Remedial Goals Based on Mass Discharge

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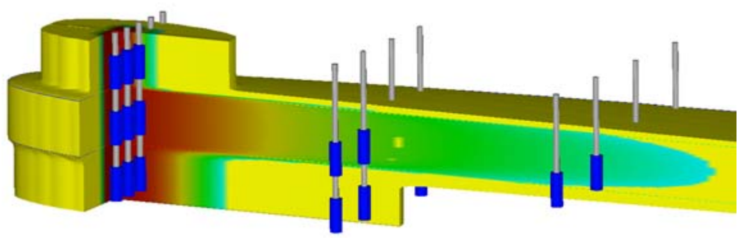

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Acknowledgement

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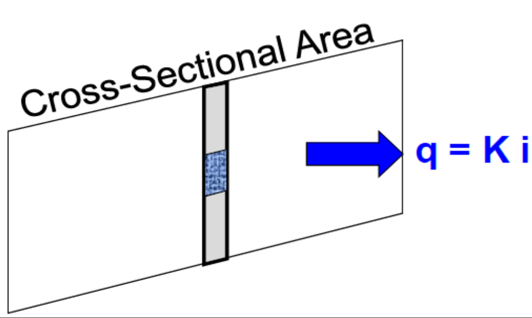
ITRC (www.itrcweb.org) – Shaping the Future of Regulatory Acceptance

- Host organization
- Network
  - State regulators
    - All 50 states, PR, DC
  - Federal partners

    DOE DOD EPA
  - ITRC Industry Affiliates Program
  - Academia
  - Community stakeholders
- Wide variety of topics
  - Technologies
  - Approaches
  - Contaminants
  - Sites
- Products
  - Technical and regulatory guidance documents
  - Internet-based and classroom training

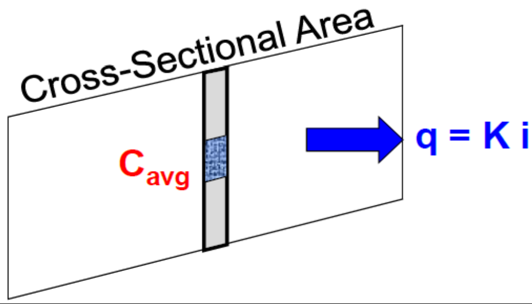
What is Mass Flux?

1. **Specific Discharge, q = K x i** **(L / m² / day)**



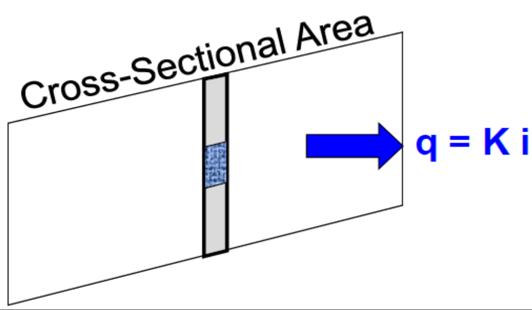
What is Mass Flux?

1. Specific Discharge, $q = K \times i$ ($L / m^2 / day$)
2. **Average concentration, C_{avg} (g / L)**



What is Mass Flux?

1. Specific Discharge, $q = K \times i$ ($L / m^2 / day$)
2. Average concentration, C_{avg} (g / L)
3. **Mass Flux, $MF = q \times C$ ($g / m^2 / day$)**



