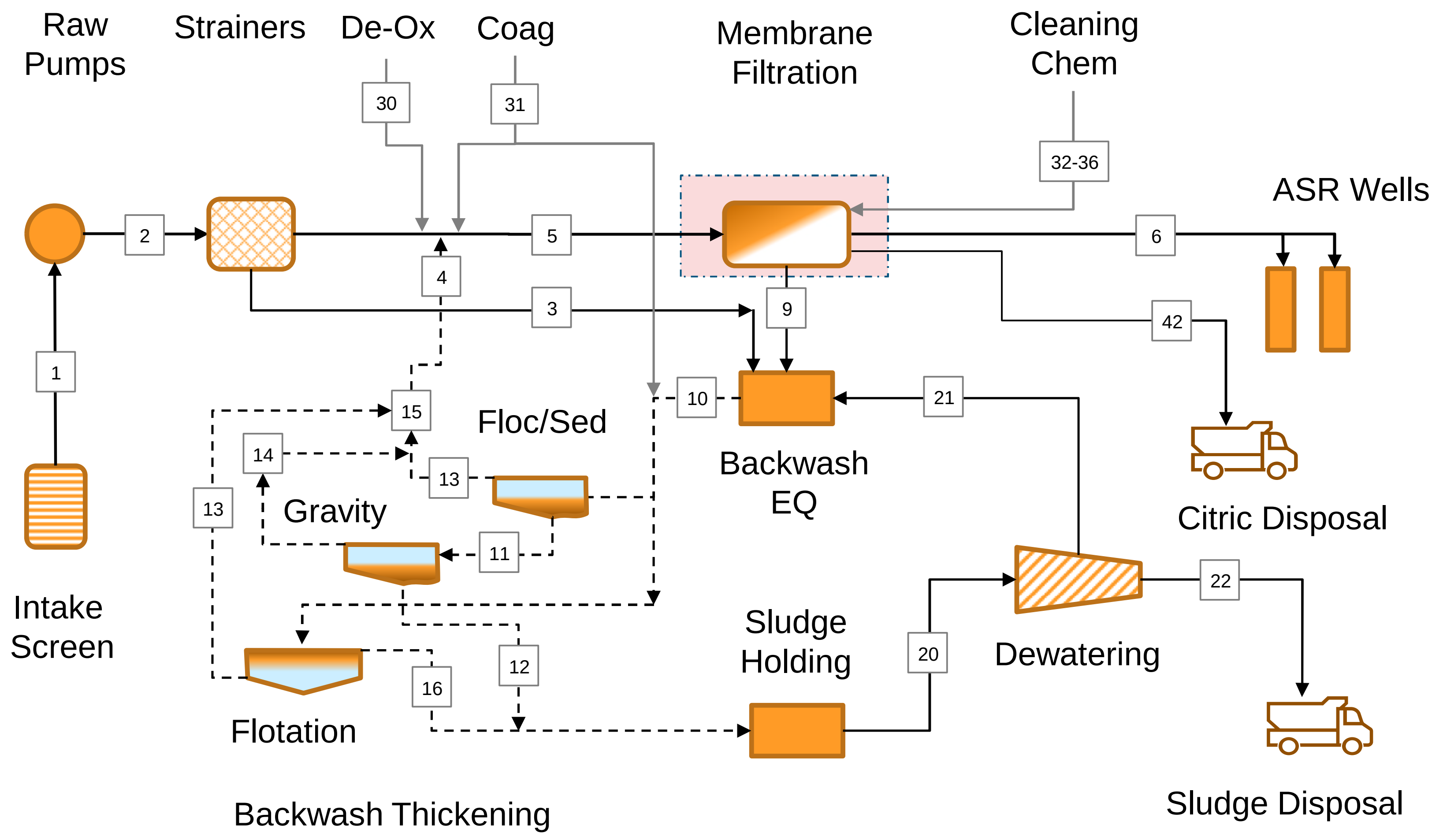
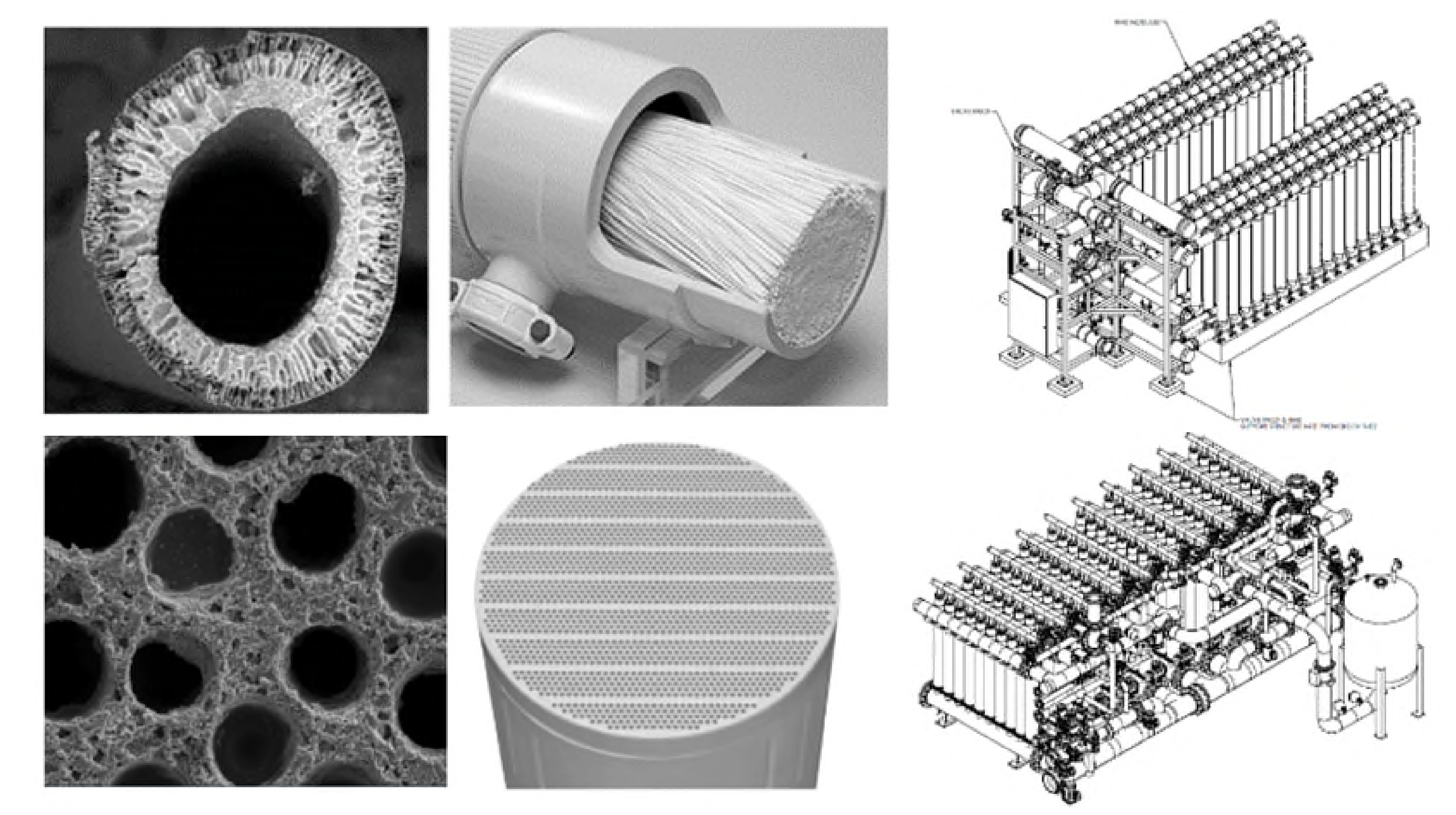
TREATMENT PROCESS OVERVIEW



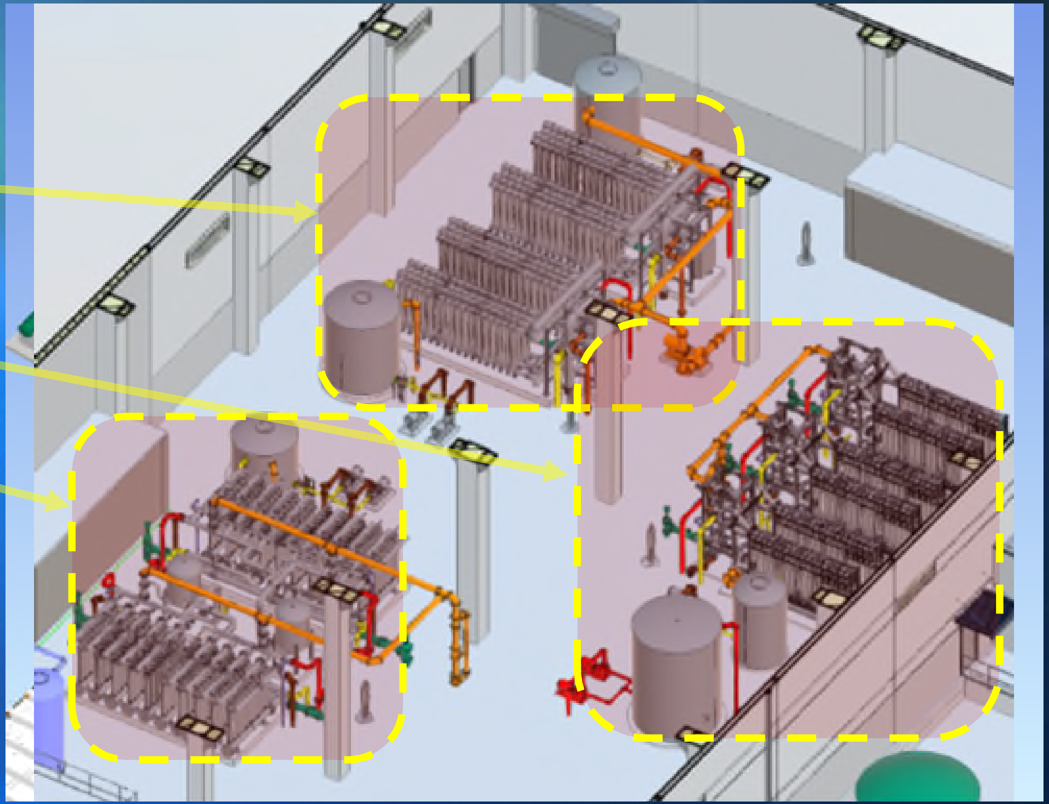
TREATMENT PROCESS: MF/UF MEMBRANES

- Membrane < Elements < Vessels < Racks < Trains
  - Veolia & FilmTec (polymeric)
  - Aqua Aerobic (ceramic)



MF/UF MEMBRANES – DEMONSTRATION TESTING

- 3 Participating Membrane Suppliers
  - Veolia (polymeric)
  - FilmTec (polymeric)
  - Aqua Aerobic (ceramic)



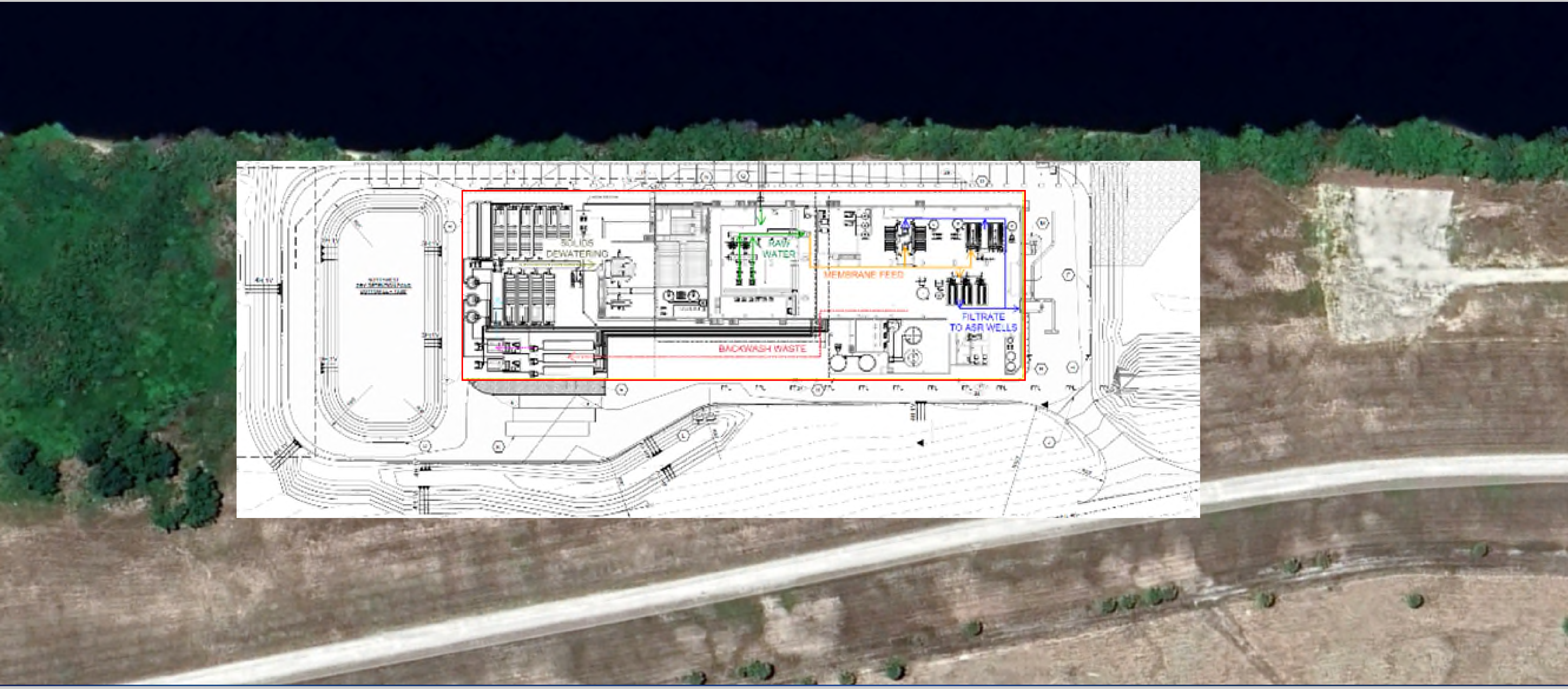
- All membranes remove coliform bacteria reliably
- However, filtrate color differs between polymeric and ceramic membranes

TREATMENT: C-38S LOCATION

TREATMENT – PHASED DESIGN

- Design of the C38-S treatment facility has been developed with a phased approach.
  - Phase 1 – 10 MGD
    - Construct facilities necessary to enable demonstration testing of membrane filtration technology and cycle testing of one well pair at a capacity of 10 MGD.
    - Membrane treatment capacity will be split evenly between 3 suppliers (3.3 MGD, each).
    - Collect operating data to quantify consumables, energy and OPEX costs, which will set the stage for a competitive Net Present Value (NPV)-based selection of membrane filtration supplier for expansion in Phase 2.
  - Phase 2 – Expansion to 50 MGD
    - Competitive NPV-based selection of membrane supplier for full-scale facility.
    - Design and expand facility from 10 to 50 MGD, based on the lowest NPV option for the District
    - Connect to 4 additional well pairs at C-38S site

TREATMENT FACILITY: SITE PLAN

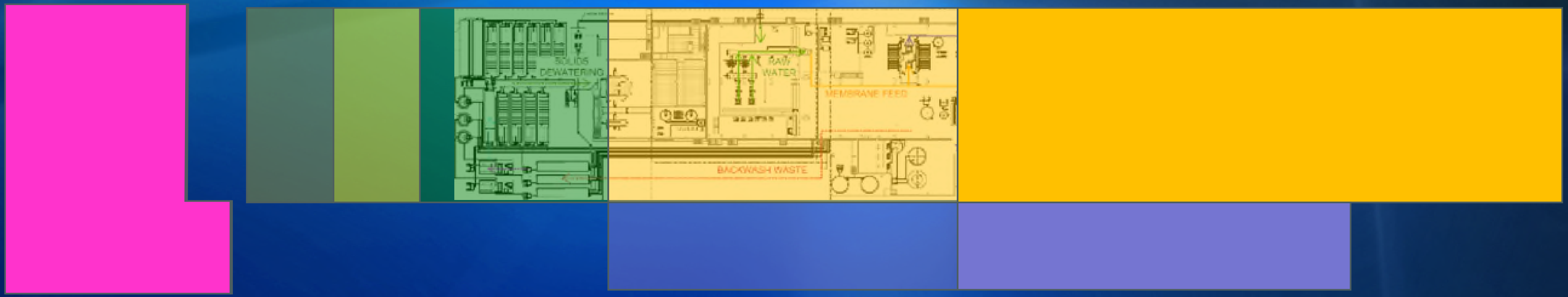


TREATMENT FACILITY - PHASING

Phase 1
(10 MGD Temp)

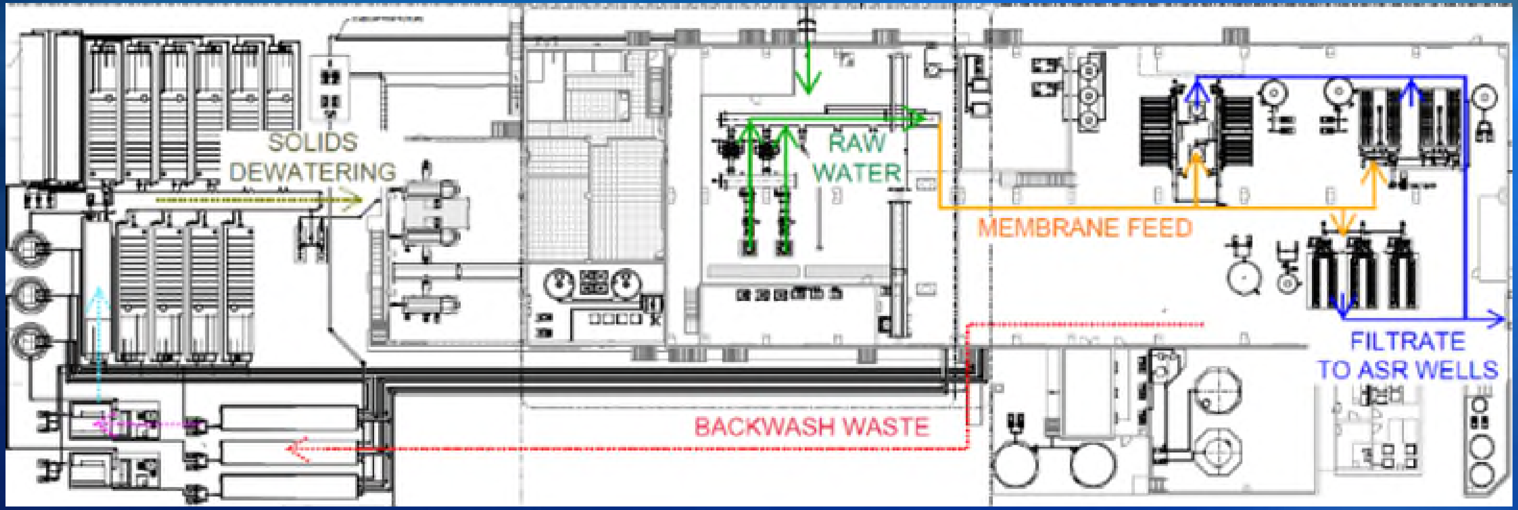
Phase 1
(50 MGD Full-scale)

Phase 1
(10 MGD Demonstration)



Phase 2
(50 MGD Expansion)

Phase 2
(50 MGD Expansion)


SOLIDS DEWATERING
RAW WATER
MEMBRANE FEED
FILTRATE TO ASR WELLS
BACKWASH WASTE

SOUTH FLORIDA WATER MANAGEMENT DISTRICT

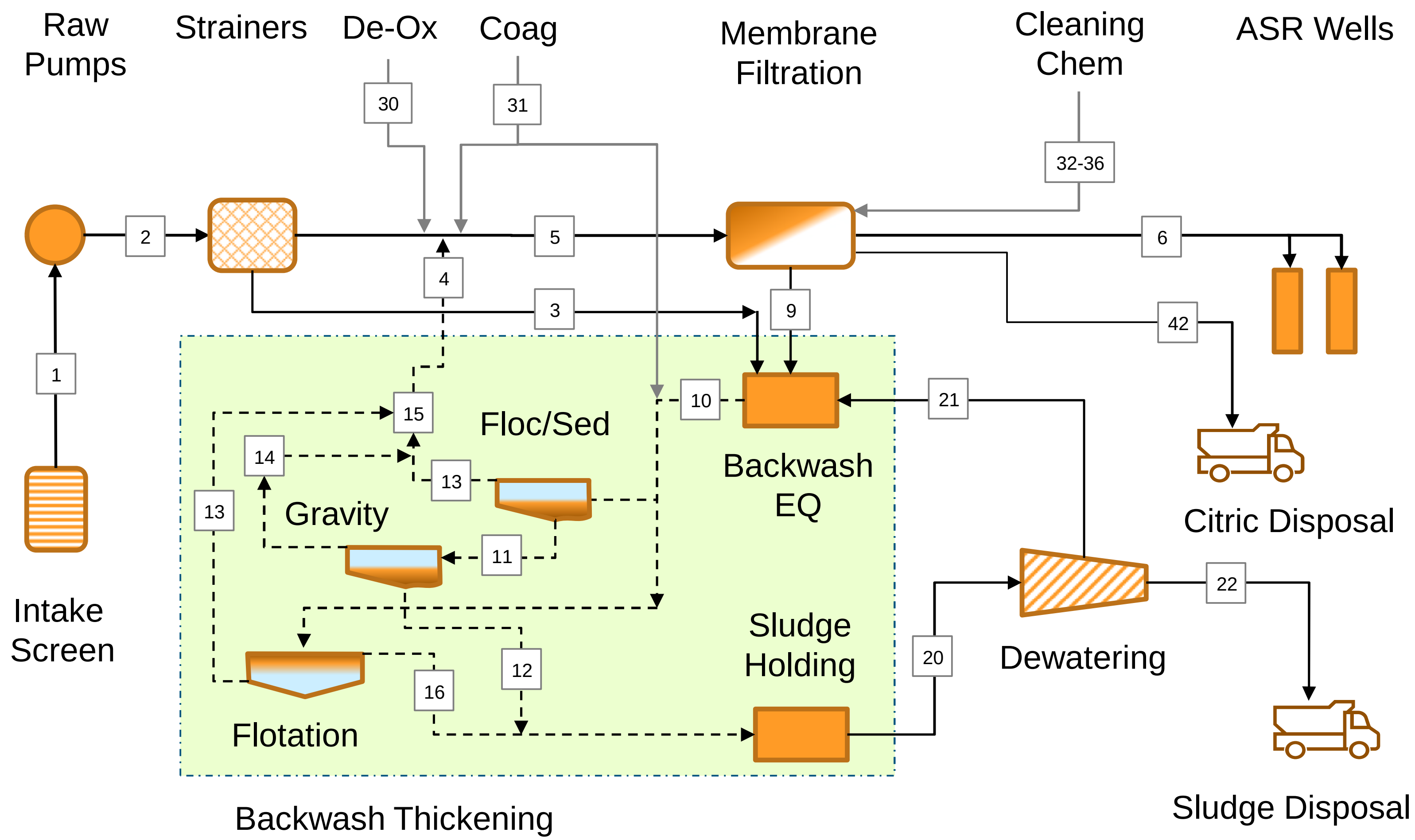
BACKWASH THICKENING AND DEWATERING

How do we treat backwash and residual solids from the treatment process?

sfwmd.gov

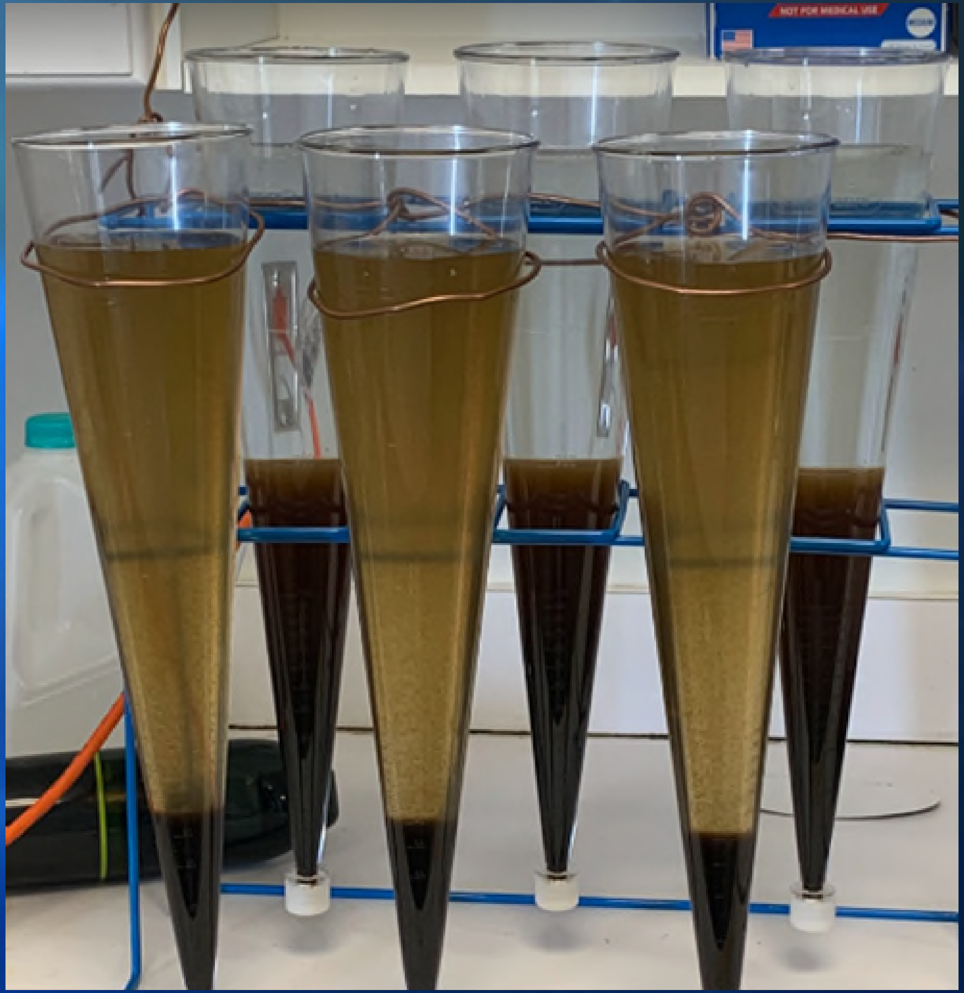
Stantec

BACKWASH TREATMENT PROCESS OVERVIEW



BACKWASH THICKENING

- Thickening of BWW is needed to minimize sludge storage volume prior to dewatering.
  - Backwash waste water (BWW) from ceramic and polymeric membrane systems differ significantly.
  - Bench scale testing conducted to thicken backwash waste (BWW) from ERDC pilot membrane filtration systems.
  - Pilot scale thickening trials conducted for gravity settling and flotation processes
- Results of testing used to inform preliminary design criteria



BACKWASH THICKENING PILOT

➢Gravity Settling

- Effective for larger particle sizes

➢Suspended Air Flotation (SAF)

- Effective for smaller particle sizes

- Thickened solids analyzed by centrifuge and screw press manufacturers for initial concentration, polymer requirements, and dewatered cake solids%.

RECOVERED WATER CONSIDERATIONS

How do we handle potential arsenic issues during recovery?

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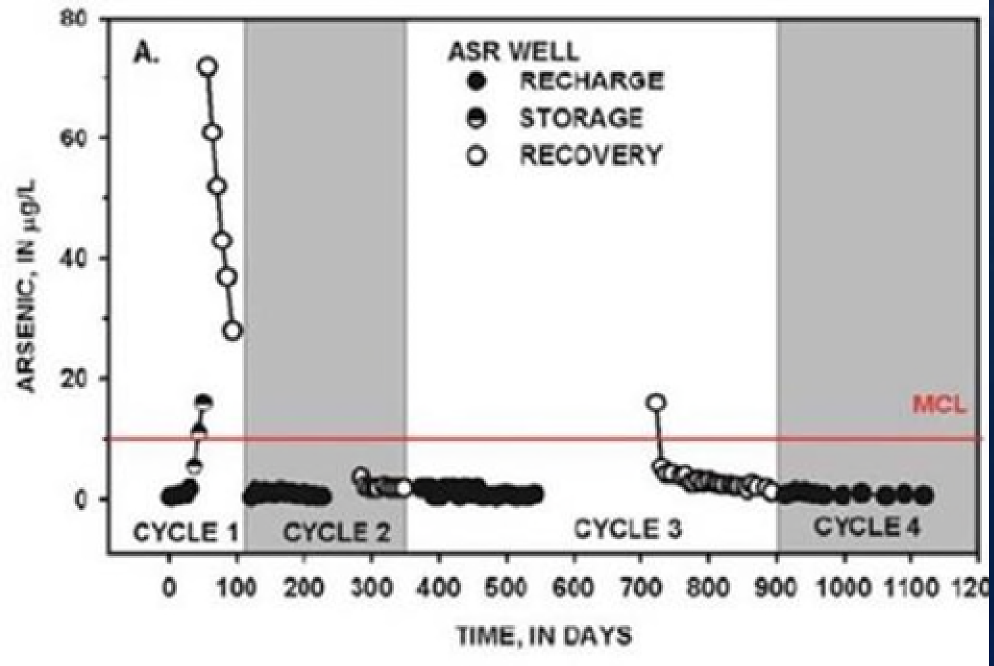
RECOVERED WATER: ARSENIC

- Arsenic is stable as a sulfide solid (pyrite and arsenopyrite) under native conditions (reducing).
  - Storing surface water with even low concentrations of dissolved oxygen (DO) will temporarily disrupt this redox environment.
- During cycle testing at KRASR, Arsenic was present in recovered water. Arsenic was 7x the MCL during cycle 1.
- Based on data from the 2013 CERP report, this situation appears to be short-term (commissioning) in nature rather than long-term.



2013 CERP ASR Final Tech Data Report

RECOVERED WATER: ARSENIC

3 Options for Arsenic Management:

1. Mixing Zone
   - A regulatory approach to establishing a mixing zone could achieve compliance with 50 ppt surface water MCL, depending on initial recovered concentration.
2. Re-treatment
   - A re-treatment approach using membrane filters could remove arsenic from recovered water.
   - Treatment facility is designed with flexibility to add hypochlorite to oxidize Arsenite (III) to Arsenate (V), to precipitate as a solid, which would be captured with coagulant and removed by membrane filters.
3. Sequestration
   - Reduce dissolve oxygen (DO) from surface water before aquifer recharge to reduce risk of arsenic mobilization.

ARSENIC SEQUESTRATION: DO REDUCTION

➢DO Reduction

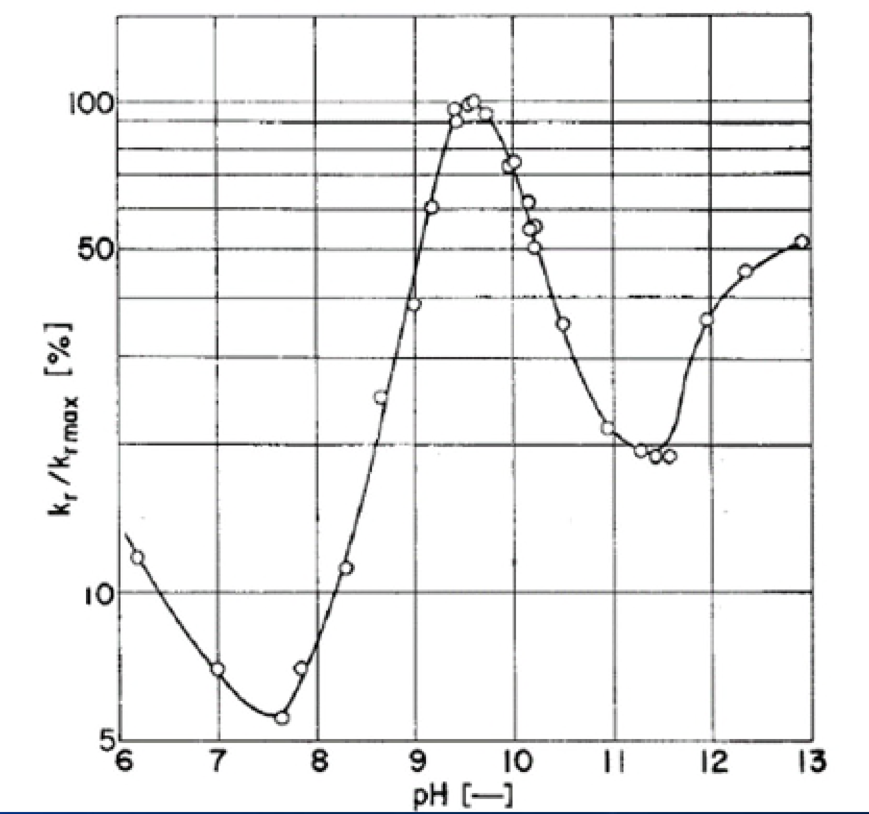
- Evaluation of 6 technologies conducted:
  - Conceptual treatment processes developed & evaluated on economic and non-economic criteria
  - Chemical DO reduction bench tested
- Utility ASR DO Reduction Survey conducted

Type	Process
Physical	Membrane Degasification (MDG)
	Vacuum Stripping
	Minox Deoxygenation
	Gas Displacement Technology (GDT)
Chemical	Sodium bisulfite
	Sodium hydrosulfide

Municipality	Source	Capacity (MGD)	DO Reduction Technology	Type	Starting DO (ppm)	Ending DO (ppm)	Status
City of Bradenton (ASR-1)	Potable	1.0	Physical	Membrane Degasification	8.0	< 0.4	Operational
City of Bradenton (ASR-2)	Potable	2.0	Physical	Vacuum Stripping	8.0	< 0.5	Operational
City of North Port	Partially Treated Surface Water	1.5	Chemical	Sodium Hydrosulfide	4.0	0.75*	Inactive
City of Deland	Potable	0.4	Chemical	Sodium Hydrosulfide	5.5	0.75*	Inactive
City of Venice	Reclaimed	3.0	Chemical	Sodium Bisulfite	not yet commissioned		Operational
City of Palmetto	Reclaimed	1.2	Chemical	Sodium Bisulfite	4.0	< 2.0	Under construction
Flatford Swamp	Potable	0.5	Chemical	Sodium Bisulfite	8.3	< 2.0	Operational

DO REDUCTION: BENCH SCALE TESTING

- Testing conducted at KRASR laboratory
  - Testing conducted in parallel with USACE ERDC researchers (March 2024)
  - Chemical DO reduction trials conducted using sodium hydrosulfide (NaHS)
    - Chemical DO reduction proved to be pH dependent
  - Physical DO reduction trials conducted by ERDC using membrane deoxygenation
    - Physical DO reduction to be evaluated further and technology selected for next design phase



Effect of pH value on Reaction Rate Constant (Yasunishi, 1976)

SCHEDULE

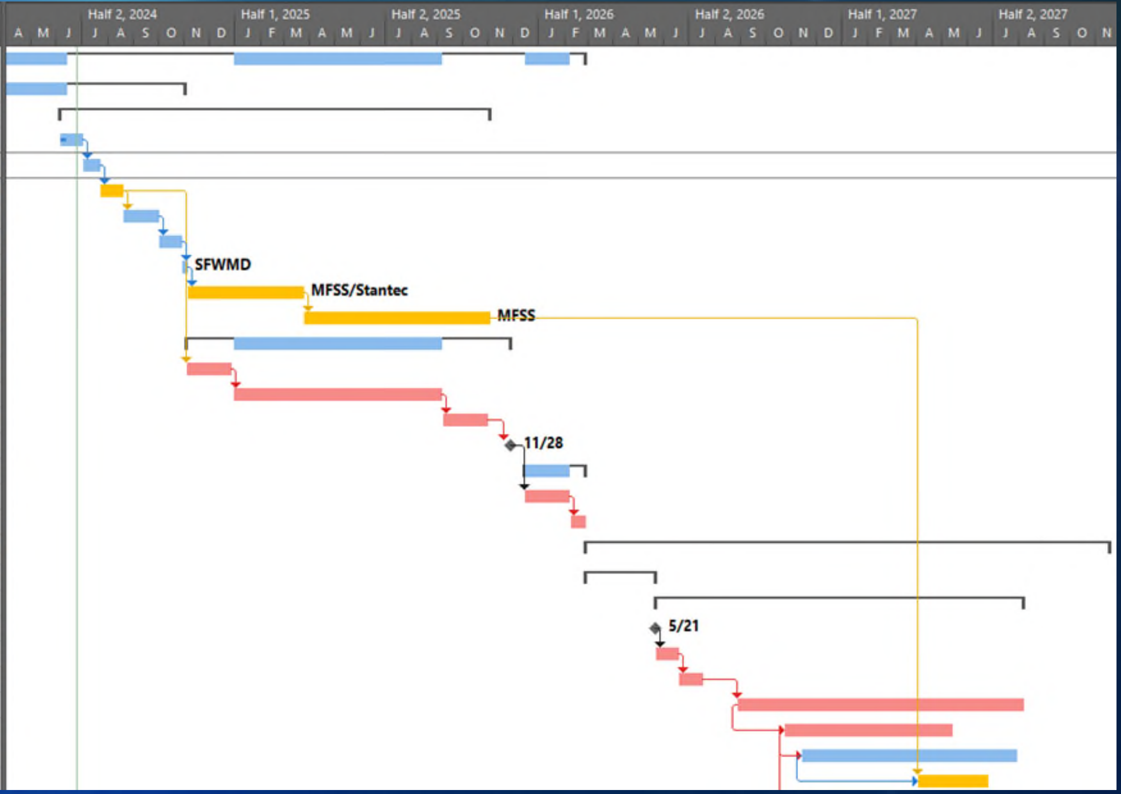
What are our milestones for Design, Bidding and Construction

CONCEPTUAL SCHEDULE – DESIGN & CONSTRUCTION

➢ Projected Design and Construction Milestones

- Preliminary Design
  - 10/24
- Final Design
  - 11/25
- Construction
  - 8/27
- Cycle Testing
  - 6/29

Task Name	Duration	Start	Finish
Design	**746 days**	**Thu 4/20/23**	**Thu 2/26/26**
Preliminary Design	**402 days**	**Thu 4/20/23**	**Fri 11/1/24**
4.1 Membrane Procurement (RFP)	**369 days**	**Wed 6/5/24**	**Mon 11/3/2!**
4.1.3 Final RFP Package for Membrane Suppliers	3.8 wks	Wed 6/5/24	Mon 7/1/24
Procurement processing	3 wks	Tue 7/2/24	Mon 7/22/24
Manufacturers Prepare Proposals	4 wks	Tue 7/23/24	Mon 8/19/24
4.1.5 Evaluation, Neg & Recommendaton to Purchase	6 wks	Tue 8/20/24	Mon 9/30/24
4.1.6 Gov Board Agenda Item	4 wks	Tue 10/1/24	Mon 10/28/2
Gov Board Approval	1 wk	Tue 10/29/24	Mon 11/4/24
Submittals Prep & Review	20 wks	Tue 11/5/24	Mon 3/24/2!
Membrane Manufacture	8 mons	Tue 3/25/25	Mon 11/3/2!
Final Design	**280 days**	**Mon 11/4/24**	**Fri 11/28/25**
Scoping	40 days	Mon 11/4/24	Fri 12/27/24
90% Final Design	180 days	Mon 12/30/24	Fri 9/5/25
SFWMD, USACE Technical Review	8 wks	Mon 9/8/25	Fri 10/31/25
TRB	0 days	Fri 11/28/25	Fri 11/28/25
Corrected Final Design	**54 days**	**Mon 12/15/25**	**Thu 2/26/26**
Corrected Final Design	2 mons	Mon 12/15/25	Fri 2/6/26
SFWMD, USACE RTA Check set	14 days	Mon 2/9/26	Thu 2/26/26
Construction	**450 days**	**Fri 2/27/26**	**Thu 11/18/2**
Bidding	**60 days**	**Fri 2/27/26**	**Thu 5/21/26**
Contracting	**316 days**	**Thu 5/21/26**	**Fri 8/6/27**
Gov Board Approval	0 days	Thu 5/21/26	Thu 5/21/26
Construction Contract Execution	4 wks	Fri 5/22/26	Thu 6/18/26
Mobilization	1 mon	Fri 6/19/26	Thu 7/16/26
Civil/Site Work + Vertical	246 days	Fri 8/28/26	Fri 8/6/27
Structural/Arch	145 days	Fri 10/23/26	Thu 5/13/27
Mechanical	185 days	Fri 11/13/26	Thu 7/29/27
Membrane Installation	3 mons	Fri 4/2/27	Thu 6/24/27

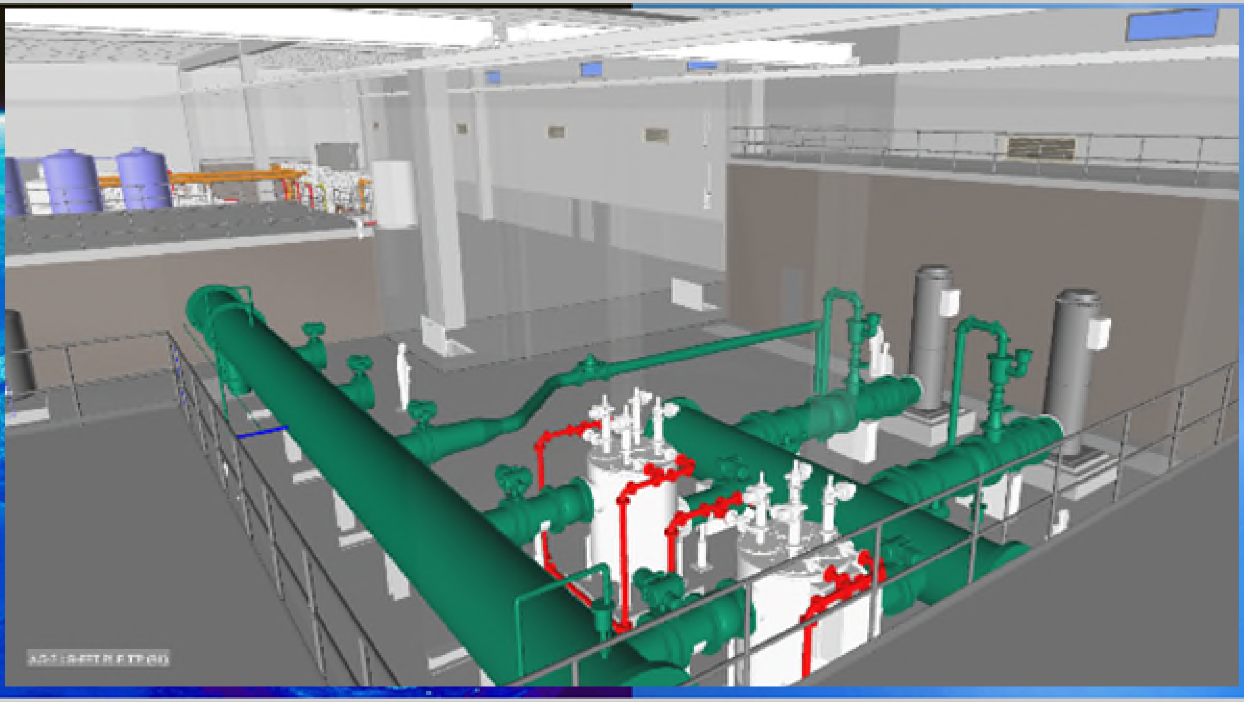


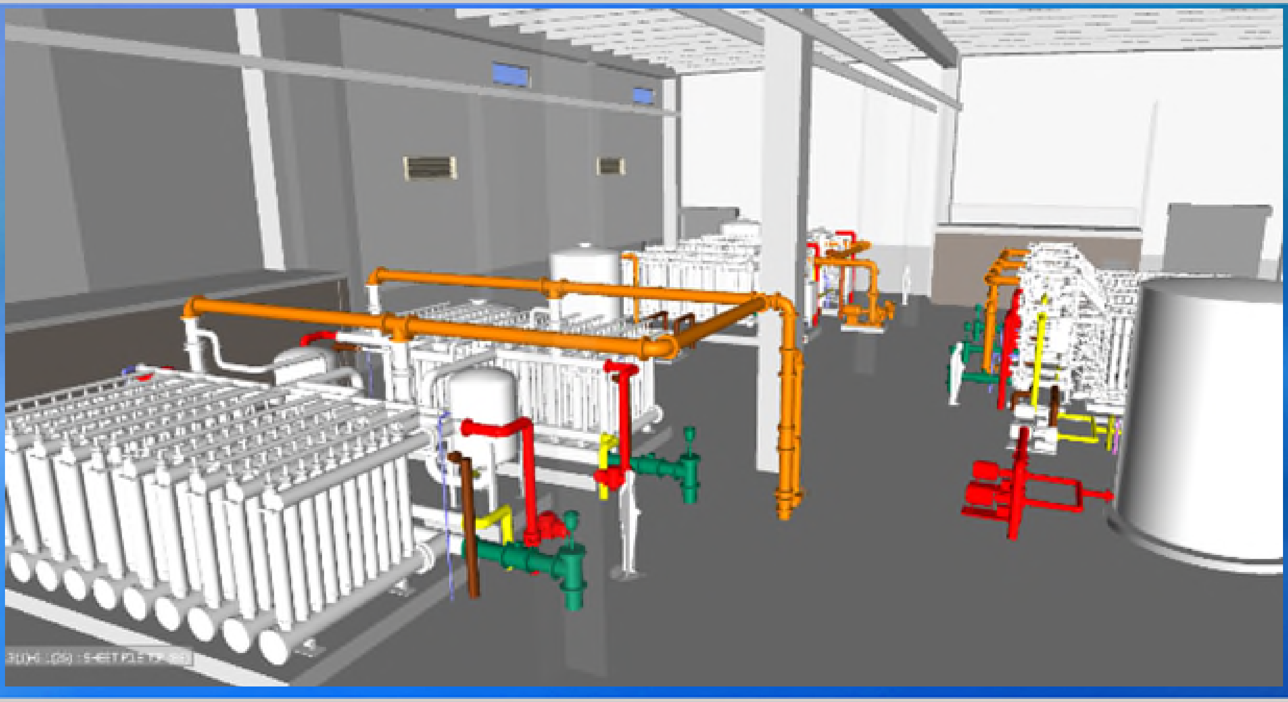
NEXT STEPS

How do we advance ASR thoughtfully and efficiently?

NEXT STEPS

- Issue Membrane RFP package to suppliers
- Integrate thickening and dewaterability results into preliminary design
- Submit Preliminary Design
- Prepare and submit FDEP permit application package
- Integrate membrane supplier equipment into next design phase
- Integrate most appropriate DO Reduction technology into next design phase





QUESTIONS/DISCUSSION?

www.sfwmd.gov/lowrp or www.sfwmd.gov/asr

2024 ASR Science Plan
Public Workshop
July 10, 2024

Multi-Well Assessment of Fracture Porosity of the Floridian Aquifer System in Support of Future ASR Wells in Northern Lake Okeechobee

07/10/2024

Victor Flores
&
Kevin J. Cunningham
USGS

USGS science for a changing world

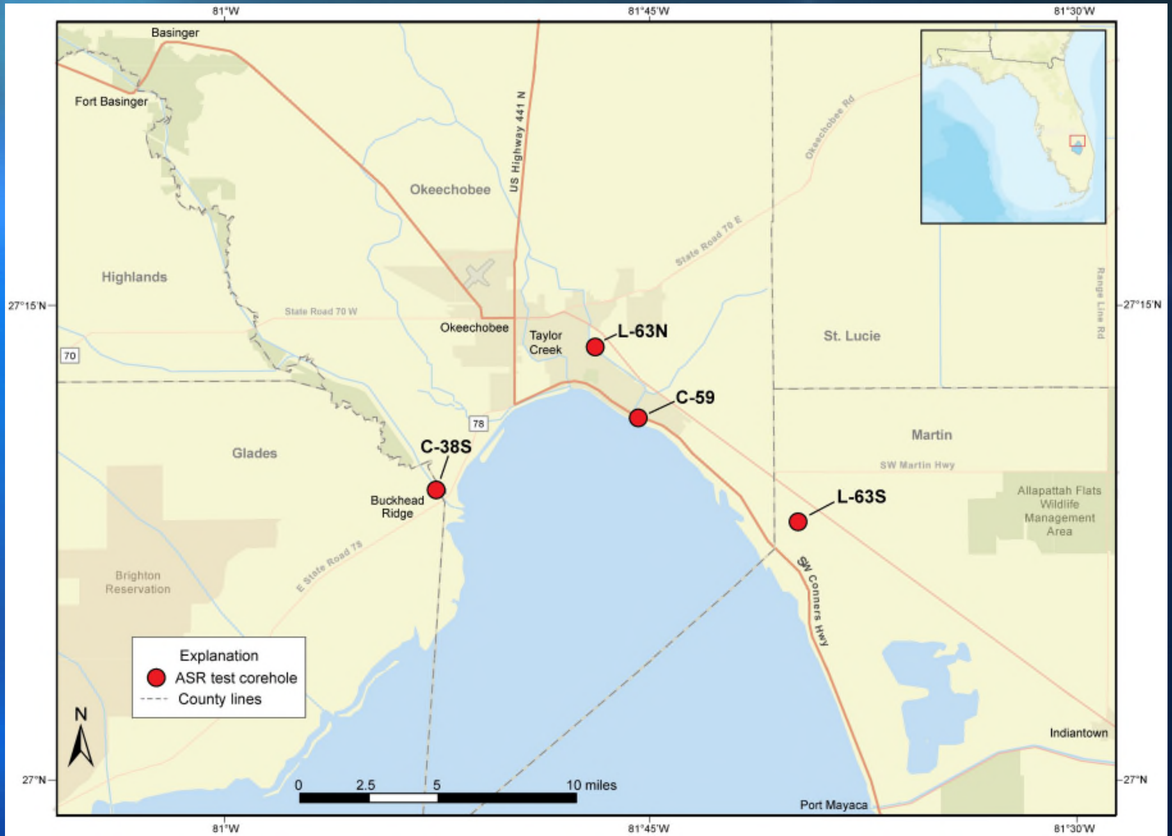
Floridan Aquifer System Fracture Study

Objectives

1) **Enhance and refine Regional Hydrogeologic Framework:** To contribute to the understanding of the Floridan aquifer system's fracture geometry and flow-system characteristics to support future drilling and construction of ASR wells and regional hydrogeologic framework projects.

2) **Inform Well Design and Groundwater Movement Controls:** To inform well design and assessment of controls on groundwater movement in support ASR utility projects and drinking water resource protection.

3) **Support Water Supply via ASR:** To provide information on aquifer zone suitability for ASR water supply at four corehole sites.



"Preliminary Information-Subject to Revision. Not for Citation or Distribution."

Floridan Aquifer System Fracture Study

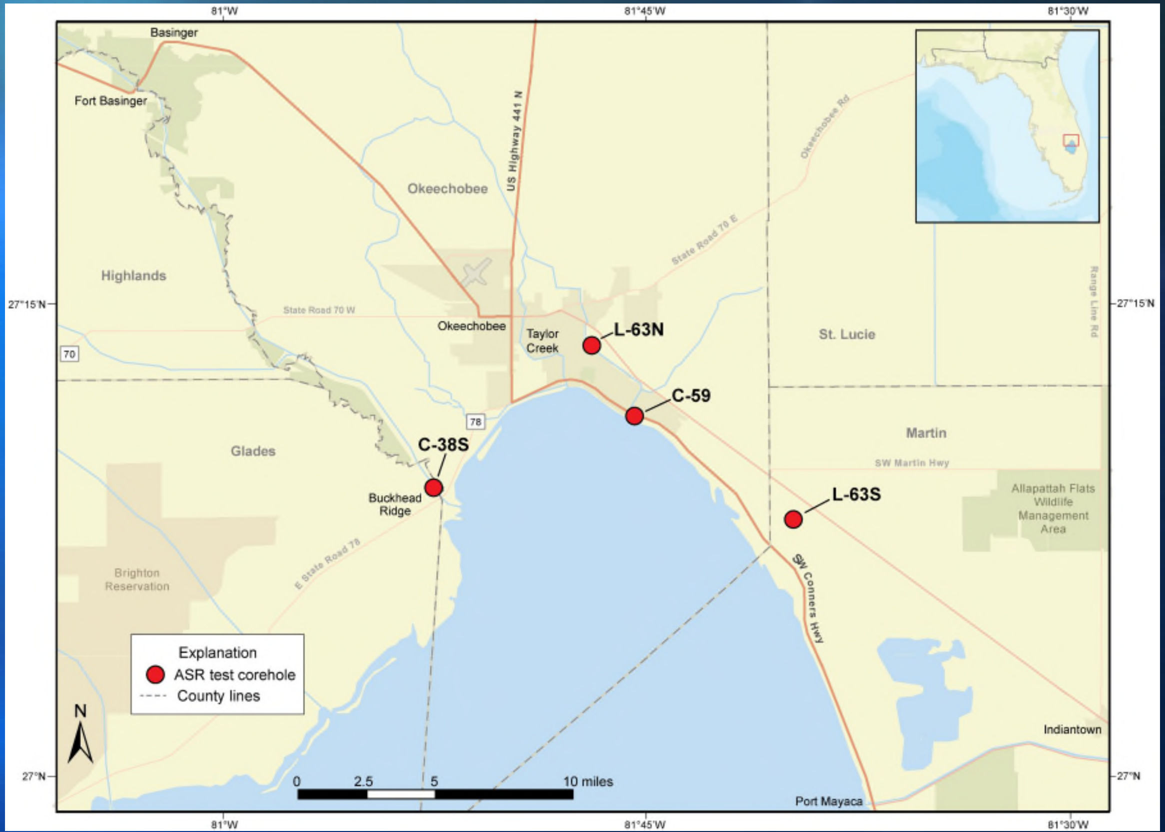
Key Findings

1) Fractures are much more prominent in brittle dolomitized rock as compared to limestone intervals

2) Natural fractures related to karst collapse zones and tectonics are commonly present in dolomite

3) Acoustic borehole image (ABI) logging should be considered for future projects. ABI logs can quantify aperture width, which is related to hydraulic conductivity

4) Packer-test specific capacity is highest at vertical intervals with a high concentration of natural fractures



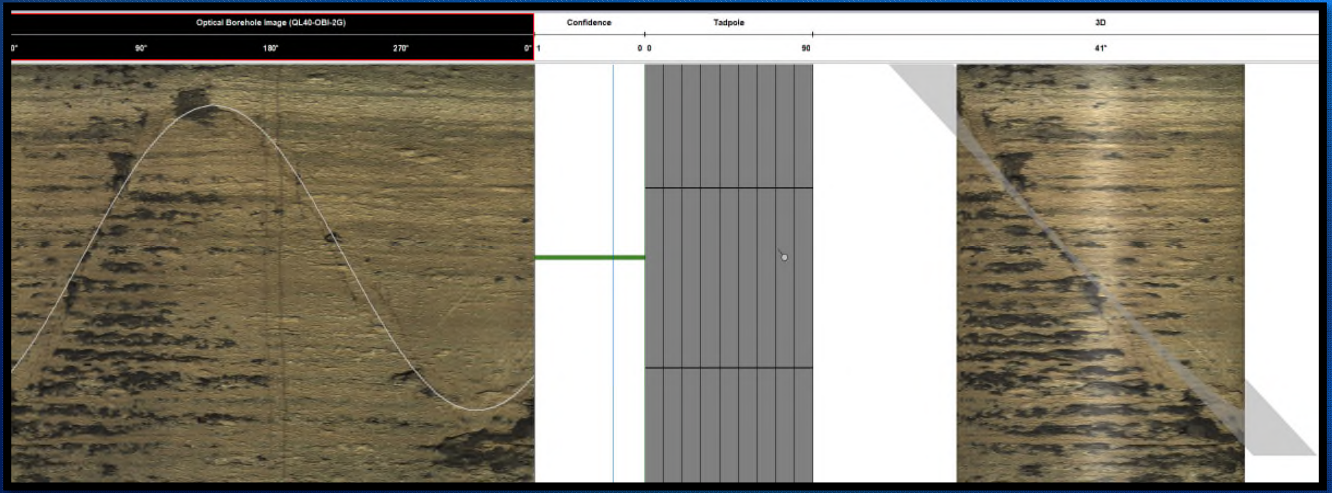
Core Photography

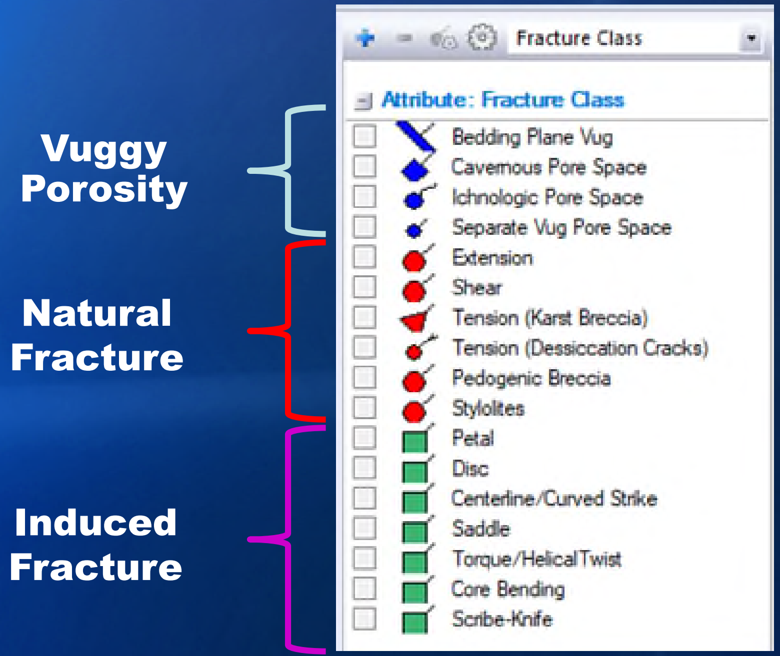
L-63S Core

Fracture Classification

- Vuggy Bedding Plane: Caused by dissolution
- Natural Fracture: Created by geologic forces and processes
- Induced Fracture: Created by drilling, coring, and handling processes

Fractures or bedding planes can be identified by outlining the sinusoid features on the OBI image.

