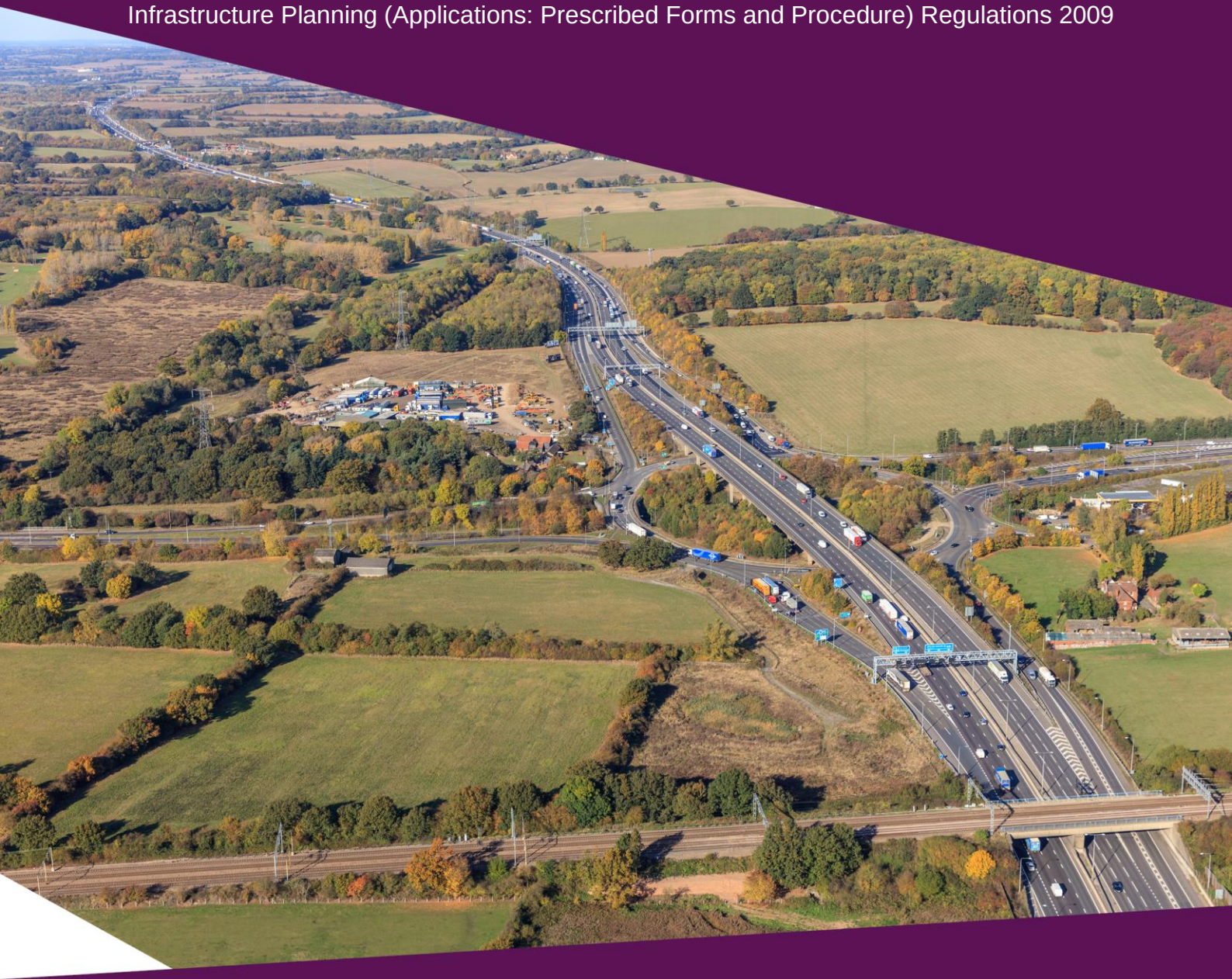
M25 junction 28 improvement scheme
TR010029
6.1 Environmental Statement
Chapter 10: Geology and soils

APFP Regulation 5(2)(a)
Planning Act 2008
Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009



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6.1 ENVIRONMENTAL STATEMENT
CHAPTER 10: GEOLOGY AND SOILS

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Executive summary

An assessment with regards to geology and soils has been carried out for the Scheme and a 250 m buffer zone from the Development Consent Order (DCO) boundary. The assessment comprises three components; land contamination, geomorphology and ground stability and agricultural land.

Identified potential sources of contamination within the DCO boundary include the inactive Brook Street Landfill, recently deposited material at Grove Farm, a railway, Made Ground / infill associated with existing infrastructure, vehicle emissions, spills and leaks on the roads, four recorded minor pollution incidents and a BPA sub-surface pipeline. Identified potential sources of contamination within 250 m from the DCO boundary include a garden centre and a waste management company (both at Grove Farm), two former fuel stations, two active fuel stations, electricity substations, a sewage treatment works, a former aerodrome, vehicle service garages, vehicle cleaning services and agricultural activities. Identified receptors of potential contamination include residents, construction workers, maintenance workers, groundwater aquifers, surface water features and infrastructure.

A preliminary geo-environmental ground investigation has been carried out on land to the northwest of junction 28 within the DCO boundary, targeting the recently deposited material at Grove Farm. This area of the Scheme was considered a cause for concern but has been de-risked as no widespread, unacceptable concentrations of chemical parameters were identified.

Without mitigation measures, the construction phase effects associated with potential contamination sources have been typically assessed as minor adverse or negligible, temporary and not significant. The exception to this outcome would be the potential effect relating to the pathway linking on-site construction workers to asbestos identified in the sub-surface during the preliminary geo-environmental ground investigation, which is considered a moderate adverse, temporary and significant effect.

Where adverse effects associated with land contamination have been identified, design and mitigation measures would be implemented. With these measures, the temporary effects to the identified receptors during construction are considered negligible, temporary and not significant, as the level of risk to receptors is expected to remain generally the same as before the Scheme. With design and mitigation measures, including the adoption of Best Available Techniques, the operational phase is considered to have a negligible to minor beneficial effect and has been assessed as permanent and not significant. The reason beneficial effects have been identified is that the reasonable worst-case scenario for the Scheme assumes that where potential sources of contamination have been identified but not intrusively investigated, contamination is present. This would lead to remediation which would therefore improve the conditions from before the Scheme.

With respect to geomorphology and ground stability, the assessment indicated that the construction phase is likely to have a minor adverse (temporary) to minor beneficial (permanent) effect and the operational phase is considered likely to have a negligible effect. These effects have been assessed overall as not significant.

The effects of the Scheme on agricultural land are neutral to slight adverse and have been assessed as not significant.

A ground investigation for the Scheme is underway to investigate the existing geology, hydrogeology and soil conditions. No intrusive construction ground works associated with the Scheme would commence until for that part a ground investigation and appropriate risk assessments have been submitted to and approved by the Secretary of State, following consultation with the Environment Agency and the relevant planning authority.

With the design and mitigation measures proposed, there are no likely significant adverse residual effects concerning geology and soils.

No cumulative effects with regards to geology and soils are assessed as a likely as a consequence of the Scheme and surrounding development.

10. Geology and soils

10.1 Introduction

10.1.1 This chapter has been prepared to identify the likely effects with respect to geology and soils resulting from the Scheme and reports the findings of an assessment of the following topics:

- Impacts associated with pre-existing soil and groundwater contamination (i.e. mobilising contamination, introducing new or changing existing contamination migration pathways, or changing/introducing receptors).
- Physical effects such as changes in topography, aggressive ground conditions, ground stability and soil erosion.
- Loss of, or disturbance to agricultural soils (in particular, Best and Most Versatile (BMV) agricultural land) and agricultural holdings.
- The possible cumulative effects of the Scheme on geology and soils, in combination with nearby proposed developments.

10.1.2 This chapter assesses hydrology and hydrogeology with respect to potential contamination impacts of the Scheme on controlled waters[1]. The Road Drainage and the Water Environment chapter (Chapter 8) assesses the potential impacts of the Scheme on the water environment as a resource and assesses impacts associated with the potential for polluting substances to reach the water environment during operation of the Scheme.

10.1.3 For consideration of the re-use, treatment and disposal of waste soils from construction, refer to the Materials and Waste chapter (Chapter 12).

10.1.4 Direct impacts on geology as a valuable resource; i.e. mineral resource sterilisation, damage or loss of geological special protection areas such as geological Sites of Special Scientific Interest (SSSI) were scoped out of the assessment at the scoping stage.

10.2 Competent expert evidence

10.2.1 This geology and soils assessment has been carried by the following individuals who have used their knowledge and professional judgement:

- A contaminated land and hydrogeology specialist with academic qualifications BSc Geology and MSc Environmental Geo-Science and over 20 years' experience in contaminated land, remediation and environmental due diligence with professional membership as a Chartered Scientist (CSci) and Specialist in Land Condition (SiLC).
- A soils specialist (BA (Hons) Geography, MSc Soil Survey and Pedology) who is a member of the British Society of Soil Science with over 40 years' experience of soil survey, agricultural land classification and agricultural consultancy. Author of a number of books and scientific papers on those subjects and has worked on numerous major infrastructure projects.

[1] Controlled Waters: As defined in the Water Resources Act (1991)

- A qualified environmental consultant (BSc (Hons) Environmental Analysis, MSc Contaminated Land Management, CSci), with over 17 years of knowledge and experience in contaminated land and risk assessments and holds professional membership with the Institute of Environmental Science and Society of Brownfield Risk Assessment.
- A hydrogeologist (BSc Geology, Post Graduate Diploma Engineering Geology, Post Graduate Diploma Hydrogeology) with over 10 years' experience in hydrogeology, contaminated land and engineering geology and holds professional membership with the Geological Society (CGeol).

10.3 Legislative and policy framework

10.3.1 Table 10.1 below identifies and describes legislation, policy and guidance of relevance to the assessment of the potential geology and soil impacts associated with the Scheme.

Table 10.1: Legislation and policy document framework summaries

Legislation/ policy/ guidance document	Summary of requirements
National	
Planning Act (2008)[2]	Section 55 of the Planning Act sets out criteria that an application for Development Consent Order should meet. Further information is provided in 10.5.3 of this ES chapter.
Environmental Protection Act (EPA) (1990)[3]	Part 2A of the EPA introduced a statutory regime for the identification and remediation of 'Contaminated Land'. It introduced a statutory definition of 'Contaminated Land' which is any land in such a condition that by reason of substances in, on or under the land that significant harm is being caused or there is significant possibility of such harm being caused or the pollution or significant pollution of controlled waters (all groundwater, inland waters and estuaries, excluding water perched above the zone of saturation) is being caused or there is significant possibility of such pollution being caused. Local authorities are the primary regulators under the Part 2A regime, with a duty to identify whether the land in their area is 'Contaminated Land', although provision is made for consultation and co-ordination with the Environment Agency in situations when pollution of controlled waters is an issue.
Water Resources Act 1991[4] (as amended)	The Water Resources Act sets controls of pollution of water sources in Chapter 57 Part III. It contains information about water quality objectives, powers to prevent and control pollution and pollution offenses.
The Landfill (England and Wales) Regulations (2002)[5]	Sets out a regime for the operation of landfills within England and Wales to ensure compliance with EU Landfill Directive (1999/31/EC).

[2] Her Majesty's Stationery Office (2008) Planning Act, Accessed on 26/06/2019 from https://www.legislation.gov.uk/ukpga/2008/29/part/6/chapter/1/data.xht?view=snippet&wrap=true
[3] United Kingdom Parliament (1990) Environmental Protection Act, Accessed on 08/02/2019 from https://www.legislation.gov.uk/ukpga/1990/43/contents
[4] UK Government (1991) The Water Resources Act, Accessed on 08/02/2019 from http://www.legislation.gov.uk/ukpga/1991/57/contents
[5] UK Government (2002) The Landfill (England and Wales) Regulations, Accessed on 11/11/2019 from https://www.legislation.gov.uk/ukdsi/2002/0110395905/contents

Legislation/ policy/ guidance document	Summary of requirements
The Hazardous Waste (England and Wales) Regulations 2005 (SI 2005/894) (as amended in 2016)[6]	The Regulations, as amended in 2009 (SI 2009/507), 2015 (SI 2015/1360) and 2016 (SI 2016/336) applies to all wastes listed as hazardous in the List of Waste (2000/532/EC) and the CLP (Classification, Labelling and Packaging) Regulation (EC 1272/2008).
The Environmental Permitting (England and Wales) Regulations 2016 (SI 2016/1154) (as amended 2018) (SI 2018/110)[7]	The Environmental Permitting Regulations 2016 (SI 2016/1154) replace the 2010 Regulations (SI 2010/675) (as amended in 2011 (SI 2011/2043), 2012 (SI 2012/630) and 2014 (SI 2014/255)). The Regulations put in place requirements to ensure that sites that produce certain materials and undertake certain activities (such as the storage, use or treatment of waste) have a permit or exemption from the regulator (i.e. the Environment Agency).
The Control of Substances Hazardous to Health Regulations (2002)[8]	This legislation covers the requirement or Health and Safety Risk Assessments, Method Statements (RAMS) and use of appropriate Personal Protective Equipment (PPE) with relation to the handling of substances that are hazardous to health.
Construction Design and Management Regulations (2015)[9]	Provides a set of requirements to manage the Health and Safety aspects of construction projects in the UK. This legislation places legal requirements on the different parties involved with the design, management and undertaking of construction work from inception to completion ensuring that Health and Safety consideration is placed at the forefront of each project.
Contaminated Land Statutory Guidance 2012[10]	The principal objectives are described in the Department for Environment, Food and Rural Affairs (Defra) Contaminated Land Statutory Guidance, which are to: • Identify and remove unacceptable risks to human health and the environment. • Seek to ensure that contaminated land is made suitable for its current use. • Ensure that the burdens faced by individuals, companies and society as a whole are proportionate, manageable and compatible with the principles of sustainable development. These objectives underlie the 'suitable for use' approach to the assessment and remediation of 'land contamination'. This approach recognises that land contamination risks will vary according to the use of the land and a wide range of other factors, such as the sensitivity of the underlying geology and the receptors which may be affected. The 'suitable for use' approach consists of three elements: • Ensuring that land is suitable for its current use. • Ensuring that land is made suitable for any new use. Limiting requirements for remediation to the work necessary to prevent unacceptable risks to human health or the environment in relation to the current use or future use of the land.

[6] UK Government (2005) The Hazardous Waste Regulations, Accessed on 11/11/2019 from http://www.legislation.gov.uk/uksi/2005/894/contents/made
[7] UK Government (2016) The Environmental Permitting (England and Wales) Regulations (SI 2016/1154) (as amended 2018) (SI 2018/110), Accessed on 11/11/2019 from http://www.legislation.gov.uk/uksi/2016/1154/made
[8] Health and Safety Executive (2002) COSHH, Accessed on 08/02/2019 from http://www.hse.gov.uk/nanotechnology/coshh.htm
[9] UK Government (2015) Construction Design and Management Regulations, Accessed on 11/112019 from http://www.legislation.gov.uk/uksi/2015/51/contents/made
[10] Department for Environment, Food and Rural Affairs (2012) Environmental Protection Act: Part 2A Contaminated Land Statutory Guidance, Accessed on 09/02/2019 from https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/223705/pb13735cont-land-guidance.pdf

Legislation/ policy/ guidance document	Summary of requirements
Water Framework Directive (WFD) (2000)[11]	The purpose of the WFD is to establish a framework for the protection of water bodies including: Inland surface waters, transitional waters, coastal waters and groundwater. It includes directions that: • Environmental objectives should be set to ensure that good groundwater status is achieved and that its deterioration is avoided. Upward sustaining trends in the concentration of a pollutant must be identified and reversed. • A good status of groundwater requires early action and stable long-term planning of protective measures, owing to the natural time lag in its formation and renewal. • Monitoring programmes should cover monitoring of the chemical and quantitative status of groundwater.
National Policy Statement for National Networks (NPS NN) (2014)[12]	The NPS NN seeks to ensure that Nationally Significant Infrastructure Projects (NSIPs) are designed to minimise social and environmental impacts and to improve quality of life. Further, in delivering new schemes, opportunities to deliver environmental benefits should also be considered as part of scheme proposals. The NPS NN sets out policies and provides detailed guidance in relation to the assessment of the likely main environmental issues that need to be considered for such schemes. It also details potential key mitigation measures that can be implemented to minimise adverse effects. Guidance and policy regarding the assessment of land stability are set out in paragraphs 5.116 to 5.119. Key requirements are that the Scheme proposals must be suitable for the location and that unacceptable risks associated with land instability are prevented. The NPS NN states in paragraphs 5.168 and 5.176 that applicants should take account of the economic and other benefits of the BMV agricultural land (defined as land in Grades 1, 2 and 3a of the Agricultural Land Classification). Where significant development of agricultural land is demonstrated to be necessary, applicants should seek to use areas of poorer quality land in preference. The decision maker should give little weight to the loss of agricultural land in grades 3b, 4 and 5, except in areas (such as uplands) where particular agricultural practices may themselves contribute to the quality and character of the environment or the local economy. Applicants should also identify effects, and seek to minimise impacts, on soil quality, taking account of the mitigation measures proposed. Where possible, developments should be on previously developed (brownfield) sites provided that they are not of high environmental value. For developments on previously developed land, applicants should ensure that they have considered the risk posed by land contamination and how it is proposed to address this. Guidance and policy concerning water quality are set out in detail in paragraphs 5.219 to 5.231 of the NPS NN. The objective is that new and existing development should be prevented from contributing to, or being put at unacceptable risk from, or being adversely affected by, water pollution. Key requirements are that the existing status of water quality, water resources and physical characteristics in the water environment must be ascertained and the impacts of the proposed project, including those associated with cumulative effects,

[11] European Parliament (2000) Water Framework Directive (Directive 2000/60/EC), Accessed on 08/02/2019 from https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF
[12] Department for Transport (2014) National Networks National Policy Statement, Accessed on 08/02/2019 from https://www.gov.uk/government/collections/national-networks-national-policy-statement

Legislation/ policy/ guidance document	Summary of requirements
	are assessed as part of the ES. Careful design to facilitate adherence to good pollution control practice can reduce the risk of impacts on the water environment.
The National Planning Policy Framework (NPPF) (2019)[13]	Ground conditions: The NPPF states that local planning policies and decisions should ensure that: • The site is suitable for its proposed use, taking account of ground conditions and risks arising from land instability and contamination. This includes risks arising from natural hazards or former activities such as mining, and proposals for mitigation including land remediation (as well as potential impacts on the natural environment arising from that remediation). • After remediation, as a minimum, land should not be capable of being determined as Contaminated Land as defined under Part IIA of the Environmental Protection Act (EPA) 1990 (see below). • Adequate site investigation information, prepared by a competent person, is presented. "Decisions should contribute to and enhance the natural and local environment by protecting and enhancing…sites of... geological value and soils". "Decisions should support appropriate opportunities to remediate despoiled, degraded, derelict, contaminated or unstable land." Water Quality: The NPPF sets out policies for water quality and resources. The key aspect associated with the assessment of geology and soils is "Preventing new and existing development from contributing to, being put at unacceptable risk from, or being adversely affected by water pollution". Paragraph 170 requires that local planning authorities should take account of the economic and other benefits of the BMV agricultural land. Where significant development of agricultural land is demonstrated to be necessary, local planning authorities should seek to use areas of poorer quality land in preference to that of higher quality.
Natural England's Guidance- Technical Information Note 049 (TIN049) (2012)[14]	TIN049 states that, for planning applications, specific consultations with Natural England are required under the Development Management Procedure Order in relation to BMV agricultural land. These are for non-agricultural development proposals that are not consistent with an adopted local plan and involve the loss of 20 ha or more of BMV land.
Land Contamination Risk Management (LCRM)[15] and Guiding Principles for Land Contamination (GPLC1)[16]	These Environment Agency documents provide a technical framework for the identification and remediation of contamination through the application of a risk management process. This is described in detail in section 10.5 of this ES chapter, along with a description on recent updates to the relevant guidance documents.

