Solidification/Stabilization treatment technology for contaminated sites in the United States and Canada

Mass Stabilisation Conference

Lahti, Finland   April 23, 2015

Charles M. Wilk
ALLU Group Incorporated
U.S.A.

What is S/S Treatment for Remediation?

Involves mixing a binding/reaction agent(s) into contaminated media such as soil, sediment, sludge or industrial waste.

S/S treatment protects human health and the environment by immobilizing hazardous constituents within treated material.

Physical (solidification) and chemical (stabilization) changes to the treated material.

Mobility Reduction Terms: Stabilisation (UK), Inertage (France), Immobilization (EU).

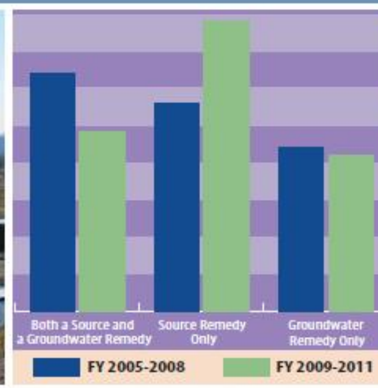
State of Remediation Technologies

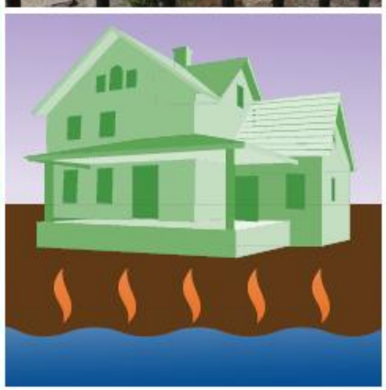
United States Environmental Protection Agency

EPA 542-R-13-016
November 2013
Solid Waste and Emergency Response
www.clu-in.org/asr
www.epa.gov/superfund

Superfund Remedy Report

FOURTEENTH EDITION

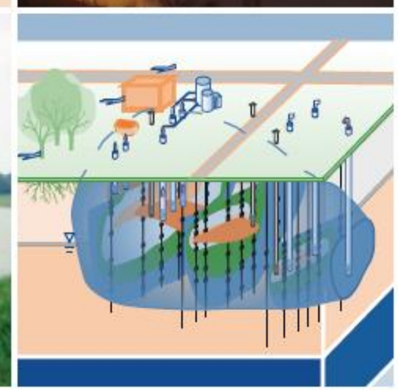
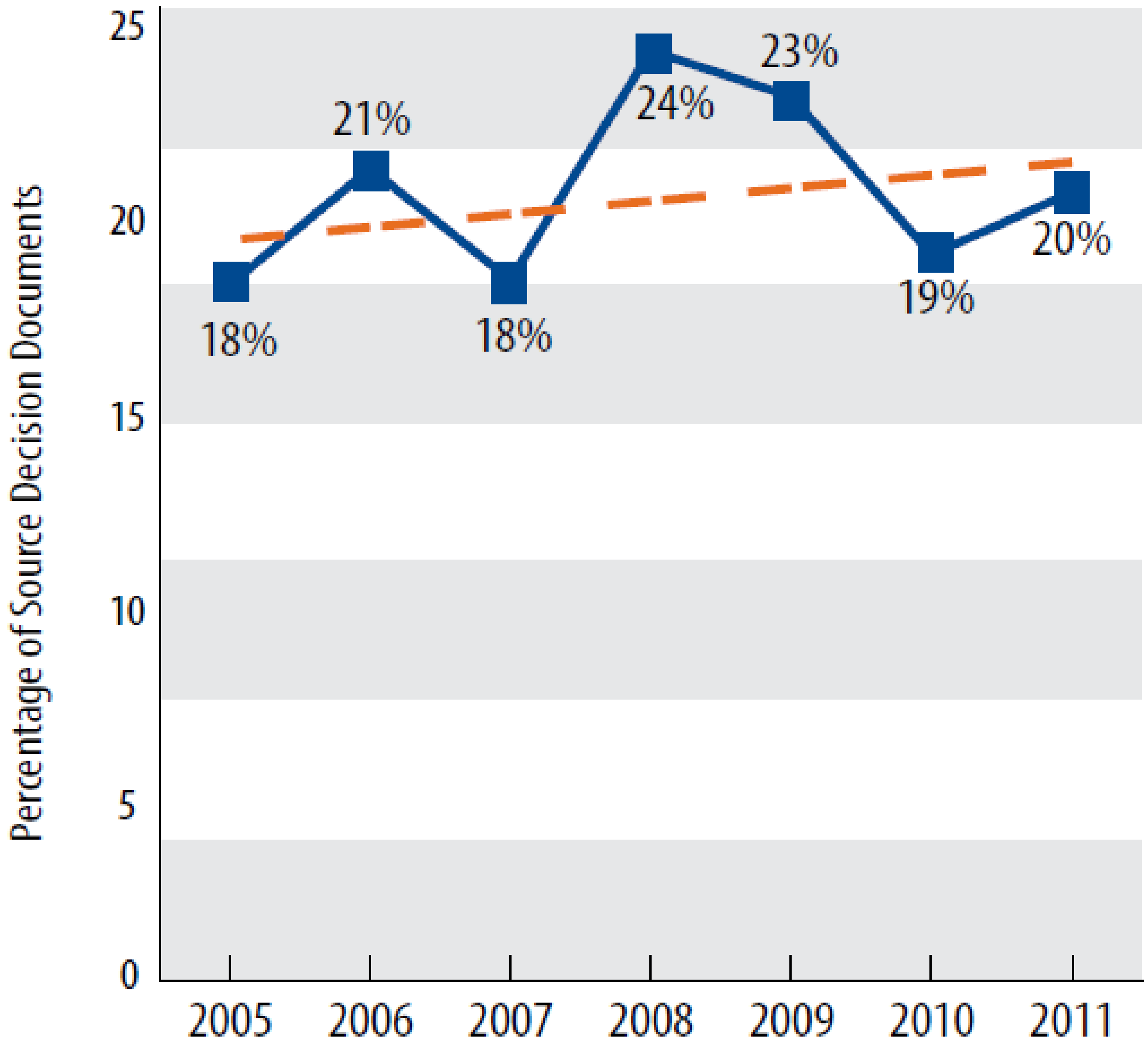


