Remediation and Reuse of Onshore Resources Task 24 Plugging Orphaned and Abandoned Wells

To Ensure Plugging Effectiveness of Onshore Wells

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October 25, 2022

U.S. DEPARTMENT OF ENERGY

Task 24.0 Plugging Orphaned and Abandoned Wells

TIMELINE EY 2021 EY 2022 EY 2023

Are there simple modifications for gel preparation and/or plugging methods that increase plugging effectiveness?

Need: Identify materials that are appropriate for plugging abandoned oil and gas wells in Pennsylvania (EY21).

The number of wells needing to be plugged will likely always exceed available funding.

Instances of well plug materials failure were identified by the Pennsylvania Department of Environmental Protection (focus on the stability of gel layers in plugged wells).

Stakeholders: PA DEP (near-term); results of value to EPA and other state environmental agencies, oil and gas regulatory agencies

Crosscutting: Methane emissions, Undocumented wells


Pittsburgh Post-Gazette

MAY 14, 2020

Could plugging orphan wells keep the suffering oil industry afloat?

Across the country, states have identified more than 55,000 ownerless wells left unplugged during past waves of oil and gas drilling. Estimates of existing but unidentified wells swelled to 750,000 or more nationwide.

Pennsylvania alone has 8,500 verified orphan and abandoned wells, plus an estimated 200,000 that have not been identified.


Pittsburgh Post-Gazette

APR 19, 2021

Infrastructure funding could be 'opportunity of a lifetime' to plug thousands of abandoned oil and gas wells

By some accounts, Pennsylvania has the worst accumulation of old, unplugged, ownerless oil and gas wells in the nation. There are an estimated 200,000 of them, and the cost to plug them could exceed $6 billion.

This project is evaluating current well plugging methods and studying the fate of plugging material in abandoned wells in collaboration with the PA DEP.

Approach

Quantify how water:bentonite mixing ratios impact the stability of gel spacer layers in between cemented layers of plugged wells through laboratory experiments.

Final Products

Experimental results that determine what happens to plugging materials in orphan wells (Pennsylvania focus).

Laboratory-based testing framework that enable future development of low-cost plugging materials across a range of basins and well types.

Ultimate Goal

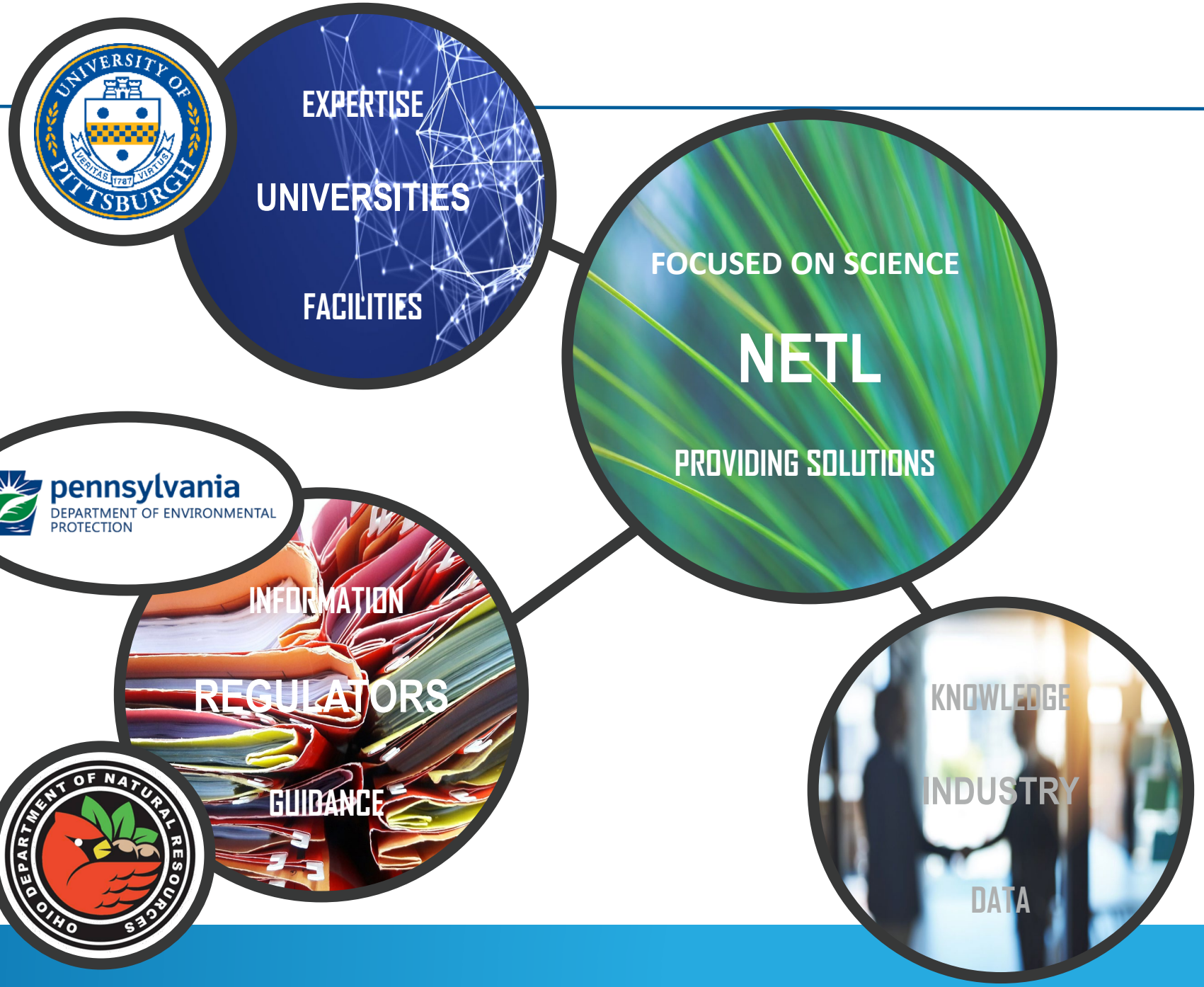
Ensure that plugged wells remain plugged and are not leaking.

Background

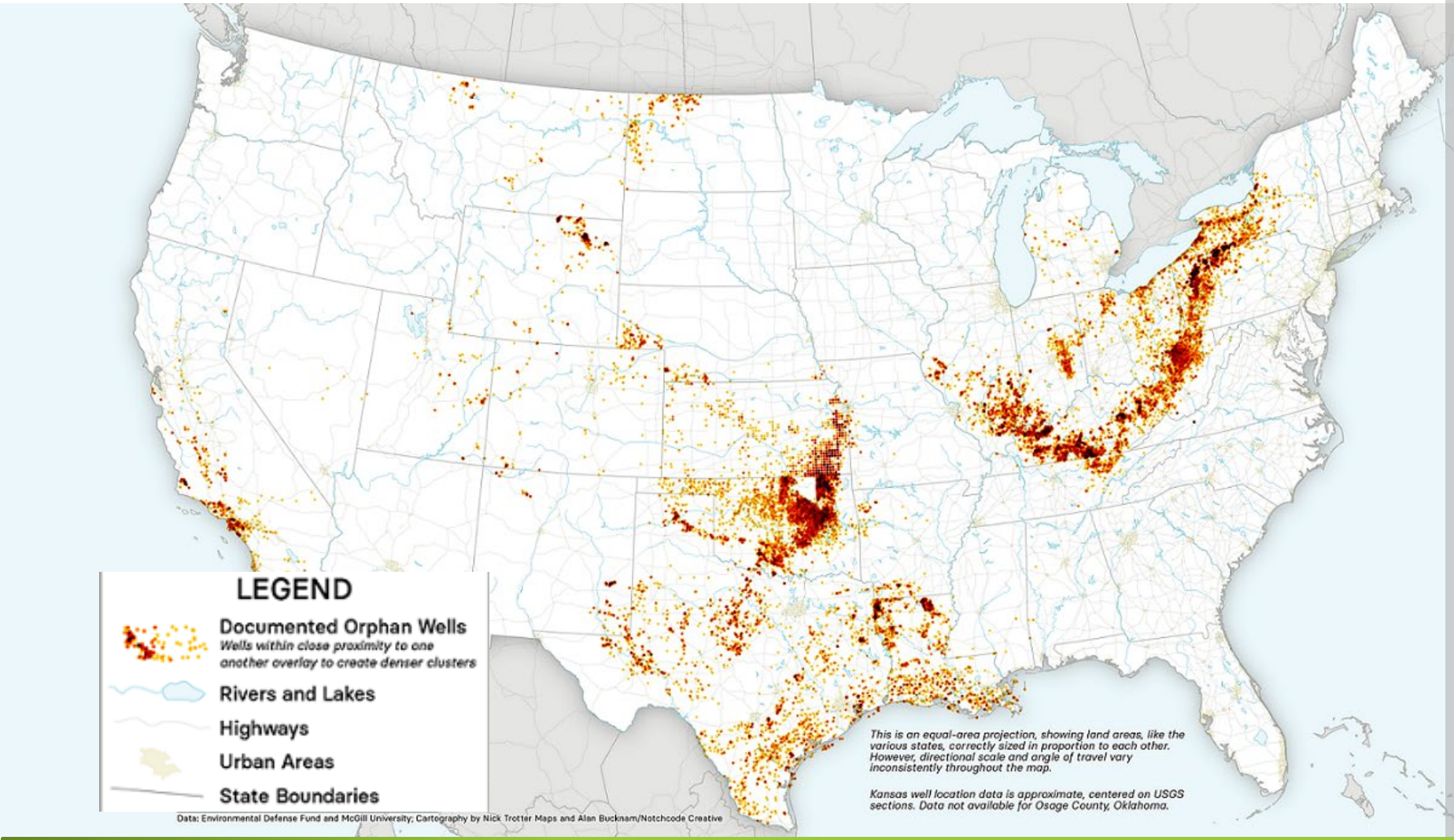
Project Structure

Project Team:

Key Personnel: Richard Spaulding (NETL), Igor Haljasmaa (NETL, Justin Mackey (NETL), Phillip McElroy (NETL), James Fazio (NETL), Dustin Crandall (NETL), John Brigham (University of Pittsburgh), Carlos A. Garcia Verdugo (Pitt PhD Student)



Documented Orphan Wells



- More than **81,000 documented** oil and gas wells across the U.S. left unplugged by former owners – previous estimate was 56,000 (Report by the Environmental Defense Fund).
- **2,150,000 Unplugged** Abandoned Wells in U.S. (EPA Estimate).
- **Cost increases with depth** (20% increase per 1000 ft), well age, and surface elevation (Environ. Sci. Technol. 2021, 55, 10224-10230).

