Knowledge… Commitment… Integrity… at Your Service

Back to previous page

Constructed Wetlands for the Remediation of Contaminated Waters

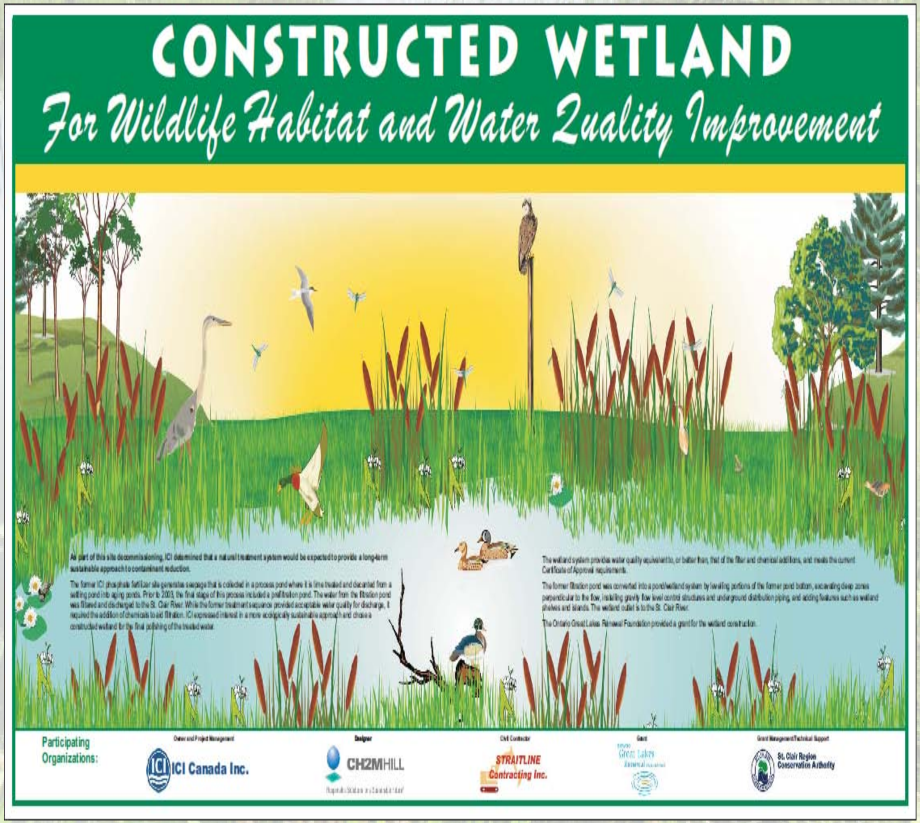
Chad Brassard, CH2M HILL
Environmental Scientist – Calgary, AB

Watertech
April 2008

CH2MHILL

Presentation Outline

- Why Treatment Wetlands?
- Treatment Processes
- Types of Wetlands
- Costs
- Case Study Examples



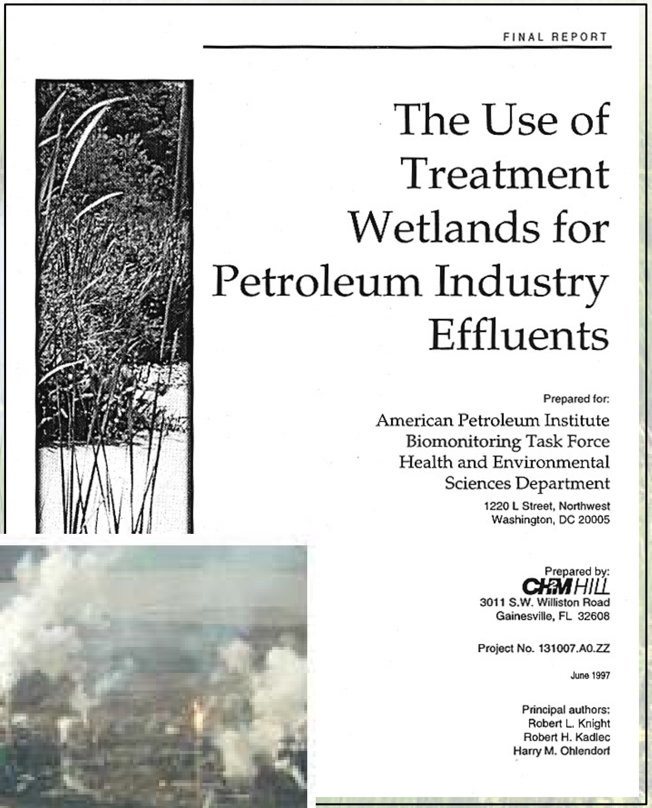
CH2MHILL

Treatment wetlands?

- Why wetlands?
  - Sustainable
  - Functional
  - Cost effective compared to alternatives
  - Aesthetic/recreational value
- Wetland questions?
  - Can they treat contaminants of concern?
  - Do they work in cold climates?
  - Can wetlands meet the needs of the site?

