Solidification/Stabilization

NEWMOA Presentation

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Presentation Outline

- Technology Overview
- Performance of S/S Treated Material
- Treatability Testing
- Implementation
- Long-Term Stewardship
- Q &A

Solidification/Stabilization

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ITRC S/S Survey – S/S

- Inconsistent criteria for development of performance specifications
- Uncertainties associated with prediction of long-term performance
- Lack of methodologies for measure of long-term compliance

*** *ITRC*** is a state-led national coalition dedicated to reduce barriers to the use of innovative environmental technologies that reduce compliance costs and maximize cleanup efficacy.

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Solidification/Stabilization (S/S)

- Solidification
  - Entrap contaminants within a solid matrix
  - Coating of contaminant molecule
  - Organics are generally immobilized due to reduced hydraulic conductivity
- Stabilization
  - Bind or complex contaminants
  - May involve chemical transformation
  - Metallic contaminants are stabilized by precipitation or by interaction (e.g. sorption) with cement matrix
- Example: Lead

$$Pb(HCO_3)_2 + CaSO_4.2H_2O \rightarrow PbSO_4\ (s) + CaCO_3 + 3H_2O + CO_2$$

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Cement-Based S/S Technology

Solidification

Process forms a granular or monolithic solid that incorporates the waste material

A solid matrix, calcium-silicate-hydrate (C-S-H) is formed in presence of water

<u>Cement Hydration Reaction (Thomas, 2004):</u>

$xCaSiO + yH_2O \rightarrow xCaO.ySiO.zH_2O + wCa(OH)_2 + Heat$

$xCaSiO$	+	yH_2O	→	$xCaO.ySiO.zH_2O$	+	$wCa(OH)_2$	+ Heat
Calcium Silicates		*Water*		*Calcium Silicate Hydrate (C-S-H)*		*Lime*	

- Reduces mobility of chemicals of concern
- Increases strength
- Reduces permeability
- Minimizes free liquid

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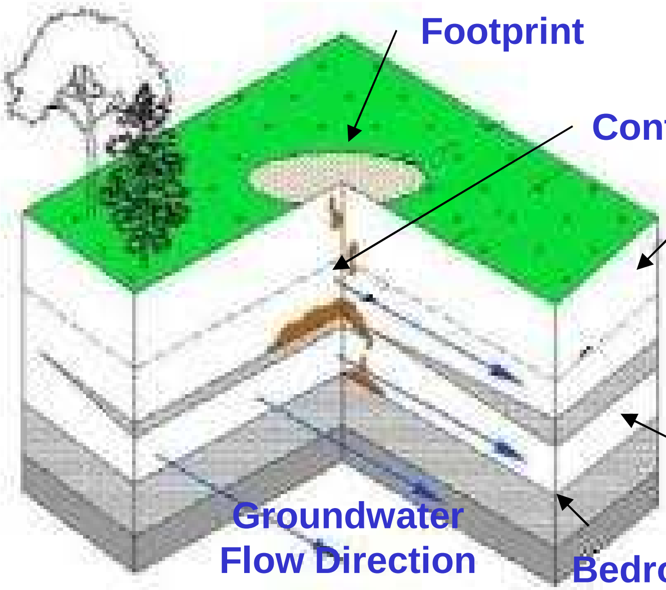
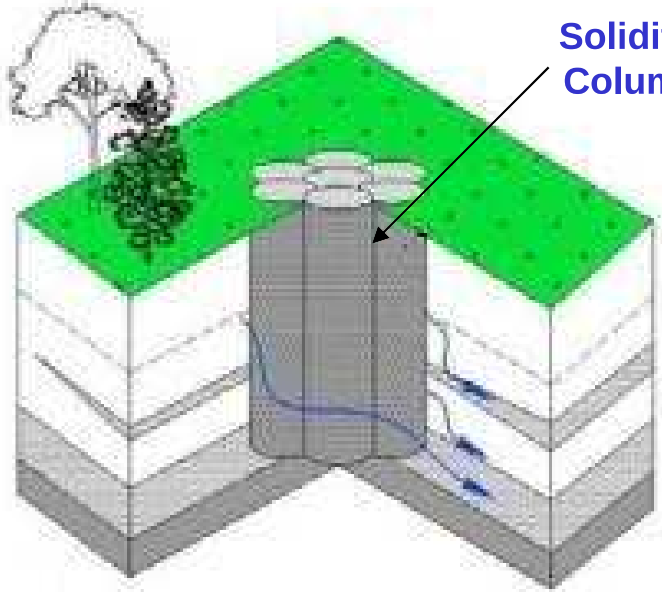
S/S Technology Process



