Phytoremediation of Petroleum Hydrocarbon Contaminated Marine Sediments with Seagrasses: Laboratory and Field Demonstration

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Site History:

- Produced Water Was Discharged into Canals For 50 Years
- Fourchon Facilities (LA) Ceased Discharges in 1995
- Canal Sediments Are Contaminated with O&G and PAHs

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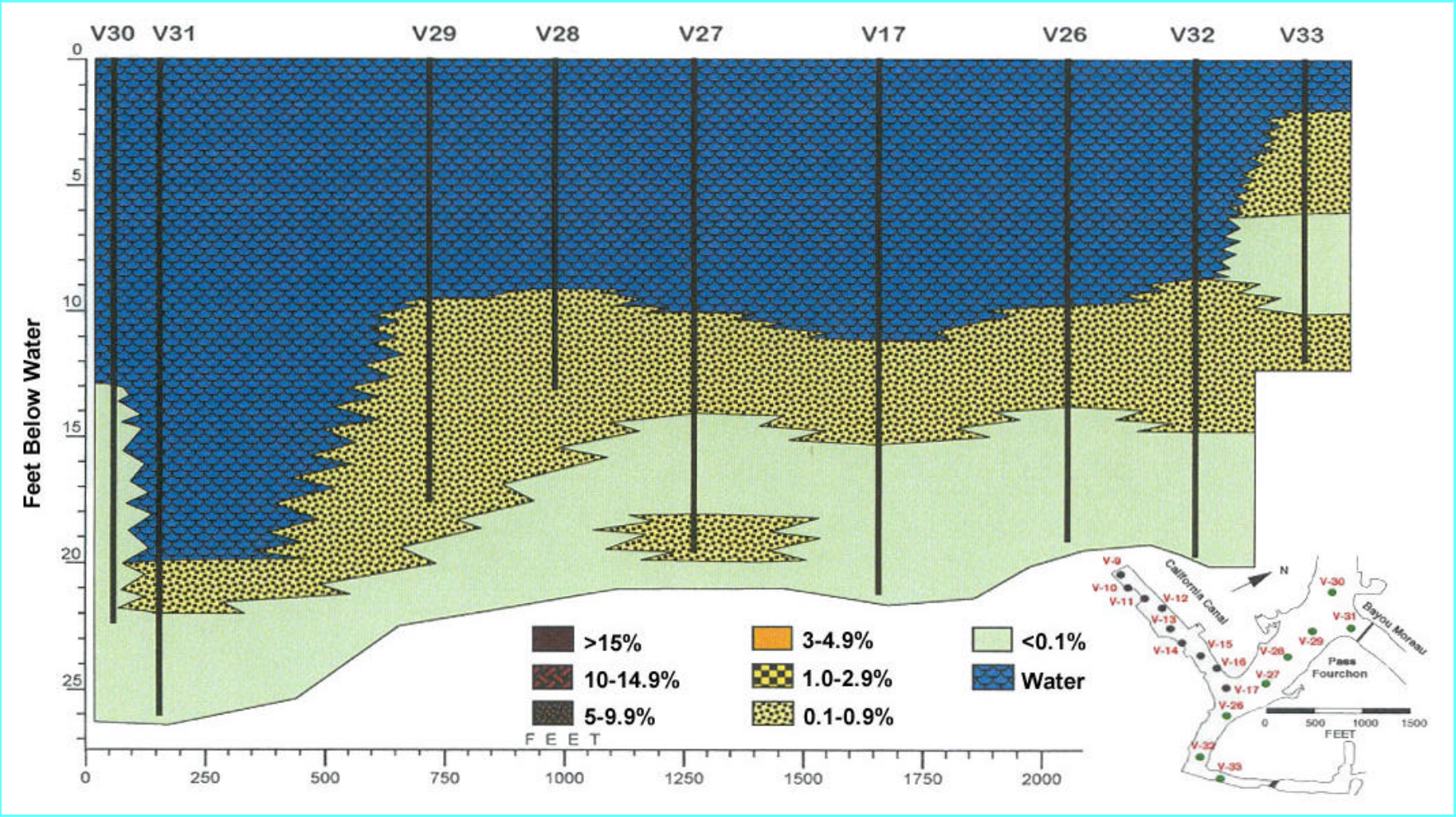
Oil&Grease in Pass Fourchon Sediments



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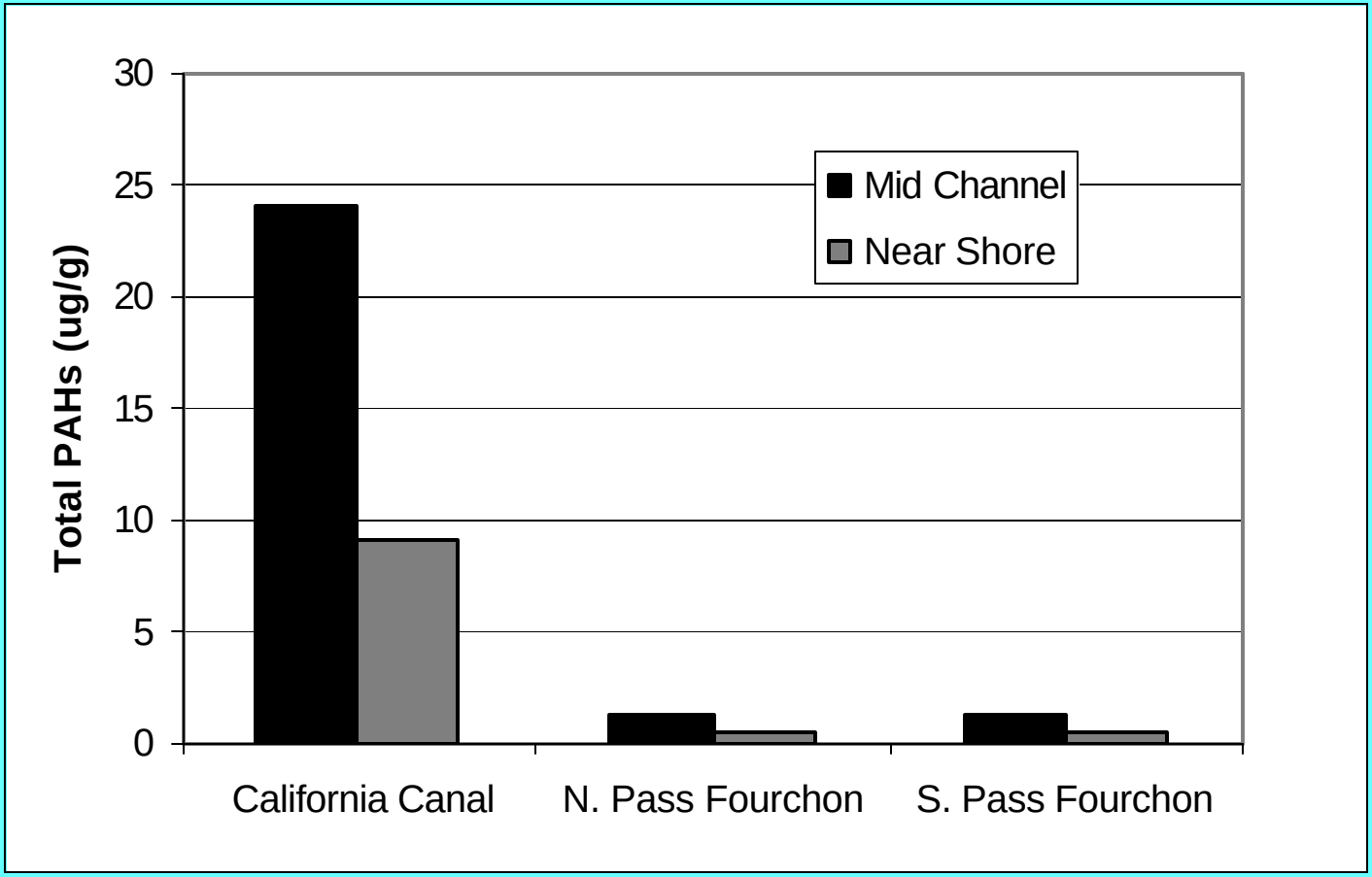
Concentrations of Total PAHs in Canal Sediments



