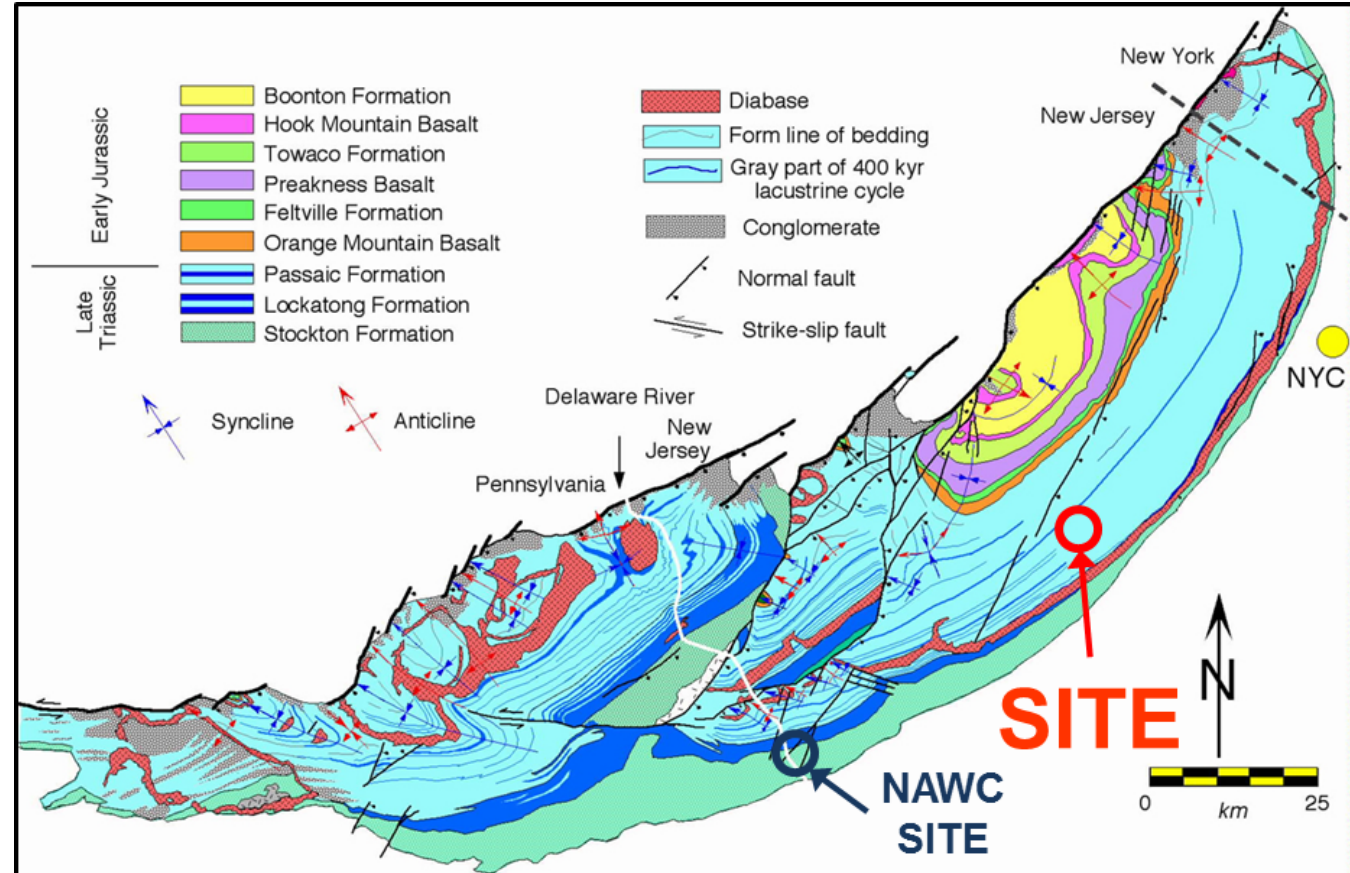
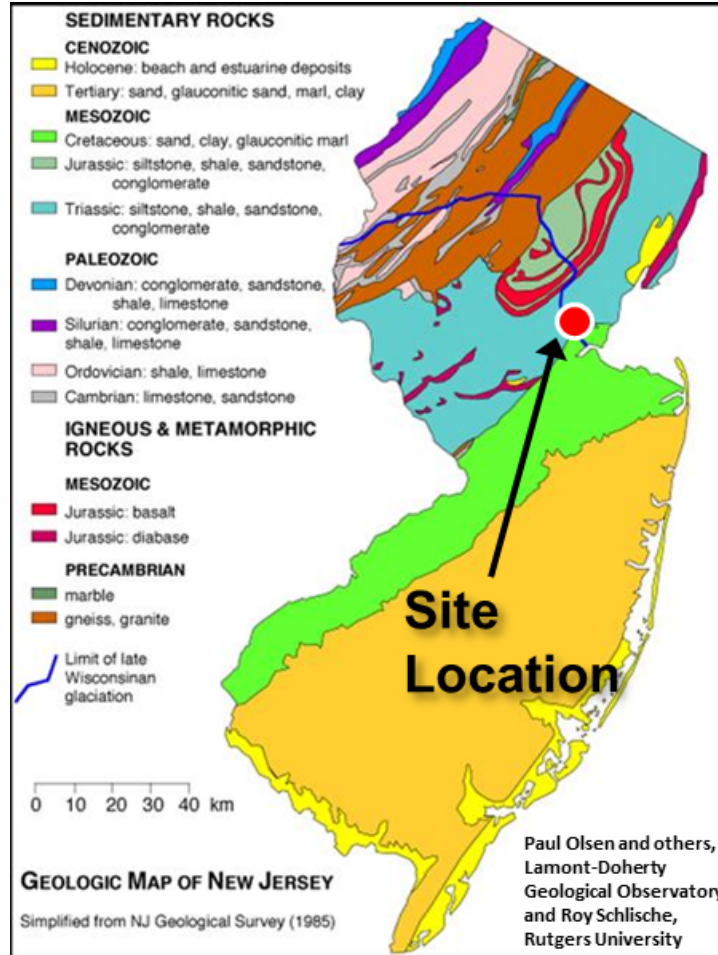


Revisiting the Role of Steeply-Dipping Extension Fractures in the Newark Basin to Improve CSMs for Remedial Design

*Kevin Kelly, P.G., Bob Bond, P.G., and Matthew Morris, P.G.
(LANGAN, Doylestown, Pennsylvania, USA)*

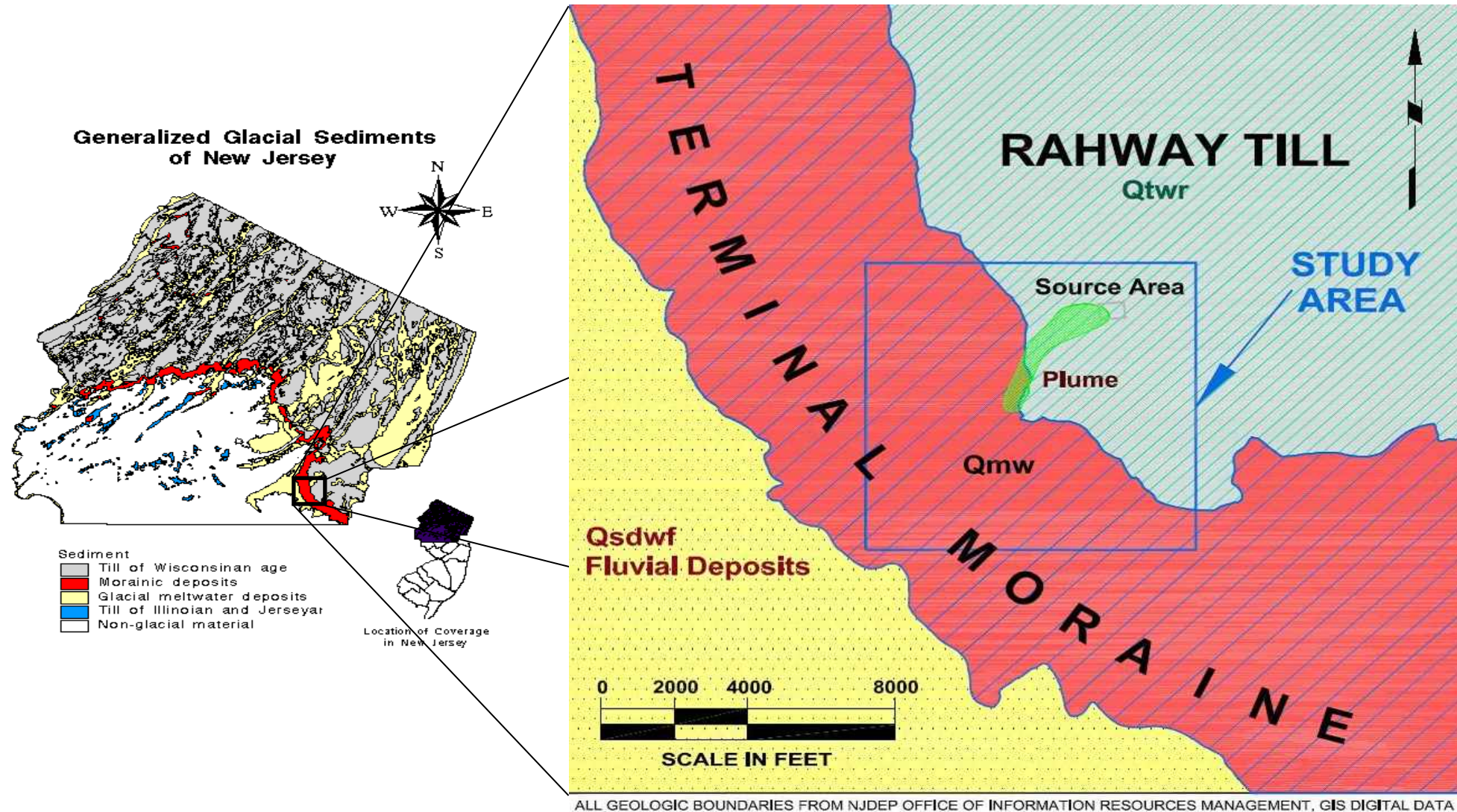
Geologic Setting – Newark Basin

Triassic Passaic Formation (Brunswick)



