THE LONDON RESORT

The London Resort Development Consent Order

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Environmental Statement
Volume 2: Appendices

Appendix 18.2 – Phase 1 Geo-environmental and Geotechnical Risk Assessment A2(T) Corridor and Access Roadway

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Planning Act 2008
The Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009
Regulation 5(2)(a)
The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017
Regulation 12(1)

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Paramount Park Entertainment Resort

Phase I Geo-environmental and Geotechnical Risk Assessment (A2 Corridor and Access Roadway)

London Resort Company Holdings

June 2015

Plan Design Enable

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List of Abbreviations

Abbreviation	Definition
AOD	above Ordnance Datum
Atkins	Atkins Limited
BGS	British Geological Survey
BH	borehole
BRE	Building Research Establishment
BS	British Standard
CIRIA	Construction Industry Research and Information Association
CKD	cement kiln dust
CLEA	Contaminated Land Exposure Assessment
CLR	Contaminated Land Report
CSM	Conceptual Site Model
CTRL	Channel Tunnel Rail Link
CWG	Criteria Working Group
DWS	Drinking Water Standard
EIA	Environmental Impact Assessment
EP	Environmental Permit
EQS	Environmental Quality Standard
GAC	Generic Assessment Criteria
GQRA	generic quantitative risk assessment
ha	hectare(s)
HS1	High Speed 1
IPPC	Integrated Pollution Prevention and Control
IRZ	Impact Risk Zone
Lafarge	Lafarge Cement UK
LPPC	Local Pollution Prevention and Control
LRCH	London Resort Company Holdings
MAGIC	Multi-Agency Geographic Information for the Countryside
MDL	method detection limit
NaFRA	National Flood Risk Assessment
NGR	National Grid Reference
NIRS	National Incident Recording System
NSIP	Nationally Significant Infrastructure Project
NVZ	nitrate vulnerable zone
OS	Ordnance Survey
PAH	polycyclic aromatic hydrocarbon
PPC	Pollution Prevention and Control
PPL	potential pollutant linkage
R&D20	The Environment Agency's Remedial Targets Methodology called 'Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources'
RTD	River Terrace Deposits

SGV	Soil Guideline Values
SPT	Standard Penetration Test
SPZ	Source Protection Zone
SSAC	Site-Specific Assessment Criteria
SSSI	Site of Special Scientific Interest
SSV	soil screening value
SVOC	semi-volatile organic compound
TP	trial pit
TPH	total petroleum hydrocarbon
UCL	Upper Confidence Limit
UXO	unexploded ordnance
VOC	volatile organic compound
WML	Waste Management Licence
WS	window sample

Executive Summary

Introduction

Atkins Limited (Atkins) has been retained by London Resort Company Holdings (LRCH) to complete a Phase 1 desk-based geo-environmental and geotechnical assessment for a section of a proposed large-scale entertainment resort located within the Swanscombe Peninsula, north Kent. This report presents an additional Phase 1 assessment, following on from a previous similar study completed for an area immediately to the north (1), and focuses on an approximately 207 hectare (ha) area comprising part of the A2 highway and an access corridor for the proposed development (herein referred to as the 'site').

The assessment is required to support a future planning application in accordance with the Planning Act 2008 for a Nationally Significant Infrastructure Project (NSIP) for the London Paramount Entertainment Resort site and to provide the information necessary to enable the consultations and submissions required under the NSIP process.

This Phase 1 assessment has been based on subdividing the site into three zones based on the current land use patterns and ownership. The site location and zoning are shown on Figure 001.

Within this Executive Summary, synopses of both the geo-environmental and geotechnical assessments are provided on a zone by zone basis and presented graphically in Figure 003 and Figure 004 in the Figures section of the report. Detailed descriptions and assessments of each of the zones are provided in the main body of the report.

Geo-Environmental Methodology

A review of both historical data and the geo-environmental site setting was undertaken in order to inform an assessment of potential land contamination liabilities. Based on this information, the potential for land contamination both on and surrounding the site has been evaluated and a preliminary assessment of the potential environmental risks has been completed. While reference to the proposed development is noted within this report, risks have been assessed for the site in its current condition.

Geotechnical Methodology

An assessment of the geological and geotechnical constraints within each zone has been undertaken by reviewing the ground conditions and assessing the potential for an adverse consequence. This information has been evaluated and reviewed to determine a risk level for each constraint identified. In turn, the number and extent of constraints for each zone have been assessed to allow a comparative level of risk for each zone to be presented.

Risk Characterisation Summary

Zone 7

Geo-environmental Summary

Zone 7 historically comprised open land which was used for excavation of chalk followed by infilling with Cement Kiln Dust (CKD) and Thanet Formation overburden. The excavated area is known as Southfleet Pit. The zone is currently used for car parking, agricultural land, roads, roundabouts and infrastructure associated with High Speed 1 (HS1). There is a former petrol station in the southern part of the zone and former Portland Cement Works wash mills were located in the north-eastern part of the zone. Springfield Nurseries are located in the south-eastern corner. The River Ebbsfleet begins at the very south-eastern corner of the zone and flows north towards the River Thames within the Zone 7 boundary. There is a scheduled monument for Neolithic sites near Ebbsfleet located in the centre of Zone 7.

Although the majority of the material deposited within Southfleet Pit was Thanet Formation, the pit was initially filled with CKD wastes. The CKD wastes represent the main source of potential soil and groundwater contamination within the zone and are considered to present a moderate level of risk to the scheduled

monument and controlled waters receptors, including local groundwater resources and the River Ebbsfleet as a result of associated leachate migration. Under the current land uses, risks to human health are considered to be low or moderate/low.

Geotechnical Summary

Within Zone 7, the general geological stratigraphy consists of Made Ground (primarily landfill) over superficial deposits of Alluvium, floodplain deposits and Head. These deposits overlie the Thanet Formation and White Chalk.

Substantial risks within Zone 7 are associated primarily with the Alluvium and the peat found within it. These beds are likely to be highly weak and compressible, which can pose a risk of settlement, leading to subsidence. In addition, the bearing capacity of these geological units is also expected to be low. It is anticipated that buried services will be encountered within Zone 7, although locations are unknown. Aggressive ground conditions are noted as being a substantial risk, due to the sulphate content in the alluvium and peat and the CKD which was deposited in the northern part of the zone. Running sand and historical works are also considered to be a substantial risk.

Medium risk constraints include buried foundations, as historically there have been very few buildings within the zone, and perched/high groundwater. From historical borehole logs, groundwater is expected to be at approximately 9 m bgl, however perched water may occur in the floodplain deposits.

Zone 8

Geo-environmental Summary

Zone 8 is located in the south-western part of the site and comprises agricultural land, roads, a former railway, residential properties, Pepperhill Recycling Centre, a garden centre and HS1 infrastructure. Zone 8 is of archaeological importance due to the Roman city of Vagniacae which was located across the majority of the zone. Historical maps indicate that there was a refuse tip located in Pepperhill prior to the development of Pepperhill Recycling Centre; however, there is no evidence to confirm whether or not landfilling actually occurred in this location or the extent or type of wastes which may be present. Under current land uses, risks to human health are considered low and risks to controlled waters are considered moderate/low.

Geotechnical Summary

Within Zone 8 the general geological succession of superficial deposits is Made Ground over Head in localised regions, while only topsoil covers the bedrock in other areas. The bedrock succession consists of Thanet Formation over much of the zone, overlying the Bullhead Beds in localised areas. These units are both underlain by undifferentiated White Chalk bedrock. The zone forms a gentle slope increasing in elevation from approximately 9 m AOD in the north-east to approximately 32 m AOD in the south-west.

Substantial risks within Zone 8 include the potential for running sand which poses a hazard, mainly associated with the Thanet Formation and any excavations into the formation will need to be closely monitored for groundwater activity. The Thanet Formation and Bullhead Beds are expected to rest unconformably on the Chalk, meaning the rockhead is likely to be variable. Solution pipes have been identified within the Chalk within Zone 8, and further dissolution is therefore likely. Finally the Head deposits are expected to have a low bearing capacity, and could fail when placed under load.

Medium risk constraints include buried services, weak compressible ground, as a result of peat deposits found within the Head, and buried foundations, which could potentially be related to the ancient Roman town.

Zone 9

Geo-environmental Summary

The zone is located in the south-western part of the site and primarily comprises part of the A2 (Watling Street), a large six-lane main road, and associated slip roads, notably the A296 (Roman Road) which is a two lane road in the western part of the zone and the B255 (Bean Lane) which is predominantly four lanes and runs perpendicular to the A2 and the A296.

Other land uses within the zone include water works in the south-easternmost part of the zone, an electricity substation towards the central portion of the zone and a small pond, industrial premises and residential properties in the western part of the zone and along the northern boundary of the zone, accessed off the A296.

Risks to controlled waters via leaching from soils were considered to be moderate. Other risks to controlled waters were considered low. Risks to human health were considered to be low to moderate/low.

Geotechnical Summary

In Zone 9 the geological succession is localised Made Ground and Head at the top of the succession, covering London Clay, Lambeth Group and Thanet Formation across the majority of the area. This succession is then all underlain by the undifferentiated White Chalk bedrock. In some areas, the Chalk is found very close to the surface, where the other deposits thin out, leaving just a layer of topsoil over the Chalk. The topography of the zone is dominated by a hill approximately in the centre, reaching about 80 m AOD in elevation, and sloping off to the east and west, with a minimum elevation of about 15 m AOD.

Substantial risks within Zone 9 include Chalk dissolution features, which can have an impact of cost and programme for works, and running sand, caused by excavations in sand breaching the water table. Historical ground works may also pose a hazard, as pits and quarries may be poorly backfilled leading to subsidence. Finally variable rockhead may cause delays to the programme and increased construction costs.

Moderate risk constraints include buried services, aggressive ground conditions, buried foundations, weak bearing materials and compressible ground.

1. Introduction

1.1. Background

Atkins Limited (Atkins) has been retained by London Resort Company Holdings (LRCH) to complete a Phase 1 geo-environmental and geotechnical desk-based risk assessment for an approximately 207 hectare (ha) area in north Kent, located near Ebbsfleet International Station. The area comprises an irregularly shaped parcel of land including part of the A2 Watling Street, B255 Bean Lane, A296 Roman Road, B259 Southfield Road and A2260. This is the second parcel of Phase 1 geo-environmental and geotechnical assessment for the proposed development following the completion of a Phase 1 risk assessment for a 400 ha area located within the Swanscombe Peninsula, to the north of the current site (1). The area forming this second parcel is herein referred to as the 'site'. The site is being considered for redevelopment as an access corridor for a large-scale entertainment resort, discussed in further detail within the first Phase 1 assessment (1). The site location is shown on Figure 001.

The site is roughly 4 km east to west and 2 km north to south and its current land use is mixed, comprising parking areas for Ebbsfleet International Station, agricultural land, roads and road infrastructure, commercial and industrial properties and a small number of residential properties.

The assessment has been undertaken in line with Atkins' Addendum No. 1 Offer of Services dated 3 February 2015 (2).

1.2. Aims and Objectives

The assessment is required to support a future Development Consent Order (DCO) application in accordance with the Planning Act 2008 for a Nationally Significant Infrastructure Project (NSIP) for the London Paramount Entertainment Resort and to provide the information necessary to enable the consultations and submissions required under the NSIP process. In addition the assessment is also intended to inform:

- liability and financial exposure;
- baseline conditions for relevant chapters of the Environmental Statement; and
- the need for and scope of more detailed studies (including ground investigation).

The specific technical objectives for Phase 1 of the assessment, as set out in the Offer of Services (2), were to undertake the following activities:

- collation and review of existing reports and data pertinent to the site and the objectives;
- determination of land use history by review of historical maps, data provided by landowners and other publically available data;
- determination of ground conditions (geo-environmental and geotechnical) by review of published maps, existing site investigation reports and data from the Environment Agency and other authoritative sources;
- determination of regulatory compliance by review of public register information from Local Authorities and the Environment Agency;
- perform a desk-based unexploded ordnance (UXO) risk assessment;
- undertake a site walkover survey to confirm current site uses, to identify surrounding land uses which could impact upon the site and to determine possible constraints on any future site investigations; and
- preparation of a Phase 1 desk study (this report) to include the construction of an initial conceptual site model (CSM), a land contamination preliminary risk assessment, a preliminary geotechnical risk assessment, and the identification of the need for, nature and scope of subsequent works necessary to enable safe development.

In accordance with the above objectives and scope, the potential for land contamination both on and surrounding the site has been evaluated and a preliminary assessment of the potential environmental risks has been completed. Potential geological and geotechnical constraints and risks have been identified and a preliminary assessment of the ground engineering implications of the potential ground conditions on-site has been completed.

While reference to the proposed development is noted within this report, risks have been assessed for the site in its current condition. This approach has been adopted as detailed development plans are currently still in preparation. Consideration of potential development constraints beyond geotechnical and land contamination issues, such as flood risk, ecology or archaeology, is outside of the scope of this assessment and is being addressed separately by LRCH.

1.3. Scope of Work

This Phase 1 assessment has been based on subdividing the site into three zones (see Figure 001), based on the nomenclature used in the previous assessment (1), previous land use patterns and current ownership. The relevant report sections for each zone comprise the following:

- a discussion of the current zone status and key associated environmental influences observable by general inspection around the site;
- a review of the historical land use of the zone and immediate surrounding area;
- a review of the current environmental setting and sensitivity of the zone based on a review of published information;
- a discussion of the anticipated ground and groundwater conditions of the zone and immediate surrounding area based on published information;
- a preliminary CSM which describes the relationship between potential sources of contamination, receptors and exposure pathways for the site as it is currently;
- a preliminary land contamination risk assessment prepared with reference to the proposed development, summarising the results of the above; and
- a preliminary geotechnical assessment summarising the available sources of information, including ground engineering and geotechnical risk assessments.

The relevant current environmental permits are shown in Figure 002.

No intrusive ground investigation has been carried out by Atkins as of the date of this report though initial, site characterisation, investigation has been scoped and is due to commence in summer 2015.

2. Methodology

2.1. Information Sources

To support this Phase 1 assessment, information has been obtained from the following sources:

- current topographic Ordnance Survey (OS) mapping;
- GroundSure reports (GeoInsight (3), EnviroInsight (4), and MapInsight (5));
- information provided on the British Geological Survey (BGS) website (6) (7) (8) (9);
- the Environment Agency website (10);
- the Multi-Agency Geographic Information for the Countryside (MAGIC) website (11);
- information contained on the Google Maps website (12);
- previous ground investigation and assessments (as cited);
- zone-specific information obtained during a site walkover on 15 April 2015;
- liaison with the Environment Agency and both Dartford Borough Council and Gravesham Borough Council (as cited);
- information supplied by Lafarge Cement UK (Lafarge) and their agents Mr Peter Coveney and Mrs Moyra Thomason of CMS-Enviro (as cited);
- a detailed UXO risk assessment (13) (Appendix A); and
- technical papers and published literature (as cited).

2.2. Geo-environmental Methodology

2.2.1. Environmental Assessment/Preliminary Conceptual Site Model

2.2.1.1. Introduction

Primary guidance for assessing and managing land contamination is presented in Contaminated Land Report (CLR) 11 (14) and the Code of Practice for Investigation of Potentially Contaminated Sites, British Standard (BS) 10175 (15).

This report has been prepared in line with the National Planning Policy Framework 2012 (16) which states that:

- the site should be suitable for its new use, taking account of ground conditions and land instability, including from natural hazards or former activities, and pollution arising from previous uses;
- the development is suitable for its location, i.e. unacceptable risks from pollution and land instability are prevented and that unacceptable risks to human health, buildings and the environment are mitigated; and
- where a site is affected by contamination or land stability issues, responsibility for securing a safe development rests with the developer and/or landowner.

Best practice guidance is given by the Environment Agency and Defra in CLR 11 (14), which follows the approach outlined in Guidelines for Environmental Risk Assessment and Management (17). CLR 11 provides a technical framework for application of a risk management process when dealing with land affected by contamination. This preliminary assessment has taken due account of the assessment framework and guidance given within these documents.

A preliminary soil and ground conditions hazards and constraints plan is presented in Figure 003.

2.2.1.2. Risk Assessment and the ‘Contaminant-Pathway-Receptor Model’

Risk assessment generally involves the identification and characterisation of the hazard source or contaminant (that has the potential to cause harm), the exposure pathway(s) for the hazard, and the effect of the exposure on a receptor. Where all three elements are present (source, pathway and receptor), or are likely to be present, they are described as potential pollutant linkages (PPLs), which can then be subjected to the risk assessment and risk management process.

The approach used for this study is that which is conventional for a Phase 1 assessment, i.e. qualitative, employing professional judgement to assess the likely nature of the potential hazard sources, pathways and receptors. Qualitative risk assessment is an established approach, in the first instance, to assessing risk, particularly when investigation data are not available. This is frequently followed by ground investigation works, in order to understand better actual site conditions and enable further detailed risk assessment to be

undertaken. Based on desk-based information alone, it is not possible to 'prove' the contamination status of the site, although some localised information has been obtained and has therefore been included within this desk-based study and report.

While reference to the proposed development is noted within this report, risks have been assessed for the site in its current condition and for the current site users in terms of human health related risks. This approach was taken as detailed development plans are not currently available.

2.2.1.3. The Preliminary Conceptual Site Models

Preliminary CSMs have been created for each development zone, along with a preliminary assessment of risk with respect to each identified PPL, for the site in its current use with no mitigation measures applied. The risk categorisations presented in the zone-specific preliminary CSMs are based on an assessment of the potential consequence of each PPL occurring, along with the likelihood that each PPL will occur, in accordance with the framework provided in Construction Industry Research and Information Association (CIRIA) 552 (C552) (18).

Contaminated land risk is a function of the probability and the consequence and is defined using the risk matrix in Table 2-1.

Table 2-1 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

The description of the classified risks as per C552 (18):

- **Very High:** There is a high probability that severe harm could arise to a designated receptor from an identified hazard, or there is evidence that severe harm to a designated receptor is currently happening. This risk, if realised, is likely to result in a substantial liability.
- **High:** Harm is likely to arise to a designated receptor. Realisation of the risk is likely to present a substantial liability.
- **Moderate:** It is possible that harm could arise to a designated receptor. However, it is either relatively unlikely that any such harm would be severe or, if any harm were to occur, it is more likely that the harm would be relatively mild.
- **Low:** It is possible that harm could arise to a designated receptor, but it is likely that this harm, if realised, would be mild.
- **Very Low:** There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe.

2.3. Geotechnical Methodology

The geotechnical assessment of the site undertaken in this report is in accordance with BS EN 1997: Part 2 (2007) (19) and the UK national annex (BS 5930) (20). The primary objectives of the geotechnical desk study are to evaluate the ground conditions based on the existing information and to plan the scope of the subsequent stages of investigation. Through reference to topographical maps, geological maps and descriptions, records of previous site use, aerial photos, previous site investigations and site walkovers. A preliminary geotechnical constraints plan is presented as Figure 004. This compares the number and extent of geotechnical and geological constraints within of all the zones to show a comparative level of risk across the site.

2.3.1. Historical Borehole Data

A number of historical borehole records have been viewed in the context of this desk study. As the published historical data can be of varying quality, each log has been graded in terms of its usefulness using the criteria set out in Table 2-2.

Table 2-2 Exploratory Hole Grading Scheme

Category	Criteria	Grade
Legibility	Readable	A
	Illegible	C
Quality of logging	Logs provide geological and geotechnical information (e.g. strength)	A
	Logs provide geological information (e.g. chalk)	B
	Logs do not provide useful information	C
Co-ordinates and elevation	Co-ordinates and elevations provided	A
	Co-ordinates provided no elevation	B
	No location information	C

The overall grade for a log is the lowest score achieved in any category. Grade A logs were given priority for use in building up the conceptual ground model; Grade B logs were used with professional judgement and Grade C logs were not used.

A Borehole Grade Map is presented as Figure 005 and a Borehole Depth Map is presented as Figure 006.

2.3.2. Geological and Geotechnical Constraints

Potential geological and geotechnical constraints have been identified from reviewing the readily available technical literature and a qualitative assessment made based on our engineering judgements.

2.3.3. Geotechnical Risk

For the purpose of this report, geotechnical risk is defined as the possibility of an adverse consequence arising from a ground hazard or circumstance.

The Geotechnical Risk Register takes into account the identified geotechnical constraints given above, along with additional project details to ensure that all significant geotechnical risks are identified, recorded, analysed and controlled. The geotechnical risks are discussed in terms of probability, severity and risk, as defined below:

***Likelihood (L)**: The perceived likelihood of the identified geotechnical hazard actually occurring (defined as a rating in Table 2-3).*

***Severity (S)**: The perceived severity, in terms of safety, financial, temporal, legal, or operational consequence, of the occurrence of the identified geotechnical hazard on the identified receptor(s) (defined as a rating in Table 2-4).*

***Risk (R)**: The perceived level of concern which should be assigned to the identified hazard, based on the likelihood of occurrence, and taking into due account the perceived severity of the impact (defined as a risk number in Table 2-5).*

The Geotechnical Risk Register and terminology adopted for this project is based on the guidance given by C.R.I. Clayton (21) and the Highways Agency (22) on managing geotechnical risk. It is a semi-quantitative assessment based on engineering judgement. The classification of probability and severity used in this Geotechnical Risk Register are summarised in Table 2-3 and Table 2-4 respectively. The risk uses the equation:

Degree of Risk (R) = Likelihood (L) x Severity (S)

The explanation of the Degree of Risk is given in Table 2-5, which gives the assessed risk level and appropriate actions.

Table 2-3 Assessment of Likelihood

Scale	Likelihood	Chance
4	Probable	> 50%
3	Likely	10% - 50%
2	Unlikely	1% - 10%
1	Negligible	< 1%

Table 2-4 Assessment of Severity

Scale	Severity	Capital Cost	Programme	Safety
4	Very High	Unsustainable costs.	Unsustainable delay.	Unsustainable chance of injury or illness.
3	High	Increased construction costs.	Increased delay to programme.	Increased chance of injury or illness.
2	Low	Small impact to costs.	Small delay to programme.	Small chance of injury or illness.
1	Very Low	Negligible impact on costs.	Negligible delay to programme.	Negligible chance of injury or illness.

Table 2-5 Perceived Degree of Risk

Risk Number	Risk Ranking	Action Required
13 to 16	High (H)	Work must not start until risk has been reduced. If risk cannot be reduced, work should not begin.
9 to 12	Substantial (S)	Work must not start until risk has been reduced. Additional resource required.
5 to 8	Medium (M)	Consider more cost-effective solutions or improvements at no extra cost.
1 to 4	Low (L)	None

The hazards identified for this project are set out in the Geotechnical Risk Register, which is a ‘live’ document and will need to be updated regularly. A précis of the Geotechnical Risk Register, as it stood at the time of issue of this document, is set out in the following section.

2.3.3.1. Risk Matrix

The matrix below shows the risk number and risk ranking.

Likelihood		Severity	
4	Probable	4	Very High
3	Likely	3	High
2	Unlikely	2	Low
1	Negligible	1	Very Low

	Severity				
Likelihood		1	2	3	4
	1	1 Low	2 Low	3 Low	4 Low
	2	2 Low	4 Low	6 Medium	8 Medium
	3	3 Low	6 Medium	9 Substantial	12 Substantial
	4	4 Low	8 Medium	12 Substantial	16 High

2.3.4. Risk Register

The Geotechnical Risk Register comprises an initial assessment of the risks identified, prior to the application of risk mitigation measures, and shows how the risks can be reduced by the application of the measures. It does not consider the site in terms of any specific development proposals.

2.3.4.1. Mitigation Measures

The mitigation measures considered are those that may be applied during design or construction, as appropriate, to mitigate the hazard identified and, in most cases, to render the risk insignificant.

2.3.4.2. Residual Risk

Following risk identification, assessment and the application of recommended mitigation/avoidance measures most risks can be revised and assessed as either “medium” or “low”. In some cases the risk may be reduced but a significant residual risk remains which must be managed, and in others the risk mitigation measure cannot reduce the likelihood of an event but will be used to mitigate potential effects.

2.4. Unexploded Ordnance Risk Assessment

A detailed UXO risk assessment for the site was commissioned by Atkins and completed by 6 Alpha Associates (13). The report follows the requirements of C681 ‘UXO – A guide for the Construction Industry’ (23) and presents an overall assessment of risk for the wider site, together with recommended risk mitigation measures for earthworks including intrusive ground investigation.

The most probable UXO threat identified is that posed by German World War 2 high explosive bombs, whilst incendiary bombs and British anti-aircraft ammunition pose a residual threat. The transformer works located on-site (within the north-eastern part of Zone 8, immediately south of Roman burial ground and later Northfleet East Grid Substation) was considered a primary bombing target, with the on-site pumping stations (those within Zones 7 and 8) and railway station (southern part of Zone 8) and the off-site reservoirs and sewage works considered to be secondary targets. It was deemed highly likely that bombs landed within the site boundary, considering the bombing densities and number of bombs that affected the nearby villages, and anecdotal evidence indicates bombs falling within the fields around Northfleet and Swanscombe.

The UXO report presents the overall risk for the site as ‘high’, and the full report is presented in Appendix A.

2.5. Assumptions and Limitations

The current assessment has been based on the collation and evaluation of readily available documentary and anecdotal information provided by the Environment Agency, BGS, GroundSure and other data sources made available to Atkins, as detailed in Section 2.1. Not all of the data requested were available at the time of writing, and additional data will therefore be discussed in subsequent revisions of this report. Some of the opinions presented herein are based on unconfirmed data and information from third parties which cannot be fully verified and, as such, no responsibility can be taken for their accuracy.

The preliminary CSMs have been developed from the available background information and the site walkover. Based upon these sources of information, a number of PPLs have been identified and are discussed herein. Not all sources of contamination, pathways or receptors may have been identified from the information sources utilised. Alternatively, sources which do not exist may have been assumed to be present.

This report should be read in light of the legislation, statutory requirements and/or industry good practice applicable at the time of the works being undertaken. Any subsequent changes in this legislation, guidance or design may necessitate the findings to be reassessed in the light of these circumstances.

3. Regional Geology and Hydrogeology

3.1.1. General

The purpose of establishing the geology is to provide a proper understanding of the lithology and diagenesis of the site. These factors control the engineering properties of the soils.

3.1.2. Regional Geology

The regional stratigraphy as described in the BGS Memoir for London and the Thames Valley and the BGS geological maps of the area, is outlined in Table 3-1 below.

Table 3-1 Regional Stratigraphy of the Swanscombe Area

Type	Period	Series	Group	Stratum	Description*
Superficial	Quaternary	Holocene		Made Ground	Variable composition, man-made deposit.
				Worked Ground	Chalk, clay, sand or sand and gravel pits with little or no fill (24).
				Head	Composed of gravels, sands and clay. Proportions are dependent on the upslope lithologies. It is a well graded deposit formed from downslope movement and creep.
				Peat	Organic rich clay which is an accumulation of a wet, dark brown partially decomposed vegetation.
			Maidenhead Formation	Boyn Hill Gravels Member	Sand and gravel with possible lenses of silt, clay or peat (River Terrace Deposits).
				Lynch Hill Gravel Member	Sand and gravel, locally with lenses of silt, clay or peat (River Terrace Deposits).
				Taplow Gravel Formation Member	Sand and gravel, locally with lenses of silty, clay or peat (River Terrace Deposits).
Bedrock	Palaeogene	Eocene	Thames Group	London Clay Formation	Poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and silt, with some layers of sandy clay. Commonly contains thin beds of carbonate concretions, shells and disseminated pyrite.
				Harwich Formation	Typically comprises glauconitic silty or sandy clays, silts and fine- to coarse-grained glauconitic sands, some gravelly, varying to flint gravel beds. Thin beds of grey clay occur in some parts, as do shell-rich beds and thin beds of argillaceous limestone.
		Palaeocene/ Eocene	Lambeth Group	Woolwich and Reading Bed Formation	Glauconitic sands at base (Bottom Bed), overlain by grey clays and sands with brackish fauna (Woolwich Beds), and interleaved red and variegated clays and sands (Reading Beds).
		Palaeocene		Thanet Formation	Glauconite-coated, nodular flint at base, overlain by pale yellow-brown, fine-grained sand that can be clayey and glauconitic. Rare calcareous or siliceous sandstones.

Type	Period	Series	Group	Stratum	Description*
	Cretaceous	Upper Cretaceous	White Chalk Group	Seaford Chalk Formation	A firm white Cretaceous Chalk with conspicuous semi-continuous nodular and tabular flint seams. It contains layers of hard ground and thin marl seams are present in the lower portions of the formation.
				Lewes Nodular Chalk	A hard to very hard nodular Chalk with hardground layers interbedded with soft to medium hard chalks and marls.

*taken from the BGS Lexicon of Named Rock Units (9).

3.1.3. Structure

The site is situated on the edge of the London basin in the North Downs; this is the northern edge of the Wealden anticline. This is the faulted region of the London platform with faults trending approximately east to west dissecting the bedrock. The site is situated in a down thrown block between two normal faults trending east to west.

3.2. Geology

Geological maps and boreholes from previous intrusive investigations were used to determine the local geology across the site and descriptions for the following units are given here:

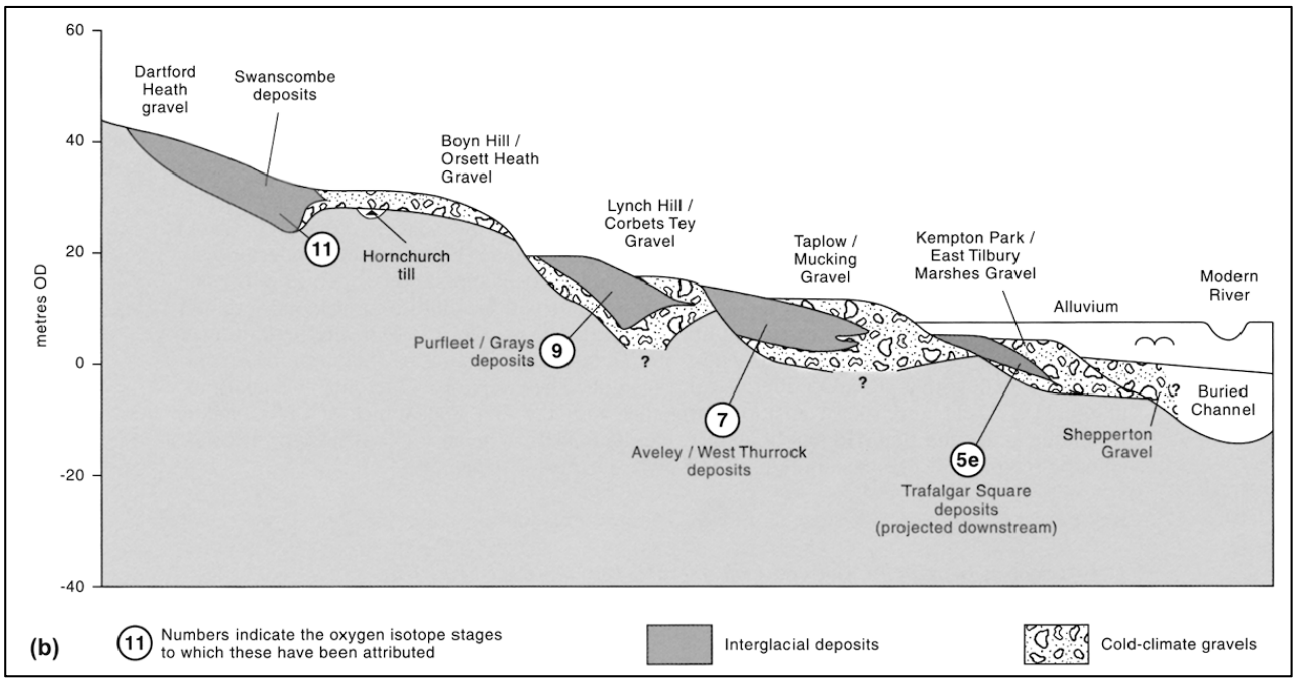
- River Terrace Deposits;
- Lynch Hill Gravel Member;
- London Clay Formation;
- Harwich Formation; and
- Lambeth Group.

3.2.1. Superficial Deposits

3.2.1.1. River Terrace Deposits

The River Terrace Deposits and the geomorphic terraces themselves, found in the Swanscombe area, were deposited during various phases of sea and river level change in response to Pleistocene climatic fluctuation (25). The Taplow Gravel Formation, and Lynch Hill and Boyne Hill Gravel Members are recorded as being present at the site. The Taplow Gravel Formation is the youngest member having been deposited around 186,000 years ago and is found lower down in the sequence. The Lynch Hill Gravel Member was deposited approximately 303,000 years ago.

Figure 1. Idealised Section Through the Lower Thames Terraces



3.2.1.2. Lynch Hill Gravel Member

The Lynch Hill Gravel Member is composed predominately of sands and gravels with various lenses of silts, clays and peats. Literature suggests that there are abundant gravel-sized flints within the deposits.

According to Bridgland (26) (27) the base of this terrace rests at approximately 15 m AOD in the Swanscombe area.

It is anticipated that this unit will exhibit a high friction angle, low compressibility and moderate to high permeability.

3.2.2. Bedrock Geology

3.2.2.1. London Clay Formation

The London Clay Formation is the uppermost sub-unit of the Thames Group and outcrops just north and south of the A2 bypass, according to geological maps. The geological maps state that the London Clay Formation in this area is likely to be up to 6 m thick.

The London Clay Formation is described as comprising firm to stiff, over consolidated, poorly laminated, blue-grey to grey-brown, silty to very silty clay to clayey silt with some beds of silt and sandy clay (9) (28). It commonly contains thin courses of carbonate concretions and disseminated pyrite as well as rare thin beds of shells and fine sand partings. Thin beds of black rounded flint gravel has been recorded throughout this unit and glauconite is present in some of the sands and in some clay beds.

Burnett and Fookes (28) have created regional trend maps of various properties of unweathered London Clay Formation in the London Basin. Table 3-2 below shows the geotechnical properties of the London Clay in the Swanscombe area determined from these maps

Table 3-2 Summary of the Geotechnical Properties of the London Clay Formation

Geotechnical Property	Approximate Result
Liquid limit	83 %
Plasticity index	51 %
Dry density	1554 kg/m^3

Geotechnical Property	Approximate Result
Undrained shear strength	17.2 MN/m^2

Source: Burnett and Fookes (28).

Further properties could not be determined for the London Clay Formation in the Swanscombe area.

3.2.2.2. Harwich Formation

Underlying the London Clay Formation is the Harwich Formation, which has a regionally variable lithology. According to the BGS (9), in the south of the London Basin, the Harwich Formation typically comprises glauconitic silty or sandy clays, silts and fine to coarse grained glauconitic sands. Thin beds of grey clay occur in some areas, as do shell-rich beds and thin beds of argillaceous limestone and volcanic ash in some parts of Kent and southern Essex.

The base of the Harwich Formation is an eroded unconformity on the underlying Lambeth Group. The base is sharply defined, being formed by a planar or slightly undulose discontinuity with a basal bed of very well-rounded flint gravel and fine to coarse quartz grains in a finer glauconitic matrix. Burrows commonly extend down into underlying beds.

3.2.2.3. Lambeth Group

The Lambeth Group (formerly the Woolwich and Reading Beds) are described by the BGS as comprising silty clay/mudstone, sandy silts and sandy clayey silts of marine origin. In this region, the Lambeth Group consists of the Woolwich Formation and the Reading Formation. The Woolwich and Reading Beds are often interbedded with one another (9) and are expected to reach up to 8 m thick in the Swanscombe area.

The Woolwich Formation consists of the Lower Shelly Clay, Laminated Beds and the Upper Shelly Clay. The Lower Shelly clay comprises dark grey to black clay with beds containing abundant shells. Some beds have been observed as being comprised entirely of cemented shells (9). The Laminated Beds are made up of a thinly interbedded succession of fine and medium sand, silt and clay with some shells present throughout (9). The Upper Shelly Clay is described as being a grey shelly clay which is thinly interbedded with greyish-brown silt and fine sand (9).

The Reading Formation consists of the Upper and Lower Mottled Clay, and is largely made up of colour-mottled, unbedded silty clay and clay. Some beds of silt, sand and gravel have also been observed in this formation. The colours include pale brown and pale grey-blue, dark brown, pale green, red-brown and crimson. The clays contain numerous fissures which give rise to a blocky texture (9).

Table 3-3 below summarises the geotechnical parameters of the Lambeth Group, obtained from CIRIA C583 (29) and Entwisle, et al., (30). These results have been obtained from a broad range of data collected during the Crossrail, HS1 and Jubilee Line Extension. Further data for the Swanscombe area has not been identified.

Table 3-3 Summary of the Geotechnical Properties of the Lambeth Group

Formation	Geotechnical Property					
	Plasticity Index (%)	Average Natural Water Content (%)	Average Bulk Density (Mg/m^3)	Cohesion (kPa)	Angle of Shear (°)	Average Undrained Shear Strength (kPa)
Woolwich Formation	15 – 35	30	2.05	4 – 34	19 – 37	80
Reading Formation	20 – 45	20	2.1	12 – 30	22	200

Source: CIRIA C583 (29) and Entwisle et al., (30).

