Lower Thames Crossing

Pre-Consultation Scheme Assessment Report

Volume 4: Engineering, Safety and Cost Appraisal

Volume 4

Lower Thames Crossing
Route Consultation 2016

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The designs shown and described in this Pre-Consultation Scheme Assessment Report have been developed for the detailed appraisal of options as part of the options phase, and may be subject to change in later stages of the scheme development.

1 Introduction

1.1 Structure of Pre-Consultation Scheme Assessment Report

1.1.1 The Pre-Consultation Scheme Assessment Report (SAR) brings together the engineering, safety, operational, traffic, economic, social and environmental appraisal of the shortlist routes for the Lower Thames Crossing. The appraisal of the longlist options was reported in the *Technical Appraisal Report* (TAR) (refer to Sections 2 and 3 of Volume 3 of the SAR).

1.1.2 Drawing on the results of the appraisal the SAR recommends which routes should be taken to public consultation. It also sets out Highways England's proposed scheme.

1.1.3 The SAR is set out in a number of Volumes, as follows:

- Volume 1 – Executive Summary
- Volume 2 – Introduction and Existing Conditions
- Volume 3 – Identification and Description of Shortlist Routes
- **Volume 4 – Engineering, Safety and Cost Appraisal**
- Volume 5 – Traffic and Economics Appraisal
- Volume 6 – Environmental Appraisal
- Volume 7 – Appraisal Conclusions and Recommendations

1.1.4 Following public consultation, this document will be reviewed and updated to produce a final Post-Consultation Scheme Assessment Report that takes account of the comments received. It will also include the report on public consultation, and the recommendation for the Preferred Option. The Preferred Option will be the scheme that Highways England recommends should be taken forward into an application for development consent.

1.2 Structure of this Volume

1.2.1 The structure of this volume is as follows:

- Section 2 sets out the engineering appraisal that has been carried out on the shortlist routes
- Section 3 describes the safety appraisal carried out on the shortlist routes
- Section 4 outlines the buildability, construction programme and construction impacts of the shortlist routes
- Section 5 sets out the operations and maintenance requirements of the highways and River Thames crossing structures
- Section 6 outlines the approach to appraisal of design and construction risk

- Section 7 sets out the capital, operating and maintenance cost estimates of the shortlist routes
- Section 8 considers the need for futureproofing at Location C crossing by provision of an additional lane in each direction
- Section 9 provides a summary of the results for the engineering, safety and cost appraisal

1.2.2 The cost estimates reported in Section 7 include for all aspects of the appraisals detailed in Sections 2, 4 and 5 to a suitable level of detail for this stage of option development.

1.2.3 All locations and features referred to in this volume are shown in Appendix 2.2 to Volume 2.

2 Engineering Appraisal

2.1 Overview of Route Options

2.1.1 **Figure 2.1** shows the shortlist routes and the key features are summarised in **Table 2.1**.

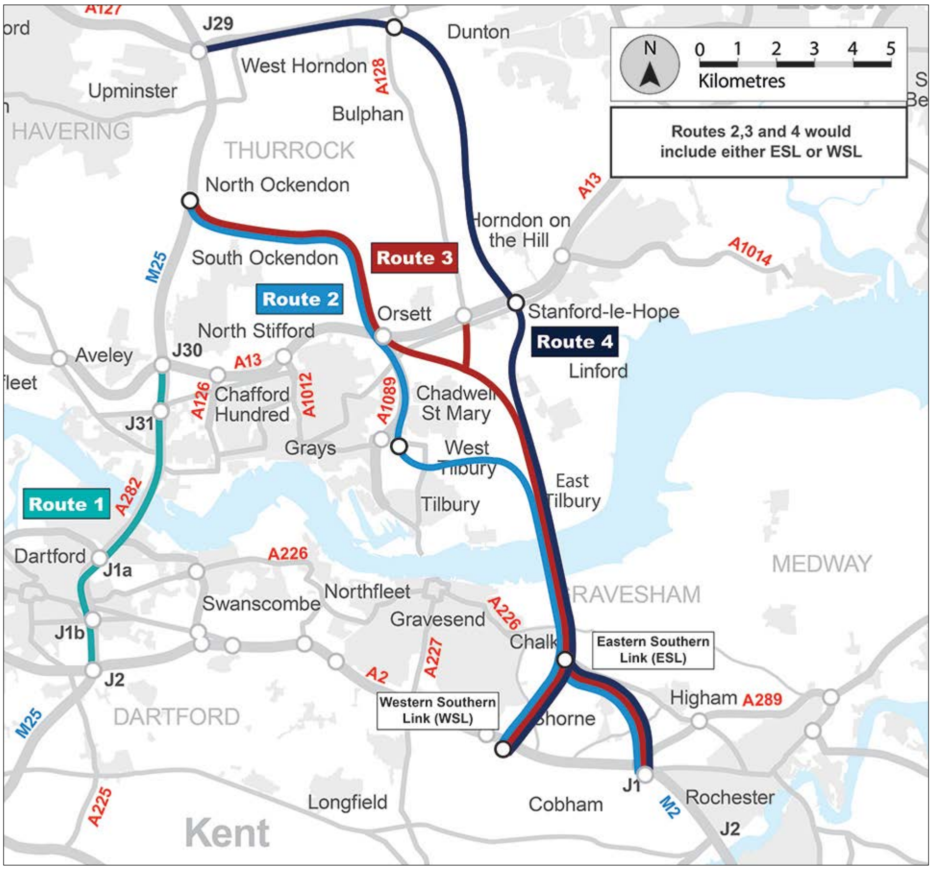

FIGURE 2.1 - SHORTLIST ROUTES

2.2 Design Standards

2.2.1 The shortlist routes have been designed in accordance with the Design Manual for Roads and Bridges (DMRB), specifically TD9/93 Highway Link Design. This design standard provides the requirements for the geometry of the road in terms of the horizontal and vertical alignment. The design speeds for the shortlist routes are shown in **Table 2.1**.

2.2.2 The lane layout for Route 1 mainline is shown in **Figure 2.2**. The mainline for Routes 2, 3 and 4 is a dual 2 lane all-purpose road standard.

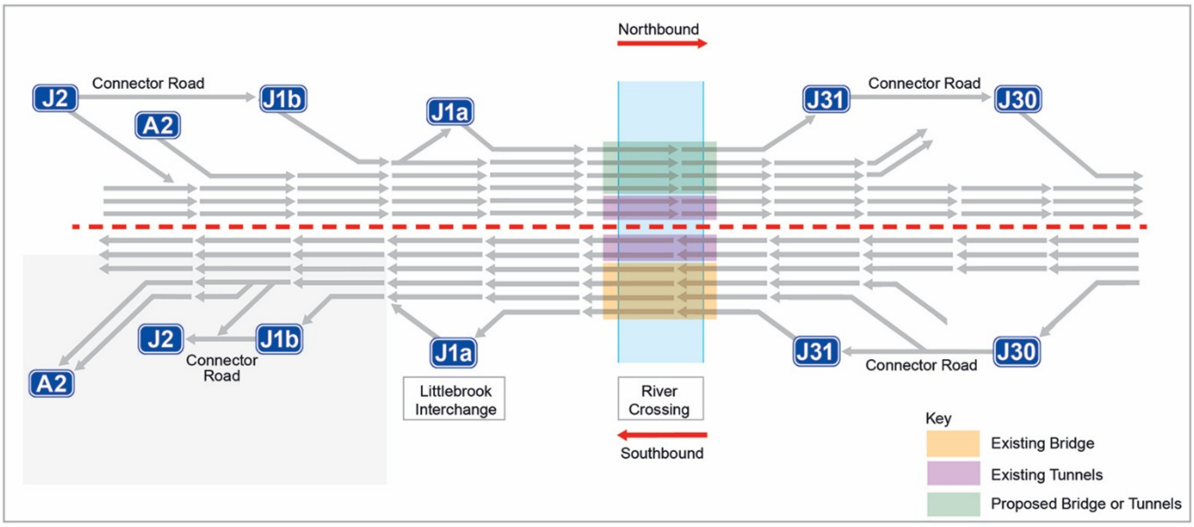

FIGURE 2.2 - ROUTE 1 SCHEMATIC LANE LAYOUT

2.2.3 In developing the highway design other DMRB standards have also been used including;

- TD 27/05 Cross-Sections and Headrooms, used to determine the carriageway cross section and clearances to structures.
- TD 22/06 Layout of Grade Separated Junctions, used to develop the junction layouts and determine their location in relation to existing junctions.

2.2.4 The design standards have a three tier hierarchy approach to situations where the desirable minimum requirements cannot be achieved. The initial steps are in the form of relaxations (1 step and 2 steps below desirable minimum standards), and the final step would be a departure.

2.2.5 In developing the shortlist routes a number of key departures have been identified. These are summarised in **Table 2.2** and set out in more detail in **Appendix 4.1**. These departures relate in the main to geometric standards and would be the same for all crossing options. Proposed departures from DMRB standard must be submitted to Highways England Professional and Technical Services Division (PTSD) and approved before inclusion in the design to ensure the safety of the scheme.

2.2.6 Initial meetings have been held with Highways England PTSD to discuss these departures. The outcome of these meetings was that PTSD did not consider the departures identified would cause significant issues. During the next stage of the scheme all remaining departures would have to be reassessed and formally submitted to PTSD for approval.

TABLE 2.1 - KEY FEATURES OF SHORTLIST ROUTES

	Route 1 (BR, BT)	Route 2, WSL (BR, BT, IT)	Route 2, ESL (BR, BT, IT)	Route 3, WSL (BR, BT, IT)	Route 3, ESL (BR, BT, IT)	Route 4, WSL (BR, BT, IT)	Route 4, ESL (BR, BT, IT)
Mainline Design Speed kph (mph)	85 (50)	120 (70)	120 (70)	120 (70)	120 (70)	120 (70)	120 (70)
Free-flow Junction Design Speed kph (mph)	70 (40)	100/ 85/ 50 (60/ 50/ 30)	120/ 100/ 85 (70/ 60/ 50)	100/ 85/ 50 (60/ 50/ 30)	120/ 100/ 85 (70/ 60/ 50)	100/ 85/ 50 (60/ 50/ 30)	120/ 100/ 85 (70/ 60/ 50)
Mainline Cross-Section	Varies – refer to Figure 2.2	Dual 2 lane All Purpose Road					
Key Features	On-line improvements, constrained by existing urban features	New off-line route, includes widening of A1089		New off-line route		New off-line route, includes widening of A127.	
		Includes new local link road south of A2	-	Includes new local link road south of A2	-	Includes new local link road south of A2 Includes new link road north of A127	Includes new local link road north of A127
Junctions	A282 Junction 1a (upgraded) M25 Junction 31 (upgraded) M25 Junction 30 (upgraded)	A2 (new) A226 (new) A1089 (new) A13 (upgraded) M25 (new)	M2 (upgraded) A226 (new) A1089 (new) A13 (upgraded) M25 (new)	A2 (new) A226 (new) Brentwood Road (new) A13 (upgraded) M25 (new)	M2 (upgraded) A226 (new) Brentwood Road (new) A13 (upgraded) M25 (new)	A2 (new) A226 (new) A13 (new) A127 (new) M25 Junction 29 (upgraded)	M2 (upgraded) A226 (new) A13 (new) A127 (new) M25 Junction 29 (upgraded)
Construction Duration (years)	6.5	4.75 (BR) 4.5 (BT and IT)					

Note:

BT - Bored Tunnel

IT - Immersed Tunnel

BR - Bridge

TABLE 2.2 - KEY DEPARTURES

	Route 1	Route 2 WSL	Route 2 ESL	Route 3 WSL	Route 3 ESL	Route 4 WSL	Route 4 ESL
Successive merge / diverge	2	3	3	-	-	-	-
Merge / diverge	13	-	1	-	1	3	4
Weaving length	3	3	6	5	8	2	5
Technology	4	-	-	-	-	-	-
Lane provision	2	-	-	-	-	-	-
Geometry	3	-	-	-	-	-	-
Total	**27**	**6**	**10**	**5**	**9**	**5**	**9**

2.3 Geotechnical

2.3.1 The geology at both Location A (Route 1) and Location C (Routes 2, 3 and 4) is similar and is generally well understood from previous works in the area. The formations and geological succession are presented in the *Technical Appraisal Report* Section 2.9.

2.3.2 The following appraisal is based on information provided in the Preliminary Sources Study Report (PSSR) as specified by DMRB HD 22/08 Managing Geotechnical Risk. Historic and geological information has been obtained from archives held by external stakeholders, local councils and bodies such as Kent County Council, the Environment Agency, Highways England, the British Geological Survey (BGS) and local landfill operators. For the River Thames crossing ground information has been utilised from the cable tunnels constructed at Dartford-Thurrock and Tilbury-Gravesend. The geotechnical appraisal may be subject to change as more information is made available.

2.3.3 Three main geological formations will be encountered at either crossing location. Superficial deposits will comprise Alluvium which is generally soft clayey silt or silty clay with beds of sand and peat horizons, and the River Terrace Gravels which comprise sand and gravel with local lenses of silt/ clay and peat. The solid geology is primarily comprised of the Upper Chalk formation which is a very fine grained Limestone with commonly occurring flint bands. To the south of the River Thames, in the vicinity of the Eastern Southern Link, the Lambeth Group and Harwich Formation are also likely to be encountered. Head, Alluvium and London Clay are likely to be found in the vicinity of the A13 and the A127/ M25.

Engineering Implications and Recommendations - Crossings General

2.3.4 The suitability of the geology at the locations for the proposed crossing structures has been carefully considered. The ground conditions are well suited to the proposed bridge and tunnel options, as the Upper Chalk is a generally competent engineering formation. It has excellent bearing capacity for bridge and viaduct foundations, and is also well suited to tunneling.

Engineering Implications and Recommendations - Bridge

2.3.5 If a bridge option is considered, the foundations for the bridge piers are likely to be similar to those constructed for the existing QEII Bridge as the geology present at either bridge crossing is considered comparable to that encountered for the QEII Bridge.

Engineering Implications and Recommendations - Tunnel

2.3.6 The ground conditions for tunneling beneath the Thames are also considered to be similar to those encountered during the construction of HS1 tunnel between Grays and Ebbsfleet, (approximately 2.5km east of the QEII Bridge, beneath the Swanscombe Peninsula), and it is anticipated that comparable engineering challenges would be met if the tunnel option is pursued.

2.3.7 Proposals for a bored tunnel would probably require the specification of an Earth Pressure Balance Tunnel Boring Machine to prevent water ingress during tunnel construction. The geotechnical conditions are also assessed as suitable for immersed tube tunnel construction, particularly at Location C where an option using this form of construction has been developed for appraisal. The construction involves a deep trench beneath the river bed that would extend into the Chalk layers and into which the large concrete tunnel units would be placed, plus lengths of deep cut and cover structure beyond where the immersed units can be used. This would require construction techniques suitable for a depth in excess of 10m below the river surface level.

2.3.8 Large quantities of excavation spoil would be anticipated from the construction of any of the proposed options, less so from the proposed bridge solutions. Excavation spoil from beneath the groundwater table, for example the tunnel crossing, is unlikely to be suitable for embankment construction without some form of treatment and sorting as it would be fully saturated and re-worked. For it to be considered for re-use the moisture content would need to be lowered to increase workability and to ensure stability. This may be achievable through air drying or lime stabilisation. Excavation spoil from the cut slopes above the groundwater table, for example from the tunnel approaches and remainder of the highways alignments, is likely to be suitable (subject to testing for reuse) as embankment material and general or landscaping fill.

2.3.9 The River Thames crossing bored tunnel options would encounter a high, tidally varying, groundwater table and two hydraulically connected permeable water bearing strata. The deepest part of the tunnel would be wholly within the Chalk aquifer with groundwater pressures in excess of 4 bar (400kPa) beneath the central section of the River Thames. Shallower tunnel sections would also encounter clayey Alluvium and water bearing river terrace deposits (sandy gravel) overlying the Chalk aquifer.

2.3.10 Groundwater controls at the tunnel portals would likely be a concern for both locations. At Location A tunnel portal elevations would be close to the groundwater table at the lowest sections and therefore groundwater control would be needed during construction and probably during operation.

2.3.11 Tunnel portals at Location C would be deeper and are anticipated to be below the groundwater table. The Location C southern tunnel portal is proposed within the top of the Chalk aquifer and below the groundwater table. The Location C northern tunnel portal would most probably be within Alluvium and landfill, and would also be below the water table. Consequently, construction and operational groundwater controls would likely be required at both Location C tunnel portals which could include the construction of cut-off walls and grouting.

Engineering Implications and Recommendations - Groundwater

2.3.12 The existing groundwater regime and groundwater flow directions could potentially be affected temporarily where there is construction groundwater control comprising pumping. Groundwater controls via pumping could also induce increased construction surface settlements as a result of changes in the effective stress.

2.3.13 Temporary groundwater pumping would most likely be proposed for any River Thames tunnel portal construction, however mitigation measures could be designed to avoid any deleterious groundwater lowering outside of the temporary land take.

2.3.14 Disruption of the groundwater regime during operation could potentially occur where there are large structures (e.g. tunnels and cuttings) which penetrate the ground beneath the water table, especially if the buried structures traverse the dominant groundwater flow direction. Hydrogeological assessments would be required to identify in detail the water control procedures required for Locations A and C.

2.3.15 The proposed crossing beneath the existing A13 (Routes 2 and 3) may encounter mixed soil conditions and the possibility of multiple, perched water bearing layers of limited recharge. Further ground condition information, including baseline groundwater level information, would be required to detail the design and confirm the most appropriate techniques for constructing underbridges beneath the existing A13 highway. The underpasses would need to be waterproofed due to the likelihood of perched groundwater levels in the future.

2.3.16 Elsewhere there is only potential for a localised change of groundwater regime as the proposed road level is typically elevated above the groundwater table. Local occurrence of shallow superficial aquifers (perched water) may mean there is potential for local change to the shallow groundwater regime if a cutting penetrates below perched water levels. However the effect would be expected to be generally insignificant and a hydrogeological assessment would be conducted to assess the effect on identified sensitive receptors such as where base flow to streams is identified.

Engineering Implications and Recommendations - Highways and Earthworks

2.3.17 The current route alignments would encounter landfills at either Location A or Location C. These areas would require careful consideration and may need to be stabilised or excavated and filled. Environmental and groundwater protection issues will be at the forefront of any proposals with the most appropriate construction method determined on a case by case basis.

2.3.18 Preliminary earthwork recommendations have been determined for all four routes, primarily based on the Transport and Road Research Laboratory (TRRL) Report 199 for the various geological formations encountered. The recommendations have been refined to four distinct areas (refer to **Figure 2.3**) based on the primary geology present in each area.

2.3.19 Area 1 is south of the River Thames flood plain where the Chalk outcrops for most of the proposed alignments. Design assumptions made are:

- Due to the nature of Chalk, cut slopes have been proposed as 2 part slopes comprising a 1V:1H lower slope angle with a 1V:2H batter slope to ground level. This would reduce the requirement for land take and amount of material required to be excavated.
- 1V:2H slope has been selected for the embankments constructed from the Chalk spoil produced form the cut slopes.

2.3.20 In Area 2, which lies within Area 1, there would be a deep cut slope in excess of 11m in depth for the Eastern Southern Link. In this area the geology present comprises Thanet Sand (clayey silty sand) and the Lambeth Group and Harwich Formation (clays, silts, sands and gravels). Due to this a 1V:3.5H cut slope has been assumed for increased stability.

2.3.21 Area 3 lies between the River Thames flood plain and the A13. Here the geology comprises mainly sands and gravels of Thanet Sand (clayey silty sand) and River Terrace Deposits (sands and gravels). Design assumptions made are:

- Cut slopes would be expected to form at a 1V:2.5H to 1V:3H slope.
- Resulting spoil used to construct embankments at a slope of 1V:2.5H.

2.3.22 Area 4 mainly lies between the A13 and the A127/ M25 where the geology is primarily clayey in nature formed of Head and Alluvium (peats, silts, clays, sands and gravels) and London Clay (silty clay). Lambeth Group deposits comprising clays, silts and silty sands are present at the southern extremity of this area. Design assumptions made are:

- Cut slopes would be formed at a 1V:3H to 1V:3.5H angle for increased stability of the cohesive materials.
- Embankments formed from the London Clay would be constructed at a 1V:2.5H to 1V:3H slope, depending on height.
- The exception to these recommendations is where Route 4 passes beneath the Shoeburyness Railway with a cut slope in excess of 12m. At this location a slope of 1V:4H would likely be required.

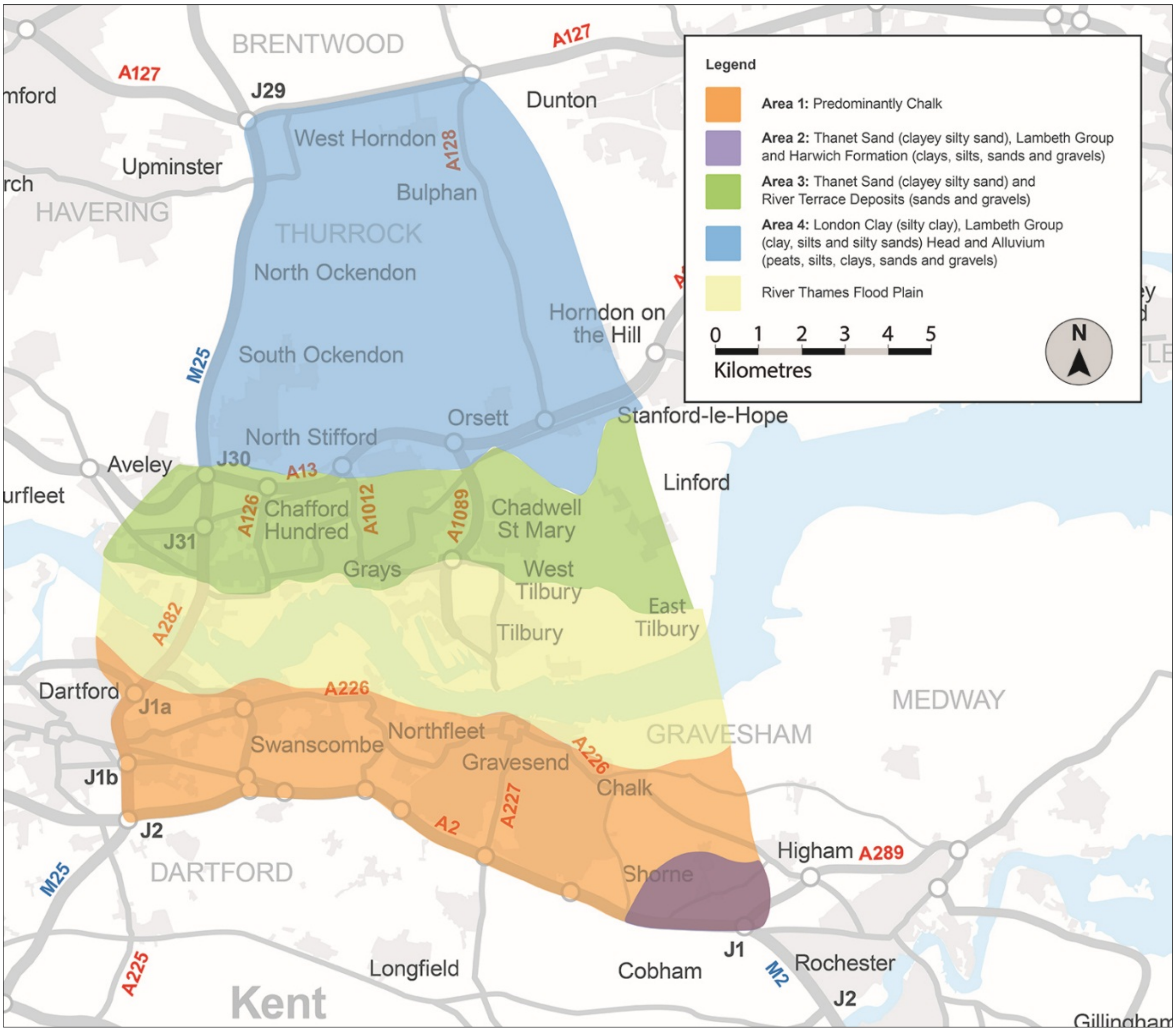

FIGURE 2.3 - PRIMARY GEOLOGICAL AREAS

2.3.23 All the recommendations discussed above would be subject to a ground investigation and appropriate modelling and analysis which would be carried out in the development phase.

Geotechnical Risk Assessment and Mitigation

2.3.24 An extensive preliminary geotechnical risk assessment for the scheme has been carried out and is presented in the Preliminary Sources Study Report, along with suggested mitigation.

2.3.25 A considerable amount of ground information is available covering the majority of the study area in the form of historic borehole and trial pit records. This information has been extracted from Highways England Geotechnical Data Management System (HAGDMS) and BGS databases, and collated into a scheme specific ground information database linked with a reports database. The two databases have been linked through a unique reference number where possible and the borehole database was then converted into Geographic Information System (GIS) format allowing efficient data analysis to be conducted. In addition numerous further datasets were acquired and procured from external bodies and stakeholders. These datasets encompass landfills and other contaminative land use datasets, various hydrological and hydrogeological data, historical development data and various geological data including geotechnical hazards. The findings, implications and conclusions are presented in the Preliminary Sources Study Report which includes a conceptual site model, encompassing contamination risks and the risk to sensitive receptors from this contamination.

2.3.26 The alignments of the different crossing structures was plotted against the available geotechnical information in the form of river crossing sections to assess the feasibility, the nature of the crossing structures and the associated risks. Refer to **Appendix 4.2** for geotechnical drawings**.**

2.3.27 Existing and historic landfills may affect the design and construction of the link roads and junctions. Ownership of these varies and various organisations such as the Environment Agency, local landfill operators and the various local authorities have been approached for information. Of the large number of landfills present within the study areas there is a wide range of waste present. This waste is reported to be a combination of household, industrial and commercial, with the majority of landfills having industrial waste present. Some of these wastes could provide a significant contaminative risk as well as a gas risk; Routes 2 and 3 encounter the landfill at South Ockendon (refer to **Figure 2.4**) which has gas and leachate extraction infrastructure in place. These risks should be mitigated through extensive testing and an appropriate engineering solution proposed.

FIGURE 2.3 - LOCATION C LANDFILL SITES

2.3.28 It should be noted there are a number of geotechnical hazards present in the study area that must be considered. These hazards include, for example, the presence of solution features where water has eroded or dissolved the Chalk creating underground voids. Another example is where excavations beneath the water table may result in running sands where loose sands become fluidised by water and begin to run. This is applicable to the Thanet Sand formation and possibly other geological formations. There is also the risk of encountering unexploded ordnance.

Geotechnical Summary

2.3.29 The routes within Locations A and C all encounter similar geology. The instances of geotechnical hazards such as solution features, contaminated ground, soft ground and other features requiring geotechnical treatment are not too dissimilar, and engineering solutions can be developed to overcome the various hazards whichever route is taken at Location C. However the presence of an engineered landfill on Routes 2 and 3, will require a detailed engineering assessment. This might lead to a modification of the route alignment to avoid this site. The experience gained from similar projects in the general vicinity of the study area will provide valuable insight into avoiding or mitigating such issues which should be accounted for in design.

2.4 Utilities

2.4.1 Existing utility information has been obtained for Locations A and C. This process has identified the location and type of significant utility infrastructure within the vicinity of the route options within Locations A and C.

2.4.2 At Location A, Route 1 has been designed to avoid the Dartford Cable Tunnel. The route alignment has also been designed assuming at least 10m clearance to the existing tunnel ventilation buildings so as not to impact on associated utilities.

2.4.3 At Location C none of the utility infrastructure identified is considered as a constraint on the route alignment development and design.

2.4.4 The utility infrastructure that is not considered a constraint has been reviewed against the route option alignments and outline diversion/ protection measures developed (refer to **Appendix 4.3**). These protection and diversion measures have been included in the cost estimates, reported in Section 7.

2.4.5 At Location A north of the river there are a number of overhead high voltage electricity cables that would require diversion.

