Lower Thames Crossing

6.3 Environmental Statement Appendices
Appendix 10.7 – East Tilbury Landfill Risk Assessment

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Lower Thames Crossing

Appendix 10.7 – East Tilbury Landfill Risk Assessment

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1 Executive summary

1.1.1 This Technical Note provides a Qualitative Risk Assessment (QRA) of potential impacts, if any, of the proposed North Portal construction on the East Tilbury Landfill. The North Portal comprises the northern tunnel entrance of the A122 Lower Thames Crossing (the Project). The East Tilbury Landfill is the only recorded hazardous co-disposal landfill within 500m of the Project. It is located approximately 350m to the east of North Portal and therefore a source specific QRA was undertaken to determine any potential risk in relation to the Project.

1.1.2 Several other non-hazardous landfills exist close to, or within the order limits of, the proposed Project. The closest of which is Goshems Farm Landfill, which is bisected by the proposed route alignment. Those landfills do not fall within the scope of the QRA as the QRA specifically addresses the hazardous East Tilbury Landfill.

1.1.3 The QRA looks specifically at the potential risk caused by the proposed dewatering during the construction phase of the North Portal. The potential for dewatering during the operational phase is not considered significant and has not been assessed further in this report, although some discussion of the operational scenario is provided.

1.1.4 The North Portal design includes a southward dipping ramp entrance and a deeper shaft area. The lowest elevation of the proposed shaft design is -24m Above Ordnance Datum (AOD). This is below the groundwater table and would therefore require dewatering from the River Terrace Deposits (RTD) and Chalk aquifers. It is anticipated that dewatering during the construction phase period of the North Portal section is a maximum of three years.

1.1.5 The scope of this QRA is to present an initial Conceptual Site Model (CSM) by outlining potentially active source – pathway – receptor linkages as per Land Contamination Risk Management (LCRM) guidance (Environment Agency, 2020). The QRA aims to refine this initial CSM by reviewing qualitative and quantitative information sources relevant to the East Tilbury Landfill and the proposed North Portal construction. The information reviewed will be discussed qualitatively to refine and update the CSM and define any remaining pathways of potential concern, if any.

1.1.6 Requests for Information were made to the Environment Agency (EA) and Thurrock Council to obtain any records available on East Tilbury Landfill. The primary sources of information reviewed for the QRA are:

a. East Tilbury Status Report (Callear and Bewers, 1993), obtained from the Environment Agency

b. North Portal Groundwater Model Technical Memo (Appendix 14.5, Annex 11, Application Document 6.3)

c. Water Features Survey Factual Report (Appendix 14.2, Application Document 6.3)

d. GQRA for the Phase 2 Investigation (Annex B, Appendix 10.9, Application Document 6.3)

e. PW07006A Pumping Test (North Portal) Hydrogeology and Geoenvironmental Review Report (Cascade, 2020)

f. C.L Associates (1997) Restoration Audit Report was also provided by Thurrock Council, however, was not deemed to contain pertinent information in relation to the scope of the QRA.

1.1.7 East Tilbury Landfill was identified as the source of concern and potentially active pollutant linkages (pathways) were identified in the preliminary CSM and assessed in the discussion section in light of the information source review. These are presented in Table 1.1.

Table 1.1 Active pollutant pathways

Pollutant pathway	Description
A	Vertical migration of Contaminants of Concern (COC) and leaching into perched water present within the Alluvium underlying the landfill, followed by lateral migration off-site leading to deteriorating of groundwater quality west of East Tilbury Landfill
B	Vertical migration of COC and leaching into groundwater present within the River Terrace Deposits and Chalk underlying the Alluvium, followed by lateral migration off-site leading to deteriorating of groundwater quality west of East Tilbury Landfill
C	Lateral migration of impacted groundwater within the underlying strata into the River Thames
D	Dermal contact and ingestion pathway for construction workers from potentially impacted groundwater flowing into the excavation during dewatering and ongoing construction works
E	Vapour inhalation pathway for construction workers from volatile COC in potentially impacted groundwater flowing into the excavation during dewatering and ongoing construction works
F	Migration of COC within groundwater towards proposed built structures, potentially impacting foundation structures
G	Potential mobilisation of ground gases associated with waste degradation at the East Tilbury Landfill by potential drawdown of the water table

1.1.8 Through the information sources review process and discussion section presented in this report of findings, pollutant linkages (pathways) a. to g. have been shown to not be active (excluding c.), nor are they likely to become active, as a direct result of the proposed dewatering at North Portal.

1.1.9 The lack of hydraulic continuity between the Alluvium and the underlying River Terrace Deposits and Chalk aquifers is the governing factor in ruling out pollutant linkages a. to g (excluding c.). This was corroborated in the numerical model carried out as part of the Project’s Hydrogeological Risk Assessment (Appendix 14.5, Application 6.3) and the continuous pumping test PW06001A Pumping Test (North Portal) (Cascade, 2020), which both concluded that the Alluvium acts as an aquitard, confining the underlying aquifers and creating artesian conditions within the Chalk and RTD.

1.1.10 The only potential pathway to remain active is pathway c, which relates to the migration of COC from East Tilbury Landfill into the River Thames. However, this was deemed to be potentially an active pathway without the effects of the Project, owing to the presence of the River Thames bordering the southern edge of the landfill, the landfill not being lined, and the known tidal influence within the landfill. As the pumping test showed no direct effect on the groundwater within the Alluvium (and therefore, the landfill), it is not considered likely that the proposed dewatering could result in an increase in COC entering the River Thames.

1.1.11 In addition to the above, fate and transport modelling was undertaken using the ConSim software to determine travel times of COC within the Alluvium towards North Portal. The modelling showed that within the time frame of the proposed dewatering, COC was not likely to reach the North Portal structure. It is important to note that this modelling was undertaken as a worst case scenario assuming migration of COC within the Alluvium can occur via a continuous groundwater body. In reality, the water encountered within the Alluvium was found to be perched and discontinuous, resulting in an overly conservative assessment.

1.1.12 As such, the identified receptors are not likely to be at an unacceptable risk via the identified pathways as a result of the proposed dewatering works at North Portal owing to there not being any active pollutant linkages.

1.1.13 The results of QRA and modelling undertaken are independent of any proposed designed dewatering mitigation measures at North Portal (although these are referenced in the report for completeness). This is due to there being no active pollutant pathways identified, irrespective of what the end design of mitigation measures at the proposed North Portal may be. Section 6 of the report should be reviewed for context of uncertainties and limitations within the updated CSM.

2 Introduction

2.1 Objectives

2.1.1 This Technical Note provides a Qualitative Risk Assessment (QRA) of potential impacts, if any, of the proposed North Portal construction on the East Tilbury Landfill. The potential for dewatering during the operational phase is not considered significant and has not been assessed further in this report, although some discussion of the operational scenario is provided.

2.1.2 The North Portal comprises the northern tunnel entrance of the A122 Lower Thames Crossing (the Project). The East Tilbury Landfill is the only recorded hazardous co-disposal landfill within 500m of the Project. It is located approximately 350m to the east of North Portal and therefore a source specific QRA was undertaken to assess any potential risks in relation to the Project.

2.1.3 The objective of this QRA is to assess whether identified receptors and environmental quality may be adversely affected by the Project, specifically during the construction phase of the North Portal which requires dewatering from the River Terrace Deposits (RTD) and Chalk aquifers.

2.1.4 The scope of this QRA is to present an initial Conceptual Site Model (CSM) by outlining potentially active source – pathway – receptor linkages. The QRA aims to refine this initial CSM by reviewing qualitative and quantitative information sources relevant to the East Tilbury Landfill and the proposed North Portal construction. The information reviewed will be discussed qualitatively to refine and update the CSM and define any remaining pathways of potential concern, if any.

2.1.5 The QRA was undertaken in line with Land Contamination: Risk Management guidance (Environment Agency, 2021).

2.1.6 The location of East Tilbury Landfill in relation to the Order Limits is shown on Figure 1.

2.2 Information sources

2.2.1 Regulatory consultations to request information on East Tilbury Landfill were made to the Environment Agency and Thurrock Council in May 2022. Record keeping on the East Tilbury Landfill was sparse and only two reports were obtained;

a. Callear and Bewers (1993) Status Report was obtained from the Environment Agency and comprised a review of the landfill post closure.

b. C.L Associates (1997) Restoration Audit Report was obtained from Thurrock Council and involved a series of hand pits in the restored landfill and focussed on assessing nutrient levels within the soils to aid grass growth.

2.2.2 The primary sources of information that are reviewed within this QRA are outlined and described in Table 2.1 below.

Table 2.1 Primary Sources of Information

Author	Date	Report	Description
Callear and Bewers	April 1993	East Tilbury Waste Disposal Site Status Report	Status report incorporating the design, changes in permitting, ownership and waste streams associated with East Tilbury Landfill.
Cascade	01/07/2022	North Portal Groundwater Model – Technical Note (as part of Appendix 14.5 Hydrogeological Risk Assessment Annex 11)	Numerical groundwater model simulating groundwater inflow into the excavation, predicted drawdown of groundwater elevation simulation of saline/freshwater interface movement supporting the wider Hydrogeological Risk Assessment.
Cascade	October 2020	PW07006A Pumping Test (North Portal) Hydrogeology and Geoenvironmental Review (Cascade, 2020)	Detailed assessment of the results of the pumping test carried out at monitoring well PW07006A, near the propose North Portal location.

2.2.3 Other pertinent sources of information include the Phase 1 Ground Investigation Factual Report (Perfect Circle Joint Venture, 2018) and Annex B of the GQRA for the Phase 2 Investigation (Annex B, Appendix 10.9, Application Document 6.3), both used for site conceptualisation and understanding the contaminant distribution as set out in Section 3.8.

2.2.4 The preliminary conceptualisation of the site and surroundings has been formed through reviewing information sources listed in Table 2.1, as well as the following online resources:

a. BGS GeoIndex Online Map Viewer and borehole scans [redacted]

b. BGS Scanned Geological Maps ([redacted]

c. DEFRA Magic Maps (MAGIC (defra.gov.uk))

d. OS Mapping on ARCGIS available and maintained as part of the Lower Thames Crossing Project.

2.2.5 Other sources of information referenced within this document are presented at the end of the document as References.

2.3 Background Project Information

2.3.1 The North Portal design includes a southward dipping ramp entrance and a deeper shaft area. The lowest elevation of the proposed shaft design is -24m Above Ordnance Datum (AOD). This is below the groundwater table.

2.3.2 As the ramp and shaft are below the groundwater table, which is approximately 1m AOD (Highways England, 2018; Cascade, 2019), dewatering of accumulated water is proposed to enable construction to proceed safely. A diaphragm wall is proposed around the perimeter of the shaft and ramp area as part of the structural design and to aid groundwater control. Depending on the amount of dewatering required and potential groundwater ingress through the diaphragm wall, groundwater control measures may have the potential to cause drawdown and changes to the direction of local groundwater flow.

2.3.3 The records for East Tilbury Landfill comprise a wide variety of waste streams (further information provided in Section 3), including hazardous materials. The landfill is understood to be unlined and primarily comprises a land raise (Callear and Bewers, 1993). The potential for contaminants from East Tilbury Landfill to be drawn towards the North Portal needs to be assessed to quantify the level of risk that this potential pollutant linkage presents.

3 Environmental Setting

3.1 Site summary

3.1.1 East Tilbury Landfill is a former hazardous waste disposal site located on the north bank of the River Thames, approximately 6km south of Stanford Le Hope, Essex.

3.1.2 East Tilbury Landfill is identified as 'East Tilbury Waste Disposal Site' within the Status Report (Callear and Bewers, 1993) and 'East Tilbury Marshes Landfill' in the Environment Agency dataset provided by Landmark. This site will be referenced as 'East Tilbury Landfill' herein, in keeping with current common reference between National Highways and the Environment Agency.

3.1.3 The landfill has been constructed as a land raise, understood to be unlined, sitting directly above the Alluvium. The land raise sits approximately 10 to 11m AOD, with the surrounding land being relatively flat, sloping very gently towards the River Thames to the south. The restoration of the site in late 1992 saw approximately 1m of soil cover imported to the site to sit above the raise (Callear and Bewers, 1993).

3.1.4 Table 3.1 presents information on the East Tilbury Landfill site.

Table 3.1 East Tilbury Landfill site details

National Grid Reference	568070,176480 (site centre point)
Perimeter length (m)	4,040
Site area (ha)	Approximately 74
Extents (m)	1,300 (north–south), 800 (east–west)
Nearest postal code	RM18 8PB
Administrative area	Thurrock Unitary Authority

Landfill Permit Information and Waste Inputs

3.1.5 The sources of information relating to East Tilbury Landfill that have been collated to date are presented in Table 3.2. All data sources are Landmark/Groundsure data (licence dated February 2018) collected from the Project GIS datasets, unless otherwise stated.

Table 3.2 Desk Study Information for East Tilbury Landfill

Data type	Information	Source and date
Local authority ID	THU017	Local authority recorded landfill sites dataset, 2018
Environment Agency landfill reference	EAHLD00554	Environment Agency historical landfill dataset, 2018
Water Research Centre ref.	1500/0522	Environment Agency historical landfill dataset, 2018
Former site licence no.	73/79	Environment Agency historical landfill dataset, 2018

Data type	Information	Source and date
Licence holder	William Cory and Son Limited	Environment Agency historical landfill dataset, 2018
Landfill operator	Cory Environmental Limited	Environment Agency historical landfill dataset, 2018
Filling dates	1933 to 1991 (Note: these are as stated in the EA historical landfill dataset, but are approximate date ranges)	Environment Agency historical landfill dataset, 2018
	'*The last waste was taken onto the site in September 1990*.'	Environment AgencyStatus Report (Callear and Bewers, 1993), paragraph 2.3
Recorded waste types	'*industrial, commercial and household wastes and liquids/sludge wastes*'	Environment Agency historical landfill dataset, 2018
	'*household, hazardous, solids and liquids*'	Local authority recorded landfill sites dataset, 2018
Licence status	'*Cancelled*'	Environment Agency historical landfill dataset, 2018
Maximum permitted input	'*Large (equal to or greater than 75,000 and less than 250,000 tonnes per year), no restrictions on waste source*'	Environment Agency historical landfill dataset, 2018
Permitted restrictions on waste source	No permitted restrictions on waste source	Environment Agency historical landfill dataset, 2018
Estimated total waste capacity of the landfill	1,000,000m^3	Status Report (Callear and Bewers, 1993)

3.2 Surrounding land use

3.2.1 East Tilbury Landfill is bounded on the north, east, and west by dual man-made drainage ditches (the Tilbury Main forms much of the western boundary). Further details on surface water features are described in Environmental Statement Chapter 14: Road Drainage and the Water Environment (Application Document 6.1) and Appendix 14.2: Water Feature Survey Factual Report (Application Document 6.3) and can be found marked on Figure 1. To the west is Goshems Farm Landfill, Tilbury Ash Fields and Shed Marsh Landfill, and to the east are agricultural fields with Coalhouse Fort beyond. South of East Tilbury Landfill is the River Thames. These features, the Project route, and the Order Limits are shown on Figure 1.

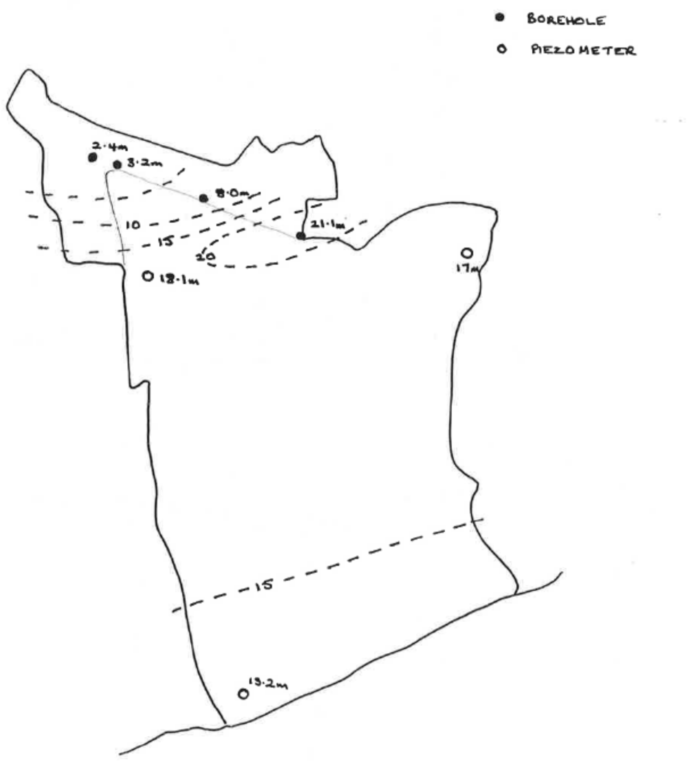
3.3 Geology

3.3.1 The Status Report (Callear and Bewers, 1993) provides a summary of the geology underlying East Tilbury Landfill as understood at the time (1993). It interprets the geological succession to be '*…Estuarine Alluvium (Alluvial Clay) overlying Thames Ballast overlying chalk*'. The Alluvial Clay (i.e. Alluvium) is considered to be continuous beneath the landfill, but '…thins rapidly along the northern margin of the site'. It is stated that the Thames Ballast strata (i.e., River Terrace Deposits) extends beneath the Thames, but '…peters out towards the north of the waste disposal site' and, further, 'The chalk underlies the whole of the site' and '…The chalk surface is virtually flat beneath most of the site but rises steeply on the northern boundary and outcrops just beyond'.

3.3.2 The Alluvium is reported to contain clayey layers that may have provided a low-permeability barrier between the land raise and the underlying River Terrace Deposits (RTD) and Chalk aquifer. The Alluvium has an average thickness of 15m across the majority of the site, however, a minimum thickness of 2.4m was observed in BH4 (in the northwest most corner of the site) (Callear and Bewers, 1993). Figure 10 from the Callear and Bewers (1993) Status Report shows conjectured clay thickness contours based on borehole records reviewed at the time. This can be viewed in Plate 3.1.

Plate 3.1 Conjectured Clay Thickness Contours Underlying East Tilbury Landfill (Callear and Bewers, 1993)

Fig. 10 Conjectured Clay Thickness Contours



3.3.3 During discussions in a meeting on 11 July 2018 between the Project and the Environment Agency, the Environment Agency advised that the landfill was unlined and forms a land raise above the existing low-lying (formerly intertidal) area. The restoration of the landfill began in 1992 and comprised placement of a cover layer of soil approximately 1m thick obtained from the Limehouse Link Project in London.

3.3.4 This description concurs with what is mapped by the British Geological Survey (BGS) Special Sheet: Inner Thames Estuary 1:50,000 Solid and Drift (BGS, 1997).

3.3.5 A review of the scanned BGS GeoIndex borehole records shows several wells present within the landfill, in conjunction with the investigations referenced in the Callear and Bewers (1993) Status Report.

3.3.6 Not all the records contained a geological log. The following records contained geological logs; TQ67NE267 (borehole 1) from the 1972 ground investigation; TQ67NE69 (borehole 3) from the 1978 ground investigation; TQ67NE10 (Cliffe 3) from 1959; TQ67NE268 (borehole 2) from 1972.

3.3.7 A Review of the scanned BGS logs shows that Made Ground (including capping material and tipped waste) ranged from 0.5m to 6.5m in thickness. Alluvium ranged from 2.4m (Plate 3.1, Callear and Bewers 1993) to 18.5m in thickness. The RTD ranged from 4.0m to 7.6m in thickness.

3.3.8 It should be noted that these ground investigations took place prior to the landfill ceasing to accept waste, and therefore, Made Ground thickness is unlikely to be representative of present-day thickness.

3.4 Hydrology

3.4.1 The Status Report (Callear and Bewers, 1993) states that East Tilbury Landfill is surrounded by drainage ditches constructed in 1978 by Cory Sand and Ballast Co. to collect leachate from East Tilbury Landfill and direct it into the River Thames via Bowater Sluice. From 1978, the leachate was collected in the inner drainage ditch and pumped back over the waste in a form of recirculation system. The sluice discharges into the River Thames at low tide. Tilbury Main is the main waterbody in the network of ditches, and forms much of the western boundary of the landfill. The Status Report (Callear and Bewers, 1993) states that dual ditches were constructed and the internal one sealed on the base and outside to prevent leachate entering the ‘clean’ outer ditch. Further information on the dimensions and construction details are not provided.

