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A Consideration of the Benefits of Various Field Procedures When Applying Enhanced Reductive Dechlorination

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B2. Successes and Continuing Challenges for Bioaugmentation and Biostimulation

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Technology Development Life Cycle Process
Reductive Bioremediation of Chlorinated Solvents

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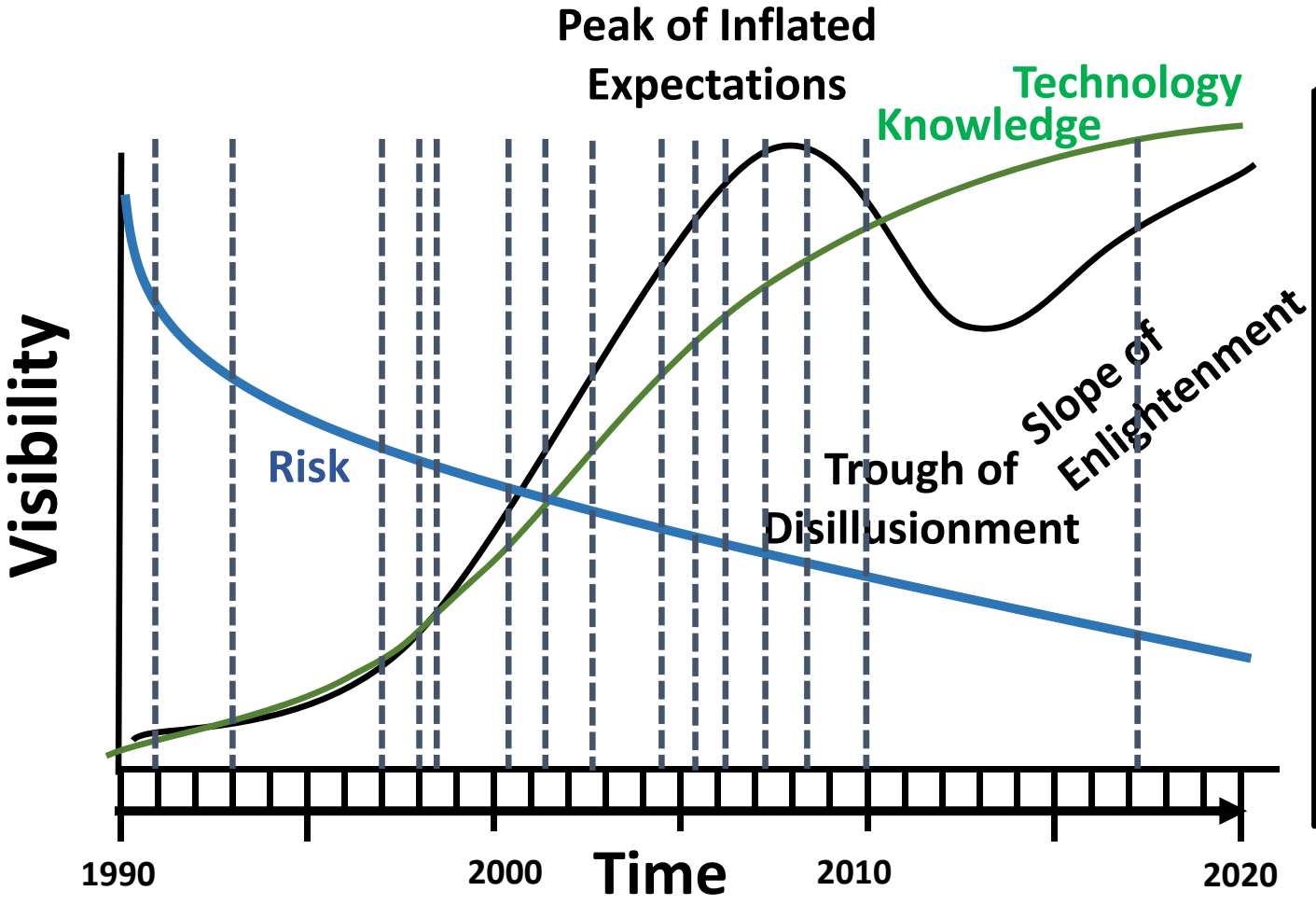

