Microbially-Induced Desaturation (MID) for Liquefaction Mitigation of Low Plasticity Silts – Portland Field Trials Longevity & Retreatment

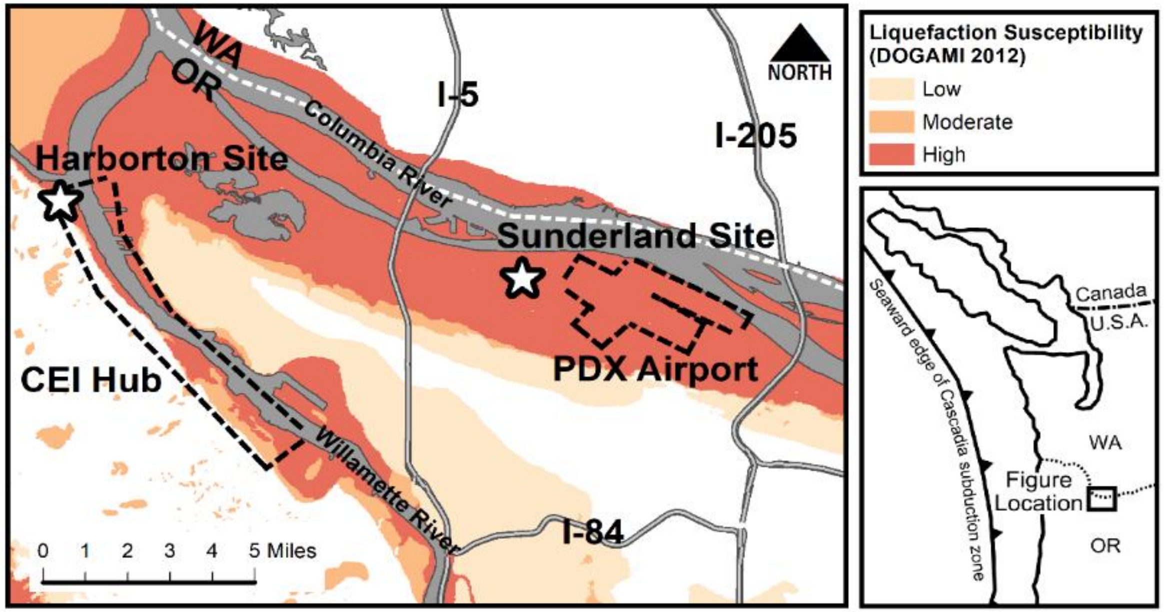
Diane Moug, Ph.D., Portland State University
Arash Khosravifar, Ph.D., P.E., Portland State University
Aaron Gallant, Ph.D., P.E., University of Maine
Luis Zambrano-Cruzatty, Ph.D., University of Maine
Leon van Paassen, Ph.D., Arizona State University

NHERI@UTexas Workshop, Portland, Oregon
September 11, 2025

Project Background

- Microbially induced desaturation (MID) field trials of MID at two sites in Portland in 2019
- Financial and in-kind contributions from the National Science Foundation and industry collaborators
- Both sites were successfully desaturated after three weeks of MID treatment injection
- Longterm monitoring at the Sunderland site indicated re-saturation five years after treatment

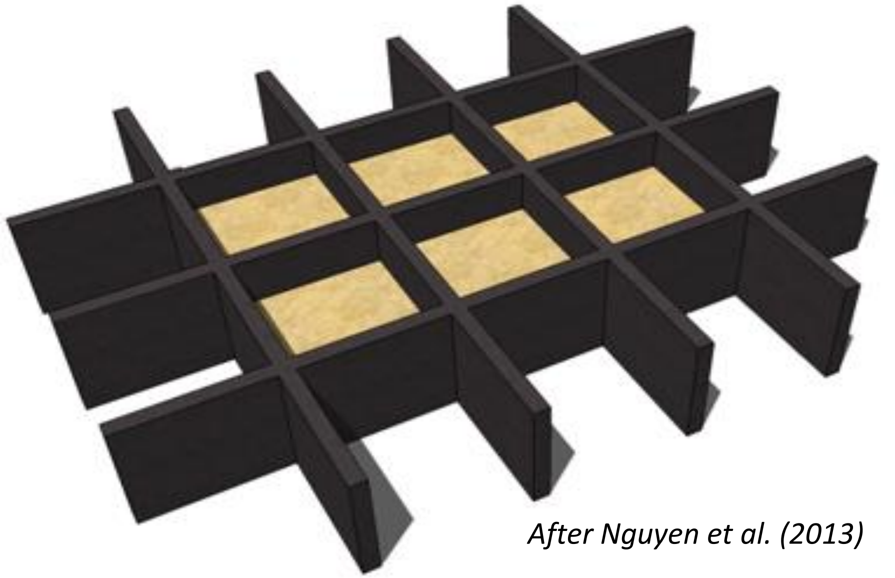
Can an MID site be successfully re-treated for maintenance of S_r reductions?



CMMI-1935670, -2242227

Mitigation of Liquefiable Fine-grained Soils

- Extensive deposits of liquefiable silt soils in Portland and the Pacific Northwest
- Common method for mitigating silt soils is deep soil cement mixing in a grid pattern



After Nguyen et al. (2013)

From Condon Johnson Associates

- This method is infeasible for application beneath existing structures.

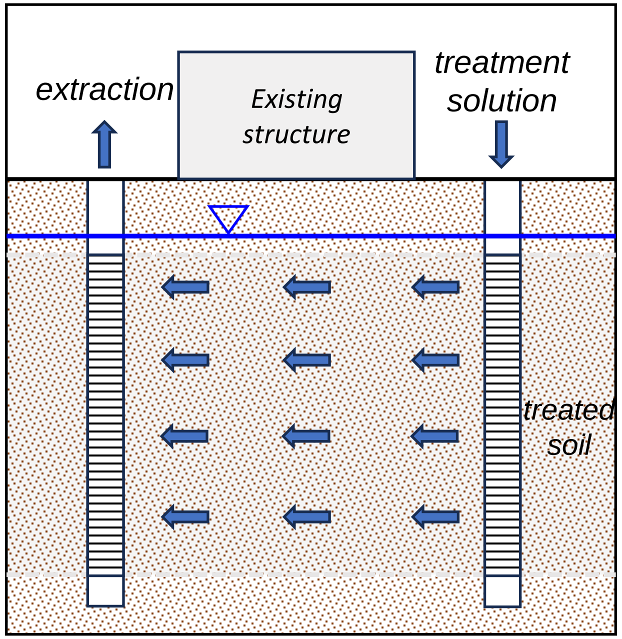
There do not exist economical methods for mitigating liquefiable silt soils beneath existing structures

