Upward Flow Wetland for Removal of Chlorinated Ethenes from Groundwater

2012 Ohio Brownfield Conference
Columbus, Ohio

Jacob Elder, Cox-Colvin & Associates, Inc.
Drs. James Amon, PhD and Abinash Agrawal, PhD, Wright State University
Drs. Michael Shelley, PhD and Garrett Struckhoff, PhD, Air Force Institute of Technology

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Overview

- Project History
- Conceptual Site Model
- Basic Design and Operation
- VOC Degradation Mechanisms
- System Testing
- Direction of Current Research
- Advantages at Brownfields
- Final Conclusions

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Project History

- "How to Restore a Fen"
- Construction of wetland at WPAFB
- Cooperative Research and Development Agreement

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Conceptual Site Model

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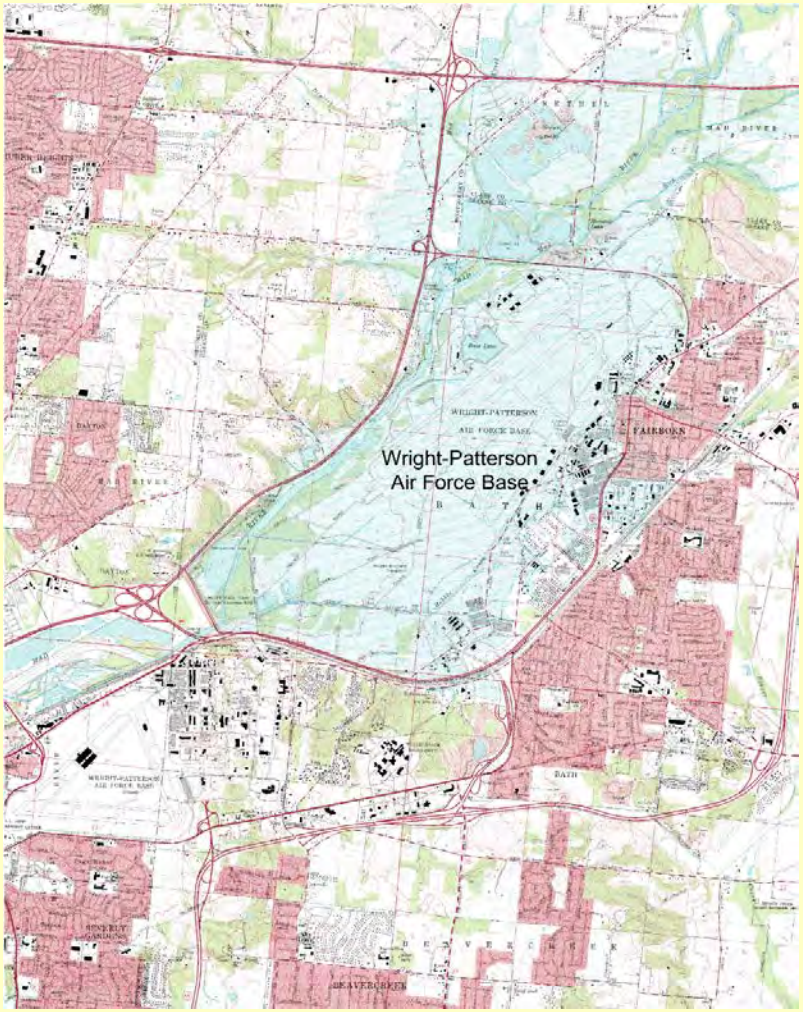
Site Location



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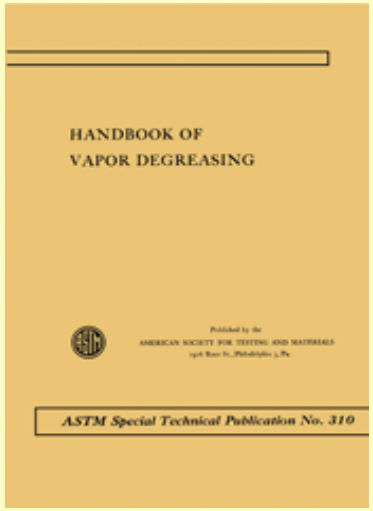
Site Geology and Hydrogeology