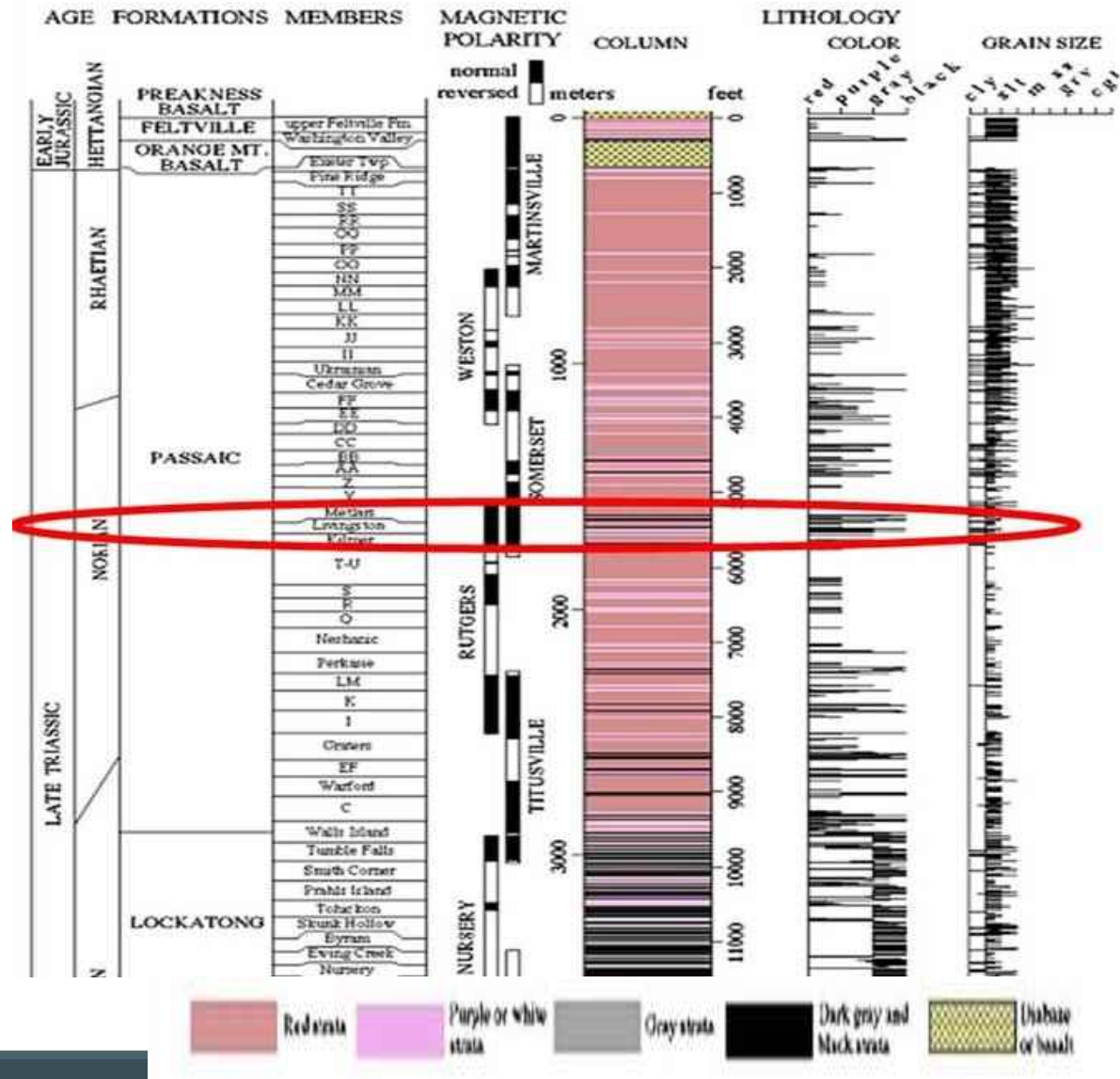
Paul Olsen and others, Lamont-Doherty Geological Observatory and Roy Schlische, Rutgers University

Study Area Buried Under Glacial Deposits



Late Triassic Passaic Formation Members

- Metlars
- Livingston
- Kilmer



Modified from Well Logging Results from the Newark Rift Basin Coring Project - D.S. Goldberg(1), D.J. Reynolds(1,3), C.F. Williams(2), W.K. Witte(1,4), P.E. Olsen(1) and D.V. Kent(1)

Bedrock Geology

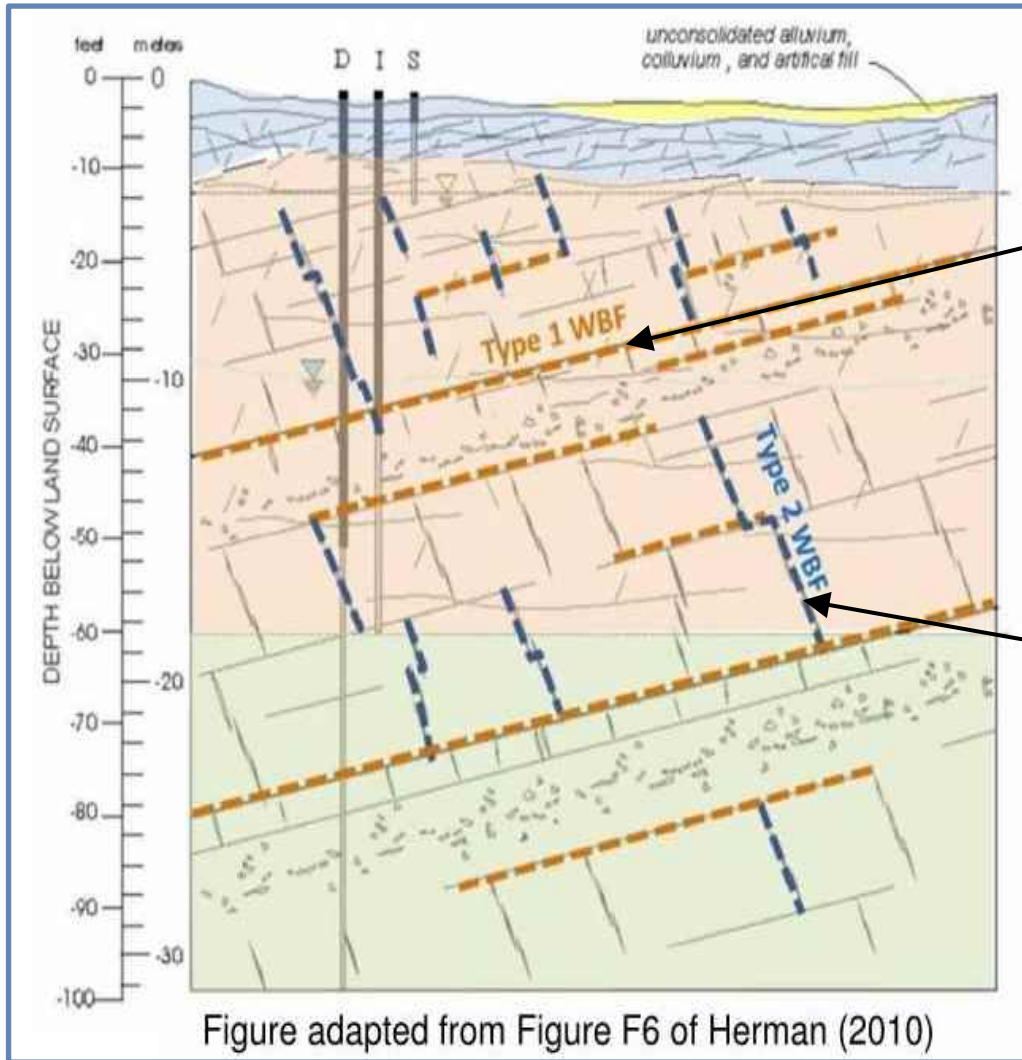
- Late Triassic Passaic Formation
- Fractured Interbedded Shales, Siltstones and Mudstones (very minor Sandstones)
- Homoclinal Structure
Average Strike N45°E
- Dip 7° - 16° NW in study area



Major Planar Features



Dipping Water-Bearing Fractures (WBF)



- **Type 1 WBF**

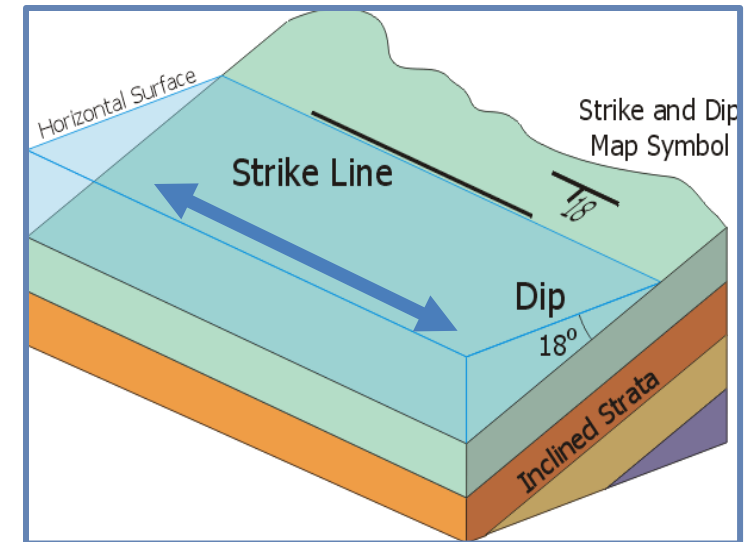
- Bedding Plane Partings
- Primary Pathway
- **Multi-Aquifer**

