

Remediation: An Evolution to Sustainable Environmental Practices

Oranjewoud / Delta Consultants – INOGEN

Michael Martinson (mmartinson@deltaenv.com; +1-612-501-9282)

Gabriel Posteuca (gposteuca@deltaenv.com)

Wilfried ter Woerds (wilfried.terwoerds@HMVT.nl)

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www.oranjewoud.eu/

www.deltaenv.com

www.inogenet.com



Global Oil & Gas Business Group



The Global Oil & Gas Business Group is comprised of the Environment and Safety Division of Oranjewoud, N.V.
Including Oranjewoud, Soresma, Sorange and Delta Consultants.

Presentation Outline: Sustainable Remediation



Processes and tools considered key factors as
“**net benefit to the environment**” to evaluate the
environmental sustainability of remediation

- **Energy** – consumption and use of renewable resources
- **Carbon Emissions** – the carbon footprint associated with the complete lifecycle of remedial approaches and system operation
- **Resources** - Water, Air, Land, Waste Disposal
- **Occupational Risks** – maintaining health & safety
- “**Green credits**” - utilizing environmentally friendly technologies and/or resource recovery efforts to off-set carbon emissions
- **Remediation Site Example**
 - Review the Site-Specific Carbon Footprint of an example site’s Remediation Alternatives
- **Recent development in Carbon Footprint Models**
 - Several applications for U.S. remediation sites

Sustainable Remediation → “Green”



Historically, contamination cleanups focused on:

- Areas of concerns
- Contaminants of concerns (CoC)
- Exposure to existing/potential receptors
- Remediation of contaminants to background levels
- Cost-effective remediation technology alternatives
- **Not on the carbon footprint**