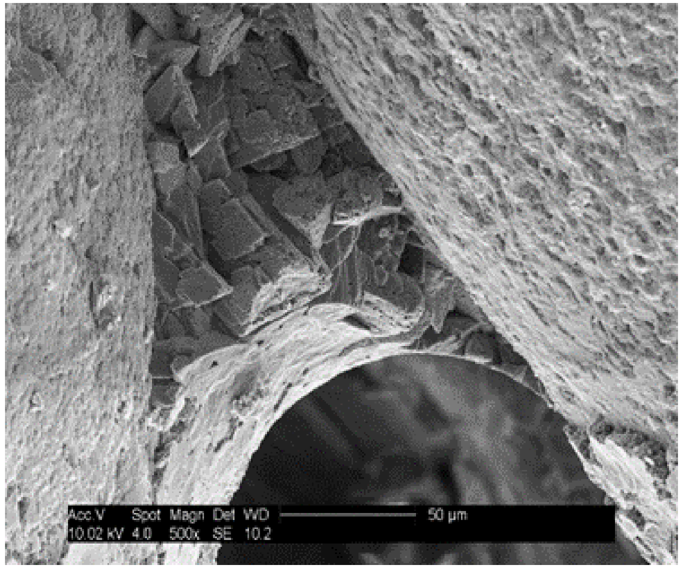
Microbially Induced Desaturation for Liquefaction Mitigation

- Potential for non-invasive treatment beneath existing structures
- Introduce treatment solution via injection to stimulate native denitrifying microbes
- Denitrification results in nitrogen and CO_2 gas which desaturate the soil

General Treatment Procedure

1. *Mix the nutrients with extracted groundwater*
2. *Inject the solution back into the ground*
3. *Wait until conversion is finished*
4. *Repeat until you reach target performance*



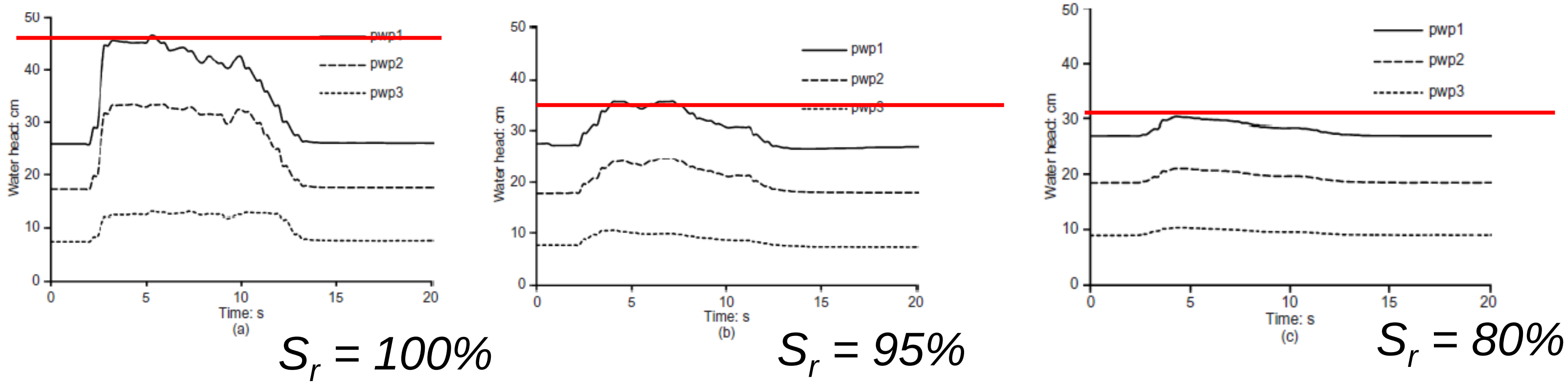


SEM image of gas bubble remnant (O'Donnell et al. 2017)

Portland State University

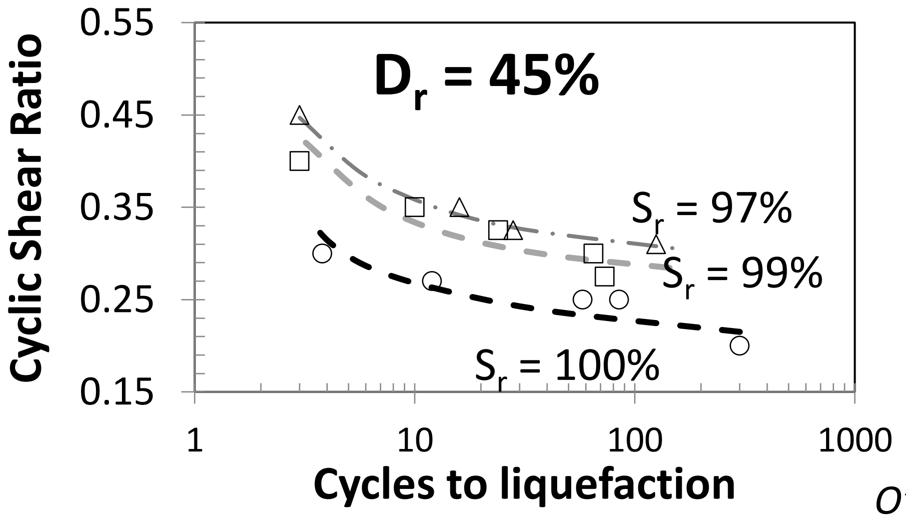
A small reduction in saturation reduces liquefaction susceptibility

- Reduced porewater pressure buildup:



He et al. (2013) shake table tests on loose sand

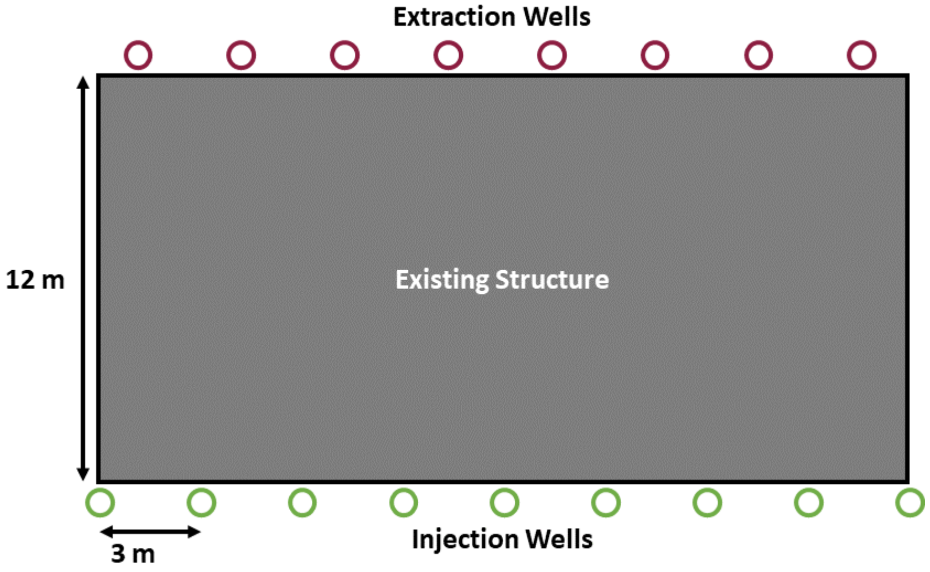
- Increased CRR:



O'Donnell et al. (2017)

MID is an economic alternative to other ground improvement approaches for existing structures