Typical Total PAH Concentrations in Produced Water Contaminated Marine Sediments

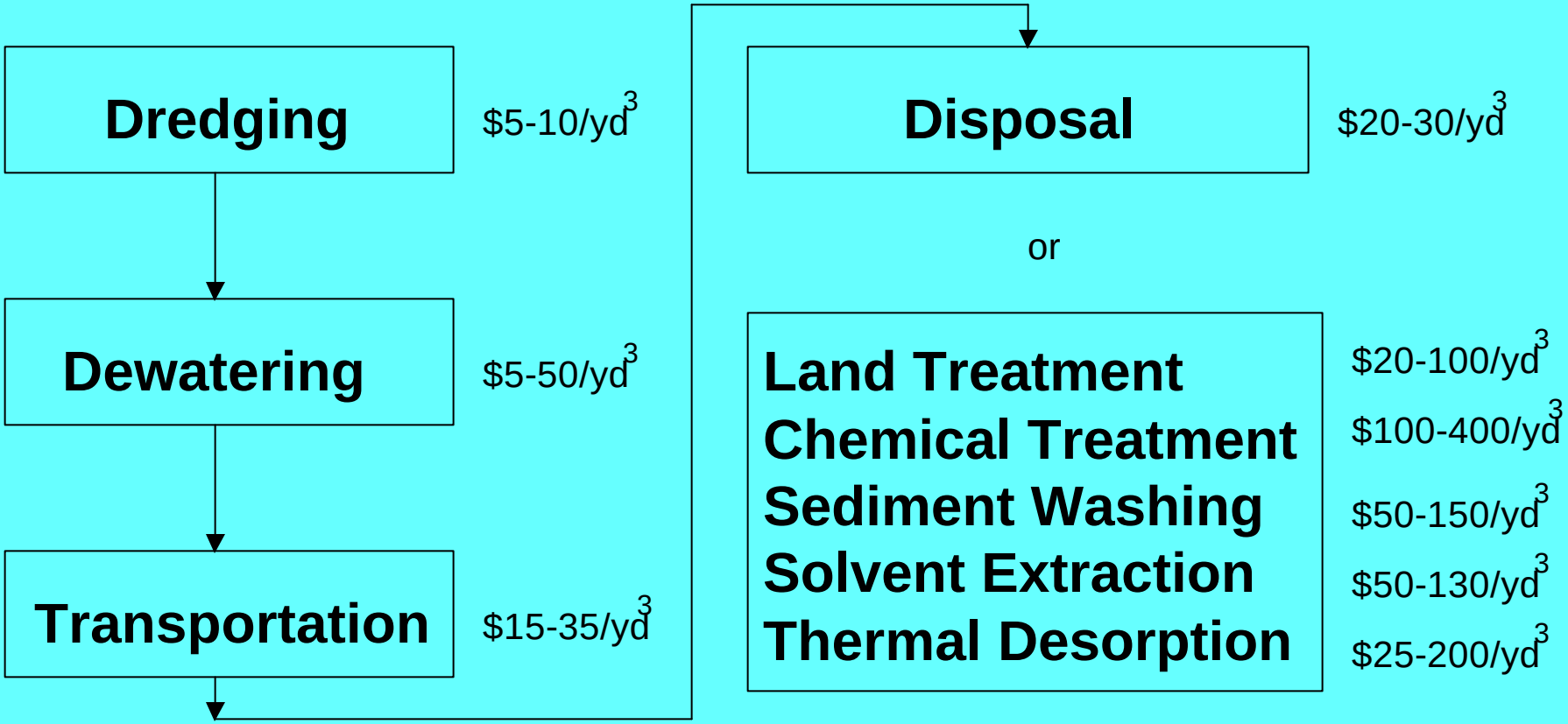
Table 17.
Concentrations of total PAHs in surficial sediments at 20 and 2000 m down-current from four offshore platforms in the northwestern Gulf of Mexico. Water depths, produced water discharge rates, and PAH concentrations in the produced waters also are given. From Dept. of Energy (1997a).

Platform	Water Depth (m)	Discharge Rate (L/d)	Produced Water PAH Concentration (µg/L)	PAH in 20-m Sediments (µg/g dry)	PAH in 2000-m Sediments (µg/g dry)
SMI236A	6	2,353,000	270	0.80	0.29
VR214A	39	1,351,000	130	1.40	0.22
SMI130B	66	3,600,000	600	0.87	0.15
HI595C	122	838,000	58	0.32	0.082

TABLE 2-1. TECHNOLOGY TYPES FOR SEDIMENT REMEDIATION

	In Place	Excavated
Containment	Capping	Beneficial use Capping/confined aquatic disposal Commercial landfills Confined disposal facility
Treatment	Bioremediation Chemical Immobilization	Chemical Biological Extraction Immobilization Physical separation Thermal