3.4.2 The River Thames is the next closest surface water feature to East Tilbury Landfill and borders the southern edge of the site. The River Thames is known to be tidally influenced in this location.

3.4.3 Appendix 14.2: Water Features Survey Factual Report (Application Document 6.3), provides further information on watercourses within the Project study area. The drainage ditches are not considered further as a potential receptor or pathway likely to be influenced by the Project. This is due to them being shallow, manmade features, specifically constructed to manage the leachate draining from the land raise of East Tilbury Landfill (Callear and Bewers, 1993). As such, they are not considered sensitive receptors and are unlikely to be in continuity with groundwater.

3.5 Hydrogeology

3.5.1 The Alluvium is classified by the Environment Agency as a Secondary (undifferentiated) Aquifer, the RTD is classified as a Secondary A Aquifer, and the Chalk as a Principal Aquifer.

3.5.2 The Status Report (Callear and Bewers, 1993) states that there is a tidal response in the groundwater beneath East Tilbury Landfill. This diminishes with increasing distance from the River Thames. Details on which units the tidal influence was observed were not provided. The pumping test report (Cascade, 2020) found that tidal influence was only observed within the RTD and Chalk aquifers, with no measurable tidal influence within the Alluvium and Made Ground. It is noted that the pumping test was not undertaken beneath East Tilbury Landfill. However, based on the proximity and understanding of local hydrogeology, it is considered to provide a suitable proxy for conditions beneath East Tilbury Landfill.

3.5.3 A groundwater flow direction could not be determined in any of the units present. Factors such as the tidal variation in the Chalk and RTD and perched water in the Alluvium and Made Ground makes inference of a flow direction difficult. However, outside of tidal cycles, a general flow direction toward the south or east towards the River Thames and estuary would be anticipated. A flow to the west from East Tilbury Landfill towards the North Portal is anticipated to be unlikely under normal conditions.

3.5.4 A review of the available BGS GeoIndex borehole logs (TQ67NE267, TQ67NE69, TQ67NE10, and TQ67NE268) shows several groundwater strikes to be encountered within the Made Ground and the Alluvium, with intervals of *"no water"* comments within the Alluvium, suggesting groundwater within those units is perched and discontinuous.

3.5.5 The Linford public water supply pumping station is located in Linford, between Lower Crescent and an unnamed stream at National Grid Reference TQ 67190 79300. The Project route passes approximately 500m to the west of Linford. The two wells at Linford Pumping Station are located 2.3km north of the landfill at the closest point. The Environment Agency licence 8/37/56/*G/0044 (Environment Agency, 2015) can be found in Annex A and states the following:

Table 3.3 Linford Abstraction Licence Details

Licence detail	Abstraction 2
Purpose of abstraction	Linford public water supply – up to and including 31 March 2023. Managing water levels within Chalk aquifer.
Maximum quantity of water to be abstracted	6,365m^3/day – Linford public water supply
	2,160m^3/day – managing water levels within Chalk aquifer.

3.5.6 No details are included above for Abstraction 1 as it relates to a well approximately 4km away from the landfill and is not considered further due to distance from the landfill and the Project. This would be outside any zone of influence from the Project works.

3.5.7 Abstraction 2, located 2.3km north of the landfill, is managed by Essex and Suffolk Water (owned by Northumbrian Water Ltd). Consultation with Essex and Suffolk Water undertaken in November 2017 has indicated that this Chalk borehole is not currently abstracting groundwater for water supply but is being abstracted to control the artesian condition, with abstracted water being discharged to an adjacent stream – Gobians Sewer (Feature OW-1N09ZZZ1 in Appendix 14.2: Water Features Survey Factual Report (Application Document 6.3)).

3.5.8 Due to the distance and upgradient direction (2.3km north) of the Linford public supply abstraction relative to East Tilbury Landfill, it is not considered further as a potential receptor that could be impacted by Contaminants of Concern (COC) from the landfill as a result of dewatering at North Portal. No other groundwater abstractions were identified as potential receptors.

3.6 Environmentally Sensitive Areas

3.6.1 The Thames Estuary & Marshes approximately 350m east of the landfill are given Ramsar and Special Protection Area (SPA) site designations to the associated wetlands.

3.6.2 A Site of Special Scientific Interest (SSSI) designation is given to the Mucking Flats and Marshes approximately 350m east of the landfill.

3.6.3 Due to the direction of the environmentally sensitive areas being hydraulically cross gradient of the landfill and proposed construction works for the Project, they are not considered further as potential receptors.

3.7 Contaminant Distribution

3.7.1 No information was available on the contaminant distribution within the landfill other than that summarised in the Callear and Bewer (1993) Status Report which concluded that evidence of leachate impact was present in both groundwater and (in low concentrations) in surface water within the landfill and the drainages ditches on the perimeter. This was mainly deduced from elevated concentrations of ammonia and potassium. Other contaminant concentrations elevated above laboratory detection limits that were reported for groundwater and surface waters included total organic carbon, biochemical oxygen demand, heavy metals, sulphate, chloride, alkalinity and dissolved oxygen.

3.7.2 Information on the contaminant distribution around the area of the proposed North Portal location is provided in Annex B of Appendix 10.9: GQRA for the Phase 2 Investigation (Application Document 6.3) and from the results of the PW07006A Pumping Test (North Portal) Report (Cascade, 2020).

3.7.3 A review of the locations within these reports was undertaken to understand contaminant distribution to the west of East Tilbury Landfill, in the vicinity of the proposed North Portal, and on the west of North Portal. Care was taken to ensure good spatial distribution to catch any potential COC coming from East Tilbury Landfill. The ground investigation follows the Project route, providing a north south distribution, whilst also looking at a wider east – west distribution, to cover the area closer to the East Tilbury Landfill.

3.7.4 Concentrations of potential contaminants were measured within the soils and groundwater samples taken in the area of the North Portal. These include metals, hydrocarbons, phenols and a limited number of isolated pesticides (Appendix 10.9, Annex B, Application Document 6.3). The distribution of COC typically included in landfill monitoring and specified as key COC in the Environment Agency landfill monitoring guidance document LFTGN02 (Environment Agency, 2003) are discussed below in the areas around East Tilbury Landfill and the proposed North Portal.

3.7.5 The maximum groundwater concentration of ammoniacal nitrogen within the Alluvium was measured as 96.3 µ/l in BH07031, located east of the Project route and immediately west of the East Tilbury Landfill. Concentrations of a similar order were measured across the area with no indication of a plume. This suggests that the source is not East Tilbury Landfill. The highest concentration of ammoniacal nitrogen was measured in the Made Ground at 470µ/l in monitoring well BH07099, along the proposed Project route with lower concentrations to the east (towards the East Tilbury Landfill), suggesting the source is not from East Tilbury Landfill. From the RTD and the Chalk, a maximum concentration of 109µg/l was measured in BH2385 (screening the Chalk), also located along the Project route with lower concentrations to the east (towards East Tilbury Landfill).

3.7.6 The maximum groundwater concentration of chloride measured within the Made Ground was 7,300µg/l in monitoring well BH07010, again this is west of the Project route. The highest concentration of chloride was measured within the Alluvium at 10,800µg/l in monitoring well BH07031, located east of the proposed route and immediately west of East Tilbury Landfill. Concentrations of a similar order were measured across the area with no indication of a plume. This suggests that the source is not East Tilbury Landfill. From the RTD and the Chalk, a maximum concentration of 8,860µg/l was measured in BH2384 (screening the RTD), also located along the proposed route of the Project with lower concentrations to the east (towards East Tilbury Landfill).

3.7.7 The maximum groundwater concentration of dissolved organic content (DOC) in the Made Ground was 1,300,000/l in monitoring well BH07046, along the proposed route, with lower concentrations located towards East Tilbury and no plume identified. The highest measured concentration of DOC was measured in the Alluvium at 4,510,000µg/l in monitoring well BH07039, to the west of the proposed route. From the RTD and the Chalk, a maximum concentration of 1,680,000µg/l was measured in BH7018 (screening the RTD), also west of the proposed route of the Project with lower concentrations to the east (towards East Tilbury).

3.7.8 Based on the groundwater monitoring data (Annex B of Appendix 10.9, Application Document 6.3), the contaminant distribution is not considered to indicate a plume from East Tilbury Landfill. Therefore, measured concentrations have not been directly attributed to the landfill.

3.8 Preliminary Conceptual Site Model

Source

3.8.1 The main identified source of COC to potentially impact the receptors is the East Tilbury Landfill site.

Receptors

3.8.2 The main identified receptors are as follows:

a. Human Health – construction workers on the Project

b. Underlying aquifers; Alluvial Deposits Secondary (undifferentiated) Aquifer, River Terrace Deposit Secondary A Aquifer, Chalk (Principal Aquifer)

c. River Thames present to the southern boundary of the East Tilbury Landfill

Pathways

3.8.3 Pathways considered to be potentially active during the construction phase are presented in Table 3.4.

Table 3.4 Active pollutant pathways

Pollutant pathway	Description
A	Vertical migration of Contaminants of Concern (COC) and leaching into perched water present within the Alluvium underlying the landfill, followed by lateral migration off-site leading to deteriorating of groundwater quality west of East Tilbury Landfill
B	Vertical migration of COC and leaching into groundwater present within the River Terrace Deposits and Chalk underlying the Alluvium, followed by lateral migration off-site leading to deteriorating of groundwater quality west of East Tilbury Landfill
C	Lateral migration of impacted groundwater within the underlying strata into the River Thames
D	Dermal contact and ingestion pathway for construction workers from potentially impacted groundwater flowing into the excavation during dewatering and ongoing construction works
E	Vapour inhalation pathway for construction workers from volatile COC in potentially impacted groundwater flowing into the excavation during dewatering and ongoing construction works
F	Migration of COC within groundwater towards proposed built structures, potentially impacting foundation structures
G	Potential mobilisation of ground gases associated with waste degradation at the East Tilbury Landfill by potential drawdown of the water table

4 Information Sources Review

4.1 Objectives

4.1.1 This section aims to undertake a review of the information sources listed in Section 2.2 that are deemed relevant to qualitatively assessing the risk from East Tilbury Landfill. The purpose of the review is to collate relevant information into the one assessment and refine the preliminary CSM outlined in Section 3 by incorporating the most relevant information available at the time of writing and ensure a robust assessment based on the available information.

4.1.2 The 1997 CL Associates Report, whilst has been reviewed, has not been discussed due to a lack of pertinent information in relation to the scope of the QRA.

4.2 East Tilbury Status Report (Callear and Bewers, 1993)

Objectives of the Status Report

4.2.1 The Status Report was published with the intention of collating all information available on East Tilbury Landfill present at the time with recommendations provided for better site management, record keeping, and contaminant delineation.

East Tilbury Landfill Legislation and Regulations

4.2.2 Prior to 1974, there was no national regulation for landfills. Information on the owners and operators and licensing of East Tilbury Landfill, as far as can be ascertained from the Status Report (Callear and Bewers, 1993), is summarised in Table 4.1.

Table 4.1 East Tilbury Landfill Timeline

Date	Event
1933	'Consent' issued for disposal of waste on East Tilbury Landfill under the Essex County Council Act 1933.
Not known	Owned and operated by F.W. Sturrage Ltd.
1968	Consent THU/580/68 – additional 8.5ha tipping area in northern boundary ('inert and decomposed' waste only). Consent THU/587/68 – additional 2.9ha tipping area in north-west corner ('household refuse' only).
1977	Acquired by Cory Sand and Ballast Company Ltd.
1978	Consent granted under the Essex County Council Act 1967 permitting addition of waste to existing disposal. Terms and conditions could not be more onerous than the 1933 Act. Perimeter leachate drainage ditches constructed.
1979	Waste Management Licence issued under the Control of Pollution Act 1974
1981	Absorbed by Ocean Trading and reorganised to Cory Environmental Ltd.

Date	Event
September 1990	Last waste deposited.
1992	Restoration of East Tilbury Landfill begins (approx. 700,000 tonnes of soil type materials generated from the Limehouse Link tunnel), imported via barge by AMEC. Aimed for 1m of soil cover over East Tilbury Landfill. No further detail available to review.

4.2.3 The date of first waste deposit appears uncertain due to lack of contemporary records. The 1933 date given in the Status Report (Callear and Bewers, 1993) and referred to in Table 4.1 may be based on the Essex County Council Act of 1933, which may not actually correspond with the first deposit of waste.

4.2.4 The Status Report (Callear and Bewers, 1993) shows disposal of liquid (known as co-disposal) occurred at East Tilbury Landfill in the 1950s and continued until at least December 1983. It is stated that no pollution prevention controls were imposed on the landfill operators by the 1933 Act. Due to the status of East Tilbury Landfill as a pre-existing locally consented site, it was exempt from the Deposit of Poisonous Waste Act 1972 and therefore subject to fewer controls on waste types and practises than other landfill sites of the time.

4.2.5 The Status Report (Callear and Bewers, 1993) states that the last waste input was in September 1990, and site restoration comprised imported material from the Limehouse Link tunnel arisings, which began at the end of 1992. No further detail or completion dates are given.

Waste Types, Potential Contaminants and Disposal Practices

4.2.6 Information stated in the Status Report (Callear and Bewers, 1993) is summarised below, and relevant ‘thumbnail’ extracts from the Status Report are also included below for ease of reading.

a. East Tilbury Landfill has a total capacity of approximately one million cubic metres.

b. East Tilbury Landfill received solid waste from the London area, and liquid wastes from Hertfordshire, Kent, London and Essex.

c. Liquid inputs started in the 1950s and peaked in the late 1970s at approximately 13 million gallons (59,000m^3) annually. Liquids were still being deposited until at least December 1988 as shown in Plate 4.1.

d. The site licence 73/79 specifies deposition of household, commercial and industrial wastes, with a hazardous waste limit of 16,000 tonnes per annum solid and eight million gallons (approximately 36,400m^3) liquid or semi-liquid, plus five million gallons (approximately 22,700m^3) of industrial waste per annum.

e. Liquids were bulked into tankers at transfer stations and were reportedly not deposited in drums.

f. Liquid disposal areas were predominantly in the centre and south of East Tilbury Landfill as shown in Plate 4.1.

g. Liquids (including waste oils) were pumped into trenches formed within the landfill and allowed to permeate into the waste. The trenches were then backfilled with further solid waste as shown in the 1977 Tipping Plan (Plate 4.2).

h. According to the Status Report, the perimeter dual surface drainage ditches and leachate recirculation were constructed in 1978. Leachate from the boundary ditches was sprayed over the surface of the landfill in the north and south in the 1970s. Excess leachate was discharged into the River Thames via Bowater Sluice. Cory are reported to have negotiated with Thames Water to discharge excess leachate direct to the River Thames, and so no formal leachate treatment plant was ever constructed.

i. Discharges into the River Thames were reportedly frequent in the 1970s as East Tilbury Landfill had no engineered containment measures but had declined to rare events by the time of the final waste inputs in 1990.

Plate 4.1 Site tipping plan 1979 to 1988 (extracted from Status Report [Callear and Bewers, 1993])

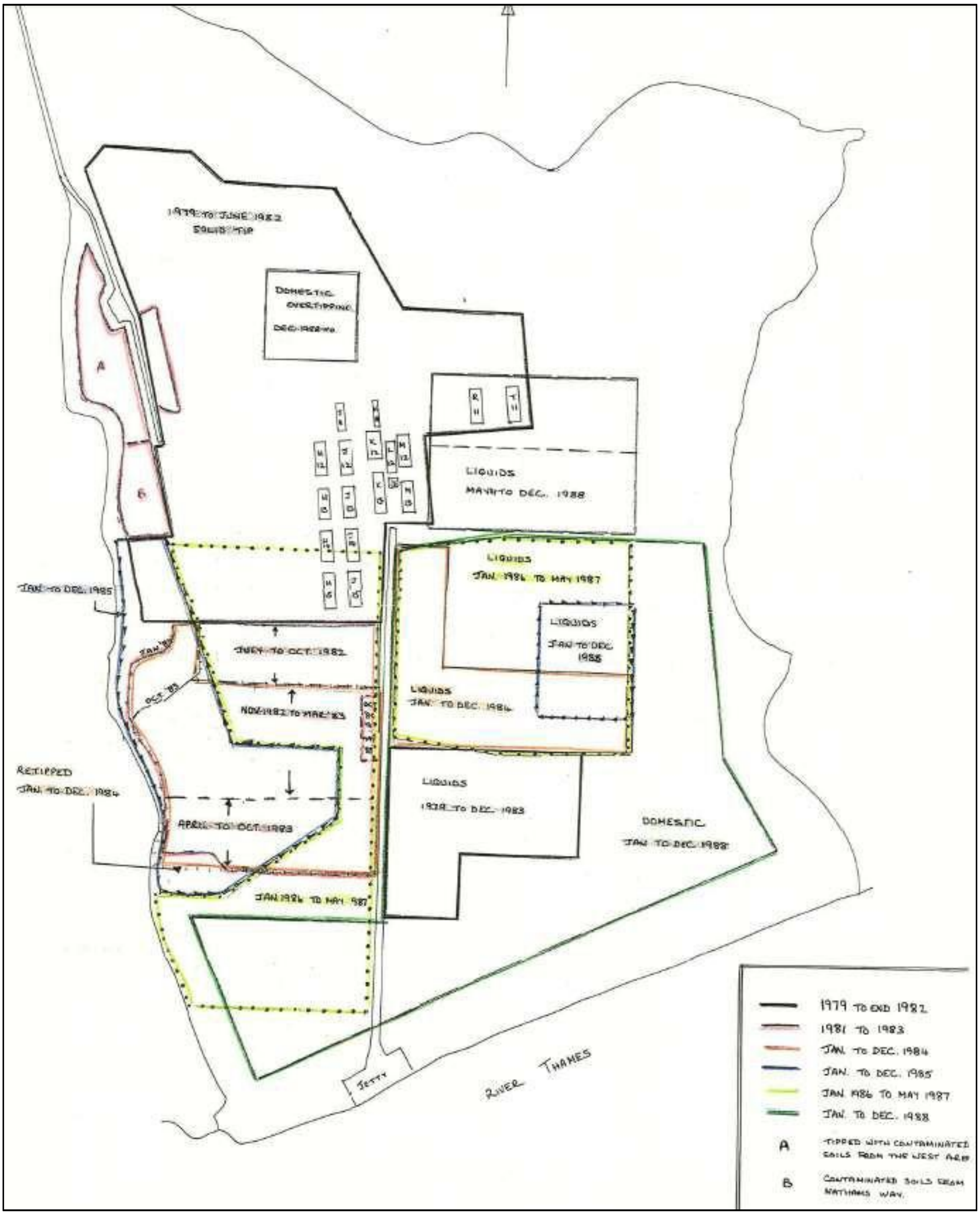
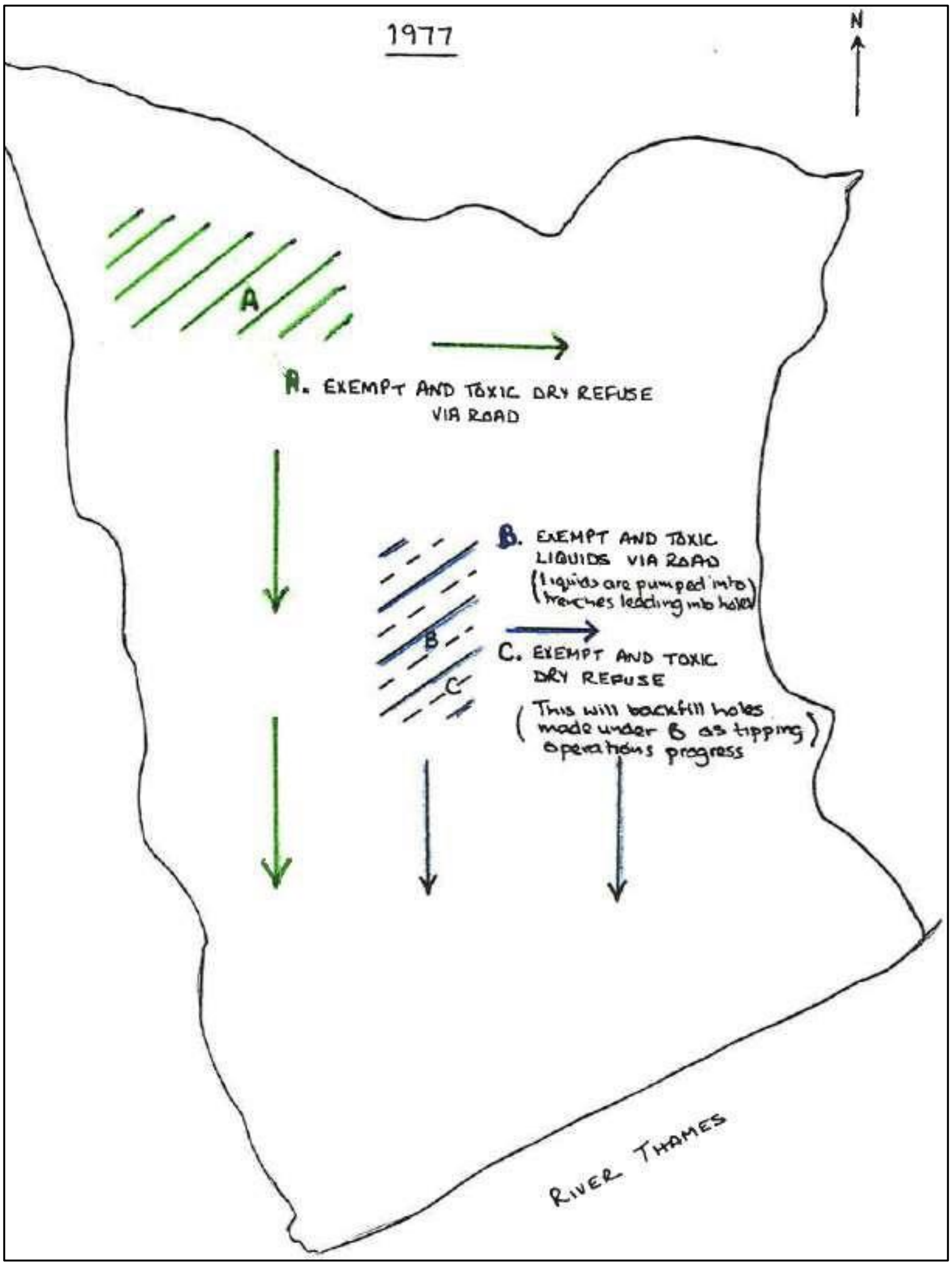


Plate 4.2 1997 Tipping Plan (extracted from Status Report [Callear and Bewers, 1993])



Status Report Environmental Findings

Leachate Impact on Groundwater and Surface Water

4.2.7 The Status Report (Callear and Bewers, 1993) concluded that evidence of leachate impact was present in both groundwater and (in low concentrations) in surface water. This was mainly deduced from elevated concentrations of ammonia and potassium. Other contaminant concentrations elevated above laboratory detection limits that were reported for groundwater and surface waters included total organic carbon, biochemical oxygen demand, heavy metals, sulphate, chloride, alkalinity and dissolved oxygen.