Before S/S



After S/S

S/S Transformation of Waste Material

Oily Untreated Soil

S/S Treated Soil

S/S Treatment

- ↑ Strength
- ↓ Hydraulic Cond.
- ↓ Leachability

Retention of Contaminants in S/S Materials

- S/S remedy does not remove contaminants
- Chemically and physically retained in material with improved characteristics
  - Inorganic Contaminants
    - Stabilized by alkalinity
    - Adsorbed to mineral surfaces
    - Incorporated into mineral structure
  - Organic Contaminants
    - Partitioned with solid organic phases
    - Adsorbed to mineral surfaces
    - Absorbed by certain additives

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MAECTITE®

- Proprietary Process uses Apatite (phosphate)and sulfate for S/S
- Apatite (Calcium Phosphate) is natural mineral containing high level of phosphate and can be used for S/S of metals – crystalline and low solubility
- Apatite - $Ca_{10-x}Na_x(PO4)_{6-x}(CO_3)_x(OH)_2$
- Apatite II – fish bone waste - Soluble phosphate induced metal stabilization - hydroxyapatite and mixed-apatite-barite minerals
- End product is hard mineral that is resistant to acidity and degradation.

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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**

S/S Technology Challenges

- Contaminants are not destroyed or removed
- Uncertainties associated with prediction of long-term performance
- Volume increases in the treated mass may require management
- Options for treatment or post-treatment modifications limited
- Requires removal of debris or underground obstructions prior to treatment

S/S column

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S/S Technology Advantages

- Effective in treating many contaminants
- Applicable for in situ or ex situ treatment
- Treatment period relatively short
- Can improve structural property of soil
- Can be applied in dry or wet conditions
- May be more cost-effective than off-site disposal

Former manufactured gas plant (MGP) site in Cambridge, Massachusetts

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Applicability to Organics Contaminants

ITRC S/S-1: Table 2-1. Documented Effectiveness of S/S Treatment Chemical Groups

Contaminants	EPA 1993/2009	Other Refs
Halogenated VOCs, Non-Halogenated VOCs (i.e. solvents, aromatics)	No documented effectiveness	Pre-treat volatiles
HSVOCs, N-HSVOCs (i.e. chlorinated benzenes, PAHs)	Documented effectiveness	Pre-treat volatiles
PCBs, Pesticides	Documented effectiveness (in 2009 document)	
Dioxins/Furans	Potential effectiveness	Demonstrated effectiveness
Organic Cyanides, Organic Corrosives	Potential effectiveness*	Demonstrated effectiveness
Pentachlorophenol, Creosotes, Coal Tar, Heavy Oils	Not evaluated	Demonstrated effectiveness

* effectiveness not evaluated in EPA for 2009, therefore assumed to be same as 1993 evaluation

Applicability to Inorganic Contaminants

ITRC S/S-1: Table 2-1. Documented Effectiveness of S/S Treatment Chemical Groups

Contaminants	EPA 1993/2009	Other Refs
Volatile and Non-Volatile Metals	Documented effectiveness	
Asbestos	Documented effectiveness*	
Radioactive Materials	Documented effectiveness*	
Inorganic Corrosives, Inorganic Cyanides, Mercury	Documented effectiveness*	
Oxidizers, Reducers	Documented effectiveness*	

* effectiveness not evaluated in EPA for 2009, therefore assumed to be same as 1993 evaluation

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Commonly Used Additives/Reagents

