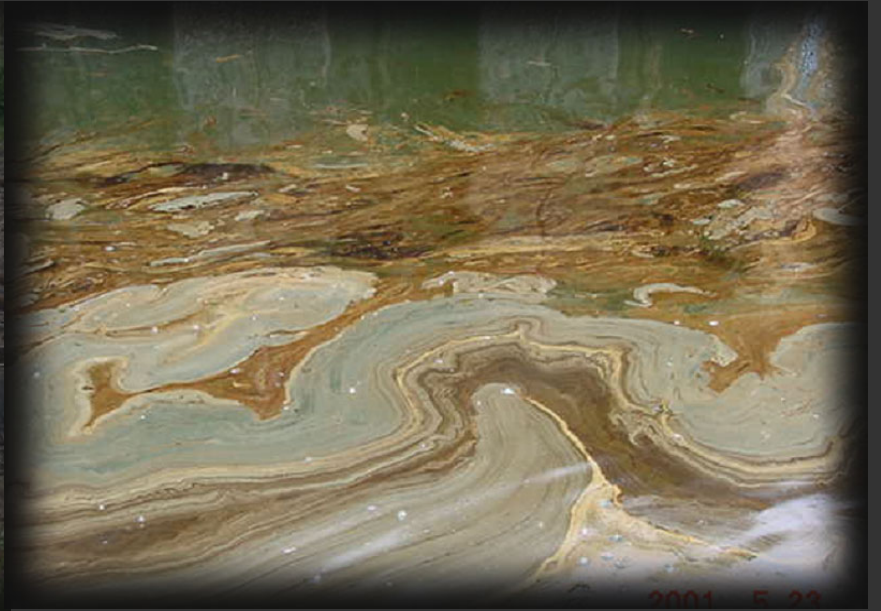


Phytoremediation of Petroleum Spills in Riparian Areas: An Overview



Sand Creek Consultants, Inc.

Rhineland, WI

Roswell, NM

Mark Nega, Phytoremediation Forestry Scientist
& Christopher J. Rog, P.G.

PHYTO = PLANT



REMEDiate = TO FIX or CURE

Definition of Phytoremediation:



Use of Vegetation to Contain, Sequester, Remove, or Degrade Organic and Inorganic Contaminants in Soils, Sediments, Surface Water, and Groundwater

- Complex system with many plant processes involved
- Applicable to a broad range of contaminants

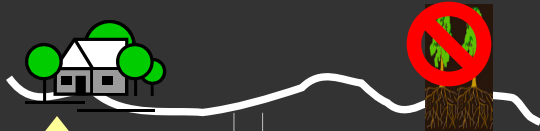
It's one of the very few technologies that can address all media and contaminants simultaneously

Petroleum Spills:

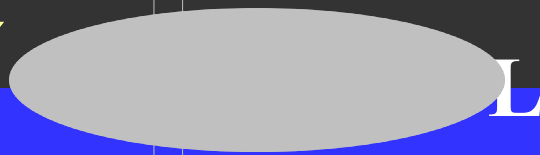
Upland vs. Riparian

5

UPLAND



*300 feet to
water
& LNAPL*



AQUIFER

Sand Creek Consultants, Inc.



New Mexico:
Pump and Treat

RIPARIAN

Indiana



0 - 5 feet to water



BTEX and other aromatics

- Rapid volatilization
- Rapid Degradation in Near Surface Environment

Relatively Easy To Bio- / Phyto -remediate

PAH and other Recalcitrants

- Slow aerobic biodegradation;
- Relatively insoluble / less bioavailable;

