



Turning Soil Liabilities into Opportunities

Brownfield Site – Definition

Solidification / Stabilization (S/S) – *Processing Soil*

Common Objectives – *What We Can Achieve*
– *How We Can Achieve It*

Success Stories – *Project Profiles*



✓ **Turning Liabilities into Opportunities**

- “A brownfield site is an abandoned or under-utilized property that cannot be easily redeveloped because it is contaminated with hazardous substances.
- Solidification and Stabilization (S/S) using cementitious materials can turn such environmental liabilities into economic opportunities.
- S/S has been applied successfully at many brownfield areas in North America, allowing the treated soil to be reused safely at the site.
- This reduces the need to remove hazardous materials and to transport such materials through communities.
- A variety of S/S application methods make the treatment suitable for a wide range of projects.
- With S/S, environmentally contaminated sites that once were thought unusable can be redeveloped safely and economically. ”

Solidification

- **Solidification**
dramatically reduces porosity, hydraulic conductivity, and permeability of soil
- A reduction in free liquid, solubility, leachability, and mobility of contaminants is achieved
- Physically entraps contaminants
- Provides a very stable base for additional engineered controls
- Changes physical properties of contaminated soil

Stabilization

- ***Stabilization*** chemically changes soil and/or contaminants
 - The high pH converts heavy metals to insoluble hydroxides
 - Hydroxides are insoluble and non-leachable (remember the solubility rules!)
 - Changes soil chemistry making it more amenable to solidification

Solidification / Stabilization (S/S) : Solubility Rules

- ✓ All common compounds of Group I and ammonium ions are soluble. (Li, Na, K, Rb, Cs)
- ✓ All nitrates, acetates, and chlorates are soluble.
- ✓ All binary compounds of the halogens (other than F) with metals are soluble, except those of Ag, Hg(I), and Pb. Pb halides are soluble in hot water.)
- ✓ All sulfates are soluble, except those of barium, strontium, calcium, lead, silver, and mercury (I). The latter three are slightly soluble.
- ✓ **Except for rule 1, carbonates, hydroxides, oxides, silicates, and phosphates are insoluble.**
- ✓ Sulfides are insoluble except for Group 1 and 2 plus ammonium

