Green Remediation

Estimating the Environmental Footprint at a Corrective Action Clean-up

Pilot Study at Romic East Palo Alto

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Green Remediation

In Theory:

Consider all environmental effects of remedy implementation and incorporate options to maximize the net environmental benefit of cleanup actions.

In Practice:

Case studies with greener remedies.

Development of tools, guides, and standards.

Pilot studies to estimate footprints.

Overview

- How we conducted our Pilot Study to estimate environmental footprints
- Applying the results to remedy decision-making
- Importance of incorporating Life-Cycle Assessment principles
- Developing a methodology for use by regulators and site owners

Pilot Site: Romic East Palo Alto

- 14-acre hazardous waste management facility

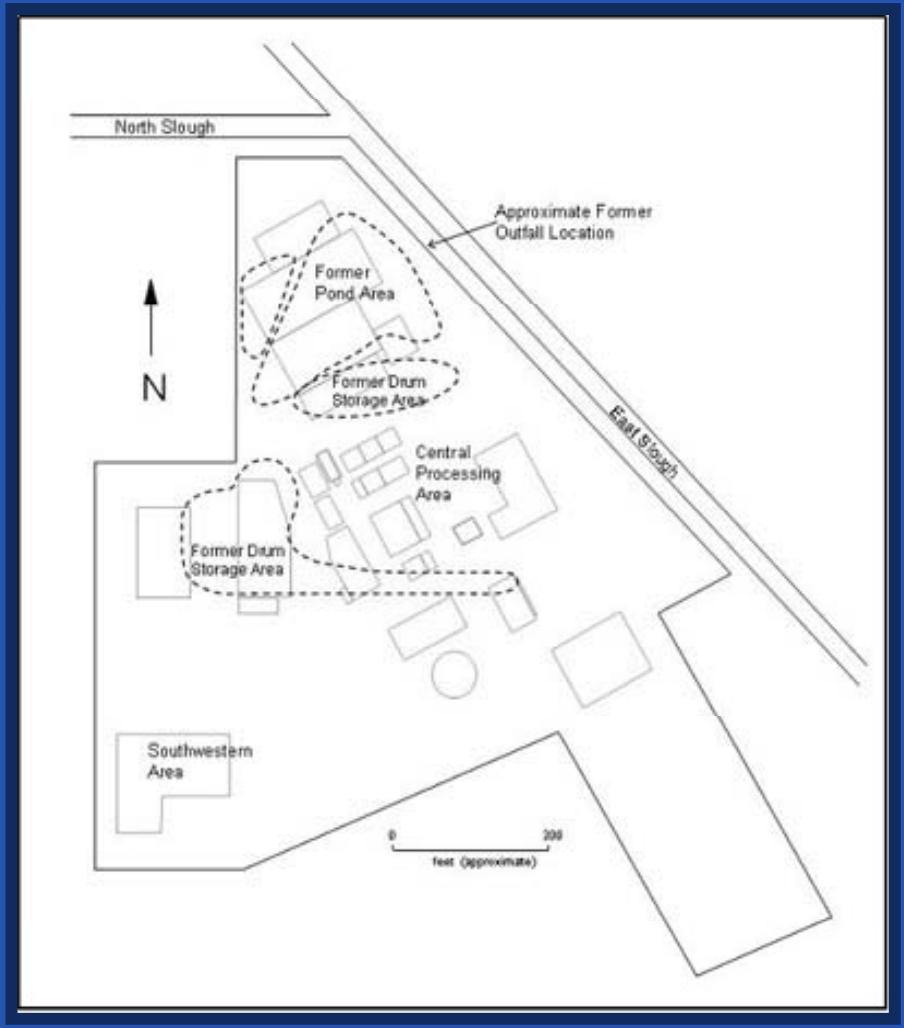
- Soil and ground water contaminated with VOCs (such as TCE and PCE)

- Area of contamination to a depth of 80 feet

Purpose of the Pilot Study

- Compare the environmental footprints of three alternative remedies at Romic
  - Is it possible to determine the environmental footprint of the alternative remedies?
  - Did we select the "greenest" remedy?
  - How important is off-site manufacture for the environmental footprint?
- Help to develop a methodology to be used at other clean-up sites

Remedy Alternatives at Romic



Alternative 2 (Hybrid)

Extraction wells *and* bioinjection wells

30 years to complete

Alternative 3 (Bioremediation)

Bioinjection wells only

10 years to complete

Alternative 4 (Pump and Treat)

Extraction wells only

40 years to complete

Alternative 3 has already been chosen for Romic, so this analysis did not affect the remedy decision.

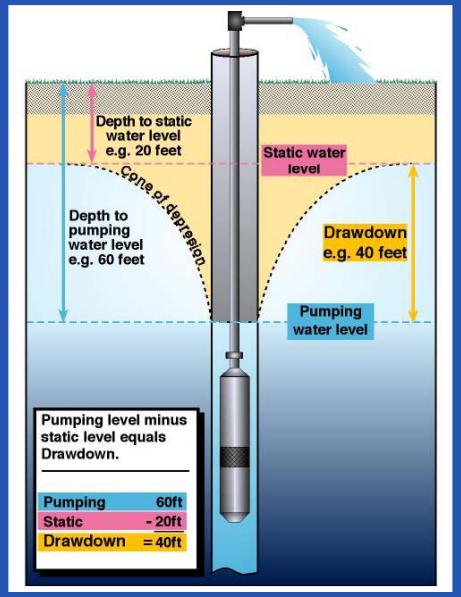
Remedy Alternatives at Romic

Bioremediation:

uses injections of cheese whey and molasses to the ground water

Pump and Treat:

includes treatment of ground water in an air stripper followed by carbon filters



Boundaries of the Pilot Study

Functional Unit:

Ground water remediation.

Temporal Boundary:

Construction and active life of each alternative remedy.

System Boundary:

On-Site Activities (Level 1)

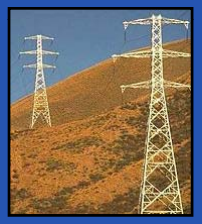
Transport To and From Site (Level 2)

Manufacture Off-Site (Level 3)

At Romic We Evaluated…

- *Resources and Energy Used*
  - Water
  - Construction Materials
  - Electricity
  - Fossil Fuel
- *Wastes Generated*
  - Spent Carbon
  - Wastewater
- *Air Emissions*
  - NO_X, SO_X, PM, CO_2

