Lower Thames Crossing

9.73 Tunnel Depth Report

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1 Executive summary

1.1.1 The Port of London Authority (PLA) have raised a number of matters relating to the depth of the tunnel and the restrictions in the river, with a focus on seeking to ensure that the tunnel would be of sufficient depth to accommodate both current and future river trade and that the tunnel does not compromise the future development of the port or navigation. The Port of Tilbury London Limited have supported the position of the PLA.

1.1.2 It has also been noted by the Applicant and by the PLA that there is an inconsistency regarding the minimum amount of cover above the tunnels reported in the Application Documents.

1.1.3 This document provides clarifications on the tunnel depth, the limits of deviation, and the layer of cover. It sets out that on a precautionary basis considering the existing river depth, the upper limit of deviation, with an allowance for the deepening of the navigable channel and a further allowance for the future installation of scour protection, there would be a level of cover at the minimum point of 0.57 times the tunnel diameter. Note that scour protection is not proposed by the Applicant, but has been considered on a precautionary basis following discussion with the PLA.

1.1.4 The report sets out the relevant assessments and confirms that, with a minimum level of cover of 0.57 times the tunnel diameter, the road tunnels would remain stable and that the environmental assessments remain valid.

1.1.5 The report provides a further update on article 33 of the draft DCO [**REP2-004**], which sets out the rights to acquire subsoil, and provides an alternative drafting relating to the datum used for the River Thames that is being considered to address potential uncertainties that could arise from the current drafting.

2 Introduction

2.1 Background

Signposting relevant parts of the application

2.1.1 The A122 Lower Thames Crossing (the Project) includes two tunnels under the River Thames, which provide for the new road. These tunnels will be constructed in accordance with the requirements set out within the draft Development Consent Order (DCO) (resubmitted at D3) and the associated controls, and restrictions will be placed onto the river in proximity to the tunnel. Key elements of the application include (but are not limited to):

a. The draft DCO [**REP2-004**]:

   i. article 6(1)(c) relating to limits of deviation

   ii. article 33 relating to the acquisition of subsoil

   iii. article 48 relating to protection of the tunnel area

   iv. Schedule 10 – Land in which only subsoil or new rights in and above subsoil and surface may be acquired

   v. Schedule 14 – Protective Provisions, Part 8 – For the Protection of the Port of London Authority

b. River Restrictions Plans [**REP1-041**]

c. Tunnel Limits of Deviation Plans [**APP-046**]

d. Statement of Reasons [**REP1-049**]:

   i. Section 5.4 sets out the tunnel zone of protection and exclusion zone, the proposals to acquire the subsoil within which the tunnels would lie and the proposals to acquire rights and impose restrictive covenants in the area identified as the zone of protection

   ii. Table 3 of Statement of Reasons Annex A sets out the purpose for which rights are required, on a plot by plot basis

e. Book of Reference [**REP1-053**]

f. Land Plans (Volume B) (Sheets 1 to 20) [**REP1-009**]: sheets 15 and 16

2.1.2 Under the River Thames, the tunnelling activity is a subsurface activity, with no impact on the riverbed, although there may be a need for geotechnical investigations to take place prior to the tunnelling. Nevertheless, potential noise impacts from the tunnel boring machine on marine life have been considered as reported in Environmental Statement (ES) Chapter 9: Marine Biodiversity [**APP-147**] supported by analysis reported in ES Appendix 9.1: Assessment of Ground-Borne Noise and Vibration, and Underwater Noise from the Tunnel Boring Machine at Marine Receptors [**APP-420**]. A clarification to the wording of this assessment was provided in the ES Addendum [**REP2-040**].

2.1.3 It has been noted by the Applicant and by the Port of London Authority (PLA) that there is an inconsistency regarding the minimum amount of cover above the tunnels reported in the Application Documents, as follows:

a. Plate 5.1 of the Statement of Reasons indicates an exclusion zone of 0.7 times the tunnel diameter, and a zone of protection above this implying the tunnel is at some depth greater than 0.7 times the tunnel diameter.

b. Table 3.15 of ES Chapter 3: Assessment of Reasonable Alternatives [**APP-141**] indicates that the minimum cover to the tunnel under the River Thames was reduced to 1.0 times the outer diameter of the tunnel.

c. The wording of the ES Chapter 9: Marine Biodiversity [**APP-147**] indicated a layer of cover of at least 0.9 times the tunnel diameter, before this was amended by the ES Addendum [**REP2-040**].

Matters raised in engagement

2.1.4 The PLA have raised a number of matters relating to the depth of the tunnel and the restrictions in the river, with a focus on seeking to ensure that the tunnel would be of sufficient depth to accommodate both current and future river trade and that the tunnel does not compromise the future development of the port or navigation. The Port of Tilbury London Limited have supported the position of the PLA.

2.1.5 Particular issues raised by the PLA are set out in the Statement of Common Ground between National Highways and the Port of London Authority [**APP-100**], including the following:

a. Item 2.1.12 – Article 6 - Limits of deviation (DCO)

b. Item 2.1.31 – Compulsory Acquisition powers in favour of National Highways

c. Item 2.1.34 – Route alignment, tunnel depth and tunnel protection zones

d. Item 2.1.40 -– Scour Protection

e. Item 2.1.41 – Works within the river

2.1.6 Further information has been provided by the PLA in their Relevant Representation [**RR-0862**] and their oral and written submissions into the Examination.

2.1.7 A critical matter raised by the PLA has been the potential that they may at some point in the future seek to deepen the navigable channel. Such an activity would result in a change in the level of the riverbed, and as such there is a level of uncertainty over the level of cover over the tunnel during construction and operation. The potential for this dredging to take place prior to construction of the tunnel has increased as a result of the two year rephase announced in the Written Ministerial Statement of 9 March 2023 (UK Parliament, 2023).

2.1.8 The PLA have raised concerns that the Lower Thames Crossing tunnel, when accounting for the restrictions placed on activities around it, would result in an increase in the requirements that would have to be met by PLA if they were to increase the depth of the navigable channel, and that these requirements could be such that it would not be possible to dredge, or that such dredging would impact on the ability of the Applicant to deliver the Project:

a. If the increase in the depth of the navigable channel were to take place after construction of the Project:

   i. The PLA are concerned that a deeper navigable channel would reduce cover over the tunnel, resulting in instability (flotation) of the tunnel, thereby presenting a safety risk that would prevent an increase in the depth of the navigable channel.

   ii. The PLA are concerned that if in the future there were to be a need for scour protection, the installation of such scour protection would lead to a reduction in the depth of the navigable channel. It should be noted that the Applicant considers that no such scour protection is needed and is not seeking consent for scour protection, but the PLA seek reassurance that scour protection could be implemented at some future date on a precautionary basis, considering the changeable nature of the river.

b. If the increase in the depth of the navigable channel were to take place before construction of the Project:

   i. The PLA seek assurance that the rights over land sought by the Applicant remain correct, considering the change in the riverbed level.

   ii. The PLA seek assurance that the assessments of impacts remain valid, and that there would not be new or materially different environmental effects that would prevent the implementation of the Project.

   iii. The PLA are concerned that a deeper navigable channel would reduce cover over the tunnel, resulting in instability (flotation) of the tunnel.

