Sustainable Remediation

Definitions, Methods, and Case Studies

Michael E. Miller, Ph.D.
CDM Smith
Buddy Bealer
Sustainable Remediation Initiative (SRI)

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Outline: Sustainable Remediation

- What is it ??? and what is it not?
- What's the difference between "green" and "sustainable"?
- What guidance is available?
- How do you apply it?
  - Illustrated by site remediation examples
- How do you measure it?

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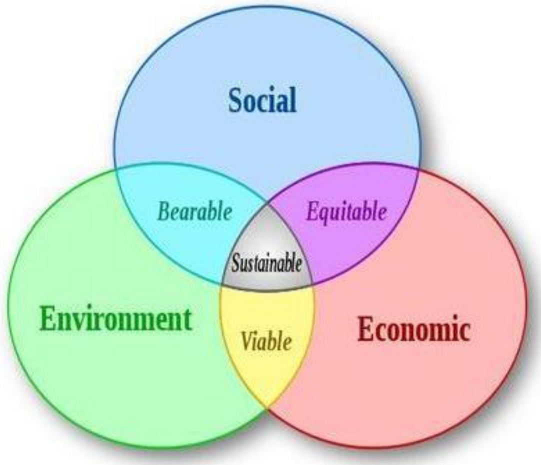
Triple Bottom Line (TBL) Sustainability Components



After Linder (2009)

SRI Sustainable Remediation Initiative

SURF

INTERSTATE TECHNOLOGY REGULATORY COUNCIL ITRC

energy API

SURF

- Founded 2006, Non Profit in 2010
- White Paper in Remediation Journal 2009
- Framework published in 2011
- Mission: maximize the overall environmental, societal, and economic benefits from the site cleanup process by
  - Advancing the science and application of sustainable remediation
  - Developing best practices
  - Exchanging professional knowledge
  - Providing education and outreach

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- Collaboration of US Organizations
  - Sustainable Remediation Forum (SURF),
  - Interstate Technology & Regulatory Council (ITRC),
  - API Energy
- seeking to promote the understanding and implementation of sustainable remediation
- supports acceptance of the ITRC Green and Sustainable Remediation (GSR) Framework

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Sustainable Remediation …

- **Is NOT**: New, Technology, or an Excuse
- **Is**: Flexible, Scalable, Holistic, Simple, Process, Concept
- **Benefits**:
  - Provides the best remediation
  - Maximizes benefits
  - Minimizes costs (environmental, social, economic)
  - Supports stakeholder participation and buy in
  - Easy to do with existing regulations (with policy)

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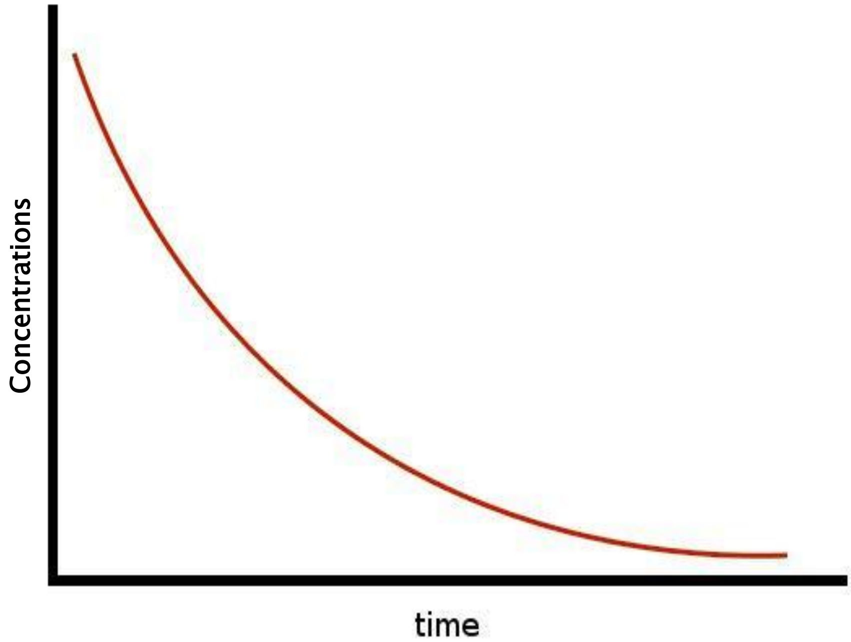