- **Type 2 WBF**

- Steeply-Dipping Fractures
- **Leaky**

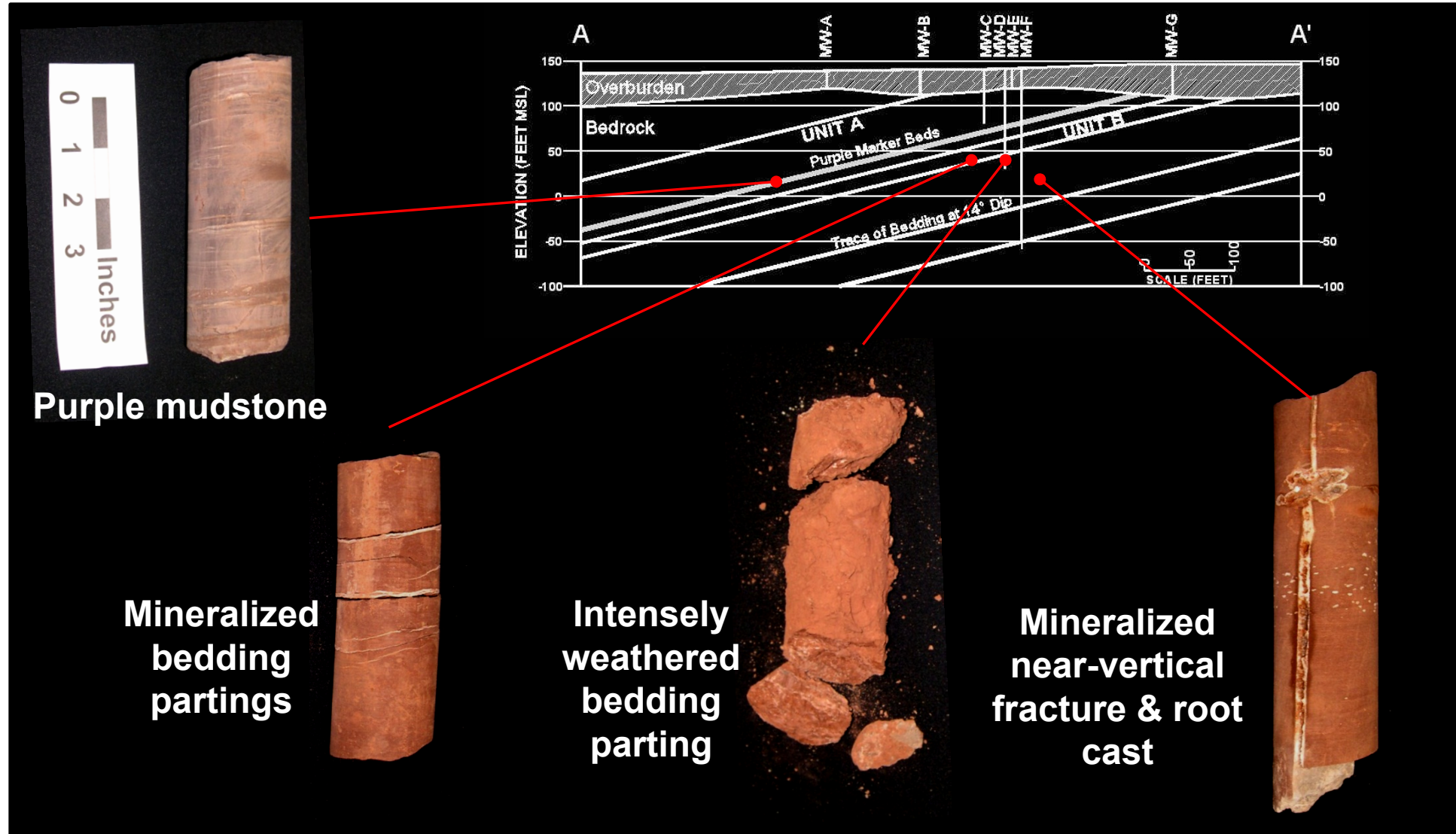
LMAS Model

Leaky Multi-Aquifer System

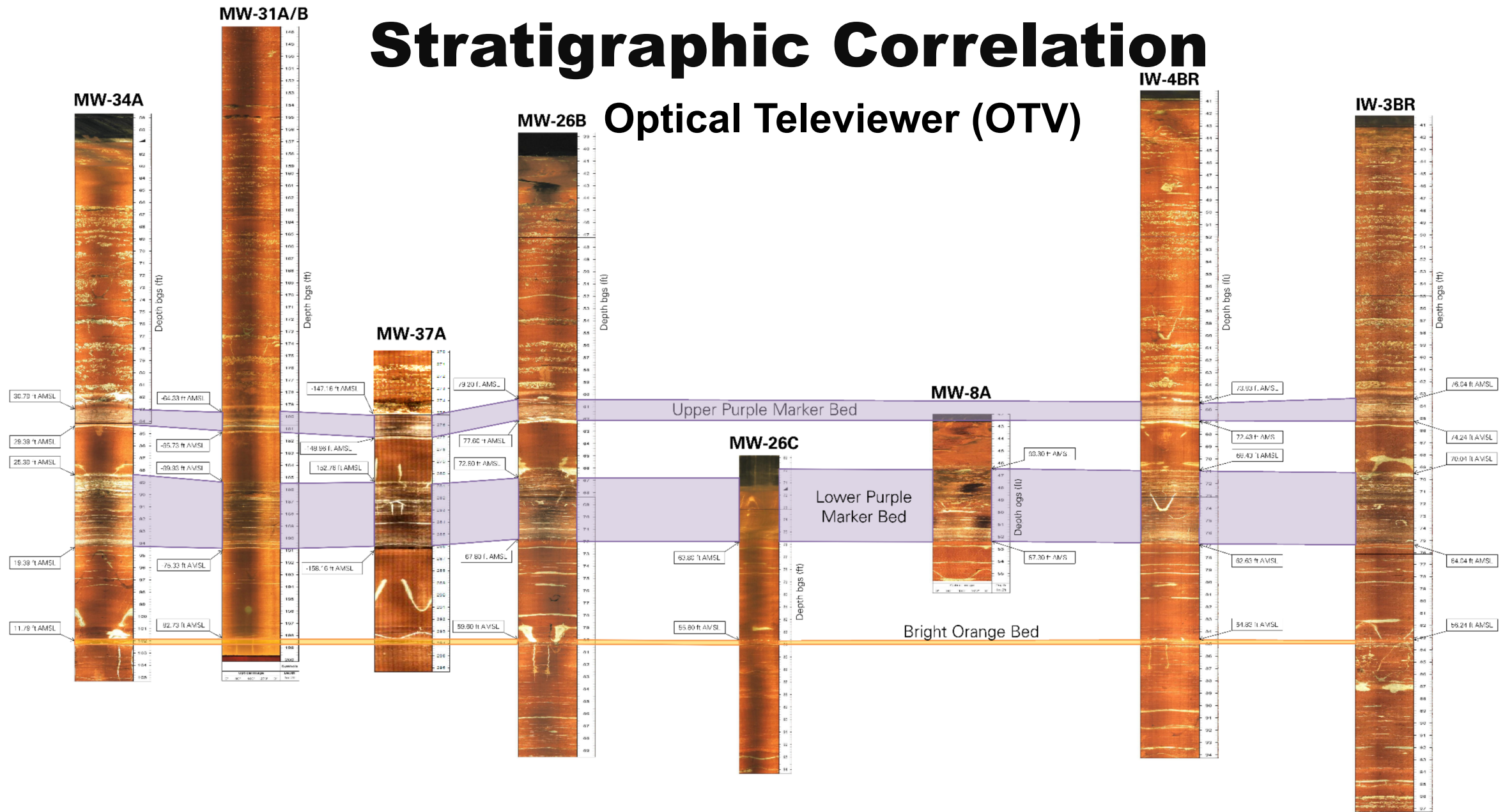


Dipping Type 1 WBFs impart first-order control on groundwater flow
– Flow along strike (generally)

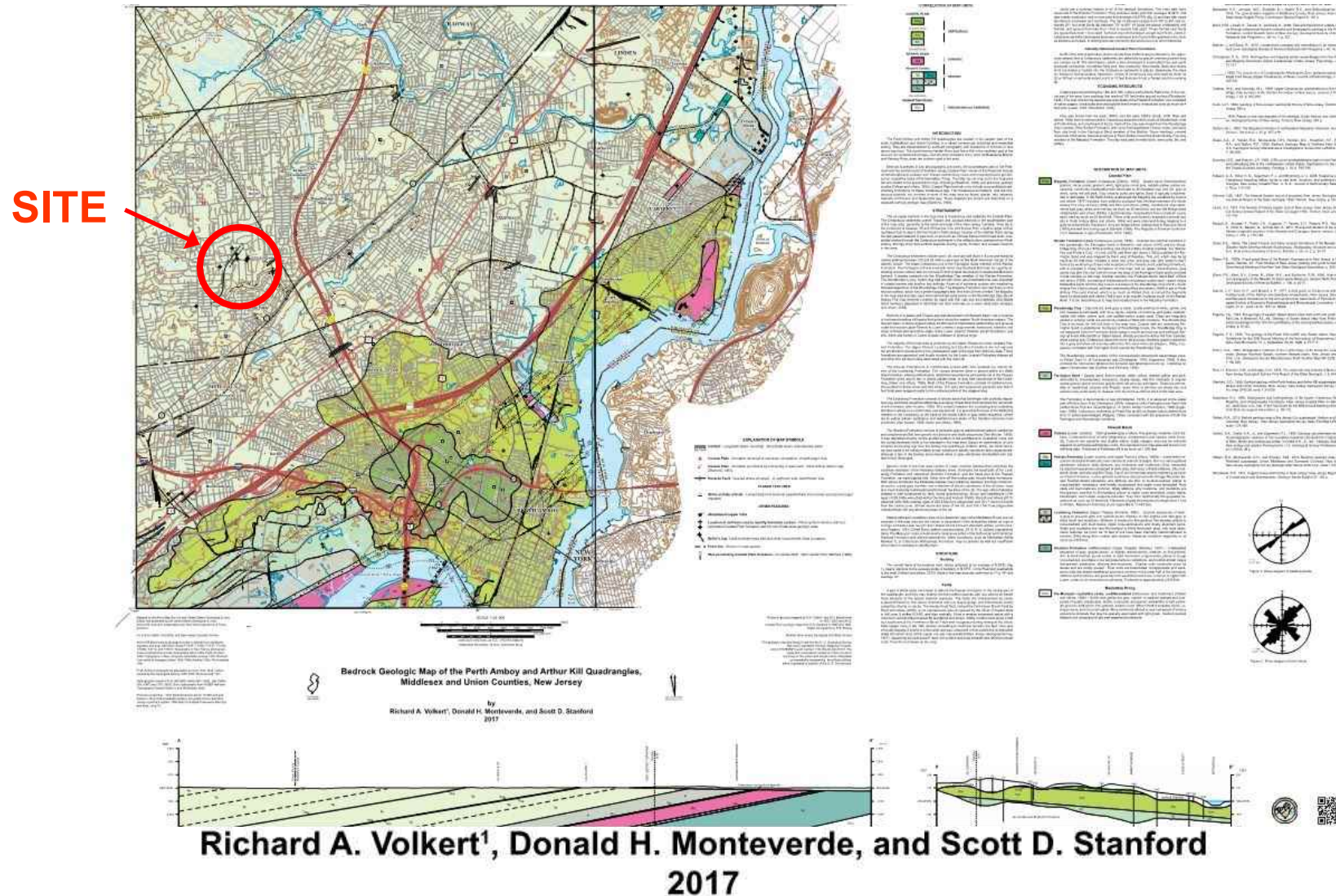
Geologic Setting – Core Samples



Stratigraphic Correlation



BEDROCK GEOLOGIC MAP OF THE PERTH AMBOY AND ARTHUR KILL QUADRANGLES, MIDDLESEX AND UNION COUNTIES, NEW JERSEY OPEN FILE MAP OFM 117



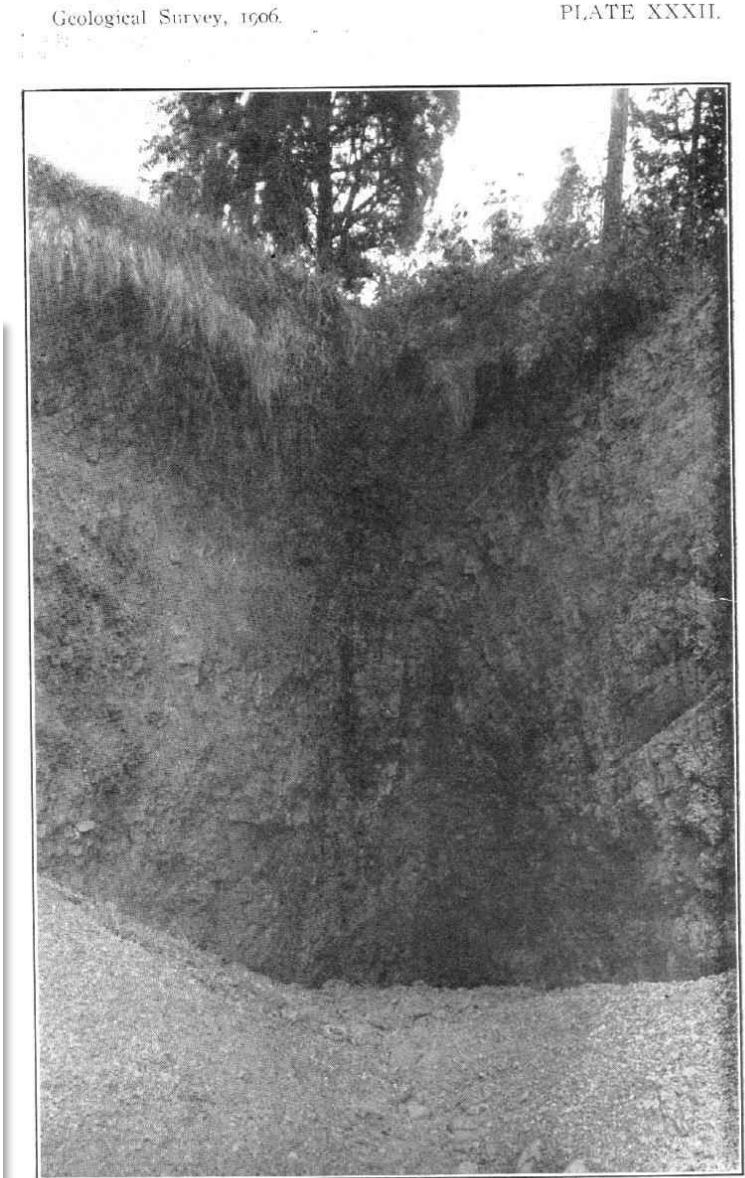
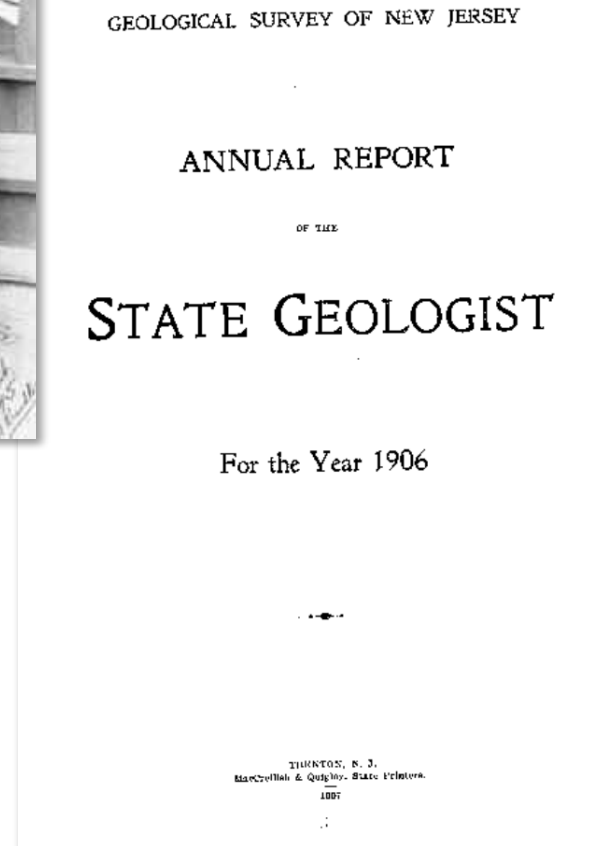
**BEDROCK GEOLOGIC MAP OF THE PERTH AMBOY AND ARTHUR KILL
QUADRANGLES, MIDDLESEX AND UNION COUNTIES, NEW JERSEY
OPEN FILE MAP OFM 117**



