



SWIFT Managed Aquifer Recharge: From Influent to the  
Aquifer and Everything In Between  
Dan Holloway, P.G. | HRSD

Groundwater Protection Council  
ASR-MAR Workgroup,  
January 16, 2024

## About Us



Population served: 1.9 million  
14<sup>th</sup> Largest Wastewater Utility



Political Subdivision created in 1940  
Serves 20 Cities and Counties



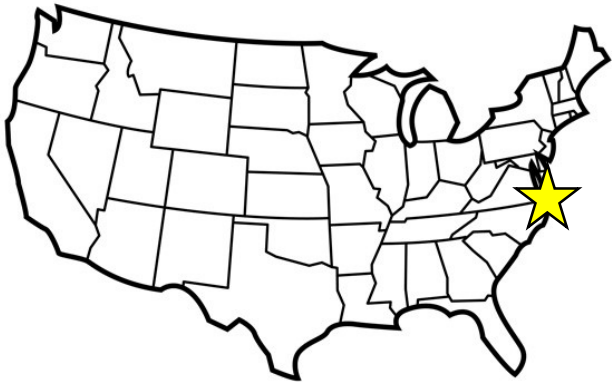
Combined wastewater treatment capacity: 225 million gallons/day



Operate 8 major and 6 smaller treatment plants and more than 100 pump stations



Separate Sanitary System with > 500 miles of pipe



Service area is approx. 5,000 square miles





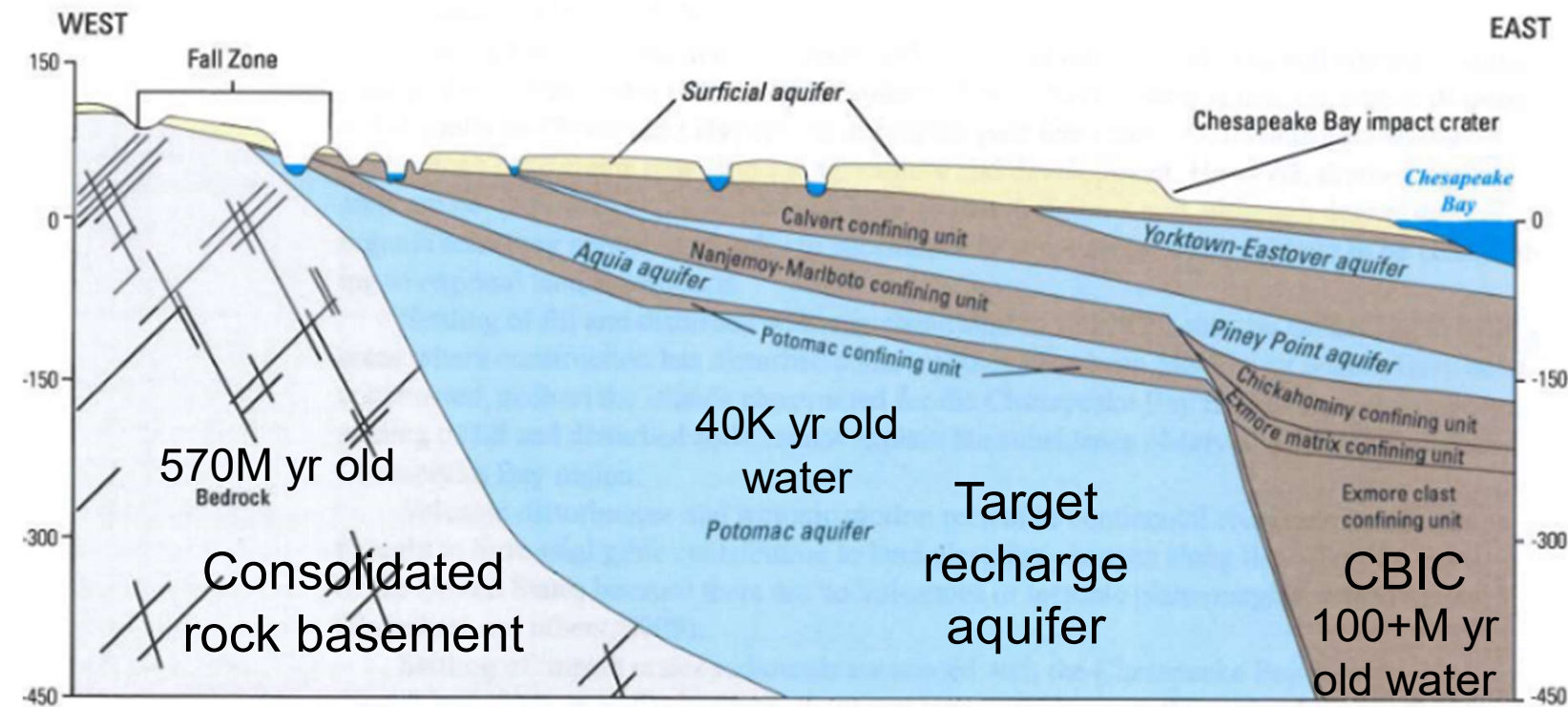
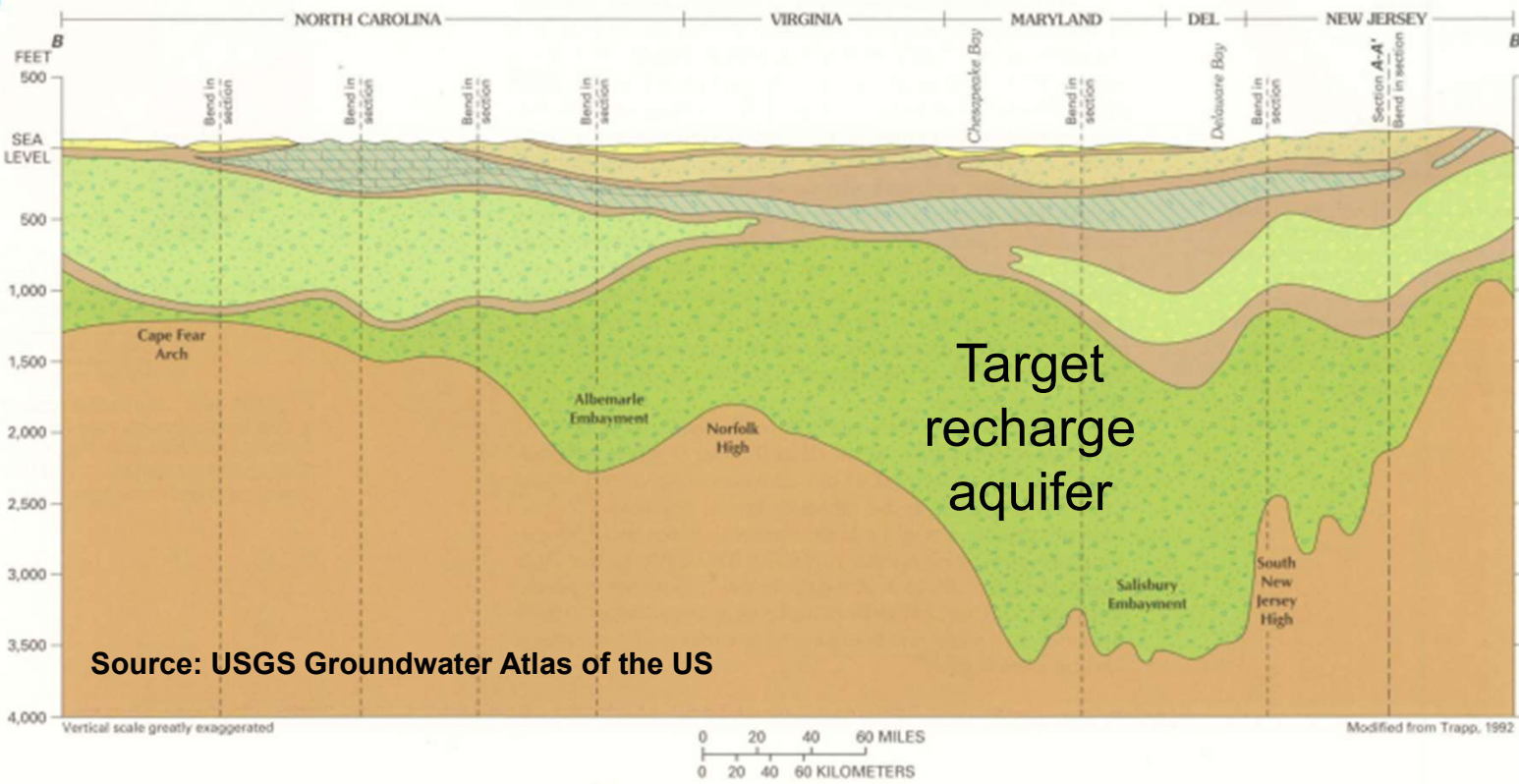
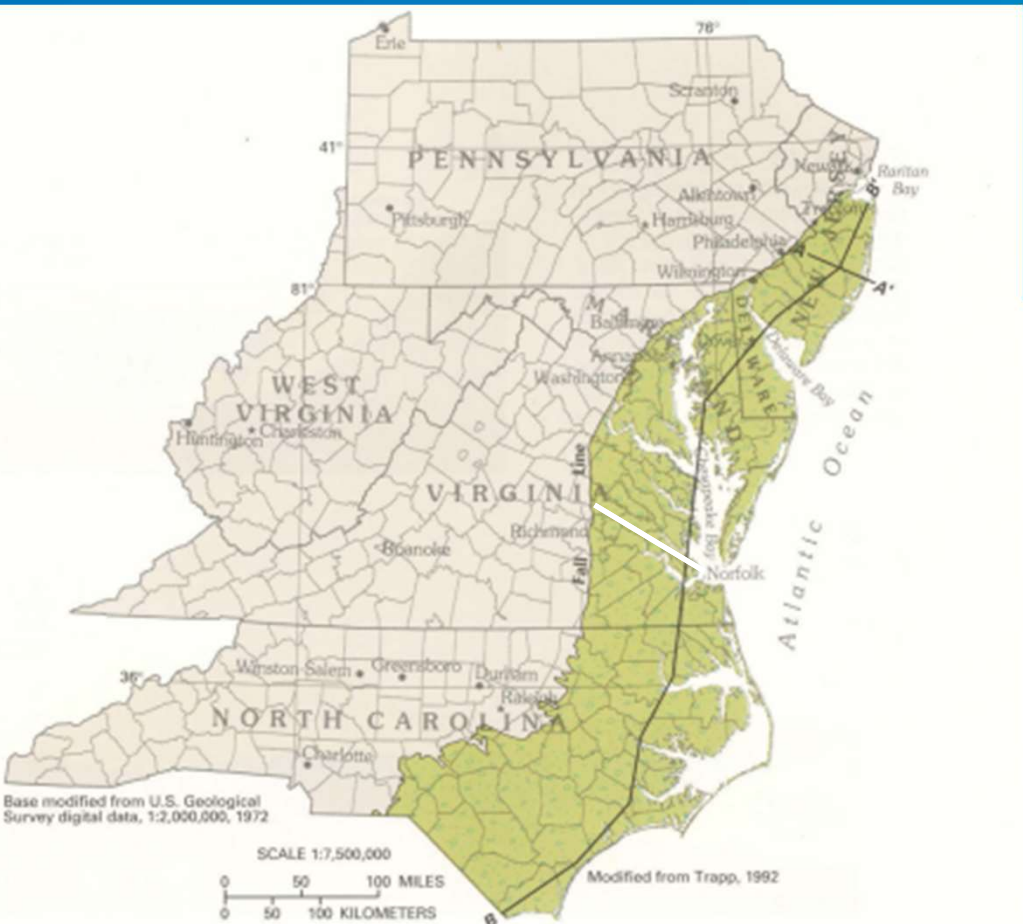
# Water Challenges for Coastal Virginia



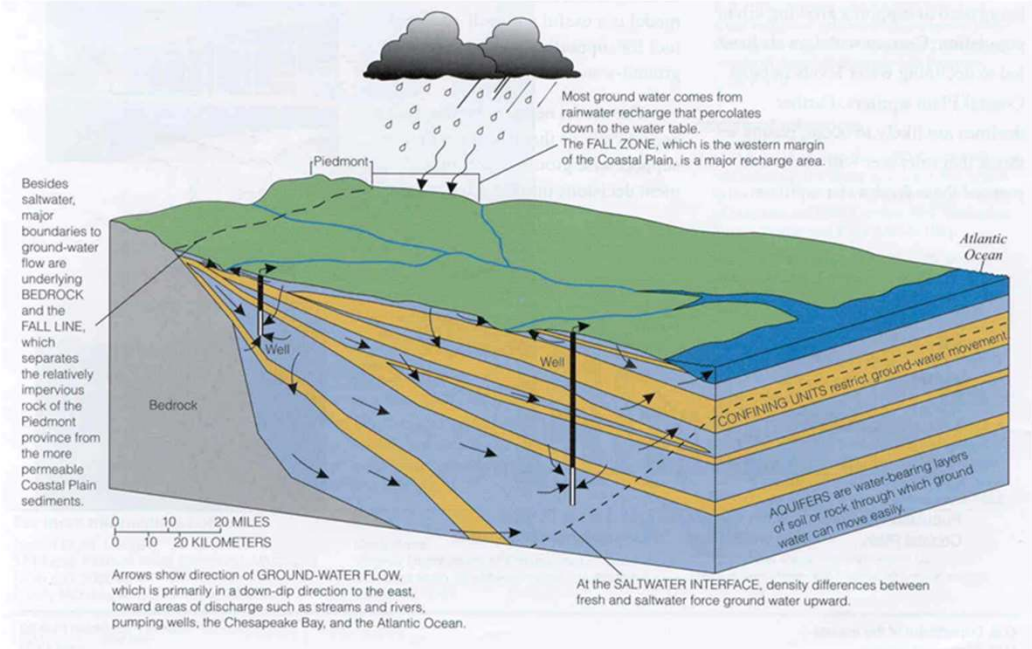
- Restoration of the Chesapeake Bay
  - Harmful Algal Blooms
  - Localized bacteria impairments (beaches, oyster grounds)
  - Urban stormwater retrofits (cost and complexity)
- Compliance with Federal enforcement action
  - Wet weather SSOs
  - Regional approach
- Adaptation to sea level rise
  - Recurrent flooding
  - More severe flooding
- Depletion of groundwater resources
  - Potential dewatering of confined aquifers
  - Potential for saltwater contamination
  - Causes land subsidence



# Mid-Atlantic Coastal Plain Aquifer System

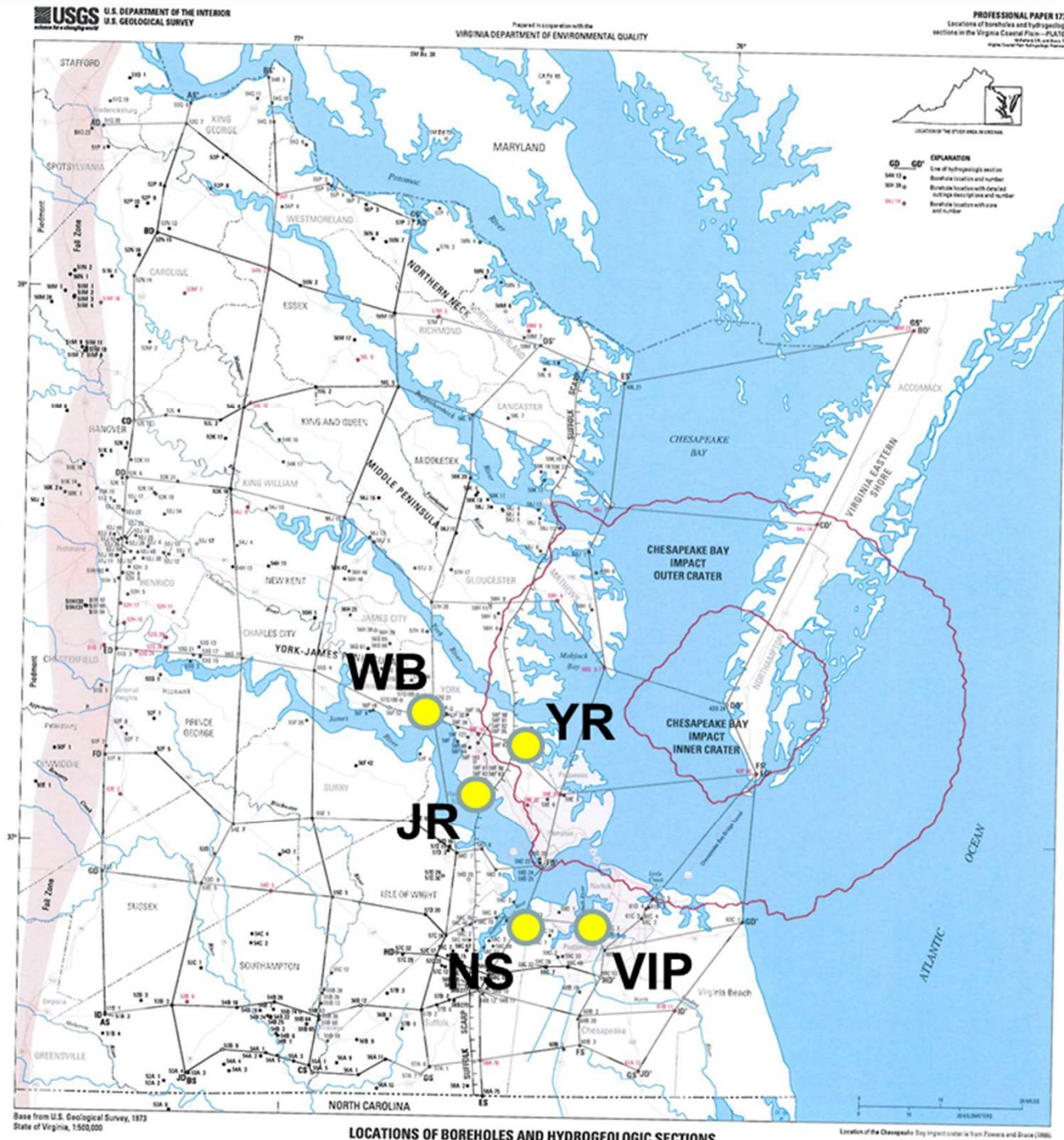


Source: USGS Professional Paper 1731, McFarland and Bruce 2006

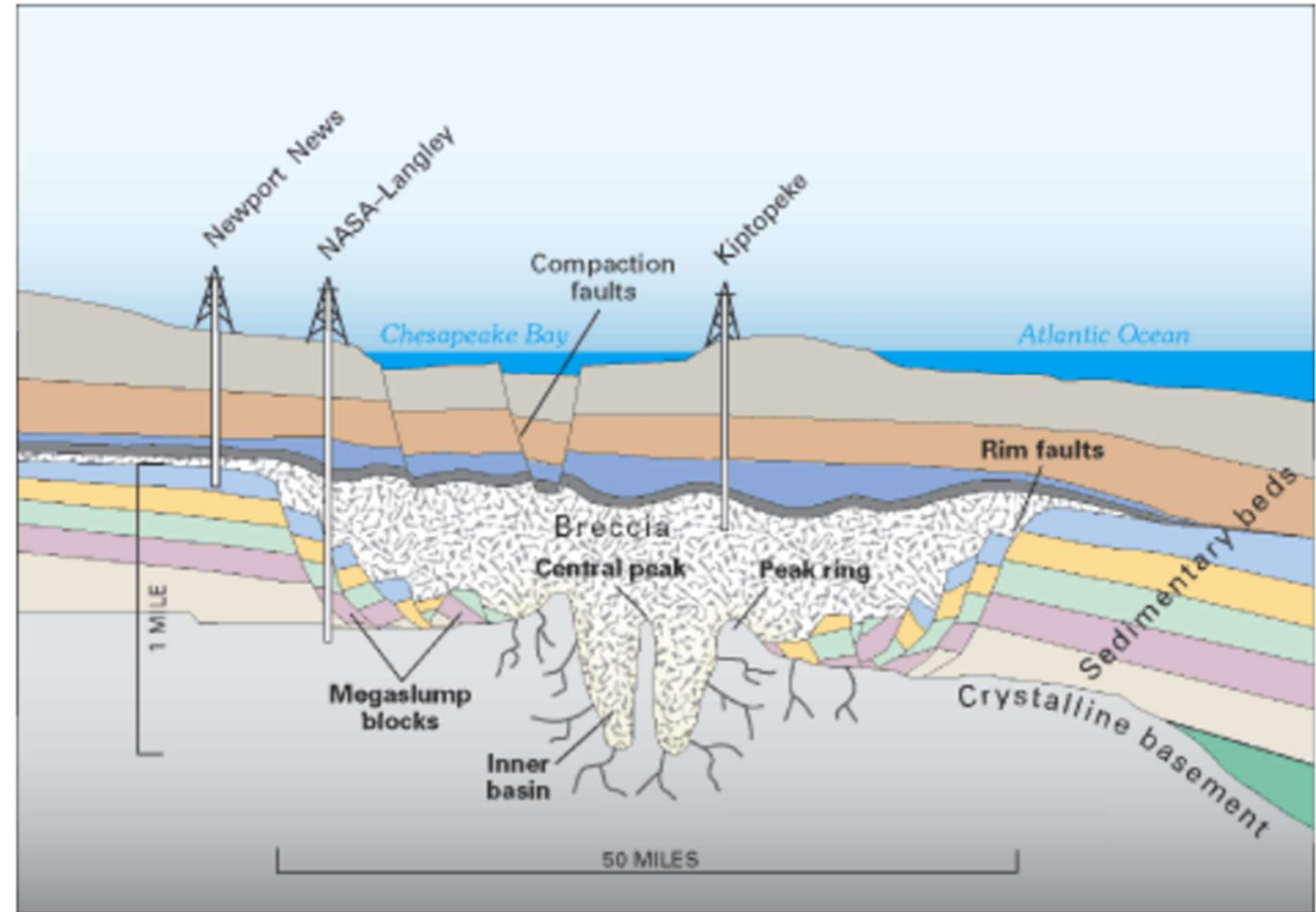




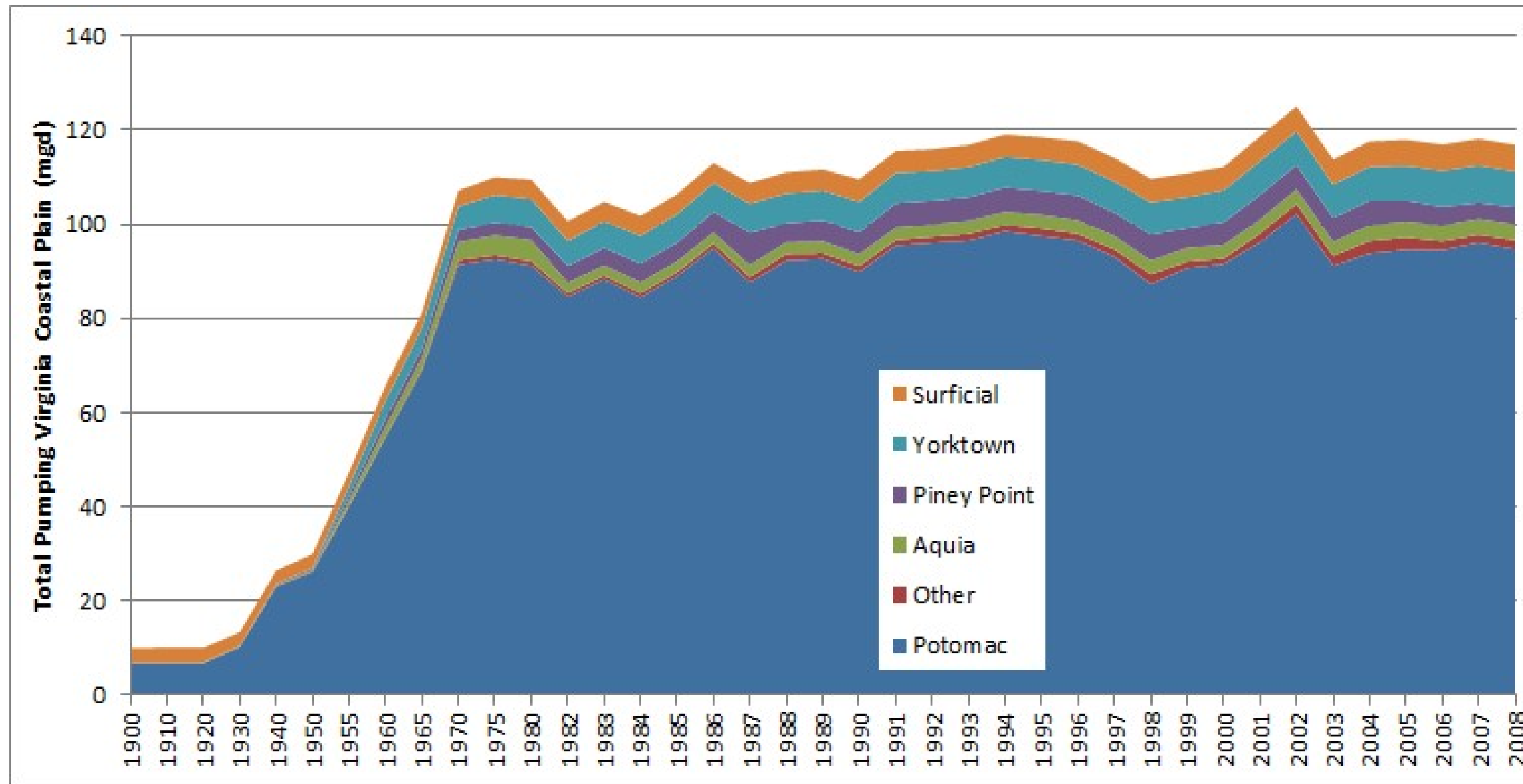
# Visitors from outer space can make an impact



