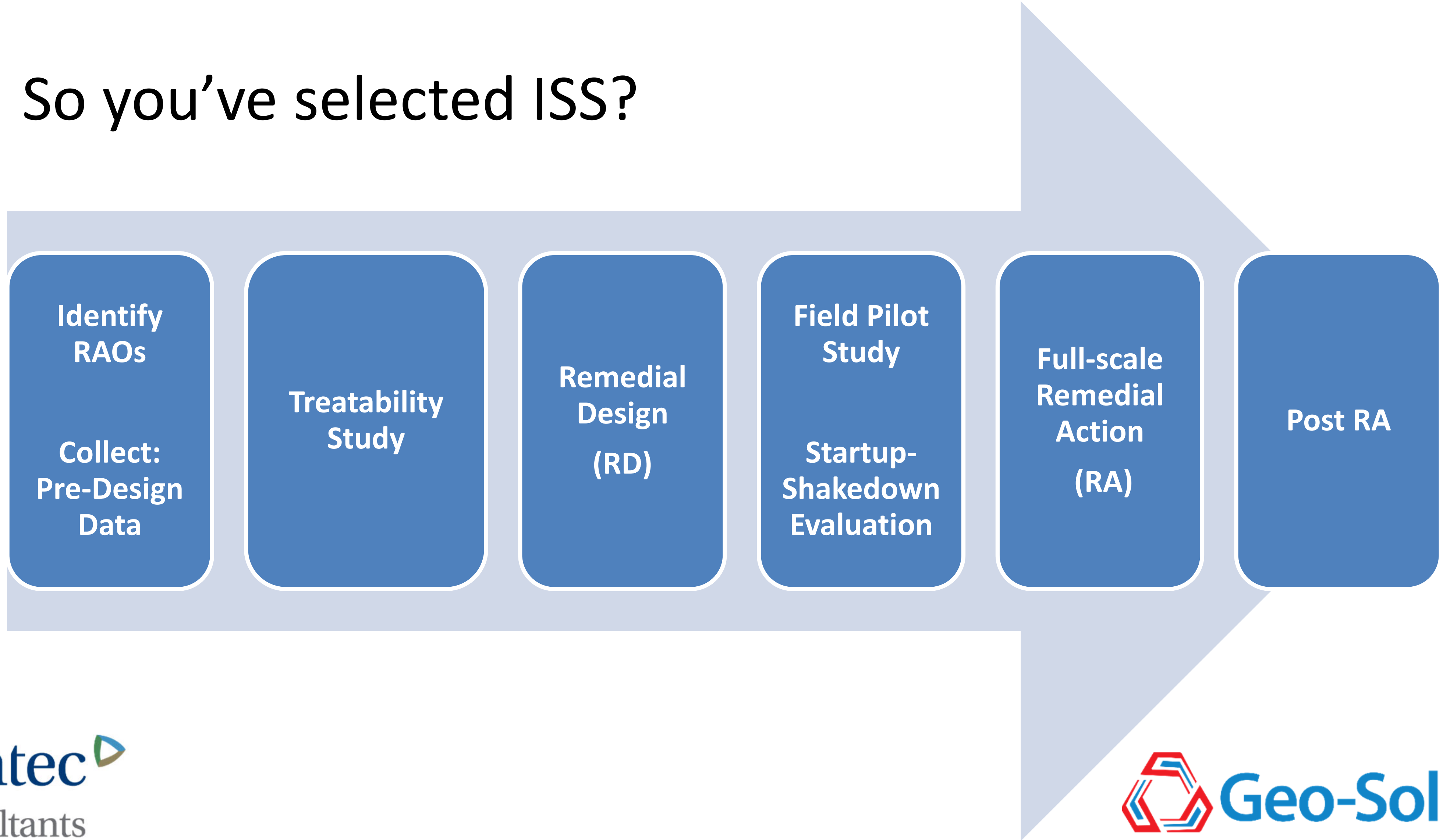
ISS Design/Implementation Process

So you've selected ISS?



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ISS is Treatment

- Defined by US EPA[1] as treatment:
- NCP provides a preference for treatment versus contaminant removal and disposal

[1]National Risk Management Research Laboratory, US EPA, 2009, "Technology Performance Review: Selecting and Using Solidification/Stabilization Treatment for Site Remediation"

- NCP establishes an expectation that the EPA will **use treatment to address the principal threats posed by a site wherever practicable** (NCP Section 300.430 (a)(1)(iii)(A)).
- **Numerous examples where ISS has been selected/implemented to treat PTWs**

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RAOs and Regulatory Landscape

- What are you trying to achieve?
  - Limit contaminant availability/transport (e.g., reduce leaching)
  - Reduce contaminant mass (e.g., destruction)
  - Remedy permanence (e.g., design life)
  - Increase durability/strength
- Points of compliance – how is success determined?
- Regulatory Landscape – are you experienced?
- Permits

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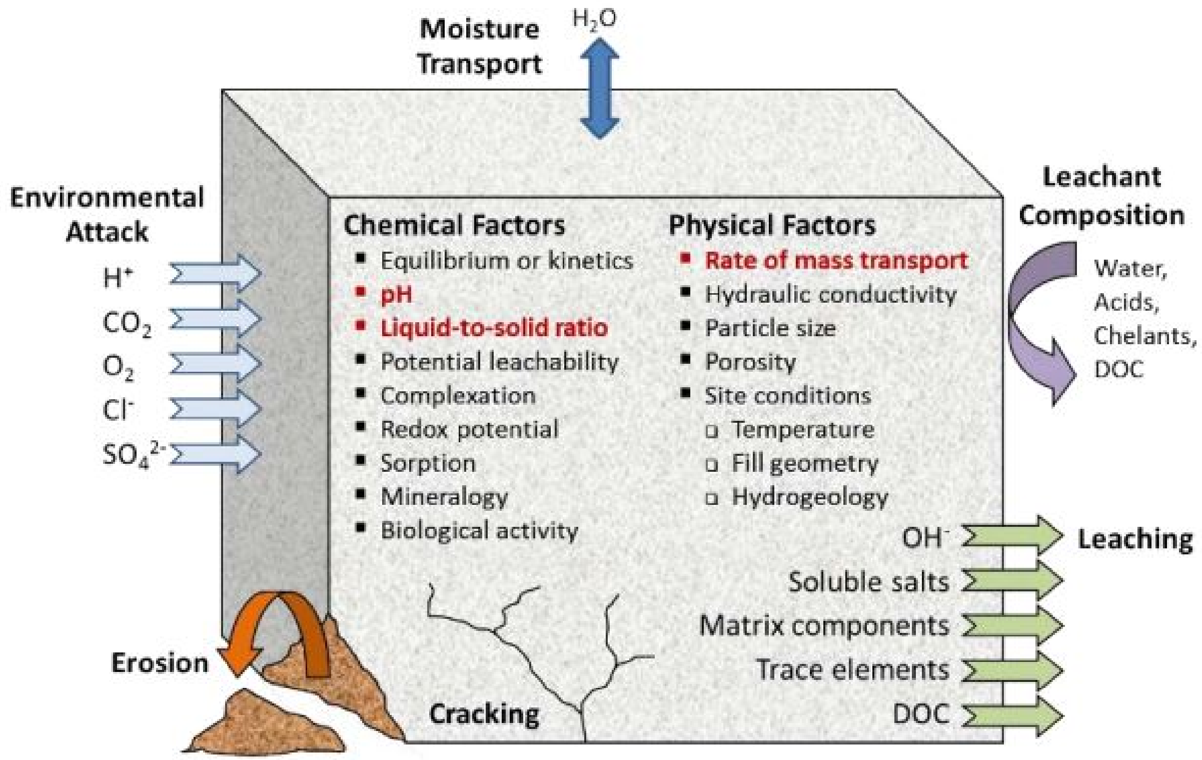
Pre-Design Data Needs

