



# Beyond traditional: Harnessing the power of soil mixing in brownfield remediation



Nathan Coughenour, P.E.  
Martin Pothier, PhD

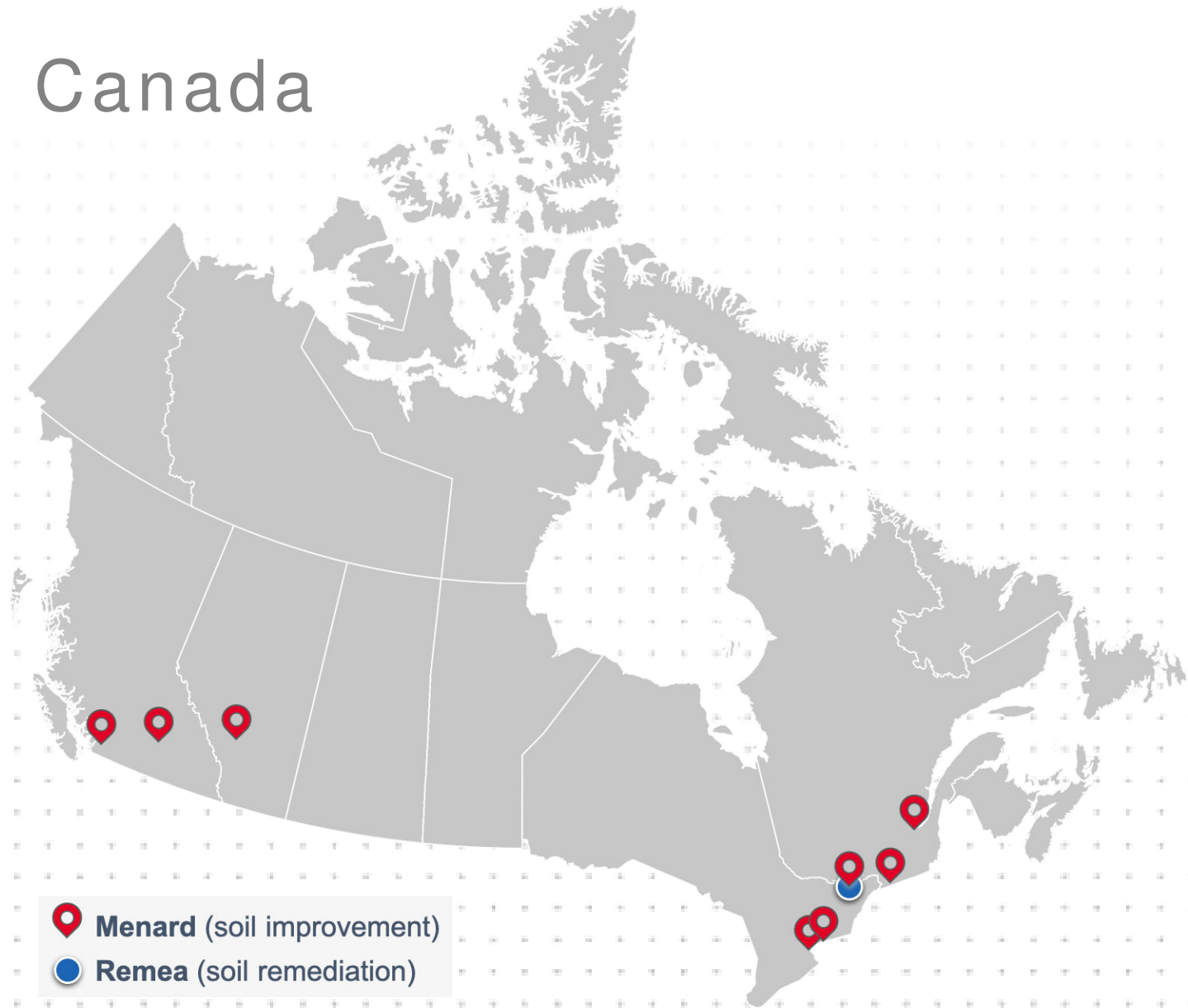
Friday October 13<sup>th</sup>, 2023



# Joining forces across Canada

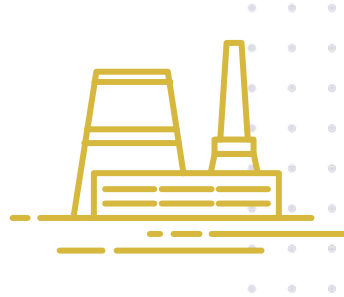
## Remea & Geo-Solutions

- Design-build heavy civil environmental contractors
- Various yard locations in Canada and US
- Access to large pool of equipment & employees
- Collaborated for over 10 years
  - Cut-off walls
  - Soil mixing
  - Geotechnical and geo-environmental applications