Source: USGS Professional Paper 1731, McFarland and Bruce 2006



Withdrawals rose sharply then generally stabilized

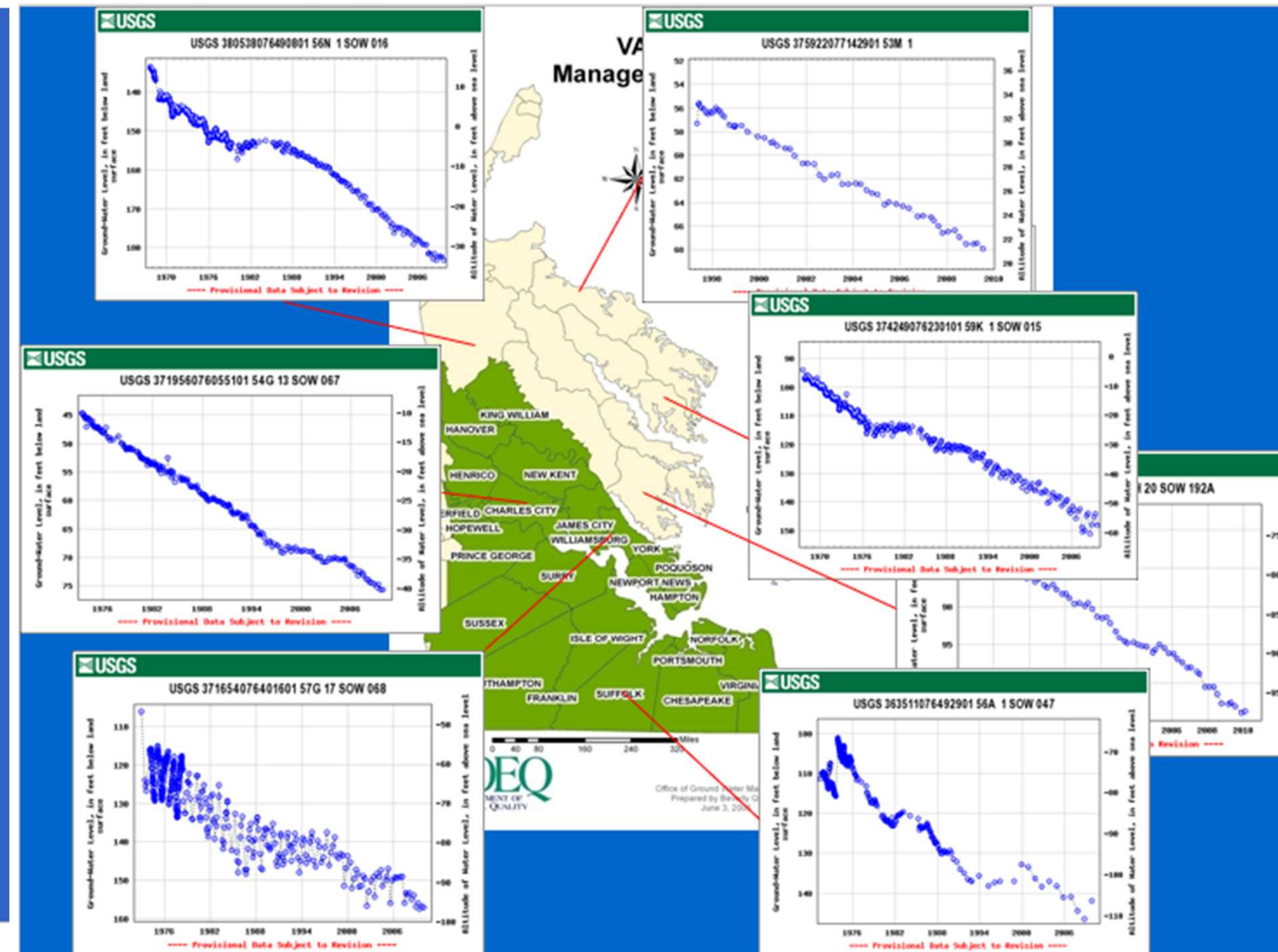
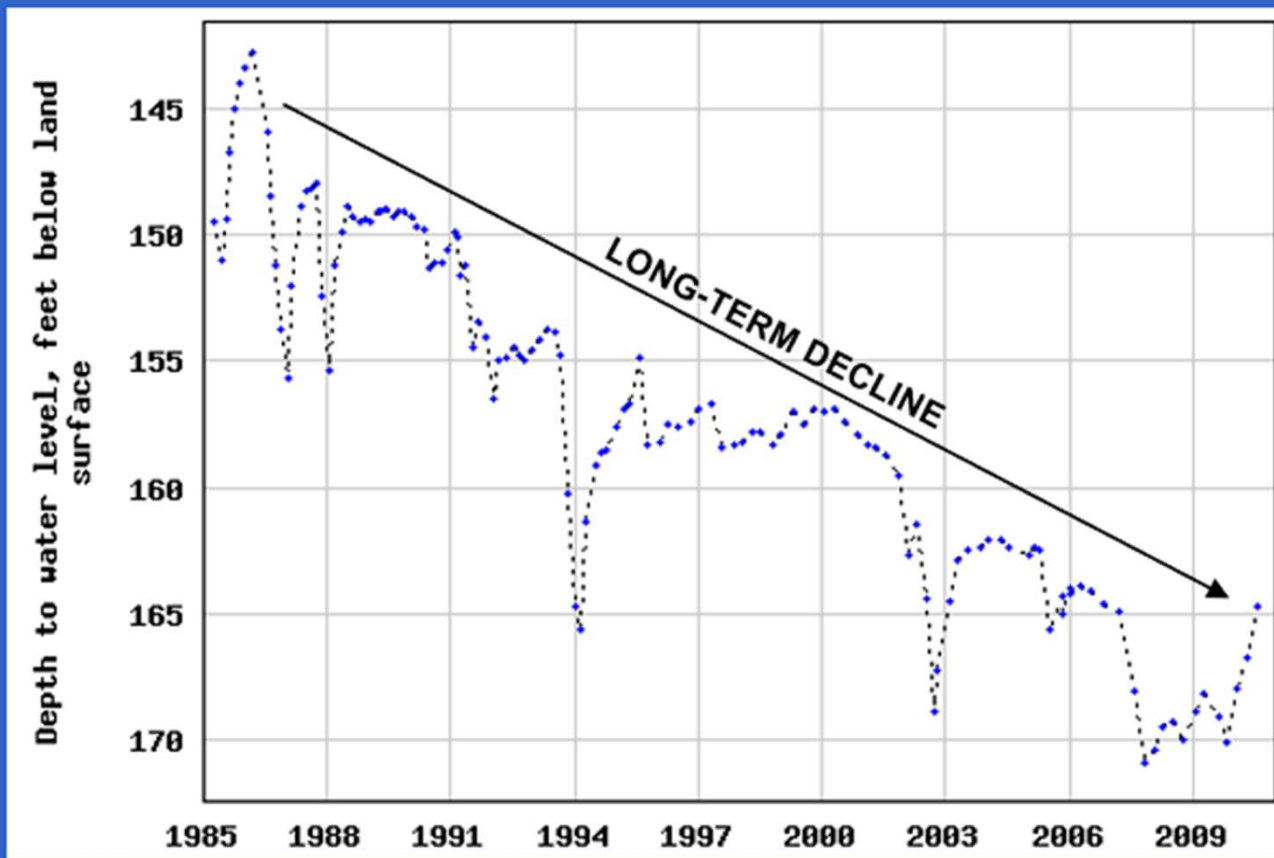


Virginia Department of Environmental Quality



However, the aquifer takes a long time to stabilize

# Long Term Water Level Decline



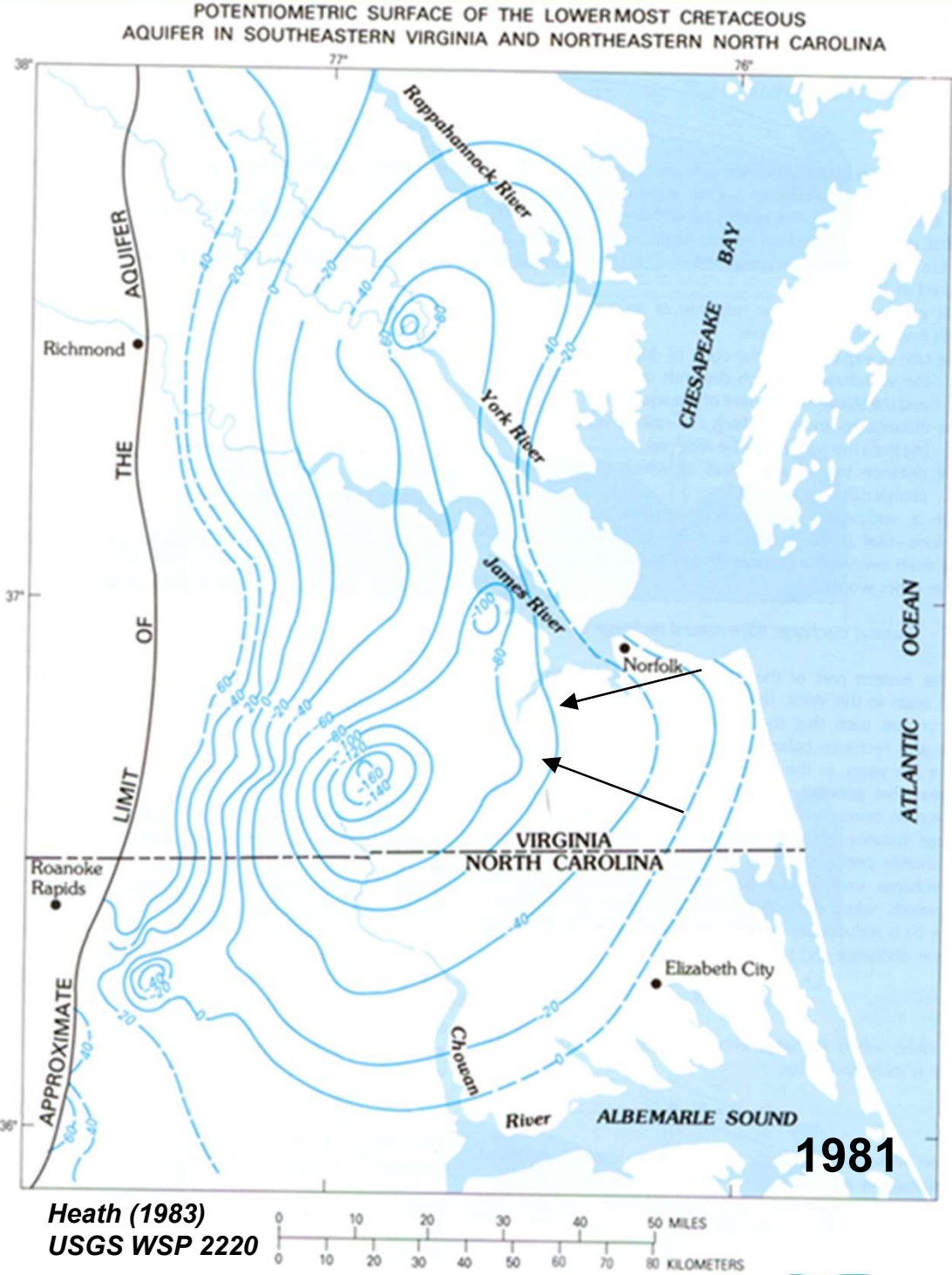
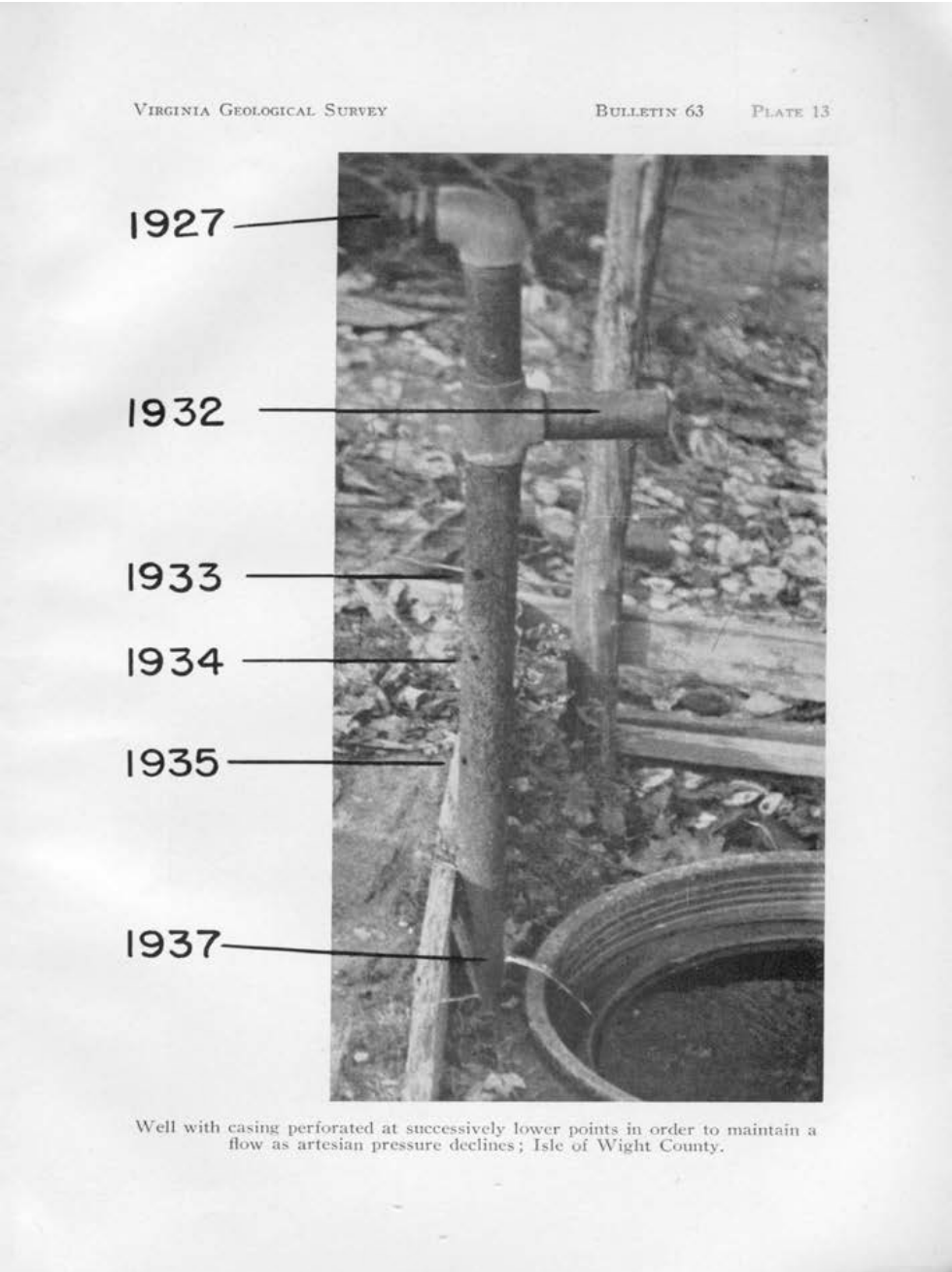
Virginia Dept of Environmental Quality



# From artesian to depression

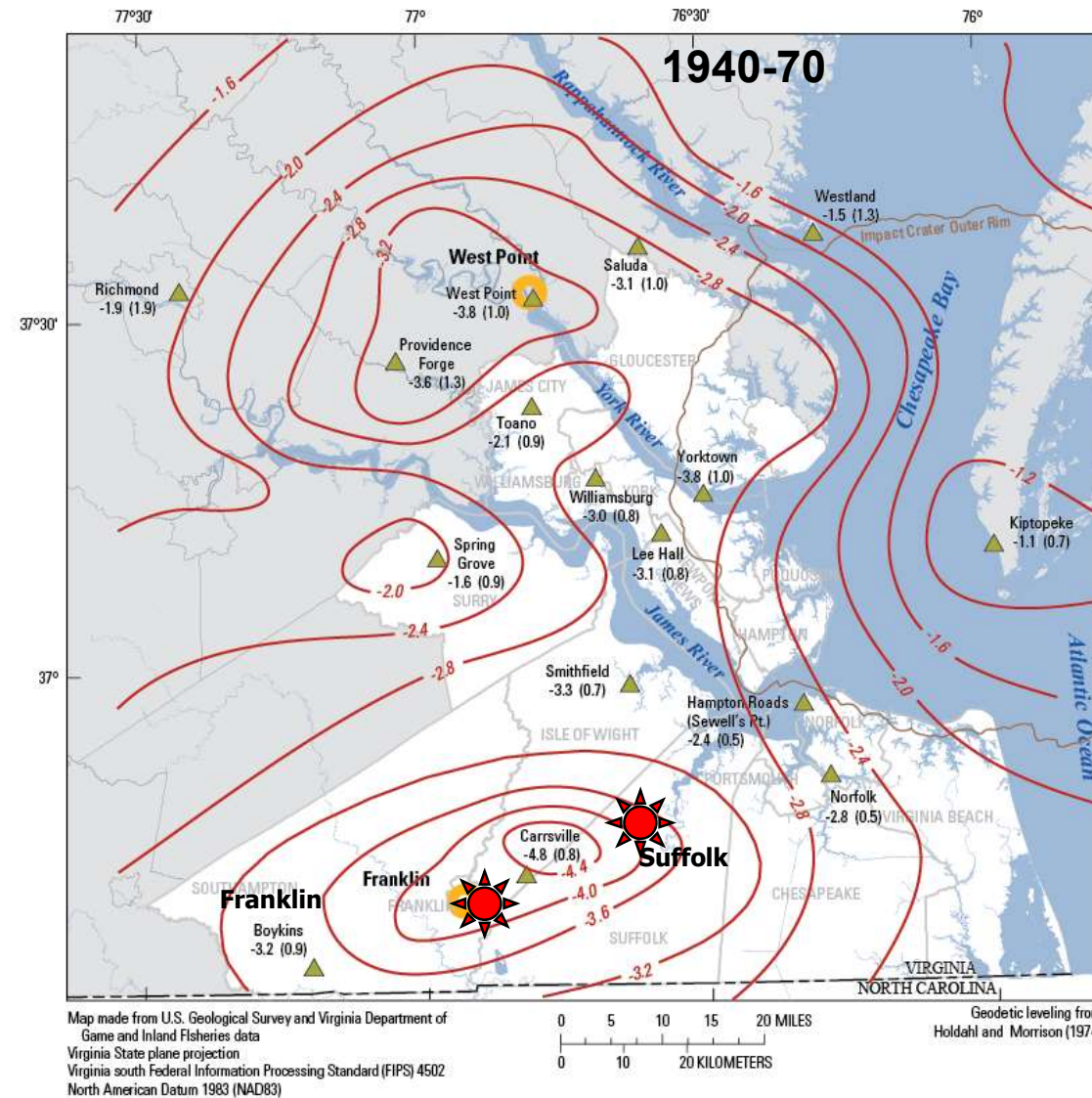


A, Overflow from artesian well in Isle of Wight County is wasted.

