



Cost Comparisons of Phytotechnologies to Other Remedial Approaches

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OVERVIEW

1. Case Study Background
2. Net Present Valuation vs. Total Life Cycle
3. Influence Factors and Weighted Probabilities of Occurrence
4. Rate of Return on (Research) Investment

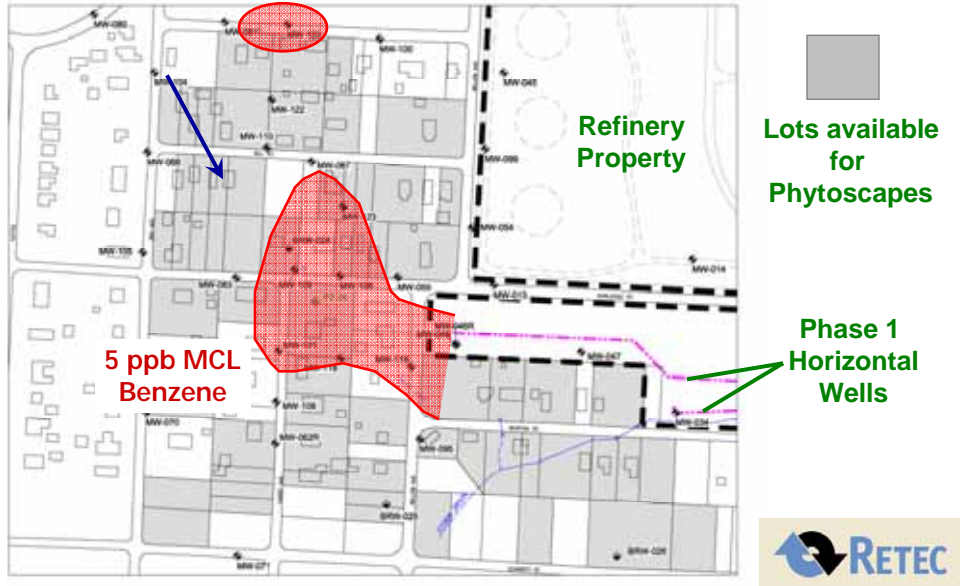
Case Study Background



- **Site Conditions:**
 - **Neighborhood properties** adjacent to a former petroleum refinery
 - Groundwater impacted with **gasoline range organics (BTEX)**
 - Portion of groundwater treated using **horizontal 3-phase extraction**
 - Groundwater 5-13 ft bgs; silty clay; **5×10^{-6} cm/s**
- **Issues:**
 - **Extraction efficiency low** (low hydraulic conductivity = low recoveries)
 - **Refinery property undergoing redevelopment**
 - **Reduce the disturbance** to the local community (minimize sound, safety risks, heavy equipment traffic)
 - **Provide some value** to the community for these under-utilized properties
- **Phytotechnology Option:**
 - Create bird / butterfly gardens (**"Phytoscapes"**) using vegetation that can promote rhizodegradation and control hydraulics

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Site Map



Phytoscapes

Concept Borrowed from BP Retail

A collage of images illustrating phytoscaped retail sites. It includes several photographs of landscaped areas with various plants and flowers, as well as a site plan diagram showing the layout of a retail site with phytoscaped areas. The text "Phytoscaped Retail Site" is centered over the collage.

Phytoscaped Retail Site

Phytoscapes: Landscapes that incorporate phytoremediation species to **clean up or prevent** environmental liabilities (small leaks and spills)

Plant Screening Experiments

Pure Gasoline Injections



Examined various deep-rooted species (naturalizing and landscape); monitored survivability over time

Injected pure gasoline (+/- 10% oxygenates) at various volumes

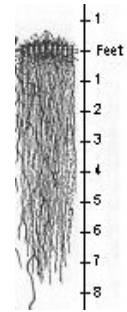
Irrigated with pure gasoline (various volumes)



Confirmed roots growing through soil (yellow)

Clean topsoil

Clayey soil



1 L total soil volume

Sub-irrigation only source of water

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Gasoline Testing Results

Not Only Tolerate, But Remediate



45 mls per 1 L cell (7.5% by wgt)



Final Soil Concentrations:

Unplanted Control Pots (not shown):

