Lower Thames Crossing

6.1 Environmental Statement Chapter 10 – Geology and Soils

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Lower Thames Crossing

6.1 Environmental Statement
Chapter 10 – Geology and Soils

List of contents

Page number

List of plates

List of tables

Page number

10 Geology and Soils

10.1 Introduction

10.1.1 This chapter presents the assessment of the likely significant effects of the A122 Lower Thames Crossing (the Project) on geology and soils during construction and operation. The assessment includes consideration of impacts to bedrock and superficial geology, soil resources, and the effects of contaminated land on human health and controlled water receptors.

10.1.2 The assessment follows, where practicable, the methodology set out in Design Manual for Roads and Bridges (DMRB) LA 109 Geology and Soils (Highways England, 2019), and relevant, up-to-date guidance including Environment Agency publications as detailed in Section 10.3. Where it has not been possible to follow LA 109 in all aspects, this is clearly set out and the rationale explained.

10.1.3 This chapter is supported by Figures 10.1 to 10.9 (Application Document 6.2), and additional information contained in the following appendices (Application Document 6.3):

a. Appendix 10.1: Geology and Soils Legislation and Policy

b. Appendix 10.2: Stability Report

c. Appendix 10.3: Site Walkover Factual Report

d. Appendix 10.4: Agricultural Land Classification Factual Report

e. Appendix 10.5: Ground Model

f. Appendix 10.6: Preliminary Risk Assessment Report

g. Appendix 10.7: East Tilbury Landfill Risk Assessment

h. Appendix 10.8: Generic Quantitative Risk Assessment Report for the Phase 1 Investigation

i. Appendix 10.9: Generic Quantitative Risk Assessment Report for the Phase 2 Investigation (Annex A–D)

j. Appendix 10.10: Unexploded Ordnance (UXO) Desk Study Report and Risk Assessment

k. Appendix 10.11: Remediation Options Appraisal and Outline Remediation Strategy

10.2 Legislative and policy framework

10.2.1 This assessment has been undertaken in accordance with the relevant legislation and having regard to national and local plans and policies.

10.2.2 Appendix 10.1 sets out how the Applicant has considered and addressed those policies in the NPSs which relate to the assessment of effects considered in this chapter of the Environmental Statement. Policies in the NPSs which relate to decision making in relation to matters of relevance to this topic of the ES are addressed in the Planning Statement (Application Document 7.2).

National policy

10.2.3 Nationally Significant Infrastructure Projects (NSIPs) are determined in accordance with the decision-making framework in the Planning Act 2008 (as amended) and relevant National Policy Statements (NPSs), as well as any other matters that are both important and relevant (which may include the National Planning Policy Framework (NPPF)) (Ministry of Housing, Communities and Local Government, 2021).

10.2.4 The National Policy Statement for National Networks (NPSNN) (Department for Transport, 2014) sets out the Government's policies to deliver NSIPs on the national road and rail networks in England. Four utilities diversions constitute NSIPs in their own right, and therefore the Project would also be assessed against the following energy policy statements:

a. Overarching National Policy Statement for Energy (EN-1) (Department of Energy and Climate Change, 2011a)

b. National Policy Statement for Gas Supply Infrastructure and Gas and Oil Pipelines (EN-4) (Department of Energy and Climate Change, 2011b)

c. National Policy Statement for Electricity Infrastructure (EN-5) (Department of Energy and Climate Change, 2011c)

10.2.5 However, the NPSNN forms the 'case-making' basis for the Project, and the need for nationally significant utilities diversions arises solely from the need for the road element of the Project.

10.2.6 National Highways has taken these policy requirements into account during the development and design of the Project and the preparation of this ES.

10.2.7 The NPPF, published in 2012 and updated in 2021 (Ministry of Housing, Communities and Local Government, 2021), sets out the Government's overarching planning policies. It provides a framework within which locally prepared plans for housing and other development can be produced. The NPPF confirms (in paragraph 5) that it does not set policy for NSIPs, and that relevant policy is to be found within the NPSs, however, the NPPF may contain policy considered important and relevant by the Secretary of State in determining the application.

10.2.8 The NPPF does not contain specific policies for NSIPs. However, the NPPF advises that local authorities' planning policies should take into account NSIPs which are located within their local areas. Paragraph 1.17 of the NPSNN states that the NPS and NPPF are consistent, and paragraph 1.18 explains that the NPPF is an important and relevant consideration, 'but only to the extent relevant to [the] project'.

10.2.9 Appendix 10.1: Geology and Soils Legislation and Policy (Application Document 6.3), lists the planning policies at a national level, including those in the NPSNN, but does not repeat the policy requirements that appear in EN-1, EN-4 and EN-5. Cross-references and individual responses to the relevant sections within the suite of Energy National Policy Statements can be seen in Appendix A of the Planning Statement (Application Document 7.2).

Local policy framework

10.2.10 Consideration has been given to county policies within Kent, Essex, the updated London Plan (for the Greater London Authority) and local policies relating to geology and soils within the following local authorities within the study area: Maidstone, Tonbridge and Malling, Gravesham, Thurrock, Medway, Dartford, Havering, and Brentwood. These are outlined in Appendix 10.1: Geology and Soils Legislation and Policy (Application Document 6.3) and are considered further within the Planning Statement (Application Document 7.2).

10.2.11 Policy documents developed by Kent and Essex County Councils and for the Greater London Authority relating to geology and soils have been considered.

10.3 Assessment methodology

Standards and guidance

10.3.1 The following standards and guidance documents have been used in devising the methodology for data collection and assessment of geology and soils impacts:

a. DMRB LA 109 Geology and Soils (Highways England, 2019)

b. Land Contamination: Risk Management (LCRM) (Environment Agency, 2021) (formerly Contaminated Land Report (CLR) 11)

c. Natural England Technical Information Note TIN049 (Natural England, 2012)

d. Code of Practice for the Sustainable Management of Soils on Construction Sites (Department for Environment, Food and Rural Affairs (Defra), 2009)

e. Good Practice Guide for Handling Soils (Ministry of Agriculture, Fisheries and Food (MAFF), 2000)

f. British Standard (BS) 3882:2015: Specification for topsoil (British Standards Institution, 2015)

Scope of the assessment

10.3.2 The scope of assessment for geology and soils comprises the following elements:

a. Effects on bedrock geology and superficial deposits, including geological designations and sensitive/valuable non-designated features

b. Effects on soil resources

c. Effects from contamination on human health, surface water and groundwater

10.3.3 To demonstrate compliance with the clauses of the NPS and the Scoping Opinion, an assessment on land stability has been undertaken and is presented in Appendix 10.2: Stability Report (Application Document 6.3). The Stability Report has taken a precautionary approach, demonstrating that there are no significant risks related to ground stability and geohazards within the study area and no issues would occur as a result of the Project construction.

10.3.4 It is however noted that since the receipt of the Scoping Opinion, the published standard DMRB LA 109 Geology and Soils (Highways England, 2019) has removed the requirement to assess geotechnical hazards and land stability within the Environmental Statement (ES). These aspects are addressed within the design through the application of the DMRB Standard, CD 622 Managing Geotechnical Risk (Highways England, 2020a).

10.3.5 A programme of field investigation works was undertaken by the Project, and is described later in Section 10.3 under 'Programme of ground investigation'. The data from these and any future investigations would continue to inform the Project ground model. Slope stability assessments have been carried out to inform the design presented in the DCO application. This has confirmed the requirements for retaining features, the earthworks design (for example embankments and cuttings slope angles), structure foundations and ground improvements as described in Chapter 2: Project Description. The validity of this work was confirmed through the data obtained via the ground investigations and therefore this demonstrates that the study area is and would remain stable as part of the development. Therefore, significant effects are unlikely to arise and this assessment has not been carried forward within the ES.

10.3.6 In addition to the requirements set by the NPSNN, it should be noted that certain utility diversions required to deliver the Project would constitute a Nationally Significant Infrastructure Project (NSIP) in their own right when tested against section 16 and section 20 of the Planning Act 2008.

10.3.7 In order to satisfy the requirements of Paragraph 2.23.2 of the National Policy Statement for Gas Supply Infrastructure and Gas and Oil Pipeline (EN-4) (Department of Energy and Climate Change, 2011) an assessment of land stability and ground conditions has been undertaken on the proposed NSIP gas works and is also presented in Appendix 10.2 (Application Document 6.3).

10.3.8 The potential impacts on minerals and mineral safeguarding areas in relation to the construction of the Project are assessed in Chapter 11: Material Assets and Waste. A Mineral Safeguarding Assessment is presented in Appendix 11.2 (Application Document 6.3).

10.3.9 The potential impacts on archaeological deposits in relation to the construction of the Project are assessed in Chapter 6: Cultural Heritage. A Palaeolithic and Quarternary Deposit Model (PQDM) and Desk-based Assessment of Palaeolithic Potential is included in Appendix 6.5 (Application Document 6.3) and a Standalone Palaeolithic Archaeological Assessment and Research Framework is included in Appendix 6.6 (Application Document 6.3).

10.3.10 The potential impacts on geomorphology, notably effects associated with hydromorphology are assessed in Chapter 14: Road Drainage and the Water Environment. The potential impacts on geomorphology in relation to landform are assessed in Chapter 7: Landscape and Visual.

10.3.11 No aspects were scoped out for the assessment on geological receptors.

10.3.12 The effects on Best and Most Versatile (BMV) land are addressed under the construction phase (i.e. the impacts, both temporary and permanent, occur at the time the land is taken). As such, effects on BMV land are not addressed again as part of the operational phase assessment.

10.3.13 This chapter has interrelationships with the following ES chapters: Chapter 5: Air Quality, Chapter 6: Cultural Heritage, Chapter 7: Landscape and Visual, Chapter 8: Terrestrial Biodiversity, Chapter 11: Material Assets and Waste, Chapter 13: Population and Human Health, and Chapter 14: Road Drainage and the Water Environment.

Limits of deviation and Rochdale envelope

10.3.14 The Projects application of the Rochdale Envelope is summarised in Chapter 2: Project Description. The Limits of Deviation (LOD) for the project (defined in the draft DCO (Application Document 3.1)) represent an ‘envelope’ within which the Project would be constructed and have informed the reasonable worst-case approach to assessment for the purposes of this chapter.

Use of the river

10.3.15 Vessel movements on the River Thames are not relevant to the assessment on geology and soils. This is because the assessment is land based and therefore geological and soils resources would not be impacted by vessel movements on the river. Use of the river is therefore excluded from the scope of this chapter.

Scoping Opinion

10.3.16 A Scoping Report (Highways England, 2017) was submitted to the Planning Inspectorate on 02 November 2017, setting out the proposed approach to this EIA. A Scoping Opinion was received from the Secretary of State on 13 December 2017, which included comments on the scope of assessment from the Planning Inspectorate and statutory environmental bodies. These comments have been taken into account in the preparation of this chapter, and a detailed response to the Scoping Opinion is set out in Appendix 4.1: The Inspectorate’s Scoping Opinion and National Highways Response (Application Document 6.3).

Consultation

Project consultation

10.3.17 Statutory Consultation under Section 42 of the Planning Act 2008 was undertaken from 10 October 2018 to 20 December 2018. This provided an opportunity for consultees to comment on the Preliminary Environmental Information Report (PEIR) (Highways England, 2018). A summary of the responses to the Statutory Consultation can be found in the Consultation Report (Application Document 5.1). Consultees comprised prescribed bodies, local authorities, people with an interest in land affected by the Project and local communities.

10.3.18 The Project design continued to be developed, which resulted in changes in the Project. These formed the basis for the Supplementary Consultation, which was undertaken from 29 January 2020 to 2 April 2020. A further Design Refinement Consultation was then undertaken from 14 July 2020 to 12 August 2020.

10.3.19 An additional Community Impacts Consultation was undertaken from 14 July 2021 to 8 September 2021. This sought feedback on the impacts of the Project at a local ward level, as well as the proposed mitigation. Changes to the Project since the design refinement consultation were also presented, along with a summary of how feedback to earlier consultation had shaped the development of the Project.

10.3.20 The Supplementary Consultation, Design Refinement Consultation and Community Impacts Consultation all included information about the environmental impacts associated with the changes presented for consultation. A summary of the responses to these consultation stages can also be found in the Consultation Report (Application Document 5.1).

10.3.21 Prior to the submission of this DCO application, Local Refinement Consultation was held between 12 May 2022 and 20 June 2022. This provided local communities with the opportunity to comment on proposed refinements to the Project.

10.3.22 These consultations all included information about the environmental impacts associated with the refinements presented for consultation. A summary of the responses to these consultation stages can also be found in the Consultation Report (Application Document 5.1).

Stakeholder engagement

10.3.23 In addition to the project consultation set out above, a summary of the stakeholder engagement specific to geology and soils is provided in Table 10.1.

Table 10.1 Stakeholder engagement

Stakeholder	Date of meeting / communication	Summary of discussions
Natural England	July 2017	Meeting to set out and agree approach to baseline data collection (including detailed Agricultural Land Classification (ALC) surveys) and assessment approach.
Natural England	January 2018	Follow up to confirm agreed baseline data collection (including detailed ALC surveys) and assessment approach.
Natural England	13 May 2020	Extent of ALC surveys and results shared with Natural England to provide information on the distribution of land at each grade affected and to explain why some land had not been surveyed and how this has been addressed in the assessment. The approach (a mix of detailed ALC surveys and predictions of ALC grade) was accepted.
Natural England	30 June 2021	The approach to the ALC assessment (both the detailed surveys undertaken and the approach to the predictive mapping to fill gaps where surveys had not been possible) and the results were shared with Natural England. The approach was accepted, and no further clarifications were required by Natural England. In a post-meeting email exchange Natural England reiterated the need for a Soil Resource Survey to inform the development of a soil handling and re-use strategy in line with the published guidance. Pre-construction soil surveys would be undertaken in un-surveyed areas (unless constrained by the presence of contaminated land or potential UXO risk). This has been incorporated as a secured Project commitment GS010 in the Register of Environmental Actions and Commitments (REAC).
Local authorities	June 2019	Request to local authorities for additional/local knowledge environmental information, such as landfill sites, pollution incidents and records of Part 2A sites to enhance the information in the baseline. Information has been received from Thurrock Council and London Borough of Havering and this has been incorporated into the baseline section (Section 10.4) of this chapter. An up-to-date database (2019) from Landmark was used to inform the baseline and therefore presents a robust understanding of the existing conditions.
Gravesham Thurrock Havering Medway Kent County Council Essex County Council	21 and 22 April 2020	A meeting with the local authorities north and south of the River Thames was held to outline the updated assessment standard, DMRB LA 109 Geology and Soils (Highways England, 2019), to be used in assessment and present the preliminary findings of the environmental assessments.

Stakeholder	Date of meeting / communication	Summary of discussions
Thurrock Council	23 August 2021	Technical engagement to discuss comments on geo-environmental appendices.
Essex Field Club	July 2019	Request for more information regarding the Local Geological Sites identified from its website. Response was received from Essex Field Club, confirming that all requested information was held on its website.
Kent Geologists Group	July 2020	Request for information regarding Local Geological Sites within the study area. Response was received from members of the group that the information was held on website and all the local sites are included in the Regionally Important Geological sites (RIGs) information.
Environment Agency	13 June 2018	Meeting to discuss the scope of geo-environmental ground investigation works for the Phase 2 packages. Presentation of identified sources of contamination along the Project route and consultation with Environment Agency subject matter experts on potential sources of contamination.
Environment Agency	11 July 2018	Meeting to discuss the potential risks of ground gas associated with the Project and present proposed intrusive surveys to investigate issues.
Environment Agency	19 July 2019	Meeting to discuss and agree the approach to groundwater modelling and the effects of drawdown on East Tilbury Landfill site at the North Portal. Agreement of model parameters.
Environment Agency	08 April 2020	Meeting to discuss the progress of the Phase 2 ground investigation and an update on the approach to geo-environmental assessments supporting the ES.
Environment Agency	29 April 2020	Meeting to discuss the progress of the ground investigation and the level of information that would be available for inclusion within the ES.
Environment Agency	04 July 2022 13 September 2022	Sharing and acceptance by the Environment Agency of the findings of the technical assessment reviewing the potential pollutant linkages to the East Tilbury Landfill site, which forms Appendix 10.7 (Application Document 6.3).

Study area

10.3.24 The construction and operational study area for geology and soils was based on the standard outlined in DMRB LA 109 Geology and Soils (Highways England, 2019). The study area considered the construction footprint (including compounds and temporary land take), the location of contaminative sources outside the Order Limits which have the potential to migrate as well as the location of on and offsite sensitive receptors (i.e. designated sites) that could be affected by the Project as a result of remobilisation or introduction of contaminants.

10.3.25 The study area for contamination includes the Order Limits and an additional buffer of 250m. This area is considered appropriate for the consideration of historical and current potentially contaminative land uses which could be impacted by, or impact on the Project. This additional buffer is based on professional experience and aligns with established industry guidance within Research and Development Publication 66 (Environment Agency, National House-Building Council and Chartered Institute of Environmental Health, 2008), which states that offsite features within an area up to 250m from the site boundary should typically be considered within the hazard identification stage. Features at greater distance should only be described if they are particularly large or have the potential to affect the land quality at the site or the wider environmental quality. A review of potentially large contaminative land uses beyond the 250m buffer has been undertaken and no such features were identified. The study area is included on all relevant figures (Application Document 6.2, Figure 10.2).

10.3.26 For the nitrogen deposition compensation sites, the study area is also the Order Limits and an additional buffer of 250m.

10.3.27 When considering the impacts on groundwater, the study area comprised the Order Limits plus a 250m buffer, however, where more detailed groundwater assessment was identified a wider study area was required in agreement with the Environment Agency.

10.3.28 In the area of the North Portal, a wider study area of 1km from the Project route was used to take into account the zone of influence from construction activities such as groundwater control/dewatering which could cause contaminants to be remobilised. This study area was appropriate given that this is where the main construction activities would take place (for example, dewatering at the North Portal) and therefore this is the point of influence. This study area enables consideration of potential impacts from tidal variations within the groundwater near to the River Thames which could cause remobilisation of contaminants. A wider study area was not considered necessary for the South Portal as the main construction activities are above the groundwater table. Detailed descriptions of the groundwater model parameters and assumptions are included within the Hydrogeological Risk Assessment (Application Document 6.3, Appendix 14.5).

10.3.29 The groundwater features identified by the assessment of Chapter 14: Road Drainage and the Water Environment are presented in Figure 14.2 (Application Document 6.2).

10.3.30 For soils, land quality (as defined by the ALC grade) and habitats they support, the study area was the land within the Order Limits as the potential impacts are associated with direct temporary or permanent disturbance to the land. This is presented in Figures 10.2, 10.3 and 10.4 (Application Document 6.2). The extent of land at each ALC grade was also put into context in terms of the prevalence of that grade on a regional basis. Likely impacts on soils related to runoff of contamination were addressed as part of the contaminated land study area, described above.

Impact assessment methodology

10.3.31 The assessment follows the general approach described in Chapter 4: EIA Methodology. This section provides topic-specific information regarding the methodology used for establishing the baseline conditions, and the methods used for the construction and operational phase assessments.

Method of establishing baseline conditions

Existing baseline

10.3.32 The existing baseline conditions in relation to geology and soils were established based on a review of existing data sources provided to the Project, stakeholder engagement (Table 10.1) and fieldwork comprising data collection from site walkover surveys and ground investigations. A number of factual and interpretative reports were also used to support the findings of the geology and soils baseline as described below.

Desk-based studies

10.3.33 A desk-based review of the following data sources has been undertaken to establish the baseline conditions across the Project study areas:

a. Preliminary Sources Study Report (PSSR) (Hyder-Halcrow, 2016)

b. Addendum PSSR (Highways England, 2018b)

c. Historical borehole logs and geological maps obtained from the British Geological Survey (BGS) online viewer (BGS, 2022)

d. Historical aerial photography (Lee et al., 2018)

e. Information on important geological sites from Joint Nature Conservation Committee (JNCC) Geological Conservation Review Database (Joint Nature Conservation Committee, 2020), Natural England / Multi Agency Geographic Information for the Countryside (MAGIC) website (Natural England, 2022) and local sites, such as the Essex Field Club (Essex Field Club, 2022) and GeoConservation Kent (GeoConservation Kent, 2022)

f. Aquifer designation maps obtained from the Environment Agency

g. Landfill Data obtained from various sources including the Environment Agency (Application Document 6.3, Appendix 10.6), local landfill operators (for example, Veolia Environmental Services), local authorities and the BGS (information contained in the PSSR (Hyder-Halcrow, 2016)

h. A preliminary geomorphological assessment was undertaken by CH2M February 2018. This comprised a high-level review of desk-based information sources such as historical aerial photographs, LiDAR data and soil/geology/landform maps to identify potential geohazards and adverse ground conditions (CH2M, 2018).

i. Soil Site Reports (National Soil Resources Institute, 2018)

j. Soilscapes (Cranfield University, 2013) and ALC mapping (Natural England from www.magic.defra.gov.uk, accessed June 2021)

k. Information requested and received from London Borough of Havering and Thurrock Council (Table 10.1)

10.3.34 The desk-based information has been used to develop the following supporting documents:

a. Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3)

b. Appendix 10.7: East Tilbury Landfill Risk Assessment (Application Document 6.3)

Fieldwork

10.3.35 Targeted site walkover surveys were conducted between July 2017 and October 2017, and in September 2018. The objectives of the walkover surveys were to gather information on the existing site conditions within the study area and to inform the planning of the ground investigation.

10.3.36 A further walkover survey, to visit the Local Geological Sites identified within the study area was completed in August 2020.

10.3.37 It was not the objective of the site walkovers to visit the entire Project, but to focus on areas of potential interest in relation to geology, soils and potentially contaminated land, as identified by the PSSR (Hyder-Halcrow, 2016) and Addendum PSSR (Highways England, 2018b).

10.3.38 Appendix 10.3: Site Walkover Factual Report (Application Document 6.3) provides a full description of the observations recorded during the different site walkover surveys, along with photographs. The locations are presented in Figure 10.1 (Application Document 6.2). Annex 1 of Appendix 10.3 presents a technical note on the Low Street Pit Local Geological Site, which was visited as part of the August 2020 site survey.

10.3.39 A review of the geology walkover survey study area using Google Earth aerial photography was undertaken in 2021 and 2022 to confirm that the baseline information recorded within Appendix 10.3: Site Walkover Factual Report (Application Document 6.3) remained valid. No significant changes were noted, however a number of sites were re-visited in 2022, where access was permitted, to confirm the current site conditions. These are included within Appendix 10.3 (Application Document 6.3).

10.3.40 Access to conduct the surveys was limited to Public Rights of Way and areas where access had been agreed with third-party landowners. At the request of the landowners, access to and observations of farmland with crops was generally made from the site boundary or existing farm tracks.

Programme of ground investigation

10.3.41 A programme of intrusive ground investigation works was carried out in two phases to help develop the preliminary design and, where data has been available, support the core assessments of the DCO application. Phase 1, which was completed in two parts between September 2017 – February 2018 and September 2018 – January 2019, was focused on the alignment of the tunnel and the areas surrounding the proposed North and South Portals.

10.3.42 Phase 2 of the ground investigation was carried out between July 2019 and October 2020 and included investigations along the whole Project route with a particular focus on the alignment of the road. Phase 2 also included further investigation works in the South and North Portal areas. Long term monitoring (ground gas and groundwater) was also undertaken as part of the Phase 2 works between January 2020 and February 2021.

10.3.43 The Phase 2 ground investigation works were split into the following four packages:

a. Package A covers the area of the route south of the River Thames. This includes the M2/A2/A122 Lower Thames Crossing junction, South Portal and land north of the South Portal to the River Thames.

b. Package B covers the area of the route immediately to the north of the River Thames, around the North Portal and north to the Tilbury and Southend Railway line.

c. Package C covers the area of the route from Tilbury and Southend Railway in East Tilbury, northwards to the A13 junction in Orsett Heath.

d. Package D covers the area of the route from the A13 junction in Orsett Heath to the M25, north of junction 29 in Great Warley.

10.3.44 Both phases of ground investigation included a range of intrusive and non-intrusive investigation, in situ testing, geotechnical and geo-environmental laboratory testing as well as hydrogeological testing.

10.3.45 Within the Package B works area, two constant-rate pumping tests were carried out adjacent to the North Portal location. These included a 30-day duration and a five-day duration test. Contaminant concentrations were monitored in surrounding wells before, during and after each test to observe any changes in concentration.

10.3.46 The Phase 1 and Phase 2 ground investigations are sufficient to develop robust conclusions on the geological environment.

10.3.47 The following supporting technical appendices were informed by data obtained through the ground investigations. Information from these appendices has been summarised in the baseline and used to validate the assessment of effects on receptors. Each document contains further details on the scope of ground investigation including plans of the exploratory holes completed for each package of works:

a. Appendix 10.2: Stability Report (Application Document 6.3)
b. Appendix 10.5: Ground Model (Application Document 6.3)
c. Appendix 10.8: Generic Quantitative Risk Assessment Report for the Phase 1 Investigation (Application Document 6.3)
d. Appendix 10.9: Generic Quantitative Risk Assessment Report for the Phase 2 Investigation (Annex A–D) (Application Document 6.3):
    i. Annex A: Package A
    ii. Annex B: Package B
    iii. Annex C: Package C
    iv. Annex D: Package D

10.3.48 ALC surveys across 566ha were undertaken in 2019 and 2022 in accordance with published guidelines (MAFF, 1988).

10.3.49 It was not possible to undertake surveys across the entire extent of agricultural land within the Order Limits due to constraints relating to the presence/likely presence of contaminated land, the potential risk category of UXO as identified by Appendix 10.10: Unexploded Ordnance (UXO) Desk Study and Risk Assessment, landowner access and delays caused by the COVID-19 pandemic restricting access in 2020 and 2021.

10.3.50 Where surveys were not possible (an area of 993ha) a methodology was agreed with Natural England on 13 May 2020 and reconfirmed on 30 June 2021 to predict the likely ALC grade using the Welsh Government's (2017) Predictive Agricultural Land Classification Map (Wales) Guidance Note and by applying desk-based information (where reliable) to the assessment process as defined by the published guidelines (MAFF, 1988).

10.3.51 For the predictive ALC, the following desk-based information was gathered for locations on a 1ha grid to assess the likely most limiting factor in relation to land grade:

a. Climate
b. Elevation
c. Gradient
d. Flood zone
e. BGS Bedrock (1:50k)
f. BGS Superficial Deposits (1:50k)
g. Soil association and associated characteristics (texture, wetness class and droughtiness)

h. MAFF Provisional (Pre-1988) ALC grade

i. Defra/Natural England 'Likelihood of Best and Most Versatile (BMV) Agricultural Land' (GIS layer available free online http://publications.naturalengland.org.uk/publication/6056482614804480).

10.3.52 The combined information from the detailed surveys and the ALC predictions was used to determine the extent of land at each grade present within the Order Limits. Details of the methodology used are presented in the Agricultural Land Classification Factual Report (Application Document 6.3, Appendix 10.4). The cumulative extent of land grades as mapped within the ALC system excludes the areas taken up with the associated farm infrastructure.

10.3.53 In addition, a soil survey was undertaken at the Low Street Pit Local Wildlife Site to assess the potential for soil materials associated with the acid grassland community to be translocated as part of the mitigation proposed for this site, as set out in Chapter 8: Terrestrial Biodiversity.

Modelling

10.3.54 A Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6) was prepared to identify potential geo-environmental constraints that may affect, or be affected by, the Project. This presents a Conceptual Site Model (CSM) for the Project. The area considered within the CSM was the Order Limits plus a 250m buffer. As detailed in the study area section above, this distance is in line with established industry guidance which states that features within 250m from the site boundary should be considered at the hazard identification stage (Tier 1, as defined below). Annex D of the Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6) presents an assessment for the eight nitrogen deposition compensation sites which have been included within the Order Limits to provide compensation measures to reduce the potential significant effects from nitrogen deposition.

10.3.55 The Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6) summarises information on potential contamination sources obtained from desk-based sources such as historical mapping, aerial photographs, online planning records and records of pollution incidents as well as observations taken during the site walkovers. A full list of information sources is included and the study is presented in Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3). Information on historical and current land uses, transport infrastructure, waste management sites and industrial sites was included. The key findings of the Preliminary Risk Assessment Report have been incorporated into the description of the existing baseline in Section 10.4.