3.2.2.4. Deneholes

Underground workings in chalk, known as deneholes are common along the Thames Estuary and dates back to the 13th and 14th Centuries. These are vertical shafts up to 20 m deep through River Terrace Deposits and the underlying Thanet Sand Formation, with footholds cut on the opposite side of the shaft so miners could climb in and out without a ladder. The Chalk was then excavated as several chambers, usually in groups of

six, arranged as a double trefoil pattern; occasionally the chalk separating the chambers was removed leaving six pillars to support the roof.

The shafts of these excavations are known to be sunk as close as possible to the field boundary so any future subsidence would not interfere with ploughing activities. Most deneholes are found singly and in distinct association with ancient field boundaries; however, some are found in groups where less than 0.9 m (3 ft) of chalk can separate the structures. The entrances to the mines were commonly blocked, often intentionally with tree stumps and vegetation. Many denehole sites are now in woods or long narrow copses (known locally as 'Shaves' or 'Shaws') where farmers have planted trees in the past to isolate the area.

- Hangman's wood, Grays, Essex over 50 shafts have been recorded with an area of 200 m^2.
- Darenth Wood, unusually shallow with uncapped 15 m vertical shaft leading to six chambers.

Alternatively Chalkwells (or draw wells) were sunk in areas where the chalk was overlain by a heavy clay soil during the 17th Century. According to Edmonds, Green and Higgingbottom (31), Chalkwells were typically above the water table. The shafts of these excavations are wider than that of deneholes, often 0.5 to 2 m in diameter, where miners were lowered down by rope, often the diameter of the shaft increased with depth to prevent rope friction. Approximately two to four roughly cut caves radiating from the base of the shaft were excavated; when enough chalk had been removed the chalkwell was sealed by installing a brick dome about 1.8 m (6 ft) down the shaft and backfilling to the surface. A later development was to widen the shaft from part way down into a beehive arrangement. The main use was for agriculture and their location as such is associated with field boundaries. In addition Chalkwell deposits were occasionally used to supplement the chalk required for brickmaking rather than the larger scale brickfields.

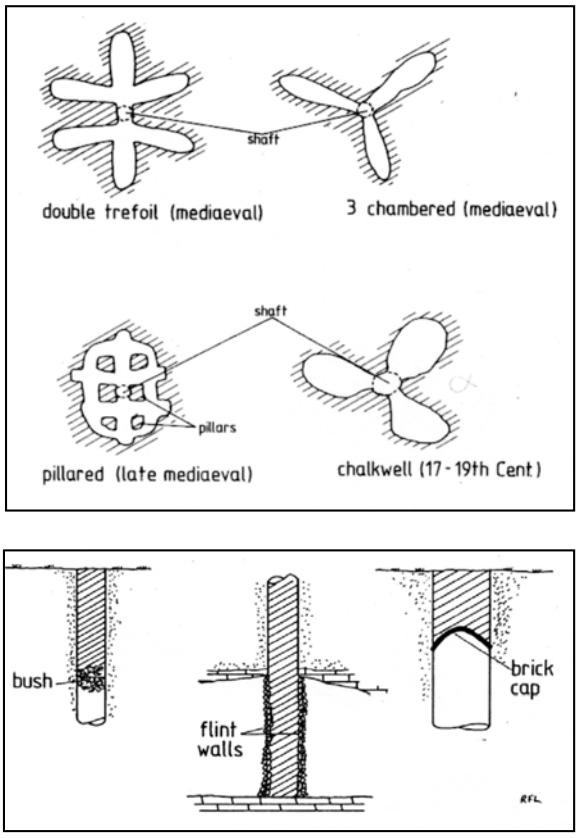


Figure 2. Denehole Types and Examples of Shaft Filling Taken from CIRIA 574 (32)

3.3. Geological Section

An additional geological section (Figure 007) has been produced based on the available borehole records and the BGS 1:10,000 geological maps using surface expression and strata dip information where available to derive a schematic geological section and capture strata succession with depth.

3.4. Hydrogeology

The Head deposits located within Zones 7, 8 and 9 are classified as a Secondary (undifferentiated) aquifer. The River Terrace Deposits within Zone 9 and the Alluvium within Zone 7 are classified as Secondary A aquifers.

The Thanet Formation (beneath parts of Zones 7, 8 and 9) and Lambeth Group (beneath parts of Zone 9) bedrock, are classified as Secondary A aquifers, and the Chalk bedrock underlying the entire site is classified as a Principal aquifer (10).

The BGS Hydrogeological Maps suggest that regional groundwater flow direction in the area is northerly, towards the River Thames (8).

Refer to the individual zone chapters for zone-specific information about the local hydrogeology.

4. Zone 7

4.1. Zone Characterisation

4.1.1. Location

Zone 7 is located to the north of the A2 and is centred on approximate National Grid Reference (NGR) TQ 61443 73090 (561443E, 173090N). Zone 7 has an approximate area of 72 ha. The majority of Zone 7 is located within the borough of Dartford except for a small part (the south-eastern section) which is located within the borough of Gravesham. The River Ebbsfleet separates the two boroughs.

4.1.2. Zone Description

Zone 7 is located to the south of Zone 6, which was assessed as part of the previous Phase 1 works (1) and to the north of Zone 8 (see Chapter 5). The zone is characterised by infrastructure to support access to Ebbsfleet International Railway Station including two large parking areas, roads, pavements, landscaped areas and roundabouts. In the south-eastern corner of the zone is Springhead Nurseries which has been located there for at least 150 years. The remainder of the zone comprises open / agricultural land, foundations of previous residential housing, and a small area formerly used as a petrol station (now demolished and cleared) located off the southernmost roundabout.

The source of the River Ebbsfleet is located in the south-eastern corner of the zone at Springhead and flows from this point north towards the River Thames along the zone's eastern boundary. There are a number of mature trees along the banks of the river. High Speed 1 (HS1), also known as the Channel Tunnel Rail Link (CTRL), is located off-site immediately adjacent to the eastern boundary of the zone. HS1 is situated above ground along the majority of the zone boundary, entering a tunnel under the A2 at the south-eastern corner of Zone 7. There is a large electricity pylon in the south-eastern section of the zone.

The elevation of the zone near the valley of the River Ebbsfleet is between 2 and 6 m above Ordnance Datum (AOD). The north-western corner of the zone, close to both the Southfleet Pit and Northfleet landfills, is at an elevation of 26 m AOD; the ground slopes from this corner down towards the southeast before levelling over the area of the parking lot, and slopes down again towards the railway, with the north-eastern corner, adjacent to HS1, situated at 7 m AOD;. Embankments along the eastern sides of the roadways slope towards the south and east (33). The A2260 (also known as Hall Road or Link Road) (33) is located at 22 m AOD. The roads within this area (B259 Southfleet Road and access roads to parking areas) are at approximately the same elevation as the A2260.

The former Northfleet West Grid Substation (a large substation which has been demolished and is earmarked for redevelopment) is located 330 m to the west of Zone 7 and adjacent to the north of Zone 9, and is discussed within Chapter 6 (Zone 9).

The majority of the ground cover across the zone is softstanding (85 %) with the remainder hardstanding comprising roads/parking lots (15 %).

For site walkover photographs, please see Appendix B. The current layout of the zone is shown on Figure 001, and key features, both current and historical, are shown on Figure 008.

4.1.3. Zone-Specific Data Sources

A site walkover was undertaken on 15 April 2015. In addition to information gained during the site walkover, the following information sources were available and utilised during the Zone 7 assessment:

- EDAW Limited. Ebbsfleet Environmental Statement. December 1995. (34);
- Land Securities Limited. Ebbsfleet Station Quarter South. Site Description, Remediation and Earthworks Strategy. April 2006. (33);
- Peter Brett Associates LLP. Northfleet Rise Disturbed and Contaminated Land Strategy. May 2008 (35).
- historical borehole records provided by the BGS;
- Victor Smith (Kent Archaeology). 1997. The Roman Road at Springhead Nurseries. *Archaeologica Cantinana, 117.* (36);
- Parsons Brinckerhoff, Remediation Strategy and Implementation Plan, Northfleet West Grid Substation, November 2013 (37);
- Erith Contractors Ltd., Addendum to Verification Report, Northfleet West Grid Substation, February 2015 (38); and

- documentation associated with the outline planning application for a hotel at the site of the former petrol station (39) (40).

A historical ground investigation has been identified through the BGS website, within Zone 7: a report is titled 'Channel Tunnel Rail Link Preliminary Ground Investigation Stage II'. It is believed that information contained within this report may be pertinent to the zone; however, at the time of writing this report the information has not been made available.

4.1.4. Surrounding Land Uses

The land uses surrounding Zone 7 are described below.

- **North:** Zone 6 and Northfleet landfill are located immediately north of Zone 7, with Ebbsfleet International Station to the north-east – see the earlier Phase 1 assessment for further details regarding Zone 6 (1).
- **East:** HS1, which runs at ground level, is located to the east of the zone, leading to Ebbsfleet International Station. Further east there is a sewage works, a light commercial area and residential area with Blue Lake (Sawyer's Lake) and Northfleet Urban Country Park beyond.
- **South:** Zone 8 is located to the south of Zone 7 – see Chapter 5 for further details regarding Zone 8.
- **West:** To the west of the zone are agricultural land, the former Northfleet West Grid Substation, Eastern Quarry, a new housing estate, and the access road to the head offices of Land Securities known as 'The Observatory'.

4.1.5. Historical Land Uses

For the adjacent historical land uses of Zone 6, reference should be made to the previous assessment (1). For the adjacent historical land uses of Zone 8 and 9, reference should be made to Chapters 5 and 6 of this report. A review of historical land uses in Zone 7, and off-site historical features (i.e. not within another zone of the site and closer to Zone 7 than to other zones), from available historical maps provided by GroundSure has been undertaken (5) and is summarised in Table 4-1. All distances given are approximate.

Table 4-1 Historical Land Uses Relating to Zone 7

Dates and Scales	Within Zone 7	Within 1 km of the Zone
1865-1866 1:10,560 **1865** 1:2,500	Zone 7 comprises mostly open land and there is a road which passes generally north to south near the zone's western edge. A farm called 'New Barn' is located off this road, in the north-western part of the zone. The River Ebbsfleet passes through the eastern part of the zone, flowing north towards the River Thames. An area known as the Brooks is located on the eastern bank of River Ebbsfleet. There are unidentified structures on the eastern bank of River Ebbsfleet, in the south-eastern part of Zone 7 labelled as Springhead. The southern boundary of Zone 7 is the track of Watling Street. A small old chalk pit is located within the south-western part of Zone 7.	A town known as Lower Northfleet is located 250 m to the north-east of the zone and the includes residential properties, a cement works, a clay mill, a gasworks and a brick works. The town of Swanscombe is located 300 m to the north-west of Zone 7 and Swanscombe Park is located approximately 500 m to the west of the zone. Portland Cement Works are located 1 km to the north-east of the site and was discussed in the first Phase 1 (1). A railway is located approximately 160 m to the north-east of the zone and Northfleet Station is located 325 m to the north.
1888-1895 1:10,560 **1897** 1:2,500	A boiler is shown adjacent to the small old chalk pit. An old clay pit is shown across the western boundary of Zone 7, near New Barn. A tramway passes through the north-eastern corner of the zone from the town of Lower Northfleet to a gravel pit and a quarry. A railway is shown to pass through the wider site and the south-eastern corner of Zone 7 running north-east to south-west.	Additional residential and commercial properties have been developed. An old clay pit and boiler are located approximately 500 m to the west of the zone. A quarry is located 370 m to the north-east of the zone. A small chalk pit is located 500 m to the east of the zone.

Dates and Scales	Within Zone 7	Within 1 km of the Zone
1907-1923 1:10,560 **1909** 1:2,500	A small quarry is shown in the north-eastern corner of the zone and a marl pit is located at the boundary between Zone 6 and Zone 7. New Barn has expanded in size.	An old rectory house is shown 800 m to the east of the zone and has a large circular structure, believed to be a tank. There are tanks located 730 m north-east and two cement works within 1 km of the zone.
1931-1938 1:10,560 **1938** 1:2,500	Springhead, in the south-eastern part of the zone, is shown as a nursery. A pumping station is located at the former location of the small old chalk pit, towards the south-western part of the zone. The old chalk pit in the north-eastern part of Zone 7 has grown considerably in size, and Portland Cement Works (wash mills) are present at the northernmost point of the pit, with a number of circular structures and tanks, separated by a tramway passing through the zone. At the boundary of Zone 7 and Zone 8 is the site of a roman kiln. Miniature rifle ranges are shown in the northern part of Zone 7, crossing into the southern part of Zone 6.	A sewage works, comprising nine tanks, is shown approximately 230 m to the east of the zone and a chalk pit is located 150 m to the east. A tramway is shown to the west of the zone from the old clay pit located near New Barn. Additional residential properties surrounding the zone have developed, especially the town of Swanscombe which now covers a much greater area. Allotment gardens are located adjacent to the north-east and east of the zone. The former tramway that passed across the zone's northernmost tip is no longer shown. There is a tennis ground, tennis court, bowling greens and pavilions located to the north of Zone 7 (east of Zone 6).
1946 1:10,560	A tramway is present along the north-eastern part of the zone, through the old chalk pit.	The chalk pit located 150 m east of the zone is now larger and contains a pump house.
1955 1:10,560 **1952-1959** 1:1,250	A possible overhead electricity cable runs north-west to south-east through the centre of Zone 7. In the north-eastern corner, near to the Portland Cement Works, is the zone of a Roman building. Further chalk excavation has taken place.	The residential areas surrounding the zone have expanded. Anglo Saxon burial grounds are located approximately 480 m to the east of the zone.
1961-1966 1:10,560 **1961-1969** 1:2,500 **1968-1972** 1:1,250	Two parallel overhead cables are shown to pass through the centre of the zone towards the sewage works. Neolithic pottery and flints were found near the centre of the eastern boundary of the zone. The majority of the zone is shown as a disused chalk pit and filled with water. New Barn is now shown to have oast houses (used for drying hops) and a tank. By the 1969 map, New Barn is a silo. The miniature rifle ranges are no longer shown.	A large substation (Northfleet West Grid Substation) is located approximately 160 m to the west of the zone. Two large tanks are shown at the former quarry to the north-east of the zone located approximately 350 m to the north-east. The large chalk pit to the east is now shown as a pond. A refuse tip is shown adjacent to the sewage works.
1971-1974 1:10,000	There are additional overhead cables crossing the zone from the Northfleet West Grid Substation to the west.	Northfleet East Grid Substation is located 100 m south-east of the zone.
1977-1982 1:10,000 **1985** 1:2,500	The disused chalk pit appears to have been infilled and the ground appears to be sloping downwards to the east. The cement works in the north-east of the zone are no longer shown and there is an electricity substation in that area.	The sewage works to the east have expanded, although contains fewer tanks.
1986-2002 1:10,000 **1981-1995**	An electricity substation is located next to the pumping station.	No significant changes.

Dates and Scales	Within Zone 7	Within 1 km of the Zone
1:2,500		
2010-2014 1:10,000	There are four roundabouts across Zone 7, a large car park and several related roads passing through the zone. There is a rail tunnel related to HS1 along the eastern boundary of the zone.	Additional residential properties have been constructed around the zone. The sports ground, tennis courts and other associated buildings located in the north-eastern corner of the zone are no longer shown.

4.1.5.1. Summary of Historical Land Uses

Zone 7 was open land until it was used for the excavation of chalk. Small-scale chalk excavations were shown on the earliest map edition dated 1865. Large-scale chalk excavation was first shown on the 1931 OS map edition. Chalk excavation primarily occurred in the northern part of Zone 7. The excavations were later infilled with reworked Thanet Formation and Cement Kiln Dust (CKD) (see Section 4.2.10) as shown on the 1977-1982 OS map. There was a Portland Cement Works wash mill shown on the zone from the 1932 OS map to the 1971-1974 OS map. A miniature rifle range was shown at the northern boundary of the zone from the 1931 OS map to the 1961 OS map. Other land uses at the site include:

- a number of Neolithic archaeological features;
- a farm and associated cottages of New Barn;
- Springhead Nurseries;
- a boiler;
- two small chalk pits;
- a small quarry; and
- overhead electricity cables and pylons.

The zone was redeveloped into a car park, roads, and roundabouts by 2010 associated with Ebbsfleet International Station.

4.2. Environmental Context

4.2.1. Historical Borehole Records

The BGS borehole record viewer has been used to collect records of all available historical exploratory hole records for review (6). In total, 30 No. borehole logs have been identified, with most ranging in depth between 10 m and 60 m bgl, and one hole reaching 86 m deep.

The boreholes for Zone 7 vary in quality and age, although most were drilled between 1994 and 1997. Some of the boreholes associated with HS1 are erroneously marked as being conducted in 1932. 18 No. boreholes were categorised as Grade A and 12 No. were categorised as Grade B. No logs were categorised as Grade C. The information from the Grade A and B logs have been used to verify the geological maps and to inform the findings of this report.

4.2.2. Geology

The 1:10,000 BGS geological map of the area (Sheet TQ67SW – Northfleet) (24) shows the local geological succession to be a variable cover of Made Ground, with Head and Alluvium superficial deposits overlying Thanet Formation and the Chalk.

No faults are recorded within the zone, or within 1 km of its boundary.

Table 4-2 Expected Stratigraphy within Zone 7

Stratum	Typical Thickness (m)	Description
Made Ground	5	Sand and silt size chalk fragments, flint gravel and clay with some landfill components.
Head	0.5	Firm, yellow-brown sandy clay, clayey sand and clayey sandy gravel.
Alluvium	3.5	Soft to firm consolidated silty clay, with beds of silt, sand, peat and basal gravel.
Flood Plain Deposits	3.5	Medium dense becoming loose grey sandy gravel with a bed of soft orange brown sandy gravelly clay.
Thanet Formation	10	Pale yellow-brown sand which is occasionally clayey or glauconitic, with a glauconite-coated nodular flint bed at its base (Bullhead Bed).
White Chalk	35 +	Moderately weak to hard Chalk with beds of flint in the upper 5 m.

Note: typical thicknesses have come from BGS borehole logs; descriptions have come from the borehole logs and the BGS Lexicon of Named Rock Units. Where the value for a thickness is marked as greater than, it means the bed has been proven in a borehole, but the total thickness is not known. Where the thickness is marked as unknown, the bed has not been proven, and is only expected, and so a value for the thickness is not known.

4.2.3. Geomorphology

Ordnance Survey maps (5) show the topography of Zone 7 dipping from 20 m AOD to 0 m AOD towards the east of the Zone. This is likely to be due to fluvial erosion by the Ebbsfleet River, which crosses the eastern part of the zone.

An old chalk pit has been identified in the north of the zone within the Groundsure report (3), but it is recorded as being infilled. This feature may cause some variability to the landscape.

4.2.4. Ground Conditions

Descriptions and geotechnical parameters provided in the following sections have been obtained from available historical exploratory hole records. It has not been possible to verify the accuracy of the geotechnical parameters or their applicability to Zone 7, therefore the information provided within this report is for guidance only. It is essential that a suitable ground investigation is designed, undertaken and interpreted to obtain zone-specific design parameters.

4.2.4.1. Made Ground

Made Ground in the area is described in borehole records as sand and silt size chalk fragments, flint gravel and clay. In one borehole (TQ67SW738) the Made Ground is described as possibly contaminated chalk/silt, with a cement odour. This is thought to relate to the CKD tipping within Southfleet Pit (see Section 4.2.10). Other boreholes (TQ67SW855, TQ67SW856) describe the Made Ground as containing bitumen and concrete gravel; fragments of wood, plastic and metal; cinder and ash; and pockets of friable coal. From this information it is clear that the Made Ground has a considerable variability in composition. The thickness of the Made Ground is inconstant across the zone, ranging from 0.3 m to 19.1 m.

Standard Penetrometer Test (SPT) results for the Made Ground were available in four of the historical borehole logs in this zone. The results were variable, with a minimum N-value of four and a maximum of 55.

4.2.4.2. Head

Head is a polymict deposit which can contain gravel, sand and clay, dependent on the upslope source and the distance from it. It is generally poorly sorted and stratified, formed mostly by solifluction, hillwash and soil creep. Locally it can contain lenses of silt, clay, peat or organic material.

Historical borehole records in Zone 7 describe the Head deposit as consisting of firm, yellow-brown sandy clay, clayey sand and clayey sandy gravel. It is recorded as being between 0.5 m and 5.9 m thick.

SPT results for the Head deposits were available in one of the historical borehole logs in this zone and show that strength increases with depth in this borehole. A minimum N-value of six and a maximum of 15 were recorded.

4.2.4.3. Alluvium

Borehole records from the area indicate that the Alluvium consists of a sandy, very silty clay, with some gravel. Thin beds of fibrous peat have been observed in historical exploratory hole records, as well as gravel sized pockets of firm calcareous silt. Historical borehole records note the thickness as being between 1.5 and 5.8m.

SPT results for the Made Ground were available in three of the historical borehole logs in this zone. The results were variable, with a minimum N-value of two and a maximum of 33. The low values are synonymous with peat.

4.2.4.4. Flood Plain Gravels

Historical borehole records note the presence of floodplain gravels underlying the Alluvium. This unit is described in historical borehole logs as being medium dense becoming loose grey sandy gravel with a bed (approximately 0.3 m thick) of soft orange brown sandy gravelly clay. The overall thickness of this unit is between 2.75 m and 4.45 m.

SPT results for the floodplain gravels were available in three of the historical borehole logs in this zone. The results were variable with minimum N-value of three and a maximum of 48.

4.2.4.5. Thanet Formation

The Thanet Formation appears in two boreholes (TQ67SW911, TQ67SW912) located within the south-eastern part of the zone. It is recorded as comprising pale yellow-brown fine grained sand that is occasionally glauconitic or clayey. According to the BGS (6) the sand is typically divided into two sub-strata: the upper low-silt content stratum and lower high-silt content stratum. It is observed that the high-silt stratum is more compressible than the low-silt under the same conditions (41). This unit, in Zone 7, is recorded in historical borehole logs as being between 9.1 m and 12.15 m thick.

Historical borehole logs in this zone note the presence of the Bullhead Beds at the base of this unit. It is approximately 0.4 m thick and is described as a medium dense, grey-green, very sandy silt with flint gravel.

SPT results for the Thanet Formation were available in two of the historical borehole logs in this zone. The results were generally homogenous with an observed average of approximately 20. A minimum N-value of 14 and a maximum of 30 were recorded. These results show the unit has medium density.

4.2.4.6. White Chalk Group

The Chalk bedrock underlying Zone 7 is undifferentiated Seaford Chalk Formation and the Newhaven Chalk Formation. Borehole records characterise the Chalk as being weak to moderately weak in strength and is slightly to moderately weathered. The upper 0.5 m of this unit is typically described as structureless silt and Chalk gravel. In total, this unit is over 35 m thick.

SPT results for the White Chalk were available in 14 of the historical borehole logs in this zone. The results show that strength generally increases with depth. A minimum N-value of three and a maximum of 52 were recorded.

4.2.5. Hydrology and Hydrogeology

4.2.5.1. Surface Water

The River Thames is located approximately 950 m to the north-east of Zone 7, at its closest point.

The River Ebbsfleet passes through the south-eastern corner of the zone and flows north towards the Thames. The River Ebbsfleet begins at Springhead, in the south-eastern corner of Zone 7, at a chalk-derived spring (42). It is heavily modified and has been classified by the Environment Agency as being of moderate potential for current ecological quality (10). Although the river was previously navigable and of historical importance, water abstractions occurring as early as 1900-1901 reduced the flow of the river considerably to the point where it was dry by April 1901 (42) (43). The amount of abstraction has led to rising water levels and the reappearance of the stream in the mid-1970s (34). However, much of the river is currently under vegetation cover, meaning it is not visible by aerial imagery. It reaches the surface between coordinates 561643E 173370N and 561745E 173752N (for approximately 400 m), within the south-eastern part of the zone.

The Environment Agency maps (10) and aerial photography (12) (44), show that the river is culverted beneath the railway line into Zone 7, and runs north-south across the zone. Two small bodies of water (approximately 50 m wide) are located in Zone 7 by the culvert.

4.2.5.2. Groundwater

Groundwater is likely to be encountered at shallow depths within the Made Ground and superficial deposits. Information provided by the Environment Agency (10) concludes that the Alluvium deposits are a Secondary A aquifer, whilst the Head deposits are a Secondary (undifferentiated) aquifer. This information suggests that a perched water table may be present in areas around the zone.

The Thanet Formation is a Secondary A aquifer and the Chalk is a Principal aquifer, with water movement primarily controlled by fractures in the rock.

4.2.5.3. Groundwater Abstractions

There are ten groundwater abstraction licences within Zone 7, as shown in Table 4-3, one of which is currently inactive. There are two active potable water supply licences within Zone 7, both known as ‘Point F’, midway along the western boundary of the Zone, at the same location as the pumping station noted on the 1931-1932 OS map. A potable water supply under licence 01/0152 was located adjacent to this well but the licence has expired. ‘Point A’ and ‘Point 1’ are also located near Point F. ‘Point B’ is located by Springfield Nurseries in the south-eastern part of Zone 7. There are an additional four abstraction licences listed in the GroundSure report that are not included in Table 4-3 below, as these related to expired, non-potable water supply, abstraction licences.

Table 4-3 Groundwater Abstractions Licences within Zone 7

Licence No.	Location	Details	Volume
SO/040/0037/006	Borehole Point F Potable water supply – direct	Start date: 23 June 2010 Expiry date: 31 March 2020	6,716,000 m^3/year
01/156	Borehole Point F Potable water supply – direct	Start date: 30 July 2004	Not given
9/40/01/0088/B/GR	Point 1, well near New Barn Process water	Start date: 30 July 1993	Not given
9/40/01/0504/G/R01	Point A General washing/process water	Start date: 1 April 2014 Expiry date: 31 March 2024	5,910 m^3/year
9/40/01/0504/G/R01	Point A Spray irrigation – direct	Start date: 1 April 2014 Expiry date: 31 March 2024	5,910 m^3/year
9/40/01/0504/G	Point A, H5 Chalk General washing/process washing	Start date: 15 Mary 1978 Issue No.: 100	Not given

Licence No.	Location	Details	Volume
9/40/01/0504/G	Point A, H5 Chalk Spray irrigation – direct	Start date: 15 May 1978 Issue No.: 100	Not given
01/152	Point B Potable water supply	Start date: 7 July 2002 Expiry Date: 30 September 2004	Not given
9/40/01/0504/G/R01	Point B, H5 Chalk General washing/process washing	Start date: 1 April 2014 Expiry date: 31 March 2024	5,910 m^3/year
9/40/01/0504/G/R01	Point B, H5 Chalk Spray irrigation – direct	Start date: 1 April 2014 Expiry date: 31 March 2024	5,910 m^3/year

There are 17 active groundwater abstractions within 1 km of Zone 7, as shown in Table 4-4. The licence relating to the area 116 m south-east of the zone relates to a medium sized water abstraction, which is held by a number of organisations including the Royal Society for the Protection of Birds and A. J. Baker and Sons.

Table 4-4 Groundwater Abstractions within 1 km of Zone 7

Distance and Orientation from Zone 7	Licence No.	Details	Status	Volume
116 m south-east	9/40/01/0051/GR	Point B at Blue Lake General use related to secondary category (medium loss)	Version start date: 22 September 2009 Issue No.: 104	1,186,000 m^3/year
116 m south-east	9/40/01/0051/GR	Point B at Blue Lake Evaporative cooling	Version start date: 27 November 2007 Issue No.: 103	1,235,375 m^3/year
116 m south-east	9/40/01/0051/GR	Point B at Blue Lake Non-evaporative cooling	Version start date: 22 September 2009 Issue No.: 104	1,186,000 m^3/year
116 m south-east	9/40/01/0051/GR	Point B at Blue Lake Spray irrigation - direct	Version start date: 22 September 2009 Issue No.: 104	1,186,000 m^3/year
116 m south-east	9/40/01/0051/GR	Point B at Blue Lake Process water	Version start date: 22 September 2009 Issue No.: 104	1,186,000 m^3/year
198 m east	9/40/01/0523/G	Point A, Wingfield Park Farm Spray irrigation - direct	Version start date: 12 March 1996	Not given
198 m east	01/0157	Point A, Wingfield Park Farm Spray irrigation - direct	Version start date: 18 July 2014 Expiry date: 31 March 2018	16,843 m^3/year
403 m east	9/40/01/0051/GR	Point A at Blue Lake Non-evaporative cooling	Version start date: 22 September 2009 Issue No.: 104	1,186,000 m^3/year
403 m east	9/40/01/0051/GR	Point A at Blue Lake Evaporative Cooling	Version start date: 27 November 2007 Issue No.: 103	1,235,375 m^3/year

Distance and Orientation from Zone 7	Licence No.	Details	Status	Volume
403 m east	9/40/01/0051/GR	Point A at Blue Lake General use relating to secondary category (medium) loss	Version start date: 22 September 2009 Issue No.: 104	1,186,000 m^3/year
403 m east	9/40/01/0051/GR	Point A at Blue Lake Process water	Version start date: 22 September 2009 Issue No.: 194	1,186,000 m^3/year
403 m east	9/40/01/0051/GR	Point A at Blue Lake Spray irrigation - direct	Version start date: 22 September 2009 Issue No.: 104	1,186,000 m^3/year
451 m east	9/40/01/0092/B/GR	Borehole 3, Springhead Lake Process water	Version start date: 1 July 1996	4,710,000 m^3/year
581 m south-east	01/154	Point A, Borehole at Springhead Enterprise Park Laundry Use	Version start date: 5 December 2014 Expiry date: 31 March 2018 Issue No.: 5	120,000 m^3/year
621 m east	9/40/01/0092/B/GR	Borehole 1 Process water	Version start date: 1 July 1996	4,710,000 m^3/year
659 m east	9/40/01/0092/B/GR	Borehole 2 process water	Version start date: 1 July 1996 Issue No.: 100	4,710,000 m^3/year
980 m east	9/40/01/0092/A/GR	Point B at Kimberly Clark Boiler feed	Version start date: 24 April 2002 Expiry date: 31 March 2018 Issue No.: 101	400,000 m^3/year

4.2.5.4. Groundwater Vulnerability

The majority of Zone 7 is located within a Source Protection Zone (SPZ) 1 (inner catchment) centred on a pumping station which was identified in historical maps and is located near the western boundary of Zone 7, for which there is an abstraction licence. Part of Zone 7 is located within a SPZ 3 (total catchment) and part is located within a SPZ 2 (outer catchment). SPZs are used to delineate catchment zones for public drinking water supplies.

The majority of the zone is located within a major aquifer high vulnerability zone, with areas of minor aquifer high and intermediate risk corresponding to the location of the Thanet Formation to the east and west of the zone.

4.2.6. Flood Risk

The Environment Agency (10) note that the zone has a medium to high risk of flooding from rivers. They also note that the rail line adjacent to Zone 7 is at a medium to high risk of surface flooding, as is the road leading to the Ebbsfleet International car park located in the centre of the zone

The banks of the River Ebbsfleet are classified as Zone 2 and Zone 3 flood risk zones (with Zone 3 comprising almost the entirety of the Zone 2 area), where there is a 1 in 100 (1 %) or greater chance of a river flood occurring in any year or a sea flood with a 1 in 200 (0.5 %) or greater chance of occurring in a year (4).

A flood risk assessment for the scheme is being compiled by Buro Happold.

4.2.7. Mineral Abstractions

Much of Zone 7 was used as a chalk quarry and there was a small clay pit near the centre of the zone.

According to the BGS Mining Plans Portal (45), the area of the A2 corridor is at risk of encountering deneholes. To the north of the A2 is a major disused chalk quarry, known as Eastern Quarry. Another quarry known as Western Quarry is located to the north-west of the Bean Road junction of the A2, and is currently occupied by the Bluewater Retail Park.

Peter Brett Associates note that no man-made cavities are located within Zone 7 (35), although seven recorded deneholes have been identified within 500 m of the zone boundary.

4.2.8. Designated Environmentally Sensitive Sites

Zone 7 is located within a Site of Special Scientific Interest (SSSI) Impact Risk Zone (IRZ), likely referring to the SSSI known as Bakers Hole located in Zone 6, to the north of Zone 7. The entirety of Zone 7 is also located within a Nitrate Vulnerable Zone (NVZ) for groundwater.

A number of archaeological features were identified on the historical maps within Zone 7 including a Roman kiln and Neolithic pottery and flints. The areas of Neolithic pottery and flints are a scheduled monument with English Heritage, known as “Neolithic sites near Ebbsfleet”, another of which is present off-site, further upstream of the River Ebbsfleet.

Although Springhead Nurseries is not a listed monument, a number of structures (including brickwork and masonry considered to be the remains of a Roman bath) and artefacts (including coins, brooches, ornaments and pottery) associated with the former Roman occupation of the area were discovered during and after the cultivation of watercress and the development of Springhead Nurseries (36).

4.2.9. Environmental Permits, Incidents and Registers

Environmental permits, incidents and registers and fuel sites within Zone 7 have been summarised in Table 4-5 (4). Only active licenced discharge consents are presented in the table below.

Table 4-5 Environmental Permits, Incidents and Registers within Zone 7

Location/ Operator	Type of Permit, Incident and/or Register	Status	Additional Information
Bakers Hole Landfill (known as Northfleet Pit and located within Zone 6)	Licenced discharge consent	Issued: 5 September 2003	Effluent type: Trade discharge – process water – water company (water treatment works) Receiving water: the River Ebbsfleet Permit number: P09808 Permit version: 2
3D, Springhead Service Station	Petrol station	Obsolete	Springhead Service Station, Watling Street

Environmental permits, incidents and registers within 500 m of Zone 7 have been summarised in Table 4-6 (4). Inactive licenced discharge consents are not included.

Table 4-6 Environmental Permits, Incidents and Registers within 500 m of Zone 7

Distance and Orientation from Zone 7	Location/ Operator	Type of Permit, Incident and/or Register	Status	Additional Information
14 m south-east	Northfleet Eastern Quarry	Licensed discharge consent	Issued: 6 October 1993	Effluent type: trade discharges – mineral workings Receiving water: the River Darent Permit number: P04660
43 m north	Lafarge Cement	Licensed discharge consent	Issued: 6 October 1993	Effluent type: Trade discharges – mineral workings Receiving water: the River Ebbsfleet Permit number: P04661
65 m north	Sainsbury's, Pepper Hill	Petrol station	Open	None
245 m south-east	Northfleet Sewage Treatment Works	List 1 dangerous substance inventory site	Active	Three active permits
245 m south-east	Northfleet Sewage Treatment Works	List 2 dangerous substance inventory site	Active	None
245 m south-east	WT Henley	List 1 dangerous substance inventory site	Active	Authorised substances: cadmium
435 m south-east	Northfleet Sewage Treatment Works	Licensed discharge consent	Active	Effluent type: sewer storm overflow – water company Receiving water: lake/reservoir Permit number: K02067

There were three pollution incidents recorded within Zone 7, these incidents are summarised in Table 4-7.

Table 4-7 Records of Pollution Incidents within Zone 7

Incident Date	Pollutant	Impacts
19 July 2005	Smoke	Air: Category 3 (minor)
14 September 2010	Pipe failure below ground of water distribution system	No impact
21 September 2005	Unknown	No impact

There were six pollution incidents recorded within 500 m of Zone 7. These incidents are summarised within Table 4-8.

Table 4-8 Records of Pollution Incidents within 500 m of Zone 7

Distance and Orientation from Zone 7	Incident Date	Pollutant	Impacts
40 m south-east	17 May 2001	Inert, mineral materials and wastes	Water impact: Category 3 (minor)
114 m south-east	17 March 2003	Crude oil	Water impact: Category 3 (minor) Land impact: Category 3 (minor)

Distance and Orientation from Zone 7	Incident Date	Pollutant	Impacts
131 m east	20 March 2002	Crude sewage	Water impact: Category 3 (minor)
318 m east	4 May 2004	Dust	Land impact: Category 3 (minor) Air impact: Category 2 (significant)
432 m north	7 November 2003	Inert material or waste	Land impact: Category 3 (minor)

4.2.10. Landfills and Other Waste Sites

The available records identify two historical landfills within Zone 7 and five off-site waste sites within 1 km of the zone, closer to Zone 7 than the neighbouring zones, and closest to Zone 7, as summarised in Table 4-9.

Table 4-9 Landfills and Other Waste Sites at or within 1 km of Zone 7

Location	Landfill Name	Operator	Waste Type	Dates of Operation
Zone 7	Northfleet Landfill, Baker's Hole Reference: 19375	Lafarge Tarmac Cement and Lime Limited	A4: Household, commercial and industrial waste	Not given
Zone 7	Southfleet Pit Reference: GR19	Blue Circle Industries plc	Inert	Not given
181 m south	Refuse tip – name not known	Not given	Not given	Not given – shown on 1969 mapping
677 m south-east	Springhead Road Reference: REIN.2/1, 21BF	Northfleet Urban District Council	Inert, industrial, commercial, household	Licence issue: 1 January 1976
683 m south-east	Refuse tip – name not known	Not given	Not given	Not given – shown on 1971 mapping
711 m south-east	Refuse tip – name not known	Not given	Not given	Not given – shown on 1971 mapping

The majority of the first landfill, Baker's Hole is also known as Northfleet Landfill and is located within Zone 6, to the north of Zone 7, and is discussed in depth within the previous Phase 1 (1).

