The influence of large scale inhomogeneities on a construction dewatering system in chalk

Dr Toby Roberts
CTRL Thames Tunnel
CTRL 320 Thames Tunnel (£133M)
Twin 2.5 km 7.15 m diameter bored tunnel beneath River Thames. Dewatering required for approach structures, 400 m by 28 m in plan by up to 18 m below groundwater level.

Project Management: RLE
(Arup Bechtel Halcrow SYSTRA)

Main Contractor: HOCHTIEF MURPHY JV

Dewatering: WJ GROUNDWATER LTD
CTRL Thames Tunnel

Cross-section of approach

- Roof slab
- Discharge main
- Standing W.L
- Internal wall
- Diaphragm wall
- Target drawdown
- Wells

[Diagram of CTRL Thames Tunnel with labeled cross-section features]
• Dewatering of a 445 m x 28 m structure with side support by diaphragm walls, divided into 4 sections (S1 to S4)
• Formation level from 18 to 6 mbgl
The extent of the Chalk outcrop

Pump test location
Chalk permeability depth profile

Depth (mOD) vs. Permeability (m/s)

North side data:
- Test in piezometers
- Packer tests

South side data:
- Test in piezometers
- Packer tests

Graph showing permeability depth profile with markers for different test methods.
Range of application of dewatering techniques

From CIRIA C515
Design Information:
Pumping Test: Terrace Gravels $k = 3 \times 10^{-3}$ m/s  260 m/d
Pumping Test: Chalk: $k_h = 2 \times 10^{-4}$ m/s  17 m/d
Packer Tests (North Side) – Chalk $k$ decreases with depth
Conventional wisdom suggests former spring line and elevated $k$ zone along line of Chalk outcrop (cut-off?)

Design Basis:
Terrace Gravels $k_h = k_v = 3 \times 10^{-3}$ m/s  260 m/d
Chalk $k_h = k_v = 2 \times 10^{-4}$ m/s  17 m/d
MODFLOW finite difference grid

3D Numerical model:
- Used as design basis
- Used to consider interaction between sections
- Used for sensitivity analysis
- Used to look at hydrostatic load on D-wall
## Dewatering Scheme Design

<table>
<thead>
<tr>
<th>Section</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (m)</td>
<td>75</td>
<td>135</td>
<td>115</td>
<td>120</td>
</tr>
<tr>
<td>Dig depth (mOD)</td>
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<td>-14</td>
<td>-11</td>
<td>-7</td>
</tr>
<tr>
<td>Design flow (l/s)</td>
<td>192</td>
<td>168</td>
<td>72/120</td>
<td>72/120</td>
</tr>
<tr>
<td>No. of wells (12 to 20 l/s)</td>
<td>16</td>
<td>14</td>
<td>6</td>
<td>6</td>
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</tbody>
</table>

Total design flow: **600 l/s**

Total No. of wells: **42 No.**
S1 192 l/s
S2 168 l/s
S3 72 to 120 l/s
S4 72 to 120 l/s

Designed dewatering well

LEGEND:
- Designed dewatering well
- Piezometer

0  50m
Internal deepwell dewatering system
Aerial view of southern approach structure
(Excavation in S1 and S2 underway)
Dewatering Wells
Water outfalls into the Thames via discharge main
Comparison between design capacity and actual flows

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<td>12</td>
<td>206</td>
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**LEGEND:**

- Designed dewatering well
- Piezometer
- Additional dewatering well

**ACTUAL FLOW**

- S1: 12 l/s
- S2: 206 l/s
- S3: 131 l/s
- S4: 290 l/s
Zone of highly permeable chalk?

NOTE: Specific capacity = flow/drawdown

Variation in well performance along approach structure
Array of remote standpipe piezometers

- Tidal fluctuations established prior to start of pumping by datalogging over 24 hr period.
- Manual dipping at weekly to monthly intervals for duration of dewatering
Variation in the quality of cores from the Chalk
Extrapolated size and location of highly permeable zone of Chalk
Model section along structure

- Alluvium
- Terrace Gravels
- Weathered Chalk
- HPZ
- Transition Zone
- Chalk Outcrop
- Base Chalk

Depth (m OD)

Excavation (445 m)

2500 m

2500 m
Design Basis:
Terrace Gravels: \( k_h = k_v = 3 \times 10^{-3} \text{ m/s} \) \( 260 \text{ m/d} \)
Chalk: \( k_h = k_v = 2 \times 10^{-4} \text{ m/s} \) \( 17 \text{ m/d} \)

Best Fit Model:
Terrace Gravels: \( k_h = k_v = 2 \times 10^{-3} \text{ m/s} \)
Chalk Outcrop: \( k_h = 6 \times 10^{-4} \text{ m/s}, \ k_v = 6 \times 10^{-5} \text{ m/s} \)
High k Chalk: \( k_h = k_v = 6 \times 10^{-2} \text{ m/s} \) \( 5,200 \text{ m/d} \)
Transition Zone: \( k_h = k_v = 5 \times 10^{-4} \text{ m/s} \) \( 40 \text{ m/d} \)
Weathered Chalk: \( k_h = 4 \times 10^{-4} \text{ m/s}, \ k_v = 1 \times 10^{-6} \text{ m/s} \) \( 0.09 \text{ m/d} \)
Base Chalk: \( k_h = 2 \times 10^{-5} \text{ m/s}, \ k_v = 2 \times 10^{-7} \text{ m/s} \)
Southern Approach Geological Section
Observations

- Site investigation did not identify high k zone
- High k zone expected but scale uncertain – cut-off?
- Anisotropic conditions hard to identify in SI
- Coped with 2 orders of magnitude change in k
- Cost/programme impacts modest in this case
- Flow and drawdown data important in early identification of issues and solution
- Relatively simple model but no unique solution (piezo residuals +/-0.4 m average, max 0.9 m)