Lower Thames Crossing

9.89 Responses to the Examining Authority's ExQ1 Appendix G – 11. Biodiversity (Part 3 of 6)

Infrastructure Planning (Examination Procedure) Rules 2010

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Lower Thames Crossing

9.89 Responses to the Examining Authority's ExQ1 Appendix G – 11. Biodiversity (Part 3 of 6)

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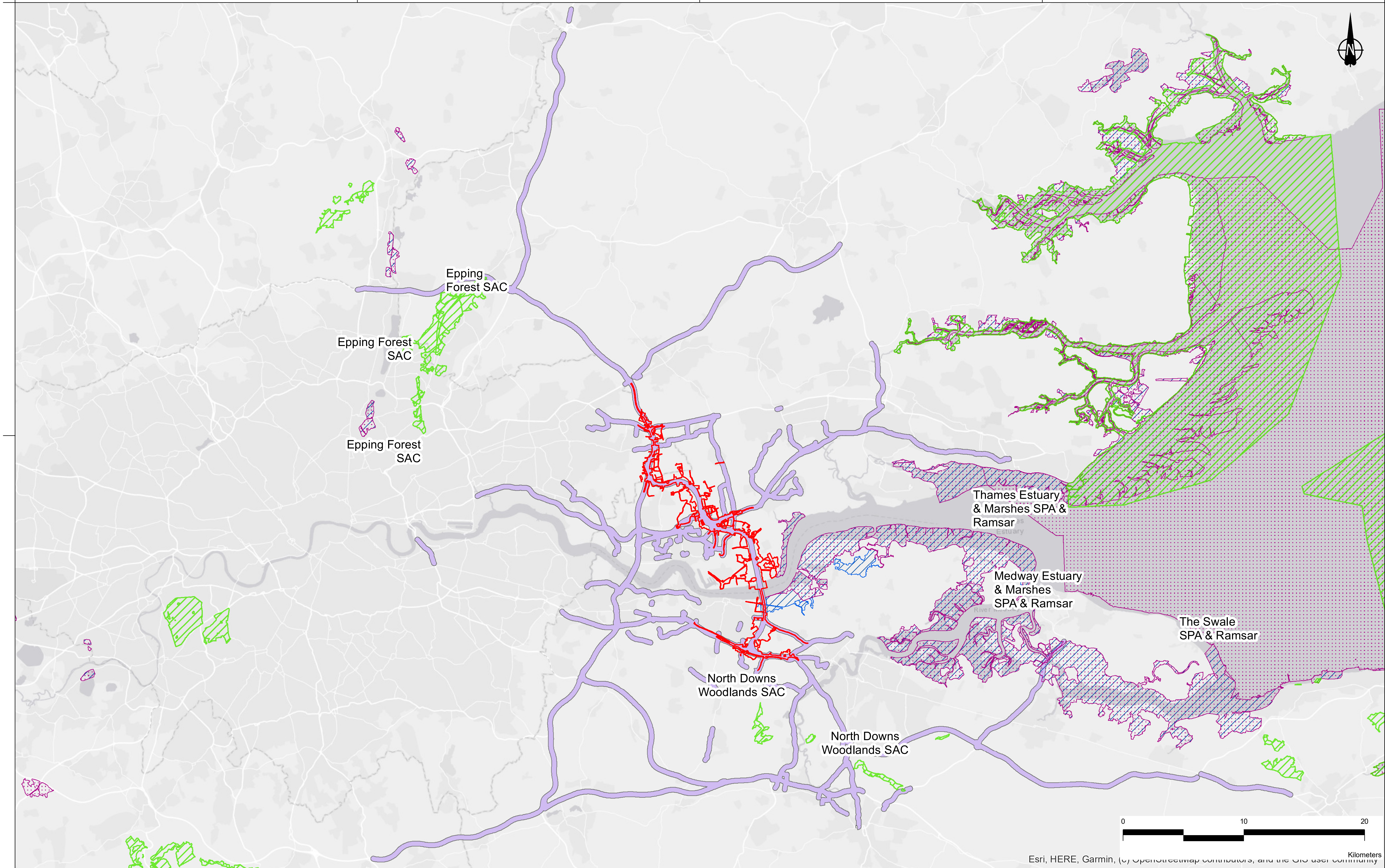


Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01.1	S0	12/01/2020	Draft for Consultation	IP	RC	RC

LEGEND

- Special Areas of Conservation (SAC)
- Special Protection Areas (SPA)
- Ramsar
- Order Limits
- Areas within 200m of the Operational ARN

Client: highways england

Project

5TH FLOOR BEAUFORT HOUSE
15 ST BOTOLPH STREET
LONDON EC3A 7DT

Status: Draft for Consultation

Original Size: A3

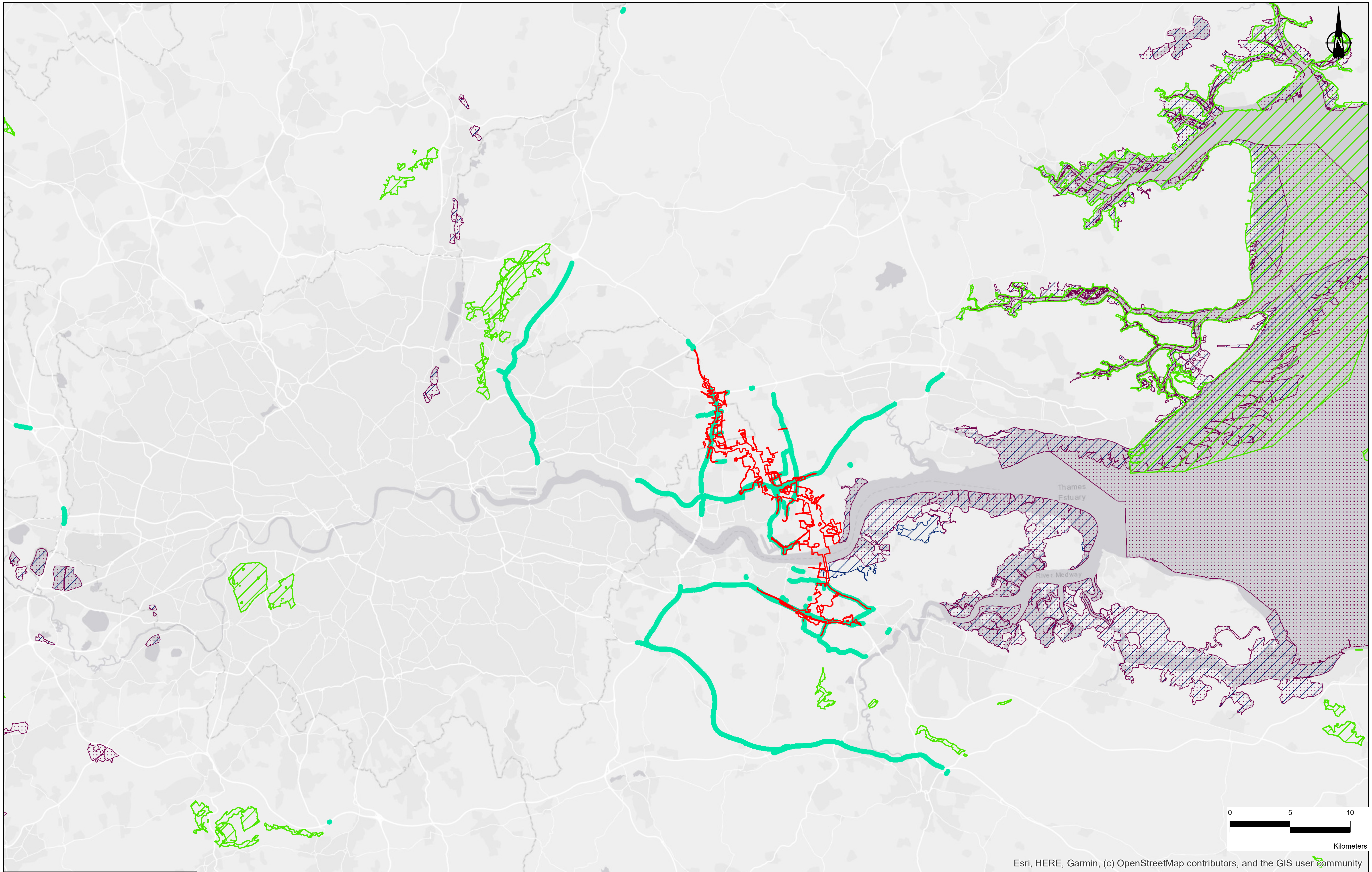
Revision

Scale: 1:280,000

Drawing title: European sites located within 200m of the Affected Road Network (ARN) - Operation (2027)

Drawing number: FIGURE 5

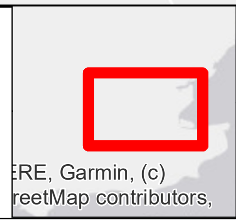
MXD Location: M:\Ben\Ecology\Jobs\LTC\LTC HRA\GIS\HRA_Fig5.mxd



Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01.1	S0	15/04/2020	Draft for Consultation	IP	RC	RC

LEGEND

- Special Areas of Conservation (SAC)
- Special Protection Areas (SPA)
- Ramsar
- Order Limits
- Areas within 200m of the Construction ARN



Client

highways england

Project

LOWER THAMES CROSSING

5TH FLOOR BEAUFORT HOUSE
15 ST BOTOLPH STREET
LONDON EC3A 7DT

Status: Draft for Consultation

Original Size: A3

Revision:

Scale: 1:280,000

Drawing title

European sites located within 200m of the Affected Road Network (ARN) - Construction

Drawing number: FIGURE 22

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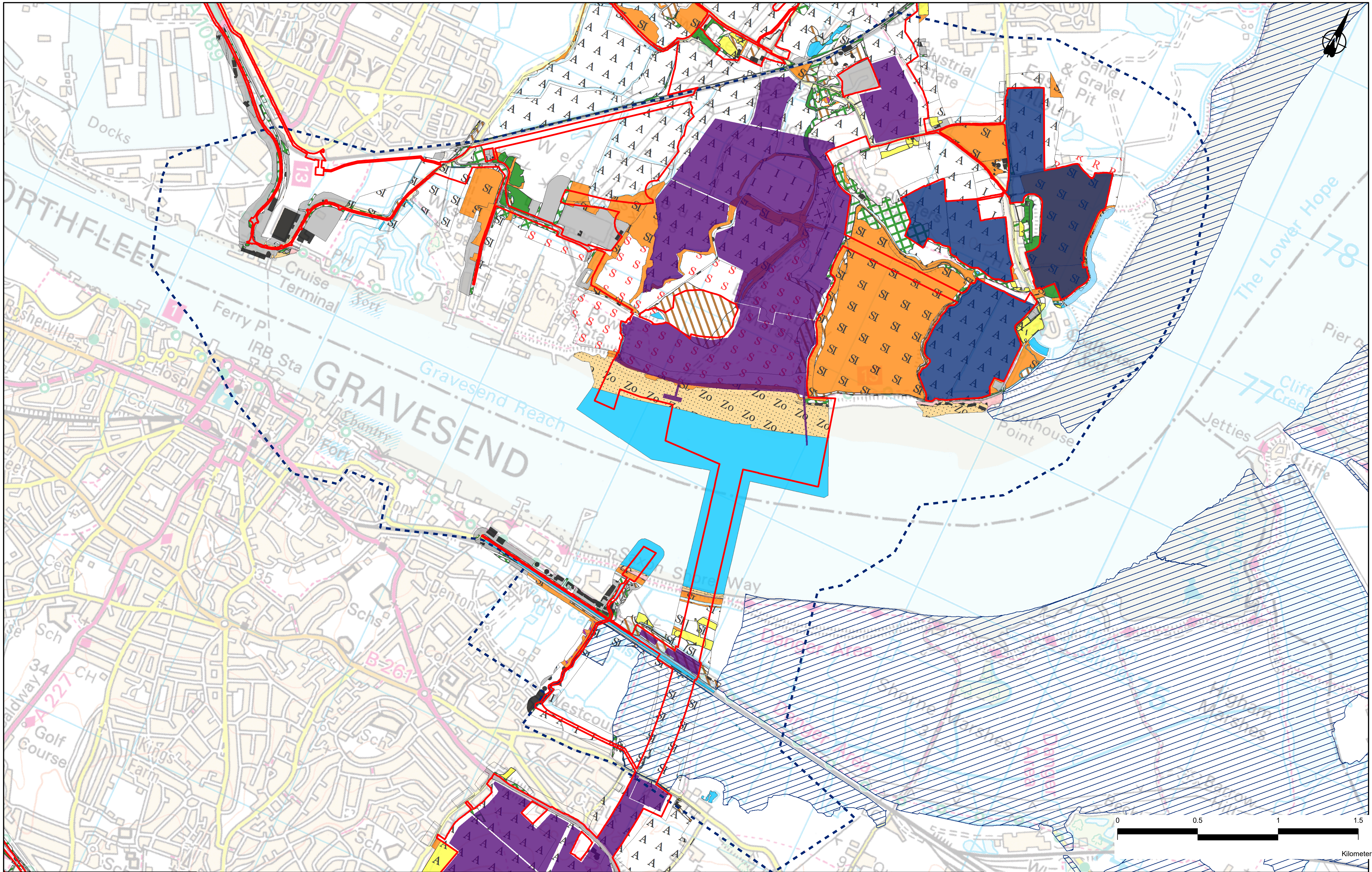
Annex W 22 May 2020 Figure showing land take in relation to European sites and functionally linked land



Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01.1	S0	22/05/2020	Draft for Consultation	IP	RC	RC

LEGEND

- Ramsar
- HRA area of interest: All suitable habitat within this area is functionally linked land
- Order Limits

Indicative areas of land take

- Construction: compounds, outfalls & jetty
- Ecology mitigation areas

Baseline: Phase1 Habitat

A1.1.1, A1.1.2, A2.1, B1.1, B2.2, B3.2, B4, B5, B6, C3.1, F1, G1, G2, H1.1, H1.2, H1.3, H2.6, H3, Hardstanding, I2.2, I2.4, J1.1, J1.2, J1.3, J1.4, J3.6, J4, J5

Client: highways england

Project: LOWER THAMES CROSSING
5TH FLOOR BEAUFORT HOUSE
15 ST BOTOLPH STREET
LONDON EC3A 7DT

Status: Draft for Consultation

Original Size: A3
Revision:
Scale: 1:21,000

Drawing title: Areas of potential habitat loss within the functionally linked land

Drawing number: FIGURE 28

MXD Location: M:\Ben\Ecology\Jobs\LTC\LTC HRA\GIS\HRA_Fig29.mxd

Annex X 22 May 2020 Approach to climate change assessment

Approach to Climate Change assessment

Introduction

Assessment in relation to Climate Change is required within the screening of effects on European sites following DMRB standard LA115 (Highways England, 2019) as it is included as an assessment criterion within the screening matrix template in table A-3 of that document. The intent to include an assessment in relation to Climate Change was included in the Draft HRA Screening report, which was shared with Natural England in December 2019. In response to the consultation, Natural England stated: "*Integrating Climate Change predictions into an HRA is challenging and potentially problematic. I think we will need to consult internally before offering a clear opinion*". In response to this advice, LTC added the Climate Change assessment to the list of Key Issues for consultation and the matter was discussed during the regular consultation call on 13 May 2020. This paper outlines the proposed scope and approach to the assessment in relation to Climate Change for further consultation as to the sufficiency of the methodology for the purposes of HRA Screening.

Scope of Climate Change within the assessment

The purpose of including Climate Change in the assessment is to ascertain whether the effects of the Project would be likely to exacerbate expected future consequences of Climate Change on European sites. The relationship between the Project, European sites and Climate Change is broadly split into:

- The contribution of the effects of the Project to Climate Change
  This is considered to relate to the contribution to greenhouse gases and so assessed as part of the environmental impact assessment for the Project within the climate topic chapter and air quality effect pathway in the HRA. The Project's contributions to environmental changes that are thought to be causes of Climate Change are not considered in the HRA assessment as there is no direct pathway to effect on European sites from greenhouse gases.
- The effects of the Project potentially exacerbating the consequences of Climate Change on European sites.
  This is considered to relate to exacerbation of consequences of Climate Change such as coastal squeeze as a result of sea level rise, changes in ecological climate space as a result of global warming and changes in water resource/precipitation as a result of erratic weather patterns.

The assessment is therefore specifically focussed on the consequences of Climate Change and whether or not the Project would result in an exacerbation of those effects at European sites.

Consequences of Climate Change

The consequences of Climate Change that could conceivably be exacerbated by development are:

- Coastal squeeze resulting from sea level rise
- Changes to ecological climate space resulting from global warming
- Changes to water resources and precipitation resulting from erratic weather patterns

Coastal squeeze resulting from sea level rise

Coastal squeeze has been identified as a specific pressure within the Site Improvement Plan (Natural England, 2014) for the Greater Thames Estuary complex of European sites that have been identified within the HRA

Screening assessment. Coastal squeeze could conceivably be exacerbated by land take from the Project affecting coastal habitats.

Shoreline Management Plans (SMP) are primarily the way in which the threats of sea level rise are managed and apply to sections of the coast around the UK. The European sites within the Greater Thames complex are part of the areas covered by Essex to South Suffolk SMP (East Anglia Coastal Group, 2010), Isle of Grain to South Foreland SMP (South East Coastal Group, 2010) and River Medway and Swale Estuary SMP (South East Coastal Group, 2010). The SMPs are supported by a HRA which assess the effects of shoreline realignment proposals on European sites and considers coastal squeeze as part of this process.

For the Project to significantly exacerbate the effects of coastal squeeze, it would need to result in the loss of coastal habitat that would compromise the implementation of the SMPs to an appreciable degree.

- The Project would lead to permanent land take (land take lasting more than 5 years) within the intertidal area. In the medium term (over 10 years), the Project would return all intertidal land to pre-construction state.
- The Project would contribute to an estuary wide enhancement/restoration programme, such as those delivered by organisations such as the Thames Estuary Partnership (TEP), as part of its obligations under the Water Framework Directive.
- The HRAs supporting both the Isle of Grain to South Foreland and River Medway and Swale Estuary SMPs indicated that habitat creation measures were required to compensate for the losses of various coastal habitats from coastal squeeze.

The intertidal habitat loss caused by the Project in the short term would be nugatory in the context of the predicted changes in the SMPs; and zero in the medium term. As climate change effects are necessarily long term effects, the Project is not expected to exacerbate the effects of coastal squeeze in the long term.

Changes to ecological climate space

The Conservation Objectives and Supplementary Advice do not identify changes in ecological climate space as a key threat or key sensitivity for any European sites that are considered within the HRA. It is therefore not considered necessary to consider potential for exacerbation of this result of Climate Change in the HRA.

Changes to water resources and precipitation patterns

The Conservation Objectives and Supplementary Advice do not identify changes to water resources and precipitation patterns through climate change as a key threat or key sensitivity for any European sites that are considered within the HRA. It is therefore not considered necessary to consider potential for exacerbation of this result of Climate Change in the HRA.

References

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[Accessed 12 May 2020].

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[Accessed 12 May 2020].

Annex Y 10 June 2020 Land take methodology

Land Take – Habitat Loss: Assessment Methodology

AIM – To set out the proposed process to determine how the Project may reduce habitat area as a result of the land take pathway and whether this effect (habitat reduction/loss) will result in an adverse effect on the integrity of the European sites.

<table>
<tr><td colspan="2">Effect: Reduction in habitat area from the land take required for the Project construction.
Key Species: SPA/Ramsar qualifying birds using functionally linked land (FLL)
European Sites Screened in:
▪ Benfleet and Southend Marshes SPA and Ramsar
▪ Medway Estuary and Marshes SPA & Ramsar
▪ Thames Estuary and Marshes SPA & Ramsar
▪ The Swale SPA and Ramsar SPA & Ramsar</td></tr>
<tr><td colspan="2">Information used to determine magnitude and extent of the impact</td></tr>
<tr><td>Location of impact</td><td>Maps to illustrate overlaps where land take interfaces with the European sites and the FLL

Locations are likely to be associated with specific Project elements that overlap with European sites or FLL.

Project elements include:
• construction compounds 3A, 3B and 5
• construction of northern outfall in the intertidal area
• retention of the jetty
• installation of the southern outfall in the Ramsar
• creation of ecological mitigation areas
• construction haul roads</td></tr>
<tr><td>Duration of impact</td><td>Land take has been assessed for the purposes of Appropriate Assessment as permanent if the loss of habitat will occur for five years or more. However, for clarity, ‘permanent loss’ has been sub-divided into ‘permanent’ and ‘semi-permanent’ loss. Temporary habitat loss has been taken to mean where habitats would be lost for less than five years.

Permanent – any land take that will be within highways infrastructure or habitats of limited value for the qualifying features being assessed once scheme is operational.</td></tr>
</table>

	Semi-permanent – any land take during construction of more than 5 years, where habitats are lost during construction, but then regenerated as before or replaced with habitats of similar utility for the qualifying features being assessed. Temporary – any land take during construction of less than 5 years, where habitats are lost, but then regenerated as before or replaced with habitats of similar utility for the qualifying features being assessed.		
Impact magnitude			
Project element	For each project element described above, record the Phase 1 habitat types lost		
Habitat lost (ha)	Using the Phase 1 data, list the habitat types and hectares. Collate all Project element data to provide Project-scale magnitude of impact.		
Information used to explore magnitude/significance of the effect (habitat loss)			
Map of FLL For the AA, FLL is taken to include supporting habitat within the European sites.	Provide GIS map of areas considered to be used by SPA/Ramsar QF birds i.e. FLL – FLL identified as phase 1 data/Corine land cover habitat that are considered likely to be suitable based on the habitat types described in Supplementary Advice, plus the area of the European sites.		
Bird species present in areas surveyed	List all the qualifying feature (QF) species and those that contribute to the assemblages (together referred to as HRA species) recorded by the following field surveys: VP surveys (5 points) day VP survey (1 point) night FLL transects – day and night		
HRA species present in land take	Provide a list of the HRA species recorded at survey locations within the areas lost to each project element.		
HRA species peak counts for all survey data collected	Graphs/Maps of peak counts recorded in the 6 VP areas Combine all species Individual species	FLL transects DAY Graphs/Maps of peak counts recorded along each transect. In each transect area	FLL transects and Jetty VP NIGHT Graphs/Maps of peak counts recorded along each transect. In each transect area
HRA species peak count in land take	Use graphs to indicate peak counts within the areas of land take For temporary loss areas, identify in what seasons the impact would occur, if for less than a full year.		
HRA species peak count as % N2K pop	Use the peak count (from all survey records) to determine the % of the “combined European sites” population and of each European Site in the survey area. For example, Black-tailed godwit – peak count recorded from field survey work – 590 (August), 250 (Jan)		

Population numbers as described on the Natura 2000 form for each site	Listed as a QF on European Sites: ▪ Medway Estuary and Marshes SPA – 957 OVERWINTER ▪ Thames Estuary and Marshes SPA – 1699 OVERWINTER ▪ The Swale Ramsar - 1504 OVERWINTER ▪ Medway Estuary and Marshes Ramsar - 721 SPRING/AUTUMN ▪ Thames Estuary and Marshes Ramsar - 1640 SPRING/ AUTUMN ▪ 6% of combined site overwinter pop = (250/(957+1699+1504))*100 ▪ 25% of combined site spring/autumn pop = (590/(721+1640))*100 ▪ 15% of the Thames Estuary and Marshes SPA overwinter population=(250/1699)*100 Similar approach (group all HRA species together) to determine contributions to an "assemblage" Also reflect on trends of the European sites in question as provided by the WeBS Alerts – and already within baseline in Stage 1 Screening report to put any % calculated in to context.
HRA species peak count in land take as % N2K pop	Use the peak count within the land take (from the surveys relevant to the land take) to determine the % of the "combined European site" population and of each European Site within the land take.
HRA species - months recorded in land take	Use graphs of survey data to illustrate the use of the land take across the year and with different tidal states. Display data as combined all HRA species and individual HRA species.
Obligatory use?	Looking at the use of the habitat by months – if there is no seasonal pattern this suggests the HRA species area not obliged to use that area i.e. use it alongside other areas as opposed to relying on it for certain seasons.
Identify the alternative habitat available to birds displaced from the lost area, noting the relationship with disturbance.	On a map show the FLL. Given the link to disturbance effect which, on a worst-case basis might "sterilise" the adjacent 300m the hectares, the available habitat to exploit will be calculated for the next 300m area. Calculate the hectares.
Alternative habitat within the 20km of the land take - FLL and supporting habitat	Map based exercise to illustrate where the available supporting habitat and FLL is present within the range of the individuals affected. Calculate the hectares.
Alternative habitat within with in 20km of the European Sites - FLL and supporting habitat	Map based exercise to illustrate where the available suitable habitat is present within the FLL in the 20km range of these sites (assumed foraging range). Calculate the hectares. Reflect against the Conservation Objectives supplementary advice that provides an indication of the amount of supporting habitat required within the European site.
% of suitable habitat within land take	Calculate % at the varying scales described above to provide an indication of significance of loss.