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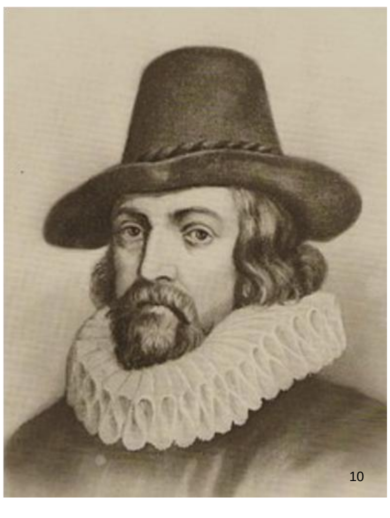
Could it be that sometimes … ?

"The remedy is worse than the disease."

Francis Bacon



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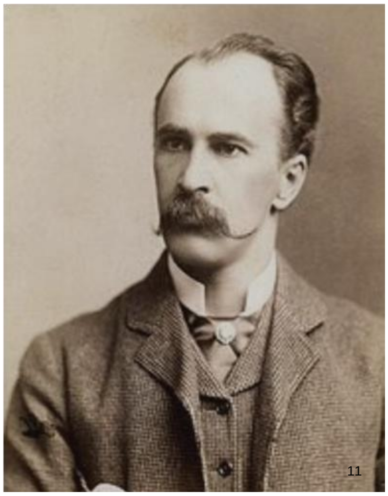
The Sustainable approach …

"The good physician treats the disease, the great physician treats the patient who has the disease."

William Osler



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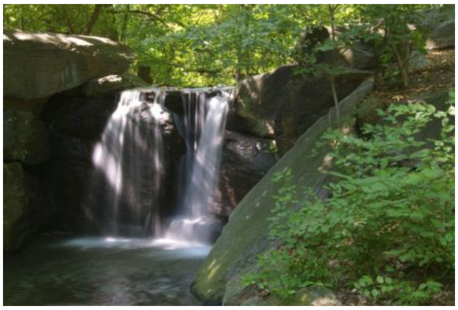
Green Remediation

- **EPA**: Green Remediation (GR) "the practice of considering all environmental effects of remedy implementation and incorporating options to minimize the environmental footprints of cleanup actions".



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Sustainable Remediation

- **SURF**: Sustainable Remediation protects human health and the environment while maximizing the environmental, social, and economic benefits throughout the project life cycle.

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Green & Sustainable Remediation

- **ITRC**: Green and Sustainable Remediation (GSR) "the site-specific employment of products, processes, technologies, and procedures that mitigate contaminant risk to receptors while making decisions that are cognizant of balancing community goals, economic impacts, and net environmental effects."

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Theory

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Theory

- make decisions based on the weight all possible risks and consequences (spatial, temporal, topical) from all possible actions or inactions

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Practice

Practice

- Stakeholders prioritize and filter issues to determine: boundaries, weighting, metrics, tools, options, and solutions

US Frameworks: ASTM, SURF, ITRC

- SURF (2009)
  - "White Paper" Remediation Journal 2009
  - "Guidance Documents" Remediation Journal 2011
    - Framework, Metrics, Footprint and LCA
- ITRC (2011)
  - GSR-1 Green and Sustainable Remediation: State of the Science and Practice
  - GSR-2 Green and Sustainable Remediation: A Practical Framework
- ASTM (2013)
  - ASTM E2876-13 Standard Guide for Incorporating Sustainable Objectives Into Cleanup
  - ASTM WK35161 – New Practice for Greener Site Assessment and Cleanup

Common SR Process Elements

1. Select appropriate stakeholder team
   - process to reach general consensus
2. Define current project status:
   - evaluate/update conceptual site model in SR terms: social, environmental, economic
3. Choose project goals, metrics, and tools:
   - prioritize key issues, select boundaries, determine appropriate evaluation level
4. Evaluate options for project:
   - develop options fit for future use of property and evaluate with weighted costs and benefits
5. Implement most appropriate option
   - document, monitor, optimize

