

Incorporating Drawdown/Derivative Analysis to Provide Insight on Complex Flow/Transport Conditions

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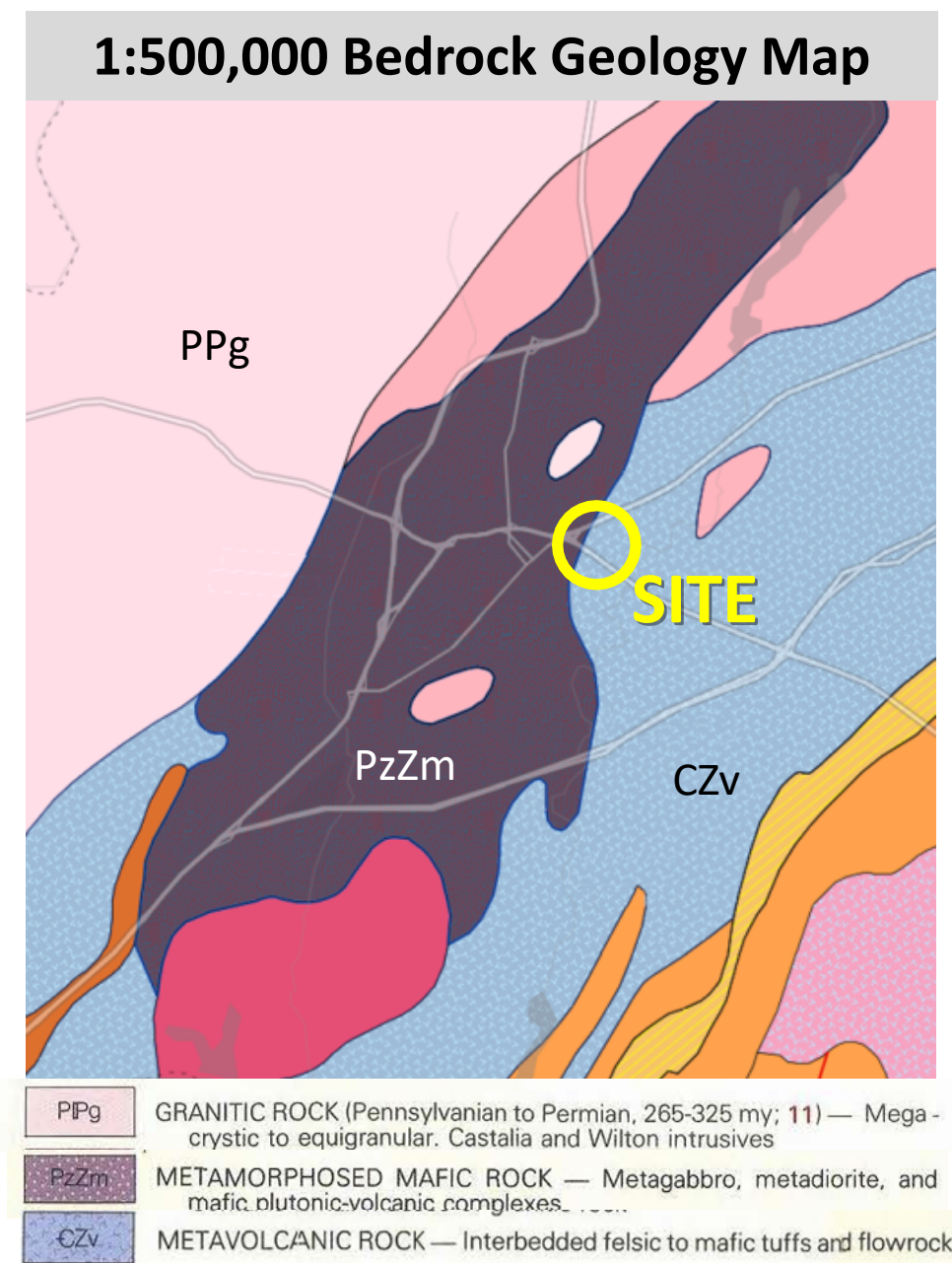
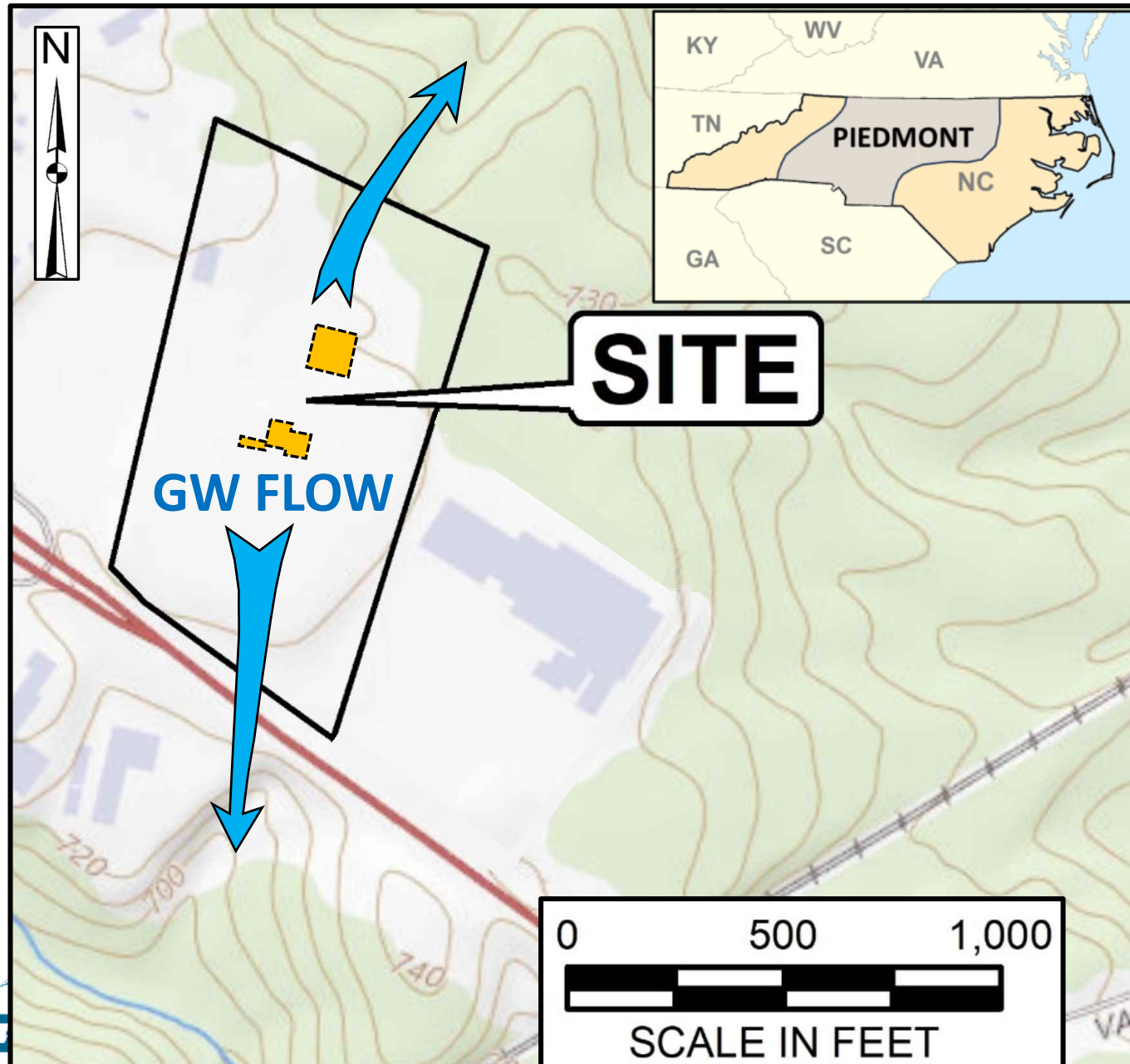


1. Site Location/Background
 - Geologic Complexities
2. Aquifer Testing/Data Workflow
3. Data Analysis
 - Response to Pumping
 - Derivative Patterns
4. Key Findings/Implications



Piedmont Region – Saprolite Heterogeneities (Photo Credit: Chris Turner, Haley & Aldrich)

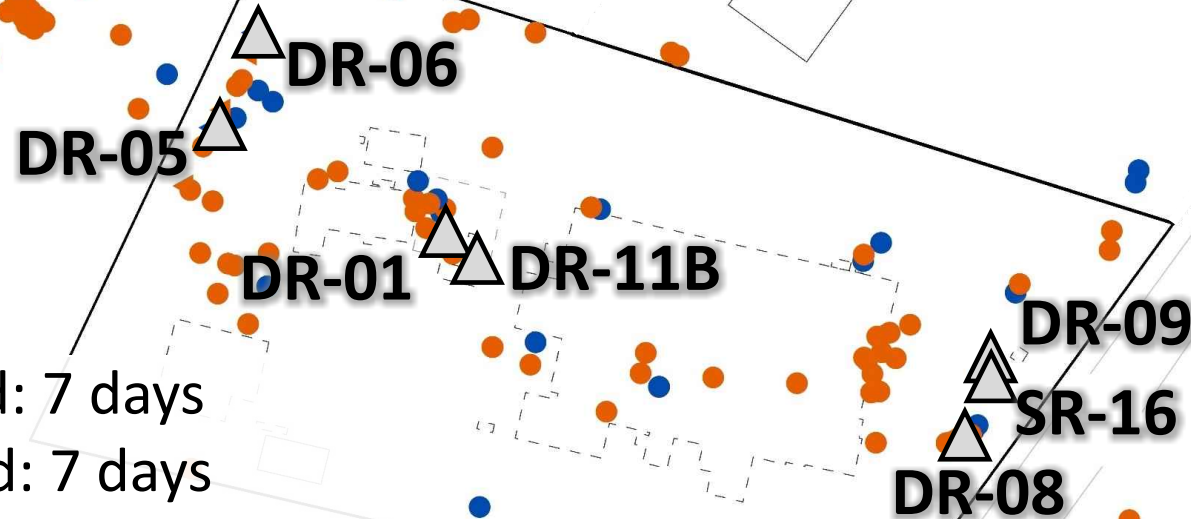
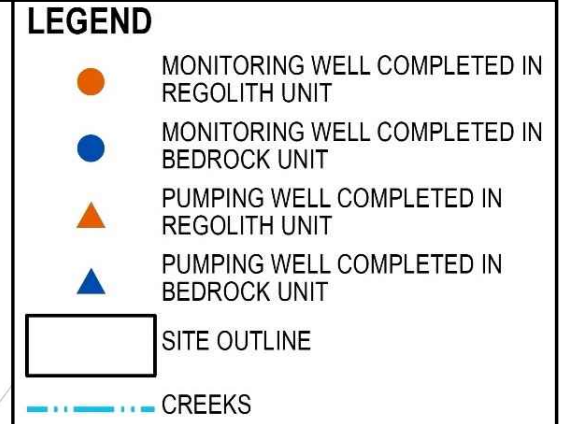
1. Site Location/Background



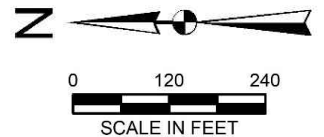
2. Aquifer Testing

~150 monitoring wells

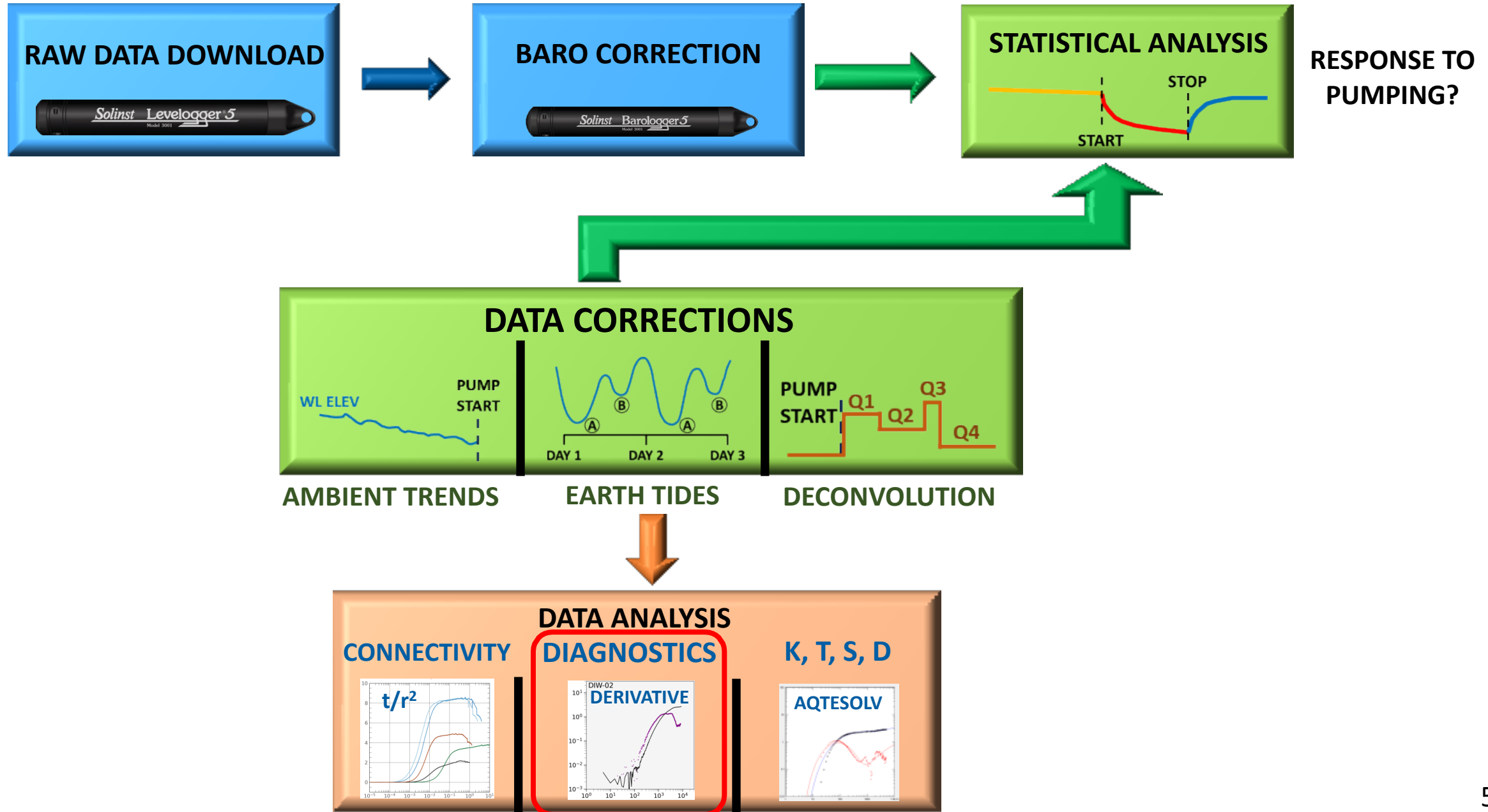
How about one more well?