- Geotechnical characteristics
  - Soil borings (pay attention to blow counts and refusals)
  - Physical parameters (e.g., grain size, moisture content, in situ density, Atterberg limits, USCS classification)
- Contaminant distribution
  - COPCs
  - NAPL
- Geochemistry
  - Salts, organics, sulfate, pH
- Treatability Studies
  - Collect samples



Source: *Modified from Garrabrants and Kosson, 2005.*

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Treatability Study

- **Study:**
  - ✓ Soil Compositing
  - ✓ Geotechnical Index Testing
  - ✓ Phase 1 – assess reagent performance with Site conditions
  - ❑ Phase 1A – optimize reagent dosage
  - ❑ Phase 2 – optimize treatment, as needed

Select Confirm Performance Criteria (Designed to Achieve RAOs)

↓

Identify Treatment Regimens – Select Mix Designs

↓

Initial Physical Performance Testing (UCS and K)

↓

Secondary Testing to Refine Mix Designs (UCS, K, Leachability, other?)

↓

Select ISS Mix Design for Pilot Scale Testing/Full Scale RA

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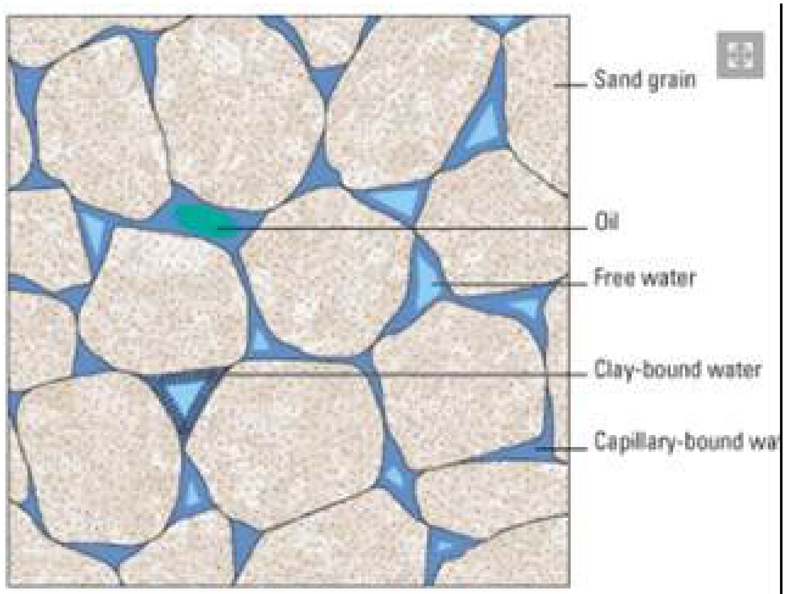
Soil Type Considerations

- **Available water**
  - Water available from soil moisture, water available from reagent grout
- Vadose zone vs. saturated zone
- Sand vs. fine-grained materials
- Geochemistry

- Experience: can be managed with water:reagent ratio easy to manag



Producible fluids include free water (light blue), or pockets of oil (green) in the larger pores. Capillary-bound water (dark blue) is held against sand grains by surface tension and cannot be produced. Clay-bound water (black) is also not producible