ITRC Evaluation Levels

ex: Level 1 – List of BMPs

Best Management Practice	***Possible*** benefit(s) arising: Environment	Social	Economic
1. Generic BMPs			
Work safely - avoid drilling in the highway or busy areas where possible		✓	✓
Minimize vehicle miles - combine jobs where possible	✓	✓	✓
Minimize waste sent to landfill	✓	✓	✓
Re-use excavated soils or secondary aggregates where fit-for-purpose	✓		✓
Minimize consumptive use of water	✓	✓	✓
Avoid creating new pollution impacts - don't drill through confining layers without appropriate protection	✓		✓
Store fuels and recovered fluids is structurally sound, stable and bunded containers	✓		✓
Avoid multiple mobilizations	✓	✓	✓
Combine remediation works with other earthworks and site development	✓	✓	✓
Adopt a sustainable procurement policy	✓	✓	✓
Hold project meetings by telephone or video conference	✓	✓	✓
Don't allow plant or equipment to run on 'idle'	✓	✓	✓
Direct vehicle movements away from residential areas		✓	
Minimise noise, vibration, dust (etc.) and limit use of such equipment to normal office hours		✓	
Inform neighbours about potentially noisy activity before it happens		✓	
Incorporate natural attenuation into remedial strategy, either as the main approach or in a 'treatment train'	✓	✓	✓
Use bailers or low-flow samplers where monitoring data will be fit-for purpose	✓	✓	✓

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ex: Level 2 – Simple Matrix

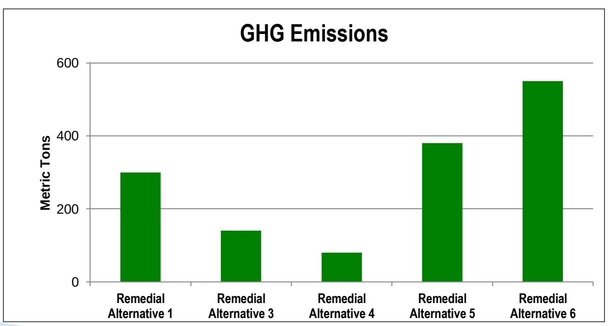
Metric	Excavation	Bioremediation	Soil Vapor Extraction
Greenhouse gases	😐 (yellow)	☺ (green)	☹ (red)
Solid waste	☹ (red)	☺ (green)	☺ (green)
Sensitive species	☹ (red)	☺ (green)	😐 (yellow)
Community disturbance	☹ (red)	☺ (green)	☺ (green)
Community acceptance	☺ (green)	☺ (green)	😐 (yellow)
Cost	☺ (green)	😐 (yellow)	😐 (yellow)

Red = low performance
Yellow = average performance
Green = good performance

ex: Level 3 – SiteWise ™ Results

Remedial Alternative	Energy (MMBTU)	Emissions (Metric Tons)			Accident Risk Injury
		GHGs	NO_x	SO_x	
Alternative 1	3.05	300	0	0	0
Alternative 3	3.05	140	0	0	0
Alternative 4	3.05	80	0	0	0
Alternative 5	0.22	380	6.0E-05	1.0E-06	3.14E-06
Alternative 6	0.22	550	6.0E-05	1.0E-06	3.14E-06

Comparative graph generated for each metric



http://www.ert2.org/t2gsrportal/SiteWise.aspx 24

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CASE STUDIES

Throughout the Remediation Project Life Cycle

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Planning and Scoping

- Engage stakeholders
- Communicate early and often
- Choose mutually beneficial endpoints
- Education
- Understanding risk
- Identify key issues
  - TBL as a guide

Gilbert-Mosley Site, Wichita, Kansas

- 4 mile X 1.5 mile chlorinated solvent plume beneath downtown
- Avoided Superfund list
  - Agreement between EPA and city
- Created tax increment district
  - Property taxes not lowered
  - Excess $ for remediation
- GW pump-and-treat
  - Aggressive / migration control
- Education center and park
- Revitalized downtown