4.2.8 The Status Report notes that non-standardised procedures may have influenced some of the data, as it was collected by two organisations (the National Rivers Authority (NRA, precursor to the Environment Agency) and Cory Environmental Ltd.) using differing sampling and testing techniques. The Status Report (Callear and Bewers, 1993) also states that the influence of saline intrusion may hide leachate impacts in groundwater, as it will affect some of the parameters used at the time to determine leachate impacts, such as chloride and sulphate concentrations and alkalinity.

4.2.9 The Status Report states that the Chalk aquifer is considered to be protected to some degree by clays and silts of the Alluvium that underlies the landfill. However, it further states that this may only be 15m thick, and significantly less in the north-west corner of East Tilbury Landfill. Potential pollution of the Chalk aquifer, from which the Linford public water supply wells abstract, is therefore considered to be of '*major concern*' in the Status Report (Callear and Bewers, 1993).

4.2.10 The 'Esso lagoon' was also mentioned in the Status Report as a potential source of contamination to local surface waters. The location and purpose of this feature is not explicitly identified in the Status Report.

Leachate Level

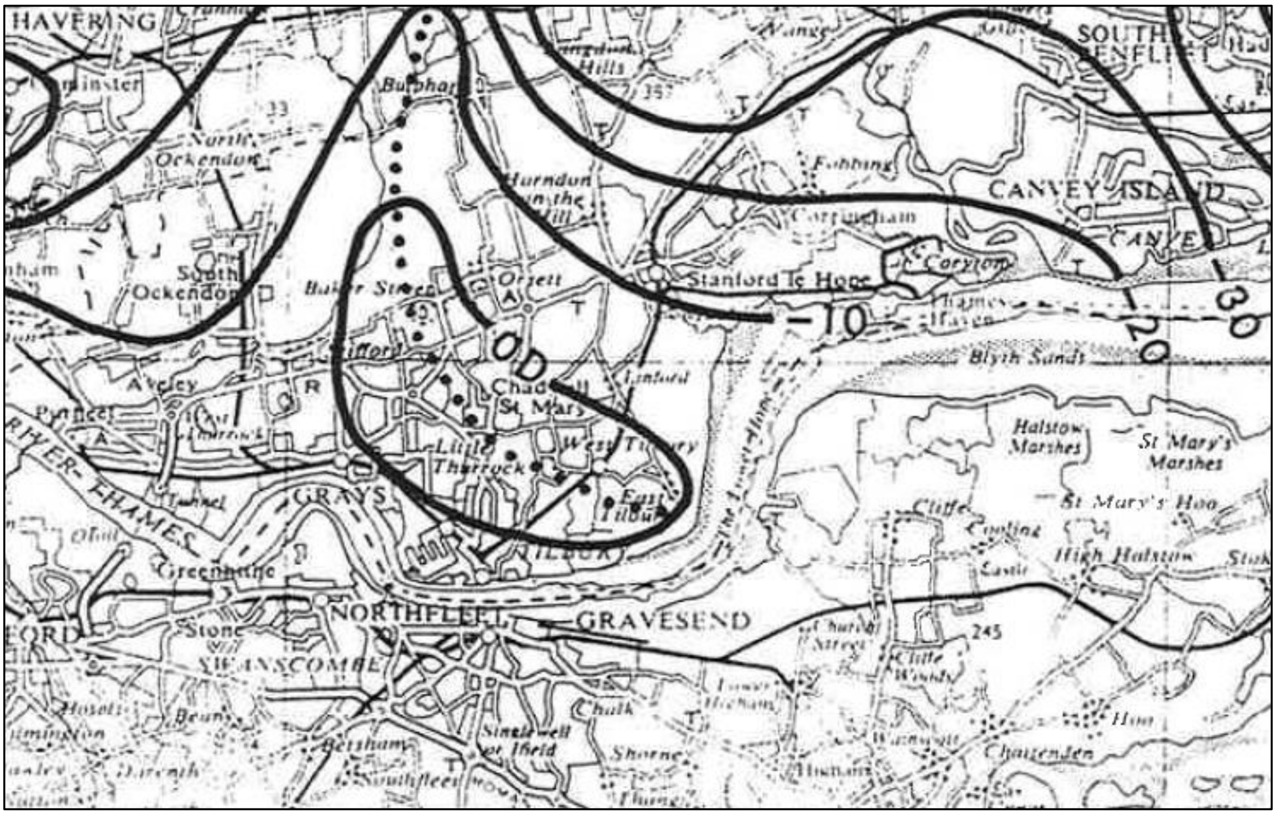
4.2.11 The main conclusions of the Status Report (Callear and Bewers, 1993) suggest that the leachate levels within the waste mass were reducing, and therefore impacts to surface waters were expected to decrease.

Groundwater Flow Direction

4.2.12 Insufficient information was available to determine groundwater flow paths at East Tilbury Landfill at the time of writing the Status Report (Callear and Bewers, 1993). Evidence from boreholes within the Chalk aquifer indicated a '*resistance*' to northerly groundwater flow towards the Linford abstraction. It was suggested in the Status Report that this may be affording a level of protection to the abstraction from contamination from the landfill migrating through the Chalk.

4.2.13 The Linford abstraction was reported to have remained of good quality and, as of 1993, not to have been affected by saline intrusion. A groundwater divide between East Tilbury Landfill and the Linford abstraction is shown on Figure 14 of the Status Report (Callear and Bewers, 1993) and in Plate 4.3. The divide is found to bisect East Tilbury Landfill in a southeast – northwest direction, and then intersects the northern end of the proposed North Portal.

Plate 4.3 Groundwater contours and groundwater divide within the Chalk (dotted line) (extracted from Status Report [Callear and Bewers, 1993])



4.2.14 A review of BGS Hydrogeological Map for the area (Dartford 1:63,360 Sheet 15, 1968), shows a divide to be present further to the north of where the divide is plotted on Plate 4.3, suggesting that it does not bisect the landfill or the proposed North Portal location, although does still show a flow towards the Linford Well Abstraction from the North Portal and East Tilbury Landfill areas to be unlikely due to the abstraction being hydraulically upgradient.

Landfill Gas

4.2.15 The Status Report (Callear and Bewers, 1993) does not consider landfill gas. No records of any landfill gas management systems for East Tilbury Landfill have been found in the information currently available to the Project.

4.3 North Portal Groundwater Model Technical Note (Application Document 6.3)

Objectives of the Groundwater Model Technical Note

4.3.1 A numerical groundwater model was developed by the Project to support the Hydrogeological Risk Assessment, which forms Appendix 14.5, Application Document 6.3. The North Portal Groundwater Model Technical Note is Annex 11 of the Hydrogeological Risk Assessment.

4.3.2 The objectives of the North Portal Groundwater Model were to form a conceptual numerical groundwater model that considered the following:

a. Construction of the conceptual model based on Phase 1 and Phase 2 ground investigation data

b. Calibration against site-specific data including a time-variant calibration of tidal response in the Chalk

c. Simulation of the groundwater inflow into the excavation

d. Simulation of drawdown prediction of the groundwater level

e. Simulation of saline/freshwater interface movement

Methodology and Limitations

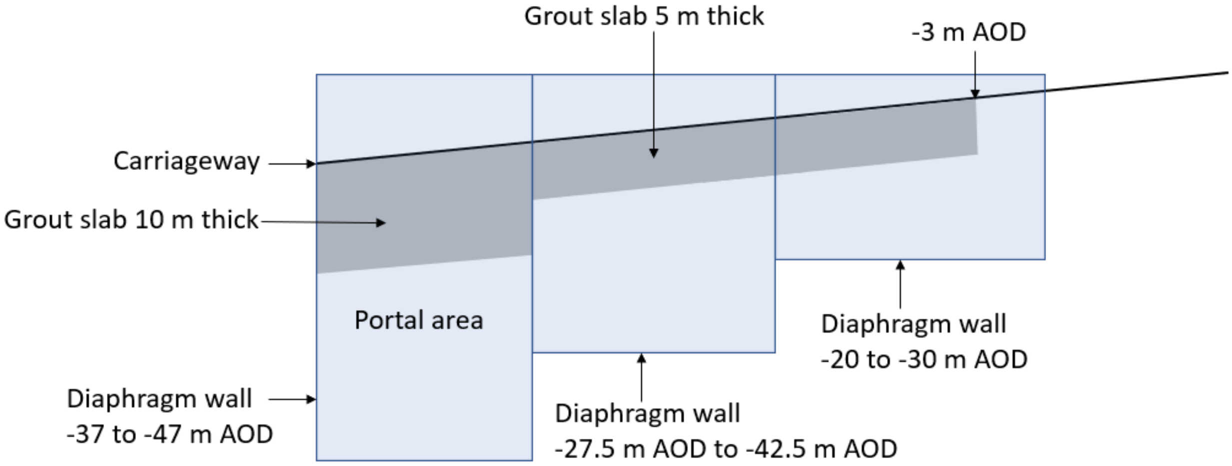
4.3.3 The model simulated various conditions based on the proposed design parameters at the time of modelling. The software adopted for this was MODFLOW and the model incorporated site-specific data collected for the Project, literature values, and a lithostratigraphic model for the area obtained from BGS.

4.3.4 The groundwater model simulates the major components of the 'main works' relating to the North Portal, ramp and main tunnel. A detailed description of the overall Project is given in Environmental Statement Chapter 2: Project Description (Application Document 6.1) and Appendix 2.1: Construction Supporting Information (Application Document 6.3).

4.3.5 The tunnel launch structure (referred to as the 'box', 'shaft' or 'portal') requires a large subterranean structure. The portal would be open during construction and incorporated into the cut and cover tunnel thereafter.

4.3.6 Plate 4.4 (taken from Appendix 14.5, Application Document 6.3) is a sketch of the suite of possible environmental mitigation measures for the North Portal excavation. The sketch includes maximum ranges for the thickness of the grout plug and depth of the diaphragm walls. The diaphragm wall would consist of individual overlapping panels filled with bentonite slurry during their excavation and displaced with concrete when completed (including reinforcement). Panels would be placed around the portal and ramp. This wall acts as ground support and is designed to be an effective groundwater flow cut-off barrier. A grouted block is proposed at the base of the excavation as further mitigation of groundwater ingress and for ground stability. Base grouting would be included along the length of the excavation where the ramp is below an elevation of -3m AOD.

Plate 4.4 Sketch of the potential environmental mitigation for the North Portal and shaft area



4.3.7 The Linford public water supply abstraction well was also incorporated and considered within the groundwater model. The location, length of screen and abstraction rates were included.

4.3.8 The following limitations and assumptions apply to the modelling:

a. The infrastructure modelled and other simulations are in steady-state unless otherwise stated.

b. The models simulate saturated conditions only. This means it is not possible for perched water tables to be computed. This is a limitation for computing the water table within non-aquifers, such as in the Alluvium. The model assumes a continuous waterbody is present within the Alluvium, in continuity with the underlying RTD and Chalk. Therefore, although drawdown maybe predicted in the Alluvium, this does not reflect the aquitard conditions present where this is less likely.

c. The conductivity of the diaphragm wall, slurry wall and concrete plug is based on advice from the Tunnel Portals Team.

d. Construction techniques and ground treatments would be used to avoid major dewatering during the excavation of the ramp and portal area. On this basis, it is assumed that rock/soil ground treatment would be achieved under 'flooded' conditions. This means that no advanced pressure relief dewatering has been included in the model.

e. Once constructed, the ramp and portal area would be made permanently watertight (to groundwater).

Conceptual Model

Geology

4.3.9 Within the Chalk, the site-specific information has shown evidence for the following:

a. A fractured zone of Chalk gravels (unstructured Chalk and missing core) at the top of the Chalk sequence underlying the RTD.

b. A thicker zone of low Rock Quality Designation (RQD) and unstructured or karstic Chalk at depth beneath the River Thames with areas of missing core.

c. Along the central part of the River Thames, the Chalk rises up towards the channel bottom. There is no low permeability barrier between the River Thames and the top of the Chalk.

4.3.10 Within the Alluvium, the site-specific information has shown the following:

a. The Alluvium is predominantly clay material.

b. There are thin layers of gravel and sand on-lapping (draping) onto the Chalk within the Alluvium deposits, forming southward dipping sinuous discontinuous features.

4.3.11 The site-specific data corresponds well with the BGS model, particularly with regard to the elevations of the Alluvium, RTD and top of the Chalk.

Hydraulic Conductivity

4.3.12 Hydraulic conductivity ranges were chosen based on site specific data collected during the site investigations, published literature values, as well as The Thames Cable Tunnel Project (Haswell *et al.,* 1970).

4.3.13 Table 4.2 shows a summary of the hydraulic conductivity ranges adopted after calibration within the model.

Table 4.2 Summary of Calibrated Parameter Values

Material	Hydraulic conductivity 50th percentile (m/s)	Specific yield (%) – Sy	Storage coefficient – S
Made Ground	$1.00x10^{-5}$	30	$5x10^{-3}$
Head Deposits	$5.00x10^{-7}$	10	$5x10^{-3}$
Alluvium	$7.90x10^{-7}$	2	$1x10^{-4}$
RTD	$6.55x10^{-4}$	0.15 (outcrop gravels) 0.05 (buried)	$1x10^{-5}$
London Clay	$1.00x10^{-7}$	2	$1x10^{-5}$
Lambeth Group	$1.00x10^{-7}$	1	$1x10^{-5}$
Harwich Formation	$1.00x10^{-5}$	8	$1x10^{-5}$
Thanet Formation	$1.00x10^{-4}$	10	$1x10^{-5}$

Material	Hydraulic conductivity 50th percentile (m/s)	Specific yield (%) – Sy	Storage coefficient – S
Unstructured Chalk	1.00×10^{-2}	0.5	1×10^{-5}
"*Belle Tout*" Chalk layer	5.00×10^{-4}	0.5	1×10^{-5}
Bulk Chalk transmissivity (m^2/d) (excluding transmissivity in the Belle Tout and unstructured Chalk zones)	Three zones 50m^2/d [1] 33m^2/d [2] 25m^2/d [3]	0.5	1×10^{-6}

[1] EA zone mapped with a transmissivity of over 250m^2/d

[2] EA zone mapped with a transmissivity of 100 to 250m^2/d

[3] EA zone mapped with a transmissivity of 20 to 100 m^2/d

4.3.14 Groundwater recharge was also included in the CSM and incorporated into the model.

Groundwater Modelling Findings

Construction Scenario

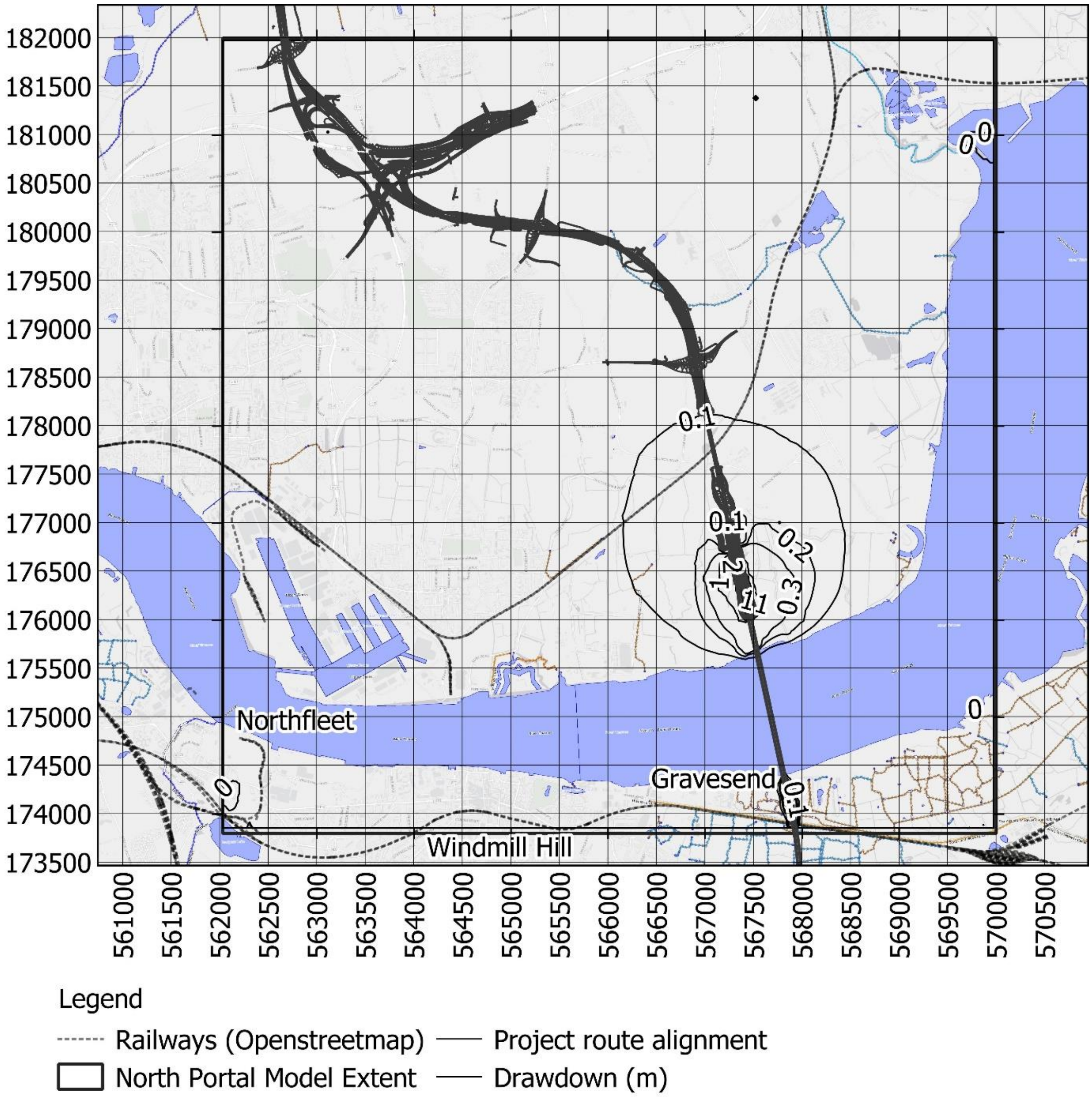
4.3.15 Plate 4.5 shows the predicted drawdown of the water table for the construction phase, in steady state conditions. Steady state is the worst-case condition as the drawdown has an infinite amount of time to propagate. In reality, the construction phase would be limited, and during operation the excavation would be watertight. The plate shows that the 0.1m drawdown contour extends 1km to the west, north and east, beyond the East Tilbury Landfill boundary. The axis of the drawdown cone is orientated parallel to the axis of the portal ramp.