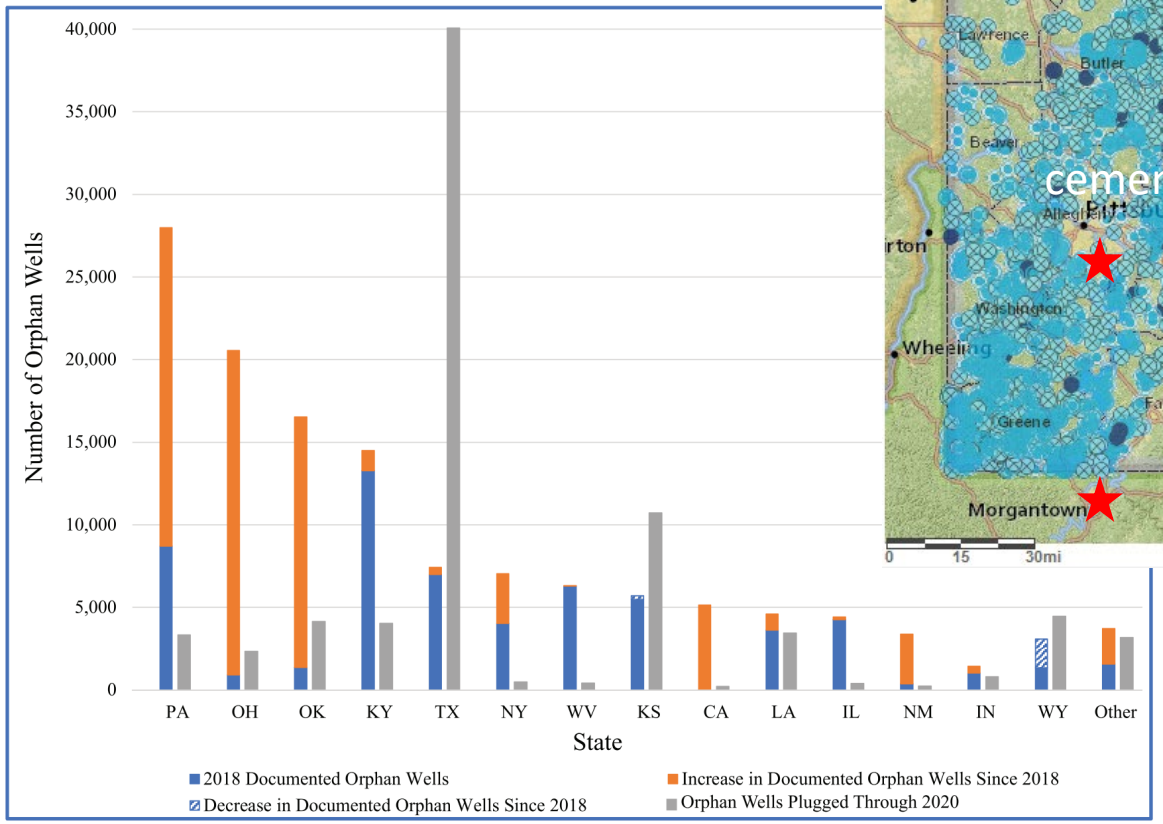
https://www.edf.org/orphanwellmap

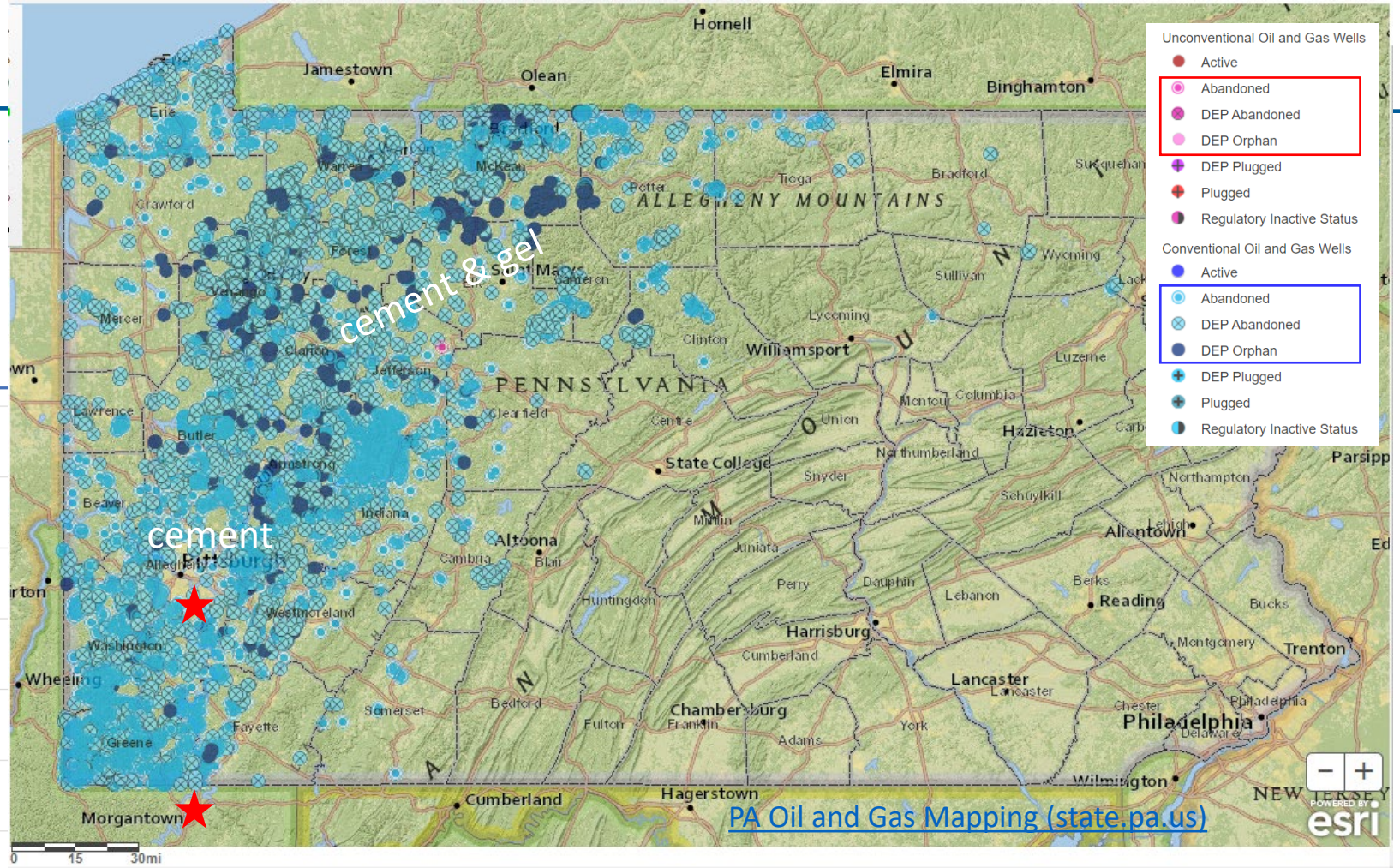
Rewriting PA's Legacy

Well Plugging in PA

Western PA has ~8,840 abandoned and unplugged wells

★ NETL





Conventional oil and gas well: $38,000

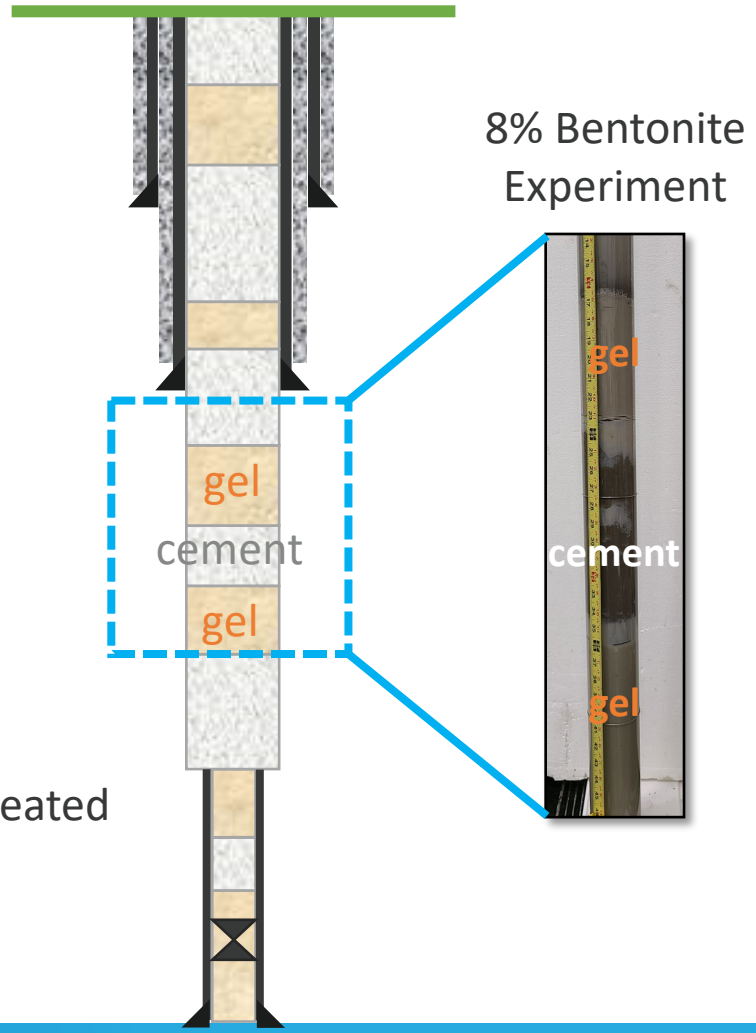
Marcellus Shale well: $83,000

For estimated 200,000 undocumented oil and gas wells drilled and left unsealed over a century prior to modern environmental regulations – potentially $6.6 billion cleanup cost. - $25,000,000 of Infrastructure funding to each state.

