This document contains information relevant to the following options:

**Woolwich**
- Ferries
- Bridges
- Tunnels

**Gallions Reach**
- Ferries
- Bridges
- Tunnels

**Belvedere**
- Ferries
- Bridge
- Tunnels

This document investigates and compares the constraints, impacts and costs of fixed high level bridges and tunnels to be built between Rainham and Belvedere.

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1. **Background and Introduction**

In February 2013, Transport for London appointed Atkins to undertake an engineering concept study into the design and construction of a new fixed link bridge at Gallions Reach as part of TfL’s overall East London River Crossings studies. In November 2013, TfL extended this commission to include ascertaining the feasibility of either a fixed bridge or a tunnel from Belvedere, connecting to the A2016 Bronze Age Way) to Barking/Dagenham (connecting to the A13). The brief was to carry out a short high level study to provide information for TfL and was contained in an email from David Fielder of TfL to Chris Mundell of Atkins dated 25th October 2013 (see Appendix A).

The Belvedere site study considered the provision of a dual carriageway link as previously developed for the Gallions Reach study. The provision of a 3.5m wide combined cycleway/footway on one side has been included.

Traffic forecast figures have not been included in this study. The junction designs will depend upon forecast demand and could be the focus of a future study if the option is to be developed further. Tolling facilities are also not included at this stage.

This report presents the findings of this study. The most feasible options for both a bridge and a tunnel are presented, taking into account the various constraints, including navigation and aviation clearances. The impact of the proposals on property, the local roads system and the environment is discussed and broad cost estimates are given for design and construction.

Information has been based on that which is available on public websites, from a site visit using public access and from information provided by TfL, primarily OS mapping. No external consultation has taken place and information obtained has not been externally verified. Views expressed regarding land use and ownership are based on observation only. It has not been part of this study to ascertain land ownership. Given the limited time available for the study there has been no scope to develop and improve the options and optimise the alignment, form of construction and impact of site constraints.
2. Highway Alignment

2.1. Connectivity with existing road network

This study considers a connection from Belvedere A2016 Bronze Age Way to the A13 at Barking/Dagenham as indicated by Figure 1 below.

![Plan of Study Area](image_url)

**Figure 1** Plan of Study Area

The logical points of connection to the existing highway network are:

- Marsh Way junction on the A13 at the eastern end of the Dagenham Ford Motor Works site. The A13 to the west is on an elevated flyover through the Ford Works as far as Ripple Road. To the east the next junction at Ferry Lane is on the edge of Rainham Marshes and would have to cut through Ferry Lane Industrial Estate.

- Picardy Manorway (B253) / Bronze Age Way (A2016) roundabout. To the west are the Crossness Sewage Treatment Works and Crossness Nature Reserve. To the east are Fishers Way Industrial Estate and a number of river wharfs. The river bends to the south at this point towards Erith Reach which would increase the length of any connection between the A13 and A2106 as the alignments diverge.
2.2. **Local topography**

The A13/Marsh Way junction comprises a dumb-bell roundabout arrangement with the number of lanes around the two roundabouts varying between two and three. The additional third lane generally becomes a dedicated lane for the roundabout exits (see Figure 2).

The arms on the southern roundabout comprise the A13 westbound on and off slip roads, Marsh Way and a private access to the Ford Estate. All are single carriageway. On the northern roundabout the arms comprise the A13 east bound on and off slip roads, dual carriageway continuation of Marsh Way, and a dual carriageway link to Consul Avenue.

Between the A13/Marsh Way junction and the River Thames the proposed crossing approach road would pass through land comprising two vehicle hardstanding areas associated with the Ford Estate, crossing Courier Road/Marsh Way and a strip of land bordering an unnamed watercourse. Courier Road runs alongside the unnamed watercourse, generally following the line. This watercourse also runs alongside Marsh Way for part of its length, and crosses underneath both roads through a culvert. A tributary of the watercourse also passes underneath Courier Road and Marsh Way on the approach to the roundabout. The vehicle hardstanding areas are raised relative to Courier Road and the unnamed watercourse. Overhead lines traverse the site, with pylons located on the strip of land. Other structures in the area include two wind turbines located on the western vehicle hardstanding area (see drawing 5118859-DR-D10-001).

On the south bank of the Thames, the A2016 is a dual two lane carriageway joining with the A206 at each end of its 5 mile length. The A2016 Bronze Age Way/Picardy Manorway junction is a standard four arm roundabout, two of the arms being the A2016 dual carriageway, one arm being the single carriageway Anderson Way, which serves several industrial estates along the south bank of the Thames, and the last being the single carriageway B253 Picardy Manorway, leading to Belvedere (see drawing 5118859-DR-D10-001).

![Figure 2](image_url)

**Figure 2** Local topography and highway alignment options

The land between the roundabout and the Thames forms part of the Isis Reach and Belvedere Industrial Estates. On the west side there is Middleton Wharf Riverside Resource Recovery linked to Borax wharf. Between Norman road and a local drainage channel there is an Iron Mountain warehouse, Asda's Erith (Chilled) Distribution Centre and an office supplies depot. These appear to be modern developments (Google maps) built on the former Belvedere power station site. The power station wharf is still existent. Between the drainage channel and Crabtree Manorway North is Burt's Wharf. Burt's Wharf is used by a number of businesses but is relatively undeveloped open yards used for material recycling or a scaffolding storage company. South of Burt's Wharf adjacent to Anderson Way is an insulation supplier (Jablite) and an
Asda Service Centre (recycling). The area east of Crabtree Manorway has a Lidl distribution centre off Fishers Way and a number of other industrial premises.

An approximately constant width strip of landscaped land separates the two industrial estates, and leads from the A2016 to the river. A ditch appears to run along the eastern edge of the strip of land. A shaft linking to a disused former cooling water outfall tunnel is located in the middle of the strip of land as shown on the Port of London Authority map (see Figure 11). The form of the land gives the appearance that it is designated as a wayleave for some purpose; this would need to be investigated further. The land is generally flat but rises on the approach to the river to meet the river wall and Thames Path.

On the south side of the river the A2016 Bronze Age Way/Picardy Manorway Roundabout would need to be enlarged in order to accommodate the additional arm leading to the crossing. This could be elongated towards the west, requiring the realignment and shortening of A2016 Picardy Manorway. The crossing approach road could use the strip of land between the Belvedere and Isis Reach industrial estates, but would also require a strip of land from the Belvedere industrial estate. The existing ditch would be diverted and the existing Jablite factory/warehouse demolished in order to accommodate the proposed entry to the enlarged roundabout. This study shows the Jablite factory as being demolished. Future design development may prove that the factory unit could be retained but at this stage it is conservatively taken as being necessary for the scheme.

Hardstanding and storage areas would also be lost along the western edge of the Belvedere industrial estate. This route would bring the line of the bridge to the east of an existing disused jetty, allowing it to be retained. In the case of tunnel options, depth of piles or removal of the jetty would not need to be a consideration.

On the north bank of the Thames, the area is dominated by the Ford Estate and associated car park hardstanding areas to the east of this. Access to the crossing would need to cross this area in order to tie-into the A13/Marsh Way dumb-bell roundabout. The roundabout would be re-modelled to combine the Courier Road access to the Ford Estate, and the Marsh Way access to the Fairview Industrial Estate with the crossing approach road, although at this stage, actual enlargement of the roundabout is thought unlikely to be required. A proposed junction on the crossing approach road would be positioned just south of the existing roundabout in order to maintain access to Courier Road and Marsh Lane, possibly subject to signal control. Without combining the Courier Road and Marsh Lanes off the roundabout with the new crossing approach road the roundabout would need to be enlarged significantly on its south side in order to accommodate the additional arms. The crossing approach road would then cut across the open land of the Hornchurch Marshes, keeping generally to the west of the unnamed watercourse, and across Ford Estate hardstanding areas.

The unnamed watercourse appears to run in an engineered channel and it is likely that this watercourse would need to be diverted or put into a culvert in order to accommodate the crossing approach road (see Figure 9Error! Reference source not found.).

Two large wind turbines are currently located on the east side of the Ford Estate’s vehicle hardstanding (see Figure 9Error! Reference source not found.). The bridge would require a least one and possibly both turbines to be relocated. The tunnel option may avoid the need to relocate the turbines but this would have to be confirmed as the design is developed.

There are no known or planned railways that are directly affected. The London Tilbury and Southend Line and High Speed 1 are north of the A13. The London Cannon Street to Dartford line is south of Bronze Age Way. Crossrail terminates at Abbey Wood although the existing route to Gravesend has been safeguarded for a potential Crossrail extension.

### 2.3. Safeguarded wharves.

The Mayor of London published a report entitled “London Plan Implementation Report Safeguarded Wharves on the River Thames” in Jan 2005, Mayor of London. This identified a number of the wharves that could be affected by a potential river crossing at Belvedere. A summary of the report’s findings for the adjacent wharves is below.
2.3.1. **London Borough of Barking and Dagenham**

**Ford Dagenham terminal**

Ford Dagenham terminal is used as a roll-on roll-off facility for cargo and vehicles from Vlissingen for on-site production and UK distribution. It can handle vessels up to 6m draught and in 2001 had 668 ships dock. The report considers that by virtue of its site characteristics, is viable or capable of being made viable for cargo-handling. The report’s recommendation was, “Identify as a Safeguarded Wharf”. The wharf is 600m upstream of the proposed bridge.

2.3.2. **London Borough of Havering**

**Phoenix Wharf/Frog Island Wharf**

Phoenix Wharf/Frog Island is not currently in use. It previously could handle ships of 6.4m draught. However, by virtue of its site characteristics and market placement, is viable or capable of being made viable for cargo-handling, particularly to accommodate the predicted growth in green industry operations or waste processing operations as identified in the Mayor’s London Plan, Economic Development Strategy and Waste Strategy. The report’s recommendation was, “Identify as a Safeguarded Wharf”. The wharf is 450m downstream of the proposed bridge.

2.3.3. **London Borough of Bexley**

**Middleton Wharf previously known as Borax Wharf/Manor Wharf**

A new jetty has recently been built as part of the Riverside Resource Recovery plant. The report noted that “Borax Wharf/Manor Wharf, by virtue of its site characteristics and market placement is viable or capable of being made viable for cargo-handling, particularly to accommodate the predicted growth in green industry operations or waste processing operations as identified in the Mayor’s “London Plan, Economic Development Strategy and Waste Strategy.” The report’s recommendation was, “Identify as a Safeguarded Wharf”. The site is an “Energy from Waste” generating station of a capacity of about 72MW, and as part the planning proposal all waste was intended to be delivered to the plant by river.

**The Former Belvedere Power Station**

The site has been redeveloped as the Isis Reach warehouse and distribution park. Bexley Council placed a condition on the permission to maintain the jetty’s availability for cargo-handling, but no comparable condition was placed on land associated with the jetty. The warehouse and distribution units are built close to the jetty and the only possible available land for cargo-handling and processing is to the rear of the site. There is therefore no likely prospect of enabling viable cargo-handling operations at the site. The report’s recommendation was, “Do not identify as a Safeguarded Wharf”.