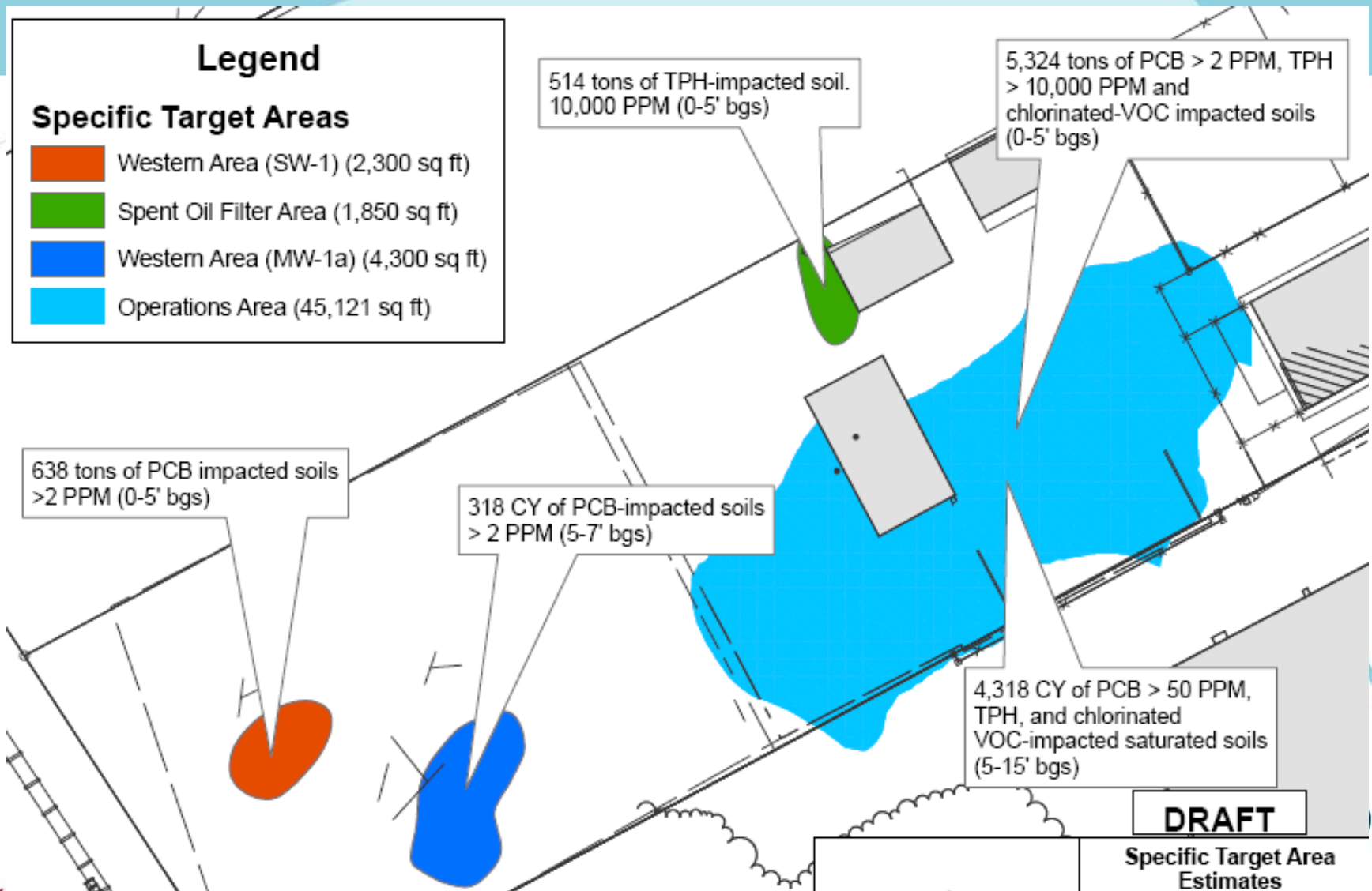
Principles of Sustainable Remediation

- **Utilize destruction technologies that do not rely upon mass transfer or transformation of CoCs**
 - **Complete mineralization or elimination, not transformation**
- **Utilize naturally occurring processes (e.g., bioremediation)**
 - **CoC + O₂ → CO₂ + basic end-products + biomass**
- **Recycle / Reuse key elements in the remediation process**
 - **Land use**
 - **Remediation spoils**
 - **Discarded equipment**
- **Limit discharges back to the environment**
 - **Air, ground water, surface water, soil**
- **Evaluate & minimize energy consumption**

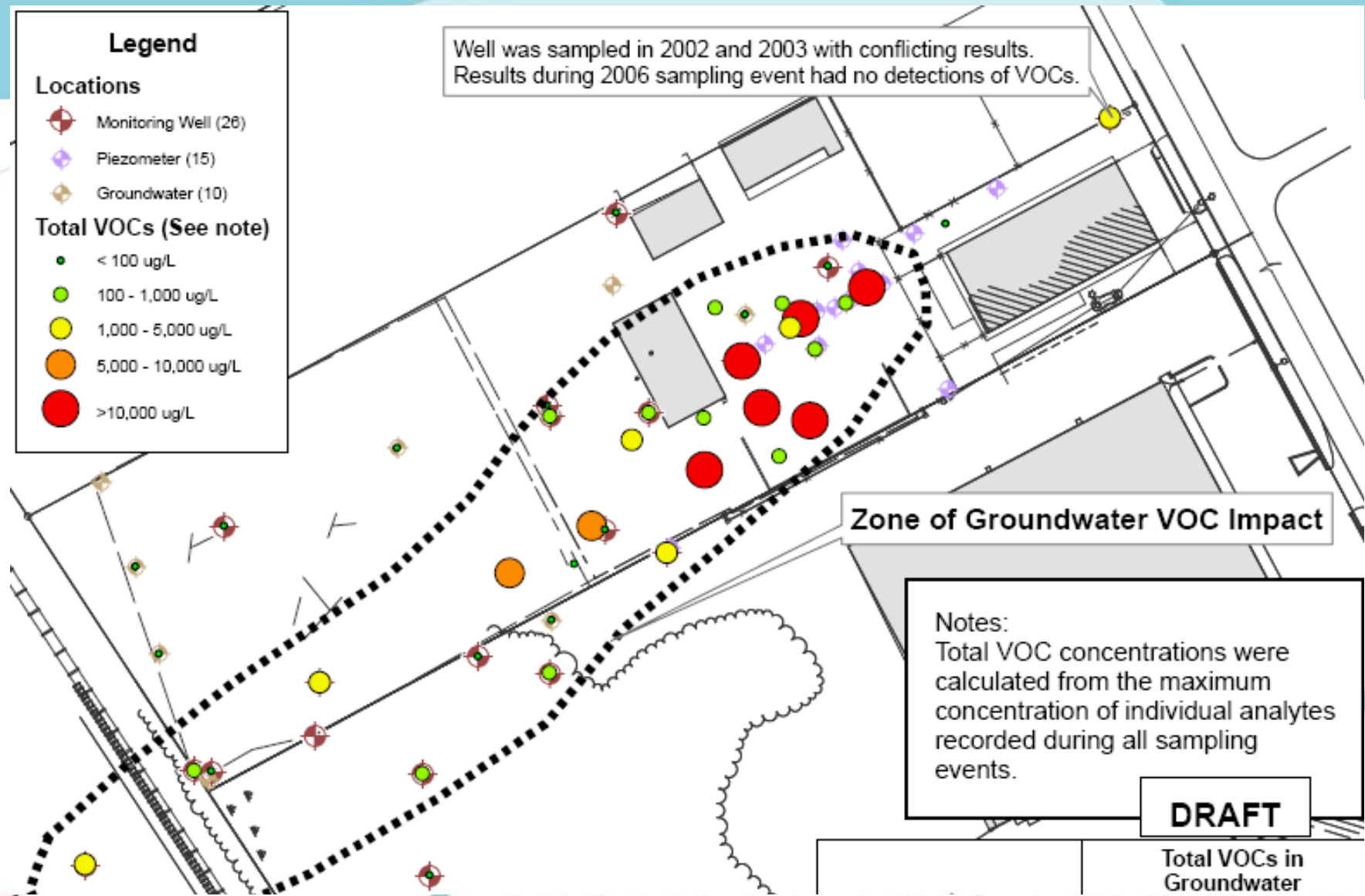
Calculating the Carbon Footprint for Remediation of a Former Waste Oil Recycling Facility



