Sustainable Remediation in DuPont

The Sustainable Remediation Forum

David E. Ellis, Ph.D.
DuPont Engineering

NEWMOA
April 2009

The significant problems we face cannot be solved at the same level of thinking we were at when we created them. Albert Einstein

Sustainability in Remediation

DuPont has been successful applying sustainability information in manufacturing. We want to do the same in the world of cleanups.

Sustainability means many different things, depending on the application and the stakeholders.

DuPont wants to use the most sustainable methods we can identify, and suggests that more sustainable cleanup methods should be given priority.

We believe that selecting a sustainable remedy may consider: protecting HH&E, global warming, recycling, resource preservation, waste generation, safety, etc…

Key Points

Sustainability can make a real difference in remedy selection and in remedy implementation. It should not dominate the decision process

Sustainability estimation can help quantify several of the current remedy selection criteria

Life cycle analysis is the method most likely to succeed

Cooperation is essential to making progress

What Sustainable Remediation Is – and What It's Not

It is:

- A thought process – with luck it is inclusive and creative
- An inclusive method to evaluate all off-site and global impacts
- A way to express your organization's values and to select cleanup methods that are fully consistent with them

It is **not**:

- A cost containment tool or a way to get MNA or TI decisions
- A fully developed method
- A regulatory philosophy, guidance or regulation
- Voodoo

DuPont Chambers Works

Largest solid waste management unit on site ~146 acres

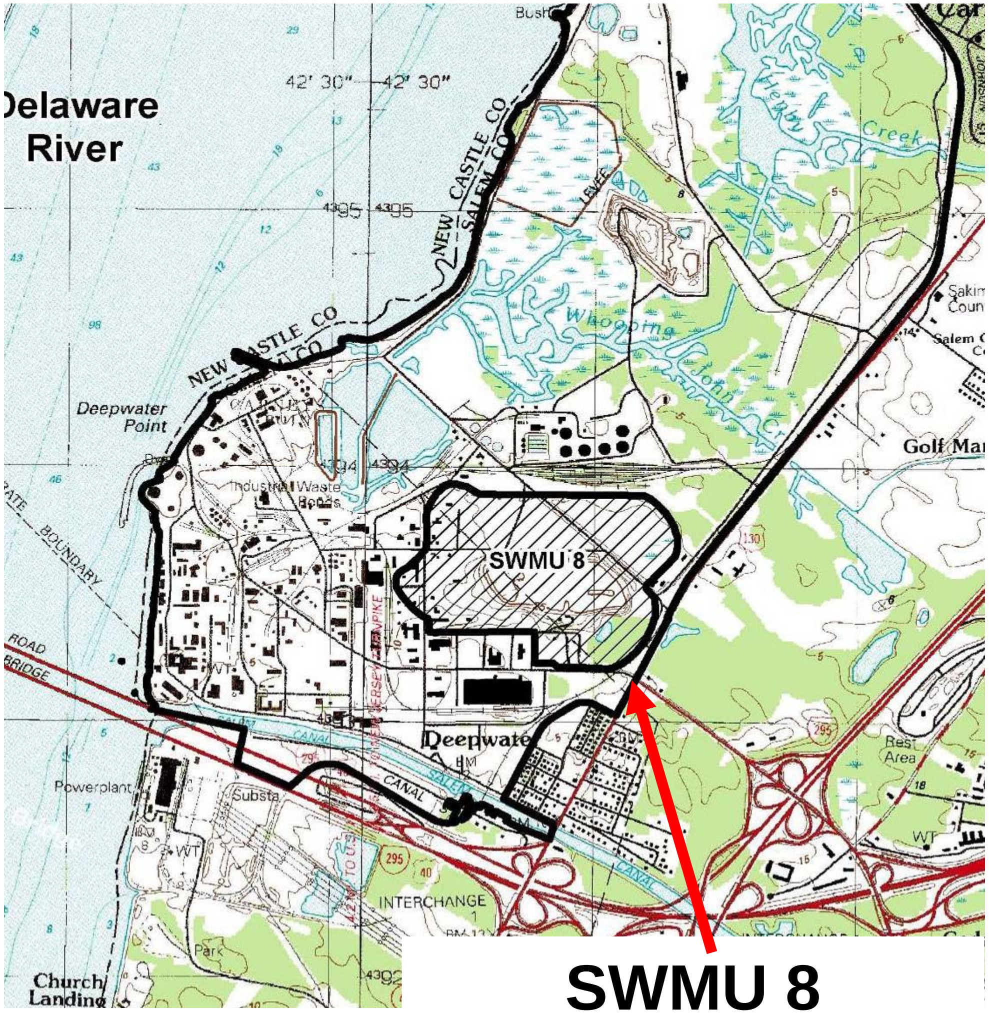
- Used for solid and liquid waste management over decades
- Numerous historic and ongoing disposal and waste management activities

Remedial Investigation

- Multiple phases of investigation
- Targeted to specific issues/requests
- Data for many key elements and areas is not complete

SWMU is contained

- Groundwater impacts contained by Interceptor Well System
- Soil impacts mitigated by soil and stone cover



SWMU 8
Chambers Works

Technologies Screened

Retained

Excavation

Stabilization

Capping

Bioventing

Landfill Bioreactor

Enhanced DNAPL Recovery (Steam and Possibly Surfactants)