2.2 Purpose of this report

2.2.1 This report has been prepared to address the following concerns:

a. Address the inconsistencies in the level of cover throughout the DCO application

b. Address the concerns of the PLA

c. Explain modifications to the drafting of the draft DCO that are being considered to address the concerns of the PLA

3 Depth of the tunnel

3.1.1 The tunnel reference design is shown on the Tunnel Limits of Deviation Plans [**APP-046**]. These plans also show the vertical upwards limit (limit of deviation (LOD)).

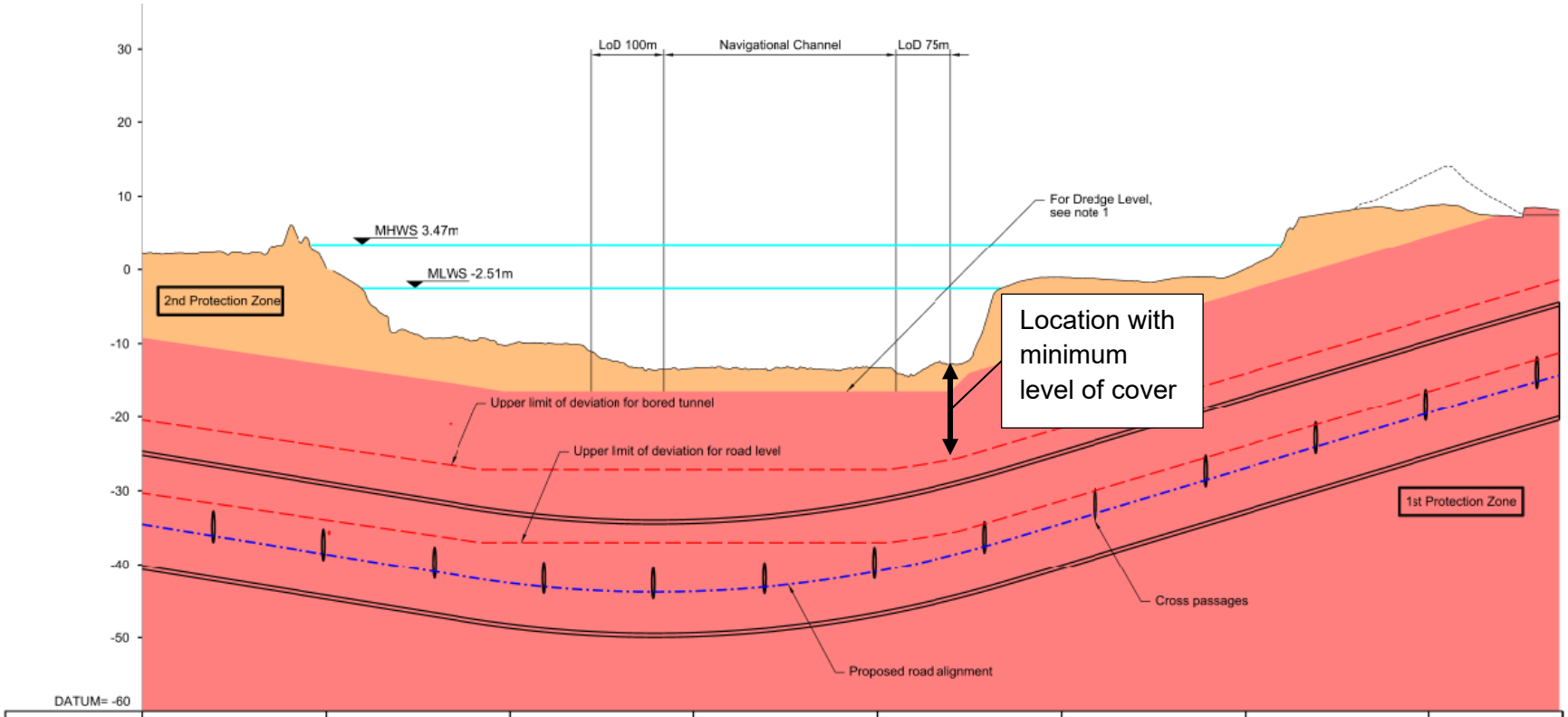
3.1.2 The depth of the tunnel varies along the cross-section of the river, as both the level of the riverbed changes and the tunnel depth changes relative to a fixed datum.

3.1.3 The level of cover over the tunnel is at a minimum on the northern edge of the navigable channel as shown in Plate 3.1.

3.1.4 At this point in the river channel, the level of cover in different scenarios is as set out in Table 3.1. These scenarios are each considered in the flotation assessment included as Appendix A.

3.1.5 In the most precautionary scenario (i.e. where the level of cover is at the minimum), characterised in Table 3.1 as CS6, the tunnel is constructed at the highest level allowed by the LOD while the riverbed is at its lowest level, allowing both for the lowering of the riverbed level to -16.12m above ordnance datum (AOD) by the PLA, and a further temporary reduction in level of 0.5m for the installation of scour protection. In this scenario the level of cover over the tunnel would be 9.1m, or 0.57 times the tunnel diameter (0.57D).

Plate 3.1 Cross-section of river showing reference design, LOD and protection zones



GROUND LEVELS	2.2	0.4	-10.1	-13.3	-13.3	-1.1	0.1	8.7
UPPER LIMIT OF DEVIATION FOR ROAD LEVEL	-30.3	-33.9	-37.0	-37.0	-37.0	-31.3	-23.9	-16.5
PROPOSED ROAD LEVELS	-34.5	-38.6	-42.6	-43.7	-40.9	-34.4	-26.9	-19.4
CHAINAGE	4+250	4+500	4+750	5+000	5+250	5+500	5+750	6+000

LONGITUDINAL SECTION

Table 3.1 Levels of cover

Section	Scenario	Description	Riverbed level	Level of cover at minimum cover location
CS1	Reference design	The case is the baseline, current alignment and assumed riverbed level.	-12.70m AOD (-9.6m CD)	15.9m (0.99D)
CS2	Future dredge/future riverbed level	Agreed dredge level, including over dredge	-16.12m AOD (-13.0m CD)	12.6m (0.79D)
CS3	Theoretical lowest riverbed level	Dredged level with further riverbed lowering to accommodate scour protection	-16.62m AOD (-13.5m CD)	12.1m (0.75D)
CS4	Maximum LOD and current riverbed level	Tunnel crown at the highest level permissible (top LOD) and assumed current riverbed level.	-12.70m AOD (-9.6m CD)	13.0m (0.81D)
CS5	Maximum LOD and agreed future dredge/ future riverbed level	Tunnel crown at the highest level permissible (top LOD) and riverbed at agreed dredge level, including over dredge	-16.12m AOD (-13.0m CD)	9.6m (0.6D)
CS6	Maximum LOD and theoretical lowest riverbed level	Tunnel crown at the highest level permissible (top LOD) and riverbed at dredged level with further riverbed lowering to accommodate scour protection	-16.62m AOD (-13.5m CD)	9.1m (0.57D)

4 Implications on assessments

The implications of a potential level of cover over the tunnel of 0.57D have been considered for each identified area of concern.