CoCs: PCBs, Chlorinated VOCs, TPH



Extent of Groundwater Contamination

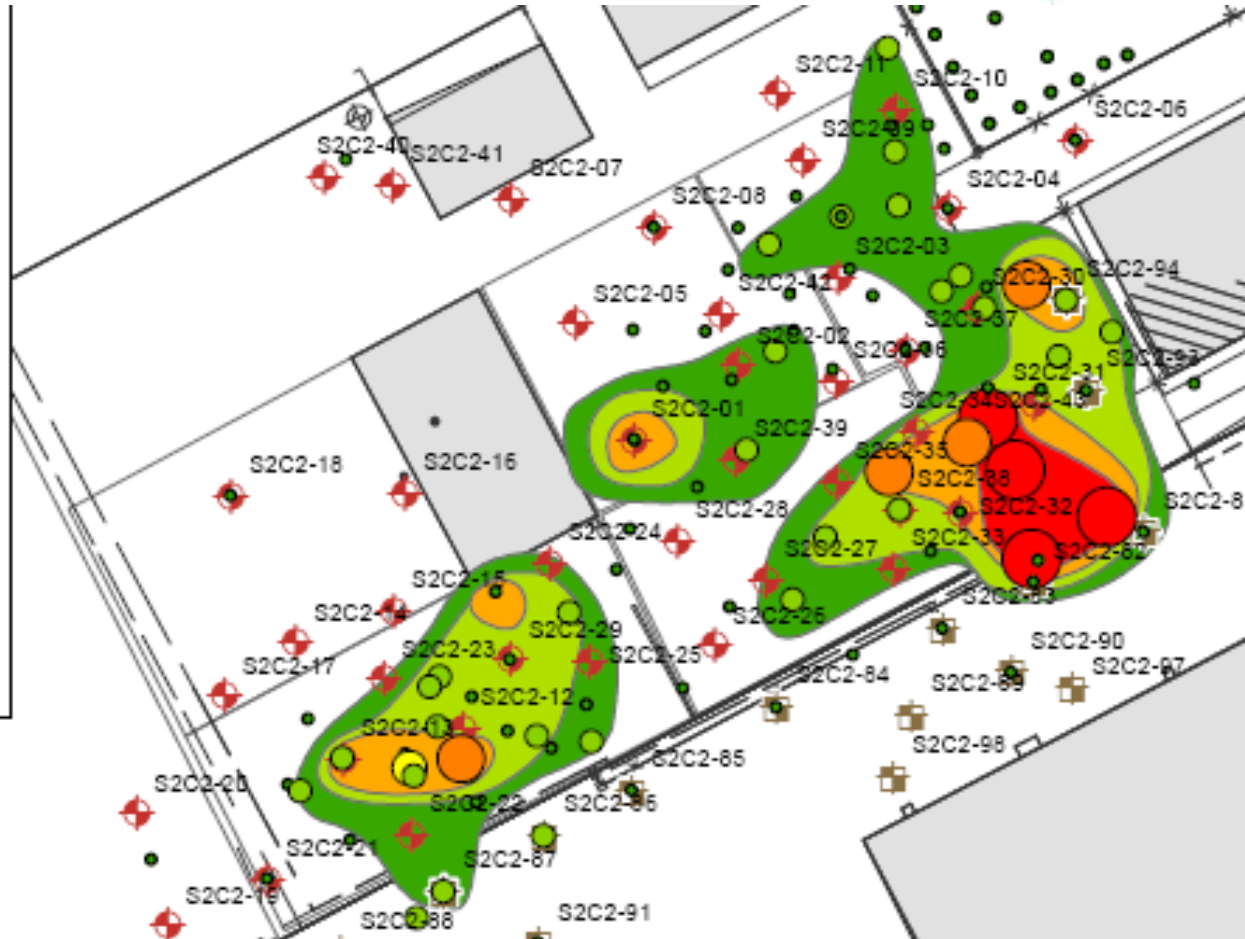
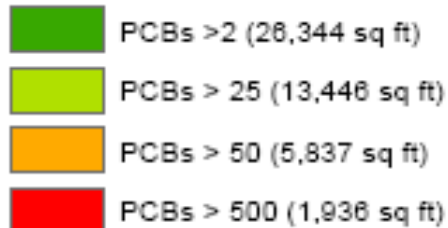


Total PCBs (mg/Kg)

Total PCBs (mg/kg)