“The shales of the vicinity have the usual bright-red to brownish-red color and dip 12 degrees toward the north. At the mine they are traversed by a vertical north-south fissure (Pl. XXXII), along which the movement has been parallel to the bedding, a nearly horizontal shove, or heave. This is indicated by both the slickensided walls and breccia of the fault and the abrupt termination of the fissure beneath undisturbed conformable shales above.

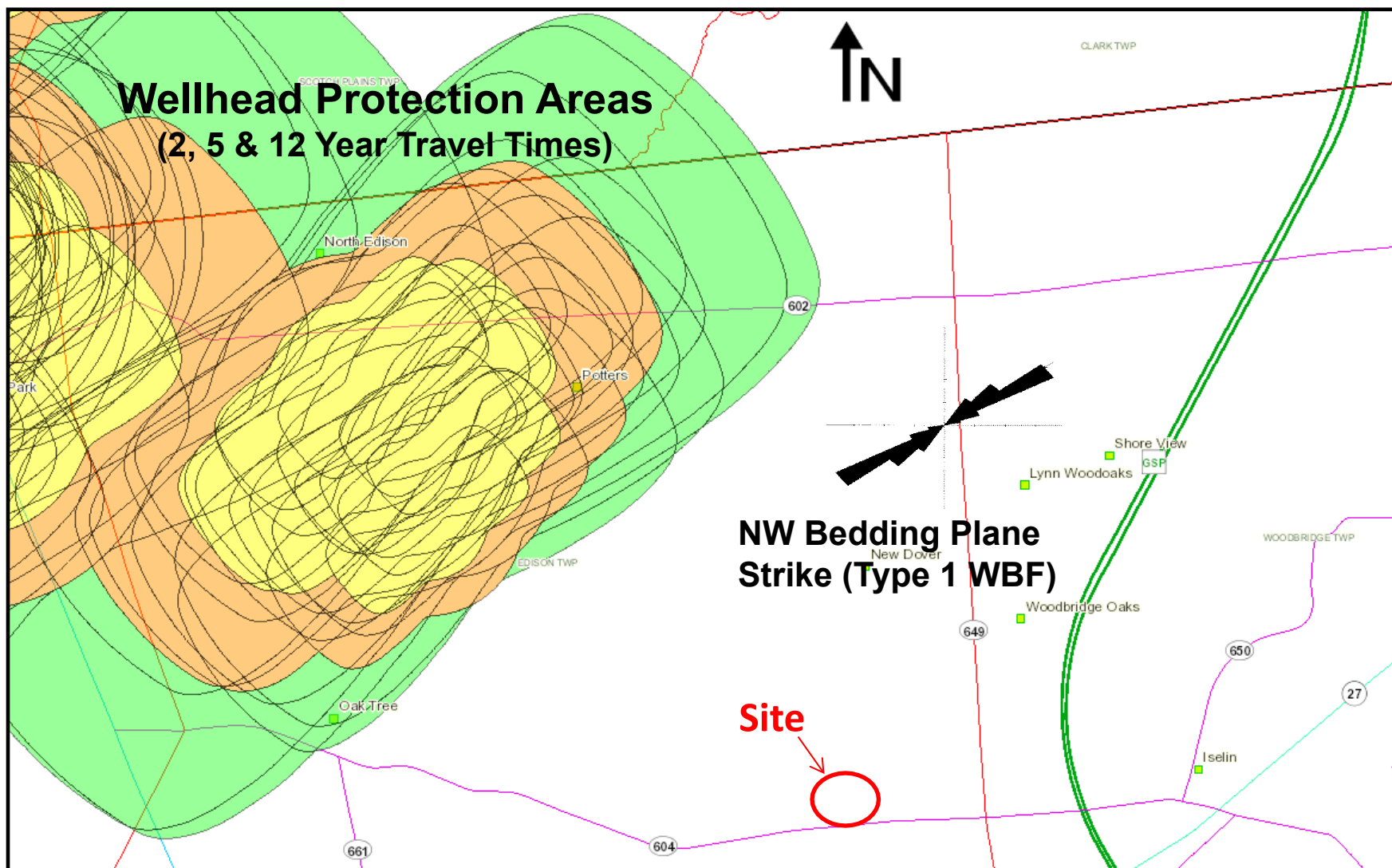


Coppermine Fault



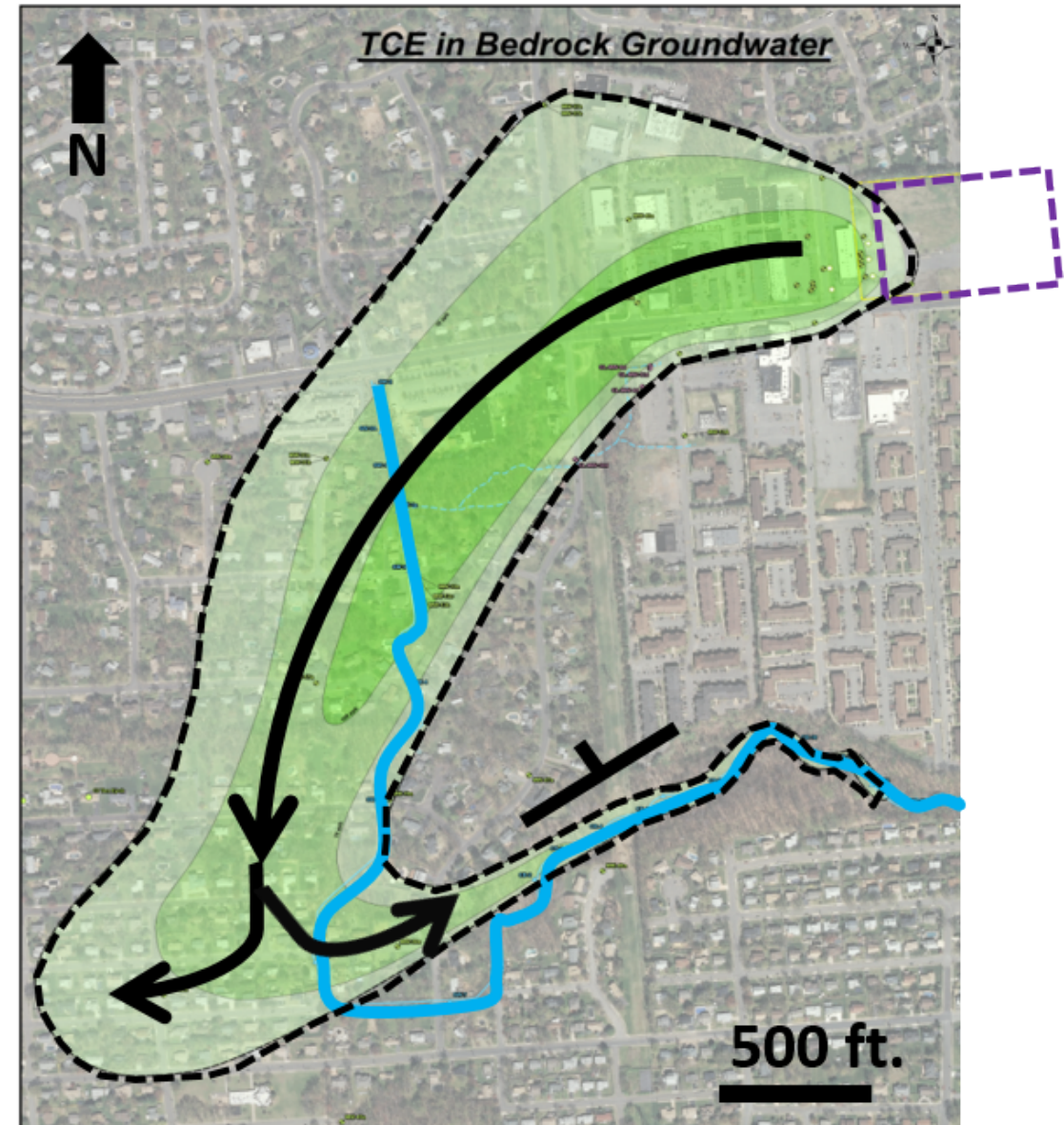
Heave fault. Old copper mine, near Menlo Park.

Anisotropic Response to Pumping



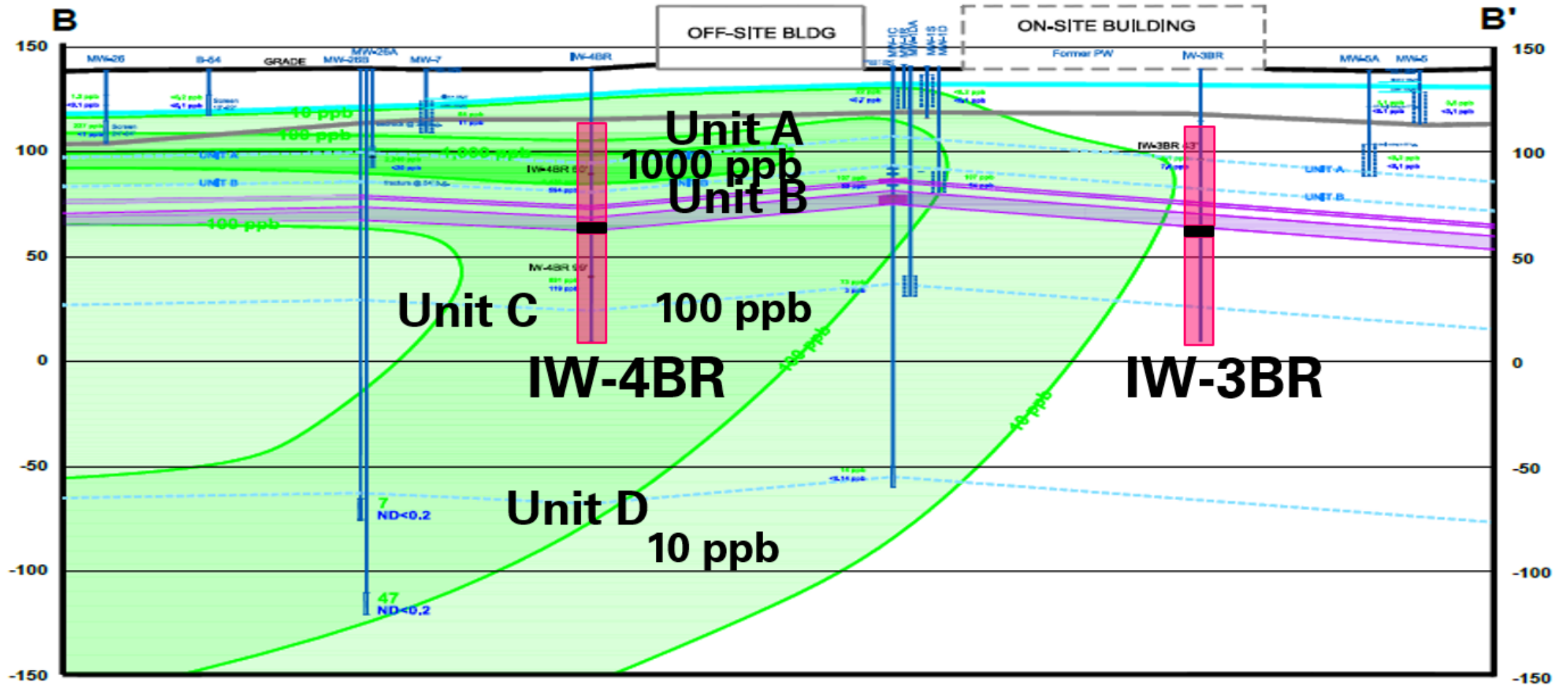
Bedrock VOC Plume

- ISRA-SRP Site
- 132 acres
- TCE and CTC drivers
- Strike NE-SW Dip 7-16° NW
- Bifurcates and disperses or discharges to creek



