


Remediation: An Evolution to Sustainable Environmental Practices

Oranjewoud / Delta Consultants – INOGEN

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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**

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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
- **<u>Not</u> on the carbon footprint**

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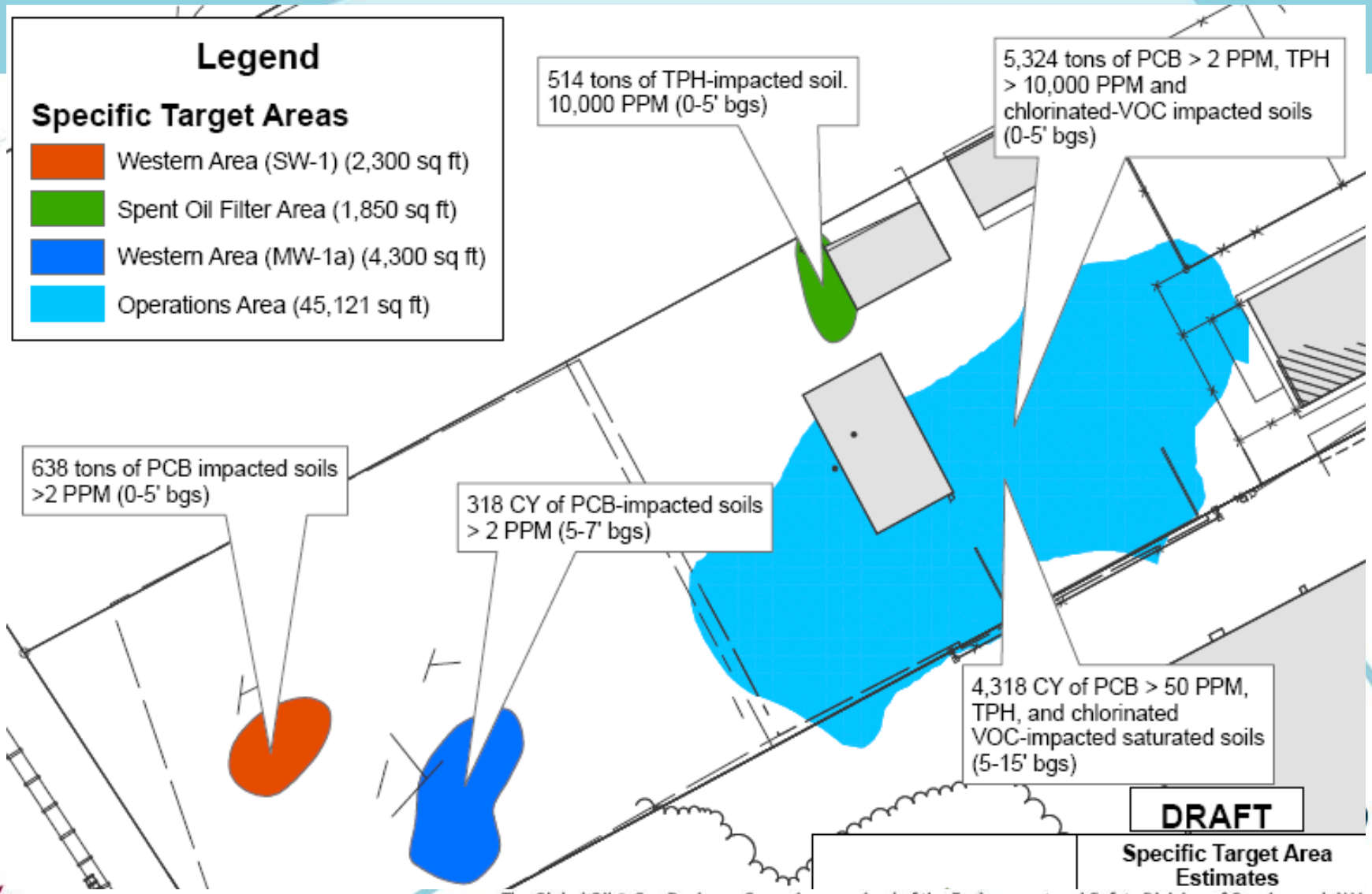
Principles of Sustainable Remediation