Ex-Situ Treatment Options and Costs



In-Situ Treatment Options and Costs

In-Situ Capping $40/yd^2

In-Situ Bioremediation $25-75/yd^2

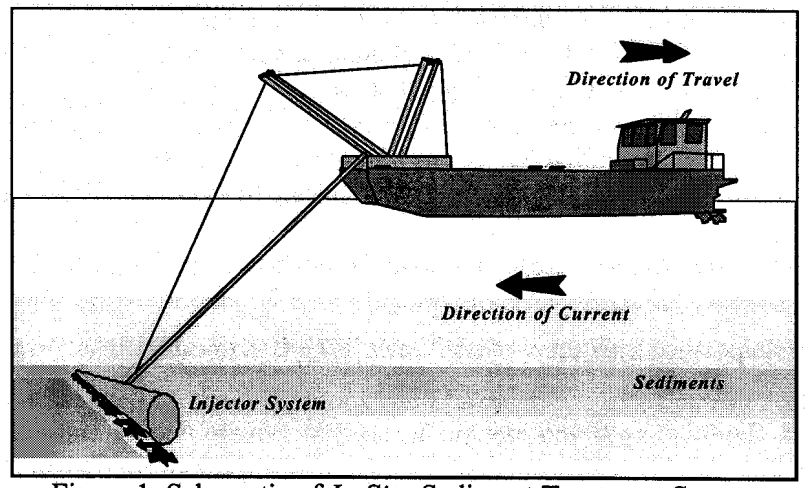


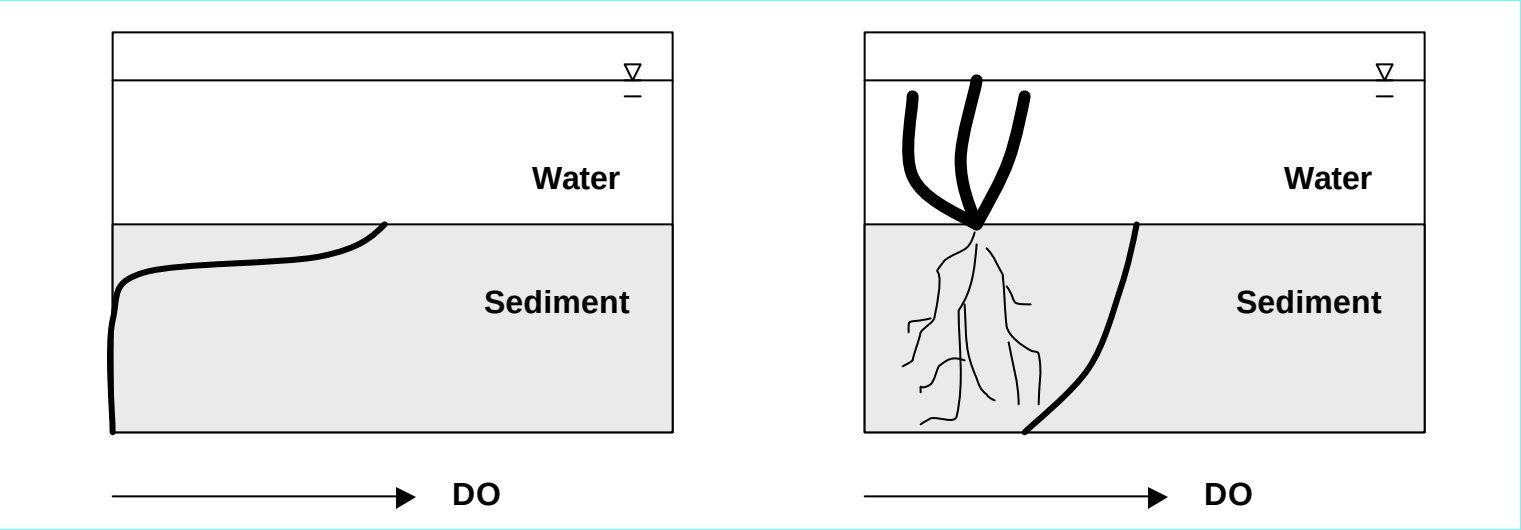
Figure 1: Schematic of *In-Situ* Sediment Treatment System

Limitations of Limnofix Technology:

- Nitrate Addition Does Not Stimulate Biodegradation of Most PAHs and TPH
- Nitrate Toxic to Sediment and Aquatic Eco-Systems

The Problem of Sediment Oxygenation

- Many Petroleum Hydrocarbons in Sediments Biodegrade Naturally as Long as Oxygen is Present
- Oxygen Diffusion in Sediment Pore Water is 10,000 Times Slower Than in Air
- Consequently, Many Sediments are only Oxygenated up to a Depth of a few Millimeters or Centimeters (< 1")
- Submerged Aquatic Plants Via Photosynthesis Generate Oxygen Which is Pumped into the Roots, Thereby Oxygenating Sediments