Solidification / Stabilization (S/S) : Solubility Rules

Periodic Table of Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1 H Hydrogen 1.00794	<div>Atomic # Symbol Name Atomic Mass</div> <div>C Solid Hg Liquid H Gas Rf Unknown</div> <div>Metals Alkali metals Alkaline earth metals Lanthanoids Actinoids Transition metals Poor metals Nonmetals Other nonmetals Noble gases</div>																2 He Helium 4.002602	
3 Li Lithium 6.941	4 Be Beryllium 9.012182																	5 B Boron 10.811
6 C Carbon 12.0107	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984032	10 Ne Neon 20.1797														11 Na Sodium 22.98976928
12 Mg Magnesium 24.3050																	13 Al Aluminum 26.9815386	
14 Si Silicon 28.0855	15 P Phosphorus 30.973762	16 S Sulfur 32.065	17 Cl Chlorine 35.453	18 Ar Argon 39.948														19 K Potassium 39.0983
20 Ca Calcium 40.078	21 Sc Scandium 44.955912	22 Ti Titanium 47.867	23 V Vanadium 50.9415	24 Cr Chromium 51.9961	25 Mn Manganese 54.938045	26 Fe Iron 55.845	27 Co Cobalt 58.933195	28 Ni Nickel 58.6934	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.64	33 As Arsenic 74.92160	34 Se Selenium 78.96	35 Br Bromine 79.904	36 Kr Krypton 83.798	37 Rb Rubidium 85.4678	
38 Sr Strontium 87.62	39 Y Yttrium 88.90585	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.96	43 Tc Technetium (97.9072)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.90550	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.710	51 Sb Antimony 121.760	52 Te Tellurium 127.60	53 I Iodine 126.90447	54 Xe Xenon 131.29	55 Cs Cesium 132.9054519	
56 Ba Barium 137.327	57–71																56 Ba Barium 137.327	
57 Fr Francium (223)	58 Ra Radium (226)	89–103																57 La Lanthanum 138.90547
72 Hf Hafnium 178.49	73 Ta Tantalum 180.94788	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.084	79 Au Gold 196.966569	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98040	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)	87 Fr Francium (223)	88 Ra Radium (226)	89 La Lanthanum 138.90547	
104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Uub Ununbium (285)	113 Uut Ununtrium (284)	114 Uuq Ununquadium (289)	115 Uup Ununpentium (288)	116 Uuh Ununhexium (292)	117 Uus Ununseptium (294)	118 Uuo Ununoctium (294)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	
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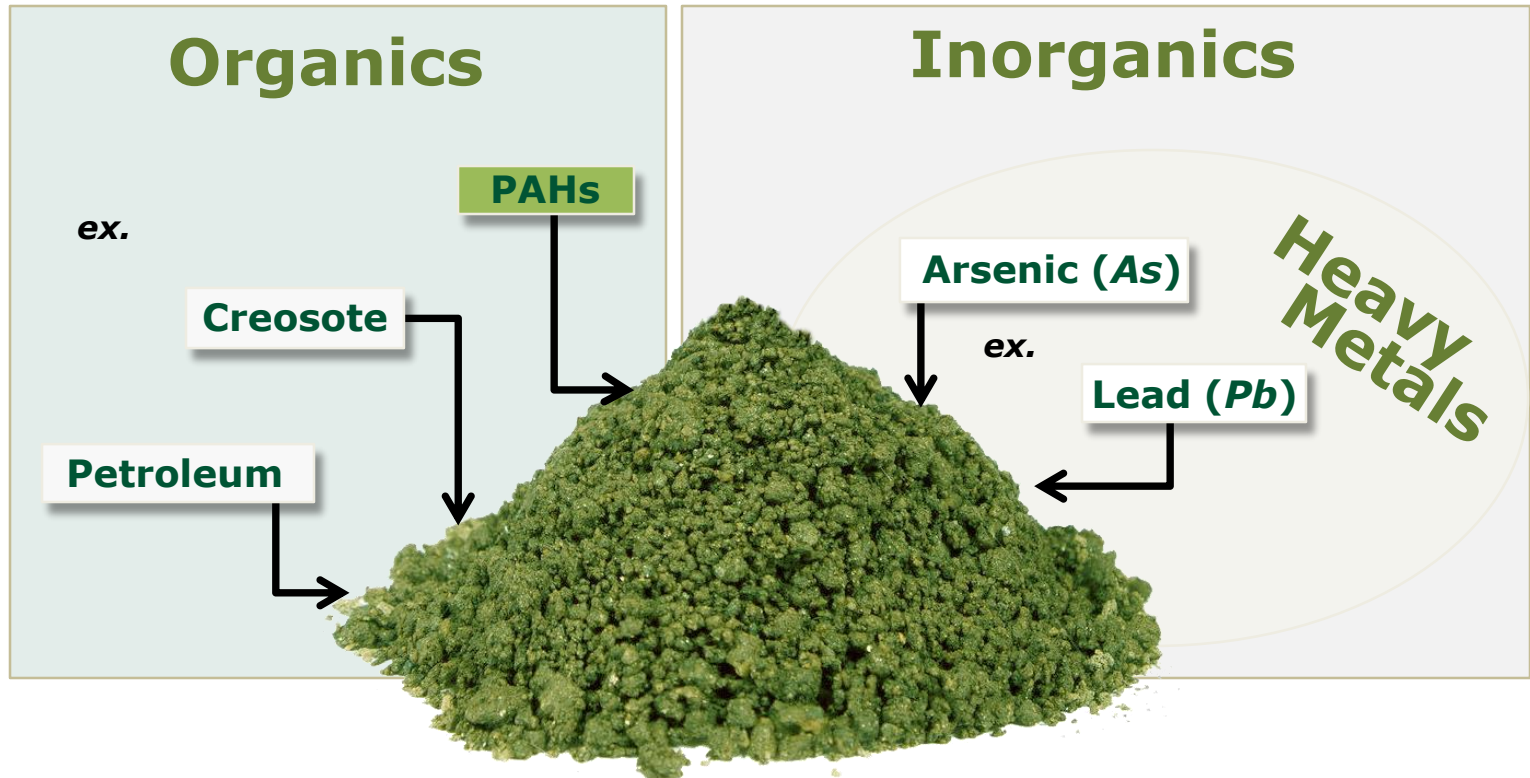
Solidification / Stabilization (S/S) : Processing Soil