2.4.6 At Location C north and south of the river there are a significant number of overhead high voltage electricity cables that would require diversion for all route options. In addition there are large gas mains (including those connecting to the National Grid pipeline in tunnel under the River Thames) and water mains that could require diversion or protection depending on the route option.

2.4.7 At both Locations A and C telecommunication cables, low voltage electricity cables, low pressure gas mains, small water mains and other utilities have been reviewed but not assessed in detail due to the current level of design development.

2.5 Lighting

Background

2.5.1 This section covers the new highways and junctions associated with the proposed shortlist routes and considers the need to provide lighting.

2.5.2 The decision to provide lighting has several contributory elements including regulatory, financial, safety and environmental factors.

2.5.3 The design standard used TA49/07 (Appraisal of new and replacement lighting on the strategic motorway and all-purpose trunk road network) sets out the requirements for the appraisal of road lighting on the strategic road network. The primary purpose of road lighting is to reduce personal injury accidents (PIA). This is a quantifiable benefit used for the purposes for considering the provision of lighting. The financial justification for providing lighting is based on a ‘Benefit Cost Ratio’ (BCR) comparison between the predicted costs of PIA's compared to the predicted costs of installing, operating, maintaining and disposing-at-end-of-life of a lighting system.

2.5.4 This economic assessment has followed the current Highways England guidance as well as the advice from the Smart Motorways Programme Operational Safety Team. This assessment has only considered the provision of lighting in the verge. This is in accordance with current best practice to avoid providing lighting in the central reserve to reduce the cost and risk of maintenance.

Route 1

2.5.5 As the existing A282, bridge and tunnels are lit then in accordance with current standards any new highway and crossing would also need to be lit.

Routes 2, 3, 4 - WSL and ESL

2.5.6 An initial economic appraisal has been undertaken indicating that the mainline route would not need to have lighting provided. This will need to be considered in more detail in the next stage of scheme development.

2.5.7 In accordance with current design standards some of the junction slip roads would require partial lighting where they link with existing lit highway sections, or have tight curve radii.

River Crossing - Bridge

2.5.8 The BCR (as calculated in accordance with TA49/07) demonstrates that a bridge would not require lighting. There are other factors such as road user, worker and navigational safety or environmental, that are outside the scope of the appraisal carried out in accordance with TA49/07 that may require a bridge to be lit. If lighting is required BS5489-1:2013 Section 7.6.1 calls for the lighting class applied to the bridge approach roads to be applied to the bridge deck itself. If a bridge option is taken forward this would be assessed in more detail during the development stage.

River Crossing - Tunnel

2.5.9 As the length of the road tunnel would be greater than 200m, lighting should be provided (BS5489-2:2003+A1:2008) for the total length of the tunnel from portal-to-portal and night time only lighting for 200m outside the portals at either end for each travel direction

2.5.10 The tunnel interior lighting would need to operate both during the day and at night, with a higher level close to each portal during the day, to help a driver's eyes to adjust to/ from the bright natural daylight outside of the portals. The tunnel lighting would need to produce a lower light level at night, as the eyes of drivers approaching the tunnels would have adapted to night time light levels on the highway outside of the tunnel.

2.5.11 The Parting Zone lighting may need to be extended beyond the required 200m (CIE88:2004 Section 5.3) from the tunnel portals, to allow for any maintenance/ exceptional load lay-bys being provided close to the tunnel entrances. This would allow drivers entering/ leaving the tunnel to see slow/ slower moving vehicles entering/ leaving the laybys outside the tunnel portals.

2.5.12 In summary, Route 1 would need to be lit throughout as the existing route is already lit and due to the proximity of junctions. Routes 2, 3 and 4 would require lighting at the junctions, and at any tunnel and its approaches. It is possible that lighting would not be required on the links between junctions (including over any bridge crossing structure), subject to further detailed assessment at the next stage of scheme development.

2.6 Drainage

2.6.1 A conceptual drainage design has been developed in accordance with current design standards and good practice and is described in the following paragraphs. The cost estimates reported in Section 7 include for this conceptual design. The drainage design will be developed in more detail during the development stage.

Surface Water Collection and Conveyance - General

2.6.2 The design of surface water collection systems would be informed by the vertical alignment of the highway and space constraints.

2.6.3 Surface water drainage channels would be the default surface water collection method. Surface water channels are the preferred edge detail solution on the Strategic Road Network (SRN) for reasons of ease of maintenance, constructability, cost and safety.

2.6.4 Surface water drainage channels constructed in the verge would be grass lined or concrete lined. Surface water drainage channels constructed in the central reserve would be concrete lined (on the assumption that the central reserve would be paved).

2.6.5 Along any kerbed sections of the highway it would be necessary to utilise linear drains or trapped gullies for the collection of surface water runoff. Gullies are the preferred method of collection along kerbed sections of road due to cost and ease of maintenance. Linear drains (e.g. combined kerb drains and slot drains) become more cost effective if gully spacing is short (10m or less) and would typically be used on flatter sections of the highway.

2.6.6 Collected surface water would be conveyed using filter carrier drains where disposal of water through infiltration is possible and permissible. Standard carrier drains would be used in all other locations.

2.6.7 Each carriageway would have a separate surface water collection and conveyance system.

Surface Water Treatment - General

2.6.8 The level of surface water runoff treatment required would vary along the route of the highway and would generally be determined by environmental constraints, discharge methodologies and likelihood of contamination. The purpose of treatment is to remove oils and other hydrocarbons, silt, sediment and debris from surface water runoff before discharge. Treatment levels would be determined in conjunction with the Environment Agency.

2.6.9 Pollution control measures would be provided to protect downstream watercourses, water bodies and drainage assets in the event of a major spillage of a hazardous liquid.

Storage and Discharge - General

2.6.10 Discharge of collected surface water runoff would, in order of preference, be into the ground, to a surface water body, to a surface water sewer or to a combined sewer.

2.6.11 If collected surface water is to be controlled prior to discharge then storage would have to be provided. As the majority of discharges would need to be controlled to equivalent greenfield runoff rates the provision of extensive storage capacity would be required for all routes.

2.6.12 Storage would be provided by oversized pipes where possible or buried tank systems. Where particularly large amounts of storage needs to be provided (e.g. pumped discharges) then detention basins or infiltration basins would be utilised if possible.

Surface Water Drainage - Route 1

2.6.13 The space constraint associated with Route 1 would generally negate the option for using drainage channels for surface water collection. Furthermore, in urban environments, such as that through which Route 1 runs, it would be normal practice to provide kerbing. For these reasons, surface water drainage collection for Route 1 would be primarily achieved using gullies, and where necessary linear drains.

2.6.14 The widening of the A282 would result in the loss of existing surface water collection provisions. However, along the widened section of Route 1 it may be possible to utilise some of the existing conveyance systems provided that they are in a serviceable condition.

2.6.15 Treatment of runoff from Route 1 would include use of and sustainable urban drainage systems (SuDS), catchpit chambers, vortex separators and by-pass oil separators.

2.6.16 Most of the collected surface water would be discharged to surface water bodies and into the ground (where possible and permissible).

2.6.17 Space constraints along widened sections of the A282 would exclude the use of above ground storage options. However, storage for these sections would only need to be provided for runoff from the widened sections of the highway and would be achieved by oversizing the carrier drains.

2.6.18 Storage requirements for collected surface water runoff from the new sections of the highway adjacent to the crossing and the bridge deck or tunnel approaches would be substantial. Large underground tanks would be required to store the collected water. Gravity discharge of collected surface water from the underground tanks would not be possible. Water from the tanks would need to be pumped to the point of discharge (at the permitted discharge rate).

Surface Water Drainage - Routes 2, 3 and 4

2.6.19 Channel drains would primarily be used for surface water collection for Routes 2, 3 and 4. Surface water collection at junctions, particular areas with space constraints and along any kerbed sections of highway would generally be achieved using gullies, and where necessary linear drains.

2.6.20 The section of Route 2 that passes between Grays and Chadwell St. Mary would be kerbed where it passes close to existing development. Drainage of these sections of highway would generally be achieved using gullies.

2.6.21 Treatment of runoff from Routes 2, 3 and 4 would include use of and sustainable urban drainage systems (SuDS), catchpit chambers, vortex separators and by-pass oil separators.

2.6.22 Most of the collected surface water would be discharged to surface water bodies and into the ground (where possible and permissible).

2.6.23 As space constraints do not generally present a problem with Routes 2, 3 and 4, storage requirements would be provided by ponds, basins or swales. In certain areas it may be necessary to provide oversized pipes or underground tanks but these would be limited.

Tunnels - General

2.6.24 The drainage provisions in a tunnel would need to deal with wash-down water, firefighting water, and any surface water runoff form the approaches that enters the tunnel. Combined kerb drains would be used to capture and convey all forms of water in the tunnel. The captured water would discharge to a pumping station at, or near, the lowest point of the tunnel.

2.6.25 A pumping station would also be required at each tunnel portal to manage surface water runoff from the tunnel approaches.

Bridges and Viaducts - General

2.6.26 Surface water runoff from bridge and viaducts decks would be collected by combined kerb drains. The combined kerb drains would discharge the collected surface water to carrier pipes that would be routed through the bridge deck/ viaduct structure until a suitable discharge point was reached.

2.6.27 Surface water contaminated with deicing chemicals used on any bridges or viaducts would need to be discharged to a wastewater treatment plant. Under normal conditions the collected water could be treated as described above but would need to be diverted to a treatment facility if deicing chemicals have been applied.

Pumping Stations - General

2.6.28 Pumping stations would only be considered where it can be demonstrated that it is not reasonably practicable or possible to convey collected flows to a suitable discharge point by means of gravity. In addition to the three pumping stations required for a tunnel, it is expected that a small pumping station would be required for Route 1 at the London Tilbury Southend Railway underpass. It is also expected that a further pumping station would be required to break up the 1900m long catchment that falls towards the southern portal for Routes 2, 3 and 4; this would improve surface water management and provide relief for the pumping station at the southern portal.

2.6.29 In summary, Route 1 would generally require a kerb and gully arrangement for surface water drainage, and the design of drainage storage features would be affected by restrictions on available space. The surface water drainage design for Routes 2, 3 and 4 would generally be provided by drainage channels, and with more space available, there would be greater flexibility in the design of storage and discharge arrangements.

2.7 Traffic Control Technology

2.7.1 All options would need technology to enable user charges to be levied. The operation of this might be combined with existing crossing charge collection. Charging technology is not addressed in the SAR as it is common to all routes and was therefore not considered a differentiator between routes at the options stage.

Difference in technology provision for bridge and tunnel crossings

2.7.2 A new tunnel crossing would require systems for safe operation, including fire detection and suppression system, public address system, lane control signs, communications, emergency services radio/ telephone system, cross passageway equipment, tunnel specific CCTV, drainage pumping systems, ventilation, emergency lighting, uninterruptable power supply, and automatic monitoring and control systems (manned/ unmanned).

2.7.3 A new bridge crossing would require technology to support operation and maintenance activities, together with weather information systems which would include wind speed/ direction, visibility to provide alerts of mist and fog, air temperature, road surface temperature to determine the possibility of ice on the carriageway, bridge structure monitoring systems, emergency telephones and/ or stranded vehicle detection.

Route 1

2.7.4 The new crossing would need to operate in conjunction with the existing crossing and the technology provided would need to be consistent with the adjacent network. Required technology would include incident detection, temporary traffic management signs, controlled motorway provision and lane control signs.

2.7.5 The existing control centre at Dartford would require relocation and modification as it would be affected by construction and operation of this route. Construction and commissioning of the new control centre would need to be carried out under an advanced works stage to the main construction works, in order to ensure that the control centre was always operational throughout construction.

2.7.6 As part of the scheme the M25/ A282 between Junction 2 and Junction 30 would be upgraded with smart motorway technology provision as outlined in Interim Advice Note (IAN) 161/13. However due to existing constraints along the A282 corridor, there are limitations as to the extent of smart motorway infrastructure that could be accommodated. For example between Junction 2 and Junction 1a there are significant retaining structures which would constrain the economic provision of Emergency Refuge Areas (ERA) and verge-mounted message signs.

2.7.7 With regard to signals and the display of Variable Mandatory Speed Limits (VMSL) it should be noted that the M25 between Junction 2 and Junction 31 remains the A282 from a legislative perspective. As such it has existing fixed-plate speed limits of 60mph and 50 mph in place. Since 40mph is the lowest VMSL display setting in standard use, there may be limits to the effectiveness of VMSL on the smart motorway section because its operating range would be between 60mph and 40mph, rather than the usual 70mph and 40mph.

2.7.8 The National Technology Control Centre (NTCC) would develop diversion routes, and templates for incidents and other events based on the technology provided. Route 1 would provide the opportunity to use technology for diversion strategies which involve closing one or more of the crossings.

Routes 2, 3 and 4

2.7.9 New technology for Routes 2, 3 and 4 could be integrated with the wider Highways England network and be interoperable with the existing Dartford Crossing.

2.7.10 Routes 2, 3 and 4 could be provided with controlled motorway-type technology, to safely manage traffic during times of high flows, as well as supporting incident management and maintenance operations. This technology would provide for variable speed limits, variable message signing, incident detection, emergency roadside telephones, CCTV and speed enforcement system.

2.8 Non-Motorised Users

2.8.1 For the purposes of this report and aligned with the requirements of the DMRB standards, non-motorised users (NMUs) are considered to be pedestrians, cyclists and equestrians. NMUs also include users of electrically assisted pedal cycles or powered wheelchairs and invalid carriages, that conform with current Department for Transport regulations.

2.8.2 All-purpose trunk roads typically carry high flows of fast moving traffic and are generally unattractive for NMUs to travel along or across. However, trunk roads often provide important links or routes for NMUs, representing the quickest, most direct route between key destinations, and are often used because of the lack of more convenient alternatives. As such there is a need to ensure that scheme designs take full account of NMU requirements, and that opportunities are taken to encourage safer and more attractive provision wherever possible.

2.8.3 During the design development of the shortlist routes existing public-rights-of-ways (including footpaths and bridleways) and cycleways have been identified. If the route option affects the NMU route then provision has been made to ensure that the route remains open, by providing under or overbridges or diversions. Refer to **Volume 3 Appendices** for plan and profile drawings which identify the NMU routes.

2.8.4 For the purposes of the detailed appraisal of the shortlist routes, no provision has been included for NMUs at the new crossing. This aspect would need to be considered further as part of the next stage of the scheme's development. In the appraisal of the shortlist routes and crossing options for crossings at Location C the exclusion of NMU provision at the crossing is not a differentiator due to the common crossing location. There are issues to consider in providing for NMUs in tunnels due to the enclosed space and requirements for separation for reasons of safety. These do not apply to bridges.

2.8.5 **Table 2.3** shows the number of identified NMU routes impacted and requiring provision of new works to maintain the NMU provision for each shortlist route. This would be the same irrespective of the crossing type.

2.8.6 The NMU routes identified have been developed from publicly available data.

TABLE 2.3 - IDENTIFIED NMU ROUTES

	Route 1	Route 2 WSL	Route 2 ESL	Route 3 WSL	Route 3 ESL	Route 4 WSL	Route 4 ESL
Bridleway	0	4	4	3	3	2	2
Cycleway	5	3	3	3	3	3	3
Footpath	5	14	18	15	19	19	23
Subway	2	0	0	0	0	0	0

2.9 Properties

Introduction

2.9.1 The number of properties affected by each route are discussed below. Routes 2, 3 and 4 can be paired with either of the Western Southern Link (WSL) or Eastern Southern Link (ESL) south of the River Thames. For these routes the number of properties affected are discussed separately for the WSL, ESL and each route north of the river. The number of properties identified for demolition are shown in **Table 2.4** for the bridge option and **Table 2.5** for tunnel options. For location of the affected properties refer to **Appendix 4.4**.

2.9.2 The route alignments have been developed to minimise the impact on property whilst meeting the scheme objectives. At junctions this is difficult as the layout has to allow for the tie-ins with existing roads which in some cases are constrained.

2.9.3 The impact on property has been assessed based on a 10m offset from the top or bottom of earthwork slopes. It should be noted that the designs are illustrative at this stage and there is potential for change during the next stage of design development. This could result in a different number of properties needing to be acquired than is reported in this appraisal.

Route 1

2.9.4 For Route 1 tunnel and bridge options 5 residential properties and 12 commercial properties would be demolished. An additional 2 residential and 10 commercial properties would be affected with a small proportion of the land acquired but would not require demolition. The affected commercial properties include a cement and aggregate works, various mineral related operations, large warehouses and distribution centres and a luxury hotel. In addition some wharfs and jetties would be affected by the construction. The difference in land acquisition necessary for construction between the tunnel and bridge options is minimal.

Western Southern Link

2.9.5 The WSL would require the demolition of 4 residential properties and 3 commercial properties (tunnel option) or 4 commercial properties (bridge option). The majority of the affected properties are located at the proposed junction with the A2. A significant commercial property to be demolished would be the service station on the A2.

Eastern Southern Link

2.9.6 The ESL would lead to the demolition of 10 residential properties and 2 commercial properties in total. The proposed slip road from the Lower Thames Crossing (LTC) southbound to the M2 southbound would affect 8 residential properties on Squires Close. At Peartree Lane the main carriageway would be in cutting and this would require the demolition of 2 residential properties.

Route 2 North of River Thames

2.9.7 North of the river Route 2 would lead to the demolition of 9 residential properties and 3 agricultural sites. A large proportion of these properties would be acquired for the construction of junctions along the A13 and A1089. Five properties would need to be demolished on the new housing estate off Baker Street near the existing A1089/ A13 junction. This is to allow for the construction of the slip roads from the A13 westbound to LTC northbound and the A13 eastbound to LTC southbound. Where these slip roads cross the A13 they would be on an elevated structure and this would continue north over Baker Street.

Route 3 North of River Thames

2.9.8 The number of properties that would be acquired for Route 3 is 36 residential properties and 3 agricultural areas. A large proportion of these properties would be acquired for the construction of the junction at the A13. Similar to Route 2 the housing estate off Baker Street would be affected with 7 properties requiring demolition. The majority of the residential properties that would need to be acquired are on the traveller site (22 plots) to the west of the A1089. The impact on this site would be more severe than Route 2 which would only require a new access to be provided, as the main LTC northbound carriageway would go through this area.

Route 4 North of River Thames

2.9.9 Route 4 would lead to 14 residential properties being demolished, 9 commercial properties and 3 agricultural areas. There are significant commercial properties that would require demolition, these include service areas on the A13 to the east of Orsett Cock on the westbound and eastbound A13 carriageway. There are also 2 service areas on the eastbound and westbound A127 carriageways that would require demolition.

2.9.10 The majority of the affected residential properties are located around the A127/ A128 junction, specifically on Tilbury Road and Thorndon Avenue.

TABLE 2.4 - PROPERTIES IDENTIFIED FOR DEMOLITION, BRIDGE OPTION

	Route 1 (BR)	Route 2 WSL (BR)	Route 2 ESL (BR)	Route 3 WSL (BR)	Route 3 ESL (BR)	Route 4 WSL (BR)	Route 4 ESL (BR)
Residential	5	13	19	18	24	18	24
Traveller plots	0	0	0	22	22	0	0
Commercial	12	4	2	4	2	13	11
Agricultural	0	3	3	3	3	3	3

TABLE 2.5 - PROPERTIES IDENTIFIED FOR DEMOLITION, TUNNEL OPTION

	Route 1 (Tunnel)	Route 2 WSL (Tunnel)	Route 2 ESL (Tunnel)	Route 3 WSL (Tunnel)	Route 3 ESL (Tunnel)	Route 4 WSL (Tunnel)	Route 4 ESL (Tunnel)
Residential	5	13	19	18	24	18	24
Traveller plots	0	0	0	22	22	0	0
Commercial	12	3	2	3	2	12	11
Agricultural	0	3	3	3	3	3	3

2.10 Future Marine Traffic

2.10.1 Information was obtained on anticipated future marine traffic so far as was available in discussions with stakeholders covering:

- The ports and berths along the River Thames
- The volume of marine traffic navigating the locations
- The size of the vessels navigating the locations

2.10.2 A functional assessment of the river channel, constraints and physical limitations has also been undertaken to assess the potential size of vessel that could pass along the river and use the terminals near the crossing locations.

2.10.3 In order to determine the design vessel characteristics, a number of different factors have been considered, including:

- Dredge depth of the river
- Existing constraints (existing agreed clearances at QEII Bridge)

- Shipping destinations and usage categories within each location
- Global vessel data, including multiple vessel types and sizes

2.10.4 Based on the above factors and information currently available on the size of vessels using the river, the minimum air draft clearance for shipping at Location A (Route 1) adopted is the same as the existing bridge crossing. The clearances are 57.5m above ordnance datum (AOD) over a clear width of 100m and 50m AOD over an additional width of 205m. New pylon foundations would likely require to be designed for similar levels of accidental ship collision as the existing crossing (accidental head on impact of a 65,000 dead weight tonnage (DWT) vessel fully laden or in ballast approaching at 10 knots).

2.10.5 At Location C (Routes 2, 3 and 4) based on the functional assessment referred to above, an air draft clearance for shipping of 75m AOD over a clear width of 305m has been assumed. Bridge pylon foundations located in the river would require to be designed to resist accidental ship collision loads from the design vessel. For a structure spanning approximately 800m at Location C, the likely design vessel is assessed as a 120,000 DWT vessel fully laden or in ballast approaching at 10 knots. If the span was reduced and the main pylon foundations moved to deeper water then the likely design vessel is assessed as increasing to 145,000 DWT vessel fully laden and in ballast. Early discussions have been held with the PLA on the principles of these proposals.

2.10.6 The final design vessels would be determined from a more detailed analysis of future shipping requirements and appraisal of collision risk that would be commissioned as part the development stage if a bridge solution was selected. This analysis would include the determination of design vessel impact loads on the main pylon supports, viaduct pier supports, and the deck (mast impact only).

2.11 Design and Visual Quality

2.11.1 One of the objectives for the scheme is to preserve and enhance quality of life in both the urban and natural environments. Ensuring a new structure is sympathetic to its surrounding environment is an important component of this. Therefore, the visual design quality and aesthetics of any crossing solution should be considered fully during the design process. Good design can be difficult to define and this can be particularly true for utilitarian infrastructure such as roads and bridges. Consideration should be given to aesthetic quality and character in order to avoid poor design that can become an unwelcome fixture. Future design would be subject to discussions with Highways England Design Panel.

2.11.2 The crossing of the River Thames will inevitably be the primary focus. It is important that the whole scheme benefits from a uniformly high quality design and that all aspects of the new highway are integrated within the landscape to provide a simple, elegant and robust solution. Bridges are a very important component of the built environment – of the scale proposed for LTC, the structures would be highly visible and would have a significant impact on their locality and on the people who live there.

2.11.3 In tunnel crossings, aspects such as the portals, approach ramps and internal fitting out would need careful consideration to ensure the visual design quality is of a level suitable for a nationally significant infrastructure project.

2.11.4 Design and visual quality would be considered in more detail in the next stage of scheme development, by developing design that would seek to:

- Be of high-quality, both structurally and visually
- Sit comfortably both across the River Thames and on approach
- Enhance the existing landscape through which it passes
- Respond to the local, specific characteristics of the site in a positive and thoughtful way
- Be a clean, well-detailed and contemporary design
- Be well integrated with the surrounding site - particularly that immediately adjacent and in the vicinity of the scheme
- Consider visual impact

2.12 Hydrodynamic Appraisal

2.12.1 Preliminary hydrodynamic and sediment movement numerical modelling has been undertaken to assess the impacts of a new crossing in the Lower Thames estuary. Selected scenarios were modelled. These scenarios comprised investigation of placing new bridge piers in the river at Location A and Location C, and dredging operations associated with forming a trench in the river bed to construct the immersed tube tunnel option at Location C. A hydrodynamic appraisal is not required for a bored tunnel. The assessment provides information on the impact on water levels and current speeds, and subsequently to determine impacts on sediment movements during dredging operations. The modelling showed that overall no unacceptable changes to the river hydrodynamics or sediment transport conditions were found. Details of the work undertaken and findings are provided in **Appendix 4.5**.

3 Safety Appraisal

3.1 Safety of Road Users

3.1.1 A road user safety appraisal has been undertaken, comparing the anticipated road safety conditions on the road network for both Location A and Location C in 2025 and 2041. The methodology for the appraisal is detailed in the following paragraphs. It is noted that this methodology does not show any difference between bridge and tunnel options. Therefore the routes have been appraised as whole routes and the crossing type has not been considered. For the purposes of this appraisal Route 1 and Route 3 have been selected as representative for Location A and Location C respectively.

3.1.2 The existing accident situation is reported in Volume 2. The existing Road Traffic Collision (RTC) rates for the LTC project have been obtained from the national database together with information from the Highways England Network Development Directorate (NDD) Route Strategy Reports for London Orbital/ M23 and Kent to M25.

3.1.3 The Fatalities and Weighted Injury (FWI) rate has been determined based on the latest available 5-year (2009 to 2013) accident data. There will be a change to the numbers of accidents on the SRN following national trends and these can be determined from extrapolated figures obtained from the Parliamentary Advisory Council for Transport Safety (PACTS) report *Prediction of road casualties in Great Britain to 2030*.

3.1.4 The FWI has considered the numbers of collisions resulting in injuries and not the number of casualties. This work will be developed in the next stage of scheme development based on casualties.

3.1.5 The FWI rate presented is per billion vehicle kilometres and is calculated for each link as:

$$\frac{\text{Number of fatal accidents} + 10\% \text{ of serious accidents} + 1\% \text{ slight injury accidents}}{(\text{Annual Average Daily Traffic (AADT)} \times 365) / \text{length of link} \times 10^{8}}$$

3.1.6 Casualty rates in 2025 and 2041 have been predicted for the Without Scheme scenario and compared with Route 1 and Route 3. The appraisal identifies the relative FWI rates, the casualty rates based on the SRN road classification and the collision rate for each link potentially affected by any of the route options. The accident severity rate is measured in FWI per billion vehicles per kilometres (FWI / Bn Veh Km).

3.1.7 For Route 1, there is a predicted increase in the number of FWI / Bn Veh Km in both 2025 and 2041 when compared with the Without Scheme scenario. The FWI / Bn Veh Km increases from 3.30 to 3.38 in 2025 and 2.64 to 2.73 in 2041, an increase of 2% and 3% respectively. The constraints of Route 1 restrict the standards that can be applied and there is less scope to make significant improvements to the network.

3.1.8 For Route 3, there is a predicted reduction in the number of FWI / Bn Veh Km in both 2025 and 2041 when compared with the Without Scheme scenario. The FWI / Bn Veh Km reduces from 3.30 to 3.23 in 2025 and 2.64 to 2.61 in 2041, a reduction of 2% and 1% respectively. In engineering terms there is greater control of design standards with the new links associated with Route 3.

3.1.9 **Figures 3.1** and **3.2** summarise the FWI rates for Route 1 and Route 3 on key links in the network. It can be seen that Route 3 leads to a reduction in the FWI rate along the A282/ M25 corridor compared to Route 1, in both 2025 and 2041.