Wetlands Treat Industrial Wastewaters

- Petroleum
  - refineries, pumping stations, storage facilities
  - groundwater impacts
- Landfill Leachates
- Oil Sands Tailings
- Pulp & Paper Wastewaters
- Acid Mine Drainage
- Site Domestic Wastewater
- Site Stormwater


FINAL REPORT

The Use of Treatment Wetlands for Petroleum Industry Effluents

Prepared for:
American Petroleum Institute
Biomonitoring Task Force
Health and Environmental Sciences Department
1220 L Street, Northwest
Washington, DC 20005

Prepared by:
CH2M HILL
3011 S.W. Williston Road
Gainesville, FL 32608

Project No. 131007.A0.ZZ

June 1997

Principal authors:
Robert L. Knight
Robert H. Kadlec
Harry M. Ohlendorf

CH2MHILL

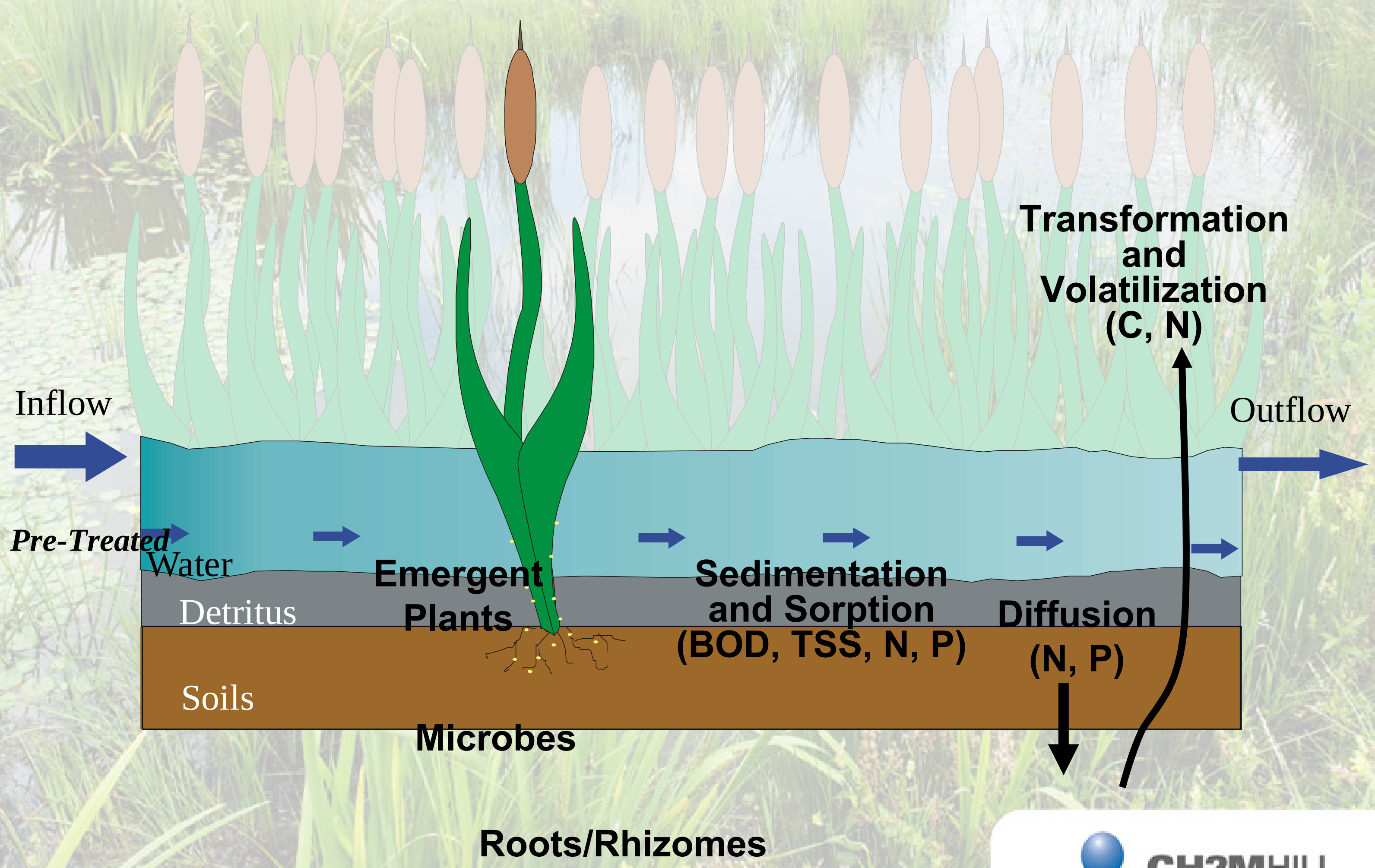
Wetlands for Remediation

- Petroleum hydrocarbons
- PAHs
- VOCs
- Heavy metals
- PCBs
- Naphthenic acids
- Nitro bodies (TNT, DNT)
- Acid mine drainage
- Ethylene glycol
- TSS, N species, P, SO_4, BOD_5, COD