- ✓ **Reduces hazardous soil contaminants to non-hazardous levels**
 - Also known as “Brownfield” remediation, in order to proceed with construction development initiatives or restore land back to its natural state
- ✓ **Brings about physical and chemical changes to soil impacted with either organic or inorganic hazardous constituents**
 - Mixing in a cementitious product as a binding reagent
- ✓ **Improves overall community health and environment by remediating the Brownfield in a sustainable fashion**
 - Reduced truck traffic, conservation of virgin material, etc.
- ✓ **Identifies an economic solution for *In Situ* or *Ex Situ* soil treatment and/or disposal**

Solidification / Stabilization (S/S) : Processing Soil

“Cement-based S/S has been used to treat a wide variety of contaminants, including inorganics —heavy metals like lead and arsenic —and organic contaminants, like creosote and petroleum products ” - Cement Association of Canada

www.cement.ca/images/stories/Cement-Base%20Remediation%20Solutions.pdf



Solidification / Stabilization (S/S) : Processing Soil

Table 2-1. Documented effectiveness of S/S treatment for chemical groups

Chemical groups	Citations for treatment effectiveness ^a		
	EPA 1993a ^b	EPA 2009b ^b	Other references ^c
<i>Organic chemicals</i>			
HVOCs ^d	N	N	D, with pretreatment (Paria and Yuet 2006)
N-HVOCs ^d	N	N	D, with pretreatment (Paria and Yuet 2006)
HSVOCs ^d	D	D	
N-HSVOCs, N-VOCs ^d	D	D	
PCBs	P	D	
Pesticides	P	D	
Dioxins/furans	P	P	D (Bates, Akindele, and Sprinkle 2002, PASSiFy Project 2010)
Organic cyanides	P	P*	D (Wilk 2007)
Organic corrosives	P	P*	D (Wilk 2007)
Pentachlorophenol	–	–	D (Bates, Akindele, and Sprinkle 2002, Wilk 2007)
Creosotes, coal tar	–	–	D (Bates, Akindele, and Sprinkle 2002, Wilk 2007)
Heavy oils	–	–	D (Wilk 2003)
<i>Inorganic chemicals</i>			
Volatile metals	D	D*	
Nonvolatile metals	D	D	
Asbestos	D	D*	
Radioactive materials	D	D	
Inorganic corrosives ^d	D	D*	
Inorganic cyanides ^d	D	D*	
Mercury	D	D*	EPA 2007b
<i>Reactive chemicals</i>			
Oxidizers	D	D*	
Reducers	D	D*	

^a Key:

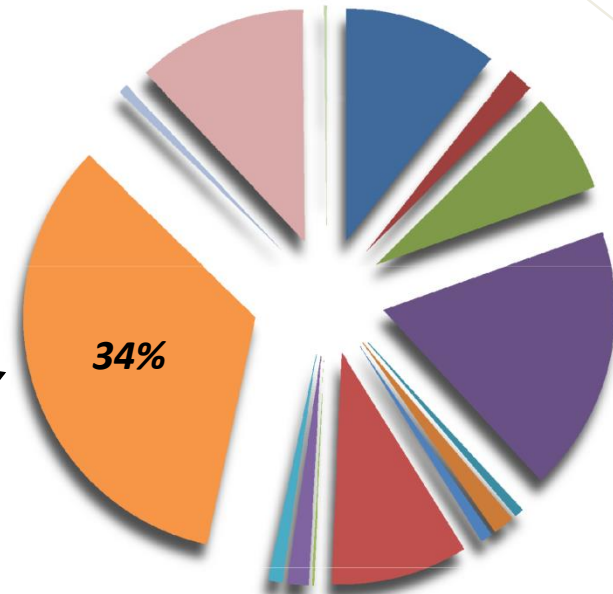
- N = no expected effectiveness, P = potential effectiveness, D = demonstrated effectiveness.
- P*/D* = S/S effectiveness was specifically stated in EPA 1993a but not in EPA 2009b; effectiveness is assumed to be the same in 2009. EPA 2007b documents the selection and use of S/S at National Priorities List (NPL) sites, but EPA does not indicate the effectiveness of the remedy.
- – = This chemical was not specifically discussed in EPA 1993a or 2009b, but effectiveness has been documented in other references (see rightmost column).