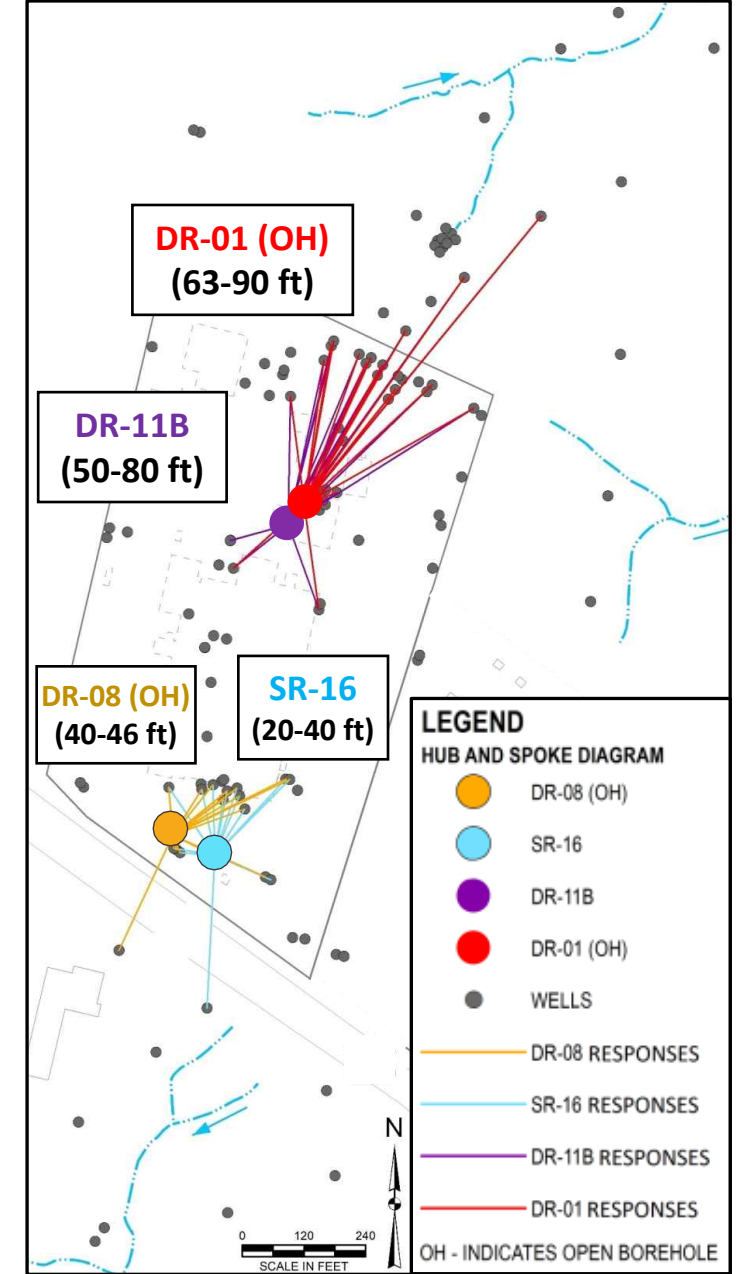
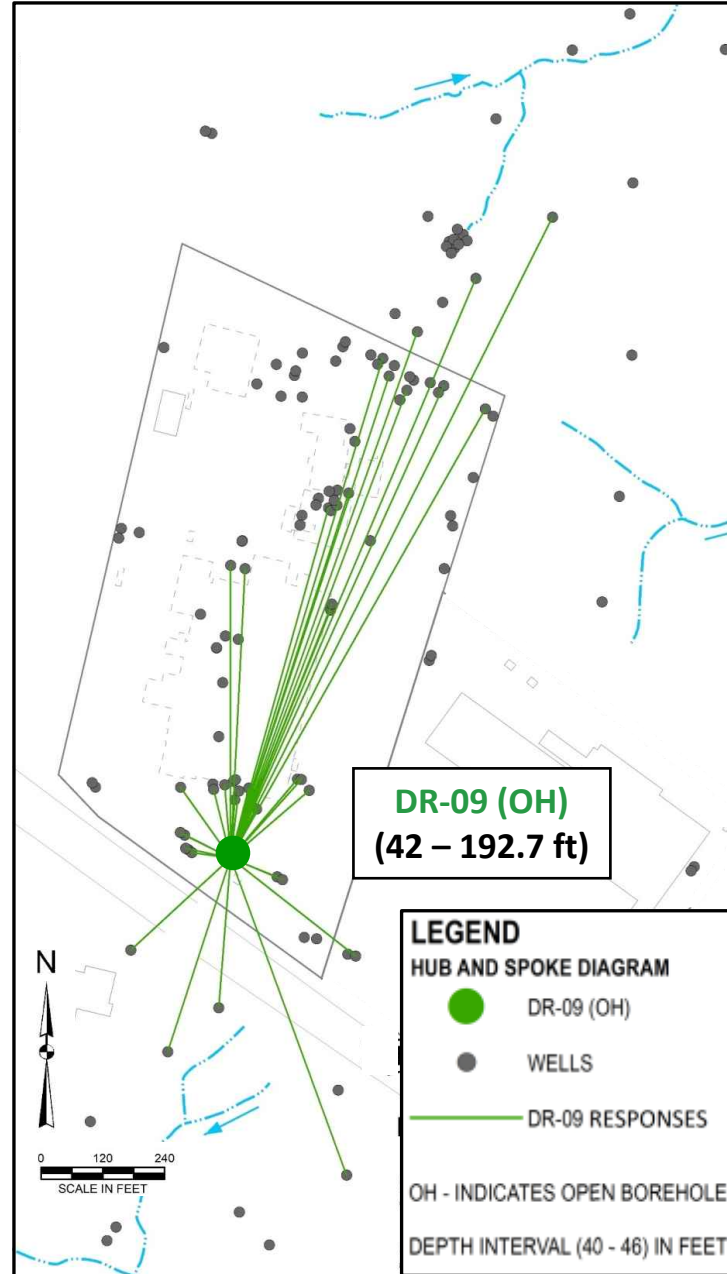
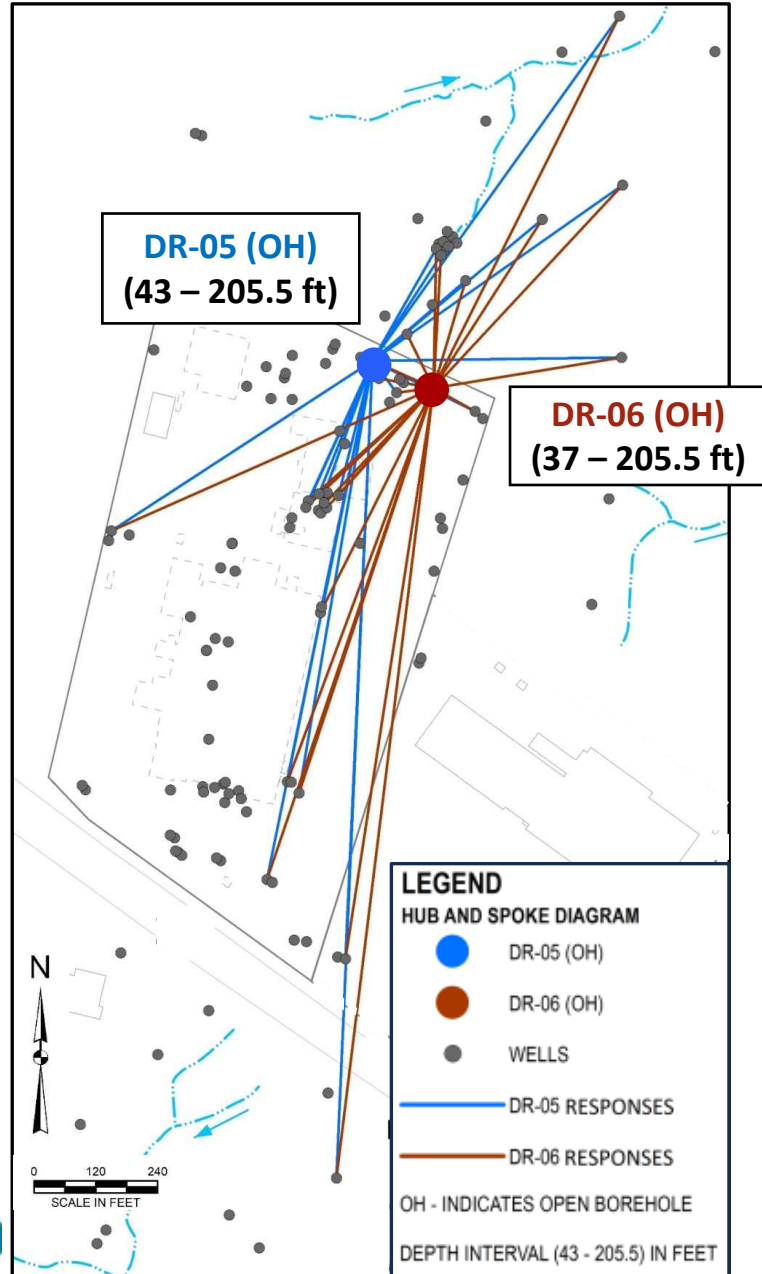
- Pumping Period: 7 days
- Recovery Period: 7 days
- Transducers: >100 wells
- Discharge → Treatment System



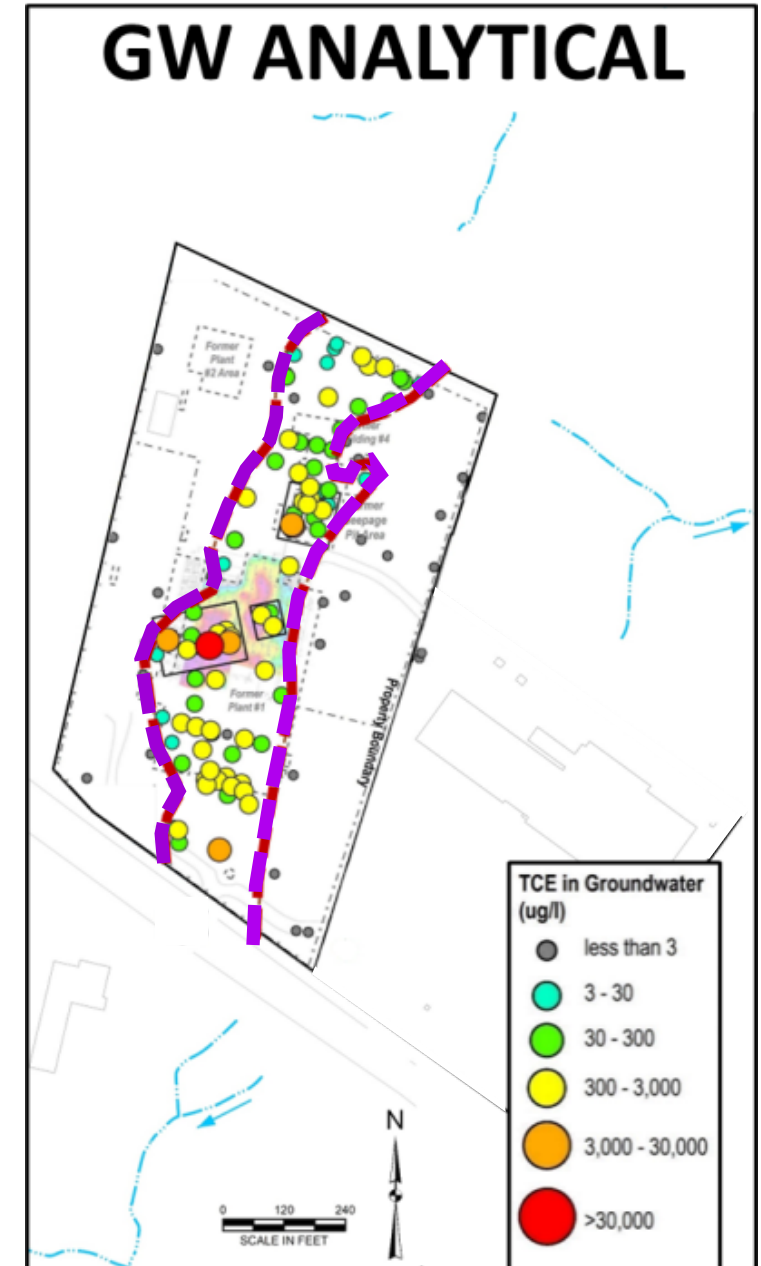
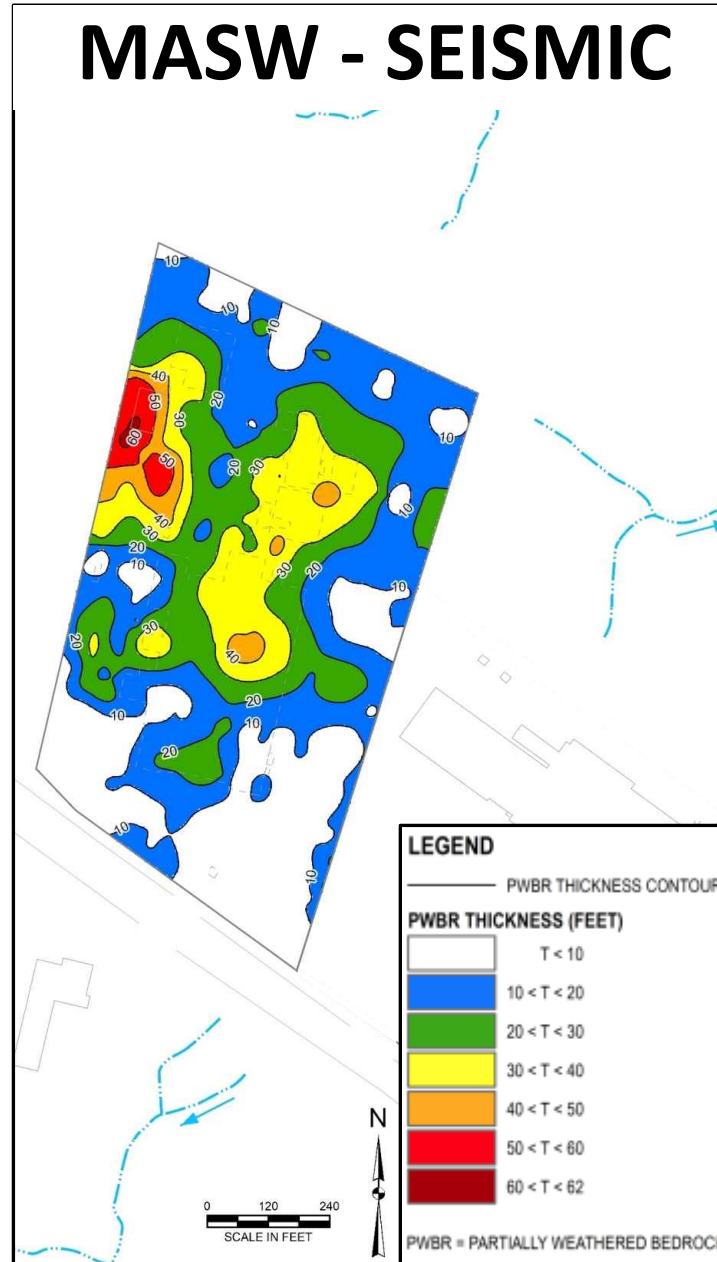
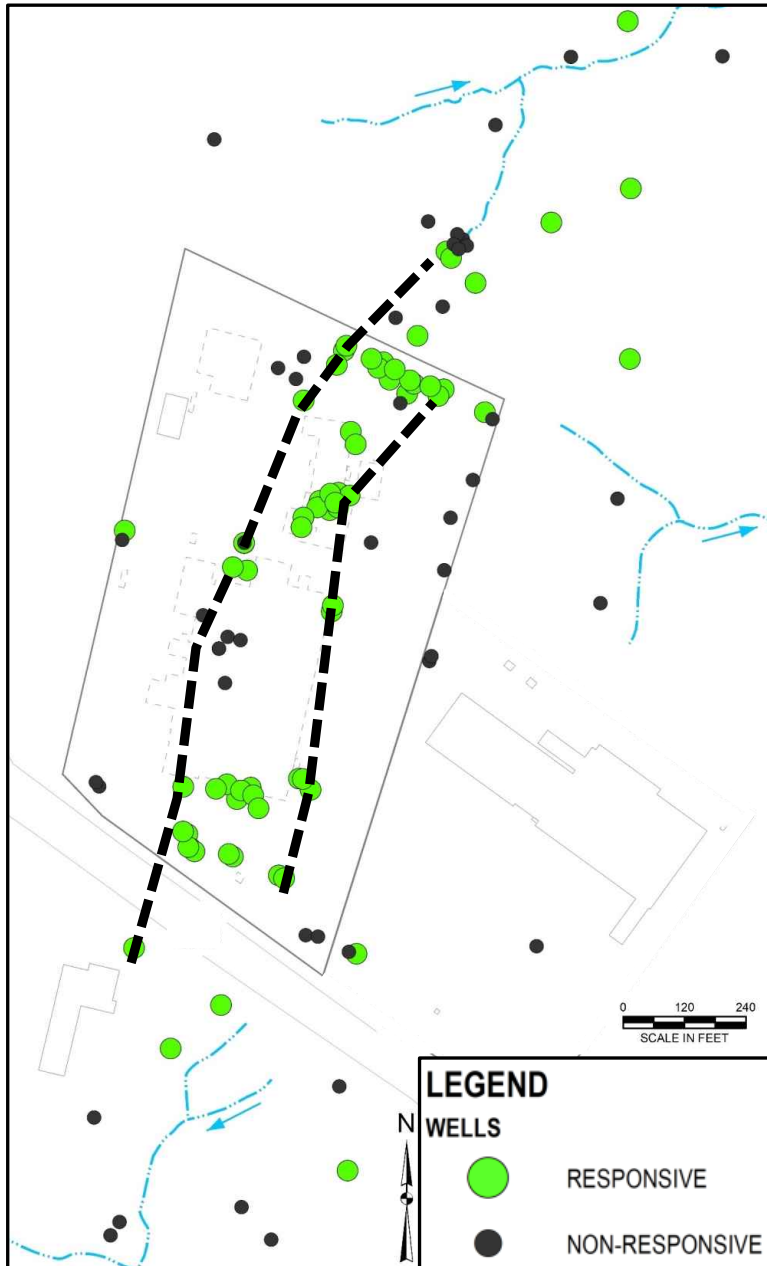
2. Data Workflow



