**Thames Tideway Tunnel**
Thames Water Utilities Limited

# Development Consent Order

Application Reference Number: WWO10001

## Documents for Certification
## September 2014

We, Lindsay Speed and Sarah Fairbrother hereby certify that this is a true copy of the environmental statement referred to in Article 61 (1) (f) of the Thames Water Utilities Limited (Thames Tideway Tunnel) Order 2014.

Lindsay Speed    Sarah Fairbrother

September 2014

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

**Thames Tideway Tunnel**
Thames Water Utilities Limited

# Application for Development Consent

Application Reference Number: WWO10001

# Environmental Statement

Doc Ref: **6.2.03**

## Volume 3: Project-wide effects assessment appendices

APFP Regulations 2009: Regulation **5(2)(a)**

Hard copy available in

Box **17.3** Folder **A**
January 2013

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**Thames Tideway Tunnel**
Thames Water Utilities Limited

# Application for Development Consent

Application Reference Number: WWO10001

# Environmental Statement

Doc Ref: **6.2.03**

## Volume 3: Project-wide effects assessment appendices

### Appendix E: Historic environment

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# Thames Tideway Tunnel

# Environmental Statement

# Volume 3 Project-wide effects assessment appendices

# Appendix E: Historic environment

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# Application for Development Consent

Application Reference Number: WWO10001

# Environmental Statement

Doc Ref: **6.2.03**

## Volume 3: Project-wide effects assessment appendices

### Appendix E.1: Building damage assessment Stage 3 report

APFP Regulations 2009: Regulation **5(2)(a)**

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# Appendix E: Historic Environment

## E.1 Building damage assessment Stage 3 report – Listed Buildings

E.1.1 The following report has its own table of contents.

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# Application for Development Consent

Application Reference Number: WWO10001

## Building Damage Assessment

### Stage 3 – Listed Buildings

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# Thames Tideway Tunnel

# Building damage assessment Stage 3
# Listed buildings

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## List of abbreviations

| | |
|---|---|
| CSO | combined sewer overflow |
| ID | Internal tunnel diameter |
| PBA | Peter Brett Associates |
| EPB | Earth Pressure Balance |
| SCL | Sprayed Concrete Lining |
| TBM | Tunnel Boring Machine |
| CTRL | Channel Tunnel Rail Link |
| BS | British Standards |
| LBA | Listed Building Assessments |

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# 1 Introduction

1.1.1 The Thames Tideway Tunnel project comprises a wastewater storage and transfer tunnel (the ‘main tunnel’) between Thames Water’s existing operational sites at Acton Storm Tanks and Abbey Mills Pumping Station that would capture combined sewage flows from 34 ‘unsatisfactory’ CSOs that discharge into the Thames Tideway. The flows would be stored in the main tunnel system and transferred to Beckton Sewage Treatment Works for treatment. The project is a component of the overall London Tideway Improvement Programme, which also comprises improvements at five sewage treatment works and the Lee Tunnel project.

1.1.2 As part of the works, Thames Tideway Tunnel Project Team has appointed Peter Brett Associates (PBA) and their sub-consultant Arup, to carry out the Thames Tideway Tunnel Building Damage Assessment.

1.1.3 The assessment includes assessing the impact of tunnel and shaft construction for Thames Tideway Tunnel on existing listed and non-listed buildings. This document presents the methodology adopted and assessment results for the Stage 3 assessment of listed buildings. The Stage 3 assessment provides a building specific assessment of the risk of damage to listed buildings potentially affected by Thames Tideway Tunnel, considering heritage, sensitivity and structural form in addition to ground movements.

1.1.4 The results for each of the listed buildings, for which a Stage 3 assessment has been carried out, for are presented in Appendices B to I of this report, grouped by London Borough. The buildings considered as part of this study are summarised in Table 1.1.

**Table 1.1: Summary of listed buildings for Stage 3 assessment**

| Building Ref | Building Name | Listed Status | Grid Reference | Local Authority |
|---|---|---|---|---|
| **London Borough of Hounslow** | | | | |
| Z0154, Z0165, Z0173 | 60-62 Bath Road | II | TQ 21625 78999 | Hounslow |
| Z4631 | Swan House | II | TQ 21949 78120 | Hounslow |
| Z4635 | Cedar House | II | TQ 21954 78125 | Hounslow |
| **London Borough of Wandsworth** | | | | |
| Z0549, Z0550 | 7-9 Church Row | II | TQ 25514 74755 | Wandsworth |
| Z0552, Z0554, Z0555, Z0557, Z0558, Z0562, Z4643, Z4644 | 1-6 Church Row | II* | TQ 25519 74730 | Wandsworth |
| Z0594 | All Saints Church | II* | TQ 25475 74720 | Wandsworth |
| Z8613 | Wentworth House | II | TQ 25550 74905 | Wandsworth |
| **Royal Borough of Kensington and Chelsea** | | | | |
| Z9287 | Lots Road Pumping Station | II | TQ 26504 77125 | Kensington and Chelsea |
| **City of London** | | | | |
| Z0379 | Hamilton House | II | TQ 31371 80859 | City of London |
| Z0735 | Telephone House | II | TQ 31400 80879 | City of London |
| Z0736 | Sion House | II | TQ 31493 80858 | City of London |
| Z0737[#] | City of London School | II | TQ 31535 80856 | City of London |
| Z0742 | 9 Carmelite Street | II | TQ 31476 80858 | City of London |
| Z0743 | Carmelite House | II | TQ 31440 80894 | City of London |
| **London Borough of Southwark** | | | | |
| Z1345 | Corbett’s Wharf | II | TQ 34697 79749 | Southwark |
| Z1346[#] | The Angel Public House | II | TQ 34817 79753 | Southwark |
| Z5893 | Chamber’s Wharf | II | TQ 34201 79815 | Southwark |
| Z5896 | 33 Bermondsey Wall East | II | TQ 34228 79798 | Southwark |
| Z9569[#] | Wheat Wharf | II | TQ 33875 79980 | Southwark |
| **London Borough of Tower Hamlets** | | | | |
| Z2095, Z2096 | Free Trade Wharf | II | TQ 35780 80814 | Tower Hamlets |
| Z2288 | Prospect of Whitby | II | TQ 35350 80485 | Tower Hamlets |
| Z3347 | British Waterways Custom House | II | TQ 36263 80795 | Tower Hamlets |
| Z3650 | British Sailors Society | II | TQ 36675 81060 | Tower Hamlets |
| Z3904 | Limehouse Town Hall | II | TQ 36702 81079 | Tower Hamlets |
| Z3930 | Limehouse District Library | II | TQ 36557 81081 | Tower Hamlets |

| Building Ref | Building Name | Listed Status | Grid Reference | Local Authority |
|---|---|---|---|---|
| Z4332 | Dowgate Wharf | II | TQ 38166 82078 | Tower Hamlets |
| Z9128, Z3604 | 777-783 Commercial Road | II | TQ 36769 81145 | Tower Hamlets |
| Z9129 | ‘A’ Metropolitan Wharf | II | TQ 35270 80430 | Tower Hamlets |
| Z9130 | ‘B &C’ Metropolitan Wharf | II | TQ 35255 80410 | Tower Hamlets |
| Z2420 | ‘D’ Metropolitan Wharf | II | TQ 35240 80398 | Tower Hamlets |
| **London Borough of Lewisham** | | | | |
| Z6003, Z6005, Z6006, Z6176 | Deptford Fire Station | II | TQ 36612 78047 | Lewisham |
| Z6259 | 227 Deptford High Street | II | TQ 37126 77670 | Lewisham |
| Z6329 | St Paul’s Church | I | TQ 37286 77480 | Lewisham |
| **London Borough of Greenwich** | | | | |
| Z3218 | Greenwich Sewage Pumping Station | II | TQ 37708 77216 | Greenwich |

# Not taken forward to individual building Stage 3 assessment, see Section 5.2.

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# 2 Thames Tideway Tunnel

2.1.1 The Thames Tideway Tunnel project comprises a wastewater storage and transfer tunnel (the 'main tunnel') between Thames Water's existing operational sites at Acton Storm Tanks and Abbey Mills Pumping Station that would capture combined sewage flows from 34 'unsatisfactory' CSOs that discharge into the Thames Tideway. The flows would be stored in the main tunnel system and transferred to Beckton Sewage Treatment Works for treatment.

2.1.2 The horizontal alignment of the main tunnel would generally follow the River Thames where possible and practical, because:

- It is an efficient route to connect the CSOs located on the north and south banks of the river
- It would allow the use of the river for construction transport (material supply and removal), where practicable and economic
- It would minimise the number of structures the tunnel would pass beneath and so reduce the number of third parties affected.

2.1.3 The route of the main tunnel would take the shortest line from Acton Storm Tanks to the River Thames and stay beneath the river from west London to Rotherhithe. It would then divert from beneath the River Thames to the northeast via the Limehouse Cut and terminate at Abbey Mills Pumping Station, where it would connect to the Lee Tunnel. The captured combined sewage would then be transferred to Beckton Sewage Treatment Works via the Lee Tunnel.

2.1.4 The main tunnel would be approximately 25km long with a nominal internal diameter of between 6.5 and 7.2m. The approximate depth of the tunnel would be between 30m in west London and 65m in east London in order to provide sufficient clearance to existing tunnels and facilities under the capital.

2.1.5 A number of additional 2.2m to 5.0m internal diameter tunnels are also required to connect the existing CSOs to the main tunnel.

2.1.6 The planned alignment for the Thames Tideway Tunnel runs mainly beneath the River Thames at depths of up to 40m below the river bed. The tunnel alignment has been designed to minimise the impact on buildings and third party infrastructure. The main tunnel is to be constructed by Slurry or Earth Pressure Balance (EPB) style Tunnel Boring Machines (TBM) while some of the smaller connection tunnels are to be constructed with Sprayed Concrete Lining (SCL) and either open face shields, or EPB machines.

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# 3 Geology

## 3.1 Route geology

3.1.1 The plans and geological cross sections contained within 100-RG-GEO-00000-000007 Rev AA “Ground investigation report, Appendix A: Maps and geological sections”, issued by Thames Tideway Tunnel Project Team have been reviewed in order to establish ground conditions along the route (it should be noted that in some areas the alignment has altered since the report was issued and geology along the new route has been conjectured from cross sections along the old route).

3.1.2 The Thames Tideway Tunnel construction will take place through a number of different strata within the London Basin. To the west, from Acton, tunnelling is carried out in the London Clay Formation, continuing through the Lambeth Group, Thanet Sand Formation, and into the Chalk Group as the tunnel location moves eastwards. Shafts are constructed through all of these strata, and the superficial strata overlying the London Clay (these include Made Ground, Alluvium and River Terrace Deposits).

3.1.3 Appropriate parameters have been used to represent the response of these strata to tunnelling and shaft excavation.

## 3.2 Listed building specific geology

3.2.1 The geological cross sections contained within 100-RG-GEO-00000-000007 Rev AA “Ground investigation report, Appendix A: Maps and geological sections”, issued by the Thames Tideway Tunnel Project Team were initially reviewed with the alignment data for the current route proposal, to summarise ground conditions beneath each of the listed buildings being assessed.

3.2.2 The boreholes identified on the Thames Tideway Tunnel project cross section plans as being in closest proximity to each of the listed buildings were obtained from the Thames Tideway Tunnel project team. Where the boreholes were located at a considerable distance from the structure, and information was available, additional borehole data was obtained from the British Geological Survey (BGS). The individual boreholes were then cross referenced against the ground conditions summarised from the cross section information.

3.2.3 The geological unit that the Thames Tideway Tunnel is proposed to be constructed through for each of the listed buildings is summarised in Table 3.1. The minimum ground level data is taken from a Digital Terrain Model within the GIS (Geographical Information System) model for the route.

**Table 3.1: Building specific geology**

| Ref | Building Name | Level Tunnel Crown (mTD) | Excavated Tunnel Diameter (m) | Minimum Ground Level (mTD) | Geological Unit Tunnel Constructed Through |
|---|---|---|---|---|---|
| **London Borough of Hounslow** | | | | | |
| Z0154, Z0165, Z0173 | 60-62 Bath Road | +81.2 | 8.1 | +104.3 | London Clay |
| Z4631 | Swan House | +79.9 | 8.1 | +104.2 | London Clay |
| Z4635 | Cedar House | +79.9 | 8.1 | +104.2 | London Clay |
| **London Borough of Wandsworth** | | | | | |
| Z0549, Z0550 | 7-9 Church Row | +87.5 | 3.6 | +104.3 | London Clay |
| Z0552, Z0554, Z0555, Z0557, Z0558, Z0562, Z4643, Z4644 | 1-6 Church Row | +87.6 | 3.6 | +104.5 | London Clay |
| Z0594 | All Saints Church | +87.6 | 3.6 | +104.5 | London Clay |
| Z8613 | Wentworth House | +87.2 | 3.6 | +104.0 | London Clay |
| **Royal Borough of Kensington and Chelsea** | | | | | |
| Z9287 | Lots Road Pumping Station | +66.5 | 4.1 | +104.9 | London Clay |
| **City of London** | | | | | |
| Z0379 | Hamilton House | +59.6 | 8.8 | +104.1 | Lambeth Group |
| Z0735 | Telephone House | +59.5 | 8.8 | +104.6 | Lambeth Group |
| Z0736 | Sion House | +59.3 | 8.8 | +105.2 | Lambeth Group |
| Z0737[#] | City of London School | +59.3 | 8.8 | +106.0 | Lambeth Group |
| Z0742 | 9 Carmelite Street | +59.3 | 8.8 | +104.9 | Lambeth Group |
| Z0743 | Carmelite House | +59.5 | 8.8 | +104.7 | Lambeth Group |
| **London Borough of Southwark** | | | | | |
| Z1345 | Corbett's Wharf | +55.0 | 8.8 | +104.3 | Chalk Group |
| Z1346[#] | The Angel Public House | +54.8 | 8.8 | +101.9 | Chalk Group |
| Z5893 | Chamber's Wharf | +55.7 | 8.8 | +100.7 | Chalk Group |
| Z5896 | 33 Bermondsey Wall East | +55.5 | 8.8 | +101.5 | Chalk Group |
| Z9569[#] | Wheat Wharf | +56.0 | 8.8 | +103.8 | Chalk Group |
| **London Borough of Tower Hamlets** | | | | | |
| Z2095, Z2096 | Free Trade Wharf | +53.1 | 8.8 | +105.8 | Chalk Group |
| Z2288 | Prospect of Whitby | +53.8 | 8.8 | +104.4 | Chalk Group |
| Z3347 | British Waterways Custom House | +52.5 | 8.8 | +105.0 | Chalk Group |

| Ref | Building Name | Level Tunnel Crown (mTD) | Excavated Tunnel Diameter (m) | Minimum Ground Level (mTD) | Geological Unit Tunnel Constructed Through |
|---|---|---|---|---|---|
| Z3650 | British Sailors Society | +51.9 | 8.8 | +106.5 | Chalk Group |
| Z3904 | Limehouse Town Hall | +51.9 | 8.8 | +107.1 | Chalk Group |
| Z3930 | Limehouse District Library | +52.2 | 8.8 | +108.1 | Chalk group / Thanet Sand |
| Z4332 | Dowgate Wharf | +49.6 | 8.8 | +104.8 | Chalk Group |
| Z9128, Z3604 | 777-783 Commercial Road | +51.7 | 8.8 | +104.1 | Chalk Group |
| Z9129 | 'A' Metropolitan Wharf | +53.9 | 8.8 | +104.4 | Chalk Group |
| Z9130 | 'B &C' Metropolitan Wharf | +53.9 | 8.8 | +103.5 | Chalk Group |
| Z2420 | 'D' Metropolitan Wharf | +53.9 | 8.8 | +102.7 | Chalk Group |
| **London Borough of Lewisham** | | | | | |
| Z6003, Z6005, Z6006, Z6176 | Deptford Fire Station | +63.1 | 6.2 | +102.9 | Chalk Group |
| Z6259 | 227 Deptford High Street | +64.8 | 6.2 | +105.5 | Chalk Group |
| Z6329 | St Paul's Church | +65.4 | 6.2 | +105.9 | Chalk Group |
| **London Borough of Greenwich** | | | | | |
| Z3218 | Greenwich Sewage Pumping Station | +66.5 | 6.2 | +103.4 | Chalk Group |

# Not taken forward to individual building Stage 3 assessment, see Section 5.2.

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# 4 Ground movement assessment

## 4.1 Tunnel excavation

4.1.1 The proposed Thames Tideway Tunnel route has been modelled using the Oasys software Xdisp. This software analyses the greenfield ground movement in terms of settlement and horizontal displacement.

4.1.2 Individual building façades selected from the GIS model were analysed at an appropriate height for the building. Displacements were calculated at the underside of foundation level of the building.

4.1.3 Ground movements were determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995).

## 4.2 Shafts and other excavations

4.2.1 There are few methods of analysis from published sources that appraise the magnitude of ground movements arising from shaft excavation in London Clay. New & Bowers (1994) back analysed data arising from construction of a 26m deep and 11m diameter caisson driven shaft in London Clay at Heathrow. The relationship is independent of shaft diameter and therefore New & Bowers (1994) cautioned the use of the relationship where the shaft diameter differs significantly from the 11m shaft monitored as part of the case study.

4.2.2 On the basis of the review of limited case study and on finite element analysis of shafts carried out as part of the Crossrail project, the New & Bowers (1994) relationship has been used for the initial calculation of settlements for the Thames Tideway Tunnel project. Horizontal movements are assumed to be of the same magnitude as vertical movements. The methodology used for calculating shaft displacement is further explained in the Arup Thames Tideway Tunnel report "Supporting information to CDS relating to ground movement assessment methodology", Doc number: 307-RG-TPI-00000-000002.

4.2.3 It should be noted that the methodologies proposed for calculating both tunnel and shaft movements are conservative and are expected to overestimate the impact of ground movement on the buildings.

4.2.4 Thames Tideway Tunnel have identified that Lots Road pumping station and Greenwich sewage pumping station may be affected by site works other than the tunnel and shaft construction. These two buildings have had 'Site interface' assessments carried out.

4.2.5 For the assessments for Lots Road pumping station and Greenwich sewage pumping station, further analysis of the shafts has been carried out using finite element analysis, in addition to the additional construction elements assessed for the site interface assessment. In addition, for the assessment of excavations other than those that can be approximated to a circular shaft, the case history data from CIRIA C580 "Embedded retaining walls: Guidance for economic design" (Gaba et al, 2003) has been used to determine likely ground movements.

4.2.6 The additional assessment works carried out for these two structures are described in Appendix A.

## 4.3 Proposed assessment parameters

4.3.1 For tunnelling induced ground movements, the displacements have been assumed to follow a Gaussian distribution in accordance with Attewell and Woodman (1982). Based on the geology summarised in Section 3, and the proposed tunnel construction methodology as discussed in Section 4.1, the following conservative parameters have been used for estimating the effect of tunnelling in soft ground.

4.3.2 A trough width parameter, k of 0.5 at ground surface has been used for tunnelling in London Clay and the Lambeth Group. The k value at any particular elevation is derived from an empirical equation in relation to depth below ground surface and distance from surface to tunnel axis level using the Mair et al. (1993) and Taylor (1995) methods.

### Volume loss – Tunnel boring machines

4.3.3 The Thames Tideway Tunnel Project Team has specified 3 values of volume loss to be considered for the assessment. These are based on a best-estimate (0.5%), a moderately-conservative (1.0%) and a conservative (1.7%) volume loss. PBA/Arup have adopted a Volume Loss VL = 1.0% for the sections of the Thames Tideway Tunnel alignment constructed by EPB or Slurry style TBMs in either London Clay, Lambeth Group, Thanet Sand or Chalk.

4.3.4 The parameters adopted are considered appropriate for tunnelling in soft ground and are conservative when compared with recorded parameters for similar tunnel projects in London. Experience from Channel Tunnel Rail Link Contract 220 (CTRL), indicates that an average volume loss of 0.5% was achieved for tunnelling with an 8.11m diameter EPB TBM in similar ground conditions, Wongsaroj et al, (2006).

### Volume loss – SCL tunnelling in London Clay or Lambeth Group

4.3.5 There is a risk that higher volume losses will occur in sprayed concrete lined tunnelling.

4.3.6 A volume loss of 1.5% has been adopted to model SCL excavations. Thames Tideway Tunnel's Design Standard and Guidance document specifies the volume loss for open face excavation as 1.5% for best-estimate, 2.0% for moderately-conservative and 3.0% for a conservative approach. However, the proposed 1.5% is conservative when compared with recent case study data from projects such as Heathrow Express and T5, Jubilee Line Extension and King's Cross (KX) Underground Station Redevelopment.

4.3.7 The most recent of these is the KX project. The working procedures anticipated for the Thames Tideway Tunnel project will reflect those used on the KX project. The SCL tunnels from the KX project were constructed in the lower units of London Clay and top of the Lambeth Group. Ground movements arising from the sprayed concrete lined tunnel excavations were monitored and recorded. The volume loss experienced in the monitored sections was between 0.6 and 1% (with a few exceptions). An average volume loss of around 0.8% was recorded. This gives confidence that the 1.5% figure adopted is robust and conservative.

### Volume loss – open face tunnelling in London Clay and Lambeth Group

4.3.8 The Thames Tideway Tunnel Project Team has specified 3 values of volume loss to be considered for open face tunnel excavation. These are based on a best-estimate (1.5%), a moderately-conservative (2.0%) and a conservative (3.0%) volume loss. PBA/Arup have adopted a Volume Loss VL = 2.0%, which should be a robust and appropriately conservative number. This is also in accordance with the Thames Tideway Tunnel project's proposed moderately conservative number for open shield excavation.

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# 5 Listed buildings potentially affected by Thames Tideway Tunnel

5.1.1 The scope of works for Thames Tideway Tunnel project building damage assessment includes the consideration of both non-listed and listed buildings, located within the calculated 1mm surface settlement contour resulting from tunnel and shaft construction. Based on analysis carried out prior to the Arup-PBA commission by the Thames Tideway Tunnel project team, the following numbers of buildings that would potentially be affected were calculated:

- Total buildings within conservative 1mm contour: 2177;
- Total buildings within conservative 10mm contour: 548;
- Listed buildings within conservative 1mm contour: 33.

5.1.2 The listed buildings identified by Thames Tideway Tunnel are given in Table 1.1.

5.1.3 The above numbers were provided to Arup/PBA by the Thames Tideway Tunnel project team. The 1mm contour calculations have been revisited as part of the update to revision AM included in this document confirming the buildings to be included in the Stage 3 listed building assessments. In addition, Wheat Wharf was added to our Scope by the Thames Tideway Tunnel project team as part of the site interface assessments, making a total of 34 listed buildings to be assessed.

## 5.2 Confirmation of listed buildings to be assessed

5.2.1 The Stage 2 screening identified that the extents of three of the listed buildings were located outside of the 1mm settlement contour. These buildings are:

- Z1346, The Angel Public House;
- Z0737, City of London School;
- Z9569, Wheat Wharf.

5.2.2 These three buildings were not taken forward in the Stage 3 assessment process to the site visit and individual assessment, as they were identified as being subject to less than 1mm of ground movement.

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# 6 Desk based heritage study of listed buildings

6.1.1 A desk based study has been carried out to assess the potential heritage issues for each of the buildings listed in Table 1.1 that were taken forward for Stage 3 assessment. The desk based study was completed prior to internal and external inspection of the buildings.

6.1.2 Each study collated available information regarding the building from sources including English Heritage and Local Authorities. The information helped to inform the building inspections and is incorporated into the assessment summary sheets included in Appendices B to I of this report.

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# 7 Damage category assessment

## 7.1 Damage category methodology

7.1.1 The thirty one remaining listed buildings have been assigned a damage category in accordance with the Burland (1995) framework, see Table 7.1. This framework appraises damage, based upon calculated tensile strains for a deep beam and relates these to the likely approximate crack widths and degrees of damage severity based upon ease of repair. The classification system was developed for load bearing masonry structures, however it is considered that the descriptions of damage with respect to ease of repair are useful for all building types. Where the individual buildings do not fit within the Burland framework consideration has been given to the applied displacements and their structural form.

**Table 7.1: Building damage categorisation, after Burland (1995)**

| Category of damage | | Description of typical damage (Ease of repair is underlined) | Approx. crack width (mm) | elim, Limiting tensile strain (%) |
|---|---|---|---|---|
| 0 | Negligible | Hairline cracks. | < 0.1 | < 0.05 |
| 1 | Very Slight | Fine cracks that can easily be treated during normal decoration. Perhaps isolated slight fracture in buildings. Cracks in external brickwork visible on inspection. | 1 | 0.05 - 0.075 |
| 2 | Slight | Cracks easily filled. Redecorating probably required. Several slight fractures showing inside of building. Cracks are visible externally and some repointing may be required externally to ensure weather tightness. Doors and windows may stick slightly. | 5 | 0.075 - 0.15 |
| 3 | Moderate | The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weather tightness often impaired. | 5 - 15 or a number of cracks > 3 | 0.15 – 0.3 |
| 4 | Severe | Extensive repair work involving breaking out and replacing sections of walls, especially over doors and windows. Windows and door frames distorted, floor sloping noticeably. Walls leaning and bulging noticeably, some loss of bearing in beams. Service pipes disrupted. | 15 – 25 but also depends on number of cracks | > 0.3 |
| 5 | Very severe | This requires a major repair job involving partial or complete rebuilding. Beams lose bearing, walls lean badly and require shoring. Windows broken due to distortion. Danger of instability. | Usually >25 but depends on number of cracks | |

Note: Crack width is only one factor in assessing category of damage and should not be used on its own as a direct measure of it.

Note: Local deviation of slope, from the horizontal or vertical, of more than 1/100 will normally be clearly visible. Overall deviations in excess of 1/150 are undesirable.

7.1.2 Façades for assessment of each building were selected from the GIS model. Ground movements for each façade were analysed in Xdisp, with appropriate height and foundation levels applied to each façade (levels assessed from desk based study and site visit). A damage category was then assigned to each building based on the critical results.

7.1.3 Where a listed building obtained a damage category score of 3 or above (described as 'moderate' damage in the work of Burland (1995)), it has been assumed to require mitigation.

7.1.4 Where a listed building obtained a damage category score of less than 3 the score has been considered in conjunction with other assessments (see Figure 8.1), as defined in Section 8.

# 8 Structural, condition and heritage sensitivity assessment

## 8.1 Introduction

8.1.1 The structural, condition and heritage sensitivity methodology has been based on the Crossrail assessment methodology and was developed in consultation with English Heritage and relevant local authorities.

8.1.2 The methodology treats each listed building as an individual case and considers the ground movements modelled during the damage category assessment. The nature of each building in terms of structure, condition and evidence of previous repair, alteration and movement has been taken into account during the scoring process. Scoring has been split into three assessment categories, ensuring that buildings which may have particular sensitivities have been accounted for.

## 8.2 Structural sensitivity background

8.2.1 The assessment of the structural sensitivity of the listed buildings is based generally on the approach adopted for Crossrail, as outlined in Crossrail Information Paper D12. There is no formal standard which codifies this approach: it identifies a number of factors which may be accepted as being of significance in the building's response to ground movement (including the building's condition) and are then reviewed in conjunction with the magnitude of such movement. Examples of such factors are given in Table 8.1.

8.2.2 The building is then given a structural sensitivity score, based on the inspection of the building and the calculated movements and damage category.

8.2.3 This score then forms one component of the overall 'total' score assigned to the building. It is the total score that is considered alongside the calculated building distortion when appraising whether mitigation is necessary.

## 8.3 Condition sensitivity background

8.3.1 As part of the Thames Tideway Tunnel project Stage 3 listed building assessments, the general condition, as found on the day of inspection, has been graded as being good, poor or very poor. This condition is then related to the damage assessment score, to enable a judgement to be made as to whether the particular condition defects of a certain building will make it more sensitive to the calculated movement.

8.3.2 The building is subsequently given a condition score, combining the damage assessment calculation with the observations on condition. The poorer the condition of a building is, the higher its sensitivity is likely to be. However, if a building is in poor condition but structurally sound, and in an area where settlement is calculated to be minimal, then its sensitivity due to condition will be low, and the works will not be expected to produce further deterioration.

## 8.4 Heritage sensitivity background

8.4.1 The Stage 3 listed building assessment (LBA) process for the Thames Tideway Tunnel project commission has been generally based on the approach used by Crossrail, refined to take account of improvements developed during the application of the Crossrail approach. However the magnitude of impact from the Thames Tideway Tunnel project works is generally significantly less than that of Crossrail on listed structures. This is due to a number of factors, including: much of the Thames Tideway Tunnel alignment is located beneath the Thames River; the Thames Tideway Tunnel only requires a single bore tunnel compared to Crossrail's dual bore; and the stations on Crossrail are major SCL excavations adjacent to numerous listed buildings, whereas the Thames Tideway Tunnel connecting structures are generally away from buildings.

8.4.2 For the Thames Tideway Tunnel project work, damage assessment information from calculated ground movement was available prior to the LBA, ensuring that heritage 'scoring' took into account the level of damage assessed for each building from the outset. This has allowed a realistic heritage sensitivity score to be allocated without the need for re-assessment.

8.4.3 For the Thames Tideway Tunnel project commission the LBAs have been conducted on an individual, building-specific basis, with external and internal (where possible) visual survey of the buildings complementing the desk based study. Scoring has been based on the building's structural form, sensitive features, fixtures and finishes, and the damage assessment results.

## 8.5 Guidance for scoring structural, condition and heritage sensitivity

8.5.1 In order to ensure a consistent approach to the derivation of scores for structural, condition, and heritage sensitivity, the following scoring matrix developed for the Thames Tideway Tunnel project, and shown in Table 8.1 has been used.

**Table 8.1: Structural and heritage scoring matrix for listed buildings**

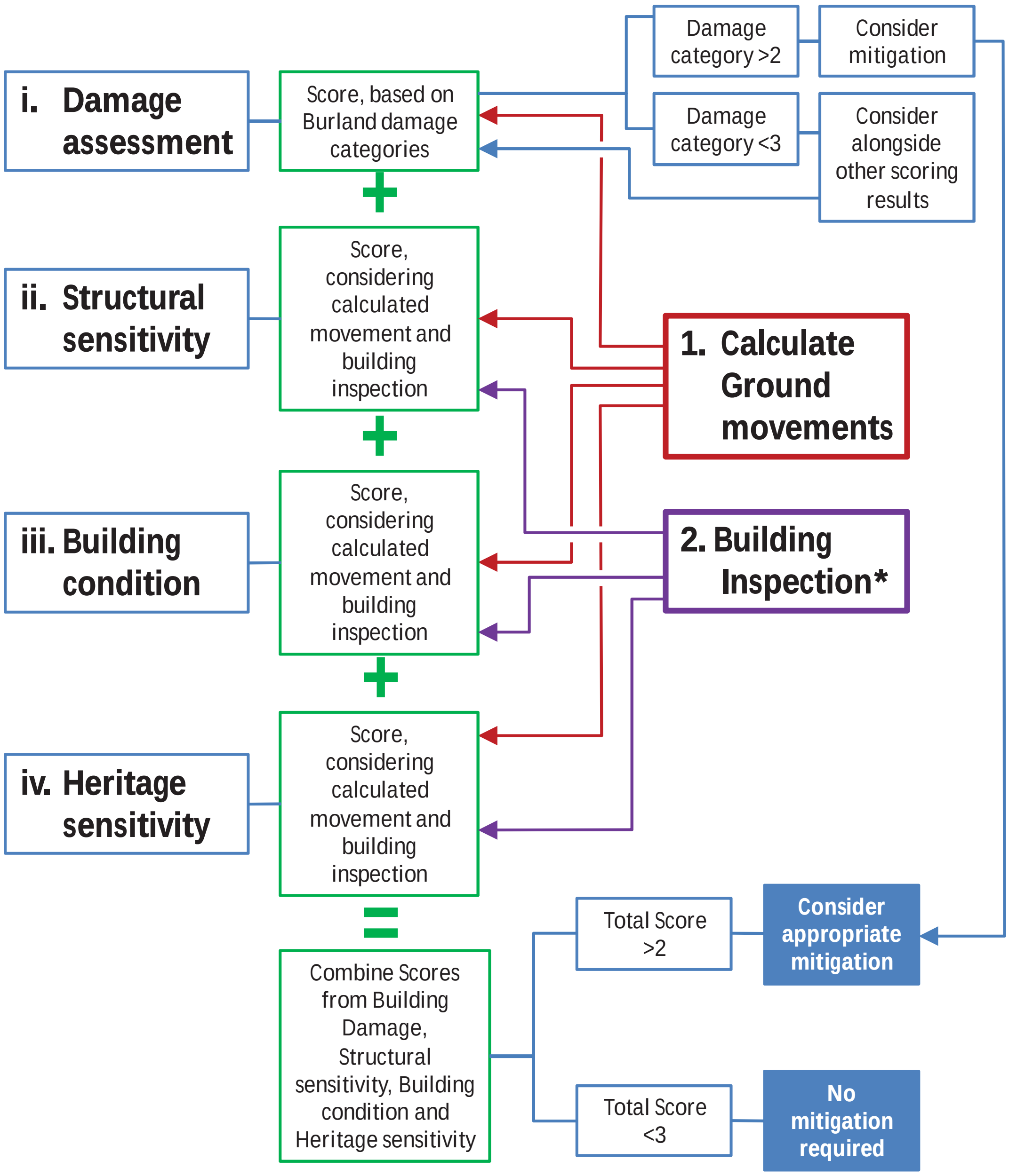
| Score | STRUCTURE | HERITAGE FEATURES | CONDITION |
|---|---|---|---|
| | **Sensitivity of the structure to ground movements and interaction with adjacent buildings** | **Sensitivity to calculated movement of particular features within the building** | **Factors which may affect the sensitivity of structural or heritage features** |
| **0** | Masonry buildings with lime mortar and regular openings, not abutted by other buildings, and therefore similar to the buildings on which the original Burland assessment was based. | No particular sensitive features | Good - not affecting the sensitivity of structural or heritage features |
| **1** | Buildings not complying with categories 0 or 2, but still with some sensitive structural features in the zone of settlement e.g.: cantilever stone staircases, long walls without joints or openings, existing cracks where further movements are likely to concentrate, mixed foundations | Brittle finishes, e.g. faience or tight-jointed stonework, which are susceptible to small structural movements and difficult to repair invisibly. | Poor - may change the behaviour of a building in cases of movement. Poor condition of heritage features and finishes. Evidence of previous movement. |
| **2** | Buildings which, by their structural form, will tend to concentrate all their movements in one location (e.g.: a long wall without joints and with a single opening). | Finishes which if damaged will have a significant effect on the heritage value of the building, e.g. Delicate frescos, ornate plasterwork ceilings. | Very poor – parlous condition of heritage features and finishes, ~~or~~ severe existing damage to structure including evidence of ongoing movement. Essentially buildings which are close to collapse or where finishes are loose such that even very small movements could lead to significant damage. |

8.5.2 The matrix in Table 8.1 is a tool, to be used in conjunction with the results of the building inspections. The scores have been used to guide judgements for the individual buildings. However the structural and heritage assessment is not purely a scoring process, more an integrated review of the available information.

## 8.6 Combining to produce overall building score

8.6.1 The scores from the building damage, structural sensiticity, condition, and heritage sensitivity assessments were combined to produce an overall score for each building. The overall scoring process is described diagrammatically in the following figure (Figure 8.1).

**Figure 8.1 Overall Listed buildingassessment process.**




* May be based on desk-based virtual inspection. Conservative view taken if so.

8.6.2 Buildings that obtained a combined score of 3 or more were subject to a further level of evaluation. This further level has been undertaken with a view to mitigating damage and draws on data from the building damage category assessment. Where a building was assessed as damage category 0 (negligible damage), consideration has been given to the structure, heritage feature and condition scores. At the same time engineering judgement has been applied by the assessor to ensure the combined score does not result in an inappropriately high total impact score for the anticipated ground movement.

# 9 Results of assessment

## 9.1 Introduction

9.1.1 The thirty one listed buildings within the 1mm settlement contour (1m below ground surface) have been subject to assessment, as described in Sections 7 and 8. The individual building assessment reports are provided in Appendices B to I, split by local authority.

9.1.2 Reasonable efforts have been made to access all thirty one listed buildings. Access has not been gained to all properties (No access to 3 buildings, and only partial access to 3 buildings – see Table 9.1) for a number of reasons, including difficulty contacting owners and tenants, and their availability to allow access. Where on-site access has not been possible, a desk based 'virtual' walk over has been carried out, and a conservative position taken in the assessment.

## 9.2 Results of damage category assessment

9.2.1 A damage category assessment has been carried out for each listed building, following the methodology described in Section 7. The individual results are presented in Appendices B to I and summarised in Table 9.1.

9.2.2 The majority of results fell within the bounds of risk of damage category 0, negligible damage, defined as hairline cracks (crack width <0.1mm). The two exceptions to this are;

- Building Z3218, Greenwich Sewage Pumping Station. The damage is likely to be in the slight (2) to moderate (3) category. Damage can be easily repaired but repairs will be visible. Category 3 is defined as *cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weather tightness often impaired. 5 – 15mm or a number of cracks > 3mm, 0.15- 0.3%*

- Building Z9287, Lots Road Pumping Station, damage category 2 (slight) to moderate (3). As for Greenwich Sewage Pumping Station, damage can be easily repaired but repairs will be visible. Category 3 is defined as *cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weather tightness often impaired. 5 – 15mm or a number of cracks > 3mm, 0.15- 0.3%*

9.2.3 None of the listed buildings assessed, other than the two described above fell into a damage category higher than 2. Therefore only these buildings have been automatically assumed to require mitigation measures, without consideration of the other assessment parameters.

## 9.3 Results of structural sensitivity classification

9.3.1 Of the listed buildings inspected internally, eight score 1 for their structural sensitivity. Of those not yet inspected (or partially inspected), provisional scores higher than 0 have been allocated to one listed building.

*9.3.2* Of the eight noted above, two are churches (All Saints Church and St Pauls Church) which have tall structures (the tower at St Paul's Church in particular) standing higher than the level of the main body of the building and also have large open structures internally. Deptford Fire Station has a cantilever staircase (in the area of calculated settlement), 7-9 Church Row shows some evidence of previous movement and comprises three main elements (No 7, No's 8/9 and the former cottages to the rear). Wentworth House has similar characteristics to 7-9 Church Row. The Prospect of Whitby public house is likely to have mixed foundations and a partial basement (making it more sensitive to ground movement). Limehouse district Library has two long brickwork elevations without openings, straddling the tunnel, and will be prone to cracking. Lots Road Pumping Station and Greenwich Sewage Pumping Station have also been given a score of 1 due to their structural form (solid walls without joints and with few, large openings).

## 9.4 Results of heritage classification

9.4.1 Of the listed buildings inspected internally, eight score 1 for their heritage sensitivity. Of those not yet (or only partially) inspected, provisional scores higher than 0 have been given to four listed buildings.

9.4.2 St Paul's Church, All Saint's Church, the Prospect of Whitby, Limehouse Town Hall, Greenwich Pumping Station, Limehouse District Library, 777-783 Commercial Road, 7-9 Church Row, Lots Road Pumping Station have all been given a score of 1, judged to have heritage features that are brittle or easily damaged, and susceptible to settlement. In many cases these elements are timber or plaster internal finishes, tightly jointed stonework, or cantilevered stairs. Of those buildings partially or not inspected 1-6 Church Row, 227 Deptford High Street and British Sailors Society have all provisionally been awarded a score of 1.

9.4.3 Historic finishes are both difficult and costly to repair due to the scarcity of specialist tradespeople and materials. The repair of any historic features and finishes damaged during the Thames Tideway Tunnel works require specific consent, local authority and English Heritage agreement on materials and method, and employment of specialist contractors.

9.4.4 No heritage building has been given a score of 2.

## 9.5 Results of condition classification

9.5.1 Of the buildings which have been visited, nine were seen to have a score of 1 due to their condition. These buildings were in a generally poor condition, with dilapidation or minor cracking making them somewhat more sensitive to settlement. Buildings with a score of 1 tended to have defects due to condition both internally and externally; condition was seen to have an impact on the ability of the features of heritage value as well as some structural elements to withstand large movements.

9.5.2 Of the buildings visited one building rated a condition score of 2, 777-783 Commercial Road. In this case the building is in a serious condition due to long term neglect and vacancy. In one area of the building this has been partially addressed in the short term by the erection of internal scaffolding and re-roofing. The damage category for this building is 0, and its structure will not be sensitive to settlement. Therefore no mitigation will be required due to the Thames Tideway Tunnel project, but there is a general need for this building to be secured against further deterioration. .

9.5.3 Of the buildings where visits have not yet been undertaken, or only partial access has been available 227 Deptford High Street has been awarded a score of above 0, rated condition category 2.

9.5.4 In all cases, where the buildings inspected were noted to be of poor or very poor condition, it must be verified prior to the works that the condition of these buildings does not deteriorate further and cause other sensitivities in the future.

9.5.5 We assume that a defect/condition survey will be undertaken for all buildings potentially affected by the construction of the tunnel, so that the responsibility for any alleged damage can be clarified.

## 9.6 Results summary

9.6.1 The individual assessment summaries for each listed building are presented in Appendices B to I. Table 9.1 summarises the listed building assessment results;

**Table 9.1: Listed building assessment result summary**

| Ref | Building name | Damage category | Structural sensitivity | Heritage sensitivity | Condition | Total |
|---|---|---|---|---|---|---|
| **London Borough of Hounslow** | | | | | | |
| Z0154, Z0165, Z0173 | 60-62 Bath Road * | 0 | 0 | 0 | 0 | 0 |
| Z4631 | Swan House ‡ | 0 | 0 | 0 | 0 | 0 |
| Z4635 | Cedar House | 0 | 0 | 0 | 0 | 0 |
| **London Borough of Wandsworth** | | | | | | |
| Z0549, Z0550 | 7-9 Church Row | 0 | 1 | 1 | 0 | 2 |
| Z0552, Z0554, Z0555, Z0557, Z0558, Z0562, Z4643, Z4644 | 1-6 Church Row * | 0 | 0 | 1 | 0 | 1 |

| Ref | Building name | Damage category | Structural sensitivity | Heritage sensitivity | Condition | Total |
|---|---|---|---|---|---|---|
| Z0594 | All Saints Church | 0 | 1 | 1 | 1 | 3 |
| Z8613 | Wentworth House | 0 | 1 | 0 | 1 | 2 |
| **Royal Borough of Kensington and Chelsea** | | | | | | |
| Z9287 | Lots Road Pumping Station | 2 | 1 | 1 | 1 | 5 |
| **City of London** | | | | | | |
| Z0379 | Hamilton House | 0 | 0 | 0 | 0 | 0 |
| Z0735 | Telephone House | 0 | 0 | 0 | 0 | 0 |
| Z0736 | Sion House | 0 | 0 | 0 | 0 | 0 |
| Z0737 | City of London School | Screened out - less than 1mm movement | | | | |
| Z0742 | 9 Carmelite Street | 0 | 0 | 0 | 0 | 0 |
| Z0743 | Carmelite House | 0 | 0 | 0 | 0 | 0 |
| **London Borough of Southwark** | | | | | | |
| Z1345 | Corbett's Wharf | 0 | 0 | 0 | 1 | 1 |
| Z1346 | The Angel Public House | Screened out - less than 1mm movement | | | | |
| Z5893 | Chamber's Wharf | 0 | 0 | 0 | 0 | 0 |
| Z5896 | 33 Bermondsey Wall East | 0 | 0 | 0 | 0 | 0 |
| Z9569 | Wheat Wharf | Screened out - less than 1mm movement | | | | |
| **London Borough of Tower Hamlets** | | | | | | |
| Z2095, Z2096 | Free Trade Wharf * | 0 | 0 | 0 | 0 | 0 |
| Z2288 | Prospect of Whitby | 0 | 1 | 1 | 0 | 2 |
| Z3347 | British Waterways Custom House | 0 | 0 | 0 | 1 | 1 |
| Z3650 | British Sailors Society ‡ | 0 | 0 | 1 | 0 | 1 |
| Z3904 | Limehouse Town Hall | 0 | 0 | 1 | 1 | 2 |
| Z3930 | Limehouse District Library | 0 | 1 | 1 | 1 | 3 |
| Z4332 | Dowgate Wharf ‡ | 0 | 0 | 0 | 0 | 0 |
| Z9128, Z3604 | 777-783 Commercial Road | 0 | 0 | 1 | 2 | 3 |
| Z9129 | 'A' Metropolitan Wharf | 0 | 0 | 0 | 0 | 0 |
| Z9130 | 'B &C' Metropolitan Wharf | 0 | 0 | 0 | 0 | 0 |
| Z2420 | 'D' Metropolitan Wharf | 0 | 0 | 0 | 0 | 0 |

| Ref | Building name | Damage category | Structural sensitivity | Heritage sensitivity | Condition | Total |
|---|---|---|---|---|---|---|
| **London Borough of Lewisham** | | | | | | |
| Z6003, Z6005, Z6006, Z6176 | Deptford Fire Station | 0 | 1 | 0 | 0 | 1 |
| Z6259 | 227 Deptford High Street ‡ | 0 | 0 | 1 | 2 | 3 |
| Z6329 | St Paul's Church | 0 | 1 | 1 | 1 | 3 |
| **London Borough of Greenwich** | | | | | | |
| Z3218 | Greenwich Sewage Pumping Station | 3 | 1 | 1 | 1 | 6 |

‡ buildings where site visits are identified as required, but access has not been arranged to all structures.

* buildings where partial access was gained – see Section 11.1.3.

9.6.2 The shaded cells in the above table are those that attained a combined score of 3 or more, from building damage, structural sensitivity, heritage sensitivity and condition assessments. Further work recommendations, and consideration of the efficacy of mitigation measures have been made for each of these buildings on the individual assessment sheets included in Appendices B to I.

## 9.7 Mitigation measures

9.7.1 In general, intrusive mitigation measures, such as compensation grouting, would be considered where this was felt necessary to provide protection to the structure or to safeguard heritage features of particular importance and sensitivity. For the buildings inspected, it is considered that such intervention is neither required nor appropriate. Such intervention (e.g. soil grouting, underpinning etc) may be more intrusive and damaging to heritage fabric than a carefully managed process of survey and repair of minor defects if required using appropriate materials and techniques.

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# 10 Risks and opportunities

10.1.1 The following risks, opportunities or assumptions have been identified from the Conceptual Design Statement (CDS) and from carrying out the Stage 3 assessment. Comment is provided with respect to gaining a better understanding of how best to resolve or mitigate risks.

**Table 10.1: Risks and opportunities**

| Risk identified | Impact * | Action taken / proposed |
|---|---|---|
| Shaft assessment methodology validated from little case study data. | Possibility that method is not transferrable to all of the Thames Tideway Tunnel shaft construction / dimensions. | Considered that the methodology for assessing shafts is conservative. FE analysis used for Lots Road pumping station and Greenwich sewage pumping station analyses.<br>Any further assessment recommendations have been made with regard to individual reports. |
| Use of Burland (1995) method for masonry buildings relies on buildings being similar to Burland case studies | Damage could be worse than predicted | Where buildings do not fit the Burland methodology this has been taken into account in the Structural Sensitivity Score. The individual reports include assessment of the Burland results where the structure does not completely fit the model. |
| Long term settlements not included in damage assessments (normal practice) | Long term settlements could increase distortion to structures | Several authors have indicated that this is not an issue.<br>A review of available Jubilee Line Extension data and finite element studies carried out as part of Crossrail design work could be carried out to review this assumption. |
| Scour features, other geological anomalies | Volume losses for use in assessments cover the normal range of geotechnical scenarios, but do not account for | Scour features report reviewed as part of Arup-PBA building assessment commission. There is a general lack of information relating to scour features further west. |

| Risk identified | Impact * | Action taken / proposed |
|---|---|---|
| | anomalies | |
| Pile lengths being longer than assumed. | Potential increase in risk of building damage | Where piled foundations have been identified as potentially present it has been assumed that pile lengths do not exceed 25m in length. This is considered to be conservative in most cases. |
| Ground movements calculated for tunnelling in chalk conservative | Increase in number of affected buildings due to conservative assessment | A review of the Lee tunnel data could be carried out when available to refine analysis parameters for chalk.<br>The tunnelling induced ground movements are conservative, therefore on average the actual damage is likely to be less than calculated. This comment can also be applied to a lesser degree to all tunnelling induced ground movements. |
| Internal surveys not carried out for all buildings | Potential for missed features which may impact damage risk categorisation. | Access could not be gained to all properties. There is a risk that important structural or heritage features may not have been identified as part of the work described in this report. Efforts are ongoing to complete inspections. |
| Damage assessment considers damage to building structure but not structural damage to piles | Not likely to have a significant impact, provided only compressive loading on the piles. | Assumption is that those piles subjected to tensile forces will be reinforced to full depth. |
| Clashes between tunnels and piles | Not likely to have a significant impact, as assumed to be reviewed by the Thames Tideway Tunnel project team. | GIS database combined with a review of the Google Streetview images has been carried out to identify buildings that may potentially present an obstruction to tunnelling. This has been passed to the Thames Tideway Tunnel project team for information. |

| Risk identified | Impact * | Action taken / proposed |
|---|---|---|
| | | Subsequent archive searches could be focussed on these structures. |
| Damage to Services entry / exit to building. Not specifically appraised in the absence of having any details. | Potential risk for brittle services that cannot accommodate movement. | No action taken, but could be considered as part of a separate study based on previous studies for the Crossrail project. |
| Access for surveys was not complete and unhindered | Potential that areas not accessed may contain features that would have altered the total score. | As complete surveys of all buildings have not been undertaken there remains some risk that features, which may have affected the final scores have not been identified. |
| The condition of some buildings was poor at the time the survey was undertaken | There is the potential that the condition of buildings will continue to degrade prior to construction of the Thames Tideway Tunnel to the extent that the building may behave differently to that anticipated. | Where considered necessary recommendations have been made that the condition should be reassessed prior to construction of the Thames Tideway Tunnel. |

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# 11 Summary and recommendations

11.1.1 Thirty four listed buildings were considered for Stage 3 building damage assessment, thirty one of these buildings were taken to the individual building assessment stage. Three buildings were screened out in an initial assessment:

- Z1346 – The Angel Public House;
- Z0737 – City of London School;
- Z9569 - Wheat Wharf.

11.1.2 Each of the thirty one buildings were assessed using the criteria and methodologies described in Sections 6, 7 and 8. However at the time of writing access could not be gained to the following properties:

- Z6259 – 227 Deptford High Street;
- Z4332 – Dowgate Wharf;
- Z3650 – British Sailors Society;
- Z4631 – Swan House;

11.1.3 Partial access was gained to the following properties;

- Z0552, Z0554, Z0555, Z0557, Z0558, Z0562, Z4643 and Z4644 – 1 to 4 Church Row accessed, no entry to 5 and 6 Church Row.
- Z0154, Z0165 and Z0173 – 60 Bath Road accessed, no entry to 62 Bath Road
- Z2095 and Z2096 – Free Trade Wharf was viewed only from the outside due to difficulty gaining permission for internal access

11.1.4 All of the buildings above were analysed for ground movement and assigned a building damage category. They were also the subject of a desk study review. The listed building assessment reports have been completed as fully as possible under the circumstances for each building and are provided in Appendices B to I of this report, separated into the relevant London Boroughs.

11.1.5 Further revisions of this report may incorporate additional buildings if access is made available and further inspections are carried out.

11.1.6 For the remainder of the buildings, where a site visit has been undertaken and a full review completed, the building assessment reports are also included in Appendices B to I.

11.1.7 The majority of buildings fell within category 0, negligible damage, when analysed for building damage category. No façade or wall analysed for any structure attained a score of category 3 or greater, therefore no building was automatically assumed to require mitigation measures without taking into consideration Structure, Heritage features and Condition scores.

11.1.8 A total of seven buildings reached a combined total of 3 or greater from the damage assessment, structural sensitivity, heritage sensitivity and condition scores. These are:

- Z6329 - St Paul's Church
- Z0594 - All Saints' Church
- Z3930 - Limehouse District Library
- Z9128 - 777-783 Commercial Road
- Z9287 - Lots Road Pumping Station
- Z3218 – Greenwich Sewage Pumping Station
- Z2659 – 227 Deptford High Street

11.1.9 Of these, all are predicted to have a damage category of 0 other than Lots Road Pumping Station, and Greenwich Sewage Pumping Station, which both have a calculated risk of damage category 3. In addition, no score greater than 1 has been allocated to either structural sensitivity, or heritage sensitivity. The condition scores allocated generally attain a value of 1 or less, the only exceptions to this are 777-783 Commercial Road that has attained a score of 2 and 227 Deptford High Street, which also attained a provisional score of 2, as a site visit has not yet been undertaken.

11.1.10 In general, mitigation measures would be considered where this was felt necessary to provide protection to the structure or to safeguard heritage features of particular importance and sensitivity. For the buildings inspected and the assessments as set out above, it is considered that such intervention is neither required nor appropriate. Intervention is likely to be more intrusive and damaging to heritage fabric than a carefully managed process of survey and repair of minor defects if required using appropriate materials and techniques. It is worth noting however, that ground interventions (such as compensation grouting) cannot mitigate against damage category 0 where ground movements are minimal.

11.1.11 In the case of Lots Road, the potential settlement is conservatively calculated at the building to be circa 15mm. The installation of compensation grouting or underpinning has been known to produce settlement or heave of up to around the same magnitude, so installation of mitigation measures of this type would result in damage similar to that expected without. Intrusive mitigation measures such as tying-in at the south and east sides of the building may cause rigidity in structure which could lead to unnatural stiffness in the façade, causing the decoration to become more damaged. It would be less intrusive to the building, in light of the level of potential damage, to allow the cracks to form, and embark on a course of sensitive repair after the works have been completed.

11.1.12 For Greenwich sewage pumping station, in common with Lots Road, the calculated movements are similar to those that would be expected from the installation of intrusive mitigation measures such as compensation grouting or underpinning. Refurbishment works are to take place to Greenwich Pumping station as part of Thames Tideway Tunnel project's aim of re-using the structure. It is considered that it would be more appropriate to repair any cracks etc as part of these works.

# Bibliography

## General

At this stage, PBA/Arup is not aware of any particular assessment requirements from the asset owners. The ground movement and building damage, structure and heritage assessments have been carried out using appropriate methods in accordance with engineering standards and codes adopted by the tunnelling industry and on projects such as Crossrail and HS1.

The codes, technical papers and best practice guides used are listed below.

## Structural codes:

| | | |
|---|---|---|
| BS | 8110-2:1985 | Structural use of concrete - Part 2: Code of practice for special circumstances |

Reference to British Standards (BS) and Eurocodes will be made where appropriate.

## Tunnel references

Attewell P B and Woodman J P (1982), Predicting the dynamics of ground settlement and its derivatives caused by tunnelling in soil. *Ground Engineering*, November 1982, 13 - 36.

Burland J B (1995). Assessment of risk of damage to buildings due to tunnelling and excavation. Invited Special Lecture: In: *1st Int. Conf. On Earthquake Geotech.Engineering*, IS Tokyo '95.

Crossrail Information Paper, D12 Ground Settlement, Version 5, 2008.

Mair R J, Taylor R N & Bracegirdle A (1993), Sub-surface settlement profiles above tunnels in clays, *Geotechnique*, Vol. 43 No. 2, pp 315-320.

New B M & Bowers K H (1994), Ground movement model validation at the Heathrow Express trial tunnel. *Proc. Tunnelling 1994*. IMM, London, pp 301-327.

Taylor R N (1995), Tunnelling in soft ground in the UK. In: *Underground construction in soft ground*. K Fujita and O Kusakabe (Eds). Balkema. pp123-126.

*Wongsaroj J et al (2006), Effect of TBM driving parameters on ground surface movements: Channel Tunnel Rail Link Contract 220, Proc. Geotechnical Aspects of Underground Construction in Soft Ground pp 335-341*

# Appendix A: Site Interface assessments for Lots Road and Greenwich sewage pumping station

Subject Rationale for FE and Xdisp modelling approach for Greenwich and Lots Road

Date 18 May 2012 Job No/Ref 217993-00

# 1 Modelling approach

Listed structures at both Lots Road and Greenwich Pumping Station were identified as requiring further analysis to assess the construction impacts at these locations. Finite Analysis modelling to refine the understanding of construction related movements for the main shafts had already been agreed and undertaken for two comparable sites at Albert Embankment Foreshore and Earl pumping Station, respectively. Given the similar ground conditions and shaft depth the results from the FE analysis have been used to estimate the displacements at Lots Road and Greenwich.

It is important to note that since the original Stage 3 Listed structures report (20 April 2012) the models for Lots Road Cremorne Wharf and Greenwich Pumping Station have been revised to include the extended scope to incorporate the construction of associated connection culverts and interception chambers. In addition, both models have been updated to reflect the new horizontal tunnel alignment AM.

# 2 Lots Road pumping station

## 2.1 Xdisp modelling assumptions

### 2.1.1 Shafts

The shaft has been modelled using the Finite Element analysis undertaken at Albert Embankment. The shafts at Lots Road and Albert Embankment are constructed within comparable ground conditions and to similar depths, hence the Finite Element (FE) results can be appropriately applied. The FE model has simulated a series of construction stages and the displacement results from the 'Volume Loss' stage has been used. The D-wall installation has been modelled with a 0.5% volume loss along the full length of the wall (*see further details for Albert Embankment FE in Section 2.2).*

The horizontal and vertical displacements specified for the shaft in Xdisp are derived from the displacements calculated from the finite element analysis. These displacements have been normalised for the shaft depth (i.e. displacement/depth of the analysed shaft). In Xdisp the software then allows these curves to be applied over a new specified depth for a given comparable shaft and the settlement results are calculated using a proportion of the normalised value as a function of the new shaft depth.

### 2.1.2 Excavations

The interception chamber has been modelled as a circular excavation using the relationship proposed by New and Bowers. The geometry of the shaft is such that the approximately square plan dimensions mean that the New and Bowers circular shaft represents a reasonable assumption for this excavation.

The connection culvert has been modelled using relationships from CIRIA C580 for secant piled walls and excavation behind a stiffly propped wall. The CIRIA curves have been normalised within Xdisp such that the surface movement contours generated can be applied at the foundation and surface level so that both maximum horizontal and vertical displacements can be calculated. This assumption is conservative at but is representative for the depth of the excavations considered. Currently the analysis does not allow for the effects of corner stiffening for the excavation which would also reduce displacements relative to the plane strain conditions assumed from the CIRIA C580 relationships.

### 2.1.3 Building facades

Figure 1 outlines the key building facades at Lots Road, the associated building displacements at surface level are illustrated in Figure 2 to 4 below.

Details of the Lots Road pumping station building founding and roof levels have been taken from TT Site Interface drawing 100-DA-CVL-PKC3X- 350127.

**Figure 1: Key Plan of Building Facades**

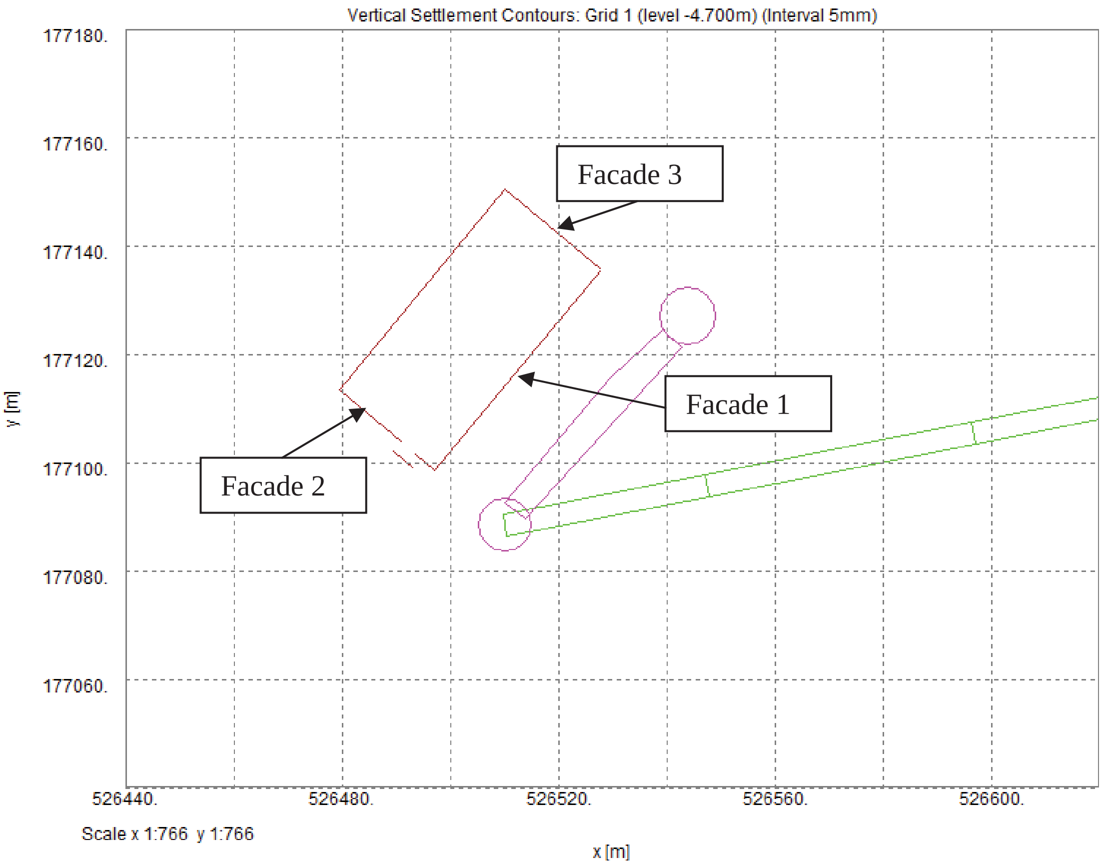


**Figure 2: Sub-structure displacements for Facade 1**

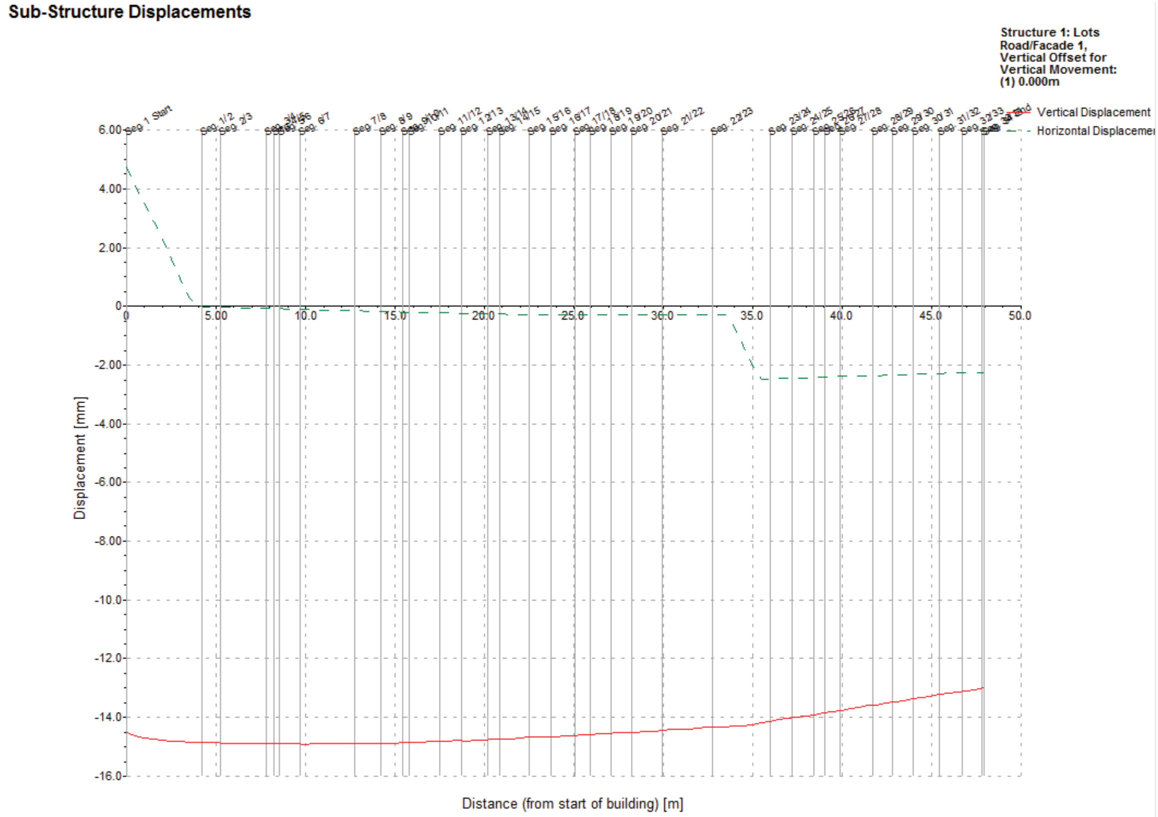



**Figure 3: Sub-structure displacements for Facade 2**

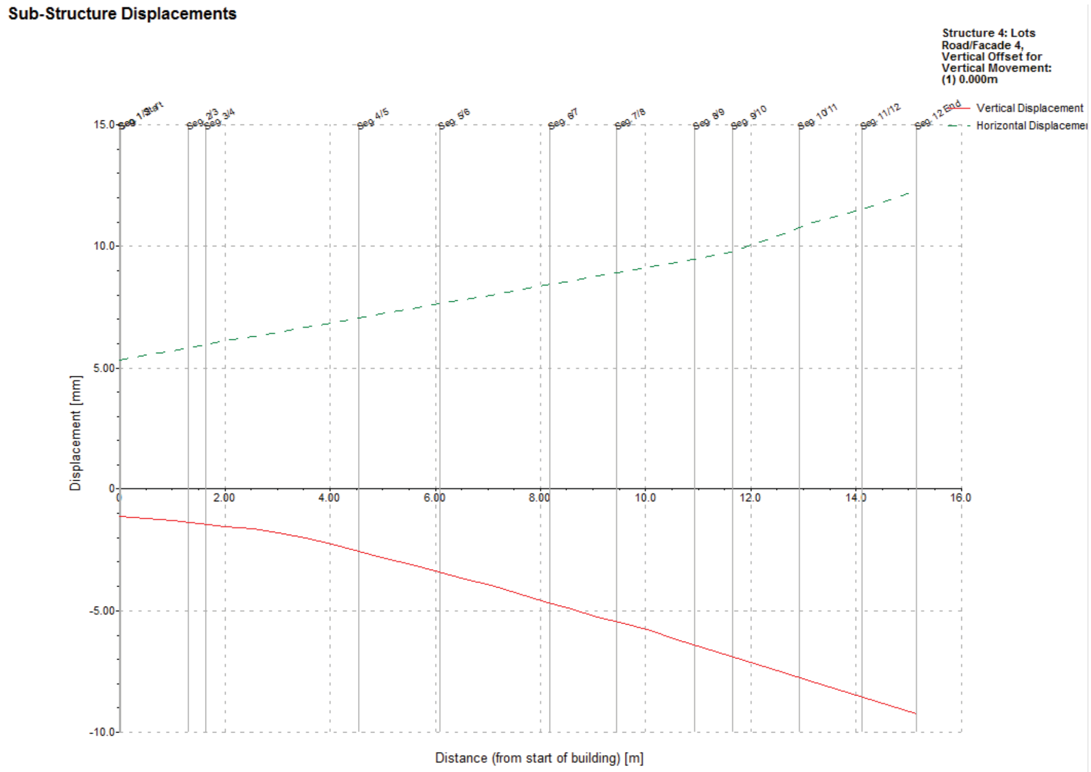
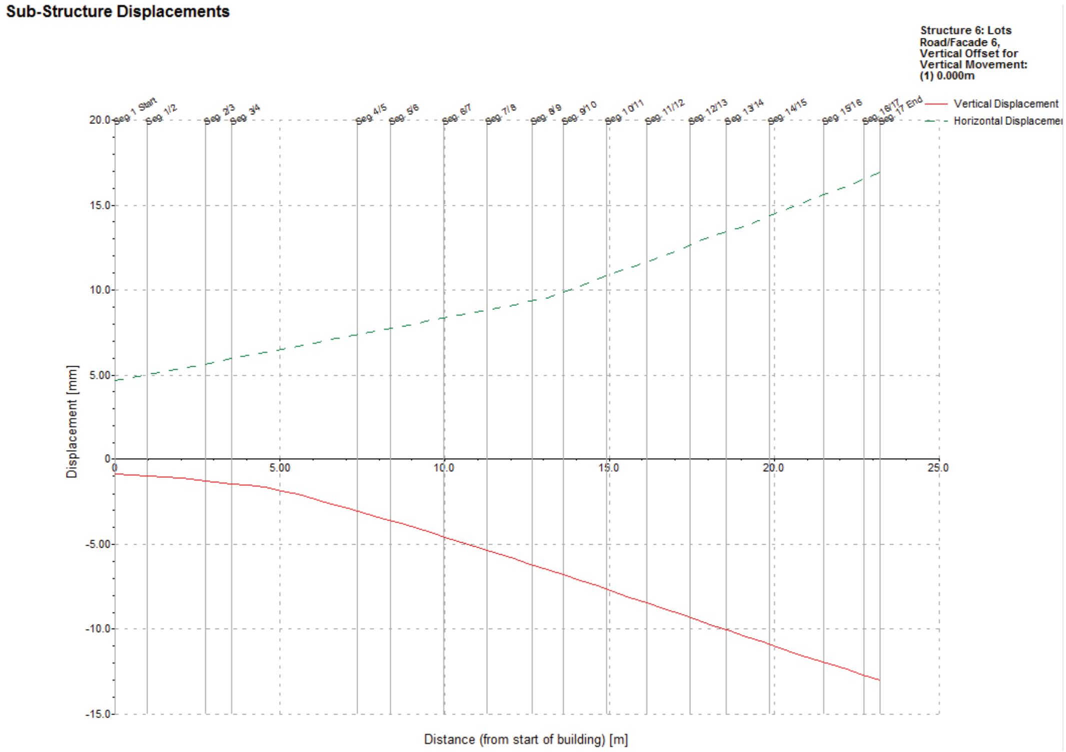


**Figure 4: Sub-structure displacements for Facade 3**



## 2.2 Finite element modelling at Albert Embankment shaft

The following assumptions outline the approach and results for the finite element modelling undertaken at Albert Embankment which have been applied to the Lots Road Pump Station modelling.

### 2.2.1 Introduction

This note summarises the input assumptions, methodology and results of the three dimensional finite element (3D FE) model for the Thames Tunnel Albert Embankment Shaft. The analysis work was carried out to inform the assessment of impacts on third party assets. The analysis is not a check on the design.

The FE analysis was performed using Oasys LS-DYNA software to provide data for the assessment of the effects of ground movements induced by the shaft excavation. The 3D FE model includes only the diaphragm wall shaft. It does not include the proposed tunnel connections, any existing structures or any other future structures or loads.

### 2.2.2 Shaft arrangement

The shaft general arrangement is given in the drawing 100-DA-CVL-PLH1X-359110_AA.

The shaft is circular in shape with an external diameter of 19m. The shaft consists of 1.5m thick diaphragm wall that is assumed to extending to 65.5m below ground level of 105.5mTD.

Excavation of the shaft will start from the ground level and continue to the underside of the base slab at 53.5mTD. Once excavation is complete the permanent base slab and the 350mm thick lining wall will be constructed.

### 2.2.3 FE model

#### 2.2.3.1 Stratigraphy and soil parameters

Borehole SR2085 provides information on the ground conditions close to the site. The borehole is shown in Geological Section100-DA-GEO-CT08X-600353 and 100-DA-GEO-PLH1X-600512. Based on this borehole information a geological stratigraphy for the general area around the Albert Embankment shaft has been derived. The soil parameters for the FE model are based on typical parameters used elsewhere for design and also taken from Standard Penetration Tests (SPTs) over the top 10m of Borehole SR2085. There is no site specific site investigation available at the time of writing this note. Table 1 summarises the stratigraphy and the soil parameters assumed in the analysis.

| Strata | Top of strata (mTD) | Soil model | Friction angle (c' = 0kN/m$^2$)$_2$ | cu (kN/m$^2$) | Unit weight (kN/m$^3$)$_2$ | Young's Modulus (MN/m$^2$)$_2$ | Permeability (m/s)$_2$ |
|---|---|---|---|---|---|---|---|
| Made Ground | 105.4 | Mohr Coulomb | 30 | - | 20 | 10 | 1e-5 |
| River Terrace Gravels | 101 | Mohr Coulomb | 35 | - | 20 | 20 | 1e-5 |
| London Clay | 96 | BRICK | 25 | 50 + 10z (z taken from 96, where z = 0 at 96mTD) [1] | 20 | BRICK | 1e-10 |
| Lambeth Group (fine grained) | 69 | BRICK | 25 | 50 + 10z (z taken from 96, where z = 0 at 96mTD) [2] | 20 | BRICK | 1e-9 |
| Lambeth Group (coarse grained) | 55 | Mohr Coulomb | 33 | - | 20 | 200 | 1e-6 |
| Thanet Sand | 51 | Mohr Coulomb | 35 | - | 20 | 400 | 1e-6 |
| Chalk | 42 | Mohr Coulomb | 33 | - | - | - | 1e-6 |

Notes:

(1) Taken from only four SPTs over the top 10m of Borehole SR2085.

(2) Assumed values based upon typical parameters used elsewhere for design. Please note that there is no site specific site investigation.

**Table 1: Assumed stratigraphy and soil parameters**

The BRICK model of soil behaviour was developed by Simpson (1992). The material model is non-linear and strain-dependent. The geological history of the soil is included as part of the BRICK model calculations. The stiffness and strength properties depend not only on the particular strain and stress state of the soil, but also the stress path history of the soil. The BRICK parameters adopted in the analysis are given in Table 2 below.

| **London Clay and Lambeth Group** | |
|---|---|
| **Strain** | **G/Gmax** |
| 3.04E-05 | 0.92 |
| 6.09E-05 | 0.75 |
| 0.000101 | 0.53 |
| 0.000121 | 0.29 |
| 0.000820 | 0.13 |
| 0.00171 | 0.075 |
| 0.00352 | 0.044 |

| London Clay and Lambeth Group | |
|---|---|
| **Strain** | **G/Gmax** |
| 0.00969 | 0.017 |
| 0.02223 | 0.0035 |
| 0.0646 | 0 |
| λ=0.1 κ=0.02 ι=0.0019 βG=4 β∅=3.0 Gvh/Ghh=0.5 | |

**Table 2: BRICK model material properties for London Clay and Lambeth Group**

### 2.2.3.2 Structural properties

The diaphragm wall for the shaft has been modelled using shell elements with anisotropic elastic properties to represent 1500mm diameter. A Young's Modulus of 14GN/m$^2$ and 2.8 GN/m$^2$ has been assumed in the out of plane direction and in the in-plane direction of the diaphragm wall respectively. The 350mm thick lining wall has been modelled with shell elements with an isotropic Young's Modulus of 14GPa.

The base slab has been modelled with solid elements with a Young's Modulus of 14 GN/m$^2$.

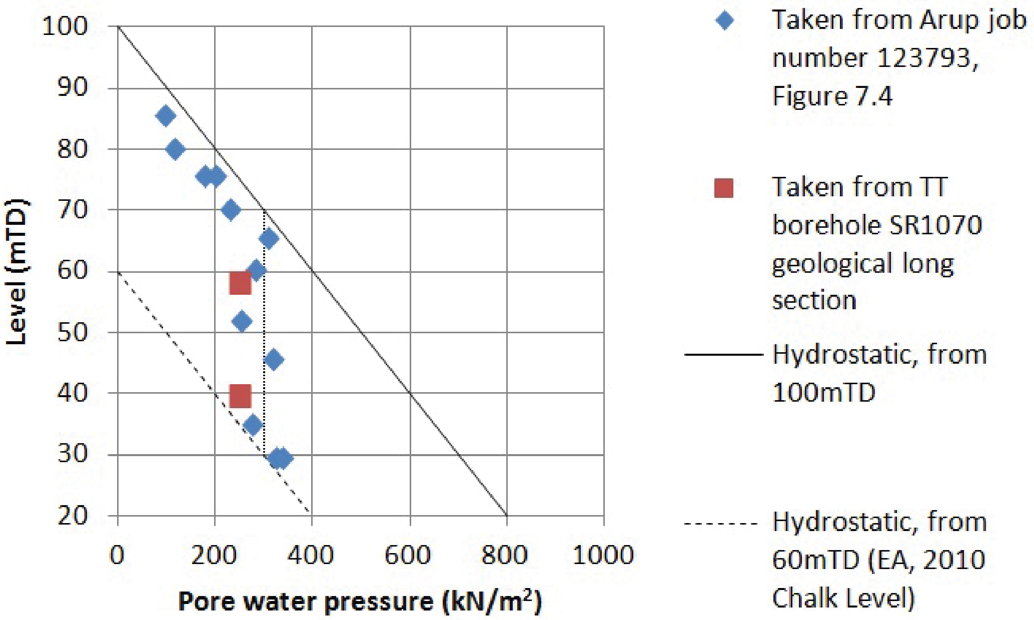
### 2.2.3.3 Groundwater condition

The groundwater conditions have been appraised from three sources.

- 2010 Chalk groundwater levels taken from the EA report, Management of the London Basin Chalk Aquifer
- Nearby piezometric readings taken in 2007 from a confidential Arup project located approximately 2km to the west of the site
- Piezometric readings reported on TT geological long section for boreholes SR1070, located approximately 400m to the west of the site. These have been taken from the geological long sections provided by the TT team.

Figure 5 plots this data and has been used in the analysis.

**Figure 5: Groundwater pressure profile**



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#### 2.2.3.4 Construction Sequence

The construction sequence adopted in the 3D FE model is presented in Table 3.

| Stage | Description | Remarks |
|---|---|---|
| 1 | Initialisation | Drained |
| 2 | Apply Volume loss 0.5% to model the installation effect | Undrained |
| 3 | Installation of 1.5m diaphragm wall | Undrained |
| 4 | Dewater inside the shaft at elevation 50mTD and 1m outside of shaft | Consolidation |
| 5 | Shaft Excavation to 90mOD | Consolidation |
| 6 | Shaft Excavation to 70mOD | Consolidation |
| 7 | Shaft Excavation to 53.5mOD | Consolidation |
| 8 | Install 3m thick base slab and Install 350mm thick secondary lining above base slab | Undrained |
| 9 | Recharging water to the original hydrostatic pressure | Drained |

**Table 3: Construction sequence**

### 2.2.4 Results

The maximum vertical and horizontal movement at the ground level occurred at the wall installation stage, and are illustrated in the cumulative displacement plots Figure 6 and Figure 7 respectively. Figure 8 and Figure 9 indicate the contours of horizontal and vertical displacement for this stage.

As the excavation proceeds from the ground level, the unloading within the shaft causes some heave movement outside the shaft. As the water recharges in the long term condition, the net movement returns to almost zero.

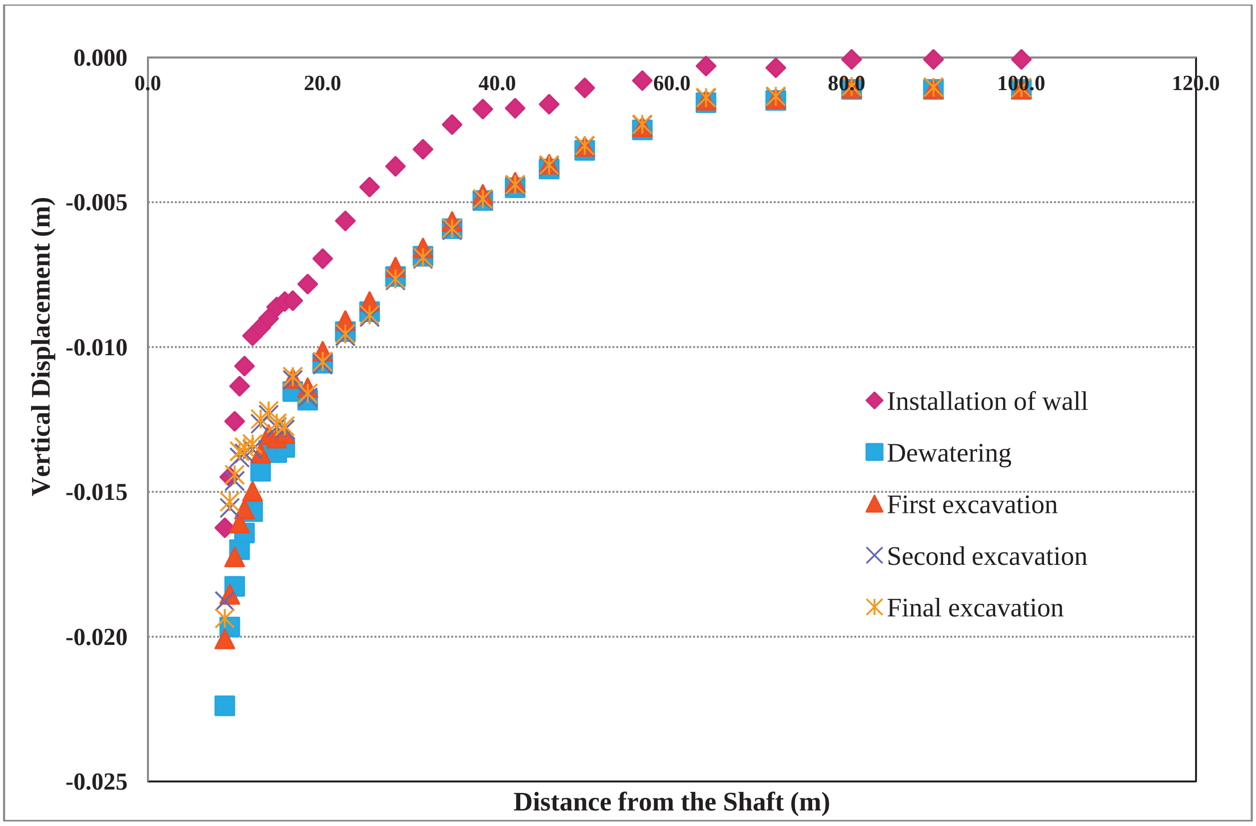



**Figure 6: Vertical Settlement caused by Shaft Excavation**

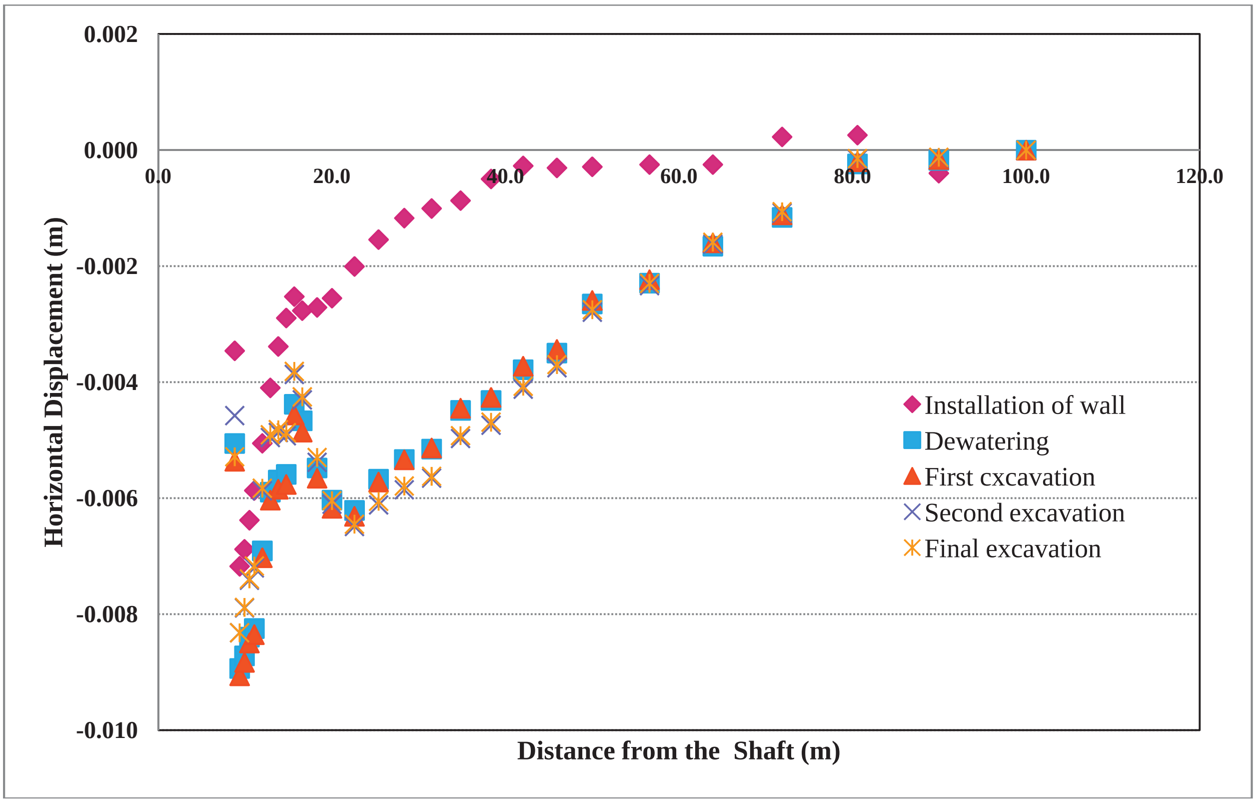



**Figure 7: Horizontal Displacements caused by shaft excavation**

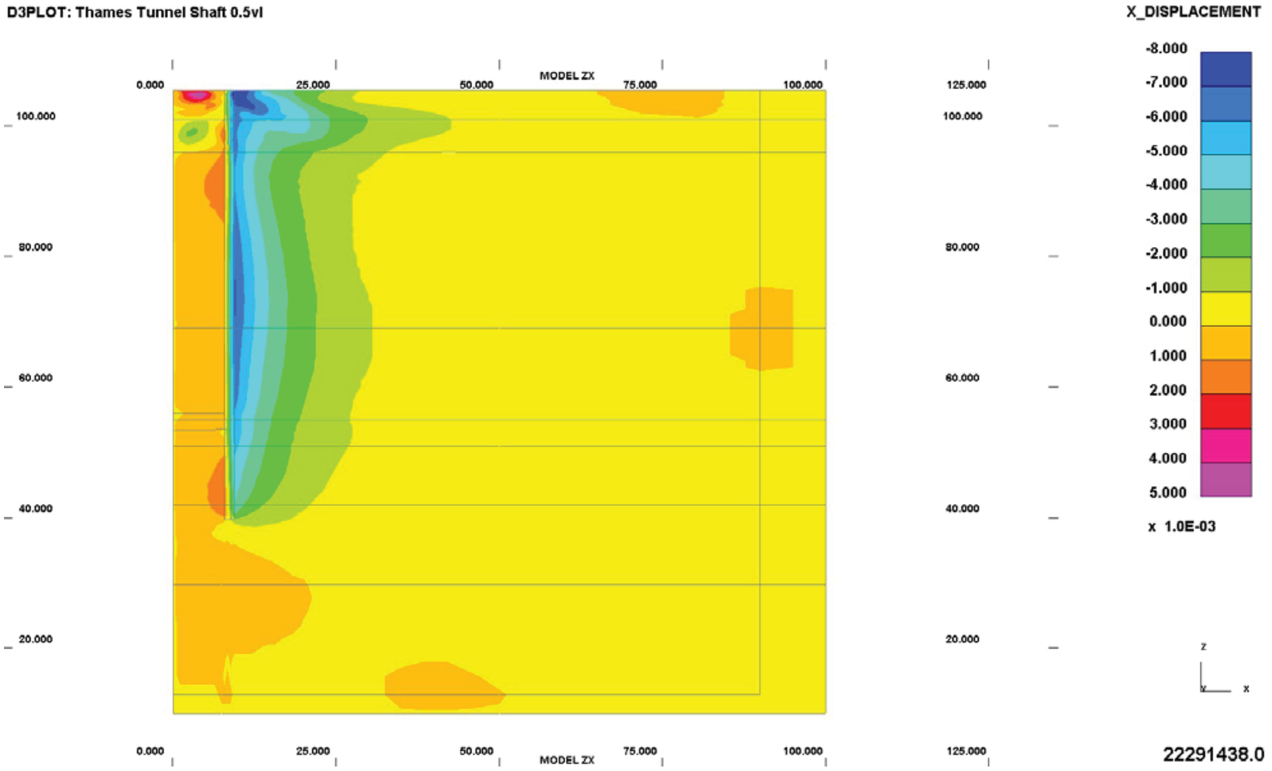



Figure 8: Horizontal displacements with distance from the shaft (wall installation stage)

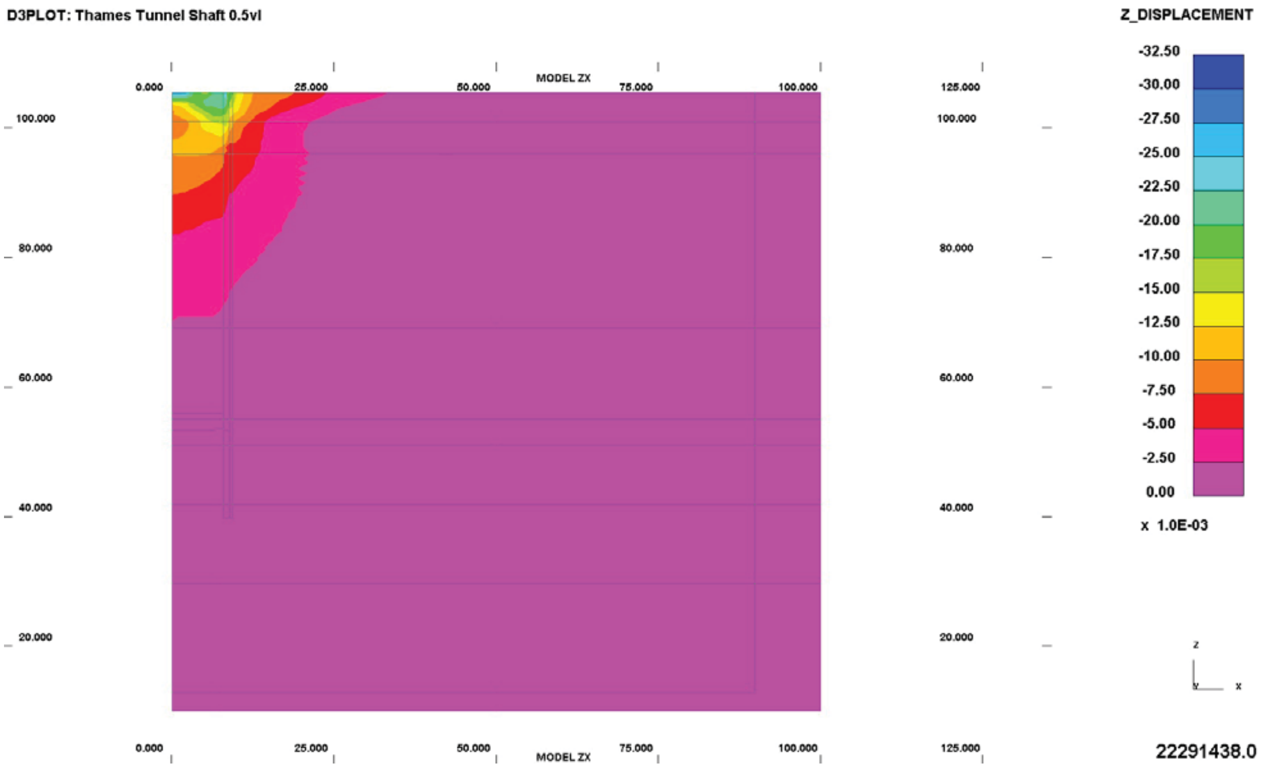



Figure 9: Vertical displacements with distance from the shaft (wall installation stage)

# 3 Greenwich Pumping Station

## 3.1 Xdisp assumptions

### 3.1.1 Shafts

The shaft has been modelled using the Finite Element analysis undertaken at Earl Pumping Station. The shafts at Greenwich and Earl Pump Station are in comparable ground conditions and depth, hence the Finite Element (FE) results can be appropriately applied.

The horizontal and vertical displacements specified for the shaft in Xdisp are derived from the displacements calculated from the finite element analysis. These displacements have been normalised for the shaft depth (i.e. displacement/depth of the analysed shaft). In Xdisp the software then allows these curves to be applied over a new specified depth for a given comparable shaft and the settlement results are calculated using a proportion of the normalised value as a function of the new shaft depth.

The largest displacements from the FE modelling have been taken which correspond to the dewatering stage. In the FE analysis at Earl Pumping Station the wall installation affects have not been modelled. Therefore wall installation affects have been represented in XDisp using the CIRIA C580 curves for ground surface movements for planar diaphragm walls in stiff clay (see Section 3.2 for further details).

The CIRIA curves are based on a limited number of case studies for shallow retaining walls (i.e. within the superficial deposits) which are expressed as normalised relationships of settlement divided by wall depth. The comparatively shallow depth of D-wall in the case studies in comparison to the D-Wall depth proposed for the CSO Shafts mean that when using the curves over long wall depths the relationships become very conservative for the deep movement particularly in the Chalk. It is known that for the shaft installations most of the wall movements occur in the superficial deposits with decreasing movement with depth and in the stiffer chalk deposits present at Greenwich. Therefore to provide a robust but not excessively conservative solution the wall installation affects have been modelled applying the CIRIA curve relationships up to the base of the Thanet Sands. This offers a more suitable use for the curves given the basis on which they were derived.

### 3.1.2 Excavations

The interception and valve chamber have been modelled using the CIRIA C580 curves. Given the relatively small plan dimensions of the boxes, plane strain will not be achieved for movements at any point around the wall. Currently the excavation does not account for the benefit of corner stiffening for the excavation. This is a conservative assumption.

The culvert between the shaft and valve chamber has been modelled as a secant piled excavation using relationships from CIRIA C580 for secant piled walls and excavation behind a stiffly propped wall. The CIRIA curves have been normalised within Xdisp such that the surface movement contours generated can be applied at the foundation and surface level so that both maximum horizontal and vertical displacements can be calculated. This assumption is conservative at but is representative for the depth of the excavations considered. Currently the analysis does not allow for the effects of corner stiffening for the excavation which would also reduce displacements relative to the plane strain conditions assumed from the CIRIA C580 relationships. . Details have been assumed from general Arrangement Drawing 100-DA-CVL-PGH4X-373112.

### 3.1.3 Building facades

The following plots outline the building displacements at surface level. Historical drawings identify Greenwich Pumping station as founded at two different levels. Founding levels were taken from the Site Interface Assessment drawings and Historical Drawings for this site. All roof heights were estimated from historical plans and photographs taken from the structural inspection.

Figure 10 outlines the key building facades at Greenwich, the associated building displacements at surface level are illustrated in Figure 11 to 14 below.