This aerial map illustrates the Borden Superfund Site, highlighting the groundwater plume and various monitoring wells. The plume is delineated by concentric contour lines representing concentrations of 10 ppb, 100 ppb, 1,000 ppb, and 10,000 ppb. Two primary remediation units are identified: UNIT A SUBCROP, shown in yellow, and UNIT B SUBCROP, shown in purple. A dashed line separates these two units. A red line, labeled B-B', indicates a cross-section through the site. Two specific wells are highlighted with red circles: IW-4BR and JW-3BR. Numerous other monitoring wells are marked with yellow circles and labeled, including MW-50a, MW-4a, MW-5a, MW-1a, MW-1c, MW-2b, MW-7a, MW-6c, MW-26a, MW-26b-1, MW-26b-2, MW-8a, MW-3a, MW-4b, MW-1b, MW-1d, MW-5b, MW-6a, MW-6b, MW-10a, MW-10b, MW-10c, MW-10d, MW-10e, MW-10f, MW-10g, MW-10h, MW-10i, MW-10j, MW-10k, MW-10l, MW-10m, MW-10n, MW-10o, MW-10p, MW-10q, MW-10r, MW-10s, MW-10t, MW-10u, MW-10v, MW-10w, MW-10x, MW-10y, MW-10z, MW-11a, MW-11b, MW-11c, MW-11d, MW-11e, MW-11f, MW-11g, MW-11h, MW-11i, MW-11j, MW-11k, MW-11l, MW-11m, MW-11n, MW-11o, MW-11p, MW-11q, MW-11r, MW-11s, MW-11t, MW-11u, MW-11v, MW-11w, MW-11x, MW-11y, MW-11z, MW-12a, MW-12b, MW-12c, MW-12d, MW-12e, MW-12f, MW-12g, MW-12h, MW-12i, MW-12j, MW-12k, MW-12l, MW-12m, MW-12n, MW-12o, MW-12p, MW-12q, MW-12r, MW-12s, MW-12t, MW-12u, MW-12v, MW-12w, MW-12x, MW-12y, MW-12z, MW-13a, MW-13b, MW-13c, MW-13d, MW-13e, MW-13f, MW-13g, MW-13h, MW-13i, MW-13j, MW-13k, MW-13l, MW-13m, MW-13n, MW-13o, MW-13p, MW-13q, MW-13r, 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Bedrock TCE Isoconcentrations



Bedrock Dye Injections



Objectives:

- Estimate groundwater velocities within different fracture units
- Confirm groundwater flow paths in the bedrock aquifer

Implementation:

- Fluorescein dye injected into IW-3br (on-site well)
- Sulforhodamine B injected into IW-4br (off-site well)
- Each injected into 3 water-bearing units (A, B, & C)



Bedrock Dye Injections



**Grab Sample with
Fluorescein Dye**



**Grab Sample with
Sulforhodamine B Dye**

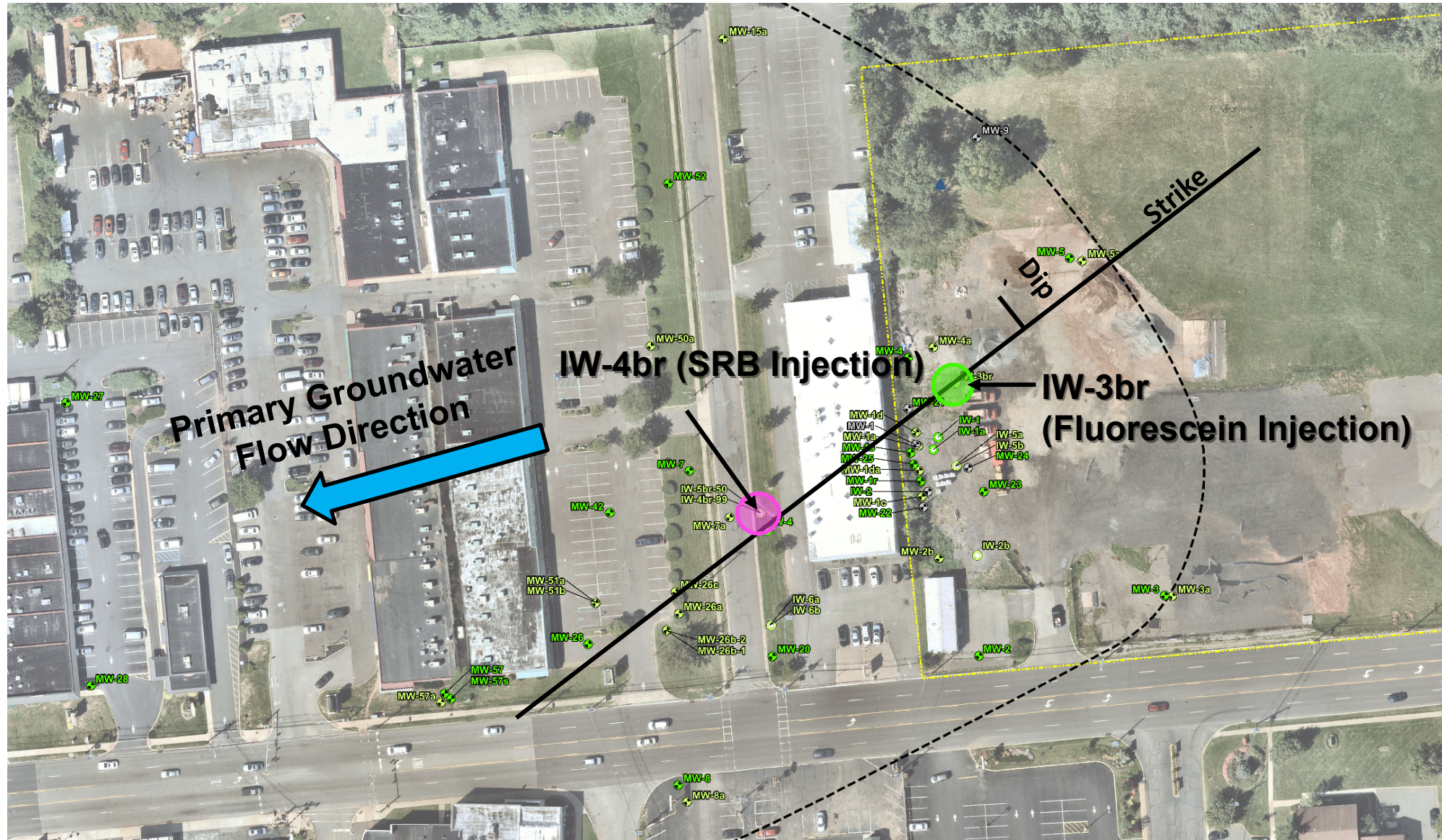
Monitoring:

- Baseline grab samples were collected prior to dye injection and post-injection monitoring was performed on a periodic grab basis for a one-year period after dye injection.
- Charcoal receptor bags were used for to provide insight into tracer concentration trends