Quarrying of Southfleet Pit, also known as Southfleet Quarry, commenced before 1909 and resumed in the 1930s. It is believed that Southfleet Pit comprised a single quarry which extended southwards into two narrow pits at completion in 1957. After dewatering, two ponds were developed, separated by a low barrier (34).

The "Southfleet Quarry Restoration Scheme" was operational in the 1970s and 1980s and comprised infilling with Thanet Formation overburden from the adjacent Eastern Quarry to the west, plus a smaller volume of cement kiln dust (CKD) derived from the Northfleet Cement Works (34) (46). The depth of restoration materials in Southfleet Pit was 20 m and began initially with CKD. The CKD was a silty sand with a 2-15 % clay and 5 % coal ash content. Initially CKD was deposited as dry dust into the north end of the pit. Only small quantities were deposited in this way and the method was abandoned and a new method was used. Water was pumped into the pit and mixed with CKD, to form a slurry which was pumped into Southfleet Pit, which, at its peak, comprised just under 300,000 tonnes per annum (34).

CKD disposal in Southfleet Quarry ceased in March 1974 and Blue Circle Cement (now Lafarge) began disposal of CKD in Swanscombe Marshes, located in Zone 1 (1). Compacted layers of Thanet Formation overburden from Eastern Quarry were then used to fill Southfleet Pit. The volume of Thanet Formation overburden was 5.3 million cubic metres (34).

The northern half of the former Southfleet Pit was licensed in October 1992 under Waste Management Licence (WML) P/1/36. The licence permitted the deposit of inert waste, slowly degradable waste, putrescible and

difficult wastes. However, the landfill operation was never implemented and the planning permission lapsed (35).

During a ground investigation undertaken in July 2005 to inform the remediation earthworks strategy for an area for HS1 known as Station Quarter South (which included part of Zone 7 and extended off-site to the east), the Made Ground material was encountered to depths of between 5 and 7 m and typically comprised re-worked Thanet Formation, described as fine-grained silty/clay backfill. At the A2260 embankment, Made Ground was encountered to 31 m bgl (33).

4.3. Information Gained from Public Sources

4.3.1. Peter Brett and Associates, 2008

A document prepared by Peter Brett and Associates in 2008, for addressing disturbed and contaminated land during the development of the Northfleet Rise part of the Ebbsfleet Development, was available through the Dartford Borough Council planning portal. The report refers to a baseline groundwater quality report which Atkins has not has access to or verified. The report (35) states:

"Groundwater from beneath Southfleet Quarry is generally impacted by the former deposition of CKD. This gives rise to elevated pH values (typically >11) elevated potassium (up to more than 2000 mg/l), elevated sulphate (up to more than 5000 mg/l), elevated chloride (up to more than 1000 mg/l) and moderate sodium concentrations (up to more than 250 mg/l). This groundwater is likely to be slowly migrating north beneath Northfleet Landfill driven by the regional groundwater flow regime."

The data were not available via the planning portal therefore Atkins is unable to assess the data in line with current good practice guidance. However, it does indicate that groundwater beneath Southfleet Pit has been potentially impacted by contamination.

4.3.2. Northfleet West Grid Substation

Northfleet West Grid Substation is located between Zones 7 and 9; however, it is closer to Zone 9 and has therefore been discussed within the Zone 9 chapter (Section 6.2.12.1).

4.3.3. Former Wash Mills

The historical maps identified Portland Cement Works (wash mills) in the north-eastern corner of Zone 7. The Environmental Statement (34) prepared for HS1 indicated that the purpose of the wash mills was to wash and crush the excavated chalk and mix it with imported clay to form a slurry which was then carried by pipeline to the Bevan's Works site (a cement works located to the west of the zone). The pipeline passes through Zone 6, into the north of Zone 7. A 1975 plan shows the wash mill to comprise at least eight small and five large tanks, used for washing and settlement, which, it was reported, may have possibly caused some localised and minor contamination (34).

4.3.4. Former Petrol Station

An outline planning application for a two storey, 33 bedroom hotel and restaurant, to be developed at the site of Springhead Service Station (located in the southern part of Zone 7) was submitted on 05 December 2014. The application included a 2008 site decommissioning report (39), which described that the known underground storage tanks and fuel distribution systems have been removed from the area although the interceptor, towards south-east, remains *in situ*. The report detailed a ground investigation and risk assessment which concluded that there may be contamination in soil which has the potential to impact groundwater; however, the report is unclear whether there were risks to human health. An additional environmental assessment report (40) from 2010 was included in the planning application which detailed a second ground investigation, conducted between 08 and 18 September 2008 (with a groundwater monitoring visit undertaken on 22 and 23 September 2008) and intended to refine the previous CSM developed. During the ground investigation, a maximum photo-ionisation detector reading (which measures volatile organic compounds) of 448 ppm was recorded in one soil sample indicating potential contamination. The report also concluded that, based on then-current guidance, there may be soil contamination which could impact groundwater. A detailed quantitative risk assessment (DQRA) was prepared in 2008 (47) which found that, based on a future commercial end use as a hotel with hardstanding across the entire area, there were no unacceptable risks to human health or controlled waters. Atkins has not undertaken an assessment of the data and has not reviewed the modelling parameters or assumptions used in the DQRA.

4.3.5. Refuse Tip at Off-site Sewage Works

In the historical maps, a refuse tip adjacent to the old sewage works was shown. According to the Environmental Statement for the Ebbsfleet Development (34), Gravesham Borough Council believe that the area may have been subject to disposal of sewage sludge from the adjacent sewage treatment works, prior to 1974, when the ownership of the sewage treatment works passed from the former Northfleet Urban District Council to Southern Water Authority. This area is located off-site and to the north-east of Zone 7.

4.4. Preliminary Geo-environmental Conceptual Site Model

4.4.1. Introduction

The approach used for the creation of the preliminary CSM is detailed in Section 2.2.1.3. Identified zone-specific potential sources, pathways and receptors of contamination are listed below, with the corresponding risk rating detailed in Table 4-10. Sources and receptors located outside of Zone 7 have not been included herein.

While reference to the proposed development is noted within this report, risks have been assessed for the zone in its current condition including the current zone users in terms of human health related risks. This approach was taken as detailed development plans have not yet been finalised and which would inform a more detailed risk assessment than currently being undertaken.

4.4.2. Potential Sources

The potential sources identified within Zone 7 include:

- CKD waste deposited within Southfleet Quarry;
- former cement works wash mills in the north-eastern part of the zone;
- former petrol station in the southern part of the zone; and
- the miniature rifle range in the northern part of the zone.

4.4.3. Potential Pathways

The primary exposure pathways that are considered applicable are:

- inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres;
- inhalation of soil- or groundwater-derived vapours;
- migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion;
- leaching from CKD/waste materials to groundwater followed by lateral migration of contamination within groundwater;
- leaching/migration of contaminants from soils;
- direct surface water run-off and sub-surface flow to surface waters;
- lateral migration of contaminated groundwater; and
- vertical migration of contaminated groundwater.

4.4.4. Potential Receptors

The potential receptors identified are:

- Neolithic scheduled monument;
- the River Ebbsfleet which flows north along the eastern boundary of the zone towards the River Thames;
- the Secondary (undifferentiated) aquifer within the Head deposits beneath the zone;
- the Secondary A aquifer within the Alluvium and Thanet Formation;
- the Principal aquifer within the Chalk;
- zone visitors and zone workers; and
- trespassers.

A schematic CSM for Zone 7 is shown in Figure 009.

Table 4-10 Preliminary Conceptual Site Model for Zone 7

Sources	Receptor	Potential Pathway	Potential Consequence	Likelihood	Classification of Risk
Zone 7: **Potential contaminants in soil/groundwater on the zone, originating from the following sources:** • Contamination resulting from CKD deposition, former petrol station, former cement works and the miniature rifle range. *Potential contaminants include highly alkaline pH, metals, PAH, TPH and other contaminants.*	Zone visitors, zone workers, and trespassers	Inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres	**Medium**	**Unlikely** The zone visitors, zone workers and trespassers are likely to spend the majority of time on hardstanding areas. The CKD is known to have been deposited below reworked Thanet Formation and therefore direct contact with CKD is unlikely. The area of the former miniature file range and the former cement works has been redeveloped into Ebbsfleet International Station and HS1, where there will be access restrictions for most zone visitors and control measures to prevent trespassers.	**Low**
		Inhalation of soil- or groundwater-derived vapours	**Medium**	**Low Likelihood** The CKD is unlikely to produce significant vapours. The former cement works and miniature rifle range are unlikely to produce significant vapours and exposure within this area is less likely due to Ebbsfleet International Station and the HS1 railway. There is a low likelihood that the former petrol station in the southern part of the zone may produce vapours.	**Moderate/Low**
		Migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion	**Severe**	**Unlikely** The deposited waste has a low biodegradable content although naturally occurring alluvium is possible associated with the River Ebbsfleet, it is not viewed as a significant gas source.	**Moderate/Low**
	Neolithic scheduled monument	Lateral migration of contaminated groundwater	**Medium**	**Low Likelihood** CKD is known to produce alkaline leachate which may cause damage to the scheduled monument, however the scheduled monument is not located within the landfill area.	**Moderate/Low**

Sources	Receptor	Potential Pathway	Potential Consequence	Likelihood	Classification of Risk
	Controlled waters – River Ebbsfleet	Leaching/migration of contaminants from soils	**Medium**	**Likely** The ground beneath the underground storage tanks at the petrol station may be impacted by contamination which could leach to controlled waters receptors. The CKD was placed directly on chalk following quarrying and a previous ground investigation indicated that the groundwater beneath Southfleet Quarry was impacted by CKD.	**Moderate**
		Lateral migration of contaminated groundwater			
		Direct surface water run-off and sub-surface flow to surface waters			
	Controlled waters – Secondary (undifferentiated) aquifer within the Head Deposits, Secondary A aquifer within the River Terrace Deposits and Principal aquifer within the Chalk beneath the zone	Leaching/migration of contaminants from soils	**Medium**		
		Vertical migration to the Principal aquifer beneath the zone	**Medium**		

4.5. Preliminary Geotechnical Risk Assessment

4.5.1. Geological and Geotechnical hazards

Table 4-11 describes the principal geological and geotechnical hazards which have been identified as part of this desk study. The list of hazards is not exhaustive and are only briefly summarised.

Table 4-11 Potential Geological and Geotechnical Hazards in Zone 7

Hazard	Description	Comment
Aggressive ground conditions	The BRE Special Digest (48) states that chemical agents, particularly sulphates, sulphides and acids can naturally occur in many soils and could be damaging to concrete.	The Alluvium deposits may contain concentrations of sulphides, which could create a risk of aggressive ground. The landfill found in this zone where CKD and reworked Thanet Formation was deposited may also pose a risk of aggressive ground conditions.
Buried foundations	Buried foundations can cause a delay to construction and incur additional costs.	Historical buried foundations are possible at the location of New Barn Farm (561216E, 173199N) and the Ebbsfleet car park buildings (561307E, 173724N). As well as historical tramway sidings noted in the GroundSure report (3).
Buried services	Damage to underground services can cause injury, significant disruption and environmental damage; it can also cause a delay to construction and incur considerable costs.	Much of the Northern section of Zone 7 is currently devoted to car parks for the Ebbsfleet International Train Station. Utility maps note the presence of gas medium pressure mains, water mains and Vodafone lines across the zone, particularly around the car park.
Chalk dissolution features	Chalk is a chemically vulnerable rock, and reactions with groundwater can lead to dissolution. These dissolution features can cause subsidence, and depending on the nature of overlying deposits, sinkholes.	The information from Peter Brett Associates (35) states that no recorded chalk dissolution features are present in this zone, however they have been observed in the surrounding area and in Zones 6 and 8 and the information does not rule out the chance of dissolution features forming. The Groundsure report (2015) records a large proportion of the zone as being at a moderate or high risk of dissolution of soluble rocks.
Historical works	Historical works such as abandoned quarries may be backfilled with hazardous materials or any poorly compacted material which is susceptible to settlement	Deneholes are recorded within 500m of Zone 7, although the Peter Brett Associates report (35) did not record any within the zone. The Southfleet chalk pit has been backfilled with CKD and Thanet Formation overburden.
Perched/high water table	The presence of high groundwater levels/perched water tables needs to be considered when undertaking construction.	Groundwater has historically been encountered within the floodplain deposits and Made Ground, suggesting the presence of a perched water table in some areas. The area around the Ebbsfleet River is likely to have a high water table, especially during periods of high rainfall.

Hazard	Description	Comment
Running sand	Running sand is the flow of sand into an excavation or void caused by water pressure. This can lead to subsidence of the surrounding ground.	The Thanet Formation is present within Zone 7, and poses a risk of running sand. This is confirmed by the GroundSure report (3).
Saline groundwater	The presence of saline groundwater (commonly at coastal sites) may result in increased corrosion of steel. Appropriate control measures will need to be taken.	The boundary of Zone 7 is approximately 1 km from the River Thames at the closest point. It is not clear whether the groundwater will be saline within this proximity, but it is possible.
Variable rockhead/deep weathering profile	A deep weathering profile or physical erosion can result in an uneven rockhead profile resulting in areas of reduced bearing capacity or potential for varying lengths of piles.	The north of the zone has undergone historical quarrying, resulting in variable rockhead. Erosion and weathering from periglacial and fluvial processes will also be a concern.
Weak bearing materials	Construction of foundations upon weak bearing strata can result in bearing capacity failure. Some geological units are particularly susceptible to reductions in strength and stiffness due to weathering and pockets of weathering may result in areas of weak bearing capacity.	The superficial deposits in Zone 7, particularly the Head and Alluvium will have low bearing capacity.
Weak, compressible ground	Loading of compressible soils and unconsolidated materials can cause excessive settlements. Materials such as peat within areas of alluvium are particularly vulnerable.	Alluvium containing peat is present in Zone 7. These soils are likely to be weak and could deform and fail as a result of the loads imposed on them. The landfill found across the zone is also likely to be compressible.

4.5.2. Geotechnical Risk Register

The Geotechnical Risk Register is presented as Table 4-12 below. It comprises an initial assessment of the risks, prior to the application of risk mitigation measures and shows how the risks can be reduced by the application of the measures. In most cases the mitigation measures will be sufficient to reduce the risk to a “low” ranking. In some cases the risk may be reduced but a significant residual risk remains which must be managed, and in other the risk mitigation measure cannot reduce the likelihood of an event but will be used to mitigate potential effects.

Prior to implementation of the proposed mitigation measures, the risks considered to be substantial are:

- aggressive ground conditions;
- buried services;
- historical works;
- running sand;
- variable rockhead;
- weak bearing materials; and
- weak compressible ground.

The remaining risks are rated as “moderate” to “low”.

4.5.3. Mitigation Measures

The mitigation measures considered are those that may be applied during design or construction, as appropriate, to mitigate the hazard identified and, in most cases, to render the risk insignificant. Mitigation measures considered appropriate for the substantial risks listed above include:

- further desk study (including a detailed walkover);
- ground investigation including *in situ* and laboratory testing;
- planned methodology for the earthworks; and
- detailed design for the temporary construction roads.

4.5.4. Residual Risk

Following risk identification, assessment and the application of recommended mitigation/avoidance measures most risks have been assessed to be “low”. However, it should be recognised that some residual risks remain, as described below.

Table 4-12 Geotechnical Risk Register for Zone 7

Category Risk No.	Constraint	Prior to Mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital Cost	Programme	Safety	Capital Cost	Programme	Safety				Capital Cost	Programme	Safety	Capital cost	Programme	Safety	
1	Aggressive ground conditions	3	3	3	1	9	9	3	S	Ground investigation to confirm geological succession and geotechnical properties across the site. Use BRE Special Digest 1 (48) to determine the concrete class from sulphate and pH results.	2	2	2	1	4	4	2	L
2	Buried foundations	2	3	3	1	6	6	2	M	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried foundations.	2	2	2	1	4	4	2	L
3	Buried services	3	3	3	3	9	9	9	S	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried services.	2	2	2	1	4	4	2	L
4	Chalk dissolution features	2	3	3	3	6	6	6	M	Ground investigation to confirm geological succession and geotechnical properties across the site. Detailed visual inspection of all chalk faces. Where necessary consider appropriately in geotechnical design.	2	2	2	2	4	4	4	L
5	Historical works	3	3	3	1	9	9	3	S	See buried foundations and buried services.	2	2	2	1	4	4	2	L
6	Perched/high groundwater	3	2	2	1	6	6	3	M	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	2	1	1	1	2	2	2	L
7	Running sand	3	3	3	1	9	9	3	S	Ground investigation to confirm geological succession and geotechnical properties across the site.	2	2	2	2	4	4	4	L

Category Risk No.	Constraint	Prior to Mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital Cost	Programme	Safety	Capital Cost	Programme	Safety				Capital Cost	Programme	Safety	Capital cost	Programme	Safety	
8	Saline groundwater	1	2	2	1	2	2	1	L	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	1	1	1	1	1	1	1	L
9	Variable rockhead	4	3	3	1	12	12	4	S	Ground investigation to confirm geological succession and geotechnical properties across the site.	3	2	2	1	6	6	3	M
10	Weak bearing materials	4	3	3	1	12	12	4	S	Ground investigation to confirm geological succession and geotechnical properties across the site.	3	2	2	1	6	6	3	M
11	Weak compressible ground	3	3	3	1	9	9	3	S	Ground investigation to confirm extent and thickness of alluvium. Where necessary consider appropriately in geotechnical design.	2	2	2	1	4	4	2	L

4.6. Zone 7 Summary

4.6.1. Geo-environmental Summary

Zone 7 historically comprised open land which was used for excavation of chalk followed by infilling with CKD and Thanet Formation overburden. The excavated and filled area is known as Southfleet Pit. The zone is currently used as parking areas, agricultural land, roads, roundabouts and infrastructure associated with HS1. There is a former petrol station in the southern part of the zone and former Portland Cement Works wash mills located in the north-eastern part of the zone. Springfield Nurseries are located in the south-eastern corner. The River Ebbsfleet begins at the very south-eastern corner of the zone and flows north towards the River Thames within the Zone 7 boundary. There is a scheduled monument for Neolithic sites near Ebbsfleet located at the centre of Zone 7.

Although the majority of the material deposited within Southfleet Pit was Thanet Formation, the pit was initially filled with CKD wastes. The CKD wastes represent the main source of potential soil and groundwater contamination within the zone and are considered to present a moderate level of risk to the scheduled monument and controlled waters receptors, including local groundwater resources and the River Ebbsfleet as a result of associated leachate migration. Under the current land uses, risks to human health are considered to be low or moderate/low.

4.6.2. Geotechnical Summary

Within Zone 7, the general geological stratigraphy consists of Made Ground (primarily landfill) over superficial deposits of Alluvium, floodplain deposits and Head. These deposits overlie the Thanet Formation and White Chalk.

Substantial risks within Zone 7 are associated primarily with the Alluvium and the peat found within it. These beds are likely to be highly weak and compressible, which can pose a risk of settlement, leading to subsidence. In addition, the bearing capacity of these geological units is also expected to be low. It is anticipated that buried services will be encountered within Zone 7, although locations are unknown. Aggressive ground conditions are noted as being a substantial risk, due to the sulphate content in the alluvium and peat and the CKD deposited in the northern part of the zone. Running sand and historical works also noted as being a substantial risk.

Medium risk constraints include buried foundations, as historically there have been very few buildings within the zone, and perched/high groundwater. From historical borehole logs, groundwater is expected to be at approximately 9 m bgl, however perched water may occur in the floodplain deposits.

5. Zone 8

5.1. Zone Characterisation

5.1.1. Location

Zone 8 is located in the far south-eastern part of the site and is approximately centred on TQ 61560 72352 (561560E, 172352N). Zone 8 has an approximate area of 63 ha the majority of which is located within the borough of Dartford, with the eastern part partially within the borough of Gravesham. Watling Road forms the boundary between the two boroughs.

5.1.2. Zone Description

Zone 8 generally comprises arable land, with a number of roads and roundabouts. There is a domestic waste recycling facility and garden centre in the eastern part of the zone. The recycling centre appeared to be well maintained and managed at the time of the site walkover, with no visible flytipping or other areas of concern. There was historically a railway passing through the zone north-east to south-west which has becoming a footpath. The station associated with this railway line has been dismantled and the station house is now a large private residence including a tennis court and a commercial open storage area of unknown use. Access could not be gained during the site walkover as the land was private. There is HS1 infrastructure located in the eastern part of the zone including balancing ponds. HS1 passes through a tunnel in the eastern-most part of the zone.

Zone 8 is of important archaeological interest as the Roman city of Vagniacae, the name of which is thought to translate as ‘marshy place’ (36), was located across the majority of the zone.

A site walkover was undertaken on 15 April 2015 (Appendix B). The key features of Zone 8 are shown on Figure 010.

5.1.3. Zone-Specific Data Sources

A number of zone-specific data sources have been used to collate this section of the report. Information held by the Environment Agency was requested and has been included herein. The following information source was available:

- Victor Smith (Kent Archaeology). 1997. The Roman Road at Springhead Nurseries. *Archaeologica Cantinana, 117.* (36).

Two historic site investigations have been identified through the BGS website for areas within the vicinity of Zone 8. They are titled as follows:

- A2 Trunk road improvements, Bean road junction and carriageway widening, Northfleet, Kent; and
- Channel Tunnel Rail Link Preliminary Ground Investigation Stage II.

It is believed that information contained within these reports may be pertinent to the zone; however, at the time of writing this report, the information has not been made available.

5.1.4. Surrounding Land Uses

The surrounding land uses from Zone 8 are described below.

- **North:** Zone 7 is located to the north of Zone 8.
- **East:** HS1 passes through the eastern part of Zone 8 and continues to the south-west. There is an electricity substation to the north-east of Zone 8, beyond which lies a large Sainsbury’s shopping centre and residential properties.
- **South:** Agricultural land and a small number of residential properties are located to the south.
- **West:** Zone 9 and agricultural land lies to the west of the zone.

5.1.5. Historical Land Uses

Zones 7 and 9 are present adjacent to Zone 8, Zone 7 is to the north and Zone 9 is to the west; for features located in these zones, please consult their respective chapters (4 and 6 respectively). A summary of historical land uses within Zone 8 is presented in Table 5-1 (49).

Table 5-1 Historical Land Uses Relating to Zone 8

Dates and Scales	Within Zone 8	Off-site and within 1 km of Zone 8
1865-1866 1:10,560 **1865-1868** 1:2,500	The majority of the zone is open land. There are a number of roads through the zone. The north-central part of the zone is noted to be the site of a Roman town, which includes a small chalk pit. A small, old chalk pit is shown along the north-eastern boundary. A second small old chalk pit is located in the eastern part of the zone.	The area approximately 100 m to the north-east of the zone is Pepper Hill. The majority of the surrounding area comprises open land or farms. Two small chalk pits are located to the south of the zone, one is directly adjacent to the zone and the other is 300 m south. The River Ebbsfleet appears to begin adjacent to the north-western part of the zone, at Springhead.
1888-1895 1:10,560 **1897** 1:2,500	Southfleet Station is located along the southern boundary of the zone on a railway which runs north-east to south-west through the zone on an embankment. The small old chalk pits within the zone are no longer shown.	The chalk pit located 300 m south of the zone is now listed as an 'old chalk pit'.
1907-1909 1:10,560 **1909** 1:2,500	A cattle pen is adjacent to Southfleet Station.	No significant changes.
1931-1955 1:10,560 **1931-1938** 1:2,500 **1952-1959** 1:1,250	Watling Road has increased in size and is now shown on embankments in some parts. The Roman city has been identified as Vagniacae. The site of a Roman temple is shown adjacent to the roundabout. Southfleet Station is labelled as "Southfleet & Springhead Station" and the railway is labelled "Gravesend West Street Branch". At least 10 overhead cables are shown across the zone, leading to what is believed to be a transformer station adjacent to the north-east of the zone. Associated pylons have been constructed on the zone.	The site of a Roman cemetery is shown adjacent to the north-east of the zone, with what is believed to be a transformer station immediately south. A large residential development has begun 800 m to the north-east of the zone. Additional residential properties have been constructed within 1 km of the zone. Residential properties have developed around the zone. The overhead cables lead to an electricity substation directly adjacent to the north-east of the zone.
1961-1966 1:10,560 **1971-1982** 1:10,000 **1960-1979** 1:2,500 **1968-1981** 1:1,250	Southfleet & Springhead Station is listed as disused. A roundabout, parking and associated roads has been developed in the eastern part of the zone. New pylons have been constructed and others have been removed such that the layout of the overhead cables has changed.	There has been development of residential properties surrounding the zone and some are directly adjacent to the zone's north-eastern boundary. The electricity substation to the north-east of the zone is labelled as Northfleet East Grid Substation.
1987-1990 1:10,000	The railway is labelled as dismantled and there is a depot and an electricity substation located at the former	The chalk pits to the south are labelled as disused.

Dates and Scales	Within Zone 8	Off-site and within 1 km of Zone 8
1985-1993 1:2,500 **1981-1993** 1:1,250	Southfleet & Springhead Station. A public refuse tip, depot and car park are noted in the eastern part of the zone.	
2002-2014 1:10,000	The overhead cables appear to be removed. There is a garden centre in the eastern part of the zone, close to the location of the former public refuse tip, which is no longer shown. There is also a recycling centre in this area. There are roads in the north-western part of the zone. HS1 passes through the eastern part of the zone.	There are balancing ponds adjacent to the north-eastern part of the zone, associated with HS1.

5.1.5.1. Summary of Historical Land Uses

The majority of Zone 8 is open land and has remained that way since the earliest map edition from 1865. There was a railway and station located within the zone which has since been dismantled and removed. There were a number of overhead cables and associated pylons across the zone. There were two small chalk pits located within the zone. There was a public refuse tip and there is currently a recycling centre in the eastern part of the zone. The recycling centre was noted during the site walkover to be a recent development and well-managed, with no unmanaged waste present. The refuse tip was first noted in 1987 and therefore, it is possible that waste was deposited prior to the development of the recycling centre.

Zone 8 is archaeologically important due to the Roman temple and Roman town of Vagniacae located across the majority of area.

5.2. Environmental Context

5.2.1. Historical Borehole Records

The BGS borehole record viewer (6) has been used to collect records of all available historical exploratory hole records for review. In total, 20 borehole logs have been identified, with the majority being 10 m to 40 m deep. One geophysical borehole, reaching a depth of 128 m, was also located.

The exploratory holes within Zone 8 vary in age, with most having been drilled between 1993 and 1998. One borehole had an unknown date. 12 No. exploratory holes were categorised as Grade A and eight were categorised as Grade B. No logs were categorised as Grade C. The information from the Grade A and B logs have been used to verify the geological maps and to inform the findings of this report.

5.2.2. Geology

The 1:10,000 BGS geological map of the area, (Sheet TQ67SW – Northfleet) (24) shows the local geological succession to comprise Head deposits which are found in laterally discontinuous beds, underlain by the Thanet Formation, which in turn overlies the White Chalk bedrock. The Thanet Formation appears to thin out towards the east of the zone, where the White Chalk bedrock is found directly below the superficial deposits. Past the eastern and southern boundaries of the zone, the Thanet Formation is found overlying the Chalk again, suggesting the thinning out could be a product of erosional fluvial processes related to the Ebbsfleet River.

No faults are recorded within the zone or within 1 km of the zone boundary.

Table 5-2 Expected Stratigraphy beneath Zone 8

Stratum	Typical Thickness (m)	Description
Made Ground	5	Predominantly sand and clay. In some areas traces of flint, ash, metal and concrete are found, along with old tarmac road surfaces. The Made Ground is variable in composition and thickness across the Zone.
Head	4	Comprising gravel, sand and clay depending on source. Locally may contain lenses of silt, clay or peat.
Thanet Formation	6	Pale yellow-brown sand which is occasionally clayey or glauconitic, with a glauconite-coated nodular flint bed at its base (Bullhead Bed).
White Chalk	>7	Moderately weak to hard Chalk with beds of flint in the upper 5 m.

Note: typical thicknesses have come from BGS borehole logs; descriptions have come from the borehole logs and the BGS Lexicon of Named Rock Units. Where the value for a thickness is marked as greater than, it means the bed has been proven in a borehole, but the total thickness is not known. Where the thickness is marked as unknown, the bed has not been proven, and is only expected, and so a value for the thickness is not known.

5.2.3. Geomorphology

Zone 8 is located almost directly south of Zone 7. Zone 8 is predominantly agricultural land, with some artificial and worked ground associated with the A2 road and a disused railway line. The ground level indicated in borehole logs is at an average of approximately 18 m AOD. However, it varies between a minimum of level of 9 m AOD in the north-eastern corner, which slowly rises from the north-east to the south-western boundary to a maximum level of 32 m AOD.

5.2.4. Ground Conditions

Descriptions and geotechnical parameters provided in the following sections have been obtained from available historical exploratory hole records. It has not been possible to verify the accuracy of the geotechnical parameters or their applicability to Zone 8, therefore the information provided in this report is for guidance only. It is essential that a suitable ground investigation is designed, undertaken and interpreted to obtain site specific design parameters.

5.2.4.1. Made Ground

Made Ground in Zone 8 is largely made up of clay and sand, locally with traces of flint, ash, metal, concrete and wire, as well as a large number of tarmac layers from existing and old road surfaces. In boreholes TQ67SW823 and TQ67SW824 a large proportion of the Made Ground consists of sand and clay used as fill material for Roman Road and the A2. This unit is recorded in the historical borehole logs as being between 0.4 m and 12.9 m thick.

SPT results for the Made Ground were available in five of the historical borehole logs in this zone. The results were variable, with a minimum N-value of four and a maximum of 40.

5.2.4.2. Head

Head is a polymict deposit which can contain gravel, sand and clay, dependant on the upslope source and the distance from it. It is generally poorly sorted and stratified, formed mostly by solifluction, hillwash and soil creep.

In historical borehole records in Zone 8, Head is described as a stiff to very stiff, slightly sandy, silt or clay with angular flint and chalk gravel, or as an angular flint gravel with occasional cobbles and chalk gravel. Borehole TQ67SW887 also describes the deepest Head deposits as highly weathered, very weak and of low density. Borehole TQ67SW885 observed peat deposits within the Head. This unit has been observed in historical borehole logs as being between 1.7 m and 4.2 m thick.

SPT results for the Head deposits were available in three of the historical borehole logs in this zone. The results were highly variable, with a minimum N-value of five and a maximum of 47.

5.2.4.3. Thanet Formation

The Thanet Formation is described in the BGS Lexicon of Named Rock Units (9) as a pale yellow-brown, fine grained sand, which is occasionally glauconitic or clayey. At its base is a bed consisting of glauconite-coated nodular flint.

Historical borehole records describe the local Thanet Formation as a green grey, locally mottled, brown, glauconitic, fine sandy clay, with extremely to closely spaced subvertical and subhorizontal iron stained discontinuities. This unit has been recorded in historical borehole logs as being between 3.3 m and 3.8 m thick, based on two boreholes records.

The Bullhead Beds found at the base of the Thanet Formation, comprise a green grey glauconitic fine clayey sand with heavy red brown iron staining. The beds in borehole TQ67SW965 are described as containing some white comminuted Chalk. This unit has been observed in historical borehole logs in Zone 8 as being between 0.3 m and 2.4 m thick.

No SPT values were available for the Thanet Formation in the available borehole logs for this zone.

5.2.4.4. White Chalk Group

The Chalk bedrock underlying Zone 8 is undifferentiated Seaford Chalk Formation and Newhaven Chalk Formation. Borehole records characterise the Chalk as being moderately weathered and of medium density. It has closely spaced infilled fractures, and many bands of flint cobbles and flint gravel. The weathered section is described as slightly weathered although locally moderately weathered, and weak. The fractures here are generally closely spaced and tight, occasionally slickensided with <10 mm infill. This unit is typically over 7 m thick. The GroundSure report (3) indicates that there are six solution pipes within Zone 8 with a further three within 100 m of Zone 8. Solution pipes are typically cone or pipe-like cavities in vertical sections, typically partially or completely infilled with overlying deposits that have subsided into the cavity created by dissolution of the soluble chalk.

At the top of the Chalk unit there is a bed of highly weathered or structureless Chalk. This bed is typically between 0.45 m and 10 m thick.

SPT results for the White Chalk were available in seven of the historical borehole logs in this zone. The results show that strength increases with depth. A minimum N-value of three and a maximum of 42 was recorded.

5.2.5. Hydrology and Hydrogeology

5.2.5.1. Surface Water

Ebbsfleet River is considered to begin directly north of Zone 8, at the area known as Springhead, located within Zone 7. There are also several land drains across the zone, one in the east and one in the west.

5.2.5.2. Groundwater

From the information provided in available borehole logs, it has been concluded that groundwater is likely to be encountered at approximately 10 m bgl. The groundwater in the borehole logs was exclusively encountered within the Chalk. Information provided by the Environment Agency concludes that the Chalk is the major aquifer in the region (as a Principal aquifer) (10) with water movement being primarily controlled by fractures in the rock. The Environment Agency also indicates that the Thanet Formation is a Secondary A aquifer in the region, and the superficial Head deposits are classified as a Secondary (undifferentiated) aquifer.

5.2.5.3. Groundwater Abstractions

There is one groundwater abstraction within Zone 8, as shown in Table 5-3.

Table 5-3 Groundwater Abstractions within Zone 8

Licence No.	Details	Status	Volume
9/40/01/0523/G	Point C, Joyce Hall Farm Spray irrigation – direct	Start date: 27 November 2006 Issue no: 101	74,066 m^3/year

There are three groundwater abstractions within 1 km of the site and closest to Zone 8 as detailed in Table 5-4.

Table 5-4 Groundwater Abstractions within 1 km of Zone 8

Distance and Orientation from Zone	Licence No.	Details	Status	Volume
402 m south	9/40/01/0500/G	Spray irrigation – direct	Start date: 23 November 2006 Issue No.: 100	86,376 m^3/year
402 m south	9/40/01/0500/G	Vegetable washing	Start date: 23 November 2006 Issue No.: 100	86,376 m^3/year
736 m south-east	9/40/01/0511/G	Wells and Adits at Hazells PS Potable water supply – direct	Start date: 27 November 2006 Issue No.: 100	17,700,000 m^3/year

5.2.5.4. Groundwater Vulnerability

Information provided by the Environment Agency (10) concludes that the majority of Zone 8 is within a SPZ 2 (outer zone), whilst the south-eastern part of the zone is within a SPZ 1 (inner zone). Groundwater vulnerability zones within Zone 8 are a mix of major aquifer intermediate risk and minor aquifer high and intermediate risk.

5.2.6. Flood Risk

The majority of the land bordering or close to the Ebbsfleet River has been identified by the Environment Agency (10) as being at high risk of flooding from rivers, indicating a 1 in 30 (3.3 %) chance of flooding in one year. The tracks associated with the Ebbsfleet International Train Station and some drainage ditches have been identified as being at high risk of flooding from surface water. Parts of Zone 8 are within Environment Agency Zone 2 and Zone 3 flood risk zones.

A flood risk assessment is being compiled by Buro Happold.

5.2.7. Mineral Abstractions

No deneholes are recorded on the BGS Mining Plans Portal (45), and the largely undeveloped nature of the Zone 8 means very little to no modern mineral abstraction has taken place within it. Information received from Peter Brett Associates (35) also indicates that there are no recorded deneholes or other man-made cavities within the zone; however, this does not rule out the possibility of undiscovered cavities.

5.2.8. Designated Environmentally Sensitive Sites

The majority of Zone 8 (the entire area south of the A2 Watling Street) is within an area of Green Belt (4) (11). Zone 8 is the site of a Roman Town known as Vagniacae and the area is of known archaeological importance. The majority of the zone is an English Heritage scheduled monument known as Springhead Roman Town. In the eastern corner of the zone, there is an English Heritage scheduled monument known as Roman enclosure south-east of Vagniacae. There was also a Roman temple, adjacent to the roundabout within Zone 8, shown on historical maps (see Table 5-1).

The A2 Watling Street was a road established by the Romans and the area has been subject to a number of archaeological excavations and a number of masonry buildings and structures have been discovered within Zone 8 (36).

The zone is within an NVZ and a SSSI IRZ.

5.2.9. Environmental Permits, Incidents and Registers

The active environmental permits, incidents and registers within Zone 8 are summarised in Table 5-5.

Table 5-5 Environmental Permits, Incidents and Registers Located within Zone 8

Owner	Type of Permit, Incident and/or Register	Status	Additional Information
Householders Waste Site and Recycling Centre	Licensed discharge consent	Active	Effluent type: trade discharges – site drainage Permit number: P10736 Permit version: 2

The active environmental permits, incidents and registers located within 500 m of Zone 8 are summarised in Table 5-6.

Table 5-6 Environmental Permits, Incidents and Registers Located within 500 m of Zone 8

Distance and Orientation from Site	Owner	Type of Permit, Incident and/or Register	Details/Status	Additional Information
153 m north	Sainsbury's Supermarket	Part B activity	Active	Process: petrol storage
181 m north, 208 m north, 285 m north-east, and 315 m north	J Sainsbury Plc Store	Licensed discharge consent	Active	Effluent type: surface water Receiving water: freshwater river Permit number: P03921
402 m south	Court Lodge Farm, Court Lodge Farm	Licensed discharge consent	Issued: 30 August 1996 Active	Effluent type: trade discharges – process effluent Receiving water: into land Permit number: P06073

There were three pollution incidents, which had an impact on water, land or air, recorded within Zone 8 and these are presented in Table 5-7.