**Figure 10: Key plan of building facades**

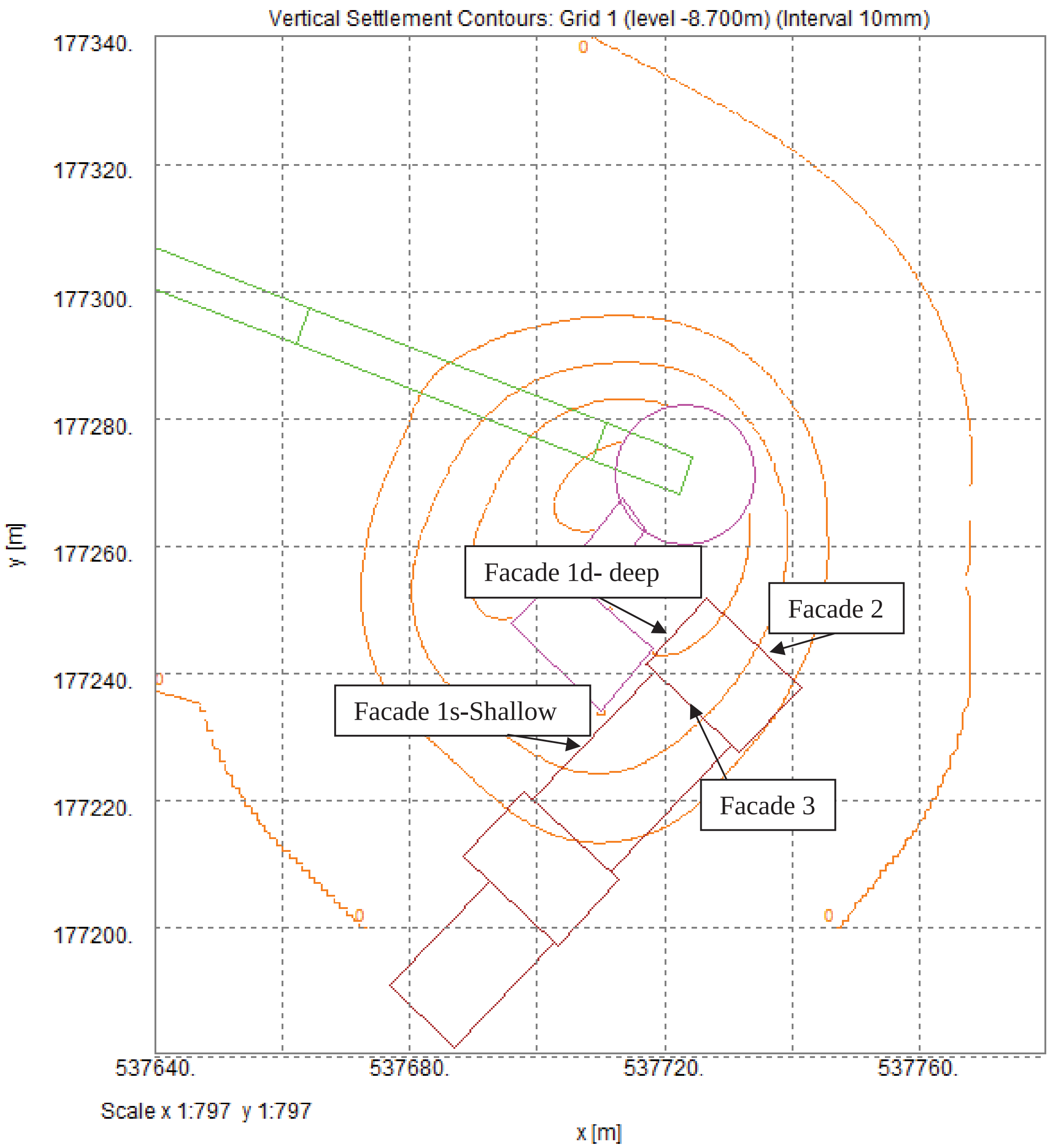


**Figure 11: Sub-structure displacements for Facade 1d deep (north west facing)**

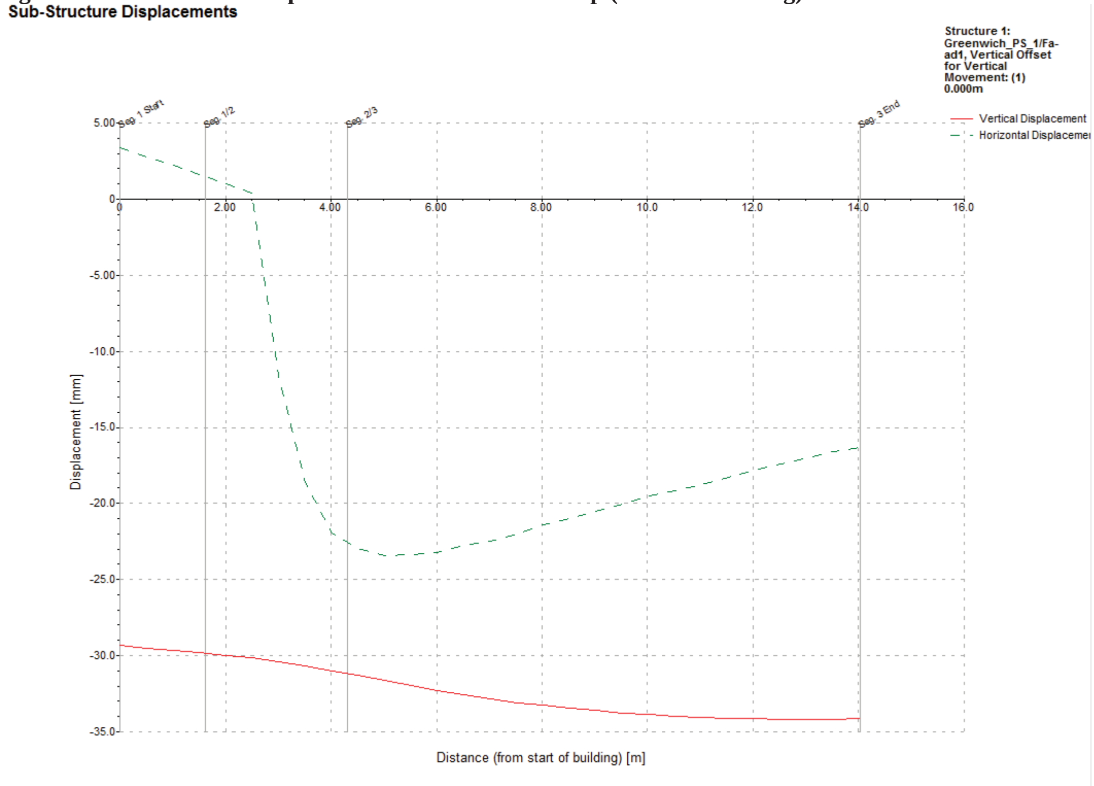



**Figure 12: Sub-structure displacements for Facade 1s – Shallow Structure Facade (north west facing)**

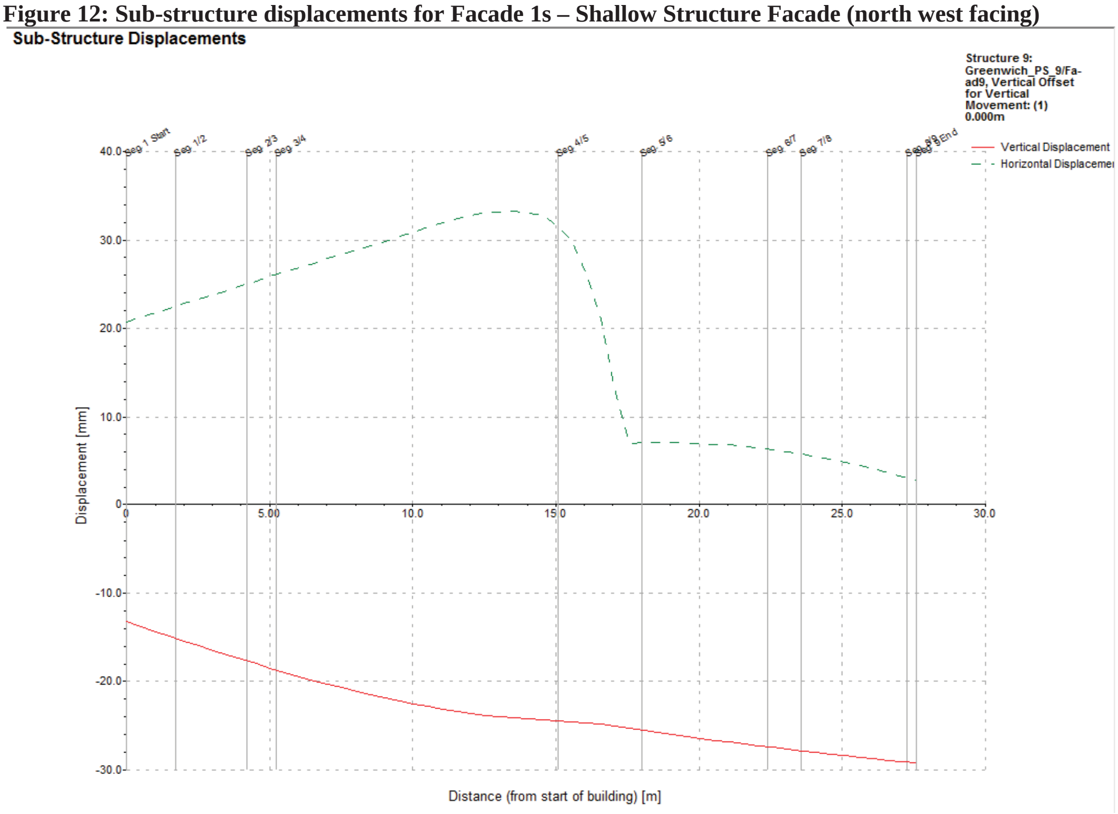


**Figure 13: Sub-structure displacements for Facade 2 (north east facing)**

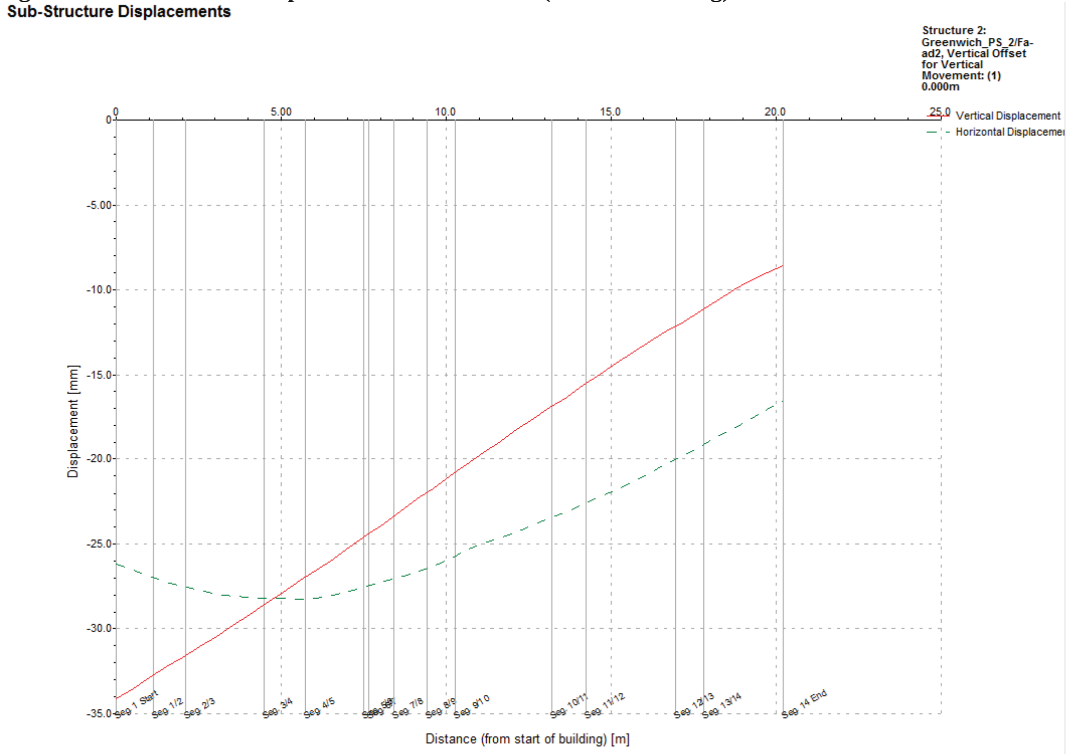
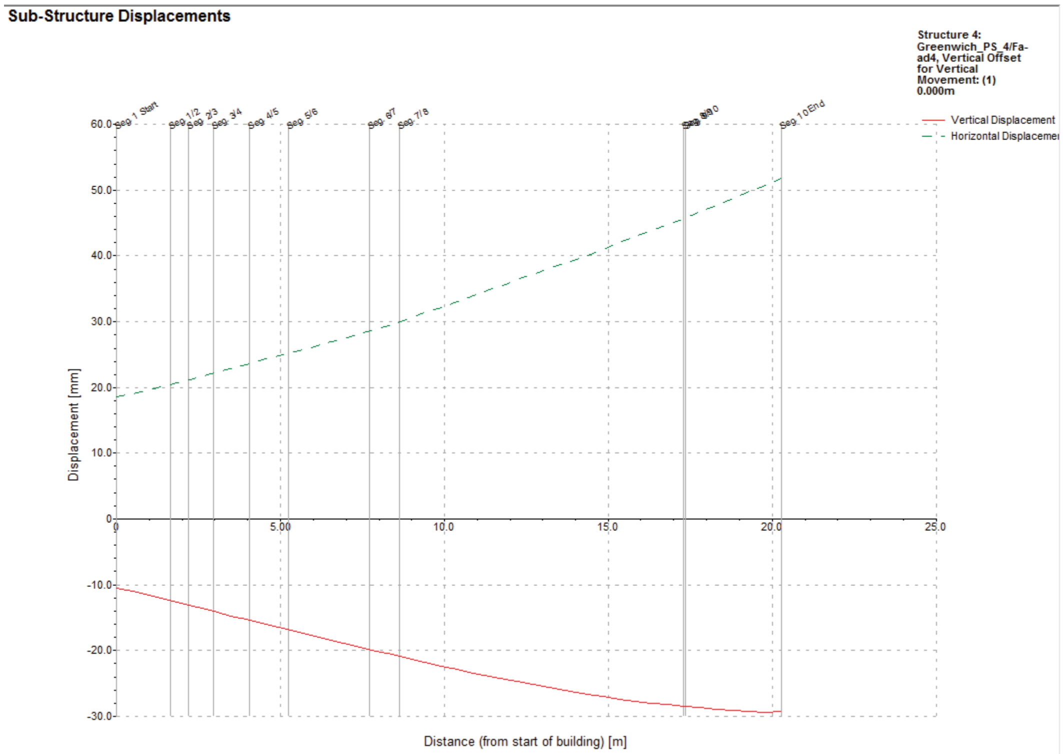



**Figure 14: Sub-structure displacements for Facade 3 (south west facing)**



## 3.2 FE modelling for Earl Pumping Station shaft

The following assumptions outline the approach and results for the Finite Element modelling undertaken at Earl Pump Station which have been applied to the Greenwich Pump Station Modelling.

### 3.2.1 Modelling assumptions

#### 3.2.1.1 Stratigraphy and soil conditions

The assumed geological stratigraphy, geotechnical parameters and the assumed water level for the Earl Pumping Station, are outlined in Table 4 and Table 5 below.

All soils were modelled using the elastic Mohr-Coulomb model, adopting the material properties summarised. These soils were considered to be drained at all stages in the analysis.

| **Stratum** | **Sub Unit** | **Generalised Description** | **Elevation of Top of Stratum (mOD)** | **Elevation of Top of Stratum (mTD)** | **Stratum Thickness (m)** |
|---|---|---|---|---|---|
| Made Ground | - | Sandy gravelly clay to sandy clayey gravel | 1.4 | 101.4 | 3.5 |
| River Terrace Deposits | - | Medium dense sand and gravel | -2.1 | 97.9 | 6.0 |
| Thanet Sand | - | Dense to very dense silty sand | -8.1 | 91.9 | 9.5 |
| Seaford Chalk | Haven Brow | Grade B1 Chalk | -17.6 | 82.4 | 12.3 |
| | Cuckmere | Grade B1 Chalk | -29.9 | 70.1 | 12.3 |
| | Belle Tout | Grade B1 Chalk | -42.2 | 57.8 | 12.4 |
| Lewes Nodular Chalk | - | Grade B1 Chalk | -54.6 | 45.4 | Not proven |

**Table 4: Assumed geology**

| **Stratum** | **Sub Unit** | **Y (kN/m$^2$)** | **$K_o$** | **E’ (MPa)** | **c’ (kPa)** | **$\phi$’ ($^o$)** |
|---|---|---|---|---|---|---|
| Made Ground | - | 18 | 0.5 | 10 | 0 | 30 |
| River Terrace Deposits | - | 20 | 0.43 | 20 + 4.17z$^{(1)}$ | 0 | 35 |
| Thanet Sand | - | 20 | 1.0 | 135 + 3.26z$^{(2)}$ | 0 | 36 |
| Seaford Chalk | Haven Brow | 20 | 1.0 | 716 | 109 | 28 |
| | Cuckmere | 20 | 1.0 | 955 | 122 | 30 |
| | Belle Tout | 20 | 1.0 | 955 | 122 | 30 |
| Lewes Nodular Chalk | - | 20 | 1.0 | 955 | 122 | 30 |

Notes:

(1) E’ is assumed to be equal to one times the SPT N-value

(2) E’ is assumed to be equal to three times the SPT N-value

**Table 5: Geotechnical parameters**

#### 3.2.1.2 Permeability

The permeability of the assumed soil profiles are outlined in Table 6 below.

| Stratum | Sub unit | Elevation of top of stratum (mTD) | Permeabilities (m/s) |
|---|---|---|---|
| Thanet Sand | -- | +91.9 | 1.0E-6 |
| Seaford Chalk | Haven Brow | +82.4 | 1.0E-6 |
| | Cuckmere | +70.1 | 1.0E-7 |
| | Belle Tout | +57.8 | 1.0E-8 |
| Lewes Nodular Chalk | -- | +45.4 | 1.0E-9 |

**Table 6: Assumed soil permeabilities**

### 3.2.2 Geometry

#### 3.2.2.1 Shaft

The following geometry was modelled for the shaft:

- Outside shaft diameter = 22.4m
- Shaft diameter modelled = 21m (22.4m – 1.4m)
- Shaft type = Diaphragm wall
- Assumed toe level = 52.24mATD

The construction of the diaphragm wall was modelled using shell elements with anisotropic stiffness. The diaphragm wall was dimensionless in the mesh and the wall installation effect was not modelled. The wall thickness was taken to be the thickness of the primary lining, 1.4m, with the anisotropic stiffness properties to allow a 80% reduction in the horizontal direction along the line of the walls (in plane) due to construction joints assumed concrete Young's Modulus of 14GN/$m^2$.

100mm wide slip elements adjacent to the diaphragm wall were modelled using the Mohr-Coulomb criterion in order to incorporate the disturbance effect of drilling the holes on the surrounding soil. The disturbance effect was modelled using a k factor of 0.5 on strength parameters for drained materials. The adopted geometry and extent and sections of the mesh are illustrated in Figure 15 below.

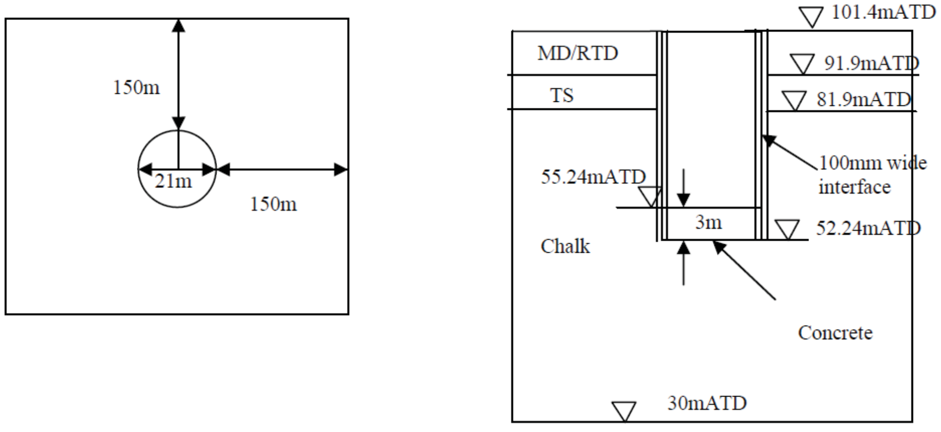



**Figure 15: Extent and sections of the mesh**

#### 3.2.2.2 Internal slabs

The base slab was modelled as solid elements with its thickness of 3m. The connection between the retaining wall and slabs was considered to be fixed.

#### 3.2.2.3 Secondary lining

The thickness of the 800mm secondary lining was allowed in the mesh.

#### 3.2.2.4 Existing buildings

The layout of the existing buildings in the vicinity of the shaft was not incorporated in the mesh. No surcharge was applied in this model.

#### 3.2.2.5 Boundary conditions

The 3D FE model extended from 101.4mTD, the existing assumed ground level, to 0mTD, the base of the model. The remote boundaries to the north, south, east and west was at a distance of at least three times the excavation depth and was free to move on the vertical direction but fixed on the horizontal direction. The base of the model was fixed from translation in all directions.

#### 3.2.2.6 Proposed construction sequences

The analysis started with 'green field' conditions, assuming 'at rest' conditions in the ground. The construction sequence was slightly modified compared with the provided information and the sequence assumed is outlined in Table 7 below.

| Stage | Description | Remarks |
|---|---|---|
| 1 | Initialisation with hydrostatic pwp profile | Drained |
| 2 | Construction of diaphragm wall and dewatering the water level to +51.3mTD (about 1m below the base of excavation at +52.20mTD) – Steady State Analysis | Drained |
| 3 | Excavate to top of Thanet Sand at 91.9mTD | Drained |
| 4 | Excavate to the bottom of Thanet Sand at 82.4mTD | Drained |
| 5 | Excavate to +52.24mATD | Drained |
| 6 | Construct 3m thick base slab | Drained |
| 7 | Construct secondary lining | Drained |
| 8 | Recharging the water to the original hydrostatic pressure | Drained |

**Table 7: Summary of construction sequence**

#### 3.2.2.7 Modelling assumptions

The assumptions and simplifications made in the models are summarised in the Table 8 below.

| Item | Modelling assumptions |
|---|---|
| 1 | Ground level was modelled at 101.4mTD. |
| 2 | The existing buildings around this site will not be modelled. No surcharge was applied. |
| 3 | No capping beam was modelled |
| 4 | A Young's modulus of 14GPa and a Poisson's ratio of 0.2 was assumed for reinforced concrete |
| 5 | When shell elements are used, the diaphragm wall was modelled with anisotropic stiffness properties to allow a 80% reduction in the horizontal direction along the line of the walls (in plane) due to the construction joints. No wall installation effect was modelled. |
| 6 | Drain conditions are modelled in all stages |

**Table 8: Summary of modelling assumptions**

### 3.2.3 Results

The maximum vertical and horizontal movement at the ground level occurred at the dewatering stage, at a magnitude of 6mm and 2mm as shown in Figure 16 and Figure 17 respectively. Figure 18 and Figure 19 indicate the contours of horizontal and vertical displacement, respectively for this stage.

As the excavation proceeds from the ground level, the unloading within the shaft causes some heave movement outside the shaft. As the water recharges in the long term condition, the net movement returns almost to zero.

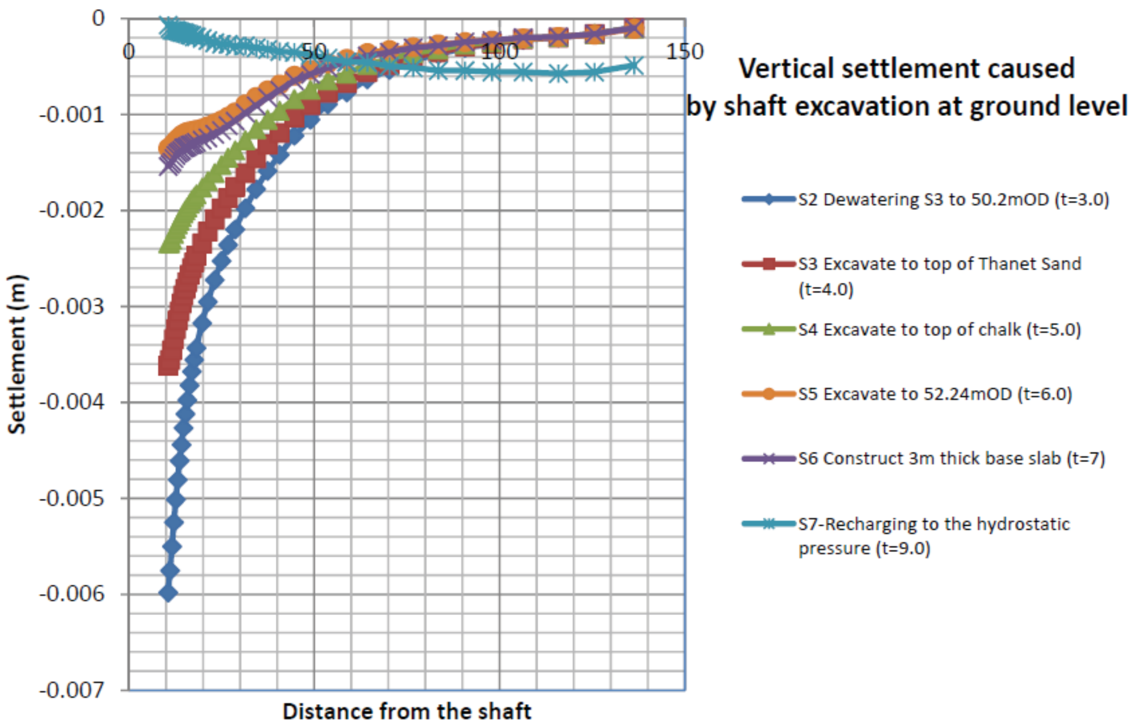



**Figure 16: Vertical Settlement caused by shaft excavation**

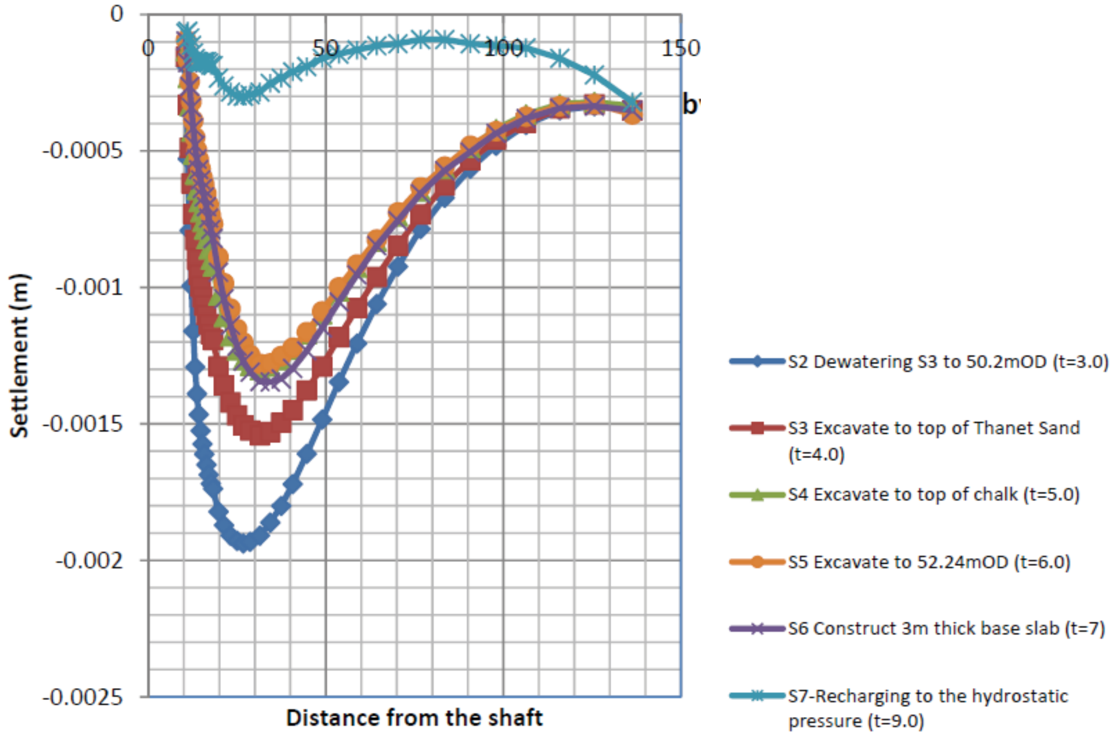



**Figure 17: Horizontal settlement caused by shaft excavation**

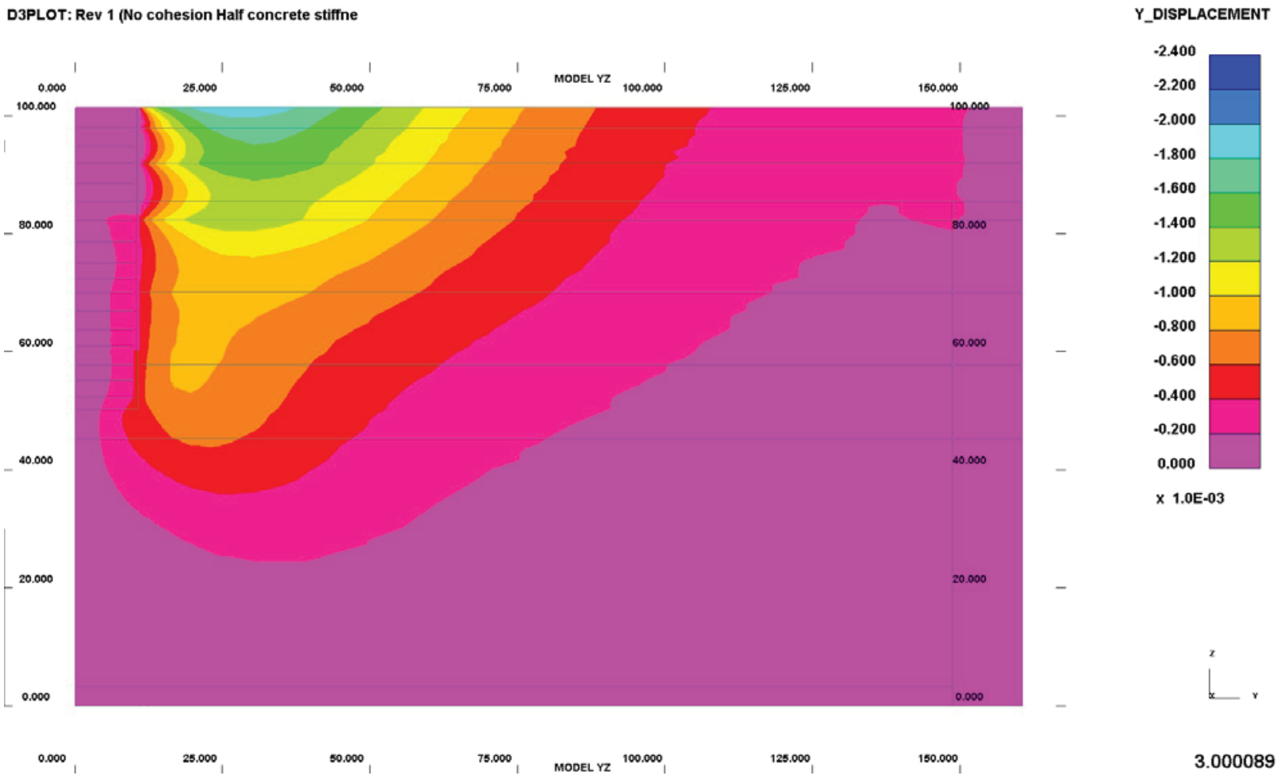



**Figure 18: Contours of horizontal displacement with distance from the shaft (Dewatering Stage)**

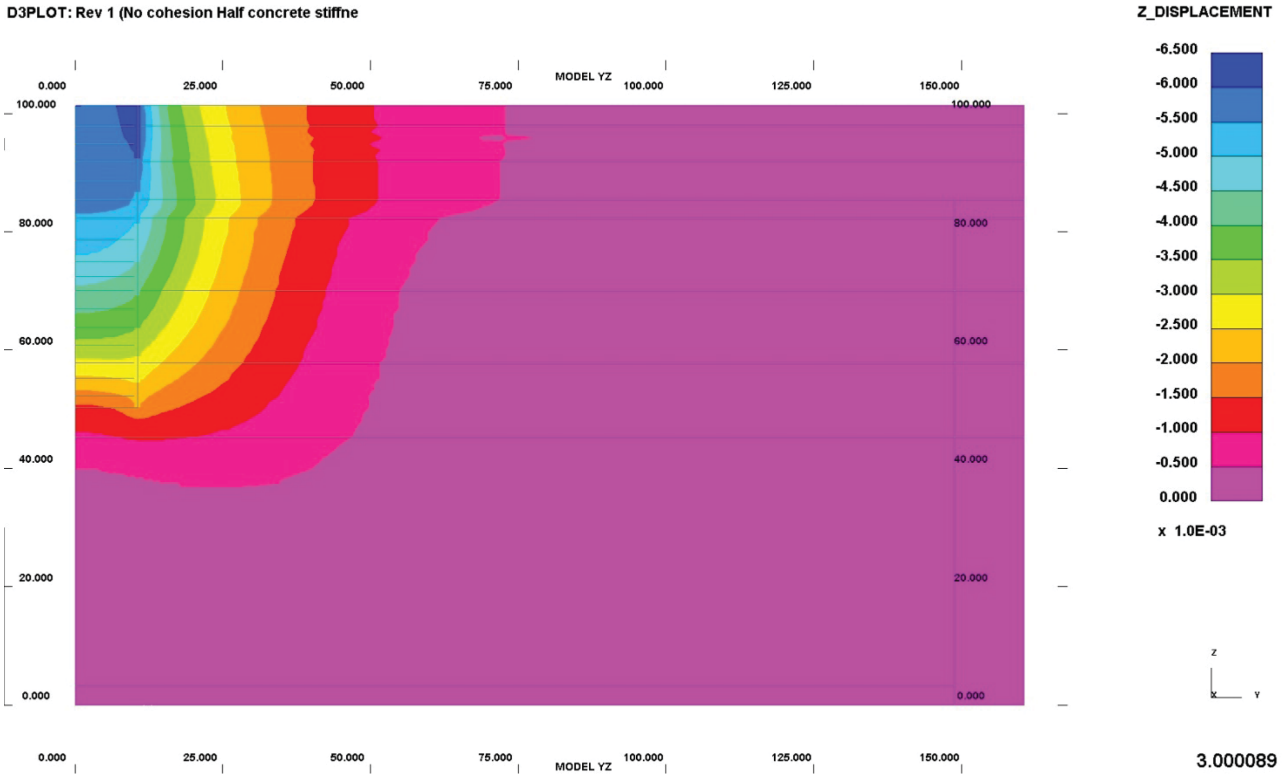



**Figure 19: Contours of vertical displacement with distance from the shaft (Dewatering Stage)**

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# Appendix B: Individual building assessment reports for the London Borough of Hounslow

# Listed building assessment

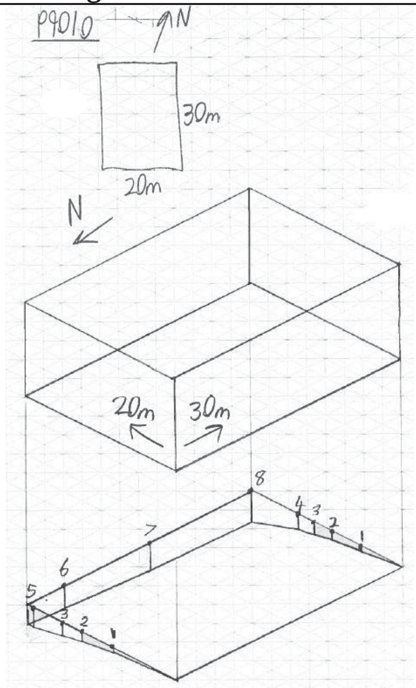
## Building information

| | |
|---|---|
| **Building reference** | Z0154, Z0165, Z0173 |
| **Building name / address** | 60-62 Bath Road, W4 1LH |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 21625 78999 |
| **Ground level (mTD)** | +104.3 to +104.8 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing)**

60-62 Bath Road are a pair of brick houses, dating from the late 19th century, which were listed as part of the wider group relating to the Bedford Park Estate. At the time of inspection, the interior of 62 Bath Road only was accessible.

To the north is the main elevation, with 60 Bath Road to the west and 62 to the east. Both buildings have two storeys plus an attic with a pair of dormer windows to each house. There is a deep modillion eaves cornice, and brick bands run beneath and above the first floor windows; the upper storey windows to both houses are timber casements with architraves and moulded sills. 62 Bath Road has an entrance door to the left, under a flat timber hood, and a timber bay window to the right. Bath road has a matching bay window to the left, and a timber porch with a tiled roof to the right. This porch includes stained glass lights and decorative moulding.

The side elevation of 62 Bath Road appears to be blank, but was only partially visible at the time of the inspection. That of 60 Bath Road, to Gainsborough Road, has a small single storey abutment of brick topped with stone pediments and featuring decorative carved brick, which stretches half the length of the full elevation. This is mainly blank, with one small window to the first floor. The rear of 60 Bath Road has a single storey brick extension to the south, and has ground floor access to the original house incorporating a set of stone steps. The first floor has a large modern opening.

The interior of 60 Bath Road has been largely modernised and refurbished. However, a number of features remain, including the stair with timber balustrades, handrails and newels, and doorways which show some distortion. To the first floor at the rear is a ‘studio’, a double height space showing the roof structure, and having a large modern window.

| **Structural description and walkover observations** | |
|---|---|
| Pair of semi-detached houses, with two storeys plus attic accommodation. It has only been possible to gain access to 60 Bath Rd, but as the houses are semi-detached it is reasonable to assume that the two houses are similar. No 60 has a recent single storey rear extension.<br><br>The brickwork under the front ground floor bay of No.60 is loose and shows evidence of past repointing, probably due to long term ground movement associated with the nearby tree; the front bay brickwork of No.62 has been rendered suggesting this may have had similar problems. The decorative brickwork to the single storey abutment to No.60 is heavily weathered. There is some evidence of past differential settlement, evidenced by diagonal cracking and distortion under the rear (S facing) first floor window of No.60, and distortions of the door openings on the N side of the internal first floor landing; hairline cracking to the internal paintwork to the landing (despite it being recently decorated) suggests that there are small ongoing movements. Minor differential movement has occurred between the old and new construction at the junction with the modern rear extension of No.60. | |
| **Condition** | Generally good; see above. |
| **Assumed foundations** | Shallow strip footings. |
| **Façade material** | Load-bearing brick. |
| **Internal support system (i.e. superstructure)** | Loadbearing brick with timber floors. |
| **Heritage** | External features are the entrance door hood to No. 62, the porch to No. 60, eaves cornice, brick bands and bay windows. Internally, the timber stair may be sensitive. |

## Building photographs

Main (northern) elevation of 62 Bath Road, with 60 to the right

Bath Road and Gainsborough Road elevations of 60 Bath Road

Rear elevation of 60 Bath Road, including recent extension

'Studio' room to the first floor, showing modern windows and rood structure

Timber stair within 60 Bath Road

Single storey abutment to 60 Bath Road, with decorative brick

## Ground movement analysis

### Tunnel and shaft details

Thames Tunnel constructed within London Clay Formation.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel crown extrados level: +77.1mTD.
Excavated diameter: 8.1m.
Closest shaft: Acton Storm Tanks shaft, located approximately 830m north-north-west – design indicates unlikely to influence ground movement at the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

### Ground conditions

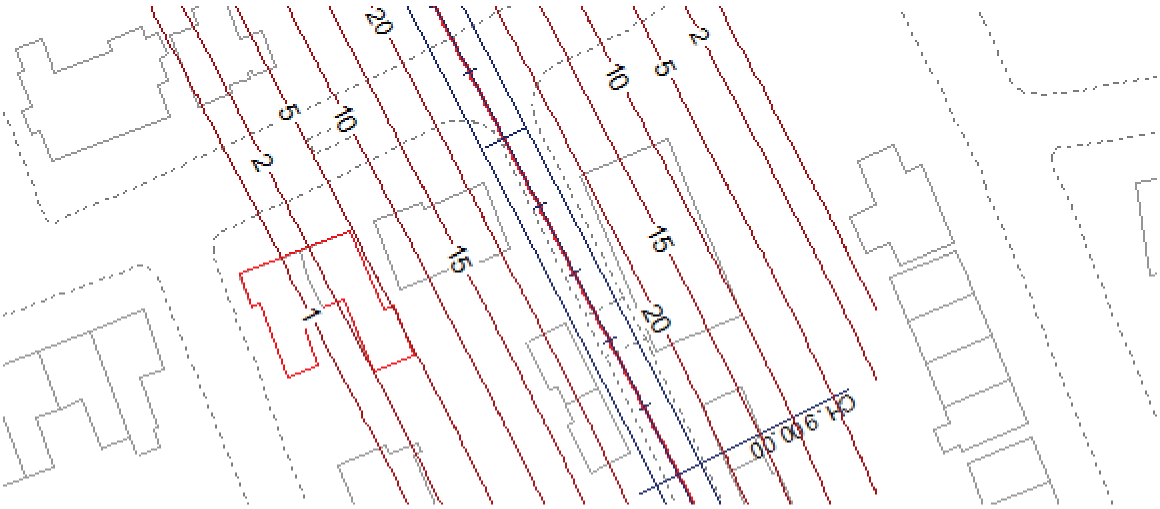
The Thames Tunnel is proposed to be constructed through London Clay Formation. The expected sequence overlying the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +104.3mTD to +104.8mTD
Top of London Clay Formation: +98.5mTD (21.4m above proposed tunnel crown level).

Review of borehole SA123B (located approximately 815m south-south-east) and BGS borehole TQ27NW407 (located approximately 295m south) does not indicate any geological features that would require a change in the current ground loss assumptions.

### Results

Settlement contours generated at +103.3mTD, approximate base slab level 1m below ground level




As shown above the building extends from the 5mm settlement contour across the 2mm, 3mm and 4mm contours.

Three key façades were selected from the GIS model. The buildings were assumed to be 9m high. Foundations were modelled as shallow, without a basement base slab at 1m bgl.

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.02% and a maximum settlement of 5mm were generated for the buildings.

The interaction of the ground settlement with the structures is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

It is estimated that there will be just 3mm differential settlement to No.62 only; No.60 is further from the proposed tunnel and no movements are predicted. Even for No.62 the level of movement is very small, and below likely seasonal movements and therefore even without knowing the internal condition it is reasonable to predict that the likely damage will be negligible.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

Sensitive features are the entrance door hood to No. 62, the porch to No. 60, eaves cornice, brick bands and bay windows. Internally, the timber stair may be sensitive. However, the predicted ground movements are very small, with no movement predicted at 60 Bath Road, and heritage features are unlikely to be sensitive to the levels of settlement that have been calculated.

***Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

The condition of this building is good, with specific area of brick deterioration which will not affect the general behaviour of the building in relation to ground movement.

***Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 0.

The structure and heritage features of 60-62 Bath Road are not sensitive to the levels of settlement and strain calculated, and therefore the building will not be taken forward for further damage assessment and will not require mitigation. Notwithstanding this, given the existing minor settlement damage it is recommended, as for all affected properties along the route, that a condition survey is undertaken prior to the works. It should be noted that this is based on incomplete inspection of 62 Bath Road.

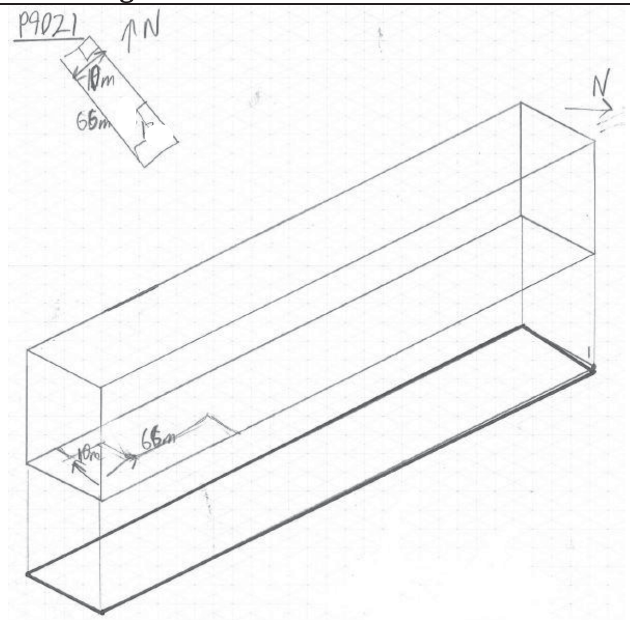
## Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z4631 |
| **Building name / address** | Swan House, W4 2PS |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 21949 78120 |
| **Ground level (mTD)** | +104.2 to +104.6 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

No inspection has been carried out to date. Therefore the English Heritage Listed Building description is quoted verbatim as follows:

*"Late C18 pair of houses. Brown brick. 3-storeys. 3 double-hung sashes in reveals with rubbed flat arches. Bands at floor levels. Swan House has left hand recessed 3-storey wing (1-storey added recently) containing arched doorway with fanlight. The adjoining premises have bow to East elevation, all windows are blocked on the ground and 1st floors and the rest are modern. Both have 1 dormer. Parapet, machine tile roof. NMR.*

*Cedar House, Swan House, Island House, Norfolk House, Garden wall, railings to Island House and Norfolk House and St John's House form a group."*

| **Structural description and walkover observations** | |
|---|---|
| No inspection has been carried out to date. The following has been inferred from a virtual walkover survey, a brief external inspection carried out at the time of visiting neighbouring Cedar House and other available information:<br><br>The building appears from the outside similar to Cedar House, its next-door neighbour. This would suggest that Swan House is also built of loadbearing masonry with timber floors. Swan House is reported by its owner to have a single level of basement, which, if it mirrors Cedar House, would be under only part of the building footprint. A dormer window is visible from the front, suggesting that a useable third floor has been created within the pitched roof. Use of imagery available on the internet suggests that, unlike its neighbour, Swan House does not have an extension to the rear.<br><br>The external brickwork appears to be in fair condition. | |
| **Condition** | Not inspected. |
| **Assumed foundations** | Shallow foundations with part basement. |
| **Façade material** | Load-bearing brick. |
| **Internal support system (i.e. superstructure)** | Loadbearing masonry with timber floors. |
| **Heritage** | Not inspected, taken from Listed Building description: external double-hung sash windows; doorway with fanlight. |

## Building photographs

NOT USED

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within London Clay Formation.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +75.8mTD.
Excavated diameter: 8.1m.
Closest shaft: Acton Storm Tanks shaft, located approximately 1,740m north-west – design indicates unlikely to influence ground movement at the building location.

| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |
|---|---|

**Ground conditions**

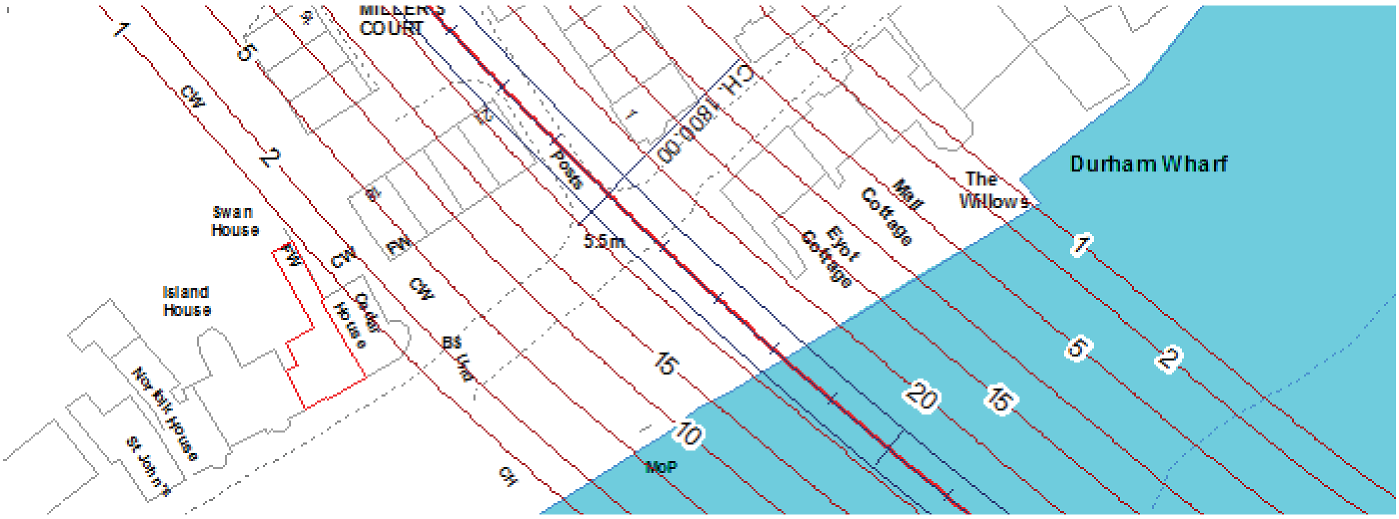
The Thames Tunnel is proposed to be constructed through the London Clay Formation. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level: +104.2mTD to +104.6mTD.
Top of London Clay Formation: +98.0mTD (22.2m above proposed tunnel centreline level).

Review of boreholes SA1123B (located approximately 230m north-east) and BGS borehole TQ27NW18 (located approximately 45m east) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions.

**Results**

Settlement contours generated at 103.2mTD approximate base slab level, assuming 1m below ground level;




As shown above the structure sits outside of the 1mm settlement contours generated.

Two key facades were selected from the GIS model and analysed for a 9m tall structure, with and without a basement on shallow foundations (foundations 4m bgl and 1mbgl respectively).

The results all fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.008% when modelled with a basement (foundations 4m bgl) and a maximum settlement of 0.8mm when modelled without a basement (foundations 1m bgl)were generated for the structure.

Interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

## Interpretation of impact

**Structural assessment and discussion**

The 1mm settlement contour appears to clip the corner of the rear garden. The building itself is very unlikely to be affected by settlement.

**Heritage features sensitivity discussion**

This building has not been inspected. In light of the Listed Building description, sensitive features may include double hung sashes and the doorway with fanlight.

These features are unlikely to be sensitive to the levels of settlement calculated.

**Condition discussion**

Not inspected.

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

In light of the desk based evidence, the total score is anticipated to be zero, and this building is unlikely to be affected by the calculated movements.

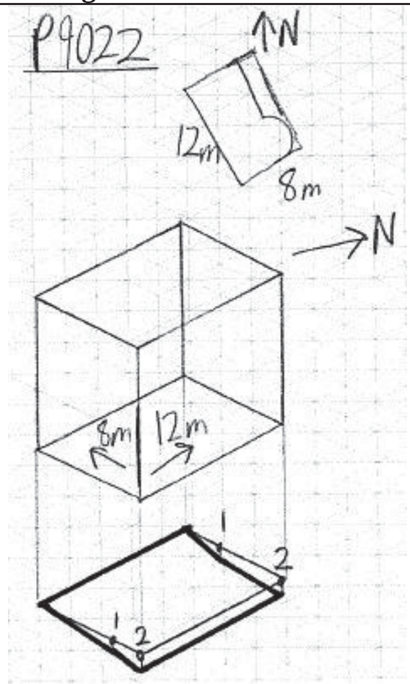
# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z4635 |
| **Building name / address** | Cedar House, W4 2PS |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 21954 78125 |
| **Ground level (mTD)** | +104.2 to +104.5 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

Cedar House is a late 18th century building of brown brick, with three storeys and three bays to its river facing (south eastern) elevation. This elevation has tall and elegant timber sash windows, with red brick flat arches above, to the ground and first floors, and squat sash windows to the second floor, again with red brick flat arches above. Brown brick bands are above the ground and first floor arches, and stretch round the south eastern and north eastern elevations. To the eastern corner , on the north east wall, is a full height bow which contains three convex sash windows at ground and first floor level; the ground floor is rendered. The second floor level bow is a later addition, constructed of timber, and with casement windows. The north eastern elevation beyond the bow has three bays; at the rendered ground floor level is a door with a timber surround and fanlight to the left hand side, and two further sash windows. The first floor has three tall sashes, and the second three squat sashes, echoing the road façade. Beyond this, to the north west, is a small, single storey extension, added to the house by the present owner as a studio. The building has two brick chimney stacks; the roof is hidden behind a small brick parapet.

Internally, the current owner of the building has reinstated Georgian-style details, as the building was a shell when she arrived. The features she has installed include panelling, a timber stair, wide floorboards, fireplaces, cornicing and timber doors and doorcases. Although these features do not have any heritage significance, they do complement the age and style of the building. Of interest are the ground and first floor shutters to the south eastern principal rooms, which appear to be original.

Cedar House, Swan House, Island House, Norfolk House, Garden wall, railings to Island House and Norfolk House and St John's House form a group. Swan House in particular adjoins Cedar House and has a similar form of construction to this building.

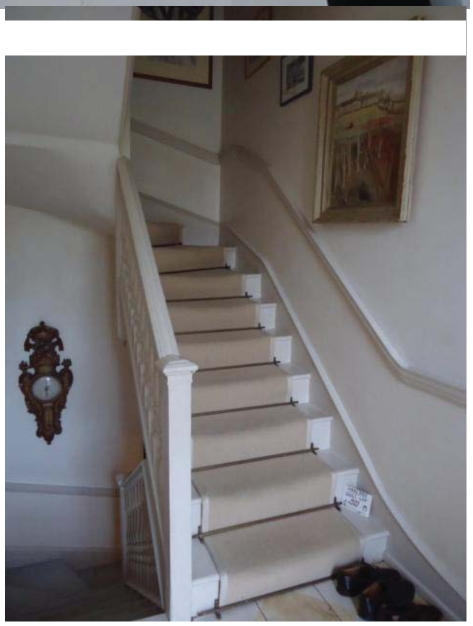
| Structural description and walkover observations | |
|---|---|
| **External**: The brickwork is in good condition. The property was extended in 2003 with a ground floor rear extension. Generally exposed brickwork. The rear wall of the original house is rendered and in good condition.<br><br>**Internal**: The building was refurbished in 2003 (reported) with wholesale replacement of the timber floor boards.<br><br>Alterations include the rear ground level single storey extension and extending the bow vertically up to the second floor (originally only ground and first).<br><br>Within the original house there is a part basement (with fireplace), this has been recently lowered (circa 500mm) using what appears to be traditional mass concrete underpinning. There is a new concrete floor with sump drain and pump. The basement appeared dry.<br><br>At ground level some hairline/fine cracks can be seen in the finishes to the original part of the house.<br><br>At first floor some hairline/fine cracks can be seen to the internal non-loadbearing walls (concentrated along wall-ceiling line and leading up from corners of door frames. Some hairline cracking can also be seen at the junction of the stairs to the walls. These are not recent and are normal in old buildings founded on shallow footings, which tend to experience movements, and in buildings with timber floors which tend to sag over time.<br><br>It was reported by the owner that cracks had become recently noticeable during construction of nearby housing. Construction vibration was reported.<br><br>A vertical hairline crack runs up the south-west corner of the room to the north east of the building at first floor and at second floor directly over. Cracking to the partition walls are due to deflection of timber floors.<br><br>At third floor level the living space had been extended up into the pitched roof space. The bottom ties of timber trusses are exposed. A fine crack can be seen running vertically in the south east external wall. However the crack cannot be seen to the external face from ground level. | |
| **Condition** | Generally in good condition. Only localised fine cracks to finishes (typically at upper levels) |
| **Assumed foundations** | Assumed to be shallow strip footings under original. Basement under part of the building has recently (2003) been lowered with local (traditional) underpinning. |
| **Façade material** | Brick (load-bearing), red brick dressings |
| **Internal support system (i.e. superstructure)** | Load-bearing masonry and timber floors. Floor boards were all replaced in 2003. |
| **Heritage** | The elegant external form of the building, especially the bow, and the elegant timber sash windows; surviving shutters to the ground and first floors. |

# Building photographs


Exterior from river (south)

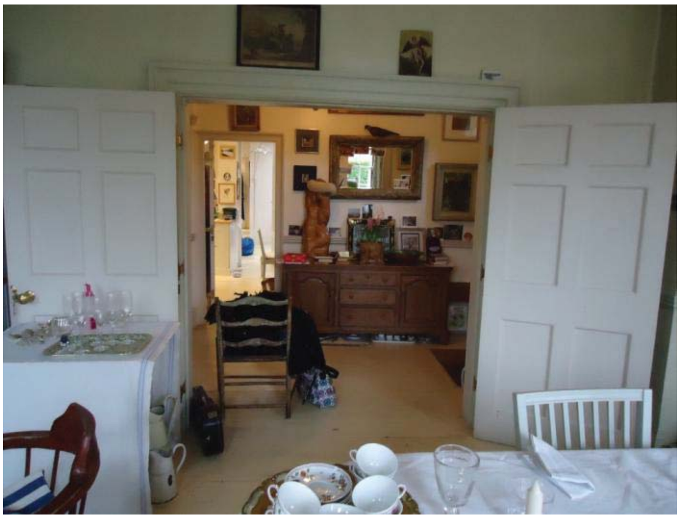
Exterior and studio extension

Shutters, ground floor



Stair

Basement fireplace



Interior features

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within London Clay Formation.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +75.8mTD.
Excavated diameter: 8.1m.
Closest shaft: Acton Storm Tanks shaft, located approximately 1,390m north-west – design indicates unlikely to influence building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

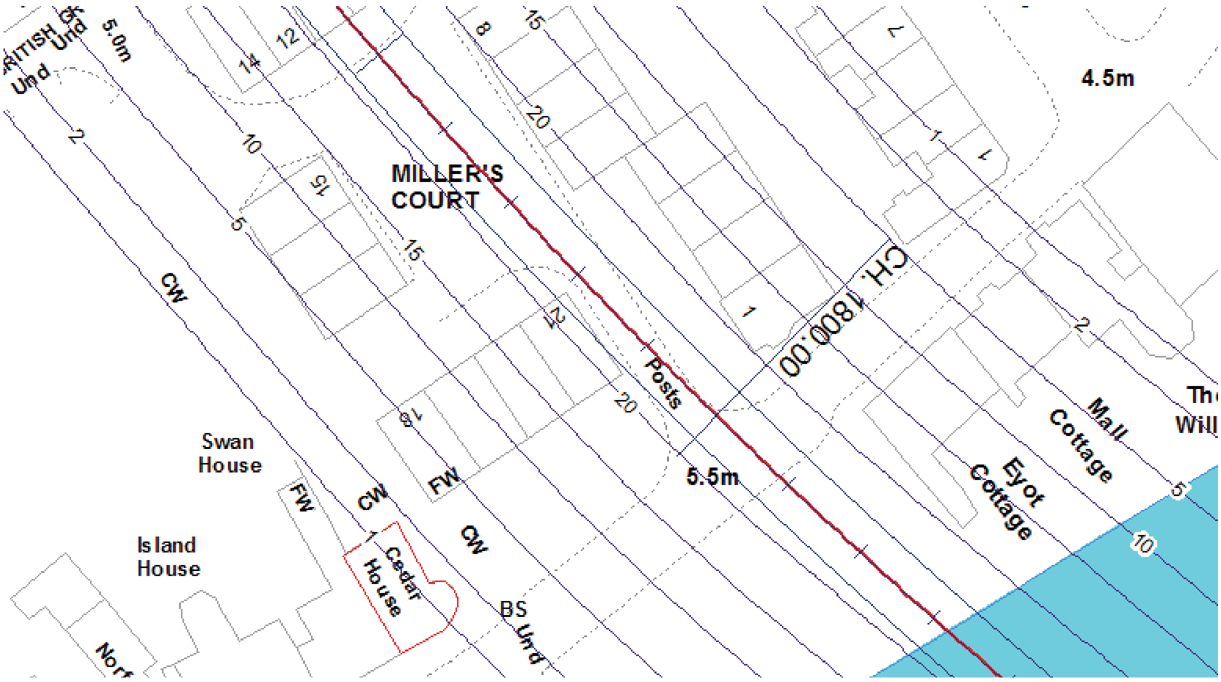
Thames Tunnel proposed to be constructed within London Clay Formation. The expected sequence above the London Clay is summarised below;

Superficial deposits/Made Ground: Ground level +104.2mTD to +104.5mTD.
Top of London Clay Formation: +98.0mTD (22.2m above proposed tunnel centreline level).

Review of borehole SA1123B (located approximately 230m north-east of the structure) and BGS borehole TQ27NW18 (located approximately 45m north-east) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions.

**Results**

Settlement contours generated at +103.2mTD, approximate base slab level, assuming 1m below ground surface;




As shown above the building sits outside of the 1mm settlement contour modelled.

Two key façades were selected from the GIS model. These were analysed with a building height of 9m, on shallow foundations, with and without a basement (foundations at 4m bgl and 1m bgl respectively).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.02% and a maximum settlement of 2mm were obtained for the building when it was modelled as 9m high, without a basement.

The interaction of ground settlements with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The structure is typically in good condition having been refurbished in recent years. Only minor cracking can be seen to internal finishes consistent with buildings of similar age on shallow footings and with timber floors. It is noted that the owner reported vibrations and cracking during recent neighbouring construction work.

Given that the calculated settlement is less than 2mm the risk of damage due to settlement is extremely low and likely to be less than seasonal movement.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

The exterior of this building retains heritage significance as part of a pair with Swan House, and as a wider group with other buildings in the area. Interior features, apart from the shutters, have been inserted recently, and are of little heritage value.

The calculated settlement to be experienced by the building is extremely low, as only its garden curtilage falls within the 1mm contour. Therefore, the heritage interest of the building, inherent is its façades and visual appearance, are not at risk.

***Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

The building is in good condition, with only some minor superficial deterioration to interior finishes. Maintenance appears to be undertaken, and there are no obvious defects.

***Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total combined score for this building is 0.

The magnitude of strain likely to affect this building is very low, placing the movement in risk of damage category 0. Therefore the sensitive structure and condition of the building will not result in levels of damage that could lead to damage of heritage features.

On reflection of the combined score and taking into account the structural and heritage features of the building and its condition, this building will not require further assessment as part of the Damage Assessment process, and will not require mitigation measures.

# Appendix C: Individual building assessment reports for the London Borough of Wandsworth

# Listed building assessment

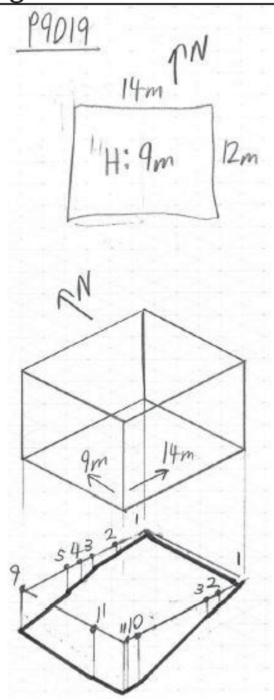
## Building information

| | |
|---|---|
| **Building reference** | Z0549, Z0550 |
| **Building name / address** | 7 to 9 Church Row, SW18 1ES |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 25514 74755 |
| **Ground level (mTD)** | +104.3 to +104.5 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 5 for building location.

**Isometric ground movement sketch**




Isometric sketch shows curtilage of property rather than structure outline

**Building description (including excerpts from English Heritage listing, where appropriate)**

Built in the early 18th Century for the Wentworth family, this three-storey, four-bay Georgian house is set behind a low brick boundary wall with wrought iron gate. To the front (western) façade are sash windows on all the upper floors of the northern three bays. The fourth bay to the south, which is set slightly forward (to the west) of the other three bays, has a projecting timber and stone element, with a doorway to the ground floor and an elegant timber bay window to the first floor. On the second floor, there is a Victorian replacement sash window. The main entrance doorway with timber surround and hood, is central to the three-bay section of the façade, with a sash window to the south and timber double-doors to a vehicle opening, which passes through the entire depth of the building leading onto the rear (eastern) courtyard. At second floor level, just below a timber eaves-cornice, are London Fire Insurance marks (plaques), with the one to the right being from the Hand in Hand Fire and Life Insurance company, which produced plaques from 1696 to 1905, and that to the left of the Westminster Insurance Office, which produced plaques between 1717 and 1906. These marks are both painted, and their material is not known.

To the east of the building is a terrace of Victorian cottages running perpendicular to the eastern façade of the main house. These cottages are two-storey with timber sash windows, each cottage has two bays. There are doorways at both levels, with a timber gallery running above the ground floor and accessed by a stair from the courtyard. This gallery culminates in what appears to be an old iron fire-stair leading to the second floor of the main house; this is in poor condition and probably now provides no access. The cottages are made of London stock brick, which has been whitewashed at ground floor level. Both the Victorian cottages and the main Georgian house are roofed in slate.

At the end of the row of cottages, away from the main house is a derelict garage/workshop, with timber doors that read ‘William Whitby and Son, Builders’.

Internally, the entrance to the main house through the central entrance leads onto a corridor, which stretches the full depth of the building. The interiors of the Georgian section include the original windows and door surrounds, mouldings, cornicing and coving in several rooms as well as some of the wainscot panelling in the corridor and stairway. The timber staircase has timber banisters with newel posts and appears to be original. No access to the basement was available, but it appears that there may have been some access to a cellar, which has now been blocked off, evidenced by a modern breeze-block section of wall under the stair.

The majority of historic features in the Victorian cottages do not survive, although these buildings are likely to have been simply decorated when built. The timber window frames, doorcases and second storey coving survive.

**Structural description and walkover observations**

No 8/9 consists of three storeys with a pitched roof and a prominent overhanging soffit board to the west gable, No 7 is also a ground floor plus two storeys, although the roof was not seen.

At the rear (east of the building) there is a hidden row of former worker’s cottages (Victorian) two storeys high, set at 90 degrees to the main house. A timber walkway runs along part of the first floor – this is a new construction and protruding beam ends show where in the past this feature went further along the row. There is a very large chimney on the eastern side of No 8, and a curious and very corroded escape stair up to the second floor in the angle formed between the row of cottages and No 8.

**External**: The flank wall (to No 9) has some crazing in the render. There are signs of some earlier repairs and modest out-of plane distortion can be seen towards the west of the building.

The western front of No 9 has a lintel (black-painted RSJ) over the garage – mirrored with a similar detail to the rear (east) of the property. The property has good features, although some erosion is visible in the brick bands and the front (western) door hood slopes to the south.

There is a vent pipe against the boundary wall to No 6, although no information as to its origin. There are no basements evident externally.

The later extension (No 7) has some cracks over the front (western) door, and there is a small lintel, possibly of cast iron, which shows some deflection at the north side.

There is an attractive bow window on the first floor over a canted lower storey.

There are signs of some movement on the eastern façade of the garage; the doors are out of alignment at ground level and first floor in the end cottage.

The garden extends eastwards to the bank of the River Wandle.

**Internal:** Within the buildings the rooms are used as studios. In the cottages there are timber floors at the first floor level in the end units, part boarded over, with floor boards running parallel to the façade. Some cracking can be seen in the end wall at ground floor level, over the door to the next unit and there is a vertical crack at the top of the stairs.

Within the main houses there are signs of significant alterations over the years. There is a low ceiling on the second floor, with probable lath construction. There are also numerous changes of level.

On the first floor there are downstand beams in the western room on the north side, the floor boards are perpendicular to the façade, while on the south side the boards are parallel (suggests some variation in the direction of joist span). The floor in the main eastern room is very uneven. There are rooflights at the rear, included within a series of irregular roof profiles – apparently installed following bomb damage.

On the second floor there is an extensive build up of flooring in the northern room, reported to be 4 layers, and a grid of battens on the ceiling, apparently added as strengthening during WWII. In the southern room there are signs of water damage, caused by blocking of the internal gutter above the ceiling.

| | |
|---|---|
| At ground floor level there is a masonry 'passage' with an arched roof behind the main rooms. There is some cracking in the 'barrel', which has modern infill under the stairs. On the north side of the house there is some lath and plaster, which may be original, exposed in the cupboard adjacent to the stairs.<br><br>Overall, this is a property that has been extended and changed over the years, and which shows some signs of movement and lack of systematic maintenance. With the exception of the rear external stair it is not in bad condition for its age. | |
| **Condition** | Fair to poor dependant on area |
| **Assumed foundations** | Assumed to be shallow ground bearing strips |
| **Façade material** | Brick (load-bearing) |
| **Internal support system (i.e. superstructure)** | Generally this will be of load-bearing masonry construction. Floors are of timber. It is possible that some steel beams could have been introduced as part of later repairs and alterations, although in general the original construction materials and form have been retained. |
| **Heritage** | External features including the sash windows, timber door case, and especially the timber/plaster bay to the western façade, and the fire insurance marks. The workers cottages to the rear are of interest. Internally, surviving elements include doorcases, coving and cornices, and the original stair to the main building. |

## Building photographs

Rear elevation with workers cottages to the left

Front façade showing bow window

Example of internal water damage

Iron stair to the rear of the building, in poor condition

## Ground movement analysis

### Tunnel and shaft details

Carnwath Road tunnel constructed within London Clay Formation.
Open face tunnelling using a shield – assumed VL = 2%.
Tunnel centreline level: +85.7mTD.
Excavated diameter: 3.6m.
Closest shaft: Dormay Street shaft, located approximately 190m north – design indicates unlikely to influence ground movements at building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

### Ground conditions

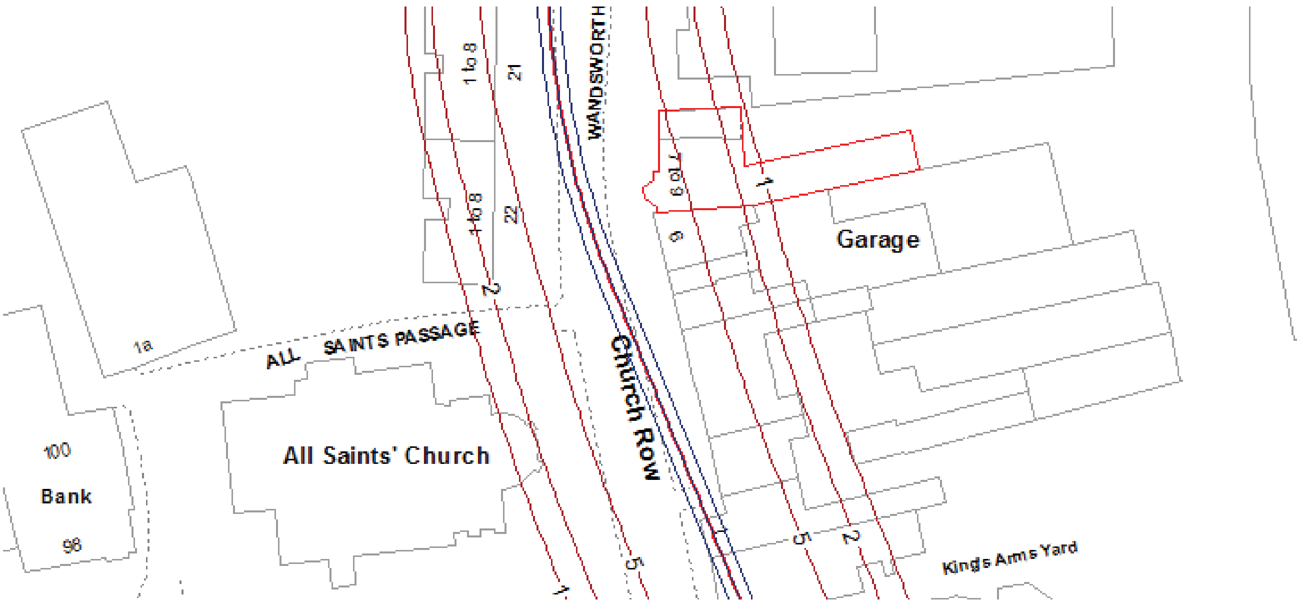
The Carnwath Road tunnel is proposed to be constructed within London Clay Formation. The expected sequence above the tunnel is summarised below;

Made Ground and Superficial deposits: Ground level +104.3mTD to +104.5mTD.
Top of London Clay Formation: +100.5mTD (14.8m above proposed tunnel centreline level).

Review of borehole SR1108 (located approximately 70m north) and BGS borehole TQ27SE54 (located approximately 80m south) does not indicate any geological features that would require a change in the current ground loss assumptions.

### Results

Settlement contours generated at +103.3mTD, assumed base slab level.




As shown above the buildings cross the 5mm, 2mm and 1mm settlement contours.

Four key façades were selected from the GIS model. Analysis assumed a building height of 9m and shallow foundations (1m bgl).

The results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.01% and a maximum settlement of 8mm were obtained for the building.

The interaction of ground settlement with the structures is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

It is noted that there are some indications of previous movement and that there are some areas which are in a poor state of repair. The calculated movements and damage category are very low and it is not anticipated that the impact will be of significance. To the extent that movement does occur this is likely to be seen as a very slight worsening of existing cracks and/or hairline cracking at junctions between parts of the building, as these will be the more vulnerable areas.

***Structural sensitivity score is therefore assessed to be 1.***

**Heritage features sensitivity discussion**

The main heritage sensitivity of this building lies in its external features, particularly to the front (western) façade. Internally the stair and wainscoting, and surviving decorative details are also of interest. To the rear (east), the workers cottages are of interest, and although they are simple, they add to the significance of the listed building. The movements due to settlement that would be experienced by this building will most affect the western façade of the building, and its attachment to the rest of the building. There is a possibility that the movement may cause very minor damage to the bay at the southern side of the western façade, where the timber and stone element is sensitive.

***Heritage sensitivity score is therefore assessed to be 1.***

**Condition discussion**

The building is generally in good condition, with solid façades and no cracking to the external faces. However, the interior has experienced some water damage and is in need of some renovation. The vestiges of the iron fire escape to the east are in poor condition. The condition of the building as it is should not present any sensitivity to the movement that occurs during the Thames Tunnel construction; should the building be allowed to deteriorate it may become more sensitive. However, at present the occupiers of the building are conducting sensitive repairs with the agreement of the local authority, and this work is due to continue.

***Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 1 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

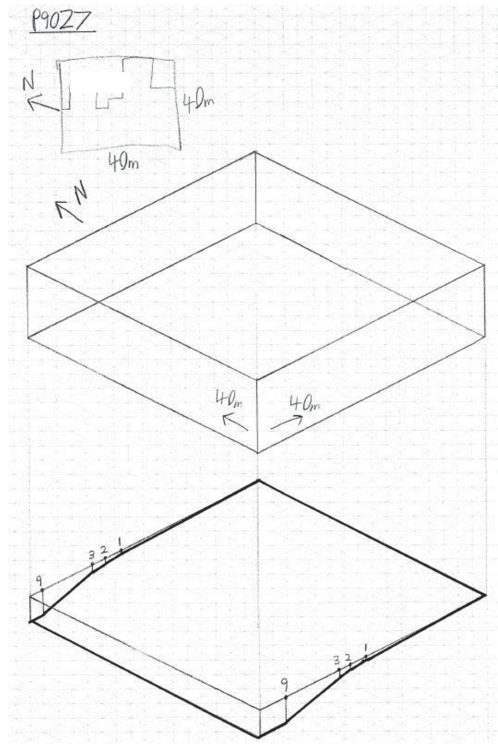
**Recommendations**

No’s.7 to 9 Church Row has a combined score of 2, and is not anticipated to experience any significant movement due to the construction of the Thames Tunnel. However, there is some risk of movement to the front façade causing some small delamination of the façade with the building behind, which may cause very minor damage to the features of the that façade.

This damage is not assessed to be significant, and it is judged that no mitigation is proposed for this building, and therefore no further assessment required as part of the damage assessment. Due to the condition of the building and the ongoing renovation works, it may be prudent to conduct a pre-works defect survey to ensure that it can be fully ascertained that the works are not causing further deterioration.

# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z0552, Z0554, Z0555, Z0557, Z0558, Z0562, Z4643, Z4644 |
| **Building name / address** | 1 to 6 Church Row, SW18 1ES |
| **Grade of listing** | II* |
| **National Grid Reference (NGR)** | TQ 25519 74730 |
| **Ground level (mTD)** | +104.5 to +104.9 |

| **Location plan** | **Isometric ground movement sketch** |
|---|---|
| <br>Satellite imagery does not align perfectly with GIS mapping – refer to page 5 for building location. |  |

**Building description (including excerpts from English Heritage listing, where appropriate)**

1 to 6 Church Row is a terrace of six Grade II* listed Georgian townhouses in Wandsworth, dating from approximately 1723. During the course of this assessment, only property Nos 1 to 4 were accessed for inspection, Nos 5 and 6 are assumed to be similar for the purposes of assessment. It is a balanced block of three storeys plus basements, with each house having three bays faced in brown brick with red brick dressings. There are projecting brick piers at either end and between the second and third house and the fourth and fifth house.

Each house is approached by stone steps leading up to wooden doorcases with plinths, fluted Corinthian pilasters and entablatures with dentil cornices. The timber doors have lights above, with some ornate tracery. The window surrounds are of gauged red brick. The central blank window (between the third and fourth houses) on the first floor level holds a sundial with the inscription “AD1723 Vigilate et Orate”. There is a modillion eaves cornice below a central modillioned pediment. The hipped roof is partially slate and partially tile. There is a ginnel between the third and fourth houses and carriageways between the first and second houses and the fifth and sixth houses. To the front are wrought iron railings to the lightwells and leading up the steps; one building retains an original boot-jack to the side of its front door.

The majority of the interior features still survive including fire surrounds, plaster coving and ceilings, panelling on walls and staircases, dado rails and staircases with turned balusters and handrails. The plan form seems largely unchanged and is typical of houses of this period, although doorways have been created in some areas between the houses to facilitate office use. Each house has a separate basement and separate stairwell.

To the rear of the row are a number of later ancillary buildings. These are mostly concrete and steel workshop and garage style buildings, except for a large office and boardroom extension at the rear of No.1 Church Row. Formerly the headquarters of the British Olympic Association, the main feature of this extension is a timber panelled boardroom with long skylights, which retains its original cabinetry, fixtures and furnishings, and appears to date from the late 1960s to early 1970s.

**Structural description and walkover observations**

The buildings comprise ground plus two upper storeys. The ground floor is raised with steps up from street level and the houses have a semi-basement with a lightwell to the street.

It was noted that the lintel over the doorcase to No 2 differs in profile from that over the others and it appears that some rebuilding of the wall above may have taken place.

There are fanlights above the doors, with ornate glass in No's 1, 3 and 4.

The front (west) elevation is generally in good condition, with some interesting heritage features:

- A bell at second floor over the arch between No's 5 and 6.
- Fire insurance plaques at first floor to the left hand side of the front doors to both No's 5 and 6. That above No 5 is inscribed 'IMPERIAL'.

There are archways over the passages leading to the rear between No's 5 and 6 and No's 1 and 2, with blind windows over both arches.

There appears to have been significant reconstruction of the front of No 1; this would be consistent with the documented removal of a former shop in the courtyard area.

Some degradation of masonry was observed above some, but not all, of the basement windows. Some cracking was also seen at the rear of No 3 at plinth level, with a vertical crack of around 1mm width in the render below one of the windows and extending in the brickwork up to cill level.

At the rear of No's 5 and 6 there are a roadway and mews (although no access was possible), while behind No's 1 to 4 there is a larger area of land with a number of separate buildings which are described further below.

In the principal buildings, there has been a degree of interconnection between No's 1 to 3 with doors inserted in party walls and through corridors. There has been construction added at the rear. No 4 is in separate use as residential accommodation.

**No's 1 to 3** were visited initially. The properties are generally interconnected, with many common features.

<u>Semi-basement</u>
Nos 1 and 2 have a brick floor; the ceiling over is low.
There is a large fireplace at the party wall between Nos 2 and 3 with splayed brickwork on both sides of the wall.
There is a crack over the doorway in the party wall and cracks in both chimney breasts. On the No 2 side the wall has a modern render.
There is a step at the party wall line down into No 3.
At the back of No 3 a low block extends beyond the general line of the rear wall.

Ground floor
The principal room at the front of the building (No 3) has a crack in what may be a false ceiling running perpendicular to the façade. A small corridor along the front wall leads into No 2.
A later addition at the rear runs across both properties and to No 1. This is an open structure with a single RHS (possibly iron) supporting the floor over behind No 2.

First Floor
The principal room in No 3 has timber floors. The building is linked by a corridor to No 2 as at ground floor.
Stairs in No 3 are at the rear against the party wall with No 4.
No 2 has a main room at the front and two smaller rooms; skew panels were noted over a small extension beyond.

Second Floor
No 3 has a modern ceiling with a lot of timber panelling on the walls which may be original.
No 1 has been much modernised and is very 'bland'.

There are original timber staircases throughout with fine tread detail.
No 4 is in single use. Overall the properties are in good condition with no significant defects observed and little to cause concern in relation to response to calculated ground movements. While there have been alterations and extensions it is not considered that these are likely to alter the response.

**No 4** is a building in single occupancy and used as a family house. It has been extensively redecorated and is in good condition, with features maintained and intact.

No cracks of particular significance were noted and those observed tended to be at wall/ceiling junctions and around the cornicing. A limited amount of distortion was seen but not inconsistent with a building of this age and construction. It has a particularly fine timber staircase.

At the rear of the property there is a long single storey building at right angles to the original houses. This is relatively modern, of loadbearing masonry with rooflights on the sloping faces. Other buildings are one and two-storey, generally of load-bearing masonry. At the rear on the north side there is a single storey workshop, with masonry walls and light steel trusses supporting the roof. Opposite this there is a single storey masonry building. Behind No 4 there is a small two-storey masonry building with corrugated sheet cladding at first floor. These show generally some degree of deterioration with some cracking and weathered paintwork; the cracking is not thought to be of significance and may indicate some historic movement.

| | |
|---|---|
| **Condition** | Good, excepting some water damage. |
| **Assumed foundations** | For the principal houses these are likely to be very shallow brick strip footings; foundations in this period were often minimal.<br>The more recent buildings at the rear are likely to be founded on shallow brick and concrete strips and pad footings. |
| **Façade material** | Brown brick with red brick and stucco dressings. |
| **Internal support system (i.e. superstructure)** | In general these are buildings of load-bearing masonry construction. Some internal iron columns have been used at the rear and there may be iron beams within the floor structures. The more recent buildings are a mixture of masonry, concrete and steel. |
| **Heritage** | External façade with cornice and pediment; sun dial; railings to lightwells; internal retained features including fireplaces, cornices, panelling, stairs with turned balusters and doorcases; boardroom extension with fixtures and fittings. No's 5 and 6 Church Row not inspected. |

## Building photographs

Main façade, from the east

Example of doorcase and over-light

Detail of timber stair with turned balusters

Example of retained fireplace

Example of decorative interior door arch

1960s/70s boardroom within rear extension

## Ground movement analysis

**Tunnel and shaft details**

Carnwath Road tunnel constructed within London Clay Formation.
Open face tunnelling using a shield – assumed VL = 2%.
Tunnel centreline level: +85.8mTD.
Excavated diameter: 3.6m.
Closest shaft: Dormay Street shaft, located approximately 200m north – design indicates shaft ground movements are unlikely to influence building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

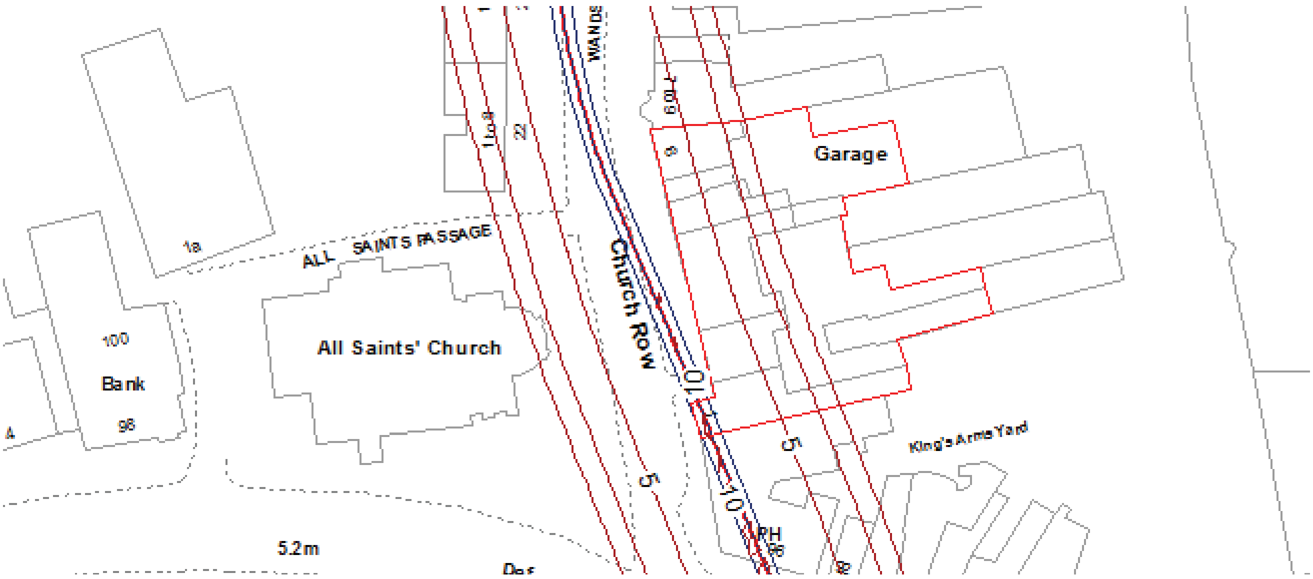
The Carnwath Road tunnel is proposed to be constructed within London Clay Formation. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +104.5mTD to +104.9mTD.
Top of London Clay: +100.5mTD (14.7m above proposed tunnel centreline level).

Review of borehole SR1108 (located approximately 75m north) and BGS borehole TQ27SE54 (located approximately 40m south-west) does not indicate any geological features that would require a change in the current ground loss assumptions.

**Results**

Settlement contours generated 1m below ground level




As shown above the buildings partially overlie the proposed Carnwath Road tunnel, crossing the 10mm, 5mm, 2mm and 1mm contours.

Analysis of two key façades selected from the GIS model, assumed a building height of 9m, with and without a basement on shallow foundations (foundations 1m bgl and 4m bgl).

The results fell within category 0, risk of negligible damage, with a maximum tensile strain of 0.02% and maximum settlement of 10mm calculatedwhen the building was modelled with a basement.

The interaction of the ground settlement with the structures is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The buildings are generally of robust construction and in good condition overall. The maximum settlement is calculated at the front of the terrace, with the highest value towards the southern end of the terrace (No 1) with differential movements seen along the party walls. Some minor cracking may occur but this would be limited in magnitude and extent.

The buildings at the rear of the site are in the zone of very small calculated movements and are not expected to see any consequential impact.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

A full inspection has not been carried out; access was gained to No's 1 to 4 Church Row and it has been assumed for the purposes of assessment that property No's 5 and 6 are similar.

There are a number of features within No's 1 to 4 Church Row that may be sensitive to settlement. These include the excellent external façade, particularly stucco elements such as the pediment and eaves cornice, and the sundial. Internally, the staircases with turned balusters may also be sensitive to large movement (however the predicted movements are relatively small).

The calculated settlement is concentrated in the area of the front (western) façade; although the settlement is not very large, there is a risk of delamination of the front façade with the structure behind, which may damage the decorative external elements of the building.

***Heritage sensitivity score is therefore assessed to be 1.***

**Condition discussion**

This building is in fair condition; some particular areas of water ingress or minor cracking were noted, particularly to the rear of the building, away from the larger settlements calculated.

These areas of poor condition are unlikely to cause this building to be sensitive to settlement.

***Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 1.

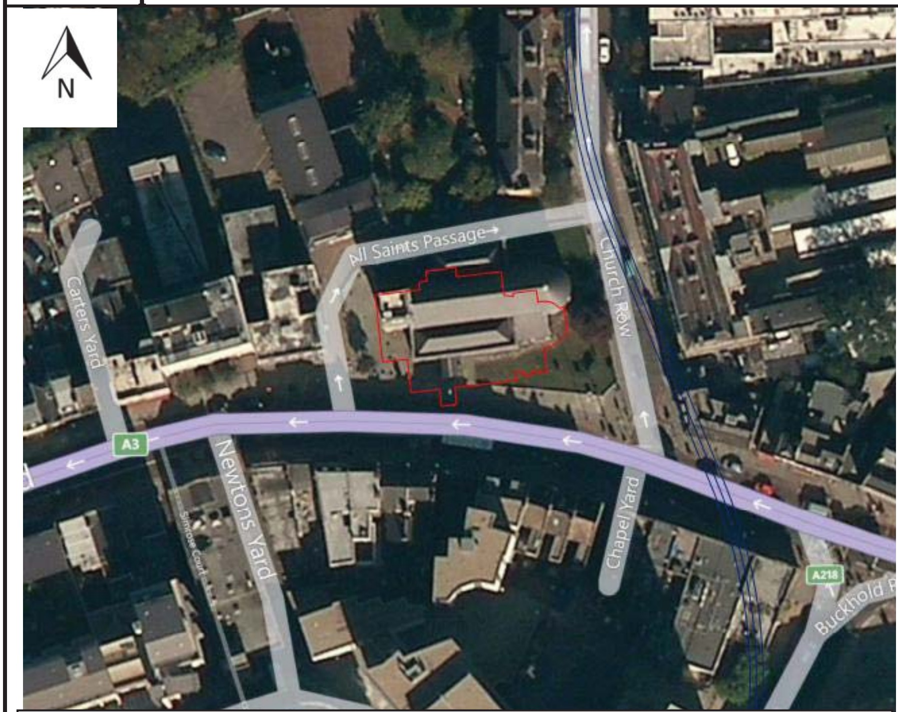
The building is not anticipated to experience any significant movement due to the construction of the Thames Tunnel. However, there is some risk of movement to the front façade causing some small delamination of the façade with the fabric behind, which may cause very minor damage to the external decorative features, potentially degrading the heritage significance of the building. Any existing cracking may tend to open up, in particular around openings (doors and windows).

This damage is not anticipated to be significant, and it is judged that no mitigation will be required to this building, therefore no further building damage assessment is required. Due to the small areas of the building currently in poor condition, it may be prudent to conduct a pre-works defect survey to ensure that it can be fully ascertained that the works are not causing further deterioration.

# Listed building assessment

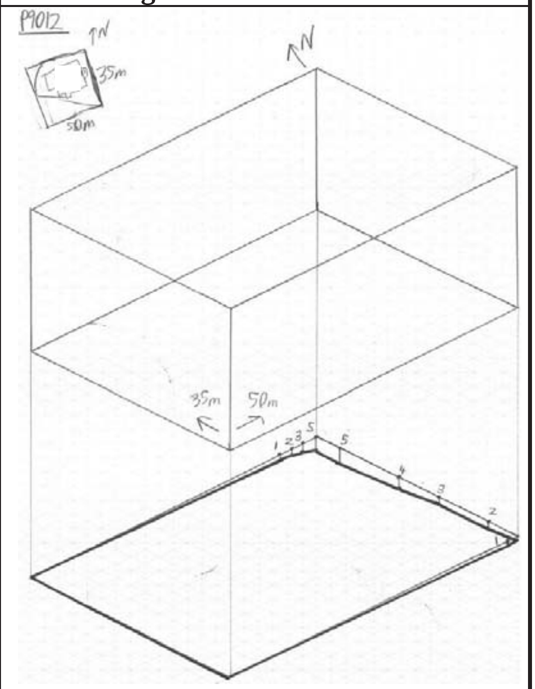
| Building information | |
|---|---|
| **Building reference** | Z0594 |
| **Building name / address** | All Saints Church, SW18 4LA |
| **Grade of listing** | II* |
| **National Grid Reference (NGR)** | TQ 25475 74720 |
| **Ground level (mTD)** | +104.5 to +105.3 |

**Location plan**




Satellite imagery does not align perfectly with GIS mapping – refer to page 5 for building location.

**Isometric ground movement sketch**




Isometric sketch shows curtilage of property rather than structure outline

**Building description (including excerpts from English Heritage listing, where appropriate)**

All Saint’s Church dates from 1630 and was significantly altered in the mid and late 18th century. A crypt is accessible from the apse end of the church, although two crypts are mentioned within the listing description: a large crypt, and a smaller crypt under the choir vestry.

The exterior of the building shows the various phases of its development through changes in brick, detailing and additions. The west tower, originally from 1630 and raised in 1841, is a square, symmetrical tower, which is divided vertically into three stages. The lower section contains a door and narrow, rectangular window with simple mouldings top and bottom and an inset brick arch from the ground level crossing over into the middle nave. This is divided from the second stage by a cornice of simple design, which then over-arches the narrow, rectilinear window below. This stage has no windows or other openings and is ornamented only by the matching brick piers that are a feature at all levels of the tower. The top, belfry segment is slightly smaller in width and depth than the two lower stages, with three round-arched windows with key stones, to the north, the south and the west faces, within a rectilinear brick inset, which creates the effect of corner pilasters. This stage is divided from the second stage by a simple stone cornice. This is all surmounted by a small stone cornice and the parapet that has carved stone crocketed corner finials. There is an extension to the north side of the tower, which contains community and office accommodation for the church.

The nave is four bays long. The four round-arched windows on the north façade are of red brick with stone key stones and springers and inset brick panels beneath. The four round-arched windows on the south façade are made of simple London Stock brick arches, matching the brick of the rest of this façade, tower and apsidal end. The nave is surmounted by a hipped roof of slate. In the east wall of the nave there are single windows of similar design on either side of the apse. The apse is of London stock brick and is of a very simple design with stone-capped brick buttresses, semi-circular lights and high-level, rectilinear, stone-mullioned lights.

The interior of the tower is very simple in design. The ground floor is little more than a corridor from the door into the church and the first floor, leading onto the gallery, is a small plain room with a tall rectilinear window to the west and a glazed archway to the gallery. The belfry was inaccessible during the site inspection, but is accessed via a small hatch and ladder.

The main body of the church is of a simple basilican plan with a single aisle to either side of the nave, with columns running the length of the nave. There is a gallery, set behind these columns in the aisles, supported on smaller, simpler columns. All columns have decorative Doric capitals, in the case of the gallery columns these are painted.

The ceiling is an unornamented coffered barrel vault which runs the length of the nave and into the apse. There are wooden pews of some interest on the ground level and box pews in the gallery. The floors in the nave are stone. The majority of the windows of the nave are of plain glass; the exception being the window in the east wall to the north of the apse which is of coloured glass with a stained glass insert.

The semi-circular lights of the apse itself are made of stained and painted glass depicting various biblical scenes. The organ sits to one side of the apse and a small vestry to the other. The floor is of marble in a checkerboard pattern.

**Structural description and walkover observations**

The church is load-bearing brick externally with stone dressings on the tower.

The eastern end is a later addition with a semi-domed ceiling. Stone coursing is visible at the pier on the south side of the apse at the junction with the nave.

There are internal columns along the line of the apse. On the north and south sides there are timber galleries supported on separate columns. On the north side the gallery is accessed by a timber stair at the west end. The gallery on the south side is continuous with the gallery at the back of the church in front of the bell tower. Access is by a winding stair in the south-west corner.

There is a room at the base of the bell tower, which has painted stone walls, generally defect free. Access to the bell tower was not possible; this is via a vertical ladder and small hatch on the south wall.

Access to the crypt is on the north side of the church through a hatch against the north wall and via a modern steel staircase. The crypt extends below the apse and is therefore assumed to be of similarly modern origin. The floor over the crypt is supported on heavy brick columns; these have corbelled brick bases in turn supported on concrete bases approximately 600mm high. The walls also have corbelled bases. The slab over is of concrete and steel joists, the latter showing corrosion in some locations although the crypt itself appears well ventilated and largely dry. The slab on the south side of the crypt is of similar construction but is lower over the southernmost section.

Internally the floor is of stone, with some of more recent origin and some appearing much older – possibly part of the original construction. It incorporates a number of tomb stones. There is also an area of timber flooring towards the front of the nave on the south side of the building. There are steps up at the eastern end in a line close to the east end of the galleries. There is some cracking in the slabs at the edge of the apse.

Hairline cracking is seen in the ceiling at the front of the church on both sides.

There is cracking over the north gallery with cracks up to approximately 1mm in the ceiling and over the windows.

There are some cracks in the ceiling over the south gallery but these are generally not seen in the window arches, unlike the arches on the north side.

At the back of the church (west side) there is more extensive cracking and signs of water ingress. There is a vertical crack approximately 1mm over the last window arch on the north side and a further crack perhaps less than 1mm in the wall just behind the gallery.

There are more significant cracks on the south side, with the largest 2 to 3mm over the last window and in the wall adjacent. Also there is water ingress and cracks above the gallery in the south-west corner are visible.

Externally, there are signs of repointing over several windows on the south side.

The worst cracking on the south wall internally is not fully reflected externally

The north side has more modern decorated window heads and any cracks would be less evident.

The porch on the south side is somewhat dilapidated.

Overall the masonry is in good condition. The different stages of construction are seen in very different brick types and styles – and there is a very obvious straight joint at the junction between the apse and the main footprint. There are straight joints also at other inter-phase junctions.

There is a barrel vault ceiling over the nave; this has some cracking and three or four holes where plaster has fallen, possibly associated with water damage.

There is modern single storey accommodation right at the back of the church on the north side. This has been newly decorated and appears to be in good condition.

| | |
|---|---|
| **Condition** | Generally poor |
| **Assumed foundations** | Shallow corbelled brick/concrete footings |
| **Façade material** | Brick/stone (Load-bearing masonry construction) |
| **Internal support system (i.e. superstructure)** | Internally the church has large open spans. There is a line of major columns at the edge of the nave and the timber side galleries are supported on separate columns. |
| **Heritage** | Decorative scheme in plaster and paint; columns and decorative pilasters; timber stairs and timber gallery with box pews; 17$^{th}$ century tower; modern and 19$^{th}$ century stained glass; monuments and plaques; late 19$^{th}$ century wrought iron screen. |

## Building photographs

Tower from west

Northern elevation

Interior of apse with columns

Porch to the east façade

Detail of damage to plaster and decorative pilasters

General interior of church towards the western entrance

## Ground movement analysis

**Tunnel and shaft details**

Carnwath Road tunnel constructed within London Clay Formation.
Open face tunnelling using a shield – assumed VL = 2%.
Tunnel centreline level: +85.8mTD.
Excavated diameter: 3.6m.
Closest shaft: King George's Park shaft, located approximately 220m to the south – design indicates unlikely to influence ground movements at this building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

The Carnwath Road tunnel is proposed to be constructed within London Clay Formation. The expected sequence above the tunnel is summarised below:

Superficial deposits/Made Ground: Ground level +104.5mTD to +105.3mTD.
Top of London Clay Formation: +100.5mTD (14.7m above proposed tunnel centreline level).

Review of boreholes SR1108 (approximately 105m north east), SR1109 (approximately 135m south) and BGS borehole TQ27SE54 (located approximately 45m south-south-east) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions.

**Results**

Settlement contours generated 1m below ground level


As shown above the building sits primarily outside of the tunnel settlement contours, with the far east of the building touching the 2mm contour.

Two key façades were selected from the GIS model for analysis. The structure was modelled at two different heights (10m and 15m), with shallow foundations (1mbgl) and with a basement and shallow foundations (4mbgl).

All results fell within the bounds of category 0, risk of negligible risk of damage. A maximum tensile strain of 0.013%and a maximum settlement of 2.3mm were obtained for the building when modelling a 10m high structure on shallow foundations (foundations 1mbgl). A maximum vertical displacement of 1.8mm and a tensile strain of 0.016% were obtained for the building when modelling a 15m high structure on shallow foundations with a basement (foundations 4mbgl).

The building is potentially founded at variable levels due to the presence of a partial crypt below the church. However the maximum tensile strains and settlements remain negligible for all of the modelling completed.

The interaction of ground settlement with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

There have been extensive alterations to the church since its original construction but the foundations appear robust. There are signs of some previous movement and of minor damage associated with water ingress. The former may be associated with the earlier alterations.

***Structural sensitivity score is therefore assessed to be 1.***

**Heritage features sensitivity discussion**

The external elevations and roof of the building are solid and austere, with the cornicing and window arches providing consistent detail on the stock brick façades. The external porch is a sensitive feature, with plaster of poor condition and decorative elements. Internally, there are a number of features related to the church use of the building, including the gallery, box pews, monuments and rood screen which provide significance, and contribute to the Grade II* listing. There are also decorative details of the structural elements including painted plaster capitals and pilasters which are fragile and in poor condition. The church shows its long usage in the graffiti on the box pews, some of which is dated from the $19^{th}$ century, and its continued use and alteration, down to the additions of toilets and community accommodation, show that this is a building important within Wandsworth.

***Heritage sensitivity score is therefore assessed to be 1.***

**Condition discussion**

Whilst the basic shell of the building, and its roof and crypt, are in generally good condition, the condition of the decoration and features within the building is poor. There is much superficial cracking in plaster work, especially to plaster and timber pilasters, and in addition there are holes in the barrel vaulted ceiling, and evidence of cracking to the interior of the window arches and in areas of stress such as around column heads and corners. The fragile heritage finishes are deteriorating.

***Condition sensitivity score is therefore assessed to be 1.***

| Summary of results | |
|---|---|
| **Scoring** | |
| **Structural sensitivity score** | 1 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 1 |
| **Damage category** | 0 |
| **Recommendations** | |
| While the total score is 3 it is the Damage Category that is of most significance. The calculated ground movements are very low – of the magnitude that might be expected from seasonal movement – and the resulting damage category is 0. The scoring results from the form of the building and its condition. The poor condition of the building has been described above; in the absence of repairs it is likely that deterioration will continue and there is a risk that, for example, further plaster detachment and/or cracking might be coincident with the tunnel works rather than being caused by them. While it appears that the vicar is aware of the current condition issues it is recommended that these should be recorded formally. A condition survey will also be required prior to the commencement of any works, to be reviewed at the time. | |

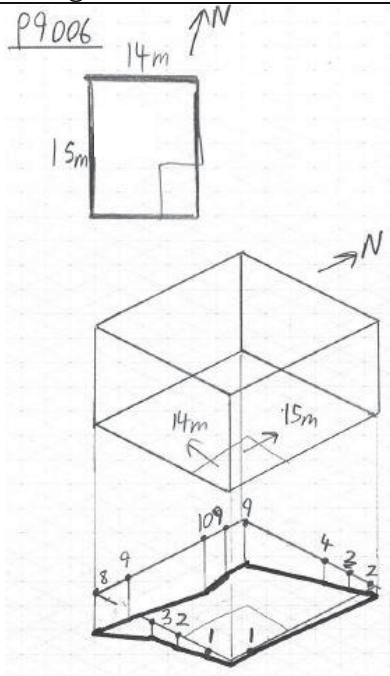
# Listed building assessment

| **Building information** | |
|---|---|
| **Building reference** | Z8613 |
| **Building name / address** | Wentworth House, SW18 1EY |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 25550 74905 |
| **Ground level (mTD)** | +104.0 to +104.4 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 5 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

Eighteenth century Wentworth House is a two storey, five bay building plus a side extension of one bay. It is constructed of brick, with a slate roof, sash windows, and an attic with dormers to the rear. There is a good quality timber door case with a decorative hood to the main front (west) elevation. The building is detached to the south (extension) side, and attached to the northern side to later workshops (not part of the listing). There are also later rear (eastern) extensions. The forecourt wall and gate piers of brick, and a wrought iron gate are all part of the listing, and are in good condition and well kept.

In detail, the exterior is as follows: The western (front) façade retains good quality historic details such as the decorative timber door hood, doorcase, and a moulded timber eaves-cornice. All of these elements, and the slate roof, are in good condition. The sash windows however are in poor condition, with rotting timber, in parts nearly completely split. Distortion to the western wall is evidenced by a bend in the brick band which runs above ground floor level, and brickwork is generally in poor condition with large areas of cement mortar repair; the cement mortar in place of more sympathetic lime mortar has caused the softer brick to crack and spall. Between the main building and the southern extension a plastic downpipe is failing, with vegetation growing from it; there is evidence of this failure in the form of damp inside the building, and in the poor condition of brickwork around the pipe which is further exacerbated by the presence of areas of cement mortar. Again, the windows are in poor condition. To the east of the building are modern extensions; the rear walls of the side extension and part of main house are visible, and there is a tie on the rear of the main house. There are also a number of bricked-up openings to this elevation, a window to the first floor and a doorway to the ground. The rear (eastern) walls show evidence of rebuilding/brick replacement, with cement mortar used. The southern elevation is of brick with area of re-pointing in cement mortar; this elevation shows distortion.

Interior details of interest are located within the main house, where the principal rooms retain some heritage features. The stair hall contains a timber stair running from ground to attic floor, with turned timber balustersand newel posts. The hall is panelled; this panelling is assumed to be original, and lends context to the significance of the stair. At ground floor level the principal rooms, either side of the stair hall, retain some panelling, now heavily painted or papered due to the modernisation of these rooms for office use. An exit has been created from the northern (left hand side) room to the rear (eastern) extension through the former cupboard next to the chimney breast; there is no surviving fire surround. The rooms of the first floor retain greater heritage significance than those of the ground floor. In the northern room, there is a chimney breast to the rear wall with a fire place, and panelled cupboards beside. The rest of the room is also panelled, and has a later opening to the north wall leading to the workshop extensions. Beneath the paper on the ceiling, there is evidence of the uneven timber principal beam. The southern room was obviously the principal room, with good quality timber panelling and a chimney breast, unfortunately now without a fire place, and again there are panelled cupboards to the side of this. The timber floor, now carpeted, is uneven. In the attic, both rooms have dormers with timber casement windows to the rear. In the southern room, a small door to the south wall opens on to the inside of the shallow roof of the extension, and a timber truss is visible.

The rooms of the side extension lack any heritage features and have modern finishes. There are large areas of damp to the north east corner wall to both ground and first floors due to the external downpipe blockage. The chimney breast of the main building is evident on the north wall of the extension. The rear (eastern) extensions are accessed up four stairs, and the interiors are uniformly modern. In the southern room is one tie plate, and another is visible on the rear wall when viewed through the window. These ties match those on the front (west) of the building, except that on the front there are three ties; the missing tie is thought to be buried in a partition wall.

**Structural description and walkover observations**

Two storeys, two bays either side of central entrance. There are later side extensions on both sides. To the south there is one full bay extension and then a narrow separation from the adjacent building. To the north there is a narrow infill between the house and extensive more recent construction. At the rear (east) there has been further extension and new development – the chronology of this is uncertain.

Internally the house has been vacant for 2 to 3 years and shows some signs of neglect. There is accommodation within the roof space, with windows to the rear only. There is extensive interconnection to the side and rear extensions, with several changes of level. There is no basement or cellar.

Beams in the principal rooms run parallel to the front (western) elevation, joists are presumed to span front to back. Suspended floors at all levels (note airbricks/grilles on front elevation), showing signs of unevenness and deflection in a number of areas.

The external joinery is in poor condition generally, with one of the front windows particularly decayed.

The downpipe at the junction between the main house and the south extension may be blocked: there is staining and brickwork deterioration to the surrounding zone, with prolific vegetation.

Internally this has manifested itself as extensive damp ingress and staining on the western wall and the cross wall to some extent.

Timber stair – reasonable condition.

There is significant distortion and unevenness in the western (front) wall – seen as both lean and bow. The wall appears to lean in at the first floor, measured in the north room at the western side as approx 22mm in 850mm [top leans in].

Ties on eastern wall seen as plate on western wall – central tie not seen internally at eastern side, may be ‘buried’ within end wall of extension. The ties appear to have been put in at an early stage as the front plate is fixed over the original window heads, others have been repaired/replaced. One of the ties is on the eastern wall of main house but within the extension – this is up four steps from the half landing between the ground and first floor.

Some vertical cracking on western wall between main house and north extension.