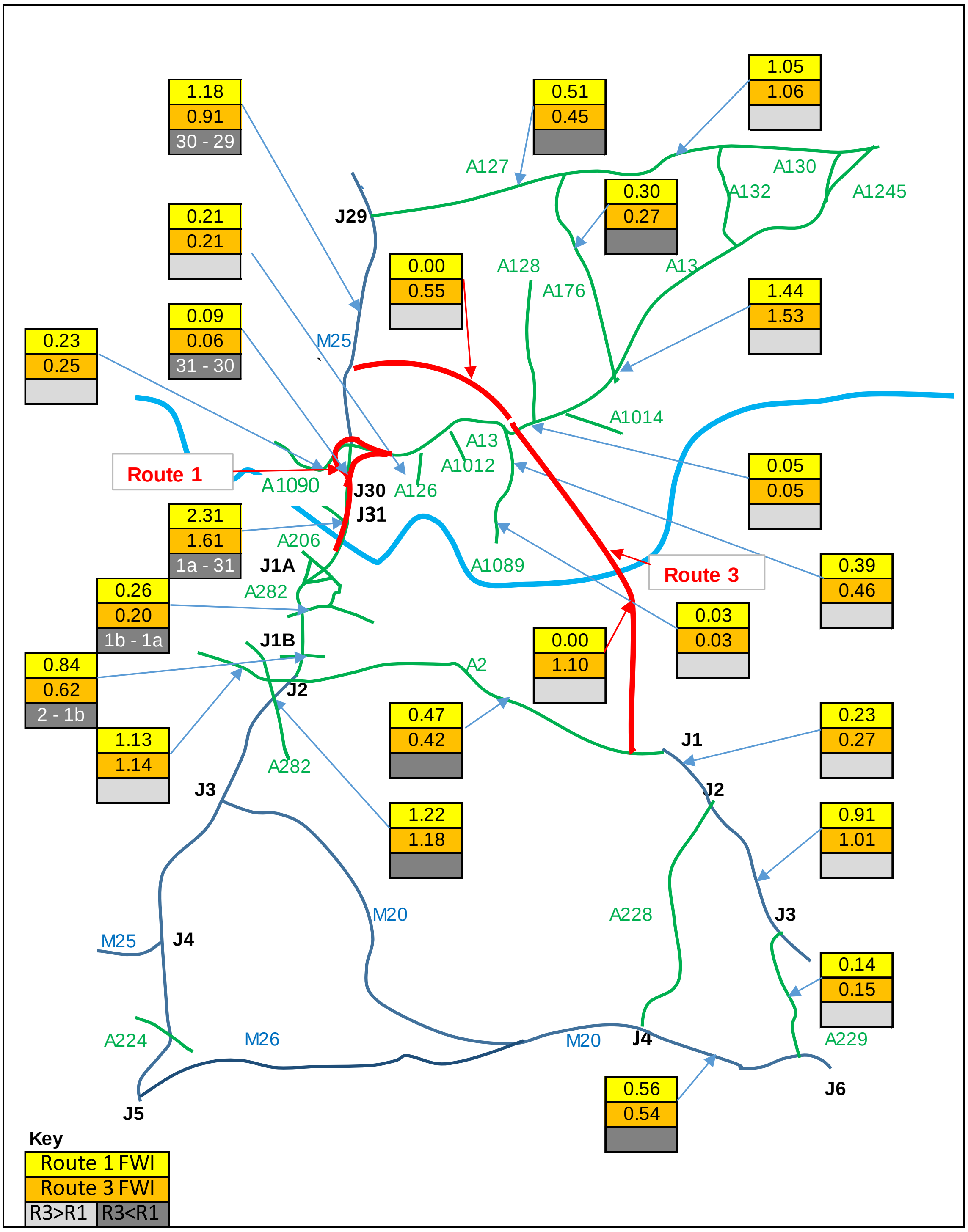

FIGURE 3.1 - SAFETY APPRAISAL RESULTS (2025)

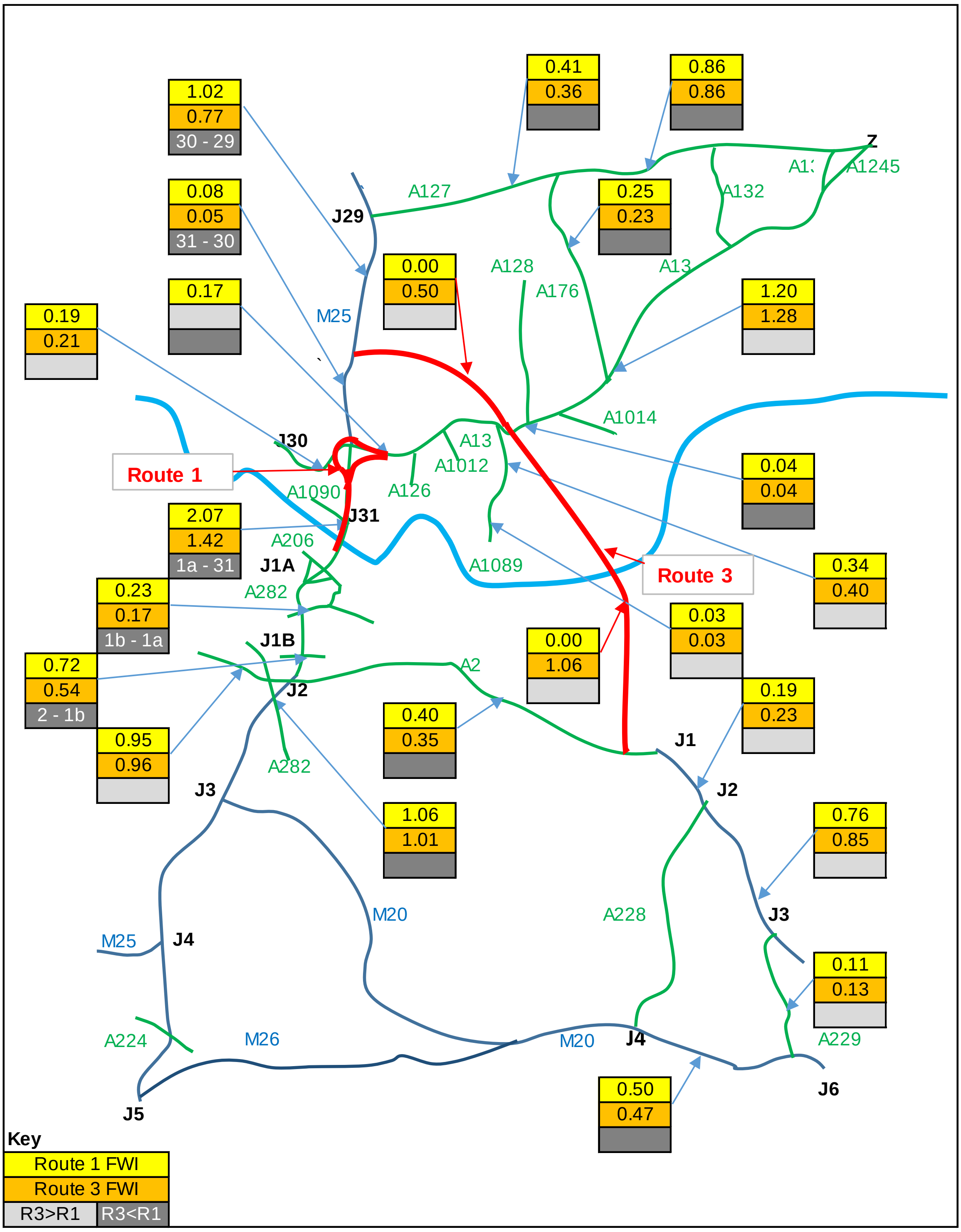

FIGURE 3.2 - SAFETY APPRAISAL RESULTS (2041)

3.2 Health and Safety of Road Workers during Construction, Operation and Maintenance

3.2.1 This section considers risks to the health and safety of road workers during construction, operation and maintenance.

3.2.2 The key risks considered are:

- Working alongside live traffic, constraints on site access, safe working areas and interface with the travelling public
- Working at height and below ground
- Hazards associated with working close to and above water
- Health risks (air quality, noise and stress)
- Underground and overhead services
- Demolition work
- Adjacent land use
- Ground conditions

3.2.3 **Tables 3.1** summarises the appraisal of the key health and safety risks to road workers which relate to Location A and C options.

TABLE 3.1 - LOCATION A AND C KEY HEALTH AND SAFETY RISKS (EXCLUDING CROSSING STRUCTURE)

	Location A	Location C
Risk in construction	On-line construction	Principally off-line construction
Working alongside live traffic including access to construction site	Significant physical constraints on access along the M25/ A282 corridor with confined working areas. Works include for demolition of structures adjacent to live traffic and with restricted working space. Railway possessions required for construction of a number of new/ widened structures adjacent to live traffic conditions and restricted working space. Detailed surveys required in areas of live traffic and restricted working space.	Majority of work would be in greenfield sites. There would be some on-line work at junctions. Railway possessions required for construction of a number of new structures.
Working at height / below ground / tunnelling	Extensive working at height on a number of structures. Most of this work would involve working over/ adjacent to live traffic with restricted working space within the M25/ A282 corridor. Below ground works include potential box jack tunneling beneath live carriageway and railway lines.	Extensive working at height on a number of structures. Some of these works would involve working over live traffic. Below ground works include potential box jack tunneling beneath live carriageway and railway lines.

	Location A	Location C
Interface with travelling public	Majority of this work is on-line requiring significant traffic management, including contraflows and narrow lanes, increasing the risk to road workers.	Extensive off-line works with on-line working at major junctions. On-line works at A1089 and A127 with Route 2 and Route 4 respectively.
Health (air quality, noise, stress)	Significant road worker exposure to particulates, fumes and noise Significant night time working likely to be required due to the need to minimise disruption to road users. There are high volumes of traffic throughout the day along the M25/A282 corridor.	Significantly less exposure than Location A as the majority of the works are off-line. Some limited exposure in areas of on-line work. Some nighttime working may be required.
Services / utilities	Some works beneath HV overhead cables. Significant diversion and protection works required. Much of the work would be carried out in confined locations.	Extensive works beneath HV overhead cables. Significant diversion and protection works required. More space available to carry out diversions.
Demolition	Significant demolition works possibly including asbestos removal and work above live highways and railways. Property demolition could include industrial facilities.	Some demolition required. Structures tend to be discrete and minor compared to Location A. Property demolition generally residential, although WSL and Route 4 would require demolition of service stations.
Land use	Predominantly urban; industrial, commercial and residential areas significantly impacted by the proposals	Predominantly agricultural and marshland; limited exposure of isolated small residential areas and farmland to the works, with the exception of section of Route 2 along the A1089.
Ground conditions	Ground likely to have been previously disturbed and to have characteristics of former industrial use. Ground contamination anticipated. Potentially some work required near Junction 30 within former landfill sites which could include contaminants.	Conditions established from existing information suggest no features that cannot be overcome by standard engineering measures. Poor ground conditions anticipated at crossing approaches. Potentially some work required at a number of locations within former landfill sites which could include contaminants.
Risk in operation and maintenance		
Access	Space available for access very restricted. Access for all but emergency operations would require extensive planning and practical measures (Traffic Management (TM), diversions). Closely spaced junctions restrict road space available for TM.	New route with hard strips provides better access than Location A.

	Location A	Location C
Maintenance	Full closures not likely to be possible except in emergencies. Maintenance workforce would be exposed to live traffic under temporary TM arrangements.	Potential for full closures as existing Dartford Crossing gives an alternative route and would provide the best working environment and minimise exposure time.

3.2.4 An appraisal of the key health and safety risks to road workers which relate to different river crossing options at Locations A or C are shown in **Table 3.2.** This covers risks during both construction and operation and maintenance.

TABLE 3.2 - CROSSING TYPES KEY HEALTH AND SAFETY RISKS

	Bridge	Bored Tunnel	Immersed Tunnel
Risk in construction			
Access to construction site	Combination of road and river access anticipated. All crossing structure types potentially would involve importing of large components e.g. bridge deck elements, float in of immersed tunnel elements, assembly of TBM. Conflict with existing road, river and rail traffic would require management		
Working at height / below ground / tunneling	Extensive working at height. High towers, piers, erection of high decks, cantilever construction of main span over river, specialist construction, market has experience (international expertise expected). Prefabrication reduces time spent working at height.	Construction underground. TBM construction for main bores. Significant deep excavations for ramps/ cut & cover sections. Relatively large tunnel diameter (greater than rail/ other tunnels in UK), Extensive tunneling works in London/ SE in similar ground so good understanding of tunneling conditions. Specialist major works, market has experience (international expertise expected).	Construction in river and from above ground. Working at height in precasting 10m high elements. Extensive deep ramp/ cut & cover structures in poor ground to construct tunnel approaches. Work underground within immersed tunnel units to complete works once units immersed.
Working close to or above water	Extensive working at height over water e.g. construction of bases, towers, piers, decks, cable installation. Potential collision risk from river traffic for works in river (foundations, towers, piers, temporary jetties, barges/ equipment when lifting in deck units from river etc.).	High ground water levels and tunneling in soft ground/ chalk under river. Extensive complex dewatering countermeasures. Tunnel flood risk. Possible use of river to export tunnel arisings.	3 to 6 month dredging operation to create trench for immersed construction. Floating in and immersion of units (24hr river possessions). Extensive use of large plant, equipment and vessels in river with channel narrowing and diversions required.

	Bridge	Bored Tunnel	Immersed Tunnel
	Cofferdams or precast caisson construction likely for tower foundations in river.		
Health (air quality, noise, Stress)	Deep foundations, work at height exposed to weather.	Underground and/ or working in deep structures. Management of air quality, noise levels, artificial lighting and dust. Specialist major tunnel construction, best practice expertise evidenced on large tunneling schemes in London/ SE (Crossrail, Thames Tideway, HS1 etc.)	
Offsite fabrication	Offsite fabrication likely e.g. steel deck prefabrication	Bored Tunnel – some anticipated e.g. precast tunnel linings, import of TBM in preassembled parts. Immersed Tunnel – local/ remote casting basin to prefabricate immersed tunnel units. Construction of casting basin (deep excavation), flooding of basin prior to floating out units. Floating of units from casting basin to site for immersion in trench.	
Services / utilities	Adjacent Dartford and Tilbury cable tunnels. Adjacent existing road tunnels and ventilation facilities, with associated services at Location A. Overhead HV power lines (diversions assumed at both Location A and C for bridge). Underwater gas pipe line downstream of Location C.		
Demolition	Significant demolition for schemes at Location A, impacts cement processing works, jetties, Dartford Control Centre (bridge and tunnel). Little demolition for schemes at Location C (bridge or tunnel).		
Ground conditions	High ground permeability. High water table. Soft alluviums, chalk bearing strata.	High ground permeability. High water table, soft alluviums, chalk bearing strata. Dewatering/ flood risk countermeasures.	High ground permeability. High water table, soft alluviums, chalk bearing strata. Dewatering/ flood risk countermeasures.
Risk in operation and maintenance			
Access	Extensive access at height for inspection/ maintenance. Platforms/ cradles/ gantries to access high towers, piers, cables and underdeck areas. Bridge Management System to be implemented. Access arrangements for inspection and maintenance, whilst keeping the bridge open, incorporated into the design	Tunnel designed for operational resilience. Safety strategy based on free-flowing traffic in tunnels, design to avoid queueing or stationary traffic in the tunnels. Planned routine maintenance under lane/single bore closures at night, Associated Traffic Management Cell (TMC) would be required to manage oversized vehicles/ restricted goods at Location A	
Access	Extensive access at height for inspection/ maintenance.	Tunnel designed for operational resilience. Safety strategy based on free-flowing traffic in	

	Bridge	Bored Tunnel	Immersed Tunnel
	Platforms/ cradles/ gantries to access high towers, piers, cables and underdeck areas. Bridge Management System to be implemented. Access arrangements for inspection and maintenance, whilst keeping the bridge open, incorporated into the design.	tunnels, design to avoid queueing or stationary traffic in the tunnels. Planned routine maintenance under lane/single bore closures at night. Associated TM cell would be required to manage oversized vehicles / restricted goods at Location A.	
Maintenance	Components would be specified to optimise maintenance intervals and operational impacts. Generally levels of equipment and associated levels of intervention necessary to maintain operations less for bridge compared to tunnel.	Requires maintenance work to be planned and managed strategically. Design for maintenance (choice/appropriate specification of equipment, design for redundancy, resilient/low maintenance systems e.g. longitudinal ventilation using jet fans).	

3.2.5 In summary, the health and safety risks associated with Location A and Location C routes and the different crossing types vary, due to the widely differing nature of the works involved. Location A routes present the greatest challenge in managing the risks to roadworkers associated with construction, due to the constraints imposed by working alongside live traffic for the entire length of the works, combined with the physical constraints at the existing crossing and along the existing M25/ A282 corridor.

4 Construction Impacts

4.1 Route 1

4.1.1 An assessment of the buildability and construction programme for Route 1 has been carried out for both bridge and tunnel options. This has taken into account the constraints of working within the heavily trafficked and constrained M25/ A282 corridor. Route 1 has significant construction challenges, and these are discussed in this section.

4.1.2 The outline construction programme is shown in **Figure 4.1**. The estimated overall construction duration for Route 1 is 80 months, including a 20 month advanced works stage which would include mobilisation.

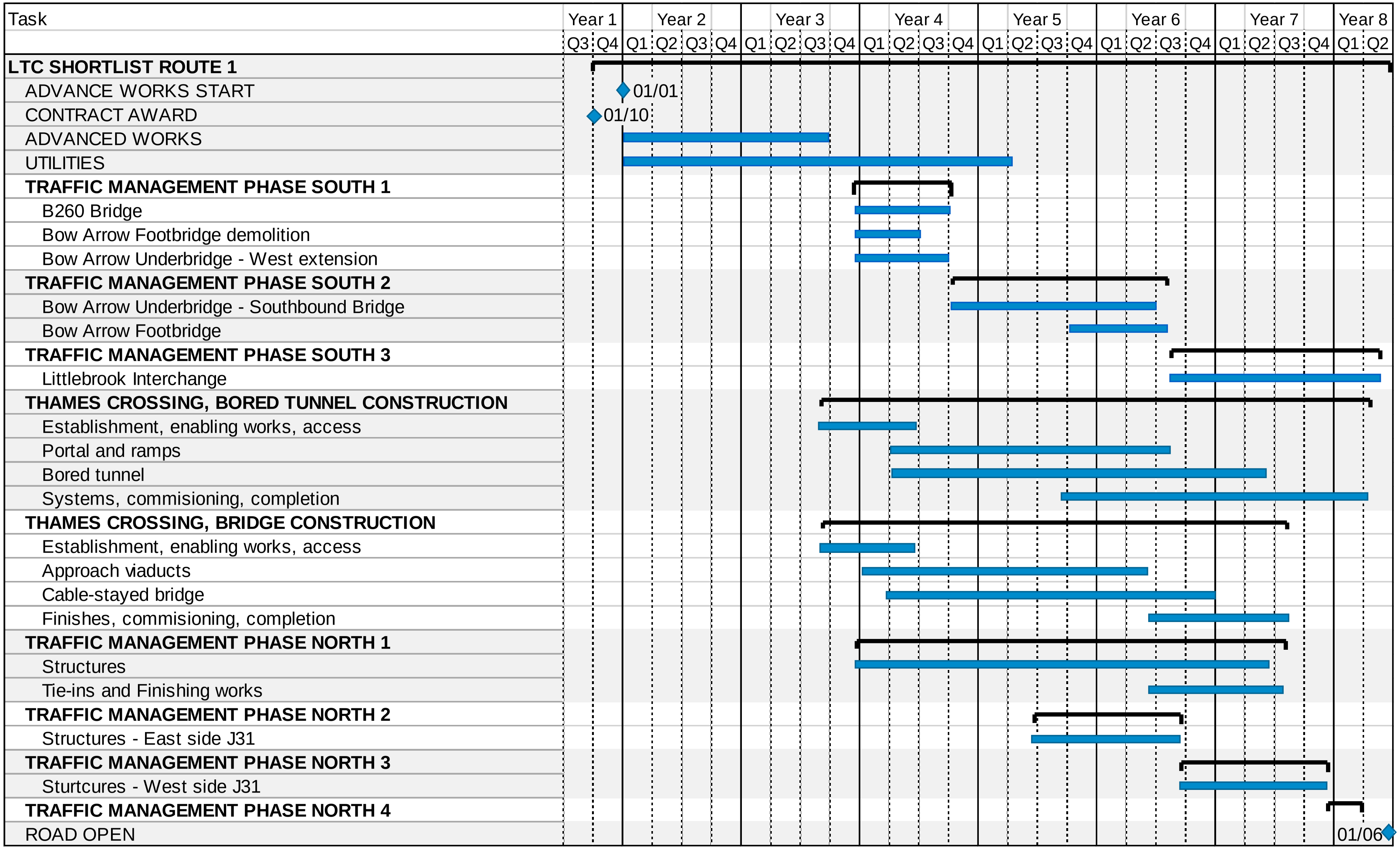

FIGURE 4.1 - OUTLINE CONSTRUCTION PROGRAMME FOR ROUTE 1

4.1.3 The existing number of lanes on the A282 (refer to Figure 4.2) would need to be maintained during the day in order to avoid unacceptable delays to road users during construction. This is very challenging, particularly from Bow Arrow Railway Bridge to Littlebrook Junction 1a, due to the constraints of existing structures and a discontinuous hard shoulder. In order to ensure a safe workplace for construction workers, temporary land would be required for construction purposes.

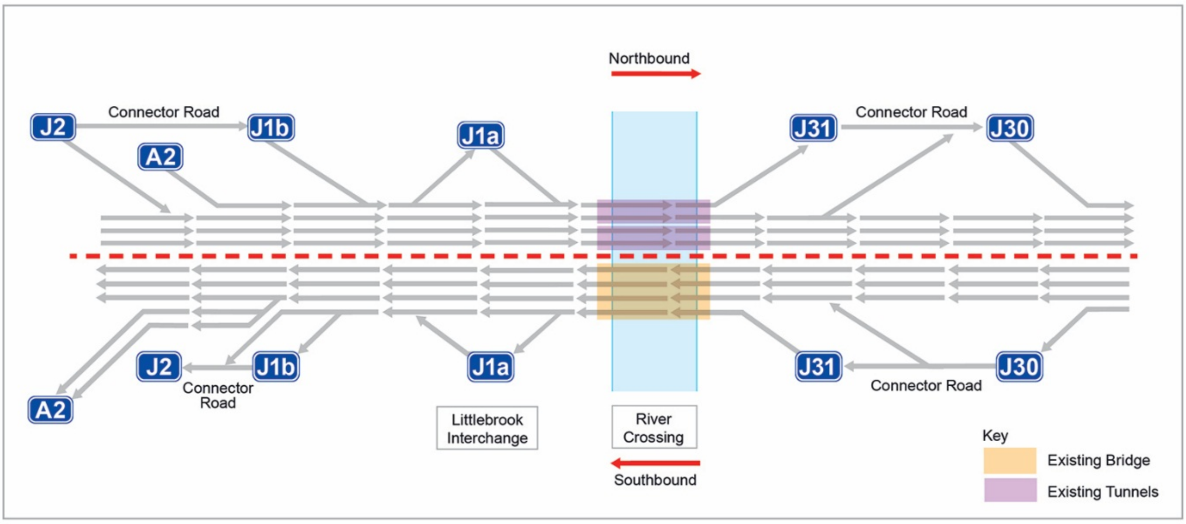

FIGURE 4.2 - EXISTING A282 LANE LAYOUT

4.1.4 North of the River Thames, construction of large retaining walls, bridges and widening around Junction 31 also has significant challenges, due to the very confined working areas.

4.1.5 In the detailed construction planning stage, a full survey of all the existing features and utilities would be required, to confirm the land required to safely construct the works. This would include consideration of the working space necessary to minimise risk to the workforce and traffic management installation crews.

4.1.6 An advanced works phase would be required with an estimated duration of 20 months which would include the work for relocating the Dartford Control Centre (DCC), rearrangement of the Dart Charge marshalling area, and the diversion of National Grid overhead conductors at the southern approach to the new crossing. Diversion and protection of other existing utilities would also be completed in this stage.

4.1.7 Traffic management would be required throughout the construction phase of the scheme, with a temporary speed restriction of 40mph and substantial periods of contraflow working. It would be necessary to avoid frequent changes to traffic management layouts, so that drivers get used to the traffic layouts. A recent proposal to ban long stretches of roadworks on motorways and major A-roads in England and impose a limit of 2 miles, would have an impact on this scheme in that more stages of construction would need to be planned, which could extend the construction phase duration beyond the estimated 5 years.

4.1.8 At Bow Arrow Railway Bridge, construction challenges include controlled removal of existing asbestos in the structure, demolition over the live railway, working space requirements for lifting operations and the level difference between the northbound and southbound carriageways across the existing bridge deck. Contraflow working would be required to construct the new east bridge. Road closures would be required on both carriageways for demolition and erection of bridge beams. Closure/ diversion of footbridges/ cycleway would also be required to allow demolition and reconstruction of the overbridges.

4.1.9 The complexity of the works and the constraints imposed by working within the existing M25/ A282 corridor would mean that some work would need to be carried out at night. However working at night close to existing properties along the A282 would be constrained by restrictions on noise and vibration, the requirements for which would need to be developed in detail with the local environmental health officers.

4.1.10 As well as substantial works required at Junction 1a to remodel the junction, the diversion and protection of many existing services would also be required. This would require complex traffic management arrangements to avoid unacceptable disruption to A282 and local road traffic. At this junction there is a large distribution centre, commercial property and local housing.

4.1.11 At Junction 30 and links for the A13 road closures would be required for bridge demolition and deck erection over the M25. The narrowing of existing lanes would be required on the A13 to provide safety zones for the workforce. Railway possessions may also be required for the construction of a jacked box under the existing railway east of the A126 junction.

4.1.12 Road closures of the A282/ M25 would be required to demolish existing structures, during which time diversion routes would be required. These closures would be either overnight or at weekends.

River Crossing – Bridge

4.1.13 A cable stayed bridge would likely involve extensive prefabrication and off-site construction. For example, deck segments would be fabricated off-site and transported to construction compounds or assembly yards prior to erection on site by heavy lifting equipment or sea cranes.

4.1.14 There would be temporary restrictions to shipping during construction of the pylons and also short closures of the river channel (of a few hours) when the deck segments were delivered to site by barge and lifted into position. These operations would require the use of large equipment, plant and vessels operating in the river for a time and would require careful planning and cooperation with the Port of London Authority (PLA) and the many regulators and agencies responsible for the river and its environment.

4.1.15 A typical construction sequence for a cable stayed bridge is as follows:

- Construct foundations. The pylon foundations would most likely be reinforced concrete caissons either cast in situ within cofferdams or precast off site and installed onto a prepared surfaced on the river bed. Approach viaduct piers would most likely comprise reinforced concrete pile caps supported on bored cast in situ piles extending down to the Chalk.

- Construct pylons, piers and abutments. The pylons would most likely be a reinforced concrete cellular structure constructed in situ using jump or slip form technology. Approach viaduct piers would also be cellular reinforced concrete structures either precast or cast in situ. Abutments would most likely be reinforced concrete structures supported on either piled or spread foundations depending on the level of the Chalk.
- Erect deck. The suspended deck option assumed is a steel concrete composite deck. The deck sections would likely be pre-assembled and delivered to the work front by barge. Heavy lifting equipment would be used to install the deck segments by cantilever erection progressively outwards from the pylons. The approach viaduct deck would either be launched, erected piecemeal or span-by-span depending on the deck form and the contractor's preference.
- Finishes and deck furniture including parapets, safety barriers, technology, surfacing and lighting would be installed once the deck structure cantilever erection is complete.
- Commission the bridge and the Wind and Structural Health Monitoring System (WASHMS) if applicable.

4.1.16 Construction of the bridge at Route 1 based on the above assumptions is expected to take approximately 45 months which is less than the overall construction programme discussed above.

River Crossing – Bored Tunnel Route 1

4.1.17 The bored tunnels are assumed to be constructed using a modern tunnel boring machine (TBM) with reinforced concrete segmental lining, sequentially erected behind it as the tunnel advances. The engineering appraisal of alternative tunnel construction methods concluded construction using TBMs was the most appropriate method at this location, for reasons of cost, risk and technical feasibility. At this location construction using a single TBM has been assumed and this would be launched from and received into a temporary works chamber constructed for the purpose and designed to be incorporated into the permanent cut and cover and ramp sections of the works that connect to the bored tunnel section. It is assumed construction of the first bore would be from north to south, the TBM turned around, and the second bore constructed south to north. Construction based on these assumptions is expected to take approximately 54 months. This is less than the overall construction programme discussed above.

4.1.18 It is generally noted that presently there is significant construction of tunnels using TBMs in the UK, in particular in London and the south east. This could present opportunity for LTC to reuse TBMs from a preceding project, subject to machines being of a suitable size/ diameter (e.g. Silvertown Tunnel).