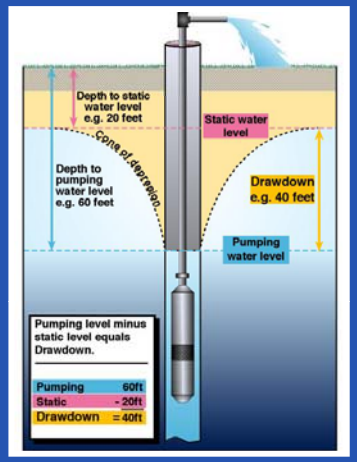






Level 1: On-Site Activities

Well Construction



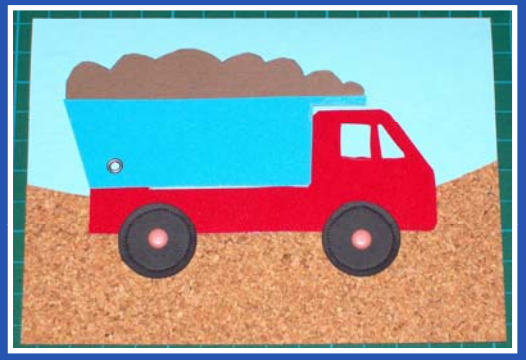
Groundwater Extraction

BioInjections

Groundwater Treatment

Level 2: Transport To and From Site

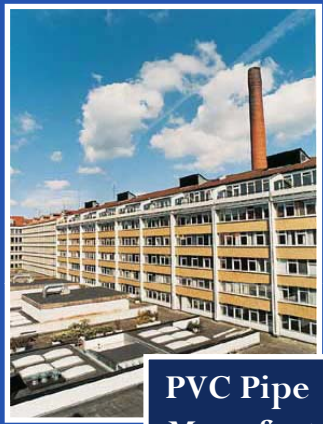
Operators to Site



Wastes off Site

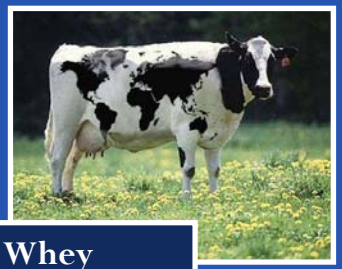
Materials to Site

Level 3: Off-Site Manufacture



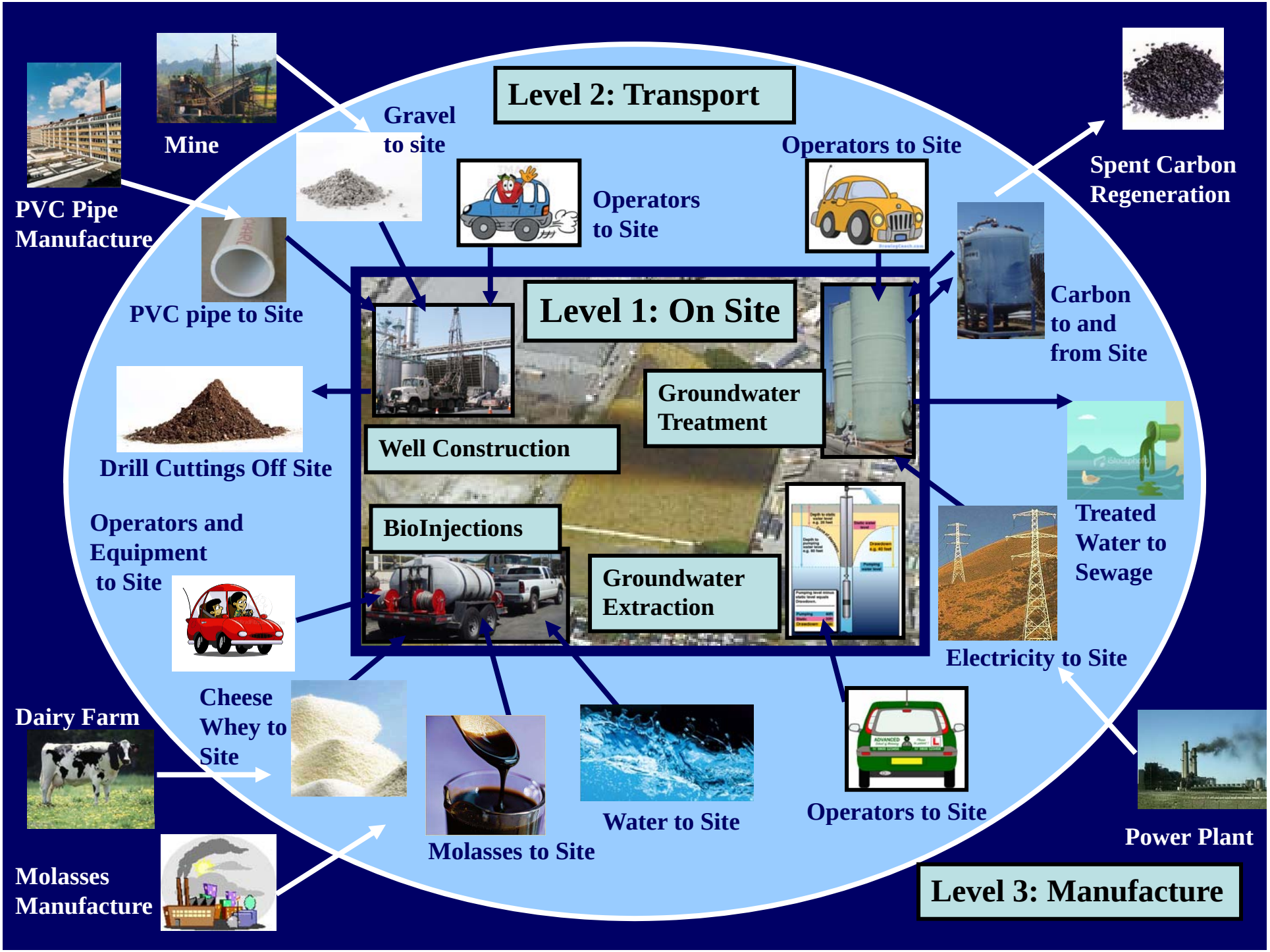
PVC Pipe Manufacture

Gravel Mining



Cheese Whey Processing

Electricity Production


Level 2: Transport
Level 1: On Site
Level 3: Manufacture
PVC Pipe Manufacture
Mine
Gravel to site
Operators to Site
Operators to Site
Spent Carbon Regeneration
PVC pipe to Site
Carbon to and from Site
Drill Cuttings Off Site
Groundwater Treatment
Well Construction
Treated Water to Sewage
Operators and Equipment to Site
BioInjections
Groundwater Extraction
Electricity to Site
Cheese Whey to Site
Dairy Farm
Molasses to Site
Water to Site
Operators to Site
Power Plant
Molasses Manufacture