On rear wall there is cracking and bowing at south end, and south wall is leaning outwards – measured as approx 20mm in 720mm near east of building.

| | |
|---|---|
| **Condition** | Poor condition. |
| **Assumed foundations** | Ground bearing – shallow foundations. |
| **Façade material** | Brick. |
| **Internal support system (i.e. superstructure)** | The original building is of load-bearing masonry. Some structural steelwork is likely to have been incorporated in the more recent additions. |
| **Heritage** | Features of heritage significance include door case and hood, timber eaves cornice, sash windows, and interior panelling and timber stair. |

## Building photographs

Front (western) façade with timber eaves cornice and hooded doorcase

Rear (eastern) elevation

Example of degradation to timber sash windows

Water damage and vegetation due to faulty down-pipe

Example of cracking and poor brick repair

Principal room with panelling and blocked in fireplace

## Ground movement analysis

**Tunnel and shaft details**

Carnwath Road Tunnel constructed within London Clay Formation.
Open face shield construction - assumed VL = 2%.
Tunnel centreline level: +85.4mTD.
Excavated diameter: 3.6m.
Closest shaft: Dormay Street shaft, located approximately 45m to the north-north-west – design indicates that the shaft is unlikely to influence ground movements at the building location.

| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |
|---|---|

**Ground conditions**

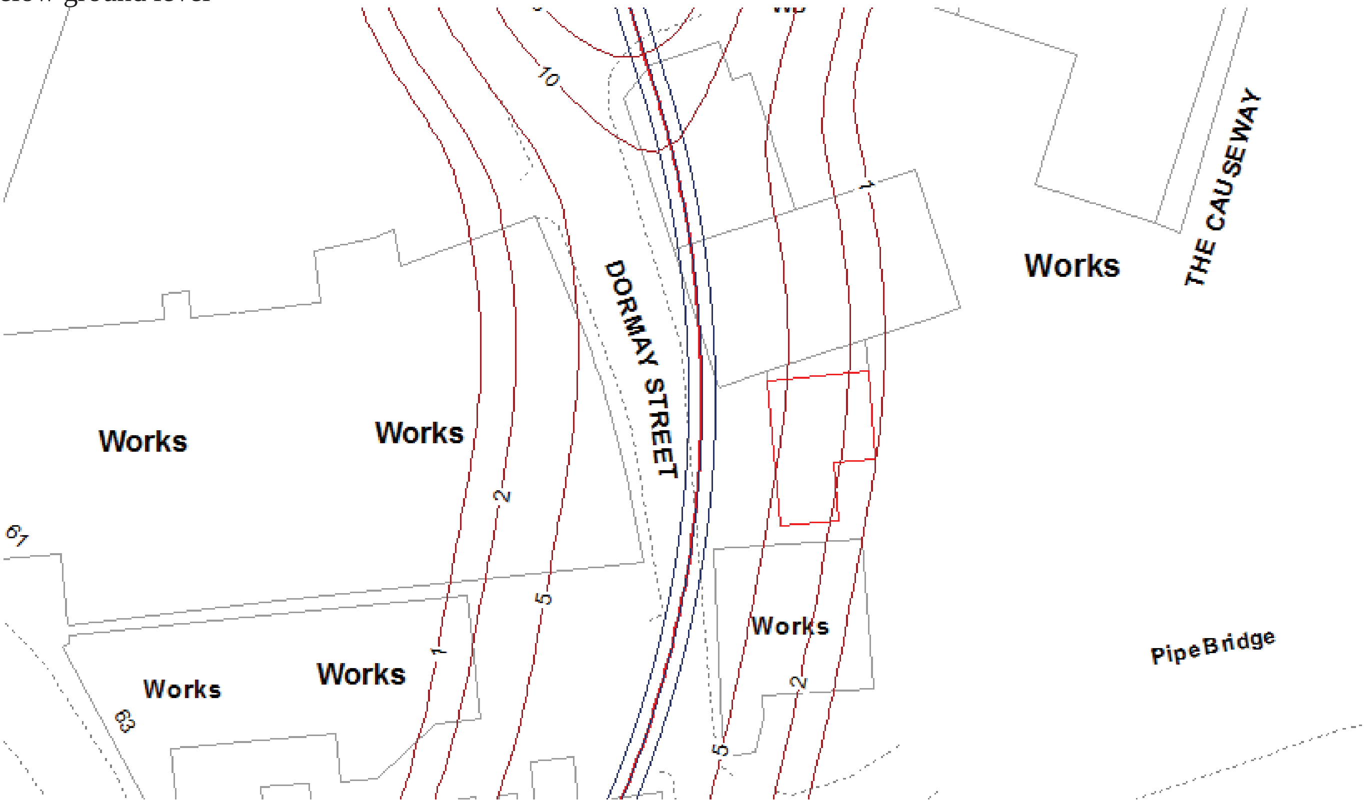
The Carnwath Road Tunnel is proposed to be constructed within London Clay Formation. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +104.0mTD to +104.4mTD.
Top of London Clay Formation: +100.0mTD (14.6m above proposed tunnel centreline level).

Review of borehole SA1106 (located approximately 45m north west) does not indicate any features such as scour that would alter the current ground loss assumptions.

**Results**

Settlement contours generated +103mTD, approximate base slab level for shallow ground bearing foundations, 1m below ground level




As shown above the building crosses the 5mm and 2mm settlement contours generated for the tunnel.

Three key façades were selected from the GIS model. These were analysed for a building height of 6m on shallow foundations, without a basement (foundations at 1m bgl).

The results all fell within the bounds of category 0, risk of negligible risk of damage. A maximum tensile strain of 0.02% and a maximum settlement of 6mm were obtained for the building.

***Building damage score is therefore assessed to be zero.***

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

## Interpretation of impact

**Structural assessment and discussion**

Bricks have been pointed with a cement mortar, and distortion has caused cracking through bricks rather than along the mortar beds. Movement may cause greater damage to bricks, requiring replacement of bricks. Some separation of the brick skin from the elevation of the extension isvisible at one side of the ground floor window.

There is evidence of past movement seen in the distortion and cracking. The former could also indicate lack of restraint in some areas to the façades. Junctions between later additions and the original construction will be more vulnerable to movement.

***Structural sensitivity score is therefore assessed to be 1.***

**Heritage features sensitivity discussion**

Early 18th century, house building for Wentworth family. Associated with associated with Youngs Brewery with its adjacent buildings including a beam engine house. Interior finishes not sensitive to minor movements. Exterior sash windows are in very poor condition and may be more sensitive in areas of bad rot/damage; however as anticipated movement at the front of the building is very minor this is unlikely except in the worst cases. Door case and hood are in good condition, with new lead flashing/covering to hood; this feature is unlikely to experience damage except in cases of more pronounced movements.

***Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

Unoccupied, possibly since 2008 judging by latest date of folders/records kept within the building. Exterior downpipe on junction between main building and extension blocked with vegetation, and interior showed signs of damp in this area on all floors. Timber of sash windows in very poor condition. Distinct distortion to western and southern elevations, and areas of minor cracking to brickwork and general poor condition of mortar and brickwork.

***Condition sensitivity score is therefore assessed to be 1.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 1 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 1 |
| **Damage category** | 0 |

**Recommendations**

The total combined score for this building is 2. The structure in its present condition may be sensitive to pronounced movement, and in general the condition of the building is poor making all elements of the building more sensitive to settlement. However, the significant heritage features are unlikely to be damaged as a result of the Thames Tunnel works.

The magnitude of strain generated by the ground movements calculated to affect this building is very low, placing the movement in damage category 0. Therefore the sensitive structure and condition of the building will not result in levels of damage that could lead to damage of heritage features.

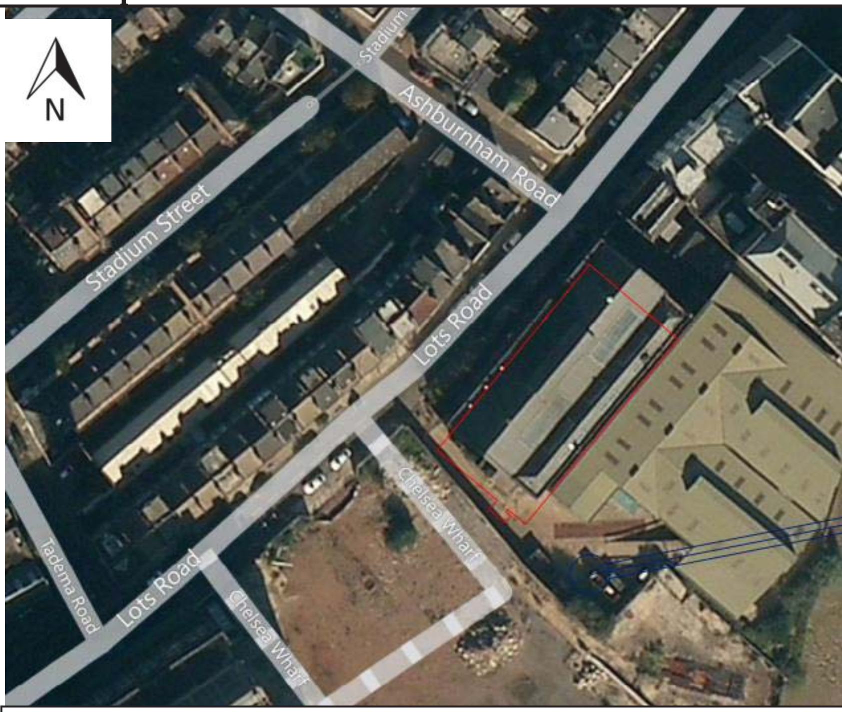
On reflection of the combined score and taking into account the structural and heritage features of the building and its condition, this building will not require further assessment as part of the Damage Assessment process, and will not require mitigation measures.

# Appendix D: Individual building assessment reports for the Royal Borough of Kensington and Chelsea

# Listed building assessment

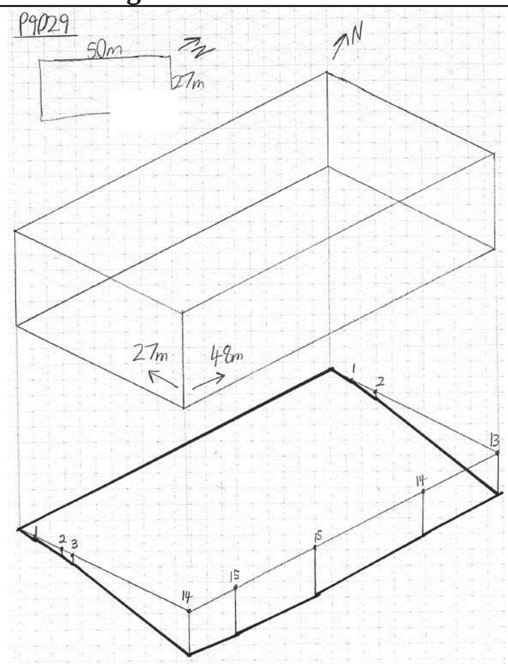
| Building information | |
|---|---|
| **Building reference** | Z9287 |
| **Building name / address** | Lots Road, SW10 0QH |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 26504 77125 |
| **Ground level (mTD)** | +104.9 to +105.5 |

**Location plan**




Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

Built in 1904 by London County Council Works Department, Lot's Road Pumping Station is a storm water pumping station, designed by Chief Engineers Sir Alexander Binnie, then Sir Maurice Fitzmaurice.

The building, which is rectangular in plan, is one tall storey high with a deep basement. The exterior is of red and glazed brick under a slate roof. The main elevation to the north-west has nine bays, the central three projecting, and shows terracotta dressings and plaques, with particularly decorative foliate roundels and lettering reading 'London County Council'. The windows are round arched and set in pairs, with terracotta voussoirs and keystones, and moulded sills. The north-east and south-west elevations have similar decorative details, and feature pedimented gables with oeil-de-boeuf windows; the north-east elevation holds a pair of double doors, and the main elevation also has central double doors. The south-east elevation, which is the rear of the building, is blank and has no decorative features. There is a doorway about half way along this façade. There is a low red brick wall with projecting piers and iron railings set in front of the main façade.

The interior of the building is topped by an iron truss roof, boarded, with glazed sky-lights. The internal walls are of glazed brick with some decorative elements. To the south-east are a number of 1930's offices, mainly of timber construction. There are also fuel and water tanks at ground and mezzanine level. The north-western side of the building holds the plant which includes electricity supply machines, motors, five 1930's combustion engines by Belliss & Morcom, and their gear boxes (by David Brown & Sons (Huddersfield) Ltd), to drive pumps. There are also a number of historic gauges (indicating sewer and tidal levels), signage and a clock.

The basement, which is accessed by stairs, contains pumps and outlet pipes dated 1931 and 1932, and wet wells for water storage.

| Structural description and walkover observations |
| --- |
| The building is of loadbearing masonry with steel/wrought iron roof trusses. The outside face is built from glazed bricks up to the top of the windows and is relatively finely jointed. The rubbed brick arches over the windows are very finely jointed. Inside is generally painted, which makes cracks very visible.<br><br>The building is built over various flood chambers and is therefore generally founded about 10m below ground level. It was only possible to inspect the chamber along the west side of the building. It is understood that water seeps into this chamber at high tide.<br><br>The building is generally in very good condition. The rear (i.e. west) wall, which has no joints and very few openings, has an external vertical crack of approximately 5mm width in the middle, widest towards the top, suggesting the corners of the building have dropped away. This is corroborated by the cracking at the western ends of the north and south walls; in the south wall a diagonal crack of approximately 2 to 3mm is present in the corner pier (visible internally and externally) and also above/between the first and second windows (only visible internally); and in the north wall 3 to 5mm diagonal cracks above the first and second windows (again only visible internally).<br><br>Four pipes approximately 1m in diameter (dated 1934 and assumed cast iron) rise up from the low level sewer, turn and pass horizontally through the western wall of the basement chamber approximately 3m below ground level. |

| | |
| --- | --- |
| **Condition** | Generally good condition, especially along street façade. Minor cracking to the side and rear elevations as noted above. Also some vehicle damage at the north-west and south-west corners dating from use as a civic amenity site. South-west corner has been rendered, possibly hiding more significant damage. |
| **Assumed foundations** | Founded about 10m below ground level on ground bearing footings. |
| **Façade material** | Brickwork. |
| **Internal support system (i.e. superstructure)** | Local brick walls. |
| **Heritage** | The exterior terracotta and glazed brick finishes and decoration; interior plant and features such as gauges, signage etc; assumed to be fragile 1930s pipes in the basement. |

# Building photographs


South-west elevation

Paired window with terracotta dressings

North-east elevation with double doors

Example of basement pipe-work dating from the 1930s

Interior, plant and decorative finishes

## Ground movement analysis

**Tunnel and shaft details**

Cremorne Wharf Tunnel constructed within London Clay Formation.
Sprayed concrete lining – assumed VL = 1.5%.
Tunnel centreline level: +64.5mTD.
Excavated diameter: 4.1m.
Closest shaft: Cremorne Wharf foreshore shaft, located approximately 12m south-east of the building location. Design indicates that associated ground movement is likely to affect the building location.
The Interception Chamber is modelled as a shaft: 10.75m diameter, 105.1mTD surface level and +92mTD base level.
The connection culvert is modelled as a secant piled excavation: Surface level +105.3mTD, 92.5mTD base of excavation and pile tip +88.2mTD.

| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |
|---|---|

**Ground conditions**

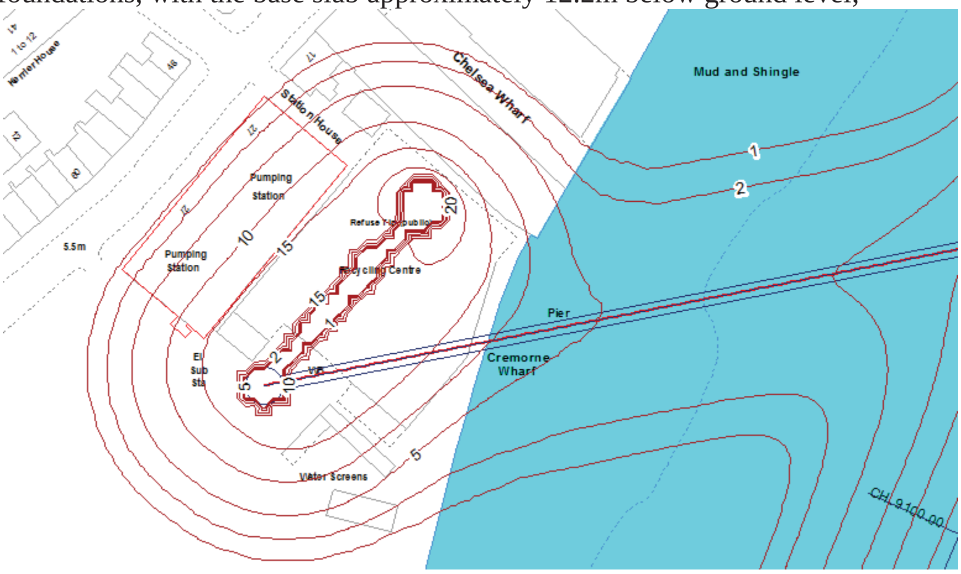
The Cremorne Wharf Tunnel is proposed to be constructed within the London Clay Formation. The expected sequence above the tunnel is summarised below:

Superficial deposits/Made Ground: Ground level +104.9mTD to +105.5mTD.
Top of London Clay Formation: +96.5mTD (32m above tunnel centreline).
Top of Lambeth Group: +59.5mTD

A review of borehole SA1098 (located approximately 30m east) does not indicate any geological features that would require a change in the current ground loss assumptions.

**Results**

Settlement contours have been analysed at +92.8mTD and +96.0mTD to represent a variation in deep basement level above and below the Suction Culvert. Settlement Contours are presented for the deepest basement level +92.8mTD, assuming shallow foundations, with the base slab approximately 12.2m below ground level;




As shown above the building extends from the 15mm contour across the 10mm, 5mm, 2mm and 1mm contours.

Six key façades were selected from the GIS model. They were analysed for a building height of 14.5m, with ground bearing foundations and a 12.2m deep basement (+92.8mTD).

Lots Road was assessed as part of the Site Interface Assessment, the assessment incorporated a secant piled interception chamber and connection adit. FE modelling was adopted for the Cremorne Wharf shaft.

The worst result for the building is within damage category 2, risk of slight damage. A maximum tensile strain of 0.08% and a maximum settlement of 15mm were obtained for the building.

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.
***Building damage score is therefore assessed to be 2.***

## Interpretation of impact

**Structural assessment and discussion**

Calculated differential settlements are concentrated along the short sides of the building. While the differential is small (about 1 in 1000), the movement is likely to be concentrated at the existing cracks, which are likely to enlarge internally and become visible externally. In addition, because of the change in foundation type from mass concrete to brick piers at the S corner of the building, it is likely that most of the building will undergo a rigid body rotation (stiffened by the deep mass concrete foundation) while the very corner of the building (built off the brick piers) will drop away, concentrating damage at the junction between the different foundation types. Careful repairs will be required both internally and externally. Because of the fine pointing of the external elevation, it may not be possible to repair the cracks invisibly. Overall damage is likely to be in the slight to moderate category.
There is unlikely to be any impact on the street elevation, since no differential settlement is predicted at this location.

***The Structural sensitivity score is therefore assessed to be 1.***

**Heritage features sensitivity discussion**

The pumping station was designated as a listed building by English Heritage due to it being '*a high quality example of Edwardian public utility architecture; The earliest and best surviving example of a storm water pumping station by the Metropolitan Board of Works and LCC and the most architecturally decorative and accomplished; A little altered original building but with secondary fixtures, fittings, office accommodation, plant and gauges of 1930's date which are also of interest*'. Damage to the exterior form and decoration therefore will reduce the heritage significance of the building, as will damage to the plant inside the building.

Due to the slight cracking already apparent in the south-west façade, significant movement may cause heritage finishes, including decoration, on this façade to fail. This façade is not as highly decorative as the main north-west façade, but nonetheless contributes to the significance of the building. The pipes and pumps held in the basement of the building are mainly located to the south-east of the building, and may also be very sensitive to large movements.

The south-east façade of the pumping station is subject to the largest settlements from shaft construction; it is likely that the southern corner of the building will settle to a greater extent than the rest of the building, which again raises the risk of sensitive features or items within the building splitting and cracking.

***The Heritage sensitivity score is therefore assessed to be 1.***

**Condition discussion**

The building is generally in good condition, with the decorative details intact and showing no major signs of disrepair. However, there are a number of small cracks evident, particularly to the rear elevation, and along the short sides. Predicted distortions along these short sides are likely to be concentrated at the existing cracks; the combination of the historic distortions, change in foundation type and new distortions means that cracks of about 5-10mm are likely to appear externally

***The Condition sensitivity score is therefore assessed to be 1.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 1 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 1 |
| **Damage category** | 2 |

**Recommendations**

The total score for this building is **5**.

Lots Road Pumping Station is located near to a shaft, the construction of which will generate ground movement that may cause damage to the structural form, heritage finishes and features of the short sides of the building away from the road, particularly the S elevation where there is a change of foundation type, leading to slight to moderate damage. Careful repairs will be required but because of the fine external pointing, the repairs are likely to be visible. Notwithstanding this, mitigation measures are not recommended since (because of the already deep foundation and the change in foundation type) these are likely to cause as much if not more damage than the ground movement.

# Appendix E: Individual building assessment reports for the City of London

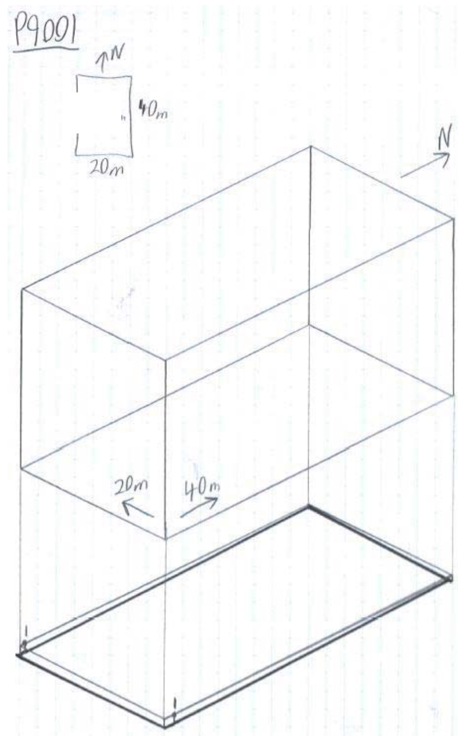
# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | P9001 |
| **Building name / address** | Hamilton House, EC4Y 0NJ |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 31371 80859 |
| **Ground level (mTD)** | +104.1 to +104.6 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing)**

Hamilton House, which dates from 1889, is a Portland stone faced commercial building with a five bay, four storey main elevation to Victoria Embankment, and an eight bay return to Temple Avenue. The exterior is ornamented, with the main elevation having a central doorway flanked by columns and surmounted by a segmental pediment. Windows to the ground floor are paired timber sashes. To the first and second floors, the central three bays are recessed with giant columns between, and the flanking bays have shallow bays with oriel windows. Above this is a whole-storey width band of yellow sandstone, with foliate carved decoration between small, paired casement windows in stone surrounds. Above are gabled dormers to the slate roof. There are cornices above the ground, second and third floors, and small balconies with stone balustrades flanking the pediment of the entrance.

The return to Temple Avenue has a similar form, but is less decorative. There is a secondary entrance to bays six and seven (from the south), flanked by pilasters and topped with a segmental pediment. Bays four to seven are set back, and the windows are within recesses. The date '1899' appears above cornice level to the southern end of this elevation.

Internally, the building has been heavily modernised to provide office accommodation, and many heritage features are hidden. The main entrance hall has decorative plasterwork, and is surrounded by plaster columns. The other principal room, known as the Hamilton Suite, is on the first floor, and again has fine plasterwork to the ceiling, coving, and timber dado panelling and fire surround. Egg and dart coving is visible where false-ceiling tiles have been removed in some areas to the ground and first floors. There are two cantilevered stairs, the principal having a modern lift shaft within its well. This stair has a mixture of cast iron and timber banisters, with timber handrails. The secondary stair has a decorative banister and timber handrail. The basement of this building has a number of small store rooms where corbelled footings are visible, and a larger space with concrete columns. Of interest here are areas of timber panelling, in very poor condition, with scroll details.

| Structural description and walkover observations |
|---|
| The main building comprises six storeys including a lower ground floor. In addition, part of the roof space is used as extra offices and there is a basement.<br><br>The external walls of the building are of loadbearing masonry; the internal walls are a mixture of load-bearing masonry and non-loadbearing partitions. Some minor cracking was observed in external brickwork visible at roof level. The internal structure is hidden by finishes but masonry piers in internal walls are visible; these may however conceal iron columns. From the basement four concrete columns (which may in fact be iron columns which have been encased in concrete) were seen supporting the ground floor lobby floor, and modern steel members had been added to provide support to the lower ground floor joists.<br><br>Floor structure was generally hidden as suspended ceilings were installed throughout, with the ceilings above these plastered (with hairline cracking in some places concealed by the false ceiling). In the basement, the lower ground floor above was seen to be of modern timber construction. On the fourth floor the floor above could be seen to be clay pot flooring. It is likely that other floors are of clay pot or filler joist construction. Towards the front of the building, larger open spaces are created by beams hidden in the ceiling plasterwork, which are presumed to be made of iron and spanning between masonry piers between windows and inside the building.<br><br>The walls and columns were seen to stand on corbelled footings suggesting shallow foundations beneath the basement.<br><br>Two cantilevered stone (or unreinforced concrete) staircases were seen extending between the lower ground and fourth floors. Both appeared in good condition although the main staircase (curved in plan) appeared to have a crack to the plaster on the underside at second floor level. The other, used as a fire escape stair, has possibly had reinforcement since construction as to every other flight of treads appeared thickened.<br><br>A timber staircase led from the fourth to fifth floors and a stone staircase led down into the basement.<br><br>The roof is pitched and made of slate with lead flashings to dormer windows; it is generally in fair condition with the occasional slate tile missing. |

| | |
|---|---|
| **Condition** | Good. |
| **Assumed foundations** | Assumed to be shallow ground-bearing strips below basement. |
| **Façade material** | Load-bearing masonry (stone). |
| **Internal support system (i.e. superstructure)** | Load-bearing masonry walls, possibly with iron columns. Floors of timber, clay pot, possibly filler joist. Cantilevered stone staircases. |
| **Heritage** | External decorative stonework; internal decorative plasterwork to principal rooms including egg-and-dart coving in most ground and first floor rooms; fireplaces, panelling, timber floors; cantilevered stairs; timber panelling with scroll details in basement. |

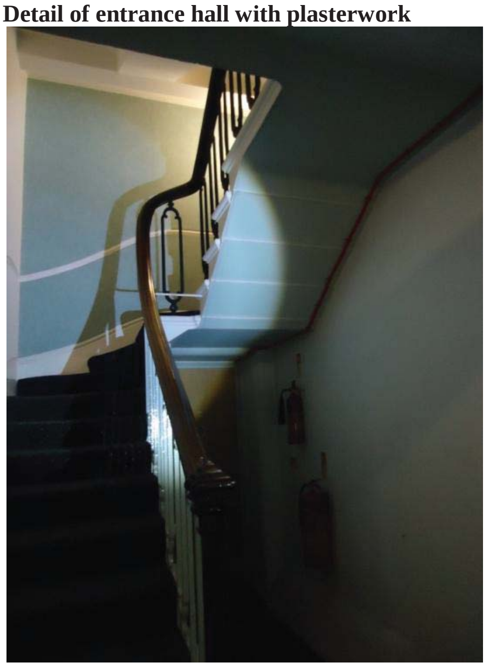
## Building photographs

Front (south) elevation to Victoria Embankment

East elevation to Temple Avenue

Detail of entrance hall with plasterwork

'Hamilton Suite' – principal room with fine plasterwork, fireplace and panelling



Secondary cantilevered stair

Example of timber panelling with scroll detail in basement

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Lambeth Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +55.2mTD.
Excavated diameter: 8.8m.
Closest shaft: Blackfriars Bridge foreshore shaft, located approximately 70m south-east – design indicates the shaft may have some negligible impact on ground movement at the building location.

| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |
|---|---|

**Ground conditions**

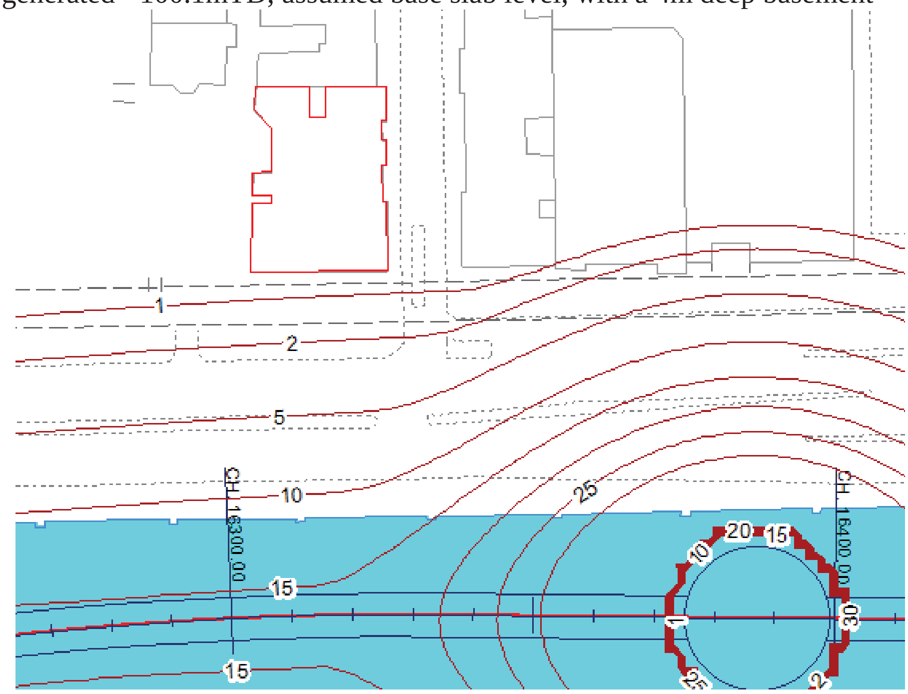
The Thames Tunnel is proposed to be constructed within the Lambeth Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +104.1mTD to +104.6mTD.
Top of London Clay Formation: +92.5mTD.
Top of Lambeth Group: +65.5mTD (10.3m above proposed tunnel centreline level).

Review of boreholes SR1058 and PR1060 (located approximately 240m north-east and 225m west respectively) and BGS boreholes TQ38SW2296 and TQ38SW2880 (located approximately 190m east and 180m north-east respectively) does not indicate any geological features, such as scour that would require a change in the current ground loss assumptions. However borehole PR1060 does note several zones of core loss within the Lambeth Group, including a 1m section due to 'blowing sands'.

**Results**

Settlement contours generated +100.1mTD, assumed base slab level, with a 4m deep basement




As shown above the building lies outside of the 1mm settlement contour.

Two key façades were selected for the building from the GIS model. Analysis was carried out for a 15m high structure, with shallow foundations and a basement (foundations assumed to be 4m bgl).

The results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.004% and a maximum settlement of 0.7mm were obtained for the building.

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.
***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The calculated movements, which are virtually zero, are anticipated to be of no significance to the structure.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

Hamilton House has particular heritage features which may be sensitive to large movements and settlement. These include cantilevered stairs, the exterior stonework, and internal plaster and timber finishes.

The calculated settlement and strain for this building is very small, as the building sits just outside the 1mm contour. It is unlikely that any of the heritage features will be sensitive to this level of movement.

***Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

This building is in good condition. The current condition will create no additional sensitivity for the building to the calculated settlement.

***Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

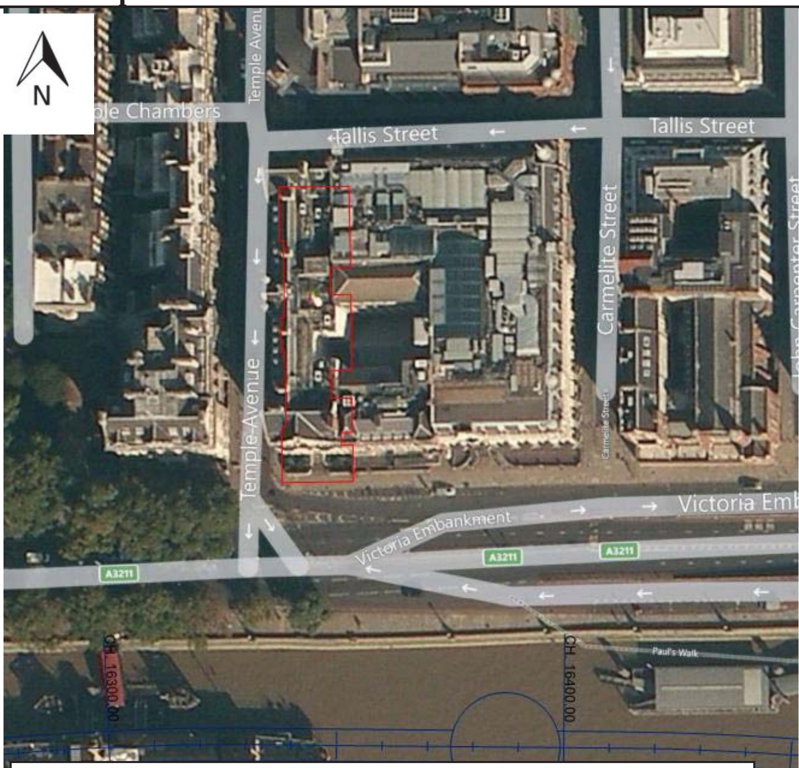
The total score for this building is 0.

The structure and heritage features of Hamilton House are not sensitive to the levels of settlement and strain calculated, and therefore the building will not be taken forward for further damage assessment and will not require mitigation.

# Listed building assessment

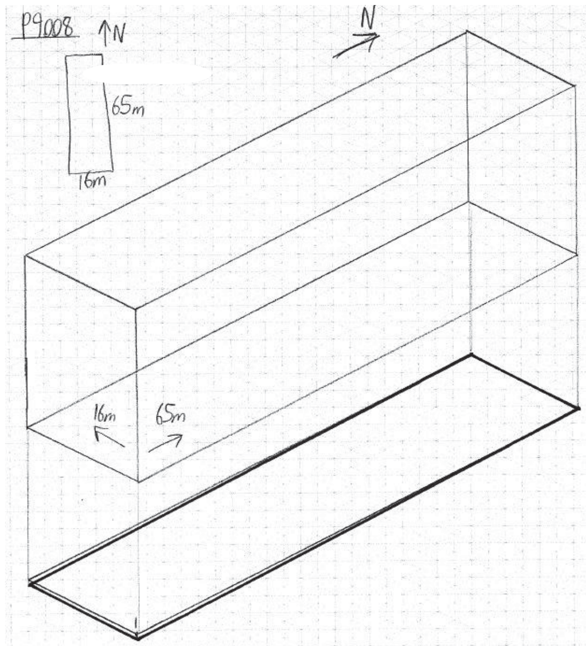
| Building information | |
|---|---|
| **Building reference** | P9008 |
| **Building name / address** | Telephone House, EC4Y 0BA |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 31400 80879 |
| **Ground level (mTD)** | +104.6 to +105.5 |

**Location plan**




Satellite imagery does not align perfectly with GIS mapping – refer to page 5 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

Telephone House is a Grade II listed building, dating from around 1900 and designed by A.N. Bromley. The building is in the Classical style; with a stone façade, and slate roof above with cupolas. There are four storeys plus an attic, lower ground level and basement, with twenty one bays to Temple Avenue and shorted returns to Tallis Street and Victoria Embankment of three bays.

The façade has classical detailing throughout, with the round-arched window surrounds having keystone details; those to the ground floor with voussoirs, and those to the upper floors having architraves with pilaster and column details. The elevation to Victoria Embankment has a flat central bay with the flanking bays having convex bay windows above the ground floor. The main elevation to Temple Avenue has a central grand entrance, including giant order columns to a broken pediment above the third floor, and rising again to an arch above which is a pediment. Above the second floor to the fourteen inner bays are cherub sculptures, including telephone motifs. The three outer bays at each end of this long elevation are set forward, and are detailed with quoins; at their top are gable ends with small windows.

Internally, entrance is to a grand hall with marble columns, backed by the principal cantilevered stair, which is partially obscured by a large modern light fitting. The basement of the building is brick throughout, with cast iron columns and concrete floors, and extensive vaulting under the pavement to the west end. The sub-basement has been modernised but retains some simple coving.

The ground, first and second floors have also been modernised for their current office use, but retain many features of interest. Of note are the parquet floors, 'TN' (Telephone Network) lettered tiled fireplaces, egg and dart coving to principal rooms, and panelling to some rooms. There are two secondary cantilevered stone stairs to the south and north ends of the building. At the northern end of the ground floor, is a garage area with full height doors, which retains an internal cast iron framed ‘stable’ area.

**Structural description and walkover observations**

The building comprises four storeys plus lower ground floor and basement.

Storey heights decrease up the building by approximately 0.5m per storey, consistent with the importance of the accommodation.

The exterior is clad with Portland stone. There is a tower on the roof at the south west corner, with a statue above (relating to the original use of the building).

The façade is relatively imperforate and there is massive masonry (brickwork) in the basement. Suspended ceilings conceal the structure in many areas but in some rooms downstand beams are seen. It is likely that the external walls are load bearing masonry with walls and columns internally i.e. part framed.

Externally the building appears to be in good condition. There is an internal lightwell with (generally) glazed bricks. Some signs of staining and past repairs, but overall this was felt to be in reasonable condition.

Internally the condition is also good. A small amount of minor cracking was seen, and there has been some water damage at fourth floor on the south end, but this is not extensive.

Cast iron columns are exposed internally, at all levels at the north end (two tapered columns) and at lower levels in the corridor to the south. The building has been extensively modernised at the upper floors, with modern partitions and ceilings inserted on the west side of the principal corridor. The work has been done to a reasonable standard and the finishes are in good condition.

There are concrete floors in all areas of the superstructure, some with raised floors installed above. It is not known if the floors are part of the original construction, as seen in one limited area in the basement.

The basement is relatively deep. There are lightwells to the south (Victoria Embankment) and west (Temple Avenue). Vaults extend out beyond the main lightwell perimeter. These are most extensive on the south side, with curved ends on plan. Masonry ‘braces’ extend from the building face to the edge of the vaults.

The basement extends below the full footprint. The vertical structure is very massive, with major piers and thick walls, all of masonry. A filler joist floor over was partially exposed in one limited area. Some alterations have taken place, with blockwork infills in some locations. There are repeat features of large circular openings and recesses at this level, but there is no definitive explanation as to their origin.

Foundations are of corbelled brickwork with corbelling exposed above the slab. There may be concrete below the masonry at formation.

The lower ground floor has a split tenancy; the south end is currently vacant and has been newly decorated to a high standard. The north half is in use in conjunction with the upper floors, there are no features of particular note and all seemed to be in good condition.

There are three cantilever stairs – to  the north the ‘back stair’ is of traditional Yorkstone construction, with plain profile and a robust and well secured handrail There are twin steel joists under the landings (floor level only, stair continuous between floors).

To the south the staircase is slightly more ambitious. Again the balusters are robust and well fixed. Perhaps reflecting the increase in storey height towards the ground floor there are joists installed from second floor downwards on the flight down from floor level and cranked under the half-landing.

The larger central stair curves round an oval well. A number of partially open joints were identified at various levels. The wedge of stone around the upright at the edge of the landing closest to the stair flight has broken away and been replaced on most levels; it has broken out again at one level.

It is recommended that the stone is properly repaired and any open joints are grouted up using appropriate specialists.

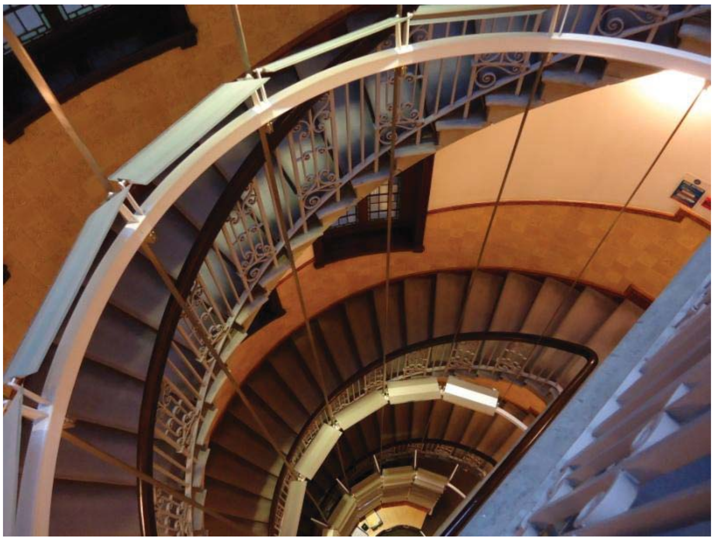
| | |
|---|---|
| **Condition** | Good. |
| **Assumed foundations** | Shallow ground bearing strips and pads of corbelled brickwork, possibly on concrete. |
| **Façade material** | Stone faced brickwork. |
| **Internal support system (i.e. superstructure)** | Loadbearing masonry and cast iron columns. |
| **Heritage** | Exterior stonework including cornices, sculptures and window and door surrounds; interior cantilevered stairs; 'TN' lettered tiled fireplaces; surviving timber work including doorcases, fireplaces, floors and panelling; cast iron columns throughout; decorative egg-and-dart plaster coving and cornices. |

## Building photographs

Southern elevation

Western elevation to Temple Avenue, with elevation to Tallis Street showing on the left

Internal cast iron column in basement – the pattern of columns is repeated throughout the building



Principal cantilevered stair

Principal board room, with panelling, egg-and-dart coving, and fireplace

Example of a 'TN' lettered tiled fireplace, found in many of the non-principal rooms to all floors

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Lambeth Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +55.1mTD.
Excavated diameter: 8.8m.
Closest shaft: Blackfriars Bridge foreshore shaft, located approximately 55m south-east – design indicates the shaft may have some minor impact on ground movement at the building location.

| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |
|---|---|

**Ground conditions**

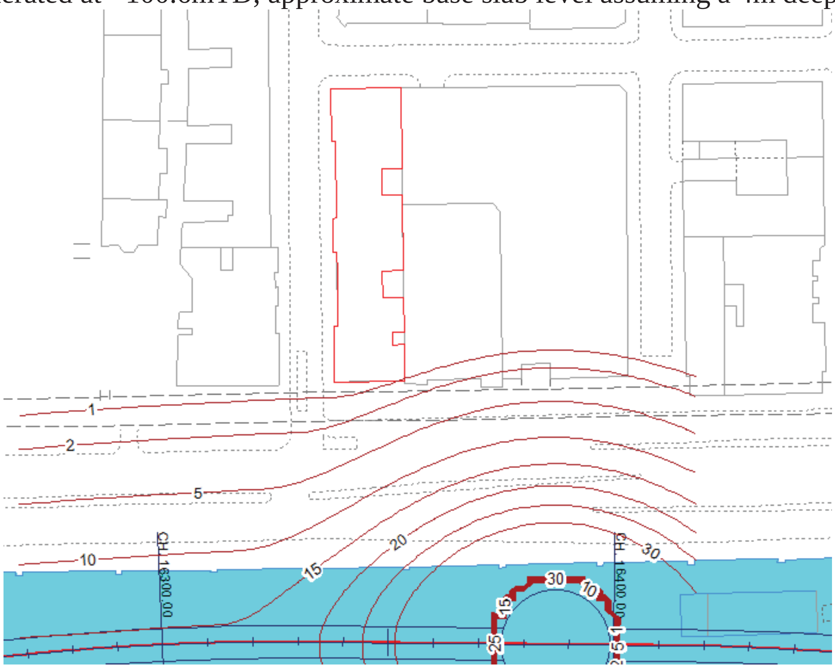
Thames Tunnel proposed to be constructed within the Lambeth Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +104.6mTD to +105.5mTD.
Top of London Clay Formation: +93.0mTD.
Top of Lambeth Group: +66.0mTD (10.9m above the proposed tunnel centreline level).
Top of Thanet Sand Formation: +49.0mTD.

Review of borehole SR1058 and PR1060 (located approximately 210m east-north-east and 260m west respectively) and BGS boreholes TQ38SW2296 and TQ38SW2880 (located approximately 160m east and 150m east respectively) does not indicate any geological features, such as scour that would require a change in the current ground loss assumptions. However borehole PR1060 does note several zones of core loss within the Lambeth Group, including a 1m section due to ‘blowing sands’.

**Results**

Settlement contours generated at +100.6mTD, approximate base slab level assuming a 4m deep basement;




As shown above the building sits just touches the 1mm ground settlement contour that has been generated.

Three key façades selected from the GIS model were analysed. The building was modelled at a height of 18m, on shallow foundations, with a basement (foundations at 4m bgl).

The results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.009% and a maximum settlement of 1mm was generated for the structure.

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero***

## Interpretation of impact

**Structural assessment and discussion**

The building is of massive construction (it was reported that the basement was used as a shelter during WW2) and in generally good condition both internally and externally. The calculated movements and corresponding strains are of a value which is comparable with seasonal variation and are not anticipated to have any impact on the structure.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

Telephone House has particular heritage features, which may be sensitive to large movements and settlement. The cantilevered stairs are fragile and show some defects. Other sensitive features include the exterior stonework which is ornate and tightly jointed, and internal plaster and timber.

The calculated settlement and strain for this building is very small, as the building sits just outside the 1mm contour. It is unlikely that any of the heritage features will be sensitive to this level of movement.

***Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

This building is in good condition. The current condition will create no additional sensitivity for the building to the calculated settlement.

***Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 0.

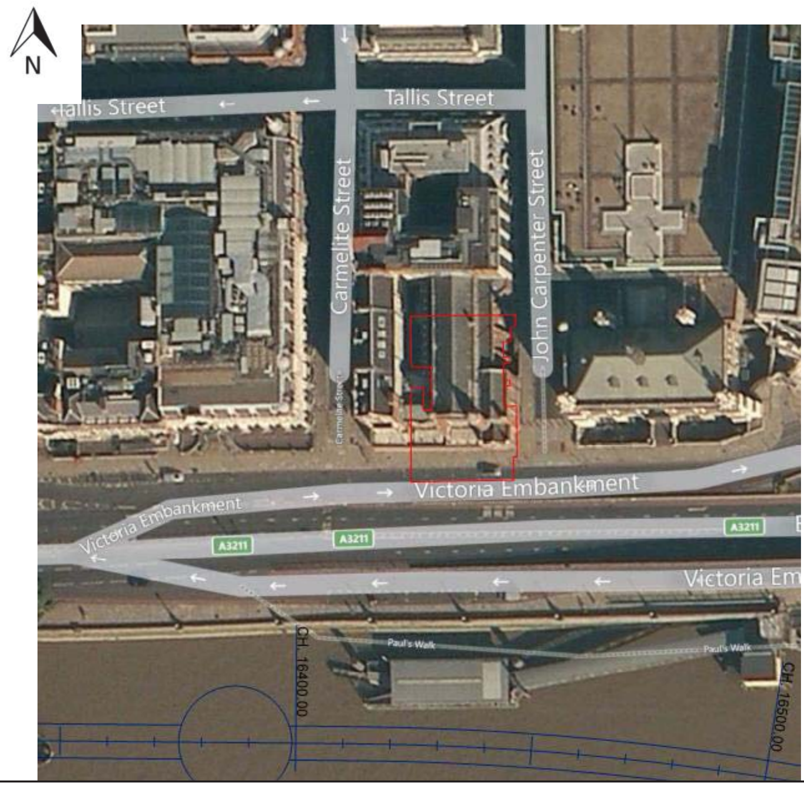
The heritage features of Telephone are not sensitive to the calculated levels of settlement and strain, and the building is in good condition. The cantilevered stairs are sensitive structural elements; however, the movements anticipated are so low that they are unlikely to be damaged in any way. Therefore the building will not be taken forward for further damage assessment and will not require mitigation.

It is recommended as a matter general building maintenance that the stone stair is properly repaired and any open joints are grouted up using appropriate specialists.

# Listed building assessment

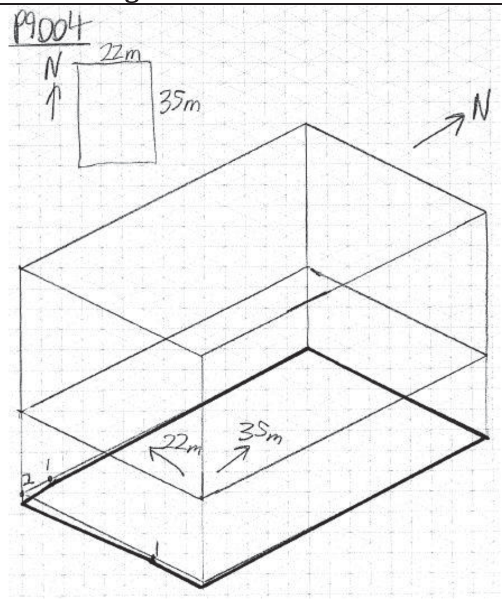
| Building information | |
|---|---|
| **Building reference** | Z0736 |
| **Building name / address** | Sion House, EC4Y 0DZ |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 31493 80858 |
| **Ground level (mTD)** | +105.2 to +105.7 |

**Location plan**




Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

Sion House is a Grade II listed former college building in Tudor Gothic style located at the junction of the Victoria Embankment and John Carpenter Street. Designed by Sir Arthur Blomfield and built in 1886, it is faced in red brick with stone dressings. There is a single storey extension from 1965 to 1966 which overlaps the return of 9 Carmelite Street at ground floor level; this extension is composed of vertically set windows in narrow recesses set in a brick façade under a flat slab roof.

Externally, Sion House is composed of irregular storeys and fenestration. The majority of windows on the John Carpenter Street façade are grouped cusped openings with stone mullions and dressings. The rear façade, not visible to the street, is filled with simpler window forms. The façade facing onto the Victoria Embankment is dominated by a double-height, stained glass window, surmounted by a cusped balustrade, behind which is a diaper patterned pediment. There is a buttress to the left which finishes in an octagonal section surmounted by a domed roof. To the right of the window is an octagonal stair tower with simple slit windows, which terminates in a traceried belvedere with a steeply pitched roof. The majority of original external features remain including stone grotesques and armorial devices and blind tracery spandrels with carved shields and the wrought iron rails surrounding basement lightwells to John Carpenter Street.

Internally, the entrance off John Carpenter Street leads into the extension, the rear of which shows the original ground floor façade of Sion House. Stairs lead down to a basement with some vaulting, containing plant and office accommodation. Off the extension, one door leads into a rear portion of the building which contains office accommodation with some panelling and plasterwork, and another at the John Carpenter Street end leads to the main hall, which holds the principal stair. This is an impressive cantilevered stone stair with timber banisters, newels and finials. Off the hall is the centerpiece of the building, the former library which is a double height vaulted space with a decorative wood ceiling supported by hammerbeams and is surrounded by an balcony with an undulating rail, with library booths off this. The railings to the balcony and the timber stairs, which lead from the balcony, are wrought iron with timber handrails. There is access from the balcony to a stone stair leading through the corner tower, which gives access behind the parapets at roof level. In the southern end wall is a double-height, five light traceried window with original stained and painted glass. Beyond this hall and accessed via a small corridor with an excellent stained glass screen are two further offices with cornices and large fireplaces with decorative surrounds. The remainder of the building is given over to office accommodation, and the rooms retain panelling, plaster mouldings, coffered wood ceilings and stone doorcases.

**Structural description and walkover observations**

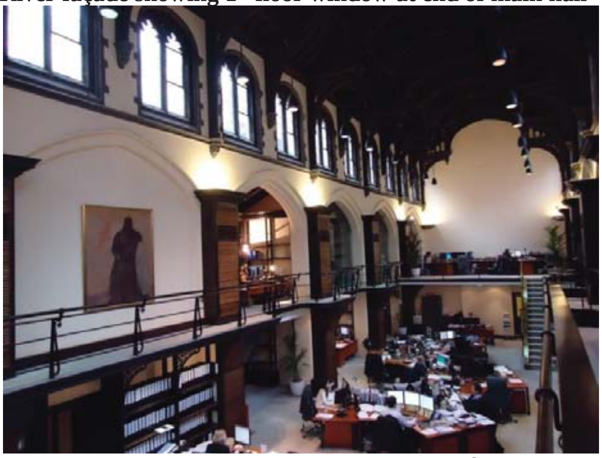
The building is of loadbearing brickwork, with internal and external stone mouldings. The interior walls are often pierced by loadbearing arches. Floor construction is not known but given the date is likely to be mainly timber with wrought iron beams supporting some of the longer spans over the large ground floor rooms. The roof trusses over the main hall are timber. There is a modern single storey extension along the river frontage. The inside of the building is mainly plastered and occasionally timber panelled.

| | |
|---|---|
| **Condition** | Internal – excellent; recently decorated.<br>External – no obvious signs of cracking, however the brick and stone are heavily weathered and locally spalling; large areas have been replaced. |
| **Assumed foundations** | The building is likely to be founded on shallow foundations, probably strip footings under the walls. There is a single level of basement; we are told that this extends under the John Carpenter St pavement, although this was not accessible. There is a large sump in the basement under the modern river frontage extension; at the time of our visit this was nearly full. |
| **Façade material** | Brick with stone dressings. |
| **Internal support system (i.e. superstructure)** | See above. |
| **Heritage** | External stone decorative dressings and general turreted and traceried form; internal former library and other principal rooms; throughout there are stained glass, timber ceilings, stone doorcases, plasterwork; fine main cantilevered stair. |

## Building photographs

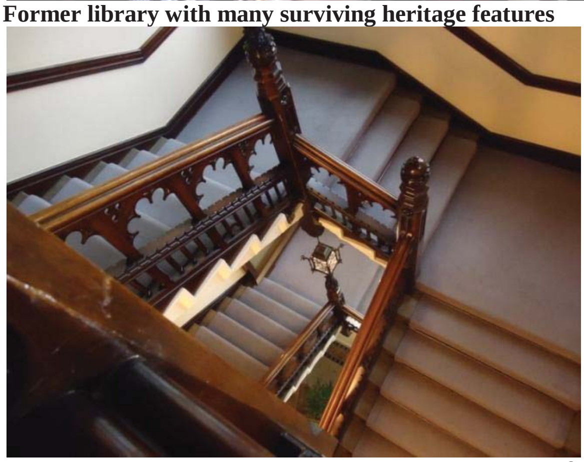
River façade showing 1st floor window at end of main hall


External railings to lightwells



Former library with many surviving heritage features

Example of high quality stained glass



Principal stair, cantilevered with timber banisters and finials

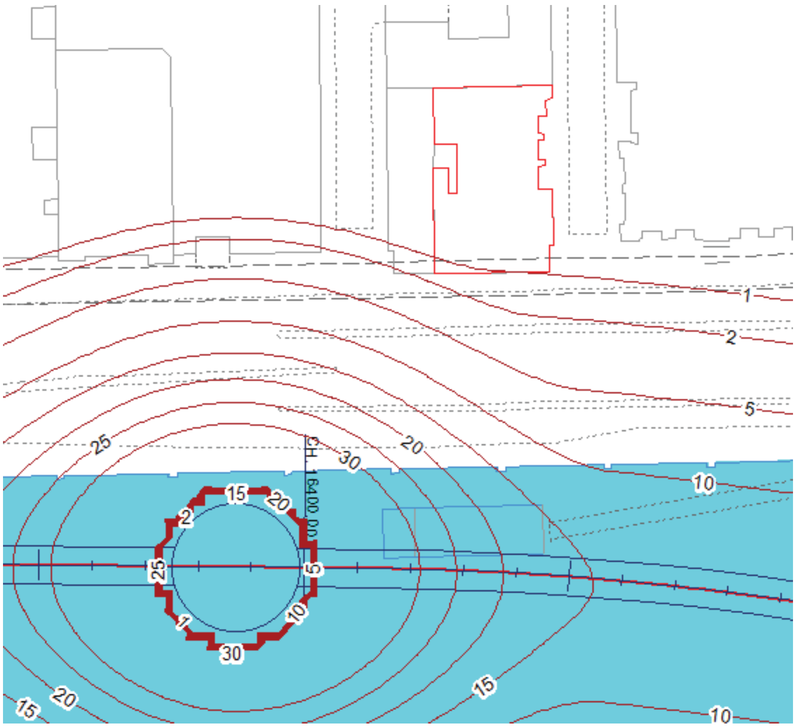
Timber screen with fine stained glass, delicately jointed

Stone stair within corner tower

Example of timber ceiling and other decorative features

| Ground movement analysis | |
|---|---|
| **Tunnel and shaft details** | |
| Thames Tunnel constructed within the Lambeth Group<br>Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%<br>Tunnel centreline level: +54.9mTD<br>Excavated diameter 8.8m<br>Closest Shaft: Blackfriars Bridge Foreshore shaft, located approximately 55m south-west of the building. Design indicates that the building is outside of the zone of significant settlement induced by the shaft. | |
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |
| **Ground conditions** | |
| The Thames Tunnel is proposed to be constructed within the Lambeth Group. The expected sequence above the tunnel is summarised below;<br><br>Superficial deposits/Made Ground: Ground level +105.2mTD to +105.7mTD.<br>Top of London Clay Formation: +94mTD.<br>Top of Lambeth Group: +66mTD (11.1m above tunnel centreline).<br>Top of Thanet Sand Formation: +51mTD.<br><br>A review of boreholes PR1060 and SR1058 (located approximately 345m west and 130m north-east respectively) and BGS boreholes TQ38SW2296 and TQ38SW2880 (located approximately 70m east and 65m north-east respectively) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions. However borehole PR1060 does note several areas of core loss through the Lambeth Group, including a 1m section due to 'blowing sand'. | |
| **Results** | |

Settlement contours generated +104.2mTD, base slab level assumed to be1m below ground level;




As shown in the extract above the building is located just within the 1mm settlement contour modelled for the tunnel.

Two key façades were selected from the GIS model. These were analysed for building heights of 10 and 19m. Foundations were assumed to be shallow, and the building was modelled with and without a basement (foundations at 4m bgl and 1m bgl respectively).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.008% and a maximum settlement of 1.5mm were obtained for the building façades, when modelled as a 10m structure, without a basement (foundations at 1m bgl).

Interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The south west corner of the building is predicted to lie just inside the 1mm contour line. The movements are very small and as such damage due to settlement is expected to be negligible.

***The Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

Sion House has particular heritage features, which may be sensitive to large movements and settlements. The cantilevered stair may be sensitive to movement, and the stained glass could be of concern as it is very finely jointed and susceptible to very small movements.

The predicted movement and strain for this building is very small, as the building sits just outside the 1mm settlement contour. Therefore it is unlikely that any of the heritage features will be sensitive to this level of movement, which is too minor to affect even the stained glass. We were also advised that some of the secondary glazing was loose and might need to be removed before the works, however in view of the small predicted movements this is not considered necessary.

***The Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

This building is in good condition and is very well maintained. The current condition will create no additional sensitivity for the building to the predicted settlement.

***The Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 0.

The structure and heritage features of Sion House are not sensitive to the levels of ground movement and strain predicted, and therefore the building will not be taken forward for further damage assessment and will not require mitigation.

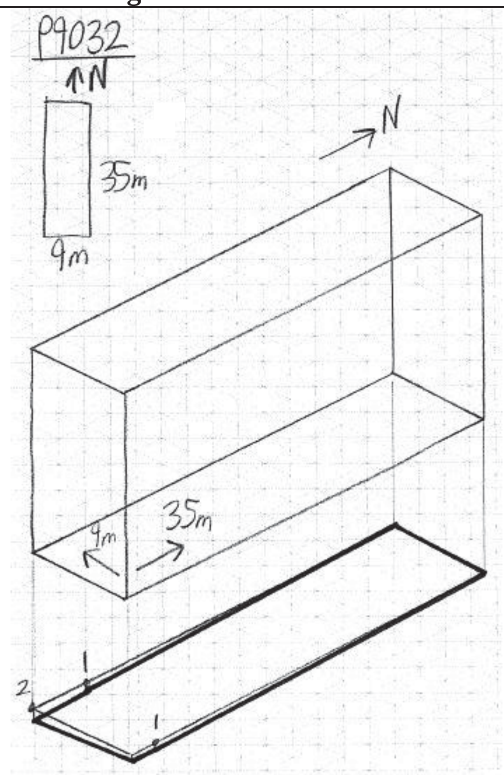
# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z0742 |
| **Building name / address** | 9 Carmelite Street, EC4Y 0DR |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 31476 80858 |
| **Ground level (mTD)** | +104.9 to +105.3 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

9 Carmelite Street is a Grade II listed office block, located in the City of London at the junction of Carmelite Street and the Victoria Embankment. Dating from 1893 to 1894 and designed by H A Hunt and H T Steward (architects & surveyors) for the Board of Conservators of the River Thames, it was built by George Trollope & Sons.

The building is of red brick in Tudor Gothic style with stone dressings, which include stone window surrounds and mullions, door surround and drip caps. The 5 storeys plus basement are surmounted by a slate roof with tall chimney stacks. The building has seven bays along the Carmelite Street façade with a single bay return to the Victoria Embankment. The ground floor of this return is obscured by an extension to Sion College next door.

The central Gothic entrance is a highly-moulded ogee arch displaying finely-carved stone insets including grotesque masks and armorial devices with double panelled doors, half glazed with tracery and traceried fanlights. To the left there is a wide elliptical arch above the basement entrance with a fine wrought iron screen, and gate of quatrefoil design. The majority of the windows are square-headed but some are pointed-arched and others are cusped. All have hoodmoulds in stone. The end bays are slightly projecting with the right hand bay being somewhat more enriched including double height 3-light traceried windows with enriched lintels through the first and second floors and a cartouche dated 1893 between the fourth floor segmental arched windows. The gabled return to the Victoria Embankment displays a beautiful double height five-light traceried oriel window with an enriched lintel. Both the main façade and the return are surmounted by a brick parapet with finials over the main entrance and on the gable peak of the return.

The interior is largely unchanged, with the main alteration being the conversion of the library, originally a double height space, into two single height spaces. Many of the original features remain including the main staircase,

| |
|---|
| windows, window and door surrounds, some with grotesques and other decoration, timber panel doors, fireplaces and many cornices. There are also some very impressive original decorative plaster ceilings in some of the principal rooms which have been very well maintained; the best of these is in the upper library. For the most part, the plan form is largely unchanged. The main staircase is an attractive stone cantilevered staircase with carved wood balustrade, handrails and suspended finials; additional support has been added, but this is unobtrusive. Vaulted plaster ceilings in the entrance and stairhall are supported by marble columns with stone bases and capitals. There are several spaces that retain their original linen-fold wood panelling. There is a basement, reached by stone steps, which is utilitarian, finished for the most part in white glazed 'hygienic' brick. Vaults stretch under the pavement to Carmelite Street, and extend under the Victoria Embankment pavement. |
| **Structural description and walkover observations** |
| The building is of loadbearing masonry; floor construction is not known but is assumed to be generally timber, with stone floors at ground floor level and stone cantilever stairs and landings. |

| | |
|---|---|
| **Condition** | Good. Recent steelwork has been added to stiffen the stone cantilever stairs and handrails. |
| **Assumed foundations** | There is a single level of basement. All walls are assumed to be founded on shallow strip footings. |
| **Façade material** | Brick with stone dressings |
| **Internal support system (i.e. superstructure)** | Loadbearing masonry, including some loadbearing arches at ground floor. |
| **Heritage** | Good quality Tudor-Gothic façades with prominent oriel window to the southern elevation; interior original features including panelling, cornices, and excellent plasterwork especially to the library at the southern end of the building; good quality cantilevered stone stair. |

## Building photographs

Façade to Carmelite Street

Decorative timber doorcase

Cantilevered stair showing later supports

Decorative plaster to walls and ceiling of the library

Interior of principal room, showing stone window surrounds and decorative plasterwork

Detail of southern oriel window

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Lambeth Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +54.9mTD.
Excavated diameter: 8.8m.
Closest shaft: Blackfriars Bridge Foreshore Shaft, located approximately 50m to the south-west. Design indicates that the building location may experience some minor impact.

| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |
|---|---|

**Ground conditions**

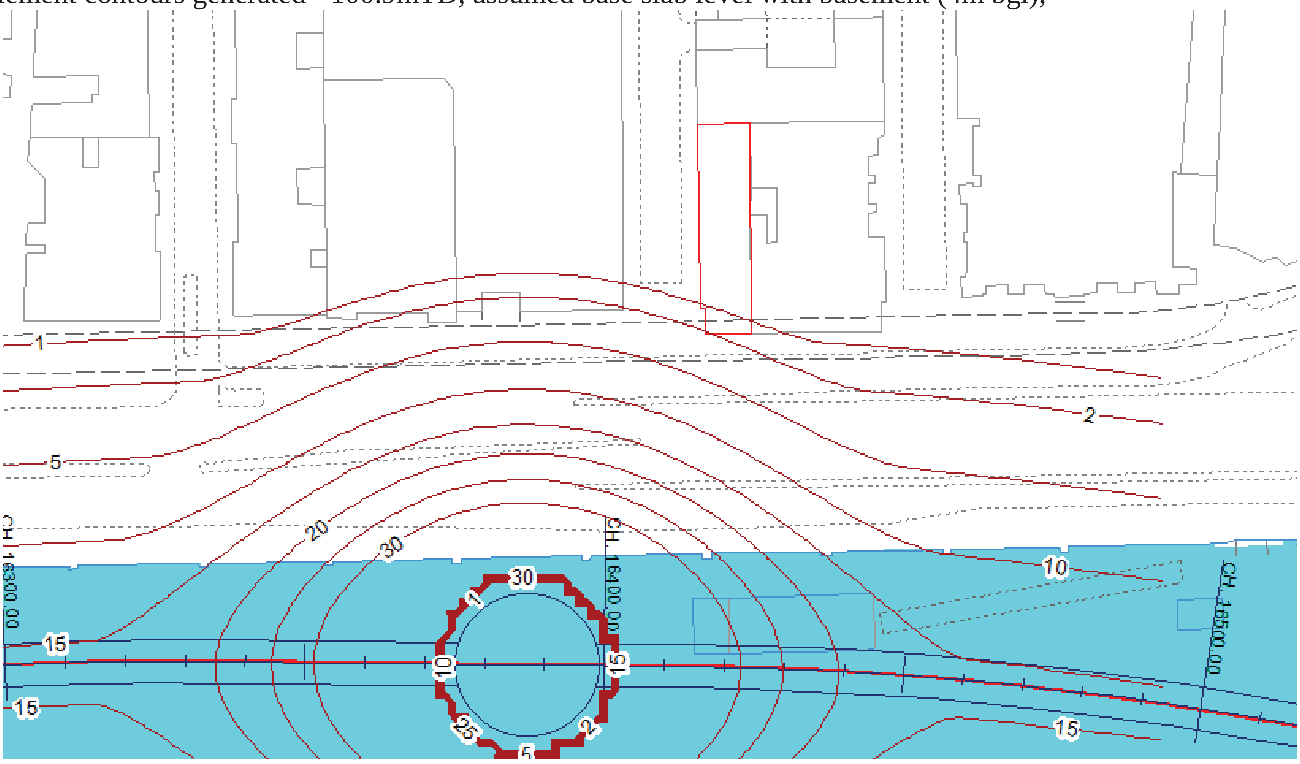
The Thames Tunnel is proposed to be constructed within the Lambeth Group. The expected sequence above the tunnel is summarised below:

Superficial deposits/Made Ground: Ground level +104.9mTD to +105.3mTD.
Top of London Clay Formation: +94.0mTD.
Top of Lambeth Group: +66.0mTD (11.1m above tunnel centreline).
Top of Thanet Sand Formation: +51.0mTD.

A review of boreholes SR1058 and PR1060 (located approximately 150m north-east and 340m west respectively) and BGS boreholes TQ38SW2296 and TQ38SW2880 (located approximately 90m east and 85m north east respectively) does not indicate any geological features that would require a change in the current ground loss assumptions. However borehole PR1060 does note several zones of core loss within the Lambeth Group, including a 1m section due to 'blowing sands'.

**Results**

Settlement contours generated +100.9mTD, assumed base slab level with basement (4m bgl);




As shown above the building sits outside the 1mm settlement contour generated for the tunnel.

Three key façades were selected from the GIS model. Analysis assumed a building height of either 16 or 20m. Foundations were assumed to be shallow and modelling was carried out with a basement (foundations 4m bgl).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.02% and a maximum settlement of 2mm were obtained for the building (settlement remained the same for both models, maximum tensile strain slightly higher for a 16m high structure).

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The south end of the building is shown to be just inside the 2mm contour line and as such it is expected to experience little to no damage due to ground movement (likely to be below seasonal movement).

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

9 Carmelite Street has particular heritage features which may be sensitive to large movements and settlement. The cantilevered stair, although now strengthened, is fragile, as it the plasterwork throughout the building, particularly that to the library.

The calculated settlement and strain for this building is very small, as the building sits just outside the 1mm contour. It is unlikely that any of the heritage features will be sensitive to this level of movement.

***Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

This building is in good condition, having been entirely refurbished, in a sensitive manner, by the current owners. The current condition will create no additional sensitivity for the building to the calculated settlement.

***Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 0.

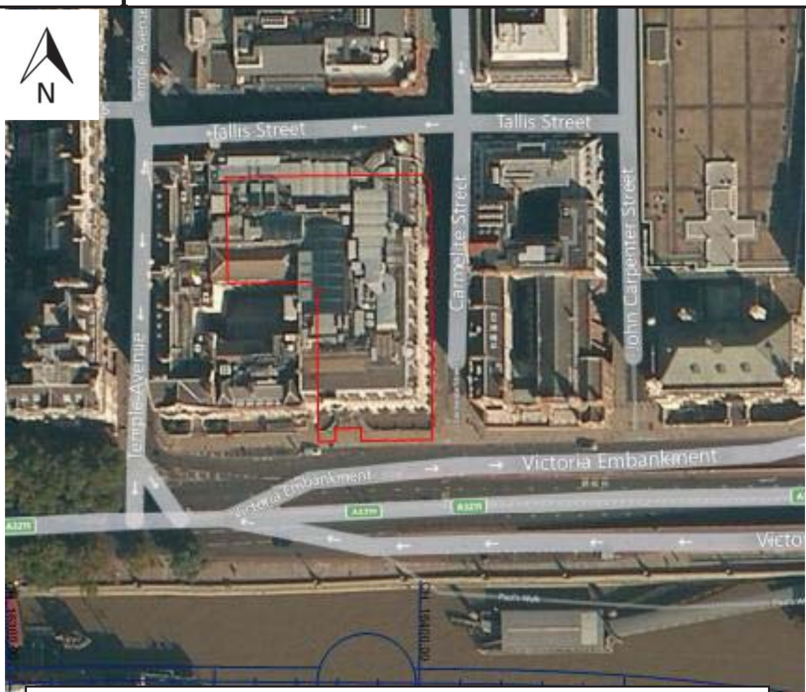
The structure and heritage features of 9 Carmelite are not sensitive to the levels of settlement and strain calculated, and therefore the building will not be taken forward for further damage assessment and will not require mitigation.

# Listed building assessment

## Building information

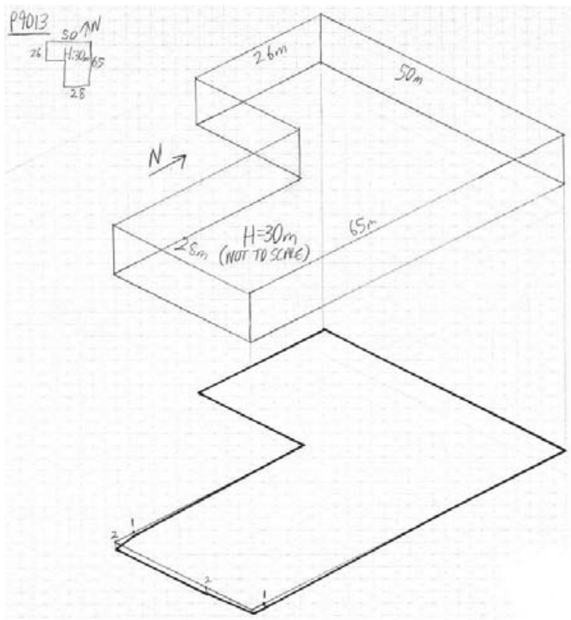
| | |
|---|---|
| **Building reference** | Z0743 |
| **Building name / address** | Carmelite House, EC4Y 0LS |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 31440 80894 |
| **Ground level (mTD)** | +104.7 to +105.1 |

**Location plan**




Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

Carmelite House is a Grade II listed building located at 8 Carmelite Street in the City of London. It dates from the late 19th Century with modern extensions at roof level. It is faced in red and blue brick with stone dressings and stone banding above the ground floor. It was originally five storeys high with a higher corner tower with an octagonal slate roof with lantern cupola, but a sixth storey has been added in the late 20th Century. Apart from the corner tower section, only the façade remains of Carmelite House; behind is a totally modern office building of six storeys, constructed of steel and glass with an atrium at its centre. There is a basement beneath the whole building footprint.

The original building has five bays to Carmelite Street and nine bays to Tallis Street. The ground floor is set onto a blue brick plinth, above which the façade is red brick. There are stone banded piers surmounted by carved stone capitals with a decorative carved stone frieze and plain stone cornice visually dividing the banded ground floor level from the upper storeys. Stone corbels within the plain cornice carry semi-octagonal brick pilasters against the piers between the windows on the first through to third floors, supporting a monumental carved stone frieze between the third and fourth floors and which continues to project beyond the original roofline finishing in stone finials.

The majority of the windows are set into stone surrounds with stone mullions around transom windows, as well as slightly recessed oriel windows located in the fourth, fifth and ninth bays along Tallis Street and the three middle bays on Carmelite Street. There are moulded brick panels between each level of windows as well as simple stone stringcourses. Dormer windows project from the slate roof. The Tallis Street elevation also holds three iron winches or pulleys, which are set from ground to second floor height.

The main entrance is from the corner of the building at the junction of Carmelite and Tallis Streets. Leading off the revolving entrance door is surrounded by a timber and glass, circular enclosure, the entrance vestibule has stone mosaic floors with a Greek key pattern, and the walls retain timber dado panels. The space is dominated by a grand stone staircase and the filigree wrought iron surround of the original Otis lift. The dado panels continue up the staircase all the way to the fourth floor, whilst the walls and ceilings above them have been decorated with neo-classical frescoes which have a Beaux-Arts feel. Panelled timber doors and doorcases on each level lead off the staircase, and into the modern office accommodation. At the top of the building, under the cupola, the original lift mechanism is still in place, and comprises the engine and winding machine.

**Structural description and walkover observations**

**External**: Façade to Carmelite Street and Tallis Street is exposed brickwork with decorative stone dressings in good condition. This façade would have originally been load-bearing and thus assumed to be of solid construction. The façade is now a retained façade.

**Internal**: The new structure is one of a steel frame with composite (concrete on profiled metal deck) floors. The building was (at the time of inspection) vacant and some areas had been soft stripped (internal finishes/partitions) removed exposing the structural frame.

A two storey basement extended (what appeared to be) the full footprint of the building (no drawings existed to confirm this). The basement was of reinforced concrete construction with blockwork internal walls. The structure was in good condition with no visible defects. There was a small area of damp, possible caused by water ingress in the stair at Thames end of basement.

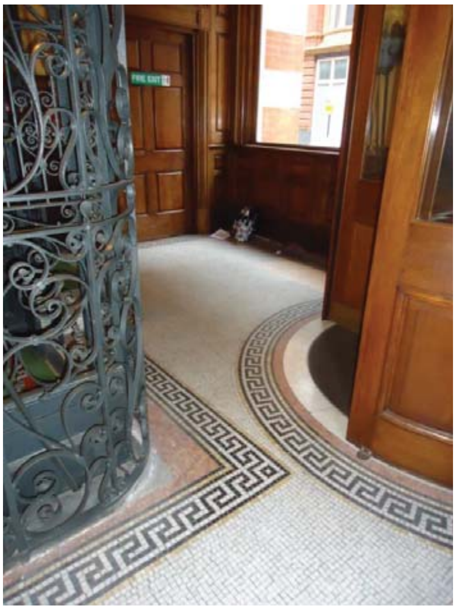
In the north-east corner the original stair core had been retained with new openings added to connect to altered floor levels of the new steel frame building. The cantilever stone stair and central lift mechanism was in good condition, with very minor hairline cracking.

| | |
|---|---|
| **Condition** | Good |
| **Assumed foundations** | Modern two storey basement assumed piled. |
| **Façade material** | Retained façade on Carmelite / Tallis Street is brick with stone dressings (original would have been load bearing). |
| **Internal support system (i.e. superstructure)** | Modern steel frame with composite (concrete on metal deck) floors. |
| **Heritage** | All significance is in the retained brick and stone façade to Carmelite and Tallis Streets, and in the entrance tower with its grand staircase, early 20$^{th}$ century lift and panelled and painted walls. |

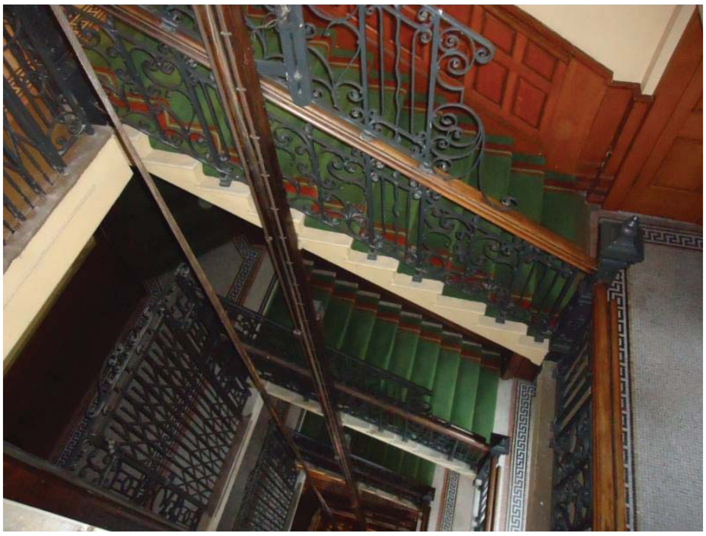
## Building photographs

**Tallis Street façade**

**Corner tower from Carmelite Street**

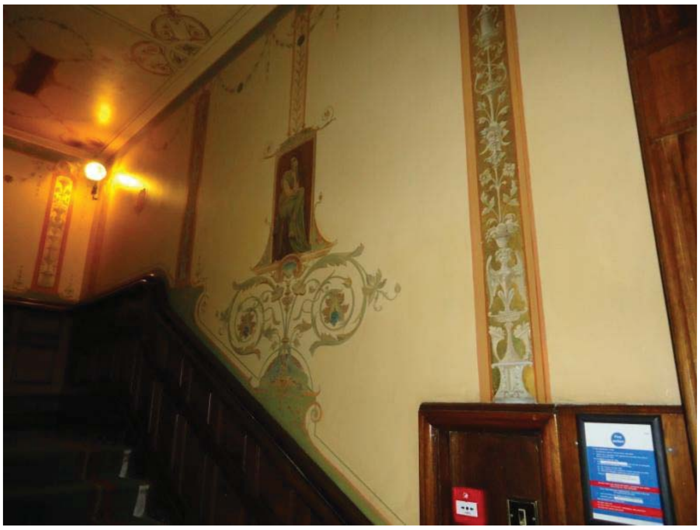


**Entrance vestibule with mosaic floor**



**Stone cantilevered stair and lift shaft**

**Filigree wrought iron lift casing**



**Dado panelling and painted decoration**

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Lambeth Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +55.1mTD.
Excavated diameter: 8.8m.
Closest shaft: Blackfriars Bridge foreshore shaft, located approximately 50m south – design indicates that the shaft may have some minor impact on the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

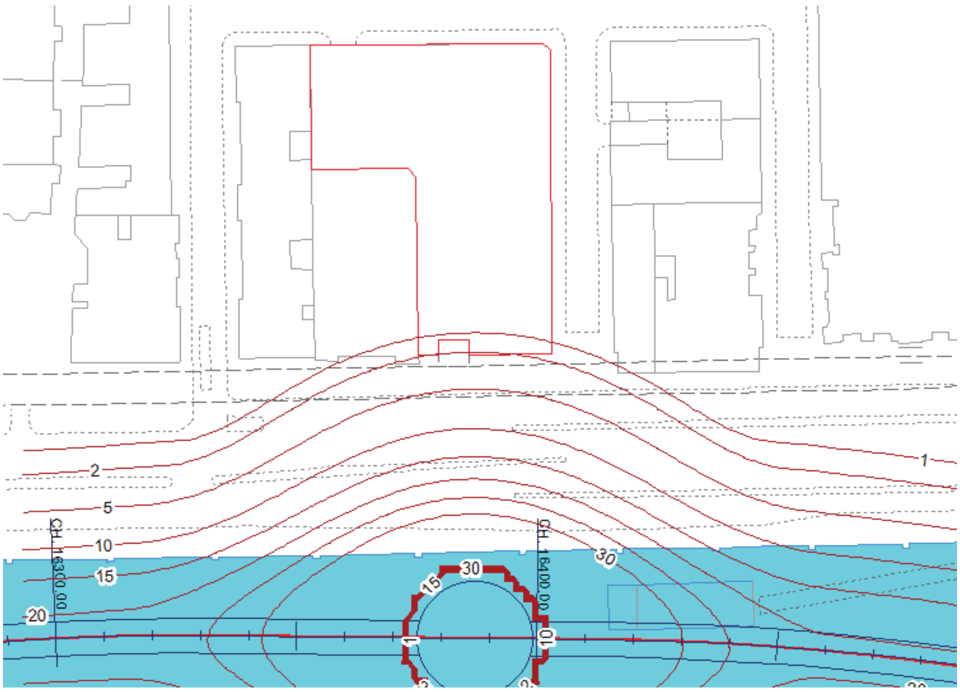
Thames Tunnel is proposed to be constructed within the Lambeth Group. The expected geological sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +104.7mTD to +105.1mTD.
Top of London Clay Formation: +93.5mTD.
Top of Lambeth Group: +66.0mTD (10.9m above proposed tunnel centreline level).
Top of Thanet Sand Formation: +50mTD.

Review of boreholes PR1060 and SR1058 (located approximately 275m to the west and 160m north-east) and BGS boreholes TQ38SW2296 and TQ38SW2880 (located approximately 110m east and 100m east respectively) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions. However borehole PR1060 does note several zones of core loss within the Lambeth Group, including a 1m section due to 'blowing sands'.

**Results**

Settlement contours generated at +82.03mTD, at 2/3 depth of assumed 25m long piles;




As shown above the building extends to the 2mm settlement contour. However the method of modelling used for the shaft in the Xdisp model is considered to be conservative (giving the shaft a greater influence on ground movement).

Two key façades for the building were selected fom the GIS model. The building was modelled as a 24m or 30m tall structure, underlain by a 2 storey (assumed 6m deep) basement. Foundations are assumed to be piled to 25m (analysis carried out at two thirds of depth).

The maximum ground settlement modelled was 2.5mm, remaining the same for either a 24m or 30m high structure.

The building damage assessment is based on the Burland model, designed for load bearing structures. The original building façade would have been load bearing, however the new structure located behind the façade is framed and does not fall within the requirements of the Burland model. If the building façade were still to be load bearing it would fall within the bounds of damage category 0, risk of negligible damage, with a maximum tensile strain of 0.02%. Due to the small ground movements modelled for the façades it is assessed that the whole structure can be regarded as having a building damage score of zero.

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The structure is a steel frame retaining the original brick façade. The significant façade is to the north of the building, a significant distance from the calculated settlement contours and thus will experience little or no movement.

The south end of the building is shown to be just inside of the 2mm contour line and as such is expected to experience little to no movement, the building is of modern construction and this end of the building is a non-structural (modern) stone façade. This façade was not inspected.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

The heritage features of Carmelite House are all located away from the modelled settlement contours, and will experience little to no movement. Therefore, although there are sensitive heritage features including the exterior stone dressings, the wrought iron lift shaft and retained lift, and stone stair, the settlement will not damage them and the heritage significance of the building will not be compromised.

***Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

The retained sections of the listed building are in good condition, and the condition of these sections and the modern building behind the retained façade will not cause heightened sensitivity to settlement for 9 Carmelite Street.

***Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 0.

The structure and heritage features of Carmelite House are not sensitive to the levels of settlement and strain calculated, and therefore the building will not be taken forward for further damage assessment and will not require mitigation.

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# Appendix F: Individual building assessment reports for the London Borough of Southwark

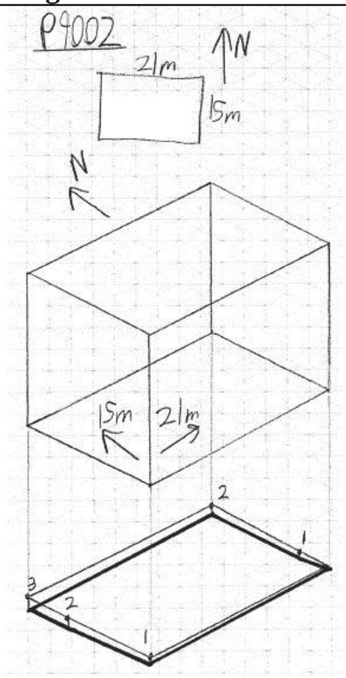
# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | P9002 |
| **Building name / address** | Corbetts Wharf, SE16 4TU |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 34697 79749 |
| **Ground level (mTD)** | +104.3 to +104.7 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




Isometric sketch shows curtilage of property rather than structure outline

**Building description (including excerpts from English Heritage listing, where appropriate)**

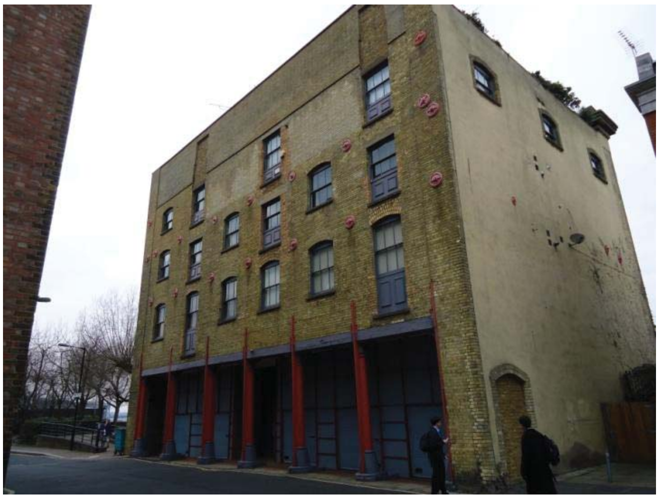
Corbett's Wharf dates from 1860 to1870. The brick north elevation has six bays and four storeys, with a high parapet above. To the ground floor are cast iron columns, and the exterior wall is set back; it is likely that these columns would originally have been internal. The second and third floors have six windows, those in the first, third and fifth bays from the west having arches with brick surrounds, and the others having flat concrete lintels; some of these windows have timber panels below, which may once have contained hoist hatches. The fourth storey has only four windows in the first, second, fourth and sixth bays, the first having a brick arch and the rest flat concrete lintels. The east elevation is rendered, with a blind opening in the first bay of the ground floor, and three windows with brick surrounds to the fourth storey. The western elevation is of brick, and has the same pattern of openings as the east. The north (riverside) elevation is of most interest, with 7 slimmer bays. The third and fifth bays have balconies to all floors, probably in the area of original hoists. The other bays have round arched windows within long recesses from the second storey to the parapet, whereas those of the ground floor are flush. To the parapet is a heavy stone cornice. The roof behind is double pitch.

Only some of the interior was accessed at the time of the inspection. The building now contains flats, and entrance is by a modern door, to a small hall with stone stairs and a lift shaft. The flat to the western ground floor has access to the space beneath the suspended floor showing brick piers and timber joists approximately one metre above the ground-level concrete slab. The main room of the flat has cast iron columns, timber floors and beams. The flat located to the north-western top floor, within the roof, has massive timber trusses showing carpenters marks, and timber floors. There are a number of storage areas to part of the ground floor; one of these was accessed, and had cast iron columns embedded in the modern partition walls.

| Structural description and walkover observations |
|---|
| The following movements are evident:-<br>- Cracks (up to approximately 5mm) at either end of the street façade and local rebuilding suggests that the wall sitting on the timber lintels has dropped slightly relative to the gable walls; this is likely to be due to a combination of shrinkage, compression and possibly also decay of the lintels.<br>- Cracks and distortion of the gable walls suggest that they (assumed to be supported on timber piles) have dropped relative to the front façade (built off the river wall) and the street façade (which is of course a long way back from the river); there is a full height vertical crack of up to approximately 5mm, where the front façade meets the western gable wall as well as evidence of local rebuilding; there is a hairline partial height vertical crack in the render where the eastern gable meets the street façade; there is visible distortion of the western gable. The centre of the gable has dropped approximately 30mm relative to the street façade.<br>- Internally there has been local 2 to 3mm settlement of the ground floor internal walls relative to the cast iron columns.<br>- Where visible, the base of the internal cast iron columns are heavily pitted, showing historic corrosion no doubt due to the brackish water.<br>- Floor ties and pattress plates have been introduced at all elevations at the level of the suspended floors. |

| | |
|---|---|
| **Condition** | Poor. |
| **Assumed foundations** | Unknown, but given the building's location alongside the river, it is possibly supported on timber piles; the north wall appears to be built directly off the river wall. There is no basement, however a new suspended timber ground floor has been installed approximately one metre above the original ground floor level. |
| **Façade material** | Generally brickwork. The east face has been rendered. There is a stone or rendered cornice on the north (river) elevation. |
| **Internal support system (i.e. superstructure)** | External walls – loadbearing brickwork; south (street) façade carried on timber lintels and cast iron columns at ground floor.<br>Internal vertical structure – cast iron columns.<br>Floors and roof – timber. |
| **Heritage** | Exterior legibility as a river warehouse; cornice to north elevation; interior cast iron columns, timbers and roof structure. |

## Building photographs

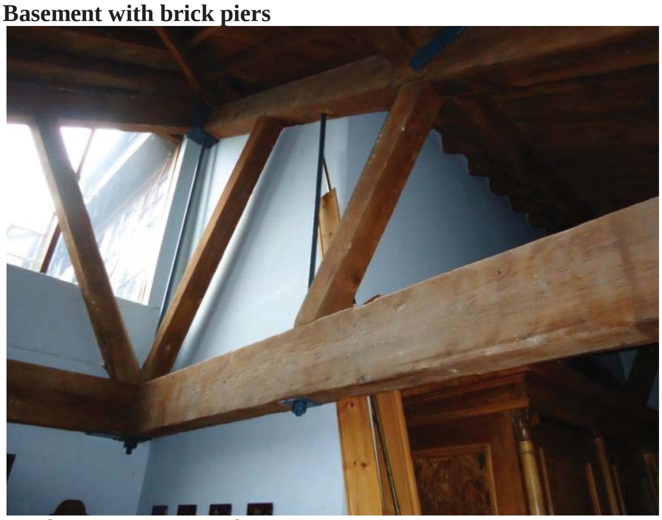


Road (south) elevation and east elevation

River (north) elevation and west elevation

Basement with brick piers

Example of cast iron columns, ground floor



Roof truss visible, top floor

Cast iron column embedded in modern wall, ground floor storage area

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +50.6mTD.
Excavated diameter: 8.8m.
Closest shaft: Chambers Wharf shaft, located approximately 300m west – design indicates unlikely to influence ground movement at the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

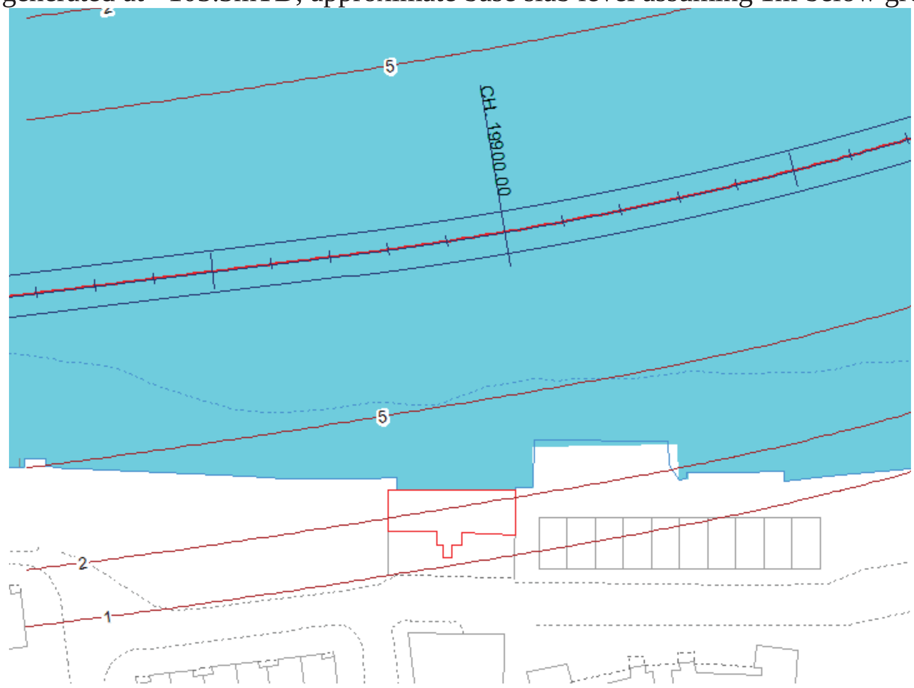
The Thames Tunnel is proposed to be constructed within the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +104.3mTD to +104.7mTD.
Top of Lambeth Group: +93.5mTD.
Top of Thanet Sand Formation: +77.0mTD.
Top of Chalk Group: +63.0mTD (12.4m above proposed tunnel centreline level).

A review of borehole SR1055 (located approximately 60m south) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions.

**Results**

Settlement contours generated at +103.3mTD, approximate base slab level assuming 1m below ground level.




As shown above the building crosses the 2mm settlement contours, sitting between the 1mm and 5mm contours.

Two key façades were selected from the GIS model. Analysis of these façades assumed that the building is 16m high, it has been modelled with piled (10m long, analysed at two thirds length) and shallow foundations (1mbgl).

All results fell within the bounds of category 0, negligible damage. A maximum tensile strain of 0.005% was obtained when the building was modelled with piled foundations and a maximum settlement of 3mm was obtained for the structure, when modelled with shallow foundations.

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero***

## Interpretation of impact

**Structural assessment and discussion**

The analysis suggests 1 to 2mm of distortion of the gable walls. While this might be slightly reduced by the inherent stiffness of the walls (which have few openings), it would be conservative to assume that the movements will concentrate at the existing cracks and that these will open by approximately 1mm. This level of movement is likely to be of a similar magnitude to daily movements of the river wall with the tides. The 1mm movement is likely to be more noticeable on the east gable because it is rendered.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

Features within Corbett's Wharf that may be sensitive to large movements include the external cornice and interior cast iron columns, timbers and roof structure. Whilst these elements could be fragile in cases of pronounced differential movements, the minor settlement calculated in the area of Corbett's Wharf is not expected to damage these heritage features.

***Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

This building is in poor condition, with external cracking evident, particularly to the south-eastern corner of the building, where there may have been previous movement. There are also area of spalled brickwork, probably due to the unsympathetic use of cement mortar when previous repairs have taken place. The movements that may occur due to settlement are likely to be concentrated at the locations of pre-existing cracks.

***Condition sensitivity score is therefore assessed to be 1.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 1 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 1.

The heritage and structure of this building are not considered sensitive to the calculated settlement. Whilst the condition is poor, any movement of this building will be concentrated in areas of existing cracking; the opening of these existing cracks due to settlement from the Thames Tunnel works will be infinitesimal.

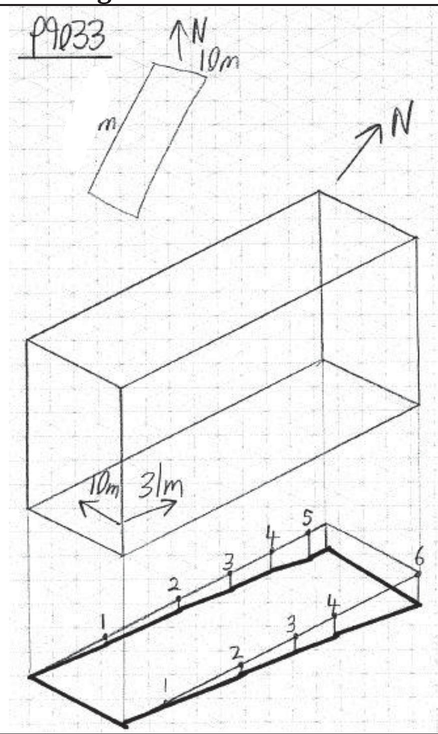
Because of the very small calculated movements, mitigation measures are not considered necessary. However, it is noted that there is significant existing cracking and it is important that a condition survey is undertaken before the works to avoid the risk of any dispute over the responsibility for the (pre-existing) cracking.

# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z5893 |
| **Building name / address** | Chambers Wharf, SE16 4ST |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 34201 79815 |
| **Ground level (mTD)** | +100.7 to +104.1 |

| **Location plan** | **Isometric ground movement sketch** |
|---|---|


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.




**Building description (including excerpts from English Heritage listing)**

Chambers Wharf is a former warehouse, dated 1865-1870, of five storeys plus a modern attic storey which is visible as a flat roofed structure above the parapet, and three bays. It is constructed of stock brick, with a recessed full height opening centrally to its southern elevation to its southern elevation, and timber casement windows within recesses under brick arches to the flanking bays. The doors and windows are modern. To the right of the top storey is a crane, and the window to this area is much smaller than the others.

The northern elevation, to the river and built off the river wall, also has three bays, This elevation was not visible during the inspection; however, it is assumed that the pattern of openings is similar to that of the southern elevation, and likely to include modern balconies. To the east of the river elevation, at the top two storeys, is a hatch-rank on two levels and a lattice jibbed crane.

The elevation to the east partially abuts a modern building, but towards the river has window and door openings with modern fittings and balconies. To the west, Chamers wharf abuts a modern building. The modern top storey has a flat roof and timber cladding, and is set back and partially hidden behind a shallow brick parapet. At the time of inspection there was no sign of a basement. The south elevation shows a number of tie-plates.

The building has been recently converted to flats, and the internal spaces show no sign of the *timber floors and posts* described within the English Heritage listing description. Access to the flats was not available at the time of inspection; the public areas showed only modern plastered walls, modern painted finishes, and new stairs.

| **Structural description and walkover observations** |
|---|
| The internal structure appeared, from communal areas, to have been completely replaced with a modern steel frame. The steel frame appeared to have welded conections decorated with fake rivets. Most of the structure was hidden by finishes; exposed structure visible in neighbouring 33 Bermondsey Wall West (part of the same modern residential development) would suggest that internal walls are likely to be a mix of blockwork and plasterboard stud partitions, with the floors being made of of composite steel and concrete. Of the original structure, only the London stock masonry brick facades remain, measured to be 2 ½ bricks thick.<br><br>The condition is generally good. Each floor has 4 ties with buttress plates, visible from the street facade. There was evidence of previous repointing and replacement of brickwork on the external walls. Externally, a lean of the north and south facing facades (of about 200-250mm at the top) was visible, away from the river. The building has similar dimensions on plan as it does in height (i.e. 16m x 18m on plan, approximately 15m high), so assuming a rigid body rotation then for the building to lean 200-25m at the head, this would imply a 200-250mm settlement of the south facade. |

| | |
|---|---|
| **Condition** | Good, modern internal structure. Lean to south facade. |
| **Assumed foundations** | The original building would have been seated on the river wall to the north, with shallow foundations or timber piles to the south. During the construction of the steel frame, additional piles may have been driven within the building footprint. |
| **Façade material** | Loadbearing brick. |
| **Internal support system (i.e. superstructure)** | Modern steel frame with composite floor. |
| **Heritage** | External features are the hatch-rank, lattice-jibbed cranes, and retained brick arches above openings. There are no visible remaining heritage features. |

## Building photographs

Southern elevation

Hatch rank to northern (river) elevation

Modern finishes within the public areas

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +51.3mTD.
Excavated diameter: 8.8m.
Closest shaft: Chambers Wharf shaft, located approximately 165m south-east – design indicates unlikely to influence ground movement in the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

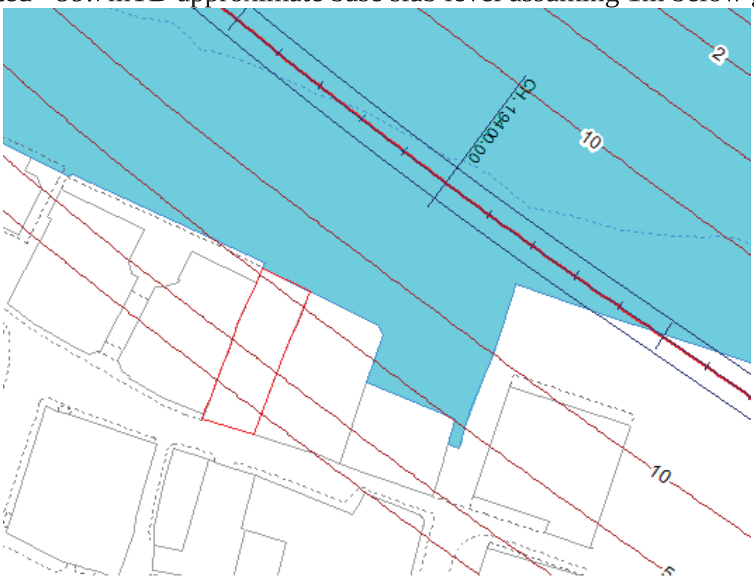
The Thames Tunnel is proposed to be installed within the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +100.7mTD to +104.1mTD.
Top of London Clay Formation: +95.0mTD.
Top of Lambeth Group: +91.5mTD.
Top of Thanet Sand Formation: +75.0mTD.
Top of Chalk Group: +62.5mTD (11.2m above proposed tunnel centreline level).

Review of borehole SR2034 (located approximately 230m east) and BGS borehole TQ37NW104 (approximately 180m west) does not indicate any geological features that would require a change in the current ground loss assumptions. The BGS borehole suggests there may be a thicker deposit of London Clay Formation, with thinner deposits of Thanet Sand and the Lambeth Group than given above. Borehole SR2034 also notes several zones of assumed core loss within the Chalk Group.

**Results**

Settlement contours generated +99.7mTD approximate base slab level assuming 1m below ground level;




As shown above the building extends from the 5mm settlement contour across the 2mm and 1mm settlement contours generated for the tunnel.

Two key façades were selected from the GIS model. These were analysed as a 18m high structure, with shallow foundations and piled foundations (piles 10m long, analysed at 2/3 depth), both with and without a basement (base slab 4m bgl and 1m bgl respectively).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.01% was obtained when the structure was modelled with a basement and piled foundations (calculation at +90.03mTD) and a maximum settlement of 6mm when modelled with shallow foundations, without a basement (foundations at 99.7mTD).

Interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The structure is hidden by plasterboard finishes internally but it is assumed to be a modern intervention (possibly only retaining the facade). There are a few 1-2mm cracks at junctions between internal partitions and the building envelope. It is estimated that there will be just 3mm differential settlement likely to occur as a rigid body rotation. On the basis that the structure has seen significantly greater movements with minimal damage then it is reasonable to predict negligible damage.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

Externally, heritage features are the hatch rank and cranes, and brick arches above window openings. The internal structure is entirely modern. The heritage significance of this building will not be affected by the relatively small ground movements predicted.

***Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

The condition of this building is good, with entirely modern finishes internally and new window and door fittings.

***Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 0.

The structure and heritage features of Chambers Wharf are not sensitive to the levels of settlement and strain calculated, and therefore the building will not be taken forward for further damage assessment and will not require mitigation.

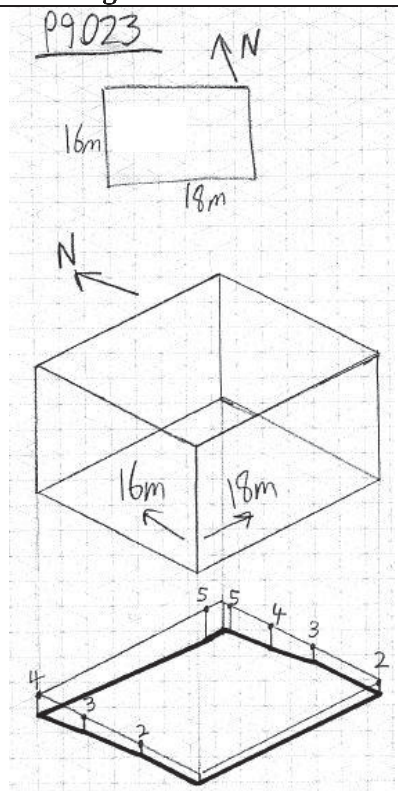
# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z5896 |
| **Building name / address** | 33 Bermondsey Wall East, SE16 4ST |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 34228 79798 |
| **Ground level (mTD)** | +101.5 to +104.2 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing)**

33 Bermondsey Wall West is a former Granary, dated 1866, of five storeys plus a modern attic storey, and five bays. It is constructed of stock brick, and is punctuated to its southern elevation with timber casement windows within recesses under brick arches. The northern elevation, to the river, has six bays, with a pattern of two bays of paired timber casements under brick arches, interspersed with one bay of double loading doors within a continuous recess, now also holding small balconies at each floor. The building has a plain brick elevation to the east, and abuts a modern building to the west; part of the western exterior wall, with a number of openings under flat brick arches, can be seen from the terrace of this modern building. The modern top storey has a flat roof and timber cladding, and is set back and partially hidden behind a shallow brick parapet. At the time of inspection there was no sign of a basement. The south and north elevations both show a number of tie-plates, with a large number to the south facade, which appears to be leaning.

The building has been recently converted to flats, and the internal spaces show no sign of the heritage features described within the English Heritage listing description, as follows: *timber with spreader capped posts supporting the floors and open timber staircases. A series of wooden chutes is said to remain in situ, descending from the top floor to the 1st floor terminating in a movable table system leading to a hand winch by the loading hatch. The chutes are provided with a weighted box breaking system.* Access to the flats was not available at the time of inspection; the public areas showed only modern plastered walls, modern painted finishes, and new stairs, except for small areas of historic brickwork under windows to the south, and the western wall which was visible to the rear of the stair. A large brick arch in this western wall shows within the brickwork, now filled in.

| Structural description and walkover observations | |
|---|---|
| The internal structure appeared, from communal areas, to have been completely replaced with a modern steel frame. Most of the structure was hidden by finishes; exposed structure visible in a room on the ground floor revealed internal walls of blockwork and floors of composite steel and concrete. Internal walls at upper levels are likely to be a mixture of plasterboard stud partitions and blockwork. Of the original structure, only the London stock masonry brick facades remain. Measurements taken at neighbouring 29 Bermondsey Wall East (Chambers Wharf) suggest that these are 2 ½ bricks thick.<br><br>The condition is generally good. Externally, a lean of the north and south facing facades (of about 200-250mm at the top) was visible, away from the river. The building has similar dimensions on plan as it does in height (i.e. 16m x 18m on plan, approximately 15m high), so assuming a rigid body rotation then for the building to lean 200-25m at the head, this would imply a 200-250mm settlement of the south facade. Each floor appears to have between 4 and 6 ties with pattress plates, visible from the street facade. There was evidence of previous repairs to cracks on the external wall and small cracks (~2mm) were visible inside the building between internal walls and the south facing facade. | |
| **Condition** | Good, historic lean to south wall. |
| **Assumed foundations** | The original building would likely have been seated on the river wall to the north, with shallow foundations or timber piles to the south. During the construction of the steel frame, additional mini piles may have been driven within the building footprint. |
| **Façade material** | Loadbearing brick. |
| **Internal support system (i.e. superstructure)** | Assumed to be a modern steel frame with composite floor (obscured by finishes). |
| **Heritage** | External surviving heritage features are limited to brick arches at openings. There are no surviving internal features. |

## Building photographs

| | |
|---|---|
|  Front (south) elevation |  Rear (north) elevation, from the riverside |
|  Small area of brickwork below southern window at each floor |  Evidence of arch, now filled in, west party wall (partially hidden by main stair) |

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +51.1mTD.
Excavated diameter: 8.8m.
Closest shaft: Chambers Wharf shaft, located approximately 130m east-south-east – design indicates unlikely to influence ground movements in the building location.

| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |
|---|---|

**Ground conditions**

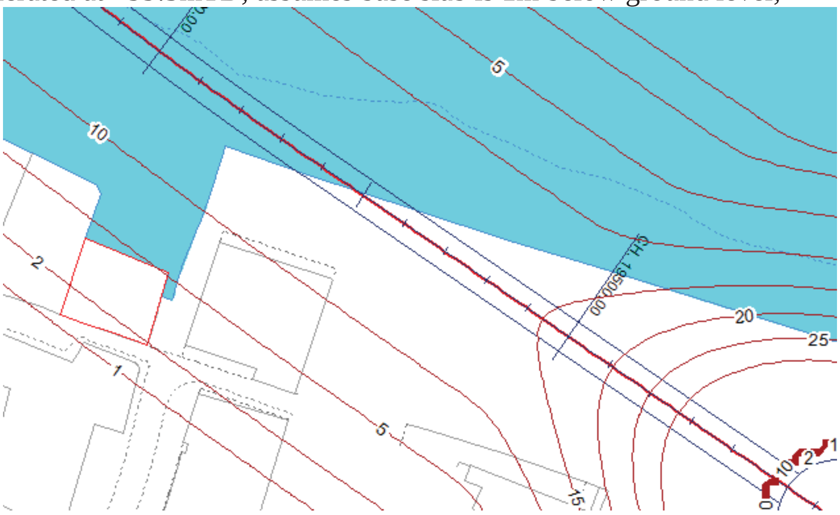
The Thames Tunnel is proposed to be constructed within the Chalk Group. The expected sequence overlying the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +101.5mTD to +104.2mTD.
Top of London Clay Formation: +95.0mTD.
Top of Lambeth Group: +91.5mTD.
Top of Thanet Sand Formation: +75.0mTD.
Top of Chalk Group: +62.5mTD (11.2m above proposed tunnel centreline level).

Review of borehole SR2034 (located approximately 200m east-north-east) and BGS borehole TQ37NW104 (located approximately 210m west) does not indicate any geological features that would require a change in the current ground loss assumptions. The BGS borehole suggests there may be a thicker deposit of London Clay Formation, with thinner deposits of Thanet Sand and the Lambeth Group than given above. Borehole SR2034 also notes several zones of assumed core loss within the Chalk Group.

**Results**

Settlement contours generated at +99.5mTD, assumes base slab is 1m below ground level;




As shown above the building sits above the 5mm and 2mm settlement contours generated for the tunnel.

Two key façades were selected for the structure from the GIS model. These façades were analysed for a 18m high structure on shallow foundations and 10m long piles (analysed at two thirds depth), with and without a basement (base slab at 4m bgl and 1m bgl respectively).

All results fell within the bounds of damage category 0, risk of negligible damage. A maximum tensile strain of 0.009% and a maximum settlement of 5mm were obtained for the structure, when modelled on piles with a basement (calculated at +90.8mTD) and on shallow foundations without a basement (calculated at +99.5mTD) respectively.

Interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The structure is hidden by plasterboard finishes internally but it is assumed to be a modern intervention (possibly only retaining the facade). There are a few 1-2mm cracks at junctions between internal partitions and the building envelope. It is estimated that there will be just 3mm differential settlement likely to occur as a rigid body rotation. On the basis that the structure has seen significantly greater movements with minimal damage then it is reasonable to predict negligible damage.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

There are very few surviving heritage features and finishes at 33 Bermondsey Wall West; externally, brick arches above window openings survive. The internal structure is entirely modern. The heritage significance of this building will not be affected by the relatively small ground movements predicted.

***Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

The condition of this building is good, with entirely modern finishes internally and new window and door fittings. There is a historic lean to the southen elevation which does not undermine the general structural integrity of the building.

***Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 0.

The structure and heritage features of 33 Bermondsey Wall West are not sensitive to the levels of settlement and strain calculated, and therefore the building will not be taken forward for further damage assessment and will not require mitigation.

# Appendix G: Individual building assessment reports for the London Borough of Tower Hamlets

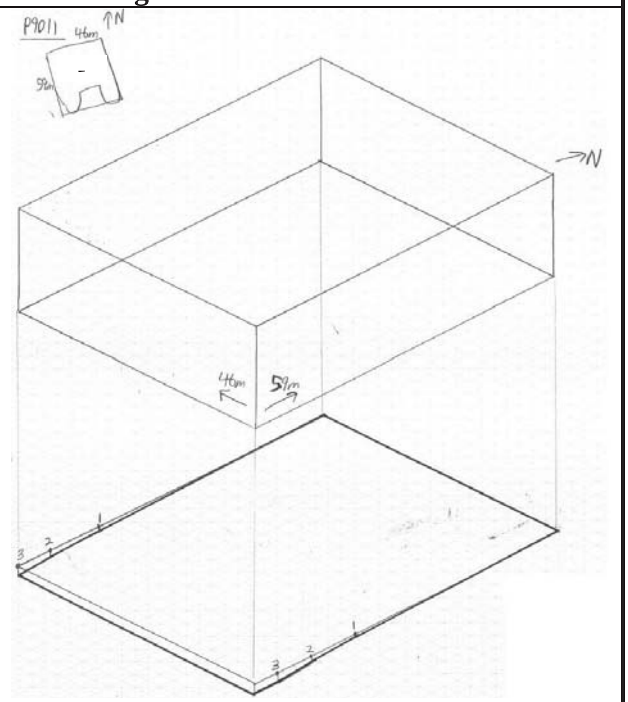
# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z2095, Z2096 |
| **Building name / address** | Free Trade Wharf, E1W 3HU |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 35780 80814 |
| **Ground level (mTD)** | +105.8 to +107.3 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing)**

Free Trade Wharf, dating from 1796, consists of two former warehouse buildings with a courtyard between. This courtyard is accessed at north and south by iron gates, those at the north being set beneath a central stone arch with voussoirs and a keystone, and topped by an entablature and cornice which bears the date 1796. EH refers to this section as having been rebuilt in 1934. Flanking this are brick arches with a stone band to above and keystone details. The southern gate is set within brick arches with stone dressings. Within the courtyard are remnants of tracks and rails which once ran into the buildings to either side. These are set within various paving types, including modern, stone flagged, and granite setts.

Both buildings are of stock brick of varying colours, and there is evidence of patching and re-built sections in modern brick.

The building to the west is four storeys high. The west elevation has service entrances at ground floor level, reported to lead into the swimming pool area. Above are three storeys of sash windows under modern brick arches. The southern elevation has two bays, four regular storeys and an offset attic storey, higher to the west. There are stone bands above ground and first floor levels, and a heavy stone cornice above third floor level. The modern windows, which include a double-height opening to the ground and first floors, are under brick arches. The stone bands and cornice run round to the east (courtyard) elevation, which also shows similar openings under brick arches. A parapet hides the roof. The northern elevation shows the stone band above ground floor level, but has no openings. There is a recessed blind brick arch.

The building to the east is similar; however, the brick elevations are patchier and show more signs of modernisation. The eastern elevation has garage entrances at ground floor level, with regular bays of sash windows above. There is a stone band beneath the first floor windows. The southern elevation has three bays, but otherwise echoes that of the building to the west, as does the western (courtyard) elevation. The northern elevation has one blank bay, and a lower wall behind which is a modern single storey plant room.

| | |
|---|---|
| Internal access to the buildings was not gained at the time of the inspection; however, timber structure could be seen within the communal areas. | |
| **Structural description and walkover observations** | |
| The conversion from the original warehouse was carried out between approximately 1984 and 1995. The swimming pool on the ground floor was part of the conversion.<br>The external brickwork is generally in good condition as seen from ground level externally; there are large areas of new brickwork, seen at high level on both the east and west blocks and also areas where repairs have been carried out.<br>A number of wall ties were observed, assumed to have been installed as part of the refurbishment works.<br>The roofs are pitched, tiled with Welsh slate also at the time of the renovation, with skylights added to increase internal lighting.<br>The walls were estimated to be approximately 700+mm thick at the piers.<br>Internally the roof timbers are exposed. There is no information on other structural elements but from the date of construction and its original use it may well contain cast iron elements in columns and possibly floors.<br>The ground floor is likely to be of solid construction, upper floors might be jack arches or timber. | |
| **Condition** | Good, but with areas of spalling and eroded brickwork. |
| **Assumed foundations** | Possibly timber piles and may be seated on a previous river wall at the end nearest the river. Shallow footings might also be used in the area remote from the river. |
| **Façade material** | Loadbearing brick with stone dressings. |
| **Internal support system (i.e. superstructure)** | Assumed iron frame with timber floors, possibly solid floors to accommodate storage.. |
| **Heritage** | This is a very early warehouse, increasing its significance on the riverside; external entablature and cornice bearing a plinth on which stand the arms of the East India Company. Courtyard area retains track and rails. Internal timbers incorporated into modern fit-out. |

## Building photographs

| | |
|---|---|
|  Southern elevations |  Courtyard between the two buildings, toward northern gateway |
|  East elevation of eastern building |  West elevation of western building |
|  Courtyard elevation of western building, also showing remaining tracks and rails |  Example of variously coloured brickwork in poor condition |

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +48.7mTD.
Excavated diameter: 8.8m.
Closest shaft: King Edward Memorial Park foreshore shaft, located approximately 190m south-west – design indicates unlikely to influence ground movement at the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

Thames Tunnel is proposed to be constructed through the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level. +105.8mTD to +107.3mTD.
Top of London Clay Formation: +96.0mTD.
Top of Lambeth Group: +95.0mTD.
Top of Thanet Sand Formation: +72.5mTD.
Top of Chalk Group: +60.5mTD (11.8m above proposed tunnel centreline level).

Review of boreholes SR1034A and PR1034A (located approximately 140 and 145m south-west respectively) and BGS borehole TQ38SE2011 (located approximately 50m west) does not indicate any geological features that would require a change in the current ground loss assumptions, however the BGS borehole TQ38SE2011 indicates a thicker layer of drift (to approximately +87.0mTD) and no London Clay Formation.

**Results**

Settlement contours generated +104.8mTD, base slab level assumed to be 1m below ground level;


As shown above the buildings cross the 2mm and 1mm settlement contours that have been generated.

Three key façades were selected from the GIS model. Analysis assumed that the buildings were 12m high, with shallow or piled foundations (10m long piles, movement calculated at two thirds depth). The buildings were modelled without a basement (shallow foundations at 1m bgl).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.006% (piled foundations) and a maximum settlement of 3mm were generated for the structures, (shallow foundations (1mbgl)).

The interaction of the ground settlement with the structures is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

This building has not been inspected internally.. The brick façades appear to be of substantial thickness, heavily fenestrated at the lower levels in particular, and the internal structure is assumed to be an iron frame.
Given that the building underwent substantial renovation within the last twenty-five years and appears sound externally it is not anticipated that there will be any impact on the structure from the very small movements predicted.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

Sensitive features at Free Trade Wharf are external stone dressings including the entablature and cornice, the gates, courtyard paving and rails. There may be sensitive timber structural elements internally. Movements are concentrated at the southern end of the building, away from the gate which has the entablature. The other features are unlikely to be sensitive to the levels of settlement calculated.

***Therefore the heritage score for this building is judged to be zero.***

**Condition discussion**

This building is in good condition, with patchy areas of brick deterioration which will not cause sensitivity to ground movement.

***Therefore the condition score for this building is judged to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 0.

The structure and heritage features of Free Trade Wharf are not sensitive to the levels of settlement and strain calculated, and therefore the building will not be taken forward for further damage assessment and will not require mitigation. However, it should be taken into account that a full internal inspection of the building was not available.

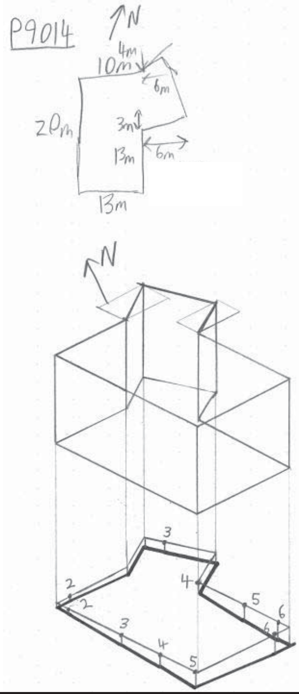
# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z2288 |
| **Building name / address** | Prospect of Whitby Public House, E1W 3SH |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 35350 80485 |
| **Ground level (mTD)** | +104.4 to +105.2 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 5 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

Grade II listed, the Prospect of Whitby dates from 1520, with later alterations including the front (north-west) façade, which was refaced in the early 19th century. This elevation has three storeys and three bays with a central door, and is faced in brick with imitation stone architraves above recessed sash windows and a wide imitation stone band beneath a cornice of the same material, carrying the name of the establishment. At ground floor level, this elevation has a timber shop-front with bow windows, columns to either side and timber stallrisers and soffit. To the north is a two storey, single bay extension, with a two-three bay single storey extension again to the north beyond this. The extensions are of brick to match the main façade, and predominately blank, with a doorway to the far north extension.

The south-west return, which runs alongside a passage leading to the Thames, comprises a full bay of brick with blind openings to first and second floor, and a circular window at ground floor level. The return continues with a brick ground floor to the first two bays and painted brick thereafter, and the upper storeys are of painted brick and punctuated with windows to the first and second floor in bay two, over a doorway with a stone surround and hood. To the Thames-end of the return is a circular window at ground floor level, just over the steps of the passageway to the foreshore.

The north-eastern elevation rises two storeys above a patio area, which is behind the front extensions. The façade is part weather-boarded, painted white, and part painted-brick, with a double-doored entrance at ground floor, and three wide bays of bay windows to the first floor. There is a balcony at ground and first floor level which stretches round to the rear of the building, The return of the main building is set back from this, and is of painted brick.

To the rear (south-east), the building is built off the river retaining wall. From the foreshore rise piers, at retaining wall level of concrete with a timber cross brace, the piers becoming timber to the upper floors. These support balconies to ground and first floor levels of the building; these balconies are of timber with recently renovated needle balustrades. Large doors lead from the interior of the building onto the balconies.

The interior of the building has been much altered, and many of the public house fittings are new or not original to the building. There is a cellar, reached by a hatch behind the ground floor bar area, which is of painted blockwork with a (clay?) tiled ceiling. A barrel drop hatch is situated to the north-west of the cellar, which leads up to the interior of the building at ground floor level.

The ground floor has a stone flagged floor, and features timber panelling and columns. Of note are the bow windows of the north-west front façade, which contain bottle glass within timber window bars. To the rear (south-east) there is a further modern dining room, leading onto the patio area, and the ground floor rear balcony. There is a timber stair leading from ground to first floor along the south-west return.

To the first floor, the rooms are timber panelled with probably clay tiled ceilings with timber beams, and timber floors; the room to the south-east (river façade) contains 18th century dado panelling which is mentioned as of note within the listing description. The north-western façade of the building features timber sash windows with some bottle glass; the room to the rear has timber casement windows. To the north-east side is a separate dining room with modern fit-out.

The top floor contains living accommodation, and has basic painted finishes and a carpeted timber floor. The windows are timber casements. The slope of the roof is visible in a number of the rooms. The front (north-west) room was not accessible at the time of the site visit.

**Structural description and walkover observations**

The building is generally of loadbearing masonry with internal timber framing.

The rear (south east) of the building has a mix of constructions extending over the foreshore, from old weathered timber posts and iron embedded in rough concrete to more recent steel beams installed below the ground floor terrace.

The building has undergone alterations over time; there are changes in level and floor construction seen through the building. At the second floor it is possible that more recent construction links what were previously separate constructions at the front (north-west) and rear (south-east). In the basement the [concrete] floor is likely to be a replacement to the original. There is some evidence of damp to the north-west of the basement, but quite limited for a building of this age and location.

Externally there are some vertical cracks on the front elevation at ground floor up to approximately 2mm, coinciding with junctions in the structure.

On the rear elevation there are some cracks on the north elevation at first floor (seen from the patio) up to approximately 1mm and a hairline crack on the rear brickwork.

On the west side, while the building appears broadly plumb at the front there is evident movement at the rear. There are several cracks generally vertical from approximately one third of the length of the wall onwards to the rear, also tending to be more inclined with a horizontal crack and evident unevenness in the wall towards the top of the Pelican Stairs.

Seen from the rear the building has a noticeable lean to the west and some skew.

| | |
|---|---|
| **Condition** | The condition of the building is largely good, with some fine cracking to the south west return elevation, and to the interior within the top storey. The cellar area is sound with little damage.<br>The sensitive piers and balcony to the river side of the building are in good condition and have recently been renovated. |
| **Assumed foundations** | The western side, fronting on to Wapping Wall has a cellar of limited depth and is assumed to have shallow footings. The eastern side sits partially on the river wall possibly with wooden piles. |
| **Façade material** | Brick with stone dressings.<br>There is render at first floor with brickwork above.<br>Much of the rear on the east side is weather boarded.<br>The east boundary wall to the ground floor terrace is modern. |
| **Internal support system (i.e. superstructure)** | Loadbearing masonry with internal timber framing |
| **Heritage** | Imitation stone architraves and cornice to parapet, hooded balcony with balustrade, bow windows, interior features. Group value with surrounding historic buildings and features, listed due to its historic associations. |

## Building photographs


South (river) elevation

Eastern elevation from ground floor

Cellar

Dado panelling to southern first floor room

North (roadside) elevation

Eastern elevation above ground floor

General view of bar, with timber columns

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +49.4mTD.
Excavated diameter: 8.8m.
Closest shaft: King Edward Memorial Park foreshore shaft, located approximately 280m north-north-east – design indicates unlikely to influence building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

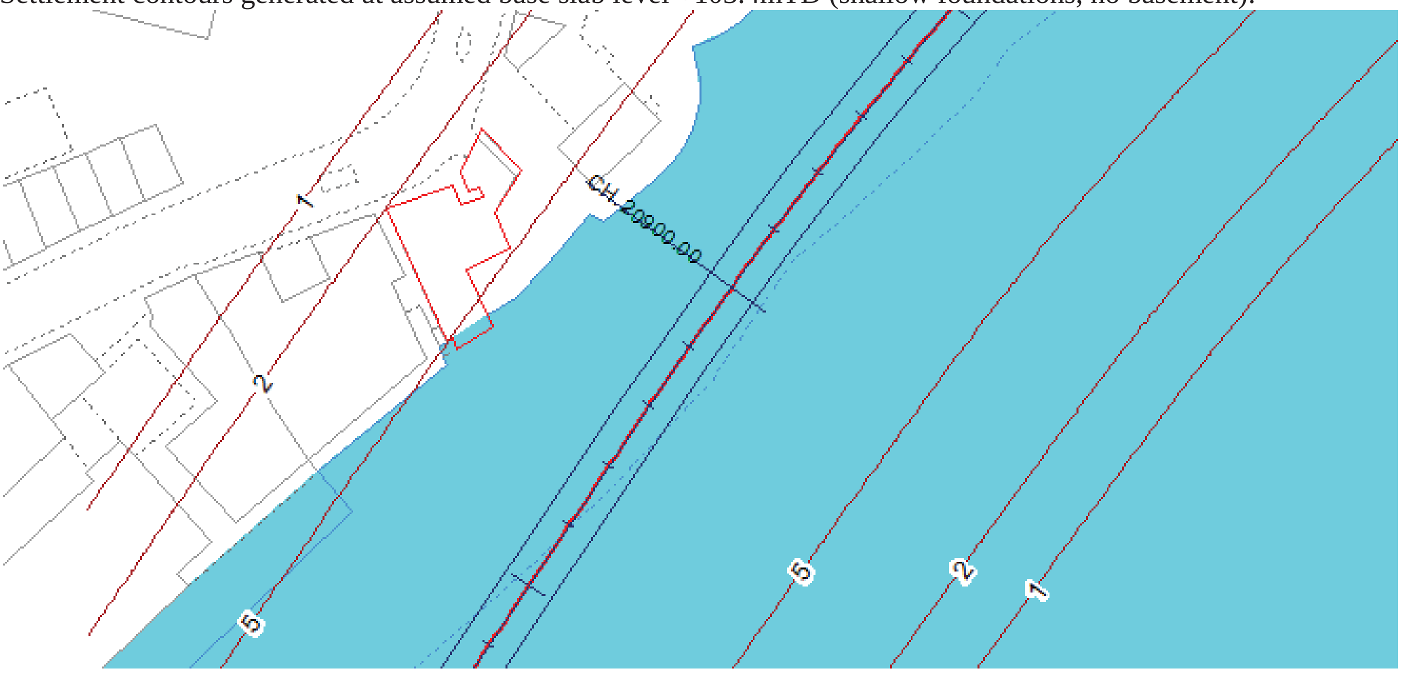
The Thames Tunnel is constructed within the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +104.4mTD to +105.2 mTD.
Top of Lambeth Group: +96.0mTD.
Top of Thanet Sand Formation: +75.0mTD.
Top of Chalk Group: +62.0mTD (12.6m above proposed tunnel centreline level).

Review of borehole SR1031 (located approximately 330m north) and BGS boreholes TQ38SE1001 (located approximately 275m south-west), TQ38SE318 (located approximately 80m west) and TQ38SE323 (located approximately 25m south-west) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions. However they do indicate the likely presence of London Clay Formation above the Lambeth Group.

**Results**

Settlement contours generated at assumed base slab level +103.4mTD (shallow foundations, no basement):




As shown above the building sits predominantly between the 2 and 5mm settlement contours.
Analysis of three key façades selected from the GIS model, assumed a building height of 9m. Foundations were modelled as shallow (1m bgl), with a part basement (3m bgl) and with 20m long piles, vertical movements modelled at 2/3 of pile depth.

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.004% and a maximum settlement of 6mm was obtained for the building, when modelling shallow 1m deep foundations.

The building potentially has mixed foundations. However the settlements and maximum tensile strains remain negligible for all of the above foundation types.

The calculated ground movements for this building are small and the settlement contours are well spaced. Any resulting strains within the building will be correspondingly small and the impact is anticipated to be negligible.

***Building damage score is therefore assessed to be zero.***

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section below.

## Interpretation of impact

**Structural assessment and discussion**

Visual inspection of the building has indicated that the structure is in good condition overall. Internally areas were concealed by finishes but there were no significant defects noted.

In principle the potential mixed foundations may result in some differential movements between the front and rear of the building but these are expected to be limited in line with the overall prediction of movements.

There are some indications of previous movement externally. Subsequent movement would be expected to be concentrated around pre-existing cracks and joints.

***Structural sensitivity score is therefore assessed to be 1.***

**Heritage features sensitivity discussion**

The Prospect of Whitby is listed primarily due to historical associations, as stated within the listing description. However, there are a number of features of heritage significance. Of greatest note are the piers and balconies to the rear of the building, which give character to the rear façade, and have been in place for over 100 years. The rear portion of the building also contains the most significant interior feature, the 18th century dado panelling. The concentration of heritage interest in this section of the building is such that larger ground movements may cause some minor damage to the heritage significance of the building, with the piers and balustrade being the most sensitive element.

Heritage features to the front of the building, though contributing to the heritage character, are much altered. The calculated movements will not cause damage to these features, and the front façade in particular, which is of great importance to the form and character of the public house, will not be adversely affected.

***Heritage sensitivity score is therefore assessed to be 1.***

**Condition discussion**

The building is in good condition, with the minor cracking to the south west elevation and the top floor interior not judged to make the building more sensitive than it may otherwise be due to the small movements calculated.

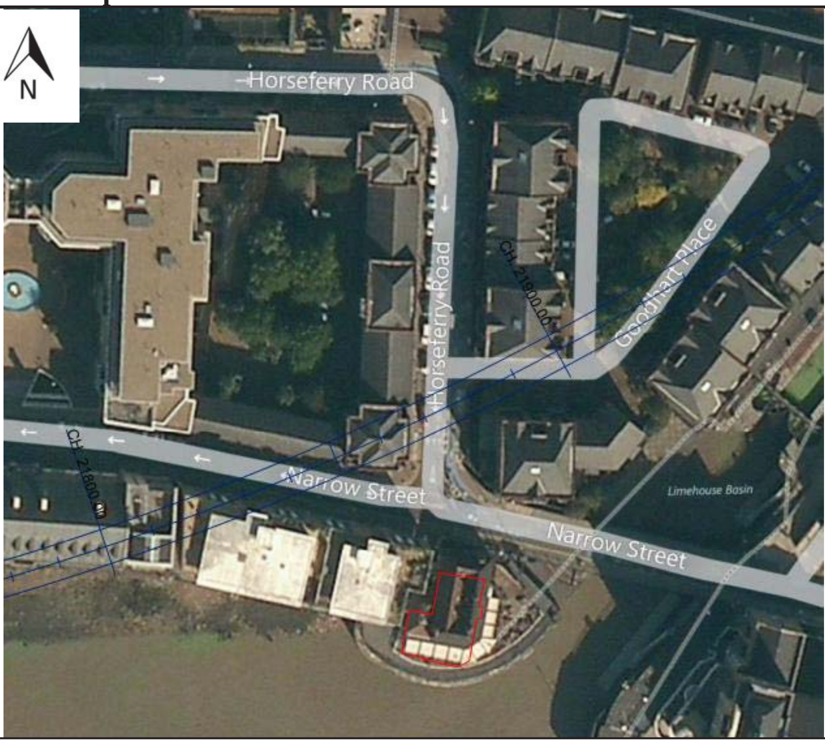
***Condition sensitivity score is therefore assessed to be zero.***

| Summary of results | |
|---|---|
| **Scoring** | |
| **Structural sensitivity score** | 1 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |
| **Recommendations** | |
| The total score attributed to this building is less than **2**. Ground movement will not cause the structural or heritage significance of this building to be compromised, and therefore it is not proposed that this building will be taken forward for further assessment.<br><br>It is understood that some works are being planned for the building; the nature and timing of these works in relation to the Thames Tunnel programme should be confirmed to assess any implications. | |

# Listed building assessment

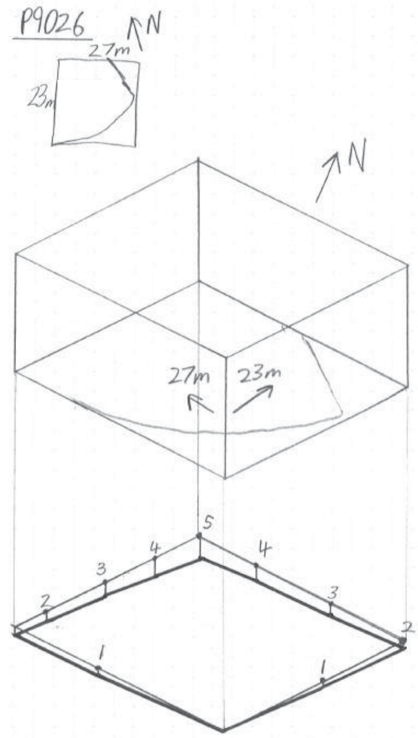
| Building information | |
|---|---|
| **Building reference** | Z3347 |
| **Building name / address** | British Waterways Custom House, |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 36263 80795 |
| **Ground level (mTD)** | +105.0 to +106.5 |

**Location plan**




Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

Custom House, now ‘The Narrow’ restaurant, is a Grade II listed building dating from approximately 1905 to 10 and built by British Waterways. It is a two storey, red brick building of a vaguely Neo-Classical design, which has six bays to the east façade with a splayed corner bay and a three bay return to the south façade. The building is set down from road level, at the corner of the Thames and the Limehouse Basin entrance.

The exterior shows rusticated stucco quoins, plinth and plat band, and there is an eaves cornice below the hipped tiled roof with modillion brackets. The windows are 6-over-6 timber sashes under flat brick arches for the most part to the east façade with narrower windows on the return. The entrance doorcase comprises an enclosed porch with pilasters and a segmental curved pediment. The door itself has a surround with architrave and a transom window above. To the north façade, which is partially obscured by the road level, is a lift with a concertina mechanism which is used to load goods from street level to the upper storey of the building.

Custom House has been extended, with a modern glazed lean-to conservatory which wraps around both façades, starting just to the west of the main entrance porch. There is also a modern extension to the west of the original building, a single storey brick structure with a tile roof and a long rectilinear rooflight.

To the ground floor there are few remaining original heritage features, the whole interior of this floor having been fitted out to accommodate the restaurant use. However, there are fireplaces, and some cornicing. The eastern timber stair is original, and leads up the first floor. A stair to the western end is a modern insertion. To the first floor, most rooms have lost their heritage features and have simple finishes. However, one room which appears to have always been a principal room retains some features including a fireplace and some wainscoting, as well as timber panel doors.

| Structural description and walkover observations | |
|---|---|
| The building has two storeys; the original house is broadly rectangular in plan and there is a single storey extension to the west side. The older part is of traditional masonry construction while the extension has masonry walls with a timber roof. The roof comprises two main trusses and a long raised rooflight.<br><br>Both the extension and the main building have pitched tiled roofs. There are three chimney stacks on the latter.<br><br>At the rear (south) of the building there is a single storey ‘conservatory, which is glazed with a fabric roof. This wraps around the rear of the building and part way down the east side.<br><br>The building is set down from the road at the front – steps at the side lead down to the entrance and to the external river walkway.<br><br>The main entrance is timber. It has a hooded porch and is offset from the centre in the east elevation.<br><br>The main building and conservatory have stone flags on the floor, with the same finish also continued on the river walkway; the extension has wooden finishes on the floor.<br><br>Internally there are two freestanding columns – boxed in, and loadbearing walls.<br><br>There are two staircases to first floor – at the rear a timber stair is constructed within the angle of the building, leading into the main rear room above.<br><br>A straight, older, timber flight leads up directly from the main side entrance.<br><br>At first floor there are a number of smaller rooms – a kitchen, stores, staff w.c. and changing rooms - in addition to the main room located at the back of the building.<br><br>Floors on the upper level are timber; the boards are seen to span both front to back and side to side in the various rooms.<br><br>A few minor cracks were noted in the walls and ceilings. Overall the building is in good condition in particular at ground floor in the public spaces.<br><br>Externally the brickwork is also generally in good condition although there is some cracking and brick spalling in the window heads.<br><br>The hip to the roof on the canal side appears to be in poor condition.<br><br>There is no cellar and details of the foundations are not known. While a building of this size and age would be expected to be on shallow footings it is possible that the riverside location may impact on this. It is proposed that details are requested from the contact at British Waterways. | |
| **Condition** | Fair. |
| **Assumed foundations** | Likely to be shallow strips/pads based on the age of the building but proximity to the river may suggest piles at the rear associated with the walkway. |
| **Façade material** | Brick. |
| **Internal support system (i.e. superstructure)** | Generally load-bearing masonry, two columns also identified in the restaurant area. |
| **Heritage** | The interesting riverside structure; timber pedimented doorcase; internal fireplaces and cornicing; original timber stair to the east end of the building. |

# Building photographs

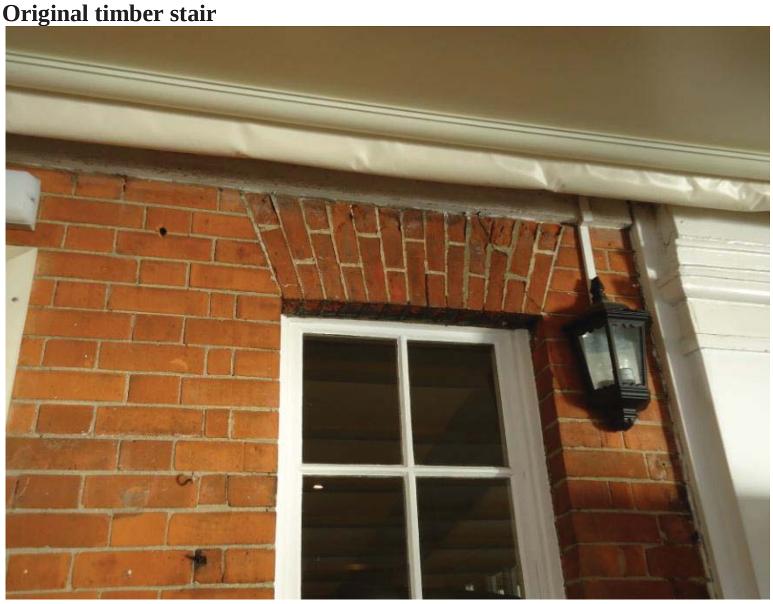
**Exterior with pedimented doorcase**

**Exterior showing lean-to extension**

**Roadside elevation with lift**

**Original timber stair**

**Example of retained fireplace**



**Brick arch with cement mortar and some brickwork failure**

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +48.1mTD.
Excavated diameter: 8.8m.
Closest shaft: King Edward Memorial Park foreshore shaft, located approximately 660m west-south-west – design indicates unlikely to influence ground movement in the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

Thames Tunnel is proposed to be constructed within the Chalk Group. The approximate expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +105.0mTD to +106.5mTD.
Top of London Clay: +101.0mTD.
Top of Lambeth Group: +92.0mTD.
Top of Thanet Sand: +73.0mTD.
Top of Chalk Group: +62.0mTD (13.9m above proposed tunnel centreline level).

Review of boreholes SR2031 and SA1038 (located approximately 130m south-west and 150m north-west respectively) and BGS boreholes TQ38SE2325 and TQ38SE2329 (located approximately 30m north-west and 80m north-east respectively) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions. However the log for borehole SR2031 notes a 0.5m drop in the casing through the Lambeth Group and several assumed zones of core loss through the Chalk Group.

**Results**

Settlement contours generated at assumed base slab (1m below ground level) +104mTD.


As shown above the building crosses the 2mm settlement contour.

Analysis of three key façades selected from the GIS model, assumed a building height of 6m on shallow foundations with and without a basement (4m bgl and 1m bgl respectively).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.002% and maximum settlement of 5mm were obtained for the building when modelled without a basement (1m bgl).

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The structure is generally in good condition; movements are calculated to be small and the strains are also likely to be low. It is therefore considered that the proposed TT construction will have minimal impact on the building.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

The majority of the heritage features of this building fall within the calculated 1mm to 2mm settlement contours; these include the timber stair and the river façade of the building with pedimented timber doorcase, timber eaves cornice, sills, band and quoins.

These features are not sensitive to this level of settlement and strain, and are unlikely to be damaged by the Thames Tunnel works.

***Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

The building is generally in fair condition. There has been some tile replacement with inferior tiles to the roof, and in areas where mortar joints have been pointed with cement mortar there has been some erosion and faliure of brickwork and minor cracking. The brickwork maybe be sensitive to settlement, and the low movements calculated may cause some slight flaking or additional cracking to the bricks.

***Condition sensitivity score is therefore assessed to be 1.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 1 |
| **Damage category** | 0 |

**Recommendations**

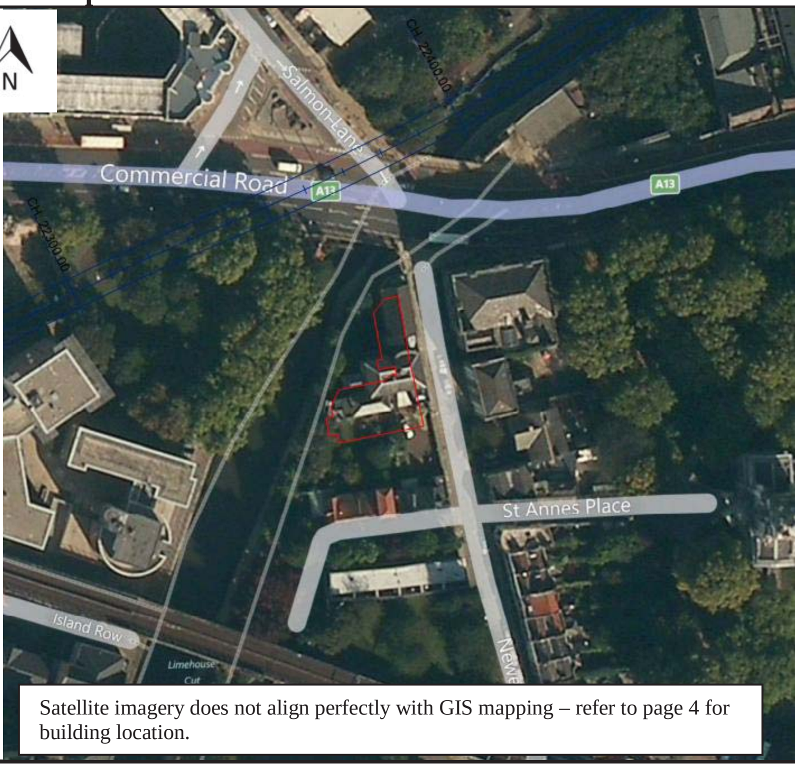
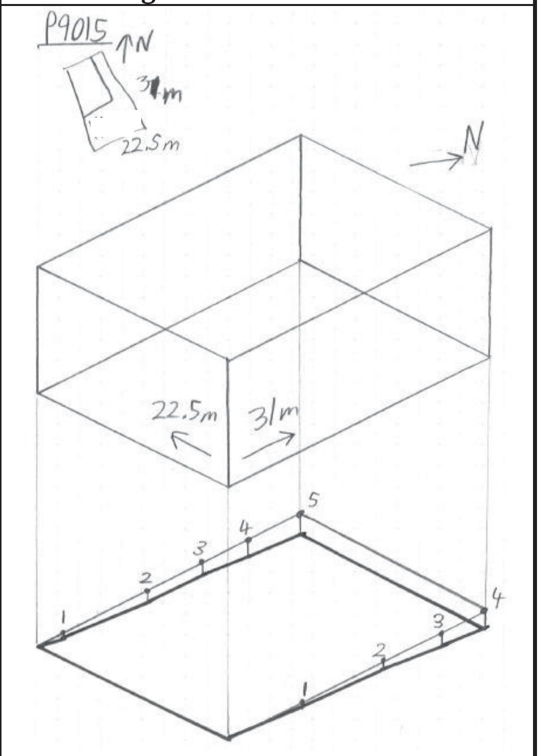
The total score for this building is 1.

The heritage features of this building are not sensitive to movement, and although the structure and condition may experience some slight deterioration due to the tunnelling works, this is anticipated to be minor and easily repairable.

Therefore this building is not judged to require further assessment or mitigation during the works, although a condition survey is recommended to ensure that the building has not deteriorated further before the start of tunnelling, and to enable monitoring of its condition throughout the works.

# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z3650 |
| **Building name / address** | British Sailor’s Society, E14 7HR |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 36675 81060 |
| **Ground level (mTD)** | +106.5 to +107.4 |

| **Location plan** | **Isometric ground movement sketch** |
|---|---|
|  |  |



Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.



**Building description (including excerpts from English Heritage listing, where appropriate)**

No inspection has been carried out to date. The English Heritage Listed Building description is quoted verbatim as follows:

*“Early C19. Formerly a sea training establishment for boys. Yellow brick, roof not visible. Rusticated stucco blind arcade of 5 bays with entrance in centre built forward from 3 storeys, 3 windows, (2 blind) building with 5 windows on return (2 on bow). Recessed sashes with glazing bars. Said to be associated with the family of Lord Nelson.*

*No 2, with Nos 11 to 23 (odd) form a group with the Garden Wall to former St Anne's Rectory, Limehouse Town Hall, St Anne's Parish Church, Churchyard Walls, Railings, Gates, Gate Piers and War Memorial, Commercial Road, and the Limehouse Church Institute, Three Colt Street.”*

The interior of this building is said to contain a historic basement swimming pool. This is understood via a photograph on the internet, to be of shallow, partially-sunken construction.

| **Structural description and walkover observations** | |
|---|---|
| No inspection has been carried out to date. The following has been inferred from a virtual walkover survey and other available information:<br><br>Likely to be loadbearing masonry with timber floors. Pitched roof with timber trusses, | |
| **Condition** | Not inspected. |
| **Assumed foundations** | Single basement on shallow footings. |
| **Façade material** | Loadbearing brick. |
| **Internal support system (i.e. superstructure)** | Loadbearing brick, possibly with iron beams for longer spans; timber floors. |
| **Heritage** | Not inspected, taken from Listed Building description: Exterior recessed sashes; interior said to contain historic swimming pool in the basement. |

## Building photographs

NOT USED

## Ground movement analysis

### Tunnel and shaft details

Thames Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +47.5mTD.
Excavated diameter: 8.8m.
Closest shaft: King Edward Memorial Park foreshore shaft, located approximately 1,130m south-west – design indicates unlikely to influence building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

### Ground conditions

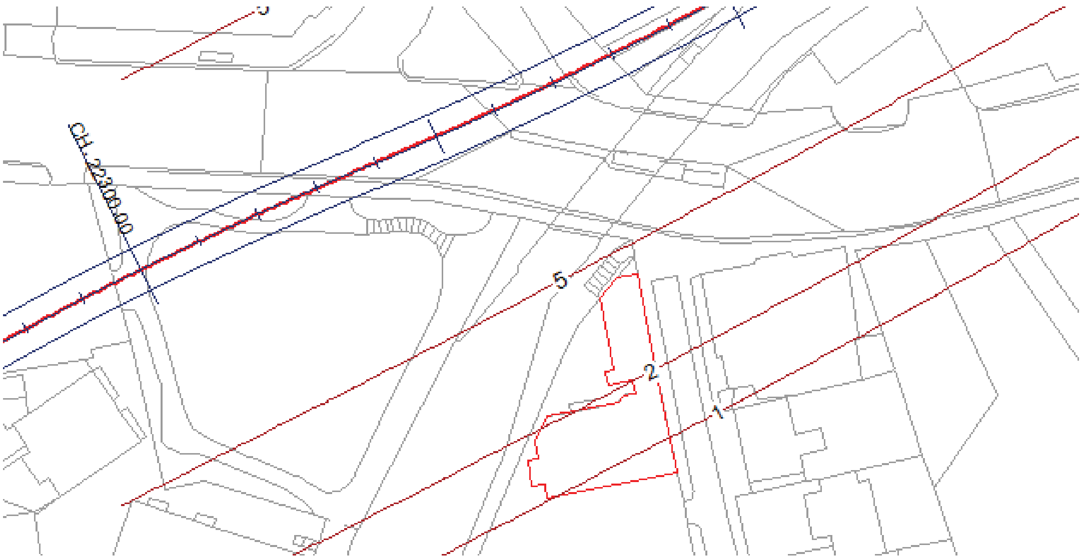
Thames Tunnel proposed to be constructed through the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +106.5mTD to +107.4mTD.
Top of London Clay Formation: +99.5mTD.
Top of Lambeth Group: +86.5mTD.
Top of Thanet Sand Formation: +68.5mTD.
Top of Chalk Group: +55.0mTD (7.5m above proposed tunnel centreline level).

Review of borehole SR3011 (located approximately 60m north-west) and BGS borehole TQ38SE616 (located approximately 75m south-west) does not indicate any geological features such as scour that would require a change in current ground loss assumptions. However borehole SR3011 does show several zones of assumed core loss within the Chalk Group.

### Results

Settlement contours generated at +102.5mTD approximate base slab level assuming a basement to 4m below ground level;




As shown above the building sits above the 2mm and 1mm settlement contours.

Three key façades were selected from the GIS model. They were analysed as a 9m high structure, with shallow foundations and a basement (foundations 4m bgl).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.005% and maximum settlement of 4mm were obtained for the structure.

Interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

## Interpretation of impact

**Structural assessment and discussion**

Small calculated settlements, no significant distortion. Façades appear to have multiple windows resulting in them being potentially more accommodating to movement.
Minor cracking could result in serviceability issues for the swimming pool.

**Heritage features sensitivity discussion**

This building has not been inspected. In light of the Listed Building description, sensitive features may include recessed sash windows, and the possible presence of the historic basement swimming pool.

The known features are unlikely to be sensitive to the levels of settlement calculated. However, the yet to be confirmed basement swimming pool may be sensitive to very small movements, and minor cracking could have a severe impact on this element.

**Condition discussion**

Not inspected.

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

In light of the desk based evidence, the total score is anticipated to be 1.

This building is unlikely to be affected by the calculated movements, however an inspection is required to confirm the presence of the basement pool and the current condition.

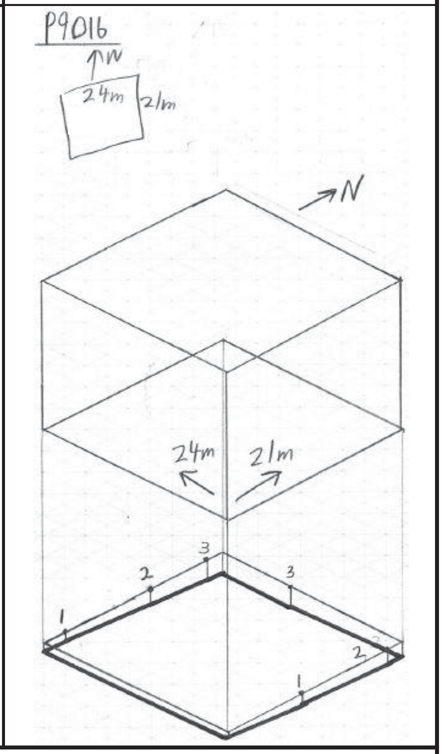
# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z3904 |
| **Building name / address** | Limehouse Town Hall, E14 7HA |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 36702 81079 |
| **Ground level (mTD)** | +107.1 to +107.8 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

Limehouse Town Hall is a Grade II listed public building on Commercial Road in Tower Hamlets. It dates from 1879 and was designed by A & C Harston.

The Commercial Road façade has five bays and two storeys, faced in white Suffolk brick and Portland stone. There is a shallow central entrance porch with a portico, which is supported on paired granite columns with stone composite capitals. This central bay is surmounted by a pediment. There are rusticated stone quoins to the ground floor and a stone cornice, which runs across the façade between the ground and first floors. All of the round arched windows on the front façade are either casements or sashes. All have archivolts springing from stringcourses at either level and the façade as a whole is topped with a stone capped parapet. This is also true of the side elevations although these are only three bays wide. There are another three bays set back from the 'formal' side bays which are significantly simpler in design, in brick with rectilinear fenestration.

The majority of the original interior details have been lost over subsequent refurbishments and upgrades. The built-in safe still remains on the ground floor and many of the doors and window surrounds and a few decorative plaster corbels survive. The grand central staircase remains as do the intricate iron balusters, which are also found on the second floor landing and on the side staircase. There is a large leaded glass rooflight above the stair hall. The tile floor in the entrance is also likely original. The plan form appears to be largely original.

The main committee room at the front on the first floor seems to be the one of the best preserved spaces and retains many of the original features. There are double pilasters between the windows supporting a decorative plaster cornice as well as large carved corbels supporting a small balcony above the entrance. The balcony has wrought iron balusters of a similar design to those of the staircase and they have similarly been capped with wood handrails. This is also true of the viewing gallery along one side of the space.

| Structural description and walkover observations |
|---|
| The building comprises external load-bearing masonry walls (exposed brickwork with stone dressings). Internal walls are also load-bearing masonry of varying thickness.<br><br>The floors are predominately timber boards and joists and appear in fair condition for a building of its age.<br><br>There is a storey height basement below the west half of the building with a crawl space existing below the east half.<br><br>There are two cantilever stone stairs; one ‘feature’ and one ‘back of house’.<br><br>The ‘back of house’ stair has had modern intervention with steel beams added to support cantilevered ‘stone’ landings and diagonal braces added to provide restraint to handrails. The ‘stone’ landing at second floor has a crack that penetrates the full depth of the ‘stone’ (possibly explaining why a beam was added to provide additional support). Over the landing the ceiling has collapsed due to water ingress from the roof over. A vertical crack can be seen running the full height of the stair (west wall).<br><br>The ‘feature’ stair is in good condition but has similarly had modern intervention in the form of steel beams supporting the flights and landings. A decorative brace provides restraint to the handrails. The plaster finishes to the internal wall of the stair shows significant water damage coming from failed waterproofing to the roof over. There is a glazed lantern set into a timber flat roof over.<br><br>The roof to the main hall is understood to comprise a series of six queen-post trusses supporting the ceiling structure. It was reported that previous water damage had been repaired (including repairs to the first floor joists) in the north-east corner.<br><br>A smaller pitched roof exists over the south-east rooms and a flat roof above the south-west stair and toilet block. It was reported that repairs to the roof were due to be undertaken in the imminent future.<br><br>An external steel escape stair was added to the north-east corner of the building. |

| | |
|---|---|
| **Condition** | Poor. |
| **Assumed foundations** | Assumed to be shallow ground bearing strips below basement. |
| **Façade material** | Load-bearing brickwork with stone dressing. |
| **Internal support system (i.e. superstructure)** | Load-bearing masonry walls. Floors are predominately timber boards and joists with the exception of cantilevered stone stair landings and balconies. |
| **Heritage** | Good quality brick façade with decorative stonework; internal floor finishes, both timber and tile; cantilevered stairs with wrought iron balustrades; plasterwork to reception hall and main hall. |

# Building photographs

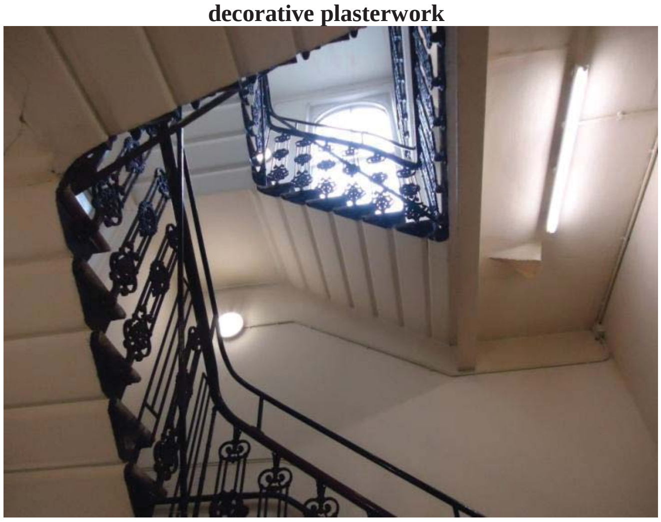
**Front (northern) elevation**

**Side (eastern) elevation showing scaffolding**

**View of ground floor hall and main stair with wrought iron banisters**

**View of the main hall, showing bombe balconette and decorative plasterwork**

**Damage from water ingress to the plasterwork of the main hall**



**Secondary stair, with some minor cracking**

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +47.5mTD.
Excavated diameter: 8.8m.
Closest shaft: King Edward Memorial Park foreshore shaft, located approximately 1,160m south-west – design indicates unlikely to influence ground movement at the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

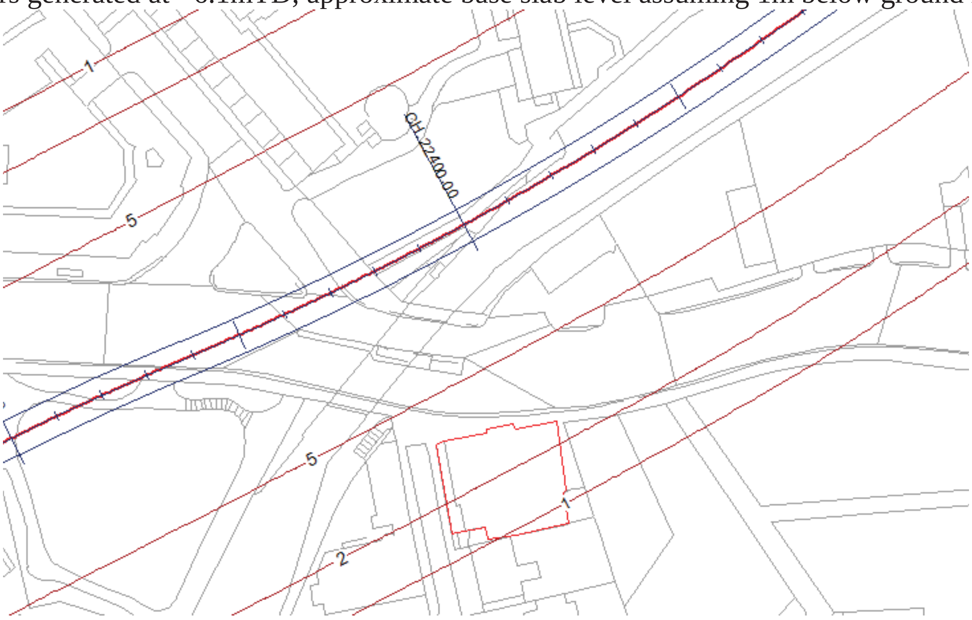
The Thames Tunnel is proposed to be constructed within the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +107.1mTD to +107.8mTD.
Top of London Clay Formation: +99.5mTD.
Top of Lambeth Group: +86.5mTD.
Top of Thanet Sand Formation: +68.5mTD.
Top of Chalk Group: +55.0mTD (7.5m above proposed tunnel centreline level).

Review of borehole SR3011 (located approximately 80m to the west) and BGS borehole TQ38SE616 (located approximately 100m south-west) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions. However borehole SR3011 does show several zones of assessed core loss within the Chalk Group.

**Results**

Settlement contours generated at +6.1mTD, approximate base slab level assuming 1m below ground level;




As shown above the building crosses the 2mm and 1mm settlement contours.

Two key façades were selected from the GIS model. Analysis was carried out for building heights of 6m and 10m, the building was assumed to be on shallow foundations and analysis was carried out for the building with and without a basement (foundations at 4 m bgl and 1m bgl respectively).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.005% and maximum settlement of 4mm were obtained for the building. The maximum settlement is marginally greater where there is no basement and the maximum tensile strain increases slightly for a lower building.

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section below.
***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

Despite the presence of some relatively sensitive structural features, e.g the cantilevered staircases, the calculated movements are very low, it is not anticipated that the impact of these movements will be of significance to the overall building structure.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

There are a number of heritage features which could be sensitive to settlement. Externally, the decorative stonework is fine-jointed and susceptible to cracking. Internally, the cantilevered stairs are sensitive to movements, and the plasterwork of the main hall including pilasters and cornices may show some deterioration.

The level of movement calculated will have minimal effect on the exterior features. However, there is some risk of minor cracking to the plasterwork, and a worsening in the small crack already visible to the cantilevered stairs.

***Heritage sensitivity score is therefore assessed to be 1.***

**Condition discussion**

The building is generally in poor condition, lack of maintenance to the roof has resulted in long term water exposure to the masonry walls and internal finishes. Existing visible damage is generally caused by this ingress of water. The works may cause some further deterioration in areas where brittle finishes have already been damaged by water ingress.

***Condition sensitivity score is therefore assessed to be 1.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 1 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 2.

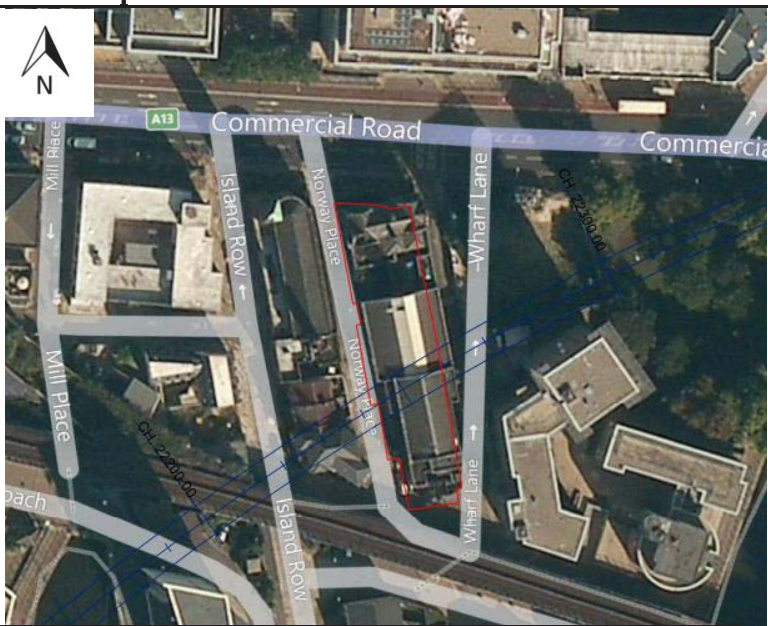
The structure of Limehouse Town Hall will not be compromised by the movements calculated in association with the Thames Tunnel works. However the condition of the building may deteriorate; the heritage features are sensitive to this condition deterioration and in their own right, particularly the plasterwork and cantilevered stairs.

This building will not require mitigation or further assessment as part of the damage assessment. However, it is advised that a defect survey be carried out prior to commencement of works, to enable any further cracking and deterioration to be noted.

# Listed building assessment

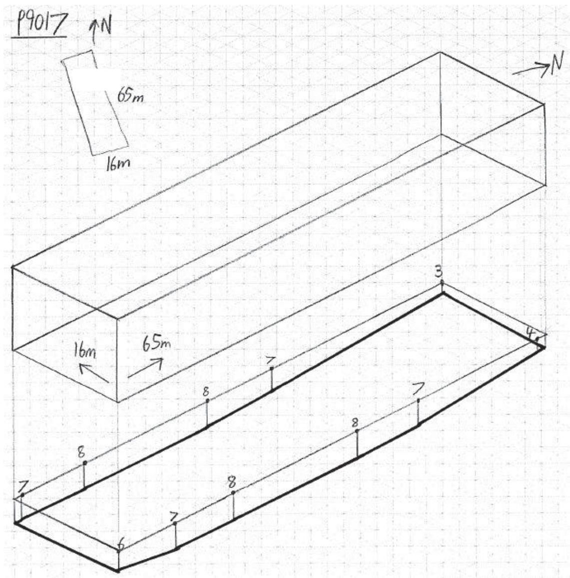
| Building information | |
|---|---|
| **Building reference** | Z3930 |
| **Building name / address** | Limehouse District Library, E14 7HS |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 36557 81081 |
| **Ground level (mTD)** | +108.1 to +108.5 |

**Location plan**




Satellite imagery does not align perfectly with GIS mapping – refer to page 5 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

The Limehouse District Library (originally called the Passmore Edwards Library) is a Grade II listed building on Commercial Road in Tower Hamlets. It was designed in 1900 by Messrs Clarkson architects and is made of Portland stone and yellow brick with lead roofs.

The façade is in a Neo-Renaissance style with a rusticated stone ground floor, tall, round arched windows and vermiculated stone quoins and window and door surrounds on the flanking, slightly projecting bays. The entire façade measures five bays and has a stone cornice between the ground and first floors. At first floor level, the central three bays are in dressed stone with rectilinear window openings and mullions and the flanking bays are in yellow brick with stone window surrounds. There are engaged stone pillars on either corner of the flanking bays supporting a stone cornice. Above this is a stone-coped Flemish gable with tripartite, rectilinear windows with stone surrounds and mullions. The side façades are of a simpler design. The façade facing onto Norway Place is eleven bays long. The first three bays in the return of the front façade are in a similar style to the front and have a rusticated stone ground floor with tall, round arched windows sitting under a stone cornice with yellow brick above. The first floor windows again are rectilinear with stone surrounds and mullions and there is one stone pilaster to the end of the third bay. There is a smaller Flemish gable above. The four bays of this façade are in yellow brick, with tall round arched windows and with the fourth bay containing a door. This section is only one storey high. The remaining four bays are two storeys high but have a single row of twin rectilinear windows with stone sills and lintels and central single-brick pilasters. Each of these bays is defined by full height brick pilasters with a stone stringcourse and capping running the length of the wing. The façade facing Wharf Lane is of plain yellow brick and is asymmetrical in its massing.  The windows are very simple, rectilinear openings with stone lintels.

The interior retains many of its original features. There are two basements, only one of which was accessed at the time of the inspection; this basement retains iron columns. From the hallway, the main staircase has stone treads and risers with cast iron balusters and timber handrail. The majority of principal spaces are double height and have clerestory windows and decorative plasterwork and columns. The internal doors have heavily moulded wood surrounds; several with impressive wood pediments above. The interior is dominated by the central space which sits under a double height, truncated barrel-vault ceiling with large rooflight. There is a first floor gantry along one side and the back wall of the space is decorated with a huge fresco called "Limehouse Reach", painted by Claire Smith in 1987 in the style of William Blake. Other internal features which remain include fireplaces in some of the offices, the plaster cornicing in many of the rooms, internal glazed partitions, and the rooflights to several of the first floor rooms.

**Structural description and walkover observations**

**Internal**;
The building has two basements (front and rear) linked by a crawl space (duct run).

The front basement (of traditional construction) comprises brick walls (not earth retaining) supporting a concrete floor slab with shallow downstand beams. The basement structure is in fair condition.

The rear basement is of (more modern) reinforced concrete construction. Concrete stairs lead down. A central column and downstand beams can be seen. Hairline cracking to the concrete floor slab is widespread. On the entrance stair to the rear basement the floor over (first floor) is of clay-pot floor construction and signs of water damage are visible in the area of the internal cast-iron downpipe.

The building can be divided in to four sections; a three storey accommodation block of load-bearing masonry and timber floors, a double height large open room with vaulted roof and balcony, a two storey framed accommodation block and finally a pair of two storey toilet blocks flanking an enclosed courtyard.

At the rear of the building there is a two storey brick extension housing toilets. Multiple cracks can be seen to all walls. Cracks typically run diagonally and are 5-10mm in width and consistent with previous ground movement. There has been a previous attempt to make the crack weather-proof but structural repairs are not evident. There is also a vertical crack to the rear (courtyard) wall linking the two flanking toilet blocks. A tell-tale has been fixed to this crack. Similar cracking exists at first floor level. An approximately10mm crack is visible at the junction of the toilet block to the main building (suggesting the toilet block has tried to rotate as a rigid body away from the main building).

A two storey reinforced concrete framed structure links the toilet blocks to the main library space. Hairline cracking can be seen to the sides of the downstand beams over the column heads. The roof structure comprises steel/iron trusses with timber purlins and timber boarding. A small section of the roof structure could be seen through a damaged ceiling panel (damaged by water). Locally to the water damaged ceiling there was water staining to the roof suggesting failure of the roof covering. The remainder of the roof structure could not be seen but on the evidence of widespread water damage to ceiling finishes it is reasonable to assume the roof is in poor condition throughout.

The main library space is a two-storey open space with a balcony/gallery to one side. The balcony is supported by (assumed) steel posts clad with timber decoration). The roof structure could not be seen but the ceiling only showed small areas of water staining. In the stairs (east wall) leading up to the gallery cracking to the external wall can be seen. Significant water damage can also be seen to the roof over in these locations.

In the front (north) three storey section, the building comprised load-bearing masonry walls with timber floors. The floors were carpeted and with a lath and plaster ceiling preventing inspection of the floor structure. In one location the ceiling finishes had collapsed exposing the timber joists and an iron beam. The roof is predominately pitched with some areas of flat (felted) roof surrounding glazed roof lanterns. Both the tiled roofs and the flat roofs were in very poor condition.

| | |
|---|---|
| **External**; The stone and brick façades to the original (north) section of the building are in fair condition for a building of this age.<br><br>Progressing down both long elevations (Wharf Lane & Norway Place) vertical cracks can be seen at regular intervals increasing in severity as you progress south.<br><br>Widespread vegetation growth at the roof level has dislodged a number of coping stones.<br><br>At the rear of the building (south), significant cracks can be seen. These penetrate the full thickness of the masonry. | |
| **Condition** | Very poor |
| **Assumed foundations** | Shallow ground bearing strips/pads at basement level |
| **Façade material** | Stone to the northern elevation, brick with stone dressings to other elevations |
| **Internal support system (i.e. superstructure)** | Mix of load-bearing masonry and timber floors at the front/north (with iron columns in basement); masonry walls and clear span roof structure; reinforced concrete frame and concrete floor slabs on load-bearing masonry to the latter toilet extensions at the rear/south. |
| **Heritage** | Stone façade to front elevation; main internal stair; timber doors surrounds and original windows; plasterwork to principal rooms; double height spaces, including central room which holds a large fresco; rooflights and cupolas. |

## Building photographs

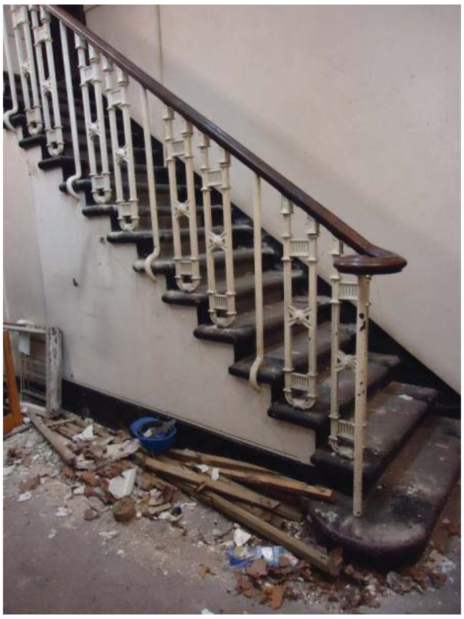
**Main (north) elevation**


**Side elevation showing entrance to Juvenile Library**

**Example of vegetation growth to the southern end of the building**

**Main library space with fresco and side gallery, signs of water ingress**

**Damaged decorative features, and failure of lathe and plaster**



**Main stair in neglected condition**

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Chalk Group and Thanet Sand Formation.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +47.8mTD.
Excavated diameter: 8.8m.
Closest shaft: King Edward Memorial Park Foreshore Shaft, located approximately 1,030m south-west – design indicates unlikely to influence building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

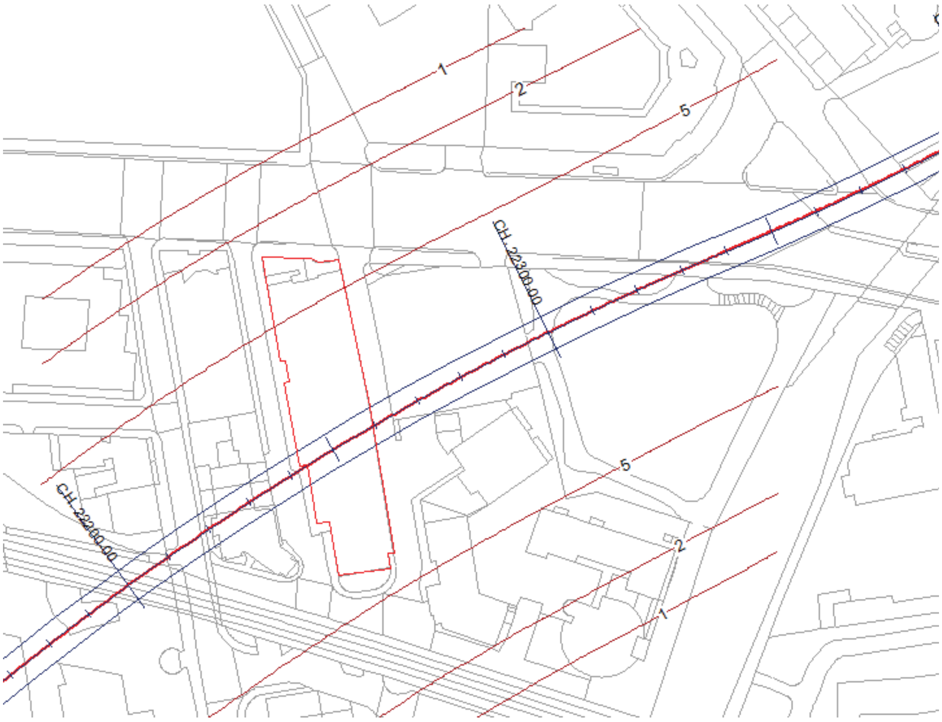
The Thames Tunnel is proposed to be constructed within the Chalk Group and Thanet Sand Formation. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +108.1mTD to +108.5mTD.
Top of London Clay: +100.0mTD.
Top of Lambeth Group: +87.5mTD.
Top of Thanet Sand Formation: +69.0mTD.
Top of Chalk Group: +55.5mTD (7.7m above proposed tunnel centreline level).

Review of borehole SR3011 (located approximately 40m to the east) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions. Although it is noted that the borehole does show zones of assumed core loss within the Chalk Group.

**Results**

Settlement contours generated at +104.1mTD, approximate base slab level assuming a basement and shallow foundations 4m below ground level;




As shown above the building straddles the tunnel and extends across the 5mm settlement contour to the north.

Analysis of five key façades selected from the GIS model, assumed a building height of 6m or 14m, with a basement and shallow foundations (foundations at 1mbgl and 4mbgl respectively).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.001% and a maximum settlement of 8mm were obtained for the building (settlement remainded the same irrespective of building height and there was a minor increase in maximum tensile strain with increase in base slab depth).

The building damage category has been assessed based on Burland (1995), which has been validated for load bearing masonry structures. Limehouse Library does not completely fall within this category, as part of the structure consists of a reinforced concrete frame. Therefore it is considered that for this structure additional weight should be given to the structural assessment, considering the absolute movements applied to the structure, as discussed in the interpretation of impact, below. As the overall score for this building exceeds 3, and further mitigation will need to be considered in any case, it is not considered necessary to refine the ground movement assessment further at this stage.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The building is a long linear block combining four structural forms of construction. Long masonry walls with very few openings run the length of the building. This makes the building susceptible to damage from ground movement. This has been proven with a number of cracks (of varying width and severity) along the length. The existing damage is focused to the rear where the two storey toilet blocks are showing severe structural cracking.

The building spans the tunnel resulting in maximum settlement just to the south of the centre of the building. The impact of this calculated settlement is that some existing cracks will widen.

***Structural sensitivity score is therefore assessed to be 1.***

**Heritage features sensitivity discussion**

The building spans over the tunnel alignment, and therefore the impact will be greater on the heritage elements to the central sections of the building. The front and rear façades, and the main stair hall and northernmost rooms are unlikely to be sensitive to the levels of movement calculated in these areas.

The central section of the building holds the very sensitive main library, with its mural, gallery, and long rooflight. There are also cupolas and rooflights throughout this section of the building, as well as plaster, both decorative and standard cornicing. This area will be sensitive to the calculated level of settlement, and there may be some minor cracking and other damage to plaster, paint and timber.

***Heritage sensitivity score is therefore assessed to be 1.***

**Condition discussion**

The condition of this building is very poor. Long term lack of maintenance has led to sustained water ingress and general failure of materials, which has damaged ceilings and floors, timber around windows and cupolas/roof lights. There has also been vegetation growth the front elevation and some rear portions of the building, exacerbating the water ingress and also causing cracking to brick and stonework. More generally, finishes internally are in a bad state with peeling paint and water damage.

The condition of the building will make Limehouse Library more sensitive to settlement, this being especially the case for the rooflights and cupolas where timber is rotting and may crack, and for the paint and plasterwork internally.

***Condition sensitivity score is therefore assessed to be 1.***

| Summary of results | |
|---|---|
| **Scoring** | |
| **Structural sensitivity score** | 1 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 1 |
| **Damage category** | 0 |
| **Recommendations** | |

The total score for this building is 3.

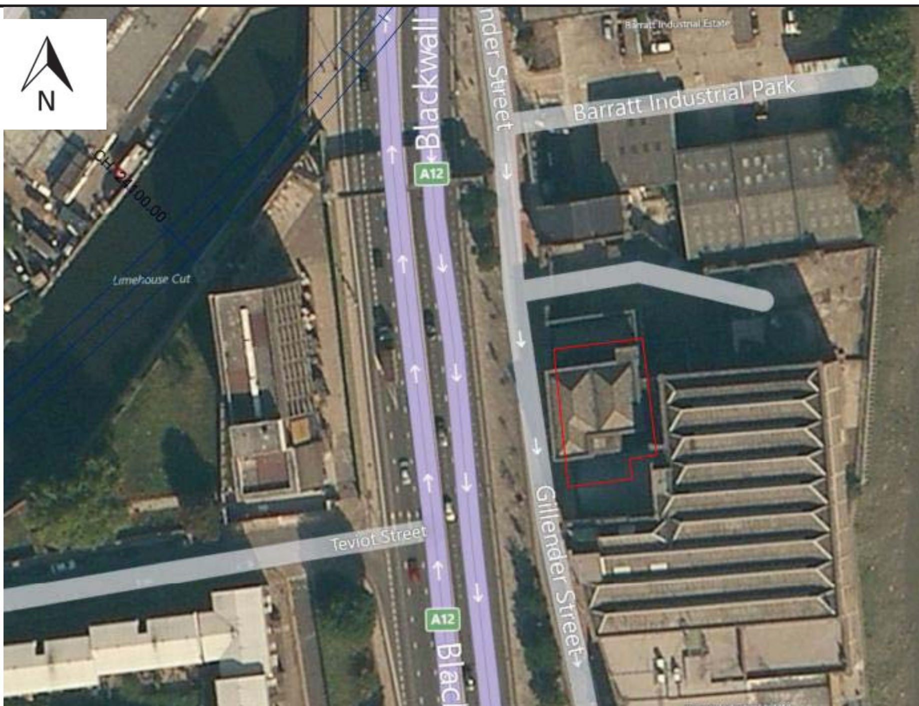
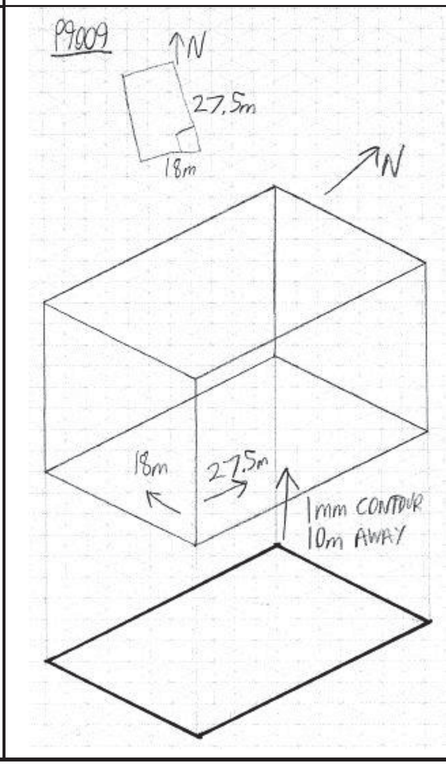
The condition of the building is very poor, affecting both the heritage and structure, and making the whole building more sensitive to movement. Particularly vulnerable are heritage elements to the centre of the building, and the structure is at risk of cracking. However the calculated settlements are not large and are not expected to change the damage classification.

Conservative inputs have been used to calculate ground movements, as such the settlements are expected to be less. Mitigation measures in the form of physical intervention (i.e. soil grouting, underpinning etc) are likely to cause more damage than what would be expected from the construction of the tunnel.

No further ground movement assessment is proposed.

# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z4332 |
| **Building name / address** | Dowgate Wharf, E3 3JX |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 38166 82078 |
| **Ground level (mTD)** | +104.8 to +105.5 |

| **Location plan** | **Isometric ground movement sketch** |
|---|---|
|  |  |



Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.



**Building description (including excerpts from English Heritage listing, where appropriate)**

No inspection has been carried out to date. The English Heritage Listed Building description is quoted verbatim as follows:

*"Dowgate Wharf P B Burgoyne & Co Ltd Warehouse. First half C19. Brick warehouse with heavy corbelled cornice and blocking course, part demolished for entrance. 2 storeys. Large window with glazing bars on top floor and smaller blocked windows on ground floor. Adjoins 4 storey portion with similar blocking course and cornice. Windows with flat arches set within brick arches.*

*The listed warehouses and associated buildings form a group on the east side of St Leonard's Street."*

| **Structural description and walkover observations** | |
|---|---|
| No inspection has been carried out to date. The following has been inferred from a virtual walkover survey and other available information:<br><br>Appears to be of loadbearing masonry construction. Due to it being a warehouse the internal structure is likely to be timber floors on cast iron or timber beams with cast iron columns. | |
| **Condition** | Not inspected. |
| **Assumed foundations** | Shallow foundations with possible single basement. |
| **Façade material** | Load-bearing brick. |
| **Internal support system (i.e. superstructure)** | Possible iron frame with timber floors. |
| **Heritage** | Not inspected, taken from Listed Building description: External heavy cornice to front façade. |

## Building photographs

NOT USED

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +45.2mTD.
Excavated diameter: 8.8m.
Closest shaft: Abbey Mills Pumping Station, located approximately 950m north-east – design indicates unlikely to influence the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

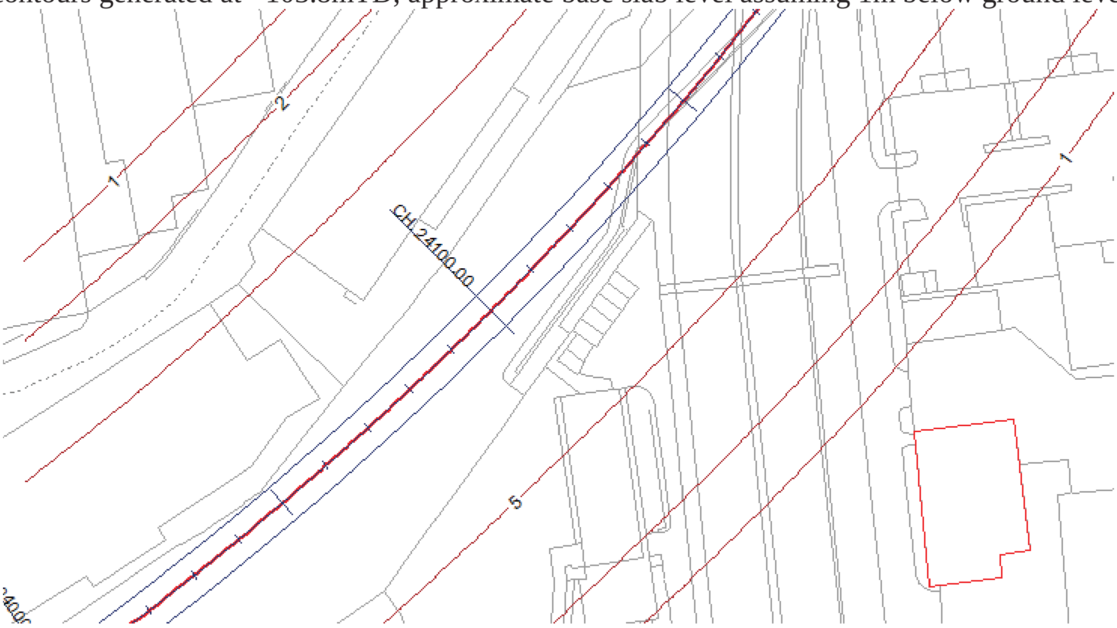
The Thames Tunnel is proposed to be constructed within the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +104.8mTD to +105.5mTD.
Top of London Clay Formation: +99.0mTD.
Top of Lambeth Group: +84.5mTD.
Top of Thanet Sand Formation: +69.5mTD.
Top of Chalk: +56.0mTD (approximately 10.8m above proposed tunnel centreline level).

Review of boreholes PR3006 (located approximately 305m south-west) and BGS boreholes TQ38SE885 A and B (located approximately 60m north) do not indicate any geological features that would require a change in the current ground loss assumptions. PR3006 shows 3.7m of assumed core loss in the Lambeth Group, described as 'Channel Sands' and numerous zones of assumed core loss within the Chalk Group.

**Results**

Settlement contours generated at +103.8mTD, approximate base slab level assuming 1m below ground level;




As shown above the building sits outside of the 1mm settlement contour that has been generated.

Two key façades selected from the GIS model have been analysed. The building was modelled at heights of 6m and 12m, with shallow foundations, with and without a basement (foundations at 4m bgl and 1m bgl respectively).

The results all fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain value of 0.001% and a maximum settlement of 0.5mm were obtained for the structure when modelled without a basement (foundations at 1m bgl), results were the same for building height of 6m and 12m.

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

## Interpretation of impact

**Structural assessment and discussion**

This building has not been inspected. It is outside of the 1mm contour and as such it is not expected that the construction of the tunnel will have any impact. Structural sensitivity is therefore 0.

**Heritage features sensitivity discussion**

This building has not been inspected. In light of the Listed Building description, sensitive features may include the heavy cornice to the front façade.

This feature is unlikely to be sensitive to the very low levels of settlement calculated.

**Condition discussion**

Not inspected.

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

In light of the desk based evidence, the total score is anticipated to be zero, and this building is unlikely to be affected by the calculated movements.

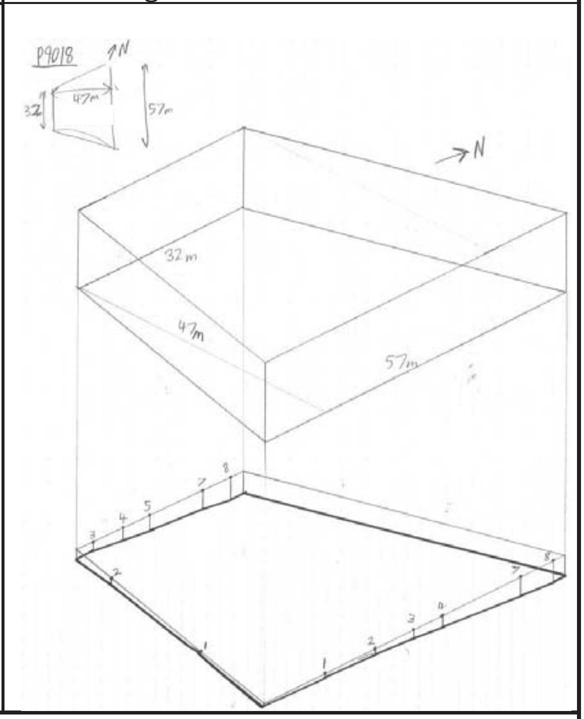
# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z9128, Z3604 |
| **Building name / address** | 777-783 Commercial Road including former Caird and Rayner Warehouse, E14 7HG |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 36769 81145 |
| **Ground level (mTD)** | +104.1 to +106.8 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

The former engineering workshop with associated office space located at 777–783 Commercial Road in Tower Hamlets, is Grade II listed. The sections of the building listed as 779-783 Commercial Road were built in 1896-1897 and the office block at 777 Commercial Road was designed by Marshall and Bradley in 1893-4. The building as a whole is formed of four blocks: the office or 'front' block', and the east, west and central blocks which are the former workshops.

The front (southern) façade is a three story, brick façade. The central and west blocks have a unified façade of an almost symmetrical layout of 9 bays wide with wooden sash windows. The windows in the first bay from the west are double the width of those in the majority of other bays. In the fifth and ninth bays, tall and wide round arched windows on the first and second floors sit under a gable capped in stone supported by full height brick pilasters. The east block is different in design and has pointed arch stucco window heads and a more regular and simpler fenestration pattern. The front (office) block has a few similar windows to the other two blocks but the majority are simple rectilinear windows of a smaller scale. Each building has large openings at ground floor level.

To the canal side, the building is seen distinctly as three blocks; east and west flanking blocks of five bays wide and a central block seven bays wide. The fenestration across the central and west blocks is of a consistent design and uses large, wide divided arched windows to both floors supported above a partially exposed lower ground floor.

The internal layout is open with two long galleried workshops running the depth of the building, in the central and eastern blocks. This depth of workshop with minimal supports was possible because of the rolled steel internal glazed frame, which carries extensively glazed steel-framed lantern roofs over the central and side aisles. The front block runs the length of the Commercial Street side of the building, also fronting the adjacent former sail-maker's loft.

The sail-maker's loft, in the west block, is listed in its own right, and dates from 1869. Built by William Cubitt and Company, with some alterations of 1894-6 by Caird and Rayner, the building is faced in brick with slate roofs, and is two storeys high plus a basement. Hidden behind the office range, the main visible elevation is to the Limehouse Cut, and has five bays with loading doors to both floors in the central bay. The other bays are articulated by cast-iron framed windows. There is a loading doorway to the sail-loft under a round arch.

The interior comprises a former warehouse to the ground floor, with the sail-maker's loft above. To the ground floor are timber posts under long cross heads, some with horizontal struts between the posts. The first floor retains queen rod roof trusses to the western half under the hipped roof.

**Structural description and walkover observations**

The building combines four structures (described below as the east, central, west and fronting blocks);

The 'fronting' block consists of three storey load-bearing masonry walls with timber floors and a pitched timber roof, all in generally poor condition (e.g. loss of roof coverings leading to severe water damage to roof trusses, timber floors and timber partition walls).

The west block (the sail-maker's loft) is a two storey timber framed structure (external masonry walls) with a basement under its full footprint. The basement has restricted headroom and comprises a cellular grid of masonry walls with small openings and timber joist and board floor. The timber floor at ground and first floor levels appears to be in reasonable condition given the general condition of the building envelope, but this is explained by the recent works to weather-tight this section of the building. A long crack was observed during the inspection at the northern end of the eastern masonry wall, and the he roof trusses were obscured by scaffolding and a working platform that had been installed to undertake the recent works.

The central block comprised a large three-storey open space with glazed pitched (steel truss) roof over. Braced steel galleries ran around three sides of the space at first and second floor levels. The steel sections are in fair condition with little significant corrosion. Sections of the glazed roof were missing. The original crane rails and hoists remain. It was reported that there are areas of basement below this central section but are inaccessible due to debris blocking the entrances. The floor slab was concrete.

The east block comprises a three storey block. The ground floor is largely a double height space. There is a step in the ground floor slab at the north end adjacent to the canal. Long vertical and diagonal cracks can be seen in this (north-east) corner of the building. Differing brickwork suggests this was rebuilt at some point (possibly following bomb damage – blast damage is shown to this section of the building, with adjacent buildings damaged beyond repair in the London County Council bomb damage maps). This end of the building is also only two storeys with a flat roof over and storey high parapet walls. The roof over the three-storey section is a post-war timber trussed rafter roof with timber purlins and timber boarding (assumed tiled over). Daylight could be seen through sections of the roof suggesting there are large sections of failed tiling. Nearly all windows are broken leaving the building fabric open to the elements. In the north-east corner a 2m by 2m section of the wall is missing.

| | |
|---|---|
| **Condition** | Very poor – this building is on the English Heritage Buildings at Risk register. |
| **Assumed foundations** | Assumed shallow strip footings at basement level (canal towpath level). |
| **Façade material** | Load-bearing Brick. |
| **Internal support system (i.e. superstructure)** | Mixture of load-bearing brick with timber floors; timber frame; braced steel galleries and concrete encased steel beams with concrete floor sat on masonry piers with arched openings. |
| **Heritage** | Industrial form and some remaining machinery; rare example of sail-maker's loft in London; queen-post truss in sail-maker's loft |

## Building photographs

Southern elevation to Commercial Road


Rear elevation to Limehouse Cut


View of queen-rod truss through scaffolding


General view of industrial interior

Example of retained machinery showing poor condition


Interior of office range in poor condition

## Ground movement analysis

| **Tunnel and shaft details** | |
|---|---|
| Thames Tunnel constructed within the Chalk Group.<br>Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.<br>Tunnel centreline level: +47.3mTD.<br>Excavated diameter: 8.8m.<br>Closest shaft: King Edward Memorial foreshore shaft, located approximately 1,240m south-west – design indicates unlikely to influence ground movements at the building location. | |
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

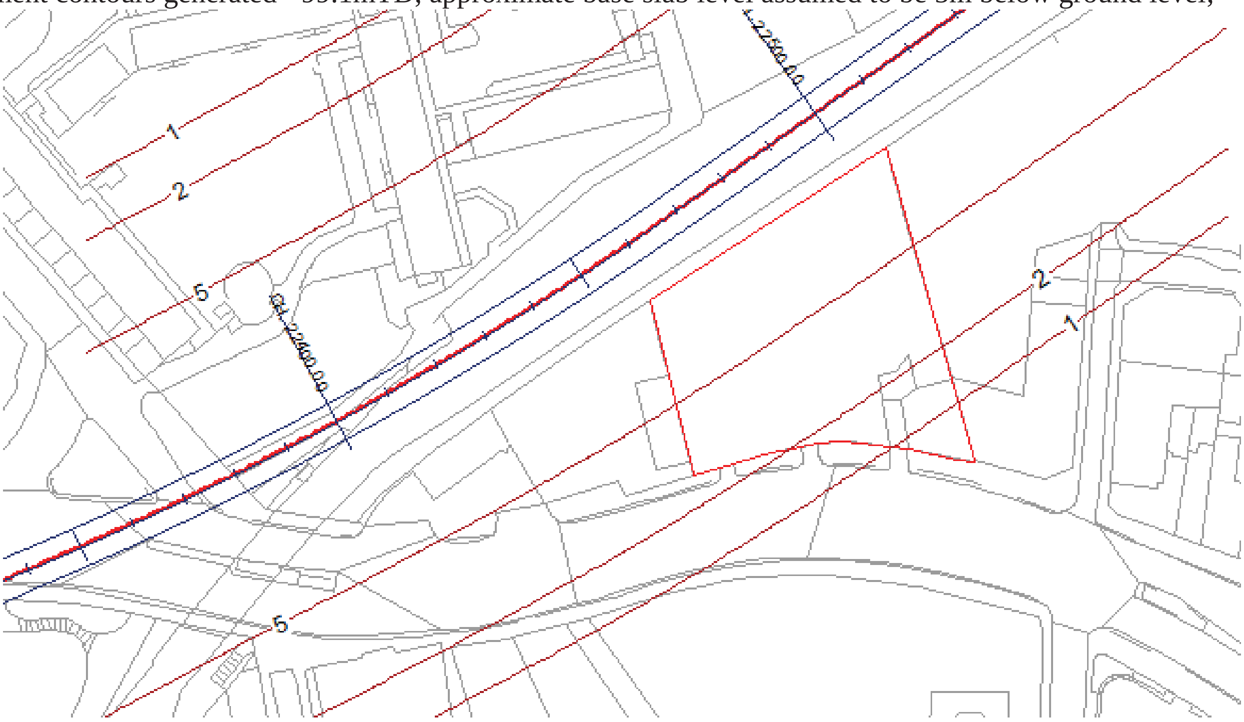
The Thames Tunnel is proposed to be constructed within the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +104.1mTD to +106.8mTD.
Top of London Clay: +99.5mTD.
Top of Lambeth Group: +86.0mTD.
Top of Thanet Sand: +68.5mTD.
Top of Chalk Group: +55.0mTD (7.7m above proposed tunnel centreline level).

Review of boreholes PR3010 and SR3011 (located approximately 155m north-east and 150m west respectively) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions. Although it has been noted (particularly in PR3010) that there are assessed zones of core loss in the Lambeth Group, Thanet Sand Formation and Chalk Group.

**Results**

Settlement contours generated +99.1mTD, approximate base slab level assumed to be 5m below ground level;




As shown above the building crosses the 5mm, 2mm and 1mm settlement contours.

Two key façades were selected from the GIS model. Analysis was carried out for building heights of 6, 9, 10 and 12m, with shallow foundations both with and without a basement (foundations at 1, 4 or 5mbgl).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.006% and maximum settlement of 8mm were obtained for the building when modelled as a 10m high structure with a 5m deep basement.

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The calculated ground movements are small and the pattern of settlement contours suggests that the building would respond as a single block, tilting from Commercial Road towards the canal. It is not anticipated that the impact of the settlement will be of significance. To the extent that movement does occur pre-existing cracks in the walls running north-south will open very slightly further.

***Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

Whilst this building is generally interesting due to its industrial form, and retention of machinery and the spaces associated with its former use, the main heritage significance lies in the sail-maker's loft. This loft is the only part of the building which is not in very poor condition, and although its condition isn't ideal it is wind and weather-tight.

The calculated movements are unlikely to cause any further damage to the sail-maker's loft. Other parts of the building may be more sensitive, including the upper galleries of the two eastern industrial ranges which are in precarious condition.

***Heritage sensitivity score is therefore assessed to be 1.***

**Condition discussion**

This building is on the English Heritage Buildings at Risk regsiter, and is categorised as priority A: "Immediate risk of further rapid deterioration or loss of fabric; no solution agreed". Urgent works were undertaken to make the building more weather-tight in 2010, however this has been restricted to the sail-maker's loft, which has also been boarded and scaffolded internally. The building is in very bad condition, with loss of roof coverings, deterioration and damage of walls and all timberwork, and severe damp and failure of plaster and areas of roof timbers in the offices. The condition of this building will make it more sensitive to movement, however, the calculated settlement in this area is very small, and there is no differential movement which could further seriously damage the fabric of the building. However, there is risk of minor deterioration of the condition during the works.

***Condition sensitivity score is therefore assessed to be 2.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 2 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 3.

Although the building is in very bad condition and this will have an effect on the ability of what would usually be a fairly robust structure and heritage features of an industrial nature to cope with ground movements, the calculated settlements are not large and are not expected to be of significance. However based observed defects the building fabric (particularly the fronting building) will continue to deteriorate which, without intervention, may lead to structural instability.

Conservative inputs have been used to calculate ground movements, as such the settlements are expected to be less. Mitigation measures in the form of physical intervention (i.e. soil grouting, underpinning etc) are likely to cause more damage than what would be expected from the construction of the tunnel.

No further assessment is proposed.

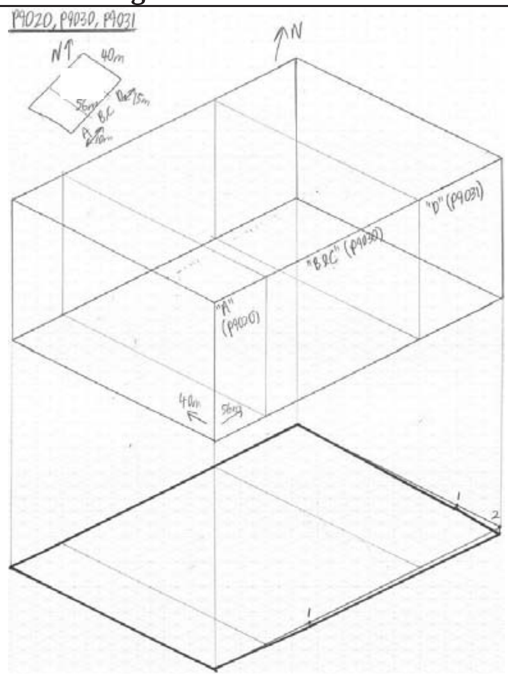
# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z9129 |
| **Building name / address** | ‘A’ Metropolitan Wharf, E1W 3SS |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 35270 80430 |
| **Ground level (mTD)** | +104.4 to +105.2 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

Metropolitan Wharf, a Grade II listed building in Wapping is made up of four warehouses (‘A’ to the east, ‘B, C’ and ‘D’ to the west) built in stock brick between 1870 and 1880.

‘A’ Warehouse has five bays, and six storeys (top two storeys added soon after original build), with a heavy moulded bracketed cornice above the fourth storey. There is a parapet coping at the top of the sixth storey. The fenestration is regular, made up of slightly bowed arched divided light windows in the first, second, fourth and fifth bays of the building from the left. The central bay is made up of glazed timber double doors at each floor with the original iron pulley arm still in place.The original jibbed pivot crane remains. To the rear is a wide balcony pier built over the river wall, stretching the length of the four blocks.

