Using Mass Discharge to Predict Attainable Goals and Timeframes

By Grant R. Carey[1,2] and Dr. Edward A. McBean[2]

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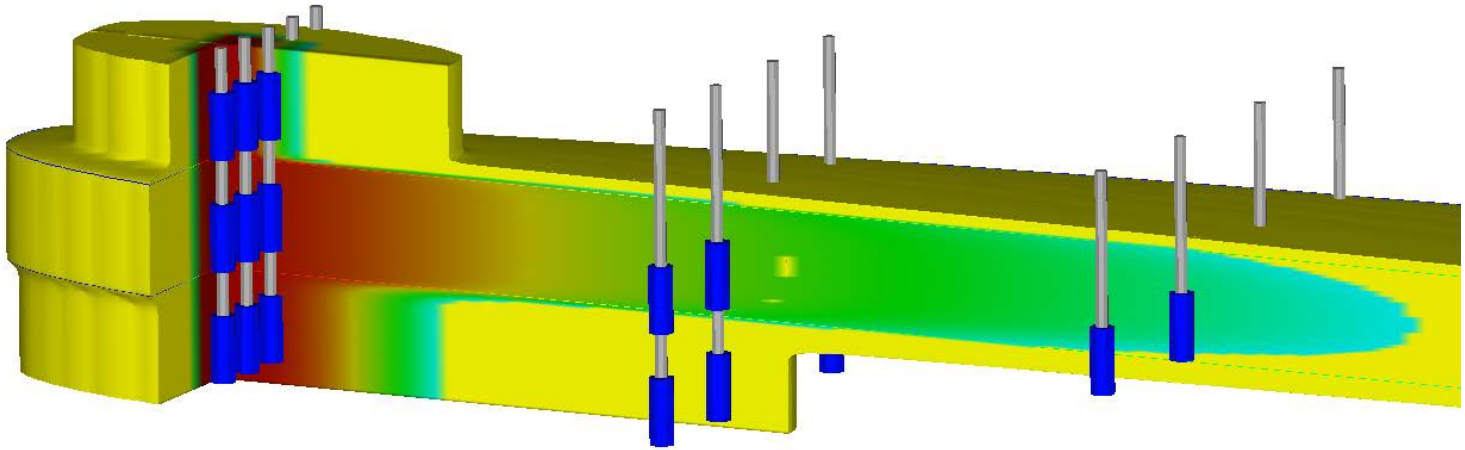

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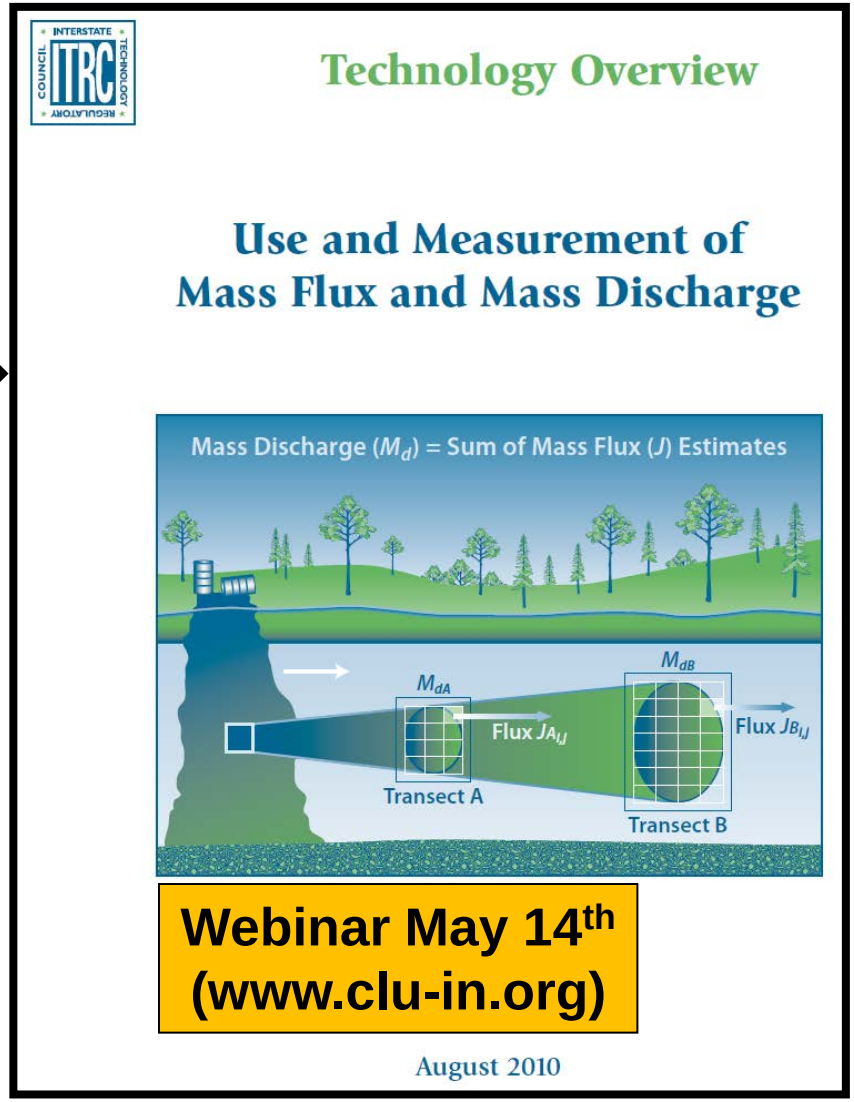
Presented at the 2013 RemTec Summit in Colorado.

Introduction

- NAPL challenges
- Mass Discharge
- ITRC Overview
- Remediation
  1. Attainable Goals
     - Back-diffusion
  2. Timeframe



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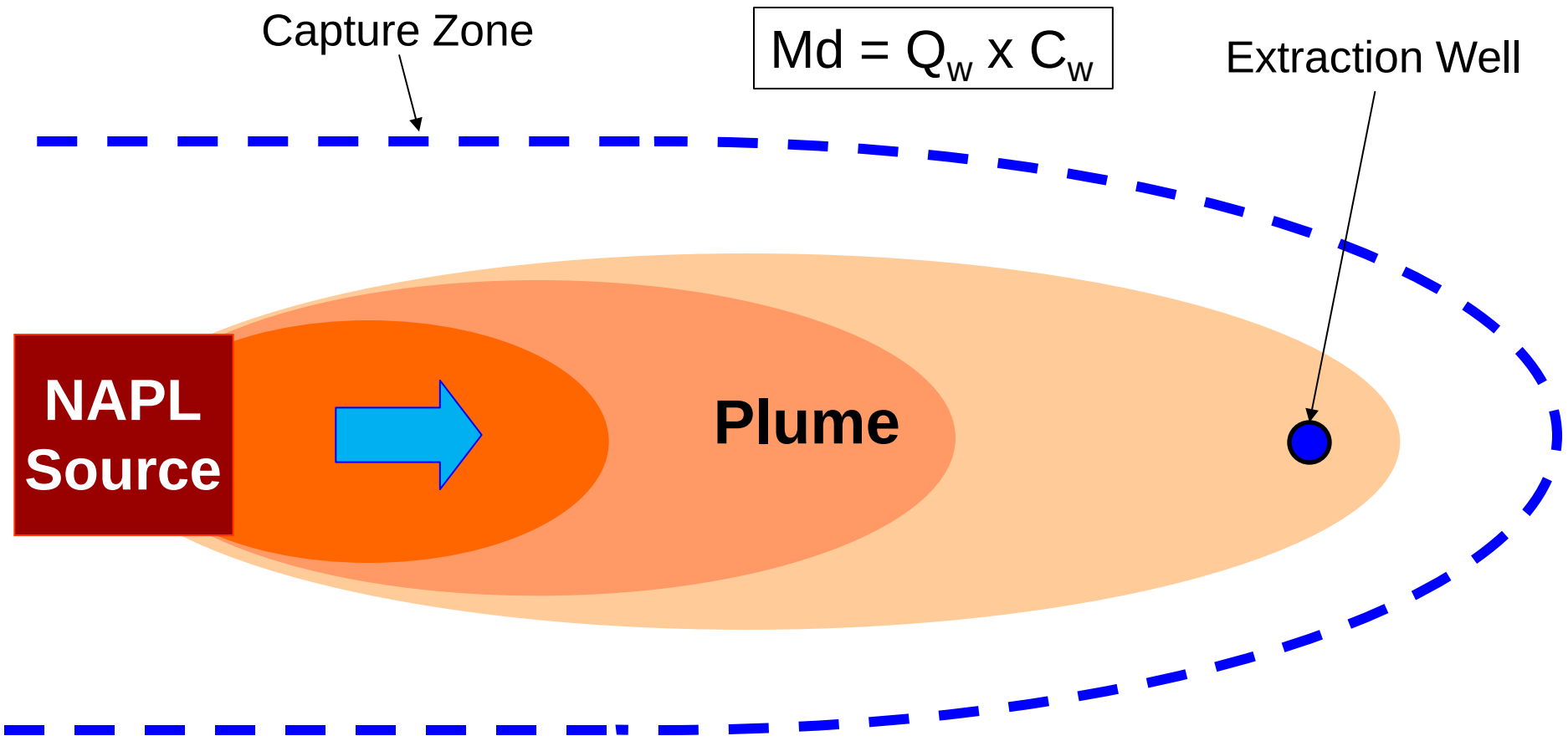
Mass Discharge (Md) = Source or Plume Strength



Source Strength governs plume length and risk.

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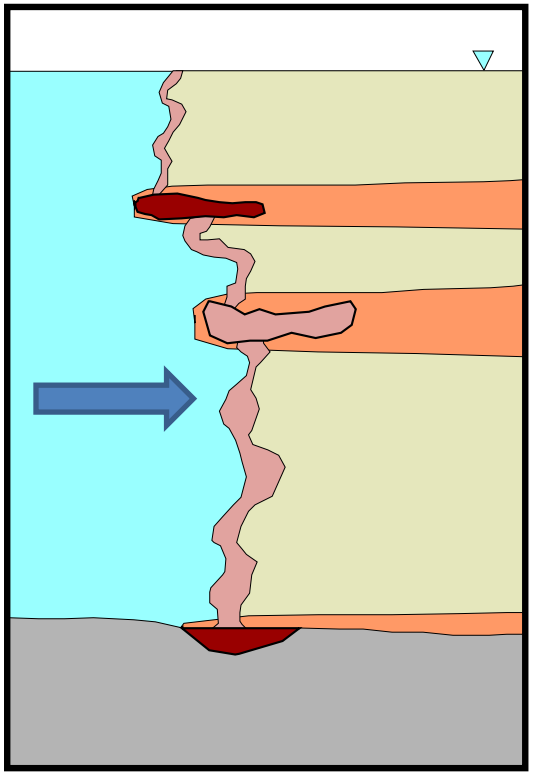
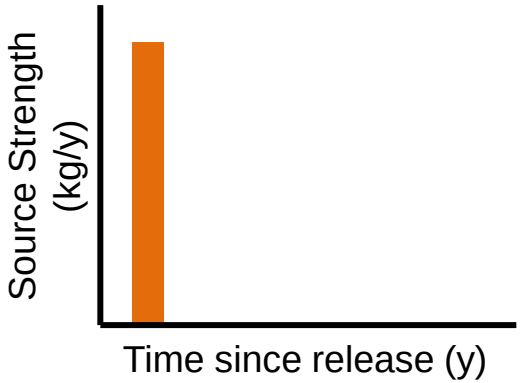
Mass Discharge Trends

Fresh Source





Fresh Source Characteristics

- Large NAPL thickness
- High *ganglia* to *pool* ratio
- High source strength
- Rapid reduction vs. time

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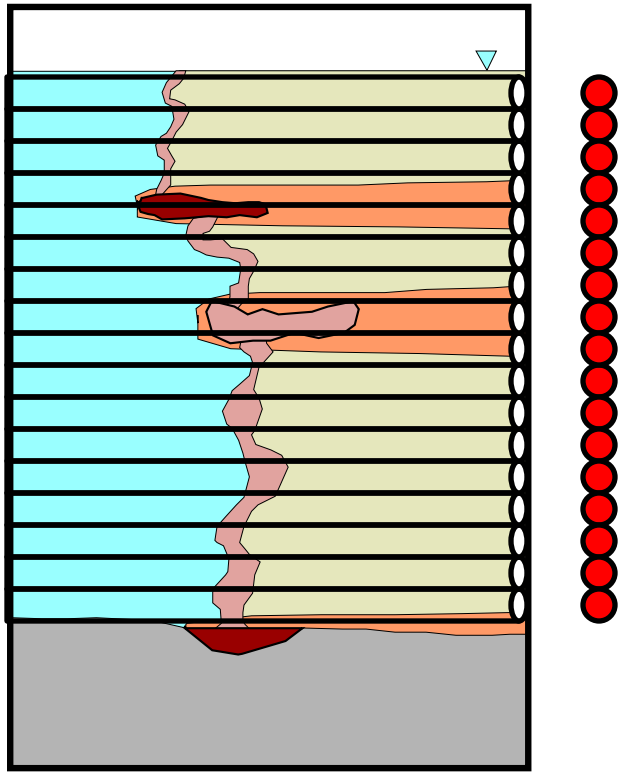
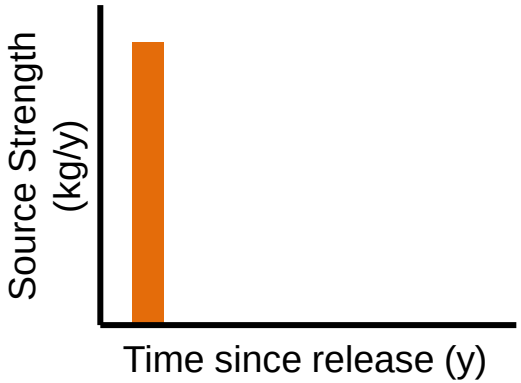
Mass Discharge Trends