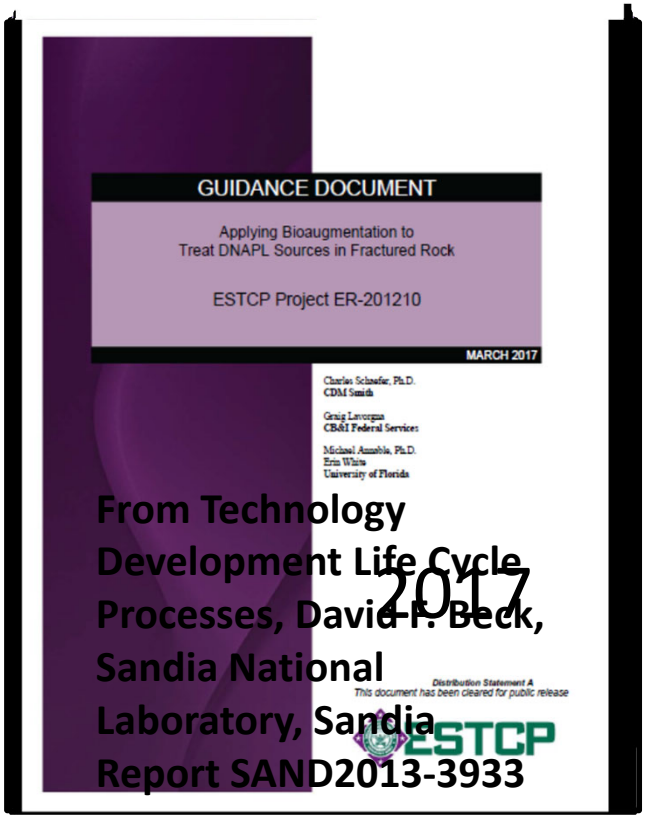

From Technology Development Life Cycle Processes, David F. Beck, Sandia National Laboratory, Sandia Report SAND2013-3933 2017

Bioaugmentation Successes

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Challenge has been to effectively apply cultures

Exposure of Dhc to oxygen is inhibitory

Aerobic conditions considered not conducive to anaerobic reductive dechlorination

Initially, we used to take extraordinary measures to protect dechlorinating cultures.

- **Establish reducing conditions in aquifer before bioaugmenting**
- **Purge injection lines**

cDCE and VC Degradation Rates of SDC-9™ Exposed to Air (With and Without Lactate)

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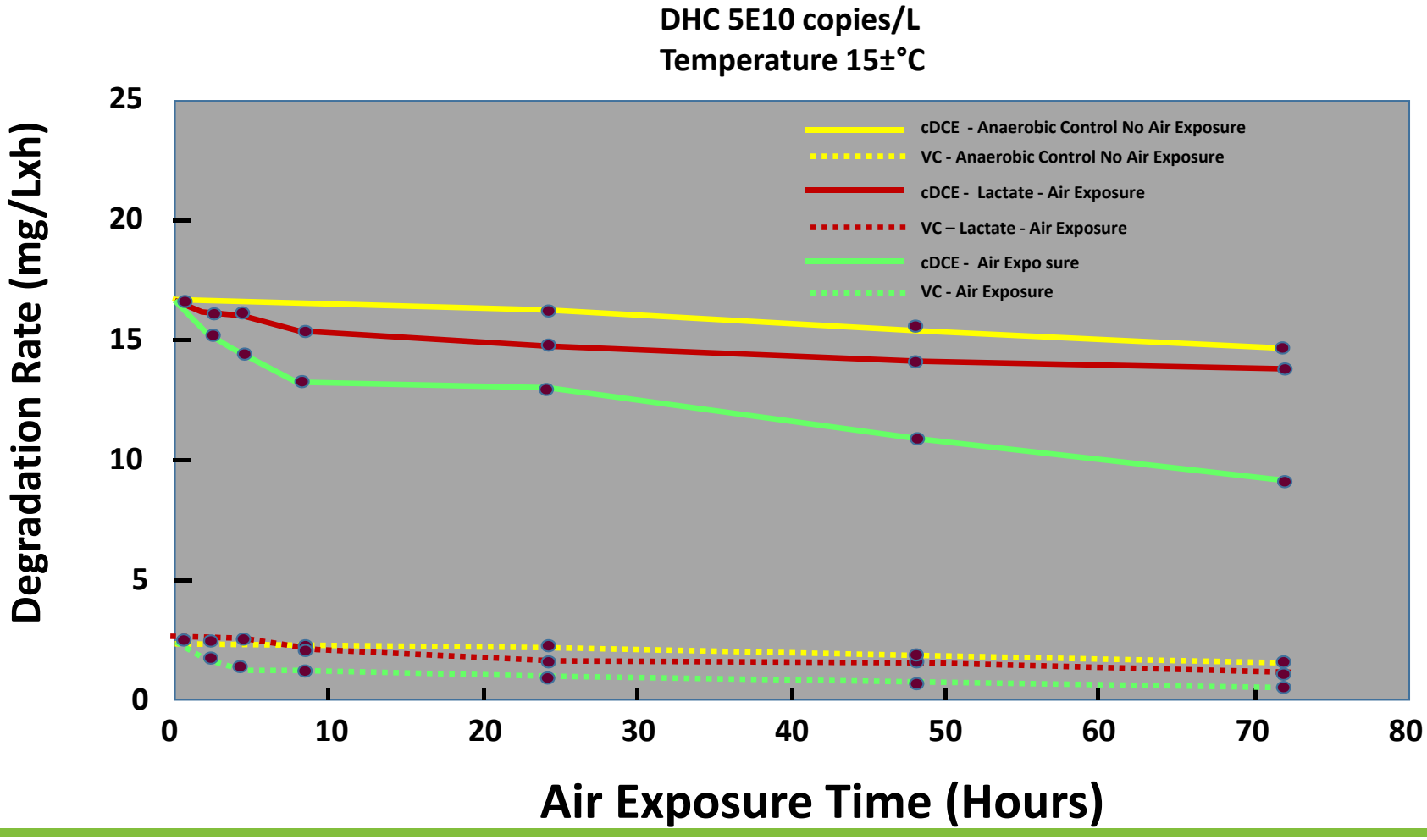