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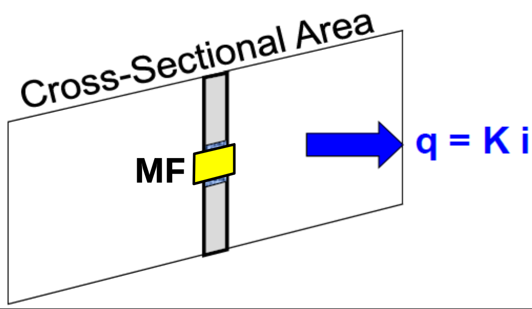
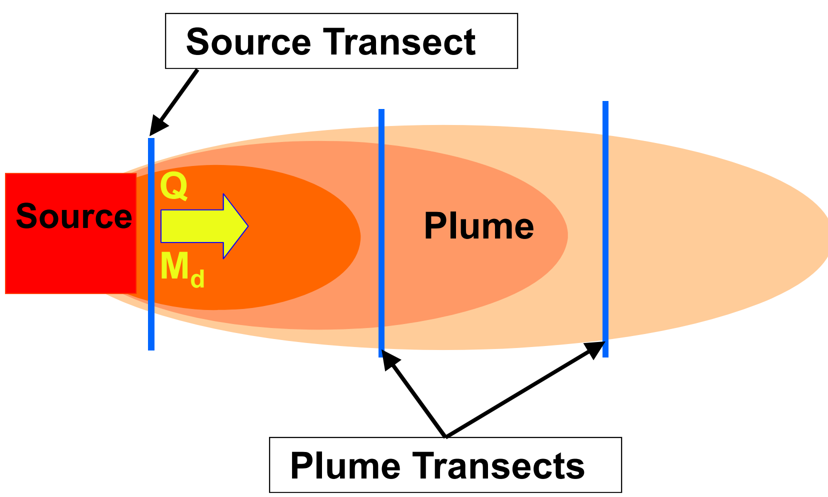


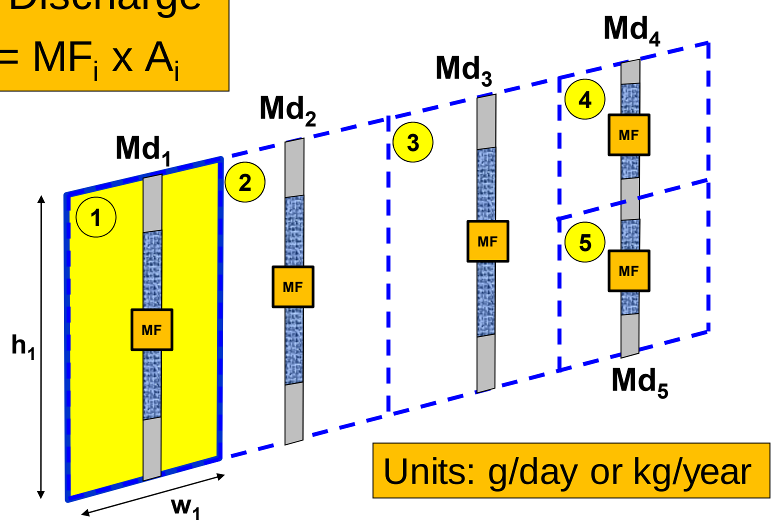
Mass Discharge – Source or Plume Strength



What is Mass Discharge?

Mass Discharge

$Md_i = MF_i \times A_i$



Units: g/day or kg/year

What is Mass Discharge?

Often people say: **Mass Flux**

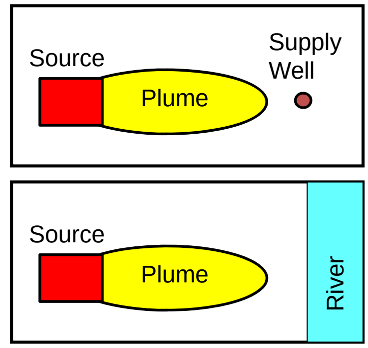
↕

When they mean: **Mass Discharge**

Mass Flux and Mass Discharge: Why Care?

Better Understanding Yields Smarter Solutions!

- **To augment concentrations, not replace them**
- **Allows targeted remediation strategies**
  – Most flux is in a small fraction of the volume
- **Provides meaningful performance metrics**
  – Links partial treatment to risk reduction
- **Recent advances in techniques**



Downgradient Risk Due to Mass Discharge NOT Concentration

Advantages and Limitations

Potential advantages

– Improved conceptual site model (CSM)

– More representative attenuation rates, exposure assessment

– Improved remediation efficiency

– Reduced remediation timeframe

Limitations

– Uncertainty

– Cost

Mass Discharge as a Remedial Goal

- NAPL source zones
  - Complete restoration difficult
  - Concentration trends highly variable
- **Realistic end goals?**
- **Influence on risk?**

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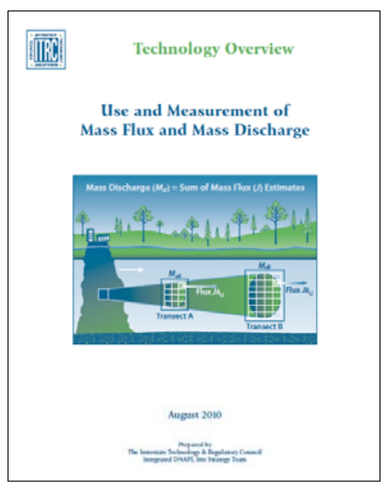
ITRC Overview Document