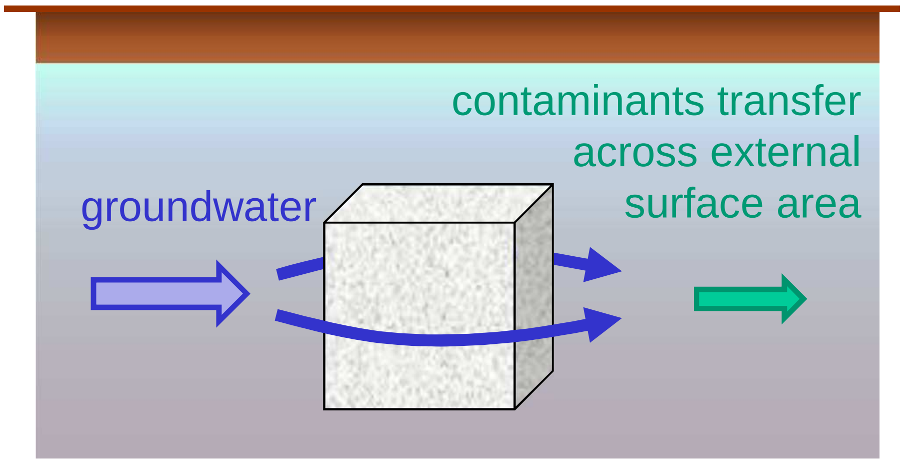
1. Ferrous sulfate, sulfides, sodium metabisulfite, calcium polysulfide, sodium hydrosulfite, ferrous chloride, phosphoric acid, triple super phosphate
2. Lime, Portland cement, soda ash, fly ash, sodium hydroxide, magnesium hydroxide, blast furnace slag
3. Soluble silicates (sodium or potassium)
4. Clays, organophilic clays, bentonite
5. Activated carbon, zeolitic materials

Three Key Performance Parameters

- Strength
  - Increased strength – withstand overlying loads
- Hydraulic Conductivity
  - Reduce Hydraulic Conductivity – manage water exposure
- Leachability
  - Reduce contaminant solubility/leaching – retain contaminants

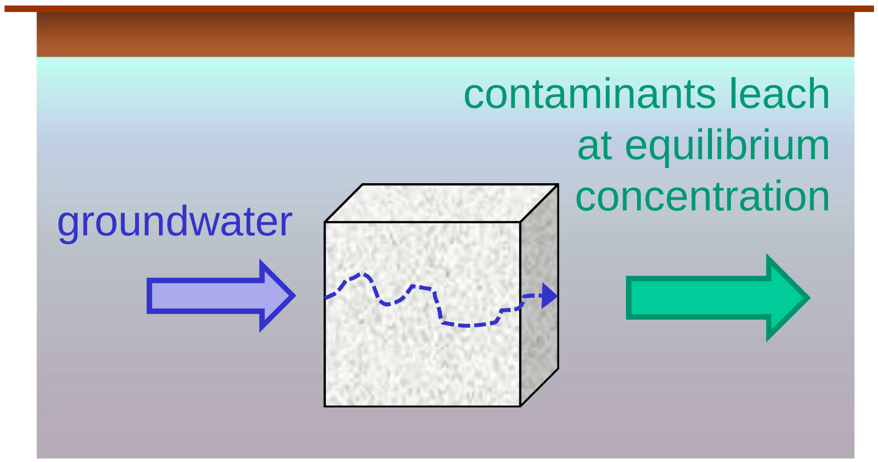
Why is Relative Hydraulic Conductivity Important?

$K_{S/S} << K_{soil}$



- Water is diverted around material
- Exposed surface area limited to external surface
- Contaminant release rate controlled by *Rate of Mass Transfer*

$K_{S/S} \sim K_{soil}$



- Water percolates through material
- Continuous pore area exposed
- Release concentrations based on *Liquid-Solid Partitioning* (local equilibrium)

Contaminant release under equilibrium conditions will always be greater than under mass transfer conditions.

Leaching Assessment Tests

- TCLP – Method 1213, Ground, Acid, RCRA Characteristics, Landfill Disposal, Equilibrium Controlled
- SPLP – Method 1312, Ground, Acid Rain, Acceptable for ISS, Equilibrium Controlled
- ANS 16.1 – Whole, Water, Nuclear Waste, Up to 90 days, Diffusion Controlled
- LEAF Methods - EPA Method 1315 – Similar to ANS 16.1, DI Water, Inorganics/Organics, Diffusion Controlled, Draft ASTM method.