10.3.56 A generic quantitative risk assessment of the Phase 1 and Phase 2 ground investigation data (soil, soil leachate, groundwater, surface water and gas results) was undertaken and the findings were included in Appendix 10.8 Generic Quantitative Risk Assessment Report for the Phase 1 Investigation and Appendix 10.9: Generic Quantitative Risk Assessment Report for the Phase 2 Investigation (Annex A–D) (Application Document 6.3).

10.3.57 Particle track modelling was undertaken to understand how contaminants in groundwater would potentially migrate during the excavation of the North Portal. Modelled scenarios also included a range of technical solutions for groundwater control. Further details on the groundwater model developed for the North Portal area are included in the Hydrogeological Risk Assessment in Appendix 14.5 (Application Document 6.3).

10.3.58 Following the completion of the constant rate pumping tests in Package B, modelling using ConSim (industry standard software) was completed to assess the potential contaminant fate and transport from the East Tilbury Landfill towards the North Portal excavation site during active dewatering. The result of this modelling exercise is included as an appendix within the East Tilbury Landfill Risk Assessment Report in Appendix 10.7 (Application Document 6.3).

Future baseline ('Without Scheme' scenario)

10.3.59 The future baseline was forecast by considering the existing site conditions at the time of the start of construction. The potential for the baseline ground conditions to change prior to construction of the Project is limited. Soil and groundwater contamination are generally historical and, therefore, already present.

10.3.60 There is the potential for climate change to affect soil characteristics, and therefore land grade. This has been assessed based on published climate change scenarios.

10.3.61 New developments in the study area would need to be suitable for its intended use, as set out by the planning regime in the NPPF (Ministry of Housing, Communities and Local Government, 2021). Remediation or mitigation measures would be required as part of this process if contamination is present or ground conditions are not suitable. This could result in some areas which are currently identified as potentially contaminated no longer being of relevance at the time of the construction of the Project.

Method of assessment – construction

Geology and soils

10.3.62 The assessment of construction phase impacts on geological and soil receptors was carried out through consideration of baseline conditions and the extent and method of construction activities.

10.3.63 The main construction activities include topsoil stripping, stockpiling and reinstatement (where practicable), construction of embankments (including any ground improvements, for example, use of band drains, grouting, piling), excavations and cuttings, construction of foundations and retaining structures (potential piling/diaphragm walls), access roads, utility diversions, groundwater control (for example, dewatering) associated with excavations, construction of compounds and construction of the bored tunnels, approach ramps and portals.

10.3.64 The assessment followed the methodology standard provided in DMRB LA 109 Geology and Soils (Highways England, 2019) which takes a staged approach: assess the value of the receptor, assess the magnitude of the impact of construction on the receptor and then combine the value and magnitude to get an overall significance of the effect. The criteria used in the assessment are set out in Table 10.2 and Table 10.3.

Land contamination

10.3.65 In relation to potentially contaminated land (from pre-existing contamination) and in line with current best practice as presented in the LCRM (Environment Agency, 2021), the assessment of land contamination has followed the Tier 1 and Tier 2 risk-based approach, as follows:

a. Tier 1: preliminary qualitative risk assessment (hazard identification stage) based on a desk-based study of available information to identify potential contaminant sources, pathways and receptors. These are presented as a CSM in Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3) and shows the potentially complete pollutant linkages and the potential risk associated with each linkage.

b. Tier 2: To assess the risk from the potential pollutant linkages identified in the Project's CSM (Appendix 10.6), an intrusive investigation should be used to provide data to inform a Generic Quantitative Risk Assessment (GQRA). The GQRA involves the comparison of site-specific results against Generic Assessment Criteria (GAC) for human health and/or controlled water receptors. For soil concentrations, appropriate screening values such as the Suitable 4 Use Levels (S4ULs) (Nathanail et al., 2015) and Category 4 Screening Levels (C4SLs) (CL:AIRE, 2014) have been adopted. Water concentrations have been screened against appropriate Water Quality Standards, such as Drinking Water Standards (DWS) and Environmental Quality Standards (EQS).

10.3.66 The impacts to the local and catchment-wide water quality, surface water (hydrology) and groundwater (hydrogeology) resources, land drainage and flood risk during construction were assessed as part of Chapter 14: Road Drainage and the Water Environment. The assessment in this chapter has considered water receptors in relation to existing historic contamination and whether pollutant linkages currently exist. The assessment also considered whether new pollutant linkages could be created during the construction phase from the mobilisation of contamination.

10.3.67 With regards to risk from ground gases, a risk assessment in accordance with CIRIA C665 (CIRIA, 2007) was undertaken within Appendix 10.8: Generic Quantitative Risk Assessment Report for the Phase 1 Investigation and Appendix 10.9: Generic Quantitative Risk Assessment Report for the Phase 2 Investigation (Annex A–D) (Application Document 6.3) to establish if mitigation measures are required within the design of the Project.

Method of assessment – operation

Geology and soils

10.3.68 The operational phase assessment considered potential effects on the underlying and adjacent soil and geological receptors from road usage. This follows the construction phase assessment approach detailed above.

10.3.69 Impacts to soils and the ALC grades they support (both temporary and permanent) would occur during the construction phase. No further effects on agricultural land in relation to its quality under the ALC system were assessed during the operational phase.

10.3.70 The effects on BMV land (both temporary and permanent) are also addressed under the construction phase (i.e. the impact occurs at the time the land is taken). No further effects on BMV land during the operational phase were assessed.

Land contamination

10.3.71 Operational phase activities have a lower potential to cause adverse impacts on sensitive receptors related to geology and soils. Effects from historic existing contaminated land would be resolved and mitigated during the construction of the Project and residual impacts would therefore be assumed to be minimal.

10.3.72 As with the construction phase assessment, the main impacts to surface water (hydrology) and groundwater (hydrogeology) during the operational phase were assessed as part of Chapter 14: Road Drainage and the Water Environment. This chapter, however, considered the water receptors in relation to contamination which may occur once the Project is operational.

Determining significance of effects

10.3.73 As described in Chapter 4: EIA Methodology, the significance of environmental effects was determined by taking into account the value (sensitivity) of the receptor and the magnitude of the impact.

10.3.74 The following paragraphs set out the value (sensitivity) and impact magnitude criteria used in this assessment, based on DMRB LA 109 Geology and Soils (Highways England, 2019). Significance of effect was then determined using the matrix approach shown in Table 4.4 of Chapter 4: EIA Methodology.

10.3.75 The assessment of significance undertaken in this chapter is used as the basis for identifying effects which are considered significant in the context of the EIA Regulations.

Defining value/sensitivity of resources and/or receptors

10.3.76 The value (sensitivity) of the identified geological and soil receptors/resources was determined using the criteria shown in Table 10.2, which is taken directly from DMRB LA 109 Geology and Soils (Highways England, 2019).

Table 10.2 Criteria for determining value (sensitivity) of geology, soils and contamination

Value (sensitivity)	Description
Very high	**Geology:** Very rare and of international importance with no potential for replacement (e.g. UNESCO World Heritage Sites, UNESCO Global Geoparks, SSSIs and Geological Conservation Review sites where citations indicate features of international importance). Geology meeting international designation citation criteria which is not designated as such. **Soils:** 1) Soils directly supporting an EU designated site (e.g. Special Area of Conservation, Special Protection Area, Ramsar), and/or 2) ALC Grade 1 and 2 land **Contamination:** 1) *Human health*: very high sensitivity land use such as residential or allotments 2) *Surface water*: watercourse having a WFD classification shown in a River Basin Management Plan (RBMP) and [1]Q95 ≥ 1.0m^3/s Site protected/designated under European Commission (EC) or UK legislation (Special Area of Conservation, Special Protection Area, SSSI, Ramsar site, salmonid water)/Species protected by EC legislation LA 108 (Highways England, 2020b) 3) *Groundwater*: Principal aquifer providing a regionally important resource and/or supporting a site protected under EC and UK legislation LA 108 (Highways England, 2020b) Groundwater locally supports Groundwater Dependent Terrestrial Ecosystems (GWDTE) Source protection zone (SPZ) 1
High	**Geology:** Rare and of national importance with little potential for replacement (e.g. geological SSSI, National Nature Reserves). Geology meeting national designation citation criteria which is not designated as such. **Soils:** 1) Soils directly supporting a UK designated site (e.g. SSSI), and/or 2) ALC Subgrade 3a land **Contamination:** 1) *Human health*: high sensitivity land use such as public open space 2) *Surface water*: watercourse having a WFD classification shown in an RBMP and Q95 < 1.0m^3/s Species protected under EC or UK legislation LA 108 (Highways England, 2020b) 3) *Groundwater*: Principal aquifer providing locally important resource or supporting a river ecosystem Groundwater supports a GWDTE SPZ2

[1] Q95 = The flow equalled or exceeded in a watercourse 95% of the time

Value (sensitivity)	Description
Medium	**Geology:** Of regional importance with limited potential for replacement (e.g. Regionally Important Geological Site). Geology meeting regional designation citation criteria which is not designated as such. **Soils:** 1) Soils supporting non-statutory designated sites (e.g. Local Nature Reserves, Local Geological Sites, Sites of Nature Conservation Interest), and/or 2) ALC Subgrade 3b land **Contamination:** 1) *Human health*: medium sensitivity land use such as commercial or industrial 2) *Surface water*: watercourses not having a WFD classification shown in an RBMP and Q95 >0.001m^3/s 3) *Groundwater*: aquifer providing water for agricultural or industrial use with limited connection to surface water SPZ3
Low	**Geology:** Of local importance/interest with potential for replacement (e.g. non-designated geological exposures, former quarries/mining sites). **Soils:** 1) ALC Grade 4 and 5 land 2) Soils supporting non-designated notable or priority habitats **Contamination:** 1) *Human health*: low sensitivity land use such as highways and rail 2) *Surface water*: watercourses not having a WFD classification shown in an RBMP and Q9 5 ≤0.001m^3/s 3) *Groundwater*: unproductive strata
Negligible	**Geology:** No geological exposures, little/no local interest. **Soils:** 1) Previously developed land formally in 'hard uses' with little potential to return to agriculture **Contamination:** 1) *Human health*: undeveloped surplus land/no sensitive land use proposed

Defining impact magnitude

10.3.77 The magnitude of impacts on geological and soil receptors/resources was determined using the criteria outlined in Table 10.3, which is taken directly from DMRB LA 109 Geology and Soils (Highways England, 2019).

Table 10.3 Criteria for determining the magnitude of impact (change) on geology, soils and contamination

Magnitude of impact (change)	Typical description
Major	**Geology:** Loss of geological feature/designation and/or quality and integrity, severe damage to key characteristics, features or elements. **Soils:** Physical removal or permanent sealing of soil resource or agricultural land. **Contamination:** 1) *Human health*: significant contamination identified. Contamination levels significantly exceed background levels and relevant screening criteria (e.g. C4SLs) SP1010 (CL:AIRE 2014) with potential for significant harm to human health. Contamination heavily restricts future use of land. 2) *Surface water:* Failure of both acute-soluble and chronic-sediment related pollutants in Highways England Water Risk Assessment Tool (HEWRAT; note National Highways was formerly known as Highways England) and compliance failure with EQS values Calculated risk of pollution from a spillage ≥2% annually (spillage assessment) Loss or extensive change to a fishery Loss of regionally important public water supply Loss or extensive change to a designated nature conservation site Reduction in water body WFD classification 3) *Groundwater*: Loss of, or extensive change to, an aquifer Loss of regionally important water supply Potential high risk of pollution to groundwater from routine runoff – risk score >250 (Groundwater quality and runoff assessment) Calculated risk of pollution from spillages ≥2% annually (Spillage assessment) Loss of, or extensive change to, GWDTE or baseflow contribution to protected surface water bodies Reduction in water body WFD classification Loss of, or significant damage to, major structures through subsidence or similar effects
Moderate	**Geology:** Partial loss of geological feature/designation, potentially adversely affecting the integrity; partial loss of/damage to key characteristics, features or elements. **Soils:** Permanent loss/reduction of one or more soil function(s) and restriction to current or approved future use (e.g. through degradation, compaction, erosion of soil resource). **Contamination:** 1) *Human health*: contaminant concentrations exceed background levels and are in line with limits of relevant screening criteria (e.g. C4SLs) SP1010. Significant contamination can be present. Control/remediation measures are required to reduce risks to human health/make land suitable for intended use.

Magnitude of impact (change)	Typical description
	2) *Surface water*: failure of both acute-soluble and chronic-sediment related pollutants in HEWRAT but compliance with EQS values. Calculated risk of pollution from spillages ≥1% annually and <2% annually. Partial loss in productivity of a fishery Degradation of regionally important public water supply or loss of major commercial/industrial/agricultural supplies Contribution to reduction in water body WFD classification 3) *Groundwater:* partial loss or change to an aquifer. Degradation of regionally important public water supply or loss of significant commercial/industrial/agricultural supplies. Potential medium risk of pollution to groundwater from routine runoff – risk score 150–250. Calculated risk of pollution from spillages ≥1% annually and <2 % annually. Partial loss of the integrity of GWDTE. Contribution to reduction in water body WFD classification. Damage to major structures through subsidence or similar effects or loss of minor structures
Minor	**Geology:** Minor measurable change in geological feature/designation attributes, quality or vulnerability; minor loss of, or alteration to, one or more key characteristics, features or elements. **Soils:** Temporary loss/reduction of one or more soil function(s) and restriction to current or approved future use (e.g. through degradation, compaction or erosion of soil resource). **Contamination:** 1) *Human health*: contaminant concentrations are below relevant screening criteria (e.g. C4SLs) SP1010. Significant contamination is unlikely with a low risk to human health. Best practice measures can be required to minimise risks to human health. 2) *Surface water*: failure of either acute-soluble or chronic-sediment related pollutants in HEWRAT Calculated risk of pollution from spillages ≥0.5% annually and < 1% annually Minor effects on water supplies 3) *Groundwater*: potential low risk of pollution to groundwater from routine runoff – risk score <150 Calculated risk of pollution from spillages ≥0.5% annually and <1% annually Minor effects on an aquifer, GWDTEs, abstractions and structures
Negligible	**Geology:** Very minor loss or detrimental alteration to one or more characteristics, features or elements of geological feature/designation. Overall integrity of resource not affected. **Soils:** No discernible loss/reduction of soil function(s) that restrict current or approved future use.

Magnitude of impact (change)	Typical description
	Contamination: 1) *Human health*: contaminant concentrations substantially below levels outlined in relevant screening criteria (e.g. C4SLs) SP1010. No requirement for control measures to reduce risks to human health/make land suitable for intended use. 2) *Surface water*: no risk identified by HEWRAT (pass both acute-soluble and chronic-sediment related pollutants) Risk of pollution from spillages <0.5% 3) *Groundwater*: no measurable impact upon an aquifer and/or groundwater receptors and risk of pollution from spillages <0.5%
No change	**Geology:** No temporary or permanent loss or disturbance of characteristics, features or elements **Soils:** No loss/reduction of soil function(s) that restrict current or approved future use **Contamination:** 1) *Human health*: reported contaminant concentrations below background levels 2) *Surface water*: no loss or alteration of characteristics, features or elements; no observable impact in either direction 3) *Groundwater*: no loss or alteration of characteristics, features or elements; no observable impact in either direction

10.3.78 In relation to soils, DMRB LA 109 Geology and Soils (Highways England, 2019) clarifies that a major magnitude impact for soils should be allocated where there is a discernible level of physical removal/permanent sealing of agricultural land.

10.3.79 For National Highways, this is detailed in an annex to DMRB LA 109 as follows:

10.3.80 Major impact magnitude – the physical removal or permanent sealing of >20ha of agricultural land.

10.3.81 Moderate impact magnitude – the physical removal or permanent sealing of 1-20ha of agricultural land or the permanent loss or reduction of one or more soil functions and restriction to current or approved future use, for example through degradation, compaction, or soil erosion.

10.3.82 The annex states that the physical removal or permanent sealing of <1ha of agricultural land should be reported as not discernible and this approach has been followed in the assessment.

Assumptions and limitations

10.3.83 General assumptions used throughout the ES, and limitations affecting the assessments are set out in Chapter 4: EIA Methodology. Relevant assumptions and any other limitations encountered during the Geology and Soils assessment are as described below. Acknowledging the assumptions and limitations identified below and in Chapter 4: EIA Methodology, the ES is considered robust and in line with relevant legislation, policy, and guidance.

10.3.84 It is noted within Appendix 10.8: Generic Quantitative Risk Assessment Report for the Phase 1 ground investigation (Application Document 6.3) that the Phase 1 investigation focused on geotechnical aspects and was limited geographically to the main crossing section between the portals and not specifically on land contamination. The potential risk of contamination or presence of pollutant linkages within these areas cannot be ruled out based on the current information and are therefore assumed present. A reasonable worst-case scenario has been adopted by the assessment assuming the presence of pollutant linkages.

10.3.85 For the Phase 2 ground investigation, a key aim of the intrusive works was to investigate potential sources of contamination, or migration pathways as identified in Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3). This was limited to areas within the Order Limits and where third-party land access was permitted. The areas investigated by the ground investigations are presented in the individual figures that support the annexes of Appendix 10.9 (Application Document 6.3).

10.3.86 Data obtained through the Phase 1 and 2 ground investigations were incorporated to give an accurate description of the baseline environment and is considered robust to inform the assessment in line with current guidance. Ground investigations would remain ongoing and would continue to be used to inform the Project ground model and detailed design. Data gaps encountered during the assessment would be targeted during further ground investigations by the Contractor during detail design as described in Section 10.5 and Appendix 10.11: Remediation Options Appraisal and Outline Remediation Strategy (Application Document 6.3).

10.3.87 ALC surveys were not undertaken across some areas within the Order Limits. A total of 566ha were surveyed, with areas not surveyed due to the following:

a. Land assessed as medium risk in relation to the potential presence of UXO, thus intrusive surveys posed a risk to surveyors

b. Land assessed as having potential contamination which posed a risk to the surveyors

c. Land access limitations due to the COVID-19 pandemic during 2020 and 2021 leading to survey delays

10.3.88 Where ALC surveys were not completed, an assessment was undertaken of the likely soil types present and the factors affecting soils at any given location to assess the potential land grade (using the MAFF revised guidelines and criteria for grading the quality of agricultural land), and this is clearly set out in the baseline (Section 10.4). It is noted that this approach has limitations when compared to ALC surveys, with the outcome for each point assessed being a modelled prediction and not definitive, albeit based on the best available data. The method adopted, however, has been used to supplement the available provisional ALC mapping at a scale of 1:250,000 (which is not considered suitable for use at a project level) to provide a greater level of refinement than using the provisional ALC 1:250,000 mapping alone. This predictive data has been used to support the data obtained via the ALC surveys and the

assessment of effects. Given the extent of land covered by detailed ALC surveys (566ha) within the Order Limits and the extent of BMV land confirmed through these surveys, the available information is sufficient to ensure that the overall assessment of significance has not been under-reported.

10.3.89 The approach to determine ALC grade of unsurveyed areas of the Order Limits was presented to and agreed with Natural England on 13 May 2020. This was reconfirmed with Natural England during technical engagement on 30 June 2021. This has been documented as a matter agreed within the Statement of Common Ground between (1) National Highways and (2) Natural England (Application Document 5.4.1.6)

10.3.90 Figure 1 of Appendix 10.4: Agricultural Land Classification Factual Report presents the results of the detailed ALC survey and outputs of the modelled prediction of ALC.

10.3.91 The DCO application has been developed on the basis of a 2030 opening year. This assumes consent is granted in 2024. Following the DCO Grant there would be preparatory works, referred to in the draft DCO as preliminary works taking place in 2024. The main construction period for the Lower Thames Crossing would start in early 2025, with the road being open for traffic in late 2030. Construction may take approximately six years, but as with all large projects there is a level of uncertainty over the construction programme, which would be refined once contractors are appointed and as the detailed design is developed. The 2030 opening year has been selected as the basis for the assessments and is representative of the reasonable worst-case scenario. This has been used consistently across the environmental assessments, transport assessments and the economic appraisal of the Project.

Nitrogen deposition compensation sites

10.3.92 The DCO application documents identify the locations of habitat creation sites proposed as compensation for the effects of nitrogen deposition. The design and management regimes for these locations would be developed as part of the detailed design, in accordance with the control plan documents including the Outline Landscape and Ecology Management Plan (OLEMP) (Application Document 6.7), Design Principles (Application Document 7.5) and the Environmental Masterplan (Document 6.2, Figure 2.4).

10.3.93 The environmental assessment of these habitat creation areas has reflected a reasonable worst case, for both construction and operation phases. This is described in Chapter 2: Project Description. A preliminary risk assessment on the nitrogen deposition compensation sites is presented in Annex D of Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3).

10.4 Baseline conditions

Existing baseline

10.4.1 The existing baseline conditions for the geology and soils study area are described from south to north of the Order Limits. Potential receptors that could be impacted by existing (historic) or resulting contamination are also considered. Reference is therefore made to groundwater (hydrogeology) and surface water (hydrology) features.

10.4.2 Throughout the baseline section, specific features have been given a historic land use (HLU) reference which refer to the credible contamination sources identified within the Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6). These features are presented in Figure 4, which supports the Preliminary Risk Assessment Report.

Geology

Published geology

10.4.3 A PSSR was prepared during the options assessment phase (Hyder-Halcrow, 2016) and was updated with an Addendum PSSR (Highways England, 2018b). These reports provide geological and ground condition information across the study area based on the available desk data.

10.4.4 The generalised geological succession for the Order Limits is detailed in Table 10.4 to Table 10.6. For these tables, the stratigraphy and thicknesses quoted were extrapolated from available historical BGS borehole logs and the geological maps.

10.4.5 The distribution of the superficial and bedrock deposits is shown in Figures 10.6 and 10.7 (Application Document 6.2).

10.4.6 The published geology relating to the nitrogen deposition compensation sites is included within the desk study review which is contained in Annex D of the Preliminary Risk Assessment Report (Document Number 6.3, Appendix 10.6).

South of the River Thames

10.4.7 The land slopes downwards from the A2 in the south towards the River Thames and the marshes at Gravesend in the north.

10.4.8 On high ground around the A2 connecting road from Cobham through the Shorne Woods Country Park to Higham, bedrock comprises the London Clay Formation underlain by the Harwich Formation at the highest parts which unconformably overlays the Lambeth Group and Thanet Formation. The published geological maps show that the Harwich Formation has been worked near Shorne Woods Country Park.

10.4.9 Natural superficial deposits (for example, Head Deposits) are generally absent across much of the area south of the River Thames.

10.4.10 Made ground is anticipated to be present associated with previously developed areas such as the North Kent Railway line (HLU0411), Thames and Medway Canal (HLU0414) and former military airport (Royal Air Force (RAF) Gravesend) (HLU0321). Made ground is also present in the area of the Filborough landfill site (HLU0413 and HLU0422).

10.4.11 The bedrock geology underlying much of the area south of the River Thames comprises the White Chalk (Seaford Chalk Formation and Newhaven Chalk Formation (to west) or Lewes Nodular Chalk Formation (to east) which outcrops at the surface where superficial deposits are absent.

10.4.12 A summary of the geological succession to the south of the River Thames is provided in Table 10.4. The distribution of the superficial and solid deposits is shown in Figures 10.6 and 10.7 (Application Document 6.2).

Table 10.4 General geological succession – south of the River Thames

Formation period/series/group	General description	Estimated stratigraphical thickness
Made ground	Likely to be associated with infrastructure earthworks and previously developed areas (e.g. the A2, former military airport (RAF Gravesend), Southern Valley Golf Club, infilled quarries, North Kent Railway, Thames and Medway Canal and flood defences)	0.5–3m
Made ground (landfill)	Made ground associated with Filborough landfill	6–8m
Head Deposits (Quaternary/Pleistocene)	Undifferentiated, pebbly sandy clay; some gravel	1–10m
London Clay Formation (Palaeogene/Eocene/ Thames Group)	Dark bluish to brownish grey clay, containing variable amounts of fine-grained sand and silt.	1–10m
Harwich Formation (Palaeogene/ Eocene/Thames Group)	Cross-bedded shelly sand (the Oldhaven Beds) with a basal pebble bed.	10–15m
Lambeth Group (Woolwich Formation) (Upnor Formation) (Palaeogene/Palaeocene/ Lambeth Group)	The upper beds are clay with shells, ferruginous sand, lignitic sand and lignite. The lower beds are coarse sand with pale grey clay partings and coarse gravel of black flint.	10–15m
Thanet Formation (Thanet Sand) (Palaeogene/Palaeocene/ Lambeth Group)	Greenish to brownish grey silty, fine-grained sand, clayey and siltier in the lower part, with a conglomerate of flint pebbles and nodular flints at the base.	10–30m
Seaford Chalk Formation (Cretaceous/Upper Cretaceous/White Chalk Subgroup)	Fossiliferous nodular chalk with bands of nodular flints, hardgrounds and marl seams.	Not proven, but estimated to be up to 70m thick
Newhaven Chalk Formation (Cretaceous/Upper Cretaceous/White Chalk Subgroup)	Soft to medium hard, smooth white chalks with numerous marl seams and flint bands, including abundant flints (notably at levels near the base). The formation is known to contain distinct phosphatic chalks of limited lateral extent.	
Lewes Nodular Chalk Formation (Cretaceous/Upper Cretaceous/White Chalk Subgroup)	Hard to very hard nodular chalks and hardgrounds with interbedded soft to medium hard chalks (some grainy) and marls; softer chalks become more abundant towards the top. Nodular chalks are typically lumpy and iron-stained (usually marking sponges). First regular seams of nodular flint, commence near the base and continue throughout.	

River Thames

10.4.13 In the low-lying marshes on either side of the River Thames and beneath the River Thames Channel, the geology consists of Alluvium overlying River Terrace Deposits overlying the White Chalk (Seaford Chalk Formation and Newhaven Chalk Formation).

10.4.14 Depths of the Alluvium have been found to range from 3 to 20m in the marshes on either side of the River Thames and thin out to approximately 3m thick below the river channel. Within the Alluvium, five distinct peat horizons have been identified. The Geology of London special memoir (Ellison et al., 2004) notes that the total thicknesses of peat beds exceed 2m in large areas between the confluence of the River Thames, River Lea and West Tilbury Main.

10.4.15 River Terrace Deposits are present beneath the Alluvium in the marshes on either side of the River Thames and beneath the river channel. These are generally found to be 5-8m thick.

10.4.16 A summary of the geological succession in the River Thames is provided in Table 10.5. The distribution of the superficial and solid deposits is shown in Figures 10.6 and 10.7 (Application Document 6.2).

Table 10.5 General geological succession – Thames

Formation period/series/group	General description	Estimated stratigraphical thickness
Alluvium (Quaternary/Holocene)	Marine and Estuarine Alluvium. Silt and clay with lenses and beds of peat, and seams of sand and gravel.	3-20m
River Terrace Deposits (Taplow Gravel Formation) (Quaternary/Pleistocene)	Gravel, sandy and clayey in part	5-8m
Seaford Chalk Formation (Cretaceous/Upper Cretaceous/White Chalk subgroup)	Fossiliferous nodular chalk with bands of nodular flints, hardgrounds and marl seams.	Not proven, but estimated to be up to 70m thick
Newhaven Chalk Formation (Cretaceous/Upper Cretaceous/White Chalk subgroup)	Soft to medium hard, smooth white chalks with numerous marl seams and flint bands, including abundant flints (notably at levels near the base). The formation is known to contain distinct phosphatic chalks of limited lateral extent.	

North of the River Thames

10.4.17 On the northern side of the River Thames, made ground (as a result of landfilling activities) of up to approximately 8m thickness has been recorded on historic BGS logs which is associated with Goshems Farm landfill area (HLU0526) and Tilbury Ash Disposal landfills (HLU0527 to HLU0533) which contain pulverised fuel ash (PFA) from the (now disused) Tilbury power station. This coincides with the area of the proposed North Portal.

10.4.18 Made ground is also anticipated to be present associated with previous and current developed areas and various light industrial activities, for example, the Low Street Brickworks historical landfill (HLU0536) is present adjacent to the Tilbury Loop railway line. In this location, the Alluvium overlies River Terrace Deposits (Taplow Gravel Member and Kempton Park Gravel) which overlie the White Chalk.

10.4.19 Further to the north between the Tilbury Loop railway line and the A13, the land slopes up from the River Thames valley and the East Tilbury Marshes. Here the Thanet Formation unconformably overlies the White Chalk (Seaford Chalk Formation and Newhaven Chalk Formation).