- ***Use and Measurement of Mass Flux and Mass Discharge***

www.itrcweb.org



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Outline

1. DNAPL source depletion trends
2. Use and Measurement of Mass Flux / Mass Discharge
3. Defining realistic remedial goals

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DNAPL Source Depletion Trends

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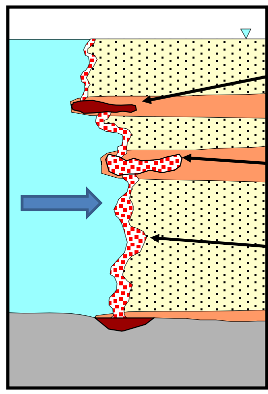
DNAPL Architecture Scenarios

Fresh Source



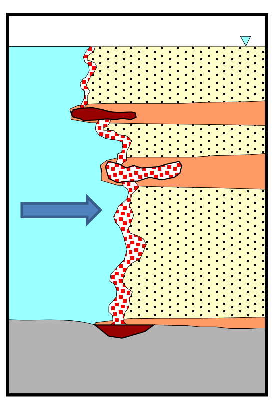
Free phase layer

Residual phase layer

Residual phase trail **(Ganglia)**

DNAPL Architecture Scenarios

Fresh Source

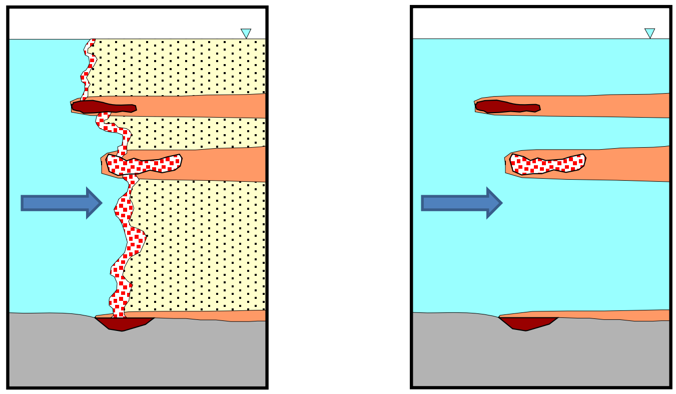


Source Strength = Mass discharge from source zone (kg/year)

High Source Strength

DNAPL Architecture Scenarios

Fresh Source | Aged Source



High Source Strength | Lower Source Strength

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DNAPL Architecture

- DNAPL architecture affects source depletion rates
  – Horizontal layers – SLOW
  – Vertical ganglia - FASTER

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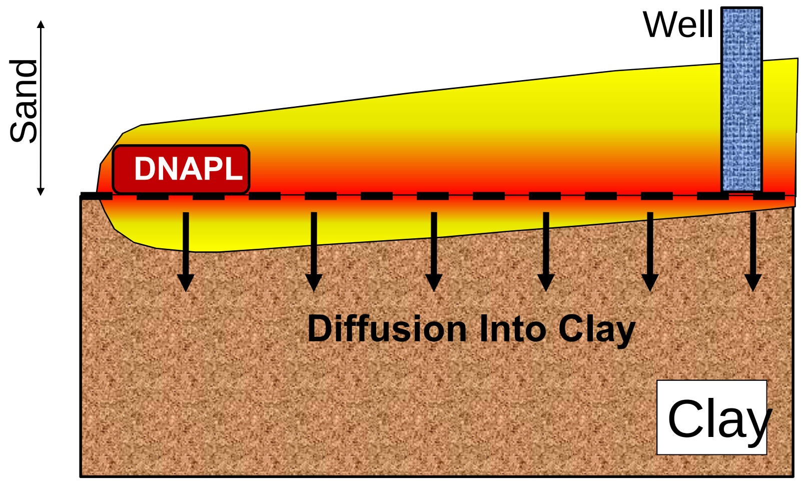
Back-Diffusion