Redox Potentials as a Function of Sediment Depth in Danish Lake

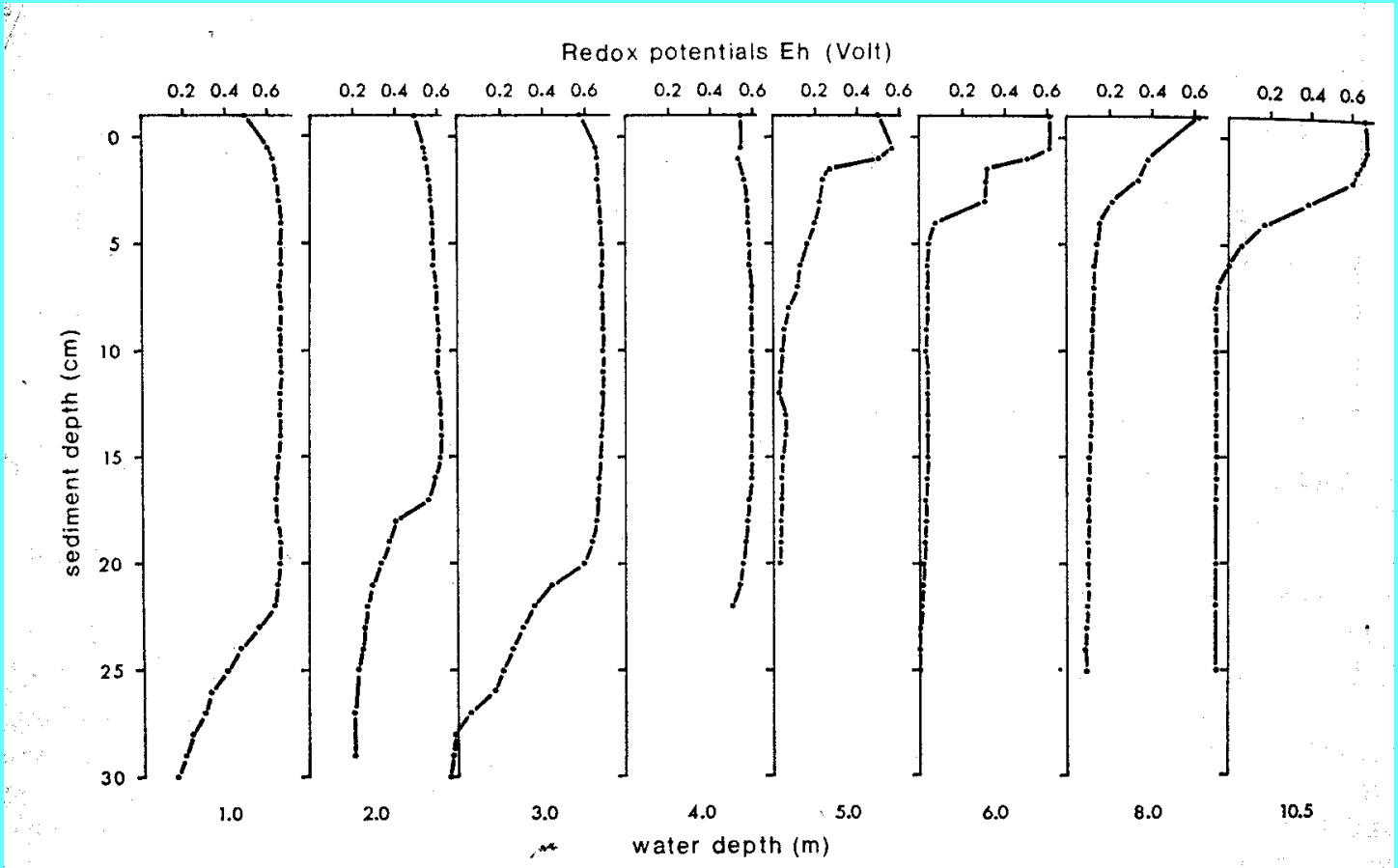