10.4.20 Adjacent to the north of the A13 junction and east of Baker Street, there is made ground (landfill) associated with Millers sand and gravel pits historical landfill site (HLU0943). Around the A13, the geology is topography related, with River Terrace Deposits overlying the Lambeth Group on the higher ground. Underlying the Lambeth Group is the Thanet Formation which in turn is underlain by the White Chalk.

10.4.21 From Orsett northwards the geology comprises Head Deposits, Alluvium and River Terrace Deposits (Lynch Hill Gravel) overlying the London Clay Formation. Alluvium deposits lie along the route of the Mardyke River and various subsidiary channels and increase in lateral extent further north up the river valley up to the A127.

10.4.22 Head Deposits are the predominant superficial deposits in this area and are present on the gently sloping valley sides from the Romford/Upminster-Grays Railway line (HLU1108) in the west to beyond Bulphan in the east. River Terrace Deposits (Boyn Hill Gravel Member and Black Park Gravel Member) are present overlying the London Clay Formation in the North and South Ockendon area.

10.4.23 In localised areas no superficial deposits are present and there are outcrops of London Clay Formation at the ground surface.

10.4.24 There are many old clay pits within the London Clay Formation. These old clay pits are shown on BGS maps as Worked Ground and made ground (described as wholly or partly backfilled pits). Between Ockendon and the M25 junction there is made ground/landfill associated with the Ockendon Landfill complex (HLU1062) and at Hall Farm (HLU1140) and Groves Farm (HLU1110) there are historical landfill sites.

10.4.25 A summary of the geological succession north of the River Thames is provided in Table 10.6. The distribution of the superficial deposits and bedrock is shown in Figures 10.6 and 10.7 (Application Document 6.2).

Table 10.6 General geological succession – north of the River Thames

Formation period/series/group	General description	Estimated stratigraphical thickness
Made ground	Made ground associated with developed/built-up areas.	0.5-2m
Made ground (landfill)	Made ground (landfill) on the northern side of the River Thames associated with historical and current landfill sites along the Project.	6-8m
Alluvium (Quaternary/Holocene)	Marine and Estuarine Alluvium. Silt and clay with lenses and beds of peat, and layers of sand and gravel.	1-20m
Head Deposits (Quaternary/Pleistocene)	Undifferentiated, pebbly sandy clay; some gravel.	1-5m
River Terrace Deposits (Taplow Gravel, Lynch Hill Gravel, Boyn Hill Gravel, Black Park Gravel, Kempton Park Gravel) (Quaternary/Pleistocene)	River Terrace Deposits – gravel, sandy and clayey in part.	1-20m
London Clay Formation (Palaeogene/Eocene/Thames Group)	Dark bluish to brownish grey clay, containing variable amounts of fine-grained sand and silt.	Up to 150m
Lambeth Group (Woolwich Formation, Upnor Formation) (Palaeogene/Palaeocene/ Lambeth Group)	The upper beds are clay with shells, ferruginous sand, lignitic sand and lignite. The lower beds are coarse sand with pale grey clay partings and coarse gravel of black flint.	5-20m
Thanet Formation (Thanet Sand) (Palaeogene/Palaeocene/ Lambeth Group)	Greenish to brownish grey silty, fine-grained sand, clayey and siltier in the lower part, with a conglomerate of flint pebbles and nodular flints at the base.	Up to 32m
Seaford Chalk Formation (Cretaceous/Upper Cretaceous/White Chalk Subgroup)	Fossiliferous nodular chalk with bands of nodular flints, hardgrounds and marl seams.	Up to 70m
Newhaven Chalk Formation (Cretaceous/Upper Cretaceous/White Chalk Subgroup)	Soft to medium hard, smooth white chalks with numerous marl seams and flint bands, including abundant flints (notably at levels near the base). The formation is known to contain distinct phosphatic chalks of limited lateral extent.	

Encountered geology

Geological ground model

10.4.26 To illustrate the geology recorded along the Project route, a Ground Model long-section was prepared based on the available ground investigation data from the Phase 1 and Phase 2 investigations and supplemented with historical BGS borehole logs. The Ground Model is presented in Appendix 10.5 (Application Document 6.3).

10.4.27 This long-section shows that the geology encountered through the investigations is generally as anticipated by the published geological mapping and the description provided in Table 10.4 to Table 10.6. It is however noted that the Newhaven Chalk Formation was not recorded during the investigations. Further details of the geology encountered in the Phase 1 and Phase 2 investigations are included in Appendix 10.8: Generic Quantitative Risk Assessment Report for the Phase 1 Investigation and Appendix 10.9: Generic Quantitative Risk Assessment Report for the Phase 2 Investigation (Annex A–D) (Application Document 6.3).

Geological Conservation Review

10.4.28 The JNCC Geological Conservation Review (GCR) database (JNCC, 2022) was studied for features such as geological SSSIs, RIGs and Local Geological Sites. The GCR volumes reviewed included:

a. Volume 7 Quaternary of the Thames (Bridgland, 1994)

b. Volume 15 British Tertiary Stratigraphy (Daley and Balson, 1999)

10.4.29 Proceedings of the Geologists' Association Special Issues viewed, included:

a. The Geology of England Volume 129 (Woods and Lee, 2018)

b. Geoconservation for Science and Society Volume 124 (Prosser et al., 2013)

c. Quaternary Geology of the British Isles: Part 1 Volume 120 (Bridgland and Golledge, 2009)

10.4.30 One entry was found within the GCR database for the Culand Pits (Lower and Upper), Burham (GCR number – 1339) which is within the study area of one of the nitrogen deposition compensation sites known as Burham Attwood's, to the south of the main route alignment. The Culand Pits (approximate grid coordinates TQ76936190) are detailed within the GCR block for Jurassic (Cretaceous Reptilia) due to the rarity of the fossil reptile material.

10.4.31 This site is designated as a SSSI by Natural England and is part of the Wouldham to Detling Escarpment. It is also designated for its biological interest.

10.4.32 The citation describes the geological interest as the sequence of Chalk in these pits has yielded rich and diverse collections of fossil fishes which complement those from Lewes in Sussex. The material is superbly preserved, frequently without significant crushing or distortion, and the fish are usually articulated, and thus have been the subject of much scientific research. The Lower and Middle Chalk of these pits has been an important source of reptiles and have yielded one of the best Lower/Middle Chalk reptile faunas.

10.4.33 Lower Culand pit is also designated as a RIG on the GeoConservation Kent website (GeoConservation Kent, 2022).

10.4.34 No other entries were identified within the study area. This is confirmed on the MAGIC online viewer (Natural England, 2022).

Local Geological Sites

10.4.35 The Essex Field Club website (Essex Field Club, 2022), Geo Essex website (Geo Essex, 2022), Kent Geologists Group website (Kent Geologists Group, 2022) and GeoConservation Kent website (GeoConservation Kent, 2022) were used to research Local Geological Sites of importance in June 2022.

10.4.36 Features identified in the study area are detailed in Table 10.7 and shown in Figure 10.8 (Application Document 6.2). These are all from the Geo Essex (2022) website and Essex Field Club (2022) website and the designations/ descriptions detailed are as shown on the websites.

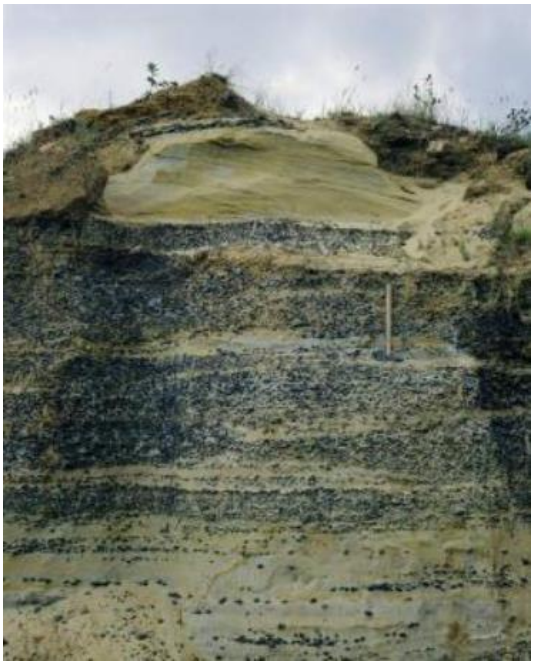
10.4.37 Prior to the site walkovers, a screening exercise was undertaken to establish which geological features were visited. This included the location of the feature in relation to the proposed construction works/Order Limits and therefore the likely impact on that feature. The type of feature, for example potential Local Geological Site or historical site, was also considered. Details of the sites visited are included in Table 10.7.

10.4.38 No Local Geological Sites were identified within the study area south of the River Thames or in the area of the tunnel.

Table 10.7 Local Geological Sites within study area – north of the River Thames

Site name	Approximate location and National Grid Reference (NGR)	Visited (Yes/No)	Description
Low Street Pit, Station Road, West Tilbury, Thurrock.	Within Order Limits approximately 30m east of the Project route (beneath embankment and proposed Tilbury Viaduct). NGR: TQ672775	Yes – would be impacted by construction works as within Order Limits	***Potential Local Geological Site***. A disused, wooded former sand and gravel pit south of Station Road. It was situated on a patch of Mucking Gravel (now known as Taplow Gravel Member). The gravel was excavated down to the Thanet Sand which is exposed on the pit floor. The pit is private and has been designated as a Local Wildlife Site. The site is situated on the southern limit of the Mucking Gravel terrace. Much of the Mucking Gravel has been excavated, with the remaining deposits towards the east of the site. The quarry sides are severely overgrown and affected by slumping. The location of the Mucking Gravel and a full description of the site is found within the Low Street Pit Technical Note in Annex 1 of Appendix 10.3: Site Walkover Factual Report (Application Document 6.3). In the Thurrock Biodiversity Study (Thurrock Council, 2007), Low Street Pit is described as 'another site that lies on the regionally important Thames terrace gravels'.
West Tilbury Wells	Approximately 100m to the north-east of the Order Limits. NGR: TQ660777	No – historical feature/no geological exposure present and unlikely to be impacted by construction works	***Historical interest only***. Medicinal spring or well which Essex Field Club describe as being no longer visible. Part of West Tilbury Hall.
Chadwell St Mary Sarsen Stone	Approximately 25m east of the Order Limits. NGR: TQ646785	No – unlikely to be impacted by construction works due to location in churchyard	***General geological site***. In the churchyard of Chadwell St Mary church is a sarsen stone (1m x 0.5m x 0.35m in size) with mammilated surfaces.

Site name	Approximate location and National Grid Reference (NGR)	Visited (Yes/No)	Description
East Tilbury Marshes, Thurrock	Approximately 200m east of the Order Limits. NGR: TQ688784	No – general geological site which is unlikely to be impacted by construction works due to location in relation to Order Limits	***General geological site***. East Tilbury Marshes Gravel (now known as Kempton Park Gravel), which underlies the alluvium of the modern Thames floodplain. The gravel is not present at the surface and has been extensively quarried at East Tilbury. These quarries are the only exposure of this gravel.
Turners Farm Gravel Pit, Mucking, Thurrock	Approximately 35m south-east of the Order Limits. NGR: TQ677801	Yes – geological exposure potentially present and potentially impacted by construction works due to location in relation to Order Limits	***Potential Local Geological Site***. Disused gravel pit with fine vertical exposures of Mucking Gravel (now known as Taplow Gravel Member). The east face of the pit is about 5m high and provides one of the finest vertical sections through Thames Terrace gravel to be seen in the Thames valley as shown in the photo below.  *Photo from Essex Field club website (Essex Field Club, 2020)* Photos from the site walkover are included in Appendix 10.3: Site Walkover Factual Report (Application Document 6.3). The pit is now filled with water.

Site name	Approximate location and National Grid Reference (NGR)	Visited (Yes/No)	Description
Orsett Cock Quarry	South of the A13, approximately 100m south-east of Orsett Cock roundabout. NGR: TQ655811	No – unlikely to be impacted by construction works	***Potential Local Geological Site***. Excellent exposures of the pebble beds of the Upnor Formation as shown in the photo below. It is the best inland exposure of this particular formation.  *Photo from Essex Field club website (Essex Field Club, 2020)*
Orsett Depot Quarry	South of A13. Approximately 125m north and 200m east of Order Limits. Within study area. NGR: TQ656809	Yes – exposures of geological feature formerly present	***Historical Site only***. A large disused sand and gravel pit formerly provided excellent exposures of the Upnor Formation on the pit faces. Photos from site walkover are included in Appendix 10.3: Site Walkover Factual Report (Application Document 6.3).
Tilbury Dock	Approximately 700m southwest of Order Limits at Tilbury. NGR: TQ635755	No – historical feature/no geological exposure present and unlikely to be impacted by construction works	***Historical Site only***. In 1882 work commenced on new docks at Tilbury. Boreholes revealed that there are five layers of peat at Tilbury, each one followed by a layer of alluvial clay. The basal peat which lay on gravel from the buried channel of the Thames was radiocarbon dated to be about 8,300 years old.

Site name	Approximate location and National Grid Reference (NGR)	Visited (Yes/No)	Description
Ockendon Clay Plant (Grange Farm Clay Pits), South Ockendon, Thurrock	Located approximately 50m south-east of Order Limits. NGR: TQ609839	No – historical feature/no geological exposure present and unlikely to be impacted by construction works	***Historical Site only***. London Clay was worked at South Ockendon since at least 1930. The clay exposed was the lower part of the London Clay formation. The pits are private property and there is no public access.
Cranham (temporary exposures of London Clay)	Located within the Order Limits approximately 30m from the Project route. West of M25 junction 29. NGR: TQ580884	No – general information/ unlikely to be impacted by construction works	***General Information***. Temporary exposures of London Clay in the area between Romford and Basildon. Examples of temporary exposures in the surrounding area associated with the construction of the M25 and subsequent widenings.
Coombe Green Sand Pit	Located approximately 250m east of Order Limits. East of M25 near Coombe Green. NGR: TQ57669045	No – geological exposure potentially present, however unlikely to be impacted by construction works due to location in relation to Order Limits	***Potential Local Geological Site***. Shallow overgrown sand pit in a triangular wooded area which has a very small exposure of typically fine-grained Bagshot Sand (extremely rare in Essex).
North Stifford Church Puddingstone, Thurrock	Located approximately 200m south-west of the Order Limits. NGR: TQ604803	No – unlikely to be impacted by construction works due to location in churchyard	***General geological site***. The only known example of puddingstone in south Essex is a boulder which supports the north-west corner of St. Mary's Church. It consists of layers of black flint pebbles set in a sarsen matrix.

Site name	Approximate location and National Grid Reference (NGR)	Visited (Yes/No)	Description
Dansand Quarry	Adjacent to the Order Limits, approximately 20m from the realigned A1013 NGR: TQ651810	No – geological exposure present within working/ existing quarry. Part of the noted exposure is adjacent to the proposed alignment of the A1013 and is unlikely to be impacted by construction works for the A1013.	***General geological site*** This site has exposures of the sands of the Woolwich Beds (now known as Woolwich Formation). They take the form of very steep to almost vertical cliffs on the northern faces which mark the edges of the original quarry. The Woolwich Beds sands are capped by Orsett Heath Gravel (now known as Boyn Hill Gravel) in places, which adds importance to these sections. These cliffs could be easily retained in any future use of the site.
Buckingham Hill Sand Quarry	Located approximately 200m north of the Order Limits. NGR: TQ 674809	No – geological exposure potentially present, however unlikely to be impacted by construction works due to location in relation to Order Limits.	***Potential Local Geological Site***. The disused Buckingham Hill Pit, north-west of Waltons Hall, was formerly operated by Tarmac and is often referred to as the Orsett Tarmac Pit. It provides fine exposures of the Woolwich Beds (now known as Woolwich Formation), which are mostly marine sand. In the sandy strata is the preservation In the cliff faces of burrows of crustaceans that lived on the sandy sea floor some 60 million years ago. This site gives the impression of a wild and remote corner of Essex and the towering cliffs of sand add to the grandeur of the scene. It is important that the cliff profiles are retained for the benefit of geology and wildlife.  *Photo from Essex Field club website (Essex Field Club, 2022)*

10.4.39 The sites detailed above are either considered to be historical sites or potential geological sites by the Essex Field Club. None of the sites have been formally designated.

10.4.40 Essex Field Club was contacted to supply any additional information about the above sites and confirmed that the website provides the most up-to-date information. No other information was received and all the information held on their website is included in Table 10.7.

Soils

10.4.41 A description of the soils is presented below for the sections south and north of the River Thames. This is followed by an assessment of the land grades supported by these soil types. The soil associations within the Order Limits are presented in Figure 10.2 (Application Document 6.2), with further detail of the soils described as part of the detailed ALC surveys presented in Appendix 10.4: Agricultural Land Classification Factual Report (Application Document 6.3). A soil association represents a group of soil series which are typically found occurring together within a landscape.

10.4.42 While the baseline conditions immediately adjacent to the River Thames are described here, this includes areas which would not be directly affected by construction activities as the tunnel portals are some distance from the riverbanks.

Soil characteristics

South of the River Thames

10.4.43 As shown in Figure 10.2 (Application Document 6.2), agricultural land along the route of the Project to the south of the River Thames is covered by soils (from north to south) in the following soil associations: Wallasea 1, Frilsham, Coombe 1 and Fyfield 4. With the exception of the Wallasea 1 soils these are generally described as well-drained loamy soils.

10.4.44 Immediately north of the A2, the soils belong to the Fyfield 4 Association. They are described as deep, well-drained and often stoneless coarse loamy and sandy soils with a naturally low fertility. South of Chalk, the soils belong to the Coombe 1 Association and are described as well-drained calcareous fine silty soils which can be deep in valley bottoms. There are also likely to be some soils belonging to the Frilsham Association, described as well-drained fine loamy soils overlying chalk.

10.4.45 All these soil types have relatively high permeabilities and high soil moisture storage capacities. They are classed as having a moderate potential to attenuate pesticide leaching and the area is considered to have a minor flood risk potential.

10.4.46 Soils adjacent to the River Thames are mapped as belonging to the Wallasea Association. These are described as deep stoneless non-calcareous and calcareous clayey soils developed in marine Alluvium. These soils are seasonally waterlogged and affected by fluctuating groundwater levels with relatively low conductivity.

10.4.47 Given the clay nature of these soils they have the potential to swell and shrink leading to foundation damage. They potentially contain elevated levels of sulphate which can lead to higher iron-corrosion risk. They are also classed as having limited ability to attenuate non-absorbed pesticides which can then leach into the groundwater.

10.4.48 These soils support a range of habitats, including designated sites. Further details of the designated sites and their characteristics, including soils where relevant, are set out in Chapter 8: Terrestrial Biodiversity and associated appendices.

10.4.49 These soils would also provide a range of soil functions in addition to supporting agricultural production and habitats. These may include absorbing and holding on to water, carbon sequestration, pollution and atmospheric gas moderation.

North of the River Thames

10.4.50 As shown in Figure 10.2 (Application Document 6.2), agricultural land along the Project route to the north of the River Thames is covered by soils in (from north to south) the Windsor, Fladbury 3, Shabbington, Fyfield 4, Hucklesbrook, and Wallasea 1 associations.

10.4.51 Between West Tilbury and the River Thames, soils of the Wallasea 1 association are present, similar to those on the southern side of the Thames and described above.

10.4.52 North of Tilbury to the A13 the soils are generally described as freely draining slightly acid loamy soils belonging to the Hucklesbrook association, often having gravel at depth.

10.4.53 Around Orsett and to the south of the A13 the soils are mapped as belonging to the Fyfield 4 and Hucklesbrook Associations. Both are well-drained coarse loamy soils in places developed over gravels. These are described as having relatively high permeabilities and high soil moisture storage capacities. Both are classed as having low leaching capacity in relation to pesticides.

10.4.54 These give way north of the A13 to slowly permeable, seasonally wet slightly acid, but base-rich loamy and clayey soils along with loamy soils with naturally high groundwater around junction 29. The soils north of the A13 to South Ockendon Hall comprise the Windsor and Fladbury 3 Associations. The Windsor Association is described as slowly permeable and seasonally waterlogged clayey soils. The Fladbury Association is described as stoneless clayey soils affected by groundwater.

10.4.55 To the west of South Ockendon Hall the soils are mapped as comprising the Shabbington Association. These are described as deep fine loamy and fine loamy over sandy soils variably affected by groundwater.

10.4.56 All the soils north of the A13 are described as moderately to highly aggressive in relation to iron corrosion. They are also generally classed as having a high leaching capacity in relation to non-adsorbed pesticides.

10.4.57 These soils support a range of habitats, including designated sites. Further details of the designated sites and their characteristics, including soils where relevant, are set out in Chapter 8: Terrestrial Biodiversity and associated appendices.

10.4.58 These soils would also provide a range of soil functions in addition to supporting agricultural production and habitats. These may include absorbing and holding on to water, carbon sequestration, pollution and atmospheric gas moderation.

Agricultural Land Classification

South of the River Thames

10.4.59 The Provisional ALC mapping is shown in Figure 10.3 (Application Document 6.2).

10.4.60 Agricultural land in England and Wales is graded between 1 and 5, depending on the extent to which physical or chemical characteristics impose long-term limitations on agricultural use. Grade 1 land is excellent quality agricultural land with very minor or no limitations to agricultural use, and Grade 5 is very poor quality land, with severe limitations due to adverse soil characteristics, relief, climate or a combination of these. Grade 3 land is subdivided into Subgrade 3a (good quality land) and Subgrade 3b (moderate quality land).

10.4.61 Grades 1, 2 and 3a are defined as BMV land.

10.4.62 The land between the M2/A2/A122 Lower Thames Crossing junction and Gravesend link is classed, based on the provisional mapping, as a mix of Grades 1, 2 and 3. The Grade 1 land is shown to occur around the A2 junction. The ALC mapping at this scale provides overall context and an indication of likely grade but is not suitable for detailed land grade assessments.

10.4.63 The ALC mapping presented in Figure 10.3 (Application Document 6.2) is published at a scale of 1:250,000. This is generally considered to be of value for strategic land use planning purposes and not site-specific assessments, although the mapping does provide a guide as to the likely land grades. The mapping does not distinguish between the Subgrades 3a and 3b.

10.4.64 Some detailed mapping is available for the area north of Thong around the Southern Valley Golf Course (Application Document 6.2, Figure 10.3). This confirms the presence of Grade 2 and 3a land, as well as some Subgrade 3b land.

10.4.65 These grades are expected given the deep, well-drained nature of the soils present, where soil wetness, depth and stoniness are not major limitations to agricultural productivity.

10.4.66 Where detailed mapping was not available from published sources, ALC surveys or ALC grade predictions were undertaken. The results of these surveys are shown in Figure 10.4 (Application Document 6.2), with full details presented in Appendix 10.4: Agricultural Land Classification Factual Report (Application Document 6.3) which includes details of the extent of each grade assessed from detailed surveys and from the predictive analysis.

10.4.67 The extent of each ALC grade within the Order Limits to the south of the River Thames is presented in Table 10.8.

Table 10.8 ALC grade distribution within the Order Limits – south of the Thames

ALC grade	Area (ha)	Area (%)
Grade 1 (Excellent)	17.22	2.5
Grade 2 (Very Good)	272.92	39.7
Subgrade 3a (Good)	89.35	13.0
Subgrade 3b (Moderate)	53.96	7.8
Grade 4 (Poor)	19.75	2.9
Grade 5 (Very Poor)	0.00	0.0
Other Land/Non-agricultural	234.40	34.1
Total	687.60	100.0

10.4.68 The collation and review of historical data and the detailed ALC surveys found agricultural land in Grades 1 (17.22ha), 2 (272.92ha), 3a (89.35ha), 3b (53.96ha) and 4 (19.75ha).

10.4.69 Grade 1, 2 and 3a land, covering approximately 55.2% of the land within the Order Limits south of the Thames, is considered to be BMV agricultural land.

10.4.70 There are no climatic, gradient or micro-relief limitations to ALC grade for land within the Order Limits to the south of the River Thames. The land is mainly located in Flood Zone 1, at low risk of flooding by rivers or the sea, with the Filborough Marshes on the floodplain of the River Thames benefiting from flood defences. While there are limited data/records to determine the duration and frequency of flooding it is not considered that flooding would significantly limit the potential land grade.

10.4.71 Interactive limitations have, however, been identified from the assessments. The land grade within the Order Limits to the south of the River Thames has been determined to be mainly limited by soil droughtiness and/or soil wetness to Grades 2, 3a and 3b. Some well-drained soil with fine sandy loam topsoil (i.e. Fyfield association) to the south of Thong has no significant limitations and is mapped as Grade 1. Conversely, some profiles on the Filborough Marshes have clay topsoil over slowly permeable clay subsoil which is waterlogged for long periods over the winter (Wetness Class IV) which is limited by soil wetness to Grade 4.

10.4.72 The National Character Area profile for Area 113: North Kent Plain shows, from information based on the Provisional ALC mapping, 16% of the area comprises Grade 1, 18% comprises Grade 2 and 16% comprises Grade 3 (which is not split into Grade 3a and 3b). The detailed assessment data presented shows a likely greater extent of Grade 2 land present within the Order Limits with less Grade 1 and Grade 3 land.

North of the River Thames

10.4.73 The Provisional ALC mapping is shown in Figure 10.3 (Application Document 6.2).

10.4.74 Land north of Tilbury to the A13, and the area around Orsett and to the south of the A13, is provisionally mapped as being Grade 2 and 3 (Grade 2 land occurring particularly around the A13 junction).

10.4.75 The area north of the A13 to South Ockendon Hall is provisionally mapped as Grade 3 land. These are generally slowly permeable, seasonally wet, slightly acid but base-rich loamy and clayey soils along with loamy soils, with naturally high groundwater around M25 junction 29.

10.4.76 To the west of South Ockendon Hall, the soils are provisionally mapped as Grade 1 land. These are generally deep fine loamy and fine loamy over sandy soils, indicating that the coarser texture facilitates better drainage so has greater productivity potential.

10.4.77 Where detailed mapping was not available from published sources, ALC surveys or ALC grade predictions were undertaken. The results of these surveys are shown in Figure 10.4 (Application Document 6.2), with full details presented in Appendix 10.4: Agricultural Land Classification Factual Report (Application Document 6.3) which includes details of the extent of each grade assessed from detailed surveys and from the predictive analysis.

10.4.78 The extent of each ALC grade within the Order Limits to the north of the River Thames is presented in Table 10.9.

Table 10.9 ALC grade distribution within the Order Limits – north of the Thames

ALC grade	Area (ha)	Area (%)
Grade 1 (Excellent)	7.40	0.4
Grade 2 (Very Good)	71.02	4.2
Subgrade 3a (Good)	358.72	21.0
Subgrade 3b (Moderate)	672.73	39.4
Grade 4 (Poor)	26.63	1.6
Grade 5 (Very Poor)	0.00	0.0
Other Land/Non-agricultural	571.13	33.4
Total	1707.63	100.0

10.4.79 The collation and review of historical data and the detailed ALC surveys found agricultural land in Grades 1 (7.4ha), 2 (71.02ha), 3a (358.72ha), 3b (672.73ha) and 4 (26.63ha).

10.4.80 Grade 1, 2 and 3a land, covering approximately 25.6% of the land within the Order Limits north of the Thames, is considered to be BMV agricultural land.

10.4.81 There are no climatic, gradient or micro-relief limitations to ALC grade for land within the Order Limits to the north of the River Thames. The land is mainly located in Flood Zone 1, at low risk of flooding by rivers or the sea, with the Tilbury area on the floodplain of the River Thames benefiting from flood defences. While there are limited data/records to determine the duration and frequency of flooding it is not considered that flooding would significantly limit the potential land grade.

10.4.82 Interactive limitations have, however, been identified from the assessments. The land grade within the Order Limits to the north of the River Thames has been determined to be mainly limited by soil droughtiness and/or soil wetness to Grades 2, 3a and 3b. Some well-drained soils with sandy loam or sandy clay loam topsoil over well-drained sandy clay loam subsoil (i.e. Shabbington association) have no significant limitations and are mapped as Grade 1. Conversely, some well-drained soil profiles with very stony (gravelly) subsoil (i.e. Hucklesbrook association) are limited by soil droughtiness to Grade 4.

10.4.83 The National Character Area profile for National Character Area 111: Northern Thames Basin shows, from information based on the Provisional ALC mapping, less than 1% of the area comprises Grade 1, 11% comprises Grade 2 and 48% comprises Grade 3 (which is not split into Grade 3a and 3b). The detailed assessment data presented shows slightly less Grade 2 land and a greater extent of combined Grade 3 land present within the Order Limits.