PCB Area Estimates

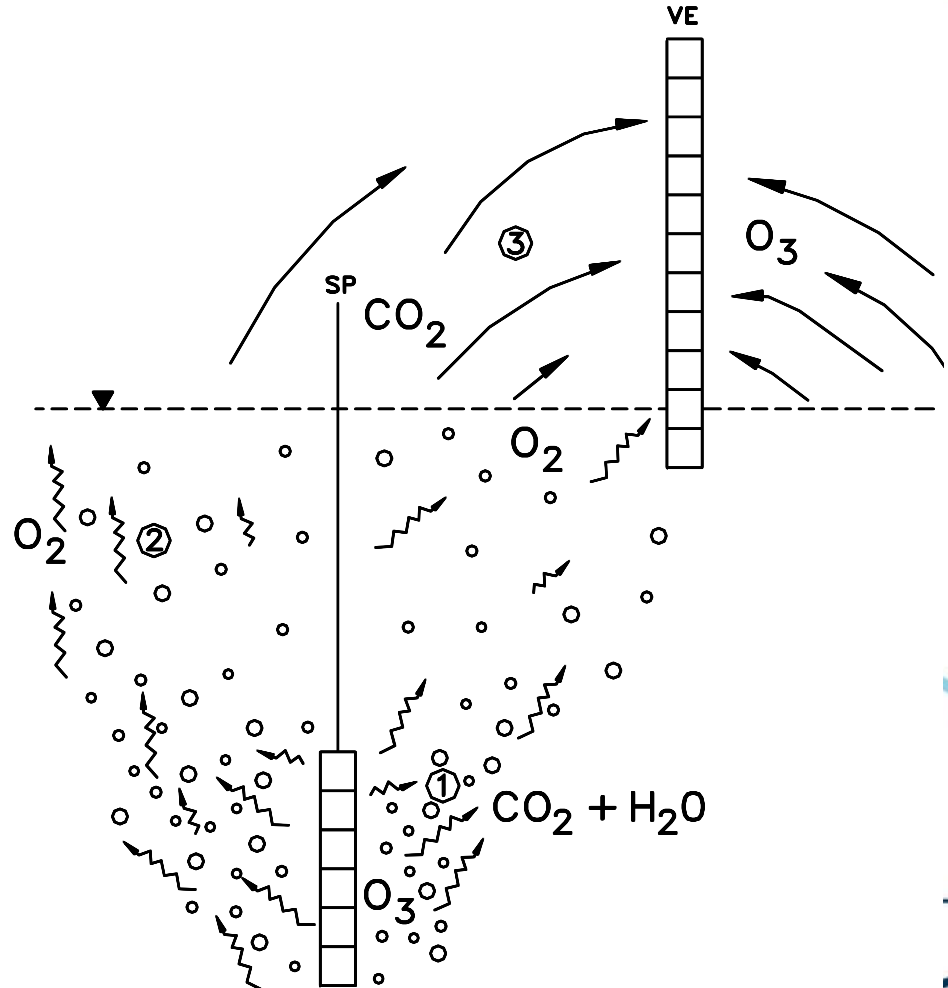


Site Remediation Alternatives Analysis

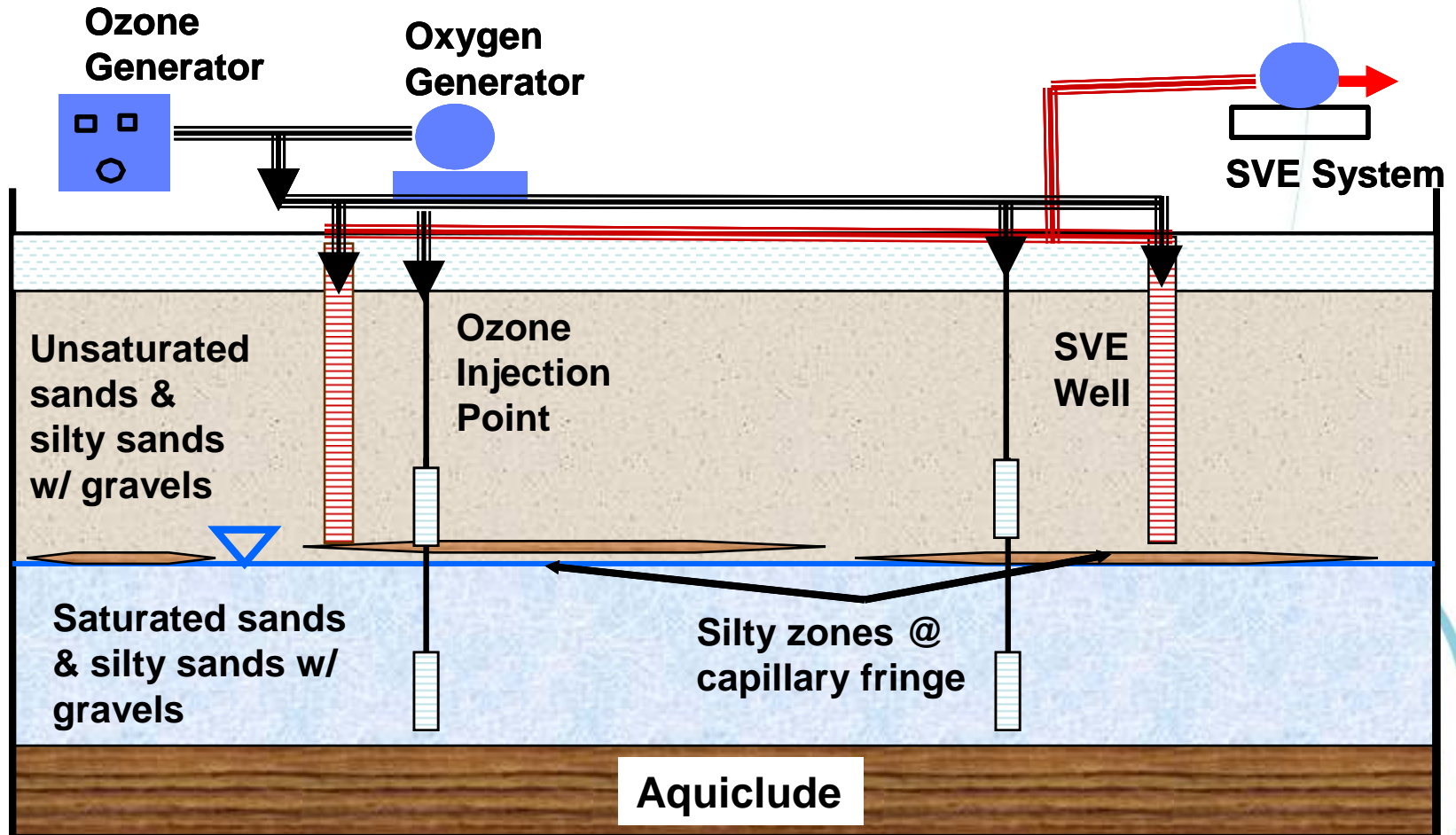
- **Three alternatives for site remediation**
 1. **Excavation of contaminated soil, disposal and groundwater treatment using pump & treat** conducted over 15 years
 2. **Limited excavation** of highest contamination levels, **disposal** and ***in-situ* chemical oxidation (ISCO)** that also encourages ***in-situ* bioremediation** conducted over 4 years
 3. **No excavation** and **ISCO / bioremediation** conducted over 3 years