MID Treatment		Jet Grouting	
Well Installation	per well	**Sleeve Port Pipe Installation**	per sleeve port pipe
Installation equipment and labor	$1,500	Installation equipment and labor	$1,036
Construction Materials	$856	Construction Materials	$706
Permitting	$285	Permitting	$145
Overhead and Markup	$660	*Overhead and Markup*	$472
Well Installation Total	$56,111	***Well Installation Total***	$80,225
Treatment Materials	kg/m^3 MID solution	**Treatment Materials**	kg/m^3 grout injection
Calcium Nitrate	$2.34	Microfine Cement	$290
Calcium Acetate	$4.43		
Overhead and Markup	$1.69	*Overhead and Markup*	$73
Treatment Materials Total	$6,043	***Treatment Materials Total***	$258,625
Injection	per hour	**Injection**	per hour
Equipment and labor	$259	Equipment and labor	$413
Overhead and Markup	$65	*Overhead and Markup*	$103
Injection Total	$84,723	***Injection Total***	$215,923
Mobilization and Demobilization	Project total	**Mobilization and Demobilization**	Project total
Installation	$5,611	Installation	$8,023
Treatment	$9,077	Treatment	$47,455
Decommissioning	$14,500		
Mobilization and Demobilization Total	$17,188	***Mobilization and Demobilization Total***	$55,477
Project Total	$176,064	**Project Total**	$610,250

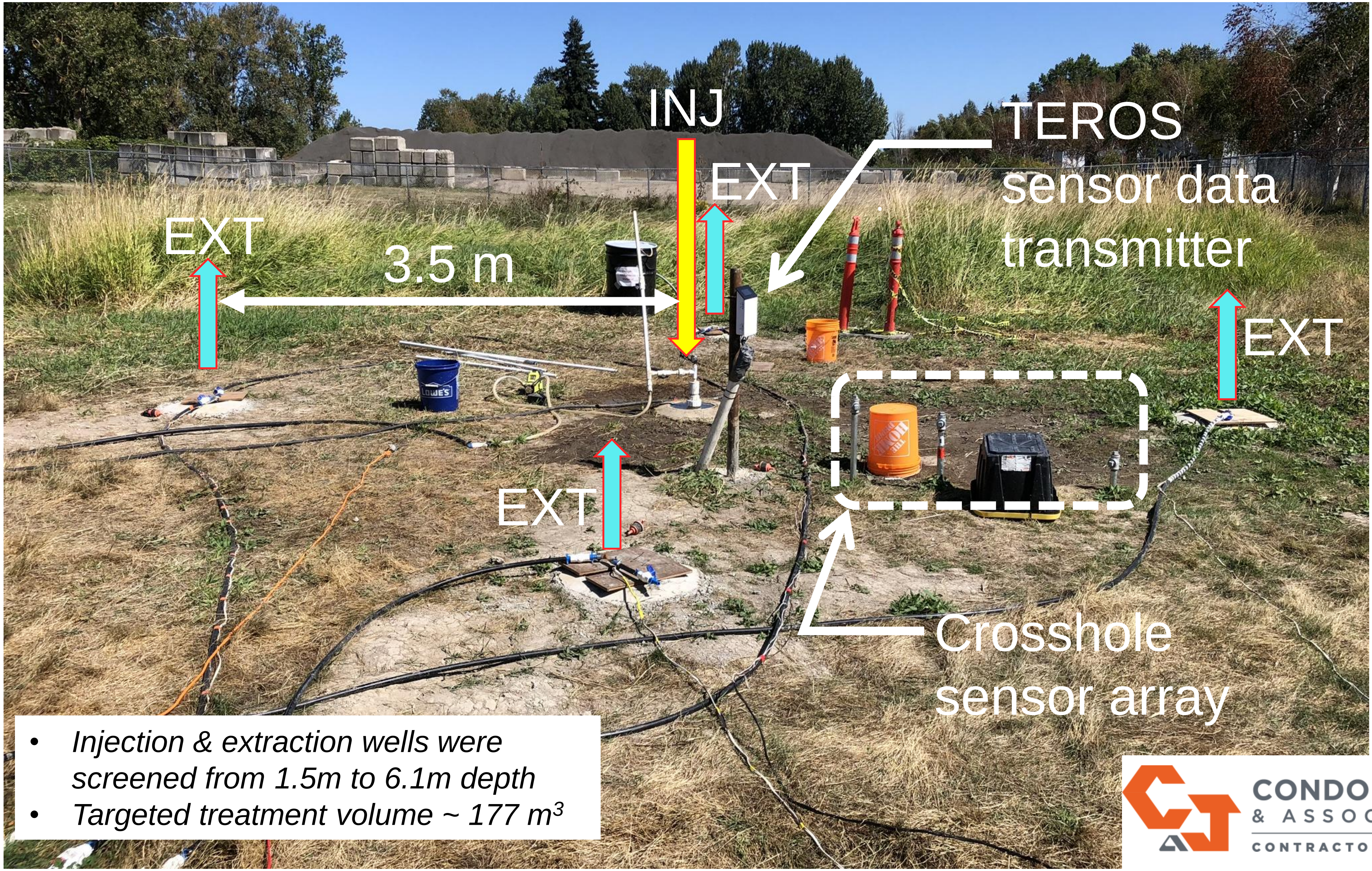


Hall, C.A., van Paassen, L.A., Kamalzare, S., Parmantier, D. and Kavazanjian E. (2022), Techno-Economic Assessment of Liquefaction Mitigation by Microbially Induced Desaturation, In: Proceedings of the ASCE San Fernando Earthquake Conference – 50 Years of Lifelines Engineering

CONDON · JOHNSON & ASSOCIATES, INC. CONTRACTORS AND ENGINEERS

ASU

2019 Sunderland Test Area Setup



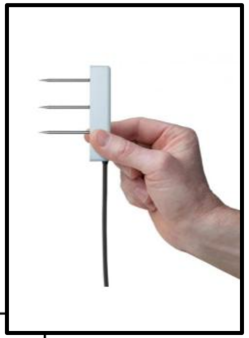
- *Injection & extraction wells were screened from 1.5m to 6.1m depth*
- *Targeted treatment volume ~ 177 m^3*

