

Removal and Fate of Chlorinated Solvents from Contaminated Groundwater

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Acknowledgments: Co-authors

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- Garrett Struckhoff, UMR
- John Schumacher, USGS - Rolla
- Bill Schneider, Roy F. Weston

Outline

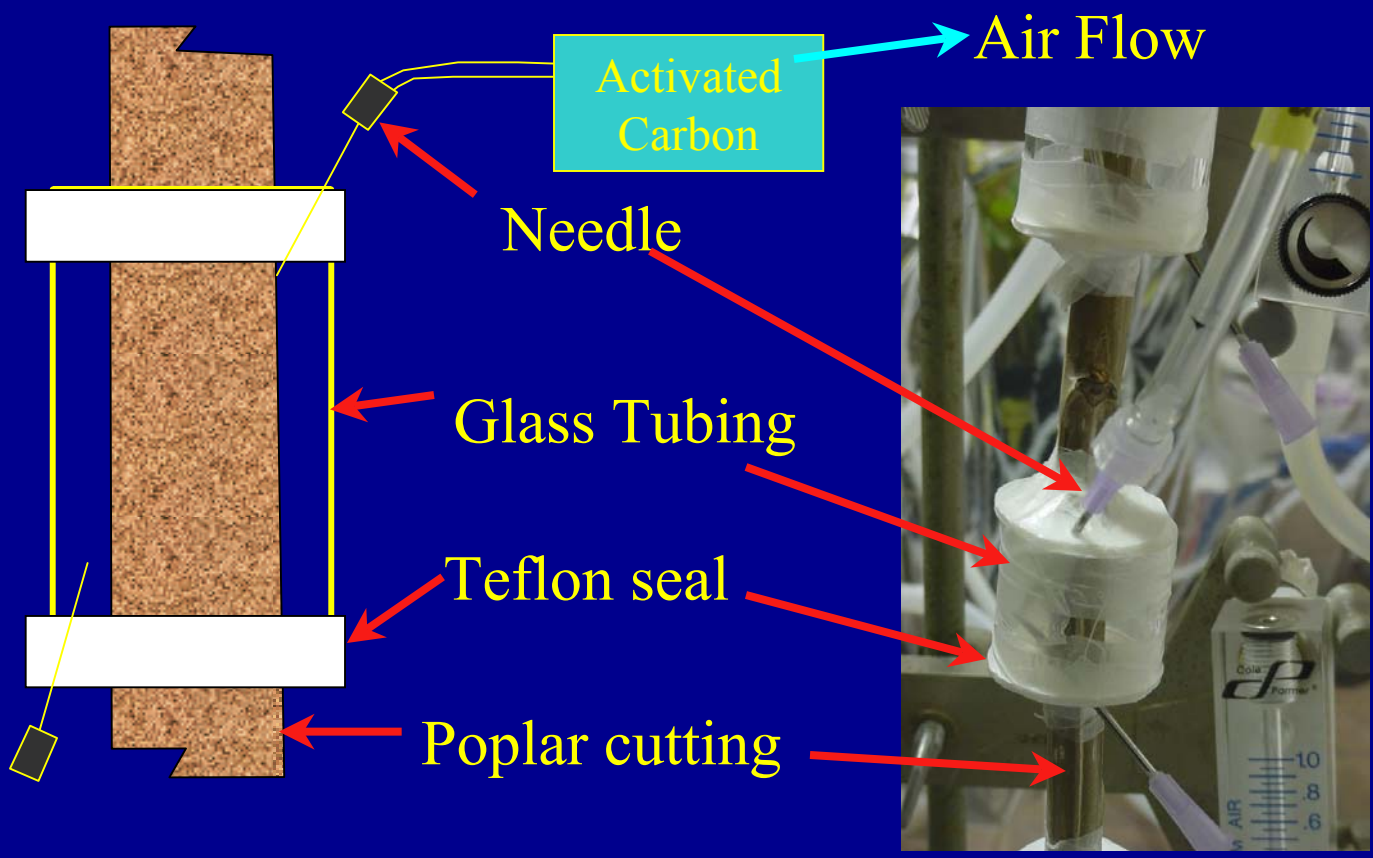
- Experimental
 - Diffusion and Fate
- Modeling
- Full-Scale Systems
- Conclusions (implications)

