Memphis Aquifer Research Project

Summer 2021 Update

CAESER
Center for Applied Earth Science and Engineering Research

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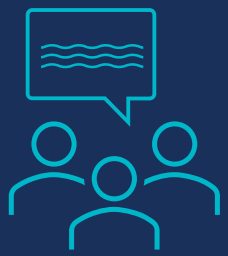
Director, CAESER

Project Overview

A large-scale study to determine the location and impact of naturally occurring windows in the protective clay layer that overlies much of the **Memphis aquifer**.



Graduate students conduct individual projects that aim to determine the best methods to detect the **presence of the windows** and **understand groundwater flow dynamics**.

Project Implementation

CAESER is producing 24 deliverables with **four** presently completed. Supporting the graduate students are faculty, staff, and undergraduates.

Project Implementation

Completed Deliverables (4)

May 2021 Deliverables (4)

May 2022 Deliverables (5)

August 2023 Deliverables (7)

Year 4 Projects (2)

Completed Deliverables

Four investigations began in 2018 and completed in 2020

COMPLETED 2020

1-1

Determine impact of known breaches in the **Sheahan well field**, determine presence of new breaches in the well field, and assess impact of Former Custom Cleaners site.

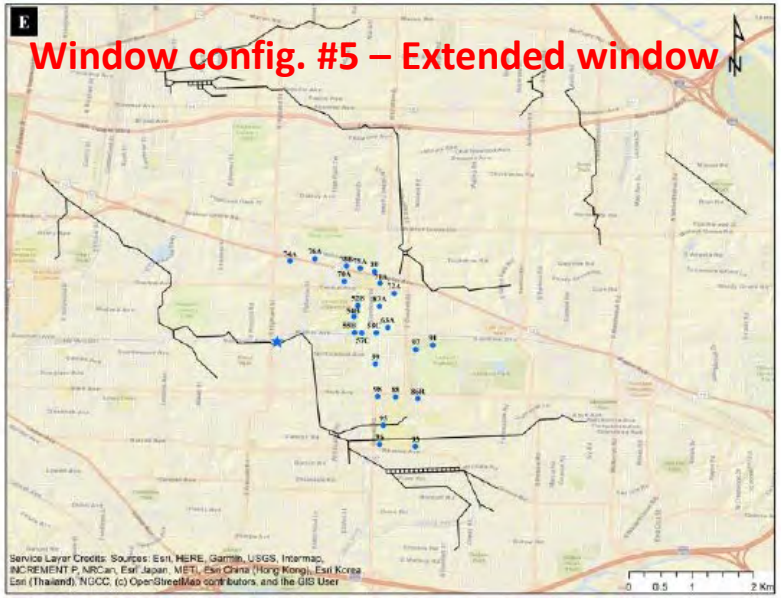
Objectives

1. To determine the impact of potential breach spatial configurations within the Upper Claiborne Confining Unit (UCCU) on the presence of modern water at the Sheahan well field in Memphis, Tennessee.
2. To determine the potential breach configuration that better supports tracer-based data from previous studies.
3. To assess the vulnerability of the well field to contaminants from the Former Custom Cleaners site.

COMPLETED 2020

1-1

Determine impact of known breaches in the **Sheahan well field**, determine presence of new breaches in the well field, and assess impact of Former Custom Cleaners site.



COMPLETED 2020

1-1

Determine impact of known breaches in the **Sheahan well field**, determine presence of new breaches in the well field, and assess impact of Former Custom Cleaners site.

- Modeling groundwater ages from seven production wells suggest that an extended paleochannel feature represents window conditions. The shapes and positions of windows proposed in earlier investigations did not contribute young water in a manner to validate their existence.
- The developed extended paleochannel is derived from drainage patterns atop the UCCU owing to the shallow aquifer depositional environment.
- The extended paleochannel does not define the window but suggests the character of a window to be investigated further.
- Simulation of groundwater conditions in the shallow aquifer as the contributor through a breach proved challenging. For this project, heads were held as constant. *Shallow aquifer simulation is is being addressed by Project 2-9.*

COMPLETED 2020

1-1

Determine impact of known breaches in the **Sheahan well field**, determine presence of new breaches in the well field, and assess impact of Former Custom Cleaners site.

- CAESER groundwater model (2005-2015) was extended back to 1960 just for Sheahan pumping to perform the backwards tracking for age. Modeling error in Sheahan was reduced, but overall model error increased as other well fields' pumping was not extended to 1960. *Model improvements are being made under Project 3-3, using data from Projects 1-3 and 1-5.*
- Not knowing window hydraulic conductivity, it was varied across three orders of magnitude to accommodate a broad possible range.
- This study was limited by the number of production wells have age-dating measurements and not knowing the hydraulic properties of the window. *All active production wells are being sampled in Project 3-3 for geochemistry, signs of contaminants and age-dating.*

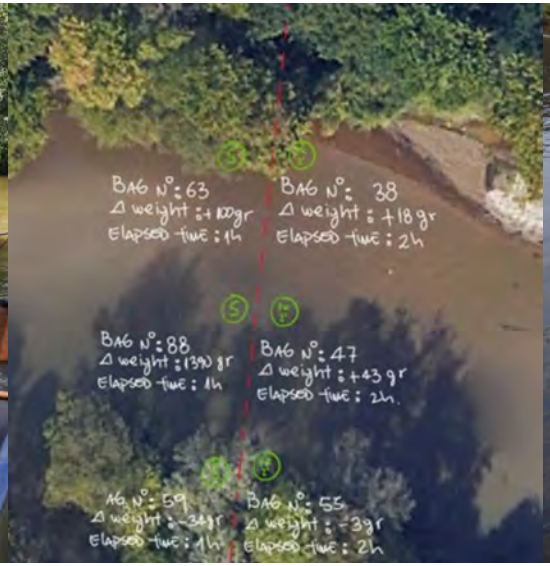
COMPLETED 2020

1-2

Determine possible new breach locations proximal to the Wolf River by conducting riverbed seepage measurements, performing detailed discharge measurements, and developing well transects to monitor groundwater/surface water exchange.

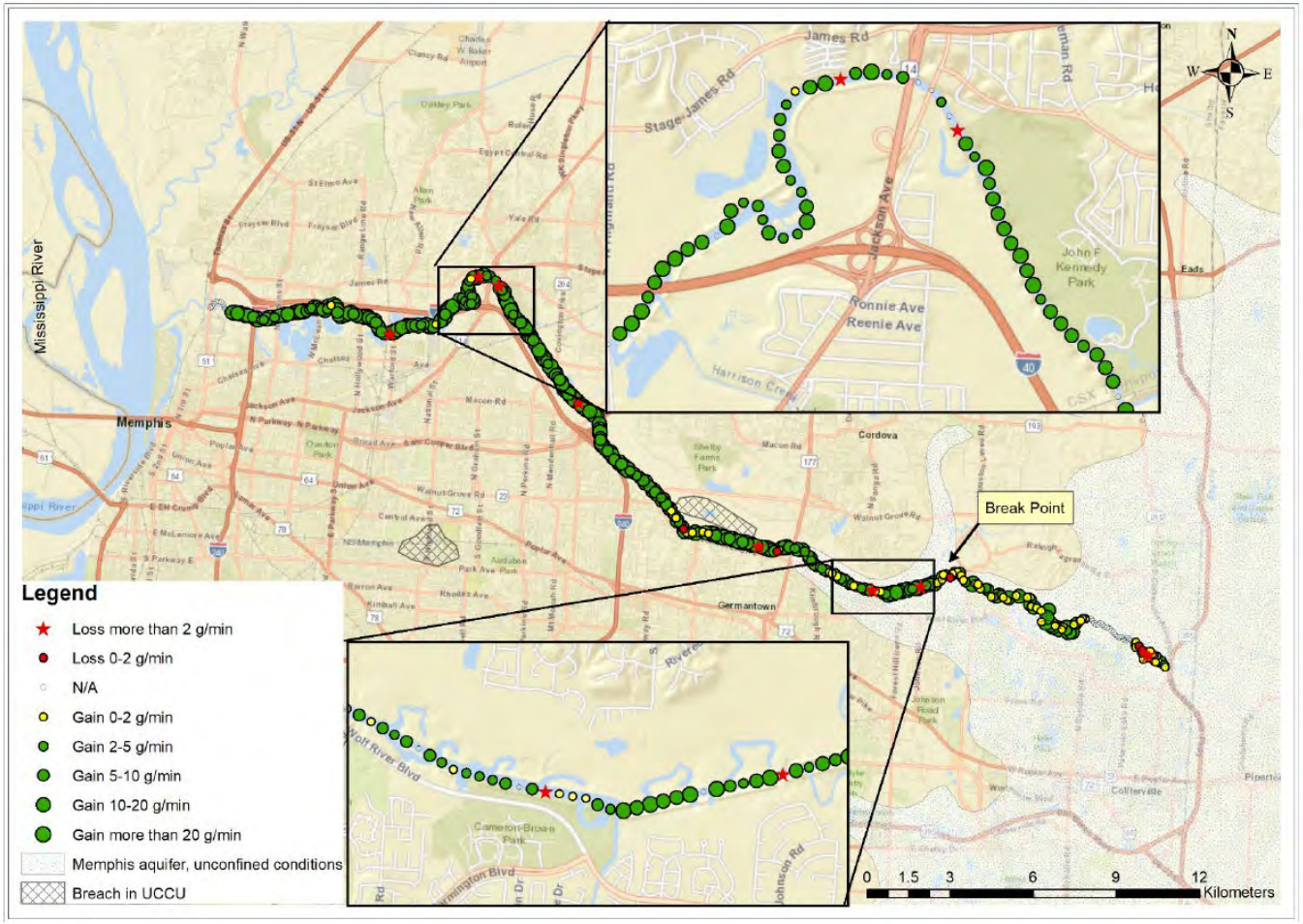
Objectives

1. Locate losing reaches along the Wolf River during low-flow condition.
2. Use different techniques to investigate riverbed seepage
3. Monitor surface water/groundwater exchange to confirm the potential presence of a nearby breach



COMPLETED 2020

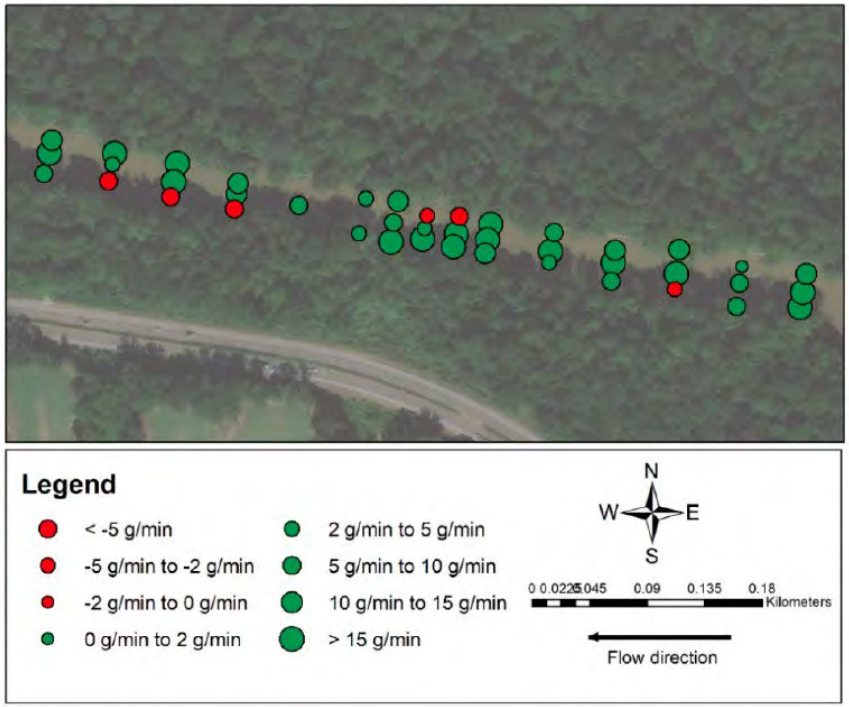
1-2 Investigate connection between the Wolf River and aquifer to identify new windows



Seepage meters were deployed along the length of the Wolf River to identify sections of abnormal loss during the *dry season* when the rivers should be gaining (receiving) from groundwater.