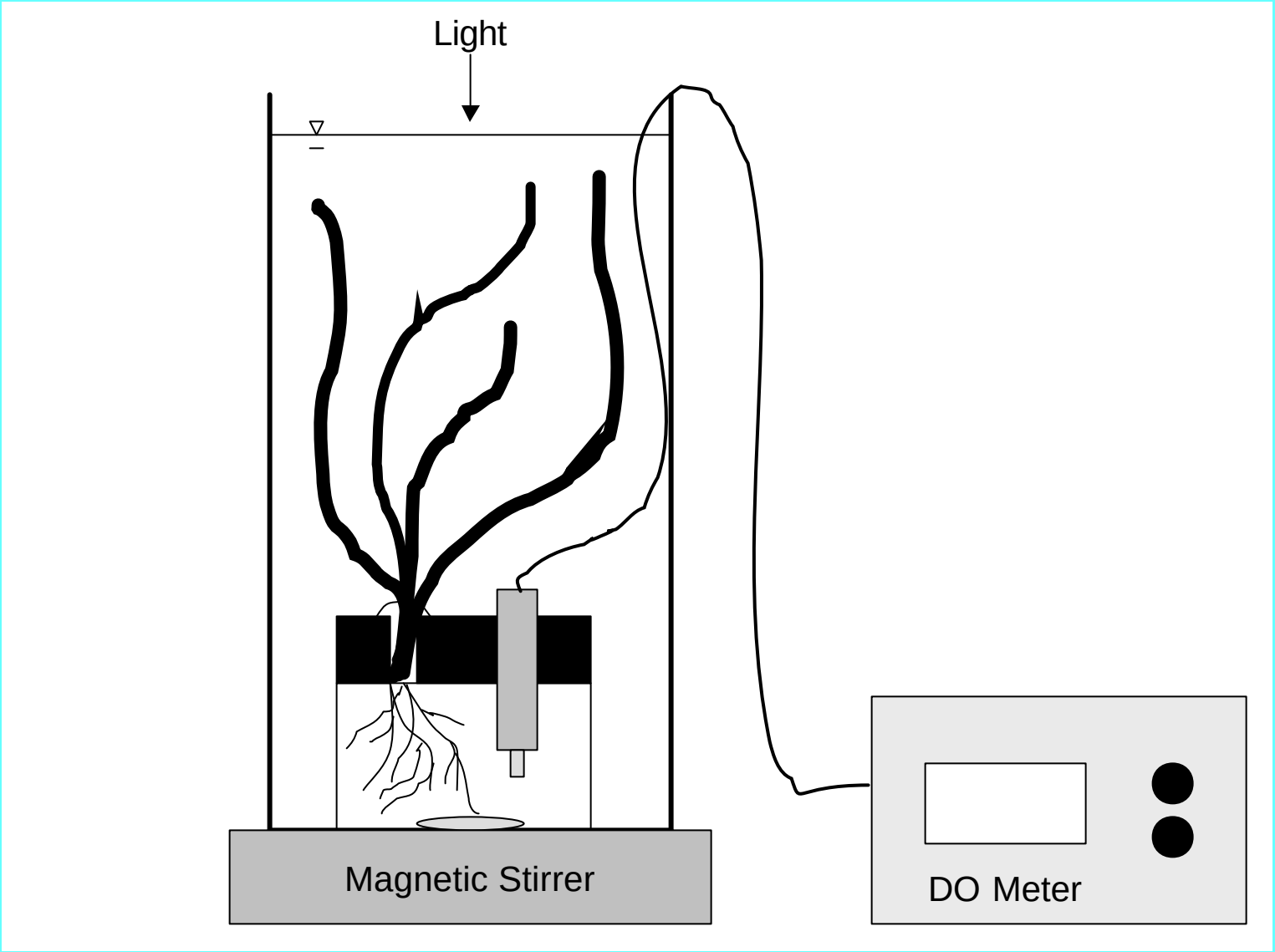
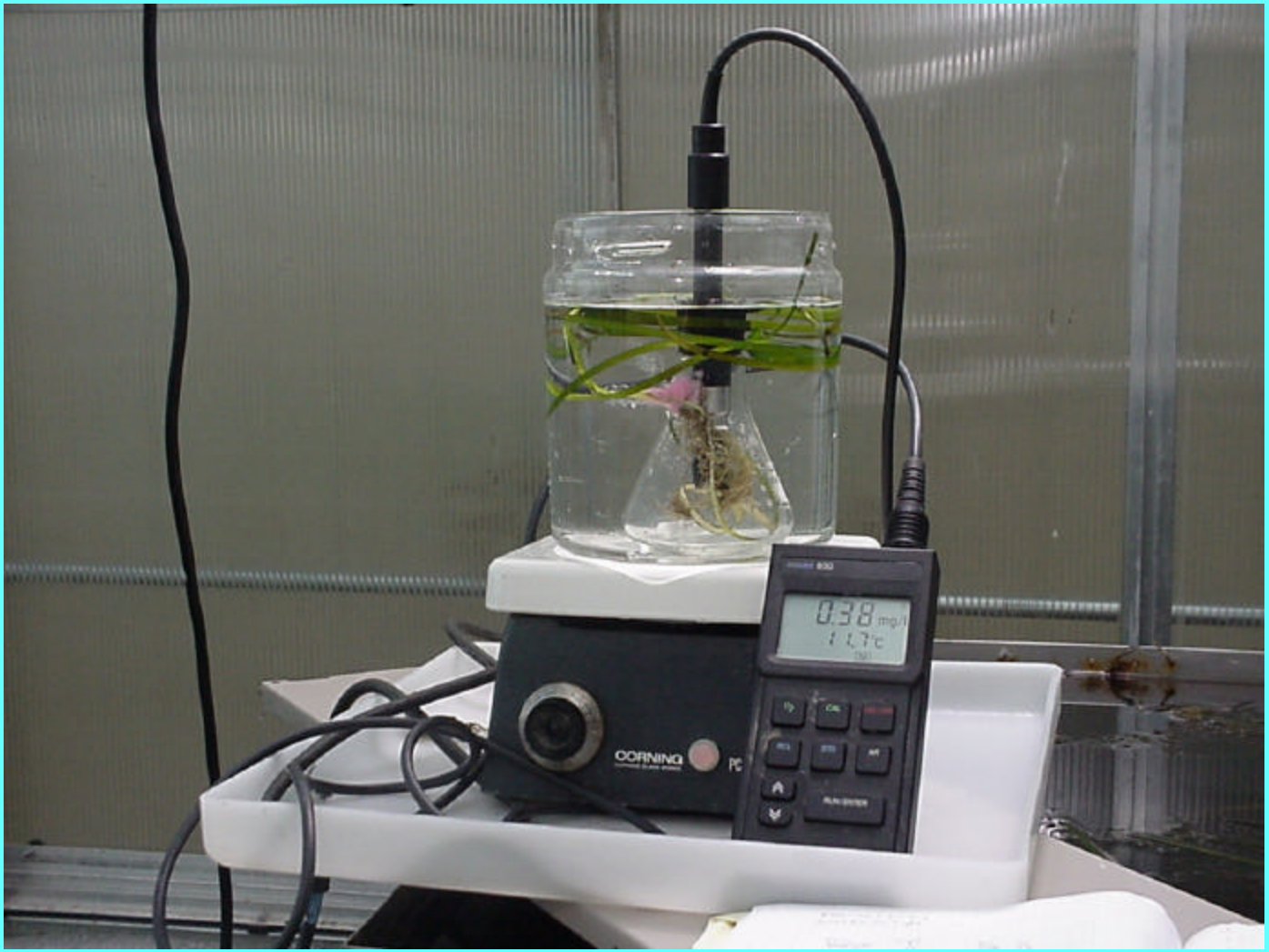
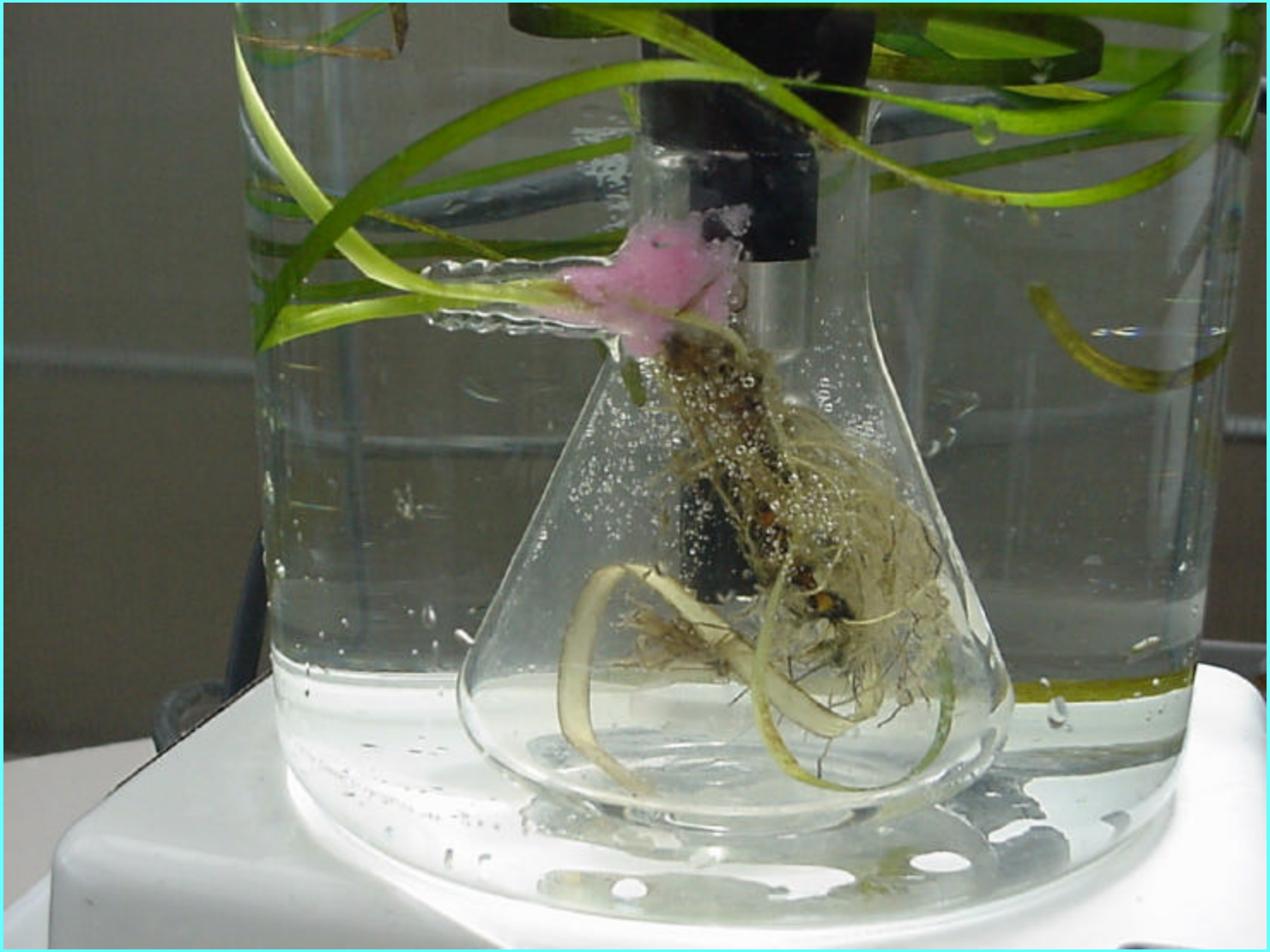