Internally, the building is open throughout the four warehouse blocks, with a basement consisting of a mixture of brick vaults or iron columns, and the majority of the floors supported on cruciform columns or circular iron columns. The floors are predominantly timber, with some instances of concrete flooring.  The topmost floors show large timber beams, some supported on timber columns; the storeys of ‘A’, ‘B and C’ blocks do not match the height of those in ‘D’ block, and the internal stairs, some cantilevered, reflect this difference. ‘A’ block contains a section which is supported off timber beams, and has a plainer attic structure than other blocks, with a simple truss.

| Structural description and walkover observations |
|---|
| **External**; Exposed brickwork with multiple windows aligned at all levels with brick arches over openings. Wall plates with iron ties back to internal floors can be seen at a number of locations. The brickwork has had a recent renovation with the brickwork appearing clean and with pointing in good condition.<br><br>**Internal**; The building is currently undergoing internal renovation. The fabric is in good condition.<br><br>A basement extends the full footprint of the building. The basement structure comprises masonry external walls with cruciform iron columns supporting wrought iron beams and tied brick jack arches. A new concrete floor screed has been laid. The rear basement wall has openings leading to concrete shafts leading to ground level over. These showed water staining and water was pooled on the floor (likely from the cover over rather than from water penetration through the walls themselves). The basement structure was generally in fair condition with some localised cracking in the masonry.<br><br>At ground floor a mix of timber beams on cast iron cruciform columns and brick jack arches (untied) supported on iron beams and circular cast iron columns. Exposed load-bearing brick walls and non-loadbearing blockwork walls could be seen. Openings had been formed to link adjacent buildings creating one large development. All structure was in good condition.<br><br>Due to tenant occupancy not all levels were entered. Upper floors were reported as being timber joists and boards with differing support structures. For example in the front half of the building at fourth floor level there are no internal columns, instead four large wrought iron plate girders span from wall to wall. At the rear of the building at fifth floor diagonal iron beams can be seen, presumably a previous roof structure that was left in place and a further storey of accommodation added over. The sixth floor comprises steel beams and columns supporting a flat roof. The roof covering could not be inspected, but the internal space of the topmost floor was dry. |

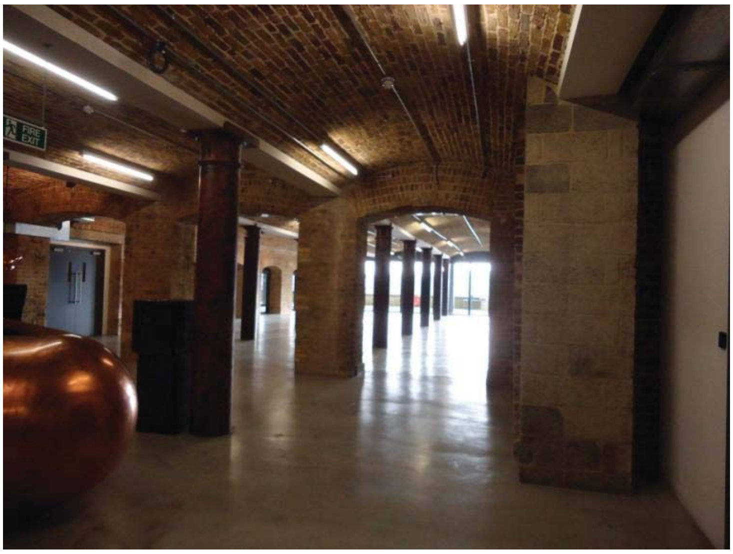
| | |
|---|---|
| **Condition** | Good |
| **Assumed foundations** | Possibly founded on timber piles with single level of basement. Likely to be part founded on old river wall. |
| **Façade material** | Load-bearing brick with some stone dressings |
| **Internal support system (i.e. superstructure)** | Mixture of load-bearing masonry walls, cast iron columns, iron and steel beams and timber beams supporting timber joists and boards. |
| **Heritage** | Exterior arches and hatch openings; interior vaulting, columns and timber floors and beams |

## Building photographs


General view of Metropolitan Wharf, with 'A' Warehouse to the far left

View of rear pier from ground floor

Typical basement view




General view of ground floor column layout and structure

Cantilevered stair between 'A' and 'B' Warehouse

Timber column and beam structure is 'A' Warehouse

## Ground movement analysis

### Tunnel and shaft details

Thames Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +49.5mTD.
Excavated diameter: 8.8m.
Closest shaft: King Edward Memorial Park Foreshore Shaft, located approximately 375m north-east – design indicates unlikely to influence ground movement at the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

### Ground conditions

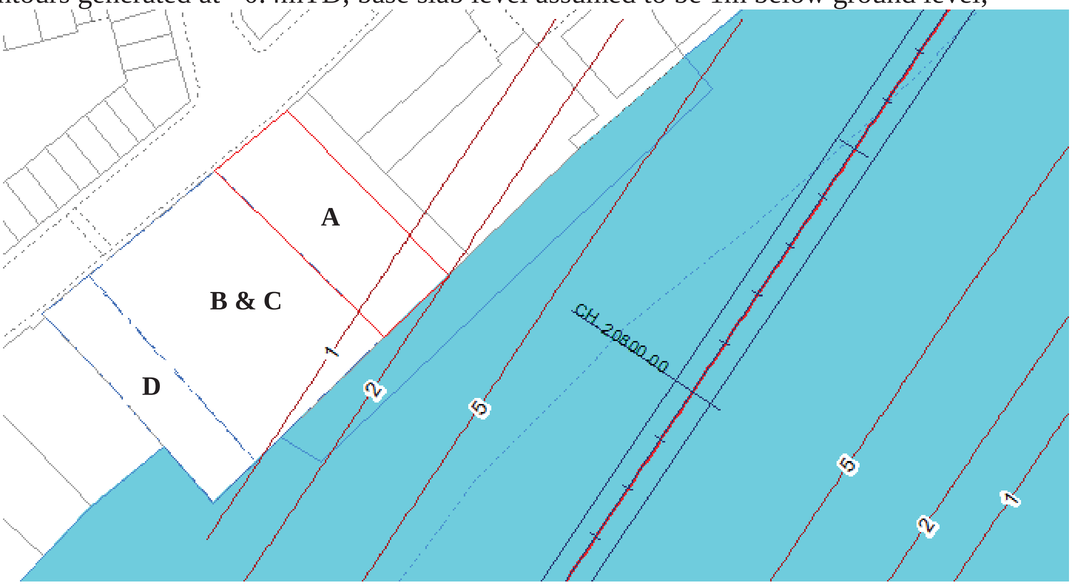
The Thames Tunnel is proposed to be constructed within the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +104.4mTD to +105.2mTD.
Top of Lambeth Group: +95.0mTD.
Top of Thanet Sand Formation: +76.0mTD.
Top of Chalk Group: +62.5mTD (13.0m above proposed tunnel centreline level).

Review of borehole SR2032 (located approximately 120m to the south-south-east), and BGS boreholes TQ38SE318 (located approximately 35m north) and TQ38SE323 (located approximately 55m north-east). The BGS boreholes suggest that London Clay is present above the Lambeth Group. However the boreholes do not indicate any geological features, such as scour that would require a change in the current ground loss assumptions.

### Results

Settlement contours generated at +0.4mTD, base slab level assumed to be 1m below ground level;




Warehouse 'A' assessed in this report – Warehouse 'B & C' and Warehouse 'D' subject of seperate reports

As shown above the building crosses the 1mm settlement contour and extends to the 2mm contour.

Analysis of two key façades selected from the GIS model, assumed a building height of 18m. The building was modelled on shallow foundations with a basement (foundations 4m bgl).

The results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.005% and a maximum settlement of 2mm were obtained for the building with and without the basement.

The building damage category has been assessed based on Burland (1995), which has been validated for load bearing masonry structures. 'A' Metropolitan Wharf does not completely fall within this category, as the internal support system is a combination of systems. However due to the small magnitude of ground movement anticipated at the building location it is assessed that the building damage category for the whole structure can be considered to be zero.

The interaction of the ground settlement with the structure is discussed in the interpretation of impact on the structure, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The structure has clearly been subject to a number of alterations throughout its life. The recent/current refurbishment has presented the structure in good condition.

The calculated settlements and damage category are very low.

***The Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

'A' Warehouse is just outside of the 2mm contour. The heritage features of this building, including external façade stone dressings, and internal structural columns and timber, and retained pulleys and hoists, will not be sensitive to the extremely small movement that may be generated by the Thames Tunnel Works

***The Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

The condition of this building is very good, and the building has recently been renovated for office use. There will be no added sensitivity to movement resulting from the condition of Metropolitan Wharf.

***The Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 0.

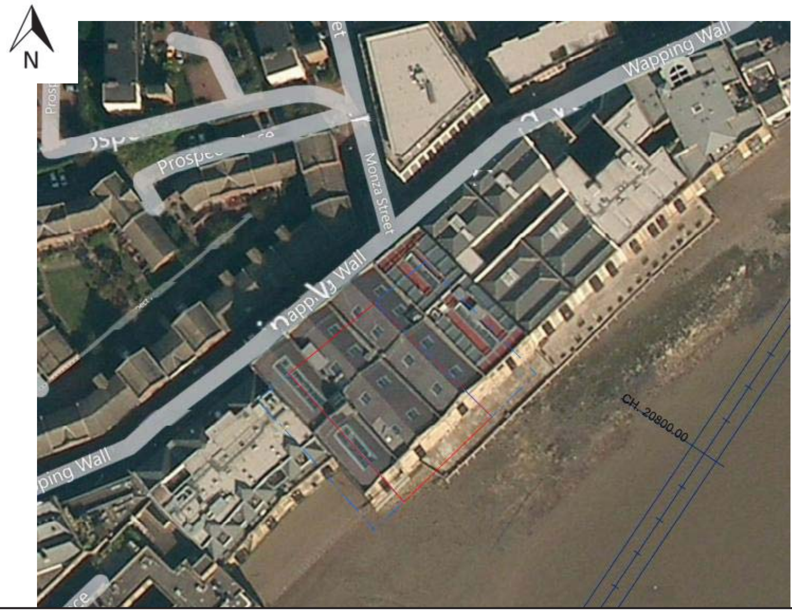
The magnitude of strain likely to affect this building is very low, placing the movement in damage category 0. Therefore the structure and condition of the building will not result in levels of damage that could lead to damage of heritage features.

On reflection of the combined score and taking into account the structural and heritage features of the building and its condition, this building will not require further assessment as part of the Damage Assessment process, and will not require mitigation measures.

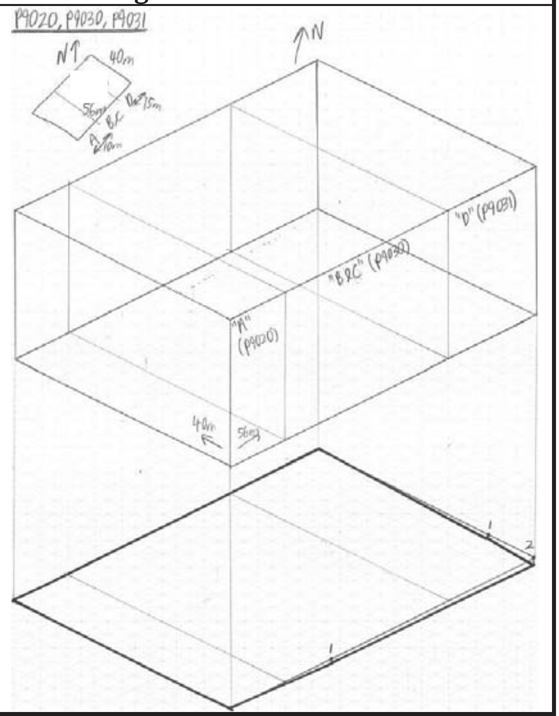
# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z9130 |
| **Building name / address** | ‘B & C’ Metropolitan Wharf, E1W 3SS |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 35255 80410 |
| **Ground level (mTD)** | +103.5 to +105.1 |

| **Location plan** | **Isometric ground movement sketch** |
|---|---|




Satellite imagery does not align perfectly with GIS mapping – refer to page 5 for building location.




**Building description (including excerpts from English Heritage listing, where appropriate)**

Metropolitan Wharf is a Grade II listed building in Wapping is made up of four warehouses (‘A’ to the east, ‘B’, ‘C’ and ‘D’ to the west) built in stock brick between 1870 and 1880.

‘B and C’ Warehouses are basically identical in layout and their frontage sits under a deep frieze inscribed with the name of the wharf under a heavy, modillion moulded cornice and parapet which is raised into two shallow pediment gables. The double door hatches are off centre on each building, sitting in the third of each four bays. Hatches have small pane glazing and flush panels and sit under the pediments on the roofline. The fenestration is regular and as in ‘A’ Warehouse and ‘D’ Warehouse, has slightly bowed arch, iron framed divided light windows. The riverside elevation is the same except at ground level, which is opened up with iron columns. To the rear is a wide balcony pier built over the river wall, stretching the length of the four blocks.

Internally, the building is open throughout the four warehouse blocks, with a basement consisting of a mixture of brick vaults or iron columns, and the majority of the floors supported on cruciform columns or circular iron columns. The floors are predominantly timber, with some instances of concrete flooring. The topmost floors show large timber beams, some supported on timber columns; the storeys of ‘A’, ‘B and C’ blocks do not match the height of those in ‘D’ block, and the internal stairs, some cantilevered, reflect this difference. The attic storeys have heavy timber truss structures.

| Structural description and walkover observations |
| --- |
| **External;** Exposed brickwork with multiple windows aligned at all levels with brick arches over openings. Wall plates with iron ties back to internal floors can be seen at a number of locations. The brickwork has had a recent renovation with the brickwork appearing clean and with pointing in good condition. The ground floor rear (riverside) elevation has three circular iron columns supporting a riveted iron beam supporting the masonry over. The ironwork appears to have been refurbished to give a high quality visual appearance.<br><br>**Internal**; Similarly to block A, a basement extends the full footprint of the building. The basement structure comprises masonry external walls with large square masonry piers supporting wrought iron beams and un-tied brick jack arches. A new concrete floor screed has been laid. The basement structure was generally in fair condition with some localised cracking in the masonry. Two cantilever stone stairs (one at each end) provide access. Both have forms of intervention (timber props supporting the free end).<br><br>At ground floor the structure comprises brick jack arches (untied) supported on iron beams and circular cast iron columns. Exposed load-bearing brick walls and non-loadbearing blockwork walls could be seen. Openings had been formed to link adjacent buildings creating one large development. All structure is in good condition.<br><br>Due to tenant occupancy not all levels were entered. Upper floors were reported as being timber joists and boards with differing support structures. The second floor comprises cast iron columns supporting timber beams. The fourth floor rear (riverside) rooms comprise twin timber beams and timber columns.<br><br>The roof is pitched with timber queen-post trusses. The riverside half of the building retains the original trusses in good condition whilst the trusses to the front of the building are new. There is evidence of crack repairs to the masonry walls. |

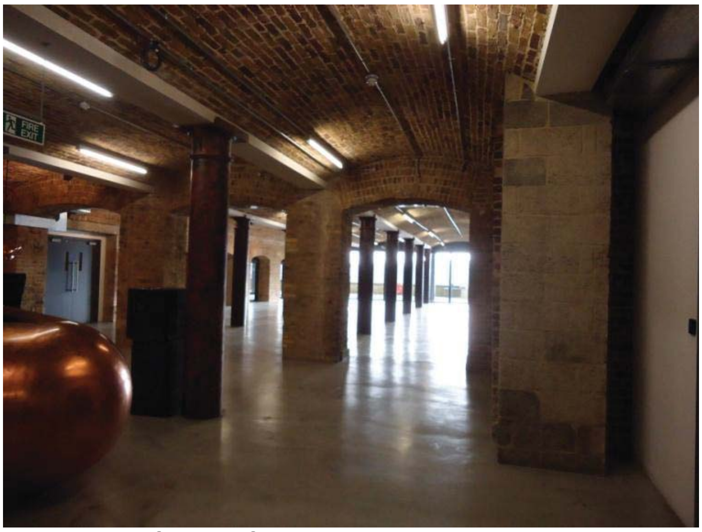
| | |
| --- | --- |
| **Condition** | Good |
| **Assumed foundations** | Possibly founded on timber piles with single level of basement. Likely to be part founded on old river wall. |
| **Façade material** | Load-bearing brick with stone dressings |
| **Internal support system (i.e. superstructure)** | Mixture of load-bearing masonry walls, cast iron columns, , iron and steel beams and timber beams supporting timber joists and boards. |
| **Heritage** | Exterior with stone dressings including cornice, frieze and lettering; door hatches; interior with columns, timber ceilings and beams. |

# Building photographs

General view of Metropolitan Wharf, with ‘B and C’ Warehouses in the centre

View of rear pier from ground floor

Typical basement view



General view of ground floor column layout and structure

Typical roof truss throughout ‘B and C’ Warehouses

Typical upper floor column layout

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +49.5mTD.
Excavated diameter: 8.8mTD.
Closest shaft: King Edward Memorial Park foreshore shaft, located approximately 395m north-east – design indicates unlikely to influence ground movement at the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

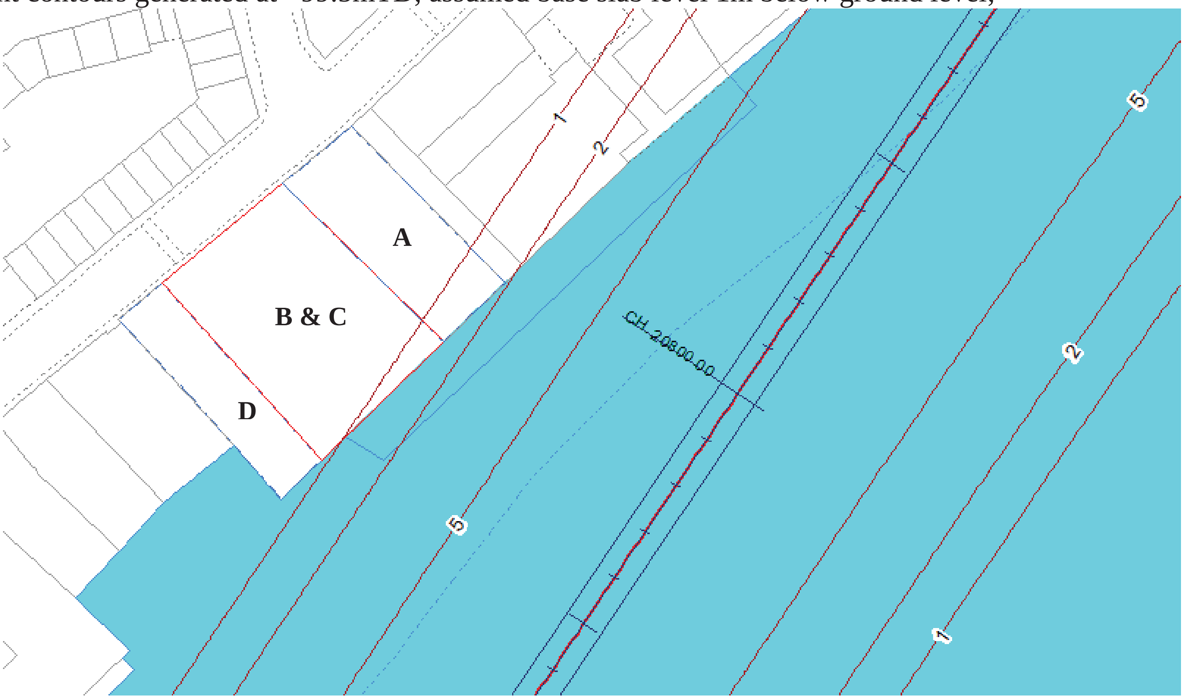
Thames Tunnel proposed to be constructed within the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +103.5mTD to +105.1mTD.
Top of Lambeth Group: +95.0mTD.
Top of Thanet Sand Formation: +76.0mTD.
Top of Chalk Group: +62.5mTD (13.0m above proposed tunnel centreline level).

Review of borehole SR2032 (located approximately 110m to the south-east) and BGS boreholes TQ38SE323 (located approximately 70m north-east) and TQ38SE318 (located approximately 50m north) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions. However the BGS boreholes indicate that a layer of London Clay is present above the Lambeth Group.

**Results**

Settlement contours generated at +99.5mTD, assumed base slab level 1m below ground level;




Warehouse 'B & C' assessed in this report – Warehouse 'A' and Warehouse 'D' subject of seperate reports

As shown above the building crosses the 1mm settlement contour.

Analysis of two key façades selected from the GIS model, assumed a building height of 18m. Foundations are assumed to be shallow, without a basement (foundations at 1m bgl).

The results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.005% and a maximum settlement of 1.5mm were obtained for the building.

The building damage category has been assessed based on Burland (1995), which has been validated for load bearing masonry structures. 'B & C' Metropolitan Wharf does not completely fall within this category, as the internal support is a combination of systems. However due to the small magnitude of ground movement anticipated at the building location it is assessed that the building damage category for the whole structure can be considered to be zero.

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The structure has clearly been subject to a number of alterations throughout its life. The recent/current refurbishment has presented the structure in good condition.

The calculated settlements and damage category are very low.

***The Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

B and C Warehouses are just inside of the 1mm contour. The heritage features of this building, including external façade stone dressings, and internal structural columns and timber, will not be sensitive to the extremely small movements that may be generated by the Thames Tunnel Works.

***The Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

The condition of this building is very good, and the building has recently been renovated for office use. There will be no added sensitivity to movement resulting from the condition of Metropolitan Wharf.

***The Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 0.

The magnitude of strain likely to affect this building is very low, placing it in damage category 0. Therefore the structure and condition of the building will not result in levels of damage that could lead to damage of heritage features.

On reflection of the combined score and taking into account the structural and heritage features of the building and its condition, this building will not require further assessment as part of the Damage Assessment process, and will not require mitigation measures.

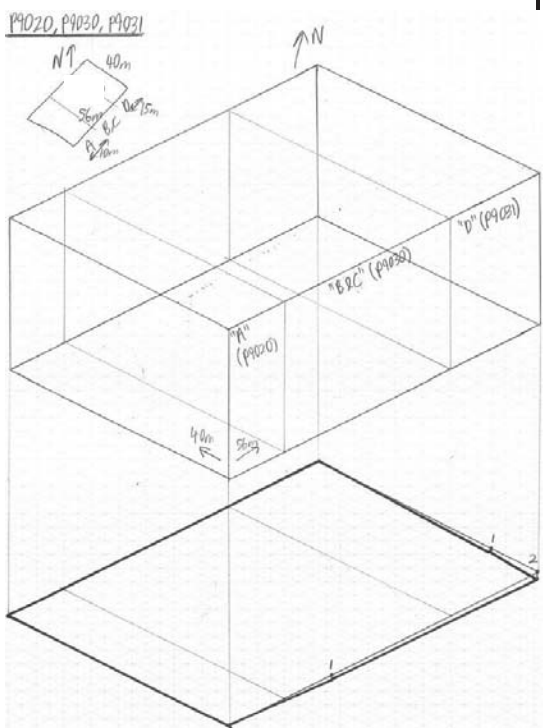
# Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z2420 |
| **Building name / address** | ‘D’ Metropolitan Wharf, E1W 3SS |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 35240 80398 |
| **Ground level (mTD)** | +102.7 to +104.8 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

Metropolitan Wharf is a Grade II listed building in Wapping, made up of four warehouses (‘A’ to the east, ‘B, C’ and ‘D’ to the west) built in stock brick between 1870 and 1880.

‘D’ Warehouse is a three bay wide, seven storey stock brick warehouse building with a parapet coping raised into a central gable. The façade differs from the other three warehouses as the windows are set into simple brick grand arches. This is the same for the third bay from the left, which houses the hatch openings. The windows are iron framed small pane divided light windows. The rear (riverside) façade is similar in layout although the hatch openings are in the central bay and the third bay is contained in two tiers of arches rather than one large arch. To the rear (riverside) is a wide balcony pier built over the river wall, stretching the length of the four blocks.

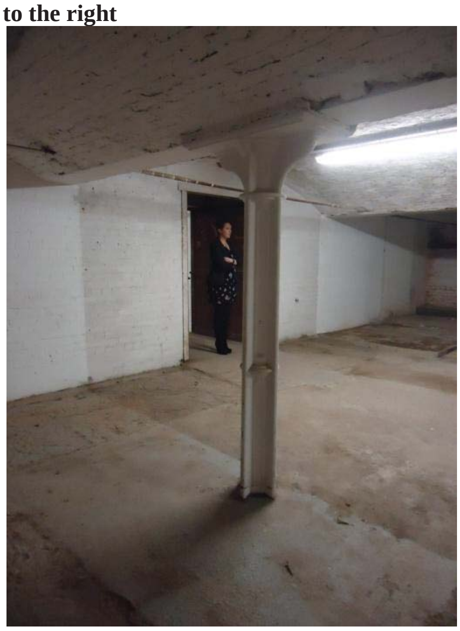
Internally, the building is open throughout the four warehouse blocks, with a basement consisting of a mixture of brick vaults on iron columns, and the majority of the floors supported on cruciform columns or circular iron columns. The floors are predominantly timber, with some instances of concrete flooring. The topmost floors show large timber beams, some supported on timber columns; the storeys of ‘A’, ‘B and C’ blocks do not match the height of those in ‘D’ block, and the internal stairs, some cantilevered, reflect this difference. ‘D’ block contains a section which is supported off timber beams, and has a plainer attic structure than other blocks, with a simple truss.

| Structural description and walkover observations | |
|---|---|
| **External;** Exposed brickwork with multiple windows aligned at all levels with brick arches over openings. Wall plates with iron ties back to internal floors can be seen at a number of locations. The brickwork has had a recent renovation with the brickwork appearing clean and with pointing in good condition.<br><br>**Internal**; Similarly to block 'A' and 'B & C', a basement extends the full footprint of the building. The basement structure comprises masonry external walls with cast-iron supporting wrought iron beams and un-tied brick jack arches. The basement structure was generally in fair condition with some localised cracking in the masonry.<br><br>At ground floor the structure comprises large circular cast iron columns, a flat ceiling disguises the floor structure. Exposed load-bearing brick walls and non-loadbearing blockwork walls could be seen. Openings have been formed to link adjacent buildings creating one large development. All structure was in good condition.<br><br>Due to tenant occupancy not all levels were entered. Upper floors were reported as being timber joists and boards with differing support structures. Beams are typically timber support by either timber of cast iron columns. Floor to floor levels are lower in block 'D' to that of 'A' and 'B & C' resulting in one additional floor in block 'D'.<br><br>The roof is pitched with retained original timber queen-post trusses. There is evidence of a few crack repairs to the masonry walls. | |
| **Condition** | Good |
| **Assumed foundations** | Possibly founded on timber piles with single level of basement. Likely to be part founded on old river wall. |
| **Façade material** | Load-bearing brick with stone dressings |
| **Internal support system (i.e. superstructure)** | Mixture of load-bearing masonry walls, cast iron columns, steel columns, iron and steel beams and timber beams supporting timber joists and boards. |
| **Heritage** | Exterior arches and hatch openings; interior vaulting, columns and timber floors and beams |

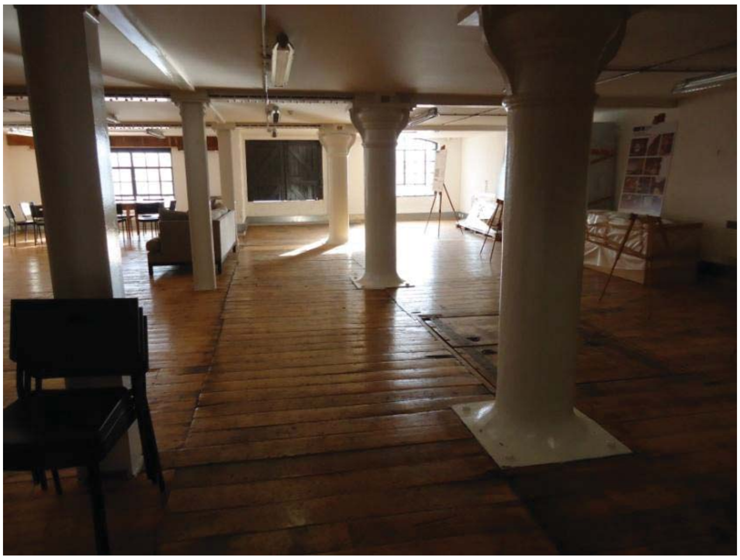
# Building photographs

General view of Metropolitan Wharf, with 'D' Warehouse to the right

View of rear pier from ground floor



Typical basement view



Ground floor columns and timber floor in 'D' Warehouse

Truss and rooflight in 'D' Warehouse

Retained hoist crane to the southern elevation, from inside the building

## Ground movement analysis

**Tunnel and shaft details**

Thames Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +49.5mTD.
Excavated diameter: 8.8m.
Closest shaft: Kind Edward Memorial Park foreshore shaft, located approximately 425m north-east – design indicates unlikely to influence ground movement at the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

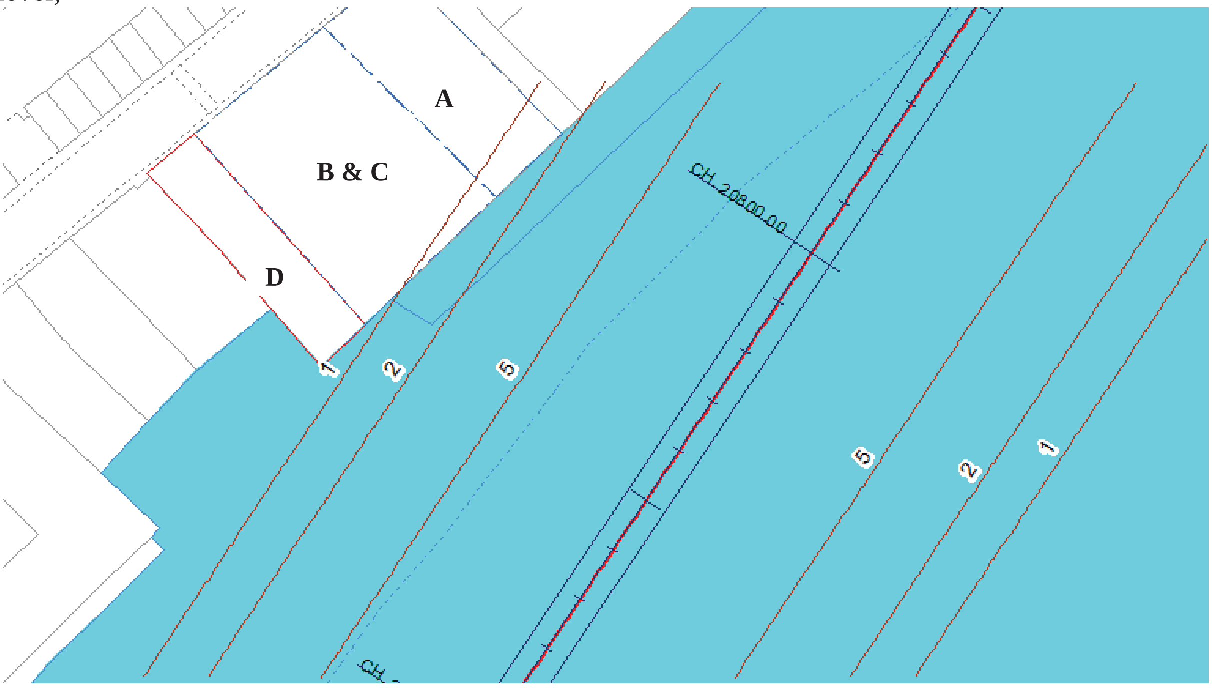
Thames Tunnel proposed to be constructed through the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +102.7mTD to +104.8mTD.
Top of Lambeth Group: +95.0mTD.
Top of Thanet Sand Formation: +76.0mTD.
Top of Chalk Group: +62.5mTD (13.0m above proposed tunnel centreline level).

Review of borehole SR2032 (located approximately 110m to the south-east) and BGS boreholes TQ38SE318 (located approximately 70m north-north-east) and TQ38SE323 (located approximately 100m north-east) does not indicate any geological features, such as scour that would require a change in the current ground loss assumptions. However the BGS boreholes do indicate the presence of London Clay above the Lambeth Group.

**Results**

Settlement contours generated -98.7mTD, assumed base slab level with a basement and shallow foundations 4m below ground level;




Warehouse 'D' assessed in this report – Warehouse 'A' and Warehouse 'B & C' subject of seperate reports

As shown above the building sits outside of the 1mm settlement contour.

Analysis of two key façades selected from the GIS model, assumed a building height of 18m. Foundations were assumed to be shallow, with a basement (foundations at 4m bgl).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile stress of 0.003% and a maximum settlement of 0.9mm were obtained for the building.

The building damage category has been assessed based on Burland (1995), which has been validated for load bearing masonry structures. 'B & C' Metropolitan Wharf does not completely fall within this category, as the internal support is a combination of systems. However due to the small magnitude of ground movement anticipated at the building location it is assessed that the building damage category for the whole structure can be considered to be zero.

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The structure has clearly been subject to a number of alterations throughout its life. The recent/current refurbishment has presented the structure in good condition.

Warehouse 'D' is located just outside of the 1mm settlement contour line, but is connected to blocks 'B & C', which lay within the 1mm contour. The calculated settlements and building damage category are thus very low.

***The Structural sensitivity score is therefore assessed to be zero.***

**Heritage features sensitivity discussion**

'D' Warehouse is just outside of the 1mm contour. The heritage features of this building, including external façade stone dressings, and internal structural columns and timber, will not be sensitive to the extremely small movements that may be generated by the Thames Tunnel Works.

***The Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

The condition of this building is very good, and the building has recently been renovated for office use. There will be no added sensitivity to movement resulting from the condition of Metropolitan Wharf.

***The Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 0.

The magnitude of strain likely to affect this building is very low, placing the movement in damage category 0. Therefore the structure and condition of the building will not result in levels of damage that could lead to damage of heritage features.

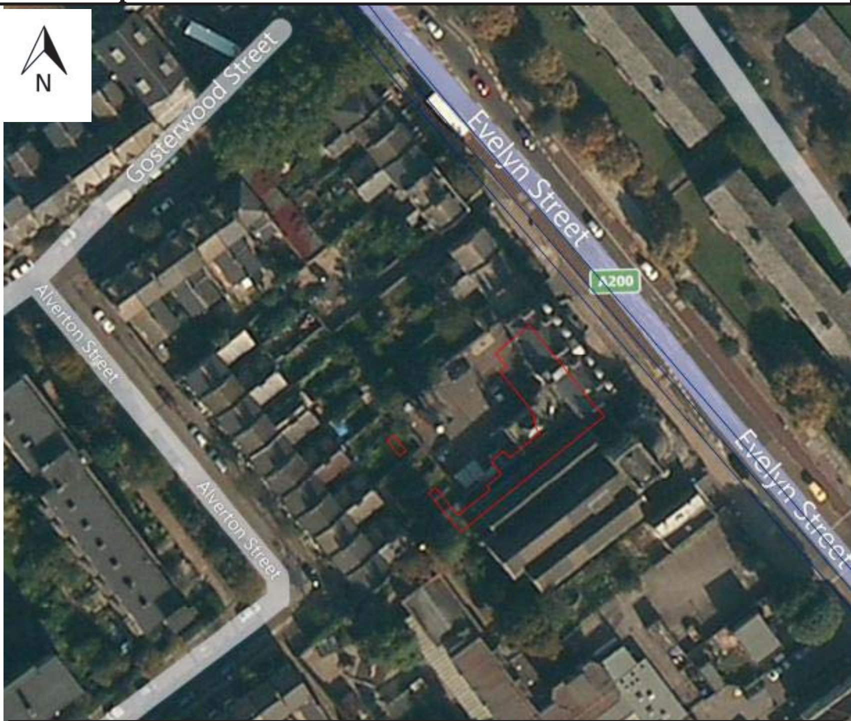
On reflection of the combined score and taking into account the structural and heritage features of the building and its condition, this building will not require further assessment as part of the Damage Assessment process, and will not require mitigation measures.

# Appendix H: Individual building assessment reports for the London Borough of Lewisham

# Listed building assessment

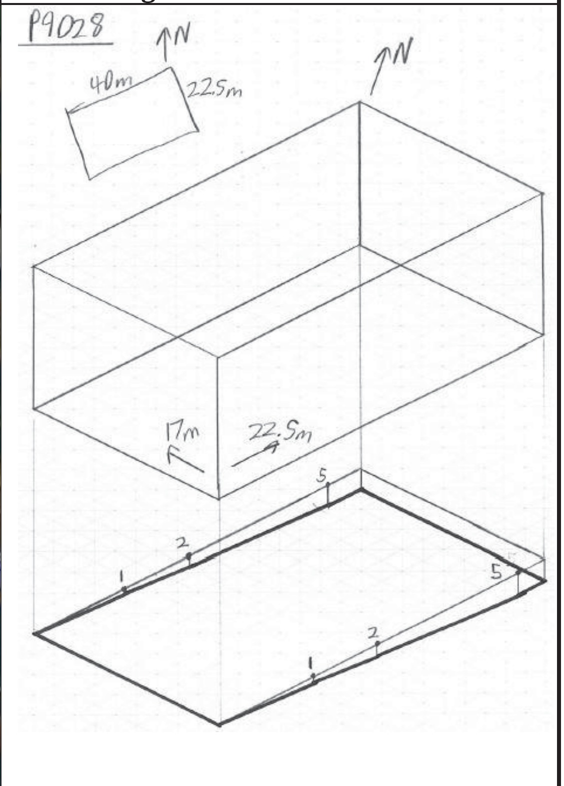
| Building information | |
|---|---|
| **Building reference** | Z6003, Z6005, Z6006, Z6176 |
| **Building name / address** | Deptford Fire Station, SE8 5DB |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 36612 78047 |
| **Ground level (mTD)** | +102.9 to +103.2 |

**Location plan**




Satellite imagery does not align perfectly with GIS mapping – refer to page 5 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

This Grade II listed fire station dates from 1903 and was built by London County Council's Fire Stations Division. The exterior is in Queen Anne style and of brick with a stone-faced ground floor to the three storey plus attic principal north eastern elevation, which has seven bays with giant order pilasters and an advancing central bay with a broken scroll pediment. The mansard roof with dormer windows is finished in slate and has exaggeratedly tall chimneys, and the central dormer takes the form of a red brick pedimented gable. The elevation at ground floor level is dominated by the two appliance bays to the right hand side (north west), and the vehicle entrance bay to the left (south-east), but does have some ornamentation over the entrance, including keystone and stone sills, and lettering above the appliance bays which reads 'LCC Fire Brigade Station Deptford 1903'. The appliance bay doors and ground and first floor windows are modern replacements, and would originally have been timber sash windows and timber doors. The rear is largely unaltered and the arrangement of accommodation remains legible, with railed, external walkways leading from a central staircase tower to flats and office/mess accommodation.

The interior has been somewhat modernised and many of its original features have been removed. The plan form is largely unchanged and reflects the fire station use. At ground floor level the appliance and engine room, which shows large riveted steel beams and is undoubtedly utilitarian in style, corresponds with the exterior entrances, with office accommodation to the north-west. To the rear of the main building, leading off by a doorway from the engine room, is a long, single storey extension of brick, currently used as a gym. To the rear of the ground floor a stone stair leads down to the basement, which has a number of plant and drying rooms, none with any noteworthy heritage features.

In the same area as the basement access, a brick stair tower leads up to all floors, and contains a stone cantilevered stair with iron balusters. From this doors at each level lead both left and right to external walkways or balconies, which in turn have doorways leading to the mess and sleeping accommodation of the fire station. The first and second floors are in use, and in some rooms retain cornicing, simple fireplaces and timber skirting. From the first floor walkway there is access onto a roof garden, above the single storey extension. This area includes a small glass and timber conservatory. The attic or third floor is in the process of renovation; the un-refurbished flats contain mid-20th century sinks and bathroom appliances, and are in a poor condition. There are areas of crazed or damaged plaster and paint, and in one area a section of ceiling has given way to the extent that timber roof joints are exposed above. Existing historic fireplaces, timber cupboards and other heritage features are being retained during the renovations.

**Structural description and walkover observations**

The building is of brick construction, with four storeys above ground, and a basement.

The ground floor is taller than the upper floors – there are three flights of stairs to the first floor, rather than two as on the upper levels.

The building has been altered over the years, particularly internally, and is currently being refurbished on the top two floors. At ground floor there are several changes of level.

There is accommodation at ground floor at the rear of the building behind the appliance bay (space for two engines). This has a flat roof terrace at first floor level; there are some issues with drainage to the rear, evidenced by ponding at the time of the visit and stains from overflow down the rear wall.

The vertical elements of the structure are of load-bearing masonry. There are concrete floors to the basement and ground floors, with timber floors above (not confirmed at all levels but likely construction).

Suspended ceilings have been installed in several areas, although with some panels removed locally giving sight of the structure above.

The walls are variously plastered/painted/dry-lined (with dry-lining to some masonry walls).

There is hard surfacing to the basement slab, while the ground floor has a mixture of carpets and exposed slabs.

The building is likely to have shallow strip footings.

It has a central cantilever staircase at the rear; access to the main accommodation is from doors offthe landing at the top of the stairs – external walkways along the rear of the building give access to the two parts of the building.

The walkways are part supported on a steel structure with sloping flat struts below the concrete slabs.

Overall the building is in good condition, both generally and for a building of this age. There is some deterioration at low level of the red brick under the arch giving access to the rear parking area and hose tower. This may be where some protection has been removed. At the upper levels there is hairline cracking in a few locations, not considered to be significant, and a few areas of damp.

There are some cracks running front to back on the walkways.

More significant cracking is seen above the doors to the external walkways from the landings at the upper floors, with cracks of approximately 1 to2mm in some cases.

The staircase has wide treads – approximately 1060mm; there is no separation between the flights. The handrail is robust and well fixed to the upper surface of the treads.

There are open cracks at the junction between the top tread and the penultimate at first, second and third floors; these should be attended to irrespective of ground movements.

The tower at the rear of the site is five storeys tall and would be potentially vulnerable to significant ground settlements and slopes.

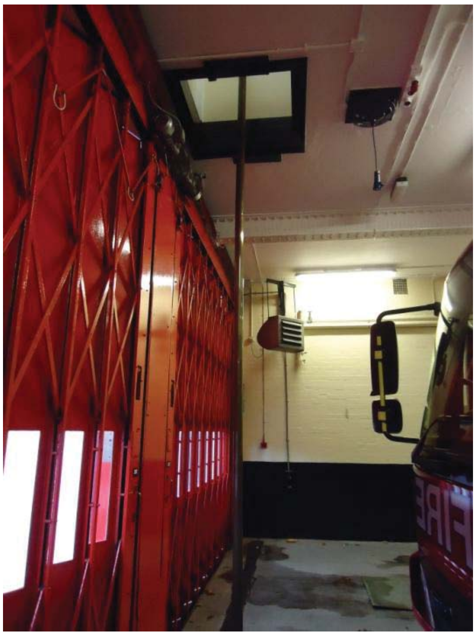
| | |
|---|---|
| The chimneys on the main building are tall and slender – as noted in the listing particulars – and could also be vulnerable if there are large movements/slopes. | |
| **Condition** | Fair, with minor defects in specific areas. |
| **Assumed foundations** | Shallow strip footings. |
| **Façade material** | Brick. |
| **Internal support system (i.e. superstructure)** | Load-bearing masonry. |
| **Heritage** | Excellent example of a particular style of LCC buildings of the age, and retained fire station use. Strong main façade, some remaining internal details including fireplaces, and interesting central stair tower with cantilevered staircase. |

# Building photographs

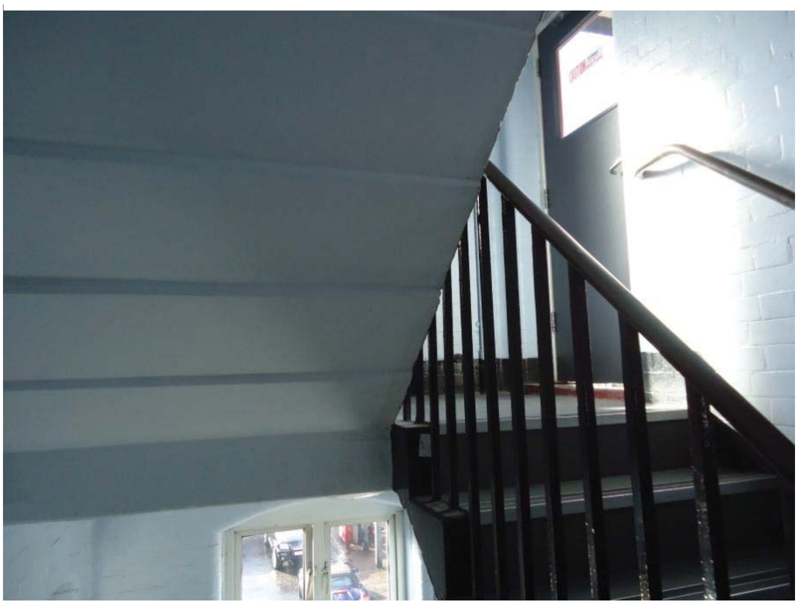
**Main façade**

**Retained historic feature - cupboards**

**Rear elevation**



**Appliance entrance and fireman's pole**



**Cantilevered stair**

| Ground movement analysis | |
|---|---|
| **Tunnel and shaft details** | |
| Chambers Wharf tunnel constructed within the Chalk Group.<br>Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.<br>Tunnel centreline level: +60.0mTD.<br>Excavated diameter: 6.2m.<br>Closest shaft: Earl Pumping Station located approximately 850m north-west – design indicates unlikely to influence ground movement in the building location. | |
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |
| **Ground conditions** | |

The Chambers Wharf tunnel is constructed within the Chalk Group. The expected sequence above the tunnel is summarised below, based on BGS boreholes TQ37NE50 (located approximately 60m north-north-west) and TQ37NE68 (located approximately 320m south-south-west);

Superficial deposits/Made Ground: Ground level +102.9mTD to +103.2mTD.
Top of Thanet Sand Formation: +96.1mTD.
Top of Chalk Group: +94.0mTD (34.0m above proposed tunnel centreline level).

Review of borehole SR1022 (located approximately 575m east) broadly corroborates with the levels above and does not indicate any geological features such as scour that would require a change in the current ground loss assumptions.

**Results**

Settlement contours generated at -98.9mTD, approximate base slab level, assuming a basement 4m below ground level;


As shown above the building extends from the 5mm settlement contour across both the 2mm and 1mm contours.

Analysis of two key façades selected from the GIS model, assumed a building height of 12m, plus a basement and shallow foundations (foundations located 4m bgl).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.005% and a maximum settlement of 5mm were obtained for the structure.

The interaction of the ground settlement and the structure is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

For the levels of settlement and damage calculated it is not considered that there will be any significant impact on the building structure. The values are not of a level that will be expected to impact on the chimneys or rear tower. Some of the existing cracks may open slightly as these will be more vulnerable to future movements.

***Structural sensitivity score is therefore assessed to be 1.***

**Heritage features sensitivity discussion**

This building was designated as a Listed Building by English Heritage because it is a “characterful and distinctive station from a significant period in the development fire station architecture. The principal façade is carefully composed in a Queen Anne style, the quality of the brickwork is also good, and the station has a municipal presence through the appliance bays and the inscription, and reflects the architectural styles of the area in the early 20th Century”.

The heritage significance of the building lies more in its form than in its features, although some of these are retained. The external elevations contribute most to the significance of the building. The main shell of the building, and its areas of decoration, will not be sensitive to the level of calculated movement.

Internally, the cantilevered stair, which does add considerable interest to the building, is suffering from a number of defects. This would make it sensitive to large movements; however, the maximum strain assessed for this building will not cause further damage to the heritage significance of the stair.

***Heritage sensitivity score is therefore assessed to be zero.***

**Condition discussion**

The condition of this building is generally good, other than where there are specific defects in certain areas. Of note are the open joints identified in the cantilevered stair, which may cause some sensitivity to more movements and should be pinned up as a matter of general maintenance. The attic storey flats are still in some disrepair. However, these are being refurbished, and at the time of the proposed Thames Tunnel works will be fully in use and renovated. The whole building is undergoing maintenance at the time of this report. It is unlikely that the calculated strain and settlement will cause more than a very minor amount of further deterioration in the condition of this building.

***Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 1 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

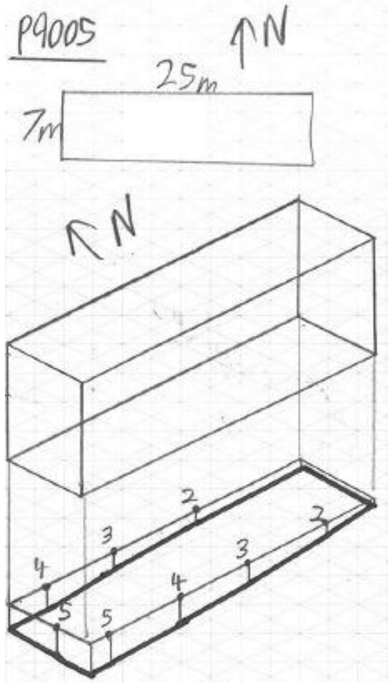
The total score for this building is 1.

The heritage significance of the fire station will not be compromised by the calculated movement associated with the Thames Tunnel works. It is equally unlikely that the condition of the building will deteriorate; however, the building is slightly sensitive structurally, with elements such as the cantilevered stair being of particular note.

This building will not require mitigation or further assessment as part of the damage assessment. However, it is advised that a defect survey concentrating on the stair tower and cantilevered stair be carried out prior to commencement of works, to enable any further cracking to be noted.

## Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z6259 |
| **Building name / address** | 227 Deptford High Street, SE8 3NT |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 37126 77670 |
| **Ground level (mTD)** | +105.5 to +105.7 |

| **Location plan** | **Isometric ground movement sketch** |
|---|---|
|  Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location. |  |





**Building description (including excerpts from English Heritage listing, where appropriate)**

No inspection has been carried out to date. The English Heritage Listed Building description is quoted verbatim as follows:

*"House and shop, and bakehouse, 1791-2 for Thomas Palmer, baker, further improvements 1801-2 and 1822-3, probably including the rear bakehouse. House of stock brick, part painted, rear wall partly rebuilt in brick, steep pitched hipped roof, pantiled to front, slated to rear. Prominent brick stacks to left party wall. Three storeys and cellars, two room plan with median partition wall with winder stair in stair box from cellar to upper floor. C19 shop front, window largely obscured, beneath triple overlight, entrance to right, replaced glazed door beneath blocked overlight. Upper floors, each a pair of recessed sashes with glazing bars at first floor 3x4 panes, at second floor 3x2 panes, all under flat brick arches, second floor with rendered cills. Rear ground floor behind slated lean-to. Upper floors each a single opening, without awindow on the first floor, with second floor replaced 2x2 pane sash. Interior: cellar kitchens , with large fireplace, in 1998 with grate, with storage behind. Ground floor shop and formerly chamber behind. First floor principal chambers, with closet between. Front room with moulded dado, presumed late C18 and later cornice and picture rail. Rear room plain panelled, with mantelpiece and flanking clothes cupboard with door and hanging rail. Upper floor rear room part panelled, cupboard flanking fireplace. Winder stair in panelled stair box from cellar to 2nd floor. Attached by later addditions at rear, former bakehouse. Brick base, timer framed, west end rebuilt in brick later C19, softwood roof part rebuilt of reused timbers, asbestos clad wall and roof, canted weatherboarded section adjacent to house. Tall lateral stack. Two storeys, with winder stair at N.E corner. Oven."*

| Structural description and walkover observations |
|---|
| No inspection has been carried out to date. The following has been inferred from a virtual walkover survey and other available information:<br><br>Three-storey assumed loadbearing masonry structure with internal timber wall and timber floors. Front façade open at street level (shop frontage) suggesting wrought iron beam over. |

| | |
|---|---|
| **Condition** | Not inspected. However, this building is on the English Heritage Buildings at Risk Register, category A. It can be assumed that the current condition is very poor. |
| **Assumed foundations** | Shallow foundations with single basement. |
| **Façade material** | Loadbearing brick, timber shop-front. |
| **Internal support system (i.e. superstructure)** | Loadbearing brick walls with timber floors. |
| **Heritage** | Not inspected, taken from Listed Building description (although bakehouse is said to have been demolished): External timber shop front; internal winder stair in stair box; cellar kitchens with fireplace; cornices, panelling and dado. |

## Building photographs

NOT USED

## Ground movement analysis

**Tunnel and shaft details**

Chambers Wharf Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel centreline level: +61.7mTD.
Excavated diameter: 6.2m.
Closest shaft: Deptford Church Street shaft located approximately 330m south-east – design indicates unlikely to influence building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

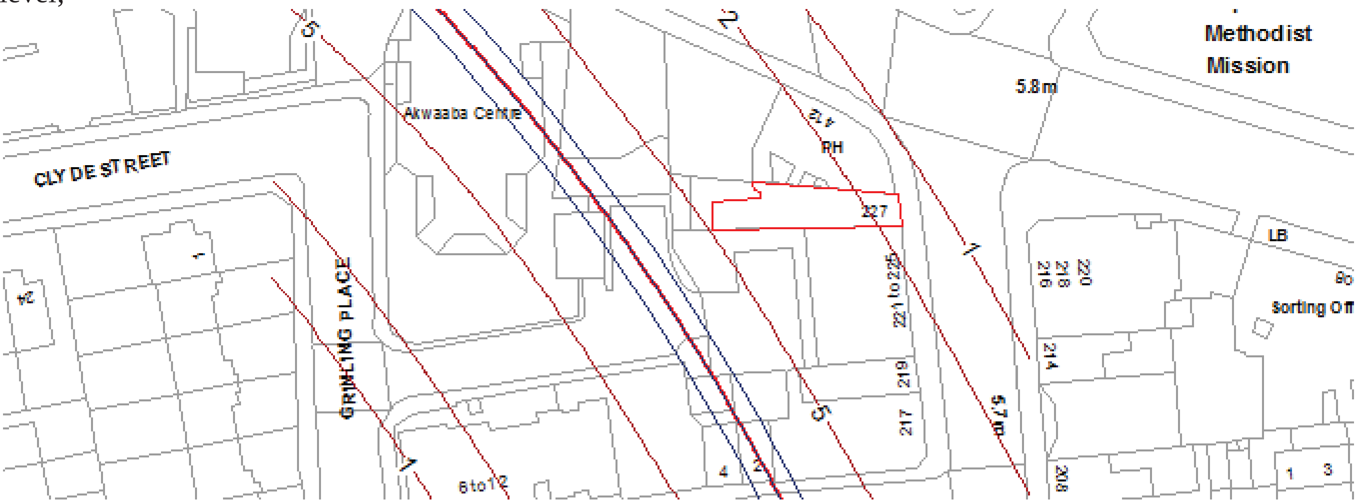
Chambers Wharf Tunnel is proposed to be constructed within the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +105.5mTD to +105.7mTD.
Top of Lambeth Group: +96.0mTD.
Top of Thanet Sand Formation: +92.5mTD.
Top of Chalk Group: +78.5mTD (16.8m above proposed tunnel centreline level).

Review of boreholes SR1022, SR1025B (located approximately 385m north and 365m north-east) and BGS borehole TQ37NE72 (located approximately 180m west) does not indicate any geological features, such as scour that would require a change in the current ground loss assumptions. However boreholes SR1022 and SR1025B show assumed zones of core loss in the Chalk Group and SR1025B also shows core loss within the Thanet Sand Formation.

**Results**

Settlement contours generated at +101.5mTD, approximate base slab level assuming a basement, 4m below ground level;




As shown above the building crosses the 2mm settlement contour.

Analysis of four key façades selected from the GIS model, assumed a building height of 9m, with a basement and shallow foundations (foundations at 4m bgl).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.002% and a maximum settlement of 5mm were obtained for the building.

The interaction of the ground settlement with the structure is discussed in the interpretation of impact section, below.

## Interpretation of impact

**Structural assessment and discussion**

Loadbearing masonry construction. Calculated settlement across building footprint (east end of site) is only 1-2mm. Despite reported poor condition, calculated settlement is very low and of no structural significance.

**Heritage features sensitivity discussion**

This building has not been inspected. In light of the Listed Building description, sensitive features may include the internal winder stair and various timber elements, and the external timber shop front. All are assumed to be in poor condition, making them more fragile.

The heritage features would not usually be sensitive to the calculated settlement, however their condition makes them more sensitive, and therefore it is possible that the movements caused by the Thames Tunnel works may damage the heritage features of this building.

**Condition discussion**

This building is on the English Heritage Buildings at Risk register, category A (Immediate risk of further rapid deterioration or loss of fabric; no solution agreed), and is described thus: *"C19 shop front in disrepair. Bake house demolished. Some repairs have been carried out to make the building wind and weather tight, and internally it has remained gutted and unoccupied."* It can be assumed that the current condition is very poor.

Although the movements are very small in this area, the condition of this building makes it sensitive to small movements; the maximum settlement calculated may cause the current condition to deteriorate.

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 0 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 2 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 3.

Although this building has no heritage features or structure that would be particularly sensitive were they in good condition, The very poor condition of the building heightens the sensitivity of all its features, making them more fragile and likely to be damaged during the Thames Tunnel works.

Therefore it is proposed that 227 Deptford High Street is taken forward for further assessment with a view to mitigation during the works.

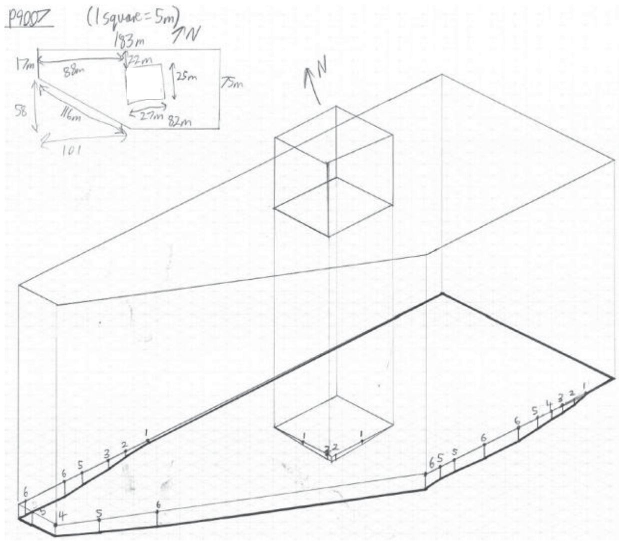
## Listed building assessment

| Building information | |
|---|---|
| **Building reference** | Z6329 |
| **Building name / address** | St Paul's Church, SE8 3DS |
| **Grade of listing** | I (Ecclesiastical Grade A) |
| **National Grid Reference (NGR)** | TQ 37286 77480 |
| **Ground level (mTD)** | +105.9 to +106.6 |

**Location plan**


Satellite imagery does not align perfectly with GIS mapping – refer to page 6 for building location.

**Isometric ground movement sketch**



**Building description (including excerpts from English Heritage listing, where appropriate)**

St Paul's is one of the churches built by the Commission for Building Fifty New Churches, set up by Act of Parliament in 1711 and funded by a tax on coal coming into London. This Grade I listed church was built between 1713 and 1730 by Thomas Archer. It was restored in 1856 and subsequently several times in the 20th Century. St Paul's is a Portland stone ashlar-faced church, in a Classical style of the kind referred to as English Baroque, displaying mainly Doric order external features. The church is set within a churchyard surrounded by a brick boundary wall punctuated by brick piers with some remaining stone caps; this wall is in itself listed, at Grade II.

From the outside, it appears to be a rectangular block with an apse at the east end and a semi-circular Doric portico reached by wide, shallow stone stairs at the western end. The exterior is articulated by rusticated pilasters and recessed arched windows with tri-part keystones. There are lunette windows over the doors, and set as lights within the stairs at the west end. The portico at the west end supports a tall, slender round tower of two stages with a two stage polygonal spire. The apse at the east end of the church holds a Venetian window, which follows the curve of the bay, and is surmounted by a pediment. The north and south transeptal projections have pediments with lunettes, and central doorways. These doorways are reached by balustraded symmetrical stairs and a balustrade terrace; under the terrace is access to the crypt. The exterior has been very little altered, and retains its original form.

The internal plan echoes the exterior form, with the apse at the east end, entrance porch at the west end, and the main nave, from which two side areas slightly project, over which are panelled oak galleries. The interior displays rich and detailed plasterwork by James Hands, and 18th century painted decoration in the apse, which has been restored. The timber galleries are extant, and contain some original box pews; these galleries are reached by elegant timber curved stairs to either side of the entrance vestibule at the west end. Around the nave, Corinthian columns support a moulded entablature which continues around the apse, with the galleries suspended behind the columns. To the west end, above the entrance, is an organ gallery which is of highly-carved timber; this gallery is slightly higher than the side galleries and stands on paired fluted Corinthian columns. The church contains many fittings of note, including pews, monuments, and a veneered bombe-shaped pulpit with wrought iron stairs. The brick crypt is vaulted, and has been modernised to provide community space. To the west end, behind the organ gallery, is access to the tower and roof space; this is reached by a very small and interesting spiral stair, predominantly of timber, some of which looks to have been reused from older construction. The roof space shows the large roof trusses of timber, and access externally shows a slate roof in reasonable condition although there are areas of slight damage. The stair continues to the bell tower, which is lit by a deep set opening to each point of the compass. The bell ropes remain, hanging down into the space, although the bells are no longer in use.

**Structural description and walkover observations**

The church is elevated above the crypt, with a stone-paved ambulatory around the exterior. It is built of stonework, including the high spire.

The church has a wide, open form; there are timber galleries on both sides above the aisles, supported behind the large circular stone columns.

Timber spiral staircases, located in the north-west and south-west corners either side of the western entrance, lead up to the galleries. There are internal downpipes within both spirals against the outer walls. There is cracking in the stone cills on both spirals, and some cracking in the landing soffit on the south side.

There are two rows of pews in the south gallery and three in the north. Each gives access to a circular room at the east end, flanking the apse. There is an internal downpipe in the north room.

The organ gallery sits over the west entrance and is accessed from the side stairs. A steep timber stair leads up on the north side to the bell tower.

Three steps lead up to the altar in the apse, from the main body of the church. The floor in the central altar area is of stone, whereas the remainder of the floor is of timber (of different types of construction).

A very tight spiral stair leads down to the crypt from below the west end of the south gallery. The crypt is close to ground level, with access on the north side of the church. It has an extensive footprint; the ceiling is vaulted brickwork and there are substantial corbelled brick piers with corbelling above floor level. It shows some signs of repairs and alterations, with corbelling at different heights. The central area has been cleared and is in regular use. Some of the perimeter areas still contain bodies and were not inspected.

The roof is generally in good condition; there are a few leaks at the east end and the main roof timbers show some splits. The connectors are unusually large elements.

It is reported that there is some ongoing maintenance, which is consistent with observations on condition. The internal paintwork and [very ornate] plasterwork are almost all in excellent condition.

Externally the stone stairs from ground level and the paving above the crypt are in less good condition with some cracking, spalling and unevenness. This is seen in particular on the steps to the south side and the adjacent wall is leaning out slightly.

The external stonework to the church itself including the spire, which was seen from close range on the roof, is in good condition, other than the north wall where there is some deterioration at low level. There is some cracking at the head of the east window in the apse.

The three bells in the tower date from the late 18$^{th}$ century and early 19$^{th}$ century; they are not now in use because of concerns regarding the supporting structure.

The window arch to the west of the bell tower shows some signs of water damage above the window. There is a fine crack at the crown and the arch is slightly flattened.

The charnel house dates from 1877 and was not inspected internally.

The boundary walls are of varying brick construction around the perimeter of the churchyard and show some signs of deterioration and distress. To the north the wall is low, with taller piers at regular spacing. There are a number of mature trees in close proximity and it is likely that these are contributing to the deterioration of the wall.

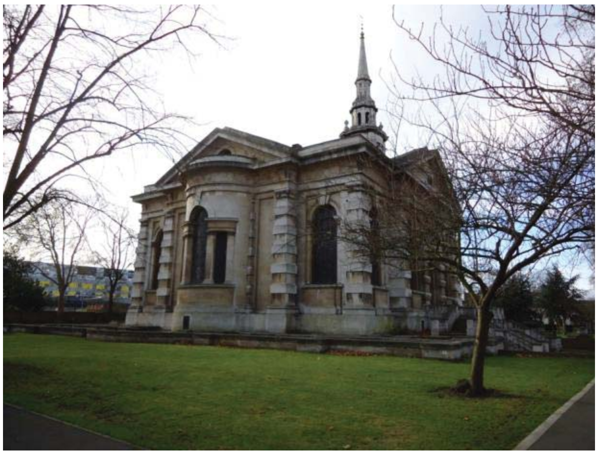
| | |
|---|---|
| **Condition** | Good, some minor defects. |
| **Assumed foundations** | Shallow brick corbelled footings to the piers and walls, on stone blocks for some elements. |
| **Façade material** | Portland stone. |
| **Internal support system (i.e. superstructure)** | This is of load-bearing masonry. |
| **Heritage** | External stonework and decorative stone, including the tall spire; heavily decorated internally, with plaster and paintwork, timber floors, some box pews and decorated pulpit; elegant timber stairs to boxes and tower access; interesting timber stair to bell tower and roof area; bells in situ but unused; good stained glass. The whole building and its contents has extraordinarily high heritage value. |

## Building photographs

External elevations from the south-east

Church tower

Boundary wall in poor condition



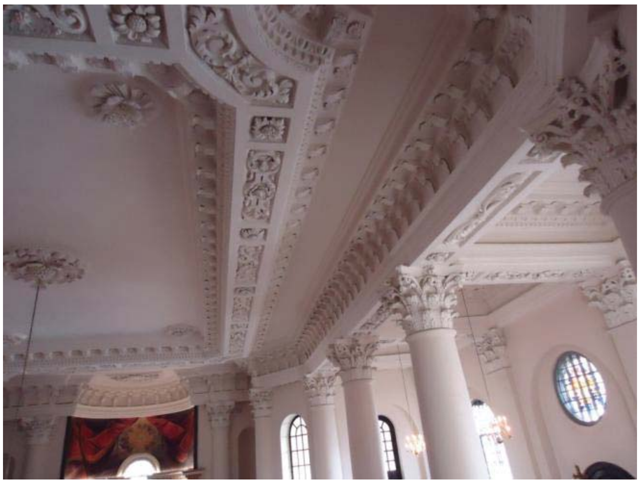
External elevations from the north-east

Example of vaulting in the crypt

**Stonework above western entrance showing opening of joints**

**Western stairs showing wear**

**Truss in roof space**



**Decorative plasterwork**

**General view of interior towards apse**

## Ground movement analysis

### Tunnel and shaft details

Chambers Wharf tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine assumed VL = 1%.
Tunnel centreline level: +62.3mTD.
Excavated diameter: 6.2m.
Closest shaft: Deptford Church Street shaft located approximately 60m south-east of the building, approximately 25m south of the property boundary. Design contours indicate that the shaft may have some minor impact within the property boundary.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

### Ground conditions

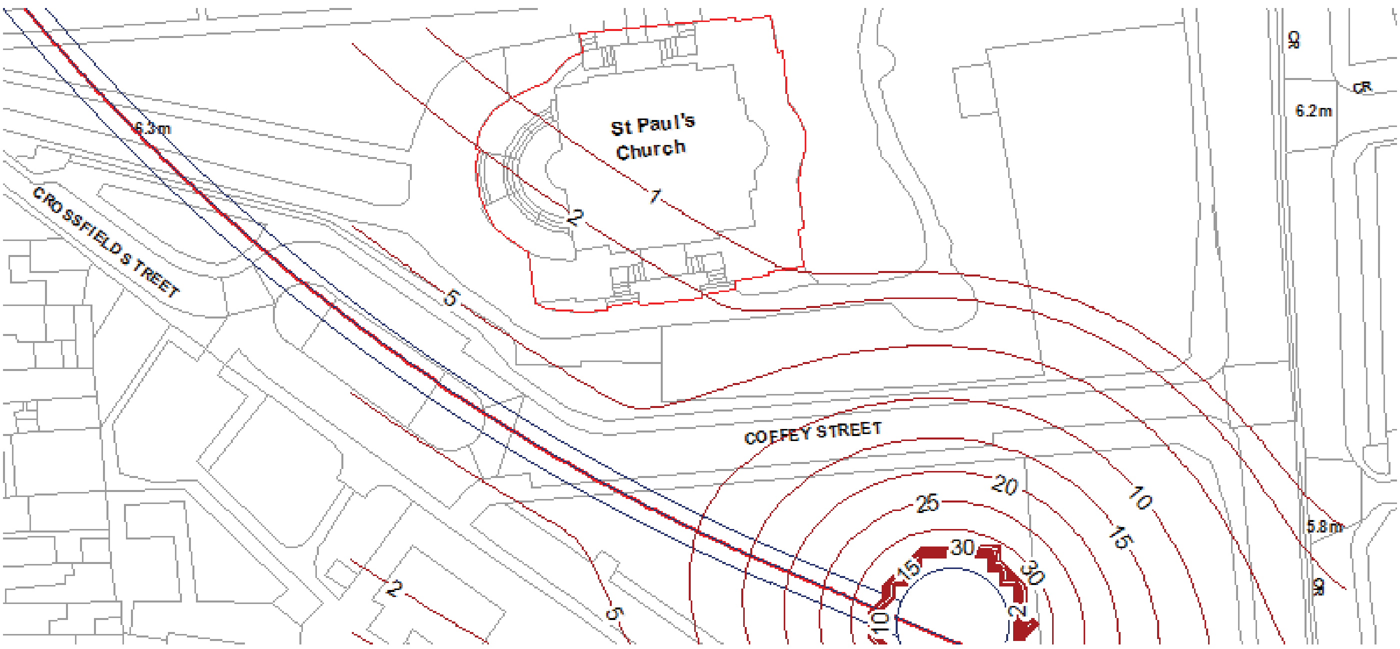
The Chambers Wharf tunnel is proposed to be constructed within the Chalk Group. The expected sequence above the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +105.9mTD to +106.6mTD.
Top of Lambeth Group: +97.0mTD.
Top of Thanet Sand Formation: +92.5mTD.
Top of Chalk Group: +77.0mTD (14.7m above proposed tunnel centreline level).

Review of borehole SR1019 (located approximately 255m to the east) and BGS borehole TQ37NE80 (located approximately 200m south-east) does not indicate any geological features that would require a change in the current ground loss assumptions.

### Results

Settlement contours generated +104.9mTD, approximate base slab level assuming 1m below ground level




As shown above the building crosses the 2mm and 1mm settlement contours.

Four key façades for the building were selected from the GIS model. Analysis was carried out for a building 3m, 4m, 5m, 10m, 15m and 20m high, depending on the location of each façade. Foundations were modelled as ground bearing (1m bgl).

All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.002% and maximum settlement of 4mm. Settlement remained the same for 10m, 15m and 20m high structures, with a slight increase in maximum tensile strain from 20m down to 10m high structures.

It is also noted that many of the walls surrounding the property have also attained listed status. As such three key walls were selected from GIS modelling. The assumed wall height was varied from 0.75 to 1.5m, with foundations extending between 0.25m bgl and 0.5m bgl. All results fell within the bounds of category 0, risk of negligible damage. A maximum tensile strain of 0.03% and a maximum settlement of 10mm were obtained for the walls, when walls were modelled as 0.75m high, with a 0.25m foundation.

The interaction of the ground settlement with the structures is discussed in the interpretation of impact section below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

### Structural assessment and discussion

The church is in good condition overall as noted in the earlier sections. There are some signs of deterioration and movement around the windows and in the external paving and walling above the crypt. These will be subject to ongoing deterioration in the absence of the necessary repairs and any ground movement will tend to be seen at these existing areas of weakness, the former in particular.

The tall spire will be sensitive to movement, although it is not expected to be affected by movements of the magnitude calculated.

Those areas of the boundary wall noted as being in poor condition currently will also be most sensitive to future movement. However the north wall and the east wall (together with the charnel house) lie outside the 1mm contour and would therefore not be expected to be affected by the calculated ground movements.

***Structural sensitivity score is therefore assessed to be 1.***

### Heritage features sensitivity discussion

English Heritage in their listing description describe this church as an "*Outstanding early 18th century parish church, one of the finest achievements of Thomas Archer, in style English Baroque but lent interest by memories of the Roman and the Imperial Baroque characteristic of its author. Its power as a work of classicism is emblematic of the English Baroque moment. The raised body of the church over the crypt, accentuated by elaborate flanking stairs, is an unusual arrangement, which emphasises the importance of burial provision. The freestanding building, standing within a large graveyard, is powerfully designed on each elevation, and displays both great power and erudition in its design. Well preserved and well restored interior, with excellent plasterwork by James Hands and 18th century painted decoration in the apse*". It is clear that both the internal and external finishes of this church are extremely significant, and any damage to the building would damage the heritage significance of the building.

There is very little calculated movement at St Paul's Church, and the majority of the external and internal heritage features will not be sensitive to this level of settlement. However, internally there are some very brittle finishes where even the slightest of cracking could be both detrimental and costly to repair. These are the plasterwork ceilings, and the painted apse.

The listed boundary wall is significant in providing context to the church, but its heritage value is not thought to be compromised by the calculated settlement due to Thames Tunnel works.

***Heritage sensitivity score is therefore assessed to be 1.***

### Condition discussion

This building is generally in good condition, with some minor wear and tear caused in part by a previous lack of maintenance, although the building is currently being well cared for. Of most note is some separation of stone jointing, and slight cracking to the western end of the exterior. The listed boundary wall is in poor condition, and there are some areas of piecemeal repair and distinct failure. The condition of the church itself is unlikely to deteriorate due to the calculated settlement, however the boundary wall may beome more unstable.

***Condition sensitivity score is therefore assessed to be 1.***

## Summary of results

| **Scoring** | |
|---|---|
| **Structural sensitivity score** | 1 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 1 |
| **Damage category** | 0 |

**Recommendations**

The total score for this building is 3.

Whilst there is very little calculated movement in the area of St Paul's Church, it is a hugely significant building with several very fragile features and finishes, which may be easily damaged.

Conservative inputs have been used to calculate ground movements, as such the settlements are expected to be less. Mitigation measures in the form of physical intervention (i.e. soil grouting, underpinning etc) are likely to cause more damage than what would be expected from the construction of the tunnel.

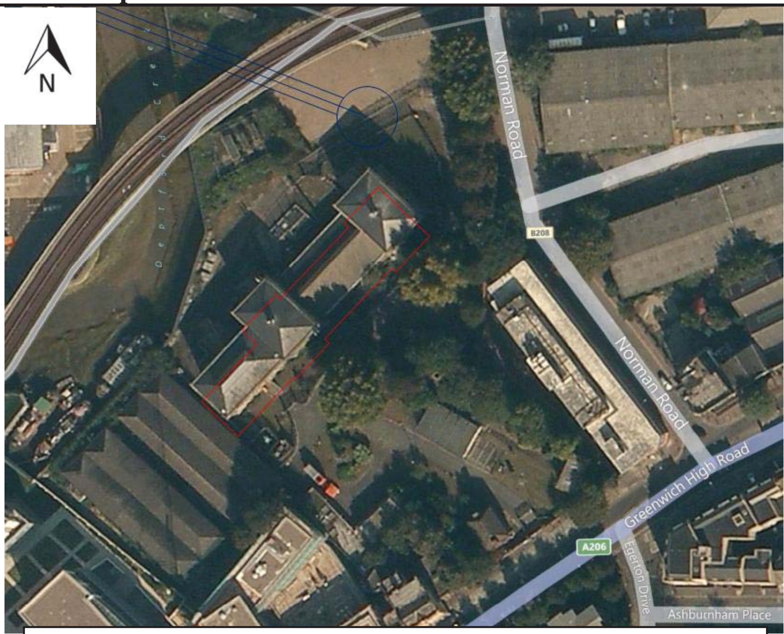
No further assessment is proposed.

# Appendix I: Individual building assessment reports for the London Borough of Greenwich

# Listed building assessment

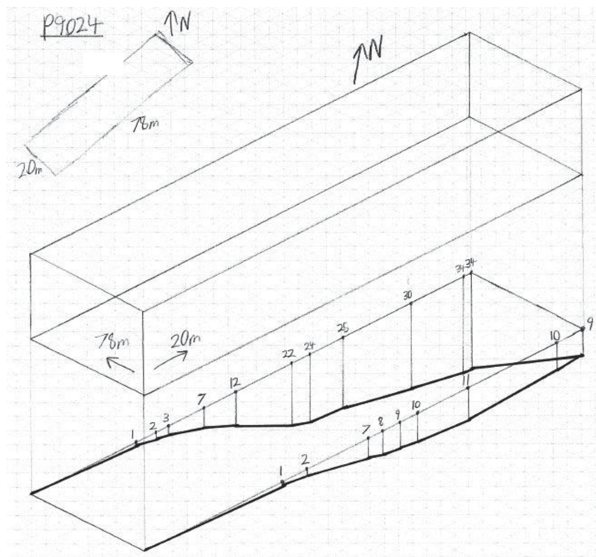
| Building information | |
|---|---|
| **Building reference** | Z3218 |
| **Building name / address** | Greenwich Sewage Pumping Station, SE10 8JL |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 37708 77216 |
| **Ground level (mTD)** | +103.4 to +104.1 |

**Location plan**




Satellite imagery does not align perfectly with GIS mapping – refer to page 4 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing)**

The pair of beam engine houses with linking boiler house at Greenwich Sewage Pumping Station were designed by Sir Joseph Bazalgette and opened in 1865. An extension to the western beam engine house was added in 1905.

The two storey eastern beam engine house is of brick with stone dressings, in Italianate style. The facades are regular, with the main (north west) façade having a central doorway with panelled double doors set in a classical architrave with an overlight, and stone steps leading to the doorway. To either side at ground are square headed windows under an architrave with stone sills. To the first floor level are three arched casements with keystones above. The other facades continue the same pattern of windows. The pitched roof is of Welsh slate, and has a lantern finial to the centre. Internally, this building has been stripped of its fittings, but shows the marks of stairs and beams in the walls. The wrought iron truss to the roof survives.

The western beam engine house matches the eastern. To the west of the original building is an extension built in the same style in 1905. This engine house, which is in operation, shows external modern pipework and ducts relating to its use. Internally, the building contains mechanical equipment dating from the early 1900s to the present day; there are also related measuring and timing devices, probably dating from the 1920s and 30s. Under the building are dry and wet wells, with massive pipe work leading to the sewers.

Running between the eastern and western beam engine houses is a single storey boiler house, with eight bays of arched windows under architraves to the north western elevation, and an arcade of eight arched openings on stone imposts to the south eastern. The slate roof has a continuous clerestory strip rooflight.

In the grounds of the sewage pumping station are other buildings of interest, including a tall chimney, thought to be a vent, and now overgrown, a headstock house with storm water sluices and controls, and an open sided storage shed with hollow iron columns and granite sett flooring.

| Structural description and walkover observations |
|---|
| The two beam engine houses (double storey in height but open internally) are each of loadbearing masonry approximately 780mm thick with an iron truss roof, as is the extension to the south west. The single storey boiler house in the middle, now used as storage and offices, is also of loadbearing masonry. The walls of all of the buildings are quite heavily fenestrated.<br><br>The west beam engine house extends approximately 11m below ground (according to record drawings) and the 1905 (south west) extension has a similar basement. Both buildings have large diameter cast-iron pipes entering and leaving below ground which would be sensitive to ground movements. The buildings are unlikely to have any foundations extending beneath the floor of these basement areas. The east beam engine house is reported to have a basement of similar form which has been filled in since it was taken out of use.<br><br>To the south west of the pumping station building are two coal sheds, each consisting of an iron truss roof supported by cast iron columns. They are open on elevation.<br><br>There are also three smaller buildings on the site: a building housing underground penstocks to the east, an electricity substation to the south and a brick ventilation chimney in the centre. The penstock building appeared to be of similar construction to the larger buildings with a similar deep basement. The substation appeared, externally, to be of similar construction but no access inside this, or the chimney, was possible.<br><br>From the outside, the condition of the brick buildings still in use are in fair condition. A crack (estimated to be approx 1-2mm) was noted high up on either side of the 1905 extension near its interface with the original building, suggesting that it has suffered some settlement causing it to fall away from the original building. Inside, some damage to finishes due to water was visible and the basement areas were clearly suffering from water ingress. The unoccupied east beam engine house was in less good condition with more obvious cracking noted. The condition of the substructure of this building is unknown.<br><br>The coal sheds were generally in good condition albeit settlement of the ground around the southern columns is visible. The columns themselves do not appear to have settled significantly. |

| | |
|---|---|
| **Condition** | Generally fair condition but localised areas are in poor condition. |
| **Assumed foundations** | Deep basement box to each end (pumping rooms). Not piled. |
| **Façade material** | Loadbearing brick with stone dressings. |
| **Internal support system (i.e. superstructure)** | Loadbearing brick. |
| **Heritage** | External pilasters with stone cornice, doorways under architraves, cornices and doorlights; lanterns with louvers; arcade and clerestory lights to boiler house; internal wrought iron roof truss to west beam engine house. |

# Building photographs


North-eastern elevation of the east beam engine house


Linking boiler house and west beam engine house beyond


North-western elevation of the west beam engine house


South eastern elevation of the east beam engine house, with linking boiler house to left


Example of curtilege building on the site, in this case the head stock house


Example of curtilege building on the site, in this case storage sheds with granite sett flooring

| | |
|---|---|
|  Interior of west beam engine house, pipework and galleries |  Interior showing roof structure of east beam engine house |
|  Interior of western section of the west beam engine house |  Ivy-covered chimney-vent to the centre of the site |

## Ground movement analysis

**Tunnel and shaft details**

Chambers Wharf Tunnel constructed within the Chalk Group.
Slurry or Earth Pressure Balance Tunnel Boring Machine – assumed VL = 1%.
Tunnel crown centreline level: +63.4mTD.
Excavated diameter: 6.2m.
Closest shaft: Greenwich Pumping Station shaft, located approximately 12m north – design indicates the shaft is likely to impact on the building location.
Interception and Valve chamber modelled as Secant piled excavation: Surface level 103.5mTD, Base of excavation +91mTD, Pile tip +86.8mTD.
Connection culvert: Surface level 103.5mTD, Base of excavation +90.9mTD, Pile tip +86.7mTD.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

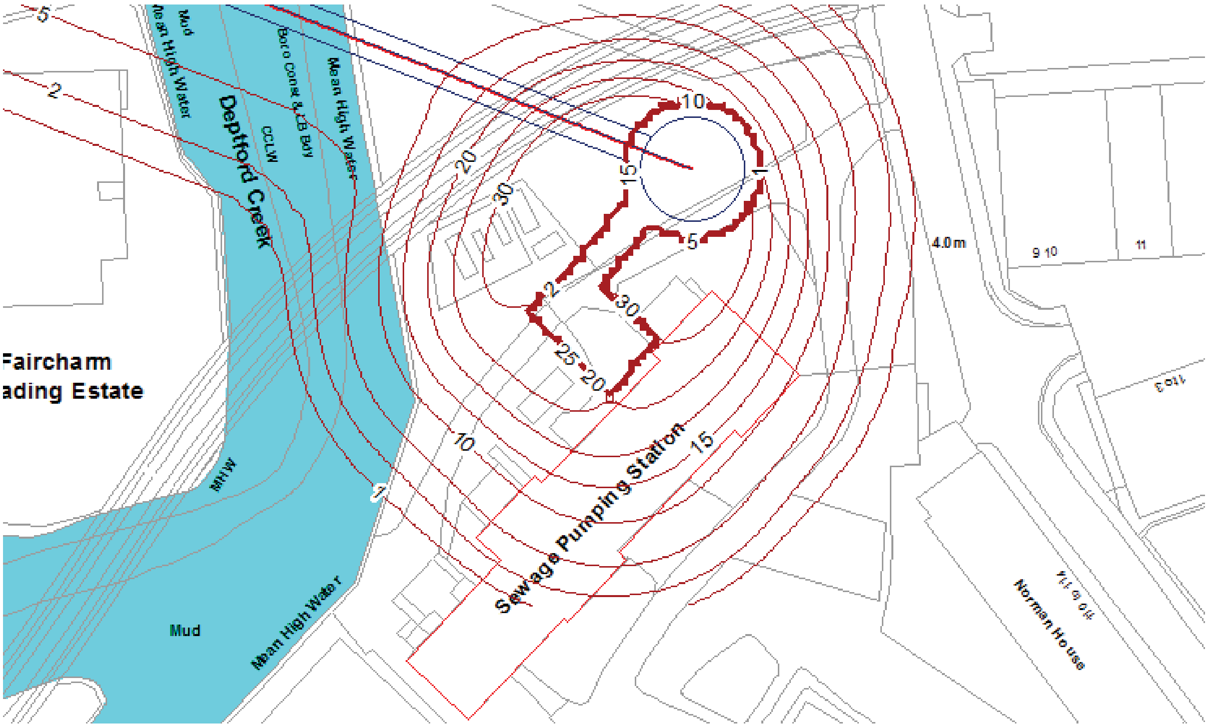
The Chambers Wharf Tunnel is proposed to be installed through the Chalk Group. The expected sequence overlying the tunnel is summarised below;

Superficial deposits/Made Ground: Ground level +103.4mTD to +104.1mTD.
Top of Thanet Sand Formation: +92.0mTD.
Top of Chalk Group: +79.0mTD (15.6m above the proposed tunnel centreline level).

Review of boreholes PR1023 and SR1024 (located approximately 20m south-east and 15m east) does not indicate any geological features such as scour that would require a change in the current ground loss assumptions. However both boreholes show assumed zones of core loss within the Chalk Group.

**Results**

Settlement contours generated at +92.5mTD, for a 11m basement on ground bearing foundations, base slab level from general arrangement drawings provided for Site Interface Assessment




As shown above the structure extends from the 15mm settlement contour, across the 10mm, 5mm, 2mm and 1mm contours.

Thirteen façades were selected for the structure from the GIS model. These were analysed for a 10m tall structure on shallow foundations, with an 11m deep basement (foundations at +92.5mTD).

This site is part of the Site Interface Assessment, with a secant piled interception chamber and connection culvert added to the model, these have been modelled using CIRIA curves. The Greenwich Pumping Station Shaft has been modelled using FE analysis.

This placed the building within category 3, risk of moderate damage. A maximum tensile strain of 0.2% and a maxmum settlement of 34mm were obtained for the structure.

Interaction of the ground settlement with the structure are discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be 3.***

## Interpretation of impact

### Structural assessment and discussion

Fairly large settlements are predicted, concentrated at the northern end adjacent to the East Beam Engine House.
The north west wall of the East Beam Engine House is predicted to experience large settlements (29-34mm), however the differential is only 6mm along its length thus damage due to differential settlement is likely to be small (very slight to slight).
The north east wall of the East Beam Engine House is predicted to experience differential settlement of 26mm. This corresponds to a gradient of approx 1 in 800. Cracking is likely to occur over windows, expected to be in the slight (damage 2) category and can be easily repaired.
A differential settlement of 20mm is predicted across the south west wall of the East Beam Engine House resulting in a gradient of approx 1 in 1000. There is an existing large crack (5mm at the head) which is likely to attract further movement. Further damage may be concentrated at the junction between the East Beam Engine House and the Boiler House. Cracking may occur at the junction between these walls and doors may stick. Damage is likely to be in the slight to moderate category.
Damage can be easily repaired but repairs will be visible.

***Structural sensitivity score is therefore assessed to be 1.***

### Heritage features sensitivity discussion

Sensitive features at the eastern and western beam engine houses include the pilasters with stone cornice, doorways and windows under architraves, cornices and doorlights, lanterns with louvres, an arcade and clerestory lights to boiler house, and internal wrought iron roof trusses.

The majority of settlement is calculated to be at the north-eastern end of the site, and is likely to impact upon the eastern beam engine house. The external heritage features may be sensitive to settlement, and particularly the stone and wrought iron which may be cracked or split. However, there are no internal sensitive features in this area, and no basement pipework or wells.

Although some damage may occur to heritage features, this would not greatly compromise the heritage significance of the whole site.

***Heritage sensitivity score is therefore assessed to be 1.***

### Condition discussion

The eastern beam engine house is in a maintained/consolidated condition, although empty and unused, and there has been recent work done to repair roof damage and ensure that pigeons cannot access the building. The buildings to the west of this are in fair condition, with no major cracking, and are in constant use. However, there are areas of localised poor condition, especially to the curtilage buildings, including vegetation growth and some water ingress.

***Condition sensitivity score is therefore assessed to be 1.***

| Summary of results | |
|---|---|
| **Scoring** | |
| **Structural sensitivity score** | 1 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 1 |
| **Damage category** | 3 |

**Recommendations**

Damage prediction is for category 2 (slight) to 3 (moderate).

The total score is 6.

Both the heritage and structure will be slightly sensitive to the predicted movements, with the north-east corner of the building particularly susceptible. In addition, the use of the building is sensitive to movement, including as it does underground connections and pipes.

Although damage of up to 3 (moderate) is predicted, physical mitigation measures such as underpinning or grouting are not appropriate for this building. The majority of the large movement is concentrated at the north east end of the East Beam Engine House, however this part of the building has been stripped of internal heritage features and will undergo repair and maintenance as part of the plans to introduce new equipment into this space. As such mitigation may take the form of continuing repair and monitoring already in progress by Thames Water at the site. The eastern beam engine house has been subject to building recording, and a plan for its management should be developed alongside the Thames Tunnel works.

**Thames Tideway Tunnel**
Thames Water Utilities Limited

# Application for Development Consent

Application Reference Number: WWO10001

# Environmental Statement

Doc Ref: **6.2.03**

## Volume 3: Project-wide effects assessment appendices

### Appendix E.2: Building damage assessment Stage 3 report - Additional listed buildings

APFP Regulations 2009: Regulation **5(2)(a)**

Hard copy available in

Box **17.3** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

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## E.2 Building damage assessment Stage 3 – Additional listed buildings

E.2.1 The following report has its own table of contents.

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Thames Tideway Tunnel
Thames Water Utilities Limited

# Application for Development Consent

Application Reference Number: WWO10001

## Building Damage Assessment

### Stage 3 – Additional Listed Buildings

Thames Tideway Tunnel
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# Thames Tideway Tunnel

# Building damage assessment Stage 3
# Listed buildings

## List of contents

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## List of abbreviations

| | |
|---|---|
| BS | British Standards |
| CSO | combined sewer overflow |
| CTRL | Channel Tunnel Rail Link |
| EPB | Earth Pressure Balance |
| GIS | Geographic Information System |
| ID | Internal tunnel diameter |
| LBA | Listed Building Assessments |
| PBA | Peter Brett Associates |
| SCL | Sprayed Concrete Lining |
| TBM | Tunnel Boring Machine |

# 1 Introduction

1.1.1 The Thames Tideway Tunnel project comprises a wastewater storage and transfer tunnel (the 'main tunnel') between Thames Water's existing operational sites at Acton Storm Tanks and Abbey Mills Pumping Station that will capture combined sewage flows from 34 'unsatisfactory' CSOs that discharge into the Thames. The flows will be stored in the main tunnel system and transferred to Beckton Sewage Treatment Works for treatment. The project is a component of the overall London Tideway Improvement Programme, which also comprises improvements at five sewage treatment works and the Lee Tunnel project.

1.1.2 As part of the works, the Thames Tideway Tunnel project team has appointed Peter Brett Associates (PBA) and their sub-consultant Arup, to carry out the Thames Tideway Tunnel Building Damage Assessment commission.

1.1.3 The assessment includes assessing the impact of construction for the Thames Tideway Tunnel project on existing listed and non-listed buildings. Document No. 307-RG-TPI-Z0000-000004 presents the methodology adopted and assessment results for the Stage 3 assessment of listed buildings. The Stage 3 assessment provides a building specific assessment of the risk of damage to listed buildings potentially affected by the Thames Tideway Tunnel, considering heritage, sensitivity and structural form in addition to ground movements.

1.1.4 This document contains the Stage 3 assessment of three additional structures which were identified by the Thames Tideway Tunnel project team after the buildings assessed in the main report.

1.1.5 The results for each of these additional listed buildings, for which a Stage 3 assessment has been carried out, are presented in Appendix A of this report. The buildings considered as part of this study are summarised in Table 1.1.

Table 1.1: Summary of listed buildings for Stage 3 assessment

| Building ref | Building name | Listed status | Grid reference | Local authority |
|---|---|---|---|---|
| GS053 | Air shaft to the Rotherhithe tunnel | II | TQ 35534 80649 | Tower Hamlets |
| GS068 | Former railway lookout tower, accumulator tower and chimney | II | TQ 36459 81059 | Tower Hamlets |
| GS107 | Garden wall to former St Anne's Rectory | II | TQ 36632 81100 | Tower Hamlets |

# 2 Thames Tideway Tunnel

2.1.1 The Thames Tideway Tunnel project comprises a wastewater storage and transfer tunnel (the 'main tunnel') between Thames Water's existing operational sites at Acton Storm Tanks and Abbey Mills Pumping Station that will capture combined sewage flows from 34 'unsatisfactory' CSOs that discharge into the Thames. The flows will be stored in the main tunnel system and transferred to Beckton Sewage Treatment Works for treatment.

2.1.2 The assessments contained in this report have been carried out using the Thames Tideway Tunnel alignment dated July 2012 (horizontal alignment revision AP).

2.1.3 The horizontal alignment of the main tunnel will generally follow the River Thames where possible and practical, because:

- It is an efficient route to connect the CSOs located on the north and south banks of the river
- It will allow the use of the river for construction transport (material supply and removal), where practicable and economic
- It will minimise the number of structures the tunnel would pass beneath and so reduce the number of third parties affected.

2.1.4 The route of the main tunnel will take the shortest line from Acton Storm Tanks to the River Thames and stay beneath the river from west London to Rotherhithe. It will then divert from beneath the River Thames to the northeast via the Limehouse Cut and terminate at Abbey Mills Pumping Station, where it will connect to the Lee Tunnel. The captured combined sewage will then be transferred to Beckton Sewage Treatment Works via the Lee Tunnel.

2.1.5 The main tunnel will be approximately 25km long with a nominal internal diameter of between 6.5 and 7.2m. The approximate depth of the tunnel will be between 30m in west London and 65m in east London in order to provide sufficient clearance to existing tunnels and facilities under the capital.

2.1.6 A number of additional 2.2m to 5m internal diameter tunnels are also required to connect the existing CSOs to the main tunnel.

2.1.7 The planned alignment for the Thames Tideway Tunnel runs mainly beneath the River Thames at depths of up to 40m below the river bed. The tunnel alignment has been designed to minimise the impact on buildings and third party infrastructure. The main tunnel is to be constructed by Slurry or Earth Pressure Balance (EPB) style Tunnel Boring Machines (TBM) while some of the smaller connection tunnels are to be constructed with Sprayed Concrete Lining (SCL) and either open face shields, or EPB machines.

# 3 Geology

## 3.1 Route geology

3.1.1 The plans and geological cross sections contained within document 100-RG-GEO-00000-000007 Rev AA “Ground investigation report, Appendix A: Maps and geological sections”, issued by Thames Tideway Tunnel Project Team have been reviewed in order to establish ground conditions along the route. It should be noted that in some areas the alignment has altered since the report was issued and geology along the new route has been conjectured from cross sections along the old route.

3.1.2 The Thames Tideway Tunnel construction will take place through a number of different strata within the London Basin. To the west, from Acton, tunnelling is carried out in the London Clay Formation, continuing through the Lambeth Group, Thanet Sand Formation, and into the Chalk Group as the tunnel location moves eastwards. Shafts are constructed through all of these strata, and the superficial strata overlying the London Clay (these include Made Ground, Alluvium and River Terrace Deposits).

3.1.3 Appropriate parameters have been used to represent the response of these strata to tunnelling and shaft excavation.

## 3.2 Listed building specific geology

3.2.1 The geological cross sections contained within document 100-RG-GEO-00000-000007 Rev AA “Ground investigation report, Appendix A: Maps and geological sections”, issued by the Thames Tideway Tunnel Project Team were initially reviewed with the alignment data for the current route proposal. This was carried out to summarise ground conditions beneath each of the listed buildings being assessed.

3.2.2 The boreholes identified on the Thames Tideway Tunnel project cross sections in closest proximity to each of the listed buildings were obtained from the Thames Tideway Tunnel project team. Where the boreholes were located at a considerable distance from the structure, and information was available, additional borehole data was obtained from the British Geological Survey (BGS). The individual boreholes were then cross referenced against the ground conditions summarised from the cross section information.

3.2.3 The geological unit that the Thames Tideway Tunnel is proposed to be constructed through for each of the listed buildings is summarised in Table 3.1. The minimum ground level data is taken from a digital terrain model within the GIS (Geographical Information System) model for the route.

**Table 3.1: Building specific geology**

| Ref | Building name | Tunnel crown level (mTD) | Excavated tunnel diameter (m) | Approxi mate ground level (mTD) | Geological unit tunnel constructed through |
|---|---|---|---|---|---|
| GS053 | Air shaft to the Rotherhithe tunnel | +53.4 | 8.8 | +105 | Chalk |
| GS068 | Former railway lookout tower, accumulator tower and chimney | +52 | 8.8 | +108.1 | Chalk |
| GS107 | Garden wall to former St Anne's Rectory | +51.8 | 8.8 | +108.2 | Chalk |

# 4 Ground movement assessment

## 4.1 Tunnel excavation

4.1.1 The proposed Thames Tideway Tunnel route has been modelled using the Oasys software Xdisp. This software analyses the greenfield ground movement and calculates settlement and horizontal displacement.

4.1.2 Individual building façades selected from the GIS model were analysed. Displacements were calculated at the underside of foundation level of the building.

4.1.3 Ground movements were determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995).

## 4.2 Shafts and other excavations

4.2.1 There are few methods of analysis from published sources that appraise the magnitude of ground movements arising from shaft excavation in London Clay. New & Bowers (1994) back analysed data arising from construction of a 26m deep and 11m diameter caisson driven shaft in London Clay at Heathrow. The relationship is independent of shaft diameter and therefore New & Bowers (1994) cautioned the use of the relationship where the shaft diameter differs significantly from the 11m shaft monitored as part of the case study.

4.2.2 On the basis of the review of limited case study and on finite element analysis of shafts carried out as part of the Crossrail project, the New & Bowers (1994) relationship has been used for the initial calculation of settlements for the Thames Tideway Tunnel project. Horizontal movements are assumed to be of the same magnitude as vertical movements. The methodology used for calculating shaft displacement is further explained in the Arup Thames Tideway Tunnel report, “Supporting information to CDS relating to ground movement assessment methodology”, Doc number: 307-RG-TPI-00000-000002.

4.2.3 The only asset assessed in this report that is affected by shaft movements is the Rotherhithe Tunnel air shaft. It is understood that the walls of the nearby Thames Tideway Tunnel shaft will be formed from diaphragm walls. The methodology proposed to calculate shaft movements is therefore considered conservative and are expected to overestimate the impact of ground movement on the buildings.

4.2.4 The assessment works for all structures are described in Appendix A.

## 4.3 Proposed assessment parameters

### General

4.3.1 For tunnelling induced ground movements, the displacements have been assumed to follow a Gaussian distribution in accordance with Attewell and Woodman (1982). Based on the geology summarised in Section 3, and the proposed tunnel construction methodology as discussed in Section

4.1, conservative parameters have been used for estimating the effect of tunnelling.

4.3.2 Both end of construction and transitory movements have been considered. The end of construction movements are found to result in most significant impact. Therefore the results given later in this report and in the summary sheets in Appendix A consider only these movements.

### Volume loss – Tunnel boring machines with face support

4.3.3 The Thames Tunnel Project Team has specified 3 values of volume loss to be considered for the assessment. These are based on a best-estimate (0.5%), a moderately-conservative (1%) and a conservative (1.7%) volume loss. PBA/Arup have adopted a Volume Loss of 1% for the sections of the Thames Tunnel alignment constructed by EPB or Slurry style TBMs in either London Clay, Lambeth Group, Thanet Sand or Chalk.

4.3.4 The parameters adopted are considered appropriate for tunnelling in soft ground and are conservative when compared with recorded parameters for similar tunnel projects in London. Experience from Channel Tunnel Rail Link Contract 220 (CTRL), indicates that a volume loss of less than 0.5% was achieved for tunnelling with an 8.11m diameter EPB TBM in Chalk and Thanet Sand, Wongsaroj et al, (2006).

### Settlement trough width

4.3.5 A trough width parameter, k of 0.5 at ground surface has been used for tunnelling in London Clay and the Lambeth Group. The k value at any particular elevation is derived from an empirical equation in relation to depth below ground surface and distance from surface to tunnel axis level using the Mair et al. (1993) and Taylor (1995) methods.

# 5 Listed buildings potentially affected by Thames Tideway Tunnel

5.1.1 The Stage 3 listed assessment report assesses 34 listed buildings identified within the 1mm settlement contour.

5.1.2 Further to issuing this report, three further Grade II listed structures have been identified within the 1mm contour. These are:

- Air shaft to the Rotherhithe tunnel;
- Former railway lookout tower, accumulator tower and chimney; and
- Garden wall to former St Anne's Rectory.

# 6 Desk based heritage study of listed buildings

6.1.1 A desk based study has been carried out to assess the potential heritage issues for each of the structures listed in Table 1.1. The desk based study was completed prior to inspections of the buildings.

6.1.2 Each study collated available information regarding the building from sources including English Heritage and Local Authorities. The information helped to inform the building inspections and is incorporated into the assessment summary sheets included in Appendix A of this report.

# 7 Damage category assessment

## 7.1 Damage category methodology

7.1.1 The listed buildings have been assigned a damage category in accordance with the Burland (1995) framework, see Table 7.1. This framework appraises damage, based upon calculated tensile strains for a deep beam and relates these to the likely approximate crack widths and degrees of damage severity based upon ease of repair. The classification system was predominantly developed for load bearing masonry structures, however it is considered that the descriptions of damage with respect to ease of repair are useful for all building types. Where the individual buildings do not fit within the applied framework, consideration has been given to the applied displacements and their structural form.

**Table 7.1: Building damage categorisation, after Burland (1995)**

| Category of damage | | Description of typical damage (Ease of repair is underlined) | Approx. crack width (mm) | elim, Limiting tensile strain (%) |
|---|---|---|---|---|
| 0 | Negligible | Hairline cracks. | < 0.1 | < 0.05 |
| 1 | Very Slight | Fine cracks that can easily be treated during normal decoration. Perhaps isolated slight fracture in buildings. Cracks in external brickwork visible on inspection. | 1 | 0.05 - 0.075 |
| 2 | Slight | Cracks easily filled. Redecorating probably required. Several slight fractures showing inside of building. Cracks are visible externally and some repointing may be required externally to ensure weather tightness. Doors and windows may stick slightly. | 5 | 0.075 - 0.15 |
| 3 | Moderate | The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weather tightness often impaired. | 5 - 15 or a number of cracks > 3 | 0.15 – 0.3 |
| 4 | Severe | Extensive repair work involving breaking out and replacing sections of walls, especially over doors and windows. Windows and door frames distorted, floor sloping noticeably. Walls leaning and bulging noticeably, some loss of bearing in beams. Service pipes disrupted. | 15 – 25 but also depends on number of cracks | > 0.3 |
| 5 | Very severe | This requires a major repair job involving partial or complete rebuilding. Beams lose bearing, walls lean badly and require shoring. Windows broken due to distortion. Danger of instability. | Usually >25 but depends on number of cracks | |
| Note: Crack width is only one factor in assessing category of damage and should not be used on its own as a direct measure of it. Note: Local deviation of slope, from the horizontal or vertical, of more than 1/100 will normally be clearly visible. Overall deviations in excess of 1/150 are undesirable. | | | | |

7.1.2 Façades for assessment of each building were selected from the GIS model. Ground movements for each façade have been analysed in Xdisp, with appropriate height and foundation levels applied to each façade (levels assessed from desk based study and site visit). A damage category was then assigned to each building based on the critical results.

7.1.3 If a listed building obtains a damage category score of 3 or above (described as ‘moderate’ damage in the work of Burland (1995)), mitigation measures are considered.

7.1.4 Where a listed building obtained a damage category score of less than 3 the score has been considered in conjunction with other assessments (see Figure 8.1), as defined in Section 8.

# 8 Structural, condition and heritage sensitivity assessment

## 8.1 Introduction

8.1.1 The structural, condition and heritage sensitivity methodology has been based on the Crossrail assessment methodology and was developed in consultation with English Heritage and relevant local authorities.