Laboratory Studies

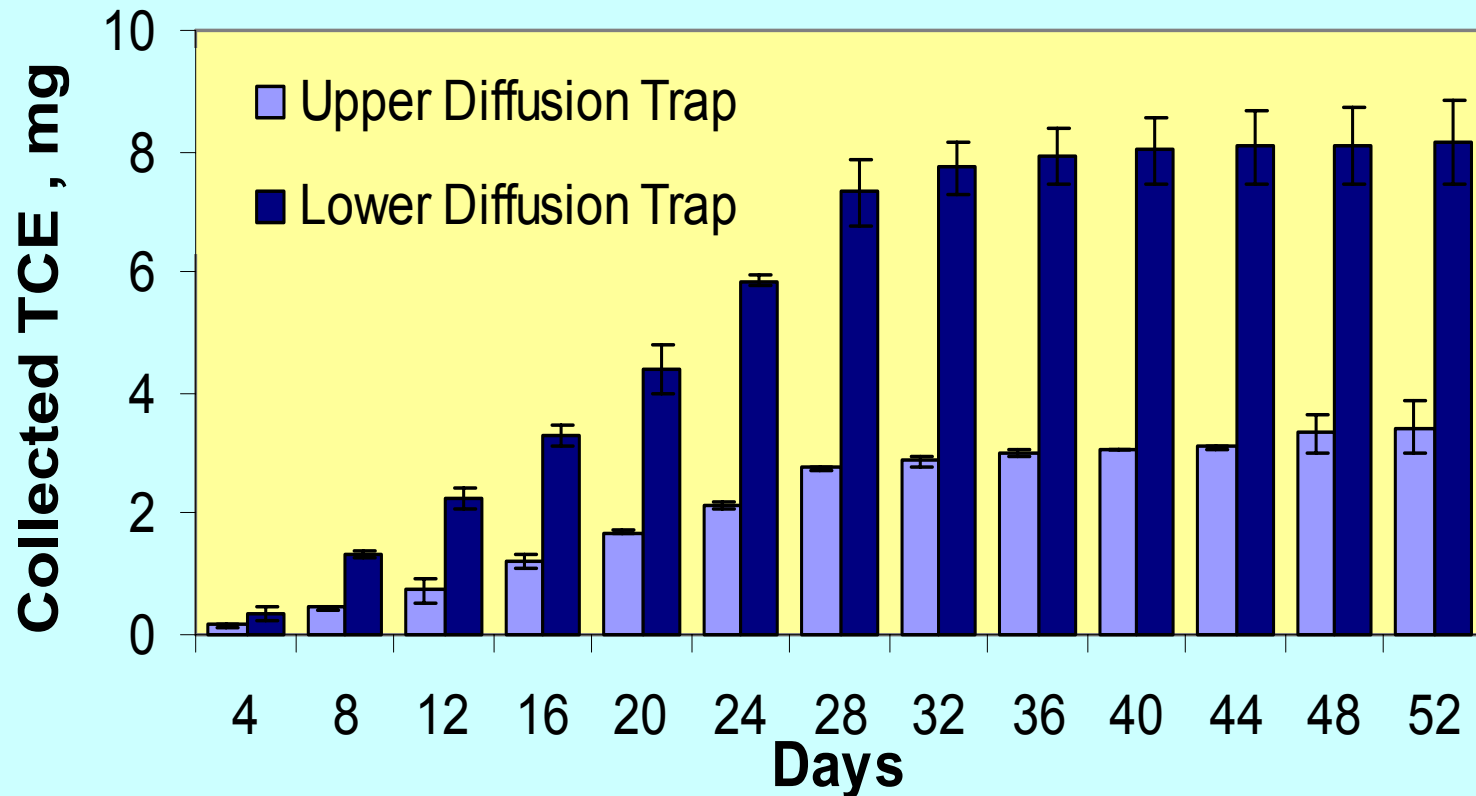
- Hybrid poplars grown in the laboratory in sand, hydroponically, or in soil
- Dosed with TCE
- Diffusion traps placed on stems
- At completion all above-septum tissues analyzed



