Haz Waste: Site Clean-up Methods

1. In-Situ Vadose Zone Soil
   - SVE, bioventing, phytoremediation
2. In-situ groundwater/aquifer tmt
   - Bioremediation, Phytoremediation
3. Ex-Situ contaminated gas treatment
   - incineration, carbon adsorption, biolog.
4. Ex-situ groundwater/sol tmt
   - Bioremediation, phytoremediation
   - Pump & Treat

Pump and Treat

- Used at 95% of Superfund sites with groundwater contamination [627 sites]
  - Often used in combination with other treatment technologies
- What is it?
  - Use one or more GW pumping wells to draw contaminated GW to surface [PUMP] and then treat the extracted GW [TREAT]

Goals of Pump and Treat

- Restore contaminated water bearing zones by decreasing dissolved contaminant concs to an acceptable level

Goals of Pump and Treat

1. Prevent or contain contaminant migration to protect down-gradient locations
2. Recover LNAPL by drawing free product into recovery wells
3. Use with other technologies
   - Dewater (lower water table) & SVE
   - Use with re-injection for in-situ bioremed.

Extraction Well

- Borehole 6-12" dia
- Well casing = 4-8" dia
- PVC or stainless steel (ss)
- Well screen = slotted PVC or ss
- Filter pack = coarse to med. sand or fine gravel
- Seal: bentonite
- Pump: submersible: 4" ~70 gpm; 6" 120 gpm head to pump to surface
- Pneumatic: up to 10 gpm less fouling problems

P&T pre Dsn Characterization

- Aquifer char.
  - K, aquifer thickness, GW flow direction and gradient, water table fluctuations
- Geologic char.
  - Grain size distribution, porosity, organic content
- Contamination extent
  - Horizontal and vertical (plan & profile)
  - NAPL product
- GW analysis
  - Inorganics (hardness, ions), pH, bacteria
Pumping out GW lowers water table (drawdown)

Use Field Tests to Meas. K
- Pump test, Jacob method:
  - Transmissivity, \( T = K b = 2.3Q/4p \) slope
  - Storativity, \( S = 2.25 T \) to/\( r^2 \)

- Storativity, \( S \) = amount of water released per unit drop in head per unit area of aquifer, \( m^3/m^2 \), unitless
- Typically 0.005 to 0.4 (related to porosity); smaller #'s for confined aquifers
- \( S = \rho_w g (\alpha + \eta \beta) b \)
  - \( \alpha = \) compressibility of porous media
  - \( \beta = \) compressibility of water
- If low \( S \), quick drawdown responses at wells and in aquifer (generally in confined aquifers)

Design: Capture Zone
- \( x = -y / tan[2p K b i y / Q] \)
- As \( x \) ? \( 8 \), \( y_{max} = +Q/2 K b i \)
- \( x_0 = -Q/2p K b i \)

Capture Zone example
- Well extraction rate, \( Q = 50,000 \) ft\(^3\)/d
- Aquifer thickness, \( b = 30 \) ft
- Hydraulic conductivity, \( K = 1000 \) ft/d
- Natural hydraulic gradient, \( i = 0.006 \)
- \( x_0 = -44 \) ft
- \( y_{max} = 277 \) ft

Multiple well designs

<table>
<thead>
<tr>
<th># wells</th>
<th>optimal dist. btw. pairs of wells</th>
<th>width of capture at line of wells (( x=0 ))</th>
<th>max width of capture zone (v. lg x)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NA</td>
<td>Q/2bKi</td>
<td>Q/Kbi</td>
</tr>
<tr>
<td>2</td>
<td>Q/pbKi</td>
<td>Q/bKi</td>
<td>2Q/bKi</td>
</tr>
<tr>
<td>3</td>
<td>( 2^{0.33}Q/pbKi )</td>
<td>3Q/2bKi</td>
<td>3Q/bKi</td>
</tr>
</tbody>
</table>
Further Design Equations

• Steady state
  – Modification of the Theim equation can be used for estimating T:
  – \[ T = \frac{43.08Q}{s_w} \]
  – where: \( Q \) = the constant well discharge in feet\(^3\)day.
  – \( s_w \) = stabilized drawdown in the well at steady flow in feet.
  – \( T \) = transmissivity = \( K_b \)
  – Applicable to both confined and unconfined zones
  – For unconfined zones, \( s_w \) must be corrected to
  – \[ s_w' = s_w - \frac{(s_w^2 / 2b)}{} \]

• Non-steady state: Jacob Method
  – \( s(r, t) = Q \ln \left[ \frac{2.25 T t/r}{S} \right] / 4 \pi T \)
  – Works for any distance \( r \) (including well radius)
  – Time, \( t \), up to steady-state or equilibrium conditions, usually 30-90 days
  – Shorter \( t \) with smaller storativity (S)
  – Do not want drawdown at well to leave less than 1-3' of water flow into well
  – If use for unconfined aquifers, use a “corrected” \( s \) in the equation:
  – \[ s_{\text{corrected}} = s_{\text{obs}} - \frac{s_{\text{obs}}^2}{2b} \]

Example (cont.)

• What drawdown at the well corresponds to the flowrate of 50,000 ft\(^3\)/d?
  • Given: \( S = 0.05 \) (small) [confined aq]
  – Therefore assume \( t = 30 \) days
  – Well diameter 6” (\( r = 0.25' \))
  – \( T = K_b = 30,000 \) ft\(^2\)/d
  • \( s(0.25', >30d) = 50,000 \) ft\(^3\)/d *
  \[ \ln \left[ \frac{(2.25*30,000 \text{ ft}/d*30d)/(0.25ft^2*2 \cdot 0.05)}{4 \pi \cdot 30,000 \text{ ft}/d} \right] \]
  • \( s @ \text{well} = 2.7 \) ft (reasonable)

Treat Pumped GW Ex-Situ

• Air stripping or steam stripping (organics)
• Carbon adsorption (organics)
• Ion exchange (metals, inorganics)
• Chemical oxidation (organics)
• Biological tmt (org; usu. in series w/ others)
• Membrane filtration (reverse osmosis)
• Fluids separation
  – Oil:water sep. for NAPLs
  – Liq/Liq extraction