Groundwater (hydrogeology)

10.4.84 A full description of hydrogeological features is included in Chapter 14: Road Drainage and the Water Environment. However, to give context on how these receptors and potential pathways relate to contaminated land, relevant details are included below.

Aquifer status

10.4.85 Information obtained from the Environment Agency, shows the location of aquifers, groundwater SPZs and abstraction licences. The aquifers are summarised in

10.4.86 Table 10.10 and shown in Figures 14.3 and 14.4 (Application Document 6.2).

10.4.87 Strata not designated below, such as London Clay Formation, are known as Unproductive strata. These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

Table 10.10 Aquifer status

Geological formation	Aquifer status
Superficial aquifers	
Alluvium	Secondary A[1] or Undifferentiated aquifer[2] (may act as an aquitard)
Head Deposits	Secondary Undifferentiated aquifer
River Terrace Deposits (Boyn Hill, Lynch Hill, Brent Park, Black Park and Taplow Gravel Members)	Secondary A aquifer
Bedrock aquifers	
White Chalk Subgroup (Lewes Nodular Chalk and Seaford Chalk)	Principal aquifer[3]
Thanet Formation	Secondary A aquifer
Lambeth Group	Secondary A aquifer
Harwich Formation	Secondary A aquifer

1. Permeable layers capable of supporting water supplies at a local rather than strategic scale and in some cases forming an important source of base flow to rivers.

2. This classification has been assigned in cases where it has not been possible to attribute either category Secondary A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.

3. These are rocks or drift deposits that have a high intergranular and/or fracture permeability – meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale.

Source protection zones (SPZ) and groundwater receptors

10.4.88 The SPZs and groundwater receptors such as licensed abstractions and discharges to ground and springs are presented in Figure 14.2: Groundwater Receptors and Resources (Application Document 6.2) and further detail is given in Appendix 14.5: Hydrogeological Risk Assessment (Application Document 6.3

10.4.89 A water features survey was completed (in four phases between September 2017 and October 2019) and the findings presented in Appendix 14.2: Water Features Survey Factual Report (Application Document 6.3). The survey has indicated that there are groundwater abstractions present within the 1km study area to the south and north of the River Thames.

Surface water (hydrology)

10.4.90 A full description of hydrological features is included in Chapter 14: Road Drainage and the Water Environment and Figure 14.1 (Application Document 6.2). However, to give context on how these receptors relate to contaminated land, pertinent details are included below for information. A full list of features is also presented in Appendix 14.2: Water Features Survey Factual Report (Application Document 6.3).

South of the River Thames

10.4.91 The Filborough and Shorne Marshes are drained by a network of man-made channels which discharge into the River Thames. The disused and partially infilled Thames and Medway Canal crosses above the alignment of the proposed tunnels to the south of the marshes.

10.4.92 There are several ponds located across the area to the south of the River Thames, some of which are man-made due to extraction of sand and gravel deposits in these areas.

10.4.93 The main watercourse is the River Thames which crosses the Project in a roughly west to east route. This watercourse is tidal/brackish at the Gravesend Reach.

North of the River Thames

10.4.94 To the north of the River Thames between the northern bank and the Tilbury Loop railway line, several artificial drainage ditches were identified which are associated with Goshems Farm historical landfill site (HLU0526) and the former Tilbury Power Station (HLU0630).

10.4.95 The West Tilbury Main and associated drainage ditches are located between Goshems Farm historical landfill site and East Tilbury historical landfill site (HLU0523 and HLU0533). They flow north to south before discharging into the River Thames.

10.4.96 Similar to south of the River Thames, there are ponds present across the area, many of which are associated with extraction of deposits.

10.4.97 To the north of the Tilbury Loop railway line, a pond was identified during the site walkover survey on farmland to the north of the railway which was said (by anecdotal evidence) to be groundwater fed.

10.4.98 Gobions Sewer is a watercourse that rises to the west of Linford. This watercourse is designated as a main river from just upstream of its crossing of East Tilbury Road to its point of discharge to the Thames Estuary.

10.4.99 Further to the north, several drainage ditches are present between the A13 and the M25 junction 29.

10.4.100 The Mardyke crosses the route north-east to south-west just to the north of the A13. Various tributaries including the Orsett Fen Sewer, Golden Bridge Sewer, Stringcock Sewer and West Mardyke Tributary are present to the north of the A13 and towards the A127.

Soil and groundwater contamination potential

Preliminary Risk Assessment Report

10.4.101 Appendix 10.6: Preliminary Risk Assessment (PRA) Report (Application Document 6.3) was prepared to identify potential geo-environmental constraints that may affect, or be affected by, the Project.

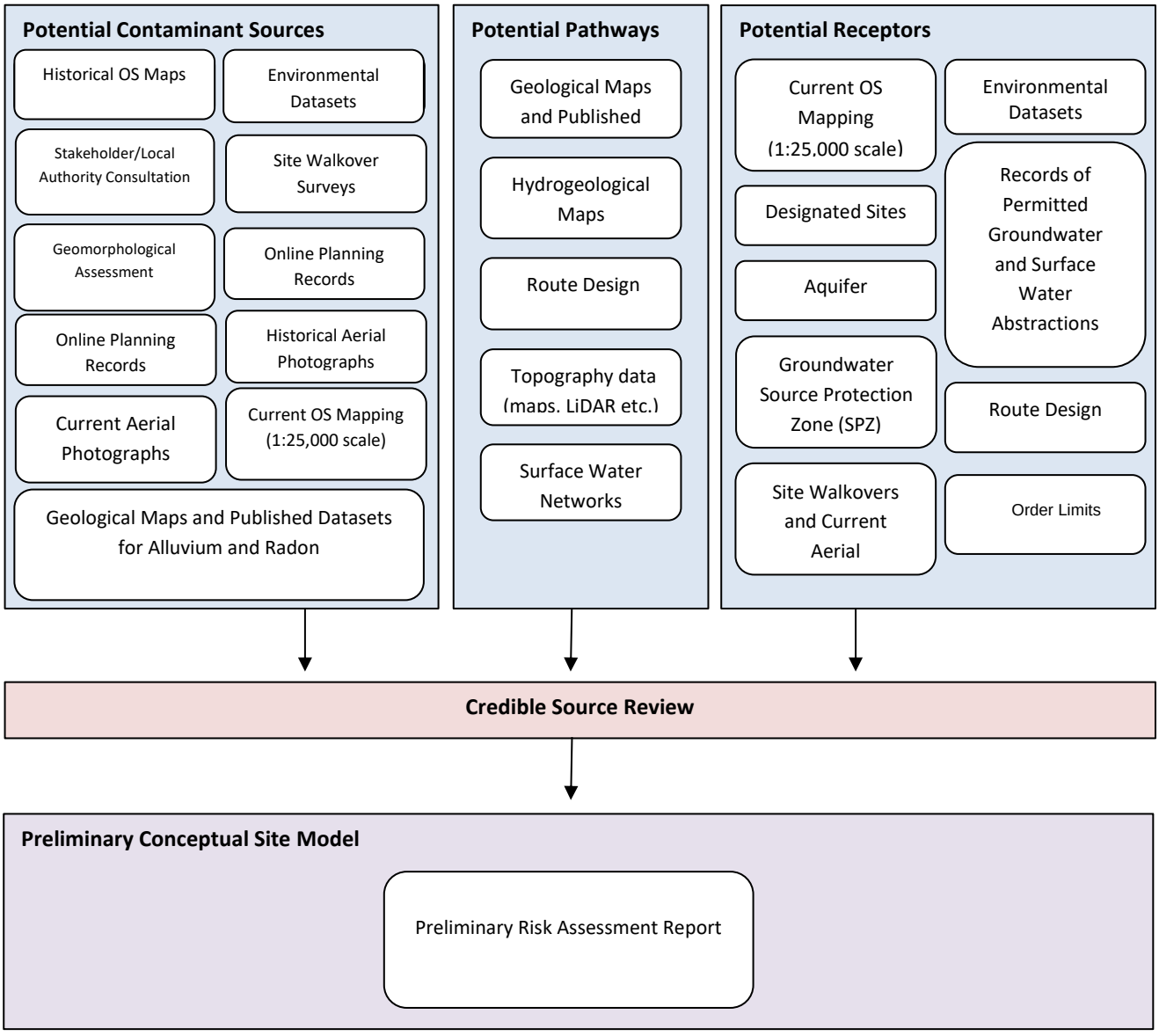
10.4.102 This was a Tier 1 preliminary qualitative risk assessment using the source, pathway and receptor approach. The assessment was based on professional judgement using information available for each potential source, the environmental setting and the likely sensitivity of the receptors at the time of the

development of the Project CSM. Further information on how the risk ratings were derived is included in Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3).

10.4.103 The principal information sources used to develop the CSM are shown in Plate 10.1 (which is taken from Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3)) and include historical mapping, aerial photographs, online planning records and records of pollution incidents as well as observations taken during the site walkovers.

10.4.104 The desk-based review of the nitrogen deposition compensation sites is included within Annex D of the Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6).

Plate 10.1 General information sources and approach to identify potentially contaminated features



10.4.105 Each potential credible source of contamination was assigned a preliminary risk rating of high, medium or low based on the likelihood of a complete pollutant linkage being present as described in Table 10.11. Details of the approach and

the preliminary risk assessment is presented in Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3).

Table 10.11 Risk ratings derived for the CSM

Risk rating	Description
High	Complete pollutant linkage is **likely** and potential for significant adverse impacts upon human health or the environment. *Ground investigation and further assessment essential*.
Medium	Complete pollutant linkage is **possible** and potential for adverse impacts upon human health or the environment. *Ground investigation and/or further assessment required*.
Low	Complete pollutant linkage is of **low likelihood** and potential for limited adverse impacts upon human health or the environment. *Limited ground investigation and/or further assessment may be prudent*.

10.4.106 Overall, over 200 features were designated as low, medium or high-risk credible sources of contamination. Of the credible sources identified, six were assigned high-risk, while a further 33 were assessed as medium with the remaining 179 assessed as low risk. A full description of all the credible sources is provided in Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3) and presented in Figure 4 which supports the Preliminary Risk Assessment Report (Application Document 6.3) with their respective HLU reference numbers.

10.4.107 With regards to Table 10.11 above, ground investigations have been undertaken which focused on the high- and medium-risk sites and are reported in Appendix 10.8: Generic Quantitative Risk Assessment Report for the Phase 1 Investigation and Appendix 10.9: Generic Quantitative Risk Assessment Report for the Phase 2 Investigation (Annex A–D) (Application Document 6.3). A precautionary approach has been assumed where a source could not be investigated, i.e. that a pollutant linkage is present.

10.4.108 HLU 9901 is identified as a general high-risk credible source in relation to the potential for ground gas (principally methane) being present within the underlying geology, such as alluvium and peat deposits, and is therefore not listed in Table 10.12 and Table 10.14 which detail specific locations. The potential for ground gas along the Project route is discussed as part of the encountered contamination from the Phase 1 and Phase 2 ground investigation (Application Document 6.3, Appendix 10.8 and Appendix 10.9).

South of the River Thames

10.4.109 A total of ten medium-risk credible contamination sources were identified to the south of the River Thames. The risks are detailed in Table 10.12 which also includes where the source is locate, i.e. within the Order Limits or the study area. Further details relating the potential contaminants that may be present at each source is included within Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3).

Table 10.12 Summary of medium-risk credible contaminant sources south of the River Thames

Name	HLU reference number	Description	Location	Risk rating
Sheep wash	HLU0207	Dated approximately 1864 to 1963	Within Order Limits	Medium
Electricity substation	HLU0206	Located north of the A2. Constructed between circa 1967.	Within Order Limits	Medium
Esso A2 Westbound Petrol Filling Station	HLU0215	Vehicle garage and petrol filling station (1972-present). Possible made ground to west.	Within Order Limits	Medium
Henhurst Road Contractors' Depot	HLU0220	Civil engineering contractors' yard and aggregate processing site (post 1993). Possible made ground.	Within Order Limits	Medium
Singlewell Service Station	HLU0224	Vehicle maintenance garage approximately 1961 to present.	Within Study Area	Medium
Former military Airport (RAF Gravesend)	HLU0321	Former civilian and military airfield. Former land uses are known or suspected to include aviation fuel storage and dispensing, firefighting, blast pens, aircraft service/ manufacture/breaking, deep made ground, and an aluminium smelter.	Within Order Limits and Study Area	Medium
Gravesend Airport Perimeter Road – North-east	HLU0322	North-east section of the concrete track forming Gravesend Airport Perimeter Road.	Within Order Limits	Medium
Gravesend Airport Perimeter Road – South-east	HLU0213	South-east section of the concrete track forming Gravesend Airport Perimeter Road, partially intact north of Claylane Wood.	Within Order Limits	Medium
Chalk Pit	HLU0309	Potentially filled between 1955 and 1962. Potential for voids from excavated tunnels and waste deposits including putrescible material and pipe bombs.	Within Order Limits	Medium
Southern Valley Golf Course	HLU0324	Golf course (1998 to present). Possible made ground	Within Order Limits	Medium

10.4.110 One credible source identified is the former petrol filling station on the north side of the A2. However, Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3) records that remediation works were carried out following the demolition of the site between 2008 and 2011. The remediation of the former petrol filling station has been approved by the Environment Agency and therefore it has been given a low-risk rating. A balance pond is indicated to the east of the former petrol station which is assumed to be for highway runoff.

10.4.111 In addition to the medium sources, over 45 low-risk credible contaminant sources have been identified to the south of the River Thames. Further details about the low-risk sites can be found in Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3).

North of the River Thames

10.4.112 Twenty-three medium-risk and six high-risk credible contamination sources were identified to the north of the River Thames, as detailed in Table 10.13 which also includes where the source is locate, i.e. within the Order Limits or the study area. These are ordered in the table as they appear along the route alignment from south to north. Further details relating the potential contaminants that may be present at each source is included within Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3).

Table 10.13 Summary of medium- and high-risk credible contaminant sources north of the River Thames

Name	HLU reference number	Description	Location	Risk rating
Goshems Farm landfill	HLU0526	Former late 19th / early 20th century landfill, reportedly mostly ash and bottles, dock and river dredgings. Currently undergoing restoration.	Within Order Limits	High
Tilbury Ash Disposal Site	HLU0532 HLU0531 HLU0530 HLU0529 HLU0528 HLU0527 HLU0534	PFA landfill for Tilbury Power Station (and potential for unrecorded disposal of other materials).	Within Order Limits	Medium
Tilbury Power Station	HLU0630	Former fossil fuel power station 1950s to 2013. Major fire in 2012.	Within Study Area	Medium
East Tilbury landfill	HLU0523 HLU0533	Former hazardous waste landfill. Filling dates approximately 1932 to 1990 with recorded industrial, commercial and household wastes and liquids/sludge wastes	Within Order Limits and within Study Area	High
Former railway	HLU0828	Railway cisterns, wells and engine house. Extant prior to	Within Order Limits	Medium

Name	HLU reference number	Description	Location	Risk rating
engine house		1865. Removed between 1967 and 1973.		
Former railway sidings at brickworks	HLU0830	Constructed between 1898 and 1921, possibly removed between 1955 and 1961.	Within Order Limits	Medium
Electricity substation	HLU0804	Constructed approximately 1955-61, still present in 2021.	Within Order Limits	Medium
Low Street landfill	HLU0535	Industrial/ commercial landfill (1969 to 1976).	Within Order Limits	High
Low Street Brickworks landfill	HLU0536	Industrial landfill (1956 to 1977).	Within Order Limits	High
Suspected quarry fill	HLU0515	Suspected partially backfilled disused gravel pit, south of Station Road.	Within Order Limits	Medium
Suspected quarry fill	HLU0537	Suspected area of fill based on historical mapping, south of Station Road.	Within Order Limits	Medium
Metal recycling facility	HLU0512	Current waste processing site including end of life vehicles and metal processing.	Within Order Limits	High
Potentially infilled pit	HLU0819	Large gravel pit east of Courtney Road, excavated from approximately 1960, potentially infilled between 1973-91.	On Order Limits	Medium
Infilled gravel pits east of Brentwood Road	HLU0823 HLU0824	Gravel pits excavated approximately 1915. Infilled between approximately 1938 and 1954.	Within Order Limits	Medium
Vehicle repair and maintenance garage at A13-A128 junction	HLU0949	Former garage and PFS built approximately 1938–1954. Listed as inactive, however buildings and likely fuel storage still present at the site.	Within Order Limits	Medium
Welcome Villa filling station	HLU0960	Former filling station (approximately 1960 onwards), now residential property. Tanks may still be present.	Within Order Limits	Medium
Millers sand and gravel pit landfill	HLU0943	Historical landfill (1948-1965), commercial and household wastes. Gravel pit excavated approximately 1938-55, removed from historical maps 1965-75.	Within Order Limits	Medium

Name	HLU reference number	Description	Location	Risk rating
Infilled gravel pit	HLU0940	Gravel pit for the extraction of sand and gravel from approximately 1895. Potentially infilled post 1960.	Within Order Limits	Medium
Former works (unspecified) and garage at Baker Street.	HLU0944	Former garage with repair, spray painting and refuelling facilities Mapped from 1955 until approximately 1993	Within Order Limits	Medium
Ockendon Grays Areas II & III Landfill	HLU1062	Active Veolia non-hazardous and inert landfill. Filled 1974 to present.	Within Study Area	Medium
Potential Asbestos-containing irrigation pipes, Hall Farm.	HLU1151	Subsurface irrigation pipes may contain asbestos.	Within Order Limits	Medium

10.4.113 Five of the six high-risk sources that were identified are landfill sites (Goshems Farm (HLU0526), East Tilbury (HLU0523 and HLU0533), Low Street (HLU0535), Low Street Brickworks (HLU0536), which are discussed in more detail in the landfill section below.

10.4.114 The sixth high-risk source is a metal recycling facility and industrial estate (HLU0512), which processes and recycles scrap metal from local activities such as the dismantling of the former Tilbury Power Station (HLU0630). A ‘works’ has been indicated on the site since 1961. Prior to this, the site was shown as a brickworks and gravel pit between 1885 and 1921.

10.4.115 In addition to the medium and high-risk contaminant sources, over 125 low-risk credible sources were identified to the north of the Thames. Further details can be found in Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3).

Landfills

10.4.116 As detailed in the above sections, most of the high-risk credible sources of contamination are landfill sites. Five credible sources relating to landfills were given a risk rating of high-risk (HLU0526 – Goshems Farm Landfill, HLU0523 – East Tilbury Landfill, HLU0533 – East Tilbury Landfill – northern extension, HLU0535 - Low Street Landfill, HLU0536 - Low Street Brickworks Landfill), all are located to the north of the River Thames and further details are provided below. These are all included within the Order Limits, with the exception that East Tilbury Landfill is mainly outside the Order Limits but within the study area.

10.4.117 The landfill sites discussed can be identified in Figure 4 of the Preliminary Risk Assessment Report (Application Document 6.3) via the HLU reference number.

10.4.118 It is noted that there may be unrecorded or pre-1947 Planning Act landfill sites, such as infilled quarries and gravel pits, which may not have been detailed in the Environment Agency or local authority data, and therefore may not have been reported. Following best practice, historical quarries and gravel pits detailed on historical mapping have however been considered within Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3) and therefore all available information has been captured and considered within the desk study. If unrecorded landfill sites are encountered during excavation works, the risk is considered to be negligible due to the age and type of the material (predominately ash) that would be encountered. This would be managed under the mitigation measures detailed in Section 10.5.

10.4.119 Thurrock Council and London Borough of Havering provided information on landfill sites within their district. This information has been summarised into the appropriate sections below and incorporated for consideration within the Project CSM presented in the Preliminary Risk Assessment Report (Application Document 6.3).

South of the River Thames

10.4.120 To the south of the River Thames, there were two historic landfill sites identified, both were designated low risk following the assessment in the Preliminary Risk Assessment Report (Application Document 6.3). Filborough Farm (HLU0413 and HLU0422), located to the north of Lower Higham Road, received inert and commercial waste until 1991. Denton-Comma Oil landfill (HLU0443), a former inert waste landfill, is believed to have accepted waste between 1966 and 1981.

North of the River Thames

Goshems Farm Landfill

10.4.121 Goshems Farm (HLU0526), a large area of historic landfilling, is situated in the area of the proposed North Portal. This landfill site is a land raise as material was placed directly onto the existing ground. It is understood that the landfill ceased accepting waste in 1958. The start date is unknown but likely to have been in the late 19th and early 20th century. It is currently undergoing permitted capping and land restoration operations, accepting inert material from infrastructure projects in central London. It is understood that there may be waste including industrial waste, dredgings, household and ash, deposited between 6 and 8m in thickness.

10.4.122 Immediately north and west of Goshems Farm landfill are the Tilbury Ash Disposal sites (HLU0527 to HLU0532). PFA originating from the former Tilbury Power Station (HLU0630) is known to have been deposited at the existing surface. Natural geological material is not believed to have been excavated, prior to landfill operations taking place. A report prepared by RWE (RWE Npower, 2004) stated that disposal operations involve shallow land raise to a maximum of 6m AOD. Observations recorded during the site walkover indicated that areas of the PFA landfill have been recently excavated for reuse as construction materials, while other areas remain capped and grassed over.

East Tilbury Landfill

10.4.123 The East Tilbury former co-disposal hazardous waste landfill site (HLU0523, HLU0533) is directly adjacent to the eastern side of Goshems Farm landfill and approximately 300m east of the proposed North Portal site. The East Tilbury landfill was active from 1930s to September 1990 and covers an approximate area of 84ha. A site specific CSM relating to the East Tilbury landfill site was prepared using relevant information received through consultation with the Environment Agency in July 2018 and a review of available desk study information. This is presented in Appendix 10.7 (Application Document 6.3) together with a risk assessment of the potential pollutant pathways which may be present based on the baseline condition.

10.4.124 The main source of information relating to the operation and conditions of the landfill comprises a status report written in 1993 by Callear and Brewers (Callear & Brewers, 1993). The status report which was prepared for the National Rivers Authority and provided as information by the Environment Agency, was prepared during the time that the landfill restoration was occurring.

10.4.125 Records indicate that approximately one million cubic metres of domestic, commercial and industrial waste including hazardous materials and liquid/sludge wastes were deposited in the landfill. It is understood from the information provided that the liquid waste was not contained in drums but pumped into trenches and allowed to disperse within the waste.

10.4.126 It is understood from the Environment Agency that the landfill was unlined and formed a land raising above the existing low-lying area. The landfill is underlain by Alluvium overlying the River Terrace Deposits and Chalk. The Alluvium contains clayey layers that may have provided a low-permeability barrier between the land raise and the underlying river deposits and chalk aquifer.

10.4.127 During initial landfill operations, no engineering pollution control measures were in place. In 1978, dual drainage ditches were constructed around the perimeter to prevent leachate being generated and spreading into the surrounding area. Excess leachate not collected from the inner drainage ditch was discharged into the River Thames via Bowater Sluice.

10.4.128 No records detailing landfill gas concentrations being generated have been made available but given the nature of the materials deposited, it is very likely that gases are still being generated within the landfill.

10.4.129 The East Tilbury Landfill Risk Assessment (Application Document 6.3, Appendix 10.7) assessed the risk of contaminant mobilisation from the East Tilbury Landfill site occurring during the dewatering activities which are required to facilitate North Portal construction works.

10.4.130 The qualitative assessment concluded that lateral migration pathway within the Alluvium is unlikely to be present due to the cohesive nature of the Alluvium resulting in discontinuous groundwater. The quality of the RTD and Chalk aquifers was also not considered to be at additional risk, primarily due to lack of hydraulic connection of perched water in the Alluvium with the underlying RTD and Chalk, in addition to the upward head present in these units.

10.4.131 Conservative quantitative fate and transport modelling was undertaken using ConSim, to assess the travel times of potential contaminants to several compliance points located between the landfill (source) and the North Portal (receptor) to give an understanding for the potential for contaminant mobility as a result of construction dewatering. The model assumed a continuous waterbody in the Alluvium is present as a worst-case scenario and does not take into account any mitigation measures present within the proposed North Portal design.

10.4.132 The ConSim model indicated that groundwater contamination resting in the Alluvium beneath East Tilbury Landfill would take a minimum timeframe in the order of decades to reach the North Portal excavation during dewatering. As the duration of dewatering is likely to be as a worst case up to 3 years, groundwater contamination resting in the Alluvium beneath East Tilbury Landfill was therefore not considered to present a significant risk to the North Portal excavation or surrounding environment.

10.4.133 It is important to note that this modelling was undertaken as a worst-case scenario assuming migration of CoC within the Alluvium can occur via a continuous groundwater body. In reality, the water encountered within the Alluvium was found to be perched and discontinuous, resulting in an overly conservative assessment. In addition to this, the proposed dewatering is planned to draw on groundwater from the RTD and Chalk aquifers, which are not in continuity with water encountered within the Alluvial deposits, this adds a further degree of conservatism to the modelling, which assumes that drawdown within those aquifers can have an impact on the Alluvium.

10.4.134 Also, according to the East Tilbury Landfill Risk Assessment Report (Application Document, Appendix 10.7), the East Tilbury Landfill is a raised landform, and was constructed on top of the Alluvium. It was considered that ground gases generated within the adjacent East Tilbury Landfills are unlikely to migrate laterally towards the North Portal. The dewatering at North Portal is unlikely to have a drawdown effect on the groundwater head present within the landfill rise, the made ground and the Alluvium, with no effect on ground gas mobilisation. In addition, any ground gases generated from within the land raise, or from the organic content within the Alluvium, is likely to preferentially migrate upwards as the landfill is not engineered to control ground gases.

10.4.135 In conclusion, the East Tilbury Landfill Risk Assessment (Application Document 6.3, Appendix 10.7) assessed the risk of contaminant mobilisation from the East Tilbury Landfill site occurring during the dewatering activities which are required to facilitate North Portal construction works. The risk assessment comprised a qualitative and quantitative element to determine the level of risk present from dewatering to potentially mobilise CoC within the East Tilbury landfill. The risk assessment concluded that regardless of mitigation measures adopted during the construction phase, no pollutant pathway linkages were present that would result in deterioration of the aquifer quality, nor impact human health, during the construction phase.

Other Landfills

10.4.136 Low Street landfill (HLU0535) and Low Street Brickworks (HLU0536) which are both considered to be high-risk credible sources, are adjacent to the south-east of the Tilbury Loop railway line. Low Street landfill received industrial and commercial waste between 1967 and 1969 and is currently used for lorry turning and skip storage by the adjacent scrap metal yard. Low Street Brickworks received industrial waste between 1956 and 1977 and is now a scrap metal yard.

10.4.137 In addition to the high-risk credible sources detailed above, two landfill sites north of the River Thames were considered to be medium-risk credible sources of contamination. These are Ockendon Grays Areas II and III Landfill (HLU1062) and Millers sand and gravel pit (HLU0943).

10.4.138 The Ockendon Grays Areas II and III Landfill is an active landfill site operated by Veolia. Clay was extracted from the area around 1928 and infilling began in 1977. Waste accepted was household, asbestos, non-hazardous industrial and commercial.

10.4.139 The Millers sand and gravel pits landfill adjacent to the A13, received commercial and household waste between 1948 and 1965. No evidence of the landfill was identified during the site walkover survey and a housing estate (Baker Street) has been built on the western edge of the former landfill and former petrol filling station/works yard.

10.4.140 Buckingham Hill landfill (HLU0864) is one of the nitrogen deposition compensation sites. This is a former sand and gravel pit (excavated approximately 1949 to 1962) infilled with household waste from approximately 1967 to 1990. Landfill base presumed unlined within the Thanet Formation. Maximum waste depth is reported as 15m (Thurrock Council, 2020). There is a current household waste and recycling centre on the eastern section of the site which is still operational. At the Tier 1 stage (Preliminary Risk Assessment) this landfill is assessed to have a low-risk rating.

10.4.141 Additional landfill sites were identified within the study area and defined as low-risk credible sources. These are described within the Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6) and presented in Figure 4 of the Preliminary Risk Assessment Report.