Table 1: Source Treatment Technologies Selected in Decision Documents

Technology	Total (FY 2005-08)	Percent Source Treatment Decision Documents (FY 2005-08)	Total (FY 2009-11)	Percent Source Treatment Decision Documents (FY 2009-11)
In Situ Treatment	72	48%	59	50%
Soil Vapor Extraction	32	21%	25	21%
Chemical Treatment	11	7%	17	14%
Solidification/Stabilization	14	9%	11	9%
Thermal Treatment	14	9%	7	6%
Bioremediation	10	7%	4	3%
Multi-Phase Extraction	6	4%	3	3%
Constructed Treatment Wetland	0	0%	2	2%
Subaqueous Reactive Cap	0	0%	2	2%
Flushing	2	1%	1	1%
Fracturing	1	1%	1	1%
Phytoremediation	2	1%	0	0%
Ex Situ Treatment	98	65%	80	67%
Physical Separation	31	21%	33	28%
Solidification/Stabilization	29	19%	15	13%
Pump and Treat	18	12%	13	11%
Unspecified Off-site Treatment	11	7%	11	9%
Recycling	15	10%	10	8%
Unspecified On-site Treatment	2	1%	6	5%
Phytoremediation	0	0%	5	4%
Chemical Treatment	5	3%	4	3%
Bioremediation	4	3%	3	3%
NAPL Recovery	1	1%	1	1%
Thermal Desorption	1	1%	1	1%
Unspecified Thermal Treatment	1	1%	1	1%
Other Ex Situ Technologies	13	9%	0	0%

Figure 10: Trends in Source Decision Documents Selecting In Situ Treatment (FY 2005-2011)



- Number of source decision documents = 645.

EPA-542-R-07-012

Technology	Total number of projects[a]	Polycyclic aromatic hydrocarbons (PAHs)	Other nonhalogenated semivolatile organic compounds[b]	Benzene-toluene-ethylbenzene-xylene (BTEX)	Other nonhalogenated volatile organic compounds[c]	Organic pesticides and herbicides	Other halogenated semivolatile organic compounds[d]	Halogenated volatile organic compounds	Polychlorinated biphenyls	Metals and metalloids
Bioremediation	113	37	51	33	33	24	17	22	2	5
Chemical Treatment	29	1	2	3	4	1	4	12	4	13
Multi-Phase Extraction	46	9	3	11	6	4	8	18	1	1
Electrical Separation	1	0	0	0	0	0	0	1	0	0
Flushing	17	3	5	5	5	1	3	11	0	5
Incineration	147	27	41	33	23	36	34	52	36	6
Mechanical Soil Aeration	7	0	0	3	1	0	1	7	0	0
Neutralization	15	2	0	0	0	0	0	0	0	6
Open Burn/ Open Detonation	4	0	1	0	0	0	0	0	0	0
Physical Separation	21	4	2	1	0	3	0	0	4	5
Phytoremediation	7	1	2	2	2	1	1	4	0	4
Soil Vapor Extraction	255	15	31	107	51	3	33	217	1	0
Soil Washing	6	1	1	0	0	2	0	0	1	2
Solidification/ Stabilization	**217**	**17**	**18**	**13**	**13**	**16**	**7**	**20**	**35**	**180**
Solvent Extraction	4	2	1	0	1	1	0	2	2	1
Thermal Desorption	71	21	17	24	15	8	12	33	16	0
In Situ Thermal Treatment	14	5	0	2	0	3	3	8	0	0
Vitrification	3	0	0	1	1	0	1	3	2	1
Total Projects	**977**	**145**	**175**	**238**	**155**	**103**	**124**	**410**	**104**	**229**

Types of Sites Applied

- Wood Preserving Sites
- Herbicide and Pesticide Sites
- Oil Refinery Sludge Lagoons
- Manufactured Gas Plants
- Sediment including PCB
- Metal Refining, Smelting, Plating, Recycling
- Residual Ash

Laboratory Formulation

Bench-scale mix design and testing utilizes high mixing shear for optimum results

S/S Agents

- Portland cement, Cement kiln dust
- Fly ash e.g. Class F and C (pozzolanic fly ashes)
- Lime e.g. quicklime, hydrated lime, lime kiln dust
- Slag e.g. ground granulated blast furnace slag
- Organoclay®
- EnviroBlend®
- Bentonite clay
- Activated carbon
- Cement-based proprietary mixtures
- Silicate, phosphate, and sulfate
  e.g. triple super phosphate

Sample Effects of Agents

- Mass strength development:
  - Cements, slags, fly ashes
- Mass hydraulic conductivity reduction:
  - Bentonite, cements, slags,
- Encapsulation: strength and lower hyd. cond.
- Sorption of hazardous constituents:
  - Activated carbon, organophilic clay
- Chemical changes to hazardous constituents
  - pH: hydroxides
  - Compounding, sulphates
  - Oxidation: insitu chemical oxidation: permanganates
  - Reducing: “hex” Cr to trivalent Cr

Physical Tests

Hydraulic Conductivity/ Permeability

- $1X10^{-5}$ to $1X10^{-7}$ cm/sec
- "Two orders of magnitude lower than surround soil"