Biogeochemical Issue
High Sulfate Aquifers

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Challenge:

- **Sulfate reduced to sulfide for complete dechlorination**
- **Often, most of substrate is required to reduce sulfate**
- **High concentrations of sulfide are inhibitory to biological activity**
- **Establishment of reducing conditions can mobilize metals.**

Success:

- **Ferrous iron can be added to injection solution.**
- **Ferrous iron acts as electron shuttle to enhance biodegradation.**
- **Precipitates sulfide as reactive iron sulfide.**
- **Inhibits production of methane**
- **Sequesters metals.**

Continuing Challenge: Distribution

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Distribution of substrates remains a significant challenge

Mass of substrate assumed to be distributed evenly over treatment zone.

Substrate generally injected by low flow/pressure through wells or direct injection tools

Substrates also injected by high pressure through direct injection tools (fracking).

Challenges: Low Pressure Injection

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Negative perception of fracking in oil and gas exploration has spilled over into environmental remediation

Used to be able to say fracturing: Now we say high pressure injection.

In some regions, only low pressure injection allowed

Removes some very important remedial options for treatment

Some materials cannot be injected under low pressures.

Low pressure injection often increases injection time, cost, and effectiveness.

Injection contractors may switch to longer screen tools to inject target substrate in a reasonable time.