Groundwater Capture

Not Retained

Barrier Walls – Sheet Pile or Slurry Wall

Chemical Oxidation

Other In Situ Thermal DNAPL Recovery

Total Waste Volume = 4,962,452 cubic yards

Example Spread Sheet: Excavation

Summary Table - Excavation - Focus Areas

Parameter	Amount	Conversion	Units	Total
Gasoline (gallons)	1,104,009	0.010	CO_2 ton/gal	11,040
Diesel (gallons)	100,574,365	0.012	CO_2 ton/gal	1,206,892
Consumable CO_2 (tons)	--	--	--	1,509,266
CO2 Emmission from	--	--	--	0
Gasoline (gallons)	1,104,009	41.6	kWh/gal	45,926,767
Diesel (gallons)	100,574,365	46.6	kWh/gal	4,686,765,389
Consumable Production and	--	--	--	1,901,115,648
Labor (hours)	--	--	--	4,909,192
Highway Miles	--	--	--	56,070,430
Groundwater (gallons)	--	--	--	0
Soil (tons)	--	--	--	12,936,858
PVC (linear feet)	--	--	--	32,500
Steel (linear feet)	--	--	--	0
Cement (tons)	--	--	--	1,916,026
Carbon (tons)	--	--	--	638,675
HDPE (square footage)	--	--	--	23,522,400

Row	A	B	C	D	E	F	G	H	I
20	**Activity**								
21	***Mobilization/Demobilization***								
22		Lump Sum	1						
23	Days	20							
24	Hours per Day	10							
25		**Total Gasoline**							**800**
26	Gasoline Vehicle	Support Trucks	Gallons per Day	Average MPG	Total Mileage		Days	Hours	Gallons
27		2	20	5	4000		20	400	800
28	Gasoline Equipment	Equipment 1	Gallons per Day				Days	Hours	Gallons
29		0	20				20	0	0
30		**Total Diesel**							**800**
31	Diesel	Support Trucks	Gallons per Day	Average MPG	Total Mileage		Days	Hours	Gallons
32		2	20	3	2400		20	400	800
33	Diesel Equipment	Equipment 1	Gallons per Day				Days	Hours	Gallons
34		0	0				20	0	0
35		**Total Labor**							**1,600**
36		Total Operators					Days	Hours	
37		4					20	800	
38		Field Crew					Days	Hours	
39		4					20	800	
40	***Site Preparation and Clearing***								
41		Acres	125.7						
42	Crews	4	Hours per Day	9					
43	Acres per day/Crew	3							
44	Days	10							
45		**Total Gasoline**							**419**
46	Gasoline Vehicle	Support Trucks	Gallons per Day	Average MPG	Total Mileage		Days	Hours	Gallons
47		2	20	2	838		10	189	419
48	Gasoline Vehicle		Gallons per Day	Average MPG	Total Mileage		Days	Hours	Gallons
49		0	35	5	0		10	0	0
50	Gasoline Vehicle		Gallons per Day	Average MPG	Total Mileage		Days	Hours	Gallons
51		0	50	8	0		10	0	0
52	Gasoline Equipment		Gallons per Day				Days	Hours	Gallons
53		0	20				10	0	0
54	Gasoline Equipment		Gallons per Day				Days	Hours	Gallons
55		0	35				10	0	0
56	Gasoline Equipment		Gallons per Day				Days	Hours	Gallons
57		0	50				10	0	0
58		**Total Diesel**							**9,428**
59	Diesel	Support Trucks	Gallons per Day	Average MPG	Total Mileage		Days	Hours	Gallons
60		1	20	2	419		10	94	210
61	Diesel		Gallons per Day	Average MPG	Total Mileage		Days	Hours	Gallons
62		0	125	8	0		10	0	0
63	Diesel		Gallons per Day	Average MPG	Total Mileage		Days	Hours	Gallons
64		0	200	8	0		10	0	0
65	Diesel Equipment	Back Hoe	Gallons per Day				Days	Hours	Gallons
66		4	100				10	377	4,190

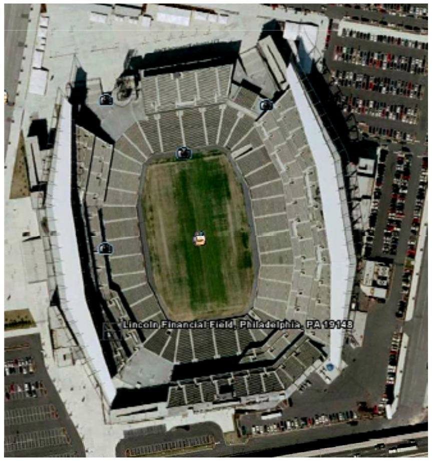
Measures of Remediation Sustainability for SWMU 8

	Excavation	Stabilization	Bioremediation
Destruction	No	No	Yes
In-situ	No	Yes	Yes
Mobility	🙂	🙂	😐
Toxicity	😐	😐	🙂
Volume	🙁	🙁	🙂
Tons CO_2	2,700,000	920,000	190,000
Exposure Hours	4,900,000	540,000	82,000
Highway Miles	56,000,000	8,000,000	1,000
Odor	High	Moderate	None
Light	High	Moderate	None
PM 10, tons	50,463	7,163	292

Some Equivalents of that CO_2 Differential

Take all 20,000 Univ of Delaware students to Hawaii for Spring Break 40 times

Drive 11,500,000 miles in Dave's Z4



Smelt 500,000 tons of steel to build 40 football stadiums

Reduce DuPont's annual CO_2 production by 8%

DuPont / EPA Sustainability Pilot Projects

DuPont volunteered our site in Martinsville, VA

We worked with EPA Region 3 and VA DEQ to evaluate three waste units that are ready for remedial action

We started by studying a previously remediated SWMU to gain mutual understanding of the process and tools