Unconfined Compressive Strength- 0.34 MPa (50 psi)

Paint Filter Test (PFT) – free liquids

Freeze-Thaw & Wet-Dry Durability

Chemical Testing

Synthetic Precipitation Leaching Procedure (SPLP)

Toxicity Characteristic Leaching Procedure (TCLP)

Multiple Extraction Procedure

Equilibrium Leach

ANS/ANSI 16.1

Dynamic Leach

LEAF

ALLU
One Step Ahead

Bench-Scale to Full-Scale

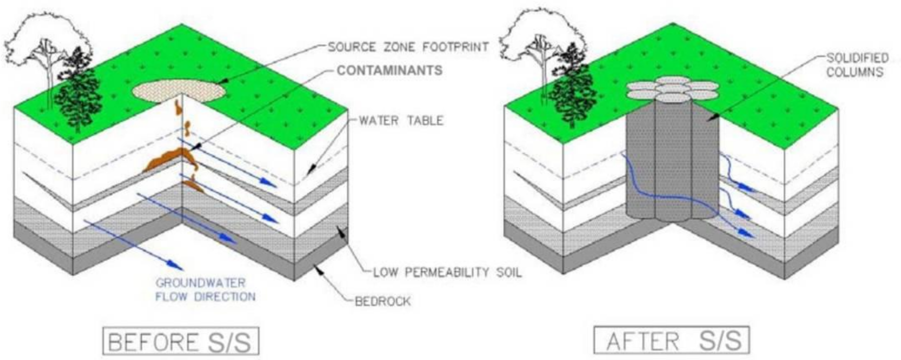
VS

Mixing Energy & Shear

25-100 RPM
12000 Nm (9000 ft-lb) torque per drum.
Provides Mixing Energy and Shear

Folding Mixing Action dependent on Operator's "Stroke"

Auger Mixing



Crane-mounted augers efficient mixing depths begin at 6 meters (20 ft) and deeper. Crane's limited range of motion.

Road Reclaimer / Soil Stabilizer

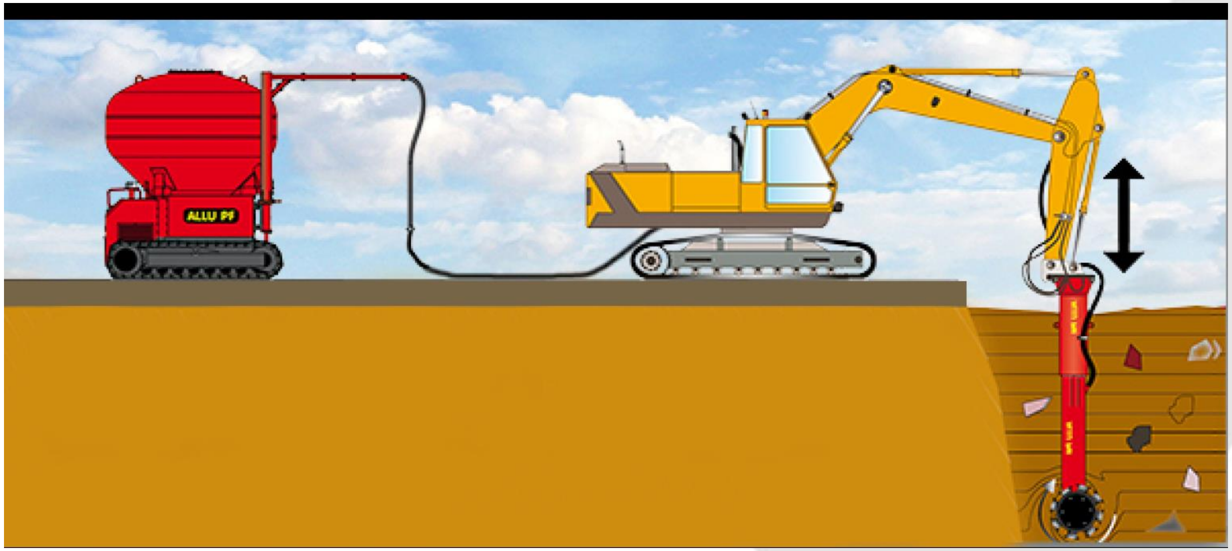
Limited mixing depth: 500 mm (20 in)

Bucket Mixing   Injector Rake

"Folding Action" Mixing Methods

One Step Ahead

Horizontal Axis Mixers



Excavator- mounted: Efficient mixing to depths of 7 meter (23 ft) . Articulated arm of excavator lessens repositioning of equipment