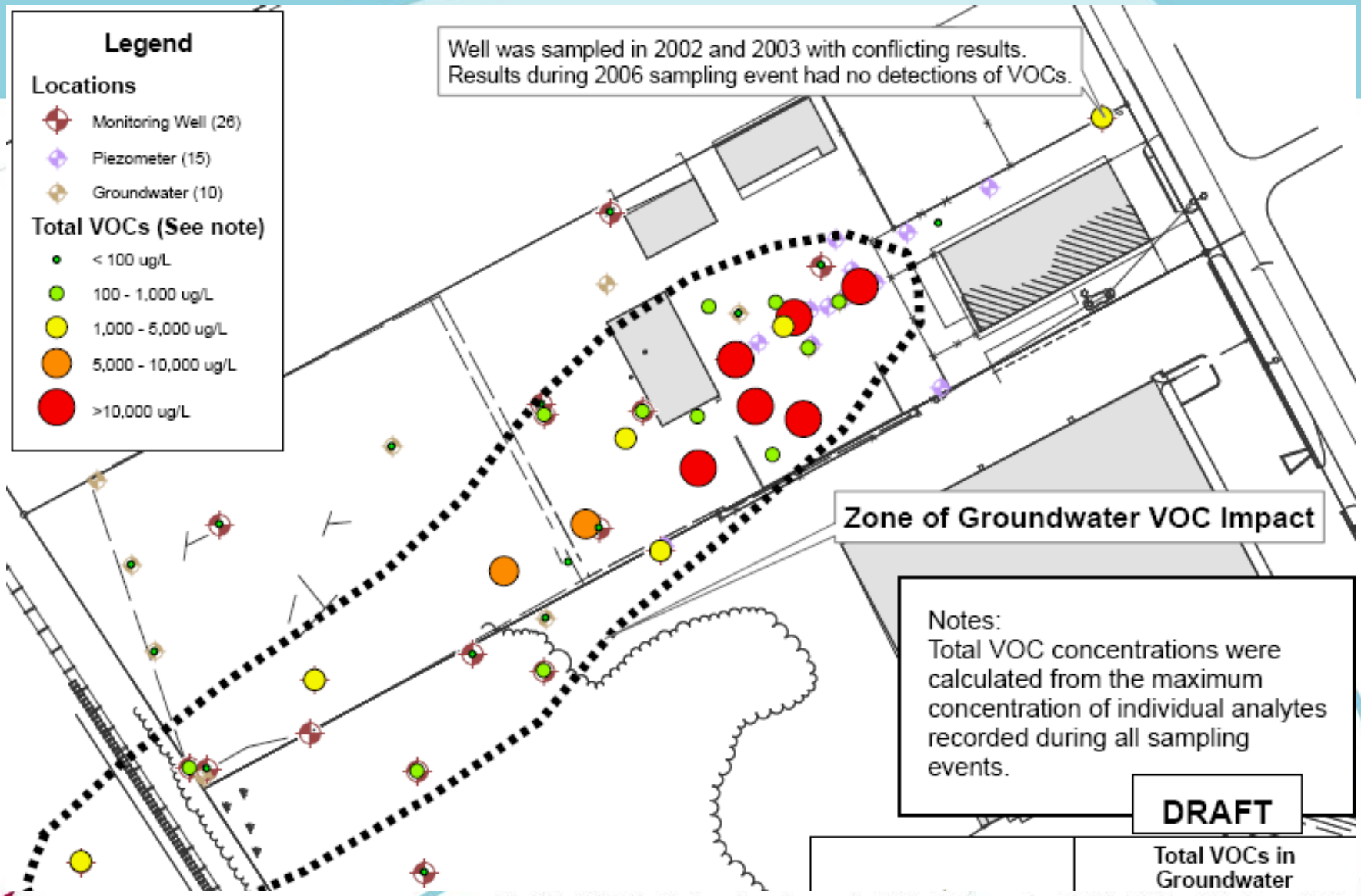
- **Utilize destruction technologies that do not rely upon mass transfer or transformation of CoCs**
  - **Complete mineralization or elimination, not transformation**
- **Utilize naturally occurring processes (e.g,, bioremediation)**
  - **CoC + O2 → CO2 + basic end-products + biomass**
- **Recycle / 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