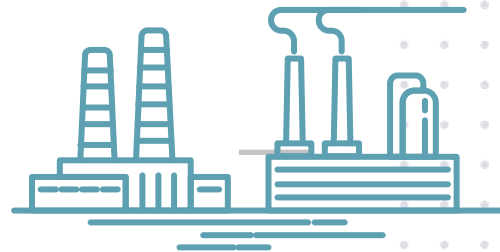
# 01 The Challenge



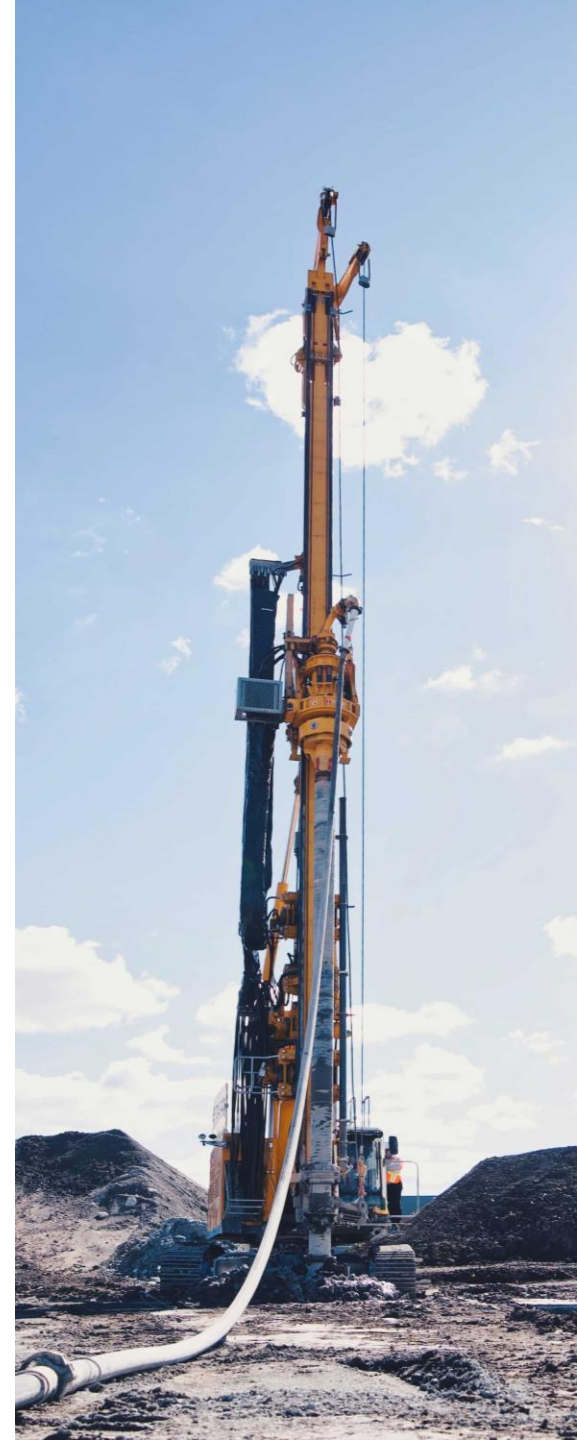
# 02 Implementation



# 03 Case Studies



# 04 Design & QC

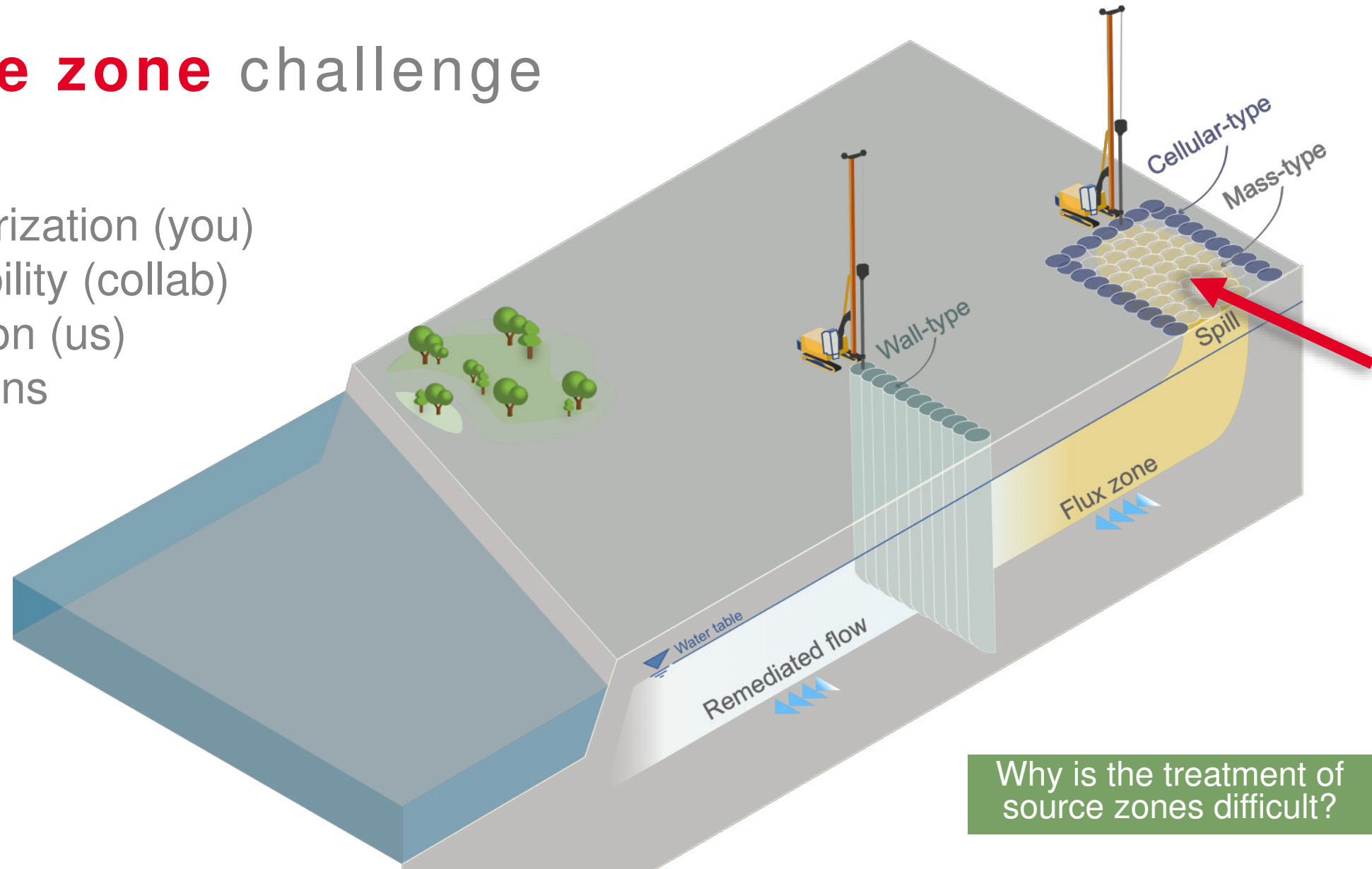


# The Challenge

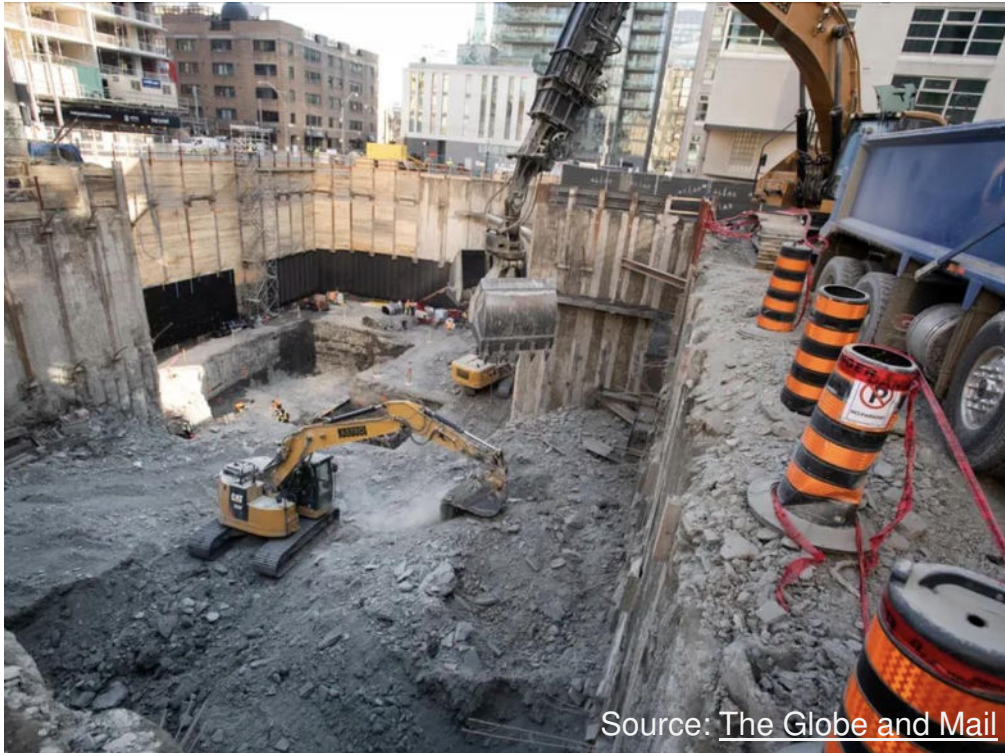


# The **source zone** challenge

- B1. Characterization (you)
- B2. Compatibility (collab)
- B3. Distribution (us)
- B4. Regulations



# Heavy civil **drill rigs**: the game changer



Ramps, pumps, trench support, casting, tracking, ... time.



Treat, ... (stabilize), verify.