Diffusion Trap

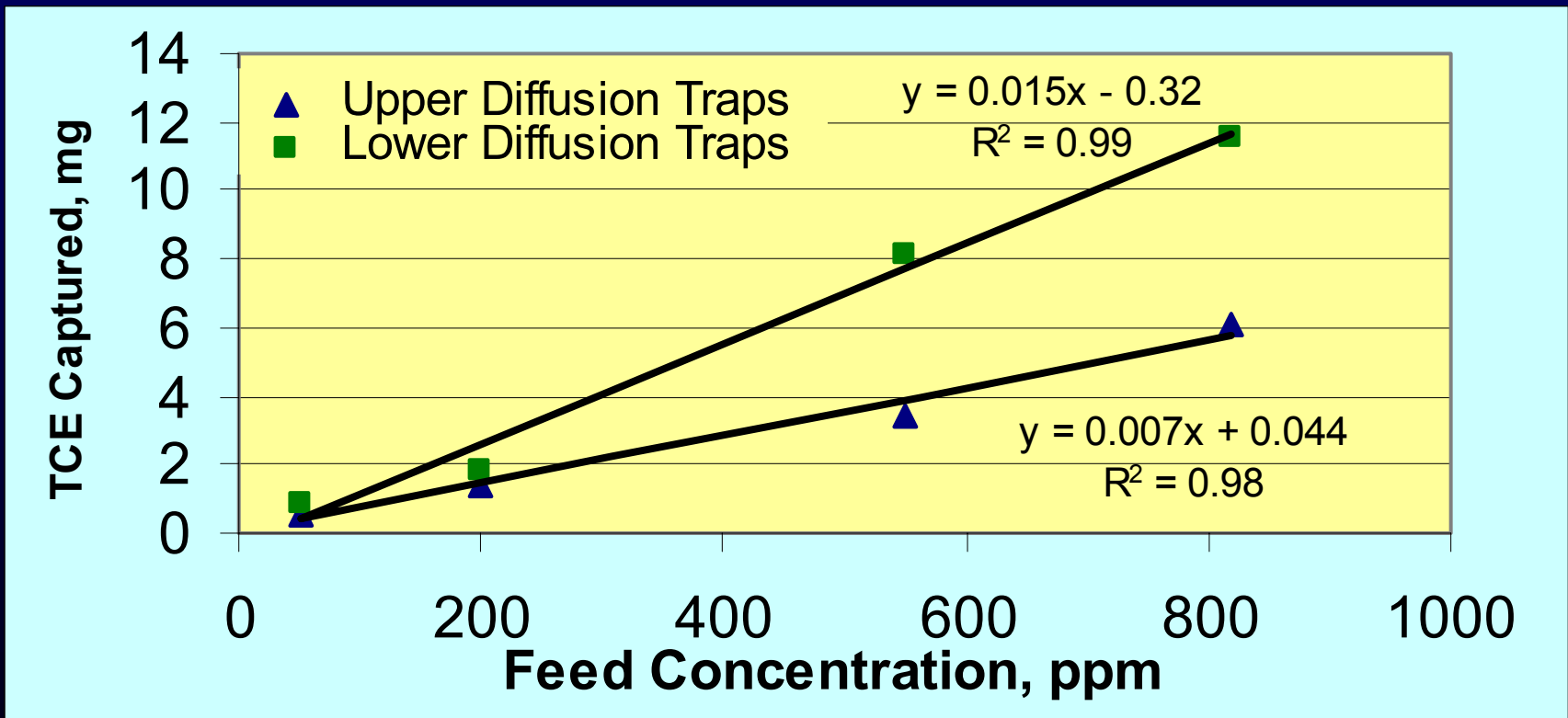


Diffusion Trap Analysis



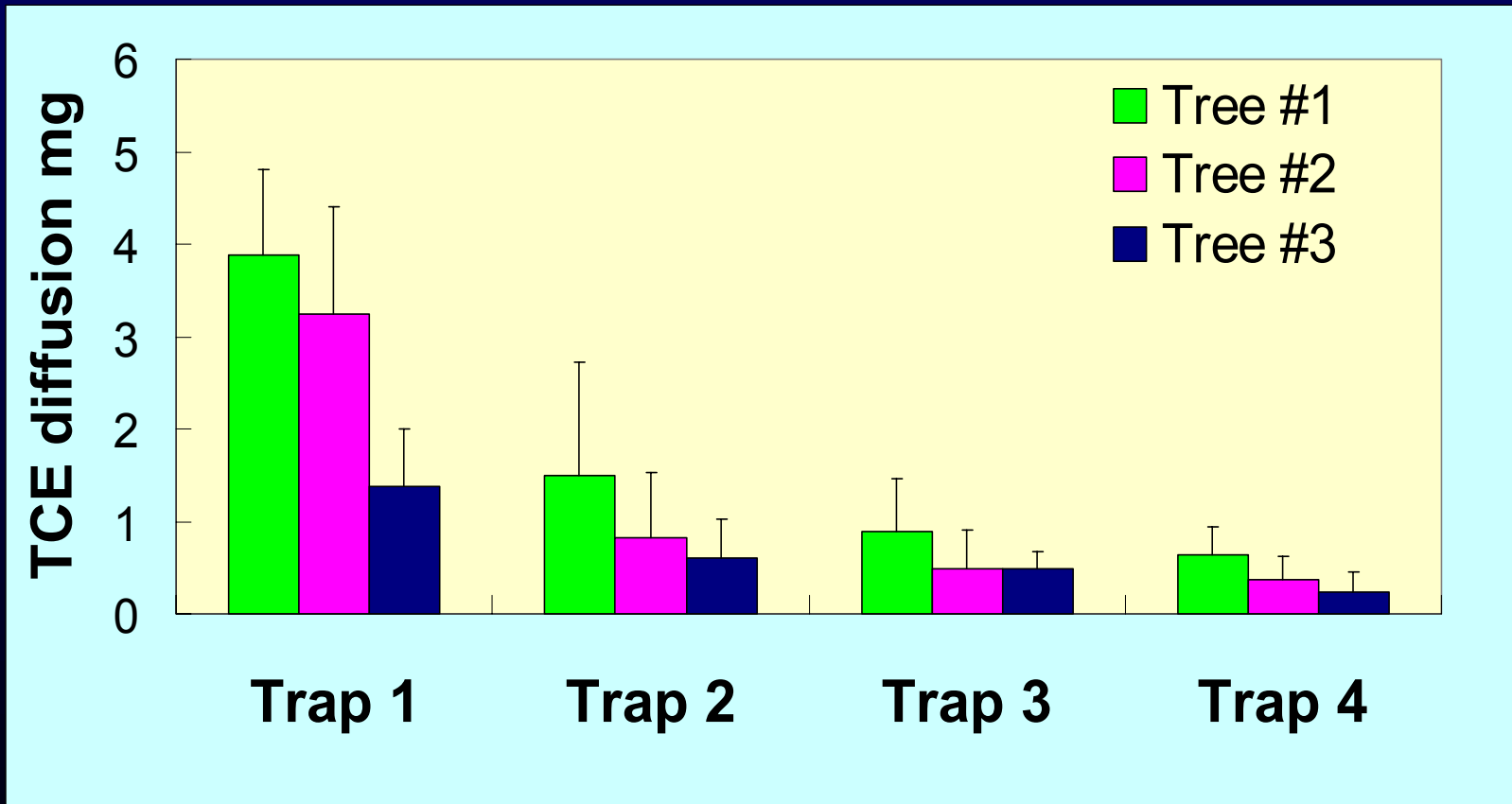
TCE dosing at 550 ppm until day 28
n = 2, S.D. shown.

Total diffusion mass vs. influent



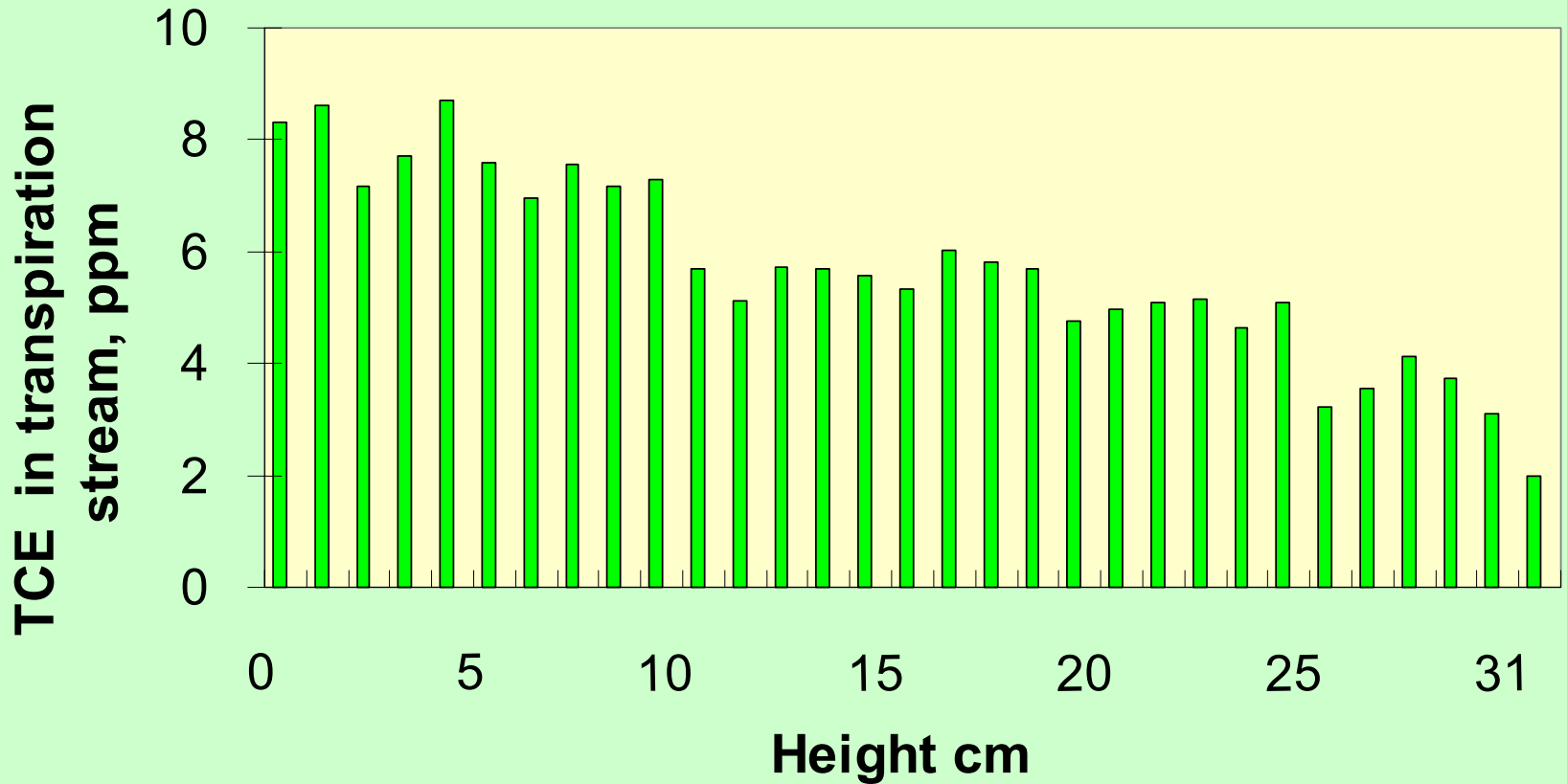
Accumulative Diffusion mass, 28 day dose period