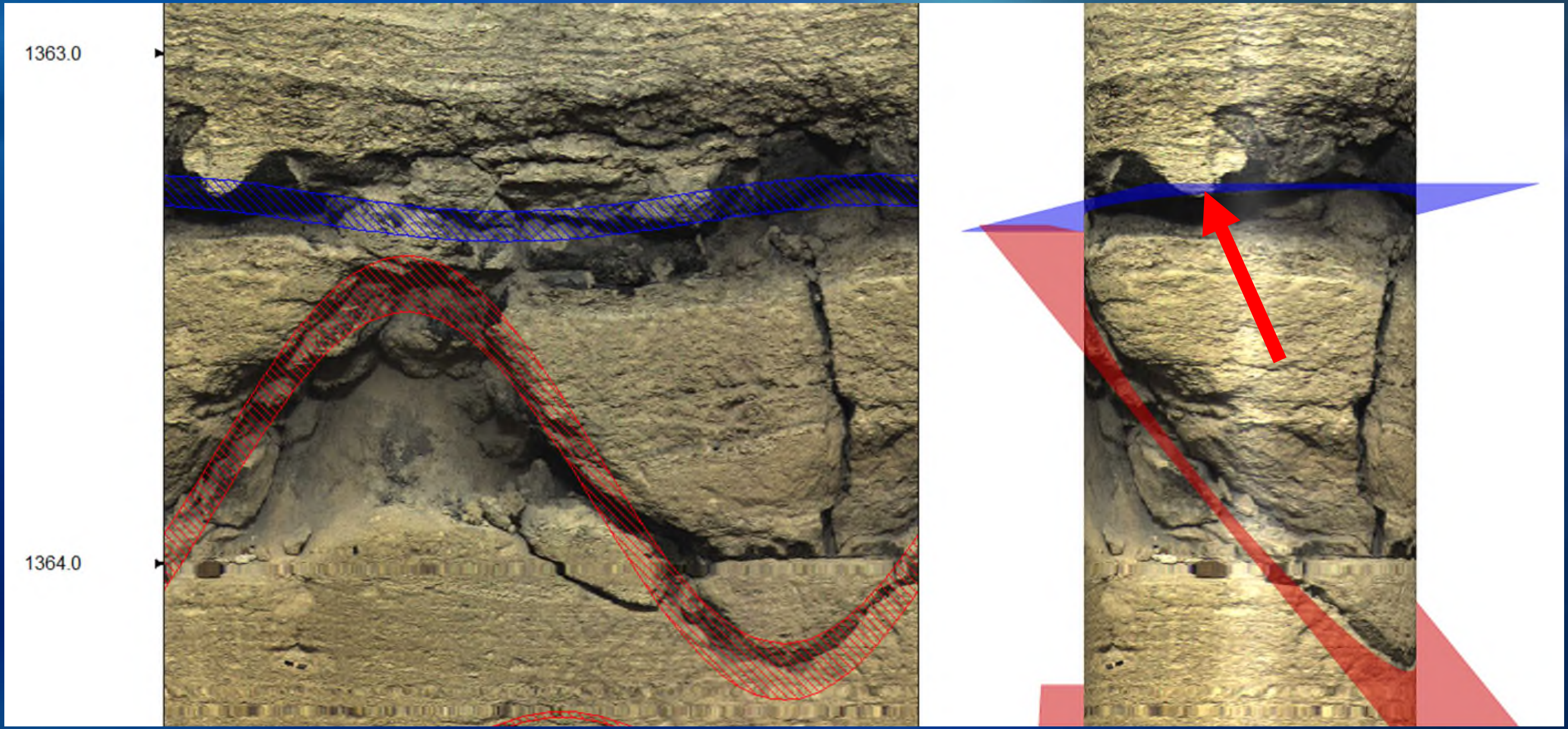




Vuggy Bedding Plane (blue) + Natural Fracture (red)

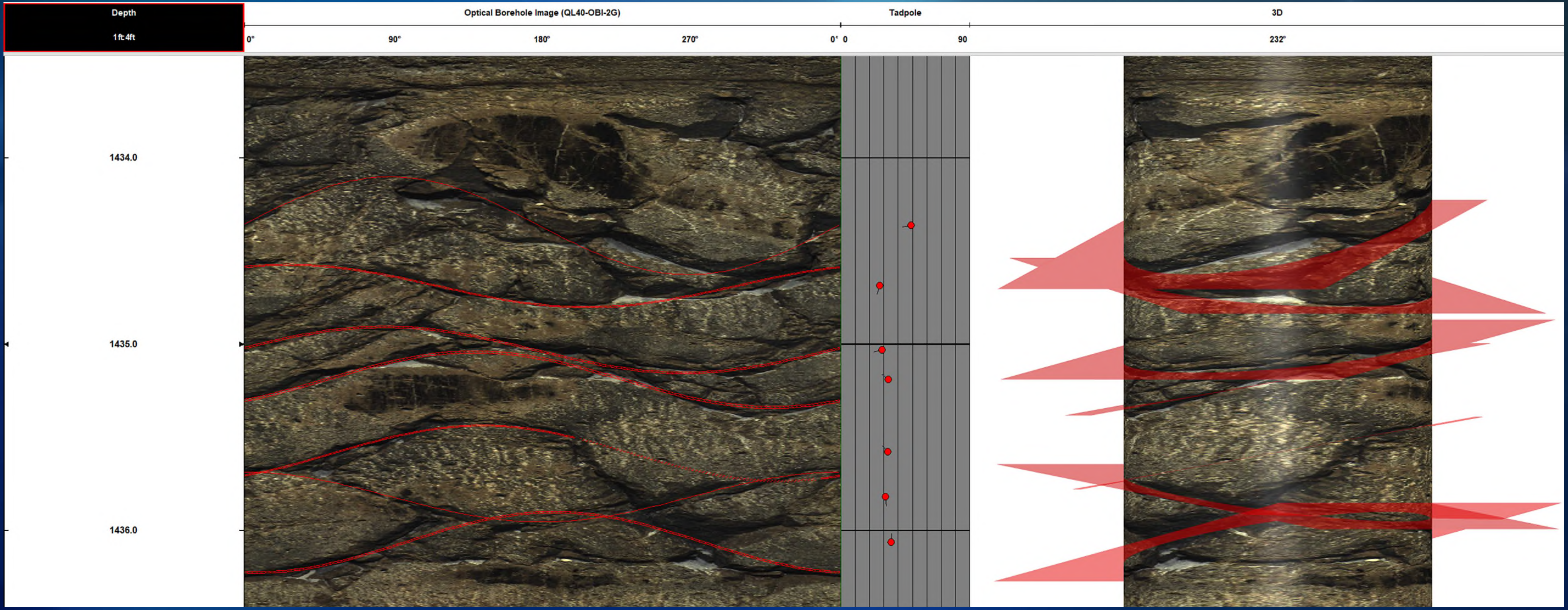
C-38S

Upper Avon Park Permeable Zone



Natural Fracture in Brittle Dolomite

L-63N
Upper Avon Park Permeable Zone



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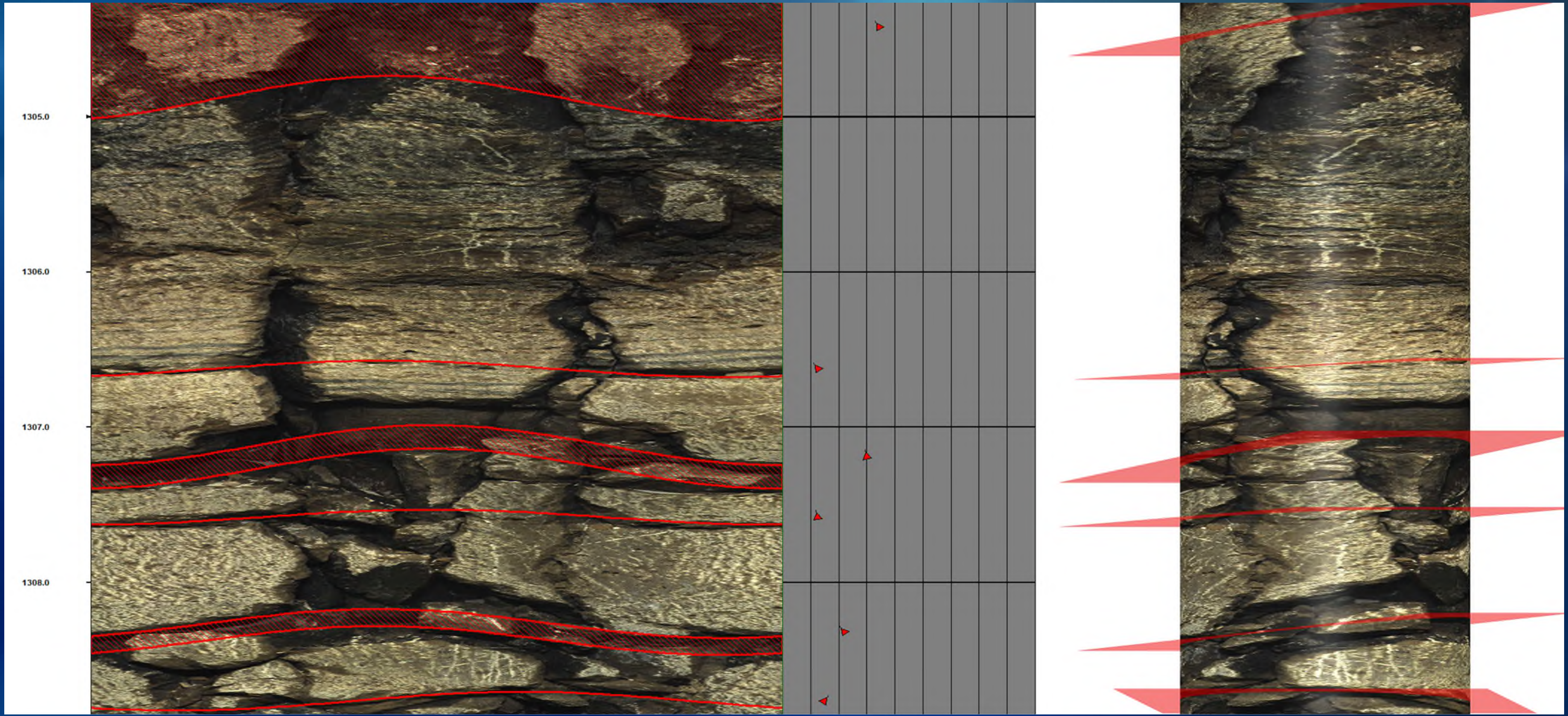
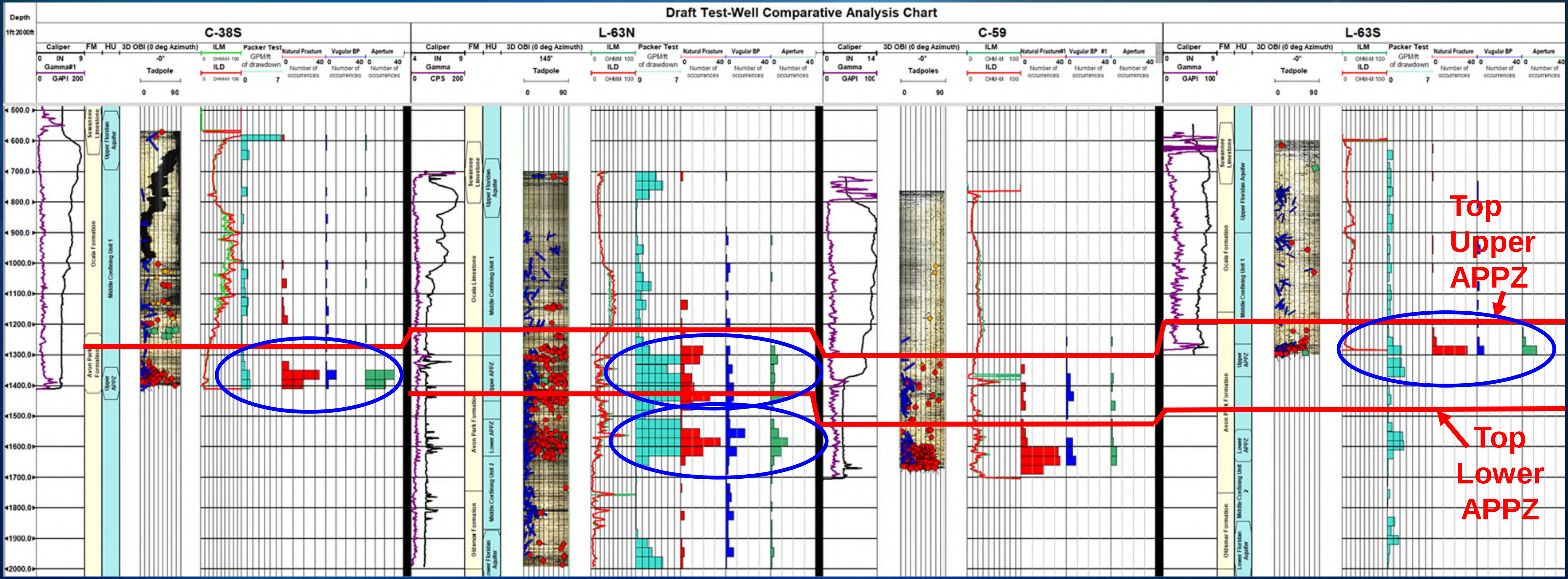
Natural Fractures in Brittle Dolomite

L-63N

Upper Avon Park Permeable Zone

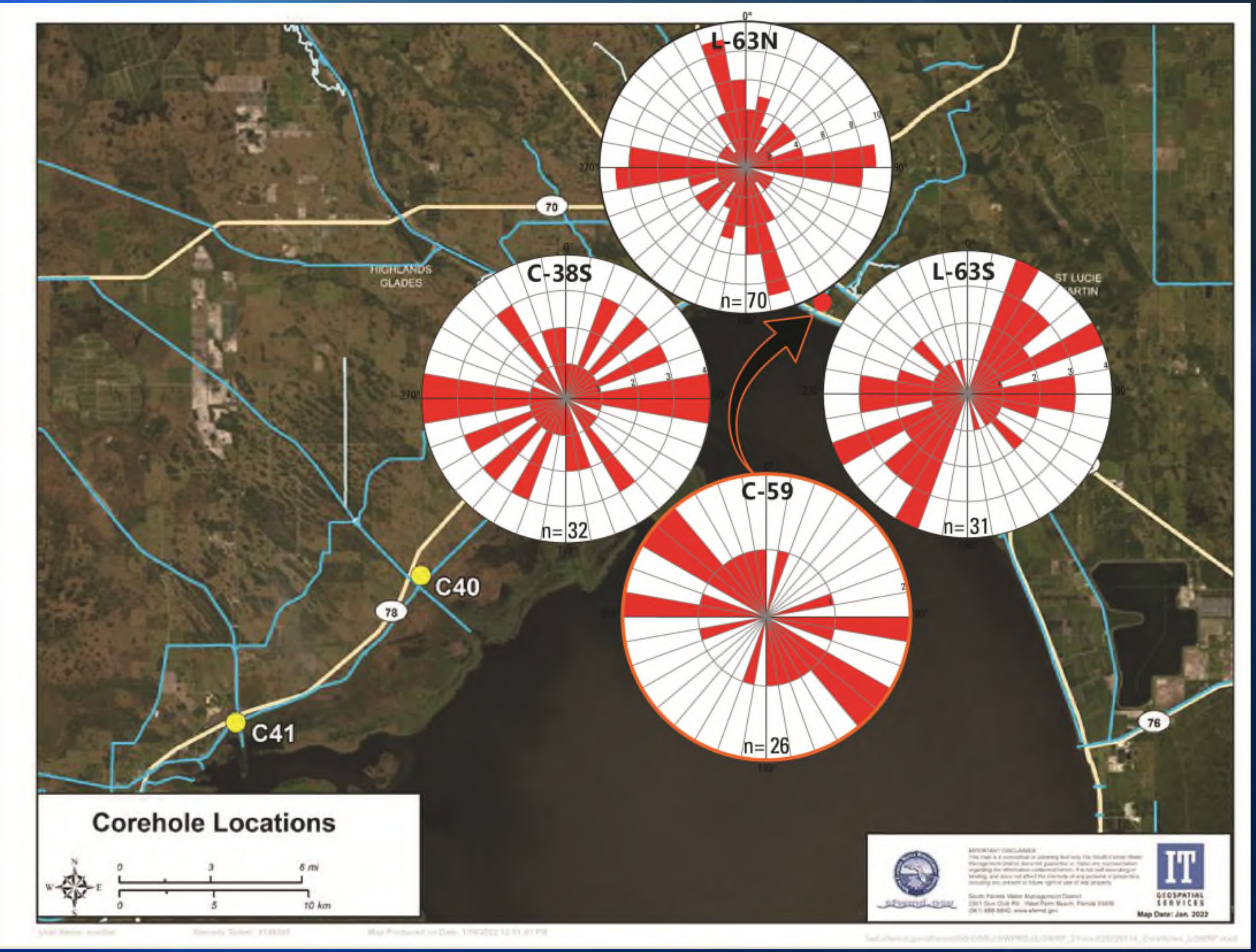


Fracture Data Analysis



Natural Fracture Data Analysis

Upper Avon Park Permeable Zone



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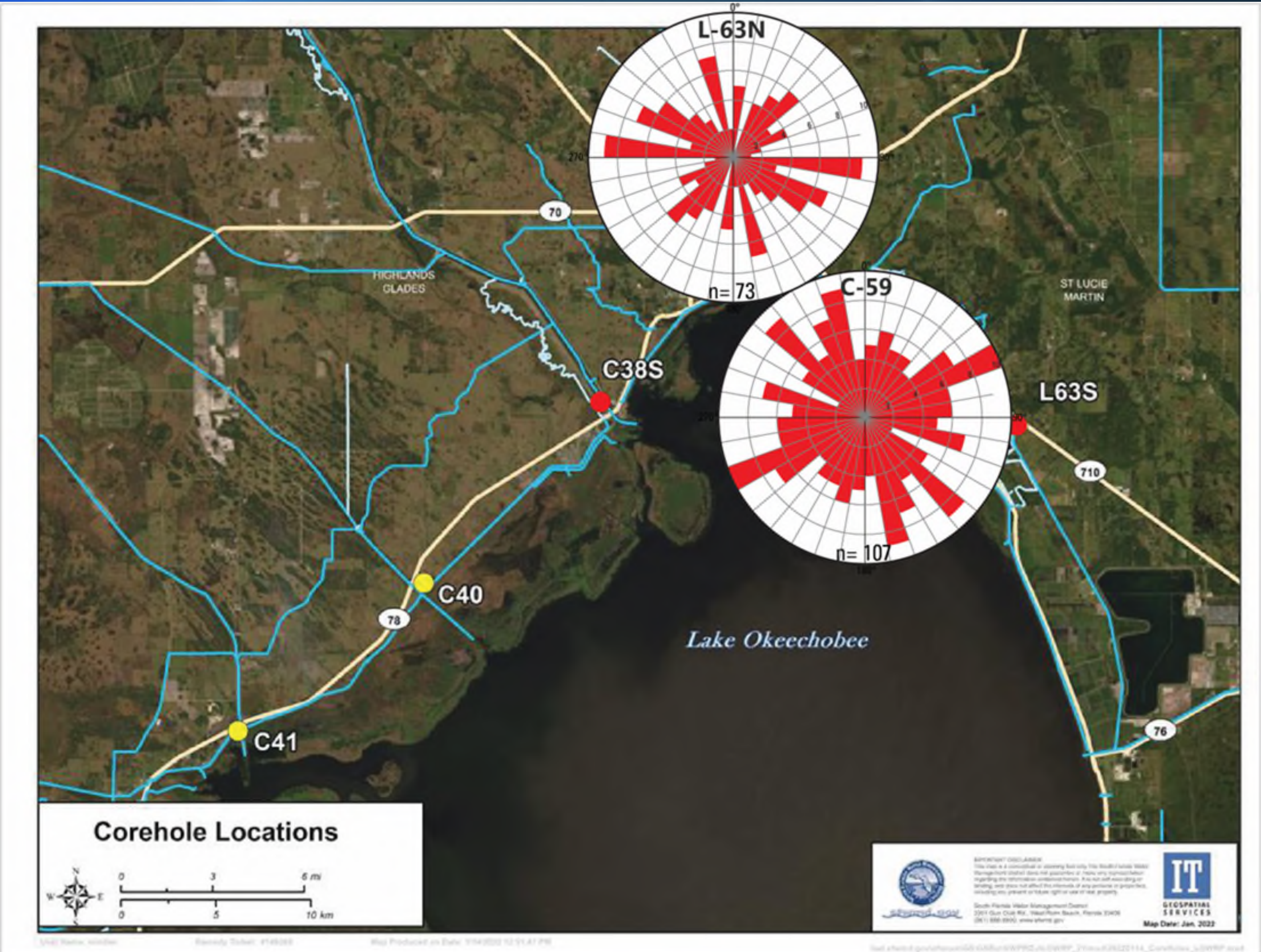
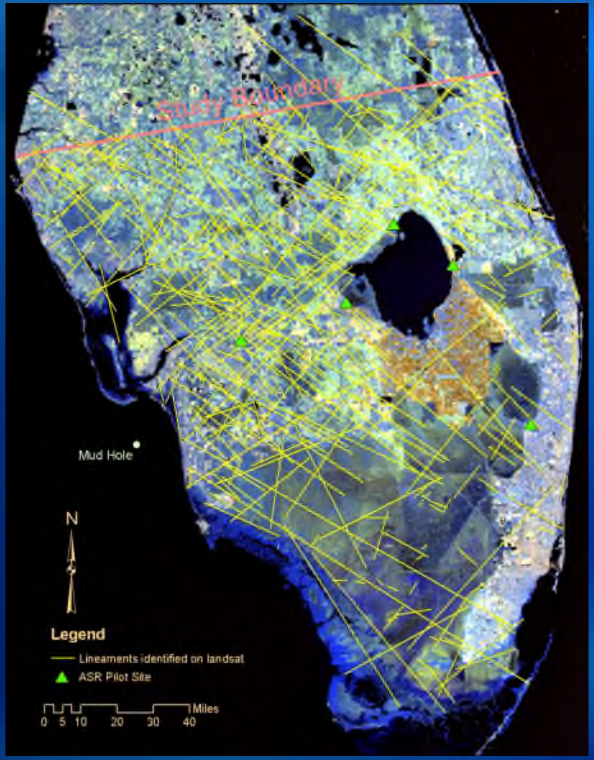
Natural Fracture Data Analysis

Lower Avon Park Permeable Zone

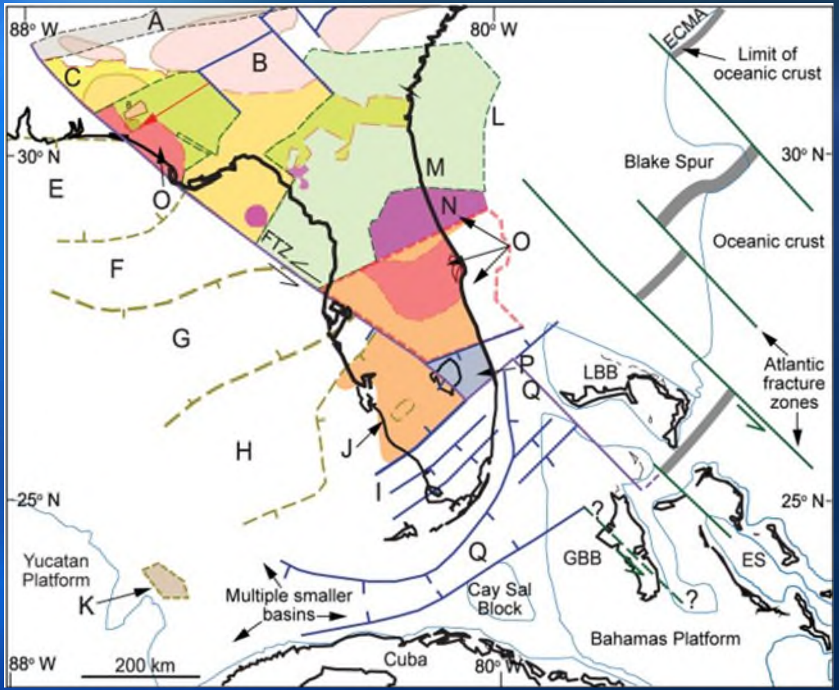


Future Tasks

- Use natural fractures with open apertures to investigate anisotropic groundwater flow
- Investigate relationship between regional geologic features & fracture orientations



Lineaments identified on Landsat
Fees (2004)



Tectonic elements & crustal features of Florida
Erlich & Pindell (2021)

Questions or Comments?

Thank You!

Characterization Of Microbial & Geochemical Processes That Contribute To Nutrient Reduction & Potential Clogging

John Lisle, PhD

US Geological Survey

St. Petersburg, FL

ASR Science Plan Peer Review Panel Virtual Workshop

July 10, 2024

Well, Groundwater, Surface Water & Above Ground Mesocosm Sites

Site	Sample Types	Sample Source
C38S	Native Groundwater	UFA APPZ
L63S	Native Groundwater	UFA APPZ
C59	Native Groundwater	UFA APPZ
Kissimmee River	Recharge Water	KRASR Intake

Collection & Processing Aquifer Cores for Packing Laboratory Columns

Core Laboratories
Houston, TX

#20 sieve size

Biofilm^{+}

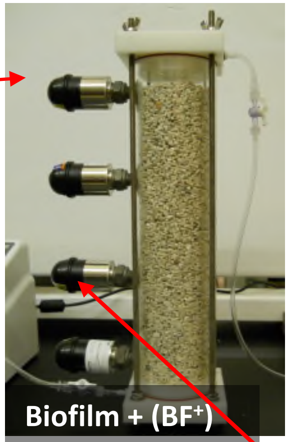
Biofilm^{-}

Bioclogging Column Preparation & System Set Up

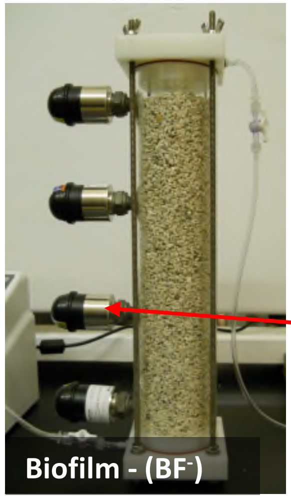
Collection of Source Water from Kissimmee River

Kissimmee River source water

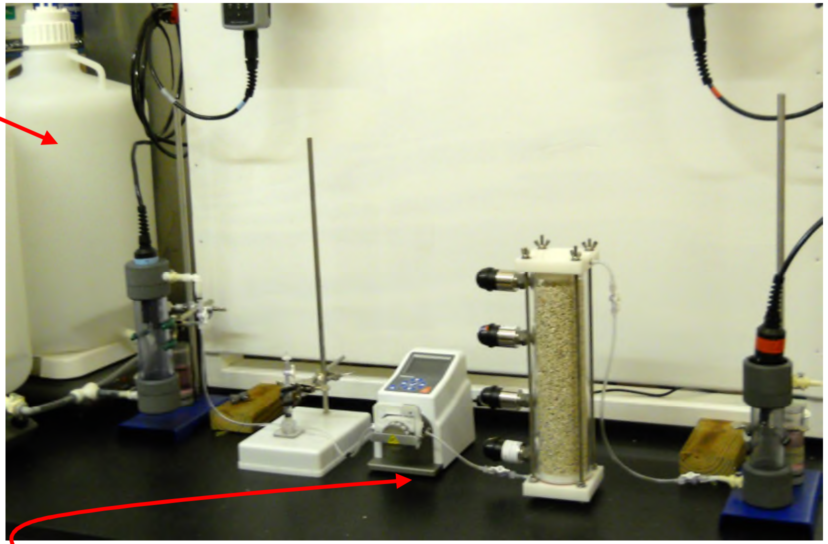
Above ground mesocosm connected to UFA at KRASR



Biofilm + (BF^+)



Biofilm - (BF^-)



BF^+ & BF^- columns connected to the Source Water pumping system

Pressure sensors installed at laboratory

Wet packed on site when collecting BF^+

Experimental Design

- **Conditioning Phase:**
  - Uses filtered sterilized groundwater from either the UFA or APPZ
  - Pumped for ~14 days through:
    - BF+ and BF- columns
    - Biofilm development rate column

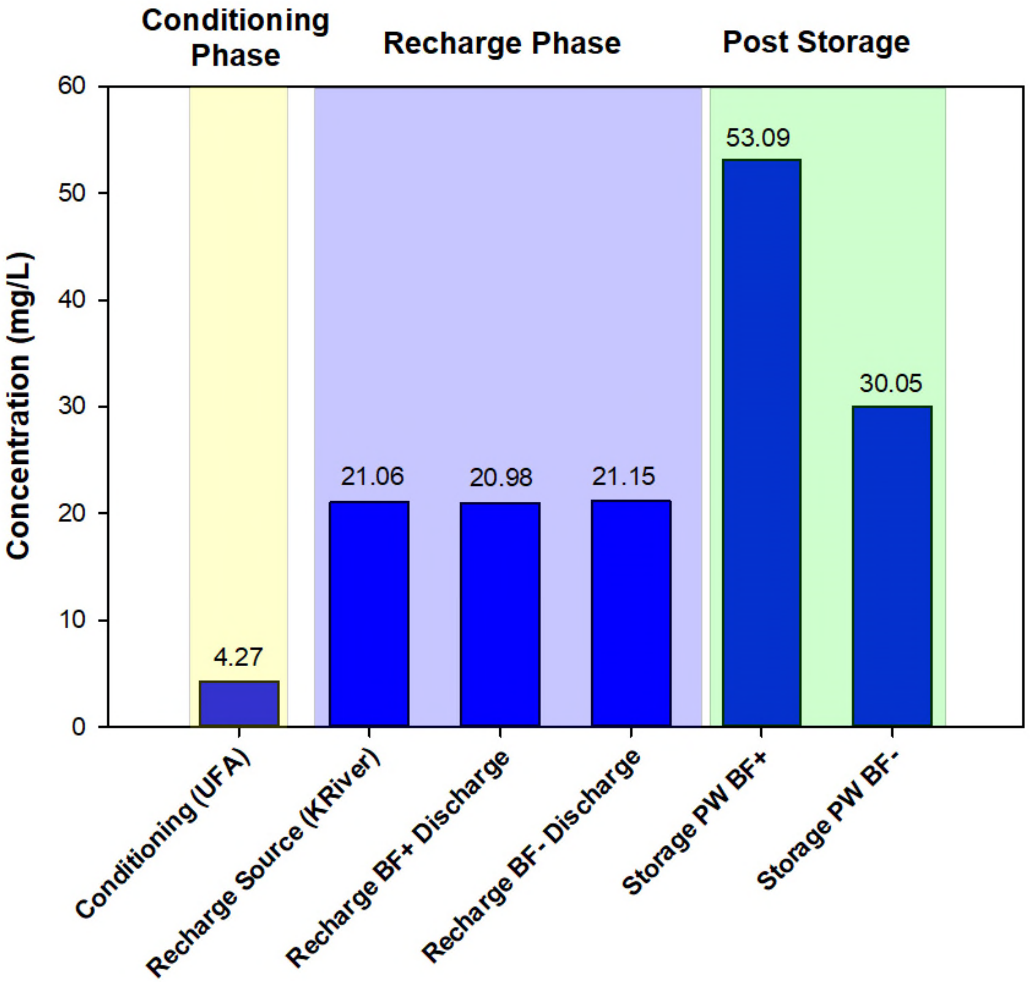
- **Recharge Phase (Primary)**
  - Uses filtered (300µm) Kissimmee River water
  - Pumped for ~21 days through:
    - BF+ and BF- columns
    - Biofilm development rate column

- **Storage Phase**
  - All columns valved off and allowed to sit static for 4 weeks

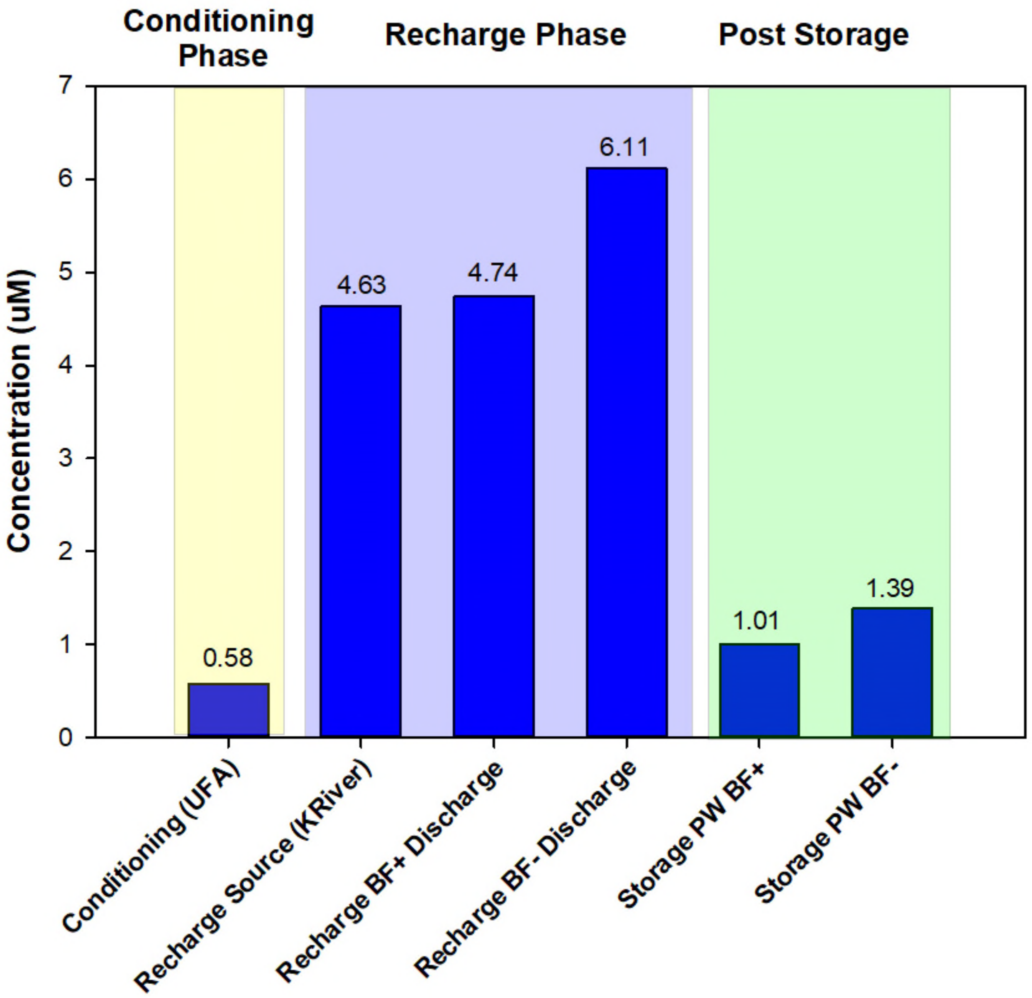
- **Recovery Phase**
  - Porewater volume from BF+ and BF- columns collected for analyses

- **Recharge Phase (Secondary)**
  - Uses filtered (300µm) Kissimmee River water
  - Pumped up to 21 days or until a significant trend in pressure increase within the columns and/or reduction in column discharge rates.

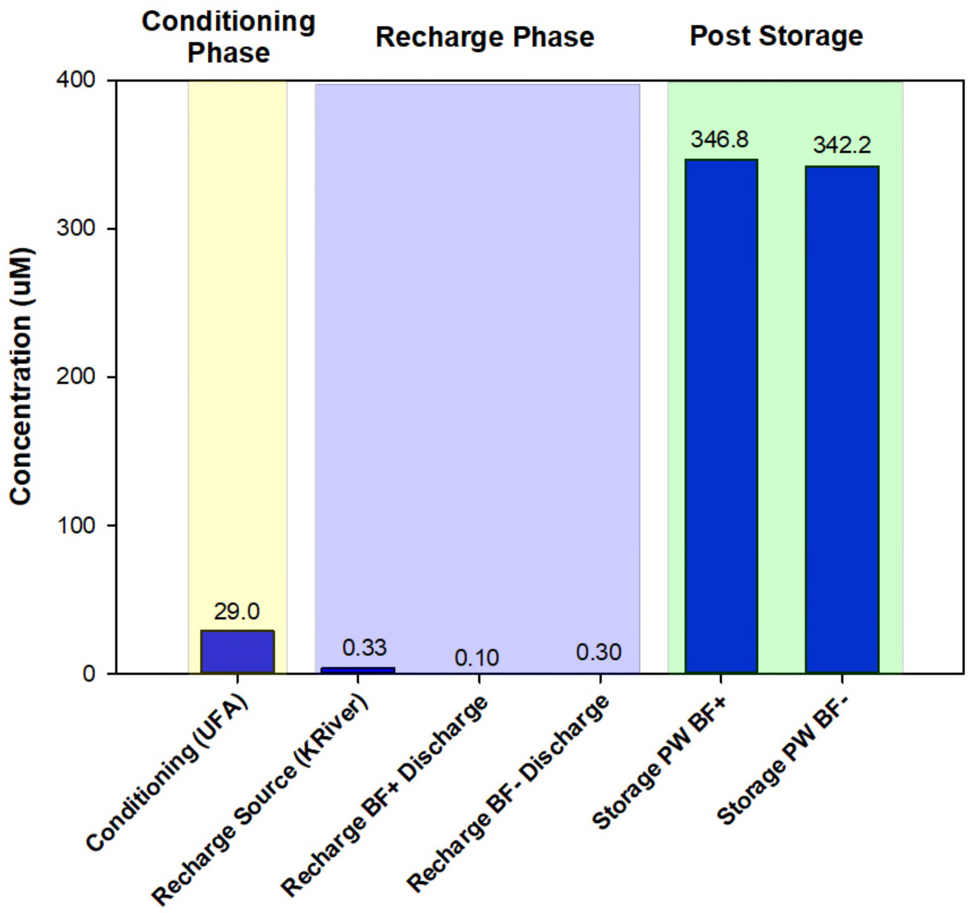
Geochemical Changes in Recharged Water During Storage C38S/UFA: *DOC*



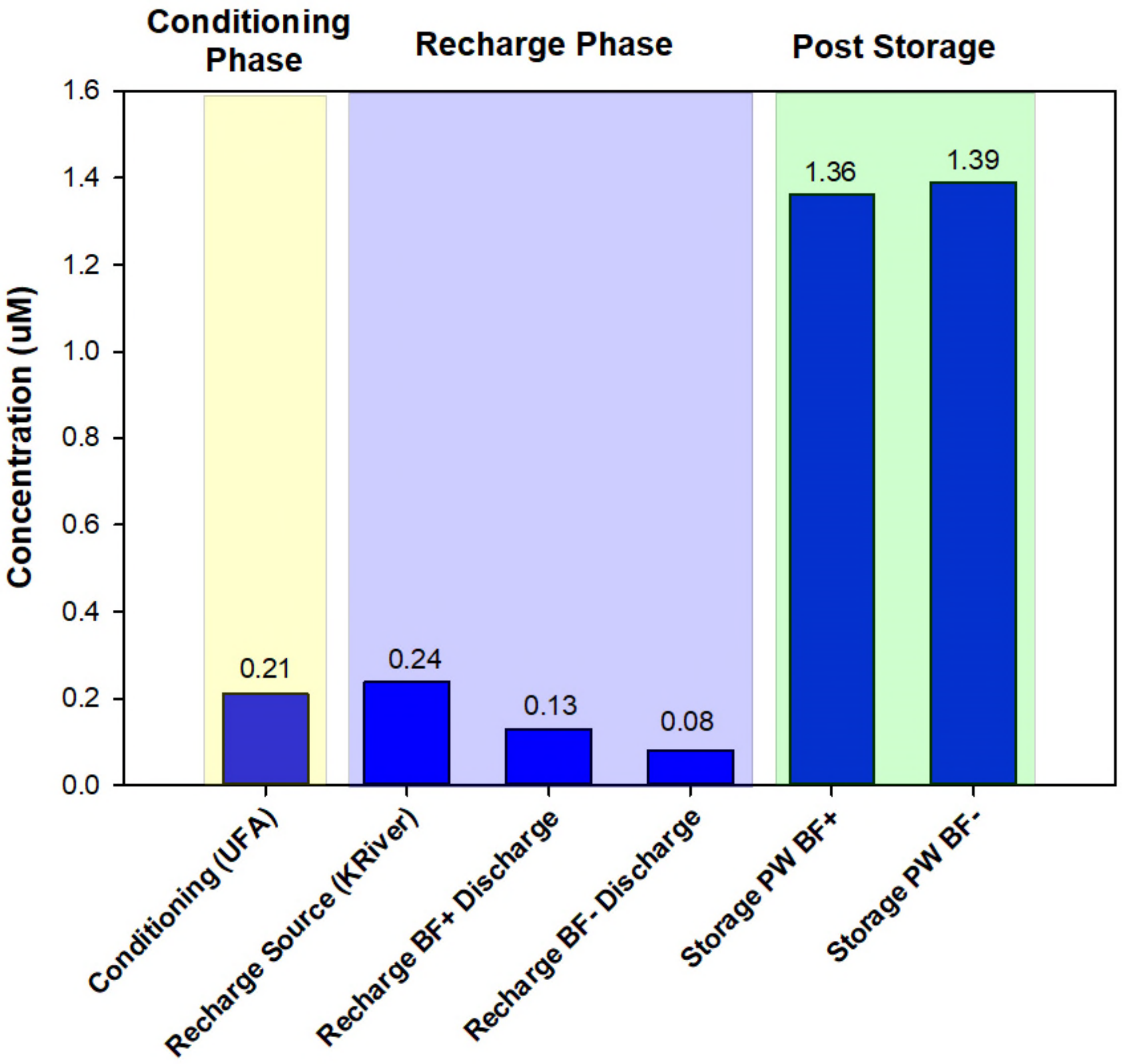
Nutrient Reductions in Recharged Water During Storage C38S/UFA: $NO_3 + NO_2$



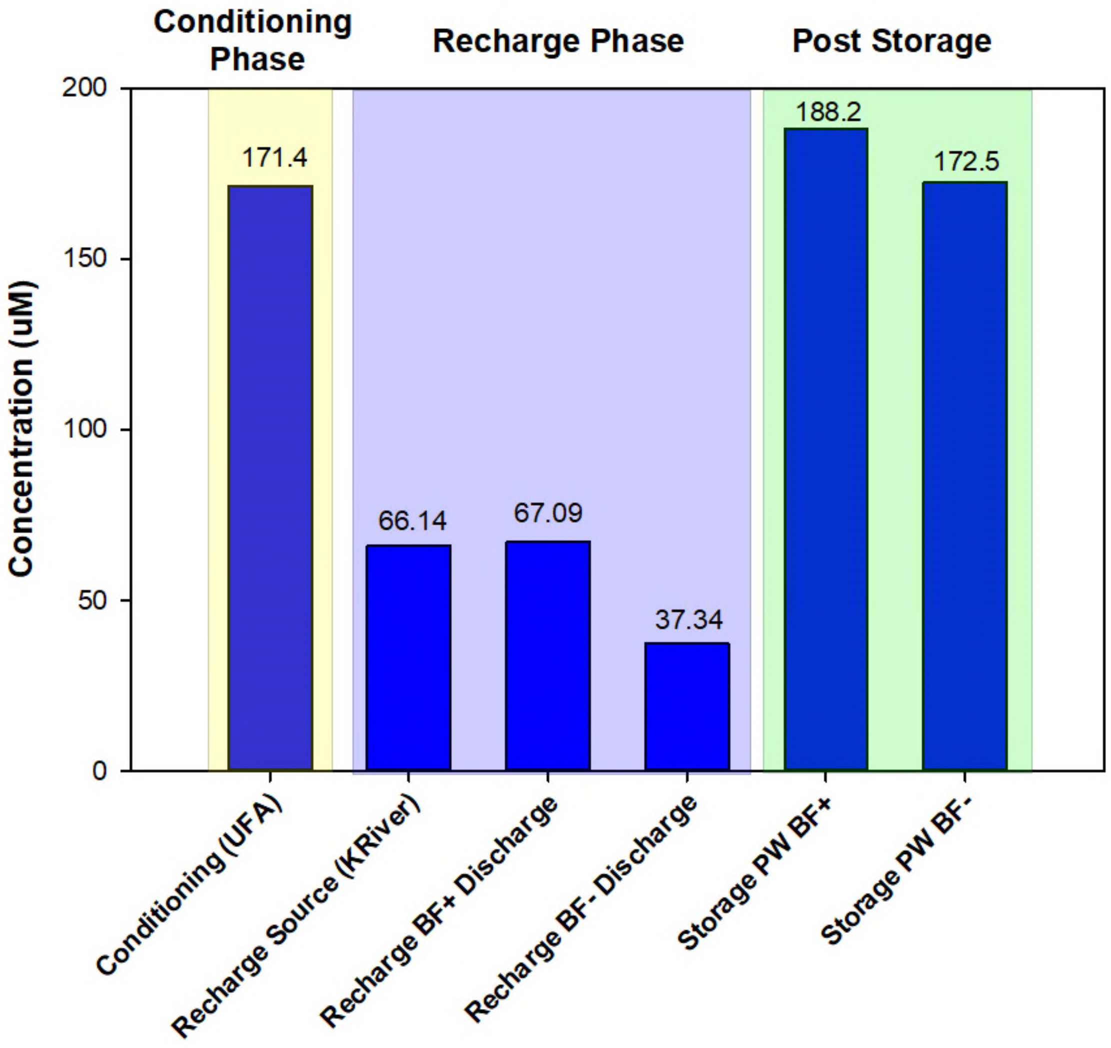
Nutrient Reductions in Recharged Water During Storage C38S/UFA: NH_4



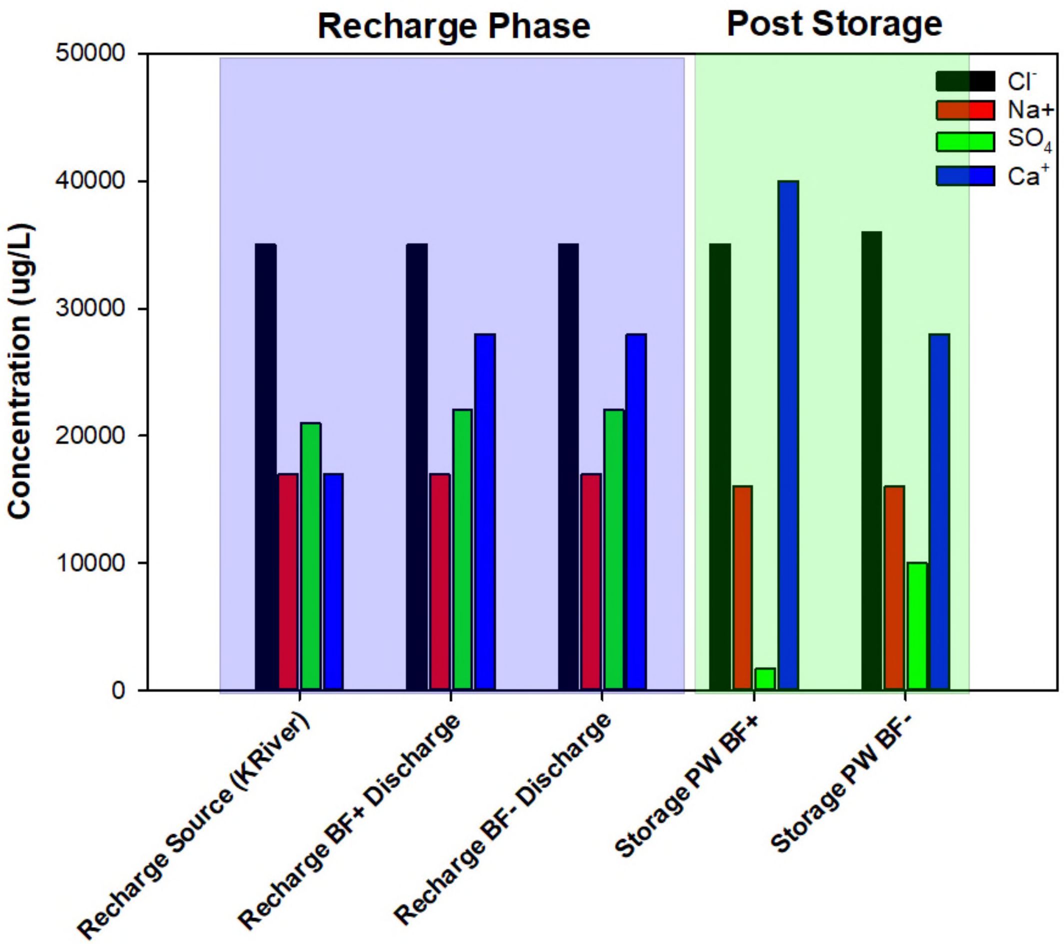
Nutrient Reductions in Recharged Water During Storage C38S/UFA: *Phosphorus (PO_4)*



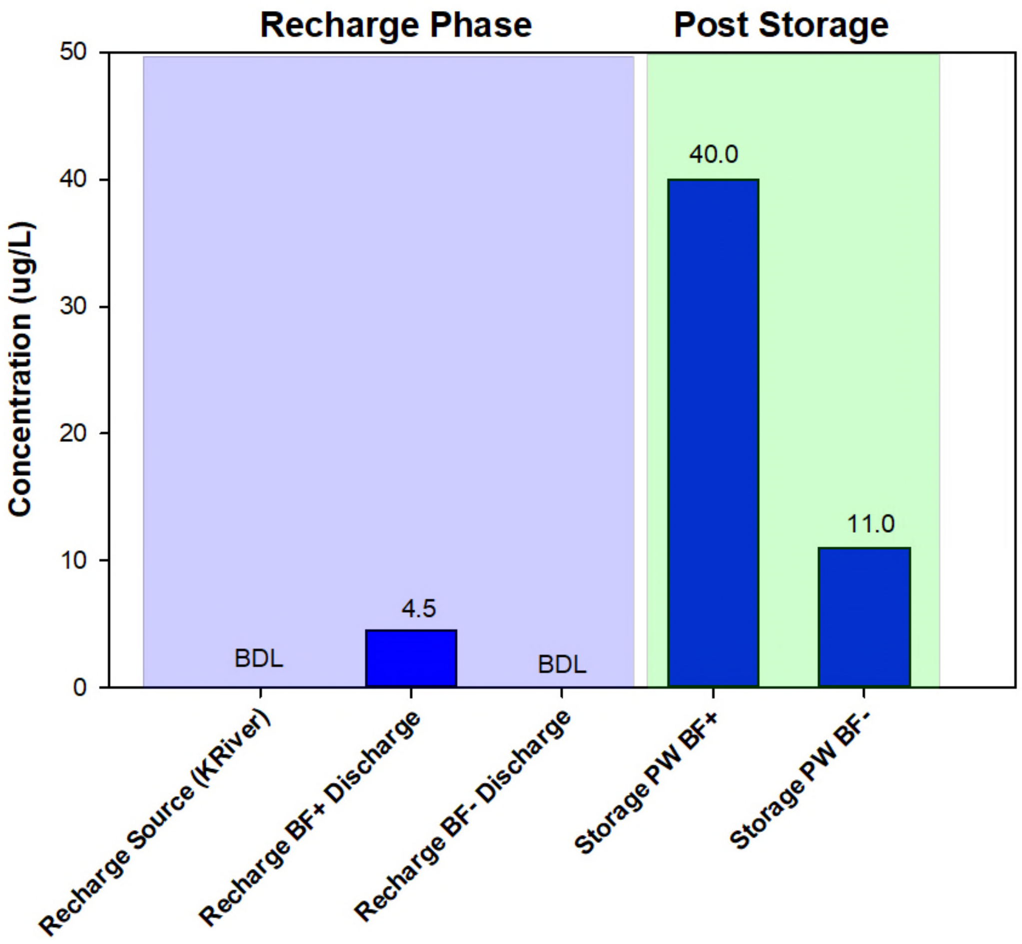
Nutrient Reductions in Recharged Water During Storage
Silicates (SiO_4)