Fresh Source





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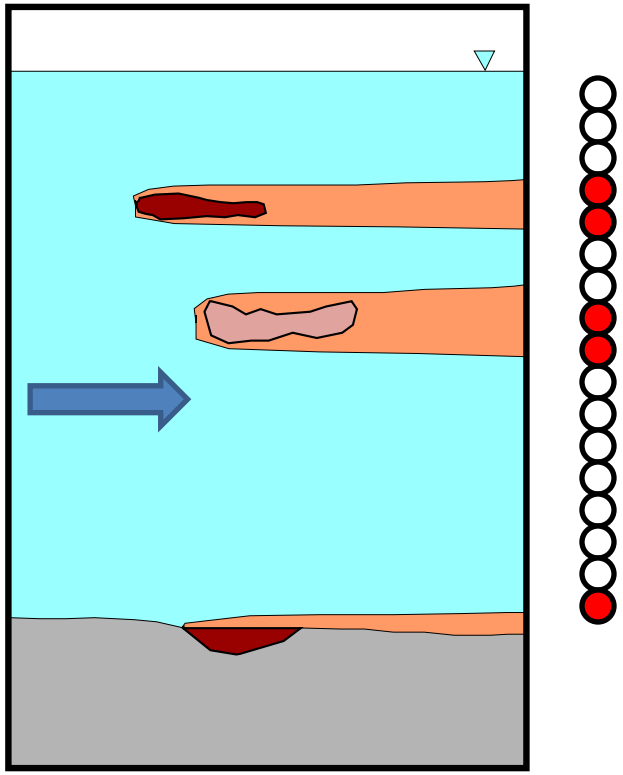
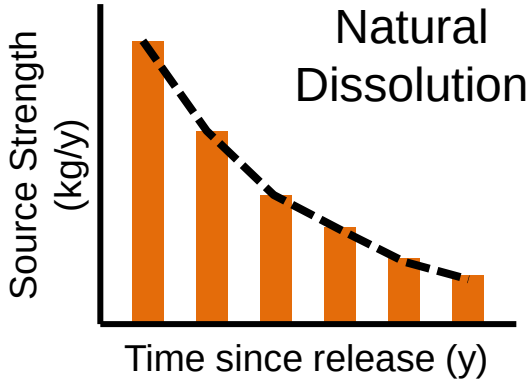
Mass Discharge Trends

Aged Source





Aged Source Characteristics

- Occasional NAPL lenses
- Low *ganglia* to *pool* ratio
- Lower source strength
- First-order or linear decline

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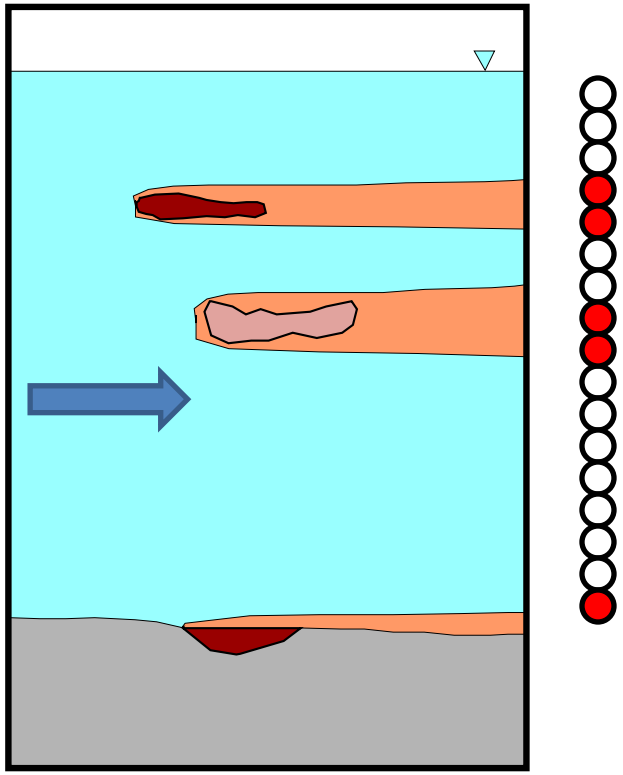
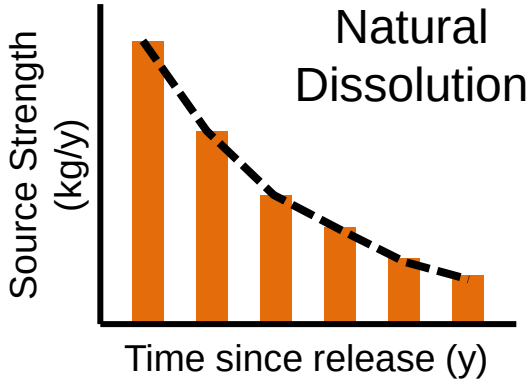
Mass Discharge Trends

Aged Source





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NATURAL vs. ENHANCED dissolution – What is attainable?

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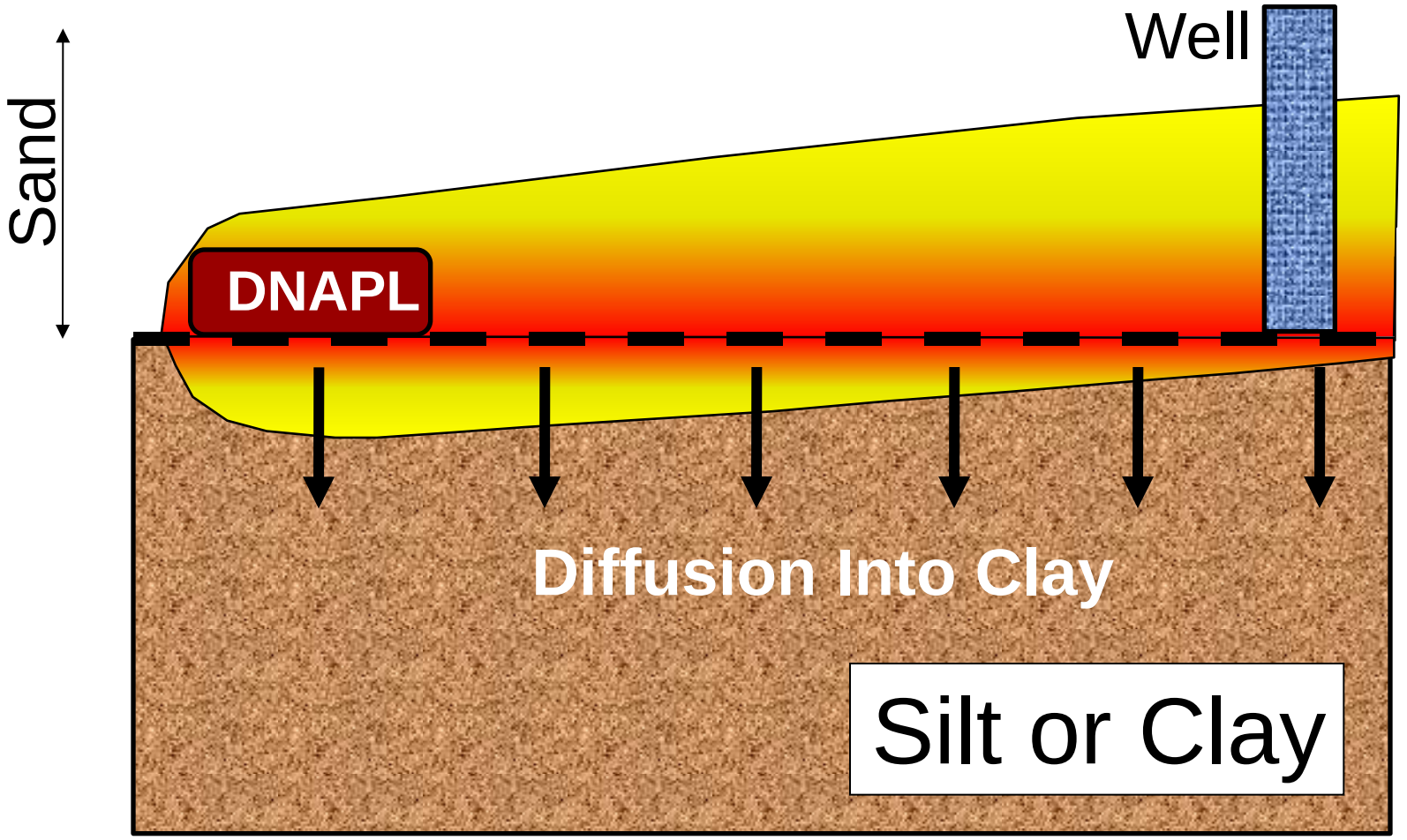
Back-Diffusion Limits Md Reduction



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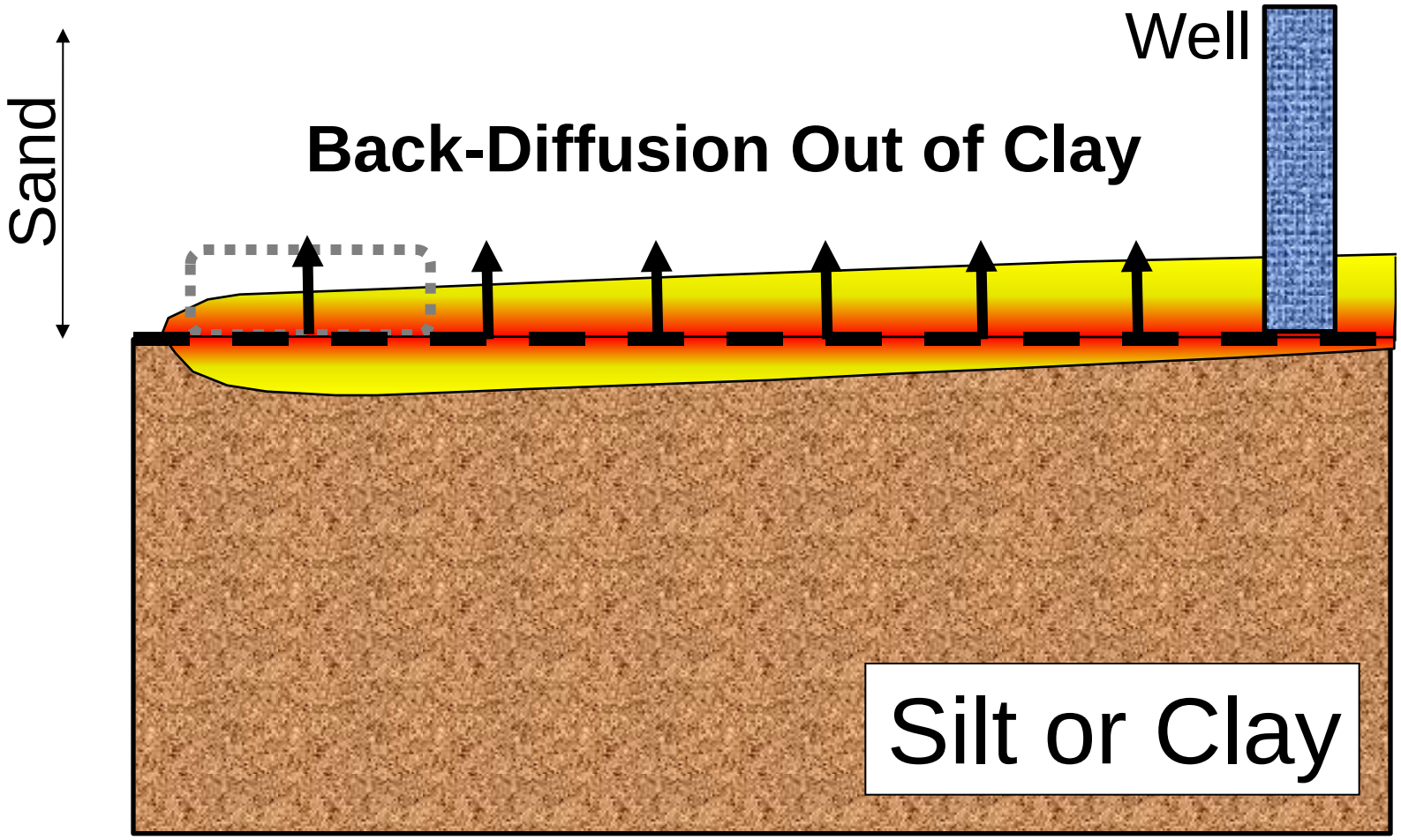
Back-Diffusion Limits Md Reduction