4.3.16 The total inflow rate for the portal and associated ramps is expected to be 10.5L/s (914m^3/d) though a range of between 9.4 and 11.7L/s is predicted (from the model sensitivity testing). The flow rate is very low due to the effectiveness of the mitigation measures incorporated into the design and modelled.

4.3.17 Sensitivity testing was carried out on the hydraulic conductivity of the grout plug and the thickness of the grout plug and showed both these parameters to be very sensitive with regards to their impact on inflow rate into the excavation.

4.3.18 Sensitivity analysis undertaken on the depth of the diaphragm walls showed that this was a less sensitive parameter owing to the depths tested being within the structured, less fractured, Chalk.

Plate 4.5 Predicted drawdown of the water table from the construction phase

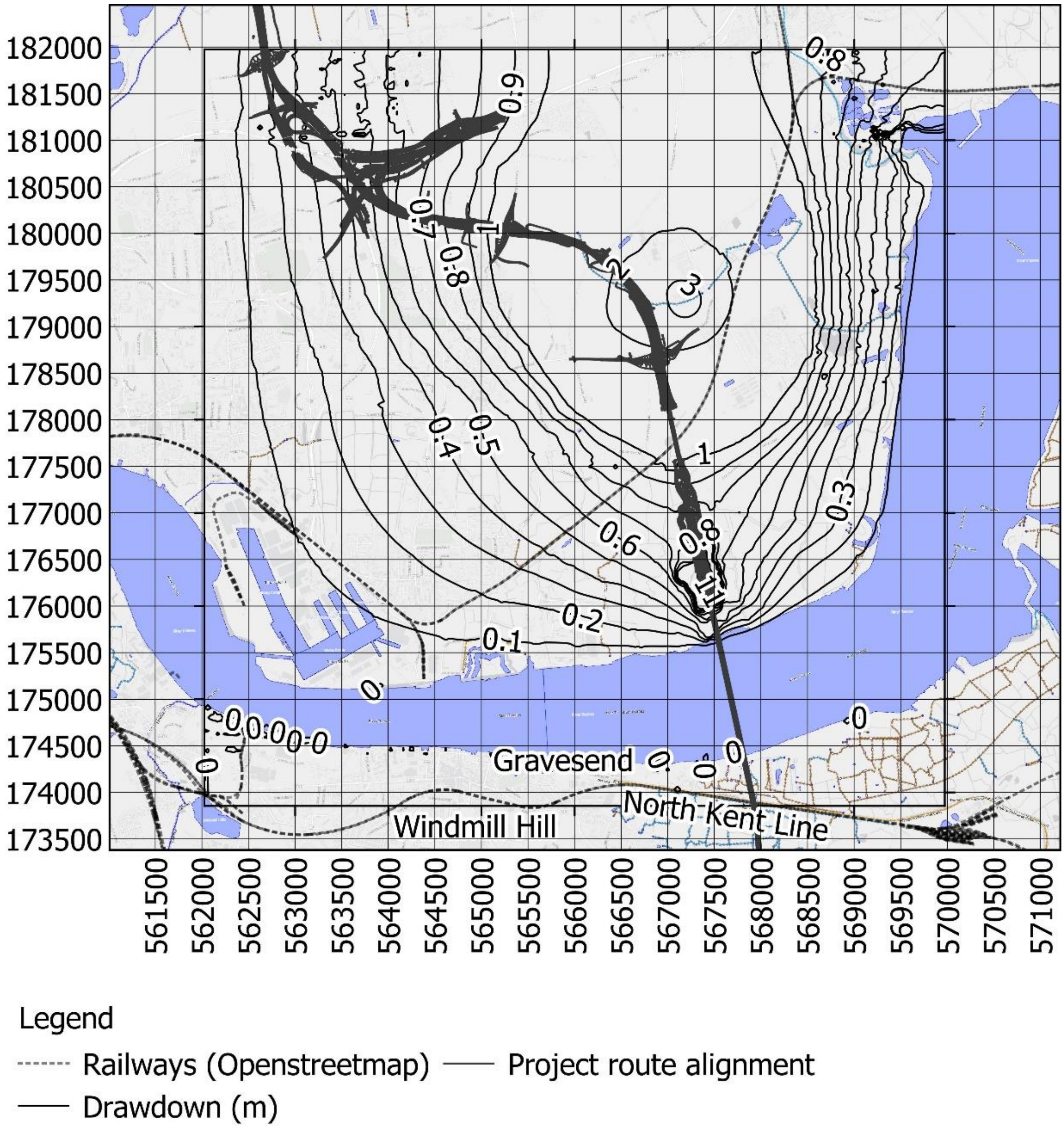


Construction Scenario with Linford Well Abstraction

4.3.19 The groundwater drawdown was then tested by incorporating different pumping rates at the Linford groundwater abstraction well, located 3km to the north of the excavation, into the model.

4.3.20 The pumping rates tested within the model were 1 ML/day, 3.5 ML/day and 6 ML/day. Plate 4.6 shows the predicted groundwater drawdown for the 3.5 ML/day pumping scenario.

Plate 4.6 Predicted drawdown for the construction phase with Linford operating at 3.5 ML/d



4.3.21 The above contour diagram shows the drawdown within Linford well to be 3m, with maximum drawdown within the East Tilbury Landfill to be 0.7m, and the maximum drawdown within the excavation area to be 1.1m. This is greater than the predicted drawdown based on de-watering in the North Portal alone and indicates that any de-watering effects from the North Portal is likely to be minor compared to the potential drawdown that could be created by the current Linford well.

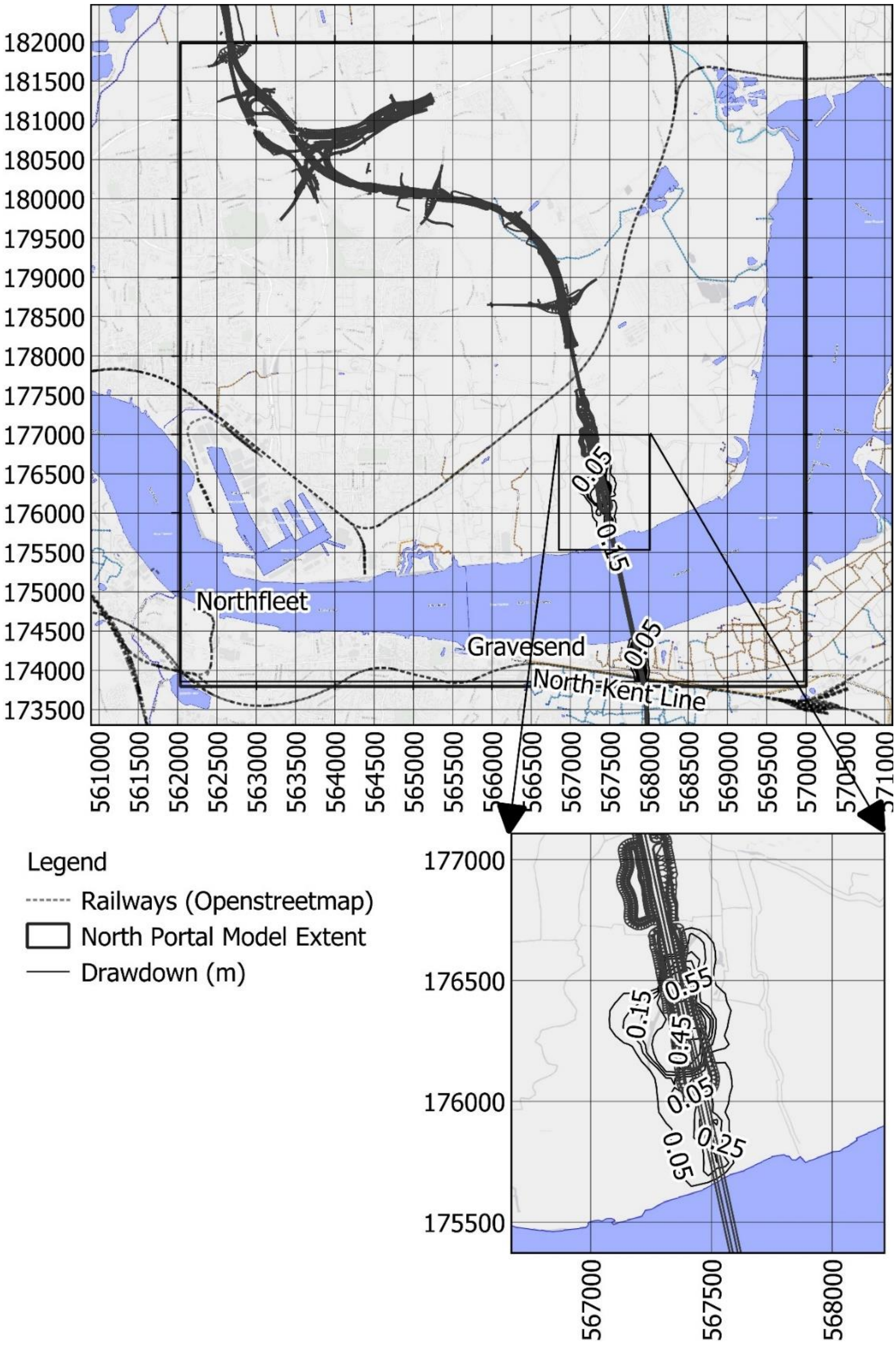
Operational Phase of the Project

4.3.22 Plate 4.7 shows the predicted drawdown of the water table in the operation scenario. The drawdown follows the line of the main tunnels. In general, it dissipates to less than 0.05m within 200m of the tunnel. Next to the portal ramp, drawdown is predicted to extend 300m westwards, along higher transmissivity zones. The predicted flow rate in the scenario is 0.5L/s (45m^3/d).

4.3.23 Such a small, predicted drawdown is likely an artefact of uncertainty within the model due to emplacement of boundaries. It is unlikely that this drawdown would manifest in an observable way in observation boreholes. The confidence in predictions of drawdowns so small is likely to be quite low and within the resolution of the model.

4.3.24 The inflow rate is controlled by the prescribed leakage rate into the main tunnels of 0.1L/d/m^2 (British Tunnelling Society and Institution of Civil Engineers, 2010).

Plate 4.7 Predicted drawdown due to the Project main tunnels (operational phase)



4.4 PW07006A Pumping Test (North Portal) Hydrogeology and Geoenvironmental Review Report (Cascade, 2020)

Objectives of the pumping test report

4.4.1 The report aimed to interpret the results of the pumping test carried out between May and June 2020. The interpretation was used to inform the North Portal numerical groundwater model (Reviewed in Section 4.3 of this report) and ensure it considered valid parameter ranges in light of the pumping test data.

4.4.2 The second objective of this report was to determine whether the pumping test carried out had any significant impact on contaminant concentration between pre-test, pumping and post-pumping conditions.

Well Location and Overview

4.4.3 The test well PW07006A is in the Project's ground investigation Area 1-Package B. It is adjacent to the proposed tunnel North Portal and approximately 400 m from the north bank of the River Thames and approximately 290m west of East Tilbury Landfill. The pumping test consisted of a single pumping well (PW07006A) and 45No. observation boreholes. The observation boreholes include both Phase 1 and Phase 2 ground investigation boreholes, and one third party borehole.

4.4.4 The PW07006A well location is shown on Plate 4.8.

4.4.5 Pumping well PW07006A was advanced using open-hole rotary drilling, therefore, no reliable borehole record is available for the well. The closest borehole record (BH07015) is 7m from PW07006A with the geology summarised in Table 4.3.

Installation Details

4.4.6 Pumping test well PW07006A consists of a single 248mm internal diameter slotted well pipe. The response zone installed in the structured Chalk between 32m to 60m bgl (-23.81m to -51.81m AOD).

4.4.7 To monitor the effects of the pumping test, 45no. observation wells were advanced for groundwater monitoring. 40no. of these were installed with a single 50mm diameter slotted standpipe, and 5no. were installed with multiple (3 to 5) vibrating wire piezometers (VWP) at variable depths. The installations target all units to observe impacts (Made Ground, Alluvium, RTD, and Chalk). In total, 58no. monitoring depths were targeted.

4.4.8 All monitoring wells were installed with automatic water level data loggers and in some instances, were also installed with Electrical Conductivity (EC) loggers. All wells were developed according to best practice prior to starting the pumping test.

Plate 4.8 Location of PW07006A. Note this extract is from Cascade (2020) and shows an historic Project alignment

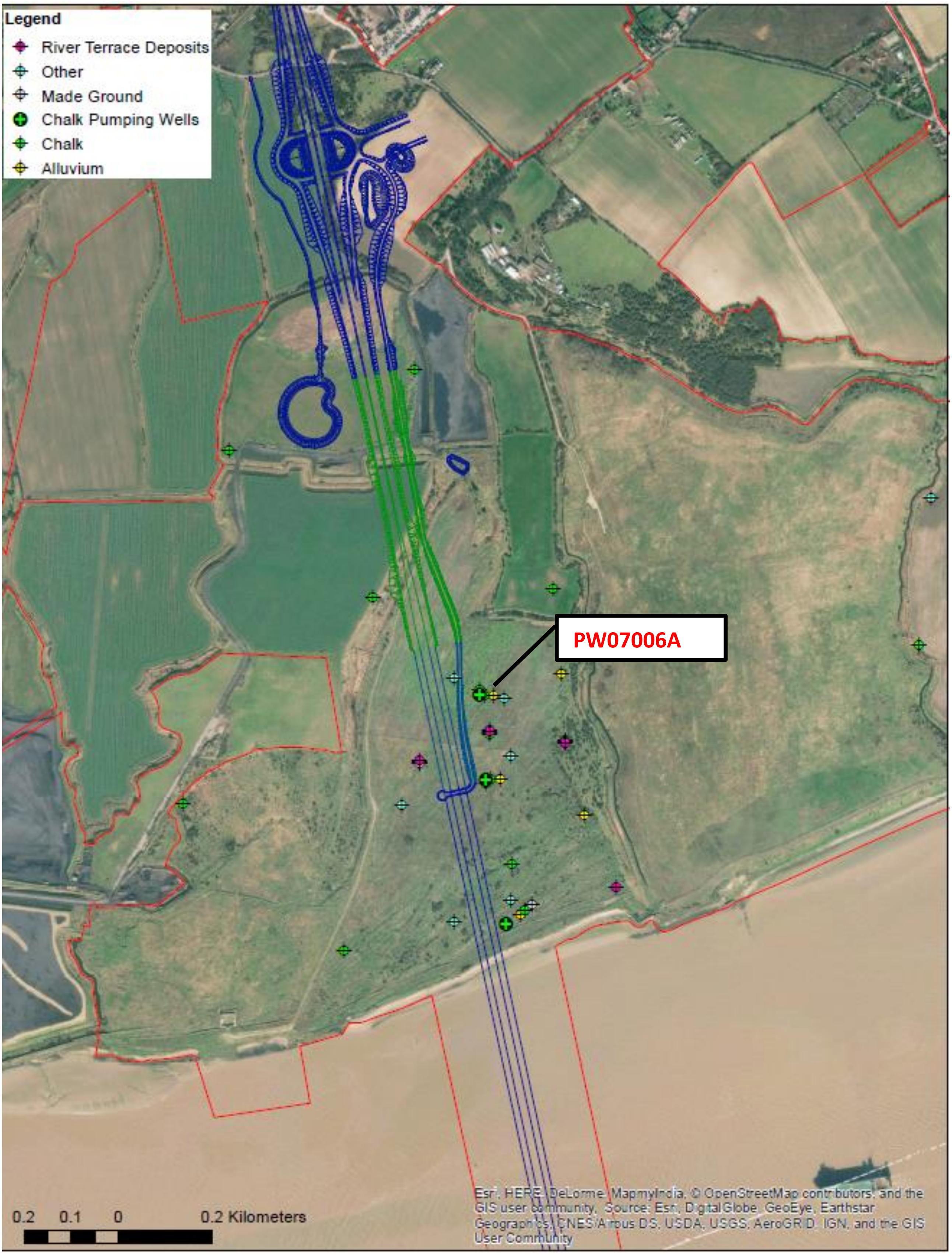


Table 4.3 Pumping well geology from BH07015 log

<table>
<tr><th colspan="2">Geology</th><th>Depth (m bgl)</th><th>Elevation (m aOD)</th><th>Description</th></tr>
<tr><td colspan="2">Made Ground</td><td>0 to 8.50</td><td>8.42 to -0.08</td><td>Soft to firm dark grey gravelly CLAY. Gravel consists of concrete, flint, brick, asphalt and occasional plastic and rubber pieces.</td></tr>
<tr><td colspan="2">Alluvium</td><td>8.50 to 23.60</td><td>-0.08 to -15.18</td><td>Soft to stiff grey silty CLAY, with occasional pockets of plastic fibrous peat. Pockets of peat become more frequent between 10 m to 15 m bgl. Small lens composed of fine to medium SAND between 21.80 m and 22 m bgl.</td></tr>
<tr><td colspan="2">River Terrace Deposits</td><td>23.60 to 28.80</td><td>-15.18 to -20.38</td><td>Brown sandy fine to coarse GRAVEL. Gravel composed of flint and occasional Chalk fragments. Named to be the Taplow Gravel Member on BGS mapping, part of the Maidenhead Formation.</td></tr>
<tr><td rowspan="2">White Chalk Subgroup</td><td>Unstructured</td><td>28.80 to 31.50</td><td>-20.38 to -23.08</td><td>White Chalk recovered as sandy GRAVEL, composed of medium strong high-density chalk and coarse flint. Chalk grade undetermined, likely to be CIRIA Dc (structureless, clast dominated Chalk) (Spink, 2002).</td></tr>
<tr><td>Structured</td><td>31.50 to base of borehole (50.50)</td><td>-23.08 to -42.08</td><td>Weak to high density white Chalk. CIRIA grade B4, progressing to A1 at depth (structured with bedding and/or joining) (Spink, 2002). Seaford Chalk Formation – Belle Tout beds to 45 m bgl, overlying Lewes Nodular Chalk Formation to the base of the borehole.</td></tr>
<tr><td colspan="5">m bgl – metres Below Ground Level, m AOD – metres Above Ordnance Datum</td></tr>
</table>

Methodology

Pump Test Methodology

4.4.9 The test was carried out in accordance with BS EN ISO22282-4:2012 Geotechnical investigation and testing. Geohydraulic testing. Pumping tests. The method included the following elements (or periods):

a. a pre-test monitoring period

b. an equipment test on the pumping well

c. a step drawdown test and a constant rate test

d. water level recovery period.

4.4.10 The test timeline was as follows:

a. Pre-test monitoring began on 6th May 2020 for surface water levels, rainfall, barometric pressure and groundwater level monitoring at all boreholes. Pre-test monitoring covered a period of 7 days, ending on the 12th May 2020

b. The equipment test was undertaken on the pumping well on the 13th May 2020

c. On the 14th May 2020 (08:00am to 15:30pm), a step drawdown test was conducted, comprising of five 90-minutes steps, after which the groundwater level was allowed to recover

d. On the 15th May 2020, at 07:00 am, a 30-day constant rate test started, with the pump being switched off on the 14th June 2020 at 07:00 am

e. The constant rate pump test groundwater level recovery was monitored for five days after pumping ceased, with the pumping test completed on 19th June 2020 and site demobilisation thereafter.