8.1.2 The methodology treats each listed building as an individual case and considers the ground movements modelled during the damage category assessment. The nature of each building in terms of structure, condition and evidence of previous repair, alteration and movement has been taken into account during the scoring process. Scoring has been split into three assessment categories, ensuring that buildings which may have particular sensitivities have been accounted for.

## 8.2 Structural sensitivity background

8.2.1 The assessment of the structural sensitivity of the listed buildings is based generally on the approach adopted for Crossrail, as outlined in Crossrail Information Paper D12. There is no formal standard which codifies this approach. The method identifies a number of factors which may be accepted as being of significance in the building's response to ground movement (including the building's condition) and are then reviewed in conjunction with the magnitude of such movement. Examples of such factors are given in Table 8.1.

8.2.2 The building is then given a structural sensitivity score, based on the inspection of the building and the calculated movements and damage category.

8.2.3 This score then forms one component of the overall 'total' score assigned to the building. It is the total score that is considered alongside the calculated building distortion when appraising whether mitigation is necessary.

## 8.3 Condition sensitivity background

8.3.1 As part of the Thames Tideway Tunnel project Stage 3 listed building assessments, the general condition, as found on the day of inspection, has been graded as being good, fair, poor or very poor. This condition is then related to the damage assessment score, to enable a judgement to be made as to whether the particular condition defects of a certain building will make it more sensitive to the calculated movement.

8.3.2 The building is subsequently given a condition score, combining the damage assessment calculation with the observations on condition. The poorer the condition of a building is, the higher its sensitivity is likely to be. However, if a building is in poor condition but structurally sound, and in an area where settlement is calculated to be minimal, then its sensitivity due to condition will be low, and the works will not be expected to produce further deterioration.

8.3.3 While the Arup/PBA scope of work required both internal and external inspections of all listed structures, due to access constraints, it was not possible to carry out internal inspections of the Air shaft to the Rotherhithe tunnel or the former railway lookout tower, accumulator tower and chimney.

## 8.4 Heritage sensitivity background

8.4.1 The Stage 3 listed building assessment (LBA) process for the Thames Tunnel project commission has been generally based on the approach used by Crossrail. This approach has been refined to take account of improvements developed during the application of the Crossrail approach.

8.4.2 It should be noted that the magnitude of impact from the Thames Tideway Tunnel project works is generally significantly less than that of Crossrail on listed structures. This is due to a number of factors, including: much of the Thames Tideway Tunnel alignment is located beneath the Thames River; the Thames Tideway Tunnel only requires a single bore tunnel compared to Crossrail's dual bore; and the stations on Crossrail are major SCL excavations adjacent to numerous listed buildings, whereas the Thames Tunnel connecting structures are generally away from buildings.

8.4.3 For the Thames Tideway Tunnel project work, damage assessment information from calculated ground movement was available prior to the LBA, ensuring that heritage 'scoring' took into account the level of damage assessed for each building from the outset. This has allowed a realistic heritage sensitivity score to be allocated without the need for re-assessment.

8.4.4 For the Thames Tideway Tunnel project commission the LBAs have been conducted on an individual, building-specific basis, with external and internal (where possible) visual survey of the buildings complementing the desk based study. Scoring has been based on the building's structural form, sensitive features, fixtures and finishes, and the damage assessment results.

## 8.5 Guidance for scoring structural, condition and heritage sensitivity

8.5.1 In order to ensure a consistent approach to the derivation of scores for structural, condition, and heritage sensitivity, the scoring matrix shown in Table 8.1 has been developed and used on the project.

**Table 8.1: Structural and heritage scoring matrix for listed buildings**

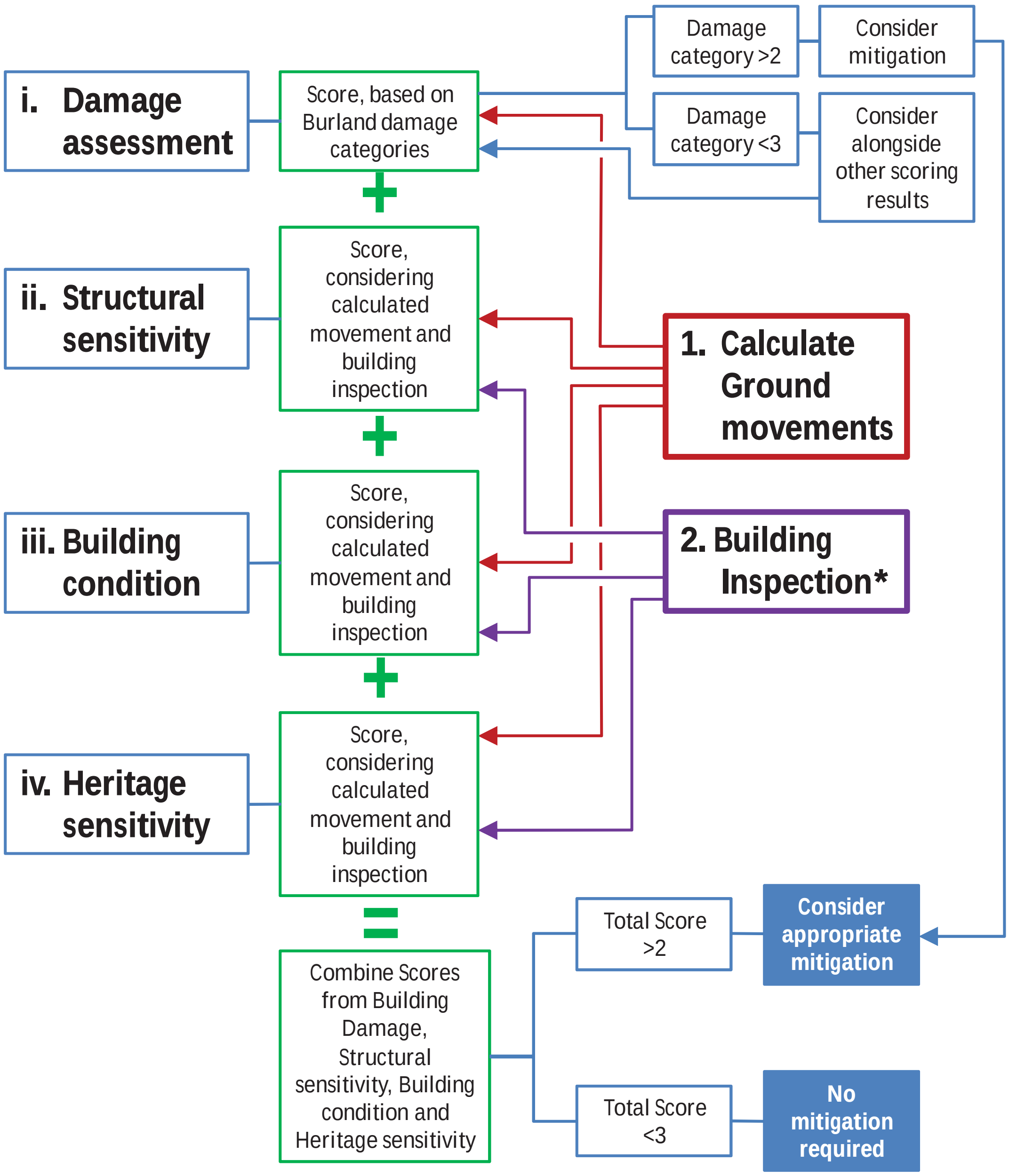
| Score | STRUCTURE | HERITAGE FEATURES | CONDITION |
|---|---|---|---|
| | **Sensitivity of the structure to ground movements and interaction with adjacent buildings** | **Sensitivity to calculated movement of particular features within the building** | **Factors which may affect the sensitivity of structural or heritage features** |
| **0** | Masonry buildings with lime mortar and regular openings, not abutted by other buildings, and therefore similar to the buildings on which the original Burland assessment was based. | No particular sensitive features | Good - not affecting the sensitivity of structural or heritage features |
| **1** | Buildings not complying with categories 0 or 2, but still with some sensitive structural features in the zone of settlement e.g.: cantilever stone staircases, long walls without joints or openings, existing cracks where further movements are likely to concentrate, mixed foundations | Brittle finishes, e.g. faience or tight-jointed stonework, which are susceptible to small structural movements and difficult to repair invisibly. | Poor - may change the behaviour of a building in cases of movement. Poor condition of heritage features and finishes. Evidence of previous movement. |
| **2** | Buildings which, by their structural form, will tend to concentrate all their movements in one location (e.g.: a long wall without joints and with a single opening). | Finishes which if damaged will have a significant effect on the heritage value of the building, e.g. Delicate frescos, ornate plasterwork ceilings. | Very poor – parlous condition of heritage features and finishes, or severe existing damage to structure including evidence of ongoing movement. Essentially buildings which are close to collapse or where finishes are loose such that even very small movements could lead to significant damage. |

8.5.2 The matrix in Table 8.1 is a tool, to be used in conjunction with the results of the building inspections. The scores have been used to guide judgements for the individual buildings. However, the structural and heritage assessment is not purely a scoring process, more an integrated review of the available information.

## 8.6 Combining to produce overall building score

8.6.1 The scores from the building damage, structural sensitivity, condition, and heritage sensitivity assessments were combined to produce an overall score for each building. The overall scoring process is described diagrammatically in Figure 8.1.

**Figure 8.1 Overall listed building assessment process.**




* May be based on desk-based virtual inspection. Conservative view taken if so.

8.6.2 Buildings that obtained a combined score of 3 or more were subject to a further level of evaluation. This further level has been undertaken with a view to mitigating damage and draws on data from the building damage category assessment. Where a building was assessed as damage category 0 (negligible damage), consideration has been given to the structure, heritage feature and condition scores. At the same time engineering judgement has been applied by the assessor to ensure the combined score does not result in an inappropriately high total impact score for the anticipated ground movement.

# 9 Results of assessment

## 9.1 Introduction

9.1.1 The three listed buildings within the 1mm settlement contour have been subject to assessment, as described in Sections 7 and 8. The individual assessment report sheets are provided in Appendix A.

9.1.2 Reasonable efforts have been made to access all three listed structures. Access has not been gained to either the Air shaft to the Rotherhithe tunnel or Former railway lookout tower, accumulator tower and chimney. Where internal access has not been possible, an external inspection has been carried out, and a conservative position taken in the assessment.

## 9.2 Results of damage category assessment

9.2.1 The results all fell within the bounds of risk of damage category 0, negligible damage, defined as hairline cracks (crack width <0.1mm).

## 9.3 Results of structural sensitivity classification

9.3.1 Of the listed buildings inspected, all three score 1 for their structural sensitivity.

9.3.2 The Air Shaft to Rotherhithe Tunnel is circular and has fine mortar beds. The Accumulator tower is a tall structure relative to the width and there is a small risk that cracks may appear at the interface between the tower and chimney. The wall to the former St Anne's Rectory is a long structure with no movement joints. These features make the structures assessed slightly sensitive to movements owing to their structural form.

## 9.4 Results of heritage classification

9.4.1 From the structures inspected, the Air Shaft to Rotherhithe Tunnel was assigned a score of 1 for heritage sensitivity. If damage was to occur to some of the finishes to this structure it may be difficult to invisibly repair.

9.4.2 The other two structures assessed have been assigned a heritage score of zero.

9.4.3 Historic finishes are both difficult and costly to repair due to the scarcity of specialist trades people and materials. The repair of any historic features and finishes damaged during the Thames Tideway Tunnel works require specific consent, local authority and English Heritage agreement on materials and method, and employment of specialist contractors.

## 9.5 Results of condition classification

9.5.1 From the structures assessed, the wall to the former St Anne's Rectory was assigned a condition score of 1. The condition of the wall is poor, and there are existing cracks to the centre of the wall, at the point of the highest settlement. These cracks may widen, and new cracks form, due to the current condition of the wall.

9.5.2 The other two structures assessed have been assigned a condition score of zero.

9.5.3 The strategy for defect / condition survey is still being defined by the Thames Tunnel Project Team. Given the heritage listed status of the buildings assessed in this report, it is considered prudent to carry out a pre and post condition surveys, so that the responsibility for any alleged damage can be clarified.

## 9.6 Results summary

9.6.1 The individual assessment summaries for each listed building are presented in Appendix A. Table 9.1 summarises the listed building assessment results;

**Table 9.1: Listed building assessment result summary**

| Ref | Building name | Damage category | Structural sensitivity | Heritage sensitivity | Condition | Total |
|---|---|---|---|---|---|---|
| GS053 | Air shaft to the Rotherhithe tunnel | 0 | 1 | 1 | 0 | 2 |
| GS068 | Former railway lookout tower, accumulator tower and chimney | 0 | 1 | 0 | 0 | 1 |
| GS107 | Garden wall to former St Anne's Rectory | 0 | 1 | 0 | 1 | 2 |

9.6.2 None of the structures assessed have a combined score of 3 or more, corresponding to the threshold when mitigation is considered.

## 9.7 Vibration assessment from site works

9.7.1 An assessment of vibration has been carried out for the Air shaft to the Rotherhithe tunnel due to the proximity of the building to the King Edward VII Memorial Park construction site.

9.7.2 The assessment has been based upon the Thames Tideway Tunnel reference design for planning drawings. The construction site arrangement at King Edward VII Memorial Park is shown on the drawing: 100-DA-CNS-PTH1X-269105 Rev A1. This indicates that the Air shaft to the Rotherhithe tunnel will be located approximately the following distances from site works that have the potential to cause vibration:

- Sheet piling to form cofferdam = 21m
- Access / haul route = 7m
- Diaphragm walling to from TTT shaft = 40m.

9.7.3 It is assumed that a vibratory method is used to advance the sheet piling. Based upon the distances, vibration levels will attenuate to less than but still 1mm/s at the location of the air shaft. Therefore the works are not envisaged to have any impact on the structure.

9.7.4 For the access / haul route, it is assumed that this will be formed from a relatively good surface, so given the distances, it is not envisaged that any significant vibration will be caused to the air shaft.

9.7.5 It is envisaged that the diaphragm walling will be constructed using a hydrofraise. Given the distances between the construction activity and air shaft, vibrations are not envisaged to have any significant effect.

## 9.8 Mitigation measures

9.8.1 From the assessments carried out, it is not considered appropriate to propose mitigation measures to limit the impact on the structures.

# 10 Risks and opportunities

10.1.1 The following risks, opportunities or assumptions have been identified from the Conceptual Design Statement (CDS) and from carrying out the Stage 3 assessment. Comment is provided with respect to gaining a better understanding of how best to resolve or mitigate risks.

**Table 10.1: Risks and opportunities**

| Risk identified | Impact * | Action taken / proposed |
|---|---|---|
| Shaft assessment methodology validated from little case study data. | Possibility that method is not transferrable to all of the Thames Tideway Tunnel shaft construction / dimensions. | None proposed. The methodology is considered conservative for the shaft in the vicinity of the Air shaft to the Rotherhithe tunnel. |
| Use of Burland (1995) method for masonry buildings relies on buildings being similar to Burland case studies | Damage could be worse than assessed | Where buildings do not fit the Burland methodology this has been taken into account in the Structural Sensitivity Score. The individual reports include assessment of the Burland results where the structure does not completely fit the model. |
| Long term settlements not included in damage assessments | Long term settlements could increase distortion to structures | Several authors have indicated that this is not an issue.<br>A review of available Jubilee Line Extension data and finite element studies carried out as part of Crossrail design work could be carried out to review this assumption. |
| Scour features, other geological anomalies | Volume losses for use in assessments cover the normal range of geotechnical scenarios, but do not account for anomalies | Scour features report reviewed as part of Arup-PBA building assessment commission. |
| Ground movements calculated for tunnelling in chalk conservative | Increase in number of affected buildings due to conservative assessment | A review of the Lee tunnel data could be carried out when available to refine analysis parameters for chalk.<br>The tunnelling induced ground movements are conservative, therefore on average the actual damage is likely to be less than calculated. This comment can also be applied to a lesser degree to all tunnelling induced ground movements. |

| Risk identified | Impact * | Action taken / proposed |
|---|---|---|
| Internal surveys not carried out for all buildings | Potential for missed features which may impact damage risk categorisation. | Access could not be gained to all properties. There is a risk that important structural or heritage features may not have been identified as part of the work described in this report. |
| Damage to Services entry / exit to building. Not specifically appraised in the absence of having any details. | Potential risk for brittle services that cannot accommodate movement. | No action taken, but could be considered as part of a separate study based on previous studies for the Crossrail project. |
| No dewatering movements included in assessment | Potential for increased settlements and distortions. The ground movement assessments do not specifically consider dewatering movements. | None proposed. It is considered likely that dewatering may take place to construct shafts along the route. While the dewatering may marginally increase settlements and strains relative to those assessed in this report, it is not considered likely that the overall conclusions will change. Further analysis would be necessary to quantify the magnitude of settlement and strain increase. |

# 11 Summary and recommendations

11.1.1 Three additional listed structures were considered in this Stage 3 building damage assessment.

11.1.2 Each of the three buildings were assessed using the criteria and methodologies described in Sections 7 and 8. However at the time of writing access could not be gained to the following properties:

- Air shaft to the Rotherhithe tunnel; and
- Former railway lookout tower, accumulator tower and chimney.

11.1.3 All of the buildings were analysed for ground movement and assigned a building damage category. They were also the subject of a desk study review. The listed building assessment reports have been completed as fully as possible under the circumstances for each building and are provided in Appendix A of this report.

11.1.4 All structures were assessed to be within category 0, negligible damage, when analysed for building damage category. Condition, structural sensitivity and heritage scores were also assigned to each structure based upon the available information and site inspection. The sum score for all of the structures assessed was less than 3.

11.1.5 The impact of vibration on the Air shaft to the Rotherhithe tunnel from site works at the King Edward VII Memorial Park construction site has been assessed. The impact from vibration is not considered to be significant.

11.1.6 Mitigation is therefore not proposed for any of the structures assessed within this report.

11.1.7 The strategy for defect / condition survey is still being defined by the Thames Tunnel Project Team. Given the heritage listed status of the buildings assessed in this report, it is considered prudent to carry out a pre and post condition surveys, so that the responsibility for any alleged damage can be clarified.

# Bibliography

## General

At this stage, PBA/Arup is not aware of any particular assessment requirements from the asset owners. The ground movement and building damage, structure and heritage assessments have been carried out using appropriate methods in accordance with engineering standards and codes adopted by the tunnelling industry and on projects such as Crossrail and HS1.

The codes, technical papers and best practice guides used are listed below.

## Structural codes:

| | | |
|---|---|---|
| BS | 8110-2:1985 | Structural use of concrete - Part 2: Code of practice for special circumstances |

Reference to British Standards (BS) and Eurocodes will be made where appropriate.

## Tunnel references

Attewell P B and Woodman J P (1982), Predicting the dynamics of ground settlement and its derivatives caused by tunnelling in soil. Ground Engineering, November 1982, 13 - 36.

Burland J B (1995). Assessment of risk of damage to buildings due to tunnelling and excavation. Invited Special Lecture: In: 1st Int. Conf. On Earthquake Geotech.Engineering, IS Tokyo ’95.

Crossrail Information Paper, D12 Ground Settlement, Version 5, 2008.

Mair R J, Taylor R N & Bracegirdle A (1993), Sub-surface settlement profiles above tunnels in clays, Geotechnique, Vol. 43 No. 2, pp 315-320.

New B M & Bowers K H (1994), Ground movement model validation at the Heathrow Express trial tunnel. Proc. Tunnelling 1994. IMM, London, pp 301-327.

Taylor R N (1995), Tunnelling in soft ground in the UK. In: Underground construction in soft ground. K Fujita and O Kusakabe (Eds). Balkema. pp123-126.

Wongsaroj J et al (2006), Effect of TBM driving parameters on ground surface movements: Channel Tunnel Rail Link Contract 220, Proc. Geotechnical Aspects of Underground Construction in Soft Ground pp 335-341

# Appendix A: Individual assessment reports

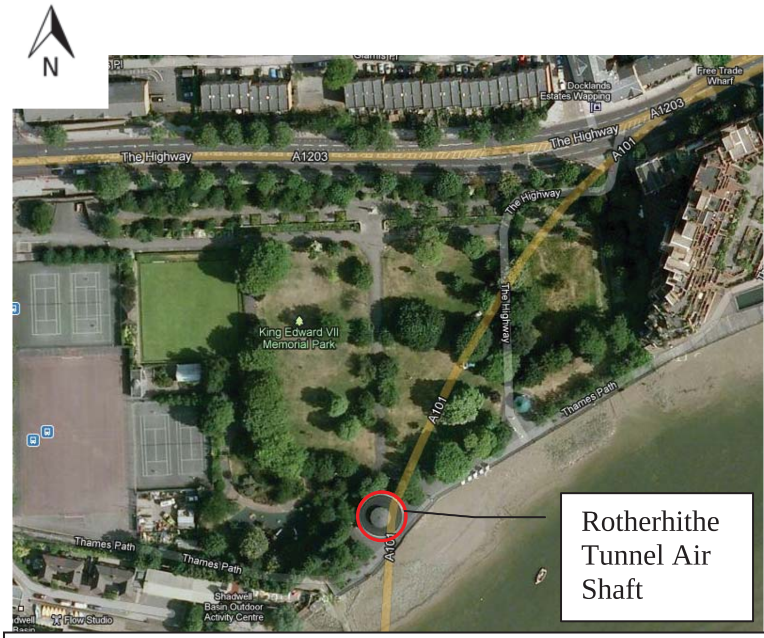


DRAFT AND CONFIDENTIAL

# Listed building assessment

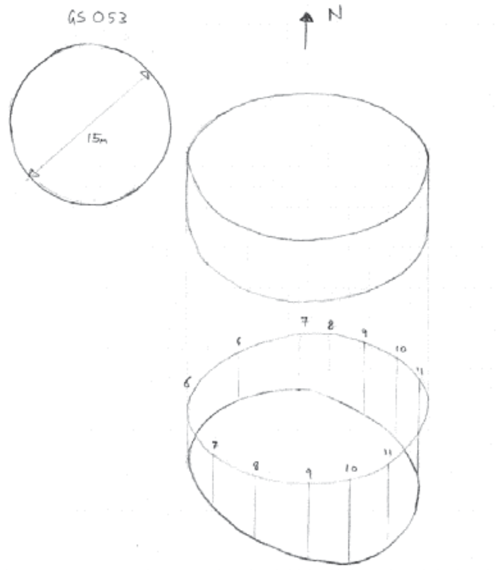
| Building information | |
|---|---|
| **Building reference** | GS053 |
| **Building name / address** | Air shaft to the Rotherhithe Tunnel |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 35534 80649 |
| **Ground level (mTD)** | +105 |

**Location plan**




Satellite imagery does not align perfectly with GIS mapping – refer to page 5 for building location.

**Isometric ground movement sketch**




Settlements in mm (1m below ground level)

**Building description (including excerpts from English Heritage listing, where appropriate)**

The air shaft to the Rotherhithe Tunnel, situated in King Edward VII Memorial Park, is a single storey red brick building with Portland stone dressings, built by Sir Maurice Fitzmaurice for the London County Council in 1904-08.

The building is circular, roofed in slate with a central brick and stone cupola. The entrance is to the south, and incorporates two openings within one bay, with stone surrounds. Each bay has a double opening, again with stone surrounds; these openings contain wrought iron tracery incorporating the letters ‘LCC’. Internally, the shaft contains an iron stair with a wrought iron balustrade, and cast iron lamp standards.

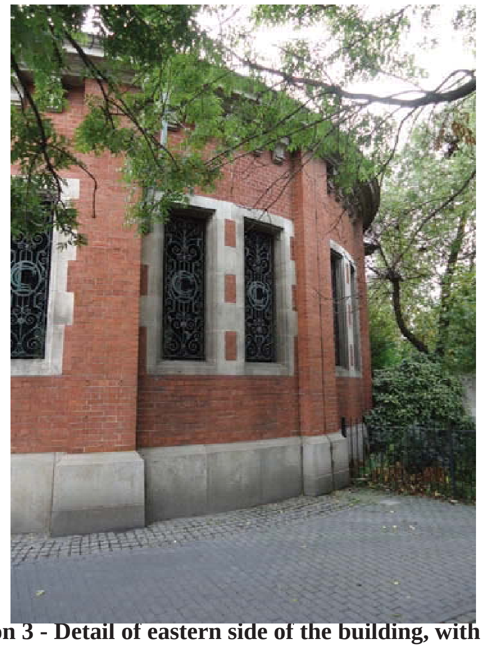
The building is generally in fair condition, with some evidence of repair to mortar, and some areas of deteriorating brick work and minor cracking.

| Structural description and walkover observations | |
|---|---|
| The air shaft is a single story circular masonry structure.<br><br>The construction and thickness of the wall is unknown however based on the external inspection it is assumed that the walls are of solid brick construction with thin mortar beds founded on a Portland stone plinth.<br><br>Both the brick and stonework show signs of deterioration with multiple ‘hairline’ to ‘fine’ cracks. | |
| **Condition** | Fair – some minor deterioration of brickwork and small cracks |
| **Assumed foundations** | Founded at depth on the tunnel structure |
| **Façade material** | Brick with Portland stone dressings |
| **Internal support system (i.e. superstructure)** | |
| **Heritage** | The building has historical and aesthetic significance. Particularly significant elements include the window openings and iron grilles with LCC lettering, the general shape and appearance of the building within its context, and the internal stair and lamp standards. |

## Building photographs

**Caption 1 – General view of air shaft**

**Caption 2 – View of air shaft from above**



**Caption 3 - Detail of eastern side of the building, with LCC grilles showing clearly**

## Ground movement analysis

**Tunnel and shaft details**

The Rotherhithe shaft is constructed through the Made ground, London Clay Formation and suspected to toe into the Lambeth Group.
The proposed tunnel is to be constructed within the Seaford Chalk
Closed face tunnelling using slurry support and shield – assumed VL = 1%.
Tunnel centreline level: +49mTD (-51mOD).
Excavated diameter: 8.8m.
Closest shaft: King Edward Memorial Park shaft, located approximately 40m east – calculations indicate shaft ground movements have a minor influence at the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). Ground movements from the shaft excavation have been calculated using the New & Bowers (1994) method. Sub-surface movements are conservatively assumed to be the same as surface movements. |

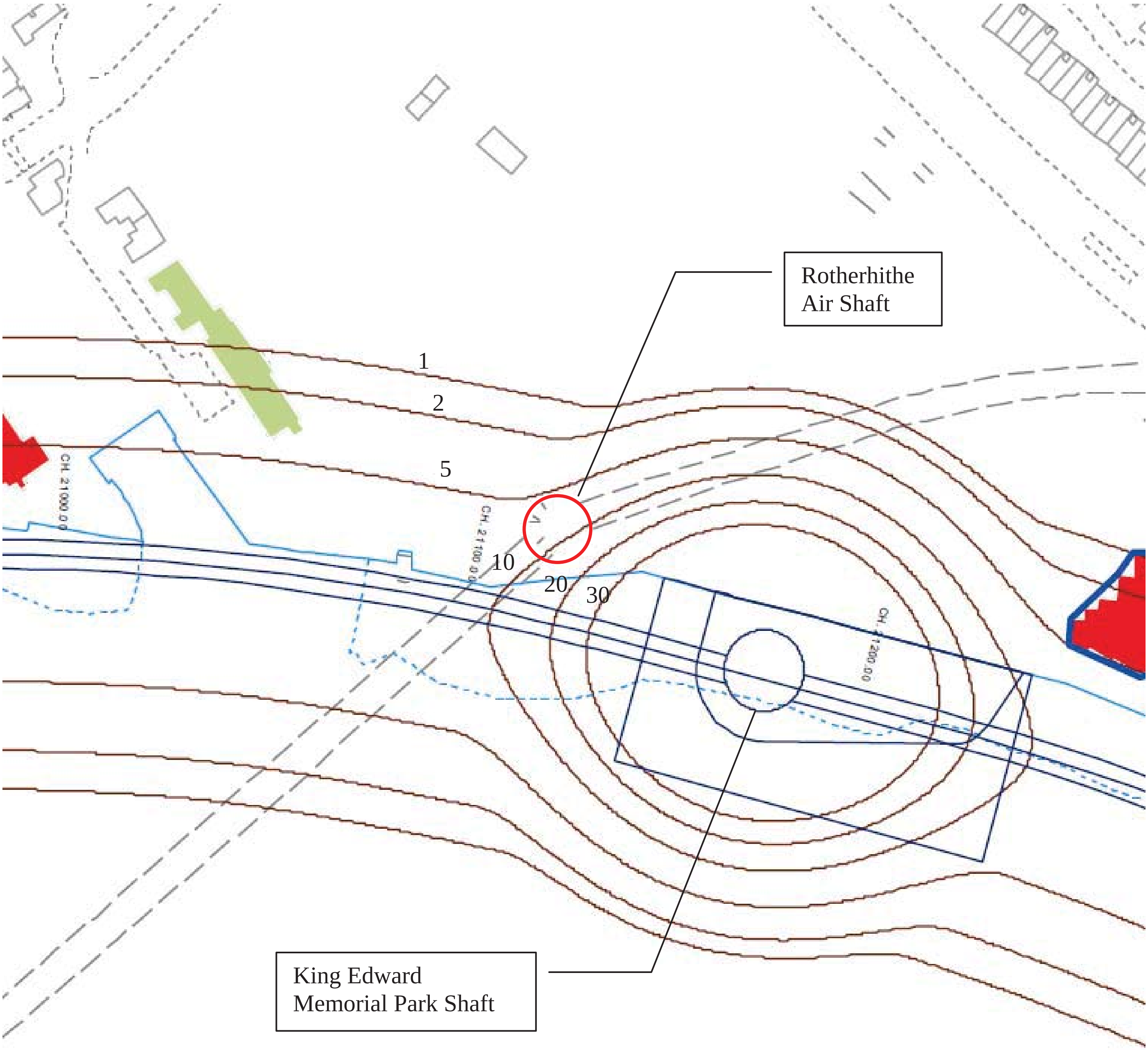
**Ground conditions**

The Rotherhithe Air Shaft is constructed within London Clay Formation. The expected sequence above the tunnel has been estimated from the Geological Section 100-DA-GEO-MT032-600356 from boreholes adjacent to King Edward Memorial Shaft, the approximated sequence is summarised below;

Superficial deposits/Made Ground: Ground level +105.2mTD to +99mTD.
London Clay: +99 to 91mTD
Lambeth Group +91mTD to +72m TD
Thanet Sand Formation +72mTD to +60mTD
Top of Chalk +60mTD (11m above proposed tunnel centreline level).

**Results**

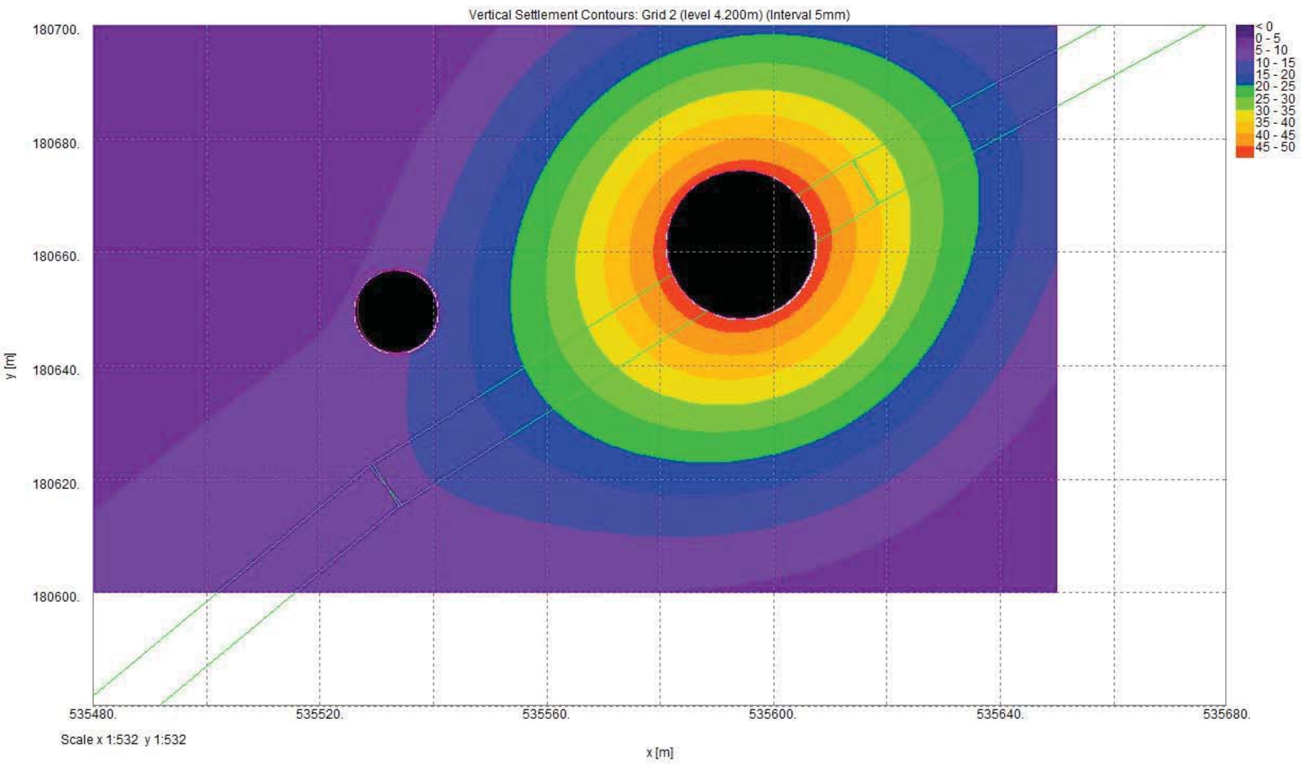
Settlement contours (mm) generated 1m below ground level



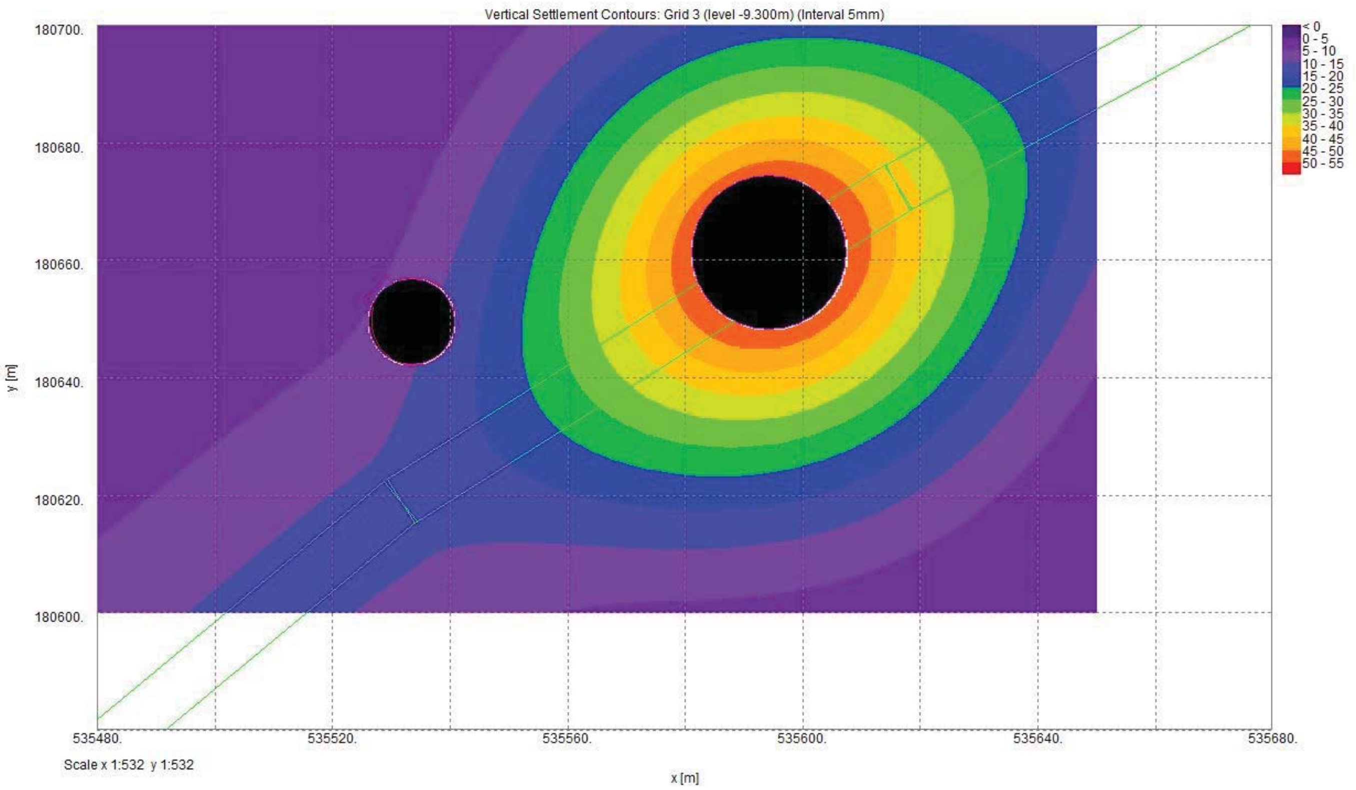

As shown above the Rotherhithe Air Shaft lies between the 5mm and 20mm contours.

Analysis of the key façades selected from the GIS model, assume a building height of 6m above ground level, with a founding level to the existing crown depth of the Rotherhithe tunnel currently assumed to be 14.5m below ground level. The shaft has been modelled 1m below gound level (+104.2mTD) and at the base of the shaft (+92.7mTD).

Settlement contours at +104.2mTD (1m below ground surface):




Settlement contours at +92.7mTD (at shaft base):




The results fall within category 0, risk of negligible damage, with a maximum tensile strain of 0.036% and maximum settlement of 12.2mm.

The interaction of the ground settlement with the structures is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The structural form (a circular structure without movement joints and thin mortar beds) will be slightly sensitive to ground movements. The condition of the structure means that some existing cracks may widen very slightly. However the differential settlement is only approximately 5mm across the footprint of the structure. Given the form of the structure and the settlement profile it is reasonable to assume that the structure will exhibit a rigid rotation and as the impact of these movements are likely to be of little significance to the structure.

***Structural sensitivity score is therefore assessed to be 1.***

**Heritage features sensitivity discussion**

The maximum settlement will be concentrated at the eastern side of the building, and may cause very minor damage to stone or brickwork in this area. This may slightly change the current aesthetic appearance of the building, which is of note within its context. There may also be a slight impact on the LCC iron grilles within window openings should damage occur to the stone and brick of the openings themselves.

***Heritage sensitivity score is therefore assessed to be 1.***

**Condition discussion**

The condition of this building is fair; although there is existing deterioration of brick work, this is very minor, and will not exacerbate damage assessed.

***Condition sensitivity score is therefore assessed to be zero.***

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 1 |
| **Heritage sensitivity score** | 1 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

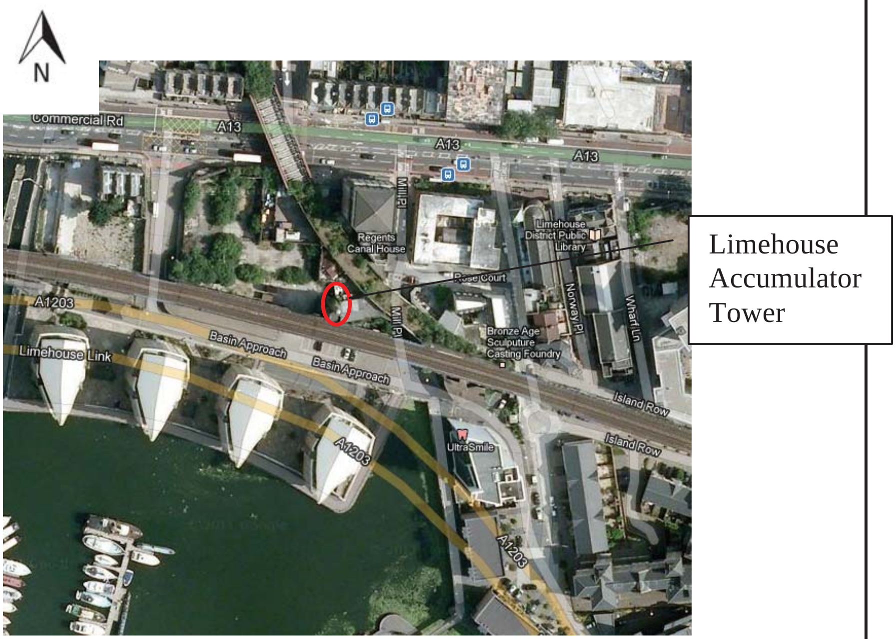
The total score for this building is 2.

The structure of the Air Shaft to Rotherhithe Tunnel is not sensitive to the levels of settlement and strain calculated and the heritage features will not suffer more than very slight deterioration due to settlement. Therefore the structure will not be taken forward for further damage assessment and will not require mitigation.

# Listed building assessment

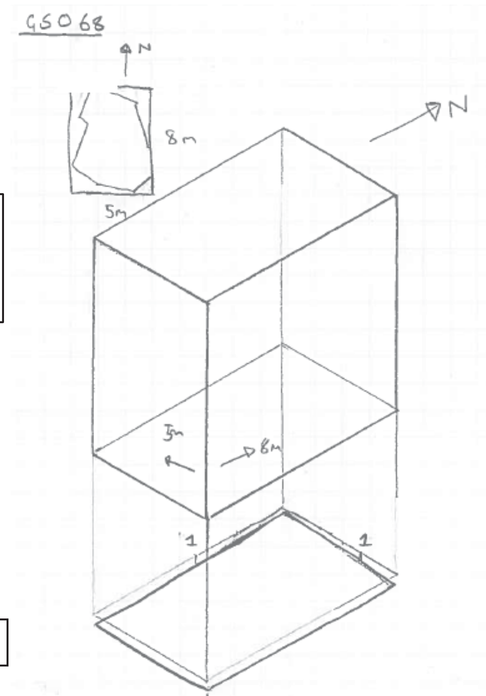
| Building information | |
|---|---|
| **Building reference** | GS068 |
| **Building name / address** | Former railway lookout tower, accumulator tower and chimney |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 36459 81059 |
| **Ground level (mTD)** | +108.1 |

**Location plan**




Satellite imagery does not align perfectly with GIS mapping – refer to page 5 for building location.

**Isometric ground movement sketch**




**Building description (including excerpts from English Heritage listing, where appropriate)**

Listed as the Former Railway Lookout Tower, this Grade II listed building is more commonly known as the Limehouse Accumulator Tower, and was erected in 1869. In the listing description, the tower is described as having been part of the Blackwall Railway, with views to Fenchurch Street. Other descriptions, including that of British Waterways, cite the building's use as a hydraulic accumulator tower, used to power winding equipment associated with the Limehouse dock and canal.

The building is currently disused, and the hydraulic machinery has been removed. Situated next to the former Blackwall railway viaduct, it is octagonal in plan, and constructed of stock brick with stone and brick dressings, including a brick blocking course above first floor level, and a stone cornice above second floor level. There are round headed arrow-slit windows to second floor level on alternate faces, with white brick surrounds; these openings now contain modern windows. To the north side of the building is a tall brick chimney.

Internally, the tower contains a modern spiral stair, used for access to a viewing tower behind the parapet at the top of the building.

**Structural description and walkover observations**

The building structure appears to be formed from load bearing masonry.

The building is in fair condition, with signs of brick replacement and repair; the upper part of the chimney has been rebuilt. There are signs of some brick erosion at ground floor level, particularly around the entrance, and vegetation growth including ivy to the north eastern façade of the tower.

This building was externally inspected from about 10m away on the south side only; no access was gained for internal inspection or for close up external inspection.

| | |
|---|---|
| **Condition** | Fair, with obvious repairs and brick replacement. Evidence of eroded brickwork to the ground floor, and vegetation growth to the north eastern side of the building. |
| **Assumed foundations** | Assumed to be shallow. However, as an engineering structure more care is likely to have been taken over the depth and founding strata compared with typical buildings of this date. |
| **Façade material** | Brick with stone and white brick dressings. |
| **Internal support system (i.e. superstructure)** | Assumed to be load bearing brickwork throughout. |
| **Heritage** | The heritage significance of this building is predominantly in its position and former use; particular features of interest include the octagonal shape, chimney, and brick and stone dressings. No machinery remains inside the building. |

## Building photographs

**Caption 1 - General view of structure**

**Caption 2 – Upper section of tower and chimney**

**Caption 3 – Upper section of tower and chimney in background**

**Caption 4 – Base of tower structure**

## Ground movement analysis

**Tunnel and shaft details**

The Limehouse accumulator tower and chimney has been constructed above the London Clay in the Superficial deposits. For the purpose of this assessment, the structure is assumed to be founded 4m below ground level (~+104mTD). However the results of the assessment are not particularly sensitive to the level that the building is assumed to be founded at.
Closed face tunnelling using slurry support and shield – assumed VL = 1%.
Tunnel centreline level: +47.55mTD.
Excavated diameter: 8.8m.
Closest CSO shaft: King Edward Memorial Park shaft, located approximately 950m south west – design indicates shaft ground movements are unlikely to influence the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

**Ground conditions**

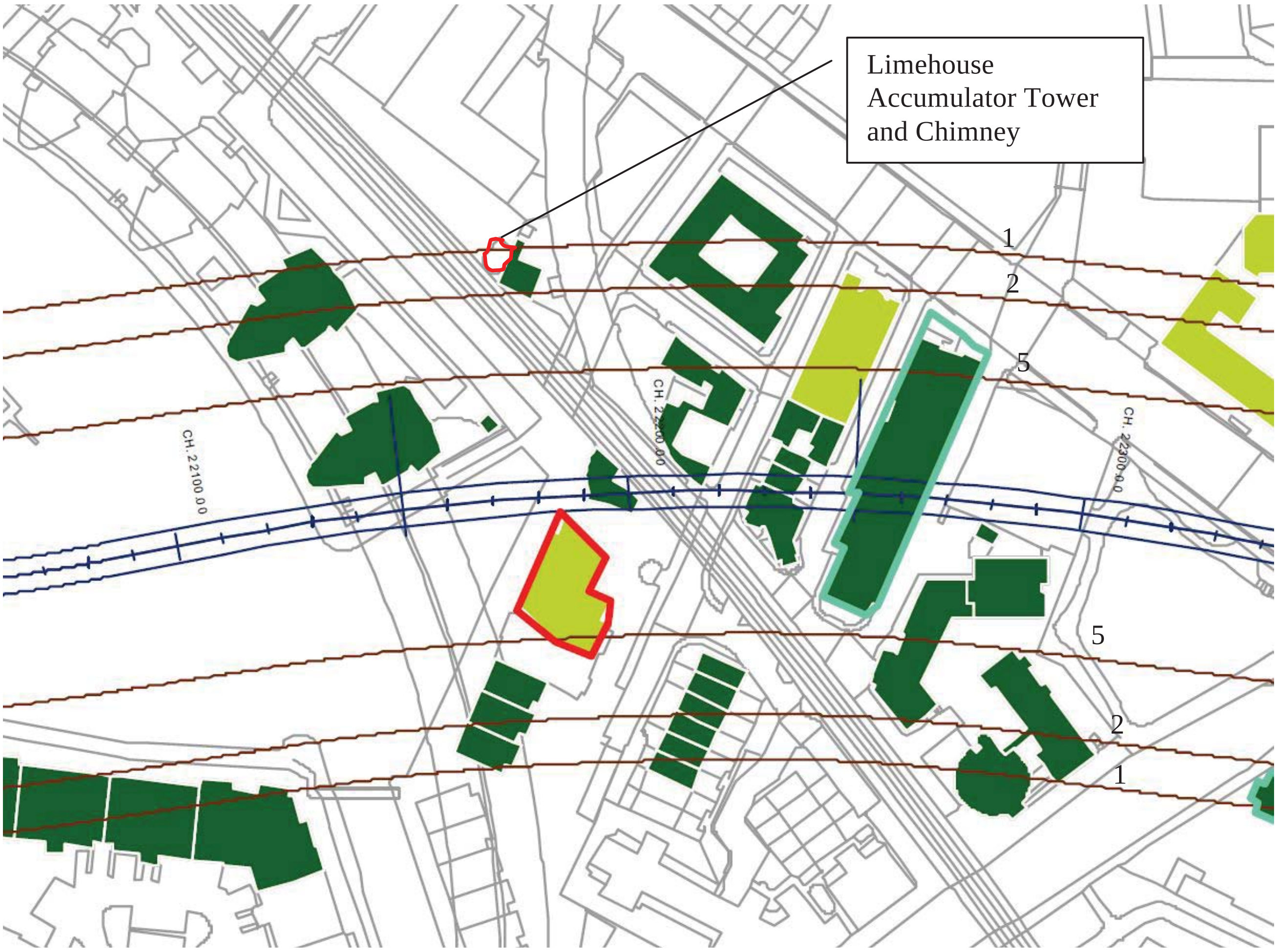
The Limehouse accumulator Tower and Chimney is constructed above the London Clay Formation. The expected sequence above the tunnel has been estimated from the Geological Section 100-DA-GEO-MT032-600357 to the east of Limehouse Basin, the closest borehole is SR3011 at the Rectory Gardens. The approximated sequence is summarised below;

Superficial deposits/Made Ground: Ground level +108.1 to +100mTD.
London Clay: +100 to +88mTD
Lambeth Group +88mTD to +70m TD
Thanet Sand Formation +70mTD to +56mTD
Top of Chalk +56mTD (8.45m above proposed tunnel centreline level).

Review of borehole SR3011 (located at the rectory Gardens to the east of the alignment) does not indicate any geological features that would require a change in the current ground loss assumptions.

**Results**

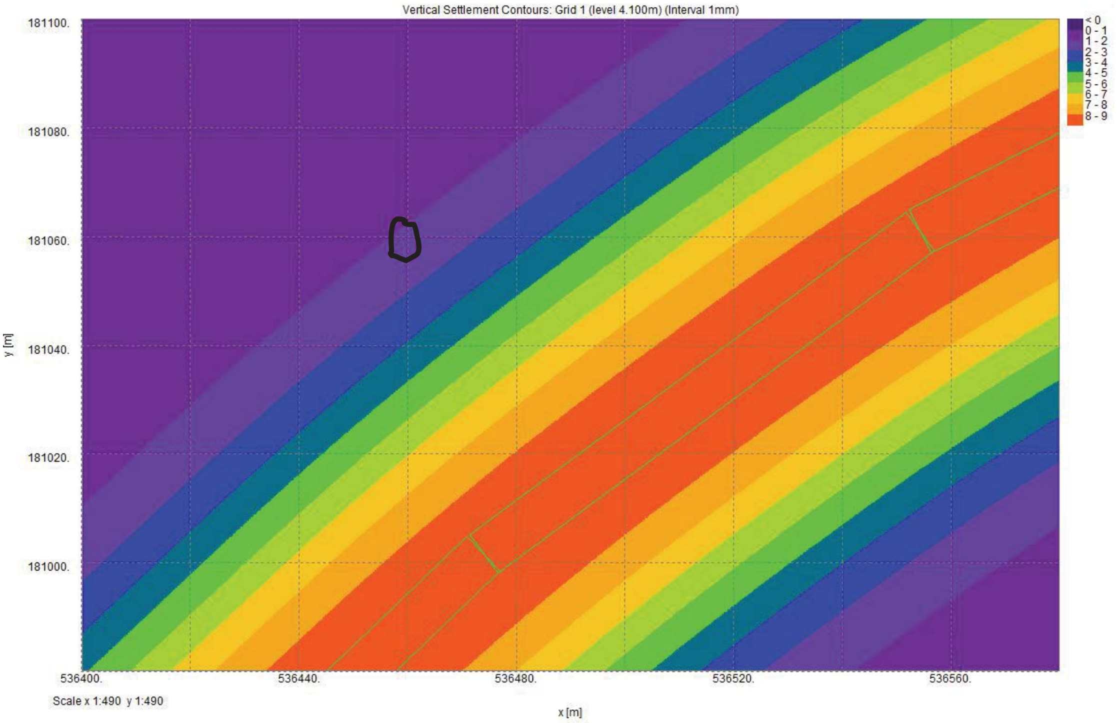
Settlement contours (mm) generated 1m below ground level




As shown above, the building lies between the 2mm and 1mm contours.

Analysis of key façades selected from the GIS model, assumed a building height of 30m above ground level, with shallow foundations (4m bgl).

Settlement contours taken at +104.1mTD, position of accumulator tower and chimney outline shown by black circular shape.




The results fall within category 0, risk of ‘negligible’ damage, with a maximum tensile strain of 0.004% and maximum settlement of 1.5mm calculated.

The interaction of the ground settlement with the structures is discussed in the interpretation of impact section, below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The tall height of the tower relative to its width means it will be very stiff and will tend to rotate as a rigid body. Since close up inspection was not possible it is not known to what extent the chimney brickwork is bonded into the main tower brickwork. If brickwork is not bonded there is a small risk of chimney and tower moving independently and a small crack opening between the two. In practice because the calculated differential settlement across the building is only about 1mm, any cracking which did occur would only be negligible to very slight.

***Structural sensitivity score is therefore assessed to be one.***

**Heritage features sensitivity discussion**

| |
|---|
| The building is robust, with its heritage features in good repair; this is particularly true of the chimney which has been rebuilt. The assessed damage to the building is negligible, and no heritage features will be affected during construction works.<br><br>***Heritage sensitivity score is therefore assessed to be zero.*** |
| **Condition discussion** |
| Close up inspection was not possible but from a distance the building appears to be in fair condition, with evidence of repairs and brick replacement. There is vegetation growth, however this does not apear to be destabilising the structure. The condition of the building will not exacerbate the level of damage assessed during the works.<br><br>***Condition sensitivity score is therefore assessed to be zero.*** |

## Summary of results

**Scoring**

| | |
|---|---|
| **Structural sensitivity score** | 1 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 0 |
| **Damage category** | 0 |

**Recommendations**

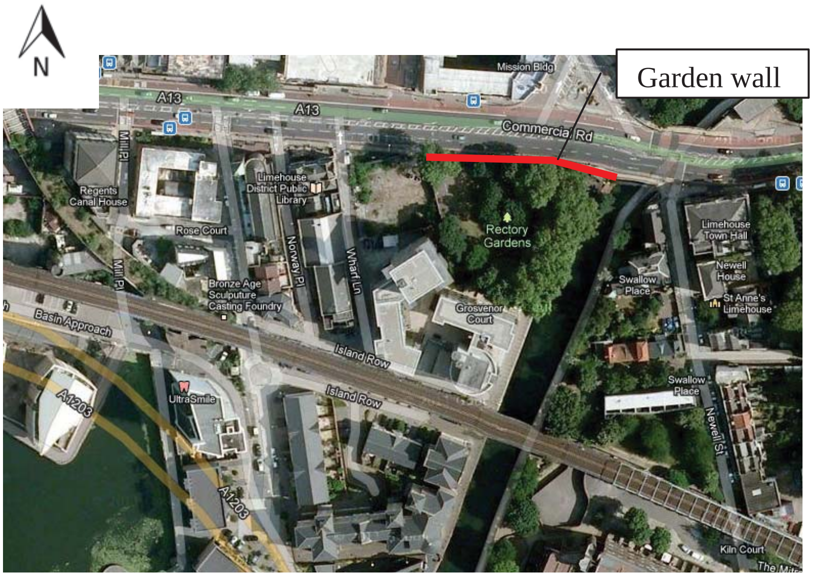
The total score for this building is 1.

The structure and heritage features of the Former Railway Lookout are not sensitive to the levels of settlement and strain calculated, and therefore the building will not be taken forward for further damage assessment and will not require mitigation.

# Listed building assessment

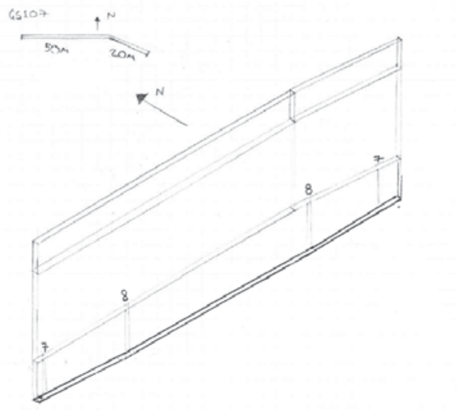
| Structure information | |
|---|---|
| **Building reference** | GS107 |
| **Building name / address** | Garden wall to former St Anne's Rectory |
| **Grade of listing** | II |
| **National Grid Reference (NGR)** | TQ 36632 81100 |
| **Ground level (mTD)** | +108.2 |

**Location plan**




Satellite imagery does not align perfectly with GIS mapping – refer to page 5 for building location.

**Isometric ground movement sketch**




**Structure description (including excerpts from English Heritage listing, where appropriate)**

The wall to the former St Anne's Rectory, listed in its own right, has two distinct phases of construction, with older brick (possibly dating from the 16th century, according to the listing description) at its eastern end, and 19th century brick to its western end.

At the eastern end the wall is approximately two metres high, and has regular brick caps; the wall is thicker at its base than its top. The older section has been repointed in cement mortar, causing some deterioration of the brick. The western end, though similar in construction, lacks the brick caps, and has lime mortar which has deteriorated. There are brick piers at either end of the wall, with the eastern pier having a brick cap, and the western pier a concrete cap.

There are a number of existing cracks through the brick to the older section of wall, caused by insensitive repointing with cement mortar. Although it appears structurally stable, the wall is in poor condition, with vegetation growth to the eastern piers.

| **Structural description and walkover observations** | |
|---|---|
| The wall projects approximately 2m from pavement level along its length. The ground level to the south-west of the wall (former grounds of St Anne's Rectory) falls approximately 0.75m from west to east such that the wall is approximately 2.75m tall at the east end where it meets the canal. There is a gated opening at the east end. The wall is typically one and a half bricks (approx 330mm) thick at the base reducing to one brick (approx 215mm) thick at the top. At each end there is a brick pier two and a half bricks thick (approx 550mm).<br><br>As described above the wall consists of two distinct phases; the east end (approx 20m) comprises older stock bricks repointed in cement mortar. There is a fine crack (approx 1mm) running from the base to mid height at the junction where the western end has been rebuilt. A further, full height, fine crack is evident in the east end of the wall approximately 9m from the gate opening. The pier at the east end of the wall (on the west of the gate opening) has been previously rebuilt with a lime based mortar. There is a 0.5-1mm crack running vertically at the interface between the pier and wall. The pier to the east of the gate opening exhibits a similar vertical crack. | |
| **Condition** | Poor; deteriorating lime mortar, and evidence of cracked bricks where cement mortar has been used. Vegetation growth to eastern end. |
| **Assumed foundations** | It is assumed that the foundations are very shallow brick strip footings; foundations to walls were often minimal |
| **Façade material** | Brick |
| **Internal support system (i.e. superstructure)** | N/A |
| **Heritage** | The wall is of interest due to its group value with the surrounding historic environment. Particular features of interest include its profile, becoming narrower at the top of the wall, and the area of 16th century brick , with regular brick caps. |

## Structure photographs

**Caption 1: General view of wall**

**Caption 2: 19th century section of wall (western end)**

**Caption 3: Eastern end of wall, showing 16th century brick and vegetation growth**

**Caption 4: Junction of 16th and 19th century brick**

## Ground movement analysis

**Tunnel and shaft details**

The Garden Wall to former St Anne's Rectory is assumed to have a 1m foundation and is founded within the superficial deposits.
Closed face tunnelling using slurry support and shield – assumed VL = 1%.
Tunnel centreline level: +47.4mTD.
Excavated diameter: 8.8m.
Closest CSO shaft: King Edward Memorial Park shaft, located approximately 1125m south west – design indicates shaft ground movements are unlikely to influence the building location.

| | |
|---|---|
| **Modelling method** | Oasys Xdisp is used to analyse the greenfield ground movement in terms of settlement and horizontal displacement. Subsurface tunnelling induced ground movement profiles are determined in accordance with the methodology described by Mair et al (1993) and Taylor (1995). |

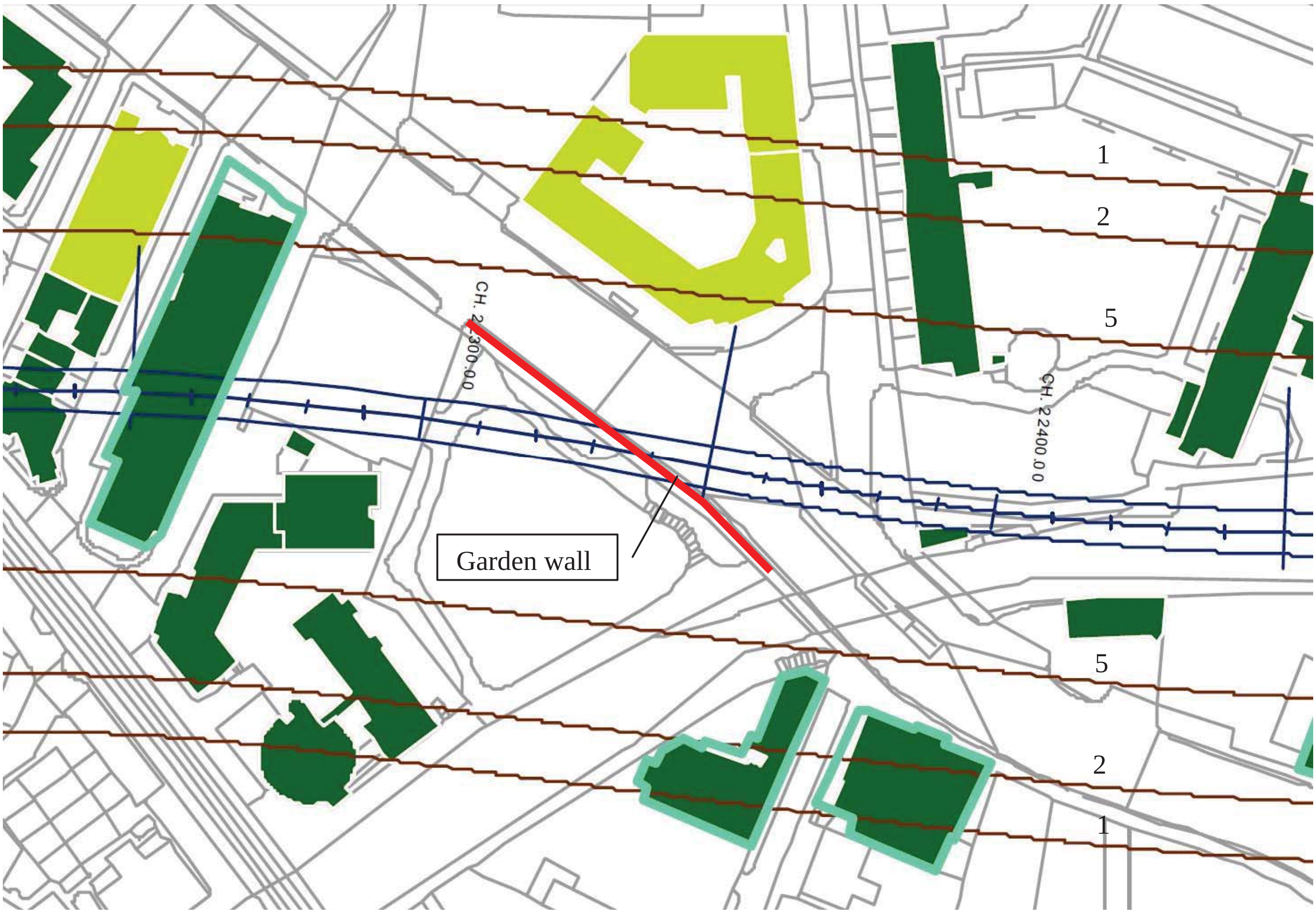
**Ground conditions**

The Garden Wall at the Rectory Gardens (formerly St Anne's Rectory) is constructed above the Superficial deposits. The expected sequence above the tunnel has been estimated from the Geological Section 100-DA-GEO-MT032-600357 using borehole SR3011which is located at the corner of the Rectory Gardens. The approximated sequence is summarised below;

Superficial deposits/Made Ground: Ground level +108.2 to +100mTD.
London Clay: +100 to 86.5mTD
Lambeth Group +86.5mTD to +68m TD
Thanet Sand Formation +68mTD to +54mTD
Top of Chalk +54mTD (11m above proposed tunnel centreline level).

**Results**

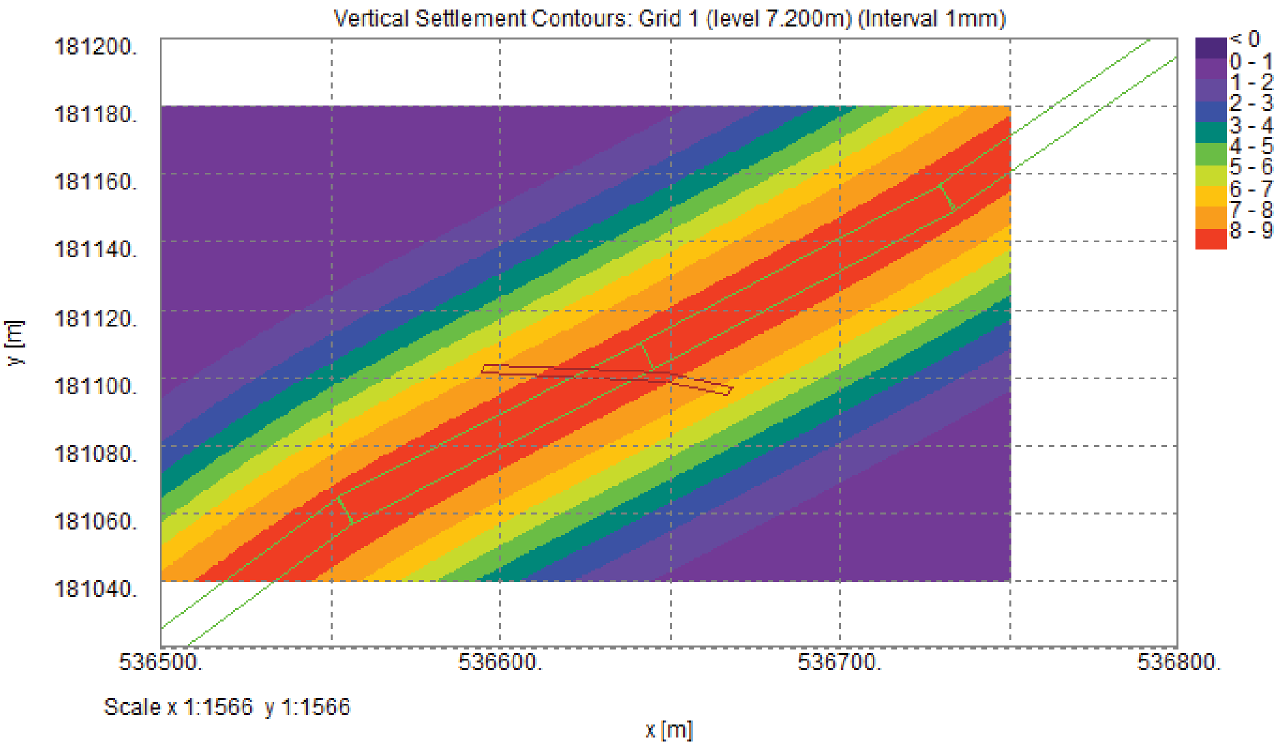
Settlement contours (mm) generated 1m below ground level




As shown above the wall spans the proposed tunnel alignment and lies between the two 5mm contours.

Analysis of the wall line has been undertaken, with an assumed height of 2m above ground level and founded 1m bgl.

Settlement contours at +107.2mTD:




The results fall within category 0, risk of negligible damage, with a maximum tensile strain of 0.0006% and maximum settlement of 8.5mm calculated.

The interaction of the ground settlement with the structures is discussed in the interpretation of impact section below.

***Building damage score is therefore assessed to be zero.***

## Interpretation of impact

**Structural assessment and discussion**

The structure is a long solid brick wall without openings and spans the route of the tunnel. It is a possibility that the movement may concentrate at points of weakness resulting in cracking. The survey highlighted a number of existing cracks likely to be caused by a combination of previous ground movement and thermal movements. It is therefore considered likely that movement due to the tunnel will be concentrated at these existing crack locations resulting in existing cracks opening up further. However, the calculated differential settlements are negligible (only 2.5mm differential settlement in the centre relative to the ends) therefore if all of the movement is concentrated on one crack, the crack would likely open up by less than 1mm. The damage category would thus be categorised as Very Slight.

***Structural sensitivity score is therefore assessed to be one.***

**Heritage features sensitivity discussion**

The wall spans the tunnel route, with the area of most movement at the junction between 16$^{th}$ and 19$^{th}$ century brick. The wall in this area shows some cracking, and the 16$^{th}$ century brick is vulnerable to settlement due to the use of inflexible cement mortar. Therefore, although movements are calculated to be negligible, there may be some widening of cracks or development of new cracks. However, this damage will not impact upon the heritage significance of the wall.

***Heritage sensitivity score is therefore assessed to be zero.***

| Condition discussion |
| --- |
| The condition of the wall is poor, and there are existing cracks to the centre of the wall, at the point of the highest settlement. These cracks may widen, and new cracks form, due to the current condition of the wall.<br><br>***Condition sensitivity score is therefore assessed to be one.*** |

## Summary of results

| Scoring | |
| --- | --- |
| **Structural sensitivity score** | 1 |
| **Heritage sensitivity score** | 0 |
| **Sensitivity due to condition** | 1 |
| **Damage category** | 0 |

| Recommendations |
| --- |
| The total score for this structure is 2.<br><br>The heritage features of the garden wall are not sensitive to the levels of settlement and strain calculated, though the condition of the wall may deteriorate. While the structural form makes it sensitive to ground movements, the magnitude of the settlements are negligible and are not considered of structural consequence. Therefore the wall will not be taken forward for further damage assessment and will not require mitigation. |

Thames Tideway Tunnel
Thames Water Utilities Limited

# Application for Development Consent

Application Reference Number: WWO10001

# Environmental Statement

Doc Ref: **6.2.03**

## Volume 3: Project-wide effects assessment appendices

### Appendix E.3: Listed bridges settlement report

APFP Regulations 2009: Regulation **5(2)(a)**

Hard copy available in

Box **17.3** Folder **A**
January 2013

Thames Tideway Tunnel
Creating a cleaner, healthier River Thames

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## E.3 Listed bridges settlement report

E.3.1 The following report has its own table of contents.

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# Thames Tideway Tunnel

# Environmental Statement

# Volume 3 Project-wide effects assessment appendices

# Appendix E: Historic environment

# Appendix E.3: Listed bridges settlement report

## List of contents

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# Appendix E: Historic environment

## E.3 Listed bridges settlement report

### Introduction

#### Scope and purpose

E.3.1 This document details the technical assessment of ground movement on listed bridges, viaducts and tunnels induced by the main tunnel itself and/or by deep excavations within Thames Tideway Tunnel sites. It should be noted that technical assessment of effects on listed buildings is detailed separately in Appendix E.1.

E.3.2 This document assesses the heritage significance and sensitivity of each structure, and assesses the damage to its significance that is expected from ground movement. The assessment is based on structural calculations which have been calculated by Thames Water.

E.3.3 Walkover surveys of each bridge were undertaken in 2012 by a heritage specialist.

#### Report structure

E.3.4 The listed structures are first described. The description identifies the key significant aspects of the structures. The significance and particularly significant features of the structures are then summarised.

E.3.5 The sensitivity of the significance of each structure is identified.

E.3.6 Each section concludes with the likely effects of the ground movement predicted on the significance of the structure and its key features.

E.3.7 Where damage is predicted to the structure's significance mitigation measures are detailed.

E.3.8 Adverse effects on the significance of each structure have been assessed in the Thames Tideway Tunnel project *Environmental Statement* (see Vol 3 Section 7), the proposed mitigation detailed, and the residual effects, remaining after mitigation, described.

## Hammersmith Bridge

### Description of Hammersmith Bridge and its significance

#### The bridge

E.3.9 Hammersmith Bridge is an elaborate three span suspension bridge, built in 1884 to the designs of Sir Joseph Bazalgette. The bridge was strengthened in 1973, and restored in 2000. This is the second bridge on the site, replacing an earlier suspension bridge built in 1824-27.

E.3.10 The bridge is 250.5m long and 13.1m wide carrying a relatively narrow (8.2m wide) 2-lane carriageway and flanking footways. The bridge deck is constructed of wrought iron girders and heavy timber beams with wrought-iron parapets and is suspended on mild steel chain links from two wrought-iron towers. Monumental anchorages survive from the earlier bridge, although these were substantially rebuilt for greater strength. The abutments and piers are of concrete clad in Portland stone and cast-iron. The pier foundations also date from the earlier bridge. The road decking dates from 1973-6.

E.3.11 The wrought-iron framework of the towers, the cross-beams and superstructure is clad in ornamental cat-iron, which is painted and gilded. The towers are surmounted by decorative finials and the whole bridge highly ornate.

E.3.12 The first bridge was built to the designs of William Tierney Clark and operated as a toll bridge. It featured stone built suspension towers, designed as archways of the Tuscan order, with octagonal toll-houses on the approaches. It was built at a cost of £80,000. By the 1870's the bridge was no longer strong enough to cope with the increasing weight of heavy traffic passing across it, and in 1870 the owners were alarmed when some 12,000 people crowded onto the bridge to watch the University Boat Race pass underneath. A temporary bridge was built in 1884, whilst a new permanent bridge was constructed.

E.3.13 The present bridge was built by Dixon, Appleby & Thorne at a cost of £82,117 and was opened by the Prince of Wales on 11 June 1887.

E.3.14 The bridge has long suffered structural problems and has been closed for lengthy periods on several occasions due to the weight of heavy traffic, for which the bridge was never designed. The bridge was strengthened in 1973 and has several phases of repair since in 1984, 1987, and 1997. A terrorist bomb in 2000 caused further damage, resulting in a further refurbishment during which the original 1887 decorative scheme was restored and new lighting installed.

E.3.15 The bridge was listed Grade II* in 2008.

E.3.16 Vol 3 Plate E.1 to Vol 3 Plate E.6 illustrate the above description.

**Vol 3 Plate E.1 Hammersmith Bridge viewed from the north**

**Vol 3 Plate E.2 Hammersmith Bridge viewed from the south-west**

**Vol 3 Plate E.3 Hammersmith Bridge viewed from the south**


**Vol 3 Plate E.4 South-west anchorage**

**Vol 3 Plate E.5 Detail of underside of bridge deck**

**Vol 3 Plate E.6 Listed Buildings on Lower Mall, Hammersmith within the setting of Hammersmith Bridge**

### Significance

E.3.17 Hammersmith Bridge is of historic, architectural and artistic significance due to its flamboyant, bold and highly ornate architectural design. With its lavish decoration and colour scheme it is one of the most distinctive bridges on the Thames.

E.3.18 The present bridge stands on the foundations of an earlier bridge which was one of the first modern suspension bridges in the world of which the foundations still survive.

E.3.19 The bridge is of technological interest for its use of materials.

E.3.20 Hammersmith Bridge was designed by the highly renowned Victorian engineer, Sir Joseph Bazalgette.

E.3.21 Hammersmith Bridge is of group value with other Listed buildings which stand in close proximity for which it contributes to their setting, including No.'s 6, 7, 8, 9, 10, 11&12, and 22 Lower Mall (Grade II).

E.3.22 The north side of the bridge lies within the London Borough of Hammersmith and Fulham in, "The Mall Conservation Area," whilst the south side of the bridge lies within the London Borough of Richmond upon Thames, 'Castelnau Conservation Area'.

### Condition

E.3.23 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in "good" condition.

E.3.24 The bridge appears to be structurally sound and well maintained.

### Sensitivity of the bridge's significant elements

E.3.25 Detailed structural calculations have been calculated by Thames Water. . The Thames Tideway Tunnel would pass in close proximity to the south end of the south approach to the bridge, at a depth of approximately 10m below anchor chamber level.

E.3.26 The analysis indicates that the settlements occurring at the structure as a result of the Thames Tideway Tunnel construction would be conservatively less than 1mm. Consequently, the structure can be considered as unaffected by the construction of the Thames Tideway Tunnel.

E.3.27 The significance of the bridge would not be affected by the construction of the Thames Tideway Tunnel.

### Conclusions

E.3.28 The assessment indicates that the settlements occurring at the structure as a result of the Thames Tideway Tunnel construction would be less than 1mm. Consequently, the structure can be considered as unaffected by the construction of the Thames Tideway Tunnel.

E.3.29 The significance of the bridge would not be affected by the construction of the Thames Tideway Tunnel.

# Putney Road Bridge

## Description of Putney Road Bridge and its significance

### The bridge

E.3.30 Putney Road Bridge is an elegant five span masonry structure constructed in channelled Cornish granite. The graceful segmental arches are of delicate design creating a most attractive architectural composition and striking landmark on this section of the Thames. The bridge carries the A219 from Putney on the south bank, across to Fulham on the north. It is reputed that this bridge is one of the few in the country to have a church at either end, St Mary's, Putney to the south, and All Saints, Fulham to the north. However, this is most likely to be by accident rather than design. Also of note on the north shore is Fulham Palace and Fulham Palace Gardens, the historic home of the Bishops of London. The bridge carries 4 lanes of traffic, plus a cycle lane and flanking footpaths.

E.3.31 The present bridge was built in 1882 to 1886, replacing an earlier timber bridge, and was opened by the Prince of Wales (later King Edward VII) on 29 May 1886. It was built to the designs of Sir Joseph Bazalgette by Jon Waddell of Edinburgh at a tendered cost of £240,433.

E.3.32 Putney has provided an important river crossing for many centuries being mentioned both in the Domesday Book, and in the household accounts of Edward I (1272-1307). The first bridge to link Putney and Fulham was a bridge of boats built during the Civil War in 1642 to carry the Parliamentary forces across the Thames and into Surrey. The first permanent bridge, however, was not built until some years later during the reign of George I. In 1726 an Act of Parliament was passed for the building of a wooden toll bridge. Built by local master carpenter Thomas Phillips to the designs of architect Sir Jacob Ackworth, the bridge comprised of 26 short spans with a toll booth at either end. Openings allowed river traffic to pass, with the widest at the centre known as "Walpole's Lock" after Sir Robert Wallpole who had helped procure the Act. The bridge remained in service for more than 150 years. In 1870 the bridge was badly damaged by a river barge, and although repaired, it was the beginning of the end for the structure. The bridge was purchased by the Metropolitan Board of Works in 1879, and the tolls lifted in 1880. Sir Joseph Bazalgette was commissioned to produce a design and a tender from John Waddell of £240,433 was accepted on 15 April 1882. Some years earlier in 1856, the Putney Aqueduct had been built immediately upstream. This was to act as a gantry for the construction of the new bridge, which was designed to carry a new main across the Thames in place of the aqueduct.

E.3.33 The bridge was widened in 1933 with 9.14m added to the east (downstream) side. The stonework was removed, the piers and roadway widened using mass concrete, and the original stonework replaced to restore the original outward appearance. The structural composition of the widened part is broadly similar to that of the original.

E.3.34 The present bridge comprises a 5-span masonry structure with a total length of approximately 190m, supported on four granite faced concrete piers and two abutments. The spans comprise of shallow elliptical arches which vary in length symmetrically about the axis from 34.14m for the shore, 39.32m for the intermediate, and 43.89m for the central span. The width of the bridge is 22.55m between the parapets. The bridge is built on granite clad concrete piers and abutments with channelled masonry used throughout. The rounded cutwaters extend out a short distance from the sides of the bridge. Above the cutwaters, the masonry of the piers rises to form broad pilasters between which run the arch parapets. A projecting cornice runs the entire length of the bridge breaking around the piers and abutments. The top of the parapets and piers run in a continuous line, topped by a simple moulded coping. The parapet is surmounted by lamp stands at the centre of each arch, each carrying 3-tiered lanterns. Floodlighting is mounted at the base of the piers just above the cutwaters. The approaches leading to the abutments are built in brick. On the north shore, the west side of the brick abutment facing into Lambeth Palace Gardens is vaulted. The granite abutment immediately adjacent is incised with an inscription which reads, “Sir J W Bazalgette GB, Edward Bazalgette Esq., Engineers 1886.” The finishes at deck level are of modern date with concrete paving slabs to the footways and asphalt to the carriageway. The footway widens at the piers where small bays provide vantage points to observe the river below. Cabling runs along the top of the cornice.

E.3.35 The deck is supported not only on the outer granite walls but also internally on a series of closely spaced brick spandrel walls running longitudinally along the bridge. The walls are believed to bear directly onto the top of the arch barrels with no fill between to prevent transverse loading. Stone slabs span between the walls, supporting the carriageway and west footway. The widened east side of the bridge is constructed in a similar manner also with internal spandrel walls but in unreinforced concrete in place of brick. The deck itself is of mass concrete, with transverse reinforcement within the east extension only. The east extension follows the design of the original; the barrel arch, however, is structurally independent simply abutting the original structure

E.3.36 Vol 3 Plate E.7 to Vol 3 Plate E.16 illustrate the above description.

**Vol 3 Plate E.7 Putney Bridge viewed from the east from Carrara Wharf**

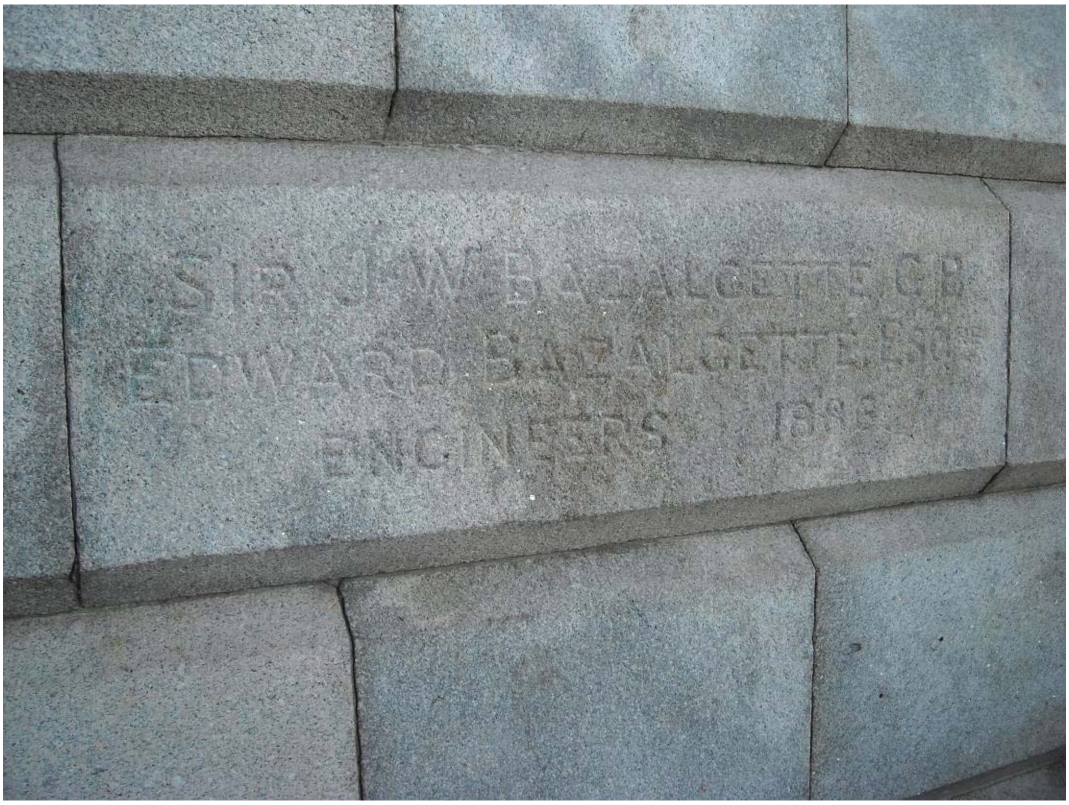
**Vol 3 Plate E.8 Putney Bridge viewed from the north-east**

**Vol 3 Plate E.9 Putney Bridge viewed from the north-east**

**Vol 3 Plate E.10 Detail of north abutment and span 5 showing effects of leaching**

**Vol 3 Plate E.11 Putney Bridge viewed from north-west**

**Vol 3 Plate E.12 Inscription on west side of north abutment**



**Vol 3 Plate E.13 View southwards towards Putney**

**Vol 3 Plate E.14 View northwards towards Fulham**

**Vol 3 Plate E.15 Bridge parapet**

**Vol 3 Plate E.16 Span 1 (Putney shore) viewed from south-east**

### Significance

E.3.37 Putney Bridge is of historic, architectural and artistic significance due to its elegant design by the renowned engineer, Sir Joseph Bazalgette. It provides a notable landmark on this section of the Thames. The quality of the materials and construction are of the highest order. Putney Bridge is a Grade II Listed Building.

E.3.38 The bridge is part of a continuum of river crossings at point where people have traversed the Thames since at least the 13th century.

E.3.39 Putney Bridge is of group value with other listed buildings in close proximity for which it contributes to their setting, including on the south shore, the Church of St Mary the Virgin (Grade II*), and the White Lion Hotel Public House (Grade II), and on the north shore, the Parish Church of All Saints (Grade II*). It also contributes to the setting of Fulham Palace (Grade I), as well as the wider Fulham Palace site which is both a Scheduled Monument and a Registered Park & Garden.

E.3.40 Putney Bridge is of further national significance due to its association with The Boat Race, the starting point for which is immediately downstream.

E.3.41 Although widened in 1933, this was undertaken with some sensitivity, and as such the bridge retains much of its original outward appearance, aesthetic intent, and original fabric. The widening of the structure included the re-use of the original outer spandrel wall, parapet and granite cladding and as such retains its intended decorative affect. Where new fabric was introduced this was done in facsimile to the original. As a consequence, the individual components of the structure and its fabric are of equally high significance. The exceptions are the asphalt finish to the roadway and the concrete paving to the footways.

E.3.42 The north side of the bridge lies within two London Borough of Hammersmith and Fulham conservation areas, namely the Putney Bridge Conservation Area, and the Bishops Park Conservation Area. The south side of the bridge lies within the London Borough of Wandsworth, Putney Embankment Conservation Area.

### Condition

E.3.43 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in “very good” condition.

E.3.44 The bridge appears to be structurally sound and well maintained.

E.3.45 Some hairline cracking was noted in the abutments, and in the masonry joints to the parapet. On the north abutment, runnel marks and moss growth were observed at low level; these may result from water leaching through the depth of the structure from the deck above.

E.3.46 Apart from the widening works of 1933, the bridge does not appear to have undergone any strengthening works.

E.3.47 No previous structural reports on the bridge were found, and consequently Atkins has undertaken a full load assessment of the structure to BD 21/01.

### Sensitivity of the bridge's significance elements

E.3.48 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movements on the bridge.

E.3.49 The main Thames Tideway Tunnel would pass perpendicularly (albeit at a slightly oblique angle) beneath the second span (from south) of the bridge, with the centreline of the tunnel running at a depth of 27.94m below river bed level. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the piers, which would in turn induce movement and stresses within the superstructure.

E.3.50 Immediately above the crown of the tunnel, a maximum vertical settlement of 15.9mm at foundation level is predicted. However, with the neighbouring piers set approximately 20m distant from this point the vertical settlement of the structure would not be as acute.

E.3.51 Analysis has shown that it is only the first pier (Putney Pier) and the second pier where movement is predicted. Movement here would induce additional movements and stresses within the superstructure to spans one, two, and three. No movement is anticipated to any of the remaining, spans, piers or abutments.

E.3.52 Minor tensions are predicted within the arch barrels due to the existing loading and the tunnel induced settlement and rotations. This tension is localised and does not extend a significant distance through the arch barrel. The induced tension could cause additional cracking in the mortar between the voussoirs[i] at the extreme faces of the arch barrel. From a structural perspective, this cracking is considered insignificant and not detrimental to the behaviour of the bridge. From an architectural and heritage perspective, visible cracks within the existing mortar joints can be re-pointed on completion of the tunnel construction or as part of the structure's future maintenance. Hairline cracking might best be left alone as the process of re-pointing may in fact cause greater visible intervention or worse put the arises of the finely tooled stonework at risk of damage in any attempted cutting out of the joints.

E.3.53 The effects of tension within the arch barrels has been investigated by Thames Water using guidance given in the national design standard, 'The Design Manual for Roads and Bridges, Volume 2, Section 2, Part 14 (BD91/04), Unreinforced Masonry Arch Bridges'. This shows that the arch barrels retain sufficient capacity for the stresses present and there is sufficient shear capacity between the voussoirs, i.e. the voussoirs would not be at risk of slippage or displacement.

E.3.54 Further detailed inspection of the deck slab, internal and external spandrel walls, block facing and intrados would be undertaken prior to tunnel construction to ensure that these elements remain in sound condition.

E.3.55 The bridge would be monitored prior, during and post tunnel construction as described in the Thames Tunnel *Code of Construction Practice* (CoCP), Part A, section 13.2. The foundations would be monitored to

[i] Voussoir – a wedge-shaped stone forming the curved part of an arch.

ensure that the actual movements are within the limits predicted, and control limits established to quantify when intervention is required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor.

E.3.56 With regard to the construction of the CSO interface, excavation would be closely controlled to avoid removal of excess material adjacent to the south abutment and care would be taken to avoid undermining the toe of the foundations.

### Conclusions

E.3.57 The assessment indicates that the bridge would be able to accommodate the effects of ground movements and the additional stresses that these would impart upon the superstructure. Minor tensions are predicted to occur in the arch barrels which may induce minor cracking within the masonry joints of the voussoirs. Cracks would be re-pointed on completion of the tunnel construction or as part of future maintenance works. Hairline cracking could be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric.

E.3.58 The bridge would be inspected and monitored prior, during and post tunnel construction and control limits established to quantify when intervention is required to prevent damage to the structure, as described in the *Code of Construction Practice*, Part A, Section 13.2.

E.3.59 The bridge would be would be monitored in terms of the effects of scour and protected as appropriate and protected from mechanical damage during the construction of the CSO interfaceas described in the *Code of Construction Practice*, Part B, Putney Embankment Foreshore, Chapter 12.

E.3.60 It is concluded that undue harm would not be caused to the special interest or significance of the structure.

# Battersea Road Bridge

## Description of Battersea Road Bridge and its significance

### The bridge

E.3.61 Battersea Road Bridge is the narrowest of all the road bridges across the Thames in London, and in 2004, it was the fifth least used. The bridge carries the A3220 from Battersea Bridge Gardens and Cheyne Walk on the north bank, across to Battersea Bridge Road on the south bank, close to the Royal College of Art Battersea Campus. The north section of the bridge lies in the London Borough of Kensington and Chelsea, the south in Wandsworth. The bridge carries the road and two flanking footpaths.

E.3.62 The bridge was built in 1886 to 1890 by John Mowlem & Co. to the designs of Sir Joseph Bazalgette. The present bridge is the second to be built on the site, replacing an earlier timber bridge between Battersea and Chelsea. The first bridge was built in 1766 to 1771 as a toll bridge. It was commissioned by a small group of investors, led by Earl Spencer, and built by John Phillips, carpenter to George III, to the designs of architect Henry Holland, at a cost of £12,800. The bridge was much derided at the time being built of timber rather than stone, and was generally regarded as an eyesore. The 19-span bridge also proved to be a considerable hazard to navigation being built on a sharp bend in the river and the widest span being only 9.8m. To help facilitate navigation, two of the central piers were later removed, the bridge reinforced, and an opening central span introduced. The proprietors of the bridge were eventually bought out in 1873 under the terms of the Parliamentary Act authorising the construction of the neighbouring Albert Bridge. Battersea Bridge was nationalised under the Metropolis Toll Bridges Act of 1877, which opened up the possibility of dealing with the problematic structure. A survey found that the bridge was indeed unsafe and a significant hazard, and generally beyond economic repair. The bridge was demolished in 1885.

E.3.63 Work on the new bridge commenced in 1886, and was completed by 1890.

E.3.64 The present bridge comprises a 5-span wrought and cast iron structure with a total length of 221.5m supported on granite piers. The spans are of unequal radii and vary in length from 36.7m for the shore, 47m for the intermediate, and 54.1m for the central span, rising to a distinct apex. Each span consists of seven “I”-section segmental cast-iron arch ribs with wrought iron spandrel columns and bracing supporting a 12m wide inverted buckle plate deck with concrete fill. The cast-iron ribs spring from cast-iron skewbacks, each skewback being secured to the pier or abutment with four 4.5m vertical anchors, forming a pinned connection. The deck is supported on elastomeric bearings at piers and abutments with expansion joints each side of the pier and at each abutment.

E.3.65 This is a very ornate and elegantly designed bridge. The piers and cutwaters are faced in granite with channelled rustication. Above the cutwaters, the piers and abutments rise in finely jointed granite ashlar with bold classical detailing. The piers are expressed as pilasters with pedestals and swept cornice, between which are cast iron balustrades.

The footpaths on either side are cantilevered from the main structure, with the outer margins of the bridge swept back in an elegant concave section with ribbed decoration. The spandrels carry plain iron panels with foliated decoration in flat relief at each end; the foliation is picked out in gold which contrasts with the green livery. Above the spans a deep cornice breaks around the stone pilasters of the piers marking the line of the road. Above the cornice is an ornate cast-iron balustrade of Moorish design, with closely set arches on double collonettes, in-filled with alternating patterns of fretwork. The balustrade is topped by a moulded cast-iron handrail. The piers and balustrade are surmounted by cast-iron lampstands, two to each span, plus one to each pier. Those to the spans carry one lantern each, those to the piers three branched lanterns. The lanterns have domed glazed tops surmounted by small conical finials.

E.3.66 Floodlighting is attached to the abutments and piers.

E.3.67 It is understood that the foundations are of mass concrete filled caissons

E.3.68 Vol 3 Plate E.17 to Vol 3 Plate E.25 illustrate the above description.

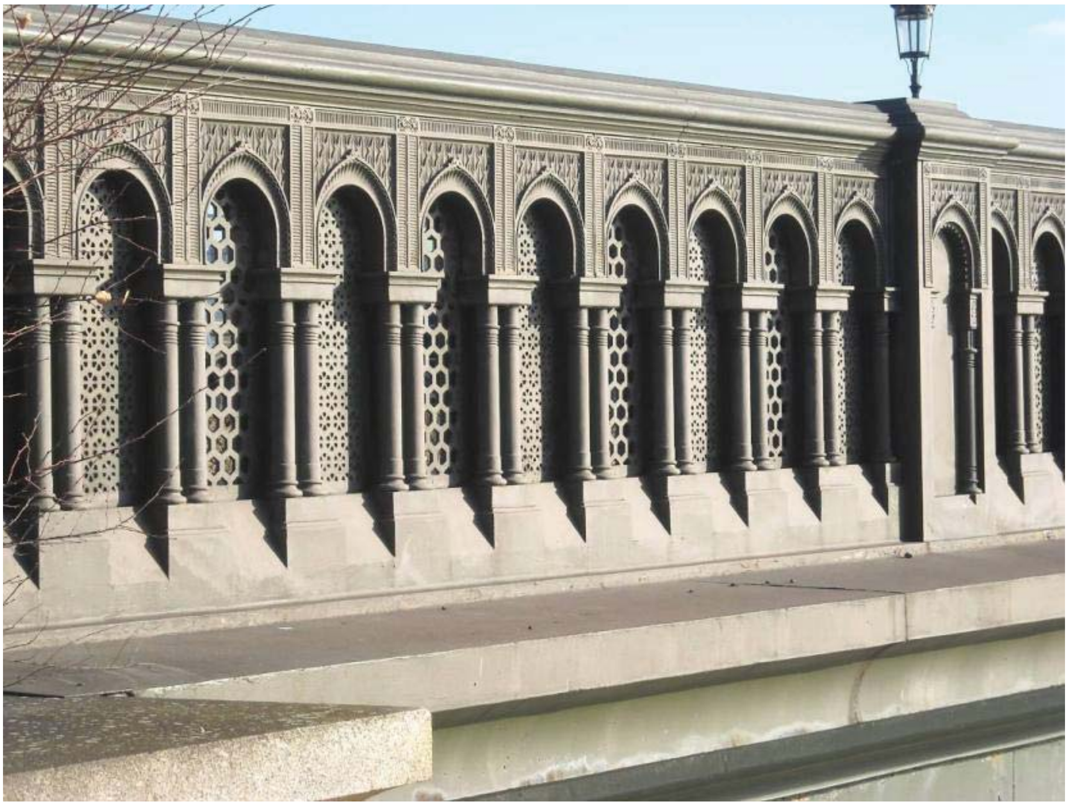
**Vol 3 Plate E.17 Bridge viewed from west**

**Vol 3 Plate E.18 Bridge viewed from west**

**Vol 3 Plate E.19 Bridge viewed from north-west**

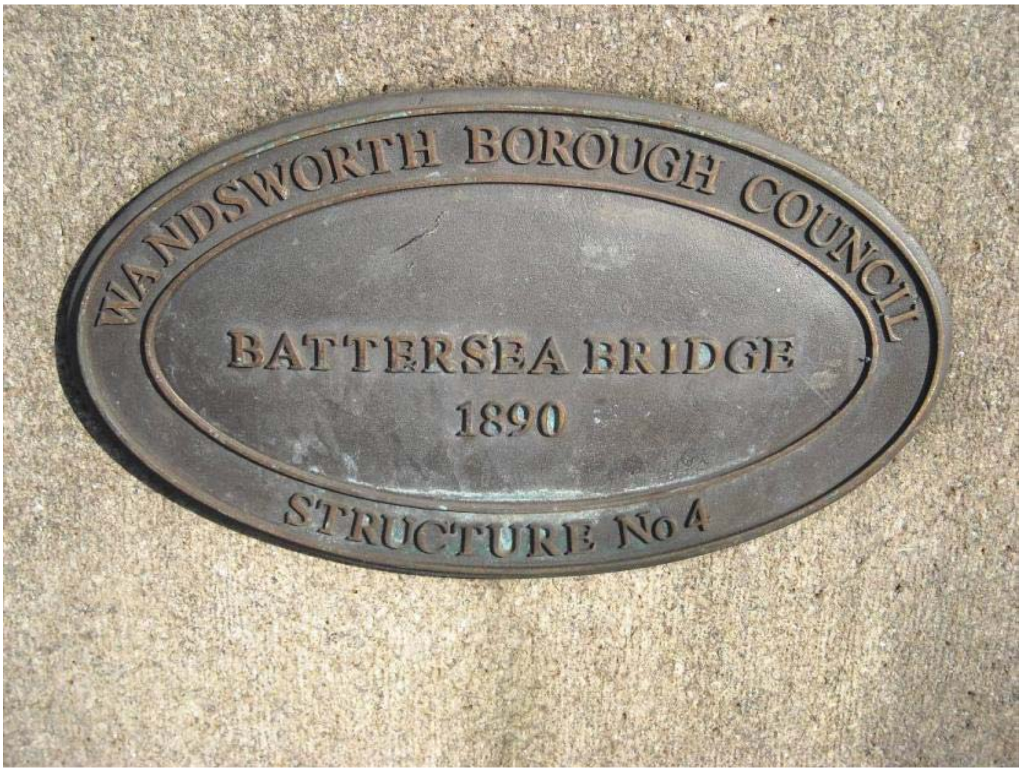
**Vol 3 Plate E.20 Bridge viewed from north-west**

**Vol 3 Plate E.21 The west balustrade**

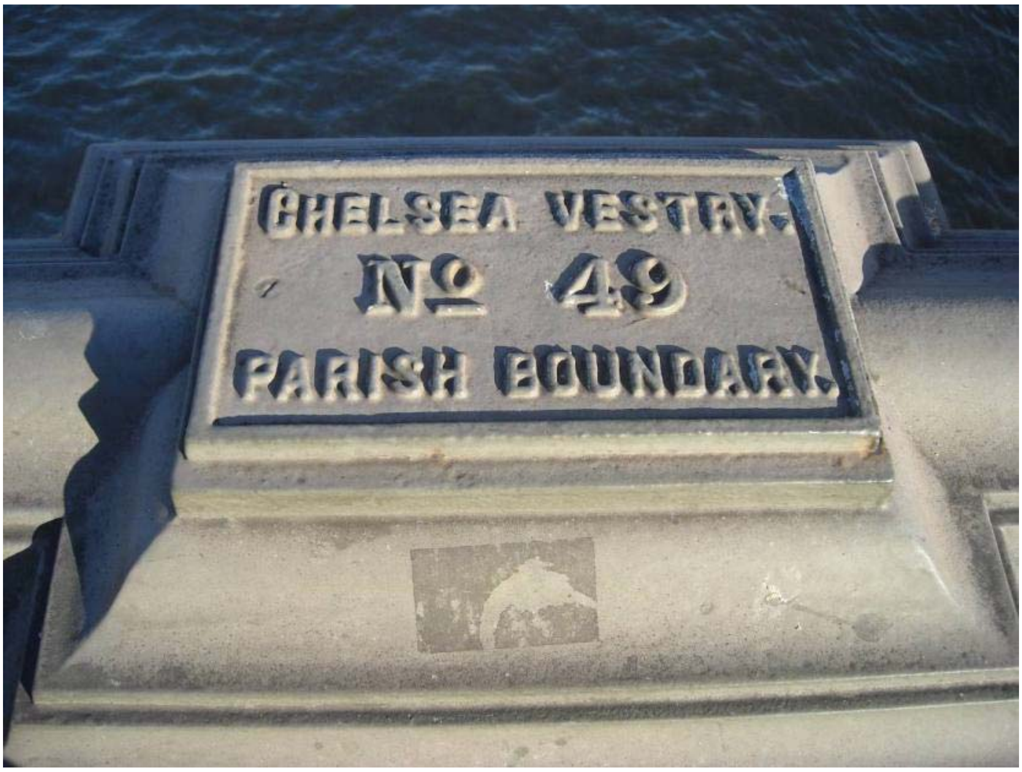


**Vol 3 Plate E.22 Typical cracking to cast-iron balustrade**

**Vol 3 Plate E.23 Plaque on bridge**



**Vol 3 Plate E.24 Plaque on balustrade**




**Vol 3 Plate E.25 Balustrade detail**

### Significance

E.3.69 Battersea Road Bridge is of historic significance as one of the works by the great 19th century Civil Engineer, Sir Joseph Bazalgette. It was the third in a number of bridges designed by him to be built in quick succession following the passing of the Metropolis Toll Bridges Act in 1877.