**Burt’s Wharf**

Industrial units have been built up to the wharfside with no operational back-land available for cargo-handling. The report’s recommendation was, “Do not identify as a Safeguarded Wharf”.

**Mulberry Wharf**

Mulberry Wharf is identified as a viable or capable of being made viable for cargo-handling and should be identified as a Safeguarded Wharf. It can handle ships of 4.0m draught and in 2001 had 40 ships dock. This site is 750m downstream of the proposed bridge.

2.4. **Plan alignment**

Three route alignments were considered for the crossing based on the indicative line in the client brief. The routes could be either as a tunnel or a bridge. Route Y was selected for further development for the reasons stated below.

The proposed crossing of the River Thames at Belvedere is 2.5 kilometres long as shown in Figure 2 (Y) and on drawing 5118859-D10-001. The highway alignment design has been produced based on the Highway Agency’s (HA) Design Manual for Road and Bridge (DMRB) for a design speed of 60kph for urban road (30mph speed limit) for all alignment options.
An alternative crossing approach road through the open land to the west of the Isis Reach Industrial Estate has been considered (Figure 2 (X)). This land is part of the Crossness Nature Reserve, and comprises two BAP Priority Habitat areas: Coastal and Floodplain Grazing Marsh, and Undetermined Grassland. The crossing point would be to the west of the Cory Riverside Resource Recovery centre. However a crossing this far west has no credible landing point on the north shore of the Thames. Sections of the Ford plant are directly opposite, with no sensible route through the complex to connect back into the A13 junction with Marsh Way. The closest adjacent junctions on the A13 are either 1.6 miles to the west, or 1 mile to the east, so an approach road from other of these junctions would be significantly offset from the equivalent approach road on the south bank of the Thames. We judge that this route is unlikely to be the best solution (see Figure 1).

An alternative alignment to the east was also considered (Figure 2 (Z)), on the other side of the Belvedere Industrial Estate adjacent to Crabtree Manorway North. This part of the industrial estate has plots and units of industrial/commercial use that would need to be crossed or demolished. Access from A2016 would be more difficult with either a new roundabout located further along A2016 to the east, or the existing roundabout enlarged. Local roads would need to be extensively re-modelled. The main and only access to the units of the Belvedere industrial estate is along Crabtree Manorway North, so access would need to be retained. The bridge approach road would also have to span existing buildings, if retained. The landing point on the north bank of the Thames would be similar to that already described, possibly re-located to the east side of the unnamed watercourse and crossing a vehicle hardstanding area. Although a link using this route would be feasible we judge that it is not likely to be better than the route developed in this study, indicated in Figure 1.

2.5. **Vertical alignment**

The adopted route of the crossing approach roads has been chosen to generally avoid existing building developments, although at least one warehouse/structure would need to be demolished on the south bank. Several areas of hardstanding used for storage and parking would need to be traversed or spanned, which cannot be avoided. Otherwise the land is relatively under-developed so the constraints that set the limit of the gradient on the approach roads are the proposed tie-in to the A2016 roundabout on the south bank of the Thames, and the proposed junction with Marsh Way and Courier Road on the north bank of the Thames. This assumes that there is sufficient headroom beneath the overhead power lines next to the Marsh Way roundabout.

The result is a gradient of 5.3% on the northern approach road, and 5.7% on the southern approach road. These exceed the desirable maximum grade of 4% for all purpose dual carriageways stated TD 9/93, however are below the 8% limit that would be considered a departure. Generally for cyclists, a maximum gradient of 3% is recommended, however this is for reasons of cyclist comfort rather than safety. The shallowest gradients that can be readily achieved within the constraints mentioned above have been adopted. A steeper approach ramp gradient, and therefore shorter approach ramp, would have no bearing on the identified demolitions. The saving would be in construction cost for a shorter bridge (see drawing 5118859-DR-D10-001).

Two tunnel structure types have been considered. For the bored tunnel approach ramps, the same constraints apply as described above. For design purposes the extrados of the bored tunnel ought to be at least a diameter below ground level or bed level. This results in a northern approach road gradient of 3.2%, and a southern approach road gradient of 3.5%. The tunnels are also affected by ventilation and fire life safety considerations with recommended gradient limits given as 4% (see drawings 5118859-DR-T01-001 and 002).

For the immersed tube tunnel solution, given the possibility of a shallower depth of the tunnel mid river, the approach ramps are correspondingly shorter (approximately 300m for both ramps) and consequently there are no issues with tie-ins. Therefore approach ramps gradients are designed at 3% but could be refined at a later stage as design constraints are verified.

2.6. **Highway cross section**

The carriageway cross section is slightly different between bridge and tunnel options. The bridge cross section is composed of dual two-lanes 7.3m, separated by a 1.80m central reserve width. A 3.5m wide combined footway/cycleway is considered on one side and 0.60m wide verge on the other. Tunnels do not normally have footways or cycleways combined with the vehicle carriageway and a separate bore for
foot/cycle tunnel is not part of the current scope. The tunnel cross section used has a 7.3m carriageway and 1.2m verges for egress by wheel chair users. Verges outside the tunnel would be grassed and not available for public use as footways, except in an emergency.

2.7. Property and land take

Photographs from the site visit are given in section 5.5

The land on the south bank of the Thames adjacent to the preferred route is dominated by industrial estates, comprising several large warehouses as well as smaller commercial premises and large plots of undeveloped land. The proposed route is bordered on the west side by the Isis Reach Industrial estate, and on the east side by the Belvedere Industrial estate. The Isis Industrial Estate comprises three large warehouses/factories, which takes up the entire length from A2016 to the banks of the Thames. Belvedere Industrial Estate is less heavily developed: apart from the Jablite warehouse opposite the A2016 roundabout, the remainder of the estate at its western extremity comprises vacant plots of undeveloped land or hardstanding areas used for storage. One plot, run by PM Highway Ltd, specialising in muck away, topsoil and recycled crushed materials has an environmental permit from the Environment Agency (EPR/MB3133AP). Stockpiled materials can be seen on site as can be seen in Figure 13.

The proposed crossing approach road utilises the strip of landscaped land between the two industrial estates, but would also require a strip of land from the western extremity of the Belvedere Industrial Estate necessitating the demolition of the Jablite warehouse and loss of some of the available storage space from the hardstanding areas.

The enlargement of the roundabout would require additional land, which is currently undeveloped.

On the north bank of the Thames, the area is dominated by the Ford car assembly plant and associated vehicle storage hardstanding areas to the east of the assembly plant. The proposed crossing approach road between the junction with the A13 and the river would traverse the hardstanding areas and a vegetated strip of land through which an unnamed watercourse runs. To the east of the hardstanding areas is the Fairview Industrial estate, accessed by Marsh Way. Marsh Way also serves the Centre of Engineering and Manufacturing Excellence (CEME) campus of the Thames Gateway College on a parcel of land between the A13, Fairview Industrial Estate and the Ford Estate hardstanding areas.

The proposed approach road to the crossing would be routed over land within the Ford Estate. The approach road would cut through the areas of hardstanding and the strip of vegetated land. The new arm from the roundabout would require stopping up of the existing Courier Road and Marsh Way arms to the roundabout. A new junction to the south of the existing roundabout and re-alignment of the two roads to connect to the websiteextracts

There are currently four planning applications filed within the considered route areas. The proposed route is likely to have an impact on one planning application which has been submitted. The outline planning application (Ref: 11/01932/OUTM) is for 6 industrial units on the land adjacent to Burt’s Wharf Resource Park (former Nufarm UK Ltd), which is on the southern bank adjacent to the route corridor between the industrial estate and distribution warehouses.

2.8. Environmental constraints

Environmental designations are identified from the Department for Environment Fisheries and Rural Affairs (DEFRA) in the ‘Magic’ website extracts in Appendix B. Information is publically available and subject to the website published disclaimers. No copyrights have been sought at this stage.

On the south side of the Thames, the tie-in to the A2016 would cut through a Deciduous Woodland BAP Priority Habitat. Mitigation compensatory planting could be established elsewhere in the vicinity. On the north side, a plot of planting, crossed by the approach road is listed in the Forestry Commission’s National Inventory of Woodland and Trees, however there are no other special designations applied to this plot. The mudflats along both sides of the Thames would be spanned by a bridge over or tunnel under. The immersed tube tunnel would disrupt the mudflats during construction so may require additional mitigation measures. As with all major projects, detailed environmental impact studies would need to be undertaken at a future date.
As outlined above, the proposed route requires the demolition of the Jablite factory. Other permanent structures along this edge of the industrial estate are not apparent, however land currently used for storage would be required for the road and approach ramps. An unidentified structure probably a shaft for the former cooling water is located in the landscaped strip of land between the Belvedere and Isis Reach industrial estates.

Both sides of the river were formerly used for heavy industry or landfill and could be expected to have the potential for contaminated land. For further detail see section 5.2.6. The area was also subjected to bombing during the Second World War so there would be a risk of unexploded ordnance.

The enlargement of the A2016 roundabout would necessitate various lane closures and traffic management on the A2016 and other roads, causing disruption and delays to the travelling public.

On the north sides of the Thames the need for demolition of existing buildings has not been identified. The removal of a wind turbine located on the bottom right-hand corner of the vehicle hardstanding area would be required by the bridge and may be required by a tunnel. A second wind turbine would potentially be rendered inoperable by the approach ramps to the bridge but is expected to be unaffected by a tunnel. The loss of the wind turbines could impact on any commitments made by the owner with respect to renewable energy production.

As the works are mostly offline, impact to users of the local highway network would be minimal. However users of Courier Road and Marsh Way would be subject to a permanent diversion as these two roads are stopped-up at the roundabout and users of the roundabout would be subject to disruption as the new tie-in is constructed.

Flood defences on the north side of the River Thames comprise a mixture of sheet pile river wall and what appears to be earth bunding. At the crossing point, the defences comprise a 50m long section of sheet pile wall on top of which is a link road crossing the unnamed watercourse and connecting two of the Ford Estate’s hardstanding areas. The sheet pile wall ties into earth bunding at each end of the wall, where the proposed alignment passes. On the south side of the Thames, in the vicinity of the crossing, flood defences comprise a sheet pile wall with concrete cladding. The Thames Walk footpath runs along the top of the wall. The flood defences would be required to be maintained during construction. Once the scheme was complete neither tunnel nor bridge would affect the permanent flood defences.