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Leaching Environmental Assessment Framework (LEAF)

- LEAF consists of:
  - Four leaching test methods
  - Data management tools
  - Assessment approaches
- Provides a material-specific “source term” for release
  - Demonstration of treatment effectiveness
  - Release estimation
  - Fate and transport modeling
- Leaching tests define characteristic leaching over a broad range of release-controlling factors

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LEAF Test Methods

Method 1313 – Liquid-Solid Partitioning as a Function of Eluate pH using a Parallel Batch Procedure

Method 1314 – Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio (L/S) using an Up-flow Percolation Column Procedure

Method 1315 – Mass Transfer Rates in Monolithic and Compacted Granular Materials using a Semi-dynamic Tank Leaching Procedure

Method 1316 – Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio using a Parallel Batch Procedure

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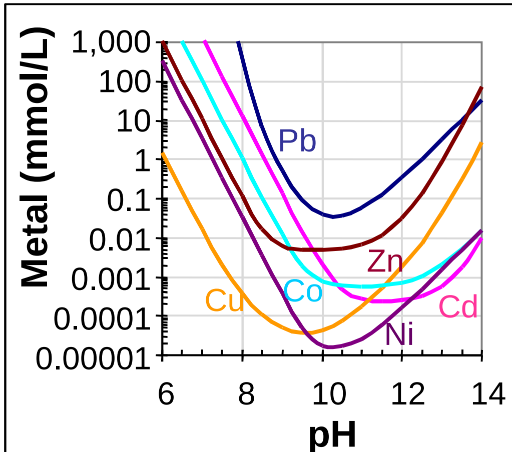
Factors Influencing S/S Material Leaching Performance



Moisture Transport

Leachant Composition

Water, Acids, Chelants, DOC

Leaching Factors

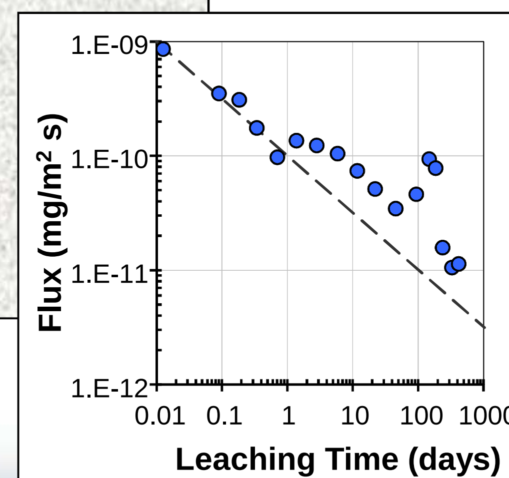
- Equilibrium or Mass Transport
- pH
- Liquid-to-solid ratio
- Rates of mass transport (flux)

Physical Factors

- Strength (durability)
- Hydraulic conductivity (water contact)

Chemical Degradation (Sulfate, Carbonation)

Physical Degradation (Erosion, Cracking)



Ref – ITRC Development of Performance Specifications for S/S

Treatability Studies Objectives

- Develop S/S formulation to meet project objectives
- Determine impact of selected reagents on contaminants
- Optimize the reagents/admixtures dosages
- Assess contaminant emissions
- Finalize material handling criteria
- Determine physical and chemical uniformity of the material
- Determine the volume increase
- Finalize construction parameters and performance criteria

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Bench and Pilot-Scale Treatability Testing

- Bench-scale– provides important information
- Pilot-scale – confirms the full-scale approach
- Selection of candidate reagents requires knowledge of:
  - Process track record
  - Interference and chemical incompatibilities
  - Metals chemistry
  - Compatibility with disposal or re-use
  - Cost

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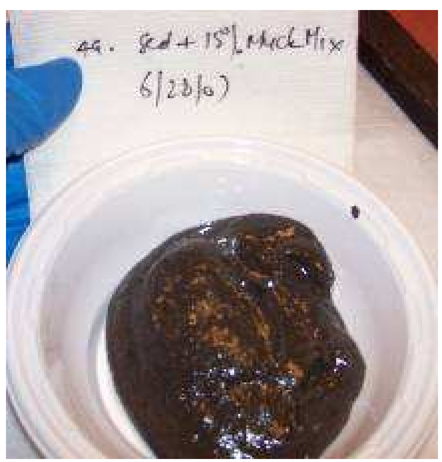
Bench-Scale Laboratory Testing

Untreated Sample in the Field

Sample Collection

Sample Characterization



S/S Sediment Sample

Treatability Testing Evaluation

Key Performance Parameter	Performance Measurement	Example Criteria
Strength	Unconfined Compressive Strength	344.7 kN/m2 (50 psi) to 689.4 kN/m2 (100 psi)
Hydraulic Conductivity	Hydraulic Conductivity	$5x10^{-6}$ to $1x10^{-6}$ cm/sec (relative K)
Leachability		
	Site conceptual model Remedial goals Risk-based limits % leaching reduction MCL or other goals Point of compliance	* With promulgation of LEAF Tests, these values will need to be based on data available from testing.