One Step Ahead

Binding Agent Pricing

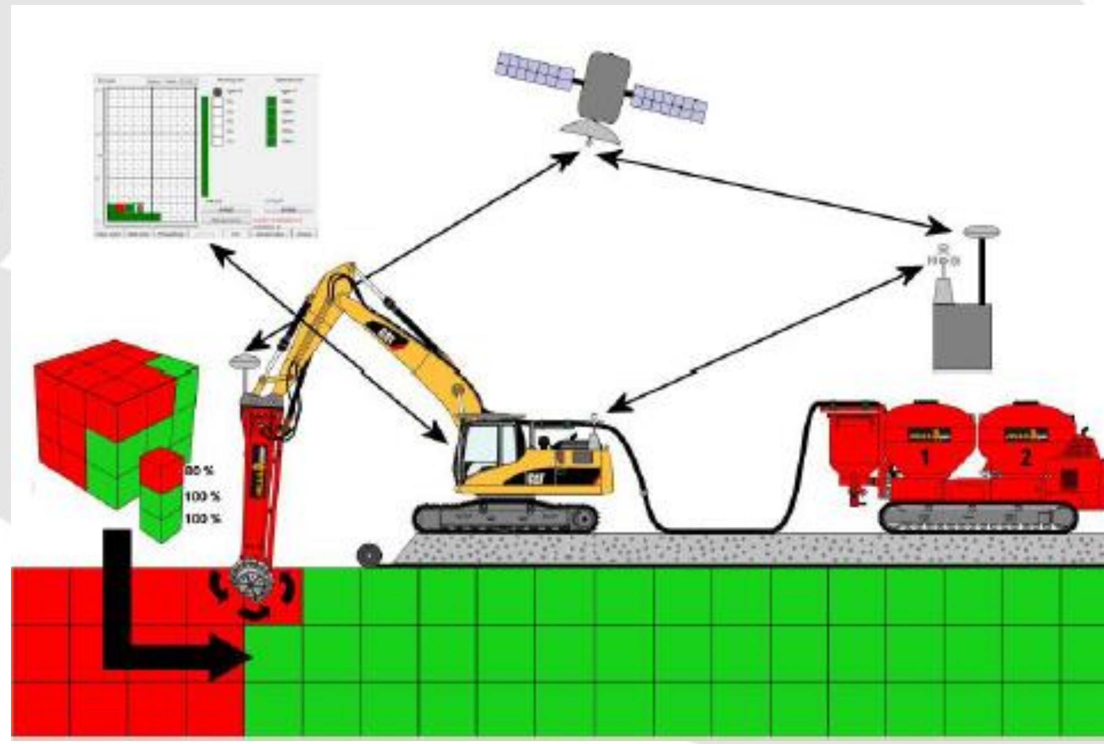
- Priced by transportation costs:
  - Industrial waste/byproducts, finely divided materials available on site, e.g. spent fullers earth, ash
- Priced per ton:
  - Common construction materials:
    - portland cement, blended cements, Class C or F fly ash, GGBFS, lime.
- Priced per pound:
  - Specialized materials, sorptive, reactive, or compounding
    - Carbons, organophilic clays, oxidizers, reducers

Efficient Use of Binders Matters

Most of the cost in a mass stabilization project comes from the binder, which represents about ***50-70 % of the total project cost.***

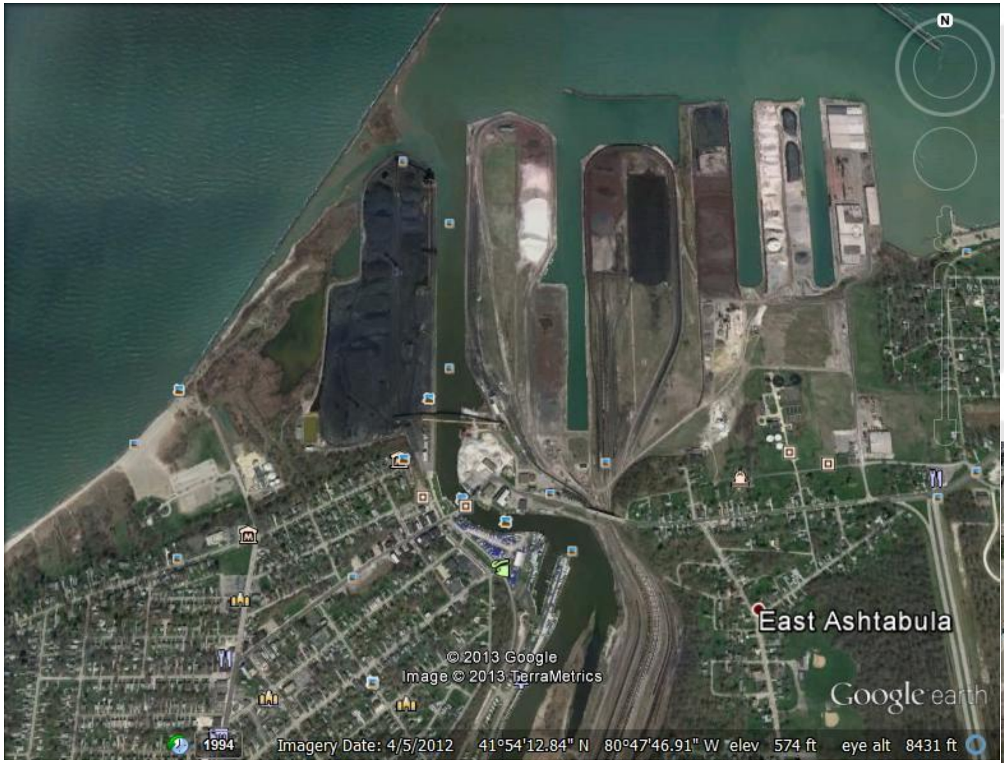
Efficiencies (Cost Savings) are **improved** by:

- Thorough mixing (mixing shear & energy) resulting in intimate contact of binder and subject material***.***
- Introduction of binder at mixing point.
- Locating and metering of binder to avoid under-dose and overdose.
- Use of dry binders in wet materials to conserve drying capacity of binders.