Would the project create barriers to access to alternative habitat?	Mapping task to identify whether access to the alternative habitat is likely to be compromised as a result of the Project. Visual assessment of map of alternative habitats to identify key flight paths Identification of project elements that might cause a barrier to using key flight paths
Mitigation	If required, this would be focused on ensuring access was retained to alternative habitat and will be linked to the disturbance assessment.
AEI ?	Professional judgement using the various determining factors described above to assess how the Conservation Objectives could be affected. We will use the Supplementary Advice and targets as a basis for our assessment. The key attributes are likely to include but not limited to – Connectivity with supporting habitats, extent and distribution of supporting habitat, supporting habitat - vegetation characteristics & landscape. Using the data / information gathered above, the assessment of AEI will be carried out against the following 18 attributes of the conservation objectives to identify whether the magnitude of the effect would be likely to prevent achievement of the target for each attribute. ▪ Assemblage of species: abundance ▪ Assemblage of species: diversity ▪ Breeding population: abundance ▪ Non-breeding population: abundance ▪ Connectivity with supporting habitats ▪ Disturbance caused by human activity ▪ Supporting habitat: conservation measures ▪ Supporting habitat: extent and distribution of supporting habitat for the breeding season ▪ Supporting habitat: extent and distribution of supporting habitat for the non-breeding season ▪ Supporting habitat: food availability ▪ Supporting habitat: landform ▪ Supporting habitat: landscape ▪ Supporting habitat: quality of supporting breeding habitat ▪ Supporting habitat: quality of supporting non-breeding habitat ▪ Supporting habitat: vegetation characteristics ▪ Supporting habitat: vegetation characteristics for feeding ▪ Supporting habitat: vegetation characteristics for nesting ▪ Supporting habitat: vegetation characteristics for roosting

Annex Z 02 June 2020 Construction traffic modelling and AQ effects briefing

Briefing on construction traffic modelling and air quality effects

On the Consultation call on 13 May 2020, LTC presented a slide in relation to their preliminary conclusion of no Likely Significant Effects (LSE) on any European sites through air quality changes from Construction Traffic. The preliminary assessment conclusion was based on the there being no European sites within 200 of the modelled Affected Road Network.

Natural England asked to see further detail of what had been considered in the traffic modelling and assessment to support the preliminary conclusion. This note provides further clarification of the approach taken and information taken into account.

The assessment of LSE as a result of air quality impacts from construction traffic consists of:

1. modelling of traffic during construction using information from the Project's construction methodology
2. application of criteria in DMRB Standard LA105 to identify an Affected Road Network (ARN)
3. identification of any European sites that lie within 200m of the ARN
4. assessment of whether any air quality changes would represent a LSE on any European sites identified

Information used in modelling of traffic during construction

The traffic modelling used to inform the LA105 assessment included use of an industry best practice modelling methodology that has been used uncontested on a number of projects such as the Tideway project. The model considers five representative phases of the construction operation and the outputs are based on the worst-case representative phase.

The impacts on the highway network during construction have been assessed using the Lower Thames Area Model. A full description of this model is provided in the Traffic Modelling Update published as a supporting document for the LTC Supplementary Consultation. This document is available at the following link. https://highwaysengland.citizenspace.com/ltc/consultation-2020/supporting_documents/TRAFFIC%20MODELLING%20UPDATE.pdf

The construction modelling was undertaken for 5 sample months during the construction process. The months selected were chosen as typical of the level and location of activities during that phase of construction activity. The road networks were modified to include all the traffic management measures associated with construction such as narrow lanes, temporary speed limits and access points into the compounds. Haul roads were added into the network to provide spatial accuracy in the modelling of traffic moving between compounds.

The amount of construction traffic was derived from a construction schedule which provided information on the number of vehicles coming into each compound by time of day. The origin of construction traffic was based on the location of likely suppliers of material.

For the workforce, the number of vehicles arriving was taken from the shift pattern at each compound site and the number of workers required at each site. The origin of the workforce trips was based on the likely residential location of the workers, based on an assessment of the availability of housing in the area and the likely home location of staff by job type.

The traffic model was used to assign the new numbers and pattern of trips onto the road network (with traffic management) and the resulting traffic flows and speeds were extracted and passed to the environment team, in the same way as for their assessment of Lower Thames Crossing operationally.

Application of criteria in DMRB Standard LA105 to identify an Affected Road Network

LA105 provides scoping criteria for identification of the Affected Road Network using the following thresholds:

- annual average daily traffic (AADT) >=1,000; or
- heavy duty vehicle (HDV) AADT >=200; or
- a change in speed band; or
- a change in carriageway alignment by >=5m.

Identification of relevant European sites

GIS analysis of the ARN and boundaries of European sites (Natural England datasets https://data.gov.uk/search?filters%5Bpublisher%5D=Natural+England) identified all European sites within 200m of the ARN.

Assessment of LSE on any European sites identified

As no European sites have been identified within 200m of the ARN it has been concluded that LSE can be discounted.

Annex AA1Technical Note Ramsar Advanced Grouting Tunnel and Main Tunnels Numerical Model (R1)

Lower Thames Crossing

Ramsar Advanced Grouting Tunnel and Main Tunnels Numerical – Technical Note

Document Number: HE540039-CJV-GEN-GEN-TNT-GEO-00001

Confidential

June 2020

Revision	Production Date	Prepared by	Checked by	Approved for release by	Sections revised
1.0	01/10/2019	[redacted]	[redacted]		
2.0	25/10/2019	[redacted]	[redacted]		Revised document. Added Appendix D
3.0	15/11/2019	[redacted]	[redacted]		Revised document. Added Appendix C and updated Appendix D.
4.0	03/06/2020	[redacted]	[redacted]	[redacted]	Updated document.

This technical note has been prepared for Highways England in accordance with the terms and conditions of appointment stated in the Lower Thames Crossing (LTC) Technical Partner Contract. LTC cannot accept any responsibility for any use of or reliance on the contents of this memorandum by any third party.

Contents

Tables

Figures

1 Introduction

1.1 Background

The Lower Thames Crossing (LTC) scheme consists of a new highway from the A2/M2 junction in Kent to M25 Junction 29 in Essex. The scheme includes two bored tunnels under the River Thames to the east of Gravesend. The total length of the route, including M2/A2 and M25 improvements, will be approximately 23 km, 4.25 km of which is in tunnel.

The South Portal has moved approximately 350m south from the position presented in 2018 Statutory Consultation. As such, it is now several meters above the maximum recorded water table and no aquifer dewatering is anticipated. On this basis, the South Portal itself is not included in this assessment.

Ground treatment is necessary to allow for below ground servicing of the TBM (tunnel boring machine); this will consist in the emplacement of concrete grout blocks at intervals along the main tunnel line. To allow this, an advanced grouting tunnel will be constructed above the alignment of the main tunnel. The ground treatment will mitigate the risks from groundwater inflows that may happen when pressure is allowed to reduce in front the TBM.

The grout tunnel will launch from a shaft located to the south of Lower Higham Road, whilst its egress shaft will be located north of the Thames and Medway Canal and North Kent Railway Line. Groundwater controls have the potential to cause drawdown and changes to the direction of groundwater flow at The Thames Estuary and Marshes Ramsar site and SSSI (hereafter Ramsar site). This is a sensitive receptor. The underlying Chalk formation itself is a Principal Aquifer (Lower Thames Crossing, 2018) and therefore a sensitive receptor.

As mitigation of groundwater ingress, watertight retaining structures, such as caisson piles will be used during construction of the portals. This will remove the need for large scale dewatering during the excavation of the launch and reception shafts (Lower Thames Crossing - Cascade, 2019 (c)).

The advanced grouting tunnel has a mid-line elevation of -6.7 m AOD and each shaft has a bottom elevation of -11.6 m AOD (Lower Thames Crossing, 2019 (d)). The main tunnels, which run parallel to this, have centreline elevations of -42 m AOD to 21 m AOD (Lower Thames Crossing, 2019 (e)).

1.2 Report and Modelling Objectives

This report focuses on the further development of the modelling of groundwater flows for the construction of the Advanced Grouting Tunnel and main tunnels, which is located in the Ramsar site to the south of the River Thames. This model incorporates further refinements as follows:

- Inclusion of site-specific data from Phase 2 ground investigation;
- Substantial updates to the conceptual model;
- New calibration against site-specific data, including a time-variant calibration of tidal response in the chalk.

Moreover, the following has been carried out:

- Simulation of the groundwater inflow into the excavation during grout tunnelling and main tunnelling operations;
- Simulation of drawdown; and
- Simulation of saline/fresh water interface movement.

1.3 Assumptions and limitations

The results presented above have the following additional assumptions and limitations:

- The infrastructure modelled and model simulations are in steady-state;
- 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 in which the Ramsar site is situated;
- The conductivity of the grouting and main tunnels boundaries is based on advice from the LTC-CASCADE Tunnel Portals team.
- As advised by the LTC CASCADE Construction team (Lower Thames Crossing - Cascade, 2019 (c)), the use of construction techniques (such as caisson) that would avoid major dewatering will be employed during the excavation of the launch and reception shafts for the advanced grouting tunnel. On this basis, no active dewatering has been included in the model for such structures. Should construction requirements change, these should be considered in future versions of the model. The mitigations embedded into the design included:
  - Use of pressurised TBM method that inhibits groundwater inflow during drilling;
  - Stopping the TBM within grout blocks for TBM maintenance;
  - Use of caisson methods and pre-grouting of ingress and egress shafts to inhibit groundwater inflow; and
  - Specification of the maximum leakage rates based on the British Tunnelling Society prescribed leakage rates for tunnels and advice from the LTC-CASCADE Tunnels Portal team.

2 Methodology

2.1 Software

The model uses MODFLOW 2005 (MF2005). MF2005 is an industry standard software, developed and maintained by the United States Geological Survey (USGS, 2005). The model has been created using FloPy (Bakker, et al., 2016). FloPY contains a set of Python scripts enabling the building, running and postprocessing MODFLOW, MT3D, SEAWAT and other MODFLOW-related groundwater programs. Visualisation and MODPATH simulations are completed in Groundwater Vistas 7, produced by ESI (Environmental Simulations International) (Environmental Simulations Inc., 2017).

2.2 Model geometry

2.2.1 Model grid geometry

Table 1 shows the model grid geometry.

Table 1 Model grid extent

Top left easting (m)	564250
Top left northing (m)	175500
Bottom right easting (m)	572500
Bottom right northing (m)	169030
Delr (cell height)	60
Delc (cell width)	60
nCol (number of columns)	109
nRow (number of rows	137
Layers (no.)	46
Layer bottom depths (m bgl)	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,22,24,26, 30,32,36,38,40,45,50,55,60,65,70,75,80,85,90,95,100, 105,110,115,120,130,150,170

The groundwater model uses a block model approach. In a block model the model layers are pre-defined and are independent of the geological layers. The geology is ascribed to the model by changing the material parameters of the individual cells to represent the geology. This approach differs from a standard approach whereby the top and bottom of model layers represents the top and bottom of geological surfaces. Advantages of this approach include:

- Rapid convergence often resulting in shorter run-times although more memory intensive. Allows for more vertical discretisation, especially in contaminant transport models;
- Avoidance of pinched-out layers inside the model or at the top surface;
- A more consistent representation of groundwater flow velocity within a layer. This can be beneficial if modelling a saline interface or contaminant transport where solute dispersion is influenced by upstream and downstream velocities.
- Better modelling of infrastructure features such as d-walls and excavations (drains). These features are often independent of or do not fully penetrate geological layers. In a block model these changes can be incorporated without changing the model layer structure, making the results comparable.
- Good and consistent vertical resolution around boundary conditions, thereby minimising model errors.
- The numerical model is a block-centred finite difference model. All the model cells have a width and length of 60 m. A 60 m cell size is ideal to simulate a tunnel of 17 m diameter, as it is approximately three times the size of the tunnel (Zaidel, Markham, & Bleiker, 2010). Within 20 m of the ground surface the thickness of the model layers is 1 m. The top layer has the elevation of the topographic surface.
- The bottom layer has a bottom elevation set to 170 m below the topography. In total there are 46 layers in the model. Model layers are thinner in the top 30 m to include for the increased geological data and project infrastructure in this zone. The top twenty layers have a thickness of 1 m, between 20 m and 30 m bgl the layers are 2 m thick and between 30 m bgl and 105 m bgl 5 m thick, beneath this the layer thickness is set to 10 m.

A disadvantage of the block model approach is difficulty in assignment of parameters if using simpler graphical interfaces. This disadvantage is not a problem whilst building a model using scripts.