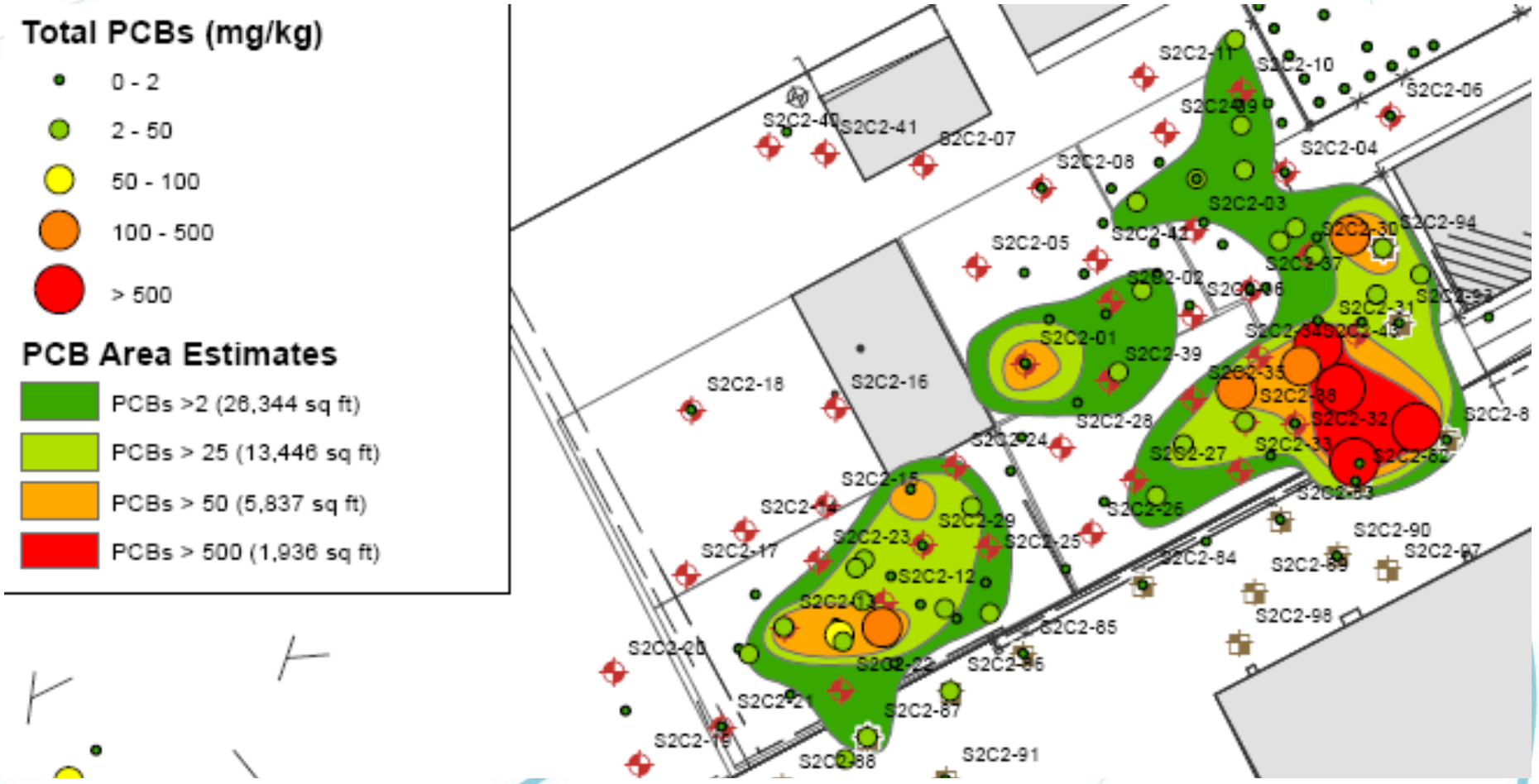
CoCs: PCBs, Chlorinated VOCs, TPH



Extent of Groundwater Contamination



Total PCBs (mg/Kg)



Site Remediation Alternatives Analysis

- **Three alternatives for site remediation**

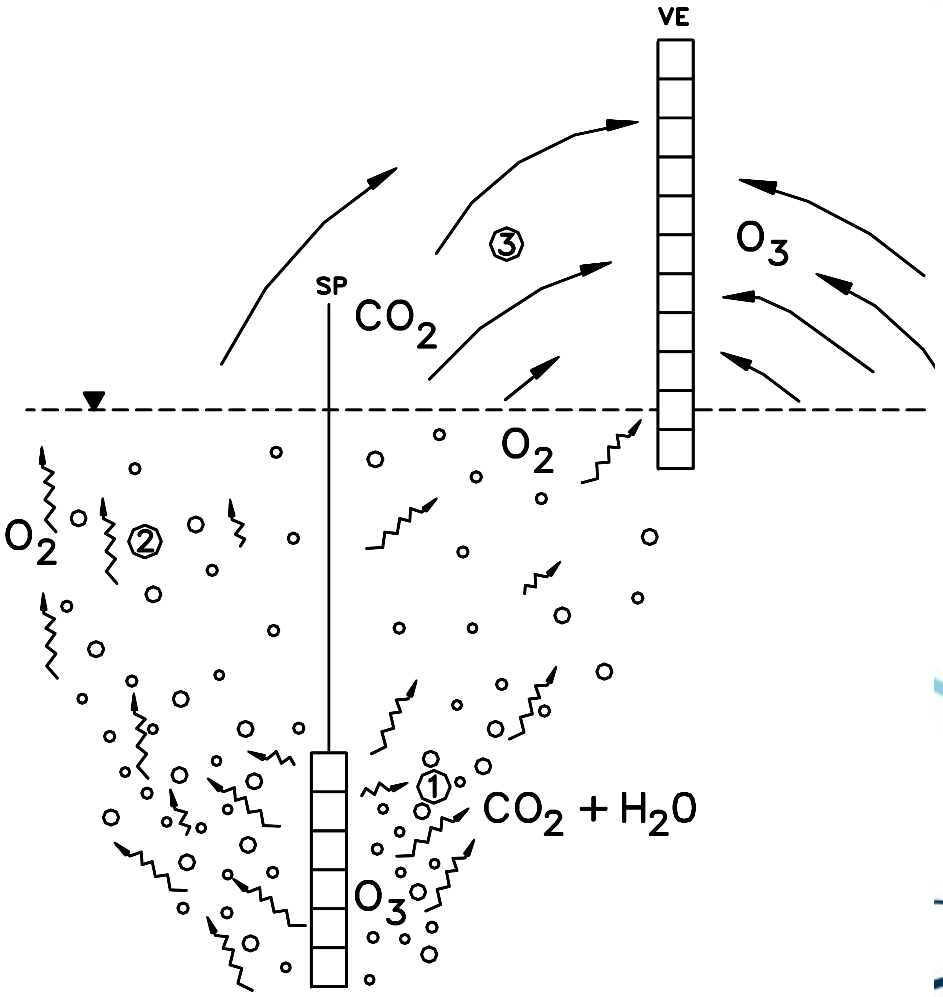
1. **Excavation of contaminated soil, disposal and groundwater treatment using pump & treat** conducted over 15 years