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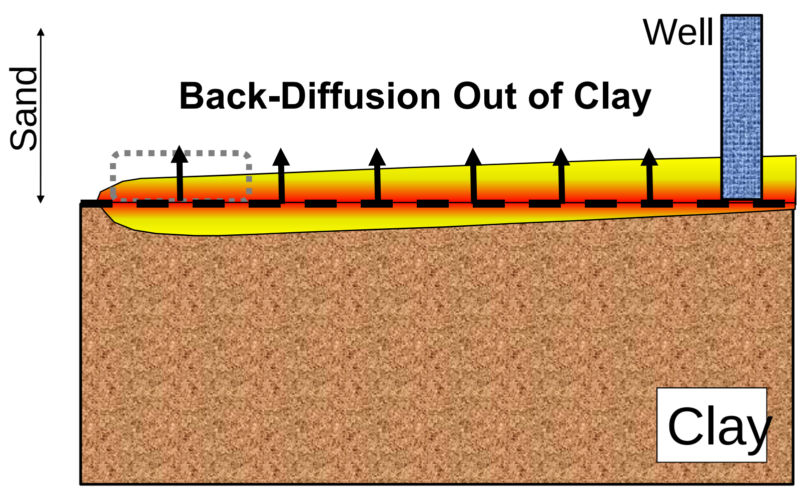
Back-Diffusion



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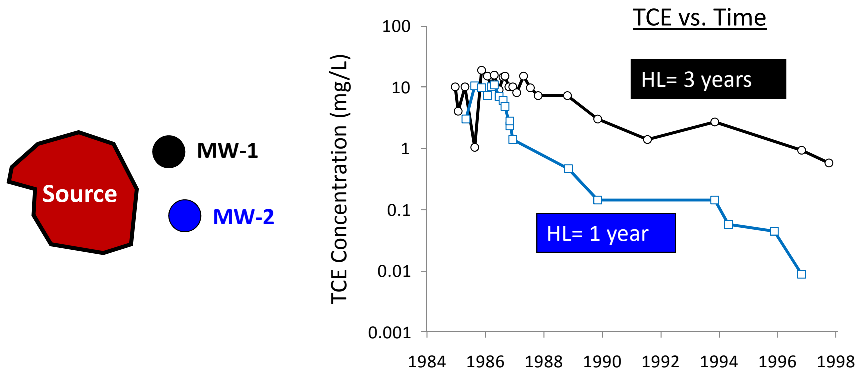
DNAPL Dissolution

- DNAPL dissolves naturally
  - Source strength ↓ as DNAPL volume ↓
  - In-situ → Accelerate dissolution



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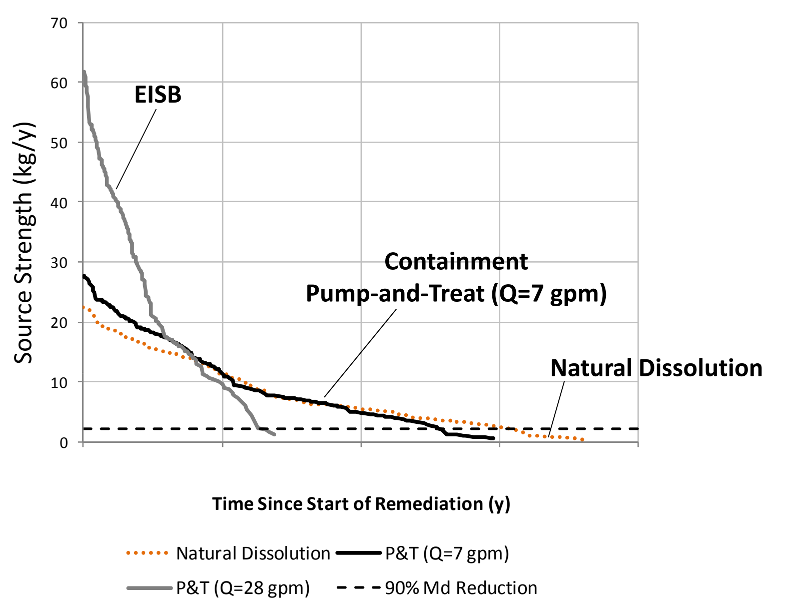
Source Strength Reduction