FIG. 2. Redox profiles in sediment from Grane Langsø 9 April 1972. Rooted vegetation disappears between 4 and 5 meters.

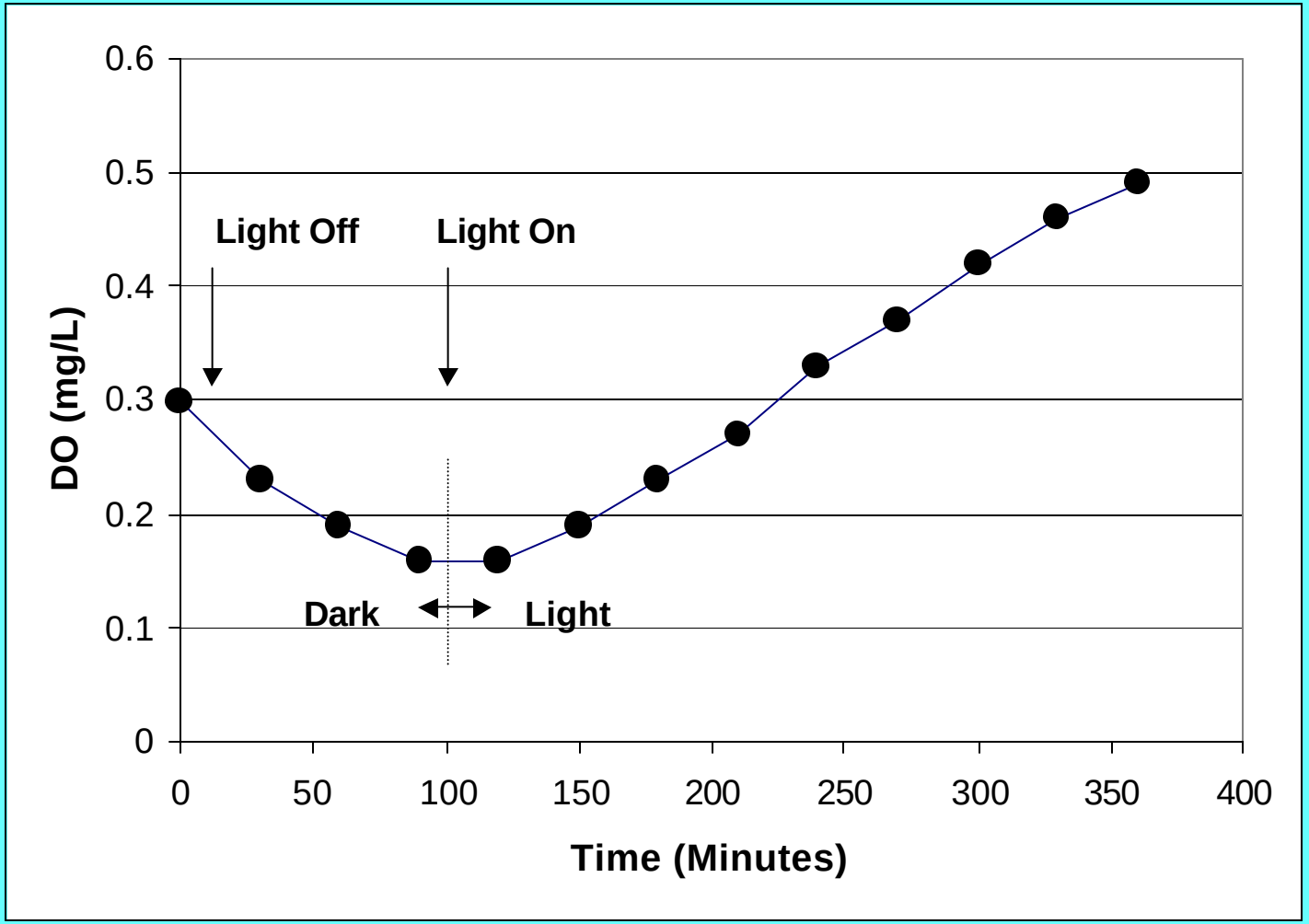
Measurement of Root Zone Oxygenation



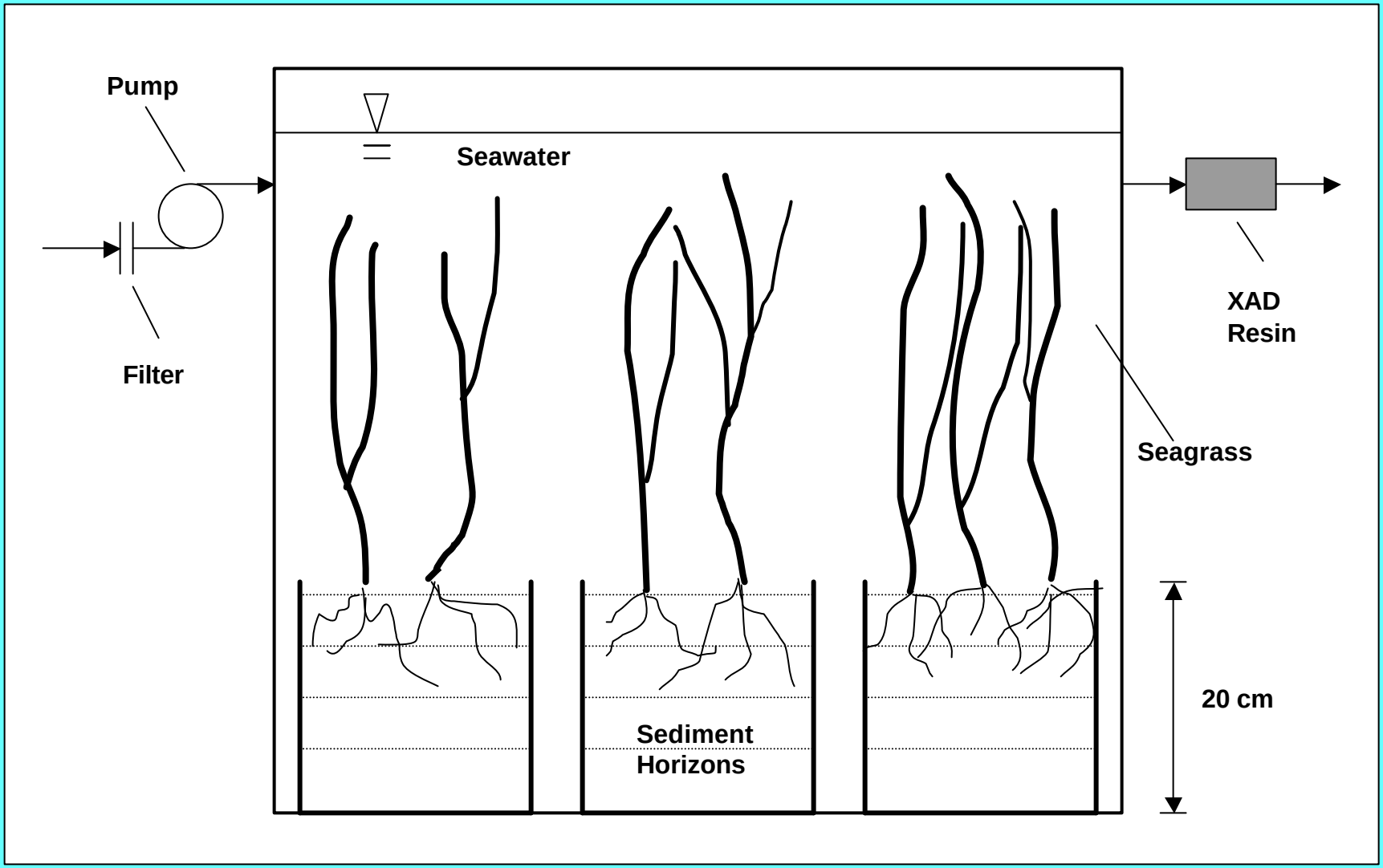

0.38 mg/l
11.7°c
CORNING



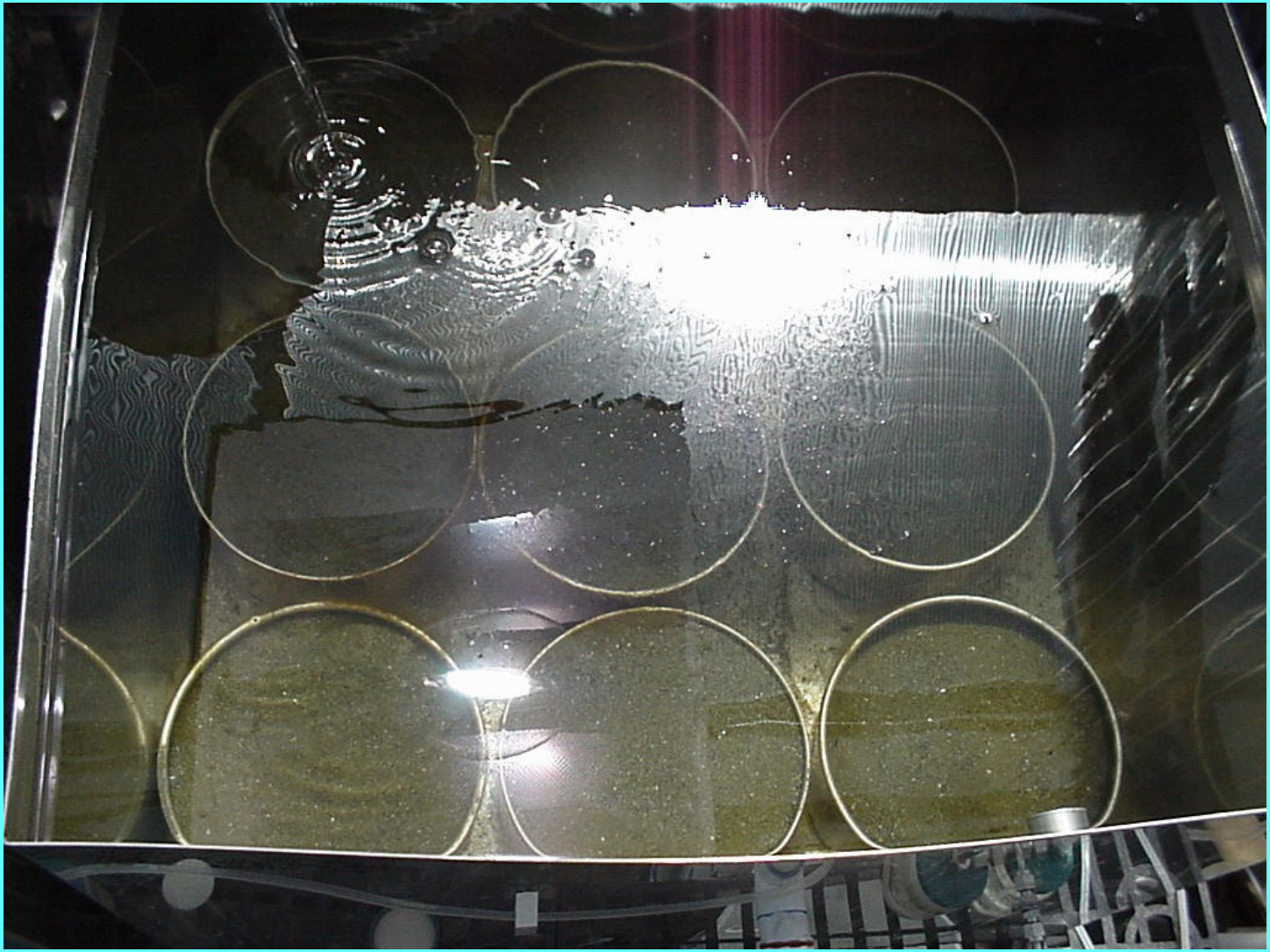
Change of DO in Root Zone Water in Response to Light