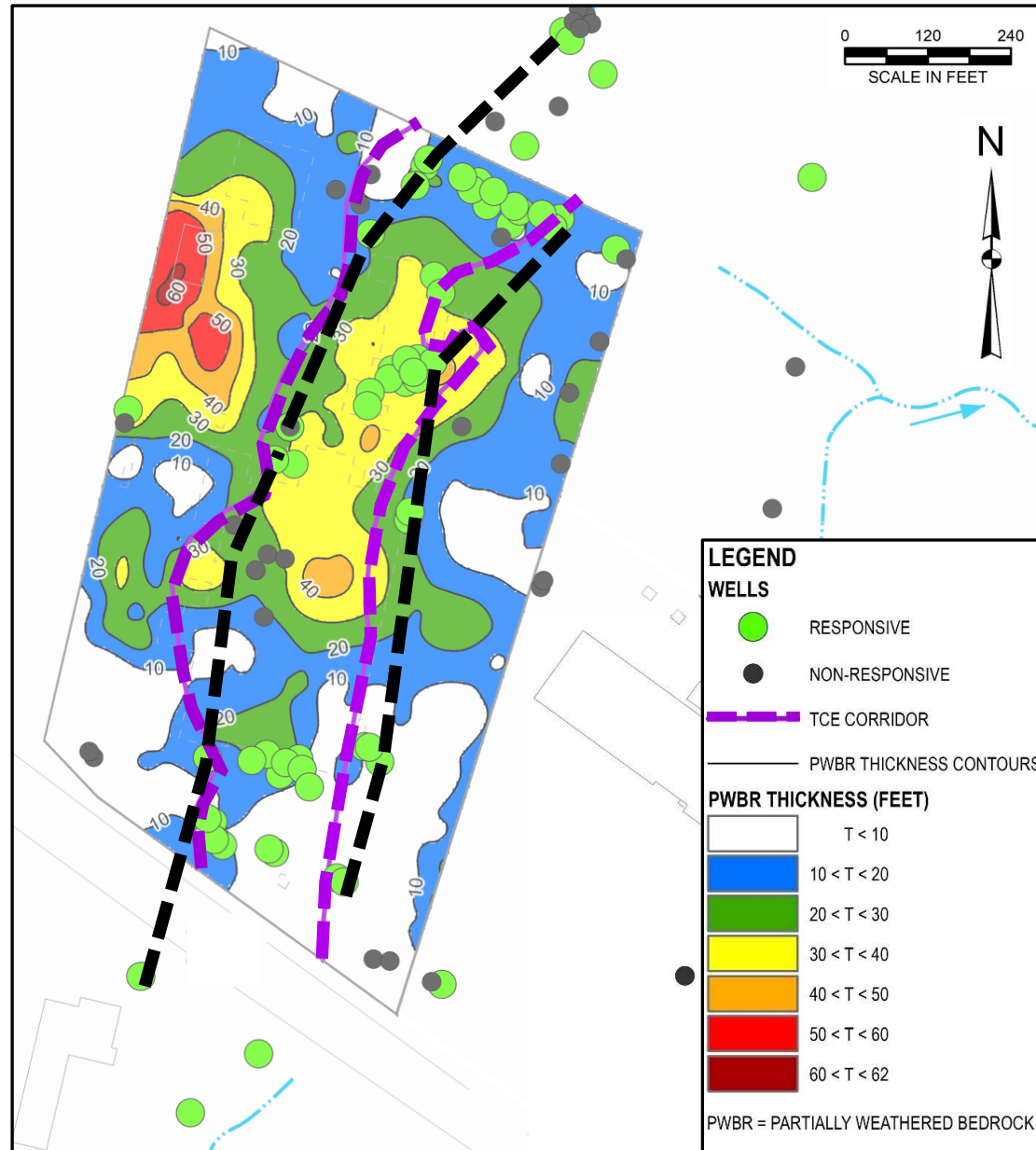
3. Data Analysis: Response to Pumping



3. Data Analysis: Responsive Corridor



3. Data Analysis: Responsive Corridor



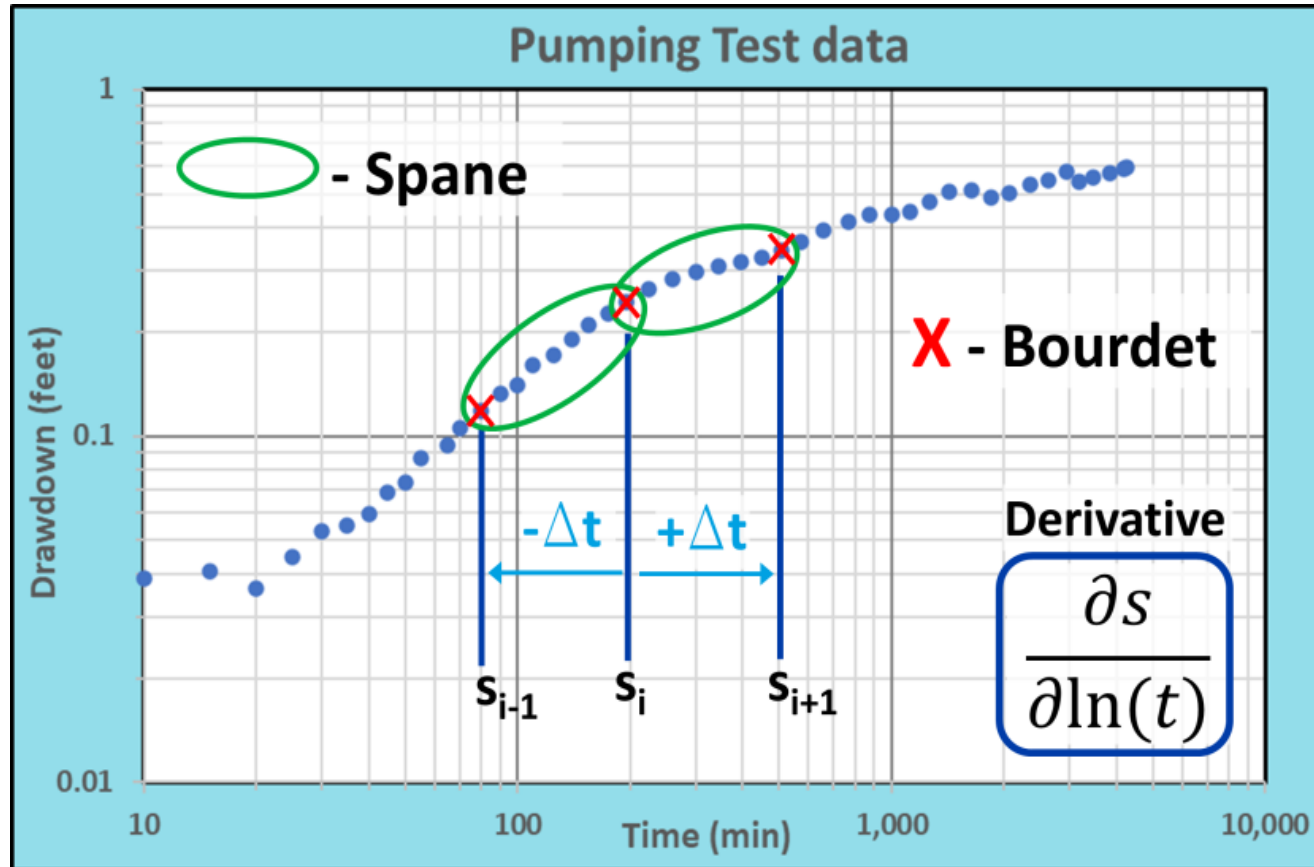
Spatial Correlation

1. Geophysics
 - Partially Weathered Zone - Thick
2. Laboratory Analytical Corridor
3. Responsive Corridor

Fracture Corridor

3. Data Analysis: Drawdown/Derivative

Smoothing Methods

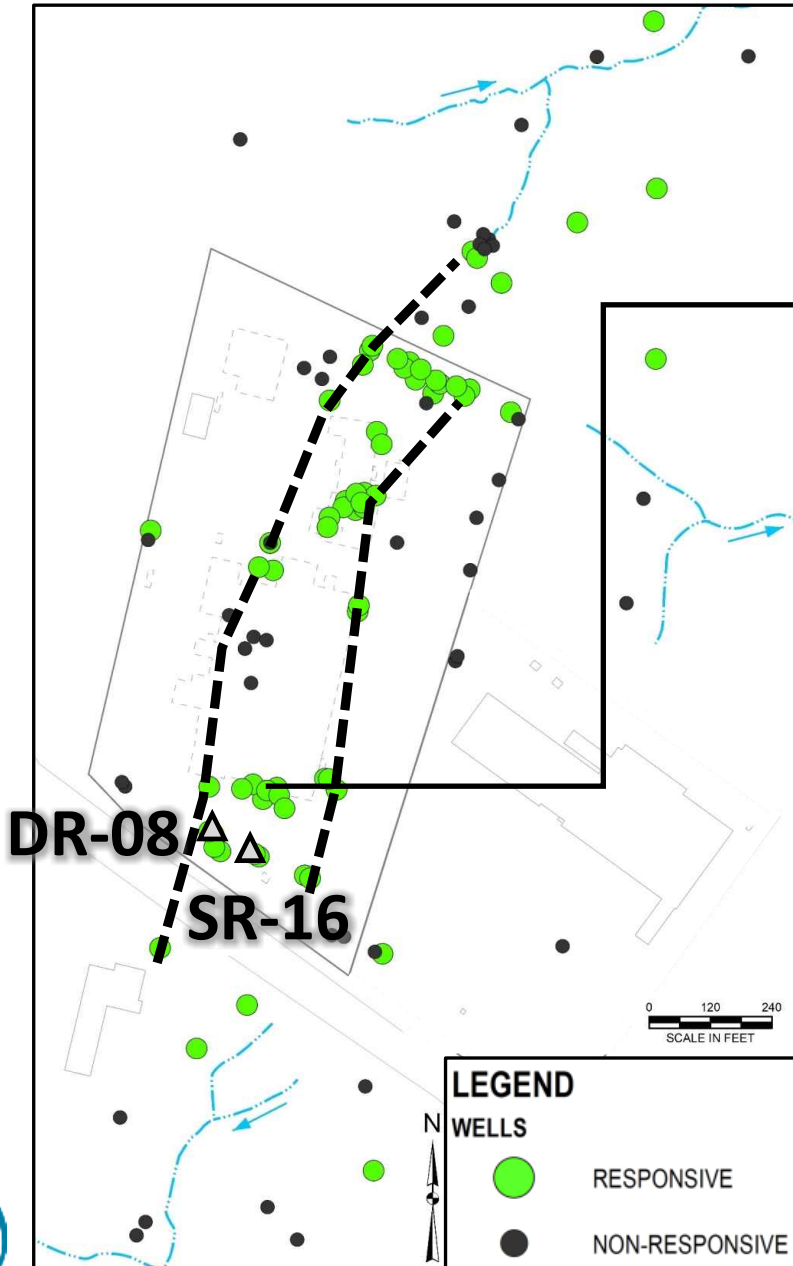


s = drawdown
t = time

Benefits of Derivative Analysis

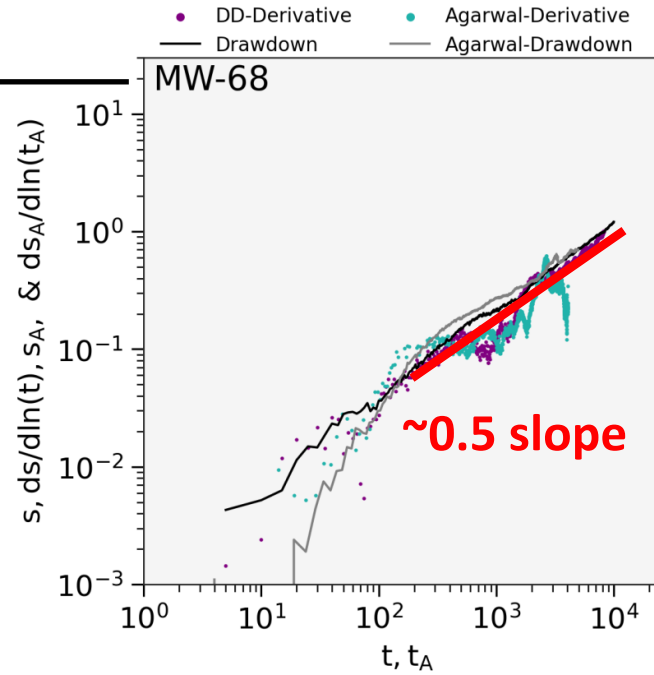
- Data interpretation: improved sensitivity
- Curve matching
- Heterogenous aquifer behavior
- Derivative patterns for flow regimes/flow characteristics/boundary conditions