Use and Measurement of Mass Flux / Mass Discharge

Six Use Categories from Case Studies

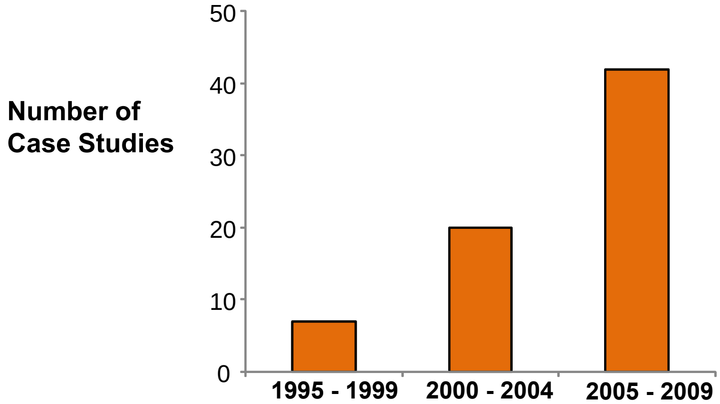
1. Site Characterization
2. Potential Impacts and Exposure Evaluation
3. Remediation Selection and Design
4. Performance Monitoring and Optimization
5. Compliance Monitoring
6. Site Prioritization

- Baseline mass discharge
- Identify hotspots
- Attenuation rates
- Low vs. high K
- Multiple sources

- Remedial action objectives (RAOs)
- Technology selection
- Remedial design
- Performance
- Optimization

Increasing Use of Mass Flux and Mass Discharge

Rapid increase in use since 1995



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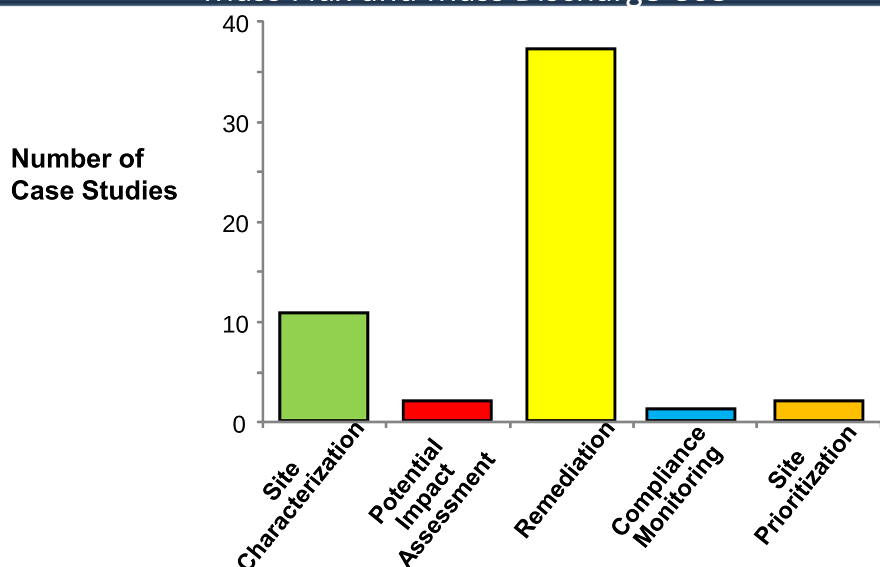
Over 61 Case Studies Documenting Mass Flux and Mass Discharge Use



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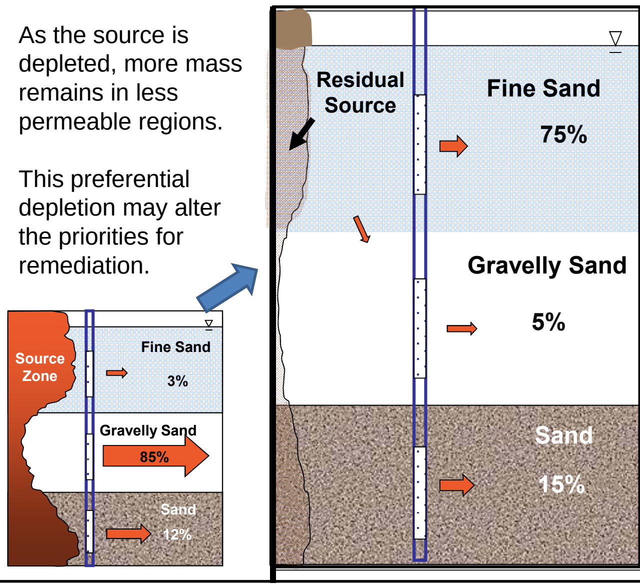
Example: Prioritizing Treatment Zones

As the source is depleted, more mass remains in less permeable regions.

