### Oblique view

Hydrostatic before tunneling

Cross section view

<table>
<thead>
<tr>
<th></th>
<th>K=50ft/d</th>
<th></th>
<th>K=0.00005ft/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1500ft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40ft</td>
<td>ht=1500ft</td>
<td></td>
<td></td>
</tr>
<tr>
<td>length=90ft</td>
<td></td>
<td></td>
<td></td>
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**Q = KiA = 5 \times 10^{-5} \text{ ft}\text{day} \times 1500-140 \text{ ft} = 1.5 \times 10^{-3} \text{ ft}^3\text{day ft}^2**

If the repository was 2000ftx1000ft then

\[
Q = 1.5 \times 10^{-3} \text{ ft}^3 \times 2000 \text{ft} \times 1000 \text{ft} = 3000 \text{ ft}^3 = 2 \text{ ft}^3 = 16 \text{ gallons day ft}^2 / \text{minute ft}^2
\]

What about the local flow to each tunnel? It will make no difference.

### Random distribution of K

- **6** 1x10^-3 cm/s
- **4** 1x10^-5 cm/s
- **2** 1x10^-6 cm/s

* sample locations assumed to be representative of the proportions

\[
\left(\frac{1}{N}(\log K_i + \log K_2 + \ldots + \log K_N)\right) = 10^{\frac{1}{12}(6 \log 1 \times 10^{-3} + 4 \log 1 \times 10^{-3} + \ldots + 2 \log 1 \times 10^{-6})} = 6.8 \times 10^{-5}
\]

This would be treated as isotropic (same K in every direction)
Realize you would only know the values shown

You might have clues based on lithology

Calculate Flow and Heads between boundaries

H1 = 20cm
H2 = 10cm
K1 = 1cm/sec
K2 = 0.2cm/sec
L1 = 30cm
L2 = 30cm
D = 2cm
Q @ H2 = ??
H3 = ??, H4 = ??
Calculate Flow and Heads between boundaries

![Diagram of flow and heads](image)

- **H1 = 20 cm**
- **H2 = 10 cm**
- **K1 = 1 cm/sec**
- **K2 = 0.2 cm/sec**
- **L1 = 30 cm**
- **L2 = 30 cm**
- **D = 2 cm**
- **Q @ H2 = ??**
- **H3 = ??, H4 = ??**

**K_wrt = Weighted Arithmetic Average:**

\[
K_wrt = \frac{1 \text{ cm/sec} \cdot 1 \text{ cm} + 0.2 \text{ cm/sec} \cdot 2 \text{ cm}}{2 \text{ cm}} = 0.6 \text{ cm/sec}
\]

**Q = KiA, no width is given so calculate per unit width**

\[
Q = \frac{0.6 \text{ cm/sec}}{2 \text{ cm}} \cdot 20 \text{ cm} - 10 \text{ cm} = 0.1 \text{ cm/sec} \cdot 2 \text{ cm} = 0.2 \text{ cm}^2/\text{sec}
\]

**per unit width**

**by inspection gradient is linear,**

and \( H_1 = H_4 \)

and they are at the midpoint

\[
H_1 = H_4 = \frac{20 \text{ cm} - 10 \text{ cm}}{2} + 10 \text{ cm} = 15 \text{ cm}
\]

**OR**

- head loss from H1 to H3

\[
V = \frac{\Delta h}{\Delta l} \Rightarrow \Delta h = \frac{V \Delta l}{K}
\]

**Use proper combination:**

- All equivalent V and K
- Or all layer 1 V and K
- Or all layer 2 V and K

**\( \Delta h = \frac{V \Delta l}{K} \)**

\[
\Delta h = \frac{0.1 \text{ cm/sec}}{K} \cdot 30 \text{ cm} = 5 \text{ cm}
\]

\[
H_3 = H_1 - \Delta h = 20 \text{ cm} - 5 \text{ cm} = 15 \text{ cm}
\]
Calculate Flow and Heads between boundaries

<table>
<thead>
<tr>
<th>H1</th>
<th>K1</th>
<th>D</th>
<th>K2</th>
<th>H2</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1 = 20cm</td>
<td>1cm/sec</td>
<td>0.2cm/sec</td>
<td>L1 = 30cm</td>
<td>L2 = 30cm</td>
</tr>
<tr>
<td>H2 = 10cm</td>
<td>K1 = 1cm/sec</td>
<td>K2 = 0.2cm/sec</td>
<td>D = 2cm</td>
<td></td>
</tr>
<tr>
<td>Q @ H2 = ??</td>
<td>H3 = ??</td>
<td></td>
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**Velocity**

\[ Q = VA = KiA, \text{ no width is given so calculate per unit width} \]

\[ Q = \left( \frac{0.33 \text{ cm}}{\text{sec}} \right) \left( \frac{20\text{cm}-10\text{cm}}{60\text{cm}} \right) = 0.05555 \text{ cm/sec} \]

\[ 2\text{cm} = 0.11 \text{ cm}^2/\text{sec} \text{ per unit width} \]

**K for path length of interest**

\[ \Delta h = \frac{VAI}{K} = \frac{0.05555 \text{ cm}}{30 \text{cm}} = 1.66 \text{ cm} \]

\[ H3 = H1 - \Delta h = 20\text{cm} - 1.66\text{cm} = 18.33\text{cm} \]
Calculate Flow and Heads between boundaries

\[ H_1 = 20\text{cm} \]
\[ H_2 = 10\text{cm} \]
\[ K_1 = 1\text{cm/sec} \]
\[ K_2 = 0.2\text{cm/sec} \]
\[ L_1 = 30\text{cm} \]
\[ L_2 = 30\text{cm} \]
\[ D = 2\text{cm} \]
\[ Q \text{ @ } H_2 = ?? \]
\[ H_3 = ?? \]

Confirm by calculating from the other side

\[ \Delta h = \frac{V^2}{2g} \]
\[ V = K \frac{\Delta h}{\Delta l} \]
\[ \Delta h = \frac{V^2}{2g} \]
\[ V = K \frac{\Delta h}{\Delta l} \]

\[ H_3 = H_2 + \Delta h = 10\text{cm} + 8.33\text{cm} = 18.33\text{cm} \]

Review keys for homework from September 13 exercises 6c 6d 6e

Remember to continually work on your cheat sheets
And
Work the sample exam problems