Common Objectives : *What We Can Achieve*

Ex Situ Treatment [1982 – 2008]

53% (598 sites)

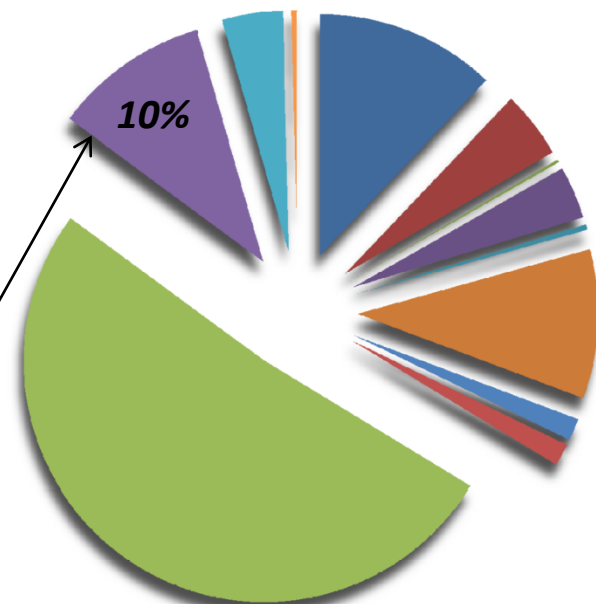
- Bioremediation
- Chemical Treatment
- Incineration (on-site)
- Incineration (off-site)
- Mechanical Soil Aeration
- Neutralization
- Open Burn / Open Detonation
- Physical Separation (incl. recycling)
- Phytoremediation
- Soil Vapor Extraction
- Soil Washing
- **Solidification / Stabilization**
- Solvent Extraction
- Thermal Desorption
- Vitrification



In Situ Treatment [1982 – 2008]

47% (537 sites)

- Bioremediation
- Chemical Treatment
- Electrical Separation
- Flushing
- Mechanical Soil Aeration
- Multi-Phase Extraction
- Neutralization
- Phytoremediation
- Soil Vapor Extraction
- **Solidification / Stabilization**
- Thermal Treatment
- Vitrification



TYPICAL PRODUCTS USED

- GU cement
- *GUL* (General-Use Limestone cement)
- GU / slag blends
- GU / Fly Ash Blends
- CKD

The Advantages of Cement in S/S

- Manufactured under strict CSA standards
- *50 years of use in a variety of projects*
- Long term performance record
- Minimize volume increase compared with other reagents
- Non-proprietary manufactured product readily available



TYPICAL SPECIFICATION REQUIREMENTS

- Unconfined compressive strength
- Leachability

Optimized mix design

- Technical expertise of Lafarge staff help in analyzing soil contaminates and selection of cement contents
- Sample preparation of contaminated material at Belleville lab
- Unconfined compressive strength tests
- Coordination of testing samples for hydraulic conductivity and leachability



Sampling and Preparation



- PREPARATION —
Each *individual* sample in the blocks is a composition of randomly extracted samples from fresh test pits on site

Pre-engineering Testing

- ☑ TOTAL ORGANIC CARBON (TOC) OF SOIL
- ☑ COMPRESSIVE STRENGTHS 7 / 28 DAYS
- ☑ OBSERVED SET TIMES & WORKABILITY

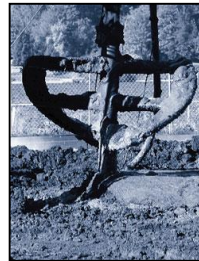
- ☑ PROCTOR DENSITY CURVE & OPT. MOISTURE
- ☑ GRADATION & IN SITU MOISTURE CONTENT
- ☑ TCLP BEFORE AND AFTER