4.1 Flotation

4.1.1 The risk of flotation of the tunnel has been considered, and it is concluded that the tunnel is stable for all scenarios, including the current riverbed level, the prospective future riverbed level agreed with the PLA, and for a precautionary scenario where additional dredging is required to install scour protection.

4.1.2 The analysis setting out this assessment is included as Appendix A.

4.2 Assessment of reasonable alternatives

4.2.1 Table 3.15 of ES Chapter 3: Assessment of Reasonable Alternatives [**APP-141**] indicates that the minimum cover to the tunnel under the River Thames was reduced to 1.0 times the outer diameter of the tunnel. This assessment demonstrates alternatives considered, and is unaffected by a different level of cover over the tunnel.

4.2.2 The Applicant does not consider it necessary to amend or update the relevant Application Document.

4.3 Marine biodiversity

4.3.1 The wording of ES Chapter 9: Marine Biodiversity [**APP-147**] indicated a layer of cover of at least 0.9 times the tunnel diameter, before this was amended by the ES Addendum [**REP2-040**].

4.3.2 A review has been completed of the analysis reported in ES Appendix 9.1: Assessment of Ground-Borne Noise and Vibration, and Underwater Noise from the Tunnel Boring Machine at Marine Receptors [**APP-420**]. This review concluded that a reduction in the level of cover to 0.57D would not result in any materially new or materially different impacts and therefore would not change the conclusions of the assessment set out in ES Chapter 9: Marine Biodiversity [**APP-147**].

4.3.3 The Applicant considers that the amendment made by the ES Addendum [**REP2-040**] is appropriate to address this matter.

5 Implications on the draft DCO

5.1 Current drafting

5.1.1 Article 33 of the draft DCO [REP2-004] sets out the rights to acquire subsoil. Extracts from the drafting are provided below:

'***Acquisition of subsoil or airspace only***

33.—(1) The undertaker may acquire compulsorily so much of, or such rights in, the subsoil of or of the airspace over the land referred to in paragraph (1) of article 25 (compulsory acquisition of land) as may be required for any purpose for which that land may be acquired under that provision instead of acquiring the whole of the land.

[…]

(6) References in paragraph (2)(a) to subsoil are references to the subsoil lying at and below the depths specified in column (2) of Schedule 10 beneath the level of the surface of the land, and references to the remaining subsoil in paragraph (2)(b) are references to the part of the subsoil lying above the shallowest part of the subsoil acquired under paragraph (2)(a) but below the level of the surface of the land.

(7) For the purposes of paragraph (6) "the level of the surface of the land" means—

(a) in the case of any land on which a building is erected, the level of the surface of the ground adjoining the building;

(b) in the case of a river, dock, canal, navigation, watercourse or other water area, the level of the surface of the ground covered by water; or

(c) in any other case, ground surface level,

at the time of this Order coming into force.'

5.2 Proposed amendments to the draft DCO

5.2.1 The Applicant acknowledges the position of the PLA, that if the depth of the navigable channel were to change prior to the DCO coming into force, there would be a resultant impact on the ability to acquire subsoil, and that this could lead to the Applicant being unable to acquire subsoil at the level required.

5.2.2 In addition, the Applicant recognises that as the level of the riverbed varies across a land plot, the PLA could consider there could be ambiguity over the relevant depth to be considered when determining the acquisition of subsoil. For the avoidance of doubt, the Applicant considered the average level of the riverbed across the plot as a datum for that plot when determining the depth of subsoil set out in Schedule 10, and set the upper level of the subsoil to be required at the highest elevation of the upper LOD for the tunnel within that plot.

5.2.3 In order to provide the PLA with further certainty and assurance, the Applicant is currently considering redrafting this aspect of the draft DCO.

5.2.4 The Applicant is reviewing a modification to article 33(7) to fix the datum for determining the depth of subsoil under the River Thames as Ordnance Datum Newlyn (a change from riverbed level). This amendment allows for better clarity over the depth of subsoil to be required, regardless of the variability of the riverbed level across the plot, and certainty that any changes to the riverbed level in advance of the DCO coming into force will not result in changes to the rights to acquire subsoil.

5.2.5 The proposed redrafted article 33(7) would be as follows:

'*(7) For the purposes of paragraph (6) and Schedule 10 "the level of the surface of the land" means−*

(a) in the case of any land on which a building is erected, the level of the surface of the ground adjoining the building;

(b) in the case of a river (except where paragraph (c) applies), dock, canal, navigation, watercourse or other water area, the level of the surface of the ground covered by water;

(c) in the case of plots 15-10, 15-11, 15-12, 16-42, and 16-43, the level of Ordnance Datum Newlyn;

(d) in any other case, ground surface level,

at the time of this Order coming into force.'

5.2.6 The Applicant is currently engaging with the PLA on this drafting, as well as other parties identified in the Book of Reference [**REP1-053**] that have interests on the relevant plots.

5.2.7 As a consequence of this amendment, the Applicant will need to update column 2 of Schedule 10 of the draft DCO to reflect the change in datum, with respect to plots 15-10, 15-11, 15-12, 16-42, and 16-43.

5.3 Other provisions of the draft DCO

5.3.1 Paragraph 99(1) of Schedule 14 (the Protective Provisions for the PLA) contains a requirement for the tunnels to be constructed and operated in accordance with the depths agreed with the PLA. These depths take precedence over the LOD, and must always be adhered to. Prior to the commencement of the tunnelling works, the PLA's protective provisions would require a submission of details confirming this design requirement is met. The PLA also has a robust set of protective provisions which requires approvals in connection with "specified works" which is defined as :

'*any part of the authorised development (which for this purpose includes the removal of any part of the authorised development), which—*

(a) is, may be, or takes place in, on, under or over the surface of land below the level of mean high water forming part of the river Thames; or

(b) may affect the river Thames or any function of the PLA'