[13] Department for Communities and Local Government (2019) National Planning Policy Framework, Accessed on 08/02/2019 from https://www.gov.uk/government/publications/national-planning-policy-framework--2
[14] Natural England (2012) Technical Information Note 049. 'Agricultural Land Classification: protecting the best and most versatile agricultural land.'
[15] Environment Agency (2019) Land Contamination Risk Management, Accessed on 25/06/2019 from https://www.gov.uk/guidance/land-contamination-how-to-manage-the-risks
[16] Environment Agency (2010) Guiding Principles for Land Contamination, Accessed on 08/02/2019 from https://www.claire.co.uk/home/news/index.php?option=com_content&view=article&id=192&catid=41&Itemid=256

Legislation/ policy/ guidance document	Summary of requirements
Guidance for the Safe Development of Housing on Land Affected by Contamination R&D66 (2008)[17]	Environment Agency and National House Building Council (NHBC) Guidance for the Safe Development of Housing on Land Affected by Contamination R&D66 provides guidance on the development and application of the consequence and probability matrix and guidance on conducting a risk assessment. R&D66 sets out land quality estimation of the level of risk by comparison of consequence and probability.
CIRIA C552 Contaminated Land Risk Management. A guide to good practice[18]	This guidance sets the context of the risk assessment process within an overall risk management approach and describes the stages involved in identifying risks and assessing their significance.
Environment Agency's approach to groundwater protection (2017)[19]	The Environment Agency's approach to groundwater protection contains position statements on Source Protection Zones (SPZs), areas identified as drinking water protected areas and aquifer designations. It states that: • The development of infrastructure should be directed to less sensitive groundwater locations. • The Environment Agency will use a risk based tiered approach to regulate activities that may impact groundwater resources. • The Environment Agency expects developers and operators to account for current and future groundwater uses and their dependent ecosystems.
Regional	
Defra's Thames River Basin District River Basin Management Plan (RBMP) (2016)[20]	The Thames River Basin District RBMP is designed to protect and improve the quality of the water environment. It provides direction on the following topics: • Plans for the protection and improvement of the water environment. • Future plans that may affect the infrastructure sector and its obligations. • Development proposal considerations regarding the requirements of the RBMP. • Environmental permit applications.
The London Borough of Havering Core Strategy and Development Control Policies (CSDCP) (2008)[21]	The London Borough of Havering CSDCP contains core policies regarding environmental management (CP15-CP16), agriculture (DC47) and development control policies on environmental management (DC48-DC60). Core policy CP15 states (with regards to geology and soils) construction and new development should minimise their use of natural resources, including the efficient use of land, avoid an adverse impact on water quality and take the necessary measures to address contaminated land issues. Core policy CP16 aims to "maintain, enhance, restore or add to Havering's rich biodiversity

[17] Environment Agency (2008) R&D66 Guidance for the Safe Development of Housing on Land Affected by Contamination, Accessed on 02/09/2019 from http://www.nhbc.co.uk/NHBCpublications/LiteratureLibrary/Technical/filedownload,33595,en.pdf
[18] CIRIA (2001) Contaminated Land Risk Assessment. A guide to good practice
[19] Environment Agency (2017a) The Environment Agency's approach to groundwater protection, Accessed on 08/02/2019 from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/620438/LIT_7660.pdf
[20] Environment Agency (2016) Thames River Basin District River Basin Management Plan. Updated 2018, Accessed on 26/06/2019 from https://www.gov.uk/government/collections/river-basin-management-plans-2015#thames-river-basin-district-rbmp:-2015
[21] London Borough of Havering (2008) Core Strategy and Development Control Policies Development Plan Document, Accessed on 08/02/2019 from https://www.havering.gov.uk/download/downloads/id/1632/core_strategy_development_control.pdf

Legislation/ policy/ guidance document	Summary of requirements
	and geological conservation interests, and protect valued rural environmental resources". DC47 (Agriculture) states the Council will not grant planning permission where the proposal would result in the loss of high-quality agricultural land (Grades 1, 2 & 3a) unless it can be shown that there is an overriding sustainability benefit, or the development is unavoidable and no lesser quality land is available. Development control policy DC51 (Water Supply, Drainage and Quality) states planning permission will only be granted for development which has no adverse impact on water quality, water courses, groundwater, surface water or drainage systems unless suitable mitigation measures can be secured through conditions attached to the planning permission, or a legal agreement. Where a development affects the lower reaches of the River Ingrebourne, contributions may be sought towards measures to improve the poor water quality. Development control policy DC53 (Contaminated Land) states "planning permission for development will only be granted where both of the following criteria are met: • Where the development is on or near a site where contamination is known, or expected to exist, a full technical assessment of the site's physical stability, contamination and/or production of landfill gas must be undertaken. Where the assessment identifies an unacceptable risk to human health, flora or fauna or the water environment, the applicant will be required to agree acceptable long-term remediation measures before planning permission is granted to ensure there is no future harm with regard to the future use of the site. Where feasible, on-site remediation, especially bio-remediation, is encouraged. • The development does not lead to future contamination of the land in and around the site."
The London Borough of Havering Contaminated Land Inspection Strategy (2016)[22]	The London Borough of Havering Contaminated Land Inspection Strategy provides information on areas considered to be potentially contaminated due to historical land use.
Essex and Southend-on-Sea Waste Local Plan (2017)[23]	This document details how to deal with all types of waste arising in Essex in a way which is least damaging to the environment. The Plan forms part of the statutory development plan and provides the policies for planning decisions for all forms of waste management development in the administrative areas of both authorities.
Brentwood Borough Council Draft Local Plan (2016)[24]	The Brentwood Borough Council Draft Local Plan sets out local policies regarding conservation and protection of the natural environment. Policy 10.15 (Contaminated Land and Hazardous Substances) states the Council will require applicants proposing development on or near known or potentially contaminated land to submit a detailed site characterisation and tiered risk assessment and to identify remedial measures that need to be carried out (including remedial treatment and monitoring arrangements), provided in a detailed Remediation Scheme. Planning permission will not be permitted for development on sites that are near or

[22] London Borough of Havering (2016) Contaminated Land Inspection Strategy, Rev. 2, Accessed on 08/02/2019 from https://www3.havering.gov.uk/Documents/Draft_Contaminated_Land_Inspection_Strategy_Rev02_2016.pdf
[23] Essex County Council and Southend-on-Sea Borough Council (2017) Southend-on-Sea and Essex Waste Local Plan. Accessed on 11/11/2019 from https://assets.ctfassets.net/knkzaf64jx5x/5MMZ5nNFmOClpF56igb0Jc/e6f7ab4cba4ed1198c67b87be7b375e7/waste-local-plan-2017-compressed.pdf
[24] Brentwood Borough Council (2016) Draft Local Plan, 2013-2033, Local development plan for Brentwood Borough, Accessed on 08/02/2019 from https://www.brentwood.gov.uk/pdf/08022016165904u.pdf

Legislation/ policy/ guidance document	Summary of requirements
	adjacent to a hazardous substance site or notifiable installation, if the safety of the future occupiers of the development could be adversely affected by the normal permitted operations of the existing uses. Paragraph 85: Agricultural land grades recognises BMV land as a national resource that needs protecting. Brentwood contains grades 2 and 3a land.
Brentwood Replacement Local Plan, Saved Policies 2008[25]	IR3 Protecting the Best and Most Versatile Agricultural Land: The plan seeks to protect BMV land stating that where there is a choice between sites of a different classification, development should be directed towards land of the lowest possible classification, unless sustainability or other material issues suggest otherwise.

Table source: Various

10.4 Study area

10.4.1 The study area has been determined to appropriately account for potential impacts from increased mobility of ground contaminants and has been determined by a number of factors; (i) the likely maximum extent of potential impacts from the Scheme, (ii) the soil, geology and hydrogeology surrounding the Scheme (including the presence, flow rate and direction of groundwater) and (iii) the nature of the proposed construction works. The construction stage is not envisaged to require active dewatering activities. The works would require localised groundwater control measures to be implemented, however, these are not envisaged to affect the water table.

10.4.2 The land contamination assessment has considered a study area extending 250 m from the extent of the DCO boundary. A plan of the Scheme and study area is provided on the topography figure, Figure 10.1 (application document TR010029/APP/6.2). For the purposes of the land contamination assessment, the identified potential sources, pathways, and receptors have been separated into those within the DCO boundary (on-site) and those within the 250 m study area outside of the DCO boundary (off-site).

10.4.3 The geomorphology and ground stability assessment has considered the area within the DCO boundary or immediately adjacent only. Based on the proposed development, any effects are not expected beyond this distance.

10.4.4 For the agricultural land and agricultural holdings assessment, the study area is confined to the soils affected temporarily or permanently by the Scheme (i.e. within the DCO boundary). For farming, it is those holdings potentially affected by the options through land-take and / or severance. Woodland is considered in the Biodiversity chapter (Chapter 7) and has not been included in this agricultural land and agricultural holdings assessment.

[25] Brentwood Borough Council (2008) Brentwood Replacement Local Plan, Saved Policies 2008, Accessed on 13/02/2019 from http://www.brentwood.gov.uk/pdf/30102013165238u.pdf

10.5 Assessment methodology

10.5.1 The assessment of the potential impacts of the Scheme on geology and soils has been undertaken over two stages:

- Stage 1 - land contamination risk assessment (potential impacts).
- Stage 2 - land contamination, geomorphology and ground stability and agricultural land and agricultural holdings assessment of effects.

10.5.2 The Design Manual for Roads and Bridges (DMRB)[26] Introduction to Environmental Assessment (formerly Volume 11, Section 2, Part 1 HA 201/08 states that the assessment process can follow either that of a 'simple assessment' or a 'detailed assessment'. A simple assessment is considered sufficient where it is established confidently that the forecast environmental effect would not be a fundamental issue in the decision-making process. Where this is not the case, a detailed assessment comprising detailed field surveys and / or quantified modelling techniques is likely to be required. The inference is that where a significant adverse impact has the potential to be present, then field surveys are required to quantify the risk. This geology and soils assessment generally follows that of a simple assessment, however, with respect to the land contamination risk assessment, newly deposited material of unknown source identified during a site walkover (see section 10.5.6 for further details), was considered to have the potential to impact decision making processes during design. Therefore, a detailed assessment was completed for this area by use of GI to quantify the risk.

10.5.3 Section 55 of the Planning Act[2] includes the statement that "the application (including accompaniments) is of a standard that the Secretary of State considers satisfactory". It is stated in the Planning Inspectorate's Advice Note six[27] that applications should ensure that the surveys required to establish baseline conditions and the assessment of likely significant effects are completed before the submission of the application and reported in the ES.

10.5.4 The land contamination assessment is primarily based on a phase 1 desk-based assessment for the Scheme as a whole and where deemed necessary / where ground investigation (GI) data was available, this has been incorporated. The assessment has been developed using the Rochdale Envelope[28] where 'realistic and likely worst case' impacts have been considered where no data are available. Mitigation measures identified are in response to these impacts. In line with DMRB[26] guidance and Section 55 of the Planning Act[2], the assessment presented herein is considered robust and it has been established that the forecast environmental effects are not a fundamental issue in the decision-making process (as per previous stages within the EIA process for the geology and soils of the Scheme).

[26] DMRB (2008) Environmental Assessment Volume 11, Sections 1-3, Accessed on 17246/12016/2019202019 from http://www.standardsforhighways.co.uk/ha/standards/dmrb/vol11/ section1.htm
http://www.standardsforhighways.co.uk/ha/standards/dmrb/vol11/section2.htm
[27] The Planning Inspectorate (2016) Advice note six: Preparation and submission of application documents, Accessed on 26/06/2019 from https://infrastructure.planninginspectorate.gov.uk/wp-content/uploads/2015/05/Advice-note-6-version-71.pdf
[28] Infrastructure Planning Commission (2011) Advice note nine: Using the Rochdale Envelope, Accessed on 05/07/2019 from https://infrastructure.planninginspectorate.gov.uk/wp-content/uploads/2013/05/Advice-note-9.-Rochdale-envelope-web.pdf

10.5.5 Information from historical GI, published data and results from a recent preliminary GI associated with this Scheme have been used in this assessment.

10.5.6 The preliminary GI was carried out to provide an initial assessment of ground conditions at a location to the northwest of junction 28 where recently deposited material (including suspected asbestos containing material (ACM)) was observed during a site visit in 2019. The deposited material was present across an inactive landfill (Brook Street Landfill, described in section 10.7.60). The preliminary GI comprised six shallow hand pits, ten trial trenches and two window samples (installed with ground gas and groundwater monitoring wells), headspace testing of soil for ionisable volatile organic compounds (VOCs), collection of geo-environmental samples for laboratory chemical analysis and interpretation and the collection of samples for waste classification.

10.5.7 The methodology associated with the preliminary GI is described in detail in Appendix 10.1 (Preliminary geo-environmental assessment report[29]) (application document TR010029/APP/6.3). A second phase of GI (the 'main' GI) has been carried out across the Scheme however, the complete factual dataset was pending at the time of writing and therefore the assessment is based on the findings of the preliminary GI only. In summary, the main GI included the following:

- Target areas where intrusive ground works will be undertaken.
- Target areas of identified potential contamination sources (i.e. the Source-Pathway-Receptor linkages (SPR) identified within the risk assessment provided in this chapter) and locations of ground instability.
- Provide an assessment of geological boundaries, thickness of strata and geotechnical testing to inform design.
- Characterise the hydrogeological regime.
- Sample identified surface water receptors to derive site-specific quality standards.
- Determine the extent and nature of fill material.
- Determine the aggressivity of the ground towards buried concrete.

10.5.8 The data and documents associated with the main GI are not included in this chapter but will be made available as soon as possible. These documents will include where necessary, a ground investigation report (GIR), Piling Risk Assessment (PRA) and generic quantitative risk assessments (GQRAs) for human health and controlled water receptors, detailed quantitative risk assessments (DQRAs) (if required) and/or remediation strategies (if required). No major groundworks within the Scheme would commence until, for that part, GI and relevant risk assessments have been carried out.

Stage 1 – Land contamination risk assessment methodology

10.5.9 The approach adopted for the land contamination risk assessment (potential impacts) is based on guidance document LCRM[15] and CIRIA C552[18]. These documents are considered key guidance in the United Kingdom and provide a

[29] Atkins (2019) Preliminary Geo-environmental Assessment Report for Highways England M25 junction 28 Road Improvement Scheme

technical framework for the application of a risk management process through the steps described in this section.

10.5.10 A desk study review of available information was undertaken to develop Preliminary Conceptual Models (PCM) in the Preliminary Environmental Information Report (PEIR)[30], which described the linkages between potential contamination sources, pathways and receptors relevant to the Scheme. Where linkages are present or considered likely to be present, under new guidance[15], they are described as Source-Pathway-Receptor (SPR) (referred to as a PCL[31] in the PEIR). These are then subject to the risk assessment process. PCMs were created for the baseline, construction and operational phases of the Scheme.

10.5.11 A Generic Quantitative Risk Assessment (GQRA) has been undertaken through comparison of the data gathered during the preliminary GI to appropriate generic assessment criteria (GAC) in order to evaluate whether the concentrations of chemical parameters present a potential risk to receptors[29].

10.5.12 The SPRs within the PEIR have been reviewed and updated in this chapter, following completion of the preliminary GI and data review. Where SPR have been identified, consideration has been given to whether they could be appropriately mitigated through design and/or remediation. The risks associated with each SPR have been determined and assessed based on estimation of consequence and probability.

10.5.13 The risk assessment applies the principles given in the NHBC and Environment Agency report R&D66[17], which provides guidance on the development and application of the consequence and probability matrix (as presented in Table 10.2) for contaminated land risk assessment.

Table 10.2: Land contamination estimation of the level of risk by comparison of consequence and probability

		Consequence			
		Severe	**Medium**	**Mild**	**Minor**
Probability	**High Likelihood**	Very high risk	High risk	Moderate risk	Moderate/low risk
	Likely	High risk	Moderate risk	Moderate/low risk	Low risk
	Low Likelihood	Moderate risk	Moderate/low risk	Low risk	Very low risk
	Unlikely	Moderate/low risk	Low risk	Very low risk	Very low risk

Table source: based on R&D66[17]

10.5.14 The potential risk to a receptor is a function of the probability and the consequence of a SPR. Probability (likelihood of an event occurring) considers both the presence of the hazard and receptor, and the integrity of the exposure pathway. Consequence considers the potential severity of the hazard and the

[30] Atkins (2018) M25 junction 28 Preliminary Environmental Information Report. Ref. HE551519-ATK-EAC-RP-LM-000001
[31] Defra and Environment Agency (2004) (Archived) The Model Procedures for the Management of Land Contamination: Contaminated Land Report 11, Accessed on 05/07/2019 from https://webarchive.nationalarchives.gov.uk/20140328160926/http:/cdn.environment-agency.gov.uk/scho0804bibr-e-e.pdf

sensitivity / value of the receptor. Appendix 10.2 includes tables which provide the definitions for classifying probability and consequence.

10.5.15 Risks have been classified for the following phases of the Scheme; baseline, construction without mitigation, construction with mitigation and operation.