4.1.19 Typical TBM construction methods would comprise slurry or earth pressure balanced. Lining segments would incorporate gaskets to ensure water tightness. The annular space between the external diameter of the lining rings and the excavated ground would be filled with grout. Excavated material would be removed from the TBM and tunnel, stockpiled on-site conditioned as needed, prior to being removed to a disposal site, possibly by river transport for minimum environmental impact. Tunnel lining segments are expected to be fabricated off-site and again could be transported to the site by feasible river transport for minimum environmental impact.

4.1.20 With the high water levels and high permeability of the ground expected in this area, additional measures would be expected to be required to construct the portals and ramp approach structures to exclude groundwater. This could involve groundwater pumping and possible recharge or ground treatment to increase strength and decrease permeability.

4.1.21 Cross passages would be provided between the bores of both the bored and cut and cover sections of tunnel assumed to be at 100m intervals for access by the emergency services or escape by tunnel users in the event of an incident. In view of the anticipated nature of the ground these passages would be formed by first undertaking extensive ground treatment (e.g. chemical grouting) from within the bored tunnels at each end of the cross passage.

4.1.22 In the cut and cover sections, for the construction of cross passages, the ground treatment could be undertaken from ground level. Once ground conditions and groundwater were at acceptable levels, the passages would be constructed by sequential excavation and sprayed concrete techniques with concrete primary lining, sheet membrane waterproofing and a concrete secondary lining. The low point sump would be constructed from the deepest cross passage by techniques similar to those for the cross passages and a drainage connection made to both bored tunnels by installing an augured drain pipe.

4.1.23 The retained ramp and cut and cover tunnel approach structures to the bored tunnel would be located in alluvium strata. This material has poor ability to sustain additional loading. The structures would therefore be founded on either bearing piles or tension piles which would be constructed from ground level before any excavation began. The structure would be formed by reinforced concrete structures working from ground level downwards. The side walls of the cut and cover tunnels would first be formed by diaphragm walling techniques and after temporary propping of the walls and excavation of the ground between, the base slabs and roof of the cut and cover tunnels would be constructed. Similarly the side walls of the retained ramp would be expected to be formed by diaphragm walling techniques but in view of the large span between side walls these would be permanently supported by inclined ground anchors embedded in the Chalk strata. The base would then be formed by reinforced concrete construction.

4.1.24 Once tunneling and other heavy civil engineering works were complete, the tunnels would be fitted out first with secondary civil works followed later by mechanical and electrical installation works. The civil fitting out would include placing compacted fill in the bored tunnel invert, installing any buried services or service ducts below road level, constructing the road pavement and emergency walkways, installing the side wall cladding. In the cross passages, the service duct would be formed and cross passage fire doors installed. The mechanical and electrical fitting out works would consist of the installation of tunnel services including ventilation, lighting, monitoring, fixed firefighting systems, fire hydrants, pump discharge mains etc. It has been assumed the tunnels are longitudinally vented using jet fans avoiding the need for ventilation buildings and other associated structures.

4.2 Routes 2, 3 and 4

4.2.1 An outline construction programme has been prepared for Route 3 with the ESL – refer to **Figure 4.3.** This programme includes activities for each river crossing option, bridge, bored and immersed tunnel to show a comparison of their construction durations. The construction programmes for Routes 2 and 4 would have the same overall period. For all routes this would be the same with the ESL or WSL because the construction of the river crossing would be the critical path.

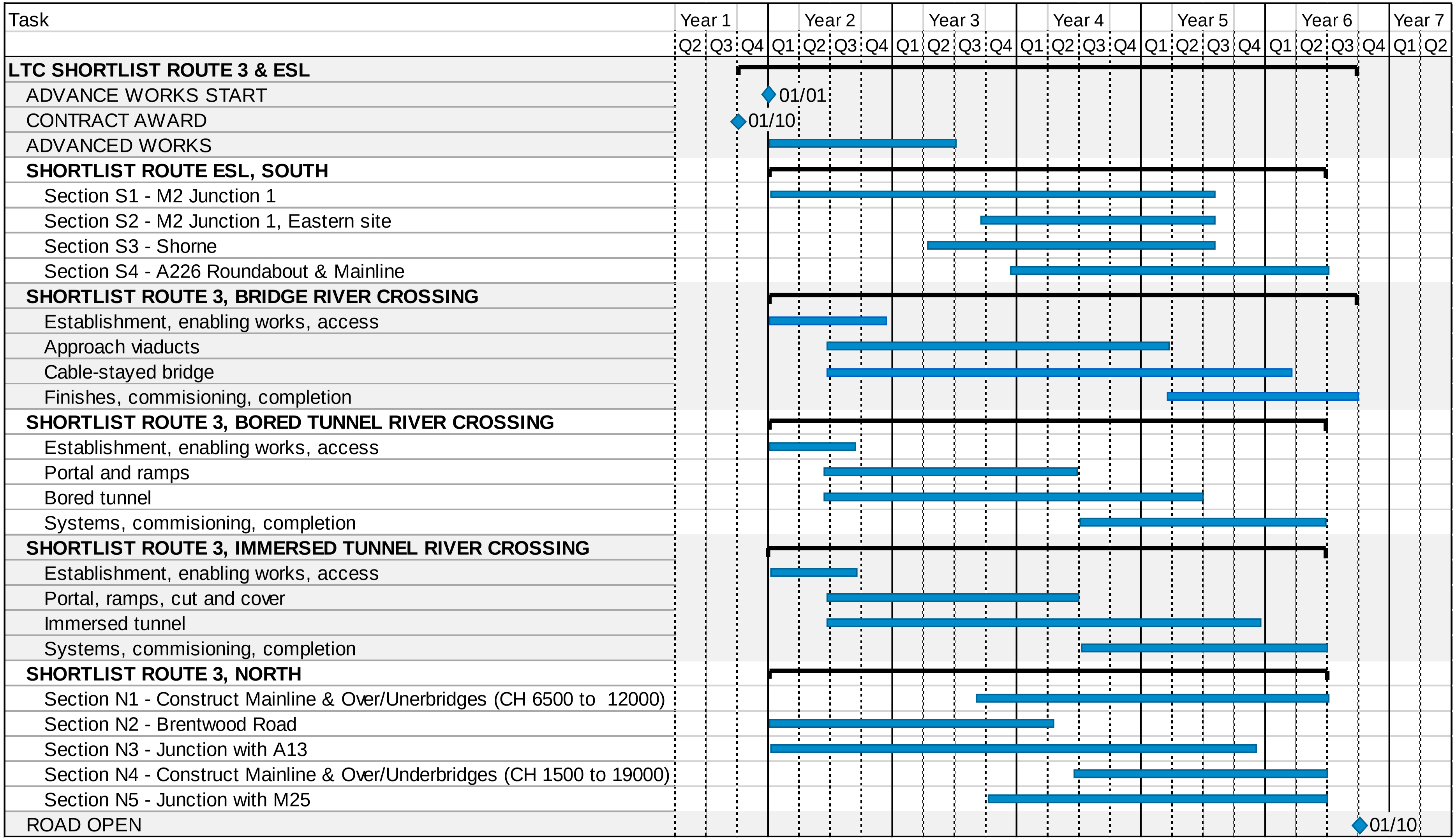

FIGURE 4.3 - OUTLINE CONSTRUCTION PROGRAMME FOR ROUTE 3

4.2.2 The routes would involve major works at a number of junctions (A2/ M2, A13, M25 and A127). During construction of these junction works, the existing number of lanes on the through route would need to be retained during the day.

4.2.3 A mobilisation period of nine months has been assumed post award of the construction contract. During this period, detailed design would be undertaken as well as utility diversions, fencing, site compounds, and access roads.

WSL Junction Construction

4.2.4 The new junction on the A2 required for the WSL (refer to **Figure 4.4**) includes the re-alignment of the existing A2 in order to enable the construction of the LTC to A2 westbound loop without impacting on HS1.

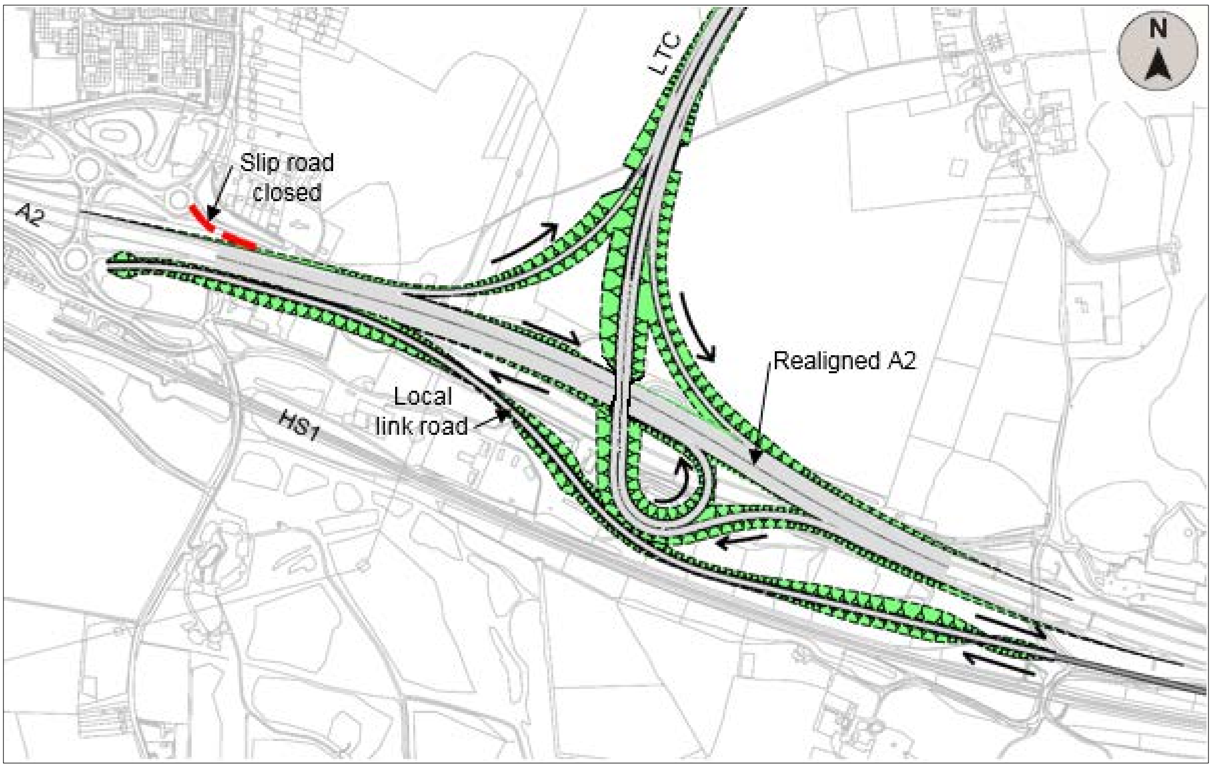

FIGURE 4.4 - WESTERN SOUTHERN LINK A2 JUNCTION

4.2.5 During construction it is assumed that all existing lanes on the A2 would remain open during the works. There would be traffic management on the A2, which would probably consist of narrow lanes with a temporary speed limit of 40 or 50mph.

4.2.6 As the A2 would be re-aligned the majority of the work could be carried out off-line. In particular this would allow the LTC underbridge structure to be constructed prior to the diversion with minimal impact on the live carriageway. The traffic could continue to use the existing A2 and would then switch onto the newly constructed carriageway in order to remove the existing A2 and complete the junction construction.

4.2.7 It might be required to close the A2 overnight for short periods in order to construct the bridge and potentially close lanes in order to tie-in the re-aligned carriageways to the existing A2.

ESL Junction Construction

4.2.8 **Figure 4.5** shows the ESL A2/ M2 Junction 1. It has been assumed that all existing lanes on the A2/ M2 mainline would remain open during the construction of this junction. It is probable that narrow lanes and a temporary speed limit (40 or 50mph) would be implemented as part of the traffic management requirements.

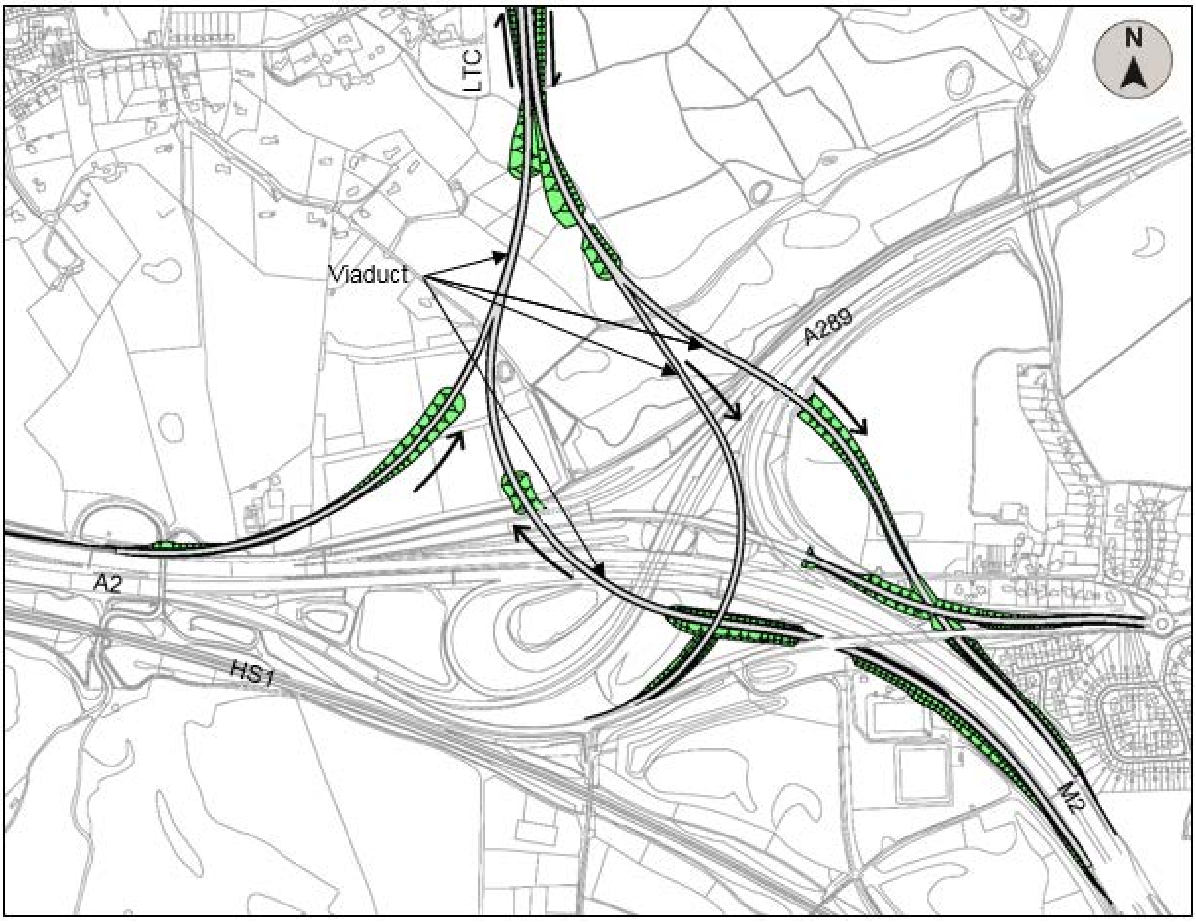

FIGURE 4.5 - EASTERN SOUTHERN LINK A2/ M2 JUNCTION 1

4.2.9 Maintaining traffic flow and reducing the overnight closure time on the M2 when structures were being constructed would be a major constraint. The M2 is a major route with high volumes of traffic, therefore access would need to be maintained and any closures kept to a minimum.

4.2.10 The proposed viaducts on this junction have several levels and most of the links are above each other. As a result programme sequencing would need to be developed on the principle of construction starting at the lowest level.

4.2.11 The working space available within and around this junction is limited and would be restricted during construction. The narrow access routes to these areas would be a constraint on the construction programme.

Route 2 North of the River Thames Junction Construction

4.2.12 This route would require the widening of the A1089 and the construction of new slip roads at the existing A13/ A1089 junction.

4.2.13 The structures required at the proposed A1089 grade-separated junction (refer to **Figure 4.6**) would present no significant buildability challenges, since the proposed roundabout would be constructed offline from the existing road network.

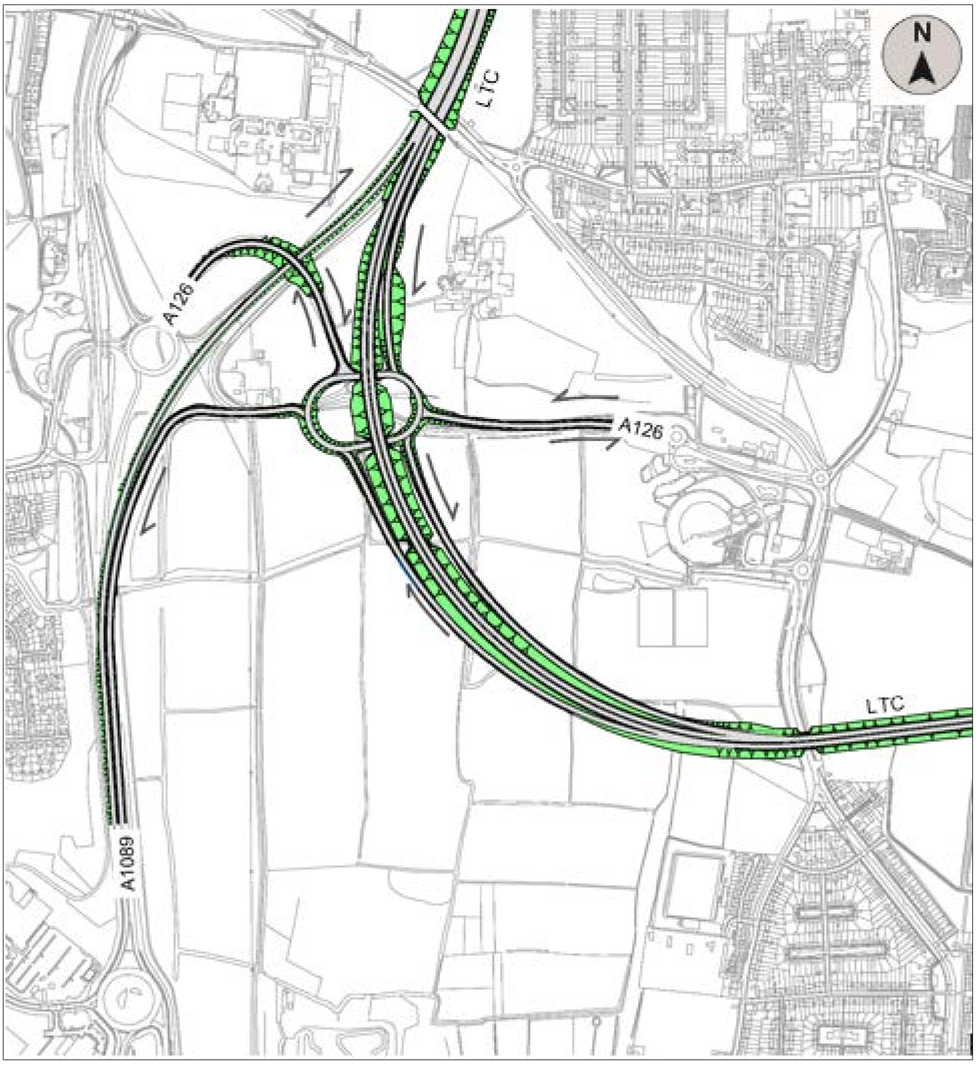

FIGURE 4.6 - ROUTE 2 A1089 JUNCTION

4.2.14 The widening of the A1089 would be symmetrical with the construction of two new lanes on each of the existing carriageways. The widening could be completed off-line from the existing carriageways but would require traffic management to be in place for the duration of these works.

4.2.15 The traffic management would involve narrow lanes with a temporary speed limit (likely to be 40mph). It would be necessary to close a lane and utilise contra-flows in order to complete the tie-ins with the existing and new slip roads.

4.2.16 The modifications on the A13 would require similar traffic management for the duration of the works. The works include construction of two viaducts associated with slip roads as shown in **Figure 4.7**.

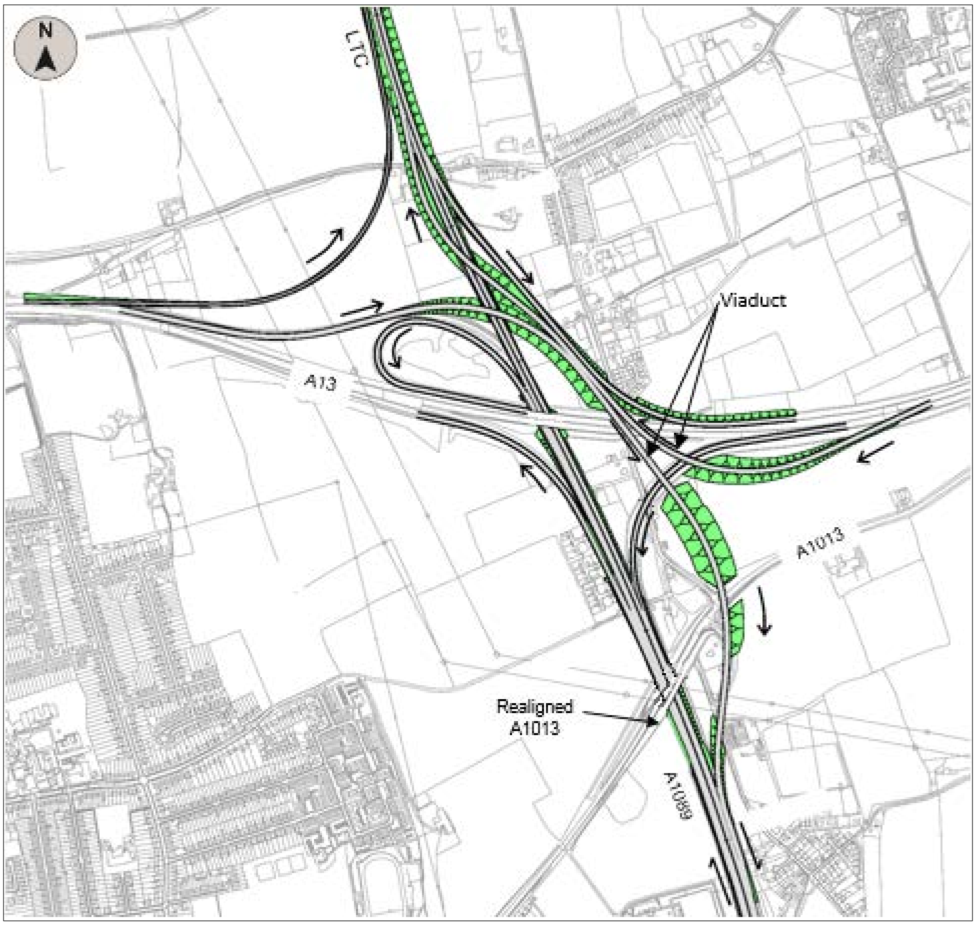

FIGURE 4.7 - ROUTE 2 A13 JUNCTION

4.2.17 This route would require a new junction on the M25 between Junction 30 and 29 (refer to **Figure 4.8**). The construction of this junction would require two new slip roads with viaducts over the M25 and Ockendon Road. The main impact on the M25 would be the construction of the viaduct associated with the northbound slip road.

FIGURE 4.8 - ROUTE 2 AND 3 M25 JUNCTION

4.2.18 This viaduct would be at a skewed angle over the M25 and would be required to cross the M25 in a single span, as the recent M25 widening works have reduced the central reserve width such that there is insufficient space for a pier between the carriageways. The assumed 50m typical span implies construction either by incremental launching or possibly by lifting in beams, although this would be likely to require weekend closures of one carriageway to erect temporary trestles and set up a suitable crane. The construction of the viaduct would require traffic management on all lanes of the M25 during the works. This traffic management would involve narrow lanes with a temporary speed limit (likely to be 50mph).

4.2.19 The construction of the slip roads would require traffic management on lanes 1 only for the majority of the works. There would be a requirement to widen this to lane 2 when undertaking surfacing works on the slip roads at the tie-in points with the M25.

Route 3 North of the River Thames Junction Construction

4.2.20 Route 3 would require the construction of a large complex interchange at the existing A1089/ A13 junction as shown in **Figure 4.9**. This construction would require traffic management on the A13 and the A1089 for the majority of the works. It is envisaged that this traffic management would be in place on all lanes of these carriageways. The traffic management would involve narrow lanes with a temporary speed limit (likely to be 40mph).

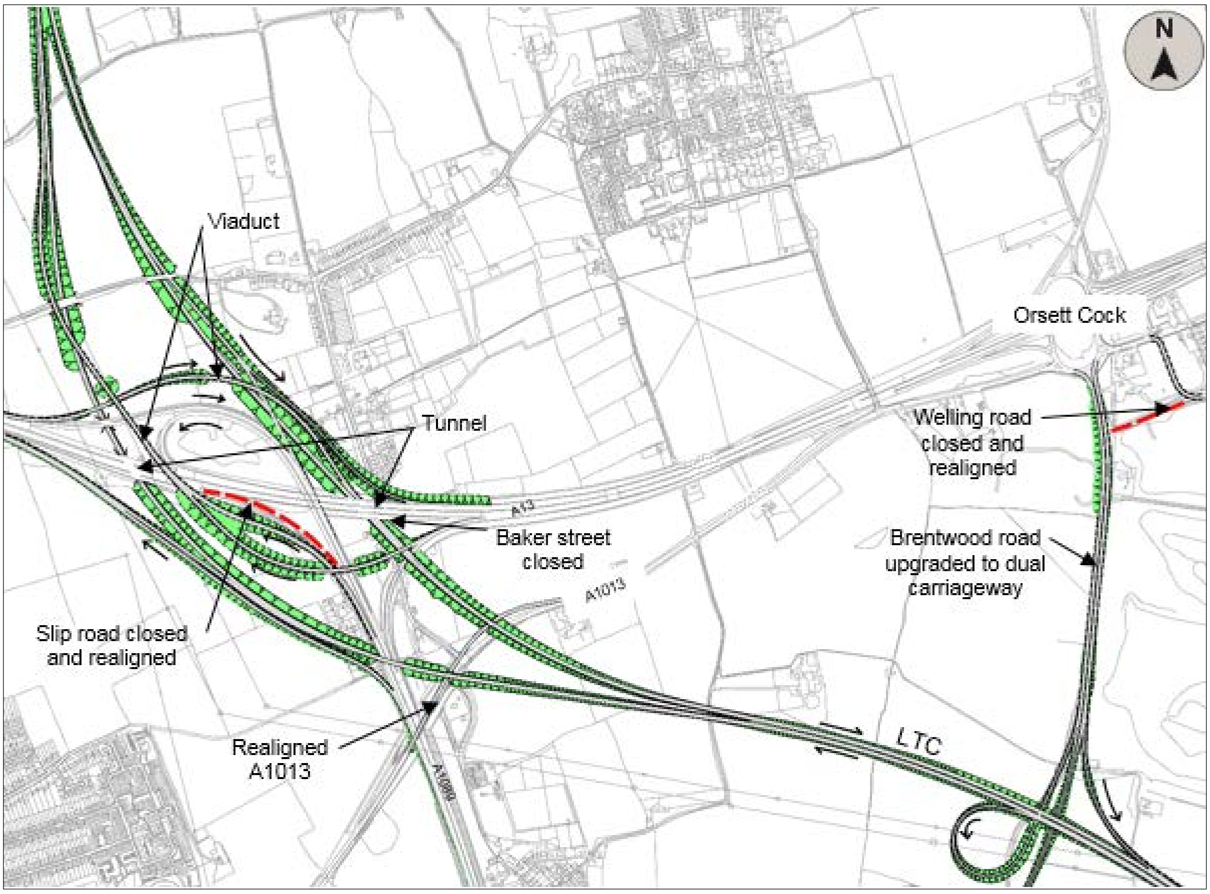

FIGURE 4.9 - ROUTE 3 A1089/ A13 JUNCTION

4.2.21 Due to the complexity of the slip roads and the number of structures there would be a requirement to close existing slip roads and potentially the main carriageways. Any closures would have to be overnight to reduce impacts on the network. At three locations structures would be required to take one of the unidirectional carriageways beneath either the A13 or A1089. To minimise traffic disruption during construction it is envisaged that these structures would be constructed by box jack tunneling under the live carriageway. The construction of the two viaduct structures would not present significant buildability issues as they would not interface directly with the existing road network.