- Wisconsinan tills and outwash deposits
- Shale and limestone bedrock
- Groundwater
  - Great Miami Basin Sole Source Aquifer
  - Bedrock valleys filled with unconsolidated valley train sediments of sand and gravel
  - Prolific yields used for municipal and industrial supplies
  - Groundwater flow generally west/southwest towards Mad River

Contamination Source

- Unknown
- Likely multiple small sources
- Historic disposal practices
- Potential dry cleaner



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General Design Parameters

- Inflow rate of approximately 10 gpm
- Initial influent concentrations
  - PCE: ranged from 33.97 to 23.93 ug/l
  - TCE: ranged from 0.63 to 0.278 ug/l
  - No daughter products present
- Effluent concentrations
  - PCE: Ranged from 5.76 to 0.796 ug/l
  - TCE: Ranged from 2.42 to 0.821 ug/l
  - No daughter products present

Basic Design and Operation

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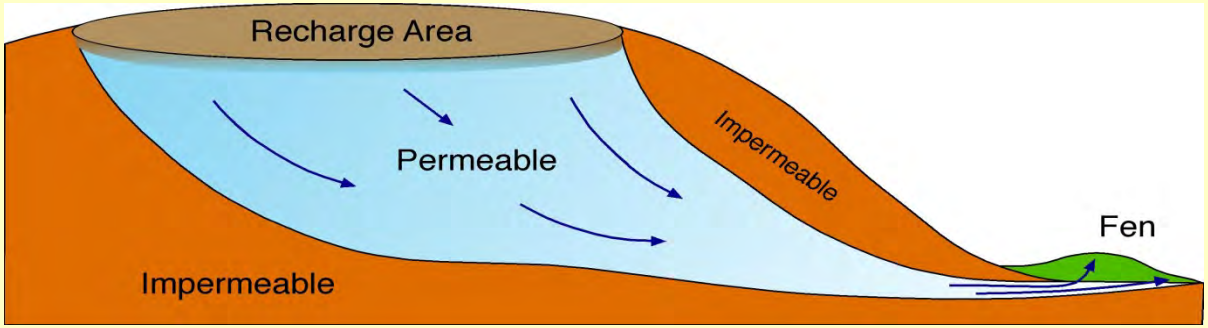
Fen System

- Treatment system mimics hydrology of natural fen systems
- Fens and other wetlands are known to have abundant bacterial activity
- Fen system well suited to temperate winters