Table 5-7 Records of Pollution Incidents within Zone 8

Incident Date	Pollutant	Impacts
13 September 2001	Inorganic chemicals or products	Water impact: Category 3 (minor) Land impact: Category 3 (minor)
31 March 2004	Flytipping of inert materials and wastes	Water impact: Category 3 (minor)
27 October 2004	Mixed/waste oils	Water impact: Category 1 (major) Land impact: Category 2 (significant)

There were two off-site pollution incidents within 500 km of Zone 8 that had an impact to air, land or water, as listed in Table 5-9.

Table 5-8 Records of Pollution Incidents within 500 m of Zone 8

Distance and Orientation from Zone 7	Incident Date	Pollutant	Impacts
23 m north-east	15 August 2001	Atmospheric pollutants and effects	Air impact: Category 3 (minor)
148 m north-east	05 November 2002	Diesel	Water impact: Category 3 (minor) Land impact: Category 3 (minor)

5.2.10. Landfills and Other Waste Sites

There are a number of active landfill and waste management permits within Zone 8. There were no other active waste management facilities within 1 km of Zone 8. The Pepperhill Recycling Centre was previously labelled as a refuse tip and although discussions with the Environment Agency indicated that no formal landfilling has occurred here, it is possible that there was localised infilling. There are a number of WMLs for processes other than infilling recorded at that location. A summary of the landfill and waste management permits is presented in Table 5-9 (4). Where there was more than one entry for the same WML listed within the GroundSure report, only the most recent has been included.

Table 5-9 Landfill and Waste Management Permits within Zone 8

Licence/ Reference Number	Landfill Name and Type	Operator	Waste Type	Details
Planning Application Reference: 05/00328/CPO	Pepperhill Recycling Centre	Pepper Hill Recycling Centre	Household waste recycling centre and a waste transfer station	Date of planning application: 18 February 2008 Planning permission was granted by Dartford Borough Council
EPR Ref: EA/EPR/KP3798HZ/V002 WML no.: 19382	Pepperhill Depot	Kent County Council	Household waste amenity site	Issue date: 30 March 1994 Modified: 11 June 2002 Annual tonnage: 25,000
EPR Ref: EA/EPR/GP3198HY/V006 WML no.: 10385	Pepperhill Waste Transfer Station	FCC Recycling (UK) Limited)	Household commercial and industrial waste transfer station	Issue date: 23 July 2007 Modified: 14 November 2012 Annual tonnage: 130,000

5.3. Information Gained from Public Records

A review of the public records including those from the Dartford Borough Council, Gravesham Borough Council and the Environment Agency was undertaken and there was no information found which was deemed relevant to land contamination issues.

5.4. Preliminary Geo-environmental Conceptual Site Model

5.4.1. Introduction

The approach used for the creation of the preliminary CSM is detailed in Section 2.2.1. Identified zone-specific potential sources, pathways and receptors of contamination are listed below, with the corresponding risk rating detailed in Table 5-10. Only sources of and receptors to contamination within Zone 8 have been considered.

While reference to the proposed development is noted within this report, risks have been assessed for the zone in its current condition and for the current zone users in terms of human health related risks. This approach was taken as the detailed masterplan is still in development.

5.4.2. Potential Sources

The potential sources of contamination in Zone 8, identified from the background searches, data review and site walkover observations for the zone are as follows:

- former railway and railway station which passed north-east to south-west through the zone;
- two small old chalk pits which may have been infilled with unknown material; and
- Pepperhill Recycling Centre in the north-eastern part of the zone.

5.4.3. Potential Pathways

The primary exposure pathways that are considered applicable are:

- inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres;

- migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion;
- leaching/migration of contaminants from soils to controlled waters receptors;
- direct surface water run-off and sub-surface flow to surface waters;
- lateral migration of contaminated groundwater; and
- vertical migration of contaminated groundwater.

5.4.4. Potential Receptors

The potential receptors identified are:

- the scheduled monument of the Roman town of Vagniacae;
- the Secondary (undifferentiated) aquifer within the superficial deposits beneath the zone;
- the Principal and Secondary A aquifers within the bedrock beneath the zone;
- the River Ebbsfleet which starts to the north of the zone;
- zone residents;
- zone visitors and workers; and
- trespassers.

A schematic CSM for Zone 8 is presented as Figure 11.

Table 5-10 Preliminary Conceptual Site Model for Zone 8

Sources	Receptor	Potential Pathway	Potential Consequence	Likelihood	Classification of Risk
Zone 8: **Potential contaminants in soil/groundwater on the zone, originating from the following sources:** • Contamination resulting from the public refuse tip, now recycling centre, the former railway and the small old chalk pits. *Potential contamination includes, metals, PAHs, TPH and other contaminants.*	Zone residents, visitors, workers and trespassers	Migration and accumulation of ground gases followed by inhalation or ignition, causing asphyxiation and/or explosion	**Severe**	**Unlikely** Material which has the potential to generate ground gases may have been deposited into the two small old chalk pits, at Pepperhill Recycling Centre and during the construction of the former railway, however it is considered unlikely that there would be migration and accumulation of sufficient gases to cause asphyxiation and/or explosion.	**Moderate/Low**
		Inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres	**Medium**	**Unlikely** There is unlikely to be inhalation, ingestion and/or dermal contact with contaminants because potential contamination at Pepperhill Recycling Centre will be managed. Contact with contaminants from the other identified sources is also considered to be unlikely.	**Low**
	Scheduled monument – the Roman town of Vagniacae	Lateral migration of contaminated groundwater	**Mild**	**Low likelihood** Pepperhill Recycling Centre is managed and therefore contamination is unlikely to migrate from the recycling centre. There may be contamination associated with the railway which could migrate to the scheduled monument, however the effect of this is considered to be mild.	**Low**
	Controlled waters – River Ebbsfleet	Leaching to groundwater followed by lateral migration of contamination within groundwater	**Medium**	**Low likelihood** There may be contamination within the Made Ground associated with the former railway and the recycling centre. There is a low likelihood that the contamination will migrate to controlled waters receptors.	**Moderate/Low**
		Lateral migration of contaminated groundwater	**Medium**		**Moderate/Low**

Sources	Receptor	Potential Pathway	Potential Consequence	Likelihood	Classification of Risk
		Direct surface water run-off and sub-surface flow to surface waters	**Medium**		**Moderate/Low**
	Controlled waters – Secondary (undifferentiated), Secondary A and Principal aquifers beneath the zone	Leaching/migration of contaminants from soils to controlled waters receptors	**Medium**		**Moderate/Low**
		Vertical migration of contaminated groundwater	**Medium**		**Moderate/Low**

5.5. Preliminary Geotechnical Risk Assessment

5.5.1. Geological and Geotechnical Hazards

Table 5-11 describes the principal geological and geotechnical hazards which have been identified as part of this desk study. The list of hazards is not exhaustive and are only briefly summarised.

Table 5-11 Potential Geological and Geotechnical Hazards in Zone 8

Hazard	Description	Comment
Aggressive ground conditions	The BRE Special Digest (48) states that chemical agents, particularly sulphates, sulphides and acids can naturally occur in many soils and could be damaging to concrete.	The local geological succession is dominated by chalk and no aggressive ground conditions are anticipated.
Buried foundations	Buried foundations can cause a delay to construction and incur additional costs.	Historic mapping does not indicate buildings for which buried foundations may be associated, however the zone contains the site of an ancient Roman town, and so historic Roman buildings may be encountered at shallow to medium depth.
Buried services	Damage to underground services can cause injury, significant disruption and environmental damage; it can also cause a delay to construction and incur considerable costs.	There are few buildings within Zone 8, however the A2 road is likely to have associated drainage services. A garden centre and recycling centre are located in the south-eastern corner of the zone, and may have buried services present.
Chalk dissolution features	Chalk is a chemically vulnerable rock, and reactions with groundwater can lead to dissolution. These dissolution features can cause subsidence, and depending on the nature of overlying deposits, sinkholes.	According to the GroundSure report (3), there is a moderate to high risk of dissolution of soluble rocks in the areas of Zone 8 where Head directly overlies the Chalk. The report has also identified six solution pipes within Zone 8, as well as a further three within 100 m of the zone boundary.
Historical works	Historical works such as abandoned quarries may be backfilled with hazardous materials or any poorly compacted material which is susceptible to settlement	There are no known historic quarries or underground mines (including deneholes) located within the zone. Along the line of the dismantled railway, the A2 road and Roman Road are various small cuttings and embankments identified through the GroundSure report (3).
Perched/high water table	The presence of high groundwater levels/perched water tables needs to be considered when undertaking construction.	Groundwater was only encountered fairly deep and in the Chalk in historic boreholes. However the Thanet Formation has been identified as a secondary aquifer, so a separate water table could be present in localised areas of the zone.
Running sand	Running sand is the flow of sand into an excavation or void caused by water pressure. This can lead to subsidence of the surrounding ground.	The GroundSure report (3) has identified a large proportion of Zone 8, corresponding to areas where the Thanet Formation is present, as being at a moderate risk of running sand.
Saline groundwater	The presence of saline groundwater (commonly at coastal sites) may result in increased corrosion of steel.	The boundary of Zone 8 is approximately 2.5 km from the River

Hazard	Description	Comment
	Appropriate control measures will need to be taken.	Thames at the closest point and therefore salinity is unlikely..
Variable rockhead/deep weathering profile	A deep weathering profile or physical erosion can result in an uneven rockhead profile resulting in areas of reduced bearing capacity or potential for varying lengths of piles.	The area is unlikely to have been quarried, but erosion and weathering from periglacial and fluvial processes will be a concern.
Weak bearing materials	Construction of foundations upon weak bearing strata can result in bearing capacity failure. Some geological units are particularly susceptible to reductions in strength and stiffness due to weathering and pockets of weathering may result in areas of weak bearing capacity.	The superficial deposits in Zone 8, particularly the Head will have a low bearing capacity value.
Weak, compressible ground	Loading of compressible soils and unconsolidated materials can cause excessive settlements. Materials such as peat within areas of alluvium are particularly vulnerable.	Head is present in Zone 8. These soils appear to be weak and could deform and fail as a result of the loads imposed on them.

5.5.2. Geotechnical Risk Register

The Geotechnical Risk Register is presented as Table 5-12 below. It comprises an initial assessment of the risks, prior to the application of risk mitigation measures and shows how the risks can be reduced by the application of the measures. In most cases the mitigation measures will be sufficient to reduce the risk to a “low” ranking. In some cases the risk may be reduced but a significant residual risk remains which must be managed, and in other the risk mitigation measure cannot reduce the likelihood of an event but will be used to mitigate potential effects.

Prior to implementation of the proposed mitigation measures, the risks considered to be substantial are:

- chalk dissolution features;
- running sand;
- variable rockhead; and
- weak bearing materials.

Most of the other risks are rated as “medium” to “low”.

5.5.3. Mitigation Measures

The mitigation measures considered are those that may be applied during design or construction, as appropriate, to mitigate the hazard identified and, in most cases, to render the risk insignificant. Mitigation measures considered appropriate for the substantial risks listed above include:

- further desk study (including a detailed walkover);
- ground investigation including *in situ* and laboratory testing;
- planned methodology for the earthworks; and
- detailed design for the temporary construction roads.

5.5.4. Residual Risk

Following risk identification, assessment and the application of recommended mitigation/avoidance measures most risks have been assessed to be “low”. However, it should be recognised that some residual risks remain.

Table 5-12 Geotechnical Risk Register for Zone 8

Category Risk No.	Constraint	Prior to Mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital Cost	Programme	Safety	Capital Cost	Programme	Safety				Capital Cost	Programme	Safety	Capital Cost	Programme	Safety	
1	Aggressive ground conditions	1	3	3	1	3	3	1	L	Ground investigation to assess presence of contamination or aggressive chemicals.	1	2	2	1	2	2	1	L
2	Buried foundations	3	3	3	1	9	9	3	M	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried foundations.	2	2	2	1	4	4	2	L
3	Buried services	2	3	3	3	6	6	6	M	Where possible review more detailed building records and service diagrams. Ground investigation to determine the location of any perceived buried services.	2	2	2	1	4	4	2	L
4	Chalk dissolution features	3	3	3	1	9	9	3	S	Search of Peter Brett Associates' natural and man-made cavity database (3). Ground investigation to confirm geological succession and risk of dissolution across the site.	2	2	2	1	4	4	2	L
5	Historical works	1	3	3	1	3	3	1	L	See buried foundations and buried services.	1	2	2	1	2	2	1	L
6	Perched/high groundwater	2	2	2	1	4	4	2	L	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	2	1	1	1	2	2	2	L
7	Running sand	3	3	3	1	9	9	3	S	Ground investigation to confirm geological succession and geotechnical properties across the site.	2	2	2	2	4	4	4	L
8	Saline groundwater	2	2	2	1	4	4	2	L	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	2	1	1	1	2	2	2	L

Category Risk No.	Constraint	Prior to Mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital Cost	Programme	Safety	Capital Cost	Programme	Safety				Capital Cost	Programme	Safety	Capital Cost	Programme	Safety	
9	Variable rockhead	3	3	3	1	9	9	3	S	Ground investigation to confirm geological succession and geotechnical properties across the site.	3	2	2	1	6	6	3	M
10	Weak bearing materials	2	3	3	1	6	6	2	M	Ground investigation to confirm geological succession and geotechnical properties across the site.	2	2	2	1	4	4	2	L
11	Weak compressible ground	2	3	3	1	6	6	2	M	Ground investigation to confirm geological succession and geotechnical properties across the site.	2	2	2	1	4	4	2	L

5.6. Zone 8 Summary

5.6.1. Geo-environmental Summary

Zone 8 is located in the south-western part of the site and comprises agricultural land, roads, a former railway, residential properties, Pepperhill Recycling Centre, a garden centre and HS1 infrastructure. Zone 8 is of archaeological importance due to the Roman city of Vagniacae which was located across the majority of the zone. Historical maps indicate that there was a refuse tip located in Pepperhill prior to the development of Pepperhill Recycling Centre and although no formal landfilling is understood to have occurred, there may have been localised infilling. Under current land uses, risks to human health are considered low and risks to controlled waters are considered moderate/low.

5.6.2. Geotechnical Summary

Within Zone 8 the general geological succession of superficial deposits is Made Ground over Head in localised regions, while only topsoil covers the bedrock in other areas. The bedrock succession consists of Thanet Formation over much of the zone, overlying the Bullhead Beds in localised areas. These units are both underlain by undifferentiated White Chalk bedrock. The zone forms a gentle slope increasing in elevation from approximately 9 m AOD in the north-east to approximately 32 m AOD in the south-west.

Substantial risks within Zone 8 include running sands which pose a hazard, mainly associated with the Thanet Formation and any excavations into the formation will need to be closely monitored for groundwater activity. The Thanet Formation and Bullhead Beds are expected to rest unconformably on the Chalk, meaning the rockhead is likely to be variable. Solution pipes have been identified within the Chalk within Zone 8, and further dissolution is therefore likely. Finally the Head deposits are expected to have a low bearing capacity, and could fail when placed under load.

Medium risk constraints include buried services, weak compressible ground, as a result of peat deposits found within the Head, and buried foundations, which could potentially be related to the ancient Roman town.

6. Zone 9

6.1. Zone Characterisation

6.1.1. Location

Zone 9 covers an area of approximately 68 ha and is located in the south-west of the site, to the west of Zone 8. The approximate NGR for the centre of the zone is TQ 60212 72667 (560212 172667). The zone is located within the Dartford Borough Council administrative area.

6.1.2. Zone Description

The zone primarily comprises part of the A2 (Watling Street), a large six-lane main road, and associated slip roads, notably the A296 (Roman Road), a two lane road in the western part of the zone, and the B255 (Bean Lane) which is predominantly four lanes and runs perpendicular to the A2 and the A296.

Other land uses within the zone include a small water works in the south-easternmost part of the zone, an electricity substation towards the central portion of the zone, and a small pond, industrial premises and residential properties both in the western part of the zone, and along the northern boundary of the central area of the zone as accessed off the A296. Zone-Specific Data Sources.

6.1.3. Zone-Specific Data Sources

A number of zone-specific data sources have been used during collation of this chapter. Information held by the Environment Agency was requested and has been included herein. The following information sources were available, relating to the off-site Northfleet West Grid Substation:

- Parsons Brinckerhoff, Remediation Strategy and Implementation Plan, Northfleet West Grid Substation, November 2013 (37); and
- Erith Contractors Ltd., Addendum to Verification Report, Northfleet West Grid Substation, February 2015 (38).

Two historical site investigation reports have been identified through the BGS GeoIndex (3) for areas within the vicinity of Zone 9. They are titled as follows:

- A2 Trunk road improvements, Bean road junction and carriageway widening, Northfleet, Kent; and
- Bluewater Park, Dartford.

It is believed that the information contained within these reports may be pertinent to the site, however at the time of writing this report the information has not been made available.

6.1.4. Surrounding Land Uses

The land uses surrounding Zone 9 are described below.

- **North –** Northfleet West Grid Substation (now demolished) and Eastern Quarry, a very large former quarry which has been earmarked for redevelopment by Land Securities, are located to the north. A former industrial compound known as Weldon and Castle Hill is within this area. Beyond Eastern Quarry is the town of Swanscombe. Bluewater shopping centre is located approximately 170 m north-west of the zone.
- **East –** Zones 7 and 8 are located to the east, north-east and south-east of Zone 9, and further details regarding these areas can be found in Chapters 4 and 5 respectively.
- **South –** The majority of the land to the south of the zone comprises agricultural land and the towns of Bean and Betsham located to the south-west and south-east of Zone 9, respectively. A caravan site and covered reservoir are located south of Zone 9, approximately 100 m and 230 m away, respectively.
- **West –** The area immediately west and south-west of the zone comprises farmland and woodland including Darenth Wood.

6.1.5. Historical Land Uses

The historical land uses of Zone 9 and its immediately surrounding area is provided below in Table 6-1, with a brief summary highlighting all key facts provided in Section 6.1.5.1.

Table 6-1 Historical Land Uses Relating to Zone 9

Dates and Scales	Within Zone 9	Off-site and within 1 km of Zone 9
1865-1866 1:10,560 **1865-1868** 1:2,500	Zone 9 comprises fields, woodland, old chalk pits and a small road (Watling Street) intersecting it from east to west. Other small roads pass through the zone and join Watling Street, predominantly in the western part of the zone. Small farm buildings are present in the south-westernmost part of the zone.	The surrounding area is largely undeveloped and comprises fields and woodlands, with few buildings. Notable woodlands include Darenth Wood to the west, The Thrift towards the west and Swanscombe Park to the east, all of which extend across the zone's boundaries. The historical site of Caerberlarber (a British village) is shown approximately 60 m north of the eastern portion of the zone, within Swanscombe Park.
1888-1895 1:10,560 **1897-1898** 1:2,500	An old chalk pit is shown on the eastern part of the zone. The farm buildings in the south-westernmost part of the zone are part of Upper Bean Farm.	A few pits (predominantly chalk) are present within the area surrounding the zone, some of which are marked as old. Powder works are shown approximately 750 m south of the southern part of the zone. A Roman foundation (from A.D 1895) was found approximately 1 km south of the western part of the zone.
1907 1:10,560 **1909** 1:2,500	Brick works (including cylindrical features believed to be tanks), a limekiln and cottages are shown within the western part of the zone. A shaft and a pumping station owned by the Metropolitan Water Board (Kent District) is shown on the eastern part of the zone. Residential properties, known as Ightham Cottages, have been constructed in the western part of the zone.	Brick works are shown approximately 85 m north of the western part of the zone. The powder works 750 m south of the zone now has two tramway lines and a testing range immediately east of it. Ancient earthworks are marked within the surrounding area, the closest of which is approximately 300 m west of the zone.
1931-1938 1:10,560 **1931-1939** 1:2,500	Watling Street (also known as Roman Road and later, the A2) has expanded, and is now a main road. Tramways intersect the northern-central zone boundary. The farm buildings in the south-westernmost part of the zone are no longer present, as Upper Bean Farm has reduced in size. By the 1938-1939 map, the brickworks in the western part of the zone are marked as disused and have a sand pit directly south of them.	A reservoir is shown approximately 230 m south of the central portion of the zone. The tramway tracks that intersect the northern-central zone boundary head north-east towards an engine shed, reservoir and Alkerden Clay Plant, approximately 300 m north of the zone, within Swanscombe Park. The powder works and tramway tracks 750 m south of the zone are no longer shown, and reservoirs are shown in this area instead. The pits within the surrounding area have grown significantly in size, and some of them are marked as old.
1946-1955 1:10,560	The pumping station on the eastern part of the zone is labelled as works.	A pumping station is shown approximately 870 m north of the western part of the Zone and a tunnel is shown approximately 740 m north, allowing tramlines to pass beneath a road into the chalk pits in this area. Alkerden Clay Plant and the engine shed 300 m north of the zone, are no longer shown, and area is now marked as containing old clay pits. A Saxon Burial site is shown within the village of Betsham, approximately 625 m south of the eastern part of the zone.
1961-1967 1:10,560	The site of the former brick works in the western part of the zone is now marked as "Brickfield Nurseries".	Excavations within the surrounding area, particularly those north of the western part of the zone, continue to increase in scale.

Dates and Scales	Within Zone 9	Off-site and within 1 km of Zone 9
1962-1968 1:2,500	"Watling Street Nursery" is present within the western half of the zone. The works on the eastern part of the zone are labelled as water works.	Northfleet West Grid Substation is shown adjacent to the northern boundary of the eastern part of the zone. A conveyor is shown to lead from the chalk pit to the north of the zone, and towards the north-east, and is shown to expand in size from 1961 and 1970. The engine shed, reservoir and Alkerden Clay Plant, approximately 300 m north of the zone is no longer shown.
1971-1993 1:10,000 **1968-1995** 1:2,500	The A2 main road has been constructed along the southern boundary of the zone and becomes the now-widened Watling Road. Associated slip roads were developed. Small industries are shown in the parcel of open space between the intersections of these three roads, as is a small pond. Upper Bean Farm is no longer shown, so the south-westernmost part of the zone is within a plain field. By 1992, Brick Field Nurseries is no longer shown on the western part of the zone.	Works are shown adjacent to the zone's northern boundary, on the western part of the zone, comprising eight large circular tanks, rectangular structures, hopper and two conveyors. By 1978, the conveyors are shown leaving from this works premises into the chalk pits to the north. The town of Bean has developed approximately 10 m south of the zone at its closest point. The reservoir to the south of the zone is marked as covered on the 1968-1972, 1:2,500 scale map. A works premises is shown adjacent to a pond approximately 630 m south of the western part of the zone. Between 1977 and 1982, a caravan site developed immediately south of the zone, north of the now covered reservoir.
2002 1:10,000	The road network within the zone has developed further, and the western part of the zone is shown in a similar arrangement to today, including roundabouts and wider roads.	The works premise adjacent to the northern part of the zone is now shown with 10 tanks. Bluewater shopping centre has been developed approximately 170 m north-west of the zone. Another building is shown north of Northfleet West Grid Substation to the north of the zone, along with a pumping station, approximately 415 m and 340 m north of the eastern end of the zone respectively.
2010-2014 1:10,000	The road network within the eastern part of the zone is shown in its present day arrangement, with the roads connecting the A2 to the A2260 (Southfleet Road) to the north.	The site walkover indicated that Northfleet West Grid Substation has been demolished and cleared, with some of the infrastructure remaining (an access bridge and embanked walls), a large stockpile of crushed material, some minor flytipping and small areas of remaining materials.

Notes: For land uses adjacent to the east, north-east and south-east of the zone (Zones 7 and 8), see Chapters 4 and 5 respectively.

6.1.5.1. Summary of Historical Land uses

6.1.5.1.1. Zone 9

The land use of Zone 9 has not changed much over time. On the earliest historical maps provided in the GroundSure report (1865-1866), Zone 9 comprised fields and woodland, with a few small roads. Between the late 19th and early 20th centuries, small excavation works and industry developed, including a brick works and pumping station within the eastern part of the zone. From the late 20th Century onwards, the road network within Zone 9 developed, with the most significant developments not taking place until the early 21st century, during which time the zone developed into its current layout.

6.1.5.1.2. Surrounding Area

Like the zone itself, the surrounding area was shown to comprise predominantly fields and woodlands on the earliest historical maps provided, and has not had a large industrial presence. Excavations occupied large areas of space over the years, notably Eastern Quarry directly north of the zone, and many archaeological features have been found, including a Roman Foundation and a Saxon burial ground, amongst others.

Potentially contaminative industries within the vicinity of Zone 9 over time have included brick works approximately 85 m north of the western part of the zone, powder works 750 m south, Alkerden Clay Plant and engine shed 300 m north and works premises, including one with 10 tanks to the north of the zone.

6.2. Environmental Context

6.2.1. Historical Borehole Records

The BGS borehole record viewer (6) has been used to collect records of all available historical exploratory hole records for Zone 9. In total, 38 exploratory hole logs have been identified, with the majority ranging in depth from 10 m to 30 m bgl, with one reaching a depth of 47 m. Two hand auger logs were also available, which reached a depth of 0.6 m bgl.

The available logs for Zone 9 vary in age, with the majority being conducted between 1985 and 1995. Of the logs available, 15 No. were categorised as Grade A and 13 No. were categorised as Grade B. Five logs were Grade C. The information from the Grade A and B logs has been used to verify the geological maps and to inform the findings of this report.

6.2.2. Geology

The 1:10,000 BGS geological maps of the area (Sheets TQ67SW – Northfleet and TQ57SE – Darenth) show the local geological succession to comprise Made Ground and superficial deposits overlying Palaeogene strata over Chalk. Across the zone, River Terrace Deposits and Head form a localised superficial covering. Underlying the superficial deposits is the London Clay, which overlies the Lambeth Group in the approximate centre of the Zone. Underlying the Lambeth Group is the Thanet Formation. Where London Clay and the Lambeth Group is not present, the superficial deposits directly overlie the Thanet Formation. The entire sequence above is underlain by undifferentiated White Chalk of the Seaford Chalk Formation and the Newhaven Chalk Formation. Table 6-2 below summarises the geological units found in Zone 9.

No faults are recorded within the site boundary, however two inferred faults are located approximately 700 m to the south of the A2 road. One of these faults is seen on maps to interact with the London Clay Formation, at the top of the succession. No superficial deposits are located near to the fault, so it is not possible to verify the modern capability of the faults.

Table 6-2 Expected Stratigraphy Below Zone 9

Stratum	Typical Thickness (m)	Description
Made Ground	7	Variable composition across the zone. Locally described as a sandy clay with flint and chalk gravel, or as a clayey or sandy silt with flint fragments. In some areas it is recoded as having brick rubble, shell fragments, tarmac, concrete and occasional coal fragments.
Head	3	Silty sand to sandy silt to slightly sandy clay with medium size chalk and flint gravel.
River Terrace Deposits	2.5	Sand and gravel, locally with lenses of silt, clay or peat.
London Clay	4	Blue-grey or grey-brown, silty clay with some sandy clay. Commonly containing concretions and pyrite, and some thin shell beds and pockets of sand.
Lambeth Group	>8	Varying sequences of sandy or silty clay, sand and gravel, minor limestone and lignites with occasional sandstone and conglomerate.
Thanet Formation	5	Pale yellow-brown sand which is occasionally clayey or glauconitic, with a glauconite-coated nodular flint bed at its base.
White Chalk	> 6.5	Moderately weak to hard Chalk with occasional flint nodules.

Note: typical thicknesses have come from BGS borehole logs; descriptions have come from the borehole logs and the BGS Lexicon of Named Rock Units. Where the value for a thickness is marked as greater than, it means the bed has been proven in a borehole, but the total thickness is not known. Where the thickness is marked as unknown, the bed has not been proven, and is only expected, and so a value for the thickness is not known.

6.2.3. Geomorphology

Zone 9 is located to the West of Zone 8 and forms an approximately 1 km long belt encompassing an area of the A2 corridor between the Bean and Northfleet junctions. The zone has an average elevation of 50 m AOD, although this varies across the site, having a minimum elevation of approximately 15 m AOD and a maximum of relatively 80 m AOD. The approximate centre of the zone is situated on a large hill, which slopes off to the east and west.

6.2.4. Ground Conditions

Descriptions and geotechnical parameters provided in the following sections have been obtained from available historical borehole records. It has not been possible to verify the accuracy of the geotechnical parameters or their applicability to Zone 9, so the information provided is for guidance only. It is essential that a suitable ground investigation is designed, undertaken and interpreted to obtain zone-specific design parameters.

6.2.4.1. Made Ground

Made Ground in Zone 9 is highly variable across the zone. In general it is described as a sandy clay with chalk and flint gravel, or as a clayey to sandy silt with flint gravel. In borehole TQ67SW266 the Made Ground is mixed with Alluvium at depth, and is described as a slightly peaty and very silty clay. Other boreholes identify brick rubble, shell fragments, tarmac, concrete and occasional coal fragments in the Made Ground. It is observed as being between 1.1 m and 12.3 m thick; however, it does not appear in all borehole logs.

SPT results for the Made Ground were available in six of the historical borehole logs in this zone. The results were variable, with a minimum N-value of eight and a maximum of 30, and an observed average of 18.

6.2.4.2. Head

Head is a polymict deposit which can contain gravel, sand and clay, dependant on the upslope source and the distance from it. It is generally poorly sorted and stratified, formed mostly by solifluction, hillwash and soil creep. Locally it can contain lenses of silt, clay, peat or organic material.

Head is described in historical boreholes in Zone 9 as comprising a silty sand or sandy silt, with increasing clay content with depth, or as a slightly sandy clay with medium size chalk and flint gravel. It is recorded as having a thickness of between 1.65 m and 5.7 m.

SPT results for the Head deposits were available in three of the historical borehole logs in this zone. The results were variable, with a minimum N-value of 12 and a maximum of 51.

6.2.4.3. River Terrace Deposits

The River Terrace Deposits are found towards the west of the A2 corridor, overlying the Lambeth Group and Thanet Formation. This unit is typically described in the local borehole logs as comprising loose slightly clayey sandy gravel with a thickness of between 2.2 m and 2.9 m. This unit only appears in two of the historical logs.

No SPT results were available for the River Terrace Deposits in this zone.

6.2.4.4. London Clay

The London Clay Formation is described in the BGS Lexicon of Named Rock Units (9) as a blue-grey or grey-brown silty clay, with some layers of clayey silt and sandy clay. The formation is generally bioturbated or poorly laminated, and commonly contains thin courses of carbonate concretions and disseminated pyrite.

Historical borehole logs in Zone 9 describe the London Clay as comprising firm to stiff grey to brown sandy gravelly clay. In localised beds the clay is thinly laminated with silt and occasionally sand dusting on laminae surfaces. Gravel is usually fine to medium in size, consisting of shell fragments. This unit is between 4.2 m and 4.5 m thick in this area.

SPT results for the London Clay were available in one of the historical borehole logs in this zone. The results show that strength generally increases with depth. A minimum N-value of 32 and a maximum of 54 are recorded.

6.2.4.5. Lambeth Group

The Lambeth Group is described as comprising vertically and laterally variable sequences of clay, with some silty or sandy clay, sands and gravels (9). Minor limestones and lignites and occasional sandstone and conglomerate have also been noted.

The Lambeth Group in Zone 9 consists of the Woolwich and Reading Beds. These beds are generally described in boreholes as being a very dense grey to brown, slightly silty, fine to medium sand. In borehole TQ67SW270 the beds are noted as containing rounded to subangular flint gravel. The colouring is also reported in some logs as turning greenish with increasing depth. This unit is recorded as being over 8.4 m thick in this area.

SPT results for the Woolwich and Reading Beds were available in two of the historical borehole logs in this zone. The results show that strength generally increases with depth, with anomalous beds of lower strength throughout. A minimum N-value of 92 and a maximum of 131 are recorded.

6.2.4.6. Thanet Formation

In local historical boreholes the Thanet Formation is described in Zone 9 as being a firm, very sandy clay, which is thickly and thinly interbedded with clayey fine sand at the top of the succession, turning into a medium density to dense silty fine sand or sandy silt with occasional sandy clay lenses with increasing depth. In boreholes TQ57SE400 and TQ67SW275 ironstone nodules were identified below 11.5 m bgl and 6.9 m bgl respectively. Within borehole TQ67SW277 the Thanet Formation beds are described as containing fine to coarse angular flint gravel. In Zone 9, this unit is recorded as being between 1.7 m to over 6.8 m thick.

SPT results for the Thanet Formation were available in three of the historical borehole logs in this Zone. The results were slightly variable, with a minimum N-value of 17 and a maximum of 45.

6.2.4.7. White Chalk Group

The Chalk bedrock underlying Zone 9 is from undifferentiated Seaford Chalk Formation and the Newhaven Chalk Formation. Borehole records characterise the Chalk as having a weak to moderately weak strength and as a slightly to moderately weathered unit. It also has a low to medium density in this zone. Flints have been identified in the Chalk and in other beds as gravel size angular to rounded pieces.

SPT results for the White Chalk were available in four of the historical borehole logs in this zone. The results show that although strength roughly increases with depth, this unit is variable at this location. A minimum N-value of nine and a maximum of 44 are recorded. The GroundSure report (3) has identified six solution pipes within the chalk in the west of Zone 9 and information from Peter Brett Associates (35) confirms this, as well as indicating five locations of solution pipes within 500 m of the zone boundary.

6.2.5. Hydrology and Hydrogeology

6.2.5.1. Surface Water

Based on aerial photographs, there is a small unnamed pond located in the western part of the zone, associated with the residential properties known as Ightham Cottage. The pond has not been classified by the Environment Agency.

In the Eastern Quarry adjacent to the A2 in the north, multiple large ponds are present, and are believed to be fed by groundwater paths in the Chalk (50). In the east of the zone, two drainage ditches associated with the A2 are found. These ditches do not permanently contain water.

6.2.5.2. Groundwater

Only two of the available borehole logs, TQ67SW909 and TQ67SW910, detected the presence of groundwater at 16 m bgl and 15 m bgl. Due to the lack of data, the overall groundwater depth across the zone is unknown, therefore further ground investigation will be required to investigate the local groundwater regime.

Information provided by the Environment Agency concludes that the Chalk is the major aquifer in the region with water movement being primarily controlled by fractures in the rock (51).

Information provided by the Environment Agency concludes that the chalk is the major aquifer in the region with water movement being primarily controlled by fractures in the rock (10).

6.2.5.3. Groundwater Abstractions

A large size groundwater abstraction is located approximately 500 m to the north of the A2 corridor. It is currently licensed for general use relating to construction by L.S. Eastern Quarry Limited, with a maximum annual abstraction limit of 1,700,204 m^3.

A second large size groundwater abstraction is located approximately 700 m to the south of the A2 corridor. It is currently licensed for potable water supply by Thames Water Utilities Ltd., with a maximum annual abstraction limit of 829,650 m^3.

There are three groundwater abstraction licences in Zone 9 listed within the GroundSure EnviroInsight (4), all with the same licence number and believed to be at the same location, as shown in Table 6-3.

Table 6-3 Groundwater Abstraction Licences within Zone 9

Licence No.	Details	Status	Volume (m^3)
9/40/01/0128/GR	Potable water supply – direct	Version start date: 22 November 2006 Active Issue No: 102	Annual volume: 829,650 Max daily volume: 4,000
9/40/01/0128/GR	Potable water supply – direct	Start date: 22 November 2006 Active Issue No: 102	Annual volume: 829,650 Max daily volume: 4,000
9/40/01/0128/GR	Potable water supply – direct	Start date: 17 June 1994 Active Issue No: 100	Not supplied

There are 23 active, or inactive potable water supply, groundwater abstractions with 1 km of Zone 9 that are closer to Zone 9 than the neighbouring zones, as shown in Table 6-4.