This preferential depletion may alter the priorities for remediation.



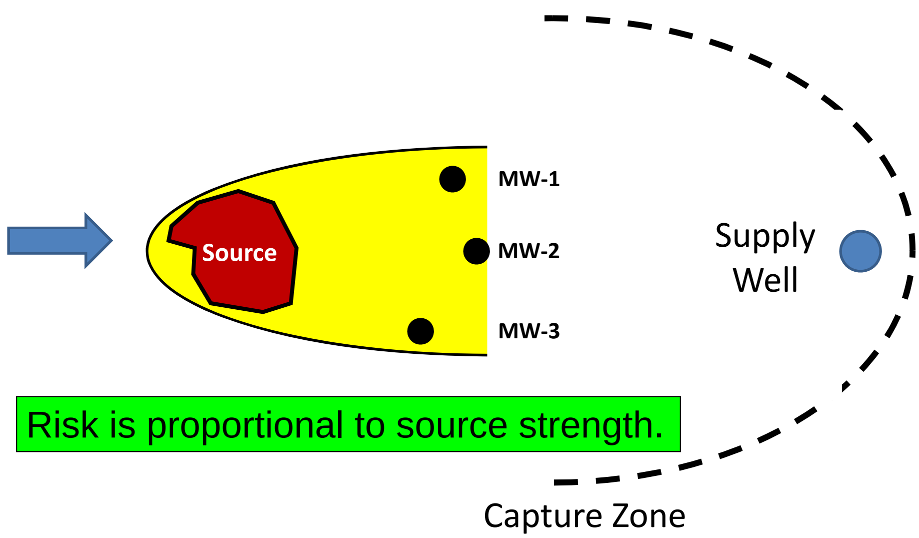
Mass Flux (*J*) = KiC

K = 1.0 m/day
i = 0.003 m/m
C = 1,000 µg/L
Mass Flux = 37.5 mg/d/m²

K = 33.3 m/day
i = 0.003 m/m
C = 50 µg/L
Mass Flux = 5 mg/d/m²

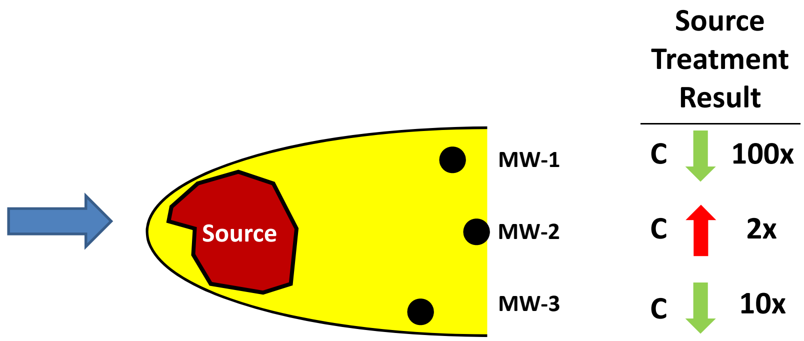
K = 5.0 m/day
i = 0.003 m/m
C = 500 µg/L
Mass Flux = 7.5 mg/d/m²

Source Treatment Goal



Risk is proportional to source strength.

Source Treatment Goal



Concentration trends difficult to predict due to high uncertainty.

Predicting source strength reduction has less uncertainty.

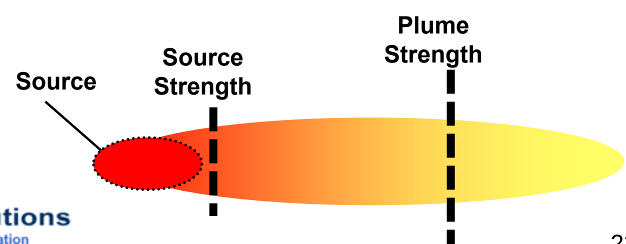
Interim Compliance Metric

Source Strength	Concentration
- Single metric	- Multiple points
- Easier to predict ("average")	- Difficult to predict (point-specific)
- Limited use for compliance	- Accepted for compliance
- Direct risk indicator	- Partial risk indicator