Stage 2 – Land contamination, geomorphology and ground stability and agricultural land and agricultural holdings assessment of effects

Land contamination assessment of effects methodology

10.5.16 The land contamination impact assessment is based on the change of risk (identified in Stage 1) between the baseline and the different phases of the Scheme (i.e. during construction and operation). The calculated increase or decrease in risk identifies the significance of effect, as described in Table 10.3, however professional judgement has been used in instances where a receptor is not present during every phase of the Scheme.

Table 10.3: Land contamination impact assessment (significance of effects)

Classification of significance	Effect
Major adverse	An increase in contamination risk from the existing baseline conditions of four or five risk levels in the risk matrix, e.g. land that has a very low contamination risk in the baseline becomes a high or very high risk.
Moderate adverse	An increase in contamination risk from the existing baseline conditions of two or three risk levels in the risk matrix, e.g. land that has a low contamination risk in the baseline becomes a moderate or high risk.
Minor adverse	An increase in contamination risk from the existing baseline conditions of one risk level in the risk matrix, e.g. land that has a low contamination risk in the baseline becomes a moderate/low risk.
Negligible	Negligible change in contamination risks.
Minor beneficial	A reduction in contamination risk from the existing baseline conditions of one risk level in the risk matrix, e.g. land that has a moderate/low contamination risk in the baseline becomes a low risk.
Moderate beneficial	A reduction in contamination risk from the existing baseline conditions of two or three risk levels in the risk matrix, e.g. land that has a high contamination risk in the baseline becomes a moderate/low or low risk.
Major beneficial	A reduction in contamination risk from the existing baseline conditions of four or five risk levels in the risk matrix, e.g. land that has a very high contamination risk in the baseline becomes a low or very low risk.

Table source: Atkins bespoke system for assessing impacts associated with land contamination

10.5.17 Following the classification, a clear statement is made as to whether the effect is 'significant' or 'not significant'. As a general rule (in line with DMRB Volume 11, Section 2, part 5 HA 205/08[26]) major and moderate effects are considered to be significant, and minor and negligible effects are considered to be not significant.

10.5.18 The time-period in which the land contamination impacts may have effect has been prescribed (temporary or permanent), based on construction generally considered to be associated with temporary effects and the operational phase generally associated with permanent effects.

Geomorphology and ground stability assessment of effects methodology

10.5.19 The value / sensitivity of a geology and geomorphology baseline condition has been considered when determining consequence of an effect in the geomorphology and ground stability assessment of effects. The sensitivity has been determined using the classifications and criteria given in Table 10.4.

Table 10.4: Criteria for classifying the value / sensitivity of geomorphological and ground stability features

Value / Sensitivity	Criteria	Examples
High	Attribute possesses key characteristics which contribute significantly to the distinctiveness, rarity and character of the site / receptor. Attribute has a very low capacity to accommodate the proposed change.	Sensitive topographic features. Major ground stability, soil compaction or erosion hazards present at the site. High potential for encountering unexploded bombs.
Medium	Attribute possesses key characteristics which contribute significantly to the distinctiveness, rarity and character of the site / receptor. Attribute has a low capacity to accommodate the proposed change.	Moderate sensitivity topographic features. Moderate, ground stability, soil compaction or erosion hazards present at the site. Moderate potential for encountering unexploded bombs.
Low	Attribute only possesses characteristics which are locally significant. Attribute has some tolerance to accommodate the proposed change.	Low sensitivity topographic features. Low ground stability, soil compaction or erosion hazards present at the site. Low potential for encountering unexploded bombs.

Table Source: Based on DMRB Volume 11[26]

10.5.20 Following determination of the sensitivity of geomorphology and ground stability baseline conditions, the magnitudes of potential impacts during the construction phase and operational phase have been determined based on the criteria defined in Table 10.5. Classification of magnitude has been assigned assuming geotechnical design and mitigation measures are implemented.

Table 10.5: Classification of magnitude of impact of geomorphology and ground stability

Classification of magnitude	Criteria
High	Total loss of major alterations to one of more of the key elements, features or characteristics of the baseline. The post-development situation will be fundamentally different.
Medium	Partial loss or alteration to one of more of the key elements or characteristics of the baseline. The post-development situation will be partially changed.
Low	Minor loss or alteration to one or more of the key elements, features or characteristics of the baseline. Post-development, the change will be discernible but the underlying situation will remain similar to the baseline.
Negligible	Very minor loss or alteration to one of more of the key elements, features or characteristics of the baseline, such that post-development, the change will be barely discernible, approximating to the “no change” situation.

Table Source: Based on DMRB Volume 11[26]

10.5.21 The overall significance of effects has been defined using the matrix presented in Table 10.6 which describes the relationship between the value/sensitivity of the feature (Table 10.4) and potential magnitude of impact (Table 10.5).

Table 10.6: Geomorphology and ground stability assessment of effects (significance of effects)

		Magnitude of impact			
		High	**Medium**	**Low**	**Negligible**
Value / Sensitivity of feature	**High**	Major	Major / moderate	Moderate	Moderate / minor
	Medium	Major / moderate	Moderate	Moderate / minor	Minor
	Low	Moderate	Moderate / minor	Minor	Negligible

Table Source: Based on DMRB Volume 11[26]

10.5.22 The classification of effect for geomorphological and ground stability impacts are described in Table 10.7.

Table 10.7: Classification of effect for geomorphology and ground stability

Classification	Example of Effect
Major adverse	Major/complete change in topography which negatively impacts the local community. Significant increase in soil erosion, soil compaction or ground instability.
Moderate adverse	Moderate change in topography which negatively impacts the local community. Moderate increase in soil erosion, soil compaction, or ground instability.
Minor adverse	Minor change in topography which negatively impacts the local community. Limited increase in soil erosion, soil compaction, or ground instability.

Classification	Example of Effect
Negligible	No measurable impact/no change to geomorphology or ground stability baseline conditions.
Minor beneficial	Minor change in topography which has a positive impact on the local community. Minor reduction in existing soil erosion, soil compaction, or ground instability issues.
Moderate beneficial	Moderate change in topography which has a positive impact on the local community. Moderate reduction in existing soil erosion, soil compaction, or ground instability issues.
Major beneficial	Major/complete change in topography which has a positive impact on the local community. Significant reduction in existing soil erosion, soil compaction or ground instability issues.

Table Source: Based on DMRB Volume 11[26]

10.5.23 Following the classification of an effect, a clear statement has been made as to whether the effect is 'significant' or 'not significant'. As a general rule, major and moderate effects are considered to be significant, and minor and negligible effects are considered to be not significant. However, professional judgement has also been applied where appropriate including the classification of the time period of the effect (temporary or permanent).

Agricultural land assessment methodology

10.5.24 The assessment of agricultural land and soils follows the approach of the DMRB, Volume 11, Section 3, Part 6[26].

10.5.25 The significance criteria address both magnitude of impact and sensitivity of the resource and consideration of the characteristics of the impact and the receptor, namely:

- Type of impact - direct or indirect
- Nature of impact - beneficial, adverse or negligible
- Duration of impact - short or long-term, reversible or not
- Frequency of impact - continuous or intermittent, changing with time or constant

10.5.26 There is no nationally recognised set of criteria for assessing the impact of infrastructure schemes on agricultural land and so a bespoke system has been developed to reflect the issues pertinent to the Scheme. It considers how the land is used at the baseline and the quality and versatility of the soils based on the Ministry of Agriculture Fisheries and Food (MAFF) Agricultural land classification (ALC) Grades and Natural England's TIN049[14]. The latter assesses the loss of 20 ha or more of BMV land as significant.

10.5.27 The following value / sensitivity criteria in Table 10.8 are applied to the agricultural land affected by the Scheme.

Table 10.8: Value / sensitivity criteria for agricultural land

Value / sensitivity	Criteria
High	Agricultural land which has an ALC of BMV grades 1,2 and 3a. Farm types or land-based enterprises in which the operation is dependent on the spatial relationship of land to key infrastructure, and where there is a requirement for frequent and regular access between the two, or dependent on the existence on the infrastructure itself, e.g. dairying; irrigated arable cropping and field scale horticulture; intensive livestock or horticultural production; commercial smallholdings and equestrian centres
Medium	Agricultural land which has an ALC grade of 3b or 4. Farm types or land-based enterprises in which there is a degree of flexibility in the normal course of operations, e.g. combinable arable crops; grazing livestock farms (other than dairying)
Low	Agricultural land which has an ALC grade of 5. Farm types and land uses undertaken on a semi-commercial or non-commercial basis such as occasional grazing by horses
Negligible	Agricultural land in a long-term state of disuse and reverting to scrub

Table source: Atkins bespoke system for assessing impacts on agricultural land

10.5.28 Magnitude of impact (change) on farm holdings is assessed using the criteria in Table 10.9 below and the magnitude of impact of the Scheme on agricultural soils (based on likely loss of BMV land) is assessed using the criteria in Table 10.10 below. These are based on professional judgement, in the absence of specific DMRB criteria for assessing farm impacts.

Table 10.9: Assessment of magnitude of impact on agricultural holdings

Magnitude	Criteria
Major	The identified impacts are predicted to result in very large damage to a farm business or rural land-based enterprise and may compromise its viability
Moderate	The identified impacts are predicted to result in moderate or large damage to a farm business or rural land-based enterprise, but with changes to management it should remain viable
Minor	The identified impacts are predicted to result in slight or moderate damage to a farm business or rural land-based enterprise, but with minor changes to management it should continue as before
Negligible	The identified impacts are predicted to result in little or no damage to a farm business or rural land-based enterprise

Table source: Atkins bespoke system for assessing impacts on agricultural land

Table 10.10: Assessment of magnitude of impact on agricultural soils

Magnitude	Criteria
Major	The identified impacts are predicted to result in a loss of >20 ha of BMV land
Moderate	The identified impacts are predicted to result in the loss of between 5 ha and 20 ha of BMV land
Minor	The identified impacts are predicted to result in a loss of between 1 ha and 5 ha of BMV land
Negligible	The identified impacts are predicted to result in the loss of <1 ha BMV land

Table source: Atkins bespoke system for assessing impacts on agricultural land

10.5.29 The consideration of the relationship between the sensitivity and the magnitude of impact defines the effect of the Scheme on agricultural land, as shown in Table 4.1 in Chapter 4.

10.5.30 Following the classification of an effect, a clear statement is made as to whether the effect is 'significant' or 'not significant'. As a general rule, major and moderate effects are significant and minor and negligible effects are not significant, in accordance with standard EIA practice. However, professional judgement is also applied to the circumstances of the effect, where appropriate.

10.5.31 This assessment covers agricultural land within the Scheme that would be acquired permanently or temporarily. Permanent land-take would include the surfaced road, service strips and land acquired for landscaping, attenuation ponds etc.

10.5.32 Temporary land-take would include construction compounds, haul roads and land disturbed by utility diversion works. Flood mitigation works would affect agricultural soils by reducing ground levels to create compensatory floodplain.

10.6 Assumptions and limitations

10.6.1 It is assumed that the existing core foundations of junction 28 would not be altered, however, based on the preliminary design, the following works are expected:

- Modification or creation of embankments and cuttings
- New retaining walls
- Removal of some existing gantries and the installation of new gantries/ cantilevers
- New bridges / underpasses including associated piling
- New footpaths
- Road widening at grade
- Utility diversion including a Cadent gas pipeline
- Pre-earthwork ditch and unlined ditches
- Realigned watercourse
- Floodplain lowering

- Proposed attenuation ponds
- Ecological mitigation areas, wildlife ponds
- Creation of two surplus construction material deposition areas
- New connections (if / where required) to and from attenuation ponds to water course/ditch
- Soakaways

10.6.2 The design is shown on the Scheme layout plans (application reference TR010029/APP/2.7).

10.6.3 For the purposes of this assessment, the 'reasonably likely worse-case' impact from the Scheme has been assumed and sought to be mitigated. The possibility of the worst-case scenario occurring is low, given the precautionary assumptions of the assessment which are as follows:

- Ground disturbance, such as those listed below, could be undertaken anywhere within the DCO boundary during the construction phase:
  - Stripping of topsoil, Made Ground or London Clay
  - Ground works including excavation and placement
  - Excavation of drainage / utility conduits (either temporary or permanent)
- The location of temporary stockpiles from the proposed earthworks and contractor's compounds have tentatively been identified but may be subject to change, therefore stockpiles could be anywhere within the DCO boundary.
- Attenuation ponds proposed as part of the Scheme, one pond is anticipated to be within the footprint of the recently deposited material and the inactive Brook Street Landfill (described in sections 10.5.6 and 10.7.60). These (along with the associated proposed connection ditches) have been assumed to not be lined.
- Where potential sources of contamination have been identified, contaminants are assumed to be present.
- Supporting GI has been carried out in areas of potential risk e.g. areas of proposed works where a risk from land contamination may be present. GI has generally not been undertaken at locations within the Scheme where construction work is not proposed and land contamination sources are not present.
- There would be areas used for the storage of hazardous material containers during the operational phase, which could be anywhere within the Scheme boundary.
- No active groundwater dewatering is thought to be required as part of the construction works.
- Intrusive GI works and piles / deep foundations could be anywhere within the DCO boundary.
- There would be areas used for parking of vehicles during the construction phase, which could be anywhere within the Scheme boundary.

- The Scheme would not permanently introduce buildings / enclosed spaces other than chambers / ducts.
- During the construction phase, access to construction zones would be limited therefore members of the public are unlikely to enter construction areas to form immediate SPRs.
- During operation, restrictions will be in place with relation to the ability of members of the public to access to highway land i.e. all areas will not be freely accessible for members of the public by foot.
- Construction best practice would be adhered to at all times during the works.

10.6.4 A Landmark Envirocheck report[32] of the Scheme was obtained, which includes historical maps (small-scale and large scale) and environmental data. The small-scale historical maps and the environmental datasheets have been included in Appendix 10.3 of this report. Following the purchase of the report, the DCO boundary has been altered, therefore the report does not cover approximately 1.5 km of the south-eastern limb (along the M25) of the Scheme. Only minor works e.g. signage upgrades are proposed within the area not covered by the report and so this is considered unlikely to affect the outcome of the assessment. This assumption is based on the preliminary design and any future design updates may incorporate features within this area that would need additional assessment.

10.6.5 Data from secondary sources are assumed to be correct and representative of site conditions.

10.7 Baseline conditions

10.7.1 This section provides a summary of the baseline geology and soil conditions of the Scheme and study area, on the basis of the available information.

Current setting

10.7.2 The main features currently situated within the DCO boundary are:

- Approximately 3.8 km of the highway boundary of the M25 (orientated northwest to southeast), approximately 2.75 km of the A12 (orientated southwest to northeast) and a small portion of the A1023 (orientated southwest to northeast).
- The inactive Brook Street Landfill and area of recently deposited material at Grove Farm.
- Open fields and agricultural land.
- Drainage ditches.
- Weald Brook flowing in a northwest to southeast direction and crossing the western limb of the Scheme, until the confluence with the Ingrebourne River which flows generally in a northeast to southwest direction.
- An area of Maylands Golf Club.
- Woodland and small pond in the northwest quadrant of the Scheme, toward

[32] Landmark Information Group (2016), Envirocheck report (report reference 88528679_1_1)

Maylands Golf Club.

- A railway line crossing the M25 approximately 390 m to the south of the centre of junction 28.

10.7.3 The wider study area comprises:

- Development at Grove Farm in the northwest quadrant of junction 28 including RJ Waste Management Recycling, skip hire and rubbish clearance, Hydroponic Growth (garden centre) and a residential property.
- Five farms (Putwell Bridge Farm, Oak Farm, the Poplars, Frenches Farm and Colmar Farm), open fields, agricultural land and wooded area.
- Maylands Golf Club.
- Open space (parks and fields not in agricultural use).
- Nags Head Lane sewage treatment works, approximately 250 m south of the western extent of the study area.
- Residential properties (in particular the village of Brook Street, Harold Park, Romford and along Nags Head Lane).
- Some commercial land-uses (including garden centre, car sales, restaurants and two active fuel stations) in various directions from the Scheme. The fuel stations are the Shell fuel station within the southeast quadrant of junction 28 and the Esso fuel station immediately north of the western limb of the Scheme.
- In addition, two former fuel stations are present within the wider study area including a former fuel station on the southern side of the A13 currently used as a traveller's site. It is not known whether this would be maintained permanently.

10.7.4 Sensitive land use designations within the study area include deciduous woodland, Ancient Woodland, areas of adopted Green Belt, grassland and woodland priority habitat network and Nitrate Vulnerable Zones[33]. No statutory environmentally sensitive land uses (i.e. Area of Outstanding Natural Beauty, SSSI) have been identified within the Scheme or study area[33].

Topography

10.7.5 The study area has a gently undulating ground profile, with topography sloping from approximately 50 m AOD in the east, to 45 m AOD in the west and a decrease in elevation to 30 m AOD at the intersection of Weald Brook.

10.7.6 North of the A12, the M25 passes the toe of a hill at Vicarage Wood. At this point the ground level rises to the north from approximately 35 m AOD to approximately 70 m AOD at the crest of the hill (850 m to the north of the centre of junction 28). Slopes to the south of the junction are shallower, with ground levels generally between 35 m AOD and 50 m AOD. Low points are located around the A12 and the Ingrebourne River. However, to the south of Nag's Head Lane bridge the topography increases to approximately 75 m AOD at the most southern extent of the Scheme[33].

[33] Defra (2019). MAGIC map, Accessed on 28/04/2020 from https://magic.defra.gov.uk/MagicMap.aspx

Scheme and study area history

10.7.7 The small-scale historical maps reviewed for the Scheme and study area are presented within Appendix 10.3 of this report. Available mapping / illustration types include historical aerial photography, Ordnance Survey Plans, 10k Raster Mapping and Vector Map Local, with scales of 1:10,000, 1:10,560 and 1:2,500 with the earliest map dated from 1868.

10.7.8 A full description of the historical maps is provided in Appendix 10.4 and the main developments which have occurred within the Scheme and the study area since 1868 are summarised below.

10.7.9 Locations of military camps, strategic sites or security sites were possibly removed or replaced by fake fields or clouds on illustrations / aerial imagery between 1878 and 1981, therefore some features typically associated with the presence of unexploded ordnance (UXO) are generally not available on public sourced aerial imagery and therefore could not be identified. There are however, records available which identify a former aerodrome (Maylands) within the DCO boundary[34], north of the A12 and west of Weald Brook (the location of the former aerodrome has been illustrated on Figure 10.2).