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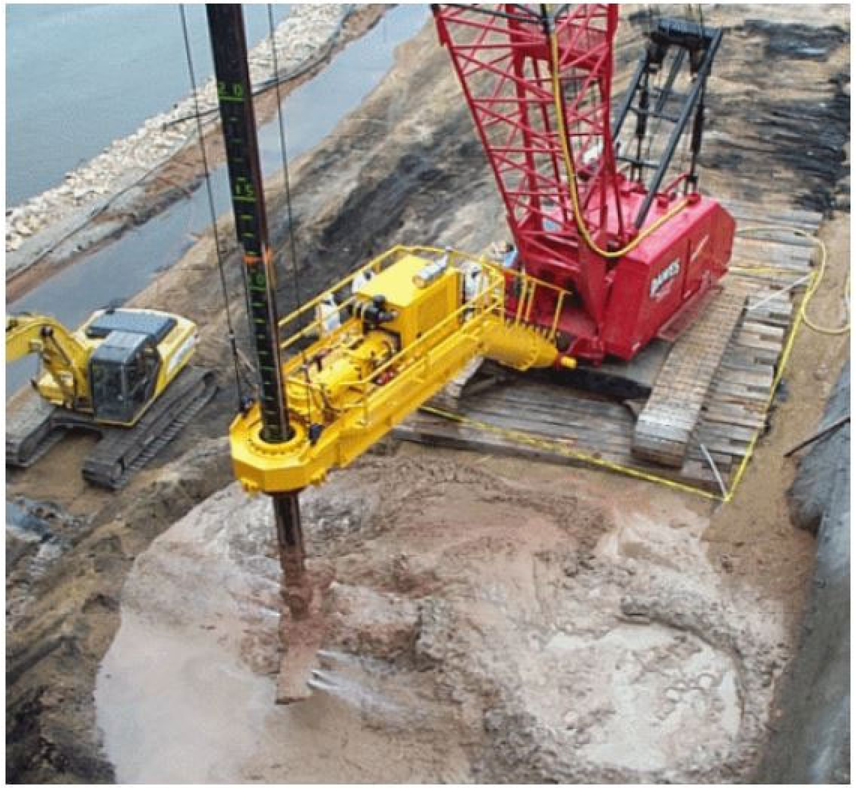
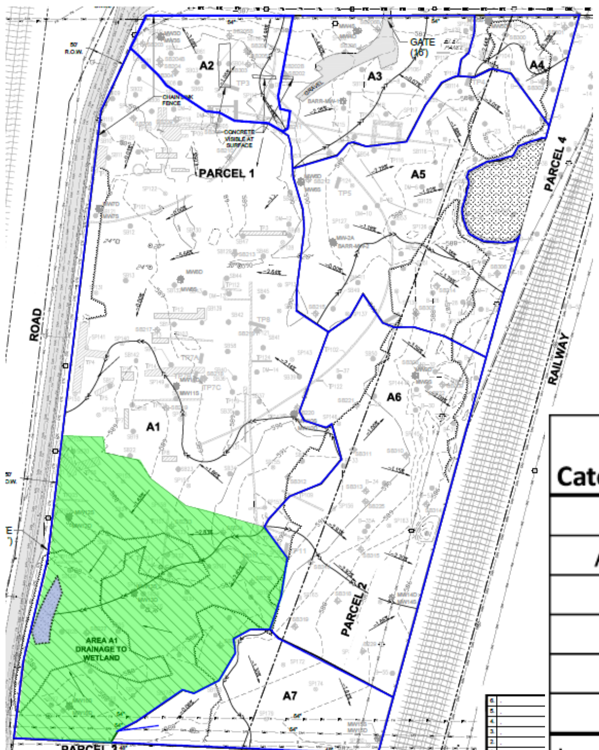
Logistic Considerations

- Proximity to sensitive structures (e.g., buildings, retaining walls, railroads)
- Overhead utilities or structures (e.g., bridges)
- Proximity to water ways
- Expansion of materials (e.g., swell)

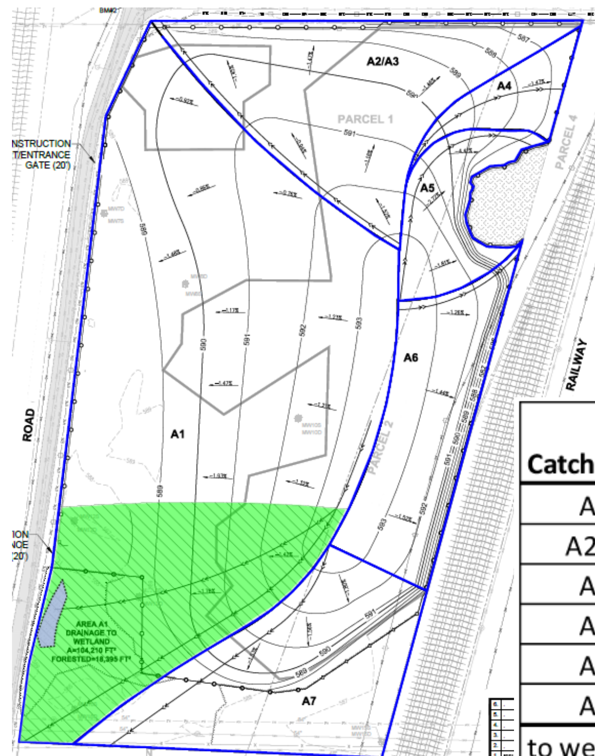


Hydrologic and Hydrogeologic Considerations

- Surface water run-off (pre- vs. post construction conditions)
  - ISS reduces surface water infiltration



Catchment	Area	Peak Flow (cfs), 2-yr 24-hr	Peak Flow (cfs), 100-yr 24-hr
A1	7.56	1.94	4.49
A2/3	1.84	1.06	2.46
A4	0.39	0.16	0.36
A5	2.26	0.62	1.44
A6	2.67	0.89	2.03
A7	1.09	0.28	0.65
to wetland	2.72	0.83	1.92



Catchment	Area	Peak Flow (cfs), 2-yr 24-hr	Peak Flow (cfs), 100-yr 24-hr
A1	8.62	2.73	6.33
A2/3	2.41	0.88	2.03
A4	0.42	0.20	0.47
A5	0.73	0.34	0.78
A6	1.52	0.97	2.25
A7	2.15	0.66	1.53
to wetland	2.39	0.84	1.94

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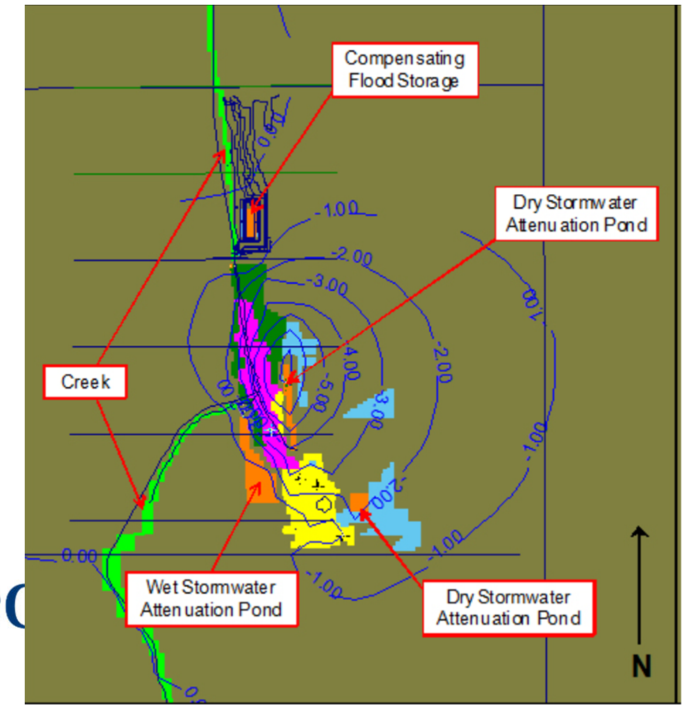
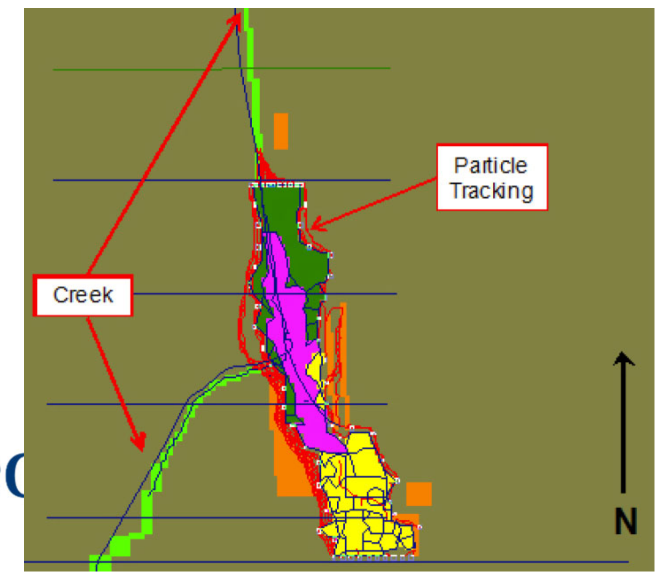
Hydrologic and Hydrogeologic Considerations