CONDON · JOHNSON & ASSOCIATES, INC.
CONTRACTORS AND ENGINEERS

Portland State UNIVERSITY

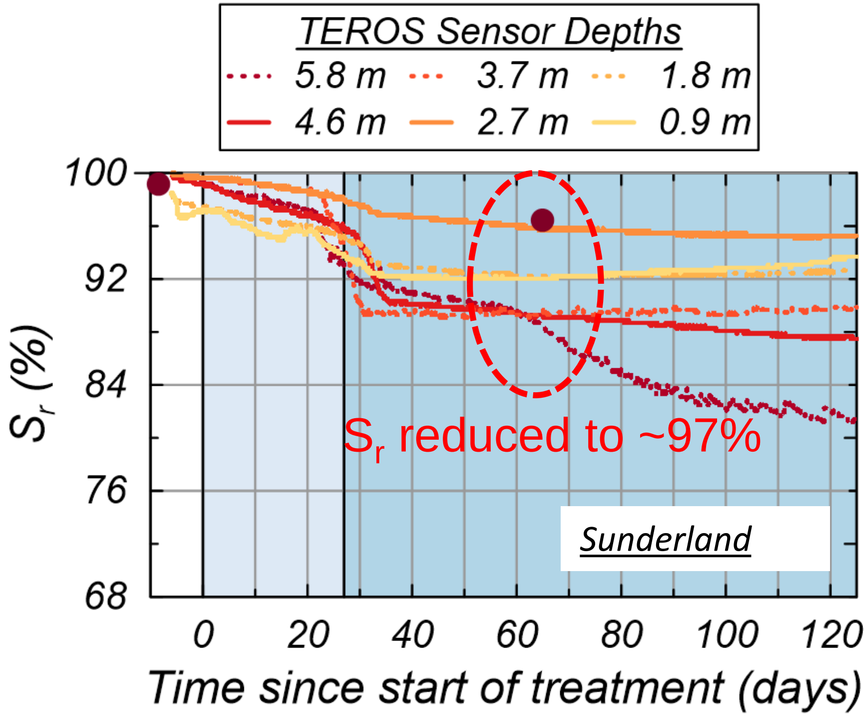
Sensor-detected reduction in Sr in the treatment zone

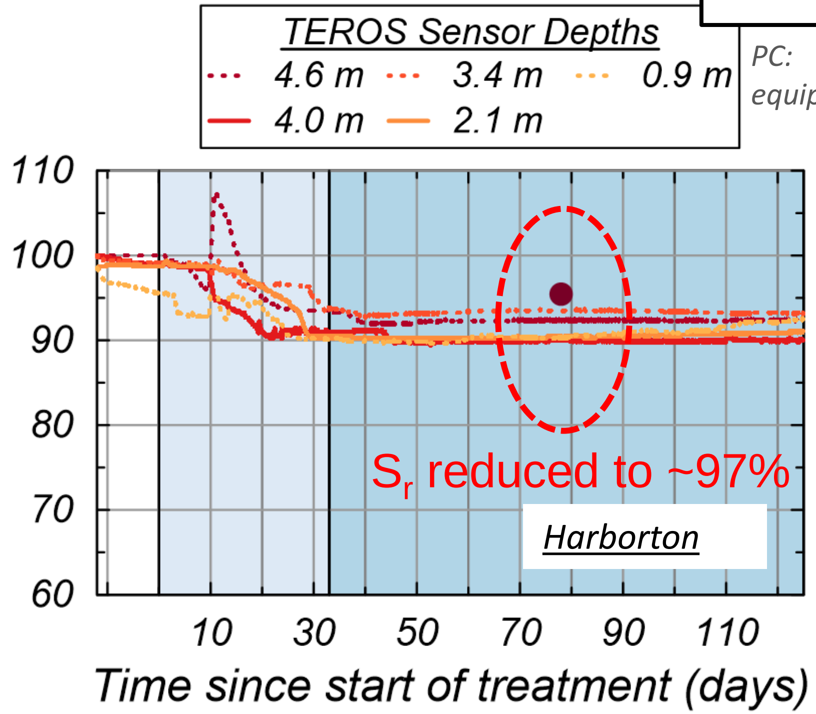
- Reduction in volumetric water content related to S_r
- Measurements on soil samples also support reduction in S_r



PC: equipment.net

metergroup

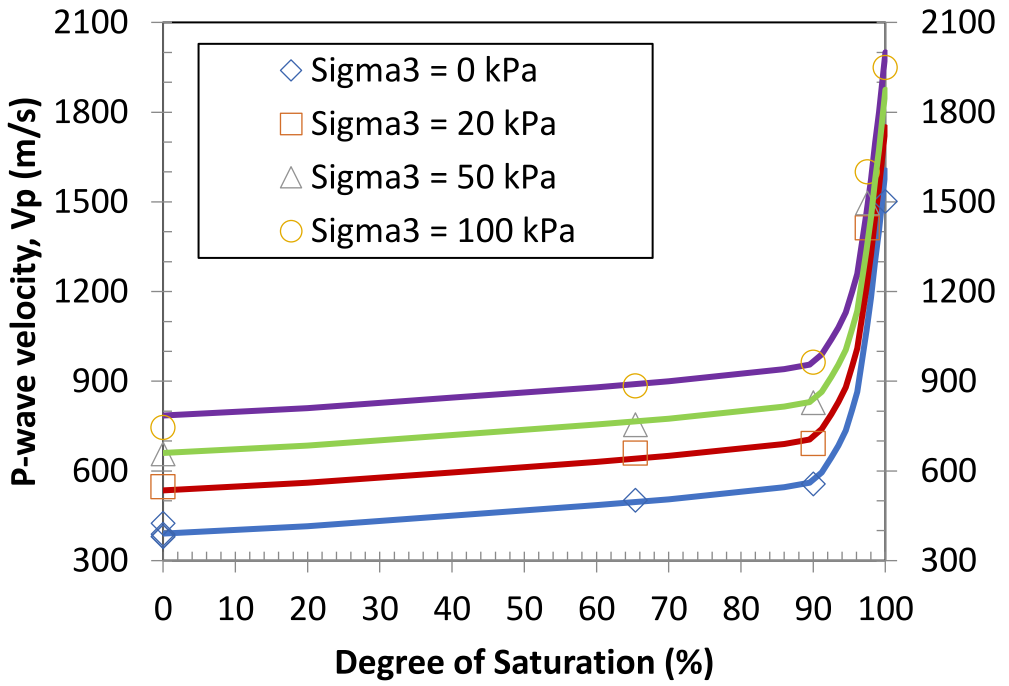




Moug, D.M., Sorenson, K.R., Khosravifar, A., Preciado, M., Stallings Young, E., Van Paassen, L., Kavazanjian Jr, E., Zhang, B., Stokoe, K.H., Menq, F.M. and Wang, Y., 2022. Field trials of microbially induced desaturation in low-plasticity silt. Journal of Geotechnical and Geoenvironmental Engineering, 148(11), p.05022005.