Photo David Dodge, Pembina Institute

CH2MHILL

Wetland Processes



CH2MHILL

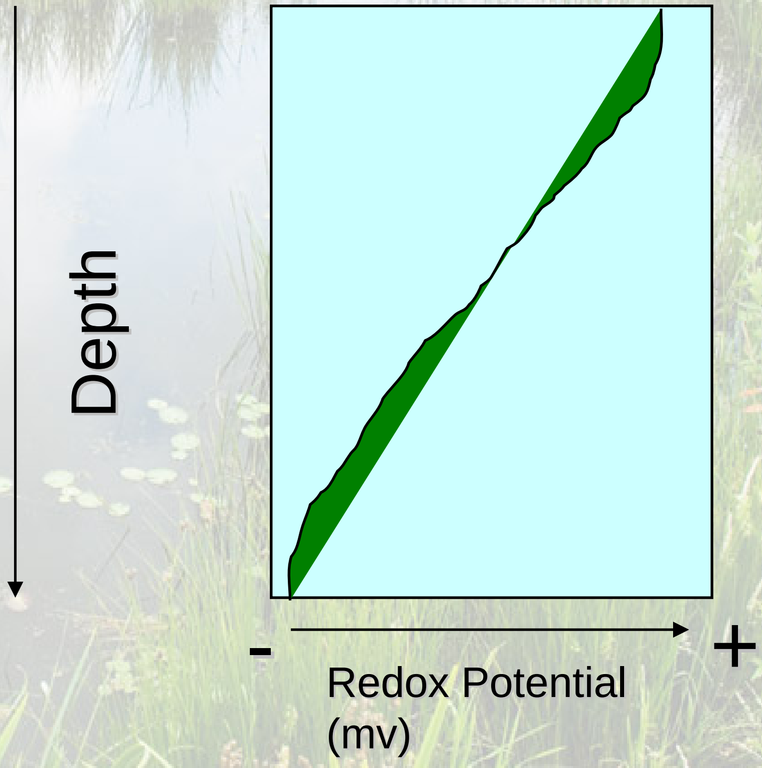
Wetlands for Remediation

- Pretreatment
- Retention time for degradation function of complexity
- First-order models generally apply for key constituents
- Microbial Degradation Pathways
  - Hydrolysis
  - De-alkalization
  - Ring cleavage (aromatics)
  - Removal of halo, nitro, acid, thio groups
- Byproducts
  - Oxidation = CO_2+H_2O
  - Reduction = CH_4 & H_2S

CH2MHILL

Redox Potential Manipulation

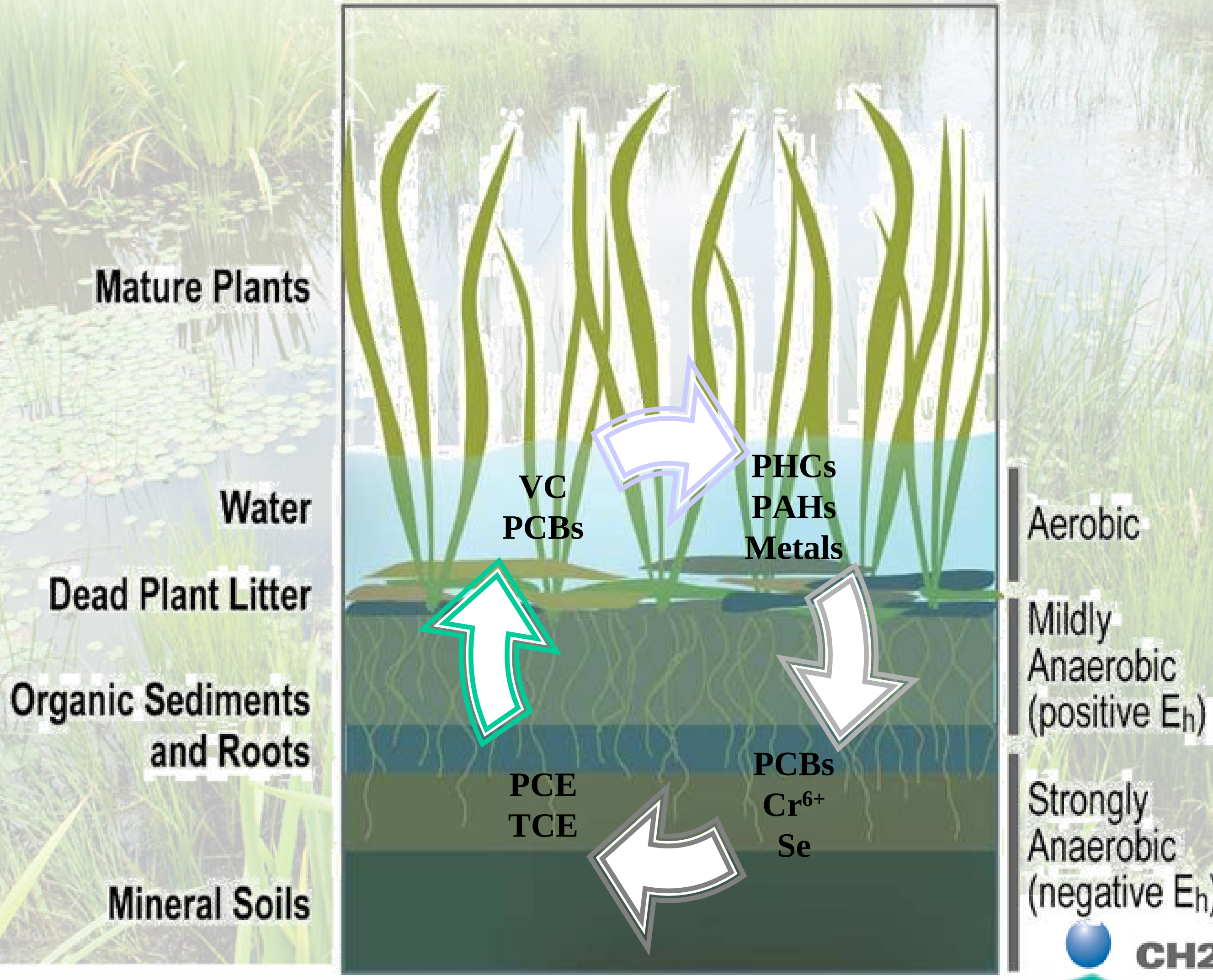
- Aerobic (O_2)
- Nitrate Reduction (denitrification)
- Mn Reduction
- Fe Reduction
- SO_4 Reduction
- Methanogenesis