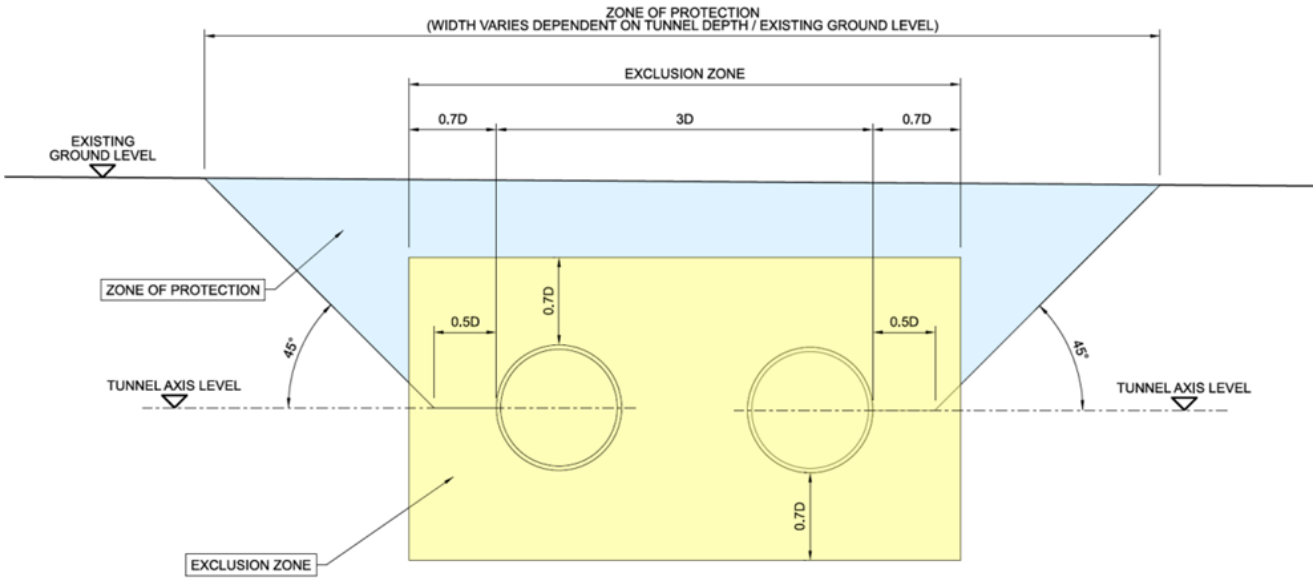
5.3.2 The PLA, at Deadline 1, requested a modification to the Tunnel Limits of Deviation Plans [**APP-046**]. The Applicant does not consider this necessary given the LOD take effect subject to the agreed depths, and the flexibility (which could be met without affecting those depths) is required. In particular, the Applicant notes that there may be changes to construction methodology or design which would enable the utilisation of the LOD without affecting the agreed and legally binding tunnelling depths.

6 Implications on Statement of Reasons

6.1 Basis of the protection zone

6.1.1 Section 5.4 of the Statement of Reasons [REP1-049] sets out the basis for the development of the protection zones set out in the River Restrictions Plan [REP1-041]. The basis is illustrated by Plate 6.1, which is reproduced below.

Plate 6.1 Illustrative cross-section showing the zone of protection and exclusion zone



6.1.2 The Applicant acknowledges that at certain points along the tunnel profile, notably the point with minimum level of cover identified in Plate 3.1, the level of cover will be less than the 0.7D set out as the basis for the first protection zone (the exclusion zone) and that in certain locations, in the event that the riverbed is lowered, there may not be a second protection zone. The Applicant is satisfied that, considering the flotation analysis referenced in Section 4.1, and the nature of the geology in this location, that the protections and controls set out in the River Restrictions Plan [REP1-041] are robust and sufficient.

6.1.3 As the plate within the Statement of Reasons is illustrative and does not define the requirements, which are set out in the draft DCO [REP2-004] and secured documents, it is not considered necessary to update this document.

References

UK Parliament (2023). Transport Update: Statement made on 9 March 2023, Statement UIN HCWS625. Accessed August 2023. https://questions-statements.parliament.uk/written-statements/detail/2023-03-09/hcws625.

Glossary

Term	Abbreviation	Explanation
A122		The new A122 trunk road to be constructed as part of the Lower Thames Crossing project, including links, as defined in Part 2, Schedule 5 (Classification of Roads) in the draft DCO (Application Document 3.1)
A122 Lower Thames Crossing	**Project**	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.
Above ordnance datum	**AOD**	Vertical datum used by the Ordnance Survey as the basis for deriving altitudes on maps.
Application Document		In the context of the Project, a document submitted to the Planning Inspectorate as part of the application for development consent.
Chart Datum	**CD**	Chart Datum is unique to each location and is usually set to be close to the lowest astronomical tide level that can occur under normal meteorological conditions. The Tilbury Chart Datum is -3.12 mAOD
Construction		Activity on and/or offsite required to implement the Project. The construction phase is considered to commence with the first activity on site (e.g. creation of site access), and ends with demobilisation.
Development Consent Order	**DCO**	Means of obtaining permission for developments categorised as Nationally Significant Infrastructure Projects (NSIP) under the Planning Act 2008.
Development Consent Order application	**DCO application**	The Project Application Documents, collectively known as the 'DCO application'.
Environmental Statement	**ES**	A document produced to support an application for development consent that is subject to Environmental Impact Assessment (EIA), which sets out the likely impacts on the environment arising from the proposed development.
Limits of deviation	**LOD**	The tolerances, both laterally and vertically, that any parts of the Project can be constructed from the lines and situations shown on the Works Plans (Application Document 2.6) and the levels shown on the Engineering Section Drawings (Application Document 2.9).
National Highways		A UK government-owned company with responsibility for managing the motorways and major roads in England. Formerly known as Highways England.
metres Above Ordnance Datum	**mAOD**	The Ordnance Datum is the basis for all the land heights that appear on Ordnance Survey maps. It is essentially the mean sea level at Newlyn in Cornwall, and is sometimes called Ordnance Datum Newlyn (ODN).
Operation		Describes the operational phase of a completed development and is considered to commence at the end of the construction phase, after demobilisation.
Ordnance datum		A standardised point representing average (mean) sea level, used by the Ordnance Survey as the basis for measurement of height (altitude) on UK maps, reported as metres 'Above Ordnance Datum'

Term	Abbreviation	Explanation
Port of London Authority	**PLA**	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.
Project road		The new A122 trunk road, the improved A2 trunk road, and the improved M25 and M2 special roads, as defined in Parts 1 and 2, Schedule 5 (Classification of Roads) in the draft DCO (Application Document 3.1).
Project route		The horizontal and vertical alignment taken by the Project road.
South Portal		The South Portal of the Project (southern tunnel entrance) would be located to the south-east of the village of Chalk. Emergency access and vehicle turn-around facilities would be provided at the tunnel portal. The tunnel portal structures would accommodate service buildings for control operations, mechanical and electrical equipment, drainage and maintenance operations.
The tunnel		Proposed 4.25km (2.5 miles) road tunnel beneath the River Thames, comprising two bores, one for northbound traffic and one for southbound traffic. Cross-passages connecting each bore would be provided for emergency incident response and tunnel user evacuation. Tunnel portal structures would accommodate service buildings for control operations, mechanical and electrical equipment, drainage and maintenance operations. Emergency access and vehicle turn-around facilities would also be provided at the tunnel portals.
Tunnel Diameter	**D**	The external diameter of one of the road tunnels, including the concrete segments.

Appendix A - Flotation Sensitivity Check to Satisfy Future Riverbed Levels

A.1 Executive Summary

A.1.1 As part of the discussions with the Port of London Authority (PLA), a flotation sensitivity analysis for the main tunnels was carried out on the future provisions with the reference design. Paragraph 99(1) of the Protective Provisions for the benefit of the PLA (in Schedule 14 of the draft Development Consent Order (DCO) [**REP2-004**]) secures future dredging by the PLA to the potential future dredge level of -12.5m chart datum (CD) (-15.62m above ordnance datum (AOD)) plus the additional allowance for 0.5m over-dredging, which would give a potential future riverbed level of -13.0m CD. The dredging has been agreed across a 475m navigational channel of the River Thames (see the River Restrictions Plan [**REP1-041**]). These depths take precedence over the limits of deviation (LOD) for the tunnels (as shown in the Tunnel Limits of Deviation Plans [**APP-046**]) as per article 6 of the draft DCO.