2. **Limited excavation** of highest contamination levels, **disposal** and ***in-situ* chemical oxidation (ISCO)** that also encourages ***in-situ* bioremediation** conducted over 4 years

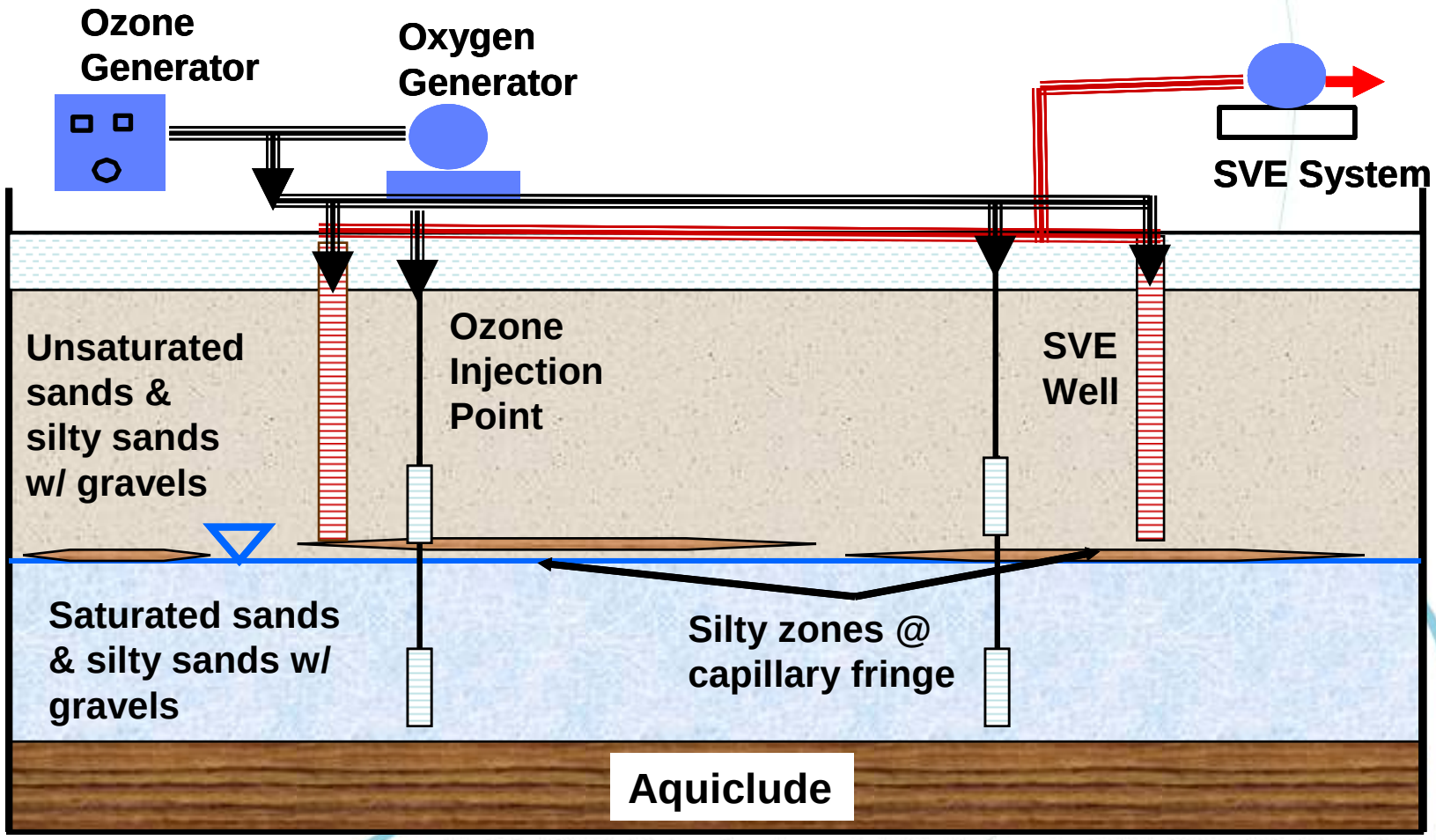
3. **No excavation** and **ISCO / bioremediation** conducted over 3 years