Riparian Spills

- PAHs persist



Much Current Phyto Research involves PAHs

Typical Riparian Spill

Riparian
Phytoremediation

Sheen on
surface water



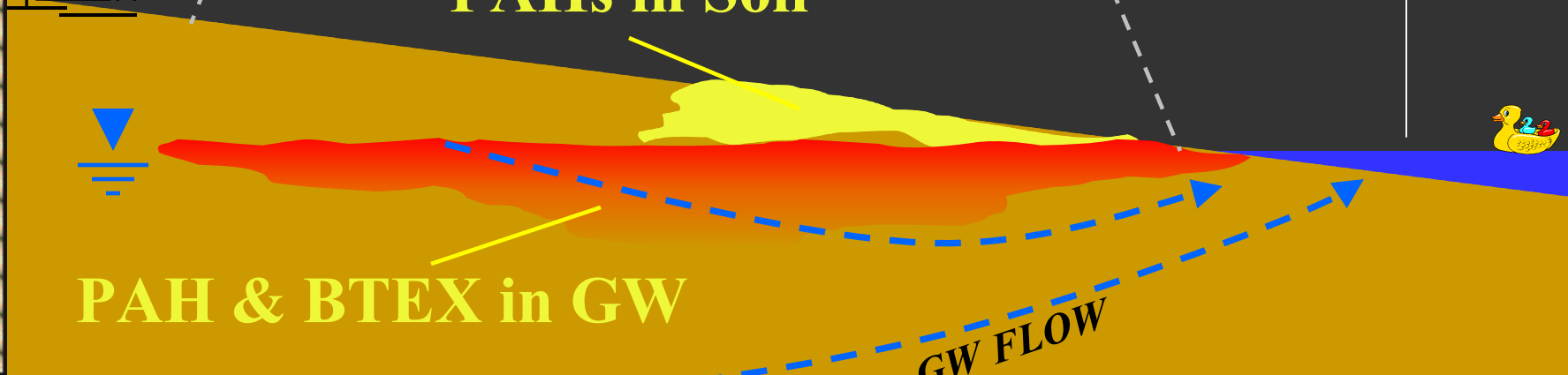
PAHs in Soil

PAH & BTEX in GW

GW FLOW



Sand Creek Consultants, Inc.



Surface Water Clean-up

Sand Creek Consultants, Inc.



**Are
Phytotechnologies
Feasible?**

Riparian Zone Clean-up

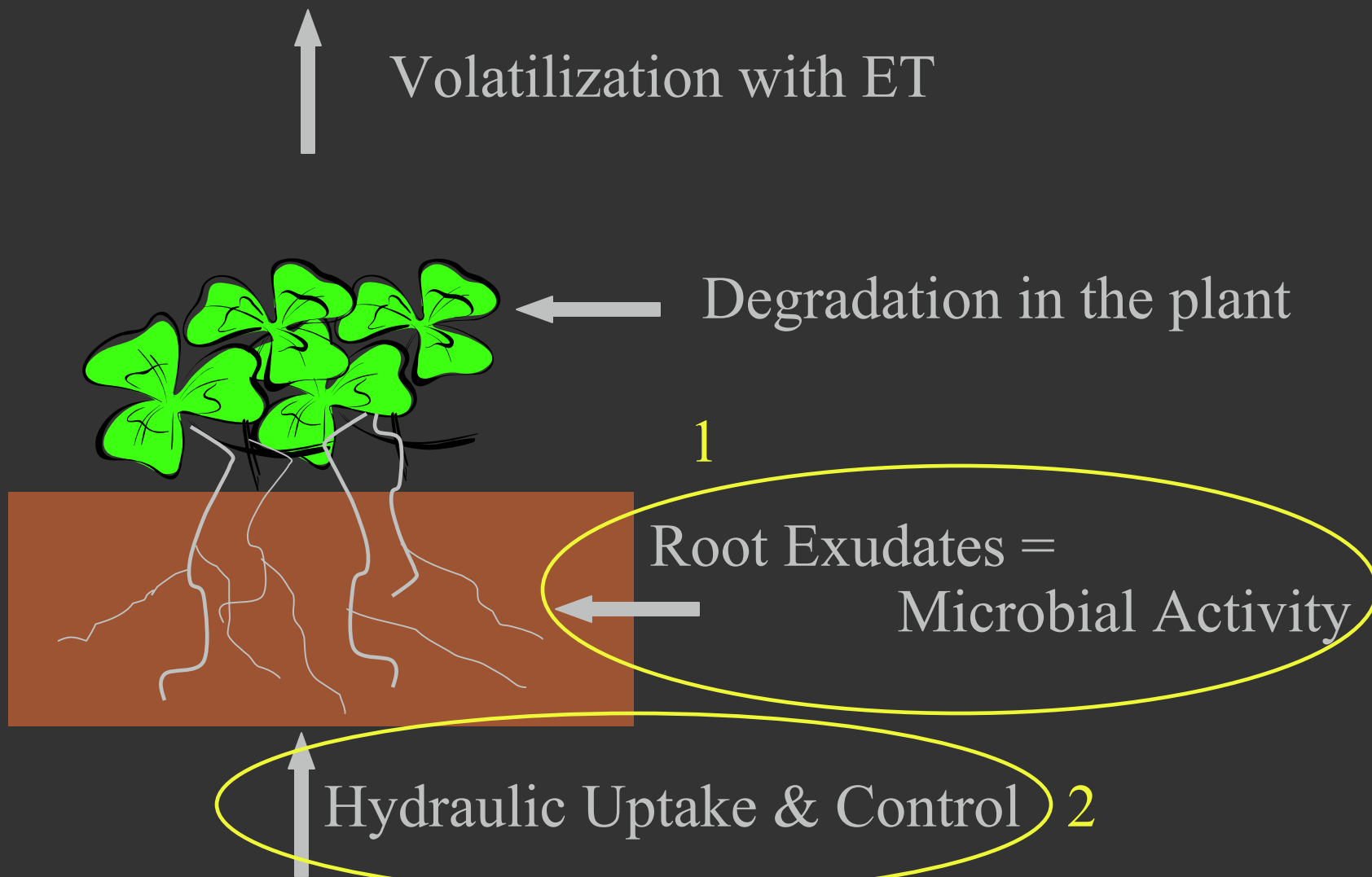
- Surface and Shallow Soils and GW Only
- GW Discharge Zones