2.9. Public utilities
The study has not investigated records of underground or overhead public utilities. Where information has been obtained from other sources this has been noted below:

- Ford Motor Works: two wind turbines and associated infrastructure, one directly affected and the second may be in the lee of a viaduct (site visit).
- HV overhead transmission power lines cross Marsh Way on the south side of the A13 junction.
- Drainage channel and sluice gate (OS mapping and Bing Aerial Maps).
- Former Belvedere Power Station:
  - Cooling water outfall tunnel and shaft (PLA Hydrographic Service Chart 328MS).
  - High probability of transmission lines still being in use.
- Middleton Wharf Riverside Resource Recovery: An energy from waste generating station at the site of a capacity of about 72MW, water supply and power lines from the site. (PLA Hydrographic Service Chart 328MS)

2.10. Key risks (highways)

- Adequacy of local road network in coping with increased traffic flows, change of desire lines, etc, that a new Thames crossing is likely to create. Risk that the project does not provide the traffic capacity required. Traffic modelling is outwith the scope of this report but would have an affect on the highway design capacity and the environmental impact.

- Vertical alignment design is based on approximately half a dozen spot levels contained on the OS background on each side of the river. Risk that design to the actual levels would have an impact on
the design solution. A full level/feature survey would be required at a later design stage in order to produce a definitive alignment.

- Access roads, turn round facilities and other infrastructure likely to be required for the operation of the Thames crossing has not been considered at this stage. Risk that the infrastructure cannot be accommodated in the available space.

- Further development or planning permission of the currently vacant plots in and around the industrial estates on both sides of the river that would impact on the crossing route as it is not currently a safeguarded route corridor. Risk that additional costs incurred as a result of given planning permission to a third party.

- Risk that suitable diversions of the water courses and mitigation of impacts to habitats, particularly on the north side of Thames cannot be easily made in order to accommodate the crossing approach roads.

- The responsible authority, possibly the Environment Agency, will have requirements relating to the unnamed water course that passes through the Ford estate. The requirements and the impact of the requirements on the scheme have not yet been determined, so a risk allowance should be included. The impact on the highway works around the A13 Marsh Way junction applies to both bridge and tunnel options. The tunnel option requires greater diversion of the water course through the Ford estate than the bridge option.

- Risk of a cost or duration increase due to the diverting public and private utilities, as well as the possibility of discovering unforeseen routes during design development or construction.

- Risk of a cost or duration increase due to reaching a negotiated settlement or securing non-objection for land currently used for commercial/industrial purposes on both sides of the river for the crossing approach roads.

- Risk of a cost increase due to maintenance of access to local businesses, to ensure business continuity.
3. Geological and Geotechnical Considerations

3.1. Introduction
Geological information relating to the proposed scheme has been taken from publically available sources, namely:

- British Geological Survey 1:50,000 Sheet 257 Romford (Solid and Drift)
- British Geological Survey 1:50,000 Sheet 271 Dartford (Solid and Drift)
- Exploratory hole logs available from the BGS website.

3.2. Geological and geotechnical conditions

3.2.1. General
The geology underlying the route corridor can be summarised as:-

Made Ground,
Recent Alluvium,
River Terrace Deposits,
London Clay,
Lambeth Group (Blackheath and Reading Beds),
Thanet Sand,
Chalk.

The route corridor is underlain by the northern flank of a local anticline. London Clay underlies the River Terrace Deposits on the north bank, beneath the channel of the River Thames and to some 400 metres south of the south shore line. South of this point the River Terrace Deposits are underlain by Lambeth Group material.

3.2.2. Made Ground
Made Ground is recorded as between 2.0 and 7.0 metres thick north of the river Thames and is generally described as brick, rubble and soft to firm clay or ash fill.

South of the river Thames the thickness of the Made Ground reduces, and is recorded in the range 1.5 to 2.5 metres and is described as clay and gravel with ash, clinker, brick and organic material.

3.2.3. Recent Alluvium
Recent Alluvium underlies Made Ground both north and south of the River Thames. North of the River Thames it is recorded as between 4.9 to 7.9 metres in thickness as is described as firm to stiff brown and grey silty CLAY with bands of firm PEAT up to 1.5 metres thick.

South of the river Thames the exploratory hole information indicates that the thickness of the Alluvium is in the range 6.9 to 8.7 metres. It is described as soft to very soft silty CLAY with bands of peat up to 3.0 metres in thickness. Laboratory determination of undrained shear strength recorded values in the range 5 to 27kN/m² with an average value of 16kN/m².

3.2.4. River Terrace Gravel
The River Terrace Gravel is relatively consistent along the route corridor, varying in thickness between 4.2 and 9.2 metres with an elevation at top of stratum between -2.05 and -4.05mAOD below Rainham Marshes deepening to -7.20 to -9.30mAOD for the remainder of the route corridor. The base of the River Terrace Gravel is recorded between -12.2 to -15.3mAOD.
The material is described as a medium dense sandy GRAVEL and recorded SPT N values are in the range 13 to 47 with an average value of 21.

3.2.5. London Clay
London Clay was encountered in all exploratory holes puncturing the River Terrace Deposits along the route corridor from the A13 to some 400 metres south of the southern River Thames frontage and is described as stiff grey slightly sandy CLAY.

Where a full thickness was proved this ranged from 12.8 to 18.9 metres with an elevation of base of stratum between -26.5 and -32.3m AOD.

3.2.6. Lambeth Group
The Lambeth Group, comprising the Blackheath and Reading Beds was encountered in exploratory holes in the south of the route corridor with full thickness proved in 1939 borehole immediately adjacent to the north bank of the River Thames.

The sequence in this borehole was:-
Blackheath Beds Gravel 9.75m thick, base at -42.1m AOD,
Reading Beds Sand 5.8m thick, base at -47.9m AOD,
Reading Beds Clay 8.1m thick, base at -56.0m AOD.

The Reading Beds seem to be absent from the southern end of the route corridor and exploratory hole logs describe Blackheath Beds directly overlying Thanet Sands. The Blackheath Beds are described as dense to very dense sandy GRAVEL with SPT N values in excess of 50.

3.2.7. Thanet Sand
Thanet Sand was encountered in exploratory holes in the south of the route corridor and its full thickness proved in two water well holes in the range 5.7 to 11.0 metres.

SPT N values are recorded in excess of 50.

3.2.8. Chalk
Chalk was encountered in two historical water well holes with the top of stratum at -67.0m AOD north of the River Thames and -56.1m AOD of the River Thames respectively.

3.3. Geotechnical considerations

3.3.1. Bridge option
The proposed bridge options typically comprise the following:

<table>
<thead>
<tr>
<th>Interval</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 230m</td>
<td>Approach Embankment</td>
</tr>
<tr>
<td>230 – 2350m</td>
<td>Multi-span Bridge</td>
</tr>
<tr>
<td>2350 – 2500m</td>
<td>Approach Embankment</td>
</tr>
</tbody>
</table>

The structure foundations will generally be situated on Made Ground overlying alluvium which is not a satisfactory bearing stratum for ground bearing foundations. All structure supports will, therefore, be founded on piled foundations. It is suggested that these are formed either as bored cast in situ or Continuous Flight Auger (CFA) piles. The pile diameter is likely to be in the range 750mm to 1500mm with the piles acting in skin friction in the London Clay and end bearing in the underlying Blackheath Beds if sufficient capacity cannot be generated in skin friction. The penetration of the base of the London Clay may preclude the use of CFA piles as they can normally be installed to a maximum 30 metres depth.

The approach embankments will be up to 6.5 metres high and founded on some 8 metres thickness of Made Ground, Alluvium and Peat. Primary Consolidation settlements up to 300mm can be expected together with an amount of secondary consolidation in the peat layers. In order to mitigate the settlement a number of pre-earthworks measures could be employed, such as;

- Surcharging
• Surcharging with band drains
• Vibro stone columns
• Driven pre-cast piles

The former two methods are likely to be successful if there is sufficient time in the construction programme to effect primary consolidation and the use of band drains will accelerate the primary consolidation allowing some secondary consolidation to occur prior to completion of construction. The use of vibro stone columns may not be effective as the undrained shear strength of the alluvium is sufficiently low (<20kN/m²) that it may not be able to provide sufficient lateral support during installation. The use of driven pre-cast piles, some 10 metres long, would provide an effective engineering solution but may not be cost effective over the full embankment footprint. It is suggested that an approach raft some 25 metre long is constructed on piles behind each structure abutment to mitigate differential settlement between the structure and adjacent earthworks.

It should be noted that the bridge option generates very little fill material and engineered fill for embankment construction will have to be imported.

3.3.2. Immersed tube tunnel option

The proposed immersed tube option (see 5.4.4.) comprises the following:

0 – 720m Approach Structure
720 – 880m Cut and Cover Structure
880 – 1660m Immersed Tube Tunnel
1660 – 1900m Cut and Cover Structure
1900 – 2500m Approach Structure

Due to the thickness of Made Ground and Alluvium on both banks of the River Thames it is envisaged that both the cut and cover and approach structures will be constructed in a structural cofferdam which could form part of the permanent structure. The shallow depth to groundwater table precludes the use of a contiguous bored pile wall but a secant piled wall or diaphragm wall solution is likely to be successful that could then be incorporated as part of the permanent works. Permanent props will be required on the approach structures due to the depth of cantilever (maximum 13.0 metres). The toe of the temporary cofferdam should be of sufficient depth to prevent significant ground flow into the base of the temporary works and prevent piping.

The base of the approach ramp excavation for the whole of the southern approach and from 2100m to 2500m on the northern approach ramp is likely to be in Made Ground and/or Alluvium material. The formation in these areas will require treatment or removal to provide a stable founding stratum for the structural approach ramp.

The immersed tube channel (maximum depth of invert -27.1m AOD) will be founded in London Clay across its construction length. It is considered that this will form a competent bearing stratum. It is envisaged that, in the dredged channel of the River Thames, temporary side slopes can be effected in the London Clay and overlying River Terrace Gravel at 1V:3H.

It should be noted that the immersed tube tunnel option will generate a significant amount of excavated material that will require disposal off-site as there is no requirement for significant engineered fill if this option is adopted (other than rock armour). Excavated Made Ground material may contain sufficiently high levels of contaminant that it requires on-site treatment prior to disposal or is disposed off-site to a special landfill with associated additional cost. Rock armour for protection of the immersed tunnel would probably be imported with Mendip Limestone or Granite from Leicestershire or Scotland being possible sources.

3.3.3. Bored tunnel option

The proposed bored tunnel option (see 5.4.3) comprises the following:-

0 -480m Approach Structure,
480 – 840m Cut and Cover,
840m Drive/Reception Shaft,
840 – 1780m Bored Tunnel,
1780m Drive/Reception Shaft,
1780 – 2100m Cut and Cover,
2100 – 2500m Approach Structure.

The invert of the bored tunnel commences at -24.2mAOD at the drive/reception shafts with a maximum depth to invert of -38.1mAOD beneath the river Thames. Considering a 12.1m OD tunnel the face conditions are likely to initially comprise London Clay with some thickness of overlying River Terrace Gravel. To the current channel of the river Thames face conditions are likely to comprise London Clay with mixed face conditions of London Clay and underlying Blackheath Beds Gravel beneath the River Thames.