Encountered contamination

Phase 1 Investigation

10.4.142 Six of the potential contamination sources identified in the PRA report were broadly within the area of the Phase 1 Ground Investigation. Geotechnical testing was carried out at each location, with environmental samples collected from exploratory holes drilled in three of the six locations as detailed below:

a. Goshems Farm landfill (HLU0526)

b. Tilbury Ash Disposal (HLU0527 to HLU0533)

c. Land adjacent to the Southern Valley Golf Course

10.4.143 A total of 110 soil samples from 29 locations (16 north of the River Thames and 13 to the south of the Thames) were sent for laboratory analysis. The samples were taken from a range of different strata as detailed in Table 10.14.

Table 10.14 Sampling depth and associated strata

Geology strata	Depth range of samples (metres below ground level (m bgl))	Number of samples taken
Topsoil	0.0-0.4	5
Made ground	0.2-8	43
Head Deposits	0.4-1.5	13
Alluvium	1-23.3	21
River Terrace Deposits	1.8-24.5	13
Chalk	0.9-30.8	15

Phase 2 Investigation

10.4.144 The Phase 2 investigation works were split into four packages (Packages A to D) as detailed in Section 10.3. Full details of the numbers of samples analysed and from which strata are included in Appendix 10.9: Generic Quantitative Risk Assessment Report for the Phase 2 Investigation (Annex A–D) (Application Document 6.3).

10.4.145 During the Phase 1 and 2 Ground Investigation works, soil and groundwater samples were analysed for a suite of contaminants including asbestos (soil only), metals, non-metals and organics (total petroleum hydrocarbons (TPH), PAH, phenol). Other contaminants such as VOCs, SVOCs, pesticides, explosives, PCBs and organotins were analysed in specific areas due to the potential contaminative sources in those areas. The analysis undertaken is detailed within Appendix 10.9: Generic Quantitative Risk Assessment Report for the Phase 2 Investigation (Annex A–D) (Application Document 6.3).

Assessment Criteria

Soil Screening

10.4.146 The soil results were screened against the current Suitable for Use Levels (S4Uls) (Nathanail et al., 2015) for public open space (residential) which is considered to be the appropriate land use scenario for the Project. This land use scenario is considered to be the most conservative screening scenario which applies to the Project and the identified receptors. In the absence of a S4UL for lead, the C4SL (CL:AIRE, 2014) were adopted. A Soil Organic Matter content of 1% has been used in the assessment, which provides the most conservative of the S4UL criteria. This was the Tier 2 assessment as detailed in the methodology in Section 10.3.

Groundwater, Surface Water and Soil Leachate Screening

10.4.147 For groundwater and soil leachate assessment, the results were screened against GACs from the UK Drinking Water Standards (DWS) and Environmental Quality Standards (EQS), which are considered protective of aquifers and surface waters respectively. The DWS are generally adopted from the Water Supply (Water Quality) Regulations 2016 and the EQS are primarily from the Water Environment (Water Framework Directive) (England and Wales) Regulations 2017. For the screening of surface water (in relevant packages only), the Freshwater and/or Saline EQS have been adopted depending of the surface water in relation to the River Thames. The EQS for copper, lead, manganese, nickel and zinc are based on bioavailable values so are considered to be conservative screening values.

10.4.148 It should be noted that soil leachate analysis represents a conservative estimation of risk as the comparison of eluate concentrations (derived from laboratory soil leaching tests) with surface water and groundwater quality standards does not factor in the potential for attenuation of concentrations in the pathway between the soil source and the receptor i.e. in the unsaturated zone with potential for dilution at the water table or dilution in the receptor itself.

Gas Screening

10.4.149 A generic screening of the methane and carbon dioxide results has been carried out against a 1% v/v methane and 5% v/v carbon dioxide threshold. For Package B, a carbon dioxide screening criteria of 1.5% v/v based on the short-term workplace exposure limit (HSE, 2020), has been used given the area conceptually has a high-risk ground gas regime compared to the other package areas. In addition, the hydrogen sulphide and carbon monoxide results have been screened directly against long-term workplace exposure limits (HSE, 2020) of 5ppm and 30ppmm respectively. This is in line with the guidance from Construction Industry Research and Information Association (CIRIA) Assessing Risks Posed by Hazardous Ground Gases to Buildings (C665) (CIRIA, 2007) and British Standard (BS) 8485: Code of Practice for the Design of Protective Measures for Methane and Carbon Dioxide Ground Gases for New Buildings (British Standards Institution, 2019).

Characterisation

10.4.150 Exceedances of contaminants were recorded in samples taken from Packages A to D during the Phase 2 Ground Investigation works as detailed in sections below. The assessment of the chemical data has been undertaken and the findings are presented in the Appendix 10.9: Generic Quantitative Risk Assessment Report for the Phase 2 Investigation (Annex A–D) (Application Document 6.3).

10.4.151 Where exceedances have been detected, remedial action or risk management may be required to reduce the overall impact. Further information on measures to manage contamination during the construction and operation phases are presented in Section 10.5.

10.4.152 The tables below summarise the findings of each package. The results from the Phase 1 investigation combined with the Phase 2 investigation are considered within the relevant packages.

Table 10.15 Package A – south of River Thames

Summary of exceedances encountered
Soil • Twenty soil samples from 18 locations, out of the 481 samples tested (145 locations), recorded exceedances of the GAC for metals (arsenic and lead) and Polycyclic Aromatic Hydrocarbons (PAH). The exceedances were within one order of magnitude of the applicable GAC. • The samples recording exceedances were primarily collected from the made ground, with two exceedances recorded in samples collected from Topsoil and the Thanet Sand Formation. • Asbestos fibres were detected by the laboratory in four soil samples, collected from the Southern Valley Golf Course (HLU0324). The fibres were interpreted as chrysotile asbestos in three of the samples (BH02003, WS02002 and WS20005) and amosite asbestos in one sample (WS02007). The quantity of fibres in two of the samples was recorded as below the limit of detection (0.001%). Asbestos was listed as a potential contaminant of concern (COC) for the Southern Valley Golf Course, and thus the asbestos soil contamination identified is reflective of this source. • The PAH and arsenic soil contamination recorded in the natural soils of TP02301 and WS01018, respectively, are considered to be attributed to background soil concentrations from diffused contamination or localised inclusions windborne and deposited, from the wider area. The soil contamination identified in the remaining soil samples and locations are considered to be reflective of anthropogenic materials within the made ground. • Photo-Ionisation Detector (PID) testing results were generally low, with only one result above 50ppm (BH01034 at 1.20-1.30m, 60.7ppmv). This PID result was taken from a sample of made ground and correlated with marginal exceedances of the GAC for PAH compounds. A strong hydrocarbon odour was noted on the corresponding exploratory hole record during drilling.
Soil leachate • Soil leachate analysis was undertaken on 435 samples collected from 145 locations. Of those samples, 378 samples from 119 locations recorded exceedances of the GAC. • The contaminants which exceeded the GAC included heavy metals and inorganics. No organic contaminants were scheduled for soil leachate analysis, due to the aggressive nature of the test. The soil leachate samples recording exceedances were collected from a range of strata, from depths between the surface and 10.00m. • There are no discernible geospatial patterns or hotspots in the locations where exceedances were recorded. As exceedances were recorded across the route, within most strata (made ground and natural strata) and at a range of depths, it is unlikely that they represent the presence of an unacceptable source of contamination. They are, however, considered to represent indicative natural background soil concentrations along the route. • Given the above, there is not considered to be an unacceptable risk from soil leachate to controlled waters present in Package A area.
Groundwater • Out of the 374 groundwater samples analysed, 372 samples collected from 43 locations, during the ground investigation (GI) and long-term monitoring (LTM) phases, recorded exceedances against the GAC. • The determinands with widespread exceedances comprised heavy metals, inorganics, and organics (PAH, TPH). Discrete exceedances were also recorded for BTEX (BH01020 and BH01025) and MTBE (BH01025).

Summary of exceedances encountered

- The samples recording exceedances were collected from locations screened within the Alluvium, River Terrace Deposits, Harwick Formation, and the White Chalk Subgroup (hereafter referred to as Chalk).
- The widespread heavy metal and inorganic groundwater exceedances were considered to be reflective of natural background conditions or diffused contamination, given their random geospatial distribution across the Package A area.
- The heavy metal and inorganic groundwater exceedances in the BH04000, BH05000, WS04000, and WS05000 series monitoring wells were considered to be attributed to saline intrusion, given their corresponding high chloride groundwater concentrations, an indicator of saline intrusion within inland groundwaters.
- The BH04000, BH05000, WS04000 and WS05000 series locations, as well as associated credible contaminative sources (e.g., Filborough Landfill and Milton Rifle Range), are located above the bored tunnel in the Package A area. No excavation works are anticipated to the north of the south tunnel portal and therefore any groundwater exceedances in the above-mentioned location series can be discounted from the risk assessment.
- Discrete groundwaters exceedances, which were repeatedly one or more orders of magnitude above the GACs, were recorded in BH01002, BH01020, BH01025, and BH01033. The inorganic groundwater exceedances in BH01002 are considered to be representative of natural background concentrations within the Harwick Formation. Petroleum hydrocarbon groundwater exceedances identified in the remaining locations have been linked to credible sources of contamination located up hydraulic gradient, such as PFS North (HLU0214), and a poultry farm (HLU0218). The PFS North site has been remediated, and residual groundwater conditions signed off by the Environment Agency. The source of the petroleum hydrocarbon groundwater exceedances has not been quantitatively confirmed. Should petroleum hydrocarbon impacted groundwaters be encountered by the Project development works, the contaminated groundwaters would be managed by commitments secured through their inclusion within the REAC (GS001, GS027, and GS028). These are described in Section 10.5.

Ground Gas

- Ground gas monitoring was undertaken at 73 locations over the period of August 2019 to January 2021, the results of which were reviewed. The number of monitoring visits at each location is included in the Package A report.
- Ground gas exceedances were recorded in BH02304, WS01005, WS04005, WS04007 and WS05001, during the monitoring programme. In addition, fluctuating negative to positive flow rates were recorded in monitoring wells across the Package A area. These observations were made following the removal of unrepresentative data from flooded monitoring wells.
- The highest peak methane exceedance was recorded in WS01005 at 40% v/v. The highest steady state carbon dioxide exceedance of 12% v/v was recorded in WS04007. BH02304 recorded the highest peak hydrogen sulphide and carbon monoxide exceedances of 130ppm and 1,500ppm, respectively.
- The peak flow rates recorded in wells during the monitoring programme ranged from -53.2l/hr to 96l/hr (both in BH05011). The steady state flow rates ranged from -9.4l/hr (in BH01013) to 12.4l/hr (in WS04007).
- A total of 570 PID readings were recorded during the monitoring programme, with the highest reading being recorded at 38.3ppm in WS05005.
- These ground gas exceedances and highly variable flow rates are considered to be associated with the Alluvium but influenced by external conditions (eg wind, tidal influence) within the monitoring wells and flow meters, rather than credible anthropogenic ground gas sources.

Summary of exceedances encountered
• The proposed south portal (bored tunnel entrance) would be excavated through made ground, Head deposits and then the Chalk. In the vicinity of the BH04000 series boreholes, the majority of the bored tunnel is anticipated to be below the Alluvium within the Chalk. Ground gas exceedances have been recorded within the Alluvium, however, these gases tend to migrate upwards or laterally, rather than downwards so away from the tunnel. Furthermore, the made ground and superficial deposits are considered to have very low to low ground gas generation potentials. • As the wells were not specifically installed for ground gas monitoring, there is some uncertainty with the concentrations which have been recorded. However, a low-risk ground gas regime, equivalent to Characteristic Situation 2 (CS2), has been identified based on the CSM, field descriptions and ground gas results to date. Therefore, it is considered that the risks posed to those working in utility corridors or the bored tunnel would be managed through the implementation of ground gas protection measures outlined in Appendix 10.11: Remediation Options Appraisal and Outline Remediation Strategy (Application Document 6.3) and secured through their inclusion in the REAC (GS018 and GS027).

Table 10.16 Package B – North of River Thames to Tilbury and Southend Railway line

Summary of exceedances encountered
Soil • Soil samples from 53 out of the 105 locations tested recorded exceedances of the GAC for metals and polycyclic aromatic hydrocarbons (PAH). The samples recording exceedances were collected from the made ground (141 samples) and the natural ground (3 samples). The majority of locations recording exceedances were found within the Goshems Farm Landfill (HLU HLU0526), with a single location within agricultural land, which is assigned to no credible contaminant source. Most of these of the exceedances were considered to be marginal, as they fall within the same order of magnitude as the GAC. • Three exceedances were recorded that were greater than one order of magnitude above the GAC. These were all for Lead and were recorded in soil samples collected from within the boundary of Goshems Farm Landfill (HLU0526). • Asbestos containing materials and fibres were detected in 64 soil samples in 37 locations, with fibre concentrations ranging from <0.001% to 4.015% weight by weight (w/w) from quantification analysis. The highest asbestos fibre concentration (4.015%w/w) was recorded in OH07036 at a depth of 2.00m bgl in Goshems Farm. 12 samples from 11 locations recorded quantification results above 0.1% w/w. Visible asbestos containing materials were confirmed in six samples from five locations. Chrysotile asbestos was confirmed in 12 samples (7 locations), amosite asbestos in 6 samples (5 locations), and crocidolite asbestos in 1 sample. The majority of the asbestos fibres detected were in the made ground of the Goshems Farm Landfill (HLU0526), with one asbestos fibre detection (TP08004 at 1.00m) in the made ground of the Low Street Landfill (HLU0535) and one asbestos fibre detection (WS08001 at 0.05m) in made ground associated with agricultural land. • Photo-Ionisation Detector (PID) testing results were generally low, with only one result above 50ppm, recorded in a sample of made ground in BH07094 located within Goshems Farm Landfill. Marginal exceedances of PAH compounds were recorded in the soil sample taken from this location and an ‘occasional hydrocarbon sheen’ were noted during the drilling of this borehole.

Summary of exceedances encountered
Soil leachate • Leachate analysis was undertaken on 1,107 samples collected from 105 exploratory locations. In total, 1,105 samples recorded at least one exceedance of the GAC. The majority of the exceedances recorded were marginal and within same order of magnitude as the GAC. • The determinands which exceeded the GAC comprised metals, inorganic compounds and phenol. The samples recording exceedances were mainly collected from the made ground and Alluvium. • Of the 105 exploratory locations, 84 locations are located within the boundary of a credible source of contamination identified in the Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6). These include 77 locations within Goshems Farm Landfill (HLU0526), five within Shed Marsh Landfill (HLU0534) and two within Low Street Landfill (HLU0535). • The soil leachate exceedances from the made ground within landfills and Alluvium immediately below them are considered to be reflective of the credible contaminative sources identified in the Preliminary Risk Assessment Report. However, soil leachate exceedances located outside the landfills or within the underlying River Terrace Deposits and Chalk are considered to be representative of natural background concentrations.
Groundwater • A total of 182 groundwater samples were collected from 73 locations. • No exceedances were noted against the internally derived GAC in relation to human health receptors. • Widespread exceedances of the controlled waters GAC were recorded for heavy metals, inorganics, speciated PAH, TPH, BTEX and phenols. In addition, discrete GAC exceedances were recorded for Di-n-butyl phthalate (BH07056 and OH06008), pesticides (BH07096, OH06008, and OH07035), Tributyltin (BH07010) and Total PFAS (BH07097). • The majority of these exceedances were recorded in groundwater samples collected from the made ground. However, the concentrations of TPH groundwater exceedances in the natural ground were generally an order of magnitude greater than those within the made ground. • The controlled waters GQRA indicates that although the landfill sites have impacted groundwaters in the made ground and Alluvium, they are not in hydraulic continuity with and are not impacting deeper more sensitive aquifers and the River Thames. • Groundwaters within the River Terrace Deposits and the Chalk appear to have been impacted by saline intrusion and up hydraulic gradient sources of hydrocarbon contamination, rather than the overlying landfill sites.
Sediment from drainage channels • Sediment samples from two (GS07003 and GS07006) of the 15 locations tested recorded exceedances of the GAC for lead. Asbestos was detected in soil sediment sample at GS07004 at 0.20m depth. • Two of the above mentioned locations are present along the boundary of the East Tilbury Landfill (HLU0523) while one lies within the Goshems Farm Landfill (HLU0526). The sediment contamination detected is considered to be associated with the adjacent landfills as lead and asbestos are listed as potential contaminants of concern within the Appendix 10.6: Preliminary Risk Assessment Report (Application Document 6.3) for these credible contaminative sources.

Summary of exceedances encountered
Sediment leachate from drainage channels • The sediment samples from the drainage channels were subjected to leachate analysis. All 15 sediment leachate samples recorded at least one exceedance of the GAC. The determinands which exceeded the GAC included metals, inorganic compounds and phenol. • The 15 sampled locations recording exceedances are within 10m of a credible source of contamination (East Tilbury Landfill, Goshems Farm Landfill, Tilbury Ash Disposal Site and Shed Marsh Landfill) identified in the Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6). Therefore, the sediment leachate results are considered to represent existing baseline conditions which are present in the Package B area.
Surface water • All of the surface water samples (15 samples from 15 locations) recorded exceedances of the GAC protective of surface water receptors. The determinands which exceeded the GAC comprised metals, inorganics, and organics (PAH). • Of the 15 surface water sample locations, 10 locations are within the boundary of a credible source of contamination, which included Tilbury Ash Disposal Site (HLU0527 to HLU0530), East Tilbury landfill (HLU0523), Goshems Farm Landfill (HLU0526) and Shed Marsh Landfill (HLU0534). The remaining five locations are all between one to 12m from their closest credible source of contamination identified in the Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6). Consequently, the surface water samples are considered to be reflective of the existing baseline conditions which are present in the Package B area.
Ground gas (periodic monitoring) • Periodic ground gas monitoring was undertaken in 50 locations. • For the purposes of the assessment threshold, values of 1% v/v and 1.5% v/v were adopted for methane and carbon dioxide respectively. A more stringent carbon dioxide threshold value was selected for the risk assessment, given the conceptually high-risk ground gas regime and proposed temporary sleeping accommodation on site. Long-term Workplace Exposure Limits were adopted as threshold values for hydrogen sulphide and carbon monoxide. Concentrations of these gases above the threshold is considered to be an exceedance. • Data from flooded monitoring wells were eliminated from the ground gas risk assessment as the readings are anomalous and considered not representative of the true ground gas regime of the surrounding unsaturated ground conditions. • Methane and carbon dioxide exceedances were recorded in up to 18 locations during the periodic ground gas monitoring programme. The maximum methane concentration recorded was 99%v/v in BH07046 and the maximum carbon dioxide concentration recorded was 36.1%v/v in BH07011. • Hydrogen sulphide exceedances were recorded in seven locations during the periodic monitoring gas monitoring programme, with a maximum concentration of 80ppm recorded in BH07046. Carbon dioxide exceedances were also recorded in eight locations during the monitoring programme, with a maximum concentration of 390ppm recorded in BH07034. • Steady state flow rates recorded in wells during the monitoring programme ranged from -14.4l/hr to 26.9/hr. • Sustained ground gas exceedances over multiple visits were primarily recorded in locations screening the made ground of the landfills and the Alluvium. Therefore, the ground gas exceedances recorded are considered to be representative of Goshems Farm Landfill (HLU0526), Shed Marsh Landfill (HLU0534) and the Alluvium. This conforms to the initial CSM outlined in the PRA report. • The ground gas concentrations and flow rates recorded in the unsaturated zone indicates the landfill sites have a high-risk ground gas regime, equivalent to Characteristic Situation 5

Summary of exceedances encountered
(CS5) (High Risk) and the underlying Alluvium has a low-risk ground gas regime, equivalent to CS2. • Given the Goshems Farm Landfill and East Tilbury Landfill are raised landforms built on cohesive Alluvium and located in an area of high groundwater levels, ground gases generated within the landfill are unlikely to migrate laterally beyond their boundaries. • The ground gases detected in the Alluvium, particularly the peat, have been generated historically, and are trapped within pore spaces of the soils in this formation. Within the addition of high groundwaters levels in the area, it is considered that ground gases within the Alluvium are unlikely to migrate laterally any significant distance into the wider area.
Ground gas (continuous monitoring) • Continuous ground monitoring was undertaken in up to 25 locations, recording both ground gases and dissolved methane. All monitoring wells are located within the boundary of the Goshems Farm Landfill. • Methane and carbon dioxide exceedances were recorded in 22 locations during the continuous ground gas monitoring programme. The maximum methane concentration recorded was 74.9%v/v in BH06014 and the maximum carbon dioxide concentration recorded was 25.14%v/v in BH07060. Steady state flow rates ranged from -7.58l/hr to 26.32l/hr during the continuous monitoring programme. • Dissolved methane gas concentrations ranged from 0.01mg/l to 52.95mg/l during the continuous monitoring programme. The highest dissolved methane concentration was recorded in the Alluvium but similarly high concentrations were recorded in the made ground, and chalk. Negative dissolved methane concentrations were recorded which were considered to anomalous and were therefore removed from the risk assessment. • The continuous ground gas monitoring graphs show that ground gases and flow rate fluctuate with changes in atmospheric pressure and groundwater levels. This suggests that the monitoring well response zones represent gas migration pathways rather than gas generating sources. Guidance states that the monitoring graphs for gas generating sources would typically show constant ground gas concentrations that are unaffected by changes in atmospheric pressure. This was not observed in Package B. • The dissolved methane concentrations have no obvious relationship with other monitoring data parameters but suggest that groundwaters beneath the Package B area have been impacted by the Goshems Farm landfill and the Alluvium. • The ground gas concentrations and flow rates recorded during the continuous monitoring programme conform to the initial CSM and the findings of the periodic monitoring programme.
Ground gas and soil vapour (samples) • In total, seven gas samples were collected from seven monitoring wells, targeting the proposed route alignment and north portal, during the monitoring programme, and were analysed for ground gases and volatile organic compounds (VOCs). All monitoring wells were located within the Goshems Farm Landfill. • For the purposes of the assessment threshold, a combination of Workplace Exposure Limits (Health and Safety Executive, 2020) and Environmental Assessment Levels (Environment Agency, 2016) were used to assess the risk from ground gases and VOCs in the unsaturated zone. • The assessment identified widespread elevated carbon dioxide, methane, and depleted oxygen gas concentrations in the made ground and Alluvium, with discrete exceedances of the carbon di-sulphide, tetrachloroethene (PCE), benzene and hexane GAC. • The ground gas concentrations recorded in gas samples conform to the findings of the periodic and continuous ground gas monitoring.

Summary of exceedances encountered
• The VOC exceedances recorded in the gas samples are considered to be dissolved VOCs, associated with a series of organic contaminant plumes in the groundwaters of the made ground and Alluvium, which have come out of solution and collected in the headspaces of monitoring wells. • Construction workers and property could potentially be at risk from ground gases and vapours during the construction work; appropriate mitigation would be applied as described in Section 10.5 and through commitments secured via their inclusion in the REAC (GS018 and GS023).

Table 10.17 Package C Tilbury and Southend Railway line to A13 junction at Orsett Heath

Summary of exceedances encountered
Soil • Four soil samples from two out of the 60 locations tested recorded exceedances of the Generic Assessment Criteria (GAC) for polycyclic aromatic hydrocarbon (PAH) compounds. One sample collected from BH12011 also contained asbestos fibres (below the limit of quantification), identified as chrysotile. • The exceedances were identified in samples interpreted as made ground and Topsoil. • BH12011 is located in Dansand Quarry which is an identified credible source of contamination (HLU0963). Based on the logs from this location it is likely that that the exceedances are reflective of the material present at this location. • WS09009 is located in agricultural land and no anthropogenic material was noted in the exploratory hole log for the position. Given that a credible source of contamination has not been identified in this location and given the lack of visual or olfactory evidence recorded in the exploratory logs, it is likely that the exceedances are related to localised sample inclusions.
Soil leachate • Leachate analysis was undertaken on 170 samples collected from 60 exploratory locations. Of those samples, 147 recorded exceedances of the GAC. The samples recording exceedances were collected from 60 exploratory locations across the Package C area. • The contaminants which exceeded the screening values included metals and inorganics. The samples recording exceedances were collected from a range of strata from depths between the surface and 47.00m. With the exception of BH12011 and WS09009, none of the locations recorded exceedances of the GAC in corresponding soil samples indicating that gross contamination is unlikely to be present or pose a risk to human health receptors. • There are no discernible spatial patterns or hotspots in the locations where exceedances were recorded. As exceedances were recorded across the route, within most strata and at a range of depths it is unlikely that they represent the presence of an unacceptable source of contamination but are considered to represent indicate natural background soil concentrations along the route. • Given the absence of identifiable gross contamination the locations and depths of the samples recording the exceedances distributed randomly along the route and the conservative estimation of leachate analysis there is not considered to be an unacceptable risk from soil leachate to controlled waters present in the Package C area.

Summary of exceedances encountered
Groundwater • Out of the 165 groundwater samples analysed, 151 collected from 20 locations recorded exceedances against the GAC. • The determinands with exceedances comprised metals, inorganics and organics (PAH and Total Petroleum Hydrocarbons (TPH)). One SVOC exceedance was also recorded. • The samples recording exceedances were largely collected from locations screened within the River Terrace Deposits, Thanet Formation or White Chalk. • Metals recorded exceedances in both soil leachate and groundwater samples collected from 17 locations. Soil samples collected from these locations did not record any exceedances of the GAC. • There are no discernible patterns in groundwater exceedances as the positions which recorded the exceedances screen various strata and are generally spread across the Package C area. The exceedances have been repeated over several rounds of monitoring suggesting the concentrations are likely to reflect the background baseline water quality in this section of the route. • While exceedances have been detected in soil leachate samples collected from 17 of the locations recording groundwater exceedances, the absence of any identifiable sources of contamination this suggests there is unlikely to be an unacceptable risk of contamination to controlled waters in the Package C area.
Surface water • Of the 37 surface water samples analysed, 34 samples collected from five locations recorded exceedances of the GAC. • The determinands recording exceedances included metals, inorganics and TPH. Metals and TPH were also recorded in groundwater samples collected from three exploratory locations positioned around the irrigation reservoir at Low Street. No exceedances of the GAC for these determinands were recorded in soil samples from exploratory positions around the reservoir. • The five locations from which the samples were collected are positioned within and around the irrigation reservoir at Low Street which is located approximately 13m north of Tilbury and Southend Railway (HLU0605) and 9m to the north-east of a railway yard industrial area (HLU0540) which are both identified as credible sources of contamination in the Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6). • Determinands recording exceedances were identified in both the surface water samples from the irrigation reservoir at Low Street and surrounding groundwater samples.
Ground gas • Ground gas monitoring was undertaken at 32 locations over the period of September 2019 to January 2021, the results of which were reviewed. The number of monitoring visits at each location is included in the Package C report. There are no proposed built structures within Package C; therefore; there are limited potential receptors which are associated with utility infrastructure (e.g. manholes/chambers) and utility corridors. • Two locations recorded methane above the 1% by volume (v/v) threshold with a maximum concentration of 4.6% v/v. Two locations recorded carbon dioxide concentrations above the 5% v/v threshold with a maximum reading of 12.3% v/v recorded. • At WS12021 concentrations of methane were recorded as 1.6% v/v on one of 16 rounds of monitoring. During this round, flow rates were recorded at a steady state of 8l/hr and a peak of 12l/hr. The atmospheric pressure was 981mbar and noted as rising and the well was noted as dry. Based on the data collected during the round it is likely the result is plausible and represents a worst-case scenario for the location. • During the rounds of monitoring at WS11002 and BH12011 where carbon dioxide exceeded the applied threshold, most of the flow rates were negligible suggesting the readings reflected a static source of ground gas. At WS11002, concentrations are likely to reflect

Summary of exceedances encountered
dissolved gases due to the response zone being flooded throughout the monitoring rounds. Given that flow rates have generally been negligible it is unlikely to be an unacceptable risk to receptors present. At BH12011 made ground and organic deposits were recorded in the exploratory log. • Carbon monoxide readings of 25ppm and 3-26ppm were recorded at BH13008 and BH10004 respectively. The readings were recorded on one round at each location and during other rounds concentrations were 3ppm or below. This suggests the elevated concentrations are likely to reflect erroneous readings. • Hydrogen sulphide recorded at 11 and 12ppm during one round of monitoring at BH13009. During the following round undertaken at the location concentrations ranged from <1ppm to 8ppm. As BH13009 is located in an area of main intrusive earthworks under the main route alignment and only two rounds of monitoring have been undertaken further monitoring by the Contractor during detailed design would be carried out at this location.