Water Quality Monitoring Methodology

4.4.11 Throughout the pre-test, pumping, and recovery phases of the test, groundwater quality was monitored at 34no. monitoring wells. Surface water was monitored at 10no. locations and sampled at 7no. of those.

4.4.12 As well as chemical laboratory testing of samples, hydrogeochemical parameters were gathered, with pH and Electrical Conductivity (EC), and temperature continuously monitored using in-well data loggers.

4.4.13 Indicator compounds were selected to assess potential change in groundwater quality. Gathered data from field measurements and lab analysis of the indicator compounds were screened against UK Drinking Water Standards (DWS), UK estuaries and coastal waters Environmental Quality Standards (EQS), and UK freshwater EQS.

Report Findings and Interpretation

Drawdown and Recovery

4.4.14 Pre-test conditions measured in the monitoring well network showed that cyclic fluctuations within the RTD and Chalk were effects of the tidal influence from the River Thames. Both the RTD and the Chalk had fluctuations of approximately 0.5m. These fluctuations were not observed within wells screening the Made Ground or the Alluvium. The exceptions to this were three wells which screened the deep Alluvium and showed an amplitude of approximately 0.1m.

4.4.15 The reach of the tidal influence within the Chalk was shown to decrease, as expected, with distance from the River Thames. At a distance of 370m from the river bank, the amplitude of the tidal fluctuation is over 0.5m, decreasing to 0.25m at a distance of 790m from the river bank. At a distance of 2.3km, no discernible tidal influence was measured.

4.4.16 The stepped drawdown test showed that pumping well PW07006A was only efficient at a pumping rate of 5L/s (70% efficiency), becoming highly inefficient at pumping rates above this.

4.4.17 The pumping well PW07006A was pumped at an average rate of 15 L/s for the entirety of the 30-day continuous pump test period. Pumping commencing on 15th May 2020 at 7:00 am, at the peak of high tide.

4.4.18 Change in the groundwater level (i.e. the drawdown) in the pumping well and observation boreholes was recorded both automatically (using data loggers connected to a telemetry system for remote assessment) and manually, using a dip-meter. Drawdown was observed in the pumping well and in 23 of 58no. observation well installations. Table 4.4 provides the groundwater level drawdown observed at the end of the continuous pump test.

Table 4.4 Constant Rate Test Results (wells with observed drawdown)

Borehole ID	Response zone midpoint (m aOD)	Target strata	Distance from PW (m)	Drawdown at end of CRT (m)
PW07006A	-37.81	Chalk	0	26.00
BH07015	-38.83	Chalk	6.56	3.00
OH07021	-27.86	Chalk	9.59	1.10
OH07024	-12.60	Alluvium	29.16	1.50
OH07026	-18.20	RTD	73.12	0.80
	-22.00	Chalk		0.80
	-35.00	Chalk		0.92
OH07023	-45.32	Chalk	73.14	1.05
OH07035	-34.64	Chalk	99.43	0.80
OH07006	-17.03	RTD	105.63	0.62
OH07007	-18.07	RTD	148.55	0.60

Borehole ID	Response zone midpoint (m aOD)	Target strata	Distance from PW (m)	Drawdown at end of CRT (m)
OH07040	-25.19	Chalk	149.48	0.65
OH07012	-30.00	Chalk	178.54	0.56
OH07022A	-21.21	Chalk	185.39	0.55
OH07037	-17.68	RTD	186.06	0.60
OH07022	-16.22	RTD	186.74	0.50
	-34.72	Chalk		0.60
BH07032	-22.20	Chalk	187.91	0.60
OH07041	-39.50	Chalk	190.42	0.60
OH07038	-25.4	Chalk	194.00	0.60
OH07036	-28.06	Chalk	221.59	0.54
BH2384	-19.21	RTD	308.25	0.48
OH07039	-40.36	Chalk	313.89	0.52
BH2385	-40.36	Chalk	420.10	0.37

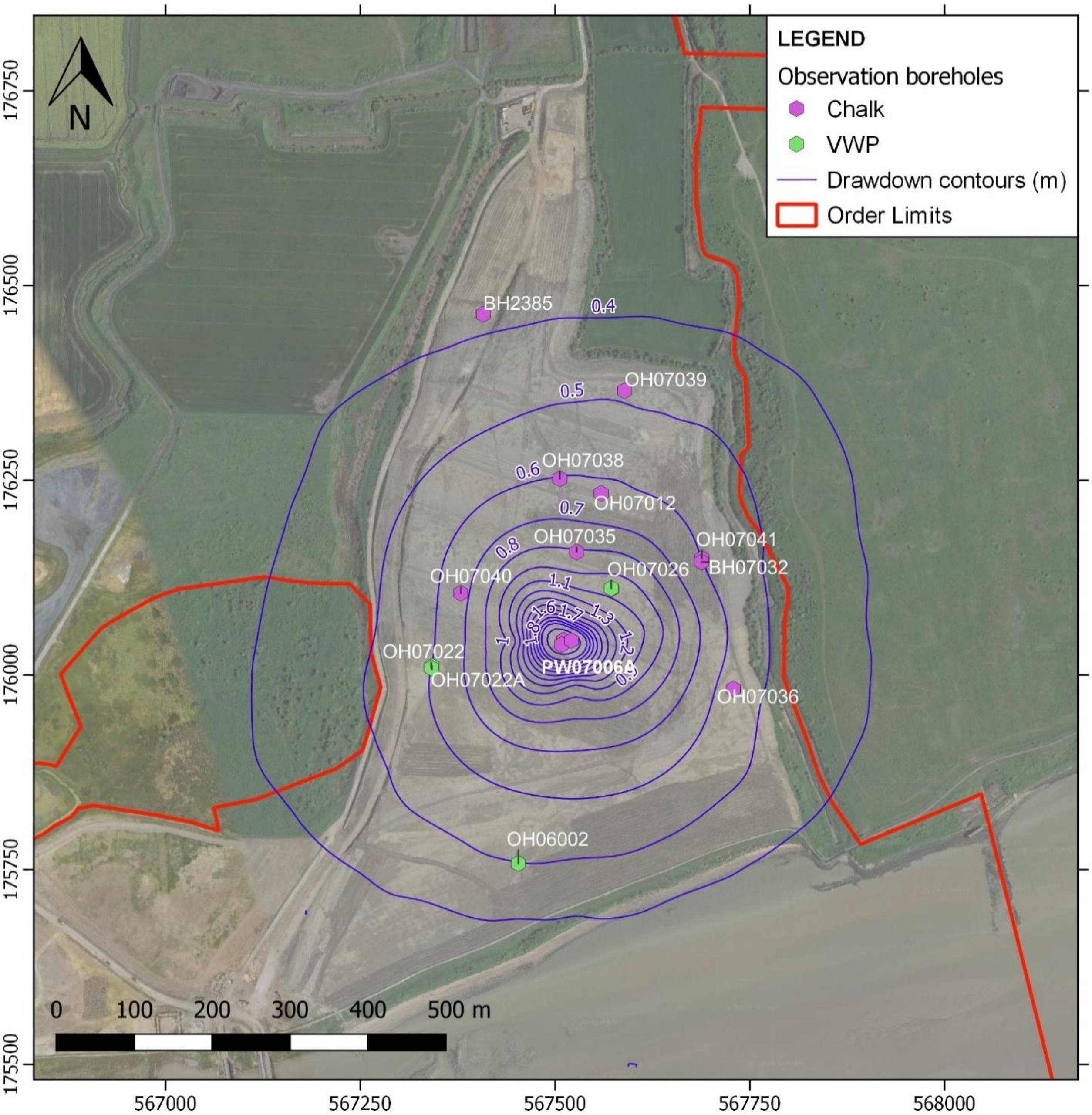
4.4.19 Drawdown was recorded in 16no. Chalk installations, 6no. RTD installations and 1no. Alluvium installation (OH07024). At the end of the CRT, a maximum drawdown of 3m was observed in the Chalk (BH07015). This monitoring well is 7m from the pumping well. In the overlying RTD, a drawdown 0.80m was observed at the end of the CRT in OH07026 (located 73m northwest of the pumping well).

4.4.20 OH07024, the only Alluvium observation borehole with a drawdown response has an installation at the base of the Alluvium, where connection between groundwater in the Alluvium and underlying RTD/Chalk aquifers is thought to occur due to the increased granular composition of the deep alluvium.

4.4.21 During the CRT the drawdown at the test well and observation boreholes stabilised. This suggests the presence of a constant-head recharge boundary, the River Thames, 370m south of the test well.

4.4.22 Plate 4.9 shows the drawdown at the end of the CRT in the Chalk. The contouring is done using a kriging interpolation with Surfer v15. Contours stop at 0.4m due to the lack of Chalk observation borehole locations between 420 m and 1600 m (BH07073, zero drawdown observed) radius from PW07006A.

Plate 4.9 Chalk aquifer: Drawdown contours at the end of the constant rate tests (inner contour = 3m drawdown)



Note: VWP = vibrating wire piezometers

4.4.23 Analysis of the results using the Theis (1935) analytical solution for non-leaky aquifers and the Moench (1984) solution for dual porosity aquifers, gave the same hydraulic conductivity value of 1.8 x 10^{-4} m/s for bulk/fracture conductivity. The Moench solution also calculated a value for matrix hydraulic conductivity at 1.8 x 10^{-8} m/s.

4.4.24 Diagnostic plot analysis showed the aquifer to be confined and of dual porosity (fracture and matrix), and this coincided with the findings from the Moench (1984) solution.

4.4.25 Results from the post-test period show the aquifer recovery in the pumping well to be rapid, with a 98% recovery rate (0.5m drawdown) achieved within 10 minutes of ceasing pumping.

4.4.26 As stated in the report, further analysis of the well recovery data showed that "The calculated S/S' ratio is 10.7. A S/S' ratio (ratio of storativity during pumping to storativity during recovery) greater than 1 indicates recharge during the constant rate test (AQTESOLV, 2020b). It is likely that this recharge is from the adjacent constant head boundary, the River Thames."

Water Quality

4.4.27 Water quality was assessed in the report using eight compounds summarised in Table 4.5, as well as chloride / bromide ratio and electrical conductivity field measurements. These were screened against Drinking Water Standards (DWS) and Environmental Quality Standards (EQS).

Table 4.5 Indicator Compounds Used for Water Quality Assessment

Chemical indicator	UK DWS	UK freshwater EQS	UK estuaries and coastal waters EQS	Units
Benzo(a)pyrene	0.01	0.00017	0.00017	µg/L
Total Petroleum Hydrocarbons (TPH) >C5-C35 aliphatics/aromatics	10	50	50	µg/L
O-xylene	250	15	15	µg/L
Ethylbenzene	300	20	20	µg/L
Nickel	20	4(bio)	8.6	µg/L
Boron	1000	2000	7000	µg/L
Ammoniacal nitrogen (Total)	NV	0.6	0.021	mg/L
Phenol (filtered)	5800	7.7	7.7	µg/L

Chloride/Bromide Ratio

4.4.28 Chloride/Bromide (Cl/Br) relationship analysis during the three test phases within the Made Ground/Alluvium showed that whilst signs of leachate pollution exists in those layers, it is likely from the landfill / Made Ground in the area, and not as a result of the pumping test. This was deduced from pre-test conditions and the fact that there was no shift in Cl/Br ratios during the test.

4.4.29 Cl/Br within the Alluvium indicated leachate, brine and saline conditions were already present within the Alluvium. During the pumping test there was a slight shift in the Cl/Br ratio towards chloride, indicating a small amount of mixing with brackish water from the Thames. This shift showed to be recovering towards pre-test concentrations when the pumping ceased. Several Alluvium locations show no change in the Cl/Br ratio during pumping, indicating little mobilisation of leachate-type fluids or brackish water within these strata during pumping. This indicates that whilst the groundwater occurring within the Alluvium superficial layers show some signs of leachate pollution or brine/animal waste influence (likely migrating under the natural groundwater flow field from the adjacent landfills and potentially associated with peat layers); this pollution has not been remobilised through these parts of the alluvium by the 30 days continuous rate pumping.

4.4.30 Pre-test conditions within the RTD put groundwater within this unit at the leachate /saltwater boundary. 2no. monitoring locations show a slight shift towards higher chloride concentrations during the pumping test. The other 2no. monitored locations show no change in Cl/Br ratio. This indicates that some mixing with the River Thames during the pumping was active in some areas of the RTD, however, leachate remobilisation as a result of pumping was not observed in any of the locations.

4.4.31 Pre-test conditions within the Chalk show groundwater to be spread between brines, saltwater and leachate compositions. A slight shift towards seawater concentration was observed in a few of the monitoring wells during the pumping, however, these were shown to shift back during the recover period after the test.

Chemical Indicator Compounds

4.4.32 The majority of samples analysed showed generally stable concentration of indicator compounds over the pumping test period. This indicates that for most locations monitored, water quality has not been significantly adversely impacted by the pumping test.

4.4.33 Trend analysis over the pre-test, pumping, and recovery stages were summarised as follows in the report;

4.4.34 Of the locations which screened the Made Ground, three were highlighted as showing variability across the indicator chemicals. The locations BH07034, BH07064 and BH07092 showed varying concentrations across hydrocarbons, ammonia, metals and phenol throughout the pumping test programme but the concentrations recorded all remained within one order of magnitude.

4.4.35 The report states “Of the locations which screened the Alluvium, four were highlighted as showing variability in concentrations across the indicator chemicals. The locations, BH07039, BH07056, BH06016 and OH07024 displayed varying concentrations across hydrocarbons, ammonia, metals and phenol throughout the pumping test programme. BH07039 was the only location where all the indicator chemicals showed concentrations which varied over one order of magnitude throughout the pumping test programme.

4.4.36 Of the locations which screened the River Terrace Deposits, one (OH07037) was highlighted as showing varying concentrations across the chemical indicators, nickel and phenol. The concentrations recorded at OH07037 varied within one order of magnitude throughout the pumping test programme.

4.4.37 Of the locations which screened the Chalk, eight were highlighted as showing variability in concentrations across the indicator chemicals. The locations, OH07036, OH07012, BH2385, BH07015, OH07035, PW07006A, OH07021 and OH07023 all showed varying concentrations throughout the pumping test programme for hydrocarbons, ammonia, metal and phenol with no distinctive trends. All the concentrations varied within one order of magnitude throughout the programme.

4.4.38 Of the locations at which surface water samples were collected, four were highlighted as showing variability in the concentrations of the indicator chemicals over the pumping test programme. The four locations, SW07024, SW07025, SW07027 and SW07028 showed varying concentrations with no distinctive trends throughout the pumping test programme. All of the concentrations varied within one order of magnitude throughout the programme.

4.4.39 In summary, there have been no definitive trends which would suggest any significant linkages between the pumping test and the surrounding water quality. This correlates with the hydrogeological assessment in that the Made Ground and Alluvium are not linked to the main underlying River Terrace Deposits and Chalk aquifer system."

Summary

4.4.40 The report concluded that good hydraulic continuity across the RTD and Chalk was observed, with both units being in continuity with the River Thames, with the Thames acting as a constant head boundary for the RTD/Chalk aquifer.

4.4.41 Analysis of the drawdown data confirmed previous findings of the Alluvium acting as an aquitard, disconnecting the Made Ground from the RTD and Chalk aquifers. The only exception to this was observed in OH07024, which was installed in the deep Alluvium, 29m from the pumping well where a drawdown of 1.5m was observed. This drawdown was attributed to the well installation being in the base of the Alluvium, where groundwater connection between the base of the Alluvium and the underlying RTD is thought to occur due to the increased granular composition of the deep Alluvium.

4.4.42 No evidence of distinctive of significant increases in trends of concentrations of the selected indicator compounds over the pre-test, pumping, or recovery period. Although, there were exceedances of the selected water quality standards in some instances.

4.4.43 The hydraulic conductivity of the structured Chalk covering the test response zone has a bulk hydraulic conductivity in the order of 1.8×10^{-4}m/s (geomean), assuming an effective aquifer thickness of 50m. This is very similar to the North Portal Groundwater Numerical Model value and provides a further line of evidence to support this choice of hydraulic conductivity value.

4.4.44 On the hydraulic conductivity of the upper, unstructured, Chalk, the report concluded that "A qualitative assessment of the pumping well geophysics under both static and pumping conditions suggests that the upper unstructured/structured Chalk above the pumping well response zone may have a much higher hydraulic conductivity. The calculation of hydraulic conductivity from transmissivity is sensitive to the effective aquifer thickness. Based on the fluid EC logs, most flow occurs above approximately 40 m bgl, implying an aquifer thickness of 13 m. In this case, the hydraulic conductivity is increased by almost an order of magnitude to 7x10-4 m/s in the test well area."

5 Review of Conceptual Site Model

5.1 Objectives

5.1.1 This section aims to revise the potentially active pollutant linkages identified in Section 3.8 in light of the Information Source Review (Section 4).

5.1.2 The potentially active pollutant linkages identified in Section 3.8 are:

a. Vertical migration of COC and leaching into perched water present within the Alluvium underlying the landfill, followed by lateral migration off-site leading to deteriorating of groundwater quality west of East Tilbury Landfill

b. Vertical migration of COC and leaching into groundwater present within the River Terrace Deposits and Chalk underlying the Alluvium, followed by lateral migration off-site leading to deteriorating of groundwater quality west of East Tilbury Landfill

c. Lateral migration of impacted groundwater within the underlying strata into the River Thames

d. Dermal contact and ingestion pathway for construction workers from potentially impacted groundwater flowing into the excavation during dewatering and ongoing construction works

e. Vapour inhalation pathway for construction workers from volatile COC in potentially impacted groundwater flowing into the excavation during dewatering and ongoing construction works

f. Migration of COC within groundwater towards proposed built structures, potentially impacting foundation structures

g. Potential mobilisation of ground gases associated with waste degradation at the East Tilbury Landfill by potential drawdown of the water table

5.2 Vertical Migration Pathways

5.2.1 Pollutant linkages a. and b. relate to vertical migration of COC from the East Tilbury Landfill followed by lateral migration westward as a result of groundwater drawdown within the landfill during the dewatering at North Portal. This Section looks at whether the vertical migration pathway is likely to be active and Section 5.3 addresses the lateral migration pathway.

5.2.2 For vertical migration of COC to occur, the dewatering at North Portal would need to have an impact on the leachate within the landfill (located approximately 350m east of North Portal). For this to occur, the groundwater within the RTD and Chalk would need to be in continuity with the Alluvium.

5.2.3 The Project design shows that the dewatering will be occurring within the Chalk and RTD since they are both in hydraulic continuity. The period of dewatering and alteration of the water table is understood to be approximately three years.

5.2.4 For drawdown to happen within the Made Ground of the landfill, the dewatering within the Chalk and RTD would need to be able to impact the groundwater levels within the Made Ground and Alluvium.

5.2.5 The Callear and Bewers (1993) Status Report highlights that the Alluvium underlying the landfill is approximately 15m thick and thins out towards the northwest end of the landfill to 2.4m, suggesting that protection to the underlying aquifers may not be afforded to the north of the site. They also noted that the landfill was observed to be tidally influenced by the River Thames, and that the tidal effect decreased with distance from the River.

5.2.6 The North Portal Groundwater Numerical Model showed that in a worst-case scenario (assuming steady state with drawdown having infinite time to propagate), with the Linford operating at 3.5 ML/day, the maximum drawdown predicted in East Tilbury Landfill is 0.7m within the Chalk. This is a conservative estimate as the construction and dewatering period will be limited in length. The drawdown of 0.7m within the Chalk is achieved due to the operation of the Linford abstraction, in the scenario where only the North Portal dewatering is active, the drawdown was simulated to be 0.1m within the Chalk. This scenario assumes mitigation measures in the form of a grout plug and diaphragm walls are in place.

5.2.7 A review of BGS Hydrogeological Map for the area (Dartford 1:63,360 Sheet 15, 1968), shows a divide to be present further to the north of where the divide is plotted on Plate 4.3, suggesting that it does not bisect the landfill or the proposed North Portal location, although does still suggest flow towards the Linford Well Abstraction from the North Portal and East Tilbury Landfill areas to be unlikely as the abstraction is hydraulically upgradient. This suggests that the predicted drawdown from the numerical model is conservative in that it overestimates the potential drawdown.