Background

Well Plugging in PA

- **PA Chapter 78.71, API Recommended Practice 65-3**
  - Hydrocarbon-producing intervals plugged with Portland cement
  - Non-producing intervals – slurry composed of no less than 4% bentonite and water "gel".
- **Higher incidence of leakage in wells plugged with cement + gel.**
- **Fate of plugging materials in well environment?**
- **Goal: Provide recommendations.**

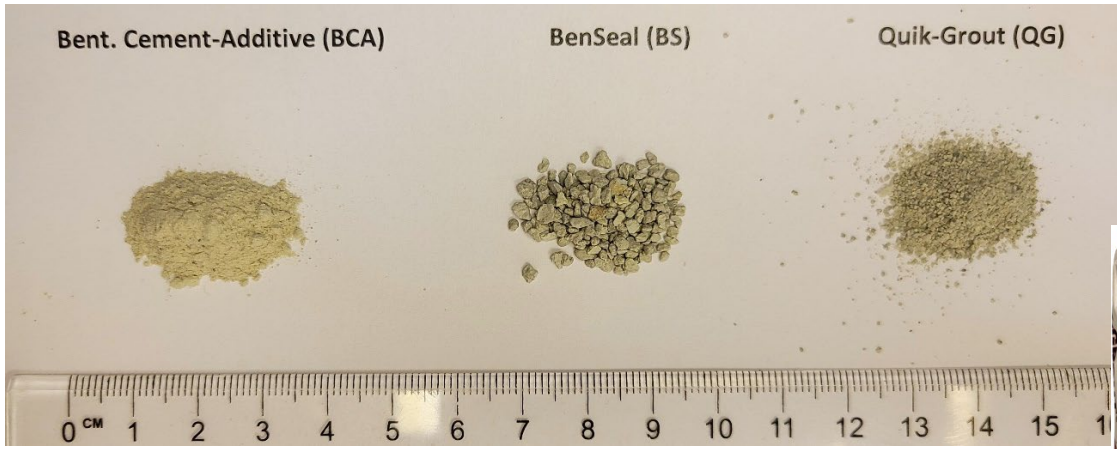


Schematic re-created from Industry contact for well plugged in NY

Plugging Orphaned and Abandoned Onshore Wells Project

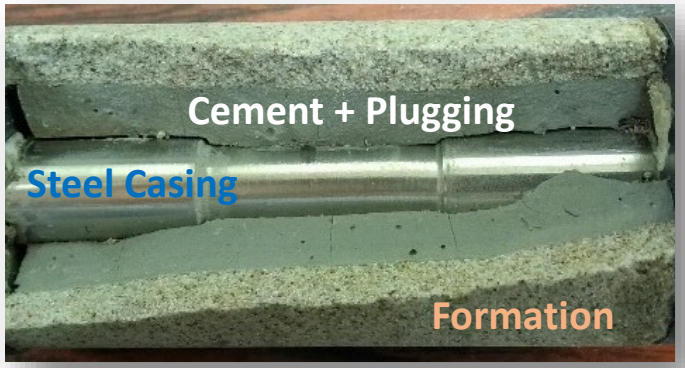
Approach

- **Characterization of Material Properties:** Rheology (viscosity), needed setting times, density, wettability, XRD, pH, etc.
- **Types of Bentonite to Test:** Powdered, granular chips, compressed, sodium bentonite, calcium bentonite, etc.
- **Experiments:** Cement/gel interface, presence of salts, influence of hole diameter, mini-wellbore experiments.
- **Modeling:** Cement/gel interface, complement experimental studies.
- **Collaboration:** PA DEP, ODNR, Pitt
- **Field:** Observation and demonstration.



Sodium bentonite tested

Bentonite gel

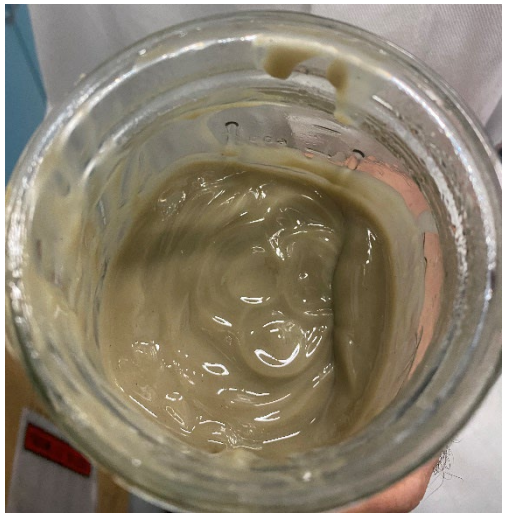


Experimental setup for CT scanner

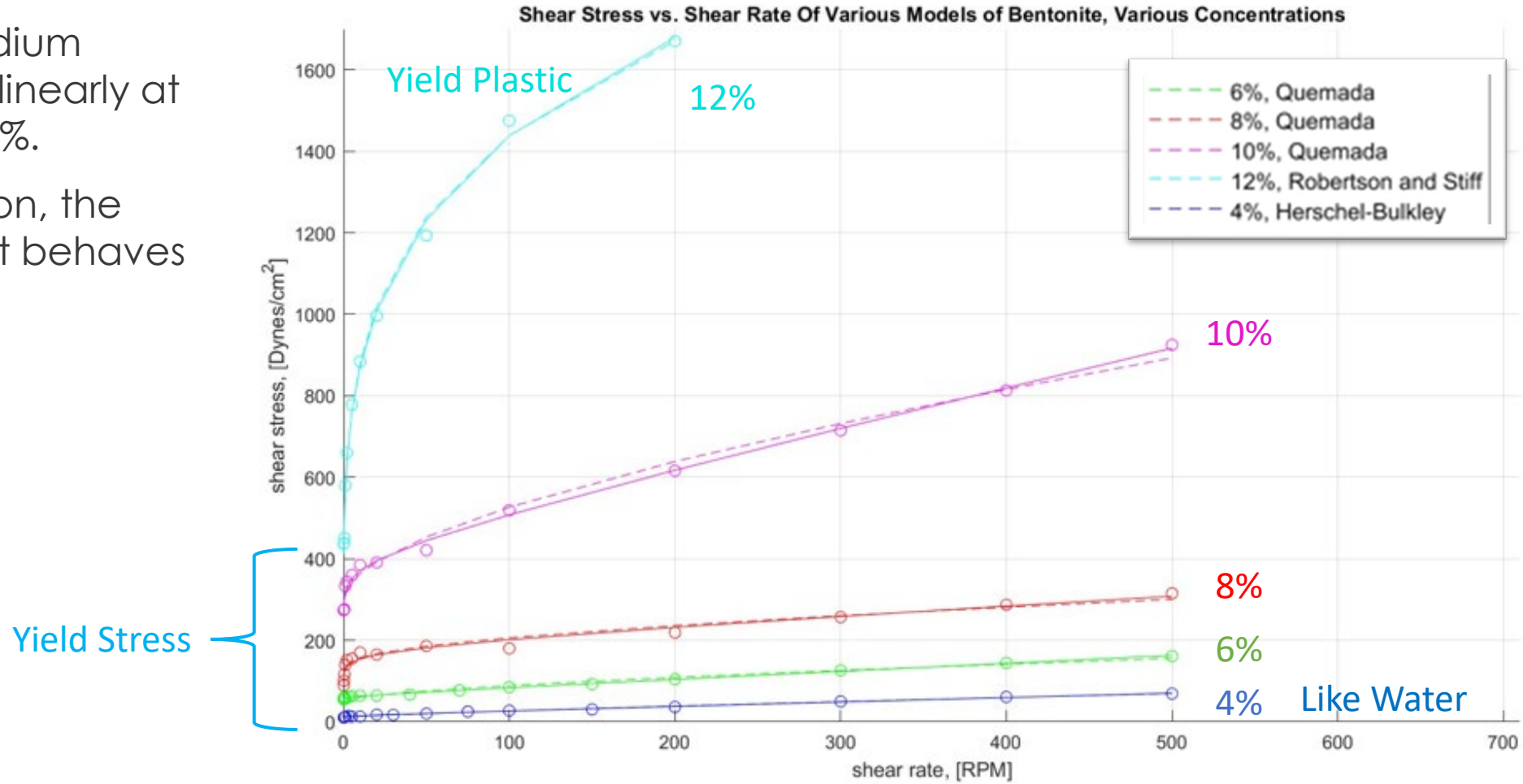
Characterization - Rheology of Bentonite

Powdered Wyoming Sodium Bentonite

- Powdered Wyoming Sodium Bentonite behaves non-linearly at concentrations above 4%.
- Above 10% concentration, the behavior changes and it behaves like a yield plastic.



10% Bentonite in water



Plug Placement Experiments

Powdered Bentonite and Cement Placement Experiments

Current practice/code

Cement falls through bentonite

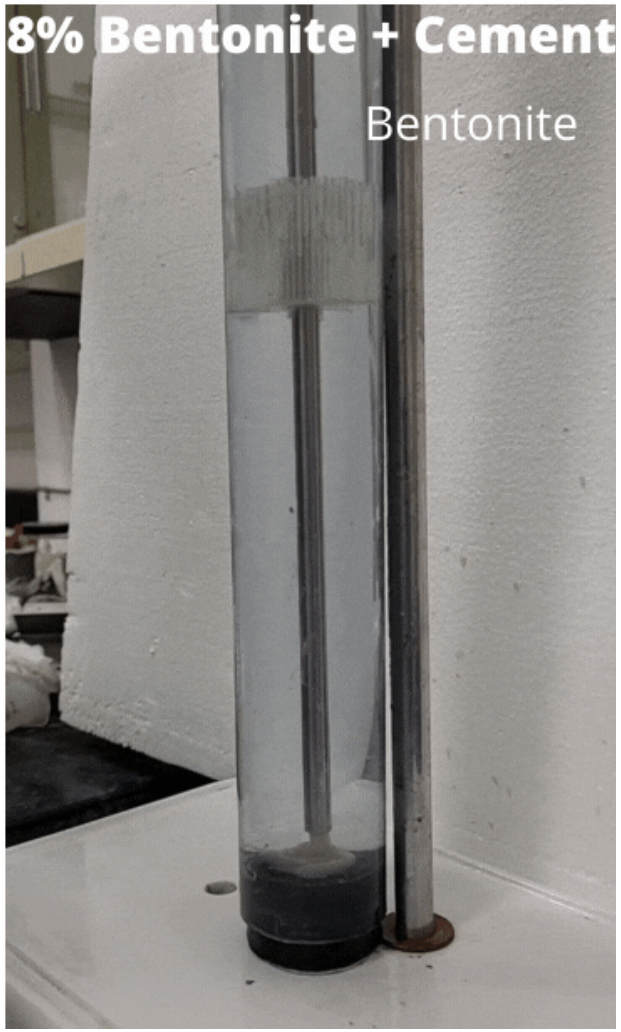
15 min +3 hr 20 min +2 hr 55 min

Separates after placement

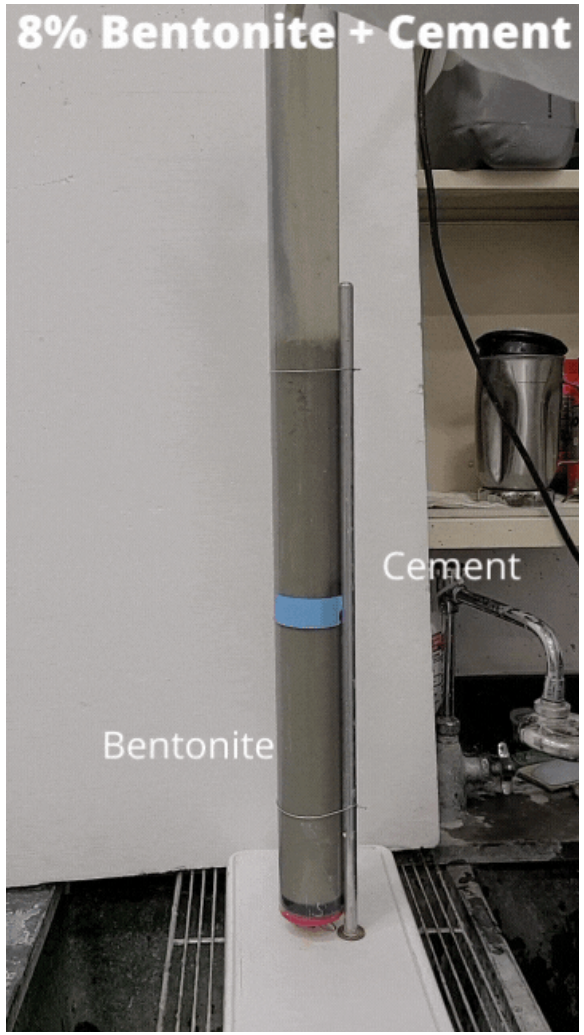
Plug Placement Experiments

Powdered Bentonite and Cement Placement Experiments 8% Bentonite + Cement (and additive)