Table 6-4 Groundwater Abstractions within 1 km of Zone 9

Distance and Orientation from Zone 9	Licence No.	Details	Status	Volume (m^3)
292 m south	SO/040/0037/006	Potable water supply – direct	Start date: 23 June 2010 Active Issue No: 1	Annual volume: 6,716,000 Max daily volume: 24,200
292 m south	01/156	Potable water supply – direct	Start date: 1 October 2004 Inactive Issue No: 3	Annual volume: 6,716,000 Max daily volume: 24,200
439 m north	9/40/01/0050/GR	General use relating to secondary category (medium loss)	Start date: 9 October 2008 Active Issue No: 104	Annual volume: 1,700,204 Max daily volume: 6,546
501 m south-east	SO/040/0037/006	Potable water supply – direct	Start date: 23 June 2010 Expiry date: 31 March 2020 Issue No: 1	Annual volume: 6,716,000 Max daily volume: 24,200
501 m south-east	01/156	Potable water supply – direct	Start date: 1 October 2004 Inactive Issue No: 3	Annual volume: 6,716,000 Max daily volume: 24,200
526 m south	SO/040/0037/006	Potable water supply – direct	Start date: 23 June 2010 Expiry date: 31 March 2020 Issue No: 1	Annual volume: 6,716,000 Max daily volume: 24,200
526 m south	01/156	Potable water supply – direct	Start date: 1 October 2004 Inactive Issue No: 3	Annual volume: 6,716,000 Max daily volume: 24,200
564 m south	01/156	Potable water supply – direct	Start date: 1 October 2004 Inactive Issue No: 3	Annual volume: 6,716,000 Max daily volume: 24,200
564 m south	SO/040/0037/006	Potable water supply – direct	Start date: 23 June 2010 Active Issue No: 1	Annual volume: 6,716,000 Max daily volume:24,200
564 m south	SO/040/0037/006	Potable water supply – direct	Start date: 23 June 2010 Active Issue No: 1	Annual volume: 6,716,000 Max daily volume:24,200
564 m south	01/156	Potable water supply – direct	Start date: 1 October 2004 Inactive Issue No: 3	Annual volume: 6,716,000 Max daily volume: 24,200
626 m south	SO/040/0037/006	Potable water supply – direct	Start date: 23 June 2010 Active Issue No: 1	Annual volume: 6,716,000 Max daily volume: 24,200

Distance and Orientation from Zone 9	Licence No.	Details	Status	Volume (m^3)
626 m south	01/156	Potable water supply – direct	Start date: 1 October 2004 Inactive Issue No: 3	Annual volume: 6,716,000 Max daily volume: 24,200
635 m south	01/156	Potable water supply – direct	Start date: 1 October 2004 Inactive Issue No: 3	Annual volume: 6,716,000 Max daily volume: 24,200
635 m south	SO/040/0037/006	Potable water supply – direct	Start date: 23 June 2010 Active Issue No: 1	Annual volume: 6,716,000 Max daily volume: 24,200
846 m north	01/152	Potable water supply – direct	Start date: 7 July 2002 Inactive Issue No: 1	Not supplied
847 m north	01/156	Potable water supply – direct	Start date: 1 October 2004 Inactive Issue No: 3	Annual volume: 6,716,000 Max daily volume: 24,200
847 m north	SO/040/0037/006	Potable water supply – direct	Start date: 23 June 2010 Active Issue No: 1	Annual volume: 6,716,000 Max daily volume: 24,200
986 m west	37/099	Spray irrigation – direct	Start date: 19 December 2014 Active Issue No: 102	Annual volume: 30,000 Max daily volume: 360
986 m west	37/099	Spray irrigation – direct	Start date: 19 December 2014 Active Issue No: 102	Annual volume: 30,000 Max daily volume: 360

6.2.5.4. Groundwater Vulnerability

All of Zone 9 is within an SPZ, ranging from SPZ 1 (inner catchment) to SPZ 3 (total catchment), with the majority of the zone being within a SPZ 2 (outer catchment). These designations relate to the potable water abstractions on and within close proximity to the zone.

The potable water abstractions within the zone boundary are in the south-easternmost part of the zone, and this area is within a SPZ 1. There is an area of SPZ 3 across the eastern portion of the zone, and the north-western part of the zone is also within a SPZ 1.

Most of the Zone is classed as being within a minor aquifer intermediate groundwater vulnerability zone, with the area to the north in Eastern Quarry forming a major aquifer intermediate vulnerability zone.

6.2.6. Flood Risk

The majority of the zone is recorded by the Environment Agency (10) as being at a very low level of risk of flooding from rivers, the sea, surface water and reservoirs – indicating a 1 in 1000 (0.1 %) chance of flooding in one year. Isolated areas of the zone which are recorded as high risk – indicating a 1 in 30 (3.3 %) chance of flooding in one year – are located around the A2 junction near Spring Head, around the Northfleet West Grid Substation and crossing the triangular area of land between the Roman Road and the A2. All of these areas are very small in area. Based on the GroundSure EnviroInsight report (4), Zone 9 is not at risk of flooding from rivers or the sea.

A flood risk assessment is being compiled by Buro Happold.

6.2.7. Mineral Abstractions

According to the BGS Mining Plans Portal (45), the area of the A2 corridor is known to encounter deneholes. Information about man-made cavities in the ground obtained from Peter Brett Associates (35) shows no recorded deneholes within the zone, although there are 16 deneholes and one Chalk mine recorded within 500 m of the zone boundary, including four within 50 m of the zone boundary.

To the north of the A2 is a major disused chalk quarry, known as Eastern Quarry. Another quarry known as Western Quarry is located to the north-west of the Bean road junction of the A2, and is currently occupied by the Bluewater Retail Park.

6.2.8. Designated Environmentally Sensitive Sites

The majority of Zone 9 is classified as greenbelt land and all of Zone 9 is within a nitrate vulnerable zone for groundwater (4) (11). There are two areas of ancient woodland located immediately adjacent to the southern zone boundary (“The Thrift” and “Parkhill Wood”), and a small area of ancient woodland within the southern part of Beacon Wood Country Park, “Beacon Wood”, approximately 860 m south of the zone.

Darenth Wood, a 122.91 ha site to the west of the zone and Lords Wood, a 32.55 ha to the south-west of the zone are classified as areas of ancient woodland and ancient replanted woodland respectively. Darenth Wood is also designated as an SSSI, as is Lords Wood which falls under the Darenth Wood SSSI designation. The majority of Darenth Wood is classified as being in a “favourable” condition, although the section west of the zone is classified as being in a “unfavourable recovering” condition. The medieval woodland boundary of Darenth Wood to the west of the zone is also classified as a scheduled monument.

There is one feature classified as a listed building within the zone boundary; the grade II Swanscombe cutting footbridge crossing the A2 east of the A296 junction. There are seven listed buildings within 1 km of Zone 9.

There is a scheduled monument called Springhead Roman Site that partially extends across the zone’s easternmost boundary, from Zone 8. This and other designated environmentally sites within Zones 7 and 8, are discussed within Sections 4 and 5.

6.2.9. Environmental Permits, Incidents and Registers

The environmental permits, incidents and registers within Zone 9 are summarised in Table 6-5.

Table 6-5 Environmental Permits, Incidents and Registers Located within Zone 9

Owner	Type of Permit, Incident and/or Register	Status	Additional Information
Forestrall Ltd.	Part B (Local Authority Pollution Prevention and Control (LAPPC))	Historical	Timber Combustion
Esso Springhead	Part B (LAPPC)	Historical	Petrol Vapour Recovery Process
Southfleet Water Treatment Works	Licensed Discharge Consent	Active	Effluent type: Trade discharge – process Permit number: P05586 Permit version: 2 Effective Date: 01 January 2010

The environmental permits, incidents and registers located within 500 m of Zone 9 are summarised in Table 6-6.

Table 6-6 Environmental Permits, Incidents and Registers Located within 500 m of Zone 9

Distance and Orientation from Zone 9	Owner	Type of Permit, Incident and/or Register	Status	Additional Information
479 m north	Lafarge Cement UK	Licensed Discharge Consent	Active	Effluent type: Sewage discharges – final/treated effluent – not water company Permit number: P10782 Permit version: 1
479 m north	Lafarge Cement UK	Licensed Discharge Consent	Active	Effluent type: Sewage discharges – final/treated effluent – not water company Permit number: P10783 Permit version: 1

There were 11 pollution incidents recorded within Zone 9 and these are presented in Table 6-7. Incidents which were classified as Category 4 (no impact), to land, water and air have not been included.

Table 6-7 Records of Pollution Incidents within Zone 9

Incident Date	Pollutant	Impacts
18 July 2001	Contaminated water: firefighting run-off	Water impact: Category 3 (minor)
21 June 2002	Materials and wastes: soils and clay	Land impact: Category 3 (minor)
15 August 2002	Oils and fuel: insulating and cable oils	Water impact: Category 3 (minor) Land impact: Category 3 (minor)
11 August 2004	Specific waste materials: metal wastes	Land impact: Category 3 (minor)
13 March 2006	Specific waste materials: metal wastes	Land impact: Category 3 (minor)
13 July 2010	Atmospheric pollutants and effects: smoke	Air impact: Category 3 (minor)
14 February 2012	Pollutant not identified	Water impact: Category 3 (minor)
10 January 2013	Atmospheric pollutants and effects: smoke	Air impact: Category 3 (minor)
11 November 2013	Contaminated water: firefighting run-off	Air impact: Category 3 (minor) Land impact: Category 3 (minor)
	Atmospheric pollutants and effects: smoke	
28 February 2014	Oils and fuel: gas and fuel oils	Water impact: Category 3 (minor)

There were eight pollution incidents recorded within 500 m of Zone 9 and these are presented in Table 6-8. Incidents which were classified as Category 4 (no impact), to land, water and air have not been included.

Table 6-8 Records of Pollution Incidents within 500 m of Zone 9

Direction and Orientation from Zone 9	Incident Date	Pollutant	Impacts
24 m west	11 July 2002	Soils and clay	Land impact: Category 3 (minor)
127 m south	05 July 2002	Construction and demolition materials and wastes	Land impact: Category 3 (minor)
224 m south	26 April 2003	Household waste	Land impact: Category 3 (minor)
244 m south	15 March 2004	Construction and demolition materials and wastes	Land impact: Category 2 (significant)
271 m north	04 March 2002	Oils and fuel: diesel	Water impact: Category 2 (significant) Land impact: Category 2 (significant)
278 m north	23 July 2001	Contaminated water: firefighting run-off	Water impact: Category 3 (minor)
305 m west	19 September 2002	Household waste	Land impact: Category 3 (minor)
369 m south	10 September 2002	Construction and demolition materials and wastes	Land impact: Category 3 (minor)

There is a National Incident Recording System List 1 record contained within the GroundSure EnviroInsight (4) relating to a substantiated pollution incident. This incident occurred on 13 January 1999 and affected a stretch of the River Darent. The water impact was considered to be major (persistent and extensive) and the land impact to be significant.

6.2.10. Landfills and Other Waste Sites

There are no landfills within Zone 9, but there is one waste management site, listed under four different permit numbers, as detailed within Table 6-9. The location of the waste management site is shown on Figure 012.

Table 6-9 Waste Management Sites within Zone 9

Site Name and Address	Site Type and Size	Operator	Licence Numbers and Reference	Licence Issue Date and Status
Oakdene, Watling Street, DA2 8AH	Metal recycling site (vehicle dismantler) Size: <25000 tonnes	Halford Clive	Permitting number: BEA002 EPR: - WML: 10386	22 June 2007 Status: issued
A2 Breakers Oakdene, Watling Street, DA2 8AH	Metal recycling site (vehicle dismantler) Size: <25000 tonnes	Mr Clive Halford and Mr Darren Winchester	Permitting number: BEA002 EPR: GP3798HT/A001 WML: 10386	22 June 2007 Status: issued
A2 Breakers Oakdene, Watling Street, DA2 8AH	Vehicle depollution facility Size: <25000 tonnes	Mr Clive Halford and Mr Darren Winchester	Permitting number: BEA002 EPR: EA/EPR/GP3798HT/V002 WML: 10386	22 June 2007 Status: modified on 15 October 2009

Site Name and Address	Site Type and Size	Operator	Licence Numbers and Reference	Licence Issue Date and Status
A2 Breakers Oakdene, Watling Street, DA2 8AH	End of life vehicle facility Size: <25000 tonnes	Mr Clive Halford and Mr Darren Winchester	Permitting number: BEA002 EPR: EA/EPR/GP3798HT/V003 WML: 10386	22/06/2007 Status: modified on 24 June 2014

There are six landfills and waste management sites within 1 km of the zone (4), as presented in Table 6-10 below.

Table 6-10 Landfill and Waste Management Sites within 1 km of Zone 9

Distance and Orientation from Zone 9	Licence/ Reference Number	Site Name and Type	Operator	Waste Type	Licence Issue Date and Status
23 m north	EPR: EA/EPR/PB3934RN/A001 WML: 40244	Washmills Recycling Centre	OCL Regeneration Limited	Treatment of waste to produce soil	Issue date: 03 June 2014 Status: issued
185 m north	None	Ground workings and refusing heap (identified on historical maps)	None provided	None provided	Map date: 1932
562 m west	DA17	Darenth Wood Road	Rural District Council of Dartford	Inert, industrial, commercial, household	Licence issue: 20 February 1980 Status: historical
574 m south-west	DA2	Darenth Wood	None given	Inert commercial	Licence issue: 01 January 1976 Status: historical
589 m north-west	EPR: BS6726IL/A001 WML: 210032	Stone Pit 2	Seer Restoration Ltd	Inert landfill	Issue date: 18/03/2004 Status: issued
646 m west	None	Refuse tip	None provided	None provided	Map date: 1971
655 m west	None	Refuse tip	None provided	None Provided	Map date: 1962
855 m north	DA14	Alkerden Lane	Blue Circle Industries plc	Inert	Licence issue: 01 January 1976 Status: surrendered

6.2.11. Potentially Contaminative Industrial Sites

There are 20 features deemed as being “potentially contaminative” within the GroundSure EnviroInsight (52), as listed in Table 6-11 below. The majority of these features are infrastructure related, such as pylons, masts and a gantry, and are not considered to have a significant impact on the contamination status of the zone.

Table 6-11 Potentially Contaminative Industrial Sites within Zone 9

Feature	Location within the Zone and Address (if Provided)	Activity	Category
Pylon	East: south of the slip road off the A2	Electrical features	Infrastructure and facilities
Electricity substation	East: on the inside of the slip road off the A2	Electrical features	Infrastructure and facilities
Pylon	East: south of the slip road off the A2	Electrical features	Infrastructure and facilities
Water works	East: south of the slip road off the A2	Non-alcoholic drinks	Foodstuffs
Pylon	East: north of the A2	Electrical features	Infrastructure and facilities
Pylon	West: in the centre of the roundabout that joins Bean Lane to the B255	Electrical features	Infrastructure and facilities
Pylon	West: north of the A2	Electrical features	Infrastructure and facilities
Gantry	East: across the A2 adjacent to where the slip road joins	Travelling cranes and gantries	Industrial features
Pylon	Central: north of the A2	Electrical features	Infrastructure and facilities
Pylon	West: adjacent to Bean Lane, south of the A2	Electrical features	Infrastructure and facilities
Pylon	Central: north of the A2	Electrical features	Infrastructure and facilities
Pylon	East: adjacent to the slip road off the A2	Electrical features	Infrastructure and facilities
Pylon	East: north of the A2	Electrical features	Infrastructure and facilities
Pylon	West: north of the A2	Electrical features	Infrastructure and facilities
Silo	East: part of the water works south of the A2 slip road	Hoppers and silos	Farming
Pylon	East: north of the A2	Electrical features	Infrastructure and facilities
Pylon	Central: north of the A2	Electrical features	Infrastructure and facilities
Mast	West: south of Roman Road	Telecommunications features	Infrastructure and facilities
Pylon	East: within the central reservation of the A2	Electrical features	Infrastructure and facilities
Pylon	West: north of Roman Road	Electrical features	Infrastructure and facilities

6.2.12. Information Gained from Public Records

6.2.12.1. Northfleet West Grid Substation

Northfleet West Grid Substation is off-site, located adjacent to the north of Zone 9, covers an area of approximately 39 ha and is owned by National Grid Property Holdings (53). According to available historical maps, the substation was developed, or at least had started to be developed, by 1961.

A verification report for statutory remediation was submitted in 2014 and approved by Dartford Borough Council (37). The substation comprised three substations set within open fields. The verification report indicated that previous reports associated with the ground investigation and remediation of the substation identified no soil impact within the arable farmland but there were low concentrations of hydrocarbons found within the shallow soils in the substation areas. There was no evidence of soil contamination at depth within the soils. Low concentrations of dissolved-phase petroleum hydrocarbons were identified within the groundwater (at 30 m bgl). The presence of these substances were attributed by Parsons Brinckerhoff to on-site contamination and off-site pollution incidents including a 20,000 litre diesel spill to the west of the substation site. The pollution incident is considered to be the incident which occurred on 4 March 2002, 271 m north of Zone 9.

Remediation works, led by Parsons Brinckerhoff Ltd, were carried out at the substation between March 2014 and May 2014, ensuring that the proposed end use is suitable for open storage, with the exception of agricultural land which will remain as such. The remediation was focussed on removing potential sources of

oil within structures and cables. Prior to remediation, the length of oil-filled cables at the substation was approximately 11.7 km, although constraints meant that cables along the southern boundary were not remediated (53).

Following remediation, the substation site was considered suitable for an open storage, and continued agricultural, land use and no unacceptable risks to identified receptors were thought to remain. Based on the site walkover, above ground structures have been demolished.

6.3. Preliminary Geo-environmental Conceptual Site Model

The approach used for the creation of the preliminary CSM is detailed in Section 2.2.1. Identified zone-specific potential sources, pathways and receptors of contamination are listed below, with the corresponding risk rating detailed in Section 2.2.1.2.

6.3.1. Potential Sources

6.3.1.1. Potential On-Zone Sources

The potential within zone sources identified from the background searches, data review and site walkover observations for the zone that have been included in the CSM are as follows:

- the main roads within the zone boundary (notably the A2, Roman Road and Bean Lane);
- Made Ground beneath the zone;
- the historical brick works in the western part of the zone;
- an electricity substation in the eastern part of the zone;
- the water works in the eastern part of the zone; and
- A2 Breakers within the western part of the zone, which has been a metal recycling site, vehicle depollution facility and an end-of-life vehicle facility.

6.3.1.2. Potential Off-Zone Sources

Potential off-zone sources of contamination are discussed earlier on in this chapter, but are not included within the CSM, as discussed in Section 2.2.1.

6.3.2. Potential Pathways

The primary exposure pathways that are considered applicable are:

- inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres;
- inhalation of soil- or groundwater-derived vapours;
- migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion;
- leaching/migration of contaminants from soils;
- direct surface water run-off and sub-surface flow to surface waters;
- lateral migration of contaminated groundwater; and
- vertical migration of contaminated groundwater.

6.3.3. Potential Receptors

As stated in Section 2.2.1, the CSM for each Chapter only considers receptors within each zone. The identified potential receptors of possible contamination are listed below:

- the Secondary A aquifer within the Thanet Formation and the Lambeth Group;
- the Secondary (undifferentiated) aquifer within the Head deposits;
- the Principal aquifer within the Chalk;
- the small pond located in the west of the zone
- residents within the properties in the western part of the zone;
- zone visitors, workers and maintenance workers; and
- trespassers.

A schematic CSM for Zone 9 is represented on Figure 012.

Table 6-12 Preliminary Conceptual Site Model for Zone 9

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
Zone 9: **Potential contaminants in soil/groundwater on the zone, originating from the following sources:** • the main roads within the zone boundary; • Made Ground; • historical brick works; • water works; and • A2 Breakers waste management facility. *Potential contaminants include metals/metalloids and oils.*	Humans (zone residents, visitors, workers, maintenance workers and trespassers)	Inhalation, ingestion and/or dermal contact with contaminants in soil and soil-derived dust/fibres	**Medium**	**Low likelihood** There are few people within the zone that are likely to come into contact with soil or soil-derived dusts/fibres. Additionally, large portions of the zone are covered with hardstanding, minimising the potential for dust generation. The residential properties were developed prior to the majority of the sources at the zone and therefore the likelihood of the residents having contact with contaminants in soil is low.	**Moderate/Low**
		Inhalation of soil- or groundwater-derived vapours	**Medium**	**Unlikely** The historical brickworks within the zone boundary and the zone's current primary use a roadway, and the presence of A2 Breakers means there is the potential for vapours to be present, especially following any kind of fuel leak. The roadway is likely to have surface water control measures which will manage potential contaminants from the use of roadway. It is	**Low**
		Migration and accumulation of ground gases, followed by inhalation or ignition, causing asphyxiation and/or explosion	**Severe**	**Unlikely** Ground gas can be generated by the Made Ground present beneath large parts of the zone. However, it is not considered to generate significant levels of ground gas based on the zone's history. No putrescible material was known to be deposited in Zone 9. There are few buildings within the zone, meaning few places that would allow the build-up of ground gas.	**Moderate/Low**

Sources	Receptor	Potential Pathway	Potential Consequence	Probability	Classification of Risk
	Controlled waters receptors: Secondary and Principal aquifers beneath the zone and the small pond in the west of the zone.	Leaching/migration of contaminants from soils, then lateral and/or vertical migration of contaminated groundwater	**Medium**	**Likely** It is considered likely that leaching/migration of contaminants from soils will occur. In those areas covered by hardstanding, recent contamination from the roadways still have the potential to impact the groundwater beneath the zone, following surface runoff from the areas covered in hardstanding to the areas where infiltration can occur. The sensitivity of the groundwater beneath the zone increases the risk associated with this pathway. The aquifers within the superficial deposits and those within the bedrock are thought to be in hydraulic connectivity with each other, thus facilitating the movement of any contamination within groundwater between the two.	**Moderate**
		Direct surface water run-off and sub-surface flow to surface waters	**Medium**	**Unlikely** Surface runoff from the zone is deemed likely, considering large portions of it are covered in hardstanding. This would allow any contamination present within the zone to be transported elsewhere. It is considered that the A2 would have surface water run-off management, preventing run-off into the surface waters. The only surface water feature within the zone is a small, unnamed pond which is not considered a critical controlled waters receptor.	**Low**

6.4. Geotechnical Context

6.4.1. Geological and Geotechnical Hazards

Table 6-13 describes the principal geological and geotechnical hazards which have been identified as part of this desk study. The list of hazards is not exhaustive and are only briefly summarised.

Table 6-13 Potential Geological and Geotechnical Hazards in Zone 9

Hazard	Description	Comment
Aggressive ground conditions	The BRE Special Digest (48) states that chemical agents, particularly sulphates, sulphides and acids can naturally occur in many soils and could be damaging to concrete.	The London Clay Formation is described as occasionally containing disseminated pyrite which can be a cause of aggressive ground conditions.
Buried foundations	Buried foundations can cause a delay to construction and incur additional costs.	Old buildings have been identified in the section of land between the Roman Road and the A2 on historic maps. Potential for encountering buried foundations.
Buried services	Damage to underground services can cause injury, significant disruption and environmental damage; it can also cause a delay to construction and incur considerable costs.	There are few buildings within Zone 9, however the A2 road is likely to have associated drainage and electrical services. Additionally, the Northfleet West Grid Substation is located along the northern boundary of the zone, and can be expected to have substantial amounts of buried electrical services.
Chalk dissolution features	Chalk is a chemically vulnerable rock, and reactions with groundwater can lead to dissolution. These dissolution features can cause subsidence, and depending on the nature of overlying deposits, sinkholes.	The GroundSure report (3) has identified six solution pipes within the chalk in the west of Zone 9. The information from Peter Brett Associates (35) confirms this, as well as indicating five locations of solution pipes within 500 m of the zone boundary.
Historical works	Historical works such as abandoned quarries may be backfilled with hazardous materials or any poorly compacted material which is susceptible to settlement	The GroundSure report (3) has identified multiple historic unspecified pits and quarries in the western portion of the zone, as well as an old chalk pit in the east, and old clay pits towards the centre of the zone.
Perched/high water table	The presence of high groundwater levels/perched water tables needs to be considered when undertaking construction.	Groundwater was undetected in all but two historical boreholes, at which the level was detected at about 15 m bgl. In both boreholes the groundwater was found within the Chalk. Given this evidence it is unlikely that a perched or high water table will be encountered within the zone.
Running sand	Running sand is the flow of sand into an excavation or void caused by water pressure. This can lead to subsidence of the surrounding ground.	The GroundSure report (3) has identified large amounts of the site area as a moderate risk of running sand. These areas mostly correspond to areas where the Thanet Formation is recorded.
Saline groundwater	The presence of saline groundwater (commonly at coastal sites) may result in increased corrosion of steel.	The River Thames is located 2 km to the north of Zone 9 and while it may have

Hazard	Description	Comment
	Appropriate control measures will need to be taken.	an impact on groundwater in this area, it is considered unlikely.
Variable rockhead/deep weathering profile	A deep weathering profile or physical erosion can result in an uneven rockhead profile resulting in areas of reduced bearing capacity or potential for varying lengths of piles.	The area is unlikely to have been quarried, but erosion and weathering from periglacial and fluvial processes will be a concern.
Weak bearing materials	Construction of foundations upon weak bearing strata can result in bearing capacity failure. Some geological units are particularly susceptible to reductions in strength and stiffness due to weathering and pockets of weathering may result in areas of weak bearing capacity.	The superficial deposits in Zone 9, particularly the Head will have a low bearing capacity.
Weak, compressible ground	Loading of compressible soils and unconsolidated materials can cause excessive settlements. Materials such as peat within areas of alluvium are particularly vulnerable.	Head with traces of peat is present in Zone 9. These soils are likely to be weak and could deform and settle as a result of the loads imposed on them.

6.4.2. Geotechnical Risk Register

The Geotechnical Risk Register is presented as Table 6-14. It comprises an initial assessment of the risks, prior to the application of risk mitigation measures and shows how the risks can be reduced by the application of the measures. In most cases the mitigation measures will be sufficient to reduce the risk to a low ranking. In some cases the risk may be reduced but a significant residual risk remains which must be managed, and in other the risk mitigation measure cannot reduce the likelihood of an event but will be used to mitigate potential effects.

Prior to implementation of the proposed mitigation measures, the risks considered to be substantial are:

- Chalk dissolution features;
- historical works;
- running sand; and
- variable rockhead.

Most of the other risks are rated as “moderate” or “low”.

6.4.3. Mitigation Measures

The mitigation measures considered are those that may be applied during design or construction, as appropriate, to mitigate the hazard identified and, in most cases, to render the risk insignificant. Mitigation measures considered appropriate for the Substantial risks listed above include:

- further desk study (including a detailed walkover);
- ground investigation including *in situ* and laboratory testing;
- planned methodology for the earthworks; and
- detailed design for the temporary construction roads.

6.4.3.1. Residual Risk

Following risk identification, assessment and the application of recommended mitigation/avoidance measures most risks have been assessed to be “low”. However, it should be recognised that some residual risks remain, as described in Table 6-14.

Table 6-14 Geotechnical Risk Register for Zone 9

Category Risk No.	Constraint	Prior to Mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital Cost	Programme	Safety	Capital Cost	Programme	Safety				Capital Cost	Programme	Safety	Capital Cost	Programme	Safety	
1	Aggressive ground conditions	2	3	3	1	6	6	2	M	Ground investigation to assess presence of contamination or aggressive chemicals.	2	2	2	1	4	4	2	L
2	Buried foundations	2	3	3	1	6	6	2	M	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried foundations.	2	2	2	1	4	4	2	L
3	Buried services	2	3	3	3	6	6	6	M	Where possible review more detailed building records. Ground investigation to determine the location of any perceived buried services.	2	2	2	1	4	4	2	L
4	Chalk dissolution features	3	3	3	1	9	9	3	S	Search of Peter Brett Associates' natural and man-made cavity database (3). Ground investigation to confirm geological succession and risk of dissolution across the site.	2	2	2	1	4	4	2	L
5	Historical works	3	3	3	1	9	9	3	S	See buried foundations and buried services.	2	2	2	1	4	4	2	L
6	Perched/high groundwater	1	2	2	1	2	2	1	L	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	1	1	1	1	1	1	1	L
7	Running sand	3	3	3	1	9	9	3	S	Ground investigation to confirm geological succession and geotechnical properties across the site.	2	2	2	2	4	4	4	L
8	Saline groundwater	2	2	2	1	4	4	2	L	Ground investigation and monitoring to determine the groundwater regime. Local experience (anecdotal evidence) to be taken into account.	2	1	1	1	2	2	2	L

Category Risk No.	Constraint	Prior to Mitigation								Proposed Mitigation Measures	Residual Risk							
		Likelihood	Severity			Risk			Risk Ranking		Likelihood	Severity			Risk			Risk Ranking
			Capital Cost	Programme	Safety	Capital Cost	Programme	Safety				Capital Cost	Programme	Safety	Capital Cost	Programme	Safety	
9	Variable rockhead	3	3	3	1	9	9	3	S	Ground investigation to confirm geological succession and geotechnical properties across the site.	3	2	2	1	6	6	3	M
10	Weak bearing materials	2	3	3	1	9	9	3	M	Ground investigation to confirm geological succession and geotechnical properties across the site.	2	2	2	1	4	4	2	L
11	Weak compressible ground	2	3	3	1	6	6	2	M	Ground investigation to confirm geological succession. Where necessary consider appropriately in geotechnical design.	2	2	2	1	4	4	2	L

6.5. Zone 9 Summary

6.5.1. Geo-environmental Summary

The zone is located in the south-western part of the site and primarily comprises part the A2 Watling Street, a large six-lane main road, and associated slip roads, notably the A296 Roman Road which is a two lane road in the western part of the zone and the B255 Bean Lane which is predominantly four lanes and runs perpendicular to the A2 and the A296.

Other land uses within the zone include water works in the south-easternmost part of the zone, an electricity substation towards the central portion of the zone and a small pond, industrial premises and residential properties in the western part of the site and along the northern boundary of the site accessed off the A296.

Risks to controlled waters via leaching from soils were considered to be moderate. Other risks to controlled waters were considered low. Risks to human health were considered to be low to moderate/low.

6.5.2. Geotechnical Summary

In Zone 9 the geological succession is localised Made Ground and Head at the top of the succession, covering London Clay, Lambeth Group and Thanet Formation across the majority of the area. This succession is then all underlain by the undifferentiated White Chalk bedrock. In some areas, the Chalk is found very close to the surface, where the other deposits thin out, leaving just a layer of topsoil over the Chalk. The topography of the zone is dominated by a hill approximately in the centre, reaching about 80 m AOD in elevation, and sloping off to the east and west, with a minimum elevation of about 15 m AOD.

Substantial risks within Zone 9 include Chalk dissolution features, which can have an impact of cost and programme for works, and running sand, caused by excavations in sand breaching the water table. Historical ground works may also pose a hazard, as pits and quarries may be poorly backfilled leading to subsidence. Finally variable rockhead may cause delays to the programme and increased construction costs.

Moderate risk constraints include buried services, aggressive ground conditions, buried foundations, weak bearing materials and compressible ground.

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Figures

Figure 001 Site Layout Plan

Figure 002 Environmental Permit Boundaries

Figure 003 Soil and Ground Conditions Hazards and Constraints Plan

Figure 004 Geotechnical Hazards and Constraints Plan

Figure 005 Borehole Grade Map

Figure 006 Borehole Depth Map

Figure 007 Geological Section A-A'

Figure 008 Zone 7: Key Features

Figure 009 Zone 7 Schematic Conceptual Site Model

Figure 010 Zone 8: Key Features

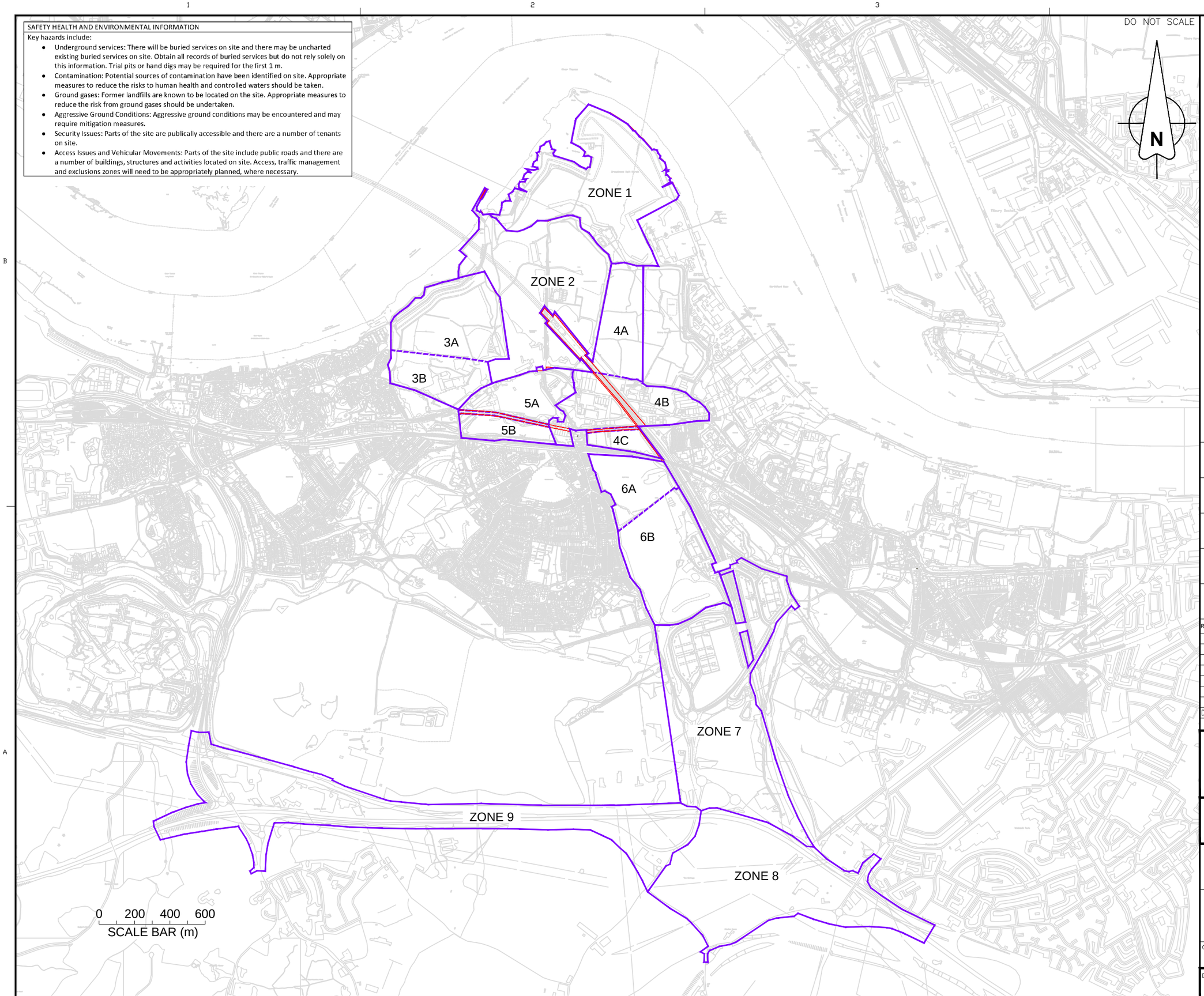
Figure 011 Zone 8 and 9: Schematic Conceptual Site Model

Figure 012 Zone 9: Key Features

SAFETY HEALTH AND ENVIRONMENTAL INFORMATION

Key hazards include:

- Underground services: There will be buried services on site and there may be uncharted existing buried services on site. Obtain all records of buried services but do not rely solely on this information. Trial pits or hand digs may be required for the first 1 m.
- Contamination: Potential sources of contamination have been identified on site. Appropriate measures to reduce the risks to human health and controlled waters should be taken.
- Ground gases: Former landfills are known to be located on the site. Appropriate measures to reduce the risk from ground gases should be undertaken.
- Aggressive Ground Conditions: Aggressive ground conditions may be encountered and may require mitigation measures.
- Security Issues: Parts of the site are publically accessible and there are a number of tenants on site.
- Access Issues and Vehicular Movements: Parts of the site include public roads and there are a number of buildings, structures and activities located on site. Access, traffic management and exclusions zones will need to be appropriately planned, where necessary.