2.2.2 MODFLOW layer setup

Layer 1 (the uppermost layer) is set as unconfined (Laycon Type 1) and so the transmissivity of the layer varies depending on the saturated thickness and hydraulic conductivity. All remaining layers are able to switch between confined and unconfined conditions (Laycon Type 3). The transmissivity of these layers also varies and is calculated from the saturated thickness and hydraulic conductivity. Specific yield or specific storage are used if the layer is unconfined or confined, respectively. Rewetting is disabled for all layers.

Figure 1 shows the top elevation of the model; this is coincident with the current topography (BGS, 2019).

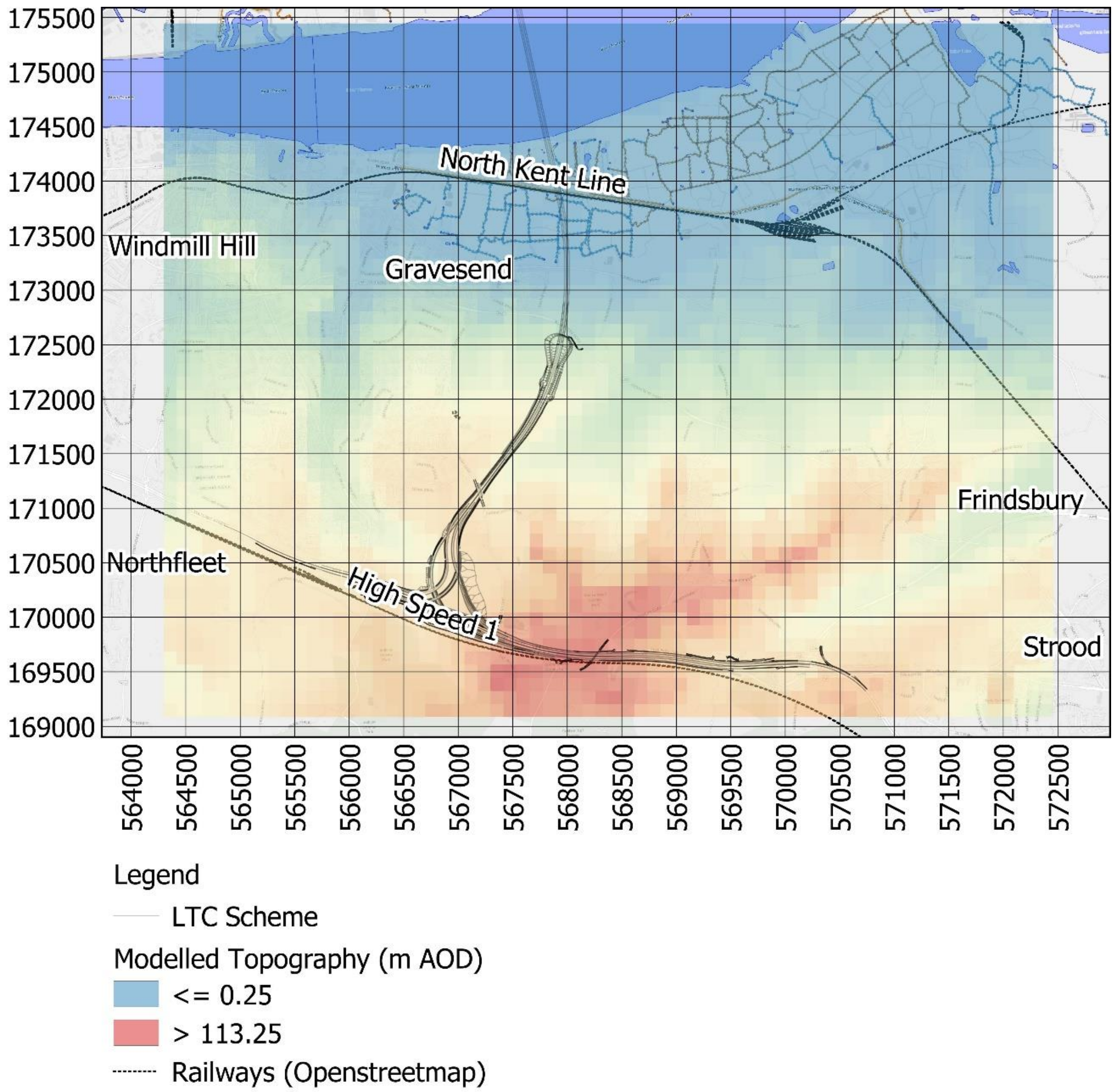


Figure 1 - Topography (m AOD)

2.2.3 BGS Geological model

A lithostratigraphic geological model purchased from the BGS (British Geological Survey) (BGS, 2014) is used for the geological model. This geological model is a checked and peer reviewed baseline. Results of the Phase 1 ground investigation (PerfectCircle JV, 2018) at the LTC site have been included in the model by the BGS.

The BGS geological model provides the skeleton of the groundwater model layers. The BGS model is assigned to the groundwater model layers by comparing the model layer elevations with the geological surfaces.

Figure 2 shows a plain view of the outcrop geology overlaid on the model grid for the model area. The blue contour lines represent the Chalk hydraulic head contours (February 2014). The contours have been digitised and interpolated from the Environment Agency regional network of observation boreholes.

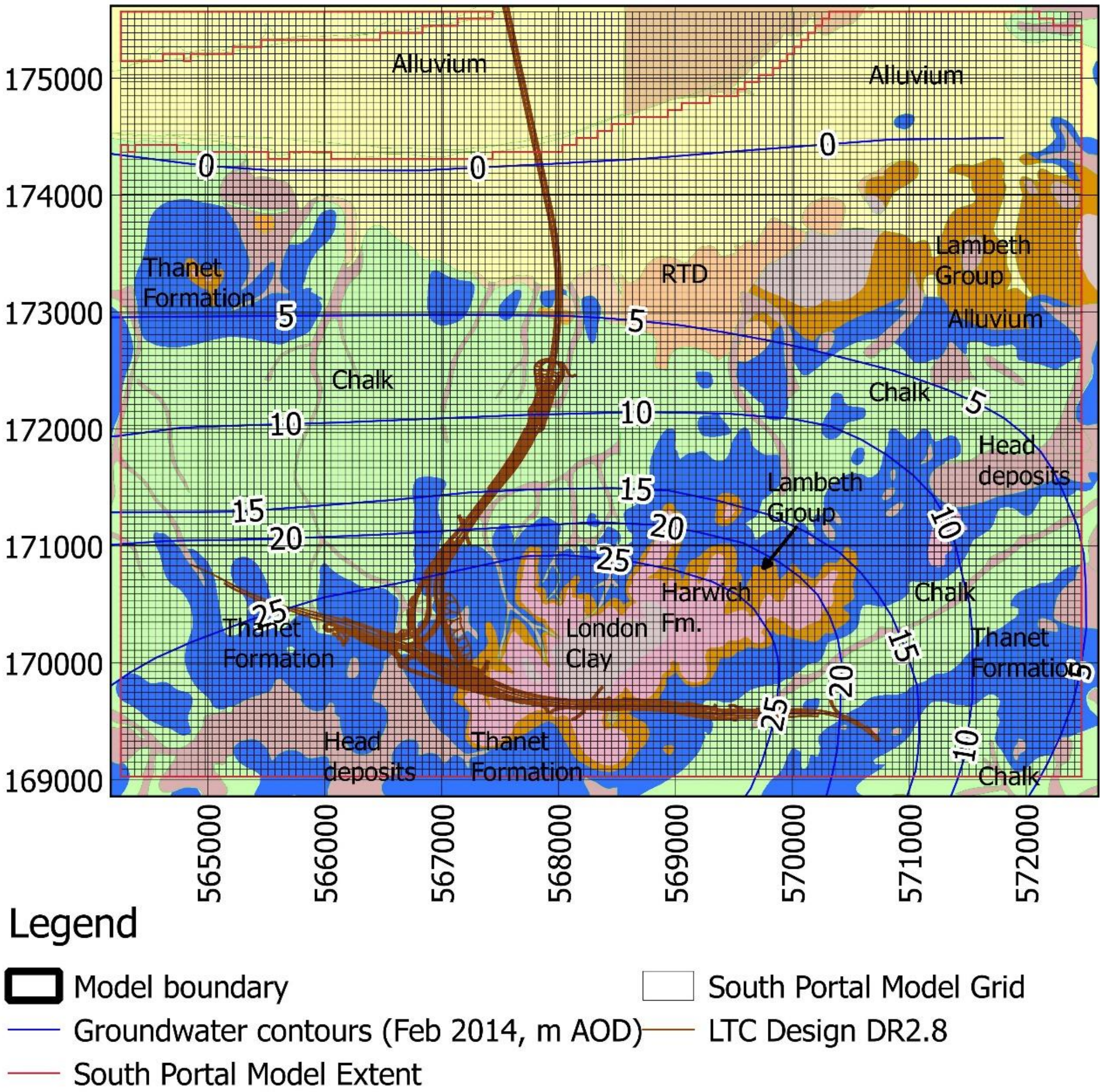


Figure 2 Model domain (6.5x8.3 km), cross section location plan and outcrop geology.

The BGS geological model contains many layers; however, there are four key surfaces/layers, described below:

- Made ground. The topography [redacted] forms the top surface of the model. The base of the made ground surface is provided by the BGS. Made ground in the model area includes areas alongside the Thames, the Thames and Medway Canal and industrial land east of Gravesend.
- Superficial deposits at outcrop including Alluvium, Head Deposits and RTD (River Terrace Deposits). River Terrace Deposits, underlying the alluvium. Assigned using elevation data from the BGS model for the bottom of the layer.
- Eocene deposits, such as the London Clay and the Lambeth Group and the Thanet Formation. These outcrop south of the South Portal capping the Chalk at higher elevations and above the water table.
- Chalk. The top of the Chalk is defined from the BGS model.

The BGS geological model includes many ASCII format grids. The grids include a top elevation, bottom elevation and thickness for each different stratum identified by the BGS. FloPy (Section 2.1) imports all these as TIF files using the GDAL module. The raster band value of the TIF file is the elevation. The TIF files are re-gridded by GDAL[1] (Warmerdam F. et al, 2019) to match the model grid arrays. A comparison is done in Python whereby each BGS elevation grid is checked against the elevation of a model cell. The BGS layer with the least residual from this comparison is assigned to the cell and the suitable parameters are then applied to the cell. This builds up a block model and overcomes many of the problems that can occur with complex geological models.

The groundwater model includes all 31 geological layers supplied in the BGS data.

2.2.4 Site-specific geological information

Site-specific geological data is gained from the site investigation and includes:

- Material type at depth intervals as described in the AGS dataset;
- Ciria Chalk grade. This is split between types ABC and type D within AGS datasets;
- RQD (Rock Quality Designation). A low value of RQD of less than 0.1 can indicate very fractured Chalk rock materials. These areas of Chalk are often not able to be screened for hydraulic pressure testing and are likely to include the highest hydraulic conductivity zones;
- Variable head pressure tests completed during fieldwork; and
- Pumping tests.

Assignment of AGS data to the model

The geology listed in the AGS data is represented in the model using by changing the hydraulic conductivity of the model cells to match parameters for the material found.

A Python module adds the AGS data into the model using the borehole location, sample interval and geological code and this new information overwrites the BGS model. Table 2 shows how the block model parameters were altered to represent the AGS data. A radius of influence of 300 m was given for each borehole site. At 300 m distance the BGS model information is used, whilst at 0 m distance the AGS data used. In between, and/or where the radius of influence of multiple samples overlap the average is given to the model cell.

[1] GDAL is a translator library for raster and vector geospatial data formats.

Table 2 Summary of AGS material included

Geological code recorded in AGS file	Conceptualisation	Kh (horizontal hydraulic conductivity)	Kz (vertical hydraulic conductivity)	Sy	Ss
Oth	Made ground	As per bulk made ground value	As per bulk made ground value	As per bulk made ground value	As per bulk made ground value
CL	Clay superficial deposits	As per bulk alluvium calibrated value	As per bulk alluvium calibrated value	As per bulk alluvium calibrated value	As per bulk alluvium calibrated value
SA	Sand superficial deposits	$1x10^{-4}$	$0.3x10^{-4}$	0.1	1e-5
SI	Silt superficial deposits	As per bulk alluvium calibrated value	As per bulk alluvium calibrated value	As per bulk alluvium calibrated value	As per bulk alluvium calibrated value
GR	Gravel superficial deposits	As per bulk RTD (River Terrace Deposits) calibrated value	As per bulk RTD (River Terrace Deposits) calibrated value	As per bulk RTD (River Terrace Deposits) calibrated value	As per bulk RTD (River Terrace Deposits) calibrated value
AZCL/CKD or RQD <0.1 (in LECH/WHCK)	Unstructured or karstic Chalk situated under the Thames or under RTD	Calibrated value based on CTRL findings	Calibrated value based on CTRL findings	Calibrated value	Calibrated value
CKABC	Structured Chalk	Calibrated parameter for the Chalk above the Belle Tout Formation	Calibrated parameter for the Chalk above the Belle Tout Formation	Calibrated parameter for the Chalk above the Belle Tout Formation	Calibrated parameter for the Chalk above the Belle Tout Formation

As there are over 50,000 lines of AGS data included in the model; this dataset is not presented in the report.