After Amon et al., 2002, Wetlands

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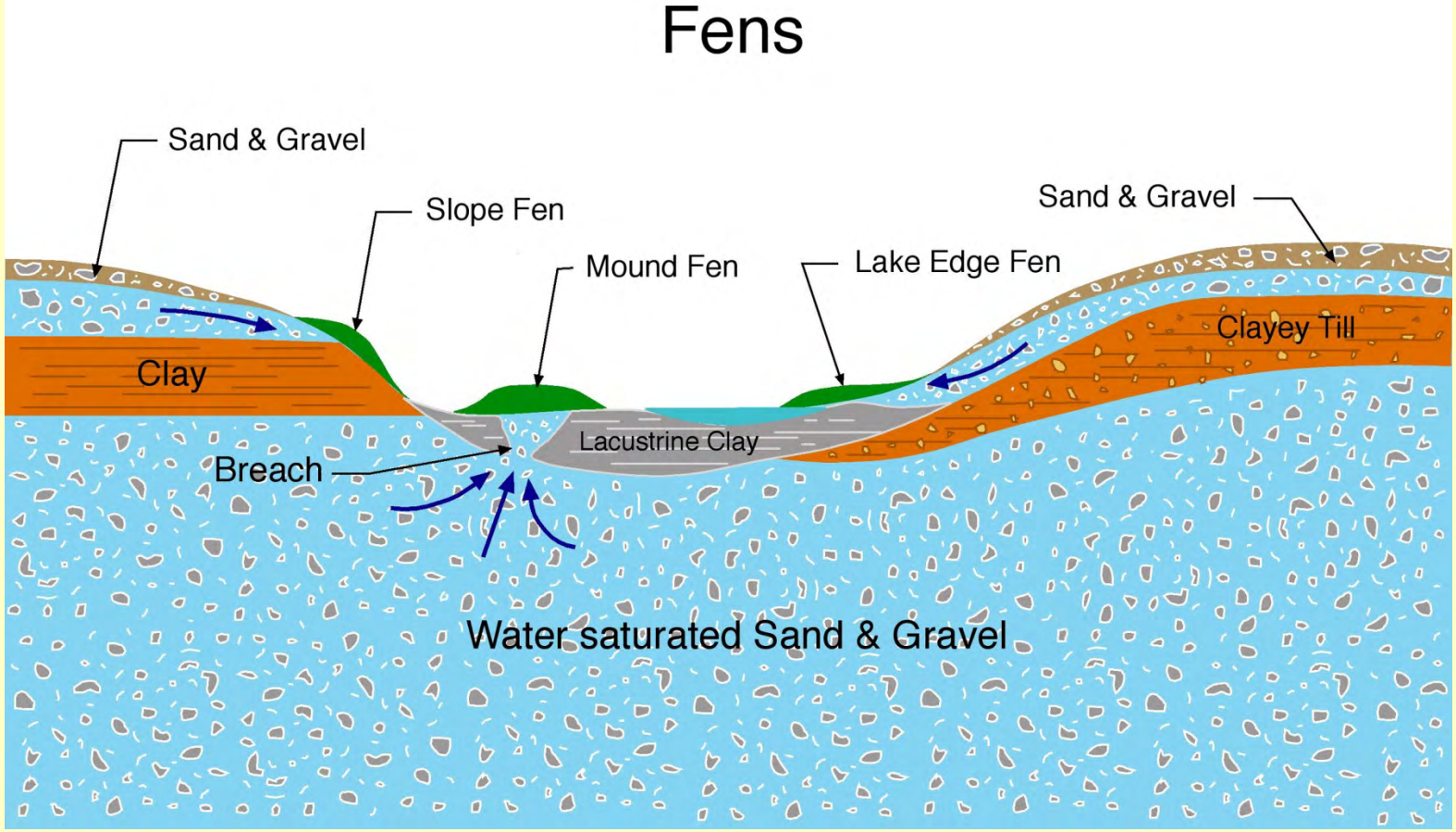
Fen System (cont.)