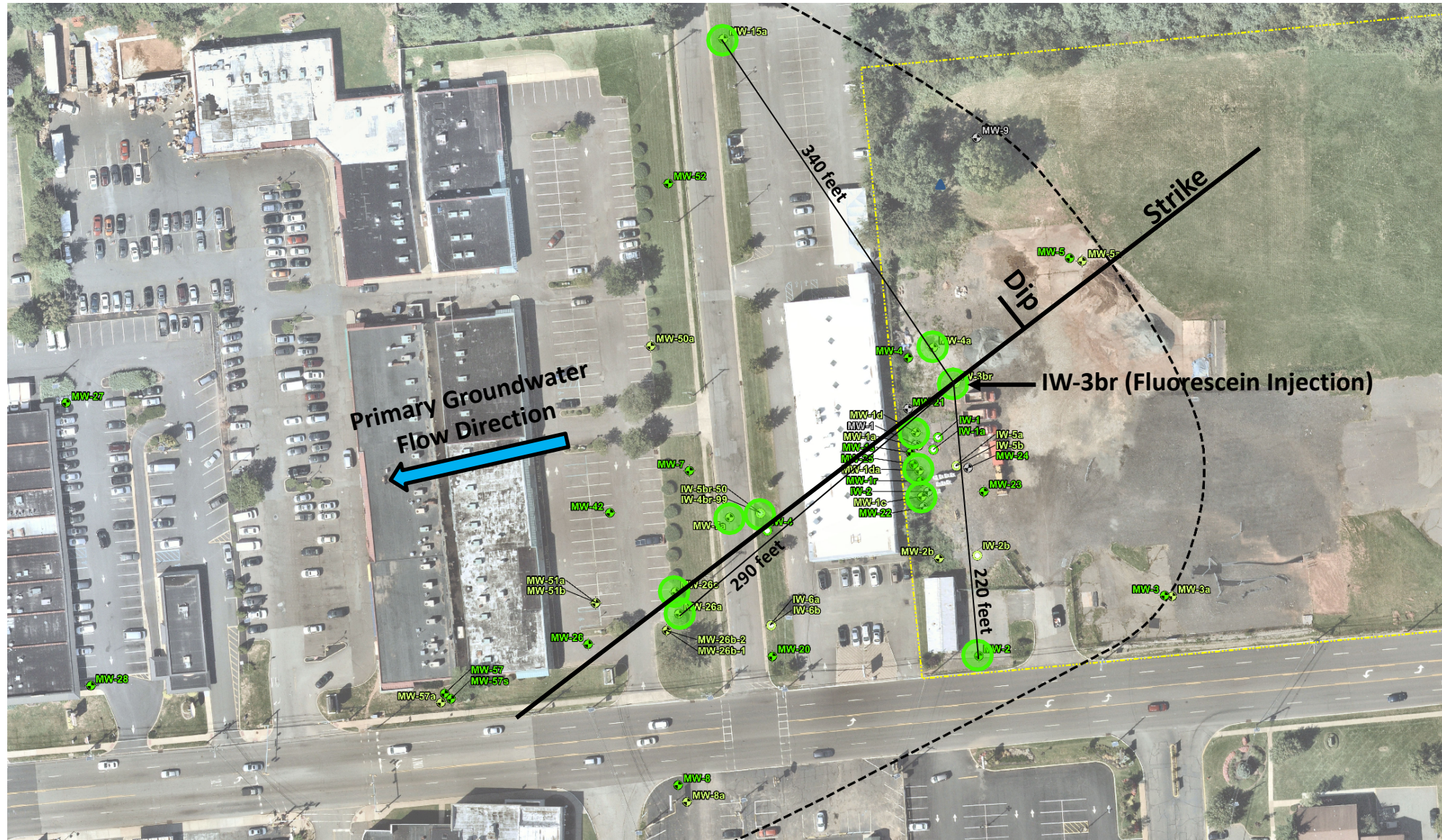


**Charcoal Dye Receptors
Bag**

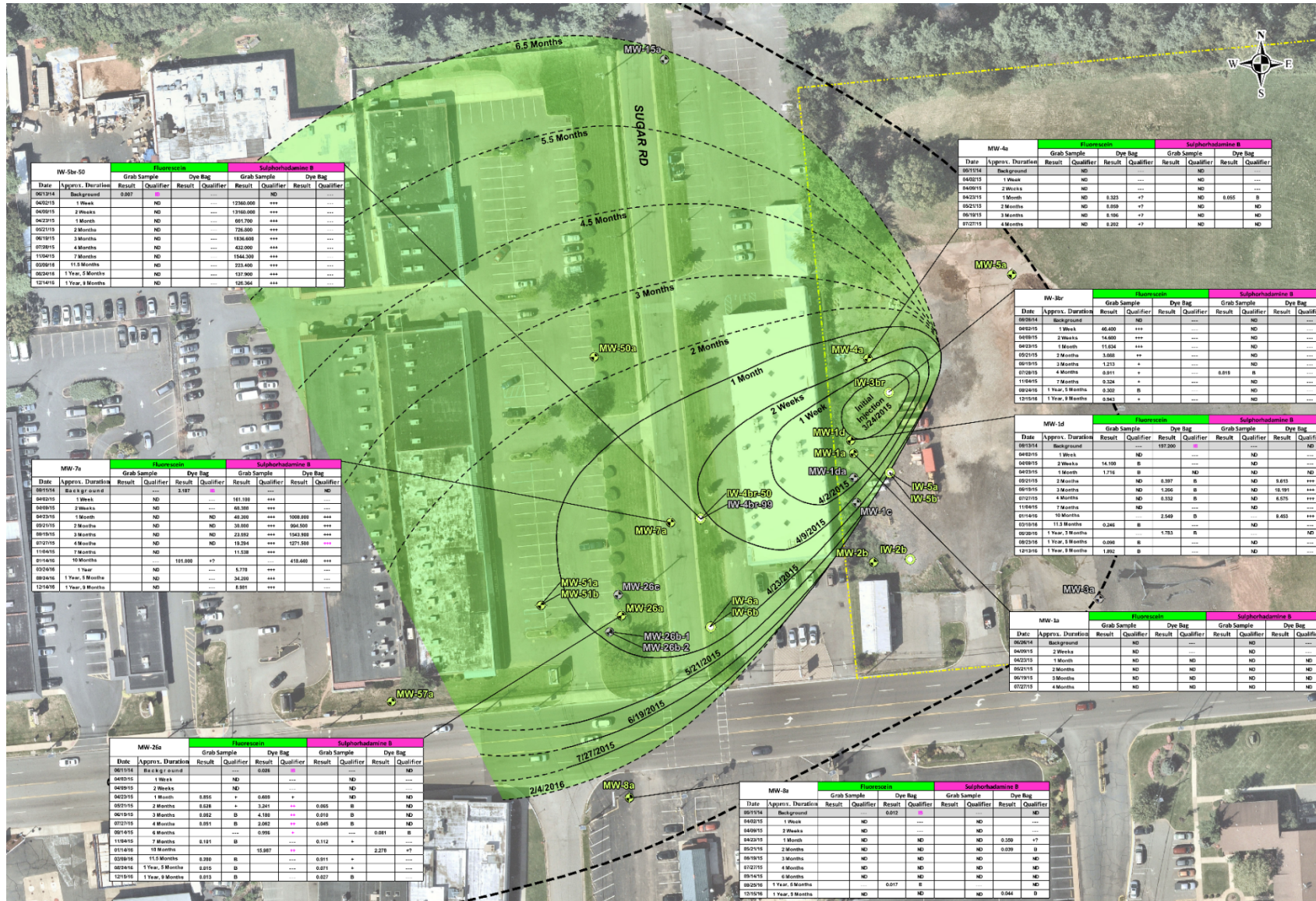
Bedrock Dye Injections



Fluorescein Distribution in Bedrock

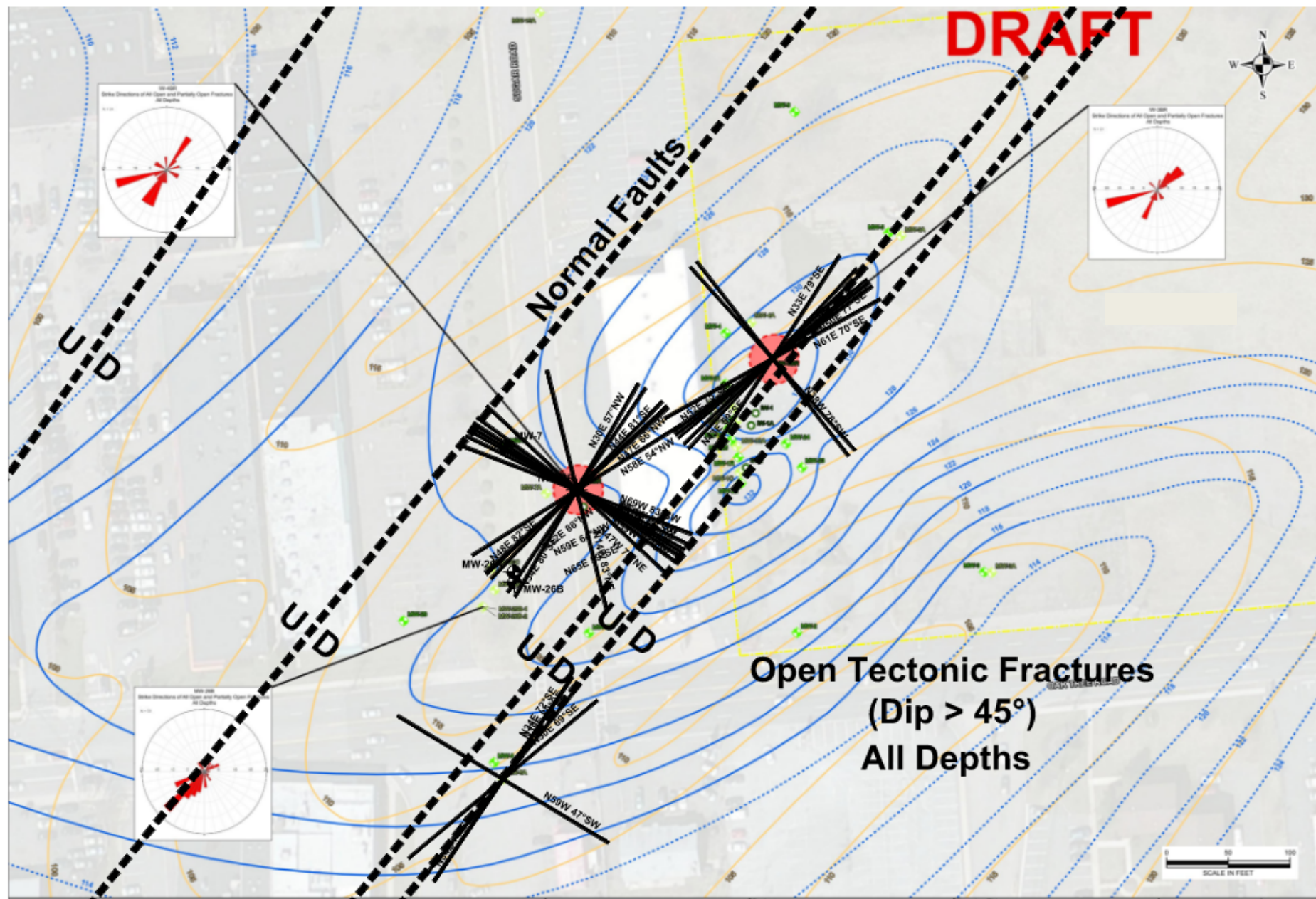


Fluorescein Distribution in Bedrock



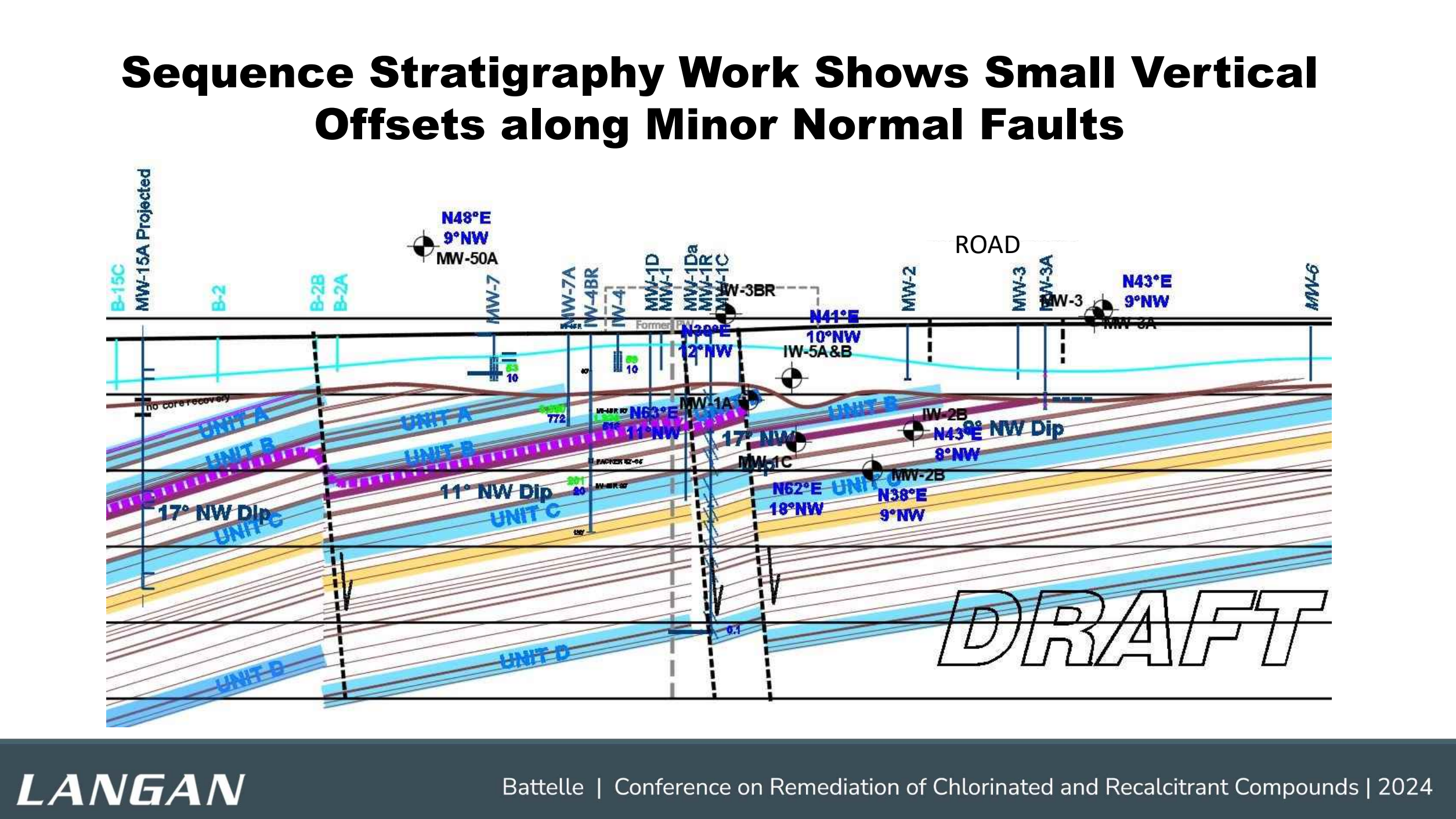
This aerial map illustrates the groundwater flow direction and the locations of various monitoring wells (MW) and injection wells (IW) at the SRB site. A blue arrow indicates the **Primary Groundwater Flow Direction** towards the left. A dashed line represents the **Strike** and **Dip** of the geological formation. The map shows several monitoring wells (MW-1 through MW-50a) and injection wells (IW-1 through IW-6a). A specific injection well, **IW-4br (SRB Injection)**, is highlighted with a pink circle. The map also shows the **210 feet** and **240 feet** distances from the injection well to the surrounding monitoring wells.