3. Data Analysis: Drawdown/Derivative

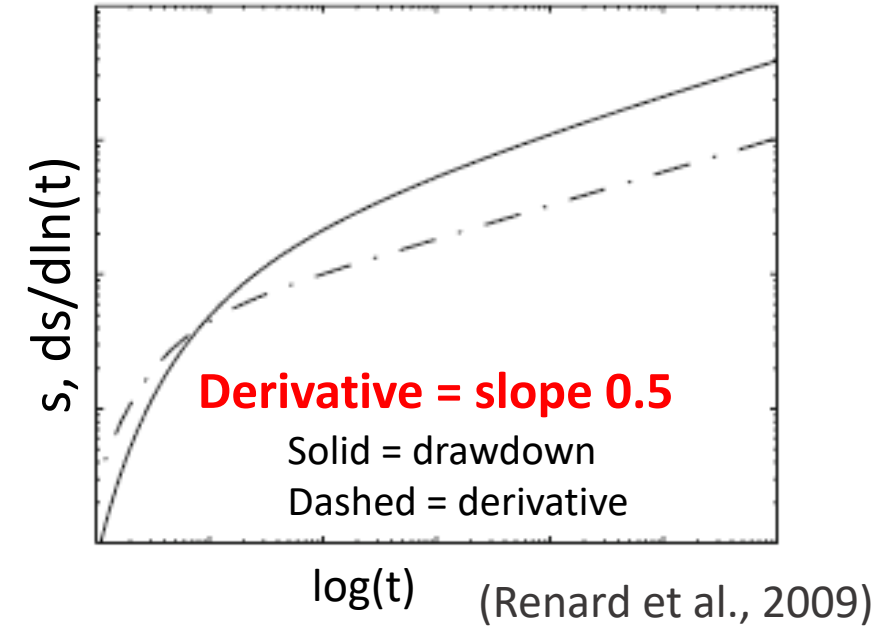


Shallow Wells - South

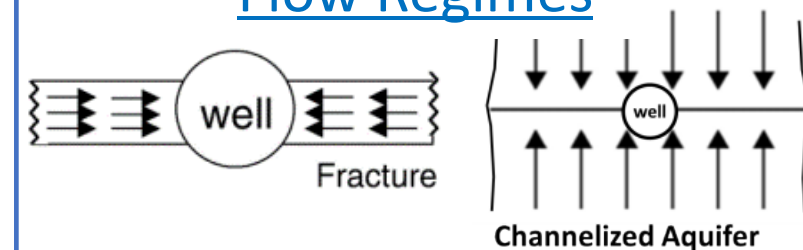
Total Depth: 25 - 50 feet bgs
Weathered Unit (saprolite)



LINEAR FLOW



Flow Regimes



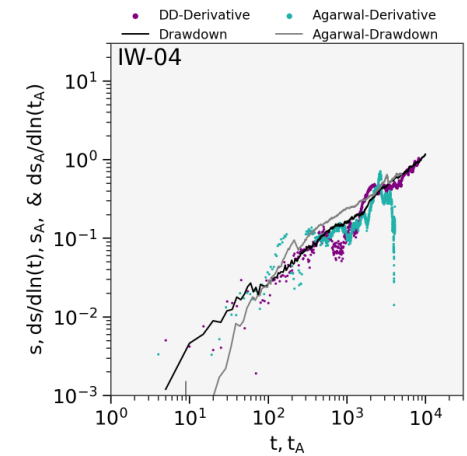
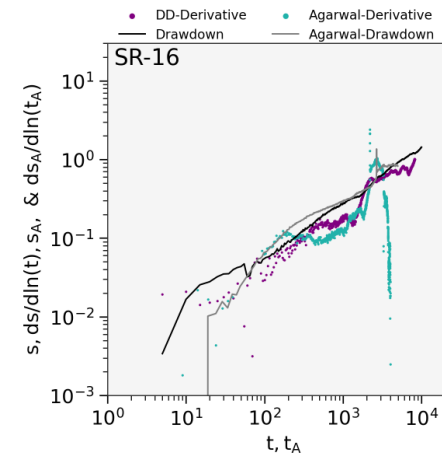
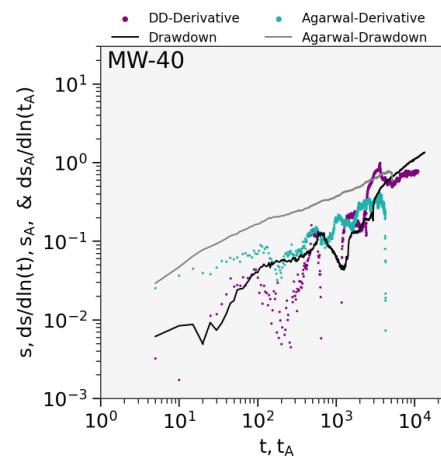
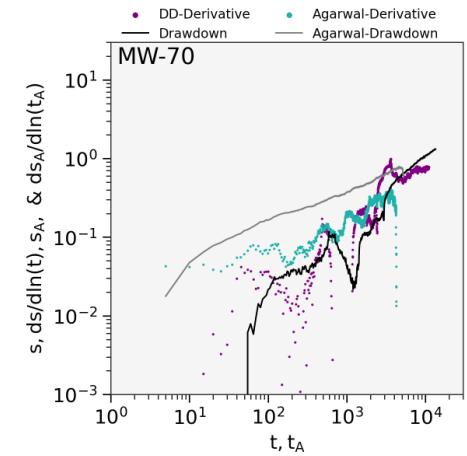
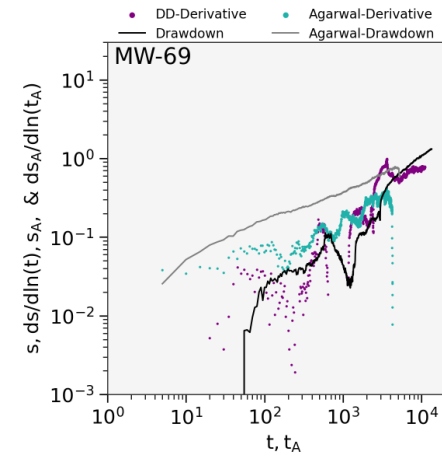
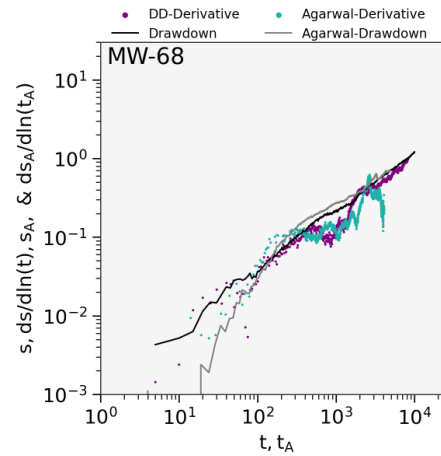
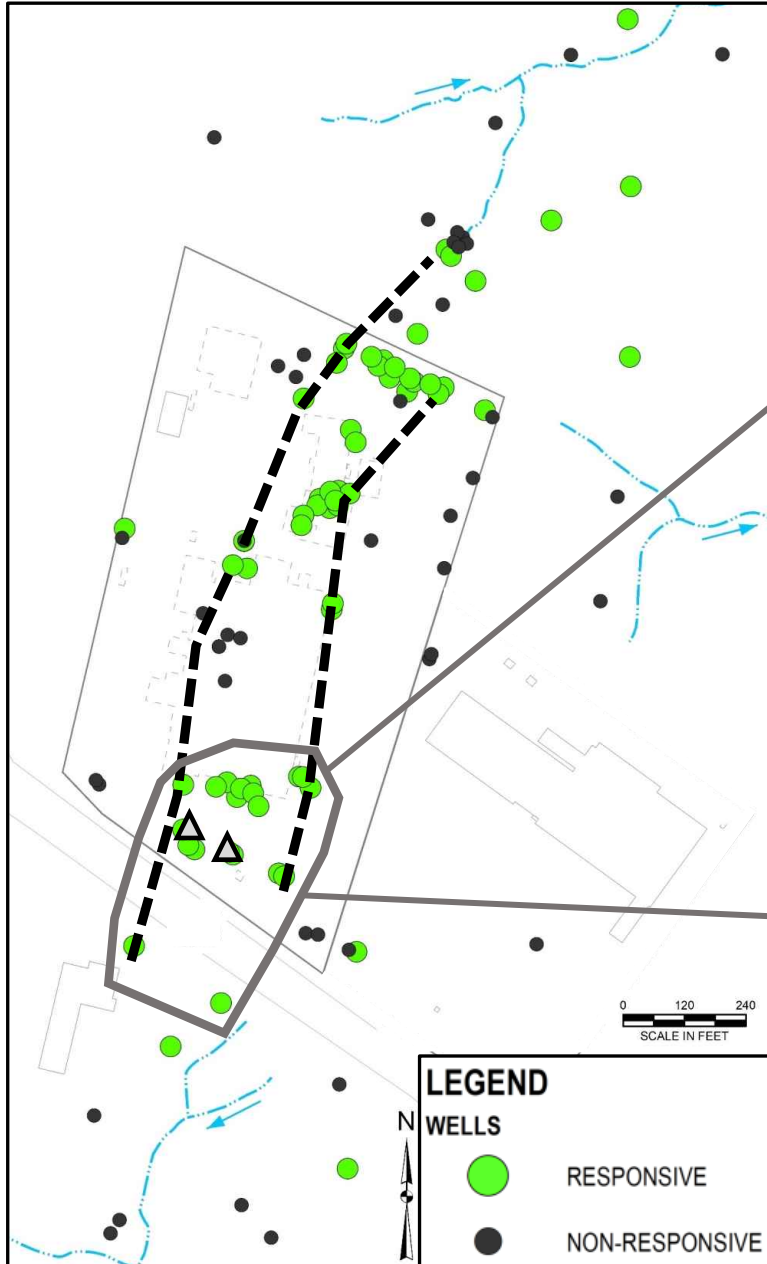
3. Data Analysis: Drawdown/Derivative

Shallow Wells - South

Total Depth: 25 - 50 feet bgs
Weathered Unit (saprolite)

LINEAR FLOW

Derivative Slope = 0.5



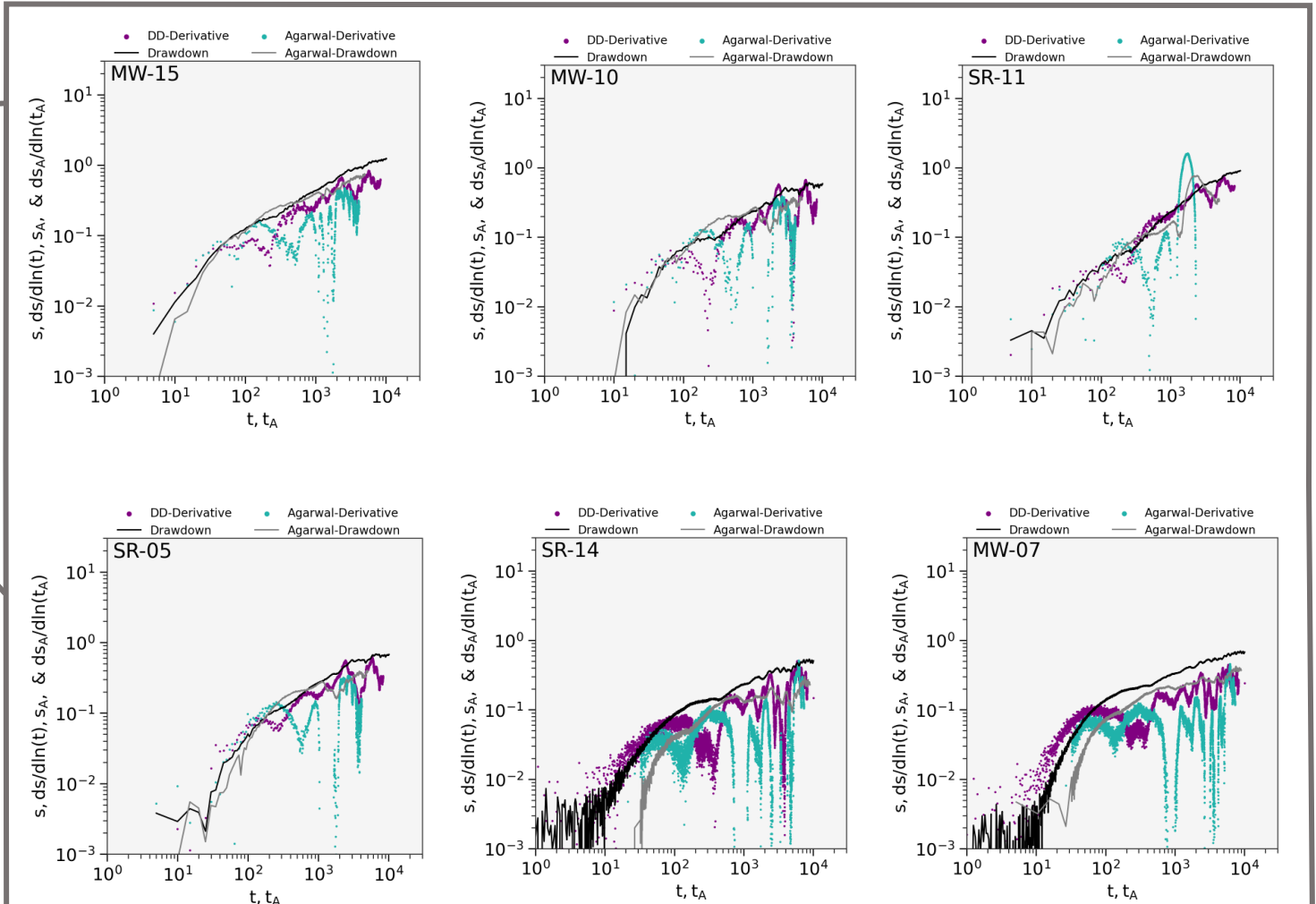
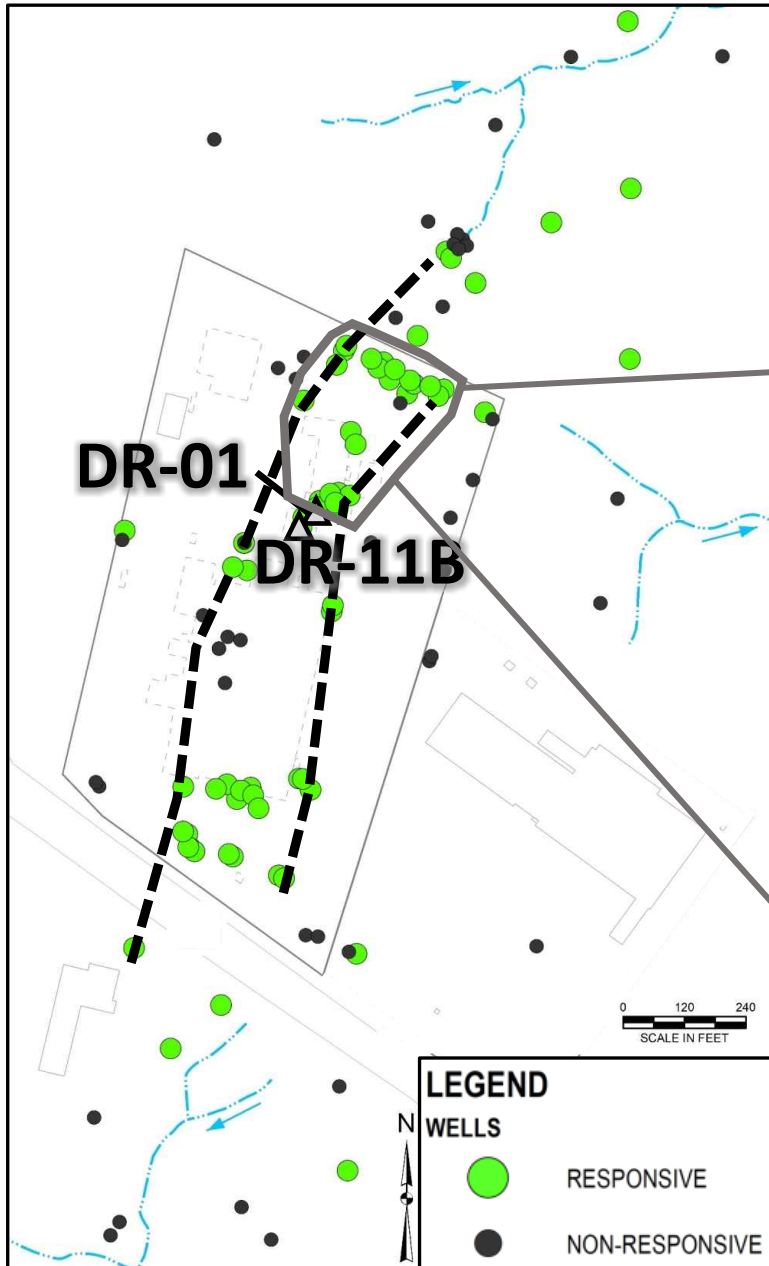
3. Data Analysis: Drawdown/Derivative