Due to the thickness of Made Ground and Alluvium on both banks of the River Thames it is envisaged that both the cut-and-cover and approach structures will be constructed in a structural cofferdam which could form part of the permanent structure. The shallow depth to groundwater table precludes the use of a contiguous bored pile wall but a secant piled wall or diaphragm wall solution is likely to be successful that could then be incorporated as part of the permanent works. Permanent props will be required on the approach structures due to the depth of cantilever (maximum 13.0 metres). The toe of the temporary cofferdam should be of sufficient depth to prevent significant ground flow into the base of the temporary works and prevent piping.

The base of the approach ramp excavation for the whole of the southern approach and from 2240m to 2500m on the northern approach ramp is likely to be in Made Ground and/or Alluvium material. The formation in these areas will require treatment or removal to provide a stable founding stratum for the structural approach ramp.

It should be noted that the bored tunnel option will generate a significant amount of excavated material that will require disposal off-site as there is no requirement for significant engineered fill if this option is adopted. Excavated Made Ground material may contain sufficiently high levels of contaminant that it requires on-site treatment prior to disposal or is disposed off-site to a special landfill with associated additional cost.

3.4. Further investigation

The exploratory hole logs used in this study were produced between 1939 and 2004 and are not specific to the proposed scheme. Additionally, historical boreholes in the River Thames are close to or at the shore line so no full geological sequence can be established from the north to south banks.

It is recommended that, for any further phase of design that a ground investigation be procured to establish the following:-

- The full stratigraphic sequence of strata below the River Thames particularly with respect to the bored tunnel option,
- The thickness, nature and geotechnical properties of Made Ground and Recent Alluvium on both the north and south banks of River Thames,
- The definition of the thickness of the London Clay on the north and south banks of the River Thames,
- The definition of the boundary between the sub-crop of the London Clay and Blackheath Beds in the southern section of the route corridor,
- The presence and concentration of contaminants in the Made Ground,
- Groundwater level for design purposes.
4. Bridge Options

4.1. Geometrical constraints

4.1.1. Navigational channels
The required navigational clearances have been assumed to be the same as those required at Gallions Reach, which is approximately 6km upstream. Port of London Hydrographic Chart PLA 328MS indicates a scaled channel width of 183m approximately mid river. Therefore we have assumed at this stage the navigation clearance is exactly the same as the figures previously published for the Thames Gateway Bridge and adopted for the Gallions Reach Study.

The clearance envelope has been taken from “Gallions Reach River Crossing Bridge Option 290m main span GA MMD-298348-TUN-705”. The central channel is 100m wide at a height of 50m above ordnance datum (AOD), and has a width of 183m at 46.38m AOD with overall width of 230m at 40m AOD. The figures published are noted as AOD rather than above chart datum. The navigational clearance envelope is illustrated on drawing number 5118859-DR-S21-001. The definitive navigational clearances will need to be discussed and agreed with the Port of London Authority (PLA) and may be different to those described above.

4.1.2. London City Airport aviation envelope
The aviation envelope has been taken from ‘Safeguarded and obstacle limitation surfaces – London City Airport’ published by the Aerodrome Standards Department, Safety Regulation Group, Civil Aviation Authority and dated August 2004.

CAA requirements cover identification and definition of Obstacle Limitation Surfaces (OLS), Take Off and Climb Surfaces (TOCS) and Landing Approach Surfaces (APPS). The point on the London City Airport (LCA) runway from which OLSs stem out in their respective planes has an elevation of 4.95m AOD.

LCA has one physical runway orientated in the east-west direction and flights can take off and land from either end of the runway. As the proposed bridges would lie on the eastern side of the LCA runway, only TOCS for taking off in the East direction and APPS for landing from the West direction have been considered.

TOCS has a 4% gradient reaching a maximum height of 150m over a distance of 3.75km. On plan, TOCS has a trapezoidal shape with its shortest side being the width of the runway, 150m, at end of Take-off Distance Available (TODA) point. Lateral boundary has a 15% divergence over a distance of 1275m.

On the other hand, APPS has an elevation of 300m at a distance of 10km, measured from a point 60m prior to the landing threshold. This elevation is maintained for the first 4km after which it drops linearly based on a 5% gradient over a distance of 6km. On plan, APPS has a trapezoidal shape with its shortest side being the width of the runway, lateral boundary has a 15% divergence over a distance of 6000m reaching a maximum width of 1950m, which is then maintained for the following 4000m.

The crossing at Belvedere is approximately 6.4km from the runway, therefore it is beyond the TOCS and just before the start of the APPS descent from 300m elevation. Any bridge structure less than 305m tall would be below the safeguard and obstacle limitation surface. This will not present a constraint to any form of bridge or bridge construction.

Another issue related to the airport is the presence of a Non-Directional Radio Beacon (NDB). It has previously been established that a bridge may impact upon the performance of the navigation aid at LCA. Locating the bridge at Belvedere will reduce the issue and may eliminate it but further discussion with the National Air Traffic Service (NATS) is required.

4.1.3. Highway gradients
For considering bridge options, we have assumed the highway gradient on the bridge approaches is not greater than 6%. This is above the desirable maximum gradient stated in Highways Agency standard
TD 9/93 ‘Highway link design’, but is within the gradients that are permitted where significant savings in construction cost can offset the higher user costs. To fit within the space available between the two roundabouts provides gradients of just less than 6% so that the actual ramps would be 5.3% north and 5.7% south respectively for the box girder bridge (which has the greatest construction depth). The bridge could be kept above the assumed Thames navigation clearances. (See drawing 5118859-DR-D10-001). The south side gradients at 5.7% provide a little tolerance for extra construction depth should it be required at a later stage of development (equates to approximately another 3m available for headroom).

There is enough land available if land is purchased from the industrial sites on either side of the river, and it is taken that the bridge could span over any drainage channel. The junction at the A13 Marsh Way will have to be reconfigured to accommodate the new link and well as the existing Marsh Way and Courier Rd (possibly privately owned by Ford Motor Works). It may be that the bridge approaches have to remain at existing ground level until clear of the overhead power lines. The detail of this would be developed at a later stage. Both north and south of the river the industrial sites would be readily adaptable as construction compounds and could be easily returned as viable business sites once construction was complete.

4.2. Options previously considered
The authors are not aware of any previous study into a crossing at this site.

4.3. Possible bridge forms
As described above, the navigational channel required is about of 230m which is assumed to be as indicated on PLA 328/MS and centred on the centre line of the river. Considering this clear span, 3 bridge forms have been reviewed: a cable-stayed bridge, a steel arch bridge and a concrete box girder bridge. The arch bridge and box girder bridge are taken from the previous study of the Gallions Reach crossing (Gallions Reach Fixed Link Bridge, Concept Engineering Options Study Report rev 2.1 October 2013)

4.3.1. Cable-stayed bridge
Cable-stayed bridges can be configured in many different forms as most of the key components can be adapted to provide visual effect. With the development of the bridge type the variations that are available allow the bridge owner to consider artistic style as well as practicality and economy. Pylon shape, height, number of cables and cable arrangement can all be used to vary the basic form. The pylon height is related to the span crossed as the cables need to be of a sufficient angle to the deck in order to be effective supports. For this study we have not attempted to look at the different options that are available but have for simplicity adopted a form similar to that used for the 2013 Mersey Gateway Bridge tender. The Mersey Gateway Bridge has a maximum span of 300m and three mono-pylons located in the central reserve. The cables were fanned out to the edges of the bridge and wind shielding was provided. The deck was a steel ladder beam structure with cable supports at 12m centres. Other tender designs included a concrete box section bridge deck and the cable plane located within the central reserve. The economies of the differing forms are dependent on the contractor’s preferred method of construction and can be left to the design and build stage of a project.

For this study we have assumed two mono-pylon supports 300m apart over the main river channel. The bridge deck comprises a steel concrete composite deck supported at the outer edge by stay cables passing over saddles located in the pylons. The main span is 300m and the backspans are 120m. The height of the pylons is approximately 105m above the bridge deck, giving an overall height of 158m. Each half span is supported by 12 cable stays spaced at 12m centres at deck level. The end spans are supported on reinforced concrete piers on piled foundations. The pylons are supported on piled or caisson foundations.

The north and south approach viaducts are multiple span continuous structures with spans of typically 100m. They comprise steel concrete composite decks supported on reinforced concrete piers and abutments on piled foundations (See drawing 5118859-DR-S21-001). The alignment shown was developed for the concrete box girder bridge so there would be room to reduce the road height as the design is developed.

4.3.2. Steel arch bridge
The arch bridge option comprises a pair of steel arches spanning 287m. Each arch is formed of 5m wide tapering steel box sections, varying in depth from 5m at the springing points to 2m at the arch crown. The arches are inclined inwards at 10°, with three transverse props near the arch crown. The hangers will be formed of steel locked coil strand cables 100mm in diameter, included parallel to the arches and spaced at
5m centres. Straight backspan members meet at each arch springing point, supporting the viaduct section. Tie-downs are also required at the backspans to balance the forces within the main superstructure. These will also provide the necessary restraint to allow the main arch to be jacked into place off the deck. The approach spans are similar to the cable-stayed bridge option and the same opportunities to reduce road alignment with the low construction depth of the arch could be realised at a later stage (See drawing 5118859-DR-S22-001).

4.3.3. Concrete box girder bridge

The total length of the bridge is 2,120m with a span arrangement of: 80, 7x100, 152, 256,152, 7x100, 80m. The bridge has been divided into three sections. Section 1 is spans 1 to 8, section 2 is spans 9 to 11 and section 3 is spans 12 to 21. The main river crossing (section 2) comprises a 560m balanced cantilever bridge with a main span of 256m and two side spans of 152m each. The approach structures (sections 1 and 3) could comprise either a steel-concrete composite bridge or a concrete box girder bridge. It is possible that a concrete box girder could be launched from each side using temporary trestles at each mid span position. The plan alignment would need to be adjusted to have a constant profile to suit launching. Steel-concrete composite approach spans would be similar to the cable-stayed bridge option but would have a distinct transition to the concrete box girder section (See drawing 5118859-DR-S23-001).

4.4. Impact statement for bridge options

4.4.1. Construction impact

Both north and south of the river are industrial areas that could be taken over for construction subject to consultation with the current owners. The areas are existing hard standing and material stores. These would provide ample site compounds and prefabrication areas. Their previous industrial use may require dealing with contaminated ground and would need to be investigated at a later stage. The existing road links on both sides are good.

It is expected that the Port of London Authority would wish to maximise use of the river for construction. The former Belvedere Power Station wharf could be reused for material deliveries with a new link (The existing disused link is considered not particularly viable as it is partially dismantled and connects to the private Iron Mountain warehouse site). The Middleton Wharf site and the Ford Dagenham Terminal could potentially be used as the road links already exist but it would need an agreement with the current operators and construction traffic may not be easily integrated with their businesses.