No 'Diving' GW Plumes



**Are
Phytotechnologies
Feasible?**

Phytoremediation Processes



Phytoremediation Processes

1) Rhizodegradation

Increase Soil Oxygen Content, Microbial Activity,
Organic Matter & Porosity

- Soil microbial counts 5 to 10,000 times higher
- Translocation of carbon from the atmosphere into soil
- Adds up to much increased biodegradation rates

One of the Most Active Areas of Current Research

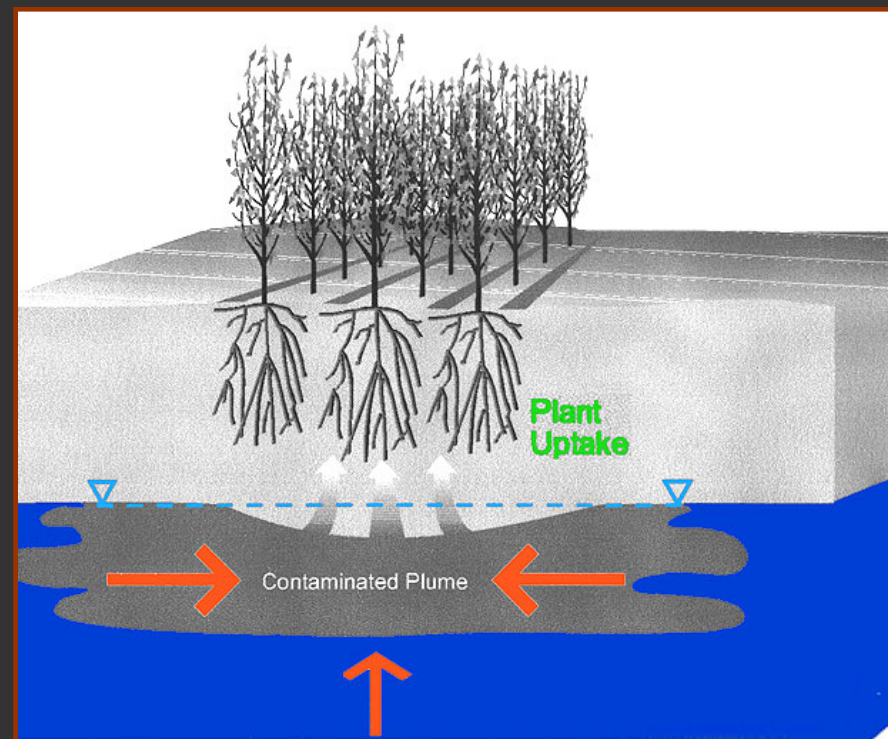
Phytoremediation Processes

2) Hydraulic Uptake & Control

Phreatophytes (hybrid poplar and willow) can transpire 20 to 500 gallons of water per tree per day

- Offers long term ground water benefit, plume control
- ~ passive process for BTEX

Nature's "Pump and Treat"



CH2M Hill, 1999

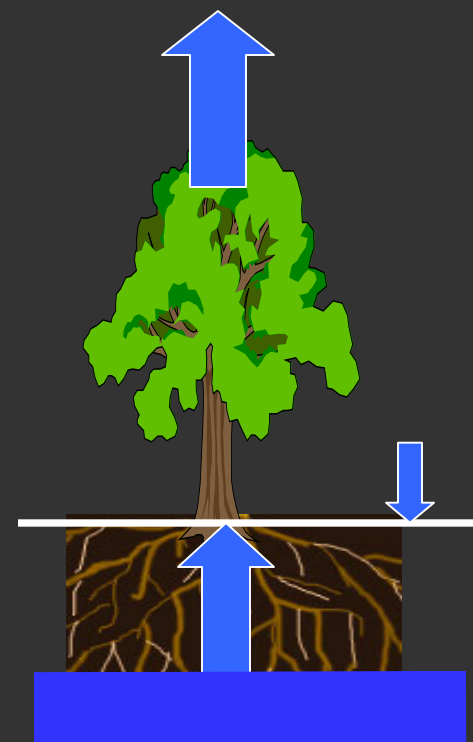
Phytoremediation Processes

2) Hydraulic Uptake & Control

Phreatophytes (hybrid poplar and willow) can transpire 20 to 500 gallons of water per tree per day.