- Surface water run-off (pre- vs. post construction conditions)
  - ISS reduces surface water infiltration
- Groundwater mounding, surface expression



Hydrologic and Hydrogeologic Considerations

- Surface water run-off (pre- vs. post construction conditions)
  - ISS reduces surface water infiltration
- Groundwater mounding, surface expression
- Groundwater flow paths changed



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Hydrologic and Hydrogeologic Considerations

- Surface water run-off (pre- vs. post construction conditions)
  - ISS reduces surface water infiltration
- Groundwater mounding, surface expression
- Groundwater flow paths changed

- Tools
  - HELP models, groundwater flow models, hydrologic runoff models
- Influences engineered cover design

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Geotechnical/Geostructural Design Considerations

- ISS is a ground improvement technology adapted for environmental remediation
- ISS can meet remediation goals and facilitate:
  - Hydraulic Control
  - Utility Installation
  - Excavation support
  - Support adjacent structures
- Additional geotechnical tests

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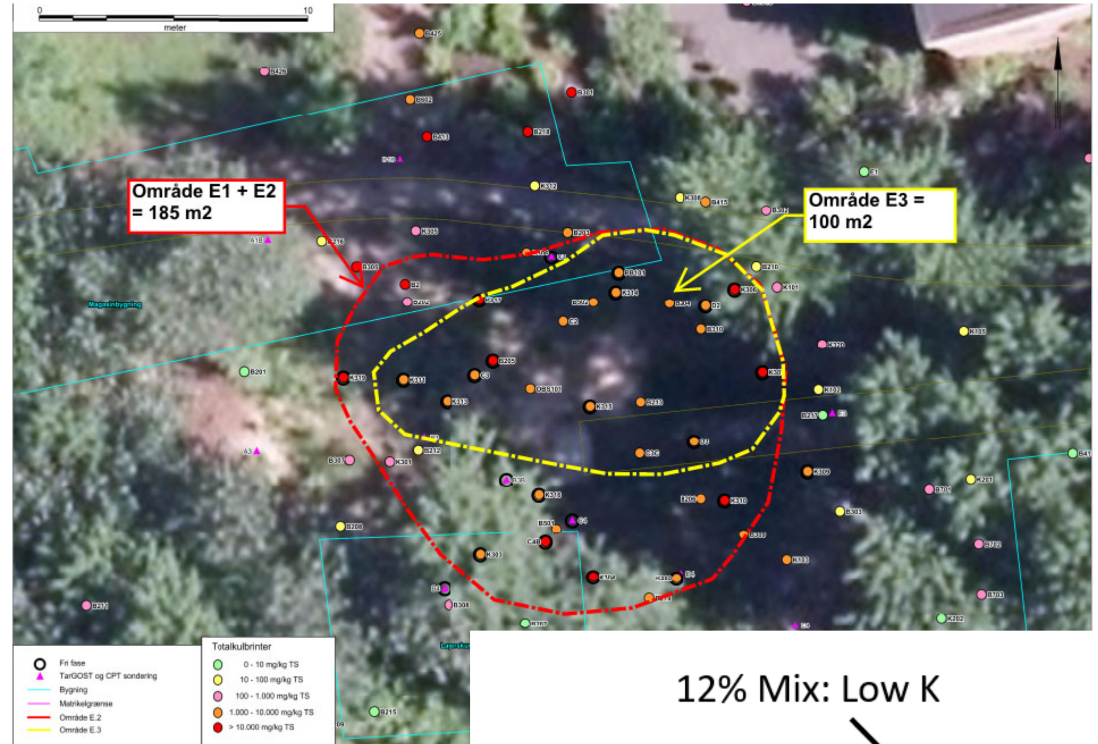
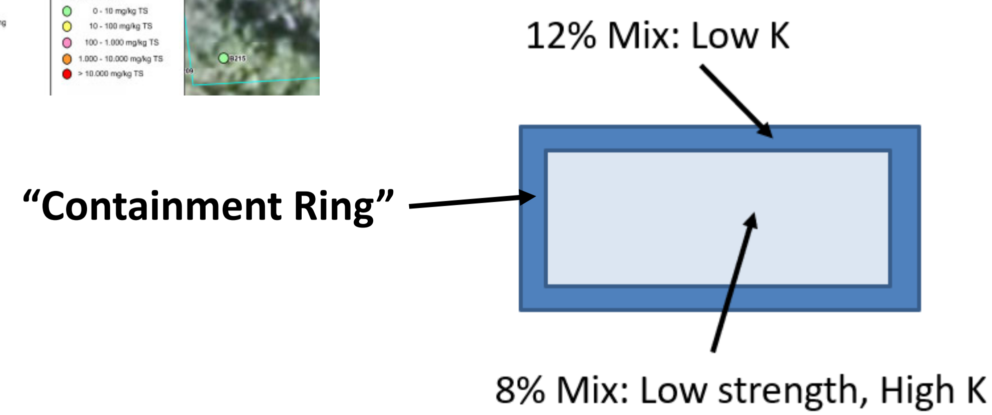
ISS Treatment Limits