Open Tectonic Fractures ($>45^\circ$ dip) All Depths



Sequence Stratigraphy Work Shows Small Vertical Offsets along Minor Normal Faults

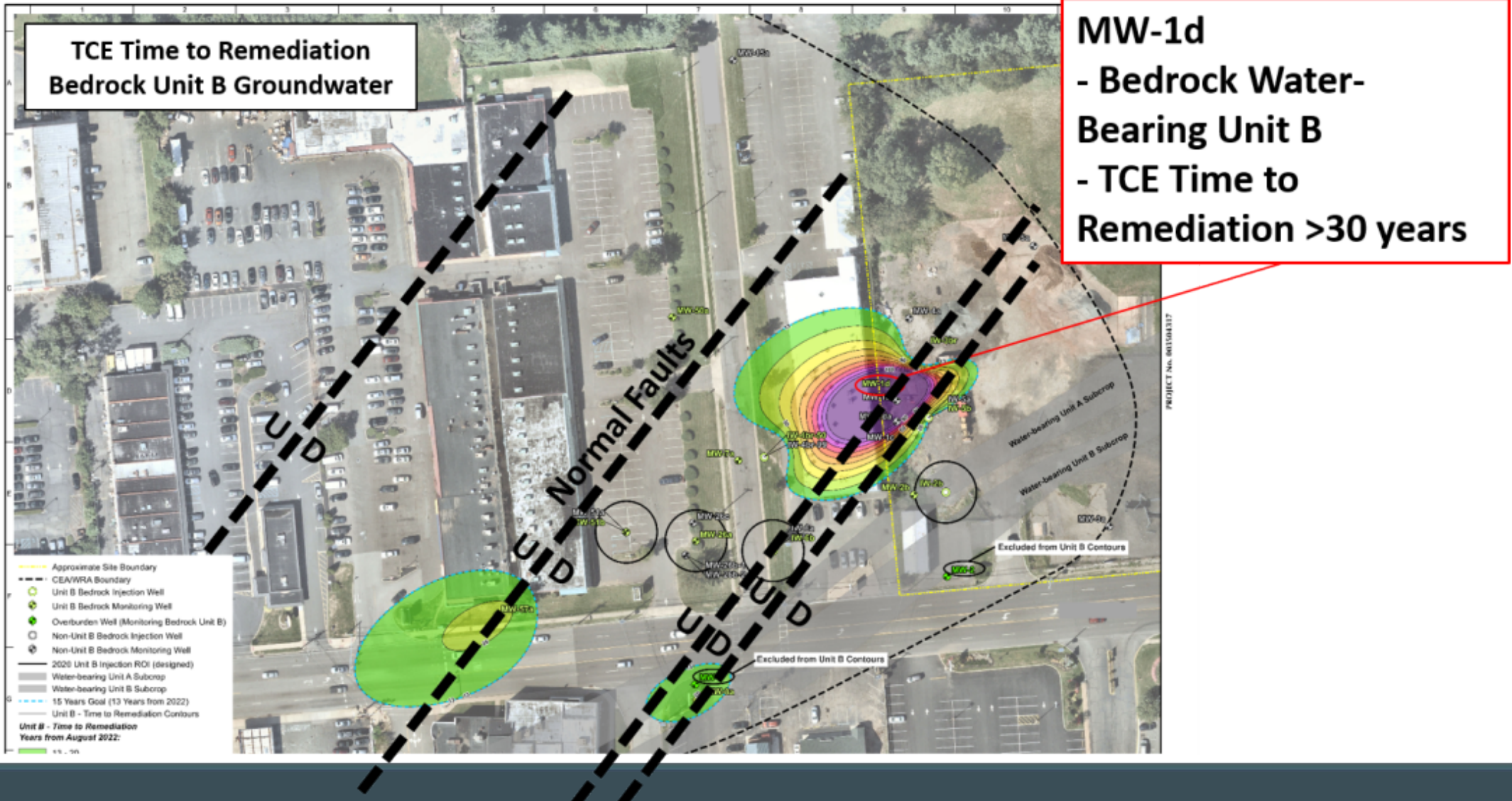
The diagram is a geological cross-section showing stratigraphic units (A, B, C, D) and minor normal faults. The units are color-coded: Unit A is light blue, Unit B is yellow, Unit C is orange, and Unit D is dark blue. The faults are indicated by dashed lines with arrows showing the direction of movement. The diagram includes well locations (MW-15A, MW-7, MW-1D, MW-1Da, MW-1C, MW-3BR, MW-2, MW-3, MW-3A, MW-6) and road locations. Dip angles are labeled for various units and faults, such as 17° NW Dip, 11° NW Dip, 17° NW, 18° NW, 9° NW, and 10° NW. A large 'DRAFT' watermark is visible in the bottom right corner.



Sequence Stratigraphy Work Shows Small Vertical Offsets along Minor Normal Faults

The diagram is a geological cross-section oriented Northwest (NW) to Southeast (SE). It shows several stratigraphic units: UNIT A (top, light blue), UNIT B (middle, yellow), UNIT C (lower middle, light blue), and UNIT D (bottom, dark blue). The units are separated by distinct boundaries. Several minor normal faults are indicated by dashed lines with arrows showing the downthrown side. Key well locations are marked with vertical lines and labels: MW-15A Projected, B-2, B-2B, B-2A, MW-7, MW-7A, IW-4BR, IW-4, MW-1D, MW-1Da, MW-1C, MW-3BR, MW-2, MW-3, MW-3A, and MW-6. A road is shown at the top right. Dip angles are noted for various units and faults: 17° NW Dip for UNIT C on the left, 11° NW Dip for UNIT B in the center, and 17° NW, 11° NW, 10° NW, 8° NW, and 9° NW for other units and faults. A large 'DRAFT' watermark is overlaid on the right side of the diagram.

TCE Time to Remediation in Bedrock

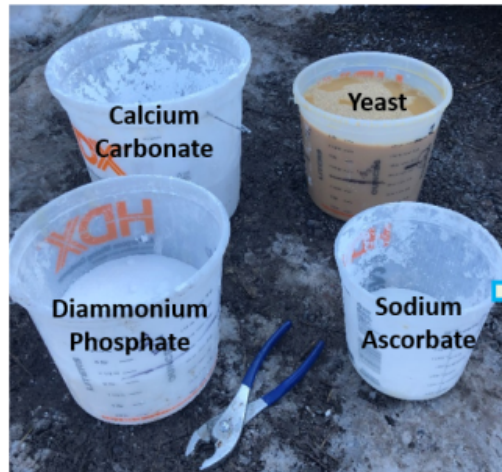


Full Scale Bedrock Injections



Emulsified
Vegetable Oil

Water



Nutrients & Buffer

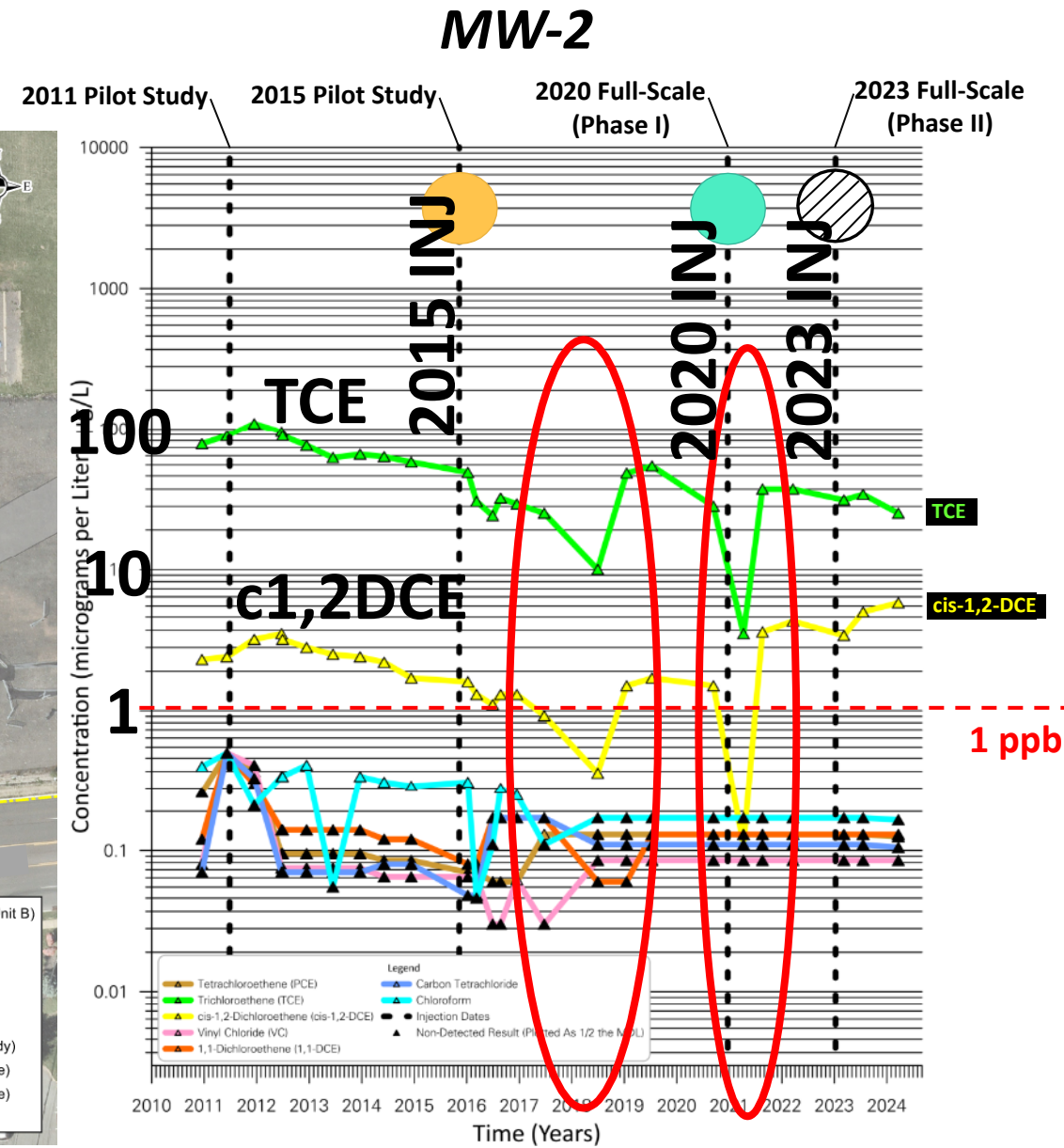
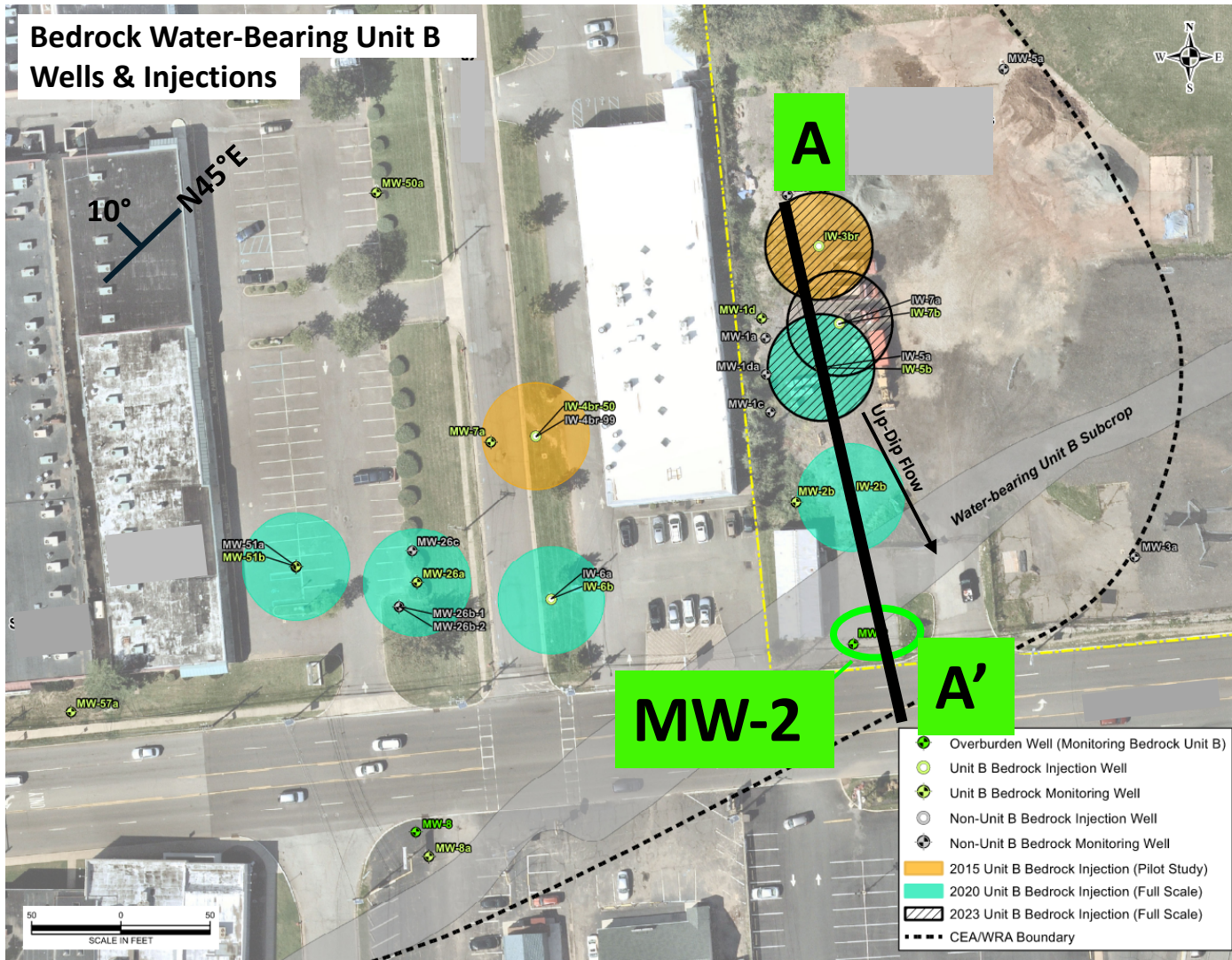
Microbes