# Implementation



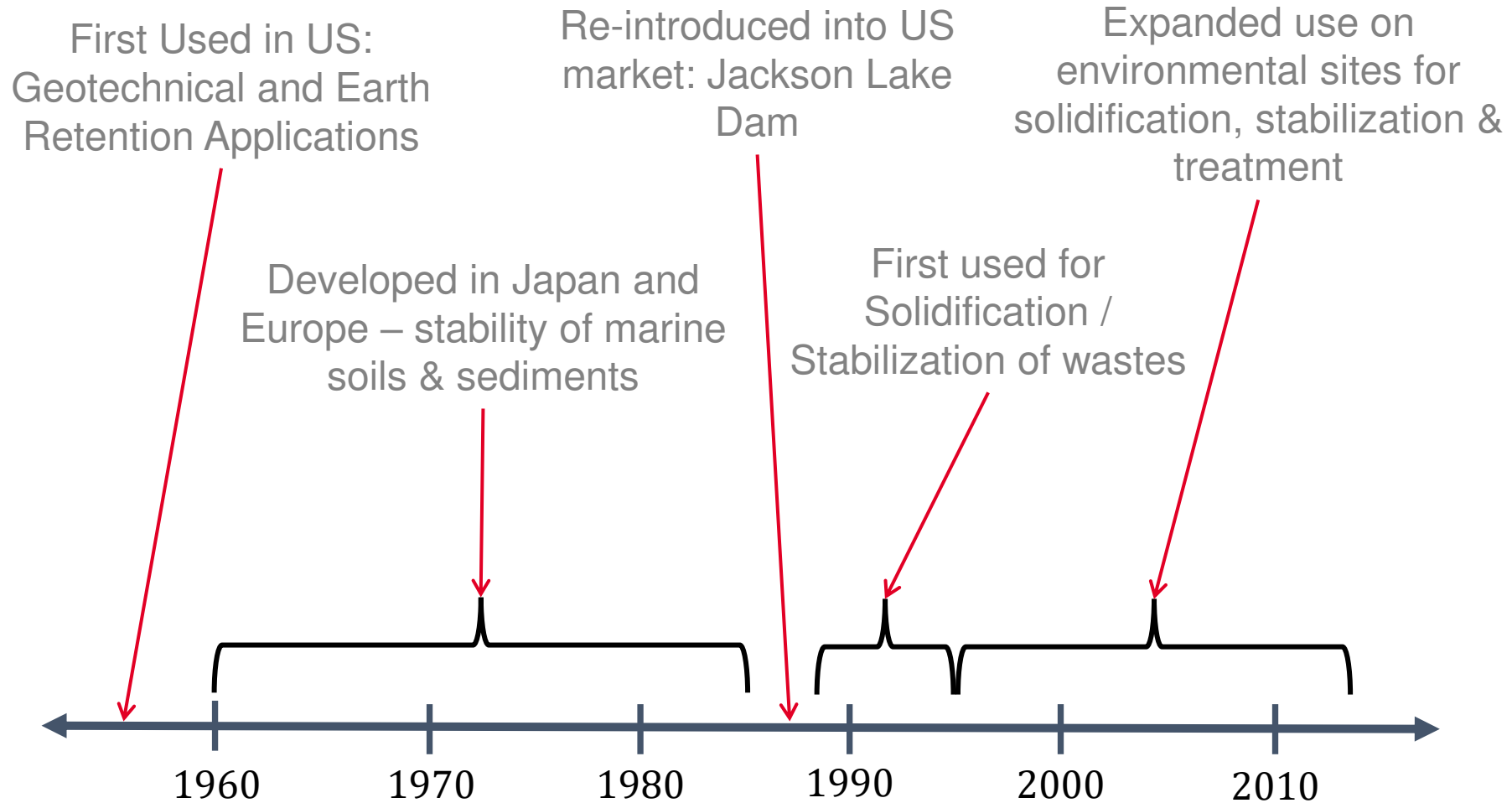
Remea



Geo-Solutions



# Soil mixing has a long **history**



# Soil mixing has a long history

**Soil mixing can be used for:**

**Geotechnical applications**

**...or both...**

**Environmental remediation**

- Ground improvement
- Excavation support
- Liquefaction control

- In-situ solidification (ISS)
- In-situ treatment (or stabilization)

# Equipment from a galaxy far far away



Rotary tool mixing



Single auger drill



Multi auger drill

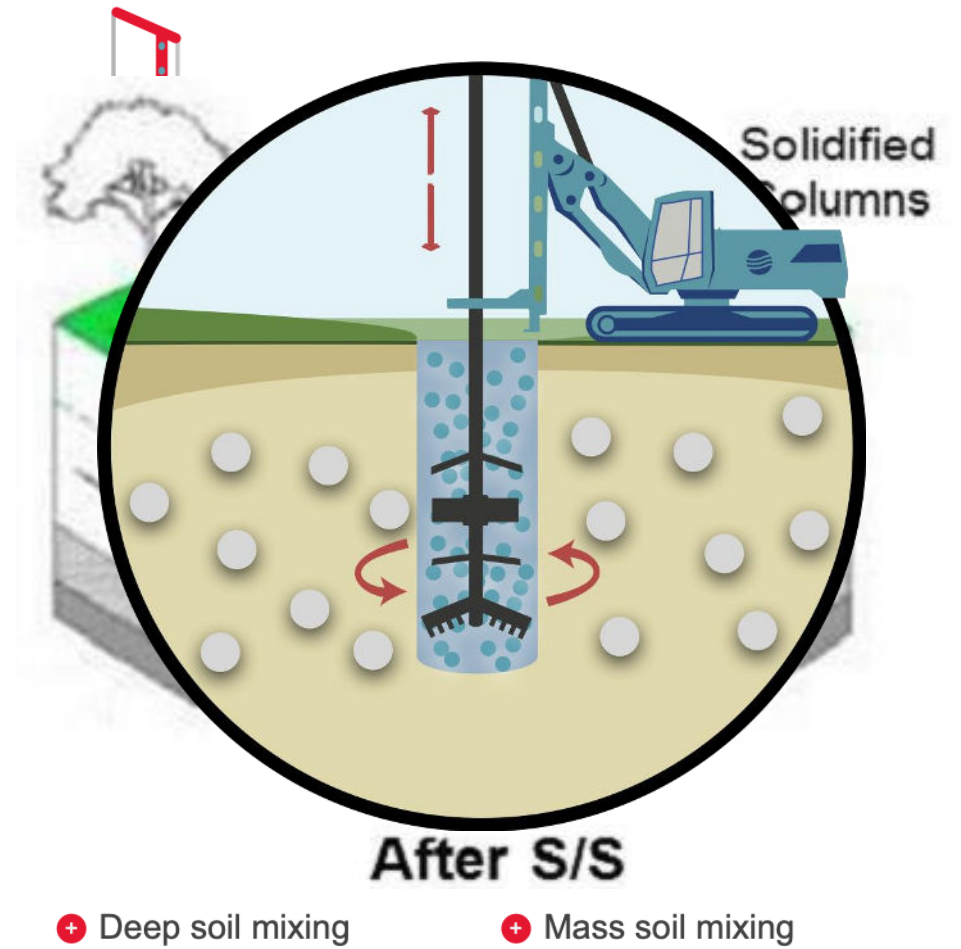


Bucket mixing

# Lots of different ways to **describe** soil mixing

## Acronyms

- Deep Soil Mixing (DSM)
- Shallow Soil Mixing (SSM)
- Stabilization & Solidification (S/S)
- In-Situ Solidification (ISS)
- In-Situ Stabilization (ISS)
  - In-Situ Treatment (IST)
  - In-Situ Chemical Oxidation (ISCO)
  - In-Situ Chemical Reduction (ISCR)



# Case Studies



# ISS: In-Situ Stabilization

Standard UCS = 350 kPA @ 28 days  
Standard permeability =  $1 \times 10^{-6}$  cm/s @ 28 days



Reaction time: days to weeks

## Original site use:

- Wood Treating
- Virginia, USA

## Contaminant of Concern

- Creosote, PAH, PCPs, Dioxins, Heavy metals

## Treated Volume Dimensions

- 40,000 m<sup>3</sup>
- Up to 9 m BGS

## Reagents

1. Portland Cement
2. Slag Cement
3. Organophilic Clay

# ISCO: In-Situ Chemical Oxidation

## Original site use:

- Glassware manufacturing
- New Jersey, USA

## Contaminant of Concern

- TCE and related by-products

## Treated Volume Dimensions

- 6,000 CMs – treated twice
- Up to 6m BGS

## Reagents

1. Potassium Permanganate
2. Portland Cement (applied 3 days post oxidation)



Reaction time: hours to days

# ISCO / ISS: Combination

## Original site use:

- Confidential
- Eastern USA

## Contaminant of Concern

- Chlorobenzene

## Treated Volume Dimensions

- 10,000 m<sup>3</sup>
- Up to 22 m BGS (clay)