Injection through wells may be selected

Radius of Distribution
Injection Distance

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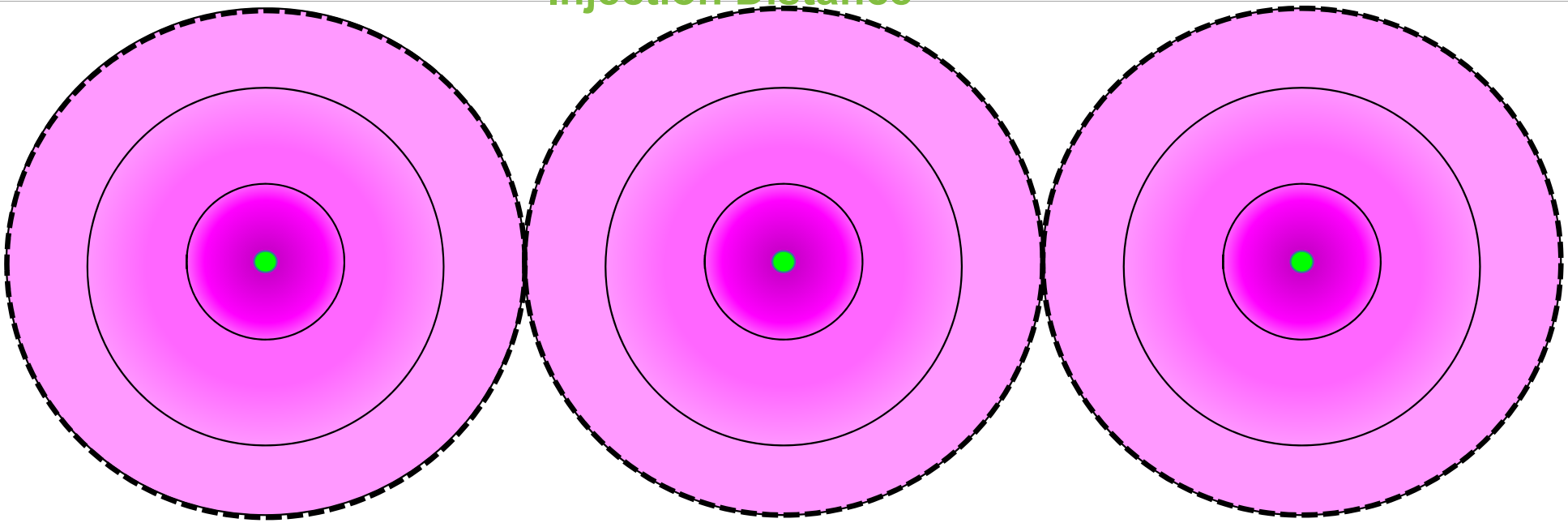

Total θ = 30%

Eff θ = 15%

Assuming Total θ

@10% R = 32 %

@50% R = 71%

@100% R = 100%

Assuming Effective θ

@5 % R = 32%

@25% R = 71%

@50 % R = 100%

Post Injection Distribution

Advective Transport and Dispersion

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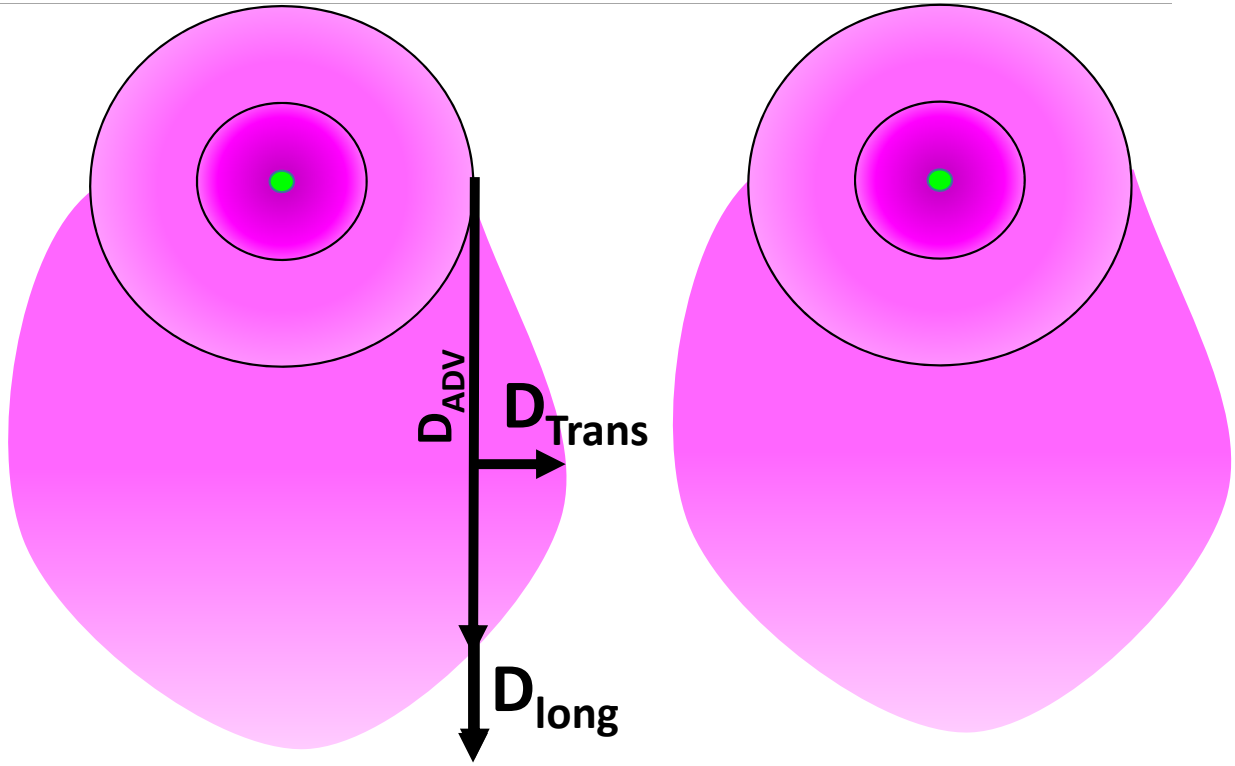
Factors Enhancing Distribution