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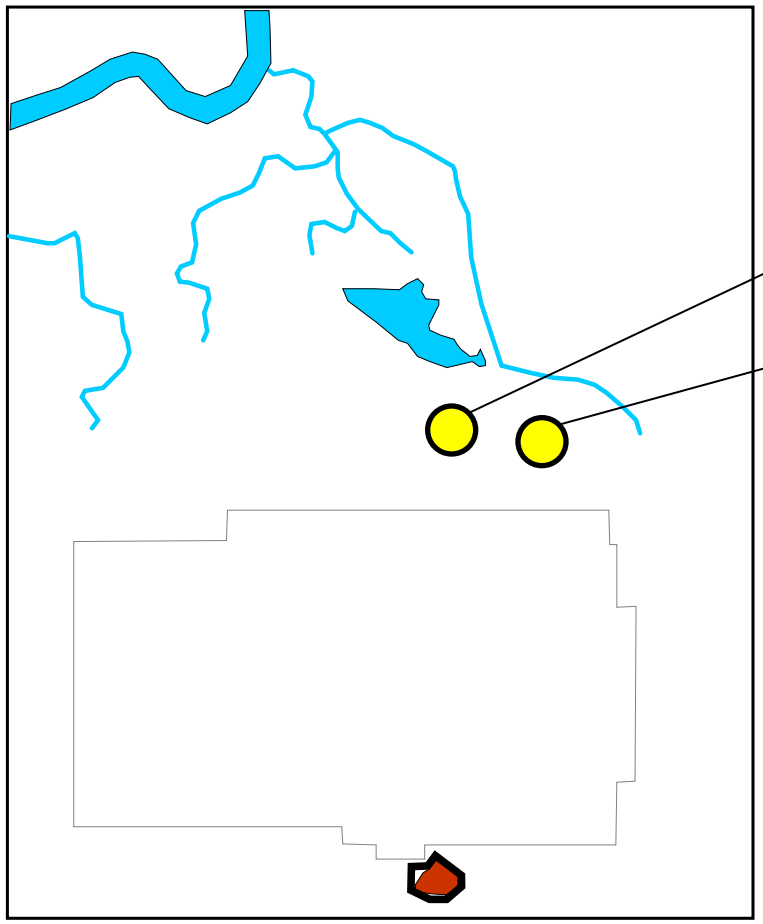
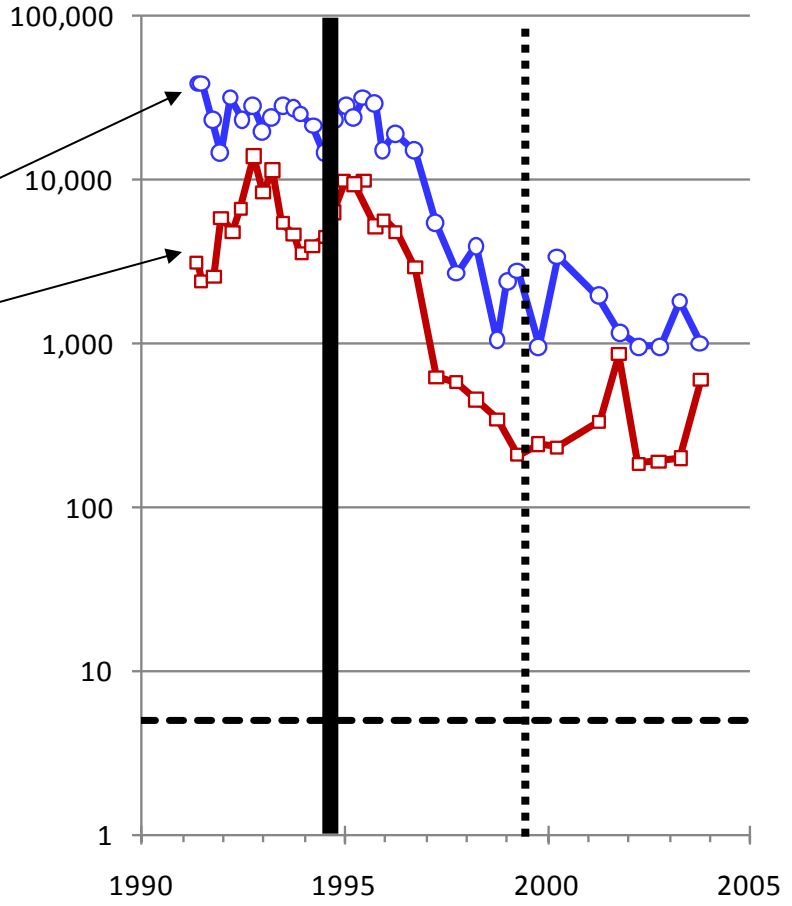
Connecticut Site (Chapman & Parker, 2005)

Md = 30 kg/y from back-diffusion



DNAPL Source Zone



Concentration reduction stalled at 93% (15x)

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Attainable Mass Discharge Goals

- Stroo et al., 2012, ES&T:
  - 90% to 99% Md reduction
  - Achieving MCL is rare
  - Technology-based Md reduction (meta study review)
- Option to model back-diffusion Md
- More reliable vs. concentration goals (less uncertainty)

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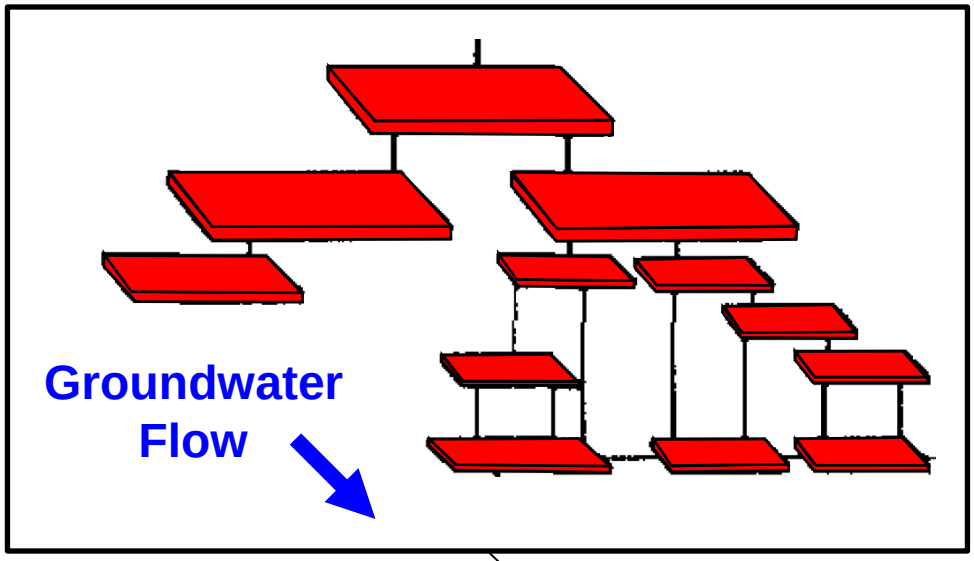
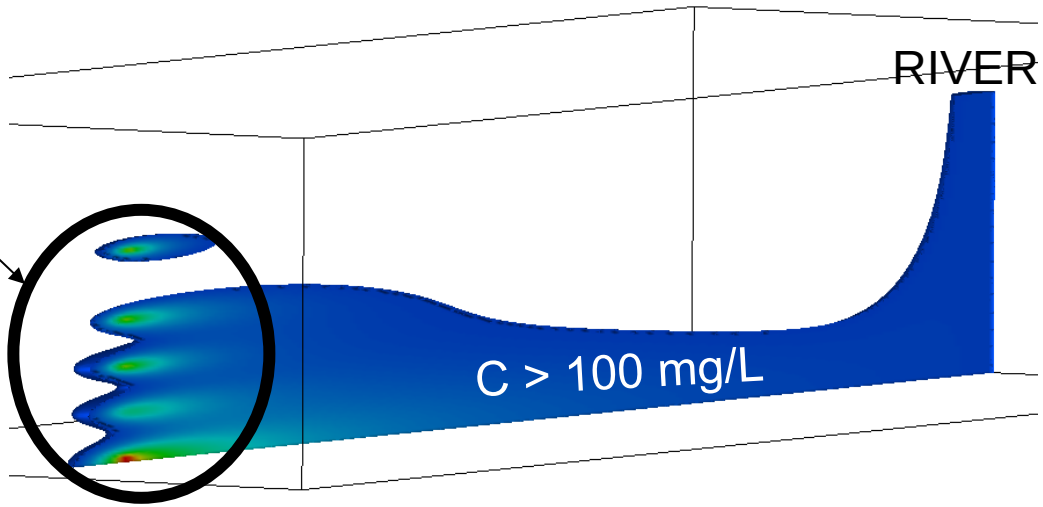
How long to reach goals?



Modified from Anderson et al., 1992

Which characteristics have the greatest influence on timeframe?



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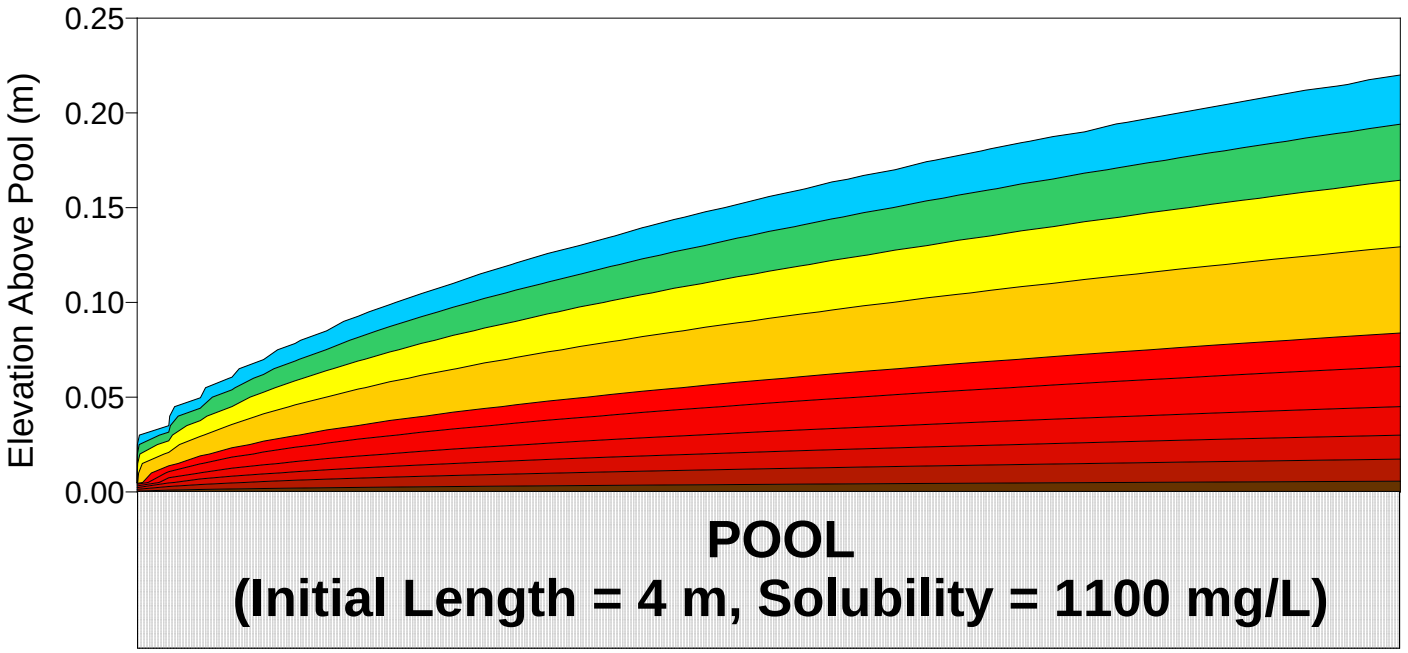
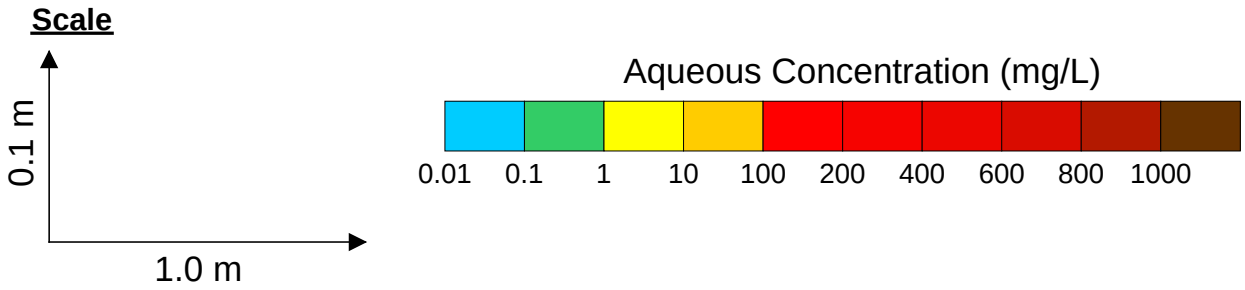
NAPL Depletion Model (NDM)