Adapted from Craft, 2001

Range in redox – ideal for chemical transformations!

Surface Flow Wetland Degradation Profile



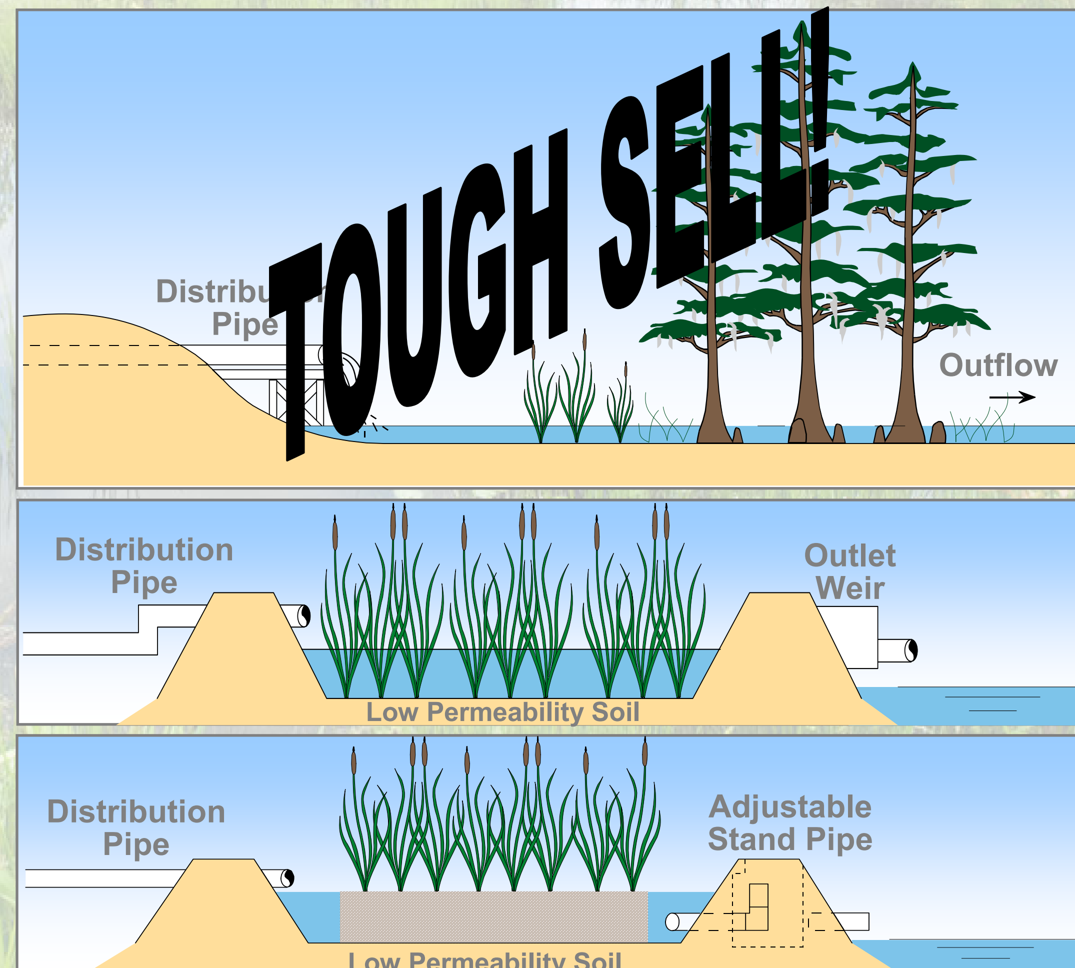
CH2MHILL

Treatment Wetlands for Recalcitrant Compounds

Natural Wetlands

Surface Flow (SF) Constructed Wetland

Subsurface Flow (SSF) Constructed Wetland



CH2MHILL

Remediation of "Waters"

- Surface Water
  - Holding ponds, lakes, water courses, stormwater
- Process Effluents
  - Industrial, municipal, residential discharges
- Groundwater
  - Unique due to method of groundwater recovery
  - Requires hydraulic isolation from "clean" surface water and/or groundwater
  - Wetland design key for reduction of water collection/transport costs
  - Some application of wetlands installed directly into groundwater for interception and treatment of impacts