Remedial Investigation

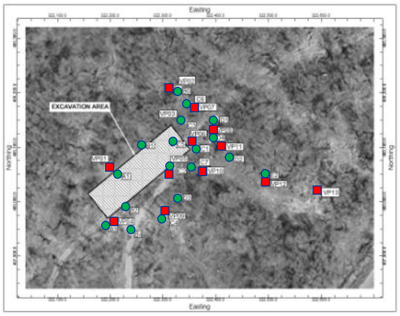
- Minimize energy use and waste
- Maximize efficiency
  - Direct-push drilling
  - Geophysical methods
  - Field screening methods
  - Low-flow or passive groundwater sampling
- Treat / recycle waste on site
- Keep stakeholders in the loop

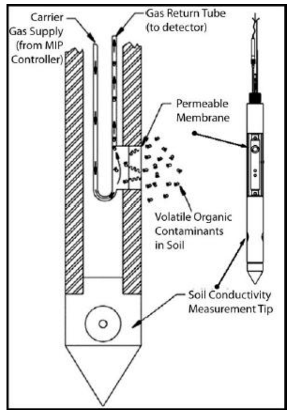
Harrison Avenue Landfill (HAL)

- Urban brownfield site, New Jersey
  - Fast-track community redevelopment
- 85-acre closed municipal landfill
- Illegal dumping
- VOCs: benzene & chlorobenzenes
- Soaked into underlying clay
  - Source for GW contamination
- **What needs to be treated?**

HAL: Phased Remedial Investigation

- Field monitoring: relative concentrations
- Dynamic field decisions based on data
- Second phase: targeted lab analyses



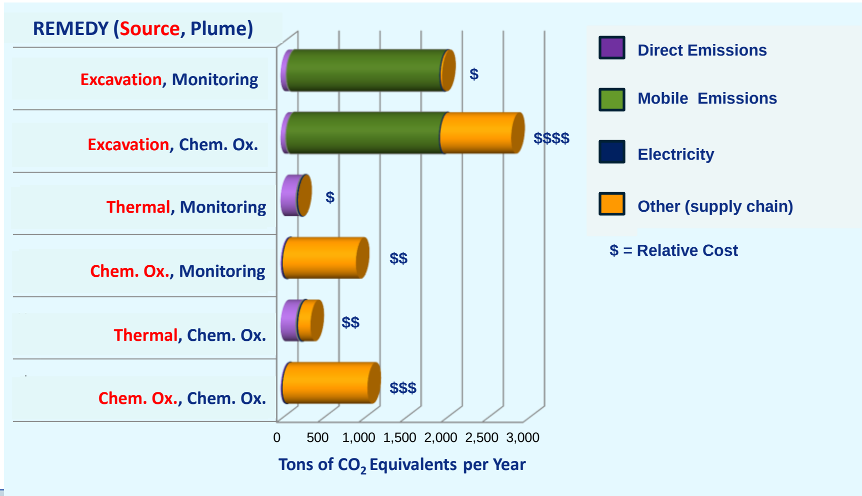


Membrane Interface Probe (MIP)

Feasibility Study / Remedy Selection

- Compare remedial alternatives
  - Effectiveness
  - Energy and resource use
  - Emissions and waste
  - Local business and economies
  - Impact on community
- Agree on weighting factors
- Rank the non-quantifiable
- Balance the TBL

HAL: Groundwater Remedy Comparison



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Remedial Design

- Detailed sustainability evaluation
- Minimize environmental footprint
- Bias toward contaminant destruction
- Balance economic and social as well
- Renewable energy
- Water re-use
- Recycle waste streams

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Petrochemical Refinery, Texas

- Marshland setting
- 8-acre on-site landfill
  - 270,000 cubic yards
- 3% material disposed as hazardous waste
- Remainder stabilized with cement
- Used to fill portion on-site marsh
- Refinery expansion with no increase in footprint

Construction

- Use local labor / contractors
- Minimize heavy equipment impacts
- Renewable fuels: bio-diesel **(?)**
- Minimize waste and recycle
- Minimize traffic, noise, odors, excess lighting
- LEED® building standards
- **Increased efficiency = Decreased Costs**