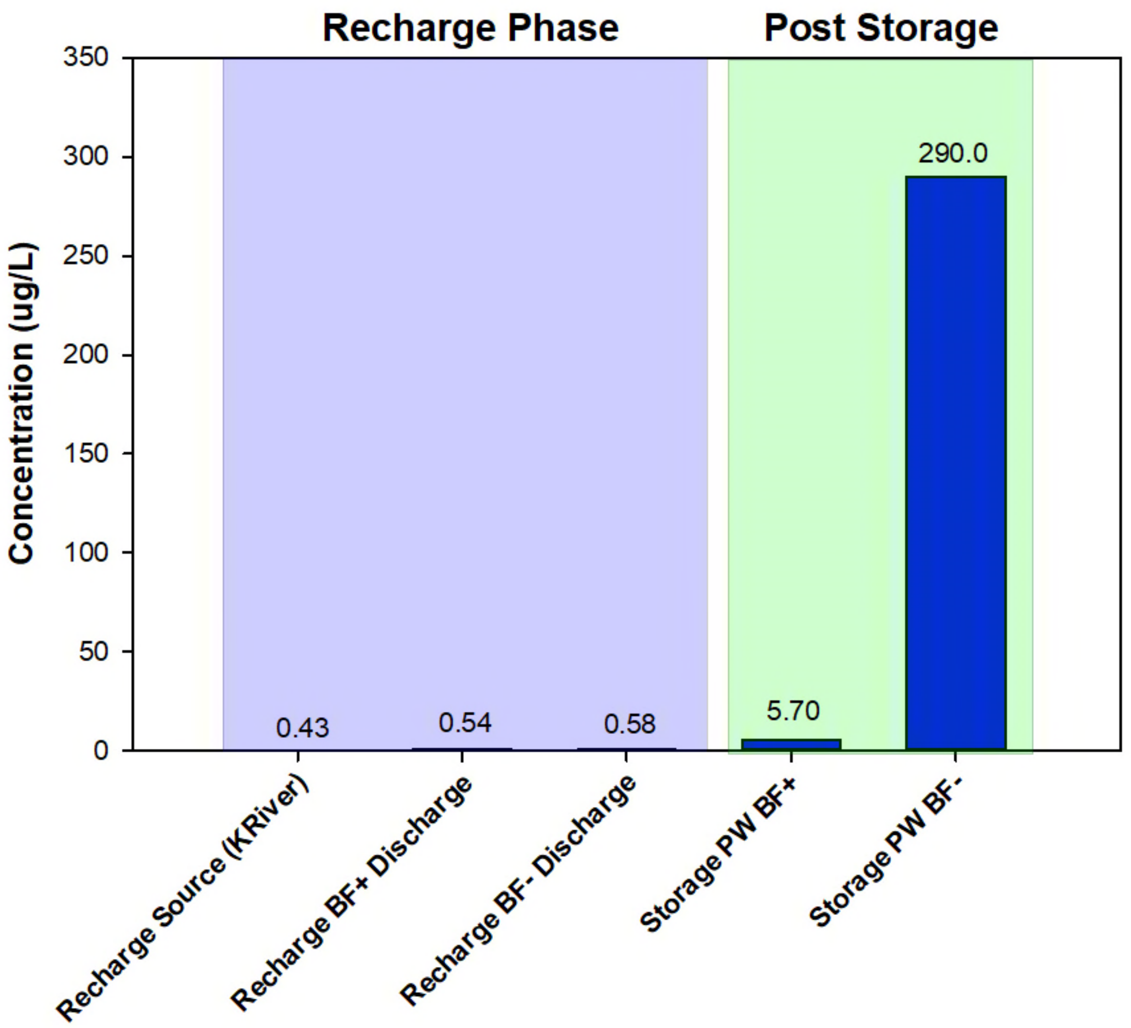
Geochemical Changes in Recharged Water During Storage C38S/UFA: Cl^- Na^{+2} SO_4 Ca^{+2}



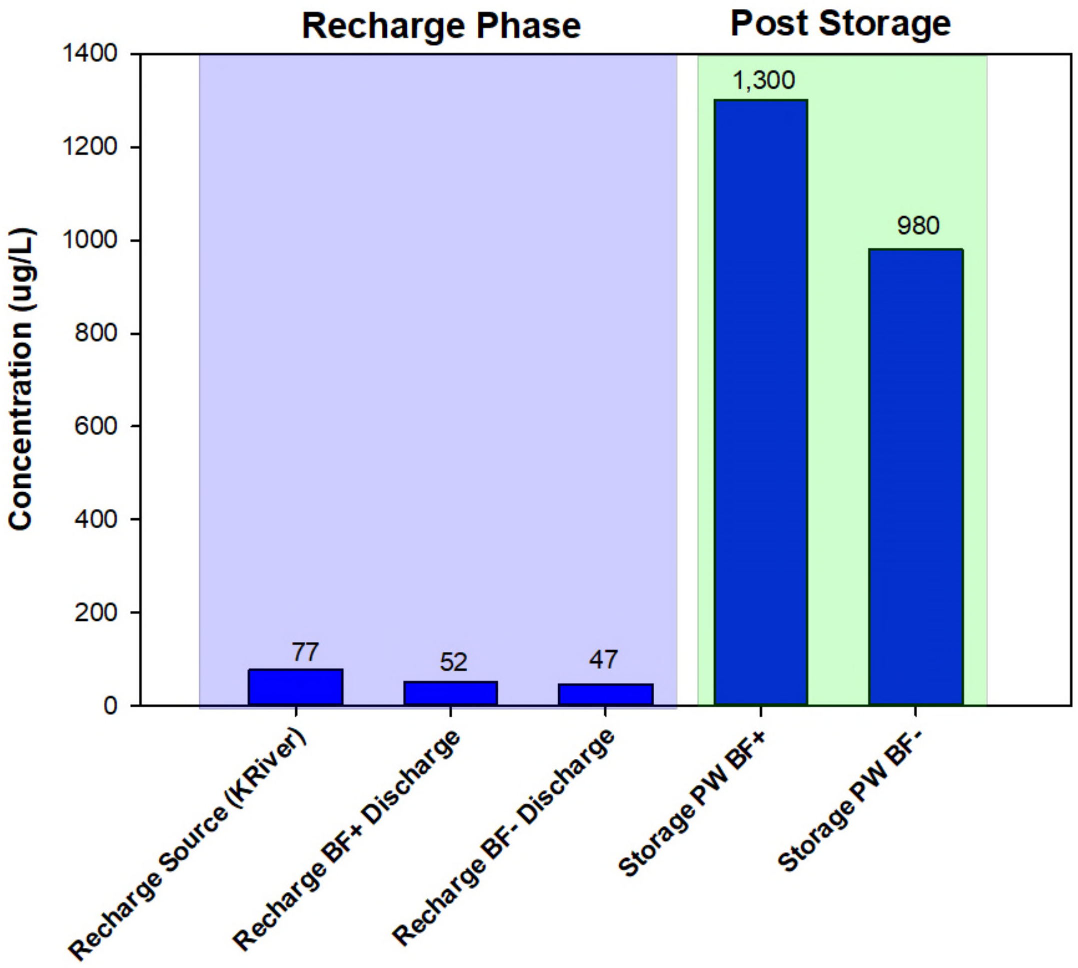
Geochemical Changes in Recharged Water During Storage C38S/UFA: *Manganese*



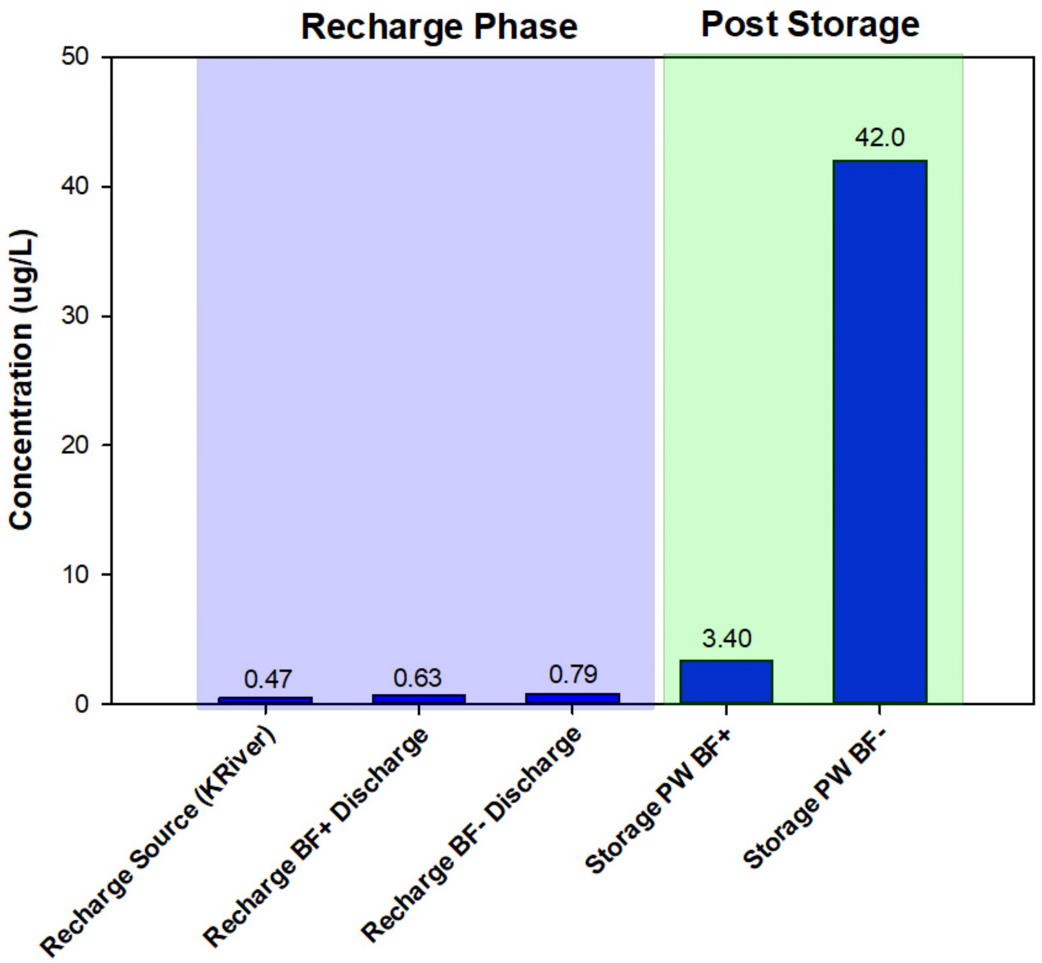
Geochemical Changes in Recharged Water During Storage C38S/UFA: *Molybdenum*



Geochemical Changes in Recharged Water During Storage C38S/UFA: *Iron*

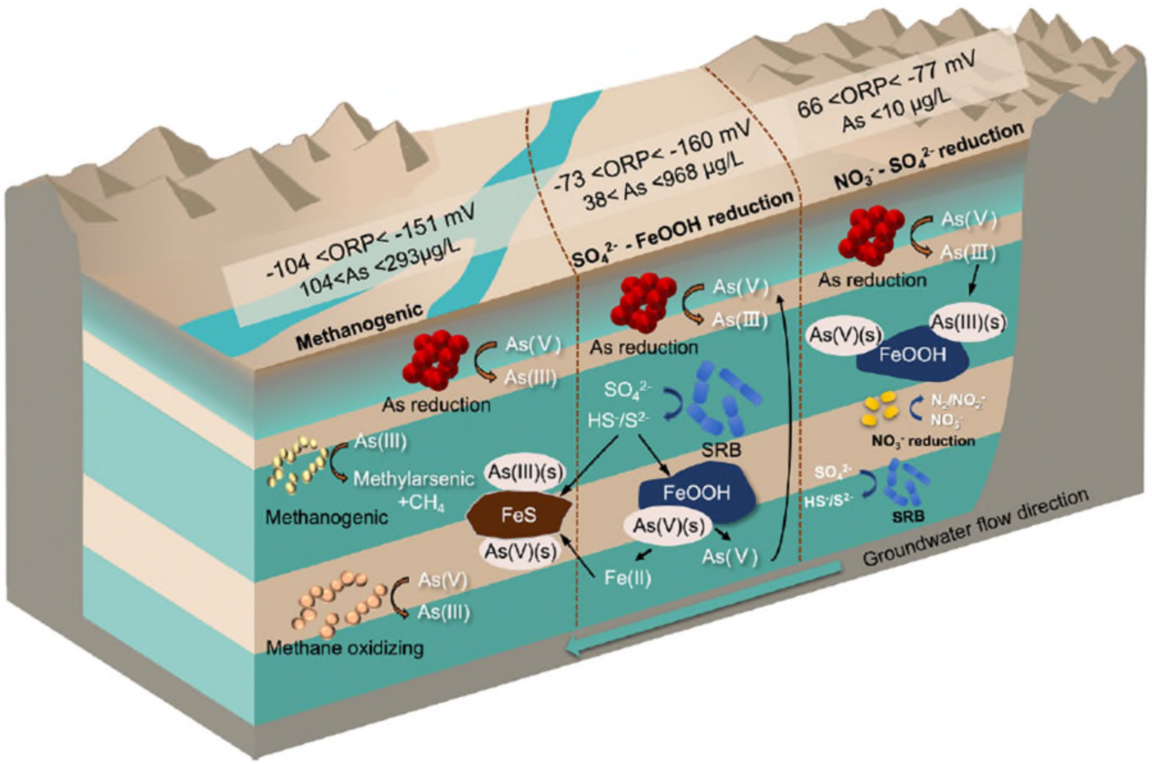


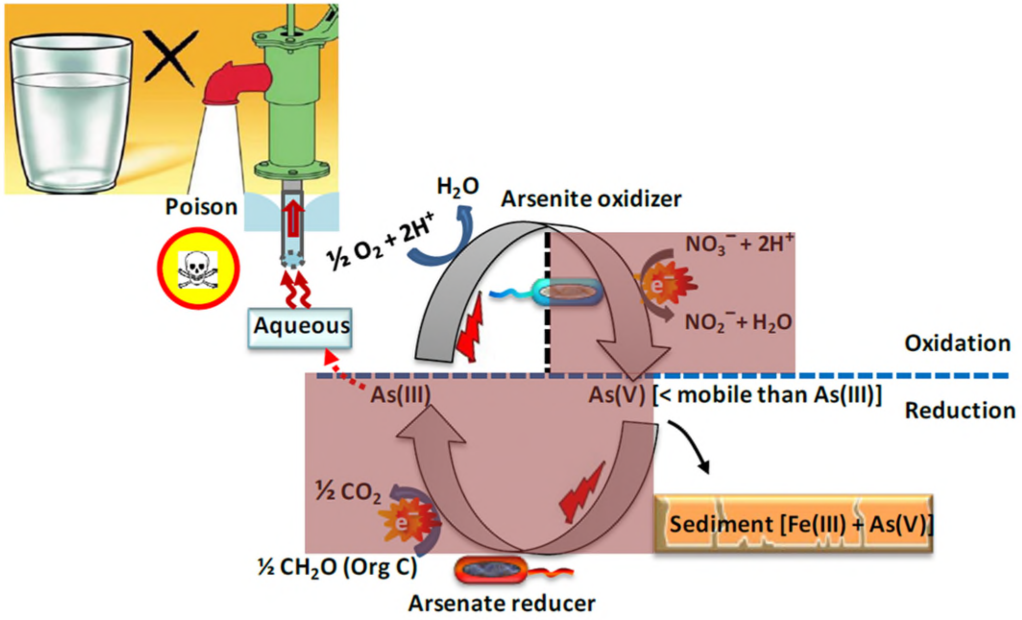
Geochemical Changes in Recharged Water During Storage C38S/UFA: *Arsenic*



What Is Driving The Increases In Arsenic & Iron During the Storage Phase?

Anaerobic Nitrogen Reduction with Iron Oxidation?

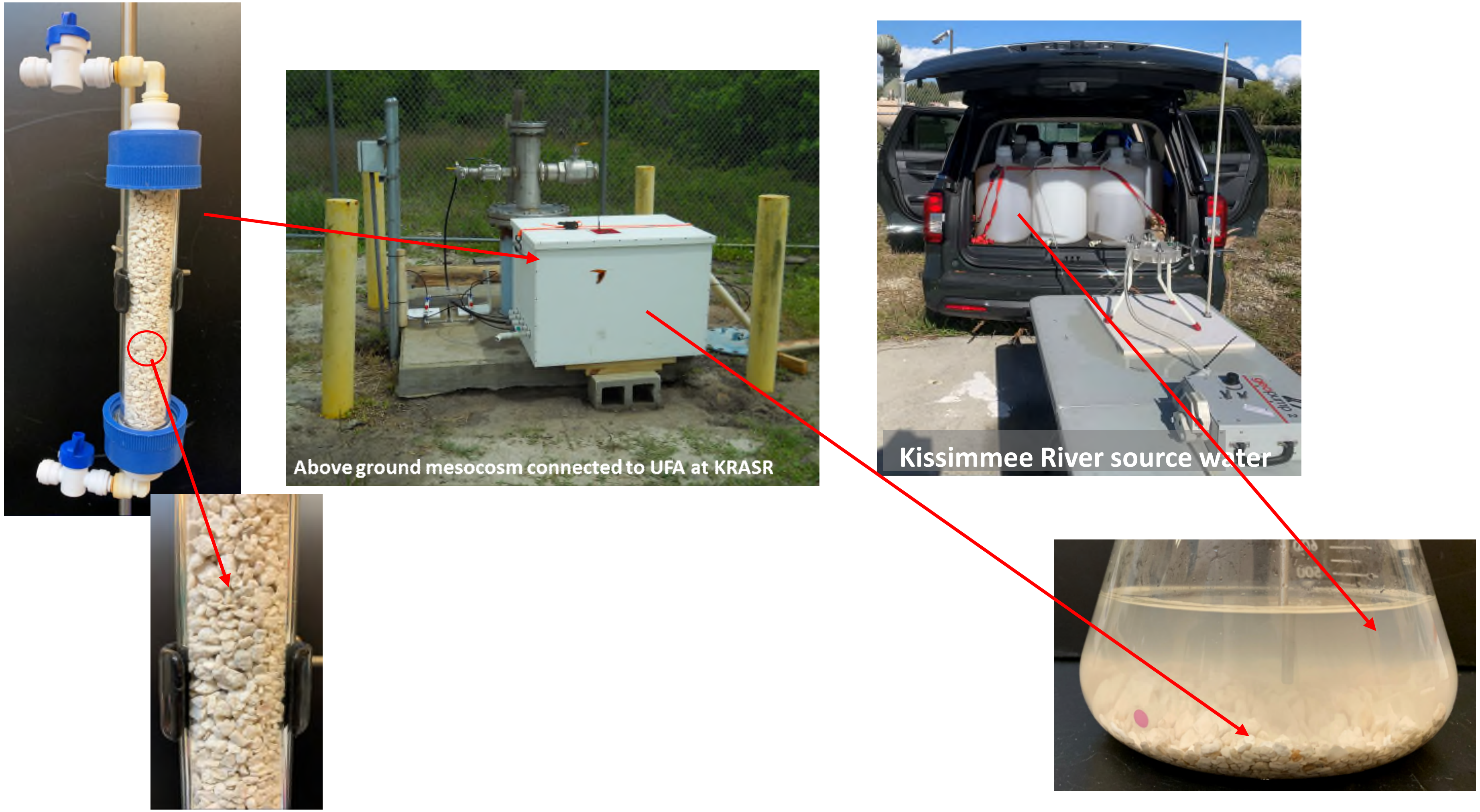


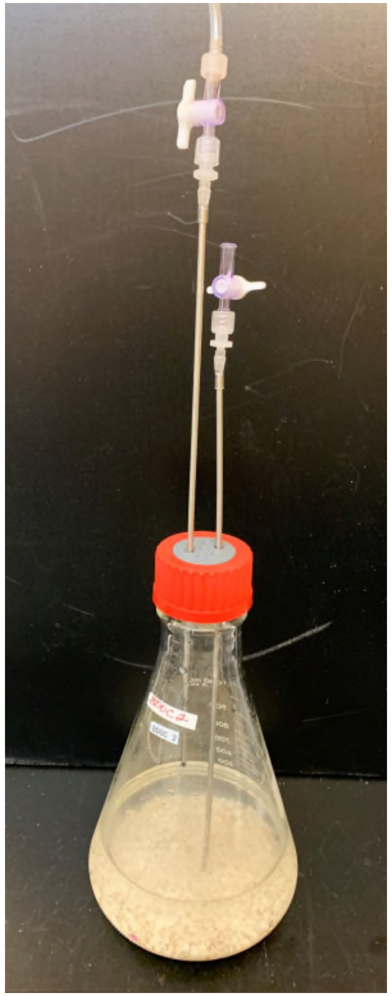


Xie, et al. (2024) Water Research 241 Article 121117.

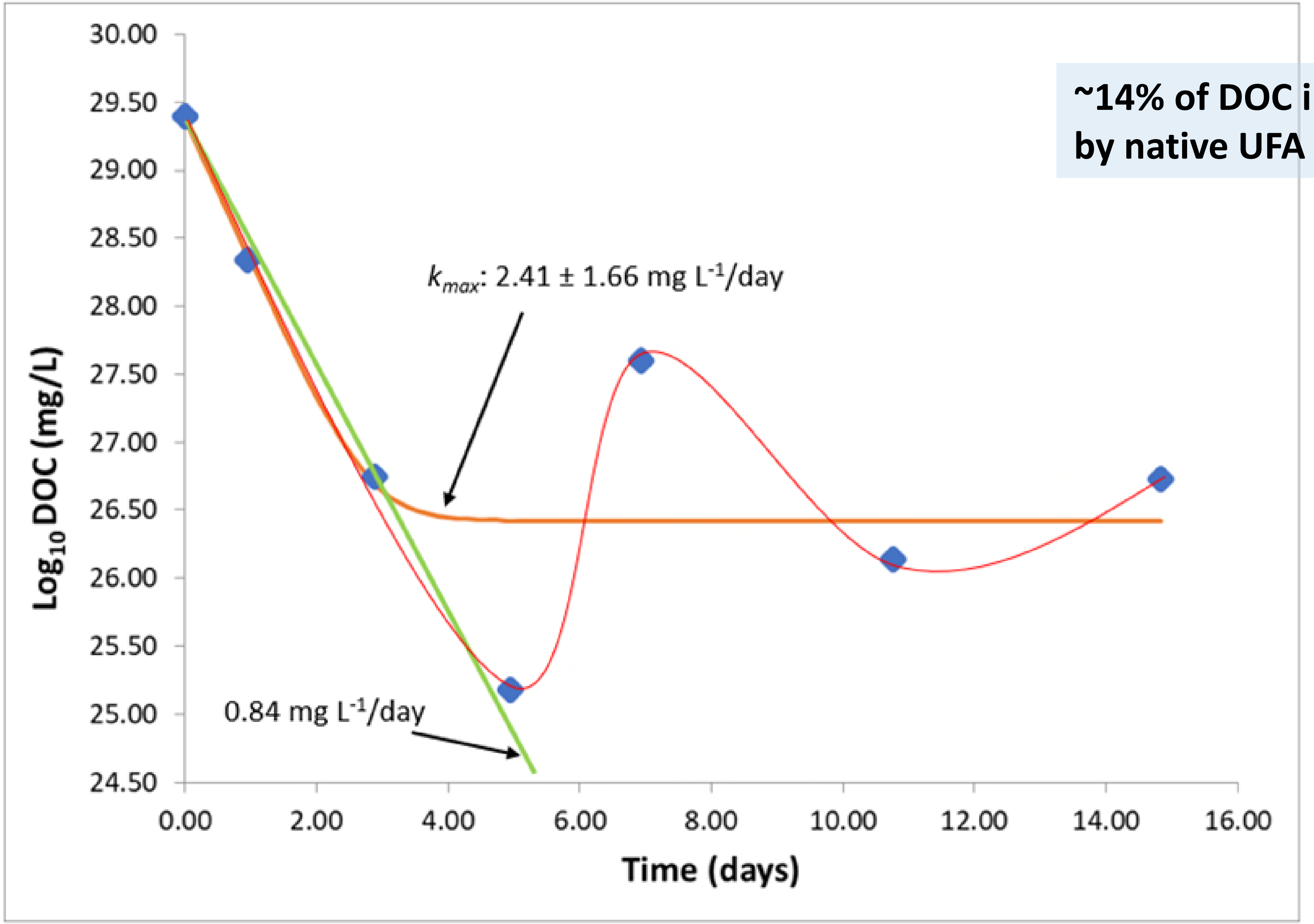
Hassan, et al. (2024) MDPI Toxics 12 Article 89.

Biodegradable DOC (BDOC) Setup for Native Groundwater Microbe Colonization



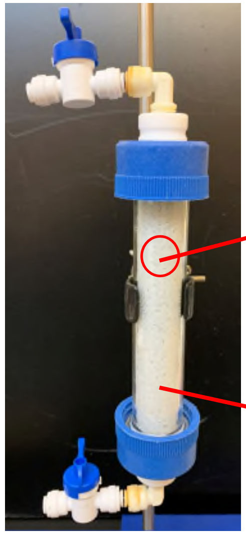


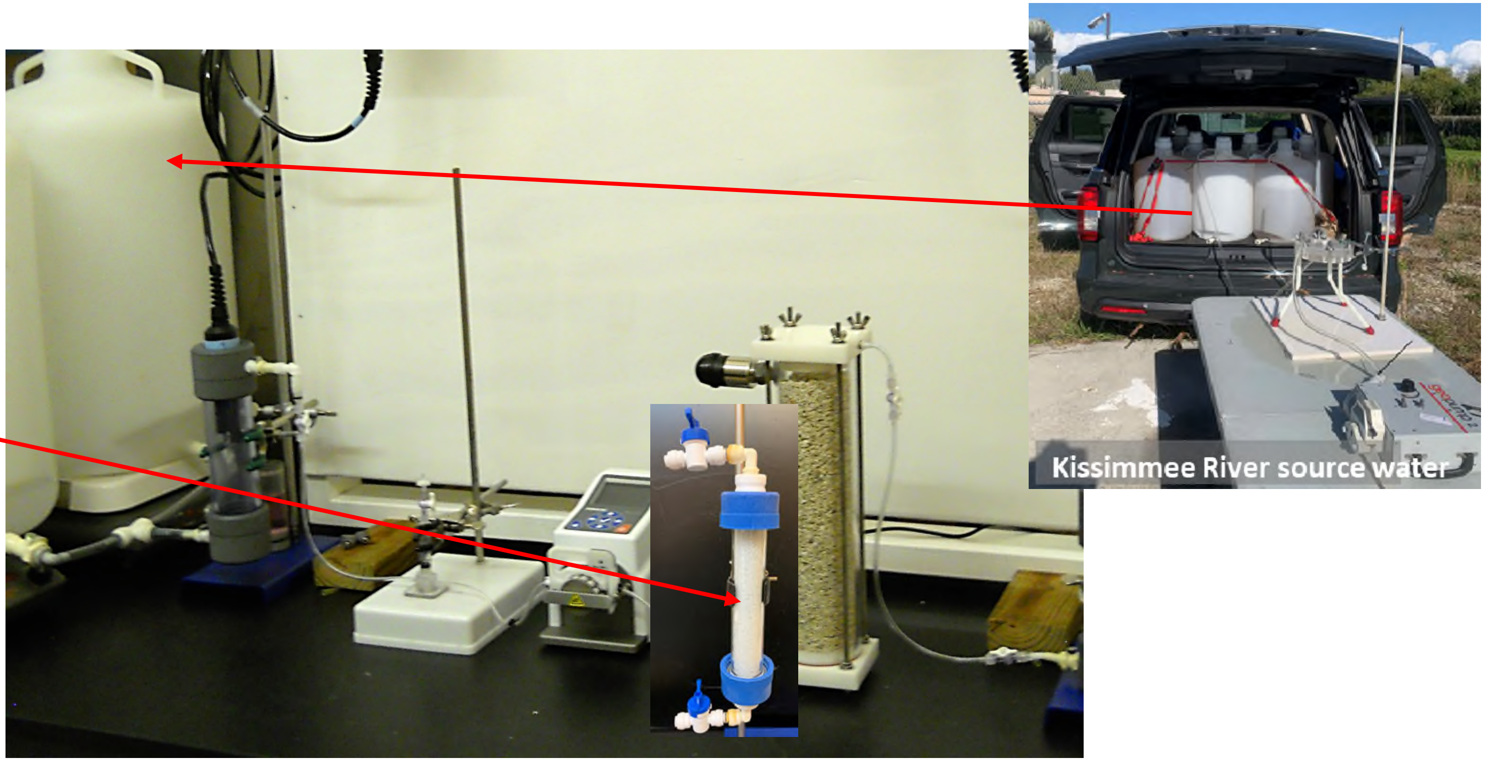
Biodegradable DOC (BDOC) In Recharged Water By Native Groundwater Microbial Communities



~14% of DOC in Kissimmee River water is assimilable by native UFA microbial communities

Biofilm Growth Rate Potential Of Recharged Water





Glass beads (2.0mm) are exposed to native groundwater during the Conditioning Phase in parallel to the BF+ and BF- columns.

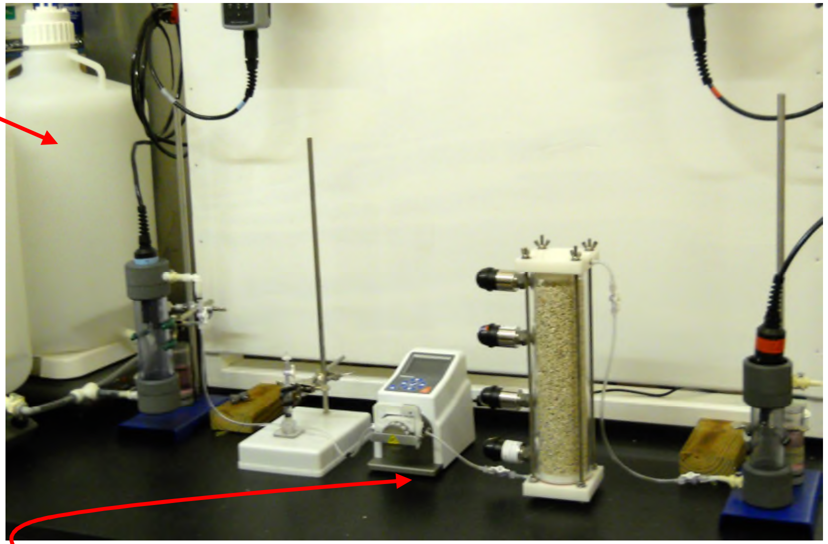
Recharged Water Source	Total Protein (mg/L)	Total Carbohydrate (mg/L)	Total Biofilm (mg/L)	Biofilm Growth Rate (mg biofilm/m²/d)
Kissimmee River	1.370	1.965	3.335	0.213

Biogenic Gas Production Post Storage Pore Water BF+ Column C38S/UFA

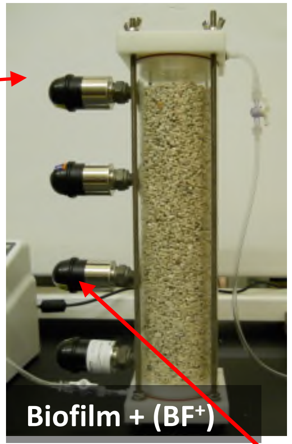
Gas	Units	Air	Column Porewater
CO_2	%	**0.04**	**1.80**
N_2	%	**78**	**69.78**
CH_4	mg/L	**1.7**	**8.1**
C_2H_4	mg/L	**BDL**	**0.0002**

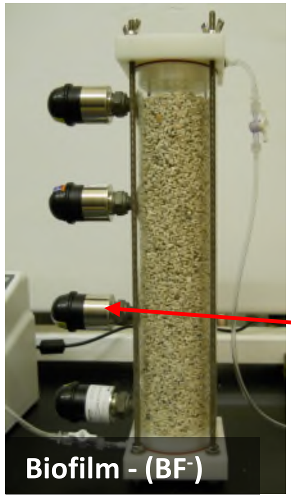
Hydraulic Conductivity

Collection of Source Water from Kissimmee River



BF^{+} & BF^{-} columns connected to the Source Water pumping system

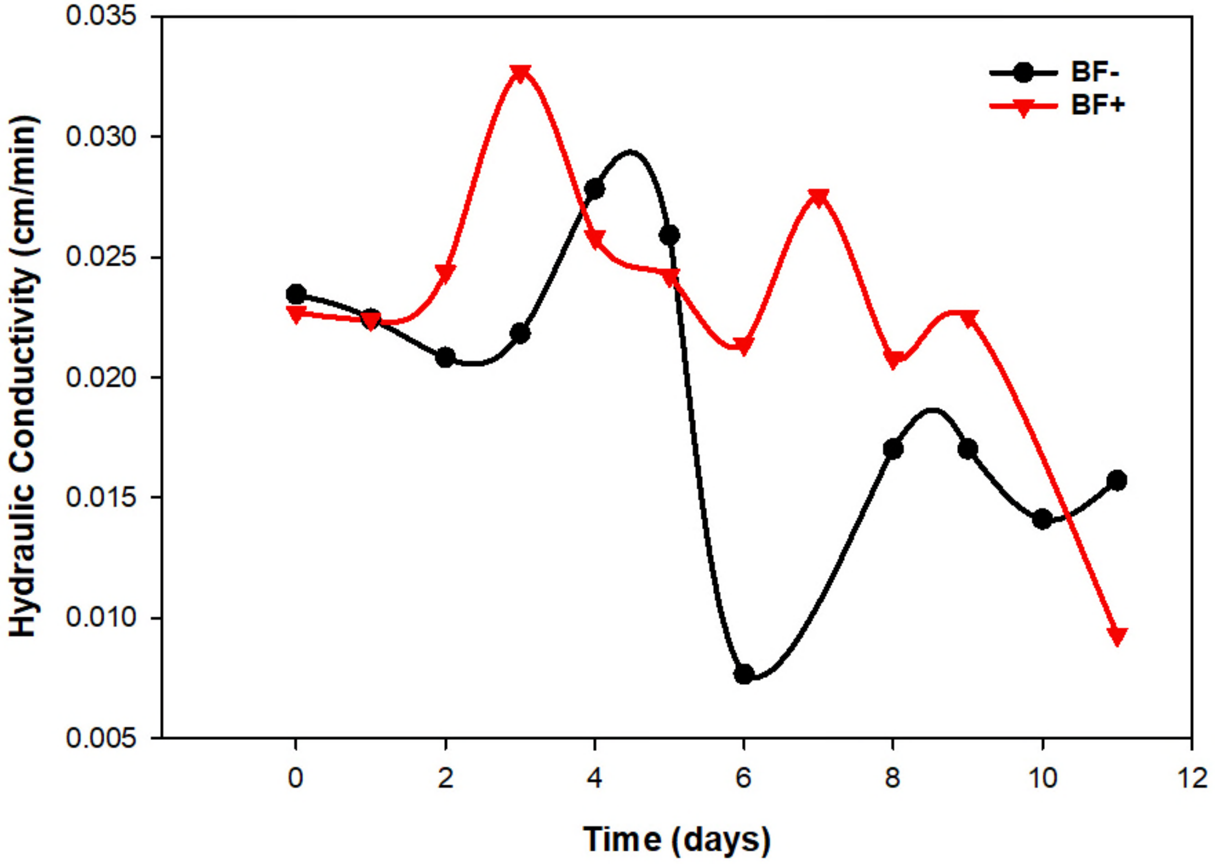




Pressure sensors installed at laboratory

Wet packed on site when collecting BF^{+}

Hydraulic Conductivity C38S/UFA



First 10 days of data not shown due to issues with pressure sensors

Next Steps

- **Completion of the C38S/APPZ crushed core column experiment**
  - Will be completed by end of July 2024
- **Initiation and completion of the L63S/UFA and L63S/APPZ crushed core column experiments and data analyses**
- **Initiation and completion of the C59/UFA and C59/APPZ crushed core column experiments and data analyses**

Panel Discussion (15 min)

Public Comment (15 min)

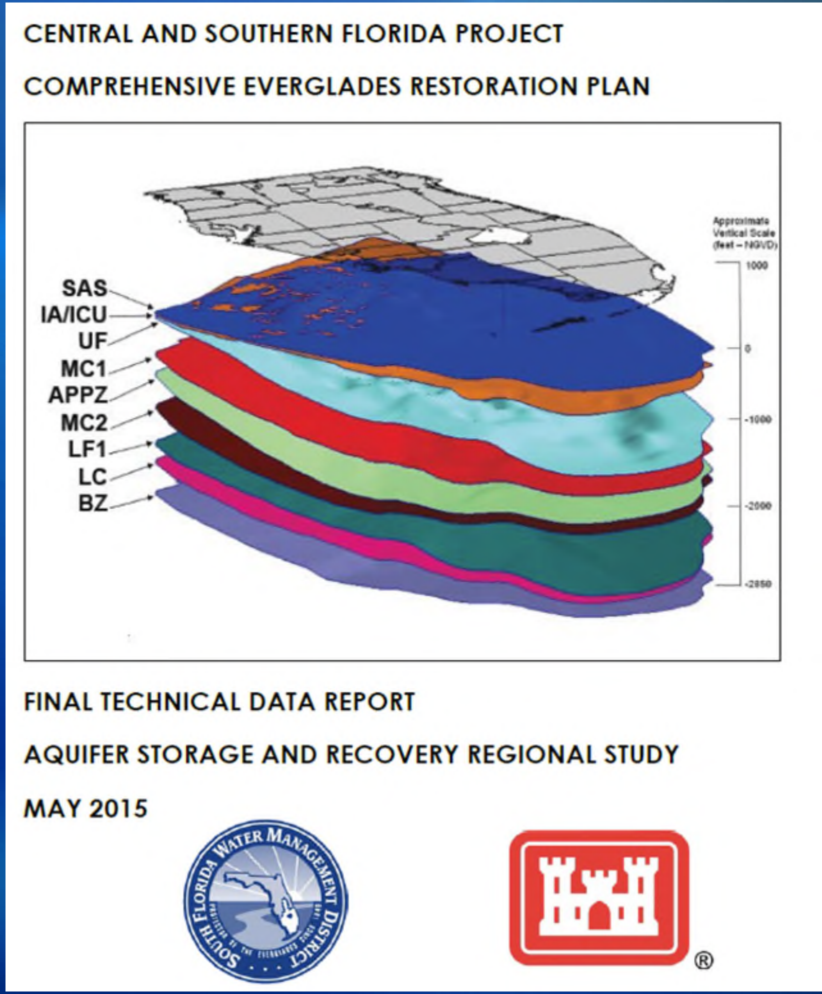
Lunch Break 12:00 – 1:00 pm

Quantitative Ecological Risk Assessment Workplan and Next Steps

Joe Allen
Principal Wildlife Biologist /Risk Assessor
Formation Environmental LLC

ASR Ecological Risk Assessment History

- Original ERA completed in 2015 as part of the ASR Regional Study
- Utilized data from 2 ASR Pilot Facilities
  - Kissimmee River ASR (KRASR)
  - Hillsborough ASR (HASR)

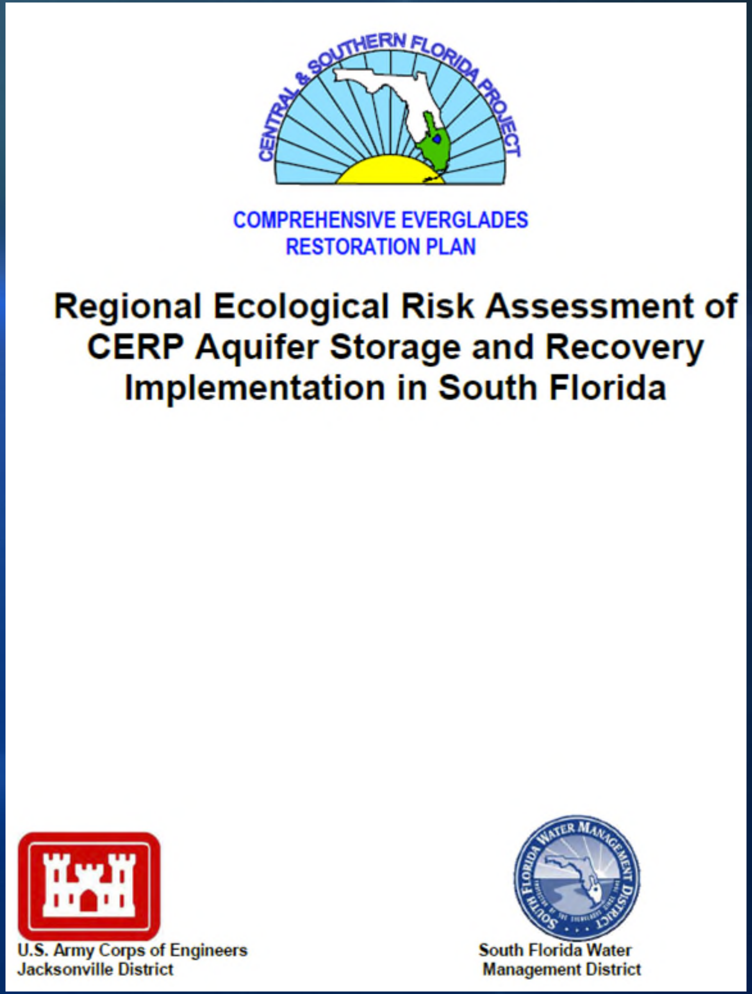

CENTRAL AND SOUTHERN FLORIDA PROJECT

COMPREHENSIVE EVERGLADES RESTORATION PLAN

FINAL TECHNICAL DATA REPORT

AQUIFER STORAGE AND RECOVERY REGIONAL STUDY

MAY 2015


CENTRAL & SOUTHERN FLORIDA PROJECT

COMPREHENSIVE EVERGLADES RESTORATION PLAN

Regional Ecological Risk Assessment of CERP Aquifer Storage and Recovery Implementation in South Florida

U.S. Army Corps of Engineers Jacksonville District

South Florida Water Management District

ASR Ecological Risk Assessment History

➢ ASR ERA Conclusions

- Low likelihood of risk to Lake Okeechobee and the Everglades.
  - Highest - Larval fish due to impingement/entrainment.
  - Low – Hg methylation.
  - Limited toxicity.
  - Minimal bioconcentration.
- ASR systems should be constructed where sufficient dilution can occur.

Photograph 3.1. Kissimmee River ASR Pilot Facility.

Photograph 3.2. Hillsboro ASR Pilot Facility.

ASR Ecological Risk Assessment History

- Comments received from NRC and PRP.
  - Look at longer storage times and larger recovery volumes.
  - Toxicity testing with adjustments to water parameters.
  - Look at effects of hardness adjustments.
  - Additional *in situ* bioaccumulation studies.
  - More quantitative risk assessment.

Review of the Everglades Aquifer Storage and Recovery Regional Study

Committee to Review the Florida Aquifer Storage and Recovery Regional Study Technical Data Report

Water Science and Technology Board

Division on Earth and Life Studies

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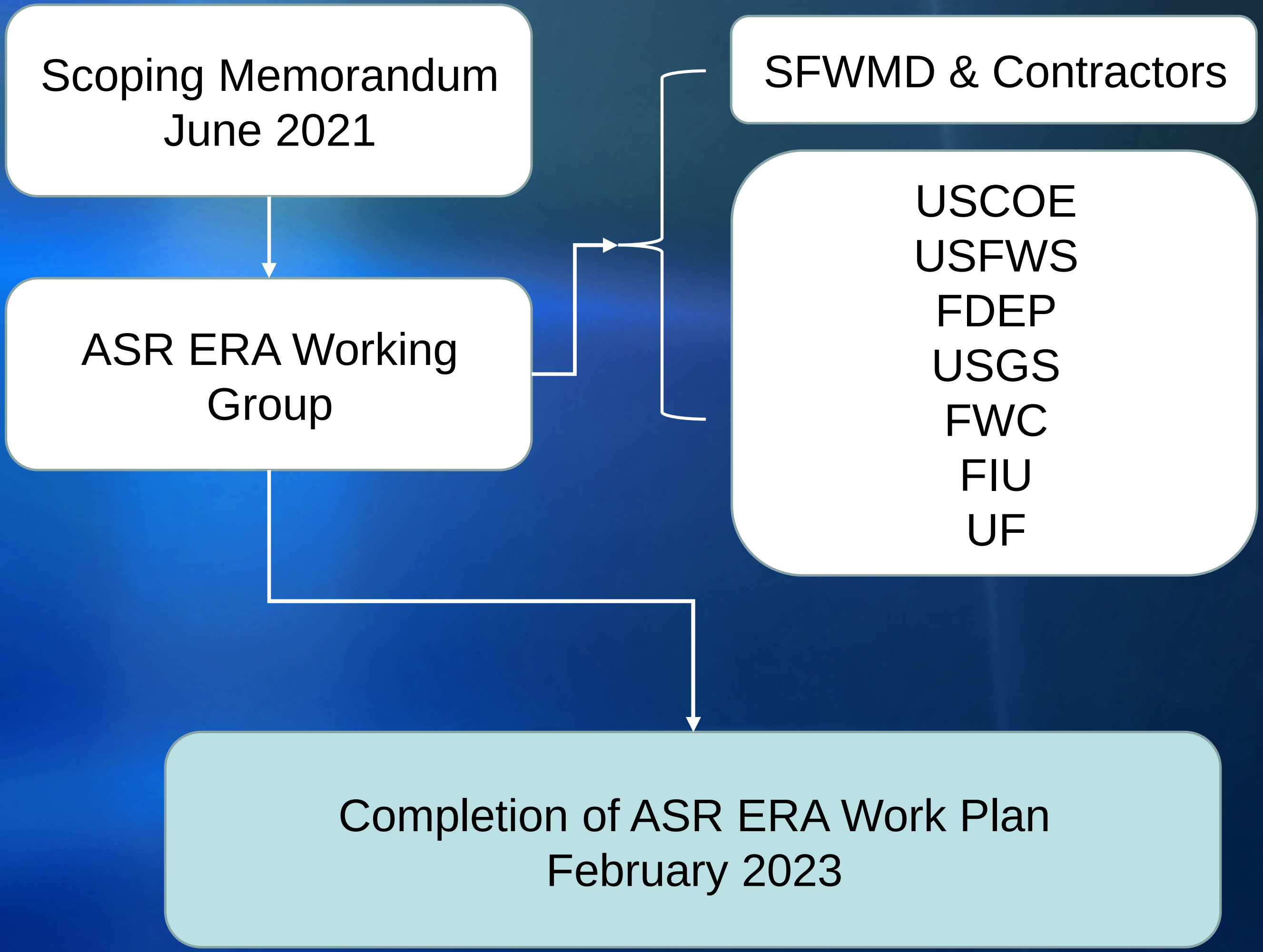
ASR Ecological Risk Assessment Path Forward

- **Public process with multiple stakeholders.**
  - **Many different approaches for analyses and data needs.**
  - **Responsive to stakeholders, but as efficient and cost-effective as possible.**
  - **Utilize comments from NRC and from 2022 PRP meeting.**



ASR ERA Process

Compile Existing Data

Data Collection

STEP 1: Screening Level
- Problem Formulation
- Toxicity Evaluation

STEP 2: Screening Level
- Exposure Estimation
- Risk Calculation

STEP 3: Baseline Problem Formulation

Toxicity Evaluation

Assessment Endpoints

Ecological Conceptual Site Model

Risk Questions

STEP 4: Study Design
- Lines of evidence
- Measurement endpoints
- Workplan and sampling plans

STEP 5: Verification of Sampling Design

STEP 6: Site Investigation and Data Analysis

STEP 7: Risk Characterization

STEP 8: Risk Management

Working Group Coordination on Completion of ASR ERA Workplan

- ERA based on USEPA guidance
- Work Plan comprises Steps 3 - 5.
- Step-wise process to build the Work Plan with input from the Working Group

Working Group Review

ERA Work Plan

ERA Work Plan
Comprehensive plan for completing the ERA (2022)

Working Group Meeting #5

Problem Formulation

Working Group Mtg. #1

- ID Risk Management Goals and Risk Decisions
- Refine Ecological Conceptual Site Model
  - Stressor Sources
  - Describe release mechanisms
  - ID complete exposure pathways
  - ID receptors of concern
- Define Risk Assessment Endpoints
  - Assessment Endpoints
  - Measurement Endpoints
- Refine list of Ecological Stressors of Potential Concern
  - Evaluate existing water quality and toxicity data to refine list of stressors
  - Use existing bioconcentration data to model risk of food web risk to refine list of stressors
- Evaluate data gaps and prepare data collection plans

Working Group Mtg. #3

Working Group Mtg. #2

Risk Analysis Plan

Working Group Mtg. #4

- Exposure analysis plan
  - Identify exposure units
  - Plan for quantitative analyses of exposure
- Effects analysis plan
  - Create hierarchy of effects benchmarks
  - Incorporate direct measures of effects (e.g. toxicity tests)

Risk Characterization Plan

- Plan for hazard quotient calculation for exposure-based risks
- Plan for the interpretation of advanced risk assessment techniques

Risk Management Goals

- **Risk management goals provide the overarching basis for the ERA.**
  - Guide sampling design.
  - Determine data needs.
  - Decision support structure.

ASR ERA Risk Management Goal

Site conditions due to operation of the planned ASR Wells should not cause significant risk of adverse ecological effects to receptors from exposure to stressors directly related to the operation of the ASR Wells.

Risk Management Goals

- Effects considered on a tiered basis

  Tier 1. Localized effects to sub-populations of ecological receptors in the vicinity of ASR Well discharges. Tier 1 ERA is defined in the 2023 Work Plan.

  Tier 2. Population- and community- level effects to ecological receptors potentially due to changes in the ecosystem from to the operation of the ASR Wells.

  Tier 3. Regional effects to ecological receptor populations downstream of the ASR Well discharges.

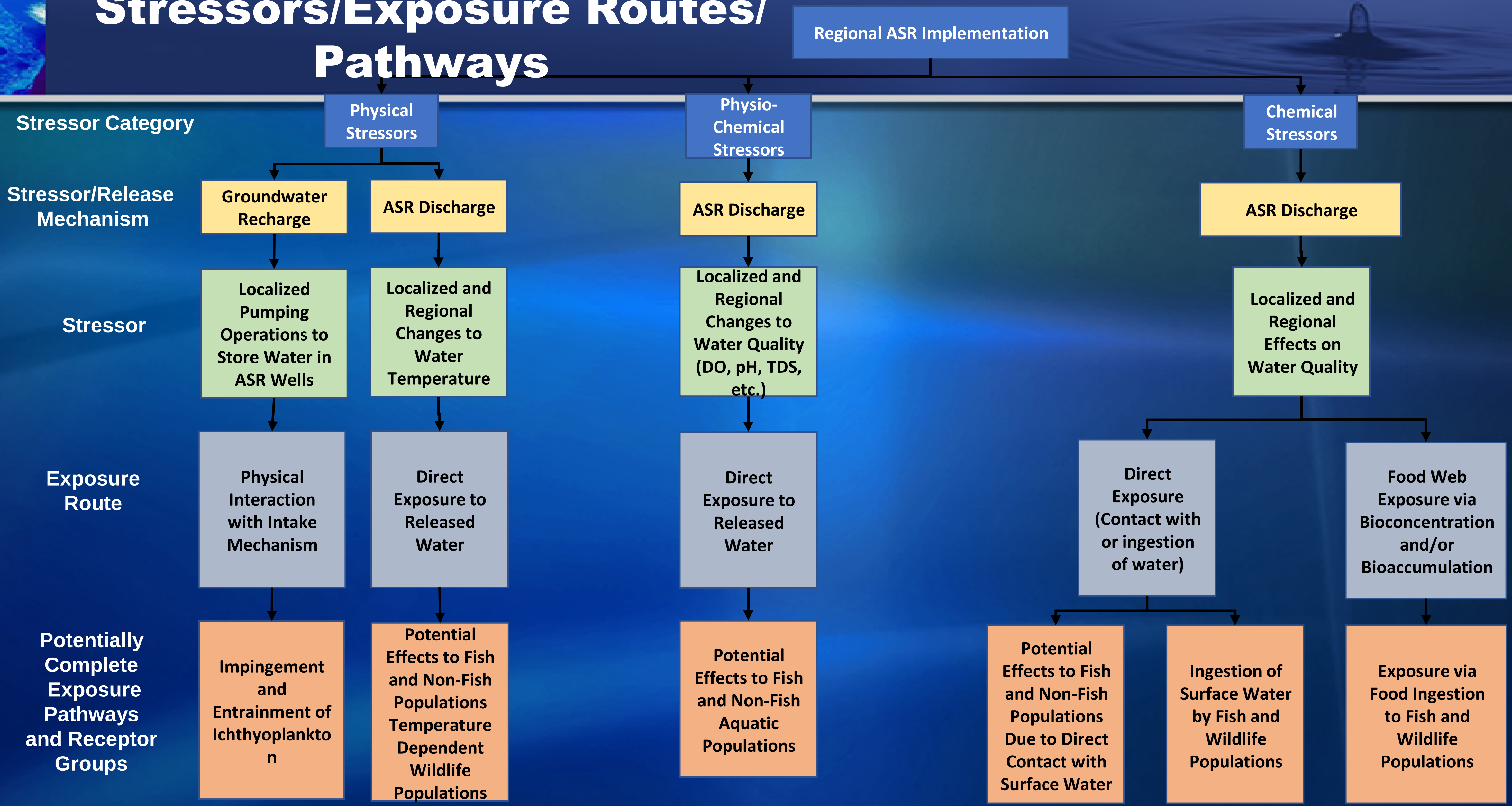
- Work Plan provides a tool for streamlining the assessment of risk at future ASR Well clusters.
  - If conditions are similar at other Sites, potential risks are also similar.
  - Focus risk assessment at other sites on where conditions are significantly different from C-38.

Risk Questions

Primary questions to be answered by the ERA

1. What stressors to ecological receptors are directly related to the operation of the ASR Wells within the Lake Okeechobee drainage?
2. What groups of ecological receptors have the potential to be impacted by the stressors associated with the operation of the ASR Wells?
3. Are the potential risks for adverse effects to ecological receptors potentially impacted by the stressors associated with the operation of the ASR Wells significant and do they warrant changes to ASR implementation plans?
4. Can the conclusions of the ASR ERA for the initial ASR Well clusters (e.g., C-38) be applied to ASR Well clusters constructed in the future? How can the conclusions of this risk assessment be used as a tool to streamline future risk assessments?

Stressors/Exposure Routes/ Pathways



Ecological Risk Assessment Stressors

Table 4-1
Stressors to be Evaluated in the ASR ERA
Regional ASR Implementation Ecological Risk Assessment Work Plan

Physical Stressors	Physicochemical Stressors	Potentially Toxic Chemical Stressors[1]
Impingement/Entrainment	Nitrogen	Aluminum
Temperature	Phosphorous	Antimony
	Alkalinity	Arsenic
	Hardness (from Ca/Mg)	Cadmium
	Dissolved Oxygen	Chromium
	pH	Mercury[2]
	Individual Cations/Anions[3]	Methyl Mercury[2]
	Turbidity	Molybdenum
		Nickel
		Selenium[2]
		Zinc

[1] - Formation 2021 (Historical Data Analysis) indicated that risks due to chemical stressors are unlikely via direct toxicity or bioaccumulation. They will, however, be assessed in the ASR ERA to address NRC comments on the effect of longer storage times and/or higher storage volumes.

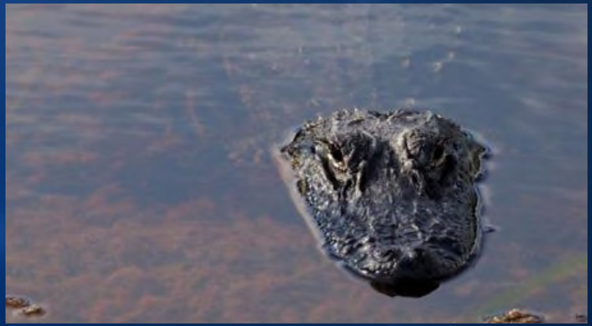
[2] - Potentially bioaccumulative chemicals to be the focus of the wildlife ROCs.