A.1.2 Sensitivity analyses have been undertaken to assess the stability of a single tunnel bore due to possible flotation at the shallowest level, which is on the northern boundary of the navigational channel adjacent to Diver Shoal (see Annex A). The tunnel has been assessed at both the vertical alignment proposed in the reference design for the DCO and the upper LOD being sought in the DCO. These two tunnel levels were investigated for various riverbed level scenarios:

a. current riverbed level

b. agreed dredge level (-16.12m AOD (-13m CD))

c. agreed dredge level with provision for scour protection -16.62m AOD (-13.5m CD) (if scour protection was needed, 0.5m thick and dredging to allow its insertion). Note: National Highways does not propose scour protection and does not consider it is necessary, but the analysis has been undertaken to provide comfort that the design of the tunnel, within the agreed dredging levels, is feasible.

A.1.3 Each scenario is based on the current tunnel alignment (reference design) as well as the upper LOD. The analysis is intended to demonstrate that the range of potential tunnel alignments under consideration are satisfactory.

A.1.4 The tunnel below the River Thames is situated in Chalk, which has appropriate shear strength, so this flotation analysis considers some shear strength within the soil. The flotation calculations satisfy the stability criteria for all tunnel horizons and riverbed levels. This analysis shows there is no impediment to the agreed dredging levels being secured. If development consent is granted, detailed plans would be submitted to the PLA in connection with the tunnelling works (as per paragraph 98 of Schedule 14 of the draft DCO [**REP2-004**]).

A.2 Introduction

A.2.1 Since the completion of the reference design, the Statement of Common Ground with the Port of London Authority (PLA) [APP-100] has been progressed. National Highways has agreed with the PLA the limits of the navigational channel (75m to the north and 100m to the south) and the right for the PLA to dredge to -12.5m chart datum (CD) (-15.62m AOD). In addition, an allowance for another 0.5m of over-dredging is contained in article 99(1) of Schedule 14 to the draft DCO [**REP2-004**] and reflected in the River Restrictions Plan [**REP1-041**].

A.2.2 Out of these discussions with PLA, it was considered necessary by the PLA to undertake sensitivity analyses to assess the depth to which the riverbed could be lowered and not require scour protection or ballasting. PLA are concerned that post-dredging of the navigational channel and any further natural deepening of the river that might occur, may need additional scour protection to protect the tunnels and this might in turn reduce the available depth for the navigational channel.

A.2.3 Sensitivity checks have been carried out on a single tunnel to assess the current vertical and horizontal alignment and the tunnel limits of deviation (LOD) against a future riverbed level of -13m CD (-12.5m dredge plus 0.5m over-dredge allowance). A likely thickness of scour protection was also calculated and an additional depth allowed for the installation of such protection without impeding the navigational channel.

A.2.4 The scour protection assessment considered previous analysis on the current riverbed stability of the River Thames carried out by National Highways. This analysis had concluded that the riverbed was stable with very little shift in depth. Despite this conclusion, a precautionary sensitivity analysis has also been carried out in relation to a theoretical scour protection by taking the dredged depth of the river and river flow rates from the Tilbury2 DCO application (Port of Tilbury London Limited , 2017) and calculating the required particle size of scour protection and the required thickness. This was calculated to be 0.5m thick with a D_{n50} grading of 0.034m.

A.2.5 The LOD have been included in the DCO to allow flexibility to optimise the detailed design and to allow for construction tolerances. This enables the detailed designer to ensure that the safest, most sustainable, and lowest carbon solution can be delivered. Considerations during detailed design will include both the construction and the long-term operation of the asset, which is designed with a 120-year design life. The detailed design will also consider how the vertical alignment would influence vehicle braking (risk of fire, brake failure), the amount of climbing on exiting (reducing fuel and air quality impacts), and also construction considerations such as minimising the requirements for hyperbaric working. In addition to these factors, any solution would also be required to comply with all aspects of the DCO, including the agreed dredging levels.

A.2.6 The PLA continues to request a modification to the Tunnel Limits of Deviation Plans [**APP-046**]. The Applicant does not consider this necessary given the LOD take effect subject to the agreed depths, and the flexibility (which could be met without affecting those depths) is required. In particular, the Applicant notes that there may be changes to construction methodology or design which would enable the utilisation of the LOD without affecting the agreed and legally binding tunnelling depths. This protection is further reinforced by the Protective Provisions for the PLA in Schedule 14 to the draft DCO [**REP2-004**], which require the PLA's approval in writing before the undertaker can begin construction of any specified work.

A.3 Flotation assessment

Analysis

A.3.1 The flotation check was carried out at one section at the northern edge of the navigational channel LOD near the toe of Diver Shoal, see Plate A.1 (extract) and Annex A (full drawing section). This location was selected as it is where flotation risk is likely to be the greatest. The analysis is therefore necessarily based on a reasonable worst-case scenario. Three riverbed levels were used for the assessment. Six tunnel cross-sections were analysed and are detailed in Table A.1.