Construction of the main bridge piers would be from temporary jetties built from either side arranged to span over existing flood defence bunds. Piling would be done within a caisson or sheet piled coffer dam to form the bridge foundations. Piers or pylons would be formed using slip forms or jump forms to the required heights and the deck erected outwards from each pier. The Gallions reach Study examined the differing forms of construction for box girder and arch bridges. The cable stay bridge would be similar to the box girder bridge with balanced cantilever construction progressing in both directions from the pylons. The deck sections could be cast insitu or prefabricated and lifted into position from a barge using a crane located at the tip of the deck cantilever. The approach spans could be constructed using crane erection from the space available alongside the bridge. Launching would be a possible alternative but may not be as economic given good crane access and lay out areas.

4.4.2. Environmental impact

The proposed bridge would have a significant adverse effect on the local environment during construction, which could last for a couple of years, and during operation as traffic pollution and noise would increase. However given the industrial nature of the existing land use, the impact of this increase is expected to be low. The area is surrounded by industrial estates on all sides. From Bing Maps the nearest residential properties are 1.4km from the middle of the bridge southwards (Norman Road/North Road) and 1.9km from the middle of the bridge northwards (Creekside Road). Construction of the bridge piers may have an adverse effect on the use of Middleton Wharf and the Ford Dagenham Terminal as ship manoeuvring may be affected. This would need to be discussed further with the Port of London Authority and the affected businesses.

The environmental effect of traffic would also have to consider the roads serving the crossing and any reallocation of trips as drivers altered their journey patterns plus the traffic generated by growth. This is outside the current scope of this report.
Construction will cause the following adverse impacts:

- Increased traffic due to construction deliveries and travel of operatives,
- Traffic disruption during works to increase the capacity of the connecting roundabouts and alter the Courier Road (Ford’s) and Marsh Way, plus associated air and noise impacts,
- Air pollution due to vehicle emissions from construction traffic and plant,
- Noise pollution due to construction operations,
- Risk of river pollution arising from pier and temporary jetty construction.

The effect of the crossing on the Crossness Nature Reserve and Rainham marsh SSSI would need to be evaluated at a later stage.

4.4.3. Key risks (bridges)

- PLA requirements:
  - Navigation clearance is greater than assumed (possibly due to operation of the upstream wharves),
  - Ship impact requirements require more costly pier foundations,
  - PLA require extensive use of the river for construction.
- Public perception of new crossing. A bridge would be more visually intrusive than a tunnel. This could be received both positively and negatively by stakeholders.
- It is assumed that the bridge piers can be configured to avoid any significant impact on the unnamed water course that passes through the Ford estate.

4.5. Cost estimate for design and construction

We have made a very high level estimate of the capital cost of the bridge, based on our experience of similar structures and using the Gallions Reach study. We have not attempted to differentiate between bridge types at this stage. Our experience would suggest that differential is not great but the cable stay bridge is likely to be the most cost effective.

Our estimate for the proposed option is £282 million at first quarter 2014 prices. This includes preliminaries, design and contractor’s overhead and profit, but excludes risk contingency, public and private utility diversions, Optimism Bias, VAT, land acquisition and compensation and client costs (including agents and consultants).

Our estimate is aligned with the costing of the options at Gallions Reach (Gallions Reach Fixed Link Bridge, Concept Engineering Options Study Report rev 2.1 October 2013). The estimating tolerance level that we would recommend is +50% / -15% to reflect the preliminary nature of this study.

The land costs could be significant if there was a major effect on the businesses that could not be mitigated. There could also be significant costs incurred in diverting existing watercourses and public or private utilities. We do not have the information to provide an estimate for these risks at this stage.
5. **Tunnel Option**

5.1. **Introduction**
Two forms of tunnelling have been considered in this feasibility study, a bored and immersed tube tunnel. The impacts and technical feasibility of each option has been considered, with several route options investigated.

5.2. **Geometrical constraints**
The proposed tunnel alignment is governed by a range of technical, environmental and social factors which are discussed in this section. In developing the preferred tunnel route, third party assets and property have been avoided where reasonably practicable within the technical constraints of alignment and cross section requirements.

5.2.1. **Local topography**
The land on the northern and southern bank of the River Thames is relatively flat with no significant impact on the route alignment. It should, be noted however that the land is low-lying and categorised as Flood Zone 3 by the Environment Agency, indicating that the area is a high risk zone, and has a 1 in 100 or greater annual probability of river flooding. The River Thames river walls protect against this, but could be overcome in extreme weather conditions. The river walls are up to a level of +6m Above Ordnance Datum (AOD) to protect the low-lying surrounding land which is largely at +1m AOD, as shown by Ordnance Survey data.

5.2.2. **Navigational channels**
The Port of London Hydrographic Chart PLA 328MS indicates the depth of the River Thames bed. A maximum depth to river bed of 8.5 metres (river bed at -11.8m AOD) has been used in developing the tunnel alignment to ensure sufficient cover from the tunnel crown. For the immersed tube tunnel option, it has been assumed that the river bed profile should remain and that dredging will be required in order to provide sufficient cover to the (rock armour protected) tunnel. A minimum of one diameter cover from the river bed to the tunnel crown has been provided to the bored tunnel option.

5.2.3. **River Thames flood defence walls**
As described in section 2.8, the alignment intersects sheet piled walls on the Southern bank and bunding on the Northern bank. The depth of the river wall foundations are unknown and should be investigated in future design stages. In sections of wall in this part of London, the flood defences are known to have been raised in the 1980’s and 90’s, requiring the construction of wall structures supported by deep (piled) foundations. In Figure 14 and [Error! Reference source not found.] lines of wooden posts can be seen, the depth of these and form is also unknown and should be investigated in the future.

Construction of an immersed tube tunnel will require local demolition of the walls, with provision to maintain the flood defence during the works.

The bored tunnel alignment needs to provide sufficient cover to the tunnel from the foundations (if present). The crown of the tunnel at this location is at -16m AOD. The depth of the flood defence walls is not known at present and has not influenced the depth of the bored tunnel option. Should the foundations be deeper than expected the tunnel would have to be lowered or the river defence wall rebuilt locally. The cost for this should be included in the risk register.

5.2.4. **Highway gradients**
The highway alignment design has been produced based on the Highways Agency’s (HA) Design Manual for Road and Bridge (DMRB). The desirable maximum gradient is 4% as per TD9/93 from the DMRB, which has been applied in developing the proposed alignment. The maximum gradient adopted for the bored tunnel is 3.5% and 3% for the immersed tube tunnel to achieve sufficient cover. The vertical alignment also requires curves of a certain length at all changes in gradient as per the DMRB which have been applied. The requirements from BD78/99 for the Design of Road Tunnels have also been used in developing the cross sections and the alignment.
The proposed alignments could be refined with further study, with a potential to steepen the approach structures gradient and thereby reducing the length of the structures, and their likely cost.

5.2.5. Tunnelling requirements

Two tunnel solutions have been developed for this study - one for a bored tunnel and the other for an immersed tube tunnel as they have different requirements. For a bored tunnel one diameter of cover is generally required at the tunnel portals and to the river bed. A sufficient gradient needs to be maintained to allow the tunnel to drain and at the low point a sump will be required. The tunnel alignment would also require sufficient cover to the river wall defence foundations as discussed in section 5.2.3.

The immersed tube tunnel alignment has been developed keeping the existing river bed depth in order to maintain the clearance to the navigation channel. This is based on the assumption that the river bed depth needs to be maintained as per the Port of London Authority Hydrographic Chart PLA 328MS. A minimum of two metres cover has been provided to the river bed from the roof of the tunnel, to allow for rock protection to the tunnel. The immersed tube tunnel alignment is shown on drawings 5118859-DR-T01-001 & 002 see Appendix A.

5.2.6. Property and land use

A high level review of major third party assets and property has been undertaken, however it is recommended that a detailed study is undertaken should this option be further investigated. The impact of the preferred route is discussed in Section 2.7.

On the northern bank of the River Thames, within the London Borough of Barking and Dagenham, the area consists of the Hornchurch Marshes and the Ford Motor Company estate. This area also contains two wind turbines. Adjacent to the A13 / Marsh Way roundabout is the Centre for Engineering & Manufacturing Excellence. To the East of Marsh Way is the Fairview Industrial Park.

There are a number of historic landfill sites in the proposed construction areas on the Northern bank at the location of the Hornchurch Marshes, consisting of the:

- ‘Ex-City of London Site’- consisting of inert, commercial and household waste;
- Ford Motor Company, Mudlands- consisting of inert waste; and
- Manor Way-no information available on the waste.

Figure 3 Historic landfill sites, Environment Agency

On the southern bank of the River Thames, within the London Borough of Bexley, the area consists of Crossness Nature Reserve to the West of the proposed route and Belvedere Industrial Estate to the East. The main site area considered is the Burt’s Wharf Industrial Estate, Alchemy Park, London Distribution Centre, Isis Reach, ASDA and Iron Mountain distribution centres.

5.2.7. Geological and geotechnical conditions

From Section 3 the geology underlying the route corridor can be summarised as:

Made Ground;
Recent Alluvium;
River Terrace Deposits;
London Clay;
Lambeth Group (Blackheath and Reading Beds);
Thanet Sand; and
Chalk.

A description of the conditions for each tunnelling option can be found in Section 3.3.2 and 3.3.3.

5.3. **Options previously considered**
The authors are not aware of any previous study into a crossing at this site.

5.4. **Proposed tunnel form and alignment**

5.4.1. **Options considered**
Based on highway alignment Route Y (Figure 2) the tunnel options have considered further sub-divisions of the route in order to check if gradient has a significant impact on the solution and to test if other routes had significant merit. Three horizontal alignment options were considered, as shown in Figure 4.

**Figure 4**  **Tunnel Alignment Options**

5.4.2. **Horizontal alignment**
Option A: The alignment joins to the A13/Marsh Way roundabout and intersects Courier Road passing under a series of HV pylons. The route then passes to the West of the existing watercourse and crosses through the Hornchurch Marshes on the edge of the Ford Motors Estate. The route then crosses the River Thames and reaches the southern bank to the east of the disused jetty and distribution warehouses, where it follows a corridor between the warehouses and adjacent industrial estate. It connects to the A2016 Picardy Manorway/Bronze Age Way roundabout. Option A is the preferred option as it minimises the impact on existing property and provides the shortest route.
Option B: The alignment joins to the A13/Marsh Way roundabout, following Marsh Way initially until crossing through the Ford Motors car compound, to the East of the disused Courier Road. The route then crosses the Thames and reaches the southern bank to the East of the disused jetty and distribution warehouses, where it passes through the industrial estate and then follows a corridor between the distribution warehouses. It finally connects to the A2016 Picardy Manorway/Bronze Age Way roundabout. Option B was considered in order to maintain the Ford Motors car compound to the West of Courier Road. It is however a longer route and is likely to have the greatest impact on existing property utilised, therefore it was discounted.