- Groundwater Flow Rate
- Dispersion
- Diffusion

Factors Limiting Distribution

- Substrate Bioavailability
- Substrate Partitioning
- Aquifer heterogeneity



$$D_{long} = 0.1\ D_{ADV}$$

$$D_{trans} = 0.3\ D_{long}$$

Hydraulic conductivity controls distribution by low flow injection through long screens or wells

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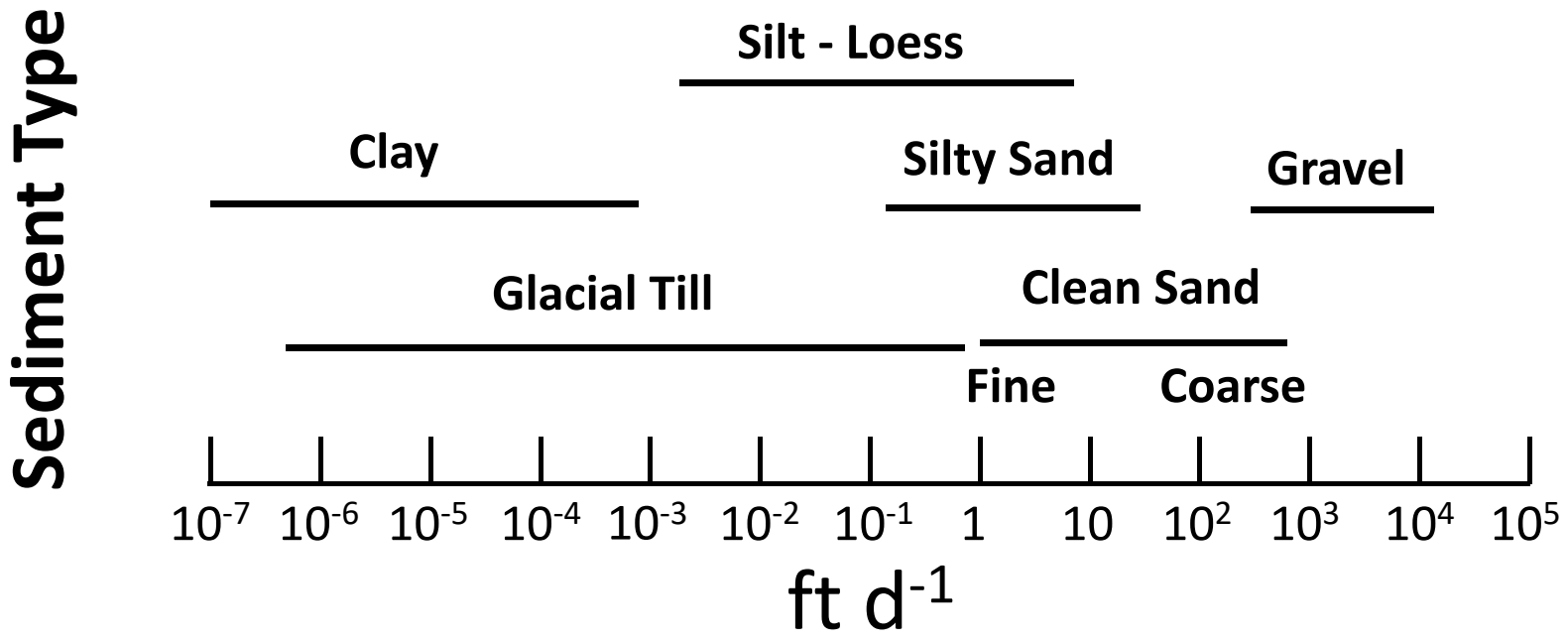
Hydraulic Conductivity of Selected Sediments