Packer and variable head tests

Packer and variable head tests are imported using the same approach as for material type data. For packer and variable head tests, the radius of influence is set to 120 m (2 model cells) and 60 m (1 model cell) respectively The hydraulic conductivity is applied to all cells within the screen interval and radius of influence, overwriting previous information. Packer and variable head tests data included in the model are presented in Appendix A.

Pumping tests

Table 3 provides details for the completed pumping tests at the test wells PW03001 and PW04001A, which are included in the model. The hydraulic conductivity field results were applied to all model cells within a radius of influence of 500 m from the boreholes, within the screened zone. Pumping tests data included in the model are presented in Appendix A.

Table 3 Pumping test results included within the model

Test site	Easting, northing	Screen interval (m bgl)	Horizontal hydraulic conductivity (m/s)	Kv/Kr	Specific Storage
PW03001	568046,172651	-29, -49.5	$1.3x10^{-4}$	0.1	$2.0x10^{-5}$
PW04001A	568108,173703	-29, -49.5	$3.6x10^{-5}$	0.1	$1.2x10^{-6}$

2.2.5 Cross sections and conceptual model

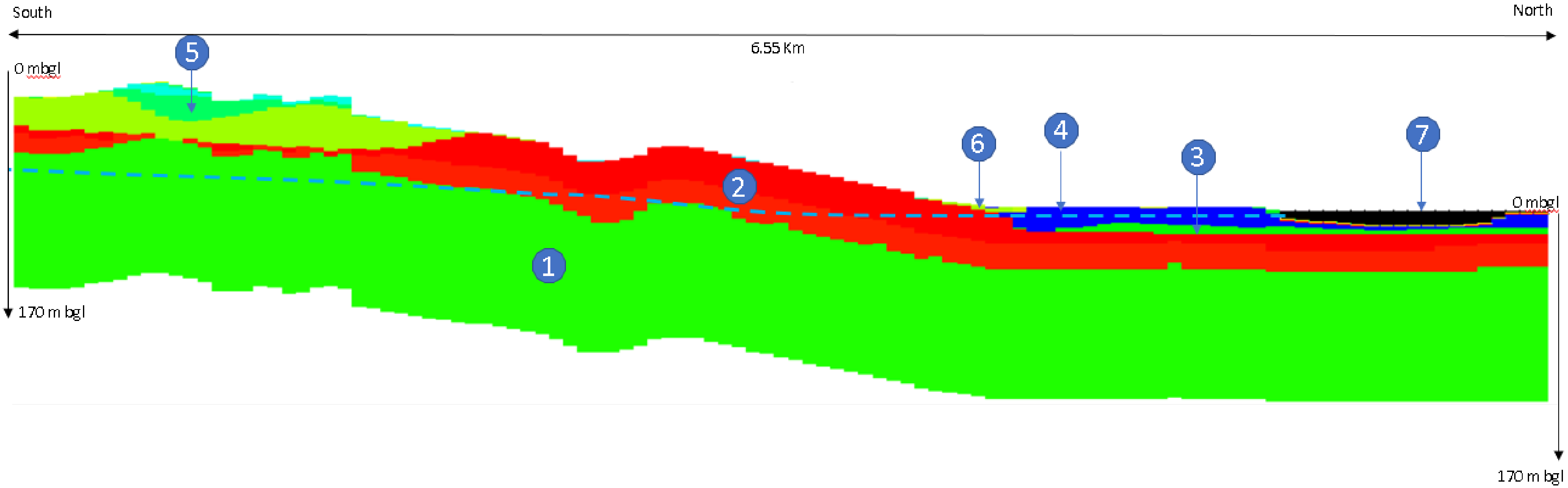
Figure 3 shows a typical cross section through the BGS skeleton geology along the line of the route (colours presented are arbitrary); this runs through model column 62 (Easting 567856). Figure 4 shows the same section after inclusion of the site-specific information. The sections in Figure 4 is colour flooded by the hydraulic conductivity of the material.

Within the Chalk, the site-won information has shown evidence for:

- A highly fractured zone of Chalk gravels (CKD and AZCL) at the top of the Chalk sequence underlying the RTD;
- A thicker zone of low RQD and CKD at depth beneath the river Thames with areas of missing core (AZCL);
- A thick zone of low RQD, CKD and AZCL straddling and below the water table at the southern periphery of the Alluvium and RTD deposits; and
- Along the central part of the 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.

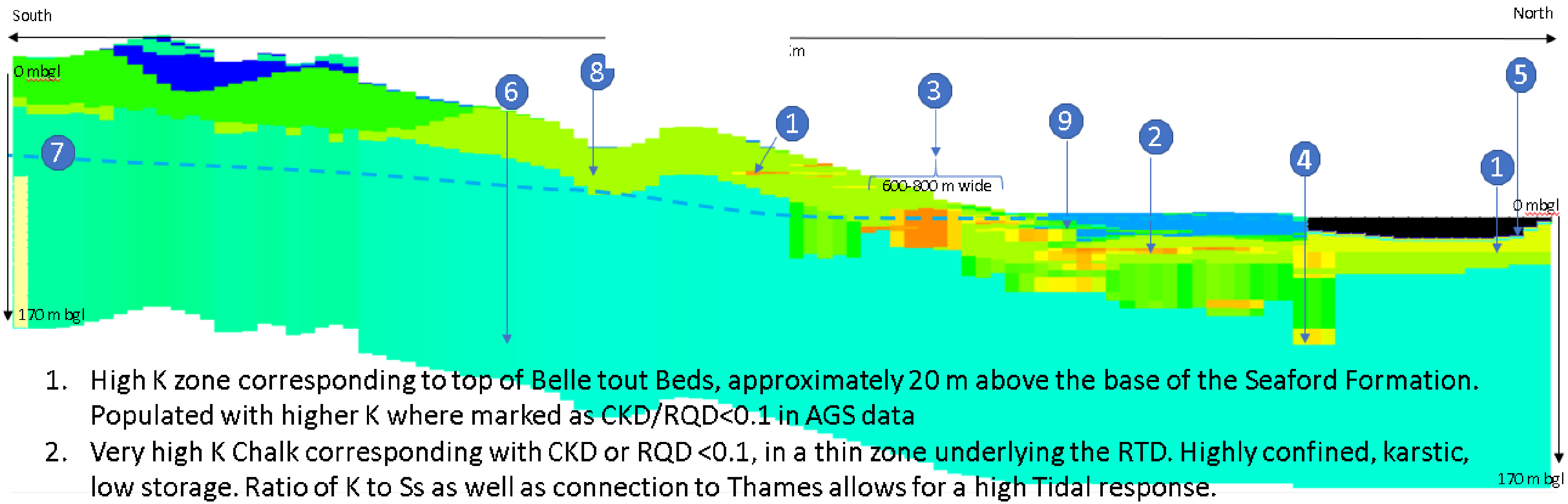
Adjacent to the southern limit of the alluvium, the site specific information has shown that there are thin layers of gravel and sand of limited northward extent. These on-lapping (draping) onto the RTD or Chalk at the southern periphery of the alluvium deposits and may be head or RTD deposits.

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



1. Deep Chalk; 2. Chalk from 20 m above the base of the Seaford Formation; 3. RTD 4. Alluvium; 5. Thanet Formation, Lambeth Group, London Clay; 6. Head deposits; 7. River Thames

Figure 3 Geological structure using the BGS skeleton along BNG (British National Grid) Easting 567856 m. Vertical exaggeration 10x.



1. High K zone corresponding to top of Belle tout Beds, approximately 20 m above the base of the Seaford Formation. Populated with higher K where marked as CKD/RQD<0.1 in AGS data
2. Very high K Chalk corresponding with CKD or RQD <0.1, in a thin zone underlying the RTD. Highly confined, karstic, low storage. Ratio of K to Ss as well as connection to Thames allows for a high Tidal response.
3. Very high K Chalk corresponding with CKD or RQD <0.1, along the margin of the ALV and RTD. Corresponds to very flat hydraulic gradient
4. Deeper zones of higher K Chalk corresponding with CKD or RQD <0.1 at depth beneath the Thames
5. Conceptualised high K zone, providing high K connection with Chalk (tidal response)
6. Deeper Chalk, simplified to total 100 m in thickness with uniform transmissivity below the water table
7. Water table – Steeper hydraulic gradient with higher altitude as the occurrence of higher K deposits below water table is less frequent
8. Flow paths – ‘dry’ valleys correspond with dips in the topography. Where the high K zone dips below the water table the groundwater velocity is rapid. These channels point towards the Thames (north)
9. Thin lens’ of sand and gravel with limited extend at the margins

Figure 4 Geological structure including AGS information in the model along cross section through BNG Easting 567856. Vertical exaggeration 6x.

The position of the high K Chalk around the Thames river is similar to that described in Younger (Younger, 1989). Figure 5 shows the conceptual cross-section developed by Younger. It describes areas of higher permeability development within the Chalk around Shallow Anabranch Channels. For the Thames area repetitive tidal action and deeper scoured channel has caused increased dissolution of the Chalk in the area of the water table and beneath the river sediments (RTD).

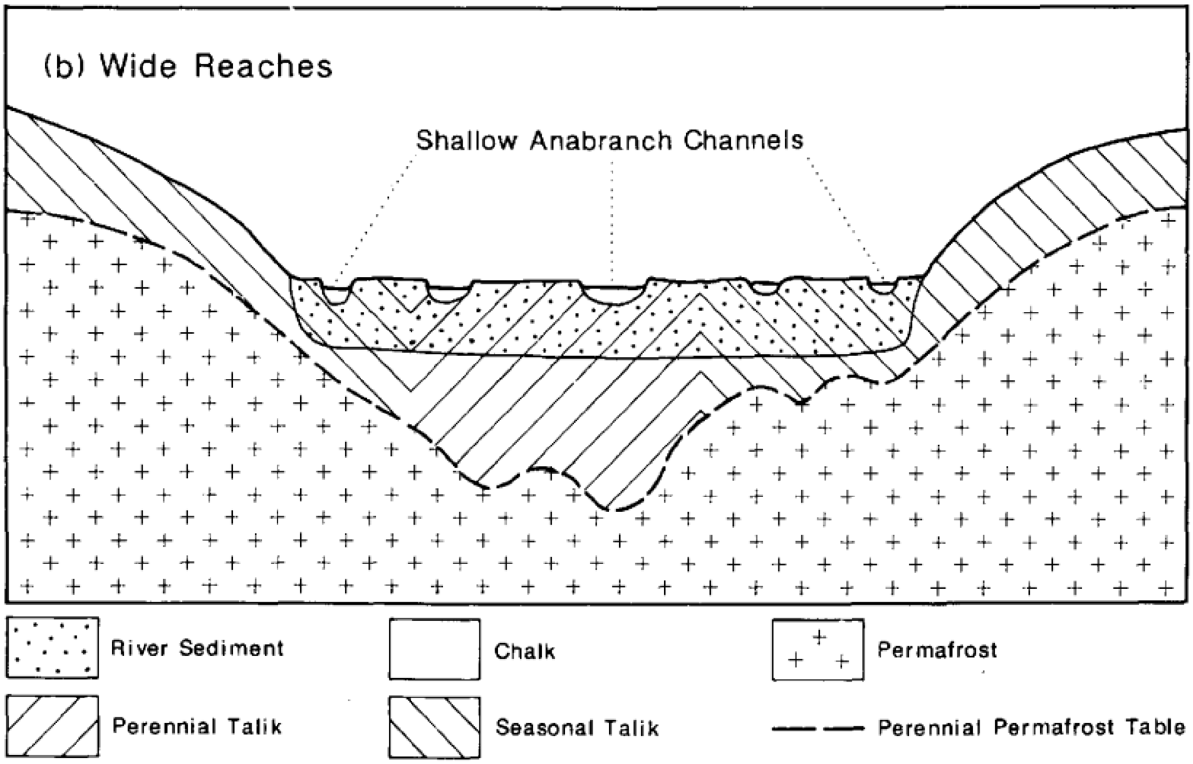
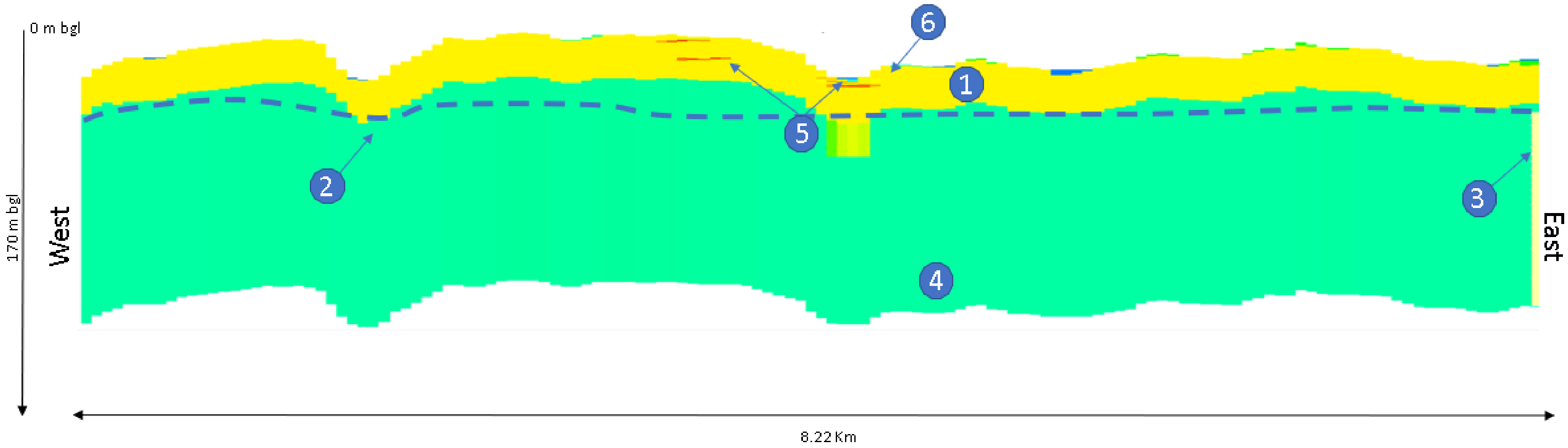