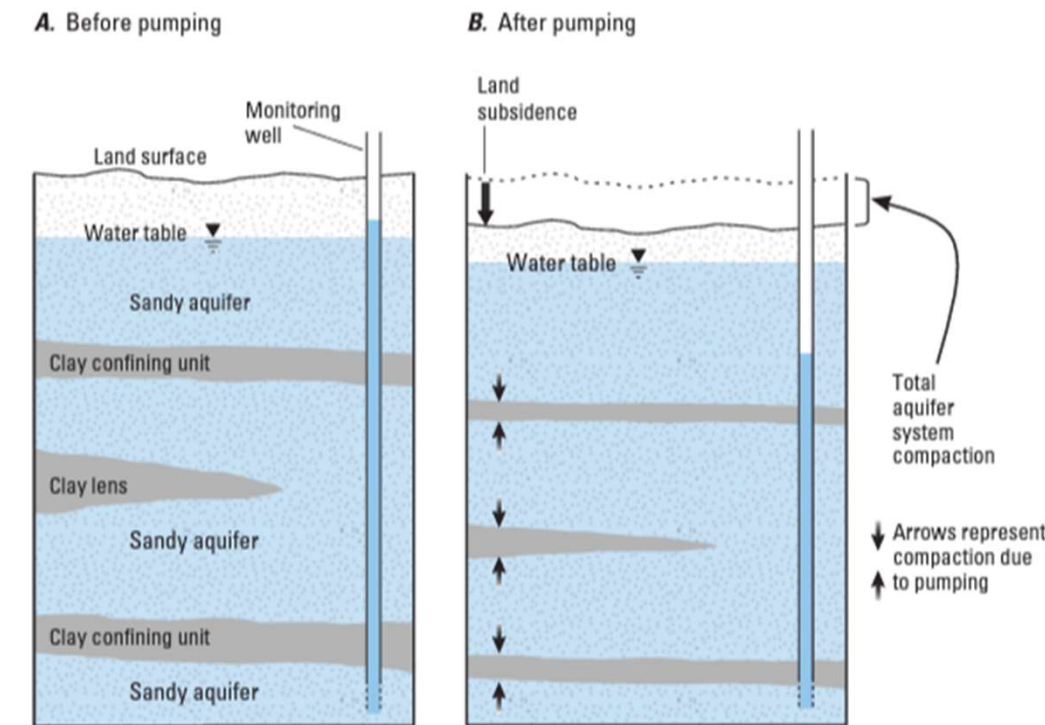
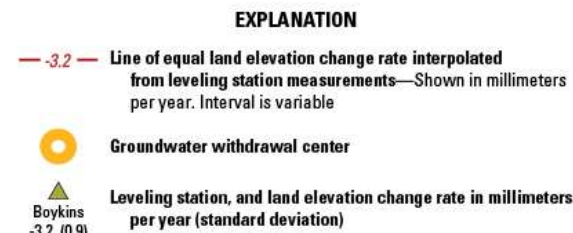




- Up to 50% of relative SLR may be due to land subsidence
- Up to 50% of land subsidence may be due to aquifer compaction
- Measured rates of aquifer system compaction (1979-96)
  - Franklin 1.6 mm/yr
  - Suffolk 3.7 mm/yr



**Holdahl and Morrison (1974)**  
*Tectonophysics*, 23(4), p. 373-390  
Taken from VA Department of Environmental Quality

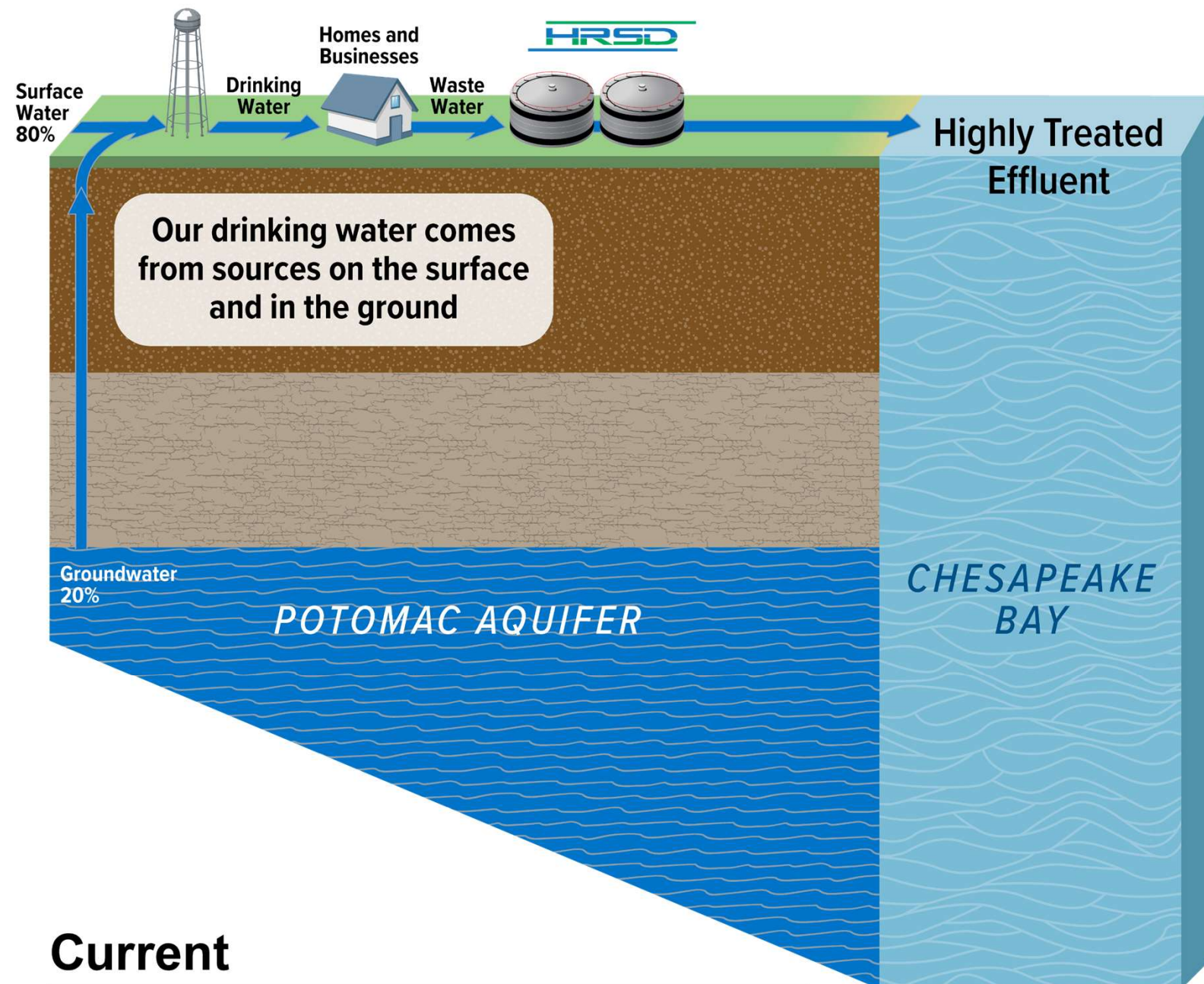


**Figure 10.** Aquifer-system compaction caused by groundwater withdrawals *A*, before and *B*, after pumping. Modified from Galloway and others (1999).

**USGS, Circular 1392, Eggleston and Pope**



# Business as usual

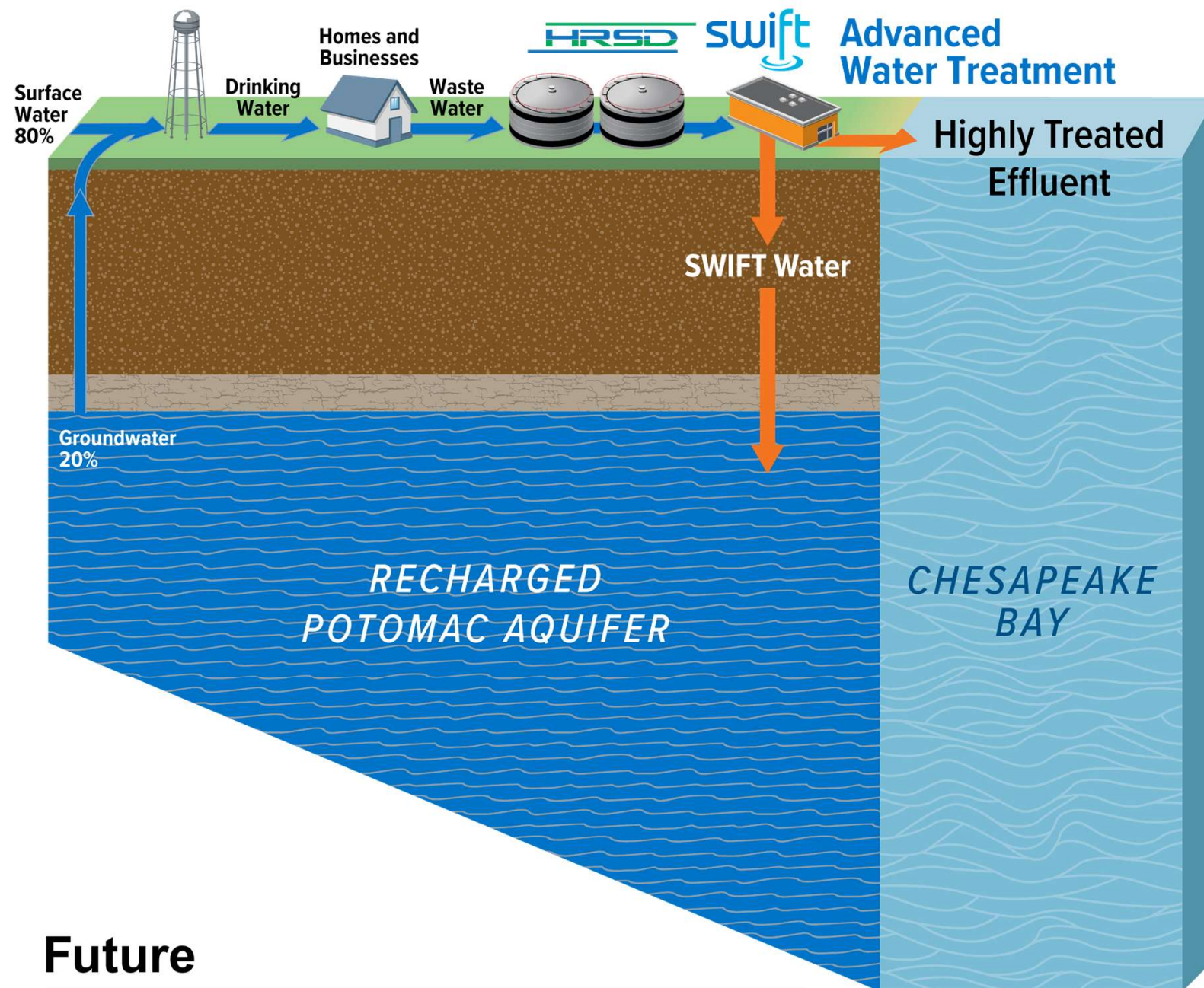


**Current**

- Withdraw ancient groundwater
- One pass use and discharge to surface water.
- Open loop system
- Not sustainable



# What is SWIFT?



Future

## BENEFITS OF SWIFT

- ✓ Protecting the Chesapeake Bay
- ✓ Reducing the rate of land subsidence
- ✓ Creating a sustainable source of groundwater
- ✓ Helping prevent groundwater contamination from salt water

## How is HRSD able to implement SWIFT?

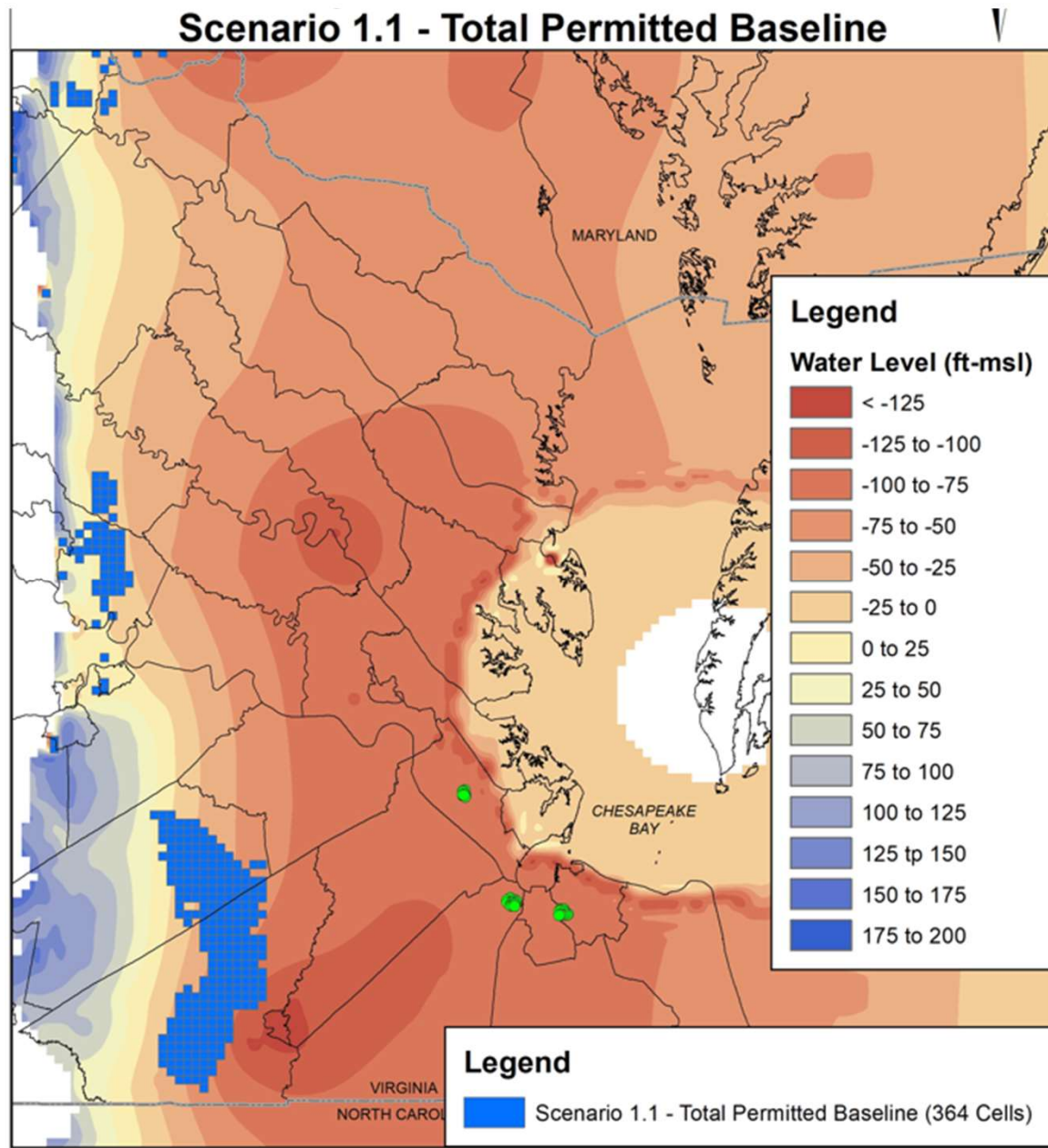
- **Hydrogeologically favorable** - large prolific confined aquifer that can take the water, water doesn't go far from recharge site, but positive pressure effect does
- **Geographically favorable** – no downstream users (Chesapeake Bay doesn't need HRSD's discharge)
- **Regulatorily favorable** – EPA's CWA integrated planning system, prioritize CWA projects and adjust spending and schedule accordingly
- **HRSD itself** – fits into our Enabling Act, Mission and Vision



# Modeling of SWIFT suggests room for permitting

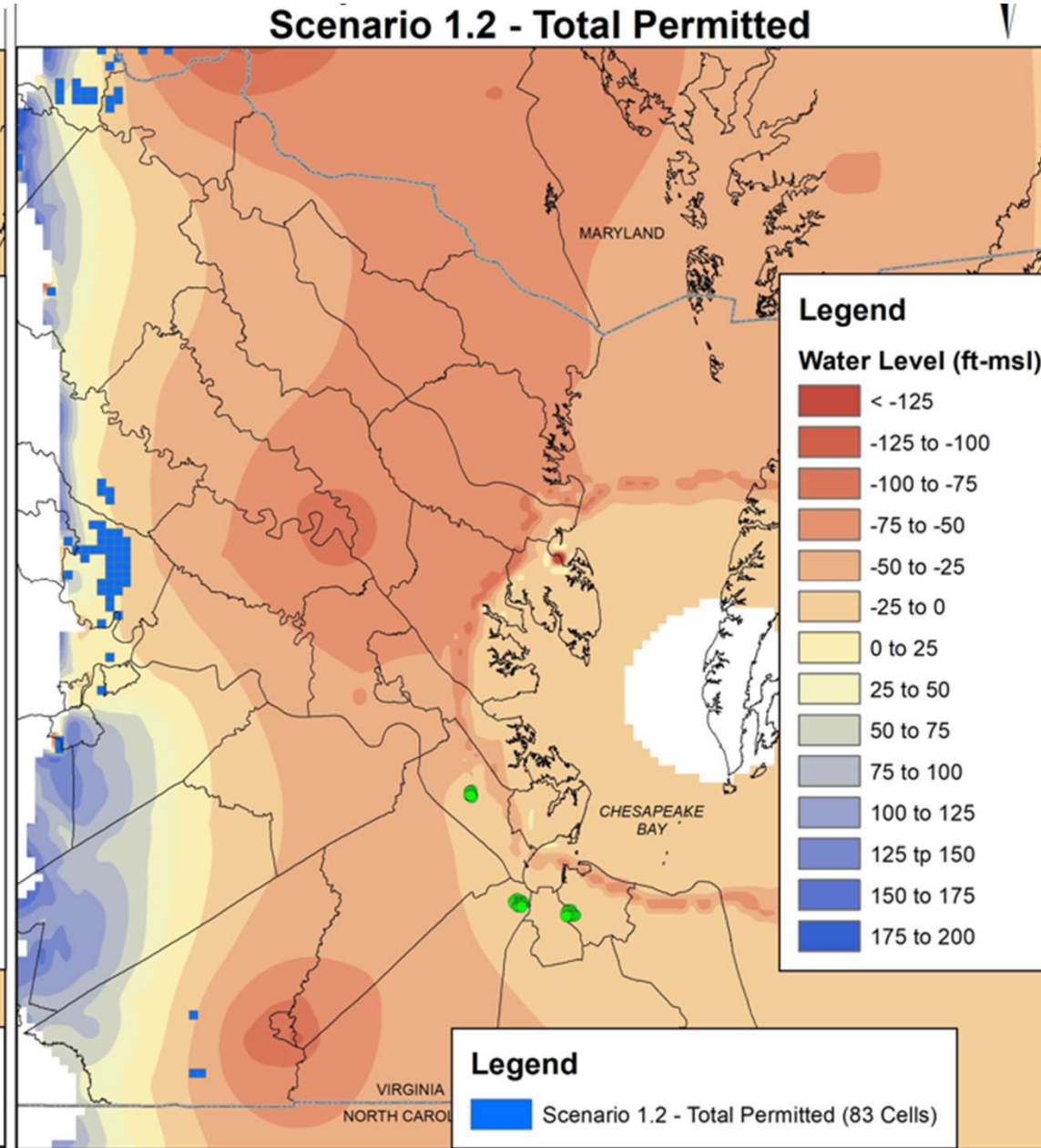
## NO SWIFT

Scenario 1.1 - Total Permitted Baseline



## W/ SWIFT

Scenario 1.2 - Total Permitted



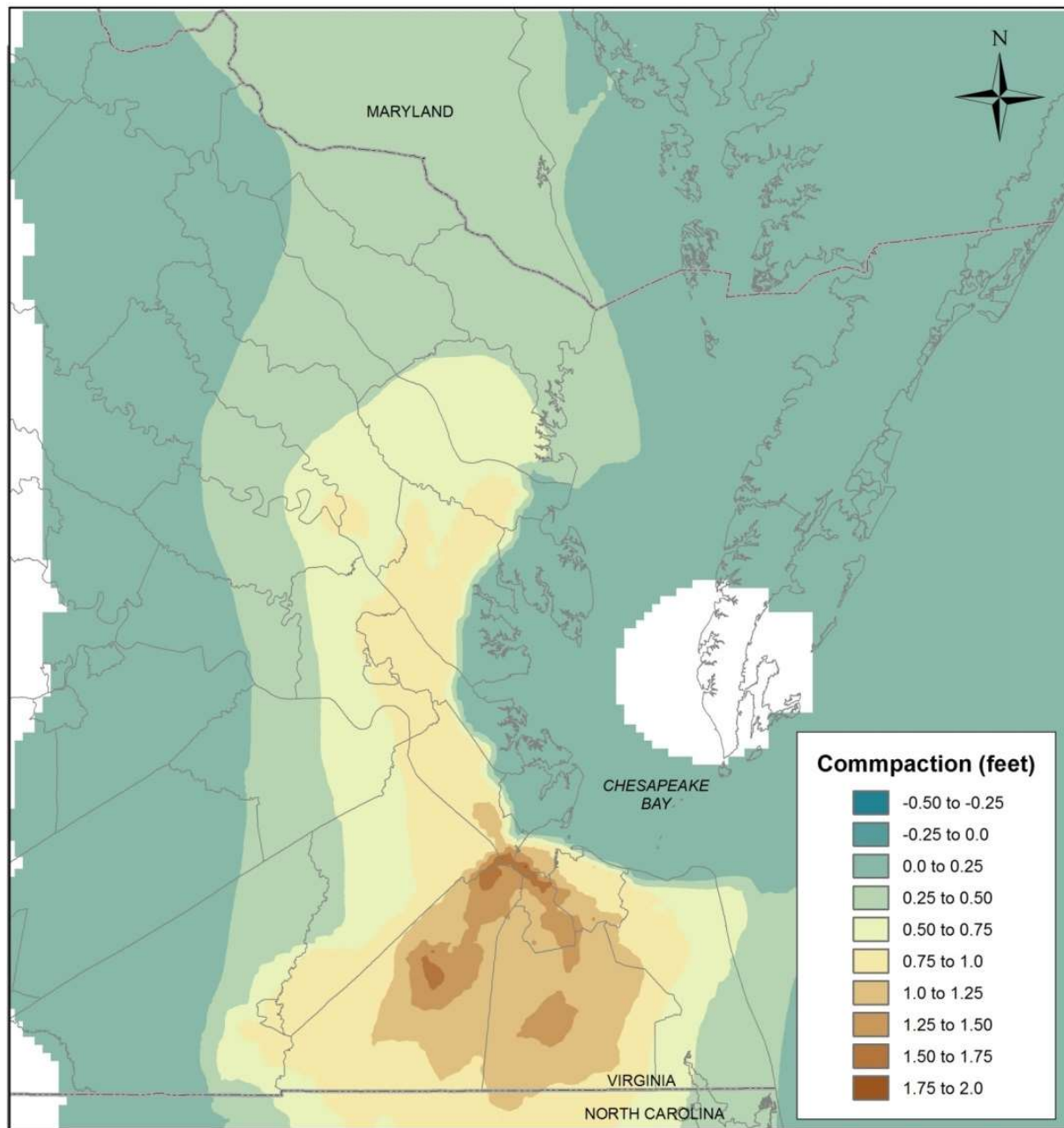
Total Permitted  
Withdrawals  
JR SWIFT  
NP SWIFT