CH2MHILL

Addressing Multiple Contaminants

Staged or Component Systems

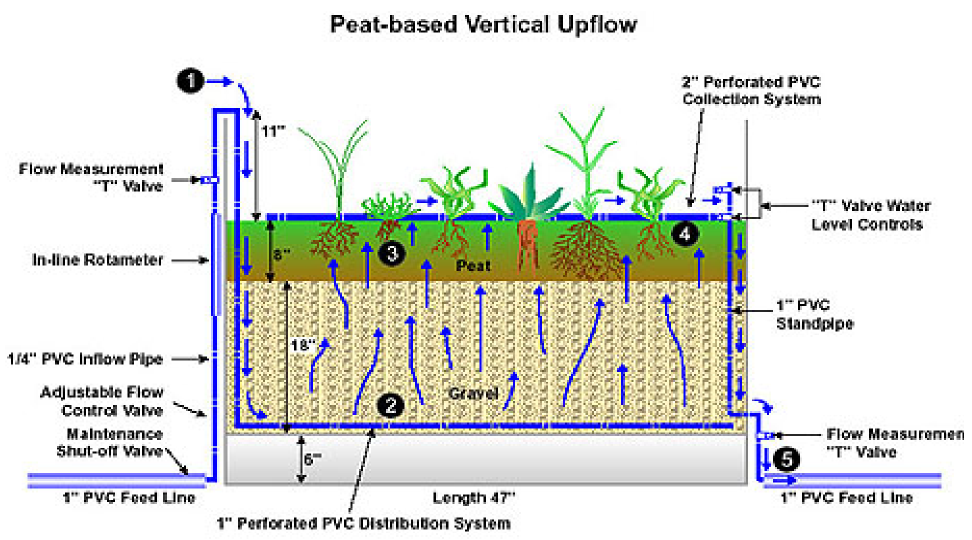
- Hybrid systems
  - Pre-treatment + subsurface flow + surface flow
  - Irrigation of partially treated effluents.
- "Engineered systems"
  - SSF may be augmented by aeration or utilizing specific reactive media
    - *phosphorous – iron slag*
    - *pH - organic wastes (compost, sawdust, etc.)*
    - *vertical flow (up or downward)*
- Impacted water treatment + managing stormwater and flood flows

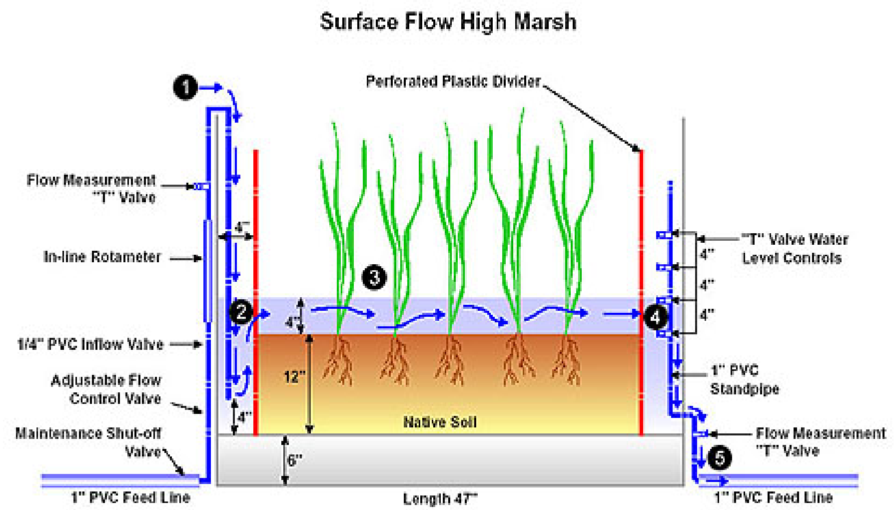
CH2MHILL

Treatment Sequencing

Sequential anaerobic-aerobic

- Purpose – to treat chlorinated and non-chlorinated organic compounds in sequence





Combination with other natural treatment systems

Winter Operations

- Surface flow
  - Manage water level to create air/snow/ice insulating layer
  - Deep zone water surface may freeze or remain open
  - Treatment efficiencies reduced but treatment continues
- Sub-surface flow
  - Water depth affects root zone processes
  - Normal range 30 - 60 cm
  - Can be 90 cm to allow winter lowering
  - Insulation with mulch, straw mats, snow
  - Microbial metabolism generates heat

CH2MHILL

O&M Requirements

- Water Quality
  - Monitoring
  - Constituent Loading
- Hydraulic Operation
  - Water Level and Flow Control
  - Flow Path Rotation
- Vegetation Management
  - Herbivory Management
  - Replacement

CH2MHILL

Wetland Size/Cost Ranges

- Wetland Area
  - SF: 0.03 to 10,000 ha
  - SSF: 0.005 to 20 ha
- Flow
  - SF: 1 to 5M m^3/d
  - SSF: 0.5 to 10,000 m^3/d
- System Cost
  - Surface Flow
    - *Avg $100,000/ha*
  - Subsurface Flow
    - *Avg $350,000/ha*
- Economies of scale