Diffusion varied with height, and transpiration rate

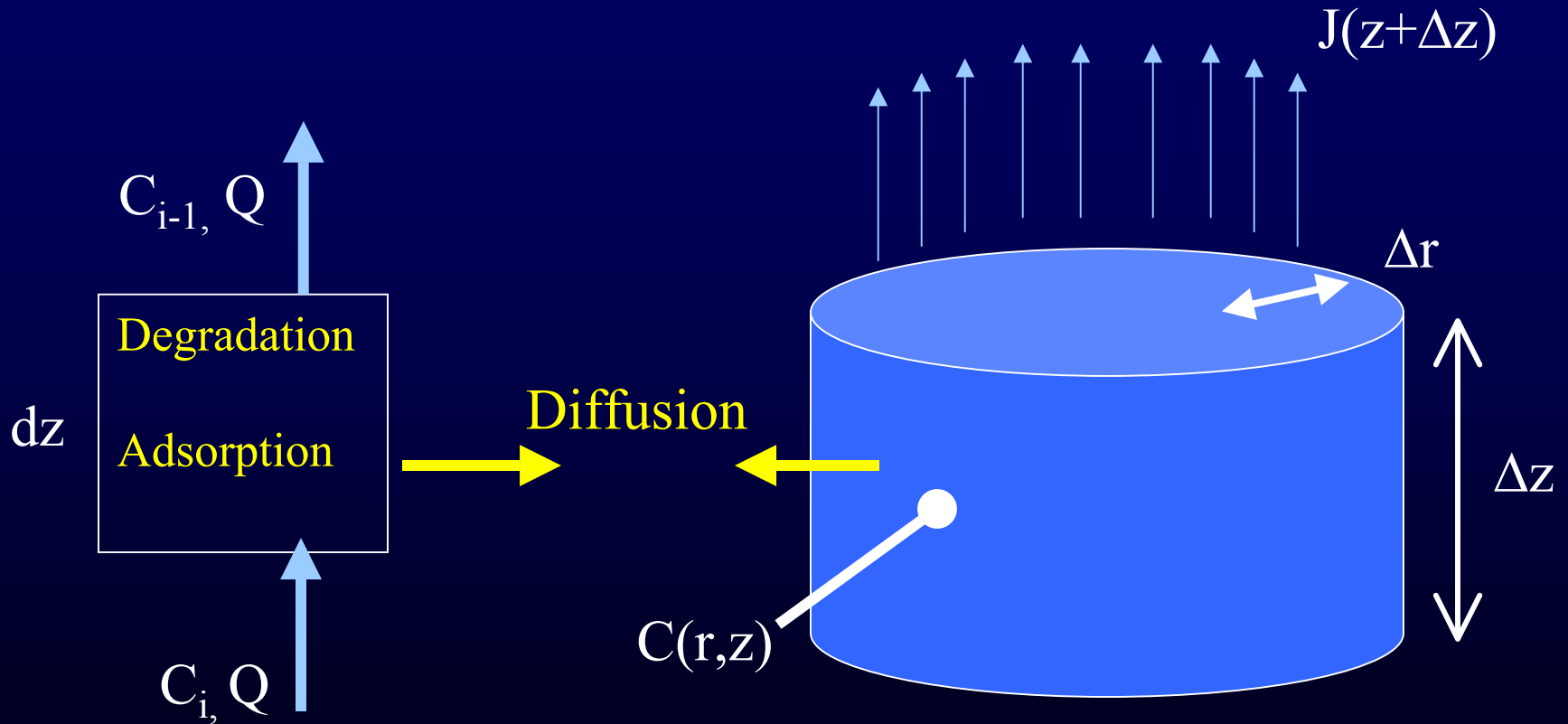


Grown in Sand, Dose concentration = 440 ppm

Mass vs Height



Modeling approach



$$V \frac{dC_i}{dt} = C_i Q - C_{i-1} Q - dN_i$$

Model equations

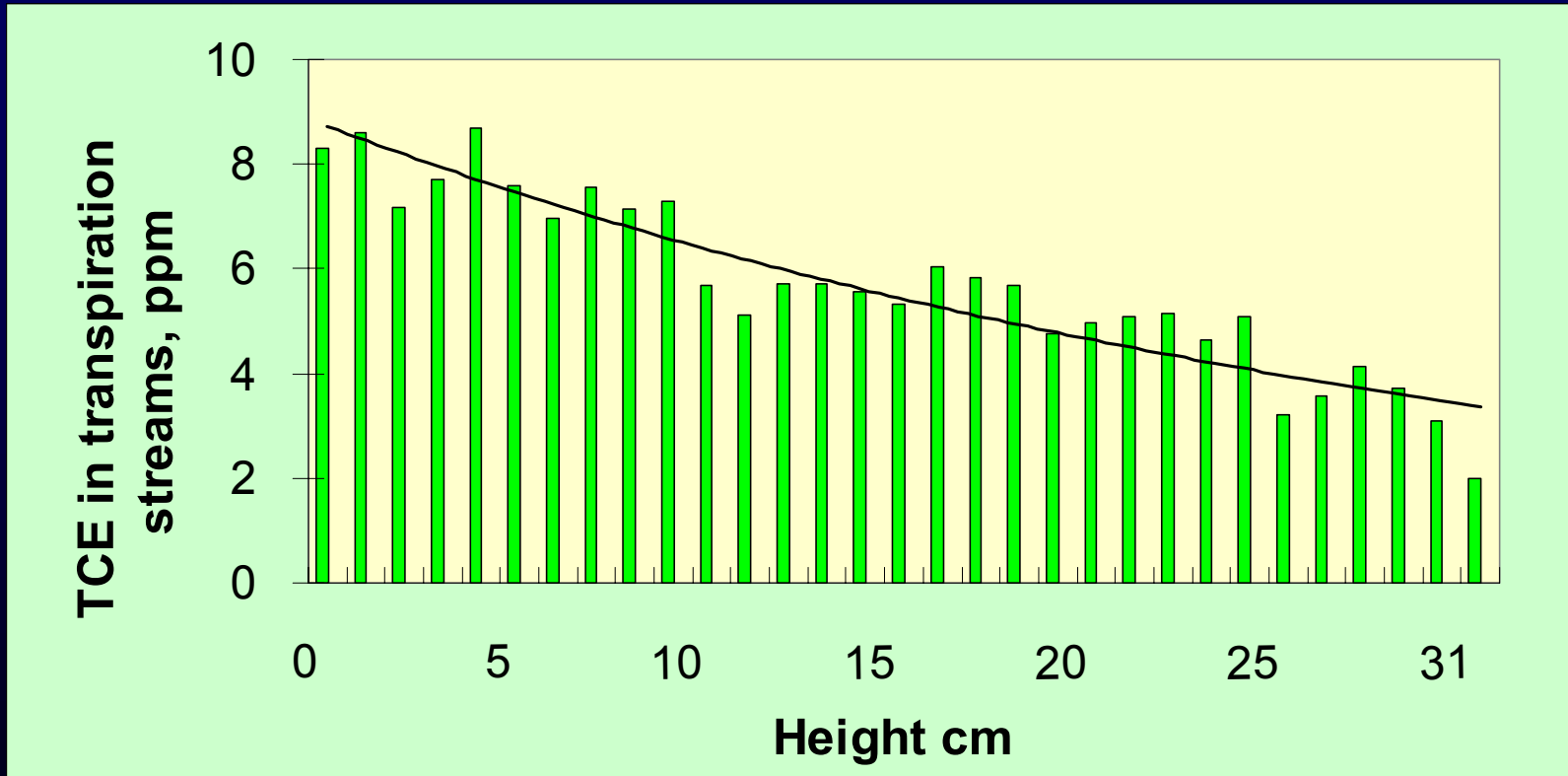