After Amon et al., 2002, Wetlands

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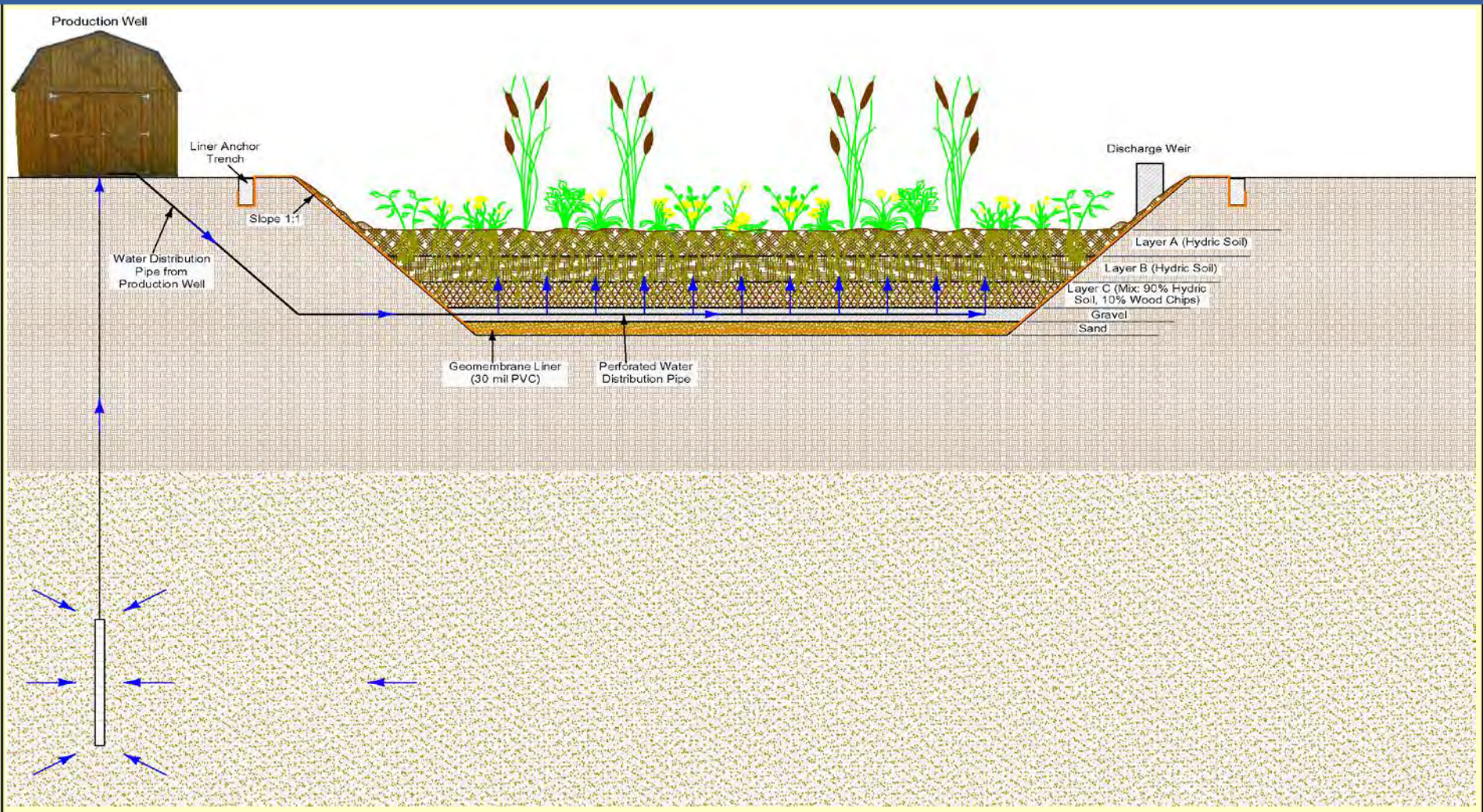
Wetland Construction