## Reagents

1. Sodium persulphate
2. Portland cement



Odor control foam  
(not PFAS)

Reaction time: 99% within hours



# ISCR: In-Situ Chemical Reduction

## Original site use:

- Dry Cleaner
- Indiana, USA

## Contaminant of Concern

- TCE, PCE

## Treated Volume Dimensions

- 6,000 CMs
- Up to 10 m BGS

## Reagents

1. Zero valent Iron (ZVI)
2. Bentonite Clay



Reaction time: weeks to months

# Steam enhanced soil mixing

Thermal remediation via hot air / steam to volatilize and capture contaminants onto a filter. Commonly used for chlorinated solvents.

## Original site use:

- Chemical Manufacturing
- New York, USA

## Contaminant of Concern

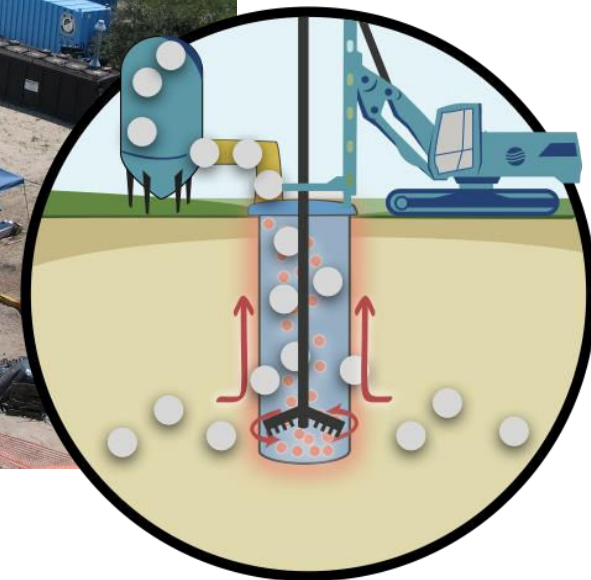