Proof of concept, thin layer diffusion
Based on geometric mean

$$V \frac{dC_i}{dt} = C_i Q - C_{i-1} Q - dN_i$$

$$C = C_0 e^{-\left(\frac{r_a}{R-r_a}\right) * \frac{D\pi}{Q} z}$$

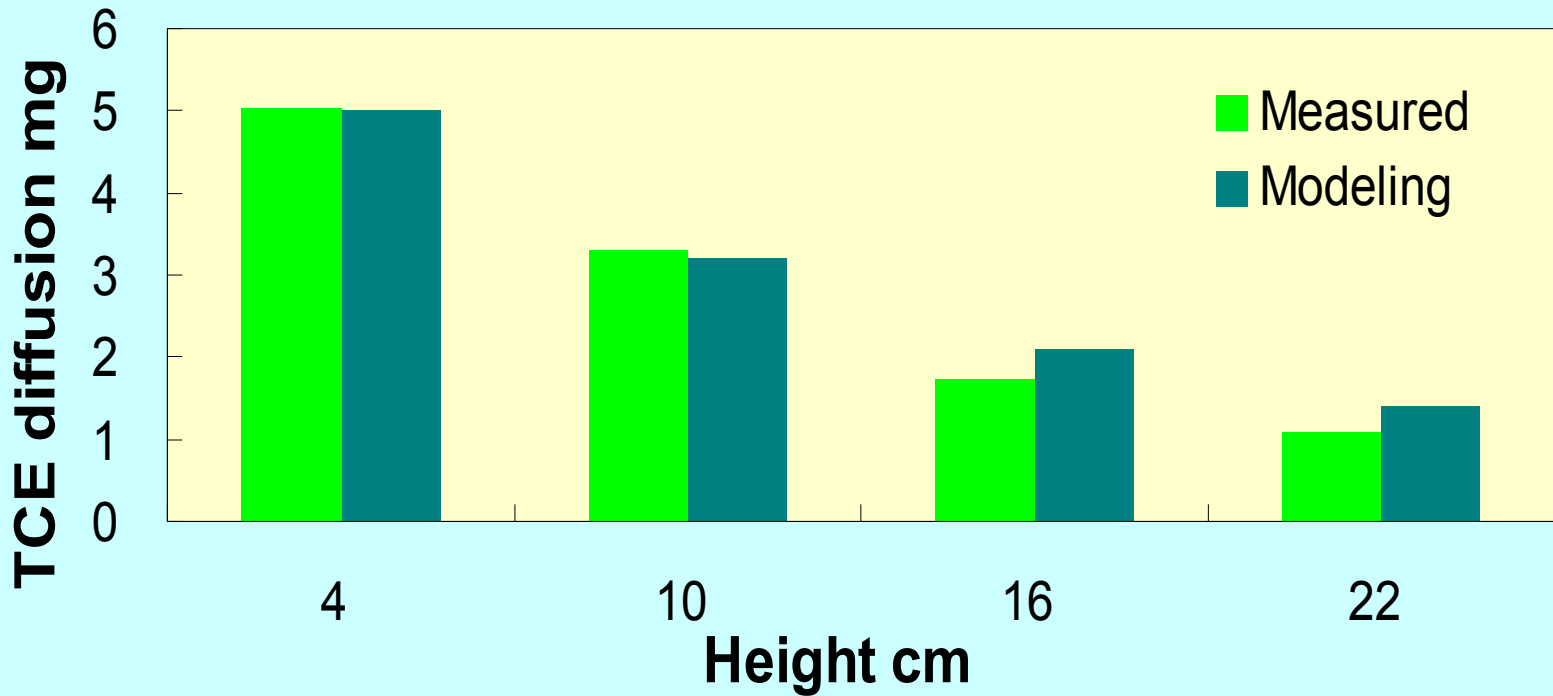
$$N_i = -C_0 Q e^{-\frac{2r_a D\pi}{Q(R-r_a)} z} \Big|_{z1}^{z2}$$