- Cut-line Approach
  - "Containment Ring"
- Administrative Boundaries
  - e.g., Railroad
- Geology / Hydrogeology
  - Depth to Water Table
- ISS Treatment Depth
  - COC Distribution
  - Hanging treatment
  - Key-in low permeability Layer
- Debris
  - Pre-excavation /removal





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Selecting Treatment Performance Criteria

- Unconfined Compressive Strength (UCS) [ASTM D1633 or D2166]:
  – 50 psi (common)
  – Can design to increase/decrease UCS
- Hydraulic Conductivity (K) [ASTM D5084]:
  – < 1 x 10^{-5} cm/s to 1 x 10^{-7} cm/s
  – 1 to 2 orders of magnitude less than native material K is desired
- Leaching [SW-846 LEAF Method 1315]:
  – Determine interval flux; cumulative release to estimate mass transfer – What are your COCs / Receptors
- **Statistical Allowance:**
  – UCS: ≥ 50 psi (90% of the samples shall meet with no sample < 40 psi)
  – K: ≤ 1 x 10^{-6} cm/s @ 10 psi (geometric mean with no sample >5 x 10^{-6} cm/s)

Source: *Development of Performance Specifications for Solidification/Stabilization*, Interstate Technology & Regulatory Council (ITRC), July 2011.

Other

- Wet/Dry – Freeze/Thaw < 10% to 15% degradation after 12 cycles
- Specialized geostructural applications (direct shear, triaxial shear test)

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Performance vs. Prescriptive Specification

- Performance-based: Contractors have the flexibility to select materials, techniques, and procedures to improve the quality or economy, or both, of the end product. *Performance specifications increase the potential for contractor innovation*

- Prescriptive-based*:* typically a compliance to set criteria and standards and/or detailed engineering design

Allocate Risk to the Party That Is in the Best Position to Control That Risk

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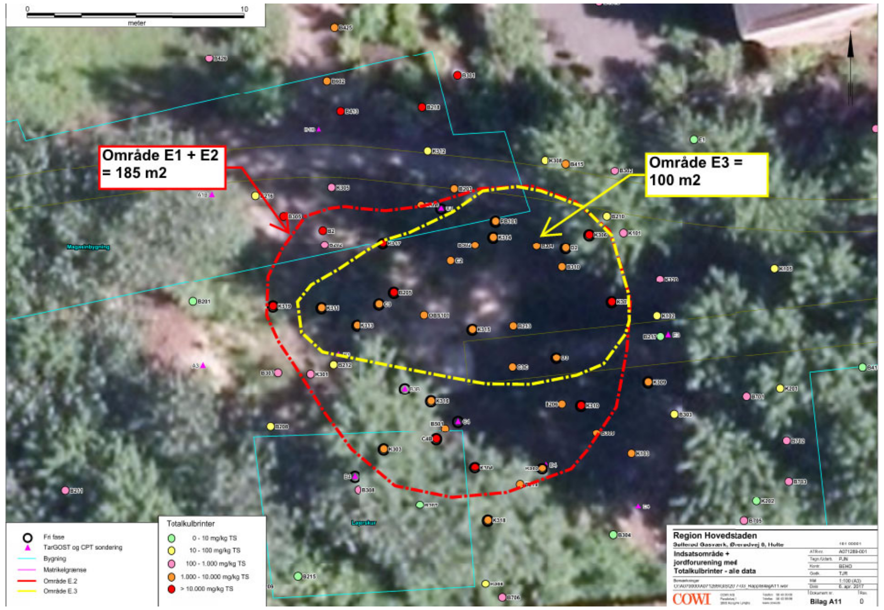
Performance vs. Prescriptive Specification

- Performance-based:
  - Equipment
  - **Mix Design** (use the Treatability Study to minimize RISK that performance criteria e.g., UCS can be met and point the contractor towards a solution)
  - Column/Treatment Cell Layout
  - Other means and methods



- Prescriptive-based:
  - Performance criteria (Physical: UCS and K)
  - Limits on equipment if needed to achieve performance criteria (e.g., prohibit excavator mixing > 25 ft bgs)

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Performance vs. Prescriptive Specification

- Performance-based:
  - Equipment
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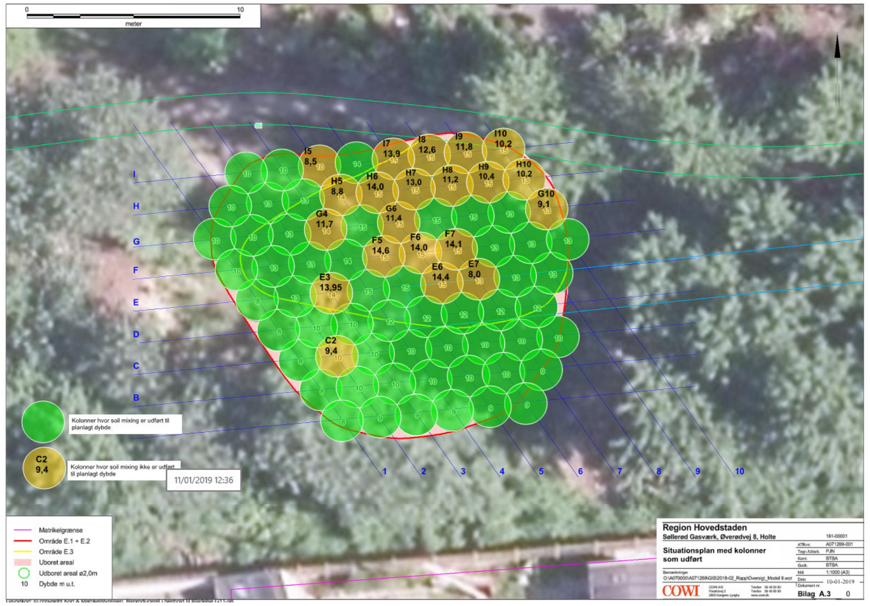
  - Column/Treatment Cell Layout
  - Other means and methods



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Long Term Monitoring Considerations

- Points of compliance – how is success determined?
  - Groundwater concentrations
  - Monitored natural attenuation
  - ISS strength/durability
- Groundwater flow model to design groundwater monitoring network
- Engineered controls (e.g., long-term cover maintenance)
- Relating leaching performance to established Cleanup Goals
  - **Leach data ≠ groundwater concentration**

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Long Term Monitoring Considerations

ITRC – Development of Performance Specifications for Solidification/Stabilization *July 2(*