- > BTEX 1,875 ug/kg
- > MTBE 2,700 ug/kg

Planted Pots: Bottom Soil Layer

- > BTEX 46 ug/kg (ND, 11, ND, 35)
- > MTBE 50 ug/kg

orders of magnitude lower

Gasoline Toxicity Results



Tolerant Species

- 3 out of 3** Buffalo grasses (*Buchloe dactyloides* spp.)
- MOST** ornamental clump grasses (*Andropogon*, *Bouteloua*, *Elymus*, *Miscanthus*, *Pennisetum*, *Saccharum*, ...)
- 1 of 1** Columbine (*Aquilegia canadensis*)
- 1 of 2** Coneflowers (*Echinacea* sp.)
- 2 of 2** Blazingstars (*Liatris* sp.)
- 3 of 3** Hollies (*Ilex* sp.)
- 1 of 1** Mugo pine (*Pinus mugo*)
- 2 of 3** Viburnums (*Viburnum* sp.)

Intolerant Species

- 2 of 3** Goldenrods (*Solidago* sp.)
- 2 of 2** Indigos (*Baptista* sp.)
- 1 of 2** Asters (*Aster* sp.)
- 1 of 1** Golden Alexanders (*Zizia aurea*)
- 1 of 1** Cardinal flower (*Lobelia cardinalis*)
- 1 of 2** Daylilies (*Hemerocallis* sp.)
- 4 of 5** Junipers (*Juniperus* sp.)
- 1 of 1** Japanese yew (*Taxus x Media*)
- 1 of 1** Emerald arborvitae (*Thuja occidentalis*)

Uses:

- Prevention and Remediation

Uses:

- Leak Detection?

See Poster





Total Life Cycle Cost Comparison



- **Option 1: Horizontal 3-Phase (H3P) Extraction System**
 - Capital (installation) \$1,000k
 - OM&M = \$150k per year for 5 years \$ 750k
 - **TOTAL Life Cycle Cost** **\$1,750k**
- **Option 2: Plant Hydraulic Barrier (Phyto) System**
 - Capital (research and development) \$ 110k
 - Includes pilot test, standard (1^o) + additional (2^o) monitoring
 - Capital (installation) \$ 200k
 - OM&M (establishment) = \$45k year 1, \$25k year 2 \$ 70k
 - OM&M = \$10k per year thereafter for 8 years \$ 80k
 - **TOTAL Life Cycle Cost** **\$ 460k**
- **Cost Savings (Value Added)** **\$1,290k**
- **“Does not consider the time-value of money... economics are not realistic”**

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Net Present Valuation (NPV) Cost Comparison

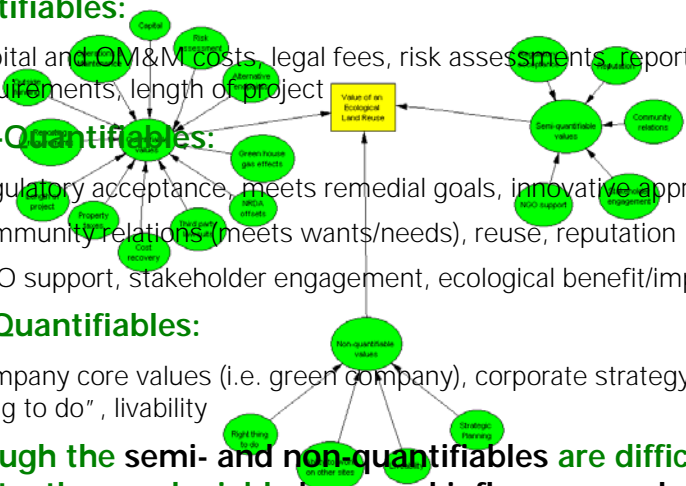


- **Option 1: Horizontal 3-Phase (H3P) Extraction System**
 - Capital (\$1,000k installation **now**)
 - OM&M (\$150k/yr for 5 years **future**)
 - **TOTAL NPV (2.5% Rate) \$1,603k**
- **Option 2: Plant Hydraulic Barrier (Phyto) System**
 - Capital (\$110k R&D **spent already**)
 - Capital (\$200k installation **now**)
 - OM&M (\$75k for 2 years establishment **future**)
 - OM&M (\$10k/yr for 8 years after establishment **future**)
 - **TOTAL NPV (2.5% Rate) \$ 416k**
- **Cost Savings (Value Added) \$1,187k**
- **“Still not a fair comparison...Option 1 could be anything outlandish...artificially creates a clear-cut decision”** ¹¹