Plate A.1 Assessed tunnel section

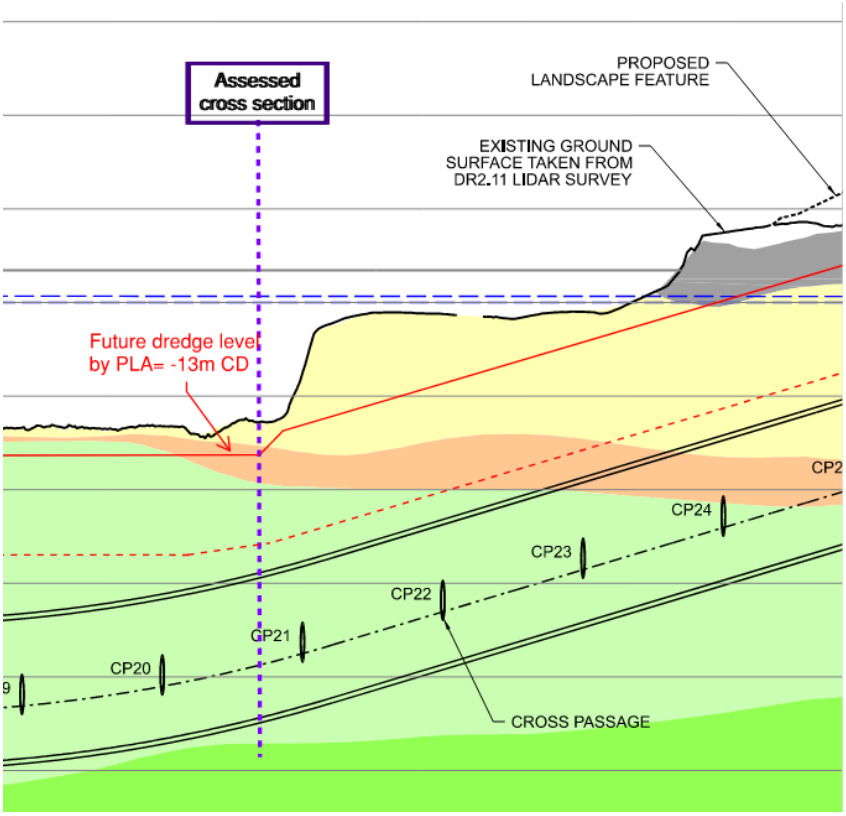


Table A.1 Analysis sections considered for flotation assessment

Analysis Section No.	Section	Riverbed level	Description
CS1	Reference design	-12.70m AOD (-9.6m CD)	The case is the baseline, current alignment and assumed riverbed level.
CS2	Reference design and agreed future dredge/future riverbed level	-16.12m AOD (-13.0m CD)	Agreed dredge level, including over dredge
CS3	Reference design and theoretical lowest riverbed level	-16.62m AOD (-13.5m CD)	Dredged level with further riverbed lowering that requires scour protection
CS4	Maximum upward LOD and current riverbed level	-12.70m AOD (-9.6m CD)	Tunnel crown at the highest level permissible (upward LOD) and assumed current riverbed level.
CS5	Maximum upward LOD and agreed future dredge/future riverbed level	-16.12m AOD (-13.0m CD)	Tunnel crown at the highest level permissible (upward LOD) and riverbed at agreed dredge level, including over dredge
CS6	Maximum upward LOD and theoretical lowest riverbed level	-16.62m AOD (-13.5m CD)	Tunnel crown at the highest level permissible (upward LOD) and riverbed at dredged level with further riverbed lowering that requires scour protection

A.3.2 For the analyses, lower bound values for the soil properties were used from the Project boreholes in the region of the analysed section. The selection of lower bound values has provided a conservative basis for the design at this stage of the Project and optimisation could occur at detailed design using median values. The analysis is therefore a reasonable worst-case scenario, and which may be refined in detailed design.

A.3.3 The tunnel and ground levels (for the riverbed) are shown below in Table A.2.

Table A.2 Section levels

Analysis Section No.	Cover (m)	Ratio of cover to diameter	Riverbed level (m AOD)	Tunnel Axis (m AOD)	Groundwater level (m AOD)
CS1	15.9	0.99D	-12.70	-36.7	6.83
CS2	12.6	0.79D	-16.12	-36.7	6.83
CS3	12.1	0.75D	-16.62	-36.7	6.83
CS4	13.0	0.81D	-12.70	-33.7	6.83
CS5	9.6	0.60D	-16.12	-33.7	6.83
CS6	9.1	0.57D	-16.62	-33.7	6.83

A.3.4 For CS3, a high-level study was undertaken to determine the likely required thickness for scour protection, if required. This used the river channel flow speeds from the Tilbury2 DCO application (Port of Tilbury London Limited, 2017) and calculating the required particle size of scour protection and the required thickness. This was calculated to be 0.5m thick with a D_{n50} grading of 0.034m.

A.4 Methodology

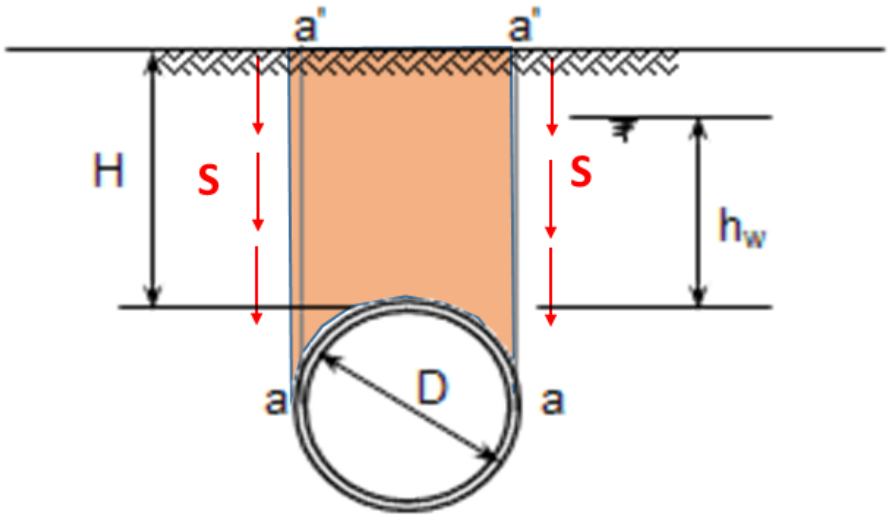
A.4.1 Table A.1 and Plate A.2 above outline the various analysis sections considered. Within each analysis section, the following assessments were undertaken.

A.4.2 The tunnel was checked for flotation using Design Codes & Standards BS EN 1997-1:2004+A1:2013 Eurocode 7 Geotechnical design (British Standards Institution, 2013) and NA+A2:2022 to BS EN 1997-1:2004+A1:2013 UK National Annex to Eurocode 7 (British Standards Institution, 2022).

A.4.3 Various design cases can be applied when assessing the stability of a tunnel due to flotation. This analysis has considered the following design case of allowing for shear resistance in the soil column above the tunnel axis.
The design case for no shear was not considered when assessing the tunnels resistance to flotation, because the tunnel's vertical alignment would place it in Chalk below the river. Therefore, discussion regarding compliance to a no shear design case can be considered too conservative.

A.4.4 In addition to the stabilising soil forces of the soil column and tunnel lining, full shear along the vertical boundary is taken into account in the design case. The average level of shear resistance along the vertical planes was taken as a conservative value for the geology above the tunnel axis. The case also considers either the effects of EC7 material partial factors in calculating the resistance or a favourable partial factor on the effect of the resistance using unfactored parameters.

Plate A.2 Shear design case



A.4.5 The flotation assessment also considered the temporary construction stage (i.e., no internal structure). Due to the river setting and the water level being above that of the soil surface, the effect of water level is not critical; however, for simplicity, the long-term flood level (6.83m AOD, 1 in 1,000-year return period) was used.

A.4.6 Due to the assessment looking at potential future scenarios that may affect the stability of the tunnel, only the worst loading cases within the tunnel have been assessed without the benefit of accidental load factors. Again, this shows how this analysis represents a worst-case scenario. Any future changes in riverbed depth are likely to occur after construction, where there would be an additional benefit from the internal structural elements (circa 250-350kN/m), road surfacing and MEICA installed in the tunnel. However, in the tunnel's lifespan, a complete retrofit may be required, and understanding if this would be possible without the need for mitigation methods is useful to provide full flexibility for the tunnel operator.

A.4.7 The calculations are carried out following BS EN 1997-1 (British Standards Institution, 2013).

A.5 Results

A.5.1 The analysis has been undertaken to see the sensitivity of the tunnels to riverbed and tunnel level when utilising lower bound (conservative) soil properties. Table A.3 shows the flotation results for each analysed section when considering an allowance for shear in the soil column above the tunnel (this is reasonable on the basis that a 'no shear' protection is infeasible given the presence of Chalk in the river). At detailed design, the parameters can be optimised, but even utilising these conservative assumptions, the results show the tunnels 'passing' in all scenarios.