USGS Water Supply Paper 2220

Aquifer Heterogeneity Partially Controls Substrate Distribution

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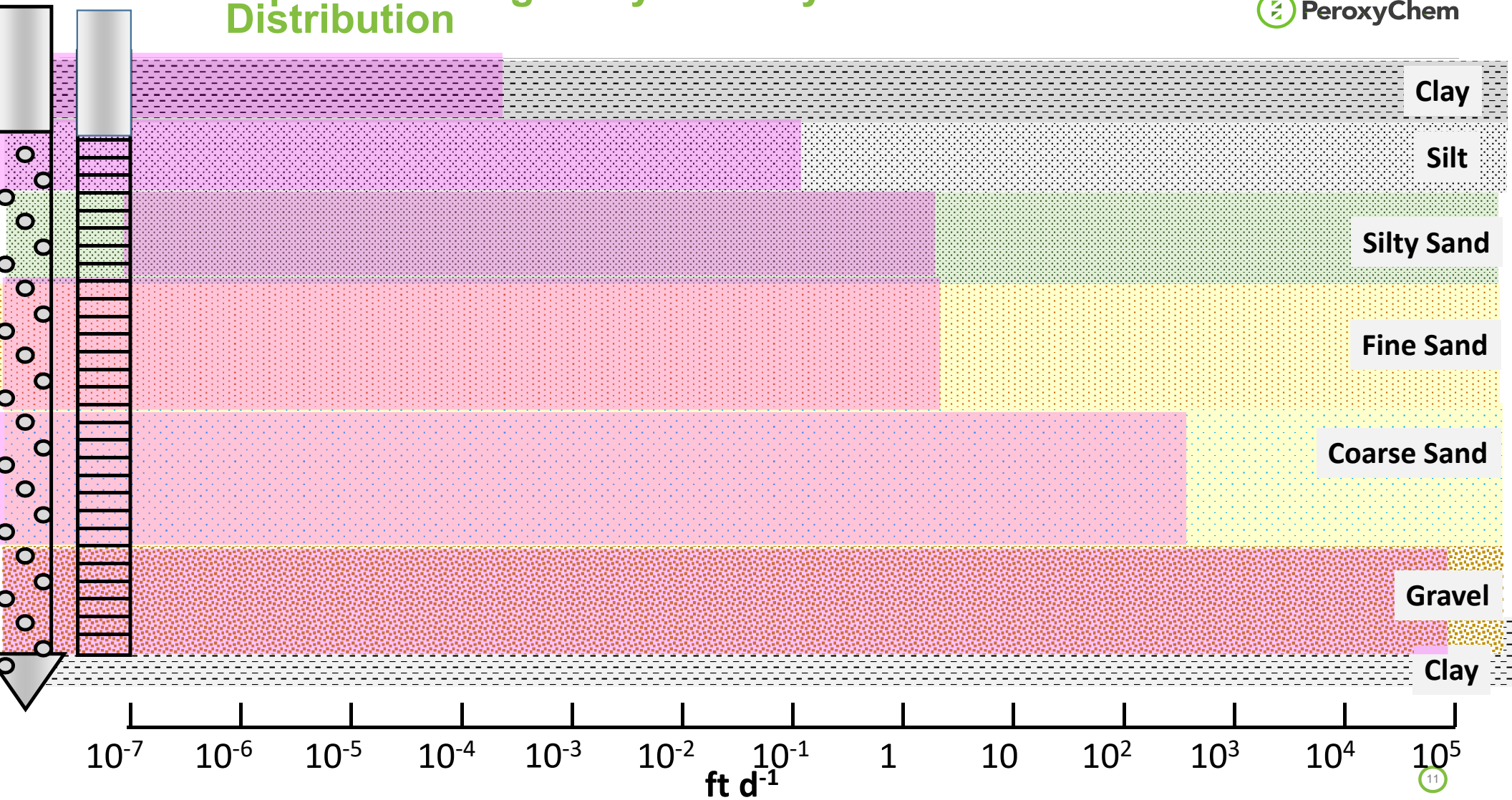