Other Influencing Factors Quantifiables to Non-Quantifiables



- **Quantifiables:**
 - Capital and OM&M costs, legal fees, risk assessments, reporting requirements, length of project
- **Semi-Quantifiables:**
 - Regulatory acceptance, meets remedial goals, innovative approaches
 - Community relations (meets wants/needs), reuse, reputation
 - NGO support, stakeholder engagement, ecological benefit/impact
- **Non-Quantifiables:**
 - Company core values (i.e. green company), corporate strategy, “right thing to do”, livability
- **Although the semi- and non-quantifiables are difficult to value, they undeniably have real influence on clean up options**



Weighted Probability of Occurrence



Influencing Factors	H3P Extract	Phyto
Quantifiables		
Financials (Net Present Valuations)	+ 0% (0%)	+100% (100%)
Semi-Quantifiables		
Meet Remedial Goals (Track Records)	+50% (50%)	- 50% (50%)
Innovative Approach (Univ. Involved)	- 5% (45%)	+ 5% (55%)
Beneficial Reuse (Fits Local Plan)	- 10% (35%)	+ 10% (65%)
Ecological Enhancement (Want/Need)	- 5% (30%)	+ 5% (70%)
Non-Quantifiables		
Livability (Complaints of H3P System)	- 10% (20%)	+ 10% (80%)
Corporate Strategy (Reuse)	- 5% (15%)	+ 5% (85%)

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Weighted Probability of Occurrence Cost Comparison



- **Option 1: Horizontal 3-Phase (H3P) Extraction System**
 - TOTAL NPV \$1,603k
 - Weighted Probability of Occurrence x 15%
- **Option 2: Plant Hydraulic Barrier (Phyto) System**
 - TOTAL NPV +\$ 416k
 - Weighted Probability of Occurrence x 85%
- **Weighted NPV Options Baseline \$ 594k**
- **ACTUAL: Plant Hydraulic Barrier (Phyto) System**
 - TOTAL NPV (100% weighted) - \$ 416k
- **Cost Savings (Value Added) \$ 178k**
- **“Very defensible accounting approach...rigorous (yet simple) process”**

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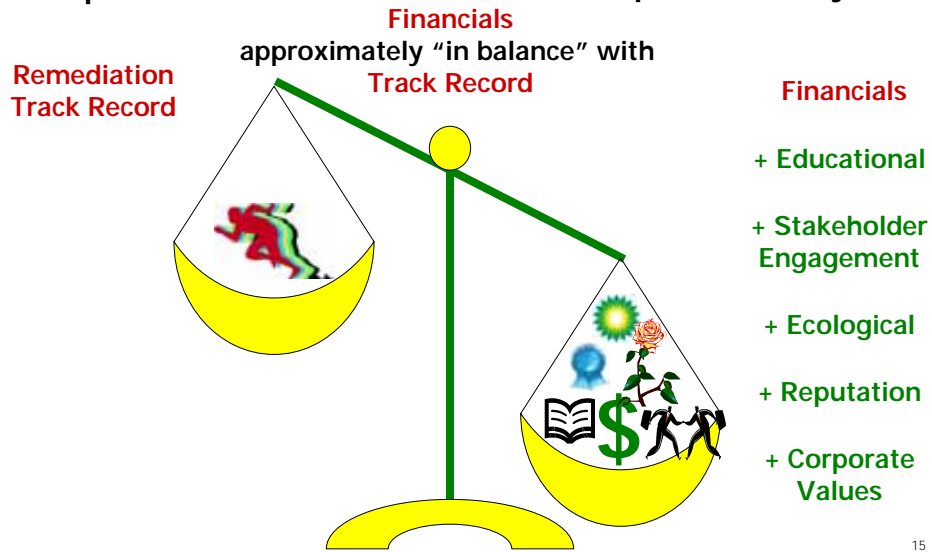
Additional Value "Tips the Scales"