Table A.3 Flotation results

Analysis Section No.	Results
CS1	Pass
CS2	Pass
CS3	Pass
CS4	Pass
CS5	Pass
CS6	Pass

A.6 Discussion

A.6.1 Resistance against flotation passes for all three riverbed levels when shear is accounted for in resisting uplift, for both the tunnel reference design and the upper LOD alignments.

A.6.2 When checking the tunnel alignment using the Project's maximum LOD with the three riverbed levels, the resistance against flotation is unsurprisingly lower. For cases where shear is allowed for, the scenario passes.

A.6.3 For all load cases, the lower bound value for bulk unit weight was considered, and permanent load factors were used. These assessments are therefore considered conservative, with the addition that no internal structural weight was considered for any of the load cases. For all scenarios, but particularly the dredged navigational channel (CS2) scenario and additional riverbed lowering (CS3), the inclusion of 250kPa for the internal structure based on the reference design would provide a significant increase beneficial loading to prevent flotation.

A.6.4 Given the time spans of construction in relation to when a future deeper channel might be dredged, it can be assumed that for CS2, CS3, CS5 and CS6 the internal structures could be utilised as a beneficial load at detailed design. This will require confirmation at the detailed design stage and prior to construction through consultation with the PLA as the baseline may change.

A.6.5 Additionally, it should be noted that for the riverbed to lower to the level in CS3 and CS6 (-16.62m AOD) it would require the erosion of the River Terrace Deposits at the point of lowest tunnel cover (Chalk elsewhere). Given the current flow rates of the river and stability of the Alluvium deposits, this would be considered unlikely to occur and, hence, levels used for CS3 and CS6 are conservative.

A.7 Conclusion

A.7.1 From the assessment above it can be concluded that, based on the reference design tunnel alignment, the stability of the tunnel can be satisfied for both the agreed future dredge levels, and there is adequate cover to allow for scour protection without impacting the future dredge levels across the width of the navigational channel.

A.7.2 The assessment also demonstrates, with conservative assumptions, that valid design solutions exist within the full range of the LODs in the draft DCO [**REP2-004**]. The proposed final alignment will be within the range of the LODs and will require thorough analysis at the detailed design stage to confirm that it can be safely constructed and maintained and does not contradict the requirements of paragraph 99(1) in Part 8 of Schedule 14 of the draft DCO [**REP2-004**].

References

British Standards Institution (2013). BS EN 1997-1:2004+A1:2013 Eurocode 7. Geotechnical design – General rules.

British Standards Institution (2022). NA+A2:2022 to BS EN 1997-1:2004+A1:2013 UK National Annex to Eurocode 7. Geotechnical design – General rules.

Port of Tilbury London Limited (2017). Proposed Port Terminal at Former Tilbury Power Station, Tilbury2, TR030003, Environmental Statement Appendix 16.D: Hydrodynamic Sediment Modelling. Accessed May 2023. https://infrastructure.planninginspectorate.gov.uk/projects/south-east/tilbury2/?ipcsection=docs&stage=app&filter1=Environmental+Statement.

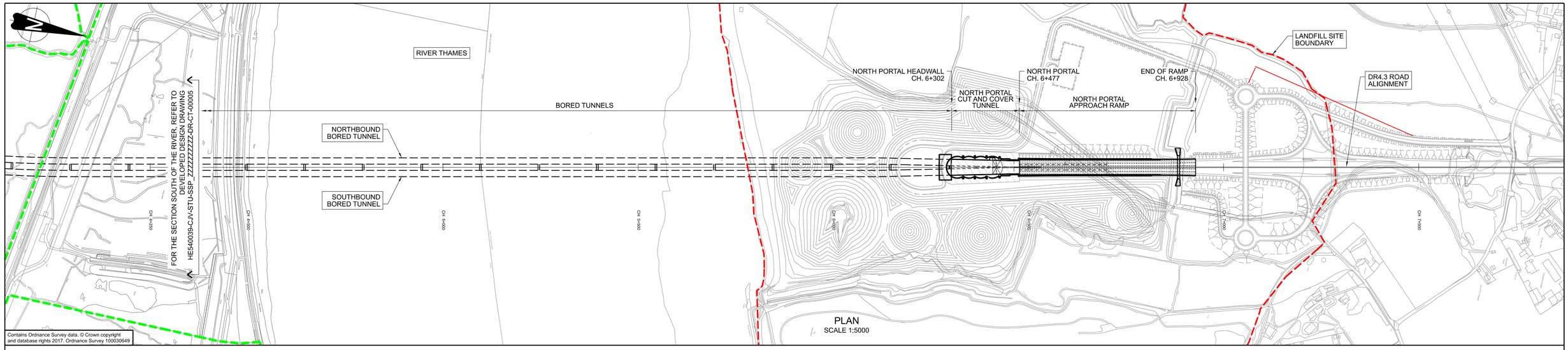
Glossary

Term	Abbreviation	Explanation
A122		The new A122 trunk road to be constructed as part of the Lower Thames Crossing project, including links, as defined in Part 2, Schedule 5 (Classification of Roads) in the draft DCO (Application Document 3.1)
A122 Lower Thames Crossing	**Project**	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.
Above ordnance datum	**AOD**	Vertical datum used by the Ordnance Survey as the basis for deriving altitudes on maps.
Application Document		In the context of the Project, a document submitted to the Planning Inspectorate as part of the application for development consent.
Chart Datum	**CD**	Chart Datum is unique to each location and is usually set to be close to the lowest astronomical tide level that can occur under normal meteorological conditions. The Tilbury Chart Datum is -3.12m AOD.
Construction		Activity on and/or offsite required to implement the Project. The construction phase is considered to commence with the first activity on site (e.g. creation of site access), and ends with demobilisation.
Development Consent Order	**DCO**	Means of obtaining permission for developments categorised as Nationally Significant Infrastructure Projects (NSIP) under the Planning Act 2008.
Development Consent Order application	**DCO application**	The Project Application Documents, collectively known as the 'DCO application'.
D_{n50}		D_{n50} is the nominal stone diameter for the median armourstone size for grading (m).
Environmental Statement	**ES**	A document produced to support an application for development consent that is subject to Environmental Impact Assessment (EIA), which sets out the likely impacts on the environment arising from the proposed development.
Limits of deviation	**LOD**	The tolerances, both laterally and vertically, that any parts of the Project can be constructed from the lines and situations shown on the Works Plans (Application Document 2.6) and the levels shown on the Engineering Section Drawings (Application Document 2.9).
National Highways		A UK government-owned company with responsibility for managing the motorways and major roads in England. Formerly known as Highways England.
metres Above Ordnance Datum	**M AOD**	The Ordnance Datum is the basis for all the land heights that appear on Ordnance Survey maps. It is essentially the mean sea level at Newlyn in Cornwall, and is sometimes called Ordnance Datum Newlyn (ODN).
Operation		Describes the operational phase of a completed development and is considered to commence at the end of the construction phase, after demobilisation.
Ordnance datum		A standardised point representing average (mean) sea level, used by the Ordnance Survey as the basis for measurement of height (altitude) on UK maps, reported as metres 'Above Ordnance Datum'

Term	Abbreviation	Explanation
Port of London Authority	**PLA**	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.
Project road		The new A122 trunk road, the improved A2 trunk road, and the improved M25 and M2 special roads, as defined in Parts 1 and 2, Schedule 5 (Classification of Roads) in the draft DCO (Application Document 3.1).
Project route		The horizontal and vertical alignment taken by the Project road.
The tunnel		Proposed 4.25km (2.5 miles) road tunnel beneath the River Thames, comprising two bores, one for northbound traffic and one for southbound traffic. Cross-passages connecting each bore would be provided for emergency incident response and tunnel user evacuation. Tunnel portal structures would accommodate service buildings for control operations, mechanical and electrical equipment, drainage and maintenance operations. Emergency access and vehicle turn-around facilities would also be provided at the tunnel portals.
Tunnel Diameter	**D**	The external diameter of one of the road tunnels, including the concrete segments.