4.2.22 The junction with the M25 would be as described for Route 2 (refer to paragraphs 4.2.17 to 4.2.19).

Route 4 North of the River Thames Junction Construction

4.2.23 At the A13 this route would require the construction of a large grade-separated free-flow junction (refer to **Figure 4.10**). The works would require the construction of two viaducts associated with slip roads, an overbridge to carry LTC over the A13 and two tunnels to take further slip roads under the A13.

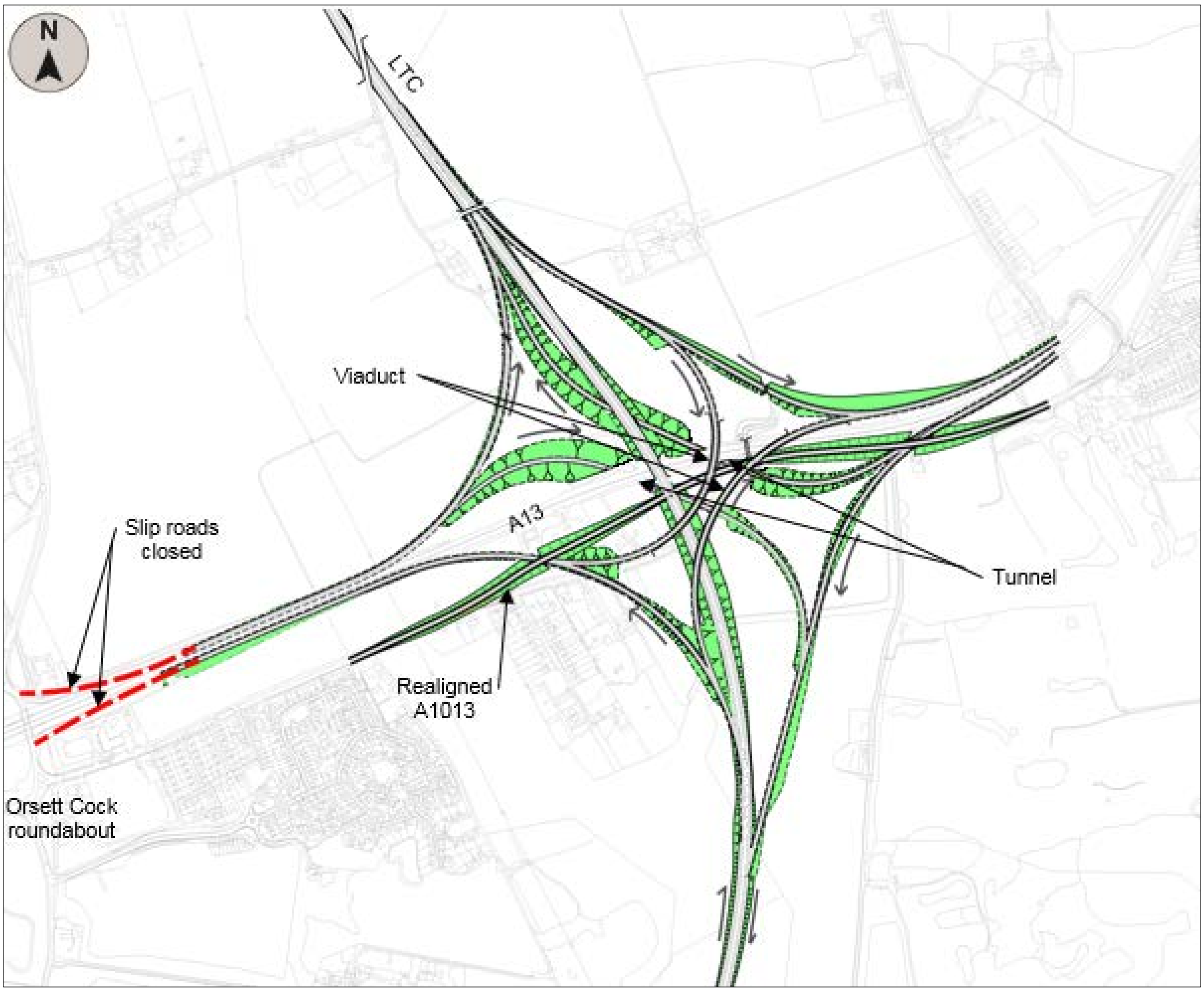

FIGURE 4.10 - ROUTE 4 A13 JUNCTION

4.2.24 The slip road viaducts would be at a skewed angle to the A13 carriageway making their construction complicated. The main LTC carriageway would cross over the A13 at right angles. It is probable that works would be required on the A13 specifically the central reserve in order to accommodate the construction of the temporary works and the bridge piers. Traffic management on the A13 would be required during the construction of these structures and this would include the imposition of a temporary speed limit (likely to be 40mph).

4.2.25 The two slip road tunnels also cross the A13 at a skewed angle and would be about 150m and 230m long. It is currently envisaged that these structures would be constructed using a combination of cut and cover and box-jacking tunneling techniques.

4.2.26 The other elements of this junction could be constructed off-line with limited traffic management on the A13. This would be required during the construction of slip road tie-ins.

4.2.27 Route 4 would pass below the Fenchurch Street to Shoeburyness railway line. It has been assumed that the structure at this location would be a pair of jack boxes which would be installed during railway possessions.

4.2.28 On the A127 traffic management would be required for long periods due to the works at the A127/ A128 junction, the widening of the A127 and the works at Junction 29.

4.2.29 The works on the A127/ A128 junction would require the construction of a skewed overbridge and slip road works as shown on **Figure 4.11**. Similar other junction works described above would be required to the A127 central reserve.

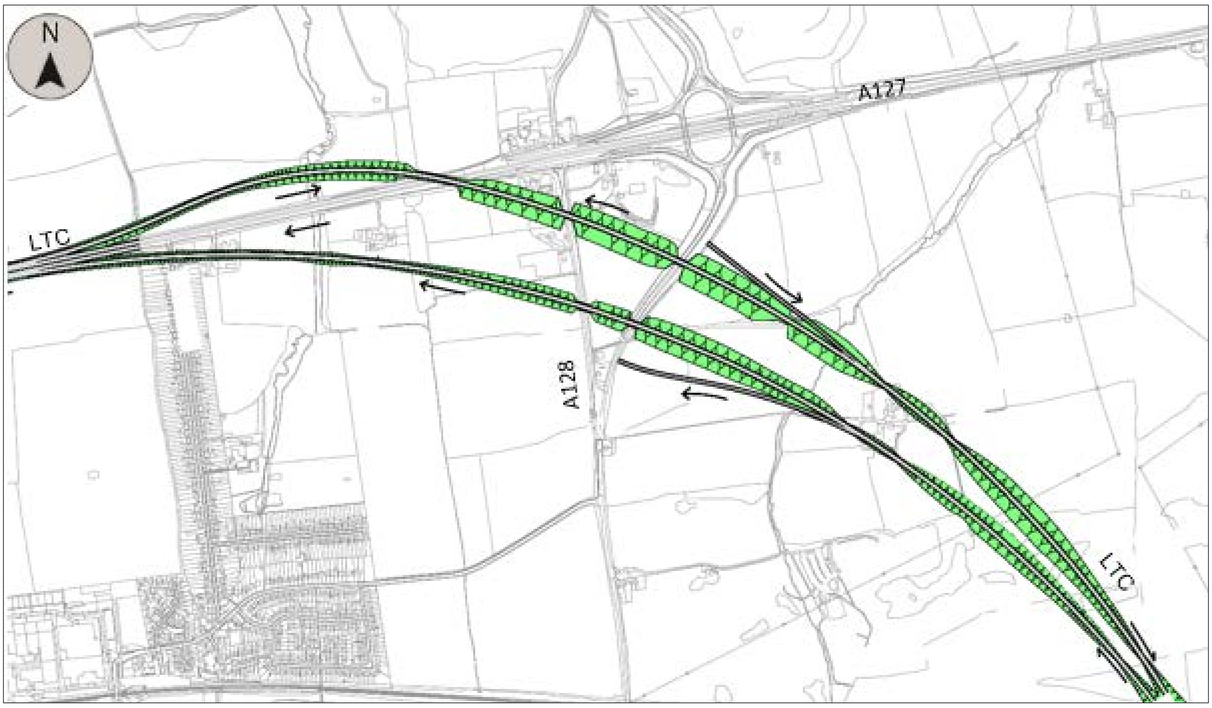

FIGURE 4.11 - ROUTE 4 A127/ A128 JUNCTION

4.2.30 The widening of the A127 would be symmetrical about the existing central reserve. The majority of the works could be constructed off-line with the existing lanes on the A127 reduced in width to provide a safe working zone. A temporary speed limit of either 50mph or 40mph would be required in association with these works.

4.2.31 The works required on the M25 at Junction 29 would be similar to those detailed for the M25 junction for Routes 2 and 3 (refer to **Figure 4.12**). Traffic management with a temporary speed limit (likely to be 50mph) would be required on the M25 for the duration of the works to enable the viaduct and slip-road tie-ins to be constructed.

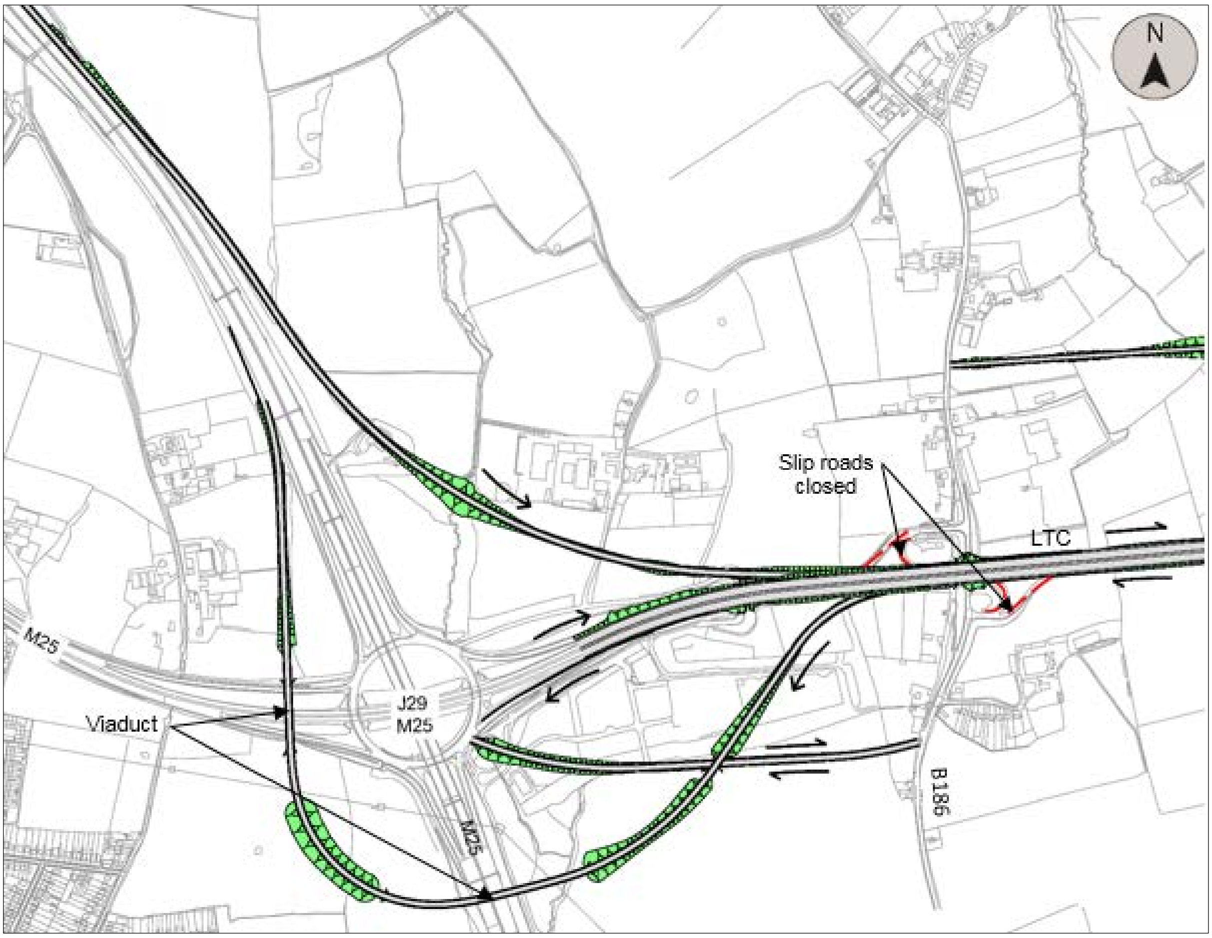

FIGURE 4.12 - ROUTE 4 M25 JUNCTION

River Crossing - Bridge

4.2.32 Refer to Route 1 River Crossing – Bridge for outline construction details. The main difference between the bridge option for Route 1 and bridge option for Routes 2, 3 or 4 is the longer main span and higher towers. The principal methods of construction would remain largely similar, with the main deck assumed to be constructed by cantilever erection using pre-assembled sections. These sections would be floated in on barges and lifted in to place with heavy lifting gear located on the deck. Construction of the bridge at Route 2, 3 or 4 is estimated to take approximately 57 months.

River Crossing – Tunnel Options

4.2.33 For Routes 2, 3 and 4 two alternative forms of construction are considered: bored tunnels and immersed tunnels. These are briefly described in this section.

Bored Tunnel Routes 2, 3, 4

4.2.34 For outline construction details refer to Route 1 Bored Tunnel (paragraphs 4.1.17 to 4.1.24). The construction period for a bored tunnel for Routes 2, 3 and 4 is estimated to be approximately 54 months. The indicative programme assumes two TBMs and associated back-ups would be procured in order to achieve the programme and reduce risk in the event of TBM breakdown or other unforeseen event. Both bores of the TBM tunnel would be driven from the north bank and dismantled on the south bank.

Immersed Tunnel Routes 2, 3, 4

4.2.35 The form of construction proposed for the immersed tunnel is known as the "segmental concrete method." With this method large rectangular concrete tunnel elements would be fabricated in a casting basin normally large enough to contain all the elements at once. Each element would be fabricated in separate segments and these would be temporarily stressed together with post tensioning cables so that each element acts as a monolithic unit. The ends would be sealed with bulkheads. The construction period for the immersed tunnel is estimated to be about 54 months.

4.2.36 The immersed tunnel crossing would involve extensive earthwork excavations on both sides of the estuary. Deep de-watered cofferdam construction (e.g. diaphragm walls) would be required for the cut and cover approach tunnels and ramps.

4.2.37 The location of a casting basin would be determined by the availability of a suitable site to construct the elements and to deliver them to site. Ideally the casting basin would be located in close proximity to the crossing. Alternatively, elements may be cast at a suitable remote facility and be towed to site.

4.2.38 Construction of an immersed tunnel requires that a deep trench is excavated across the river between the cofferdams. Once this was completed it would be kept clean of sediment and each of the tunnel elements would be towed out in turn and lowered and placed in the bottom of the trench. They would be progressively joined together and backfilled.

4.2.39 These operations would require the use of large equipment, plant and vessels operating in the river for some time and would require careful planning and cooperation with the PLA and the many regulators and agencies responsible for the river and its environment. Early discussions have been held with the PLA on the principles of these proposals.

4.2.40 There are two main options for the choice of dredger used by the contractor for the excavation of the tunnel trench. The first (base-case solution) is to use a large "back-hoe" dredger which has a long mechanised arm which reaches down into the water. The excavated material (alluvium, gravels and Chalk bedrock) would be raised to the surface and discharged into ocean-going barges for transport to a licensed disposal site at sea.

4.2.41 The alternative would be to use a large cutter-suction dredger. This operates in a different fashion. It has a rotating cutter-head at the end of a long supporting tube. Excavated material is reduced to a slurry and pumped through the tube into a pipeline for transport to a series of disposal lagoons located on land. The use of a cutter-suction dredger is quicker than with a back-hoe dredger as it has greater capacity but would require a large area of land to be made available for the disposal lagoons. The slurry would then either be allowed to dry-out e.g. for agricultural use, or left in flooded/slurry form for wild-life habitat.

4.2.42 With either type of dredger, some of the excavated material would be lost into the river system during the excavation process. Preliminary hydrodynamic modelling work has been carried out to investigate this aspect and is reported separately. In general the studies show that additional sedimentation lost from the dredging operations would be relatively modest in comparison with the volumes of sediment being deposited naturally in this part of the river.

4.2.43 To carry out construction, the existing navigation channel in the estuary would need to be narrowed in width and diverted from side to side to allow construction to take place. Channel diversions may need to be present for approximately 18 to 24 months. In addition a series of 24 hour closures of the navigation channel would be required each time a tunnel element was being lowered into position and joined to the preceding element. This is to prevent waves and currents from passing ships de-stabilising these sensitive operations.

4.2.44 Ten tunnel elements each approximately 127m long have been assumed. Each 24 hour closure of the channel would be required at approximately one month intervals to coincide with suitable tides and fit with scheduled shipping services using the river. All channel diversions and closures would need to be planned and advertised well in advance.

5 Operation and Maintenance

5.1 Highways Infrastructure Operation and Maintenance

5.1.1 Day-to-day operations of the SRN comes under the authority of Highways England NDD. The network is to be operated to provide safe passage of all road users on a daily basis in all weather conditions, 24 hours a day. Daily operations would involve monitoring, traffic management, accident assistance and planning inspections and routine maintenance. This work is carried out by agents working on behalf of NDD.

5.1.2 The operation and maintenance of the new LTC will have to be carried out so as to meet Highways England's performance target of ensuring lane availability does not fall below 97% in any one rolling year[1].

5.1.3 Highway maintenance requirements include activities such as surface renewals, drainage maintenance and full depth pavement reconstruction. Wherever possible maintenance operations should be carried out avoiding lane closures.

5.1.4 During maintenance temporary speed limits would be generally 20mph less than the permanent speed limits. Maintenance activities carried out commonly on a 5 year cycle include activities such as resurfacing, road markings, lighting, vegetation clearance, barriers and signage. Major maintenance would be carried out approximately every 20 years and includes activities such as pavement strengthening/ reconstruction and maintenance of structures. Operational plans would also include allowance for unplanned/ unforeseen maintenance (e.g. to make emergency repairs) when needed.

5.1.5 The following general principles have been assumed for the appraisal of future routine maintenance requirements:

a) Maintenance periods based on opening of scheme in 2025.

b) Lane closures during night shift for carriageways with at least 3 lanes.

c) Full carriageway closures during night shift with diversion routes for carriageways with 2 lanes or less.

d) There may be opportunities to optimise closures by carrying out multiple maintenance activities simultaneously.

Route 1

5.1.6 For Route 1 it would be impractical to implement full carriageway closures other than in exceptional circumstances (e.g. in the event of an emergency) due to the volume of strategic and local traffic. The diversion route and disruption to traffic would be significant.

[1] Highways England Delivery Plan 2015 - 2020.

5.1.7 The close proximity of the existing junctions on the M25/ A282 between Junctions 2 and 30, presents a major constraint for maintenance because it restricts the length of closures that can be implemented.

5.1.8 It is envisaged that maintenance works for Route 1 could be carried out between junctions, which would simplify traffic management and minimise the number of slip road closures. However the constrained works areas would lead to reduced productivity of maintenance works compared to a route without these restrictions (for example at Location C). The distance between junctions ranges from 500m to 1500m and would dictate the length of closures.

5.1.9 The lane configuration of the M25/ A282 along Route 1 varies between 3 and 6 lanes. This combined with the relative short spacing of junctions may cause weaving issues that would need to be carefully controlled under traffic management.

5.1.10 From Junction 2 to 1b the implementation of smart motorway technology with discontinuous hardshoulder and all lane running from Junction 1b to 1a would require complex temporary traffic management measures and would limit the length of closures that could be implemented.

5.1.11 Any routine maintenance works around Junction 1a and the Dartford Control Centre would require extensive planning and co-ordination with the operator so that the operation of the traffic management cell for dangerous goods vehicles, overheight vehicles and abnormal loads using the river crossing could be maintained.

5.1.12 Route 1 may also attract greater operational risks compared to other routes within Location C because of its reliance on the co-ordination of any routine maintenance works with other M25 programmed construction works.

Route 2, 3, and 4 (ESL and WSL)

5.1.13 The constraints and risks associated with maintaining and operating Routes 2, 3, and 4 are similar to Route 1 however to a lesser degree. The main reason is that the proposed crossing locations associated with Routes 2, 3 and 4 allow for a wider distribution of traffic during lane closures.

5.1.14 The lane configuration is generally consistent on Routes 2, 3, and 4, mostly being 2 lanes in each direction. The cross section of the carriageway for Routes 2, 3 and 4 would also have hardstrips providing additional width for the implementation of traffic management. Furthermore the spacing of the junctions are greater when compared to Route 1.

5.1.15 Maintenance activities may require full carriageway closures with diversions because significant lengths of Location C routes would have 2-lanes. Any closures would provide greater work outputs and provide the benefit that the workforce will not be exposed to live traffic and that multiple maintenance activities could be carried out thereby reducing costs.

5.1.16 The provision of Location C crossing would allow either the existing or new crossing to be closed whilst using the other crossing as the diversion route. This would therefore be less disruptive than the current situation.

5.2 Bridge Crossing Operation and Maintenance

5.2.1 The bridge design would be based on operational requirements that would minimise the need for lane or carriageway closures. Day-to-day operation of the bridge would involve condition monitoring, traffic management and planned interventions for inspection and maintenance. It is assumed that the operation of a new bridge would be fully integrated with the existing crossings under the jurisdiction of Highways England NDD.

5.2.2 The bridge is assumed to include wind shielding and this would limit the number of occasions high sided vehicles may be restricted from using the bridge during extreme wind events. This would be dependent on the extent (e.g. height) of wind shielding provided. This would be investigated further as the design developed.

Design for optimum maintenance

5.2.3 The design of the permanent works would be developed considering whole life costs for the cable stayed bridge and approach viaducts. Whole life costs consider not only the initial capital cost of designing and constructing the bridge, but also the maintenance and operational activities over the design life. Provision for whole life costs has been included in the cost estimates reported in Section 7.

5.2.4 A bridge has a design life of 120 years, but components would need to be replaced at shorter intervals as they reach the end of their serviceable life. For the purpose of the appraisal assumptions on the design life of components and materials have been made in accordance with DMRB standards (e.g. surfacing, repainting, bearings, movement joints). All parts of the bridge would be designed to be inspected rapidly, safely and easily and replaced where necessary. The number and time between maintenance interventions can be extended through higher specification components or materials. To ensure value for money, the case would have to be proved considering both initial Capex costs with future Opex costs using whole life costing.

5.2.5 Access for replacement and inspection purposes would be designed to limit impact on the traffic and ensure traffic is kept flowing as far as possible. Design requirements would be developed to ensure exceptional maintenance activities, such as replacement of bridge bearings or cable stays, are possible with some restrictions on traffic to limit loading whilst the works were being carried out.

5.2.6 To ensure the safety of road users, maintenance and operation personnel, the design and specification of parts accessible to traffic would be carefully considered. On major bridges these components include joints, surfacing, drainage, parapets, wind shielding, lighting and Intelligent Transportation System (ITS). To maximise lane availability and minimise health and safety risks, it is preferable to maximise the time between maintenance interventions through high specification materials and construction methods.

5.2.7 High quality construction can be achieved by maximising off-site construction and prefabrication which also minimises health and safety risks during the construction phase and the risk of unplanned maintenance during service due to defects or deterioration. By considering off-site at an early stage in the design process, whole life costs would be optimised.

5.2.8 Once construction of the bridge is complete, deterioration effects, such as due to traffic or the environment would be monitored and interventions made where necessary to prevent failure of components or systems impacting on the serviceability of the crossing.

5.2.9 A maintenance and operation manual which is specifically tailored to the crossing would be prepared. It would contain an inventory which described all of the component and bridge items from the design and construction and would detail the lifespan and method of inspection and replacement.

5.2.10 The condition and rate of deterioration of the bridge and its components would be determined through monitoring and inspection of the bridge. In the United Kingdom, a standard regime and method of inspection is specified in DMRB and also the Management of Highways Structures, a Code of Practice, published by the Roads Liaison Group. The regimes and methods contained in the documents would have to be tailored to suit the specific requirements of a cable stayed bridge.

5.2.11 There are routine maintenance activities, e.g. cleaning of drainage which would be planned and cyclical. Other maintenance activities such as concrete repairs would be non-cyclical. These would be based on a whole life costing analysis to determine the optimum solution and best time for intervention.

5.2.12 A maintenance manual would define the activities and the timing which will enable a maintenance profile to be developed helping to reduce the risk of unplanned incidents impacting the use of the bridge.

Maintenance

5.2.13 A range of facilities for inspections and maintenance of the structure would be considered as part of the scheme development. These would include fixed access facilities throughout the bridge such as walkways, stairs, ladders and lifts in the towers. Due to the length and height of the bridge, motorised access would be considered for access to the underside of cable stayed deck, and specialist platforms for accessing the cables, external tower surfaces, bearings and expansion joints.

5.2.14 The strategy for the facilities would be to ensure that for routine and preventative inspection and maintenance activities, as far as possible lane closures were avoided and disruption to traffic minimised. Easy and safe access for inspection and maintenance personnel must be ensured.

5.2.15 Structural health monitoring system are commonly installed on structures of such scale and strategic importance. These supplement the inspection and maintenance regime and will be considered should a bridge option be taken forward.

5.2.16 The design should permit the removal and replacement of the stay cables and any cables used as tension ties for anchoring of the side spans.

5.3 Tunnel Crossing Operation and Maintenance

5.3.1 The LTC would be a key part of London and south-east England's road network and therefore operational resilience is a high priority. Key design decisions and a suitable contractual relationship with a competent tunnel operator would be needed to ensure the operational continuity and safety of modern road tunnels.

Design for Resilient Tunnel Operations

5.3.2 The tunnel design has a critical influence on the resilience of operations and maintenance. Design assumptions have been made for the purposes of the options appraisal and would be further assessed and developed in the next stage.

5.3.3 The following points summarise specific aspects of tunnel design that would contribute to operational resilience and sustainability:

- Unidirectional, free-flowing traffic, controlled from the road network to prevent congestion.
- Resilient, low maintenance longitudinal tunnel ventilation systems using jet fans in accordance with sustainability objectives.
- Tunnel category A, no restriction on passage of dangerous goods.
- Design for maintenance; choice of equipment, technology, materials, tunnel space and access. Redundancy meaning traffic can flow even when incidents/ failures occur.
- Tunnel systems including lighting, traffic management and safety systems making best use of technology whilst limiting the need for specialist or sole source contractors for maintenance activities.
- Coordinated operation of existing Dartford tunnels, QEII Bridge and new LTC tunnels and diversions on the surrounding road network. Sequential and coordinated maintenance plan.
- Kent and Essex fire brigades available near-by and on short call, police working closely with tunnel operator.
- Modern mist fire suppression system providing business continuity by preventing most severe fires combined with low impact testing that does not require tunnel closure.
- Passive fire protection to prevent extended periods of tunnel closure due to fire without reliance on the fire suppression system.
- Planned routine inspections under single lane/bore closure as required.
- Local compound and rescue station near the tunnel allowing rapid response.

Traffic Control

5.3.4 In order to implement Dart Charge, and allow the toll plazas to be removed, a traffic management cell was implemented. The Traffic Management Cell (TMC) identifies and stops oversized vehicles or those carrying restricted dangerous goods from entering the tunnels. It enables restricted dangerous goods vehicles to be escorted through the tunnels safely and stops traffic in the event of an incident in the tunnels. The need for a traffic management cell restricts capacity at the crossing.