Semi- and Non-Quantifiables



Option #1 – H3P

Option #2 – Phyto



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Justifying R&D

Pilot Study Costs of \$110k



Planting

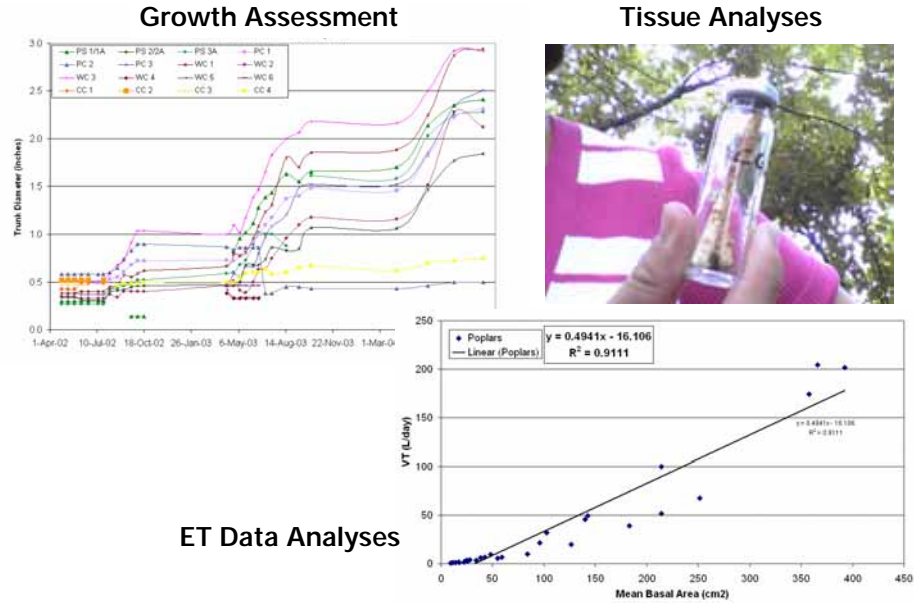


Weather Parameters / Sap Flow

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Pilot Study

Other Components



Rate of Return on Investment



- **Research Investment to conduct phyto pilot: \$110k**
 - **Not known up front** whether it would prove successful
 - **Compete against capital projects** (revenue-generating)
- **Concept of a Rate of Return (RoR):**
 - If you invest \$1, you **want to get back more** than \$1 in revenue
 - Common industry practice uses a **hurdle RoR**, i.e. 15% (\$1.15 back)
 - A project that **does not exceed hurdle usually will not get funded**
- **How do you incorporate this into remediation?**
 - Generally, **remediation is only a cost-center** (no revenue generated)
 - But, there is a **cost savings** in using alternative approaches
 - **Use the NPV and weighted outcomes to include semi- and non-quantifiables**

Rate of Return on Investment



• Option 1: H3P System Total NPV x Weighting	\$240k
• Option 2: Phyto System Total NPV x Weighting	<u>+\$354k</u>
• Weighted NPV Options Baseline	\$594k
• ACTUAL: Phyto System Total NPV	<u>-\$416k</u>
• Cost Savings (Value Added)	\$178k
• Phyto R&D Investment	\$110k
• Rate of Return on Investment	

$$\text{RoR} = \frac{\$178k - \$110k}{\$110k} \times 100\% = 62\% !!$$

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Conclusions and Recommendations



- **Corporate Perspective**
 - Economics of remediation evaluated on a **common accounting basis**
 - Use **net present valuation** over life cycle costs
 - Use **probabilities of occurrence** to weight options
 - Demonstrate a beneficial **rate of return on investment**
- **Benefits of this to the Site Owners**
 - Provides **justification** to spend on remediation
 - Advocate **semi- and non-quantifiable influencing factors** to managers and regulators alike (step through the **holistic thought process**, “**tell the whole story**”)
- **Benefits of this to the Environmental Consulting Community**
 - Puts the **economics in terms that site owners understand**
 - Keeps it realistic (**believable and credible**)
- **Benefits of this to the Academic Community**
 - Provides justification to **secure R&D funding from site owners**

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QUESTIONS !!!