Shallow Wells – North

Total Depth: 25 - 50 feet bgs
Weathered Unit (saprolite)

LINEAR FLOW OR BILINEAR FLOW

Derivative Slope = 0.25

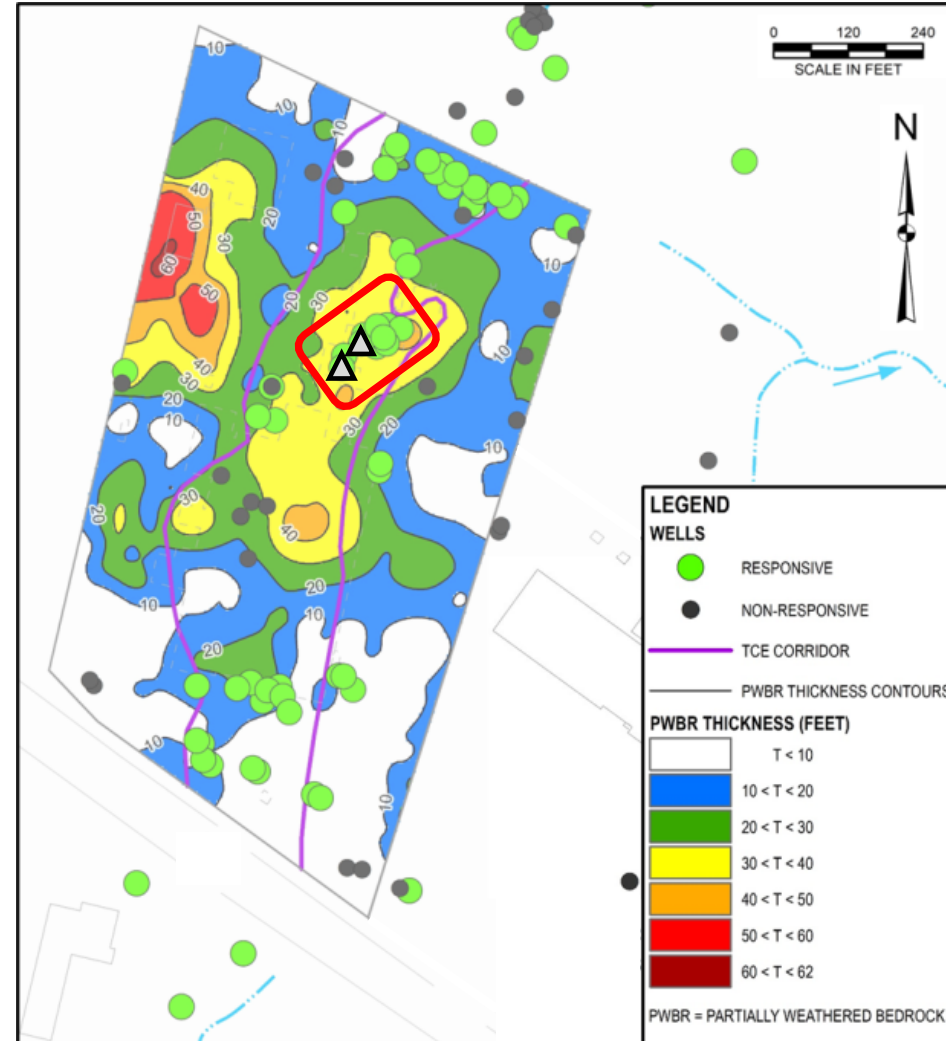
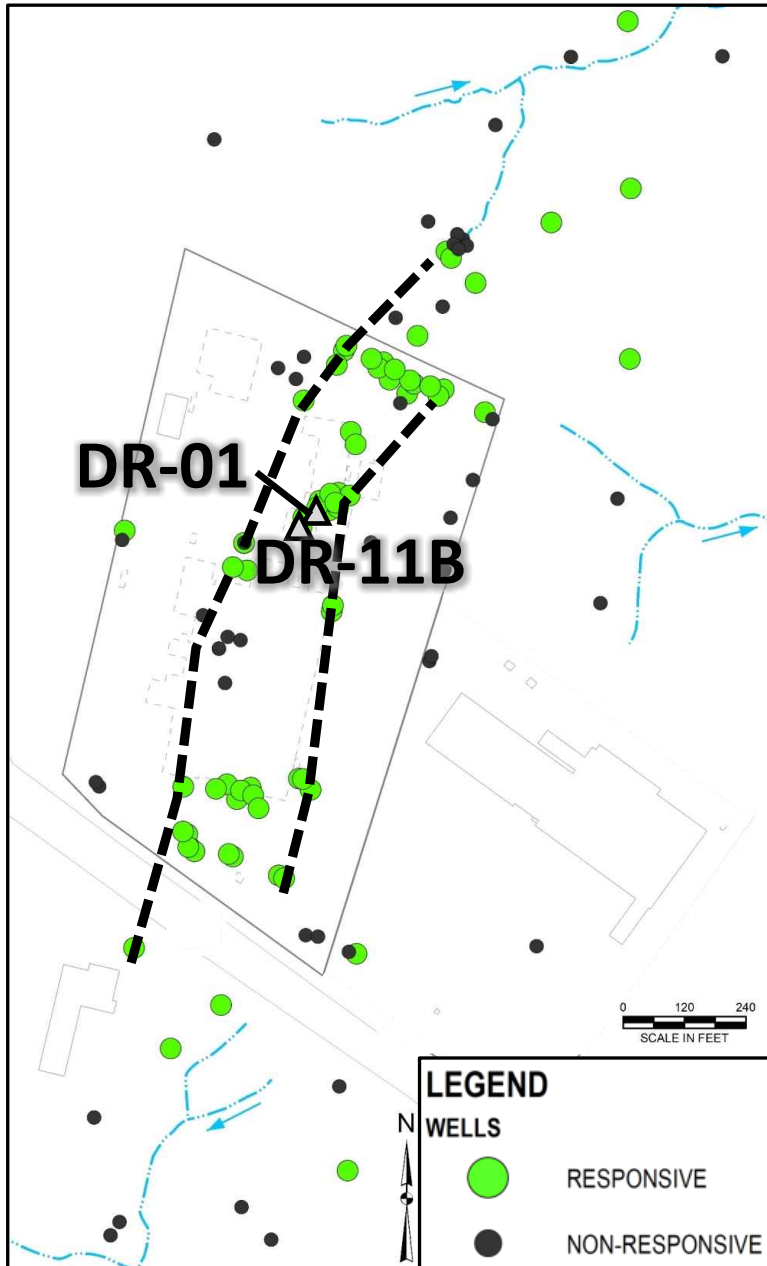


3. Data Analysis: Drawdown/Derivative

Intermediate Wells – Central

Total Depth: 65 - 90 feet bgs

Partially Weathered Unit

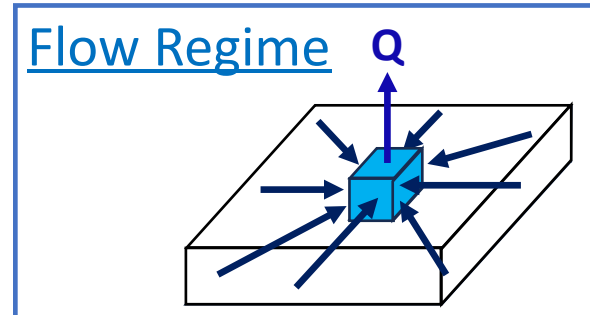
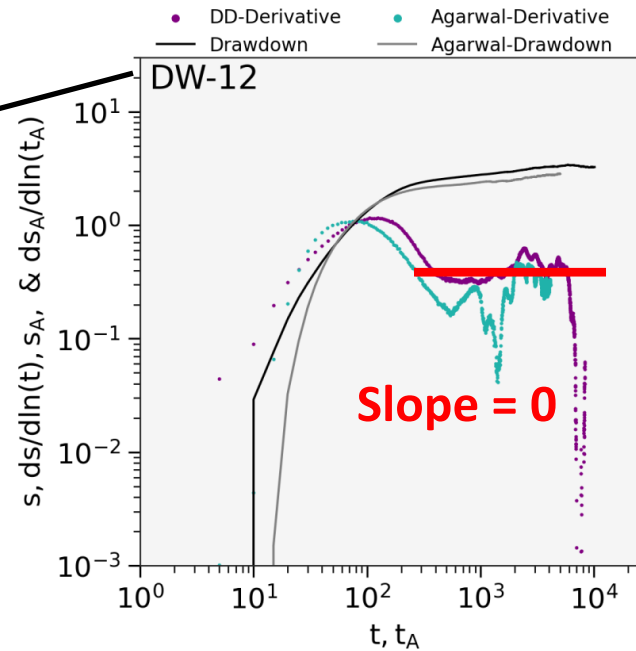
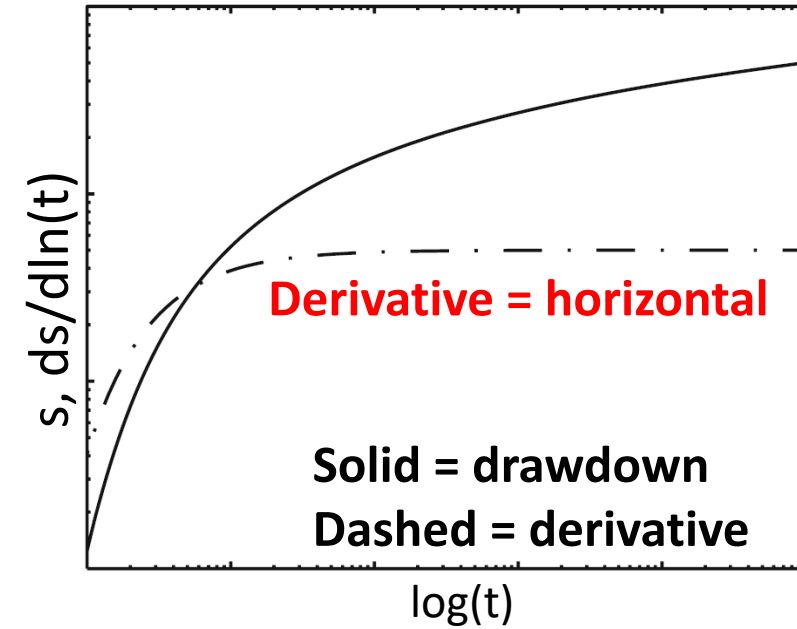


3. Data Analysis: Drawdown/Derivative

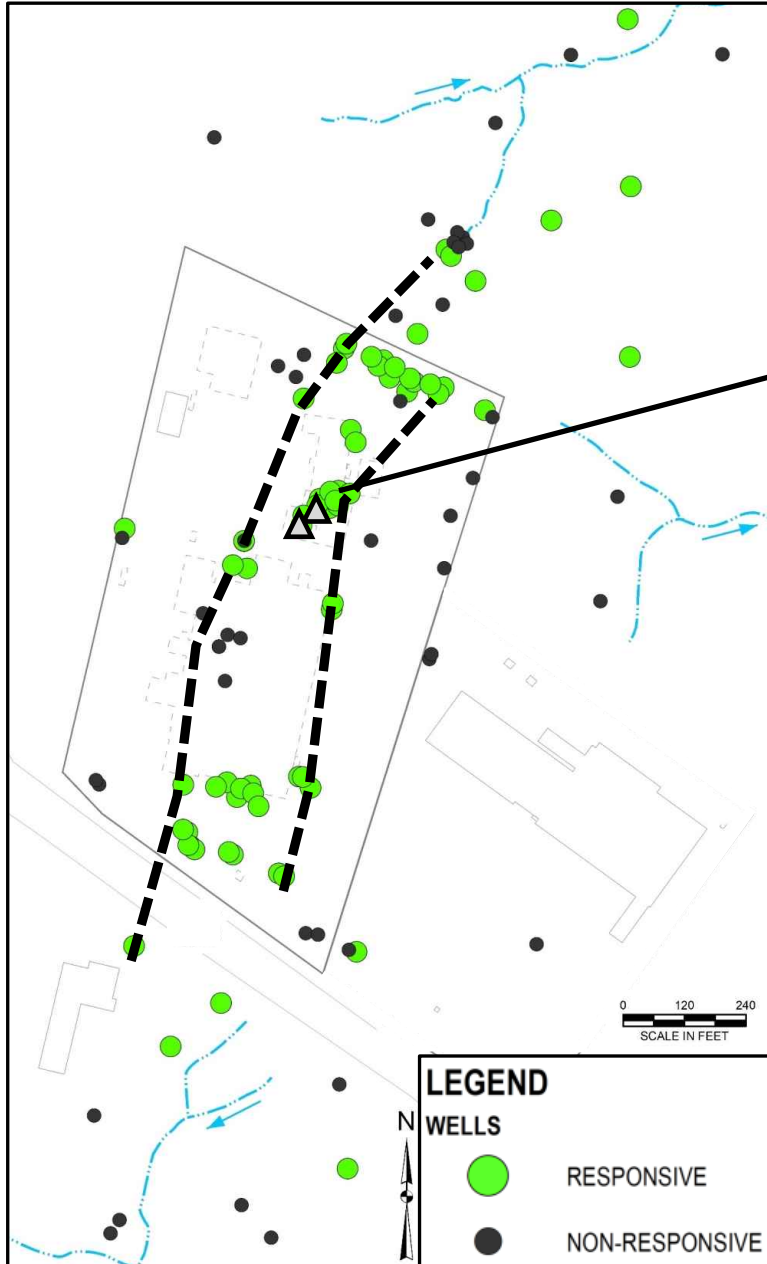
Intermediate Wells – Central

Total Depth: 65 - 90 feet bgs
Partially Weathered Unit

RADIAL FLOW



(Renard et al., 2009)



