Dr Ursula Lawrence

Soft Ground Tunnelling through London
Contents

• Introduction to Crossrail
• Ground conditions
• Ground Risk
• Excavated material
Crossrail Route

28 existing surface stations upgraded (11 major reconstructions)

56m/90km of existing surface network

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Central Section

13m/21 km of new sub-surface twin-bore railway through London

9 sub-surface stations

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GDP benefits of at least £36bn

10% added to London’s rail-based network capacity

Up to 14,000 people required at peak of construction

Crossrail Benefits
Total outturn ‘Cost of the Project’ £15.9 Billion

National tax revenues of at least £14.8bn

Approximately 200 million journeys generated in first year

1.5 million people brought within a 60 min commute of central London

24 trains an hour in peak through central part of route

Approximately 200 million journeys generated in first year

1.5 million people brought within a 60 min commute of central London

24 trains an hour in peak through central part of route

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Summary Programme

- **2005**: Bill
- **2006**: Funding
- **2007**: Scheme Design
- **2008**: Detailed Design
- **2009**: Procurement
- **2010**: Enabling Works
- **2011**: Commence Main Works 2010
- **2012**: Royal Assent Summer 08
- **2013**: Launch 1st TBM mid 2011
- **2014**: Central Area Tunnelling & Stations
- **2015**: Systems Installation
- **2016**: Rolling Stock
- **2017**: Commissioning
- **2018**: Operational Readiness
  - New trains on existing infrastructure
  - Phased Opening

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Comparative Running Tunnels

- **Crossrail**: 6.00m
- **Jubilee Line Extension**: 4.35m
- **Victoria Line**: 3.81m
- **Thames Tideway**: 7.20m
- **Channel Tunnel Rail Link**: 7.15m

All dimensions refer to internal diameter.
Central Tunnels Section
Tunnel Boring Machines

Following recent tunnelling experience in London, CLRL will utilise Earth Pressure Balance TBMs except for the Thames crossing where a Slurry machine will be employed.

TBMs will be the primary source for controlling ground movements.
Tunnelling Strategy

Proposed TBM Drives
1. Royal Oak to Farringdon
2. Limmo to Farringdon
3. Stepney Green to Pudding Mill Lane
4. Limmo to Victoria Dock Portal
5. Plumstead to North Woolwich
Typical Platform Tunnel Cross Section

- Primary Lining
- Secondary Lining

1st Stage Concrete

10.0m

12.35m

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Central Tunnels Geology Long Section 1

Royal Oak Portal – Isle of Dogs Station

- SUPERFICIAL DEPOSITS
- RIVER TERRACE DEPOSITS
- LONDON CLAY
- LAMBETH GROUP
- THANET SAND
- CHALK
- EASTBOUND TUNNEL
- UNCERTAIN GEOLOGICAL BOUNDARY

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## London Clay

<table>
<thead>
<tr>
<th>Formation</th>
<th>Unit / Member / Bed</th>
<th>General Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>London Clay Formation (units as King, 1981)</td>
<td>Unit C</td>
<td>Homogeneous, bioturbated, silty clay with dispersed glauconite at its base.</td>
</tr>
<tr>
<td></td>
<td>Unit B</td>
<td>Homogeneous, slightly calcareous silty clay with several thin beds of very silty clay / clayey silt. Basal unit is a sparsely glauconitic sandy clay. Regular succession of semi-continuous claystone bands at 2 to 3m spacing.</td>
</tr>
<tr>
<td></td>
<td>Unit A3</td>
<td>The basal unit is a homogeneous clay containing a number of semi-continuous claystone bands. Above this the remainder of Unit A3 consists of silty clay and very silty clay with thin silt and sand partings. Further thin claystone bands may occur. Pyrite is present throughout.</td>
</tr>
<tr>
<td></td>
<td>Unit A2</td>
<td>Very silty clays and sandy silts on a metric scale, notably pyritic, non-calcareous and containing glauconite. Thin basal unit of glauconitic sandy clay with flint pebbles.</td>
</tr>
</tbody>
</table>
Lambeth Group

Formations
- Woolwich Formation
- Reading Formation
- Upnor Formation

Informal units
- Upper Shelly Clay
- Laminated beds
- Lower Shelly Clay
- Upper Mottled beds
- Lower Mottled beds