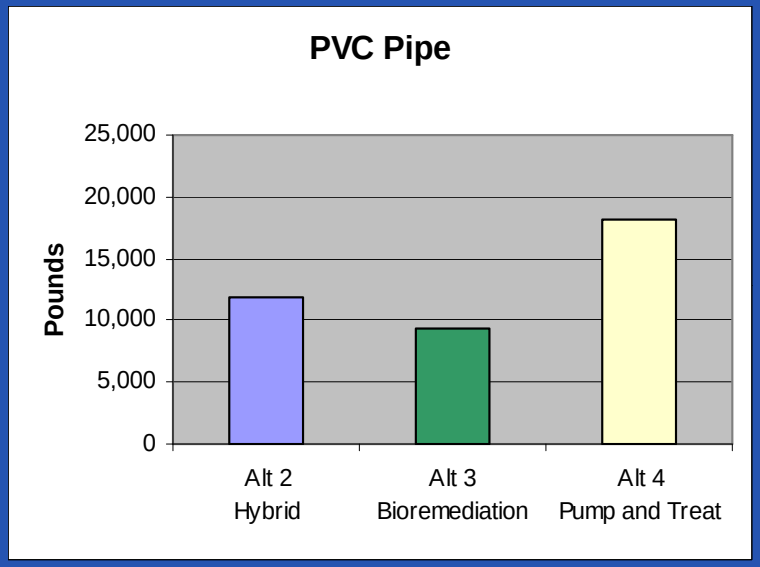
Sources of Information

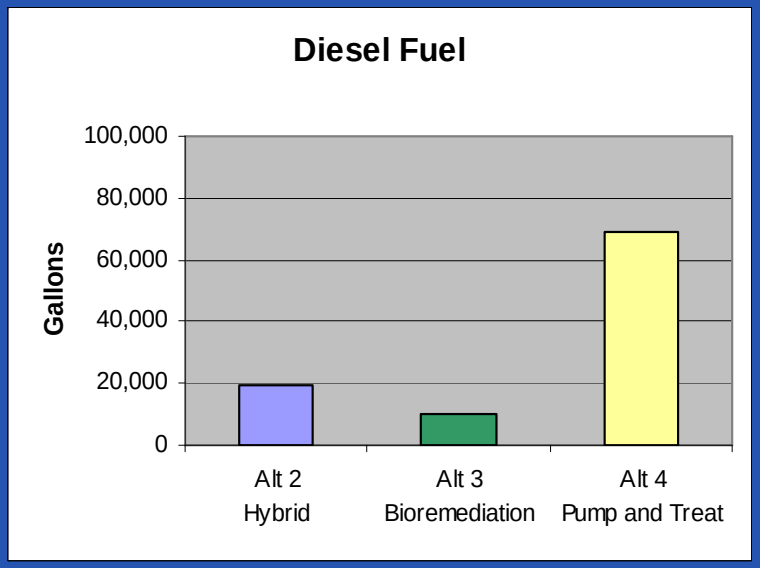
1. EPA Project Managers
2. Official Documentation
3. Romic Staff and Consultants
4. Analyst Assumptions
5. Web Searches
6. Back-of the Envelope Estimates

Results!

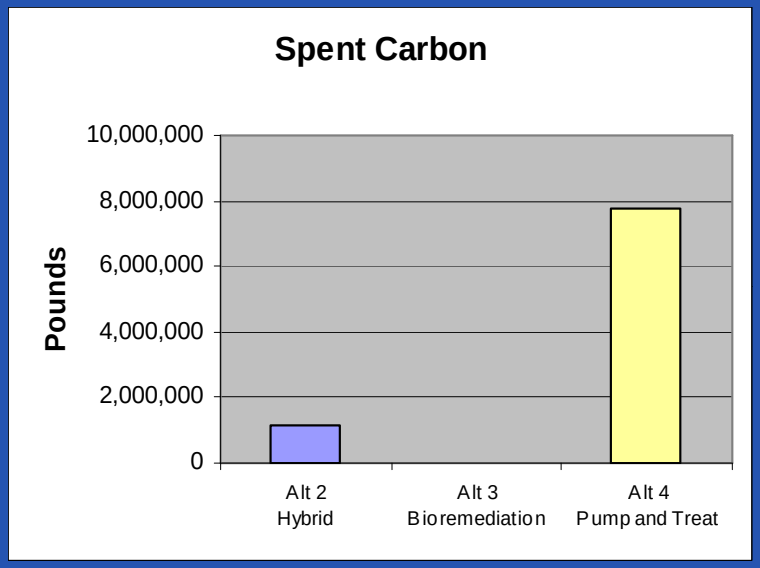
Pilot study is still in progress and results at this stage are preliminary.