DO NOT SCALE

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KEY:

- ZONE BOUNDARY
- SUB-ZONE BOUNDARY
- SITE BOUNDARY

Rev.	Description	By	Date	Chk'd	Auth
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	Purpose of issue	Rev	Date		Authorised

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Consulting Engineers,
Woodcote Grove,
Ashley Road,
Epsom, Surrey, England, Fax (01372) 740055
KT18 5BW Tel. (01372) 726140

©

Client: LONDON RESORT COMPANY HOLDINGS

Project: PARAMOUNT PARK ENTERTAINMENT RESORT

Title: SITE LAYOUT PLAN

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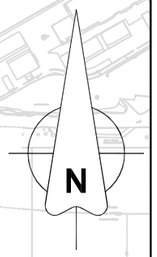

KEY:

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- SOUTH FLEET PIT
- SITE BOUNDARY

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SOUTH FLEET PIT GR19

A2 BREAKERS EPR/GP3798HT

ZONE 7

ZONE 9

ZONE 8

PEPPERHILL HOUSEHOLD WASTE RECYCLING CENTRE EPR/KP3798HZ EPR/GP3198HY

PEPPERHILL HOUSEHOLD WASTE RECYCLING CENTRE LICENSED DISCHARGE CONSENT P10736

SOUTH FLEET WATER TREATMENT WORKS LICENSED DISCHARGE CONSENT P05586

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Client
LONDON RESORT COMPANY HOLDINGS

Project
PARAMOUNT PARK
ENTERTAINMENT RESORT

Title
ENVIRONMENTAL
PERMIT BOUNDARIES
(ZONE 7, 8 AND 9)

Original Scale	Drawn	Checked	Authorised	
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	Date 03.04.15	Date -	Date -	

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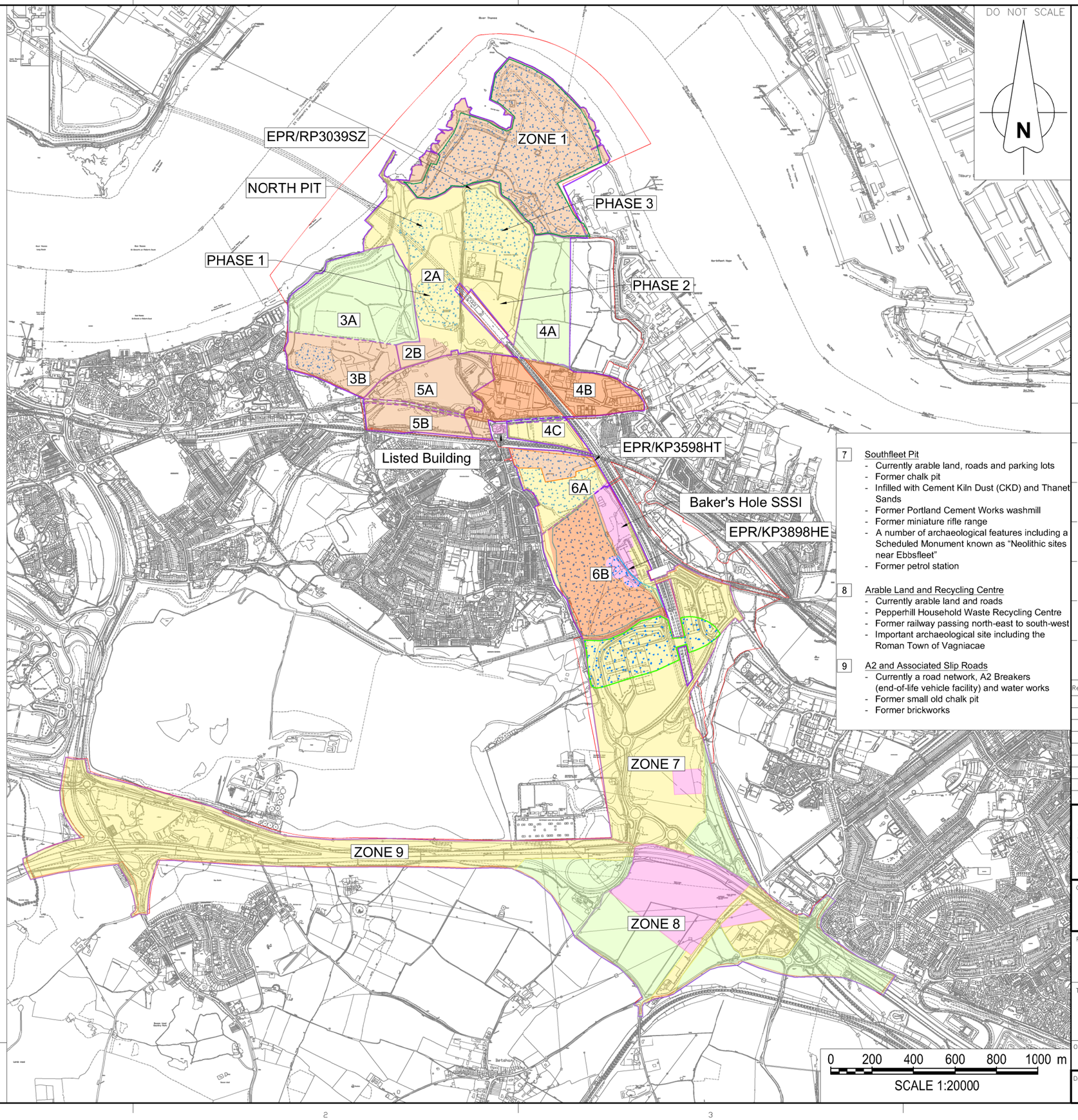

DO NOT SCALE

N

1 Broadness Landfill

- Cement Kiln Dust (CKD) deposited across entire zone
- Leachate collection system in place
- Under monitoring programme
- Pre-licensing needs and without land-based permits

2A North Pit, South Pit & Surge Pile Landfills

North Pit - CKD deposited
- Licence WML P/1/11 (handed back)

South Pit & Surge Pile - CKD deposited
- Phase 1 CKD deposited under WML P/1/11A
- Phase 2 not used for infilling
- Phase 3 re-permitted as RP3039SZ
- Disused sewage works

2B Cement Works

- Historical cement works
- Associated railways, gasworks and tanks
- Current use: old building foundations

3A Swanscombe Marshes

- No significant risk
- Historically and presently predominantly marshland

3B Former Whiting Works

- Chalk pits (possible infilling)
- Later whiting works with associated tanks
- Currently used as a welding works (operated by Basic Engineering Co Ltd)

4A Botany Marshes

- No significant risk
- Historically and presently marshland/agricultural land

4B Northfleet Industrial Estate

- Historically quarried and contained paper mills, chemical works, tar distilleries, tanks and a reservoir for industrial discharge
- Currently Kent Kraft Industrial Estate with potential contaminative activities

4C Former quarry

- A historical quarry that used to contain a rifle range
- Now overgrown and disused

5A Cement Works

- Historically a cement works
- Currently an industrial estate with commercial/industrial warehouses

5B HS1 Infilled Area

- Historically a quarry
- Infilled with High Speed 1 material

6A Bamber Pit Landfill

- Commercial waste from paper mills & cement works
- Also received domestic wastes
- Under a current monitoring programme
- WML 1937Y

6B Northfleet Landfill

- Received domestic, industrial and commercial waste
- Under monitoring programme including landfill gas extraction
- Closed to new waste
- WML1937S

7 Southfleet Pit
- Currently arable land, roads and parking lots
- Former chalk pit
- Infilled with Cement Kiln Dust (CKD) and Thanet Sands
- Former Portland Cement Works washmill
- Former miniature rifle range
- A number of archaeological features including a Scheduled Monument known as "Neolithic sites near Ebbsfleet"
- Former petrol station

8 Arable Land and Recycling Centre
- Currently arable land and roads
- Pepperhill Household Waste Recycling Centre
- Former railway passing north-east to south-west
- Important archaeological site including the Roman Town of Vagniacae

9 A2 and Associated Slip Roads
- Currently a road network, A2 Breakers (end-of-life vehicle facility) and water works
- Former small old chalk pit
- Former brickworks

ATKINS

- ZONE BOUNDARY
- SUB-ZONE BOUNDARY
- BROADNESS LANDFILL
- BAMBER PIT LANDFILL
- NORTHFLEET LANDFILL
- DCO BOUNDARY
- SOUTHFLEET PIT
- LOW
- MODERATE/LOW
- MODERATE
- HIGH
- SPECIAL CONSIDERATION
- INFILLED LAND

Drawing Number 5134008-ADD-PHASE1-FIGURE003 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
A	FOR INFORMATION / COMMENT		24.04.15		RS
	Purpose of issue		Rev Date		Authorised

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Client
LONDON RESORT COMPANY HOLDINGS

Project
PARAMOUNT PARK ENTERTAINMENT RESORT

Title
SOIL AND GROUND CONDITIONS HAZARDS AND CONSTRAINTS PLAN

Original Scale	Drawn	Checked	Authorised	
1:20000	JA	LD	RS	A3
	Date 24.04.15	Date 24.04.15	Date 24.04.15	

Drawing Number 5134008-ADD-PHASE1-FIGURE003 Rev A

Job Dept. Sub Unique No.

1 BROADNESS MARSH/LANDFILL
- AGGRESSIVE GROUND CONDITIONS (S)
- BURIED SERVICES AND FOUNDATIONS (S)
- CKD (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- HISTORICAL WORKS (M)
- HIGH GROUNDWATER (M)
- RUNNING SAND (M)
- SALINE GROUNDWATER (M)
- VARIABLE ROCKHEAD (M)

2A NORTH PIT, SOUTH PIT AND SURGE PILE LANDFILLS
- AGGRESSIVE GROUND CONDITIONS (S)
- BURIED SERVICES AND FOUNDATIONS (S)
- CKD (S)
- HISTORICAL WORKS (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- HIGH GROUNDWATER (M)
- RUNNING SAND (M)
- SALINE GROUNDWATER (M)

2B CEMENT WORKS
- AGGRESSIVE GROUND CONDITIONS (S)
- BURIED SERVICES AND FOUNDATIONS (S)
- HISTORICAL WORKS (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- HIGH GROUNDWATER (M)
- SALINE GROUNDWATER (M)

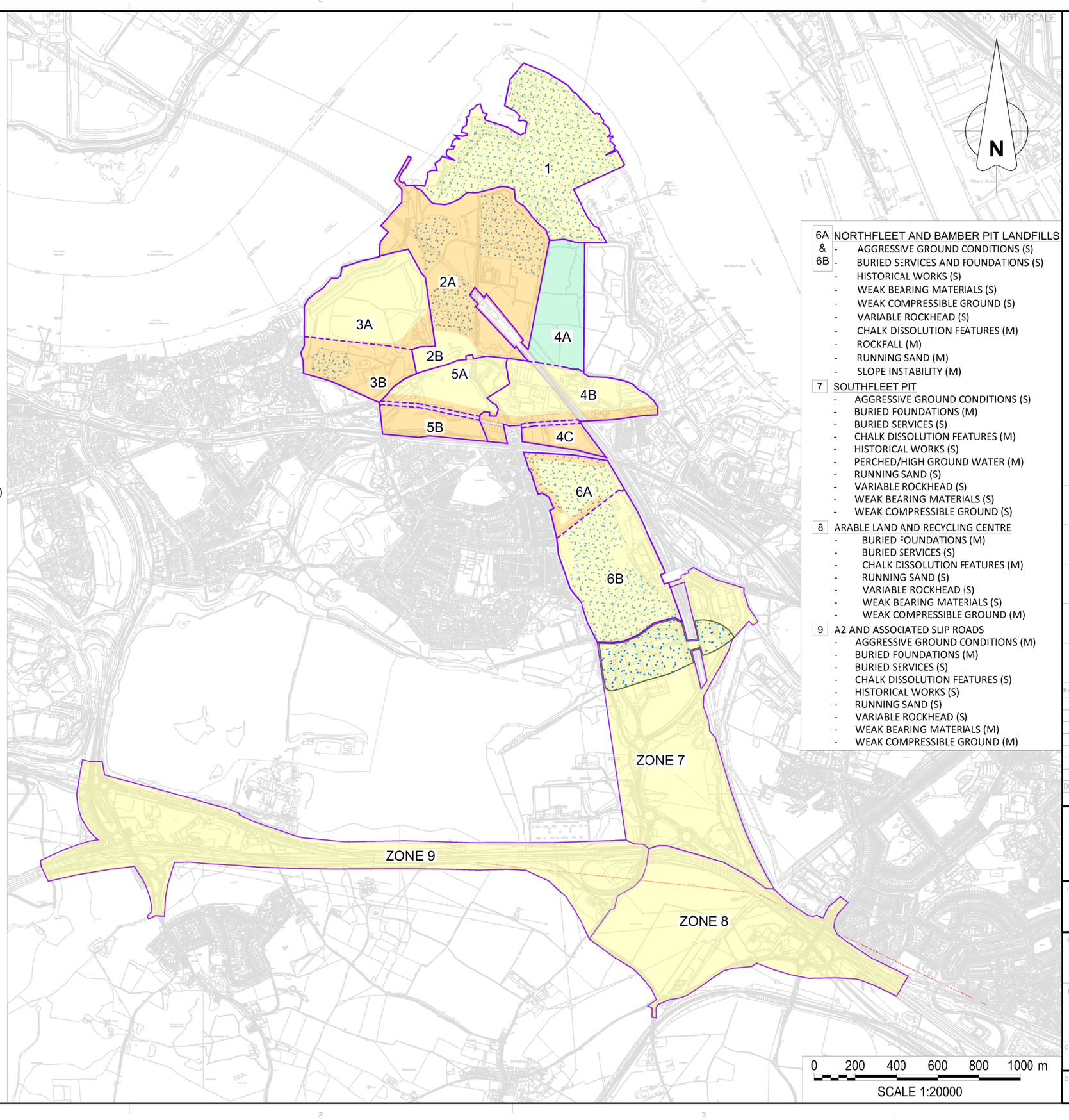
3A SWANSCOMBE MARSH
- BURIED SERVICES AND FOUNDATIONS (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- AGGRESSIVE GROUND CONDITIONS (M)
- CKD (M)
- HISTORICAL WORKS (M)
- HIGH GROUNDWATER (M)
- RUNNING SAND (M)
- SALINE GROUNDWATER (M)

4A BOTANY MARSHES
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- AGGRESSIVE GROUND CONDITIONS (M)
- HIGH GROUNDWATER (M)
- SALINE GROUNDWATER (M)

4B & 4C NORTHFLEET INDUSTRIAL ESTATE AND SPORTS FIELD
- BURIED SERVICES AND FOUNDATIONS (S)
- HISTORICAL WORKS (S)
- ROCKFALL (S)
- VARIABLE ROCKHEAD (S)
- WEAK BEARING MATERIALS (M)
- WEAK COMPRESSIBLE GROUND (M)

5A WHITECLIFF PARK AND MANOR WAY
- BURIED SERVICES AND FOUNDATIONS (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- CHALK DISSOLUTION FEATURES (S)
- HISTORICAL WORKS (S)
- ROCKFALL (S)
- AGGRESSIVE GROUND CONDITIONS (M)
- RUNNING SAND (M)

5B CTRL INFILLED AREA
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- CHALK DISSOLUTION FEATURES (S)
- HISTORICAL WORKS (S)
- ROCKFALL (S)
- AGGRESSIVE GROUND CONDITIONS (M)
- BURIED SERVICES AND FOUNDATIONS (M)
- RUNNING SAND (M)



DO NOT SCALE

6A & 6B NORTHFLEET AND BAMBER PIT LANDFILLS
- AGGRESSIVE GROUND CONDITIONS (S)
- BURIED SERVICES AND FOUNDATIONS (S)
- HISTORICAL WORKS (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)
- VARIABLE ROCKHEAD (S)
- CHALK DISSOLUTION FEATURES (M)
- ROCKFALL (M)
- RUNNING SAND (M)
- SLOPE INSTABILITY (M)

7 SOUTHFLEET PIT
- AGGRESSIVE GROUND CONDITIONS (S)
- BURIED FOUNDATIONS (M)
- BURIED SERVICES (S)
- CHALK DISSOLUTION FEATURES (M)
- HISTORICAL WORKS (S)
- PERCHED/HIGH GROUND WATER (M)
- RUNNING SAND (S)
- VARIABLE ROCKHEAD (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (S)

8 ARABLE LAND AND RECYCLING CENTRE
- BURIED FOUNDATIONS (M)
- BURIED SERVICES (S)
- CHALK DISSOLUTION FEATURES (M)
- RUNNING SAND (S)
- VARIABLE ROCKHEAD (S)
- WEAK BEARING MATERIALS (S)
- WEAK COMPRESSIBLE GROUND (M)

9 A2 AND ASSOCIATED SLIP ROADS
- AGGRESSIVE GROUND CONDITIONS (M)
- BURIED FOUNDATIONS (M)
- BURIED SERVICES (S)
- CHALK DISSOLUTION FEATURES (S)
- HISTORICAL WORKS (S)
- RUNNING SAND (S)
- VARIABLE ROCKHEAD (S)
- WEAK BEARING MATERIALS (M)
- WEAK COMPRESSIBLE GROUND (M)

ATKINS

KEY:
- ZONE BOUNDARY
- SUB-ZONE BOUNDARY
- SITE BOUNDARY
- LOW RISK
- MEDIUM RISK
- SUBSTANTIAL RISK
- INFILLED GROUND

NOTE:

THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE REPORT PHASE 1 GEO-ENVIRONMENTAL AND GEOTECHNICAL RISK ASSESSMENT 5134008/ADDITIONAL PHASE1/ REV1.0

CONSTRAINTS HAVE BEEN IDENTIFIED USING READILY AVAILABLE SOURCES OF DATA AND RISK CATEGORIES APPLIED USING ATKINS' ENGINEERING JUDGEMENT.

THE SUBSTANTIAL (S) AND MEDIUM (M) GEOLOGICAL OR GEOTECHNICAL RISKS FOR EACH ZONE ARE LISTED AND THE LEVEL INDICATED BY THE SUFFIXED LETTER. FURTHER, ZONE-SPECIFIC DETAILS ON EACH RISK IS GIVEN IN THE REPORT.

Rev.	Description	By	Date	Chk'd	Auth
A	DRAFT FOR INFORMATION/COMMENT	JA	-		JS
	Purpose of issue		Rev	Date	Authorised

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Project
PARAMOUNT PARK ENTERTAINMENT RESORT

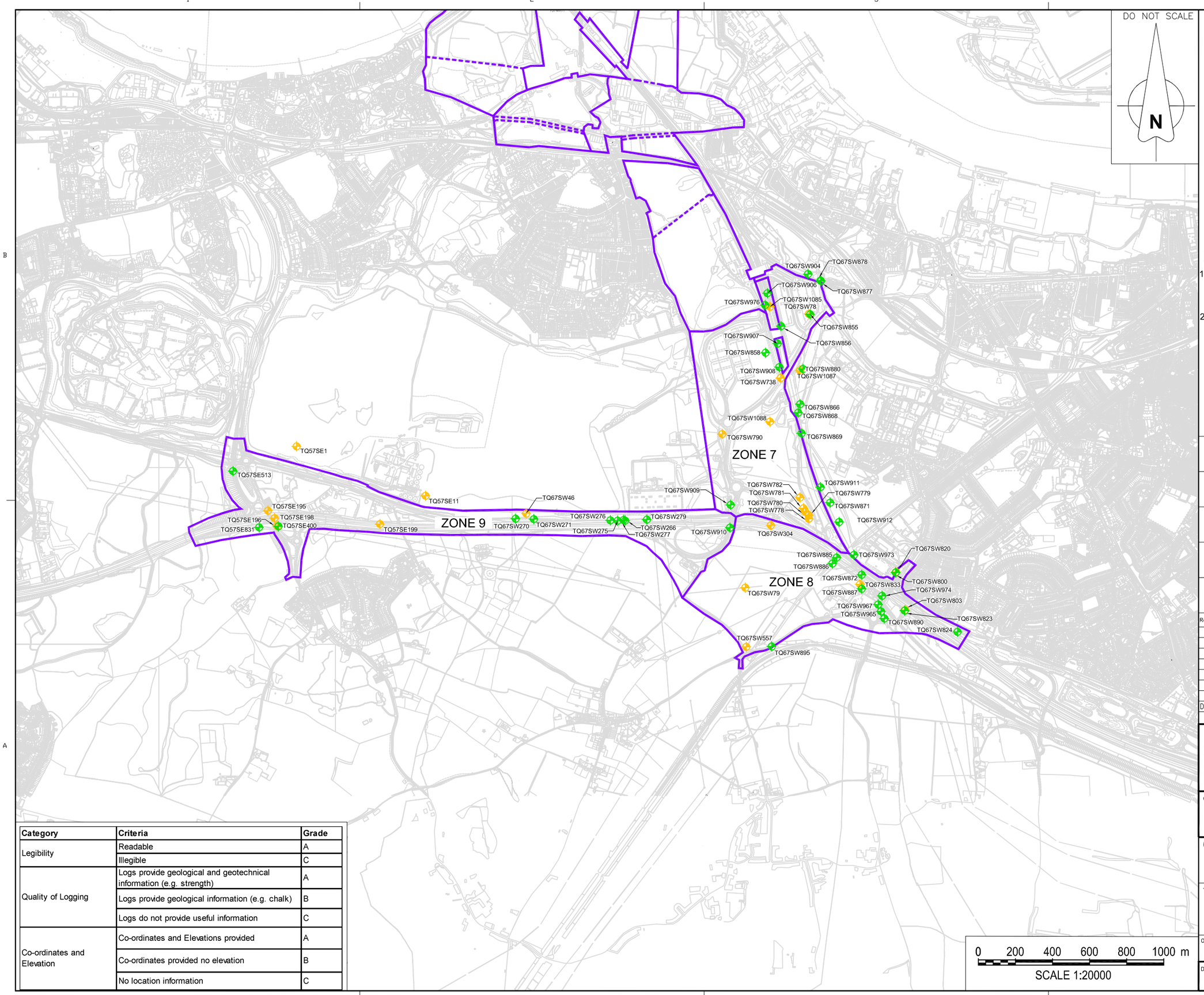
Title
GEOTECHNICAL HAZARDS AND CONSTRAINTS PLAN

Original Scale	Drawn	Checked	Authorised	
1:20000	JA	LD	JS	A3
	Date 23.04.15	Date -	Date -	

Drawing Number	Rev
5134008-ADD_PHASE1-FIGURE004	A

Job Dept. Sub Unique No.

Drawing Number 5134008-ADD_PHASE1-FIGURE004
Rev. A



Category	Criteria	Grade
Legibility	Readable	A
	Illegible	C
Quality of Logging	Logs provide geological and geotechnical information (e.g. strength)	A
	Logs provide geological information (e.g. chalk)	B
	Logs do not provide useful information	C
Co-ordinates and Elevation	Co-ordinates and Elevations provided	A
	Co-ordinates provided no elevation	B
	No location information	C

ATKINS

KEY:

- ZONE BOUNDARY
- GRADE A EXPLORATORY HOLE
- GRADE B EXPLORATORY HOLE

NOTE:

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ATKINS REPORT REF. 5134008/ADDITIONAL PHASE1/REV1.0
2. LOCATIONS OF EXPLORATORY HOLES HAVE BEEN TAKEN FROM THE BGS GEOINDEX. NO INDEPENDENT VERIFICATION OF THE LOCATIONS HAS BEEN UNDERTAKEN BY ATKINS.

Rev.	Description	By	Date	Chk'd	Auth
	DRAFT FOR INFORMATION/COMMENT	A	22.04.15		RS
	Purpose of issue	Rev	Date		Authorised

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Project
PARAMOUNT PARK
ENTERTAINMENT RESORT

Title
BOREHOLE
GRADE MAP
(ZONE 7, 8 AND 9)

Original Scale	Drawn	Checked	Authorised	
1:20000	NV	LD	RS	A3
	Date 22.04.15	Date –	Date –	

Drawing Number
5134008-ADD_PHASE1-FIGURE005

Rev
A

Job Dept. Sub Unique No.

Drawing Number 5134008-ADD_PHASE1-FIGURE005 Rev. A

DO NOT SCALE

N

ZONE 7

ZONE 8

ZONE 9

TQ67SW904 TQ67SW878 TQ67SW877 TQ67SW906 TQ67SW976 TQ67SW78 TQ67SW855 TQ67SW1085 TQ67SW856 TQ67SW907 TQ67SW858 TQ67SW880 TQ67SW908 TQ67SW1087 TQ67SW738 TQ67SW866 TQ67SW868 TQ67SW1088 TQ67SW790 TQ67SW869 TQ67SW911 TQ67SW782 TQ67SW909 TQ67SW780 TQ67SW871 TQ67SW778 TQ67SW779 TQ67SW912 TQ67SW910 TQ67SW304 TQ67SW885 TQ67SW973 TQ67SW800 TQ67SW886 TQ67SW872 TQ67SW820 TQ67SW832 TQ67SW833 TQ67SW974 TQ67SW79 TQ67SW887 TQ67SW803 TQ67SW967 TQ67SW965 TQ67SW823 TQ67SW890 TQ67SW824 TQ67SW557 TQ67SW895

TQ57SE1 TQ57SE513 TQ57SE11 TQ67SW46 TQ67SW277 TQ67SW266 TQ57SE195 TQ57SE196 TQ57SE198 TQ57SE831 TQ57SE199 TQ67SW270 TQ67SW271 TQ67SW279 TQ57SE400 TQ67SW276 TQ67SW275

0 200 400 600 800 1000 m

SCALE 1:20000

KEY:

- ZONE BOUNDARY
- GRADE A EXPLORATORY HOLE
- GRADE B EXPLORATORY HOLE
- GRADE C EXPLORATORY HOLE
- GRADE D EXPLORATORY HOLE

NOTE:

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ATKINS REPORT REF. 5134008/ADDITIONAL PHASE1/REV1.0
2. LOCATIONS OF EXPLORATORY HOLES HAVE BEEN TAKEN FROM THE BGS GEOINDEX. NO INDEPENDENT VERIFICATION OF THE LOCATIONS HAS BEEN UNDERTAKEN BY ATKINS.

Depth (m)	Depth Category
0-9.99	D
10-29.99	C
30-49.99	B
50+	A

Rev.	Description	By	Date	Chk'd	Auth
DRAFT FOR INFORMATION/COMMENT		A	22.04.15		RS
Purpose of issue		Rev	Date		Authorised

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Project
PARAMOUNT PARK
ENTERTAINMENT RESORT

Title
BOREHOLE
DEPTH MAP
(ZONE 7, 8 AND 9)

Original Scale	Drawn	Checked	Authorised	
1:20000	NV	LD	RS	A3
	Date 22.04.15	Date –	Date –	

Drawing Number
5134008-ADD_PHASE1-FIGURE006

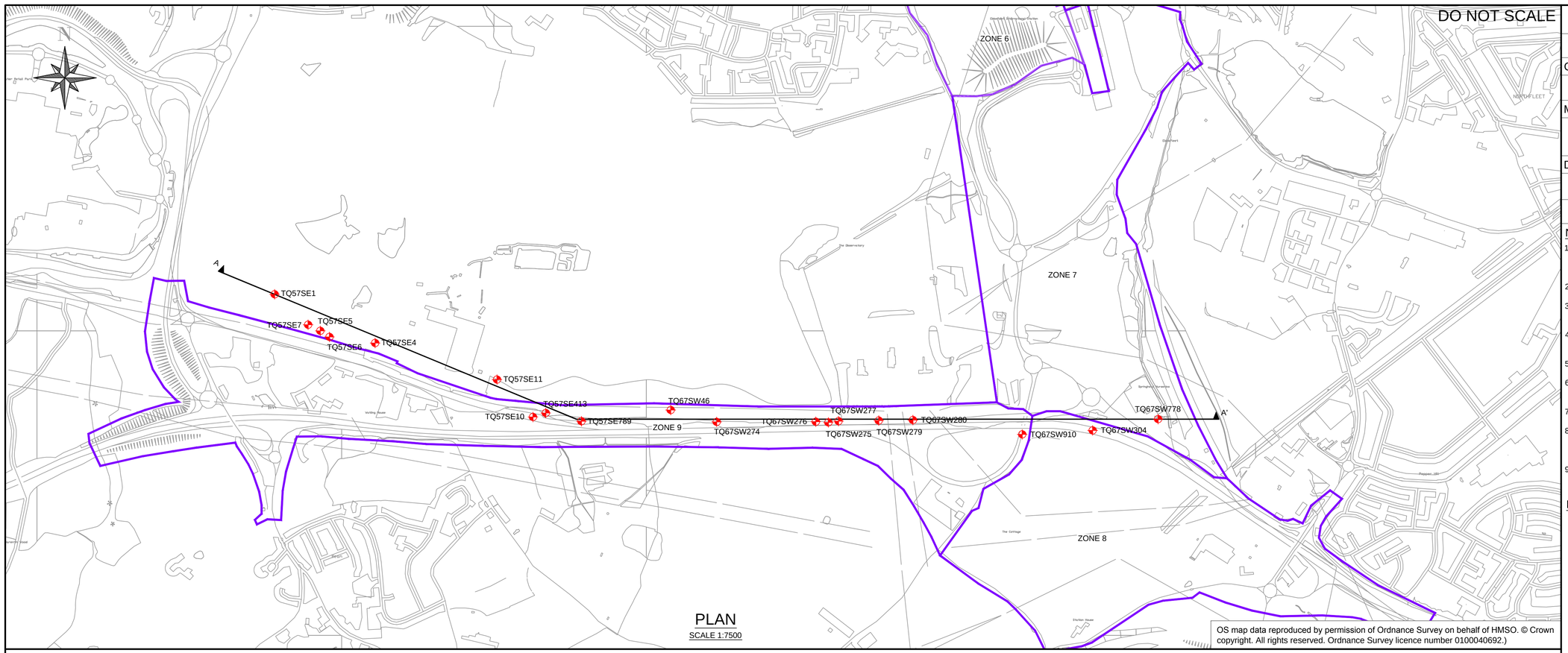
Rev
A

Job Dept. Sub Unique No.

Drawing Number 5134008-ADD_PHASE1-FIGURE006 Rev. A

DO NOT SCALE

Millimetres 100 0 10



PLAN

SCALE 1:7500

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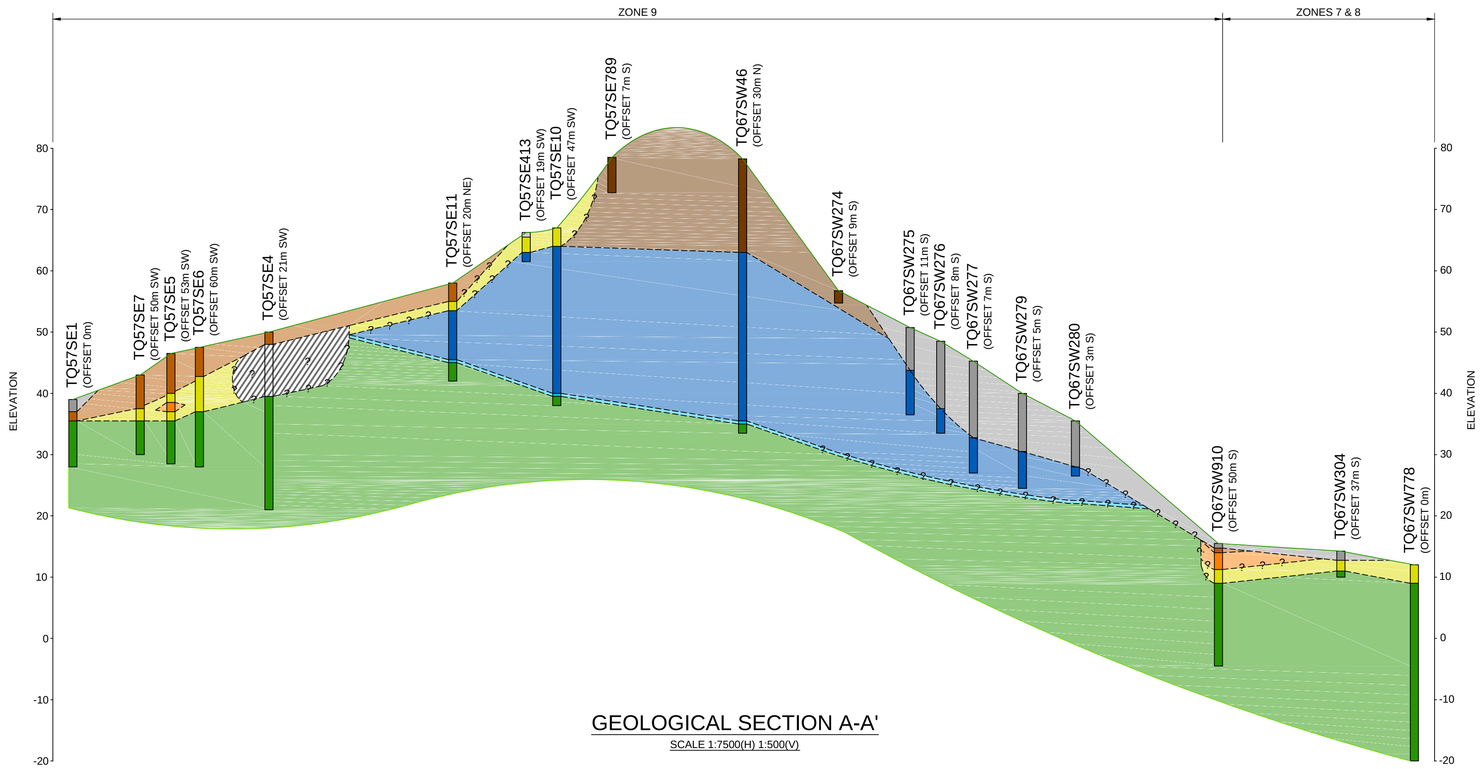

GEOLOGICAL SECTION A-A'

SCALE 1:7500(H) 1:500(V)

N

100m 0m 100m 200m 300m

Scale 1:7500 HORIZONTAL

10m 0m 10m 20m 30m

Scale 1:500 VERTICAL

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

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

CONSTRUCTION

MAINTENANCE/CLEANING

DECOMMISSIONING/DEMOLITION

It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement

NOTES

1. THIS DRAWING SHOULD BE READ IN CONJUNCTION WITH THE REPORT PHASE 1 GEO-ENVIRONMENTAL AND GEOTECHNICAL RISK ASSESSMENT (A2 CORRIDOR AND ACCESS ROADWAY) 5134008/PHASE1/ACCESS/REV1.0.
2. THE GEOLOGICAL INTERPRETATION IS BASED ON THE BGS1:50,000 MAPS SHEETS (270/271).
3. A SELECTION OF RECORDS FROM THE ONLINE BGS BOREHOLE DATABASE HAVE BEEN USED TO FURTHER DEFINE THE GEOLOGICAL BOUNDARIES.
4. THE SURFACE EXPRESSION AND DIP OF STRATA (WHERE AVAILABLE) HAVE BEEN USED TO DEVISE SCHEMATIC SECTIONS OF INDICATE STRATA SUCCESSION WITH DEPTH.
5. GIVEN THE STRUCTURAL, GEOLOGICAL AND ANTHROPOGENIC HISTORY OTHER FEATURES MAY BE PRESENT.
6. THE GEOLOGICAL PROFILE IS INDICATIVE AND REPRESENTS ONLY ONE POSSIBLE INTERPRETATION OF THE GEOLOGICAL UNITS, OTHER INTERPRETATIONS MAY BE POSSIBLE.
7. THE EXTENT OF THE MADE GROUND HAS NOT BEEN VERIFIED AND IS EXPECTED TO BE PRESENT OVER MUCH OF THE SITE.
8. NO TOPOGRAPHIC PROFILE WAS AVAILABLE. THE PROFILE PRESENTED IS BASED ON LINEAR EXTRAPOLATION BETWEEN BOREHOLES AND OUR KNOWLEDGE OF LOCAL TOPOGRAPHIC FEATURES FROM SITE VISITS AND ORDNANCE SURVEY MAPS.
9. THE CHALK IS WELL DOCUMENTED TO EXTEND TO DEPTH GREATER THAN THOSE PROVEN BY THE BOREHOLES AND IS SHOWN AS SUCH.

KEY

- TQ GI LOCATION
- INFERRED GEOLOGICAL BOUNDARY
- MADE GROUND
- SLUMP DEPOSITS (UNCONFIRMED)
- HEAD
- TERRACE GRAVELS
- TERRACE CLAYS
- LAMBETH GROUP
- THANET BEDS
- BULLHEAD BEDS
- WHITE CHALK

Rev.	Date	Description	By	Chk'd	App'd

Drawing Status: FOR INFORMATION

Suitability: SO

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Client: LONDON RESORT COMPANY HOLDINGS

Project Title: PARAMOUNT PARK ENTERTAINMENT RESORT

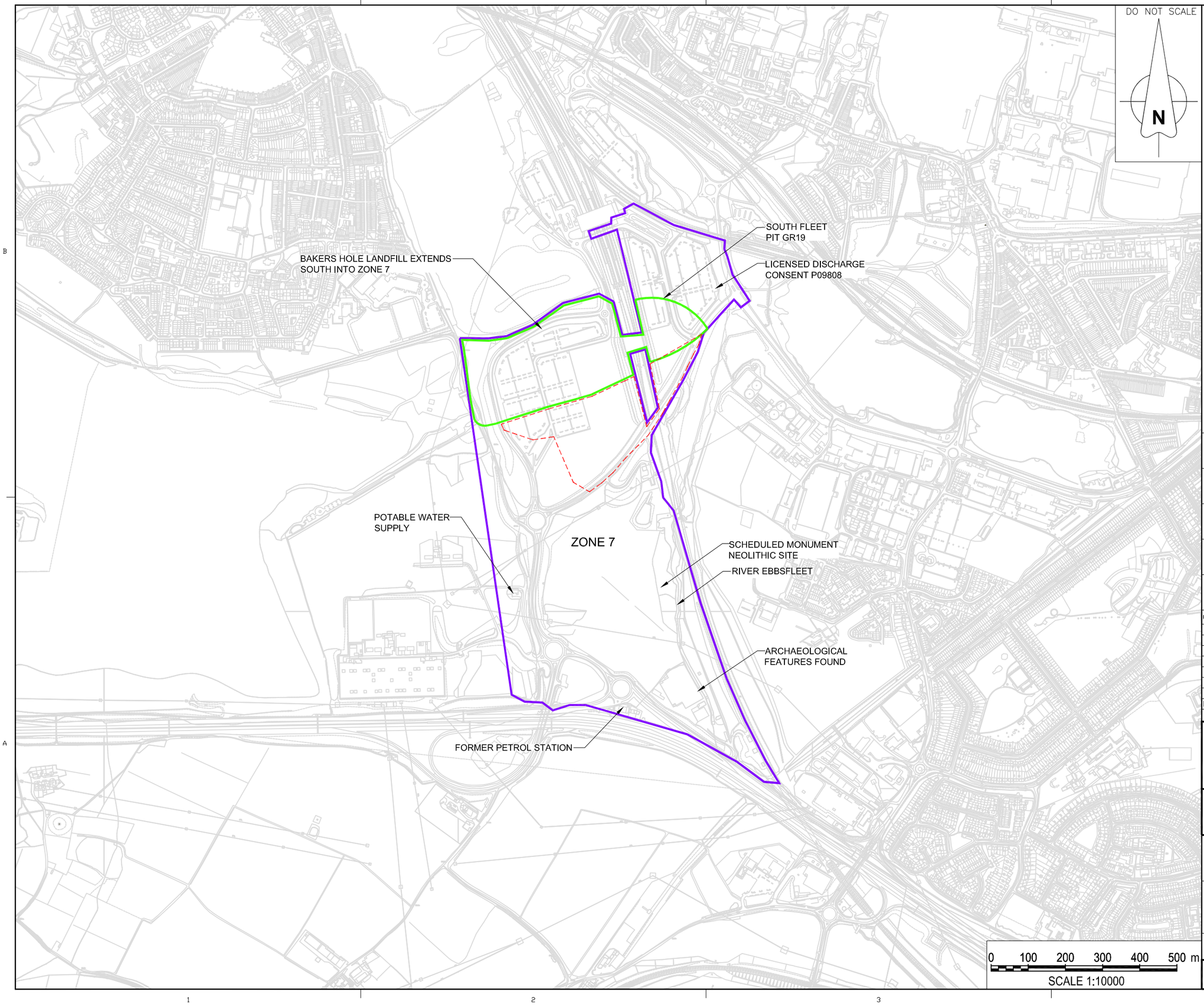
Drawing Title: GEOLOGICAL SECTION A-A'

Scale	Designed	Drawn	Checked	Authorised
AS SHOWN	HEF	TT	--	--
Original Size	Date	Date	Date	Date
A1	--/--/--	--/--/--	--/--/--	--/--/--

Drawing Number: 5134008-ADD_PHASE1-FIGURE07

Revision: A

Drawing file: P:\1GBEMCW and E\GE\HKU080\201UD\39 Paramount Entertainment Kesgn, Kent\ /J G I HM Output\ /5 CAUIE-B' Cross Sections\5134008-ADD_PHASE1-FIGURE07.dwg



DO NOT SCALE

N

ATKINS

KEY:

- ZONE BOUNDARY
- SOUTH FLEET PIT (KNOWN INFILLING)
- POSSIBLE EXTENT OF INFILLING

Drawing Number 5134008-ADD_PHASE1-FIGURE008 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
	DRAFT FOR INFORMATION/COMMENT	A	22.04.15		RS
	Purpose of issue	Rev	Date		Authorised

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Client
LONDON RESORT COMPANY HOLDINGS

Project
PARAMOUNT PARK ENTERTAINMENT RESORT

Title
ZONE 7: KEY FEATURES

Original Scale	Drawn	Checked	Authorised	
1:10000	NV	LD	RS	A3
	Date 22.04.15	Date –	Date –	

Drawing Number 5134008-ADD_PHASE1-FIGURE008 Rev A

Job Dept. Sub Unique No.