Seismic Pressure Wave Velocity to Monitor S_r

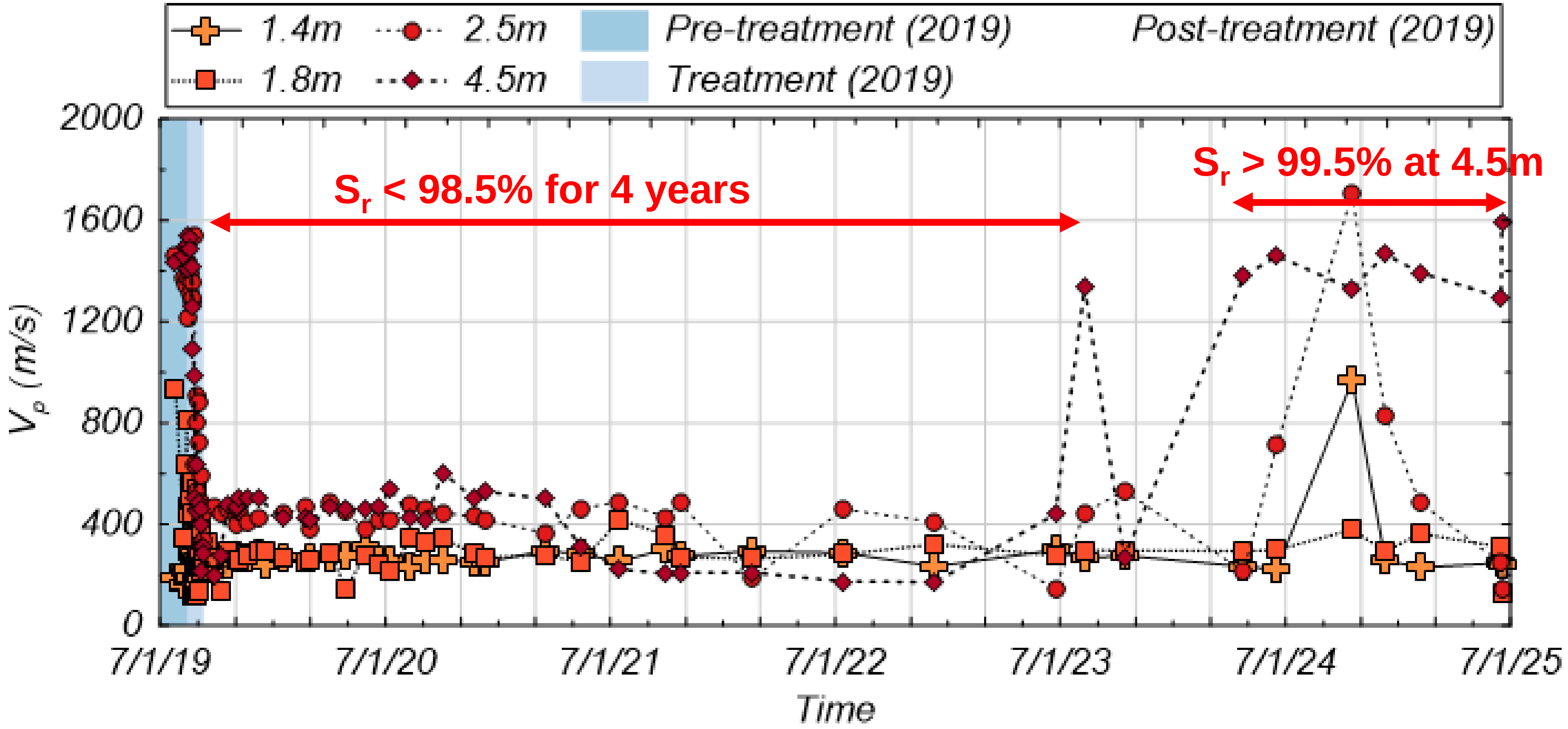
- Pressure wave velocity (V_p) drastically decreases as S_r decreases (Valle-Molina & Stokoe 2012):
  - $S_r > 99.5\%$, $V_p \approx 1600$ m/s
  - $S_r < 98.5\%$, $V_p \approx 400$ m/s



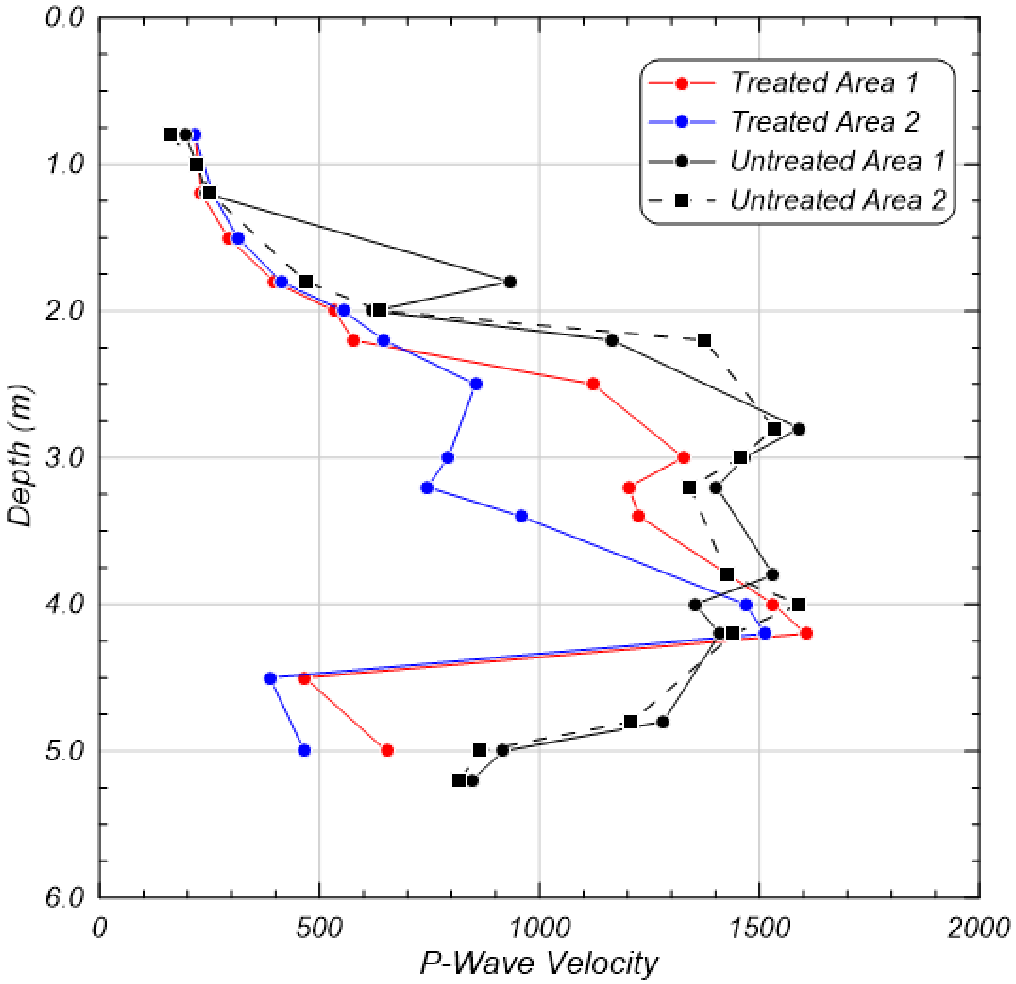
O'Donnell 2016 dissertation (data from Ottawa Sand)

Crosshole V_p values show S_r reductions sustained for about 4.5 years

- Re-saturation at deepest sensor in crosshole array



2024 direct push crosshole V_p measurements indicate re-saturation of treated soils