Powdered Bentonite in 1.5” Tube



Powdered Bentonite in 2” Tube



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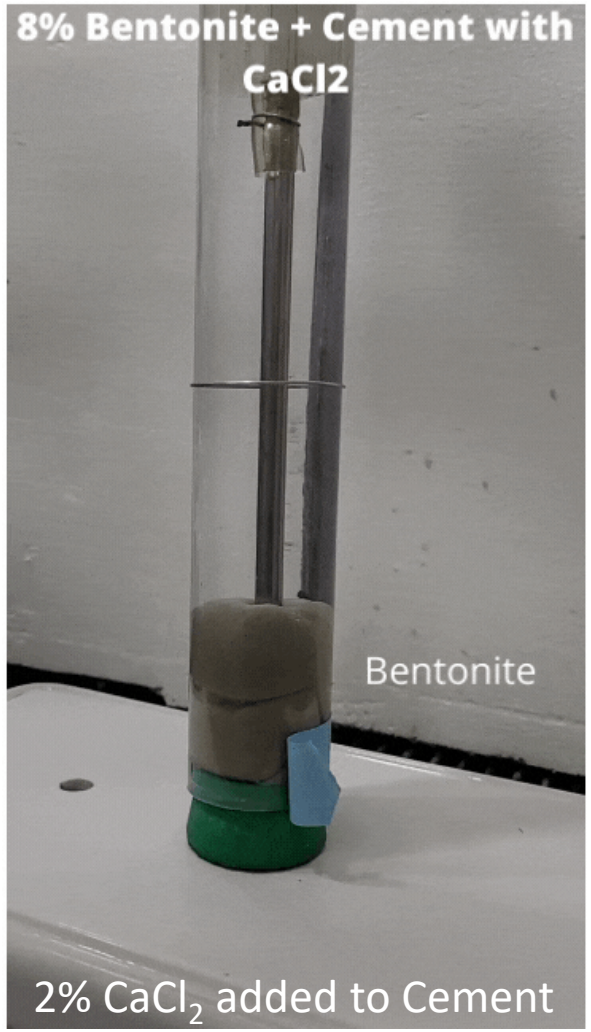
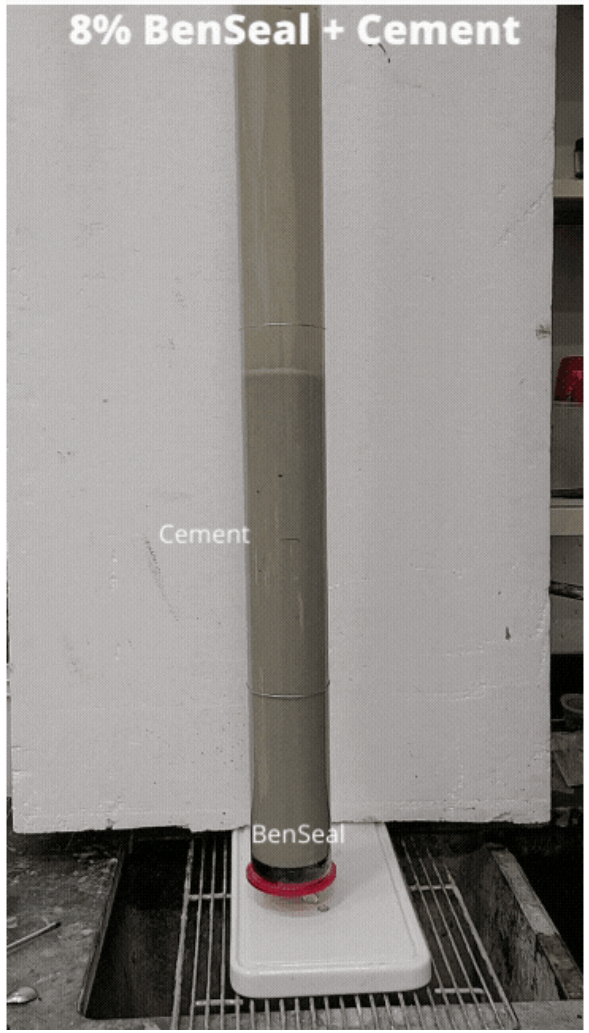


Cement remains on top of bentonite

Plug Placement Experiments

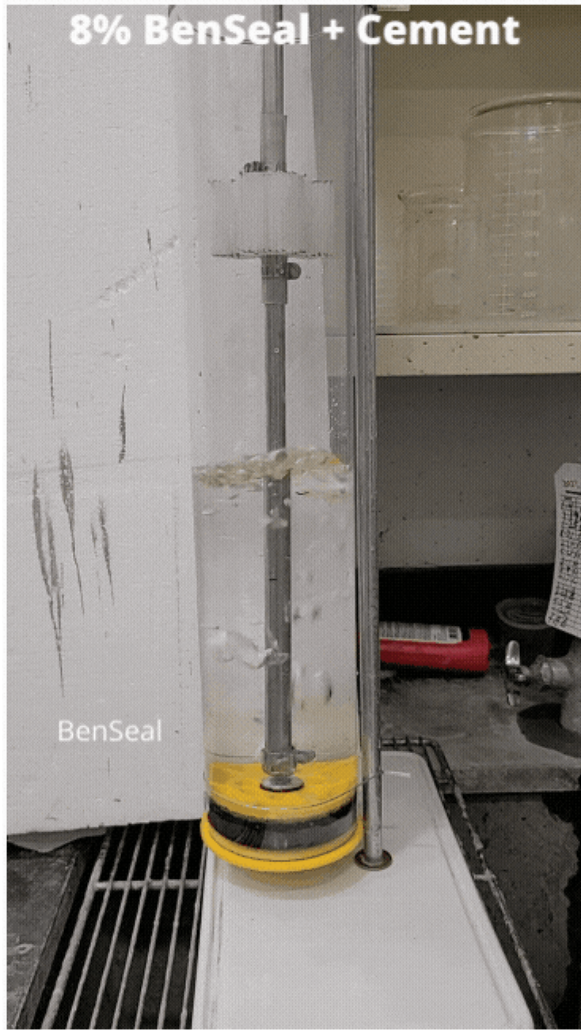
Ben Seal and Cement Placement Experiments 8% Bentonite + Cement

8% BenSeal Bentonite in 3” Tube



Substance	Percent
Bentonite	60-100%
Crystalline silica, cristobalite	0-1%
Crystalline silica, tridymite	0-1%
Crystalline silica, quartz	1-5%

8% BenSeal Bentonite in 4” Tube

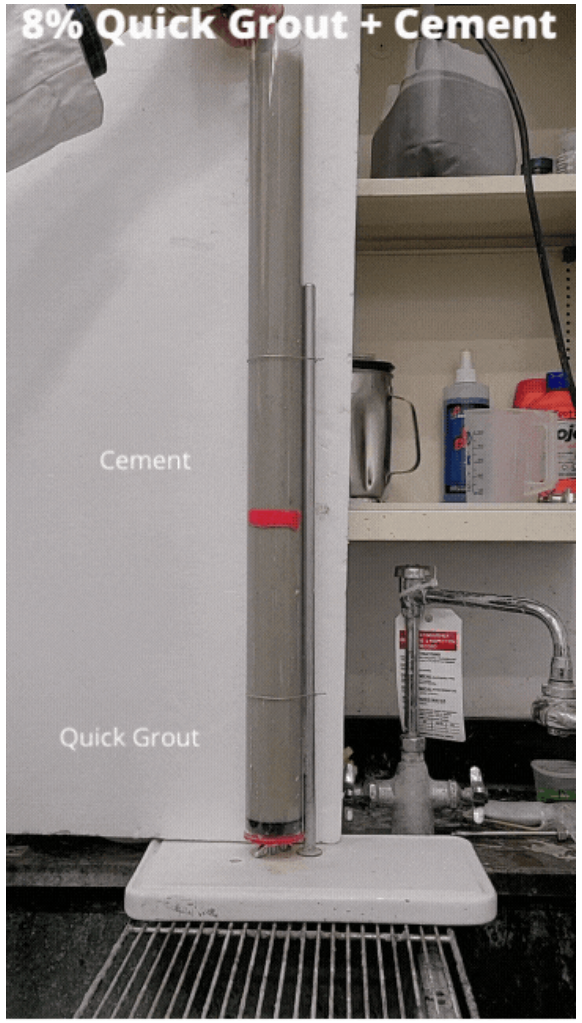


Plug Placement Experiments

(1%-5% Ammonium Sulfate)

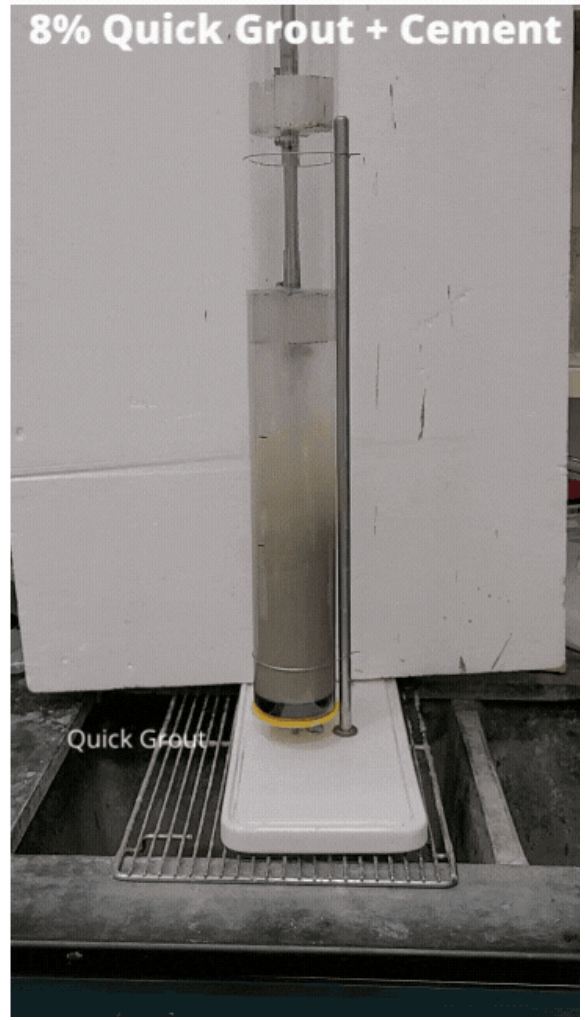
Quick Grout and Cement Placement Experiments 8% Bentonite + Cement