EQUIPMENT



Twin shaft pugmill

**Methods recommended
ensure proper dispersion
and soil interaction**



Common Objectives : *How We Can Achieve It*

PRE-ENGINEERING TESTING

LAFARGE

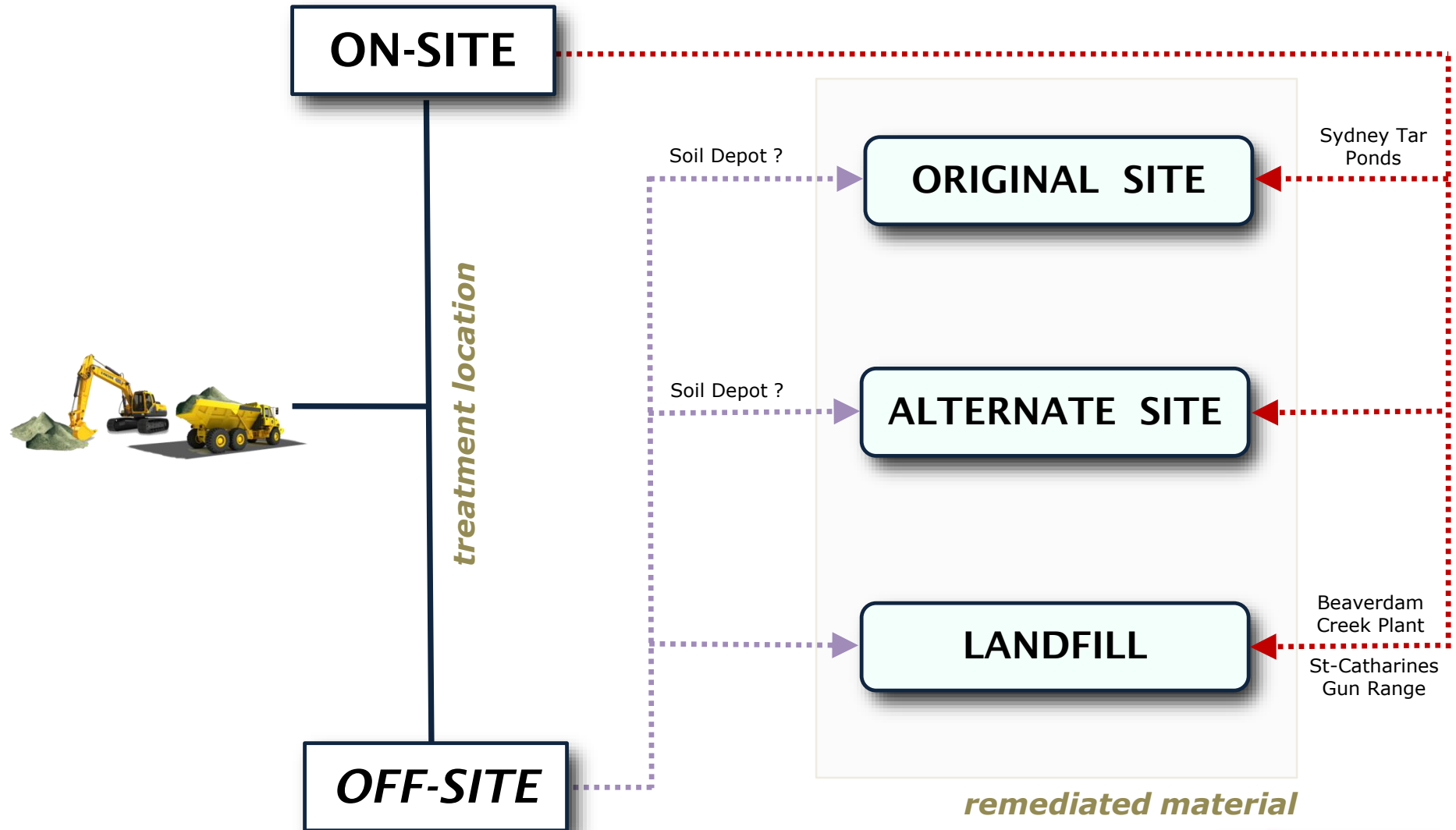


OUTGOING MATERIAL TESTING

LAFARGE



Common Objectives : *How We Can Achieve It*



PROJECT

Steel Mill – Vancouver, BC

Site : Western Steel: 2013

Challenges :

- **Heavy metal** contaminants, and unstable geotechnical attributes

Requirements :

- Stabilization in situ and permits paving of top layer of RCC and asphalt

Project / Application :