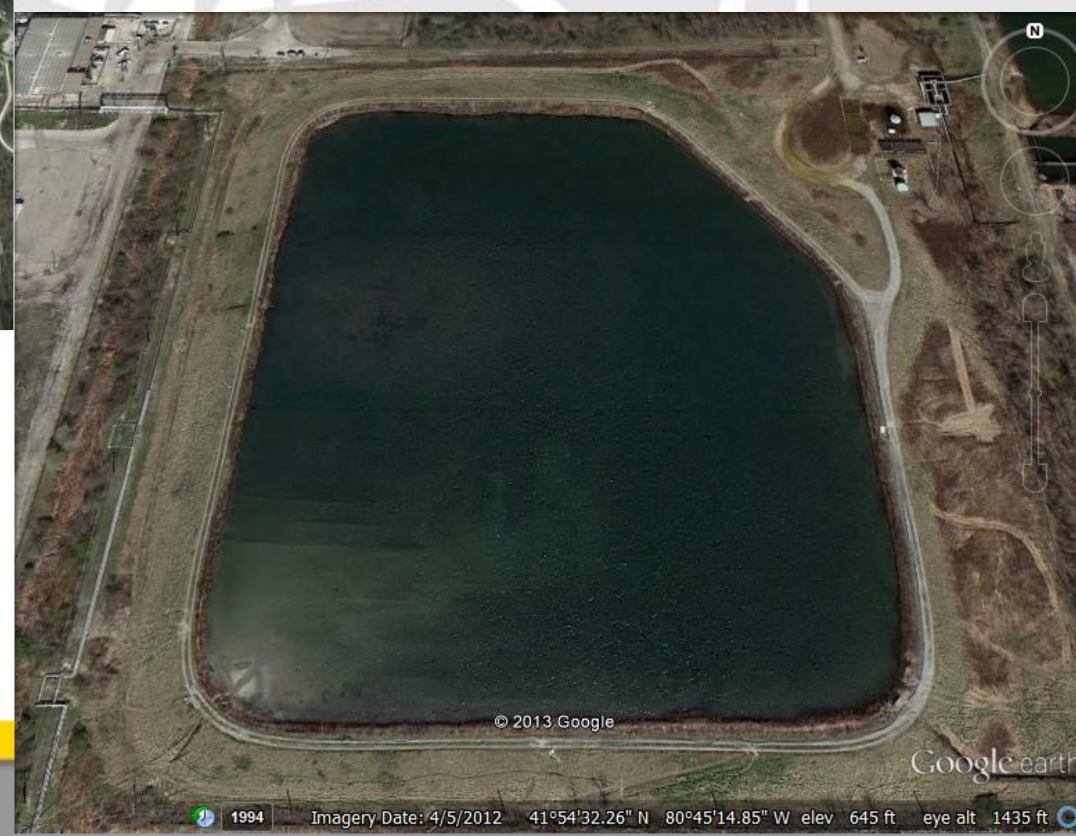
North American Projects

Solidification: Ashtabula Harbor, OH



Dredge and S/S treat 120,000 CY (92,000 m^3) of contaminated sediment.

Placement of S/S treated dredge into Elkem 5C Pond, a 3.6 hectare (9 acre) former settling pond. Additional material needed to facilitate closure of pond