Annexes

Annex A Tunnel Profile and Geological Section



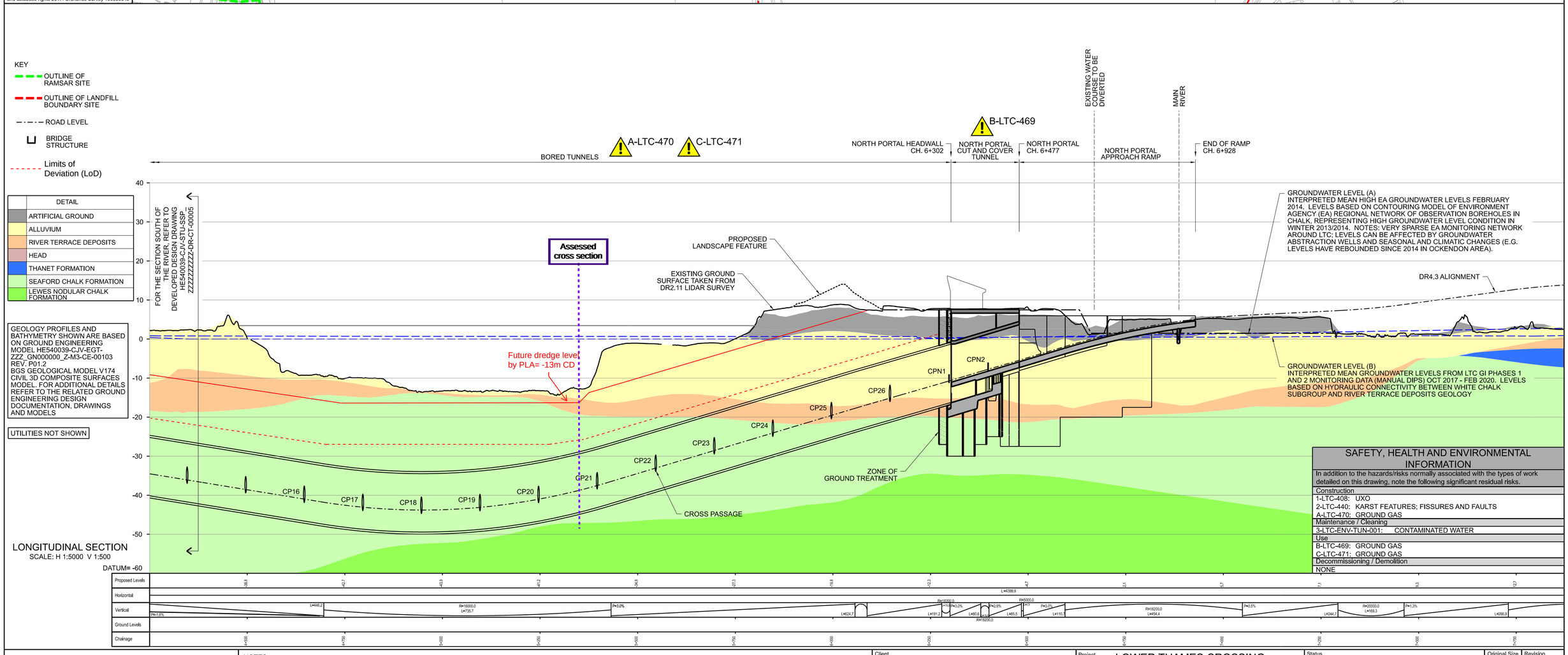
PLAN
SCALE 1:5000

KEY
- OUTLINE OF RAMSAR SITE
- OUTLINE OF LANDFILL BOUNDARY SITE
- ROAD LEVEL
- BRIDGE STRUCTURE
- Limits of Deviation (LoD)

DETAIL
ARTIFICIAL GROUND
ALLUVIUM
RIVER TERRACE DEPOSITS
HEAD
THANET FORMATION
SEAFORD CHALK FORMATION
LEWES NODULAR CHALK FORMATION

GEOLOGY PROFILES AND BATHYMETRY SHOWN ARE BASED ON GROUND ENGINEERING MODEL HE540039-CJV-EGT-ZZZ_GN000000_Z-M3-CE-00103 REV. P01.2
BGS GEOLOGICAL MODEL V174
CIVIL 3D COMPOSITE SURFACES MODEL. FOR ADDITIONAL DETAILS REFER TO THE RELATED GROUND ENGINEERING DESIGN DOCUMENTATION, DRAWINGS AND MODELS

UTILITIES NOT SHOWN



LONGITUDINAL SECTION
SCALE: H 1:5000 V 1:500
DATUM= -60

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In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks.

Construction
1-LTC-408: UXO
2-LTC-440: KARST FEATURES; FISSURES AND FAULTS
A-LTC-470: GROUND GAS

Maintenance / Cleaning
3-LTC-ENV-TUN-001: CONTAMINATED WATER

Use
B-LTC-469: GROUND GAS
C-LTC-471: GROUND GAS

Decommissioning / Demolition
NONE

NOTES:
1. ALL DIMENSIONS IN MILLIMETRES AND ALL LEVELS IN METRES UNLESS SHOWN OTHERWISE.
2. ALL LEVELS ARE IN METRES AND RELATE TO ORDNANCE DATUM UNLESS STATED OTHERWISE.
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4. CHAINAGES AND LEVELS SHOWN ON THE LONGITUDINAL SECTION ARE FOR THE NORTHBOUND ALIGNMENT ONLY. CHAINAGES AND LEVELS FOR THE SOUTHBOUND ALIGNMENT MAY BE DIFFERENT.
5. THIS DRAWING IS FOR INFORMATION ONLY AND DOES NOT FORM PART OF THE CONTRACT.

0 50 100 150 200 250 300 350 400 450 500
SCALE 1:5000 (A1) METRES
SCALE 1:10000 (A3)

0 10 20 30 40 50
SCALE 1:500 (A1)
SCALE 1:1000 (A3) METRES

Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S2	05/04/2022	DESIGN RELEASE 4.3	RT	NP	JBG

Client: highways england

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London EC3A 7DT

Project: LOWER THAMES CROSSING DEVELOPMENT PHASE

Drawing title: MAIN CROSSING PLAN & PROFILE CATERPILLAR OPTION (NORTH)

Status: Fit for Information

Original Size	Revision
A1	P01

Scale AS SHOWN

Drawn	RT	Date - 05/04/2022
Checked	NP	Date - 05/04/2022
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