Figure 5 Cross section proposed in Younger (1989)

Figure 6 shows a west-east trending cross section through the hinterlands south of the RAMSAR site and south of the main tunnels. In this area the hydraulic gradients can be reproduced reasonably well, by allowing the Chalk water levels to be controlled by drainage within higher transmissivity zones along north-south orientated topographical depressions, typically mapped with head deposits at the surface.



1. Higher hydraulic conductivity in the upper part of the Chalk potentially due to weathering, dissolution from recharge or water table movement. Potentially associated with the Belletout beds within the Seaford Formation.
2. Water levels in the Chalk may be controlled by higher transmissivity zones beneath ‘dry’ stream channels. In these zone dissolution may have occurred in the past.
3. The water level dips to the east, though groundwater flow is likely dominated by flows beneath ‘dry’ river channels towards the north. The eastern boundary must be controlled with a boundary condition.
4. The deeper Chalk is bulked into a single unit for simplicity as there is little data on it.
5. Some boreholes indicate the presence of weathered zones within the near surface chalk area.
6. Superficial deposits are limited in thickness and the Chalk is at outcrop.

Figure 6 Conceptualisation of the hydrogeology and geology south of the scheme on the Chalky hillside

2.3 Hydraulic conductivity

The model hydraulic conductivity (or permeability) ranges are from derived from site investigations (PerfectCircle JV, 2018), the Thames Cable Tunnel Project (Haswell, 1969) and the Addendum PSSR (Preliminary Sources Study Report) (Tables 36-38, pages 130-132 (Lower Thames Crossing, 2018)). Table 4 provides parameter ranges for the model calibration. Figure 2 shows the hydraulic conductivity mapped to the outcrop geology in Layer 1 of the model. Figure 3 and Figure 4 show the hydraulic conductivity in cross section.

Table 4 – Summary of Hydraulic Conductivity ranges

Geological Unit	Hydraulic Conductivity minimum (m/s)	Hydraulic Conductivity maximum (m/s)	Hydrogeological behaviour and influences
Made Ground	-	Variable, approximately $1x10^{-5}$ to $1x10^{-4}$	Variable - depends on material content. Acknowledged to be cohesive in places but assuming higher values for worst-case.
Head Deposits	-	Variable, $1x10^{-8}$ to $1x10^{-6}$	Variable - depends on underlying geology
Alluvium	-	$k_h = 1 \times 10^{-7}$; $k_v = 1 \times 10^{-8}$ (1)	Aquitard or Aquifer – depending on whether predominantly clay or granular material in the field but mapped as a single unit with an equivalent bulk permeability.
River Terrace Deposits	Lower values where clayey	2×10^{-5} (1) to $1x10^{-3}$	Aquifer – depends on lateral extent and thickness
London Clay	Non aquifer	Non aquifer	This is a confining unit and has very limited potential to supply a water resource. On a broader scale may support underlying aquifers through slow leakage.
Harwich Formation	$1.09x10^{-5}$(2)	$1.1x10^{-3}$(2)	Aquifer
Lambeth Formation (Reading and Woolwich Fm.)	$3.47x10^{-8}$ (2)	$2.29x10^{-3}$ (2)	Variable hydro-stratigraphy but generally not considered to be an aquifer
Thanet Formation	2×10^{-5} (2)	4×10^{-5} (2)	Aquifer

Geological Unit	Hydraulic Conductivity minimum (m/s)	Hydraulic Conductivity maximum (m/s)	Hydrogeological behaviour and influences
Chalk	May vary with Chalk weathering grade and site-specific ground conditions. See Table 5 and Table 6		Aquifer

References for Table 4:

1. Bevan, M.A. et al (2010). Géotechnique 60 No. 8, 634-649 Influence of large-scale inhomogeneities on a construction dewatering system in chalk (Bevan, Influence of large-scale inhologeneities on a construction dewatering system in chalk, 2010);
2. BGS, EA (2000), The Physical Properties of Minor Aquifers in England and Wales, BGS Technical Report WD/00/04, Environment agency R&D Publication 68 (BGS, 2014)

Table 5 – Chalk weathering grade and Hydraulic Conductivity range

CIRIA grade	Munford grade	Chalk type*	Approximate Hydraulic Conductivity range (m/s)
A	I and II	Structured with bedding and/or jointing.	Highly variable because of presence of fissures
B and C	III and IV	Structured with bedding and/or jointing.	1 x 10^{-5} m/s to 1 x 10^{-3} m/s
Dc	V and V	Structureless, clast dominated.	1 x 10^{-5} m/s to 1 x 10^{-2} m/s in relatively harder Chalk with chalk 'bearings' or frost shattered chalk evidenced
Dm	V and VI	Structureless, matrix dominated.	1 x 10^{-7} m/s to 1 x 10^{-9} m/s
AZCL		Weak, no core return	1x10^{-5}

References for Table 5:

- *After Spinck (Spinck, 2002)
- Preene M., Roberts T. O.L. Construction dewatering in Chalk. Proceeding of the Institution of Civil Engineers. Geotechnical Engineering 170 August 2017 Issue GE4 Pages 367-390 (Preene & Roberts, 2017).

Table 6 – Project specific Hydraulic Conductivity results

Location	Chalk lithology	Reported Chalk Hydraulic Conductivity (m/s)
Thames Cable Tunnel (North Shaft), Tilbury, East London	Upper 9 m of Chalk of high permeability, permeability reduced significantly at depths greater than 15 m below top of the Chalk. During the shaft sinking the upper 6 m of the	1 x 10^{-3} m/s to 4 x 10^{-6} m/s in upper zones of Chalk from in situ permeability tests. 2 x 10^{-5} m/s to 2 x 10^{-6} m/s below 15m from top of Chalk, from Lugeon tests.

Location	Chalk lithology	Reported Chalk Hydraulic Conductivity (m/s)
	Chalk indicated to be completely disintegrated. Similar to CKDc (structureless chalk) reported in LTC AGS data. Also likely to have significant core loss (AZCL).	
Medway Crossing, Chatham, Kent	Upper 2 m to 5 m of Chalk was noted to be structureless (Mundford grade VI to V) with grade III to IV structured Chalk below. Similar to CKDc (structureless chalk) reported in LTC AGS data. Also likely to have significant core loss (AZCL).	1 x 10^{-3} m/s to 1 x 10^{-5} m/s in structured Chalk (Mundford grade III to IV) estimated from in situ and laboratory tests 9 x 10^{-4} m/s back-analysed from dewatering system flow rate. 1 x 10^{-7} m/s to 1 x 10^{-9} m/s in structureless Chalk (Mundford grade VI to V) estimated from in situ and laboratory tests.
CTRL Thames Tunnel, south side, Swanscombe, Kent	Upper Chalk. Implied that a high-permeability zone exists at the top of the Chalk beneath the RD and at the edge of the Alluvium outcrop.	2 x 10^{-6} m/s to 1 x 10^{-4} m/s from borehole packer tests. Numerical modelling to back analyse the dewatering system implied that a high-permeability zone of the order of 3 x 10^{-2} m/s to 7 x 10^{-2} m/s may have existed in Chalk in part of the excavation.

Figure 7 illustrates how the hydraulic conductivity of the Chalk reduces with its depth (Lower Thames Crossing, 2019). The ability to include this in the model is gained by subdividing the Chalk into CKD (unstructured Chalk), Belle Tout and Chalk.

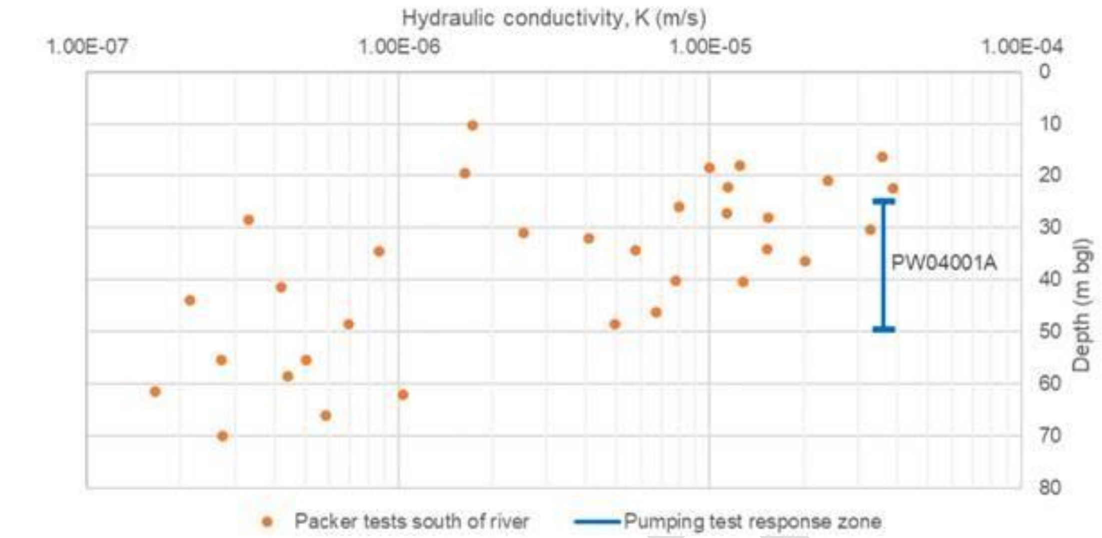


Figure 7 Chalk horizontal hydraulic conductivity results from double packer testing carried out in boreholes located to the north and south of the River Thames in lowland areas.