Critical cell failures  
Baseline – 364  
Scenario 1.2 – 83

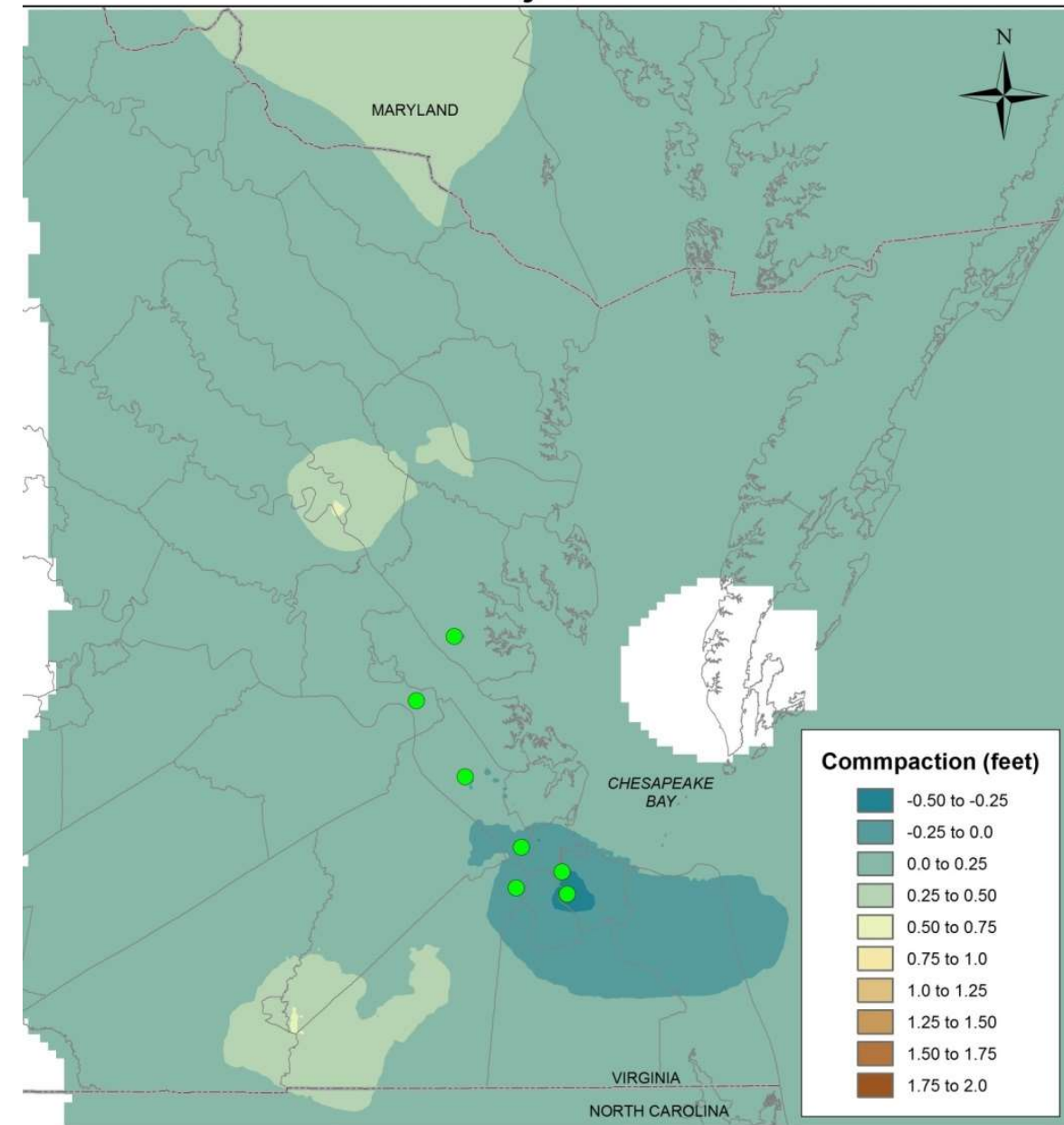


“All models are wrong, but some are useful” George E. P. Box

Simulated Total Aquifer System Compaction  
from 1890 to 2064 - Total Permitted



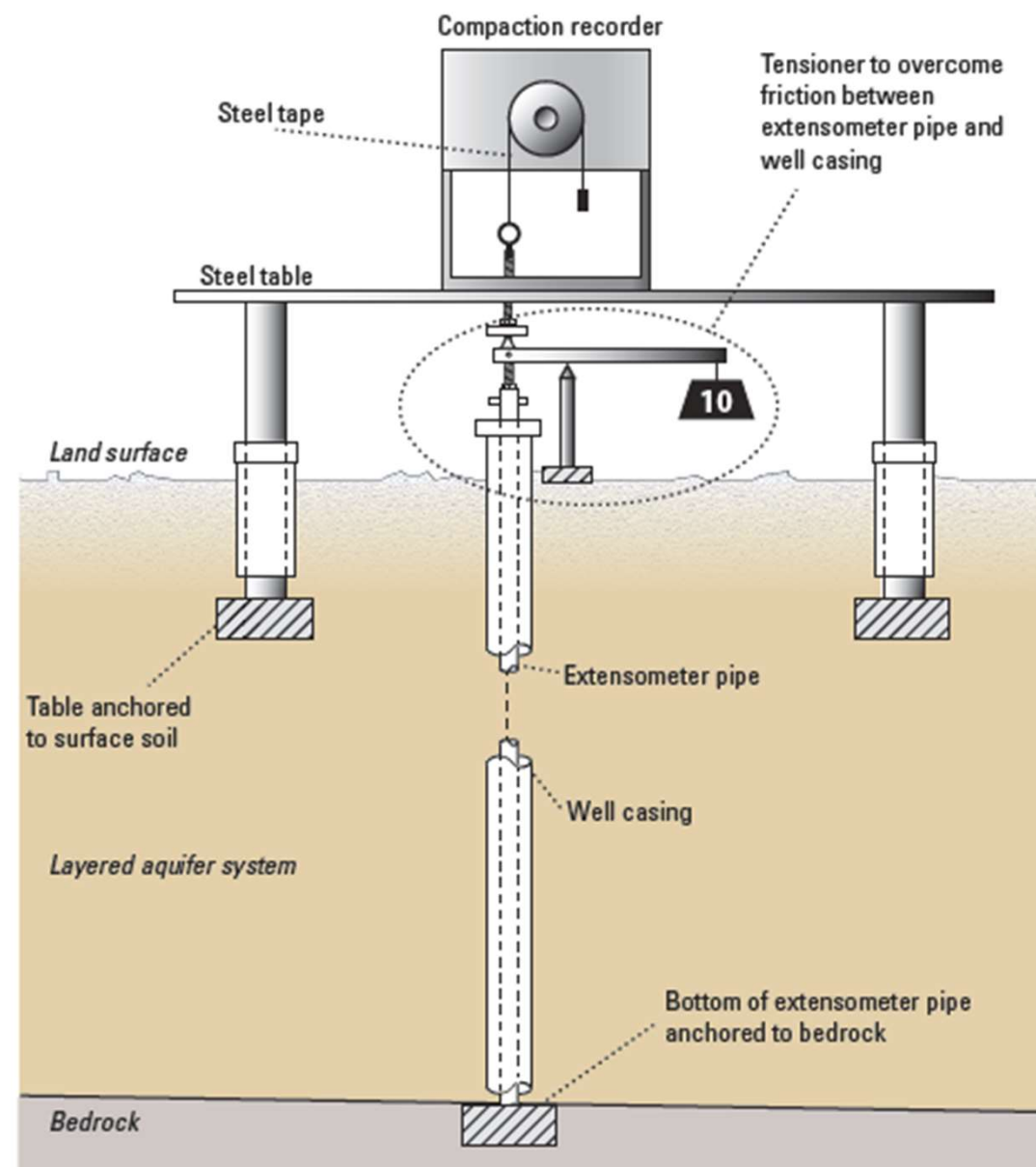
Simulated Total Aquifer System Compaction  
from 1890 to 2064 - Total Permitted  
with All Injection Wells





# Elastic Rebound of land subsidence is real

## Extensometer



### Two types of deformation

- Irreversible inelastic
- Recoverable elastic

**Ground surface rebounded 32 mm from withdrawal shutdown in Franklin from 2009-2010.**

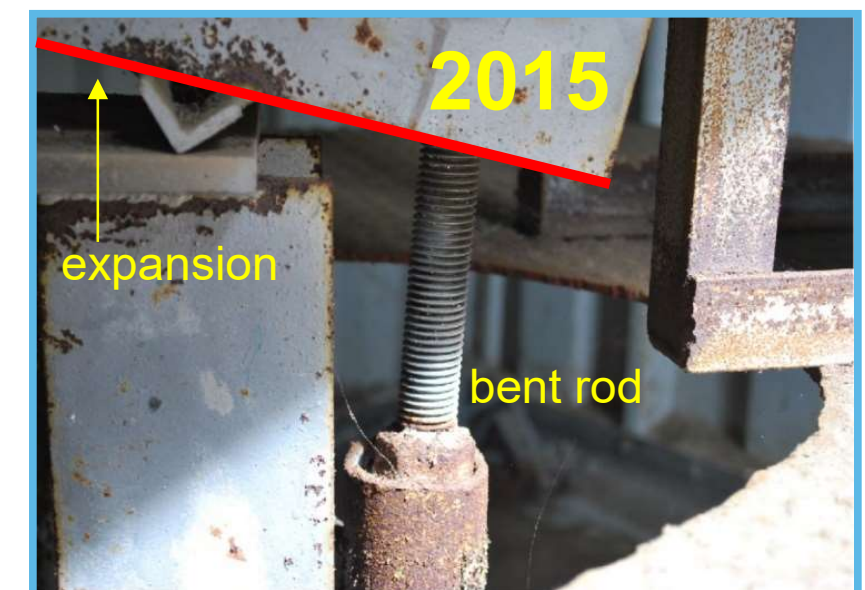
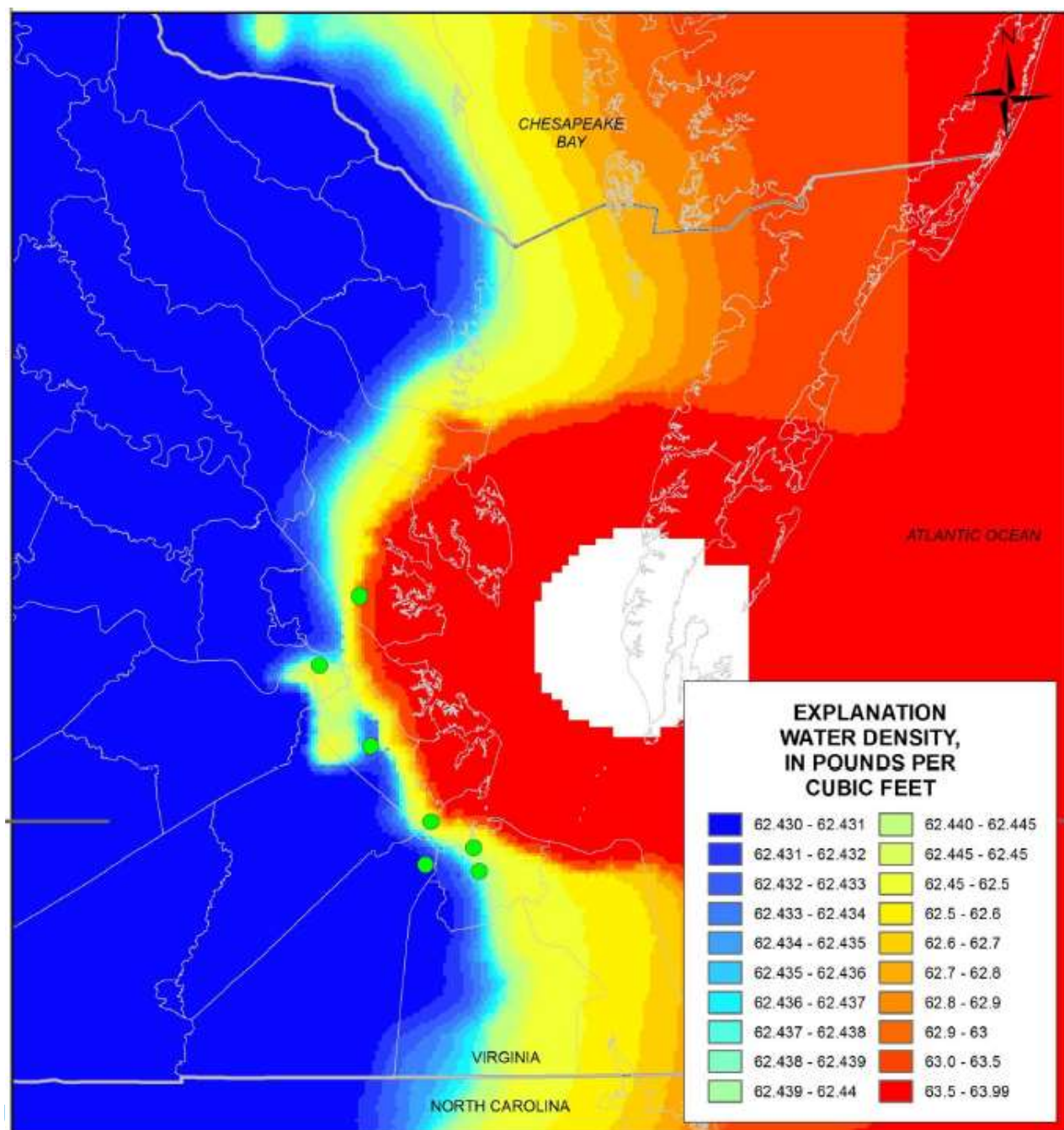


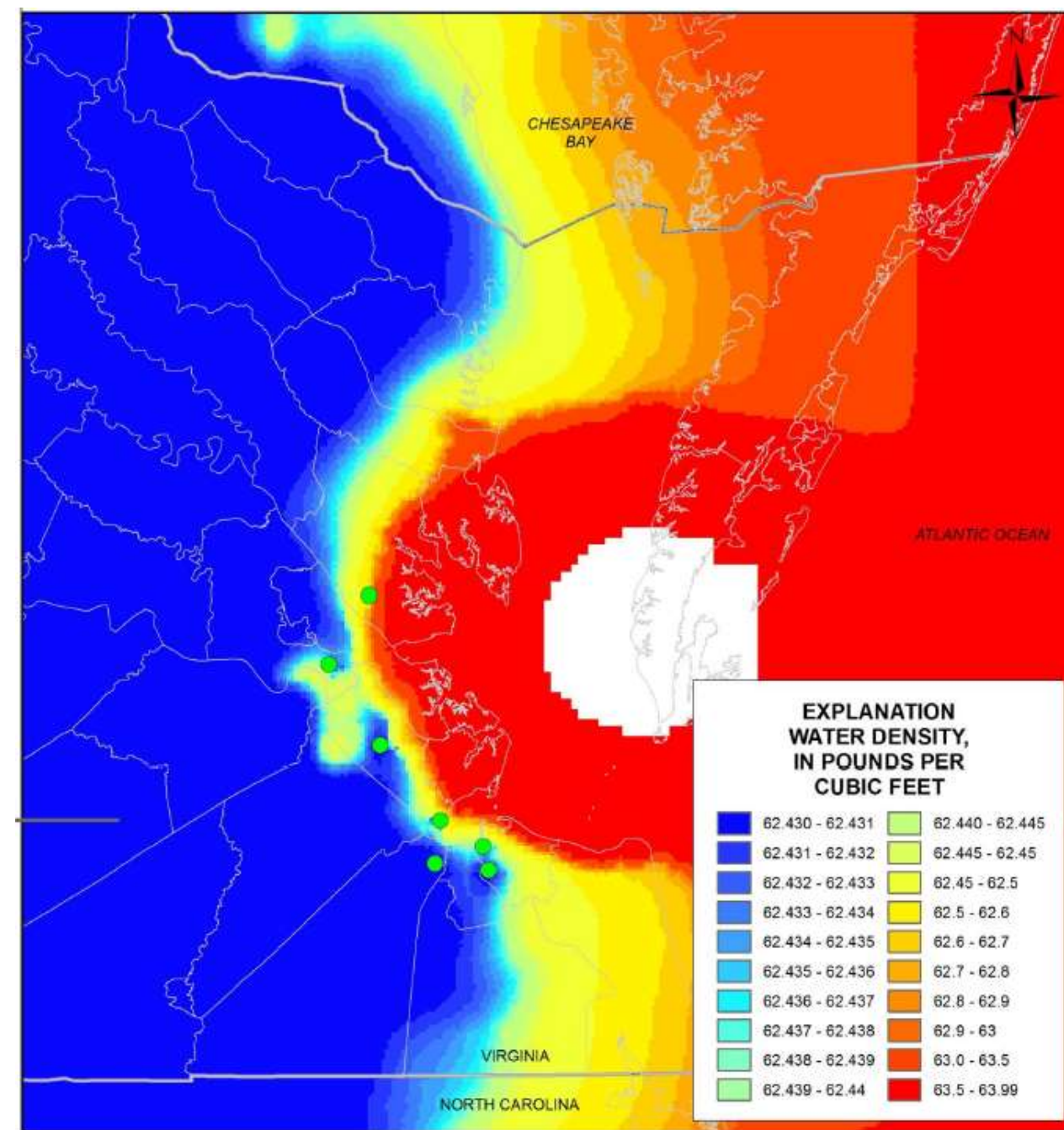
Figure 8. The borehole extensometer in Franklin, Virginia. Modified from Pope (2002).



Baseline (w/o SWIFT Recharge)

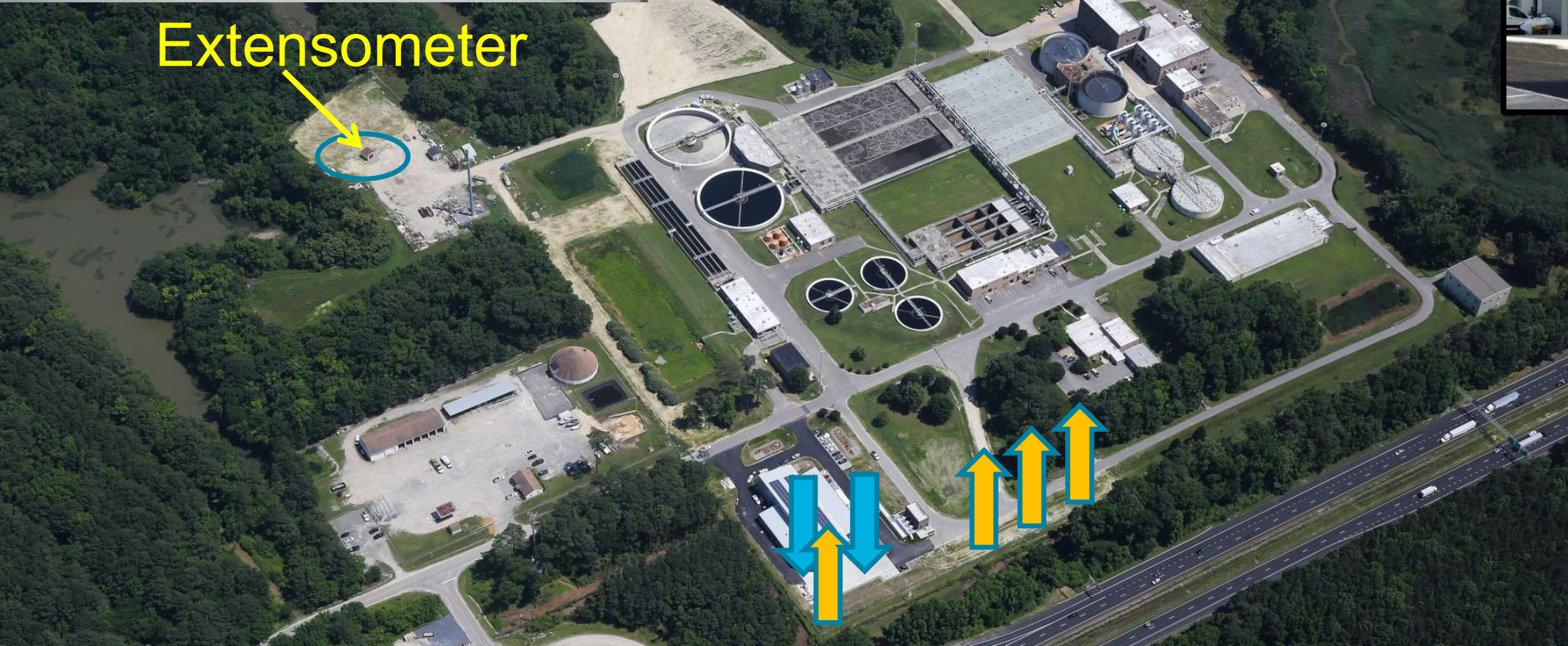


SWIFT Recharge





# SWIFT Research Center: demonstration of many things



## 1.0 MGD Demonstration Facility

AWT + recharge well + monitoring wells + public outreach and education center + research facilities

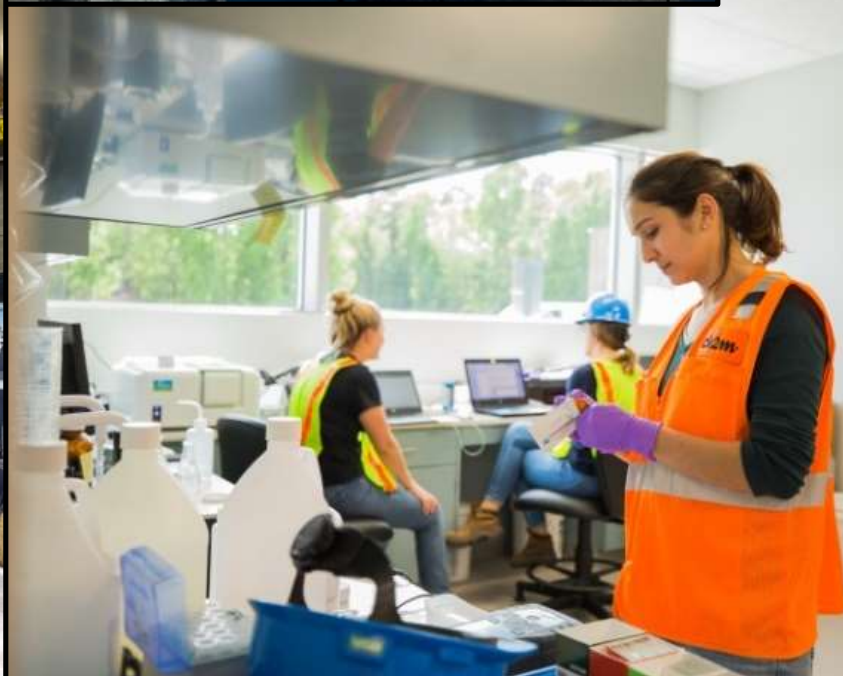
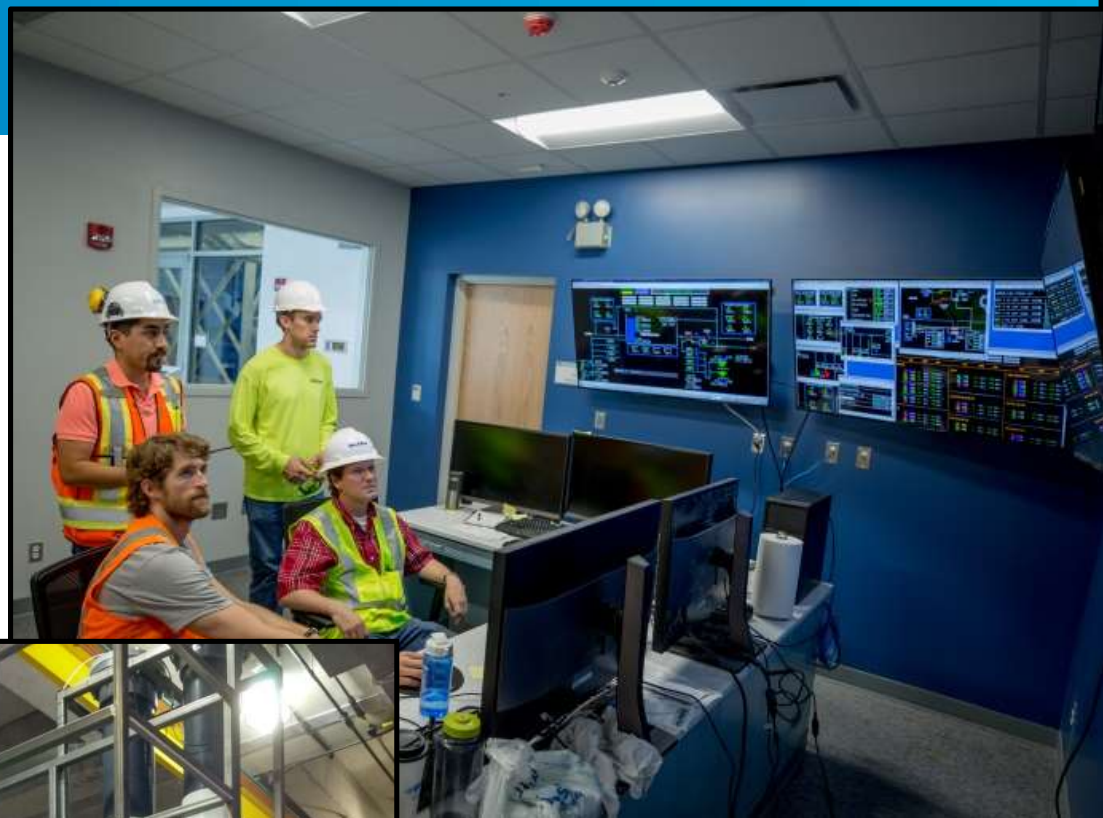
800,000,000+ Gallons recharged into the Potomac Aquifer