- Acetone

## Treated Volume Dimensions

- 18,000 CMs
- Up to 30' BGS

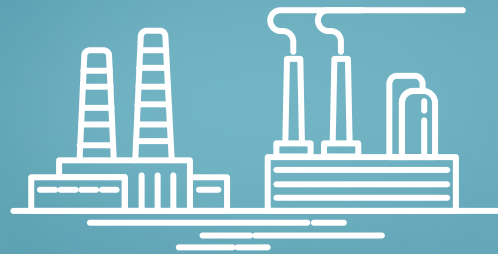
## Reagents – Post steam mixing

1. Ammonium Sulfate
2. Potassium Chloride
3. Phosphoric Acid
4. Calcium Peroxide



Reaction time: minutes to hours

# Soil Mixing Design & QC

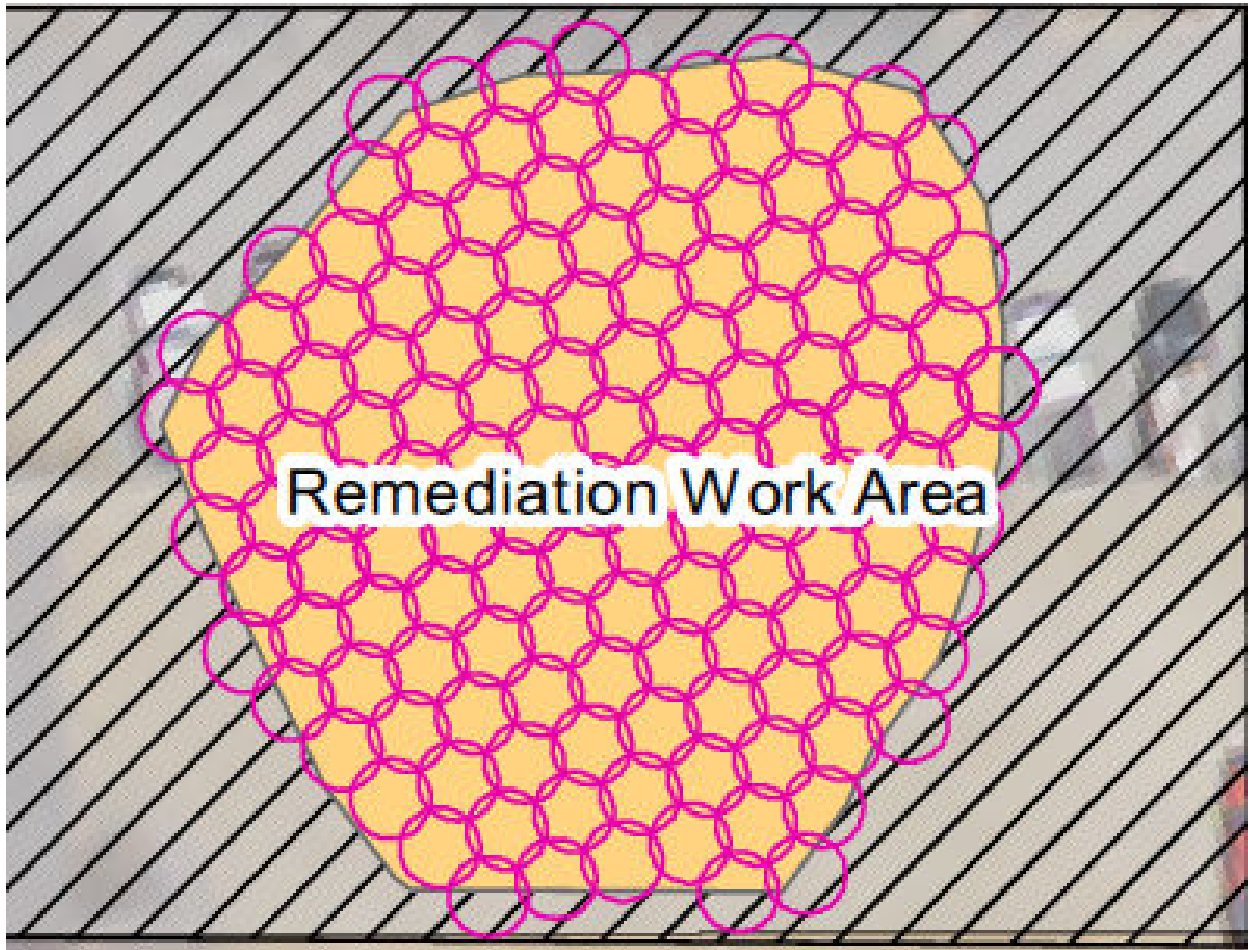


Remea



Geo-Solutions

# Complete coverage of source zone



## Overlapping honeycomb pattern

- 100% source zone treatment

# Client-defined usability of the site post-treatment



Usable site

## ISCO

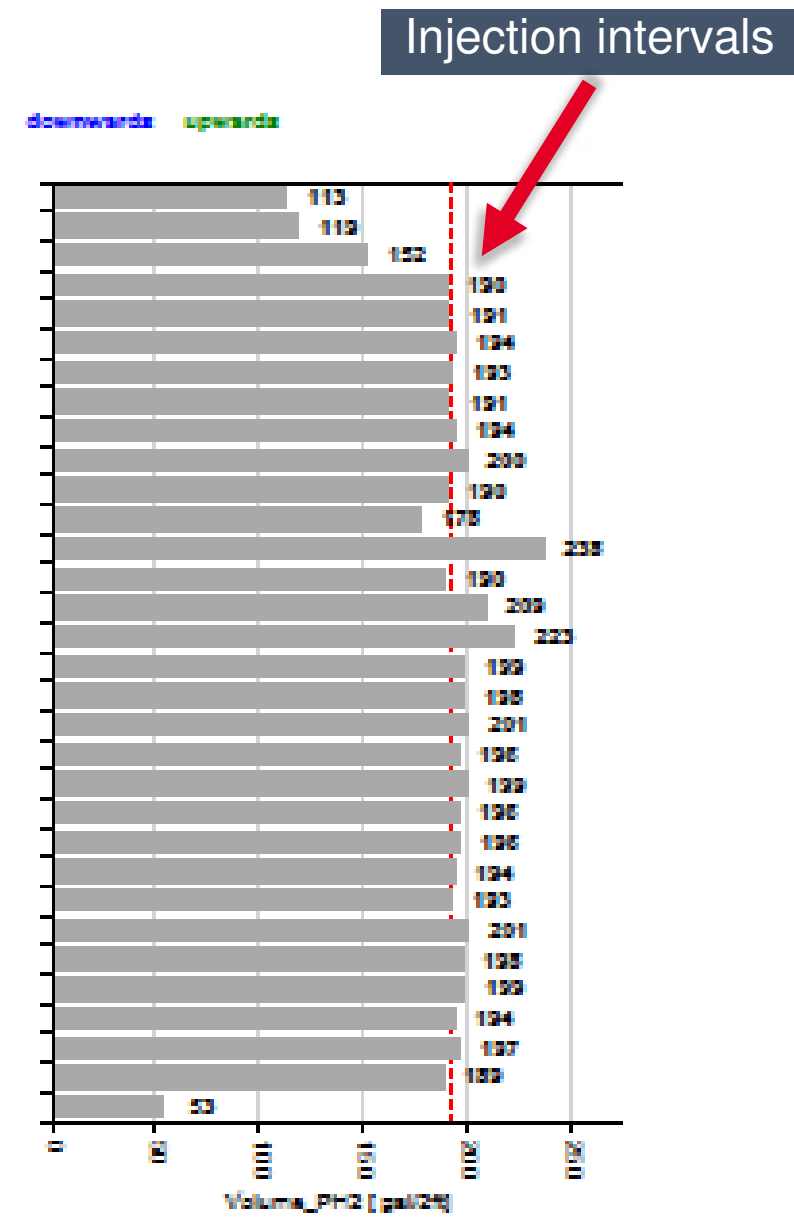
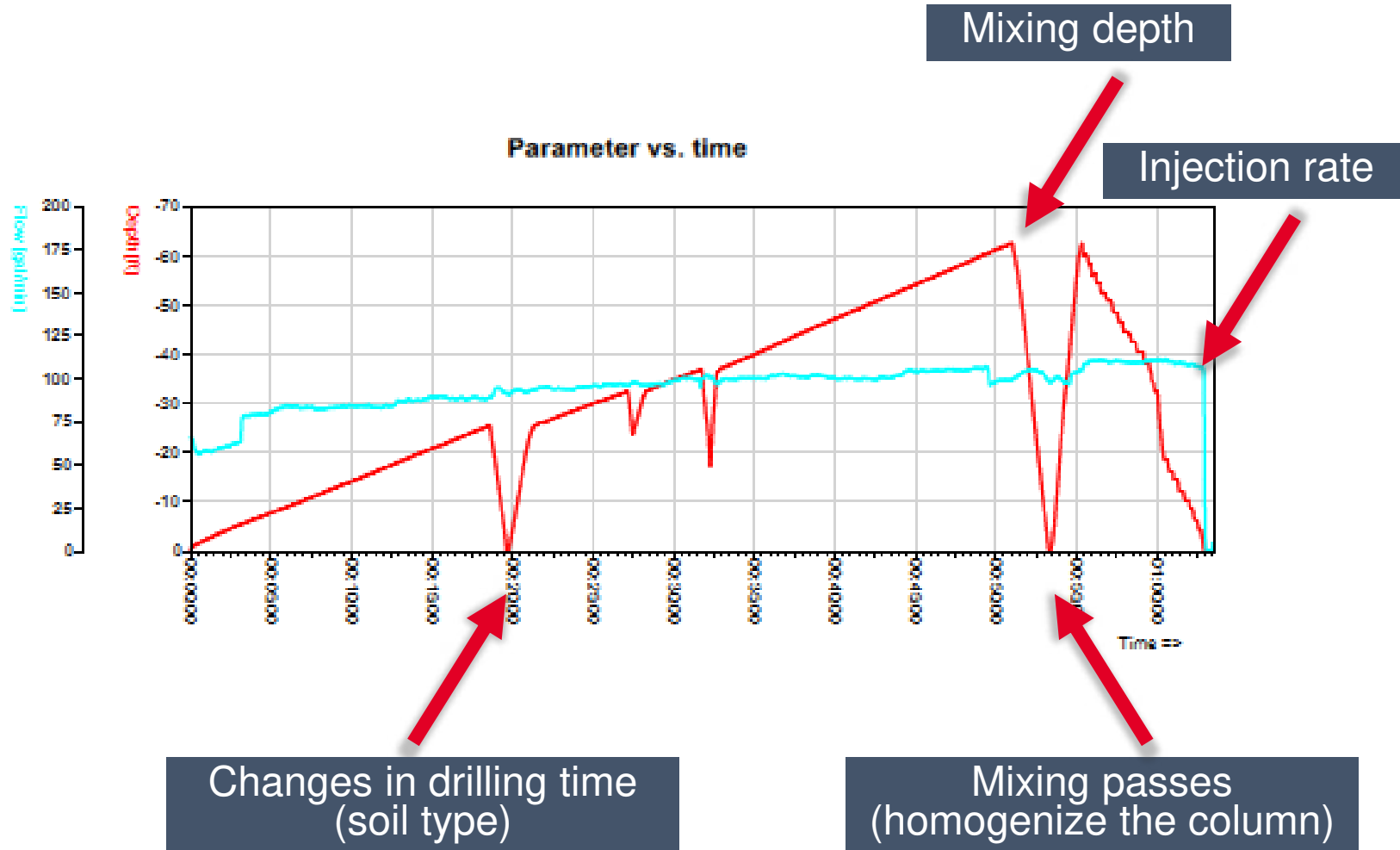
- Reagents dissipate within weeks