Hunt et al., 1988



M_d = 1.4 kg/y
per metre width



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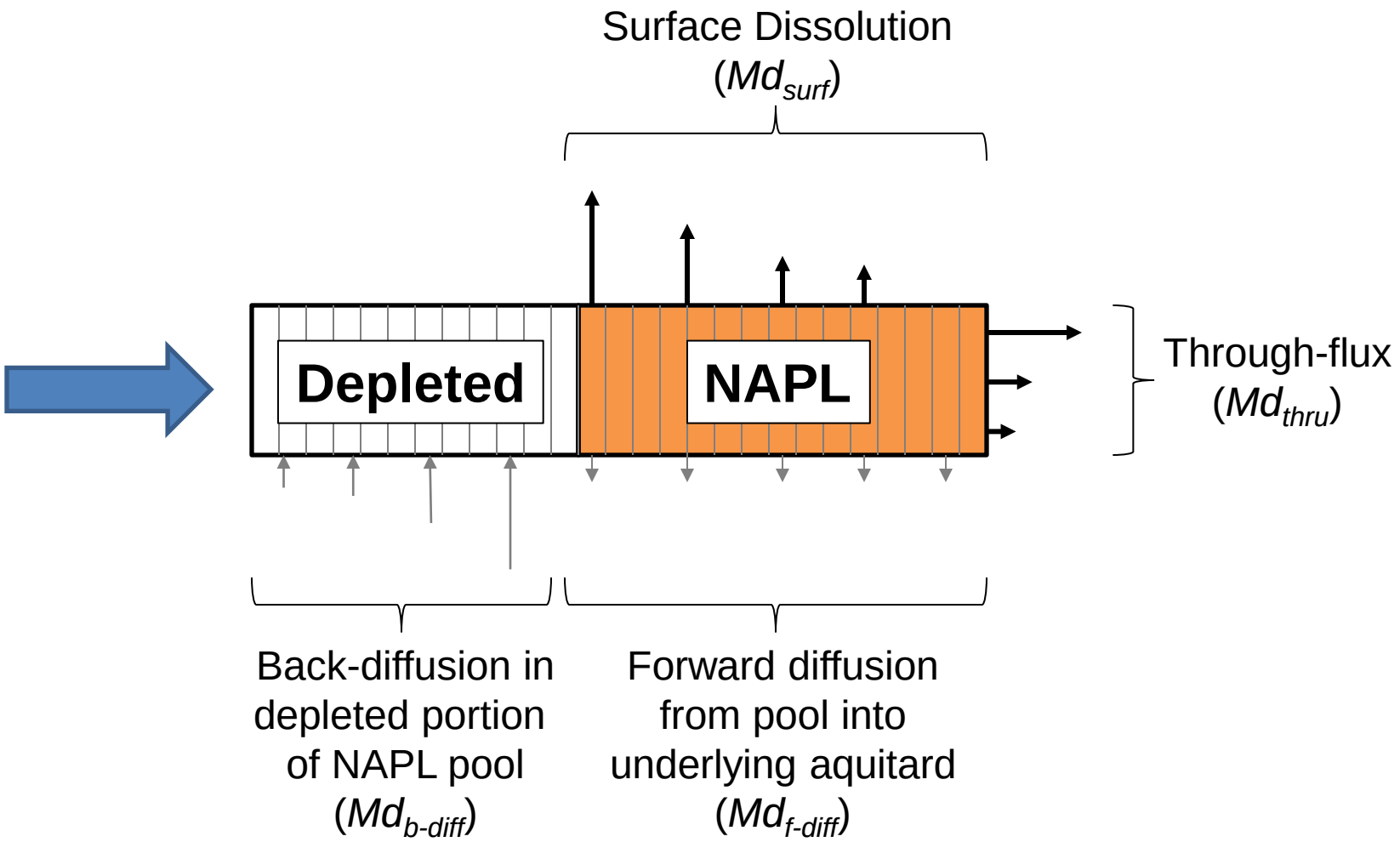
NAPL Depletion Model (NDM)



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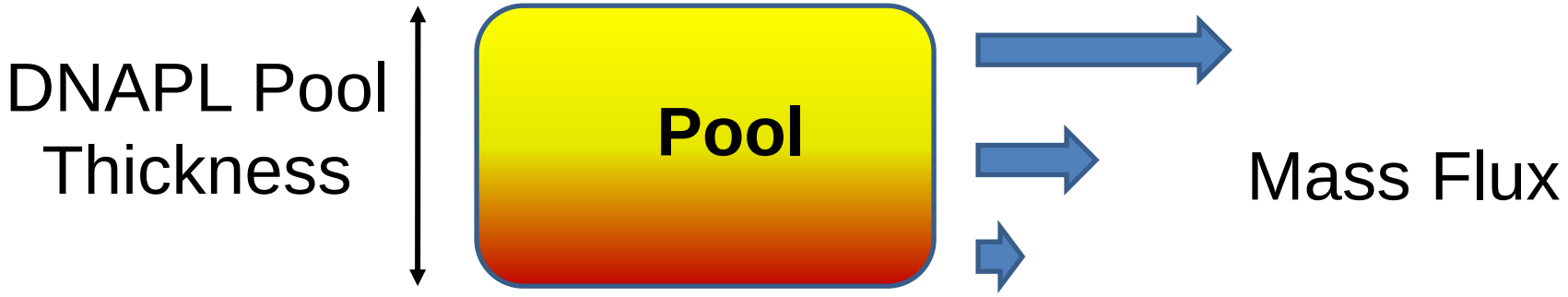
NAPL Depletion Model (NDM)

- Natural and enhanced dissolution
  - MNA / PRB, EISB, Strategic P&T
- Semi-analytical approach
  - Hunt et al. (1988) solution – surface flux
    - Declining length vs. time
  - S_n and flux vs. depth (pool)
  - Changes in groundwater velocity
  - Multi-component NAPL

DNAPL Dissolution



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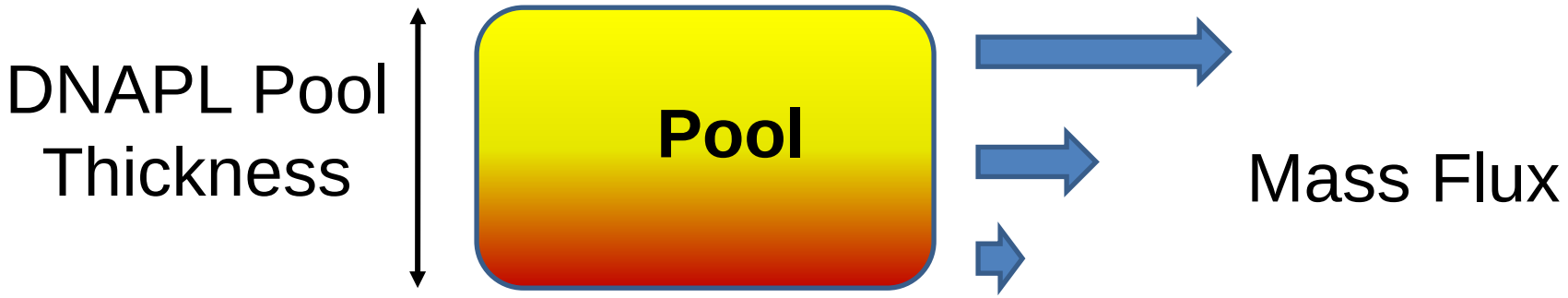
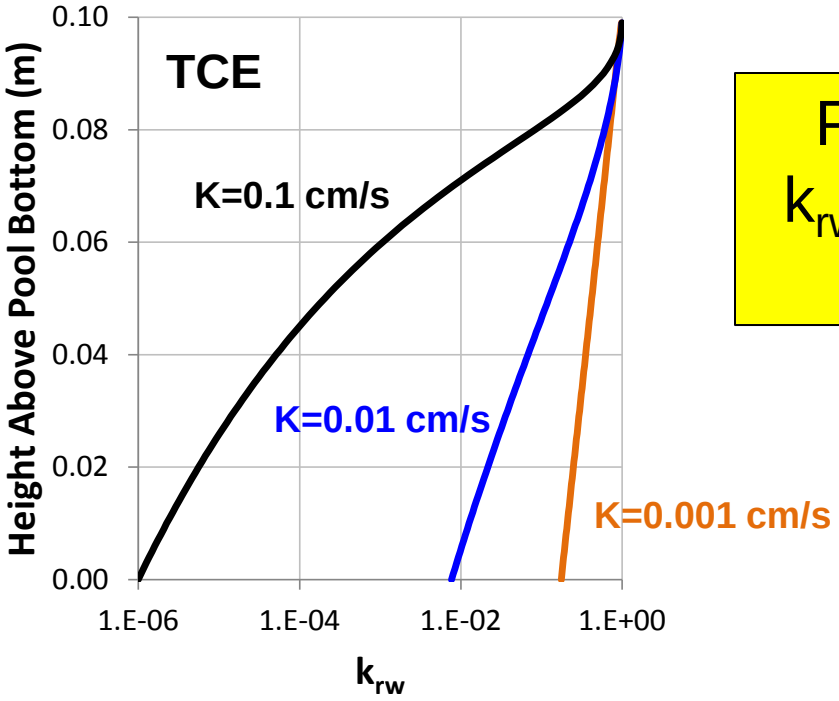
DNAPL Dissolution





Pc-Sw parameters influence k_{rw} and mass in pools, and are proportional to K_s.

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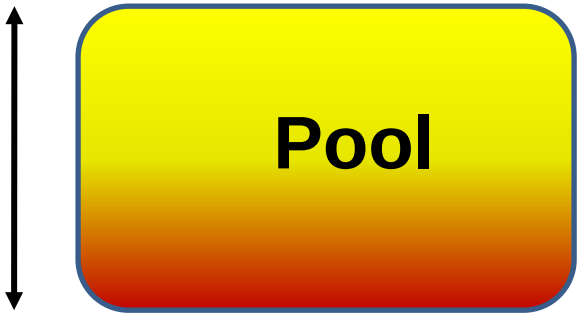
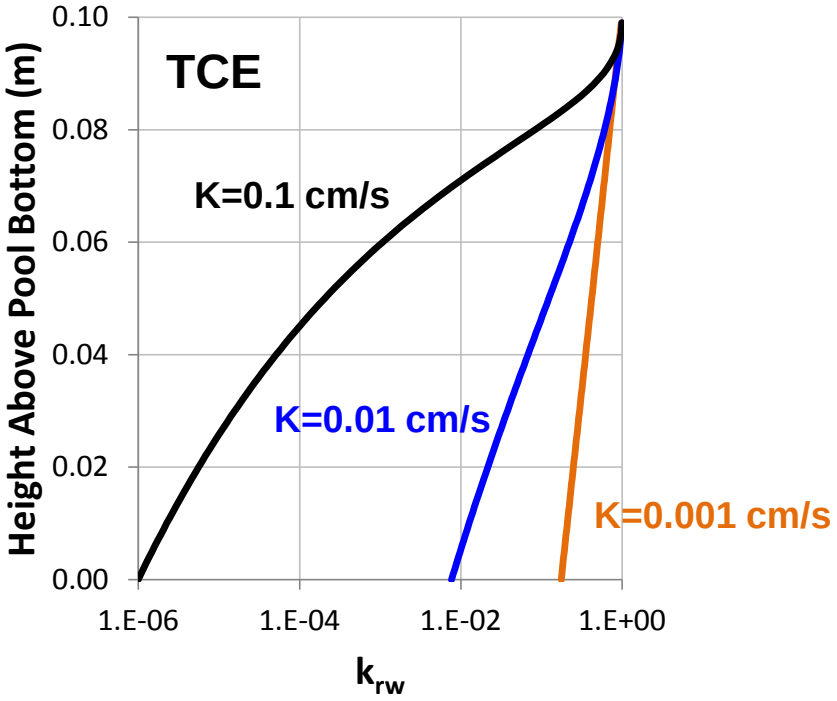
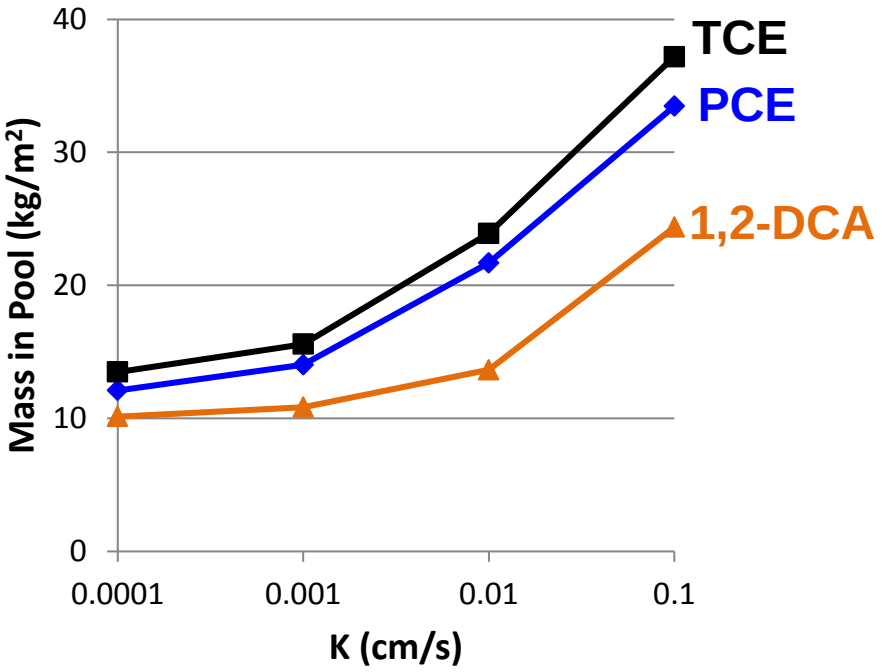
DNAPL Dissolution