In-situ Ozone Chemical Oxidation with Enhanced Biodegradation

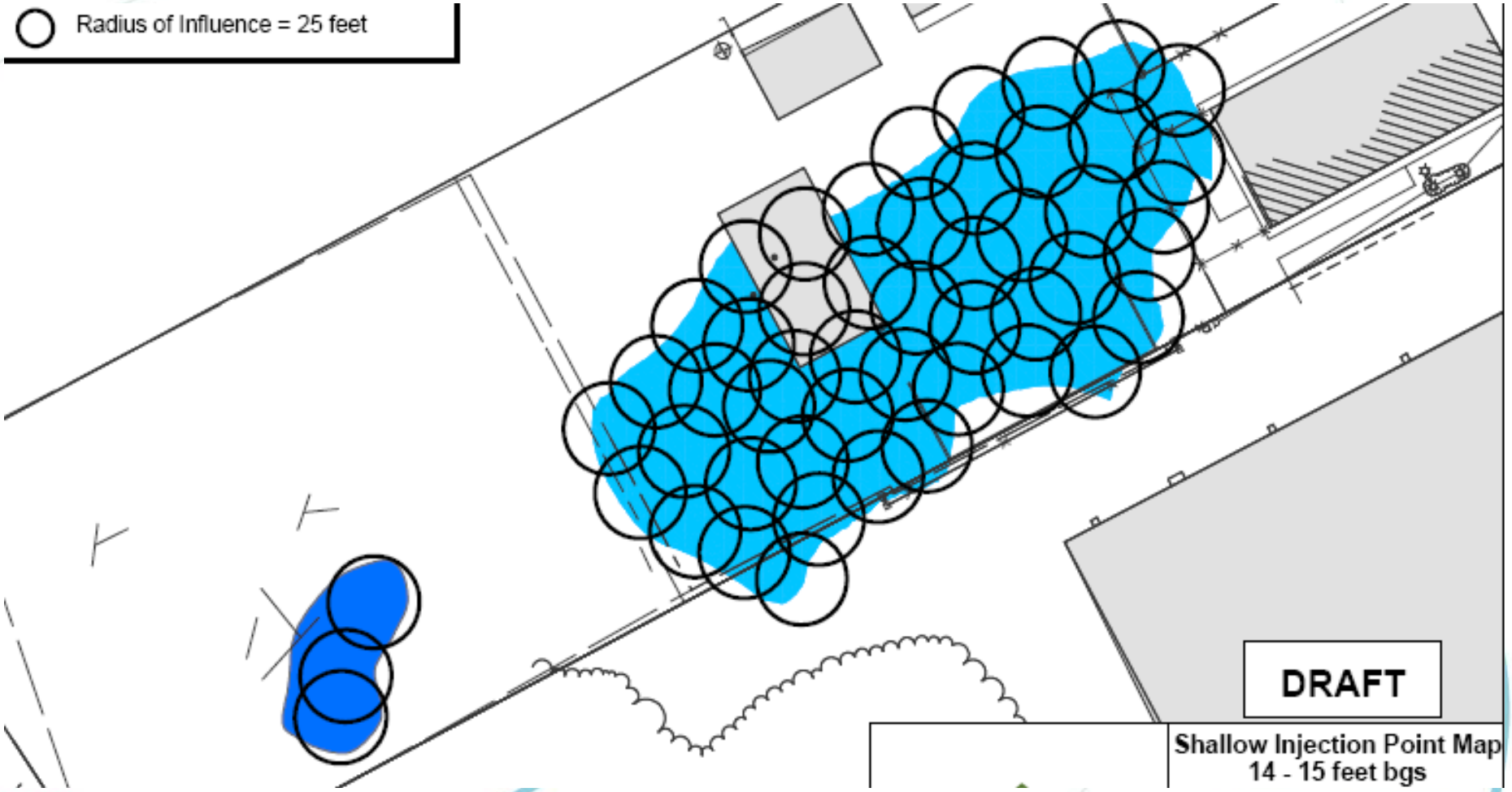
- Ozone reaction zone
  - Ozone reacts with CoCs
  - CO_2 and H_2O are produced
- Enhanced bioremediation zone
  - Ozone reaction continues
  - O_2 produced by O_3 injection accelerates biodegradation
  - Additional O_2 and CO_2 produced
- Vapor collection zone
  - Unreacted O_3 & O_2 collected
  - Oxidation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