[3] - Individual cations and anions include Ca, Mg, Na, K, Cl^-, S^{2-} and SO_4^{2-}

Receptors of Concern

Population Level Receptors

- Aquatic-Dependent Birds
  - Wood and Mottled Ducks (herbivores)
  - Little Blue Heron and Great Blue Heron (omnivores)
  - Osprey (piscivore)
- Aquatic Reptiles
  - Florida Soft Shelled Turtle (omnivore)
  - American Alligator (carnivore)



Assessment Endpoint

Survival, growth, and reproduction downstream of the ASR discharge adequate to sustain populations.

Receptors of Concern

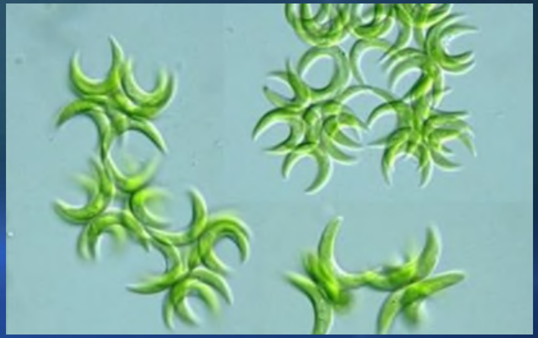
Population Level Receptors

- **Species representative of feeding guilds.**
  - Fish
    - Fathead Minnow (Trophic Level 2)
    - Black Crappie and Bluegill (Trophic Level 3)
    - Largemouth Bass (Trophic Level 4)
  - Aquatic or Semi-Aquatic Mammals
    - Raccoon (omnivore)
    - River Otter (piscivore)

Receptors of Concern

Community Level Receptors

- Primary Producers
  - Periphyton Community
  - Submerged Aquatic Vegetation Community
- Primary Consumers
  - Aquatic Macroinvertebrate Community
  - Ichthyoplankton Community
- Amphibians
  - Amphibian Community



Assessment Endpoint

Maintenance of community composition and function downstream of the ASR discharge.

Receptors of Concern

Individual Level Receptors (i.e. species with special regulatory status)

- Aquatic-Dependent Birds
  - Wood Stork (omnivore)
  - Everglade Snail Kite (invertivore)
- Aquatic Mammal
  - West Indian Manatee (herbivore)

Assessment Endpoint

Survival, growth, and reproduction of individuals downstream of the ASR discharge.

Ecological Risk Measurement Endpoints

Measures of Exposure

- Describe the location and magnitude of stressors in abiotic and biotic media.
- Used to estimate the exposure of receptors to the stressors.
  - Measured water quality data.
  - Measured and estimated tissue data for use in food chain exposure modeling.

Ecological Risk Measurement Endpoints

Measures of Effects

- Changes in an attribute of the assessment endpoint in response to exposure.
  - Direct toxicity testing.
  - Direct measures of tissue data compared to effect-based benchmarks.
  - Literature-based exposure measures.
  - Measures of tolerance of thermal and/or physicochemical changes.
  - Direct measures of effects via *in-situ* or mesocosm testing.
  - Modeled effects data related to intake structure operation.

Ecological Risk Measurement Endpoints

Measures of Ecosystem and Receptor Characteristics

- Measurements of aquatic community and population characteristics before and after ASR operations.

- Modeling ecosystem parameters (e.g. modeled changes to Lake Okeechobee algal communities or SAV biomass due to modeled water quality changes) based on water quality changes due to ASR Well discharge.

Figure 5.27-- Periphytometers during initial deployment (left), and after a 28-day deployment (right)

Tier 1 Risk Assessment Data Needs

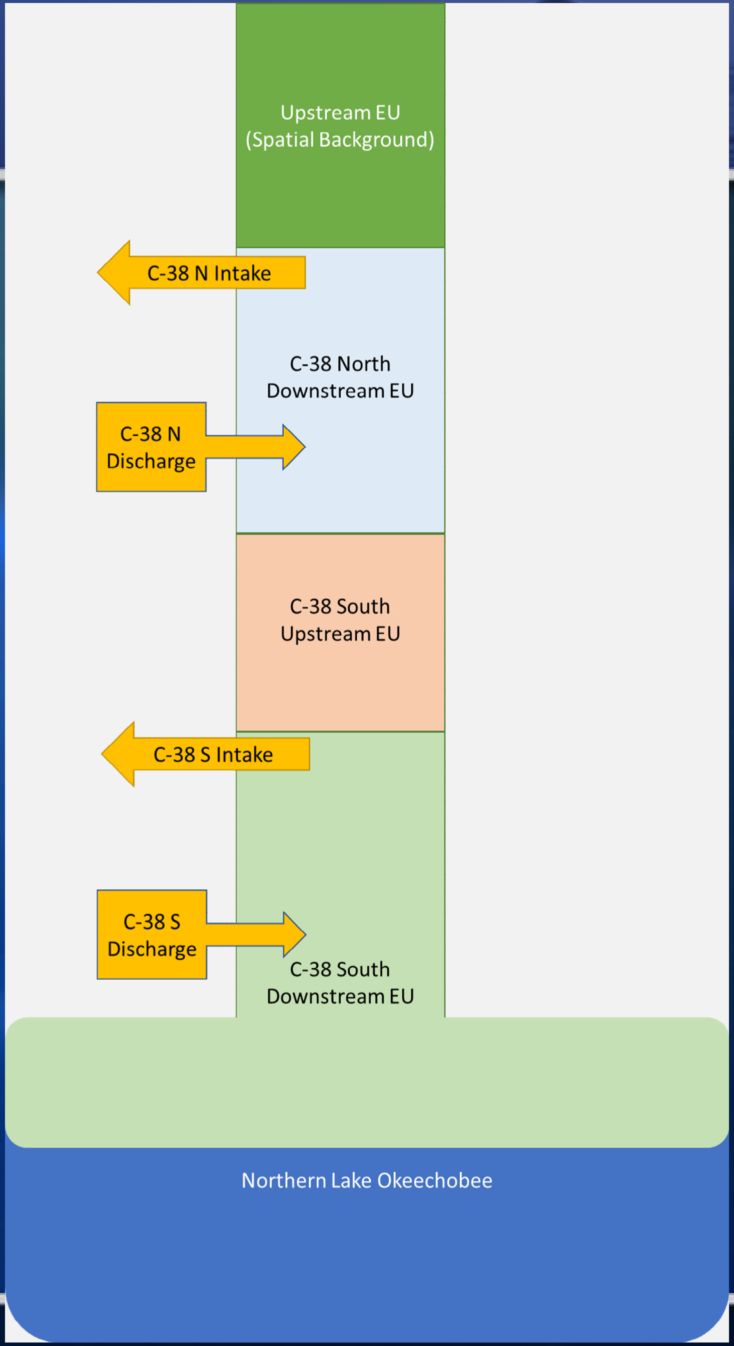
- Three types of data needed to meet the needs of the assessment and measurement endpoints
  - Field/Laboratory Data (in process)
  - Risk Assessment Data (included in the Work Plan)
  - Modeling Data (in process)
- Both spatial and temporal data are needed
  - Spatial – Upstream, mixing zone and downstream of the mixing zone
  - Temporal – Before and after ASR well operation

Risk Analysis

- **Exposure Analysis**
  - Quantify the degree of exposure to receptors from stressors
    - Exposure Units (EUs)
    - Exposure Point Concentrations (EPCs)
- **Effects Analysis**
  - Determine the relationship between exposure and effects
    - Toxicity Reference Values
    - Direct measures (toxicity testing, bioconcentration testing and community measures)

Exposure Units (EUs)

- Upstream EU
    - Provides data about anthropogenic background stressors
- C-38 North Downstream EU
    - Area of highest potential impact from C-38 N Well
- C-38 South Upstream EU
    - Fully mixed water from C-38 N discharge
- C-38 South Downstream EU
    - Area of highest potential impact from C-38 S Well
- Sitewide EU
    - Overall estimate of potential risk from the C-38 Well Clusters
- **Final locations of the EUs provided following finalization of construction plans and mixing zone modeling.**



Exposure Analysis

Exposure Point Concentrations (EPCs)

- Maximum EPC (Max EPC)
  - Maximum exposure to stressors
    - Conservative screening tool

- Upper Bound EPC (UBEPC)
  - 95% Upper Confidence Limit on the Mean (95UCL)

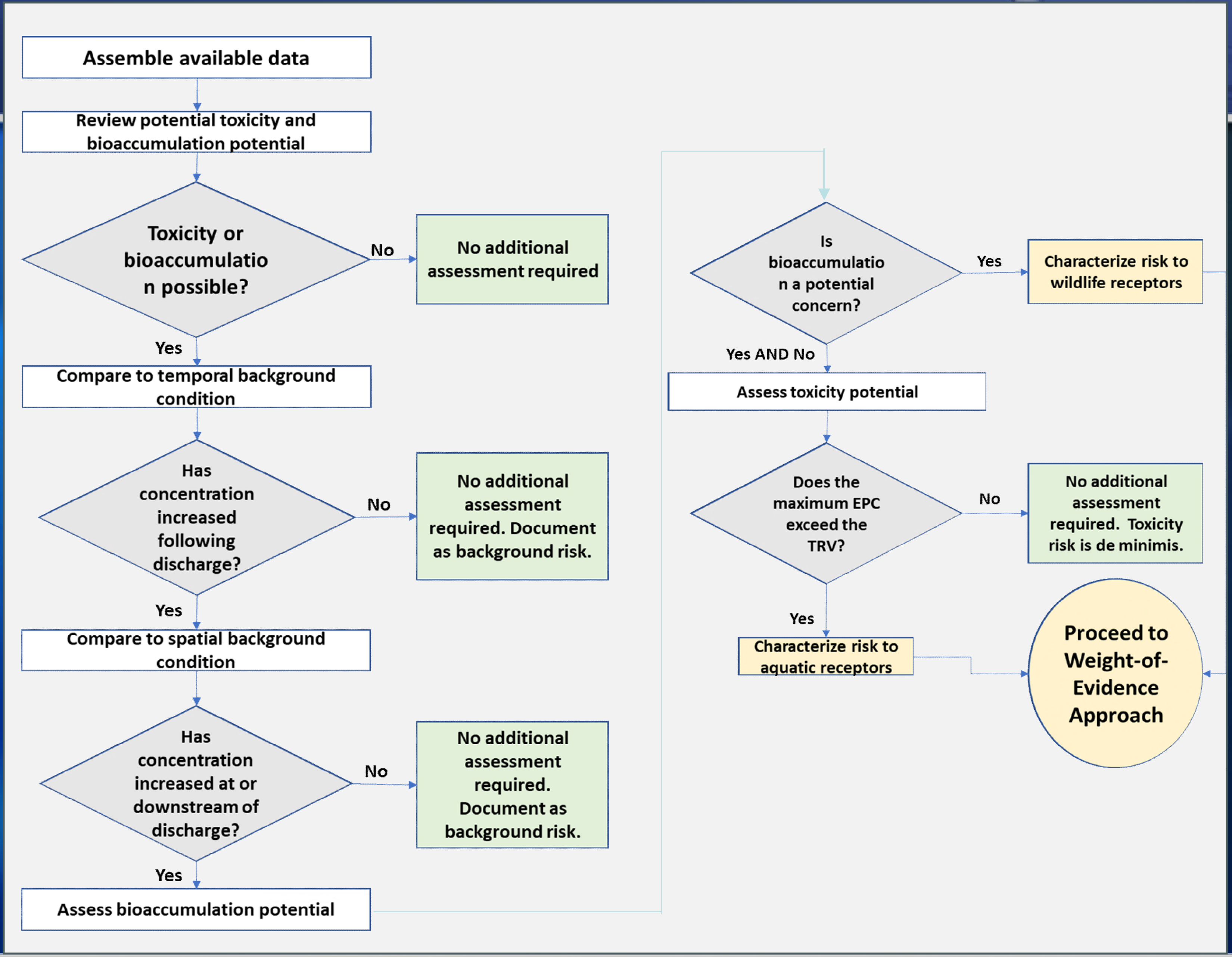
- Central Tendency EPC (CT EPC)
  - Geometric mean
  - Estimates ‘average’ risk

Risk Characterization

- **Risk Estimation**
  - Comparison of EPCs to TRVs
  - Analysis of direct measures of effects (i.e. toxicity tests and community studies)
- **Risk Description**
  - Quantitative and qualitative discussion
    - Risk estimation results
      - Hazard Quotients
      - Results of direct measures
    - Uncertainty
    - Weight-of-Evidence (WOE) approach (USEPA 2016)
- **Provide Defensible Conclusions**
  - Defines quantitative likelihood of risk for each endpoint in each EU

Risk Estimation

- **Decision Making Framework**
  - Repeatable and consistent process
  - Describe which stressors and receptors are carried forward into the detailed Risk Characterization

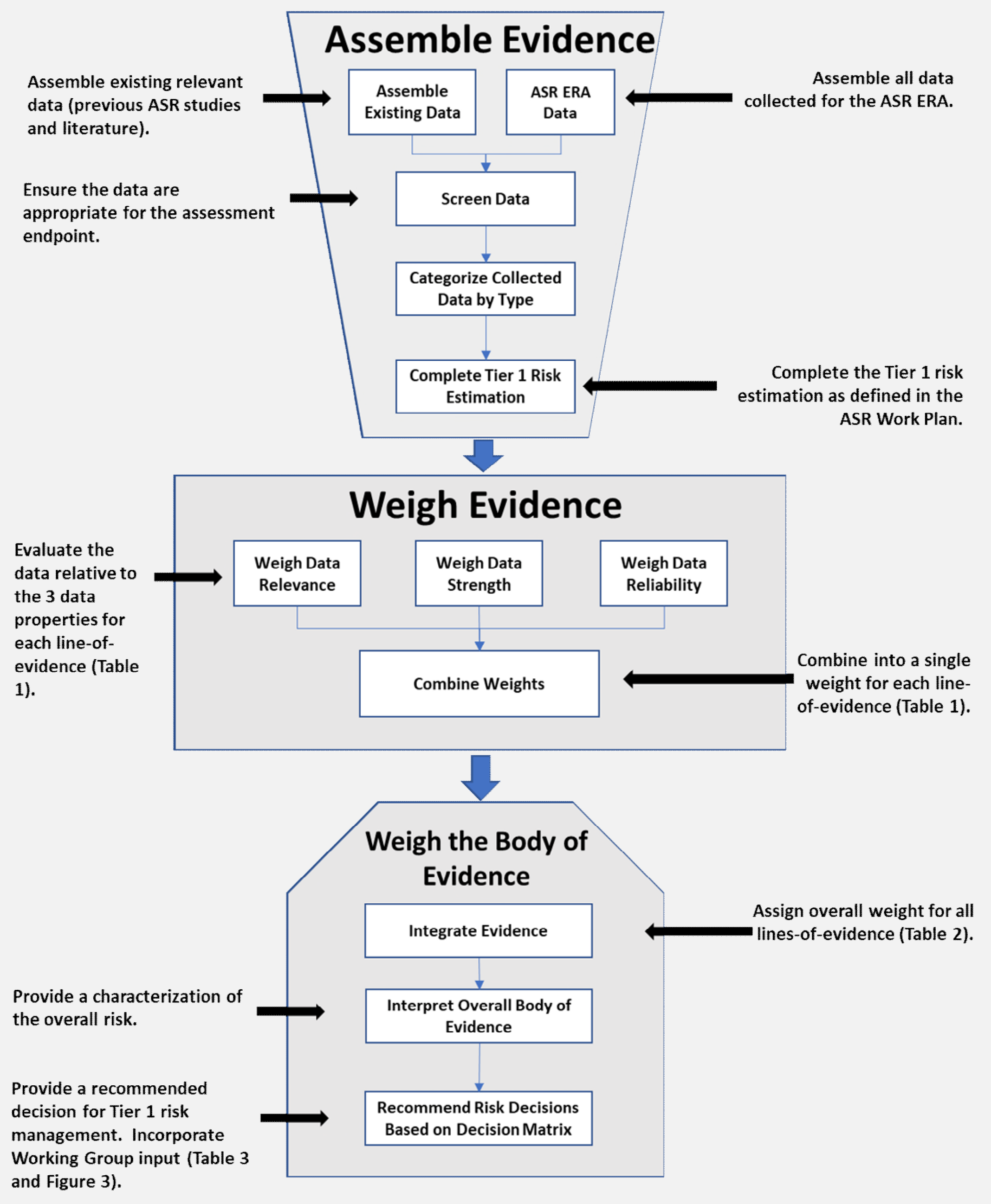


Risk Description, Weight-of-Evidence (WOE) Approach

- Stressors/Receptors ID'd in the Decision Framework
- USEPA (2016) guidance
- Provides a mechanism for weighting the range of data available
  - Not all lines-of-evidence (LOEs) have same strength or reliability
  - Incorporates uncertainty inherent in each LOE
  - Provides an overall estimate of the strength and reliability of the Risk Characterization

Weight-of-Evidence Approach

- Low Risk
  - When the WOE scores for all LOEs indicate low risk potential.
  - Where only the LOEs with the lowest weight have potentially elevated risk.
- Recommend Tier 2 Assessment
  - Where WOE scores indicate that risks cannot be determined to be low in Tier 1
- Additional Assessment of Uncertainty
  - Where the potential for risks is equivocal and additional data may be helpful
- Consider Probabilistic Risk Assessment in Tier 1
  - Where additional analyses could significantly aid in reducing uncertainty



Recommended Additional Assessment

- **Tier 2 Assessment**
  - Localized effects near ASR Wells and downstream
    - More detailed assessment of individual assessment endpoints and interconnected nature of endpoints
      - Probabilistic Risk Assessment
      - Interconnected exposure models
- **Tier 3 Assessment**
  - Regional effects from ASR Well discharge

Tiers 2 and 3 will be data intensive and determined based on results of Tier 1. Procedures not defined in the Work Plan

Adaptive Management

- **ERA Work Plan will be completed in advance of the full design and implementation of the ASR Wells**
  - Abundant data will be available between the completion of the Work Plan and the ERA
  - Flexibility is key
    - Incorporate new data into the ERA
      - Periodic review of data and data collection
      - Incorporate into appendix in ERA Work Plan
      - Modify Work Plan if needed
    - Decision tools for determining use of new data
    - ***Adaptive management of future well clusters based on data ASR ERA data/results***

ASR Ecological Risk Assessment

Thank you.

Questions?

Joe Allen
Principal Wildlife Biologist / Risk Assessor
Formation Environmental
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724-454-7011

FORMATION ENVIRONMENTAL

Aquifer Storage and Recovery Ecological Risk Assessment Pre-Operational Ecological Monitoring Along the C-38 Canal and N Lake Okeechobee Year 1 Results

Jen Mathia-ECT

ECT
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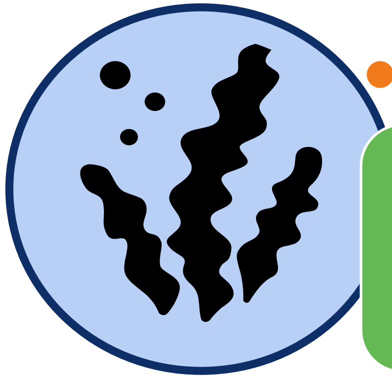
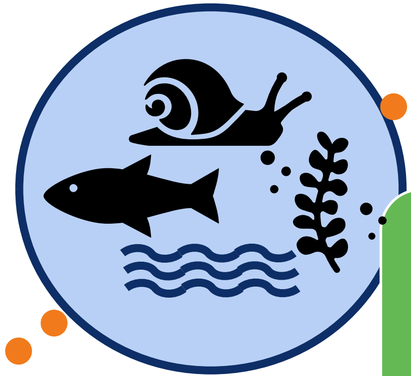
Estimated Timeline



Past

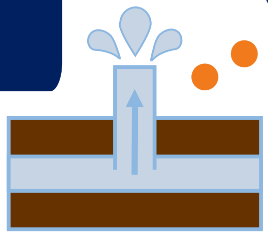
- >Pre-operational Studies (Year 1)
- >Mobile Lab Construction
- >ERA Work Plan Development

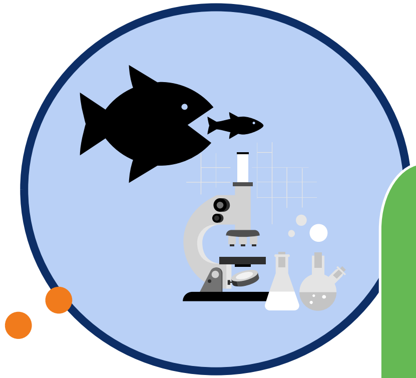


Current

- >Pre-operational Studies (Year 2 onward)

ASRs Online





Future

- >Mesocosm Studies
- >Acute and Chronic Toxicity Tests
- >Bioconcentration Studies
- > Monitoring during ASR Cycle testing

Study Purpose

- The ERA Work Plan defined specific measurement endpoints:
  - Data needed to assess the potential risk of ASR to ecological receptors (e.g., ASR ERA Risk Management Goal)
- Program designed to monitor ecological receptors within vicinity of:
  - C38 canal ASRs well clusters (C38N and C38S)
  - Kissimmee River ASR (KRASR)
  - C38 canal mixing zone at mouth of the canal in N Lake Okeechobee
- Monitoring designed based on:
  - Studies designed based on NRC (2015) uncertainties
  - Panel recommendations included in 2022 Science Plan
  - Specific needs of ERA Work Plan to fill data gaps for quantitative risk assessment identified by inter-agency ERA Working Group in 2021

Monitoring Program Overview

ASR ERA Data Collection Needs

- Surface water data (physicochemical and biological water quality parameters)
- Sediment and tissue chemical data
- Aquatic community and population characteristics

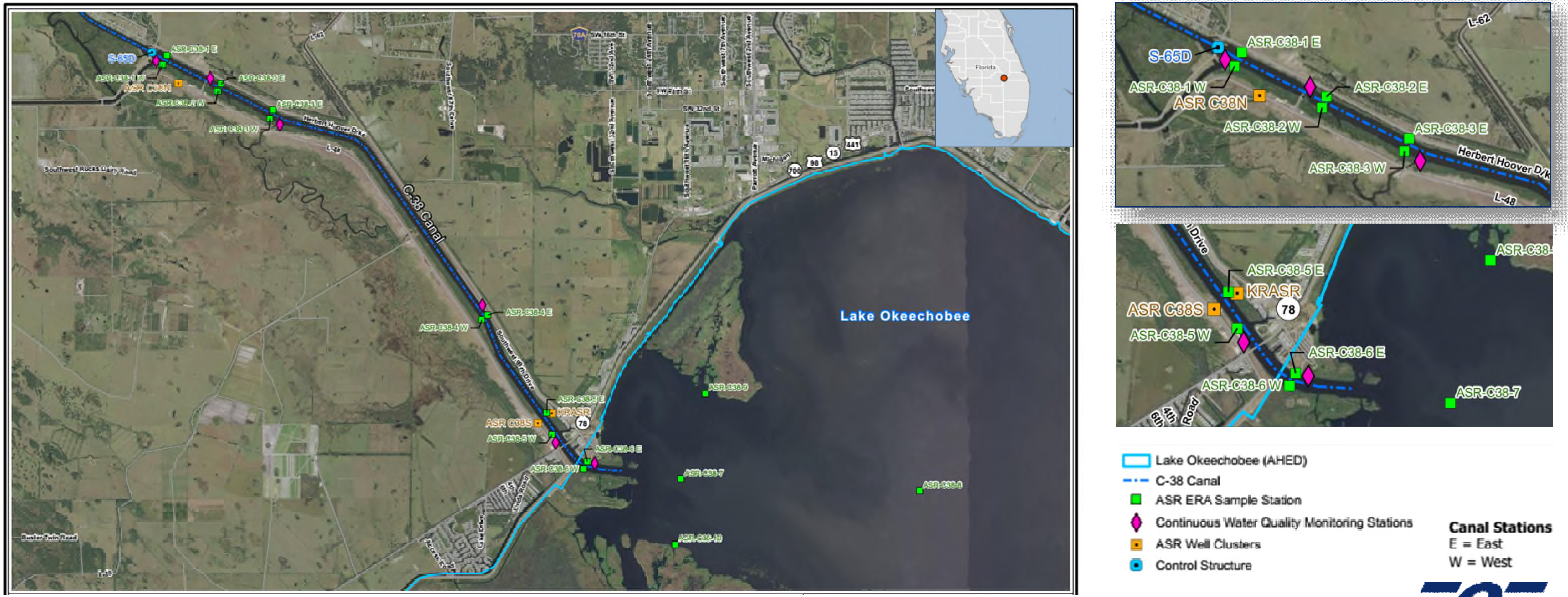
Monitored Environmental Matrices and Receptors	Metal Concentrations	Nutrient Concentrations	Diversity Indices
Surface Water	✓	✓	x
Periphyton	✓	✓	✓
Submerged Aquatic Vegetation	x	x	✓
Benthic Macroinvertebrates	x	x	✓
Sediment	✓	✓	x
Apple Snails	✓	x	x
Mussels	✓	x	x
Fish	✓	x	✓
Ichthyoplankton	x	x	✓

Year 1 Schedule

Year	2022							2023							
Season	Wet				Dry								Wet		
Month	July	August	September	October		November	December	January	February	March	April	May		June	July
Sampling Event		Event 1		Event 2			Event 3		Event 4		Event 5			Event 6	
Media															
Surface Water		✓		✓			✓		✓		✓			✓	
Periphyton			✓			✓		✓		✓		✓			✓
Submerged Aquatic Vegetation			x												
Benthic Macroinvertebrates			✓							✓					
Sediment			✓							✓					
Apple Snails		x									✓				
Mussels			✓						✓						
Fish Population			✓				✓		✓					✓	
Fish Tissue			✓						✓						
Ichthyoplankton								✓	✓				✓	✓	

Pre-Operational Studies

Study Area



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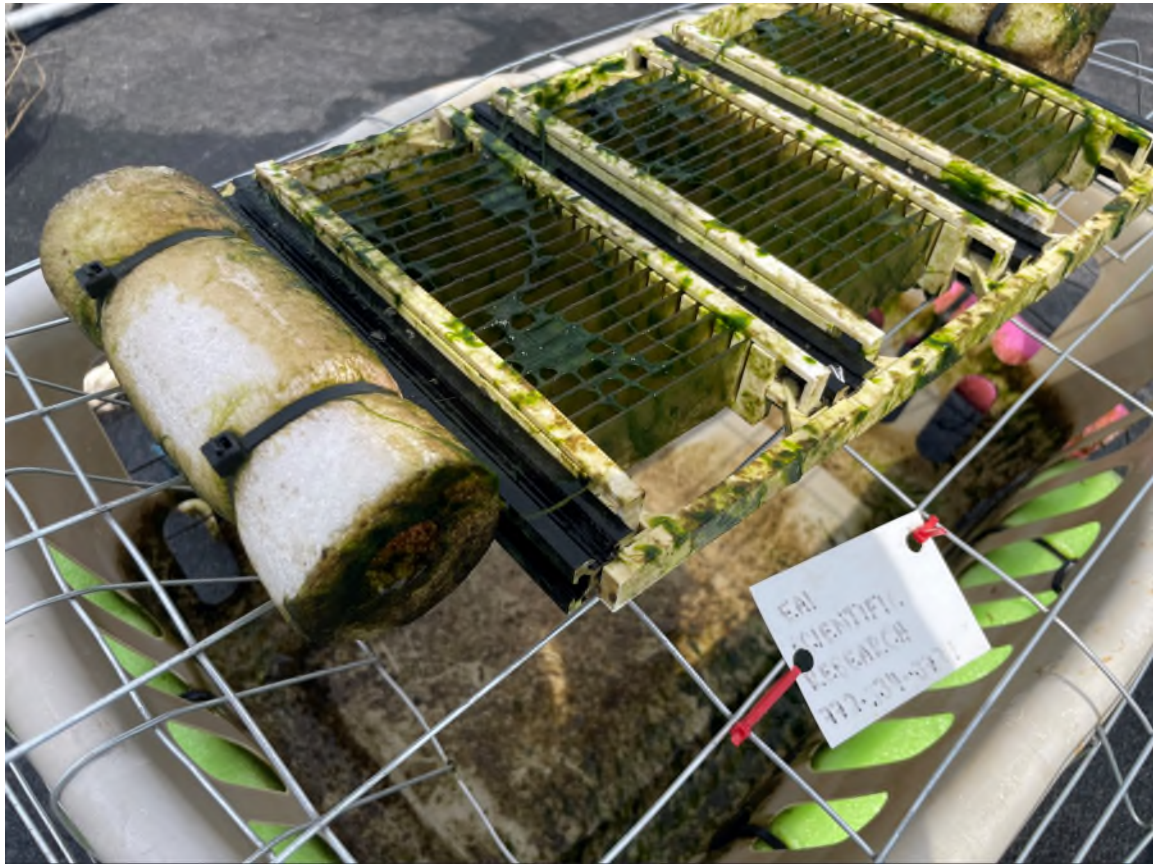
Work Plans Development

- Develop for each component in collaboration with Formation Environmental to support ASR ERA
- Utilize FDEP SOPs to the extent possible
- Complement PQAP and QASR
- Reviewed and approved through District DrChecks process
- Modified following onset of monitoring studies to better suite conditions encountered in the field (e.g., wildlife interactions, vandalism, water levels)



Project Team

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- Environmental Consulting & Technology, Inc (ECT)
  - Project management
  - Subcontractor coordination
  - Data analysis and reporting
- Ecological Associates, Inc. (EAI)
  - Field collections
  - Benthic taxonomy
  - Fish and ichthyoplankton taxonomy
- Florida International University (FIU)
  - Periphyton taxonomy
  - Periphyton nutrient analysis
- Eurofins Laboratory
  - Periphyton metals analysis
  - Chemical analysis of surface water, sediments, apple snails, mussels, fish

EAI ECOLOGICAL ASSOCIATES, INC.
www.ecological-associates.com

FIU FLORIDA INTERNATIONAL UNIVERSITY

eurofins

Monitored Components

Periphyton

- Tissue metal concentrations
- Tissue nutrient concentrations
- Community structure and biomass dynamics
- Floating periphytometers

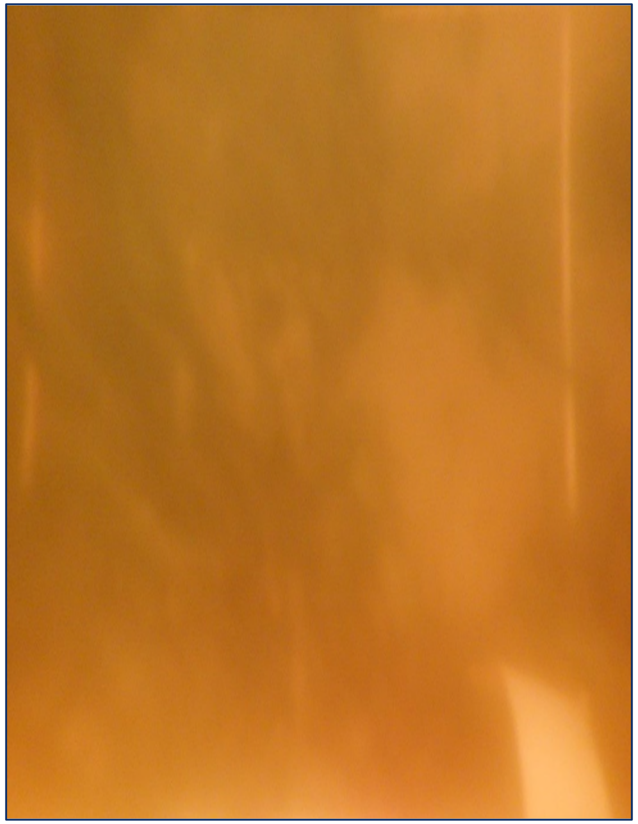
Benthic Macroinvertebrates

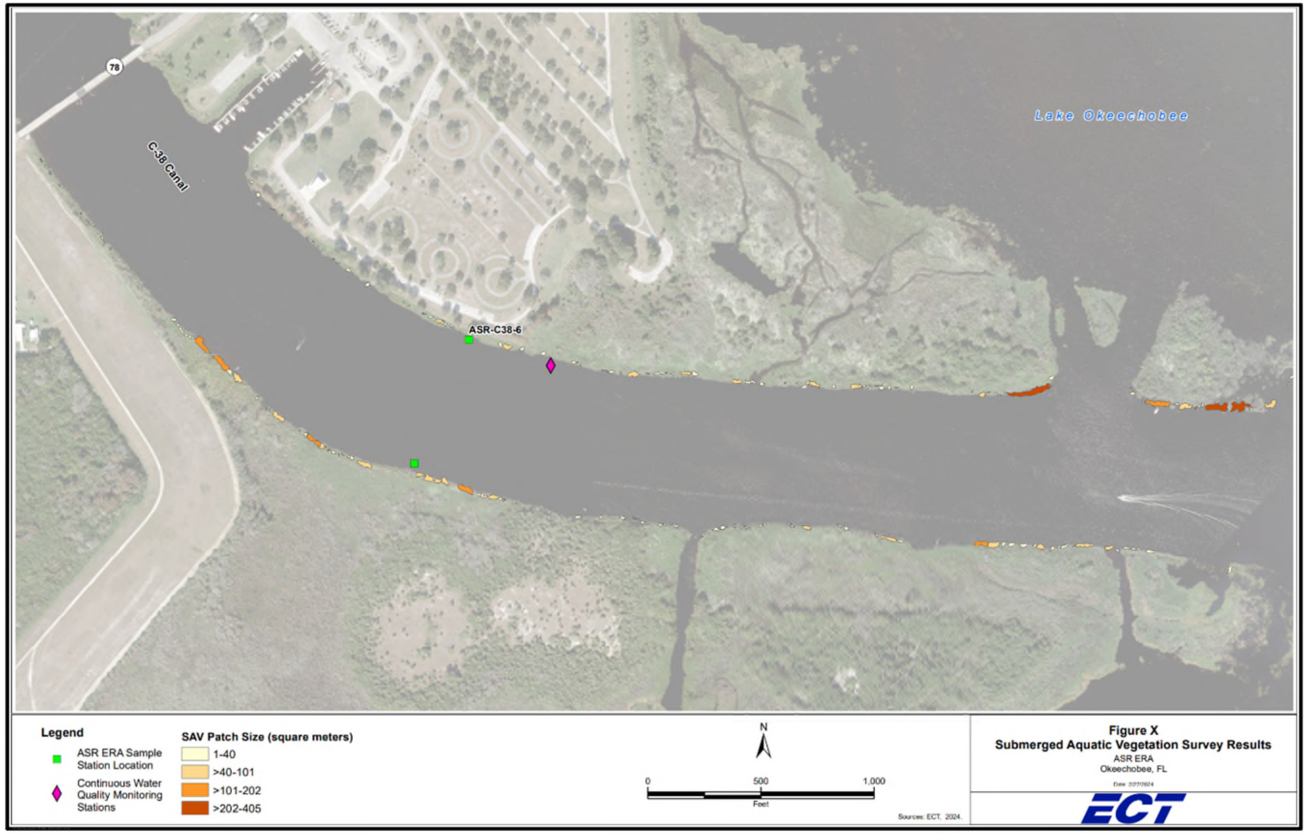
- Community structure dynamics
- Suspended Hester Dendy Samplers

Monitored Components

Submerged Aquatic Vegetation

- SAV monitoring attempted
- Incomplete due to high water levels post Hurricane Ian





Monitored Components

Surface Water

- Metal, nutrient, additional parameter concentrations
- Ambient water quality (grabs)
- Grabs during all monitoring events
- Continuous monitoring with YSI EXO2

Sediment

- Metal and nutrient concentrations
- Petite ponar sampler
- Three grab composite




Monitored Components

Mussels

- Tissue metal concentrations
- Flea rake
- Three replicates per station

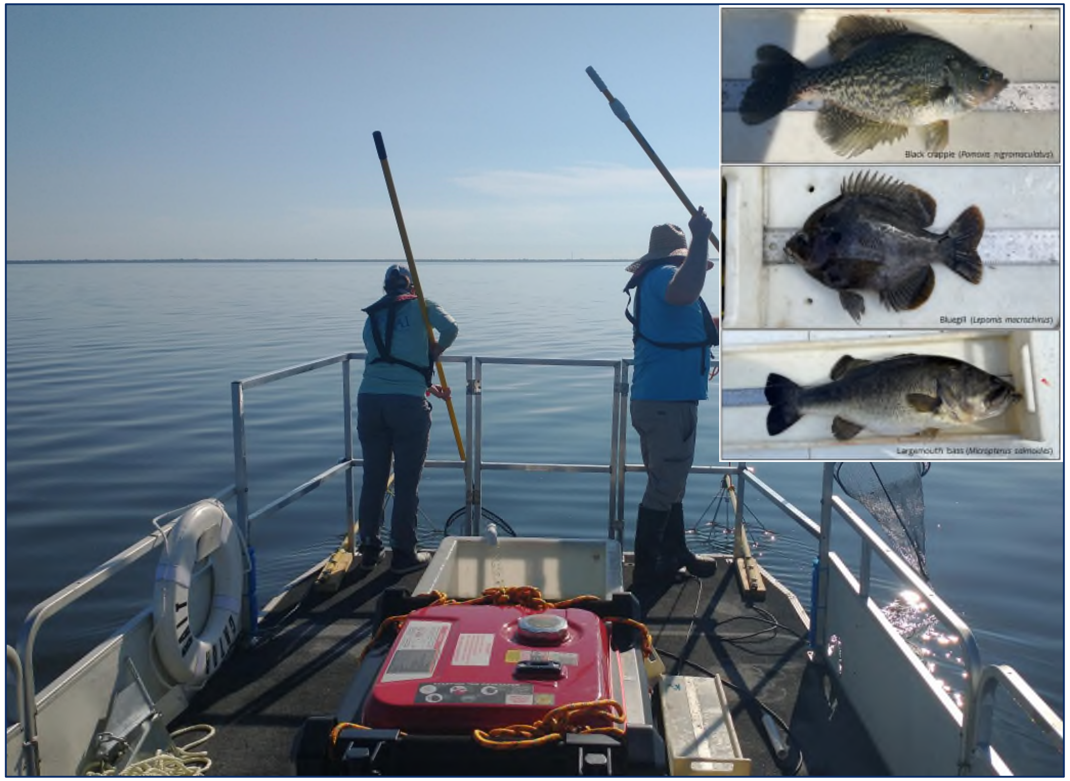
Apple Snails

- Tissue metals concentrations
- Baited minnow traps
- Three replicates per station

Monitored Components

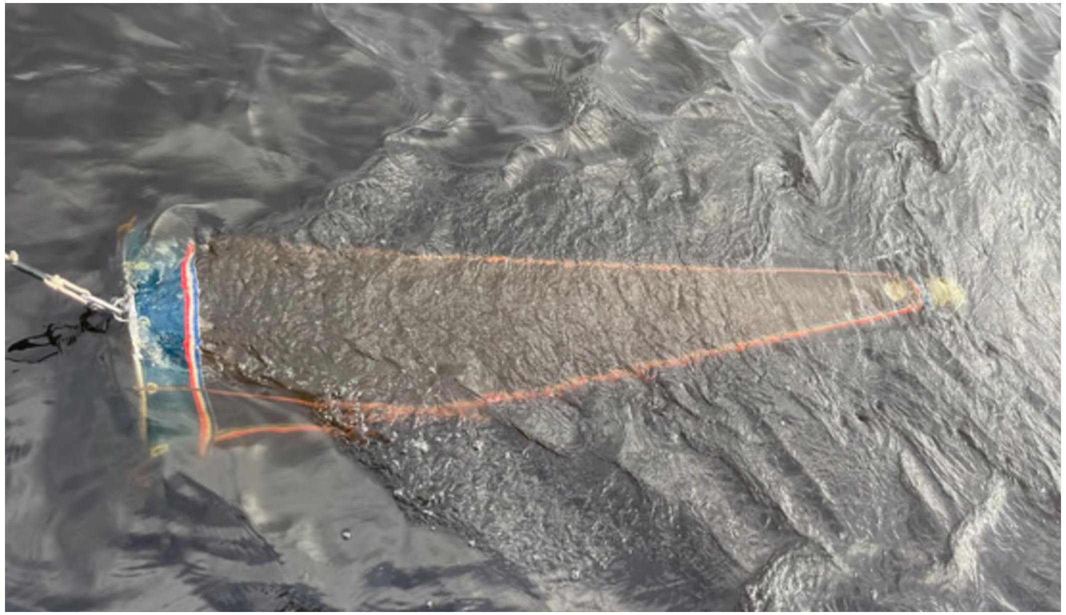
Fish

- Tissue metals concentrations
- Community
- Electrofishing
- Dip netting nearshore



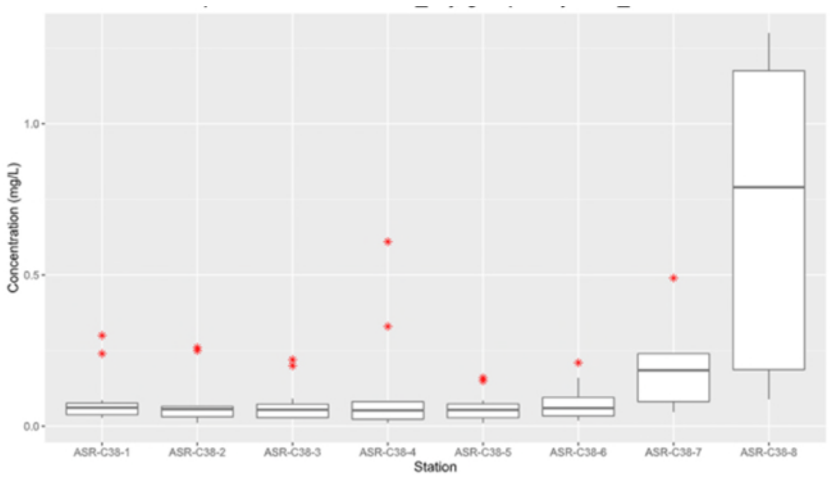
Ichthyoplankton

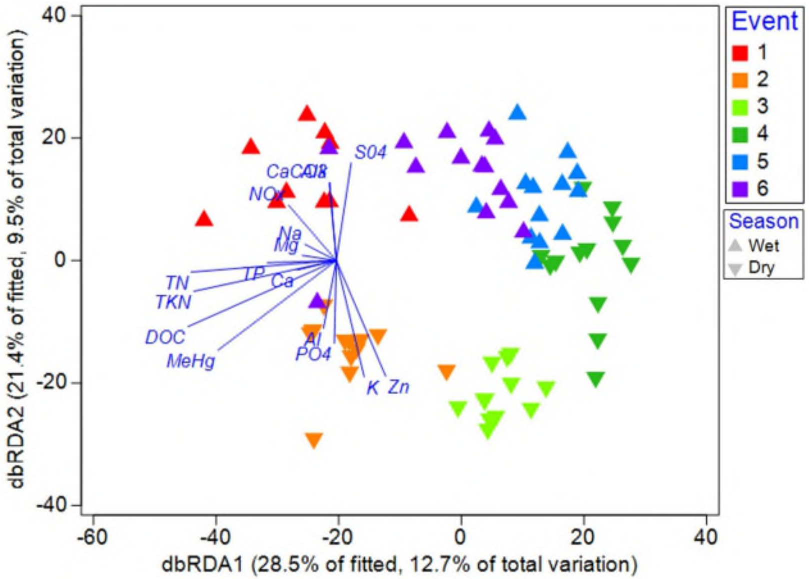
- Community
- Plankton tows
- Three depths



Data Analysis

- Basic summary stats and univariate statistical testing
  - Differences in concentrations and communities by station, season, side
- Data visualizations and multivariate analysis to visualize patterns and examine groupings





Sample Type	Descriptive Statistics and Box Plots	Univariate Comparisons	Data Visualizations	Multivariate Comparisons
Metal and Nutrient Concentrations				
Water Quality	Station, season, canal side	Station, season, canal side	PCA	ANOSIM, SIMPER
Periphyton	Station, season, canal side	Station, season, canal side	PCA	ANOSIM, SIMPER, dbLM
Sediment	Station, season, canal side	Station, season, canal side	PCA	ANOSIM, SIMPER
Apple Snail Tissue	Data to enable analysis not available; metal tissue concentrations from single sampling event are included.			
Mussel Tissue	Station, season, canal side	Station, season, canal side	PCA	ANOSIM, SIMPER
Fish Tissue	Species, station, season	Summarized patterns in station and season	PCA	ANOSIM, SIMPER
Taxonomy Data				
Periphyton	Station, season, canal side	Summarized patterns in station and season	PCA	ANOSIM
Submerged Aquatic Vegetation	Data to enable analysis not available; map of SAV included.			
Benthic macroinvertebrate	Diversity indices across station and season	Diversity indices across station and season	nMDS	ANOSIM, SIMPER
Fish	Diversity indices across station and season	Diversity indices across station and season	nMDS	ANOSIM, SIMPER
Ichthyoplankton	Diversity indices across depth, time of day, station, and season	Diversity indices across depth, time of day, station, and season	nMDS	ANOSIM, SIMPER

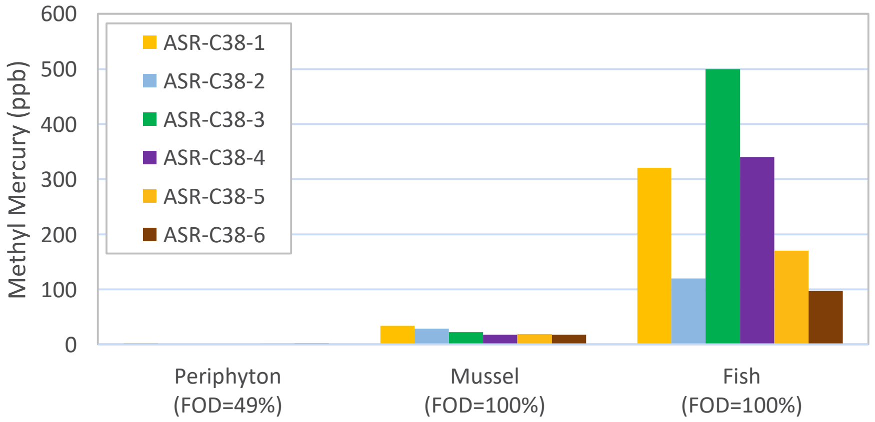
Year 1 Results

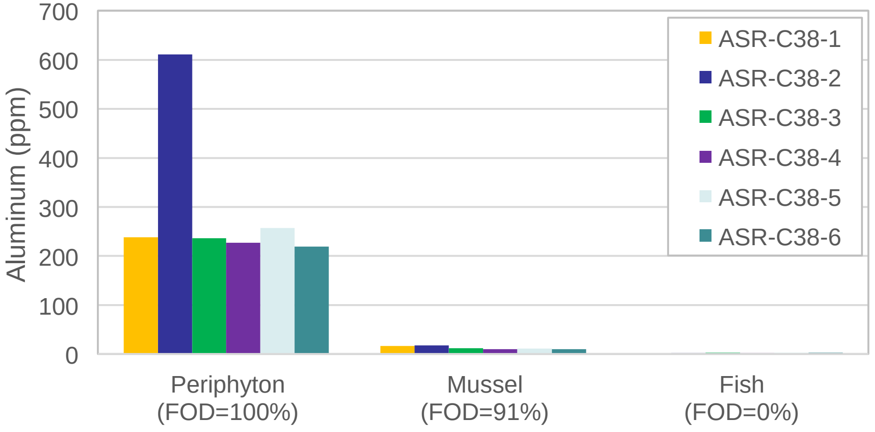
General Overview

- Nutrients measured in water, periphyton, and sediment samples and were frequently detected
- Detections of metals were more variable across both analytes and monitored components
- Observed some expected patterns of biomagnification
- Also observed spatial and seasonal variation

% = Frequency of detection of 0%
% = Frequency of detection <50%
% = Frequency of detection ≥50%

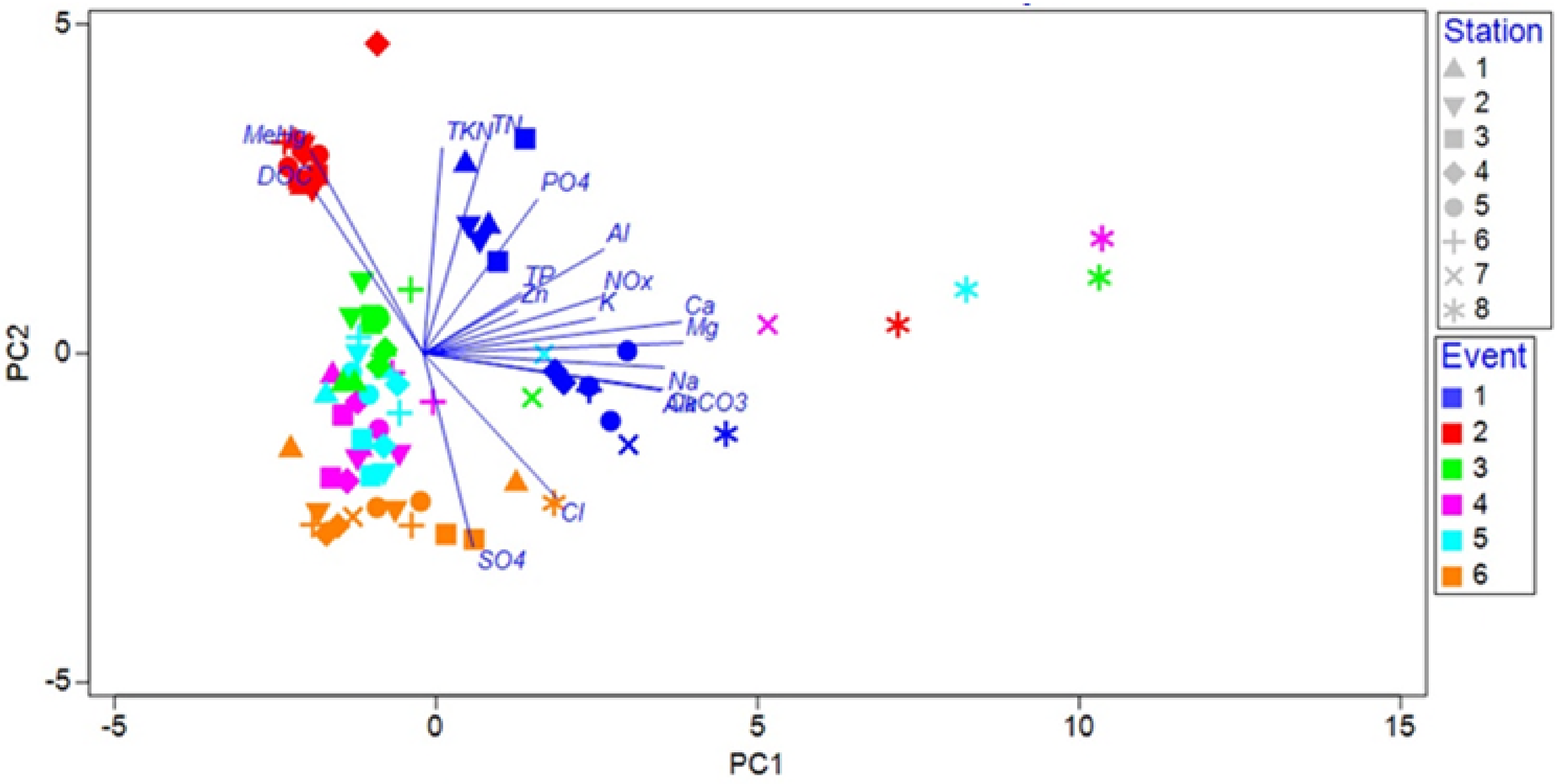
Sample Type	Metal										
	Aluminum	Antimony	Arsenic	Cadmium	Chromium	Mercury	Methyl Mercury	Molybdenum	Nickel	Selenium	Zinc
Water	96%	0%	15%	0%	24%	0%	99%	0%	0%	0%	19%
Sediment	100%	0%	11%	0%	68%	43%	89%	0%	21%	7%	4%
Periphyton	100%	0%	98%	0%	98%	32%	49%	55%	70%	24%	97%
Apple Snail	100%	0%	90%	0%	100%	50%	100%	90%	100%	20%	100%
Mussel	91%	0%	100%	99%	87%	100%	100%	91%	96%	77%	100%
Fish	0%	0%	29%	0%	52%	100%	100%	0%	0%	71%	100%