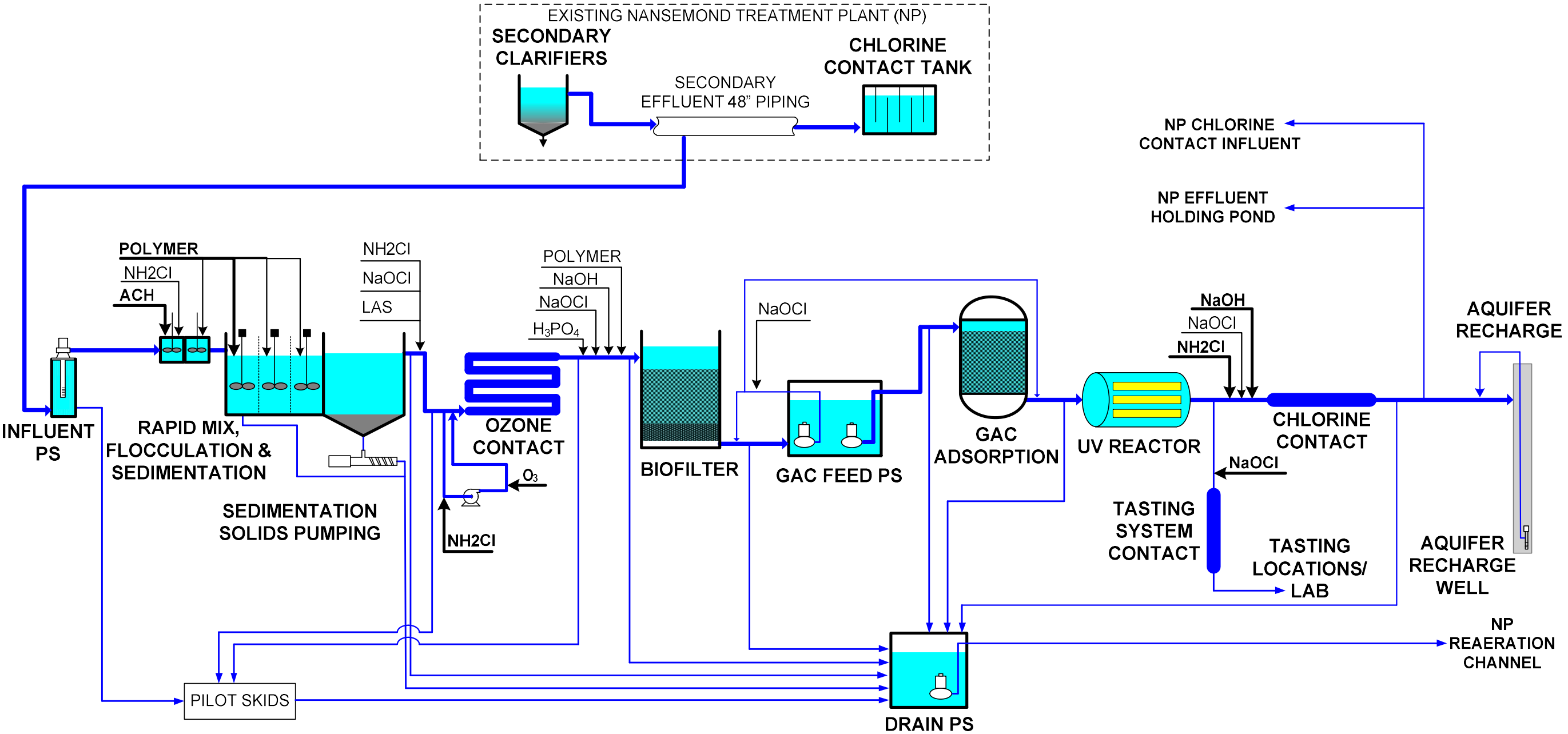








# Process Flow Diagram for SWIFT Research Center

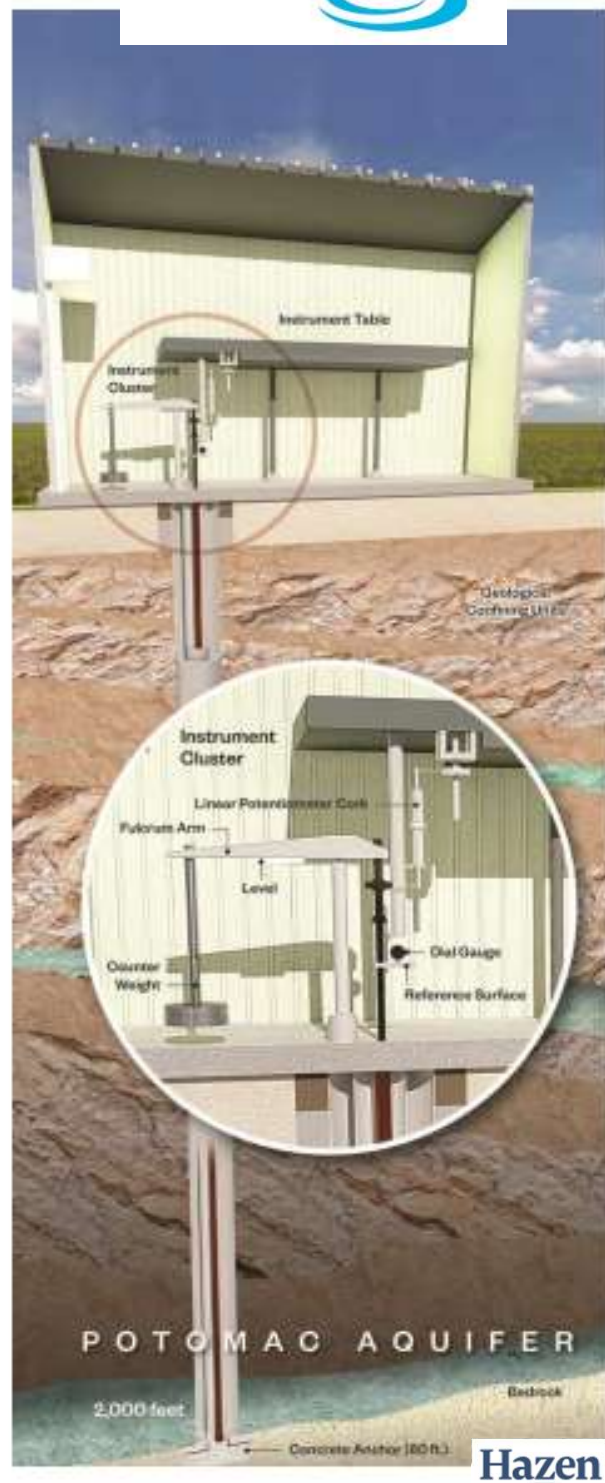


SWIFT RESEARCH CENTER PROCESS FLOW DIAGRAM





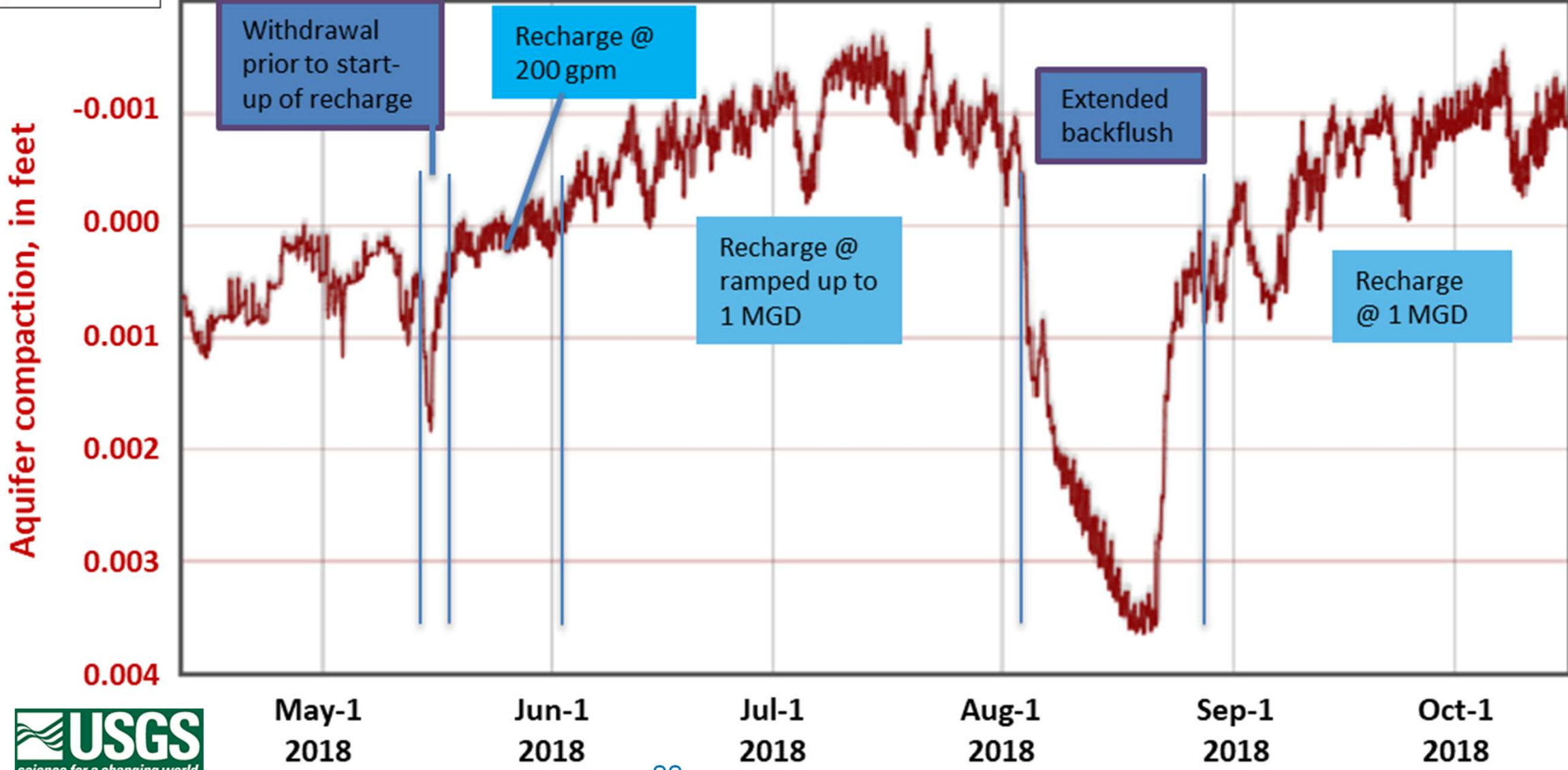
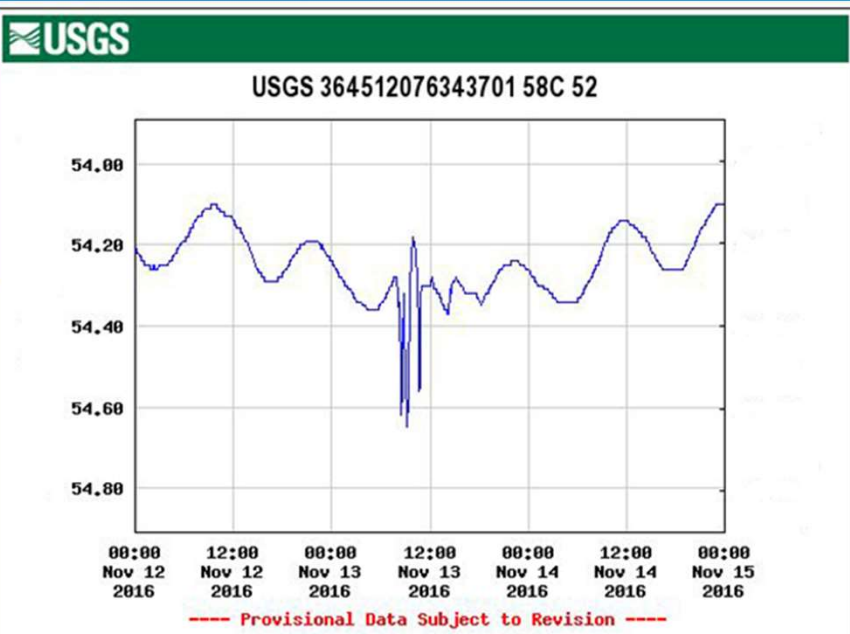
How will SWIFT effect vertical land motion?





# Aquifer compaction and superposition

## First three months of operation





# Geochemical challenges to putting water into the aquifer

## Operational concerns

- Clay destabilization
- Well plugging

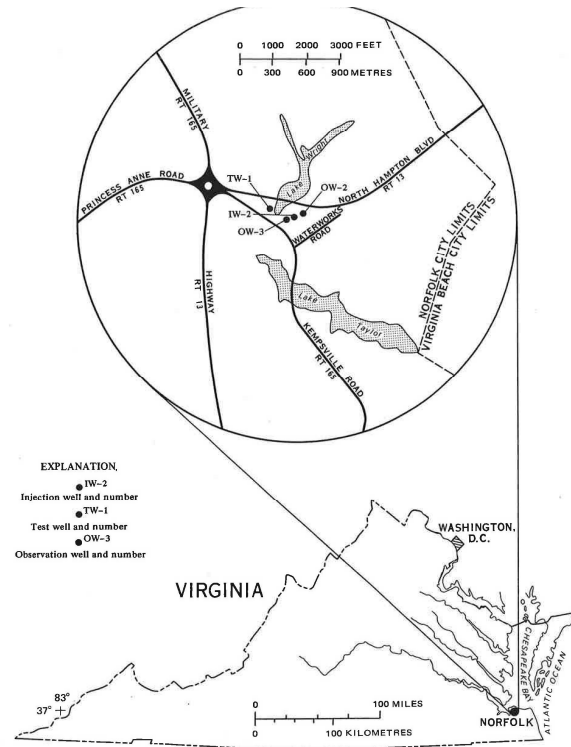
## Environmental/Regulatory concerns

- Liberating metals
- Metals migration in the aquifer

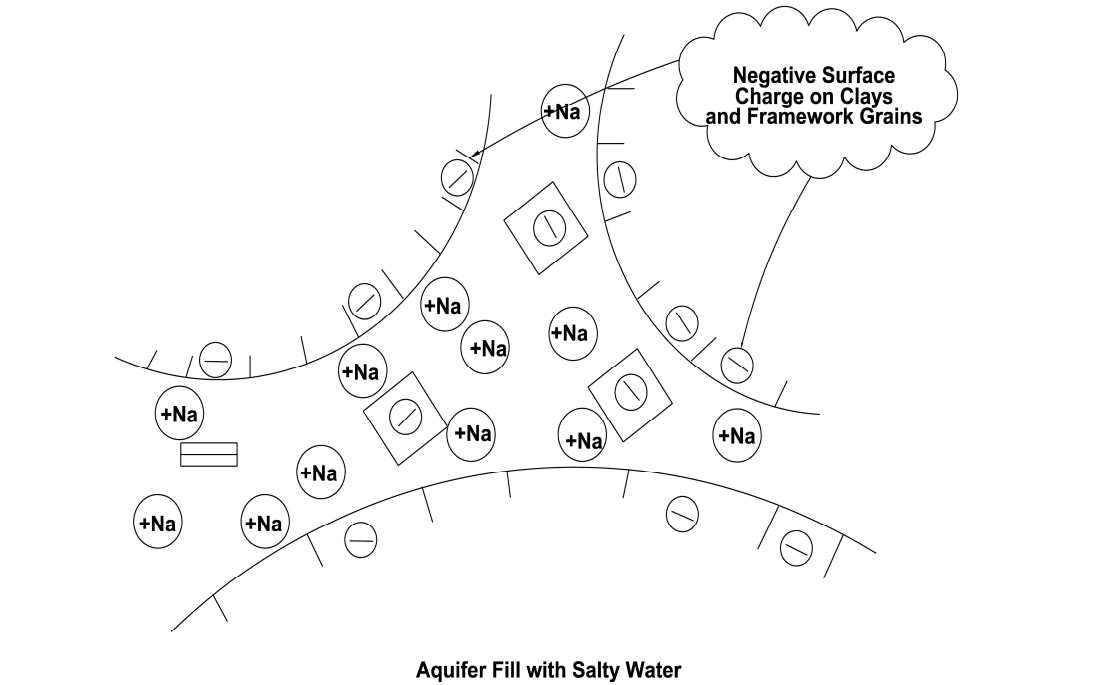
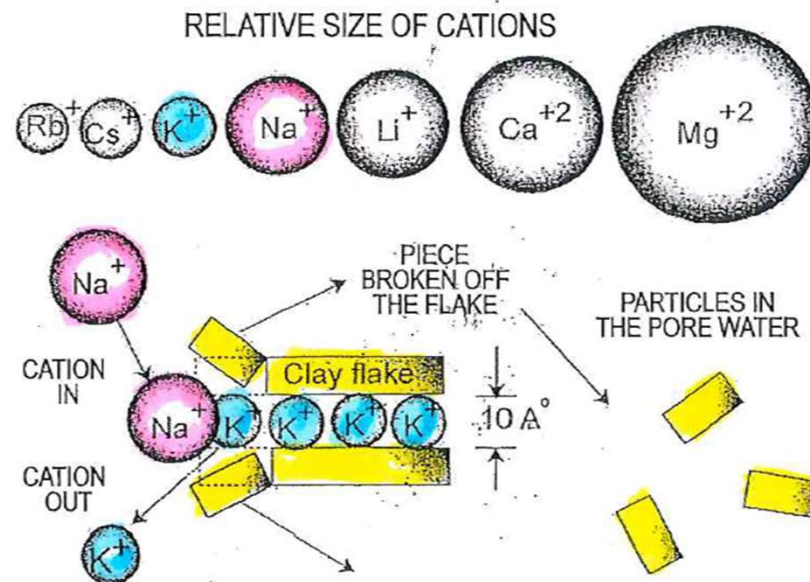




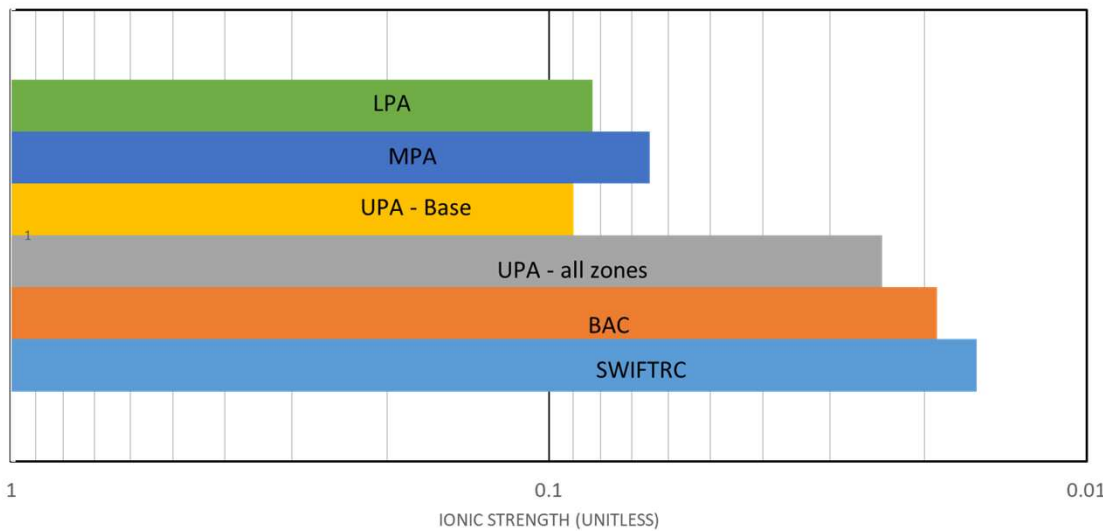
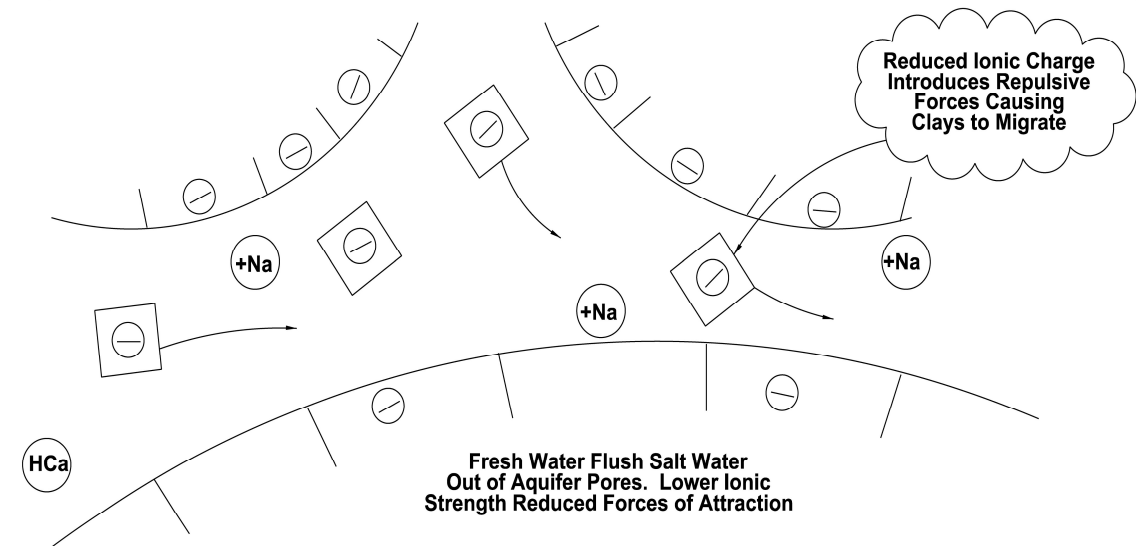
# Challenges with MAR at HRSD SWIFT sites