In-situ Ozone Chemical Oxidation with Enhanced Biodegradation

- Ozone reaction zone
 - Ozone reacts with CoCs
 - CO_2 and H_2O are produced
- Enhanced bioremediation zone
 - Ozone reaction continues
 - O_2 produced by O_3 injection accelerates biodegradation
 - Additional O_2 and CO_2 produced
- Vapor collection zone
 - Unreacted O_3 & O_2 collected
 - Oxidation and enhanced bio by-products (CO_2) collected

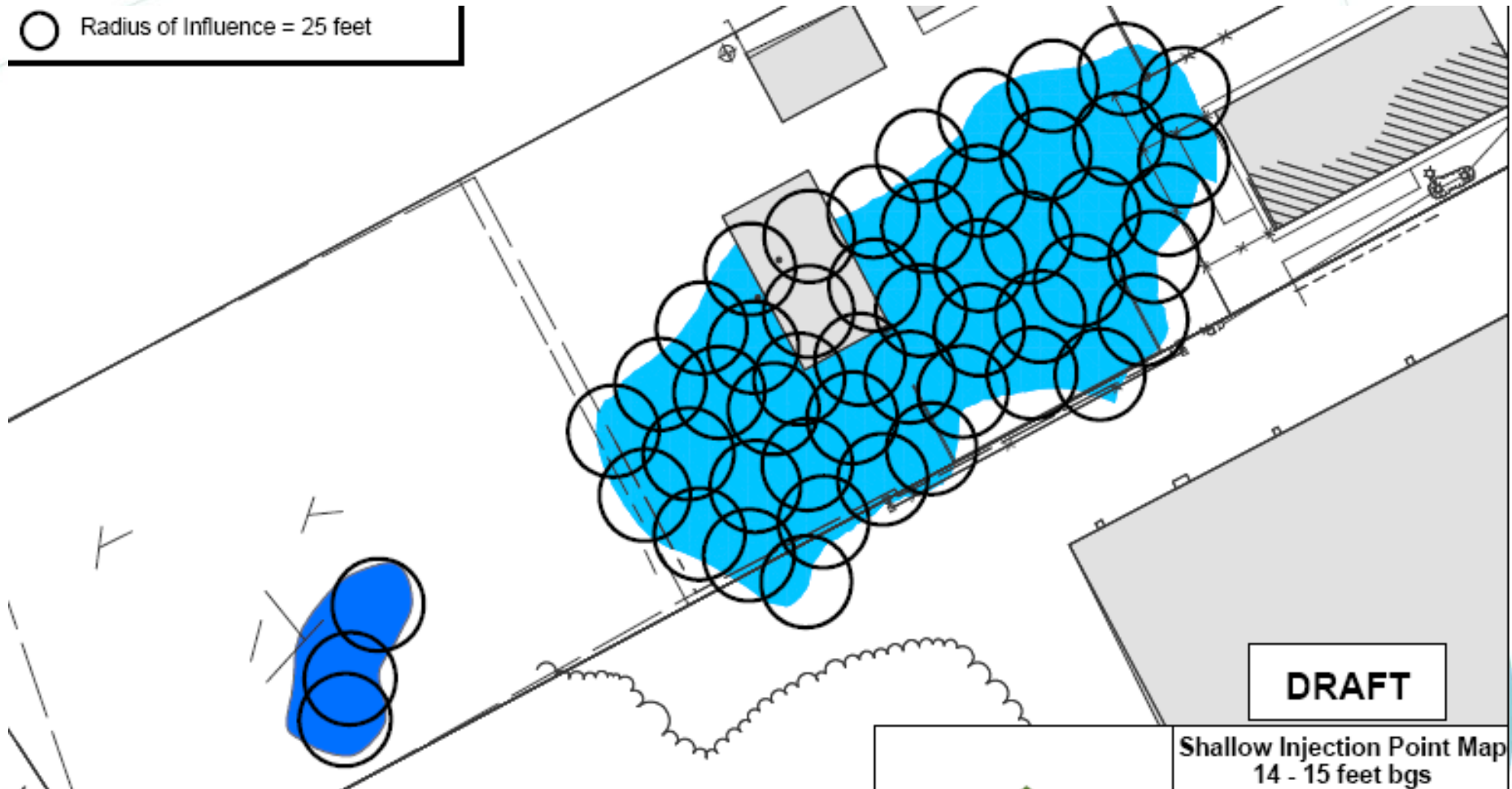


In-situ Ozone Injection Process



Ozone Injection Locations: ~15 ft (4.5 m) bgs

○ Radius of Influence = 25 feet

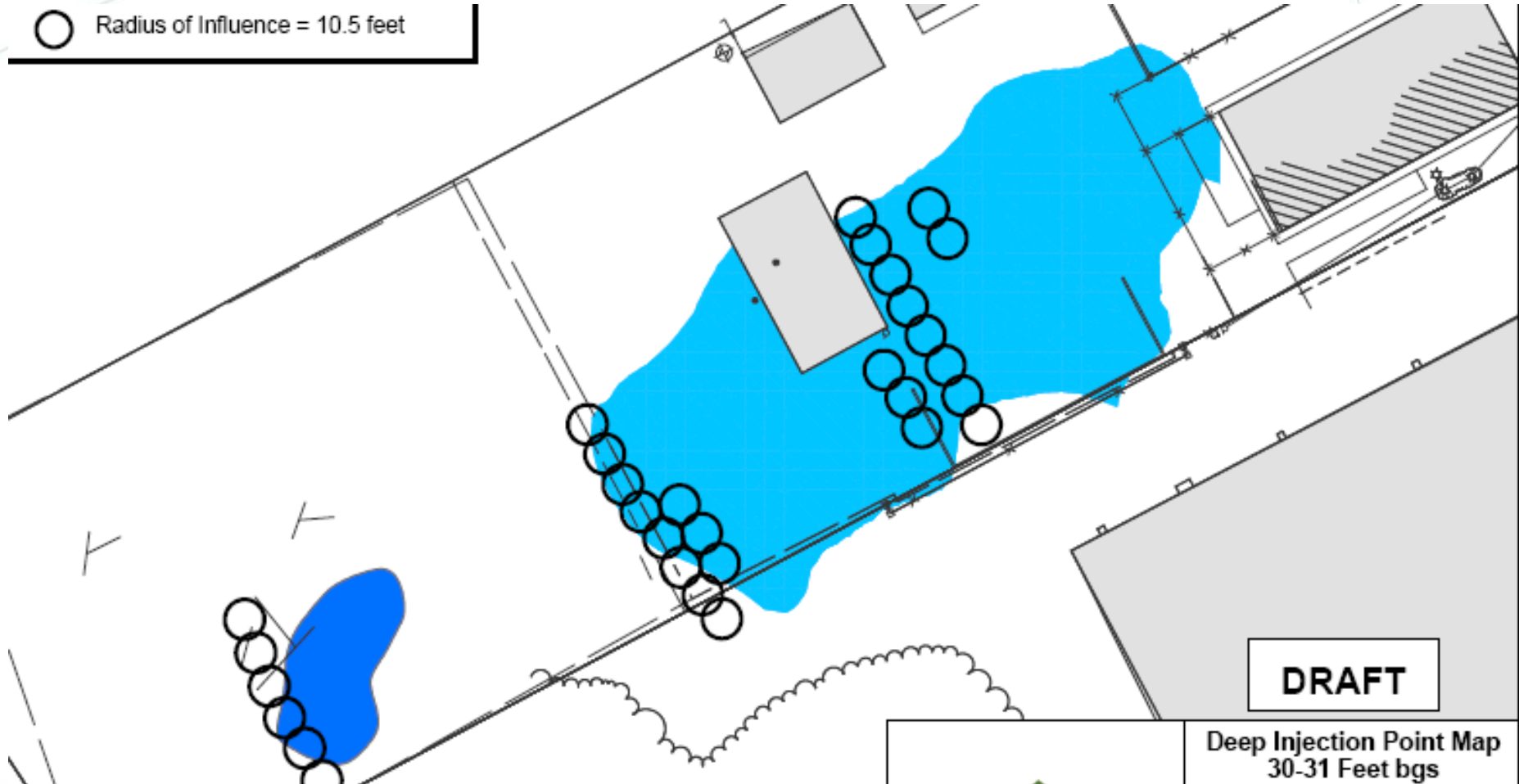


DRAFT

Shallow Injection Point Map
14 - 15 feet bgs

Ozone Injection Locations: ~30 ft (9 m) bgs

○ Radius of Influence = 10.5 feet



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**Deep Injection Point Map
30-31 Feet bgs**