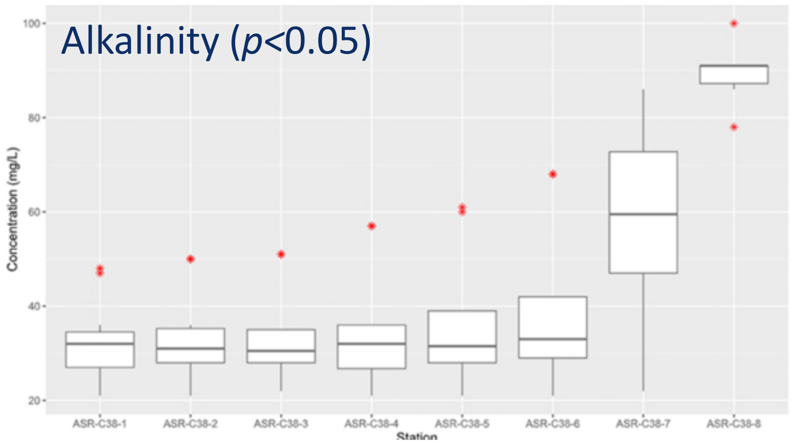


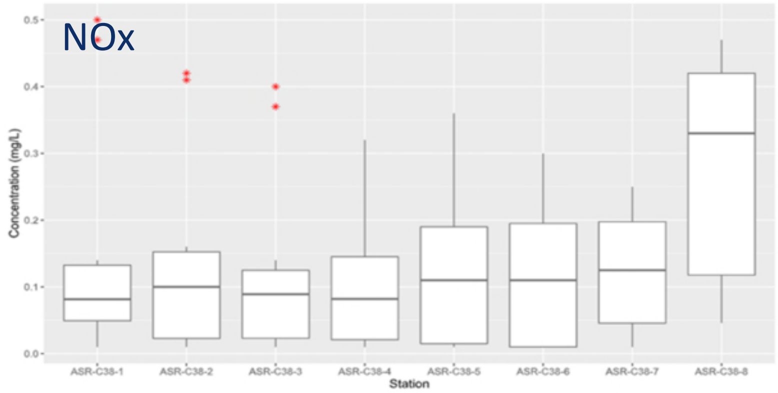


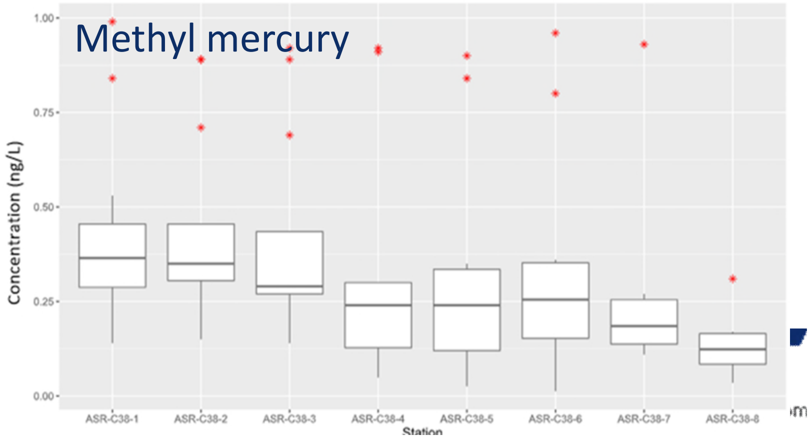
Surface Water

Spatial Differences



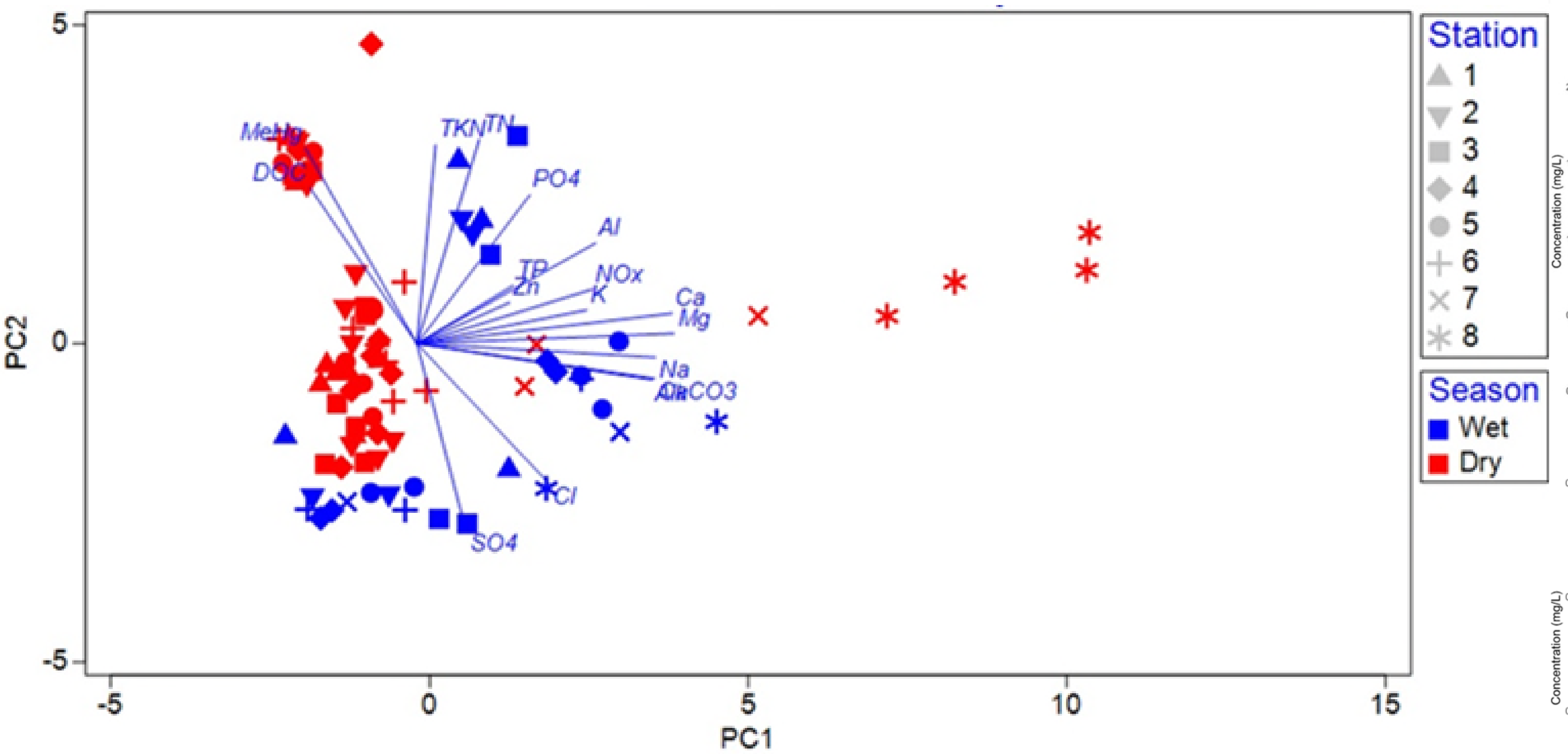


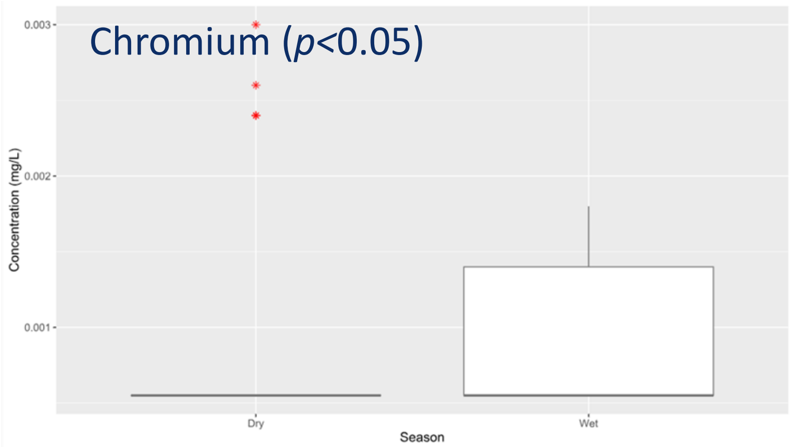


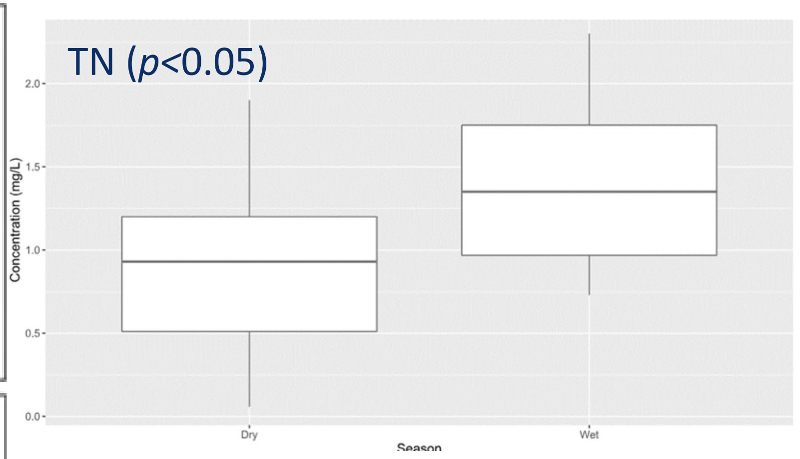


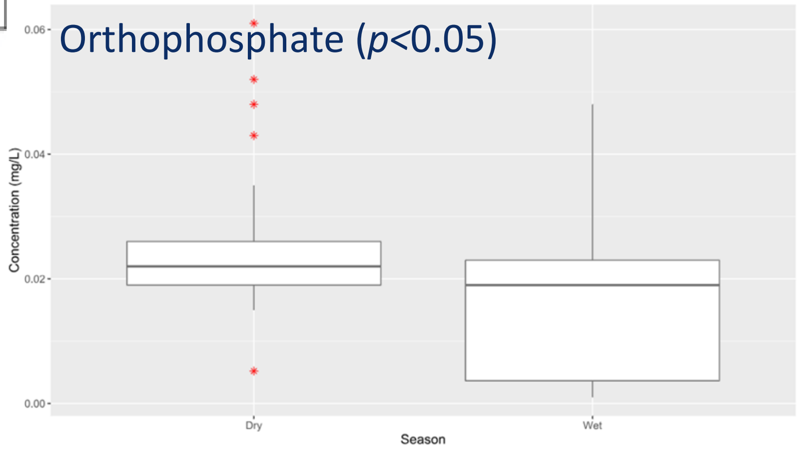
Surface Water

Seasonal Differences



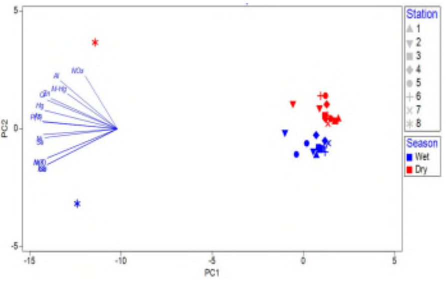


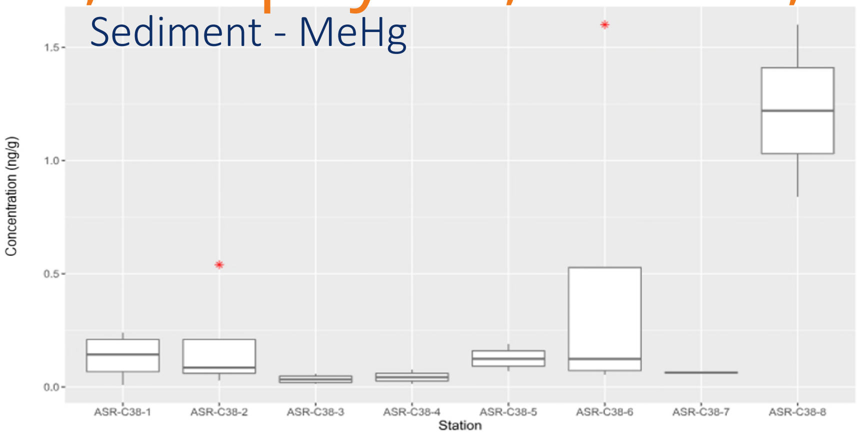


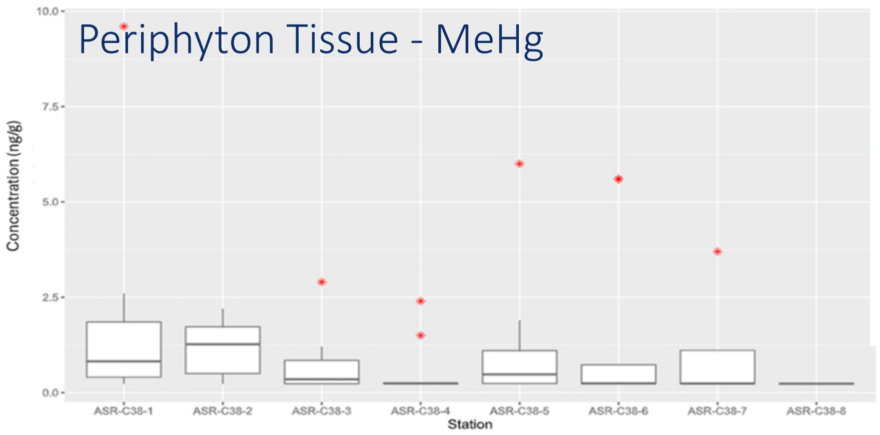


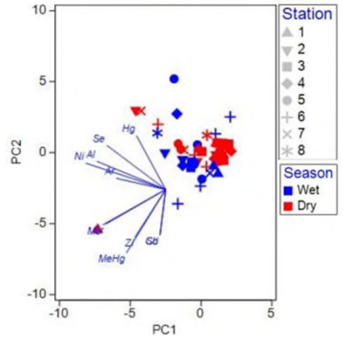
Methyl Mercury Example

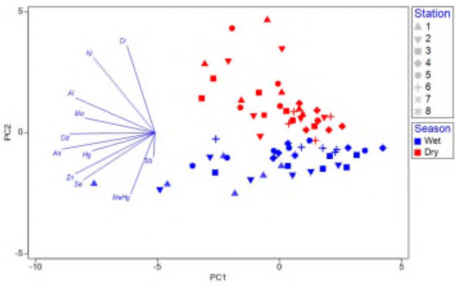
Sediment, Periphyton, Mussel, and Fish Tissue Concentrations

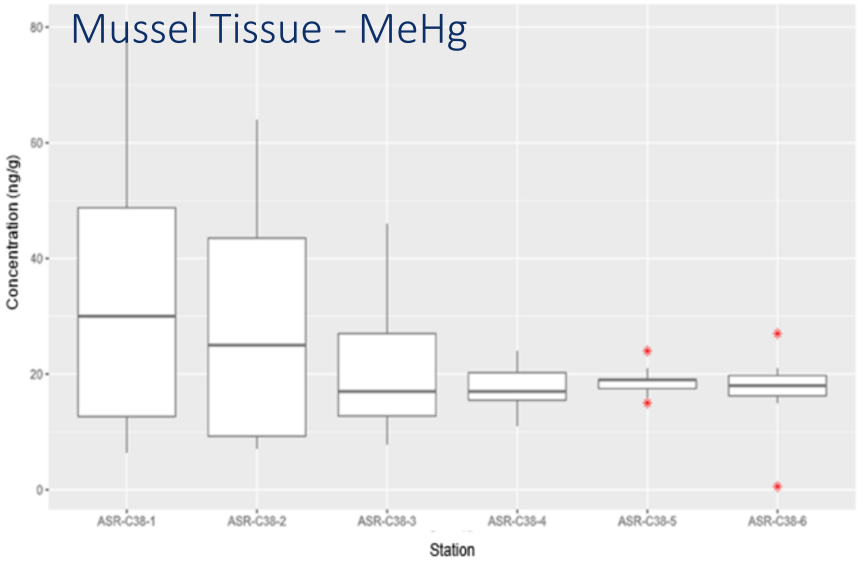


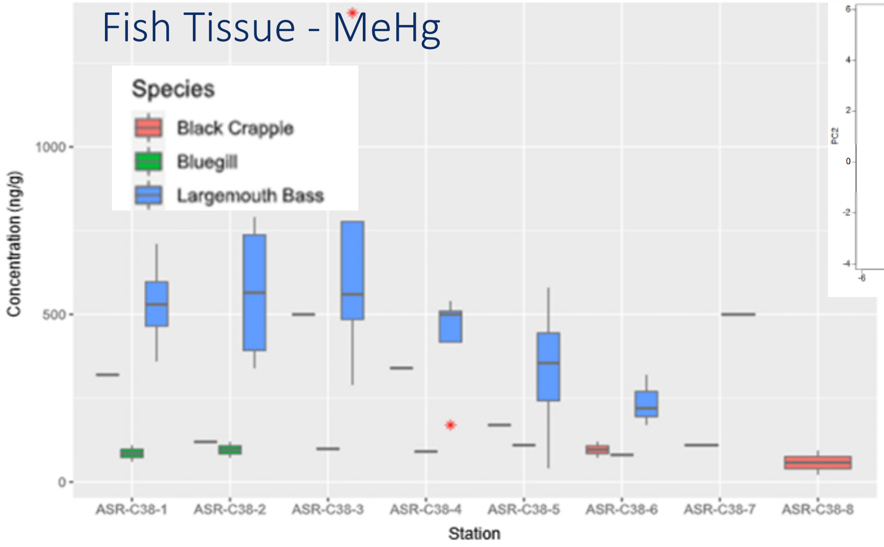


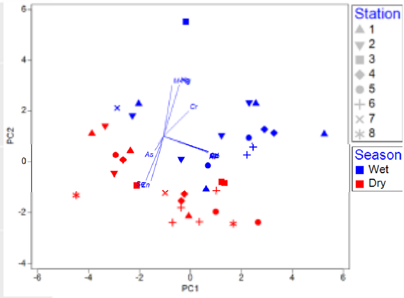












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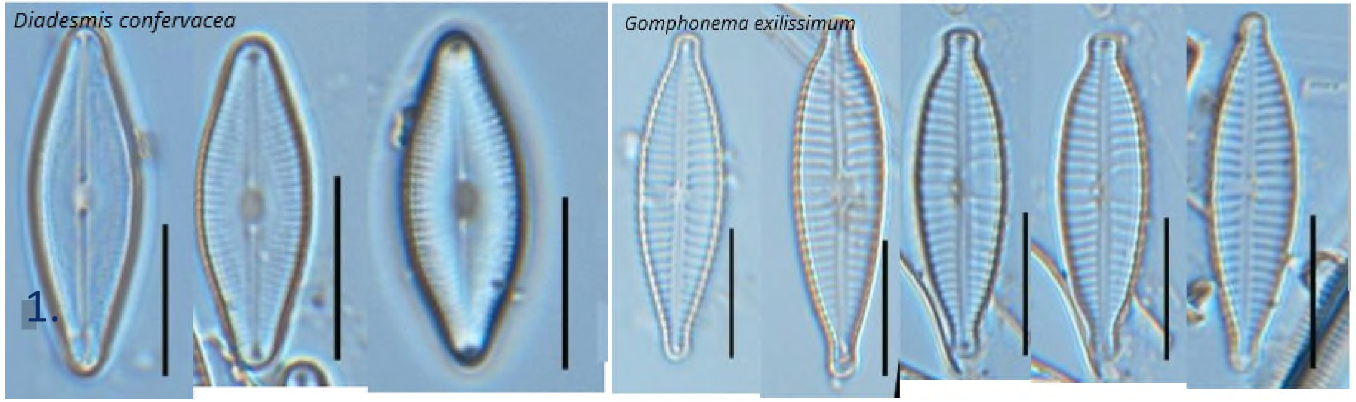
Periphyton

Seasonal and spatial differences in diatom community structure



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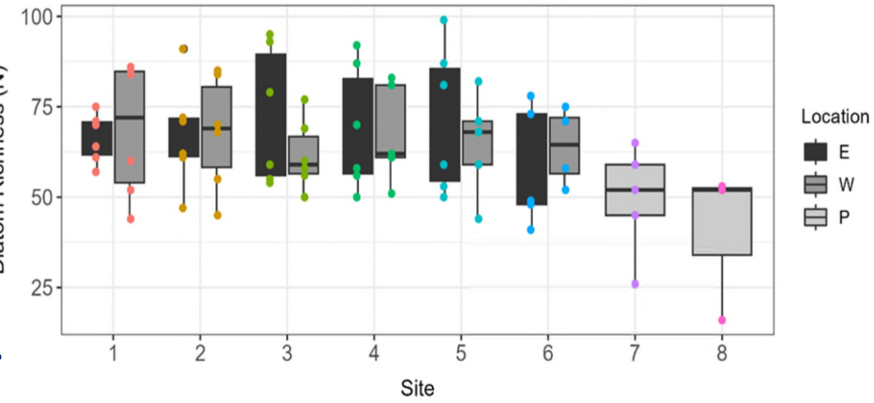

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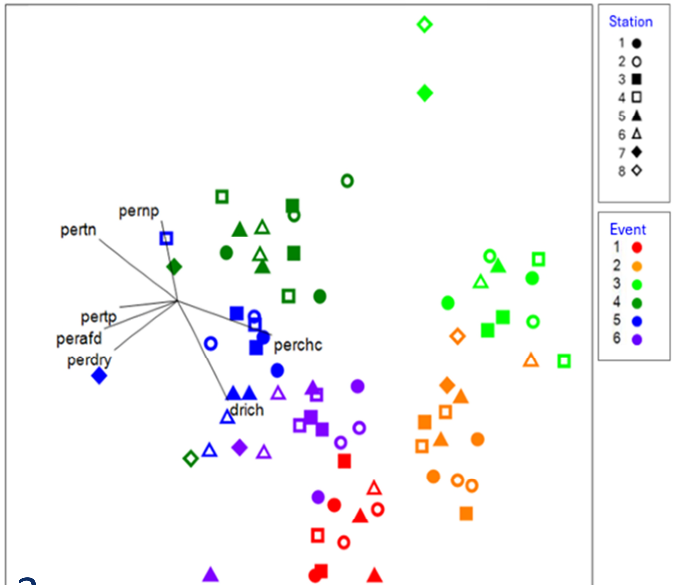

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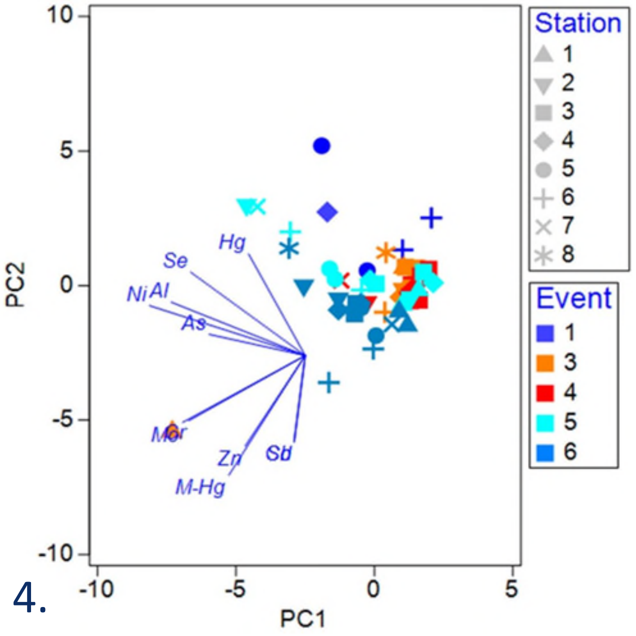

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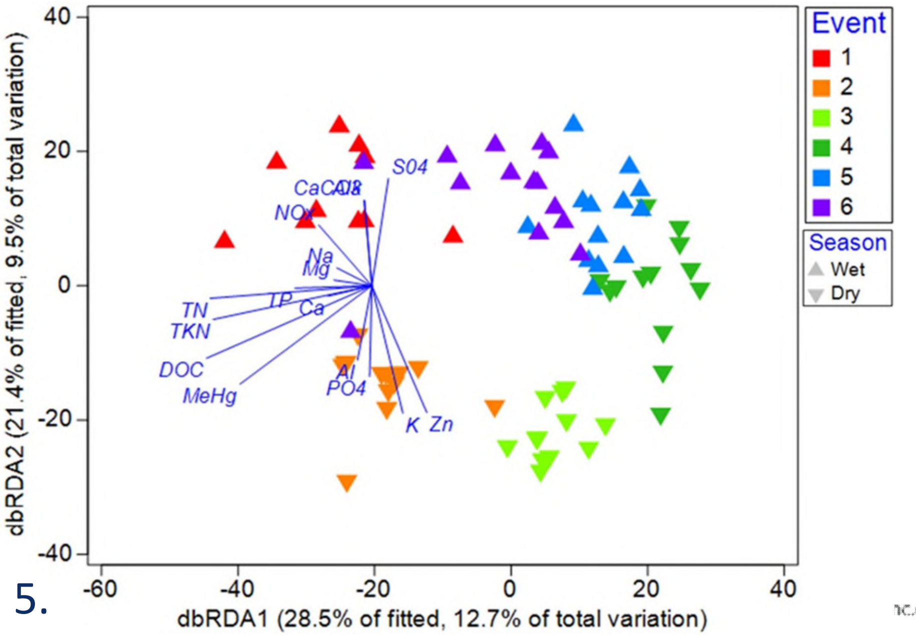
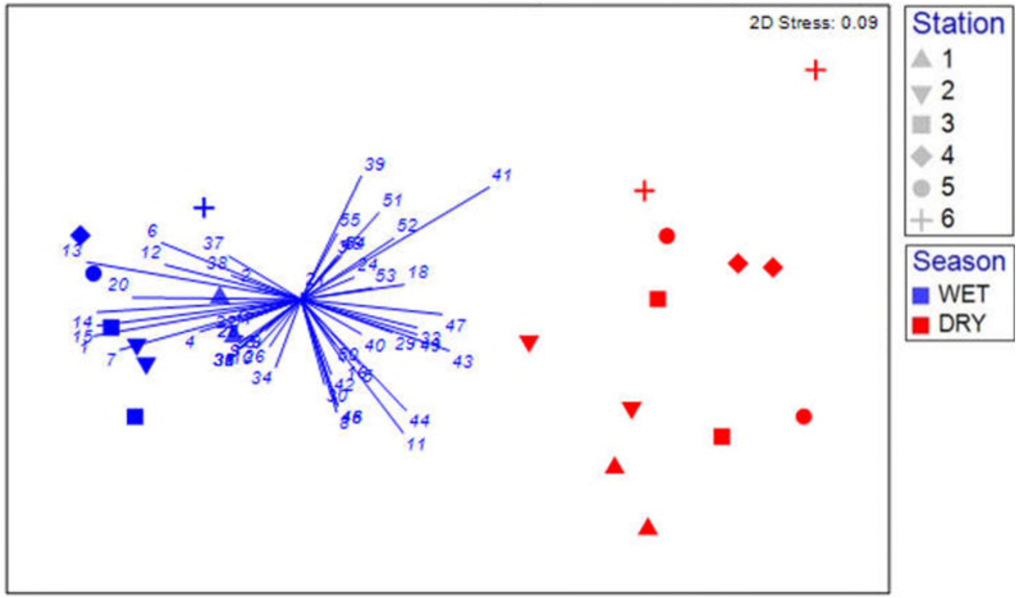
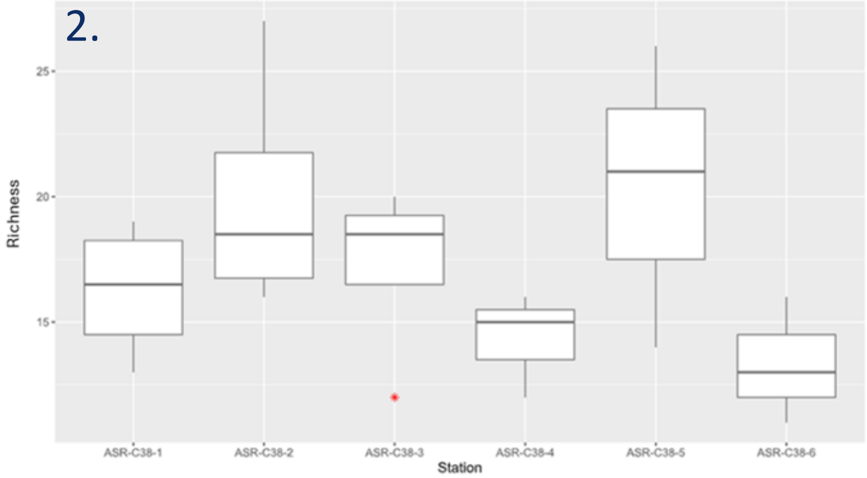


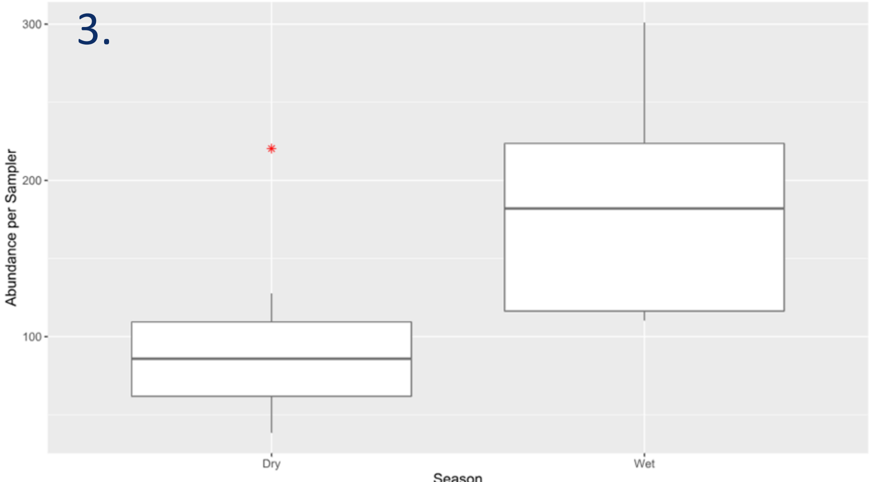
5.

Benthic Macroinvertebrates

Seasonal and spatial differences in community structure



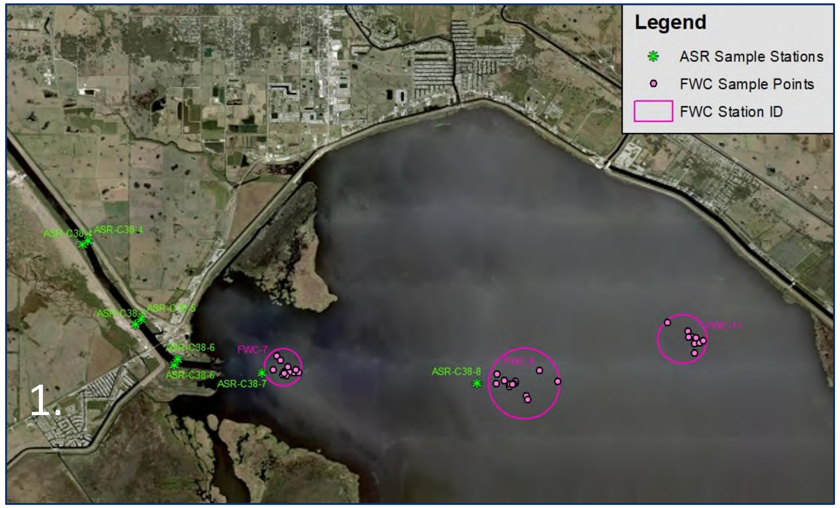




1	*Gammarus* spp	29	*Amphichaeta* spp
2	*Glyptotendipes* sp. F	30	Planariidae
3	*Goeldichironomus carus*	31	*Oecetis cinerascens*
4	Ischnura spp	32	*Pseudochironomus* spp
5	*Caenis* spp	33	Tubificinae
6	*Glyptotendipes* sp. B	34	*Orthocladius* spp
7	*Pristina* spp	35	*Pyrgophorus* spp
8	*Stylaria lacustris*	36	*Nanocladius* spp
9	*Polypedilum beckae*	37	*Planorbella (Seminola) scalaris*
10	*Nais* spp	38	*Goeldichironomus holoprasinus*
11	*Dicrotendipes simpsoni*	39	Melanoides
12	*Cyrnellus fraternus*	40	*Chaetogaster* spp
13	*Hyalella azteca*	41	*Microspectra* spp
14	*Desserobdella phalera*	42	*Tribelos fuscicorne*
15	*Dero* spp	43	*Elliptio jayensis*
16	*Helobdella stagnalis* complex	44	*Argia* spp
17	*Ablabesmyia ramphe* group	45	*Labiobaetis* spp
18	Ancylidae	46	*Dineutus* spp
19	Autobranchia	47	*Rhithrogena* spp
20	*Parachironomus* spp	48	*Elimia* spp
21	*Orthotrichia* spp	49	Hydrobiidae
22	*Micromenetus* spp	50	*Coelotanypus* spp
23	*Viviparus georgianus*	51	*Chironomus decorus* group
24	*Physa* spp	52	*Littoridinops monroensis*
25	*Ischnura* spp	53	*Palpomyia* complex
26	*Chironomus crassicaudatus*	54	*Tanytarsus* spp
27	*Cassidinidea ovalis*	55	*Procladius* spp
28	*Enallagma* spp		

Fish

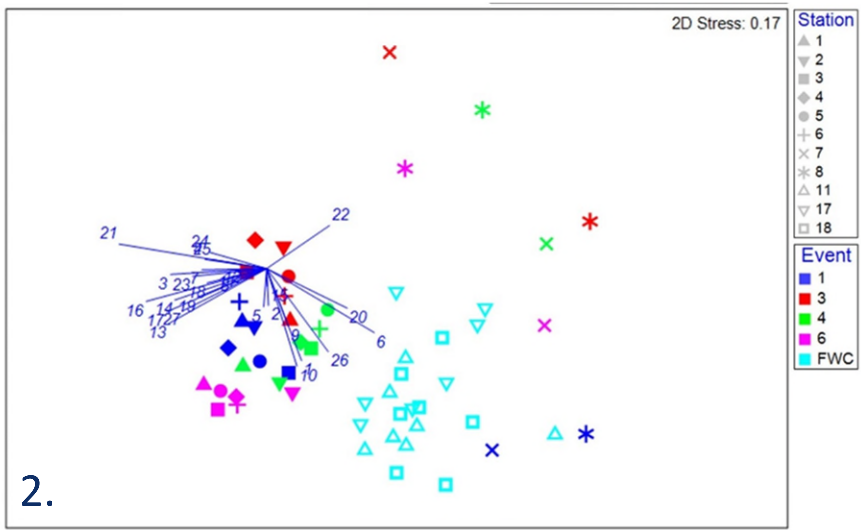
Seasonal and spatial differences in community structure

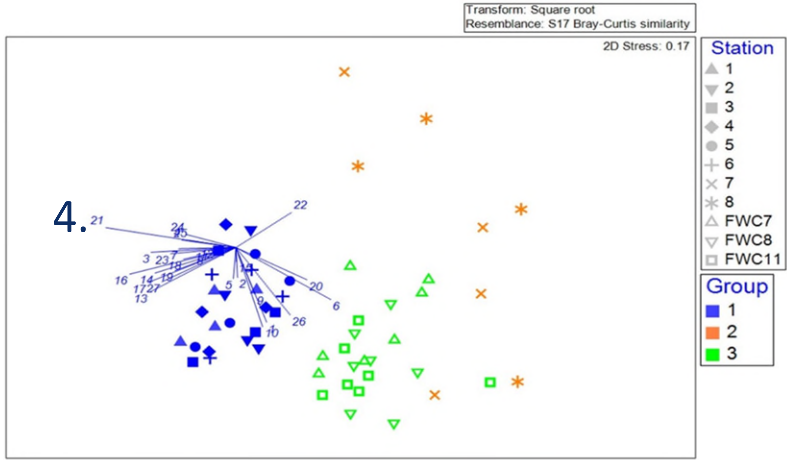


3.

	ASR-C38-1	ASR-C38-2	ASR-C38-3	ASR-C38-4	ASR-C38-5	ASR-C38-6	ASR-C38-7	ASR-C38-8	FWC 7	FWC 8	FWC 11
ASR-C38-1											
ASR-C38-2	45.04										
ASR-C38-3	45.38	45.52									
ASR-C38-4	47.62	48.23	45.82								
ASR-C38-5	45.68	45.35	47.04	46.32							
ASR-C38-6	49.61	50.46	49.77	51.42	48.03						
ASR-C38-7	90.47	84.25	85.54	87.3	85.28	90.09					
ASR-C38-8	93.52	88.52	90.1	90.2	88.4	91.99	72.06				
FWC 7	71.95	68.03	68.42	72.16	67.91	65.13	76.66	80.09			
FWC 8	74.55	70.1	69.93	74.14	71.98	73.16	75.92	79.16	55.66		
FWC 11	74.19	70.28	70.35	73.33	71.59	72.04	77.42	80.23	56.11	43.56	

Group 1
Group 2
Group 3



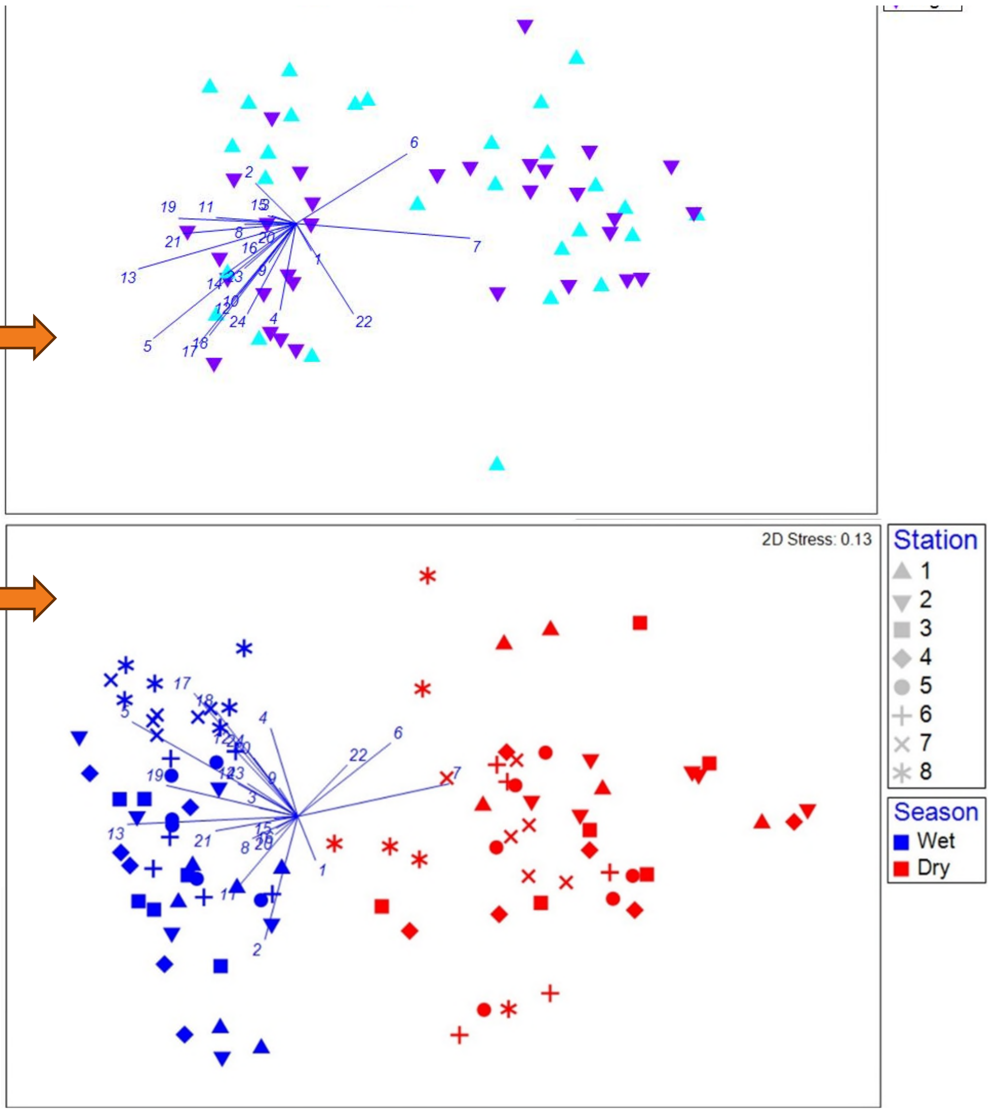


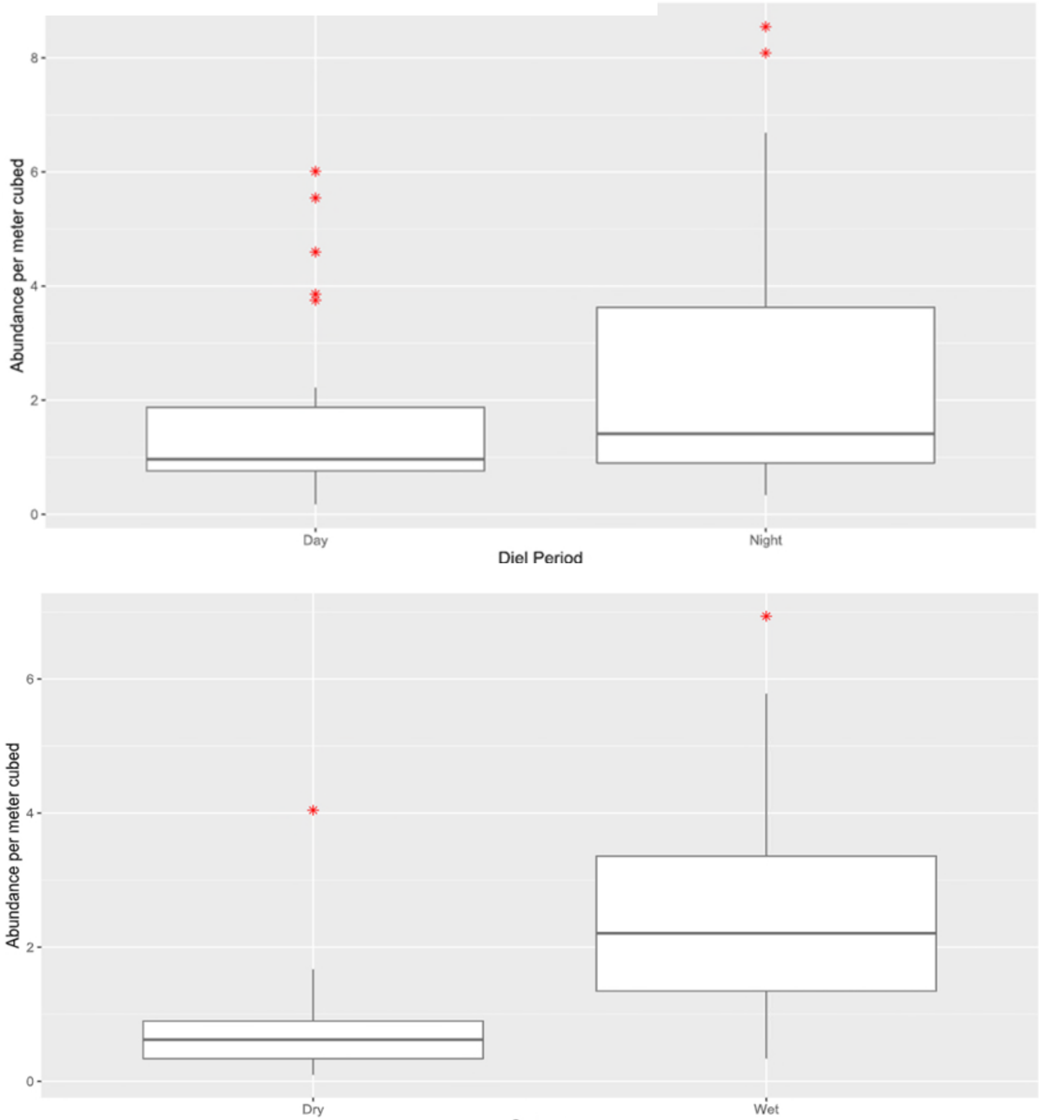
Group 1	Largemouth bass	*Micropterus salmoides*
	Florida gar	*Lepistosteus platyhincus*
	Bluegill	*Lepomis macrochirus*
Group 2	Shad spp.	*Dorosoma* spp.
	Black crappie	*Pomoxis nigromaculatus*
Group 3	Largemouth bass	*Micropterus salmoides*
	Bluegill	*Lepomis macrochirus*
	Black crappie	*Pomoxis nigromaculatus*
	Florida gar	*Lepistosteus platyhincus*
	Threadfin shad	*Dorosoma petense*
	White catfish	*Ameiurus catus*
	Channel catfish	*Ictalurus punctatus*

Ichthyoplankton

Season and diurnal differences in community structure

1	*Actinopterygii*
2	*Ameiurus catus*
3	*Cyprinidae*
4	*Dorosoma cepedianum*
5	*Dorosoma petenense*
6	*Dorosoma* spp.
7	*Etheostoma fusiforme*
8	*Fundulus seminolis*
9	*Gambusia holbrooki*
10	*Gobiosoma bosc*
11	*Ictalurus punctatus*
12	*Labidesthes vanhyningi*
13	*Lepomis macrochirus*
14	*Lepomis microlophus*
15	*Lepomis* spp.
16	*Lucania goodei*
17	*Menidia beryllina*
18	*Microgobius gulosus*
19	*Microphis lineatus*
20	*Noturus gyrinus*
21	*Oreochromis aureus*
22	*Pomoxis nigromaculatus*
23	*Pterygoplichthys* spp.
24	*Strongylura marina*





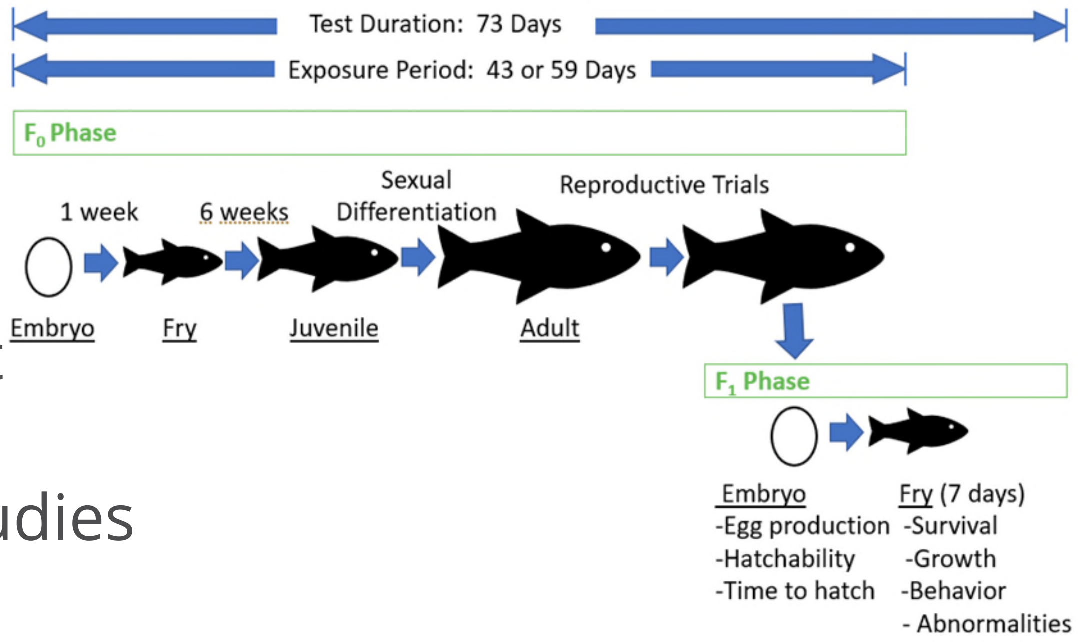
> ectinc.com

Year 1 Results

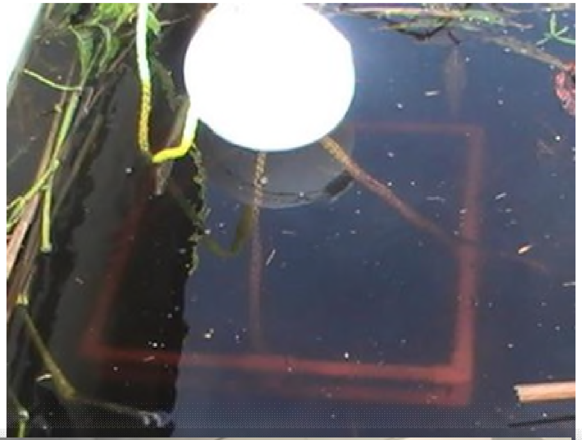
Take-Aways

- Variable detections of parameters within the matrices studied
- Mussels showed high frequency of detections of metals supporting their use as an indicator of potential impacts from ASR operations
- Periphyton results suggest individual stations may oscillate between nitrogen- and phosphorus-limitation over time
- Taxonomic data suggest communities differ between canal and lake stations as well as seasonally
- Periphyton abundance appeared to be strongly moderated by time of year
- Surface water quality predicts approximately 45% of periphyton community structure and is a poor predictor of periphyton tissue metal concentrations.
- Variability suggests potential influence from additional sources other than in-lake processes (e.g., stormwater runoff, other canal inflows to Lake Okeechobee)
- As data collection continues, more robust inferences on seasonal and spatial relationships and response to surface water quality will be possible
- Additional data collection needed under pre-operational conditions to establish stronger relationships between parameters measured to help inform potential effects of ASR operations and support the ERA.

> Next Steps



- Year 2 annual report
- Year 3 monitoring
- Bioconcentration studies
  - Mobile laboratory
  - Fish and mussels
  - Tissue testing
  - Concurrent water quality monitoring
- In-situ bioaccumulation studies
  - Mussels and periphyton
- Toxicity Testing
  - Ecotoxicity tests
  - NDPES and CERP permits
  - Longer-term chronic toxicity study



Questions?

Acknowledgements:

Chris McHan and Suzy Baird - ECT

Mark Mohlmann and Matt Scripter, and team – EAI

Evelyn Gaiser and team – FIU

Eurofins Laboratories

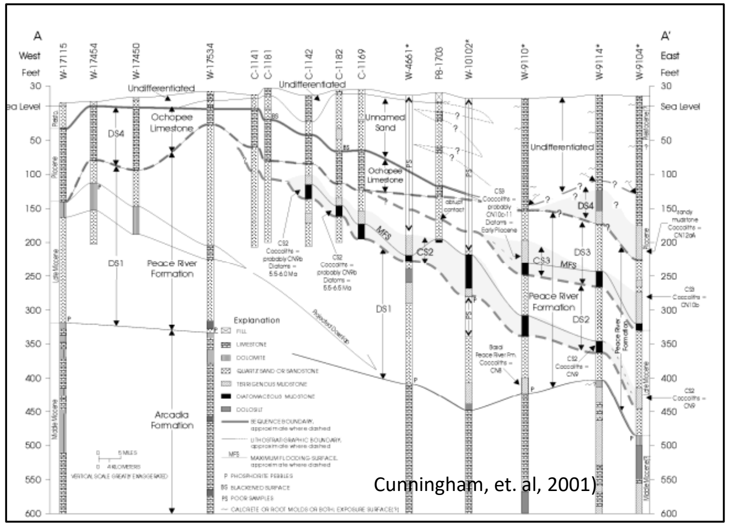
Break (15 min)

SFWMD Okeechobee 2D Seismic Program

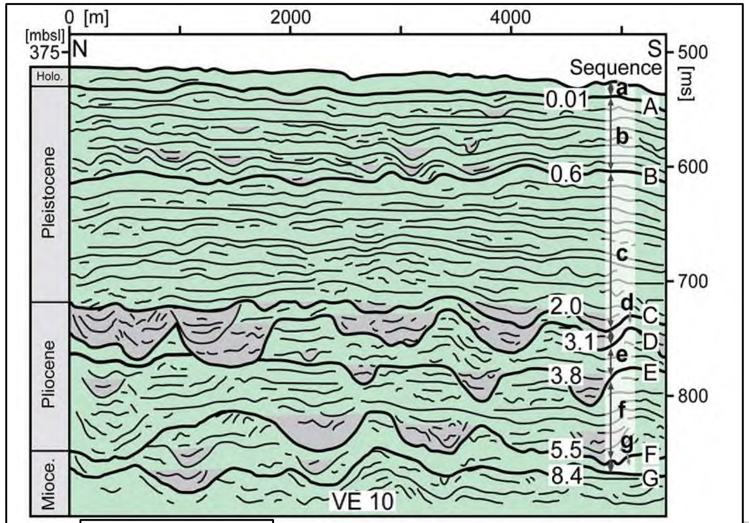
SFWMD ASR Science Plan Workshop Presentation
(July 10, 2024)

Presenters: Ted Stieglitz, Ph.D, Senior Geophysicist, and
John Jansen, Ph.D., Principal Geophysicist, Collier Consulting

The Need for Seismic Reflection Data



Cunningham, et. al, 2001)



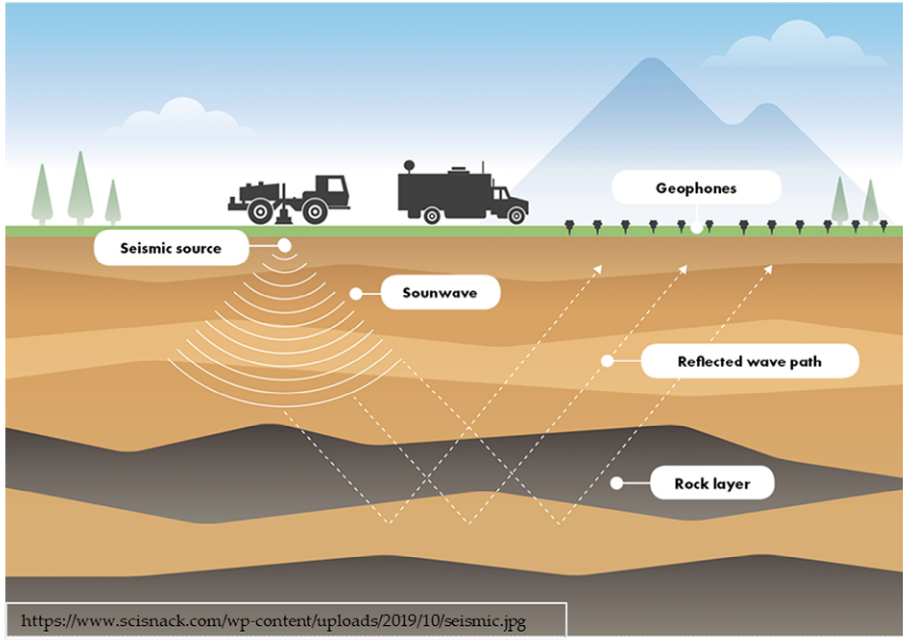
Wunsch, et. al, 2018

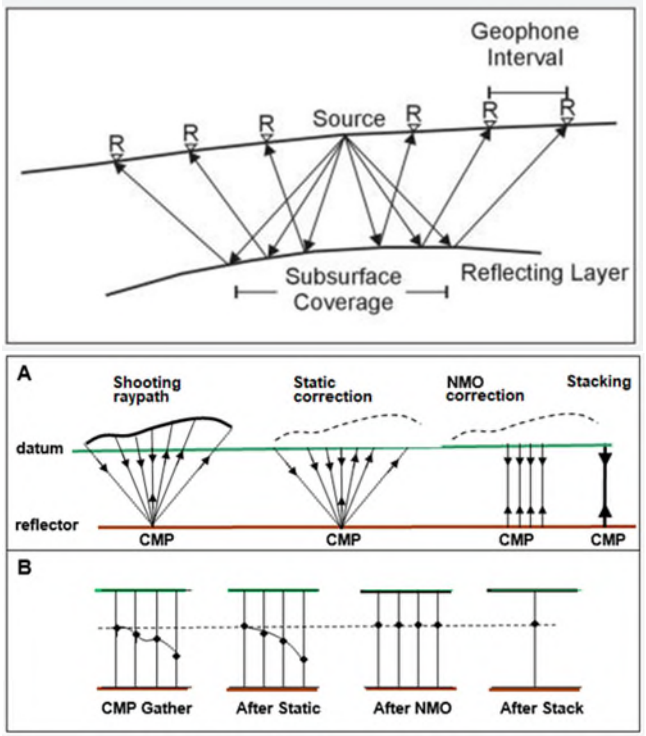
- We tend to work with site conceptual models that look like this

- As Geologists, we know the subsurface looks more like this
- The differences are important for well yield, contaminant transport, recharge,…..
- How do we get closer to reality? **(Geophysics)**

COLLIER GEOPHYSICS

Seismic Reflection: Map Structure and Stratigraphy

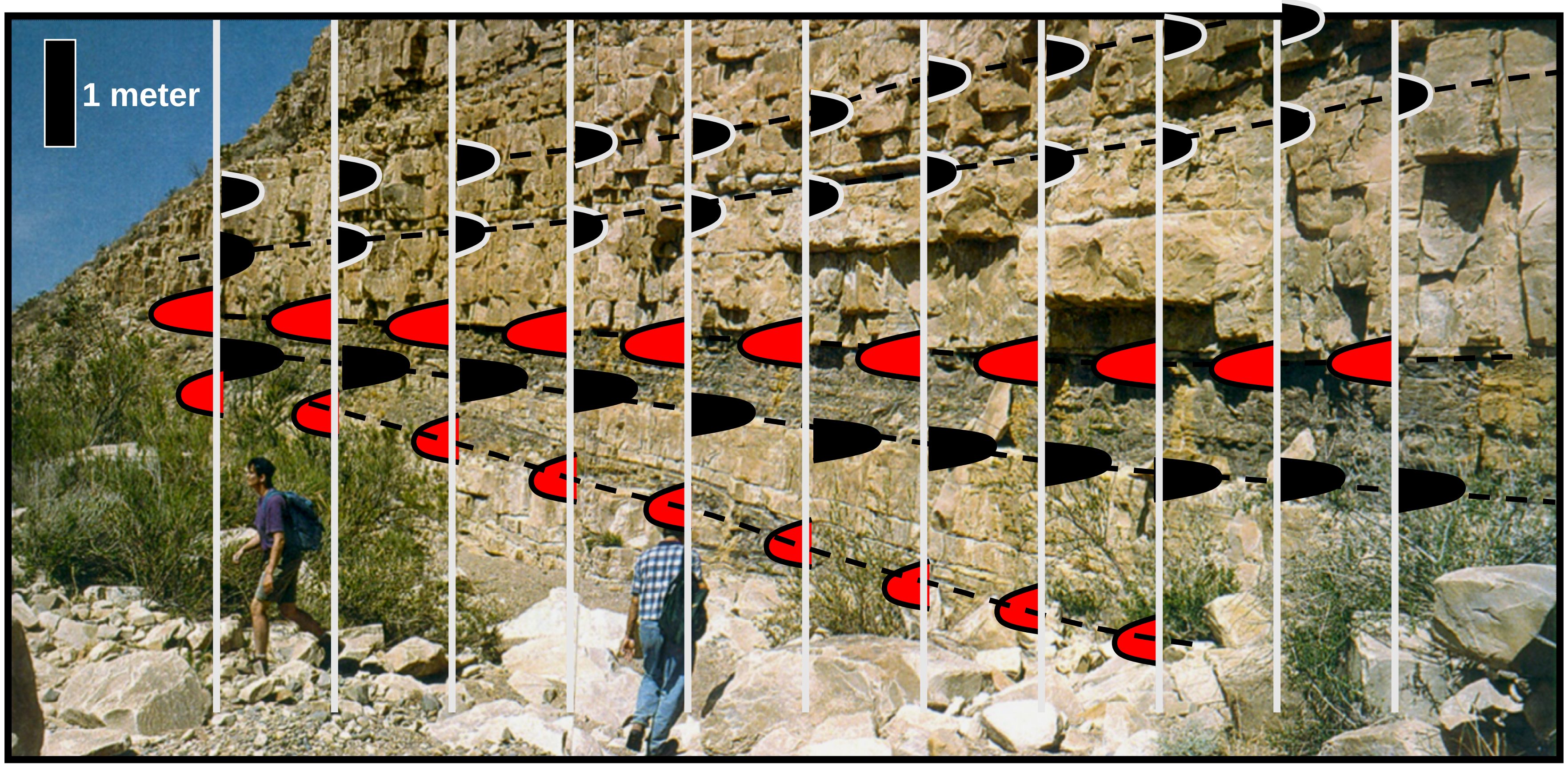




- Seismic reflection provides high-resolution images of the subsurface to screen optimal production well and ASR well locations
- Map major faults, fracture zones and other structure
- Map target zone depth and thickness, lithology and porosity (and permeability?)