Martinsville Unit H1
Former Finish Oil Disposal Pond

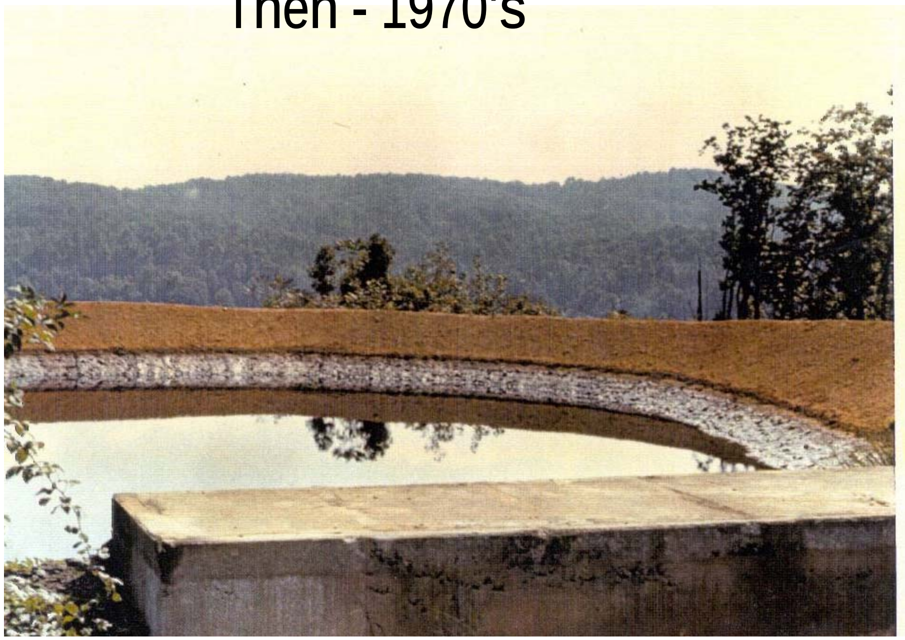
COPC: Chlorinated VOCs in soil, soil vapor and groundwater; PCBs, coal ash (arsenic) in soil only.

Former pond filled with coal ash and site soils

Nearly round, approximately 100' diameter

Residual impacts 3.5 to 4.5 feet bgs

Then - 1970's



Now - 2004

April 10 Outcome: Unit H1 Potential Remedial Measures

- **Source remediation – mitigate groundwater impacts**
- **Soil**
  - ****Excavation (source material removal) and landfill**
  - ****Cap (geomembrane)**
  - ***SVE**
  - In-situ Stabilize
  - ****Chem-reduction - ZVI/Clay optimized treatment**
  - Enhanced bio
  - In-situ thermal & vapor capture
  - **(--)Excavate & Ex-situ thermal treatment**
  - **(--)Excavate & Chem-ox (not effective chlorinated orgs & high oil demand)**
  - Excavate and soil wash
- **Groundwater – Meet MCL's (GPS) in plume and surface water standards in discharge to river**
- **Groundwater (source area or river)**
  - ***MNA**
  - **(--)PRB – Iron (river)**
  - ***Enhanced bioremediation**
  - ***Pump and treat (strip and carbon adsorption) – source and river**
  - Air sparge w/vapor capture (akin to Unit G) – option w/windmills - source
  - In-situ chem-ox (source)
  - In-well stripping

Framework for Sustainable Remediation Assessment

Information Sources	Step	People Involved
• RI and Other Reports	**Assess soil and ground water impacts** • Aerial and vertical extent • Groundwater: volume, flow, constituents (concentration and mass) • Soil: volume, constituent mass	• Project Team • Sustainability Resources
• Regulations • Business needs	**Identify remedial action objectives**	• Project Team • Sustainability Resources • Regulators, community
• ITRC • Technology Forums	**Identify candidate technologies**	• Project Team • Sustainability Resources • Technology Specialists • Regulators
• Prior Assessments	**Scope remedial option tasks** • Duration • Staff • Materials • Equipment	• Project Team • Sustainability Resources • Technology Specialists • Regulators
• Life Cycle Analysis	**Estimate remediation impacts** • Structure templates to reflect technologies	• Project Team • Sustainability Resources • Technology Specialists
• Regulatory Framework	**Analyze remedial alternatives** • Include with balancing criteria	• Project Team • Sustainability Resources • Peer Review • Regulators

Martinsville H1 Technology Screening

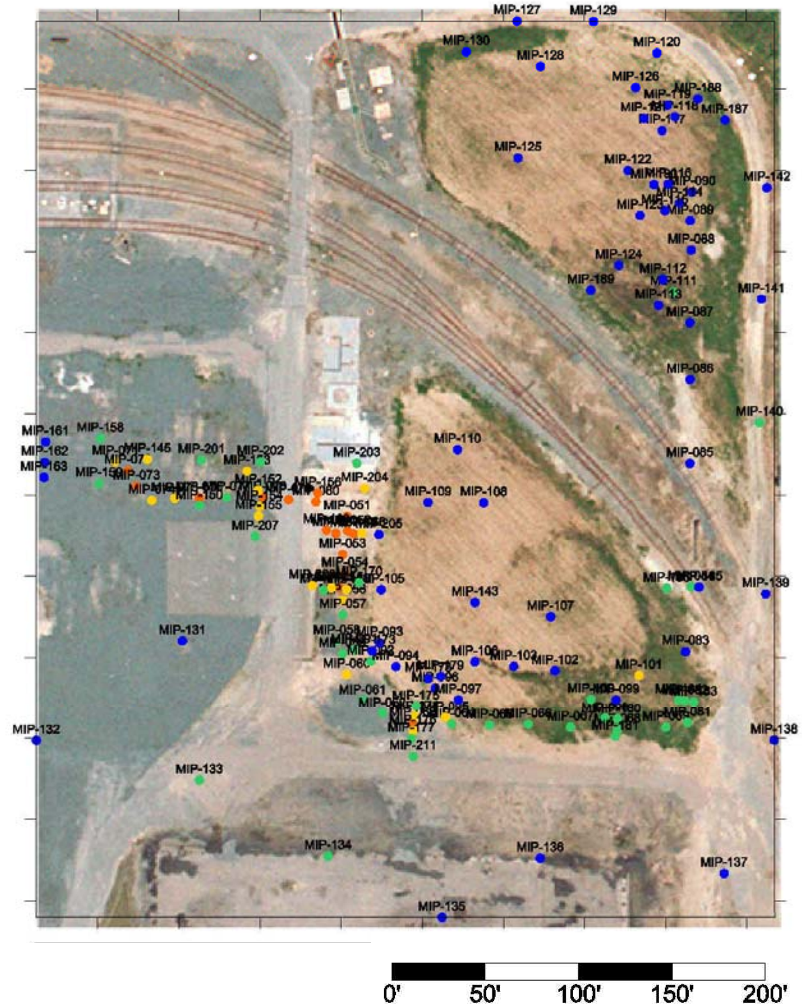
Source Area Remedies	Protect HH &E	Control Sources	Meet Cleanup Objectives	Selection
Bio-barrier	Unlikely	Unlikely, source concentrations high (bio not very effective at high concentrations)	Unlikely	**Poor**
Bioventing	Unlikely	Uncertain, oxygen demand will be very high due to waste oil in source	Uncertain. Reduces some constituents, but source concentrations likely inhibit degradation.	**Poor**
Capping	Yes, when combined with MNA	Yes, by eliminating migration	Yes (constituents remain)	**Good**
Chemical Oxidation (In Situ)	Unlikely	Uncertain, oxygen demand will be very high due to waste oil in source. CFC-11 expected to be highly resistant to oxidation	Uncertain. Other constituents, including waste oils may interfere with reaction	**Poor**
Chemical Reduction	Unlikely	Source is already highly reduced. CFC-11 appears resistant to reduction.	Uncertain. Other constituents, including waste oils may interfere with reaction.	**Poor**
Excavation & Off-Site Disposal	Yes, when combined with MNA	Yes, by removal	Yes (complete removal)	**Good**
Ex-Situ Thermal Desorption	Yes, when combined with MNA	Yes, by treatment	Yes (some constituents remain, metals)	**Good**
In Situ Bioremediation	Unlikely	Unlikely, No evidence of degradation to CFC-11	Unlikely	**Poor**
Options graded "**Good**" are considered adequate treatment options and are passed onto the selection screening, which factors in balancing criteria.				
Options graded "**Fair**" are not recommended and would only be considered in the absence of more effective options.				
Options graded "**Poor**" are either not applicable to the treatment of the constituents present or there is such great uncertainty regarding the effectiveness of the option at this location				