Modeling: Biomass TCE vs. Height



Diffusion Coefficient = $2 \times 10^{-6} \text{ cm}^2/\text{s}$, TSCF = 0.2 (C_o also measured)

Modeling: Diffusion vs. Height



Field Sampling

- Collect a core sample of the trunk/stem
- Core sample placed into headspace vial
- After equilibration time headspace is analyzed via GC
- Partition coefficients are used to determine initial concentrations
- Field-scale Diffusion traps installed



Aberdeen Proving Ground,
Edgewood, MD

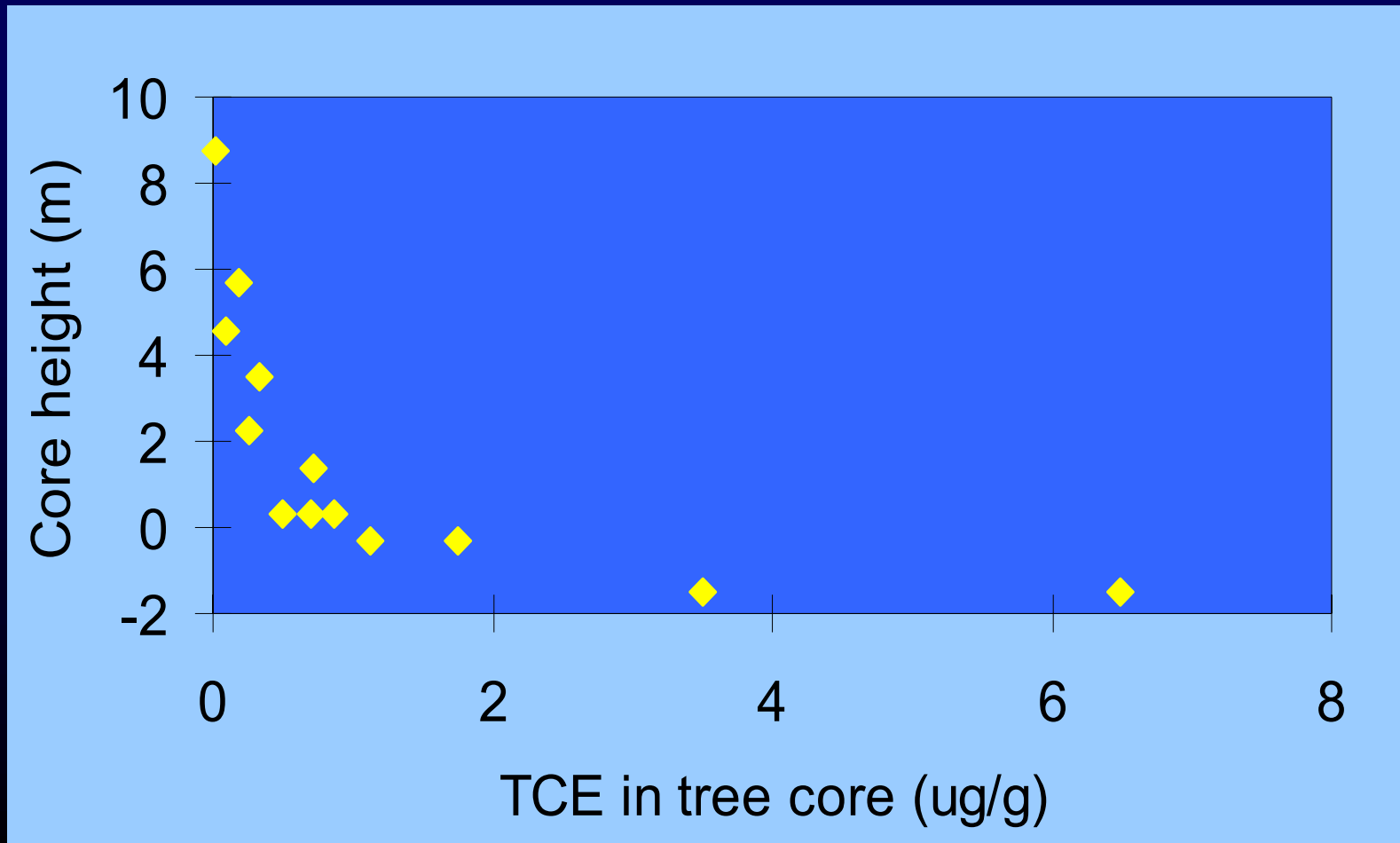
Collected Cores and Spatially



Vertical Sampling to Subsurface



Concentration in Biomass vs. height



Diffusion at Field Site

- Diffusion samplers similar to lab-scale, using tedlar & portable pumps.

3 Methods in 3 Labs

- Filtered effluent air through Act. Carbon – GC (hours)
- Static SPME – GC/MS (10 min)
- Summa Canisters – GC/MS (2 1)