Within the Scheme

10.7.10 The earliest available maps (1868) show that within the Scheme boundary there is an unnamed Roman Road, which followed a similar alignment to the present day A12 with open fields present across the majority of the study area. The Great Eastern Railway is present in its current orientation (southwest to northeast). The Weald Brook is located on the western extent of the Scheme, flowing in a north to south direction where it meets the Ingrebourne River.

10.7.11 In 1961, the electricity pylons associated with the present-day overhead power line are mapped. In 1968 a large roundabout had been constructed at the location of the current junction 28. By this time, the A12 was also shown in its current configuration, however the M25 had not been constructed and the roundabout connected only the A12 and the A1023 (also known as Brook Street and was previously referred to as the Roman Road).

10.7.12 A map dated 1974 displayed a field drain immediately southwest of the Scheme, which connected to the Ingrebourne River. Between 1978 and 1984, the M25 was constructed in its current configuration, which comprised significant embankment construction around junction 28 and on the southern extent of the Scheme. In addition, field boundaries and a small pond which were previously located in the northwest quadrant of the junction were no longer illustrated on the 1984 map. It is thought that this is due to the creation of Brook Street Landfill associated with the construction of the M25 in this area.

10.7.13 No significant changes are shown on maps after 1992.

[34] Merritt, L & Flute, D (2014) UK Airfields and Airports a Guide to the history of British Flying Sites within the UK, Accessed on 18/03/2019 from http://www.ukairfieldguide.net/airfields/Maylands

Within the 250 m study area

10.7.14 The 1868 mapping shows the wider study area to be farms, open fields and several woodlands. The village of Brook Street is shown as a small settlement around a set of crossroads, which are the present-day Brook Street (A1023) and Mascalls Lane/Spital Lane. By 1898, the sewage treatment works had been developed off Nags Head Lane to the southwest.

10.7.15 By 1938, further development had occurred along Nags Head Lane, to the south of the present-day location of junction 28 and in Harold Park to the west. An aerial photograph in 1947 indicated the expansion of the sewage treatment works. Significant development of Brook Street village and the Harold Park suburb of Romford, located in the east and west of the study area respectively, was shown on the 1968 map.

10.7.16 In 1974, a garage was mapped close to the location of the present-day Shell South Weald fuel station (east of the present-day location of junction 28). Another garage and a nursery were also mapped to the east, situated on the northern side of Brook Street (A1023).

10.7.17 The 1992 map labels the garage in the location of the present-day Shell South Weald fuel station as a filling station. New development included residential and commercial properties (in particular, RJ Waste Management Recycling, skip hire and rubbish clearance) in the north-west quadrant of junction 28.

10.7.18 A filing station was present 100 m southwest from the centre of junction 28, immediately south of the A12 and was shown as active on historical maps until at least 1992.

10.7.19 The Esso fuel station in Harold Park, located in the west of the study area was shown in its present-day configuration in 1999 and the garage and nursery off Brook Street (A1023) were no longer shown. A golf course is shown from 1999 to the northwest of the DCO boundary.

10.7.20 There appear to have been no significant changes to the study area since 1999 other than the development of further residential and commercial properties.

Historic features

10.7.21 There are three listed buildings located along Brook Street, which are located between 210 m and 240 m southeast from the DCO boundary (Nag's Head Inn, 17, 19 and 21 Brook Street and the Bull Inn). These are discussed further in the Cultural Heritage chapter (Chapter 11).

Unexploded ordnance

10.7.22 No air dropped bombs are recorded to have fallen within the DCO boundary or study area, with the nearest approximately 100 m to the west of the former aerodrome[35]. It is, however, recorded within a different source that the closure of Old Mayland's Aerodrome in 1940 was a result of bomb damage to all the aircrafts present on the airfield at the time[36]. An unexploded bomb risk map

[35] BombSight (2013) Mapping the WW2 bomb Census, Accessed on 15/02/2019 from http://bombsight.org/#14/51.6100/0.2669
[36] UK Airfields and Airports (2014) Maylands Airfield, Accessed on 11/11/2019 from https://www.ukairfieldguide.net/airfields/Maylands

provided by Zetica identified the majority of the Scheme and study area as having a moderate UXO hazard level, with the southern extent of the Scheme (approximately 500 m south of Nag's Head Lane) having a high UXO hazard level[37]. Based on the recommendations therein, a detailed UXO desk study of the GI areas was obtained prior to the breaking of ground. The risk map provided by Zetica and the detailed UXO desk study for this area are provided within Appendix 10.5, which prescribed UXO safety awareness briefings for site personnel, but no further mitigation measures were prescribed.

Services

10.7.23 An overhead electricity transmission line (UKPN), a below ground British Pipeline Agency (BPA) fuel pipeline (close to the alignment of the Weald Brook) and a high-pressure gas main (Cadent) are present in a north to south orientation, which intersect the Scheme to the west of junction 28. To the east of junction 28, another high-pressure gas main intersects the Scheme.

10.7.24 There are a number of other above and below ground services (including low pressure gas and UK power network cables) present within the DCO boundary and wider study area.

Agricultural land

10.7.25 The quality of agricultural land has been assessed using data from published soil and ALC maps (see 10.7.27) and information on land use has been obtained from ongoing consultations with the affected land owners regarding the impact of the Scheme on their holdings and appropriate forms of mitigation.

Agricultural soils

10.7.26 There is no detailed published soil map of the Scheme or study area. The only available map is the 1:250,000 soil map of South East England published by the Soil Survey of England and Wales in 1983[38]. This shows most soils to be the Windsor series of slowly permeable, seasonally waterlogged (Wetness Class IV) clayey soils over London Clay Formation. Head deposits on valley sides may contain the Wickham and Lawford series with heavy clay loam topsoils, but even these are slowly permeable and seasonally waterlogged (Wetness Class III to IV) and pass onto London Clay Formation. The narrow floodplain of the Weald Brook contains wet, clayey Alluvium. Brook Street Landfill once in operation at Grove Farm (see 10.7.60) has been restored to grassland.

10.7.27 BMV land is in MAFF's ALC Grades 1, 2 and Subgrade 3a[39], as defined in paragraph 112 and Annex 2 of the NPPF[13] and in TIN049[13].

10.7.28 The published MAFF 1:250,000 Provisional ALC Map of London and the South East[40] provides only a broad indication of land quality and should not be used

[37] Zetica (2019) Unexploded bomb risk map, Accessed on 15/02/2019 from https://zeticauxo.com/downloads-and-resources/risk-maps/
[38] Soil Survey of England and Wales (1983) Soils of England and Wales, Sheet 6 South East England. Rothamsted Experimental Station, Harpenden.
[39] MAFF (1988) Agricultural Land Classification of England and Wales. Revised Guidelines and Criteria for Grading the Quality of Agricultural Land, Accessed on 10/02/2019 from http://webarchive.nationalarchives.gov.uk/20130402151656/http:/archive.defra.gov.uk/foodfarm/landmanage/land-use/documents/alc-guidelines-1988.pdf
[40] Natural England (n.d). Regional Agricultural Land Classification Maps. London and the South East, Accessed on 10/02/2019 from http://publications.naturalengland.org.uk/publication/141047?category=5954148537204736

definitively on specific sites smaller than 80 ha. Moreover, the published map does not subdivide Grade 3 into Subgrades 3a and 3b and so cannot be used definitively in areas that are marginal to BMV. The area around junction 28 is shown as an area of Grade 3 (good to moderate quality).

10.7.29 The ALC classification has been applied to the published soil information to divide the soils further into Subgrade 3a and 3b. Windsor soils have clay topsoils, are slowly permeable within 40 cm (Wetness Class IV) and cannot be better than Subgrade 3b in the local climate. Likewise, Wickham and Lawford soils, with heavy clay loam topsoils are slowly permeable within 40 to 60 cm (Wetness Class III to IV) also cannot be better than Subgrade 3b. Strips of Alluvium are in subgrade 3b to Grade 4.

10.7.30 It is possible that there are small pockets of less dense, better drained soils but these will be of small extent and would not affect the overall assessment of the area as being of non-BMV quality.

Agricultural holdings

10.7.31 There are two holdings within the northwest quadrant of junction 28 that own land inside the DCO boundary. These are Grove Farm and land belonging to Maylands Golf Club, of which only the former is agricultural. The Weald Brook is the boundary between these holdings. Scheme impacts associated with Maylands Golf Club are assessed in the People and Communities chapter (Chapter 13) of the ES.

10.7.32 Grove Farm has 7.0 ha of rough grassland within the DCO boundary which is currently not in agricultural use. No alternative activities are taking place that would prevent it being farmed again and so, for the purposes of this assessment, it is still classed as agricultural. However, 7.0 ha would only support a small-scale, part-time livestock enterprise unless additional land were rented[41].

10.7.33 None of the Scheme or study area is within Defra's Countryside Stewardship Scheme, which is the main grant aided agri-environment scheme for England[33].

Geology

Structural geology

10.7.34 The Scheme is located within the London Basin, with the northeast to southwest trending axial trace of the London Basin Syncline located approximately within 1 to 2 km south of junction 28[42].

10.7.35 The BGS GeoIndex[43] indicates that the closest major fault is situated 11 km to the southwest of the Scheme.

Artificial ground

10.7.36 Made Ground is expected beneath the Scheme associated with the construction of localised infrastructure, in particular the M25, A12, the railway and

[41] Agricultural Budgeting and Costing Book, Agro Business Consultants Ltd, November 2019
[42] Royse et al. (2012). Geology of London. Proceedings of the Geologists' Association, 123(1), pp. 22-45
[43] BGS. (2017). Onshore GeoIndex (Online), Accessed on 15/02/2019 from http://mapapps2.bgs.ac.uk/geoindex/home.html

embankments. Made Ground is also expected in areas of infilled water features and the historical landfill (see 10.7.60 and 10.7.62).

10.7.37 The 176 published exploratory logs consulted for the assessment of the Scheme mainly located in the vicinity of the M25 and A12 indicate that 74 positions included Made Ground. In 22 of the exploratory holes, the thickness of Made Ground exceeded 2.0 m. The maximum thickness of Made Ground encountered was 7.6 m, associated within an embankment immediately east of the junction 28 roundabout (BGS exploratory hole ID- TQ59SE459[43]). However, superficial deposits at this location may have been misinterpreted as Made Ground.

10.7.38 The preliminary GI[29] was carried out at the location of the inactive Brook Street Landfill, located northwest of the centre of the junction 28 roundabout (see 10.7.60 for further details). The Made Ground at this location is different to elsewhere across the Scheme and generally comprised three separate Made Ground strata. These strata comprised an average of 0.40 m (where present) of recently deposited material, over an average of 1.10 m of recently deposited landfill material, overlaying an average of 4.10 m of landfill material assumedly associated with the inactive Brook Street Landfill. The descriptions of these strata have been provided in Table 10.11.

Superficial deposits

10.7.39 Geological mapping[44] suggests that localised superficial deposits of Head are expected across the Scheme. The 176 published exploratory hole records consulted for the assessment[45] indicated Head deposits present at 49 exploratory holes, with a maximum thickness of 3.70 m encountered on the westbound A12 off-slip (BGS exploratory hole ID- TQ59SE472[43]).

10.7.40 Alluvium deposits are anticipated in the vicinity of the Ingrebourne River, Weald Brook and their tributaries. Alluvium was reported during historical GI at 34 locations within the Scheme (mostly within the central A12 section of the Scheme. The maximum thickness encountered was 4.88 m (BGS exploratory hole ID- TQ59SE363[43]) between the westbound A12 off-slip and the westbound carriage of the A12. A log for BGS exploratory hole TQ59SE138 located immediately west of Weald Brook, approximately 400 m north of the A12 and 230 m west of the M25, noted Alluvium to be a firm to stiff brown slightly sandy silty clay with some plant roots at the surface[43].

10.7.41 Superficial deposits were not encountered during the preliminary GI[29].

Bedrock geology

10.7.42 The underlying solid bedrock is London Clay Formation. The full thickness of the London Clay Formation was not proven in the exploratory holes within the study area. Several historical boreholes within the Scheme have proven the base of the London Clay Formation at approximately 30 m below ground level (bgl). The final pile depth is yet to be finalised but at present it is anticipated that this would not exceed 20 m bgl so penetration of the London Clay Formation is unlikely.

[44] BGS. (1996). 1:50,000 Geological Map, Sheet 257: Romford. Solid and Drift.

[45] BGS. (2017). Geology of Britain Viewer, Accessed on 15/02/2019 from http://www.bgs.ac.uk/discoveringGeology/geologyOfBritain/viewer.html

10.7.43 The Claygate Member comprises the uppermost beds of the London Clay Formation and is expected to be present on the southern extent of the Scheme and in the northeast of study area.

10.7.44 The Preliminary GI[29] at the location of inactive Brook Street Landfill encountered London Clay Formation at the base of two exploratory holes, at 5.30 m and 5.60 m bgl. The description of the stratum has been provided in Table 10.11.

10.7.45 BGS mapping suggests Bagshot Formation is not present beneath the Scheme but is anticipated to be present approximately 100 m east of the southern extent of the Scheme within the study area.

10.7.46 Beneath the London Clay Formation is the Lambeth Group, the Thanet Formation and the White Chalk Subgroup[43]. These three units have not been considered in the assessment as the overlying layer of London Clay provides a sufficient barrier between the Scheme and these units[45].

10.7.47 A summary of the geology is provided in Table 10.11. Full details of the ground conditions historically encountered across the Scheme are provided in the PEIR[30] and more recent findings for the location of the deposited material and inactive Brook Street Landfill are provided in the Preliminary Geo-environmental Assessment Report[29] (Appendix 10.1).

Table 10.11: Summary of geology beneath the Scheme and study area

Stratum	Description	Location expected	Maximum or average thickness encountered (m)
Made Ground (inactive Brook Street Landfill)	Firm dark brown gravelly sandy clay with coarse limestone, flint, brick, quartz, concrete, ceramics, glass, wood, metal, plastic, polystyrene and rare rootlets	Inactive Brook Street Landfill, located northwest of the centre of the junction 28 roundabout (see 10.7.60 for further details).	Average thickness of 0.40
	Firm / firm to stiff dark brown gravelly sandy clay with limestone, brick and slag fragments. Rare fragments of ceramic tile, plastic, glass, silicone, wood, metal and occasional slag. Gravel is subangular to rounded fine and coarse flint.		Average of 1.10 m, encountered 0.40 -1.50 m bgl
	Stiff brown mottled greyish brown stained black slightly sandy, gravelly clay with pockets of orangish brown silt and rare decomposing plant matter, wood and roots. Gravel is subangular to rounded fine and medium sandstone, flint, brick, concrete, chalk, coal. Rare fragments of wood and ceramic tile.		Average of 4.10 m, encountered 1.50 - 5.60 m bgl
Made Ground (infra-structure and infill)	Highly variable materials associated with construction or infilling of ground. Made Ground in these locations will likely comprise reworked superficial deposits and materials from the London Clay Formation.	Made Ground is anticipated along the M25, A12, railway and infilled pits/ponds.	7.60 m
Alluvium	Normally soft to firm consolidated, compressible silty clay, but can contain layers of silt, sand, peat and basal gravel. A	Restricted to within Approximately 50 m of the Weald Brook,	4.88 m

Stratum	Description	Location expected	Maximum or average thickness encountered (m)
	stronger, desiccated surface zone may be present.	and the Ingrebourne River.	
Head	Gravel, sand and clay depending on upslope source and distance from source. Poorly sorted and poorly stratified deposits. Essentially comprises sand and gravel, locally with lenses of silt, clay or peat and organic material.	Found within close proximity to the Ingrebourne River, Weald Brook and their tributaries.	3.70 m
Bagshot Formation	Mainly beds of gravelly fine to medium sand, gravelly sandy clay and very gravelly sand.	Within the southern extent of the study area	1.80 m
Claygate Member	Mainly comprises beds of stiff slightly sandy clay or clayey sand.	Within the southern extent of the Scheme	6.80 m
London Clay Formation	Mainly comprises bioturbated or poorly laminated, fissured, blue-grey or grey-brown (when weathered), slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay. Thin interbedded fine sands are present in the uppermost beds (Claygate Member). The upper portions of the London Clay Formation are moderately to highly weathered[46]. Logged as stiff laminated orangish brown clay with thin and thick laminae of light bluish grey clay and rare selenite crystals in location of the inactive Brook Street Landfill[29].	Found throughout the areas of proposed works. Underlies Made Ground and superficial deposits (where present) beneath the Scheme.	30.0 m
Lambeth Group	Mainly dark grey sand with some silty clay content.	Expected to be present throughout.	46.0 m thick encountered at 72 m bgl in borehole 570 m south-west from centre of junction 28 roundabout.
Thanet Formation	Mainly flints overlain by pale yellow-brown, fine sand, sometimes clayey.	Not encountered between Lambeth Group and chalk in borehole 570 m south-west from centre of junction 28 roundabout however is likely to be present elsewhere.	Not encountered.
White Chalk Subgroup	Encountered at 118 m bgl 570 m south-west from centre of junction 28 roundabout.	Expected to be present throughout.	Depth not proven.

[46] BGS. (2017) BGS Lexicon of named rock units, Accessed on 15/02/2019 from http://www.bgs.ac.uk/lexicon/

Mining activity and quarrying

10.7.48 The BGS and National Geoscience Information Service indicate the Scheme and study area are unlikely to have been mined for coal[47]. There are no records of other mining activities having occurred within the study area[32].

Ground stability hazards

10.7.49 The 1:50,000 scale ground stability maps provided in the Envirocheck report[32] have been used to inform the potential for ground stability hazards for the Scheme and study area, these are displayed on Figure 10.3 and are summarised below:

- The Scheme is in an area with a very low potential for collapsible ground.
- Most of the Scheme has a moderate potential for shrinking or swelling clay to cause a stability hazard, which is likely associated with the Claygate Member and London Clay Formation.
- The potential for running sand as a ground stability hazard varies between very low (i.e. where Head Deposits are anticipated) and low (where Alluvium is anticipated) and likely to be moderate in the locations of the Bagshot Formation which is expected outside of the DCO boundary.
- The potential for compressible ground as a ground stability hazard is considered moderate where Alluvium is anticipated.
- The potential for landslides as a ground stability hazard is shown to vary across the Scheme and study area, with the hazard potential shown as very low across most of the Scheme. Areas where groundworks or man-made slopes associated with the A12 and M25 are present are considered to form a moderate to low potential for landslides as a ground stability hazard. Head deposits are associated with historical downhill movement of material. There may be a low angle shear surface or a series of shears within the top part of the clay[48], which presents a zone of potential displacement occurring.
- Due to the unknown geotechnical integrity of the Made Ground, there is the potential that this unit poses a ground stability hazard where present.