- Intra-Site Comparison

Five Methods for Mass Discharge

- *Method 1:* Transect Method (Sect. 4.1)
- *Method 2*: Well Capture/Pumping Methods (Sect. 4.2)
- *Method 3:* Passive Flux Meters (Sect. 4.3)
- *Method 4*: Using Existing Isocontour Data (Sect. 4.4)
- *Method 5*: Solute Transport Models (Sect. 4.5)



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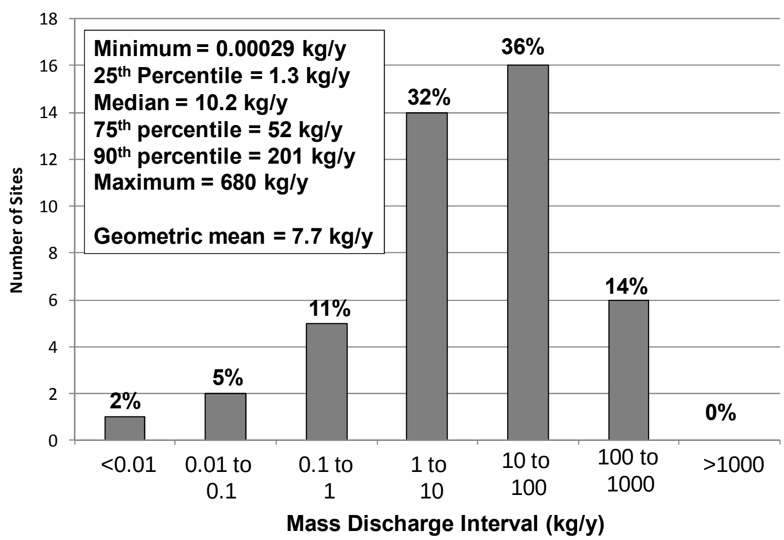
ITRC 2010 Case Study Review



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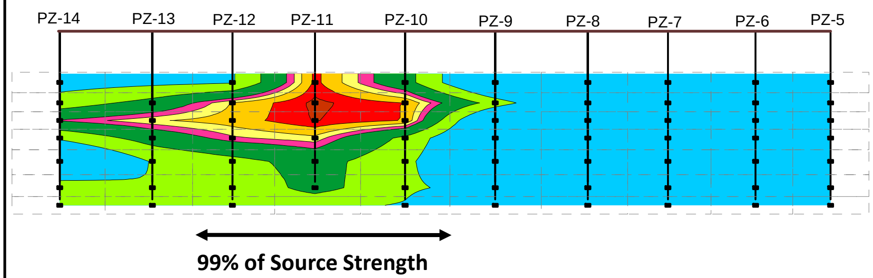
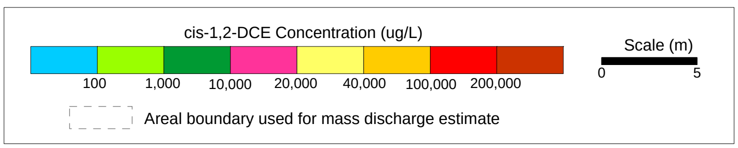
Alameda Naval Station, CA



- 80% of mass in 7% of transect area
- 90% of mass occurs where C > 20,000 ug/L

Data Source:
Einarson and MacKay, 2001



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Source Strength as Interim Goal

Well 12A Site, Washington

- FFS evaluation:
  - If Source strength (Md) reduced by 90% with active treatment, MNA will be sufficient to achieve compliance in GW
- Mass flux and mass discharge
  - Performance metric → treatment efficiency
  - Interim target for transitioning from active treatment to MNA