COLLIER GEOPHYSICS

Seismic Reflection Images Vertical and Lateral Lithologic Contacts



Increase in Impedance

Decrease in Impedance

Able to resolve boundaries of beds a few feet thick

http://archives.aapg.org/slide_resources/schroeder/13/index.cfm

Traditional Cable Seismic System

Stringing geophone cables

Group of geophones at each take out

Common Seismic Sources

Vibrosies Source

Accelerated Impact Seismic Source
No explosives, minimal disturbance

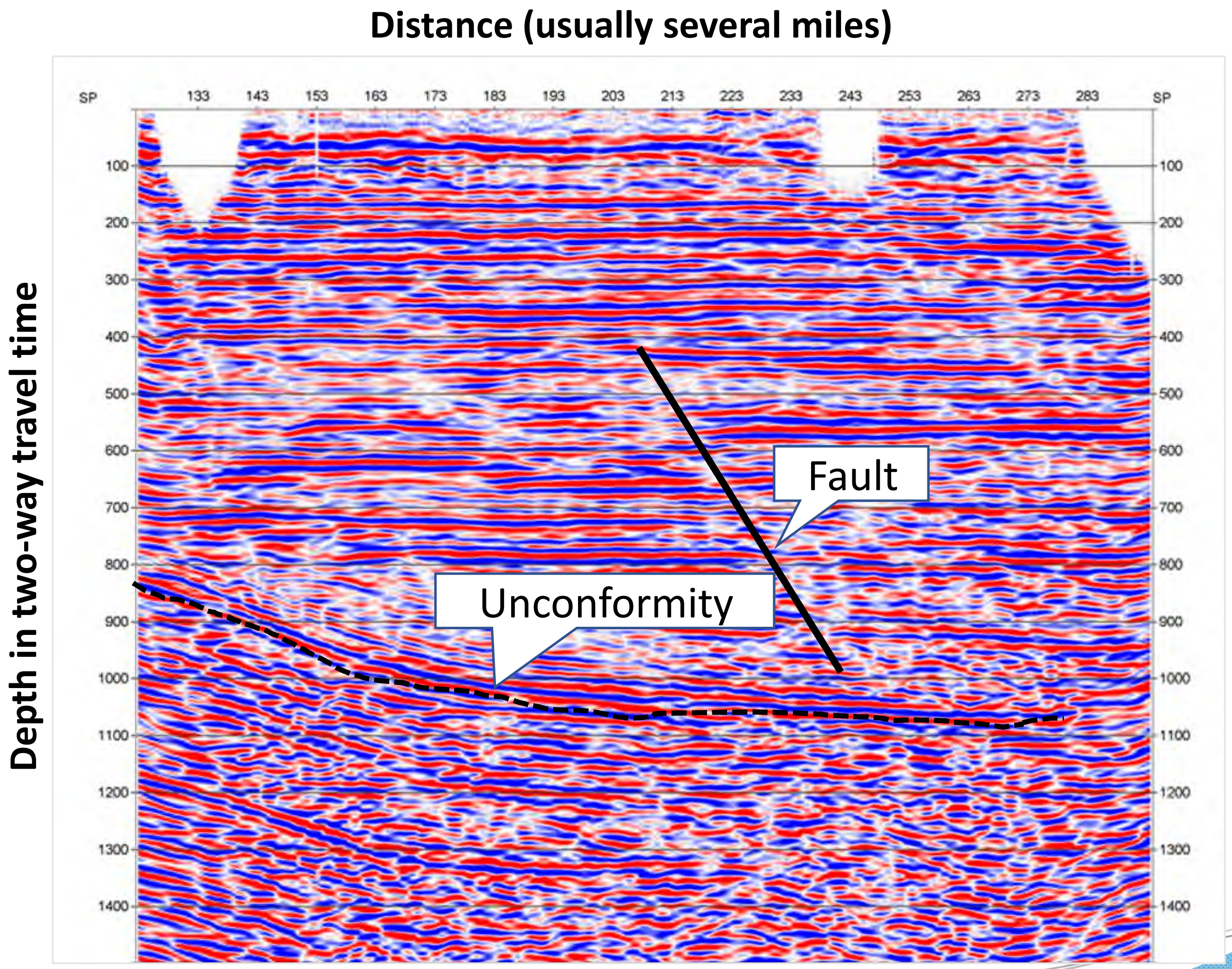
Wireless Data Acquisition

Wireless Geophones
No cables

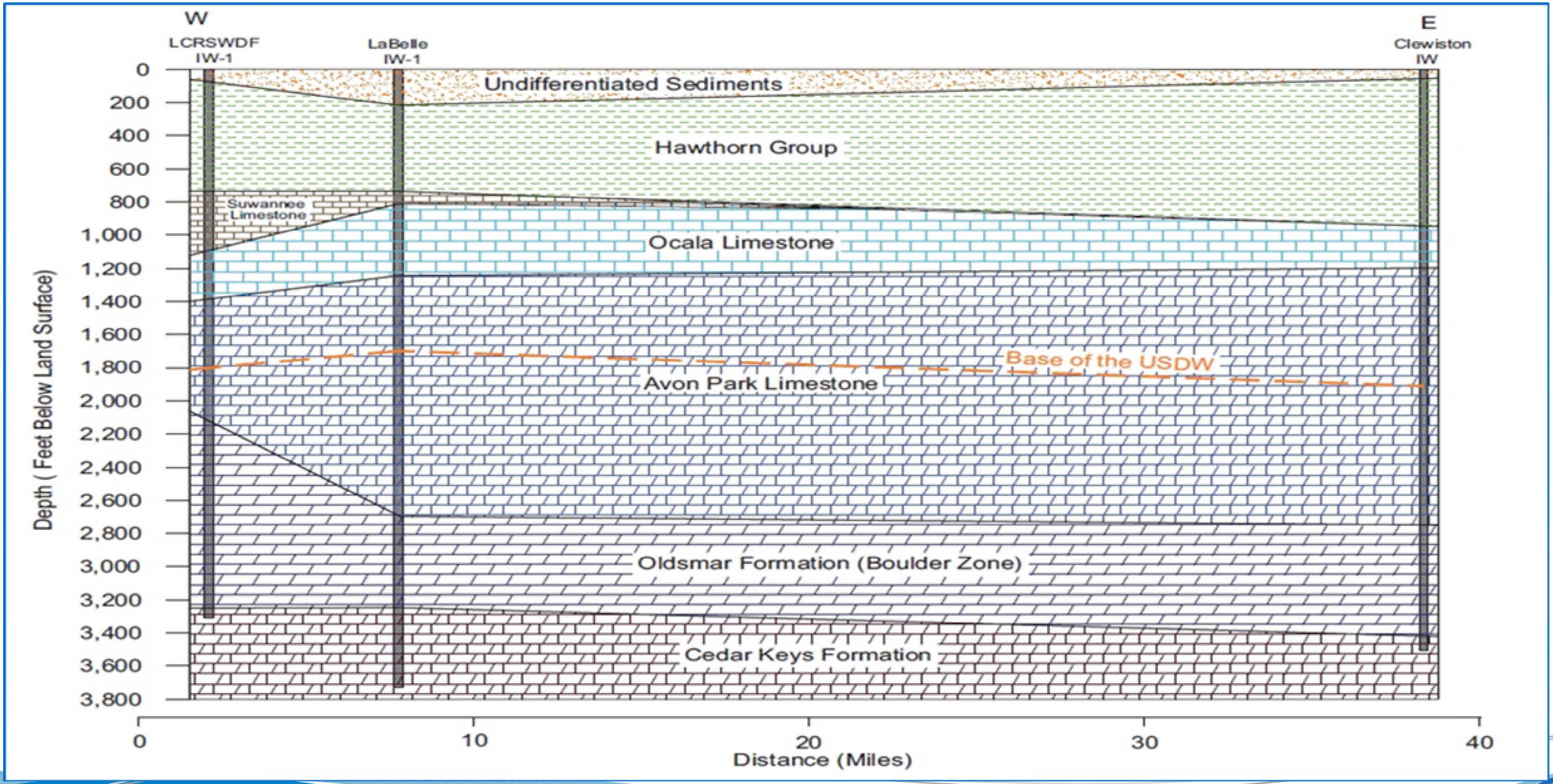
COLLIER GEOPHYSICS

Typical 2D Seismic Section

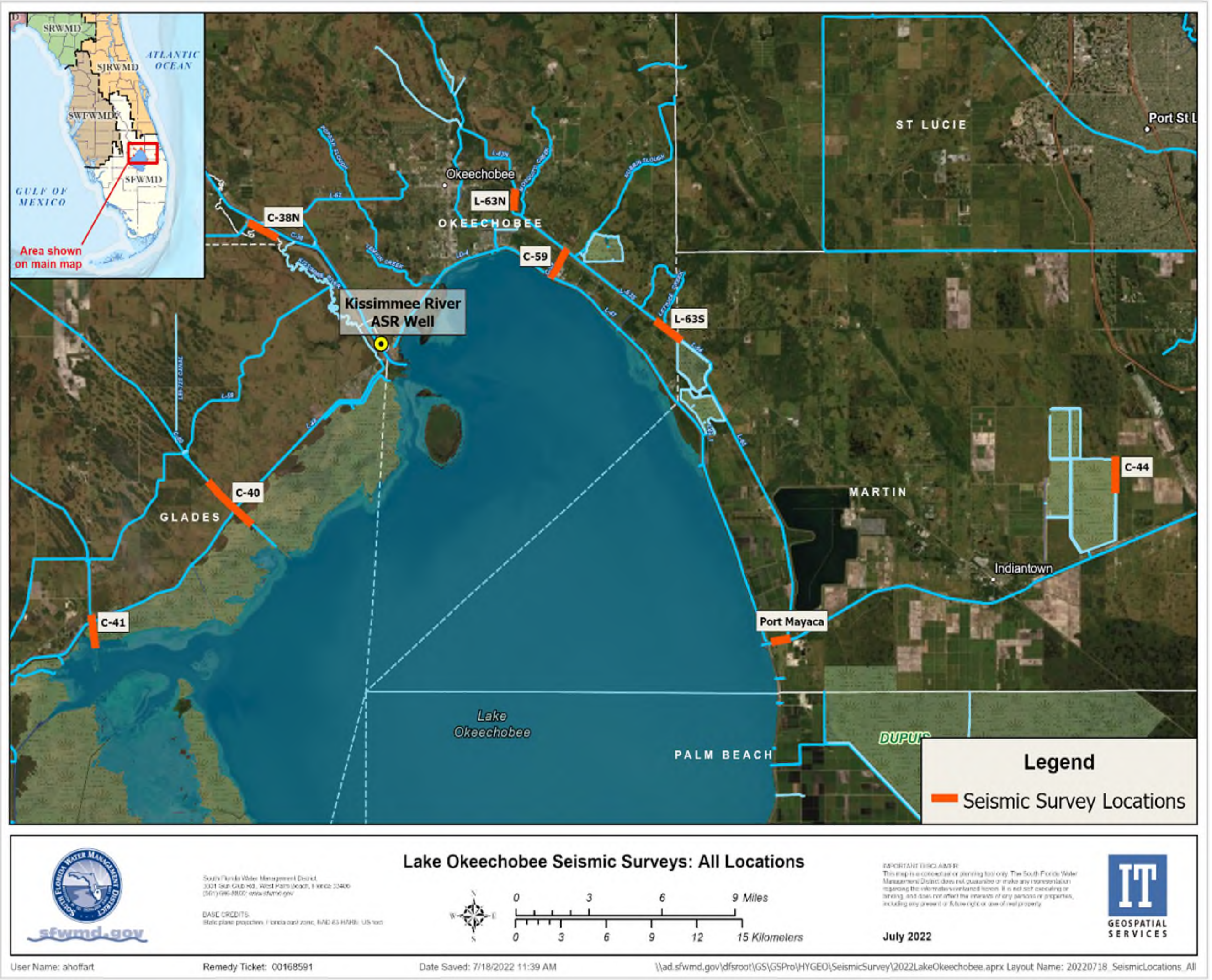
- Data processed into seismic section
- Plots combined seismic traces at common depth points
- Each reflector (peak and trough) is a geologic layer
- Depth in two-way travel time
- Need velocity measurement to convert time to depth



2018 Lithological Well Log Cross-Section



2022 SFWMD 2D Seismic Program & Parameters



SFWMD 2022 2D Seismic Program

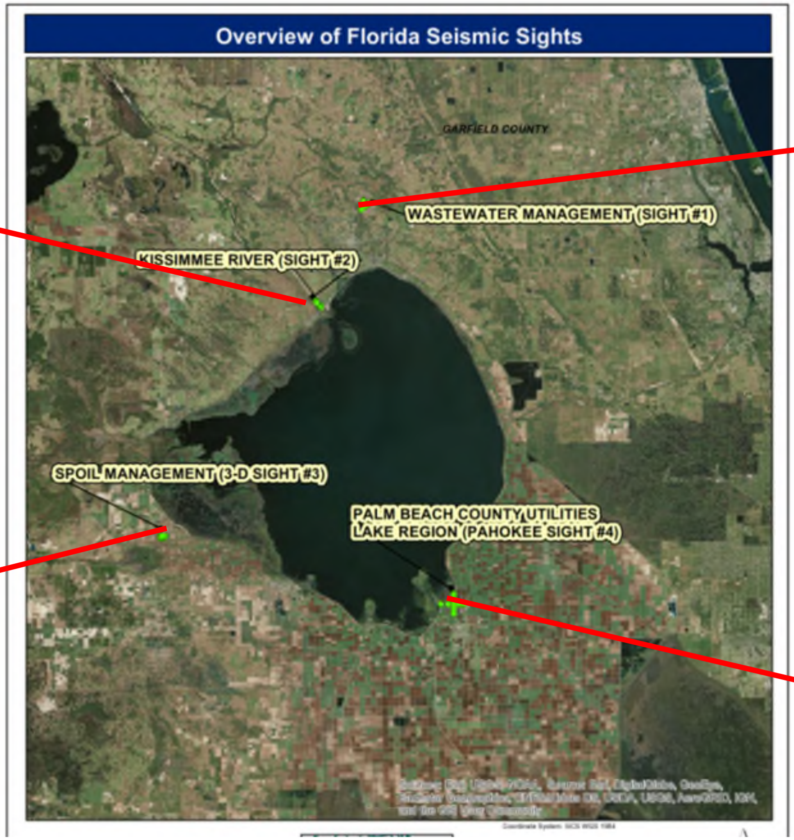
- Line C-38N (1 Mile)
- Line C-40 (2 Miles)
- Line C-41 (1 Mile)
- Line C-44 (1 Mile)
- Line C-59 (1 Mile)
- Line L-63N (1/2 Mile)
- Line L-63S (1 Mile)
- Port Mayaca Line (1/2 Mile)

Data Acquisition Parameters

- RCVR Interval : 50ft
- SRC Interval : 100ft
- Seismic Sampling : 0.5 ms
- Record Length : 3 seconds
- PreAmp Gain : 24dB

2018 SFWMD Lake Okeechobee Seismic Program

<u>2D swath survey</u>



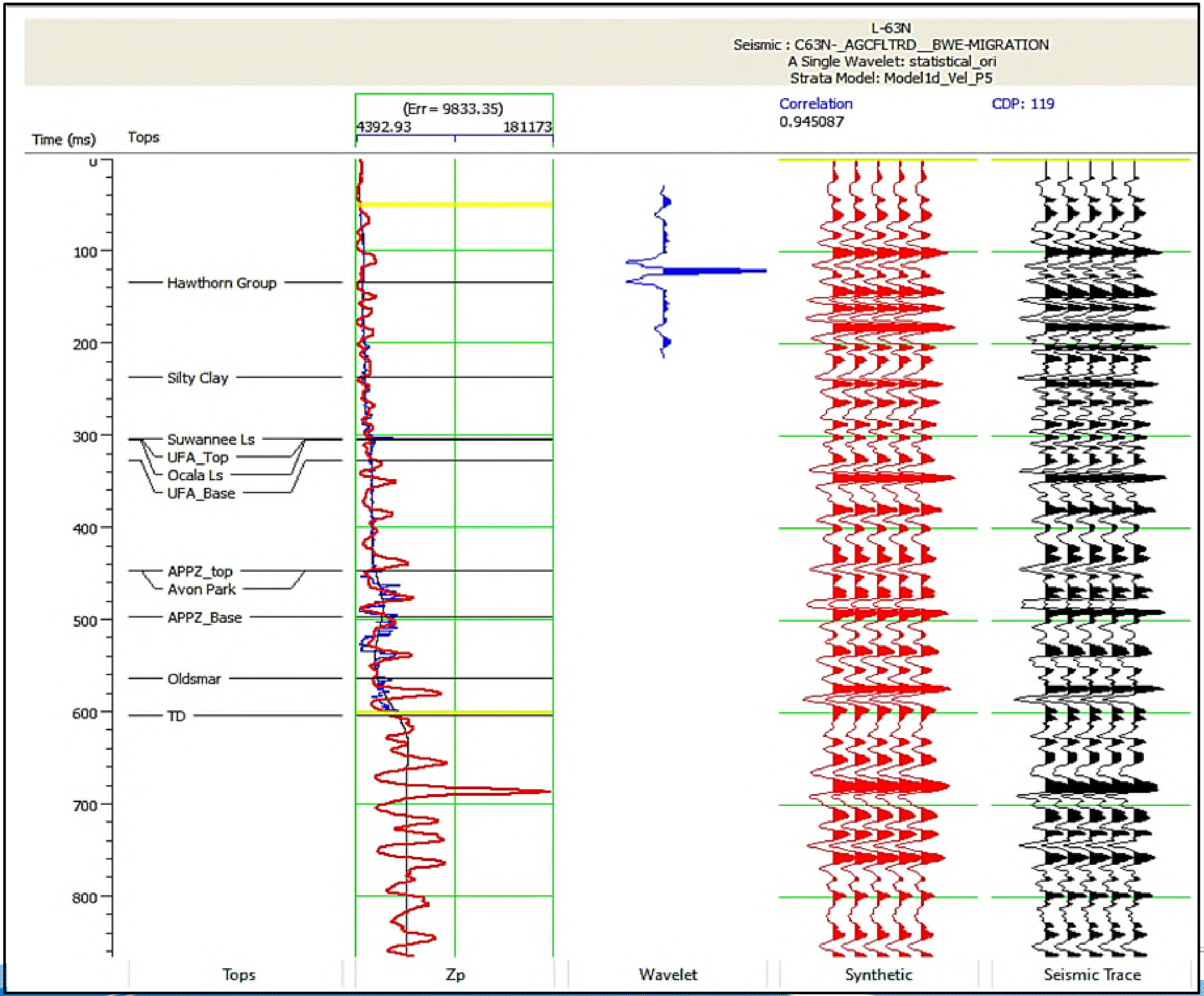
2D swath survey

<u>3D survey:</u>
8 receiver lines with 11 source lines

2 Orthogonal 2D Survey Segments

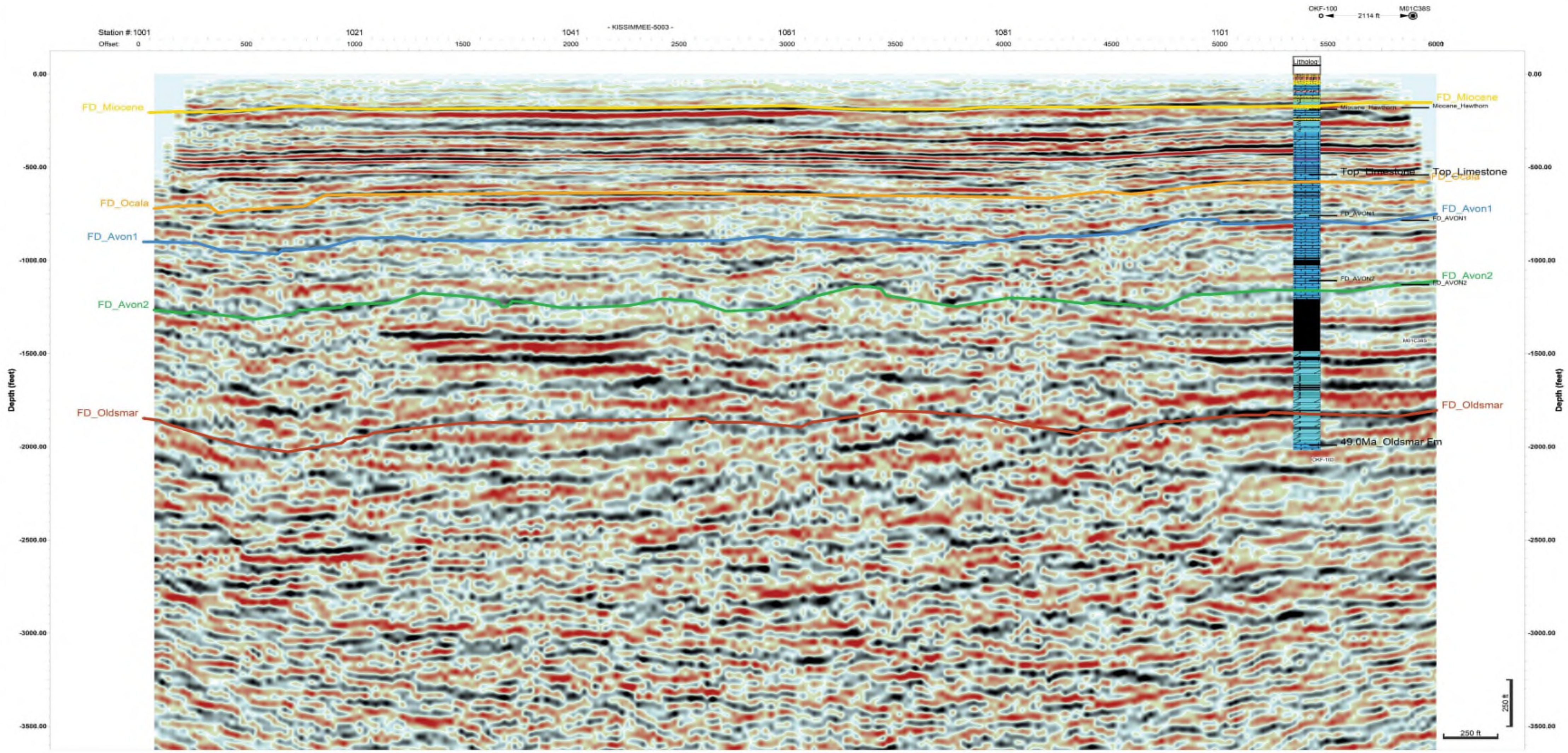
COLLIER GEOPHYSICS

Synthetic Seismogram and Seismic Inversion Results



- Using the Acoustic Impedance from the well log data (blue curve), along with the seismic wavelet derived from the seismic data, a new Acoustic Impedance curve is generated (red curve).
- Using "recursive" seismic inversion, a more precise synthetic seismogram is generated. Correlation of the synthetic seismogram with traces at CDP 119 have a 94% fit.
- The next step is to generate the seismic attributes sections, co-blending Acoustic Impedance, Variance Attribute, Well Log Porosity and Permeability data, with the seismic data inversion process.

COLLIER GEOPHYSICS



Seismic Depth Image of Line C-38S with Interpretation

Figure 21

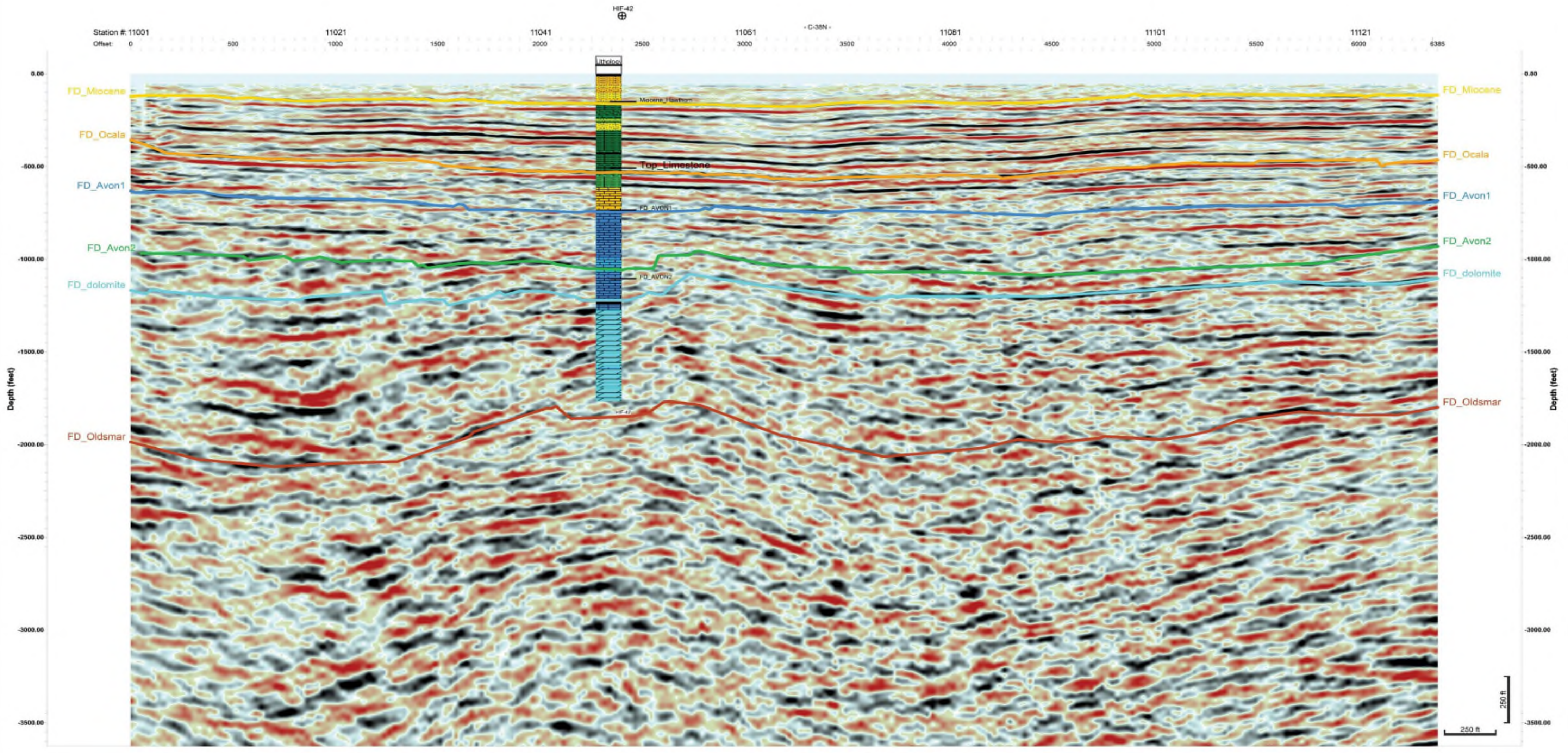
Locator Map Datum/Projection:
NAD83 StatePlane FL East (US Ft)

Created: Aug 4, 2023 (CVW)

Source(s): Collier Geophysics, ESRI Street

sfwmd.gov

COLLIER GEOPHYSICS



Seismic Depth Image of Line C-38N with Interpretation

Figure 23

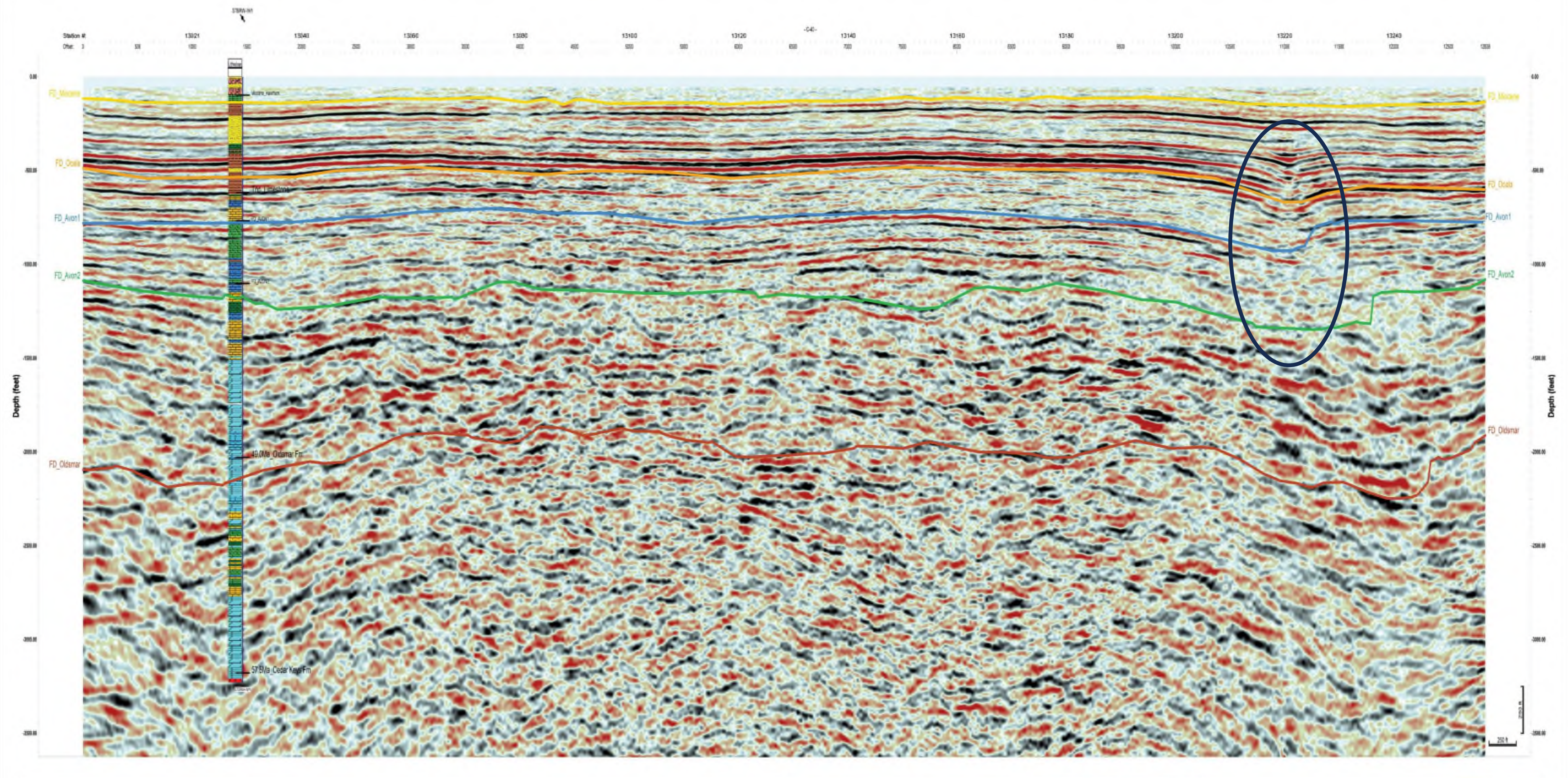
Locator Map Datum/Projection:
NAD83 StatePlane FL East (US Ft)

Created: Aug 3, 2023 (CVW)

Source(s): Collier Geophysics, ESRI Street

sfwmd.gov

COLLIER GEOPHYSICS



Seismic Depth Image of Line C-40 with Interpretation

Figure 31

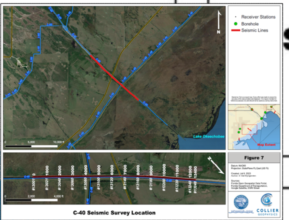
Locator Map Datum/Projection:
NAD83 StatePlane FL East (US Ft)

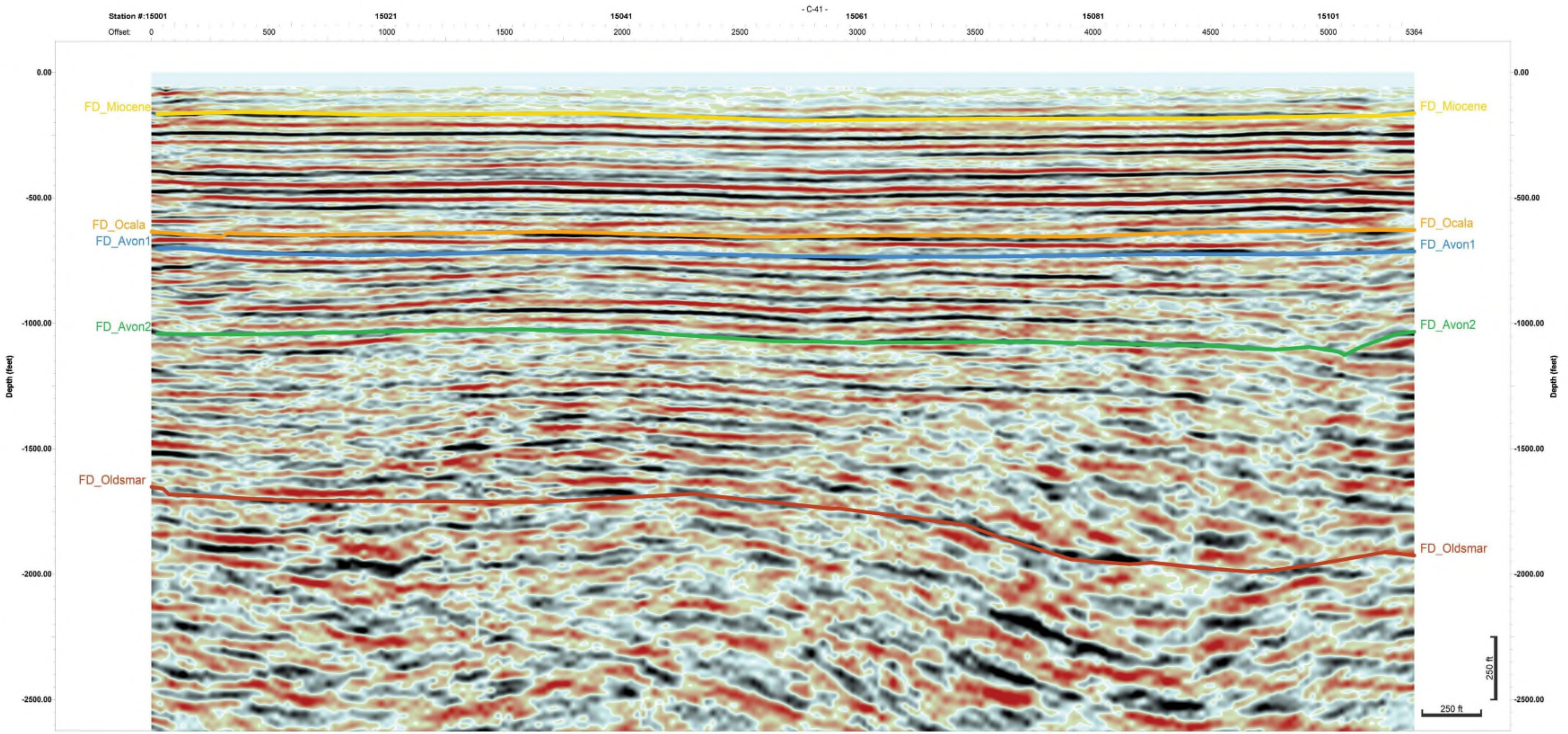
Created: Aug 4, 2023 (CVW)

Source(s): Collier Geophysics, ESRI Street

sfwmd.gov

COLLIER GEOPHYSICS





Seismic Depth Image of Line C-41 with Interpretation

Figure 33

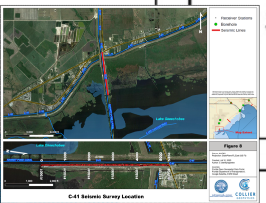
Locator Map Datum/Projection:
NAD83 StatePlane FL East (US Ft)

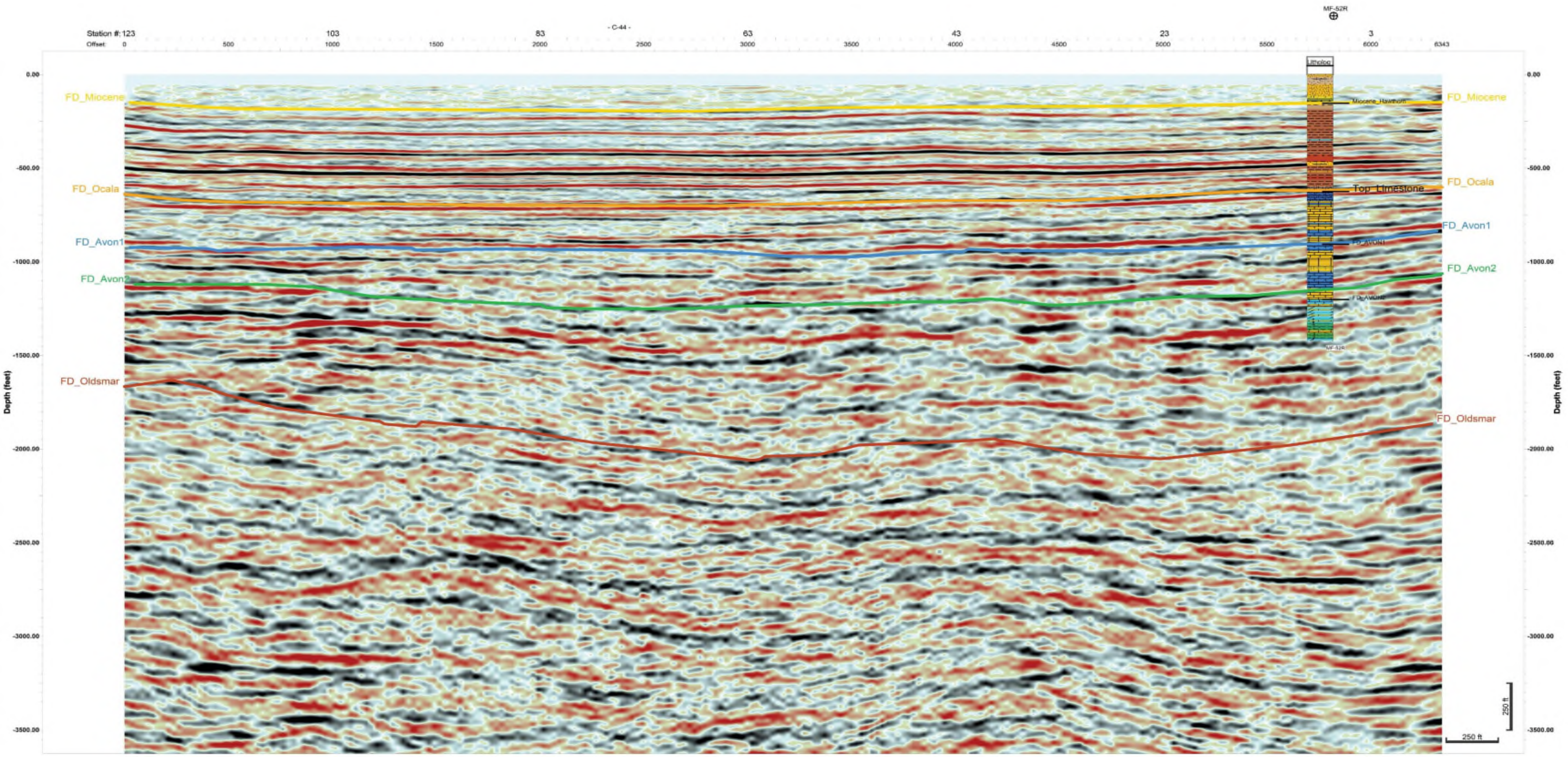
Created: Aug 4, 2023 (CVW)

Source(s): Collier Geophysics, ESRI Street

sfwmd.gov

COLLIER GEOPHYSICS





Seismic Depth Image of Line C-44 with Interpretation

Figure 35

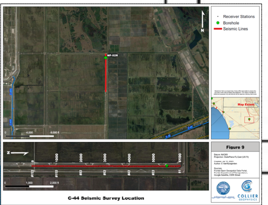
Locator Map Datum/Projection:
NAD83 StatePlane FL East (US Ft)

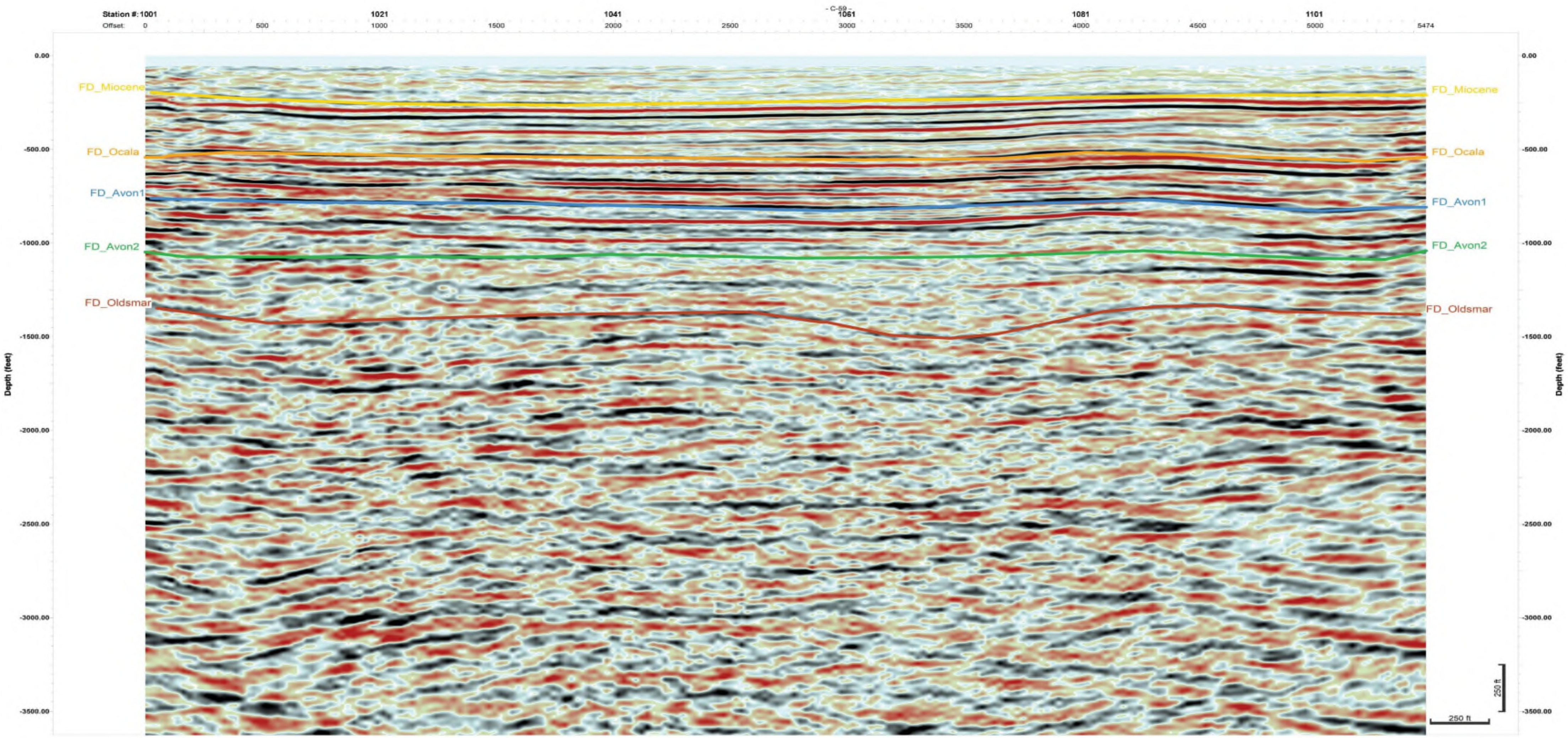
Created: Aug 4, 2023 (CVW)

Source(s): Collier Geophysics, ESRI Street

sfwmd.gov

COLLIER GEOPHYSICS





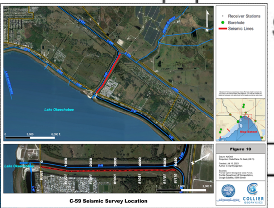
Seismic Depth Image of Line C-59 with Interpretation

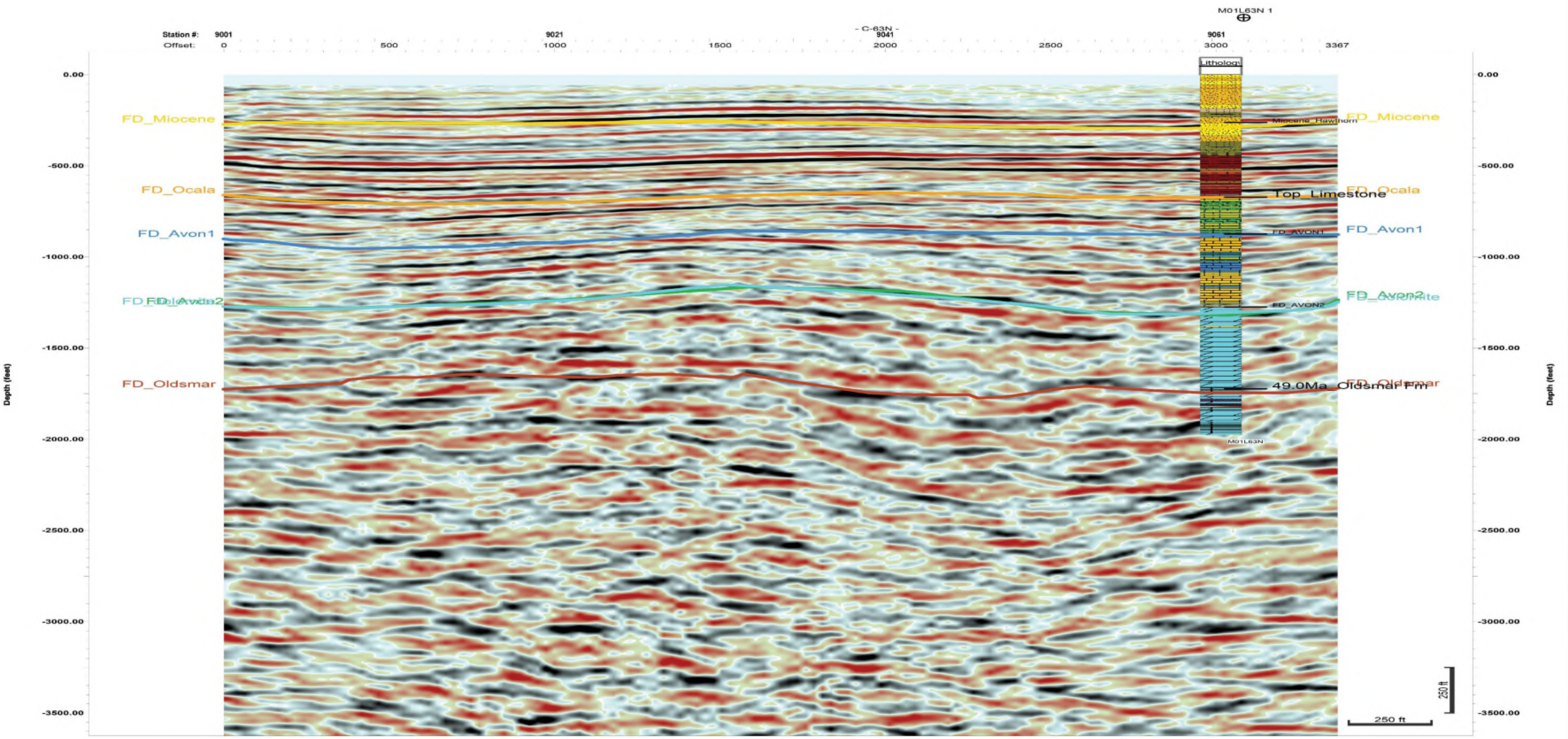
Figure 27

Locator Map Datum/Projection:
NAD83 StatePlane FL East (US Ft)

Created: Aug 4, 2023 (CVW)

Source(s): Collier Geophysics, ESRI Street





Seismic Depth Image of Line L-63N with Interpretation

Figure 25

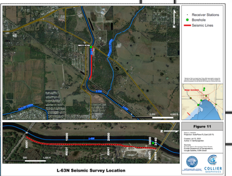
Locator Map Datum/Projection:
NAD83 StatePlane FL East (US Ft)

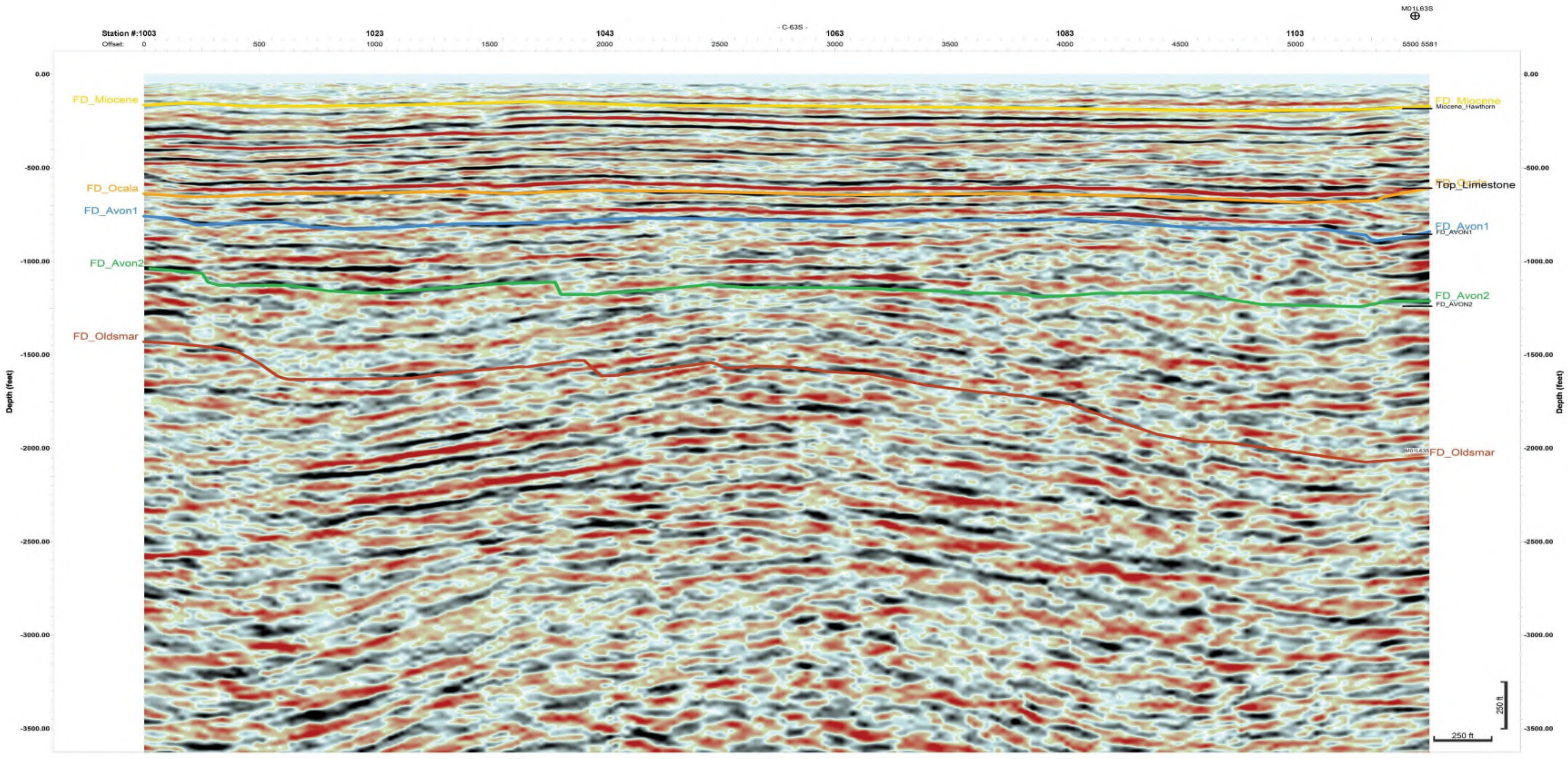
Created: Aug 4, 2023 (CVW)

Source(s): Collier Geophysics, ESRI Street

sfwmd.gov

COLLIER GEOPHYSICS





Seismic Depth Image of Line L-63S with Interpretation

Figure 29

Locator Map Datum/Projection:
NAD83 StatePlane FL East (US Ft)

Created: Aug 4, 2023 (CVW)

Source(s): Collier Geophysics, ESRI Street

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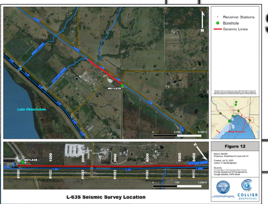
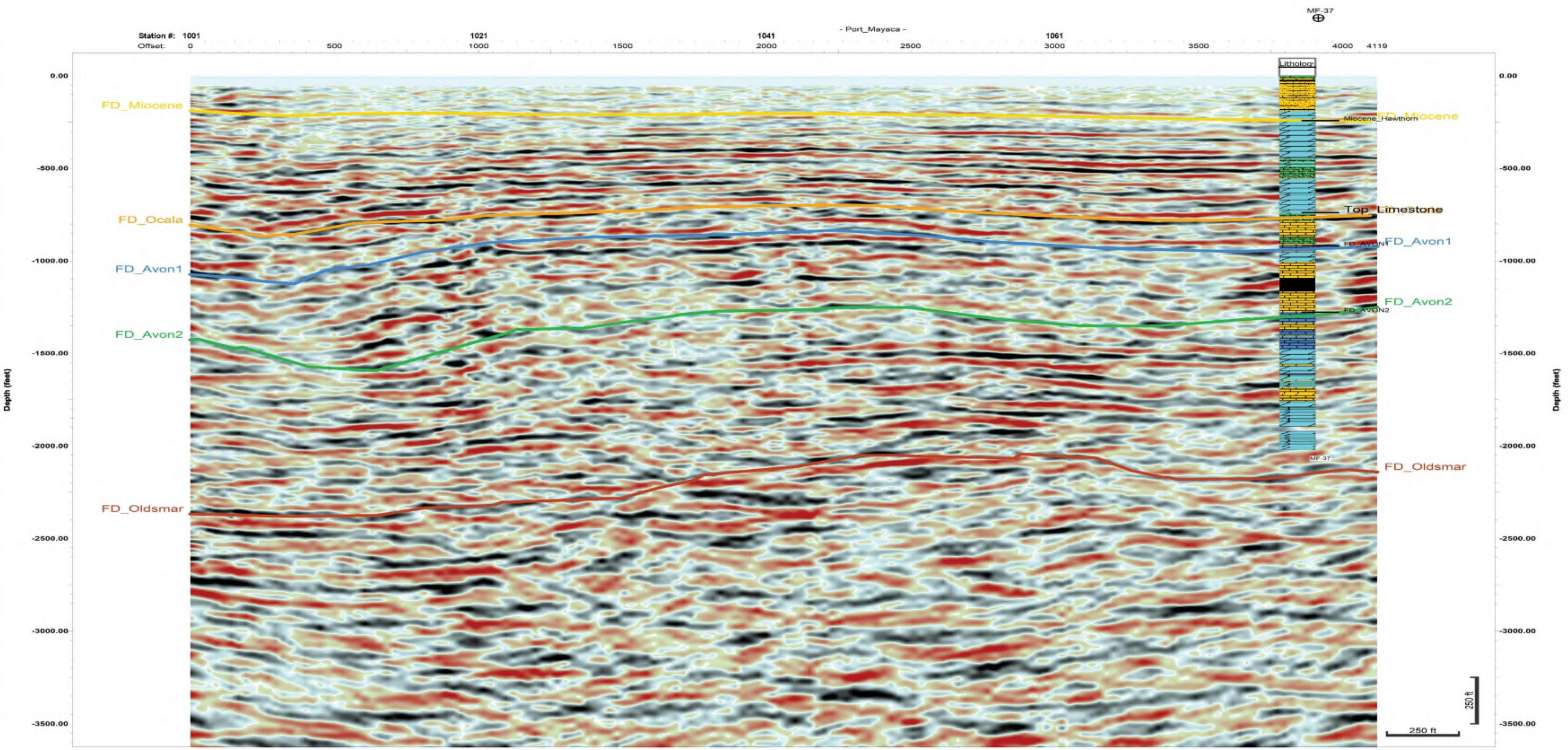
COLLIER GEOPHYSICS





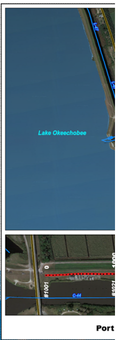


Figure 37

Seismic Depth Image of Line Port Mayaca with Interpretation

Locator Map Datum/Projection:
NAD83 StatePlane FL East (US Ft)

Created: Aug 4, 2023 (CVW)

Source(s): Collier Geophysics, ESRI Street

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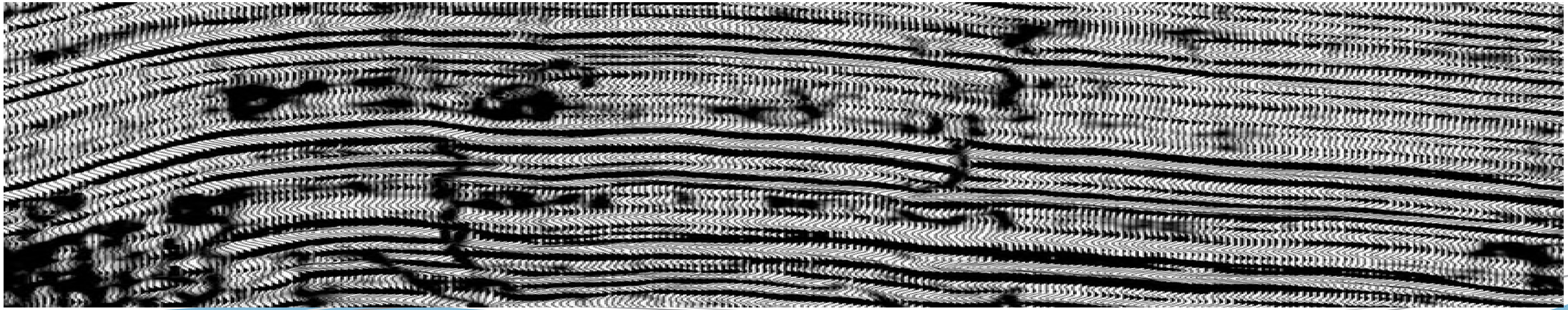
COLLIER GEOPHYSICS

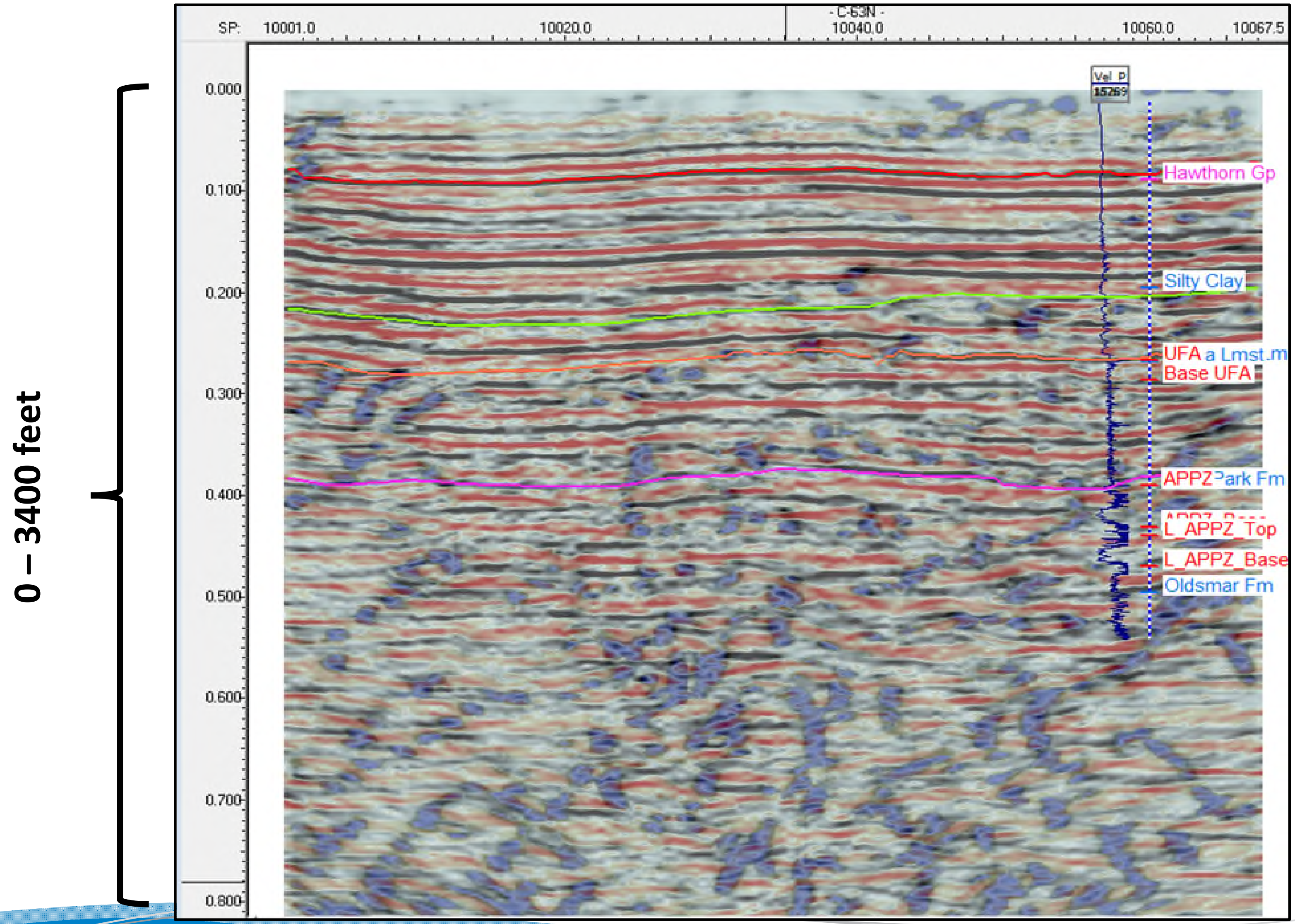
What is a Seismic Attribute?