DNAPL Pool Thickness



Mass Flux





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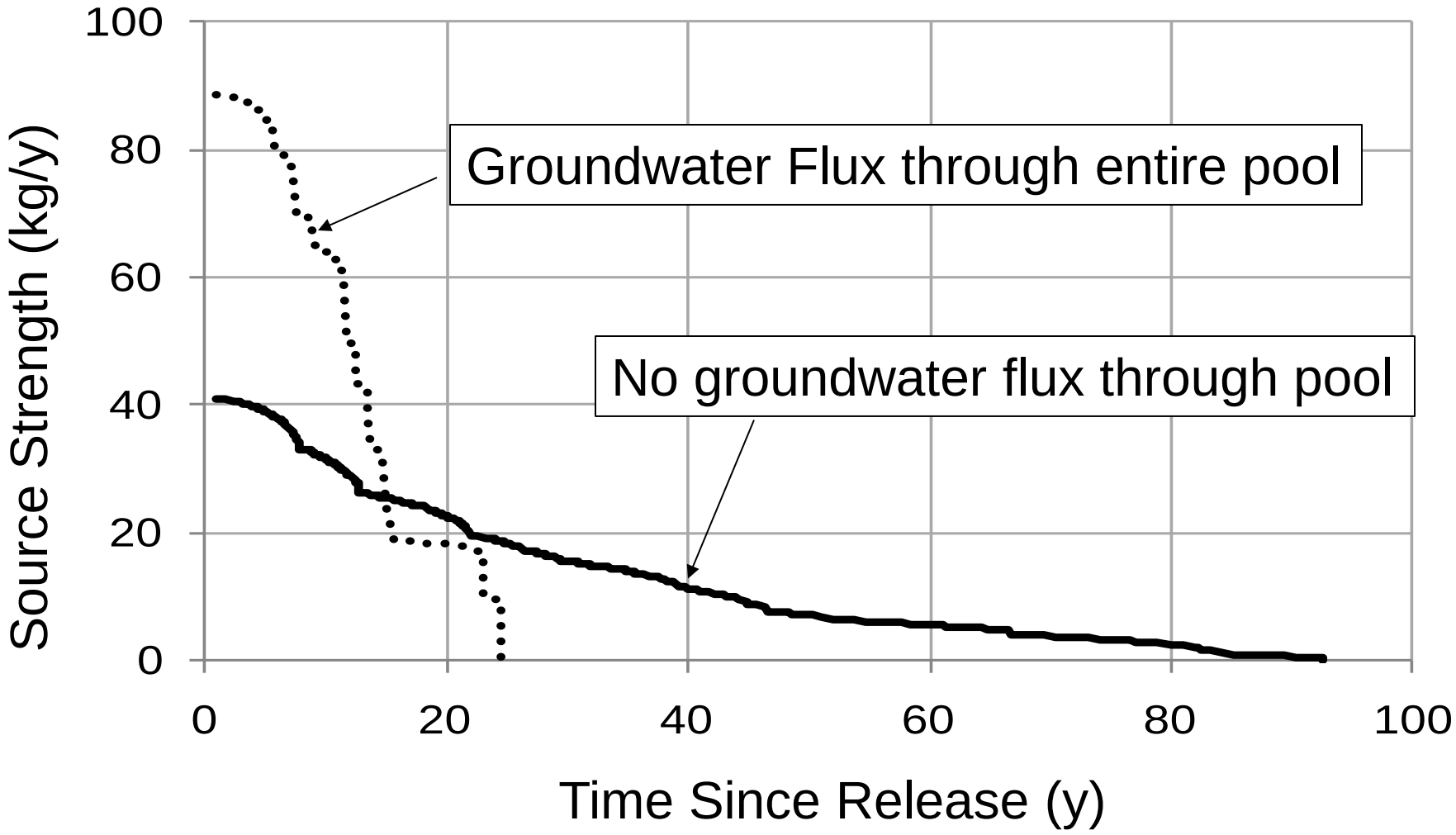
Influence of Through-Flux on Md



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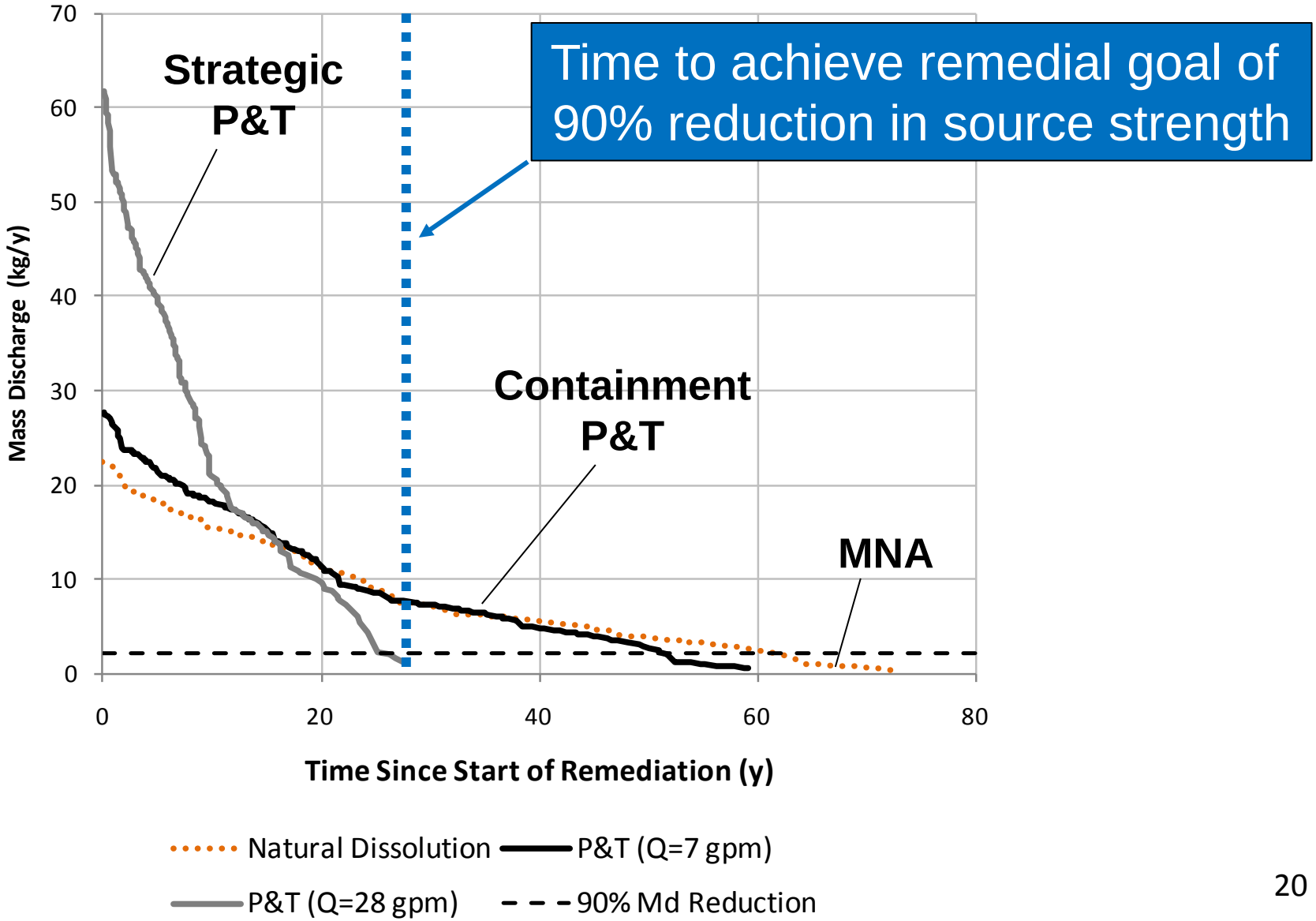
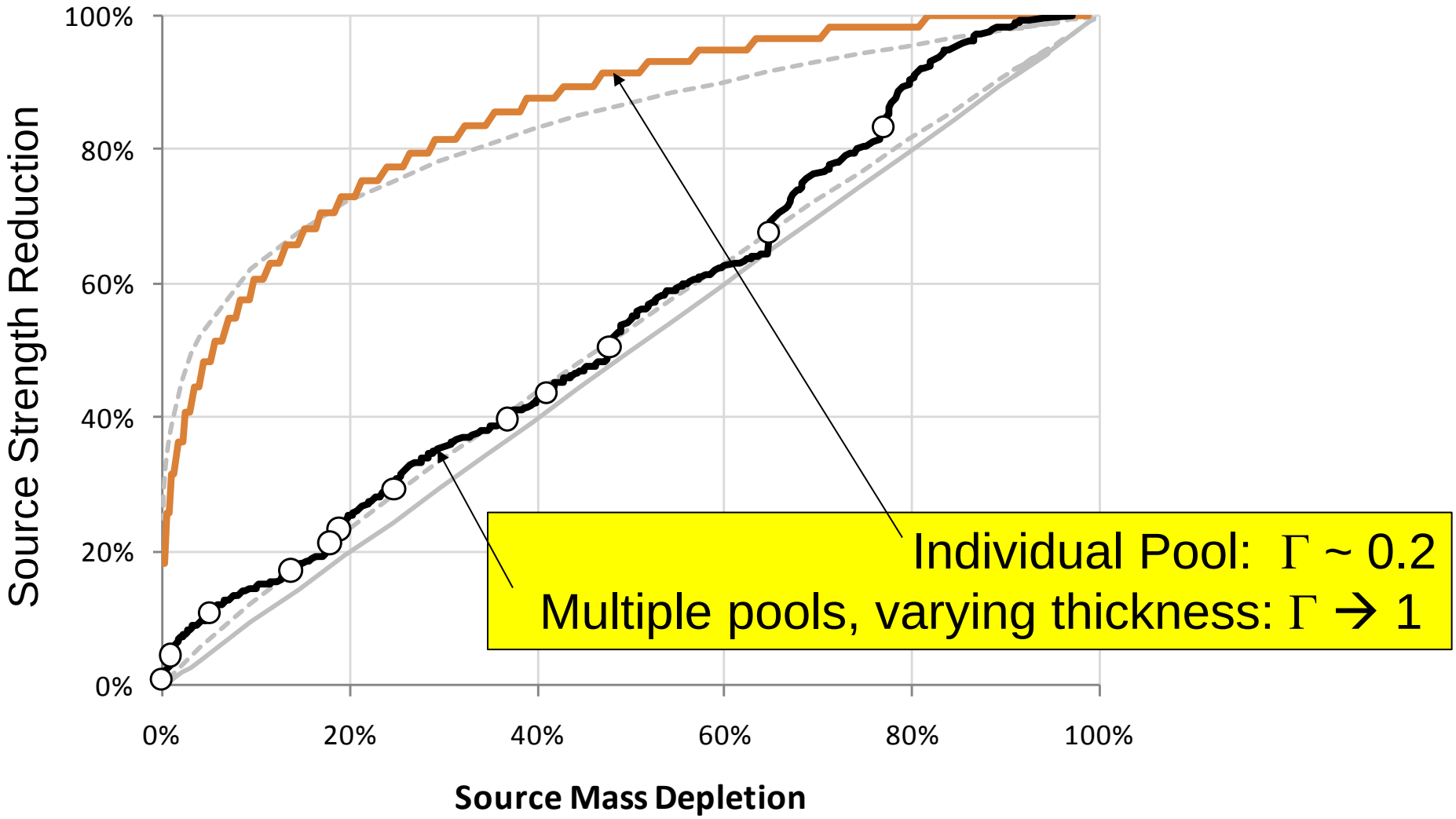
Relative Remediation Timeframes