8% Quick Grout Bentonite in 2” Tube



Substance	Percent
Bentonite	60-100%
Crystalline silica, cristobalite	0-1%
Crystalline silica, tridymite	0-1%
Crystalline silica, quartz	1-5%
Ammonium sulfate	1-5%

8% Quick Grout Bentonite in 3” Tube w/New Pump



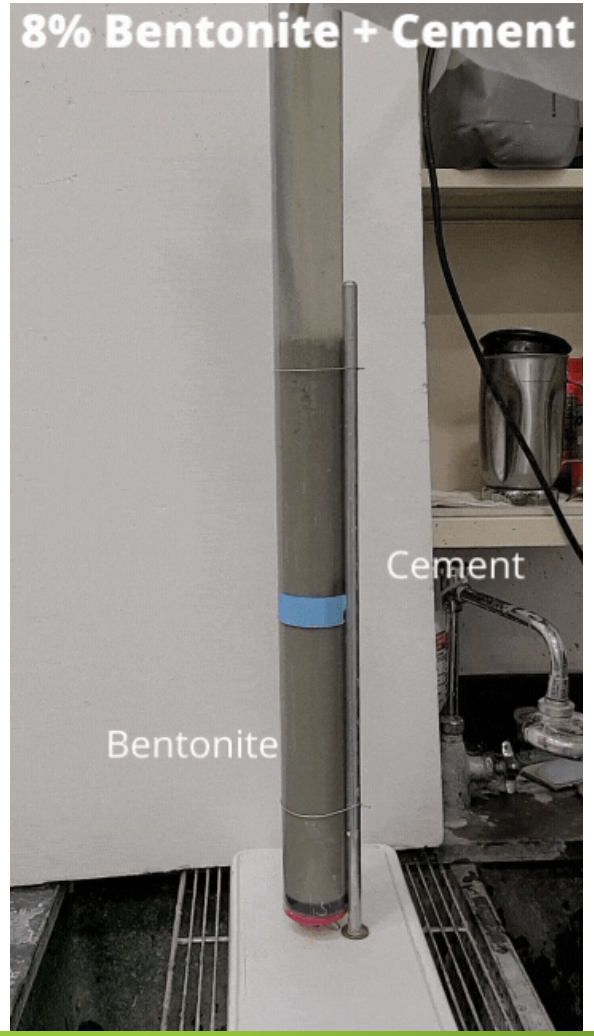
6% QG does not support cement and 7% QG allows cement to sink below target zone.

Providing Solutions to PA DEP

Research to revise recommendations

"Gel" – allowed by current PA code requirements

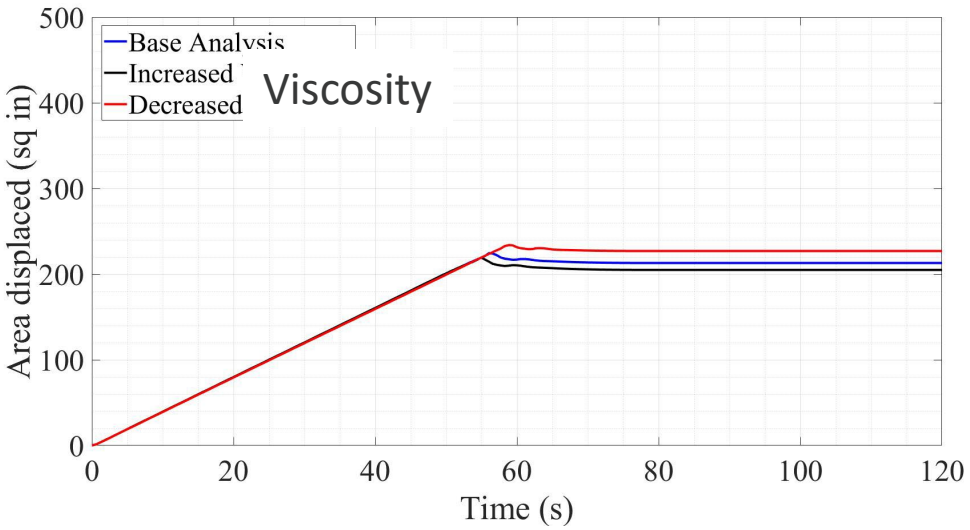
NETL recommended bentonite concentration and process.

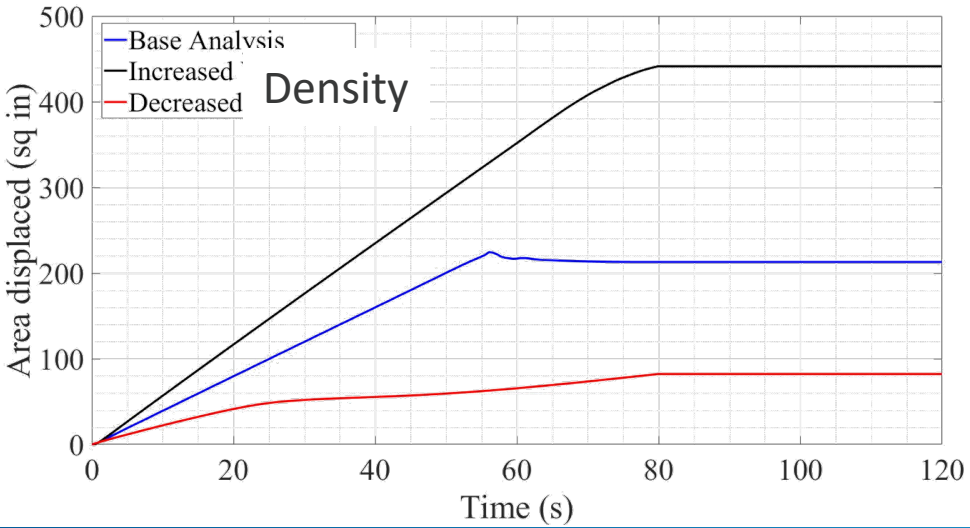


Powdered Bentonite in 2" Tube

Cement and Bentonite Simulation

Lattice Boltzmann Method (LBM)



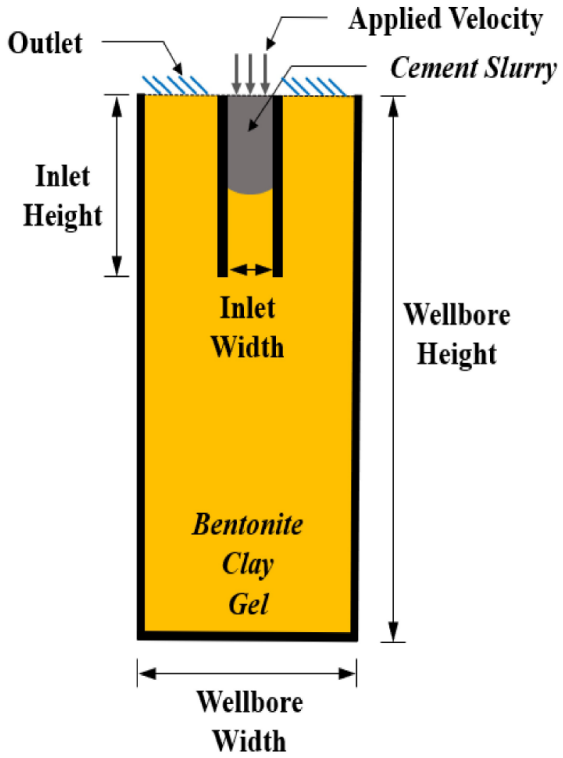


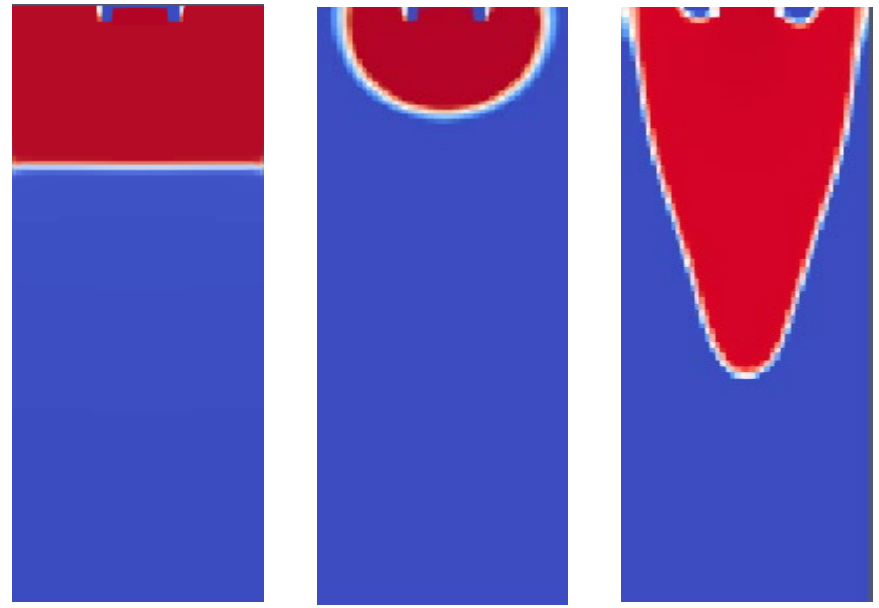
Two immiscible non-Newtonian fluids interacting in an infinite channel.
Bentonite 6% concentration.

Cement slurry

Bentonite

Effects on Cement Slurry reaching the steady state.