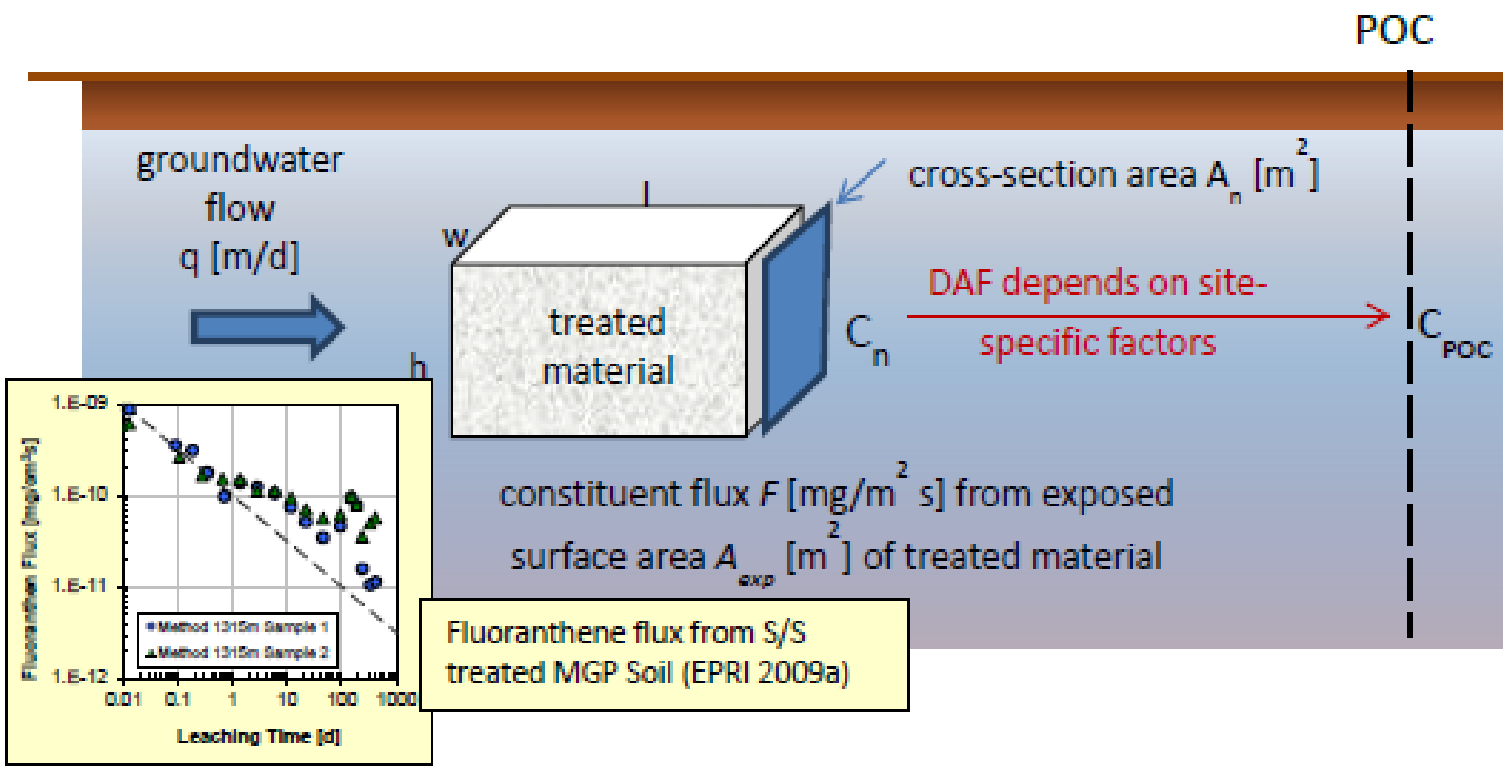

Figure 4-2. Mass flux approximation showing relationship between leaching test flux an(d) concentrations in groundwater at the treated material and at a downgradient POC.

$$C_n = \frac{F \cdot A_{exp}}{A_n \cdot q} \qquad \text{(Eq. 1)}$$

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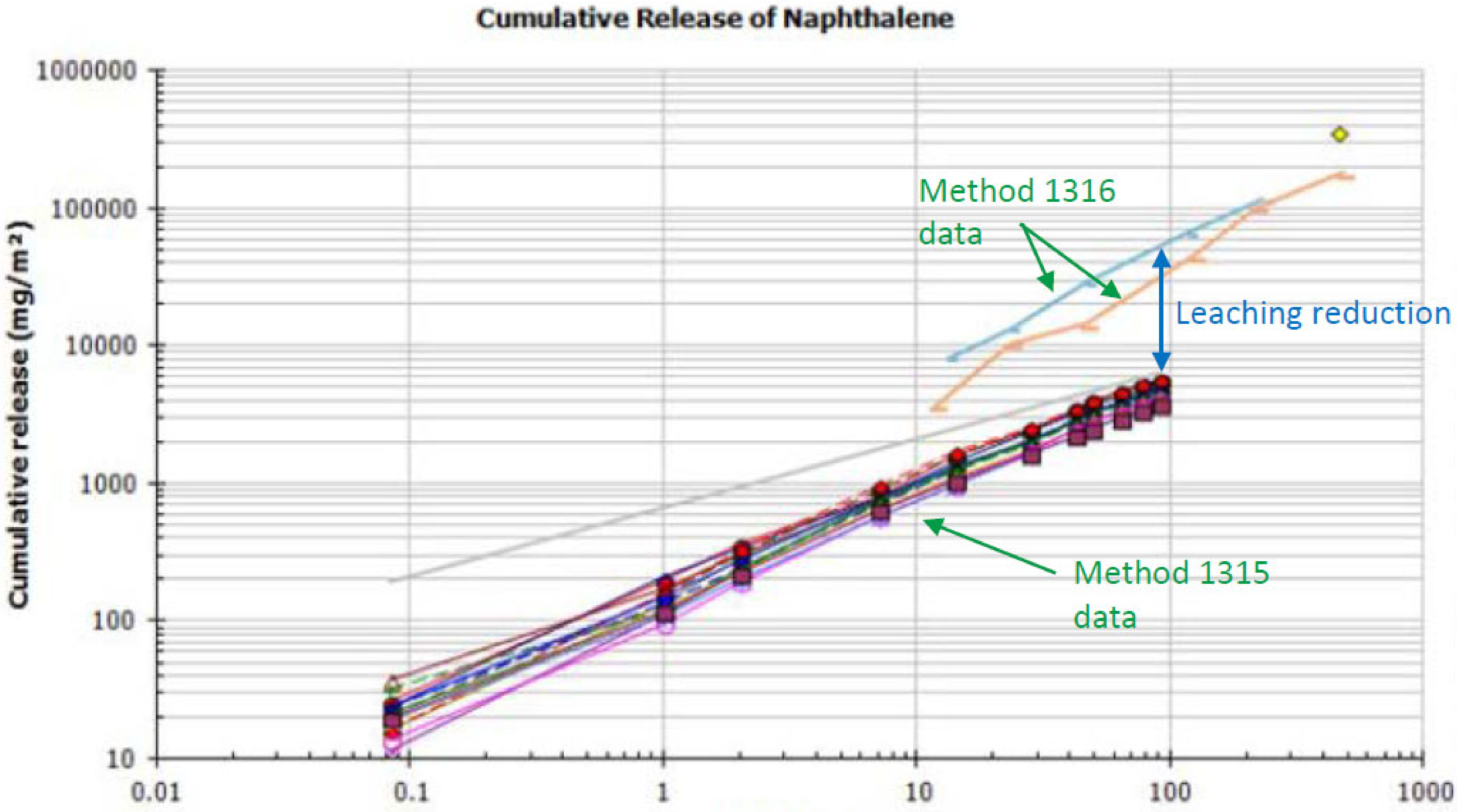
Long Term Monitoring Considerations