Source Strength vs. Source Mass



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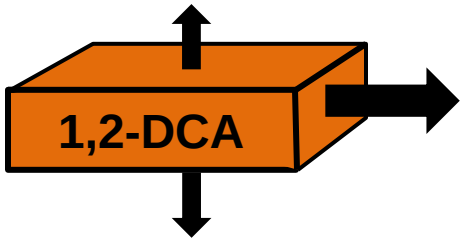
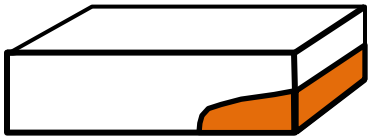
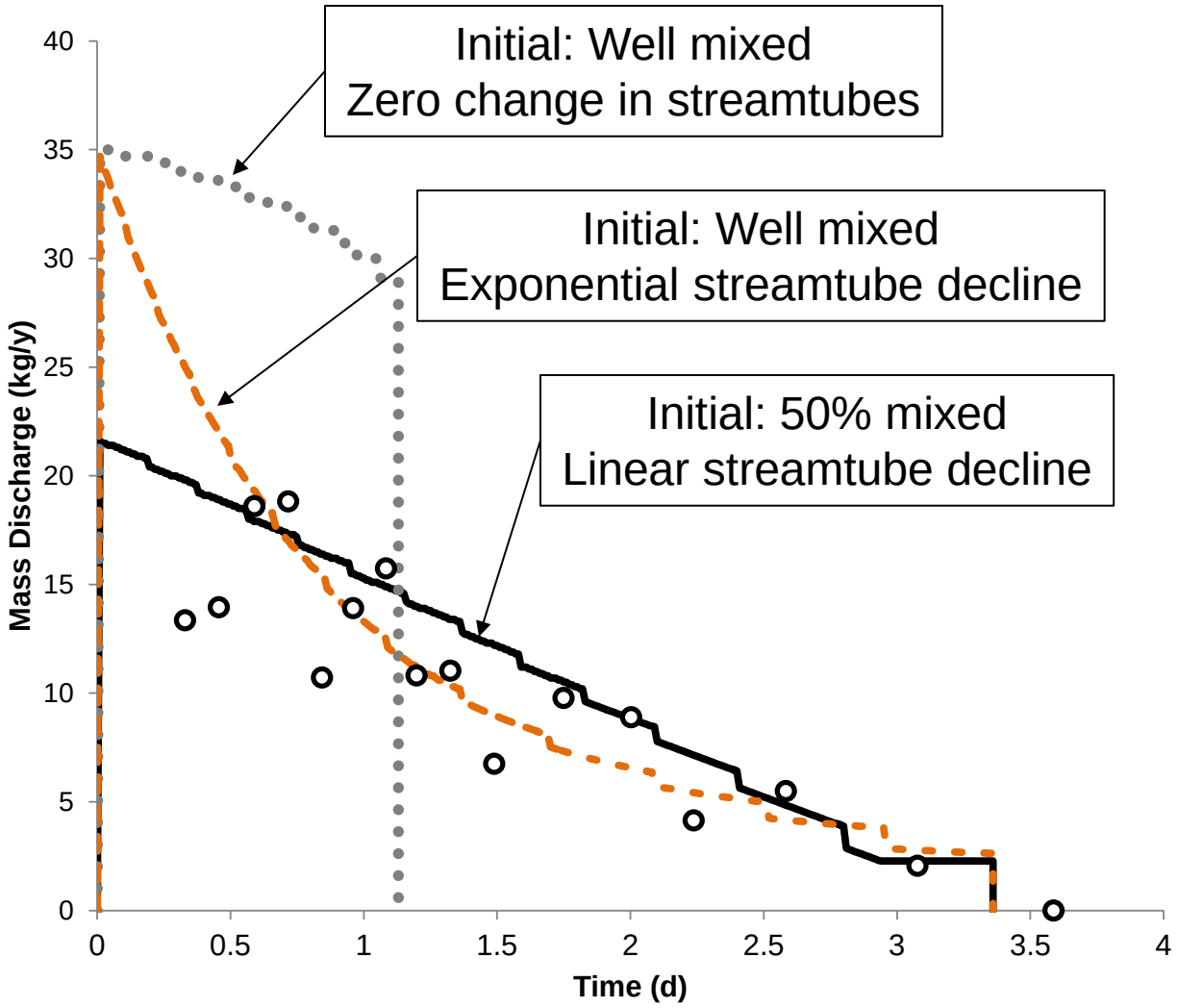
NDM Validation to Lab Studies
Brusseau et al., 1992 (Residual 1,2-DCA)

Initial Zone



Thinning Profile





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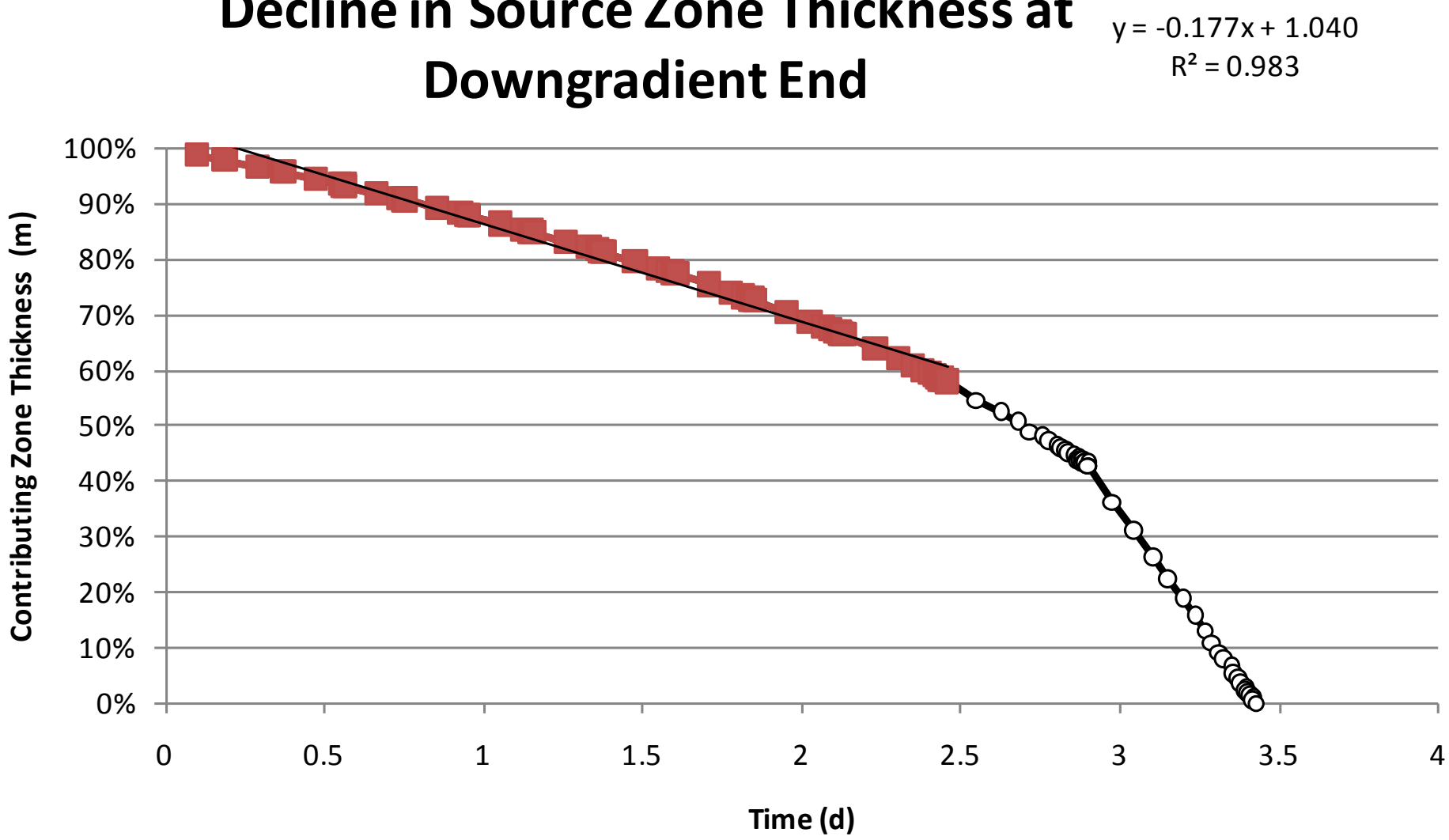
Decline in Source Zone Thickness at Downgradient End



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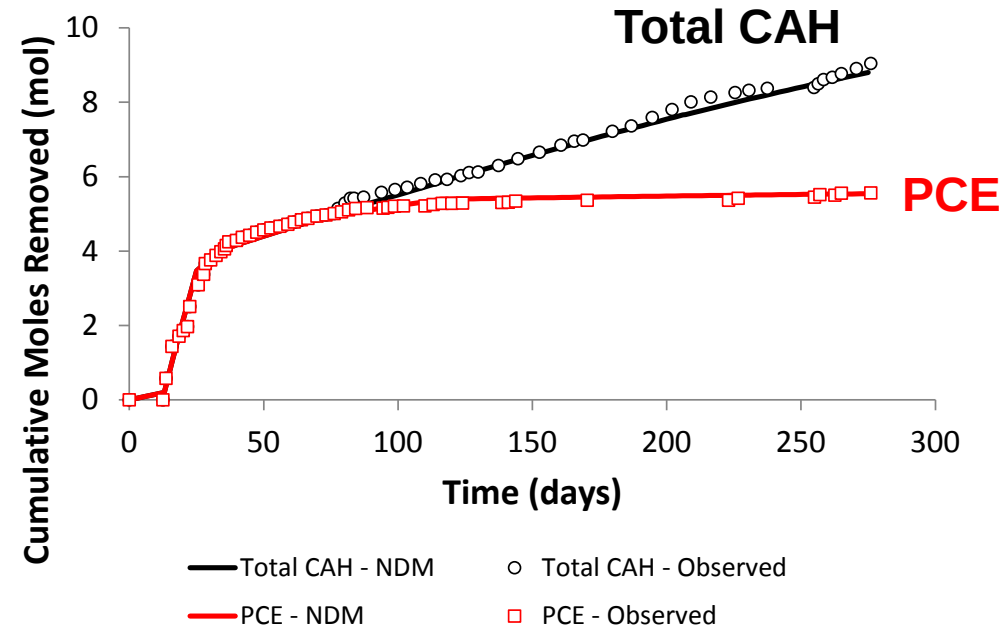
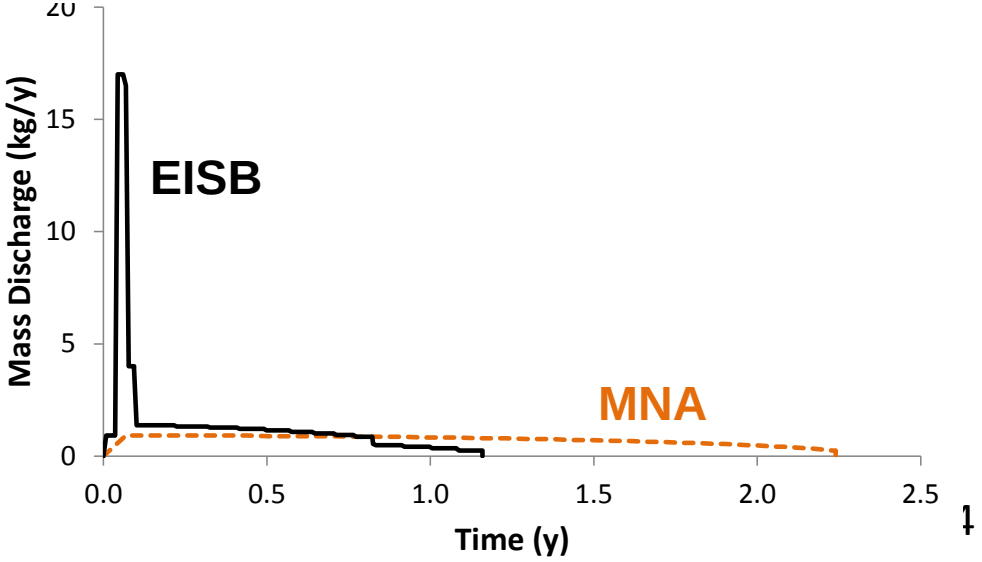
NDM Validation to Lab Studies
Ward et al., 2009 (EISB of PCE Pool)