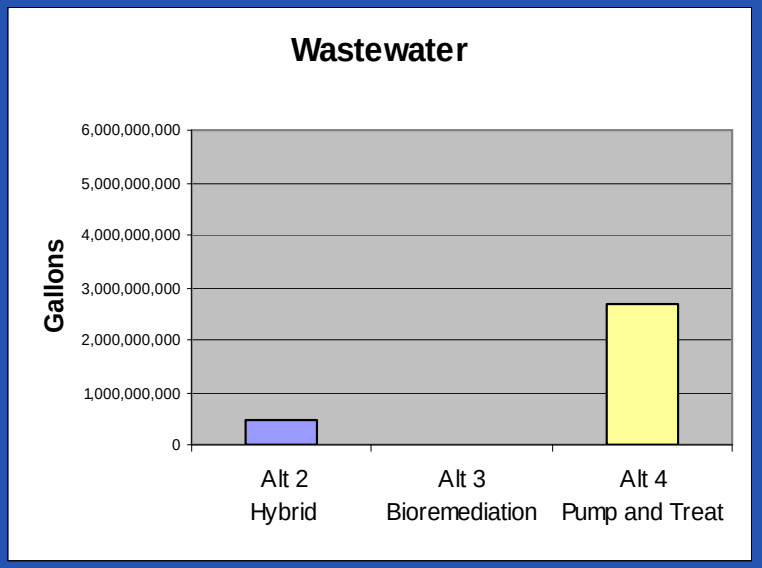
Results – Materials and Fuel



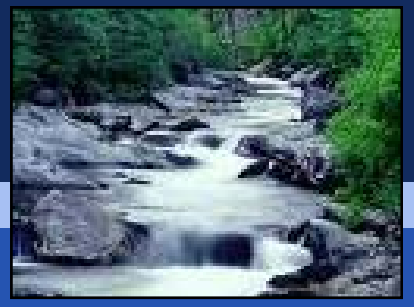


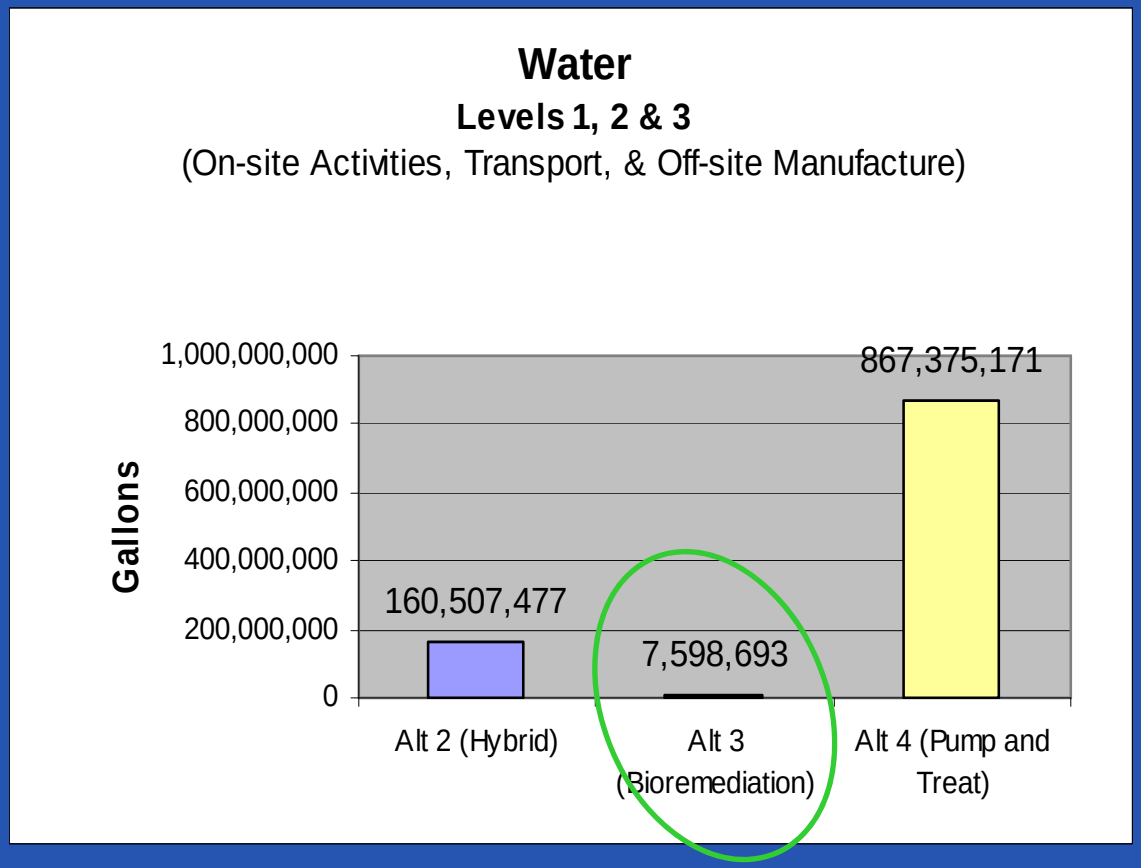
Results – Wastes Generated





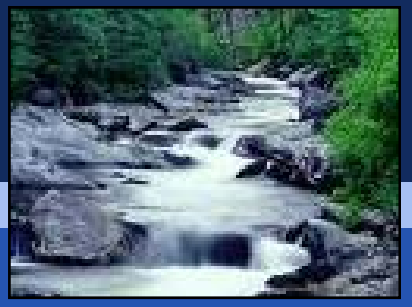
Results – Water



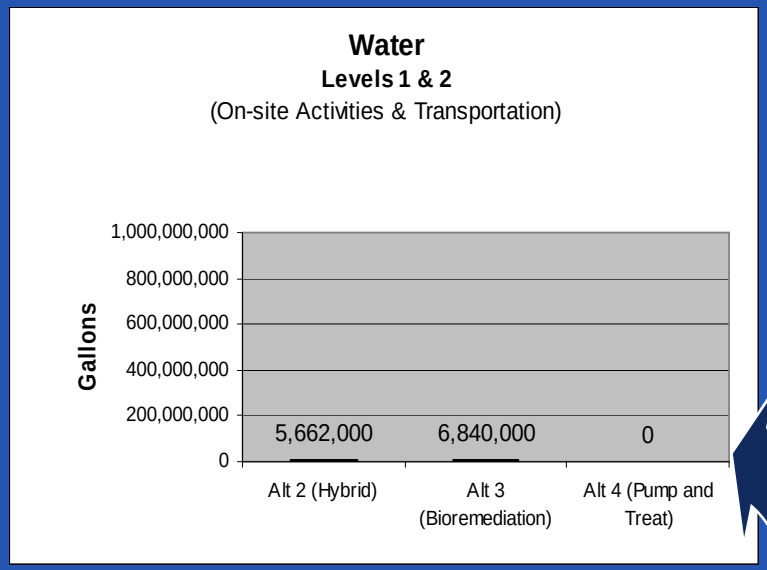


These values are for the life-time of each alternative remedy.

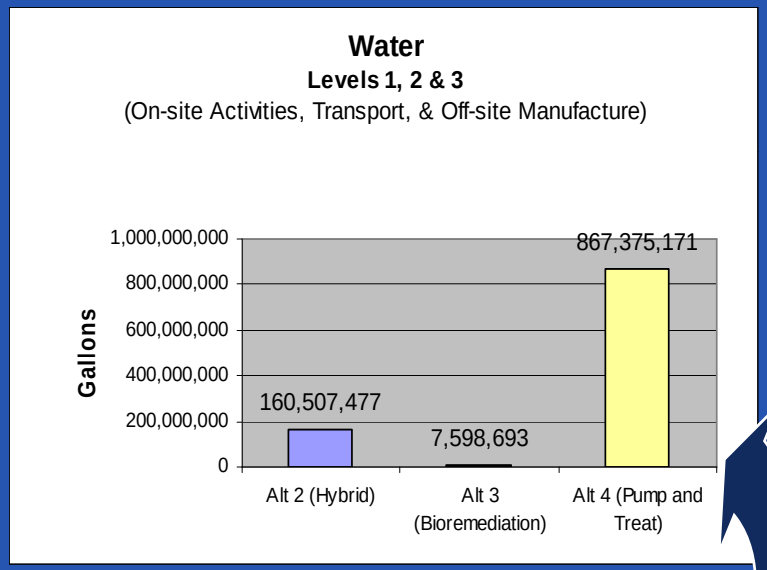
Results – Water



Including Level 3 activities in the analysis substantially increases our estimate of the water footprint.



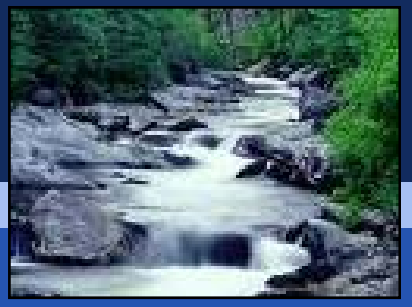
Looking at on-site activities and transportation only



Looking at activities in all three levels

These values are for the life-time of each alternative remedy.

Results – Water



Issues related to water:

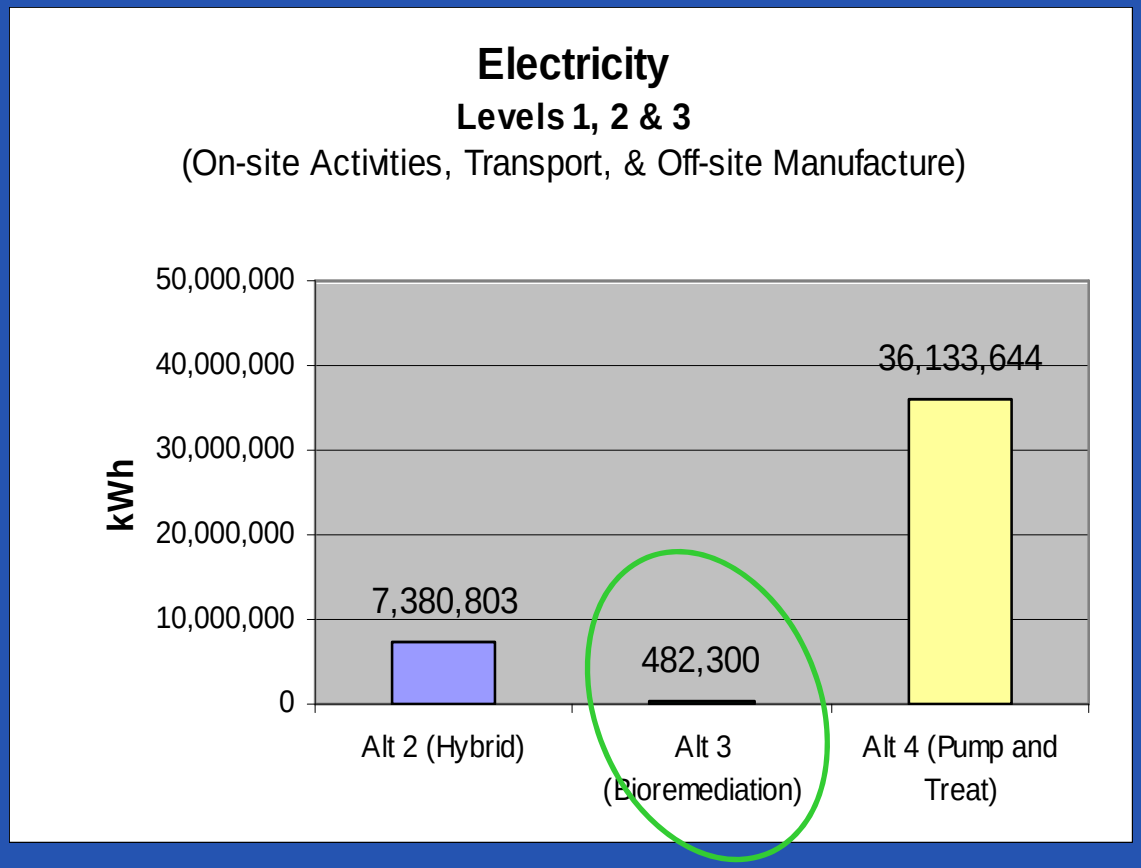
- Water withdrawn vs water consumed.

- Water withdrawn in "water scarce" areas vs water withdrawn in "water abundant" areas.

- Include non-potable water in the total water used?

Maybe all water is not equal… how should we take this into consideration?

Results – Electricity



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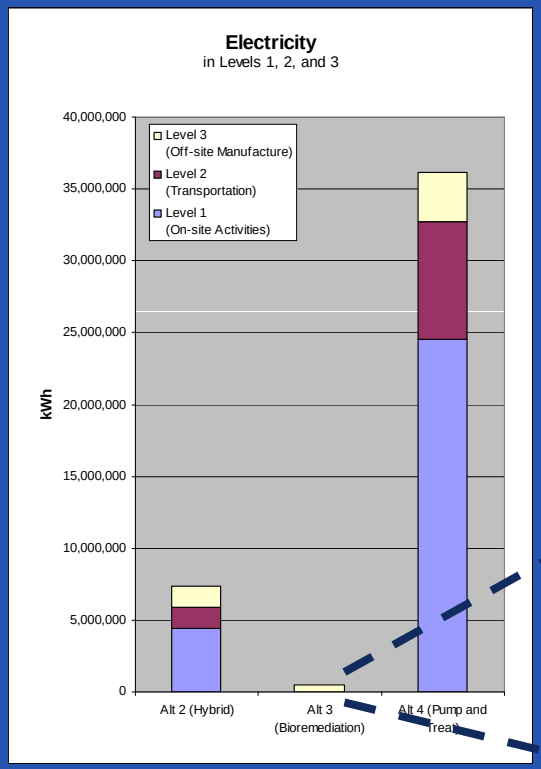
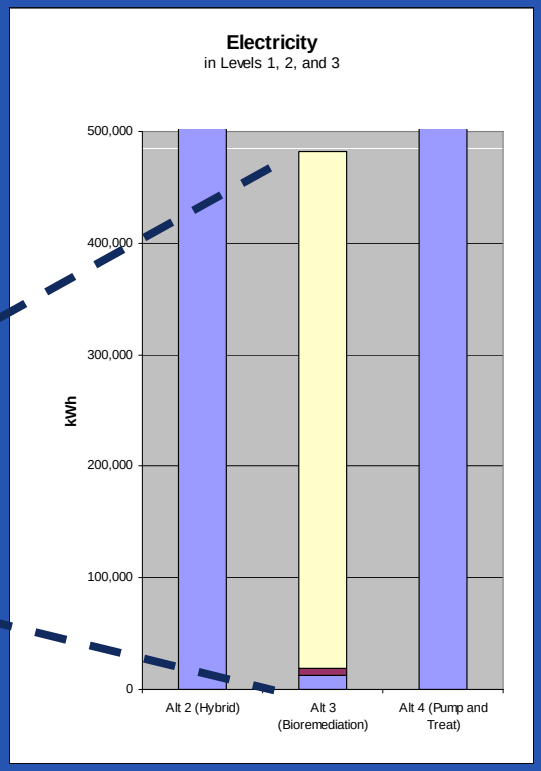
Results – Electricity





These values are for the life-time of each alternative remedy.

We are used to taking into account on-site electricity in evaluating environmental footprints.

However, electricity used for transport and manufacture are also important.