5.3.5 At present the TMC is only required on the south side of the crossing for northbound traffic. Southbound traffic is routed via the QEII Bridge and is not subject to the same restrictions. Route 1 would require one bore of the existing tunnel crossing to be used for northbound traffic (west tunnel) and one for southbound (east tunnel). This would therefore require a TMC or other means of diverting restricted traffic in the southbound direction from the east tunnel. However, since Route 1 provides 4 unrestricted lanes in both directions it is anticipated that hazardous goods and over-height vehicles could be routed to use these lanes. The level of operation of the TMC would be reduced compared to the current level. Over height vehicles which are in the wrong lane when approaching the tunnels northbound and southbound would be stopped, turned around and sent back to the previous junction to approach the tunnels again in the correct lane. Alternatively vehicles may be instructed to use an alternative route.

5.3.6 The tunnels would be a strategic link in a complex strategic road network; traffic management would therefore require careful development with a need for skilled operators. Incidents that interrupt traffic flow can have serious consequences, not only to those involved and to the traffic in the tunnel but also on the surrounding road network.

5.3.7 The safety strategy would be based on free-flowing traffic in the tunnels (i.e. design to avoid queueing or stationary traffic in the tunnels). The aims would be to prevent congestion by using progressive lane closures to regulate upstream traffic flows.

5.3.8 The requirement for no escort or checking of tankers in any new tunnels would remove many of the traffic issues associated with dangerous goods experienced at Dartford tunnels. The engineering solutions for tunnel options include assumed appropriate diversion facilities as part of the systems and traffic management, addressing the risk of abnormal loads. However, as discussed above there would still be a requirement for the TMC to control access by restricted vehicles to the existing Dartford tunnels.

Maintenance

5.3.9 The inspection, testing and monitoring regime would be designed around resilience and keeping traffic moving. Diversion routes are assumed as part of operating any new route. Maintenance work can be broadly categorised as follows:

- Preventative, either periodic or condition based
- Corrective, for equipment approaching failure
- Improvement to existing or to add new equipment

5.3.10 Preventative maintenance and development/ improvement projects would be programmed to fit in with the windows of opportunity within the daily traffic pattern and coordinated via the regional control centre; the use of electronic/IT systems would help improve scheduling of maintenance activities for the local network. Provision has been assumed for efficient on-site storage of safety critical tunnel systems including tunnel lighting and signage, spares for ventilation equipment and sprinkler heads. The strategy should incorporate future opportunities to improve maintenance, fault fixes and technology reliability by using ideas like remote diagnostics for equipment, upgrade to higher specification equipment, and emerging technologies such as self-healing displays for signs.

5.3.11 Inspection frequencies and maintenance requirements for the tunnels would be in accordance with DMRB BD 78/99 *Design of Road Tunnels*, complemented by DMRB BA 72/03 *Maintenance of Road Tunnels* and comply with the European Directive 2004/54/EC.

Strategy for Tunnel Operations and Closure

5.3.12 The strategy for tunnel operations may be based around three scenarios.

- Within a range of acceptable ‘normal’ operating conditions, events and minor equipment malfunctions may occur that do not substantially affect the traffic flow.
- An ‘incident’ scenario would be due to an event affecting traffic or by the loss of tunnel systems or functions.
- An ‘emergency’ scenario is time-critical and requires rapid response.

5.3.13 Most traffic/ environmental/ technical events would have consequences limited to the traffic flow or tunnel operation, i.e. users’ safety is not affected and the tunnel is operated under a controlled degraded mode.

5.3.14 Partial planned closures (one or more lanes or a single tunnel bore) would be used as part of the overall strategy for resilience; and would always start before the entrance portal. These would take place during periods of low traffic (e.g. nighttime) and be coordinated with the local network. Total closures of both tubes are not envisaged due to the necessity to maximise availability.

5.3.15 The closure procedure would be designed for all foreseeable events, including non-emergency incidents (vehicle breakdown, debris on road) emergency incidents (fires or severe accidents) and tunnel technical failures

5.4 Maintenance of Structures

5.4.1 The overall purpose of inspection, testing and monitoring is to check that highway structures are safe for use and fit for purpose and to provide the data required to support effective maintenance management and planning.

5.4.2 Inspections, and where required testing and monitoring, should:

- Observe and provide information on the current condition, performance and environment of a structure, e.g. severity and extent of defects, material strength and loading.
- Inform analyses, assessments and processes, e.g. change in condition, cause of deterioration, rate of deterioration, identification and quantification of maintenance needs, effectiveness of maintenance and structural capacity.

- Compile, verify and maintain inventory information, e.g. structure type, dimensions and location.

5.4.3 **Table 5.1** provides a summary of inspection types and intervention periods:

TABLE 5.1 - SUMMARY OF INSPECTION TYPES AND INTERVENTION PERIODS

Inspection Type	Nominal interval	Description
Safety inspection (or routine surveillance)	At frequencies, not exceeding one month, which ensure timely identification of safety defects and reflect the importance of a particular route or asset.	Regular visual inspections to identify defects that are likely to create a danger to the public or staff or lead to unnecessarily high maintenance costs or disruption to traffic. These are carried out by cursory inspection from a slow moving vehicle or on foot.
General inspection	2 years	General inspections comprise a thorough visual inspection of representative parts of the civil infrastructure involving visual inspection from the ground level. Report on the physical condition of all civil infrastructure elements visible from ground level.
Principal inspection	6 years	A Principal inspection will comprise a close and detailed examination of all accessible parts of the structure involving close visual examination, within touching distance; utilising as necessary, suitable inspection techniques. Report on the physical condition of all inspectable civil infrastructure parts.
Special inspection	Programmed or when needed	Detailed investigation (including as required inspection, testing and/or monitoring) of particular areas of concern

5.4.4 The purpose of maintenance planning and management is to enable the maintenance manager to develop and implement cost effective and sustainable maintenance plans while delivering the required asset performance and levels of service. The maintenance strategy would optimise on opportunities presented by planned closures of the structures where needed and avoid unplanned closures where possible.

5.4.5 To keep the structure in a good state of repair and to avoid the need to replace items and employ specialist services it is necessary to frequently perform basic maintenance. Routine maintenance is minor work carried out on a regular or cyclic basis that helps to maintain the condition and functionality of the structures and reduce the need for other maintenance works.

5.4.6 Preventative maintenance (planned or unplanned) is work carried out to keep the infrastructure open and safe to use and maintain the condition of the structure by protecting it from deterioration or slowing down the rate of deterioration. By timely intervention, preventative maintenance reduces the need for essential work and/ or the likelihood of essential work arising prematurely in the future.

5.4.7 Major overhauls and refurbishment of elements such as tunnel fabric are undertaken on a basis that ensures the long term preservation of investment by acting on the agreed recommendations of the Principal Inspection reports.

5.4.8 All of the route options being considered involve major items of civil infrastructure and would require comprehensive monitoring, inspection and maintenance plans to be developed if they are to remain in service for their expected design life and beyond. The options involve extensive lengths of new highways, junctions, earthworks, bridges, tunnels drainage and other items of highways infrastructure including complex mechanical and electrical systems. All of these would require a programme of maintenance and periodic renewals.

5.4.9 The maintenance requirements for the river crossing would be the largest and costliest component of the scheme. The general maintenance assessment requirements for the different types of principle structure (bridge, bored tunnel or immersed tunnel) are discussed in the sections above.

5.5 Technology Maintenance

5.5.1 For the existing tunnel crossing, a cyclic maintenance programme is undertaken during planned night time tunnel closures with traffic management to ensure safe working practices and to protect the maintenance workforce. It is envisaged that for Route 1, a similar maintenance strategy could be adopted if the proposed new crossing were a tunnel.

5.5.2 For the existing bridge crossing, planned closures are undertaken overnight, with the existing Dartford tunnels running a contraflow system to alleviate any potential congestion. For Route 1, it is envisaged that a similar maintenance strategy could be adopted, the additional capacity provided by the new crossing giving a greater range of options for traffic diversion during maintenance.

5.5.3 Remote monitoring for the diagnostic evaluation of roadside equipment would allow faster response times to faults and reduce the risk to the maintenance teams.

5.5.4 There are a number of future technologies that, as they become more widely available, would assist in providing a cohesive maintenance strategy. These technologies would help to minimise maintenance intervention and include:

- **IP enabled equipment** – reduces the need for equipment outstations and technology infrastructure required for the scheme, meaning less infrastructure to maintain. In addition, IP enabled equipment allows easier remote monitoring and diagnostics, reducing maintenance visits to the roadside equipment that is installed.
- **Materials technology** – Developments in this area include self-healing display screens and self-cleaning surfaces.

- **Higher specification of equipment** – higher grade equipment could extend equipment life and increase durability. Examples include longer back-up battery lives in equipment such as emergency light fittings, or uninterruptable power supplies. Consequently, this would mean less need to access equipment for maintenance.
- **Infrastructure Inspections** – With the increased use of drone technology, it is likely that more maintenance work will be carried out remotely, for example bridge pier inspections via CCTV.
- **In-vehicle technology** – as communication technology speeds increase, it is highly likely that next generation telecommunications will provide road users with more information via mobile phone and in-car systems. This is currently being trialed around the world, and may reduce the amount of roadside infrastructure required, thus reducing maintenance and improving workforce safety.

6 Appraisal of Design and Construction Risk

6.1 Project Risk Register

6.1.1 The Project Risk Register provides a tabulated summary of the risks that may affect the project. Risks are categorised, the potential impact with measures to control or mitigate the risk assessed and recorded.

6.1.2 The risk process is continual. The register is updated generally monthly through the Stage 1 Option Identification and Stage 2 Option Selection phases. The process is managed by Highways England Project Management Office.

6.1.3 Risks were assessed in 5 stages:

- **Identify**; identification of risk events, assessment of cause and likely effect or consequence.
- **Analyse & Evaluate**; qualitative assessment of likelihood and cost, time, quality, reputation, safety or environment impact. Qualitative thresholds adopted are described in **Table 6.1**.
- **Response**; assessment of whether to treat, transfer, tolerate, terminate or take opportunity. Response measure and cost of mitigating assessed.
- **Analyse & Evaluate Residual Risk**; qualitative assessment of residual risk.
- **Review**; regular updating of risk appraisal, generally monthly for the Option Stages.

TABLE 6.1 - COST AND TIME IMPACT THRESHOLDS ADOPTED FOR RISK EVALUATION

Rating	1	2	3	4	5
	Very Low	Low	Medium	High	Very High
Probability	<5%	5% - 20%	21% - 50%	51% - 75%	>75%
Cost (£M)	0-1	1-3	3-6	6-34	>34
Time (weeks)	0 -1	1-4	4-8	8-12	>12

6.2 Design and Construction Risks

Key design and construction risks identified through the risk process are shown in **Table 6.2**.

TABLE 6.2 - KEY DESIGN AND CONSTRUCTION RISKS

Ref	Risk	Routes affected	Mitigation
1	Options capacity estimates for additional 4 lanes at A or dual 2 lane ‘expressway’ standard route at C prove	All routes	Potential for change assessed. Order of Magnitude costs of larger river crossing structures at Location C to accommodate dual 3 lane arrangements estimated

Ref	Risk	Routes affected	Mitigation
	insufficient in future appraisals of traffic demand. More lane capacity required. Scheme costs increase. Technical risks increase (e.g. due to larger tunnel bore diameter).		under Options and covered in SAR. Likelihood of extra lanes being provided in a scheme at Location A assessed as low.
2	Tunnel cross section increases over initial assumptions in order to provide an emergency lane under European Road Tunnel Safety Regulations. Scheme costs increase. Technical risk increase (due to larger bore diameter or larger immersed tunnel units).	All tunnel routes	Change assessed and Order of Magnitude costs of larger tunnels at location C estimated and covered in SAR. Low likelihood of requirement at location A. Emergency lane need subject to future full cost benefit / disproportionate cost assessment. Note overlap with potential dual 3 provision.
3	Underestimate of impact on property/businesses and relocation/compensation costs. Opposition by affected parties and compensation demands greater than assessed. Scheme costs increase. Delay risk.	All Routes	Greater risk at Location A due to value of businesses directly affected by Route 1. DV engaged to assess land and compensation costs. High impact on business under Route 1 option noted in particular. Future mitigation to include early assessment of land take requirements in the Development Phase, provide for early negotiations, and early Stakeholder Engagement team action to work with land owners and business impacted by preferred route.
4	Delays/congestion impacts due to high levels of on-line highways works at Location A underestimated, reducing capacity, causing unacceptable delay and affecting operation of the TMC.	Route 1	Contractor engaged to review Options construction phasing programme. Route 1 construction programme duration increased for advanced works period (to include moving control centre).
5	Changes required to the scheme after the DCO application has been submitted, e.g. due to late discovery of protected species or conflict with related developments or authority/landowner objections.	All routes	Use the non-statutory consultation to develop the Project’s understanding of stakeholder requirements so that there are “no surprises” during consideration of DCO application. Consult with the Planning Inspectorate and take specialist advice to determine the minimum level of design needed to support an application while maintaining flexibility in the designs. Maintain engagement with external organisations whose requirements could affect the design and construction of the Project. Formally agree their design requirements and identify any changes which may emerge and impact on the Project.
6	Insufficient suitable compensation land available to mitigate impacts on European designated sites.	Routes 2, 3 and 4.	Options assessment based on preliminary HRA. Prioritise early detail assessment in the Development Phase and engagement with Natural England to

Ref	Risk	Routes affected	Mitigation
			agree process for identifying compensatory land, confirm requirements and identify suitable land as compensation alternatives.
7	Future more detailed assessment of Air Quality results exceed EU limits for Air Quality.	All routes	Options assessment scope covered relatively detailed air quality assessment/comparison of impacts for all shortlist routes. Subject to full detail assessment in preferred route development stage.
8	Underestimate of utility impacts/diversion requirements due to uncertainty of data and/or assumptions, leading to higher diversion and/ or delay	All routes	Options assessment included C2 enquiries and utilities risk provision. Preferred route stage to carry out early data gathering and site investigations to confirm Options assumptions/findings. Review risk allocation and advance works options to ensure contracts fit with allocation of risk to those best placed to deal with.
9	Future development of scheme proposals unable to satisfy the requirements of the Habitats Directive or obtain a derogation.	Routes 2, 3 and 4.	Options assessment based on preliminary HRA and proposals tested with specialist legal counsel. Commence as soon as possible a programme of observations and surveys to build evidence to support DCO application and/or application for derogation. Consult further with special interest groups to assess risk. Confirm the availability of compensation land.
10	Underestimate of complexity of acquiring land to construct the new route causes design changes necessary to accommodate new land restrictions increasing cost and/ or causing delay.	All routes	Detail desk study of land for construction assumptions carried out for Options. DV engaged to assess land and compensation costs. Important early development stage action to confirm land take requirements/assumptions against delivery schedule and identify critical areas/risks.
11	Development Consent Order application delayed or refused e. g. as a result of opposition from statutory consultees; or inadequate consultation; or delay in Options phase completion; or delay in Development phase completion.	All routes	Plan for Development phase. Early meeting with Planning Inspectorate to develop submission requirements. Use lessons from A14 DCO application. Ensure strict adherence to application requirements.
12	Significant opposition or legal challenge by public or special interest groups causing delay or cancellation.	All routes	Considerable investment made at Options stage in Stakeholder Engagement work stream to understand the needs and priorities of stakeholders, and work to build support for scheme. Risk of challenge mitigated through tight compliance with process and peer review. The consultation process is being externally assured.

Ref	Risk	Routes affected	Mitigation
13	Change in scheme requirements and/ or scope due to new information resulting from studies and investigations (e.g. extra NMU provision), leading to change in scheme design, causing increase in cost and/or delay.	All routes	Provision for re-work, if needed, in place for consultation period to mitigate potential for delay. Risk that the extent of changes required might result in the consultation period being extend or, if substantial, new consultation being needed.
14	Environmental surveys show that a higher number, or more types, of protected species than anticipated are found within areas impacted by the scheme.	All routes	Options stage includes preliminary HRA. Desk study based appraisal. Commence as soon as possible programme of early surveys and site investigations to supplement data gathered during Options Phase and confirm findings/assumptions.
15	Underestimate of impact on LTC of interface with existing long term M25 DBFO and/ or other network O&M contracts. Risk of increase in cost and/or delay.	All routes	Engagement with Connect Plus and Sanef and the Area 4 team in the Options stage. Considerable investment made at Options stage in Stakeholder Engagement work stream to understanding the needs and priorities of stakeholders, and work to build support for LTC. The risk of challenge is mitigated through tight compliance with process and peer review. The consultation process is being externally assured.
16	Unexpected ground conditions (e.g. geology, underground workings, archaeology, groundwater, unexploded ordnance) impacts design proposals, leading to additional cost and/ or delay.	All routes	Options stage development desk study based. Level of geotechnical data for stage generally high for Location A, reasonable for Location C. Early focus in development stage on surveys and site investigations to supplement options stage data/assumptions. Crossing solution ground risk; bored tunnel solution higher than immersed and tunnels higher than bridge.
17	Information provided by third parties proves incorrect, incomplete or unreliable, or third party requirements change, affecting design, requiring design change leading to additional cost and/ or delay.	All routes	Considerable investment made at Options stage in Stakeholder Engagement work stream to understanding the needs and priorities of stakeholders covering design requirements alongside work to build support for LTC. This has included early discussion on critical design requirements e.g. navigation clearances and ship vessel sizes for design purposes with PLA, and independent assessment to verify criteria where appropriate. Maintain engagement with external organisations whose requirements affect design/construction. Seek early formal agreement of requirements.
18	New technology fails to deliver (stringency of BIM requirements increasing, supply chain as yet inexperienced).	All routes	Plan to include sufficient allowances to anticipate technology failures. Design to avoid technology risk.

Ref	Risk	Routes affected	Mitigation
19	Uncertainty relating to other developments and schemes e.g. Paramount development, associated A2 widening.	All routes	Options baseline for development based on DfT/ HM Treasury guidance. Establish baseline and implement strict change control. Assure impacts/benefits in response to possible changes.
20	The LTC benefit cost ratio does not achieve the required level either due to future increase in estimated costs and/or reduction in estimated benefits.	All routes	Continual review and sensitivity testing of benefit cost ratios. Value engineering to improve ratios.
21	Development of Development Stage traffic model delayed.	All routes	Proposals for model developed and submitted for approval in Options Stage. Proactive and wide engagement with approvers and stakeholders.
22	Damage to existing tunnels when constructing crossing at location A.	Route 1	Options stage engineering appraisal completed using existing data. Detail investigation and confirmation affects not critical to option selection.
23	Major unexpected event during construction of large complex crossing structures e.g. ship collision with structure constructed in river, loss of a bridge deck or immersed tunnel element during construction, loss of a TBM due to abandonment	All routes	Rigour in development of feasible, optimised, well-engineered solutions. Thorough surveys and investigations to confirm assumptions and fully appraise risks. Selection of competent designers and contractors familiar with and successful track records in delivering similar scale and types of structures proposed. Care in setting contract technical requirements.
24	The supply chain fails to deliver to the Project requirements	All routes	Rigorously examine and test the capability and capacity of the supply chain with additional scrutiny given to the critical elements. Take advice from IUK and assess the expected programme of major construction activity elsewhere that may affect LTC. Devise contingency plan in case of failure to deliver.
25	Enabling works by others delay LTC work.	All routes	Engage early with others to confirm, agree and contract delivery requirements. Ensure integration of LTC programme with others and monitor critical dependencies. Where possible include incentives and damages clauses in contracts.
26	Safety-related incidents on site delay the work and/ or add cost	All routes	Ensure that the Project leads with safety at all stages, include safety as a principal selection for all suppliers, create a safety culture throughout the Project and become a key element of Highways England's drive for safety.

6.3 Estimating Risk Costs

Estimates of risk adjustment cost included in the capital cost estimates for the shortlisted routes are presented in Section 7.

7 Capital, Operating and Maintenance Cost Estimates

7.1 Capital Cost Estimates

7.1.1 Capital cost estimates have been developed for each of the shortlisted routes. Range estimates of out-turn costs have been prepared in accordance with Highways England Commercial Services Division's standard practice. The Cost estimate structure consists of the following components:

- Base cost estimate
- Project-level risk and residual uncertainty assessment
- Roads Portfolio-level risk assessment
- Inflation to out-turn prices (nominal terms)

7.1.2 Residual uncertainty assessment considers risks that cannot be easily quantified, supplementary to the project risk assessment. The calculation of residual uncertainty is based on project-specific allowances reflecting a top-down view of overall risk profile to avoid focussing solely on known or easily-defined risks.

7.1.3 Portfolio-level risk assessment considers risks that act at the Highways England Roads Portfolio level (i.e. across all of Highways England's portfolio of schemes) based on a portfolio risk register. These risks are allocated across schemes and an allowance is included in the individual project's cost estimate.

7.1.4 Range estimates are prepared using three point estimating techniques with outputs based on 10% (P10), Most Likely (Mode) and 90% (P90) levels of probability.

All costs have been estimated in real terms at a price base of quarter 1, 2014 prior to the application of inflation. Further details of the estimating methodology are contained in **Appendix 4.6**.

7.2 Approach to Capital Cost Estimates

7.2.1 Out-turn costs have been produced using the Highways England Commercial Services Division Cost Estimation Summary Spreadsheet (CESS). The CESS provides a breakdown of costs incurred throughout scheme life from the options phase through to completion of construction and handover based on work breakdowns aligned to the Project Control Framework. Rates are based on the Highways England Commercial Services Division current rate data base.

7.2.2 The engineering solutions on which the estimates are based are described in Volume 3 and shown on the drawings in Volume 3 Appendices. Construction methodology assumptions for the crossing types were agreed and recorded in the estimate assumptions. A comparison with costs reported from other recent bridge and tunnel projects of comparable scale and nature, including projects in Europe and elsewhere in the world, was carried out as part of the review of the assured costs.

7.2.3 Statutory Undertakers' costs of protecting and diverting utilities services has been based on a schedule of utilities works setting out assumed requirements developed from C2 enquiry responses and data received from the utility companies (refer also to **Appendix 4.3**).

7.2.4 Indicative estimates of land purchase and compensation costs have been based on an assessment of affected land by the DV. Close reference has been made to rates used for the HS2 project. An assessment of forecast expenditure outside the existing highway boundaries has been made to calculate Non-Recoverable VAT at current rates.

7.2.5 Costs for the Development stage assume development of a single preferred scheme and delivery of consents through a DCO process. Procurement and construction phase costs assume the works are procured on a design and build basis.

7.2.6 Inflation has been applied using the Commercial Services Division's inflation profile previously set with the Department for Transport. This has been compared with the most recent Infrastructure UK forecast which is broadly similar up to 2020/ 21 (the extent of the Infrastructure UK forecast).

7.3 Capital Cost Estimate Summary Tables

7.3.1 The most likely estimated capital costs for the 20 alternatives considered for the shortlisted routes are summarised in **Tables 7.1** to **7.4**. Costs denoted as unassured have been derived by manually adding an extra over cost of the ESL to the relevant assured WSL cost. The extra cost of the ESL is calculated from the difference in assured Route 3 costs with ESL and with WSL (for the bored tunnel crossing option).

Three point minimum, most likely and maximum out-turn capital costs are summarised in **Tables 7.5** to **7.8**. **Figure 7.1** provides a comparison of the minimum, most likely and maximum out-turn capital costs.

TABLE 7.1 - SUMMARY ROUTE 1 ESTIMATED CAPITAL COST (MOST LIKELY)

	Route 1	
	Bridge	Bored Tunnel
Base Estimate	£1934 M	£2036 M
Project Risk adjustment	£253 M	£275 M
Uncertainty Allowance	£122 M	£128 M
Estimate @ Q1, 2014 Prices excl. Inflation and Portfolio Risk	£2310 M	£2439 M
Inflation adjustment	£839 M	£892 M
Portfolio Risk adjustment	£216 M	£229 M
ESTIMATED OUT-TURN (nominal)	**£3365 M**	**£3560 M**

TABLE 7.2 - SUMMARY ROUTE 2 ESTIMATED CAPITAL COST (MOST LIKELY)

	Route 2					
	WSL			ESL		
	Bridge	Bored Tunnel	Immersed Tunnel	*Bridge	*Bored Tunnel	*Immersed Tunnel
Base Estimate	£2131 M	£2088 M	£2279 M	£2238 M	£2195 M	£2386 M
Project Risk adjustment	£256 M	£233 M	£262 M	£252 M	£228 M	£258 M
Residual Uncertainty Allowance	£181 M	£218 M	£198 M	£206 M	£242 M	£223 M
Estimate @ Q1, 2014 Prices excl. Inflation and Portfolio Risk	£2568 M	£2538 M	£2739 M	£2696 M	£2666 M	£2867 M
Inflation adjustment	£966 M	£955 M	£1034 M	£1026 M	£1015 M	£1094 M
Portfolio Risk adjustment	£244 M	£241 M	£260 M	£258 M	£255 M	£274 M
ESTIMATED OUT-TURN (nominal)	**£3778 M**	**£3735 M**	**£4034 M**	**£3979 M**	**£3936 M**	**£4234 M**

TABLE 7.3 - SUMMARY ROUTE 3 ESTIMATED CAPITAL COST (MOST LIKELY)

	Route 3					
	WSL			ESL		
	Bridge	Bored Tunnel	Immersed Tunnel	*Bridge	Bored Tunnel	*Immersed Tunnel
Base Estimate	£2120 M	£2076 M	£2269 M	£2228 M	£2184 M	£2377 M
Project Risk adjustment	£256 M	£233 M	£262 M	£252 M	£228 M	£258 M
Residual Uncertainty Allowance	£181 M	£217 M	£197 M	£205 M	£242 M	£222 M
Estimate @ Q1, 2014 Prices excl. Inflation and Portfolio Risk	£2557 M	£2526 M	£2729 M	£2685 M	£2654 M	£2857 M
Inflation adjustment	£965 M	£953 M	£1033 M	£1024 M	£1013 M	£1092 M
Portfolio Risk adjustment	£244 M	£241 M	£260 M	£257 M	£254 M	£273 M
ESTIMATED OUT-TURN (nominal)	**£3765 M**	**£3720 M**	**£4021 M**	**£3966 M**	**£3921 M**	**£4222 M**

TABLE 7.4 - SUMMARY ROUTE 4 ESTIMATED CAPITAL COST (MOST LIKELY)

	Route 4					
	WSL			ESL		
	Bridge	Bored Tunnel	Immersed Tunnel	*Bridge	*Bored Tunnel	*Immersed Tunnel
Base Estimate	£2327 M	£2289 M	£2482 M	£2434 M	£2397 M	£2588 M
Project Risk adjustment	£255 M	£233 M	£262 M	£251 M	£228 M	£258 M
Residual Uncertainty Allowance	£216 M	£253 M	£233 M	£241 M	£277 M	£258 M
Estimate @ Q1, 2014 Prices excl. Inflation and Portfolio Risk	£2798 M	£2775 M	£2976 M	£2926 M	£2903 M	£3104 M
Inflation adjustment	£1034 M	£1023 M	£1103 M	£1093 M	£1083 M	£1162 M
Portfolio Risk adjustment	£265 M	£263 M	£282 M	£279 M	£276 M	£295 M
ESTIMATED OUT-TURN (nominal)	**£4097 M**	**£4061 M**	**£4361 M**	**£4298 M**	**£4262 M**	**£4562 M**

TABLE 7.5 - ROUTE1 OUT-TURN CAPITAL COST RANGE ESTIMATES

		Route 1	
		Bridge	Bored Tunnel
Estimate in real terms @ Q1, 2014 excl. Inflation and Portfolio Risk	Low	£1376 M	£1444 M
	Most Likely	£2310 M	£2439 M
	High	£3912 M	£4096 M
ESTIMATED OUT-TURN (nominal)	Low	£2655 M	£2796 M
	Most Likely	£3365 M	£3560 M
	High	£4909 M	£5151 M