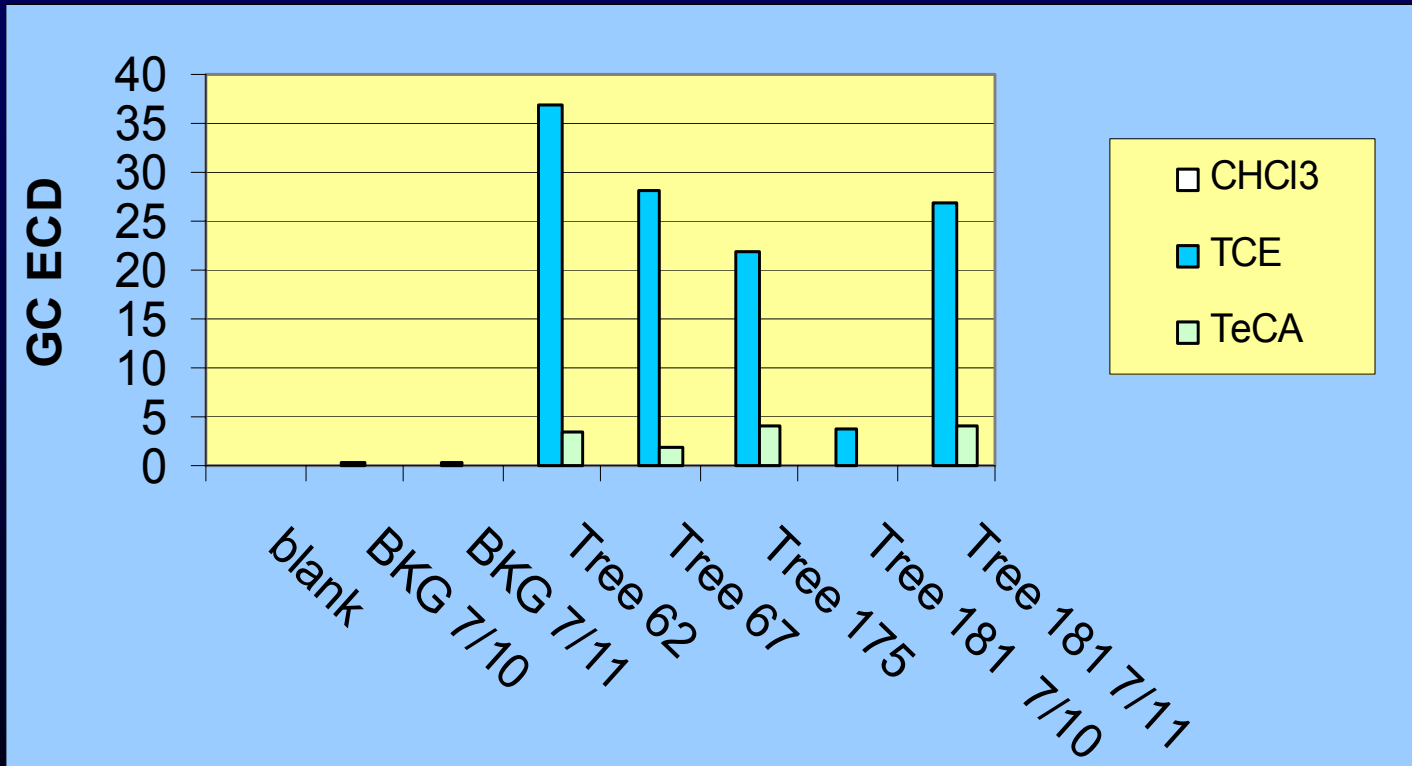
Diffusion Trap Sampling

Tree #	Carbon Tube (μg)	SPME (ng)*	Summa (ppbv)**
174	61 - 446	50 - 880	9
149	71 - 252	50 - 70	7
149 gum	105 - 298	230 - 380	72
67	60 - 680	920 - 950	46

* Data courtesy of John Schneider, Lou Martino; Argonne Nat Labs

** Data courtesy of John Wrobel-DoD; Steve Hirsch, Scott Fredrickson-EPA

SPME Analysis



SPME analysis by John Schneider, Argonne National Labs

Conclusions

- Chlorinated VOCs are translocated from contaminated plumes
- Tree Cores can provide quantitative information for groundwater concentrations (not absolute)
- Mass removal relates to ET rates, C_{GW}
- Diffusion to the atmosphere is a dominant fate

Riverfront Superfund Site

John Schumacher, USGS Rolla



LARGE DOD CONTRACT FOR TENTS 1950S-1970s

U.S. Environmental Protection Agency, Region VII
U.S. Geological Survey



FOUR OPERABLE UNITS

OU-1 (Riverfront Site)

*Former Al pole swaging
PCE used and dumped*

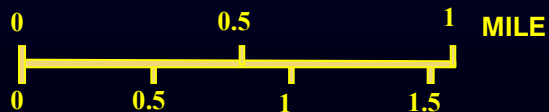
OU-2 (Kellwood Site)

*Tube mill
PCE used and dumped*

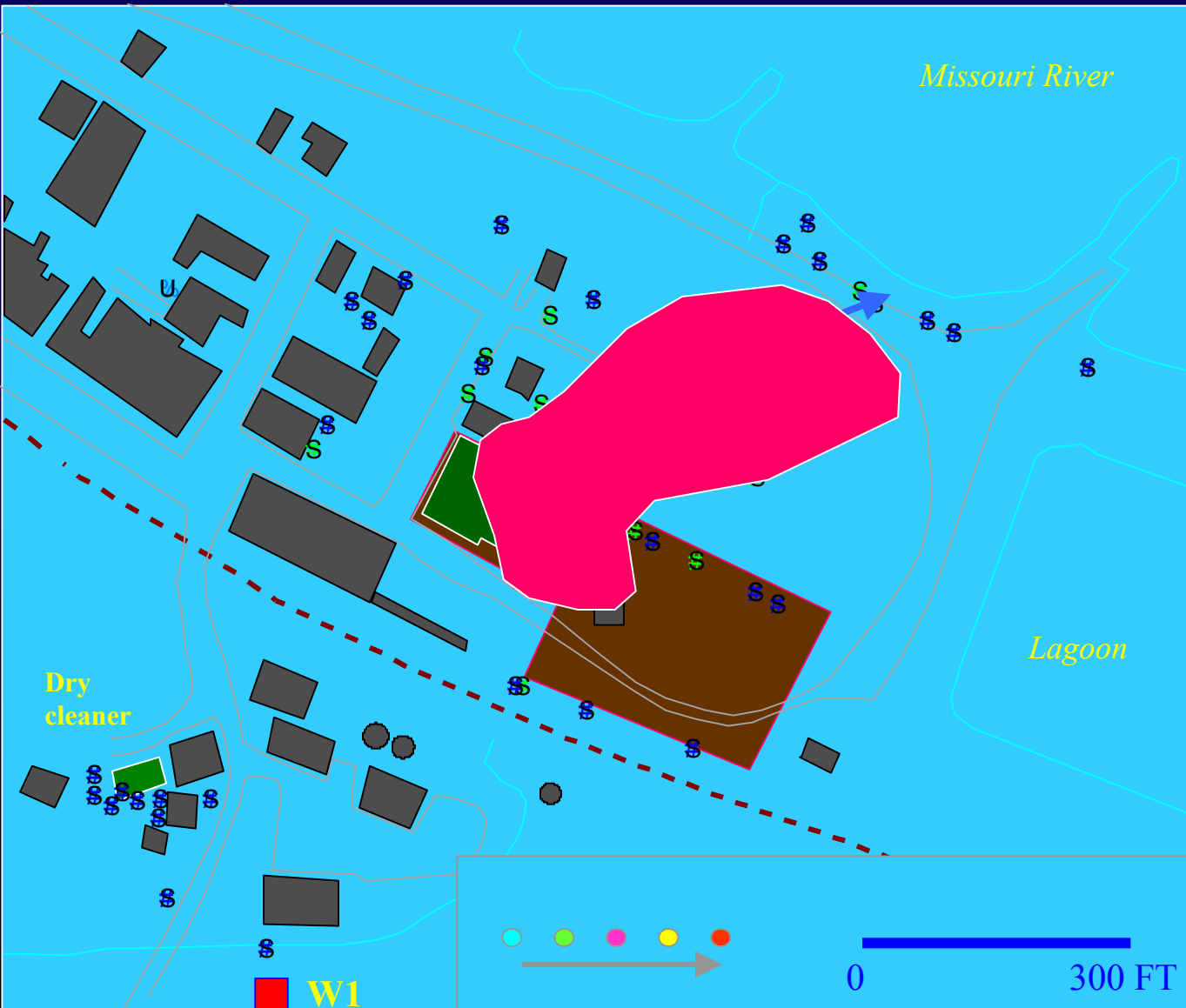
OU-3 (Old City dump)

