Headquarters U.S. Air Force

Integrity - Service - Excellence

Attainable Mass Depletion and Associated Cost

Forced Advection Technologies

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Mass Recovery
(Forced Advection)

- Physical
  - Free Product Recovery
  - Soil Vapor Extraction
  - Air Sparging
- Surfactant/Cosolvent Flushing
- Thermal
  - Hot water flushing
  - Steam
  - Electrical Heating

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Performance Estimation

$$V_{produced} = E_{Sweep} E_{T\arg et} E_{Techno\log y} V_{initial}$$

$$\boxed{V_{remaining}} = V_{initial} - V_{produced}$$

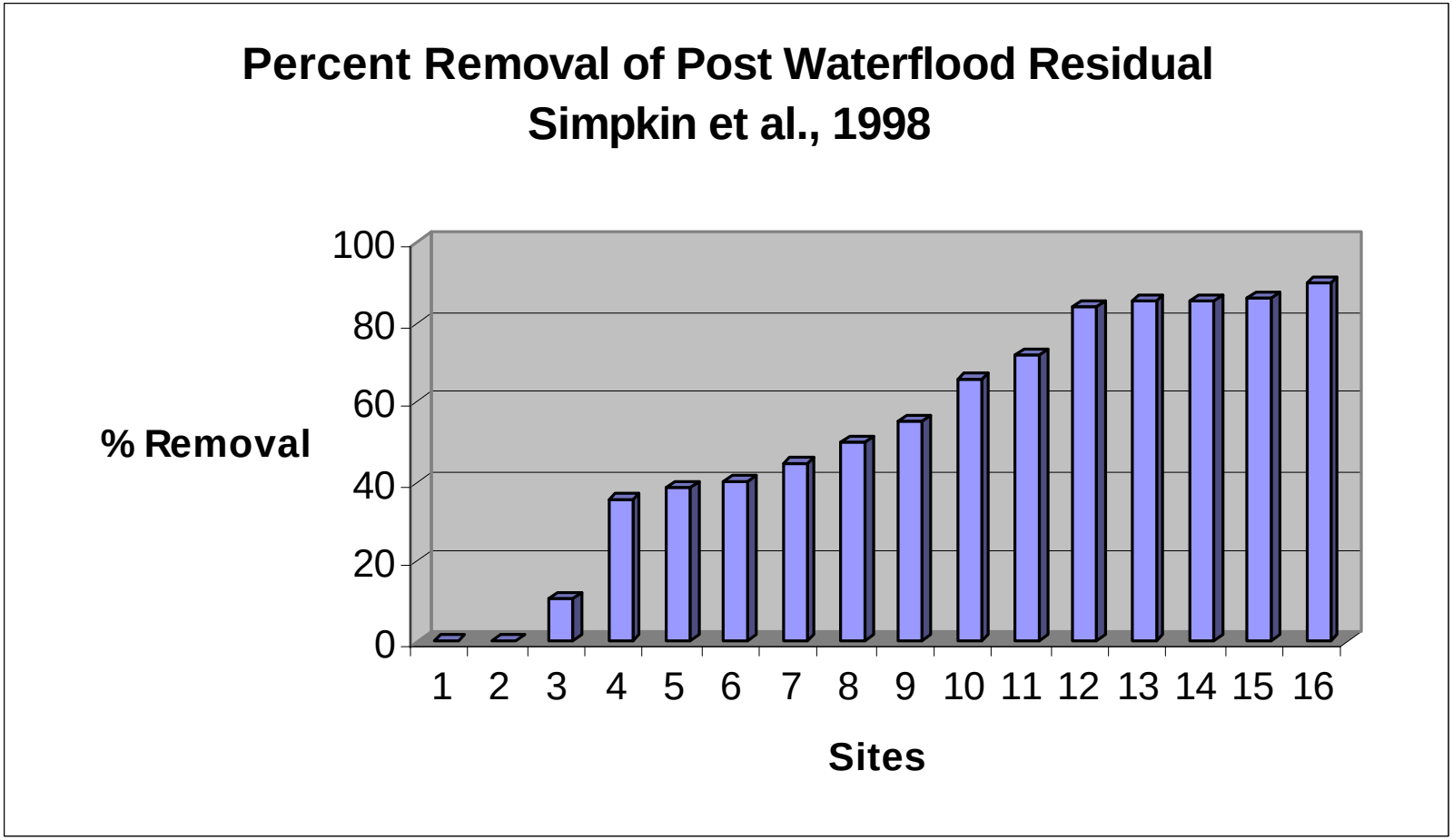
$$\boxed{V_{remaining}} = V_{initial}\left(1 - E_{sweep} E_{t\arg et} E_{techno\log y}\right)$$