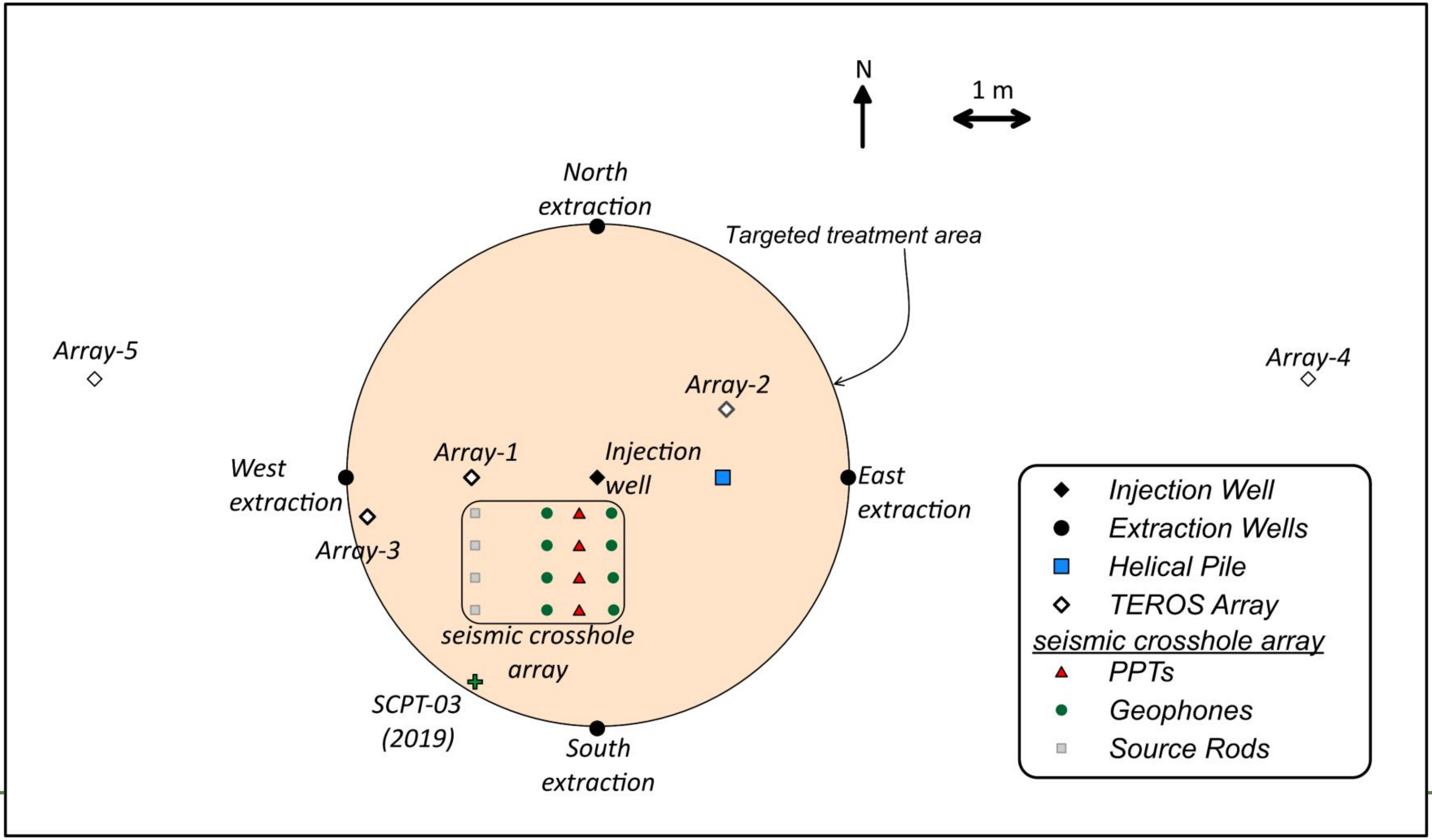
MID Re-Treatment Summer 2025

Can MID treatment be re-applied to maintain S_r reductions?

- Inject 0.12 mol/L calcium nitrate and calcium acetate treatment solution from July 31 to September 5
- Use existing injection and extraction wells

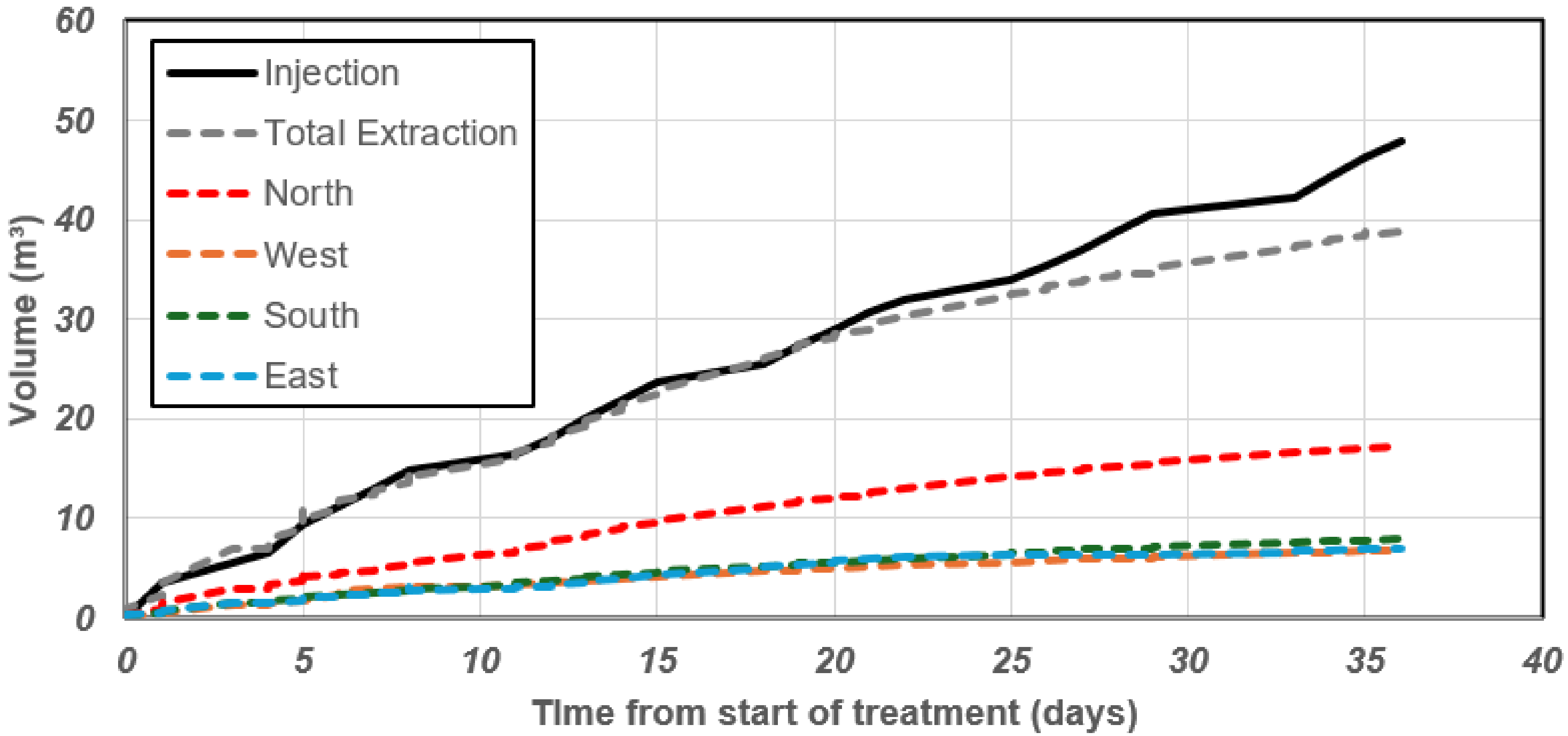
MID Re-Treatment Summer 2025

- Continue crosshole V_p monitoring
- Additional TEROS monitoring arrays
- Monitor injection and extraction rates at each well