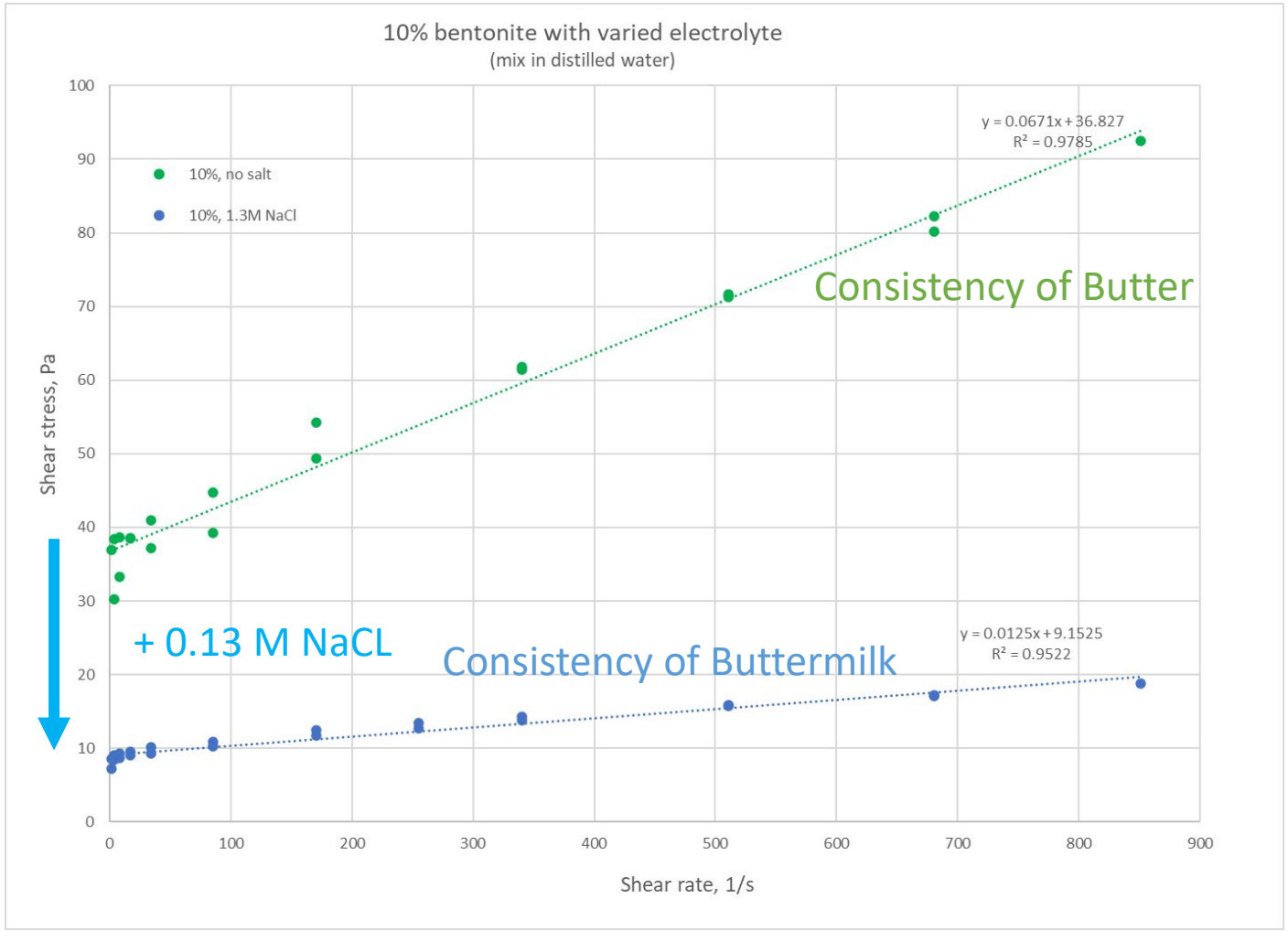




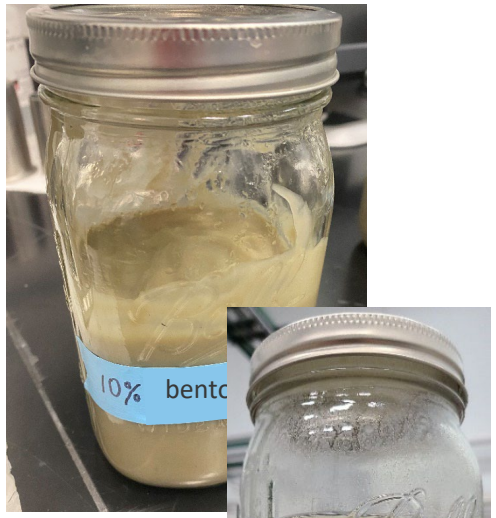
$\rho_b = \rho_c$ $\rho_b = 0.5\rho_c$ $\rho_b = 2\rho_c$

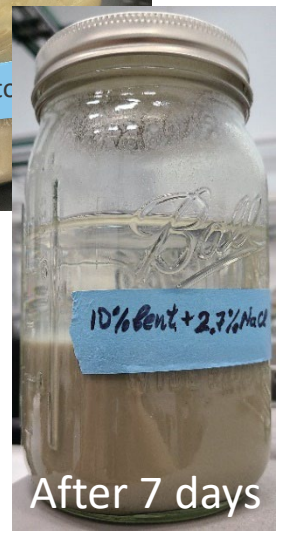
Rheology of Bentonite – Effects of Electrolyte