Size matters

Product of efficiencies always < 1

Surfactant/Cosolvent

$E_{Technology}$ = 0-90 (median 53%)



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Sweep efficiency between parallel drains in a homogeneous isotropic aquifer $E_{sweep}=1$

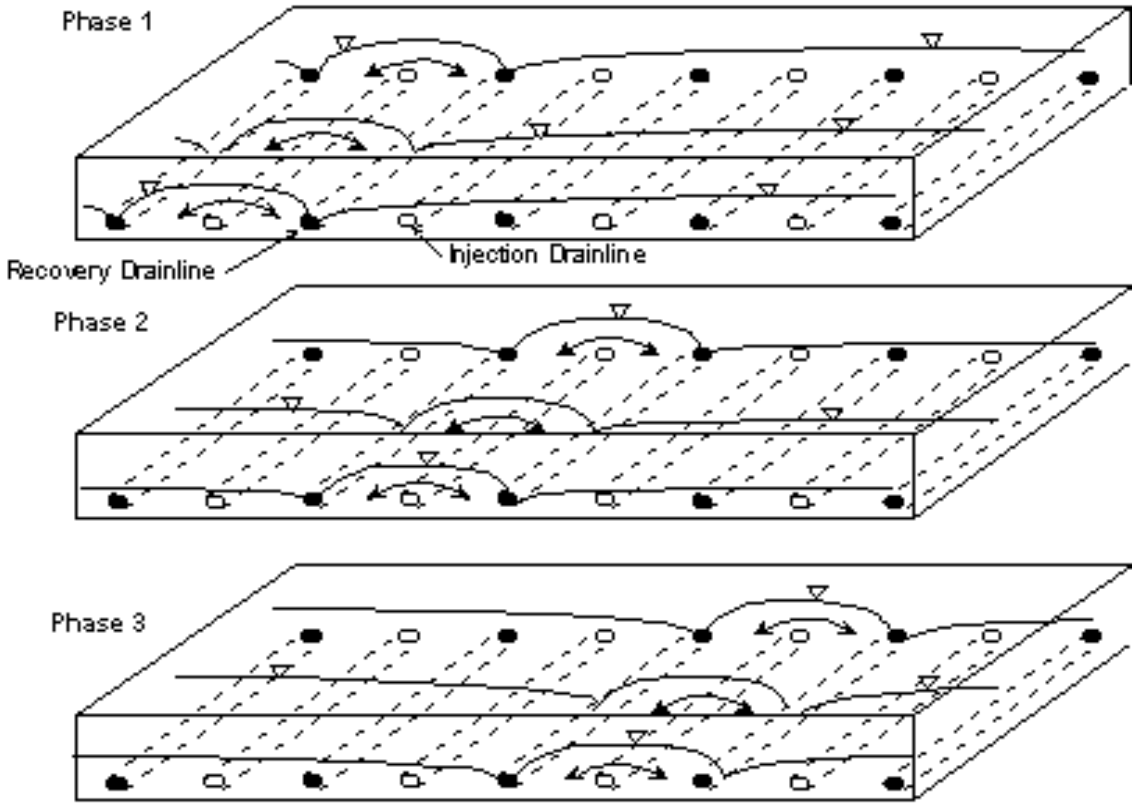
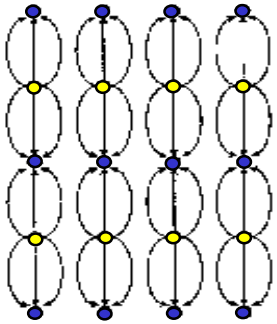


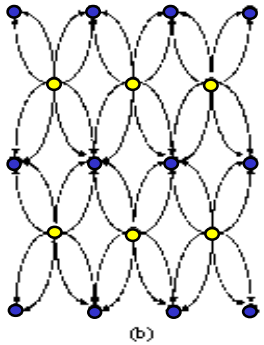
Figure 6-17
Conceptualization of a phased modular implementation approach