Chemical attack on concrete

10.7.50 Made Ground, Alluvium and London Clay Formation are anticipated to have potentially elevated concentrations of sulphates and sulphides which can contribute to chemical ground conditions aggressive to concrete structures[49].

Hydrogeology

Aquifer designations

10.7.51 Perched groundwater is likely to be present in Made Ground. Groundwater may also be present within any permeable superficial deposits and potentially in the

[47] BGS. (2017) Coal Authority Interactive Map (Online), Accessed on 07/03/2019 from http://mapapps2.bgs.ac.uk/coalauthority/home.html.
[48] Ellison, R.R., Woods, M.A., Allen, D.J., Forster, A., Pharaoh, T.C. & King, C. (2004) Geology of London. Special Memoir for 1:50,000 Geological sheets 256, 257, 270 & 271
[49] BFS (2017) Sulphates and sulphides, Accessed on 15/02/2019 from https://www.bgs.ac.uk/research/environmentalModelling/GeoProperties/SulphatesSulphides.html

upper, more weathered and permeable layers of the Claygate Member or London Clay Formation.

10.7.52 The Environment Agency aquifer designations for the identified geological units are presented in Table 10.12.

Table 10.12: Aquifer designations

Unit	Environment Agency designation[32]
Made Ground	No designation
Alluvium	Secondary A aquifer
Head Deposits	Secondary (undifferentiated) aquifer
Bagshot Formation	Secondary A aquifer
London Clay Formation (Claygate Member)	Secondary A aquifer
London Clay Formation	Unproductive stratum
Lambeth Group	Unproductive stratum
Thanet Formation	Principal aquifer
White Chalk Subgroup	Principal aquifer

Notes:

The London Clay Formation is considered to act as a hydraulic barrier between shallow groundwater bodies and deeper groundwater

Secondary A aquifer (superficial and bedrock): “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. These were formerly classified as minor aquifers”.

Secondary (undifferentiated) aquifer: “has been assigned in cases where it has not been possible to attribute either category 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”.

Unproductive Strata: “geological strata with low permeability that have negligible significance for water supply or river base flow”.

Groundwater within the Alluvium is likely to be in continuity with the rivers.

Groundwater levels

10.7.53 During various stages of historical GI, groundwater was occasionally observed within the Made Ground and superficial deposits typically between 0.90 and 7.20 m bgl. Groundwater levels within the bedrock varied between 2.80 m bgl and 28.60 m bgl[30].

10.7.54 During the preliminary GI[29] which targeted land partially within the inactive Brook Street Landfill, groundwater seepages were encountered in three of eighteen exploratory holes, all within the historical landfill stratum, ranging between 1.80 m and 2.80 m bgl. A slow inflow was recorded in one exploratory hole at 3.83 m bgl and in another at 4.18 m bgl. The recorded ingress was likely to be related to perched groundwater and was considered to be discontinuous at the time.

Groundwater abstraction

10.7.55 No known active groundwater abstractions are licenced within the Scheme or study area[32]. For further details refer to the Road Drainage and Water Environment chapter (Chapter 8). Email correspondence with relevant water companies is provided in Appendix 10.6.

10.7.56 A zone III total catchment SPZ is present across the north-eastern and south-eastern sections of the Scheme and study area. This outer zone appears to be connected to a groundwater abstraction (inner zone I), approximately 12.7 km south-south-east of the centre of the junction 28 roundabout[33]. The inner zone is centred on Davy Down, where Stifford Pumping Station is located which is utilised by Essex and Suffolk Water Company to abstract groundwater from the deep Chalk aquifer[50].

Hydrology

10.7.57 Watercourses that cross the A12 and M25 within the Scheme include the Ingrebourne River and Weald Brook. The course of the Ingrebourne River has been modified during construction of the A12 and subsequent M25 highways.

10.7.58 Other surface water features present within the study area include ponds to the west and to the northeast of the junction 28 roundabout and several drainage ditches throughout the study area.

10.7.59 No known licensed surface water abstractions are within the study area[32].

Potential land contamination

Landfill sites

10.7.60 There is one known historical landfill site within the Scheme and study area[32,51]. The inactive Brook Street Landfill is within the northwest quadrant of junction 28 and is recorded to have accepted inert waste associated with the construction of the M25 from an unknown date until 1983[32]. The Environment Agency, Essex County Council and London Borough of Havering Council have been contacted regarding this landfill. However, no further information was available other than the fill is surplus material associated with the construction of the M25. Email correspondence is provided in Appendix 10.6. Part of the historical landfill site was targeted by the preliminary GI, as detailed in 10.7.38.

10.7.61 No active landfill sites with licences are present within the Scheme or the study area[32].

Potentially infilled land

10.7.62 Potential infilled land (water features) within the DCO boundary and study area have been identified[32], including:

- Three beneath the current M25 alignment in the northern extent of the

[50] The Land Trust (2020). Davy Down. Accessed on 28/04/2020 from https://thelandtrust.org.uk/space/davy-down/?doing_wp_cron=1588084300.6317939758300781250000
[51] Queen Mary University of London (n.d). School of Geography. Online maps. Accessed on 08/11/2019 from https://www.qmul.ac.uk/geog/research/research-projects/historiclandfill/maps/

Scheme.

- One within the location of the historical Brook Street Landfill site, 150 m west of the M25 and approximately 120 m north of development at Grove Farm.
- Three between 5 m and 200 m to the south of the eastern extent of the Scheme close to Belverdere Road.
- One alongside Brook Road, approximately 220 m to the south of the eastern extent of the Scheme.
- One 250 m to the north of the western limb of the Scheme, towards the golf course.
- One in the study area, approximately 460 m to the north of the centre of junction 28.
- One immediately south of the Scheme within the study area, approximately 590 m to the west from the centre of the junction.

Potentially contaminative land uses

10.7.63 Google Maps[52] and the Envirocheck report[32] have been used to identify historical and active industrial land uses within the Scheme and study area. These include:

- Activities and land use within Grove Farm, including RJ Waste Management Recycling, skip hire and rubbish clearance and a garden centre.
- There are two active fuel stations and two former fuel stations in the study area. These comprise the Shell fuel station within the southeast quadrant of junction 28 and the Esso fuel station immediately north of the western limb of the Scheme, alongside the A12. The former fuel stations include the historical filling station located to the southwest of junction 28, situated on the south of the A12. The extent of decommissioning undertaken on the fuel station is unknown.
- Former Old Maylands Aerodrome located between Woodstock Avenue, Weald Brook, the A12 and Maylands Golf Club. Development associated with the former land use included hangers and a fuel storage area[36].
- Other potentially contaminative current and historical activities within the study area which include road runoff from both the M25/A12, electrical substations, garage services, vehicle service and repair garages, MOT centre, vehicle cleaning services, farms, garden centre (present in the southeast quadrant of the junction, alongside Vicarage Close), the railway line and sewage treatment works and associated tanks (although the sewage treatment works lies mostly outside of the 250 m study area).

Pollution incidents

10.7.64 Twelve pollution incidents with impacts to controlled waters have been recorded within the study area, of which four occurred within the Scheme[32] and are listed in Table 10.13. Information on the incident which occurred in 2017 was obtained from the Environment Agency and is provided in Appendix 10.6

[52] Google (2018) Google Maps, Accessed on 08/03/2019 from https://www.google.co.uk/maps/@51.3283531,0.6628474,16.08z

Table 10.13: Pollution incidents to controlled waters

Incident Severity	Pollutant Type	Year	Distance and orientation from centre of junction 28
Category 3 - Minor	Sewage	1999	40 m to the east
Category 3 - Minor	Oils	1989	60 m to the west
Category 3 - Minor	Chemicals	1994	100 m to the northeast
Category 3 – minor (land) and 4 – substantiated with no impact (air and water)	Oils - diesel	2017	2.10 km to the southeast

10.7.65 Due to the age of the pollution incidents and/or the minor nature of them, any pollutants if still in-situ are not expected to remain in significant concentrations.

10.7.66 On a site walkover carried out on the 17 October 2017 by an Atkins' representative (non-geology and soils specialist), an observation of potential contamination was made in the vicinity of the BPA pipeline which is located close to the alignment of the Weald Brook. This was not a recorded incident with the Environment Agency or local authorities, however, Atkins' representatives (geology and soils specialists) have since carried out site walkovers after being made aware of the observation and have reported there to be no visual or olfactory signs of contamination within the area. It is considered likely that the observed material was black, decomposing organic material. No further information about this occurrence is available.

Radon

10.7.67 Public Health England information[53] and the Envirocheck report[32] indicate that the study area is not located in an area that is affected by radon.

Historical ground investigation data

10.7.68 Within the historical logs reviewed for this assessment from BGS viewer[45] and reports provided on HAGDMS (discussed in the PEIR[30]) there is little visual or olfactory signs of contamination reported. Slag was noted in Made Ground in WS90 (0.20 - 0.60 m bgl), located in the northern extent of the Scheme.

10.7.69 Historical contamination test results for seven soil samples taken predominantly from Made Ground but including a single sample of natural clay were available on HAGDMS. These were taken from test pits and boreholes located within the central reserve and verges of the M25 and A12 and were compared to relevant GAC for human health risk, for indicative purposes only as part of the PEIR[30]. No exceedances were reported from any of the seven soil samples, however, due to the location and limited number of the soil samples, this is not considered to be representative of conditions present across the Scheme.

10.7.70 The HAGDMS website and the local authority planning portals have been searched for any new documents of relevance to the Scheme and study area, which may have been produced since the option selection stage and the

[53] Public Health England (n.d). UK Maps of Radon. Accessed on 08/11/2019 from https://www.ukradon.org/information/ukmaps

assessment provided within the PEIR[30]; however, no records of recent GI were identified.

Preliminary Ground Investigation data

10.7.71 Findings from the preliminary GI presented in the Preliminary Geo-environmental Assessment Report[29] (Appendix 10.1) have been summarised in this section. The preliminary GI was carried out in the northwest quadrant of junction 28 where recently deposited material was identified during a site walkover. The area of deposited material coincides with the inactive Brook Street Landfill. The preliminary GI comprised six shallow hand pits (to 1.20 m bgl), ten trial trenches (to approximately 3.00 m bgl), and two window samples (to 7.00 and 8.50 m bgl). A total of 37 geo-environmental soil samples were collected and analysed and further composite samples were collected and analysed for waste acceptance criteria (WAC) testing.

10.7.72 Visual and/or olfactory signs of contamination noted during the recent preliminary GI have been described in Table 10.14.

Table 10.14: Visual and/or olfactory signs of contamination noted during the preliminary GI

Borehole	Depth (m bgl)	Stratum and description
ATK-P-101	0.5-2.0	Recently deposited Made Ground: Frequent fragments of concrete, slag, blue plastic, polystyrene, wood and clear glass. Faint hydrocarbon odour.
	2.45-3.05	Historical Landfill: Rare fragments of copper pipe and decomposing wood. 2.70 - 2.80 m: Frequent pockets of black clay. Faint hydrocarbon odour.
ATK-P-005	1.6-3.0	Historical Landfill: Frequent black staining
ATK-P-006	2.3-3.0	Historical Landfill: Abundant black staining
ATK-P-007	1.0-1.8	Recently deposited Made Ground: Frequent black staining
	1.8-3.0	Historical Landfill: Frequent black staining

10.7.73 Headspace test readings were undertaken within all exploratory holes during the preliminary GI. All readings were recorded at <10 ppm which indicates that concentrations of ionisable VOCs within the soil are likely to be low. Headspace readings of soil from two strata with faint hydrocarbon odours in ATK-P-101 were 0 ppm and 5.9 ppm, suggesting ionisable volatile organic hydrocarbon concentrations were low. Laboratory testing carried out on samples taken from this exploratory hole found that VOCs were present below the laboratory method detection limit and concentrations of hydrocarbons were well below the relevant GAC. Given how infrequent and localised these instances were, the potential for effect on human receptors from hydrocarbon vapours is considered to be limited. It is considered possible that the odours noted during the GI may have been related to the breakdown of organic matter in the soil.

10.7.74 The black staining noted in the deeper Made Ground, described in Table 10.14, is considered likely to originate from decomposing organic material rather than

from hydrocarbon or other contamination, based on observations on site and Atkins' experience with other similar materials.

10.7.75 An assessment of the risk to sensitive human receptors and surface water receptors from Made Ground deposits was carried out as part of the preliminary GI. This was undertaken by means of a comparison of the results of chemical testing of representative geo-environmental soil samples taken during the GI against appropriate GAC. The main findings of the risk assessment for human health and controlled waters (surface water) were:

- Asbestos was identified within four of 105 soil samples taken from 18 locations across the area and screened for asbestos. These locations were not concentrated within a particular locality nor were they associated with a single Made Ground unit however, were generally associated with the more recent deposition of materials within the top 1.0 m and not the historical landfilling. Subsequently, the presence of further instances of asbestos within Made Ground in the area cannot be easily predicted and there is a high probability of asbestos impacted materials being excavated during the proposed works, therefore further assessment of the risk and mitigation measures are required.
- An exceedance of the human health GAC for public open space[54] was identified for beryllium at one location within the historical landfill material at 2.50 m to 3.00 m. This location approximately corresponded to a cutting for a new slip road. The recorded concentration at this location was only slightly greater than the GAC and as the level of exposure to end users at this location is likely to be far less frequent than the assessment assumes (the ground will be covered and access will be limited as the areas will be a slip-road), this exceedance is not considered to be of concern if it remains in-situ. The risks to human health from contamination within the area investigated, associated with the proposed development, are considered to be low.
- Elevated concentrations of metals and inorganics were identified within soil-derived leachate samples, when compared to Freshwater Environmental Quality Standards (EQS-f) as set out in the Water Framework Directive[55] (although the assessment did not consider bioavailability and so a conservative approach was adopted). No continuous shallow groundwater was identified during the preliminary GI. Furthermore, the Made Ground and superficial deposits were logged as predominantly clay. Therefore, there is considered to be limited potential for the migration of contamination to surface water and groundwater receptors within the study area. Whilst proposed drainage features may have the potential to create pathways to sensitive receptors, it is anticipated that appropriate mitigation measures would be implemented to ensure risks to controlled waters would be adequately mitigated. The assessment assumed that attenuation ponds would be unlined but the requirement for lining of the attenuation pond at the inactive Brook Street Landfill will be reviewed during detailed design to assess if this is likely to pose an unacceptable risk. The risks to controlled waters from contamination within the recently deposited material, associated with the proposed development, are considered to be low. Further GI including groundwater rest level monitoring can inform whether lining may be required

[54] Environment Agency (2009) Contaminated Land Exposure Assessment (CLEA) Model
[55] European Parliament (2005) Water Framework Directive 2000/60/EC

for the proposed attenuation pond.

- No ground gas or groundwater monitoring was undertaken as part of the preliminary GI. This will be included as part of the main GI.

Potential sources

10.7.76 Sources of potential contamination identified within the Scheme and study area are summarised below and shown on Figure 10.2:

- On-site recently deposited material. Investigated during the preliminary GI – infrequent asbestos identified. Overall potential risks to human health and controlled waters receptors considered to be low.
- On-site inactive Brook Street Landfill (comprising inert material associated with the construction of M25). Overall potential risks to human health and controlled waters receptors considered to be low.
- On-site railway line.
- On-site BPA fuel pipeline.
- Former aerodrome (on-site and extending off-site).
- On-site minor pollution incidents (four).
- On-site and off-site Made Ground/infill in areas not previously investigated beneath areas of existing development (i.e. along the M25, A12, watercourses, embankments and railway) and potentially infilled water features.
- On-site vehicle emissions, unrecorded spills and leaks from the long-term use of the roads.
- Off-site activities and land uses associated with Grove Farm, including a garden centre and RJ Waste Management Recycling, skip hire and rubbish clearance.
- Off-site land uses including fuel stations (two active - Shell and Esso and two former - both unknown name); electricity substations, sewage treatment works, railway line, vehicle service garages, farms and associated agricultural activities, vehicle cleaning services.

10.7.77 Potential chemical parameters of concern (organics and inorganics) include metals, metalloids, polycyclic aromatic hydrocarbons (PAH), total petroleum hydrocarbons (TPH), unleaded kerosene/naphthalene (associated with former aerodrome), solvents, asbestos, polychlorinated biphenyls (PCBs), BTEX (benzene, toluene, ethylbenzene and xylene), herbicides, pesticides and ground gases (elevated concentrations of methane, carbon dioxide, carbon monoxide, hydrogen sulphide and depleted concentrations of oxygen).

Potential receptors

10.7.78 Receptors of potential contamination are identified as human health, controlled waters and property. These are listed below.

10.7.79 Potential human health receptors include:

- On-site members of the public using public rights of way and public spaces (non-motorised users).
- On-site future construction workers and site maintenance workers associated with the Scheme.
- Off-site residents (including Grove Farm and traveller's site).
- Off-site workers / visitors / users of commercial / industrial premises and recreational areas including those at Grove Farm (garden centre, RJ Waste Management Recycling, skip hire and rubbish clearance, agricultural land workers) and Maylands Golf Club, members of public using public rights of way and public spaces and workers / visitors at industrial, agricultural and commercial premises and recreational facilities.

10.7.80 Exposure to potential sources of contamination to members of the public using the highways would be of limited frequency and duration. As such, they have not been considered as receptors.

10.7.81 Potential controlled waters receptors include:

- Groundwater bodies beneath the Scheme and within the study area, including localised deposits of Alluvium (secondary A aquifer) and Head deposits (secondary (undifferentiated) aquifer) and the secondary A aquifers associated with the Bagshot Formation and Claygate Member bedrock in the study area.
- Surface water receptors within the Scheme and study area, including the Ingrebourne River and Weald Brook.
- Potential new surface water features including attenuation ponds and drainage features.

10.7.82 The outer zone III SPZ present on the south-east and north-east of the Scheme and study area is considered to be associated with groundwater abstraction from groundwater in the Chalk approximately 12.7 km south-south-east of the junction 28 roundabout. The Chalk Group as well the Lambeth Group and Thant Sands Formation underly a layer of London Clay Formation expected to be approximately 30 m thick. Based on the presence of London Clay Formation and the proposed depth of earthworks it is considered that deep groundwater within the Lambeth Group, Thanet Sand Formation and Chalk Group, including the SPZ are not regarded as receptors with respect to the development of the Scheme..

10.7.83 Potential property receptors include:

- On-site underground services including the Cadent high-pressure gas main and BPA pipeline, existing structures, piles and foundations associated with residential, industrial, agricultural and commercial properties and future structures, services, piles and foundations.
- Off-site existing structures, services, piles and foundations associated with residential, industrial, agricultural and commercial properties including listed buildings. Other off-site property including crops and livestock.