Total injection of 60% of treatment zone volume

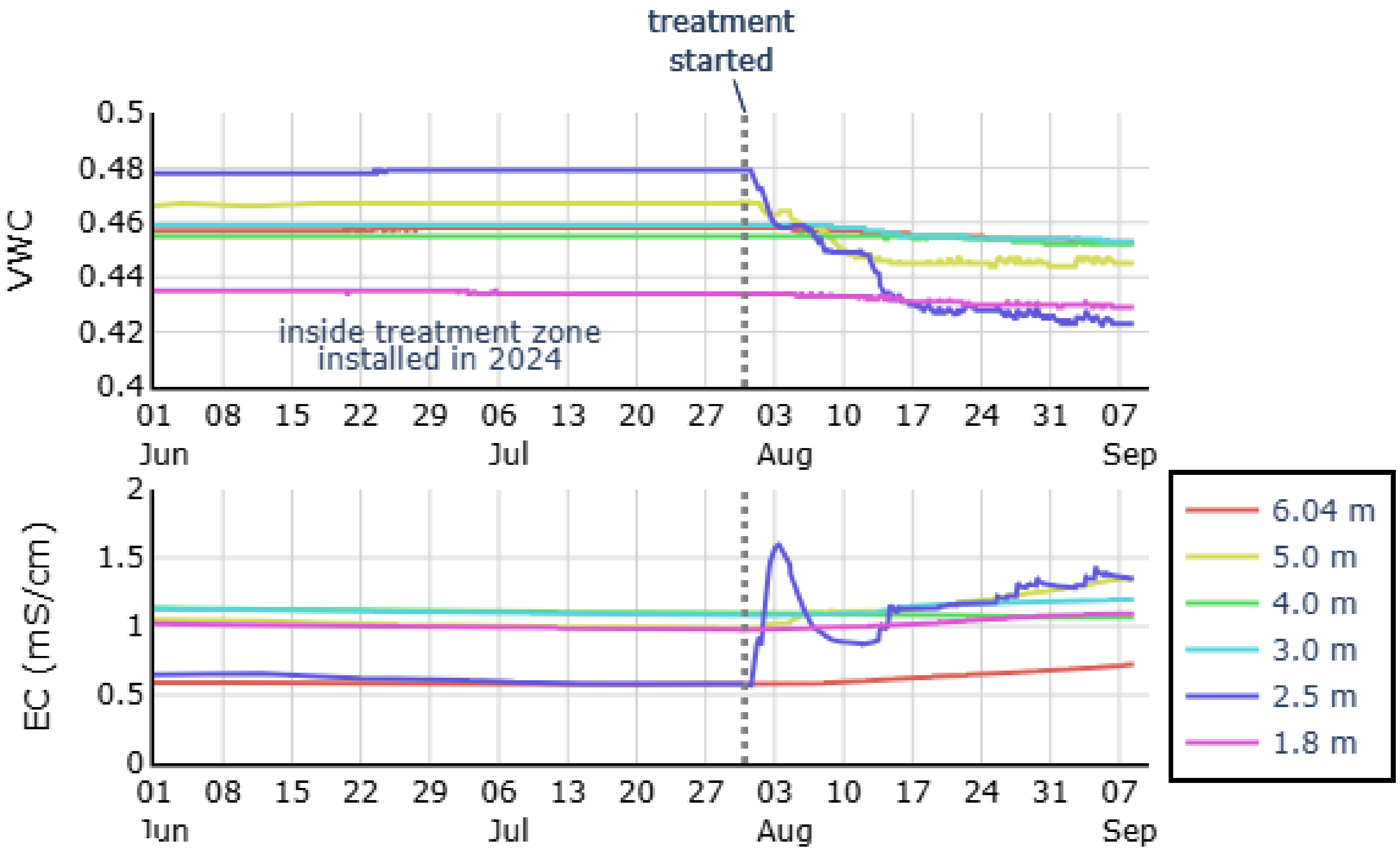
- In total 48 m^3 injected (45% of treatment zone pore volume)
- Extraction wells provided 39 m^3 with allowable water drawdown to 2.0 m
- Injection supplemented with auxiliary groundwater partway through treatment