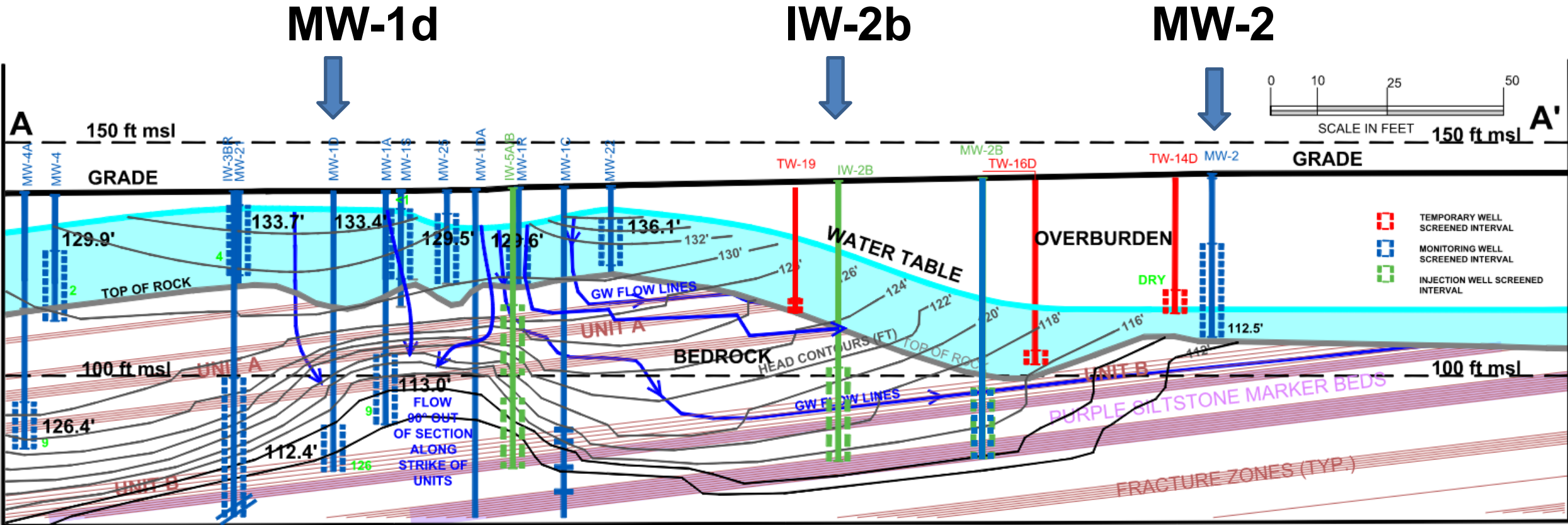
Phase 1 Injections: December 2020

-
- The map displays the following monitoring wells (MW) and investigation wells (IW):
- Monitoring Wells (MW):** MW-4, MW-4a, MW-21, MW-1d, MW-1, MW-1a, MW-1b, MW-25, MW-1da, MW-1r, MW-2, MW-1c, MW-22, MW-7a, MW-26c, MW-26a, MW-26b-1, MW-26b-2, MW-20, MW-8, MW-8a, MW-2, MW-3, MW-3a.
 - Investigation Wells (IW):** IW-3br, IW-7a, IW-7b, IW-5a, IW-5b, IW-1, IW-1a, MW-23, IW-2b, IW-2a, IW-4br-50, IW-4br-99, IW-4, IW-6a, IW-6b.
- The map also shows a large white building, a parking lot, and a road intersection. A red dashed line outlines a specific area of interest. A north arrow and a scale bar (0 to 50 feet) are included in the bottom right corner.

Rebound



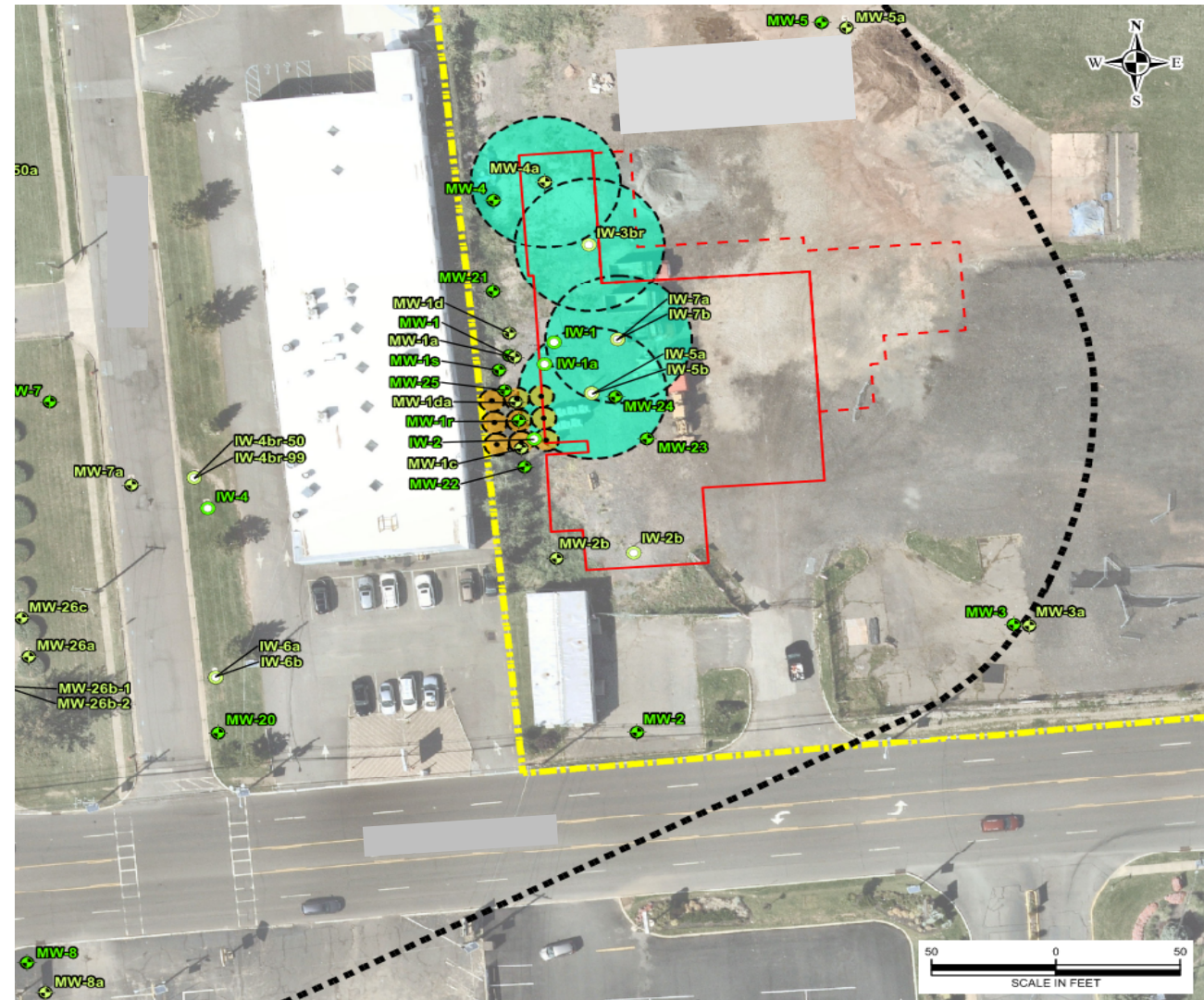
On-Site Groundwater Mounding



Remedial Action Workplan – Full-Scale Implementation

Phase 2 Injections: January 2023

- **13,800 gallons** into Bedrock Aquifer (6 wells)
- **2,400 gallons** into Overburden Aquifer (1 well & 8 DPT)
- ISEB in Bedrock & Combined ISEB + ISCR (ZVI) in Overburden
- Targeted Former Source Area
- Performance Monitoring in Progress (under DGW-PBR)



Next Steps

- Address Groundwater Mound
- Performance Monitoring / Demonstrate MNA
- NJDEP Mandatory Timeframe 2028



Questions?

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kkelly@langan.com

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Matt Morris – Langan

Don Monteverde – NJGS

Rich Volkert – NJGS