Martinsville H1 Remedy Selection Matrix

	Protect HH &E	Control Sources	Meet Cleanup Objectives	Long-term reliability	Reduction of T, M, V	Short-term effectiveness	Ease of implementation	Cost	Community acceptance	State acceptance	Sustainability
Source Area Remedies											
ZVI-Clay In-Situ Treatment	Yes, when combined with MNA	Yes, by treatment	Yes	High	High due to treatment	Moderate 3,800 hours 9,900 miles	Moderate	$$	Highly acceptable	Highly acceptable	CO_2 182 ton Adj. CO_2 41 ton Efficiency: 0.003
Excavation & Off-Site Disposal	Yes, when combined with MNA	Yes, by treatment	Yes	High	None	Moderate 4,400 hours 109,000 miles	Simple	$$	Acceptable	Acceptable	CO_2 251 ton Adj. CO_2 251 ton Efficiency: 0.000
Ex-Situ Thermal Desorption	Yes, when combined with MNA	Yes, by treatment	Yes	High	High due to treatment	Low 7,100 hours 11,800 miles	Complex	$$	Acceptable	Acceptable	CO_2 592 ton Adj. CO_2 451 ton Efficiency: 0.0008
Soil Vapor Extraction	Yes, when combined with MNA	Yes, by treatment	Yes	High	Moderate	Low 6,700 hours 17,000 miles	Moderate	$$	Highly Acceptable	Highly acceptable	CO_2 677 ton Adj. CO_2 536 ton Efficiency: 0.0007
Capping	Yes, when combined with MNA	Yes, by treatment	Yes	Moderate	Moderate, eliminate mobility	High 820 hours 1,600 miles	Simple	$	Acceptable	Acceptable	CO_2 24 ton Adj. CO_2 24 ton Efficiency: 0.000
Groundwater - MNA in addition to those listed above (assessment not included with above)											
MNA	Yes, mitigate migration	N/A	Yes	Yes	High	1,000 hours 8,600 miles	Simple	$	Acceptable	Acceptable	CO_2 5 ton Adj. CO_2 0 ton Efficiency: 0.09

Oakley, CA: DTSC Pilot Project, EPA Region 9

- **Sustainability of investigation methods: Done**
- **Value of information: Done**
- **Scope of remedial action: In progress**
- **Remedy selection: Not started**