Table 10.18 Package D A13 junction at Orsett Heath to M25

Summary of exceedances encountered
Soil • Of 235 soil samples from 83 locations analysed one sample recorded an exceedance of GAC. • The exceedance was for lead and was collected from the Topsoil at CT17009A. The exceedance was marginal and fell within the same order of magnitude as the GAC. • Given that the sample was obtained from natural topsoil with no credible source of contamination identified and the duplicate sample was below GAC, it is likely this exceedance relates to a localised inclusion in this particular sample and as such does not represent an unacceptable risk to human health and can be discounted with no further assessment or remedial works required. • No asbestos was detected above the limit of detection in any of the 232 samples analysed.
Soil leachate • Leachate analysis was undertaken on 230 samples collected from 83 exploratory locations. Of those samples, 219 recorded exceedances of the GAC with 19 samples collected from made ground and 198 collected from natural ground. The samples recording exceedances were collected from 83 exploratory locations across the Package D area. The contaminants which exceeded the screening values included metals, inorganics and phenolics. • The samples recording exceedances were collected from a range of strata from depths between 0.05 and 22.30m. None of the locations recording exceedances of GAC in leachate were reflected in corresponding soil samples indicating that gross contamination is unlikely to be present or pose a risk to human health receptors. • There are no discernible spatial patterns or hotspots in the locations where exceedances were recorded. As exceedances were recorded across the route, within most strata and at a range of depths it is unlikely that they represent the presence of an unacceptable source of contamination but are considered to represent indicate natural background soil concentrations along the route. • Given the absence of identifiable gross contamination the locations and depths of the samples recording the exceedances distributed randomly along the route and the conservative estimation of leachate analysis there is not considered to be an unacceptable risk from soil leachate to controlled waters present in the Package D area.

Summary of exceedances encountered
Groundwater • Out of the 193 groundwater samples from 32 locations analysed, 191 recorded exceedances against relevant GAC for determinands. The majority of exceedances fall within one order of magnitude of the GAC. • The determinands with exceedances included metals, inorganics and organics (PAHs, TPH, VOC, SVOC, BTEX, phenolics and pH. • Exceedances were recorded across several strata and across several monitoring rounds. Monitoring records identify staining and odours in six exploratory positions. • Although elevated concentrations were not observed in samples from all sampling rounds from exploratory holes, groundwater monitoring indicated deterioration of groundwater around the Package D area. • Localised elevated concentrations of TPH and BTEX were recorded in several locations in proximity. There are no identifiable sources of TPH and BTEX in proximity to the exploratory positions and as such elevated concentrations may be a result of a localised plume or possible attributed to credible sources of contamination HLU1062, HLU1059, HLU1030, HLU1051 and HLU0943. • With the exception of TPH and BTEX, there is no discernible trend where exceedances are recorded. Given the lack of any soil samples recording exceedances at the same locations is likely that the concentrations recorded are reflective of background natural baseline conditions. • While exceedances have been recorded in both leachate and groundwater samples, the lack of exceedances observed in soil samples suggests there is no particular contaminative source which attributes to these concentrations, with the exception of those discussed. • It is considered that the groundwater exceedances recorded during the monitoring programme are associated with diffused groundwater contamination and natural baseline quality. Exceedances recorded within the groundwater are not considered to warrant remediation to facilitate construction of the proposed route alignment for the Package D area as there is no particular source that can be targeted.
Ground gas • Ground gas monitoring was undertaken at nine locations over the period of March 2020 to February 2021, the results of which were reviewed. The number of monitoring visits at each location is included in the Package D report. There are no proposed built structures within Package D; therefore, there are limited potential receptors which are associated with utility infrastructure (e.g. manholes / chambers) and utility corridors • Monitoring data from flooded wells has been eliminated as they are not characteristic of the gas flow; therefore, data from two wells was analysed. • Ground gas concentrations for methane, hydrogen sulphide and carbon monoxide were not detected above monitoring instrument detection limits. • One exceedance of the screening criteria (5% v/v) for carbon dioxide was recorded at BH14017 on one monitoring round of eight with a reading of 8.2% v/v. During this round flow rates were not recorded above the equipment limit of detection and the atmospheric pressure was recorded as 1015mbar. Based on the data collected from this location it is likely the result is plausible. • The location falls within 14m of credible source of contamination HLU0943 Millers sand and gravel pit landfill.

Soil and Groundwater contamination

10.4.153 The results from each package show that soil and groundwater contamination is present across the Project, but in general the exceedances are localised and reflect the made ground that has been recorded.

10.4.154 The Phase 2 ground investigation has targeted the main route alignment and areas where proposed intrusive works are planned as part of the construction phase. Where exploratory locations have recorded an exceedance of the applicable GAC and fall within a credible source of contamination identified within the CSM, it suggests that the exceedances may be reflective of impacts from that particular source and the presence of a complete pollutant linkage. Where the GAC are exceeded, the results have been evaluated to determine whether the level of risk is acceptable or whether further assessment would be required to be completed at the detailed design stage of the Project.

10.4.155 The results of the GQRA have been assessed in terms of the identified credible sources of contamination to refine the CSM for the Project. This has been undertaken for the credible source of contamination for each package and has included an assessment of the project alignment and proposed works following best practice and taking into account the measures secured within the Code of Construction Practice and REAC (Application Document 6.3, Appendix 2.2). The sources were given a revised risk rating on this basis.

10.4.156 The refined CSM across the Project has identified one high-risk credible sources of contamination,15 medium-risk sources with the remaining credible sources being rated as low risk. Of the low-risk sources, 100 have been assessed as needing no further assessment and the remaining 102 low-risk sources would be sufficiently managed by the measures secured within the Code of Construction Practice and the REAC (Application Document 6.3, Appendix 2.2).

10.4.157 Goshems Farm Landfill (HLU0526) has been identified as a high risk within the Package B area. The risk rating is based on the refined CSM which takes into consideration the project alignment and proposed works within the HLU. Goshems Farm Landfill has been identified as a potentially significant source of pollution to surface and groundwaters and potentially significant source of landfill gas that could impact the route in the vicinity of the north portal. The potential source may be disturbed by proposed construction or operation activities and as such a pathway may be created. Therefore, there is a possible plausible pollutant linkage. The potential source requires further assessment and possible remedial works / specific design which would be undertaken by the Contractor at detailed design (as committed to in GS001 in REAC).

10.4.158 The revised risk ratings for each credible contamination source based on the findings of the GQRA presented in Annex A-D of Appendix 10.9 (Application Document 6.3) are presented in Figure 10.5 (Application Document 6.2).

10.4.159 The medium-risk sites identified for each package are detailed in Table 10.19.

Table 10.19 Summary of medium-risk credible contaminant sources within the refined CSM

HLU	Reason
Package A	
Esso A2 Westbound Petrol Filling Station (PFS) (HLU0215)	An operational PFS and has not been subjected to a targeted ground investigation. There are currently no boreholes or monitoring wells located onsite that are down hydraulic gradient or within the vicinity of the underground fuel storage tanks. Heavy metal and inorganic soil leachate exceedances have been recorded on site, but these are considered to be reflective of natural background concentrations. The site is within the footprint of the main route alignment and any associated contaminants are likely to be disturbed as part of the development works. As the contamination status of the site is not fully understood, data gaps and uncertainties remain which require further consideration at the construction phase of the Project.
Nursery (HLU0330)	Uncertainty remains in this HLU regarding the presence of potential contamination due to limited investigation work in this area as noted from the Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6). Further assessment would be undertaken by the Contractor at detailed design (as committed to in GS001 in REAC).
Southern Valley Golf Course (HLU0324).	The results of the ground investigation have indicated the presence of contaminants such as lead, asbestos fibres, and PAH soil contamination in made ground and natural soil samples taken from the golf course. Specific management to mitigate risks to identified receptors would be required. A residual risk remains which would require further assessment and/or remedial works to be considered.
Package B	
Tilbury Ash Disposal Site – Area C2 (HLU0527)	These potential sources are located within or adjacent to the main works area for the north portal. Intrusive utility works are proposed in the area of these potential sources. The potential sources are likely to be disturbed by proposed construction or operation activities and as such a pathway may be created. Therefore, there is a possible plausible pollutant linkage. The potential source requires further assessment and/or possible remedial works. Further assessment would be undertaken by the Contractor at detail design (as committed to in GS001 in REAC).
Tilbury Ash Disposal Site – Area C (HLU0528)	
Tilbury Ash Disposal Site – Area B (HLU0529)	
Tilbury Ash Disposal Site – Area A3 (HLU0530)	
Tilbury Ash Disposal Site – Area A2 (HLU0531)	
Tilbury Ash Disposal Site – Shed Marsh Landfill (HLU0534)	
Low Street Landfill (HLU0535)	The site is located at the proposed main route alignment where the route is elevated on viaduct and at proposed intrusive utility works.

HLU	Reason
	The potential source may be disturbed by proposed construction or operation activities and as such a pathway may be created. Therefore, there is a possible plausible pollutant linkage.
Package C	
Welcome Villa Petrol Filling Station (HLU0960)	No ground investigation undertaken within HLU; therefore, uncertainty remains regarding the presence of potential contamination noted from the Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6).
Dansand Quarry (HLU0963)	The presence of PAH, asbestos and metals within soil and leachate samples indicates that the material would require specific management to mitigate risks to identified receptors. A residual risk remains which would require further assessment and/or remedial works to be considered.
Buckingham Hill Landfill (HLU0864)	The potential source is to be utilised as a nitrogen deposition compensation sites, intrusive activities may be required to develop the area. The potential source may be disturbed by proposed groundworks and as such a pathway may be created. Historical reports reviewed indicates impact of landfill gas on crop growth. Therefore, there is a possible plausible pollutant linkage. Further information is presented in Annex D of Appendix 10.6.
Package D	
Ockendon Grays Areas II and III Landfill (HLU1062)	The absence of exploratory positions within the HLU and given the proposed intrusive works, the potential source may be disturbed by proposed construction and as such a pathway may be created. A residual risk remains which would require further assessment and/or remedial works to be considered.
Potentially asbestos containing irrigation pipes at Hall Farm (HLU1151)	The pipes are located beneath the proposed main route alignment and a proposed main works construction area. Given the location of this credible source of contamination and that the presence and composition of the potential asbestos has not been investigated as the pipes were still in use at the time. A residual risk therefore remains which would require further assessment and/or remedial works to be considered. Further investigation and assessment would be undertaken by the Contractor at detailed design (as committed to in GS001 in REAC).

10.4.160 Exceedances have been recorded in both soil leachate and groundwater samples in all the Packages, however the lack of exceedances observed in soil samples suggests that there is no particular contaminative source which attributes to these concentrations and are generally likely to reflect baseline background conditions. No groundwater remediation is proposed.

Ground Gases

10.4.161 With regards to ground gases, humans are the main receptors via the inhalation pathway. During construction of the Project, construction workers are the main receptors, however in the operational phase, onsite and offsite receptors could be at risk via direct exposure of ground gases and the migration of gases offsite via the creation of preferential pathways (for example, utility corridors).

10.4.162 From the gas monitoring obtained to date, ground gases have been recorded to varying concentrations across the Project and in particular where landfill sites are present.

10.4.163 During the construction phase, there is a risk of accumulation of ground gases within deep trenches which would be excavated as part of the work especially in the area of the North Portal. The gas regime may also change from the current situation due to the construction works and particularly the dewatering activities which would take place. The health and safety of the construction workers would be covered under the relevant health and safety legislation framework (Construction Design Management, 2015) with restricted access to confined spaces and excavations. Where work in confined spaces is unavoidable, site-specific and task-specific risk assessments would be undertaken prior to commencement of the works. Monitoring of confined spaces for potential ground gas accumulation would be carried out and the works would be undertaken by suitably trained personnel with the use of specialist personal protective equipment where necessary. Project commitments in relation to the management of ground gas are further described in Section 10.5.

10.4.164 Mitigation measures as detailed in Section 10.5 and in the Remediation Options Appraisal and Outline Remediation Strategy (Application Document 6.3, Appendix 10.11) would provide protection to onsite and offsite receptors during the operational phase of the Project. This includes undertaking further gas monitoring by the Contractor so that appropriate gas protection measures are included within enclosed and confined spaces (for example, tunnel portals, manhole chambers) and the design of utility corridors (for example, use of clay stanks) to prevent preferential pathways for the migration of gases offsite. In areas of open space, ground gases would naturally vent to the air, reducing the risk to users of such areas.

Phosphatic chalk and radon gas

10.4.165 Phosphatic deposits occur naturally in many chalk strata and are generally a minor component of the rock. Phosphatic chalk is associated with elevated levels of radon-222, a naturally occurring radioactive gas. Radon is generated by the decay of trace amounts of uranium isotopes naturally present in varying concentrations in most soil and rock types.

10.4.166 Inhalation of radon gas and its decay products can present a hazard to human health when it has built up in enclosed and occupied spaces such as buildings.

10.4.167 Further information about Phosphatic Chalk and radon gas is included within the Preliminary Risk Assessment Report (Application Document 6.3, Appendix 10.6).

10.4.168 The majority of the route is classified as the lowest risk for radon (‘*less than 1% of homes are estimated to be at or above the Action Level*’). Some of the route is classified as an intermediate probability area (‘*1 to 3% of homes are estimated to be at or above the Action Level*’).

10.4.169 No evidence of Phosphatic Chalk was identified during the Phase 1 or Phase 2 investigations and therefore the risk from radon gas is considered to be low.

Unexploded ordnance

10.4.170 An UXO desk-based study was carried out by Zetica for an area of approximately 76 square kilometres, centred on a route of approximately 31km between Great Warley in Essex and Cobham in Kent. The Zetica report is included within Appendix 10.10 (Application Document 6.3). The desk study was prepared using the current Order Limits of the Project.

10.4.171 Figure 10.9 (Application Document 6.2) shows the predicted UXO hazard-level along the assessed area.

10.4.172 Within the assessment area, five potentially significant sources of UXO hazard have been identified and these areas have been assigned a moderate UXO hazard level. The areas have been given a code (M1 to M5) and are discussed below and shown in Figure 10.9 (Application Document 6.2).

a. World War II (WWII) Bombing (M1) – Records indicate that during WWII, in excess of 512 high explosive bombs fell across the Order Limits. At least 183 of these were recorded as unexploded bombs (UXB). A moderate UXO hazard level has been assigned to ten parts of the Order Limits where an elevated bombing density and high percentage of UXB were recorded. These are shown in Figure 10.9 (Application Document 6.2). Estimated bomb penetration depths in these areas vary between 2.5m and 18.5m depending on the weight of the bomb and the underlying geological materials. Further information is presented in the Appendix 10.10: Unexploded Ordnance (UXO) Desk Study and Risk Assessment (Application Document 6.3).

b. River Thames (M2) – Several potential sources of UXO hazard have been identified encompassing the River Thames. The main anticipated ordnance hazard is from air-dropped UXB due to the heavy WWII raids in the region and unexploded anti-aircraft shells fired from the numerous gun batteries in the vicinity of the Order Limits. This part of the Order Limits is therefore assigned a moderate UXO hazard level.

c. Milton Range (M3) – Part of the Order Limits encompasses Milton Range (south bank of River Thames), which has been in use from the 19th century until the present day as a practice firing area for the Metropolitan Police Specialist Training Centre.
In addition to training with small arms ammunition, records indicate that the range was used for mortar practice during WWII, providing a potentially significant hazard. Milton Range is assigned a moderate UXO hazard level due to the potential presence of mortars (and other close combat munitions such as hand grenades) at shallow depths.

d. Pipe Mines at RAF Gravesend (M4) – Canadian pipe mines were laid under the runways and perimeter track at RAF Gravesend at the beginning of WWII so that the airfield could be destroyed in the event of a German invasion. Part of the Order Limits encroaches upon the area of the former RAF Gravesend that was pipe-mined and records suggest that not all of the

mines were removed during WWII and post-WWII clearances. In 1956 RAF Gravesend was decommissioned. The airfield has since been redeveloped into housing. This area has therefore been assigned a moderate UXO hazard level to account for the possibility that pipe mines remain in situ.

e. Bomber aircraft crashes (M5) – There are records of two WWII bomber aircraft crashes on the site at Botany Farm, near Orsett, and at Clay Tye Hill, near North Ockendon. No records have been found to indicate whether the bombs being carried by these aircraft had already been dropped, exploded on impact, or were retrieved from the crash site. These parts of the site have been assigned a moderate UXO hazard level due to the possibility that UXB are present at shallow depths.

10.4.173 In the remaining areas of the Project, no records of significant bombing or sources of UXO were identified and therefore other areas were assigned a low UXO hazard rating.

10.4.174 It should be noted that during WWII the Order Limits was located in an area subjected to heavy bombing due to its proximity to Continental Europe and being on the flightpath to important strategic targets. Numerous Anti-Aircraft (AA) batteries were established to defend against air raids.

10.4.175 Large parts of the Order Limits comprised marshland during WWII and it possible that bomb and shell impacts may have been missed and gone unrecorded in uninhabited areas.

10.4.176 As such, the potential for encountering a UXB or UXAA shell anywhere on the Site cannot be discounted.

10.4.177 Other findings include that in 1944 land within and near to the Project was part of the D-Day Marshalling Area during WWII which included military roads, storage areas and camps at Great Warley and Orsett. This activity is not considered to be a significant source of UXO hazard.

Future baseline ('Without Scheme' scenario)

10.4.178 The future baseline identifies anticipated changes to the existing baseline over time in the absence of the Project and is used as a basis against which to predict the potential impacts of the Project. A description of how the future baseline has been considered within the assessment is provided in Chapter 4: EIA methodology.

10.4.179 It is considered unlikely that the baseline conditions associated with soils and the associated land grade would change between now and the construction of the Project. The grade of agricultural land is determined predominantly by the soil's physical characteristics (in particular, texture and related structure) which would not change.

10.4.180 Climate change can have an effect on soil characteristics (resulting from increased temperatures and increased intensity of rainfall events), potentially reducing soil carbon levels and affecting yields. However, where the soils are well-drained, they would already be affected by droughtiness and where heavy-textured, they would have resilience in relation to their water-holding capacity. It is therefore considered that the baseline in relation to ALC grade would not alter over this time period.

10.4.181 For the geological resource, the existing baseline conditions are unlikely to change significantly between now and the construction of the Project. Contamination is generally due to historic land uses as the operations and procedures of current modern industry are more tightly controlled. Therefore, the existing baseline conditions for the assessment of effects on geology are considered likely to represent the future baseline conditions for the Project.

10.4.182 It is not possible to predict future changes to regulatory policy and frameworks, so the future baseline assumes no significant change from current methodology. It is considered unlikely that future minor changes or refinements in the area of the Project would materially affect the assessments made herein.

Receptors potentially affected

10.4.183 Based on the information presented within the baseline, Table 10.20 details the receptors identified and their associated value. As confirmed through the Scoping Opinion, construction/maintenance workers are not considered in this chapter to be receptors as they are governed by health and safety legislation. Construction workers are considered within Chapter 13: Population and Human Health.

Table 10.20 Geology and soil – receptors potentially affected

Receptor	Value	Reason
Geological receptors		
General geology	Negligible	Geology is of little or low local interest.
Culand Pit, Burham	High	Within GCR Review and designated as a SSSI of national importance.
Low Street Pit	Medium	Potential Local Geological Site is defined as regionally important with exposures of Mucking Gravel formation around the former quarry (Application Document 6.3, Appendix 10.3).
Turners Farm Gravel Pit	Medium	Potential Local Geological Site is considered to be regionally important as it has the same formation as Low Street Pit and medium value.
Orsett Cock Quarry	Low	Potential Local Geological Sites which are considered to be of local interest or importance with the potential of replacement. All have non-designated geological exposures due to previous extraction / quarrying, hence low value.
Coombe Green Sand Pit		
Buckingham Hill Sand Quarry		
Chadwell St Mary Church Sarsen Stone	Low	These are sites of local importance or interest with potential for replacement. Many are former quarries which have non designated geological exposures, hence low value.
East Tilbury Marshes		
Orsett Depot Quarry		
North Stifford Church Puddingstone		
Dansand Quarry		
West Tilbury Wells	Low	Mainly historical sites with no geological exposure but have local importance or interest.
Tilbury Dock		
Ockendon Clay Pit		

Receptor	Value	Reason
Cranham		
Agricultural land quality (based on the ALC system)		
BMV land	Very high to High	BMV land (Grades 1, 2 and 3a) are considered to comprise the best quality land.
Land contamination		
Human health		
Residential land use	Very high	Residential properties are present in the study area. As per the criteria set out in DMRB LA 109 Geology and Soils (Highways England, 2019) and presented in Table 10.2.
Public Open Space land use	High	Public open spaces are present in the study area. As per the criteria set out in DMRB LA 109 Geology and Soils (Highways England, 2019) and presented in Table 10.2.
Commercial / industrial land use	Medium	Commercial/industrial properties are present in the study area. As per the criteria set out in DMRB LA 109 Geology and Soils (Highways England, 2019) and presented in Table 10.2.
Highways land use	Low	Users of highways and pedestrians are present in the study area. As per the criteria set out in DMRB LA 109 Geology and Soils (Highways England, 2019) and presented in Table 10.2.
Surface water		
Ditch networks at Filborough and Shorne Marshes, including the Denton New Cut (SSSI and Ramsar site)	High	As detailed in Table 10.2. Value presented corresponds with the most sensitive value for surface water body detailed in Table 14.9 in Chapter 14: Road Drainage and the Water Environment.
Thames and Medway Canal	Medium	
River Thames	Very High	
West Tilbury Main	Medium	
Gobians Sewer	Medium	
Mardyke/Mardyke West Tributary	High	
Orsett Fen Sewer, Golden Bridge Sewer and Stringcock Sewer	Medium	
Unnamed ordinary watercourses, ponds and recreational lakes at Stubbers Adventure Centre	Medium	

Receptor	Value	Reason
Groundwater		
Principal aquifer (Chalk) supporting SPZ and abstractions	Very high	Aquifer present within study area. As per the criteria set out in DMRB LA 113 Road Drainage and the Water Environment (Highways England, 2020c) and presented in Table 10.2.
Secondary A aquifer (various strata)	Medium	Aquifer present within study area. As per the criteria set out in DMRB LA 113 Road Drainage and the Water Environment (Highways England, 2020c) and presented in Table 10.2.
Unproductive strata (London Clay)	Low	Aquifer present within study area. As per the criteria set out in DMRB LA 113 Road Drainage and the Water Environment (Highways England, 2020c) and presented in Table 10.2.

10.5 Project design and mitigation

10.5.1 Environmental considerations have influenced the Project throughout the design development process, from early route options assessment through to refinement of the Project design. An iterative process has facilitated design updates and improvements, informed by environmental assessment and input from the Project engineering teams, stakeholders and public consultation.

10.5.2 The Project includes a range of environmental commitments. Commitments of relevance to geology and soils are set out in this section under the following categories:

a. Embedded mitigation: measures that form part of the engineering design, developed through the iterative design process summarised above.

b. Good practice: standard approaches and actions commonly used on infrastructure development projects to avoid or reduce environmental impacts, typically applicable across the whole Project.

c. Essential mitigation: any additional Project-specific measures needed to avoid, reduce or offset potential impacts that could otherwise result in effects considered to be significant in the context of the EIA Regulations. Essential mitigation has been identified by environmental topic specialists, taking into account the embedded and good practice mitigation.

10.5.3 Embedded mitigation is included within the Design Principles (Application Document 7.5) or as features presented in Figure 2.4: Environmental Masterplan (Application Document 6.2). Good practice and essential mitigation are included in the Register of Environmental Actions and Commitments (REAC). The REAC forms part of Appendix 2.2: Code of Construction Practice (CoCP) (Application Document 6.3). Each entry in the REAC has an alpha-numerical reference code (REAC Ref. GS0XX) to provide cross reference to the secured commitment. Relevant good practice and essential mitigation to reduce geology and soils are identified below. Please note that the numbering is not continuous, with the following numbers not used; GS007 and GS008.

10.5.4 The Design Principles, Environmental Masterplan, CoCP and REAC all form part of the Project control plan. The control plan is the framework for mitigating, monitoring and controlling the effects of the Project. It is made up of a series of 'control documents' which present the mitigation measures identified in the application that must be implemented during design, construction and operation to reduce the adverse effects of the Project. Further explanation of the control plan and the documents which it comprises is provided in the Introduction to the Application (Application Document 1.3).

10.5.5 Enhancement measures have been directly incorporated into the Project as part of the application of 'good design' principles. Enhancements are measures that are considered to be over and above any measures to avoid, reduce or remediate adverse impacts of the Project. Relevant beneficial effects arising as a consequence of this good design process are provided below.

Embedded mitigation

10.5.6 The principles of avoidance were applied during the selection of the preferred route which considered the presence of BMV land and areas of potential contamination risk. Additionally, the existing baseline conditions have helped to inform the siting of construction compounds, the construction approach and the development of the Project design.

10.5.7 No specific embedded construction or operational phase mitigation is presented for geology and soils within the Design Principles (Application Document 7.5).