In-situ Ozone Injection Process

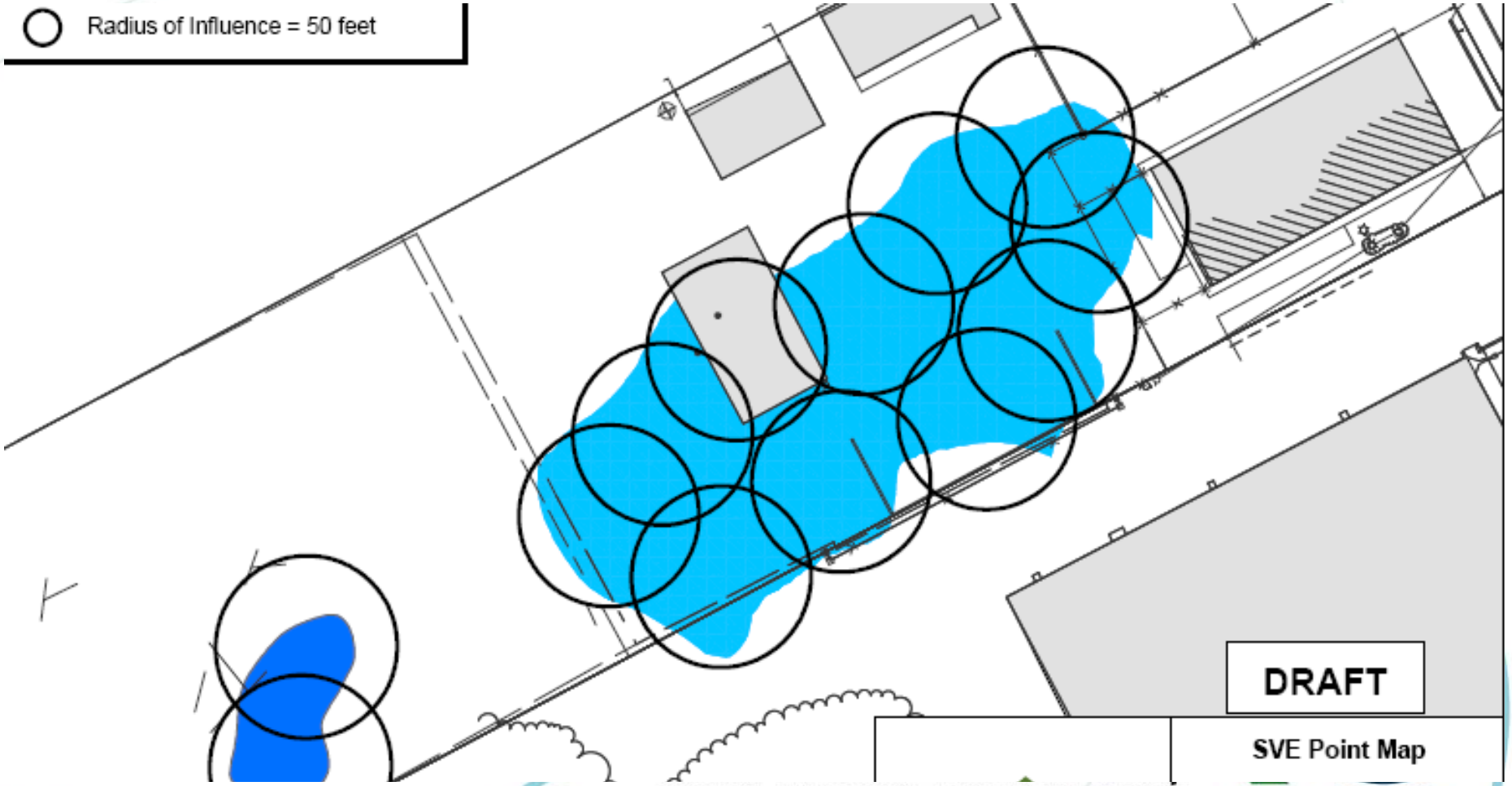


Ozone Injection Locations: ~15 ft (4.5 m) bgs



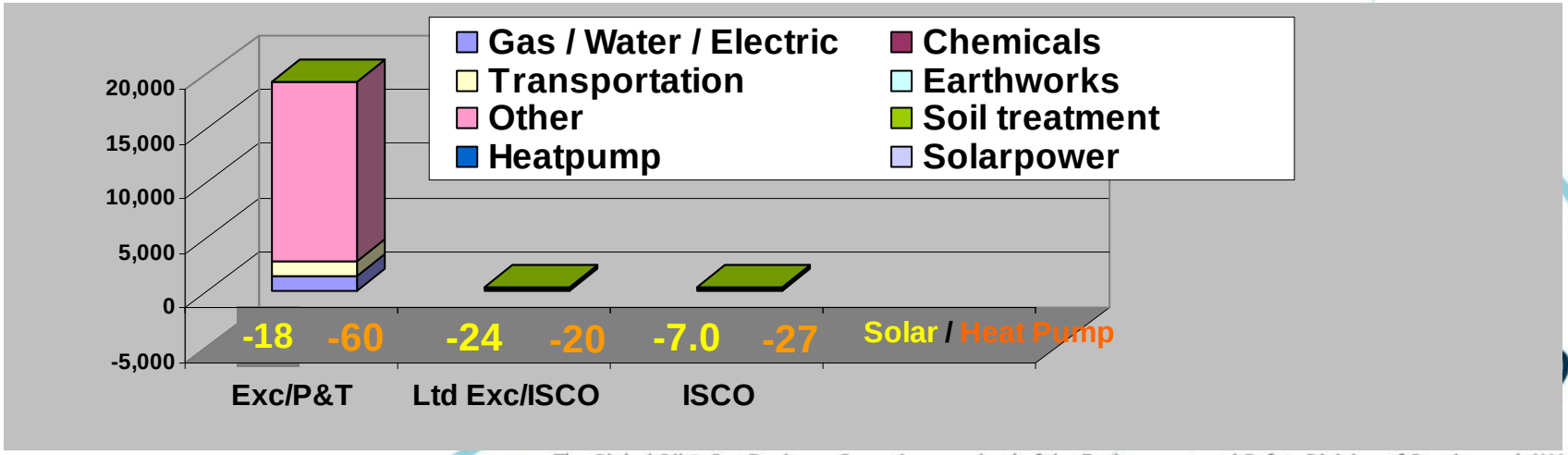
Ozone Injection Locations: ~30 ft (9 m) bgs