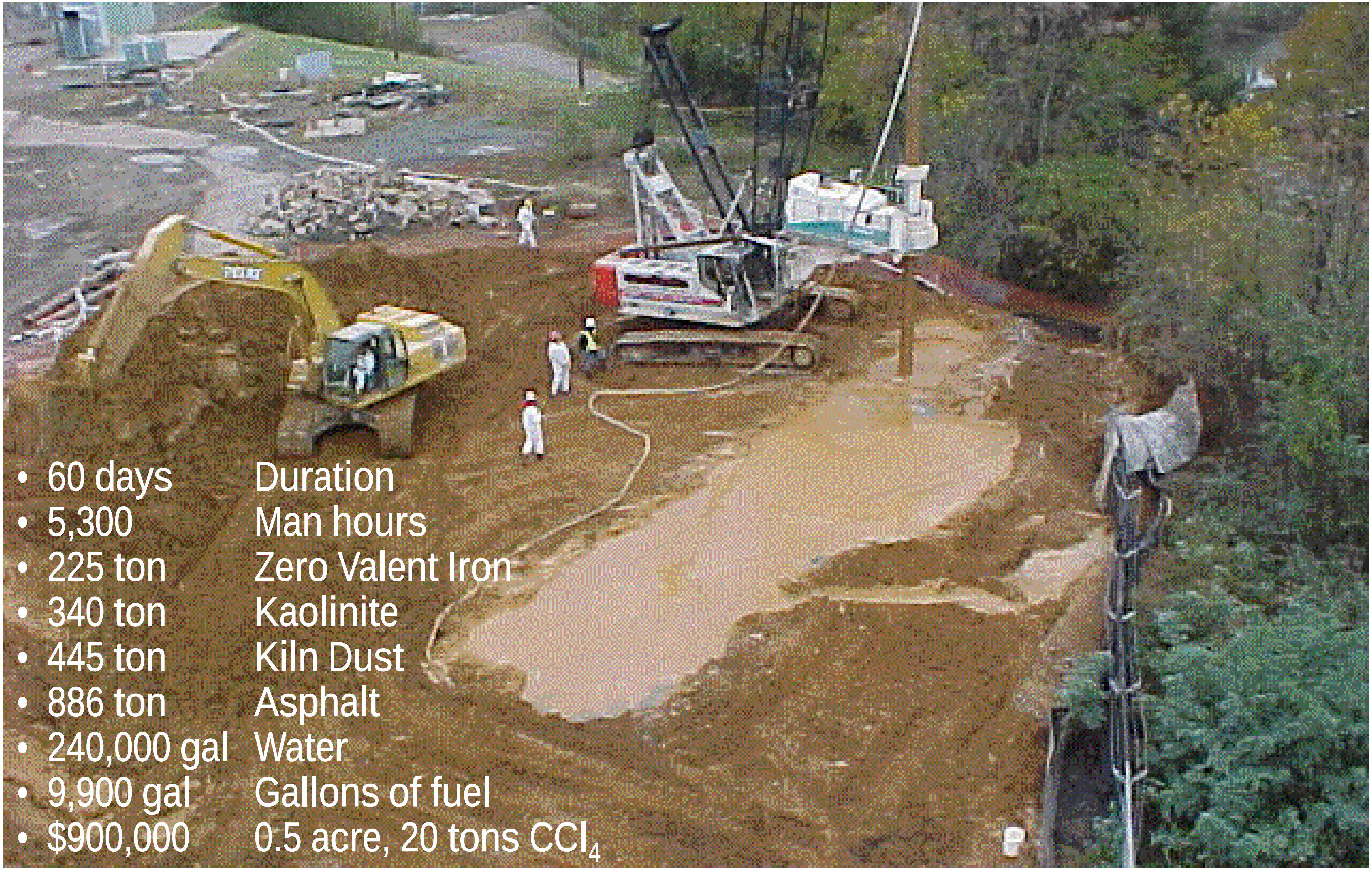


DuPont

Life Cycle Analysis for Sustainability

- **A internationally standardized tool for evaluating the overall impacts of any products or activities**
- **Based on peer-reviewed data**
- **Helps one consider the holistic environmental burdens resulting from products or processes**
- **Inform consumers, industry, and government on the environmental tradeoffs of alternative products/services**
- **Enables a simple comparison of on-site vs. off-site impacts and the impact of including consumables**

Impacts of CSU’s ZVI/Clay Remediation



• 60 days	Duration
• 5,300	Man hours
• 225 ton	Zero Valent Iron
• 340 ton	Kaolinite
• 445 ton	Kiln Dust
• 886 ton	Asphalt
• 240,000 gal	Water
• 9,900 gal	Gallons of fuel
• $900,000	0.5 acre, 20 tons CCl_4