- *Contractor* : BIRCO Environmental
- Used pugmill to blend GU
- Treated soil directly on site

Benefits to Customer :

- Provided high strength location for the stacking of shipping containers
- Reduced costs of traditional dig / haul to contaminate sites



CONTAMINANT LEVELS

Contaminant	Untreated	Regulatory Limit	After Treatment	% Reduction
Cadmium	1.2 mg/L	0.5 mg/L	<0.05 mg/L	-98%
Lead	14 mg/L	5 mg/L	<0.1 mg/L	-99%
Zinc	250 mg/L	500 mg/L	<0.05 mg/L	-99%

PROJECT

Sydney Tar Ponds Clean Up

Site : Tar Ponds, Sydney, NS

Date : 2007 - Present

Challenges :

- 700 kMT of material needing to be excavated
- Cooling pond sludge from coke ovens
- Over 3.8 tonnes of **PCBs**, **raw sewage** and **benzene**

Requirements :

- Minimal dust, unconfined compressive strengths and permeability specs
- Future site uses: park, walking trails, sports fields, and wetlands

Project / Application :

- *Contractors* : Nordlys Environmental and Van Zutphen Construction / *Material Supplier* : Lafarge
- Remediate ~100-hectare surface area
- In situ treatment, stabilization and solidification of soil/sludge, filling ponds

Benefits to Customer :

- Site stabilized and hazardous chemicals immobilized
- One of Canada's largest and more infamous sites, converted to parkland
- Avoided most widely used method of destroying PCBs via incineration





PROJECT

Port de Montréal

Site : Montréal, QC

Date : 2013

Challenges :

- **Heavy metal** contaminants, and unstable geotechnical attributes

Requirements :

- Stabilization in situ and permits paving of top layer of RCC and asphalt

Project / Application :

- *Contractor* : Pavages Chenail / *Material Supplier* : Lafarge
- Used pugmill to blend ~20% GUb-SF cement
- Treated soil was transported in dump trucks, and compacted directly on site

Benefits to Customer :

- Provided high strength location for the stacking of shipping containers
- Reduced costs of traditional dig / haul to contaminate sites
- Improved engineering properties
- Project cost savings of ~\$3 000 000



PROJECT

St. Catharines Shooting Range

Site : Welland Canal, St. Catharines, ON

Date : Oct 2007

Challenges :

- 26 kMT of soil failed Ontario's residential standards test
- Previously a skeet shooting range (Brownfield classified)
- **Hazardous lead** and **PAHs (Polycyclic Aromatic Hydrocarbons)**

Requirements :

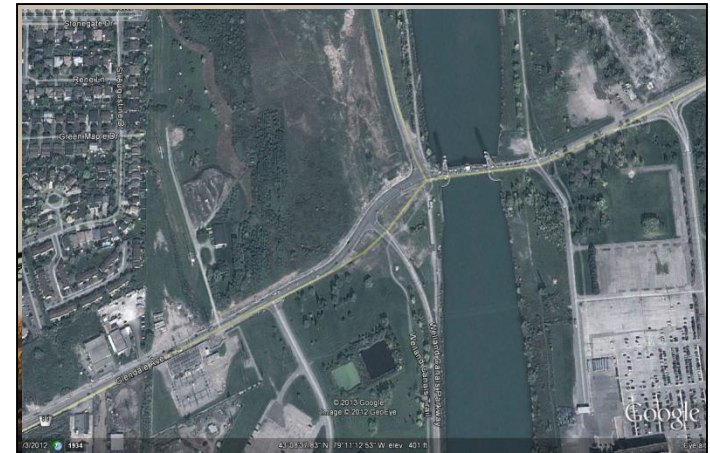
- Remediated site required passing environmental assessment for residential
- Cement product to stabilize and immobilize lead to acceptable levels

Project / Application :

- *Contractor* : Quantum Remediation / *Material Supplier* : Lafarge
- Remediate 5-hectare property (26 kMT soil)
- Reduce concentration of lead to a range below that of regulatory standards
- In situ treatment and removal of stabilized soil for off-site disposal

Benefits to Customer :

- Brownfield stabilized and hazardous chemicals immobilized
- Site prepped for residential housing
- Project resulted in 40% cost-savings vs. original budget