Ward, 2009, ESTCP ER-0438





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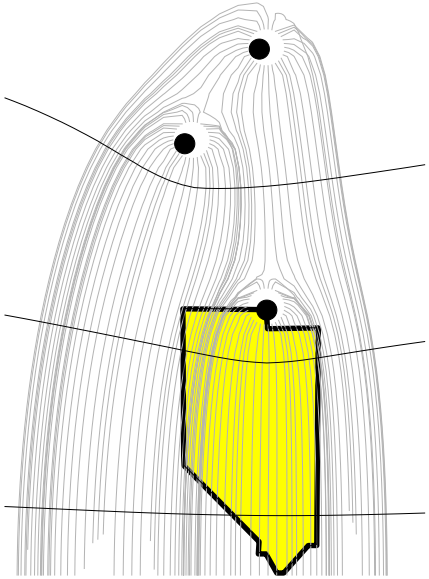
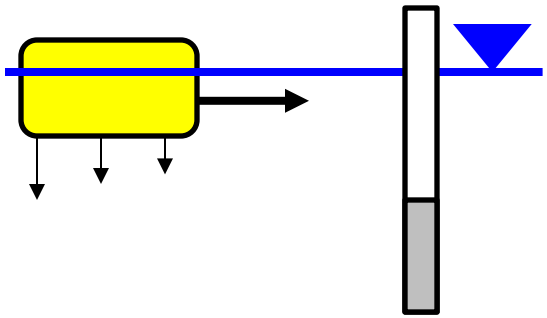
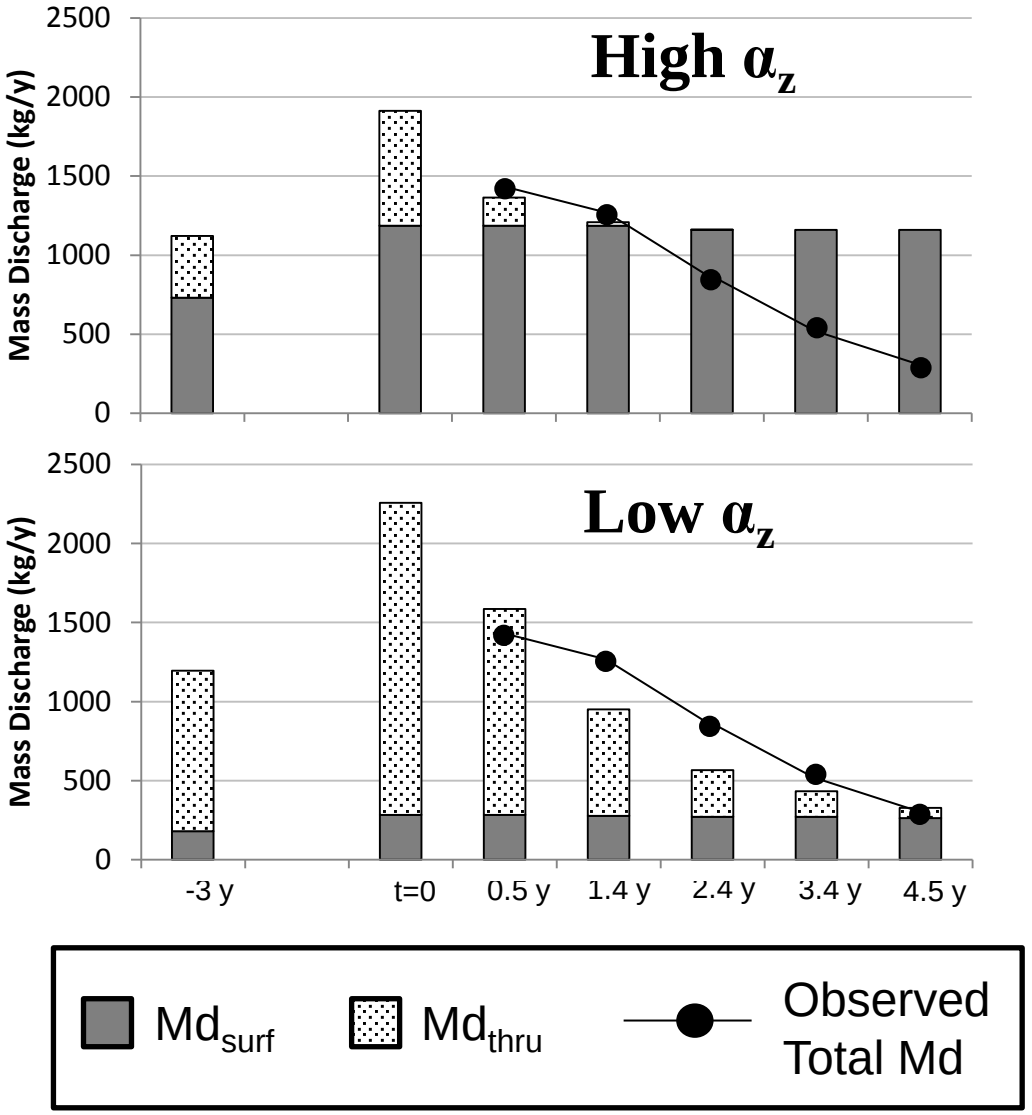
NDM for Forensic Analysis of LNAPL Architecture Schafer and Therrien, 1995 Field Study



Case I:
Initially thin
with fast decline
in thickness

Case II:
Initially thick
with slow decline
in thickness





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Summary

- Md is a remediation game-changer!
- Easier to define attainable goals
  - Empirical evaluation, B-D models
- NAPL Depletion Model (NDM): Md vs t
  - Understanding dissolution dynamics
  - Timeframe (natural and enhanced diss.)
  - NAPL architecture forensic analysis

Thanks for Your Attention!

Contact to Receive NDM:

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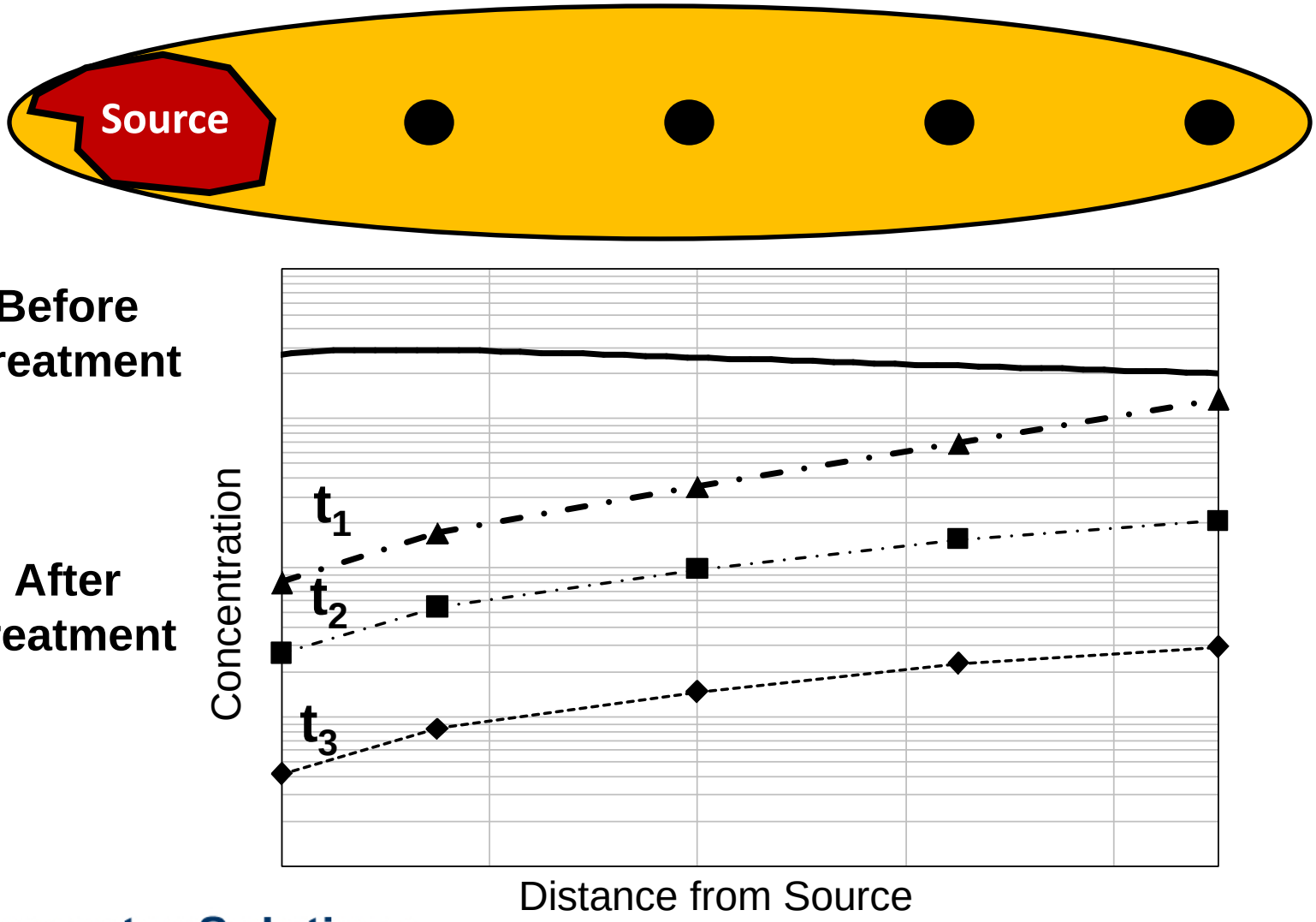
Back-Diffusion Trends



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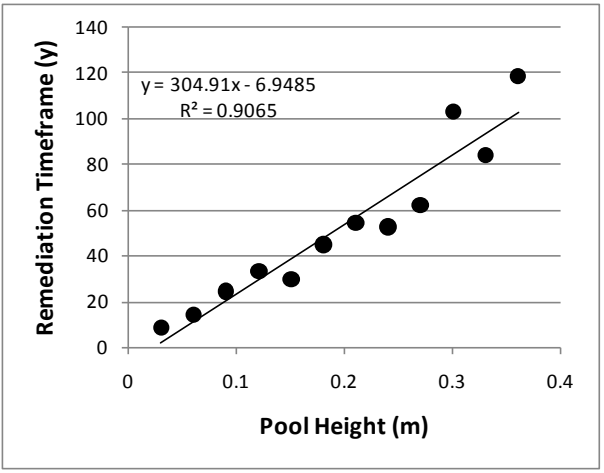
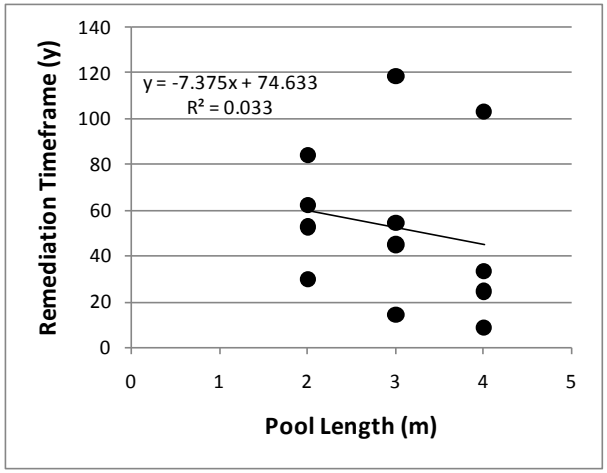
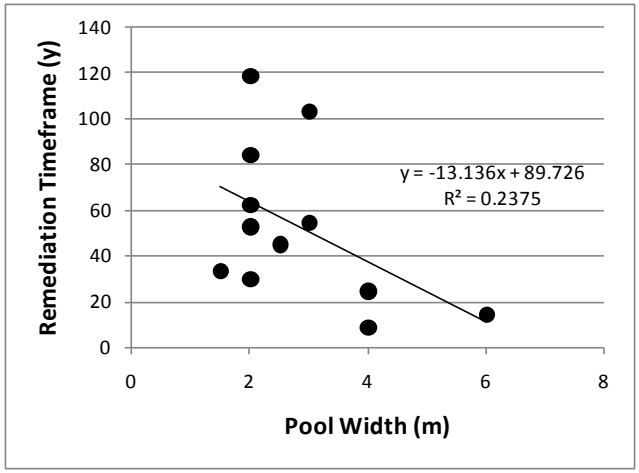
NDM Options

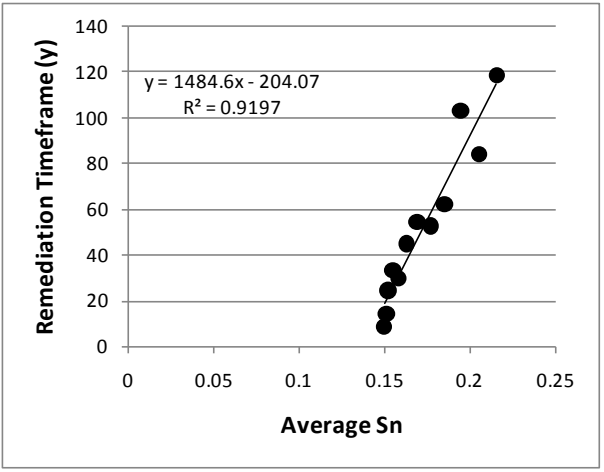
- Through-flux multiplier (0 to 1)
- Through-flux interfacial area decline
  - i.e. # streamtubes intercepting NAPL
  - Constant, linear, or exponential model
- Dissolution only after depletion of upgradient or overlying zone
- Enhanced dissolution factor
- Daughter product ratio

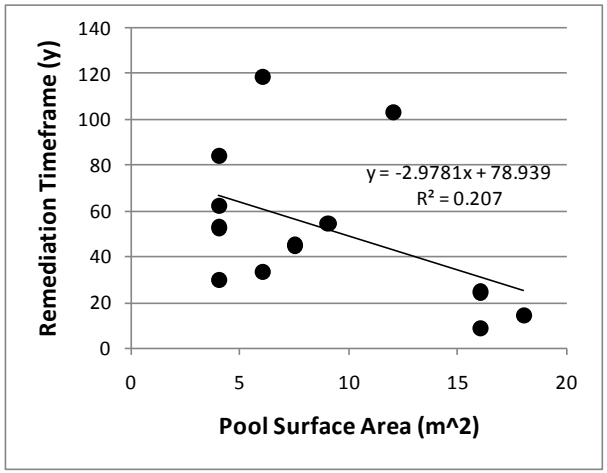
RTF Correlation with Pool Properties

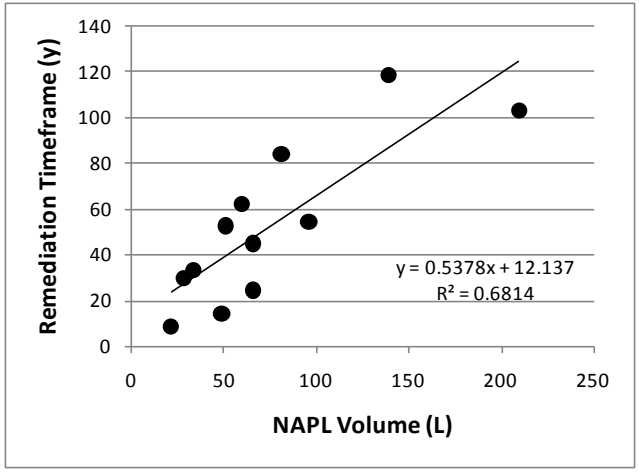












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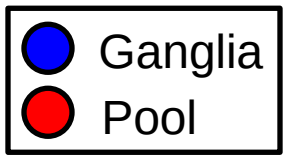
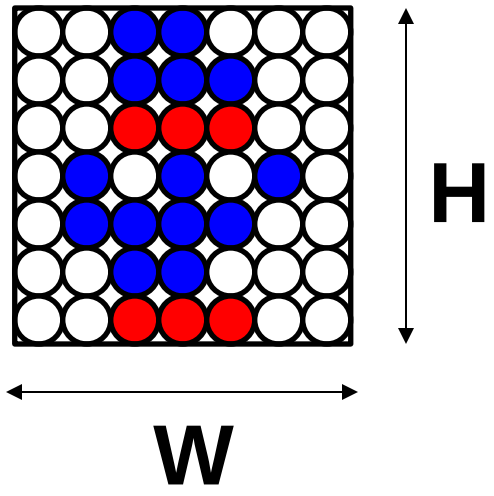
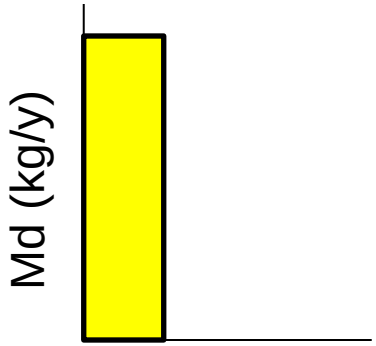
Source Zone Transect with Streamtubes