- **In reflection seismology, a seismic attribute is a quantity and/or quality extracted or derived from seismic data that can be analyzed or processed in order to enhance information that might be more subtle in a traditional seismic image, providing a better geological or geophysical interpretation of the data.**

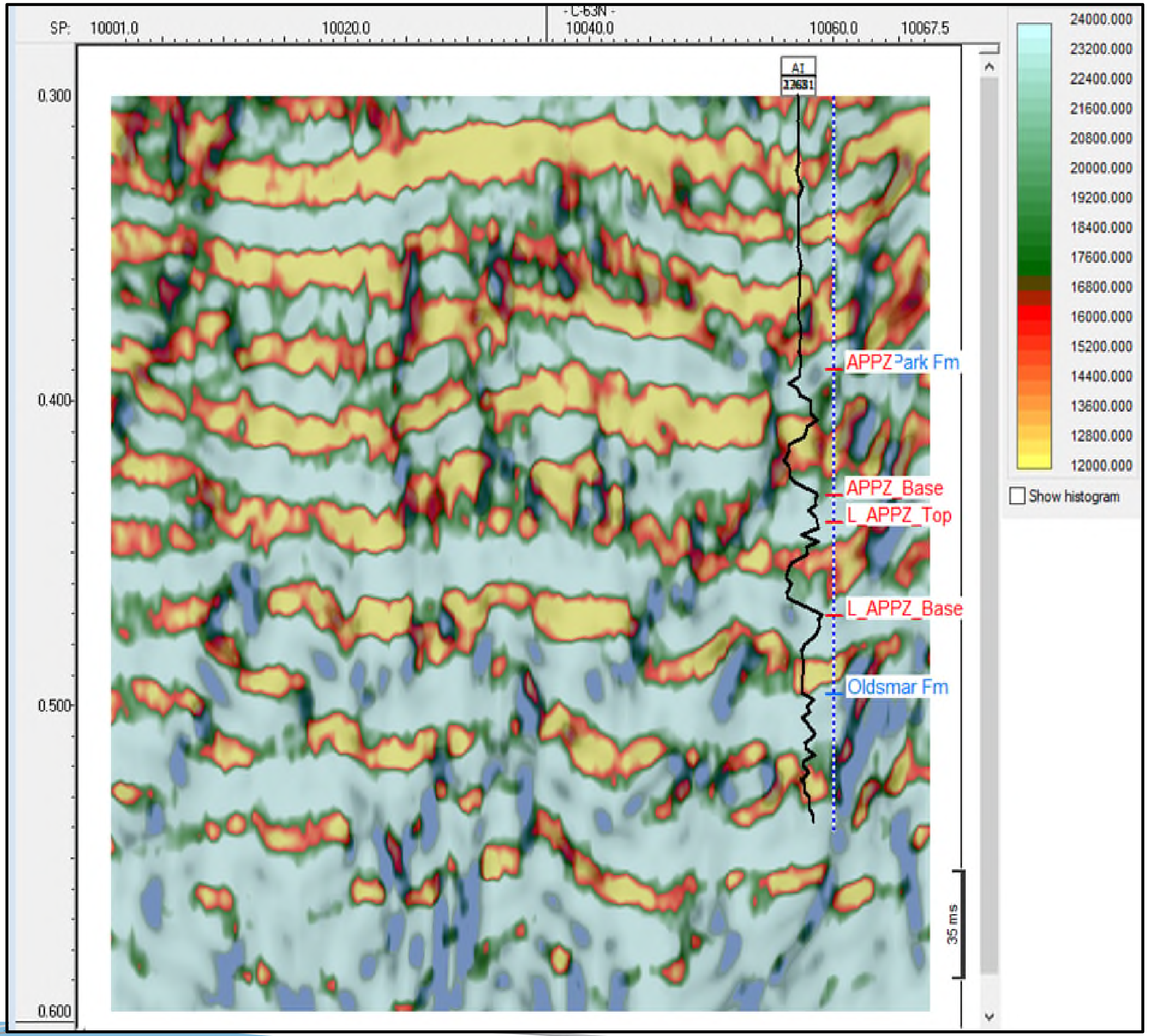
- **For aquifer delineation projects, the integration of seismic and well log information can be used to expand and extend understanding of the hydro-stratigraphic structure, porosity and permeability zones, general flow patterns…..and more!**



L-63N 2D Seismic Data Co-Blended with Variance Attribute



Acoustic Impedance Co-Blended with Variance Attribute

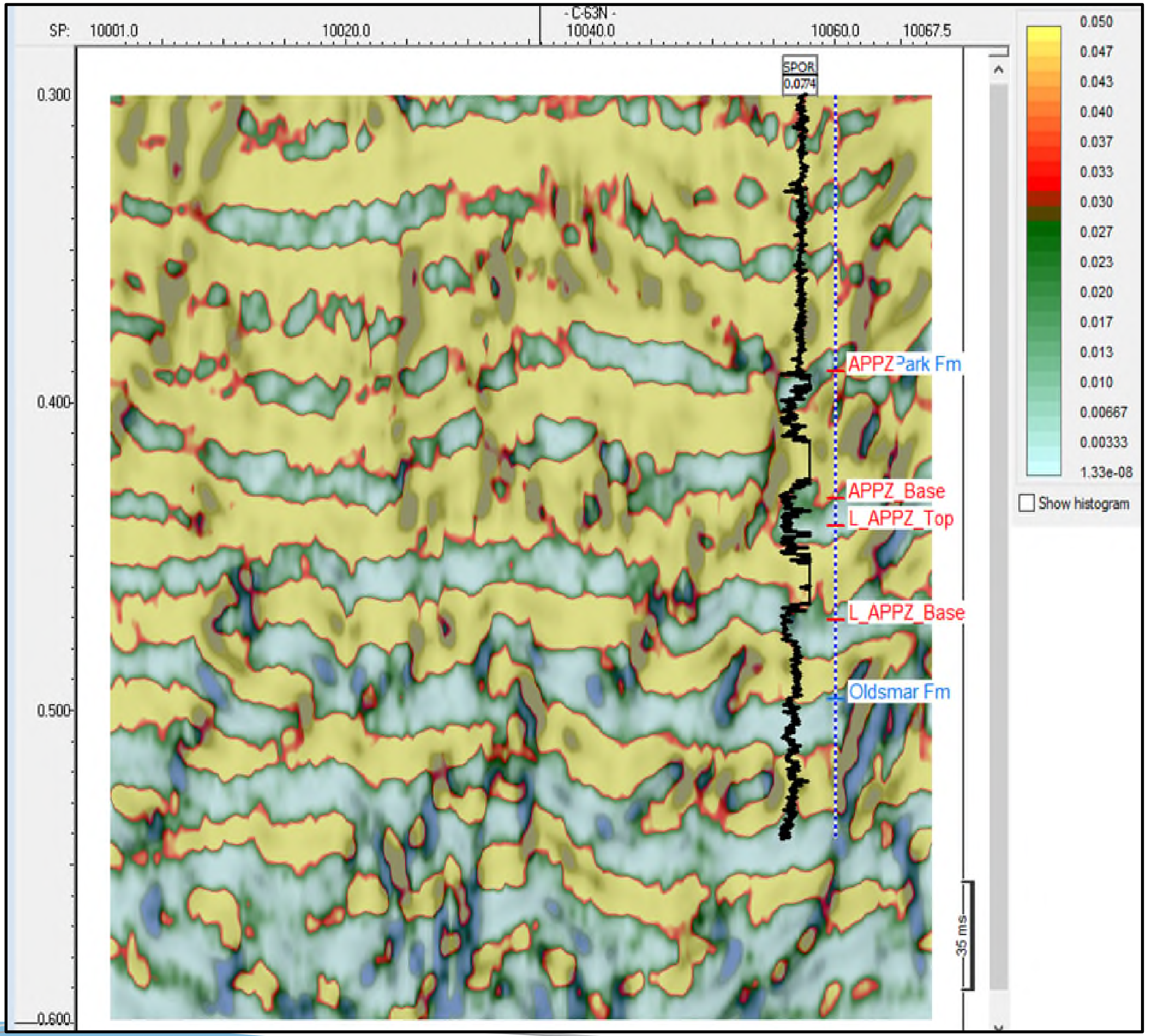


~800 – 2400 feet

Acoustic Impedance Section

Porosity Section from Converting AI using Well Log Crossplot Data

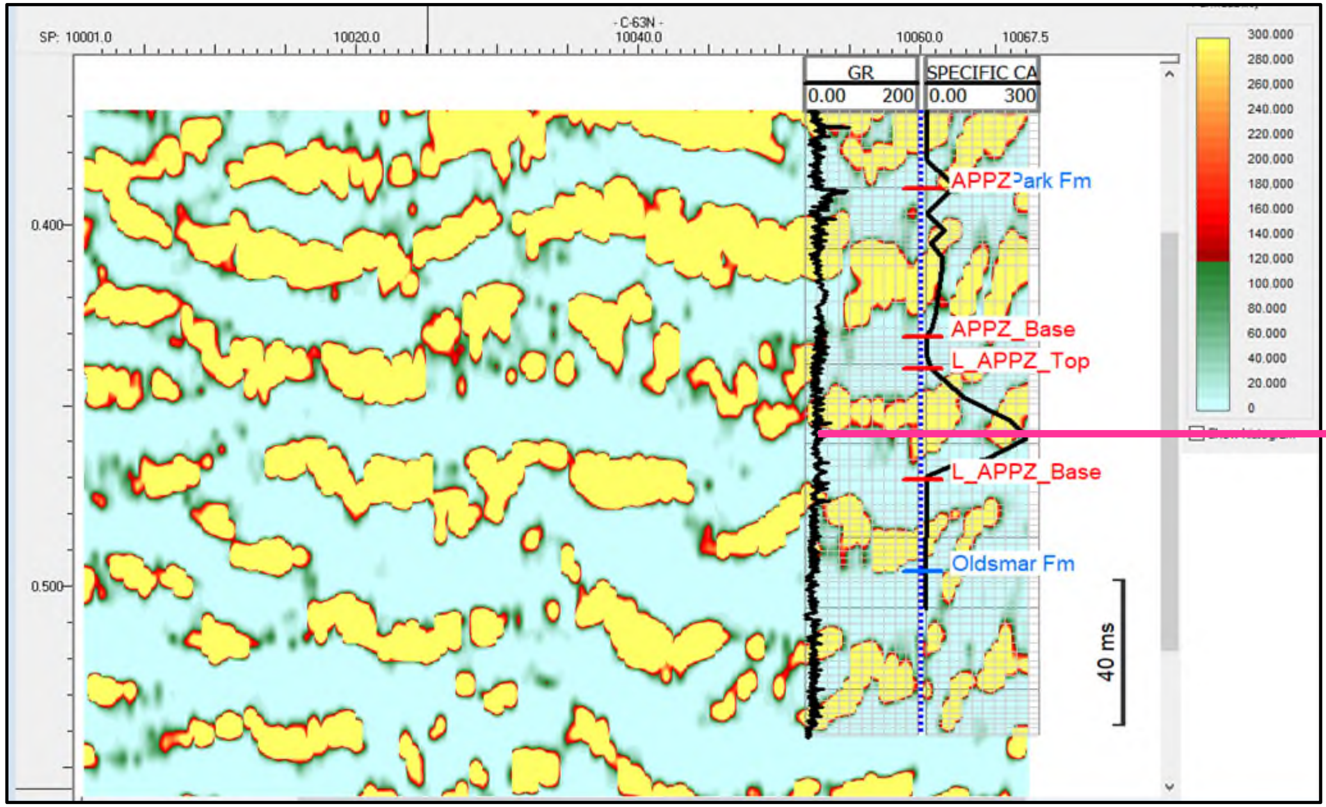
~800 – 2500 feet

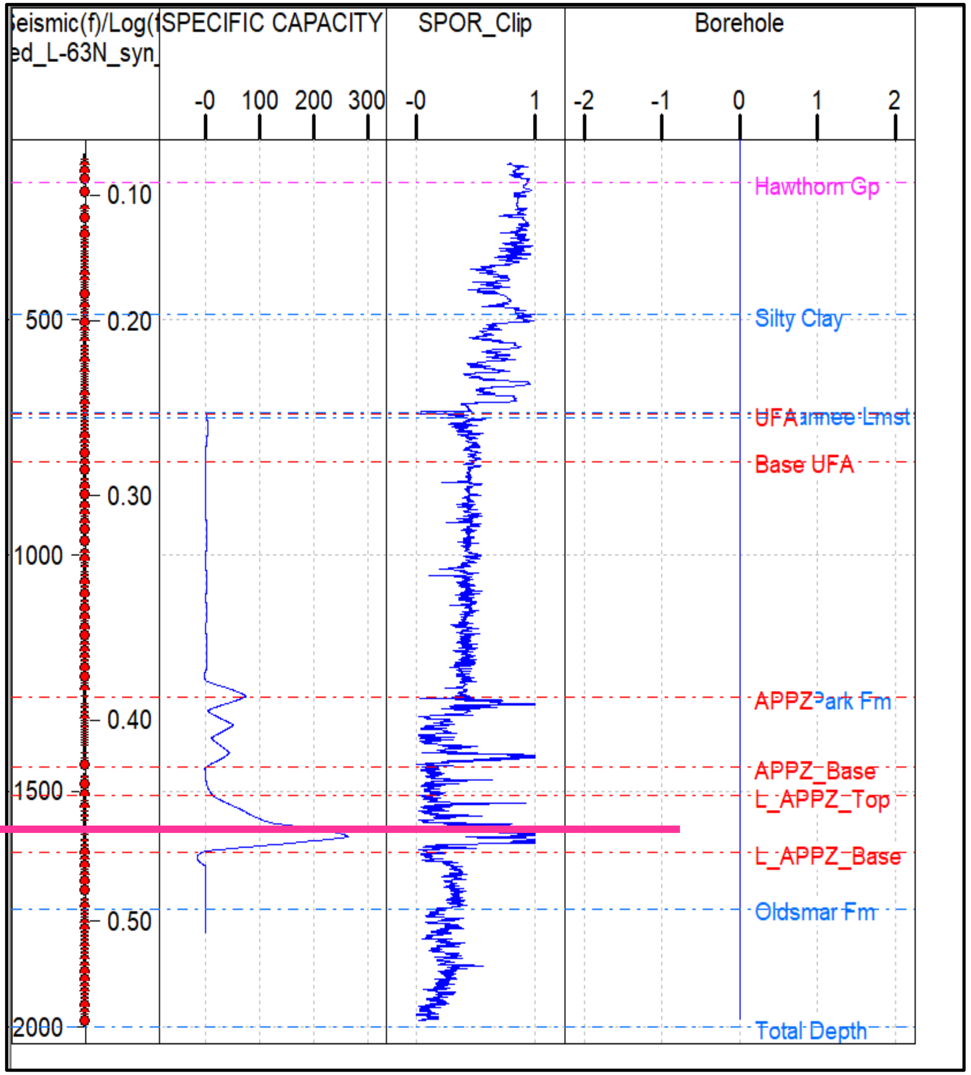


Porosity Section

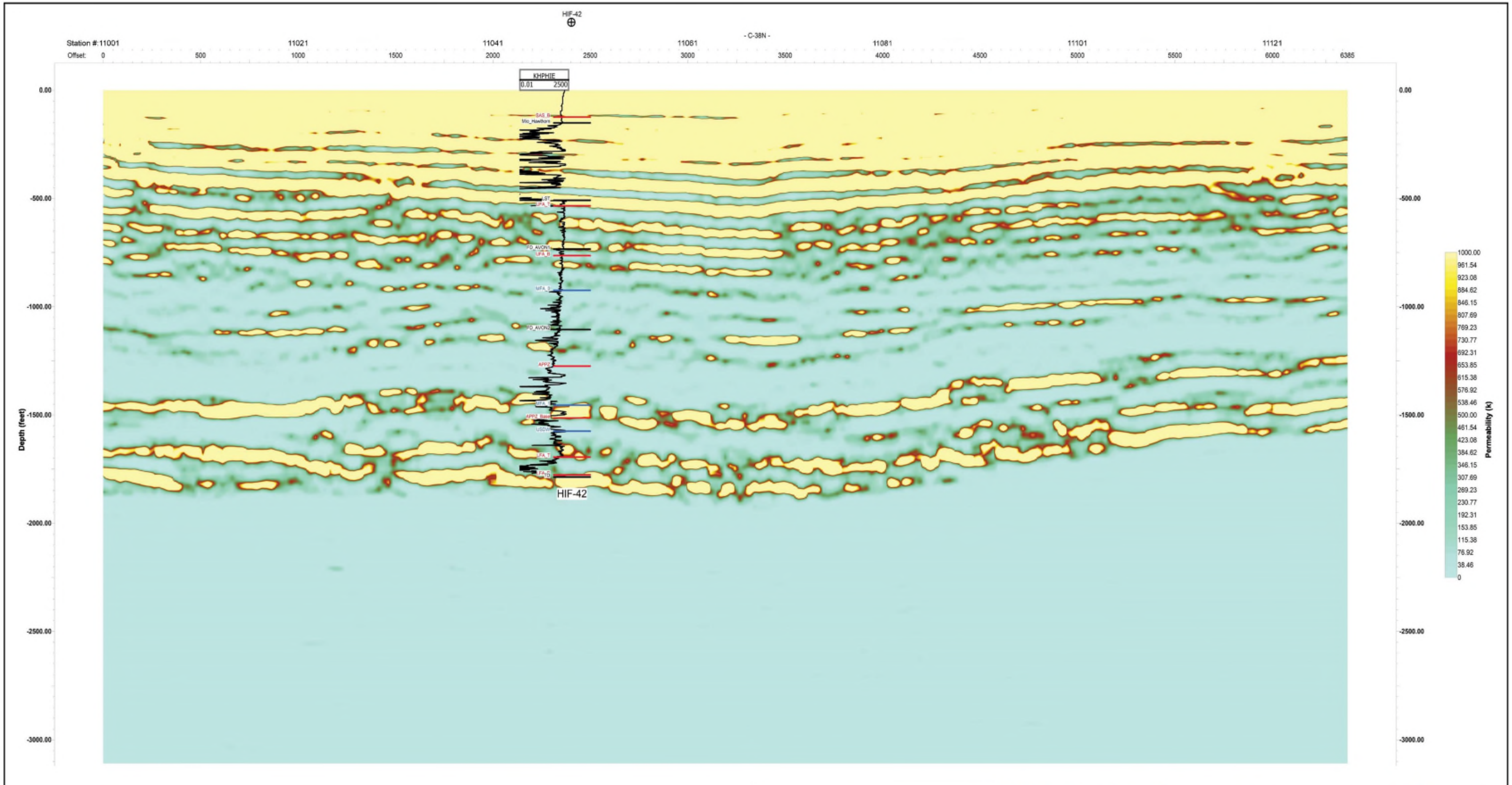
COLLIER GEOPHYSICS

Permeability Section Derived from Sonic Porosity vs Permeability Well Log Crossplot Data





COLLIER GEOPHYSICS



Permeability Estimate for Line C-38N

Figure 59

Locator Map Datum/Projection:
NAD83 StatePlane FL East (US Ft)

Created: Aug 6, 2023 (CVW)

Source(s): Collier Geophysics, ESRI Street

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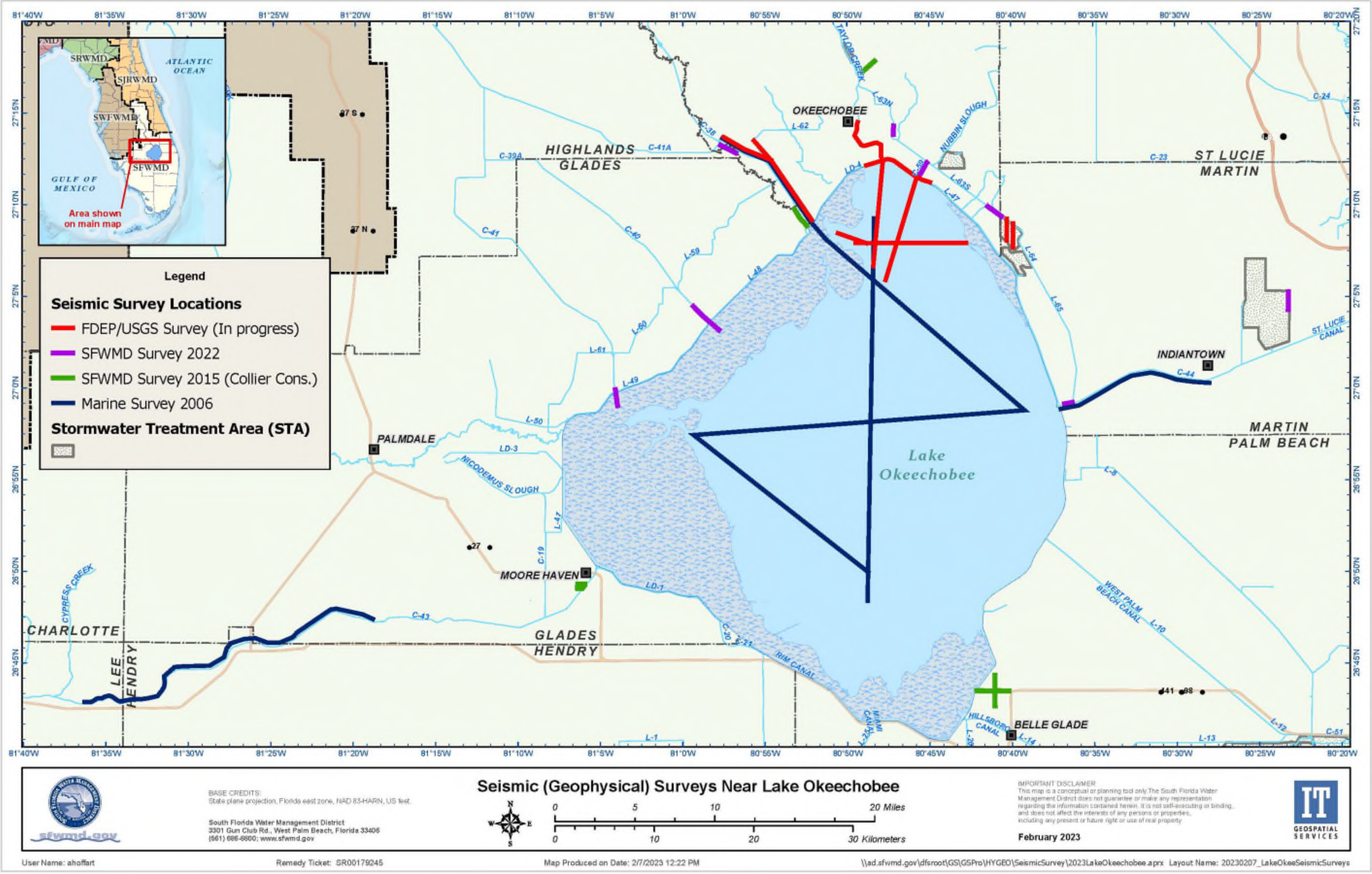
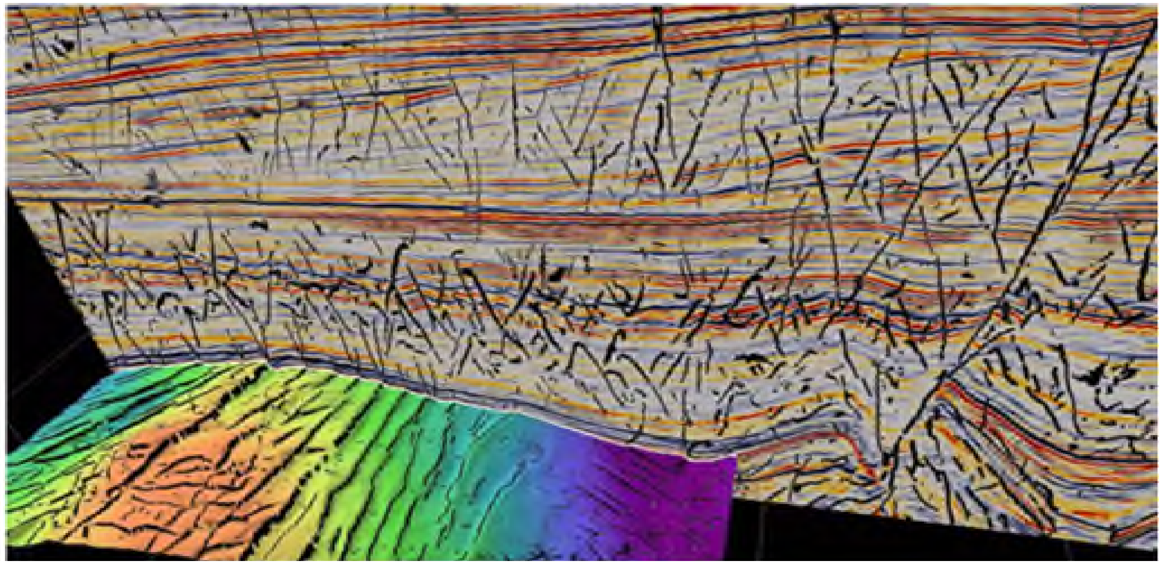
COLLIER GEOPHYSICS

Bringing Together the Multiple Data sets into a Single Data Set With Common Processing



Questions & Discussion



ERDC LOWRP ASR STUDIES

Matthew Farthing, Tony Bednar, Jay Clausen, Mandy Michalsen, Chuck Downer, Martin Page
US Army Engineer Research and Development Center

Fred Day-Lewis, Jim Szecsody
Pacific Northwest National Lab

July 10, 2024

U.S. ARMY

US Army Corps of Engineers®

ERDC
ENGINEER RESEARCH & DEVELOPMENT CENTER

BACKGROUND

Background: Three categories of engineering considerations associated with Aquifer Storage and Recovery (ASR) element of the Lake Okeechobee Watershed Restoration Project (LOWRP):

- Mobilization and release of pollutants, contaminants, or hazardous substance, and hazardous, toxic, and radioactive wastes (HTRW) constituents;
- First-cost construction; and
- Long-term O&M cost.

Approach: Five interrelated tasks, primarily focused on water quality concerns around arsenic mobilization.

Key requirements:

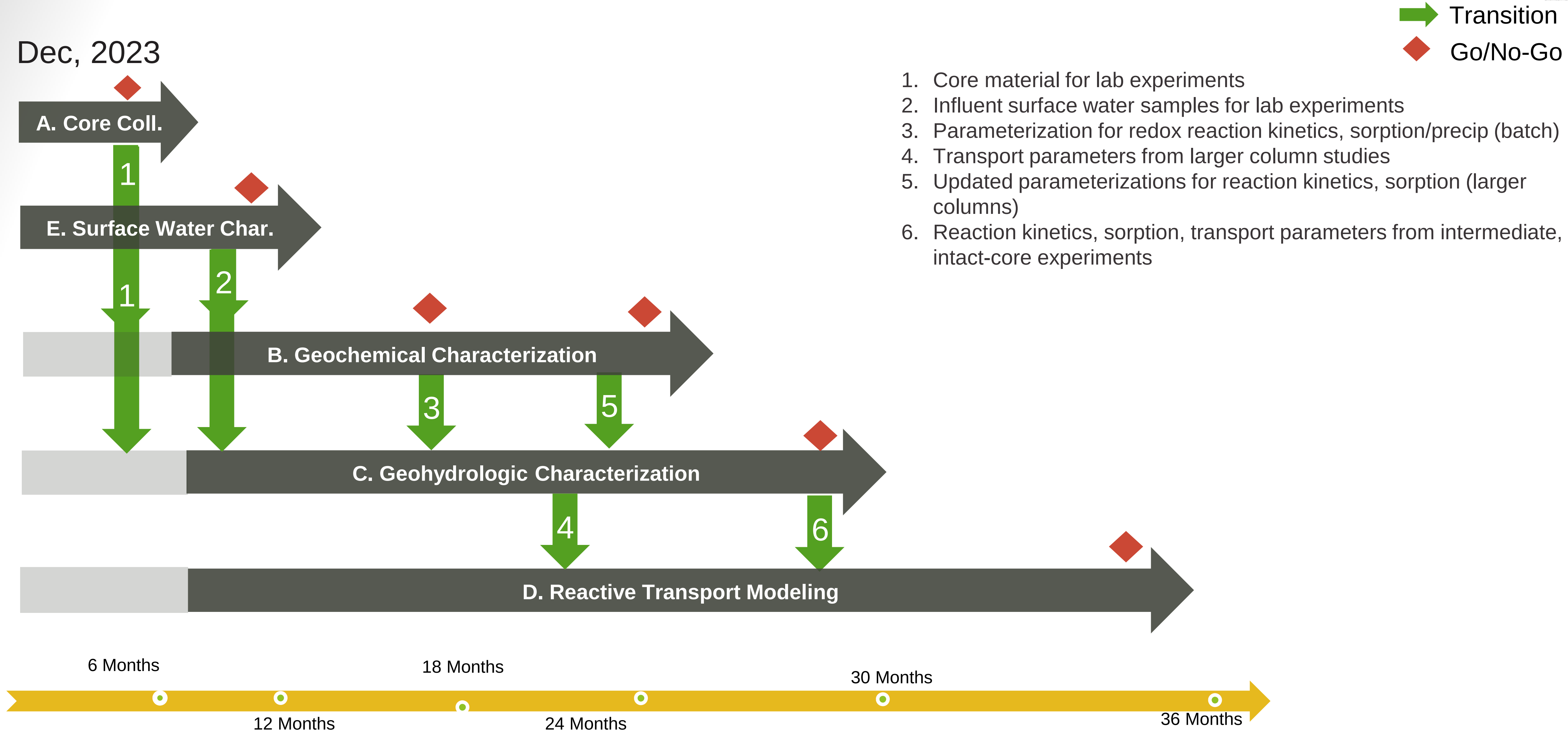
- ERDC work will pursue only *ex situ* (i.e., lab and modeling) investigations
- ERDC will collaborate and coordinate with on-going and planned SAJ and SFWMD LOWRP investigations
- Science-based consensus on acceptable risk-levels

Key partners: Pacific Northwest National Lab (PNNL)

Tasks

1. Core collection: Michalsen (EL), Bednar (EL)
2. Geochemical Characterization: Clausen (CRREL), Bednar (EL)
3. Geohydrologic Characterization: Michalsen (EL), Day-Lewis (PNNL), Szecsody (PNNL)
4. Reactive Transport Modeling: Chuck Downer (CHL)
5. Surface Water Characterization: Martin Page (EL)

PROPOSED TASKS



1. Core material for lab experiments
2. Influent surface water samples for lab experiments
3. Parameterization for redox reaction kinetics, sorption/precip (batch)
4. Transport parameters from larger column studies
5. Updated parameterizations for reaction kinetics, sorption (larger columns)
6. Reaction kinetics, sorption, transport parameters from intermediate, intact-core experiments

TASK A: CORE COLLECTION FIELD ACTIVITIES

Team Members

ERDC: Mandy Michalsen, Jay Clausen, Stephen Turnbull, Tony Bednar, Matthew Farthing

PNNL: Fred Day-Lewis, James Szecsody

SFWMD: Jennifer Gent

Stantec: Caroline Smith, John Wu, Rick Cowles

Objectives

Obtain subsurface core material and groundwater from the Upper Floridan Aquifer (UFA) and Avon Park Permeable Zone (APPZ)

- Required for laboratory experiments planned during Tasks B & C
- Preserve anoxic/suboxic conditions

Transport materials to participating organizations to perform subsequent project tasks

- ERDC-EL, Vicksburg, MS
- ERDC-CRREL, Hanover, NH
- PNNL, Richland, WA

Core sample collected by Stantec/All Webbs Drilling

Approach

Leverage drilling of APPZ Aquifer Storage Recovery wells at L63-N for core collection

- Cores extruded while submersed in tank filled with UFA water
- Core sections placed in 6-inch diameter PVC tubes while submersed
- Sodium dithionite (1 g/tube) added to consume trace oxygen, and cores sealed with minimal headspace

Maintain sample integrity and chain-of-custody in transport

- ERDC personnel drove core samples to each organization

Assess initial core sample storage water for Arsenic; suitability screening

- Analyzed core sample storage water by GFAAS as first-order assessment of equilibrated arsenic levels in UFA water in core chambers
- Screened select core chamber contents for suitability at PNNL

Core sample collection and preservation

Results

Twelve samples collected from nine cores

- 10 from the UFA (694–754 feet bls)
- 2 from the APPZ (1301–1311 feet bls)
- Each 4-feet long and 4-inch diameter

All core materials delivered to labs

- 6 cores delivered to PNNL, in storage (arrive 28-Mar)
- 6 cores delivered to CRREL, in storage (arrive 26-Mar)

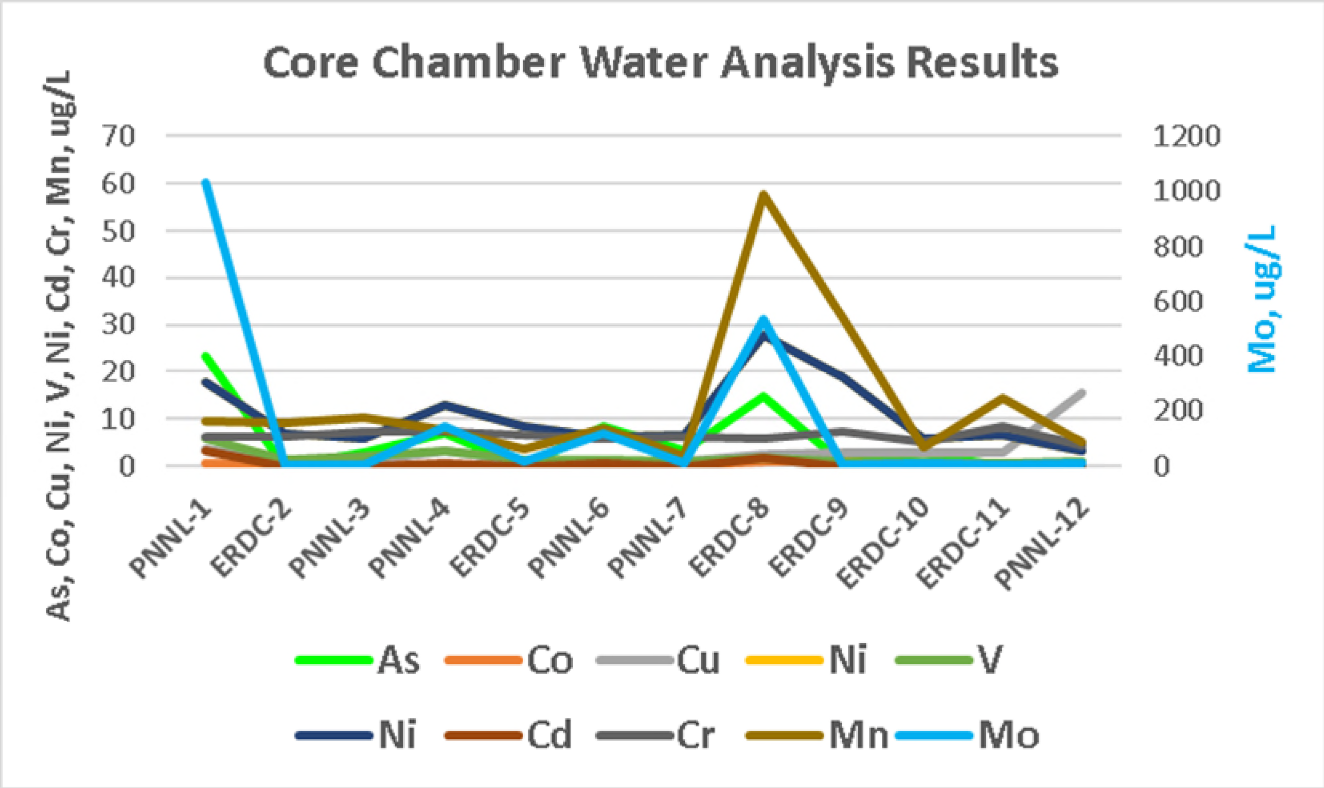
Highly variable As in core storage water

- Measured Arsenic concentration in adjacent samples varied from below the method detection limit (1 ppb) to 23 ppb

Sample ID	Zone	Storage Water As (µg/L)
PNNL-1	UFA[1]	23.3
ERDC-2	UFA[1]	<1
PNNL-3	UFA[1]	2.9
PNNL-4	UFA[1]	6.9
ERDC-5	UFA[1]	<1
PNNL-6	UFA[2]	8.5
PNNL-7	UFA[2]	3.3
ERDC-8	APPZ	14.9
ERDC-9	APPZ	0.7 J
ERDC-10	UFA[1]	2.7
ERDC-11	UFA[1]	<1
PNNL-12	UFA[1]	0.5 J

Initial assessment of Arsenic in core sample storage water. [1]Swanee [2]Ocala

Results



Sample ID	Zone	Storage Water As (µg/L)
PNNL-1	UFA[1]	23.3
ERDC-2	UFA[1]	<1
PNNL-3	UFA[1]	2.9
PNNL-4	UFA[1]	6.9
ERDC-5	UFA[1]	<1
PNNL-6	UFA[2]	8.5
PNNL-7	UFA[2]	3.3
ERDC-8	APPZ	14.9
ERDC-9	APPZ	0.7 J
ERDC-10	UFA[1]	2.7
ERDC-11	UFA[1]	<1
PNNL-12	UFA[1]	0.5 J

Initial assessment of Arsenic in core sample storage water. [1]Swanee [2]Ocala

Initial Core Processing at PNNL

Are core materials suitable for planned tests?

Are samples properly preserved? Do solids contain arsenopyrite?

- Selected single core chamber, PNNL-7, for initial analysis to assess suitability of core materials for Task B and C tests planned
- Collected core chamber water samples (~20 mL in triplicate) for analysis of total As, Ca, Fe, Mg, S

<u>**Notes and observations**</u>

- Notable sulfide odor present in PNNL-7 chamber upon opening.
- Water samples were collected into falcon tubes under N_2 headspace with clean tygon tubing (PNNL-7, PNNL-7A, PNNL-7B). N_2 atmosphere was maintained when core chamber was open.
- Dissolved O_2 was measured in PNNL-7 core chamber water via electrode at < 1% O_2 saturation.
- Prepared 144 mg Na_2CO_3/L solution to replace sampled PNNL-7 water volume and to ensure minimal headspace during storage. Added Na_2CO_3 to 18.2 MΩ water on stir plate with N_2 sparge for ~ 1 hr then filtered with 0.2 μm filter. Confirmed < 1.3% O_2 saturation prior in Na_2CO_3 solution, added it to replenish headspace, then resealed chamber PNNL-7 for storage.

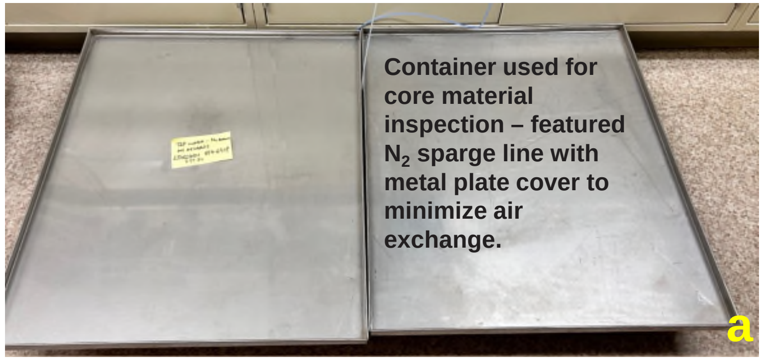
Collecting water samples (a,b), preparing and replacing headspace in core chamber prior to resealing PNNL-7 (c,d) at PNNL lab facility, Richland, WA on 28-Mar-2024.

Initial Core Processing at PNNL

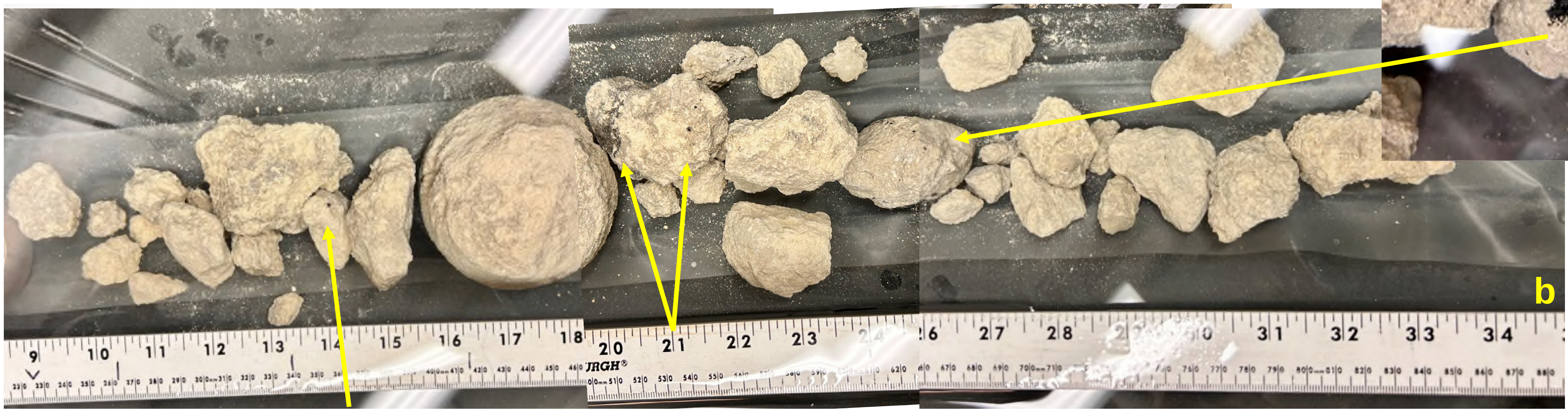
Are core materials suitable for planned tests?

Are samples properly preserved? Do solids contain arsenopyrite?

- Solids were removed from the core chamber and placed in CO_3 saturated water, which was sparged overnight with N_2 (a). Water contained O_2 < 1% saturation prior to use on 28-Mar-2024.
- Core material accessible by hand was removed from PNNL-7 core chamber and placed in container (a) below water surface on parafilm for imaging (b).
- Samples with and without black staining (PNNL-7 black, PNNL- noblack, (c)) were collected in plastic containers and transferred to an anaerobic chamber pending geochemical analysis.



Container used for core material inspection – featured N_2 sparge line with metal plate cover to minimize air exchange.



Arrows note potential arsenopyrite observed; inset shows flip side of segment with staining.

Initial Core Analysis

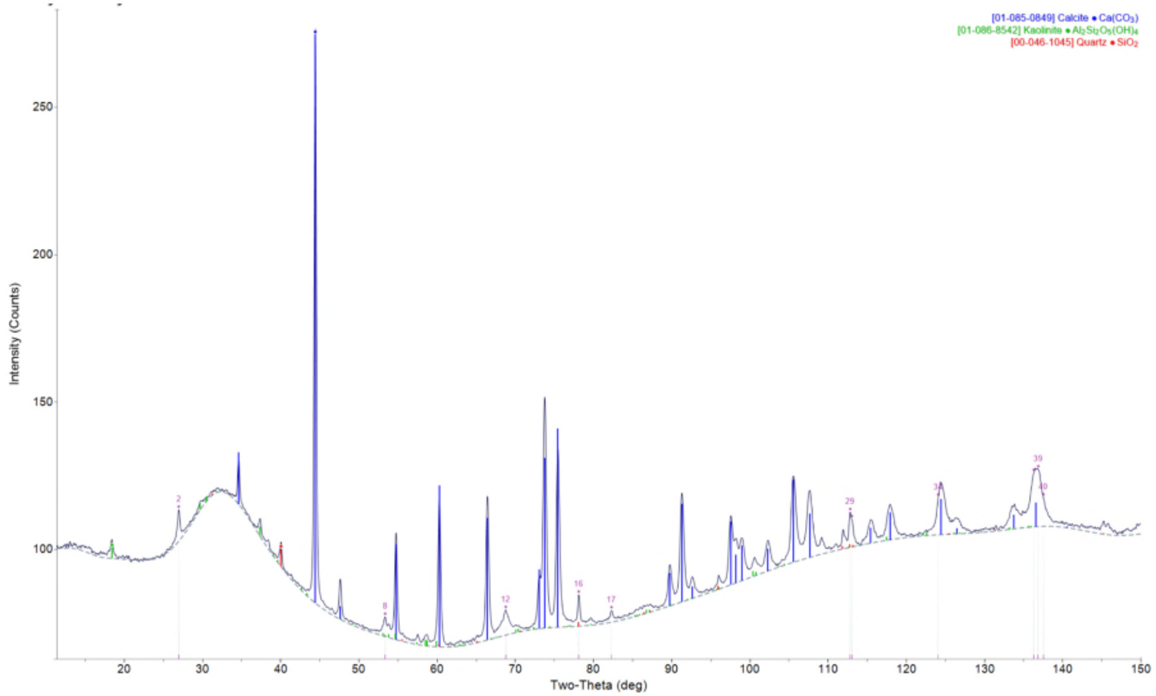
Solids Identification by X-Ray Diffraction

- matrix rock: >99% calcite

- black spots: >90% calcite (blue peaks on XRD)
  <5% kaolinite (green peaks on XRD)
  <2% quartz (red peaks on XRD)
  metallic iron (broad peak #12 at 68 degrees
  no Fe sulfides, no Fe oxides, no MnO_2

interpretation: black spots may be material introduced by drilling (kaolinite from drilling mud, iron from core barrel)

- XRD detection limit ~0.5% (5,000 ug/g), but dependent on minerals and crystallinity (i.e., broad peaks generally indicate amorphous structure)



Solids Identification by Acid Dissolution and Metals Analysis

- fraction of pyrite and arsenopyrite from molar ratio of Ca to Fe and S
- fraction of arsenopyrite in pyrite from molar ratio of Fe to As
- additional analysis of trace metals to identify substitution fraction

- aqueous metals analysis by ICP-OES and ICP-MS varies with metal but typically 0.01 to 1 ppb (10^{-5} to 10^{-3} ug/g) so presence of metals is much lower than XRD, although minerals are not identified

Challenges, Corrective Actions, Next Steps

Challenge: Leakage

- Some core storage tubes leaked small amounts of aquifer water, This appeared not to have impacted the redox status of PNNL-7. Excess dithionite added at time of collection likely minimized any impact to geochemistry of cores in chambers that leaked.
- No corrective action required.

Challenge: Core breakage

- Some cores broke or otherwise had pieces detach during ~3,500 mile road transport. However, substantial core material remains intact for column experiments. No impact on Task B. No impact to Task C either because Task C columns will be prepared by drilling subcores through intact segments.
- No corrective action required.

Next steps

- Collect groundwater samples and distribute to partner organizations
- Submit Task A technical memo documenting methods and results of core collection and screening-level analysis of PNNL-7 water and core material samples.