OU-4 (East New Haven)

PCE in creeks



OU1 RIVERFRONT SITE – Tree core recon.



30 feet alluvium

GW 17-25 feet

60 Trees cored

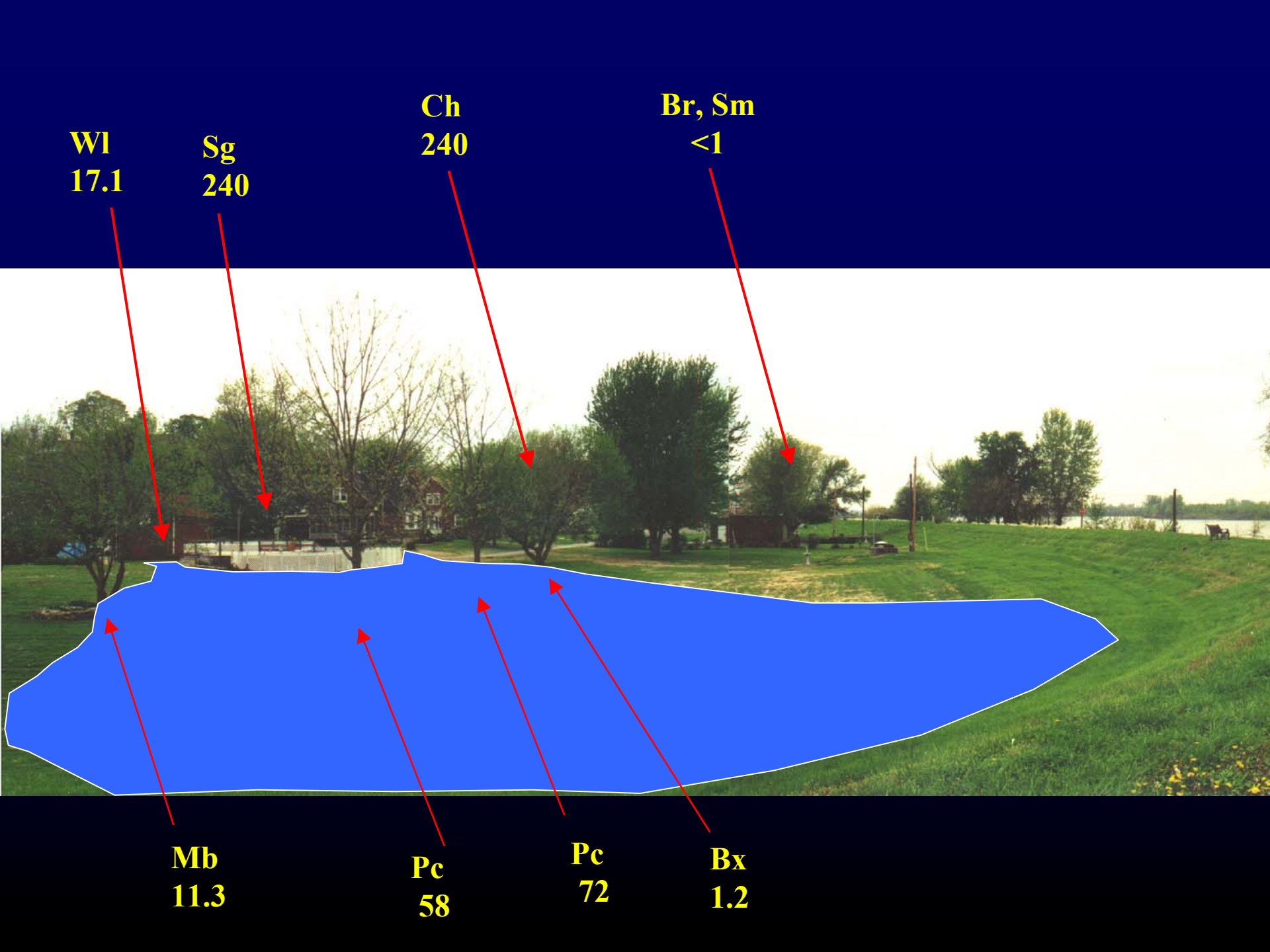
7 Residences

PCE in 29 trees

0.1 – 7,600 ug/L

Screen out

- Dry cleaner
- Bulk tank area
- Old Auto dealer



Wl
17.1

Sg
240

Ch
240

Br, Sm
<1

Mb
11.3

Pc
58

Pc
72

Bx
1.2

OU1 RIVERFRONT SITE – 1999-2001 well installation

Based on tree-cores:

- 17 Direct-push holes
- 7 alluvial wells
- GW 17 – 25 ft deep



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