COMPLETED 2020

1-2 Investigate connection between the Wolf River and aquifer to identify new windows

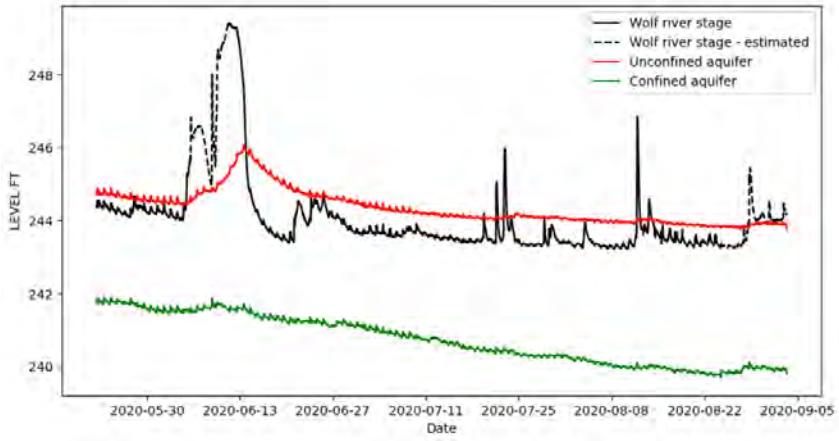


- Results were sporadic so a clustering analysis against the original data was used to target likely locations to perform a dense monitoring survey.
- Losses and gains were distributed across the channel
- Three suspected locations of abnormal loss were identified: near Austin Peay, at Shelby Farms, and Lansdowne Park

COMPLETED 2020

1-2 Investigate connection between the Wolf River and aquifer to identify new windows

- Temperature measurements were made at a few locations to determine their applicability in detecting directional leakage. *Lessons learned are being implemented in Project 2-6.*
- Shelby Farms was known to have a losing reach so corroborating that was good
- Decision to drill at Lansdowne Park a shallow and deep well proceeded and were instrumented with water level reading devices. Included installation of a stilling well in the Wolf River so water levels in a three systems could be systematically observed. *Readings continue at this location to capture seasonal variation for future study.*



COMPLETED 2020

1-2 Investigate connection between the Wolf River and aquifer to identify new windows

- Drilling at Austin Peay was placed on hold as land access was not ideal and secondary drill location was too distant from the Wolf River.
- Design modification to the seepage meter to make them deeper, deploying more sensitive temperature sensors for periods of 24 hrs+ and design of a piezomanometer for measuring very small differences in surface water/groundwater levels are outcomes of this research to improve loss detection and proximity of nearby windows to rivers.

COMPLETED 2020

1-3

Perform aquifer characterization across Shelby County to constrain numerical model parameter estimation.

Objective

- Determine localized aquifer parameters of the Memphis aquifer in Shelby County such as transmissivity and storativity in order to improve the accuracy of numerical model solutions by reducing model non-uniqueness.

- Of the *three* factors governing groundwater movement, one has been measured over the past half-century over 140 times with only 27 accurate calculations.

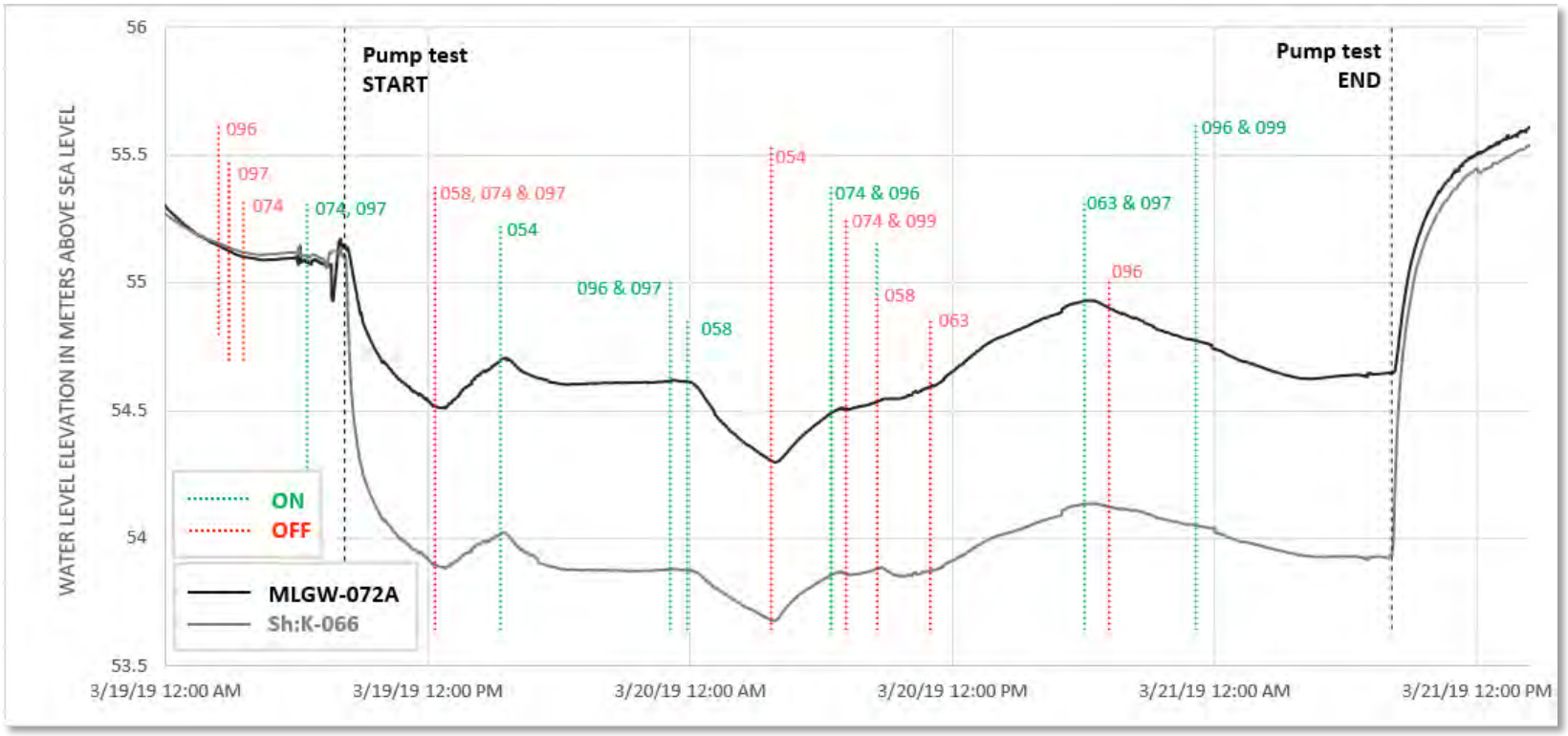
COMPLETED 2020

1-3 Perform aquifer characterization across Shelby County to constrain numerical model parameter estimation.

- Ideal aquifer tests are performed in a single stressed environment: one production well pumping with nearby observation wells
- Production wells were chosen based on three criteria:
  1. Well-distributed across the county;
  2. Availability of an associated observation well screened at a similar interval than that of the production well; and
  3. Observation wells located as distant as possible from the production well to reduce the influence of additional production wells as well as the effects of partial penetration
- Nearby productions wells were to be turned off during testing to approximate near-ideal conditions of singular stress, but that did not happen. Acquisition of SCADA data from MLGW was used to model *other* production well influences as could be seen in drawdown curves.
- Conditions of the tests followed ASTM D4050-14 and a grading matrix developed by CAESER in conjunction with the USGS as part of a Congressional earmark in 2005. This tests provides confidence in the results.

COMPLETED 2020

1-3 Perform aquifer characterization across Shelby County to constrain numerical model parameter estimation.



- Inclusion of these added stresses were able to be accommodated and values of hydraulic conductivity and storativity determined.

COMPLETED 2020

1-3 Perform aquifer characterization across Shelby County to constrain numerical model parameter estimation.

Wellfield	Average discharge (GPM)	Well	Pumping test			Recovery test	
			Transmissivity (m^2/day)	Storativity	r/B	Transmissivity (m^2/day)	Storativity
Sheahan	1485	Sh:K-066	1600	0.0007	0.37	1300	0.0005
		MLGW-72A	1500	0.0005	0.66	1500	0.0002
Morton	1420	Sh:P-113	3100	0.009	---	---	---
Germantown	700	Sh:L-089	2500	0.002	---	---	---
Davis	1400	Sh:J-140	2700	0.001	--	---	---
		MLGW-401	2800	0.002	0.32	---	---
Mallory W.	1400	MLGW-001C	1800	---	0.09	1700	N/A
Mallory E.	1150	Sh:O-212	600	0.002	0.29	640	0.002
		MLGW-016C	900	0.0006	0.24	900	0.001

3250 (Sheahan: 1600 + 1500)

2137 (Germantown: 2500 + Davis: 2700)

2415 (Mallory E.: 600 + 900)

0.0014-0.0006

N/A – Not applicable

- Values of K and S will better constrain modeling of the Memphis aquifer, reducing situations that lead to non-uniqueness that can impact post-analysis of results and decision making. *These values are informing the modeling effort in Project 3-3.*

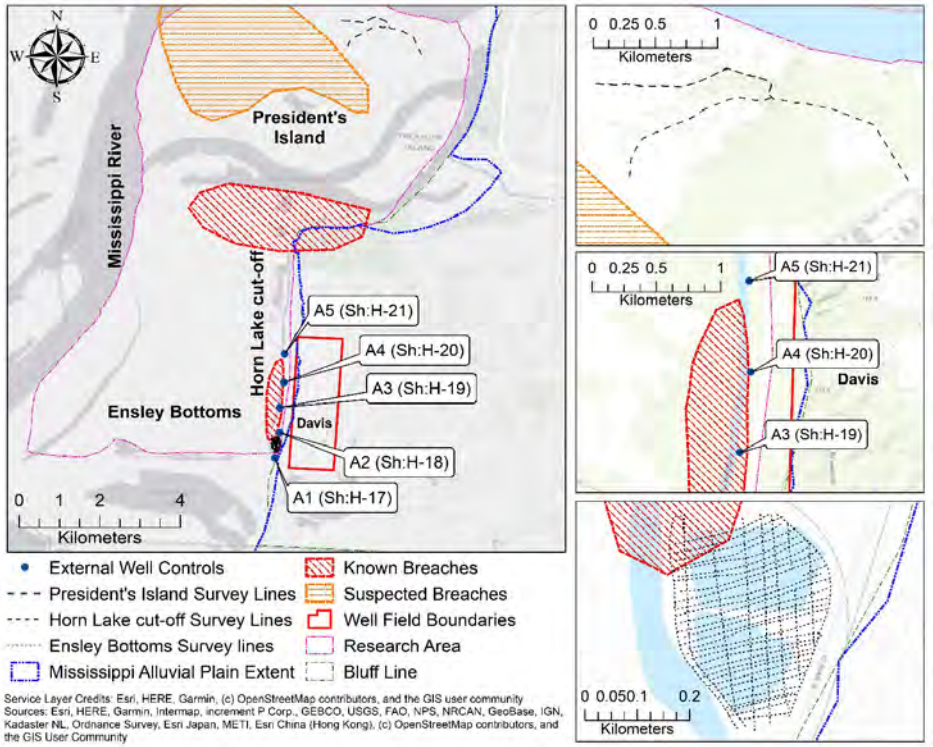
COMPLETED 2020

1-4

Map potential aquitard breaches in Ensley Bottoms near the **Davis well field**, TVA, and proximal to the Allen well field using geophysical techniques.