Good practice

Construction phase

10.5.8 Construction phase good practice of relevance to geology and soils is as follows:

a. Supplementary ground investigations would be undertaken to assess residual contamination risks as detailed in the Remediation Options Appraisal and Outline Remediation Strategy (Application Document 6.3, Appendix 10.11). If, during further intrusive ground investigations, drilling is required in areas underlain with contaminated soils, drilling and excavation techniques in line with the latest versions of BS 5930:2015 Code of practice for ground investigations (British Standards Institution, 2020) and BS 10175:2011 Investigation of potentially contaminated sites – Code of Practice (British Standards Institution, 2017) would be adopted (for example, environmental seals) to reduce the risk of creating pollutant pathways. The Contractors would provide ground investigation method statements for acceptance of National Highways in consultation with the Environment Agency and relevant Local Authorities prior to commencement of the works (REAC Ref. GS001).

b. Prior to any construction compound area being prepared, a pre-condition survey would be undertaken to determine the current land quality across the compound area. A repeat survey would be done after the compounds have been removed to confirm that the area has been restored in line with article 35 of the draft DCO (REAC Ref. GS002).

c. To proactively manage the potential impacts from geohazards, such as land instability, during detailed design and construction activities the Contractors would carry out further ground investigation and establish a programme of instrumentation and monitoring in line with Section 7 of Appendix 10.2 (Application Document 6.3). A geotechnical risk register would continue to be maintained and updated throughout the development of the Project, in line with the requirements set out in DMRB CD 622 (REAC Ref GS003).

d. Construction site compounds where chemical, waste oils or fuel storage and refuelling activities take place, would be managed in line with the following measures: (REAC Ref. GS004).

    i. Within the construction site compounds, specific areas would be designated for the storage of chemicals, waste oils and fuel and refuelling activities.

    ii. These designated areas shall not be located within Source Protection Zone 1 (both published SPZ1 and default or bespoke SPZ1 (in agreement with the Environment Agency) where a potable water abstraction is identified). These are presented in Figure 14.2 (Application Document 6.2). These designated areas would be bunded to provide capacity for at least 110% of the largest container and placed on hardstanding to prevent downward migration of contaminants.

    iii. These designated areas would be designed with drainage to include measures for isolating spillages.

    iv. Any transfer of fuel or other potentially contaminated liquids would only take place within a designated transfer area.

    v. Drip trays would be provided to reduce the risk of spillages

e. Due to the transient nature of the Project construction works, refuelling activities would have to take place on worksites outside of construction compounds. To reduce the risk of a pollution event caused by spillages, the following measures would be followed when refuelling on worksites outside of construction compounds: (REAC Ref. GS005)

    i. Only construction equipment and vehicles free of oil/fuel leaks would be permitted on worksites.

    ii. Drip trays would be placed below static mechanical plant and procedures for emptying developed.

    iii. All refuelling activities would take place above drip trays or on an impermeable surface (for example, plant nappy) and at an appropriate distance from watercourses and sensitive areas.

iv. Spill kits would be made available during all refuelling activities either at the worksite or on the refuelling vehicle.

v. No refuelling activities shall take place within a Source Protection Zone (SPZ) 1 (both published SPZ1 and default or bespoke SPZ1 (in agreement with the Environment Agency) where a potable water abstraction is identified). These are presented in Figure 14.2 (Application Document 6.2).

f. All excavated materials and soils proposed for re-use under a Materials Management Plan would be required to meet risk-based acceptability criteria applicable to its intended use. The procedures and criteria to be used would be set out in the Materials Management Plan (REAC Ref. MW007) prior to commencement of that part of the works (REAC Ref. GS006).

g. Soils would be handled and stored to allow their sustainable reuse in line with the Defra Construction Code of Practice for the Sustainable Use of Soil on Construction Sites (2009) and the MAFF Good Practice Guide for Soil Handling (2000). Full details of the soil resources present and the procedures for soils management (covering vegetation clearance, setting out haul routes, soil stripping, stockpile creation and management, soil reconditioning (where required) and soil reuse) would be set out prior to any soil stripping works commencing, covering all proposed end uses (for example, agricultural land, woodland or other habitat types) (REAC Ref. GS009).

h. Characterisation of the existing soil to determine its resilience to handling and stripping depths would be based on detailed soil surveys. Where information is not available (i.e. from the detailed ALC surveys), pre-construction soil surveys would be carried out by the Project to inform the development of appropriate soils management procedures (REAC Ref. GS010).

i. Soil on land identified in Figure 2.4, the Environmental Masterplan, which is used during construction, would be profiled to support the land use identified in the Environmental Masterplan (Application Document 6.2, Figure 2.4). The soil would be fully restored, in accordance with the soil reuse requirements in the soils management procedures (REAC ref. GS009), and would be recreated in the correct sequence of horizons, in such a manner that there are good fissures to facilitate soil profile drainage and plant root development (REAC Ref. GS011).

j. Reinstatement of soils affected by temporary works would aim to avoid any reduction in soil function. For agricultural land this would be measured by the quality of the land as defined by the ALC system (with a soil profile recreated to 1.2m below ground level where this was the pre-construction soil depth). For areas of landscape planting or habitat creation, this would be measured by the successful restoration of the soil profile (both physical and chemical characteristics) defined for that particular habitat in the soils management procedures suitable to allow the establishment and long-term health of the habitat (REAC Ref. GS012).

k. Procedures for the management of soil resources would include provisions for: (REAC Ref. GS013)

   i. Ensuring soils are stripped and handled in the driest condition practicable.

   ii. Ensuring topsoil and subsoil resources are stripped and stockpiled separately.

   iii. Keeping records of excavated and stored soils.

   iv. Confining vehicle movements to defined haul routes until all the soil resource has been stripped.

   v. Protection of stockpiles from erosion through establishment of a grass cover unless the soil materials are to be re-used in a short timeframe (<60 days) in which case alternative erosion control measures may be required, such as silt fencing or the use of geotextile blankets.

   vi. Protection from tracking over, using signage or fencing.

   vii. Ensuring the physical condition of the replaced soil profile to at least 1.2m below ground level, and that is sufficient for the post-construction use.

   viii. The use of toolbox talks to inform all those working on the site of the requirements for soil handling, storage and re-use.

l. Following soil reinstatement there would be a five-year aftercare period during which defects would be corrected. The Contractor would prepare and present to National Highways for acceptance, a schedule of aftercare monitoring, maintenance and defect correction. This would include soil testing, appropriate to the target specification (for example, land grade where restoration is to agricultural use or specific characteristics where restoration is to support habitat creation or re-provision). Implementation of the aftercare monitoring, maintenance and defect correction would be overseen by an Environmental Clerk of Works (REAC Ref. GS014).

m. The Contractor would have in place an agricultural liaison officer or named deputy who shall be contactable by telephone 24 hours a day, seven days a week during construction activities on agricultural land (REAC Ref. GS015).

n. A verification report would be prepared by the Contractor after completion of work to remediate contamination at each site where this is undertaken. This would identify the locations of the remediation works undertaken and the final tested ground quality. These reports would be provided to the relevant local authority and Environment Agency as a record (REAC Ref. GS016).

o. The ground gas regime across the Project and especially in close proximity to landfill sites would be investigated to inform a design of enclosed and confined spaces (for example, service ducts/boxes) to reduce the risk to human health (asphyxiation) and buildings or structures (explosion). No confined spaces associated with the Project would be accessible to the public (REAC Ref. GS018).

p. Pre-construction risk assessments and an emergency response procedure for the management of UXO prior to construction are detailed within the CoCP (Application Document 6.3, Appendix 2.2). The Contractors would carry out pre-construction risk assessments to determine the possibility of finding UXO within the construction area. An emergency response procedure would be prepared and implemented by the Contractors to respond to the discovery of UXO. This would include notifications to the relevant local authorities and emergency services. The Contractors would comply with the recommendations of the Unexploded Ordnance (UXO) Desk Study and Risk Assessment (Application Document 6.3, Appendix 10.10).

q. Dewatering may be required during excavation works which could potentially cause waterborne contaminants to mobilise and flow in the groundwater towards the excavation. If dewatering is required, then the Contractor would treat groundwater from dewatering works to standards agreed with the Environment Agency before discharge (REAC Ref. GS022).

r. Accommodation and welfare facilities are proposed within the northern tunnel entrance compound which would service the North Portal construction activities. Ground gas associated with the historic landfill sites which may be present in the area could pose a risk to health. Prior to the accommodation being constructed, a gas assessment (investigation and monitoring) would be undertaken in the area to determine the need for appropriate gas protection measures (REAC Ref. GS025).

s. Construction of foundations (including piling and ground improvement works) has the potential to create pollution pathways and mobilise contaminants. The Contractors would prepare a detailed foundation risk

assessment report in line with the ES Appendix 10.11 (Application Document 6.3), during detailed design specific to structures and ground conditions. This would be submitted to the Environment Agency for review prior to commencement of that part of the works to which the report relates. (REAC Ref. GS026).

t. Where supplementary investigation is undertaken to assess residual contamination risks in accordance with GS001, appropriate assessment in accordance with LCRM (Environment Agency, 2021) would be undertaken, and where unacceptable risks are identified, the Contractors would develop proposals for site-specific remediation strategies and implementation plans in consultation with the relevant local authorities prior to implementation. The Contractors would have regard for ES Appendix 10.11, Remediation Options Appraisal and Outline Remediation Strategy (Application Document 6.3), which identifies techniques that could be implemented by the Contractors for the remediation of contamination (REAC Ref. GS027).

u. The construction works would include the removal of vegetation, stripping of topsoil, excavation and earth movements. These activities could cause the spreading and mobilisation of contaminants: (REAC Ref. GS028).

   i. During earth movement works, a watching brief protocol would be implemented under the supervision of an Environmental Clerk of Works.

   ii. Site workers would be vigilant to ensure visual or olfactory signs of contamination are noted and that contaminated soil is kept separate from other materials.

   iii. Appropriate analysis and assessment would be undertaken by a suitably qualified person on suspected contaminated soils to establish the action required

Operational phase

10.5.9 Operational phase good practice of relevance to geology and soils is as follows:

a. The findings of the verification report (REAC Ref. GS016) would be available for inclusion within the operations Health and Safety file or equivalent (REAC Ref. GS017).

b. If any incident were to occur which resulted in localised contamination, soils which had become significantly affected would be assessed and, if necessary, removed to reduce the risk of contamination migrating across a wider area or entering controlled waters (REAC Ref. GS019).

10.5.10 In relation to ground gas, it is assumed that the design measures implemented as part of the construction phase would provide protection during the operational phase and no further additional mitigation measures are required.

Essential mitigation

Potentially significant effects

10.5.11 An iterative appraisal of the Project design taking into account design principles and good practice, was undertaken to identify any potentially significant effects that would require essential mitigation. Potentially significant effects on geology and soils were identified as follows:

a. Disturbance of pre-existing contamination at the East Tilbury landfill site to facilitate the construction and operation of a temporary access road

b. Creation of pollution pathways and potential for remobilisation of pre-existing contamination into the surface water and groundwater environments resulting from the construction and operation of the main tunnels, construction of foundations and installation of utility corridors

c. Risk to human health from ground gases generated from landfill sites during the construction and operational phase of the main tunnels

d. Impact on geological resource due to the mobilisation of pre-existing contamination during the construction phase and the operation of the main tunnels

e. Partial loss of geological feature at the Low Street Pit potential Local Geological Site during the construction of the Tilbury Viaduct.

Construction phase

10.5.12 Construction phase essential mitigation of relevance to geology and soils is as follows.

a. A temporary access route would be created across East Tilbury Landfill site. The temporary access route would be designed to safeguard the capping layer on the landfill and minimise the risk of liquid waste being brought to the surface by the consolidation of the ground along the temporary access route. The design would be agreed with the Environment Agency in consultation with Thurrock Council unless otherwise agreed with the Secretary of State prior to installation. Vehicle movements and the type of vehicles (tonnage) would be restricted to further reduce the risk of damaging the integrity of the cap and the wider environment. The temporary access route would be removed as soon as it is no longer required. (REAC Ref. GS020).

b. Potential contaminants from historical land uses and saline water have the potential to be drawn towards the construction area of the North Portal and ramps due to the level of groundwater control required during excavation works. This would be mitigated through the construction of a deep barrier around the excavations to reduce groundwater ingress. The depth of the barrier walls would be informed by the results of modelling and consultation

with the Environment Agency and Thurrock Council prior to the commencement of excavation works to construct the North Portal box structure and ramps.

c. The need for any supplementary mitigation measures and any necessary monitoring would be informed by the results of modelling and consultation with the Environment Agency prior to the commencement of excavation works. Technical solutions would be developed by the Contractors following further investigation and assessment. Potential solutions could include:

   i. Ground treatment such as grouting to form a low permeability plug below the depth of excavation to reduce the risk of water inflow and uplift pressure.

   ii. Ground improvements (for example a low permeability barrier) to decrease the permeability of the ground to lessen the risk of contaminant mobilisation.

   iii. Potential to reduce the footprint of the structure by optimising the tunnel bore spacing and layout of the tunnel boring machinery launch structures (REAC Ref. GS021).

d. The North Portal is located within an area historically used for landfill. Groundwater control during the excavation and construction activities for the tunnel boring machinery launch may cause an increased volume of gases to escape as soils, made ground and underlying alluvium become unsaturated. In addition, drilling through the area of historic landfill could lead to a build-up of gases behind the tunnel boring machinery. These factors would be considered during the detailed design to establish appropriate and safe procedures and working methods to construct the tunnel and North Portal. Gas monitoring would be undertaken during the construction phase for the launch and use of the tunnel boring machinery to detect changes in the gas regime as a safeguard to protect construction workers (REAC Ref. GS023).

e. The design of the main crossing tunnel boring machinery may require the construction of a ground protection tunnel beneath the Thames Estuary and Marshes Ramsar site. The Environment Agency would be consulted on measures to reduce the risk of blow-out and spreading of grout during tunnelling if a ground protection tunnel is required (REAC Ref. GS024).

f. Surplus clean chalk soils generated from construction works south of the River Thames may be stockpiled to facilitate control of offsite Heavy Goods Vehicle traffic. Stockpiles of surplus clean chalk would be designed to safeguard the underlying soils and groundwater and the design would be agreed by the SoS in consultation with the Environment Agency prior to stockpiling commencing (REAC Ref. GS029).

g. Construction work (both temporary and permanent) is proposed across the former Esso petrol station (HLU0214) on the eastbound side of the

M2/A2/A122 Lower Thames Crossing junction. The former petrol station is identified in the ES Appendix 10.6, Preliminary Risk Assessment Report (Application Document 6.3) as a low-risk site as remediation has taken place and signed-off by regulators. Prior to the construction of both the temporary and permanent works, the Environment Agency would be consulted on the works to ensure that potential disturbance of residual contamination present in this area is avoided and the construction works would not disturb remediation works in this area (REAC Ref. GS030).

h. Low Street Pit has been identified as a potential Local Geological Site due to the presence of Mucking Gravels (now known as the Taplow Gravel Member). The Project has the potential to impact the Mucking Gravels during the construction of the Tilbury viaduct and the associated embankment earthworks and drainage, as well as due to the required diversion of statutory undertakers' impacted apparatus, located within the Low Street Pit. Construction activities on the eastern side of Low Street Pit, where an area of Mucking Gravels is present, would be restricted to prevent any excavations of the Mucking Gravels in this area and retain the existing eastern quarry slope. Figure 4 Proposed restricted area Annex A, Appendix 10.3 Site Walkover Factual Report, of the Environmental Statement (Application Document 6.3) shows the area that would be subject to these restrictions (REAC Ref. GS031).

Operational phase

10.5.13 Operational phase essential mitigation of relevance to geology and soils is as follows:

a. Water infiltration into the tunnel bores and cross passages during operation would be reduced by measures including gaskets (for segmentally lined tunnels) and membranes (for sprayed concrete lined tunnels), compliant with the Project tunnelling specification (REAC Ref. RDWE027).

Enhancement

10.5.14 There are no specific enhancement measures included in the Project for Geology and Soils.

10.6 Assessment of likely significant effects

10.6.1 This section presents the assessment of likely significant effects on geological and soil receptors resulting from the construction and operational phases of the Project. This is based on the design of the Project and takes into account the mitigation as presented in Section 10.5.

10.6.2 The assessment considers the value/sensitivity and impact magnitude criteria as presented in Table 10.2 and Table 10.3 respectively, and significance of effects has been determined in accordance with the matrix provided in Table 4.4 of Chapter 4: EIA Methodology and through the use of professional judgement.

Construction phase

Geology

10.6.3 Excluding the Geological SSSI and the Local Geological Sites detailed below, the sensitivity of the superficial and bedrock geology within the study area and presented in Table 10.4, Table 10.5 and Table 10.6, is negligible as it is of little or no local interest. The magnitude of impact from the construction of the Project on the superficial and bedrock geology would be negligible as the overall integrity of the resource would not be affected. The Project would have a neutral effect on geology, which is **not significant**.

Geological SSSI

Culand Pits, Burham

10.6.4 The Culand Pits are designated as a Geological SSSI and are considered to be of high value due to its national importance. The pits are located adjacent to the proposed nitrogen deposition compensation sites at Burham. Work in close proximity to this feature involves the biodiversity enhancements. The magnitude of impact to this feature is no change as there would be no temporary or permanent loss or disturbance of characteristics or features. The significance of effect is neutral which is **not significant**.

Local Geological Sites

Low Street Pit

10.6.5 Low Street Pit is considered to be a Potential Local Geological Site and is described as being regionally important in the Thurrock Biodiversity study. This geological site is partially (approximately 65%) within the footprint of the Project and a portion is located under a proposed embankment and viaduct structure. This receptor is considered to have a medium value due to its regional importance. Mitigation is proposed to restrict construction activities within the eastern area of Low Street Pit to preserve an area of Mucking Gravel (REAC Ref. GS031) on the existing quarry slope which is the main feature to be preserved. The magnitude of impact of the works on this geological feature within Low Street Pit is minor adverse as the Project would result in a minor loss or alteration of the geological feature. This would result in a slight adverse effect, which is **not significant**.

10.6.6 This site was also identified as a Local Wildlife Site. Mitigation in the form of compensation is in place for the loss of this wildlife site and further information is included in Chapter 8: Terrestrial Biodiversity.

West Tilbury Wells

10.6.7 This historical geological feature is located outside the Order Limits but within the study area. It is considered to have a low value as it is of local interest. Construction work in close proximity to this feature involves the improvements to existing roads. The magnitude of impact to this feature is no change as there would be no temporary or permanent loss or disturbance of characteristics or features. The significance of effect is neutral which is **not significant**.

Chadwell St Mary Sarsen Stone

10.6.8 This geological feature is located just outside the Order Limits but within the study area. It is located within the local churchyard and is given a low value due to its local importance and potential for replacement. No construction work is taking place in the churchyard and therefore the magnitude of impact is no change. The significance of effect is neutral which is **not significant**.

East Tilbury Marshes, Thurrock

10.6.9 This geological feature which is 200m east of the Order Limits is of local interest and is considered to be of low value. No construction work is taking place within this feature and therefore the magnitude of impact is no change as there would be no temporary or permanent loss or disturbance of characteristics or features. The significance of effect is neutral which is **not significant**.

Turners Farm Gravel Pit, Mucking, Thurrock

10.6.10 This gravel pit is considered to be a potential Local Geological Site and is located 35m outside the Order Limits but within the study area. The gravel pit comprises the same geological feature as Low Street Pit which is considered to be regionally important. It is considered to be of medium value. Construction work in close proximity to this feature involves the improvements to existing roads which would result in a magnitude of impact of no change as there would be no temporary or permanent loss or disturbance of characteristics or features. The significance of effect is neutral which **not significant**.

Orsett Cock Quarry

10.6.11 This former quarry is considered to be a potential Local Geological Site and is located approximately 100m outside the Order Limits but within the study area. Geological exposures are present which are of local interest with potential for replacement, therefore it is considered to be of low value. Construction work in close proximity to this feature involves the improvements to existing roads which would result in a magnitude of impact of no change as there would be no temporary or permanent loss or disturbance of characteristics or features. The significance of effect is neutral which is **not significant**.

Orsett Depot Quarry

10.6.12 This disused sand and gravel pit is located 125m outside the Order Limits but within the study area. Geological exposures are present which are of local interest with potential of replacement. It is therefore considered to be of low value. Construction work in close proximity to this feature involves improvements to existing roads which would result in a magnitude of impact of no change as there would be no temporary or permanent loss or disturbance of characteristics or features. The significance of effect is neutral which is **not significant**.

Tilbury Dock

10.6.13 This historical site is located to the west of the Order Limits but within the study area. This site is considered to be of low value as of local interest. No construction work is taking place within the docks, resulting in a magnitude of impact of no change as there would be no temporary or permanent loss or disturbance of characteristics or features. The significance of effect is neutral which is **not significant**.

Ockendon Clay Plant (Grange Farm Clay Pits), South Ockendon, Thurrock

10.6.14 This geological site is located partially within the Order Limits and comprises pits where London Clay was previously worked. These are now privately owned and used for landfilling activities and is therefore considered to be of low value as of local interest. Construction work in close proximity to this feature involves the improvements to existing roads. The magnitude of impact to this feature is no change as there would be no temporary or permanent loss or disturbance of characteristics or features. The significance of effect is neutral which is **not significant**.

Cranham

10.6.15 This geological site is located within the Order Limits and comprises temporary exposures of London Clay. This site is considered to be of low value as of local interest. Construction work in close proximity to this feature involves the improvements to existing roads. The magnitude of impact to this feature is no change as there would be no temporary or permanent loss or disturbance of characteristics or features. The significance of effect is neutral which is **not significant**.

Coombe Green Sand Pit

10.6.16 This overgrown sand pit is located 250m outside the Order Limits but within the study area. Geological exposures are present which are of local interest with potential for replacement; therefore, this geological site is considered to be of low value. No construction work is taking place in close proximity to this feature resulting in a magnitude of impact of no change as there would be no temporary or permanent loss or disturbance of characteristics or features. The significance of effect is neutral which is **not significant**.

Buckingham Hill Sand Quarry

10.6.17 This overgrown sand pit is located 225m outside the Order Limits but within the study area. Geological exposures are present which are of local interest with potential for replacement and therefore this geological site is considered to be of low value. No construction work is taking place in close proximity to this feature resulting in a magnitude of impact of no change as there would be no temporary or permanent loss or disturbance of characteristics or features. The significance of effect is neutral which is **not significant**.

North Stifford Church Puddingstone, Thurrock

10.6.18 This site of interest is the only known example of Puddingstone in south Essex and therefore it is considered to be of low value due to its local interest with potential for replacement. No construction work is taking place in the churchyard and therefore the magnitude of impact is no change. The significance of effect is neutral which is **not significant**.

Dansand Quarry

10.6.19 This quarry is a general geological site due to the fine exposures of the sands of the Woolwich Beds (now Woolwich Formation) which are capped by the Orsett Heath Gravel (now known as Boyn Hill Gravel). The Essex Field Club has identified the northern boundary of the quarry site as the geological feature of interest, which runs adjacent to the highway boundary of the A1013. The exposure follows the northern boundary of the quarry in a south-westerly direction. The Dansand Quarry general geological site is considered to be of low value due to its regional interest and limited potential for replacement. Although the Project works associated with the A1013 realignment and A13 junction are likely to take place adjacent to a small part of the exposure, the works are only likely to result in minor loss or alteration to the feature and would not cause the loss of the integrity of the resource. Therefore, the magnitude is negligible. The significance of effect is neutral which is considered to be **not significant**.

Soils

Permanent and temporary loss of BMV land

10.6.20 The areas of land at each ALC grade required are presented in Table 10.21. This shows the total area of each grade affected, the total required permanently, and the total area reinstated by the end of the construction phase.

Table 10.21 Permanent and temporary loss of agricultural land

ALC grade	Total area (ha)	Area required permanently (ha)	Area reinstated by the end of the construction phase (ha)
South of the Thames			
1	17.22	15.24	1.98
2	272.92	200.28	72.64
3a	89.35	71.80	17.55
BMV land	379.49	287.32	92.17
3b	53.96	16.29	37.67
4	19.75	0.00	19.75
5	0.00	0.00	0.00
Total agricultural land	453.20	303.61	149.59
Non-agricultural	234.40	173.33	61.07
Sub Total	**687.60**	**476.94**	**210.66**

ALC grade	Total area (ha)	Area required permanently (ha)	Area reinstated by the end of the construction phase (ha)
North of the Thames			
1	7.40	7.40	0.00
2	71.02	38.94	32.08
3a	358.72	205.57	153.15
BMV land	*437.13*	*251.90*	*185.23*
3b	672.73	420.57	252.16
4	26.63	8.17	18.46
5	0.00	0.00	0.00
Total agricultural land	1136.50	680.65	455.85
Non-agricultural	571.13	329.19	241.94
Sub Total	**1707.63**	**1009.84**	**697.79**
North and South of the Thames			
1	24.62	22.64	1.98
2	343.94	239.22	104.72
3a	448.07	277.37	170.70
BMV land	*816.62*	*539.22*	*277.40*
3b	726.69	436.86	289.83
4	46.38	8.17	38.21
5	0.00	0.00	0.00
Total agricultural land	1589.70	984.26	605.44
Non-agricultural	805.53	502.52	303.01
Total	**2395.23**	**1486.78**	**908.45**

10.6.21 As shown in Table 10.21, during construction the Project would result in the total loss of 1589.70ha of agricultural land at the start of the construction phase. A total of 816.62ha (34.1% of the land within the Order Limits) comprises BMV land.

10.6.22 However, by the end of the construction phase, land required temporarily would be reinstated, leaving a permanent loss of 984.26ha of agricultural land. Of this land affected permanently, 22.64ha is Grade 1, 239.22ha Grade 2 and 277.37ha Grade 3a.

10.6.23 The assessment of these impacts is set out in Table 10.22 and Table 10.23 below for each grade. For the impacts during the construction phase (i.e. before any land has been reinstated) the impact relates to the physical removal of the soil, where removal of greater than 20ha is considered of major magnitude.

Table 10.22 Assessment of impacts relating to the impact on agricultural land during the construction phase

ALC grade	Receptor sensitivity	Area required during the construction phase (ha)	Magnitude of impact	Significance of effect
1	Very high	24.62	Major	Very large
2	Very high	343.94	Major	Very large
3a	High	448.07	Major	Large or very large
BMV land		*816.62*	Major	Very large
3b	Medium	726.69	Major	Moderate or large
4	Low	46.38	Major	Slight or moderate
5	Low	0.00	N/A	N/A

10.6.24 The assessment of these impacts shows there is a **very large adverse** effect on BMV land for the duration of the construction phase, which is considered to be **significant**.

Table 10.23 Assessment of impacts relating to the permanent loss of agricultural land (following reinstatement of land required temporarily during the construction phase)

ALC grade	Receptor sensitivity	Area required permanently (ha)	Magnitude of impact	Significance of effect
1	Very high	22.64	Major	Very large
2	Very high	239.22	Major	Very large
3a	High	277.37	Major	Large or very large
BMV land		*539.22*	*Major*	*Very large*
3b	Medium	436.86	Major	Moderate or large
4	Low	8.17	Moderate	Slight
5	Low	0.00	N/A	N/A

10.6.25 The assessment of these impacts shows that, by the end of the construction phase once all land required temporarily has been reinstated, there is a **very large adverse** impact on BMV land which is **significant** and is permanent.

Permanent and temporary impacts on soils supporting designated and non-designated notable habitats

10.6.26 Soils supporting a range of habitats are directly affected during construction, as detailed in Chapter 8: Terrestrial Biodiversity. These include UK designated sites, Local Wildlife Sites and other non-designated habitats. Where possible, in line with the soil handling methodologies which would be developed, soils would be stripped and re-used appropriately according to the required end use, including the creation of new habitat areas, to maintain soil function.

10.6.27 The sensitivity of these receptors would range from high to low, depending on the habitat designations they support. While soil re-use would enable a range of soil functions to be retained, the often undisturbed nature of the soils affected means there could be a permanent or long-term loss of some soil functions (for example changes to the microbial community present in ancient woodland soil) and therefore an indirect effect on terrestrial biodiversity (Chapter 8: Terrestrial Biodiversity).

10.6.28 The magnitude of the impacts would range from moderate to minor, resulting in **large adverse** to **neutral** effects, of which the former would be considered to be **significant**.

Land contamination

Human health

10.6.29 Human health receptors potentially affected by the Project during the construction phase include residents living close to the Project (very high value), people using public open spaces (high value), and those using commercial/industrial properties (medium value) within the study area.

Exposure to contamination

10.6.30 Exposure to contaminants could occur through various pathways such as dermal contact, ingestion and inhalation. The main exposure to these receptors is considered to be fugitive dust (potentially containing contaminants) generated by excavation/earth movements during the construction of the Project. Depending on weather conditions, this could be blown into nearby residential, public open spaces and commercial properties. It is noted that much of the study area is rural and therefore the risk of exposure to fugitive dust would vary.

10.6.31 Following the implementation of design and mitigation measures (for example, dust suppression and covering vehicles to avoid dust being spread during transport) to manage such impacts as detailed in the CoCP (Application Document 6.3, Appendix 2.2) and described in Chapter 5: Air Quality, the magnitude of impact to human health receptors is negligible.

10.6.32 For residential receptors of very high value, this would result in a slight adverse effect. For public open space users of high value, this would result in a slight adverse effect. For commercial/industrial land users of medium value, this would result in a neutral effect. These effects are likely to be short term during periods of major earthwork movements and are therefore considered to be **not significant**.

Exposure to ground gases

10.6.33 Exposure to ground gases could occur during the construction works via the inhalation pathway. The main receptors would be the construction workers in the vicinity of excavations. Mitigation measures for construction workers would be through Health and Safety legislation (for example, CDM) and mitigation measures detailed in Section 10.5.

Disturbance of unidentified UXO

10.6.34 During construction of the Project, there is a risk of disturbance of currently unidentified UXO potentially resulting in explosion. The main risk is to human health receptors within the study area. With the implementation of the UXO mitigation detailed in Section 10.5 and in the CoCP (Application Document 6.3, Appendix 2.2), the magnitude of impact on these receptors is considered to be negligible as the overall risk to human health is low.

10.6.35 For residential receptors of very high value, this would result in a slight adverse effect. For public open space users of high value, this would also result in a slight adverse effect. For commercial/industrial land users of medium value, this would result in a neutral effect. These effects are likely to be short term during periods of major earthwork movements and piling activities and are therefore considered to be **not significant**.

Surface water

10.6.36 From the ground investigations undertaken, pre-existing contamination has been encountered within the underlying soils and groundwater. This contamination could be remobilised during construction activities and impact the underlying geology with the potential for contamination to migrate into the surface water environment. The introduction of new contamination into surface water receptors from activities undertaken during the construction of the Project, for example fuel spillages and runoff, are assessed within Chapter 14: Road Drainage and the Water Environment. Each surface water receptor is assessed in turn below.

10.6.37 Indirect effects on aquatic ecology in surface water receptors from the release of contaminants is assessed within Chapter 8: Terrestrial Biodiversity, and Chapter 9: Marine Biodiversity.

Ditch networks at Filborough and Shorne Marshes, including the Denton New Cut (SSSI and Ramsar site)

10.6.38 This ditch network is considered to have high sensitivity as it supports the SSSI/Ramsar site. As presented in Table 10.15, the Package A ground investigation has recorded minor elevated soil leachate concentrations, which could impact water quality in the ditch network, however, these were noted as marginal exceedances and generally within the shallow soils. No surface works are proposed within the boundary of the Ramsar site at the location of the exceedances, however, minor construction works to install the pipework associated with the construction phase outfall/discharge would be required. This would be carried out via trenchless techniques which would limit the potential for disturbance of any pre-existing contamination. The magnitude of impact from land contamination is considered to be no change. The significance of effect is neutral which is **not significant**.