Powdered Wyoming Sodium Bentonite

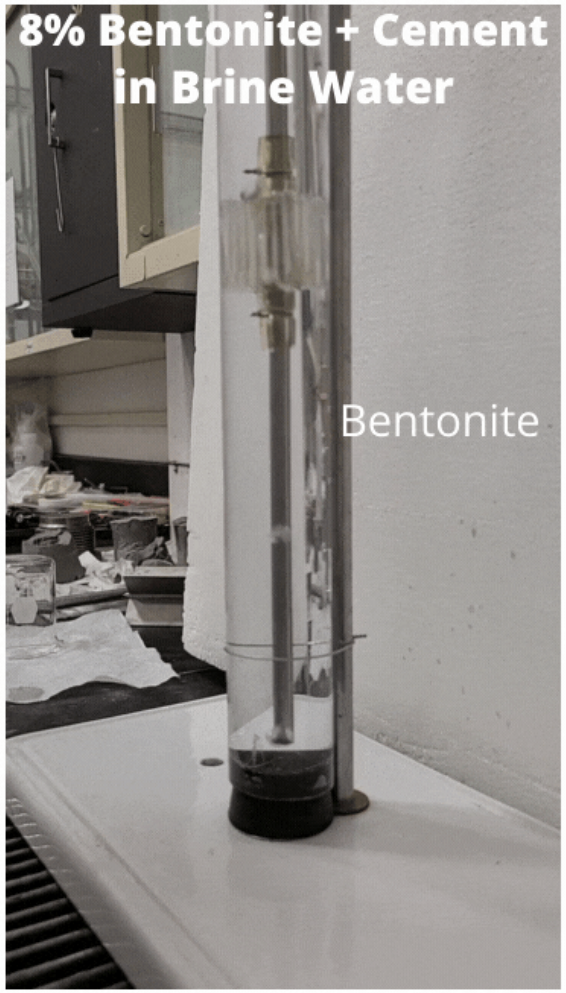


Salt reduces viscosity and yield stress.
NaCl – 0.13 M
Sea Salt – 0.6 M



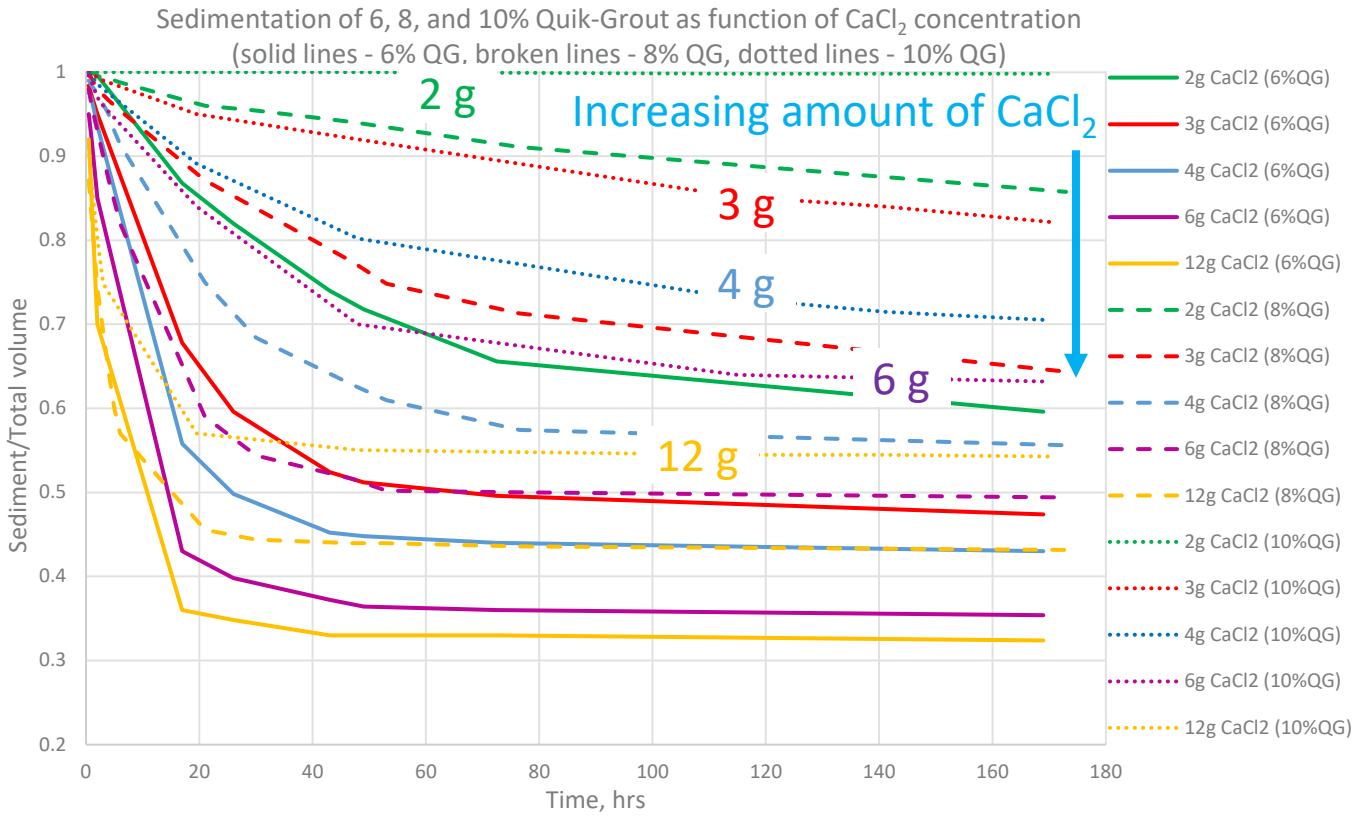


Powdered 8% Bentonite in 1.5” Tube in Brine Water

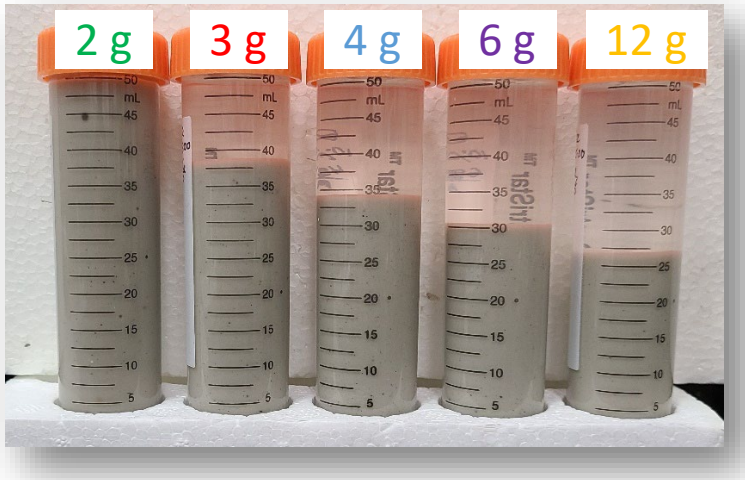


Instability Due to Electrolytes

Critical Coagulation Concentration



10% Quik Grout dispersed in grams of $CaCl_2$ per liter of distilled water



—— 6%

– – 8%

····· 10%

Identify Instability Region

Rewriting PA's Legacy

Well Plugging in PA

Western PA has ~8,840 abandoned and unplugged wells

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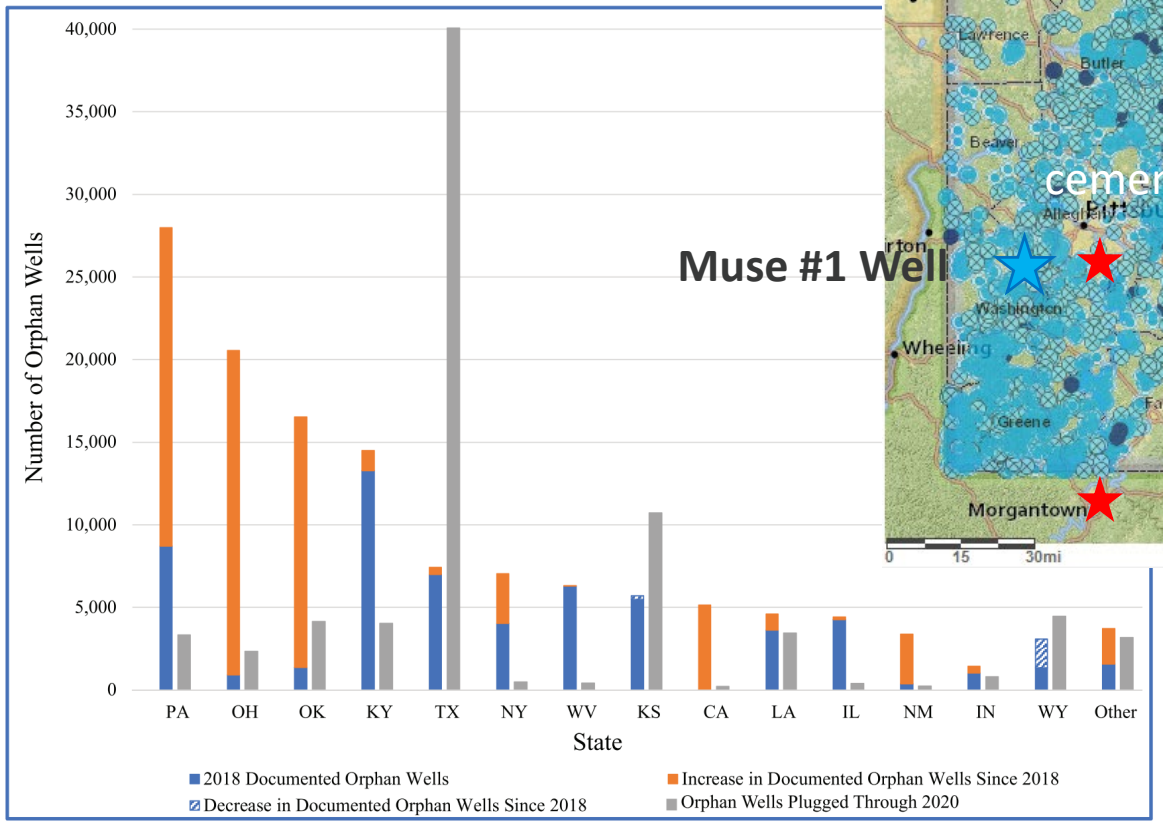