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Wetland Construction (cont.)

- Wetlands were planted with common fen plants and winter-tolerant sedges and rushes
- Dense root system stabilized soil substrate
- Roots penetrated entire 5 foot depth of treatment system

Wetland Construction (cont.)

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Wetland Construction (cont.)

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Wetland Construction (cont.)

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Wetland Construction (cont.)

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Wetland Construction (cont.)

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Wetland Construction (cont.)

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Wetland Construction (cont.)

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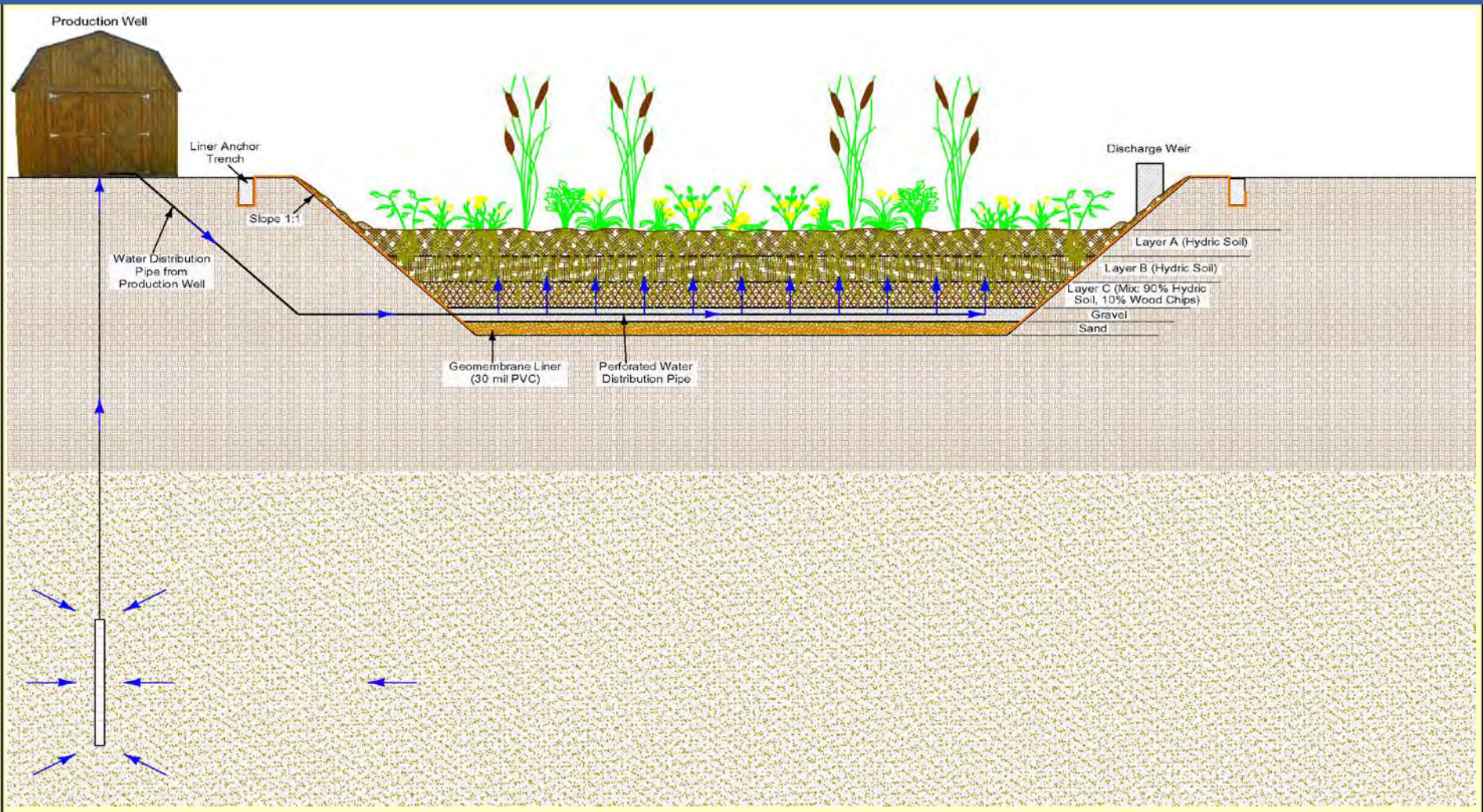
Contaminated Groundwater

- Pumped from nearby production well
- Fed into system through gravel layer at bottom
  - Disperses evenly under equal pressure
- Rises to surface where it flows to the outflow weir
- Discharged under permit to sanitary sewer

Contaminated Groundwater (cont.)



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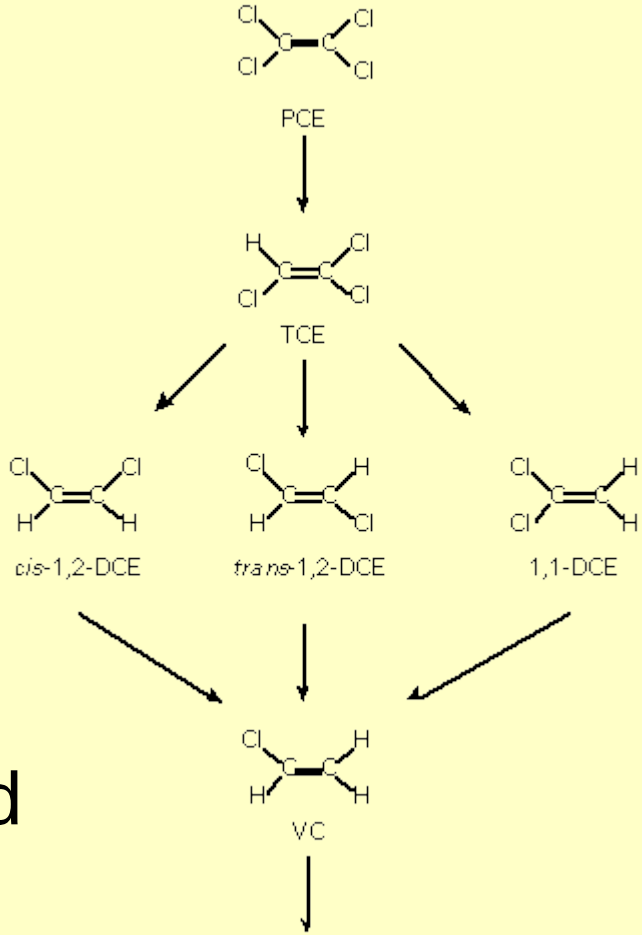
VOC Degradation Mechanisms