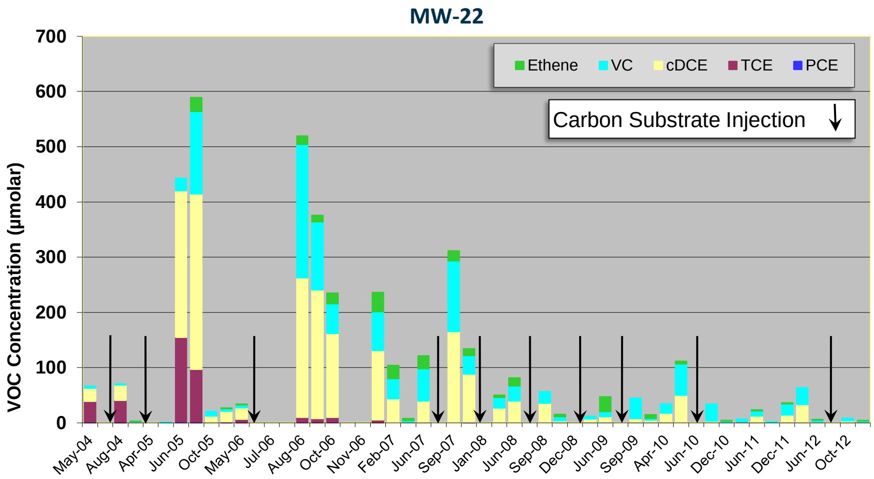
Operation & Maintenance

- Continuous optimization of processes
- Change remedial technologies as concentrations decrease
- Low energy / low impact sampling and analysis

Manufacturing Facility, Connecticut

- TCE contaminated groundwater beneath factory bldg.
- Pump-and-treat
  - Decreasing efficiency
- Switched to *in situ* anaerobic bioremediation
  - Low energy
  - Minimal water use
  - Destroys TCE

Manufacturing Facility, Connecticut



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Decommissioning / Site Close-Out

- Re-use equipment elsewhere
- Recycle waste streams
- Restore habitats
- Enhance property value
- Bring in new business
- Residential development
- Include green space

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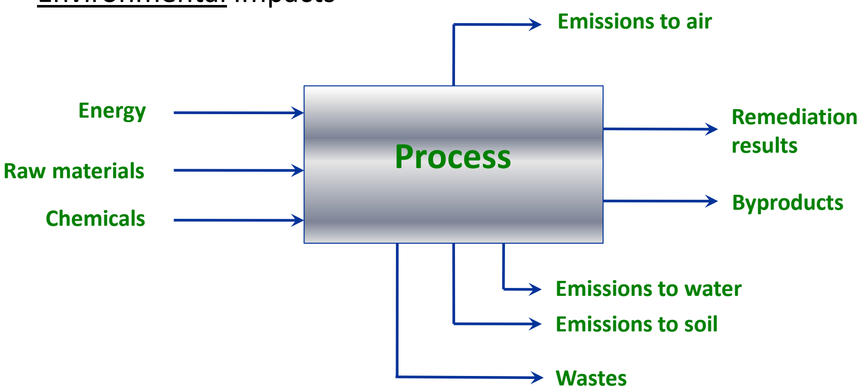
Central Artery / Tunnel, Boston, Massachusetts

- Excavated 18 million cubic yards of soil and fill
- Characterization: only 0.56% was hazardous waste
- Majority re-used throughout the region
  - Landfill daily cover
  - Filled abandoned quarry: 400-acre park
  - Converted old landfill to 120-acre park

Measurement: Life-Cycle Assessment (LCA)