Kodiak Landfill

Wakodahathchee, FL

Capital Cost Comparison - Groundwater

- Options
  – MNA, In-situ, pump and treat, deep well injection
- Pump & Treat
  – Treatment Wetland vs. Mechanical Pump & Treat
  – Large range of TW cost depending on feedstock
  – TW vs. MP&T
    • *Capital costs somewhat comparable*
      – TWs 10 – 20 % lower

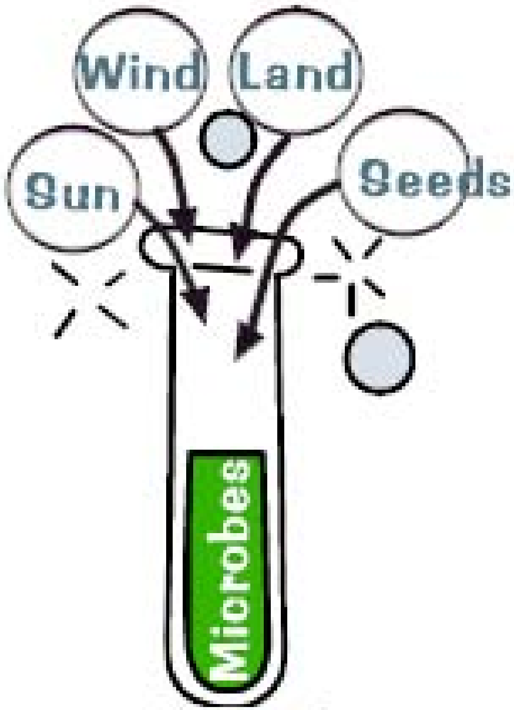
VS

Operation & Maintenance Costs

- Mechanical pump and treat = $5/m^3 (EPA 542-R-00-013)
  - Whole system O&M cost
- Surface flow wetland = $0.05/m^3 (IWA, 2000)
  - Additional considerations for contaminated sites
    - *Extraction infrastructure O&M not included (if groundwater)*
    - *Pretreatment*
    - *Lab*
  - Increased O&M for subsurface flow systems
    - *media maintenance (replacement?)*
- Bottom Line
  - Apples and Oranges?
    - *Maybe but the discrepancy here is too large to ignore*
    - *If surface water or industrial effluent – Granny Smith & Macintosh!*
  - TWs, **when appropriate**, tend to be more cost effective
    - *Provide ancillary benefits*

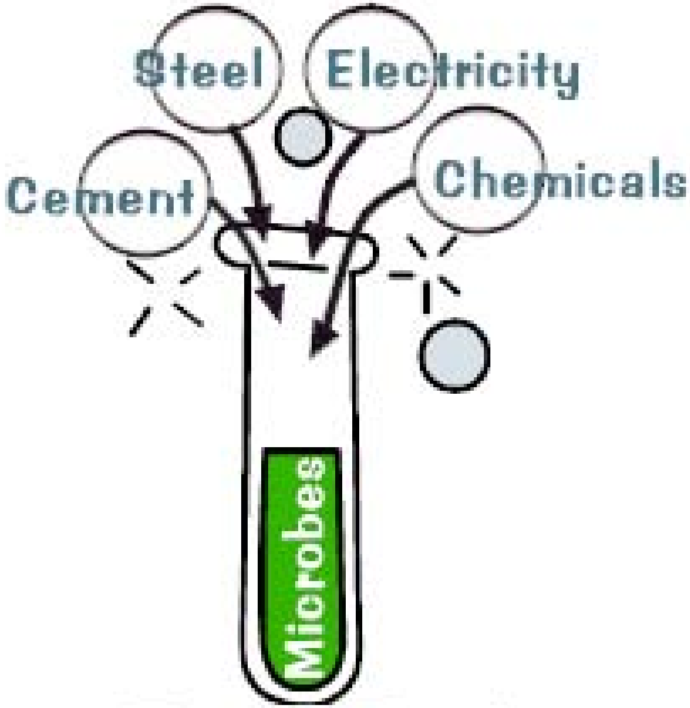
CH2MHILL

Natural Systems



Land Intensive

Conventional Systems



Fossil Fuel Intensive

Case Studies

CH2MHILL

Elmendorf AFB, Anchorage, Alaska

- Infiltration of contamination
- Groundwater from multiple seeps is collected and pumped to the wetland treatment system
- Two stage system
- Additional uncontrolled/unmeasured seeps flowing direct to wetland

- Overland flow cell: inclined concrete pad, liner, gravel. Volatilization & oxygenation.
- Surface flow wetland: average 8 day residence time
- Effectively removes PAHs and BTEX

Elmendorf AFB, Anchorage, Alaska

Parameter	Influent*/ Mid-system** (µg/L)	Effluent (µg/L)	Removal Efficiency
Benzene	0.0025**	Non-detect	100%
TCE	14**	2.3	84%
Total Aromatic Hydrocarbons	0.822*	0.832	- 1%
Total Aqueous Hydrocarbons	1.003*	1.031	- 3%