- Anaerobic PCE destruction through sequential reductive dechlorination in wetland soil (diagram shown)
- Aerobic mineralization of TCE, DCEs and VC through co-metabolism by methanotrophs and ammonia oxidizers in roots
- Microbes for both pathways found at all depths in the system



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VOC Degradation Mechanisms

- Plant roots and exudates
  - important source of organic and inorganic nutrients
  - O_2 delivery to deeper soil layers for cometabolic VOC degradation
  - physical substrate for microbial colonization
- Venting of VOCs to atmosphere through plants

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Degradation of VOCs, Fumigants, Metals

- Bench-scale studies show cometabolic degradation of dichloroethane (1,2-DCA), 1,3-dicholopropene, methylene chloride and numerous THMs (trihalomethanes), such as chloroform, bromoform, and bromochloromethanes
- Wetlands have shown potential for removal of various other contaminants through reductive pathways, such as perchlorate, nitrate, and metals (As and Cr)

Roots of ***Carex comosa*** and ***Scripus atrovirens***

Powell and Agrawal, 2011

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System Testing

	Units	Inflow	Bottom Layer (C)	Middle Layer (B)	Top Layer (A)	Outflow
PCE						
January 2002	ug/L	33.97 (1.63)	27.431 (1.36)	1.15 (0.02)	0.81 (0.08)	5.76 (0.63)
January 2003	ug/L	32.59 (0.70)	26.27 (0.87)	0.319 (0.14)	0.17 (0.81)	8.64 (0.49)
July 2003	ug/L	21 (0)	6.52 (5.41)	0.40 (2.06)	0.19 (0.40)	nd
September 2003	ug/L	22 (0)	10.13 (7.75)	1.25 (0.84)	1.26 (0.86)	nd
October/November 2003	ug/L	23.93 (0.68)	7.55 (0.60)	0.101 (0.035)	0.066 (0.02)	0.796 (0.49)
TCE						
January 2002	ug/L	0.63 (0.34)	0.71 (0.17)	0.17 (0.11)	0.18 (0.11)	2.42 (2.64)
January 2003	ug/L	0.17 (0.01)	0.54 (0.09)	0.44 (0.17)	0.095 (0.04)	0.51 (0.04)
July 2003	ug/L	0.41 (0)	1.79 (1.50)	0.75 (1.13)	0.36 (0.50)	nd
September 2003	ug/L	0.1 (0)	1.90 (1.94)	0.31 (0.37)	0.32 (0.33)	nd
October/November 2003	ug/L	0.278 (0.11)	1.451 (0.09)	0.853 (0.15)	0.070 (0.01)	0.821 (1.13)
cis-DCE						
January 2002	ug/L	0	0	0	0	0
January 2003	ug/L	0	0	1.35 (0.57)	0	0
July 2003	ug/L	0	1.29 (1.26)	2.41 (2.20)	0.02 (0.01)	nd
September 2003	ug/L	<0.03	0.79 (1.23)	1.23 (0.59)	0.02 (0.01)	nd
October/November 2003	ug/L	0	5.582 (0.47)	0.043 (0.03)	0	0
VC						
January 2002	ug/L	0	0	0	0	0
January 2003	ug/L	0	0.02	0.50 (0.17)	0.11 (0.05)	0
July 2003	ug/L	nd	nd	nd	nd	nd
September 2003	ug/L	nd	nd	nd	nd	nd
October/November 2003	ug/L	0	0	3.149 (0.59)	3.692 (0.78)	0

() = ± standard deviation after outliers removed

0 = not detected

nd = not determined

after Amon et al., 2007, Ecological Engineering

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Direction of Current Research

- Laboratory microcosm experiments
  - Scrutinize microbial seed
  - Striking similarities between treatment system microbes and natural fens
  - Microbial inoculation material will be inexpensive and easy to obtain

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Advantages at Brownfield Sites

- Scalability
- Reduced O+M Costs
- Reduced Energy Costs
- Wide Range of Contaminants
- Habitat Creation/Open Space
- Carbon Sequestration
- Green & Sustainable

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Final Conclusions

- Very effective
- Can be used with higher concentration plumes
- Low O&M and energy costs
- Green & Sustainable

Questions?