3. Data Analysis: Drawdown/Derivative

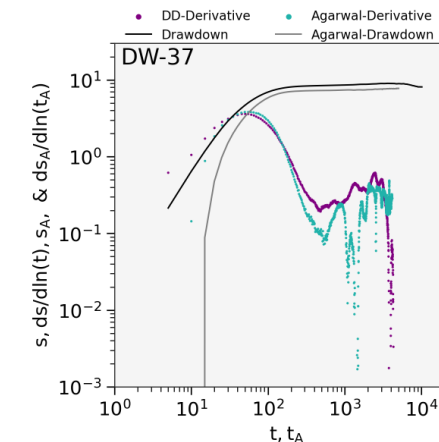
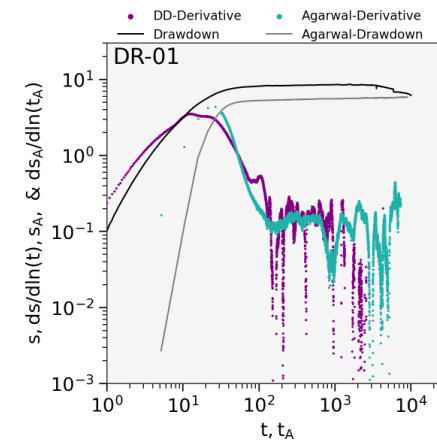
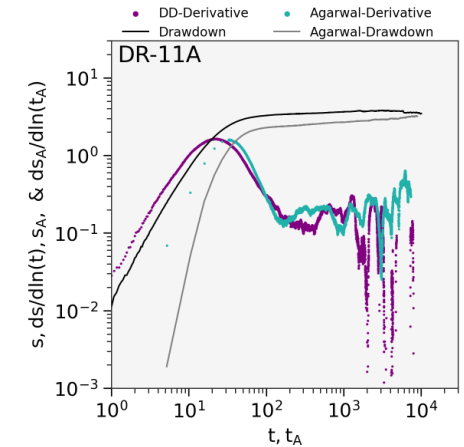
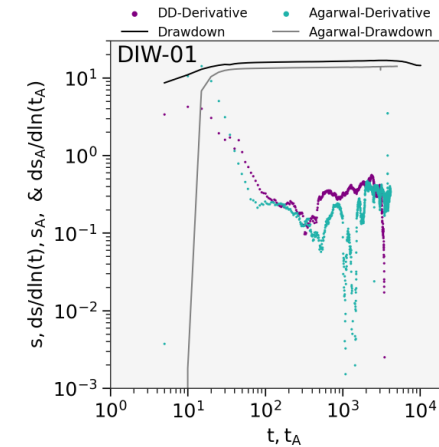
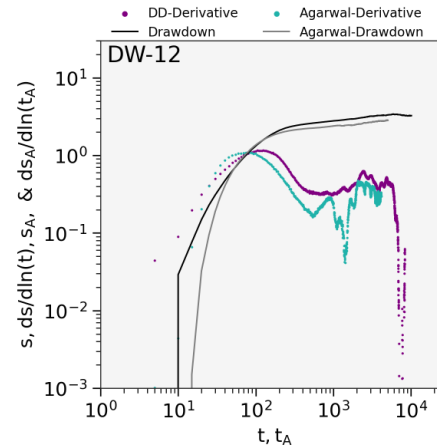
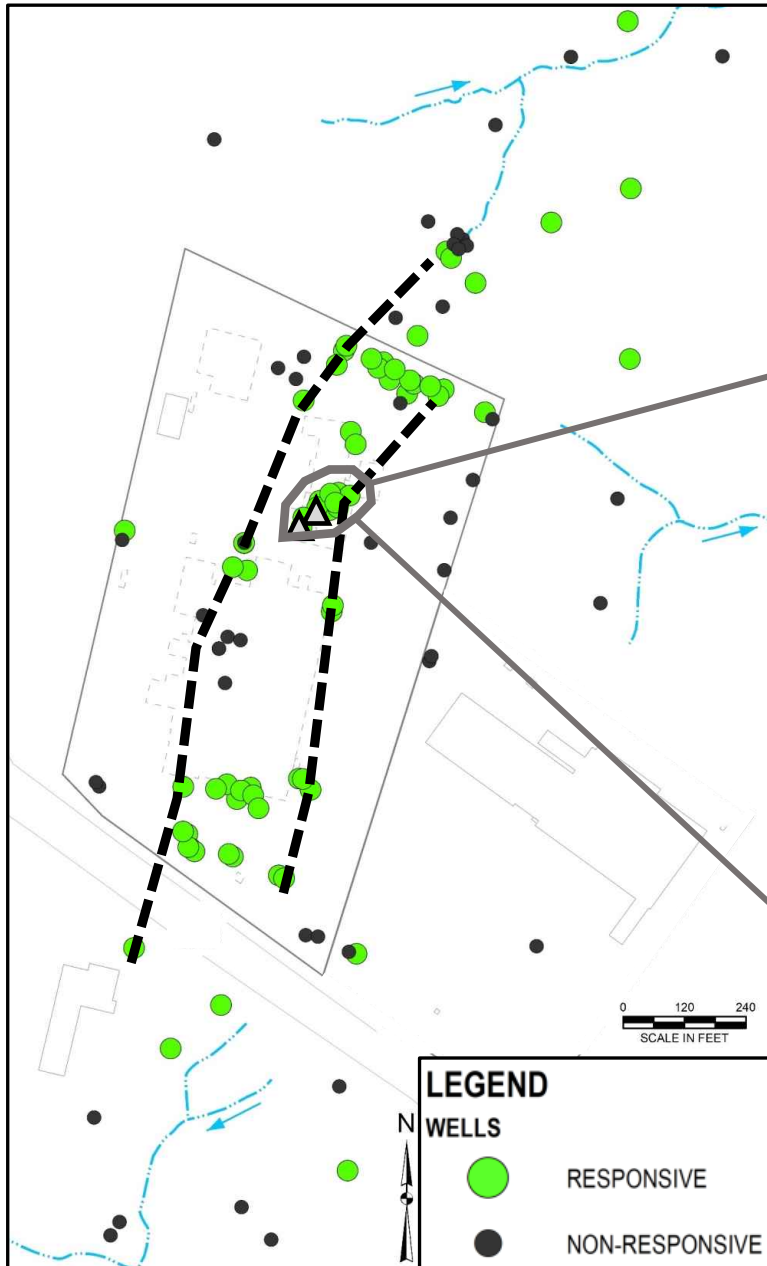
Intermediate Wells – Central

Total Depth: 65 - 90 feet bgs

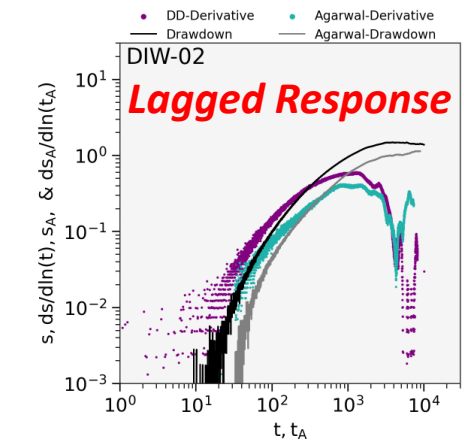
Partially Weathered Unit

RADIAL FLOW

Derivative = Horizontal

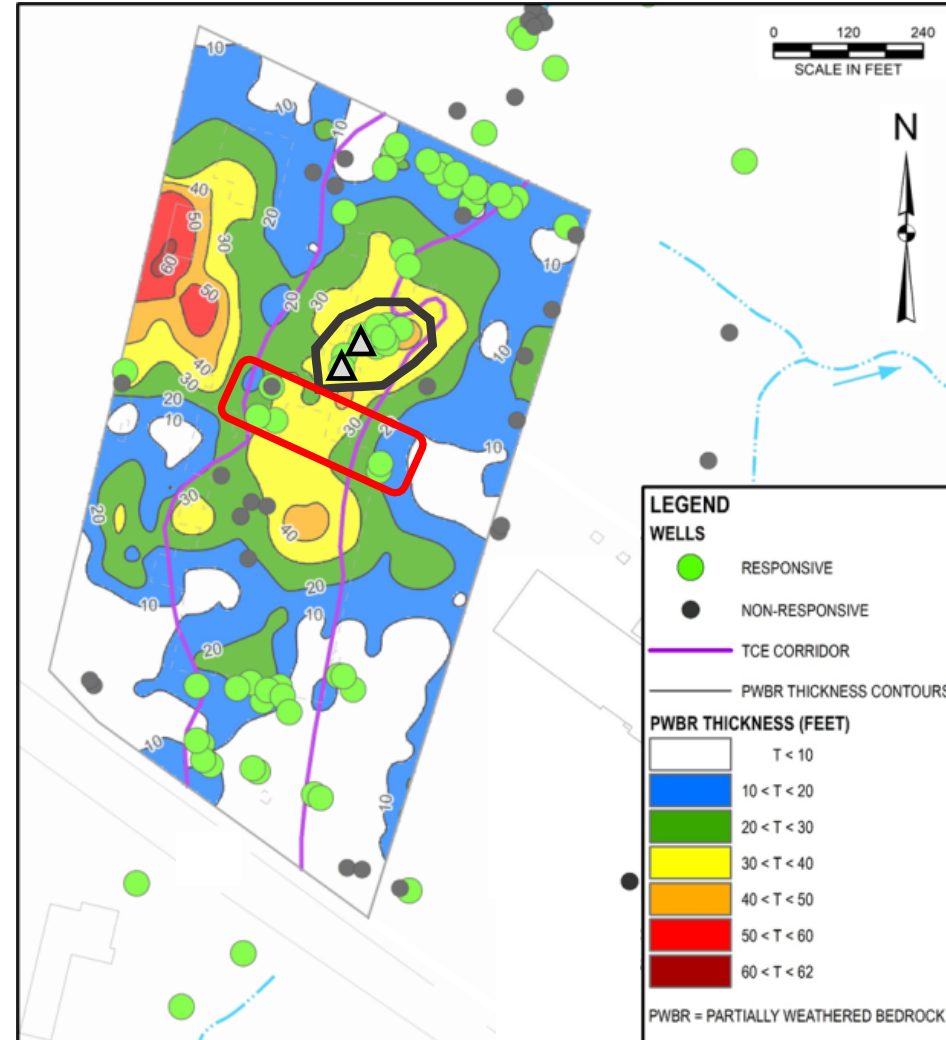
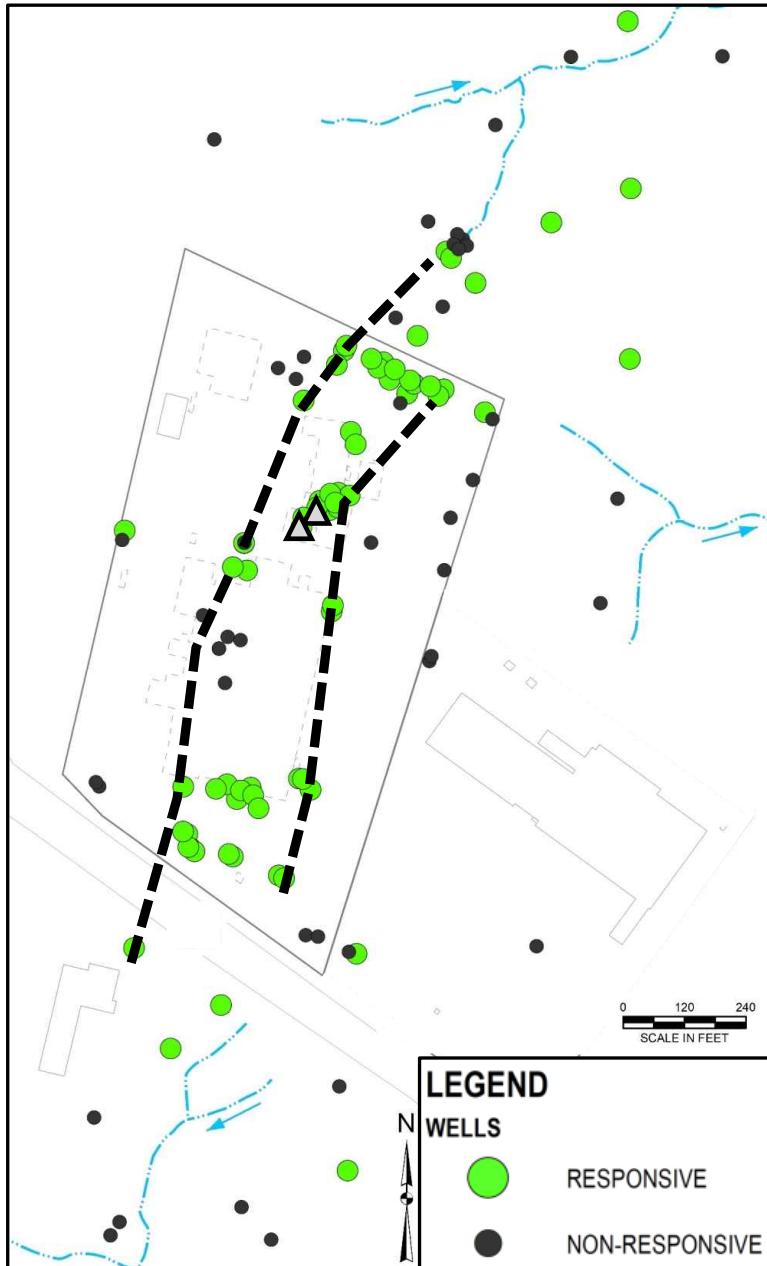