5.2.8 Northumbrian Water Limited, which operates the Linford water supply as Essex and Suffolk Water, has advised that, based on historical pumping data, the sustainable yield is 3.5ML/d, suggesting abstractions above this rate are not likely to take place (Appendix 14.5, Application Document 6.3).

5.2.9 Consultation with Essex and Suffolk Water undertaken in November 2017 has indicated that this Chalk borehole is not currently abstracting groundwater for water supply, but is being abstracted at 2,160m^3/day to control the artesian conditions present within the Chalk. This indicates that the predicted drawdown by the numerical model is likely conservative for the current scenario based on pumping rates alone.

5.2.10 Further to this, it also confirms a rising head, indicating that aquifer recovery is likely to be quick from any effects of dewatering at North Portal in conjunction with abstraction at Linford well. This was evidenced during the post pumping test recovery period where it was shown that the aquifer recovery in the pumping well was rapid, with a 98% recovery rate (0.5m drawdown) achieved within 10 minutes of ceasing pumping.

5.2.11 For drawdown within the RTD/Chalk to affect the perched water within the Alluvium, hydraulic continuity must exist between the two units. Review of the PW07006A Pumping Test report (Cascade, 2020) has conclusively shown that the is Alluvium acting as an aquitard, disconnecting the Made Ground from the RTD and Chalk aquifers. The only exception to this was in on monitoring location where the well was installed at 29m bgl within the deeper Alluvium (which in some instances has a more granular composition towards the base of the Alluvium / top of the RTD). Data gathered from the shallower Alluvium showed no drawdown response.

5.2.12 Water quality data from the Pumping Test Report (Cascade, 2020) showed that with regards to Cl/Br ratios, the Alluvium showed leachate/brine concentrations already present from pre-rest conditions. A slight shift towards Cl was observed in a few of the wells during the pumping, with some wells showing no change at all. The ratio of Cl-Br was shown to recovery rapidly towards pre-test conditions during the recovery period. These findings indicate little mobilisation of leachate-type fluids or brackish water within these strata during pumping.

5.2.13 Whilst the groundwater occurring within the Alluvium superficial layers show some signs of leachate pollution or brine/animal waste influence (likely migrating under the natural groundwater flow field from the adjacent landfills and potentially associated with peat layers); this pollution has not been remobilised through these parts of the alluvium by the 30 days continuous rate pumping.

5.2.14 The evidence presented from the pumping test and the numerical modelling have both shown that the Alluvium is likely acting as an aquitard to the underlying aquifers, with the water within the Alluvium likely to be perched and not in continuity with the deeper water table within the RTD/Chalk.

5.2.15 This is further corroborated with groundwater elevation data from the monitoring well network which shows resting groundwater within the Chalk and RTD to be similar and deeper than those within the Alluvium. Groundwater levels within the Alluvium were found to be the most varied, likely owing to the cohesive and low permeability nature of the Alluvium which is predominantly composed of clays and silt (Highways England, 2018).

5.2.16 Monitoring wells BH07034 (screening Made Ground), OH07034 (shallow Alluvium), OH07006 (RTD), and OH07035 (Chalk) are located within 10m of each other and show groundwater was perched within the Alluvium at around 8m AOD (7.62–8.02m AOD). Tidal variation within the Chalk caused fluctuating water levels between -0.59m AOD and 1.33m AOD. Similarly, water levels in the RTD varied between -0.22m AOD and 1.21m AOD. Within the Made Ground, water was perched at 3.46m AOD to 3.67m AOD (Highways England, 2018).

5.2.17 Based on the above points, it is considered unlikely that a migration pathway exists between the landfill rise and the underlying RTD and Chalk aquifers. This is owed to the lack of hydraulic continuity between the Alluvium and the underlying aquifers as a result of the cohesive nature of the Alluvium. Evidence of the Alluvium acting as a confining layer the RTD/Chalk by the presence of artesian conditions within the Chalk also suggest vertical migration of COC to be an unlikely pathway.

5.3 Lateral Migration Pathways

5.3.1 Lateral migration pathways a., b., c., d., e., and f. all relate to lateral migration of COC towards the North Portal and the River Thames. As discussed above, in order for lateral migration to occur, vertical migration either into the Alluvium or into the RTD and Chalk must first occur.

a. Vertical migration of COC and leaching into perched water present within the Alluvium underlying the landfill, followed by lateral migration off-site leading to deteriorating of groundwater quality west of East Tilbury Landfill

b. Vertical migration of COC and leaching into groundwater present within the River Terrace Deposits and Chalk underlying the Alluvium, followed by lateral migration off-site leading to deteriorating of groundwater quality west of East Tilbury Landfill

c. Lateral migration of impacted groundwater within the underlying strata into the River Thames

d. Dermal contact and ingestion pathway for construction workers from potentially impacted groundwater flowing into the excavation during dewatering and ongoing construction works

e. Vapour inhalation pathway for construction workers from volatile COC in potentially impacted groundwater flowing into the excavation during dewatering and ongoing construction works

f. Migration of COC within groundwater towards proposed built structures, potentially impacting foundation structures

5.3.2 The land raise is built on the flood plain of the River Thames within an intertidal area (Callear and Bewers, 1993). As such, this Pathway c. is considered potentially active without the influence of the Project. Discharge of leachate into the Thames is understood to have been active at the time of operation of the landfill owing to historical leachate discharge being directed into the Thames via Bowater Sluice (Figure 1). This was later stopped by redirecting leachate to the landfill and the construction of dual drainage ditches in 1978. These ditches were repaired during site restoration in 1992, however, their present condition is unknown.

5.3.3 Pathways a., b., d., e., and f. would require lateral migration of COC within the Alluvium, RTD and Chalk, to travel 350m towards North Portal.

5.3.4 As the dewatering at North Portal will be drawing on the groundwater within the RTD and Chalk aquifers, it would require the groundwater within those aquifers to be sufficiently polluted to pose a risk via dermal, ingestion, or vapour inhalation pathways within the excavation.

5.3.5 As discussed in Section 5.2 Vertical Migration Pathways, it is considered unlikely that COC from the landfill are migrating vertically downwards into the RTD and Chalk aquifers. A review of groundwater sampling chemical laboratory data of wells screening the RTD and Chalk have consistently shown that COC associated with landfills have been below laboratory method detection limits (MDL), with few isolated detections either at, or within the same magnitude of, the MDL.

5.3.6 Limited vertical migration of COC from the landfill into the perched water within the Alluvium cannot be ruled out as the landfill is unlined.

5.3.7 It is noted that during the pump testing sampling regime, detections of COC were noted in the RTD and Chalk, however, long term monitoring data does not coincide with the pre-test sampling data.

5.3.8 A review of a selection of wells which were discussed in the Pumping Test Report (Cascade, 2020) and shown to have detections of COC within the RTD and Chalk as part of their baseline (pre-test) conditions was undertaken. The concentrations measured during the pre-test conditions were compared with long term monitoring data, which shows a discrepancy between the findings. In this instance, it would be more prudent to rely on the larger body of long-term monitoring data for trend analysis.

5.3.9 It should be noted that the presence of peat throughout the Alluvium can act as a source of TPH, as well as acting to retard (by means of adsorption of) COC that may have entered the Alluvium. Pockets and bands of peat have been consistently found throughout the Tilbury area during the various phases of ground investigation associated with the Project, as well as from reviewing online BGS borehole scans in the area.

5.3.10 The Pumping Test Report (Cascade, 2020) concluded that the chemical analysis carried out throughout the three stages of the pumping test showed no distinct correlation with the continuous rate pumping test. Due to the sporadic nature of the detections, it was concluded that the pumping test did not have an influence on the measured concentrations through the testing.

5.3.11 Analysis of the tidal effect within the Project area shows that whilst tidal fluctuations were observed within both the RTD and the Chalk, no measurable tidal effect was observed within the monitoring well network screening the Made Ground and the Alluvium (Cascade, 2020). This is a further line of evidence to support the conclusion of the Alluvium acting as an aquitard with a very low vertical and horizontal conductivity.

5.3.12 In order to support a lines-of-evidence approach, fate and transport modelling was undertaken to further assess lateral migration within the Alluvium.

Fate and Transport Modelling

5.3.13 The Pumping Test Report suggested that groundwater within the Alluvium was found to be of a basin brine / animal waste, salt water, and leachate composition.

5.3.14 Assuming a worst-case scenario whereby leachate from the East Tilbury Landfill land rise is seeping into more granular lenses within the Alluvium, it was considered prudent to undertake further modelling.

5.3.15 To better understand potential travel time within the Alluvium, fate and transport modelling was undertaken using ConSim software. ConSim modelling assumes that the groundwater within the modelled aquifer (in this case, Alluvium) is a continuous water body, however, in reality, the groundwater within the Alluvium has been shown to be discontinuous and perched.

5.3.16 The hydraulic gradient within the Alluvium was estimated using drawdown data from the pumping test data. High end estimates of the gradient were used as a worst-case assumption.

5.3.17 Travel times within the RTD and Chalk were not modelled as the vertical migration pathway through the Alluvium was ruled out in Section 5.2.

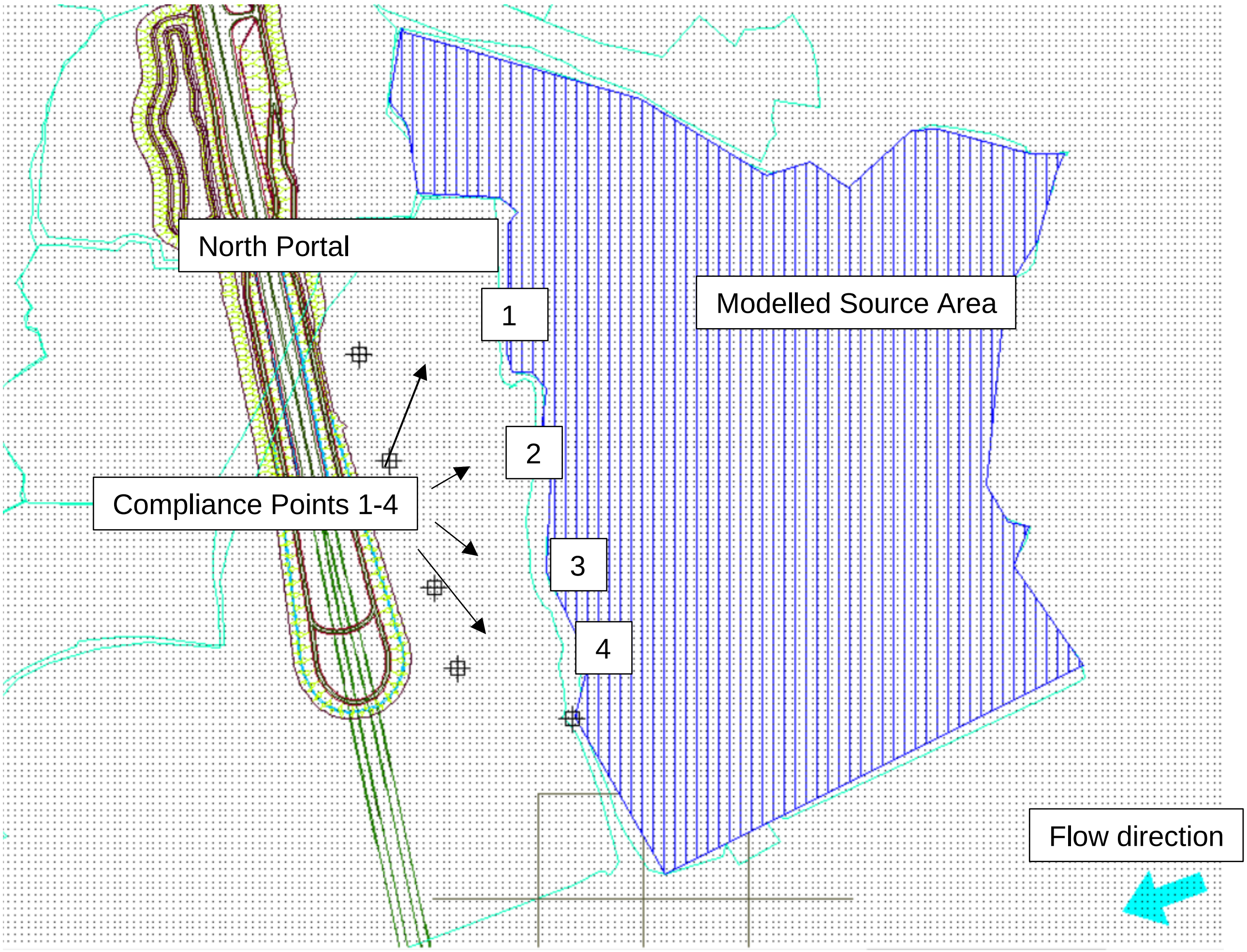
5.3.18 The entirety of the East Tilbury Landfill was modelled as a potential source of contamination for the purpose of the modelling. The full methodology and parameters of the modelling can be viewed in Annexe B.

5.3.19 Contaminant concentrations and concentration trends within the landfill are unknown. Overall contaminant mass is likely to be declining within the landfill due to degradation and leaching over time. However, concentrations of contaminants within leachate also have the potential to increase as contaminants partition off of soils/liquids within the waste. Given the relatively short duration of the planned North Portal excavation (in the order of years) when compared with the time elapsed since filling of the landfill ceased (in the order of decades), it is considered reasonable to assume a non-declining source term over the modelled period (i.e. the modelling completed has assumed a constant source concentration/mass).

5.3.20 The presence of designed mitigation measures are not incorporated into the ConSim modelling, owing to the model looking at travel times and degradation of COC within the aquifer over specific distances (i.e. distance to receptor, in this instance, North Portal). The model assumes there is a pathway between the source and receptor and calculates the amount of time it would take a given contaminant to reach the receptor considering attenuation.

5.3.21 Travel time from the modelled source area to four defined compliance points along the North Portal at a 50m distance was calculated to account for the irregular shape of the landfill. These are presented in Plate 5.1.

Plate 5.1 Modelled Source Area and Compliance Points



Model Output

5.3.22 To demonstrate the sensitivity of the predicted concentrations at the compliance point, the model was run for 1,001 iterations using the Monte Carlo (probabilistic) sampling approach. The model output is in two forms, the latter of which was selected for the assessment:

a. Graphical representation, plotting predicted travel time versus probability, or confidence level (reverse cumulative plot).

b. Statistical (numerical listing of travel times to the compliance point for different confidence levels).

5.3.23 Statistical outputs are calculated by ConSim in percentiles from 5% to 95%. The 95% value means that 95% of calculated values were less that this value, whereas for the 5% value, 5% of calculated values were less that this value (meaning that 95% were greater).

5.3.24 When assessing travel times, it is the lowest estimate (shortest travel time) that provides the ‘worst case’ scenario.

5.3.25 Retarded travel times have been used in order to account for partitioning effects of COC. An unretarded travel time does not account for these partitioning effects and is based on groundwater flow velocity alone.

Modelling Results

Predicted Travel Times

5.3.26 Predicted travel times from the modelled source area towards each of the four compliance points were calculated. A small variation between the four compliance points was observed. The lowest estimate (shortest travel time) has been assessed and is presented in Table 5.1 below. Compliance Point 1 had the shortest predicted travel times.

5.3.27 Where a contaminant takes in excess of 1,000 years at the 5% output to migrate, a travel time has not been presented. COC with travel times in excess of 1,000 years are presented in Table 5.2.

Table 5.1 Predicted Travel Times in the Alluvium

COC	5% travel time (years)	50% travel time (years)	95% travel time (years)
Unretarded travel time (not COC specific)	7.69	29.00	109
Benzene	169	884	4,830
Phenol	205	1,080	5,930
Tetrachloroethene (PCE)	630	3,430	19,100
Toluene	481	2,600	14,500
Trichloroethene (TCE)	337	1,810	10,000
Vinyl chloride	52.7	246	1,260

Table 5.2 Contaminants with Predicted Travel Times >1,000 years

Metals	Oil and combustion derived hydrocarbons	Inorganics	Organic compounds
Arsenic Cadmium Chromium (III) Chromium (VI) Copper Lead Mercury Nickel Zinc	Polycyclic aromatic hydrocarbons Naphthalene Benzo(b)fluoranthene Benzo(k)fluoranthene Benzo(a)pyrene Indeno(123cd)pyrene Benzo(ghi)perylene Aliphatic hydrocarbons >C5-C6 >C6-C8 >C8-C10	Cyanide	Ethylbenzene Xylenes

Metals	Oil and combustion derived hydrocarbons	Inorganics	Organic compounds
	>C10-C12 >C12-C16 >C16-C35 Aromatic hydrocarbons >EC8-EC10 >EC10-EC12 >EC12-EC16 >EC16-EC21 >EC21-EC35		

5.3.28 The minimum predicted travel time is 52.7yrs at the lowest (5%) estimate and was calculated for vinyl chloride. This is greater than the likely duration of dewatering (three years).

5.3.29 Outside of this three-year period, there would not be the head of water artificially created by the dewatering which may cause migration towards the North Portal.

5.3.30 As such, the travel time assessment was undertaken on the basis that, if predicted travel times are greater than the likely duration of the dewatering, then the risk to the North Portal excavation is not significant.

5.3.31 Based on the above points, lateral migration within the Alluvium is not considered to pose a risk to human health of the construction workers at North Portal, nor the structures at North Portal.

5.3.32 As such, pollutant linkages c., d., e., and f. are not considered a significant risk to the Project’s identified receptors.

5.3.33 In relation to pathways a. and b. and the potential for deterioration in the quality of the underlying aquifer, qualitative assessment indicates a lateral migration pathway within the Alluvium is unlikely present due to discontinuous groundwater. The quality of the RTD and Chalk aquifers is not considered to be at additional risk, primarily due to lack of hydraulic connection of perched water in the Alluvium with the underlying RTD and Chalk in addition to the upward head present in these units. The conservative quantitative modelling undertaken, which assumes a continuous waterbody in the Alluvium, indicates a low potential for movement of COC within the Alluvium, providing further evidence that the North Portal works will not adversely affect groundwater quality.

5.3.34 This conclusion is irrespective of whether mitigation measures such the presence of diaphragm walls or a grout plug are present at North Portal as their presence is not taken into account in the ConSim modelling.

5.4 Ground Gas Mobilisation

5.4.1 Ground gas data for the East Tilbury Landfill is not known to exist / was not made available for review. It is not known whether or not a monitoring plan is currently in place for the East Tilbury Landfill.

5.4.2 Potentially active pollutant linkage g. identifies the potential for ground gas mobilisation to occur should the groundwater regime within the landfill, Made Ground and Alluvium be affected by the dewatering proposed at North Portal.

5.4.3 For a potential increase in ground gas mobilisation to occur, the dewatering at North Portal would need to have a drawdown effect on the groundwater head present within the landfill rise, the Made Ground and the Alluvium. This has consistently been shown to be unlikely.

5.4.4 Further to this, any ground gases generated from within the land raise, or from the organic content within the Alluvium, is likely to preferentially migrate upwards as the landfill is not engineered to control ground gases.

5.4.5 As such, the mobilisation of gases from the landfill, or the Alluvium, are not considered to be of significant risk as a result of dewater at North Portal.

6 Updated Conceptual Site Model

6.1.1 Based on the above discussions a review of the preliminary CSM (Section 3.8) is presented in this Section.

Source

6.1.2 The main identified source of COC to potentially impact the receptors is the East Tilbury Landfill site.

6.1.3 This has not changed as the purpose of this Technical Note was to assess the risks from the East Tilbury Landfill to the Project.

Receptors

6.1.4 The main identified receptors are as follows:

a. Human Health – construction workers on the Project

b. Underlying aquifers; Alluvial Deposits Secondary (undifferentiated) Aquifer, River Terrace Deposit Secondary A Aquifer, Chalk (Principal Aquifer)

c. River Thames present to the southern boundary of the East Tilbury Landfill

6.1.5 The identified Receptors have also not changed as those are still present with regards to human health of the construction workers on the Project, or the water resource receptors.

Pathways

6.1.6 Pathways a. to g. which were previously identified in Section 3.8 and discussed throughout Section 5 have been shown to not be active, nor are they likely to become active, as a direct result of the proposed dewatering at North Portal.

6.1.7 The only exception to this is potentially pathway c., which relates to the migration of COC from East Tilbury Landfill into the River Thames. However, this was deemed to be potentially active pathway out with the effects of the Project, owing to the presence of the River Thames bordering the southern edge of the landfill, the landfill not being lined, and the landfill being built on an intertidal area. As the pumping test showed no direct effect on the perched water within the Alluvium (and therefore, the landfill) it is not considered likely that the proposed dewatering could result in an increase in COC entering the River Thames.