- Offers long term ground water benefit
- Prevents dissolved plume migration

**ET >> Great Lakes Rainfall.....
.....by 6- to 50-fold**



Federal Phytoremediation Research Support

Riparian
Phytoremediation

Nov-2001

\$6 Million to
Purdue from
EPA



Dr. Kathy Banks, Purdue University

Christie Whitman, EPA

Example Project Design

Step 1) Basic Site Assessment

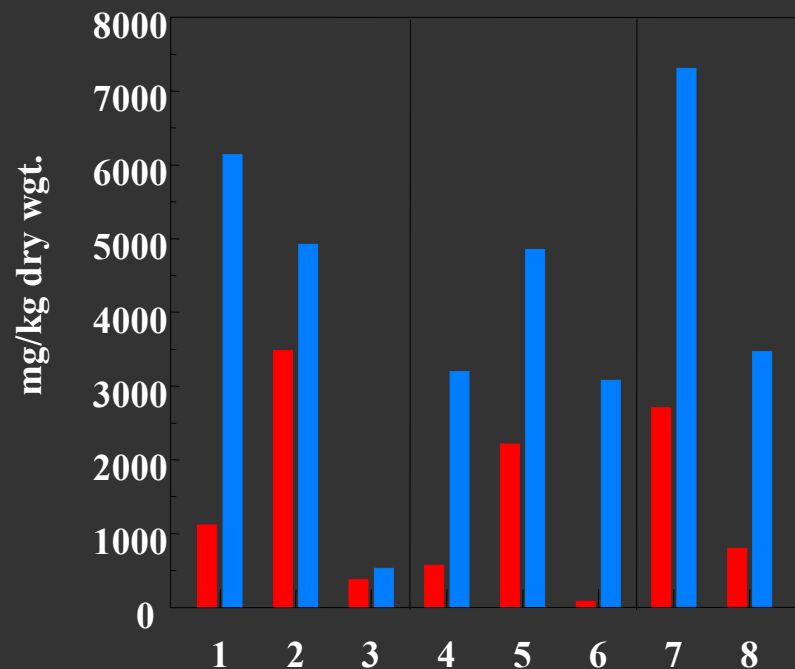
Soil and GW sampling, VOCs, PAHs, nutrients
salts, metals

Example Project Design

Step 1) Basic Site Assessment

Soil and GW sampling, VOCs, PAHs, nutrients
salts, metals

■ Total alkanes ■ Total PAHs



Example Project Design

Step 2) Survey of Existing Plant Community (if any)

Do they *Phytoremediate*, or merely tolerate?



Example Project Design

Step 2) Survey of Existing Plant Community (if any)

Do they *Phytoremediate*, or merely tolerate?



Arrowhead
(*Sagittaria latifolia*)

Example Project Design

Step 2) Survey of Existing Plant Community (if any)

Do they *Phytoremediate*, or merely tolerate?



Example Project Design

Step 3) Literature:

a) Known Effective Phytoremediation Plants

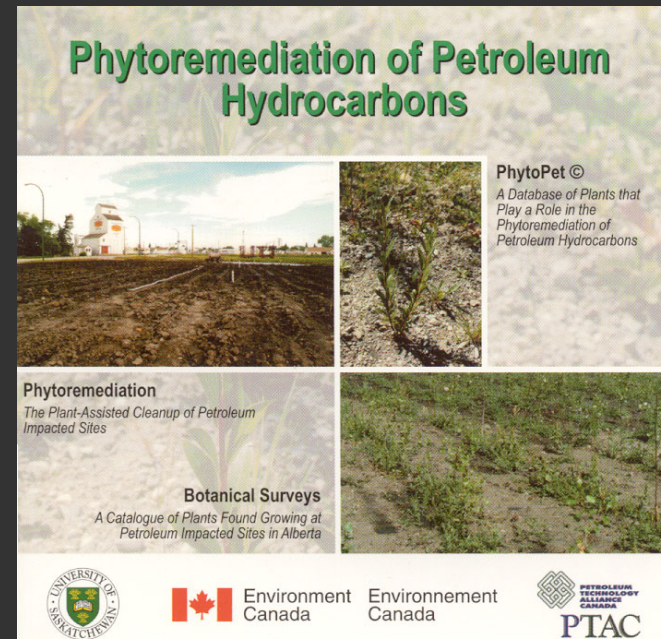
Can we add any ‘new’ plants to the list?