E.3.70 The bridge is of considerable historic, architectural and artistic significance due to its elegant design, its use of materials, and the fact that it remains little altered since its original construction. The bridge is a significant landmark and an important contribution to the rich history of the lower Thames.

E.3.71 The piers and majority of the superstructure date from the original construction and are of considerable significance. Later interventions to the deck, however, are of recent date and hence of lesser significance; these include the carriageway and pavement finishes, trief kerbs, and steel handrails which flank the pavements.

E.3.72 The bridge is a Grade II Listed Building.

E.3.73 The bridge lies partly within the Royal Borough of Kensington and Chelsea's Thames Conservation Area.

### Condition

E.3.74 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in "good" condition.

E.3.75 The bridge appears to be structurally sound and well maintained.

E.3.76 Major strengthening works were undertaken in 1992 to 1993. This included the strengthening of the piers, the provision of movement joints at piers and abutments, footpath strengthening, the introduction of trief kerbs and handrails to protect against vehicle impact damage, and the application of a waterproof membrane to the deck. At the same time, the bridge was restored to its original decorative scheme. Reproduction lampstands and lanterns were installed in 1994.

E.3.77 Being located on a sharp bend in the river, the bridge has continued to present a hazard to navigation. There have been a number of collisions over the years, the most recent in 2005, when the bridge was struck by a 200 tonne gravel barge causing serious structural damage. Repairs took four months to complete at a cost of £500k.

E.3.78 At the time of inspection the décor was found to be peeling, exposing the metal beneath to surface corrosion. Self set vegetation was also gaining a hold within the masonry joints.

## Sensitivity of the bridge's significant elements

E.3.79 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movements on the bridge.

E.3.80 The main Thames Tideway Tunnel would pass perpendicularly beneath the second span from north, midway between the first and second piers, at a depth of 27.84m below river bed level. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the piers, which would in turn induce movement and stresses within the superstructure.

E.3.81 Immediately above the crown of the tunnel, a maximum vertical settlement of 17.5mm at foundation level is predicted. However, with the neighbouring piers set more than 20m distant from this point the vertical settlement of the structure would not be as acute.

E.3.82 Analysis has shown that it is only the first and second piers from north where movement is predicted. Movement here would induce additional movements and stresses within the superstructure to spans one, two and three from north. No movement is anticipated to any of the remaining, spans, piers or abutments.

E.3.83 A maximum vertical settlement of 10.69mm is predicted to occur to the south-west corner of pier 1 (from north), with piers one and two, both settling in a broadly similar manner. The two piers would tend to tilt towards each other, albeit marginally. The differential settlement between piers 1 and 2 would be less than 2mm, between pier 1 and the north abutment just in excess of 3mm, and between piers 2 and 3 just in excess of 2mm.

E.3.84 The predicted ground movements would be comparatively small and the differential settlement would have a negligible effect on the abutments and piers. Any cracking within the masonry would be relatively minor in nature, typically no more than hairline cracking, and would affect piers 1 and 2 only. The stiffness of the bridge would act to resist movements at foundation and superstructure level and no damage is predicted to occur at superstructure level.

E.3.85 Assessment predicts a potential increase in movement range at the bearings and movement joints of 20%. This would require due consideration but would have no significant impact on the archaeological, architectural, historic, or artistic significance of the bridge.

E.3.86 During the walk over survey it was noted that the panels within the spandrels are fabricated from a number of individual butt jointed iron plates. It is presumed that these will be able to move independently from each other and hence accommodate any small differential movements without the risk of cracking developing. The bridge must be subject to considerable thermal movement already for which there were no visible signs of distress on the outward faces. It was noted that the cast-iron balustrade has been subject to distress in the past and a number of cracks are clearly visible close to where to balustrade abuts the adjacent stone piers and abutments. Given past damage, further minor cracking would not unduly harm the structure’s significance.

E.3.87 Should for any reason, the predicted ground movements induce hairline cracking within the masonry of the piers, this would not be of detriment to the architectural or historic significance of the bridge. Hairline cracking could be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric.

### Conclusions

E.3.88 Assessment indicates that the bridge would be able to accommodate the effects of tunnel induced ground movements and the additional stresses that these would impart upon the structure.

E.3.89 IThe bridge would be monitored prior, during and after the construction of the tunnel as described in the Thames Tunnel *Code of Construction Practice* (CoCP), Part A, section 13.2. The foundations would be monitored to ensure that the actual movements are within the limits predicted, and control limits established to quantify when intervention is required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

E.3.90 Further inspection of the movement joints would be undertaken prior to tunnel construction to enure that these remain in sound and operable condition.

E.3.91 It is concluded that undue harm would not be be caused to the special interest or significance of the structure.

# Albert Bridge

## Description of Albert Bridge and its significance

### The bridge

E.3.92 Albert Bridge is a three-span, modified cable-stayed bridge carried on two pairs of cast-iron piers and towers, and masonry clad concrete abutments. A further central pier was introduced in 1973. Visually, this is an extremely delicate and picturesque bridge and is of historic note as one of only two bridges in central London not to be replaced, the other being Tower Bridge. The bridge is also of note for its tollbooths which although unused are the only surviving examples of bridge tollbooths in London. The bridge is a prominent landmark, strikingly illuminated at night, and a gateway to Battersea and Battersea Park.

E.3.93 Albert Bridge was built between 1870 and 1873 to the designs of the notable English Engineer, Roland Mason Ordish (1824-1886). Ordish's other works include the engine shed roof at St Pancras Station which he designed in association with William Henry Barlow, the roof of the Royal Albert Hall, and the Dublin Winter Gardens. Ordish patented a system of bridge suspension which he used in the design of bridges across several European rivers. The system, consisting of a rigid girder suspended by inclined straight chains, was known as, 'Ordish's straight-chain suspension system.'

E.3.94 The bridge is gothic in style comprising of four cast-iron towers joined at high level to form turreted arches, from which suspension chains and wrought iron bars radiate to carry the deck below. The towers comprise a central cast-iron cylinder to which non-structural cast-iron decorative work is attached. The chains and bars carry wrought iron parapet stiffening girders which also act as parapets, rising 1.3m above the footway. The parapet girders are coffered on their outer face with cast-iron floral motifs applied to each bay. The inner faces of the parapet girders are similarly divided by vertical stiffening members, again with decorative motifs applied to each bay. The parapets carry transverse girders. These support two layers of structural timbers which in turn carry a timber deck. The bridge carries a single asphalt carriageway (A3031 Albert Bridge Road), flanked by two asphalt covered footways. The towers are connected directly to concrete filled cast-iron piers which act as foundations. At the time the 4 piers were the largest castings ever made.

E.3.95 The construction of the bridge was much delayed by the slow building of the Chelsea Embankment. The original programme of one year became three and costs escalated to £200k. Soon after opening, deficiencies in the design became apparent and a weight restriction was imposed. Soldiers from the nearby Chelsea Barracks were ordered to break step when crossing the bridge, and signs to this effect erected at the time remain in place today. Strengthening works were undertaken in 1884-87 by Sir Joseph Bazalgette including the replacement of the original wire ropes with steel bars. Deterioration of the bridge led to proposals for its demolition after WWII but these were fiercely opposed by prominent campaigners including Sir John Betjeman. The bridge was reprieved and strengthening and repair works undertaken in 1972-75. Works included the introduction of a central pier and when re-opened a 2 ton weight limit was imposed. Further Strengthening and repair works were carried out in 2010-11 at a cost of £7.2m which included new carriageways, redecoration, and re-lighting. Structurally, the bridge is now of an unusual hybrid design but aesthetically retains much of its original character and appearance.

E.3.96 The bridge now comprises a four-span modified bridge with a total length of 220m supported on three intermediate piers and abutments. The centre spans are 61m each, with the shore spans 49m each. There is an elastomeric bearing on the central pier and rocker bearings and expansion joints at each abutment. There is no drainage system. The bridge has a weight restriction of 7.5 tonnes. The bridge carries the A3031 from Chelsea Embankment on the north bank, across to Battersea Park on the south.

E.3.97 Albert Bridge was designated a Grade II* Listed Building in 1975. (The National Heritage List for England reference 1065576, Listed Building UID 206969).

E.3.98 Vol 3 Plate E.26 to Vol 3 Plate E.31illustrate the above description.

**Vol 3 Plate E.26 Albert Bridge viewed from the west**

**Vol 3 Plate E.27 Albert Bridge viewed from the south-west**

**Vol 3 Plate E.28 Albert Bridge looking north**

**Vol 3 Plate E.29 Albert Bridge looking north**


**Vol 3 Plate E.30 South-east tollbooth**

**Vol 3 Plate E.31 Detail of tower**

### Significance

E.3.99 Albert Bridge is of historic and architectural significance due to its striking aesthetic design and its association with the notable Victorian Engineer, R M Ordish. The bridge provides a notable landmark on this section of the Thames, with the Grade II Battersea Bridge immediately upstream, and Grade II Chelsea Bridge immediately downstream. It provides one of the main routes from Chelsea across the river to Battersea Park, for which it was specifically built. The construction of the bridge was suggested by Prince Albert after whom it was named. Consequently, the bridge has a strong historical association with the park and the 19th century redevelopment of the former Battersea Fields. Albert Bridge is a Grade II* Listed Building.

E.3.100 Albert Bridge is of group value with other heritage assets in the vicinity for which it contributes to their setting, including Battersea Bridge (Grade II), Chelsea Bridge (Grade II), numerous buildings on Cheyne Walk (all Grade II), Chelsea Embankment (Grade II), various memorials and statues in Embankment Gardens (all Grade II), two K2 phone boxes (Grade II), the Entrance Gates to Battersea Park (Grade II), and Battersea Park (Grade II*).

E.3.101 The bridge although altered since its original construction, retains much of its intended character and appearance, as well as the much of its original fabric. As a consequence, the individual components of the structure and its fabric are of equally high significance. The exceptions are the asphalt finish to the roadway and footway, and the intermediate pier inserted in

1973. The bridge is of technological significance as an example of an Ordish's straight-chain suspension system. The Ordish–Lefeuvre system, or Ordish–Lefeuvre principle, is an early form of cable-stayed bridge design, patented by Rowland Mason Ordish and William Henry Le Feuvre in 1858. The Ordish–Lefeuvre system differs from conventional suspension bridges in that, while as with a conventional suspension bridge a parabolic cable supports the centre of the bridge, inclined stays support the remainder of the bridge's load. Each stay consists of a flat wrought iron bar attached to the bridge deck, and a wire rope connects the wrought iron bar to one of four octagonal support columns. Only two major bridges were built using the Ordish–Lefeuvre principle, namely Albert Bridge in Chelsea, and the Franz Joseph Bridge over the Vltava in Prague to the same design as that intended for Albert Bridge. The Franz Joseph Bridge was demolished in the 1950's, leaving Albert Bridge as the only surviving example of a significant bridge built using the Ordish–Lefeuvre principle.

E.3.102 The north side of the bridge lies within the Royal Borough of Kensington & Chelsea Thames Conservation Area, and in the setting of the Cheyne Conservation Area. The south side of the bridge lies within the London Borough of Wandsworth, Battersea Park Conservation Area.

### Condition

E.3.103 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in "very good" condition.

E.3.104 The bridge was extensively repaired, resurfaced and redecorated in 2010-11 at a cost of £7.2m.

E.3.105 At the time of the inspection the bridge appeared to be in excellent condition.

### Sensitivity of the bridge's significant elements

E.3.106 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movements on the bridge.

E.3.107 The main Thames Tideway Tunnel would pass perpendicularly beneath the central span of the bridge midpoint between the central and north piers, with the centreline of the tunnel running at a depth of 32.23m below river bed level. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the piers, which would in turn induce movement and stresses within the superstructure.

E.3.108 Immediately above the crown of the tunnel, a maximum vertical settlement of 16.98mm at foundation level. However, with the neighbouring piers set more than 30m distant from this point the vertical settlement of the structure would not be as acute. The abutments and all other piers lie outside the zone of settlement.

E.3.109 Analysis has shown that the greatest settlement would occur at central pier, with a maximum value of approximately 3mm on completion of the tunnelling works, with the north pier experiencing very similar settlement values. The bow wave caused by the advance of the tunnel would also be most acute at the central pier, but again the degree of movement would be slight. The horizontal movements parallel and perpendicular to the bridge would be small with maximum values of approximately 2.7mm and 0.4mm respectively. Movements at foundation level would induce additional movements and stresses within the bridge superstructure, most notably the piers, towers, and longitudinal stiffening girders. Analysis has shown that the actual stresses would be within acceptable limits. The other suspension chains, hangers and transverse girders would experience no significant increase in force due to the settlement and rotation effects.

E.3.110 Calculations indicate that the expected movement range during the Thames Tideway Tunnel construction are likely to be up to 82% of the current predicted movement range from temperature effects. Further detailed examination of the movement joints and bearings would be undertaken prior to tunnel construction to ensure that they are articulating as predicted and have sufficient capacity to accommodate the anticipated movements.

E.3.111 The bridge would be inspected and monitored prior, during, and after tunnel construction and control limits established to quantify when intervention is required to prevent damage to the structure, as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2.

### Conclusions

E.3.112 Detailed structural calculations have been undertaken by Thames Water based on a number of conservative assumptions due to limits in available structural information. The results are regarded as conservative. Further calculations would be undertaken should further information become available.

E.3.113 The assessment indicates that the bridge would be able to accommodate the effects of ground movements and the additional stresses that these would impart upon the superstructure.

E.3.114 Further detailed inspection of the joints and bearings would be undertaken prior to tunnel construction to ensure that these remain in sound and operable condition. The expansion joints would be examined to ensure that they have sufficient capacity to accommodate the additional movement due to tunnel construction in addition to the normal thermal movements.

E.3.115 The bridge would be monitored prior, during and after the construction of the tunnel as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2. The foundations would be monitored to ensure that the actual movements are within the limits predicted, and control limits established to quantify when intervention is required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

E.3.116 No site specific mitigation measures would be necessary for the superstructure.

E.3.117 It is concluded that no harm would be caused to the special interest or significance of the structure.

# Chelsea Bridge

## Description of Chelsea Bridge and its significance

### The bridge

E.3.118 Chelsea Bridge is a three span steel suspension bridge carried on granite faced reinforced concrete piers and abutments. It is historically notable as the UK's first self-stabilising (self-anchored) suspension bridge, built in 1935-7. A self-stabilising suspension bridge is one where the ends of the suspension cables are secured to the bridge deck as opposed to being anchored into the ground. This relieves the pressures that might otherwise be imparted to the abutments or surrounding ground, a key consideration here given the relatively soft ground on which the embankments are founded. Not only was the design revolutionary, but so too was the extensive use of high tensile steel which was required to realise this ground breaking design. The bridge is somewhat minimal and utilitarian in appearance with little in the way of ornamentation. It is characterised by its four simple, somewhat squat towers, which carry the main cables, two large box girders which are suspended from the main cables, a simple art deco balustrade, and large elegantly expressed rocker bearings. The form of the bridge echoes that of Albert Bridge immediately upstream. At close quarters the overwhelming character is of heavily engineered and riveted steelwork. It has been suggested that the recently completed Battersea Power Station so dominated the context that it was decided that the bridge's appearance was not that important. More likely, however, is that the bridge was built at a time of financial austerity and there simply was not the funding available to spend on lavish ornamentation. The design was also clearly influenced by the architectural trends of the time, with the bold from influenced by both Modernism and Art Deco. The principle ornamentation comprises two lamp posts at each entrance carrying pairs of lanterns and surmounted by gilded galleons. The outward facing sides of all four posts carry the coat of arms of London County Council. The inward facing sides of the south posts display the Dove of Peace of the Metropolitan Borough of Battersea, the north-west post the winged bull, lion, boar's head and stag of the Metropolitan Board of Chelsea, and the north-east post the portcullis and Tudor roses of the Metropolitan Board of Westminster. The name 'Chelsea Bridge' is incised into the stonework on the inner face of the south-west abutment. Close by is a bronze plaque celebrating the opening of the bridge in 1937. The bridge carries the A3216 from Chelsea Embankment on the north bank, across to Battersea Park on the south.

E.3.119 Chelsea Bridge is the second bridge to be built on this site. It was begun in 1934, and was opened by the Prime Minister of Canada, William Lyon Mackenzie King on 6 May 1937. It was designed under the direction of Sir T Peirson Frank assisted by London County Council architects Sir Topham Forrest and E P Wheeler. The bridge was built by Holloway Brothers of London. It was built during the Great Depression and received funding on the understanding that it had to be fabricated from materials sourced entirely from the British Empire, hence its opening by the

Canadian Prime Minister whose country had provided the necessary timber.

E.3.120 The site of Chelsea Bridge is believed to have been an ancient ford across the Thames. Important archaeological artefacts including numerous Celtic and Roman weapons were recovered from the river during the construction of the first bridge, leading some to believe that the area is the site of Julius Caesar’s crossing of the Thames during the Roman invasion of Britain in 54BC.

E.3.121 The first bridge, also a suspension bridge, was built in 1851-8 to provide access from the densely populated north bank to the newly developed Battersea Park. The park was created by reclaiming the former marshlands of Battersea Fields, an area once renowned for its lawlessness. The bridge was designed by the Engineer, Thomas Page, initially operating as a toll bridge. It was opened on 31 March 1858 by Queen Victoria and was named ‘Victoria Bridge’. Soon after completion, however, doubts were expressed as to the safety of the bridge which was thought to be structurally inadequate. Strengthening works were undertaken in 1861, a weight restriction imposed, and the bridge renamed ‘Chelsea Bridge’ so as any potential failure of the structure be distanced from the Royal Family. The bridge was acquired by the Metropolitan Board of Works in 1877 and the tolls abolished that same year. By 1926 the narrow design and limited capacity of the bridge was unable to cope with the vastly increased use placed upon it, in particular the introduction of the motor car, and plans were drawn up for its replacement. The bridge was closed in 1934 and the new extant bridge built in 1934-7.

E.3.122 The bridge has been little altered since its original construction. A new footbridge was constructed in 2004 to carry the Thames Path which passes below the south end of Chelsea Bridge. Chelsea Bridge was designated Grade II Listed Building in 2008. (The National Heritage List for England reference 1393009, Listed Building UID 496889).

E.3.123 The present bridge comprises a 3-span self-anchoring suspension bridge with a total length of 213m supported on two intermediate granite faced reinforced concrete piers and abutments. The spans comprise 53m for the north span, 107m for the centre, and 54m for the south. The bridge is 20m wide; the central deck is 12m wide and carries 3 lanes of traffic and 2 cycle ways; the cantilevered footways are each 3.7m wide. Two towers to each side carry large box girders which are suspended from the main cables on smaller suspension cables set at regular intervals along the length of the bridge. Between these main box girders are transverse and longitudinal steel joists which support the buckle plate deck. The carriageway surfacing is laid on an in-situ concrete slab, with hot rolled asphalt base and wearing course. The footways are cantilevered out on each side of the bridge separated from the carriageway by the large box girders. Each footway is constructed of steel trough decking and a macadam wearing course with mastic skirting. Each of the principle cables is formed from 37 wire ropes bundled to form a large hexagonal cable.

E.3.124 The piers stand on the site of the earlier piers but were entirely rebuilt constructed of granite faced mass concrete with mass concrete spread foundations. Permanent steel sheet piles run around the outside of the mass concrete foundations. The abutments are also of granite faced mass concrete with mass concrete spread foundations. Permanent steel pile formwork has been used on the river face of the abutments.

E.3.125 It is understood that record drawings indicate that there are 9 movement joints located along the length of the bridge, however, only 4 remain visible at the piers and abutments. The towers are supported on large rockers bearings at the piers.

E.3.126 The design of the bridge negates the requirement for substantial ground anchors thereby relieving pressure on the abutments which are founded on relatively soft ground.

E.3.127 Vol 3 Plate E.32 to Vol 3 Plate E.39 illustrate the above description.

**Vol 3 Plate E.32 Chelsea Bridge viewed from the south-west with Battersea footbridge in foreground**

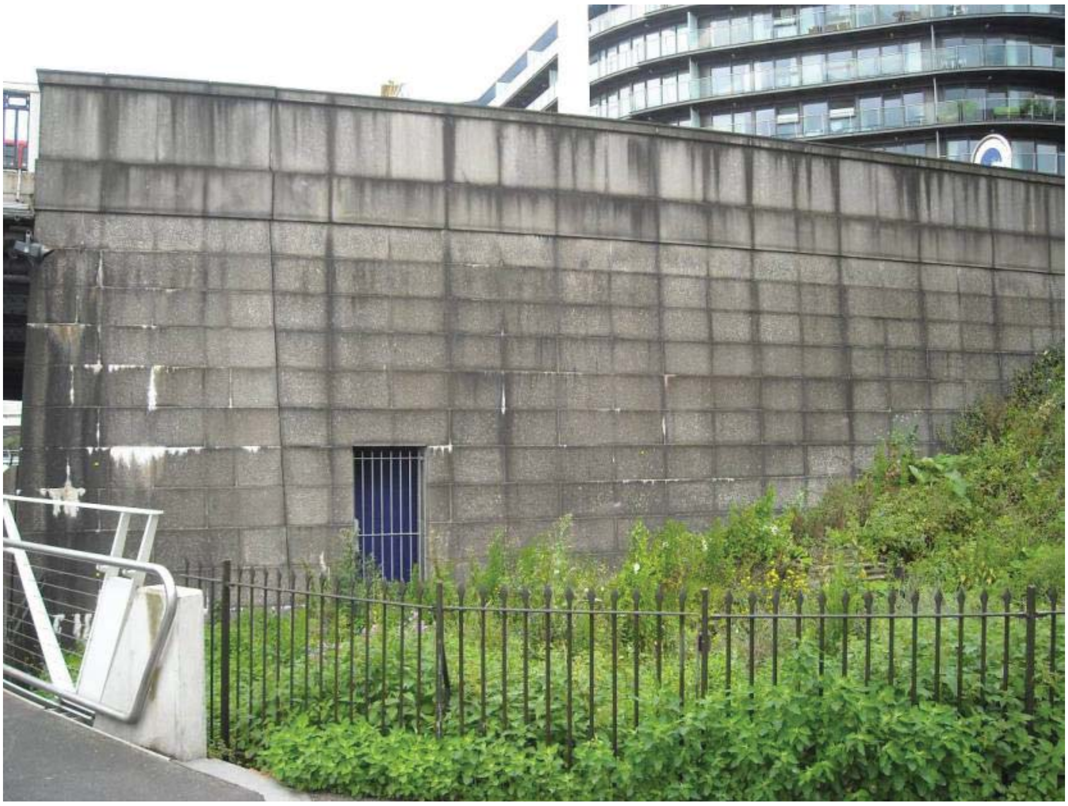
**Vol 3 Plate E.33 Chelsea Bridge viewed from the north-east**

**Vol 3 Plate E.34 Chelsea Bridge looking south**

**Vol 3 Plate E.35 Chelsea Bridge looking south**

**Vol 3 Plate E.36 Underside of bridge deck viewed from south**

**Vol 3 Plate E.37 South abutment**



**Vol 3 Plate E.38 Detail of cracking to handrail**

**Vol 3 Plate E.39 Detail of south-west abutment with name and ceremonial plaque**


### Significance

E.3.128 Chelsea Bridge is of historic and architectural significance due to its revolutionary design, being the first self-stabilising (self-anchored) suspension bridge built in the UK. The bridge provides a notable landmark on this section of the Thames, echoing the design of Albert Bridge immediately upstream. It provides one of the main routes from Chelsea across the river to Battersea Park, for which its predecessor was specifically built. Consequently, the bridge has a strong historical association with the park and the 19th century redevelopment of the former Battersea Fields. Chelsea Bridge is a Grade II Listed Building.

E.3.129 The bridge is part of a continuum of river crossings at a point where it is believed Julius Caesar crossed the Thames during the Roman invasion of Britain in 54BC.

E.3.130 The bridge incorporates symbolic ornamentation celebrating the former London County Council and the London Boroughs in which it was built.

E.3.131 Chelsea Bridge is of group value with other heritage assets in the vicinity for which it contributes to their setting, including Albert Bridge (Grade II*), the group of Listed Buildings at the Western Pumping Station (Grade II), the Lister Institute of Preventative Medicine (Grade II), the Royal Hospital, Chelsea and Ranelagh Gardens (Grade II), the Entrance Gates to the North Entrance of Battersea Park (Grade II), and Battersea Park (Grade II*).

E.3.132 The bridge has been little altered since its original construction and retains the entirety of its intended design and decorative scheme. As a consequence, the individual components of the structure and its fabric are of equally high significance. The exceptions are the asphalt finish to the roadway and footway. The bridge is of particular constructional interest as a self-stabilising suspension bridge, the first of its kind in the UK, with the extensive use of high tensile steel, predating the first British Standard, affording it added technological importance.

E.3.133 The north side of the bridge lies within two conservation areas, namely the City Of Westminster Churchill Gardens Conservation Area, and the Royal Borough of Kensington & Chelsea Thames Conservation Area. The south side of the bridge lies within the London Borough of Wandsworth, Battersea Park Conservation Area.

#### Condition

E.3.134 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in “very good” condition.

E.3.135 The bridge appears to be structurally sound and well maintained.

E.3.136 Unlike many of the historic bridges over the Thames within London, Chelsea Bridge appears to remain as originally constructed.

E.3.137 At the time of the inspection the bridge appeared to be in good condition. Some minor weathering to the decorative coatings and minor cracking to the decorative balustrade was noted, but otherwise the structure appeared to be in excellent order.

### Sensitivity of the bridge’s significant elements

E.3.138 Detailed structural calculations have been undertaken by Thames Water to assess the effects of ground movements on the bridge.

E.3.139 The main Thames Tideway Tunnel would pass perpendicularly (albeit at a slightly oblique angle) beneath the central span of the bridge, with the centreline of the tunnel running at a depth of 32.98m below river bed level. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the piers, which would in turn induce movement and stresses within the superstructure. The tunnel would pass to the south of the centreline of the bridge and hence the effects of settlement would be more pronounced at the south pier.

E.3.140 Immediately above the crown of the tunnel, a maximum vertical settlement of 15.79mm at foundation level is predicted. However, with the neighbouring piers set more than 50m distant from this point the vertical settlement of the structure would not be as acute.

E.3.141 Analysis has shown that the greatest settlement would occur at the south pier, with a maximum value of 1.26mm on completion of the tunnelling works. The bow wave caused by the advance of the tunnel would also be most acute at the south pier, but again the degree of movement would be slight with a maximum heave of less than 0.5mm. The horizontal movements parallel and perpendicular to the bridge would be small.

Movement of the piers would induce additional movements and stresses within the bridge superstructure, most notably the central span. Detailed structural calculations have found that the increase in stresses are within acceptable limits and as a consequence the bridge members can be considered as adequate, with no requirement for mitigation or strengthening work.

E.3.142 The predicted ground movements would be comparatively small and the differential settlement would have a negligible effect on the bridge. The piers and abutments have mass concrete foundations. These would act as single very stiff elements, transferring settlement effects into the superstructure via the bearings. It is not anticipated that any cracking of the piers and abutments would occur, the abutments themselves lying outside the zone of settlement.

E.3.143 The settlement assessment recommends a series of monitoring, and investigation works, coupled with further analysis.

### Conclusions

E.3.144 The assessment indicates that the bridge would be able to accommodate the effects of ground movements and the additional stresses that these would impart upon the superstructure. No overstressing or cracking is predicted.

E.3.145 Further detailed inspection of the joints and bearing would be undertaken prior to tunnel construction to ensure that these remain in sound and operable condition. The expansion joints would be examined to ensure that they have sufficient capacity to accommodate the additional movement due to tunnel construction in addition to the normal thermal movements.

E.3.146 The bridge would be monitored prior, during and after the construction of the tunnel to determine its behaviour as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2. The foundations would be monitored to ensure that the actual movements are within the limits predicted, and control limits established to quantify when intervention is required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

E.3.147 It is concluded that no harm would be caused to the special interest or significance of the structure.

## Cremorne Bridge (Chelsea River Bridge)

### Description of Cremorne Bridge and its significance

#### The bridge

E.3.148 The Chelsea River Bridge was historically known as Cremorne Bridge, named after the Cremorne pleasure gardens which formerly stood on the site now occupied by the Lots Road Power Station. The Cremorne Bridge was built in 1863 to the designs of William Baker, Chief Engineer of the London and North West Railway Company (LNWR), and his counterpart T H Bertram of the Great Western Railway (GWR). The construction was undertaken by Brassey and Ogilvie, and the bridge opened on 2nd March 1863. The Cremorne Bridge is a five-span wrought-iron arch bridge, which is flanked at either end by six-span brick arch viaducts on the east and west shores of the river. Each of the river spans is approximately 44m, with the total length of the structure (including the shoreline arches) some 387m. The bridge was built to connect the main northbound lines out of Paddington and Euston with the southbound lines from Waterloo, Victoria, and Clapham Junction through the West London Extension Railway, an enterprise jointly owned by four of the railway companies including the LNWR and GWR. The overall aim of the West London Extension Railway was to form a connection between the GWR lines to the north and the Channel Ports to the south. The bridge was designed to carry not only Standard Gauge, but also the wide GWR Broad Gauge designed by Brunel. The opening of the bridge led to a significant increase in freight traffic and it was not until 1904 that the bridge was used for passenger services.

E.3.149 The bridge is of particular historic significance as it was one of the earliest railway bridges to cross the Thames, and among the earliest surviving examples. The initial expansion of the railways during the 1840’s and 1850’s had little effect upon the Thames, partly due to the prohibition the government placed on the building of surface railways within central London. By the time the ban was lifted in 1846, the now familiar historic pattern of railway termini encircling the middle of the city had become established, and there was little financial incentive for the railway companies to link the north and south banks of the Thames within the city. Consequently, the first railway river crossings were built in outlying districts. The first was at Barnes in 1848 (Grade II), followed by Richmond soon after that same year (although subsequently replaced / re-built in 1908). The 1860’s saw rapid development to the south of the Thames which led to the construction of 6 further bridges of which the Cremorne Bridge is one of the earliest, and one that survives in its original form. The bridge has been little altered since its construction 1863, although there have been repairs and strengthening works and the original deck has been replaced. The fact that the bridge is both of early date and retains much of its original historic fabric and integrity makes it especially significant, as recognised by its Grade II* listed status.

E.3.150 The main bridge comprises a 5-span wrought iron arch structure supported on stone piers, with the piers set skew to the line of the bridge at an angle of approximately 17º. The spans are carried on riveted wrought-iron arched ribs arranged in pairs which are joined by lattice spandrel members to the deck girders. There are three pairs of ribs to each span, with the inner ribs cross braced. Some of this cross bracing is later 20th century strengthening work. The upper and lower chords of the arches and the lattice spandrel members between, however, appear entirely of wrought iron and are presumed to be original fabric. The river piers are constructed of brick, faced with large ashlar chamfered blocks of coursed grain sandstone. The stone is reputed to be “Bramley Fall”, but this seems unlikely as production at the original Bramley Fall quarry near Leeds ceased in 1839. It is more likely to be “Rough Rock” which was and continues to be obtainable from other quarries in the area. The piers are founded on masonry, and are carried up in ashlar with deep roll moulded cornices at parapet level. Internally, the piers are likely to be backfilled with either mass or rubble concrete. The abutments are similarly faced in ashlar chamfered stonework and back onto brick masonry arch viaducts.

E.3.151 The two centre piers are surmounted by scrolls as if for the base of some former architectural feature such as a lamp. A painting of 1897 by James Dredge appears to illustrate what are lamps on these centre piers which may have been placed to aid river navigation.

E.3.152 The bridge is surmounted by lattice metal parapets which appear to be of modern date and have been designed to reflect the character of the lattice spandrels below. The metal parapet is attached to a modern precast concrete base, which is faced with glass-reinforced plastic (GRP) cladding, designed to reflect the appearance of the original roll moulded cornice.

E.3.153 Vol 3 Plate E.40 to Vol 3 Plate E.46 illustrate the above description.

**Vol 3 Plate E.40 Bridge viewed from south (upstream)**

**Vol 3 Plate E.41 Bridge viewed from west**

**Vol 3 Plate E.42 Bridge viewed from west**

**Vol 3 Plate E.43 Pier 1 from west**

**Vol 3 Plate E.44 West abutment viewed from south**

**Vol 3 Plate E.45 West abutment with flanking viaduct viewed from south**

**Vol 3 Plate E.46 West viaduct**

### Significance

E.3.154 The bridge deck, tracks and all services are of modern date, and are not of archaeological, architectural, artistic or historic significance. The remainder of the main bridge is of considerable archaeological, architectural and historic significance due to its comparatively early date, its materials, its role in the historical development of the railway network, and the fact that it remains little altered since its original construction. The flanking brick viaducts are of slightly lesser significance, but are none the less of group value, designed and built as part of the overall river bridge design. The bridge is a significant landmark and an important contribution to the rich history of the lower Thames.

### Condition

E.3.155 The bridge was observed with the aid of binoculars from both sides of the river during the walkover survey. From visual observation the bridge appears to be in “fair” condition. It is understood that the bridge was refurbished in 1969 and again in 1992. It was struck by a barge in 2003 necessitating repairs to some of the lower structural elements which were completed in 2004. The bridge has recently been assessed and a strengthening design is currently in hand.

E.3.156 Although the bridge appears to be structurally sound, maintenance works are becoming necessary. The surface coatings are peeling away exposing the underlying metalwork and surface corrosion is evident. This gives the bridge a patchy appearance. Self-set vegetation is gaining a hold on the piers and the later cementitious pointing is falling away.

### Sensitivity of the bridge's significant elements

E.3.157 Assessment indicates that two of the piers would be affected by ground movement, namely the 1st and 2nd piers from west, with the new tunnel passing below the mid-span of the 2nd arch from west. East and west piers are predicted to settle by 6.2mm and 6.3mm at bed level respectively. In addition, the piers would be subject to horizontal movements. The west pier is predicted to move 2.5mm eastwards parallel to the bridge (i.e. along the length of the bridge), and 1.4mm southwards perpendicular to the bridge. The east pier is predicted to move 2.4mm westwards parallel to the bridge and 1.4mm northwards perpendicular to the bridge. In effect, the two piers would incline slightly towards each other. This would place the arch above the tunnel (arch 2) into compression, hogging upwards slightly, and the arches either side (arches 1 and 3) into tension, and sagging slightly. Ground movement at the base of the piers would act to increase the amount of horizontal movement at superstructure level. However, analysis shows that such movements will be resisted by the deck superstructure, resulting in the sagging and hogging noted above. The predicted horizontal movement of 2.5mm at foundation level would generate a movement of 0.5mm at the level of the arch supports. During construction there would be a brief period of differential vertical settlement between the east and west piers of 3.6mm. The remaining piers, spans and abutments would not be affected by ground movement.

E.3.158 At superstructure level, the stresses induced by the ground movements would be small, amounting to approximately 3.5% of the stress induced by thermal effects under normal working conditions.

E.3.159 The piers have been assessed and compared with the damage risk categories defined by Burland (1977) and Boscardin & Cording (1989); the likely level of damage risk falls within Category 0 – Negligible degree of severity of damage; typically this is no more than hairline cracks. The largest tensile strain will be 7% of the Category 0 limit, and hence it is considered very unlikely that even hairline cracks would appear.

E.3.160 Architecturally, the bridge is of bold design with no fine architectural detail or ornamentation. Should for any reason, the predicted ground movements induce hairline cracking, this would not be of detriment to the architectural or historic significance of the bridge. Hairline cracking would be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric. However, as stated above, it should be borne in mind that movements and stresses would be small, and even hairline cracking seems unlikely in this instance.

### Conclusions

E.3.161 Assessment indicates that the movements and stresses induced by the tunnel construction would be small, and that no resultant damage is predicted. The bridge is of bold design with no fine architectural detail or ornamentation. It is concluded that there would be no risk to the significance of the bridge from tunnel induced movements. There would not be any need for any site specific mitigation measures.

# Vauxhall Bridge

## Description of Vauxhall Bridge and its significance

### The bridge

E.3.162 Vauxhall Bridge is a five span steel arch bridge with concrete piers and abutments faced in granite. It is a particularly elegant structure, and is of outstanding architectural significance for the fine sculptures by Alfred Drury and Frederick Pomeroy which adorn the piers. The bridge carries the A202 from Millbank on the north bank, across to Albert Embankment on the south bank, where it alights adjacent to the SIS Building at Victoria Cross, close to Vauxhall Railway Station and the new Vauxhall bus station. The north section of the bridge lies in the City of Westminster, the south in the London Borough of Lambeth. The bridge was designed to carry a double tram track in the centre which has since been removed and is now capable of carrying 6 lanes of traffic, cycleways, and two flanking footpaths.

E.3.163 The bridge was built in 1904 to 1906 to the designs of two of London County Council's Chief Engineers, Sir Alexander Binnie (1839-1916), and his successor Sir Maurice Fitzmaurice (1861-1924). The contractors for the piers and foundations were Messrs. Pethick Bros, and for the superstructure Mr. Charles Wall. It was opened in 1906 by the Prince of Wales, who later became King George V, and was built at a cost £466,725. This was the first bridge to carry trams across the Thames.

E.3.164 It is believed that there has been a river crossing at or very near to this site for the past 3,500 years. In 1988, the remains of an oak crossing were discovered and dated to c.1500 BC. The present bridge is the second of the modern era to be built on the site, replacing an earlier cast-iron bridge, which was formerly known as, "Regent's Bridge." The first bridge was built in 1811 to 1816. It had been the intention to build a stone bridge for which a foundation stone was laid on 9th May 1811, but due to financial difficulties, a new Act of Parliament was passed permitting the Vauxhall Bridge Company to build a cheaper iron bridge. After further false starts, with designs by John Rennie rejected, and Samuel Bentham called into question, the first bridge was eventually completed under the design direction of James Walker. The nine span cast-iron arch bridge (on stone piers) was the first iron bridge to be built across the Thames. The bridge was bought out by the Metropolitan Board of Works (MBW) in 1879 and the tolls lifted. Following the removal of Old London Bridge in 1831, there had been a serious alteration to the tidal flow of the river. Inspections undertaken by the MBW revealed that the central piers were badly eroded due to scour, exposing the foundations. Emergency repairs were undertaken but these too were soon washed away. The centre piers were removed and a large central span inserted. The bridge was now in very poor condition and in 1895 London County Council gained Parliamentary permission to renew the bridge. Demolition commenced in 1898.

E.3.165 London County Council's Chief Engineer, Sir Alexander Binnie's first designs for a steel bridge proved unpopular and he was asked instead to draw up an alternative proposal for a concrete structure faced with granite.

Work commenced on the construction of this design but it was soon beset with problems. The design was criticized and even ridiculed by leading architects. It was found that the south abutment would effectively block the River Effra which had to be diverted so as to join the Thames to the north of the bridge, delaying construction. On completion of the stone piers it was then discovered that the clay of the riverbed would not be able to support the weight of a concrete bridge. It was therefore decided to build a steel superstructure onto the completed piers and abutments. A steel superstructure 247m long and 24m wide was designed by Binnie and Maurice Fitzmaurice. The new bridge was eventually opened on 26th May 1906, five years behind schedule.

E.3.166 The new bridge was considered stark in appearance and a number of architects were consulted in the final stages of construction for ideas on relieving the functional appearance of the structure. After consultation with Richard Norman Shaw, it was decided to erect a series of monumental bronzes on the piers and Alfred Drury, George Frampton, and Frederick Pomeroy were commissioned to provide designs. Frampton withdrew from the commission, but Drury and Pomeroy produced four statues each, which were installed in 1907. On the upstream piers are Pomeroy's Agriculture, Architecture, Engineering and Pottery; whilst on the downstream piers are Drury's Science, Fine Arts, Local Government and Education. Each statue weighs approximately two tons.

E.3.167 The bridge was altered in 1973 to accommodate an extra lane of traffic by narrowing the pavements and altering the balustrades. The replacement of the original cast-iron balustrades with low box-girder structures caused considerable outcry at the time. Apart from this, the bridge remains little altered.

E.3.168 The present bridge comprises a 5-span steel structure with a total length of 231.76m supported on four steel piers and two abutments. The upper parts of the piers are of steel which are carried on stone cutwaters, with stone continued below the waterline. The stone piers and abutments actually comprise of granite faced concrete chambers founded on steel caissons filled with concrete. The Westminster abutment is additionally founded on piles. The spans comprise of shallow elliptical arches which vary in length symmetrically about the axis from 42.04m for the shore, 48.64m for the intermediate, and 50.40m for the central span. The width of the structure between the parapets is 24.4m.

E.3.169 The bridge deck is formed from flat steel plates overlaid by a mass concrete slab and protected with bituminous waterproofing below the asphalt carriageway surface. The footways are of concrete paving slabs. The deck cantilevers outwards from the outer arch with a convex steel plate to give the visual effect of a cornice. The deck is supported on cross beams which are in turn supported on the main longitudinal beams. The longitudinal beams are supported on spandrel columns which are in turn carried by the arch ribs below. The outer ribs which carry the footpaths are shallower than the inner ribs which carry the road. The inner ribs also vary in cross section along their length. The ribs and spandrel columns are cross braced, with further bracing completing the span structure. The ribs spring from steel skewbacks with a knuckle joint to accommodate movement.

E.3.170 The longitudinal beams are carried on rubber pad bearings at the abutments, with sliding plates at expansion joints. There are ten expansion joints in total, two on each side of each pier, and one at each abutment. The expansion joints have been renewed on a number of occasions, most recently in 1987 and 1994, with further refurbishment and overhaul in 2002.

E.3.171 The bridge is painted in a burgundy and orange colour scheme with blue and white trim. The outer spandrel columns are clearly expressed, picked out in contrasting colour.

E.3.172 The cutwaters are boldly detailed with a simple roll moulding at the top. Floodlighting is mounted on the cutwaters.

E.3.173 Above the cutwaters, the piers feature the impressive bronze statues by Drury and Pomeroy.

E.3.174 The masonry construction and detailing of the abutments appears slightly incongruous in juxtaposition to the steel spans. This is due to the abutments forming part of an earlier bridge design which was abandoned due to prohibitive costs, see above. At deck level the abutments feature screen walls with arched openings and balustrades. The inward face of south-west and north-east abutments are incised with the name, “Vauxhall Bridge,” in bold lettering in-filled with gold leaf. On the south side the riverside footpath passes beneath the road by means of a vaulted passage which runs through the abutment.

E.3.175 Vol 3 Plate E.47 to Vol 3 Plate E.60 illustrate the above description

**Vol 3 Plate E.47 Bridge viewed from south-west**

**Vol 3 Plate E.48 South abutment and pedestrian underpass viewed from south-west**

**Vol 3 Plate E.49 Detail of bridge viewed from south-west**

**Vol 3 Plate E.50 Detail of south abutment knuckle joints**

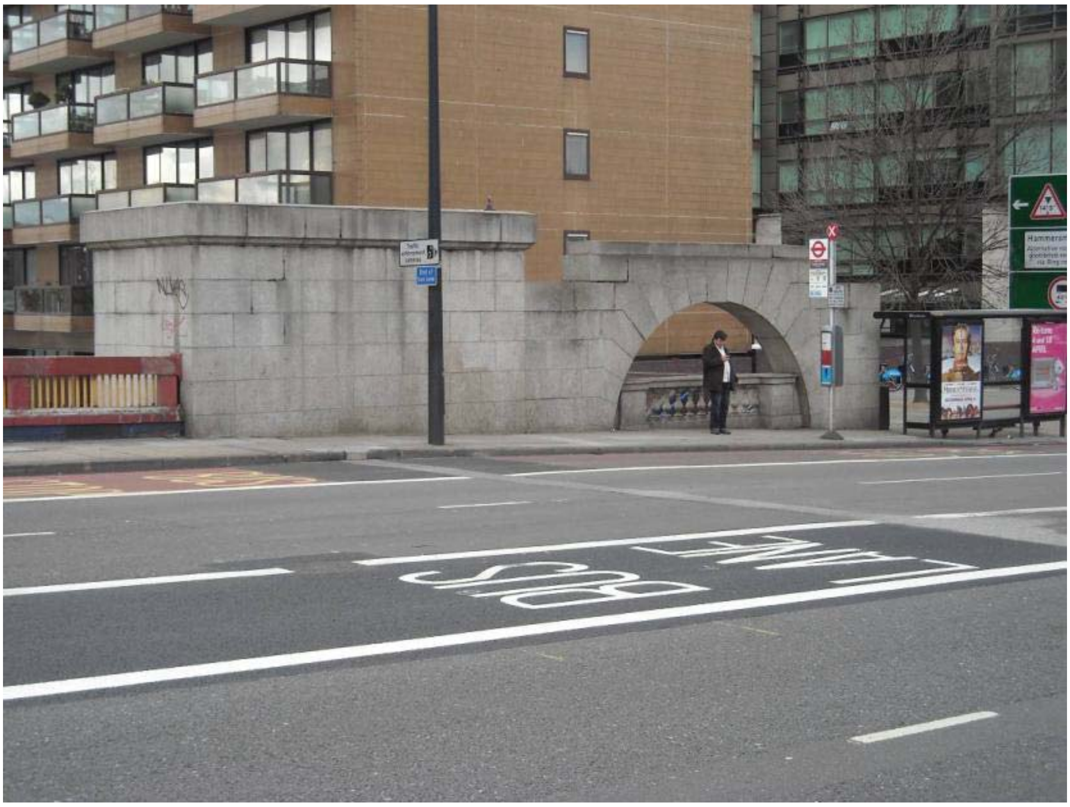
**Vol 3 Plate E.51 South most (Lambeth) arch viewed from east**

**Vol 3 Plate E.52 Bridge viewed from south-east**

**Vol 3 Plate E.53 Bridge viewed from south-west**

**Vol 3 Plate E.54 North abutment viewed from north-west**

**Vol 3 Plate E.55 North-west abutment walls viewed from deck level**




**Vol 3 Plate E.56 North-east abutment walls viewed from deck level**

**Vol 3 Plate E.57 South-east abutment walls and balustrade viewed from deck level**

**Vol 3 Plate E.58 East parapet showing typical failure of surface coatings & corrosion**

**Vol 3 Plate E.59 Vauxhall Bridge in context looking towards Lambeth**

**Vol 3 Plate E.60 View downstream to Lambeth Bridge**

### Significance

E.3.176 Vauxhall Bridge is of historic, architectural and artistic significance due to its elegant design, and the outstanding bronze statues by Alfred Drury and Frederick Pomeroy which adorn it. Despite the unfortunate alterations to the parapets, the bridge retains much of its visual and structural integrity. It stands in the setting of a number of listed buildings and is of group value with Lambeth Bridge immediately downstream. The bridge is a significant landmark and an important contribution to the rich history of the lower Thames.

E.3.177 The piers, abutments, and the majority of the superstructure date from the original construction and are of considerable significance. Later interventions to the deck and parapet, however, are of more recent date and hence of far lesser significance; these include the carriageway and pavement finishes, and trief kerbs.

E.3.178 The bridge is a Grade II* Listed Building. The statues contribute considerably to the overall artistic significance of the structure.

E.3.179 The north side of the bridge is bounded by the City Of Westminster, Pimlico and Millbank Conservation Areas, whilst the south side lies within the Borough of Lambeth, Albert Embankment Conservation Area.

### Condition

E.3.180 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in “fair” condition.

E.3.181 The bridge appears to be structurally sound and maintained. However, it is now overdue for redecoration. The surface coatings are life expired, exposing the underlying metal to corrosion and creating a somewhat shabby appearance. If left unchecked the corrosion effects will over time become more serious.

E.3.182 The bridge was altered in 1973 to accommodate an extra lane of traffic by narrowing the pavements. Strengthening works undertaken at that time saw the replacement of the original cast-iron balustrades with low box-girder structures.

E.3.183 The bridge was assessed in 1994 by Parkman Buck Limited and was found to have adequate capacity for 40 tonne loading in accordance with the national design standard, ‘The Design Manual for Roads and Bridges, Volume 2, Section 2, Part 14 (BD 21/93), Unreinforced Masonry Arch Bridges.’ However, further analysis by Thames Water has identified an existing overstressing of some of the internal deck bracing members.

E.3.184 At the time of inspection the décor was flaking with significant areas of rusting evident. The piers and abutments appear to be free of cracking, although some of the stones are open jointed, most notably the high level masonry on the abutments. The asphalt carriageway is good condition, although the drainage gullies appear to be blocked with silt. The concrete paving to the footways is worn but serviceable.

### Sensitivity of the bridge's significant elements

E.3.185 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movements on the bridge.

E.3.186 The main Thames Tideway Tunnel would pass perpendicularly (albeit at a slightly oblique angle) beneath the fourth span from north, midway between the third and fourth (Lambeth) piers, with the centreline of the tunnel at a depth of 36.49m below river bed level. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the piers, which would in turn induce movement and stresses within the superstructure.

E.3.187 Immediately above the crown of the tunnel, a maximum vertical settlement of 15.2mm at foundation level is predicted. However, with the neighbouring piers set more than 20m distant from this point the vertical settlement of the structure would not be as acute.

E.3.188 Analysis has shown that it is only the third and fourth (Lambeth) piers from north where movement is predicted. Movement here would induce additional movements and stresses within the superstructure to spans three, four and five from north. No movement is anticipated to any of the remaining, spans, piers or abutments.

E.3.189 A maximum vertical settlement of less than 8mm is predicted to occur at pier three, and just over 10mm at pier four (Lambeth pier), both piers settling in a broadly similar manner. The two piers would tend to tilt towards each other, albeit marginally. The differential settlement between piers two and three would be in the order of 8mm, and three and four would be in the order of 10mm.

E.3.190 The predicted ground movements would be comparatively small and the differential settlement would have a negligible effect on the abutments and piers. The piers and abutments have mass concrete foundations. These would act as single very stiff elements, transferring settlement effects into the superstructure via the bearings. It is not anticipated that any cracking of the piers and abutments would occur.

E.3.191 The superstructure is free to move at deck level via the expansion joints at each pier and abutment, with the parapets also incorporating expansion joints. No distress or cracking of the parapets is predicted.

E.3.192 No cracking or damage to the statues is predicted.

E.3.193 Assessment has concluded that the structure would adequately accommodate the effects of settlements with the majority of members able to accommodate the additional stresses. The sole exception to this is the bracing members within the deck superstructure which according to calculation are already in a state of over-stress. Prior to construction of the tunnel, these bracing members would be inspected for signs of distress and if found deficient, the existing rivets would be replaced with high strength bolts. No strengthening of the bracing members themselves would be necessary.

E.3.194 Ultimately, should strengthening of the internal deck members be deemed necessary, this would be readily accommodated without detriment to the outward appearance or significance of the bridge.

E.3.195 Although not currently anticipated, should for any reason the predicted ground movements induce hairline cracking within the masonry of the piers and abutments, this would not be of detriment to the architectural or historic significance of the bridge. Hairline cracking would be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric.

### Conclusions

E.3.196 Assessment indicates that the bridge would be able to accommodate the effects of ground movements and the additional stresses that these would impart upon the superstructure. According to detailed calculations undertaken by Thames Water the bracing members within the bridge superstructure are already in a state of over-stress. Prior to construction of the tunnel, these bracing members would be inspected for signs of distress and if found deficient, the existing rivets would be replaced with high strength bolts. No strengthening of the bracing members themselves would be necessary.

E.3.197 The bridge would be monitored prior, during and after the construction of the tunnel as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2. The foundations would be closely monitored to ensure that the actual movements are within the limits predicted, and control limits established to quantify when intervention is required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

E.3.198 Further detailed inspection of the joints and bearing would be undertaken prior to tunnel construction to ensure that these remain in sound and operable condition. The expansion joints would be examined to ensure that they have sufficient capacity to accommodate the additional movement due to tunnel construction in addition to the normal thermal movements. It is concluded that no harm would be caused to the special interest or significance of the structure.

# Lambeth Bridge

## Description of Lambeth Bridge and its significance

### The bridge

E.3.199 Lambeth Bridge is a five span steel arch structure carried on granite faced reinforced concrete piers and abutments. It displays an interesting mix of steel and stone and a graceful arched profile. The bridge poses symbolic ornamentation which celebrates the former London County Council and the reign of George V, with the red livery reflecting the colour of the benches within the House of Lords; this contrasts with the green livery of Westminster Bridge immediately downstream which reflects the colour of the benches within the House of Commons. The bridge carries the A3203 from Lambeth Palace on the east bank, across to Millbank and Westminster on the west. It carries 3 lanes of traffic, with 2 flanking footpaths. The east section of the bridge lies in the London Borough of Lambeth, the west in the City of Westminster. In 1965, the bridge was the first to be tunnelled beneath to provide pedestrian access along the south embankment.

E.3.200 Lambeth Bridge was begun in 1929, and was opened by King George V and Queen Mary on 12 July 1932. It was built to the designs of the Civil Engineer, Sir George Humphreys KBE (1863 to 1945), with Sir Reginald Blomfield and George Topham Forrest as consulting architects. The bridge was fabricated and erected at an approximate cost of £80k by Dorman Long & Co Ltd, one of the foremost bridge building firms of the era who also built the Tyne Bridge (1925-1928), and the Sydney Harbour Bridge (1928-1932).

E.3.201 The site of Lambeth Bridge has been an important river crossing and landing stage for some 800 years, with Lambeth Palace (the residence of the Archbishop of Canterbury since the C13th) on one side of the river, and the King’s Palace at Westminster on the other. As use of the crossing increased, a horse ferry was introduced between Lambeth and Millbank under the control of the Archbishop, hence the name, “Horseferry Road.” Despite numerous discussions and several bills and acts of Parliament, it was not until 1861 that the Lambeth Bridge Act incorporated a company to construct a toll bridge to connect Church Street (now Lambeth Road), Lambeth, with Market Street (now Horseferry Road), Westminster.

E.3.202 The first Lambeth Bridge was built to the designs of Peter Barlow at a cost of £48,924, and was opened on November 1862. The bridge was a stiffened suspension type, 252.4m long, divided into three spans. Doubts about its safety, coupled with its awkwardly steep approaches deterring horse-drawn traffic, meant it soon became used almost solely as a pedestrian crossing. It ceased to be a toll bridge in 1879 when the Metropolitan Board of Works assumed responsibility for its upkeep; it was by then severely corroded. Major repairs were carried out in 1887. Despite this, the state of the bridge continued to deteriorate and in 1910 it was closed to vehicular traffic. Proposals for rebuilding the bridge were delayed by the Great War, but in 1924 powers were granted to London County Council to construct a new bridge and to widen, re-grade and realign the approaches at either end. In 1929 a temporary footbridge was built alongside and the old bridge demolished. The new bridge was completed in 1932.

E.3.203 The bridge was strengthened in 1996 to provide a 40 tonne loading capacity in accordance with BD 21/93. The works, however, did not alter the outward appearance of the structure, and it remains little altered since its original construction.

E.3.204 The present bridge comprises a 5-span steel structure with a total length of 236.5m supported on four granite faced reinforced concrete piers and two abutments. The spans comprise of shallow elliptical arches which vary in length symmetrically about the axis from 38.1m for the shore, 45.4m for the intermediate, and 50.3m for the central span. The shallow steel arches each consist of nine ribs which carry a reinforced concrete roadway. The coat of arms of London County Council are sculpted on the piers, below which is a simple projecting cornice, and pairs of concave granite arms which sweep elegantly down to the top of the cutwaters. The structural deck comprises longitudinal steel girders which support a steel trough topped with reinforced concrete, with transverse and diagonal steel girders between. The arch ribs are made from plated and riveted sections. The outer spandrels are in filled with plated and riveted steel panels which conceal the inner structure of the arches from view. Above the spandrels a simple projecting ledge acts as a cornice. The parapet comprises a steel lattice balustrade with intermediate box section steel piers, topped by a moulded cast-iron handrail, which runs between the piers. The piers are surmounted by granite obelisk lamp stands carrying pairs of lanterns, with further single lanterns on steel latticework pylons set at intervals along the balustrade. Tall granite obelisks at either end of the bridge are surmounted with stone pinecones, ancient symbols of hospitality, decorated in gold leaf. Flights of stone steps at each abutment afford pedestrian access from the riverside path up to deck level. A tunnel all passes through the east abutment.

E.3.205 At deck level the footways are of riven Yorkstone paving with asphalt to the carriageway. The piers provide recessed stone benches. Views are afforded upstream to Vauxhall Bridge, and downstream to Westminster Bridge. The width of the bridge is 18.3m between the parapets.

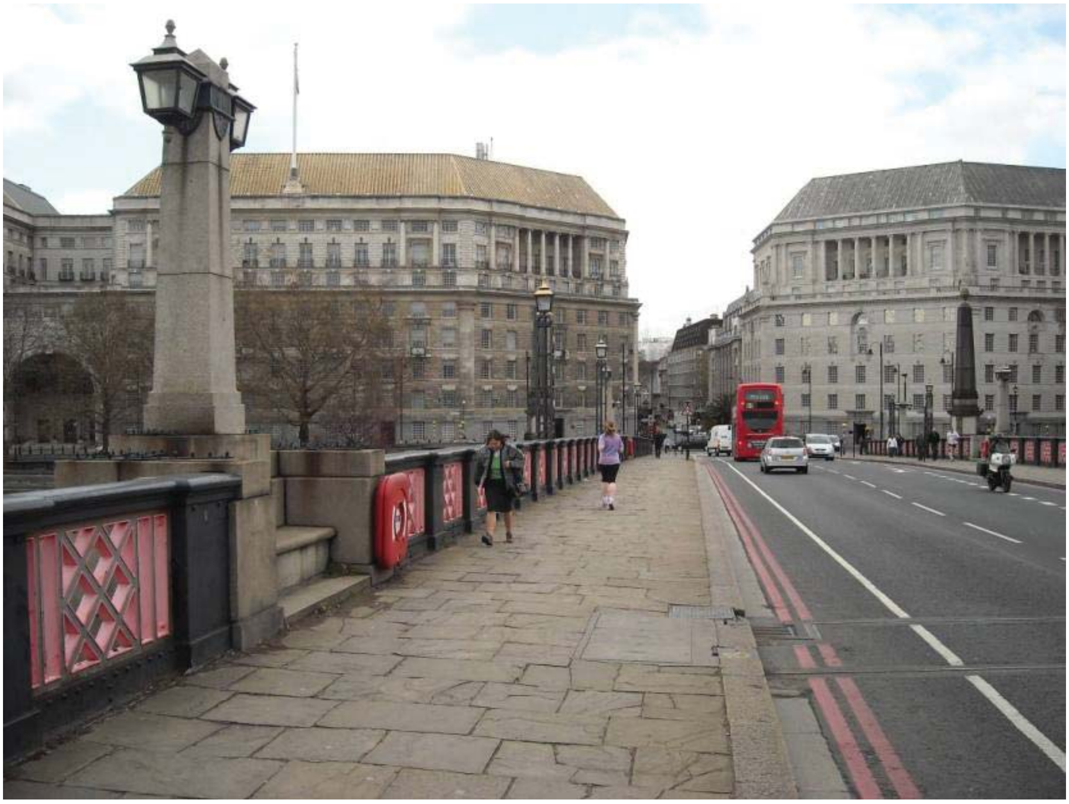
E.3.206 Vol 3 Plate E.61 to Vol 3 Plate E.67 illustrate the above description.

**Vol 3 Plate E.61 Lambeth Bridge viewed from the south from Millbank Pier**

**Vol 3 Plate E.62 Lambeth Bridge viewed from the south-west**

**Vol 3 Plate E.63 Lambeth Bridge viewed from the south-west**

**Vol 3 Plate E.64 Looking west at deck level towards Norwest and Thames House**



**Vol 3 Plate E.65 Detail of junction between balustrade/parapet and pier**

**Vol 3 Plate E.66 Looking north (downstream) towards Westminster Bridge**

**Vol 3 Plate E.67 West abutment and obelisks**

### Significance

E.3.207 Lambeth Bridge is of historic, architectural and artistic significance due to its elegant design, which incorporates an interesting mix of stone and steel. The bridge provides a notable landmark on this section of the Thames. Lambeth Bridge is a Grade II Listed Building.

E.3.208 The bridge is part of a continuum of river crossings at a point where people have traversed the Thames since the 13th century.

E.3.209 The bridge incorporates symbolic ornamentation celebrating the former London County Council and the reign of George V. The red livery is of further note symbolising the House of Lords. The symbolism of the ornamentation links the bridge to the unique political institutions along this stretch of the Thames including the Palace of Westminster and the former headquarters of the London County Council at County Hall.

E.3.210 Lambeth Bridge is of group value with these buildings and others in close proximity for which it contributes to their setting, including Lambeth Palace (Grade I), the Palace of Westminster (Grade I), the Church of St Mary-in-Lambeth (Grade II*), the contemporary Norwest and Thames Houses of 1928 (Grade II) which frame the northern approach, and Westminster Bridge (Grade II*).

E.3.211 The bridge has been little altered since its original construction and retains the entirety of its intended decorative scheme. As a consequence, the individual components of the structure and its fabric are of equally high significance. The exceptions are the asphalt finish to the roadway and later interventions into the footways. From a purely visual perspective, the inner structure of the arches is of slightly lesser significance being largely hidden from view behind the outward facing spandrels.

E.3.212 The north side of the bridge lies within two City Of Westminster conservation areas, namely the Westminster Abbey & Parliament Square Conservation Area, and the Smith Square Conservation Area. The south side of the bridge lies within the Borough of Lambeth, Lambeth Palace Conservation Area.

#### Condition

E.3.213 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in “very good” condition.

E.3.214 The bridge appears to be structurally sound and well maintained.

E.3.215 Unlike many of the historic bridges over the Thames within London, Lambeth Bridge remains as originally constructed, with only a relatively modest scheme of strengthening works undertaken in 1996 to the inner arch ribs.

E.3.216 The bridge was assessed by the City of Westminster in 1996. It was found that the central web plate towards the centre of the inner ribs failed to meet the stress limitation criterion for the 40 tonne loading assessment. The bridge was subsequently strengthened by the addition of steel plating in these areas in order to meet the 40 tonne loading in accordance with the national design standard, ‘The Design Manual for Roads and Bridges, Volume 2, Section 2, Part 14 (BD 21/93), Unreinforced Masonry Arch Bridges’.

E.3.217 The bearings have also been the subject of special inspection and analysis by the City of Westminster in February 2008.

E.3.218 At the time of the inspection the bridge appeared to be in good condition. Some weathering to the decorative coatings was noted and there appeared to be some leaching and efflorescence on the stonework of the piers and abutments. Rusting of the spikes on the tops of the piers appears to be causing some unsightly staining on the stonework below. At deck level, the Yorkstone paving is uneven and broken and there is some localised corrosion to the metalwork of the parapet. There is a sizeable expansion gap between the handrail and the piers which can readily accommodate existing and possible future movements. Traffic vibration is very noticeable when standing on the bridge.

### Sensitivity of the bridge's significant elements

E.3.219 Detailed structural calculations have been undertaken by Thames water to assess the effect of ground movements on the bridge.

E.3.220 The main Thames Tideway Tunnel would pass perpendicularly (albeit at a slightly oblique angle) beneath the central span of the bridge, with the centreline of the tunnel running at a depth of 36.54m below river bed level. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the piers, which would in turn induce movement and stresses within the superstructure.

E.3.221 Immediately above the crown of the tunnel, a maximum vertical settlement of 15.9mm at foundation level is predicted. However, with the neighbouring piers set more than 20m distant from this point the vertical settlement of the structure would not be as acute.

E.3.222 Analysis has shown that it is only the second and third piers where movement is predicted. Movement here would induce additional movements and stresses within the superstructure to spans two, three, and four. No movement is anticipated to any of the remaining, spans, piers or abutments.

E.3.223 A maximum vertical settlement of less than 6mm is predicted to occur at pier two, and just over 7mm at pier three, both piers settling in a broadly similar manner. The two piers would tend to tilt towards each other, albeit marginally.

E.3.224 The predicted ground movements would be comparatively small and the differential settlement would have a negligible effect on the abutments and piers. The piers and abutments have mass concrete foundations. These would act as single very stiff elements, transferring settlement effects into the superstructure via the bearings. It is not anticipated that any cracking of the piers and abutments would occur.

E.3.225 It is concluded that the structure would remain adequate under full 40 tonne live loading following the differential settlement caused by the construction of the Thames Tideway Tunnel. This is due in part to the previous strengthening works undertaken in 1996. No over-stressing of the structure has been identified.

E.3.226 No distress or cracking to the parapets is predicted due to discontinuities in the deck and parapets.

E.3.227 The settlement assessment recommends a series of monitoring, and investigation works, coupled with further analysis.

## Conclusions

E.3.228 Assessment indicates that the bridge would be able to accommodate the effects of ground movements and the additional stresses that these would impart upon the superstructure. No overstressing or cracking is predicted.

E.3.229 Further detailed inspection of the movement joints and bearings would be undertaken prior to tunnel construction to ensure that these remain in sound and operable condition. The expansion joints would be examined to ensure that they have sufficient capacity to accommodate the additional movement due to tunnel construction in addition to the normal thermal movements.

E.3.230 The bridge would be monitored prior, during and after the construction of the tunnel to determine its behaviour as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2. The foundations would be monitored to ensure that the actual movements are within the limits predicted, and control limits established to quantify when intervention is required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

E.3.231 It is concluded that no harm would be caused to the special interest or significance of the structure.

## Westminster Bridge

### Description of Westminster Bridge and its significance

#### The bridge

E.3.232 Westminster Bridge is the oldest surviving bridge across the Thames in London. It is a road bridge, carrying the A302 across the Thames, and links the Palace of Westminster and Westminster Pier on the west bank, with the old County Hall Buildings and London Eye on the east bank. The bridge deck carries the road and two flanking footpaths.

E.3.233 The bridge was built in 1854 to 1862 to the designs of architect Charles Barry, and engineer Thomas Page, to reflect the gothic design of the Palace of Westminster which was then undergoing reconstruction following the devastating fire of 1834. The present bridge is the second to be built on the site. The first was built in 1738 to 1747 to the designs of Swiss architect, Charles Labelye, a stone bridge comprising 15 arches. This was an engineering marvel of its day and was widely painted by artists of the day, including Canelleto and Samuel Scott. However, before the bridge could be opened to traffic, it started to suffer from settlement. This necessitated the rebuilding of two of the arches, and it was not until November 1750 that the bridge was finally opened.

E.3.234 Settlement continued to be a problem throughout the service life the bridge with several major phases of strengthening and underpinning works undertaken. By 1831, however, the condition of the bridge was continuing to deteriorate, exacerbated by the effects on the flow of water by construction works elsewhere along the river. Alterations to the banks and the construction of numerous wharfs diminished the width of the river thereby displacing large volumes of water, and increasing the rate of flow. This caused increased erosion to the river bed with some 8 feet of sediment washed away in a matter of only a few decades.

E.3.235 Work on the new bridge commenced in 1854, and was completed by 1862.

E.3.236 The present bridge comprises a 7-span wrought and cast iron structure with a total length of 250m supported on granite piers. The spans vary in length from 32m for the ends to 40m for the central span. The width of the bridge is 26m across the piers, 18.3m between balustrades. The primary deck comprises 15 segmental arched wrought iron girders supporting a reinforced concrete deck slab. The main girders are braced with transverse iron girders. The spans are supported on concrete piers, faced in grey granite, with the arches bolted to the piers. Aesthetically, the bridge has gothic detailing in keeping with the Palace of Westminster, with cast iron pierced work panelled spandrels with shields, and gothic pierced work balustraded parapets. The ends of the piers are expressed as octagonal shafts which rise up to parapet level to form dies for cast-iron lamp standards with twin bracketed and central crowning octagonal lanterns.

E.3.237 It is understood that the foundations are of mass concrete filled caissons.

E.3.238 Vol 3 Plate E.68 to Vol 3 Plate E.71illustrate the above description.

**Vol 3 Plate E.68 Bridge viewed from the London Eye**

**Vol 3 Plate E.69 Bridge viewed from north-east**

**Vol 3 Plate E.70 Bridge viewed from west**


**Vol 3 Plate E.71 Bridge viewed from north-east**

### Significance

E.3.239 Westminster Bridge is of great historic significance being the oldest surviving bridge across the Thames in London.

E.3.240 The bridge is of considerable historic, archaeological, architectural and artistic significance due to its comparatively early date, its materials, its design which complements the Palace of Westminster, and the fact that it remains little altered since its original construction. The bridge is a significant landmark and an important contribution to the rich history of both Westminster and the lower Thames generally.

E.3.241 The piers and majority of the superstructure are of considerable significance. The upper most part of the deck, however, is of more recent date and hence of lesser significance; this includes the carriageway and pavement finishes.

E.3.242 The bridge forms an important contribution to the setting of the Palace of Westminster, an iconic composition recognised throughout the world.

E.3.243 The bridge lies partly within the Westminster Abbey and Parliament Square Conservation Area and stands within the proposed buffer zone to the Westminster World Heritage Site.

### Condition

E.3.244 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in “good” condition.

E.3.245 The bridge appears to be structurally sound and well maintained.

E.3.246 The bridge deck was strengthened in 1997 making it a composite deck.

E.3.247 The bridge was substantially refurbished in 2005 to 2007. The scheme replaced 14 cast iron decorative fascias and refurbished 28 spandrels and 32 decorative shields. The cast-iron lamp standards and lanterns were renewed, and the entire bridge redecorated.

## Sensitivity of the bridge’s significant elements

E.3.248 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movements on the bridge.

E.3.249 The main Thames Tideway Tunnel would pass perpendicularly beneath the third span from west, midway between the second and third piers, at a depth of 33.76m below river bed level. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the piers, which would in turn induce movement and stresses within the superstructure.

E.3.250 Immediately above the crown of the tunnel, a maximum vertical settlement of 13.6mm at foundation level is predicted. However, with the neighbouring piers set some 15m distant from this point the vertical settlement of the structure would not be as acute.

E.3.251 Analysis has shown that it is only the second and third piers from west where movement is predicted. Movement here would induce additional movements and stresses within the superstructure to spans two, three, and four from west. No movement is anticipated to piers one and four, or to any of the remaining, spans, piers or abutments.

E.3.252 A maximum vertical settlement of approximately 10mm is predicted to occur to piers two and three, both settling in a broadly similar manner. The two piers would tend to tilt towards each other, albeit marginally.

E.3.253 The predicted ground movements would be comparatively small and the differential settlement would have a negligible effect on the abutments and piers. Detailed calculation has confirmed that the structure would remain adequate for 40 tonne loading in combination with the tunnel induced ground movements. The bridge would be able to accommodate the effects of ground movements and the additional stresses that these would impart upon the superstructure. No cracking or damage is predicted.

E.3.254 Should for any reason, the predicted ground movements induce hairline cracking within the masonry of the piers, this would not be of detriment to the architectural or historic significance of the bridge. Hairline cracking would be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric.

### Conclusions

E.3.255 Assessment indicates that the bridge would be able to accommodate the effects of ground movements and the additional stresses that these would impart upon the superstructure. No overstressing or cracking is predicted.

E.3.256 The bridge would be monitored prior, during and after the construction of the tunnel to determine its behaviour as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2. The foundations would be monitored to ensure that the actual movements are within the limits predicted, and control limits established to quantify when intervention is required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

E.3.257 Further detailed inspection of the movement joints and bearings would be undertaken prior to tunnel construction to ensure that these remain in sound and operable condition. The expansion joints would be examined to ensure that they have sufficient capacity to accommodate the additional movement due to tunnel construction in addition to the normal thermal movements

E.3.258 It is concluded that no harm would be caused to the special interest or significance of the structure.

# Waterloo Bridge

## Description of Waterloo Road Bridge and its significance

### The bridge

E.3.259 Waterloo Bridge is a seven-span reinforced concrete cantilever box girder bridge supported on abutments, two shore piers, and four river piers. The bridge carries the A301 over the Thames, the South Bank, and Victoria Embankment. Outwardly, the bridge appears very much like a traditional arched structure with five arched spans, one over Victoria Embankment, one over the South Bank and a further three clear spans across the river. The design, however, is far more complex as can be witnessed when the bridge is viewed on the underside from either South Bank or Victoria Embankment. The reinforced concrete superstructure is faced with Portland stone, the piers with granite. The Portland stone parapet is surmounted by a simple three rail tubular metal balustrade.

E.3.260 Waterloo Bridge was built in 1939 to 1945 to the designs of Rendel Palmer and Tritton, engineers, with Sir Giles Gilbert Scott acting as consulting architect. The architectural form of the bridge was largely Scott's design, which proved difficult to implement. But the end result provided a graceful form of wide shallow arches.

E.3.261 Waterloo Bridge is the second bridge to be built on this site. The first bridge was designed in 1811 by John Rennie for the "Strand Bridge Company". This comprised a granite bridge of nine arches, each 120 feet (36.6m) supported on double Grecian-Doric stone columns. The bridge was approximately 750m long including approaches. The bridge was officially opened on 15 June 1817 under the new name of "Waterloo Bridge" on the 2nd anniversary of the Battle of Waterloo by the Prince Regent accompanied by the Duke of Wellington. It cost over £1m and as a toll bridge was a financial failure, making many of the shareholders insolvent. The bridge was nationalised in 1878 when it was taken over by the Metropolitan Board of Works and the tolls removed. In the 1880's serious problems of river bed scour were discovered following the demolition of Old London Bridge which increased river flow. Strengthening works were undertaken in 1882-84 to protect the foundations which were becoming exposed but problems continued. In 1923 settlement in the pier on the Lambeth side of the central arch and subsidence in the parapet and carriageway gave warning that the structure was in a dangerous condition. Remedial works proved ineffective and on 11 May 1924 the bridge was closed to traffic. A temporary steel bridge was built alongside which continued in use for the next ten years whilst controversy raged as to what to do about the old bridge. In the end London City Council decided to demolish and replace the bridge with a new structure by Sir Giles Gilbert Scott and engineers Ernest Buckton and John Cueral of Rendel Palmer & Tritton. To guard against the risk of further subsidence from scour the piers were given a number of jacks which can be used to level the structure.

E.3.262 Demolition of the old bridge commenced on 20 June 1934, taking nearly three years to complete. Work on the new bridge commenced in 1937 with progress delayed by the war. Being built during the war much of the work was undertaken by a largely female workforce and as a consequence the bridge is sometimes referred to as the “Ladies Bridge”. The bridge was partially opened in 1942, with one lane in each direction, and was eventually completed in 1945.

E.3.263 Structurally, the bridge is unusual comprising a partly cantilevered design. The central section of the centre span (span 4) is supported on adjacent cantilevered sections on each side, and both shore sections (spans 1 and 7) are also cantilevered from the out-most piers (piers 1 and 6). The northern section of the bridge spans from the north abutment monolithically supported on piers 1, 2 and 3. This section cantilevers south of pier 3 to the drop in section in span 4. The southern section of the bridge similarly spans from the south abutment monolithically supported on piers 6, 5 and 4. This section cantilevers north of pier 4 to the other side of the drop in section in span 4. The spans vary in length and comprise 23.7m for the outer north shore and south cantilevers, 73.2m for the Victoria Embankment and South Bank spans, and 76.3m for each of the main three spans across the Thames. The bridge is 423m long and 25.3m wide.

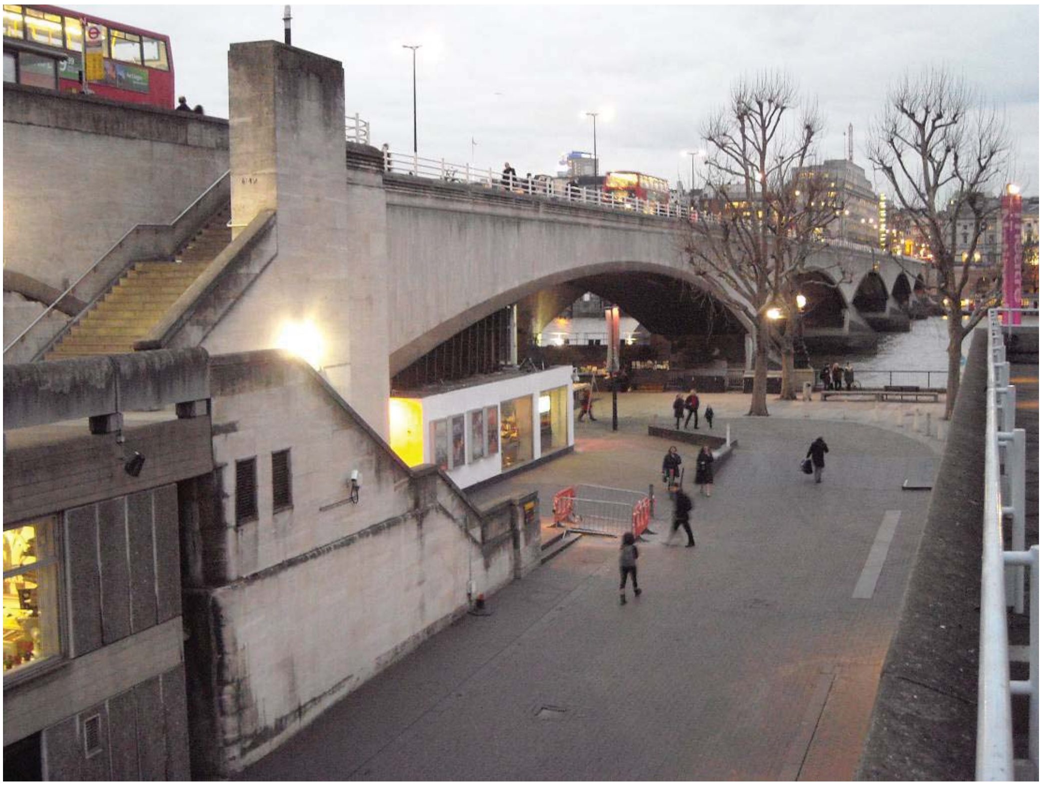
E.3.264 The parallel wide segmental arched girders rest on boat shaped cutwaters with bracketed buttresses at the arch springers. The piers are 35m long by 5m wide and rest on 2m thick concrete foundations 10.5m below the river bed. The piers are hollow with transverse walls and steel bracing and are faced in granite which was salvaged from the old bridge. Projecting quadrant abutments incorporate dog leg stone stairs down to Embankment and the South Bank. The Portland stone parapet has a ribbed band and is surmounted by steel guard rails. Some of Rennie’s work survives in the south abutment; a section of balustrade and two Doric columns are preserved in the abutment.

E.3.265 The bridge carries 2 lanes of traffic in each direction with an artificial stone central reservation. The carriageway is flanked on both sides by a footway of Yorkstone paving with granite kerbs.

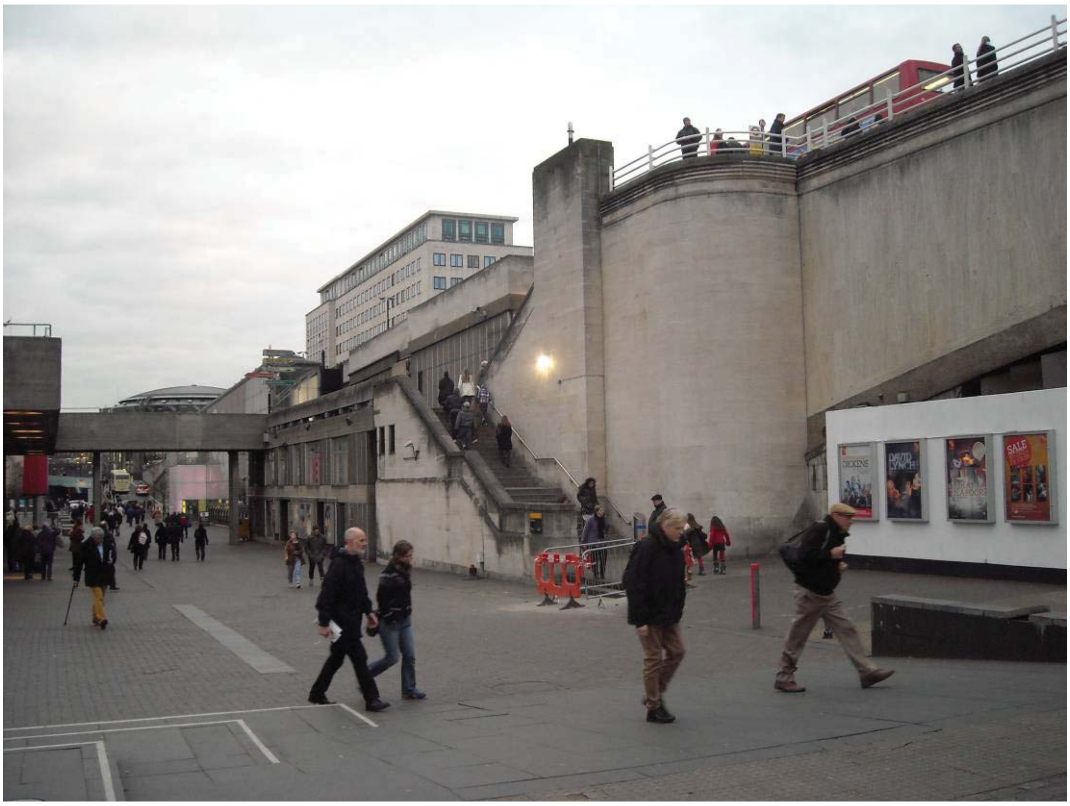
E.3.266 The National Film Theatre and Museum of the Moving Image are built directly underneath the south spans of the bridge.

E.3.267 Vol 3 Plate E.72 to Vol 3 Plate E.78 illustrates the above description.

**Vol 3 Plate E.72 Waterloo Bridge viewed from The Royal National Theatre**



**Vol 3 Plate E.73 Waterloo Bridge south shore pier with dog leg staircase**



**Vol 3 Plate E.74 Waterloo Bridge viewed from south-west**

**Vol 3 Plate E.75 Waterloo Bridge South Bank span**

**Vol 3 Plate E.76 Underside of bridge viewed from south**

**Vol 3 Plate E.77 Detail of stone clad reinforced concrete box girder**

**Vol 3 Plate E.78 Waterloo Bridge looking north**

### Significance

E.3.268 Waterloo Bridge is of historic and architectural significance due to its design due to its striking aesthetic design and its association with the notable engineers, Rendel Palmer & Tritton, and architect, Sir George Gilbert Scott. The bridge provides a notable landmark on this section of the Thames, with the Grade II* Westminster Bridge immediately upstream, and Grade II Blackfriars Bridge immediately downstream. It provides one of the main routes from Southwark across the river to Whitehall and The Strand. Waterloo Bridge is a Grade II* Listed Building.

E.3.269 Waterloo Bridge is of group value with other heritage assets in the vicinity for which it contributes to their setting, including Westminster Bridge (Grade II*), Blackfriars Bridge (Grade II), the Royal National Theatre (Grade II*), Somerset House (Grade I), Victoria Embankment (Grade II), and Victoria Embankment Gardens (Grade II* Park & Garden).

E.3.270 The bridge remains unaltered since its original construction and retains the entirety of its intended design and decorative scheme. As a consequence, the individual components of the structure and its fabric are of equally high significance. The exceptions are the surface finishes to the carriageway and footway. The bridge is of particular constructional interest affording it added technological importance.

E.3.271 The north side of the bridge lies within two City of Westminster conservation areas, namely the Savoy Conservation Area, and the Strand Conservation Area. The south side of the bridge lies within the London Borough of Lambeth, South Bank Conservation Area.

### Condition

E.3.272 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in “good” condition, but minor sign of deterioration were noted.

E.3.273 Generally, the bridge appears to be structurally sound and well maintained.

E.3.274 Areas of spalling of the concrete can be seen across the underside of the bridge, with corroding reinforcement visible in places. Rust staining is visible in many places including below the joints of the central span drop in section. Isolated cracking is also visible. The defects although widespread are relatively minor in nature and should not affect the structural performance of the bridge. Deterioration of the concrete is most likely related to localised defects in the mix and placing of the concrete, and in insufficient cover to the underlying reinforcement. At deck level, the paving slabs to the footways are extensively broken and the movement joints appear silted up.

## Sensitivity of the bridge’s significant elements

E.3.275 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movements on the bridge.

E.3.276 The main Thames Tideway Tunnel would pass perpendicularly beneath the 3rd span from north of the bridge (i.e. the span immediately north of the centre span), with the centreline of the tunnel running at a depth of 39.16m below river bed level. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the adjacent piers, which would in turn induce movement and stresses within the superstructure.

E.3.277 Immediately above the crown of the tunnel, a maximum vertical settlement of approximately 14.2mm at foundation level is predicted. However, with the neighbouring piers set more than 38m distant from this point the vertical settlement of the structure would not be as acute. The maximum vertical settlement at the pier foundations would be 2.2mm.

E.3.278 There would be small settlements and rotations at the base of the piers. Analysis has shown that due to the design of the bridge and the relatively flexible bearings, there would be little increase in the stresses within the bridge superstructure and that it would readily accommodate the tunnel induced settlements. However, detailed structural calculation has also shown that there are already considerable stresses within the internal walls of the piers which warrant further consideration. The tunnelling works themselves would in fact help relieve these stresses, but consideration may need to be given by the bridge owner to introduction of a weight limit on the bridge, regardless of the tunnel construction.

### Conclusions

E.3.279 Assessment indicates that the bridge would be able to accommodate the effects of ground movements and the additional stresses that these would impart upon the superstructure. No overstressing or cracking is predicted. The only caveat is with regard to the existing safe loading capability of the bridge, which is a matter not directly associated with the proposed tunnelling works.

E.3.280 Further detailed inspection of the joints and bearings would be undertaken in advance of tunnel construction to ensure that these remain in a sound and operable condition. The expansion joints would be examined to ensure that they have sufficient capacity to accommodate the additional movement due to tunnel construction in addition to the normal thermal movements.

E.3.281 The bridge would be monitored prior, during and after the construction of the tunnel to determine its behaviour as described in the Thames Water *Code of Construction Practice* (CoCP), Appendix A, section 13.2. The foundations would be monitored to ensure that the actual movements are within the limits predicted, and control limits established to quantify when intervention is required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

E.3.282 Consideration would need to be given to the introduction of a weight restriction on the bridge, regardless of the tunnelling works. This would need to be discussed with the bridge owner and may require further detailed engineering assessment.

E.3.283 It is concluded that no harm would be caused to the special interest or significance of the structure.

# Blackfriars Bridge

## Description of Blackfriars Bridge and its significance

### The bridge

E.3.284 The bridge was built in 1869 probably by James Cubitt. The adjacent Blackfriars railway, of which only the piers survive, was designed by Joseph Cubitt in 1864. The spans of the two bridges aligned with each other and the piers that are all that survive of the railway bridge form an important element in the setting of the road bridge. Blackfriars Bridge was widened by approximately 11m in 1909. It has four granite clad piers displaying gothic decoration and two abutments, the southern abutment projecting from the bank of the river and the northern abutment set inland on the north side of the 1960s underpass of the Victoria Embankment.

E.3.285 Each span has 12 fabricated riveted shallow arched wrought iron plate girders. Those facing the river have embossed medallions. The outer lattice spandrels have floral decoration. Between the arched girders there are lattice braces attached to the web stiffeners. There are lattice spandrels composed of flat and angle sections, above the girders over which the transverse beams that support the bridge deck are laid. There are further ‘T’ section cross braces between the arched girders. The arched girders and embossed lattice spandrels provide the bridge with its

E.3.286 The southern approach to the bridge has Portland stone parapets with gothic style moulded copings and granite end piers. The southern abutment is faced in granite, with areas of laminated sandstone seating on each side of the abutment, at the level of the bridge deck. The granite outer facing to the abutment, at the base of the parapet has dog tooth decoration and there are gothic mouldings on the outer walls (see Vol 3 Plate E.80). The river stairs to the west form an integrated design with the abutment. The segmental arched 1995 underpass, inland from the southern granite abutment, has Portland stone facing and decorative glazed tiles depicting historic scenes. The underpass is not significant.

E.3.287 There was no access to the northern abutment during the site walkover.

E.3.288 Vol 3 Plate E.79 to Vol 3 Plate E.82 illustrate the above description.

**Vol 3 Plate E.79 Detail of the cast iron balustrade**

**Vol 3 Plate E.80 The southern granite clad abutment**

**Vol 3 Plate E.81 The bridge piers**

*Bridge piers with finely decorated engaged column supporting the seating areas over the pier ends*

**Vol 3 Plate E.82 The wrought iron arched girders, showing the lattice bracing beneath**

### Significance

E.3.289 The piers are a particularly significant element of the bridge. They are clad in granite and have engaged polished red granite end columns, with Portland stone capitals and bases (see Vol 3 Plate E.81). The capitals are very ornate with carved sea birds and other decorative devices. The only classical elements are the ovolo column bases and medallions on the wrought iron arched girders. At road level there are seating areas, with laminated sandstone seats that project out from the bridge over the ends of the piers on either side of the bridge, their ends being supported on the red granite engaged columns. The cast iron balustrade is hollow but is elaborately decorated, with the balusters having varied gothic capitals and variedly decorated shafts. The arches above the balusters have trefoil heads (see Vol 3 Plate E.79). Below the balustrade projecting base of the bridge parapet balustrade is supported on decorative cast iron brackets.

E.3.290 The York stone paving is also significant. At the north end of the bridge there is an awkward junction between the northernmost granite clad pier and the 1960s concrete structures that currently provide pedestrian access to the stairs from the lower level embankment walkway. Although these have granite copings they detract from the significance of the Victorian and Edwardian bridge.

E.3.291 The most significant elements of the bridge are its elaborately decorated shallow arched girders and embossed lattice spandrels, the lavishly decorated granite piers and the cast iron gothic balustrade. The fact that the ironwork of the outer girders and of the balustrade is painted red compliments the red granite engaged columns of the piers, and echoes the red of the adjacent gothic piers of Cubitt's railway bridge.

### Condition

E.3.292 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in "good" condition.

E.3.293 The bridge appears to be structurally sound and well maintained.

E.3.294 There is rusting to small areas of steelwork, and isolated cracks and staining to the piers and abutments.

E.3.295 The paving to the footways is cracked throughout.

E.3.296 The parapet is lightly corroded and cracked in places.

## Sensitivity of the bridge's significant elements

E.3.297 Although significant the wrought iron arched girders are not particularly sensitive to movement.

E.3.298 If the cast iron balustrade were to snap there would be a loss of significance. However, its top rail is composed of short, 2.03m lengths of iron, which can accommodate a degree of movement without damaging the balustrade. It is understood that the balustrade's bottom rail is concrete, in approximately 6m lengths with wrought iron plate facings. There appears to be sufficient movement in the joints to prevent undue strains being put on the more significant and harder to repair cast iron elements.

E.3.299 The granite piers are in good condition and the significance of the decorative elements, especially the engaged columns, with their bases and capitals, would be adversely affected if they cracked. Detailed structural calculations undertaken by Thames Water indicate that this is not expected to take place.

E.3.300 The granite abutments are robust structures that are unlikely to be significantly damaged.

### Conclusions

E.3.301 Assessment indicates that the bridge would be able to accommodate the effects of ground movements and the additional stresses that these would impart upon the superstructure. No overstressing or cracking is predicted.

E.3.302 Only relatively small movements are predicted to occur to the bridge, all of which would easily be exceeded by existing temperature and live load movements alone. Negligible resultant damage is predicted.

E.3.303 An assessment of potential effects on the bridge from the construction of the Blackfriars foreshore shaft and diversion of the Fleet sewer has also been undertaken. The predicted settlements have been found to be less than the 1mm threshold and no resultant damage is predicted.

E.3.304 The bridge would be monitored prior, during and after the construction of the tunnel to determine its behaviour as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2. The foundations would be monitored to ensure that the actual movements are within the limits predicted, and control limits established to quantify when intervention is required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

E.3.305 The bridge would be protected from damage from construction works on the adjacent foreshore as described in the Thames Water *Code of Construction Practice*, Part B, Blackfriars Bridge Foreshore, chapter 12.

E.3.306 It is concluded that no harm would be caused to the special interest or significance of the structure.

## Southwark Bridge

### Description of Southwark Bridge and its significance

#### The bridge

E.3.307 Southwark Bridge is a particularly attractive Edwardian structure. The bridge carries the A300 from Queen Street on the north bank, across to Bankside on the south bank, where it alights adjacent to the former FT offices and to the east of the Tate Modern and Globe Theatre. The north section of the bridge lies in City of London, the south in the London Borough of Southwark. The bridge carries a carriageway and two flanking footpaths.

E.3.308 The bridge was built in 1913 to 1921 by Sir William Arrol & Co. to the designs of Engineers Mott Hay and Anderson, and Architect Sir Ernest George RA. The present bridge is the second to be built on the site, replacing an earlier cast-iron bridge, which was formerly known as, "Queen Street Bridge." The first bridge was built in 1814 to 1819 to the designs of engineer, John Rennie, at a cost of £800k. It was a stunning feat of engineering, crossing the river in just three large cast-iron spans supported on granite piers. At 73m, the central span was the largest cast-iron arch ever made. The removal of old London Bridge in 1856, however, changed the tidal currents around Southwark Bridge, scouring away a considerable amount of settlement and eroding the river bed in proximity to the foundations of Southwark Bridge. In the early years of the 20th century it was eventually decided to build a new bridge on the site.

E.3.309 Work on the new steel bridge commenced in 1913, and was completed in 1921. The 5-span bridge was designed to align with the spans of Blackfriars Bridge and London Bridge immediately downstream, thereby aiding the safe navigation of river traffic. The piers were completed by the outbreak of war. Work continued on the bridge during the course of the war but with increasing delays due to a shortage of materials. After the war mounting traffic congestion made the completion of the bridge a priority and it was one of the first public works projects to be resumed after the Armistice. The bridge was opened by King George V in 1921.

E.3.310 The present bridge comprises a 5-span steel structure with a total length of 216m supported on granite piers. The spans vary in length from 37.49m for the shore, 40.16m for the intermediate, and 42.88m for the central span. Each span consists of seven "I"-section ribs fabricated from riveted plate and angle sections, with bracing between. These support spandrel columns which in turn carry "I"-section longitudinal members. On top of these are transverse girders and minor longitudinal RSJ members which support a steel buckle plate deck with lightweight concrete fill on which the carriageway and footways sit. The ribs spring from steel skewbacks with a knuckle joint to accommodate movement. There are no movement joints in the carriageway or footways. The arches are carried on granite faced masonry piers and abutments. The abutments are vaulted to accommodate pedestrian access beneath.

E.3.311 This is an ornate and elegantly designed bridge, with Edwardian architectural detailing typical of the period. The abutments, piers and cutwaters are faced in granite with channelled rustication within the tidal water level. Above the cutwaters, the piers and abutments rise in finely jointed granite ashlar with bold classical detailing. The piers are expressed as blocked pilasters, with deep channelled flush panels on their outer face, topped by pierced lunettes with swept pediments, between which are cast iron balustrades. The footpaths on either side are cantilevered out from the arches below with the buckle plate deck visually expressed. The outer spandrel columns are clearly expressed, picked out in a contrasting colour. Above the spans the edge of the deck is covered by a cast-iron cornice which runs between the stone pilasters. Above the cornice is a cast-iron balustrade of simple geometrical design, with decorative panels set between two orders of intermediate cast-iron piers. The balustrade is topped by a moulded cast-iron handrail. The larger intermediate piers break the line of the handrail and are surmounted by cast-iron lampstands, which carry one lantern each. The lanterns have conical tops and are surmounted by small finials.

E.3.312 Floodlighting is attached to the abutments and cutwaters.

E.3.313 It is understood that the foundations to the abutments are of concrete raft type, those to the piers of mass concrete filled caissons.

E.3.314 Vol 3 Plate E.83 to Vol 3 Plate E.94 illustrate the above description.

**Vol 3 Plate E.83 Bridge viewed from east**

**Vol 3 Plate E.84 Bridge viewed from south-east**

**Vol 3 Plate E.85 Bridge viewed from south-east**

**Vol 3 Plate E.86 Bridge viewed from south-west**

**Vol 3 Plate E.87 South abutment vaulted access**

**Vol 3 Plate E.88 View looking north along deck**

**Vol 3 Plate E.89 South abutment viewed from east**

**Vol 3 Plate E.90 Detail of cast-iron balustrade**

**Vol 3 Plate E.91 Balustrade detail**

**Vol 3 Plate E.92 Commemorative plaque**


**Vol 3 Plate E.93 Typical damage to cast-iron balustrade**

**Vol 3 Plate E.94 Typical damage to cast-iron balustrade**

### Significance

E.3.315 Southwark Bridge is of historic, architectural and artistic significance due to its elegant design, its use of materials, and the fact that it remains little altered since its original construction. It is one of few bridges across the Thames in London with a distinct Edwardian character. The bridge is a significant landmark and an important contribution to the rich history of the lower Thames.

E.3.316 The piers and majority of the superstructure date from the original construction and are of considerable significance. Later interventions to the deck, however, are of recent date and hence of lesser significance; these include the carriageway and pavement finishes, and trief kerbs.

E.3.317 The bridge is a Grade II Listed Building.

E.3.318 The bridge lies partly within the Borough of Southwark Bankside and Bear Gardens Conservation Area.

### Condition

E.3.319 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in “good” condition.

E.3.320 The bridge appears to be structurally sound and well maintained.

E.3.321 Unlike many of the historic bridges over the Thames within London, Southwark Bridge appears not to have undergone major strengthening work and largely remains as originally constructed. The upper section of the concrete deck beneath the carriageway was replaced with a lightweight concrete infill. Trief kerbs were introduced in 2005. The bridge was extensively refurbished and redecorated in 2009 to 2010.

E.3.322 At the time of inspection the décor was generally in excellent condition with just a few isolated areas of deterioration. There is some cracking within the masonry of the abutments, most likely as a result of settlement. The piers appear to be free of cracking, although some of the stones have become separated with loose and open joints, and vegetation is gaining a hold on the cutwaters. The asphalt carriageway and York stone paving are worn with cracking clearly visible above the piers and abutments. The cast-iron handrail has become displaced and cracked where it adjoins the piers. Some of the cracking is visually prominent.

### Sensitivity of the bridge's significant elements

E.3.323 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movements on the bridge.

E.3.324 The main Thames Tideway Tunnel would pass perpendicularly beneath the third span from north, midway between the first and second piers, at a depth of 34.45m below river bed level. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the piers, which would in turn induce movement and stresses within the superstructure.

E.3.325 Immediately above the crown of the tunnel, a maximum vertical settlement of 12mm at foundation level is predicted. However, with the neighbouring piers set more than 20m distant from this point the vertical settlement of the structure would not be as acute.

E.3.326 Analysis has shown that it is only the second and third piers from north where movement is predicted. Movement here would induce additional movements and stresses within the superstructure to spans two, three and four from north. No movement is anticipated to any of the remaining, spans, piers or abutments.

E.3.327 A maximum vertical settlement of approximately 9mm is predicted to occur at piers two and three, both settling in a broadly similar manner. The two piers would tend to tilt towards each other, albeit marginally. The differential settlement between piers one and two, and three and four would be in the order of 9mm.

E.3.328 The predicted ground movements would be comparatively small and the differential settlement would have a negligible effect on the abutments and piers. Only relatively small movements are predicted to occur to the bridge, all of which would easily be exceeded by existing temperature and live load movements alone. Negligible resultant damage is predicted

E.3.329 Should for any reason, the predicted ground movements induce hairline cracking within the masonry of the piers, this would not be of detriment to the architectural or historic significance of the bridge. Hairline cracking would be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric. The parapets have already suffered significant displacement and crack damage from historic movements and any slight worsening of existing damage would not harm the significance of the structure.

### Conclusions

E.3.330 Assessment indicates that the bridge would be able to accommodate the effects of ground movements and the additional stresses that these would impart upon the superstructure. No overstressing or cracking is predicted.

E.3.331 The bridge would be monitored prior, during and after the construction of the tunnel as described in Thames Water Code of Construction Practice (CoCP), Part A, section 13.2. The foundations would be monitored to ensure that the actual movements are within the limits predicted, and control limits established to quantify when intervention is required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

E.3.332 Further detailed inspection of the knuckle joints at the springing of the arches would be undertaken in advance of tunnel construction to ensure that these would provide sufficient flexibility to accommodate the predicted movements and that they remain in a sound and operable condition.

E.3.333 It is concluded that no harm would be caused to the special interest or significance of the structure.

# Tower Bridge

## Description of Tower Bridge and its significance

### The bridge

E.3.334 Tower Bridge is a three-span, part suspension, part bascule bridge, comprising two suspended shore spans and a central high level walkway with a central double leaf bascule span below. It is the most iconic of London's bridges and an internationally recognised Landmark which has come to portray the image of London worldwide. Visually, this is an immensely picturesque bridge and is of historic note as one of only two bridges in central London not to be replaced, the other being Albert Bridge. The bridge is a prominent landmark, strikingly illuminated at night, and a gateway to the city of London for boats travelling up the Thames.

E.3.335 Tower Bridge was built between 1886 and 1894 to the designs of, Sir Horace Jones, the City Architect, and Sir John Wolfe Barry, engineer. The design was selected in 1884 following a somewhat controversial open competition. It is hard to believe that Jones' and Barry's design was widely criticized at the time for being dishonest in its use of materials, being in fact a steel structure but clad in masonry and architecturally dressed as a Gothic building. The bridge is now recognised as a masterpiece of design which combines both immense architectural skill with technical innovation.

E.3.336 Increased commercial development in the East End had led to calls for a new river crossing downstream of London Bridge. The new bridge had to be designed to allow tall-masted ships to access the port facilities in the Pool of London between Tower Bridge and London Bridge. It was Barry's idea to incorporate a centre bascule to facilitate this.

E.3.337 Construction commenced in 1886 and took 8 years to complete with 5 major construction contracts to cover the various aspects of the structure and its equipment. Sir Horace Jones died in 1887 and George D Stevenson became acting architect. The final appearance of the bridge owes much to the work of Stevenson. He decided to replace Jones' original design of brick elevations for a more ornate Victorian Gothic style in granite and Portland stone to harmonize with the adjacent Tower of London. The bridge cost £1,184,000 (approximately £100m in 2012) and was opened on 30 June 1894 by the Prince of Wales (later King Edward VII).