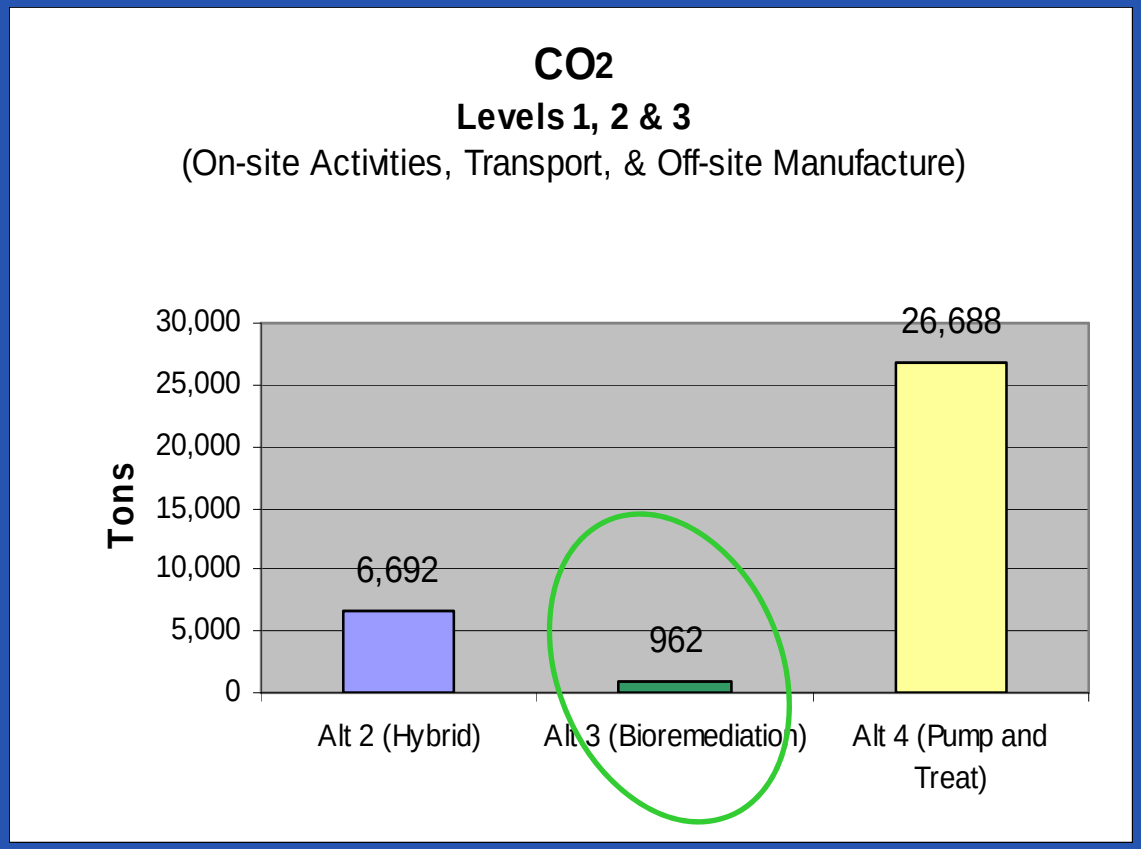
Results – Electricity

Issues related to electricity:

- Electricity use also contributes to CO_2 emissions – be careful to avoid "double counting".

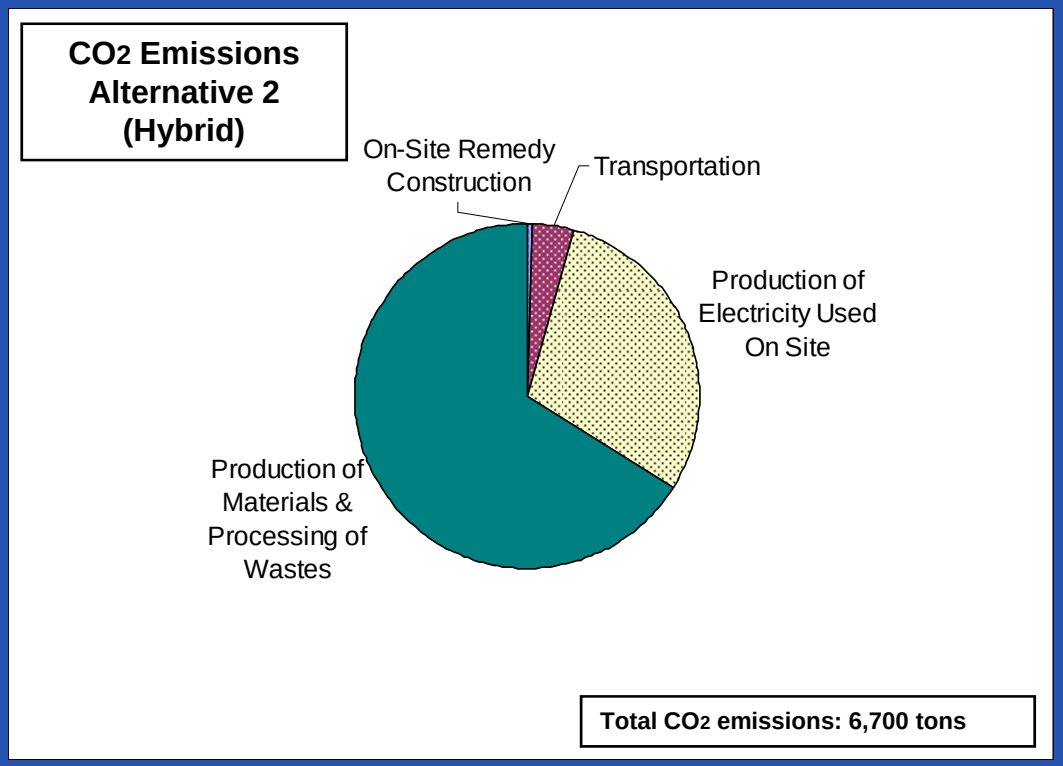
- We still may want to report electricity use because of infrastructure impacts.

Results – CO_2 Emissions



These values are for the life-time of each alternative remedy.

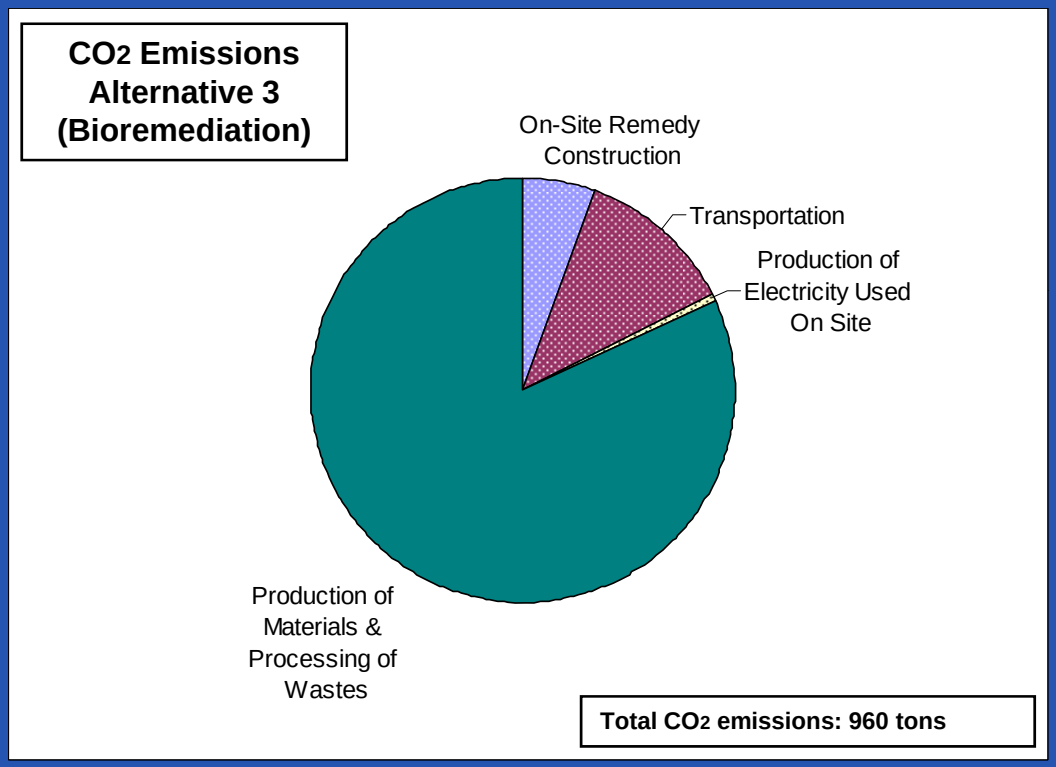
Results – CO_2 Emissions



These values are for the life-time of the alternative remedy.