Thames and Medway Canal

10.6.39 A construction compound and temporary haul road are proposed to the north of the Thames and Medway Canal which would support the excavation of the ground protection tunnel and shafts. These works could cause the mobilisation of existing contamination. As presented in Table 10.15, the Package A ground investigation has recorded elevated soil leachate concentrations, which could

impact water quality in the canal, however, these were noted as marginal exceedances and generally within the shallow soils. The Thames and Medway Canal is considered to have a medium sensitivity and with the implementation of good practice environmental design and mitigation measures as detailed in Section 10.5 and in the CoCP (Application Document 6.3, Appendix 2.2), the magnitude of impact on the canal is considered to be negligible as the risk of pollution is low. The significance of effect is assessed as slight adverse and would be short term during main construction activities. This effect is **not significant**.

River Thames

10.6.40 The River Thames is considered to have a very high sensitivity. Significant construction work taking place to the north of the River Thames with the excavation of the North Portal could lead to the remobilisation of pre-existing contamination within the adjacent areas of landfill of Goshems Farm Landfill which has been encountered during the Package B ground investigation (Table 10.16). With the implementation of measures to reduce the groundwater ingress during the excavation of the North Portal as well as the good practice construction methods detailed in Section 10.5 and in the CoCP (Application Document 6.3, Appendix 2.2), the magnitude of impact on the River Thames is considered to be negligible as mobilisation would be minimised. The significance of effect is assessed as slight adverse and would be short term during main construction activities. This effect is **not significant**.

10.6.41 With regards to East Tilbury Landfill, it should be noted that the assessment of East Tilbury Landfill (Application Document 6.3, Appendix 10.7) concluded that the proposed dewatering at North Portal would not have an adverse impact on CoC entering the River Thames. There is already an independent and active direct pollutant linkage between the landfill and the River Thames which would not be affected by the construction works.

River Thames – Creation of Tilbury Fields

10.6.42 Tilbury Fields is a proposed landform for public parkland and open mosaic habitat to the south and east of the North Portal. It would be constructed from excavated material and treated tunnel arisings placed on top of the existing Goshems Farm Landfill (a land raise) and would consist of a series of sculptural landscaping mounds, which would range from 13m to 17m above existing ground level (18m to 24m AOD) in height.

10.6.43 The placement of the materials to form Tilbury Fields has the potential to lead to additional surcharge loading on top of the existing land raised materials within Goshems Farm, mobilising the existing leachate within the landfill.

10.6.44 The made ground within the Goshems Farm Landfill is not considered to be hydraulically connected to the underlying aquifer due to a significant thickness (approximately 16m) of continuous cohesive soils within the underlying Alluvium acting as an aquitard and therefore vertical migration of leachate has been discounted. The Ground Model is presented in Appendix 10.5 (Application Document 6.3).

10.6.45 Migration of leachate through existing pathways, via the sides of the land raised area of Goshems Farm could potentially affect the neighbouring water environment which includes the River Thames and the West Tilbury Main.

10.6.46 The material that would be used to create the landscaped feature would be defined by the permitting arrangements which would be obtained for this work and would be required to be suitable for use both chemically (i.e. protective of human health and the environment) and geotechnically. The commitment for this requirement is made in the REAC through items MW007 and GS006.

10.6.47 As discussed in Appendix 10.2: Stability Report (Application Document 6.3), the placement of large quantities of material to form the landscaping mounds would result in settlement occurring over the extent of their footprint. Industry best practice earthworks construction approaches (such as those detailed in Manual of Contract Document for Highway Works Volume 1 Series 600 of the Specification for Highway Works (Highways England, 2016)) would be adopted to ensure that potential settlement is managed and allowed for in the man-made or natural materials underlying the landscaping mounds.

10.6.48 Geotechnical risk would be managed in accordance with REAC GS003. An earthworks construction sequence would be designed, which would likely include elements such as progressively depositing materials in layers of a maximum defined thickness uniformly over the footprint of the mounds; applying hold periods before deposition of subsequent layers and adjusting earthworks thicknesses to allow for settlement. Installing and monitoring earthwork control instrumentation and in situ testing would also be carried out in line with REAC GS003. In addition, the detailed design would determine the best approach to manage surface water run-off and control pore pressure within the underlying ground, if required.

10.6.49 As described in Section 10.4 and Appendix 10.9: Generic Quantitative Risk Assessment for the Phase 2 Investigation (Application Document 6.3), groundwater strikes within the made ground at Goshems Farm were encountered along with intervals of “no water” indicating that the groundwater is likely to be perched, very localised and therefore does not form a continuous body of water. Any leachate within the landfill material would likely be present within perched water and pore spaces. Leachate within pore spaces near to the sides of the landfill may be able to seep out when additional load is applied, however this would be a finite quantity. Leachate in the body of the landfill would not be able to be discharged, as there is no pathway for the leachate to flow to the sides. This leachate would dissipate within the body of the landfill itself. A scheme of environmental monitoring of surface water features would be undertaken during construction as set out in the Remediation Options Appraisal and Outline Remediation Strategy (Application Document 6.3, Appendix 10.11) and committed to in REAC GS027.

10.6.50 In the longer term the compaction of the ground is also considered likely to reduce the overall permeability of the materials, reducing the potential for leachate mobility. The placement of additional fill materials above with landscaping and sloped terrain is likely to reduce vertical percolation and hence production of leachate

10.6.51 It should be noted that Goshems Farm has been operating for many years with no controls on leachate, with additional materials placed on top of the original historical landfill. Leachate discharge from the sides of the land raised area would be currently occurring through existing pathways. The placement of additional materials in the development of the Tilbury Fields is not considered likely to change or significantly affect the discharge of leachate.

10.6.52 With the implementation of measures detailed above as well as the good practice construction methods detailed in Section 10.5 and in the CoCP (Application Document 6.3, Appendix 2.2), the magnitude of impact on the River Thames is considered to be negligible during the creation of Tilbury Fields. The significance of effect is assessed as slight adverse and would be short term during main construction activities. This effect is **not significant**.

West Tilbury Main

10.6.53 This surface water feature runs between Goshems Farm landfill and the East Tilbury landfill site. This is adjacent to the northern tunnel entrance compound and is considered to have a medium sensitivity. West Tilbury Main may be impacted by the construction of a temporary access road across the East Tilbury landfill site. This could result in the risk of liquid waste/leachate present within the landfill, being brought to the surface by consolidation of the landfill material under the temporary road. This liquid waste could migrate into the West Tilbury Main and the wider water environment.

10.6.54 The Package B ground investigation within the Goshems Farm area encountered pre-existing metal and PAH contaminants that exceed the GAC in the soil and soil leachate samples.

10.6.55 Owing to the commitments and likely design restrictions with respect to the design of the temporary access road detailed in Section 10.5, the magnitude of impact on the West Tilbury Main is considered to be negligible. The effect is assessed as slight adverse and short term in nature. This effect is **not significant**.

10.6.56 It should be noted that any proposed dewatering at North Portal is not considered to have a potential effect on West Tilbury Main owing to it being a shallow man manmade feature that is not in continuity with the groundwater.

West Tilbury Main – Creation of Tilbury Fields

10.6.57 The West Tilbury Main is adjacent to the proposed landforms that make up Tilbury Fields and the existing Goshems Farm landfill. As detailed in the section titled ‘River Thames – Creation of Tilbury Fields’, the effect pathways for the West Tilbury Main are the same as the River Thames and control measures implemented would manage the potential effects. Therefore, with the implementation of the good practice construction methods detailed in Section 10.5 and in the CoCP (Application Document 6.3, Appendix 2.2), the magnitude of impact on the West Tilbury Main is considered to be negligible during the creation of Tilbury Fields. The significance of effect is assessed as slight adverse and would be short term during main construction activities. This effect is **not significant**.

Gobians Sewer

10.6.58 This surface water feature is considered to have a medium sensitivity. Construction work would take place in the vicinity of this watercourse as the Project crosses the Gobians Sewer which would be culverted beneath it. The Package D ground investigation recorded one exceedances of soils samples (lead); however, soil leachate exceedances were recorded for metals, inorganics and phenolics (Table 10.18). This was found not to present an unacceptable contamination risk to surface water receptors. With the

implementation of good practice environmental design and mitigation measures, including the completion of foundation work risk assessments (as detailed in Section 10.5 and in the CoCP (Application Document 6.3, Appendix 2.2)), the magnitude of impact on the Gobians Sewer is considered to be negligible as the risk of pollution is low. The effect is assessed as slight adverse and would be short term during main construction activities. This effect is **not significant**.

Mardyke/Mardyke West Tributary

10.6.59 These surface water features are considered to have a high sensitivity. Construction work would take place in the vicinity of these watercourses as the Project bridges over them. An existing culvert under the M25 would be lengthened to support the Mardyke West Tributary. The Package D ground investigation recorded one exceedances of soils samples (lead); however, soil leachate exceedances were recorded for metals, inorganics and phenolics (Table 10.18). This was found not to present an unacceptable contamination risk to surface water receptors. With the implementation of good practice environmental design and mitigation measures, including foundation work risk assessments (as detailed in Section 10.5 and in the CoCP (Application Document 6.3, Appendix 2.2)), the magnitude of impact on the Mardyke / Mardyke West Tributary is considered to be negligible as the risk of pollution is low. The effect is assessed as slight adverse and would be short term during main construction activities. This effect is **not significant**.

Orsett Fen Sewer, Golden Bridge Sewer and Stringcock Sewer

10.6.60 These surface water features are considered to have a medium sensitivity. Construction work would take place in the vicinity of these watercourses as the Project crosses them on structures. The Package D ground investigation recorded one exceedances of soils samples (lead); however, soil leachate exceedances were recorded for metals, inorganics and phenolics (Table 10.18). This was found not to present an unacceptable contamination risk to surface water receptors. With the implementation of good practice environmental design and mitigation measures, including foundation work risk assessments (as detailed in Section 10.5 and in the CoCP (Application Document 6.3, Appendix 2.2)), the magnitude of impact on the Gobians Sewer is considered to be negligible as the risk of pollution is low. The effect is assessed as slight adverse and would be short term during main construction activities. This effect is **not significant**.

Unnamed ordinary watercourses, ponds and recreational lakes

10.6.61 A number of unnamed water features are noted within the Order Limits. Construction activities that take place near to such features could cause a potential impact. They are considered to have a medium sensitivity. The ground investigation carried out has encountered contamination however, this was found not to present an unacceptable contamination risk to surface water receptors. With the implementation of good practice environmental design and mitigation measures as detailed Section 10.5 and in the CoCP (Application Document 6.3, Appendix 2.2), the magnitude of impact on these watercourses is considered to be negligible. The effect is assessed as slight adverse and would be short term during main construction activities. This effect is considered to be **not significant**.

Groundwater

10.6.62 From the ground investigations undertaken, pre-existing contamination has been encountered within the underlying soils and groundwater as detailed within Table 10.15 to Table 10.18. The soil and groundwater contamination could be remobilised during construction activities and impact the groundwater which in turn could migrate into the wider water environment. During the construction of new structures, for example bridges and tunnel portals, there is the potential for the creation of pathways into the underlying aquifers via techniques such as piling. Each groundwater receptor is assessed in turn below.

10.6.63 Indirect effects relating to changes in groundwater levels and the remobilisation of pre-existing contamination have been considered as part of the assessment.

Principal chalk aquifer, supporting licensed and unlicensed abstractions

10.6.64 The bedrock Principal chalk aquifer within the study area is assigned a very high value. It is present to the south and north of the River Thames and is close to the surface to the south where superficial deposits are absent. Taking into account the Project's ground investigation, no unacceptable contamination risks to the Principal chalk aquifer have been identified. Measures detailed within Section 10.5 and in the CoCP (Application Document 6.3, Appendix 2.2) have been identified to protect the Principal aquifer and include the implementation of a foundation works risk assessment. Good practice measures for the control and handling of contamination during the construction phase are also committed to by the Project and would prevent the introduction of new contamination pathways into the chalk. Owing to these commitments, the magnitude of impact on the Principal aquifer is negligible. The effect is assessed as slight adverse and would be short term during main construction activities. This effect is considered to be direct and **not significant**.

10.6.65 The groundwater in the Chalk aquifer in the area of the North Portal is considered to have very high value. The results of the groundwater numerical modelling, presented in the Hydrogeological Risk Assessment Report (Application Document 6.3, Appendix 14.5), show that with the implementation of mitigation measures as detailed in Section 10.5, the magnitude of impact is considered to be negligible as groundwater ingress into the excavation would be controlled and minimised. The East Tilbury Landfill Risk Assessment (Application Document 6.3, Appendix 10.7) concluded that irrespective of mitigation measures implemented for groundwater control for construction purposes, a pathway for CoC migration between the landfill, the aquifers, and North Portal, does not exist.

10.6.66 ConSim modelling analysis is presented in Appendix 10.7 (Application Document 6.3). Using data taken from the constant rate pumping test carried out in Package B, fate and transport modelling was undertaken to determine envisaged travel times for contamination through the Alluvium from the East Tilbury landfill site to the North Portal. The modelled travel time if a viable pathway existed was approximately 53 years for the most mobile CoC, which far exceeded the duration of dewatering of maximum three years. The effect is therefore considered to be slight adverse, indirect and **not significant**.

Secondary A aquifer, supporting licensed and unlicensed abstractions

10.6.67 As detailed in

10.6.68 Table 10.10, underlying superficial deposits (Alluvium, Head Deposits and River Terrace Deposits) and bedrock (Thanet Formation, Lambeth Group and Harwich Formation) support secondary aquifers across the Project. This aquifer is assigned a medium value. Construction would take place within these strata which could remobilise pre-existing contamination impacting this groundwater receptor. Taking into account the Project's ground investigation, no unacceptable risks to the Secondary A aquifer were identified, however, measures detailed within Section 10.5 and in the CoCP (Application Document 6.3, Appendix 2.2) have been identified to protect the groundwater resources and include the implementation of a foundation works risk assessment. Good practice measures for the control and handling of contamination during the construction phase are also committed to by the Project. Owing to these commitments, the magnitude of impact on this receptor is considered to be negligible. The effect is assessed as slight adverse and would be short term during main construction activities. This effect is direct and **not significant**.

Unproductive Strata

10.6.69 London Clay is present mainly to the north of the River Thames and is unproductive strata, assigned a low value. Construction would take place within this stratum especially where it is near to the surface. Mobilisation is likely to be limited due to the low permeability of the clay and with the implementation of good practice construction measures as detailed in Section 10.5 and the CoCP (Application Document 6.3, Appendix 2.2), the magnitude of impact on this receptor is considered to be negligible. The effect is assessed as neutral, direct and **not significant**.

Operational phase

Geology

10.6.70 The operation of the Project would result in no change to geological resources of all values. Therefore, the resultant effect would be neutral which is **not significant.**

Introduction of new contamination

10.6.71 During the operation of the road, there is the potential for contamination from road spray and pollution incidents associated with road usage and traffic accidents (for example, fuel/oil spillages). Geology within the study area is considered to have a negligible value and could be impacted during such incidents but this is likely to be minor as the majority would be diverted to the drainage system. If any incident were to occur which resulted in localised contamination, soils which had become affected would be assessed and if necessary, removed to reduce the risk of contamination migrating across a wider area and/or entering controlled waters (as committed to in REAC GS019). The magnitude of impact is therefore considered to be negligible. The effect is assessed as neutral. This effect is likely to be short term after the spillage/incident and is **not significant**.

Exposure of geological areas

10.6.72 The construction of the Project has the potential to expose areas of geological interest through the operational phase especially in areas of deep cutting. This would benefit the knowledge of local geological groups and the wider community who could view the exposed geology from public footpaths. This is likely to be permanent with a beneficial impact.

Land contamination

Human health

Exposure of contamination

10.6.73 The main human receptors affected by the Project during the operation phase include future users of the road (low value), residents living close to the Project (very high value), people using public open spaces (high value) and those using commercial/industrial properties (medium value) in proximity to the Project.

10.6.74 Exposure to contaminants could occur through various pathways, including through dermal contact, ingestion, and inhalation. However, once the Project has been constructed, the risk of exposure to contaminated soils by human health receptors is low as the road itself would create a barrier to underlying soils. In addition, mitigation and measures implemented to manage the risk of pre-existing contamination during the construction phase would further reduce the risk to human health receptors during the operation phase. Owing to this, it is unlikely that a pathway to residential receptors and users of open space would exist and therefore the magnitude of impact is envisaged to be no change. The effect is considered to be neutral which is **not significant**.

10.6.75 For road users (low value), the majority of their time would be spent inside their cars. If however they need to stop and be on the roadside (for example, breakdown or accident), slight exposure could occur, although the magnitude of impact is considered to be negligible. The effect is considered to be neutral which is **not significant**.

10.6.76 Tilbury Fields is a proposed landform comprising an area of public parkland and open mosaic habitat to the south and east of the North Portal. The parkland would be created from excavated material and treated tunnel arisings on top of the Goshems Farm landfill site. The material that would be used to create the landscaped feature would be defined by the permitting arrangements which would be obtained for this work. Under this arrangement, the material would be required to be chemically suitable for use and protective of human health (and the environment). The commitment for this requirement is made in the REAC through items MW007 and GS006.

10.6.77 These controls would ensure that there would be a negligible risk to users of the public open space who are considered to have a high value. The magnitude of impact is envisaged to be negligible and the significance of the effect is considered to be neutral which is **not significant**.

Exposure of ground gases

10.6.78 Landfill sites are present along the Project route and especially in the area of the North Portal. High concentrations of ground gases could be present in such areas posing a risk to road end users of the tunnel and portal areas. Road users are assigned a low value and taking account of the ground gas prevention measures included within the design of confined spaces and the tunnel portal as detailed in Section 10.5, the magnitude of impact is considered to be negligible. The effect is considered to be slight adverse for road users which is **not significant**.

10.6.79 Utility works are proposed which could create preferential pathways to offsite receptors for contamination and ground gases. Mitigation measures are included with the Remediation Options Appraisal and Outline Remediation Strategy (Application Document 6.3, Appendix 10.11) to reduce this risk. Residents living close to the Project are considered to be very high value, people using public open spaces are high value with those using commercial/industrial properties medium value. With the implementation of mitigation measures as detailed in Section 10.5 and in particular in the Remediation Options Appraisal and Outline Remediation Strategy, the magnitude of impact is considered to be negligible. The effect is considered to be slight adverse effect for the offsite receptors which is **not significant.**

Surface water and groundwater

Contamination from road spray, pollution incidents associated with road usage (for example, fuel/oil spillages) and traffic accidents

10.6.80 During the operation of the road, there is the potential for contamination of surface water and groundwater receptors from road spray and pollution incidents associated with the road usage (for example, fuel/oil spillages) and traffic accidents. Design and mitigation measures are detailed in Section 14.5 in Chapter 14: Road Drainage and the Water Environment and the significance is assessed in Chapter 14. The surface water bodies that would receive operational drainage are assessed as being high to medium importance and the impact magnitude has been assessed as negligible. The overall effect is therefore permanent slight adverse to neutral which is **not significant**.

Mobilisation of contamination resulting from groundwater drawdown caused by leakage into the main tunnel

10.6.81 During the operation of the main tunnel, there is potential for groundwater leakage into the tunnel which could indirectly mobilise contamination from East Tilbury landfill into the wider groundwater environment. The results of the groundwater numerical modelling, presented in the Hydrogeological Risk Assessment Report (Application Document 6.3, Appendix 14.5), show that, with the implementation of mitigation measures as listed in Section 14.5 of Chapter 14 Road Drainage and the Water Environment and including adherence to industry standards for watertightness of the tunnel liner system, the impact on groundwater drawdown would be negligible. The groundwater (Principal aquifer) is assessed as being of very high importance and the overall indirect effect is permanent slight adverse, which is **not significant**.

10.6.82 Any remediation works undertaken to pre-existing contamination in soils and groundwater during the construction of the Project would be expected to result in a benefit to the local environment. The risk of mobilisation and migration of contamination would be reduced. This is likely to be permanent with a beneficial impact.

10.7 Cumulative effects

Intra-project effects

10.7.1 Cumulative effects of the Project can occur as a result of interrelationships between different environmental topics, which are referred to as 'intra-project effects'. For geology and soils, interrelationships are identified with air quality (Chapter 5: Air Quality), terrestrial biodiversity (Chapter 8: Terrestrial Biodiversity), materials (Chapter 11: Material Assets and Waste), communities (Chapter 13: Population and Human Health) and the water environment (Chapter 14: Road Drainage and the Water Environment) and are summarised below:

a. Air quality – human health exposure to dust containing contaminants during construction works.

b. Terrestrial biodiversity – construction activities that alter soil characteristics could result in the degradation of some plants and habitats that have close affinities to particular soil types, including some that form qualifying features of designated sites. A particular overlap relates to the impact from construction activities on Low Street Pit Local Wildlife Site, which is a potential Local Geological Site.

c. Material assets and waste – reuse of suitable excavated soils during the construction to avoid cross-contamination.

d. Road drainage and the water environment – construction activities which cause the mobilisation of contaminants into the water environment (groundwater and surface water).

e. Population and human health – interrelationships related to effects associated with soil quality which have been taken into account in the assessment of effects on agricultural landholdings. A further area of overlap relates to the assessment of potential sources of pollution (land and water) and unexploded ordnance, and the potential impact these may have in relation to human health.

10.7.2 The above interrelationships have been considered as part of the assessment reported in this chapter, and the relevant topic chapters identified above.

10.7.3 Pollution effects associated with geology and soils have been considered as part of the assessment of intra-project effects on residential receptors reported in Chapter 16: Cumulative Effects Assessment.

Inter-project effects

10.7.4 In addition to intra-project effects, cumulative effects can also occur due to the Project in combination with other existing and/or approved development. These are known as 'inter-project' effects and, are considered separately in Chapter 16: Cumulative Effects Assessment.

10.8 Monitoring

10.8.1 Significant effects have been identified in relation to agricultural land. Monitoring would be undertaken in accordance with REAC Ref. GS014 to demonstrate the restoration of land in line with the desired end use, for example the pre-construction ALC grade or specific characteristics for habitat/landscape planting establishment.

10.8.2 No further likely significant adverse residual effects have been identified, for geology and soils receptors. The REAC within the CoCP (Application Document 6.3, Appendix 2.2) documents any additional monitoring that would be required during the construction phase.

10.9 Summary

10.9.1 Table 10.24 provides a summary of all predicted impacts in this chapter, taking into account the Project design and mitigation set out in Section 10.5.

Table 10.24 Geology and soils impact summary table

Impact description	Importance sensitivity/ value of receptor	Magnitude of impact	Effect	Significance
Construction				
Geological receptors				
Impact on geology – degradation of geological resource	Negligible	Negligible	Neutral	Not significant
Culand Pits – no impact predicted	High	No change	Neutral	Not significant
Low Street Pit – partial loss of potential Local Geological Site	Medium	Minor adverse	Slight adverse	Not significant
West Tilbury Wells – no impact predicted	Low	No change	Neutral	Not significant
Chadwell St Mary Sarsen Stone – no impact predicted	Low	No change	Neutral	Not significant
East Tilbury Marshes – no impact predicted	Low	No change	Neutral	Not significant
Turners Farm Gravel Pit – no impact predicted	Medium	No change	Neutral	Not significant
Orsett Cock Quarry – no impact predicted	Low	No change	Neutral	Not significant

Impact description	Importance sensitivity/ value of receptor	Magnitude of impact	Effect	Significance
Orsett Depot Quarry – no impact predicted	Low	No change	Neutral	Not significant
Tilbury Dock – no impact predicted	Low	No change	Neutral	Not significant
Ockendon Clay Plant – no impact predicted	Low	No change	Neutral	Not significant
Cranham – no impact predicted	Low	No change	Neutral	Not significant
Coombe Green Sand Pit – no impact predicted	Low	No change	Neutral	Not significant
Buckingham Hill Sand Quarry – no impact predicted	Low	No change	Neutral	Not significant
North Stifford Church Puddingstone – no impact predicted	Low	No change	Neutral	Not significant
Dansand Quarry – no impact predicted	Low	Negligible	Slight adverse	Not significant
Soils				
Soils – loss of BMV land during the construction phase	Very high	Major	Very large adverse	**Significant**
Soils – permanent loss of BMV land following reinstatement of land required temporarily	Very high	Major	Very large adverse	**Significant**
Temporary and permanent impacts on soils supporting designated and non-designated notable habitats	High to low	Moderate to minor	Moderate adverse to neutral	**Significant**
Land contamination – human health receptors				
Offsite receptors of residential area – exposure to contaminants and UXO	Very high	Negligible	Slight adverse	Not significant
Offsite receptors of public open space – exposure to contaminants and UXO	High	Negligible	Slight adverse	Not significant
Offsite receptors of commercial/ industrial areas – exposure to contaminants and UXO	Medium	Negligible	Neutral	Not significant

Impact description	Importance sensitivity/ value of receptor	Magnitude of impact	Effect	Significance
Land contamination – surface water receptors				
Ditch networks at Filborough and Shorne Marshes, including the Denton New Cut – reduction in surface water quality. Migration of remobilised contaminants to surface watercourses.	High	No change	Neutral	Not significant
Thames and Medway Canal – reduction in surface water quality. Migration of remobilised contaminants to surface watercourses.	Medium	Negligible	Slight adverse	Not significant
River Thames – reduction in surface water quality. Migration of remobilised contaminants to surface watercourses, creation of Tilbury Fields	Very High	Negligible	Slight adverse	Not significant
West Tilbury Main – reduction in surface water quality. Migration of remobilised contaminants to surface watercourses, creation of Tilbury Fields.	Medium	Negligible	Slight adverse	Not significant
Gobians Sewer – reduction in surface water quality. Migration of remobilised contaminants to surface watercourses.	Medium	Negligible	Slight adverse	Not significant
Mardyke/Mardyke West Tributary – reduction in surface water quality. Migration of remobilised contaminants to surface watercourses.	High	Negligible	Slight adverse	Not significant
Orsett Fen Sewer, Golden Bridge Sewer and Stringcock Sewer – reduction in surface water quality. Migration of remobilised contaminants to surface watercourses.	Medium	Negligible	Slight adverse	Not significant
Unnamed ordinary watercourses, ponds and recreational lakes –	Medium	Negligible	Slight adverse	Not significant

Impact description	Importance sensitivity/ value of receptor	Magnitude of impact	Effect	Significance
reduction in surface water quality. Migration of remobilised contaminants to surface watercourses.				
Land contamination – groundwater receptors				
Principal aquifer – reduction of groundwater quality due to mobilisation and migration of pre-existing contamination Leaching of contaminants to underlying aquifers. Migration of contaminants through preferential pathways (e.g. via piling) to groundwater in underlying aquifers.	Very high	Negligible	Slight adverse	Not significant
Secondary aquifer – reduction of groundwater quality due to mobilisation and migration of pre-existing contamination. Leaching of contaminants to underlying aquifers. Migration of contaminants through preferential pathways (e.g. via piling) to groundwater in underlying aquifers.	Medium	Negligible	Slight adverse	Not significant
Unproductive aquifer – reduction of groundwater quality due to mobilisation and migration of pre-existing contamination. Leaching of contaminants to underlying aquifers. Migration of contaminants through preferential pathways (e.g. via piling) to groundwater in underlying aquifers.	Low	Negligible	Neutral	Not significant
Operation				
Geology				
Impact on geology	Negligible	No change	Neutral	Not significant
Introduction of new contamination – road usage, traffic accidents	Negligible	Negligible	Neutral	Not significant

Impact description	Importance sensitivity/ value of receptor	Magnitude of impact	Effect	Significance
Exposure of geological areas – benefit knowledge of local geological groups	-	-	-	N/A
Land contamination – human health receptors				
Offsite receptors of residential area – exposure to contaminants, ground gases	Very high	Negligible	No change	Not significant
Offsite receptors of public open space – exposure to contaminants, ground gases	High	Negligible	No change	Not significant
Offsite receptors of commercial/ industrial areas – exposure to contaminants , ground gases	Medium	Negligible	No change	Not significant
Onsite road users – exposure to contaminants and ground gases (especially North Portal location)	Low	Negligible	Neutral	Not significant
Onsite users of Tilbury Fields	High	Negligible	Neutral	Not significant
Land contamination – groundwater receptor				
Principal aquifer – reduction in groundwater quality due to mobilisation of contamination from East Tilbury due to tunnel leakage	Very high	Negligible	Sight adverse	Not significant
Remediation of pre-existing contamination – benefit to the local environment due to reduction of mobilisation and migration of contaminants	-	-	Beneficial	N/A

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