E.3.338 The design comprises of two tall principal towers on river piers with two smaller towers on the shore abutments. The suspension chains for the two shore spans are supported between the main towers and the shore abutment towers, passing inside the central high level walkways, and are anchored beyond the shore towers in chambers built below the bridge approaches. The towers are constructed from 4 hollow octagonal steel columns approximately 1.8m in breadth, with horizontal beams and diagonal bracing between, and are clad in granite and Portland stone. The tower columns take the vertical loads from the high level walkways and suspension chains down to foundation level. The walkways themselves consist of lattice girders which are cantilevered out from the towers, with a suspended middle section. The walkways act as ties for the two principal towers. The suspension "chains" for the shore spans take the form of curved lattice girders from which hangers carry the spans. The shore spans consist of riveted steel transverse girders which support longitudinal girders and concrete filled deck troughs. The bascule spans each consist of four open lattice girders counterbalanced at the pier tower ends, and are covered with a timber deck. The counter balances are housed in chambers built within the base of the piers.

E.3.339 Architecturally, the principal towers are of four stages with corner turrets surmounted by pinnacles, a steeply pitched slate roof, and battlemented parapet. There are elaborate Gothic style windows and stringcourses to each level with each elevation surmounted by a central gabled dormer. The turrets and roofs are surmounted by numerous gilded finials.

E.3.340 The bridge is 224m in length with the two principal towers each 65m high. The central bascule span is 61m between towers split into two equal leaves weighing over 1,000 tons each. The two shore spans are each 82m long. The walkway is 44m above river level at high tide.

E.3.341 Some of the early hydraulic machinery is preserved under the south approach viaduct. Built into the east side of the south approach is an accumulator tower and chimney stack.

E.3.342 Tower Bridge was designated a Grade I Listed Building in 1973. (The National Heritage List for England reference 1357515, Listed Building UID 206282).

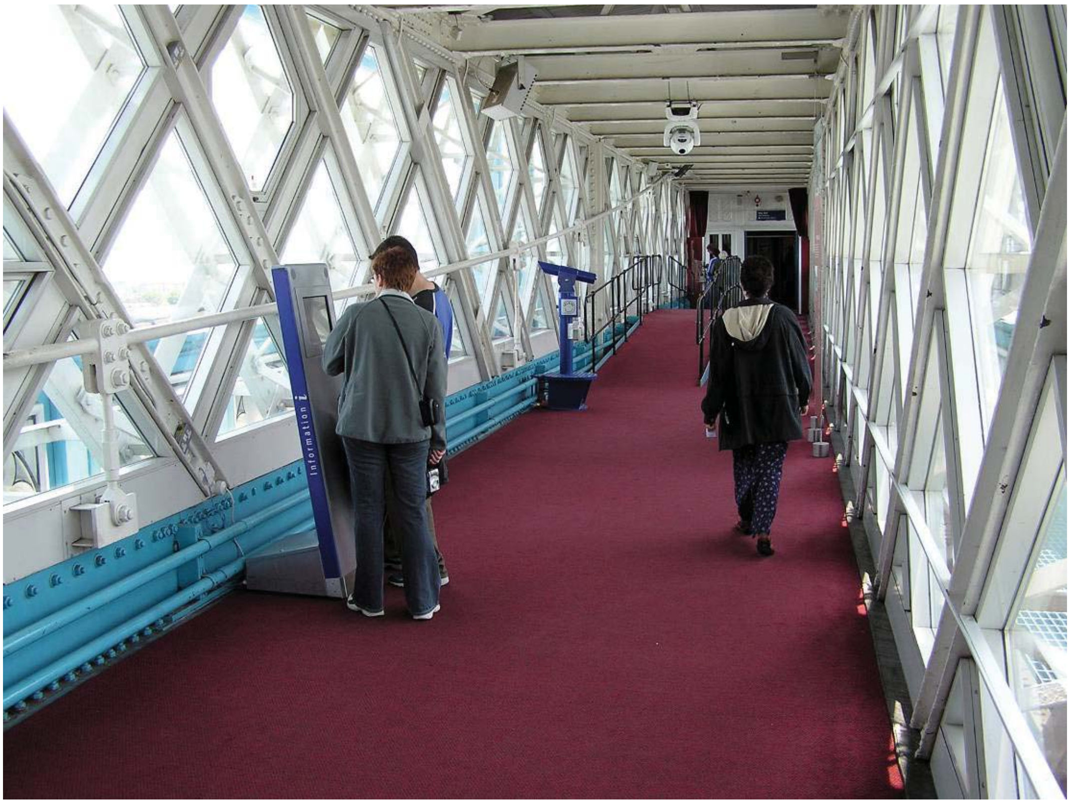
E.3.343 Vol 3 Plate E.95 to Vol 3 Plate E.98 illustrate the above description.

**Vol 3 Plate E.95 Tower Bridge viewed from the south-west**

**Vol 3 Plate E.96 Tower Bridge viewed from London City Hall**

**Vol 3 Plate E.97 Tower Bridge with bascules raised**

**Vol 3 Plate E.98 Tower Bridge high level walkway**




### Significance

E.3.344 Tower Bridge is of historic and architectural significance due to its striking architectural design, its technical innovation, and its association with the notable Victorian engineer, Sir John Wolfe Barry. The bridge provides an internationally recognised landmark and harmonizes with the historic setting of the Tower of London, a World Heritage Site. The bridge provides a river gateway to the city of London and was until the opening of the Queen Elizabeth Suspension Bridge in 1991, the furthest downstream bridge on the Thames. Tower Bridge is a Grade I Listed Building.

E.3.345 Tower Bridge is of group value with other heritage assets in the vicinity for which it contributes to their setting, including the Tower of London (World Heritage Site, Scheduled Monument, and multiple Listed Buildings), Tower Bridge Approach (Grade I), St Katharine's Dock (Grade II), Dockmaster's Office (Grade II), Accumulator Tower and Chimney Stack to East Side of Tower Bridge (Grade II), and Tower Bridge Bridgemaster's House and Gate to Side (Grade II).

E.3.346 Architecturally, the bridge has been little altered since its construction, retaining the entirety of its intended character and appearance, as well as the much of its original fabric. As a consequence, the individual components of the structure and its fabric are of equally high significance. The exceptions are the surface finishes to the roadway and footway, and the visitor centre entrance. The bridge is of technological significance as one of the finest examples of a bascule bridge. Originally, Tower Bridge was a hydraulically operated bridge, using steam power from coal-burning boilers to pump river water into six hydraulic accumulators so that power was readily available when required. The water for the boilers was provided by a well. The hydraulic accumulators powered the bascule engines, which raised and lowered the bascules. Today, the bascule mechanism is driven by oil and electricity rather than by water and steam, although parts of the original steam driven mechanism are preserved in-situ.

E.3.347 The north side of the bridge lies within the London Borough of Tower Hamlets Tower of London Conservation Area, and in the setting of the Tower of London World Heritage Site. The south side of the bridge lies within the London Borough of Southwark, Tower Bridge Conservation Area.

#### Condition

E.3.348 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in “good” condition.

E.3.349 The bridge was extensively repaired, resurfaced and redecorated in 2008-11 at a cost of £4m.

E.3.350 At the time of the inspection the bridge appeared to be in “very good” condition. Some degradation of the paintwork and surface corrosion was noted. There is some cracking in the stone cladding. Generally, however, the bridge appears to be in excellent structural order.

### Sensitivity of the bridge’s significant elements

E.3.351 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movements on the bridge.

E.3.352 The main Thames Tideway Tunnel would pass perpendicularly beneath the central span of the bridge, with the centreline of the tunnel running at a depth of 40.41m below river bed level. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the piers, which would in turn induce movement and stresses within the superstructure.

E.3.353 Immediately above the crown of the tunnel, a maximum vertical settlement of 12mm at foundation level is predicted. However, with the neighbouring piers set more than 25m distant from this point the vertical settlement of the structure would not be as acute. The abutments and all other piers lie outside the zone of settlement.

E.3.354 The north and south river piers would experience a maximum vertical settlement on the tunnel facing side of the piers of 4.6mm. The outer faces of the piers, however, would settle less, with the principal towers tending to rotate inwards towards each other, placing new stresses on the walkways, suspension system, and shore spans. Analysis has shown that although the high level tie would slacken, it would remain in tension and that the towers themselves would be more than capable of accommodating the increased stresses. The greatest effects of settlement would be experienced in the vertical hangers for the shore spans. Here the inward rotation of the towers would pull on the suspension chains, causing the shore spans to hog.

E.3.355 The inward rotation of the towers would also result in each bascule experiencing a downward and inward displacement, resulting in a 10mm reduction in the gap between the bascule leaves. These movements, although there are no stresses associated with them, would necessitate some adjustment to the nosings of the bascule leaves which must be locked into position for the bridge to be operational for road traffic.

E.3.356 The applied loadings and stresses would have no effect on the external appearance of the bridge, as the stone cladding is non-load bearing.

### Conclusions

E.3.357 Assessment indicates that the bridge would be able to accommodate the effects of ground movements and the additional stresses that these would impart upon the superstructure. No overstressing or cracking is predicted.

E.3.358 The inward rotation of the towers would result in a closing of the gap between the bascule leaves by 10mm. This would require mitigation by means of initial monitoring, followed by possible physical adjustments to the nosings of the bascule leaves, and/or the nosing bolts. The scope of physical intervention (if required) would be determined after a period of monitoring and in agreement with the asset owner. The scope of physical works to the bascule leaves would be relatively minor in nature and would not compromise the character, appearance, or significance of the bridge. Physical adjustment (if required) would be undertaken over the course of a single weekend.

E.3.359 The predicted ground movement would have little if any effect on the architectural character and significance of the structure and that the majority of interest focuses on the continued efficient operational serviceability of the bridge.

E.3.360 The bridge would be monitored prior, during and after the construction of the tunnel as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2. The foundations would be monitored to ensure that the actual movements are within the limits predicted, and control limits established to quantify when intervention is required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

E.3.361 It is concluded that no harm would be caused to the special interest or significance of the structure.

# Brunel Thames Tunnel

## Description of the (Brunel) Thames Tunnel and its significance

### The tunnel

E.3.362 The (Brunel) Thames Tunnel is a Grade II* Listed Building and is officially Listed as, “Thames Tunnel,” National Heritage List for England Entry Numbers 1242119 & 1378391 (Listed Building UID’s 441472 & 470692).

E.3.363 The tunnel was constructed in 1825-43 by Sir Marc Isambard Brunel, assisted by his son Isambard Kingdom Brunel. It is of great historical significance as the first shield-driven subaqueous tunnel, and the first tunnel to be built beneath a river anywhere in the world. It was constructed using Thomas Cochrane and Marc Isambard Brunel’s newly invented tunnelling shield technology.

E.3.364 The structure consists of two parallel horseshoe section brick vaulted tunnels which are joined at intervals by semi-circular headed cross arches resting on Greek Doric pilasters with square abaci. Many of the interlinking archways have since been in-filled. The tunnel vaults each measure 14 feet wide by 16 feet high, with the twin tunnels encased within a single brick framework 37 feet wide by 22 feet tall. At each end of the tunnel are vertical shafts, 50 feet in diameter, which provided access to the tunnel. The brickwork is bonded in Roman Cement to provide some waterproofing. The interior of the tunnel is lined with clay tiles covered in stucco. The stucco was originally scored in imitation of ashlar stonework. The tunnel passes beneath the Thames between Wapping and Rotherhithe Stations. The majority of the tunnel was lined with concrete during repairs undertaken in 1996-7. Only the southernmost section of tunnel retains its original appearance.

E.3.365 The section of tunnel which will be subject to ground movement has a 200mm thick cast in-situ concrete lining.

E.3.366 The tunnel has been used for the passage of trains since 1869 and was used for many years as part of the London Underground network. The tunnel now forms part of the London Overground network.

E.3.367 Vol 3 Plate E.99 to Vol 3 Plate E.100 illustrate the above description.

**Vol 3 Plate E.99 The twin vaults of the Thames Tunnel viewed from the south**

**Vol 3 Plate E.100 Inside the Thames Tunnel**

### Significance

E.3.368 The (Brunel) Thames Tunnel is of great historic significance. It is the first shield-driven subaqueous tunnel, and the first tunnel to be built beneath a river anywhere in the world. It was designed for but never used by horse-drawn carriages.

E.3.369 The need for a land connection between the north and south banks of the Thames to link the expanding docks on each side of the river was first identified at the turn of the 19th century. Due the height of the ships' masts, a bridge was not thought practicable in this location; bascule bridge technology as was later realised at Tower Bridge had yet to be advanced. Consequently, attention was focused on the idea of constructing a tunnel. Several attempts were made including several by Cornish miners but all failed to overcome the soft ground conditions and were lost to flooding.

E.3.370 In 1818 Thomas Cochrane and Marc Isambard Brunel patented a new tunnelling system comprising a shield system which would help support the surrounding ground during tunnel construction. In 1823 Brunel put forward a plan for a tunnel beneath the Thames, private finance was raised for the venture, and the Thames Tunnel Company formed in 1824. Work started on the tunnel in 1825 with the construction of a vertical shaft at Rotherhithe. Once this was complete tunnelling commenced northwards towards Wapping.

E.3.371 Despite the use of the shield, excavation of the tunnel was extremely hazardous and progress slow. The tunnel was constructed at a relatively shallow depth, only 14 feet beneath the river bed at its shallowest point. The seeping river water was sewage laden and the workings were often filled with methane gas. Despite the shield, the roof of the tunnel was breached on several occasions and the workings flooded. One flood in 1828 almost claimed the life of the young Isambard Kingdom Brunel himself. The slow progress and continued flooding led to the project being abandoned for 7 years as funds for the work dried up. Further finance including a loan from the Treasury allowed the project to recommence with tunnel construction completed in 1841. The tunnel was fitted out in 1841-42 and opened on 25 March 1843. With funds exhausted the original proposal to extend the entrances to accommodate horse drawn carriages was never undertaken, and the tunnel was to provide pedestrian access only until purchased in 1865 by the East London Railway Company and converted to rail use.

E.3.372 The tunnel was used for many years as part of the London Underground network until repairs necessitated its closure in 1995. Extensive repair and relining of the tunnel was undertaken in 1996-7. The tunnel now forms part of the London Overground network.

E.3.373 The tunnel is part located within the Tower Hamlet's Wapping Wall Conservation Area, although its subterranean nature means that its contribution to the character and appearance of the conservation area is limited. Above ground, two ventilation shafts, one on each bank, are each separately designated Grade II Listed Buildings.

E.3.374 The tunnel is of architectural and historic significance and engineering interest being the first tunnel ever constructed beneath a river, and the first shield-driven tunnel. On its opening it was referred to as the 8th Wonder of the World and millions came to visit. It was built by two of the 19th century's great engineers, Marc Isambard Brunel and his son Isambard Kingdom Brunel. The fact that the tunnel continues in use today adds to its significance.

E.3.375 The majority of the original fabric is now concealed from view by concrete linings installed in 1996-7. The south section of the tunnel, however, survives in its original form. None the less, all parts of the structure are statutorily Listed and protected under planning law.

#### Condition

E.3.376 The tunnel has not been inspected by a heritage specialist as part of this assessment. However, it is understood that the tunnel remains in good order following its extensive repair and relining in 1996-7.

### Sensitivity of the bridge's significant elements

E.3.377 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movement on the tunnel.

E.3.378 The main Thames Tideway Tunnel would pass obliquely beneath the northern half of the tunnel with the apex of the new Thames Tideway Tunnel lying approximately 28m below the invert of Brunel's tunnel. At this point the axis of the Thames Tideway Tunnel would be approximately 43m below riverbed level.

E.3.379 Assessment indicates that the maximum vertical settlement at the invert of Brunel's tunnel would be 13mm. The stress induced in the structure would be very slight and as a consequence negligible damage is predicted.

E.3.380 The architectural and historic character of the tunnel in the area under consideration has been lost due to the lining of the tunnel in concrete. Hence even if hairline cracking were to occur it would not be of detriment to the architectural or historic significance of the structure.

E.3.381 The effect of the ground movements on the curvature of the track would also be negligible.

### Conclusions

E.3.382 The movements and stresses induced by the tunnel construction would be small, and negligible resultant damage is predicted. The section of tunnel under consideration has been lined in concrete and hence the original form and appearance effectively lost. It is concluded that there would be no risk to the significance of the tunnel from tunnel induced ground movements. There would be no need for any site specific mitigation measures.

E.3.383 Route wide monitoring measures would be adopted during construction as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2, to ensure that the actual ground movements are within the limits predicted, and control limits established to quantify when intervention may be required to prevent damage to the structure. The tracks within the tunnel would also be monitored during construction of the Thames Tideway Tunnel to ensure that any track movement remains within the operator's track tolerance limits.

# Mechanics Path Viaduct

## Description of the Mechanics Path Viaduct and its significance

### The viaduct

E.3.384 Mechanics Path Viaduct, historically formed part of London's first passenger railway, the London and Greenwich Railway, which opened in 1836. This was the first steam railway to have a terminus in the capital, the first of any to be built specifically for passenger service, and the first example of an elevated railway.

E.3.385 This viaduct is in fact part of a longer viaduct structure which runs from Deptford Creek westwards through to North Kent Junction, near South Bermondsey Station, and is officially listed as part of the, "Railway Viaduct between Deptford Creek and North Kent Junction," National Heritage List for England Entry Number 1253151(Listed Building UID 436292). Following subsequent alterations along the route, the Mechanics Path Viaduct comprises an uninterrupted length of thirty arches, which run continuously from Deptford Church Street westwards to Deptford High Street. The viaduct carries two tracks between Deptford and Greenwich. This section of viaduct adjoins the Railway Bridge over Deptford Church Street to the east (BR467) (NKL523), and the Railway Bridge over Deptford High Street to the west (NKL522).

E.3.386 The London and Greenwich Railway was conceived by Colonel G. T. Landmann, a former Royal Engineer, and George Walter. The company was floated on 25 November 1831. An important feature of the railway was that it would run close to London Bridge, thus making it convenient for journeys to the City. The line would eventually be some 4 miles (6 km) in length, the majority elevated on a continuous 878 brick arch viaduct. This was to avoid level crossings over the many streets which were already appearing in the south of London at that time. It was Landmann's original intention that the arches be a means of providing low cost housing, but it was soon apparent that this would be impractical; instead many of the arches became used as workshops. On completion, the line ran from Tooley Street, (now known as London Bridge), to Greenwich. The first section, between Spa Road in Bermondsey and Deptford, opened on 8 February 1836, with the line completed in 1838. The line reached a temporary station at Church Row in Greenwich on 24 December 1838, having been delayed by problems in crossing Deptford Creek. The section of the line passing along Mechanics Path Viaduct was opened in 1838 on completion of the Deptford Creek Lifting Bridge.

E.3.387 By 1844, the annual passenger numbers had risen to over 2 million, with an average fare of 5.2d. The London and Greenwich Railway company continued in existence until January 1923, although by that time control had been passed to South Eastern Railway. Sadly, the company was never financially successful due to the need to repay the very high capital expenditure in building the line.

E.3.388 To overcome the ground conditions encountered along the route, Landmann pioneered the use of concrete to reinforce the foundations beneath the piers of the new elevated railway.

E.3.389 Mechanics Path Viaduct is an underline bridge consisting of thirty regular semi-circular arches running between Deptford Church Street and Deptford High Street. The arches are of similar form to those elsewhere along the route of the former London and Greenwich Railway. The arches are 4 bricks thick, with brick spandrels above. On the north side the brickwork continues upwards to form a continuous parapet 1.2m in height, whilst on the south side the viaduct is surmounted by a metal handrail 1.6m in height which is attached to a reinforced concrete capping beam on top of the spandrel wall. Both types of parapet terminate where they abut the staggered platforms of Deptford Station. The arches are carried on plain rectangular brick piers, 2.2m in height, by 1.2m in width, and 10m in length. The spans match those of the rest of the viaduct and are approximately 5.5m in width.

E.3.390 The viaduct is a utilitarian structure constructed with no attempt at architectural embellishment.

E.3.391 The viaduct appears to have been subject to brick replacement and general refurbishment and repair, but generally retains its original form.

E.3.392 All of the arches along this stretch of the viaduct have been infilled to form workshop premises. A single storey extension to these premises has been built along the north side of the viaduct, concealing all but five of the arches.

E.3.393 The arches and associated premises were substantially refurbished in 2000 to 2003 to provide new light industrial units. Prior to refurbishment, the arches were in very poor condition and needed considerable investment. Traditionally the arches had been used for the rag and bone trade. This was replaced in the 1970s by vehicle repair uses. At the time of refurbishment many of the arches were vacant with derelict rear additions.

E.3.394 The platforms to Deptford Railway Station cantilever out at the west end of the viaduct.

E.3.395 Vol 3 Plate E.101 to Vol 3 Plate E.102 illustrate the above description.

**Vol 3 Plate E.101 Mechanics Path Viaduct viewed from south-east**


**Vol 3 Plate E.102 Mechanics Path Viaduct viewed from south-west**

### Significance

E.3.396 Mechanics Path Viaduct is of great historic significance. It forms part of the original viaduct of the London and Greenwich Railway. Built in 1836 to 1838 this was London's first railway, and hence the viaduct is one of the city's earliest railway structures.

E.3.397 The majority of the original historic fabric appears to remain and the fact that it continues in use as a railway to this day makes it an all more remarkable survival.

E.3.398 This stretch of the viaduct running from Deptford Church Street to Deptford High Street has been subject to alteration. All of the arches have been infilled, the north side obscured by workshop premises, and the south parapet replaced with a metal handrail. None the less the viaduct remains an impressive structure and local landmark which contributes positively to the Deptford High Street Conservation Area.

E.3.399 The viaduct forms part of the, "Railway Viaduct between Deptford Creek and North Kent Junction," a Grade II Listed Building, National Heritage List for England Entry Number 1253151.

E.3.400 The viaduct stands within the Deptford High Street Conservation Area.

E.3.401 The piers, arches and spandrels are of greatest architectural and historic significance being contemporary with the original construction of the railway. The date of the parapet on the north side is uncertain; for the time being it should be presumed to date from the original construction and be regarded as of equal importance to the structure below. The metal parapet on the south side is of modern date and not of significance. It is presumed that the viaduct deck is also of modern date and this too will be of lesser significance. Although not part of this detailed study, the platform structures associated with Deptford Station may also be of significance. Deptford Station is one of the oldest surviving suburban railway stations in the world, being built in 1836 to serve the London and Greenwich Railway. The suspended platforms over Deptford High Street date from the original construction of the railway and are highly significant. The recent refurbishment and extensions to the workshop premises are of lesser significance.

### Condition

E.3.402 Both sides of the viaduct were observed from street level during the walkover survey. From visual observation the viaduct appears to be in 'good' condition.

E.3.403 The viaduct appears to be structurally sound and well maintained.

E.3.404 A comprehensive scheme of refurbishment was undertaken in 2000 to 2003, when the arches and premises were overhauled and the new extension built. Listed building consent and planning permission for the refurbishment of the Mechanic's Path arches, including new infills and new extensions, was granted in November 2000.

### Sensitivity of the viaduct's significant elements

E.3.405 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movement on the viaduct.

E.3.406 Two items of work are proposed in the vicinity of Mechanics Path Viaduct, the construction of which would induce ground movement.

E.3.407 The Deptford Church Street Shaft would be constructed close to Deptford Church Street, approximately 40m to the north of the viaduct. The excavated diameter of the shaft would be 22.4m, with an internal diameter of 17m; the shaft foundations would be at a depth of 54m below ground level. Running north-westwards from the shaft on a diverging path to the viaduct would be a combined sewer overflow tunnel (CSO).

E.3.408 At its closest point, the combined sewer overflow tunnel would pass within 25m of Mechanics Path Viaduct at a depth of approximately 43.6m below ground level. The excavated diameter of the CSO would be 6.2m, with an internal diameter of 5m.

E.3.409 Analysis has shown that the CSO would be the main contributor to any ground movements experienced by the viaduct, but due to its proximity, the shaft would contribute to the magnitude of that movement. The combined effects have been assessed.

E.3.410 The construction works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the structure, which would in turn induce movement and stresses within the structure itself. In broad terms, the greatest settlement is predicted to occur on the north side of the east most piers nearest the CSO. The ground movements would cause the structure to rotate southwards, albeit marginally. The greatest ground movements would occur at the completion of construction.

E.3.411 The greatest settlement is predicted to occur at the east most pier, with a settlement at the centreline of 1.6mm, and on the north side of 2.1mm. The maximum horizontal movement parallel to viaduct would be small at 0.41mm, occurring at the east most pier. The maximum horizontal movement perpendicular to the viaduct would be 1.25mm at foundation level, 2.8mm at track level, occurring adjacent to the shaft.

E.3.412 The tensile stress induced in the structure would be very small (considerably less than 0.05%) and hence the level of predicted damage is considered negligible. The structure has been assessed and compared with the damage risk categories defined by Burland (1977) and Boscardin & Cording (1989); the likely level of damage risk falls within Category 0 – Negligible degree of severity of damage; typically this is no more than hairline cracks.

E.3.413 Architecturally, the viaduct is of simple design with no fine architectural detail or ornamentation. Should for any reason, the predicted ground movements induce hairline cracking, this would not be of detriment to the architectural or historic significance of the viaduct. Hairline cracking would be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric. Given the very low predicted stresses, even hairline cracking seems unlikely in this instance.

E.3.414 The effect of the ground movements on the curvature of the track would be negligible.

### Conclusions

E.3.415 The movements and stresses induced by the tunnel construction would be small, and negligible resultant damage is predicted. The viaduct is of simple design with no fine architectural detail or ornamentation. It is concluded that there would be no risk to the significance of the viaduct from tunnel induced ground movements. There would be no need for any site specific mitigation measures.

E.3.416 Route wide monitoring measures would be adopted during construction as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2, to ensure that the actual ground movements are within the limits predicted, and control limits established to quantify when intervention may be required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

## Brown House and Farrer House Viaduct

### Description of Brown House and Farrer House Viaduct and its significance

#### The viaduct

E.3.417 Browne House and Farrer House Viaduct, historically formed part of London's first passenger railway, the London and Greenwich Railway, which opened in 1836. This was the first steam railway to have a terminus in the capital, the first of any to be built specifically for passenger service, and the first example of an elevated railway.

E.3.418 This viaduct is in fact part of a longer viaduct structure which runs from Deptford Creek westwards through to North Kent Junction, near South Bermondsey Station, and is officially listed as part of the, "Railway Viaduct between Deptford Creek and North Kent Junction," National Heritage List for England Entry Number 1253151(Listed Building UID 436292). Following subsequent alterations along the route, the Browne House and Farrer House Viaduct forms but part of an uninterrupted length of 32 arches, which run continuously from Deptford Creek westwards to Deptford Church Street. This is regarded as the most attractive part of the line, with most of the arches remaining open. The viaduct carries two tracks between Deptford and Greenwich. This section of viaduct adjoins the Railway Bridge over Creekside to the east (BR1469) (NKL525), and the Railway Bridge over Deptford Church Street to the west (BR467) (NKL523).

E.3.419 The London and Greenwich Railway was conceived by Colonel G. T. Landmann, a former Royal Engineer, and George Walter. The company was floated on 25 November 1831. An important feature of the railway was that it would run close to London Bridge, thus making it convenient for journeys to the City. The line would eventually be some 4 miles (6 km) in length, the majority elevated on a continuous 878 brick arch viaduct. This was to avoid level crossings over the many streets which were already appearing in the south of London at that time. It was Landmann's original intention that the arches be a means of providing low cost housing, but it was soon apparent that this would be impractical; instead many of the arches became used as workshops. On completion, the line ran from Tooley Street, (now known as London Bridge), to Greenwich. The first section, between Spa Road in Bermondsey and Deptford, opened on 8 February 1836, with the line completed in 1838. The line reached a temporary station at Church Row in Greenwich on 24 December 1838, having been delayed by problems in crossing Deptford Creek. The section of the line passing along Browne House and Farrer House Viaduct was opened in 1838 on completion of the Deptford Creek Lifting Bridge.

E.3.420 By 1844, the annual passenger numbers had risen to over 2 million, with an average fare of 5.2d. The London and Greenwich Railway company continued in existence until January 1923, although by that time control had been passed to South Eastern Railway. Sadly, the company was never financially successful due to the need to repay the very high capital expenditure in building the line.

E.3.421 To overcome the ground conditions encountered along the route, Landmann pioneered the use of concrete to reinforce the foundations beneath the piers of the new elevated railway.

E.3.422 Browne House and Farrer House Viaduct is an underline bridge consisting of seventeen regular semi-circular arches running between the Railway Bridge over Creekside and the Railway Bridge over Deptford Church Street. The arches are of similar form to those elsewhere along the route of the former London and Greenwich Railway. The arches are 4 bricks thick, with brick spandrels above. On the north side the brickwork continues upwards to form a continuous parapet 1.2m in height, whilst on the south side the viaduct is surmounted by a metal handrail 1.6m in height which is attached to a reinforced concrete capping beam on top of the spandrel wall. The arches are carried on plain rectangular brick piers, 2.2m in height, by 1.2m in width, and 10m in length. The spans match those of the rest of the viaduct and are approximately 5.5m in width.

E.3.423 The viaduct is a utilitarian structure constructed with no attempt at architectural embellishment.

E.3.424 The viaduct appears to have been subject to brick replacement and general refurbishment and repair, but generally retains its original form.

E.3.425 In between the Browne House and Farrer House sections is the Addey Street span. Shown in historical maps, the road no longer exists. The span is listed under reference NKL 524 and is included in this overall section of viaduct.

E.3.426 Vol 3 Plate E.103 to Vol 3 Plate E.105 illustrate the above description.

**Vol 3 Plate E.103 Browne House and Farrer House Viaduct viewed from north-east**

**Vol 3 Plate E.104 Browne House and Farrer House Viaduct viewed from south**

**Vol 3 Plate E.105 View from Sun Wharf Viaduct towards Browne House and Farrer House Viaduct**

### Significance

E.3.427 Browne House and Farrer House Viaduct is of great historic significance. It forms part of the original viaduct of the London and Greenwich Railway. Built in 1836 to 1838 this was London's first railway, and hence the viaduct is one of the city's earliest railway structures.

E.3.428 The majority of the original historic fabric appears to remain and the fact that it continues in use as a railway to this day makes it an all more remarkable survival.

E.3.429 This stretch of the viaduct running from Creekside to Deptford Church Street remains little altered, with all of the arches remaining open, and gives an excellent impression of how the railway would have appeared when first opened. The viaduct is an impressive structure and a local landmark which contributes positively to the Deptford Creekside Conservation Area.

E.3.430 The viaduct forms part of the, "Railway Viaduct between Deptford Creek and North Kent Junction," a Grade II Listed Building, National Heritage List for England Entry Number 1253151.

E.3.431 The particular stretch of viaduct adjoins western boundary of the Deptford Creekside Conservation Area.

E.3.432 The piers, arches and spandrels are of greatest architectural and historic significance being contemporary with the original construction of the railway. The date of the parapet on the north side is uncertain; for the time being it should be presumed to date from the original construction and be regarded as of equal importance to the structure below. The metal parapet on the south side is of modern date and not of significance. It is presumed that the viaduct deck is also of modern date and this too will be of lesser significance.

### Condition

E.3.433 Both sides of the viaduct were observed from street level during the walkover survey. From visual observation the viaduct appears to be in "fair" condition.

E.3.434 The viaduct appears to be structurally sound and reasonably well maintained.

E.3.435 Self-set vegetation is apparent on the south side on the top of the spandrel wall. The surface coating to the metal guard rail above is weathering, exposing the underlying metalwork. The reinforced concrete capping beam on top of the spandrel wall has been subject to graffiti.

E.3.436 The brickwork shows evidence of a long history of patch repairs and re-pointing. The brickwork is gently eroding in places but otherwise perfectly serviceable. Some of the re-pointing has been poorly executed and the use of hard impervious cementitious mortar has promoted decay of the brickwork in places. Some of the brickwork joints are loose or open jointed.

E.3.437 Within the arches there is evidence of water penetration from the deck above and some of the masonry is damp.

### Sensitivity of the viaduct's significant elements

E.3.438 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movement on the viaduct.

E.3.439 A combined sewer overflow tunnel (CSO) would pass to the north of the viaduct on a diverging path at a depth of 42.3m below ground level. The CSO would be at its closest at the east end of the viaduct where it would pass within 10m. The excavated diameter of the CSO would be 6.2m, with an internal diameter of 5m. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the structure, which would in turn induce movement and stresses within the structure itself.

E.3.440 A maximum vertical settlement of 6mm is predicted to occur on completion of the tunnel construction at the north end of the east abutment. The ground movement would cause the piers to settle and rotate in a northwards direction, albeit marginally.

E.3.441 The maximum horizontal movement parallel to the viaduct on completion would be small at 0.31mm, occurring at the west end of the viaduct. During construction, horizontal movement parallel to the viaduct would be slightly greater at 0.79mm, occurring at the east end of the viaduct. The maximum horizontal movement perpendicular to the viaduct would be 1.18mm at foundation level, 2.75mm at track level, occurring at the west-most pier.

E.3.442 The tensile stress induced in the structure would be very small (considerably less than 0.05%) and hence the level of predicted damage is considered negligible. The structure has been assessed and compared with the damage risk categories defined by Burland (1977) and Boscardin & Cording (1989); the likely level of damage risk falls within Category 0 – Negligible degree of severity of damage; typically this is no more than hairline cracks.

E.3.443 Architecturally, the viaduct is of simple design with no fine architectural detail or ornamentation. Should for any reason, the predicted ground movements induce hairline cracking, this would not be of detriment to the architectural or historic significance of the viaduct. Hairline cracking would be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric. Given the very low predicted stresses, even hairline cracking seems unlikely in this instance.

E.3.444 The effect of the ground movements on the curvature of the track would be negligible.

### Conclusions

E.3.445 The movements and stresses induced by the tunnel construction would be small, and negligible resultant damage is predicted. The viaduct is of simple design with no fine architectural detail or ornamentation. It is concluded that there would be no risk to the significance of the viaduct from tunnel induced ground movements. There would be no need for any site specific mitigation measures.

E.3.446 Route wide monitoring measures would be adopted during construction as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2, to ensure that the actual ground movements are within the limits predicted, and control limits established to quantify when intervention may be required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

# Railway bridge over Creekside

## Description of Railway Bridge over Creekside and its significance

### The bridge

E.3.447 The Railway Bridge over Creekside, historically formed part of London's first passenger railway, the London and Greenwich Railway, which opened in 1836. This was the first steam railway to have a terminus in the capital, the first of any to be built specifically for passenger service, and the first example of an elevated railway.

E.3.448 The bridge is fact part of a long viaduct which runs from Deptford Creek through to North Kent Junction, near South Bermondsey Station, and is officially listed as part of the, "Railway Viaduct between Deptford Creek and North Kent Junction," National Heritage List for England Entry Number 1253151. Following subsequent alterations along the route, the Railway Bridge over Creekside forms but part of an uninterrupted length of 32 arches, which run continuously from Deptford Creek westwards to Deptford Church Street. This is regarded as the most attractive part of the line, with most of the arches remaining open.

E.3.449 The London and Greenwich Railway was conceived by Colonel G. T. Landmann, a former Royal Engineer, and George Walter. The company was floated on 25 November 1831. An important feature of the railway was that it would run close to London Bridge, thus making it convenient for journeys to the City. The line would eventually be some 4 miles (6 km) in length, the majority elevated on a continuous 878 brick arch viaduct. This was to avoid level crossings over the many streets which were already appearing in the south of London at that time. It was Landmann's original intention that the arches be a means of providing low cost housing, but it was soon apparent that this would be impractical; instead many of the arches became used as workshops. On completion, the line ran from Tooley Street, (now known as London Bridge), to Greenwich. The first section, between Spa Road in Bermondsey and Deptford, opened on 8 February 1836, with the line completed in 1838. The line reached a temporary station at Church Row in Greenwich on 24 December 1838, having been delayed by problems in crossing Deptford Creek. The section of the line passing over Creekside was opened in 1838 on completion of the Deptford Creek Lifting Bridge.

E.3.450 By 1844, the annual passenger numbers had risen to over 2 million, with an average fare of 5.2d. The London and Greenwich Railway company continued in existence until January 1923, although by that time control had been passed to South Eastern Railway. Sadly, the company was never financially successful due to the need to repay the very high capital expenditure in building the line.

E.3.451 To overcome the ground conditions encountered along the route, Landmann pioneered the use of concrete to reinforce the foundations beneath the piers of the new elevated railway.

E.3.452 The Railway Bridge over Creekside comprises two of the regular semi-circular arches of the viaduct which span across the road and footpath. The present road narrows to a single lane at this point to pass beneath the east span, with the footpath passing beneath the adjacent west span. The arches are 4 bricks thick, with brick spandrels above. On the north side the brickwork continues upwards to form a continuous parapet 1.2m in height, whilst on the south side the bridge is surmounted by a metal handrail 1.6m in height attached to the reinforced concrete capping beam on top of the spandrel wall. Historic images would appear to indicate that the viaduct was originally built without parapets. The arches are carried on plain rectangular brick piers, 2.2m in height, by 1.2m in width, and 10m in length. The spans match those of the rest of the viaduct and are both 5.5m in width.

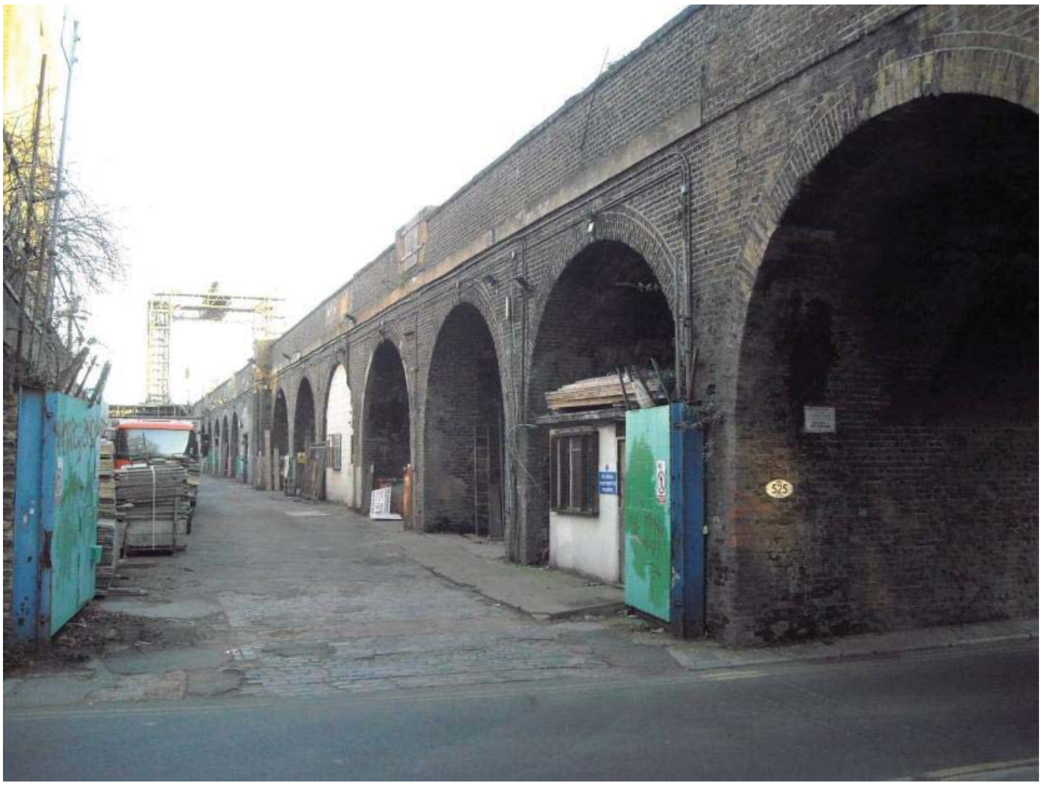
E.3.453 The bridge is a utilitarian structure constructed with no attempt at architectural embellishment.

E.3.454 The bridge appears to have been subject to brick replacement and general refurbishment and repair, but generally retains its original form.

E.3.455 Vol 3 Plate E.106 to Vol 3 Plate E.108 illustrate the above description.

**Vol 3 Plate E.106 Railway Bridge over Creekside viewed from south**

**Vol 3 Plate E.107 Railway Bridge over Creekside viewed from north-west**



**Vol 3 Plate E.108 Railway Bridge over Creekside viewed from south-east**

### Significance

E.3.456 The Railway Bridge over Creekside is of great historic significance. It forms part of the original viaduct of the London and Greenwich Railway. Built in 1836 to 1838 this was London's first railway, and hence the bridge and viaduct are among the city's earliest railway structures.

E.3.457 The majority of the original historic fabric appears to remain and the fact that it continues in use as a railway to this day makes it an all more remarkable survival.

E.3.458 This stretch of the viaduct running from Deptford Creek to Deptford Church Street is the best preserved and most attractive stretch of the 6km elevated railway.

E.3.459 The bridge forms part of the, "Railway Viaduct between Deptford Creek and North Kent Junction," a Grade II Listed Building, National Heritage List for England Entry Number 1253151.

E.3.460 The bridge stands within the Deptford Creekside Conservation Area and is cited in the draft Deptford Creekside Conservation Area Character Appraisal (public consultation draft December 2011) as both a notable building and key landmark.

E.3.461 The piers, arches and spandrels are of greatest architectural and historic significance being contemporary with the original construction of the railway. The date of the parapet on the north side is uncertain; for the time being it should be presumed to date from the original construction and be regarded as of equal importance to the structure below. The metal parapet on the south side is of modern date and not of significance. It is presumed that the bridge deck is also of modern date and this too will be of lesser significance.

### Condition

E.3.462 Both sides of the bridge were observed from street level during the walkover survey. From visual observation the bridge appears to be in "good" condition.

E.3.463 The bridge appears to be structurally sound and reasonably well maintained.

E.3.464 Self-set vegetation is apparent on the south side on the top of the spandrel wall. The surface coating to the metal guard rail above is weathering, exposing the underlying metalwork. The reinforced concrete capping beam on top of the spandrel wall has been subject to graffiti.

E.3.465 The brickwork shows evidence of a long history of patch repairs and re-pointing. The brickwork is gently eroding in places but otherwise perfectly serviceable. Some of the re-pointing has been poorly executed and the use of hard impervious cementitious mortar has promoted decay of the brickwork in places. Some of the brickwork joints are loose or open jointed.

E.3.466 Within the arches there is evidence of water penetration from the deck above and some of the masonry is damp.

### Sensitivity of the bridge's significant elements

E.3.467 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movement on the viaduct.

E.3.468 A combined sewer overflow tunnel would pass obliquely 7m to the north of the bridge at a depth of 41.2m below ground level. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the structure, which would in turn induce movement and stresses within the structure itself.

E.3.469 A maximum vertical settlement of 6mm is predicted to occur at the north end of the east pier. However, because the piers will be moving in a similar manner, the differential settlement would be relatively small. The vertical differential settlement calculated to be caused by the tunnelling works is calculated as 0.2mm on completion of construction with the east pier settling more than the west.

E.3.470 A slight downwards tilt from south to north would develop across the width of each pier, with a maximum tilt of 1.2mm occurring at the west pier.

E.3.471 The tensile stress induced in the structure would be very small and hence the level of predicted damage is considered negligible. The structure has been assessed and compared with the damage risk categories defined by Burland (1977) and Boscardin & Cording (1989); the likely level of damage risk falls within Category 0 – Negligible degree of severity of damage; typically this is no more than hairline cracks.

E.3.472 Architecturally, the bridge is of simple design with no fine architectural detail or ornamentation. Should for any reason, the predicted ground movements induce hairline cracking, this would not be of detriment to the architectural or historic significance of the bridge. Hairline cracking would be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric.

### Conclusions

E.3.473 The movements and stresses induced by the tunnel construction will be small, and negligible resultant damage is predicted. The bridge is of simple design with no fine architectural detail or ornamentation. It is concluded that there would be no risk to the significance of the bridge from tunnel induced ground movements. There would be no need for any site specific mitigation measures.

E.3.474 Route wide monitoring measures would be adopted during construction as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2, to ensure that the actual ground movements are within the limits predicted, and control limits established to quantify when intervention may be required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

# Sun Wharf Viaduct

## Description of Sun Wharf Viaduct and its significance

### The viaduct

E.3.475 Sun Wharf Viaduct, historically formed part of London's first passenger railway, the London and Greenwich Railway, which opened in 1836. This was the first steam railway to have a terminus in the capital, the first of any to be built specifically for passenger service, and the first example of an elevated railway.

E.3.476 This viaduct is in fact part of a longer viaduct structure which runs from Deptford Creek westwards through to North Kent Junction, near South Bermondsey Station, and is officially listed as part of the, "Railway Viaduct between Deptford Creek and North Kent Junction," National Heritage List for England Entry Number 1253151(Listed Building UID 436292). Following subsequent alterations along the route, the Sun Wharf forms but part of an uninterrupted length of 32 arches, which run continuously from Deptford Creek westwards to Deptford Church Street. This is regarded as the most attractive part of the line, with most of the arches remaining open. The viaduct carries two tracks between Deptford and Greenwich. This section of viaduct adjoins Deptford Creek Lifting Bridge to the east (BR102) (NKL526), and the Railway Bridge over Creekside to the west (BR469) (NKL525).

E.3.477 The London and Greenwich Railway was conceived by Colonel G. T. Landmann, a former Royal Engineer, and George Walter. The company was floated on 25 November 1831. An important feature of the railway was that it would run close to London Bridge, thus making it convenient for journeys to the City. The line would eventually be some 4 miles (6 km) in length, the majority elevated on a continuous 878 brick arch viaduct. This was to avoid level crossings over the many streets which were already appearing in the south of London at that time. It was Landmann's original intention that the arches be a means of providing low cost housing, but it was soon apparent that this would be impractical; instead many of the arches became used as workshops. On completion, the line ran from Tooley Street, (now known as London Bridge), to Greenwich. The first section, between Spa Road in Bermondsey and Deptford, opened on 8 February 1836, with the line completed in 1838. The line reached a temporary station at Church Row in Greenwich on 24 December 1838, having been delayed by problems in crossing Deptford Creek. The section of the line passing along Sun Wharf Viaduct was opened in 1838 on completion of the Deptford Creek Lifting Bridge.

E.3.478 By 1844, the annual passenger numbers had risen to over 2 million, with an average fare of 5.2d. The London and Greenwich Railway company continued in existence until January 1923, although by that time control had been passed to South Eastern Railway. Sadly, the company was never financially successful due to the need to repay the very high capital expenditure in building the line.

E.3.479 To overcome the ground conditions encountered along the route, Landmann pioneered the use of concrete to reinforce the foundations beneath the piers of the new elevated railway.

E.3.480 Sun Wharf Viaduct is an underline bridge consisting of fifteen regular semi-circular arches running between Deptford Creek Lifting Bridge and the Railway Bridge over Creekside. The arches are of similar form to those elsewhere along the route of the former London and Greenwich Railway. The arches are 4 bricks thick, with brick spandrels above. On the north side the brickwork continues upwards to form a continuous parapet 1.2m in height, whilst on the south side of the viaduct, with the exception of a short length of brick parapet to the west, the viaduct is surmounted by a metal handrail 1.6m in height which is attached to a reinforced concrete capping beam on top of the spandrel wall. Historic images would appear to indicate that the viaduct was originally built without parapets. The arches are carried on plain rectangular brick piers, 2.2m in height, by 1.2m in width, and 10m in length. The spans match those of the rest of the viaduct and are approximately 5.5m in width.

E.3.481 The viaduct is a utilitarian structure constructed with no attempt at architectural embellishment.

E.3.482 The viaduct appears to have been subject to brick replacement and general refurbishment and repair, but generally retains its original form.

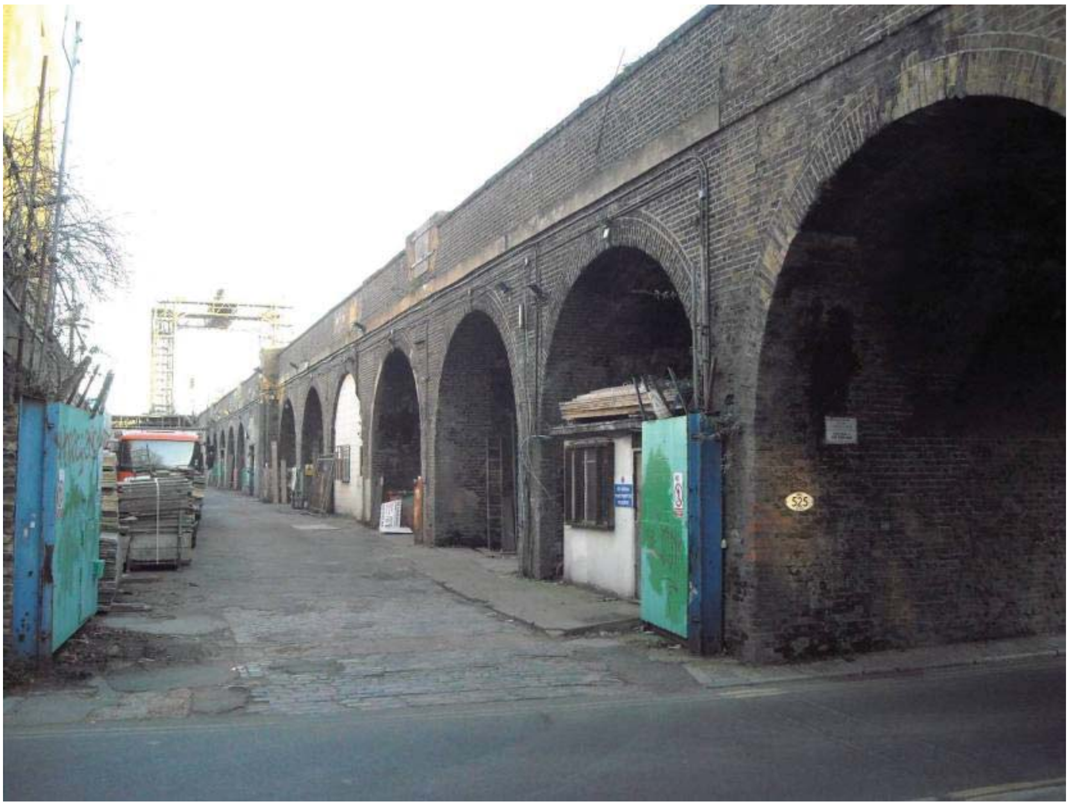
E.3.483 Vol 3 Plate E.109 to Vol 3 Plate E.112 illustrate the above description.

**Vol 3 Plate E.109 Sun Wharf Viaduct viewed from south-east, note displaced brick panel in second archway**

**Vol 3 Plate E.110 Sun Wharf Viaduct viewed from south-east**

**Vol 3 Plate E.111 Sun Wharf Viaduct adjoining Creekside**

**Vol 3 Plate E.112 Sun Wharf Viaduct viewed from north-west**



### Significance

E.3.484 Sun Wharf Viaduct is of great historic significance. It forms part of the original viaduct of the London and Greenwich Railway. Built in 1836 to 1838 this was London's first railway, and hence the viaduct is one of the city's earliest railway structures.

E.3.485 The majority of the original historic fabric appears to remain and the fact that it continues in use as a railway to this day makes it an all more remarkable survival.

E.3.486 This stretch of the viaduct running from Deptford Creek to Creekside has been subject to alteration. Many of the arches have been infilled, most notably on the south side of the viaduct, and the south parapet replaced with a metal handrail. None the less the viaduct remains an impressive structure and local landmark which contributes positively to the Deptford Creekside Conservation Area.

E.3.487 The viaduct forms part of the, "Railway Viaduct between Deptford Creek and North Kent Junction," a Grade II Listed Building, National Heritage List for England Entry Number 1253151.

E.3.488 The viaduct stands within the Deptford Creekside Conservation Area and is cited in the draft Deptford Creekside Conservation Area Character Appraisal (public consultation draft December 2011) as both a notable building and key landmark.

E.3.489 The piers, arches and spandrels are of greatest architectural and historic significance being contemporary with the original construction of the railway. The date of the parapet on the north side is uncertain; for the time being it should be presumed to date from the original construction and be regarded as of equal importance to the structure below. The metal parapet on the south side is of modern date and not of significance. It is presumed that the viaduct deck is also of modern date and this too will be of lesser significance.

### Condition

E.3.490 Both sides of the viaduct were observed from street level during the walkover survey. From visual observation the viaduct appears to be in “fair” condition.

E.3.491 The viaduct appears to be structurally sound and reasonably well maintained.

E.3.492 Self-set vegetation is apparent on the south side on the top of the spandrel wall. The surface coating to the metal guard rail above is weathering, exposing the underlying metalwork. The reinforced concrete capping beam on top of the spandrel wall has been subject to graffiti.

E.3.493 The brickwork shows evidence of a long history of patch repairs and re-pointing. The brickwork is gently eroding in places but otherwise perfectly serviceable. Some of the re-pointing has been poorly executed and the use of hard impervious cementitious mortar has promoted decay of the brickwork in places. Some of the brickwork joints are loose or open jointed.

E.3.494 Within the arches there is evidence of water penetration from the deck above and some of the masonry is damp.

E.3.495 The brick panel in the 2nd arch west from Deptford Creek Lifting Bridge (span 61) is out of plumb and leaning outwards from the structure. The brickwork does not appear to be bonded or tied to the viaduct itself and appears to be poorly founded.

## Sensitivity of the viaduct’s significant elements

E.3.496 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movement on the viaduct.

E.3.497 A combined sewer overflow tunnel (CSO) would pass obliquely beneath the centre of the viaduct at a depth of 41.1m below ground level. The excavated diameter of the CSO would be 6.2m, with an internal diameter of 5m. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the structure, which would in turn induce movement and stresses within the structure itself.

E.3.498 A maximum vertical settlement of 6.3mm is predicted to occur at the west pier to span number 69, the 6th span from west, and the east pier to span number 65, the 7th span from east, the points at which the path of the CSO interfaces with the line of the viaduct above. Because all the piers would be moving in a similar manner, the differential settlement would be relatively small.

E.3.499 The maximum horizontal movement parallel to the viaduct on completion would be small at 0.34mm, occurring at the east end of the viaduct. During construction, horizontal movement parallel to the viaduct would be slightly greater at 0.82mm, occurring at the centre of the viaduct. The maximum horizontal movement perpendicular to the viaduct would be 1.15mm at foundation level, 2.6mm at track level, occurring at the east-most pier.

E.3.500 The tensile stress induced in the structure would be very small (considerably less than 0.05%) and hence the level of predicted damage is considered negligible. The structure has been assessed and compared with the damage risk categories defined by Burland (1977) and Boscardin & Cording (1989); the likely level of damage risk falls within Category 0 – Negligible degree of severity of damage; typically this is no more than hairline cracks.

E.3.501 Architecturally, the viaduct is of simple design with no fine architectural detail or ornamentation. Should for any reason, the predicted ground movements induce hairline cracking, this would not be of detriment to the architectural or historic significance of the viaduct. Hairline cracking would be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric. Given the very low predicted stresses, even hairline cracking seems unlikely in this instance.

E.3.502 The effect of the ground movements on the curvature of the track would be negligible.

### Conclusions

E.3.503 The movements and stresses induced by the tunnel construction would be small, and negligible resultant damage is predicted. The viaduct is of simple design with no fine architectural detail or ornamentation. It is concluded that there would be no risk to the significance of the viaduct from tunnel induced ground movements. There would be no need for any site specific mitigation measures.

E.3.504 Route wide monitoring measures would be adopted during construction, as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2, to ensure that the actual ground movements are within the limits predicted, and control limits established to quantify when intervention may be required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

# Harts Wharf Viaduct

## Description of Harts Wharf Viaduct and its significance

### The viaduct

E.3.505 Harts Wharf Viaduct, historically formed part of London's first passenger railway, the London and Greenwich Railway, which opened in 1836. This was the first steam railway to have a terminus in the capital, the first of any to be built specifically for passenger service, and the first example of an elevated railway.

E.3.506 This viaduct is in fact part of a longer viaduct structure which runs from Greenwich Station westwards to Deptford Creek, and is officially listed as part of the, "Railway Viaduct extending from platforms of Greenwich Railway Station to Deptford Creek," National Heritage List for England Entry Number 1253722 (Listed Building UID 437019). The brick arches of the viaduct are not continuous, however, with a modern steel bridge spanning Norman Road. Harts Wharf Viaduct comprises a length of 13 arches, running from Deptford Creek Lifting Bridge westwards to the west side of Norman Road. A further length of 5 arches continues westwards from the east side of Norman Road up to Greenwich Station. The viaduct carries two tracks between Deptford and Greenwich. This section of viaduct adjoins Deptford Creek Lifting Bridge to the west (BR102), and Norman Road Bridge to the east.

E.3.507 The London and Greenwich Railway was conceived by Colonel G. T. Landmann, a former Royal Engineer, and George Walter. The company was floated on 25 November 1831. An important feature of the railway was that it would run close to London Bridge, thus making it convenient for journeys to the City. The line would eventually be some 4 miles (6 km) in length, the majority elevated on a continuous 878 brick arch viaduct. This was to avoid level crossings over the many streets which were already appearing in the south of London at that time. It was Landmann's original intention that the arches be a means of providing low cost housing, but it was soon apparent that this would be impractical; instead many of the arches became used as workshops. On completion, the line ran from Tooley Street, (now known as London Bridge), to Greenwich. The first section, between Spa Road in Bermondsey and Deptford, opened on 8 February 1836, with the line completed in 1838. The line reached a temporary station at Church Row in Greenwich on 24 December 1838, having been delayed by problems in crossing Deptford Creek. The section of the line passing along Harts Wharf Viaduct was opened in 1838 on completion of the Deptford Creek Lifting Bridge.

E.3.508 By 1844, the annual passenger numbers had risen to over 2 million, with an average fare of 5.2d. The London and Greenwich Railway company continued in existence until January 1923, although by that time control had been passed to South Eastern Railway. Sadly, the company was never financially successful due to the need to repay the very high capital expenditure in building the line.

E.3.509 To overcome the ground conditions encountered along the route, Landmann pioneered the use of concrete to reinforce the foundations beneath the piers of the new elevated railway.

E.3.510 Harts Wharf Viaduct comprises thirteen regular semi-circular arches of similar form to those elsewhere along the route of the former London and Greenwich Railway. The arches are 4 bricks thick, with brick spandrels above. On both sides of the viaduct the brickwork continues upwards to form continuous parapets 1.2m in height. Historic images would appear to indicate that the viaduct was originally built without parapets. The arches are carried on plain rectangular brick piers, 2.2m in height, by 1.2m in width, and 10m in length. The spans match those of the rest of the viaduct and are approximately 5.5m in width.

E.3.511 The viaduct is a utilitarian structure constructed with no attempt at architectural embellishment.

E.3.512 The viaduct appears to have been subject to brick replacement and general refurbishment and repair, but generally retains its original form.

E.3.513 Vol 3 Plate E.113 illustrated the above description.

**Vol 3 Plate E.113 Harts Wharf Viaduct viewed from south-east**

### Significance

E.3.514 Harts Wharf Viaduct is of great historic significance. It forms part of the original viaduct of the London and Greenwich Railway. Built in 1836 to 1838 this was London's first railway, and hence the viaduct is one of the city's earliest railway structures.

E.3.515 The majority of the original historic fabric appears to remain and the fact that it continues in use as a railway to this day makes it an all more remarkable survival.

E.3.516 This stretch of the viaduct running from Greenwich Railway Station to Deptford Creek to Deptford Church Street is one of the best preserved and most attractive stretches of the 6km elevated railway.

E.3.517 The viaduct forms part of the, “Railway Viaduct extending from platforms of Greenwich Railway Station to Deptford Creek,” a Grade II Listed Building, National Heritage List for England Entry Number 1253722.

E.3.518 The piers, arches and spandrels are of architectural and historic significance being contemporary with the original construction of the railway. The date of the parapets is uncertain; for the time being they should be presumed to date from the original construction and be regarded as of equal importance to the structure below. It is presumed that the viaduct deck is of modern date and consequently of lesser significance.

### Condition

E.3.519 The south side of the viaduct was observed from street level during the walkover survey. From visual observation the viaduct appears to be in “fair” condition.

E.3.520 The viaduct appears to be structurally sound and reasonably well maintained.

E.3.521 Self-set vegetation is gaining a hold within open joints in the brickwork.

E.3.522 The brickwork shows evidence of a long history of patch repairs and re-pointing. The brickwork is gently eroding in places but otherwise perfectly serviceable. Some of the re-pointing has been poorly executed and the use of hard impervious cementitious mortar has promoted decay of the brickwork in places. Some of the brickwork joints are loose or open jointed.

E.3.523 Within the arches there is evidence of water penetration from the deck above and some of the masonry is damp.

### Sensitivity of the viaduct’s significant elements

E.3.524 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movement on the viaduct.

E.3.525 Two items of work are proposed in the vicinity of Harts Wharf Viaduct, the construction of which would induce ground movement.

E.3.526 The Greenwich Pumping Station shaft is to be constructed close to Norman Road, approximately 40m to the south of the viaduct. The excavated diameter of the shaft would be 22.4m, with an internal diameter of 17m; the shaft foundations would be at a depth of 52m below ground level. Running north-westwards from the shaft on a converging path to the viaduct would be a combined sewer overflow tunnel (CSO).

E.3.527 At its closest point, the combined sewer overflow tunnel would pass within 16m of Harts Wharf Viaduct at a depth of approximately 40.4m below ground level. The excavated diameter of the CSO would be 6.2m, with an internal diameter of 5m.

E.3.528 Analysis has shown that the CSO would be the main contributor to any ground movements experienced by the viaduct, but due to its proximity, the pumping station shaft would also have some effect. The combined effects have been assessed.

E.3.529 The construction works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the structure, which would in turn induce movement and stresses within the structure itself. In broad terms, the greatest settlement is predicted to occur on the south side of the west most piers nearest the CSO, and to those piers nearest the Greenwich Pumping Station shaft. The ground movements would cause the structure to rotate southwards. The greatest ground movements would occur at the completion of construction.

E.3.530 The greatest settlement is predicted to occur at the west abutment, with a settlement at the centreline of 3.2mm, and on the south side of 4mm. The maximum horizontal movement parallel to viaduct would be small at 0.76mm, occurring adjacent to the shaft. The maximum horizontal movement perpendicular to the viaduct would be 3.2mm at foundation level, 6.7mm at track level, again occurring adjacent to the shaft.

E.3.531 The tensile stress induced in the structure would be very small (less than 0.05%) and hence the level of predicted damage is considered negligible. The structure has been assessed and compared with the damage risk categories defined by Burland (1977) and Boscardin & Cording (1989); the likely level of damage risk falls within Category 0 – Negligible degree of severity of damage; typically this is no more than hairline cracks.

E.3.532 Architecturally, the viaduct is of simple design with no fine architectural detail or ornamentation. Should for any reason, the predicted ground movements induce hairline cracking, this would not be of detriment to the architectural or historic significance of the viaduct. Hairline cracking would be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric.

E.3.533 The effect of the ground movements on the curvature of the track would be negligible.

### Conclusions

E.3.534 The movements and stresses induced by the tunnel construction would be small, and negligible resultant damage is predicted. The viaduct is of simple design with no fine architectural detail or ornamentation. It is concluded that there would be no risk to the significance of the viaduct from tunnel induced ground movements. There would be no need for any site specific mitigation measures.

E.3.535 Route wide monitoring measures would be adopted during construction, as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2, to ensure that the actual ground movements are within the limits predicted, and control limits established to quantify when intervention may be required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

E.3.536 The viaduct would be protected from damage from construction works at the adjacent Greenwich Pumping Station site as described in the Thames Water *Code of Construction Practice*, Part B, Greenwich Pumping Station, chapter 12.

# Deptford Creek Lifting Bridge

## Description of Deptford Creek Lifting Bridge and its significance

### The bridge

E.3.537 Deptford Creek Lifting Bridge historically formed part of London's first passenger railway, the London and Greenwich Railway, opened in 1836. It was the first steam railway to have a terminus in the capital, the first of any to be built specifically for passenger service, and the first example of an elevated railway.

E.3.538 The railway was conceived by Colonel G. T. Landmann, a former Royal Engineer, and George Walter. The company was floated on 25 November 1831. An important feature of the railway was that it would run close to London Bridge, thus making it convenient for journeys to the City. The line would eventually be some 4 miles (6 km) in length, the majority elevated on a continuous 878 brick arch viaduct. This was to avoid level crossings over the many streets which were already appearing in the south of London at that time. It was Landmann's original intention that the arches be a means of providing low cost housing, but it was soon apparent that this would be impractical; instead many of the arches became used as workshops. On completion, the line ran from Tooley Street, (now known as London Bridge), to Greenwich. The first section, between Spa Road in Bermondsey and Deptford, opened on 8 February 1836, with the line completed in 1838. The line reached a temporary station at Church Row in Greenwich on 24 December 1838, having been delayed by problems with the Deptford Creek lift bridge. The present Greenwich station opened on 12 April 1840.

E.3.539 By 1844, the annual passenger numbers had risen to over 2 million, with an average fare of 5.2d. The London and Greenwich Railway company continued in existence until January 1923, although by that time control had been passed to South Eastern Railway. Sadly, the company was never financially successful due to the need to repay the very high capital expenditure in building the line.

E.3.540 One of the many challenges to overcome in the construction was in crossing Deptford Creek. Landmann had pioneered the use of concrete to reinforce foundations along the route of the viaduct, but even so, he experienced great difficulties with the foundations here at Deptford Creek. This probably explains why the bridge has been replaced on successive occasions.

E.3.541 The first bridge was a balanced lifting bridge, required to permit the passage of masted vessels in and out of the creek to the Thames. This was operated by 8 men. A pen and ink sketch of 1841, gives us a representation as to how the original bridge may have appeared. The original bridge was replaced in 1884 by a similar double drawbridge, more utilitarian in character, with each section winched up to a simple steel frame superstructure on either side of the bridge. A photograph of 1932 in the National Maritime Museum illustrates the bridge in operation, see below, and drawings of this later bridge are contained in Appendix C of the Settlement Assessment Report. The present bridge was designed by A H

Cantrell, Chief Civil Engineer, British Rail Southern Region, and built by Sir William Arrol & Co. of Glasgow, and was opened in December 1963.

E.3.542 The present bridge comprises two spans with a central pier located in the middle of the creek. The east span (9.6m) comprises a vertical lifting bridge, whilst the west span (8.25m) comprises a brick arch. Historically, it would appear that it has only ever been the east span which has incorporated an opening mechanism, whilst the west span has been a fixed structure. The two spans in the original bridge appear to have been similar in character, presumably fabricated in iron, set between the masonry abutments and central pier. With the reconstruction of the bridge in 1884, both spans were replaced. The east opening span was fabricated in iron and timber, whilst the west fixed span was replaced with the brick arch extant today. The 1963 bridge saw the replacement of the opening span and associated works to the abutments, central pier and cutwaters.

E.3.543 The central monumental sandstone pier is contemporary to the 1838 viaduct, although it has been subject to a degree of alteration to accommodate the replacement spans.

E.3.544 The cut waters to the east span have opposing slots on their south side which may have previously accommodated dock gates.

E.3.545 The present bridge comprises two spans across the dual channels of the creek at this point. The west channel is bridged by a brick arch. The arch has five orders of bricks laid soldier course, with brick spandrels, and parapets surmounted by galvanised steel guard rails. The brick parapets are of a different brick to the arch and appear to later in date. The arch and central pier are included in the listing for the viaduct between Deptford Creek and North Kent Junction (National Heritage List for England Entry Number 1253151). The east channel is bridged by the vertical lift bridge. This comprises four braced, square-section, steel columns (approximately 20m in height) containing the lifting hoists, one pair on either side of the channel, joined by a steel box-truss. The two supports are linked at their centre by a further truss (parallel with the railway line) which carries the enclosed steel-clad gantry containing the electrical operating gear. The supports rest on large concrete blocks, which in turn rest on the footings of the original bridge, encased in dressed Portland stone. The vertical lift track section is supported on large steel I-beams which bear the name of the Lanarkshire Steel Company. The parapets to the lifting section comprise metal railings cantilevered out from the outer edge beams.

E.3.546 The lifting bridge is no longer operational and was welded shut in the late 1970’s. The lifting mechanism was disconnected and the counterweights removed.

E.3.547 The lifting bridge is a purely utilitarian structure constructed with no attempt at architectural embellishment.

E.3.548 Although not separately listed, the lifting bridge is regarded as being a curtilage structure the adjoining Grade II listed viaducts to east and west, and hence has the same level of statutory protection as that afforded to the viaducts themselves.

E.3.549 Immediately to the south side of the Lifting Bridge is a steel footbridge of modern date which replaced an earlier structure known as the, “Ha’penny Hatch,” which provided a pedestrian crossing over the creek for a halfpenny charge.

E.3.550 Vol 3 Plate E.114 to Vol 3 Plate E.122 illustrate the above description.

**Vol 3 Plate E.114 Deptford Creek Lifting Bridge viewed from south-east**

**Vol 3 Plate E.115 Deptford Creek Lifting Bridge viewed from south-west**

**Vol 3 Plate E.116 Footbridge**

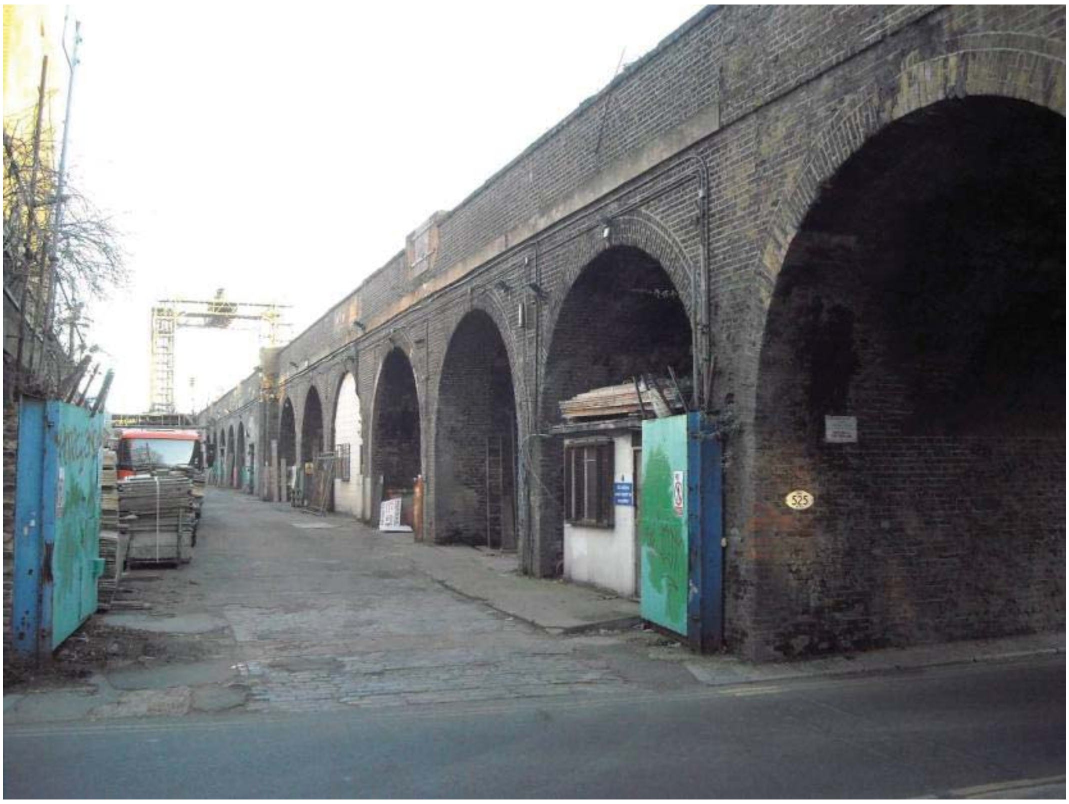
**Vol 3 Plate E.117 Central pier east face**

**Vol 3 Plate E.118 West arch**


**Vol 3 Plate E.119 West arch and abutment**

**Vol 3 Plate E.120 West viaduct (south side) viewed from footbridge**

**Vol 3 Plate E.121 West viaduct (north side) viewed from Creekside**



**Vol 3 Plate E.122 Deptford Creek Lifting Bridge viewed from south**

### Significance

E.3.551 The lifting bridge is of modern date and is a curtilage structure to the adjacent Grade II Listed viaducts (National Heritage List for England Entry Numbers 1253151and 1253722). The bridge was recently assessed by English Heritage for potential designation, following a proposal by Network Rail to demolish the structure. The assessment report of January 2012 concluded that the bridge was not of sufficient quality or significance to warrant its addition to the List. In its conclusions the report stated that:

E.3.552 "Despite being a local landmark with a considerable presence in the cityscape and the successor to earlier railway bridges across Deptford Creek, for which it is certainly of local interest, the Deptford Creek vertical lift bridge has neither special architectural nor historic interest in a national context. In architectural terms it is purely functional and is not innovative in its use of materials, design or technology. Historically it is of a relatively recent date and whist an unusual (for this country) building type it is not the earliest surviving vertical lift bridge nor is it the earliest railway example. For these reasons it is not recommended for designation."

E.3.553 "The railway vertical lift bridge over Deptford Creek, built in 1963, is not recommended for designation for the following principal reasons:

a. Lack of architectural interest: although a relatively rare type of lifting bridge in this country, it is a purely utilitarian structure of steel, box-frame construction. Elements of its design are crude and it lacks any design quality or the grandeur of scale exhibited by the listed example across the River Tees dating from the 1930s;

b. Lack of technological innovation: vertical lift bridges have been in use since the mid-C19 and large scale, steel-built examples since the 1890s with little change in the basic technology. It no longer functions as a lifting bridge;

c. Lack of historical interest: of relatively late date, particularly in terms of the history of the railways."

E.3.554 Although not included on the national list of buildings of architectural or historic interest, the lifting bridge has been recommended for inclusion on the local list administered by the London Borough of Lewisham. The bridge stands within the Deptford Creekside Conservation Area and is cited in the draft Deptford Creekside Conservation Area Character Appraisal (public consultation draft December 2011) as both a notable building and key landmark.

E.3.555 Discussions with local authority planning officers have also confirmed that the lifting bridge would be regarded as a curtilage structure to the Grade II Listed viaducts.

E.3.556 The central pier and abutments of the bridge are of great historic significance as these are contemporary with the original viaducts and hence to the construction of London and Greenwich Railway. The pier and abutments contain original fabric and monumental architectural detailing.

E.3.557 The brick arch is of later date (1884) and of lesser significance to the other components of the structure being neither contemporary to the original construction of the railway, nor of outstanding historic, archaeological, architectural, or artistic interest. The arch does, however, provide a physical record of the historic development of the bridge.

E.3.558 The adjacent footbridge is not of significance.

### Condition

E.3.559 The south side of the bridge was observed from the adjacent public footpath and footbridge during the walkover survey. From visual observation the bridge appears to be in "fair" condition.

E.3.560 Although the bridge appears to be structurally sound, maintenance works are becoming necessary. The surface coatings appear to have weathered away, exposing the underlying metalwork, and surface corrosion is now widespread. This gives the bridge a somewhat dilapidated appearance.

E.3.561 The concrete bank seats supporting the lifting deck are weathered and covered with a heavy build-up of guano.

E.3.562 Self-set vegetation is gaining a hold on the central pier and abutments. The stonework on the south side of the west abutment is heavily eroded in its upper section, including to the dentils set below the deep cornice. There is a heavy build of sulphates which will cause further damage to the masonry in the longer term. Above the cornice, the stonework appears to have been displaced. Beneath the span of the bridge, the west abutment is open jointed at lower level.

E.3.563 The central pier displays deep open joints at water level throughout. The east face is particularly eroded at water level with some stonework potentially loose. At higher level on this face, there is evidence of horizontal cracking within the stones themselves. Whether this is as a result of historic movement or cramp damage would require further investigation.

E.3.564 The east abutment is similarly eroded at low level with deep open joints and areas of loose stonework.

E.3.565 The brickwork on the south face of the west span is spalling and displays some surface efflorescence, probably as result of water permeating through the bridge deck above. The erosion is exacerbated by the hard cementitious mortar used in subsequent repointing.

E.3.566 The viaduct to the west has been much patched. The two adjacent arches have been infilled in brickwork on their south side, although they remain open to the north. The brick panel in the 2nd arch west from the bridge is out of plumb and leaning outwards from the structure. The brickwork does not appear to be bonded or tied to the viaduct itself and appears to be poorly founded.

### Sensitivity of the bridge's significant elements

E.3.567 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movements on the bridge.

E.3.568 A combined sewer overflow tunnel would pass close to the south side of the bridge at a depth of 38.5m below river bed level. With the tunnel passing obliquely to the south of the bridge, the structure would be subject to a complex set of movements both vertically and horizontally. Horizontal movements perpendicular to the span of the bridge would be greater than those parallel to the span. The foundations would settle differentially to give a slight downward tilt from north to south, with each abutment and pier settling differentially to its neighbour. The total horizontal movement perpendicular to the span of bridge would be 1.2mm at foundation level and negligible parallel to the bridge. Ground movements at foundation level would serve to increase the amount of horizontal movement at superstructure level. This would result in a maximum horizontal movement 0.3mm parallel to the span, and 3.2mm perpendicular to the span. However, because the abutments and piers would be moving in a similar manner, the differential horizontal movements at superstructure level would be small at 0.1mm parallel to the span, and 0.2mm perpendicular to the span.

E.3.569 The maximum vertical settlement at the abutments would be less than 5mm. Again, however, because the abutments and piers would be moving in a similar manner, the differential settlement would be relatively small. The maximum differential vertical settlement between the east abutment and central pier would be 0.7mm, and between the west abutment and central pier 0.6mm. The maximum differential settlement north to south perpendicular to the span would be 2.2mm. It would be the settlement and subsequent movement perpendicular to the bridge which would induce the greatest stresses. Due to the relatively small differential movements, however, the additional stresses induced in the structure would also be small.

E.3.570 The additional stress in the steel deck as a result of ground movements has been found to be negligible.

E.3.571 The additional stress induced in the lifting towers has been found to be small. The additional loads in combination with the existing loads induced by thermal actions would be comfortably accommodated.

E.3.572 The effects of ground movements on the arch have been found to be minimal. A hairline crack of 0.1mm may develop in the arch barrel due to the differential settlement. This would not affect the significance, appearance or strength of the structure.

E.3.573 The abutments have been assessed and compared with the damage risk categories defined by Burland (1977) and Boscardin & Cording (1989); the likely level of damage risk falls within Category 0 – Negligible degree of severity of damage; typically this is no more than hairline cracks.

E.3.574 Architecturally, the bridge is of bold design with no fine architectural detail or ornamentation. Should for any reason, the predicted ground movements induce hairline cracking, this would not be of detriment to the architectural or historic significance of the bridge. Hairline cracking would be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric.

### Conclusions

E.3.575 The movements and stresses induced by the tunnel construction will be small, and negligible resultant damage is predicted. The bridge is of bold design with no fine architectural detail or ornamentation. It is concluded that there would be no risk to the significance of the bridge from tunnel induced ground movements. There would be no need for any site specific mitigation measures.

E.3.576 Route wide monitoring measures would be adopted during construction, as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2, to ensure that the actual ground movements are within the limits predicted, and control limits established to quantify when intervention may be required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

## Railway Bridge over Deptford Church Street

### Description of Railway Bridge over Deptford Church Street and its significance

#### The bridge

E.3.577 The Railway Bridge over Deptford Church Street, historically formed part of London's first passenger railway, the London and Greenwich Railway, which opened in 1836. This was the first steam railway to have a terminus in the capital, the first of any to be built specifically for passenger service, and the first example of an elevated railway.

E.3.578 The bridge is fact part of a long viaduct which runs from Deptford Creek through to North Kent Junction, near South Bermondsey Station, and is officially listed as part of the, "Railway Viaduct between Deptford Creek and North Kent Junction," National Heritage List for England Entry Number 1253151.

E.3.579 The bridge was built in c.1969, replacing the original arched structure, to accommodate the widening of Deptford Church Street in the late 1960's / early 1970's. The modern steel single-span bridge is utilitarian in character and is not regarded as being of archaeological, architectural or artistic significance.

E.3.580 However, although not separately listed, due to its proximity and attachment to the Listed viaduct, and the fact that the bridge carries the historic route of the original London and Greenwich Railway, it is regarded as being a curtilage structure to the adjoining Grade II listed viaduct on either side, and hence has the same level of statutory protection as that afforded to the viaduct itself.

E.3.581 The London and Greenwich Railway was conceived by Colonel G. T. Landmann, a former Royal Engineer, and George Walter. The company was floated on 25 November 1831. An important feature of the railway was that it would run close to London Bridge, thus making it convenient for journeys to the City. The line would eventually be some 4 miles (6 km) in length, the majority elevated on a continuous 878 brick arch viaduct. This was to avoid level crossings over the many streets which were already appearing in the south of London at that time. It was Landmann's original intention that the arches be a means of providing low cost housing, but it was soon apparent that this would be impractical; instead many of the arches became used as workshops. On completion, the line ran from Tooley Street, (now known as London Bridge), to Greenwich. The first section, between Spa Road in Bermondsey and Deptford, opened on 8 February 1836, with the line completed in 1838. The line reached a temporary station at Church Row in Greenwich on 24 December 1838, having been delayed by problems in crossing Deptford Creek. The section of the line passing over Creekside was opened in 1838 on completion of the Deptford Creek Lifting Bridge.

E.3.582 By 1844, the annual passenger numbers had risen to over 2 million, with an average fare of 5.2d. The London and Greenwich Railway company continued in existence until January 1923, although by that time control had been passed to South Eastern Railway. Sadly, the company was never financially successful due to the need to repay the very high capital expenditure in building the line.

E.3.583 To overcome the ground conditions encountered along the route, Landmann pioneered the use of concrete to reinforce the foundations beneath the piers of the new elevated railway.

E.3.584 The Railway Bridge over Deptford Church Street originally comprised a wide elliptical arch over the road, with smaller side arches on either side to accommodate the footpaths, breaking the otherwise regular repetitive rhythm of the viaduct. With the widening of Deptford Church Street to a dual carriageway, a new single-span steel bridge was constructed which saw not only the loss of the original road and footpath crossings, but a further two arches of the viaduct as well.

E.3.585 The present bridge comprises a single span of approximately 23m. The superstructure comprises two steel box girders connected with sixteen cross girders at right angles and is in-filled with a reinforced concrete deck. The depth of the main box girders is 1.98m with the total width of the bridge deck 9.8m. The superstructure is supported on steel bearings mounted on a reinforced concrete cill beam on top of the abutments. The abutments are of mass concrete with brick cladding. The abutment foundations are ground bearing of mass concrete and brick construction. The bridge is surmounted by a parapet comprising a steel rectangular hollow section handrail fixed to the main box girder.

E.3.586 The bridge is a utilitarian structure constructed with no attempt at architectural embellishment.

E.3.587 Vol 3 Plate E.123 and Vol 3 Plate E.124 illustrate the above description.

**Vol 3 Plate E.123 Railway Bridge over Deptford Church Street viewed from south**

**Vol 3 Plate E.124 Railway Bridge over Deptford Church Street viewed from north**

### Significance

E.3.588 The Railway Bridge over Deptford Church Street is not regarded as being of archaeological, architectural or artistic significance. However, although not separately listed, due to its proximity and attachment to the Listed viaduct, and the fact that the bridge carries the historic route of the original London and Greenwich Railway, it is regarded as being a curtilage structure to the adjoining Grade II listed viaduct on either side, and hence has the same level of statutory protection as that afforded to the viaduct itself.

E.3.589 Due to bridge being a curtilage structure, the potential effects of the predicted ground movements must none the less be duly considered.

E.3.590 The bridge borders the south-east corner of the St Paul’s Conservation Area, Deptford.

### Condition

E.3.591 Both sides of the bridge were observed from street level during the walkover survey. From visual observation the bridge appears to be in “fair” condition.

E.3.592 The bridge appears to be structurally sound and reasonably well maintained. The surface coatings to the metalwork, however, are heavily weathered, exposing the underlying metalwork, and as a result surface rusting is widespread.

## Sensitivity of the bridge’s significant elements

E.3.593 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movements on the bridge.

E.3.594 A combined sewer overflow tunnel would pass 30m to the north of the bridge at a depth of 42.5m below ground level. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the structure, which would in turn induce movement and stresses within the structure itself.

E.3.595 A maximum vertical settlement of 3.1mm is predicted to occur at the north end of the east abutment. However, because the abutments would be moving in a similar manner, the differential settlement would be relatively small. The vertical differential settlement calculated to be caused by the tunnelling works is calculated as 0.8mm on completion of construction with the east abutment settling more than the west.

E.3.596 A slight downwards tilt from south to north would develop across the width of each abutment, with a maximum tilt of 1.1mm occurring at the east abutment.

E.3.597 Horizontal movement parallel to the bridge would be very small. Horizontal movement perpendicular to the bridge would be a maximum of 2.7mm at superstructure level.

E.3.598 The tensile stress induced in the structure would be very small and hence the level of predicted damage is considered negligible. The structure has been assessed and compared with the damage risk categories defined by Burland (1977) and Boscardin & Cording (1989); the likely level of damage risk falls within Category 0 – Negligible degree of severity of damage; typically this is no more than hairline cracks.

E.3.599 Architecturally, the bridge is of simple design with no fine architectural detail or ornamentation. Although a curtilage Listed structure, the bridge is not regarded as being of archaeological, architectural or artistic significance. Should for any reason, the predicted ground movements induce hairline cracking, this would not be of detriment to the architectural or historic significance of the bridge. Hairline cracking would be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric.

### Conclusions

E.3.600 The movements and stresses induced by the tunnel construction would be small, and negligible resultant damage is predicted. The bridge is of simple design with no fine architectural detail or ornamentation and is not regarded as being of archaeological, architectural or artistic significance. It is concluded that there would be no risk to the significance of the bridge from tunnel induced ground movements. There would be no need for any site specific mitigation measures.

# DLR brick arched viaduct over Island Row

## Description of DLR brick arched viaduct over Island Row and its significance

### The viaduct

E.3.601 The DLR Brick Arch Viaduct at Island Row is a Grade II Listed Building and is officially Listed as, “Railway Viaduct to North of Regents Canal Dock between and including Branch Road Bridge and Limehouse Cut up to Three Colt Street,” National Heritage List for England Entry Number 1242220 (Listed Building UID 441615). The viaduct under consideration in the settlement assessment forms but part of this longer viaduct structure.

E.3.602 The viaduct was constructed in 1839 by engineers George Stephenson and G P Bidder and was built as part of the London & Blackwall Railway, which opened in 1840. The entire structure comprises several lengths of brick arched viaduct interspersed by three elliptical arch bridges over Branch Road, the Grand Union Canal, and Limehouse Cut, and a further three simply supported underbridges over Basin Approach, Mill Place, and Island Row. The majority of the structure lies outside the zone of tunnel induced settlement. All three elliptical arch bridges over Branch Road, the Grand Union Canal, and Limehouse Cut lie outside the zone of influence. The underbridge over Basin Approach also lies outside. Those parts of the structure which do lie inside the zone of influence comprise 17 arches of the multi-span masonry viaduct, and the underbridges over Mill Place and Island Row.

E.3.603 The viaduct is of architectural and historic significance forming part of one of the earliest railways to serve the docks, before the great railway expansion of the 1840’s. It was built by one the century’s great engineers, George Stephenson, and its fine arches and skilfully designed bridges are of considerable architectural merit.

E.3.604 The multi-span arch viaduct is constructed of London stock brick and features an articulated stone stringcourse supported on console corbels, with a brick parapet above. The brick parapet is surmounted by a railing comprising cast-iron posts with two horizontal wrought-iron rails between. The arches span between 9m and 12m. The underbridges were rebuilt in the 1980’s to carry the twin track DLR. Each now comprises a series of pre-stressed concrete reinforced concrete beams with a 150mm thick concrete slab above. The original cast-iron outer girders remain in place and at Mill Place there are also longitudinal cast-iron props beneath the concrete deck beams. The abutments to the underbridges are original and comprise of mass brickwork probably built of spread footings of brickwork or possibly mass concrete.

E.3.605 The viaduct appears to have been subject to brick replacement and general refurbishment and repair, but generally retains its original form. The underbridges have been substantially rebuilt but outwardly retain their original appearance.

E.3.606 Vol 3 Plate E.125 to Vol 3 Plate E.128 illustrates the above description.

**Vol 3 Plate E.125 Aerial view of DLR Viaduct at Island Row viewed from the south**

**Vol 3 Plate E.126 DLR Viaduct viewed from south-west**

**Vol 3 Plate E.127 Underbridge over Mill Place**

**Vol 3 Plate E.128 Underbridge over Island Row**

### Significance

E.3.607 The DLR Brick Arch Viaduct at Island Row is of great historic significance. It forms part of the original Blackwall & London Railway. Originally called the Commercial Railway, the London & Blackwall railway ran from Minories to Blackwall via Stepney, with a branch line to the Isle of Dogs, thus connecting central London to many of the docks. It was operational from 1840 to 1926 for passengers, and until 1968 for goods, closing after the decline of London’s inner docks. Much of the former infrastructure was to be re-used by the Dockland Light Railway.

E.3.608 This was one of London's earliest railways and was unusual in that it was operated by cable haulage for the first nine years. The engines to drive the cable winding gear were located a short distance from each of the terminals, at Minories and Blackwall. From the cable houses there was an upwards gradient to slow down arriving trains and enable departing trains to run to the winding station under their own impetus. Each of the two tracks had its own hemp rope some seven miles in length. The hemp ropes were replaced with wire in 1841. With expansion of the railway it was decided to change the gauge and convert to steam haulage, re-opening in 1849.

E.3.609 The majority of the original historic fabric appears to remain and the fact that it continues in use as a railway to this day makes it an all more remarkable survival, due largely to its re-use for the DLR.

E.3.610 This stretch of the viaduct running from Limehouse Cut to Mill Pace has been subject to alteration. A number of the arches have been infilled, and the underbridges rebuilt. None the less the viaduct remains an impressive structure and local landmark which contributes positively to the St Annes Church, Regents Canal, and neighbouring Narrow Street Conservation Areas.

E.3.611 The multi-span viaduct and underbridges form part of the, “Railway Viaduct to North of Regents Canal Dock between and including Branch Road Bridge and Limehouse Cut up to Three Colt Street,” a Grade II Listed Building, National Heritage List for England Entry Number 1242220 (Listed Building UID 441615).

E.3.612 The viaduct stands within Tower Hamlet’s St Annes Church and Regents Canal Conservation Areas and borders Tower Hamlet’s Narrow Street Conservation Area which lies immediately to the south. The viaduct provides a prominent and positive contribution to all three conservation areas as well as defining the boundary between them.

E.3.613 The viaduct is of group value with other heritage assets in the vicinity for which it contributes to their setting, including the Former Railway Lookout Tower (Grade II), and Accumulator Tower & Chimney (Grade II) which stand immediately adjacent on the north side of the viaduct, Limehouse District Library and its associated Gate Piers and Railings (all Grade II), 604-608 Commercial Road (Grade II), and the British Sailors Society (Grade II).

E.3.614 The viaduct is of architectural and historic significance and railway engineering interest forming part of one of the earliest railways to serve the docks, before the great railway expansion of the 1840’s. The railway was to revolutionise docking methods and buildings in the 1850’s. It was built by one the century’s great engineers, George Stephenson, and its fine arches and skilfully designed bridges are of considerable architectural merit.

E.3.615 The majority of the fabric of the multi-span viaduct is contemporary to the original construction of the railway and hence of equally high architectural and historic significance. The underbridges, however, were rebuilt in the 1980’s as part of the DLR construction works and with the exception of the outward facing cast-iron girders, their fabric was renewed. Consequently, the underbridges are of lesser significance. None the less, all parts of the structure are statutorily Listed and protected under planning law.

#### Condition

E.3.616 Both sides of the viaduct were observed from street level during the walkover survey. From visual observation the viaduct appears to be in “good” condition.

E.3.617 The viaduct appears to be structurally sound and reasonably well maintained. The metalwork appears to be regularly painted and little self-set vegetation is evident.

E.3.618 The brickwork shows evidence of repair and re-pointing. The brickwork is gently eroding and spalled in places but otherwise perfectly serviceable. Some of the re-pointing has been poorly executed and the use of hard impervious cementitious mortar has promoted decay of the brickwork in places. Some of the brickwork joints are loose or open jointed.

E.3.619 There are areas of efflorescence within the arches and on the underbridge abutments. Water penetration from the deck above is leading to wet patches on the brickwork below.

E.3.620 There are areas of minor cracking within the brickwork joints which may result from slight differential and thermal movements.

### Sensitivity of the bridge’s significant elements

E.3.621 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movements on the viaduct.

E.3.622 The main Thames Tideway Tunnel would pass obliquely beneath the viaduct in a south-west to north-east direction, under three spans between Mill Place and Island Row before travelling north-east under the Limehouse Cut.

E.3.623 By this point, the main Thames Tideway Tunnel would be running at significant depth passing 53m below the foundations of the viaduct.

E.3.624 The predicted ground movements for the multi-span arched viaduct structure between Basin Approach and Island Row are relatively small and would not cause significant effects on the arch superstructures and substructures. The tensile stress induced in the structure would be very small (considerably less than 0.05%) and hence the level of predicted damage is considered negligible. The structure has been assessed and compared with the damage risk categories defined by Burland (1977) and Boscardin & Cording (1989); the likely level of damage risk falls within Category 0 – Negligible degree of severity of damage; typically this is no more than hairline cracks.

E.3.625 The magnitude of the predicted ground movements for the composite underbridge structures is also small. At Island Row underbridge, differential settlement between abutments of 0.96mm and horizontal movement of 1.88mm are predicted. At Mill Place underbridge, differential settlement of 2.00mm and horizontal movement of 1.99mm are predicted. These magnitudes are considered to be insignificant and as such would have a negligible effect on the composite structure. As described above, the Basin Approach underbridge lies outside the zone of settlement.

E.3.626 Architecturally, the viaduct and underbridges are of simple design with no fine architectural detail or ornamentation. The underbridges are free to articulate on elastomeric bearings. Should for any reason, the predicted ground movements induce hairline cracking within the masonry, this would not be of detriment to the architectural or historic significance of the viaduct. Hairline cracking would be repaired during the cyclical maintenance programme if desired, although the act of re-pointing could actually risk causing far greater damage to the historic fabric than simply leaving it. Hairline cracking would not affect the performance or longevity of the structural fabric. Given the very low predicted stresses, even hairline cracking seems unlikely in this instance.

E.3.627 The effect of the ground movements on the curvature of the track would be negligible.

### Conclusions

E.3.628 The movements and stresses induced by the tunnel construction would be small, and negligible resultant damage is predicted. The viaduct is of simple design with no fine architectural detail or ornamentation within the section under consideration. It is concluded that there would be no risk to the significance of the viaduct from tunnel induced ground movements. There would be no need for any site specific mitigation measures.

E.3.629 Route wide monitoring measures would be adopted during construction, as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2, to ensure that the actual ground movements are within the limits predicted, and control limits established to quantify when intervention may be required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

E.3.630 The tracks would be monitored during construction of the Thames Tideway Tunnel to ensure that any track movement is within DLR's track tolerance limits.

# Twelvetrees Crescent Bridge

## Description of Twelvetrees Crescent Bridge and its significance

### The bridge

E.3.631 Twelvetrees Crescent Bridge is a wrought and cast-iron bridge which spans the Lea Navigation and Bow Creek immediately north of Bow Locks. The bridge was built in 1872 for the Imperial Gaslight and Coke Company to give access to their gas works which were built on the east side of the creek in 1873. The bridge was designed by civil engineer Peter William Barlow (1809 to 1885). Barlow was a renowned bridge engineer and is probably best known for his work on the first Lambeth Bridge and for his advances in tunnel construction, patenting designs for the cylindrical tunnelling shield which was to be used in the digging of the Tower Subway in 1870. Today, the bridge carries an unadopted highway across the creek and navigation to the ProLogis Park industrial estate.

E.3.632 The bridge was strengthened in the 1990’s.

E.3.633 The bridge comprises two spans with a central pier and abutments. The widest span is over the Lea Navigation at c.42m, with a span of c.39m over Bow Creek, which runs parallel to the navigation at this point. The spans comprise shallow wrought-iron arches which bear onto a central brick pier and long brick abutments. The spans are constructed from seven wrought-iron “I”-section girders, fabricated from riveted plates and angle sections, cross-braced at regular intervals along their length with a slender lattice of wrought-iron members. Strengthening plates have been bonded to the bottom flange of each girder over the mid span. A reinforced concrete deck slab spans transversely across the girders. The deck is attached to the top flange of the inner three girders, while the outer four girders have the deck slab cast around the top flange. The deck is relatively new and was installed as part of the strengthening works in the 1990’s by Robert West Consulting. The carriageway and footways are placed directly on top of the reinforced concrete deck incorporating a waterproofing layer. A vaulted tunnel passes through the width of the east abutment.

E.3.634 The bridge is of elegant design with a shallow camber along its length. The spandrels are of simple iron plate with no ornamentation. A cast-iron cornice projects above the spandrel, with a cast-iron balustrade parapet of interlacing segmental arches and simple moulded handrail above. The parapet has been raised with the addition of a modern tubular steel key clamp type handrail which is secured to the original with steel brackets and straps. The spans are separated by the masonry of the central pier which rises up between them. The bridge is surmounted by six cast-iron gas lamp holders, one to each side of the central pier and each abutment. The brick pier and abutments are faced in stone on their outward (north and south) elevations, with a simple moulded stone cornice returning at the springing of the arches. The metalwork is painted off-white, which contrasts with the weathered and blackened appearance of the sandstone masonry. At deck level, the carriageway is of asphalt finish with asphalt and raised concrete kerbs to the footways.

E.3.635 Little is known about the foundations of the bridge but given its date it is presumed to be founded on pad type masonry foundations.

E.3.636 There are no movement joints.

E.3.637 The strengthening works undertaken in the 1990's included a new deck, additional cross bracing, and bonded flange plates to the main girders.

E.3.638 Vol 3 Plate E.129 to Vol 3 Plate E.138 illustrate the above description

**Vol 3 Plate E.129 Twelvetrees Crescent Bridge viewed from south (Bow Locks)**

**Vol 3 Plate E.130 West span viewed from south**

**Vol 3 Plate E.131 East span viewed from south**

**Vol 3 Plate E.132 Underside of west span, with 1990's strengthening plates to girders**

**Vol 3 Plate E.133 Deck level looking eastwards**

**Vol 3 Plate E.134 Cast-iron balustrade and handrail, note cracking**

**Vol 3 Plate E.135 Historic gas lamp on south-east abutment (one of six)**

**Vol 3 Plate E.136 Detail of gas lamp base displaying manufacturer's name**


**Vol 3 Plate E.137 View of Bow Locks from Twelvetrees Crescent Bridge**

**Vol 3 Plate E.138 View north along Limehouse Cut towards Bow Locks and bridge**

### Significance

E.3.639 Twelvetrees Crescent Bridge is an elegant structure of its type, displaying an interesting mix of iron and masonry. The bridge is a significant landmark within the historic setting of Bow Locks.

E.3.640 The bridge is of group value and stands within the setting of the former gas works.

E.3.641 The piers, abutments and the majority of the superstructure including the balustrade and gas lamps are of considerable significance. The deck, together with the carriageway and footways, however, are of recent date and of no architectural, artistic, archaeological or historic significance.

E.3.642 The bridge is a Grade II Listed Building.

E.3.643 The west most part of the bridge lies with the London Borough of Tower Hamlets Limehouse Cut Conservation Area. The remainder of the bridge lies within the London Borough of Newham.

### Condition

E.3.644 The bridge was observed in detail from street level during the walkover survey. From visual observation the bridge appears to be in “good” condition.

E.3.645 The bridge appears to be structurally sound and reasonably well maintained.

E.3.646 The bridge deck was strengthened in the 1990’s.

E.3.647 The stonework and brickwork of the abutments and pier are generally open jointed with some areas of masonry suffering erosion. Self-set vegetation is gaining a hold. The brickwork has areas of efflorescence and the sandstone carries sooty deposits. The surface coatings to the metalwork are starting to degrade with surface corrosion evident in many places. Corrosion is worst on the outer face of the outer girders, due to water run-off from the balustrade and cornice above. A steel fence has been bolted to the top of the west abutment approach walls; this is leaning, causing damage to the brickwork below. The historic cast-iron handrail is cracked and corroded in a number of places.

### Sensitivity of the bridge’s significant elements

E.3.648 Detailed structural calculations have been undertaken by Thames Water to assess the effect of ground movements on the bridge.

E.3.649 The main Thames Tideway Tunnel would pass obliquely beneath the central pier at some depth within the underlying chalk. The tunnel works would cause some vertical settlement, horizontal movement, and rotation of the ground beneath the pier, which would in turn induce movement and stresses within the superstructure. The maximum predicted settlement of the pier foundations is 15.7mm. Settlement of the pier would lead to deflection of the arch spans on either side.

E.3.650 Analysis has shown that due to the structural design of the bridge, small to moderate settlement of the foundations would only result in small increases in working stress within the main girders. The maximum increase in stress in any one girder has been found to be less than a quarter of the agreed acceptance criteria. It has also been determined that settlement would not result in an increase in stress within the central pier. Due to the inherently brittle nature of the cast-iron, the balustrade parapets have been separately assessed; an increase of less than 1% of capacity is predicted and consequently the parapets are regarded as sufficiently robust to withstand the effects of the predicted settlement.

### Conclusions

E.3.651 It is concluded that no harm would be caused to the special interest or significance of the structure as a result of tunnel induced movements.

E.3.652 Route wide monitoring measures would be adopted during construction, as described in the Thames Water *Code of Construction Practice* (CoCP), Part A, section 13.2, to ensure that the actual ground movements are within the limits predicted, and control limits established to quantify when intervention may be required to prevent damage to the structure. As described in the CoCP, the design and installation of instrumentation and monitoring would be undertaken by the contractor in agreement with Thames Water and the asset owner.

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