Implementation

- Performance verification during implementation
- Sampling and testing considerations
- Test data evaluation
- Long-term performance considerations

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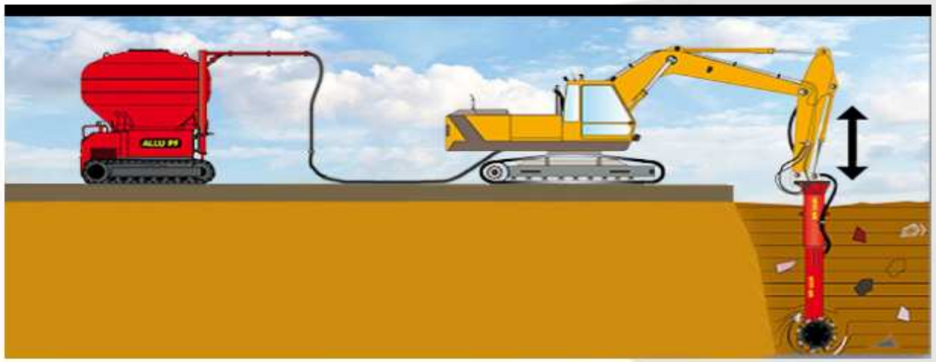
In-Situ Mixing System

ALLU
One Step Ahead

Horizontal Axis Insitu Mixers



One Step Ahead

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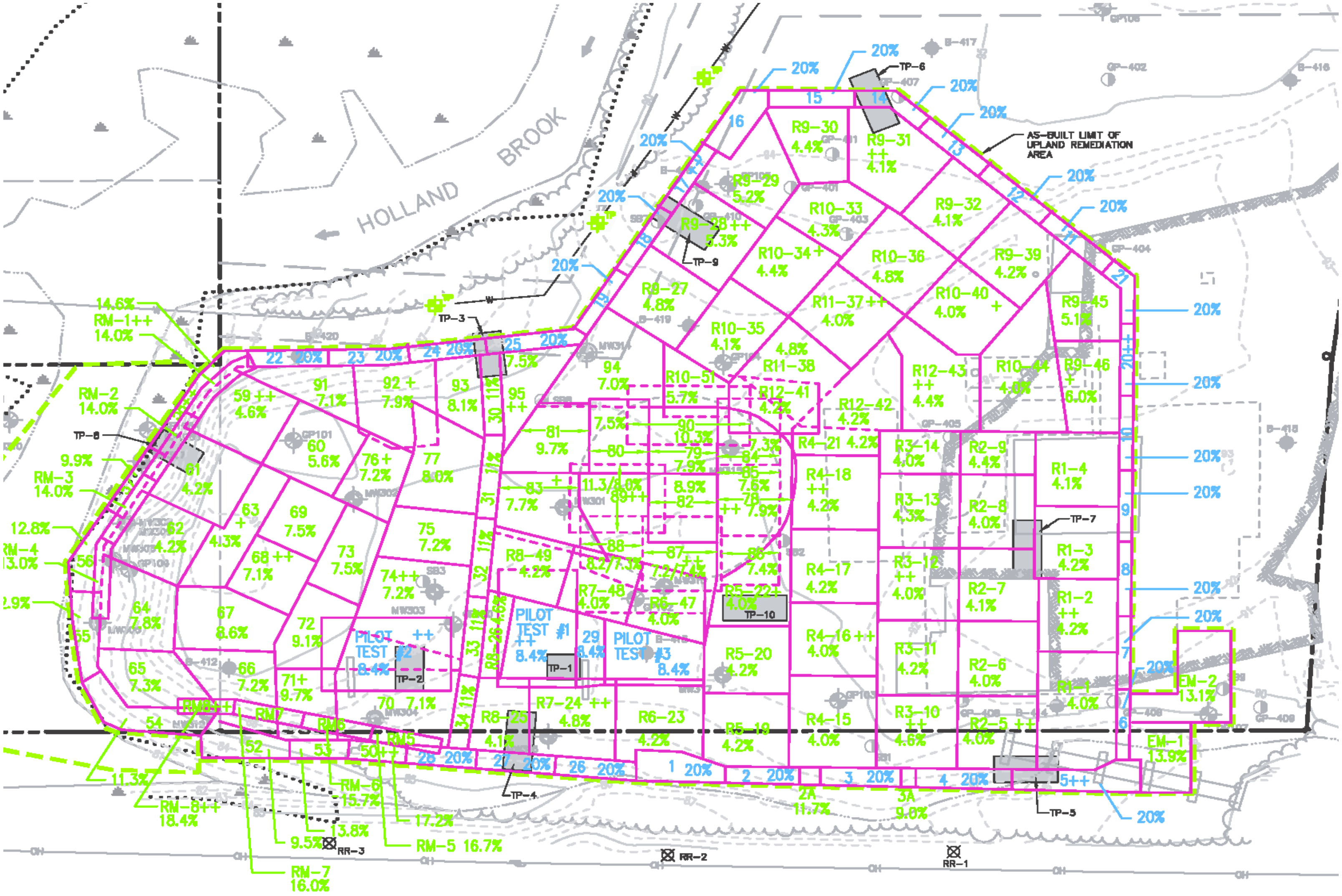
04/26/2007