Patterns for well based delivery/recovery systems*

Line Drive

E_{sweep}= 0.3-0.9**



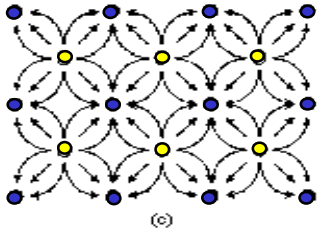


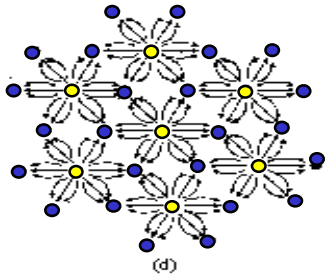
Offset Line Drive

E_{sweep}= 0.75-0.92**

Five Spot

E_{sweep}= 0.78**



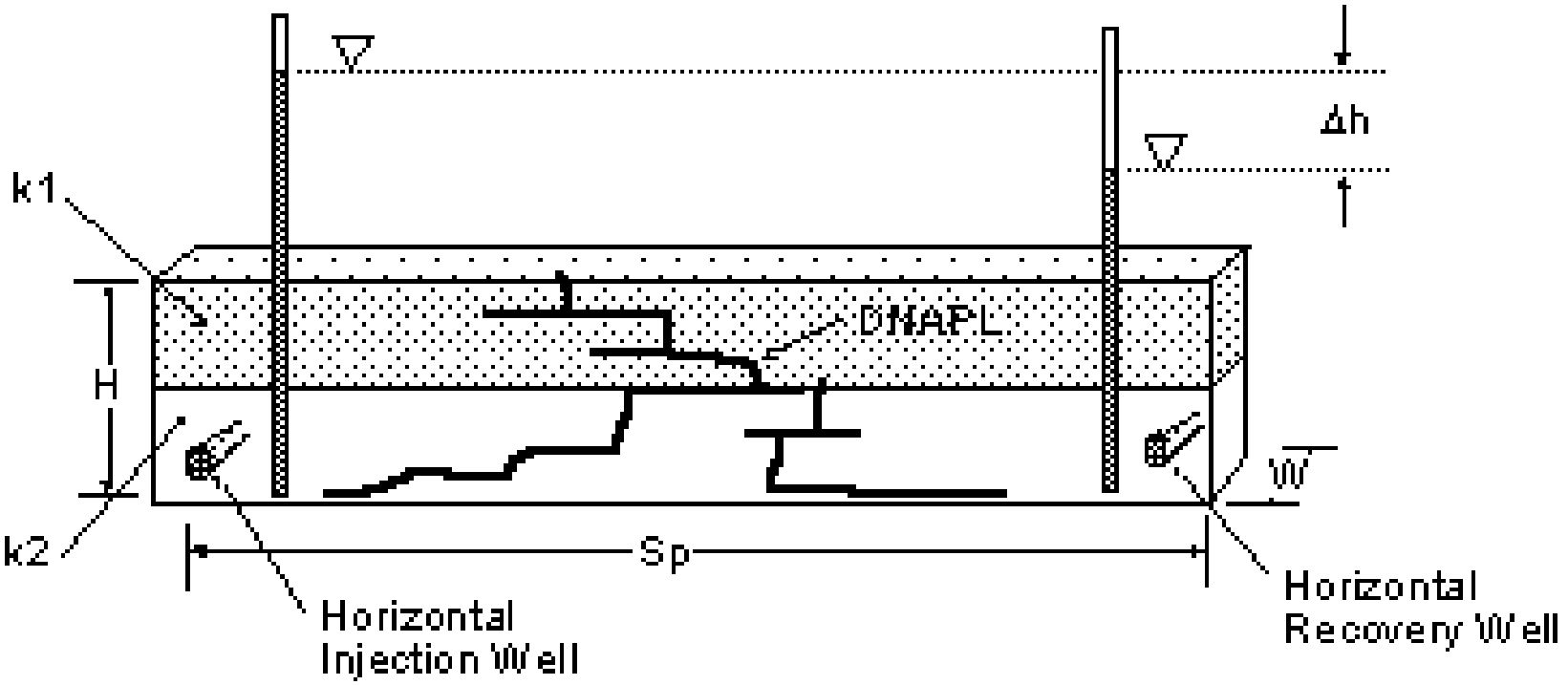


Seven Spot

Figure 4-16
Various injection/withdrawal patterns including (a) line drive, (b) offset line drive, (c) five-spot, and (d) seven-spot