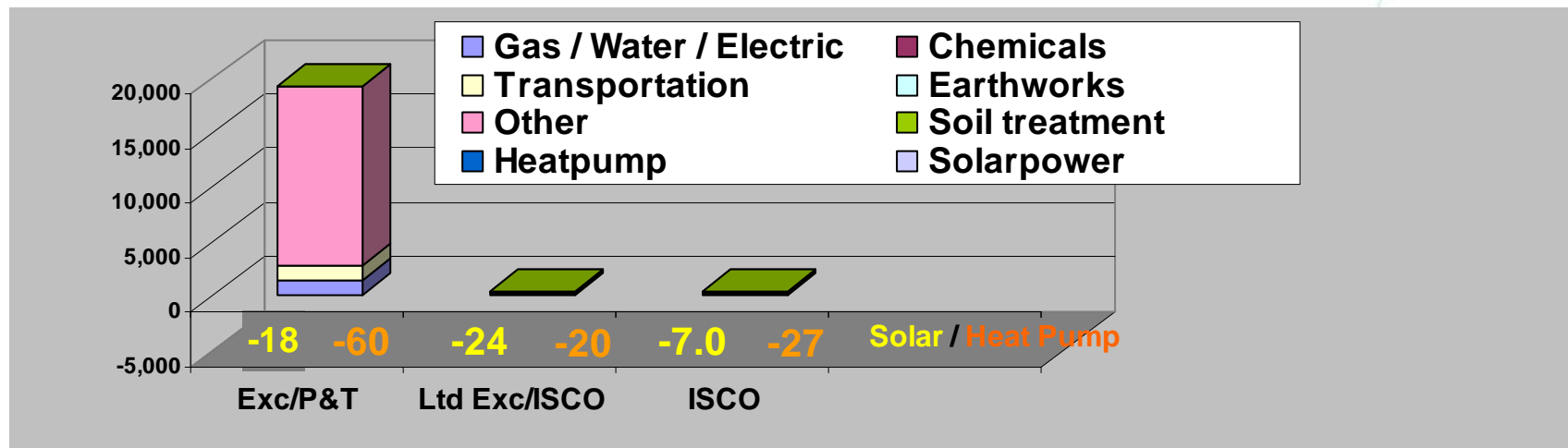
Soil Vapor Extraction Well Locations

○ Radius of Influence = 50 feet



What is the Carbon Footprint for Remediation of this Site?

- Three alternatives evaluated for site remediation
 - **Excavation** of contaminated soil, disposal and groundwater treatment using **Pump & Treat**
 - **Limited Excavation** of highest soil contamination levels and overall treatment using *in-situ* **chemical oxidation (ISCO) & bioremediation**
 - No excavation – **ISCO & bioremediation only**



Carbon Footprint Model: Comparisons

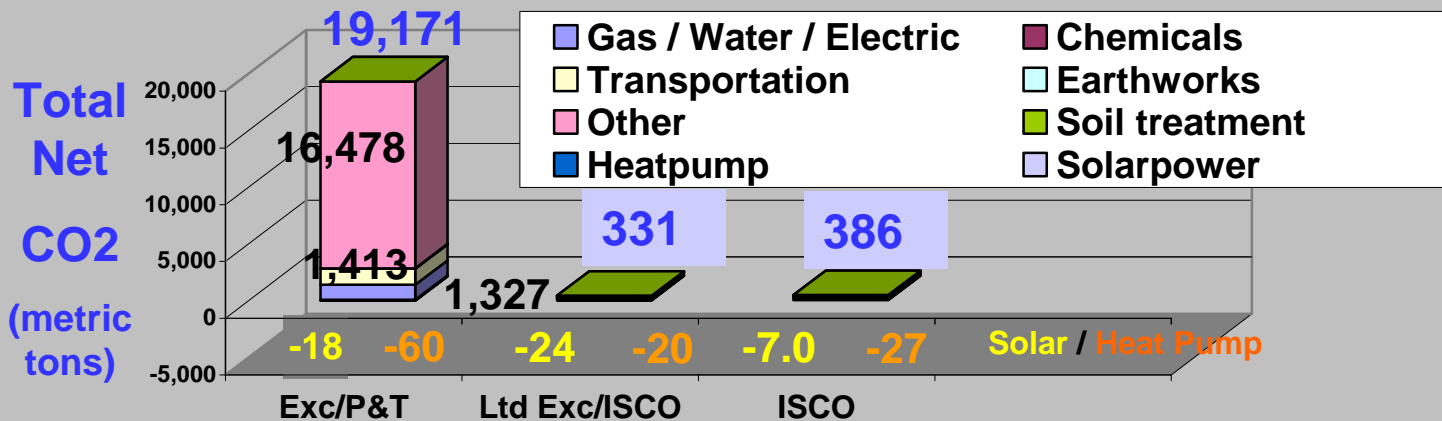
Comparison carbon footprint

CO₂ emissions in tons

	Exc/P&T	Ltd Exc/ISCO	ISCO
Gas / Water / Electric	1327.1	226.6	246.6
Chemicals	0.0	85.2	113.6
Transportation	1412.6	11.4	12.4
Earthworks	32	3	1
Soil treatment	0.0	0.0	0.0
Other	16477.6	48.2	45.7
Heatpump	-60	-20	-27
Solarpower	-18.3	-24.0	-7.0
Total CO₂ emission (ton):	19170.9	330.5	385.7
Total household equivalent:	3834.2	66.1	77.1
CO₂ emission soil (ton/m³):	1.88	0.01	0.01
CO₂ emission contamination load (ton/kg):	0.18		
CO₂ emission removed contamination (ton/kg):	1.28	-0.01	-0.01
CO₂ emission yearly (ton/year):	1278.06	110.18	96.43

Name variants

Variant	Name
1	McCandless (Excavation and Pump & Treat)
2	McCandless (Limited Excavation and In-situ Ozone/ISCO)
3	McCandless (In-situ Ozone/ISCO)



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- “Other” - GAC for water & vapors **(Total Net CO2 in metric tons)**
- Gas/Water/Electric
- Transportation (Exc/P&T)
- Chemicals (ISCO)