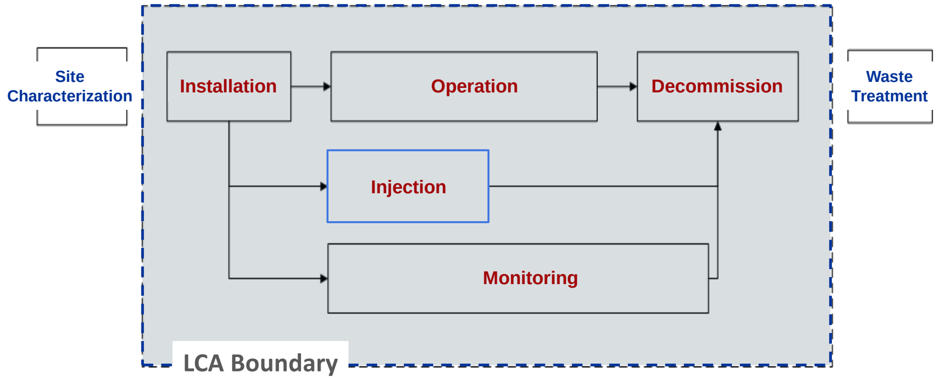
Green-washing antidote

- Inputs and Outputs
- Environmental Impacts



LCA Example: *In situ Anaerobic Bioremediation with Downgradient Pump-and-Treat*

- Manufacturing site, mid-Atlantic U.S.
- Chlorinated solvent contaminated groundwater
- LCA included all items consumed on site



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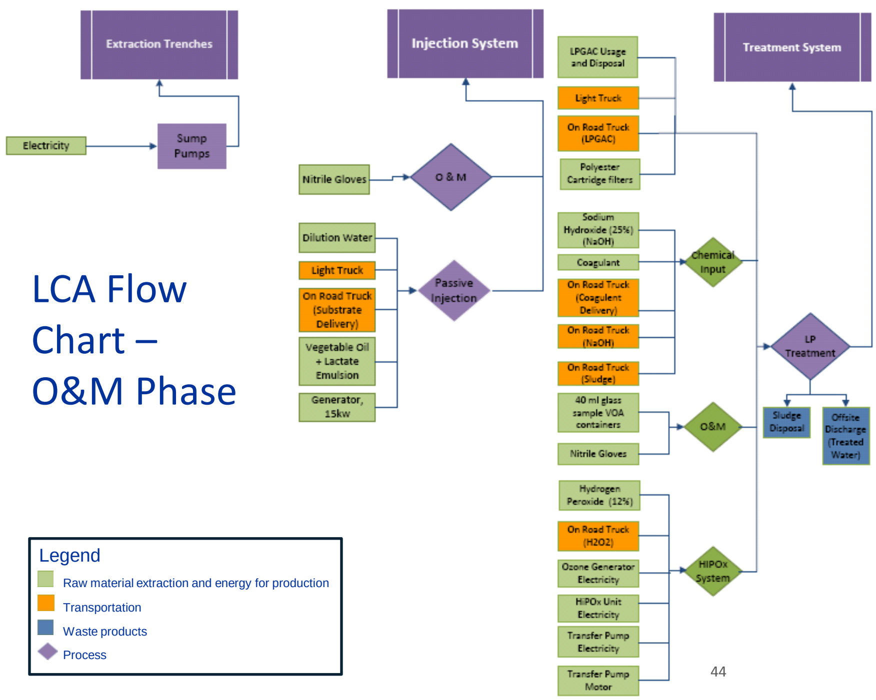
LCA Flow Chart – O&M Phase



LCA Inventory – O&M Phase

- **Complete inventory:** all phases = 250 items

Operation Phase		
Extraction Trench		Final Value
Extraction System	Electric Submersible Pumps (energy)	156943 kWh
Injection System		Final Value
Passive Injection	Generator, 15 KW	720 hrs
Passive Injection	Vegetable Oil + Lactate Emulsion	54,000 kg
Passive Injection	On Road Truck (Substrate)	2400 mi
Passive Injection	Light Truck	9000 mi
Passive Injection	Dilution Water	970,000 kg water
O&M	Nitrile Gloves	45 kg nitrile gloves (49 boxes)
Treatment System		Final Value
LP Treatment	LPGAC Usage and Disposal	7 GAC replacement vessels
LP Treatment	On Road Truck (LPGAC)	2100 mi
LP Treatment	Light Truck	42,000 mi
LP Treatment	Sludge Disposal	89,000 kg
LP Treatment	Offsite Discharge	80,000,000 kg water
O&M		*Final Value*
O&M	40 ml glass sample VOA containers	25 kg of VOAs or 864 VOAs
O&M	Nitrile Gloves	20 kg nitrile gloves (23 boxes)
Chemical Input		*Final Value*
LP Treatment /Chemical Input	Sodium Hydroxide (25%)	35,000 kg NaOH
LP Treatment /Chemical Input	On Road Truck (NaOH)	5840 mi
LP Treatment /Chemical Input	Coagulant	2,900 kg tramfloc
LP Treatment /Chemical Input	On Road Truck (Sludge)	800 mi
LP Treatment /Chemical Input	On Road Truck (Coagulant)	1168 mi
HiPox Unit		*Final Value*
LP Treatment / Hipox System	Hydrogen Peroxide	6600 kg
LP Treatment / Hipox System	On Road Truck (H2O2)	1600 mi
LP Treatment / Hipox System	Ozone Generator (energy)	252455 kWh
LP Treatment / Hipox System	HiPox Unit (energy)	17532 kWh
LP Treatment / Hipox System	Transfer Pumps (energy)	117707 kWh
LP Treatment / Hipox System	Transfer pump motor	45 kg steel
Backwash		*Final Value*
LP Treatment/Backwash	Polyester Cartridge filters	1400 kg filters