Option C: The alignment joins to the A13/Marsh Way roundabout, following Marsh Way initially until crossing through the Ford Motors Estate, to the East of Courier Road. It then runs down the east side of the car compound, adjacent to Frog Lane and the Fairview Industrial Estate. The route then crosses the Thames and reaches the southern bank to the East of the disused jetty and distribution warehouses, where it passes through the industrial estate and then follows a corridor between the distribution warehouses. It finally connects to the A2016 Picardy Manorway/Bronze Age Way roundabout. Option C was considered in order to maintain the Ford Motors car compound to the West of Courier Road and to retain the western section of the eastern car compound. It is however the longest route and is likely to have a greater impact on existing property utilised compared to Option A, therefore it was discounted. The option also impacts on a planning permission for the construction of a Sustainable Energy Facility off Marsh Way (Reference P0558/12).

<table>
<thead>
<tr>
<th>Option A</th>
<th>Option B</th>
<th>Option C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortest Route (+)</td>
<td>Longer Route (-)</td>
<td>Longest Route (-)</td>
</tr>
<tr>
<td>Lowest impact on land take at Burt’s Wharf (+)</td>
<td>Greater impact on land take at Burt’s Wharf (-)</td>
<td>Greatest impact on land take at Burt’s Wharf (-)</td>
</tr>
<tr>
<td>River on North bank between the Ford East and West car compounds will require diverting (-)</td>
<td>No river diversion required (+)</td>
<td>No river diversion required (+)</td>
</tr>
<tr>
<td>Possible impact on one wind turbine of Ford Motors site (-)</td>
<td>No impact on wind turbines on Ford Motors site (+)</td>
<td>No impact on wind turbines on Ford Motors site (+)</td>
</tr>
<tr>
<td>Least impact on hard paved areas. Northern site is largely on Hornchurch Marshes. (+)</td>
<td>Greater impact on hard paved areas and utilised land. (-)</td>
<td>Greater impact on hard paved areas and utilised land (-).</td>
</tr>
<tr>
<td>Cheaper option due to shorter route and length of tunnel (+)</td>
<td>More expensive option due to shorter route and length of tunnel (-)</td>
<td>More expensive option due to shorter route and length of tunnel (-)</td>
</tr>
</tbody>
</table>

Table 1 Tunnel Alignment Options

5.4.3. Bored tunnel

A twin bored tunnel with an external diameter of 12.1m in common with TfL’s current proposals for the Silvertown Tunnel Crossing (Silvertown Crossing Study, Tunnel Engineering, June 2012) would be required for the proposed carriageway and tunnel equipment, see Figure 5. Each bore would carry a 2 lane carriageway with a 1.2 metre verge on each side to allow for wheelchair access. Due to its circular geometry a bored tunnel is less space efficient than an immersed tube tunnel. The two bores would be separated by 24 metres centre to centre with cross-passages provided to allow access to the adjacent bore. Cross passages would usually be spaced at 100 metre centres in accordance with BD78/99, however a risk-based Fire Life Safety assessment of the need would potentially allow this to be increased and could be investigated at future design stages.
The bored tunnel would commence where there is one diameter of cover, starting at chainage 840 and finishing at chainage 1780, therefore a 940m tunnel. At each end a launch/reception chamber would be required followed by a cut-and-cover section of 360m on the north side and 320m on the south side. Approach ramps would lead to the cut-and-cover tunnel sections. The cut-and-cover tunnels will initially be substantially wider due to the bored tunnel separation of 24 metres, transitioning to approximately a 1.2m thick central wall to meet the approach road. The cut-and-cover tunnels and approach ramps are longer than those required for the immersed tube tunnel due to the tunnel being deeper. At the low point of the tunnel, a sump would be required for tunnel drainage (conventionally this would be integrated within a cross passage between tunnels). Fans for tunnel ventilation and other M&E equipment would be housed in the crown of the tunnel clear of the carriageway headroom envelope. A ventilation and service building would be required as would access to both tunnel portals. The buildings would need to be located near to the tunnel portals and could be a single storey building of approximately 25 metres by 35 metres.

<table>
<thead>
<tr>
<th>Chainage (m)</th>
<th>Length (m)</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 200</td>
<td>200m</td>
<td>Northern approach road</td>
</tr>
<tr>
<td>200 to 480</td>
<td>280m</td>
<td>Northern approach ramp</td>
</tr>
<tr>
<td>480 to 840</td>
<td>360m</td>
<td>Northern cut-and-cover tunnel</td>
</tr>
<tr>
<td>840 to 1780</td>
<td>940m</td>
<td>Bored tunnel</td>
</tr>
<tr>
<td>1780 to 2100</td>
<td>320m</td>
<td>Southern cut-and-cover tunnel</td>
</tr>
<tr>
<td>2100 to 2380</td>
<td>280m</td>
<td>Southern approach ramp</td>
</tr>
<tr>
<td>2380 to 2505</td>
<td>125m</td>
<td>Southern approach road</td>
</tr>
</tbody>
</table>

The tunnel would be constructed using a Tunnel Boring Machine (TBM). It is likely that it would be an earth pressure balance TBM which are intended for soft and cohesive materials. The construction site for a bored tunnel requires considerable space and power to operate the TBM. The principal work site for the TBM would likely be on the North bank due to more available space. It is likely that the tunnel would be driven from north to south and then returned to the north bank for a second drive. It may however be advantageous to avoid disassembly and reassembly of the machine, therefore driving north-south and then turning the machine around at the south and driving south-north. The north bank site would however require the diversion of the unnamed water course and therefore part of the Ford estate to the east side of the river would be needed, therefore reducing the available construction site. North and south construction sites are shown in Figure 6.
Figure 6  Possible work sites for TBM
5.4.4. Immersed tube tunnel

An immersed tube tunnel with a width of 25.1 metres and height of 10.6 metres would be required for the proposed carriageway and tunnel equipment, see Figure 7 (Silvertown Crossing Study, Tunnel Engineering, June 2012). The 10.6m deep section would be required at localised sections to accommodate ventilation fans and a drainage sump. Further development may be able to reduce the tunnel depth at the critical mid river cross section by design of localised fan niches and compact drainage sumps. The tunnel would likely be a three cell reinforced concrete box, with a central cell to provide emergency egress, access from the adjacent carriageway for the emergency services and to allow routine maintenance; as shown on the cross-section on drawing 51189-DR-T01-003. Each main cell would carry a 2 lane carriageway with a 1.2 metre verge on each side to allow for wheelchair access. In the tunnel soffit fans are to be provided for tunnel ventilation. Refinement of the design to locate fans in niches would be tested at a later stage of development. An immersed tube tunnel is more space efficient than a bored tunnel due to its rectangular cross-section. Mass concrete would be required in the base of the tunnel elements to act as ballast against uplift. Emergency access doors would usually be provided also at 100 metre spacing. Outside of the tunnel a service building would be required. The buildings would need to be located near to the tunnel portals and could be a single storey building of approximately 25 metres by 35 metres.

![Typical Immersed Tube Tunnel Cross Section](image)

Figure 7 Typical Immersed Tube Tunnel Cross Section, as per TfL Silvertown Study

The alignment for the immersed tunnel option can be found on drawing 51189-DR-T01-001 & 002. Due to the shallower nature of the tunnel, the cut-and-cover tunnels and approach ramps are shorter than a bored tunnel. The depth of the cut-and-cover tunnel is also less, which is likely to lead to a cost saving. The worksite required would also be smaller, requiring less land for construction. The land-take in the permanent state and during construction is also less as the width of the cut-and-cover tunnel is not impacted by the twin bore spacing, as per the bored tunnel option.

<table>
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<th>Chainage (m)</th>
<th>Length (m)</th>
<th>Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 420</td>
<td>420m</td>
<td>Northern approach road</td>
</tr>
<tr>
<td>420 to 720</td>
<td>300m</td>
<td>Northern approach ramp</td>
</tr>
<tr>
<td>720 to 880</td>
<td>160m</td>
<td>Northern cut-and-cover tunnel</td>
</tr>
<tr>
<td>880 to 1650</td>
<td>770m</td>
<td>Immersed tube tunnel</td>
</tr>
<tr>
<td>1650 to 1900</td>
<td>250m</td>
<td>Southern cut-and-cover tunnel</td>
</tr>
<tr>
<td>1900 to 2260</td>
<td>360m</td>
<td>Southern approach ramp</td>
</tr>
<tr>
<td>2260 to 2505</td>
<td>245m</td>
<td>Southern approach road</td>
</tr>
</tbody>
</table>

Table 3 Summary of tunnel/structure elements for the immersed tube tunnel option
Although the tunnel scheme fits within the length between the two roundabouts there is little room to develop any ancillary facilities needed either side of the tunnel. Typically there could be tolling facilities (which are assumed to not be required in this study); lane control for single bore operation during routine maintenance and turn back facilities for prohibited vehicles. Similarly it may not be desirable to have tailbacks of queuing traffic blocking the tunnel. This operational detail would need to be developed in conjunction with a Tunnel Design and Safety Consultation Group at a future stage.

5.4.5. Preferred tunnel option

The preferred option is an immersed tube tunnel; however a bored tunnel is also technically feasible. It is anticipated that the costs of an immersed tube tunnel would be less than a bored tunnel due to a reduced depth, a shorter length tunnel, shorter length and smaller cross-sections of approach structures. The preferred horizontal alignment is Option A as per Section 5.4.2. The plan, cross-section and long section drawings can be found in Appendix A (Drawings 5118859-DR-T01 001-003).

The river crossing section would be by immersed tube tunnel with the sections on land constructed in a cut-and-cover tunnel leading to approach ramps and the highway at grade to link to the existing junctions. The River Thames bed would require dredging in order to create a trench for the immersed tube elements to be sunk. It is proposed for the existing depth of the river to be maintained and the river bed profile reinstated after the installation of the immersed tube elements. The approach ramps on the northern and southern bank are proposed to be constructed in cuttings transitioning to retaining structures where the depth and land take make it economic. The existing River Thames flood defences would need to be modified to allow construction and prevent flooding of the surrounding areas. In the permanent case, it would also be important to ensure that the approach ramps and tunnel aren’t flooded.

The tunnel elements would be reinforced concrete pre-cast segments. These elements can be constructed in a casting basin on or off-site. For Belvedere, an off-site casting basin is proposed as it would reduce the landtake required on the local site and as on-site construction offers no economic advantage. An off-site existing casting basin would reduce the cost of setting up a new facility. The elements can be transported using tugs to the site. The elements have temporary bulkheads in order to seal them so that they can be floated into their permanent location. A section of the approach cut and cover tunnel needs to be constructed first in order for the first immersed element to be sunk and pushed up against it. A “Gina” gasket then provides a seal to the next element, and as the water between the units is pumped out, the elements push together to form a watertight seal. A prepared sand bed is pumped or placed prior to settling the units on the river bed. Once all of the elements are sunk into position, the tunnel is then backfilled and a layer of rock protection is provided. As the tunnel will largely be constructed within the London Clay, the dredged trench will need shallow slopes with a gradient of approximately 1:3. Dredging within the River Thames is regulated by the Port of London Authority (PLA) and requires a licence where the environmental impact is also taken into account. It is however important to note that an immersed tube tunnel will have a greater impact on the river than a bored tunnel.
5.5. Site Visit Photographs

A site visit was undertaken to assess the impact on the local area. Access to the northern site was limited due to it being private land owned by Ford Motors. The southern site was largely accessible from public rights of way, from which the following photographs have been taken.