Early Stage







No. Streamtubes Intercepting DNAPL
20

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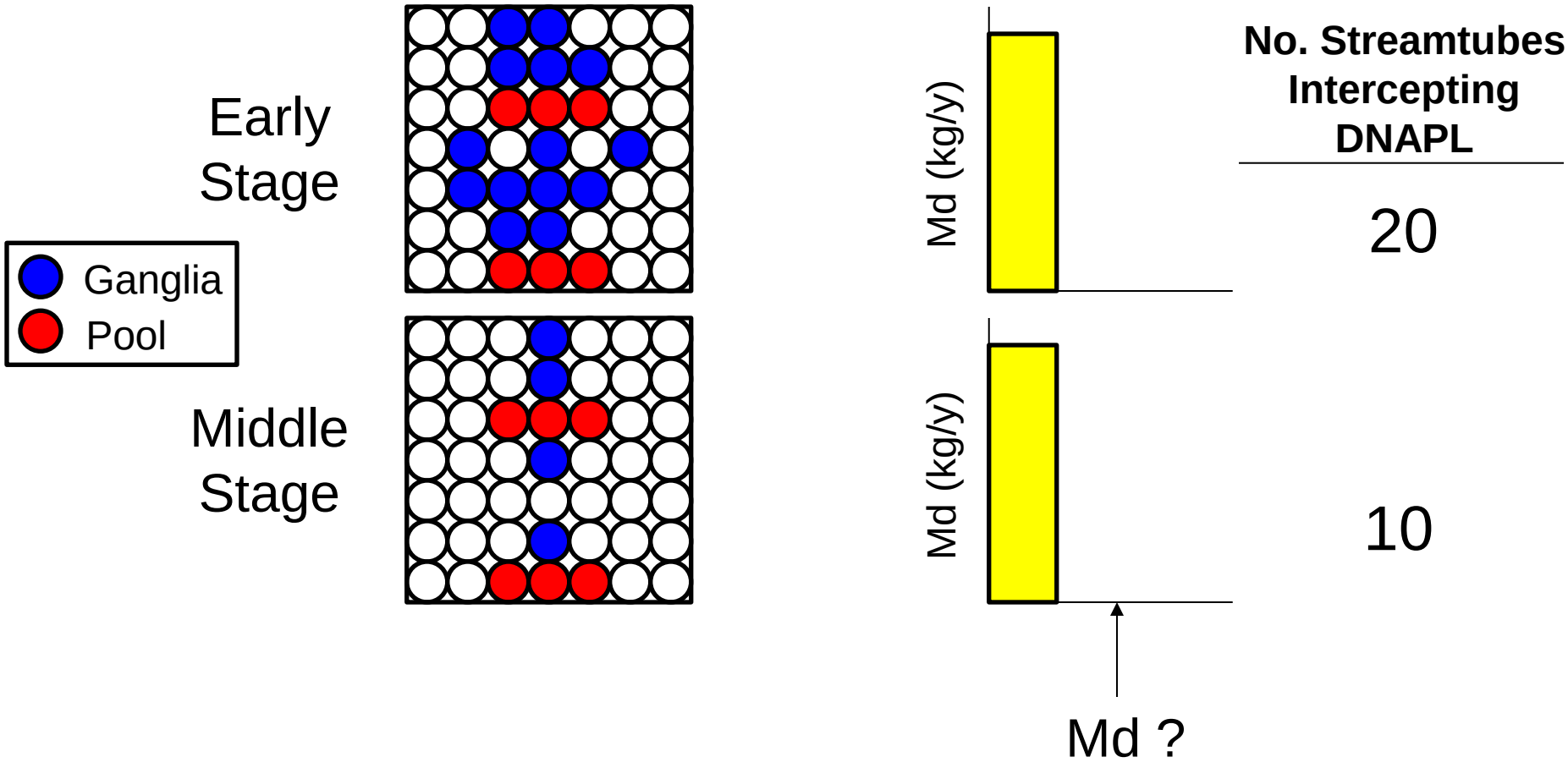
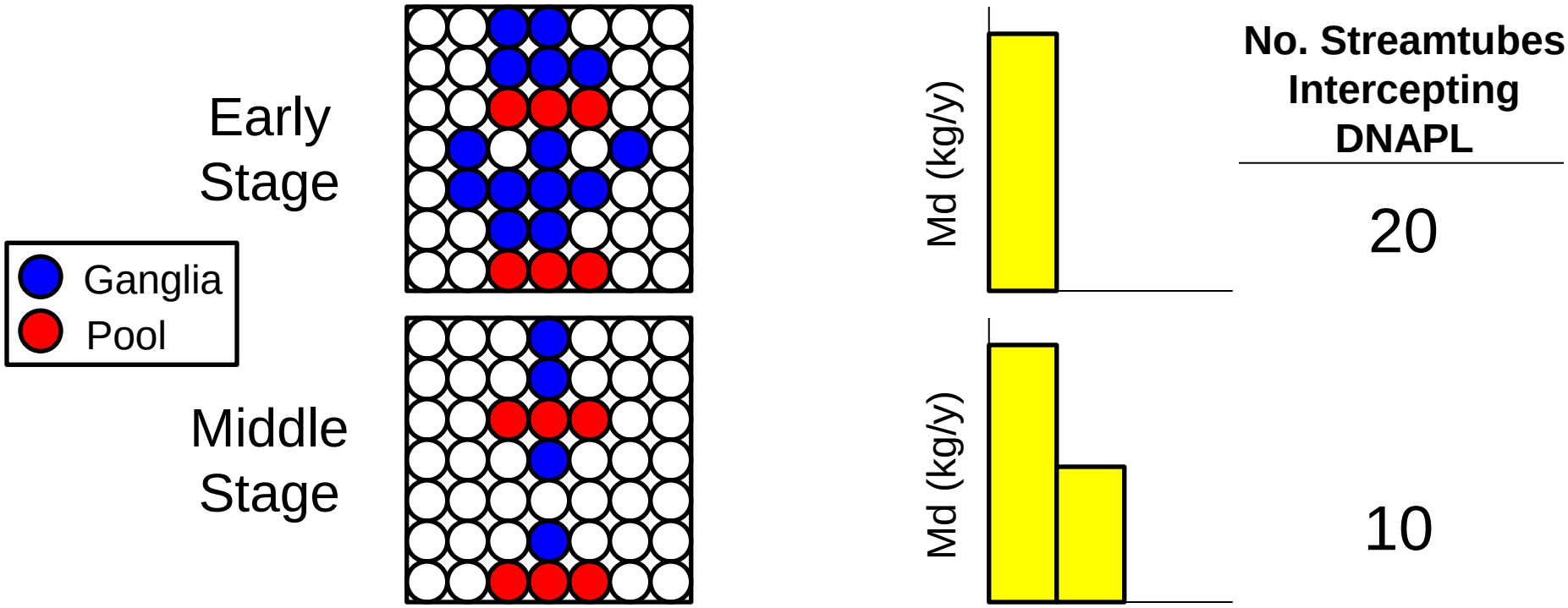
Source Zone Transect with Streamtubes



Source Zone Transect with Streamtubes



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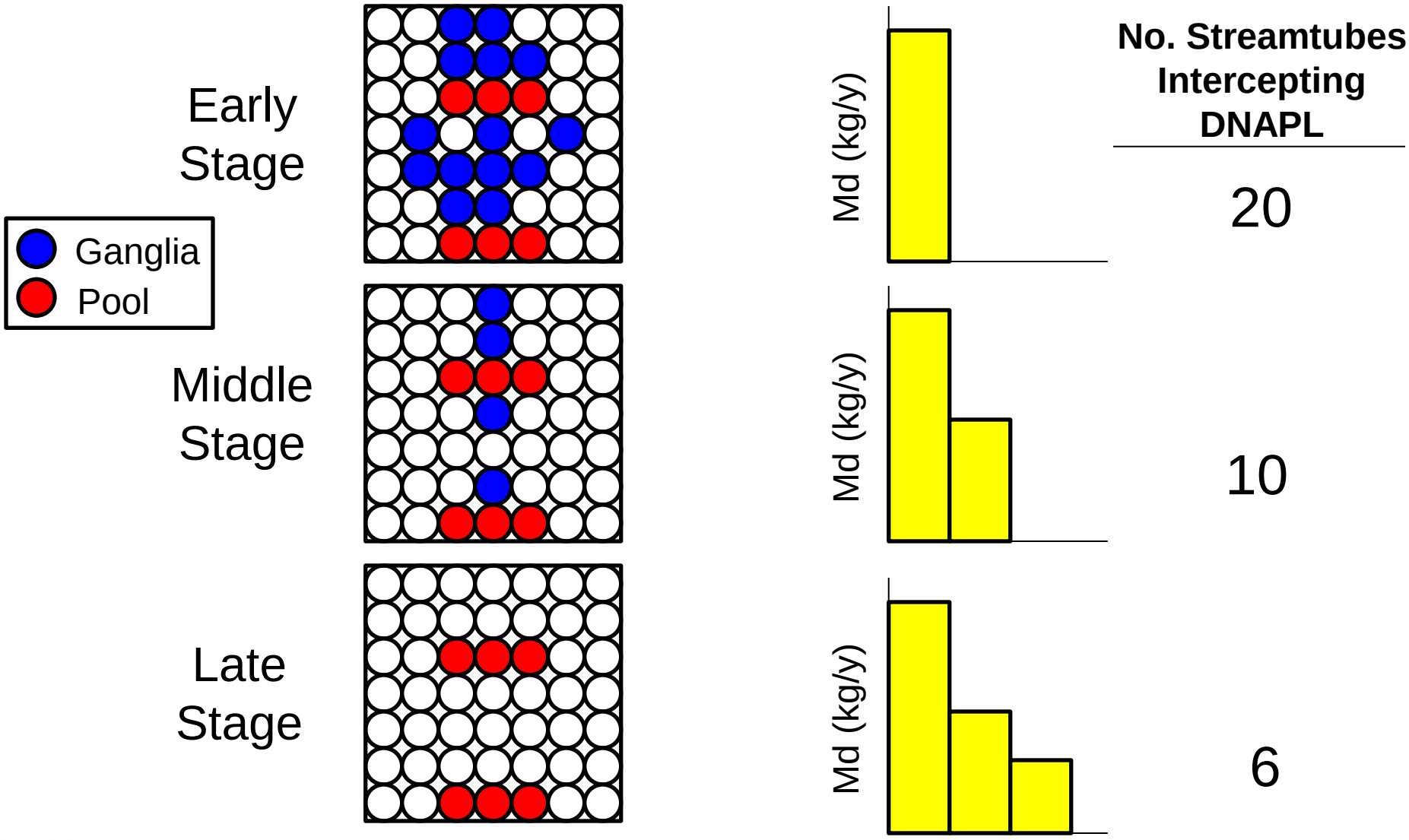
Source Zone Transect with Streamtubes



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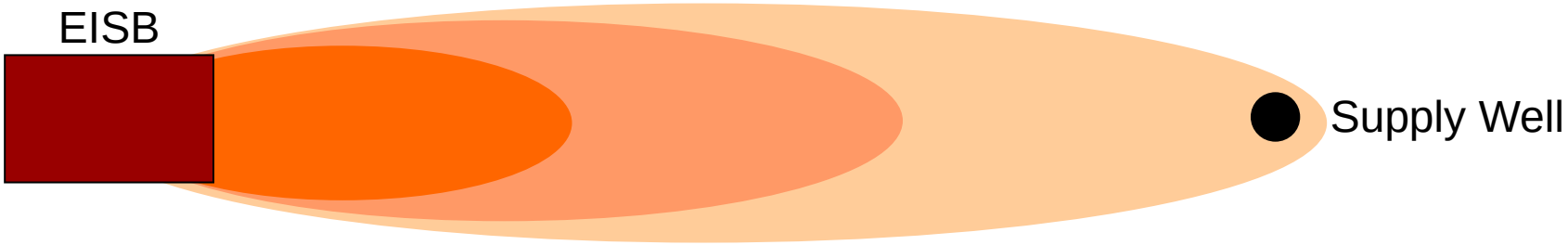
Mass Discharge as Interim Goal

Well 12A Superfund Site, Washington

STEP 1: Active source treatment until 90% reduction in source strength



STEP 2: After 90% reduction, transition to MNA in source zone

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