Objectives

1. Investigate the depth of penetration of 30-35 m with ground-penetrating radar (GPR).
2. Image the significant change in the electromagnetic properties at the contact of the MRVA and UCCU.
3. Image potential structures that might allow groundwater movement from the MRVA to the Memphis aquifer.



COMPLETED 2020

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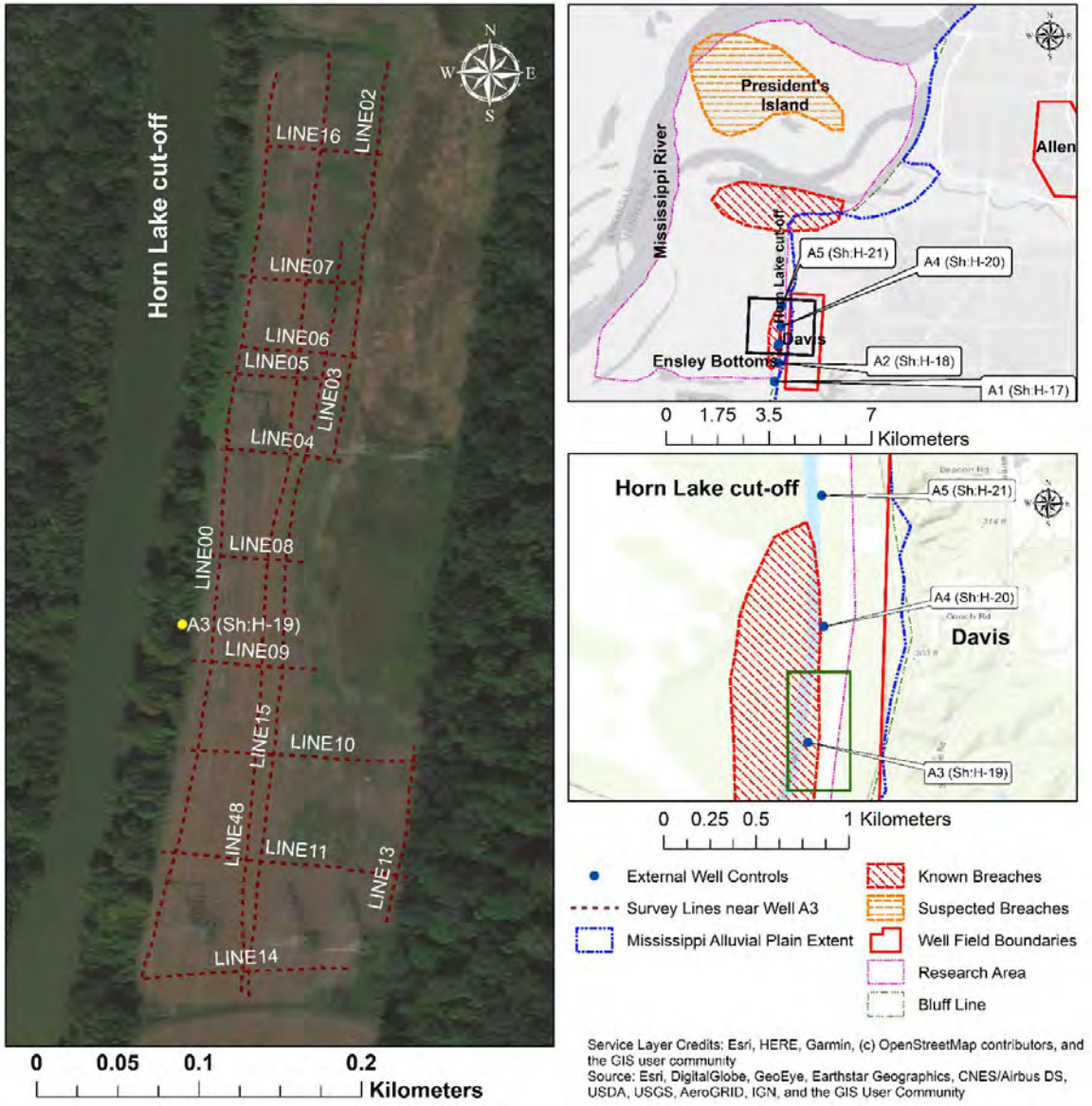
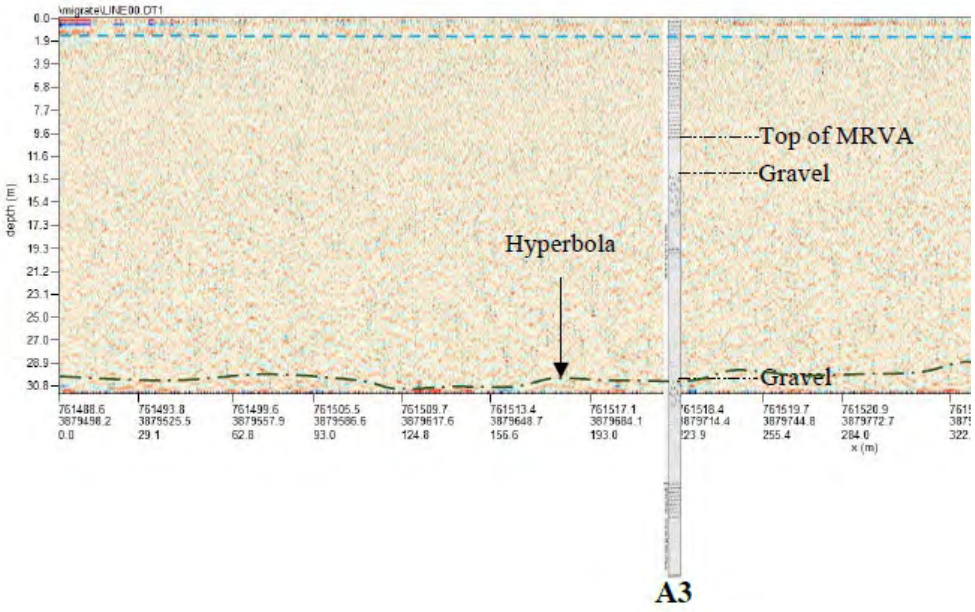
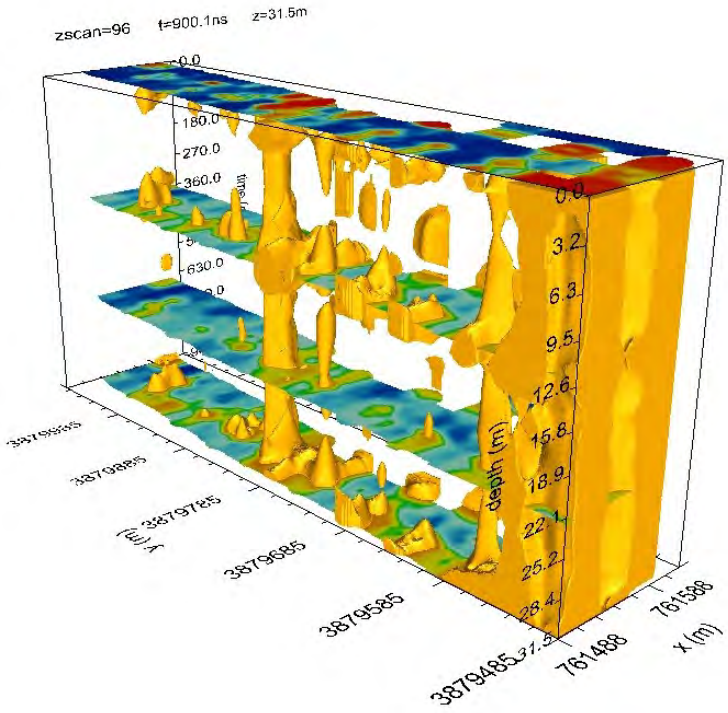


COMPLETED 2020

1-4 Map potential aquitard breaches in Ensley Bottoms near the **Davis well field**, TVA, and proximal to the Allen well field using geophysical techniques.





- High-frequency antennas did not offer enough penetration depth to see the UCCU. A low-frequency antenna was obtained, but it also was not able to penetrate to the depth of the UCCU. GPR is found to be only useful for shallow depths of ~20 m.

Upcoming Deliverables: May-August 2021

Three investigations began in 2019 and will be completed in 2021

PENDING COMPLETION MAY-AUG 2021

2-5

Refine and quantify source waters to the Memphis aquifer at the **Davis wellfield** through water chemistry, groundwater age-dating, characterization of hydrogeologic properties, and numerical modeling.

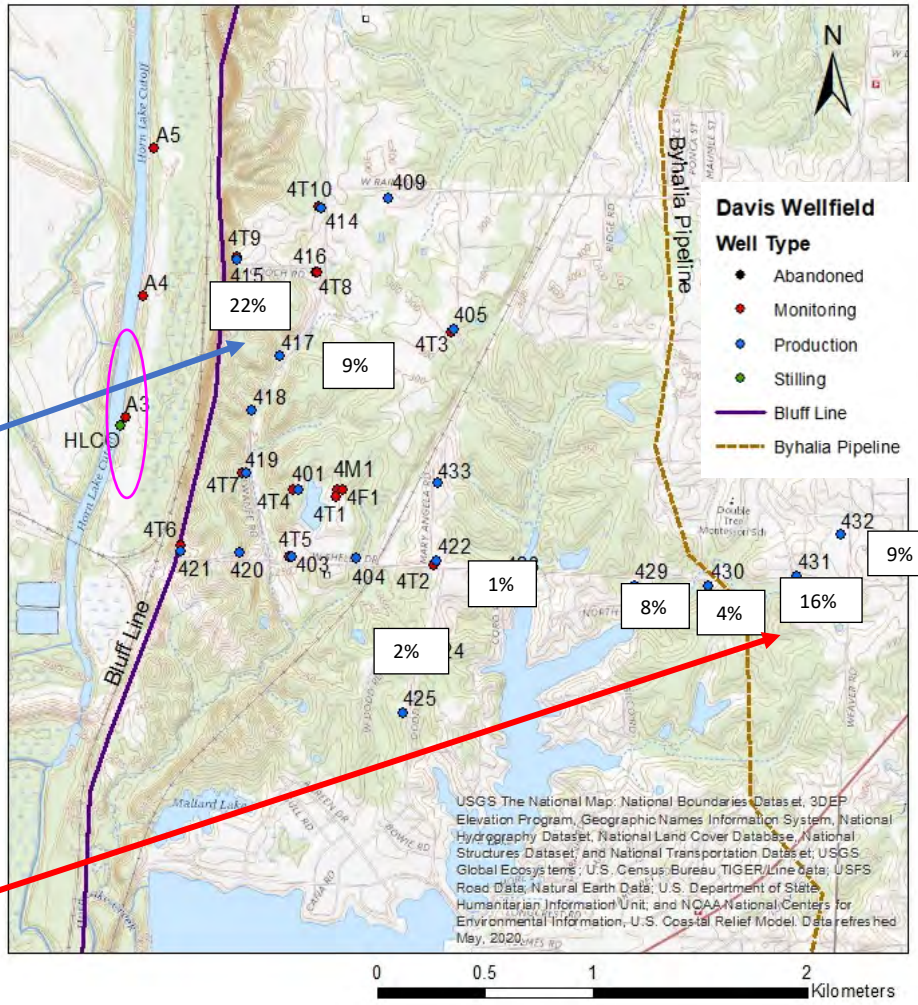
"Fast-Track" Path:

Bluff Recharge (Known west window)

- MRVA source
- Characterized by no DO, less depleted $\delta^{18}O$

Eastern Recharge (Suspected window? Fault)

- Fluvial – Terrace deposits & deep subsurface source
- Identified by low DO, more depleted $\delta^{18}O$ & enriched He