b) “Ballpark” Phytotoxicity Limits

PhytoPet®

Environment Canada

October, 2000



Common Plant Choices



Poplar trees (*Populus deltoides x nigra*)
 big bluestem (*Andropogon gerardi*)
 side oats grama (*Bouteloua curtipendula*)
 blue grama (*Bouteloua gracilis*)
 carrot (*Daucus carota*)
 Canada wild-rye (*Elymus canadensis*)
 soybean (*Glycine max*)
 duckweed (*Lemna gibba*)
 alfalfa (*Medicago sativa* L.)
 bush bean (*Phaseolus vulgaris* L.)
 winter rye (*Secale cereale* L.)
 little bluestem (*Schizachyrium scoparius*)
 sorghum (*Sorghum bicolor*)

western wheatgrass (*Agropyron smithii*)
 annual ryegrass (*Lolium multiflorum*)
 perennial ryegrass (*Lolium perenne* L.)
 Verde kleingrass (*Panicum coloratum*)
 switchgrass (*Panicum virgatum*)
 common buffalograss (*Buchloe dactyloides*)
 prairie buffalograss (*Buchloe dactyloides*)
 bell rhodesgrass (*Chloris gayana*)
 Bermuda grass (*Cynodon dactylon* L.)
 tall fescue (*Festuca arundinacea* Schreb.)
 Arctared red fescue (*Festuca rubra*)
 sudangrass (*Sorghum vulgare* L.)
 Meyer zoysiagrass (*Zoysia japonica*)



Example Project Design

Step 4) Treatability / Feasibility Studies

- a) Confirm remediate vs. tolerate
- b) Establish Efficacy for Client / Regulators