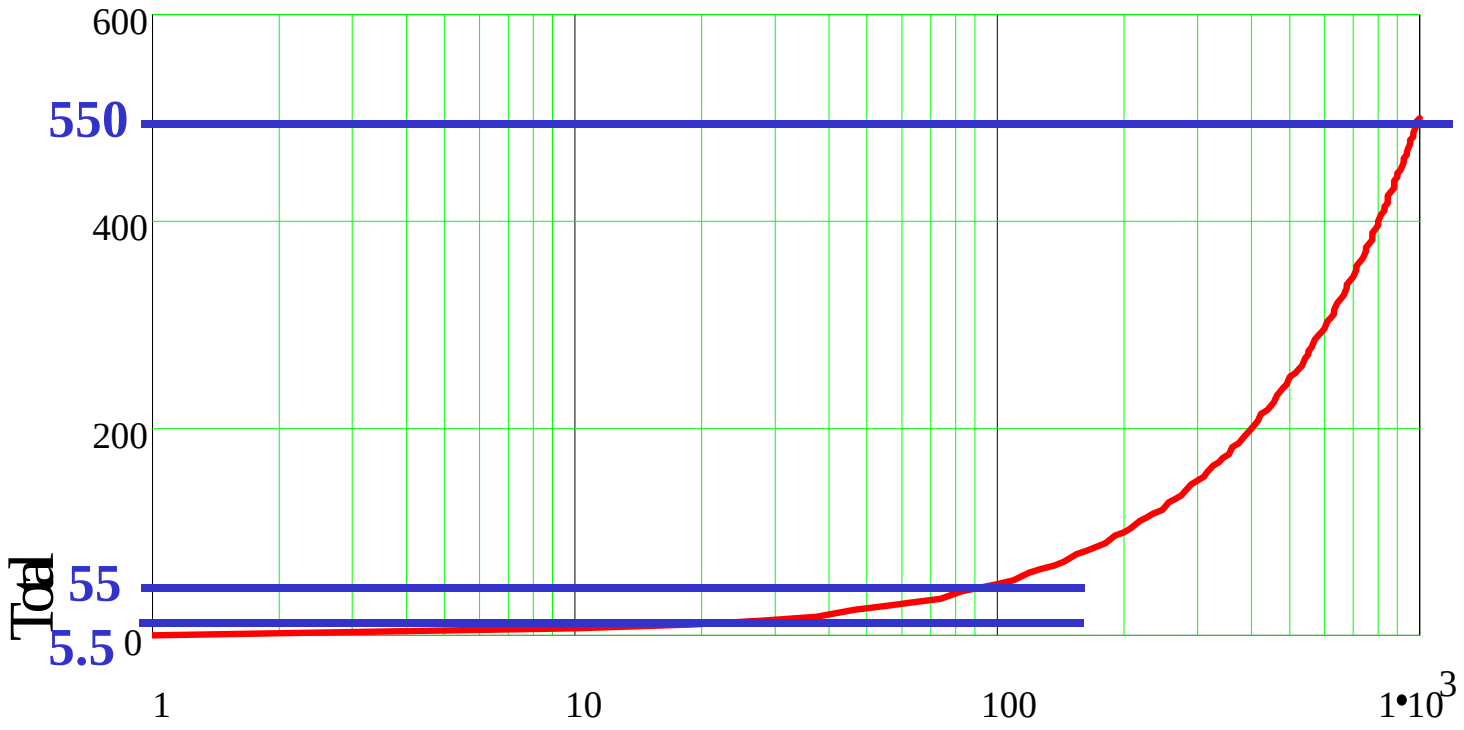
*Frick and Tayor (1960)

**Muskat and Wyckoff (1934)



Following Muskat and Wyckoff (1934) $E_{sweep} = 0.55$ when $k_1/k_2 = 1/10$

Required number of pore volumes to deliver one pore volume to the low permeability layer as a function of layer permeability contrast



Sample Calc - Mobile NAPL Depletion

$$V_{initial} = 1{,}000\,gal$$

$$E_{sweep} = 0.85 \qquad E_{techno\log y} = 0.5 \qquad E_{t\arg et} = 0.95$$

$$V_{remaining} = 600$$

Cost = $100,000 - 300,000 /acre

Sample Calc - Aggressive NAPL Depletion (e.g. surfactants)

$$V_{initial} = 1{,}000\,gal$$

$$E_{sweep} = 0.85 \qquad E_{techno\log y} = 0.9 \qquad E_{t\arg et} = 0.95$$

$$V_{remaining} = 270$$

Cost** = $500,000 - 7,500,000 /acre
= $64 - 588 yrd^3
= $21 -239 gallon

** Simpkin et al., 1998

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Insitu Mass Destruction Technologies

- **Chemical Oxidation**
  - **Potassium Permanganate**
  - **Peroxide**
- **Biological**
  - **Bioventing**
  - **Biosparging**
- **Thermal Oxidation**