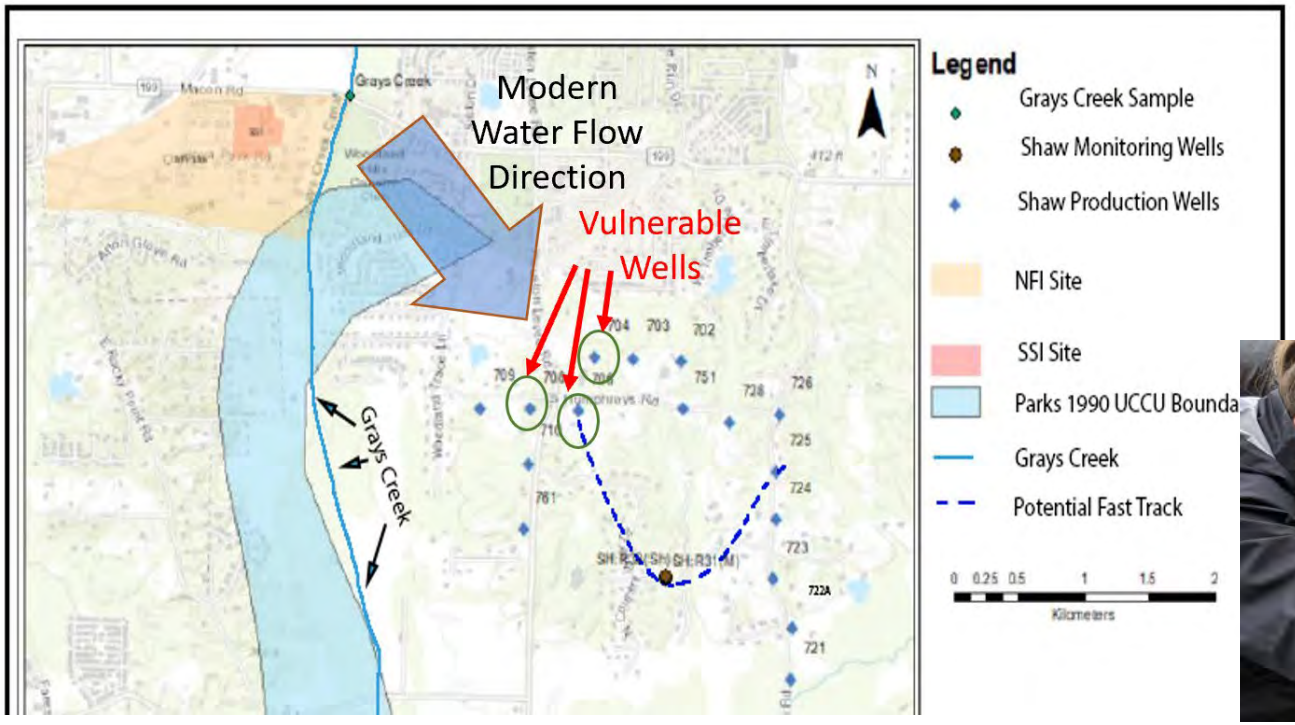
PENDING COMPLETION MAY-AUG 2021

2-7

Investigate **Shaw wellfield** to determine source waters and modern water migration into the Memphis aquifer, development of unconfined conditions and vulnerability to nearby contaminated sites.

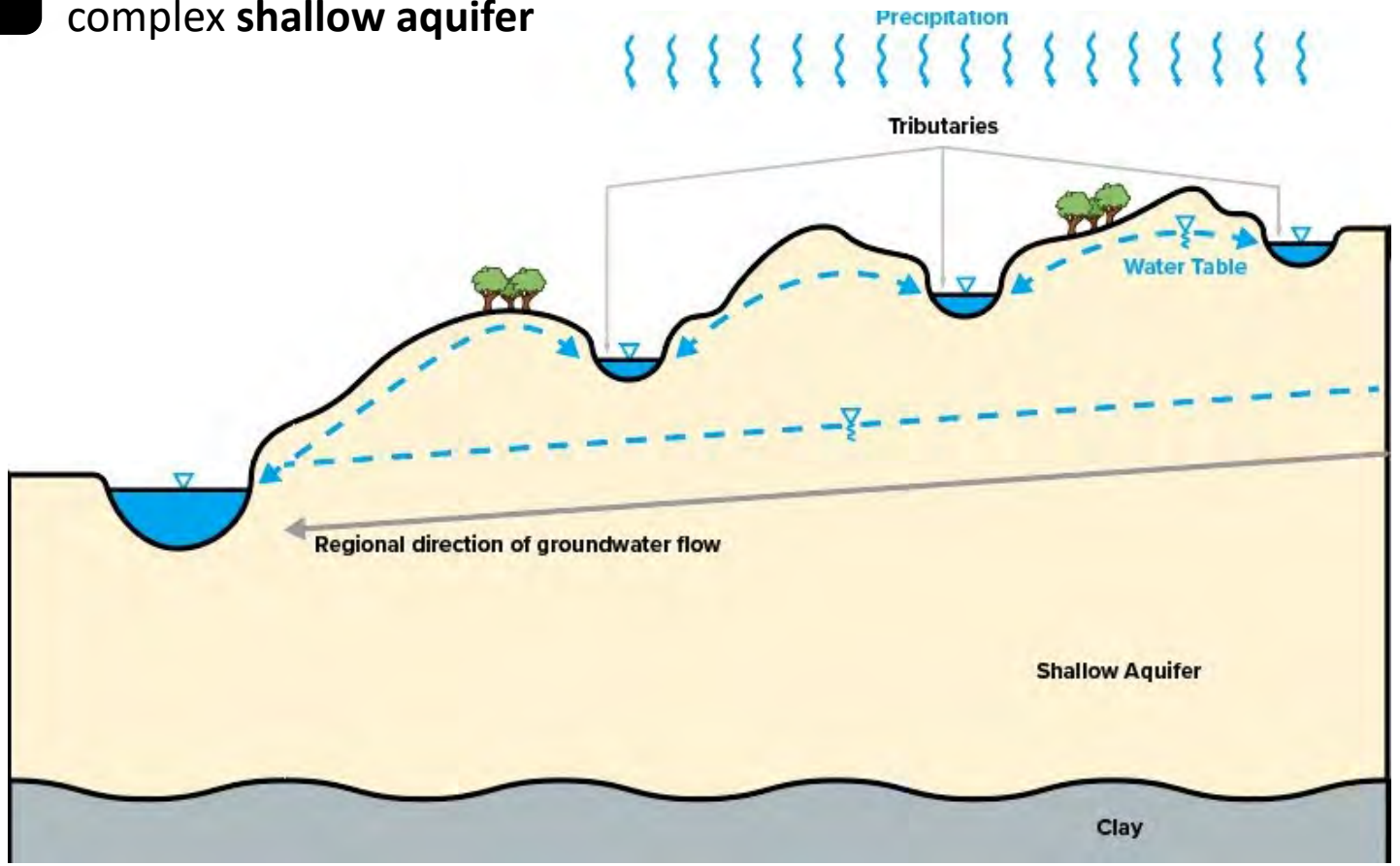
"Fast-Track" Path: NW corner of Shaw Wellfield appears vulnerable to modern water

- Grays Creek and absent clay likely reason for leakage
- Preliminary results show wells with 19-31% modern water



PENDING COMPLETION MAY-AUG 2021

2-9 Determine best practices for simulating groundwater conditions in the complex **shallow aquifer**

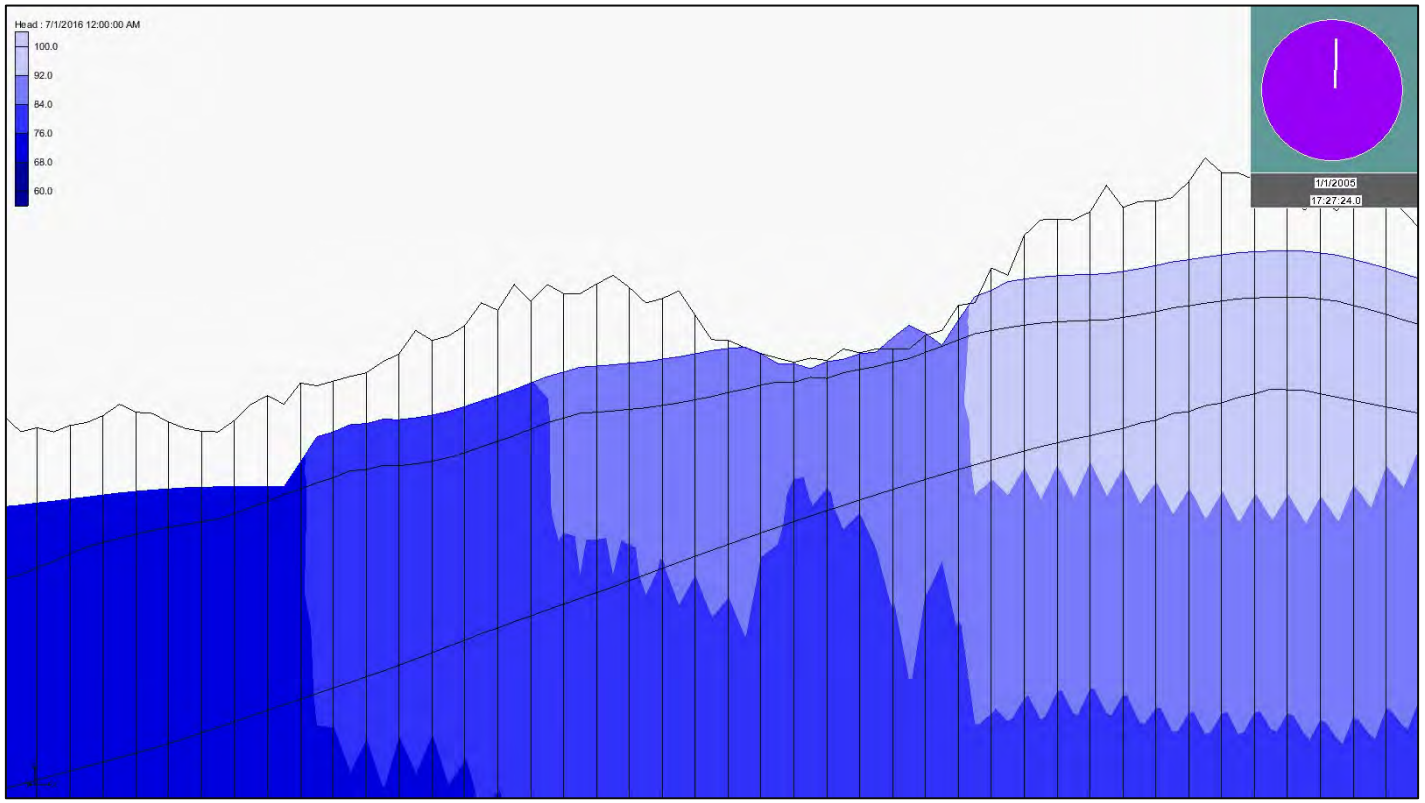


* Inclusion of a ***denser stream network*** will vastly improve shallow aquifer gradients, especially around windows and in drying/unconfinement situations like at Lichterman wellfield.

PENDING COMPLETION MAY-AUG 2021

2-9 Determine best practices for simulating groundwater conditions in the complex **shallow aquifer**

windows can locally cause the **shallow aquifer to go dry**, draining groundwater into the Memphis aquifer. This condition that adds great complexity when modeling aquifer water exchange.