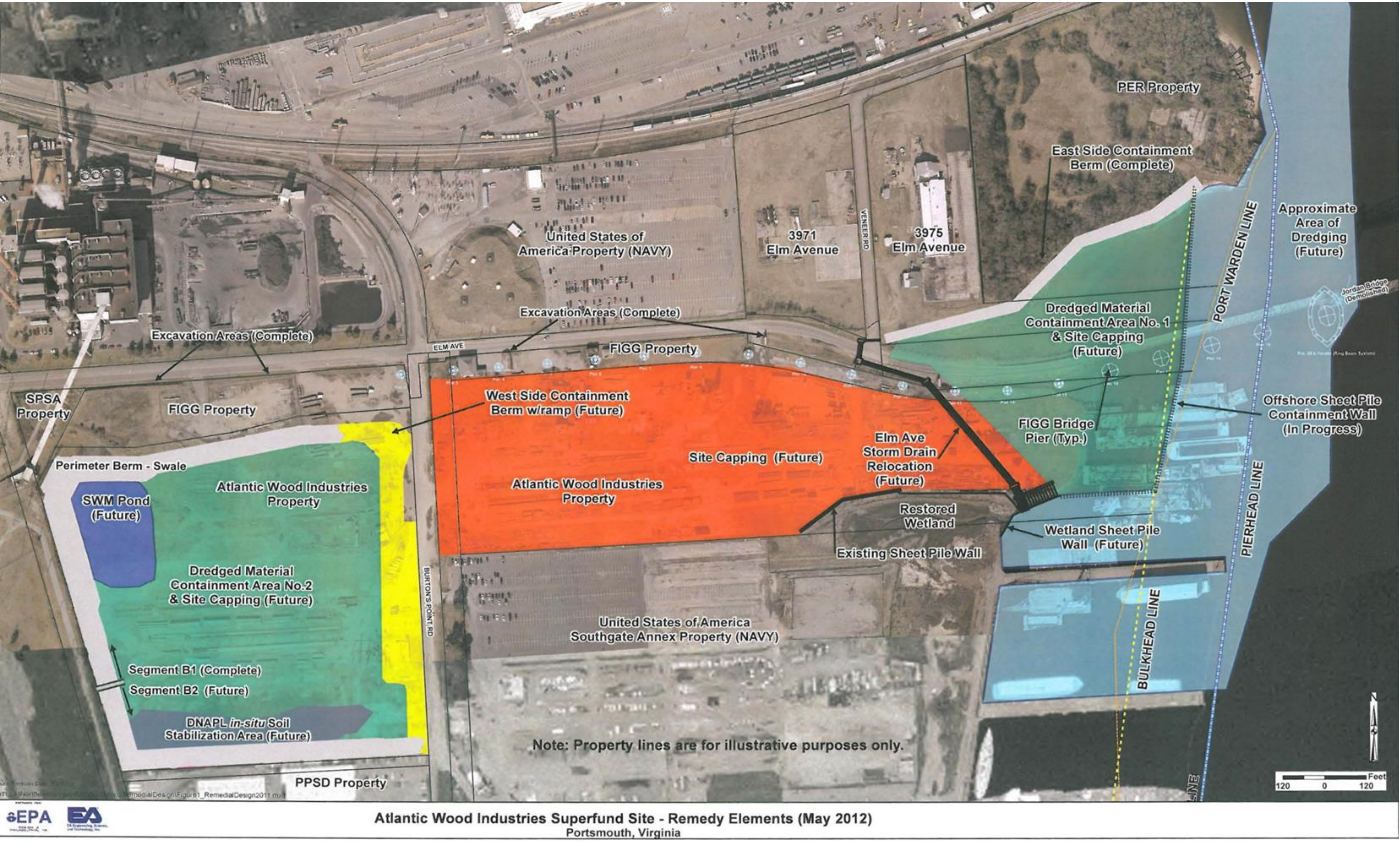


Ashtabula Harbor: Elkem 5C Pond

Calciment (binder) added dry 20% by weight. UCS goals range from 0.05 to 0.07 MPa (1,000 psf to 1,500 psf). Unconsolidated shear strength goal of 0.08 MPa (1,250 psf)
Mixing depths variable – 1.5 to 6 m (5 - 20 ft)

- Solidification of existing contents 153,000 m^3 (200,000 CY)

Solidification: Atlantic Wood Industries



AWI Project

- Insitu S/S of 36,000 m^3 (47,000 CY) creosote- and pentachlorophenol-impacted soils
- Treatment depths ranging from 2.4 to 8.2 m (8-17 ft)
- Performance standard
  - >0.34MPa (50 psi) UCS
  - <4 X 10^{-6} cm/sec

One Step Ahead

Atlantic Wood Industries Portsmouth, Virginia

Performance Standard:

- 50 psi (0.34 MPa) UCS
- 4 x 10^{-6} cm/s hydraulic conductivity

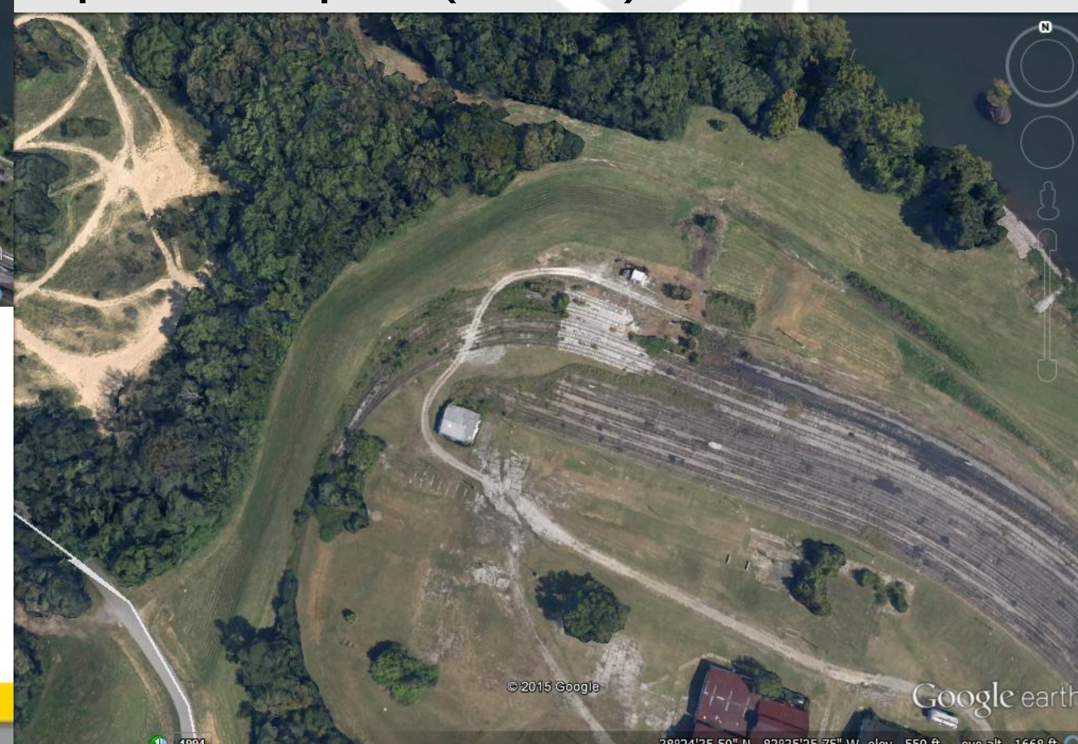
Three-part mix: portland cement, slag, and organophilic clay.

AWI Mix Design

- 23,500 m^3 (30,500 CY) treated with:
  - 8% portland cement/slag and
  - 1% organophilic clay
- 11,600 m^3 (15,200 CY) treated with:
  - 8% portland cement/slag and
  - 3% organophilic clay
- Cement/clay mixture injected as slurry and mixed by ALLU Power Mixer.

Insitu Chemical Oxidation: WV Terminals Site, Kenova, WV

Chemical Oxidation and Solidification Treatment of petroleum-impacted soil. Contaminants as non aqueous phase liquid (NAPL) and metals.



One Step Ahead

ISCO at WV Terminals Site

Excavation and set aside of top 1.2 meter (4 feet) of soil. Loosening of soil 1.2 – 2.4 meters (4-8 feet) below grade.

ALLU Power Mixer used to mix oxidizer and binder into soil 8,400 m^3 (11,000 CY) treated.