Soil Vapor Extraction Well Locations



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

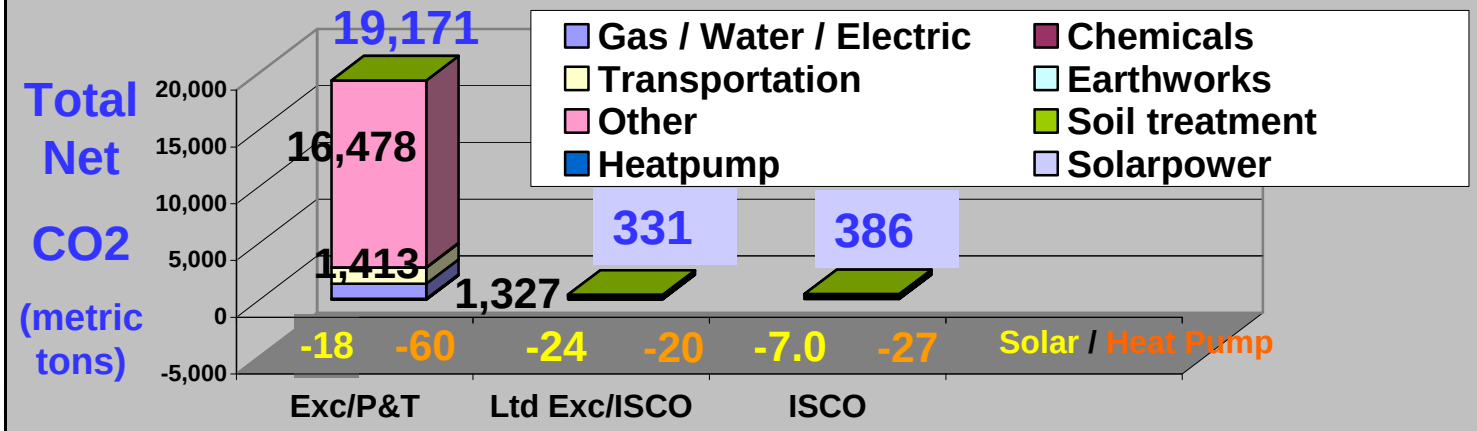
Comparison carbon footprint

CO_2 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 CO_2 emission (ton):	**19170.9**	**330.5**	**385.7**
Total household equivelants:	**3834.2**	**66.1**	**77.1**
CO_2 emission soil (ton/m^3):	**1.88**	**0.01**	**0.01**
CO_2 emission contamination load (ton/kg):	**0.18**		
CO_2 emission removed contamination (ton/kg):	**1.28**	**-0.01**	**-0.01**
CO_2 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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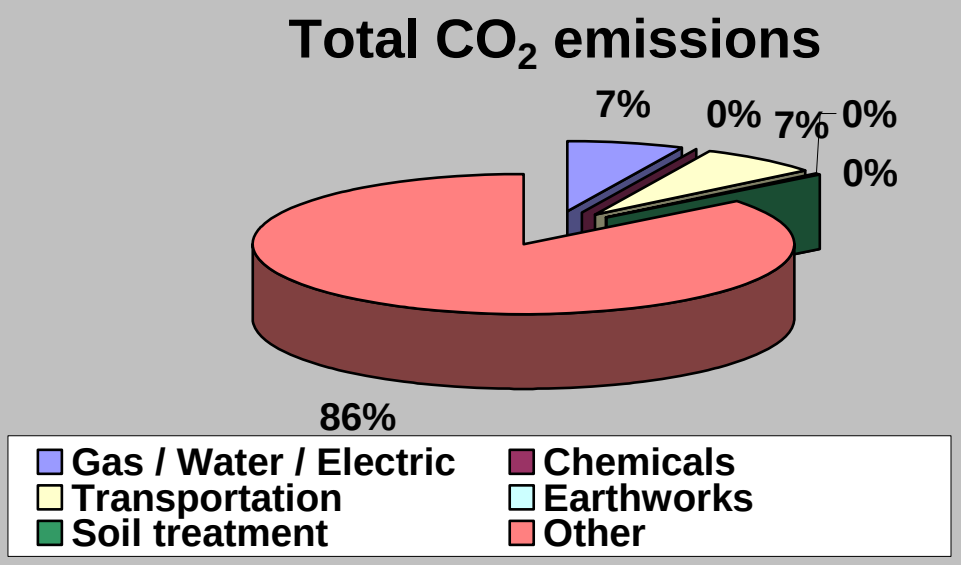
- "Other" - GAC for water & vapors
- Gas/Water/Electric
- Transportation (Exc/P&T)
- Chemicals (ISCO)