Aquifer Heterogeneity Partially Controls Substrate Distribution

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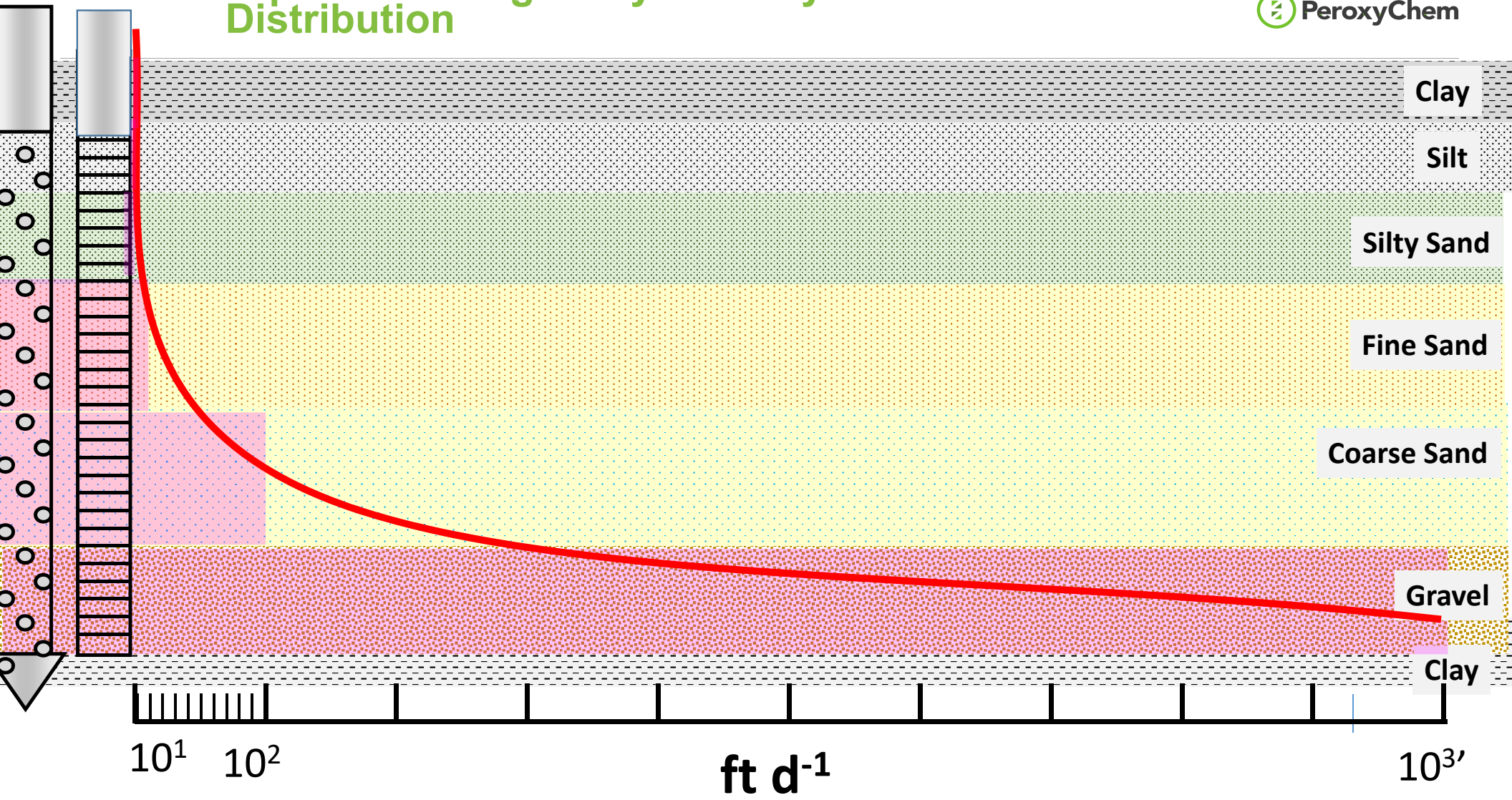