TABLE 7.6 - ROUTE 2 OUT-TURN CAPITAL COST RANGE ESTIMATES

		Route 2					
		WSL			ESL		
		Bridge	Bored Tunnel	Immersed Tunnel	*Bridge	*Bored Tunnel	*Immersed Tunnel
Estimate in real terms @ Q1, 2014 excl. Inflation and Portfolio Risk	Low	£1512 M	£1454 M	£1596 M	£1588 M	£1529 M	£1672 M
	Most Likely	£2568 M	£2538 M	£2739 M	£2696 M	£2666 M	£2867 M
	High	£3805 M	£4199 M	£4427 M	£3951 M	£4345 M	£4574 M
ESTIMATED OUT-TURN (nominal)	Low	£2899 M	£2863 M	£3107 M	£3044 M	£3008 M	£3252 M
	Most Likely	£3778 M	£3735 M	£4034 M	£3979 M	£3936 M	£4234 M
	High	£4917 M	£5267 M	£5592 M	£5131 M	£5481 M	£5806 M

TABLE 7.7 - ROUTE 3 OUT-TURN CAPITAL COST RANGE ESTIMATES

		Route 3					
		WSL			ESL		
		Bridge	Bored Tunnel	Immersed Tunnel	*Bridge	Bored Tunnel	*Immersed Tunnel
Estimate in real terms @ Q1, 2014 excl. Inflation and Portfolio Risk	Low	£1517 M	£1459 M	£1601 M	£1592 M	£1534 M	£1676 M
	Most Likely	£2557 M	£2526 M	£2729 M	£2685 M	£2654 M	£2857 M
	High	£3767 M	£4159 M	£4388 M	£3913 M	£4305 M	£4534 M
ESTIMATED OUT-TURN (nominal)	Low	£2894 M	£2857 M	£3100 M	£3039 M	£3001 M	£3245 M
	Most Likely	£3765 M	£3720 M	£4021 M	£3966 M	£3921 M	£4222 M
	High	£4876 M	£5223 M	£5549 M	£5089 M	£5437 M	£5763 M

TABLE 7.8 - ROUTE 4 OUT-TURN CAPITAL COST RANGE ESTIMATES

		Route 4					
		WSL			ESL		
		Bridge	Bored Tunnel	Immersed Tunnel	*Bridge	*Bored Tunnel	*Immersed Tunnel
Estimate in real terms @ Q1, 2014 excl. Inflation and Portfolio Risk	Low	£1648 M	£1596 M	£1863 M	£1723 M	£1671 M	£1938 M
	Most Likely	£2798 M	£2775 M	£2976 M	£2926 M	£2903 M	£3104 M
	High	£4479 M	£4515 M	£4745 M	£4625 M	£4661 M	£4892 M
ESTIMATED OUT-TURN (nominal)	Low	£3177 M	£3122 M	£3450 M	£3322 M	£3267 M	£3595 M
	Most Likely	£4097 M	£4061 M	£4361 M	£4298 M	£4262 M	£4562 M
	High	£5660 M	£5677 M	£6026 M	£5874 M	£5890 M	£6240 M

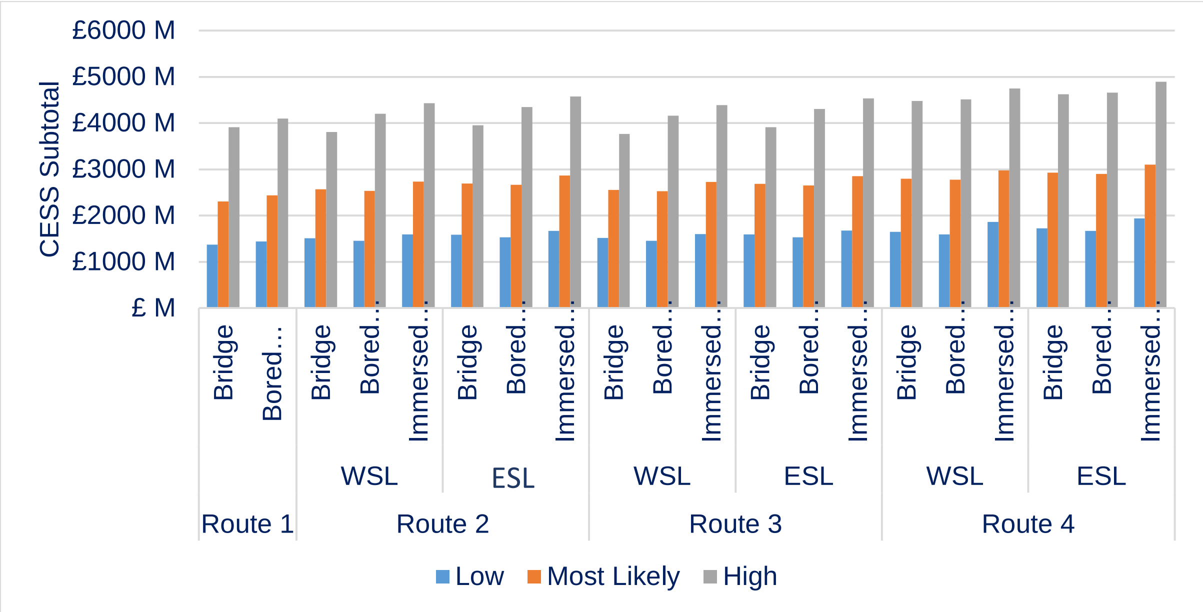

FIGURE 7.1 - COMPARISON OF THREE POINT OUT-TURN CAPITAL COST ESTIMATES

*Notes to **Tables 7.1** to **7.8** and **Figure 7.1**:*

1. *Base estimate date is Q1, 2014*

2. ** denotes unassured estimate. Costs are derived using extra over cost of ESL calculated from difference in assured Route 3 costs with ESL and with WSL (for bored tunnel crossing). Extra over cost for ESL is added to relevant assured estimate.*

7.4 Operating and Maintenance Cost Estimates

7.4.1 Operation and Maintenance (O&M) cost estimates have been developed by Highways England Commercial Services Division for each shortlisted route. Costs are provided for Routes 1, 2, 3 and 4. Costs for Routes 2, 3 and 4 assume the WSL. An extra over cost has been provided for the ESL, which has then been applied to the WSL costs in order to obtain total O&M costs for all 20 alternatives considered.

7.4.2 The estimated O&M costs are derived in three parts:

- The annual costs of routine maintenance activities (e.g. winter maintenance, road sweeping, litter picking, grass cutting, routine inspection programmes, etc.) and routine operation of the highway assets, e.g. energy costs and core operation and incident response capability. Note vehicle operating costs and the costs of traffic delays at roadworks are excluded here and assessed elsewhere through the scheme's traffic modelling and economic assessment work;
- The costs of periodic asset renewals such as pavement resurfacing, replacement of safety barriers, bridge bearings, tunnel lighting, etc;
- An assessment of any betterment resulting from the scheme's replacement of ageing infrastructure with new assets and improved efficiency of future operation and maintenance working practices.

7.4.3 The estimates produced represent the incremental costs of operation and maintenance of each scheme compared with the do-minimum base case. The estimates are for an assessment period of 60 years from the end of construction and exclude allowance for relative price increase above general inflation. Costs are summarised in real terms at 2025 (quarter 2) prices to reflect the planned completion of construction

7.4.4 Maintenance in a tunnel would cover requirements for cleaning, maintaining lighting and drainage, checking communication equipment, fire safety systems and ventilation equipment. Periodic asset renewals for tunnels would include mechanical and electrical equipment. For the main bridge, major items would include replacement of bearings, movement joints and repainting steel structures. Cable stays are assumed to have a design life of 60 years or more so replacement is outside the estimate period.

7.4.5 Reference was made to costs for operating and maintaining the existing Dartford Crossing where relevant but it is noted these costs are significantly affected by the age of the existing Dartford Crossing tunnels and care needs to be taken in comparing with costs for operating and maintaining a new tunnel designed to modern standards and reflective of latest industry best practice.

7.4.6 Total O&M costs developed for the shortlist routes are summarised in **Table 7.9** and illustrated in **Figure 7.2**. Further details of the estimating methodology and resulting summary O&M cost estimates are contained in **Appendix 4.6**.

TABLE 7.9 - SUMMARY OPERATION AND MAINTENANCE COST ESTIMATES ALL ROUTES

	Route 1	
	Bridge	Bored Tunnel
Estimated O&M	£241 M	£351 M

	Route 2					
	WSL			ESL		
	Bridge	Bored Tunnel	Immersed Tunnel	*Bridge	*Bored Tunnel	*Immersed Tunnel
Estimated O&M	£308 M	£537 M	£519 M	£324 M	£553 M	£535 M

	Route 3					
	WSL			ESL		
	Bridge	Bored Tunnel	Immersed Tunnel	*Bridge	*Bored Tunnel	*Immersed Tunnel
Estimated O&M	£327 M	£569 M	£547 M	£344 M	£586 M	£563 M

	Route 4					
	WSL			ESL		
	Bridge	Bored Tunnel	Immersed Tunnel	*Bridge	*Bored Tunnel	*Immersed Tunnel
Estimated O&M	£349 M	£591 M	£559 M	£365 M	£607 M	£576 M

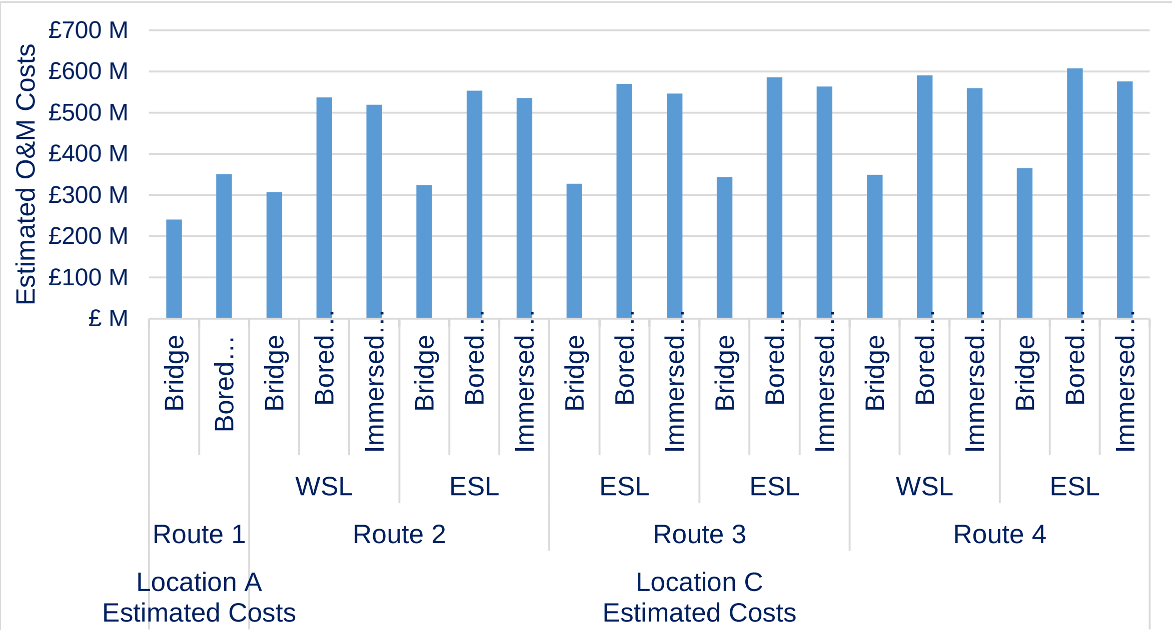

FIGURE 7.2 - SUMMARY COMPARISON OF OPERATION AND MAINTENANCE COST ESTIMATES

Notes to **Table 7.9** and **Figure 7.2**:

1. *Costs are summarised in real terms at 2025 (quarter 2) prices.*
2. ** denotes estimate derived using extra over cost of ESL added to relevant WSL O&M cost.*

8 Future-proofing Provision at Location C River Crossing

8.1 Basis of Appraisal and Consideration of Need for Future-proofing

8.1.1 As described in **Table 2.1** the shortlist routes at Location C have been assessed on the basis of a dual 2 lane solution. This section considers the risk associated with this assumption, and whether provision should be included in the scheme for future-proofing, to facilitate a future dual 3 lane solution. This risk is referred to in **Table 6.2** (Risk Ref 1).

8.2 Capacity Test Using Congestion Reference Flow

8.2.1 A capacity test has been undertaken on Route 3 with the Eastern Southern Link, using Congestion Reference Flow (CRF) analysis, based on a dual 2 lane solution. The CRF of a link is an estimate of the Annual Average Daily Traffic (AADT) flow at which the carriageway is likely to be congested in the peak periods on an average day. The CRF is affected by the proportion of heavy goods vehicles, peak hour to daily flow ratio, peak hour directional split and weekday/weekly flow ratio.

8.2.2 The mainline links which have been analysed in this test are shown on **Figure 8.1**. The forecast AADT is compared with the CRF for each mainline link in years 2025 and 2041, for both the Core growth and High growth scenarios; the different growth scenarios are described in Volume 5. The results of this analysis are shown in **Table 8.1** (Core growth) and **Table 8.2** (High growth).

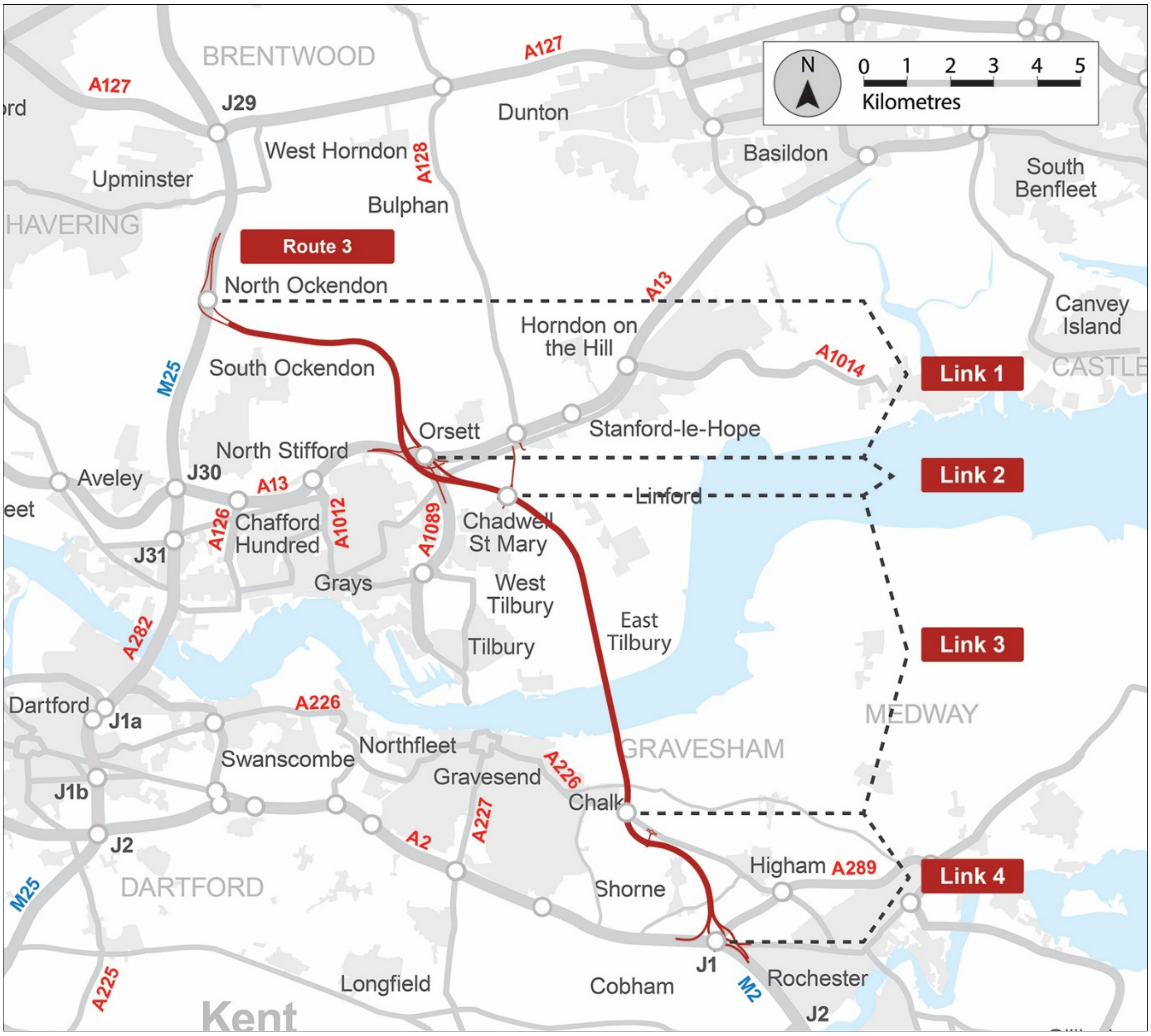

FIGURE 8.1 - CONGESTION REFERENCE FLOW LINKS

TABLE 8.1 - CONGESTION REFERENCE FLOW COMPARED TO 2 WAY ANNUAL AVERAGE DAILY TRAFFIC, 2025 AND 2041 CORE GROWTH SCENARIO

			2025		2041	
	Carriageway Link	Link No	CRF	2way AADT	CRF	2way AADT
Route 3 with ESL	M25 to A13 (N)	1	91,676	60,079	92,185	65,421
	A13 (N) to A13 (S)	2	98,621	52,899	100,557	60,846
	A13 (S) to A226	3	83,637	78,492	86,697	**89,544**
	A226 to M2	4	87,327	71,007	89,818	76,969

TABLE 8.2 - CONGESTION REFERENCE FLOW COMPARED TO 2 WAY ANNUAL AVERAGE DAILY TRAFFIC, 2025 AND 2041 HIGH GROWTH SCENARIO

			2025		2041	
	Carriageway Link	Link No	CRF	2way AADT	CRF	2way AADT
Route 3 & ESL	M25 to A13 (N)	1	90,887	62,696	91,887	68,605
	A13 (N) to A13 (S)	2	98,132	54,805	100,296	63,054
	A13 (S) to A226	3	84,839	81,271	87,701	**92,608**
	A226 to M2	4	88,599	73,609	90,866	79,940

8.2.3 It can be seen from **Tables 8.1** and **8.2**, that the 2 way AADT flows are generally less than the Congestion Relief Flows, indicating that a dual 2 lane solution will perform satisfactorily.

8.2.4 With Link 3, which includes the river crossing, the results show:

- In 2025 with Core and High growth, the forecast AADT flow is less than the CRF in 2025.
- In 2041 with Core and High growth, the forecast AADT flow is greater than the CRF by between 3% and 6% (as indicated by the bold red figures).

8.2.5 This test indicates that consideration should be given to adopting a future-proofed solution at the river crossing, by providing an additional lane in each direction at the river crossing structure. Details of the engineering and cost implications for a dual 3 lane river crossing are described below.

8.3 River Crossing Cross Sections

8.3.1 A dual 3 lane bridge is shown in **Figure 8.2.** The increase in deck width is 7.7m compared to the illustrative dual 2 lane arrangement.

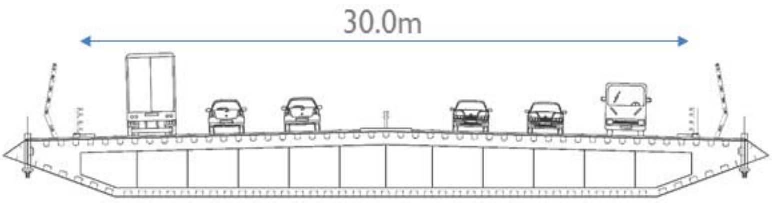

FIGURE 8.2 - INDICATIVE DUAL 3 LANE BRIDGE CROSS SECTION

8.3.2 A dual 3 lane bored tunnel is shown in **Figure 8.3**. The increase in the external diameter of each bore is 3.7m compared to the illustrative dual 2 lane arrangement.

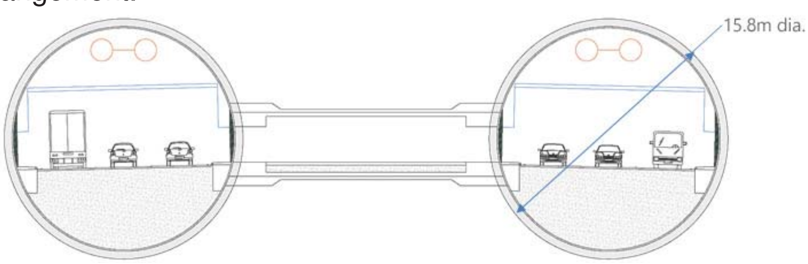

FIGURE 8.3 - INDICATIVE DUAL 3 LANE BORED TUNNEL CROSS SECTION

8.3.3 A dual 3 lane immersed tunnel is shown in **Figure 8.4**. This increases the width of the tunnel by 7.4m compared to the illustrative dual 2 lane arrangement.

FIGURE 8.4 - INDICATIVE DUAL 3 LANE IMMERSED TUNNEL CROSS SECTION

8.3.4 In addition to providing a future-proofed solution at the crossing, a third lane would also provide safety and operational benefits – refer to **Appendix 4.7:** Provision of a tunnel emergency lane at Location C.

8.4 Capital Cost Estimate for Provision of a Third Lane at the Crossing Structure

8.4.1 The estimated extra over out-turn costs (P10, P50, P90) for constructing a third lane at the river crossing structures is shown in **Table 8.3**.

TABLE 8.3 - SUMMARY EXTRA OVER OUT-TURN COST FOR RIVER CROSSING WITH THIRD LANE

	Extra over out-turn cost range (£m)		
	Low (P10)	Most Likely (P50)	High (P90)
Bridge	210	274	360
Bored Tunnel	280	358	500
Immersed tunnel	170	216	300

8.5 Conclusion

8.5.1 Whilst current traffic forecasts do not justify a dual 3 lane solution, it is recognized that potential future levels of traffic on the river crossing link could require dual 3 lane provision.

8.5.2 Provision of a third lane at the crossing structure would provide a future-proofed solution for this critical piece of infrastructure. The cost estimates used in the appraisal in **Section 9** therefore include for the cost of the additional lane at the crossing structure.

9 Summary of Results

9.1.1 This section provides a high level summary of the key differences between options in order for a comparison to be made. The comparisons are for:

- Location A, Route 1 (**Table 9.1**)
- Location C River crossings (**Table 9.2**)
- Location C, Western and Eastern Southern Links (**Table 9.3**)
- Location C, Routes 2, 3 and 4 (**Table 9.4**)

9.1.2 **Table 9.1** presents a summary for Location A, Route 1.

TABLE 9.1 - LOCATION A (ROUTE 1)

Scheme Objective	Criteria	Route 1 (Bridge)	Route 1 (Bored Tunnel)
Relieve the congested Dartford Crossing and approach roads and improve their performance by providing free flowing north south capacity	Design Standards	Route 1 is an on-line improvement to the A282 corridor. The design speed is 50 mph, due to the constraints imposed by existing housing, commercial development and infrastructure including the existing northbound tunnels and rail crossings along the route.	
	Impacts during construction	Estimated construction duration 80 months, including a 20 month advanced works phase required to relocate the Dartford Control Centre (DCC), rearrange the Dart Charge marshalling area, and undertake advanced service diversions. The long construction period reflects the significant traffic management required throughout the construction phase. A 40 mph temporary speed limit would be required throughout the construction period, with substantial periods of contraflow working.	
		Bridge has greater impact on users of the river and the adjacent jetties, which would need to be managed through liaison with the Port of London Authority (PLA) and the owners and operators of the jetties. Construction duration 45 months.	Bored tunnel has higher risk of construction impacts on existing tunnels. Bored tunnel requires removal of large volume of spoil which would be difficult in the confined area. Construction duration 54 months (assuming one tunnel boring machine).
Improve safety	Safety of Road Users	It is forecast that there will be an increase in FWI rate per billion vehicle km when compared with the Without Scheme scenario, increasing from 3.30 to 3.38 in 2025 and 2.64 to 2.73 in 2041, an increase of 2% and 3% respectively.	

Scheme Objective	Criteria	Route 1 (Bridge)	Route 1 (Bored Tunnel)
		Bridge is a safer overall solution for road users.	With bored tunnel northbound traffic is segregated in three separate tunnels, with two lanes of traffic in each tunnel. This would lead to weaving and signing difficulties for merging traffic at Junction 1a and diverging traffic at Junction 31.
Minimise adverse impacts on health and the environment	Impacts on property (demolition)	Residential 5 Commercial 12 Agricultural 0	
Be affordable to government and users, and achieve value for money	Out-turn Capital Cost Range P50/ P90 (£m)	3,365 – 4,909	3,560 – 5,151
	Operation and Maintenance Costs over 60 years (£m)	241	351

9.1.3 **Table 9.2** provides a summary of the crossing options for Location C. The costs that have been included are based on Route 3 with ESL.

TABLE 9.2 - LOCATION C CROSSING

Scheme Objective	Criteria	Bridge	Bored Tunnel	Immersed Tunnel
Relieve the congested Dartford Crossing and approach roads and improve their performance by providing free flowing north south capacity	Impacts during construction	Construction will impact on river operations requiring consents from PLA.	Large amount of spoil from tunnel will need to be removed/ re-used in works. No impact on river operations.	Remote casting basin or local onsite casting basin required. Significant impact on river operations requiring consents from PLA.
Be affordable to government and users, and achieve value for money	Out-turn Capital Cost Range P50/ P90 (Route 3 ESL) £m	4,240 – 5,449	4,279 – 5,937	4,438 – 6,063
	Operation and Maintenance Costs over 60 years (Route 3 ESL) £m	344	586	563

9.1.4 **Table 9.3** provides a summary of the Western Southern Link and Eastern Southern Link. The costs and property demolition figures that have been included are based on Route 3 with a bored tunnel crossing.

TABLE 9.3 - LOCATION C WESTERN SOUTHERN LINK VERSUS EASTERN SOUTHERN LINK

Scheme Objective	Criteria	Western Southern Link (WSL)	Eastern Southern Link (ESL)
Relieve the congested Dartford Crossing and approach roads and improve their performance by providing free flowing north south capacity	Mainline Design Standard	Dual 2 lane all-purpose solution, 70 mph design speed	
	Junction Design Standard	New A2 junction has a compact layout arrangement with 30/ 50 mph loop and link road design speeds, due to existing property, environmental and HS1 constraints.	Modified A2/ M2 junction. Link roads have 50/ 70 mph design speeds, providing a better free-flow arrangement than WSL ESL provides a better free-flow arrangement at the A2/ M2 junction than WSL
	Impacts during construction	New A2 junction - majority of works would be constructed off-line, requiring less traffic management than ESL junction with A2/ M2	Modified A2/ M2 junction - major viaducts would need to be constructed over live carriageways, and some local traffic diversions are likely to be required during construction.
Minimise adverse impacts on health and the environment	Impacts on property (demolition) (Route 3 Bored Tunnel)	Residential 4 Commercial 3	Residential 10 Commercial 2
Be affordable to government and users, and achieve value for money	Out-turn Capital Cost Range P50/ P90 (Route 3 Bored Tunnel) £m	4,078 – 5,723	4,279 – 5,937

9.1.5 **Table 9.4** provides a summary of the comparison of Routes 2, 3 and 4 all with a bored tunnel crossing and Eastern Southern Link.