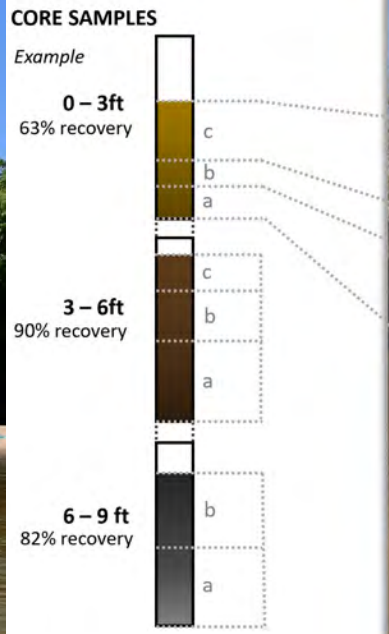
Upcoming Deliverable: Dec 2021

One investigation began in 2019 and will be completed in Dec. 2021

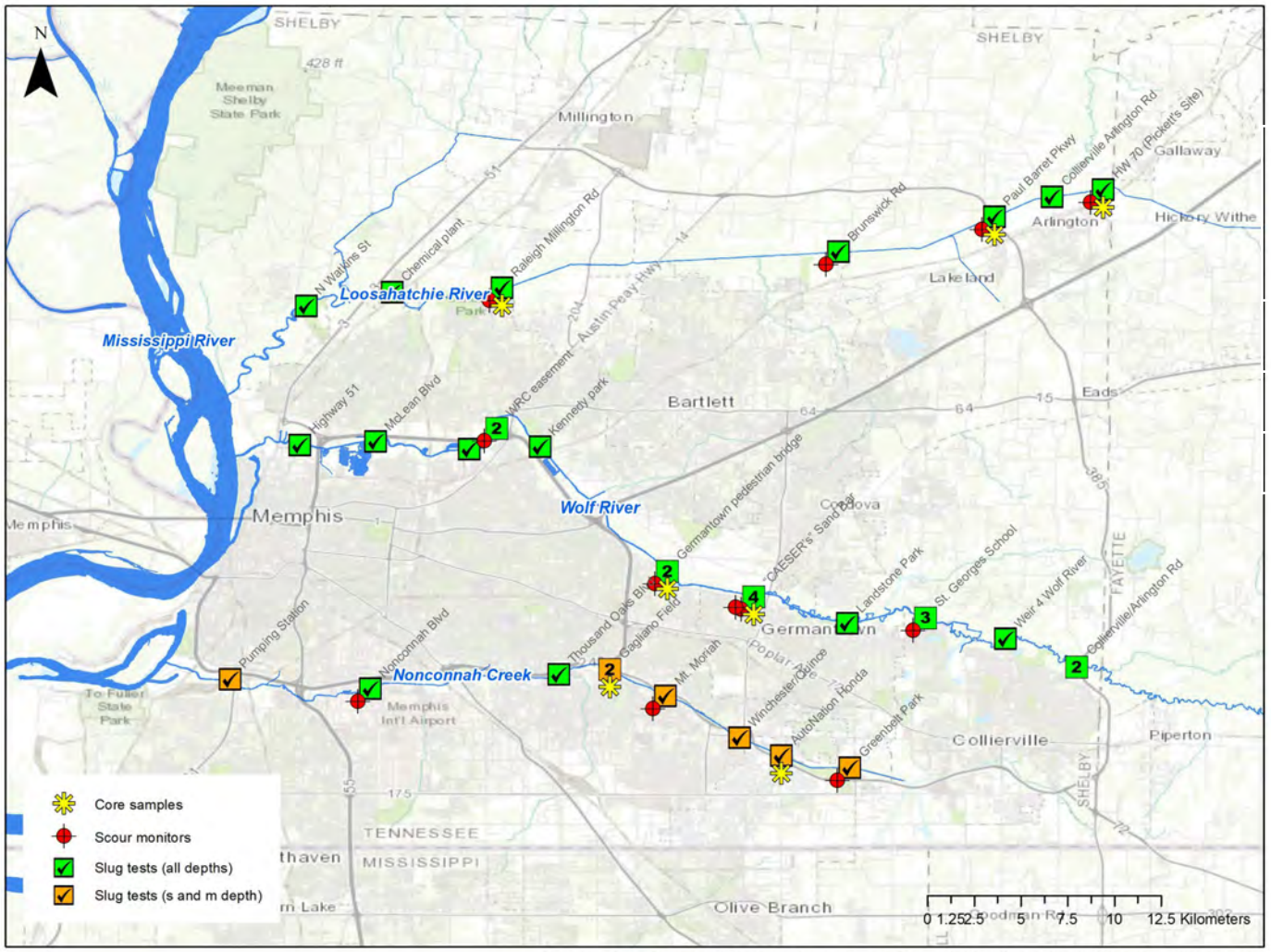
PENDING COMPLETION MAY-AUG 2021

2-6

Determine hydraulic conductivity and thickness for the riverbeds of the Loosahatchie River, Wolf River and Nonconnah Creek to further constrain the Shelby County numerical groundwater model and for site-scale hydrogeologic analyses.



* *Streambed properties reveal **many reaches are highly transmissive** while determination of actual bed thicknesses are still being investigated.*



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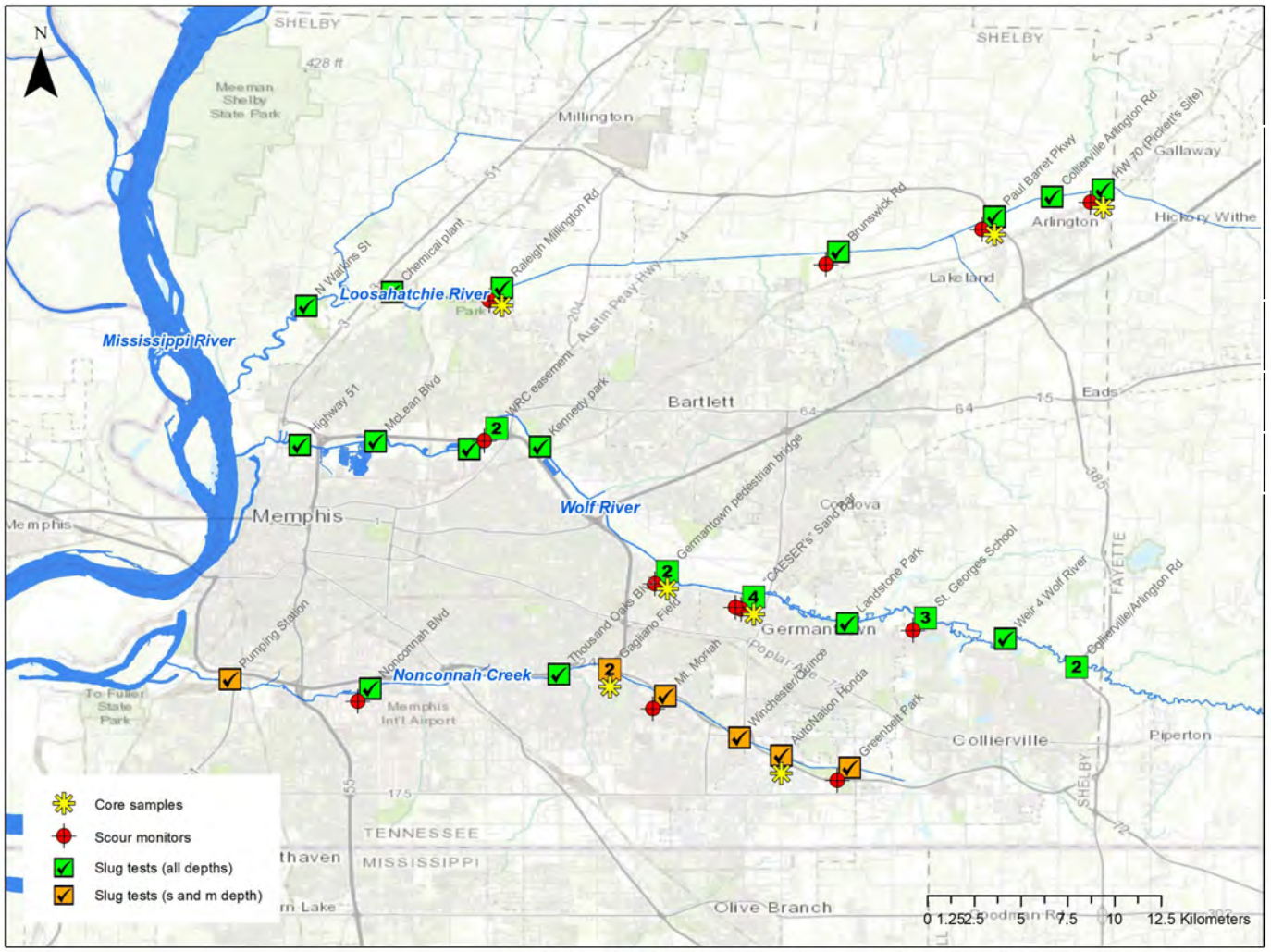
LOCATIONS

	Slug tests	Scour monitors	Samples
LR	7	4	3
WR	11	4	2
NC	8	3	2

Slug tests

	Total points tested	Tests (xdepth)	Approx. slug tests (curves)
LR	7	21	84
WR	19	57	228
NC	9	20	80
	Tot	98	396



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LOCATIONS

	Slug tests	Scour monitors	Samples
LR	7	4	3
WR	11	4	2
NC	8	3	2

Samples

	Core samples	Samples after sectioning
LR	11	26
WR	6	11
NC	6	13
	Tot	50

Location code	K (m/d)		
	d (1.5m)	m (1.0m)	s (0.5m)
CLV	11	102	90
WR4	72	74	67
STG	170	132	129
LSP	43	85	116
CSB	5	95	95
GWP	159	215	180
KPK	98	94	102
WRC	86	105	73
NHL	86	112	144
MCL	152	197	121
H51	121	171	156
Average	**91**	**126**	**116**

Tentative results on “riverbed” hydraulic conductivity

Scour monitor device to determine riverbed thickness

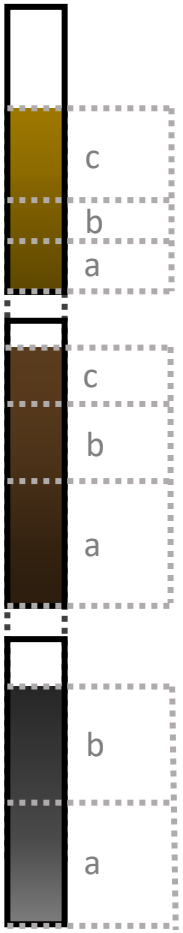
CORE SAMPLES

Example

0 – 3ft
63% recovery

3 – 6ft
90% recovery

6 – 9 ft
82% recovery



Fine Sediment Content **Summary**

Interval	Sample	Section	Wolf River: Near Gtown Rd. (CAESER Sandbar)	Wolf River: Near Greenway pedestrian bridge	Loosahatchie River: HW 70 (Pickett's site)	Loosahatchie River: HW 385 (Paul Barrett Pkwy)	Loosahatchie River: Raleigh Millington Rd	Nonconnah Creek: Raleigh Millington Rd	Nonconnah Creek: AutoNation Honda 385
			WRA	WRB	LRA	LRB	LRC	NCA	NCB
0 - 3ft	1	c		0.15%		0.21%		0.85%	TBE
		b	0.22%	0.06%	0.15%	1.06%	0.30%	0.21%	
		a	0.15%	0.15%	0.30%	0.15%	0.39%	3.53%	
3 - 6ft	2	c			0.60%		1.40%	1.61%	TBE
		b		0.77%	5.64% 0.27%	0.84%	1.90% 3.36%	6.05%	
		a	1.40%	6.25%	1.79% 0.82%	53.24%	0.00% 4.69%	47.30%	
6 - 9 ft	3	c					12.41%		
		b	0.17%		1.52%	48.55%	18.57%	TBE	TBE
		a	0.05%	12.60%	4.83%	5.45%	6.55%		

TBE – To be estimated.