Off-site activities, even those not related to production of electricity used on-site, are a big part of the CO_2 footprint.

Results – CO_2 Emissions



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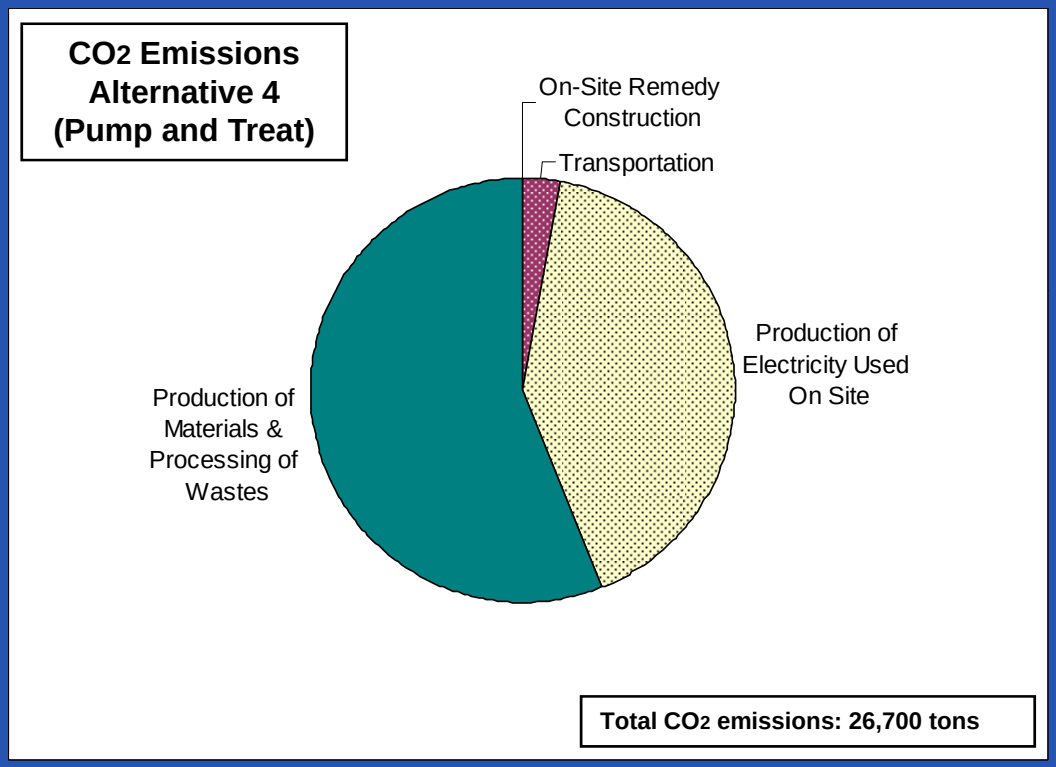
Results – CO_2 Emissions



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Off-site activities, even those not related to production of electricity used on-site, are a big part of the CO_2 footprint.

Results – CO_2 Emissions

Issues related to CO_2:

- Some CO_2 emission factors may include resource extraction and others may not, resulting in inconsistency in the analysis.

- Should we take into account likely lower emissions of CO_2 per unit material produced in the future?

Observations

for our bioremediation system…

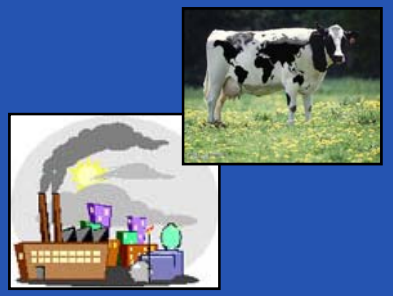
- Most of the fresh water use occurred in on-site activities.
- Most of the electricity use occurred in off-site activities.
- Electricity used on site accounted for only 1% of the total CO_2 footprint.
- Other off-site manufacture accounted for about 80% of the total CO_2 footprint.

Especially important for the CO_2 footprint were:

-- bioremediation materials (whey, molasses)

-- production of fossil fuels

-- manufacture of well construction materials



Observations

for our pump and treat system…

- All the fresh water use occurred in off-site manufacture.
- About a third of the electricity use occurred in off-site activities.
- Electricity used on site accounted for about 40% of the total CO_2 footprint.
- Other off-site manufacture accounted for about 55% of the total CO_2 footprint.

  Especially important for the CO_2 footprint were:
  -- reactivation of granulated carbon
  -- treatment of wastewater

Applying results to our decision-making

We need to balance the various aspects of each remedy.

Applying results to our decision-making

	Alternative 2 Hybrid	Alternative 3 Bioremediation	Alternative 4 Pump and Treat
Materials Used			
Water (gallons)	200,000,000	8,000,000	900,000,000
Electricity (kWh)	7,000,000	500,000	40,000,000
Waste Generation			
Spent Carbon (lbs)	1,000,000	0	8,000,000
Wastewater (gallons)	500,000,000	0	3,000,000,000
Air Emissions			
CO_2 (tons)	7,000	1,000	30,000
Other			
Road Distance (miles)	300,000	200,000	600,000
Remediation Time (years)	30	10	40

Comparison of impacts among alternatives:

relatively high impact
relatively medium impact
relatively low impact
impacts similar

- **Balance local effects with global effects.**
- **Balance effects of disparate items:**
  - **natural resource depletion**
  - **waste generation**
  - **environmental contamination**
  - **years to complete remedy**

Applying results to our decision-making

- Metrics for environmental impacts are not the only factor in a remedy decision, but would be one of several balancing factors.

- In all cases the remedy must first meet threshold criteria, such as protection of human health and the environment.

Using results to improve remedies

	Alternative 2 Hybrid	Alternative 3 Bioremediat	Treat
Materials Used			
Water (gallons)	200,000,000	8,000,000	900,000,000
Electricity (kWh)	7,000,000	500,000	40,000,000
Waste Generation			
Spent Carbon (lbs)	1,000,000	0	8,000,000
Wastewater (gallons)	500,000,000	0	3,000,000,000
Air Emissions			
CO_2 (tons)	7,000	1,000	30,000
Other			
Road Distance (miles)	300,000	200,000	600,000
Remediation Time (years)	30	10	40