Suwannee Limestone - Ocala Limestone Contact (Stantec)

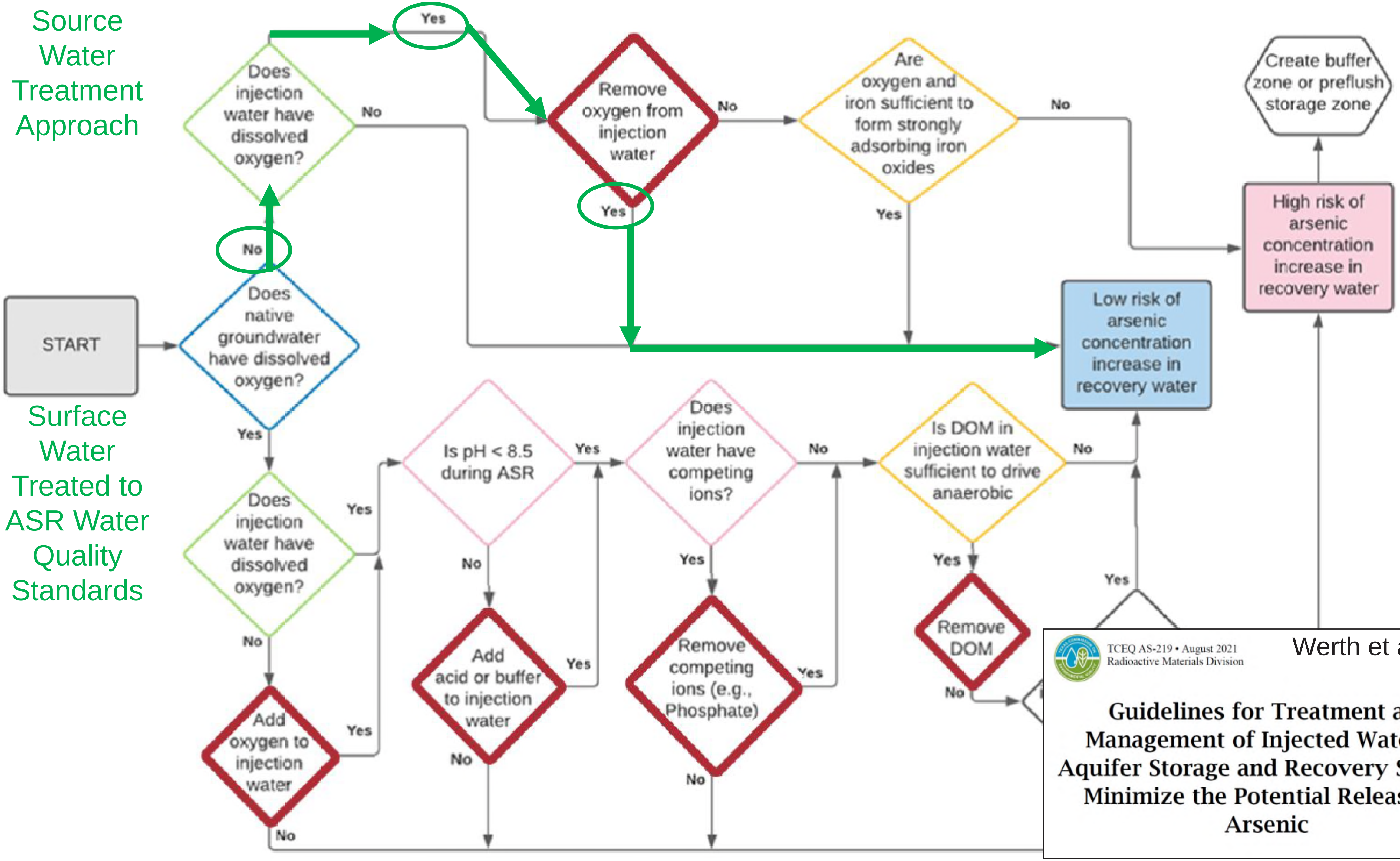
TASK E: SOURCE WATER TREATMENT

Team Members

Dr. Martin Page, Dr. Andy Hur, Yongkyu An, Bruce MacAllister, Kathryn Gunderson, Eric Strigotte, Cody Sloat, Dr. Sam Beal, Jenifer Netchaev, and Dr. Jay Clausen

Source Water Treatment Approach

Surface Water Treated to ASR Water Quality Standards



Werth et al., 2021

TCEQ AS-219 • August 2021
Radioactive Materials Division

Guidelines for Treatment and Management of Injected Water at Aquifer Storage and Recovery Sites to Minimize the Potential Release of Arsenic

Objectives

1. Generate baseline 'treated source water' samples for use in batch and column studies on potential contaminant mobilization during storage.

- Achieve water quality standards and match Proof-of-Concept pilot results previously achieved by Stantec/SFWMD.
- Generate sufficient sample volumes during representative environmental conditions for ASR operations.

2. Assess candidate deoxygenation and water stabilization methods and generate test samples.

- Assess physical and chemical deoxygenation methods.
- Assess chemical stabilization methods.

3. Generate representative membrane backwash water samples

- Support ongoing solids management design and optimization by Stantec for SFWMD.

Membrane	Deoxygenation	Stabilization
Ceramic	None	None
	Chemical reductant	None
		pH and alkalinity adjustment
	Membrane degassing	None
		Hardness and pH adjustment
Polymeric	None	None
	Chemical reductant	None
		Hardness and pH adjustment
	Membrane degassing	None
		Hardness and pH adjustment

Matrix of source water treatment designs to support arsenic mobilization studies and ongoing design optimization efforts.

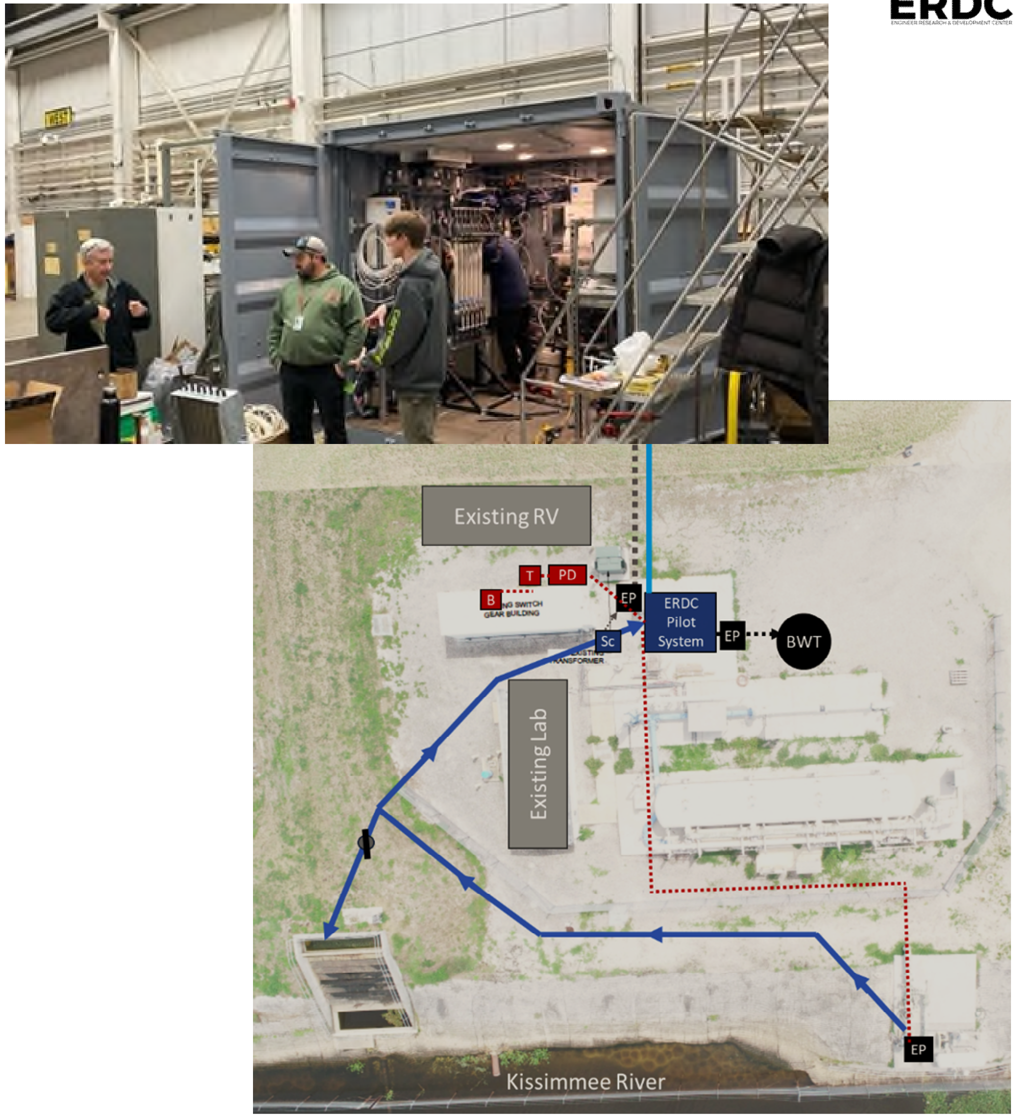
Approach

Design & build a new ASR source water treatment pilot system

- Sufficient flow to generate samples
- Representative of full-scale operations
- Allow head-to-head comparison of polymeric and ceramic membranes
- Includes new physical and chemical deoxygenation capabilities

Generate representative water samples and assess design performance at Kissimmee River ASR pilot site

- Baseline testing without deoxygenation or stabilization
- Physical deoxygenation testing with and without stabilization
- Chemical deoxygenation testing with and without stabilization



ERDC pilot assembly (December 2023, Champaign, IL) and KRASR site test plan schematic.

Results (Design/Assembly of Pilot Treatment System)

Drafted design and acquired components

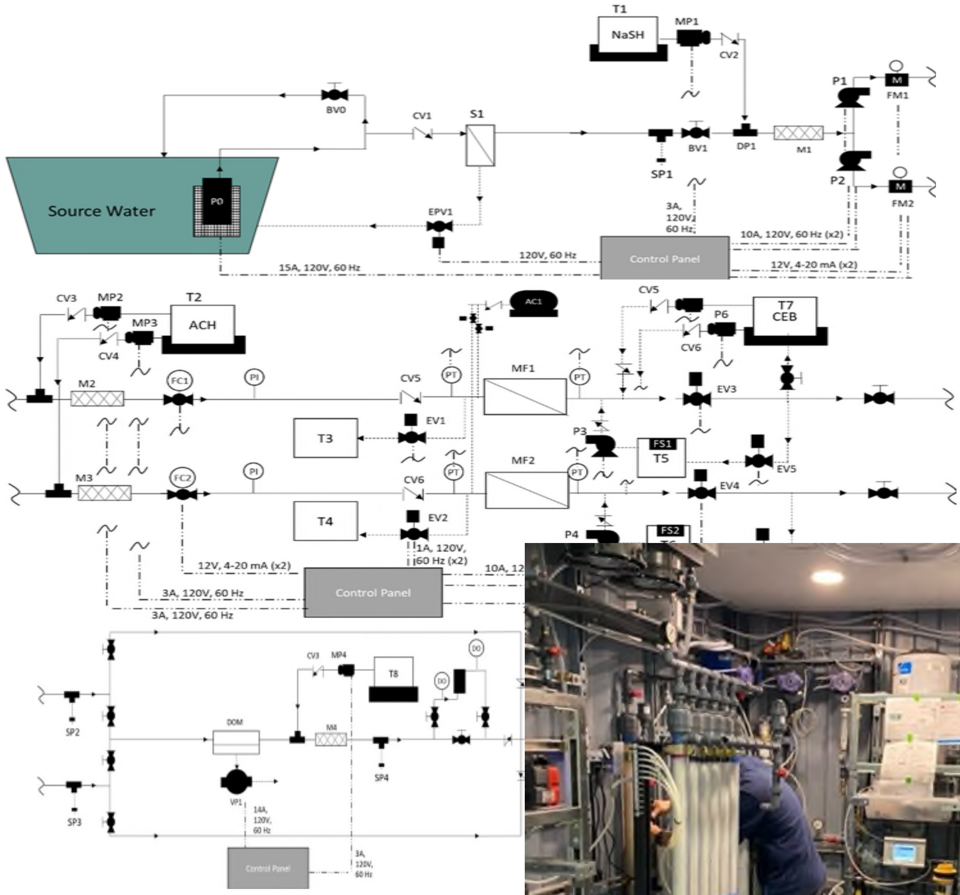
- Capable of testing polymeric and ceramic membranes plus deoxygenation systems
- Matched coagulant dosing and membrane loading rates (flux) to full scale design parameters from previous Stantec/SFWMD study

Assembled framing, plumbing, electrical, mechanical and controls

- Adjustable pump speeds to maintain target flows
- Automated system with digital controls

Design reviews and input from Stantec, Hazen & Sawyer, SFWMD, and membrane manufacturers

- Updated design to parallel membrane operation to facilitate head-to-head operation
- Increased polymeric membrane capacity to 1.25 gpm for backwash water generation
- Added and automated chemically-enhanced backwash process based on manufacturer guidelines



Process & Instrumentation Diagram and assembly of pilot treatment system

Results (Objective 1- Baseline Field Samples)

Kissimmee river water treated by the new pilot system was consistent with previous POC study (Stantec, SFWMD)

- Removal of organic matter (color, DOC) was higher with the ceramic membrane approach (attributable to higher ACH dose).
- Removal of particulates (turbidity) was high with both membrane approaches.

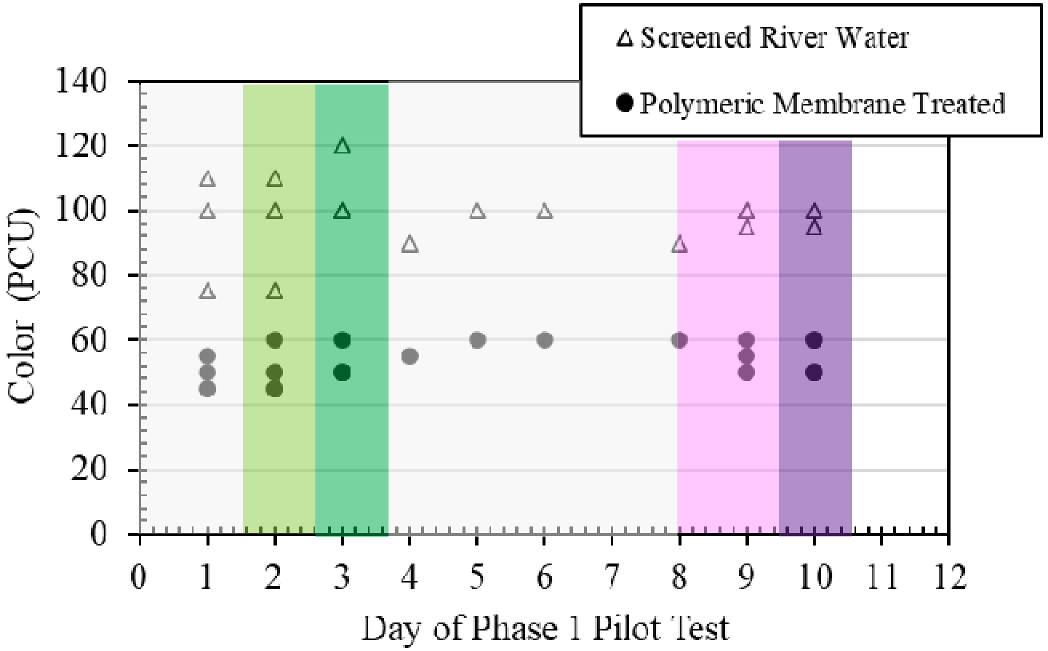
Observations

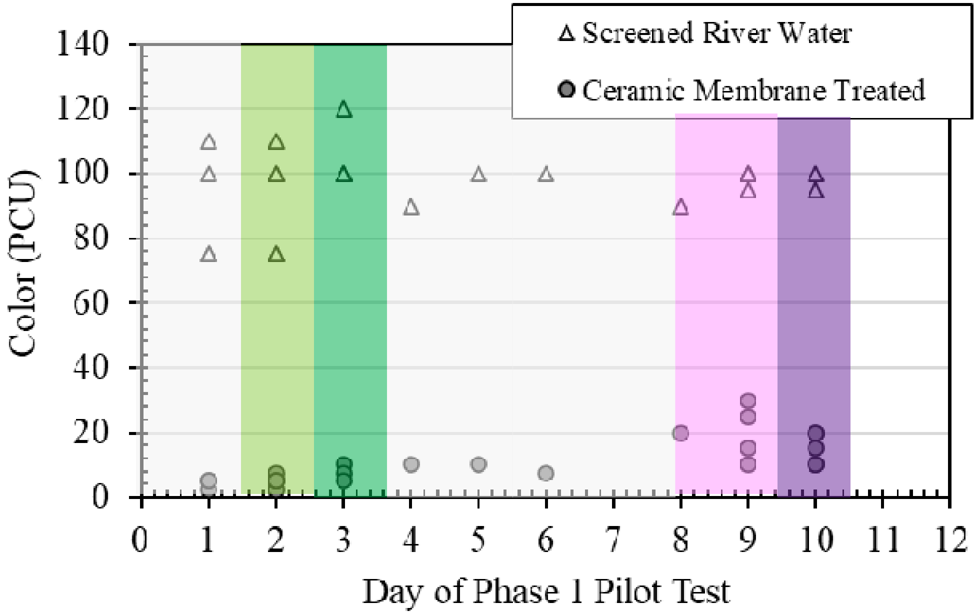
- Feed pressure and fouling rates were higher with the ceramic membranes
- The difference in ACH coagulant dosing for the two membrane types is the likely cause of the treated WQ differences and fouling rates.
  - Large flocs and high turbidity in ceramic feed water
  - Not an apples-to-apples comparison
  - Potential implications for arsenic mobilization potential due to residual dissolved organic carbon in polymeric membrane treated water

Water Sample	WQ Parameter	POC Study	Current Study
Kissimmee River Raw Water	Turbidity	3.4	2.13
	DOC	18.7	15.8
	Color	100	103
	pH	7.14	7.19
Polymeric Membrane Filtered (Zeeweed)	Turbidity	0.028	< 0.1
	DOC	14.9	12.8
	Color	50	48
	pH	7.03	7.18
Ceramic Membrane Filtered (AquaAerobic)	Turbidity	0.018	< 0.1
	DOC	7.7	6.3
	Color	7.5	7.9
	pH	7.05	7.28

SELECT WATER QUALITY DATA

COLOR

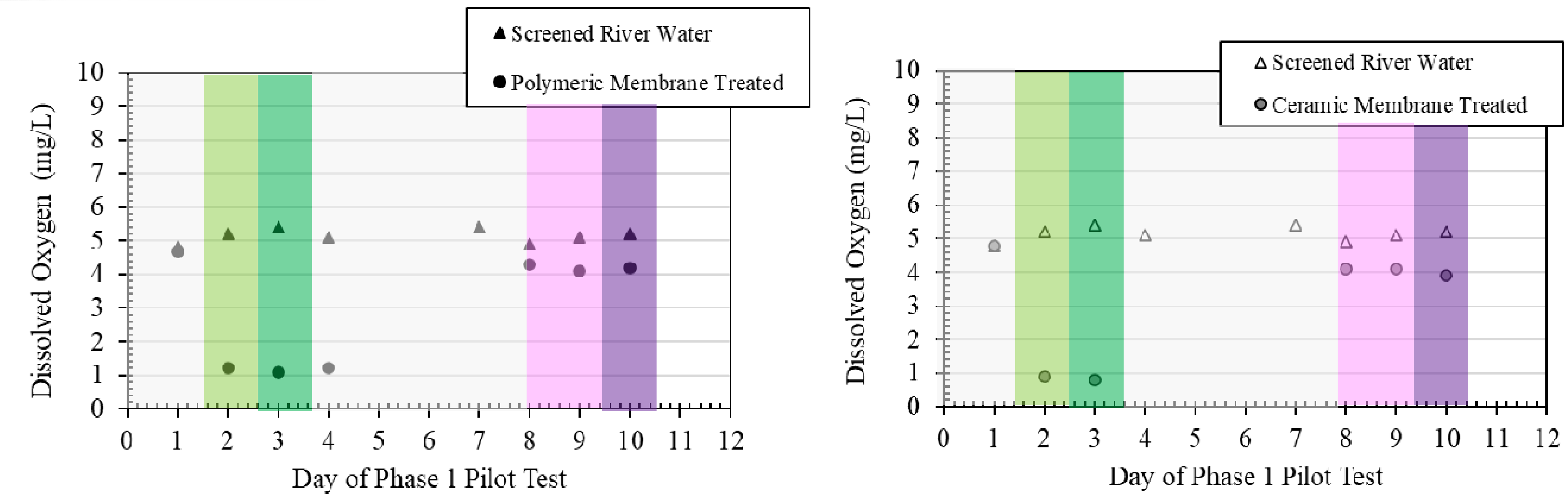




Baseline
Phys Deox
Phsy Deox + $CaCl_2/Ca(OH)_2$
NaSH Deox
NaSH Deox + $CaCl_2/Ca(OH)_2$

SELECT WATER QUALITY DATA

DISSOLVED OXYGEN



Baseline
Phys Deox
Phsy Deox + $CaCl_2/Ca(OH)_2$
NaSH Deox
NaSH Deox + $CaCl_2/Ca(OH)_2$

Results (Objective 2- Deoxygenation & Stabilization)

Physical deoxygenation approached but did not meet target of < 0.5 ppm dissolved oxygen level

Vacuum pressure of -11 psi applied through a hollow fiber gas permeable membrane to removed dissolved oxygen

- 1.1-1.4 ppm DO levels at higher flow rate (1.25 gpm)
- 0.7-0.9 ppm DO levels at lower flow rate (0.25 gpm)
- Need to assess water quality impacts, fouling impacts, cleanability, and scalability of the membrane degassing approach

Chemical deoxygenation with NaSH did not approach target DO levels

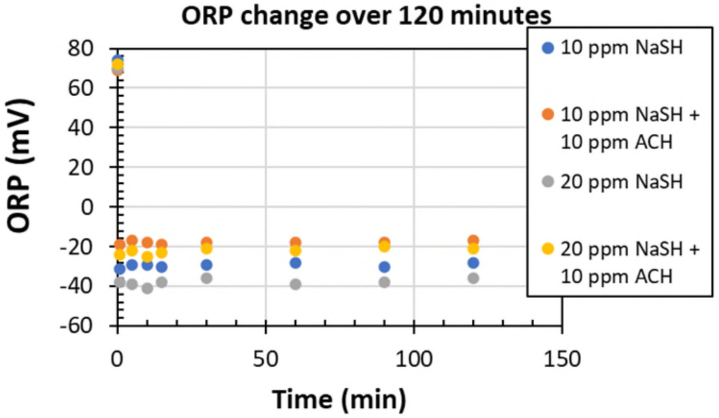
NaSH dosed at 10 ppm (in excess of the stoichiometric DO demand)

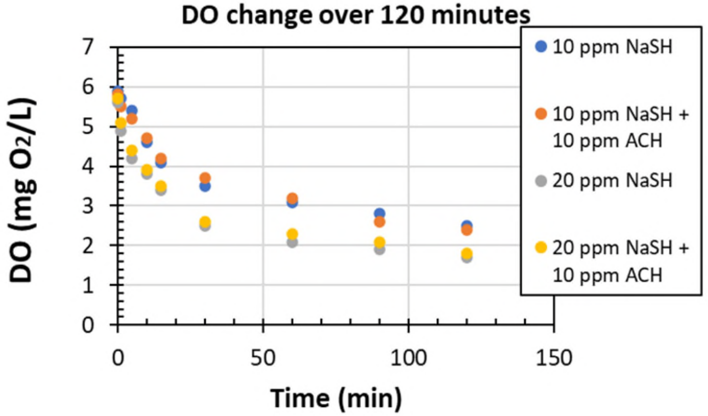
- While ORP reduction was rapid, DO removal required > 90 minutes to achieve < 2.0 ppm.
- Bench scale studies indicate potential interaction with ACH, but this interaction did not appear to impact DO removal rates significantly or floc formation.
- Caution needed for future bench scale studies of arsenic mobilization- need to consider kinetic effects.

Chemical stabilization with $CaCl_2$ and $Ca(OH)_2$ as tested had limited impacts on pH and alkalinity.

- Need to split stock solutions and consider NaOH.

Purging and displacement anoxic water sample collection system





Results of NaSH jar tests explaining why effluent DO levels were high in pilot studies

Results (Objective 3- Generate backwash water samples)

System operated continuously for 21 days in May 2024 to generate enough water for Stantec/SFWMD

- Turbidity ~30 NTU for several days after intense rains
- Sustained product water quality; membrane fouling did not change significantly

Continuous physical deoxygenation testing

- -26 inHg sustained vacuum pressure over 3-week operation
- Achieved 0.6-0.8 ppm DO @ 0.25 gpm (ceramic membrane effluent)
- Design optimization studies recommended

Membrane backwash samples

- ~90% recovery rate for both polymeric and ceramic membranes
- Adjusted solids content by proportionally decanting settled solids to represent filter water recovery rates of full scale design (95% for polymeric, 93% for ceramic)
- Transferred to Stantec for dewatering studies.

Stantec engineers and ERDC researchers collaborating and leveraging resources to support broader project objectives

Algae along shoreline near KRASR intake structure after intense rains (May 2024)

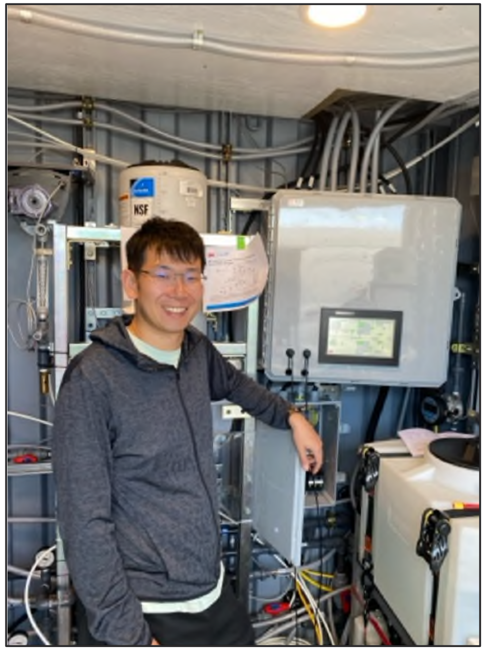
Next Steps for Task E Team

Provide technical support for Task B

- Advise on water quality control to achieve representative testing conditions in bench scale batch studies of potential contaminant mobilization during aquifer storage of the treated source water.

Future Pilot Field Studies

- Support generation of water samples for batch arsenic mobilization studies during rainy season
- Generation of water samples for aquifer core column testing (Task C)
- Support potential additional studies needed by SFWMD to inform future design work (pending approvals, funding).



Yongkyu An (controls engineer) after completing automation of pilot system operations.

Sam Beal (ERDC CRREL) will be performing batch studies on arsenic mobilization as part of Task B.

QUESTIONS

Panel Discussion - Q/A with Presenters

(30 min)

Public Comment Period

(15 min)

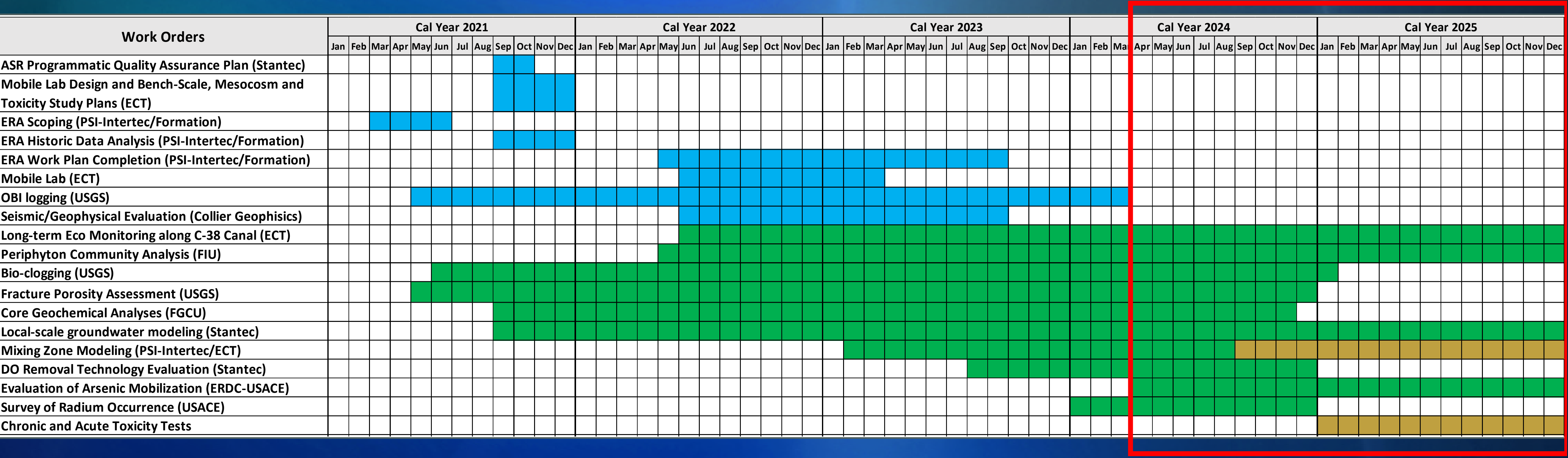
ASR Science Plan Panel Workshop
June 10, 2024

Closing Remarks and Expected Progress Over The Next Two Years

Presenter: Anna Wachnicka, Ph.D.
Principal Scientist/ASR Science Plan Project Manager, SFWMD

Contributors: June Mirecki, PhD (Geochemist, USACE-JAX)
Rick Cowles, P.G. (Principal Hydrogeologist, Stantec)

Expected Progress Over the Next Two Year



Status of the Studies

- Completed
- Ongoing
- Planned

Quantitative ASR Ecological Risk Assessment – Next Steps

Completed

Phase 1:
Project Scoping & Working Group Formulation

- **Goal:** Develop scoping document outlining a path forward for planning and implementation of the revised Quantitative ASR ERA & assemble a Working Group composed of subject matter experts

Phase 2:
Eco Risk Assessment Planning

- **Goal:** Identify data gaps and develop a Work Plan for completion of the Quantitative Ecological Risk Assessment (ERA)

Current Work

Phase 3:
Data Collection

- **Goal:** Collect the data identified in the ERA Work Plan to complete the ERA

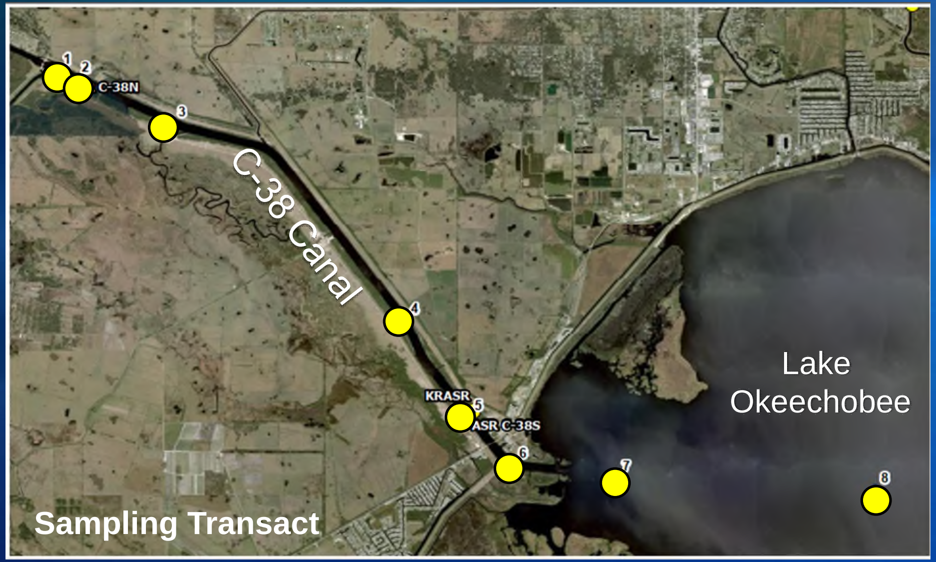
Planned for ~2026

Phase 4:
Performing Ecological Risk Assessment

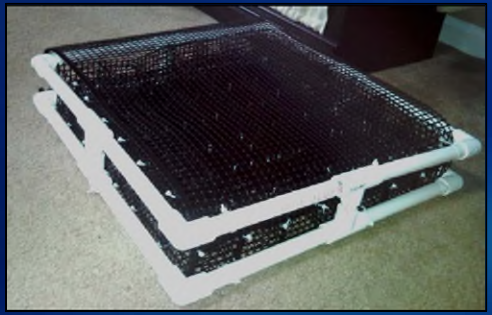
- **Goal:** Provide a technically defensible assessment of ecological risks from the operation of the planned ASR wells

Long-Term Eco Monitoring- C-38 Canal and N Lake O. – Current Status and Next Steps

Study Area

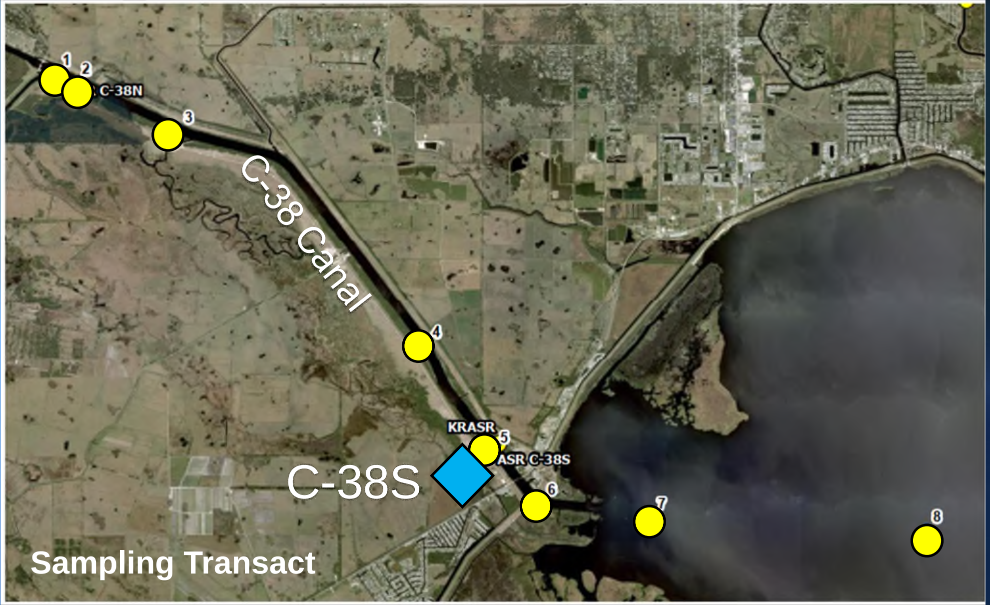


- **Goal: Evaluation of long-term bioaccumulation and community-level responses at different temporal and spatial scales**
  - **Pre-Operational monitoring (2022 - 2026)**
  - **2 – 3 years monitoring once cycling begins (2026 - 2029)**
- **Monitoring Eco Components: periphyton, mussels, invertebrates, fish/ichthyoplankton**
- **If significant accumulation of chemical compounds found, monitoring of upper trophic level organisms may be added**



Bench-Scale Chronic and Acute Toxicity Tests - Forthcoming

- **Goal: Evaluation of responses of selected organisms to varying phys-chem. water quality conditions using source, recovered and mixed water**
- **Completed and Planned Activities**
  - Mobile temperature-controlled flow-through laboratory constructed in 2023
  - Test of Survival, Growth, Reproduction under varying conditions of interest planned for ~2025-2027



Mixing Zone Modeling – Current Status and Next Steps

Modeling Goals

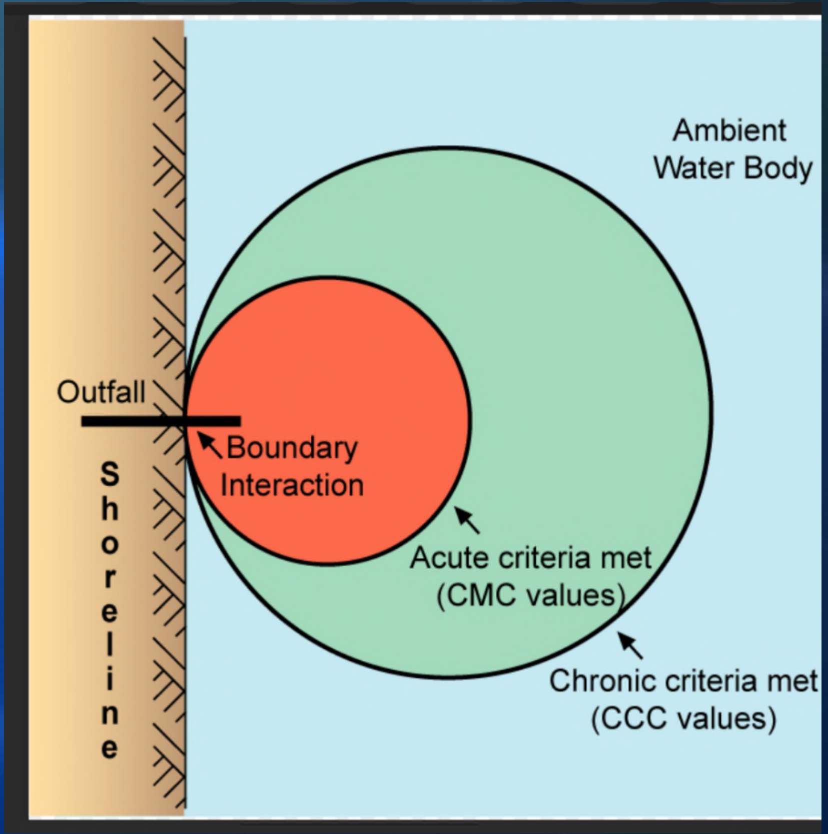
- Support SFWMD ASR permitting
- Support ASR Ecological Risk Assessment
- Support ASR outfall design/blending/pre-treatment and engineering specifications

Work Completed in 2023-2024

- Modeling completed for C-38S
  - ✓ Establishment of initial conditions (WQ info w/ bathometric surveys)
  - ✓ Impacts analysis
  - ✓ Multi-beam survey of one-mile C38S - C38N section

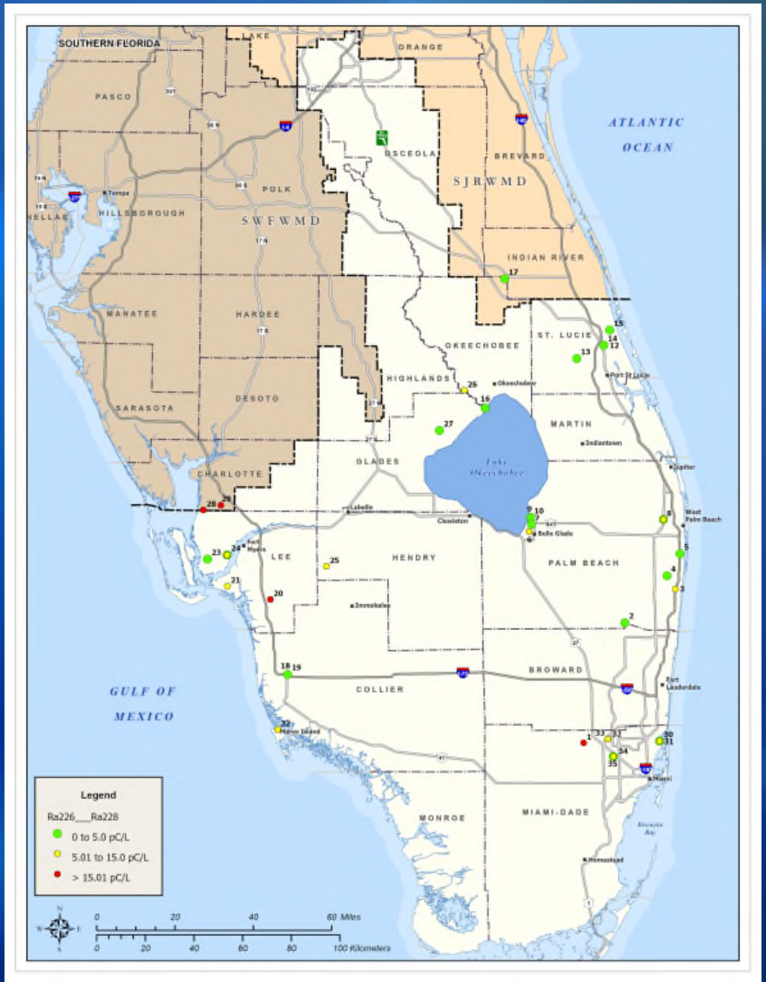
Next Steps

- Modeling may be conducted at other ASR locations e.g., L-63N
- More detailed mixing zone modeling may be implemented

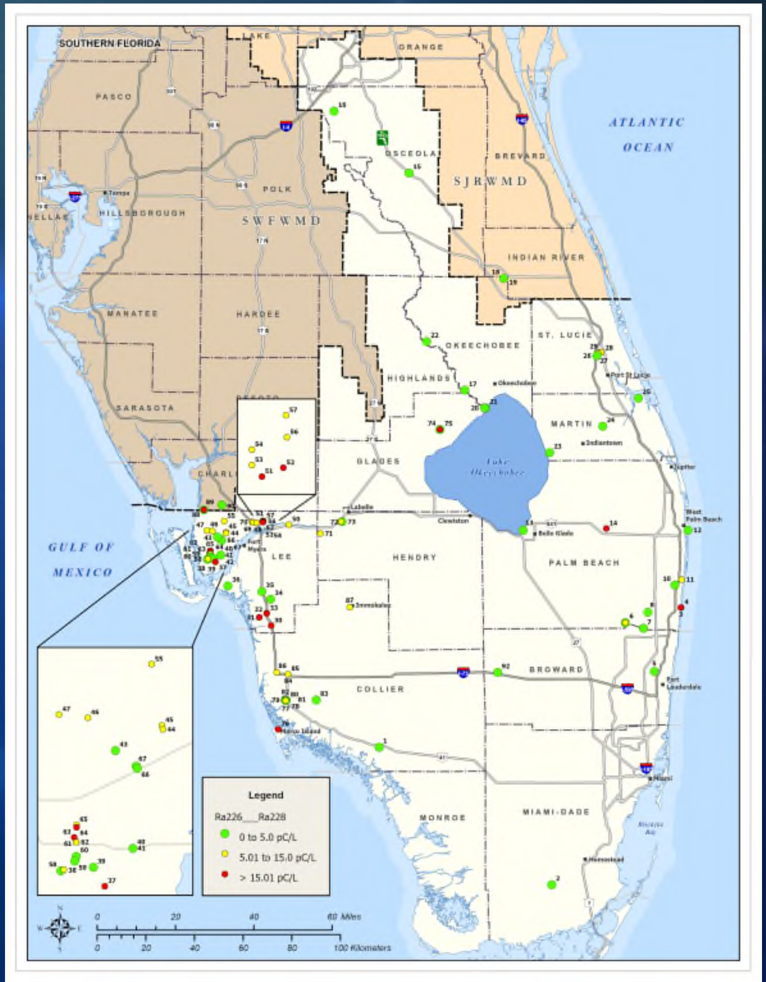


Survey of Radium Occurrence in Native UFA and APPZ - Current Status and Next Steps

- Radium isotope and Gross Alpha data were compiled from 85 well construction reports throughout South Florida
- Data obtained from UFA, APPZ, Hawthorn, and Boulder Zone aquifers
- Radium isotope exceedances found mostly in native groundwater in Lee County and Collier County wells
- Tech memo summarizing results is forthcoming in 2024



Ra226 + Ra228 in APPZ wells



Ra226 + Ra228 in UFA wells

Local Scale Groundwater Model C-38N and C-38S - Current Status and Next Steps

Modeling Setup

- MODFLOW (USGS Groundwater Model Code)
- SEAWAT Density and Viscosity Dependent Flow to Evaluate Upconing Potential and Recovery Efficiency
- 50 MGD - Each ASR Well Field (100 MGD combined)
  - 25 MGD Stored and Recovered in the UFA and APPZ Aquifers (5 MGD each ASR well)
- Model Domain – 40 miles on each side
- Variable Gid – 50-foot grid size around each ASR well
- Model consists of 22 Layers

Modeling Goals

- Determine ASR Well Spacing
- Evaluate Upconing Potential
- Determine Storage Zone Bubble Geometry
- Estimate Recovery Efficiently
- Evaluate Effects on Legal User

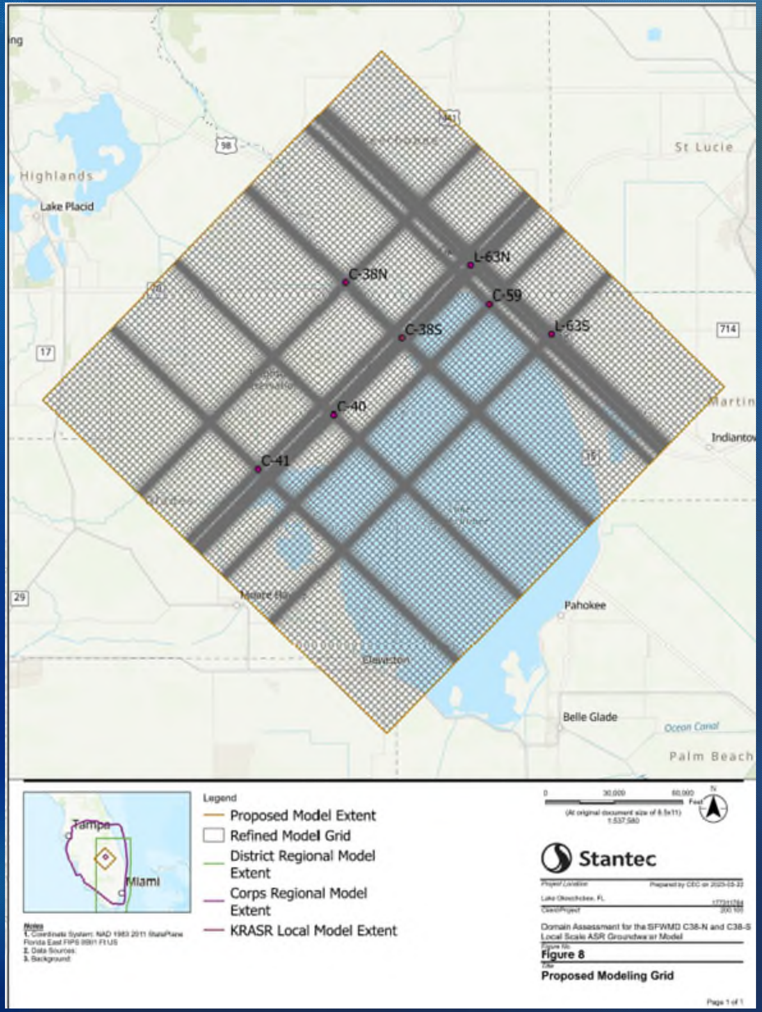
Groundwater Model Layers

Hydrogeologic Unit	Number of Model Layers
Surficial Aquifer System (SAS)	1
Intermediate Confining Unit (ICU)	2
Upper Floridan (UFA)	5
Upper Middle Confining Unit (MC1)	2
Avon Park Permeable Zone (APPZ)	5
Lower Middle Confining Unit (MC2)	2
Lower Floridan (LF)	2
Lower Confining Unit (LC)	2
Boulder Zone (BZ)	1

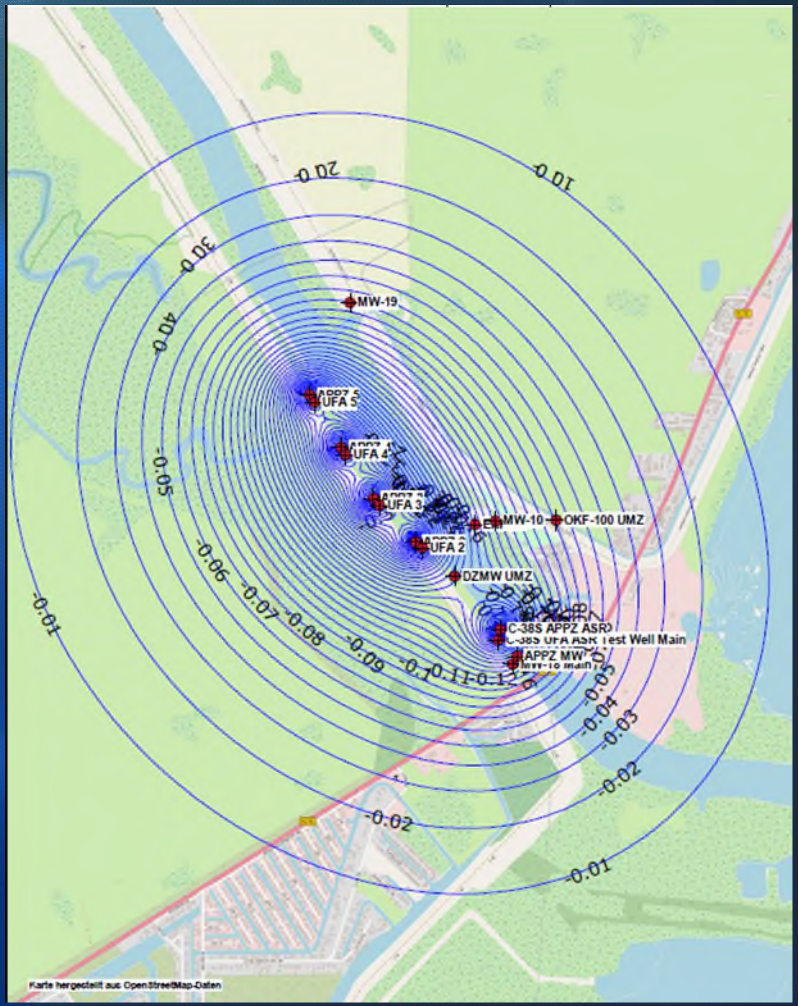
Local Scale Groundwater Model C-38N and C-38S - Current Status and Next Steps

- Model Domain Includes Future ASR Wellfields for future model development
- Modeling Confirms 1,000 feet between ASR Well Pairs
- Modeling is Expected to be Complete by the end of July 2024

Model Domain and Grid



ASR Well Spacing Evaluation



Borehole Fracture Interpretation and Analysis - Current Status and Next Steps

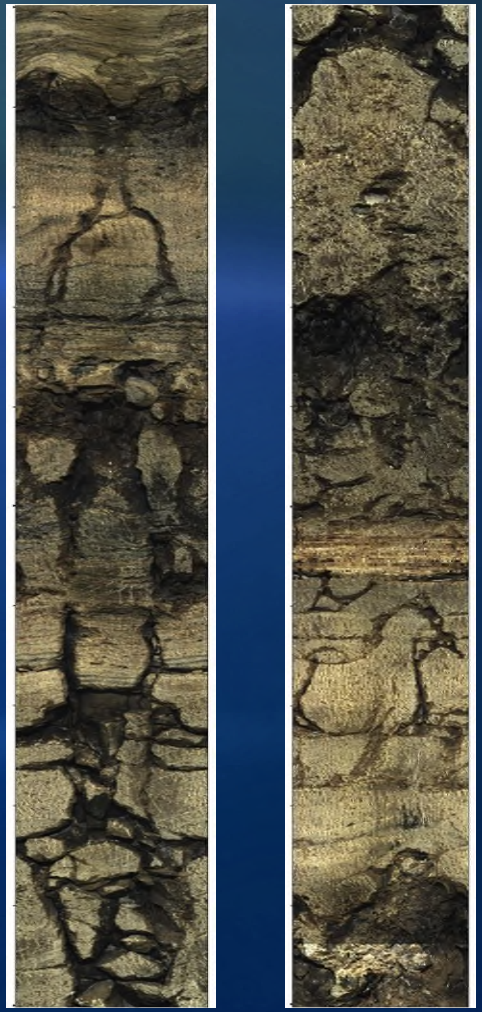
Modeling Setup

- Utilizing WellDAD (RockWare software)
- Raw OBI data – C-38N, C-38S, L-63N, C-59, L-63S
- Raw geophysical log (.las) files and Video Logs - C-38N, C-38S, L-63N, C-59, L-63S
- E. Richardson data
- Lineament study data
- Stantec, SFWMD, and USGS cross-sections
- Seismic Attribute Processing for Fracture Mapping (both 2D and 3D)

Modeling Goals

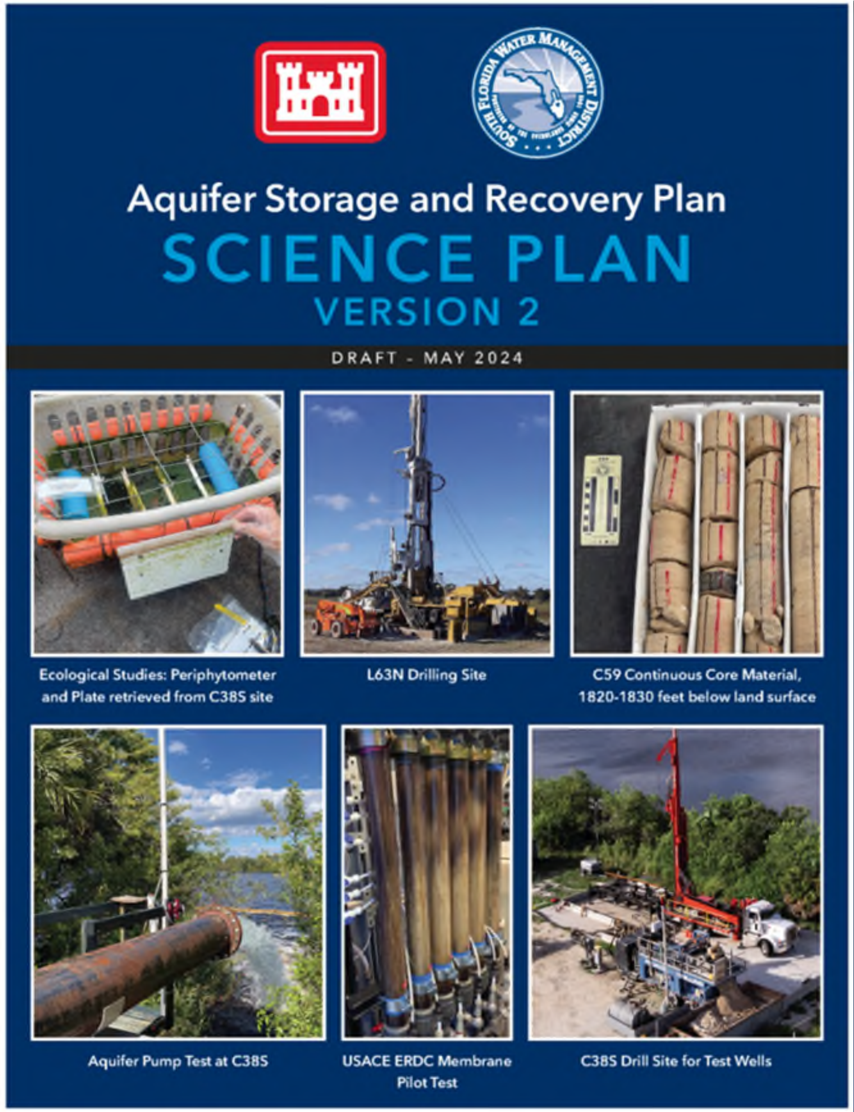
- Identify Reginal and Local Fracture Trends
  Including location, apparent dip, and aperture of the fractures
- Determine General Flow and Non-Flowing Fractures
- Identify Voids vs Fractures where Possible
- Determine Preferential Groundwater Flow Direction

Fracture in APPZ



Expectations from Peer Review Panel and 2024 ASR Science Plan (Version 2.0) Next Steps

- Each panelist to prepare a memorandum – August 12th
- Chair to compile memos into the 2024 Peer Review Panel Report – September 9th
- SFWMD/USACE to revise the Draft 2024 ASR Science Plan Report – September 23rd
- Reconvene with the Peer Review Panel – late September
- Release Draft Report for 30-day public review – early-October
- Finalize Comment/Response Matrix and release Final 2024 ASR Science Plan in November-December 2024



Thank You!

www.sfwmd.gov/lowrp or www.sfwmd.gov/asr