10.7.84 No statutory ecological receptors of land contamination have been identified, with the exception of ecological receptors within the aquatic environment which are considered as part of the assessment to controlled waters (surface water).

Potential pathways

10.7.85 Possible exposure pathways of contamination to human health receptors may include but are not limited to:

- Inhalation, ingestion and/or dermal contact with contaminants in soil, soil-derived dust and ACM fibres.
- Inhalation, ingestion and/or dermal contact with contaminants within perched water and shallow groundwater.
- Migration and accumulation of ground gases and/or vapours followed by inhalation and / or ignition causing asphyxiation and/or explosion.
- Inhalation, ingestion and dermal contact with contaminants within surface water.

10.7.86 Possible exposure pathways of contamination to controlled water receptors may include but are not limited to:

- Leaching / vertical migration of contaminants in soils into underlying groundwater.
- Lateral migration of contaminants in groundwater.
- Migration of contaminants entrained in surface water / run-off.
- Lateral migration of contaminants in shallow groundwater / perched water to surface waters.
- Migration of perched/shallow groundwater and / or surface water via preferential pathways e.g. attenuation ponds and pond outfalls.

10.7.87 Possible exposure pathways of contamination to property receptors may include but are not limited to:

- Chemical attack of buried structures in contact with chemical parameters in soil or groundwater.
- Migration of ground gases and / or vapours along preferential pathways including permeable ground, services trenches and service entry points and accumulation in enclosed spaces such as services ducts or access points.
- Lateral migration of contaminants in shallow groundwater / perched water to surface waters, followed by crop uptake
- Inhalation, ingestion and dermal contact with contaminants in windblown soil-derived dust by livestock.

10.8 Potential impacts

10.8.1 A summary of the potential impacts to geology and soils is presented below in three sections; those associated with land contamination, those associated with geomorphology and ground stability and those associated with agricultural land.

Land contamination potential impacts

10.8.2 The Scheme would introduce new receptors, including construction workers, future site workers and property (structures, foundations, piles and services).

10.8.3 The following construction phase activities may contribute to the creation of possible contaminant linkages:

- Disturbance and mobilisation of existing contamination.
- Introduction of additional receptors.
- Preferential contamination migration pathways created through piling, drainage infrastructure or excavations during construction.
- Earthworks, including the deposit of surplus construction materials, potentially leading to increased runoff with a high sediment load (and potential contamination) impacting surface water receptors.
- Groundwater control methods have the potential to mobilise contaminated groundwater and enhance lateral migration of contamination within the superficial and bedrock aquifers and potentially into surface water features.

10.8.4 The proposed attenuation pond to be created within the footprint of the recently deposited material / inactive Brook Street Landfill has the potential to introduce new pathways connecting leachable contaminants with existing controlled waters e.g. Weald Brook and groundwater receptors.

10.8.5 During the operational phase, new pathways may be introduced by workers entering any confined spaces, such as manholes, service chambers and ducts, where hazardous ground gases and / or vapours may accumulate. Vehicle related accidents/incidents have the potential to introduce new sources, however this is assessed in the Road Drainage and Water Environment Chapter (Chapter 8).

10.8.6 A summary of the potential impacts with regards to land contamination for the Scheme is provided in Table 10.15 below. The mitigation measures listed in the table are described in detail in section 10.9. The full land contamination risk assessment (potential impacts) is presented in Appendix 10.7.

Table 10.15: Summary of land contamination risk assessment (potential impacts)

Source	Receptor	Pathway	Classification of risk at baseline (assuming reasonable worst-case scenario)	Classification of risk (construction without mitigation)	Mitigation measures	Classification of risk (construction with mitigation)	Classification of risk (operation)
Potentially impacted soil/groundwater and gases/vapours associated with the following on-site sources: •Inactive Brook Street landfill; •Recently deposited material; •Made Ground/infill in areas not previously investigated beneath areas of existing development (i.e. along the M25, A12, watercourses, embankments and Great Eastern Main Line railway) and potentially infilled water features/pits; •Four recorded minor pollution incidents; •On-site vehicle emissions, unrecorded spills and leaks (including from drainage) from the long-term use of the roads; •Land uses including electricity substations, former aerodrome, railway line, agricultural activities; and • BPA sub-surface pipeline. Potential chemical parameters of concern including heavy metals, metalloids, PAH, TPH, unleaded kerosene/naphthalene (associated with former aerodrome), solvents, asbestos, PCBs, herbicides and pesticides and ground gases.	On-site members of the public in public spaces within the Scheme boundary	Inhalation, ingestion and/or dermal contact with chemical parameters in soil, soil-derived dust and ACM fibres*	Low (Moderate/Low Risk)	Moderate (High) Risk	GI and risk assessments as necessary to define risk. Remediation/ removal of existing contamination if risk assessments deem necessary. Use of ventilated temporary structures during construction if risk assessments deem necessary. Use of appropriate hazard signage and/or ground gas protection measures within below ground chambers and ducts if risk assessments deem necessary. Implementation of measures in the Construction Environmental Management Plan (CEMP) such as good management of stockpiles in accordance with Environment Agency's archived Pollution Prevention Guidelines (PPG)** and replacement Guidance for Pollution Prevention (GPP), implementation of pollution incident control e.g. plant drip trays and spill kits. Implementation of dust management systems. RAMS to be completed prior to construction and risk management with appropriate PPE. See section 10.9 for further details.	Low (Moderate/Low) Risk	Low (Low) Risk
		Inhalation, ingestion and/or dermal contact with chemical parameters within perched water and shallow groundwater	Low Risk	Moderate/Low Risk		Low Risk	Low Risk
		Migration and accumulation of ground gases and/or vapours followed by inhalation and/or ignition causing asphyxiation and/or explosion	Moderate Risk	Moderate Risk		Moderate Risk	Moderate/Low Risk
		Inhalation, ingestion and/or dermal contact with chemical parameters within surface water	Moderate/Low Risk	Moderate/Low Risk		Moderate/Low Risk	Low Risk
	On-site future construction workers and site maintenance workers associated with the Scheme	Inhalation, ingestion and/or dermal contact with chemical parameters in soil, soil-derived dust and ACM fibres*	Receptor not present at baseline	Moderate/Low (Moderate) Risk		Low (Moderate/Low) Risk	Low (Moderate/Low) Risk
		Inhalation, ingestion and/or dermal contact with chemical parameters within perched water and shallow groundwater		Moderate Risk		Moderate/Low Risk	Low Risk
		Migration and accumulation of ground gases and/or vapours followed by inhalation and/or ignition causing asphyxiation and/or explosion		Moderate/Low Risk		Moderate/Low Risk	Moderate/Low Risk
		Inhalation, ingestion and/or dermal contact with chemical parameters within surface water		Moderate Risk		Moderate/Low Risk	Low Risk
	Off-site workers/visitors/users at industrial, agricultural and commercial premises and recreational facilities including those at Grove Farm (garden centre, RJ Waste Management Recycling, skip hire and rubbish clearance), agricultural land workers and residents including those at property on Grove Farm	Inhalation, ingestion and/or dermal contact with chemical parameters in windblown soil-derived dust and ACM fibres*	Low (Moderate/Low) Risk	Moderate/Low (Moderate) Risk		Low (Moderate/Low) Risk	Low (Low) Risk
		Inhalation, ingestion and/or dermal contact with chemical parameters within perched water and shallow groundwater	Low Risk	Low Risk		Low Risk	Low Risk
		Migration and accumulation of ground gases and/or vapours followed by inhalation and/or ignition causing asphyxiation and/or explosion	Moderate/Low Risk	Moderate/Low Risk		Moderate/Low Risk	Moderate/Low Risk
		Inhalation, ingestion and/or dermal contact with chemical parameters within surface water	Low Risk	Moderate/Low Risk		Low Risk	Low Risk

Source	Receptor	Pathway	Classification of risk at baseline (assuming reasonable worst-case scenario)	Classification of risk (construction without mitigation)	Mitigation measures	Classification of risk (construction with mitigation)	Classification of risk (operation)
	On-site groundwater (superficial Secondary A aquifer and Secondary Undifferentiated aquifer). Surface water features (Ingrebourne River and Weald Brook). Potential new surface water features including attenuation ponds and drainage features	Leaching/vertical migration of chemical parameters in soils to underlying groundwater	Moderate/Low Risk	Moderate Risk	GI and risk assessment as necessary to define risk. Remediation/ removal of existing contamination if risk assessments deem necessary. Appropriate design measures for attenuation ponds, if risk assessments deem necessary e.g. incorporating pond lining. Use of appropriate piling methods. Implementation of measures in the CEMP such as good management of stockpiles in accordance with Environment Agency PPG and GPP, implementation of pollution incident control e.g. plant drip trays and spill kits. Control of run off and implementation of dust management systems. See section 10.9 for further details.	Moderate/Low Risk	Low Risk
		Lateral migration of chemical parameters in groundwater	Moderate/Low Risk	Moderate Risk		Moderate/Low Risk	Low Risk
		Migration of chemical parameters entrained in surface water/run-off	Moderate/Low Risk	Moderate Risk		Moderate/Low Risk	Low Risk
		Lateral migration of chemical parameters in shallow groundwater/perched water to surface waters	Moderate/Low Risk	Moderate Risk		Moderate/Low Risk	Low Risk
		Migration of perched / shallow groundwater and / or surface water via preferential pathways e.g. via piling, attenuation ponds (if unlined) and pond outfalls	Pathway not present at baseline	Moderate Risk		Moderate/Low Risk	Low Risk
	Off-site groundwater (superficial Secondary A aquifer and Secondary Undifferentiated aquifer) and surface water features (Ingrebourne River and Weald Brook)	Leaching/vertical migration of chemical parameters in soils to underlying groundwater	Moderate/Low Risk	Moderate Risk		Moderate/Low Risk	Low Risk
		Lateral migration of chemical parameters in groundwater	Low Risk	Moderate/Low Risk		Low Risk	Low Risk
		Migration of chemical parameters entrained in surface water/run-off	Moderate/Low Risk	Moderate Risk		Moderate/Low Risk	Low Risk
		Lateral migration of chemical parameters in shallow groundwater/perched water to surface waters	Low Risk	Moderate/Low Risk		Low Risk	Low Risk
	On-site underground services including the NG high pressure gas main and BPA pipeline, existing structures, piles and foundations associated with residential, industrial, agricultural and commercial properties and future structures, services, piles and foundations	Chemical attack of buried structures in contact with chemical parameters in soil or groundwater	Moderate/Low Risk	Moderate/Low Risk	GI and risk assessment as necessary to define risk. Remediation/ removal of existing contamination if risk assessments deem necessary. Appropriate assessment and design of services resistant to chemical attack if risk assessments deem necessary. Use of appropriate hazard signage and/or ground gas protection	Moderate/Low Risk	Low Risk
		Migration of ground gases and/or vapours along preferential pathways including permeable ground, services trenches and service entry points and accumulation in enclosed spaces such as services ducts or access points	Moderate/Low Risk	Moderate/Low Risk		Moderate/Low Risk	Low Risk
	Off-site existing structures, services piles and foundations associated with residential, industrial, agricultural and commercial properties. Other property including agricultural crops and livestock	Chemical attack of buried structures in contact with chemical parameters in soil or groundwater	Moderate/Low Risk	Moderate/Low Risk		Moderate/Low Risk	Low Risk
		Migration of ground gases and/or vapours along preferential pathways including permeable ground, services trenches and service entry points and accumulation in enclosed spaces such as services ducts or access points	Low Risk	Low Risk		Low Risk	Low Risk

Source	Receptor	Pathway	Classification of risk at baseline (assuming reasonable worst-case scenario)	Classification of risk (construction without mitigation)	Mitigation measures	Classification of risk (construction with mitigation)	Classification of risk (operation)
		Migration of contamination in shallow groundwater and uptake by crops	Very Low Risk	Very Low Risk	measures within below ground chambers and ducts if risk assessments deem necessary. See section 10.9 for further details.	Very Low Risk	Very Low Risk
		Inhalation, ingestion and dermal contact with contaminants in windblown soil-derived dust by livestock	Very Low Risk	Very Low Risk		Very Low Risk	Very Low Risk
Potential chemical parameters in soil/groundwater and gases/vapours associated with the following off-site sources: •Made Ground/infill of unknown provenance associated with existing roads, off-site development infilled pits/ponds/watercourses; •Activities and land uses associated with Grove Farm, including a garden centre and RJ Waste Management Recycling, skip hire and rubbish clearance; •Other land uses including two active fuel stations and two former fuel stations; electricity substations, sewage treatment works, former aerodrome (wider area from the Scheme boundary), vehicle service garages, garden centre, farms and associated agricultural activities, vehicle cleaning services; and •Eight recorded pollution incidents. Potential chemical parameters of concern include a range of inorganic and organic contaminants including heavy metals, metalloids, PAH, TPH, unleaded kerosene/naphthalene (associated with former aerodrome), solvents, asbestos, PCBs, herbicides and pesticides.	On-site members of the public in public spaces within the DCO boundary	Inhalation, ingestion and/or dermal contact with chemical parameters in soil, soil-derived dust and ACM fibres	Moderate/Low Risk	Moderate Risk	GI and risk assessment as necessary to define risks. Use of ventilated temporary structures during construction if risk assessments deem necessary. Use of appropriate hazard signage and/or ground gas protection measures within below ground chambers and ducts if risk assessments deem necessary. RAMS to be completed prior to construction and risk management with appropriate PPE. See section 10.9 for further details.	Moderate/Low Risk	Low Risk
		Inhalation, ingestion and/or dermal contact with chemical parameters within perched water and shallow groundwater	Moderate/Low Risk	Moderate Risk		Moderate/Low Risk	Low Risk
		Migration and accumulation of ground gases and/or vapours followed by inhalation and/or ignition causing asphyxiation and/or explosion	Moderate/Low Risk	Moderate/Low Risk		Moderate/Low Risk	Moderate/Low Risk
		Inhalation, ingestion and/or dermal contact with chemical parameters within surface water	Moderate/Low Risk	Moderate Risk		Moderate/Low Risk	Low Risk
	On-site future construction workers and site maintenance workers associated with the Scheme	Inhalation, ingestion and/or dermal contact with chemical parameters in soil, soil-derived dust and ACM fibres	Receptor not present at baseline	Moderate/Low Risk		Moderate/Low Risk	Low Risk
		Inhalation, ingestion and/or dermal contact with chemical parameters within perched water and shallow groundwater		Moderate/Low Risk		Low Risk	Low Risk
		Migration and accumulation of ground gases and/or vapours followed by inhalation and/or ignition causing asphyxiation and/or explosion		Moderate/Low Risk		Moderate/Low Risk	Moderate/Low Risk
		Inhalation, ingestion and/or dermal contact with chemical parameters within surface water		Moderate/Low Risk		Moderate/Low Risk	Low Risk
	On-site groundwater (superficial Secondary A aquifer and Secondary Undifferentiated aquifer). Surface water features (Ingrebourne River and Weald Brook). Potential new surface water features including attenuation ponds and drainage features	Leaching/vertical migration of chemical parameters in soils to underlying groundwater	Moderate/Low Risk	Moderate/Low Risk	GI and controlled water risk assessments as necessary to define risks.	Moderate/Low Risk	Moderate/Low Risk
		Lateral migration of chemical parameters in groundwater	Low Risk	Low Risk		Low Risk	Low Risk
		Migration of chemical parameters entrained in surface water/run-off	Moderate/Low Risk	Moderate/Low Risk		Moderate/Low Risk	Moderate/Low Risk
		Lateral migration of chemical parameters in shallow groundwater/perched water to surface waters	Moderate/Low Risk	Moderate/Low Risk		Moderate/Low Risk	Moderate/Low Risk
		Migration of perched/shallow groundwater and/or surface water via preferential pathways e.g. via piling	Pathway not present at baseline	Moderate/Low Risk		Low Risk	Low Risk

Source	Receptor	Pathway	Classification of risk at baseline (assuming reasonable worst-case scenario)	Classification of risk (construction without mitigation)	Mitigation measures	Classification of risk (construction with mitigation)	Classification of risk (operation)
	On-site underground services including the NG high pressure gas main and BPA pipeline, existing structures, piles and foundations associated with residential, industrial, agricultural and commercial properties and future structures, services, piles and foundations	Chemical attack of buried structures in contact with chemical parameters in soil or groundwater	Moderate/Low Risk	Moderate/Low Risk	GI and risk assessment as necessary to define risks. Appropriate assessment and design of services resistant to chemical attack if risk assessments deem necessary. Use of appropriate hazard signage and/or ground gas protection measures within below ground chambers and ducts if risk assessments deem necessary. See section 10.9 for further details.	Moderate/Low Risk	Moderate/Low Risk
		Migration of ground gases and/or vapours along preferential pathways including permeable ground, services trenches and service entry points and accumulation in enclosed spaces such as services ducts or access points	Low Risk	Low Risk		Low Risk	Low Risk

*Risk relating to on-site asbestos containing material in brackets

**PPGs are a (now archived) series of documents developed by the Environment Agency. Each PPG is targeted at a particular type of business or activity and covers environmental good environmental practice to minimise pollution. Replacement guidelines are currently being produced (GPP).

10.8.7 Without mitigation measures, the potential risks associated with asbestos exposure in the area of the recent deposits at the inactive Brook Street Landfill area identified during the preliminary GI, have been assessed as high during construction to on-site human receptors and a number of moderate risks may be realised elsewhere in the Scheme to other receptors. However, with the implementation of design and mitigation measures (see section 10.9), these high risk and moderate risks are considered to be moderate/low and low risks. Risks during operation are assessed as moderate/low or low.

Geomorphology and ground stability potential impacts

10.8.8 The Scheme has the potential to impact the topography during construction with the presence of stockpiles. New structures may also have a localised impact on topography. This is discussed in the Landscape and Visual chapter (Chapter 9).

10.8.9 Construction activities and land clearance have the potential to increase soil erosion and degrade soil quality.

10.8.10 Ground instability caused by areas with a high-water table.

10.8.11 The proposed attenuation pond at the area of recently deposited material / inactive Brook Street Landfill, has the potential to increase the water content within the landfill material and subsequently introduce land stability issues caused by seepage face at the base of the landfill material.

10.8.12 Groundworks have the potential to expose unexploded ordnance which may be present.

10.8.13 Compressible and low strength material such as Made Ground, infilled land, landfill, Head and Alluvium Deposits could cause unacceptable settlement after construction due to increased loadings on these materials.