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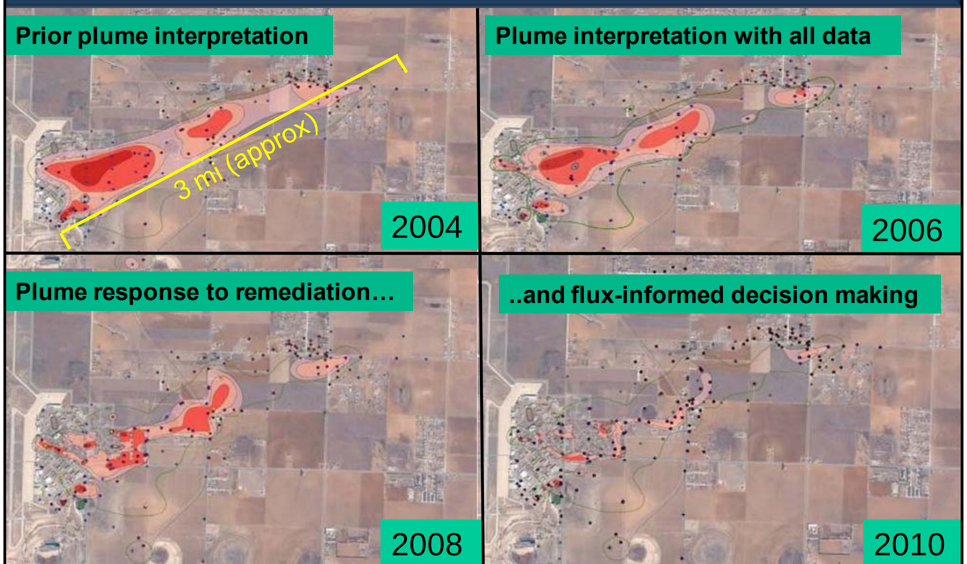
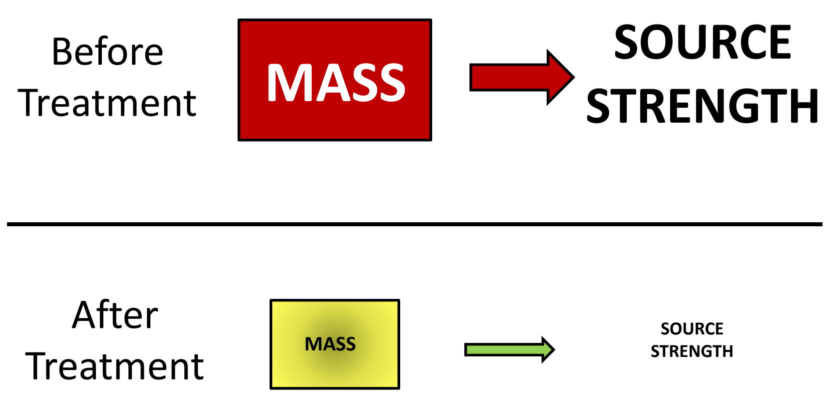
EISB at Reese Air Force Base



Defining Realistic Remedial Goals

Source Strength Reduction



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McGuire et al., 2006

- 147 wells at 59 sites (42 full-scale)
  - Up to 4 wells in source zone per site

Median Reduction in Parent CVOC Concentration

All technologies:	92%
EISB:	95% (n=26)
ISCO:	88% (n=23)
Thermal:	97% (n=6)
Surfactant/Cosolvent:	95% (n=4)

e.g. McGuire et al., 2006, Ground Water Monitoring and Remediation, 26(1): 73-84.

McGuire et al., 2006

Performance Statistics for Parent Compound Concentrations

EISB: **4.5x** **20x** **100x**

Technology	Number of Sites (n)	25th Percentile	Median	75th Percentile
EISB	26	77%	95%	99%
ISCO	23	71%	88%	96%
Thermal	6	69%	97%	100%
Surfactant/Cosolvent	4	92%	95%	99%

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McGuire et al., 2006

Median Parent CVOC Concentration Reduction Over Time

Time Period	EISB
Immediately following treatment	77%
One to five years after Treatment	96%

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McGuire et al., 2006

Median Parent CVOC Concentration Reduction Over Time

Time Period	EISB	ISCO
Immediately following treatment	77%	90%
One to five years after Treatment	96%	78%

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Other Studies

Sale et al., ESTCP, 2008

"Well-implemented in situ remediation projects are likely to reduce source zone groundwater concentrations by about one to possibly two orders of magnitude (90-99% reduction) from pretreatment levels."

ESTCP, 2008, Frequently Asked Questions Regarding Management of Chlorinated Solvents in Soil and Groundwater. Report ER-0008

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What about your Site?

- Review broad performance ranges at other sites
  – E.g. ESTCP: DNAPL Technology Evaluation Screening Tool
- Site-specific limiting factors?

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Summary

- Mass discharge is beneficial as a performance metric
  – Empirical data from other sites
  – More realistic remedial goals
  – Directly related to risk reduction

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