Screen: 90 – 120' bgs

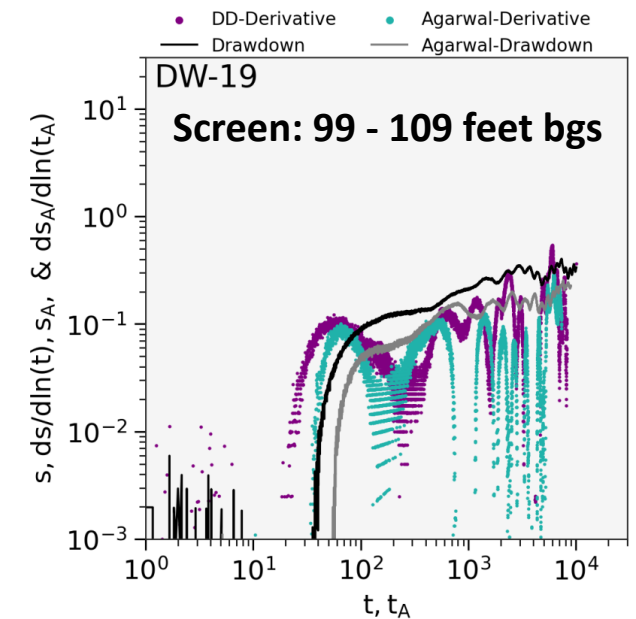
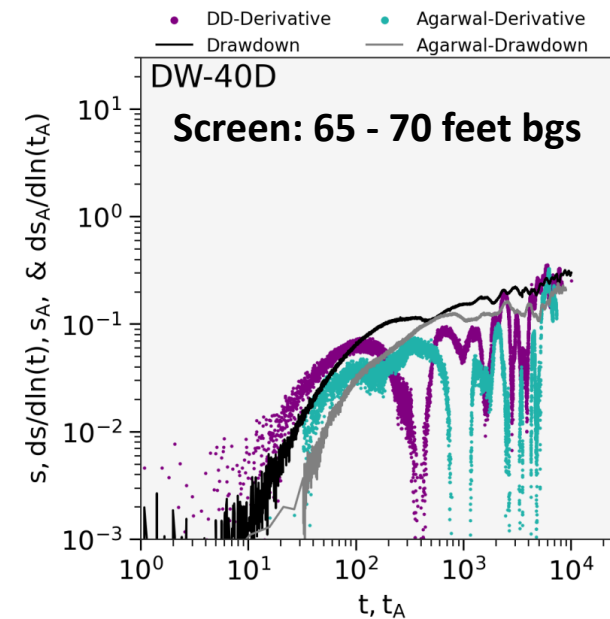
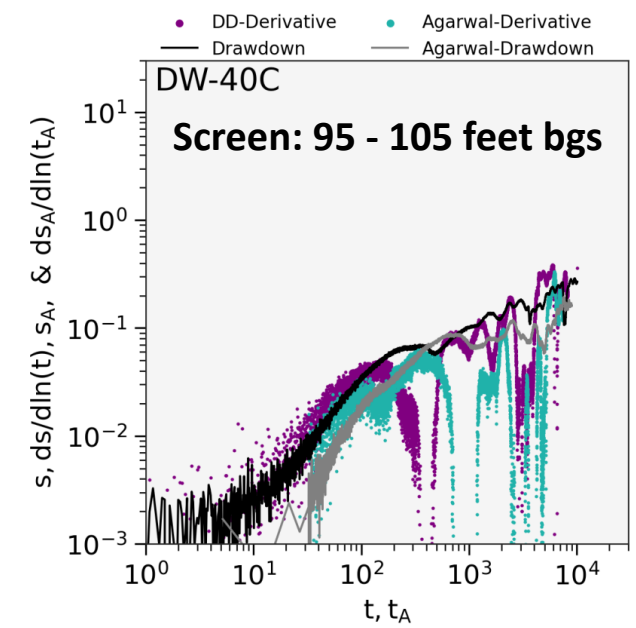
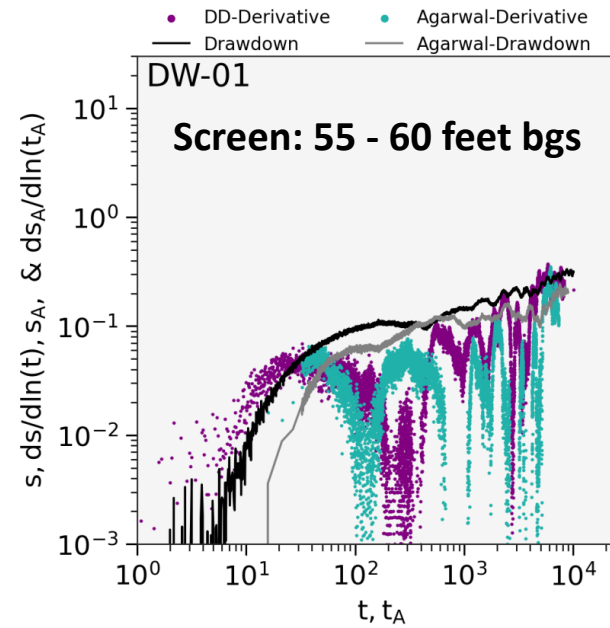
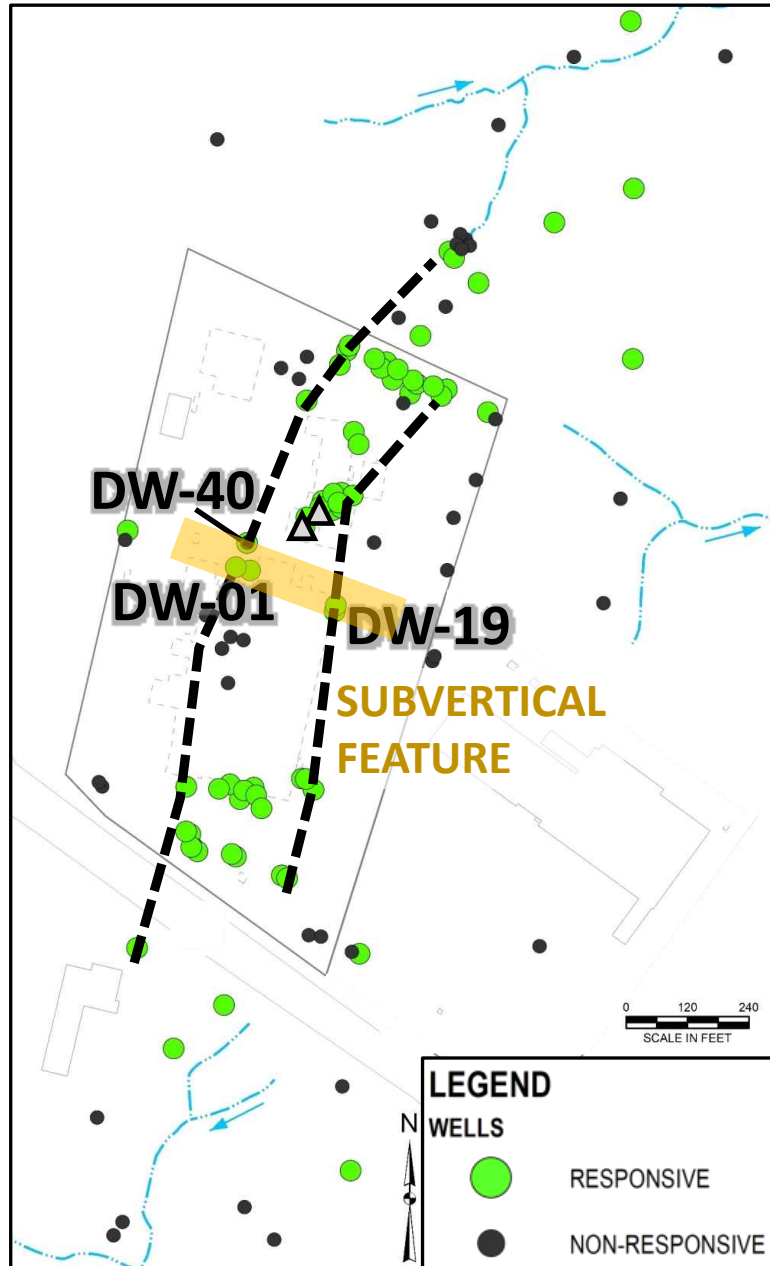


3. Data Analysis: Drawdown/Derivative

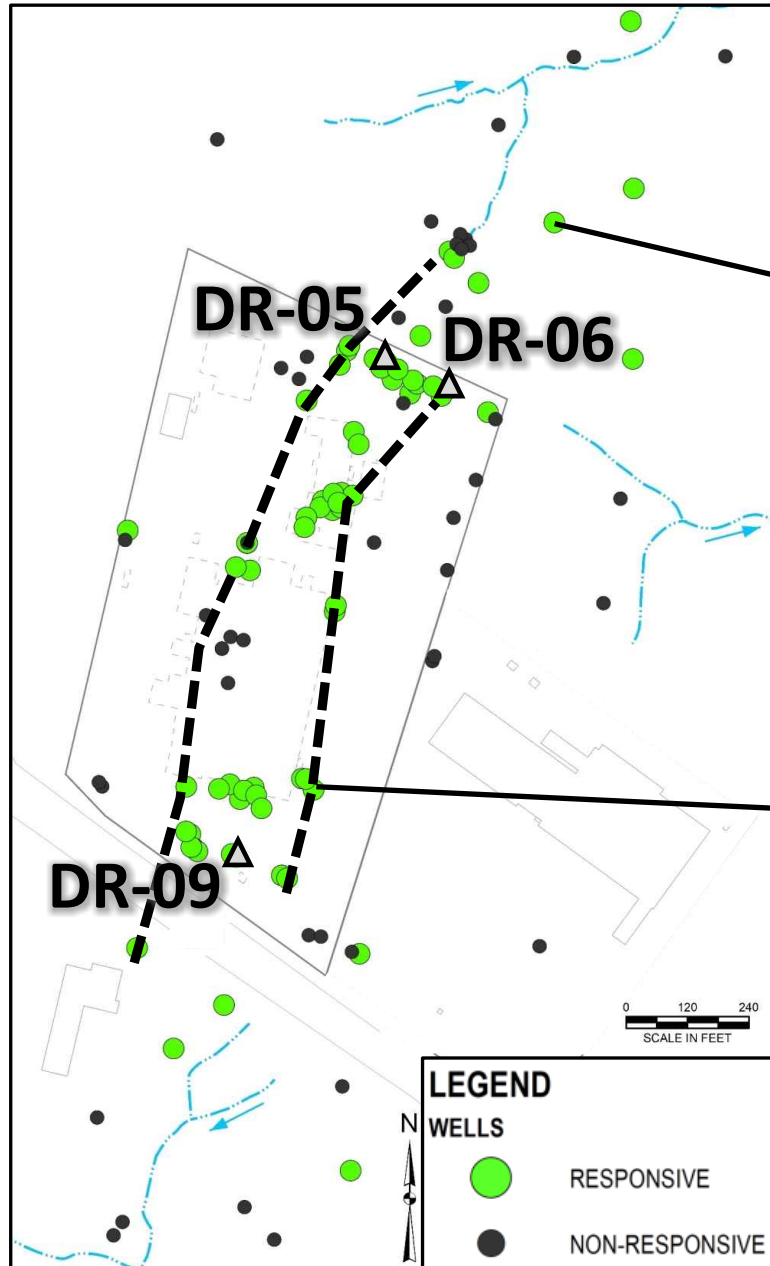
Intermediate Wells – Central Total Depth: 60 - 110 feet bgs Partially Weathered Unit



3. Data Analysis: Drawdown/Derivative

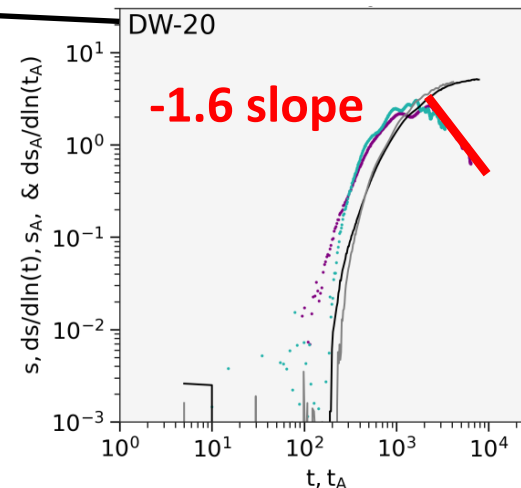
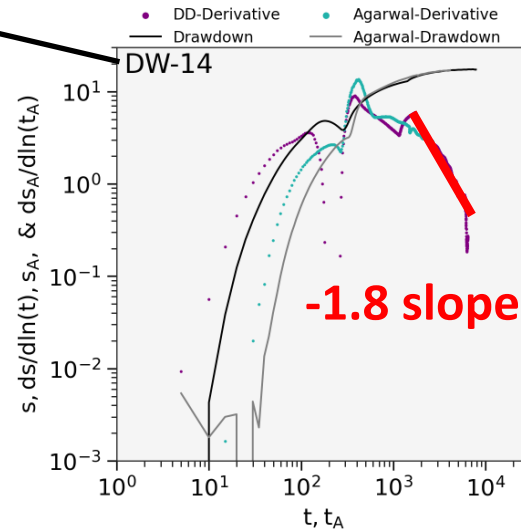