Look at opportunities to reduce fresh water use:

use reclaimed water for bioinjections of cheese whey and molasses

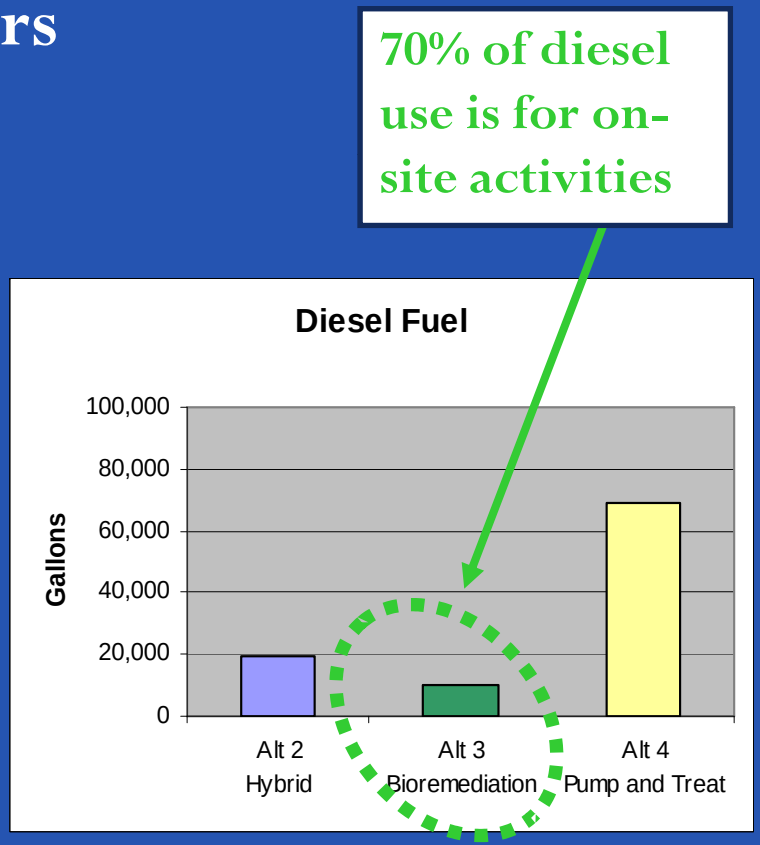
Comparison of impacts among alternatives:

relatively high impact
relatively medium impact
relatively low impact
impacts similar

Reducing Impacts – Diesel Fuel

During remedy construction Romic has agreed to:

* Use diesel particulate filters
* Reduce idling time
* Use ultra low sulfur diesel or another clean fuel



Life-Cycle Assessment Principles

- Life-Cycle Assessment principles helped us greatly in developing our conceptual approach to the Pilot Study
- It was important to include activities outside the fence line of the facility
- Off-site manufacture may account for a large portion of water use, electricity requirements, and CO_2 emissions resulting from clean-up remedies

Life-Cycle Assessment Principles

Benefits of using Life-Cycle Assessment principles to evaluate clean-up alternatives

- Quantify on- and off-site environmental impacts
- Recognize local and global impacts
- Compare relative impacts of remedial technologies
- Focus efforts in reducing impacts prior to construction of a remedy

Life-Cycle Assessment Principles

Difficulties encountered in applying Life-Cycle Assessment principles to a clean-up remedy

- Establishing the boundaries of the clean-up remedy
- Quantifying materials to be used hypothetically (before a remedy is constructed and operating)
- Finding information about environmental footprints for manufacturing of materials used in the remedies

Life-Cycle Assessment Principles

Improving Level 3 (Manufacturing) Estimates for the Romic Pilot Study

We performed complete (but back-of-the envelope) Level 3 calculations for:

- Water use
- Electricity use
- CO_2 emissions

We would like to add Level 3 calculations for:

- Wastes generated
- Fossil fuels consumed
- Air toxics emitted

We are working with EPA life-cycle analysis experts (in EPA's Research Office in Cincinnati) to improve and add to our Level 3 calculations.

Life-Cycle Assessment Principles

- We plan to run calculations for other remedial activities at Romic:
  - soil excavation
  - groundwater monitoring
  - capping contaminated areas

- We would like to identify aspects of the remedies at Romic that make minimal contribution to the overall footprints – to streamline for analyses at other sites

Developing a Methodology

- Conduct four more Pilot Studies this year
- Outline a methodology for use by regulators and site owners
- Methodology may be used at clean-up sites for:
  - Deciding among alternative remedies
  - Improving existing remedies

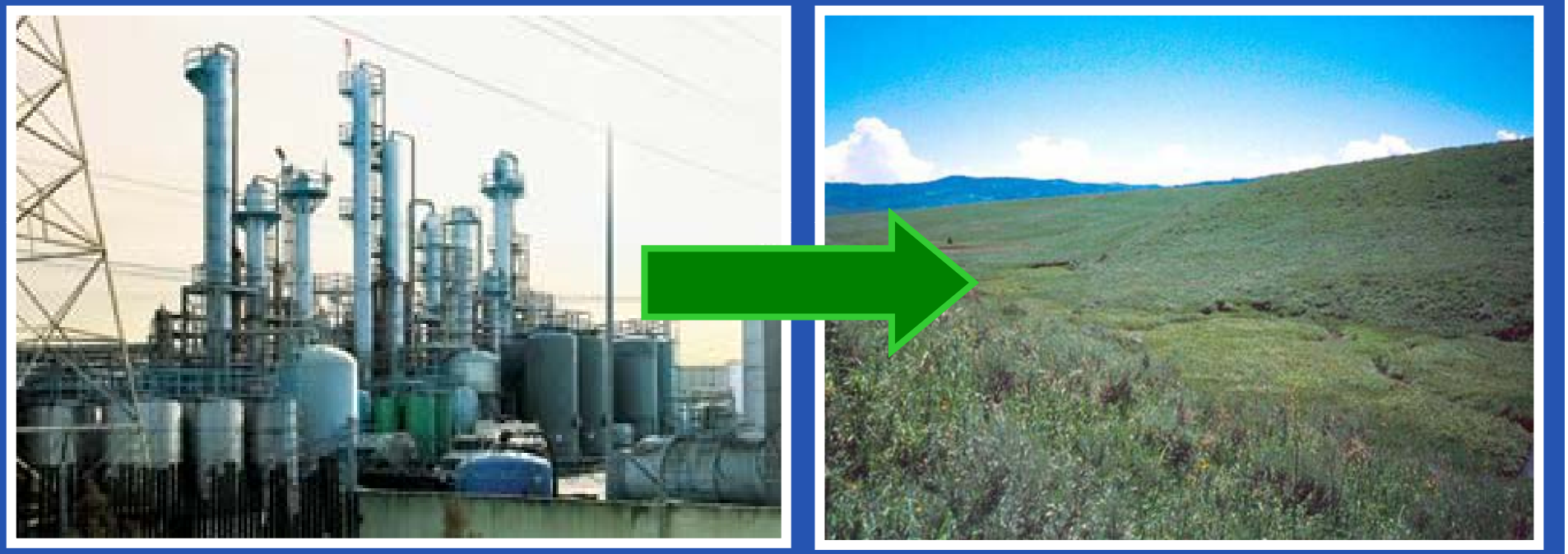
Conclusions

- **Yes, it's feasible to estimate the environmental footprint of a corrective action remedy.**
- **Importance of including off-site manufacturing activities in estimations of the environmental footprint.**
- **A methodology would be helpful for conducting this type of study at other sites.**

NEXT STEPS

- Complete four additional pilots
- Continue to refine the methodology
- Develop guidance document
- Promote Green Remediation in general and exchange information with others interested

Promoting Green Remediation



Reducing the Environmental Footprints of Our Site Clean-ups