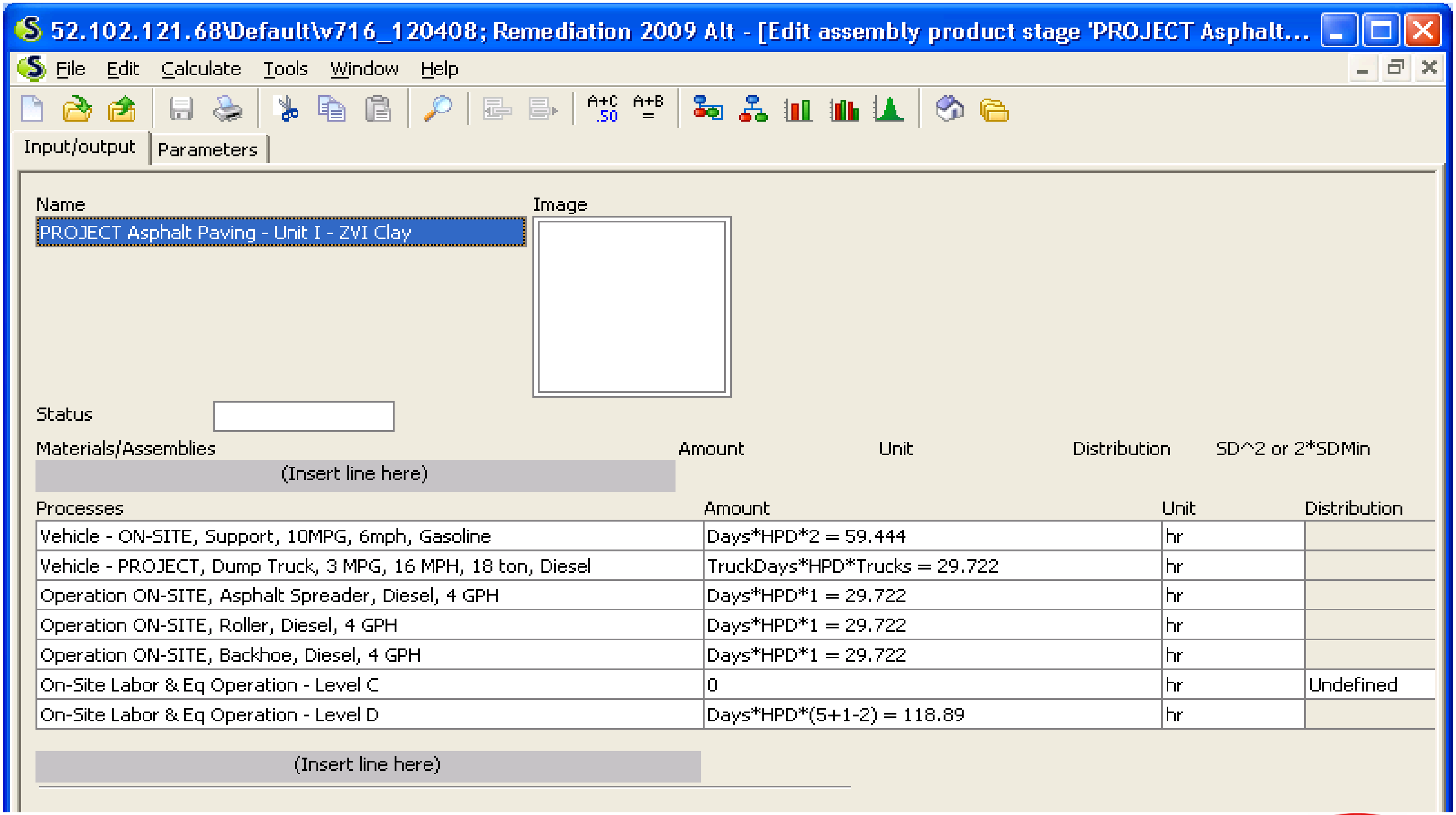
Microsoft Excel - CRG_Unit I_011509.xls

DuPont Confidential

Greenhouse Gases (Tons of CO_2 Equivalents)		Energy Usage (kWh)		Occupational Risk		Resource Usage		Local		Consumables	
Gasoline	9	Gasoline	38,678	Level A Exposure Hrs	--	Potable Water (gal)	250,000	Dust Generation	Moderate	Gasoline (gal)	930
Diesel	129	Diesel	467,628	Level B Exposure Hrs	1080	Total Groundwater (gal)	0	Noise Level	Moderate	Diesel (gal)	10,035
Contaminant Degradation	6.38	PVC	0	Level C Exposure Hrs	--	Groundwater Retained in F	0	Traffic Congestion	Moderate	PVC (Total lb)	0
PVC	0	Steel	0	Level D Exposure Hrs	4,519	Soil (tons)	450	PM-2.5, ton	2	Steel	0
Steel	0	HDPE	0	Total G&D On-Site Mileag	8,998	Landfill Space (ac-ft)	0	PM-10, ton	14	HDPE	0
HDPE	0	GranulatedCarbon	0	Total D Off-Site Mileage	5,683	Land (Acre)	0.25	NOx , ton	3.16	GranulatedCarbon	0
GranulatedCarbon	0	Cement	0	Total G Off-Site Mileage		Air	0	SOx, ton	0.27	Cement	0
Cement	0	Concrete	0					VOCs, ton	0.17	Concrete	0
Concrete	0	ZVI	1,669,500							ZVI	225
ZVI	297	Kaolinite	1,055,700							Kaolinite	345
Kaolinite	162	Kiln Dust	358,670							Kiln Dust	445
Kiln Dust	340	Potable Water	1,000							Asphalt	428
Potable Water	0	Total Groundwater	0							Grid Energy	0
Total Groundwater	0	Soil	3,600							Propane	0
Soil	1	Asphalt	309,629								
Asphalt	20	Grid Energy	0								
Grid Energy	0	Propane	0								
Propane	0										
TOTAL	**966**	**TOTAL**	**3,904,405**								

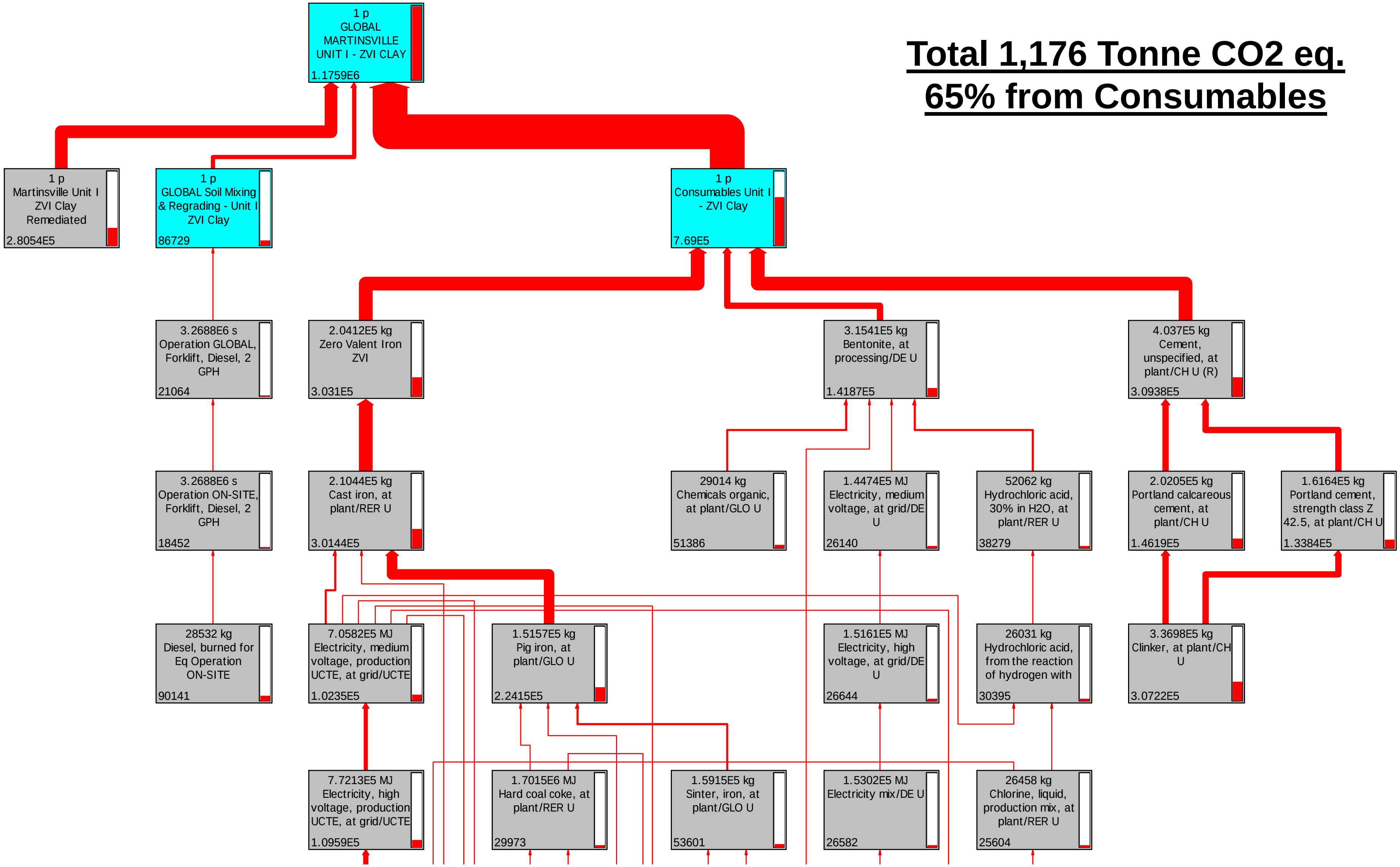
OS / P_NoC / Worker_Exp / P / G_NoI / G / ZVI-Clay In-Situ Treatment / **ZVI-Clay In-Situ**