Fines: 4 phi (≤0.0625mm)

Upcoming Deliverables: 2022-2023

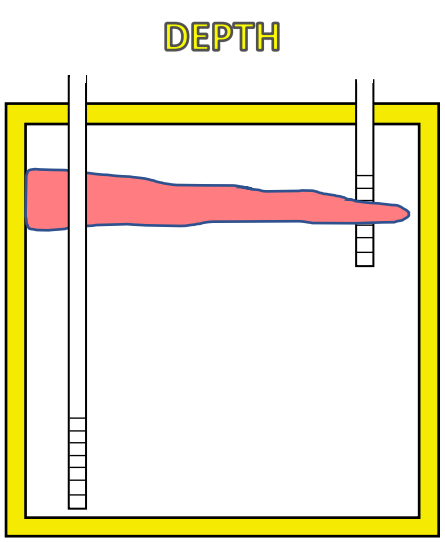
Twelve investigations initiated that will be completed by June 2023

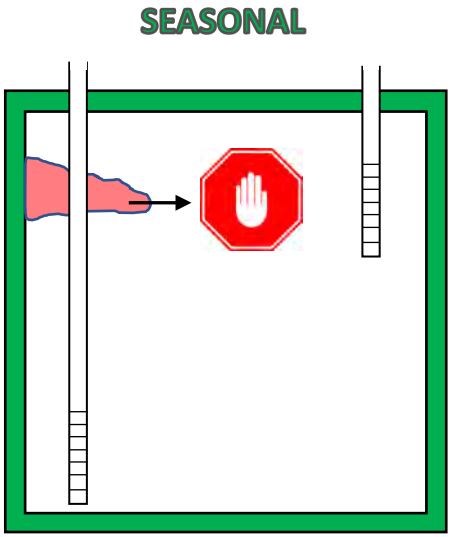
PENDING COMPLETION MAY 2022

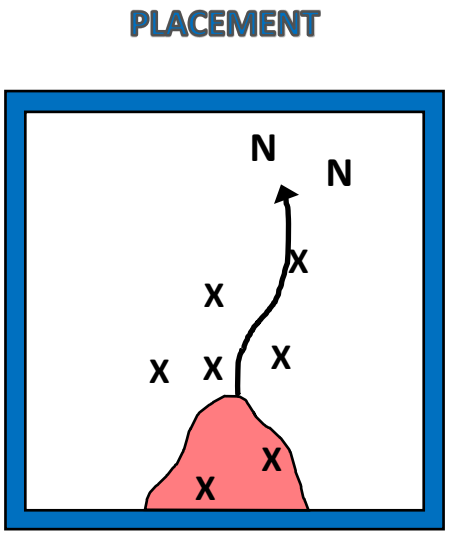
1-5 Groundwater pumping optimization to minimize contaminant movement from the water table aquifer to Memphis Aquifer using stochastic modeling.

152 production wells + **16** known/suspected windows + **~10** zones for well screen placement = **Enumerable well placements**

Number of permutations is astounding







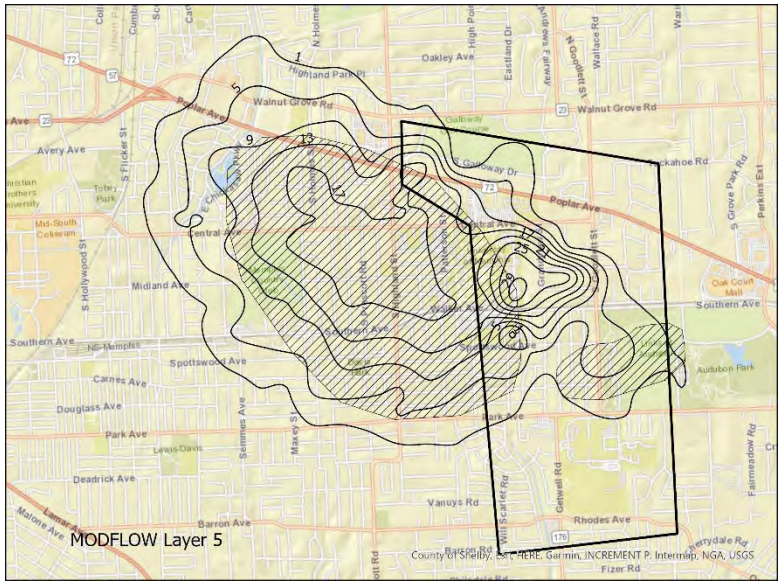
*Over **100,000** model simulations reveal protection from contamination, saving the aquifer, extending a wellfield's life, or sometimes no help possible.*

PENDING COMPLETION MAY 2022

1-5 Groundwater pumping optimization to minimize contaminant movement from the water table aquifer to Memphis Aquifer using stochastic modeling.

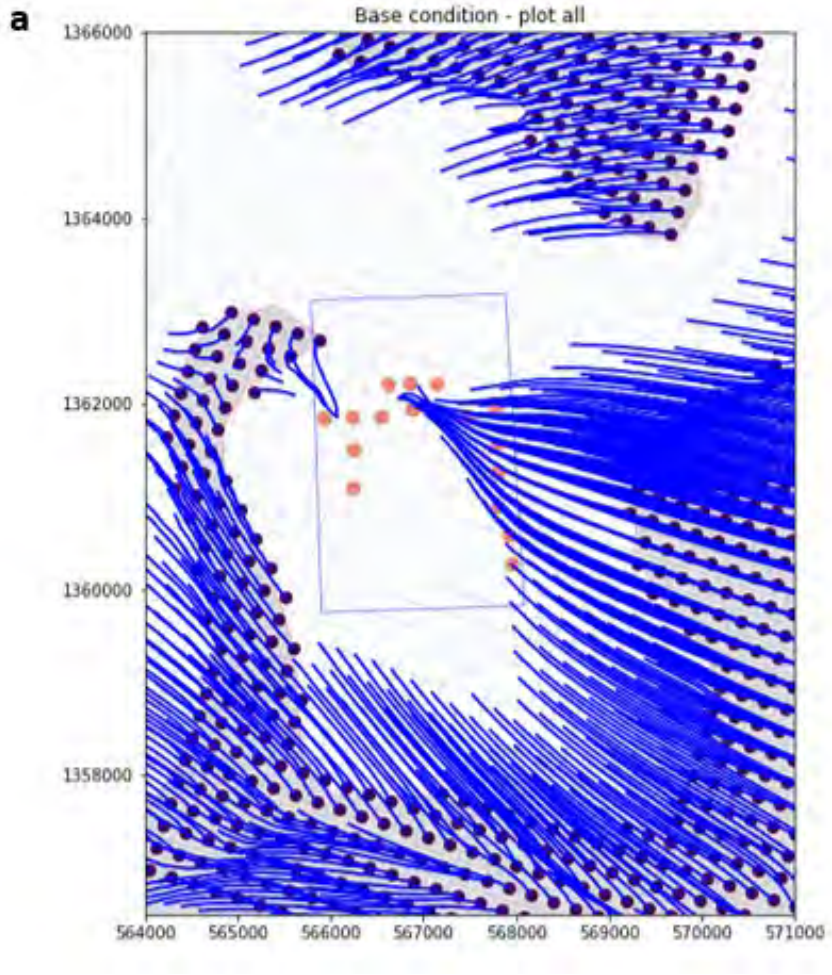
Results showed that the optimization could eliminate the contamination at the Allen, Davis, McCord, and Shaw well fields through the 50 years simulation. It also lowered the contamination by 92 and 86 percent at the Lichterman and Sheahan well fields.

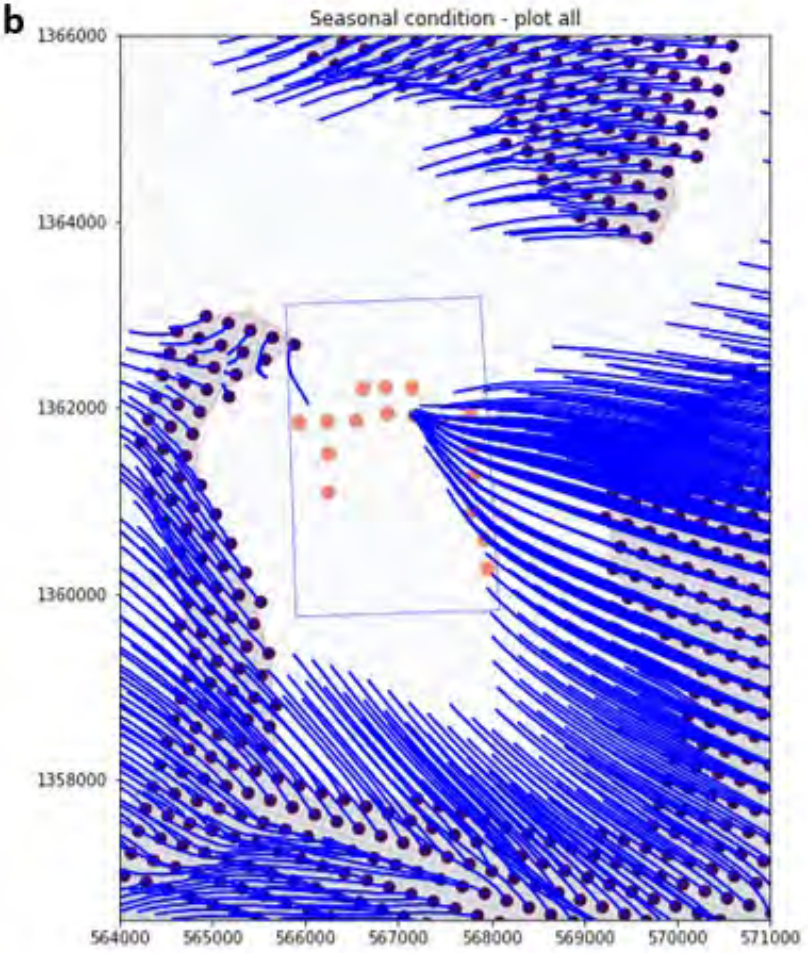
Allen and Davis well field since most wells at these well fields are screened in the upper part of the Memphis aquifer



PENDING COMPLETION MAY 2022

1-5 Groundwater pumping optimization to minimize contaminant movement from the water table aquifer to Memphis Aquifer using stochastic modeling.