*** Maximum influent concentrations from 1998 to 2006**

**** Maximum mid-system concentration from 1998 to 2006**

CH2MHILL

Shepard Landfill Stormwater Wetland – Calgary, AB

Douglas Road Landfill, IN

- **Former gravel borrow pit used for disposal of residential, industrial and 1,200 m^3 hazardous waste. Closed to avoid RCRA compliance.**
- **Groundwater contaminant plume extending 3800 feet from site, affecting private residences and businesses with VOCs and metals exceeding GLs.**
- **5 extraction wells to contain and extract groundwater**
- **Discharge to infiltration basin and storm sewer if necessary**

CH2MHILL

Douglas Road Landfill, IN

Parameter	Influent (µg/L)	Effluent (µg/L)	Removal Efficiency
TCE	6.3*	Non-detect	100%
Arsenic	5.5*	Non-detect	100%
Lead	1.0*	0.5	50%
1,1-Dichloroethane	0.6*	0.1	84%

*** Maximum influent results from 2000 to 2006**

Kodiak Landfill, Alaska

- Impacted Leachate
  - VOCs and metals
- Gravity perimeter drain collection
- HRTs from 6 to 30 days
- Three stage treatment process:
  1. "Trickling Filter"
  2. Constructed SSF wetland cells
  3. Natural wetlands polishing – large natural wetland buffer downstream

CH2MHILL

Kodiak Landfill, Alaska

Parameter	Influent (mg/L)	Effluent (mg/L)	Removal Efficiency
TDS	940	780	17%
COD	86	52	40%
NH_4	110	70	36%
Iron	29.8	0.27	99%
Manganese	4.5	2.5	44%
Benzene	0.001	Non Detect	100%
2-Butanone (MEK)	0.044	Non Detect	100%

Chevron Refinery - Richmond, CA

- Used for polishing all wastewater
- 36 ha, treating 9500 m^3/d
- Removals:
  - NH_4-N: 76%
  - NO_3-N: 69%
  - BOD: 51% (low in influent)
  - TSS: 45% (low in influent)
  - Zn, Cr, Se removal
- Extensive ecological studies show net benefits of wetland system

CH2MHILL

Acid Mine Drainage

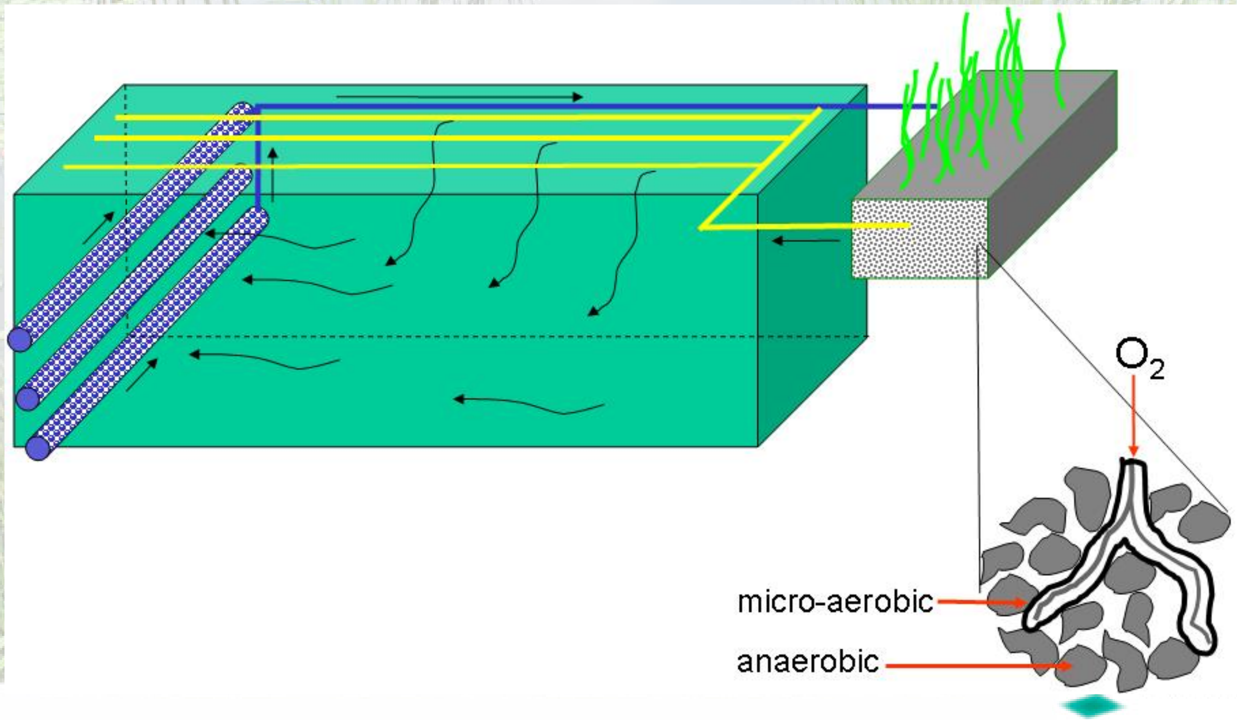
- Coal Storage Facility – Savannah River Site, Aiken, SC
- Pilot scale research vertical flow wetland used to treat low pH ferric iron-dominated acid rock drainage
- Data for multiple treatments