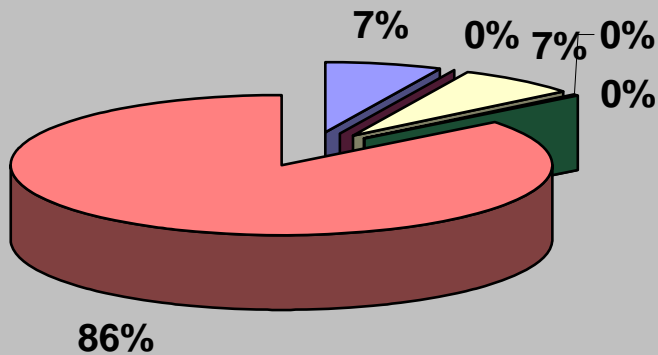
Soil Excavation with GW Pump & Treat

Green sheet

	Saved emissions	Percentage of total
Heatpumps	60	0.3%
Solarpower	18	0.1%

Total CO₂ emission (ton): 19171
Total household equivalent: 3834

Total CO₂ emissions



■ Gas / Water / Electric	■ Chemicals
■ Transportation	■ Earthworks
■ Soil treatment	■ Other

- 86% of carbon emissions due to Pump & Treat GAC system plus vapor emissions GAC as **“Other”**
- **Soil Excavation & Transportation = 7%**
- **Gas/Water/Electric = 7%**

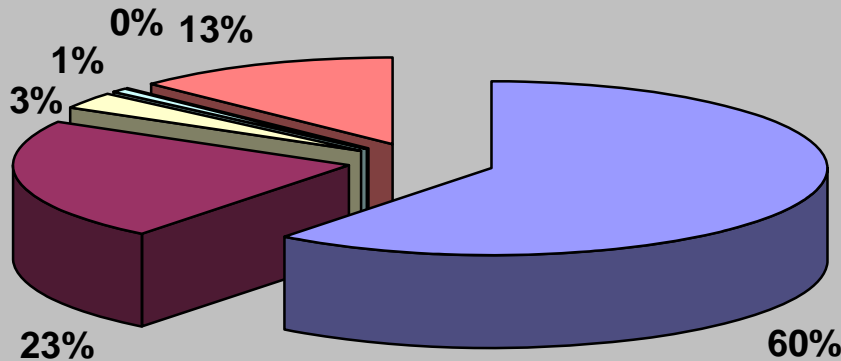
Limited Soil Excavation & ISCO

Green sheet

	Saved emissions	Percentage of total
Heatpumps	20	5%
Solarpower	24	6.4%

Total CO₂ emission (ton): 331
Total household equivalent: 66.1

Total CO₂ emissions



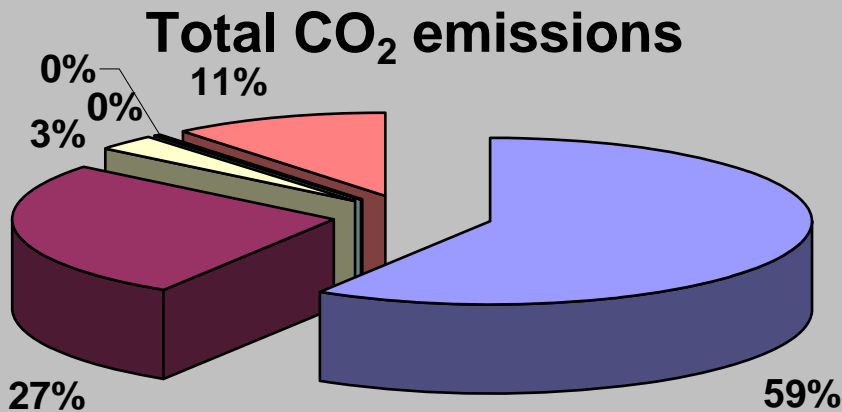
- **Gas/Water/Electric** are largest portion (60%) of carbon emissions
- **ISCO Chemicals** (H₂O₂) = 23%
- GAC for vapor emissions as **“Other”** = 13%
- **Soil Excavation & Transportation** = 3%

In-situ Ozone / ISCO

Green sheet

	Saved emissions	Percentage of total
Heatpumps	27	6%
Solarpower	7	1.7%

Total CO₂ emission (ton): 386
Total household equivalent: 77.1



■ Gas / Water / Electric	■ Chemicals
■ Transportation	■ Earthworks
■ Soil treatment	■ Other

- **Gas/Water/Electric** are largest portion (59%) of carbon emissions
- **ISCO Chemicals** (H₂O₂) = 27%
- GAC for vapor emissions as **“Other”** = 11%
- **Soil Excavation & Transportation** = 3%

Principles of Sustainable Remediation Summary

- Understand the principles of Sustainable Remediation
 - Energy consumption
 - Carbon emissions
 - Resources
 - Occupational Risks
 - Green Credits
- Many aspects of remediation projects have opportunities to conserve energy and utilize resources in a “green” fashion
 - Need to understand carbon footprint of remediation alternatives
 - Evaluate highest carbon impact areas of remediation operations
- Utilize the various available tools to calculate carbon footprint
- Review & evaluate where to practice “Green Decision-Making”
- Implement Green Credits technology for your remediation