In-field

and/or

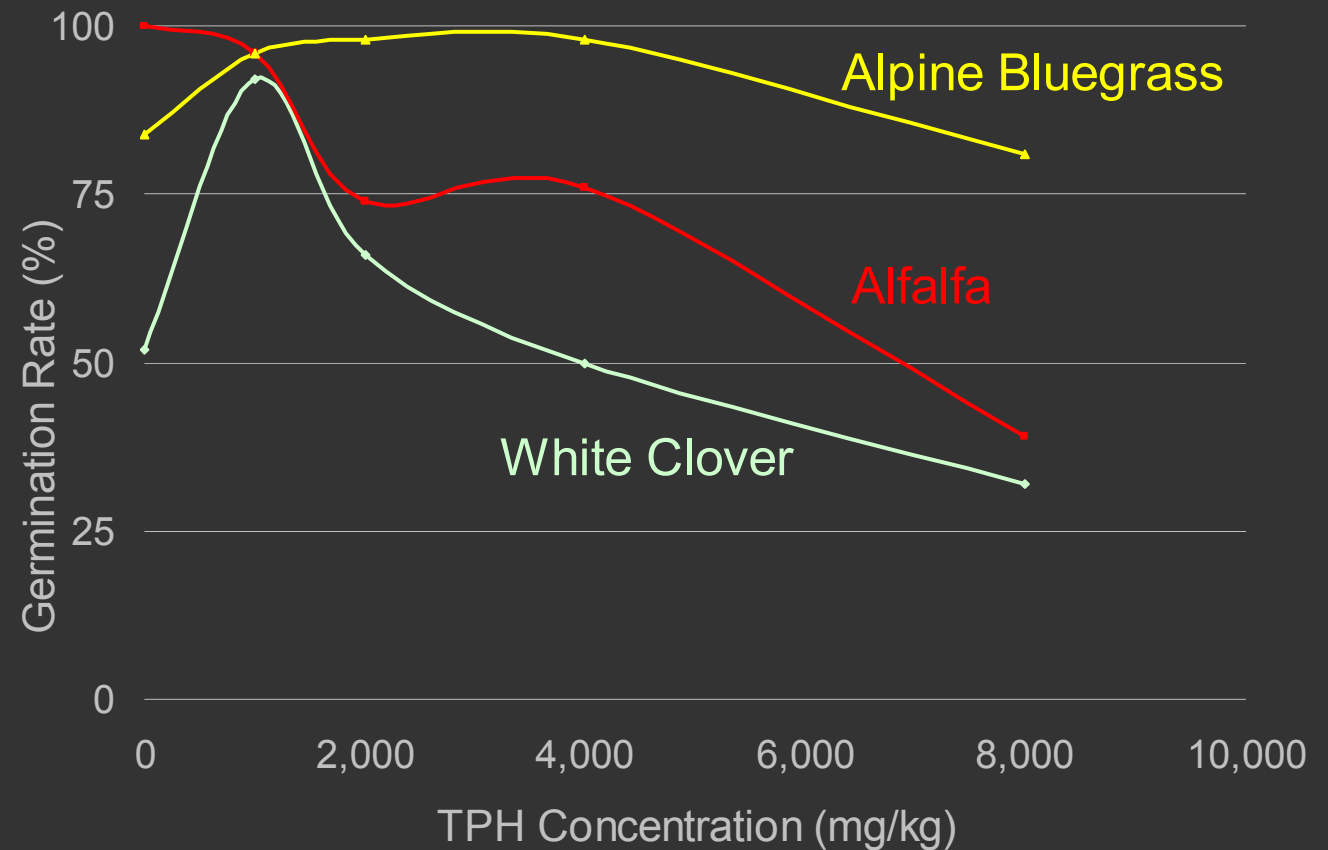
Greenhouse

Germination Rates

Riparian
Phytoremediation

are not always the same as

Survival Rates



Survival Rates

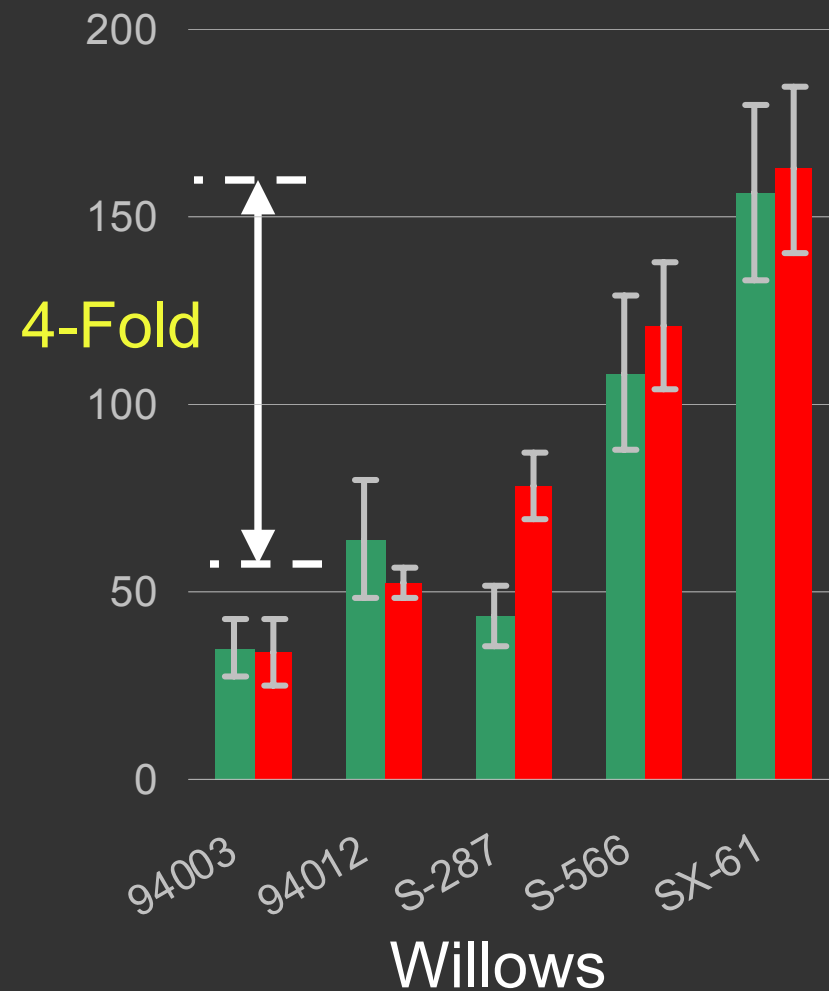
Riparian
Phytoremediation

are not always the same as

Remediation Rates

*Year-End
Biomass*

- Leachate-watered
- Control-watered



Example Project Design

**Treatability / Feasibility Studies
Are Not Optional !!**

Sand Creek Consultants, Inc.



Example Project Design

Riparian
Phytoremediation

Step 5) Final Design

Sheen on
surface water



PAHs in Soil

PAH & BTEX in GW

GW FLOW



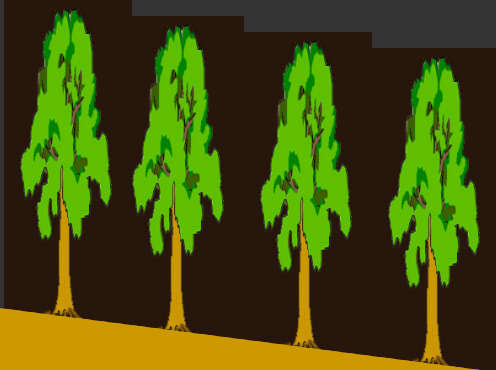
Example Project Design

Step 5) Final Design

Hybrid Poplar (*populus, spp.*)

Willow (*salix, spp.*)