Parameter	Influent (mg/L)	Effluent (µg/L)	Removal Efficiency
pH	1.6 - 3.0	5.5 - 7.1	NA
Total Iron	92 - 237	ND - 123	~ 90%
Aluminum	39 - 274	0 - 9.3	> 99%
Sulphate	926 - 3385	490 - 2732	~ 50%

Other Applications

PCBs, PAHs & Heavy Metals

- *In-situ* soil/*ex-situ* groundwater remediation using groundwater collection + nutrification + SSF wetland + reinjection = Closed loop



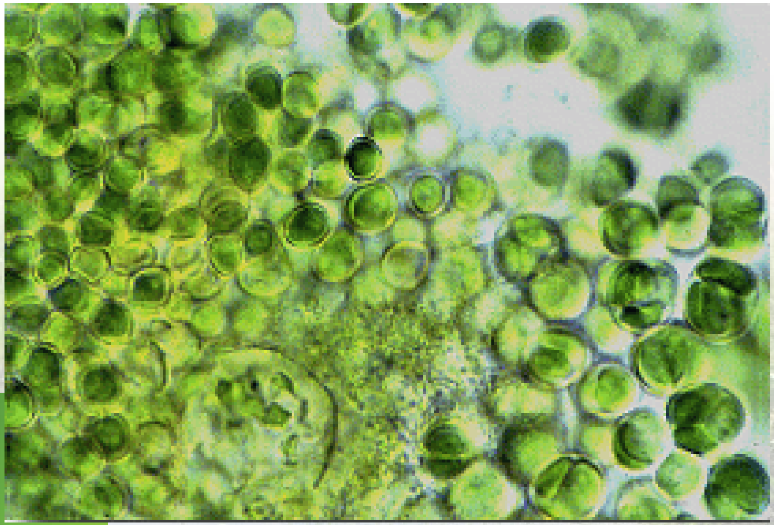
MHILL

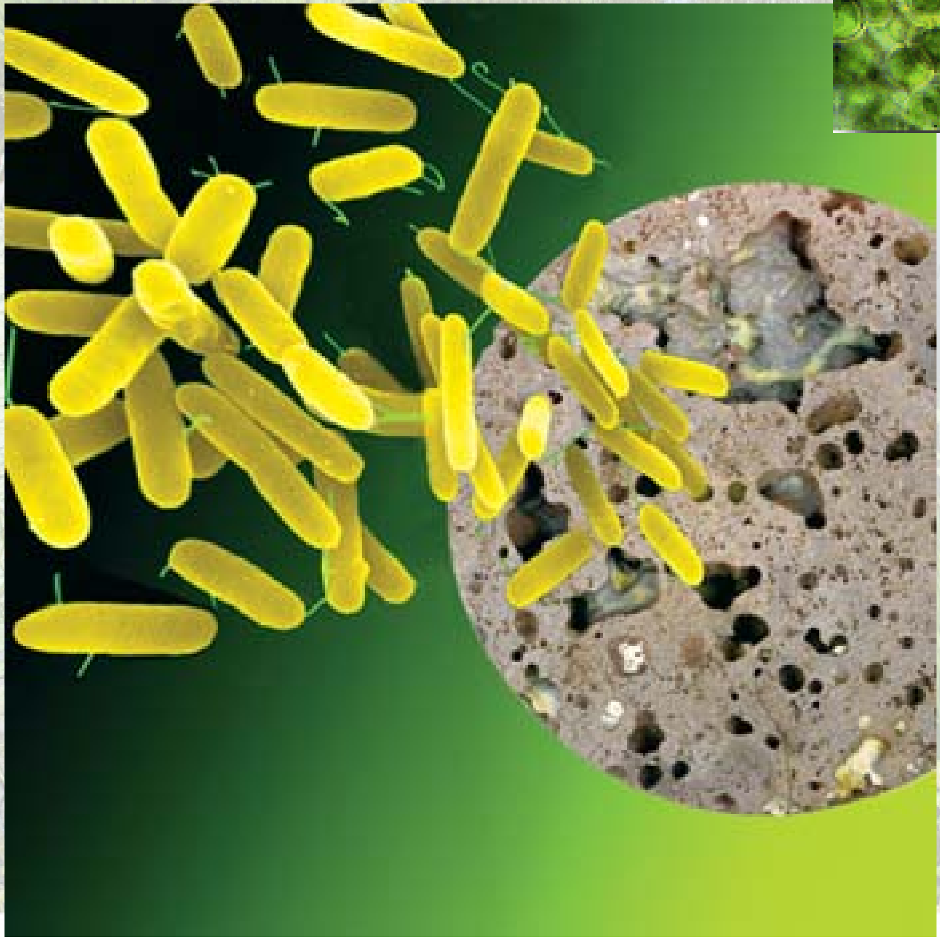
Other Applications Continued …
Oil Sands Tailings Remediation

- Current closure planning uses wet-cap method
  - Aerobic degradation of ejected naphthenic acids
  - Likely issues with design, depth and turbidity resulting in anaerobic environment
- Combination of wet-cap method, passive treatment (wetland) and mechanical treatment systems
  - Phase-out of mechanical component
  - Leave wetland in place following closure

CH2MHILL

Questions?





CH2MHILL