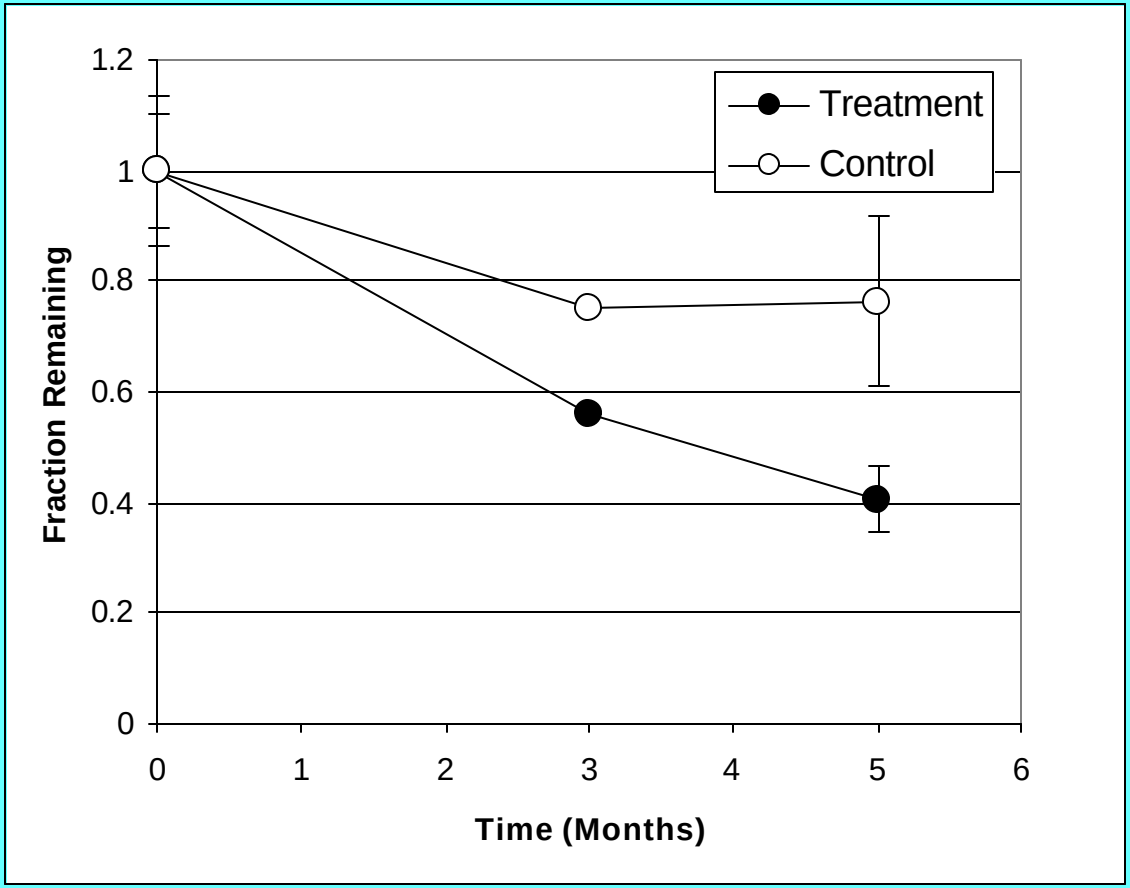
Experimental Aquarium Setup



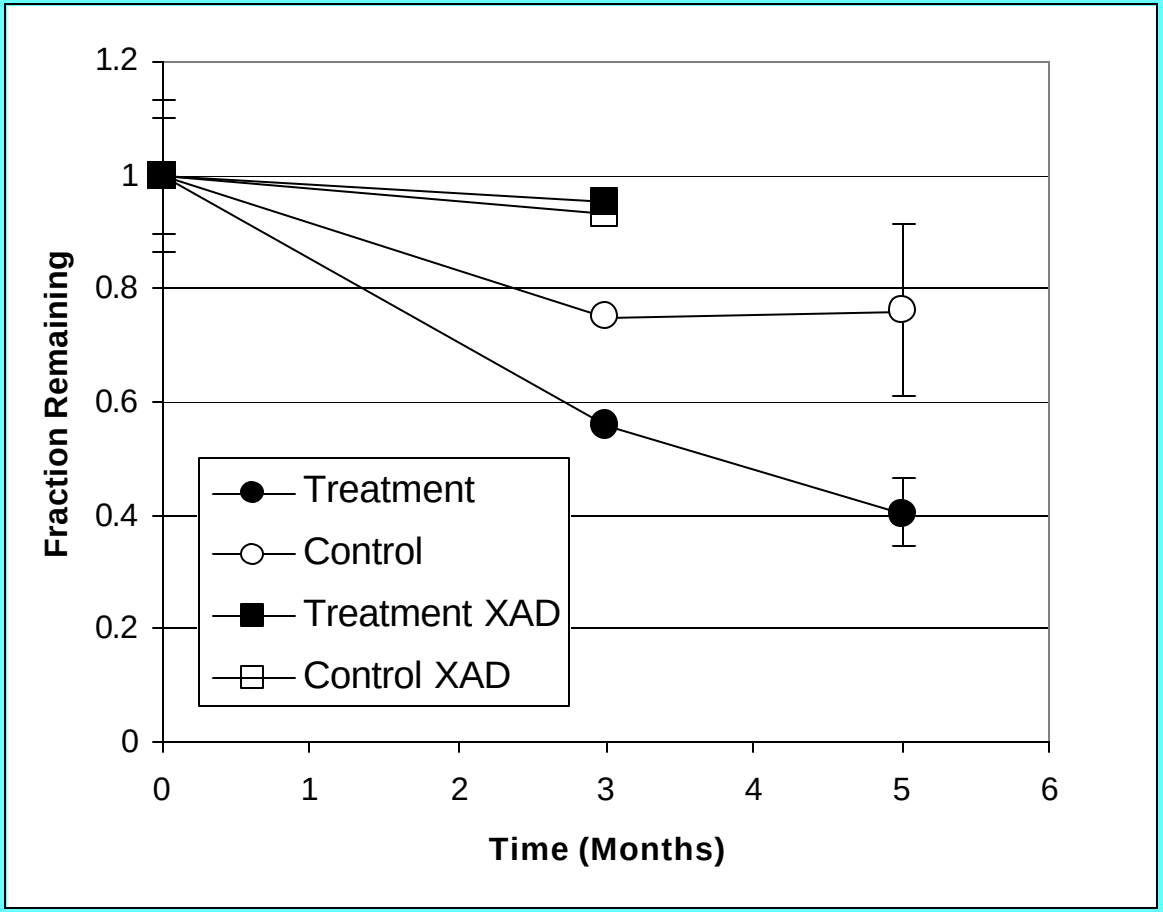

SUN SYSTEM



Total PAHs as a Function of Time



Estimate of PAH Desorption Losses



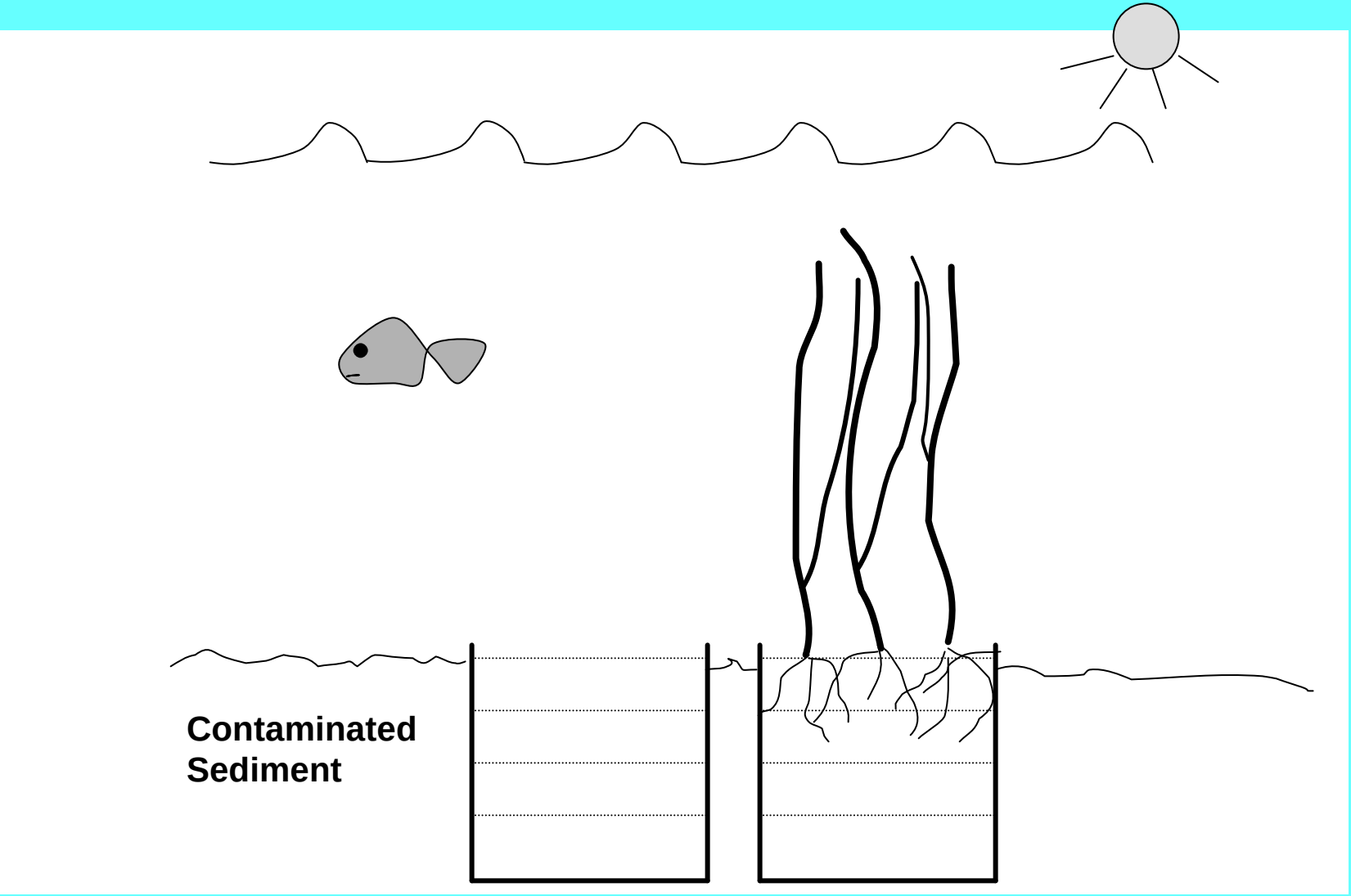
Research Questions

- Is Biodegradation the Primary PAH Loss Mechanism?
- Are PAHs Taken Up by Plant Roots and Shoots?
- What is the Rate of PAH Desorption and Dissolution?
- How Deep do the Plant Roots Grow?
- What is the PAH Removal as a Function of Depth?
- Do Plant Roots Stimulate Bacterial Activity?
- Are Other Submerged Aquatic Plant Species Able to Enhance PAH Biodegradation?
- Does Eelgrass Phytoremediation Work in the Field?
- Does the Presence of Plants Reduce Eco-Toxicity and Speed up Ecosystem Recovery?

Proposed Laboratory Experiments

- Carry Out Seagrass Phytoremediation Experiments Using Produced Water Contaminated Sediments That Are Placed in Treatment and Control Aquaria
- Measure PAHs and TPH as a Function of Time (2 y) and Sediment Depth (4 Horizons)
- Measure PAHs in Roots and Shoots
- Determine PAH Losses Via Desorption (XAD Trap)
- Determine Maximum Depth of Root Penetration
- Compare Bacterial Activity in Treatment and Controls

Proposed Field Demonstration



Field Demonstration Tasks

- Select Field Site with Produced Water Contamination
- Bury Buckets Containing Homogenized Contaminated Sediment into Field Sediments (in-situ)
- Treatment Buckets are Planted (Eelgrass, Turtlegrass)
- Control Buckets Remain Unplanted
- Leave Buckets in Field for up to 2 Years
- Periodically Sample Treatment and Control Buckets and Measure PAHs/TPH as a Function of Depth
- Measure PAHs in Roots and Shoots