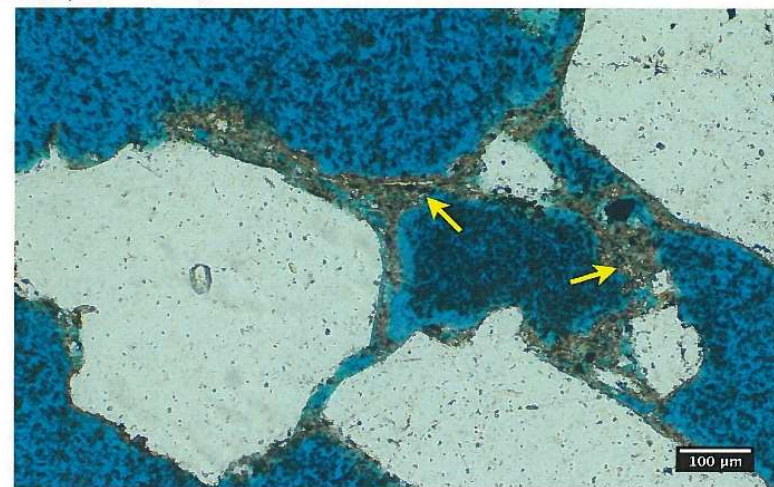
USGS, PP 939, Brown and Silvey, 1977



Aquifer Fill with Salty Water



80-990'; MI#16187-10

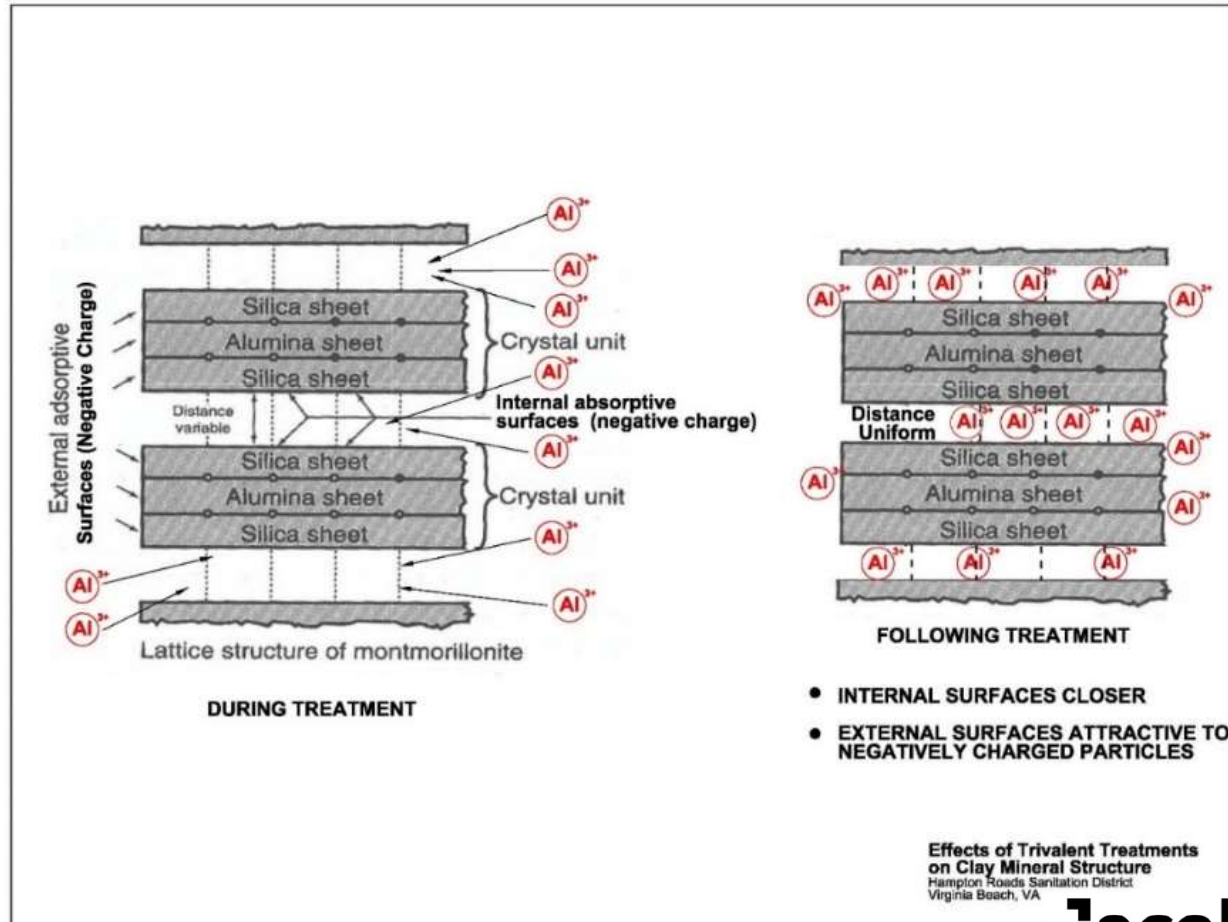


The grain-coating detrital clay (red) is dominated by montmorillonite. The grain-coating matrix locally bridges the intergranular pore throats (yellow).

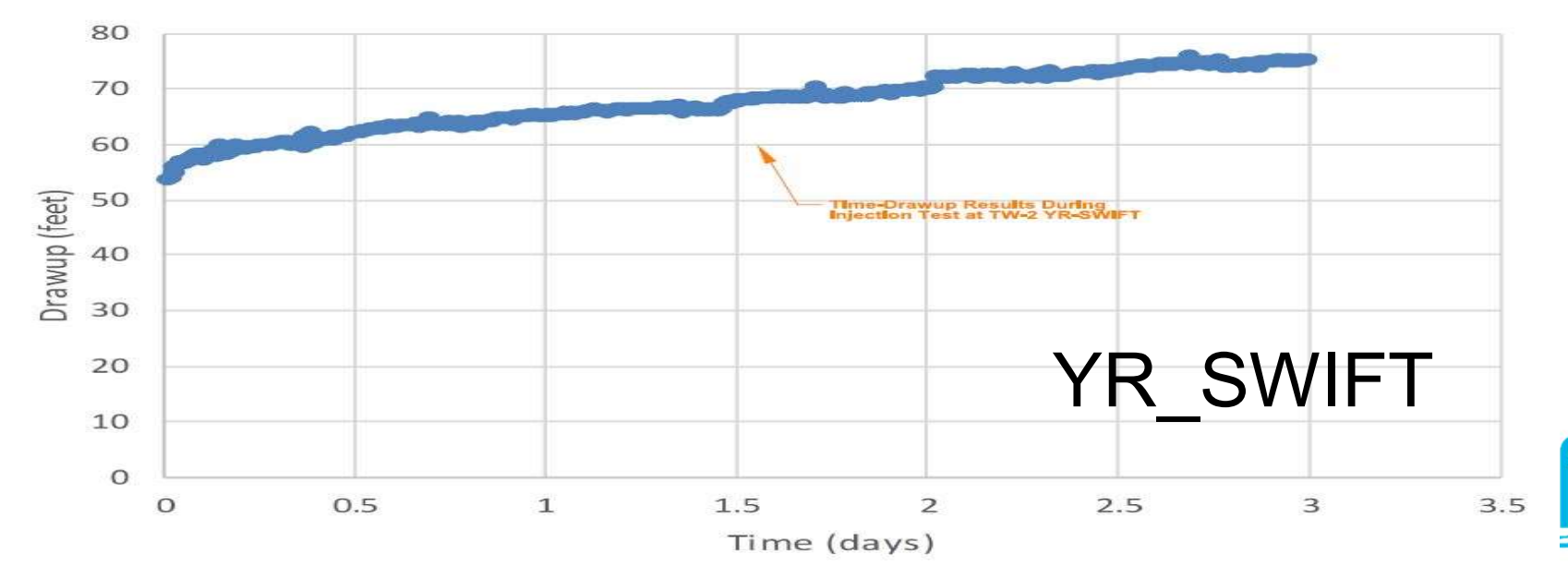
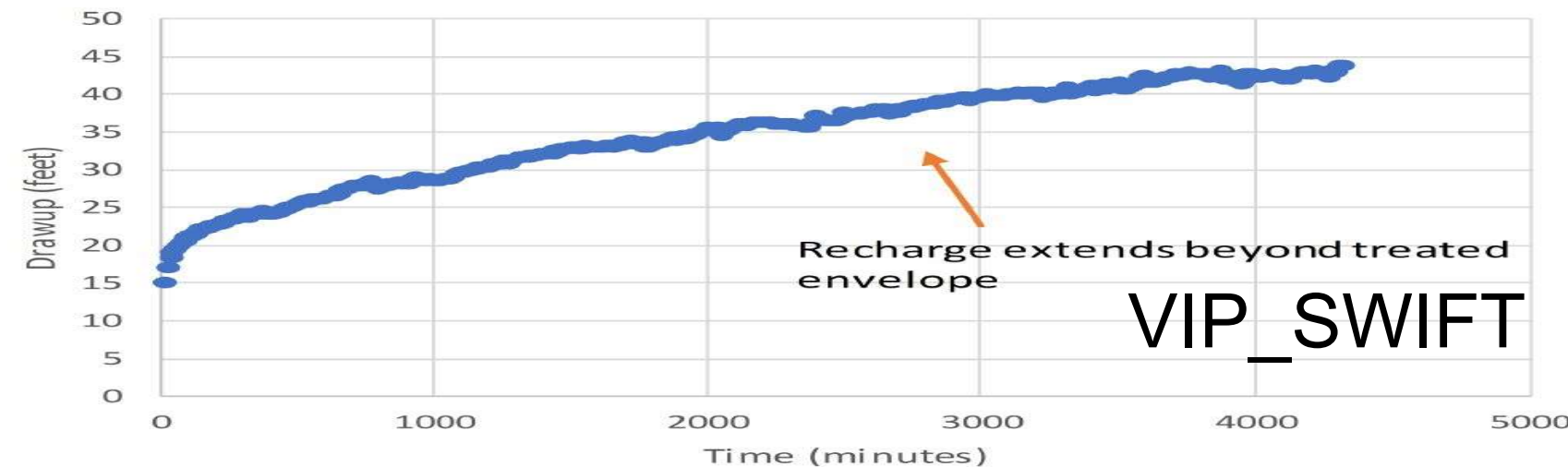
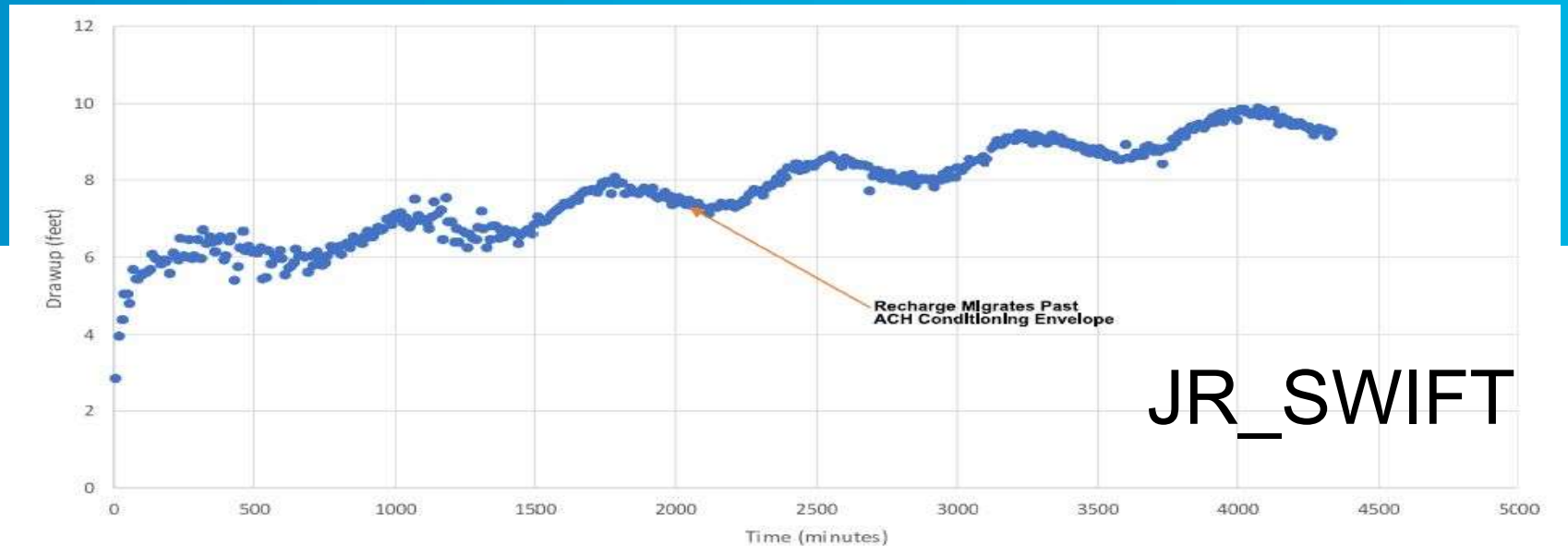




# ACH conditioning and testing was successful



**Jacobs**





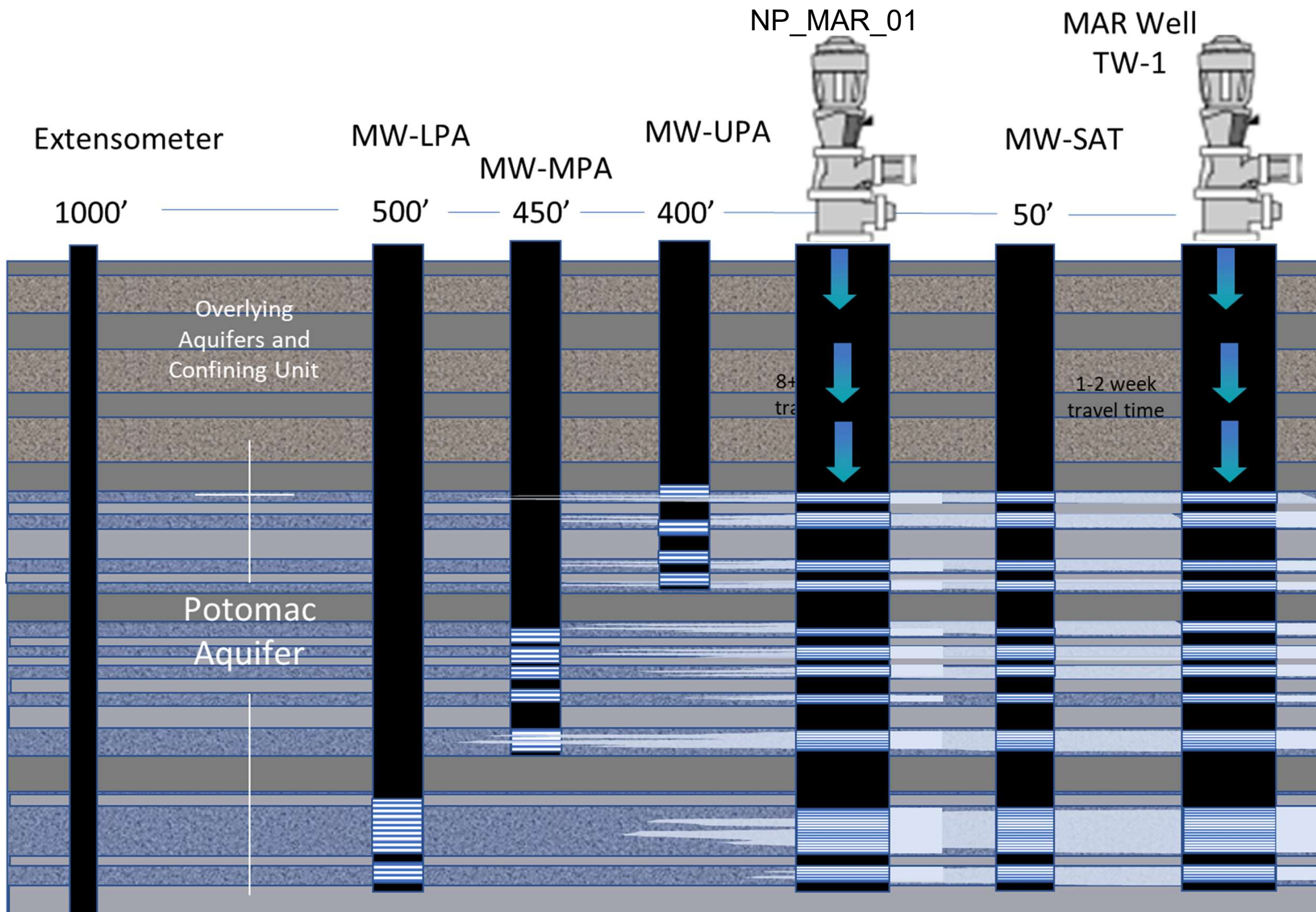
# Differences in water quality can cause metals mobilization

- Didn't observe As – **must assume it is present**
- Increase SWIFT Water pH above the solubility limit of iron,
- Buffers the dissolution of iron-bearing minerals, and
- Precipitating **Hydrous Ferric Oxide (HFO)** on the surface of the minerals, which performs the following:
  - **Inhibits the reactivity of reduced metal-bearing minerals (passivate)**
  - **Adsorbs arsenic migrating in the aquifer**
  - **Adsorbs potential competitive oxyanions**
- The approach works well in aquifers rich in iron-bearing minerals and redox-transitional zones, like the Potomac aquifer in the SWIFT site areas





# MW\_SAT, a discretized look

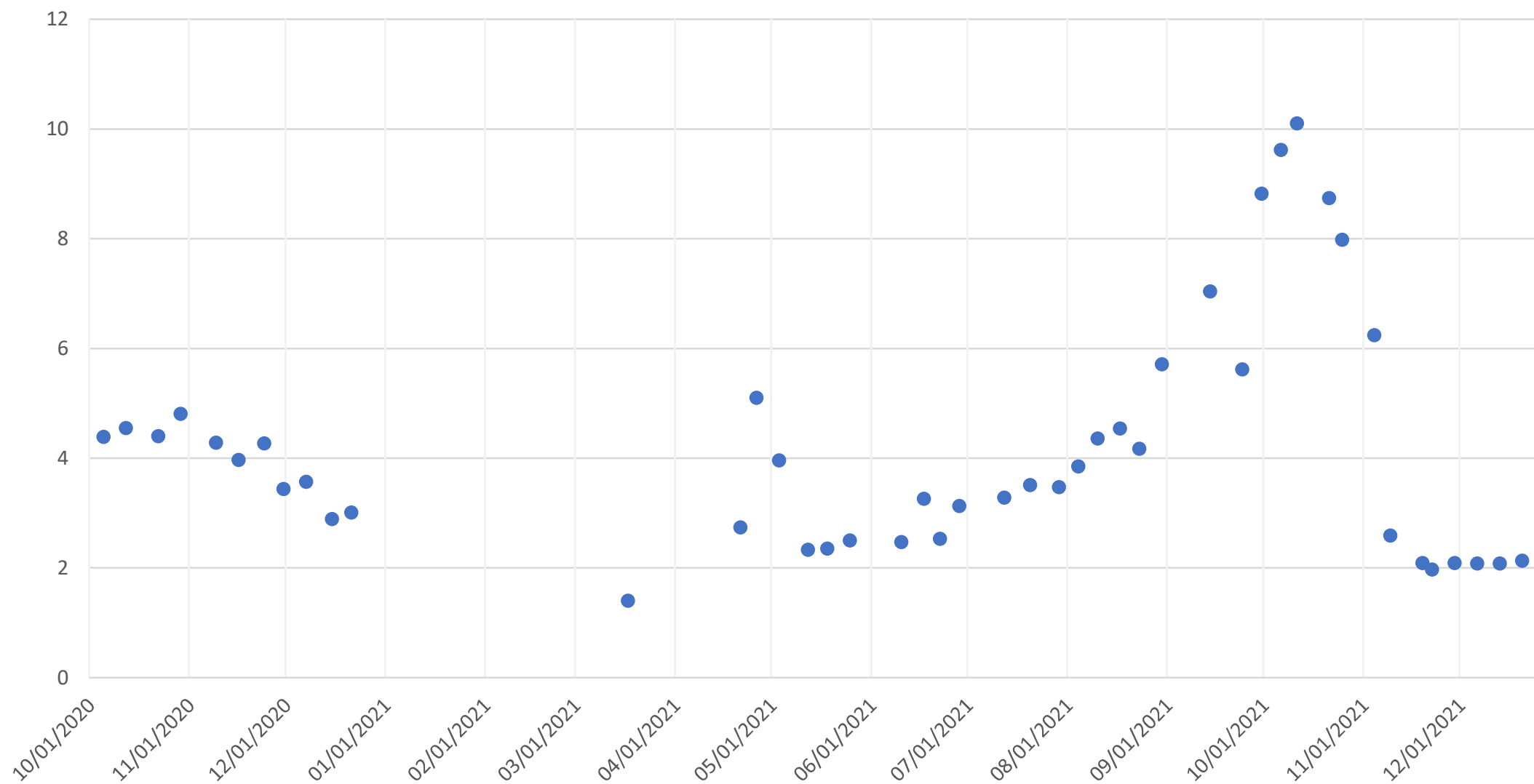


- Sister well, matches TW-1
- Research, not compliance
- 11 screen zones
- FLUTE sampling system
- Sample each screen separately



# SWIFT Research Center, MW-SAT: screen 9

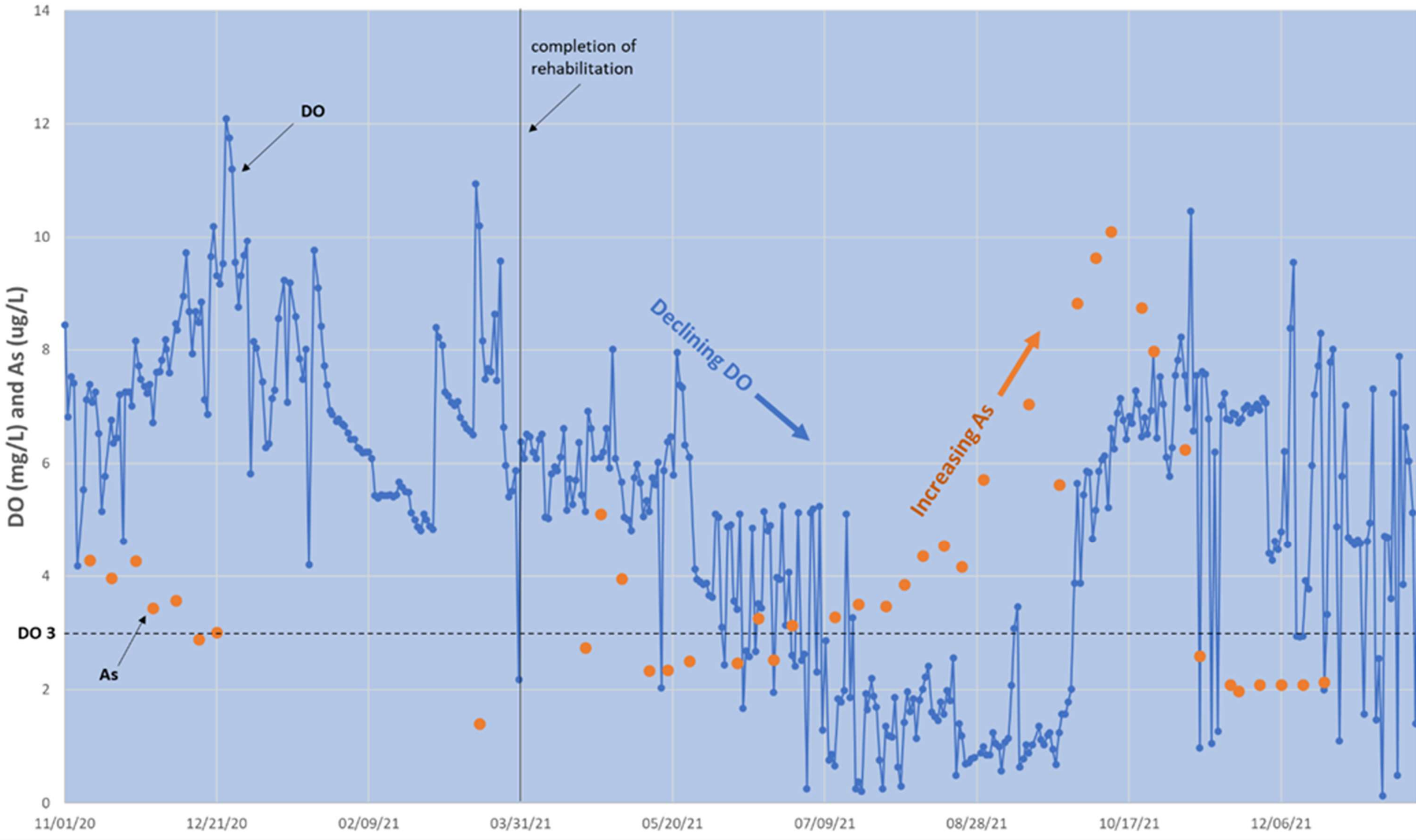
Arsenic in MW-SAT, Interval 9



- Pyrite Oxidation, (melting pyrite) – occurs at leading edge of bubble
- Competitive desorption (phosphate kicks off the arsenic) – occurs later in recharge operations
- **Reductive dissolution** of arsenic-bearing iron oxides (melting HFO),