10.8.14 The risk of landslides can increase by removing the toe or increasing the load at the crest of existing embankments. Construction works within the Claygate Member and the London Clay Formation have the potential to activate pre-existing shear surfaces, or where slopes are not adequately battered could create new slip surfaces.

10.8.15 Clay strata are susceptible to shrink-swell and volume changes which may cause differential settlement of any structures associated with the Scheme.

10.8.16 Made Ground, Alluvium, Claygate Member and London Clay Formation are expected to have elevated concentrations of pyrite, sulphate and sulphides which can contribute to aggressive ground conditions detrimental to buried concrete structures.

Agricultural land potential impacts

10.8.17 Loss of BMV land is not a Scheme impact given the affected land is in ALC grades 3b or 4.

10.8.18 The Scheme impacts relate to temporary and permanent land acquisition.

10.8.19 Grove Farm has 7.0 ha of grassland (the woodland is not included in this assessment). In the construction phase it would lose 3.0 ha of this grassland, as follows:

- Temporary acquisition for a construction compound – 1.0 ha.
- Permanent acquisition for highway works and attenuation pond – 2.0 ha.

10.8.20 Grove Farm would permanently lose 2.0 ha of grassland to the new highway during the operational phase.

10.9 Design, mitigation and enhancement measures

Design measures

10.9.1 The mitigation hierarchy presented in the Department for Communities and Local Government EIA: Guide to Good Practice and Procedures[56] aims to make sure consideration of environmental effects is carried out during the design stages of a development. One of the objectives of the GI is to further inform the design and confirm/ optimise the proposed mitigation measures identified within this chapter.

10.9.2 Geotechnical risk would be managed in accordance with DMRB Volume 4 Geotechnics and Drainage[57] and the main GI will assess the potential for ground collapse/investigate settlement and provide data from which adequate foundation solutions can be designed.

10.9.3 Following the main GI, the GIR will be produced which will inform the Geotechnical Design Report (GDR) and other related documents. The GDR will include stability analyses and design calculations for new and modified earthworks and structures, to be adopted to maintain their short and long-term stability. Chemical testing for pyrite, sulphate and sulphide concentrations has been included in the main GI scope and an assessment of the aggressivity of the ground and groundwater conditions will be undertaken in accordance with British Research Establishment Special Digest[58].

10.9.4 Detailed drainage design would consider the land contamination and ground stability risks and designers may be required to use lined drainage systems. Depending on the findings of the GI and groundwater monitoring, a lining may be required for the proposed attenuation ponds (and connection ditches). Sustainable urban drainage design aims to make sure the operational phase of a development is an improvement from the baseline with regards to management of potentially polluted surface water run-off. Further information and assessment on drainage design is presented in the Road Drainage and Water Environment chapter (Chapter 8).

10.9.5 If the risk assessments (i.e. GQRA) carried out after the main GI identify unacceptable risk from contamination, the appropriate design measures shall be integrated into the design. For example, mitigation may consist if appropriate piling design to mitigate risks to controlled waters and appropriate hazard

[56] Department for Communities and Local Government (2006) Environmental Impact Assessment: A Guide to Good Practice and Procedures (archived)
[57] DMRB (2008) Volume 4 Geotechnics and Drainage, Accessed on 26/06/2019 from http://www.standardsforhighways.co.uk/ha/standards/dmrb/vol4/index.htm
[58] British Research Establishment (2005) Special Digest 1:2005 Concrete in aggressive ground, third edition. BRE Bookshop, Watford, UK

signage and / or ground gas protection measures within below ground chambers and ducts where gas may accumulate.

Mitigation measures

10.9.6 Mitigation measures which are summarised in Table 10.15 above are detailed below, along with proposed mitigation methods to alleviate agricultural land and geology and geomorphology impacts. Mitigation measures are also outlined in the Outline Construction Environmental Management Plan (CEMP) (application document TR010029/APP/7.2) and the Register of Environmental Actions and Commitments (REAC) (application document TR010029/APP/7.3) for the Scheme.

10.9.7 If soil and / or groundwater contamination is identified during the GI which poses a risk to sensitive receptors, appropriate remediation would be undertaken. This could include excavation and appropriate landfill or off-site Soil Treatment Centre disposal of contaminated soils; imported clean cover material, on-site bio-remediation etc, depending on the type of contamination identified.

10.9.8 Standard mitigation measures and adherence to codes of construction practice would be incorporated into the construction process where appropriate. These include (but are not limited to):

- Health and safety RAMS and appropriate PPE for the protection of construction workers in accordance with the Control of Substances Hazardous to Health (COSHH) Regulations. Risks to construction workers are expected to be managed by their employers as required by the Health and Safety Executive[59].
- Implementation of appropriate dust suppression measures to prevent migration of contaminated dust and ACM fibres as appropriate, as set out in the Air Quality chapter (Chapter 5).
- Working method statements during construction to manage groundwater and surface water appropriately and ensure that there is no run-off from the works, material / waste stockpiles or from storage containers into adjacent surface watercourses in line with the WFD.
- Stockpile management (such as water spraying and avoiding over stockpiling to reduce compaction of soil and loss of integrity, covering of stockpiled materials and use of battering of exposed soil slopes) and timely removal of stockpiled soil to prevent windblown dust and entrainment of soil in surface water run-off.
- Effective design of traffic control measures to reduce dust generation and minimise the amount of traffic within working areas, use of wheel washes and spraying of working areas and roadways.
- Limiting the area of earthworks at any one time to reduce temporary effects on topography, soil compaction and erosion.
- Limiting the duration of soil exposure and timely reinstatement of vegetation or hardstanding to prevent soil erosion.

[59] Health and Safety Executive (1992) Personal Protective Equipment at Work Regulations.

- Appropriate measures during construction to collect any contaminated water as set out in the Outline CEMP.
- Implementing appropriate pollution incident control measures e.g. plant drip trays and spill kits during construction.
- Implementing appropriate and safe storage of fuel, oils and equipment during construction.
- Completion of any construction phase monitoring (if identified as required following the main GI and subsequent RAMS).
- Implementation of a Materials Management Plan (MMP) and Site Waste Management Plan (SWMP) (see Chapter 12).
- Implementation of suitable piling methodologies.
- Inspection of existing infrastructure and assessment of movements which can be tolerated.
- Design of the temporary and permanent works to minimise movement (including appropriate analysis to predict magnitude of movements).
- Monitoring during the construction works to measure movements, with agreed trigger levels and action plans.
- Review of detailed UXO desk studies for the Scheme to assess the UXO hazard level and appropriate mitigation measures to be adopted prior to the breaking of ground.
- Implementation of a watching brief and discovery strategy.
- Exclusion of non-site inducted persons from construction areas during the construction phase.
- Compound buildings required during construction would have integral gas protection measures / be raised above ground.

10.9.9 It has been assumed that hardstanding would be placed across the majority of the proposed works associated with the carriageway. Hardstanding would minimise the generation of dust, direct contact and ingestion pathways and would minimise infiltration during the operational phase. Proposed soft landscaping and imported 'clean' material are also likely to have the same mitigating affect.

10.9.10 The Scheme would be operated in accordance with the relevant regulations and best practice guidance in applying Best Available Techniques (BAT) and the Environment Agency’s PPG and replacement GPP.

10.9.11 The CEMP for the Scheme will address how incidents would be managed and detail the emergency management procedures to be implemented in such an event.

10.9.12 There is no environmental mitigation for permanent agricultural land-take. Financial compensation is a matter for the District Valuer and outside the scope of this assessment.

10.9.13 Engineered and other mitigation measures to minimise construction impacts on agricultural soils would be agreed with land owners and tenants before and during the construction process. Proposed measures are:

- Demarcation of the construction working corridor once defined, in order to prevent disturbance to adjacent land.
- Diversion or restoration of existing land drainage systems affected by the engineering works.
- Restoration of land occupied or disturbed during the construction process that is not permanently acquired for engineering and landscaping to a condition equivalent to its original, where this has been agreed with the owner. It would be subject to an aftercare period (duration to be agreed), during which time problems with settlement, drainage and weed infestation would be rectified.

10.9.14 The quality and quantity of soil on-site would be maintained by implementing appropriate techniques for stripping, stockpiling and reinstatement, in accordance with Defra's 2009 Code of Practice for the Sustainable Use of Soils on Construction Sites[60]. This will be included in the CEMP / MMP.

10.10 Assessment of effects

Effects associated with land contamination

10.10.1 The land contamination assessment of effects is summarised in Table 10.16 and the full land contamination assessment of effects is provided in Appendix 10.7.

[60] Defra (2009) Construction Code of Practice for the Sustainable Use of Soils on Construction Sites

Table 10.16: Summary of land contamination assessment of effects

Source	Receptor	Pathway	Impact (construction without mitigation)	Impact (construction with mitigation as listed in Table 10.15/section 10.9)	Impact (during operation phase assuming mitigation as listed in Table 10.15/section 10.9 was implemented)
Potentially impacted soil/groundwater and gases/vapours associated with the following on-site sources: •Inactive Brook Street Landfill; •Recently deposited material; •Made Ground/infill in areas not previously investigated beneath areas of existing development (i.e. along the M25, A12, watercourses, embankments and Great Eastern Main Line railway) and potentially infilled water features/pits; •Four recorded minor pollution incidents; •Vehicle emissions, unrecorded spills and leaks (including from drainage) from the long-term use of the roads; •Land uses including electricity substations, former aerodrome, railway line, agricultural activities; and • BPA sub-surface pipeline. Potential chemical parameters of concern including heavy metals, metalloids, PAH, TPH, unleaded kerosene/naphthalene (associated with former aerodrome), solvents, asbestos, PCBs, herbicides and pesticides and ground gases.	On-site members of the public in public spaces within the Scheme boundary	Inhalation, ingestion and/or dermal contact with chemical parameters in soil, soil-derived dust and ACM fibres*	Moderate Adverse	Negligible	Negligible (Minor Beneficial)
		Inhalation, ingestion and/or dermal contact with chemical parameters within perched water and shallow groundwater	Minor Adverse	Negligible	Negligible
		Migration and accumulation of ground gases and/or vapours followed by inhalation and/or ignition causing asphyxiation and/or explosion	Negligible	Negligible	Minor Beneficial
		Inhalation, ingestion and/or dermal contact with chemical parameters within surface water	Negligible	Negligible	Minor Beneficial
	On-site future construction workers and site maintenance workers associated with the Scheme	Inhalation, ingestion and/or dermal contact with chemical parameters in soil, soil-derived dust and ACM fibres*	(Impact predicted to be moderate adverse given sensitivity of receptor)	(Impact predicted to be negligible given reduced likelihood of pathway being realised)	(Impact predicted to be negligible given reduced likelihood of pathway being realised)
		Inhalation, ingestion and/or dermal contact with chemical parameters within perched water and shallow groundwater			
		Migration and accumulation of ground gases and/or vapours followed by inhalation and/or ignition causing asphyxiation and/or explosion			
		Inhalation, ingestion and/or dermal contact with chemical parameters within surface water			
	Off-site workers/visitors/users at industrial, agricultural and commercial premises and recreational facilities including those at Grove Farm (garden centre, RJ Waste Management Recycling, skip hire and rubbish clearance), agricultural land workers and residents including those at property on Grove Farm	Inhalation, ingestion and/or dermal contact with chemical parameters in soil, soil-derived dust and ACM fibres*	Minor Adverse	Negligible	Negligible (Minor Beneficial)
		Inhalation, ingestion and/or dermal contact with chemical parameters within perched water and shallow groundwater	Negligible	Negligible	Negligible
		Migration and accumulation of ground gases and/or vapours followed by inhalation and/or ignition causing asphyxiation and/or explosion	Negligible	Negligible	Negligible
		Inhalation, ingestion and/or dermal contact with chemical parameters within surface water	Minor Adverse	Negligible	Negligible
	On-site groundwater (superficial Secondary A aquifer and Secondary Undifferentiated aquifer). Surface water features (Ingrebourne River and Weald Brook). Potential new surface water features including attenuation ponds and drainage features	Leaching/vertical migration of chemical parameters in soils to underlying groundwater	Minor Adverse	Negligible	Minor Beneficial
		Lateral migration of chemical parameters in groundwater	Minor Adverse	Negligible	Minor Beneficial
		Migration of chemical parameters entrained in surface water/run-off	Minor Adverse	Negligible	Minor Beneficial
		Lateral migration of chemical parameters in shallow groundwater/perched water to surface waters (including the proposed pond).	Minor Adverse	Negligible	Minor Beneficial
		Migration of perched / shallow groundwater and / or surface water via preferential pathways e.g. via piling, attenuation ponds (if unlined) and pond outfalls.	(Impact predicted to be minor adverse given sensitivity of receptor)	(Impact predicted to be negligible given reduced likelihood of pathway being realised)	(Impact predicted to be negligible given reduced likelihood of pathway being realised)
	Off-site groundwater (superficial Secondary A aquifer and Secondary Undifferentiated aquifer) and surface water features (Ingrebourne River and Weald Brook)	Leaching/vertical migration of chemical parameters in soils to underlying groundwater	Minor Adverse	Negligible	Minor Beneficial
		Lateral migration of chemical parameters in groundwater	Minor Adverse	Negligible	Negligible
		Migration of chemical parameters entrained in surface water/run-off	Minor Adverse	Negligible	Minor Beneficial

Source	Receptor	Pathway	Impact (construction without mitigation)	Impact (construction with mitigation as listed in Table 10.15/section 10.9)	Impact (during operation phase assuming mitigation as listed in Table 10.15/section 10.9 was implemented)
		Lateral migration of chemical parameters in shallow groundwater to surface waters	Minor Adverse	Negligible	Negligible
	On-site underground services including the NG high pressure gas main and BPA pipeline, existing structures, piles and foundations associated with residential, industrial, agricultural and commercial properties and future structures, services, piles and foundations	Chemical attack of buried structures in contact with chemical parameters in soil or groundwater	Negligible	Negligible	Minor Beneficial
		Migration of ground gases and/or vapours along preferential pathways including permeable ground, services trenches and service entry points and accumulation in enclosed spaces such as services ducts or access points	Negligible	Negligible	Minor Beneficial
	Off-site existing structures, services piles and foundations associated with residential, industrial, agricultural and commercial properties. Other property including agricultural crops and livestock	Chemical attack of buried structures in contact with chemical parameters in soil or groundwater	Negligible	Negligible	Minor Beneficial
		Migration of ground gases and/or vapours along preferential pathways including permeable ground, services trenches and service entry points and accumulation in enclosed spaces such as services ducts or access points	Negligible	Negligible	Negligible
		Migration of contamination in shallow groundwater and uptake by crops	Negligible	Negligible	Negligible
		Inhalation, ingestion and dermal contact with contaminants in windblown soil-derived dust by livestock	Negligible	Negligible	Negligible
Potential chemical parameters in soil/groundwater and gases/vapours associated with the following off-site sources: •Made Ground/infill of unknown provenance associated with existing roads, off-site development infilled pits/ponds/watercourses; •Activities and land uses associated with Grove Farm, including a garden centre and RJ Waste Management Recycling, skip hire and rubbish clearance; •Other land uses including two active fuel stations and two former fuel stations; electricity substations, sewage treatment works, former aerodrome (wider area from the Scheme boundary), vehicle service garages, garden centre, farms and associated agricultural activities, vehicle cleaning services; and •Eight recorded pollution incidents. Potential chemical parameters of concern include a range of inorganic and organic contaminants including heavy metals, metalloids, PAH, TPH, unleaded kerosene/naphthalene (associated with former aerodrome),	On-site members of the public in public spaces within the Scheme boundary	Inhalation, ingestion and/or dermal contact with chemical parameters in soil, soil-derived dust and ACM fibres	Minor Adverse	Negligible	Minor Beneficial
		Inhalation, ingestion and/or dermal contact with chemical parameters within perched water and shallow groundwater	Minor Adverse	Negligible	Minor Beneficial
		Migration and accumulation of ground gases and/or vapours followed by inhalation and/or ignition causing asphyxiation and/or explosion	Negligible	Negligible	Negligible
		Inhalation, ingestion and/or dermal contact with chemical parameters within surface water	Minor Adverse	Negligible	Minor Beneficial
	On-site future construction workers and site maintenance workers associated with the Scheme	Inhalation, ingestion and/or dermal contact with chemical parameters in soil, soil-derived dust and ACM fibres	(Impact predicted to be moderate adverse given sensitivity of receptor)	(Impact predicted to be negligible given reduced likelihood of pathway being realised)	(Impact predicted to be negligible given reduced likelihood of pathway being realised)
		Inhalation, ingestion and/or dermal contact with chemical parameters within perched water and shallow groundwater			
		Migration and accumulation of ground gases and/or vapours followed by inhalation and/or ignition causing asphyxiation and/or explosion			
		Inhalation, ingestion and/or dermal contact with chemical parameters within surface water			
	On-site groundwater (superficial Secondary A aquifer and Secondary Undifferentiated aquifer). Surface water features (Ingrebourne River and Weald Brook). Potential new surface water features including attenuation ponds and drainage features	Leaching/vertical migration of chemical parameters in soils to underlying groundwater	Negligible	Negligible	Negligible
		Lateral migration of chemical parameters in groundwater	Negligible	Negligible	Negligible
		Migration of chemical parameters entrained in surface water/run-off	Negligible	Negligible	Negligible
		Lateral migration of chemical parameters in shallow groundwater/perched water to surface waters (including the proposed pond).	Negligible	Negligible	Negligible
		Migration of perched / shallow groundwater and / or surface water via preferential pathways e.g. via piling.	(Impact predicted to be minor adverse given	(Impact predicted to be negligible given reduced	(Impact predicted to be negligible given reduced

Source	Receptor	Pathway	Impact (construction without mitigation)	Impact (construction with mitigation as listed in Table 10.15/section 10.9)	Impact (during operation phase assuming mitigation as listed in Table 10.15/section 10.9 was implemented)
solvents, asbestos, PCBs, herbicides and pesticides.			sensitivity of receptor)	likelihood of pathway being realised)	likelihood of pathway being realised)
	On-site underground services including the NG high pressure gas main and BPA pipeline, existing structures, piles and foundations associated with residential, industrial, agricultural and commercial properties and future structures, services, piles and foundations	Chemical attack of buried structures in contact with chemical parameters in soil or groundwater	Negligible	Negligible	Negligible
		Migration of ground gases and/or vapours along preferential pathways including permeable ground, services trenches and service entry points and accumulation in enclosed spaces such as services ducts or access points	Negligible	Negligible	Negligible
*Risk relating to on-site asbestos containing material in brackets					

10.10.2 If no mitigation measures are implemented, the construction phase effects associated with land contamination have been typically assessed as negligible or minor adverse, temporary and not significant. The exception to this is the creation of the pathway between on-site users to identified dust and asbestos which is considered a moderate adverse, temporary and significant effect.