Key

- MADE GROUND
- HEAD
- ALLUVIUM
- WHITE CHALK GROUP
- THANET FORMATION
- INFILLED LAND
- WATER TABLE
- SCHEDULED MONUMENT

Sources

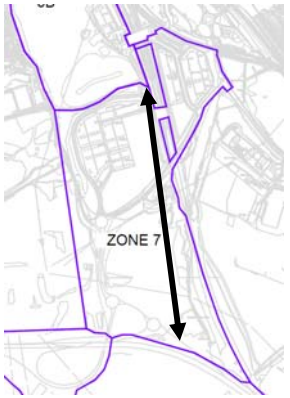
- S1 FORMER CEMENT WORKS WASHMILLS
- S2 REWORKED THANET SANDS AND CEMENT KILN DUST DEPOSITED INTO SOUTHFLEET PIT
- S3 FORMER MINIATURE RIFLE RANGE
- S4 FORMER PETROL STATION

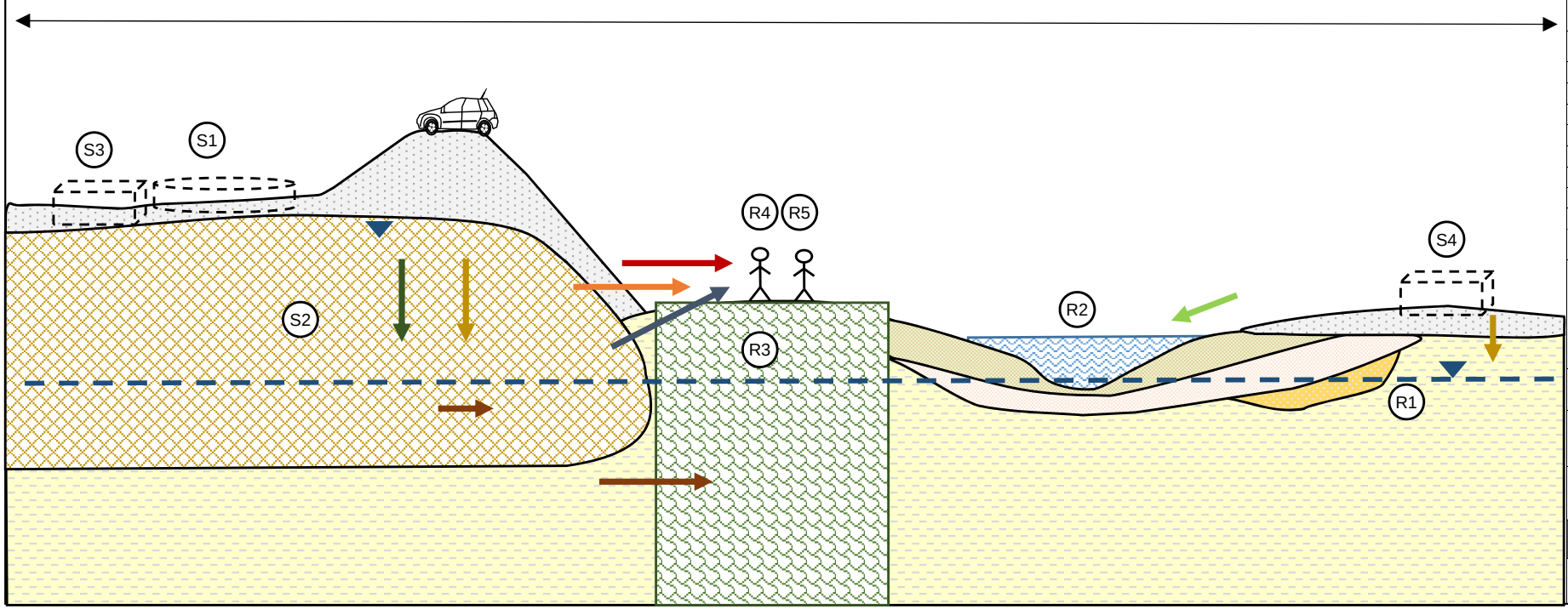
Pathways

- INHALATION, INGESTION AND/OR DERMAL CONTACT WITH CONTAMINANTS IN SOIL AND SOIL-DERIVED DUST/FIBRES
- INHALATION OF SOIL- OR GROUNDWATER-DERIVED VAPOURS
- MIGRATION AND ACCUMULATION OF GROUND GASES
- LEACHING FROM SOILS/CKD
- DIRECT SURFACE WATER RUN-OFF AND SUB-SURFACE FLOW TO SURFACE WATERS
- LATERAL MIGRATION OF CONTAMINATED GROUNDWATER
- VERTICAL MIGRATION OF CONTAMINATED GROUNDWATER

Receptors

- R1 SECONDARY A AQUIFER AND PRINCIPAL AQUIFER
- R2 RIVER EBBSFLEET
- R3 SCHEDULED MONUMENT: NEOLITHIC SITE
- R4 ZONE VISITORS & WORKERS
- R5 TRESPASSERS





Rev.	Description	By	Date	Chk'd	Auth
	FOR INFORMATION / COMMENT	-			

Purpose of Issue	Rev	Date	Authorised

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Client
LONDON RESORT COMPANY HOLDINGS

Project
PARAMOUNT PARK
ENTERTAINMENT RESORT

Title
ZONE 7:
SCHEMATIC CONCEPTUAL SITE MODEL

Original Scale	Drawn	Checked	Authorised	
NTS	LAD	DM	RS	A4
	Date 17/4/15	Date 21/4/15	Date 28/4/15	

Drawing Number
5134008-ADD_PHASE1-FIGURE009

Rev
A

Drawing Number
5134008-ADD_PHASE1-FIGURE009
Rev.
A

DO NOT SCALE

N

ATKINS

KEY:

ZONE BOUNDARY

SCHEDULED MONUMENT
ROMAN TOWN

PEPPERHILL HOUSEHOLD
WASTE RECYCLING CENTRE

ZONE 8

DISMANTLED RAILWAY

SCHEDULED MONUMENT
ROMAN ENCLOSURE OF
VAGNIACAE

0 100 200 300 400 500 m

SCALE 1:10000

Drawing Number 5134008-ADD_PHASE1-FIGURE010 Rev. A

Rev.	Description	By	Date	Chk'd	Auth
	DRAFT FOR INFORMATION/COMMENT	A	22.04.15		RS
	Purpose of issue	Rev	Date		Authorised

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Client

LONDON RESORT COMPANY HOLDINGS

Project

PARAMOUNT PARK
ENTERTAINMENT RESORT

Title

ZONE 8: KEY FEATURES

Original Scale	Drawn	Checked	Authorised	
1:10000	NV	LD	RS	A3
	Date 22.04.15	Date –	Date –	

Drawing Number 5134008-ADD_PHASE1-FIGURE010 Rev A

Job Dept. Sub Unique No.

Key

- MADE GROUND
- HEAD
- RIVER TERRACE DEPOSITS
- WHITE CHALK GROUP
- THANET FORMATION
- LAMBETH GROUP
- LONDON CLAY FORMATION
- WATER TABLE
- SCHEDULED MONUMENT

Sources

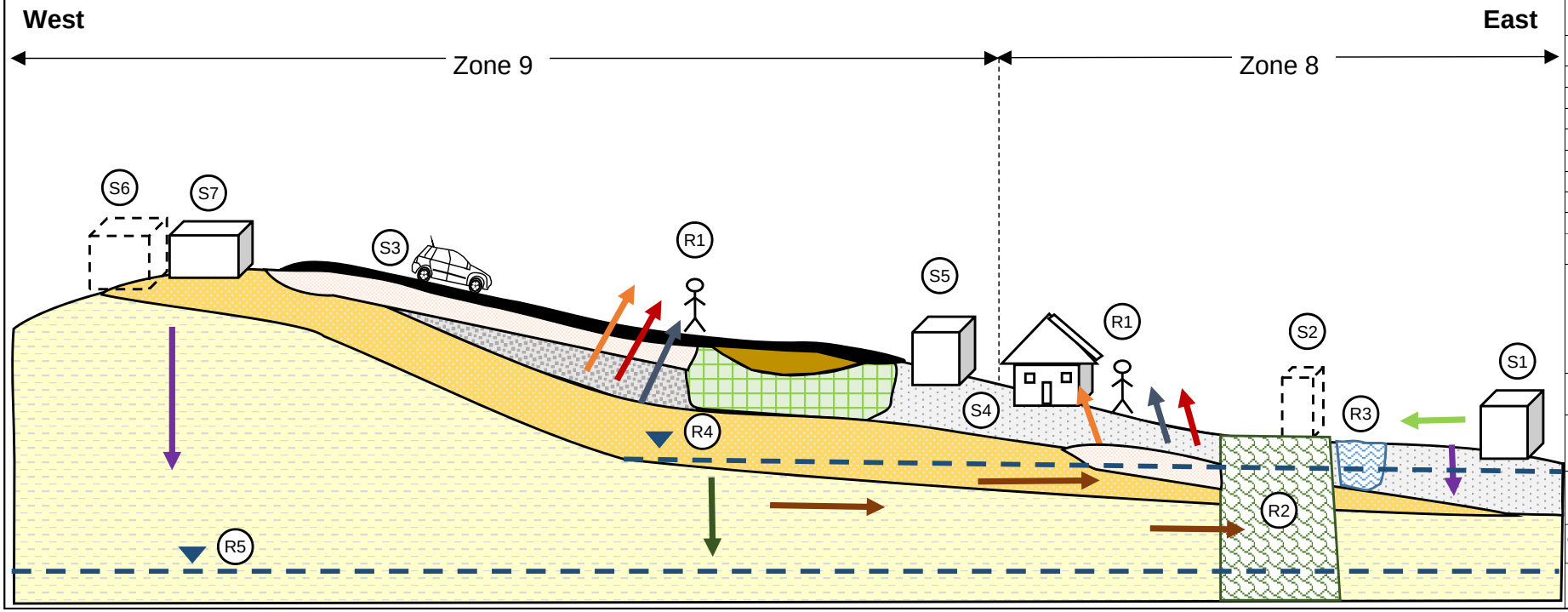
- S1 PEPPERHILL RECYCLING CENTRE
- S2 FORMER RAILWAY
- S3 ROADS
- S4 MADE GROUND
- S5 WATER WORKS
- S6 FORMER BRICK WORKS
- S7 VEHICLE RECYCLING CENTRE

Pathways

- INHALATION, INGESTION AND/OR DERMAL CONTACT WITH CONTAMINANTS IN SOIL AND SOIL-DERIVED DUST/FIBRES
- INHALATION OF SOIL- OR GROUNDWATER-DERIVED VAPOURS
- MIGRATION AND ACCUMULATION OF GROUND GASES
- LEACHING/MIGRATION OF CONTAMINANTS FROM SOILS
- DIRECT SURFACE WATER RUN-OFF AND SUB-SURFACE FLOW TO SURFACE WATERS
- LATERAL MIGRATION OF CONTAMINATED GROUNDWATER
- VERTICAL MIGRATION OF CONTAMINATED GROUNDWATER

Receptors

- R1 ZONE RESIDENTS, WORKERS, MAINTENANCE WORKERS, VISITORS AND TRESPASSERS
- R2 SCHEDULED MONUMENT ROMAN VILLAGE OF VAGNIACAE
- R3 RIVER EBBSFLEET
- R4 SECONDARY AQUIFER
- R5 PRINCIPAL AQUIFER



Rev.	Description	By	Date	Chk'd	Auth
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	Purpose of Issue	Rev	Date	Authorised	

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Client
LONDON RESORT COMPANY HOLDINGS

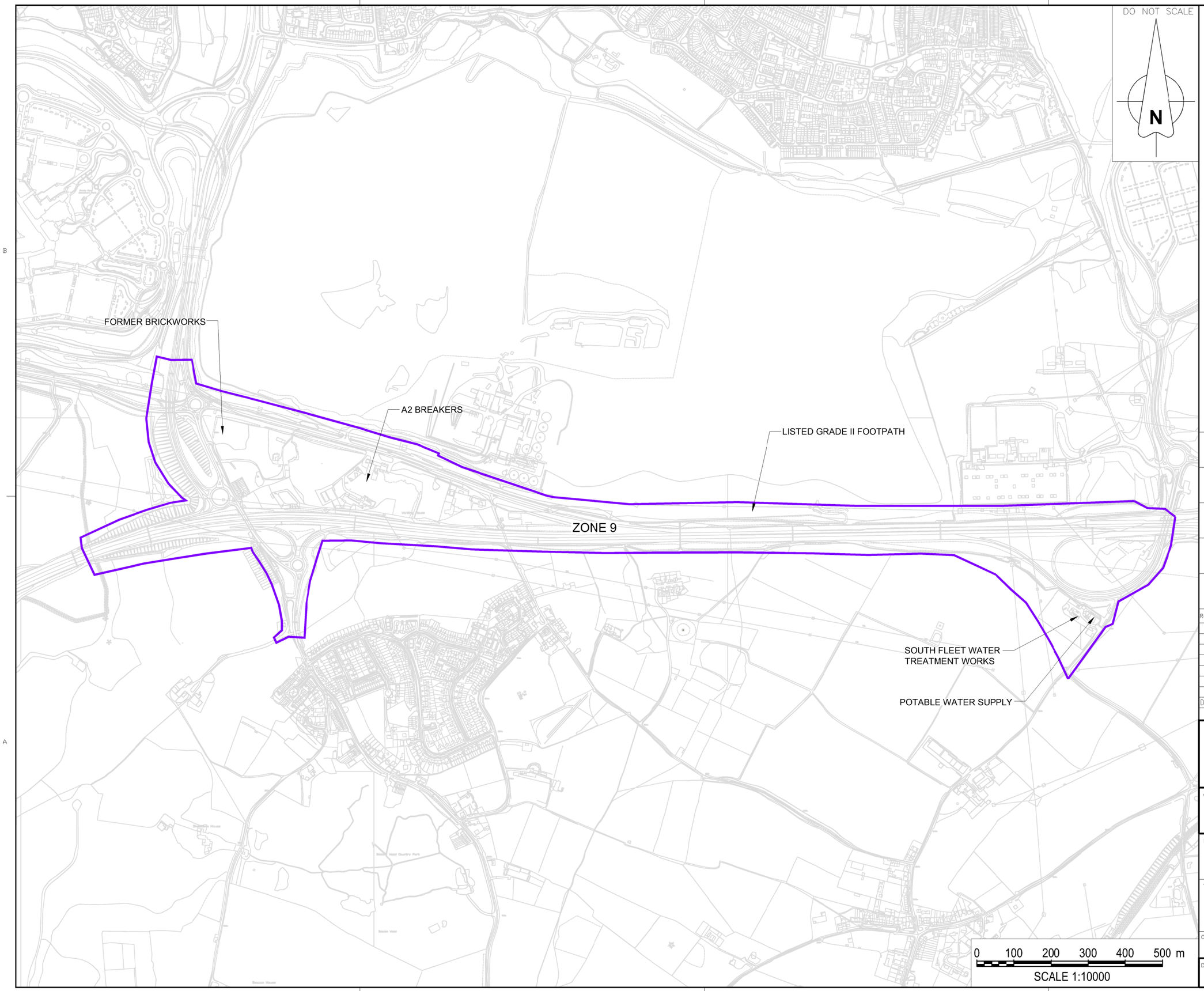
Project
PARAMOUNT PARK
ENTERTAINMENT RESORT

Title
ZONES 8 & 9:
SCHEMATIC CONCEPTUAL SITE MODEL

Original Scale	Drawn	Checked	Authorised	
NTS	LAD	DM	RS	A4
	Date 17/5/15	Date 22/5/15	Date 28/5/15	

Drawing Number
5134008-ADD_PHASE1-FIGURE011
Rev
A

Drawing Number
5134008-PHASE1-FIGURE011
Rev.
A



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KEY:

ZONE BOUNDARY

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Client

LONDON RESORT COMPANY HOLDINGS

Project

PARAMOUNT PARK
ENTERTAINMENT RESORT

Title

ZONE 9: KEY FEATURES

Original Scale	Drawn	Checked	Authorised	
1:10000	NV	LD	RS	A3
	Date 22.04.15	Date –	Date –	

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Appendices

Appendix A. Unexploded Ordnance Report

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Detailed Unexploded Ordnance (UXO) Threat & Risk Assessment

Meeting the requirements of CIRIA C681 "Unexploded Ordnance (UXO) – A guide for the Construction Industry" Risk Management Framework

6 Alpha Project Number: P4483
Client: Atkins
Site: Paramount Resort Extension, Kent

Originator: Jennifer Russell (18th May 2015)
Technical Review: Robin Rickard (27th May 2015)
Released By: Lisa Askham (29th May 2015)

Delivered By

alpha ASSOCIATES
special risks consultancy

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Acronyms and Abbreviations

AA	Anti-Aircraft
AAA	Anti-Aircraft Ammunition
AAC	Army Air Corps
AFS	Advanced Flying School
ALARP	As Low As Reasonably Practicable
AOD	Above Ordnance Datum
ARP	Air Raid Precaution
ATS	Auxiliary Territorial Service
AXO	Abandoned Explosive Ordnance
BD	Bomb Disposal
BDO	Bomb Disposal Officer
bgl	Below Ground Level
BGS	British Geological Survey
BH	Borehole
BPD	Bomb Penetration Depth
CDP	Cast Driven Piles
CFA	Continuous Flight Auger
CIRIA	Construction Industry Research and Information Association
CPT	Cone Penetration Testing
CS	County Series
EFTS	Elementary Flying Training School
ELG	Emergency Landing Ground
EO	Explosive Ordnance
EOC	Explosive Ordnance Clearance
EOD	Explosive Ordnance Disposal
ERW	Explosive Remnants of War
FAA	Fleet Air Arm
FPP	Flight Pilot Pool
FTS	Flight Training School
GI	Ground Investigation
GIS	Geographic Information Systems
GL	Ground Level
GP	General Purpose
GPS	Global Positioning Systems
HAA	Heavy Anti-Aircraft
HE	High Explosive
HO	Home Office
HSE	Health and Safety Executive
IB	Incendiary Bomb
IED	Improvised Explosive Device
JSEODOC	Joint Service Explosive Ordnance Disposal Operations Centre
kg	Kilograms
km	Kilometres
LAA	Light Anti-Aircraft
lb	Pounds
LCC	London County Council
LDV	Local Defence Volunteers
LE	Low Explosive
LSA	Land Service Ammunition
m	Metres
MACP	Military Aid to the Civil Power
MoD	Ministry of Defence
mm	Millimetres
NATO	North Atlantic Treaty Organisation
NEQ	Net Explosive Quantity
NFF	National Filling Factory
NGR	National Grid Reference
OD	Ordnance Datum
OS	Ordnance Survey
OTU	Operational Training Unit
PBG	Polar Blasting Gelignite
PM	Parachute Mine
PoW	Prisoner of War
RADAR	Radio Detection And Ranging
RAF	Royal Air Force
RBL	Rifle Breach Loaded
RDX	Research Department Explosives
RFC	Royal Flying Corps
RML	Rifle Muzzle Loaded
RN	Royal Navy
RNAS	Royal Naval Air Service
ROF	Royal Ordnance Factory
SAA	Small Arms Ammunition
Sqn	Squadron
TA	Territorial Army
TNT	Trinitrotoluene
UK	United Kingdom
UN	United Nations
USAAF	United States Army Air Force
UXB	Unexploded Bomb
UXO	Unexploded Ordnance
V Weapons	*Vergeltungswaffe* – Vengeance Weapons
WAAF	Women's Auxiliary Air Force
WD	War Department
WWI	World War One
WWII	World War Two

EXECUTIVE SUMMARY

Study Site

The Client has described the Study Site as "Paramount Resort Extension, Kent". The Site is located at NGR 561040, 172580.

Risk Level

HIGH

Potential Threat Sources

The most probable UXO threat is posed by WWII *German* HE bombs, whilst IBs and *British* AAA projectiles (which were used to defend against *German* bombing raids) pose a residual threat.

Risk Pathway

Given the types of UXO that might be present on Site, all types of aggressive intrusive engineering activities may generate a significant risk pathway.

Key Findings

The Study Site was located within three boroughs, which recorded different bombing densities. *Dartford Rural District* recorded 73 HR bomb strikes, *Swanscombe Urban District* recorded 81 HE bomb strikes and *Northfleet Urban District* recorded 86 HE bombs per 1000 acres; a relatively moderate level of bombing.

Luftwaffe aerial reconnaissance photography identified a transformer works (located on-Site) as a primary bombing target. In addition, pumping stations (located on-Site), a railway station (located on-Site), reservoirs (located 185m to the south and 405m to the north) and a sewage works (located 310m to the east) may have been considered secondary bombing targets.

ARP records associated with the Site could not be located. Nonetheless, anecdotal historical evidence indicates that the area was subjected to bombing. Several bomb strikes falling just outside of 500m from the Site boundary to the north and east.

It is highly likely that bomb strikes landed within the Site boundary, given the bombing densities and number of bombs which impacted the nearby villages. Anecdotal evidence indicated bombs falling in fields around *Northfleet* and *Swanscombe*. It is possible they were not recorded given the undeveloped nature of the Site.

Furthermore, whilst IBs may have fallen within the Study Site, they fell in such large numbers they were considered ubiquitous and accurate record keeping was non-existent and/or perfunctory.

Pre and post WWII mapping indicates that the Site was predominately undeveloped, consisting of farmland and woodland. It is unlikely that bomb strikes would have been noted precisely within fields, if recorded at all. In addition, it is unlikely that fields were subjected to post-air raid inspections, and therefore, it is considered highly unlikely that UXB entry holes would have been observed and reported.

Given that the Site has undergone some development post-war, it is possible that UXO discovered within the foundations would have been removed, however given that evidence to support this could not be obtained, the entire Site is considered at risk of encountering UXO and that the issue remains extant. Moreover and mindful that this report is an extension of a previous report for Atkins P4181 dated December 2014 it is considered appropriate that as the site is adjacent to the above (ibid) in part and although the risk is predominately associated nonetheless it makes eminent sense that the risk level be aligned in order to demonstrate a consistent approach.

EXECUTIVE SUMMARY (…continued)

Recommended Risk Mitigation

All Groundworks in All Areas:

1. Operational UXO Risk Management Plan; appropriate Site Management documentation should be held on Site to guide and plan for the actions which should be undertaken in the event of a suspected or real UXO discovery, (this plan can be supplied by 6 Alpha);

2. UXO Safety & Awareness Briefings; the briefings are essential when there is a possibility of explosive ordnance encounter and are a vital part of the general safety requirement. All personnel working on the Site should receive a briefing on the identification of a UXB, what actions they should take to keep people and equipment away from such a hazard and to alert Site management. Information concerning the nature of the UXB threat should be held in the Site office and displayed for general information on notice boards, both for reference and as a reminder for ground workers. The safety awareness briefing is an essential part of the Health & Safety Plan for the Site and helps to evidence conformity with the principles laid down in the CDM regulations 2007, (this briefing can be supplied by 6 Alpha).

Trial Pits in All Areas

3. EOD banksman Support; EOD engineer(s) to survey and/or supervise the excavations and/or geotechnical investigations >1m bgl in all areas for UXO and to identify any suspicious items as the work proceeds in the EOD banksman role, (6 Alpha can provide this service).

Boreholes in All Areas

4. Intrusive Magnetometer Survey; an intrusive survey (employing down-hole magnetometer or MagCone techniques) ahead of boreholing is strongly recommended. Such a survey should extend to the maximum bomb penetration depth or to the maximum depth of the works, whichever is encountered first, (this service can be provided by 6 Alpha).

For further information, please contact 6 Alpha Associates:

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ASSESSMENT METHODOLOGY

Approach

6 Alpha Associates is an independent, specialist risk management consultancy practice, which has assessed the risk of encountering UXO (as well as buried bulk high explosives) at this Site, by employing a process advocated for this purpose by CIRIA. The CIRIA guide for managing UXO risks (C681) not only represents best practice but has also been endorsed by the HSE. Any risk mitigation solution is recommended *only* because it delivers the Client a risk reduced to ALARP at best practice.

UXO hazards can be identified through the investigation of Local and National archives associated with the Site, MoD archives, local historical sources, historical mapping as well as contemporaneous aerial photography (if it is available). Hazards will have only been recorded if there is specific information that could reasonably place them within the boundaries of the Site. The amalgamation of information is then assessed to allow the consultant to provide relevant and accurate risk mitigation practices.

The assessment of UXO risk is a measure of *probability of encounter* and *consequence of encounter*; the former being a function of the identified hazard and proposed development methodology; the latter being a function of the type of hazard and the proximity of personnel (and/or other 'sensitive receptors', such as equipment) to the hazard, at the moment of encounter.

If UXO risks are identified, the methods of mitigation we have recommended are considered reasonably and sufficiently robust to reduce these to ALARP. We advocate that the adoption of the legal ALARP principle because it is a key factor in efficiently and effectively ameliorating UXO risks. It also provides a ready means for assessing the Client's tolerability of UXO risk. In essence, the principle states that if the cost of reducing a risk significantly outweighs the benefit, then the risk may be considered tolerable. This does not mean that there is never a requirement for UXO risk mitigation, but that any mitigation must demonstrate that it is beneficial. Any additional mitigation that delivers diminishing benefits and that consume disproportionate time, money and effort are considered *de minimis* and thus unnecessary. Because of this principle, UXB and UXO risks will rarely be reduced to zero (nor need they be).

Important Notes

Key source material is referenced within this document, whilst secondary/anecdotal information may be available upon request.

Although this report is up to date and accurate at the time of writing, our databases are continually being populated as and when additional information becomes available. Nonetheless, 6 Alpha have exercised all reasonable care, skill and due diligence in providing this service and producing this report.

The assessment levels are based upon our professional opinion and have been supported by our interpretation of historical records and third party data sources. Wherever possible, 6 Alpha has sought to corroborate and to verify the accuracy of all data we have employed, but we are not accountable for any inherent errors that may be contained in third party data sets (e.g. National Archive or other library sources), and over which 6 Alpha cannot exercise control.

STAGE ONE – SITE LOCATION AND DESCRIPTION

Study Site

The Client has described the Study Site as "Paramount Resort Extension, Kent". The Site is located at NGR 561040, 172580. The Site location and Site boundary are presented at *Figures 1* and *2* respectively.

Location Description

The Study Site is situated within the county of *Kent,* to the south of the *River Thames,* and within the town of *Swanscombe.*

The Study Site is large and irregular in shape, covering an area of 214.05 hectares (ha). The Site currently comprises several main roads; the A2 passes through the entire length of the Site, with several other public roads branching from it. In addition, large areas of open ground, housing, car parks, and areas of industry also occupy the Site.

Furthermore, the Site is bounded by:

- North: former quarry pits, large areas of open ground, a works and a sub station;
- East: a sewage works, *Springhead Enterprise Park* and housing developments;
- South: large areas of woodland, agricultural fields and a housing development;
- West: large area of woodland.

Aerial Photography (Current) (*Figure 3*)

Current aerial photography reveals that the Site's main features included several main roads, mainly the A2, large areas of open ground, housing, car parks, and areas of unknown industrial infrastructure.

Proposed Works

The Client has described the following GI activities which may be undertaken: Zones 7, 8 and potentially 9 will have site investigations consisting of trial pits to 3.5m and cable percussive boreholes to 10m.

If the proposed works are subject to change, please inform 6 Alpha Associates.

Ground Conditions

Using BGS boreholes located on-Site or in close proximity, the following geology may be encountered in each of the Zones.

Zone 7 (borehole TQ67SW868):

- 0m to 0.30m – Made ground – soft clay with decaying bone and vegetation;
- 0.30m to 3m – Alluvium – soft dark brown clay;
- 3m to 7.50m – Floodplain deposits – sandy gravel;
- 7.50m to30m – Upper Chalk – white chalk.

Zone 8 (borehole TQ67SE831):

- 0m to 1.20m – Made ground - ceramics, brick, duel ash, flint, glass and chalk gravel;
- 1.20m to 4.75m – Made ground – ash sand, brick, flint, clay;
- 4.75m to 7m – Clay with sand and gravel;
- 7m to 30m – Upper Chalk – white chalk

STAGE ONE – SITE LOCATION AND DESCRIPTION (…continued)

Ground Conditions (…continued)

Zone 9 (borehole TQ57SE401):

- 0m to 3.10m – Made ground - brown gray clay, bricks and chalk flint fill;
- 3.10m to 9.70m – Grey sand;
- 9.70m to 13.50m – Slight clayey brown silty sand;
- 13.50m to 14.50m – Thanet beds - sand with flint gravel;
- 14.50m to 33m – Upper Chalk - white chalk

There are likely to be variations within the Site's geology given that it covers a vast area.

It is important to establish the specific ground conditions in order to determine the maximum German UXB penetration depth as well as the potential for other types of munitions to be buried.

If the Site investigations and/or construction methodologies change, and/or if a specific methodology is to be employed, and/or if the scope of work is focused upon a specific part of the Site, then 6 Alpha are to be informed so that the prospective UXO risks and the associated risk mitigation methodology might be re-assessed. Certain ground conditions may also constrain certain types of UXO risk mitigative works e.g. magnetometer survey is adversely affected in mineralised ground.

STAGE TWO – REVIEW OF HISTORICAL DATASETS

Sources of Information Consulted

The following primary information sources have been used in order to establish the background UXO threat:

1. 6 Alpha's Azimuth Database;
2. Home Office WWII Bomb Census Maps;
3. WWII and post-WWII Aerial Photography;
4. Official Abandoned Bomb Register;
5. Information gathered from the National Archives at Kew;
6. Historic UXO information provided by 33 Engineer Regiment (Explosive Ordnance Disposal) at Carver Barracks, Wimbish.

Potential Sources of UXO Contamination

In general there are several activities that can contaminate a site with UXO, the three most common ways that UXO ends up on a site include; legacy munitions from military training/exercises, deliberate or accidental dumping (AXO) and ordnance resulting from war fighting activities (ERW).

During WWII, the *Luftwaffe* undertook bombing campaigns all over the UK. The most common UXO discovered today is the aerially delivered HE bomb; these bombs were comparatively thick-skinned and dropped from enemy aircraft at height. If the bomb did not detonate, the force of impact allowed the UXO to penetrate the ground, leaving behind it a UXB entry hole. These entry holes were not always apparent and some went unreported, leaving the bomb buried and unrecorded. More rarely, additional forms of *German* UXO are occasionally discovered including *inter alia* 'V1' and 'V2' rockets, IBs and Anti-personnel (AP) bomblets.

Although the *Luftwaffe* had designated primary bombing targets across the UK, they jettisoned unused HE bombs over opportunistic targets and residential areas; thousands of buildings were damaged and civilian fatalities were common.

As the threat of invasion lingered over *Britain* during WWII, defensive actions were undertaken. The *British* and *Allied Forces* requisitioned large areas of land for military training and bomb storage (including HE bombs, naval shells, artillery and tank projectiles, explosives, LSA and SAA). Thousands of tonnes of these munitions were used for the *Allied Forces* weapon testing and service staff training alone. It has been estimated that at least 20 per cent of the UK's land has been used for military training at some point.

CIRIA C681 suggests that approximately 10 per cent of all munitions deployed failed to function as designed; therefore it is considered self evident that ERW are still occasionally found during intrusive works.

Furthermore, in exceptional circumstances UXO is discovered unexpectedly and without rational explanation; there are several ways this may occur:

- When *Luftwaffe* aircraft wanted to swiftly escape from an attack they would jettison all of their bombs and flee, this is commonly referred to as *'tip and run'* and has resulted in bombs being found in unexpected locations;
- Transportation of sediment containing munitions to an area that was previously free of UXO, usually related to construction activities such as manufacturing of aggregate and dredging;
- Poor precision during targeting (due to high altitude bombing/poor visibility) resulted in bombs landing within the surrounding area.

STAGE TWO – REVIEW OF HISTORICAL DATASETS (…continued)

Site History

From an analysis of the CS and OS historical mapping associated with the Site, the following Site history can be deduced:

Pre-WWII – The Site was comprised of undeveloped woodland and farmland with associated farm buildings. Small quarries and pits occupied areas of the Site, particularly the northern section of the Site. There are small areas of industry, such as *Portland Cement Works* located in the north of the Site. A railway line dissects the central area of the Site.

During WWII – The Site comprised undeveloped woodland and farmland. A brick works was located in the west of the Site, and a large public road (*Roman Road*) extends the length of the Site.

Post-WWII – A major highway was built extending the length of the Site, and large portions of woodland were removed. Some of the former gravel pits have been reclaimed, or filled with water. Car parks have been constructed in the north of the Site. More recently, railway lines have been constructed through the Site as part of the *Channel Tunnel Rail Link.* A water works was constructed in the centre of the Site and *Northfleet West Grid sub station* was constructed to the north of the Site.

WWII Site Use

The CS mapping prior to WWII (1938), shows that the Study Site was located within a rural setting, and consisted primarily of woodland and farmland. Some areas of the Site were used as quarries or pits, or for industry, such as *Portland Cement Works* and a nursery.

Aerial Photography (1945)

The aerial photography (1945) associated with the Site was poor quality, but collaborated what was shown in the mapping (1938).

WWII Bombing of *Swanscombe* and *Northfleet*

Swanscombe and *Northfleet* were subjected to numerous air raids, given the towns were situated under the flight path to *London.* It is estimated that as a result of air raids, and 'V1' and 'V2' rocket attacks in *Swanscombe*, 62 people died, 250 people were injured and almost 500 buildings were damaged. In addition, there were 211 HE bombs recorded to have landed within the *Swanscombe* area, as well as 5000 IBs and 10 flying bombs. *Northfleets* worst air raid occurred on 16th August 1941, when 106 HE bombs were dropped over the town, killing 29 people, injuring 27 and damaging two schools.

STAGE TWO – REVIEW OF HISTORICAL DATASETS (…continued)

WWII Luftwaffe Bombing Targets (*Figure 4)*

Prior to WWII, the *Luftwaffe* conducted numerous aerial photographic reconnaissance missions over *Britain*, recording key military, industrial and commercial facilities for attack, in the event of war. In addition, logistical infrastructure and public services, such as railways, canals, power stations, reservoirs and gas works, were also considered to be viable bombing targets.

Luftwaffe aerial reconnaissance photography identified a transformer works (located on-Site) as a primary bombing target. In addition, pumping stations (located on-Site), a railway station (located on-Site), reservoirs (located 185m to the south and 405m to the north) and a sewage works (located 310m to the east) may have been considered secondary bombing targets. Information regarding the bombing of these targets could not be located.

As the war progressed, the *Luftwaffe* switched to carpet bombing as opposed to specific targets, which resulted in damage and destruction to residential areas as well as industry and infrastructure.

Areas of WWII Bombing Activity (*Figure 5*)

During WWII, ARP wardens compiled detailed records of bomb strikes across their respective districts. ARP records associated with the Site could not be located. Nonetheless, anecdotal historical evidence indicates that the area was subjected to bombing. Several bomb strikes falling just outside of 500m from the Site boundary to the north and east.

It is highly likely that bomb strikes landed within the Site boundary, as anecdotal evidence indicated bombs fell in fields around *Northfleet* and *Swanscombe*. It is possible they were not recorded given the undeveloped nature of the Site.