Principal lithologies
- Clay
- Sand
- Shell beds
- Gravel beds
- Limestone

© NERC
Historic groundwater

Groundwater levels at Trafalgar Square 1845-2005

Annual mean water levels (mOD)

Source: Centre for Ecology and Hydrology, Wallingford

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Stratigraphic Ground risks

- Obstructions – London Clay nodules
- Hazardous gases posing a risk to workforce
- Irregular groundwater flows in Lambeth Group Sand Channels and Harwich Formation
- Aggressive groundwater from oxidation of sulphates in London Clay
- Smectite rich clays in London Clay and Lambeth Group affects material handling and processing
Site Specific Risks in London

- Faulting and fissuring
- Scour features and buried river channels
- UXO
- Obstructions
- Sensitive structures
- Deep Aquifer
- River Thames
faulting

Figure 42 Principal geological structures of the district.
Farringdon Station 3D geological model

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Faulting
Scour Features
1. Bathymetry

Bathymetry Survey

TRC 1

Woolwich Reach

River flow

Bathymetry (metres OD)

Boreholes TRC 1 to 5

0 m OD

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Eroded and backfilled feature in seismic section

Clay/silt (generic)  Chalk  Fine sand

370 m  Eroded & backfilled feature  Up to 9.2 m thick

TWTT (ms)

N  TRC2  TRC3  S
Chalk logging
Sensitive Structures

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WW2 bomb density map

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Bomb census maps
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CIRIA UXO

Unexploded Ordnance (UXO) - A Guide for the Construction Industry
K. Stone, A. Murray & S. Cooke
## Excavated Material

<table>
<thead>
<tr>
<th>Material</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>2.3M m³</td>
</tr>
<tr>
<td>Piling &amp; Diaphragm Walling Arisings</td>
<td>0.68M m³</td>
</tr>
<tr>
<td>Sprayed Concrete Lining</td>
<td>1.4M m³</td>
</tr>
<tr>
<td>Sand &amp; Gravels</td>
<td>1.15M m³</td>
</tr>
<tr>
<td>Chalk</td>
<td>0.6M m³</td>
</tr>
<tr>
<td>Lambeth Group</td>
<td>0.9M m³</td>
</tr>
<tr>
<td>Demolition arisings</td>
<td>0.27M m³</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>9.5m cu yds (7.3M m³)</strong></td>
</tr>
</tbody>
</table>

- Recovery/Recycling Aggregate & hardcore: **-2.0M m³**

**FOR BENEFICIAL REUSE**  6.9M cu yds 5.3M m³
Excavated Material Histogram

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Excavated Material

• Over 200k m³ per month at peak
• Material generated 2010 – 2015
• Initial transport
  – 14% by rail  – 1M m³ 1.3M cu.yds
  – 39% by barge  – 2.9M m³ 3.8M cu.yds
  – 47% by road  – 3.4M m³ 4.4M cu.yds
• Overall 85% of transport is by water and rail on a volume/mileage basis
Movement of Excavated Material

- **Westbourne Park - Western Tunnelling Site**: 1 M m³
- **Limmo - Eastern Tunnelling Site**: 3.1 M m³
  - **Manor Wharf**: 2.3 M m³
  - **East London Wharf**: 3.2 M m³
  - **Northfleet Embankment/Queenborough**: 0.3 M m³
  - **Wallasea Island**: 4.1 M m³
- **Plumstead Portal/Woolwich Station**: 0.9 M m³
- **Recycled**: 2 M m³

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Transport

Generally 300 loads per day in Central London
Peak: 150-200 lorries moving c600 loads per day Crossrail wide

4 trains of 20 wagons per day

5x 2000 tonne ships per day plus barges
Location of Sites

- Wallasea Island
- Queenborough & Rushenden
- Northfleet Embankment

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Wallasea Island

- RSPB scheme to transform, in a phased and managed way, 620 hectares of arable farmland into the coastal marshland it once was.
- The newly restored landscape will be a wetland mosaic of mudflats and saltmarsh, shallow lagoons and pastures.
- Criss-crossed by higher level bunds to provide access.
- Capacity to take approximately 10M m³ bulked.
- All excavated material delivered by water.
- Planning application submitted
Wallasea Island
Wallasea Island
Delivering a world-class affordable railway safely through effective partnerships