- Determine Reduction in Eco-Toxicity Using Standard EPA Sediment Quality Assessment Procedures

Budget and Schedule

Tasks	FY03	FY04	FY05
Laboratory Experiments			
▪Setup Aquaria and Sediments/Plants	$30K		
▪Measure PAHs/TPH (Time, Depths)	$85K	$30K	
▪Measure PAHs in Roots and Shoots	$10K	$15K	
▪Determine PAH Losses Via Desorption	$15K		
▪Measure Bacterial Densities	$5K	$5K	
In-Situ Phytoremediation Demonstration			
▪Bury Treatment and Control Buckets		$25K	
▪Measure PAHs/TPH (Time, Depths)		$30K	$95K
▪Measure PAHs in Roots and Shoots			$15K
▪Determine Reduction in EcoToxicity		$30K	$30K
Supplies (No New Equipment Needed)	$15K	$10K	$5K
Travel to Field Site		$15K	$15K
TOTAL ($480K)	$160K	$160K	$160K

Large-Scale Implementation

- Planting of Seagrasses with Divers
- Seeding of Sediments Using Sled
- Cost Estimate: $18 per yd^2

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Limitations of Proposed Technology

- **Limited by the Depth of Light Penetration**
  (Up to 90 ft in Clear Water, But Generally 20-30 ft)
- **High Contaminant Levels May be Toxic to Plants**
  (Total PAHs = 30 ug/g in our Study, 25 times Higher than Reported in Gulf of Mexico Sediments)
- **Addresses Only Top Sediment Layer**
  (Possibly up to 1 ft – This is Biologically Active Zone)

Benefits to the Oil Industry

- **Simple and Easily Implemented Technology**
- **Applicable to Wide Range of Sediments**
  (Oceans, Bays, Lakes and Rivers)
- **Suitable in Wide Range of Climates/Geographies**
  (12 Genera of Sea Grasses, from Artic to Tropics)
- **Promotes Natural Attenuation and Reduces Sediment Toxicity and Ecosystem Risks**
- **Extremely Cost Effective Compared to Other Options**