PROJECT

Beaverdam Creek Recycling Plant

Site : Thorold, ON

Date : Nov 2008 – Dec 2010

Challenges :

- 12 kMT of material of contaminated material
- Proximity to creek, potential water supply contamination

Requirements :

- Stabilize **PCB** contaminant from 1960s carbonless copy paper recycling plant

Project / Application :

- *Contractor* : Severson Environmental / *Material Supplier* : Lafarge
- In situ treatment and removal off-site due to economical cost advantage
- Soil remediation using 700 MT of cement

Benefits to Customer :

- Reduced cost due to in situ treatment before removal
- Protect water supply



PROJECT

U.S. Military Base Gun Range

Site : Michigan, U.S.

Date : 2004

Challenges :

- **Lead contamination** in first meter of soil

Requirements :

- Stabilization in situ and permits paving of top layer of asphalt

Project / Application :

- *Contractor* : Aker Contracting / *Material Supplier* : Lafarge
- Used pulverizer to blend 8% cement by dry weight in conjunction with water
- Treated soil was compacted using sheep's foot roller, then smooth drum

Benefits to Customer :

- Provided parking lot at a lower cost
- Reduced costs of original proposed dig / haul by roughly half
- Reduced long term liability, changing status of soil to non-hazardous



PROJECT

Old Dow Chemical Facility

Site : Bay City, MI

Date : Summer 2013

Challenges :

- 40 K tons of impacted soil
- Former chemical manufacturing plant)
- In-situ solidification/stabilization
- **Hazardous heavy metals, PAHs** and other organics

Requirements :

- Remediated site required passing environmental assessment for TCLP
- Portland Cement to solidify and immobilize organic fraction
- CKD to stabilize heavy metals (originally Portland was specified)

Benefits to Customer :

- **No off-site landfilling**
- Project resulted in 50% cost-savings vs. original budget of dig and haul



PROJECT

Recycled Barrel Facility

Site : Lansing, MI

Date : March 2012

Challenges :

- 10,000 tons of material of lead-contaminated soil; 1,900-8,000 mg/Kg total Pb
- 10-150 ug/L in TCLP extraction
- Proximity to commercial and residential properties

Requirements :

- Stabilize lead in soil to less than 5 mg/L in a TCLP extraction
- In-situ solidification/stabilization using CKD

Benefits to Customer :

- Reduced cost due to in situ treatment before removal and landfilling
- Dramatic reduction in landfill cost; non-haz vs hazardous
- Project resulted in 50% savings vs original budget of dig and haul



REDUCE

- Significantly **fewer trucks** on the roads around our towns and cities:

Less Traffic

ex:

$$\begin{array}{c} \text{60 000 m}^3 \\ \text{Incoming virgin material} \end{array} = \left[\begin{array}{c} \text{20 m}^3 / \text{truck} \\ \text{Outgoing hazardous material} \end{array} \times (3\,000 + 3\,000) \right] = 6\,000 \text{ trips}$$

- VS -

$$\begin{array}{c} \text{60 000 m}^3 \\ \text{40 MT / truck} \end{array} = \text{290 trips}$$

REUSE

- An **on-site** solution means material is *treated* –and *not* condemned to outside unusable hazardous waste sites. Instead, producing an engineered construction product

Recycled Material

RETHINK

- The U.S. Environmental Protection Agency (EPA) has identified S/S with cement as a *Best Demonstrated Available Technology* for **more than 50** Resource Conservation and Recovery Act (RCRA) listed wastes

Proven

CEMENT BASED SOLIDIFICATION/STABILIZATION : Benefits

- PROVEN TECHNOLOGY FOR MORE THAN 60 YEARS
- STABILIZES HEAVY METALS
- ELIMINATES HAZARDOUS CHARACTERISTIC
- SOLIDIFIES ORGANIC MATERIAL
- HYDRAULIC CONDUCTIVITY OF $<10^{-7}$ cm/sec OR LESS
- PROVIDES STABILITY FOR FUTURE STRUCTURES
- LOWEST ENVIRONMENTAL REMEDIATION IMPACT
- USUALLY THE LOW COST OPTION

THANK YOU
ANY QUESTIONS