3. Data Analysis: Drawdown/Derivative

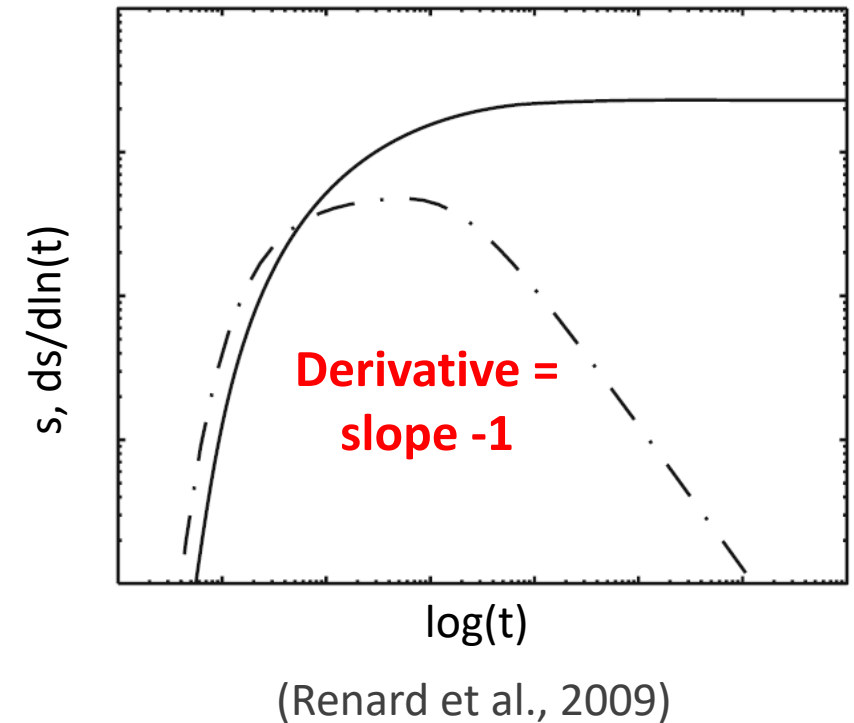


Deep Wells – Site-Wide

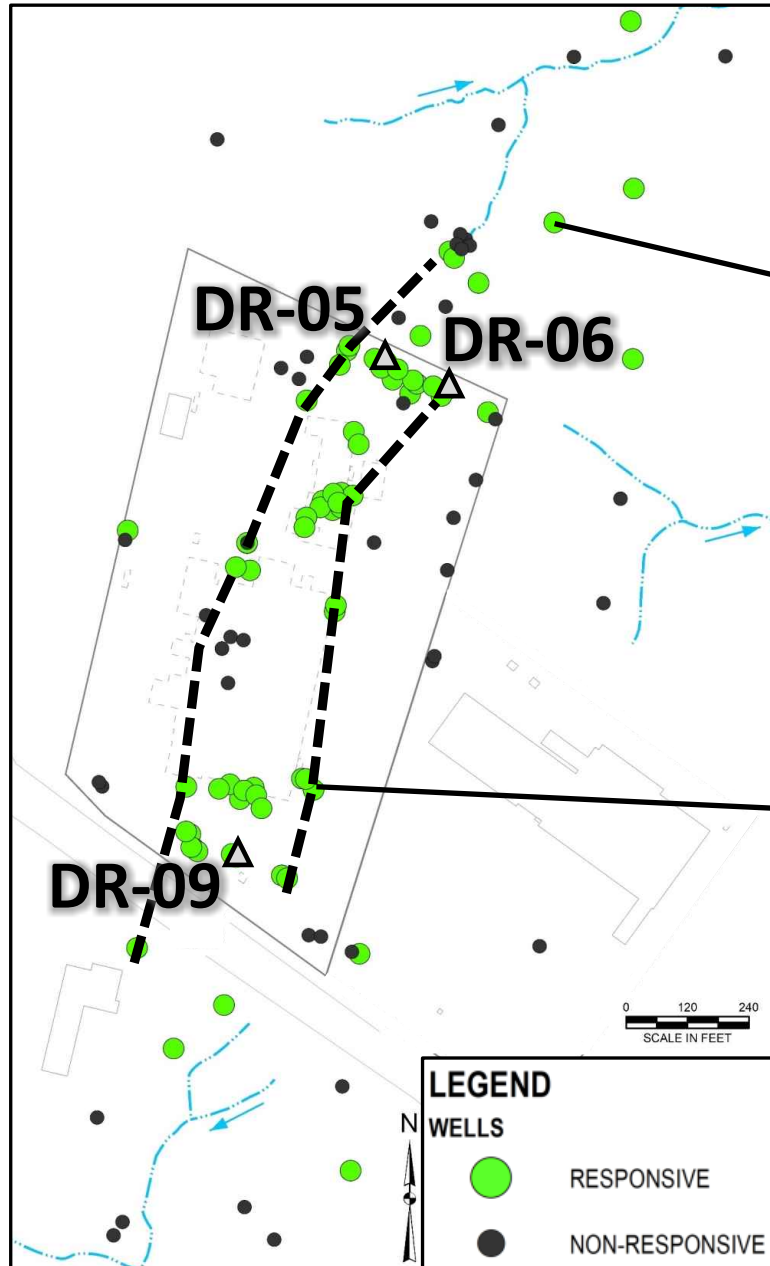
Total Depth: 140 - 205 feet bgs
Competent Bedrock



Constant Head Boundary

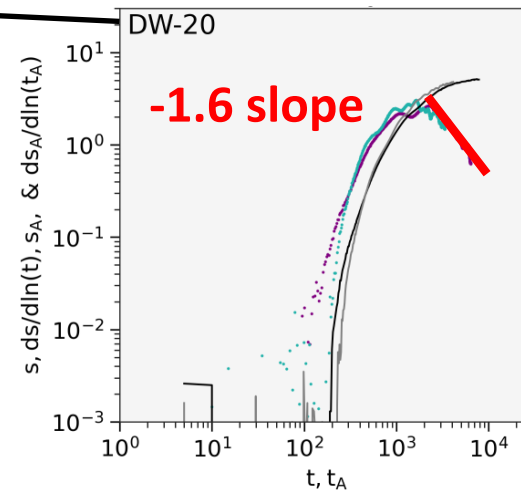
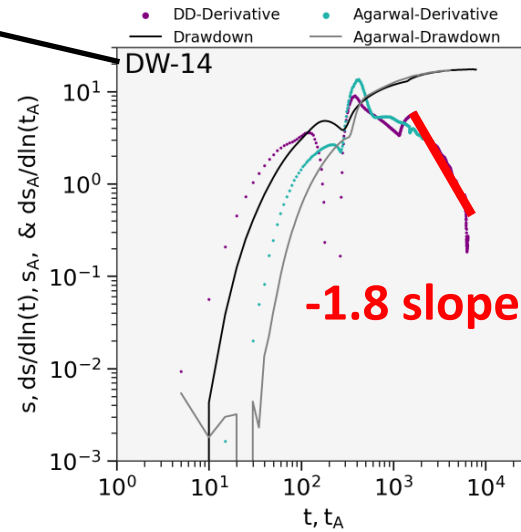


3. Data Analysis: Drawdown/Derivative

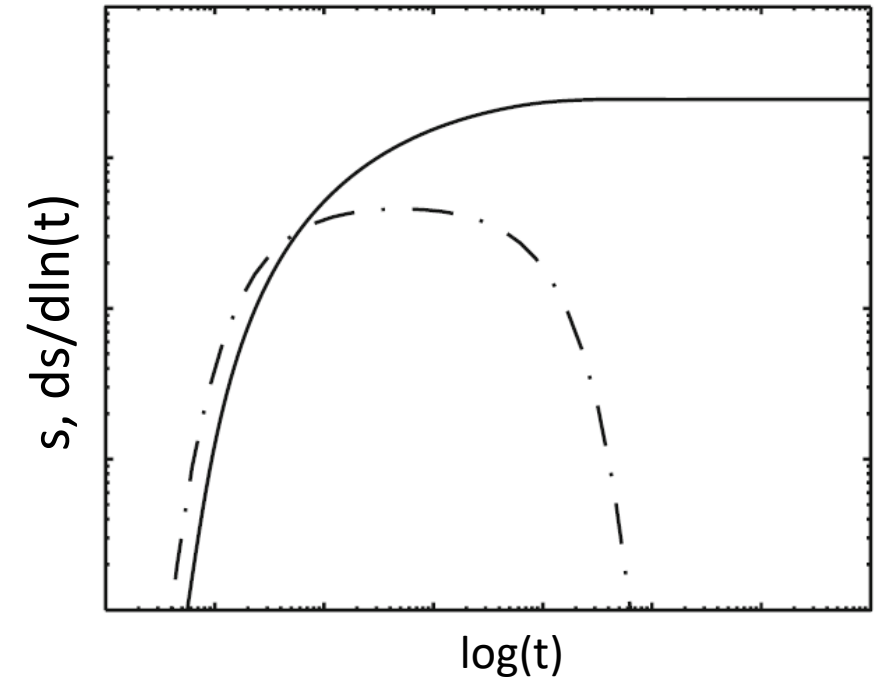


Deep Wells – Site-Wide

Total Depth: 140 - 205 feet bgs
Competent Bedrock



Leakage/Leaky Aquifer



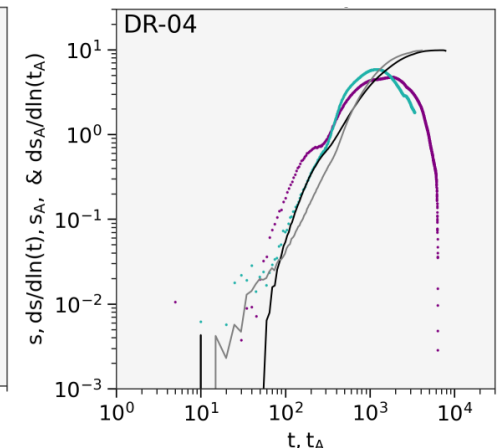
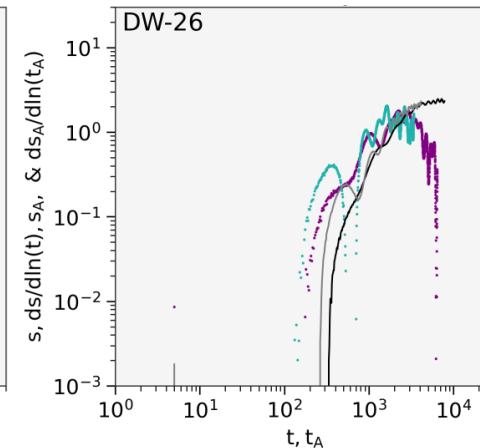
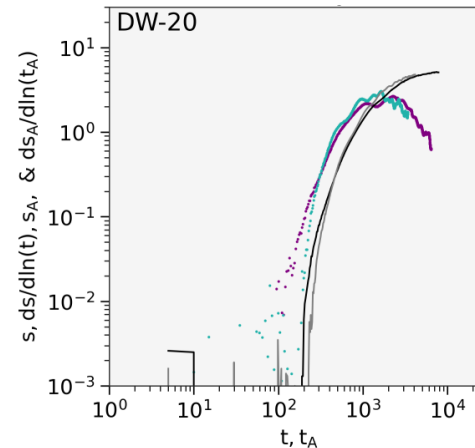
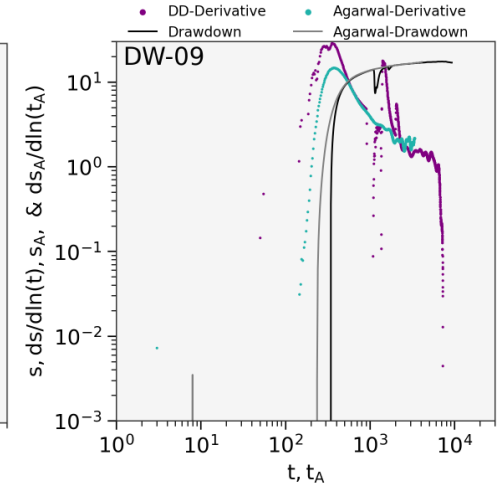
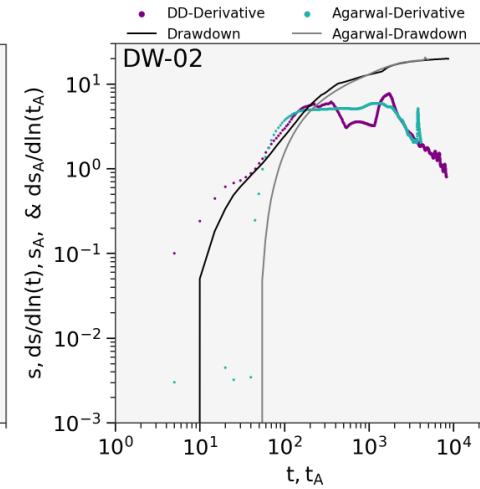
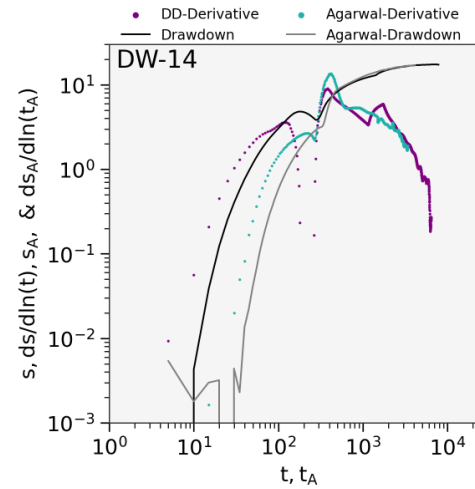
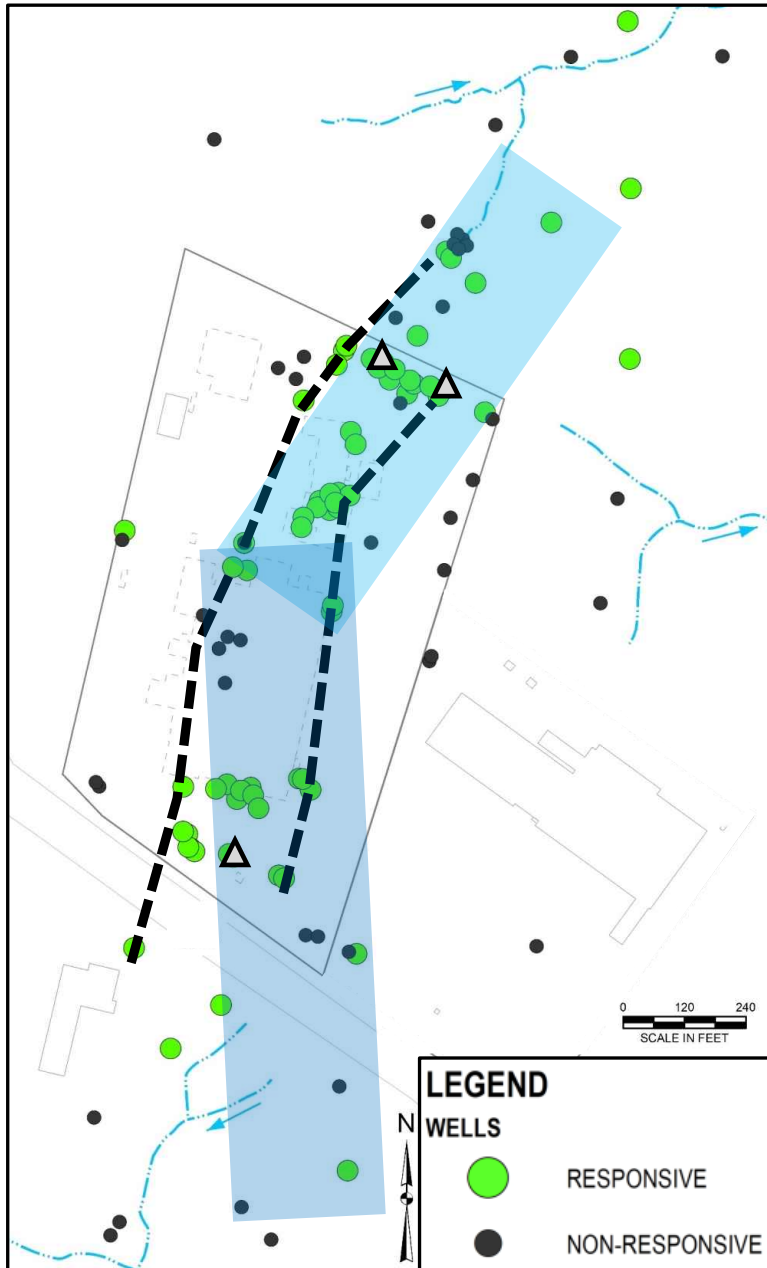
(Renard et al., 2009)

3. Data Analysis: Drawdown/Derivative

Deep Wells – Site-Wide

Total Depth: 140 - 205 feet bgs
Competent Bedrock

Leakage/Leaky Aquifer
Steep Negative Derivative



4. Key Findings/Implications

Key Findings

1. Pronounced responses to pumping are aligned in elongated N-S corridor.
2. Derivative patterns provide supporting evidence to distinguish responses to pumping for separate (vertical) zones.
3. Communication is observed between the regolith and bedrock (leakage observed in deeper bedrock under pumping conditions).

Implications

1. Deep pumping exacerbates downward gradients, coupled with leakage. Potential to increase vertical downwards transport of residual shallow impacts.
2. Optimization of pumping system.
3. Utilization of applicable well hydraulic solutions.
4. Identification of separate Geo-Hydraulic Units (GHUs).

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