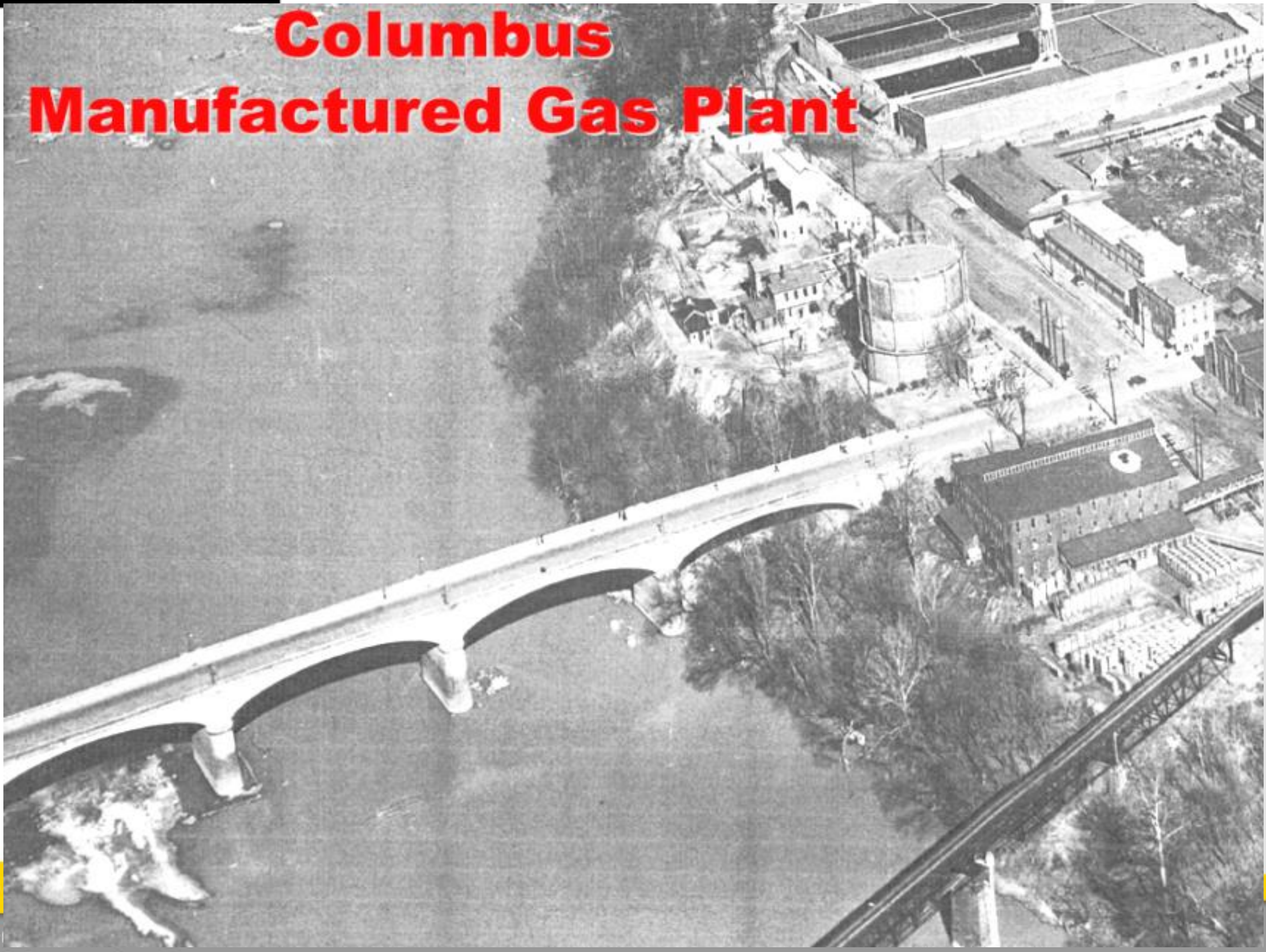
One Step Ahead

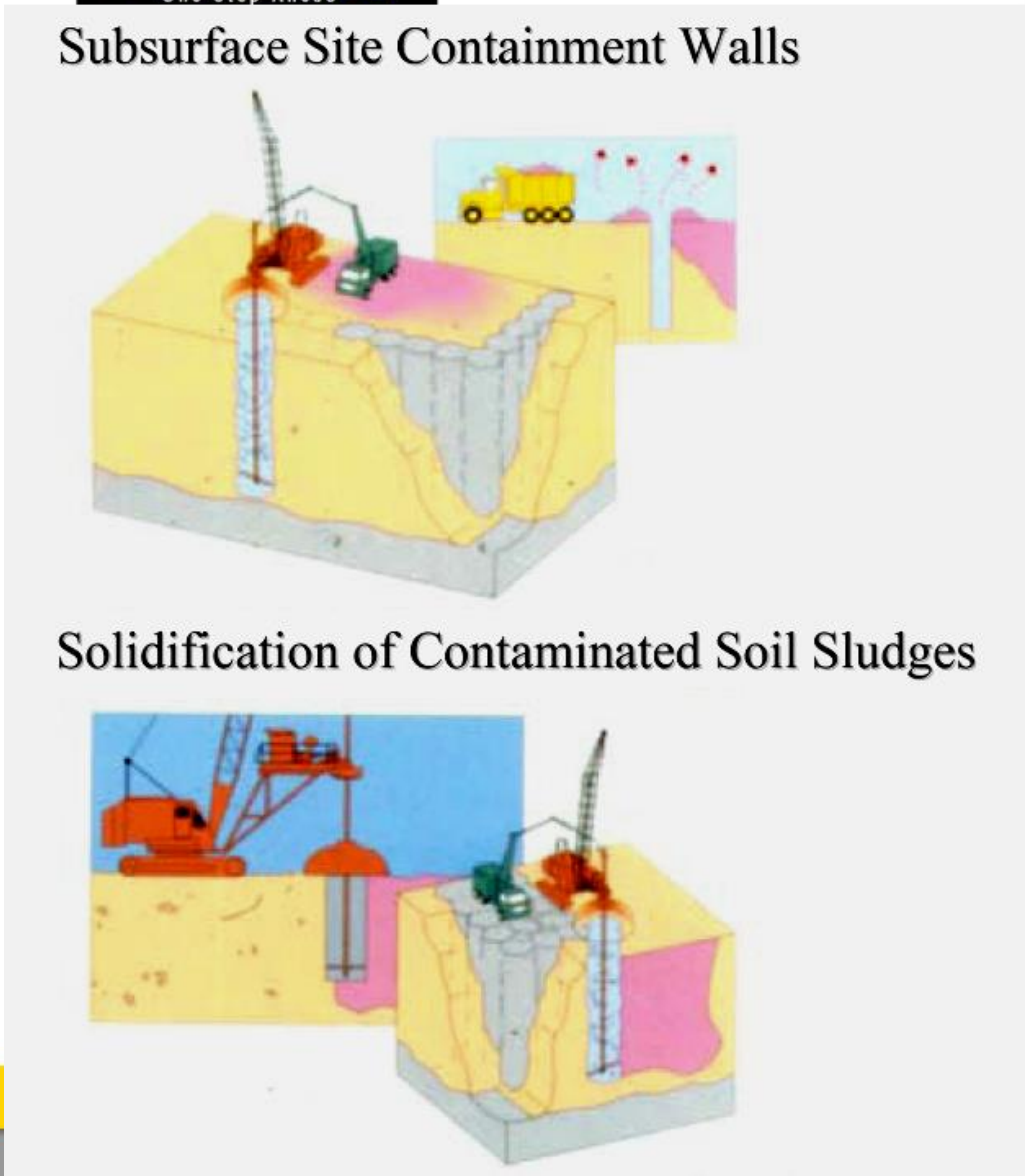
ISCO at WV Terminals Site

Mix Design: Sodium Persulfate (oxidizer) 5% by weight of soil
Portland Cement (binder) 10% by weight of soil

One Step Ahead

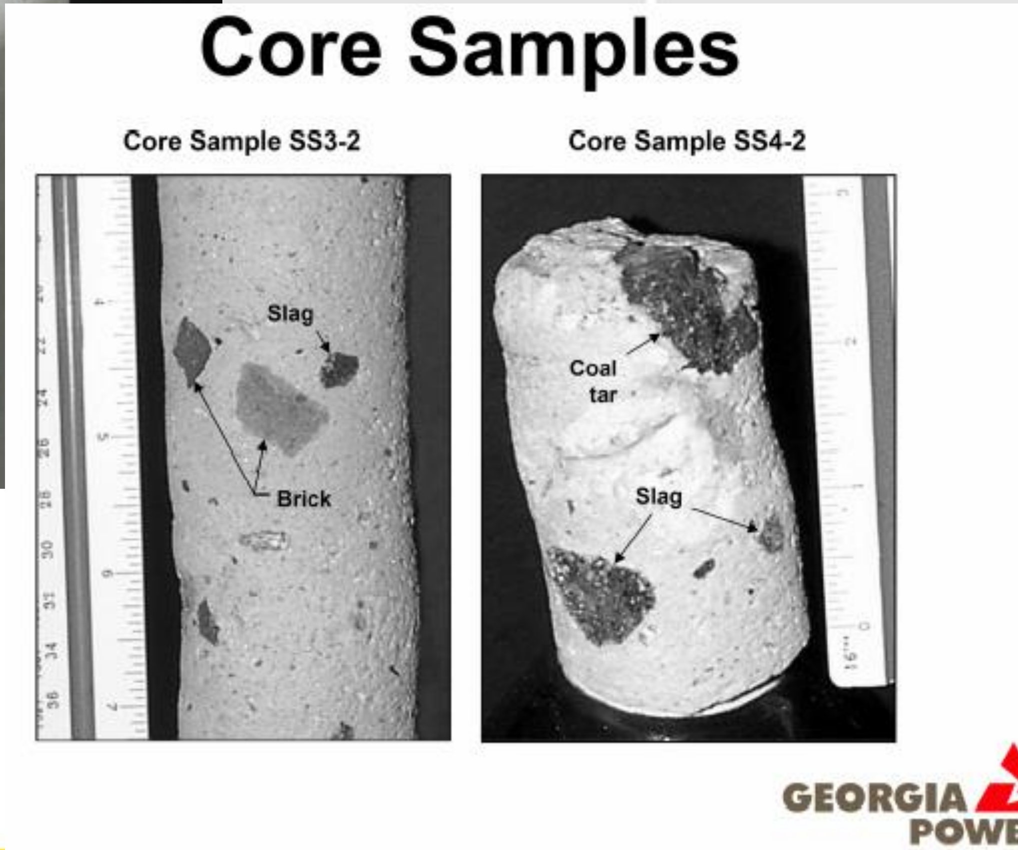
Columbus Manufactured Gas Plant





- 25% Cement addition
- 10% Cement addition

Inclusions



Former MGP Sites

Evaluation of the Effectiveness of In-Situ Solidification/Stabilization at Georgia Manufactured Gas Plant (MGP) Site

1009095

Final Report, September 2003

EPRI Project Manager
A. Coleman

EPRI • 3412 Hillview Avenue, Palo Alto, California 94304 • PO Box 10412, Palo Alto, California 94303 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com

GEORGIA POWER
A SOUTHERN COMPANY

Sydney Tar Ponds , Sydney, NS

Canadian Forces Base Esquimalt, Victoria Island, BC

Contact

Charles Wilk

Manager, Stabilization and Remediation Applications

ALLU Group Incorporated

Teterboro, New Jersey, USA

847-714-2754

charlesw@allu.net