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Emerging Applications

Where can ISCO aide ISS?

- Contaminants are not destroyed or removed
- Effectiveness for some contaminants (e.g., CVOCs) may require additional design measures
- Uncertainty in long term behavior / protection of sensitive receptors

Where can ISS aide ISCO?

- Contact and distribution of ISCO using LDA techniques
- Alleviate soft ground after treatment
- Residual contaminants rendered immobile

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Emerging Applications

- PFAS: ISS to encapsulate and reduce leaching
- CVOCs: Sulfidated zero valent iron (sZVI with Portland cement) other oxidant combinations
-
- Steam/ZVI

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Questions?

- Contact Info:
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  - 262.834.0232
  - Website:
    - www.Geosyntec.com

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Søllerød Gasværk Site - One-Step Combined ISS/ISCO

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- **Challenges:**
  - Extremely tight site setting – surrounded by residential structures on all sides – 100 + years old
  - Challenging Geology: 3m to 5m peat – stability concerns, highly plastic clay, confined aquifer
  - Downgradient waterworks – ISS alone not acceptable to Regulators
  - How do we combine chemical oxidation with ISS – opposing chemistry
  - Limited Contractor experience in DK
- **Solution:** Developed simultaneous ISS/ISCO treatment using slag/cement ISS mix designed to activate persulfate upon injection
- **Result:** Effective remedy addressing all aspects former MGP site:
  - Stability
  - Contaminant Destruction – Reduce Leaching
  - Strength > 0.35 MPa   K < 1x 10^{-7} cm/s

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Simultaneous ISS/ISCO Treatment Solution

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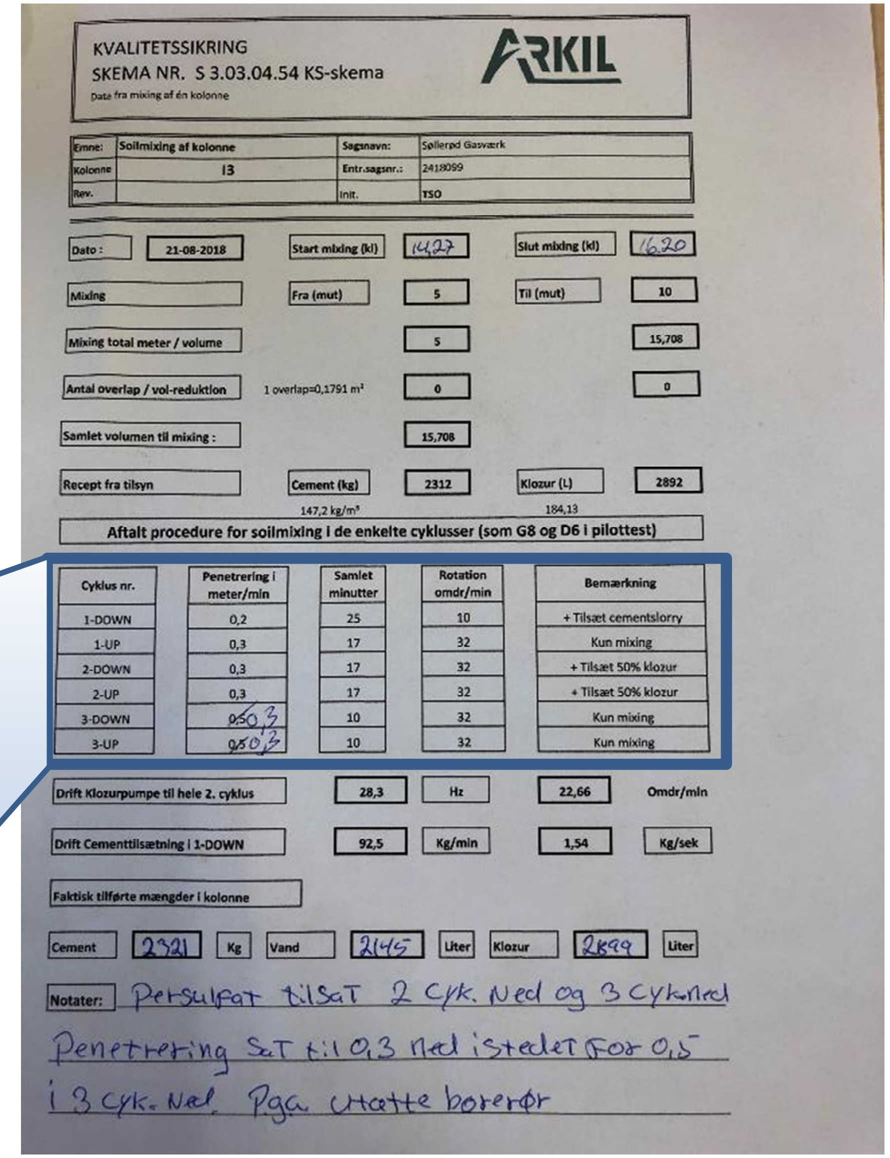
- **ISS/ISCO Solution:**
  - Performed phased treatability study: ISS, ISCO, ISCO then ISS, simultaneous ISS/ISCO
  - Persulfate reduces strength, slows curing
  - Used slag/cement to protect from long-term SO_4^{2-} attack and slow cure to maximize contaminant oxidation
  - Transitioned treatability to full-scale application process