# SWIFT Water DO and MW-SAT As

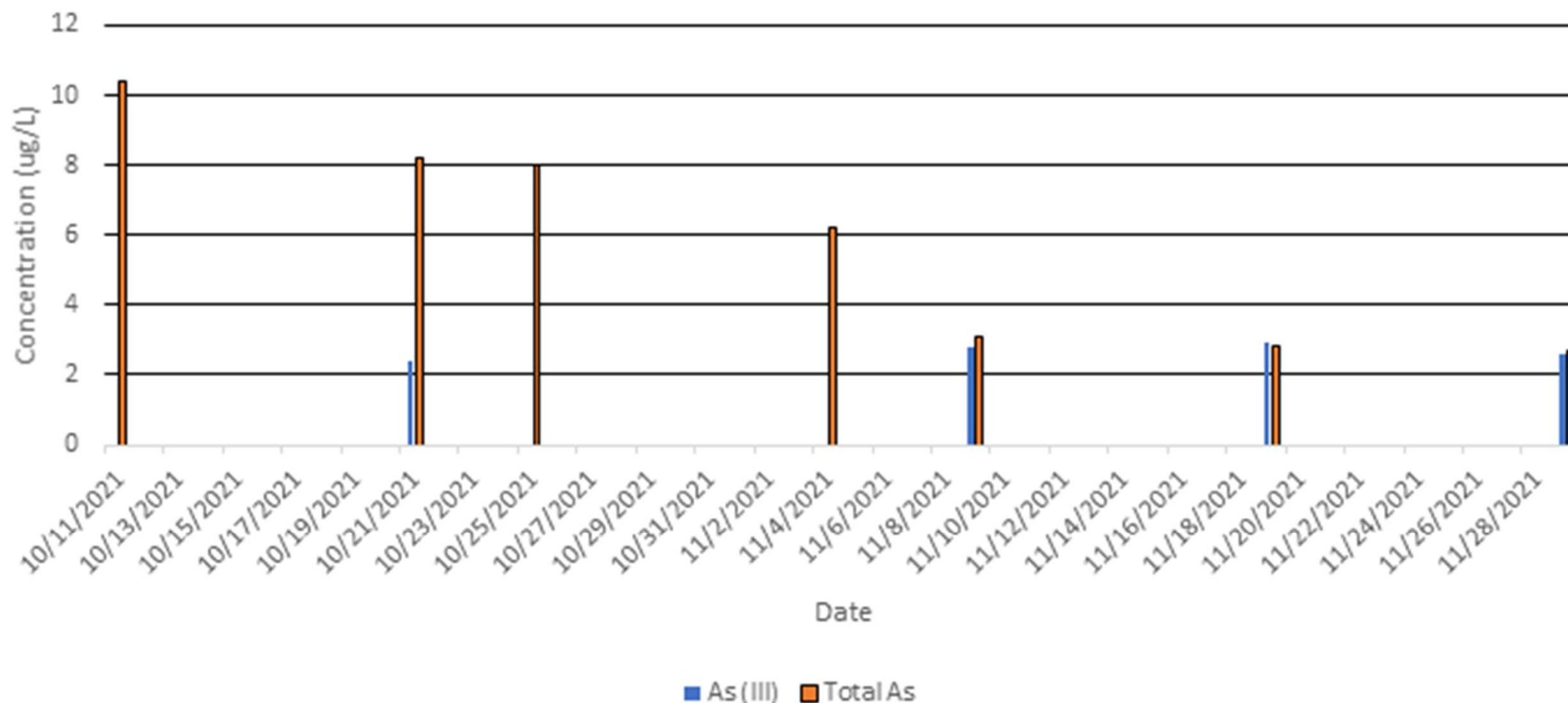




# Arsenic speciation

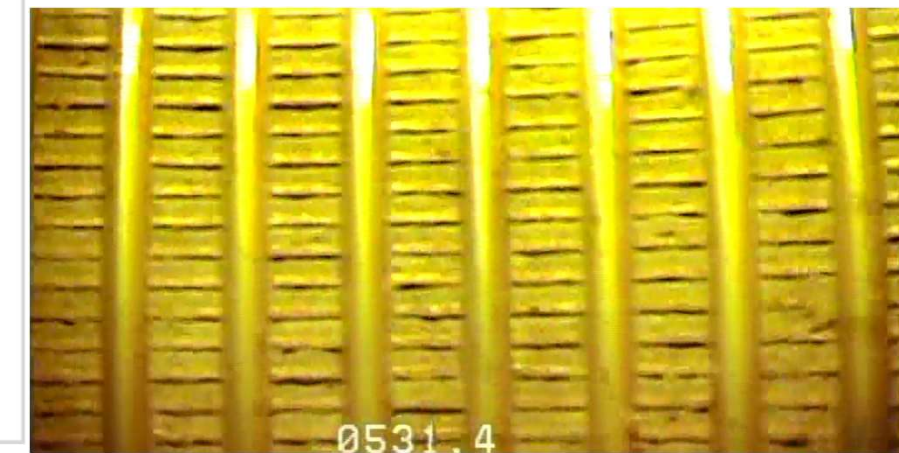
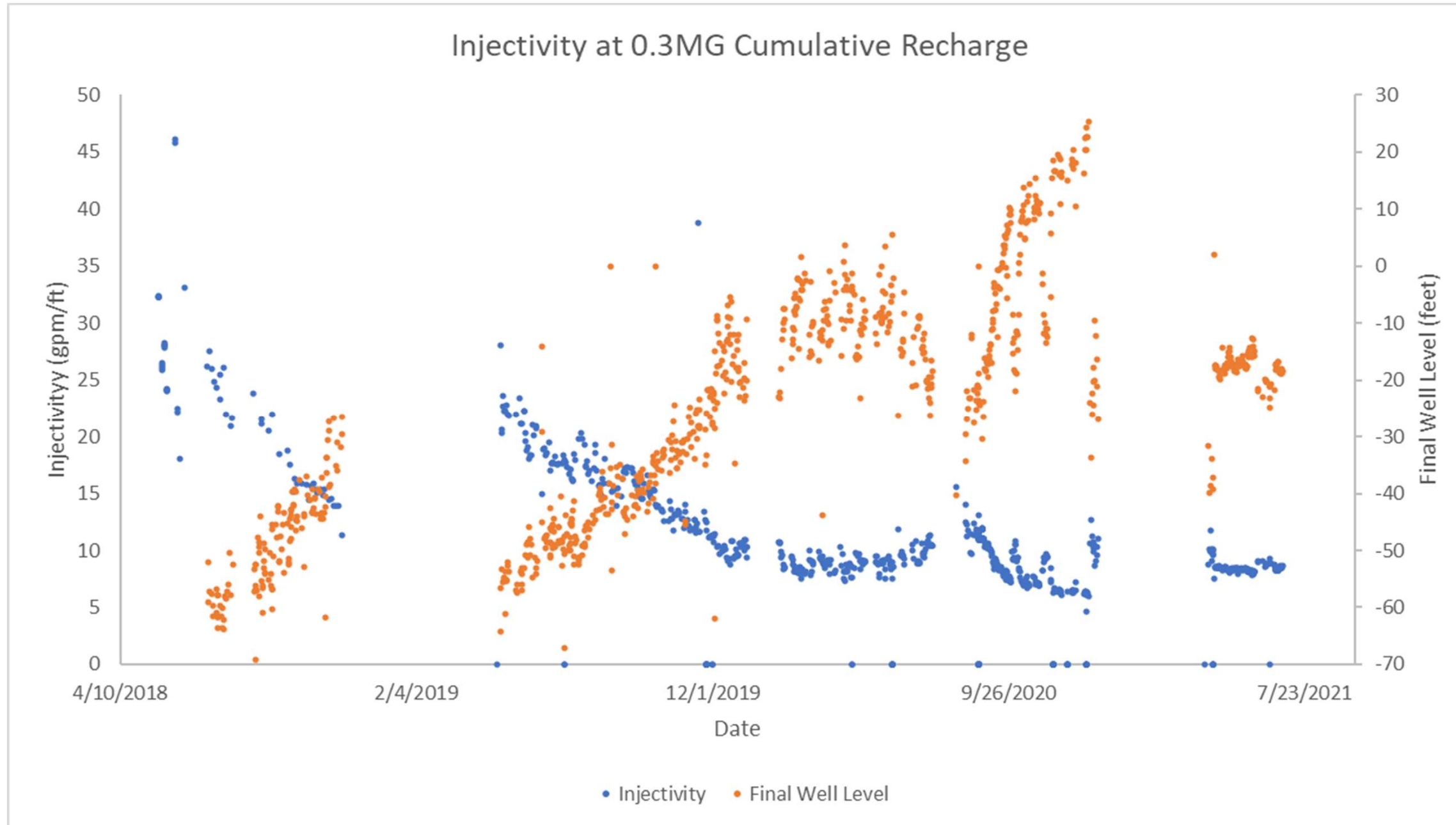
- Arsenic III is very stable across the speciated samples, just above 2 Ug/L
- When As values are low, As (III) dominates
- When As concentration is elevated, As (III) stable, As (V) increases
- Points to reductive dissolution
- Declining DO in the SWIFT Water produce reducing conditions and dissolve HFO – increase in As V

Total As & As (III) in Screen 9 October 11 to November 29, 2021



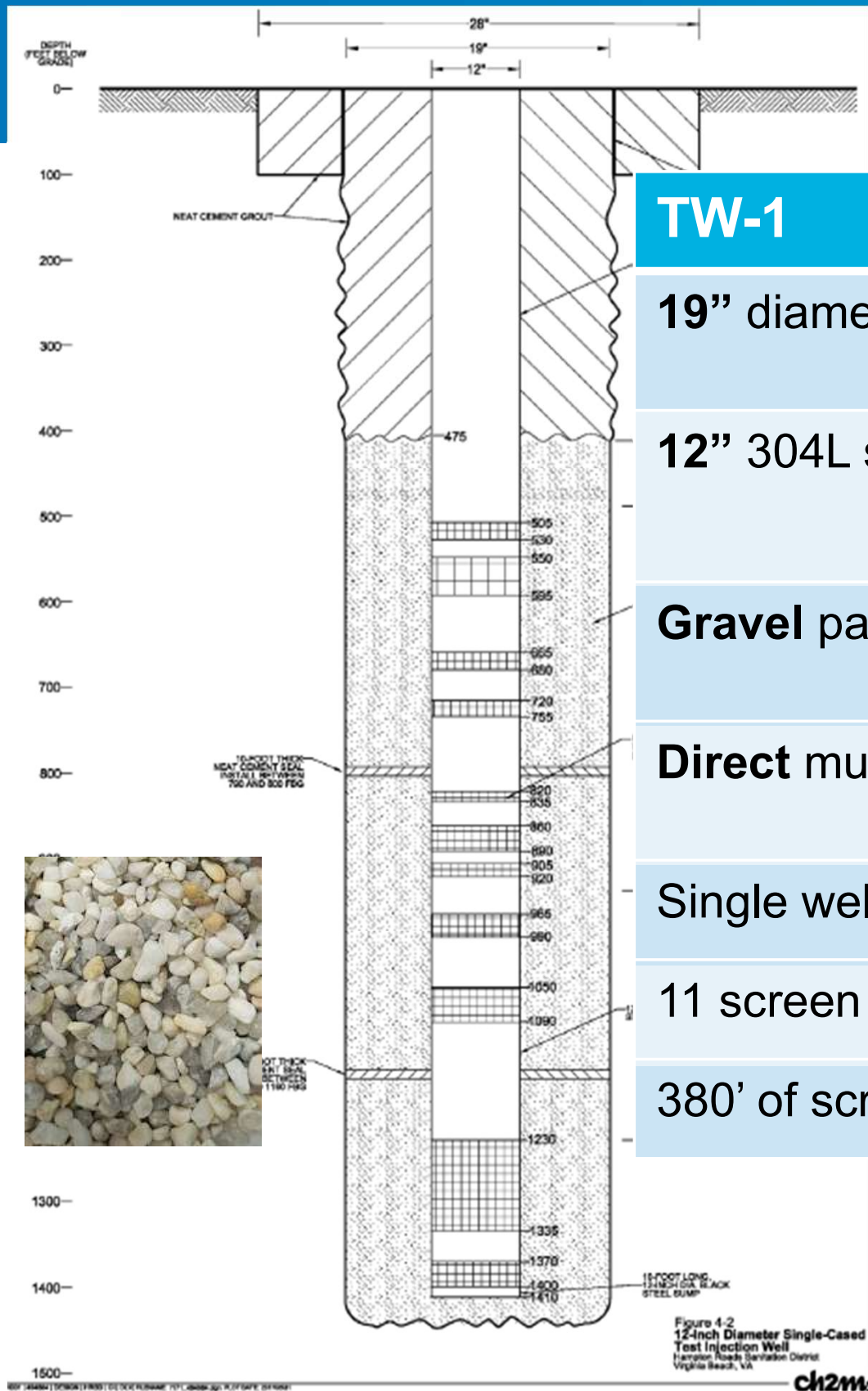


# Injectivity tracking at TW-1

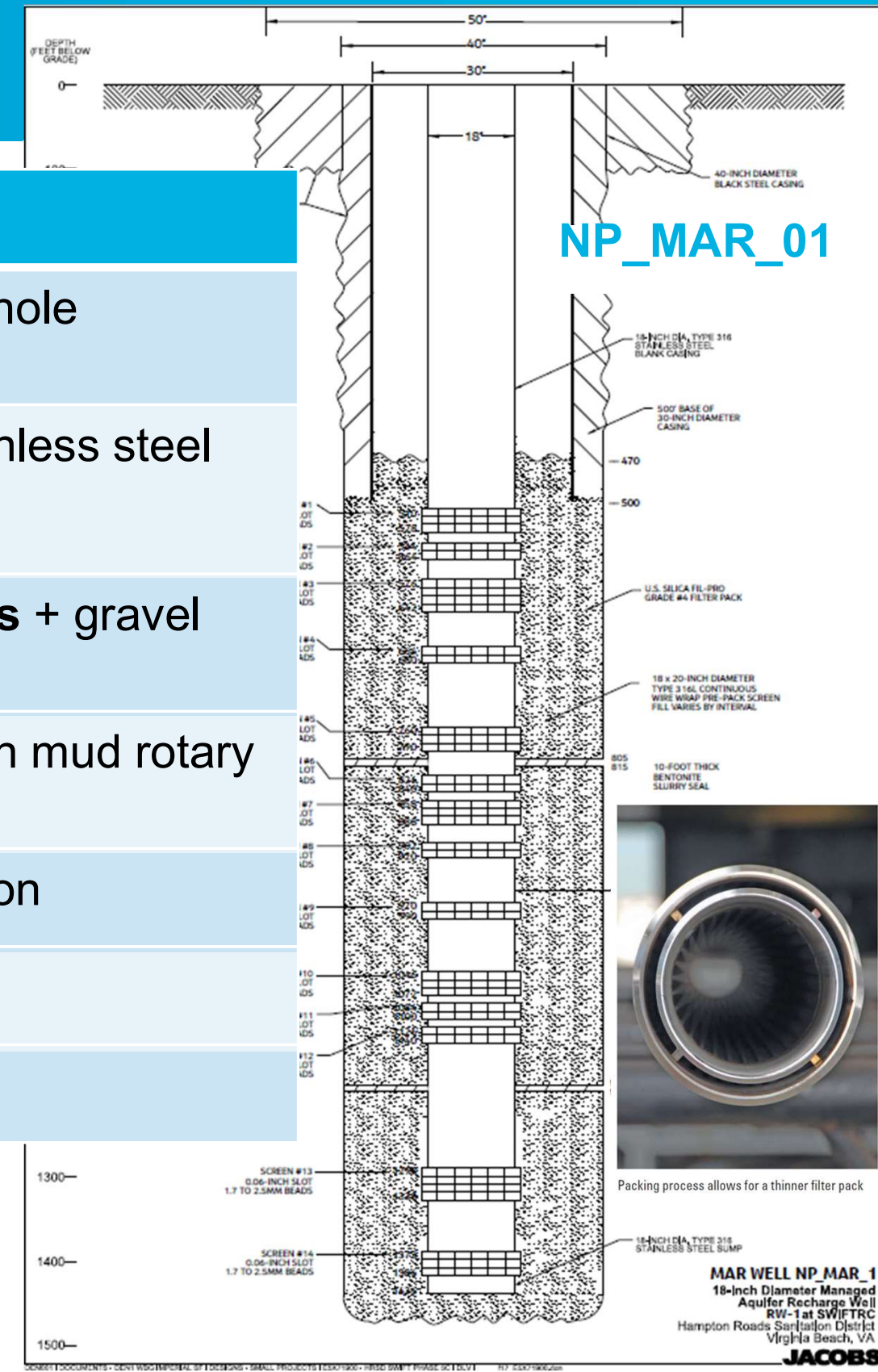




# TW-1 vs NP\_MAR\_01



TW-1	NP_MAR_01
19" diameter borehole	30" diameter borehole
12" 304L stainless steel screen	18"x20" 316L stainless steel pre-packed screen
Gravel pack only	Si spherical beads + gravel pack
Direct mud rotary drilling	Reverse circulation mud rotary drilling
Single well casing/screen	Overlap construction
11 screen zones	14 screen zones
380' of screen	342' of screen





## NP\_MAR\_01 Performance

- Pumped topped out at 2,813 gpm (4 MGD!)
- Specific Capacity @ 2,700 gpm = **69 gpm/ft**
- TW-1 SC @ 1,100 gpm = 37 gpm/ft
- NP\_MAR\_01 @ 1,220 gpm = 83 gpm/ft

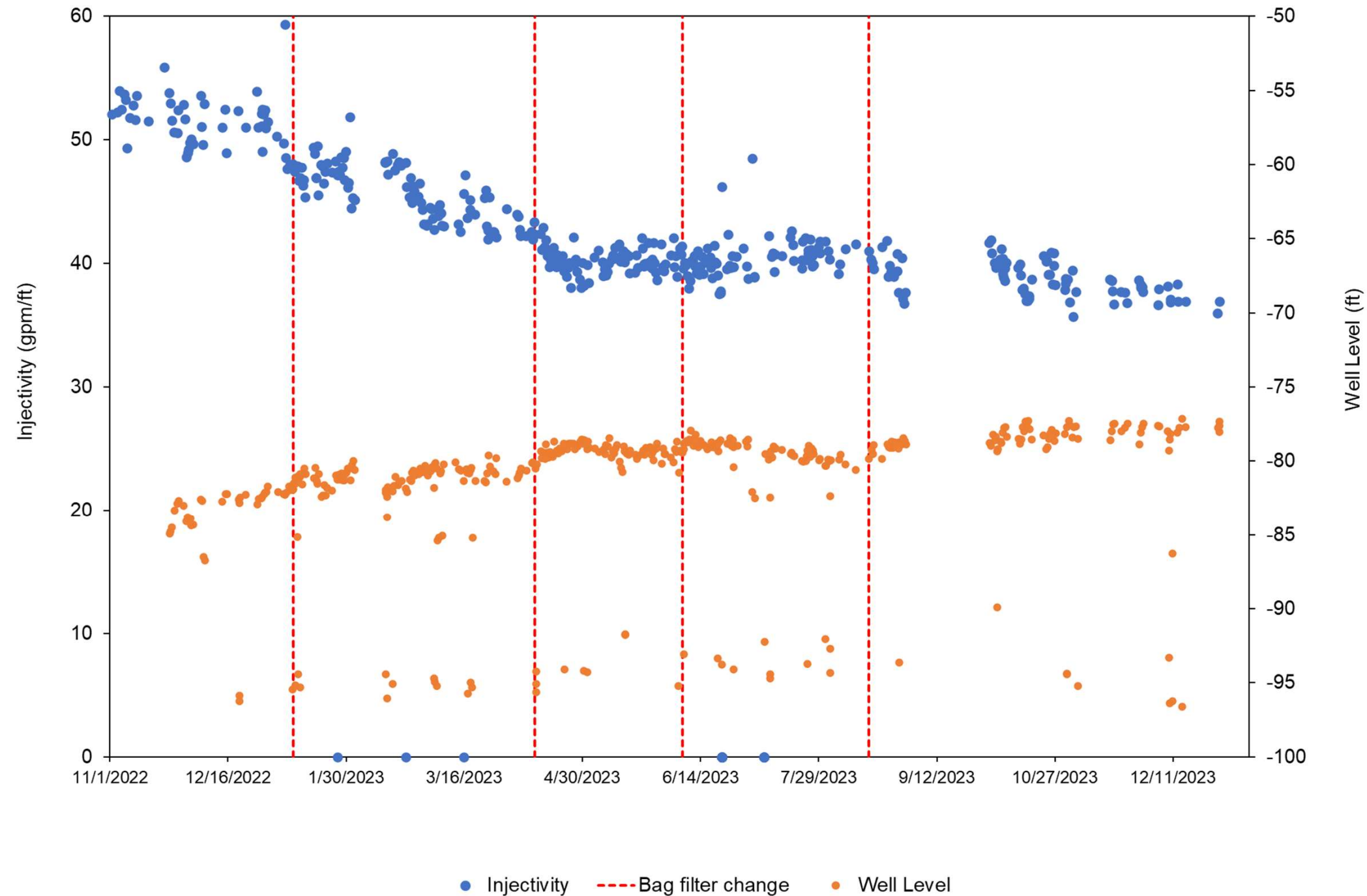


- Transmissivity (ft<sup>2</sup>/day)
  - Ranged 31,200 – 57,500
  - Average 41,500