VENEZIA
03/09/2007


KOMATSU
90-LTC
04/25/2007

Documenting Mix Cells and Test Data



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290-LTC
STAY BACK 300 FEET
CO.


LANG TOOL CO.
STAY BACK 300 FEET
290-LTC
04/14/2007


03/09/2007


KOMATSU
DEERE
03/13/2007


04/23/2007


10/16/2007

Long-Term Stewardship

- Long-Term Durability
- Groundwater Monitoring
- Institutional and Engineering Controls
- Land Use
- Community Concerns

Long-Term S/S Performance

- Properly designed S/S remedies can be expected to last on the order of decades to centuries. Success tied to remedial goals!
- Research studies have been conducted to evaluate the long-term performance of S/S remedies.
  - PASSiFy project
  - EPRI study
  - Other literatures
- EPA has used S/S effectively on many sites.

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Long-Term Performance Assessment Studies – PASSiFy

- Performance Assessment of Solidified/Stabilized Waste Forms – PASSiFy, 2010, Largest Study
- Ten ISS sites (1989 – 2004) in 3 countries - USA, UK, and France
- Strength, permeability, leaching, microstructure investigation, modeling, MINTEQ, etc.
- Properties of the treated material typically did not change significantly
- Continue to meet the original remedial goals
- Affirms the viability of S/S as an effective long-term treatment technology.

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Long-Term Performance Assessment Studies – EPRI Study

- Evaluation at a former MGP site 10 years after S/S implementation
- Testing - geotechnical, chemical, leaching, and solid-phase geochemical analyses, F &T modeling.
- Treated contaminated material was meeting the performance criteria as designed
- Contaminant concentrations at point of compliance were predicted to continue meeting performance criteria for at least 10,000 years

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Key Points

- S/S treatment has demonstrated long-term effectiveness for a number of contaminants
- Performance specifications - critical for S/S
- Treatability studies assess S/S treatment feasibility
- QA/QC, consistency, and compliance testing during implementation
- Long-term stewardship typically used with S/S

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Key Points

- ISS is a permanent remedy
- ISS reduces potential risk of groundwater impact
- ISS eliminates direct contact risk
- ISS supports future use of the site
- Typical cost of ISS ranges from $65 to $110 (including dewatering)

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References/Resources

- http://www.clu-in.org/conf/itrc/SS/resource.cfm
- Review of scientific literature on the use of stabilisation/solidification for the treatment of contaminated soil, solid waste and sludges, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/290656/scho0904bifp-e-e.pdf

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"We're still not sure what happened here, but I think we can all agree that we're glad it's over."

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THANK YOU

QUESTIONS

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