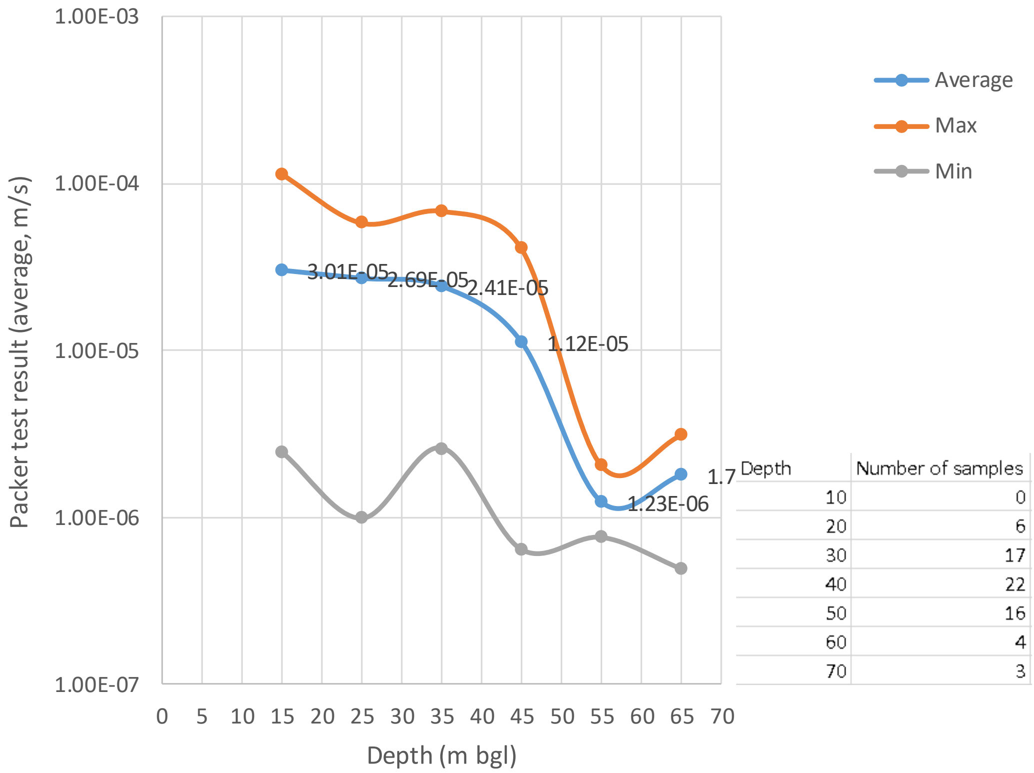


Figure 8 Packer test results against depth (2019-2020 AGS/SI packages)

Figure 8 shows the relationship of depth and hydraulic conductivity results from packer tests completed in LTC ground investigation packages A-E. The reduction in hydraulic conductivity at between 50 and 60 m AOD may correspond with the base of the Seaford Chalk Formation. A trend to lower hydraulic conductivity within the Chalk is present from around 35 m bgl, possibly coinciding with the top of the Belle

Tout Formation, present from approximately 15 m above the base of the Seaford Formation.

There are various mechanisms by which this depth-trend may occur, a selection of examples might include:

- Enhancement of discontinuity apertures by groundwater flows around the water table resulting in an increase in hydraulic conductivity. This enhancement may also occur at greater depths of burial where there has been an ancient water table;
- Historical frost-thaw weathering of the near-surface Chalk during glacial periods (Younger, 1989);
- Closing of fractures due to burial resulting in a decrease in hydraulic conductivity with depth; and
- Presence of marl or shale beds at depth causing lower hydraulic conductivity horizons and likely reducing vertical hydraulic conductivity significantly.

Table 5 does includes an upper range for the CKD (unstructured Chalk) hydraulic conductivity that is similar to that encountered by CTRL (Bevan, Powrie, & Roberts, Influence of large scale inhomogeneities on a construction dewatering system in the Chalk, 2010). Bevan et al. (2010) found that a zone of hydraulic conductivity in the range of $1x10^{-2}$ to $5x10^{-2}$ m/s was present. The conceptual model was that this zone extended beneath the RTD and at the margins of the RTD deposits (Figure 9). Beneath the RTD the zone was labelled the ‘Transition Zone’ whilst at the margin of the RTD it was labelled the ‘HPZ (highly productive zone’). The performance of their dewatering system could not be explained without these zones. This distribution has similarities with the distribution of high transmissivity zones shown in Figure 4, caused by the presence of CKD and chalk RQD of less than 0.1.

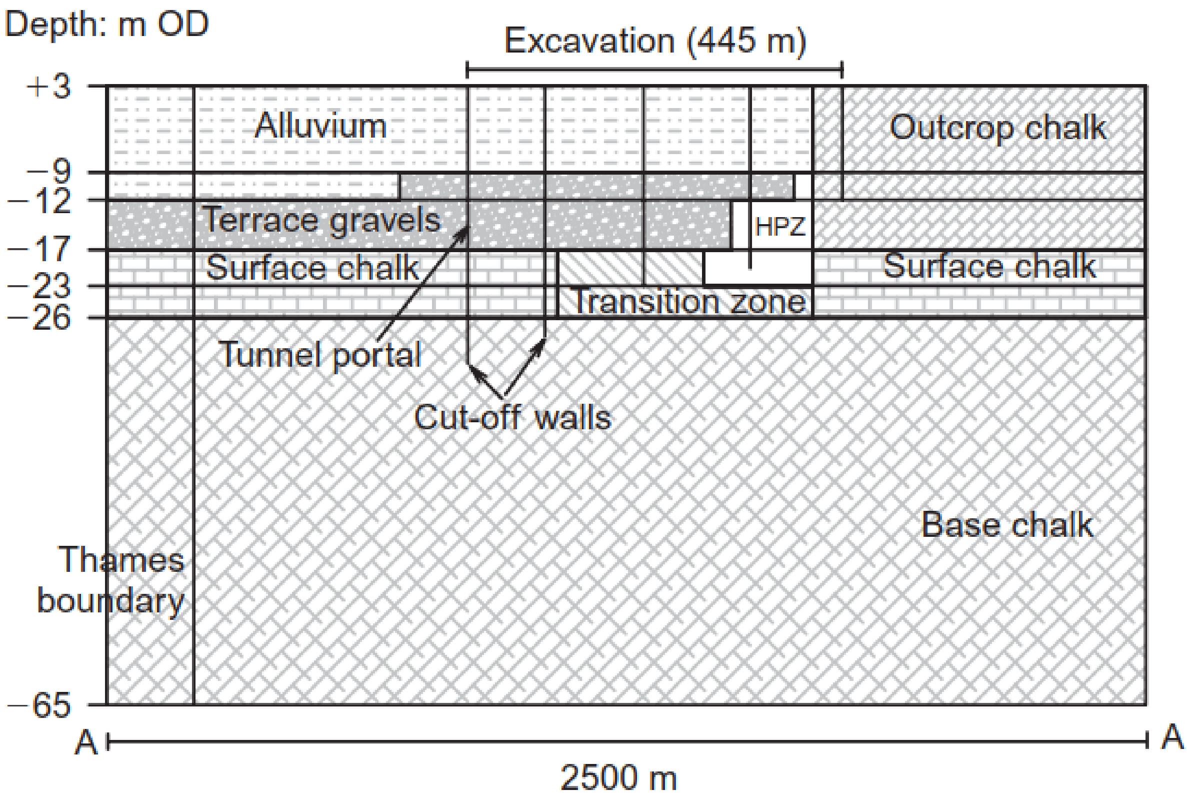


Figure 9 Extract from Bevan et al. (2010)

2.4 Boundary conditions

2.4.1 River Thames

Figure 10 shows the location of the river boundary conditions. The Thames Estuary is on the Northern model boundary. This is a river boundary condition with a river bottom elevation, stage and conductance. The river boundary conditions allow for water to move out or into the boundary from the aquifer.

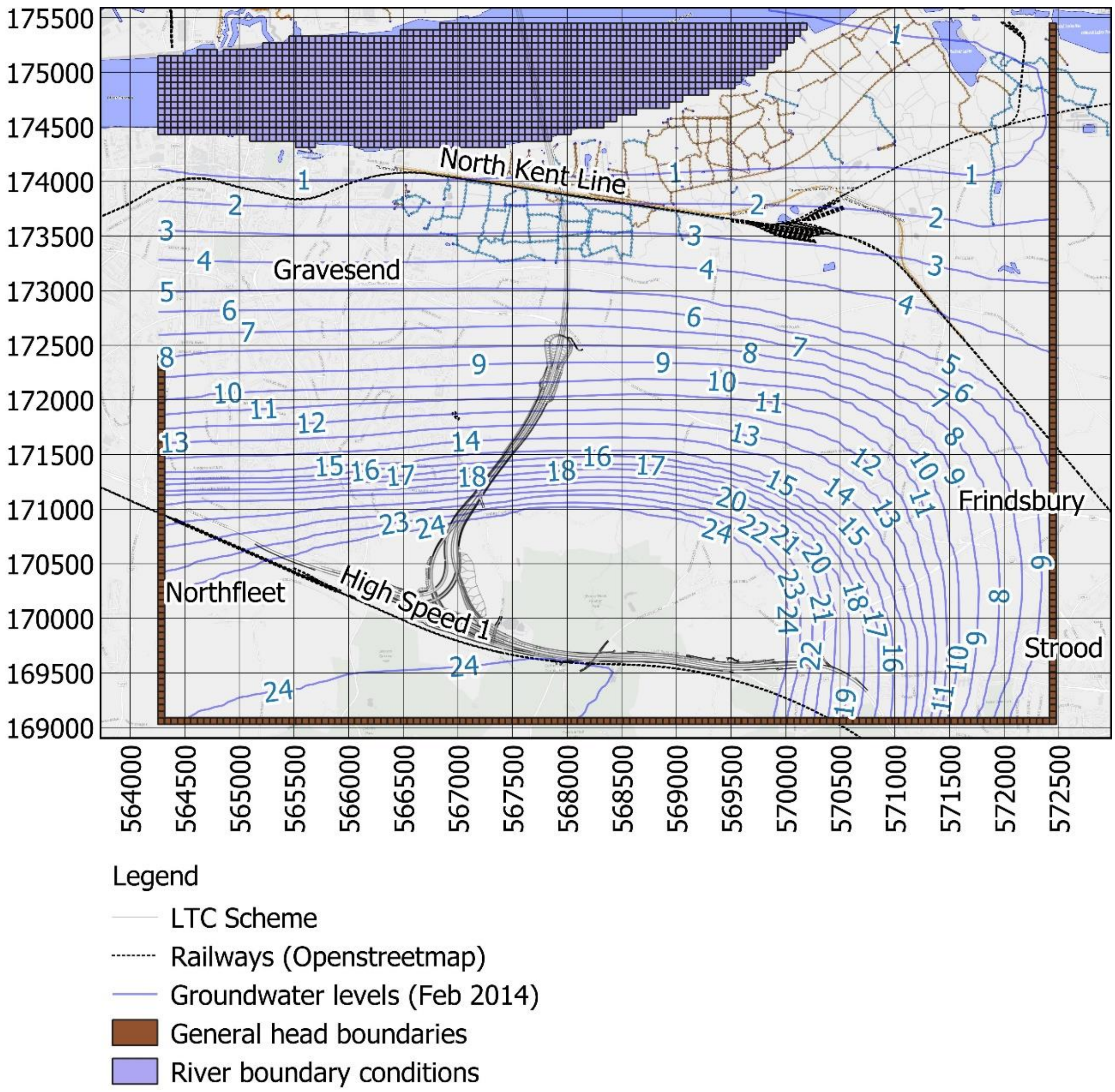


Figure 10 River and general head boundaries, with the February 2014 hydraulic head contours.

The boundary is assigned into the single layer that encompasses the river bottom elevation. Layers above this are made inactive.

The stage is 0 m AOD in steady state conditions. The time-variant simulation starts at 09:50 am on 1/11/2019 and the stage follows the Thames tide at 1 hour steps.

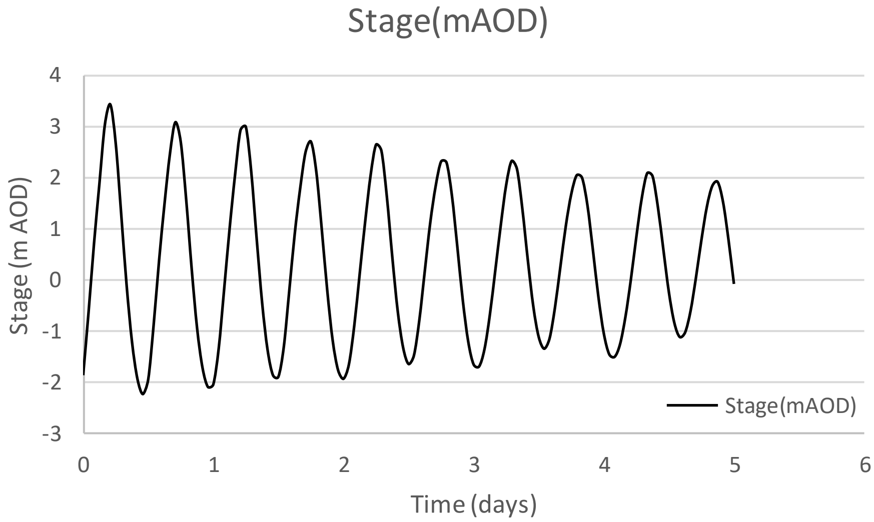


Figure 11 Stage for the Thames tide time-variant model

The rate of flow (per meter length of boundary) is dependent on the conductance of the boundary and a river 'stage'. The conductance is a function of the hydraulic conductivity, cell size and thickness of the riverbed in which the boundary resides. In practice this is often a calibrated value as riverbed information is not known. For this model, the riverbed conductance is the hydraulic conductivity of the river boundary model cell multiplied by the area of the cell.