Figure 8 Site visit photograph locations
Figure 9  North bank at location of tunnel and earth bunding

Figure 10  South bank Burt’s Wharf industrial estate and warehouses
Figure 11  Route corridor between Burt’s Wharf industrial estate and warehouses

Figure 12  Infinity House site on Anderson Way
Figure 13    PM Highway Ltd material stockpiles on Burt’s Wharf site

Figure 14    River walls on the South bank
5.6. **Impact statement for the Immersed Tube Tunnel**

5.6.1. **Construction impact**

Both north and south of the river are industrial areas that could be taken over for construction subject to consultation with the current owners. The areas are existing hard standing and material stores. These would provide ample site compounds. Their previous industrial use may require dealing with contaminated ground and would need to be investigated at a later stage. The existing road links on both sides are good.

The towing, immersing and backfilling of the immersed tube tunnel elements to the River Thames would need to be agreed in conjunction with the PLA as well as dredging works that would be required. There may be a necessity for temporary river closures to accommodate construction activities. The river works will also include installation of cofferdams. The construction methodology would need to be developed at future design stages in order to establish the exact impact. Key stakeholders to the immersed tunnel construction method would include the PLA, Environment Agency and Natural England.

Areas of land would need to be acquired for permanent works and also for temporary sites for construction work sites. The proposed scheme has a number of significant impacts:

- The Hornchurch marsh area to the West of Courier Road will be required for permanent works and is a likely location for a work site,
- The South-East corner of the Ford Motors car compound (to the west of Courier Road) will be required for permanent works,
- Possible demolition of one of the wind turbines, on the Ford Motors Estate, see Error! Reference source not found.,
- Diversion of the unnamed river to the west of Courier Road to the Ford Motors car compound to the east of Courier Road,
- A section of the Burt’s Wharf industrial estate - larger site during construction and a smaller site for permanent works, see Figure 10,
- The corridor of space within the boundary fences of the distribution centres and on to the side of Burt’s Wharf industrial estate, see Figure 11,
- The shaft and section of the cooling water outfall would be removed from the current location in the corridor between the distribution warehouses and Burt’s Wharf industrial estate, see Figure 11,
- Demolition of Infinity House on Anderson Way currently occupied by Jablite, see Figure 12,
- Remote casting yard suitable for the construction of the immersed tube units.

5.6.2. **Environmental impact**

The proposed tunnel would have a significant adverse effect on the local environment during the construction, which could last for perhaps 3 to 4 years, and during operation as the traffic pollution and noise would increase. However given the industrial nature of the existing use, the impact of this increase is expected to be low. The area is surrounded by industrial estates on all sides. From Bing Maps the nearest residential properties are 1.4km from the middle of the crossing southwards (Norman Road/North Road) and 1.9km from the middle of the crossing northwards (Creekside Road). The largest environmental impact is likely to be upon the River Thames during construction. The impact on the Crossness nature reserve to the west of Norman Road would also need to be assessed.

Construction will cause the following adverse impacts:-

- Increased traffic due to construction deliveries and travel of operatives,
- Traffic disruption during works to increase the capacity of the connecting roundabouts and alter the Courier Road (Ford’s) and Marsh Way, plus associated air and noise impacts,
- Air pollution due to vehicle emissions from construction traffic and plant,
- Noise pollution due to construction operations,
- River disturbance arising from cofferdam and immersed tube tunnel construction.

5.6.3. **Connectivity with local roads**

On the northern bank the approach road will connect to the A13/Marsh Way roundabout. The roundabout will require modification; however the adjacent roads are likely to be unaffected. Courier Road which provides access to the Ford Motors car compound is intersected, however it would require re-routing due to construction sites and the permanent land take required. If access needs to be maintained between the two
sites, the road could potentially be reinstated over the cut-and-cover tunnel section or access provided from the roundabout. An access would also be needed to any tunnel service building situation on the north side of the river.

On the southern bank the approach road will connect to the A2016 Picardy Manorway/Bronze Age Way roundabout. The roundabout will require modification; however the adjacent roads are likely to be unaffected. Access any tunnel service buildings would also be required.

5.7. Cost estimate
We have made a very high level estimate of the capital cost of the tunnel, based on our experience of similar structures. Our estimate is based upon an immersed tube tunnel.

Our estimate for the proposed option is £340 million at first quarter 2014 prices. This includes preliminaries, design and contractor's overhead and profit, but excludes risk contingency, public and private utility diversions, Optimism Bias, VAT, land acquisition and compensation and client costs (including agents and consultants).

Our estimate is aligned with the costing of the options at Gallions Reach (Gallions Reach Fixed Link Bridge, Concept Engineering Options Study Report rev 2.1 October 2013). The estimating tolerance level that we would recommend is +50% / -15% to reflect the preliminary nature of this study.

The land costs could be significant if there was a major effect on the businesses that could not be mitigated. There could also be significant costs incurred in diverting existing watercourses and public and private utilities. We do not have the information to provide an estimate for these risks at this stage.

5.8. Key Risks (tunnels)

- The ground conditions considered in this report are based upon BGS maps and exploratory hole logs. The exploratory hole logs used in this study were produced between 1939 and 2004 and are not specific to the proposed scheme. It is recommended that for any further phase of design that a ground investigation be procured.

- In selecting the immersed tube tunnel option it has been assumed that the Port of London Authority (PLA) would approve the construction and dredging works on the River Thames.

- The immersed tube tunnel option has undoubtedly a larger impact on the River Thames. The non-objection of the Environmental Agency (EA) would be required along with their imposed conditions.

- The north bank site areas are historic industrial and landfill sites. Contaminated material could therefore be encountered.

- The tunnel is located across the existing Thames flood defences. We have not currently included raising the approach road above a flood defence level. If the road needs to be raised to match the flood defence level (for asset protection) then there could be an additional 150m – 200m of ramp which may be difficult to accommodate with a straight alignment. The operational feasibility of alternative flood risk mitigation, such as deployable barriers, could in future be investigated, but are thought likely to be too disruptive to the tunnel use.

- The approach infrastructure in advance of the tunnel has not been developed at this stage and will require input from the TDSCG (e.g. control and turn back facilities). As noted for the flood defences above, space either side of the portal is limited so there may be significant costs with accommodating special requirements.

- The vehicle emissions from the tunnel will be concentrated at the portals or may need to be managed using a ventilation building and exhaust stack.

- The construction methodology and temporary work site layout requires further development. At this stage, assumptions have been made therefore additional land may be required.
Belvedere Crossing Options Report

- The tunnel cross-section is subject to further refinement and therefore savings could be made with design development e.g. spacing of cross-passages etc.

- The responsible authority, possibly the Environment Agency, will have requirements relating to the unnamed water course that passes through the Ford estate. The requirements and the impact of the requirements on the scheme have not yet been determined, so a risk allowance should be included. The tunnel option requires greater diversion of the water course through the Ford estate than the bridge option.

- The river wall foundations may be deeper than currently assumed. This would increase the cost if building a bored or immersed tube tunnel. The impact on the bored tunnel construction would be greater. Mitigation could be to lower the tunnel alignment or reconstruct the river defence wall locally.
6. Cost Estimate For Design And Construction

6.1. Summary quantities
An approximation of the key quantities involved with the options has been produced to assist with environmental assessment of the options. This exercise is a first approximation and covers the major permanent works elements as well as some temporary works elements such as haul roads and site compound hardstanding. The figures are given in Appendix D. As the bridge option figures are similar between options the calculations have been prepared for the concrete box girder bridge which will probably be conservative with regard to transportation of bulk material. The steel arch bridge and the cable stay bridge would have increased steel tonnage brought to site as fabricated units but less concrete and bar reinforcement tonnage. Stay cable tonnage for the cable stay bridge would in the same order of magnitude as the prestressing strand tonnage for the box girder bridge.

The tunnels would have very different volumes of material. The immersed tube tunnels have significant dredging impacts but the cross section is smaller and tunnel elements are shipped to site from a remote casting basin. The bored tunnel would have a precast segmental lining delivered to site and muck away from the TBM face would be conveyed to the access shaft. As the immersed tube tunnel is the preferred option these figures have been prepared.

6.2. Bridge option
High level construction costs have been estimated for the bridge option without differentiating between the various forms of construction, at this stage. The costs for the bridge are presented in the Table 4. It is likely that the cable stay bridge route will turn out to be the cheapest option as the design develops.

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<thead>
<tr>
<th>Description of cost head</th>
<th>Cost (£million)</th>
</tr>
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<tbody>
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<td>Approach Roads &amp; Ramps</td>
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<tr>
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<td>12.2</td>
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<td>Piers and end supports</td>
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<td>Project Management</td>
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<td><strong>Total</strong></td>
<td><strong>282.0</strong></td>
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Table 4 Bridge Option Costs

Costs for bridge construction have been derived from the Gallions Reach study. Costs are at first quarter 2014. The estimating tolerance level that we would recommend is +50% / -15% to reflect the preliminary
nature of this study. The difference in cost compared to the cost of a similar bridge used in Gallions Reach project arises from the increased bridge approach length at Belvedere. The extent of alluvial deposits does not favour construction of tall approach embankments. The most economic balance of earthworks and bridge deck would be established at a further stage of project development.

The following are excluded from the above estimate:

- risk
- Optimism Bias
- VAT
- land costs and compensation
- permitting and licensing
- diversion of watercourses and public or private utilities including wind turbines
- TfL management costs

### 6.3. Tunnel option

High level construction costs have been estimated for the immersed tube tunnel route and are presented in the Table 5.

<table>
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<td>M&amp;E including service buildings</td>
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<td>Design</td>
<td>14.1</td>
</tr>
<tr>
<td>Project Management</td>
<td>8.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>340.0</strong></td>
</tr>
</tbody>
</table>

**Table 5** Immerged Tube Tunnel Option Costs

Costs for tunnel construction have been derived from the recent alternative Forth road crossing and the Silvertown tunnel immersed tube options. Costs are at first quarter 2014. The estimating tolerance level that we would recommend is +50% / -15% to reflect the preliminary nature of this study.

The following are excluded from the above estimate:

- risk
- Optimism Bias
- VAT
- land costs and compensation
- permitting and licensing
• diversion of watercourses and public or private utilities including wind turbines
• TFL management costs

6.4. Maintenance Costs
Costs for maintenance of the bridge and tunnel have not been evaluated at this stage. The costs of operating the tunnel & mechanical and electrical equipment as well as the routine renewal of the plant approximately every 25 years will result in higher operating costs for the tunnel option.