6.1.8 As such, the identified receptors are not likely to be at a significant risk via the identified pathways as a result of the proposed works at North Portal owing to there not being any active pollutant linkages.

6.1.9 Figure 2 shows a schematic cross-section of the CSM based on the information reviewed within.

Uncertainties within the CSM

6.1.10 The following uncertainties within the data review and design have been noted.

a. Concentrations of COC within the leachate within the land raise at East Tilbury Landfill and the underlying groundwater in the RTD and Chalk.

b. Any present measures in place to control or manage leachate and ground gases at East Tilbury Landfill.

c. No data was obtained from monitoring wells within the landfill throughout the various site investigation phases related to the Project as no such wells are currently understood to exist and permission has not been granted to install new wells due to the potential for creation of preferential pathways.

d. The extent of dewatering during the construction phase is not known precisely, and therefore, the extent of the drawdown is unknown.

e. The extent and continuity of the granular horizons within the Alluvium that can contain perched water and accommodate lateral migration.

6.1.11 Whilst acknowledging the above uncertainties present within the CSM and design scenario, the QRA remains conservative and robust due to being based on site-specific data and worst case scenarios taken into account.

7 Summary

7.1.1 This report sets out to produce a qualitative risk assessment of the potential impacts of the proposed North Portal construction on the identified receptors.

7.1.2 The primary concern around the construction related to the proposed dewatering activity to aid the construction of the North Portal, and how this could potentially lead to drawdown of COC within East Tilbury Landfill and impact groundwater quality and other receptors, including human health and the proposed structures associated with the Project.

7.1.3 A preliminary CSM was formed by reviewing the Callear and Bewers (1993) Status Report around the construction of the landfill and the site setting. This showed the landfill to be formed by means of an unlined land raise, sitting directly over the Alluvium. Various waste streams were accepted into the landfill, including hazardous waste types.

7.1.4 Through a review of the most pertinent information sources to the East Tilbury Landfill and the Project, the preliminary CSM was refined to produce an updated CSM.

7.1.5 The updated CSM shows the only active pathway is likely to be that of the leachate from East Tilbury Landfill entering the River Thames. However, this pathway exists irrespective of the proposed Project and dewatering activities, and it is not known whether this is being currently managed by the present landowner of East Tilbury Landfill. This pathway is considered unlikely to be adversely affected by the Project. As such, it is concluded that the Project will have a negligible impact on environmental quality by either affecting existing pathways or by the creation of new pathways, irrespective of mitigation measures at North Portal.

7.1.6 The qualitative risk assessment concluded that the remainder of the reviewed potentially active pollutant linkages were not active, and that no risk is present to the identified receptors from the proposed dewatering at North Portal.

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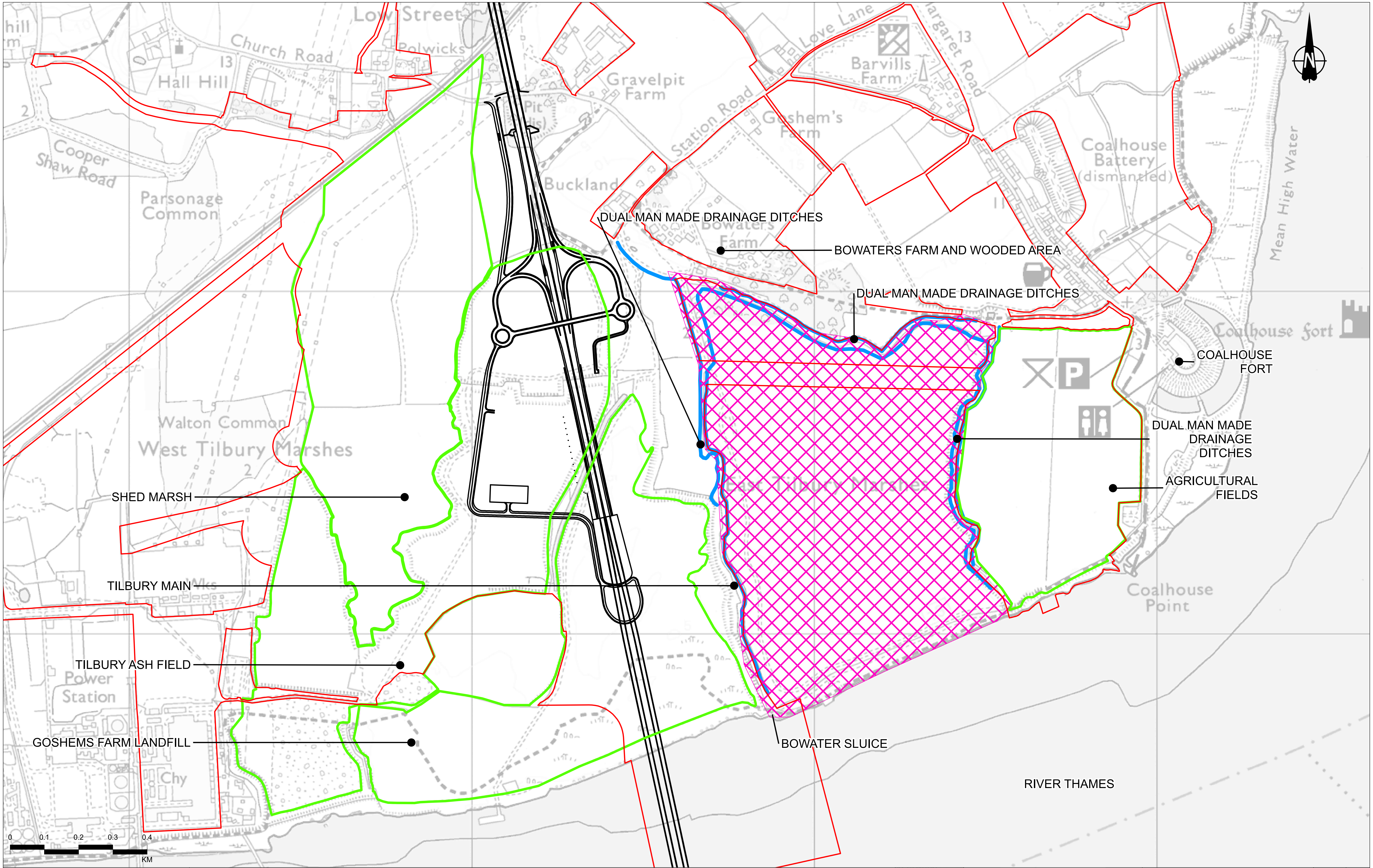
Figures



Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P02	S8	10/10/2022	DCO Application	LK	MW	BF

Note:

Drawing to be read in conjunction with Application Document 6.3, Appendix 10.7

Legend

- Route alignment
- Order Limits
- East Tilbury Landfill
- Nearby sites of potentially contaminated land near to East Tilbury landfill
- Watercourse

Client: national highways

Project: LOWER THAMES CROSSING

Status: DCO APPLICATION

Original Size: A3

Revision: P02

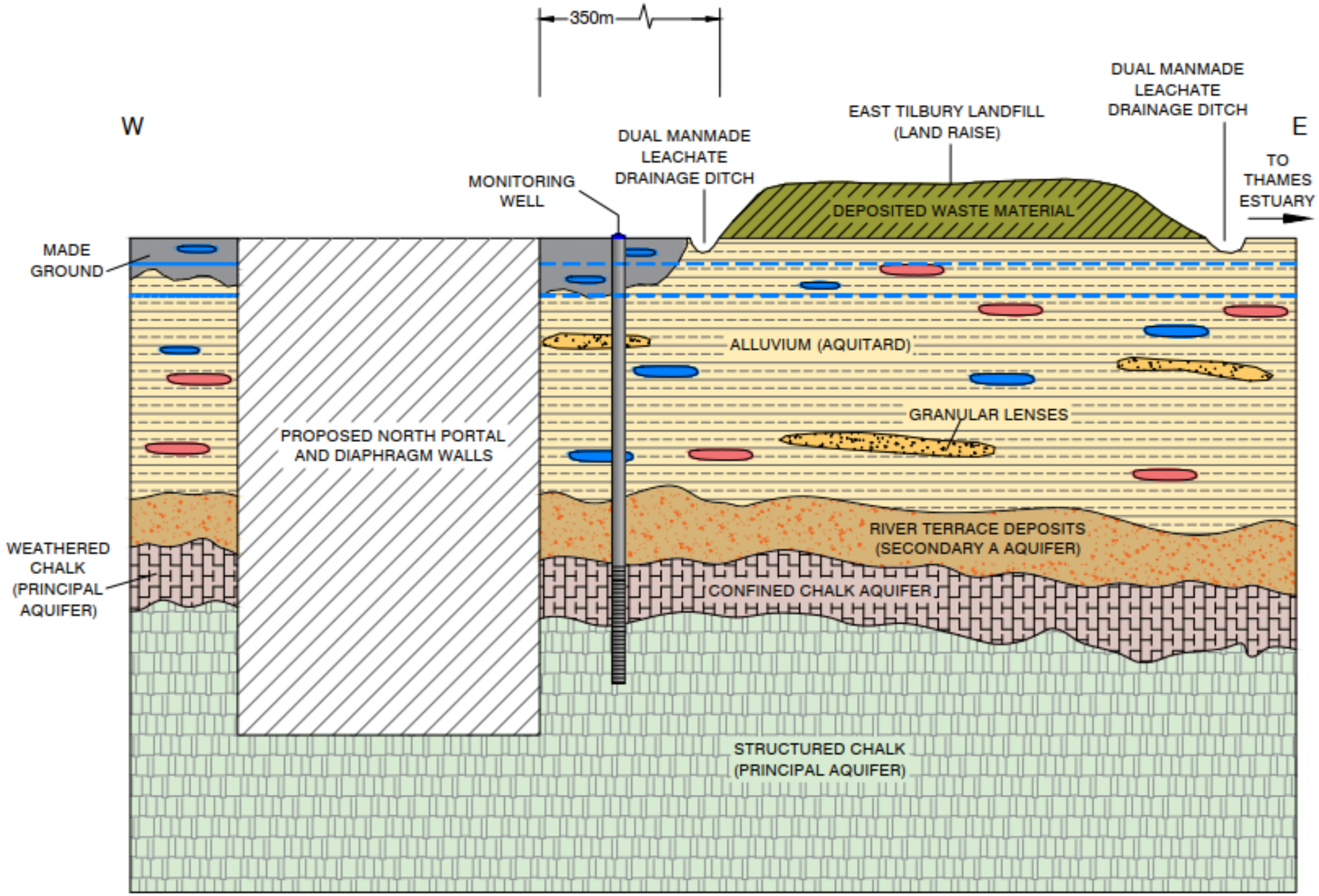
Application Document Number: TR010032/APP/6.3

Scale: 1:10,000

Drawing Title: Figure 1 - East Tilbury Landfill

Drawing Number: HE540039-CJV-EGT-ZZZ_ZZZZZZZZZZ-SK-CE-00001

Z:\Environment\Environmental Statement\10. Geology and Soils\Appendix 10.7new\HE540039-CJV-EGT-ZZZ_ZZZZZZZZZZ-SK-CE-00001.aprx



GROUNDWATER FLOW DIRECTION TO SOUTH / SOUTHEAST
TOWARDS RIVER THAMES AND ESTUARY

Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P02	S8	29/09/2022	DCO Application	LK	MW	BF

Key

- Minimum and maximum potentiometric surface of groundwater in chalk
- Perched groundwater
- Peat dominant layers

Client: national highways

Project: LOWER THAMES CROSSING

Status: DCO APPLICATION

Original Size: A3

Revision: P02

Application Document Number: TR010032/APP/6.3

Scale: N/A

Drawing Title: Figure 2 - Conceptual site model cross section

Drawing Number: HE540039-CJV-EGT-SZP_EGNE00000000-DR-LE-50165

Z:\Environment\Environmental Statement\10. Geology and Soils\Appendix 10.7new\HE540039-CJV-EGT-SZP_EGNE00000000-DR-LE-50165 - Figure 2 - Conceptual site model cross section.aprx

Annexes

Annex A Abstraction Licence Linford Water Supply

Environment Agency

Water Resources
LICENCE TO
ABSTRACT
WATER

Environment Act 1995
Water Resources Act 1991 as amended by the Water Act 2003
Water Resources (Abstraction and Impounding) Regulations 2006

IMPORTANT NOTES

Need for safekeeping

This licence is an important document. The permission or right to abstract water may be valuable to your landholding. So -

- **Keep the licence safe, preferably with your deeds etc.**
- **Take careful note of the comments below about "transfer and apportionment" and "death and bankruptcy".**

This is to ensure that the permission and any rights granted by the licence continue if you need to pass it on to someone else.

If you want to:

- **revoke (cancel) the licence;**
- **vary (change/amend) the licence in any way or**
- **change your contact address (but you continue to hold the licence).**

Please write to WR Permitting Support, PO Box 4209, Sheffield, S9 9BS

Details of this licence are placed on a register, kept by the Environment Agency and open for inspection by the public. The public may also obtain further details about it by virtue of the Environmental Information Regulations 2004 (see also Disclosure of Information) except in special cases (for advice please contact us at the address shown on the front page of the licence).

Transfer and apportionment

If you need to pass this licence or any part of it to someone else, you must contact the Environment Agency and obtain the appropriate application forms. Temporary licences cannot be transferred or apportioned. The licence holder remains responsible for compliance with the terms of the licence and any charges payable until the licence has been transferred or apportioned.

Death or bankruptcy of the licence holder

If a licence has been **'vested'** in you, as a result of the death or bankruptcy of the licence holder, please contact the Environment Agency in writing, telling us the licence number(s) and the date that the licence vested in you as a personal representative or trustee of the licence holder. This is necessary in order to enable you to subsequently transfer the licence.

'Vesting' is the transfer of responsibility and ownership of a licence when an existing licence holder is no longer able to hold the licence either through death or bankruptcy.

You do not have to complete a form, but you must notify us in writing within 15 months of the date of vesting, giving the full names of all personal representatives or trustees and a contact address.

Time limits

Your licence may be subject to a time limit (stated on the front of your licence). All new abstraction licences are legally required to include a time limit. For variations to licences, time limits are added in accordance with our policy.

The duration of a time limit is determined in accordance with our time limiting policy. The time limit is linked to the next or subsequent review of water resources within a Catchment Abstraction Management Strategy (CAMS).

There will be a presumption of renewal providing three tests are met: environmental sustainability is not in question; there is continued justification of need; and water is being used efficiently. Any application for renewal will still be subject to the normal statutory considerations.

If your licence is time limited and you wish to renew it when it expires, you will need to apply for a new licence to replace the existing one. You are advised to submit this application at least three months before it expires. To allow you to give early consideration to this, we will send you a reminder approximately 18 months before the expiry date.

If your licence cannot be renewed, we will endeavour to give at least six years notice. We will also endeavour to give at least six years notice where the licence is likely to be renewed on different terms and will significantly impact upon the use of the licence.

In exceptional circumstances, for example where there are other overriding statutory duties such as the Habitats Regulations, it may not be possible to provide six years notice.

Charges

Unless specifically exempted, we may levy an annual CHARGE for water AUTHORISED to be abstracted by this licence, in accordance with our abstraction charges scheme in force at the time.

The licence may be revoked if charges are not paid.

Quantity and quality of water

You must not abstract more than the quantity specified in the licence.

The Environment Agency does not, by issue of this licence or otherwise, in any way guarantee that the source of supply will produce the quantity of water authorised to be abstracted by this licence, nor that the water is fit for its intended use.

The quantity of water authorised for abstraction is given in cubic metres. One cubic metre is approximately 220 gallons.

(The precise conversion is 1 cubic metres = 219.969 gallons).

Source of supply and authorised point of abstraction

You may abstract from the point(s) specified in the licence and from no other points. If you want to add or change the authorised point(s) of abstraction, you must apply to us to vary the licence.

Land on which water is authorised to be used

Where this condition applies, you may only use the water you abstract on the area specified in the licence. You must apply to us to vary the licence if you wish to extend or alter this area or remove it.

Purpose for which water is authorised to be used

You may only use the water for the purpose(s) specified in the licence. You must apply to us to vary the licence if you wish to add to or change the purpose(s).

Offences

Under the Water Resources Act 1991 it is an offence:-

- to abstract water, or cause or permit any other person to abstract water, unless the abstraction is authorised by and in accordance with an abstraction licence, or is subject to an exemption;
- to do anything to enable abstraction, or to increase abstraction, except in accordance with an abstraction licence or exemption;
- to fail to comply with the conditions of an abstraction licence.
  Note in particular that it may be a condition of the licence to maintain the meter or other measuring device etc. and failure to do so will be an offence;
- to interfere with a meter or other device which measures quantities of water abstracted so as to prevent it from measuring correctly;
- to fail to provide information which we have reasonably required for the purpose of carrying out any of the Environment Agency's water resources functions;
- to knowingly make false statements for the purpose of obtaining a licence or consent or in giving required information.

The requirement for a licence is subject to some exemptions, set out in the Water Resources Act 1991 as amended. If in any doubt as to whether you need a licence, contact us at the address shown at the bottom of the front page of the licence.

Right of appeal

If you are dissatisfied with our decision on your licence application, you may appeal.

If you are in England, you should write to the Secretary of State for the Environment, Food and Rural Affairs, care of The Planning Inspectorate at:
Room 4/19 Eagle Wing,
Temple Quay House,
2 The Square,
Temple Quay,
Bristol,
BS1 6PN.

If you are in Wales, you should write to The National Assembly for Wales care of The Planning Inspectorate at:
Crown Buildings,
Cathays Park,
Cardiff,
CF10 3NQ.

You must serve notice of appeal within 28 days of the date of receipt of this licence (although the Secretary of State and The National Assembly have power to allow a longer period for serving notice of appeal). See Water Resources Act 1991, section 43.

Disclosure of information

Information about this licence is available in the public Register held by the Environment Agency. Members of the public are also entitled to ask us for other "environmental information" it holds, including any activities likely to affect "the state of any water" or any "activities or other measures designed to protect it". That would include the information additional to the licence document e.g. any related agreement or abstraction returns. In certain restricted circumstances it is possible to claim that information should be kept confidential. If you require more information about keeping this information off the public register because it is confidential, please contact us by writing to the address shown on the front page of the licence within 28 days of receiving this licence.

Licence Serial No:	8/37/56/*G/0044

Please quote the serial number in all correspondence about this licence

Environment Agency

FULL LICENCE TO ABSTRACT WATER

The Environment Agency ("the Agency") grants this licence to:-

Northumbrian Water Limited ("the Licence Holder")
Northumbria House
Abbey Road
Pity Me
Durham
DH1 5FJ

Company registration number: 02366703

This licence authorises the Licence Holder to abstract water from the source of supply described in the Schedule of Conditions to this licence and subject to the provisions of that Schedule. The licence commences from the effective date shown below and shall remain in force until the date of expiry shown below. Where no expiry date is specified the licence shall remain in force until revoked.

Signe[redacted]

Keith Grimwood
Permitting Team Leader

Environment Agency
Permitting and Support Centre
Water Resources Team
Quadrant 2
99 Parkway Avenue
Parkway Business Park
Sheffield
S9 4WF

Date of issue .... 23 December 2015

Date effective .... 23 December 2015

Date of original issue......................... 6 June 1968
(if this document is a reissue or revision of the licence originally granted for this abstraction)

The licence should be kept safe and its existence disclosed on any sale of the property to which it relates. Please read the 'important notes' on the cover to this licence.

Note: References to "the map" are to the map which forms part of this licence.
References to "the Agency" are to the Environment Agency or any successor body.

Environment Act 1995
Water Resources Act 1991 as amended by the Water Act 2003
Water Resources (Abstraction and Impounding) Regulations 2006

Licence Serial No:	8/37/56/*G/0044

SCHEDULE OF CONDITIONS

1. SOURCE OF SUPPLY

1.1 Abstraction Point 1

Underground strata comprising of chalk at Stifford, Essex.

1.2 Abstraction Point 2

Underground strata comprising of chalk at Linford, Essex.

2. POINTS OF ABSTRACTION

2.1 Abstraction Point 1

At National Grid Reference TQ 59245 80050 marked ‘Abstraction Point 1’ on map 1.