KVALITETSSIKRING
SKEMA NR. S 3.03.04.54 KS-skema
Data fra mixing af én kolonne

ARKIL

Emne:	Soilmixing af kolonne	Sagsnavn:	Søllerød Gasværk
Kolonne	13	Entr.sagsnr.:	2418099
Rev.		Init.	TSO

Dato :	21-08-2018	Start mixing (kl)	14,27	Slut mixing (kl)	16.20
Mixing		Fra (mut)	5	Til (mut)	10
Mixing total meter / volume			5		15,708
Antal overlap / vol-reduktion	1 overlap=0,1791 m³		0		0
Samlet volumen til mixing :			15,708		
Recept fra tilsyn		Cement (kg)	2312	Klozur (L)	2892
		147,2 kg/m³		184,13	

Aftalt procedure for soilmixing i de enkelte cyklusser (som G8 og D6 i pilottest)

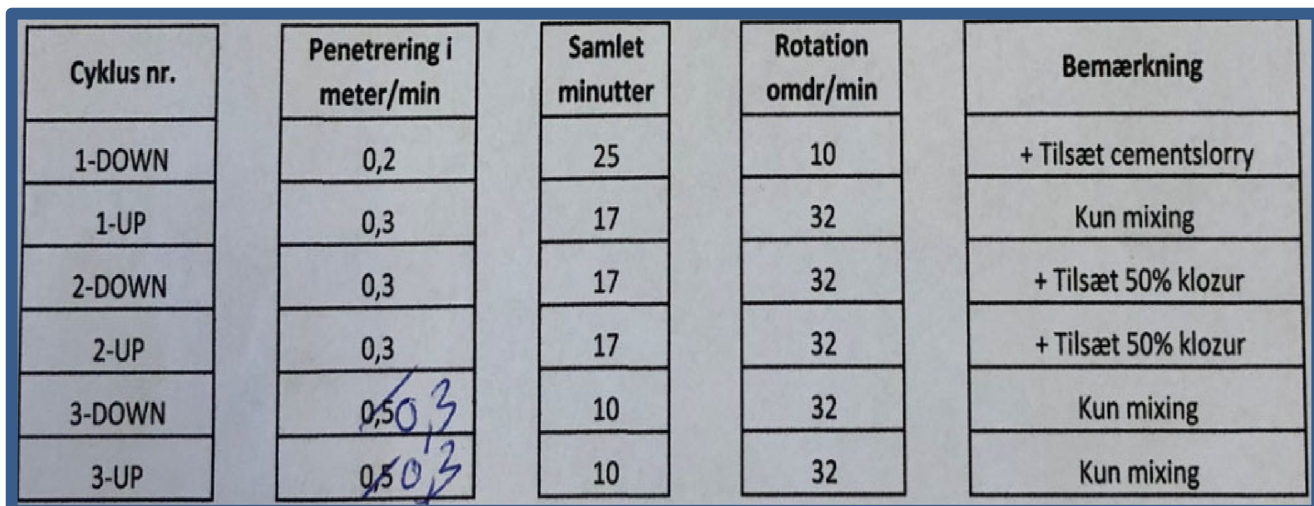
Cyklus nr.	Penetrering i meter/min	Samlet minutter	Rotation omdr/min	Bemærkning
1-DOWN	0,2	25	10	+ Tilsæt cementslorry
1-UP	0,3	17	32	Kun mixing
2-DOWN	0,3	17	32	+ Tilsæt 50% klozur
2-UP	0,3	17	32	+ Tilsæt 50% klozur
3-DOWN	~~0,50~~ 0,3	10	32	Kun mixing
3-UP	~~0,50~~ 0,3	10	32	Kun mixing

Drift Klozurpumpe til hele 2. cyklus	28,3	Hz	22,66	Omdr/min
Drift Cementtilsætning i 1-DOWN	92,5	Kg/min	1,54	Kg/sek

Faktisk tilførte mængder i kolonne

Cement	2321	Kg	Vand	2145	Liter	Klozur	2899	Liter

Notater: Persulfat tilsat 2 cyk. ned og 3 cyk. ned
Penetrering sat til 0,3 ned istedet for 0,5
i 3 cyk. ned pga. utætte borerør



Cyklus nr.	Penetrering i meter/min	Samlet minutter	Rotation omdr/min	Bemærkning
1-DOWN	0,2	25	10	+ Tilsæt cementslorry
1-UP	0,3	17	32	Kun mixing
2-DOWN	0,3	17	32	+ Tilsæt 50% klozur
2-UP	0,3	17	32	+ Tilsæt 50% klozur
3-DOWN	~~0,50~~ 0,3	10	32	Kun mixing
3-UP	~~0,50~~ 0,3	10	32	Kun mixing

ISS/ISCO - Geology/Stability Solutions

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- **Geology/Stability Solution:**
  - Excavated peat in 2m DIA steel casing to 3 to 5 mbs
  - ISS through each casing
  - 3 mixing passes – established optimum BRN to mix plastic clay
  - Performed hydrostatic uplift calculations for confined aquifer penetration
  - Achieving Strength > 0.35 MPa $K < 1x\ 10^{-7}$ cm/s

OPTIMIZE — Min/m

Mixing total meter / volume		5	16.0	15.708	
Cyklus nr.	**Penetrering i meter/min**	**Samlet minutte**	**Rotation omdr/min**	**Bemærkning**	**BRN**
1-DOWN	0.2	25	10	+ Tilsæt cementslorry	50
1-UP	0.3	17	32	Kun mixing	107
2-DOWN	0.5	10	32	+ Tilsæt 50% klozur	64
2-UP	0.5	10	32	+ Tilsæt 50% klozur	64
3-DOWN	0.5	10	32	Kun mixing	64
3-UP	0.6	8	32	Kun mixing	53
	Mixing Time:	**80**		**Total BRN:**	402

Questions?

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- Next up….
  - Darin Payne

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Questions?

Thank you for your time!

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