LCA Impact Categories (TRACI)

- Global warming/climate change
- Acidification
- Eutrophication
- Photochemical oxidation (smog)
- Ecotoxicity
- Human health: criteria air pollutants
- Human health: carcinogenics
- Human health: non-cancinogenics
- Fossil Fuel

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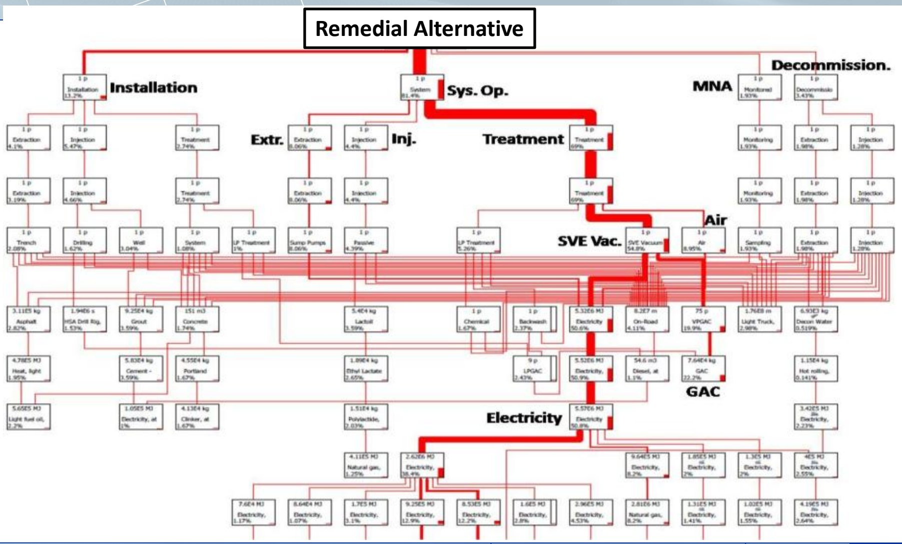
LCA Network: Climate Change, 1% Cut-Off



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Social Life-Cycle Assessment

- Remediation *and* site end use
- Overall: contribute to human well-being
- Quantitative: Costs borne by society
  - Quality of life
  - Health
  - Air quality
  - Resources
  - Employment
- Semi-quantitative
  - Interviews
  - Observations

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Costs Borne By Society

Environmental Impact Analysis Sustainability Metrics × Unit Societal Cost of Sustainability Metrics = Costs Borne by Society

Social Impact Metric	Social Cost in 2012
GHG (per metric ton)[1]	**$107**
NO_x (per metric ton)[2]	**$319**
SO_2 (per metric ton)[2]	**$1,238**
PM_{10} (per metric ton)[2]	**$217**
Total Energy Used (MMBTU)[3]	**$12**

Sources: [1]US Government 2013; Marten et al. 2012; [2]Muller et al 2010; [3]Greenstone 2011.

Benefits of Sustainable Remediation

Environmental Stewardship

Increases Net Environmental Benefit

Social Responsibility

Enhances Community Quality of Life

Economic Growth

Stimulates Local Economy

•••••••• Balance is key ••••••••

Q&A and Discussion

Q&A

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