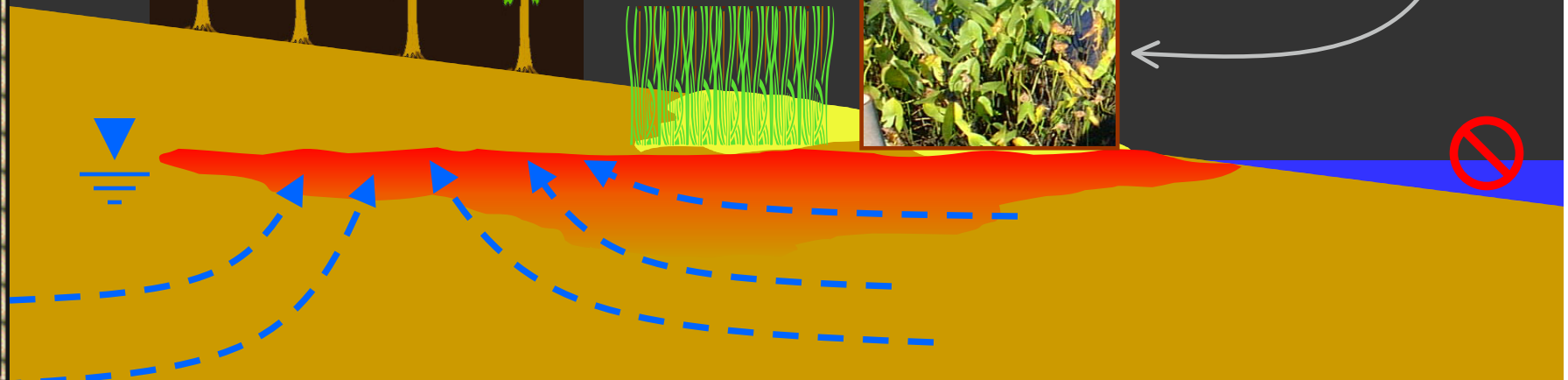
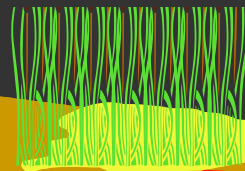
Plume control and
stabilization



Tall Fescue (*Festuca arundinacea*)

Arrowhead (*Sagittaria latifolia*)

Rhizosphere Degradation



Managing & Maintaining Phytoremediation Systems

Riparian
Phytoremediation

- Maintain Healthy Plants
 - Proper Nutrients
 - Weed/ Pest Control
 - Irrigation
 - Monitor Contaminant Levels



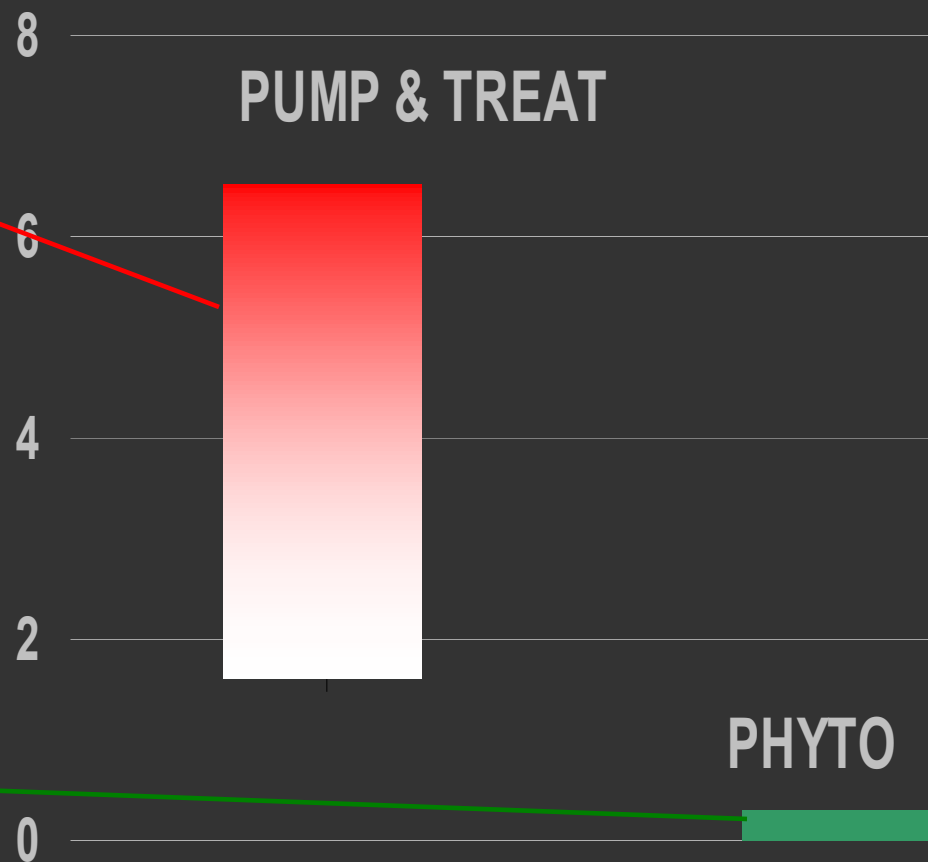
GROUND WATER:

Riparian
Phytoremediation

REMEDIATION COSTS



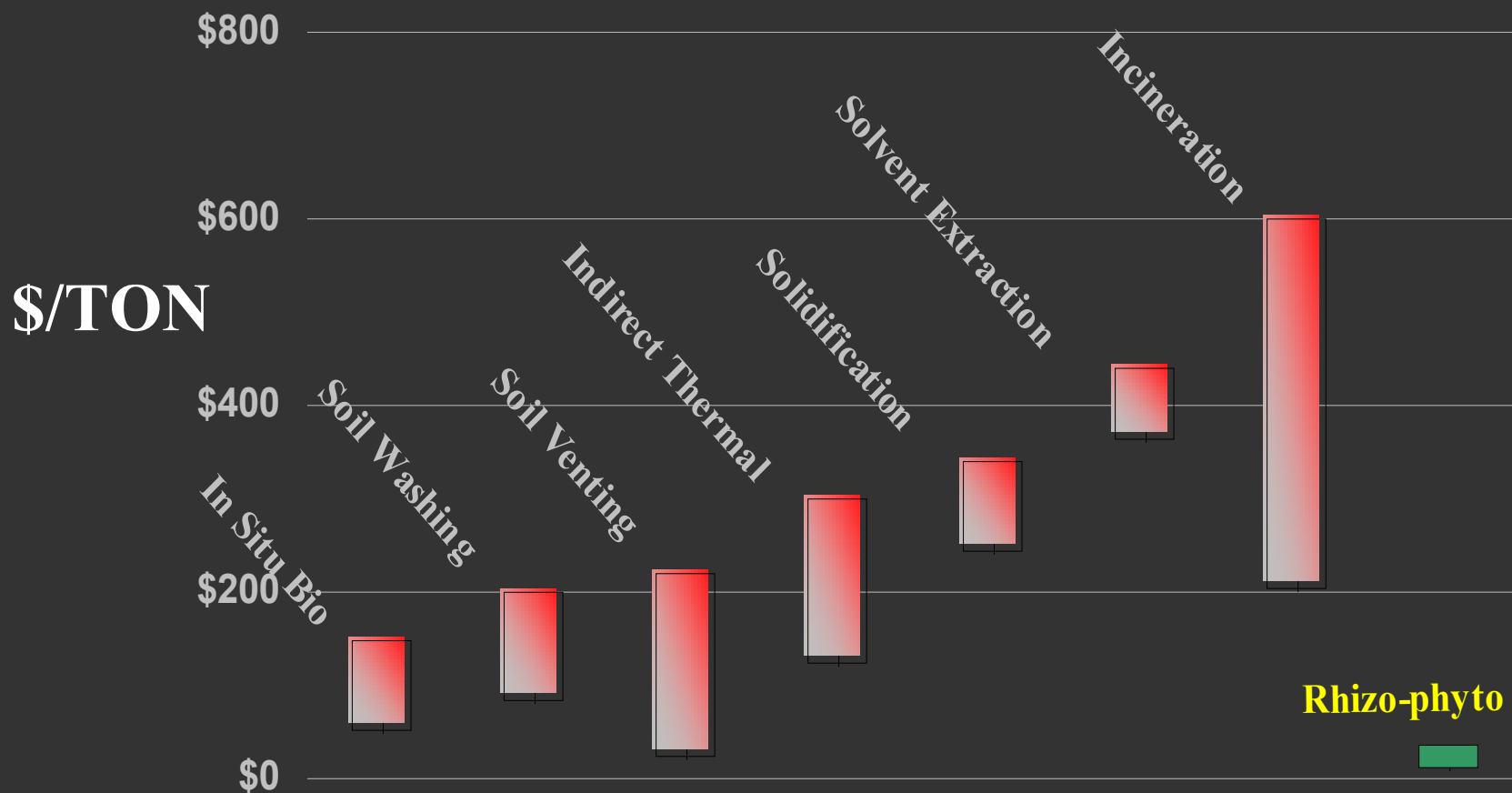
Annual O&M
\$ per 10,000 Gallons



- 6 acres , Great Lakes area

SOIL: REMEDIATION COSTS

Riparian
Phytoremediation



REGULATORY ISSUES NATIONAL CONTINGENCY PLAN

*Phytoremediation does not require any
'special exemptions' from existing rules*

LEADERS

Research, Guidance, and Case Histories

Experience: BP Amoco
CH2M Hill
U.S. EPA / Env. Canada /
Purdue Univ. / U of Wash
Many others.....



Closing



- ◆ Phytotechnologies are well-established as effective
- ◆ Plant selection & treatability studies are key
- ◆ No longer considered ‘innovative’ for petroleum
- ◆ Riparian areas are ideal for phytotechnologies