# NP\_MAR\_01 much better!

MAR-1 Injectivity

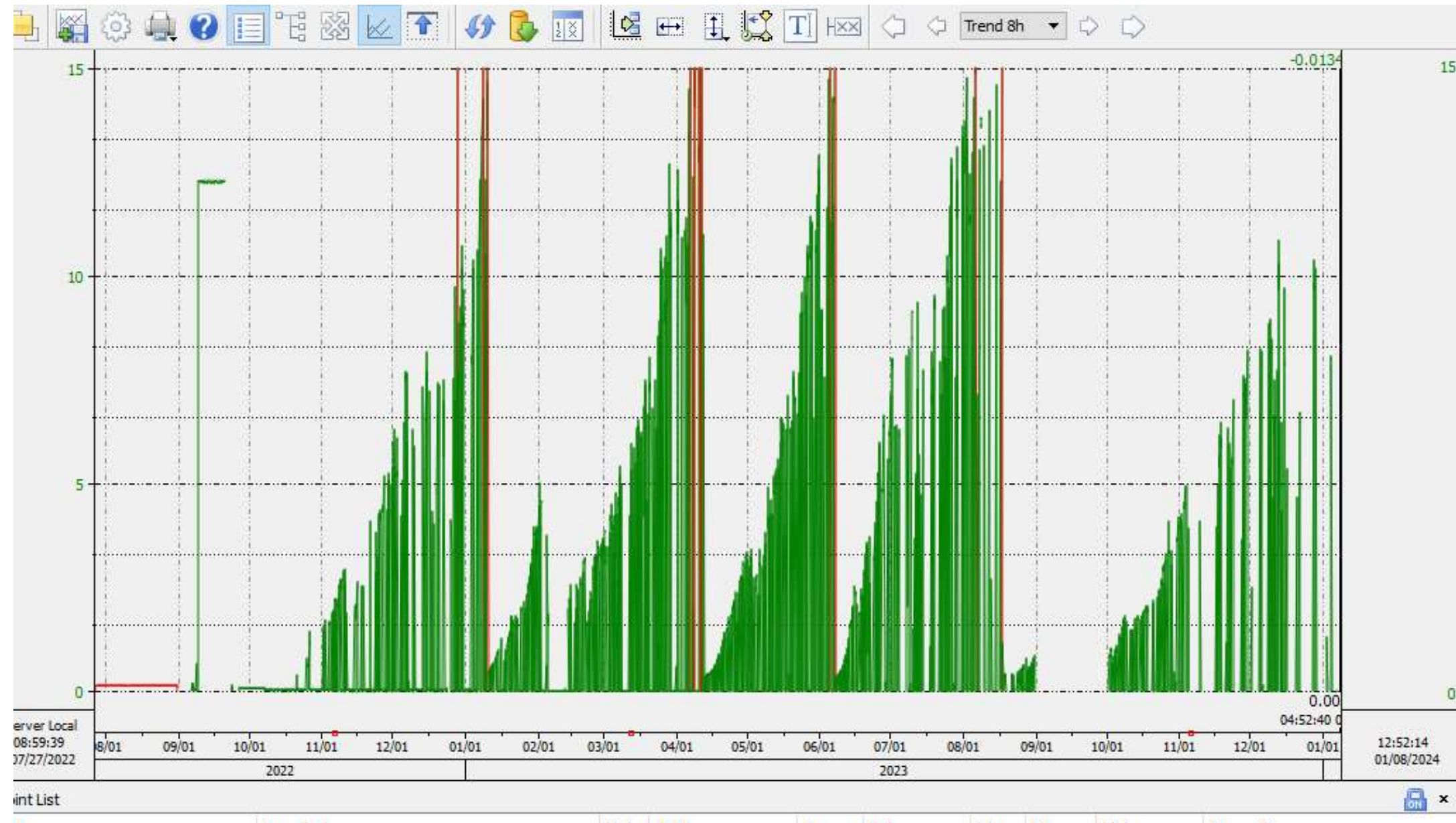






## Wellhead filtration to learn

- Filter bags replaced approximately every 2 months
- Reminder: Currently using absolute filters (0.5 micron – Efficiency 99.99%)
- Normally using nominal (1 micron – Efficiency 70%)





# Regulatory Structure

- SWIFT falls under EPA's Region 3 Underground Injection Control Program

- Class V Well
- SRC EPA Permit by Rule
- JR SWIFT Area Permit

- Independent Monitoring and Oversight

- Developed oversight framework in collaboration with regulators and key stakeholders
- Oversight committee includes representation from regulatory community and local stakeholders
- Incorporates Potomac Aquifer Monitoring Research Laboratory
  - Jointly managed by Virginia Tech and Old Dominion University
- Quarterly meetings since August 2019



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY  
REGION III  
Four Penn Center  
1600 John F Kennedy Blvd  
Philadelphia, Pennsylvania 19103-2852

**UNDERGROUND INJECTION CONTROL AREA PERMIT NUMBER**  
**VAS5B170028617**  
**AUTHORIZATION TO OPERATE CLASS V INJECTION WELLS**

In compliance with provisions of the Safe Drinking Water Act, as amended, 42 U.S.C. §§ 300f *et seq.* (SDWA) and the SDWA implementing regulations promulgated by the U. S. Environmental Protection Agency at 40 CFR 141.44-147 of Title 40 of the Code of Federal Regulations, this Permit authorizes



## SWIFT Monitoring Program Framework

October 2017

The Hampton Roads Sanitation District (HRSD) is currently pilot testing and will soon be demonstrating technologies to treat water from its treatment plants to meet drinking water standards as part of the Sustainable Water Initiative for Tomorrow (SWIFT) project. HRSD plans to pump this highly treated wastewater (SWIFT Water) into the Potomac Aquifer - a drinking water supply for over 200,000 individual well owners and thousands of public water system customers. HRSD plans to deploy this technology at multiple treatment plants in the coming years, with the first demonstration scale injection wells scheduled to come online in 2018. SWIFT is designed to replenish groundwater supply, mitigate land subsidence, reduce saltwater intrusion into the Potomac Aquifer, and reduce nutrient loads into surface water sources within the Chesapeake Bay watershed.

Representatives from HRSD, local, state, and federal government, academic institutions, and the private sector agreed on the need to establish a monitoring program to ensure the integrity of the Potomac Aquifer in light of the planned injections of SWIFT Water. This document lays out a framework for a SWIFT Monitoring Program based on the outcomes of the Potomac Aquifer Monitoring Program Workshop (Workshop) that took place July 20, 2017 at HRSD's North Shore Operations Center in Virginia. This framework is meant to capture points of agreement and document the workshop and supporting materials were developed by Meridian Institute. Additional information on the discussions is available in the workshop summary document and supporting materials that shaped this framework. Appendix 1, a list of Workshop participants (Appendix 2), and Appendix 3, a list of Workshop participants (Appendix 3), provide additional information on the discussions. This framework will be the foundation for the Potomac Aquifer Monitoring Program. The framework will be implemented in partnership with DEQ and VDH to implement the Potomac Aquifer Monitoring Program before replenishment begins. The Monitoring Program is in addition to and independent of any state or federal requirements that may be required by any state or federal agency.

## DRAFT LEGISLATION HRSD SWIFT GROUNDWATER REPLENISHMENT PROJECT

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TO ESTABLISH ADDITIONAL OVERSIGHT MECHANISMS FOR THE  
HRSD SWIFT GROUNDWATER REPLENISHMENT PROJECT

BILL NO. \_\_\_\_\_  
11282017 DRAFT

A BILL to amend the Code of Virginia by adding section 62.1-14.15, adding Chapter 26 to Title 62.1, and adding sections 62.1-271, 272, 273, and 274, relating to the establishment of Potomac Aquifer Recharge Monitoring Program for the Hampton Roads Sanitation District's Sustainable Water Initiative for Tomorrow (SWIFT) Project.

Be it enacted by the General Assembly of Virginia:  
1. That the Code of Virginia (as amended) be and it shall be amended to read:  
§ 62.1-2008 [ODU]. Potomac Aquifer Recharge Monitoring Lab.  
A. Purpose. The Potomac Aquifer Recharge Monitoring Lab is established as a component of the monitoring program for the Hampton Roads Sanitation District's Sustainable Water Initiative for Tomorrow (SWIFT) Project, which is designed to achieve multiple public benefits including groundwater supply replenishment, land subsidence mitigation, saltwater intrusion reduction, and Chesapeake Bay watershed nutrient load reduction. The purpose of the overall monitoring program is to provide independent monitoring and oversight of the SWIFT Project and specifically its effects on the Potomac Aquifer. Within the broader monitoring program, the specific responsibilities of the Potomac Aquifer Recharge Monitoring Lab are as established in this section.  
B. The Potomac Aquifer Recharge Monitoring Lab shall be located at Old Dominion University and shall be a unit thereof. The principal administrative officer of the monitoring lab shall be the monitoring lab administrative director, who shall be a faculty member of the University with appropriate technical and scientific knowledge and who shall also serve as the director for technical services. The monitoring lab administrative director shall be appointed by the president of the University with the concurrence of the Director of the Virginia Department of Environmental Quality and the State Health Commissioner. The monitoring lab administrative director shall carry out the duties imposed upon him by law and other specific duties imposed upon him by the president of the University. The monitoring lab administrative director shall be listed below, the direction of the University and, with respect to the duties under § 62.1-271.  
C. Duties and Functions. The monitoring lab shall be responsible for performing the following functions:  
1. Monitoring the impact of the SWIFT Project on the Potomac Aquifer by reviewing and synthesizing relevant water quality data;  
2. Identifying needs and recommending options for filling gaps, such as recommending changes to monitoring locations and recommending options for filling gaps, such as recommending changes to monitoring locations and protocols;  
3. Conducting sampling and analysis of SWIFT Project water and groundwater on a local scale near SWIFT Project injection wells and other monitoring wells;  
4. Generating, assimilating, interpreting, managing and consolidating data to help inform decision making related to the impact of the SWIFT Project on the Potomac Aquifer, which may include creating a clearinghouse for aquifer and SWIFT Project data and synthesizing





Takes a village to put water into the ground



Chief of Design & Construction  
HRSD



Program Management  
AECOM & Hazen



Managed Aquifer Recharge  
Earth Data Inc.

Individual Project Teams

## Phase 1

- James River SWIFT (16 MGD): US-A DB Team, AC Schultes of Maryland, 2026
- Nansemond SWIFT (33 MGD): Active Procurement, 2029
- VIP SWIFT: Tertiary treatment to reduce nutrients, no recharge Phase 1

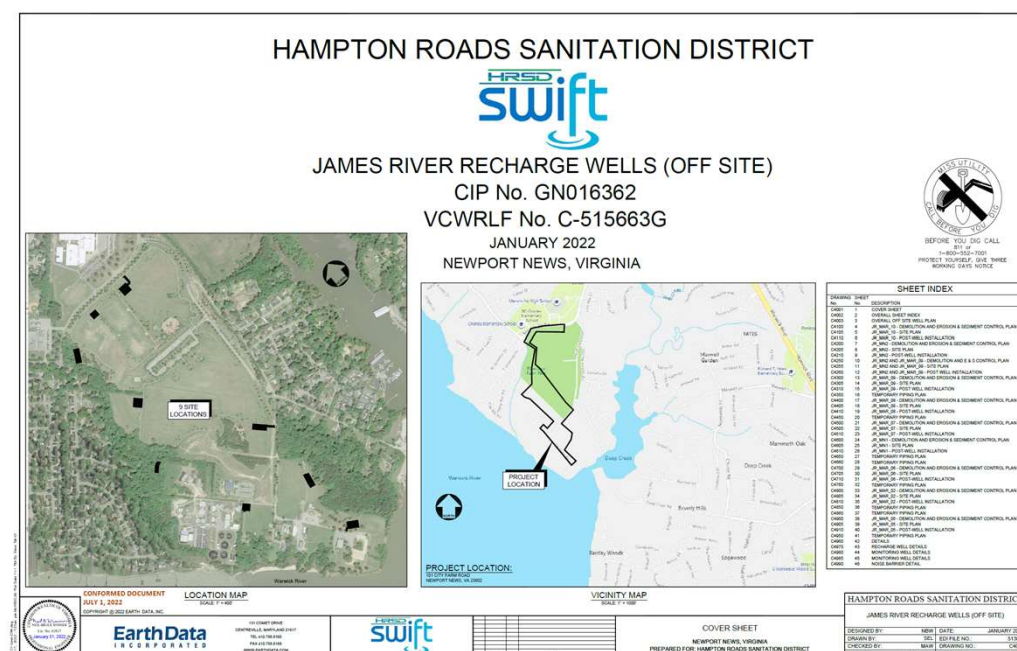
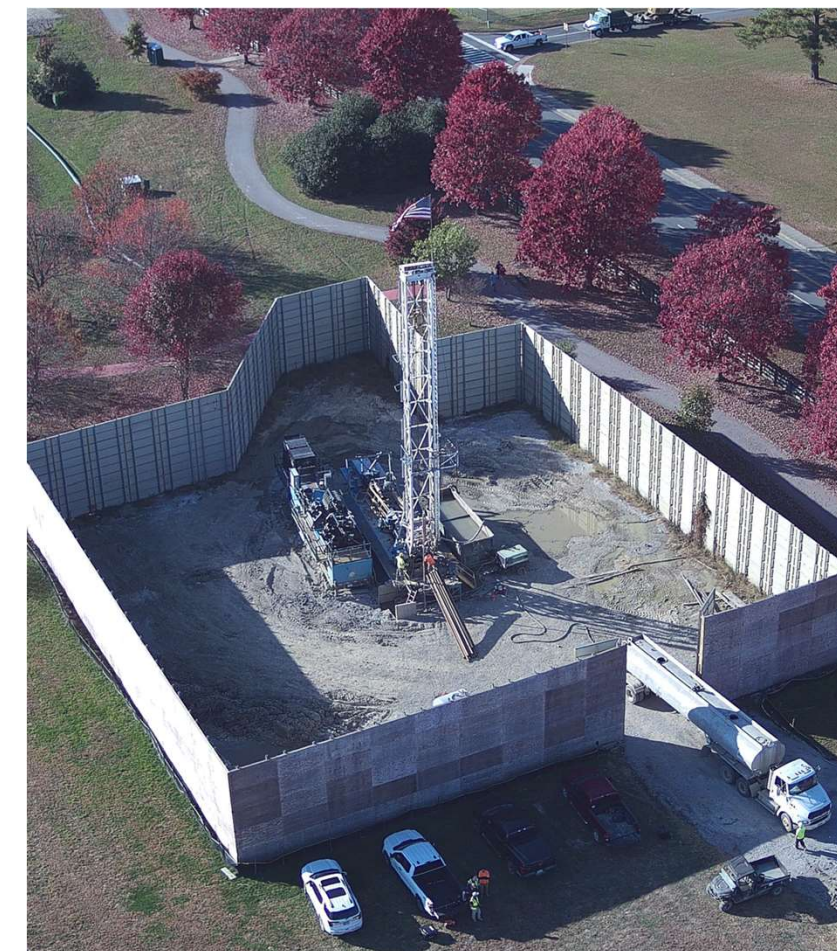




# James River SWIFT Wells, not just a pipe in the ground

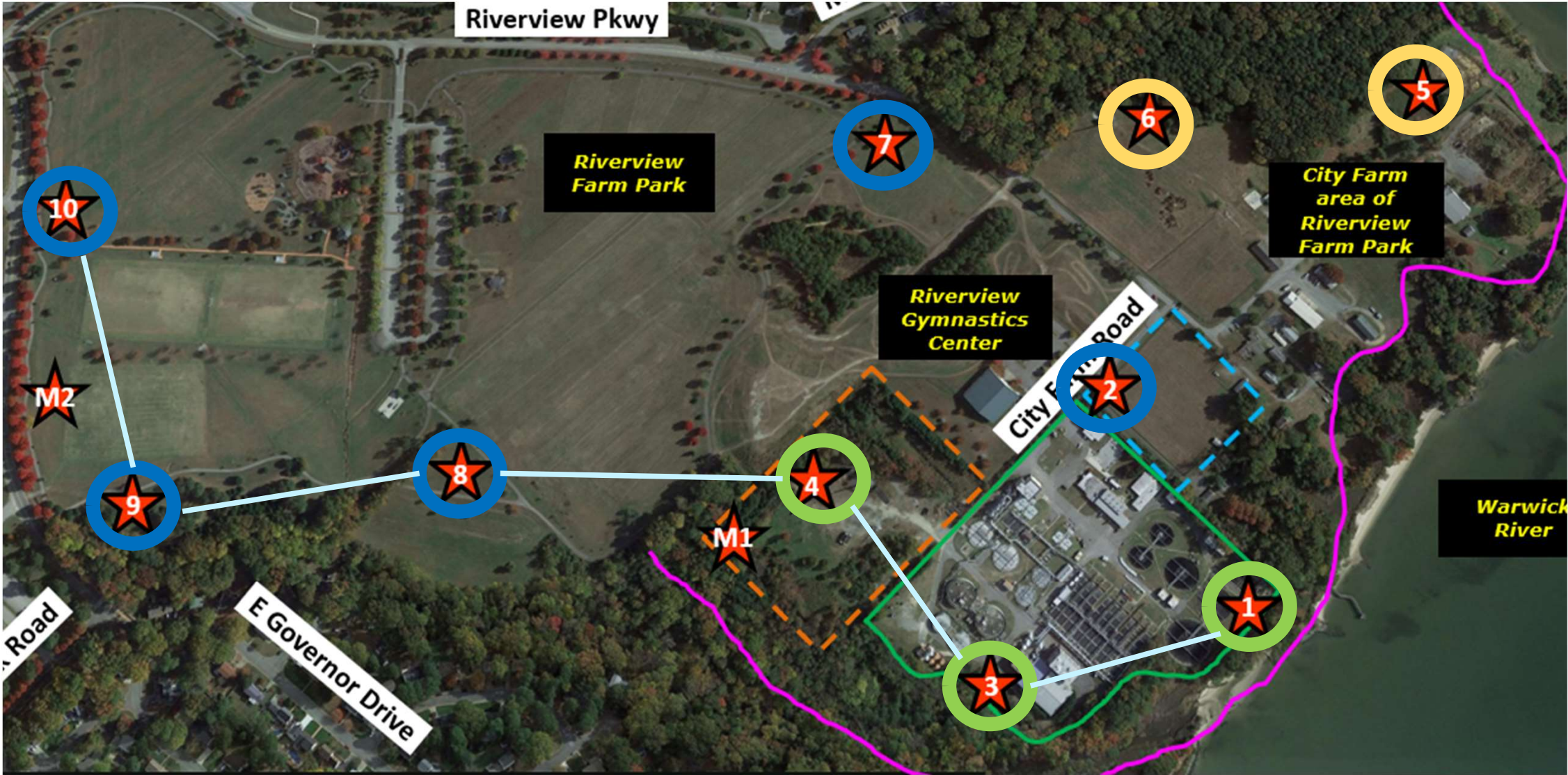
## Recharge Well Profile

- Total depth: ~1250 feet below ground
- 30-inch SS diameter upper casing X 20-inch diameter SS screen
- Screen/blank section starting ~500 feet below ground
- 10+ Multiple screen sections
- Pre-packed screens likely
- 4 MGD withdrawal capacity, 2 MGD recharge capacity
- Reverse circulation drilling pass
- Conditioning aquifer with ACH





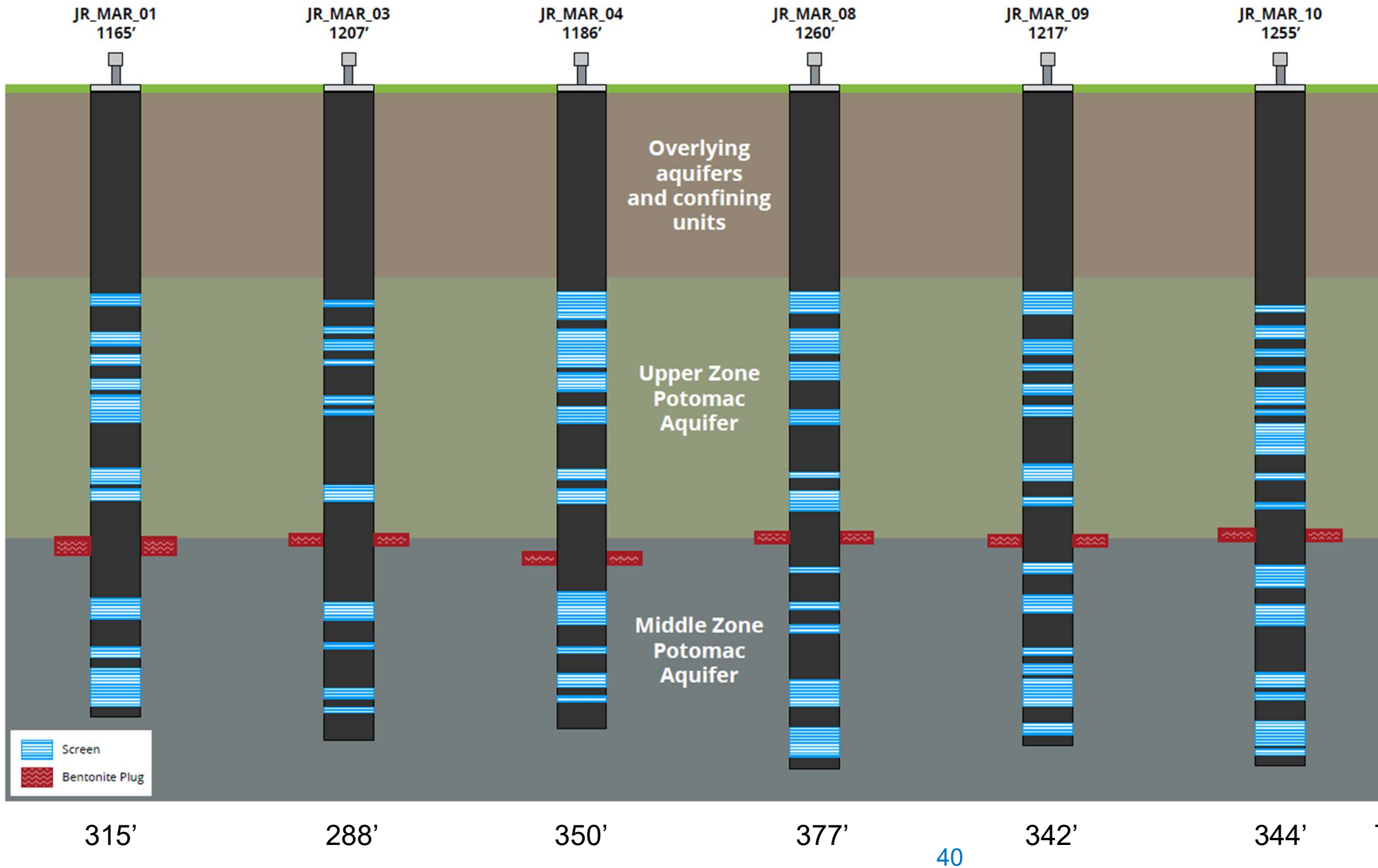
# James River SWIFT MAR Wells



- Complete
- Active
- Site prep



# James River SWIFT MAR Wells general comparison



MAR Well ID	flow rate (gpm)	specific capacity (gpm/ft)
JR_MAR_01	2112	58
JR_MAR_03	2088	55
JR_MAR_04	2100	76
JR_MAR_10	2083	60
NP_MAR_01	2112	69



# Save the Date – HRSD SWIFT Industry Day 2024

SWIFT Industry Day is an annual opportunity to learn about the status of the SWIFT program and upcoming opportunities to join us in providing sustainable water for the future of eastern Virginia. Come meet with members of our program management team, HRSD leaders, and project-specific teams!

January

25

2024

Holiday Inn Newport News – Hampton  
980 Omni Boulevard  
Newport News, VA 23606

- 8:30 a.m. – 9:30 a.m. Networking Breakfast
- 9:30 a.m. – 11:00 a.m. Presentation and Discussion
- 11:00 a.m. – 12:00 p.m. Continued Networking

*Scan the QR code to register  
and for more information*





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P.G.**

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**757-813-5126**