10.10.3 Where adverse effects have been identified, design and mitigation measures would be implemented. With the implementation of design and mitigation measures as listed in section 10.9, the effects to the identified receptors during construction are assessed as negligible, temporary and not significant, as the level of risk to receptors is expected to remain generally the same as baseline.

10.10.4 With design and mitigation measures including the adoption of BAT, it has been considered that during operation there would be negligible, minor beneficial effects to baseline conditions. The reason for the beneficial effects is under the reasonable worst-case scenario, anywhere that potential sources of contamination have been identified, contamination has been assumed to be present, therefore any necessary remediation would improve the conditions from baseline. The anticipated negligible and minor beneficial effects during the operational phase are considered to be permanent and not significant.

Effects associated with geomorphology and ground stability

10.10.5 A qualitative approach has been taken to assess the potential effects of the overall Scheme on geomorphology and ground stability baseline conditions.

10.10.6 The baseline conditions have all been assigned a value / sensitivity based on the rationale presented in Table 10.4. Mitigation methods have been factored in to the geomorphology and ground stability assessment of effects, with the main GI expected to provide further information related to the identified potential risks. The assessment is presented in Table 10.17 below.

Table 10.17: Geomorphology and ground stability assessment of effects summary (assuming design and mitigation measures are implemented)

Sub topic	Value/ sensitivity	Construction (assuming design and mitigation measures are implemented)		Operation (assuming design and mitigation measures are implemented)	
		Magnitude of impact	Significance of effect	Magnitude of impact	Significance of effect
Topography	Low	Negligible	Negligible	Negligible	Negligible
Soil erosion	Low	Low	Minor adverse	Negligible	Negligible
Compressible ground	Medium	Negligible	Minor beneficial	Negligible	Negligible
Collapsible ground (including anthropogenic cavities)	Low	Negligible	Negligible	Negligible	Negligible

Sub topic	Value/ sensitivity	Construction (assuming design and mitigation measures are implemented)		Operation (assuming design and mitigation measures are implemented)	
		Magnitude of impact	Significance of effect	Magnitude of impact	Significance of effect
Landslides	Medium	Negligible	Minor beneficial	Negligible	Negligible
Running sands	Low	Negligible	Negligible	Negligible	Negligible
Aggressive ground	Medium	Negligible	Negligible	Negligible	Negligible
Shrinking or swelling clay	Medium	Negligible	Minor beneficial	Negligible	Negligible
UXO	Medium	Negligible	Minor beneficial	Negligible	Negligible

10.10.7 Potential changes in geomorphology and ground stability baseline conditions as a result of the Scheme are discussed below:

- Topography. Earthworks would be required to facilitate the design which is expected to cause localised changes to the topography within the Scheme. The existing topography is considered as low value as there are no significant topographic features in the Scheme. As per Table 10.4 topography includes characteristics that are locally significant and have the capacity to accommodate the proposed change. The magnitude of impact that construction would have on topography is considered temporary and negligible as there would be very minor topographical changes during construction. The mitigation measures proposed for the construction works would reduce potential impacts to topography, which includes timely removal of stockpiles and therefore the construction impacts are not considered significant. During operation, the effect on topography is considered to be negligible and permanent, as the changes in topography from baseline would be localised and the impact is therefore considered to be not significant.
- Soil erosion. There is likely to be a temporary increase in soil erosion as a result of the stripping of topsoil, vegetation clearance, earthworks, temporary stockpiling and the movement of heavy plant during construction. There is also potential for increased runoff during groundworks with a high sediment load to impact surface water receptors during construction. Due to the nature of the geology beneath the site it is considered likely that any water discharge to ground at Brook Street Landfill has the potential to cause a seepage face which has the potential to increase the risk of soil erosion at the London Clay/Made Ground boundary. Mitigation measures such as those outlined in Section 10.9 would reduce the potential for soil erosion and areas required for temporary works would be reinstated. Consequently, the effect on soil erosion during construction is considered to be (temporary) minor adverse and during operation the effect is considered permanent and negligible, therefore the effects are not considered as significant.

- Compressible ground. The Envirocheck report[32] indicates that there is a localised moderate risk of compressible ground where Alluvium is present, and low risk elsewhere within the Scheme; however, there is no risk rating for locations where Made Ground is anticipated and an elevated level of risk is anticipated at these locations. Where compressible ground is confirmed during the main GI, the risks to proposed engineering structures would be mitigated by design (likely either by excavation and replacement with more competent material or the use of foundations). In the scenario of the compressible ground being excavated and replaced with more competent material, the effect of the development would be permanent minor beneficial during construction and is considered not significant. Assuming mitigation measures have been adopted during construction, a potential negligible magnitude would be present during operation and this corresponds to a negligible (not significant) effect.
- Collapsible ground. There is a very low potential for collapsible ground under baseline conditions[32]. The likely degree of change to this risk rating as a result of the Scheme is considered negligible during construction and operation and therefore the overall effect is considered as not significant and permanent.
- There are localised potential moderate risks of landslide, generally where areas of groundworks or man-made slopes associated with the A12 and M25 are present. Where water is discharged to ground during either construction or operation this has the potential to increase the water content and subsequently reduce the shear strength increasing the risk of landslides. This risk will be assessed through the main GI and would be mitigated through design. There are no other landslide risks considered present elsewhere throughout the Scheme.
- There is a very low risk of running sands where Made Ground or Head Deposits are anticipated) and low (where Alluvium is anticipated).
- There is a potential risk from aggressive ground, which is generally associated with high sulphate, sulphide and phosphate concentrations within clay, Made Ground and Alluvium, all of which are found within the Scheme.
- There is a moderate risk for shrinking and swelling clay where the Claygate Member and London Clay Formation are anticipated[32]. The risk from shrinking and swelling clay could be exacerbated by the scheme through discharges of water to ground during either construction or operation, this risk will be assessed through the GI and would be mitigated through design where appropriate.

10.10.8 If the main GI identifies a possible risk from landslides, aggressive ground or shrinking and swelling clay, proposed structures would be mitigated by design therefore it is considered that no change to these geological features would occur as a consequence of the development relative to the baseline. For example, the proposed attenuation pond within the footprint of the former landfill has the potential to introduce land stability issues through the increased water content that could occur in soil material at this location, if this proposed feature is unlined. If the main GI and subsequent assessments demonstrate that this is the case, the pond would be lined to mitigate the risks. The effects during construction are considered to be permanent minor beneficial and not significant.

Assuming mitigation measures have been adopted during construction, only a potential negligible magnitude would be present during operation and this corresponds to a negligible and permanent effect.

10.10.9 There is generally a moderate to low risk of encountering unexploded ordnance in the Scheme and study area and a localised high risk in the southern portion of the study area[37]. A detailed UXO desk study has been obtained to advise on necessary UXO precautions, in preparation for the preliminary GI. For this area, no further mitigation was deemed necessary other than safety awareness briefings for site personnel. Further desk study is required for the remainder of the Scheme prior to the breaking of ground. If the recommendation of additional detailed UXO desk studies deem it necessary, land clearance would result in the removal of UXO encountered, therefore the significance of effect during construction is considered as permanent minor beneficial and not significant. Assuming mitigation measures are adopted during construction, then a potential negligible magnitude would be present during operation and this corresponds to a negligible effect.

10.10.10 Suitable design and construction works would minimise impacts and it is assumed that the Scheme would be operated in accordance with the relevant regulations and best practice guidance including BAT. This would therefore further reduce impacts to geomorphology and ground stability baseline conditions. Consequently, the overall effect of the Scheme during the construction phase and operational phase on geomorphology and ground stability is considered permanent negligible to minor beneficial and not significant.

10.10.11 GI information is not available for the locations of the proposed ecological compensation ponds however these features would be designed appropriately.

Effects associated with agricultural land

10.10.12 As none of the affected land is of BMV quality, there is no adverse effect on agricultural soils.

10.10.13 Grove Farm is an agricultural receptor of low sensitivity as the area of grassland is small and only capable of supporting a small-scale, part-time farming enterprise. Grove Farm would experience a major impact in the construction phase through loss of grazing land. The effect of this is assessed as moderate adverse, which is significant and temporary.

10.10.14 The impact of the Scheme on agricultural land would be major during the construction phase, due to loss of use of nearly half the farmable land. With mitigation, through the restoration of disturbed land to a farmable condition, the operational impact of land-take on Grove Farm's 7.0 ha of grassland would be moderate.

10.10.15 Following the restoration and handing back of land temporarily acquired in the construction phase, the operational impact would be moderate and the effect slight adverse. This is not considered to be significant.

Significant effects

10.10.16 With the implementation of mitigation measures as listed in section 10.9, no significant effects have been identified associated with land contamination or with geomorphology and ground stability.

10.10.17 No permanent significant effects have been identified associated with agricultural soils and land use.

Residual effects

10.10.18 The residual effects of the Scheme associated with land contamination, geomorphology and ground stability and agricultural land are summarised in Table 10.18, Table 10.19 and Table 10.20 respectively. For land contamination, where a negligible residual effect remains, this has not been detailed in the tables below however, can be viewed in Table 10.16 and Table 10.17.

Table 10.18: Residual effects of the Scheme after mitigation – land contamination

Source	Receptor	Pathway	Residual effect
Potentially impacted soil/ groundwater/ gases/ vapours associated with on-site sources	On-site members of the public in public spaces within the Scheme boundary	Inhalation, ingestion and/or dermal contact with chemical parameters in soil, soil-derived dust and ACM fibres	Minor beneficial during operation
		Migration and accumulation of ground gases and/or vapours followed by inhalation and/or ignition causing asphyxiation and/or explosion	
		Inhalation, ingestion and/or dermal contact with chemical parameters within surface water	
	Off-site workers/visitors/users at industrial, agricultural and commercial premises and recreational facilities including those at Grove Farm (garden centre, RJ Waste Management Recycling, skip hire and rubbish clearance), agricultural land workers and residents including those at property on Grove Farm	Inhalation, ingestion and/or dermal contact with chemical parameters in windblown soil-derived dust and ACM fibres	Minor beneficial for risk from ACM fibres during operation
	On-site groundwater (superficial Secondary A aquifer and Secondary Undifferentiated aquifer). Surface water features (Ingrebourne River and Weald Brook). Potential new surface water features including attenuation ponds and drainage features	Leaching/vertical migration of chemical parameters in soils to underlying groundwater	Minor beneficial during operation
		Lateral migration of chemical parameters in groundwater	
		Migration of chemical parameters entrained in surface water/run-off	
		Lateral migration of chemical parameters in shallow groundwater/perched water to surface waters (including the proposed pond).	
	Off-site groundwater (superficial Secondary A aquifer and Secondary Undifferentiated aquifer) and surface water features (Ingrebourne River and Weald Brook)	Leaching/vertical migration of chemical parameters in soils to underlying groundwater	Minor beneficial during operation
		Migration of chemical parameters entrained in surface water/run-off	
	On-site underground services including the NG high pressure gas main and BPA pipeline, existing structures, piles and foundations associated with residential, industrial, agricultural and commercial	Chemical attack from chemical parameters in soil or groundwater	Minor beneficial during operation
		Migration of ground gases and/or vapours along preferential pathways including permeable ground,	

Source	Receptor	Pathway	Residual effect
	properties and future structures, services, piles and foundations	services trenches and service entry points and accumulation in enclosed spaces such as services ducts or access points	
	Off-site existing structures, services piles and foundations associated with residential, industrial, agricultural and commercial properties	Chemical attack from chemical parameters in soil or groundwater	Minor beneficial during construction and operation
Potential impacted soil/ groundwater/ gases/ vapours associated with off-site sources	On-site members of the public in public spaces within the DCO boundary	Inhalation, ingestion and/or dermal contact with chemical parameters in soil, soil-derived dust and ACM fibres	Minor beneficial during operation
		Inhalation, ingestion and/or dermal contact with chemical parameters within perched water and shallow groundwater	Minor beneficial during operation
		Inhalation, ingestion and/or dermal contact with chemical parameters within surface water	Minor beneficial during operation

Table 10.19: Residual effects of the Scheme after mitigation – geomorphology and ground stability

Subtopic	Value / Sensitivity	Residual Impact
Compressible Ground	Medium	Minor beneficial
Landslides	Medium	Minor beneficial
Shrinking or swelling clay	Medium	Minor beneficial
UXO	Medium	Minor beneficial

Table 10.20: Residual effects of the Scheme after mitigation – agricultural land

Holding	Sensitivity	Magnitude of impact pre mitigation	Effect	Mitigation	Residual effect
Grove Farm	Low	Major	Moderate adverse	Restore construction compound and working areas to original agricultural quality.	Slight adverse

10.10.19 The residual effects associated with the land contamination and geomorphology and ground stability assessments are minor beneficial and therefore not significant. The agricultural land residual effects are slight adverse and therefore are also not significant.

10.11 Cumulative effects

10.11.1 With reference to Table 10.18, Table 10.19 and Table 10.20 above, no significant residual effects have been identified within the assessment for geology and soils, therefore in-combination effects during construction or operation are unlikely.

10.11.2 With reference to the Assessment of Cumulative Effects chapter (Chapter 15), 22 proposed developments with the potential to present cumulative effects have been identified within 2 km of the Scheme. Six of the proposed developments are present or partially present within the geology and soils study area and have been short listed and assessed in Table 10.21 below with regards to land contamination and geomorphology and ground stability. Potential for cumulative effects associated with agricultural land is discussed below.

Table 10.21: Geology and soils cumulative effects

Other development	Geology and soils – Cumulative effects during construction	Geology and soils – Cumulative effects during operation
Small, Medium, Large Wind Development Sites	The proposed development overlaps the Scheme DCO boundary and some of the sites overlap the former aerodrome. The development may have a slight adverse effect on the geology and soils with the potential for cumulative effects. However, best practice measures and appropriate design and mitigation measures are anticipated, and effects are not considered to be significant. **Neutral**	Cumulative effects are not anticipated during operation.
Cycleway Proposals	Partially overlaps the study area assessed in the geology and soils chapter. The development is considered to have negligible potential for cumulative effects. Best practice measures and appropriate design and mitigation measures are anticipated so there is negligible potential for any cumulative effects on geology and soils. **Neutral**	Cumulative effects are not anticipated during operation.
Lower Thames Crossing	The very edge of the development partially overlaps the geology and soils study area. The development may have a minor adverse effect on the geology and soils with the potential for cumulative effects. However, best practice measures and appropriate design and mitigation measures are anticipated, and effects are not considered to be significant. **Neutral**	Cumulative effects are not anticipated during operation.
Caravan Park, Putwell Bridge	Overlaps DCO boundary. The development may have a slight adverse effect on the geology and soils if the developments occurring concurrently, with the potential for cumulative effects. However, best practice measures and appropriate design and mitigation measures are anticipated and effects are not considered to be significant. **Neutral**	Cumulative effects are not anticipated during operation.
Land East of Nags Head Lane	The development is located mostly outside of the geology and soils study area. The development may have a slight adverse effect on the geology and soils with the potential for cumulative effects. However, best practice measures and appropriate design and mitigation measures are anticipated and effects are not considered to be significant. **Neutral**	Cumulative effects are not anticipated during operation.
Gardens of Peace (formerly known as Land at Oak Farm)	Mostly within the DCO boundary. The development may have a slight adverse effect on the geology and soils with the potential for cumulative effects. However, best practice measures and appropriate design and mitigation measures are anticipated and effects are not considered to be significant. **Neutral**	Cumulative effects are not anticipated during operation.

10.11.3 The Scheme involves the permanent loss of 2.0 ha of non-BMV quality agricultural land. With regards to the wind turbine farms, the probability of these being built is not known at this time. Given the extent of the clay soils in the neighbourhood, the likelihood is that they would be on non-BMV land and would not give rise to a significant cumulative effect. The two nearby proposed developments which are expected to be on greenfield sites (Land East of Nags

Head Lane and Land at Oak Farm) are small in agricultural terms and do not involve the loss of BMV land. Therefore, no significant cumulative effects with regards to BMV land have been identified.

10.12 NPS NN compliance

10.12.1 The Scheme would comply with the NPS NN by leaving the Scheme area in better condition than prior to development and it is proposed that:

- Economic and other benefits of BMV agricultural land have been considered during the development of the Scheme.
- The new and existing development should be prevented from contributing to, or being put at unacceptable risk from, or being adversely affected by, water pollution.

10.12.2 The mitigation measures outlined in Section 10.9 should be adhered to and considered throughout all stages of the Scheme to ensure compliance with NPS NN guidance.

10.13 Monitoring

10.13.1 The main GI specification allows for the installation of groundwater and ground gas monitoring wells and a subsequent monitoring programme to confirm baseline conditions (including the monitoring of the two wells installed during the preliminary GI).

10.13.2 If required, monitoring plans for the construction and operational phases would be developed and agreed with relevant authorities, as appropriate.

10.13.3 Disturbed land restored to farming would be subject to a five-year aftercare period, during this time, unacceptable issues associated with settlement, drainage and noxious weeds would be reasonably rectified.

10.14 Summary

10.14.1 This chapter has considered the effects of the Scheme on geology and soils in accordance with the regulatory policy framework presented in Section 10.3.

10.14.2 With regards to the entirety of the Scheme, if no mitigation measures are implemented, the construction phase effects associated with land contamination have been typically assessed as negligible or minor adverse, temporary and not significant. The exception to this outcome without mitigation during construction, is associated with the pathway linking on-site human receptors to identified (isolated) dust and asbestos, which is considered a moderate adverse, temporary and significant effect.

10.14.3 Where adverse effects have been identified, design and mitigation measures would be implemented. With these measures, the effects to the identified receptors during construction are assessed as negligible, temporary and not significant, as the level of risk to receptors is expected to remain generally the same as baseline.

10.14.4 With design and mitigation measures including the adoption of BAT, the impact assessment indicates that the operational phase would have negligible to minor

beneficial, permanent effects and are assessed as not significant. The reason beneficial effects have been identified is that the reasonable worst-case scenario assumes that that contamination is present associated with the identified potential sources and therefore remediation would improve the conditions from baseline.

10.14.5 With respect to geomorphology and ground stability, the assessment indicated that the construction phase is likely to have a minor adverse (temporary) to minor beneficial (permanent) effect and the operational phase is considered likely to have a negligible effect and has been assessed overall as not significant.

10.14.6 With mitigation, the residual effects of the Scheme on agricultural land use are slight adverse and assessed as not significant.

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