TABLE 9.4 - LOCATION C ROUTE SELECTION

Scheme Objective	Criteria	Route 2 ESL (BT)	Route 3 ESL (BT)	Route 4 ESL (BT)
Relieve the congested Dartford Crossing and approach roads and improve their performance by providing free flowing north south capacity	Mainline Design Standard	Dual 2 lane all-purpose solution, 70 mph design speed		
	Impacts during construction	Route 2 requires online widening of the A1089 section of the route	Route 3 is the shortest route, with more offline works requiring less traffic management and disruption to existing traffic.	Route 4 requires online widening of the A127 section of the route
Improve safety	Safety of Road Users	All three routes are new routes designed to high standards of safety for road users.		
Minimise adverse impacts on health and the environment	Impacts on property (demolition) south of River Thames	Residential 10 Traveller plots 0 Commercial 2 Agricultural 0 Cemetery 0	Residential 10 Traveller plots 0 Commercial 2 Agricultural 0	Residential 10 Traveller plots 0 Commercial 2 Agricultural 0
	Impacts on property (demolition) north of River Thames	Residential 9 Traveller plots 0 Commercial 0 Agricultural 3 Cemetery 1	Residential 14 Traveller plots 22 Commercial 0 Agricultural 3	Residential 14 Traveller plots 0 Commercial 9 Agricultural 3
Be affordable to government and users, and achieve value for money	Out-turn Capital Cost Range P50/ P90 (£m)	4,294 – 5,981	4,279 – 5,937	4,620 – 6,390
	Operation and Maintenance Costs over 60 years (£m)	553	586	607

10 References

Title	Document number
DMRB – Layout of Grade Separated Junctions	TD 22/06
DMRB – Design of Road Tunnels	BD 78/99
DMRB – Maintenance of Road Tunnels	BA 72/03
DMRB – Cross-Sections and Headrooms	TD 27/05
DMRB – Appraisal of New and Replacement Lighting on the Strategic Motorway and All-Purpose Trunk Road Network	TA 49/07
Code of Practice: Management of Highways Structures	Roads Liaison Group, 4 August 2011
EC Directive: Minimum safety requirements for tunnels	2004/54/EC
Guide for the lighting of road tunnels or underpasses	CIE88:2004
Highways England Interim Advice Note - Managed Motorways All Lane Running	IAN 161/13
Prediction of road casualties in Great Britain to 2030	Parliamentary Advisory Council for Transport Safety (PACTS)

11 Abbreviations and Glossary

Abbreviation	Description
2025 Opening year	A modelled year in the LTC traffic model in which flows are estimated for each option
2041 Design year	A modelled year in the LTC traffic model. The design year is typically 15 years after opening, but for LTC 2041, 16 years after opening, was assessed as it is the maximum horizon year for current growth assumptions. Traffic flows are estimated for each option.
AADT	Average Annual Daily Traffic
AECOM	AECOM Technology Corporation
Affected Road Network	This comprises the area within which roads could be considered within the air quality model (selection of the roads within the model depends upon a number of criteria such as changes in Heavy Duty Vehicle flows).
Alignment	The alignment is the horizontal and vertical route of a road, defined as a series of horizontal tangents and curves or vertical crest and sag curves, and the gradients connecting them.
AM	07:00 to 10:00
AMCB	Analysis of monetary costs and benefits
AMI	Advanced Motorway Indicator, with optical feedback for enforcement.
ANPR	Automated Number Plate Recognition
AOD	Above ordnance datum, vertical datum used by an ordnance survey as the basis for delivering altitudes on maps.
AONB	Area of Outstanding Natural Beauty: Statutory designation intended to conserve and enhance the ecology, natural heritage and landscape value of an area of countryside.

APS	Annual Population Survey
APTR	All-purpose trunk road
AQMA	Air Quality Management Area: an area, declared by a local authority, where air quality monitoring does not meet Defra’s national air quality objectives.
AQSO	Air Quality Strategy Objective: Objective set by the Air Quality Strategy for England, Scotland, Wales and Northern Ireland to improve air quality in the UK in the medium term. Objectives are focused on the main air pollutants to protect health.
Armour	Riprap - also known as rip rap, rip-rap, shot rock, rock armour or rubble - is rock or other material used to armour shorelines, streambeds, bridge abutments, pilings and other shoreline structures against scour, water or ice erosion.
ASC	Asset Support Contract(or)
AST	Appraisal Summary Table; a summary of impacts of introducing new infrastructure, setting out impacts using a structured set or economic, social and environmental measures.
AURN	Defra’s Automatic Rural and Urban Network: the UK's largest automatic monitoring network and the main network used for compliance reporting against the Ambient Air Quality Directives.
BAP	Biodiversity Action Plan: National, local and sector-specific plans established under the UK Biodiversity Action Plan, with the intention of securing the conservation and sustainable use of biodiversity.
Batter slope	In construction is a receding slope of a wall, structure, or earthwork. The term is used with buildings and non-building structures to identify when a wall is intentionally built with an inward slope.
BCR	Benefit-Cost Ratio, the net benefit of a scheme divided by the net cost to Government. The ratio of present value of benefits (PVB) to present value of costs (PVC), an indication of value for money.
BGS	British Geological Survey: a partly publicly funded body which aims to advance geoscientific knowledge of the United Kingdom landmass and its continental shelf by means of systematic surveying, monitoring and research.
Bluewater	Bluewater Shopping Centre, an out of town shopping centre in Stone, Kent, outside the M25 Orbital motorway, 17.8 miles (28.6 km) east south east of London's centre.
BMS	Bridge Management System
BR	Bridge (when used as part of a LTC shortlist Route reference) Bridleway
BT	Bored tunnel
BTO	British Trust for Ornithology: an organisation founded in 1932 for the study of birds in the British Isles.
Capex	Capital expenditure, the cost of developing or providing non-consumable parts of the product or system.
Catchpit chamber	Catchpits are a precast concrete drainage product that are recommended for use as a filter and collector in land drainage systems that do not make use of any sort of geo-membrane. A catchpit is essentially an empty chamber with an inlet pipe and an outlet pipe set at a level above the floor of the pit. Any sediment carried by the system settles out whilst in the catchpit, from where it can be periodically pumped out or removed
CCTV	Closed-circuit television. Highways England CCTV cameras are used to monitor traffic flows on the English motorway and trunk road network primarily for the purposes of traffic management.
CDA	Critical Drainage Area(s): As defined in the Town and Country Planning (General Development Procedure) (Amendment) (No. 2) (England) Order 2006 a Critical Drainage Area is “an area within Flood Zone 1 which has critical drainage problems and which has been notified… [to]…the local planning authority by the Environment Agency”.
CESS	Highways England Commercial Services Division Cost Estimation Summary Spreadsheet

CFMP	Catchment Flood Management Plan: A strategic planning tool through which the Environment Agency works with other key decision-makers within a river catchment to identify and agree policies for sustainable flood risk management.
Chart Datum	The level of water from which charted depths displayed on a nautical chart are measured.
CKD	Combined kerb drain(s): a combined kerb and drainage system.
CO2e	Carbon dioxide equivalent; a standard unit for measuring carbon footprints. The idea is to express the impact of each different greenhouse gas in terms of the amount of CO2 that would create the same amount of warming.
COBALT	New ‘light touch’ version of COBA, COst Benefit Analysis computer program, DfT’s tool for estimating accident benefits. The COBA program compares the costs of providing road schemes with the benefits derived by road users
Connect Plus	Connect Plus (M25) Ltd, management company for the Dartford-Thurrock Crossing.
CRM	Customer relationship management
C.RO Ports	C.RO is the brand name for the subsidiaries of C.RO Ports SA that operate ro-ro terminals in the UK, the Netherlands and Belgium.
CSR	Client Scheme Requirements
D2AP	Dual two-lane all-purpose road
Dart Charge	The Dartford Crossing free-flow electronic number plate recognition charging system (operates between 0600 and 2200).
Dartford Cable Tunnel	An £11m tunnel upstream of the Dartford Crossing, built in 2003-4, whose diameter is ~3m. It is designed to carry and allow for maintenance of 380kV National Grid electrical cable beneath the River Thames.
DBFO	Design, build, finance, operate: a way of creating "public–private partnerships" (PPPs) by funding public infrastructure projects with private capital.
DCC	Dartford Crossing Control Centre
DCO	Development Consent Order
Defra	Department for Environment, Food and Rural Affairs: the government department responsible for environmental protection, food production and standards, agriculture, fisheries and rural communities in the United Kingdom of Great Britain and Northern Ireland.
Deneholes	An underground structure consisting of a number of small chalk caves entered by a vertical shaft.
DFFC	Dartford Free Flow Crossing (tollbooths removed)
DfT	Department for Transport: the government department responsible for the English transport network and a limited number of transport matters in Scotland, Wales and Northern Ireland that have not been devolved.
DGV	Dangerous goods vehicle
DI	Distributional Impact
Disbenefit	A disadvantage or loss resulting from something.
DMRB	Design Manual for Roads and Bridges: A comprehensive manual (comprising 15 volumes) which contains requirements, advice and other published documents relating to works on motorway and all-purpose trunk roads for which one of the Overseeing Organisations (Highways England, Transport Scotland, The Welsh Government or the Department for Regional Development (Northern Ireland)) is highway authority. The DMRB has been developed as a series of documents published by the Overseeing Organisations of England, Scotland, Wales and Northern Ireland. For the Lower Thames Crossing the Overseeing Organisation is Highways England.
DP World	Dubai Ports World, London Gateway Port
DRCC	Dartford River Crossing Control Centre
DVS	DVS Property Specialists, the specialist property arm of the Valuation Office Agency (VOA).

DWT	Deadweight tonnage, a measure of how much weight a ship is carrying or can safely carry.
EA	Environment Agency: The Environment Agency was established under the Environment Act 1995, and is a Non-Departmental Public Body of Defra. The Environment Agency is the leading public body for protecting and improving the environment in England and Wales. The organisation is responsible for wide-ranging matters, including the management of all forms of flood risk, water resources, water quality, waste regulation, pollution control, inland fisheries, recreation, conservation and navigation of inland waterways.
EB	eastbound
ELHAM	TfL's East London Highway Assignment Model
EMME	Equilibre Multimodal, Multimodal Equilibrium, a complete travel demand modelling system for urban, regional and national transportation forecasting.
EMMEBANK	Neue *Emme Bank* Vorm.Amtsersparniskasse Burgdorf
ERA	Emergency Refuge Area: on roads for use in emergency or breakdown only, located approximately every 800 metres and separated from the main carriageway.
ERT	Emergency roadside telephone(s)
ESL - Eastern Southern Link	The Eastern Southern Link (ESL) is an alternative for shortlist Routes 2, 3 and 4 to the south of the River Thames. The route would connect into Junction 1 of the M2 and would pass to the east of Shorne and then northwest towards Church Lane and Lower Higham Road. This route could connect into any of the Routes 2, 3 and 4 north of the river utilising all of the crossing options for these route options.
EU	European Union: A politico-economic union of 28 member states that are located primarily in Europe.
Fastrack	A bus rapid transit scheme operating in the Thames Gateway area of Kent, operated by Arriva Southern Counties.
FP	Footpath
FSA	Flood Storage Area: a natural or man-made area basin that temporarily fills with water during periods of high river levels.
FWI	Fatalities and Weighted Injuries: a statistical measurement of all non-fatal injuries added-up using a weighting factor to produce a total number of 'fatality equivalents'.
GDP	Gross Domestic Product
GIS	Geographic information system: an integrated collection of computer software and data used to view and manage information about geographic places, analyse spatial relationships, and model spatial processes.
GVA	Gross Value Added
Ha	Hectares
HADECS	Highways England Digital Enforcement Camera System
HAGDMS	Highways England Geotechnical Data Management System
HAM	TfL's Highway Assignment Model
Hanson	Hanson UK, part of the HeidelbergCement Group.
HATO	Highways Agency Traffic Officer
HATRIS	Highways England journey time database
HGV	Heavy Goods Vehicle
HHJV	Halcrow Hyder Joint Venture: a joint venture between Halcrow Group Limited and Hyder Consulting Limited.
HRA	Habitats Regulations Assessment: A tool developed by the European Commission to help competent authorities (as defined in the Habitats Regulations) to carry out assessment to ensure that a project, plan or policy will not have an adverse effect on the integrity of any Natura 2000 or European sites (Special Areas of Conservation, Special Protection Areas and Ramsar sites), (either in isolation or in combination with other plans and projects), and to begin to identify appropriate mitigation strategies where such effects were identified.

HS1	High Speed 1 rail line (formerly Channel Tunnel Rail Link (CTRL))
IAN	Interim Advice Notice: Issued by Highways England from time to time. They contain specific guidance, which should only be used in connection with works on motorways and trunk roads in England.
Inter-peak	10:00 to 16:00
IP	Internet Protocol
IT	Immersed tunnel
ITS	Intelligent Transportation System
Jacked box tunnelling	Jacked box tunnelling is a method of construction that enables engineers to create underground space at shallow depth in a manner that avoids disruption of valuable infrastructure and reduces impact on the human environment.
KMEP	Kent and Medway Economic Partnership
Lafarge Tarmac	Lafarge Tarmac Limited is a British building materials company headquartered in Solihull, Birmingham.
Lakeside	Lakeside Shopping Centre, branded as Intu Lakeside, is a large out-of-town shopping centre located in West Thurrock, in the borough of Thurrock, Essex just beyond the eastern boundary of Greater London.
LATS	London Area Transport Surveys
LCS	Lane Control Signs
LDP	London Distribution Park: offers 70 acres (28Ha) of land for industrial and logistics development 6.5 miles from the M25, adjacent to Port of Tilbury, London.
LGV	Light Goods Vehicle
Location A	The location for LTC route options close to the existing Dartford crossing.
Location C	The location for LTC route options connecting the A2/ M2 east of Gravesend with the A13 and M25 (between Junctions 29 and 30) north of the River Thames.
Location C Variant	As for options at Locations C and A with additional widening of the A229 between the M2 and the M20.
London Gateway	A new deep-water port, able to handle the biggest container ships in the world, and part the London Gateway development on the north bank of the River Thames in Thurrock, Essex, 20 miles (32 km) east of central London.
LPER	Refer to Paramount London
LTC	Lower Thames Crossing: a proposed new crossing of the Thames estuary linking the county of Kent with the county of Essex, at or east of the existing Dartford Crossing.
LTS railway	London Tilbury Southend railway
LWS	Local wildlife site
Mainline	The through carriageway of a road as opposed to a slip road or a link road at a junction
Mardyke	A small river, mainly in Thurrock, that flows into the River Thames at Purfleet, close to the QEII Bridge.
MIDAS	Motorway Incident Detection and Automatic Signalling
MMO	Marine Management Organisation: An executive non-departmental public body in the UK established under the Marine and Coastal Access Act 2009. The MMO exists to make a significant contribution to sustainable development in the marine area, and to promote the UK government's vision for clean, healthy, safe, productive and biologically diverse oceans and seas.
MS4	The latest generation of Variable Message Signs designed to display both pictograms and text; uses internationally recognised warning symbols and provides a dual colour display matrix for amber and red coloured characters or symbols.
MTM	Medway Traffic Model
NB	northbound

NCR	National Cycle Route: a cycle route part of the National Cycle Network created by Sustrans to encourage cycling throughout Britain.
NDD	Highways England Network Development Directorate
NIA	Noise-important area(s): Defra published noise maps for England's roads in 2008, with the noise action plans following 2 years later in 2010. The action plans set out a framework for managing noise, rather than propose specific mitigation measures, and were designed to identify 'Important Areas' that are impacted by noise from major sources and therefore must be investigated. NIAs are where the 1% of the population that are affected by the highest noise levels from major roads are located, according to the results of Defra's strategic noise maps.
NMU	Non-motorised user, e.g. pedestrians, cyclists, equestrians.
NO2/ NO_2	Nitrogen dioxide
NPPF	National Planning Policy Framework: published in March 2012 by the UK's Department of Communities and Local Government, consolidating over two dozen previously issued documents called Planning Policy Statements (PPS) and Planning Policy Guidance Notes (PPG) for use in England.
NPS	National Policy Statement (refer to NPSNN)
NPSNN	National Policy Statement for Networks National: The NPSNN sets out the need for, and Government's policies to deliver, development of nationally significant infrastructure projects on the national road and rail networks in England. It provides planning guidance for promoters of nationally significant infrastructure projects on the road and rail networks, and the basis for the examination by the Examining Authority and decisions by the Secretary of State.
NSIP	Nationally significant infrastructure project: major infrastructure developments in England and Wales, such as proposals for power plants, large renewable energy projects, new airports and airport extensions, major road projects etc.
NPV	Net present value, a measure of the total impact of a scheme upon society, in monetary terms, expressed in 2010 prices.
NRTS	National Roads Telecommunications Services
NTCC	National Technology Control Centre: based in the West Midlands, the NTCC is an ambitious telematics project aimed at providing free, real-time information on England's network of motorways and trunk roads to road users, allowing them to plan routes and avoid congested areas.
NTEM	DfT's National Trip End Model
NTS	National Transport Survey
O&M	Operations and Maintenance
OD	Origin-destination: origin-destination data (also known as flow data) includes the travel-to-work and migration patterns of individuals, cross-tabulated by variables of interest (for example occupation).
ONS	Office for National Statistics: the executive office of the UK Statistics Authority, a non-ministerial department which reports directly to the UK Parliament.
Opex	An operating expense or operating expenditure or operational expense or operational expenditure: an ongoing cost for running a product, business or system.
Orifice plate	A device used for measuring flow rate, for reducing pressure or for restricting flow (in the latter two cases it is often called a restriction plate). Either a volumetric or mass flow rate may be determined, depending on the calculation associated with the orifice plate.
Orthotropic steel deck plate	An orthotropic bridge or orthotropic deck is one whose deck typically comprises a structural steel deck plate stiffened either longitudinally or transversely, or in both directions. This allows the deck both to directly bear vehicular loads and to contribute to the bridge structure's overall load-bearing behaviour. The orthotropic deck may be integral with or supported on a grid of deck framing members such as floor beams and girders.
PA	Public accounts Public address

PACTS	Parliamentary Advisory Council for Transport Safety: a registered charity and an All-party parliamentary group of the UK parliament. Its charitable objective is to protect human life through the promotion of transport safety for the public benefit.
PA metrics	Production and attraction metrics
Paramount Park, London	London Paramount Entertainment Resort (LPER). A proposed theme park and entertainment precinct on the Swanscombe peninsula, Kent. Construction could begin in autumn 2016 with the opening estimated for Easter 2021.
PCF	Highways England Project Control Framework process.
PCM	Pollution Climate Model
pcu	passenger car units. This is a metric to allow different vehicle types within traffic flows in a traffic model to be assessed in a consistent manner. Typical pcu factors are: 1 for a car or light goods vehicle; 2 for a bus of heavy goods vehicle; 0.4 for a motorcycle; and 0.2 for a pedal cycle.
Peel Ports	Britain's second largest group of ports, part of the Peel Group.
Penstock	A sluice or gate or intake structure that controls water flow, or an enclosed pipe that delivers water to hydro turbines and sewerage systems. It is a term that has been inherited from the earlier technology of mill ponds and watermills.
PIA	Personal Injury(ies) Accident(s)
PLA	Port of London Authority: a self-funding public trust established by The Port of London Act 1908 to govern the Port of London. Its responsibility extends over the Tideway of the River Thames and its continuation (the Kent/ Essex strait). It maintains and supervises navigation, and protects the river's environment.
PM	16:00 to 19:00
PM_{10}	Particulate matter (in this example, particulates smaller than 10µm that can cause health problems).
PRoW	Public Right of Way: A right possessed by the public, to pass along routes over land at all times. Although the land may be owned by a private individual, the public may still gain access across that land along a specific route. The mode of transport allowed differs according to the type of public right of way which consist of footpaths, bridleways and open and restricted byways.
pSPA	*Potential Special Protection Area: Sites which are approved by Government that are in the process of being classified as Special Protection Areas.*
PSSR	Preliminary Sources Study Report
PTSD	Highways England Professional and Technical Services Division
PV	Present Values
PVB	Present value of benefits: PVBs less PVCs provide estimates of Net Present Values (NPVs) and the ratio of the PVB to the PVC constitutes the BCR.
PVC	Present value of costs: a measure of the monetary cost of a scheme, less revenues, discounted to and expressed in 2010 prices.
QEII Bridge	Queen Elizabeth ll Bridge, part of the Dartford-Thurrock crossing.
QUADRO	QUeues And Delays at ROadworks computer program: a Highways England sponsored computer program maintained and distributed by TRL Software; its primary use is in rural areas. It estimates the effects of roadworks in terms of time, vehicle operating and accident costs on the users of the road. Individual roadworks jobs can be combined to produce the total cost of maintaining the road over time.
RADAR	Radar is an object-detection system that uses radio waves to determine the range, angle, or velocity of objects, including motor vehicles.
Ramsar site	A wetland of international importance, designated under the Ramsar convention.
RCC	Regional Control Centre
RET	Range Estimation Tool

RFID	Radio-frequency identification, the wireless use of electromagnetic fields to transfer data, for the purposes of automatically identifying and tracking tags attached to objects. The tags contain electronically stored information.
rMCZ	Recommended Marine Conservation Zone: A site put forward for designation under the Marine and Coastal Access Act 2009 to conserve the diversity of nationally rare, threatened and representative habitats and species.
RSPB	Royal Society for the Protection of Birds: A charitable organisation that works to promote conservation and protection of birds and the wider environment through public awareness campaigns, petitions and through the operation of nature reserves throughout the United Kingdom.
RTMC	Regional Technology Maintenance Contract(or)
RTC	Road traffic collision
RWE npower	A leading integrated UK energy company.
SAC	Special Area of Conservation: defined in the European Union's Habitats Directive (92/43/EEC), also known as the *Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora*. SACs are to protect the 220 habitats and approximately 1000 species listed in annex I and II of the directive which are considered to be of European interest following criteria given in the directive.
SANEF	Société des Autoroutes du Nord et de l'Est de la France, a motorway operator company.
SAP	LTC Stakeholder Advisory Panel: comprises key local authority stakeholders to share local knowledge, their needs, priorities and opinions with respect to LTC. SAP meetings have been held at key stages of the LTC project; bi-lateral meetings with SAP members have also been held.
SAR	HHJV's Pre-Consultation Scheme Assessment Report of the Lower Thames Crossing.
SATURN	Simulation and Assignment of Traffic to Urban Road Networks, Transport Model
SCADA	Supervisory Control and Data Acquisition
S-CGE	Spatial Compatible General Equilibrium
SEB(s)	Statutory Environmental Body(ies): Any principal council as defined in subsection (1) of section 270 of the Local Government Act 1982 for the area where the land is situated. Where the land is situated in England; Natural England, Historic England, the Environment Agency, Natural Resources Wales and the National Assembly for Wales where, in the opinion of the Secretary of State, the land is sufficiently near to Wales to be of interest to them and any other public authority which has environmental responsibilities and which the Secretary of State considers likely to have an interest in the project.
SELEP	South East Local Enterprise Partnership: the business-led, public/ private body established to drive economic growth across East Sussex, Essex, Kent, Medway, Southend and Thurrock.
Setting	This is defined in the National Planning Policy Framework as 'The surroundings in which a heritage asset is experienced. Its extent is not fixed and may change as the asset and its surroundings evolve. Elements of a setting may make a positive or negative contribution to the significance of the asset, may affect the ability to appreciate that significance or may be neutral.'
SGAR	Stage Gateway Assessment Review: part of Highways England Project Control Framework (PCF) process.
Shortlist Route 1	A new trunk road connecting M25 Junction 2 to M25 Junction 30, with a new 4 lane bridge crossing or a 4 lane twin-bored tunnel to the west of Dartford crossing, with significant improvements to Junctions 30 and 31. Smart Motorway Technology is to be implemented from Junction 2 to 1b (with no widening) and Junction 1b to 1a (with widening to dual 5 lanes).
Shortlist Route 2	A new trunk road connecting A2 (2 km east of Gravesend) to M25 between Junctions 29 and 30, using A1089 (upgrading), with dual 2 lane crossing option of a bridge / twin-bored tunnel / immersed tunnel. Refer also to Eastern Southern Link and Western Southern Link.
Shortlist Route 3	A new trunk road connecting the A2 (2 km east of Gravesend) to the M25 (between Junctions 29 and 30), with dual 2 lane crossing option of a bridge / twin-bored tunnel / immersed tunnel. Junction with the A13 at the existing junction with the A13 and A1089

	and a junction with Brentwood Road, with Brentwood Road upgraded to dual 2 lane to Orsett Cock interchange. Refer also to Eastern Southern Link and Western Southern Link.
Shortlist Route 4	A new trunk road connecting A2 (2 km east of Gravesend) to M25 at Junction 29, using A127 (upgrading), with dual 2 lane crossing option of a bridge / twin-bored tunnel / immersed tunnel. Single carriageway road provided from B186 to A128 parallel with the A127. Refer also to Eastern Southern Link and Western Southern Link.
SIA	Social Impact Appraisal
Smart motorway	Term for a range of types of actively controlled motorway, using technology to optimise use of the carriageway including the hard shoulder.
SPA	Special Protection Area: A designation under the European Union Directive on the Conservation of Wild Birds.
SPECS	Average Speed Enforcement Camera System
SPZ	Source protection zone: EA-defined groundwater sources (2000) such as wells, boreholes and springs used for public drinking water supply. These zones show the risk of contamination from any activities that might cause pollution in the area.
SRN	Strategic Road Network, the core road network, managed in England by Highways England.
SSSI	Site of Special Scientific Interest: A conservation designation denoting an area of particular ecological or geological importance.
SuDS	A sustainable drainage system designed to reduce the potential impact of new and existing developments with respect to surface water drainage discharges.
SWMP	Surface Water Management Plan: Plan to provide sufficient information to support the development of an agreed strategic approach to the management of surface water flood risk within a given geographical area by ensuring the most sustainable measures are identified.
TAG	Transport Analysis Guidance: national guidance document produced by the Department for Transport.
TAR	HHJV's Technical Appraisal Report of the Lower Thames Crossing.
TBM	Tunnel boring machine, machine used to excavate tunnels with a circular cross section.
TDSCG	Tunnel Design and Safety Consultation Group: formed to ensure effective design, construction and operation within the context of safety.
TE2100	EA's Thames Estuary 2100 project (formed November 2012) to develop a comprehensive action plan to manage flood risk for the Tidal Thames from Teddington in West London, through to Sheerness and Shoeburyness in Kent and Essex.
TEE	Transport Economic Efficiency (economic efficiency of the transport system)
TfL	Transport for London: created in 2000, the integrated body responsible for London's transport system.
TM	Highways England's Traffic Management (directorate)
TMC	Traffic Management Cell
TRADS	Traffic Flow *Data* System (holds information on traffic flows at sites on the network)
TRRL	Transport and Road Research Laboratory (now TRL Ltd): a fully independent private company offering a transport consultancy and research service to the public and private sector. Originally established in 1933 by the UK Government as the Road Research Laboratory (RRL), it was privatised in 1996.
TTMS	Temporary Traffic Management Signs
TUBA	Transport Users Benefit Appraisal (DfT economic appraisal software tool)
UPS	Uninterruptible power supply
Urban All Purpose	A road in an urban area designed for all types of traffic in accordance to the relevant DMRB Standards.
V/C	Volume over Capacity (volume/capacity)
VMS	Variable Message Sign, typically mounted on a portal gantry.

VMSL	Variable Mandatory Speed Limits
Vopak	Royal Vopak N.V. is a Dutch company that stores and handles various oil and natural gas-related products.
Vortex separator/ device	A vortex separator is a device for effective removal of sediment, litter and oil from surface water runoff.
vpd	Vehicles per day
WASHMS	Wind and Structural Health Monitoring System: the process of implementing a damage detection and characterisation strategy for engineering structures.
WB	westbound
WEBs	Wider economic benefits
WebTAG	Department for Transport's web-based multi-modal guidance on appraising transport projects and proposals.
WFD	Water Framework Directive: A European Community Directive (2000/60/EC) of the European Parliament and council designed to integrate the way water bodies are managed across Europe.
WI	Wider Impacts, land use-related economic consequences of transport interventions, not directly related to impacts on users of the transport network, such as increased productivity.
Without Scheme/ With Scheme	Without Scheme: The scenario where government takes the minimum amount of action necessary and is used as a benchmark in the appraisal of options. With Scheme: An option that provides enhanced services by comparison to the benchmark Without Scheme scenario.
WSL - Western Southern Link	The Western Southern Link (WSL) is an alternative for shortlist Routes 2, 3 and 4 to the south of the River Thames. The route would connect into the A2 to the east of Gravesend and would go to the west of Thong and Shorne and east of Chalk towards Church Lane and Lower Higham Road. This route could connect into any of the Routes 2, 3 and 4 north of the river utilising all of the crossing options for these route options.

12 Appendices

	Title
Appendix 4.1	Key Departures
Appendix 4.2	Geotechnical Drawings
Appendix 4.3	Major Utilities Affected
Appendix 4.4	Affected Property
Appendix 4.5	Hydrodynamics Appraisal
Appendix 4.6	Basis of Estimate Report
Appendix 4.7	Provision of a tunnel emergency lane at Location C

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The Pre-Consultation Scheme Assessment Report details the assessment of options leading up to consultation. A final Scheme Assessment Report will be published post consultation.