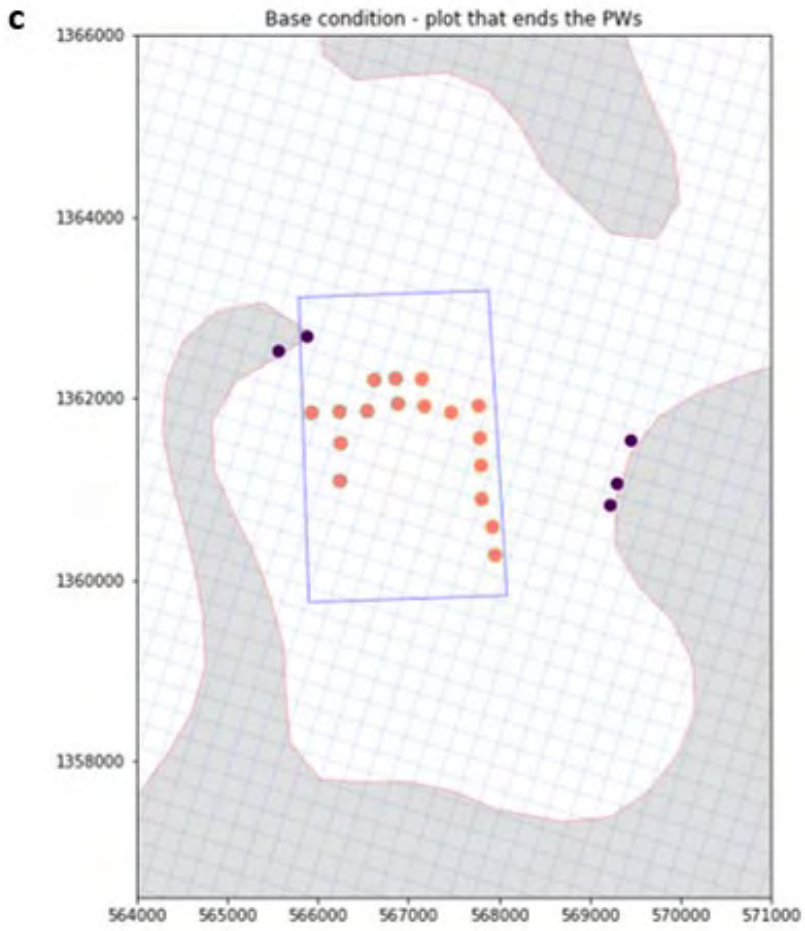


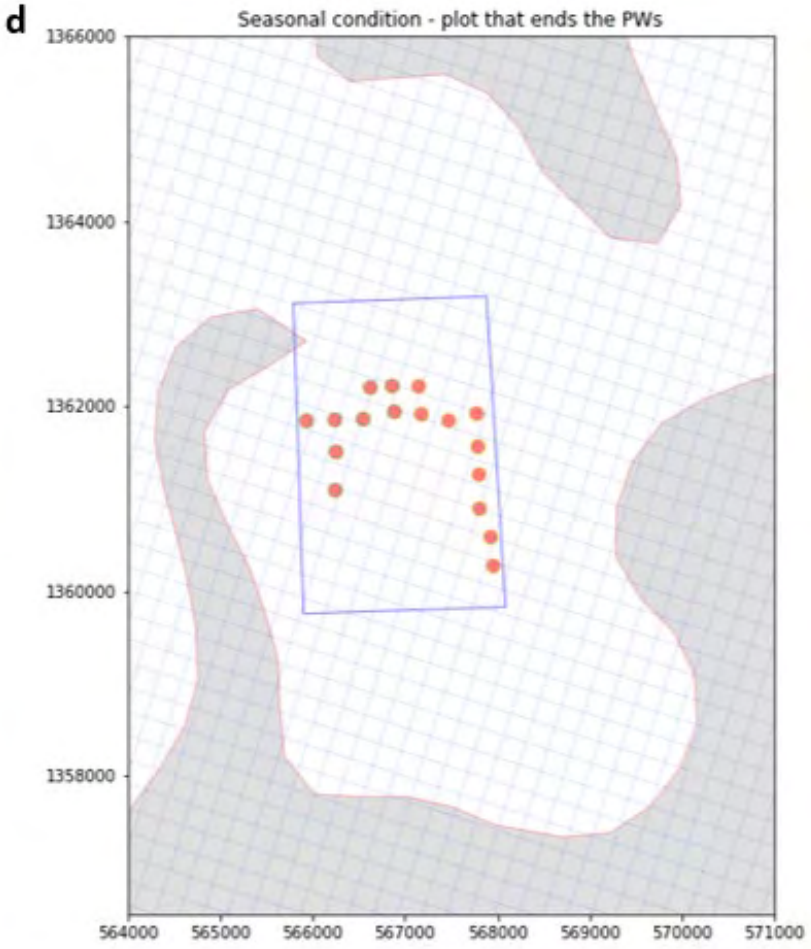


PENDING COMPLETION MAY 2022

1-5

Groundwater pumping optimization to minimize contaminant movement from the water table aquifer to Memphis Aquifer using stochastic modeling.

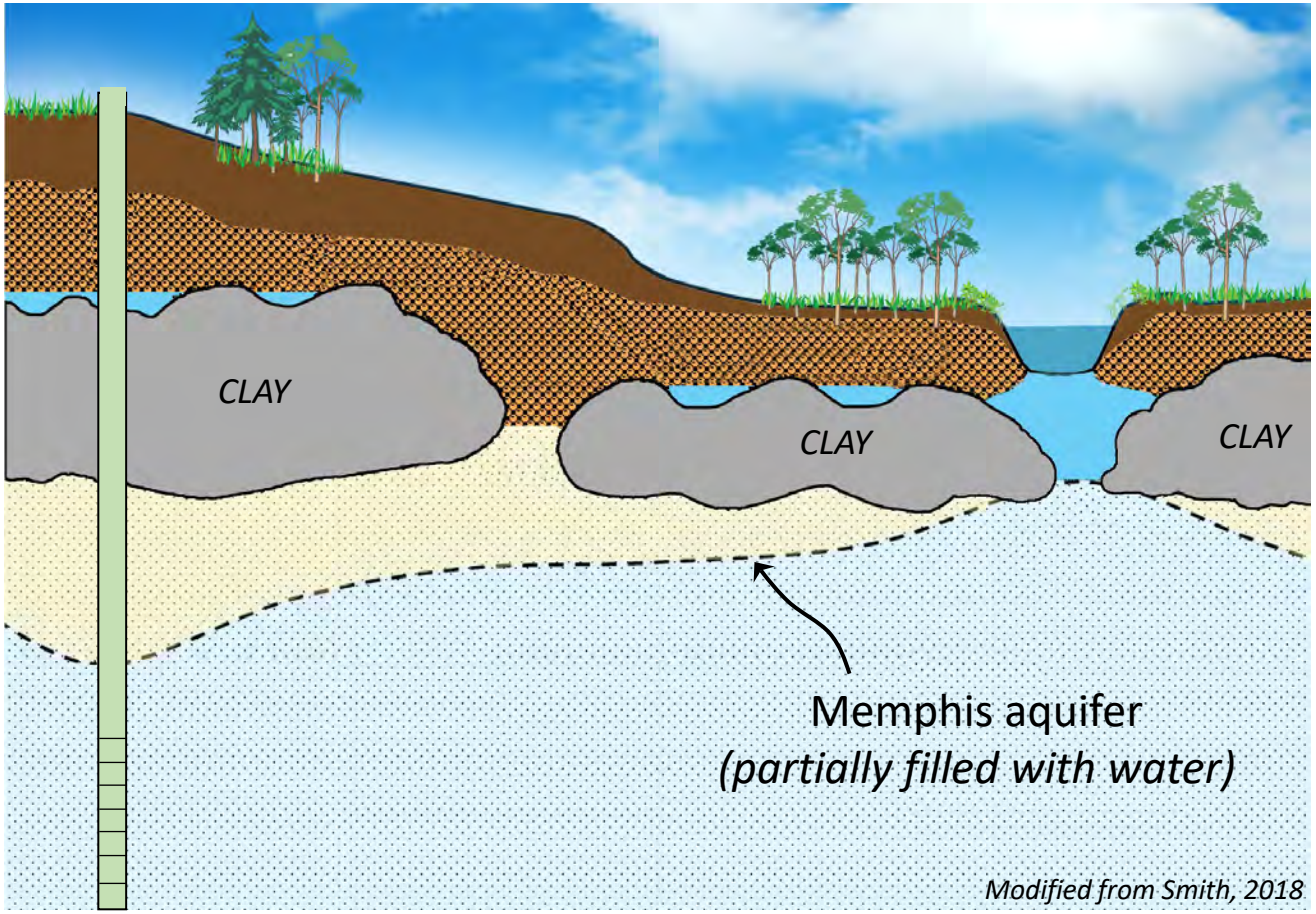




PENDING COMPLETION AUGUST 2022

2-8

Determine recharge mechanisms and rates to the **shallow aquifer** within Shelby County that contributes to its replenishment and source of additional inflow to the Memphis aquifer through windows.



- Urban recharge methodologies differ from rural recharge
- We must consider the many artificial (man-made) inputs of water in addition to natural inputs (e.g., precipitation).

PENDING COMPLETION MAY 2022

3-1

Investigate a suspected aquitard breach near McCord well field by using electric resistivity and possibly other geophysical techniques within available open space. Project to include drilling as well for stratigraphic control.

- Will follow similar procedures to that of **2-5, 2-7** and **3-2** (Shaw, Davis and Mallory, respectively)
- Sampling event is being planned for late spring/early summer

PENDING COMPLETION MAY 2022

3-2 Refine and quantify source waters to the Memphis aquifer at the **Mallory wellfield** through water chemistry, groundwater age-dating, characterization of hydrogeologic properties, and numerical modeling.

Sampling the McNairy well +2,600 ft deep Feb. 2021

- Geophysical testing (**2-2** and **5-1**) will support identification of windows west of Mallory beneath the MS River

PENDING COMPLETION MAY 2022

3-3 Incorporate age-dating of **Sheahan production wells** into numerical model to resolve the probable location of window(s) in the southern portion of the well field

For the **<u>first time</u>**, we have a measurement of a window's properties

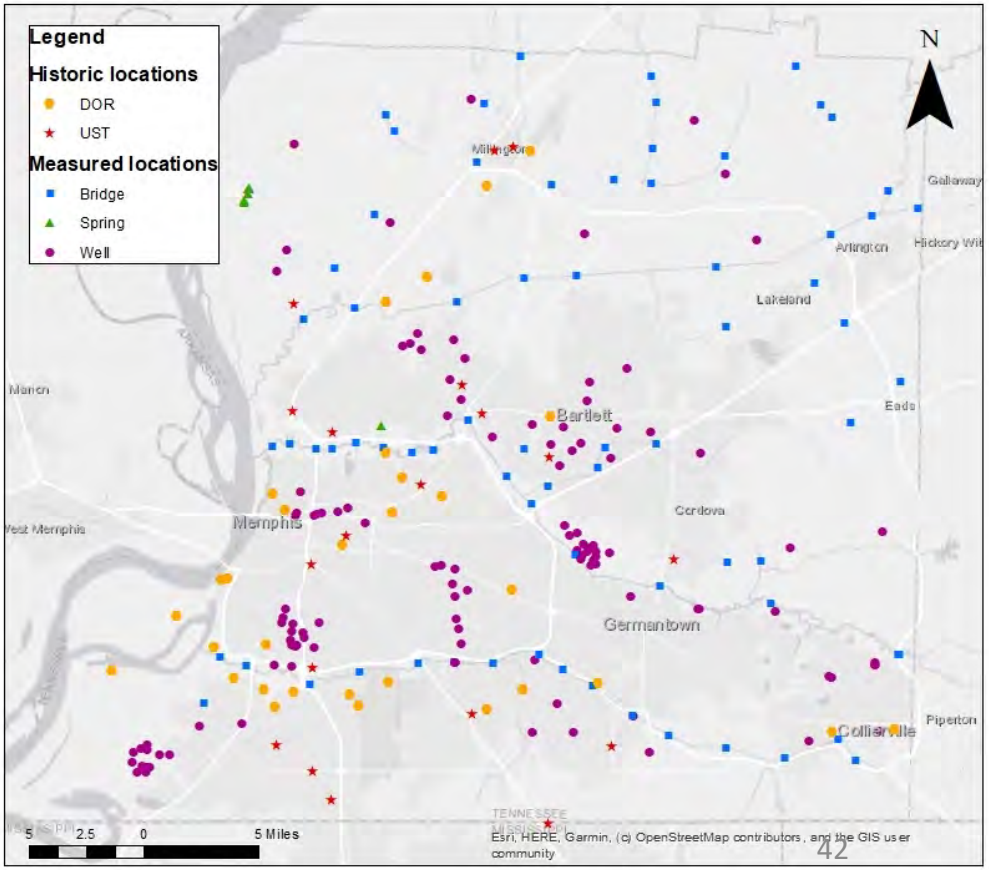
Sample Notation	Sample Depth interval (ft)	Grain-Size Classification	Hk (m/day) (Sheperd) (Horizontal)	Vk (m/day) (Permeameter) (vertical)
#26 (R8B)	64-74	Medium to Fine Sand	43.705	4.27
#41(R14C)	124-134	Fine Sand	9.637	0.44
#48(R17B)	144-154	Fine Sand	16.790	1.57
#61(R21B)	194-204	Fine Sand	17.790	1.62
#78(R25C)	234-244	Fine to Medium Sand	24.263	2.07
#83(R27B)	254-264	Fine Sand with Silt & Clay	3.071	0.00046

PENDING COMPLETION MAY 2022

3-4 Conduct a county-wide water level survey of the **shallow aquifer**.

Extremely accurate measures of shallow aquifer water levels are being obtained during seasons of high and low levels.