Portland State University

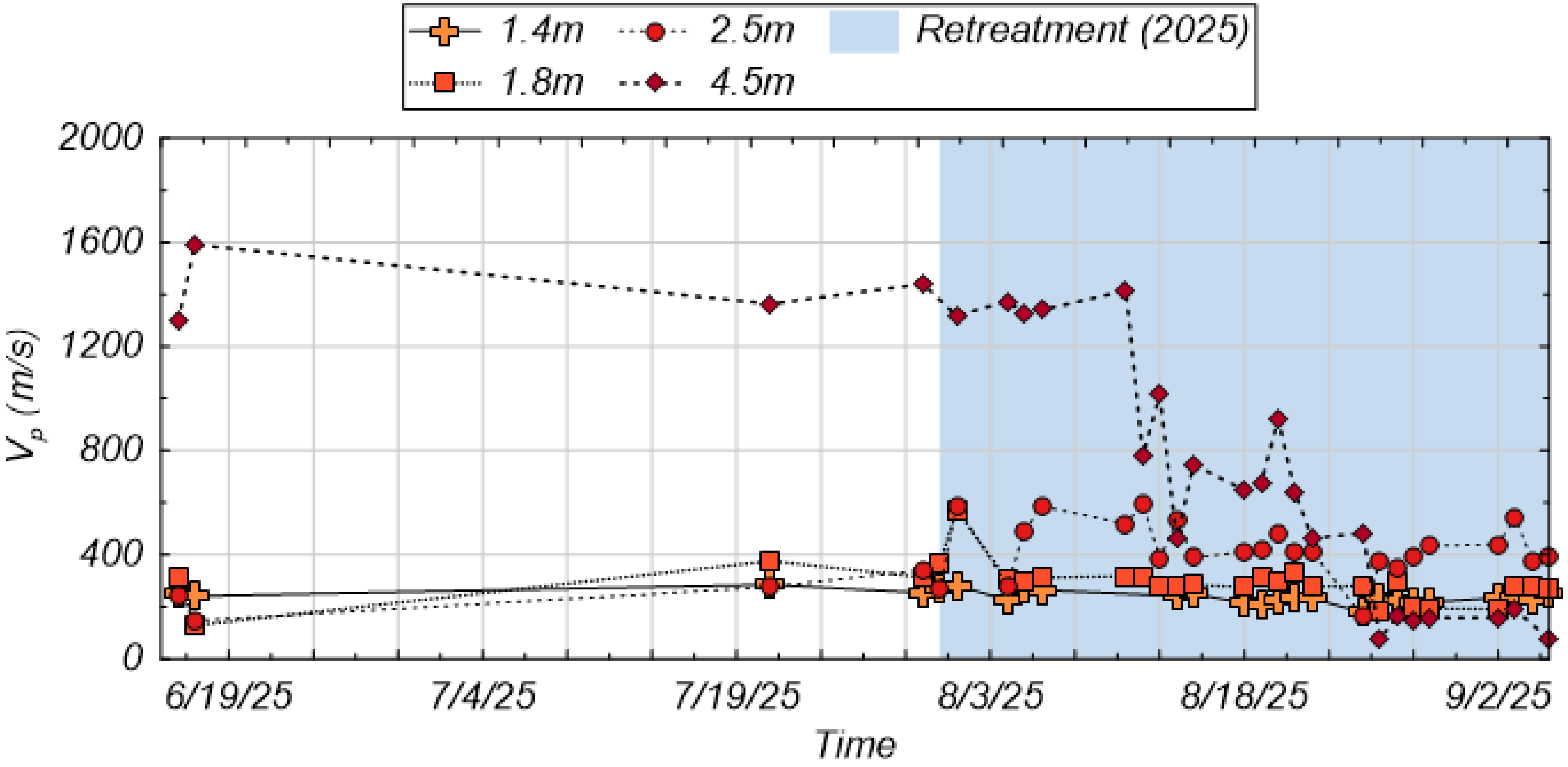
TEROS Monitoring Array-2

- Distribution of treatment solution within treatment zone
- Reduction of volumetric water content



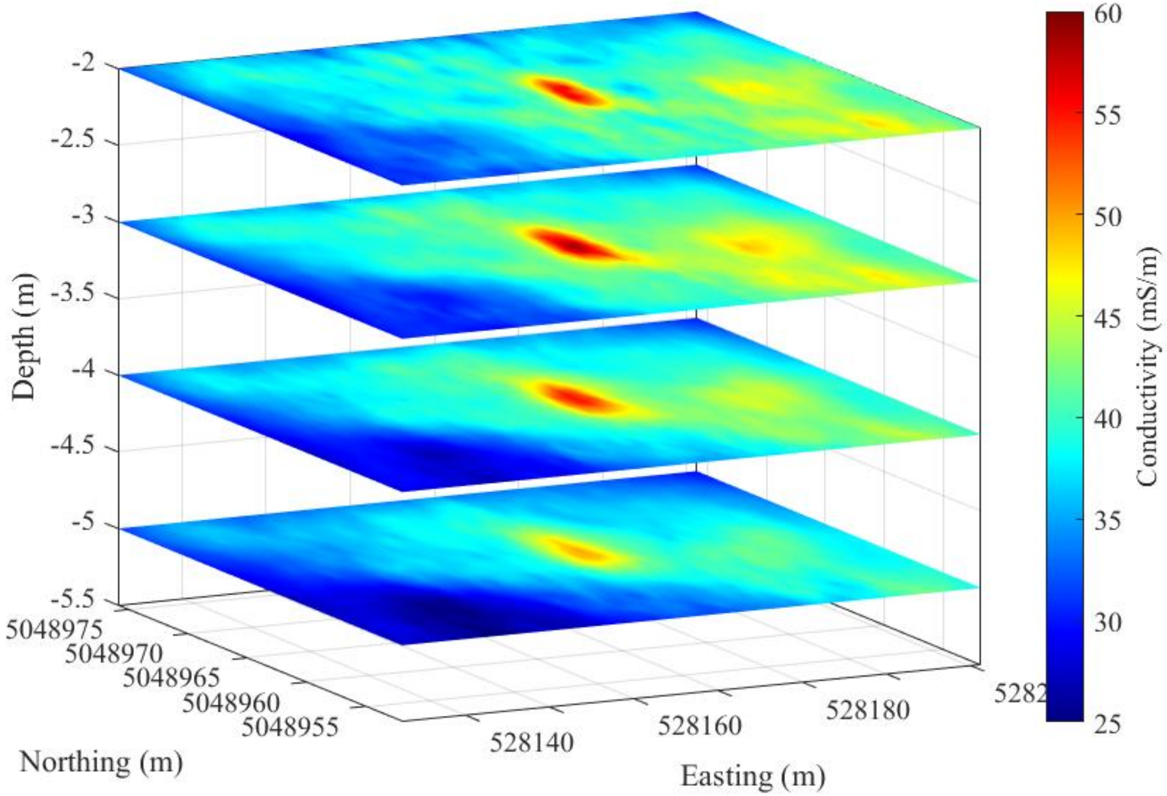
S_r reduced below 98.5% again at seismic crosshole array

- V_p at 4.5 m crosshole returned to ~400 m/s after 15 days of treatment
- V_p at other crosshole depths remain ~200 to 400 m/s
- UTexas V_p at helical pile also shows S_r < 98.5%



Electrical Resistivity Tomography

- ERT surveys performed before, during, and after treatment (ongoing)
- Track changes in electrical resistivity due to treatment solution and biogas
- Monitoring and analysis ongoing



Cordoba-Ordonez, A. et al. GeoCongress 2026. Site Characterization Using Electrical Resistivity Tomography After Microbially Induced Desaturation Treatment

Future and ongoing work

- Enhanced T-Rex testing of the treated soils
  - Are there measurable differences in porewater pressure between natural and treated soils?
- Analyze electrical resistivity tomography (ERT) surveys
  - Track subsurface distribution of treatment solution throughout treatment
- Ongoing V_p and TEROS monitoring
- Future pumping test to examine S_r longevity with induced seepage gradients

Conclusions

- MID is an economical and non-invasive potential ground improvement approach for liquefiable fine-grained soils beneath existing structures
- 2019 Portland field trials show that MID treatment can be effectively applied to fine-grained soils under field conditions
- S_r reductions at the Sunderland site sustained for 4.5 years following treatment
- MID re-treatment effectively restored $S_r < 98.5\%$ at monitored points

Acknowledgements

Graduate/Undergraduate Researchers:

- Kayla Sorenson, Fadzai Zivanai, Iman Ahmad (PSU)
- Andres Cordova, University of Maine
- Andy Gombac, Texas State University
- Joey Coleman, Arizona State University

Additional Support:

- Condon Johnson & Associates, Inc.
- City of Portland
- Stacey Kulesza, Texas State University
- NHERI@UTexas
- ConeTec
- CBBG & ASU
- Oregon Department of Geology and Mineral Industries (DOGAMI)
- Geosyntec Consultants
- Jill Marshall (PSU)
- Andy Siemens (Siemens & Associates)

CMMI-1935670, -2242227

Questions?

Measuring V_p

- Example crosshole Vp for geophone 5&6, located 2.5 m bgs. Distance between geophones = 0.925m.