f_{oc} Partially Controls Contaminant Distribution

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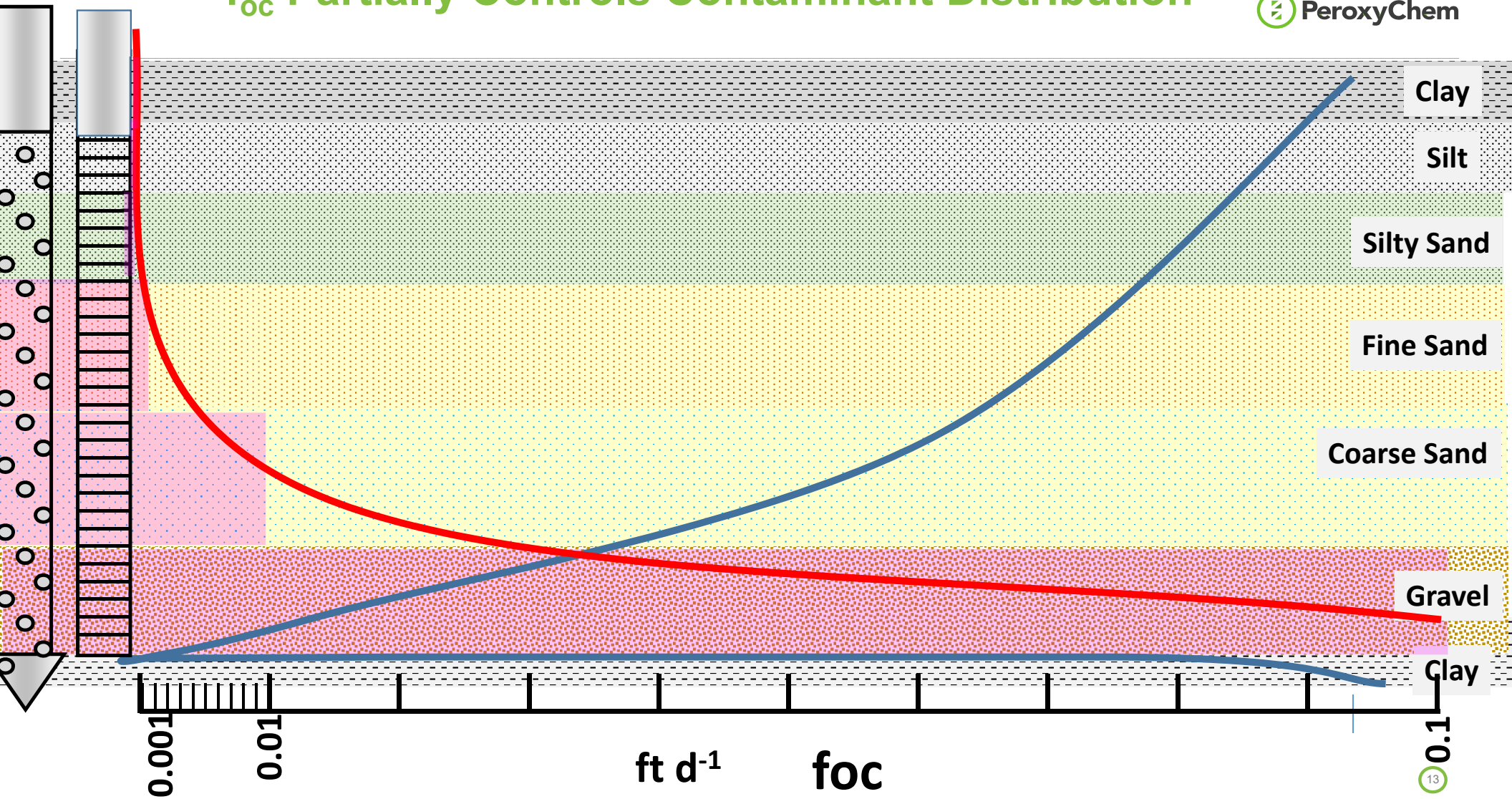

Where Are We Now

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Application of one amendment (Dhc) substantially changed this technology

Resulted in generation and modification of many guidance documents

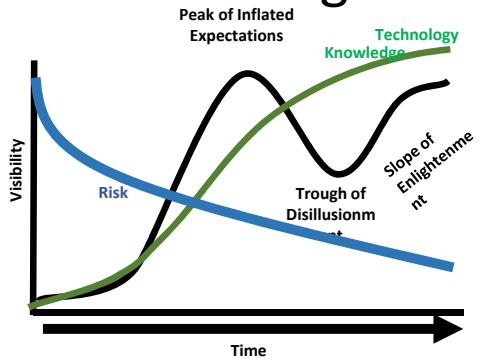
Major challenge has been and continues to be distribution of substrates

We may be going backwards (no high pressure injection)

Advancements in technology but no modifications of guidance documents

Many new amendments being added to this process without guidance documents

- Activated carbon
- Antimethanogenic materials
- Biogeochemical substrates



Questions?

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