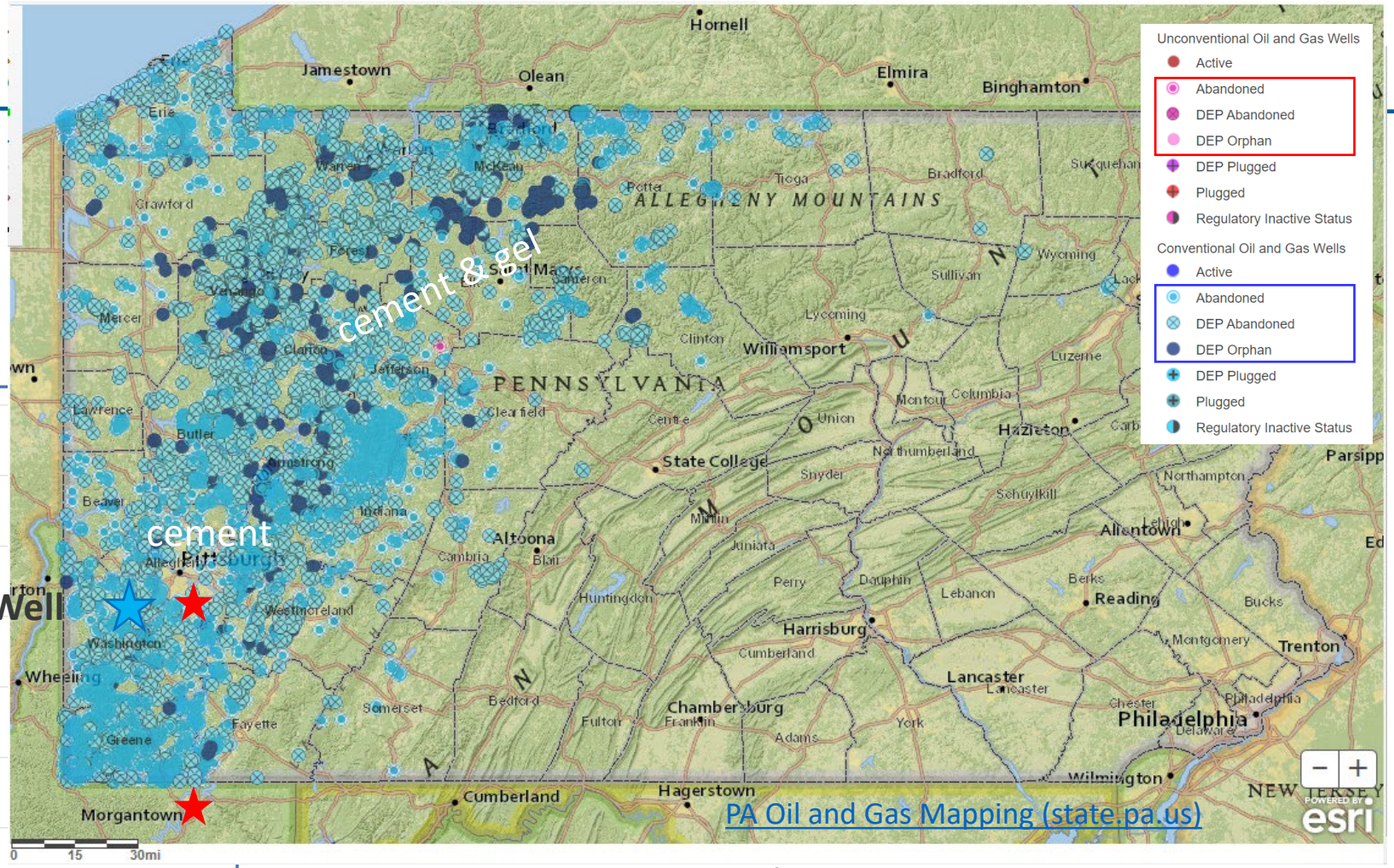

Conventional oil and gas well: $38,000

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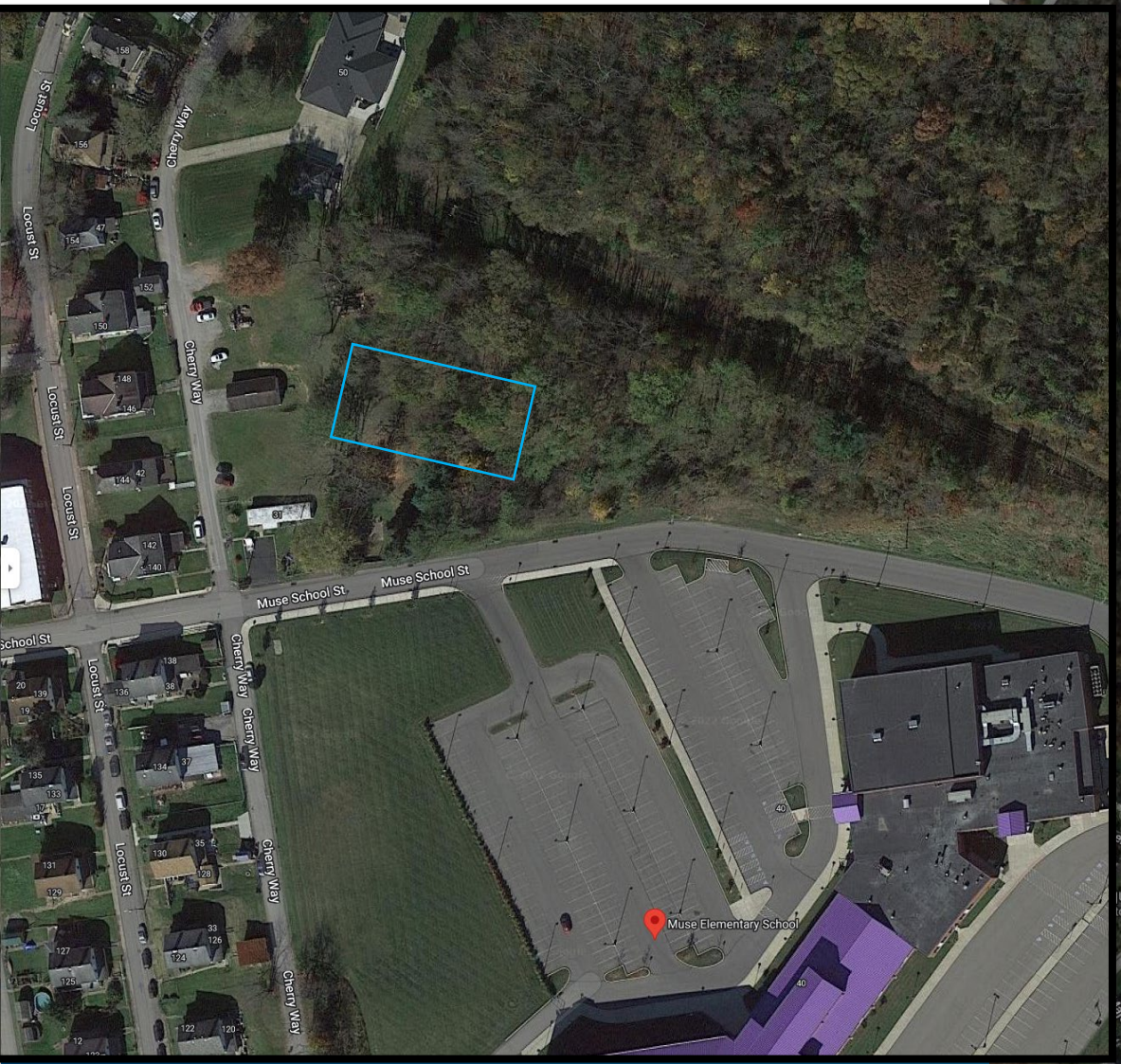
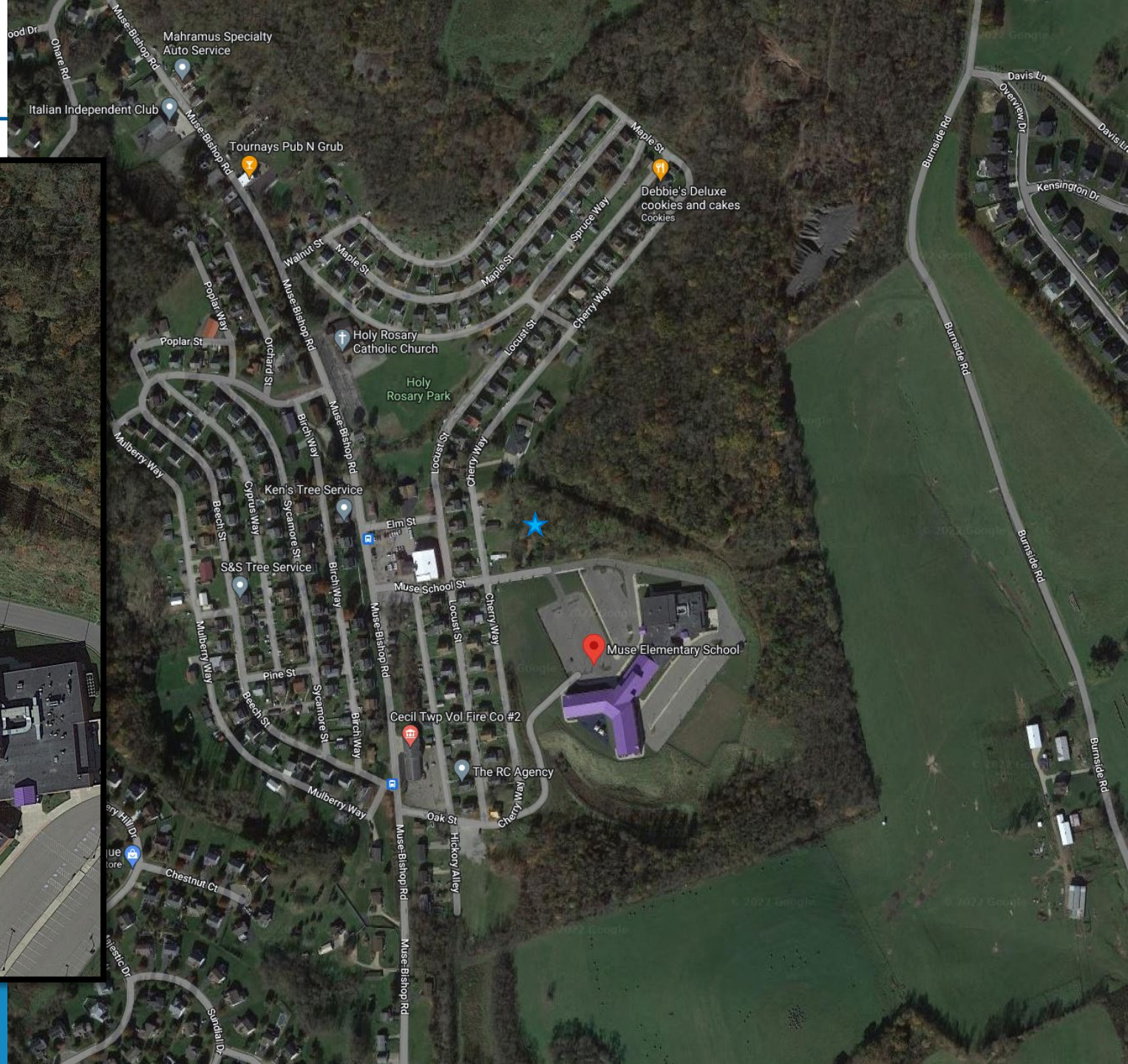
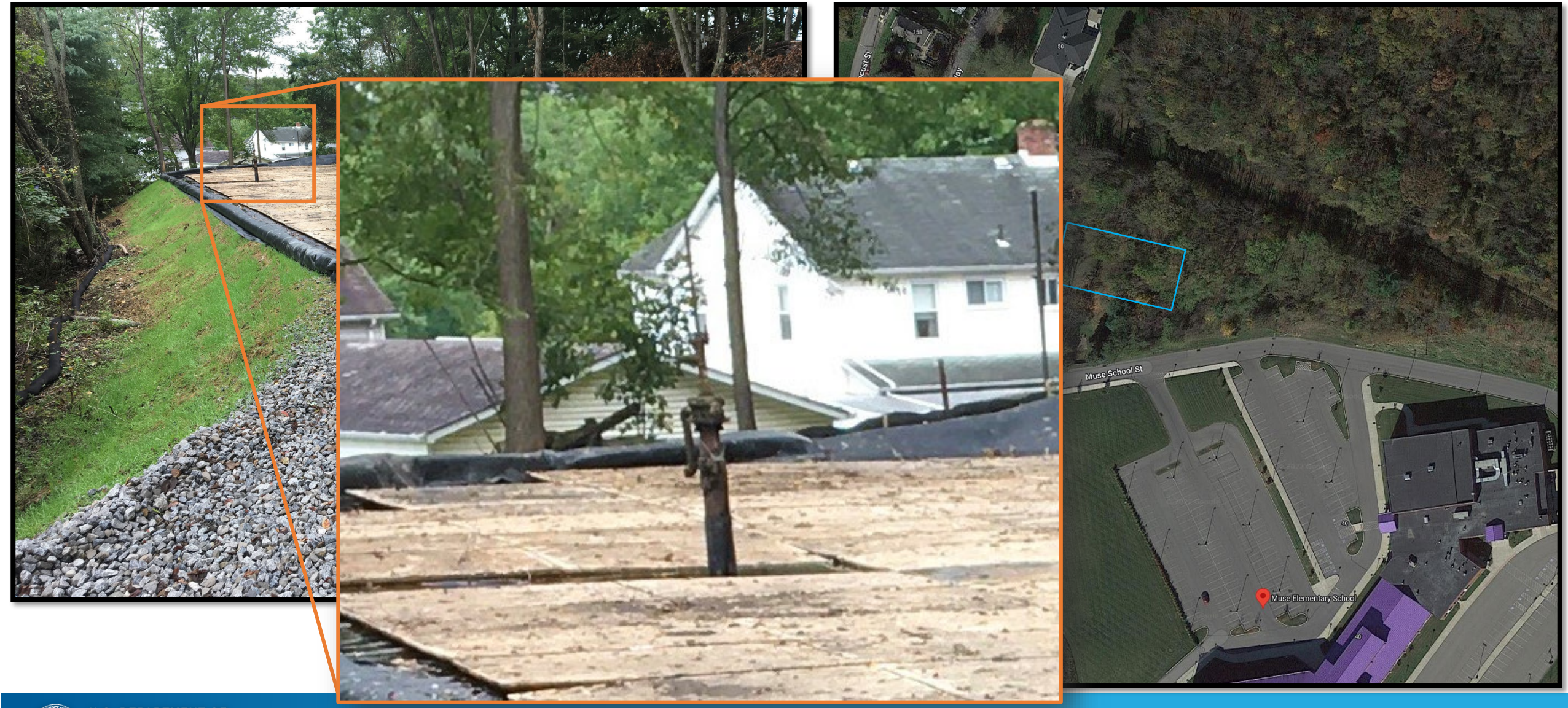
Muse Well #1


Locust St
Cherry Way
Muse School St
Muse Elementary School


Mahramus Specialty Auto Service
Italian Independent Club
Tournays Pub N Grub
Debbie's Deluxe cookies and cakes
Cookies
Holy Rosary Catholic Church
Holy Rosary Park
Ken's Tree Service
S&S Tree Service
Muse Elementary School
Cecil Twp Vol Fire Co #2
The RC Agency
Muse-Bishop Rd
Burnside Rd
Davis Ln
Kensington Dr
Overview Dr
Maple St
Walnut St
Spruce Way
Poplar St
Poplar Way
Orchard St
Birch Way
Elm St
Pine St
Oak St
Mulberry Way
Cyprus Way
Sycamore St
Beech St
Hickory Alley
Chestnut Ct
Locust St
Cherry Way
Muse School St

Muse Well #1



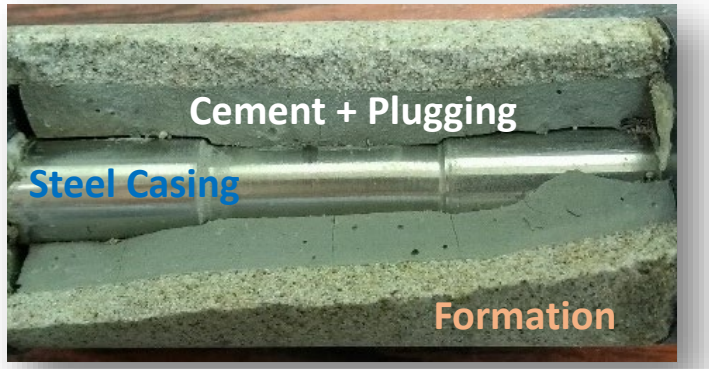
Muse Well #1

Type IL Cement

Summary

Recommendations for New Procedure/Code Requirements

- Brine water in the well should not impact bentonite plug unless thoroughly mixed with bentonite – e.g. in mix water (powdered, Quick Grout, Ben Seal).
- Provided suggestions for bentonite concentration and process changes.
- Currently quantifying instability region for bentonite dispersions.
- Density, viscosity, and injection rate were studied with simulations
  - Density is a parameter that showed the greatest effect



Experimental setup for CT scanner

Take Away – Spacer materials can be used in non-producing zones to plug wells if the properties are sufficient to provide effective and efficient fluid isolation.

Outreach

Technology Transfer and Workforce Development

- Garcia Verdugo, Carlos A.; Rosenbaum, E.; Spaulding, R.; Haljasmaa, I.; Sharifi, N.; Vandenbossche, A.; Iannacchione, A.; Brigham, J.; "Numerical Approach to Simulate the Behavior of Wellbore Plugging Materials", TBD, 2022.
- I. Haljasmaa, E. Rosenbaum, Spaulding, Mackey, McElroy, "Study of Concentration and Added Salt on the Instability of Bentonite Mixes Used for Plugging Oil and Gas Wells", NETL Technical Report Series, 2022.
- McElroy, Rosenbaum, "A Review of Present and Emerging Technologies Useful for Permanent Wellbore Plugging & Abandonment in Pennsylvania", Review paper, invited Special Issue of Energies.
- Garcia, Rosenbaum, Vandenbossche, Iannacchione, Sharifi, Brigham, "A Numerical Investigation of Well Plugging Scenarios Using the Lattice Boltzmann Method", EMI 2022, Baltimore, MD, May 31-June 3, 2022.
- Rosenbaum, Well Plugging materials research to ensure plugging effectiveness, DOE-NETL Briefings to BSEE/BOEM Webinar 2: Well Integrity, August 1, 2022.
- Rosenbaum, "Well Plugging Materials Research: To Ensure Plugging Effectiveness of Onshore Wells", AAAS EPI Center Orphaned and Abandoned Wells Working Group, September 22, 2022.

thank you

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