Furthermore, whilst IBs may have fallen within the Study Site, they fell in such large numbers they were considered ubiquitous and accurate record keeping was non-existent and/or perfunctory.

In addition to IBs and HE bomb strikes, during the latter part of the war when aerial bombing had significantly declined, the main threat came from 'V' type weapons. A 'V2' impacted in a small river 50m to the southeast of the Site boundary. *Taunton Road* (located 800m to the north) was subjected to a 'V1' rocket impact on 30th July 1944, in which 13 people were killed.

(Please note, the points marked on figure 5 are not precise locations of HE bomb strikes, but the vicinity of where a HE bomb strike is suspected to have impacted).

WWII Bomb Damage

Bomb damage mapping associated with the Site could not be obtained. Nonetheless, anecdotal historical evidence determined that bomb damage occurred to multiple buildings within *Swancombe* and *Northfleet* (to the north and east of the Site). There was no bomb damage identified within the Site boundary, most likely due to the fact it was undeveloped.

WWII HE Bomb Density (*Figure 6*)

The Study Site was located within three boroughs, which recorded different bombing densities. *Dartford Rural District* recorded 73 HR bomb strikes, *Swanscombe Urban District* recorded 81 HE bomb strikes and *Northfleet Urban District* recorded 86 HE bombs per 1000 acres.

STAGE TWO – REVIEW OF HISTORICAL DATASETS (…continued)

Abandoned Bombs

An examination of the official abandoned bomb records has not identified any abandoned bombs within 1,000m of the Site.

Post-WWII BDO Tasks

Post-WWII BDO tasks associated with the area could not be located.

STAGE THREE – DATA ANALYSIS

Was the ground undeveloped during WWII?

Predominantly, Yes; according to the CS mapping prior to WWII (1938), the Study Site was primarily composed of farmland and woodland, with the occasional farm associated building, road and train line.

Is there a reason to suspect that the immediate area was a bombing target during WWII?

Yes; *Luftwaffe* aerial reconnaissance photography identified a transformer works (located on-Site) as a primary bombing target. In addition, pumping stations (located on-Site), a railway station (located on-Site), reservoirs (located 185m to the south and 405m to the north) and a sewage works (located 310m to the east) may have been considered secondary bombing targets.

As WWII progressed, major towns and cities became targets within their own right as the *Luftwaffe* switched from specifically targeting industrial and military facilities to a more general method of bombing ('carpet bombing), and as a result, suburban and residential areas were bombed (as witnessed in *London*).

Is there firm evidence that ordnance landed on Site?

No; ARP records associated with the Site could not be located. Nonetheless, an evaluation of anecdotal historical evidence did not identify any HE bomb strikes within the Site. However, given that the Site was predominately undeveloped, it is highly likely that bomb strikes impacted within the Site and went unrecorded.

Furthermore, whilst IBs may have fallen within the Study Site, they fell in such large numbers they were considered ubiquitous and accurate record keeping was non-existent and/or perfunctory.

Is there firm evidence of bomb damage on Site?

No; bomb damage mapping associated with the Site could not be located. Anecdotal historical evidence determined that bomb damage occurred to multiple buildings within *Swancombe* and *Northfleet* (to the north and east of the Site). There was no bomb damage identified within the Site boundary, most likely due to the fact it was undeveloped.

Would a UXB entry hole have been observed and reported during WWII?

Unlikely; the Site was predominately farmland and woodland, so it is highly unlikely that any inspections would have been carried out post-air raid. In addition, vegetation is likely to have masked any entry holes.

Is there any reason to suspect that live firing or military training may have occurred at this location?

No; there is no supporting evidence to suggest that military training, guns or associated artillery (or other types of) munitions were ever stored, manufactured, located and/or fired from this Site during WWII. There was a small rifle range located to the north of the Site, however it is unlikely that this would have affected the Site.

What is the expected level of UXO contamination?

The most likely source of UXO contamination is from *German* aerially delivered ordnance, which ranges from small IBs through to large HE bombs (of which the latter forms the principal threat). Additional residual contamination may be present from *British* AAA projectiles (which were used to defend the UK against *German* bombing raids).

STAGE THREE – DATA ANALYSIS (…continued)

Would previous earthwork have removed the potential for UXO to be present?

Possibly; from an analysis of the post-WWII mapping associated with the Site, there has been some areas of redevelopment, however given that the scale and depth of these developments is unknown (presumed relatively shallow), it is considered that the potential for deep buried UXO to be present across the Site remains extant.

Does the probability of a UXO discovery vary across the Site?

No; given that the Site was predominately undeveloped, the probability of UXO discovery across the Site is considered homogenous.

STAGE FOUR – RISK ASSESSMENT

Threat Items

The most probable UXO threat items are *German* HE bombs, whilst IBs and *British* AAA projectiles pose a residual threat. The consequences of initiating *German* HE bombs are more severe than initiating IBs or AAA projectiles, and thus they pose the greatest prospective risk to intrusive works.

Maximum Bomb Penetration Depth

Considering the ground conditions for all Zones, (highlighted in Stage 1), the average BPD for a 250kg *German* HE bomb is assessed to be approximately 5m bgl, with the maximum BPD considered to be approximately 14m bgl. Although it is possible that the *Luftwaffe* deployed larger bombs in the area, their deployment was infrequent, and to use such larger (or the largest) bombs for BPD calculations are not justifiable on either technical or risk management grounds.

WWII *German* bombs have a greater penetration depth when compared to IBs and AAA projectiles, which are unlikely to be encountered at depths greater than 1m bgl.

Risk Pathway

Given the types of UXO that might be present on Site, all types of aggressive intrusive engineering activities (i.e. groundworks) may generate a significant risk pathway. Whilst not all UXO encountered aggressively will initiate upon contact, such a discovery could lead to serious impact on the project especially in terms of critical injury and project delay.

Prospective Consequences

Consequences of UXO initiation include:

1. Kill and/or critically injure personnel;
2. Severe damage to plant and equipment;
3. Deliver blast and fragmentation damage to nearby buildings;
4. Rupture and damage underground utilities/services.

Consequences of UXO discovery include:

1. Delay to the project and blight;
2. Disruption to local community/infrastructure;
3. The expenditure of additional risk mitigation resources and EOD clearance;
4. Incurring additional time and cost.

UXO RISK CALCULATION

Site Activities

Although there is some variation in the probability of encountering and initiating items of UXO when conducting different types of intrusive activities, a number of investigative and construction methodologies have been described for analysis at this Site. The consequences of initiating UXO vary greatly, depending upon, *inter alia* the mass of HE in the UXO and how aggressively it might be encountered. For this reason, 6 Alpha has conducted separate risk rating calculations for each investigative and construction methodology that might be employed.

Risk Rating Calculation

6 Alpha's Semi-Quantitative Risk Assessment assesses and rates the risks posed by the most probable threat items when conducting a number of different activities on the Site. Risk Rating is determined by calculating the probability of encountering UXO and the consequences of initiating it.

STAGE FOUR - RISK ASSESSMENT (…continued)

UXO RISK CALCULATION TABLE – ALL AREAS

Activity	Threat Item	Probability (SHxEM=P)	Consequence (DxPSR=C)	Risk Rating (PxC=RR)
Trial Pits (<3.5m bgl)	HE Bombs	2x1=2	2x3=6	2x6=12
	AAA Projectiles	1x1=1	3x1=3	1x3=3
	IBs	1x1=1	3x1=3	1x3=3
Cable Percussive Boreholes (<10m bgl)	HE Bombs	2x3=6	2x3=6	6x6=36
	AAA Projectiles	1x3=3	3x1=3	2x3=6
	IBs	1x3=3	3x1=3	2x3=6

Abbreviations – Site History (SH), Engineering Methodology (EM), Probability (P), Depth (D), Consequence (C), Proximity to Sensitive Receptors (PSR) and Risk Rating (RR).

STAGE FIVE – RECOMMENDED RISK MITIGATION MEASURES

If a geophysical survey is required are the ground conditions an issue?

Non-Intrusive Methods of Mitigation – May be effective as majority of Site is undeveloped. Magnetometer results are may be affected by ferro-magnetic contamination in areas where previous construction activities and made ground have occurred.

Intrusive Methods of Mitigation – Intrusive magnetometry may be effective on this Site, prior to boreholing. However, any ferrous metal/red brick contamination in made ground/old foundations is likely to adversely affect the detection capability of the UXB survey equipment, as it passes through the contaminated layer especially.

MITIGATION MEASURES TO REDUCE RISK TO 'ALARP'

Activity/Area	Risk Mitigation Measures	Final Risk Rating
All Activities in All Areas	**1. Operational UXO Risk Management Plan;** appropriate Site Management documentation should be held on Site to guide and plan for the actions which should be undertaken in the event of a suspected or real UXO discovery, (this plan can be supplied by 6 Alpha); **2. UXO Safety & Awareness Briefings;** the briefings are essential when there is a possibility of explosive ordnance encounter and are a vital part of the general safety requirement. All personnel working on the Site should receive a briefing on the identification of a UXB, what actions they should take to keep people and equipment away from such a hazard and to alert Site management. Information concerning the nature of the UXB threat should be held in the Site office and displayed for general information on notice boards, both for reference and as a reminder for ground workers. The safety awareness briefing is an essential part of the Health & Safety Plan for the Site and helps to evidence conformity with the principles laid down in the CDM regulations 2015, (this brief can be supplied by 6 Alpha).	**ALARP**
Trial Pits in All Areas	**3. EOD banksman Support;** EOD engineer(s) to survey and/or supervise the excavations and/or geotechnical investigations >1m bgl in all areas for UXO and to identify any suspicious items as the work proceeds in the EOD banksman role, (6 Alpha can provide this service).	
Boreholing in All Areas	**4. Intrusive Magnetometer Survey;** an intrusive survey (employing down-hole magnetometer or MagCone techniques) ahead of boreholing is strongly recommended. Such a survey should extend to the maximum bomb penetration depth or to the maximum depth of the works, whichever is encountered first, (this service can be provided by 6 Alpha).	

This assessment has been conducted based on the information provided by the Client, should the proposed works change then 6 Alpha should be re-engaged to refine this risk assessment

Report Figures

www.6alpha.com - +44 (0)2033 713 900
enquiry@6alpha.com

Figure One

Site Location

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enquiry@6alpha.com

BRITISH NATIONAL GRID

PARAMOUNT RESORT EXTENSION, KENT

Site Location

BOMB SEARCH
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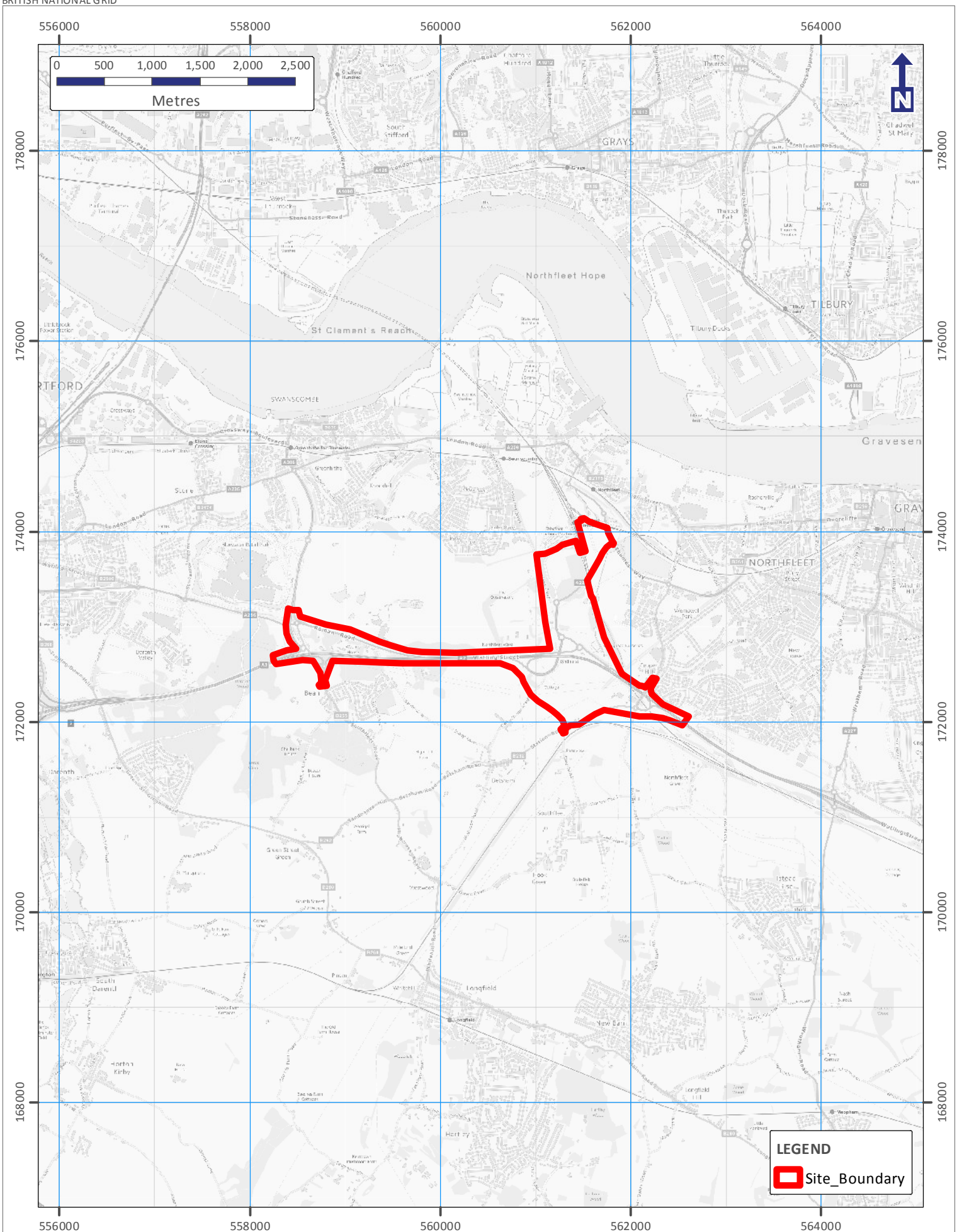

PROJECT NO.	FIGURE NO.	DRAWN BY	CHECKED BY	DATE		
P4483	1	DR	RR	18 May 2015	Contains Ordnance Survey data © Crown copyright and database right 2015	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.

Figure Two

Site Boundary

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PARAMOUNT RESORT EXTENSION, KENT

Site Boundary

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P4483	2	DR	RR	18 May 2015	

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Figure Three

Aerial Photography (Current)

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PARAMOUNT RESORT EXTENSION, KENT

Aerial Photography (2009)

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PROJECT NO.	FIGURE NO.	DRAWN BY	CHECKED BY	DATE		
P4483	3	DR	RR	18 May 2015	Map data: Google, Infoterra Ltd & Bluesky	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.

Figure Four

WWII Luftwaffe Bombing Targets

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BRITISH NATIONAL GRID

PARAMOUNT RESORT EXTENSION, KENT

WWII Luftwaffe Bombing Targets

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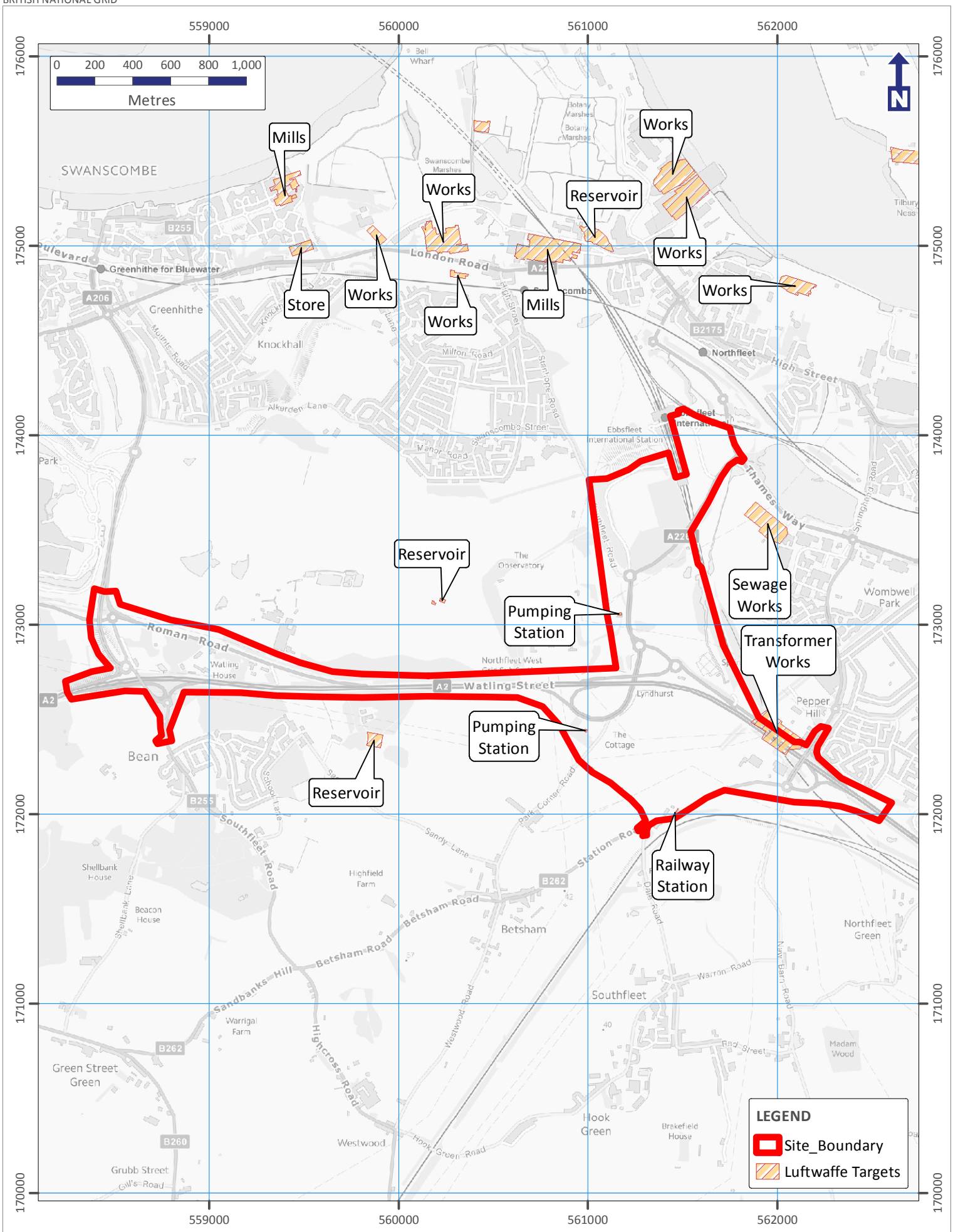

PROJECT NO.	FIGURE NO.	DRAWN BY	CHECKED BY	DATE	
P4483	4	DR	RR	26 May 2015	

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Figure Five

Areas of WWII Bombing Activity

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PARAMOUNT RESORT EXTENSION, KENT

Areas of WWII Bombing Activity

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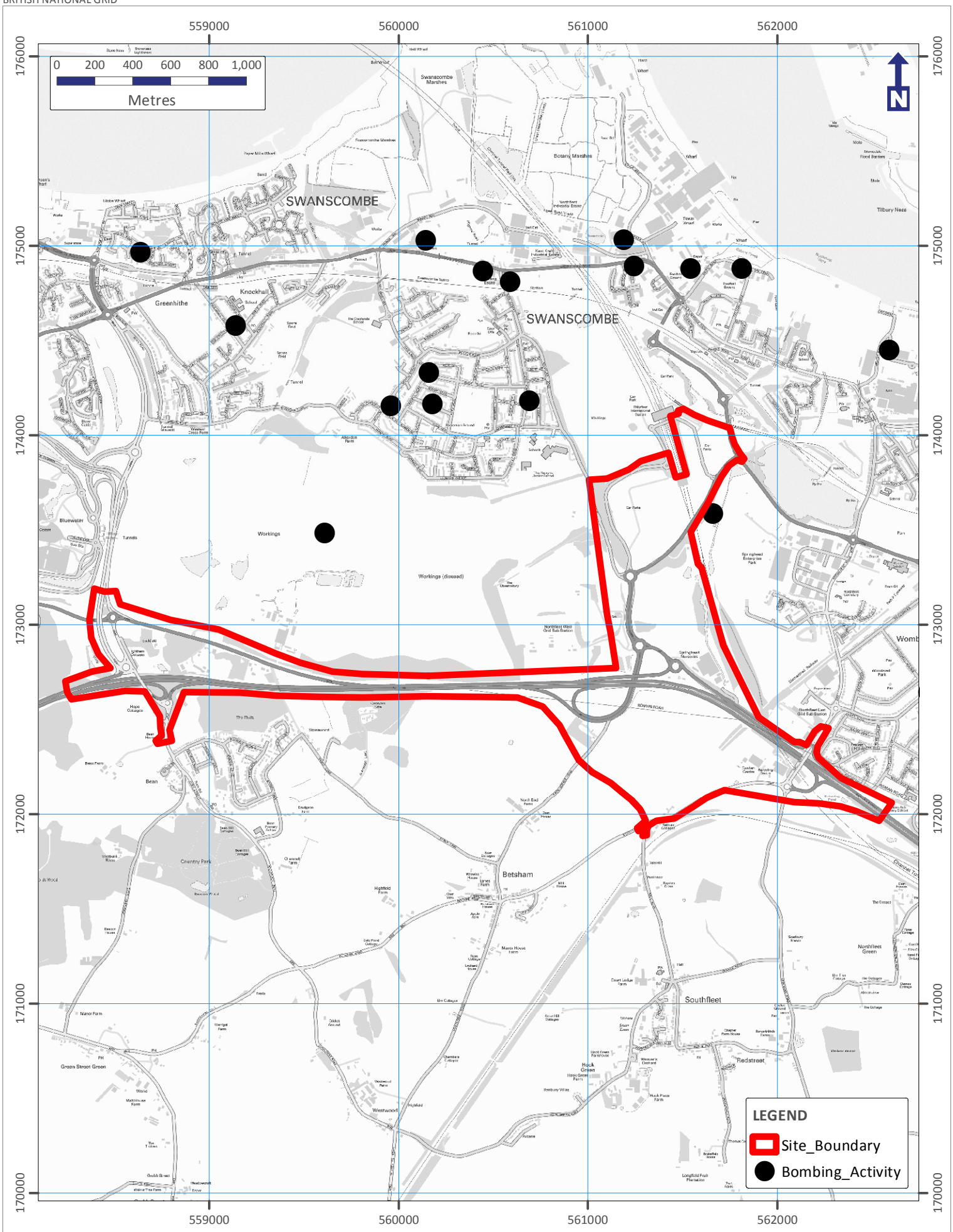

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P4483	5	DR	RR	26 May 2015	

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Figure Six

WWII High Explosive Bomb Density

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BRITISH NATIONAL GRID

PARAMOUNT RESORT EXTENSION, KENT

WWII High Explosive Bomb Density

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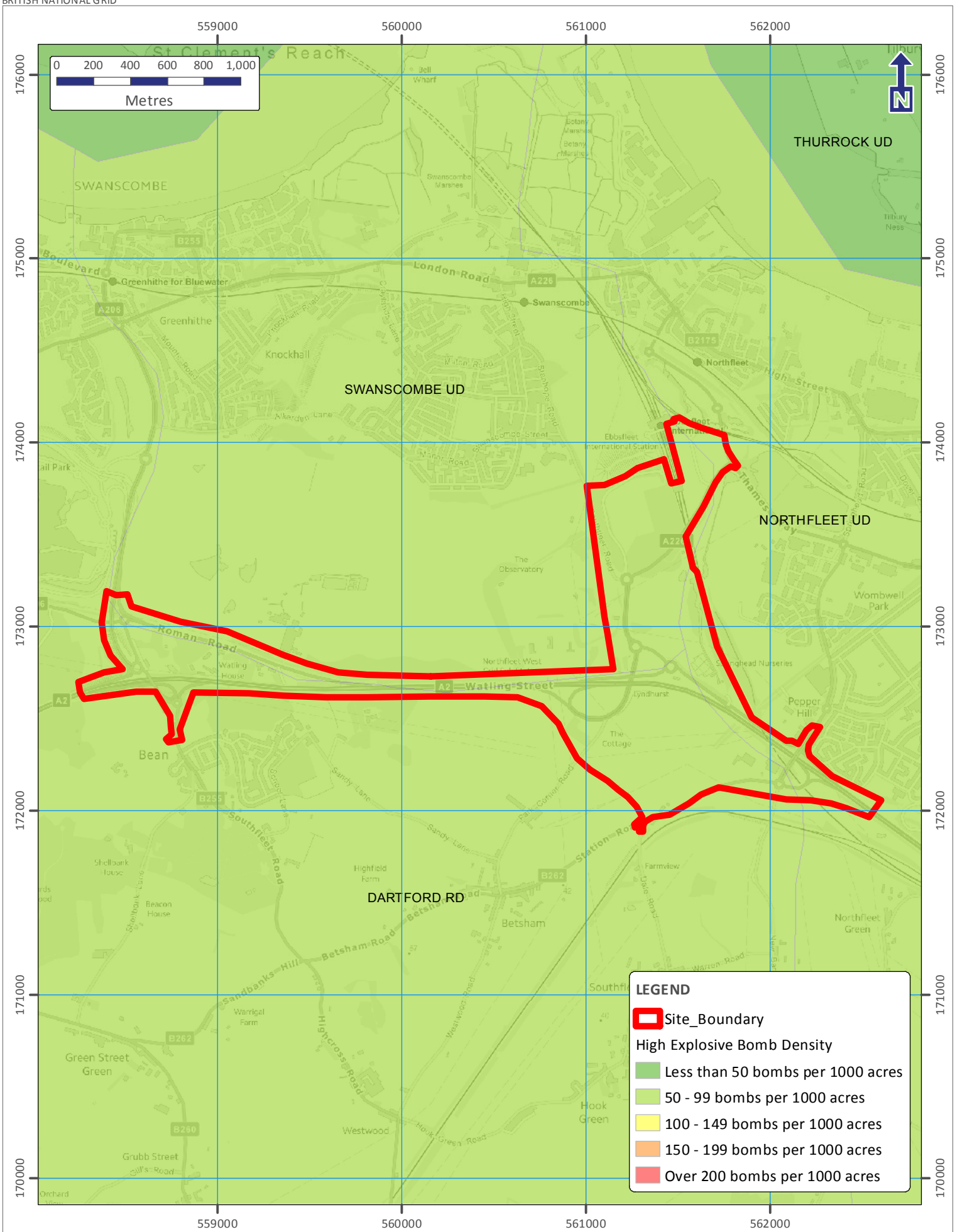

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Appendix B. Site Walkover Photographs

Appendix B: Site Walkover Photos

Zone 7

Photo 1. Photo looking northeast over vacant land located below Ebbsfleet International Parking Lot ‘D’ towards HS1.

Photo 2. Photo showing location of former petrol station, showing site clearance and remaining materials.

Appendix B: Site Walkover Photos

Photo 3. Photo showing minor flytipping in front of former petrol station gates.

Photo 4. Photo looking north showing vacant land within southern portion of Zone 7 to the east of the existing roadway.

Appendix B: Site Walkover Photos

Photo 5. Photo showing demolished Northfleet West Grid Substation adjacent to Zones 7 and 9, looking northwest.

Photo 6. Photo showing demolished Northfleet West Grid Substation adjacent to Zones 7 and 9, looking northeast.

Appendix B: Site Walkover Photos

Zone 8

Photo 7. Photo showing entrance to waste and recycling facility at Pepperhill in Zone 8.

Photo 8. Photo showing rear of Pepperhill Recycling Centre.

Appendix B: Site Walkover Photos

Photo 9. Photo showing residential property and arable land within the southern corner of Zone 8. Historical maps indicate an unknown depot to the rear of the property; personnel could not access private land.

Photo 10. Photo looking northeast showing farmland in Zone 8.

Appendix B: Site Walkover Photos

Zone 9

Photo 11. Entrance to Washmills Recycling Centre, located at former works adjacent to Zone 9.

Photo 12. Photo showing sign at entrance of former works.

Appendix B: Site Walkover Photos

Photo 13. Photo looking southeast showing access road and various businesses in the western portion of Zone 9.

Photo 14. Photo showing stockpile of aggregate material located in the western portion of Zone 9.

Appendix B: Site Walkover Photos

Photo 15. Photo looking north showing water treatment works located in the eastern portion of Zone 9.

Photo 16. Photo looking west showing farmland adjacent to Zone 9 and the A2 within Zone 9.

Appendix C. Summary of Borehole Records

ZONE	ID	EASTING	NORTHING	ELEVATION (m AOD)	DEPTH (m)	GRADE
7	TQ67SW78	561680	173870	4.5	60	B
7	TQ67SW738	561521	173507	7.4	16.71	B
7	TQ67SW778	561680	172710	12.19	32.16	B
7	TQ67SW779	561680	172730	12.19	32	B
7	TQ67SW780	561660	172750	12.19	31.09	B
7	TQ67SW781	561650	172770	12.19	12.19	B
7	TQ67SW782	561630	172830	12.19	30.48	B
7	TQ67SW790	561190	173190	17.5	45	B
7	TQ67SW855	561688	173868	4.9	10.51	A
7	TQ67SW856	561523	173801	6.2	23.65	A
7	TQ67SW858	561435	173650	8.3	24.97	A
7	TQ67SW866	561631	173359	2.01	12.01	A
7	TQ67SW868	561620	173311	1.91	30.01	A
7	TQ67SW869	561639	173194	4.4	25.01	A
7	TQ67SW871	561801	172801	27.4	25.46	A
7	TQ67SW877	561749	174057	2.47	30.01	A
7	TQ67SW878	561746	174059	2.48	11.41	A
7	TQ67SW880	561647	173558	2.52	10.01	A
7	TQ67SW904	561676	174096	3.16	25.45	A
7	TQ67SW906	561446	173987	8.01	25.43	A
7	TQ67SW907	561503	173702	7.43	25	A
7	TQ67SW908	561513	173569	7.49	25.45	A
7	TQ67SW911	561746	172889	23.02	15.2	A
7	TQ67SW912	561852	172692	25.51	15.2	A
7	TQ67SW973	561936	172506	19.7	30.01	A
7	TQ67SW976	561433	173920	9.42	35	A
7	TQ67SW1085	561460	173910	7.58	34.4	B
7	TQ67SW1087	561630	173550	7.02	27	B
7	TQ67SW1088	561460	173260	5.44	33	B
8	TQ67SW79	561320	172320	29	86	B
8	TQ67SW557	561326	171985		70	B
8	TQ67SW800	562174	172409	24.29	40.86	B
8	TQ67SW803	562226	172194	18.07	32.46	B
8	TQ67SW820	562172	172406	24.16	30.01	A
8	TQ67SW823	562223	172190	18.04	30.01	A
8	TQ67SW824	562522	172070	21.02	20.46	A
8	TQ67SW832	561589	172369	17.08	21	B
8	TQ67SW833	561970	172339	10.07	20	B
8	TQ67SW872	561980	172393	13.5	25.01	A
8	TQ67SW885	561838	172491	11.57	20.2	A
8	TQ67SW886	561814	172457	19.8	25.5	A
8	TQ67SW887	561980	172314	10.72	15.5	A
8	TQ67SW890	562108	172146	18.27	21.1	A
8	TQ67SW895	561470	171987	27.01	10.3	A
8	TQ67SW965	562089	172186	16.9	25.01	A
8	TQ67SW967	562073	172225	20.4	25.01	A
8	TQ67SW974	562095	172274	16.19	15.05	A
8	TQ67SW304	561465	172673	14.9	3	B
8	TQ67SW778	561680	172710	12.19	32.16	B

ZONE	ID	EASTING	NORTHING	ELEVATION (m AOD)	DEPTH (m)	GRADE
9	TQ57SE1	558780	173120	38.71	10.82	B
9	TQ57SE11	559510	172840		15.54	B
9	TQ57SE195	558618	172756	65.29	12.19	B
9	TQ57SE196	558670	172669	67.18	12.19	B
9	TQ57SE198	558655	172714	64.62	17.37	B
9	TQ57SE199	559252	172680	57.85	6.09	B
9	TQ57SE400	558676.88	172667.4	67.66	24	A
9	TQ57SE513	558420	172980	48.05	15	A
9	TQ57SE831	558567.62	172661.4	62.94	14.31	A
9	TQ67SW46	560080	172740		46.93	B
9	TQ67SW266	560640	172700	61.08	14	A
9	TQ67SW270	560019.8	172710.5	80.26	17	A
9	TQ67SW271	560123.06	172708	74.97	14	A
9	TQ67SW275	560597.6	172699.3	50.97	13.2	A
9	TQ67SW276	560556.5	172701.6	48.51	15	A
9	TQ67SW277	560631.11	172703.4	45.07	16.5	A
9	TQ67SW279	560762.99	172705.3	39.95	15.5	A
9	TQ67SW304	561465.2	172673.08	14.19	3.1	B
9	TQ67SW909	561237	172789	16.52	20.01	A
9	TQ67SW910	561234	172660	15.64	20.01	A
9	TQ57SE7	558890	173020	45.62	13	B
9	TQ57SE6	558960	172980	46.86	36.57	B
9	TQ57SE5	558930	173000	46.53	17.07	B
9	TQ57SE4	559110	172960	49.68	28.8	B
9	TQ57SE413	559628	172717	66.24	4	B
9	TQ57SE789	559787	172703	77.97	5.38	A
9	TQ67SW274	560231	172701	66.6	9.5	A
9	TQ67SW280	560875	172707	35.38	9	A

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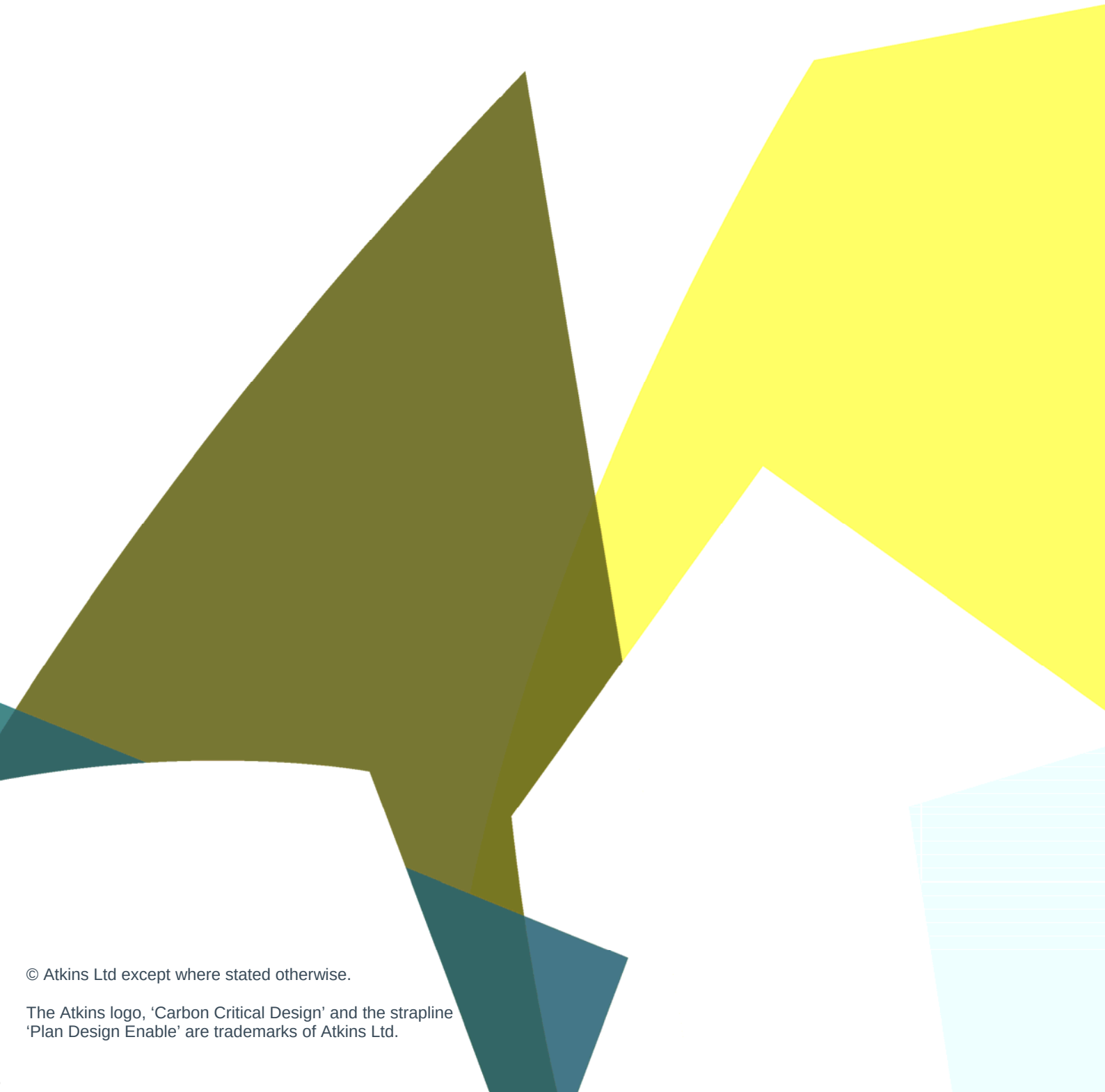

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