## ISCO / ISS

- Serves geotechnical purposes



# Data monitoring system



# Performance testing



Wet sample retriever  
(varying depth)

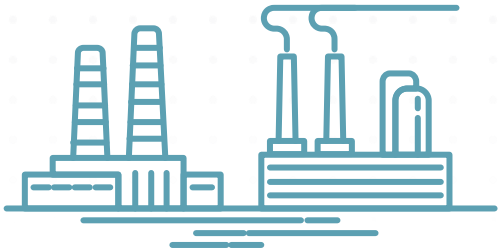
## Commonly tested for:

- Unconfined Compressive Strength
  - Standard: 350 kPa
- Permeability
  - Standard:  $1.8 \times 10^{-6}$  cm/s
- Analytical
  - Site specific



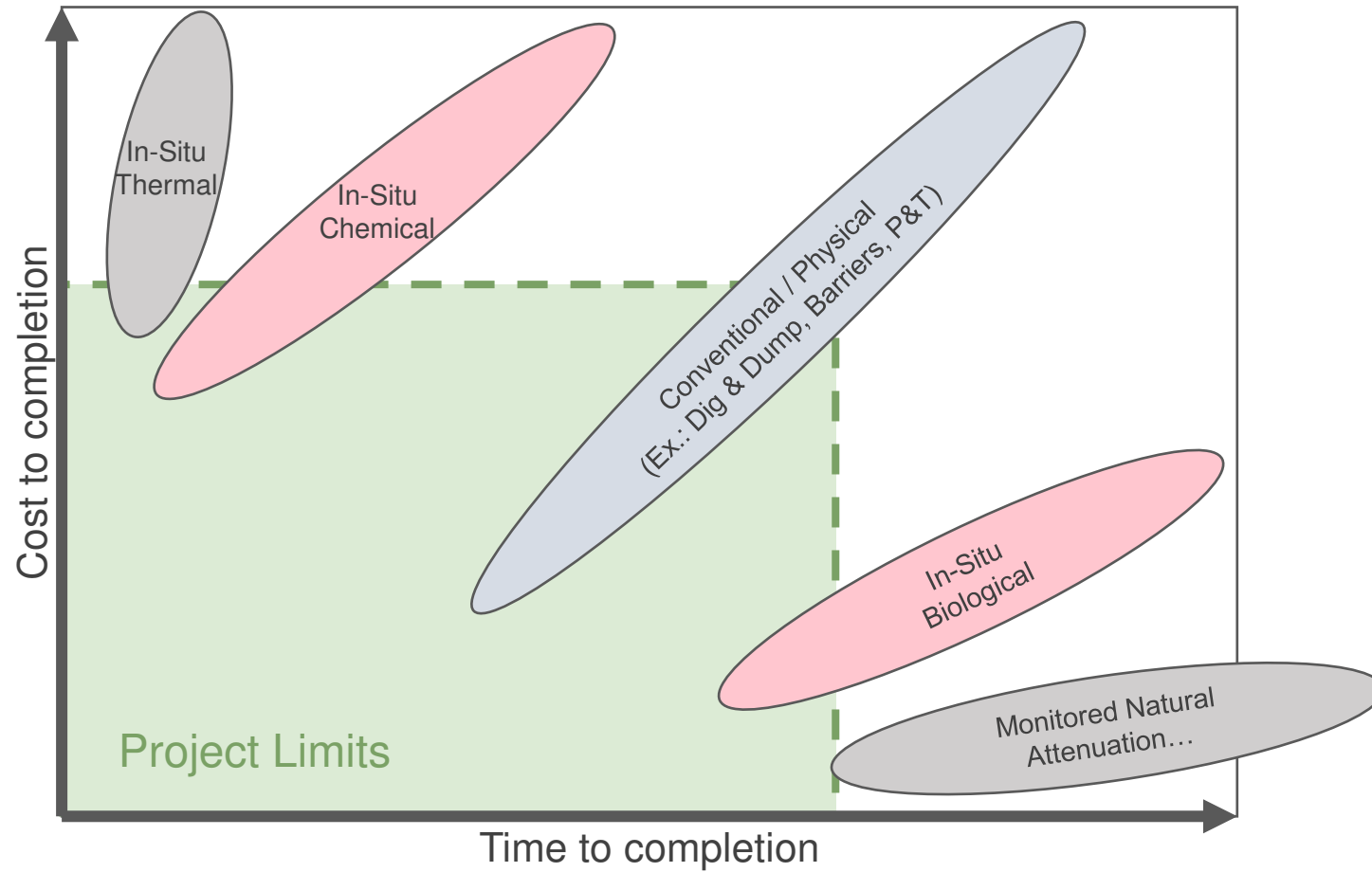


# Recap





# Considering alternative options



# Example work **sequence**

Month	1	2	3	4	5	6	7	8	9	10	11	12
Determining feasibility	X											
Consulting & constructability	X	X	X	X	X							
Treatability (bench-scale)		X	X	X	X							
Procurement					X	X	X					
Field implementation								X	X	X		
QA / QC								X	X	X	X	
Project Closeout												X



Winter months?

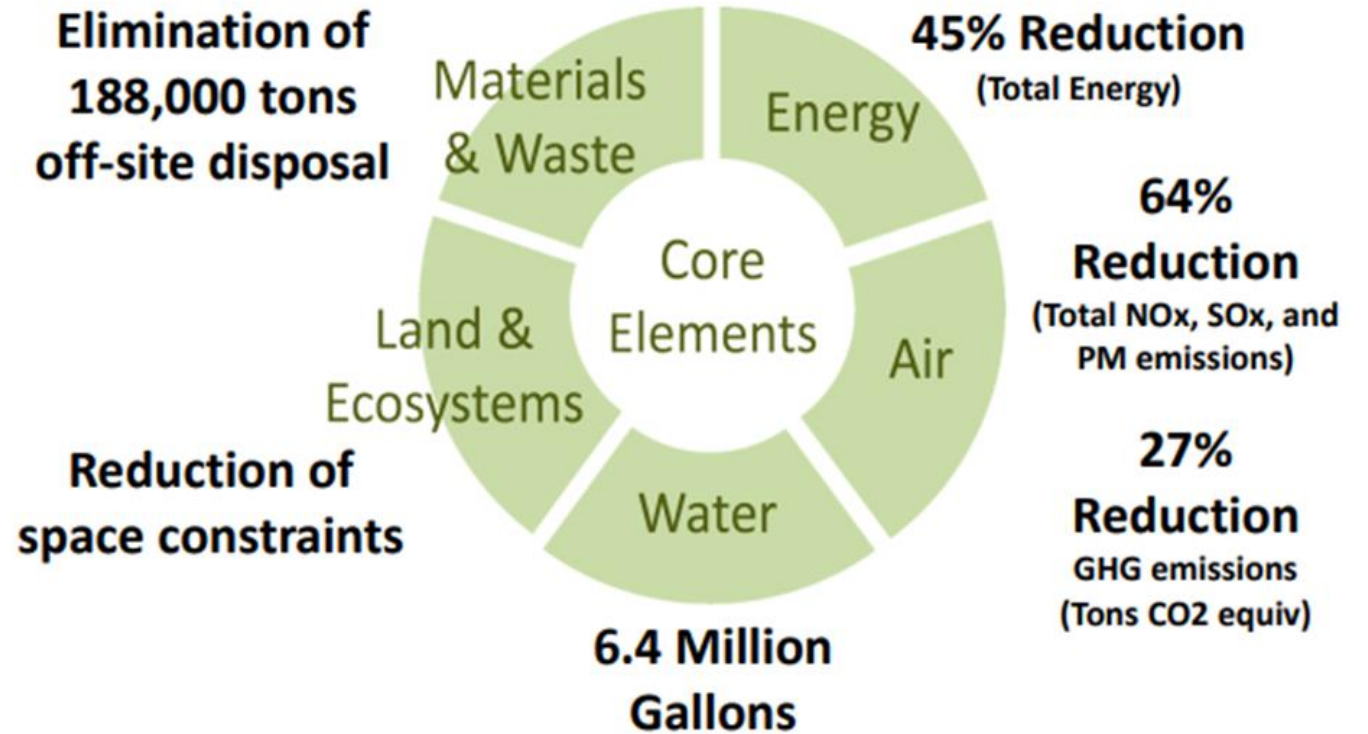


Remediation & Ground Improvement?

# Sustainability comparison (ISS vs excavation/disposal)

Compared to excavation and disposal

- Reduced trucking
- Reduced waste production
- Reduced total energy consumption
- Reduced emissions



Source: Carr, J., Robb, C.. "In Situ Stabilization/Solidification as a Sustainable Alternative for the Remediation of Heavy Hydrocarbon Sites." Fourth International Symposium on Bioremediation and Sustainable Environmental Technologies, Miami, FL, May 2017



remea

## Contact

Martin Pothier, PhD

[Martin.pothier@remea-group.com](mailto:Martin.pothier@remea-group.com)

[www.remea.ca](http://www.remea.ca)



Geo-Solutions

## Contact

Nathan Coughenour, P.E.

[ncoughenour@geo-solutions.com](mailto:ncoughenour@geo-solutions.com)

[www.geo-solutions.com](http://www.geo-solutions.com)

*“Do or do not, there is no try”  
- Yoda*