SimaPro Remediation Assemblies



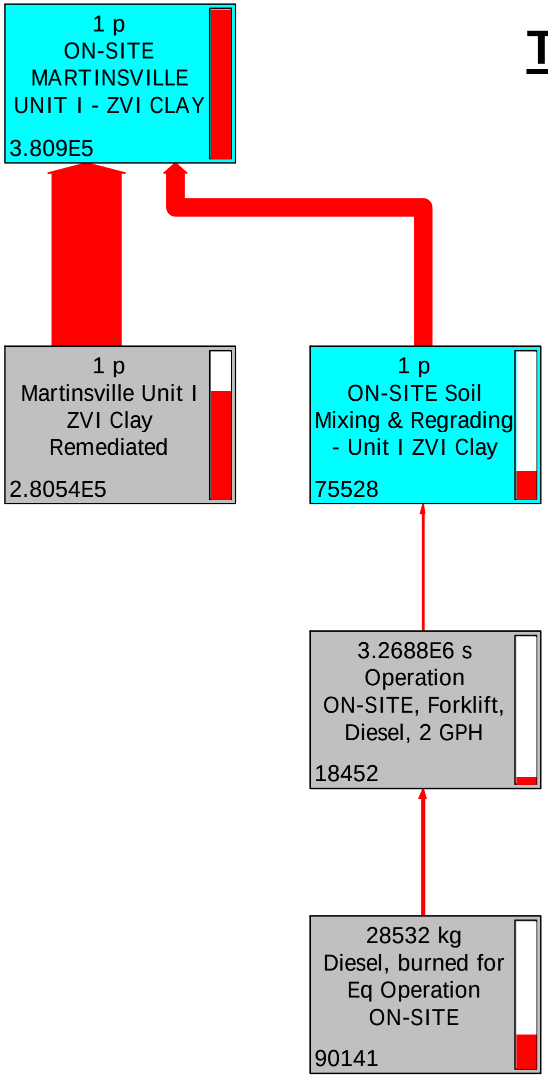
Martinsville Unit I - All GHG Impacts

Total 1,176 Tonne CO2 eq.
65% from Consumables

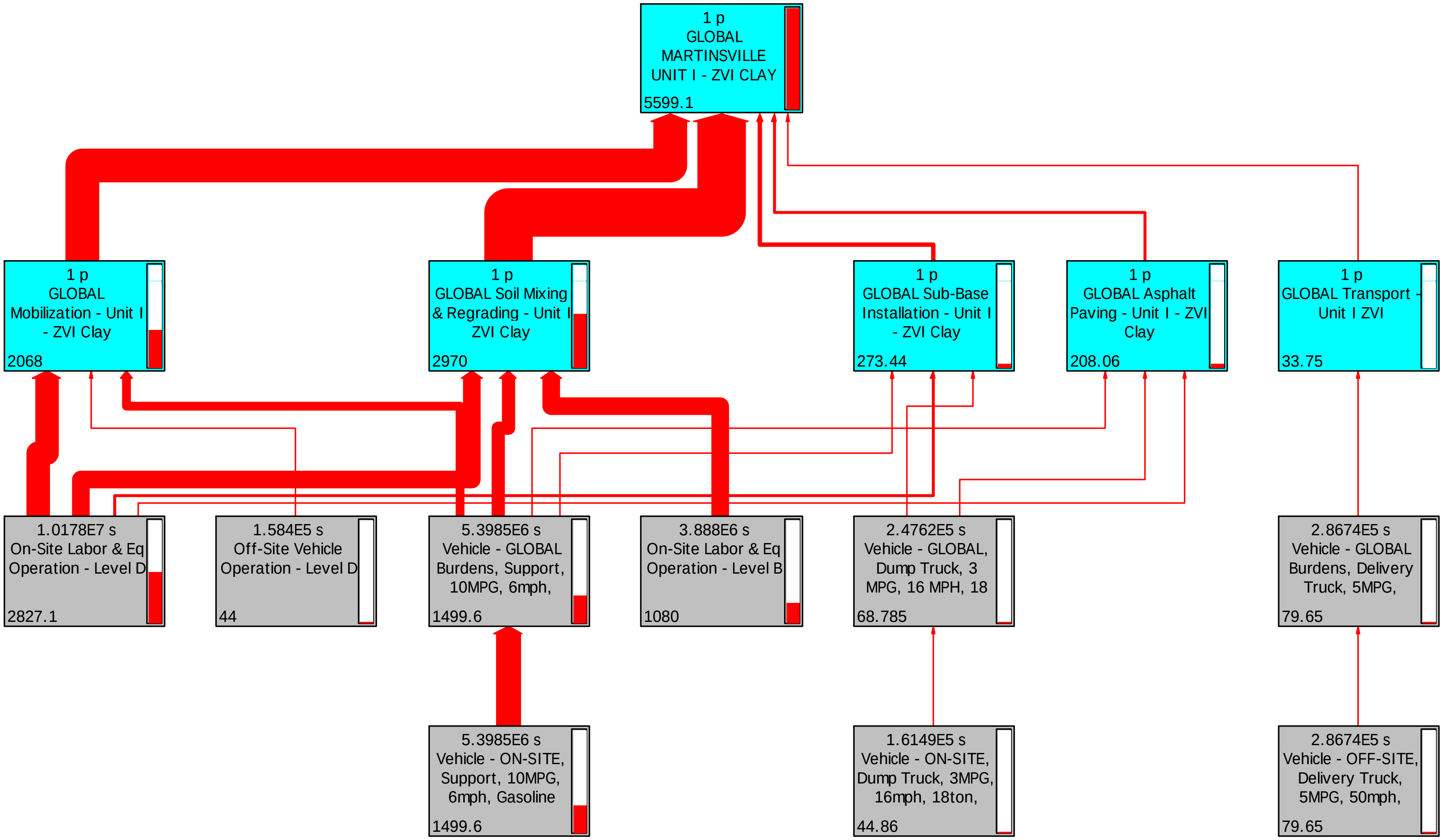


Martinsville Unit I On-Site GHG – kg CO2 eq.

Total 381 Tonne CO2 eq.



Martinsville Unit I – Worker exposure by Process



LCA Conclusions and Recommendations

Life cycle analysis provided much more complete information than other methods

VOC losses should be considered to fully understand the net environmental benefit or impact of a remedial action

The impact of off-site and on-site consumables must be included in remediation sustainability estimates

Sustainable Remediation Forum

A collaborative forum to develop ability to use sustainable concepts in remedial action decision making

Share perspectives, experiences, site-specific examples

A public forum

- State and federal agencies: US EPA, California DTSC, DNREC, UK Environment Agency, US DOE, US ACE, NJ DEP and others
- Industry: DuPont, BP, Shell, CN Rail, Chevron, National Grid, Waste Management, United Technologies, etc…
- Consultants: GeoSyntec, URS, Terra Systems, AECOM, ERM etc…
- Academics: NJIT, Colorado State, Univ. of Edinburgh
- Public stakeholders: CL:AIRE

All are welcome. Meeting records are publicly available

SURF UK is creating a UK regulatory framework for SR

Sustainable Remediation Forum (SURF)

Mission Statement:

To establish a framework that incorporates sustainable concepts throughout the remedial action process, that provides long-term protection of human health and the environment, and that achieves public and regulatory acceptance

SURF Sustainable Remediation Principles

In fulfilling our obligation to remediate sites to be protective of human health and the environment we will embrace sustainable approaches to remediation that provide a net benefit to the environment.

To the extent possible, our approaches will:

- Minimize or eliminate energy consumption or the consumption of other natural resources
- Reduce or eliminate releases to the environment, especially to the air
- Harness or mimic a natural process
- Result in the reuse or recycling of land or otherwise undesirable materials
- Encourage the use of remedial technologies that permanently destroy contaminants

Public Engagement – Sustainable Remediation Forum

How SURF Operates

- Membership in SURF is based upon contribution of effort
- SURF members are asked to be active contributors to projects. This includes a significant amount of time working on our projects *in addition to time spent attending meetings*
- SURF finds that it is very helpful if there is continuity from member organizations - i.e. the same person represents them at all meetings
- Agendas are created by ad hoc committees who volunteer at the end of each meeting
- SURF is evolving from an information sharing group to a working group. More of our time together is spent in work groups charged with specific tasks