No account of any effects of the differing base dates of the two estimates has been taken made in this comparison.
6.5. Cost Comparison with Gallions Reach Study

Table 6 below provides a comparison of the Belvedere Options Study, the Atkins Gallions Reach Study and the report produced by Mott MacDonald in 2012. The relevant estimates are contained within paragraph 6.5 of Mott MacDonald Gallions Reach River Crossings study (current at January 1 2012) and the Gallions Reach Fixed Link Bridge Concept Engineering (current at June 2013)

This comparison is made between Belvedere Bridge Option, The Gallions Reach estimate for Option 1A-2 (Concrete box girder bridge on TGB alignment with dual carriageway lanes and at-grade junctions) and the Mott MacDonald estimate for dual twin carriageway with cycle path.

<table>
<thead>
<tr>
<th>Element</th>
<th>Belvedere Bridge Option 2014</th>
<th>Gallions Reach Option 1-A2 Atkins 2013</th>
<th>MM 2012</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approaches and Main Span</td>
<td>£193M</td>
<td>£127M</td>
<td>£210M</td>
<td>Belvedere 2125m long structure 21.5m wide (45,686m²). Gallions Reach 1476m long structure 21.5m wide (31,734m²). MM study 2440m long structure generally 22.4m wide (54,890m²).</td>
</tr>
<tr>
<td>Highways Connections North</td>
<td>Inc above</td>
<td>£2M</td>
<td>N/A</td>
<td>Belvedere junctions and access road diversions more complex. Approach ramps on piled embankments No costs separately identified in MM study</td>
</tr>
<tr>
<td>Highways Connections South</td>
<td>Inc above</td>
<td>£7M</td>
<td>£6M</td>
<td>Gallions Reach study proposes shorter approach viaduct therefore greater general highways cost</td>
</tr>
<tr>
<td>Preliminaries</td>
<td>£56M</td>
<td>£39M</td>
<td>£58M</td>
<td>Atkins propose a higher percentage allowance for both Belvedere and Gallions Reach, but due to higher MM approach and main span forecast costs the overall MM value for preliminaries is higher.</td>
</tr>
<tr>
<td>Design</td>
<td>£14M</td>
<td>£7M</td>
<td>£21M</td>
<td>Atkins propose a lower percentage allowance for both Belvedere and Gallions Reach.</td>
</tr>
<tr>
<td>Contractor's OH &amp; P</td>
<td>£19M</td>
<td>£13M</td>
<td>£29M</td>
<td>Atkins have used the same percentage allowance for both Belvedere and Gallions Reach but only applied it to the base construction cost</td>
</tr>
</tbody>
</table>

| Sub total                      | £282M                        | £195M                                  | £324M   |                                                                                                                                               |
| Subtotal cost per m² of deck   | £6172                        | £6145                                  | £5903   |                                                                                                                                               |
| Risk Allowance                 | excluded                     | excluded                               | £45M    |                                                                                                                                               |
| Total                          |                              |                                        | £369M   |                                                                                                                                               |
Table 6  Comparison of Belvedere Bridge option with Previous Gallions Reach Studies

The comparison shows that the longer bridge length adopted for the Belvedere study increases the main construction cost but price per m² of bridge is not dissimilar to the Gallions Reach study, or the Thames Gateway report. The Belvedere bridge is longer, owing to the decision to span over the approaches on each side of the river rather than build a tall approach embankment. Spanning over the approaches was chosen to avoid the significant cost of a piled embankment above the thick alluvial deposits and to minimise the footprint of the road on the two industrial estates. The balance of embankment vs. bridge length and land take could be investigated further to the next stage of development. Both junctions and the realigned Marsh Way access roads are also more complex compared to the other options.
7. Conclusions

Options have been investigated for a new crossing of the River Thames at a site from A2016 Picardy Manorway, Belvedere, via Burt's Wharf to the A13 at Marsh Way Dagenham. Options for a bridge or a tunnel crossing have been considered and from the limited investigations done to date; both appear to be technically feasible. Traffic capacity studies are not part of this report.

Of the bridge options considered, the cable-stayed bridge is likely to have the lowest cost and risk profile. The box girder bridge will require a higher alignment and the arch bridge is technically more complex. Appearance has not been considered in developing the bridge solutions but may have a major impact on stakeholder acceptance.

The immersed tube tunnel is preferred over the bored tunnel on the basis that construction would be shallower and length shorter. The visual impact of a tunnel would be markedly less than a bridge. Other environmental impacts could be higher than a bridge solution, particularly the impact on the River Thames bed.

The land required would create some disruption to businesses, but given the observed level of use, this is not likely to be a major restriction.

The indicative costs are:
- Bridge option £282 million
- Tunnel option £340 million

Information has been based on that which is available on public websites, from a site visit using public access only and from information provided by TfL, primarily OS mapping. No external consultation has taken place and information obtained has not been externally verified. Given the limited time available for the study there will be scope to develop and improve the options and optimise the alignment, form of construction and impact of site constraints. Further investigation and consultation will lead to more information on the impact of the scheme and its affect on third parties that will also serve to develop any design proposal that is taken forward.
Appendices
Appendix A. Client Brief

From: Fielder David [mailto:DavidFielder@tfl.gov.uk]
Sent: 25 October 2013 14:43
To: Mundell, Chris
Cc: Evans John F; Tye, Andy; Smith, David A; King Tom
Subject: RE: Updated Gallions Reach Documents

Chris

Thanks, please find the draft scope below.

TfL would like to extend the Task 92 commission. It concerns ascertaining the feasibilities of either a fixed bridge or a tunnel (both to be considered) from Belvedere (connecting to the A2016 Bronze Age Way) to Barking/Dagenham (connecting to the A13). The attached plan indicates the area to be considered. A brief high-level study is required to provide information on the feasibility for TfL.

In summary the two options to be considered are:

- A fixed bridge (assume 2 lanes each way = 4 lanes total)
- A tunnel (either bored or immersed – the lowest cost solution to be chosen) (assume 2 lanes each way = 4 lanes total)

The deliverable for the work is a brief report covering the following aspects:

- Plan drawing
- Long section and cross section(s)
- Budget/broad cost estimate for design & construction
- Description of your work and its major assumptions, this should include:
  - Impacts
  - Alignment selection
  - Property and land-take requirements (both during construction and in the permanent state)
  - Connectivity to the road network
  - Key risks
  - Any other issues (engineering & environmental) that are considered relevant by you (e.g. the challenges presented by immersed tunnel casting basin or remote manufacture)

The work is to be completed & delivered to TfL by Wednesday 13th November 2013.

I’m on leave next week so Tom King will send out the finalised scope including the plan, which should be ready early next week. John Evans will be covering for me next week in case of any queries.

Regards

Dave
Appendix B. General arrangement drawings

Drawing no 5118859-DR-D10-001 rev A – Highway Alignment
Drawing no 5118859-DR-S21-001 rev A – Option 1 Cable Stayed Bridge
Drawing no 5118859-DR-S22-001 rev A – Option 2 Steel Arch Bridge
Drawing no 5118859-DR-S23-001 rev A – Option 3 Concrete Box Girder Bridge
Drawing no 5118859-DR-T01-001 rev A – Immersed Tube Tunnel Alignment (Sheet 1 of 2)
Drawing no 5118859-DR-T01-002 rev A – Immersed Tube Tunnel Alignment (Sheet 2 of 2)
Drawing no 5118859-DR-T01-003 rev A – Immersed Tube Tunnel Typical Cross Section (Sheet 1 of 1)
CROSS SECTION AT FAN LOCATION

SCALE 1:500
Appendix C. DEFRA Magic plots
## Appendix D. Summary Quantities

### Concrete Box Girder Bridge

<table>
<thead>
<tr>
<th>Material description (please be as detailed as possible)</th>
<th>Volume / tonnage (3 dimensional measurements, accounting for void spaces where possible, would also be fine)</th>
<th>Construction stage. i.e. demolition, excavation, construction</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site clearance</td>
<td>5Ha</td>
<td>Demolition</td>
<td></td>
</tr>
<tr>
<td>Demolition</td>
<td>1 factory unit, 2 wind turbines, 1 material storage area, 1 car parking area</td>
<td>Demolition</td>
<td>Data is as observed on site. We do not have further details at this stage.</td>
</tr>
<tr>
<td>Fencing</td>
<td>1800m</td>
<td>Construction</td>
<td>Post and wire</td>
</tr>
<tr>
<td>Safety Barrier</td>
<td>800m</td>
<td>Construction</td>
<td>Single sided N2</td>
</tr>
<tr>
<td>Soils and stones / spoil</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imported fill</td>
<td>25,000m³</td>
<td>Construction</td>
<td></td>
</tr>
<tr>
<td>Excavations</td>
<td>34,900 m³</td>
<td>Excavation</td>
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<td>Disposal of unacceptable excavations</td>
<td>95%</td>
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<td>This as a % of the total excavations</td>
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<tr>
<td>Reuse of acceptable materials</td>
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<td>This as a % of the total excavations</td>
</tr>
<tr>
<td>Balancing pond, lined 1800m³, bypass interceptor 900L, spillage containment 25m³</td>
<td>2 No.</td>
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<td>Bituminous materials</td>
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<td></td>
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<tr>
<td>Base Course 200 thk</td>
<td>15600 m²</td>
<td>Construction</td>
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</tr>
<tr>
<td>Binder Course 60 thk</td>
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<td>Construction</td>
<td></td>
</tr>
<tr>
<td>Surface Course 40 thk</td>
<td>60750 m²</td>
<td>Construction</td>
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<tr>
<td>Kerbing and Edging</td>
<td>14700 m</td>
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<tr>
<td>Footway paving</td>
<td>18800 m²</td>
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<tr>
<td>Bridge deck waterproofing</td>
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<td></td>
<td></td>
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<td>Construction stage. i.e. demolition, excavation, construction</td>
<td>Comments</td>
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<tr>
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<td><strong>Concrete</strong></td>
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</tr>
<tr>
<td>Piling bored cast insitu</td>
<td>8740 m</td>
<td>Construction</td>
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</tr>
</tbody>
</table>

- Includes temporary haul road and site compound
- Excludes temporary jetties, and formwork travellers and temporary props
## Immersed Tube Tunnel

<table>
<thead>
<tr>
<th>Material description (please be as detailed as possible)</th>
<th>Volume / tonnage (3 dimensional measurements, accounting for void spaces where possible, would also be fine)</th>
<th>Construction stage. i.e. demolition, excavation, construction</th>
<th>Comments</th>
</tr>
</thead>
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<tr>
<td>Demolition</td>
<td>I factory unit 2 wind turbines 1 material storage area 1 car parking area</td>
<td>Demolition</td>
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<tr>
<td>Imported fill rock armour</td>
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<td>Volume / tonnage (3 dimensional measurements, accounting for void spaces where possible, would also be fine)</td>
<td>Construction stage. i.e. demolition, excavation, construction</td>
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</tr>
<tr>
<td>----------------------------------------------------------</td>
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<tr>
<td>Piling bored cast insitu</td>
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<td></td>
</tr>
</tbody>
</table>

- Assumes tunnel units fabricated off site so casting basin not included in quantities.
- Immersed units brought to site by sea. They are included in quantities.
- Includes temporary haul road and site compound.