2.2 Abstraction Point 2

At National Grid Reference TQ 67168 79280 marked ‘Abstraction Point 2’ on map 2.

3. MEANS OF ABSTRACTION

3.1 Abstraction Point 1

A well not 42.67 metres in depth and 4,057 millimetres in diameter with steel tubing to 11 metres and brick lined from 11 to 42.67 metres with a pump.

3.2 Abstraction Point 2

A well not exceeding 64.9 metres in depth and 3,600 millimetres in diameter with plain lining from 0 to 17.7 metres and brick lined from 17.7 to 45 metres, with a pump.

4. PURPOSES OF ABSTRACTION

4.1 Abstraction Point 1

Public water supply.

4.2 Abstraction Point 2

4.2.1 Public water supply.

Up to and including 31 March 2023

4.2.2 Managing water levels.

5. PERIODS OF ABSTRACTION

5.1 All year.

6. MAXIMUM QUANTITY OF WATER TO BE ABSTRACTED

6.1 <u>Abstraction Point 1</u>
11,700 cubic metres per day

6.2 <u>Abstraction Point 2</u>

For purpose 4.2.1 (Public water supply):

6,365 cubic metres per day

For purpose 4.2.2 (Managing water levels):

2,160 cubic metres per day

At an instantaneous rate not exceeding 25 litres per second.

6.3 The aggregate quantity of water authorised to be abstracted under this licence shall not exceed 3,728,000 cubic metres per year.

Up to and including 31 March 2023

6.4 The aggregate quantity of water authorised to be abstracted from Abstraction Point 2 shall not exceed 6,365 cubic metres per day.

7. MEANS OF MEASUREMENT OF WATER ABSTRACTED

7.1 (i) No abstraction shall take place unless the Licence Holder has installed meters to measure quantities of water abstracted for each purpose.

(ii) The Licence Holder shall position and install the meters in accordance with any written directions given by the Agency.

(iii) The Licence Holder shall maintain, repair or replace the meters to ensure that accurate measurements are recorded at all times.

(iv) The Licence Holder shall keep all records of meter repair or replacement including evidence of current certification for a period of 6 years.

8. RECORDS

8.1 The Licence Holder shall take and record readings of the meters specified in condition 7 at the same time each day during the whole of the period during which abstraction is authorised or as otherwise approved in writing by the Agency.

8.2 The Licence Holder shall send a copy of the record or summary data from it to the Agency within 28 calendar days of 31 March in each year or within 28 days of being so directed in writing by the Agency.

8.3 Each record shall be kept and be made available during all reasonable hours for inspection by the Agency for at least 6 years.

9. FURTHER CONDITIONS

9.1 The discharge of water to Gobians Sewer at National Grid Reference TQ 67160 79265 shall not exceed the rate of 25 litres per second.

9.2.1 No discharge to Gobians Sewer shall take place when the level of water in the Gobians Sewer as measured at the Bridge at National Grid Reference TQ 67153 79263 is equal to or greater than 4.3 metres Above Ordnance Datum or at such other level as may be approved in writing by with the Agency.

9.2.2 No discharge to Gobians Sewer shall take place unless the Licence Holder has installed a gauge board and water level sensor device in the Gobians Sewer at the Bridge at National Grid Reference TQ 67153 79263.

9.2.3 The Licence Holder shall monitor and maintain the gauge board and water level sensor device in such a condition, and if necessary replace them, so as to ensure that accurate measurements are recorded at all times.

9.3.1 The Licence Holder shall use the measuring device specified in condition 9.2.2 to record the level every fifteen minutes during the whole of the period during which discharge is authorised or as otherwise approved in writing by the Agency.

9.3.2 The Licence Holder shall send a copy of the record or summary data from it to the Agency within 28 calendar days of 31 March in each year or within 28 days of being so directed in writing by the Agency.

9.3.3 The Licence Holder shall keep each record required by 9.3.1 and make them available during all reasonable hours for inspection by the Agency for at least 6 years.

ADDITIONAL INFORMATION

Note: the following information is provided for information only. It does not form part of the licence.

REASONS FOR CONDITIONS

The abstraction is required to be metered to demonstrate compliance with the terms of the licence and to provide information on actual water usage for water planning purposes.

The licence variation is time-limited to a date to reflect a reasonable time period required to construct a water treatment work.

The Licence Holder shall obtain all the necessary permits or consents required to discharge water abstracted for the purpose of managing water levels.

IMPORTANT NOTES

Abstraction period details
Note: an hour means any period of 60 consecutive minutes, a day means any period of 24 consecutive hours and a year means the 12 month period beginning on 1 April and ending on 31 March.

Metering
The Agency will have regard to its Abstraction Metering Good Practice Manual (or equivalent guidance) in directing any of the following: where the meter should be located or how it should be installed; whether the meter measures accurately, and/or is properly maintained; whether it is necessary to require repair or replacement of the meter.

Condition 9.2.1
The Licence Holder shall contact the Asset Performance Team at the following address if it is determined that a change to the to level specified in condition 9.2.1 is necessary:

Environment Agency
Brook End Road
ChelmsfordEssex
CM2 6NZ

or email: eaessexoperations@environment-agency.gov.uk

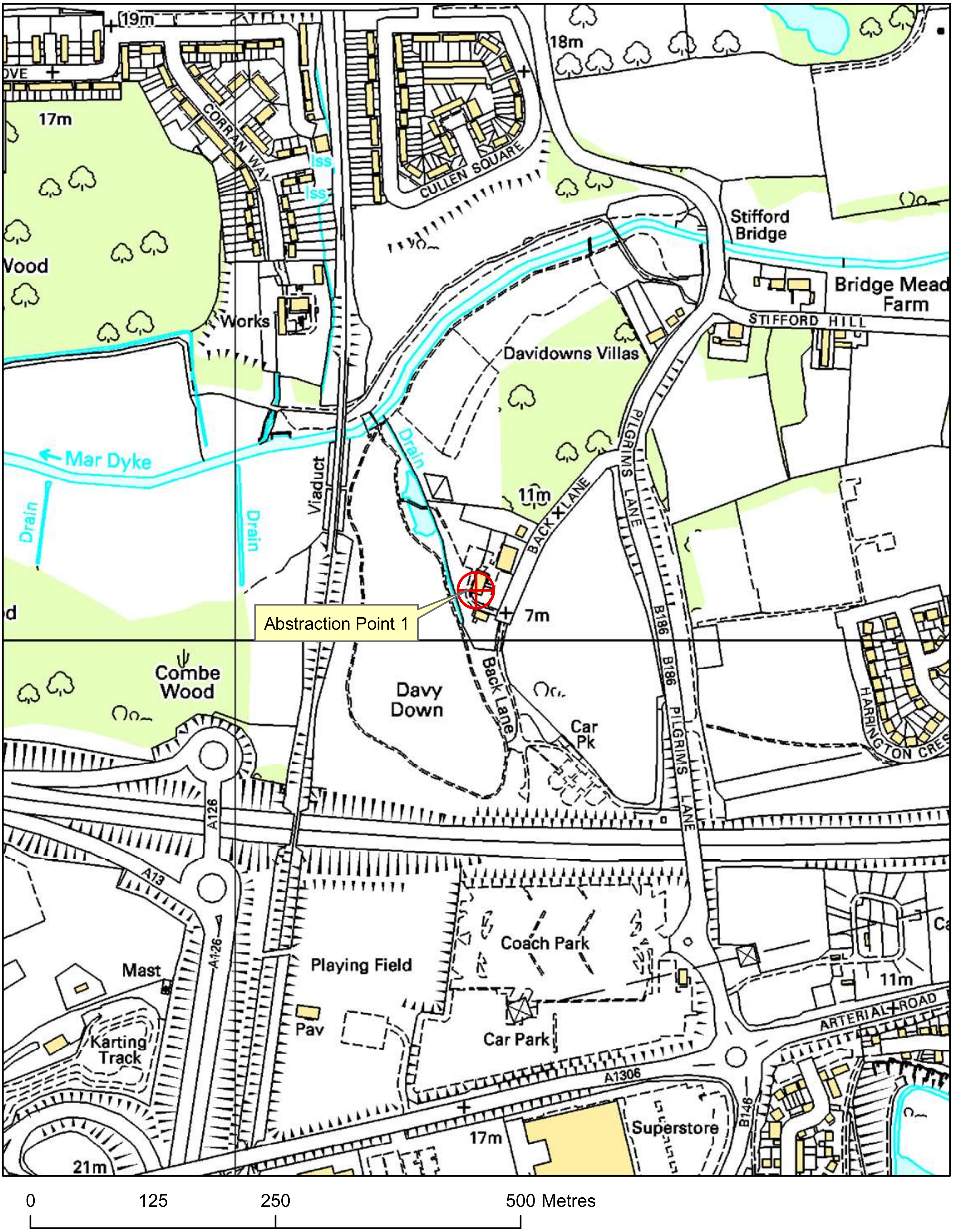
Water level data
The Licence Holder shall send data in accordance with condition 9.3 to:

eaessexoperations@environment-agency.gov.uk or :

Asset Performance Team
Environment Agency
Brook End Road
Chelmsford
Essex
CM2 6NZ

Licence History

Licence serial number	Issue date	Expiry date	Summary of changes
8/37/56/*G/0044	6 June 1968	n/a	Licence first issued.
8/37/56/*G/0044	31 October 1994	n/a	Licence holder name change.
8/37/56/*G/0044	1 April 2000	n/a	Licence amended to correct two administrative errors.
8/37/56/*G/0044	30 November 2009	n/a	Licence holder name change.
8/37/56/*G/0044	23 December 2015	Variation until 31 March 2023	Application number: NPS/WR019854 to add an additional purpose of abstraction to Abstraction Point 2 of ‘Managing water levels’ and to include conditions relating to the discharge to Gobians Sewer.



MAP ACCOMPANYING LICENCE NUMBER 8/37/56/*G/0044 MAP 1

Scale: 1:5,000

Environment Agency

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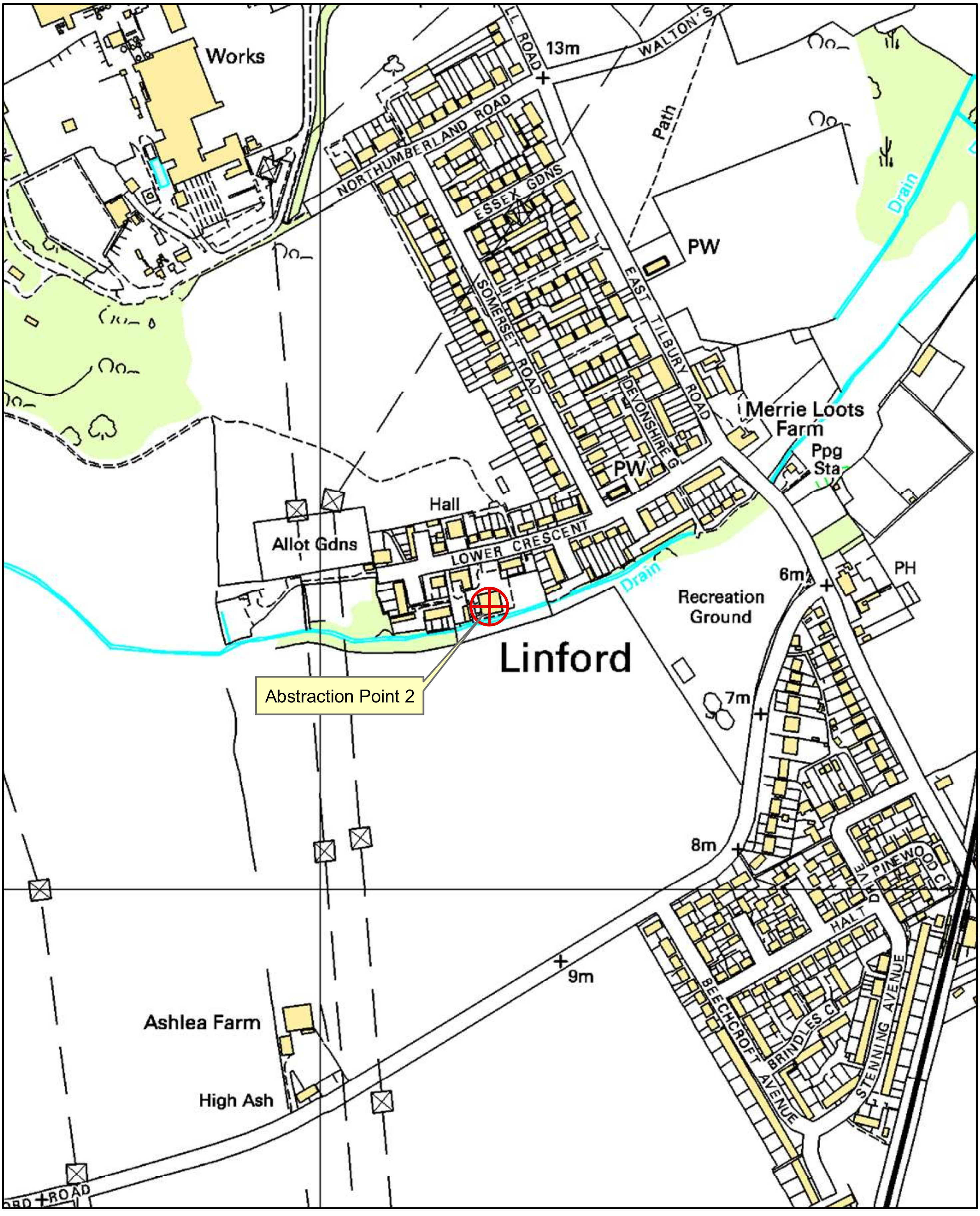

Environment Agency

MAP ACCOMPANYING LICENCE NUMBER
8/37/56/*G/0044 MAP 2

Scale: 1:5,000

N

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08708 506 506 (Mon-Fri 8-6)

email
enquiries@environment-agency.gov.uk

or visit our website
www.environment-agency.gov.uk

incident hotline 0800 80 70 60 (24hrs)
floodline 0845 988 1188

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Annex B ConSim Modelling Methodology

Annex B-B 1		
Chemical Input Parameter Values		
Contaminant	Partition Coefficient	Organic Carbon Coefficient
Symbol	Kd	K_{oc}
Units	l/kg	l/kg
Geological Unity	Alluvium	-
Metals and Inorganics		
Arsenic	117 - 500	-
Cadmium	3.7 - 74 - 1500	-
Chromium III	6.3 - 67 - 4400	-
Chromium VI	8.5 - 67 - 4400	-
Copper	295 - 316	-
Lead	27 - 270 - 27000	-
Mercury (inorganic)	450 - 500	-
Nickel	20 - 400 - 8100	-
Zinc	1.1 - 200 - 36000	-
Total Cyanide	9.9 - 1000	-
Ammonium (NH4)	0.5 - 2 - 3.2	-
Total Petroleum Hydrocarbons		
Aliphatic $>C_5-C_6$	-	790
Aliphatic $>C_6-C_8$	-	4 000
Aliphatic $>C_8-C_{10}$	-	32 000
Aliphatic $>C_{10}-C_{12}$	-	250 000
Aliphatic $>C_{12}-C_{16}$	-	5×10^6
Aliphatic $>C_{16}-C_{35}$	-	1×10^9
Aromatic $>C_8-C_{10}$	-	1 600
Aromatic $>C_{10}-C_{12}$	-	2 500
Aromatic $>C_{12}-C_{16}$	-	5 000
Aromatic $>C_{16}-C_{21}$	-	16 000
Aromatic $>C_{21}-C_{35}$	-	130 000
BTEX Compounds		
Benzene	-	67.6
Ethylbenzene	-	447
Toluene	-	204
Xylenes	-	457
Polycyclic Aromatic Hydrocarbons		
Naphthalene	-	645.7
Benzo(b)fluoranthene	-	104713
Benzo(k)fluoranthene	-	147911
Benzo(a)pyrene	-	128825
Indeno(123cd)pyrene	-	87096
Benzo(ghi)perylene	-	416869
Phenolics		
Phenol	-	83.18
Chlorinated VOC		
Tetrachloroethene (PCE)	-	269.000
Trichloroethene (TCE)	-	141.000
Vinyl Chloride (VC)	-	16.600

Notes

kd and Koc values determined by literature review. Sources considered include EA Science Report 7 (SR7) (EA, 2008), ConSim help files (ConSim, 2000) and TPHCWG 1997 (TPHCWG, 1997). Where available, kd values for cohesive materials have been adopted.

Annex B-B 2			
ConSim Modelling - Physical Parameter Values			
Parameter	Distribution	Value	Source
Source			
Size	Single value	Approximately 1,300m by 800m	Based on digitised known extent of East Tilbury Landfill.
Infiltration (mm/year)	Normal	200.5 (20.05)	Calculated based on average rainfall data in NERC (2008) for rain gauges 37031 at Mar Dyke, 40012 at Hawley and 40016 at Crayford. Effective rainfall (30%) was then calculated based on EA regional data 2002 to 2005 for the Thames region assuming no hardstanding or drainage present.
Alluvium (Aquifer)			
Thickness (m)	Triangular	7-15-18	Range considered to be reasonable based on the variability of the alluvium between route alignment and East Tilbury Landfill. Typical thickness based on BH7015
Hydraulic Conductivity (m/s)	Triangular	2.6 x 10-7 - 7.7 x10-7 - 3.7 x 10-6	5th, 50th and 95th%ile values adopted from North Portal hydrogeological model (HE540039-CJV-GEN-GEN-TNT-GEO-00117).
Hydraulic Gradient	Uniform	0.02-0.05	Estimated based on anticipated draw down during dewatering of North Portal excavation. Calculated based on the head along East Tilbury Landfill boundary of between approximately -1 and 8mbgl in Alluvium (BH07049, BH07031) and -0.3 and 1mbgl in the Chalk or River Terrace Deposits (OH07036, OH07037, OH07039, OH07041).
Bulk density (g/cm3)	Uniform	2-2.25	Based on literature values for a Clay from ConSim (2000) (1 - 2.4) and a gravel-sand-clay from Tomlinson (1995) (2.0 - 2.25).
Fraction of Organic Carbon (%)	Log normal	2.59 (2.0)	Literature values from ConSim (2000) for alluvium (0.06 - 0.74 - 6.2) were considered along with site TOC data from the North Portal Area from depths of between 7 and 18m bgl (estimated region of Alluvium). Any made ground and peat containing samples were removed from the dataset.
Effective Porosity	Uniform	0.075-0.125	Based on literature values for effective porosity from McWorter & Sunada (1997) for a coarse gravel (0.21 arithmetic mean), and a clay (0.06). This range was further refined by referring to di Casadio & Elmi (1995) value for a sandy clay/clayey sand of 0.075 - 0.125.
Distance to Receptor	Single	250	Minimum distance between East Tilbury Landfill Boundary and route alignment, minus approximately 50m to model outside the main zone of influence from de-watering.
Longitudinal Dispersivity	Single	25.0	10% of the migration in the aquifer pathway
Laterall Dispersivity	Single	7.50	30% of the longitudinal dispersivity

References

ConSim (2000)	CONSIM Software, 2000. EA & Golders Associates.
Tomlinson (1995)	Tomlinson, M.J., 1995. Foundation Design and Construction. Sixth Edition.
McWorter & Sunada (1977)	McWorter, D.B. and Sunada, D.K., 1977. Groundwater Hydrology and Hydraulics, Ft. Collins.
di Casadio & Elmi (1995)	diCasadio, M. and Elmi, C., 1995. Il Manuale Del Geologo, Pitagora Editrice Bologna
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NERC (2008)	NERC, 2008. Marsh, T. J. and Hannaford, J. (Eds). 2008. UK Hydrometric Register. Hydrological data UK series. Centre for Ecology & Hydrology, 25pp.

Distribution Type

Input parameter ranges can be defined in a number of ways, depending on the available data. For datasets which can be demonstrate to conform to a statistical distribution, either a normal or log normal distribution may be used. A triangular distribution can be used to defined values for the high and low ends in the range along with a ‘most likely’ value. Triangular distributions are typically used where certainty is higher but a statistical distribution cannot necessarily be identified.

Where certainty is lower in the parameter value, a uniform distribution is generally selected with no value within the range considered more likely than the other. The probability of a value lying outside of the range is zero. The total probability accounted for within the distribution is 1. The probability of all values within the range is equal.

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