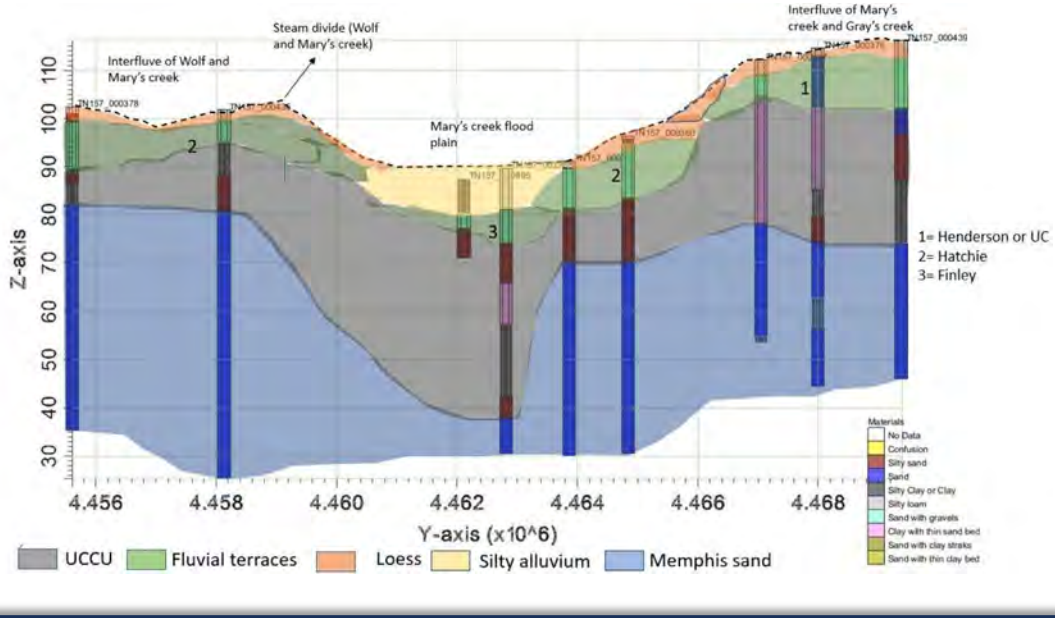
2020-2021 Water Level Survey Locations



PENDING COMPLETION JUNE 2023

2-1 Use geophysical well records to investigate hypothetical paleo-drainage network atop the upper Claiborne confining unit.

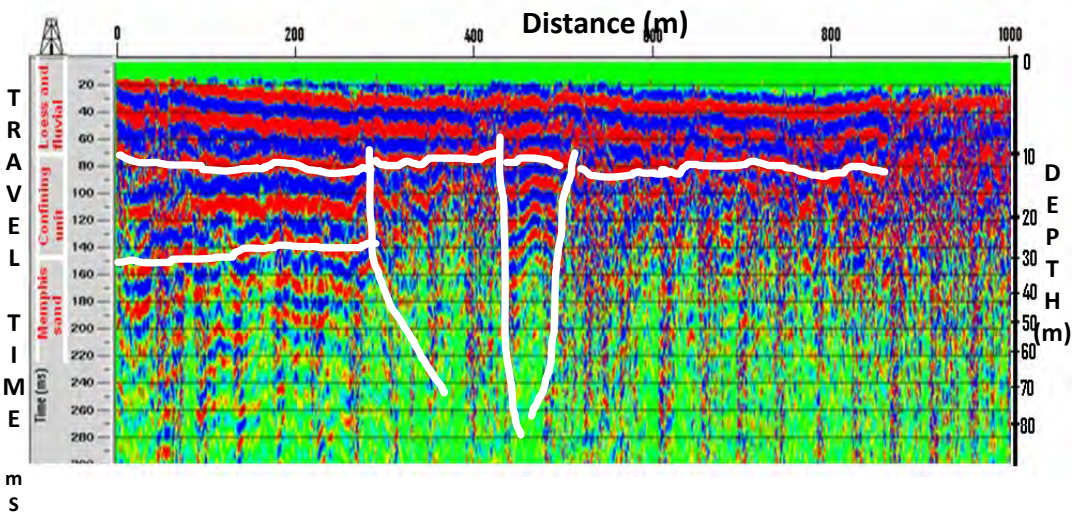
Proper modeling of **water movement in the shallow aquifer** towards windows requires unravelling its complex geologic structure.



* *Detailing shallow stratigraphy will aid in **recharge, contaminant migration, and mapping paleochannels** – the latter helps target window locations.*

PENDING COMPLETION JUNE 2023

2-2 Subsurface mapping of geologic units to identify the presence of aquitard windows and characterize the hydraulic properties of identified windows.



- Investigating using a variety of geophysical methods to map the subsurface such as p-wave (shown here), electric resistivity, and others.

PENDING COMPLETION JUNE 2023

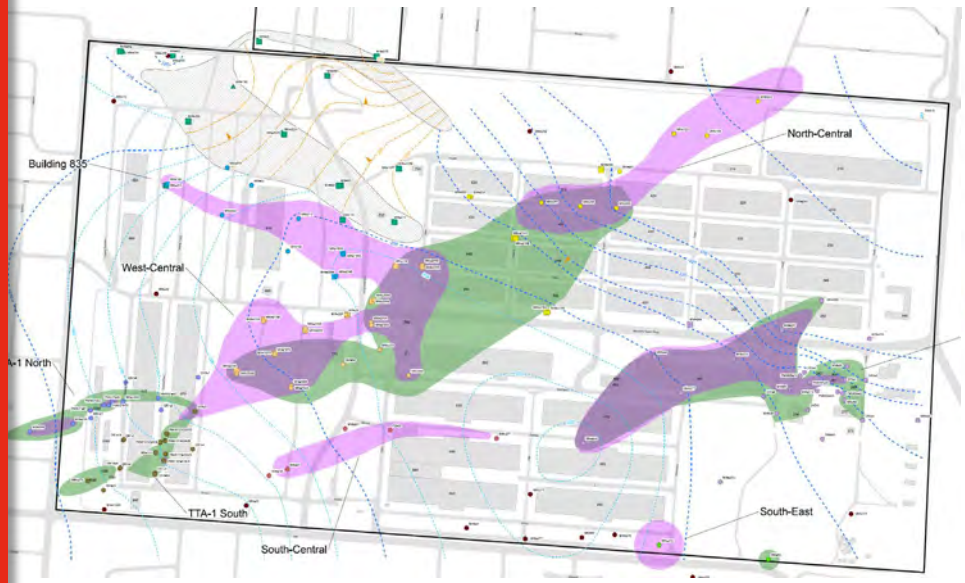
2-3

Investigate surface water-groundwater interactions along the Loosahatchie River and Nonconnah Creek. Incorporate findings plus those of the Wolf River (Project 1-2) into Shelby County numerical model.

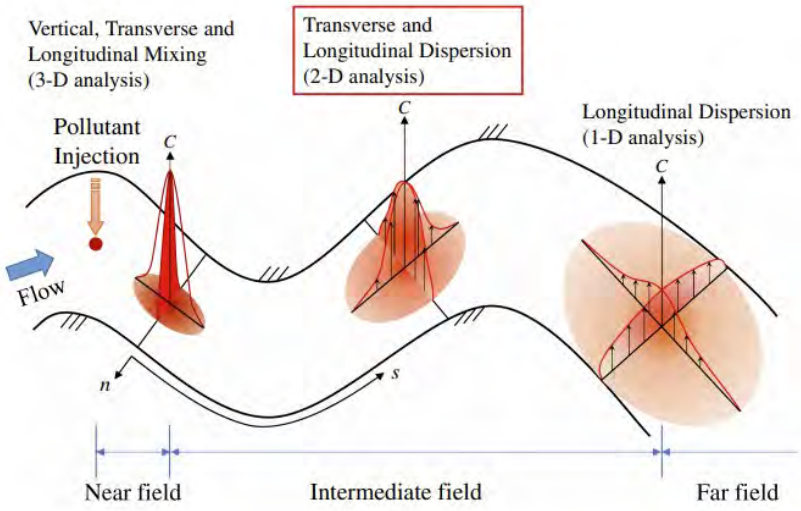
- Phase 1: Redesign instrumentation from project 1-2
- Phase 2: Specify and Design final instrumentation
- **Phase 3: Data collection**
- Phase 4: Data analysis and Modeling

PENDING COMPLETION JUNE 2023

2-4 Development of hypothetical groundwater models focusing on groundwater sustainability and modeling the fate, transport of contaminants



Example plume – Army Depot

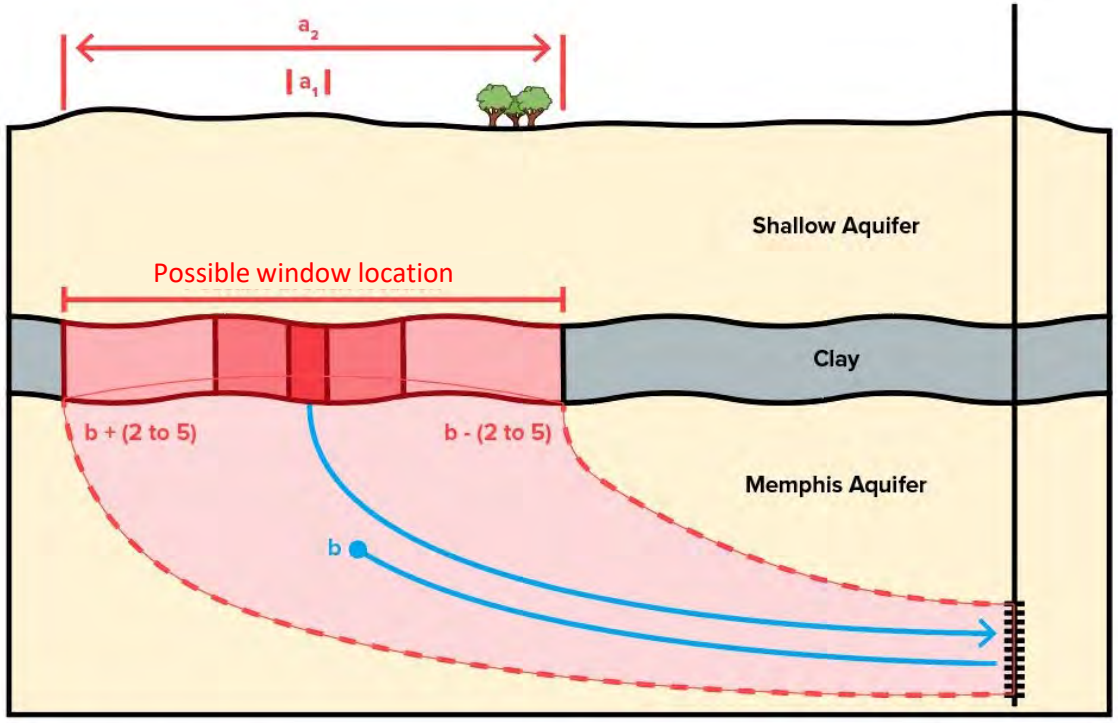


Concept of dispersion

* ***Dispersion*** is the spreading of a contaminant plume in groundwater. We are attempting to use temporal contaminant concentrations to derive an initial range of values, although there is still a lack of data.

PENDING COMPLETION JUNE 2023

2-10 Numerical modeling to correlate age-dating and geochemical observations to known/potential windows that will include possible paleo drainage atop the upper Claiborne confining unit.



a: distance
b: age

PENDING COMPLETION JUNE 2023

2-11 Formulate and test methodologies to reduce or eliminate preferential inter-aquifer water exchange

We are tackling the commonly asked question,
“Can you fill a window?”

We are testing ***approaches to filling a window,*** such as using a clay slurry to reduce the soil’s hydraulic conductance – 30% clay has significant impact to impeding water flow in coarse sediment.

Year 4 Projects

1. *Fly AEM (airborne electromagnetism) over section of north Shelby County that includes a suspected window location*
2. *Develop lithologic database of well logs for Shelby County for 3D representation and use for stratigraphic mapping*