(Total Net CO2 in metric tons)

Soil Excavation with GW Pump & Treat

Green sheet		
	Saved emisions	Percentage of total
Heatpumps	60	0.3%
Solarpower	18	0.1%

Total CO_2 emission (ton):	**19171**
Total household equivelants:	**3834**

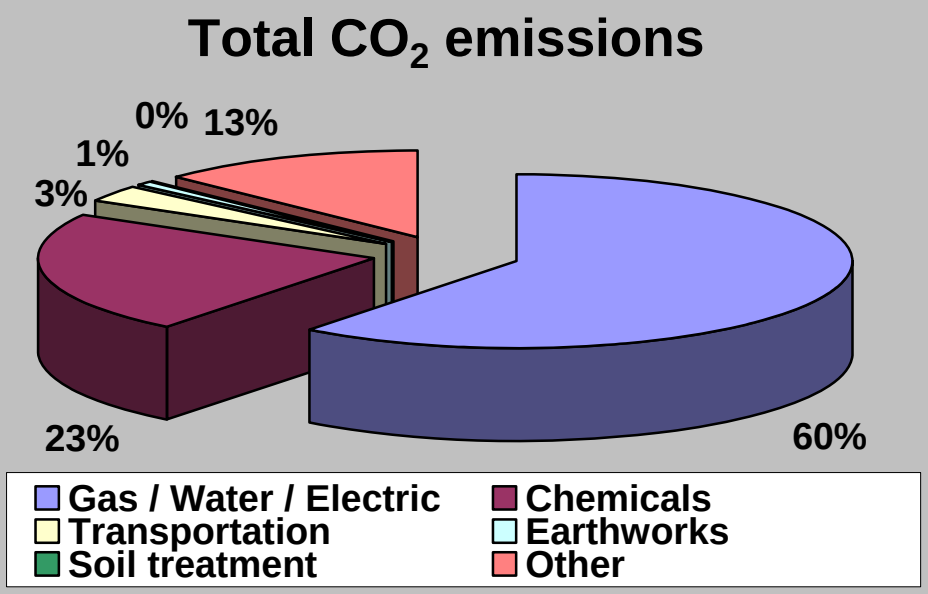


- 86% of carbon emissions due to Pump & Treat GAC system plus vapor emissions GAC as "**Other**"
- Soil Excavation & **Transportation** = 7%
- **Gas/Water/Electric** = 7%

Limited Soil Excavation & ISCO

Green sheet		
	Saved emisions	Percentage of total
Heatpumps	20	5%
Solarpower	24	6.4%

Total CO_2 emission (ton):	**331**
Total household equivelants:	**66.1**



- **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%

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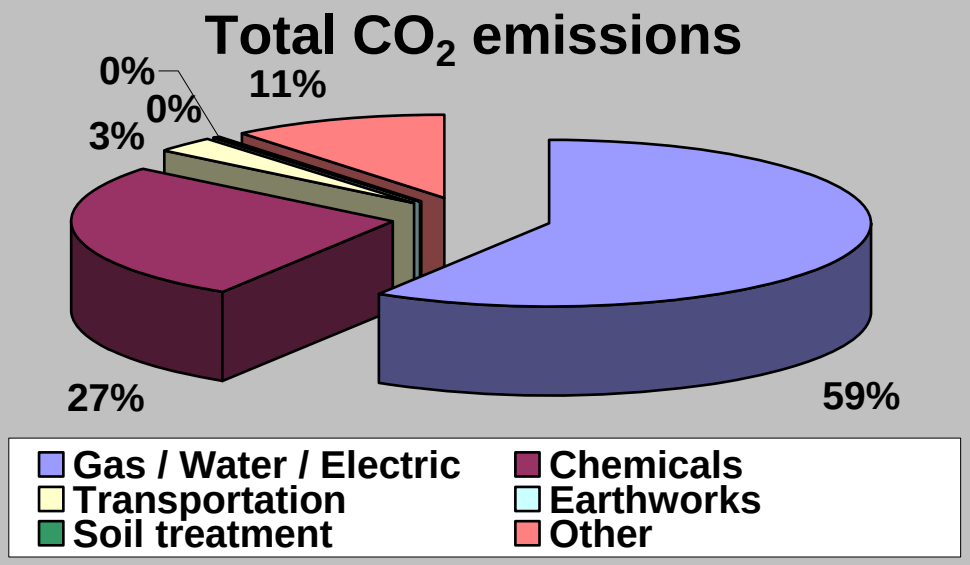
In-situ Ozone / ISCO

Green sheet		
	Saved emisions	Percentage of total
Heatpumps	27	6%
Solarpower	7	1.7%

Total CO_2 emission (ton):	**386**
Total household equivelants:	**77.1**



- **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**