SURF White Paper - "*Integrating Sustainability Principles, Practices and Metrics into Remediation Projects*"

The purpose of the SURF white paper is to collect, clarify, and communicate the thoughts and experiences of SURF members on sustainability in remediation.

- Introduction and Scope: Dave Ellis & Paul Hadley
- Current Status of Sustainability in Remediation: Dick Raymond
- Sustainability concepts and Practices in Remediation: Stephanie Fiorenza
- A Vision for Sustainability: Paul Favara
- Impediments and Barriers: Dave Major
- Application of Sustainable Principles, Practices, and Metrics to Remediation Projects: Brandt Butler
- Summary, Conclusions, and Recommendations: Dave Ellis & Paul Hadley

The white paper will be published as a special issue of "***Remediation***"

Next Steps for SURF

- **Create a formal organization**
- **Communicate what we are learning and will learn**
- **Participate in developing and implementing appropriate atandards and metrics across our industry**
- **Help society develop a consensus on the value of sustainability relative to other values used for making remedial decisions**

Sustainable Remediation Process Observations

- Only remedies that are fully protective of human health and the environment should be considered
- Considering sustainability changes our thought process
- Our engineers worked together more closely, quality improved
- Some unexpected and very creative remedies have been proposed. Some are less costly, others more costly
- Processing potential remedies and sustainability together with agencies allows more efficient decision making
- Don’t over analyze – it’s dark underground

Remediation Sustainability Challenges

- Work together
- Find appropriate ways to represent sustainability in regulation
- Maintain a balance between sustainability and other criteria
- Develop useful sustainability methods and metrics – LCA
- Be deliberate about the tradeoffs you make

Key Points

Sustainability can make a real difference in remedy selection and in remedy implementation. It should not dominate the decision process

Sustainability estimation can help quantify several of the current remedy selection criteria

Life cycle analysis is the method most likely to succeed

Cooperation is essential to making progress

What Sustainable Remediation Is – and What It's Not

It is:

- A thought process – with luck it is inclusive and creative
- An inclusive method to evaluate all off-site and global impacts
- A way to express your organization's values and to select cleanup methods that are fully consistent with them

It is **not**:

- A cost containment tool or a way to get MNA or TI decisions
- A fully developed method
- A regulatory philosophy, guidance or regulation
- Voodoo

Discussion

“If you don’t know where you are going, you might end up someplace else”

Yogi Berra