Figure 12 shows the Thames bathymetry data collected for the project. The riverbed elevation is matched to bathymetry information where it is available. The riverbed elevation is set to -13 m AOD where it is not known. This is an approximation inferred from river geophysical survey results. The river bottom elevation is checked against the model layer elevations during assignment to avoid errors.

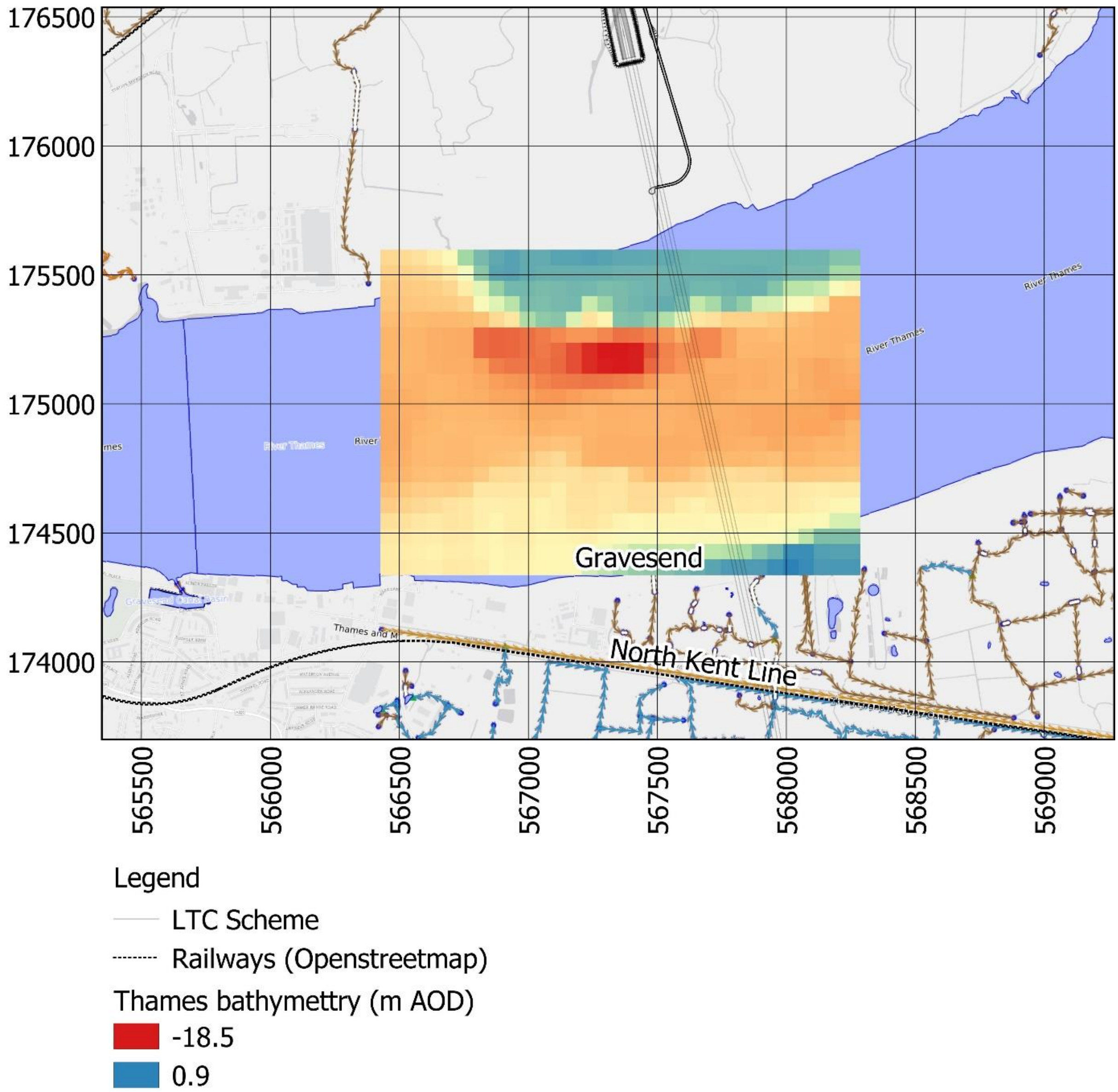


Figure 12 Thames bathymetry data

During the model build process, the river bottom is checked against the minimum stage in the tidal range simulated. River cells are not applied where the minimum stage is less than the river bottom. This scenario may occur when modelling a tidal scenario at the river edges.

Where the Thames Estuary is not present on the boundary, the boundary is assumed to be no-flow. This includes the easternmost 2,400 m of the model edge (30 %) and 3,300 m from the LTC scheme.

2.4.2 General head boundaries

The model simulates a part of the broader Chalk aquifer and so the aquifer continues out of the model to the north and east. A GHB represents a constant head at a distance from the boundary cell. The amount of flow from or into the cell depends on:

- the head difference between the model and the GHB;
- the GHB head value; and

- the conductance of the cell.

The GHB is useful where boundary effects are possible. The boundary assignment uses the MODFLOW-GHB module. A GHB is defined using a head and a conductance. The conductance is a combination of the hydraulic conductivity of the cell, boundary cell area and the distance to the conceptual source of recharge.

Figure 10 shows the locations of the GHB in the groundwater model. A GHB is assigned to the eastern and southern edges of the model domain. This is used to represent the coast and Medway channels east of the model domain and the continuation of the aquifer in the south. It is assigned with a hydraulic head that matches the February 2014 water level observed data.

2.4.3 Infrastructure – portals and tunnel outflows

The DRN (drains) and WEL packages are used to create the infrastructure boundary conditions.

The drain boundaries simulate:

- The shafts of the grout tunnel.

The WEL boundaries simulate the prescribed inflow rates into the:

- Grout tunnel; and
- Main tunnel.

The hydraulic conductivity for infrastructure cells must be altered to include for the presence of the infrastructure.

Table 7 provides details of the infrastructure boundaries used in the model.

Table 7 Infrastructure boundary conditions

Feature simulated	**Drain elevation**	**Boundary**
Grouting tunnel shafts (2 no.)	-11.6 m AOD Diameter 9.7 m	The DRN package is used. The drain conductance is a factor of the area of the shaft within the cell, the interface hydraulic conductivity ($1x10^{-7}$ m/s) and the thickness of the interface (0.5 m). For the shaft this is the surface area of the portal shaft. For the bottom of the tunnel shaft an additional conductance is added representing the area of the base of the shaft. Figure 13 shows a plan view of the boundary conditions relating to the grouting tunnel. Appendix C provides the locations of the grout tunnel boundary conditions in cross section.

Grouting tunnel (1 no.)	-9.7 m AOD. The centreline is at -6.8 m AOD, but the tunnel is 5.8 m in diameter	The WEL package is used. A single well is included in every cell encompassing the tunnel. The flow rate is calculated in advance, based on a prescribed inflow rate of 0.1 L/d/m^2. It is a calculated using the prescribed inflow rate and the area of the circumference of the tunnel within the model cell, considering cells size and height. The calculated inflow rate to the grouting tunnel is calculated to be just 1.16 m^3/d (0.01 L/s) in total. If a rate of 0.5 L/d/m^2 were used the flow rate is proportionately larger. Figure 13 shows a plan view of the boundary conditions relating to the grout tunnel. Appendix C provides the locations of the grout tunnel boundary conditions in cross section.
Main tunnels (2 no.)	Variable elevation 16.8 m diameter	The WEL package is used. A single well boundary per model cell with tunnel. The flow rate is calculated in advance, based on an inflow rate of 0.1 L/d/m^2. It is a factor of the prescribed inflow rate and the area of the circumference of the tunnel within the model cell, considering the cell thickness. Using a 60 m cell size, each tunnel is located in a single cell. The total flow calculated for the main tunnels within the model area is 18.4 m^3/d (0.2 L/s). If a rate of 0.5 L/d/m^2 were used the flow rate is proportionately larger. The tunnel is to be surrounded by a concrete perimeter (lining), which is assumed to have a low hydraulic conductivity ($1x10^{-7}$ m/s). The tunnels make up a large part of the volume of a model cell. It is necessary to reduce the hydraulic conductivity of the cell, to determine any mounding impact of the tunnel. This is calculated by comparing the volume of the tunnel in each cell with the remaining volume of the cell. With a 60 m grid spacing, the two tunnels are across two model cells. There is 1 tunnel per cell

		width, but multiple model layers cross the tunnels. Figure 14 shows a plan view of the boundary conditions relating to the main LTC tunnel. Appendix D shows the locations of the main tunnels in cross section.

Figure 13 shows the grout tunnel infrastructure boundary conditions in the model.

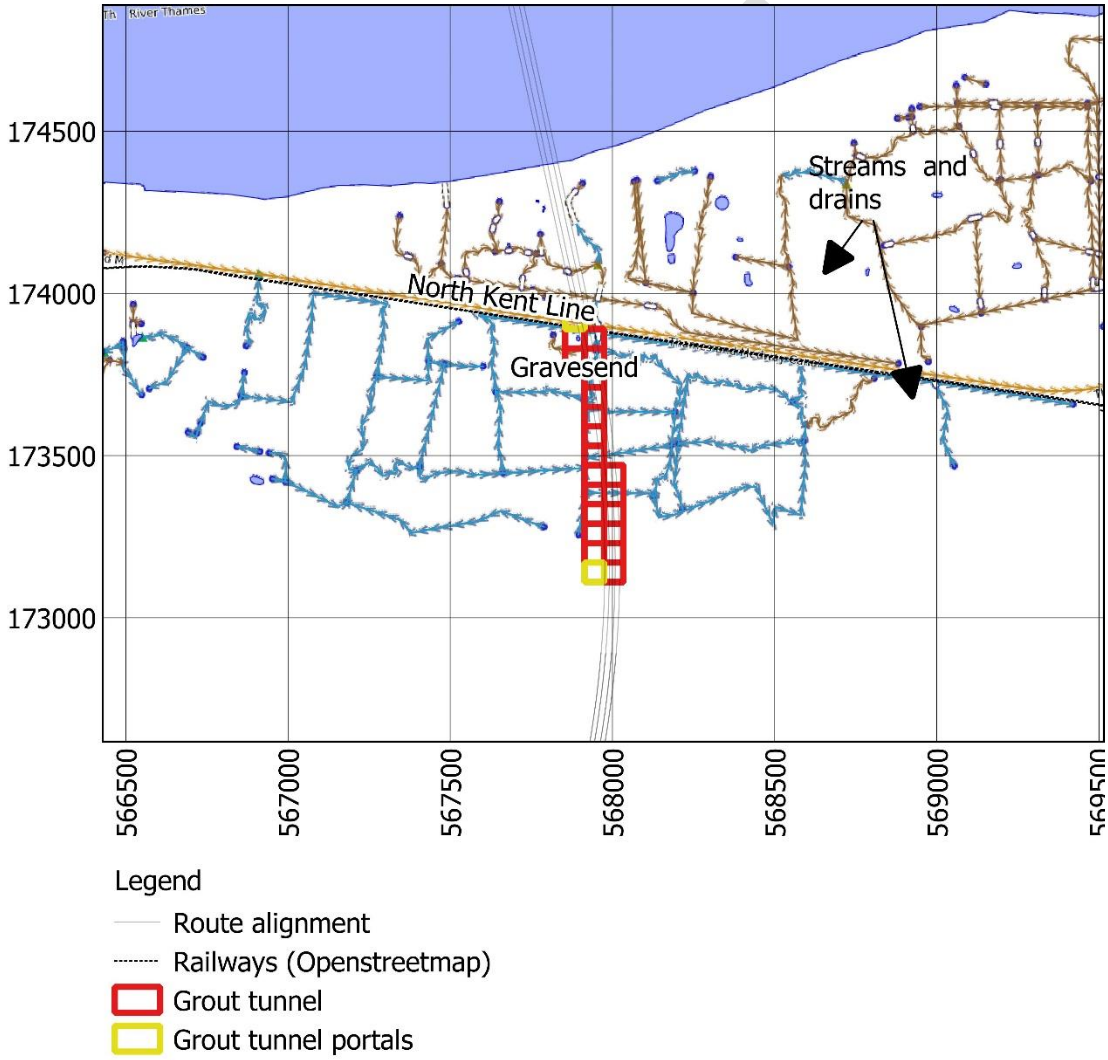


Figure 13 Grout portal (shafts) boundary conditions

Figure 14 shows the main tunnel boundary conditions in the model.

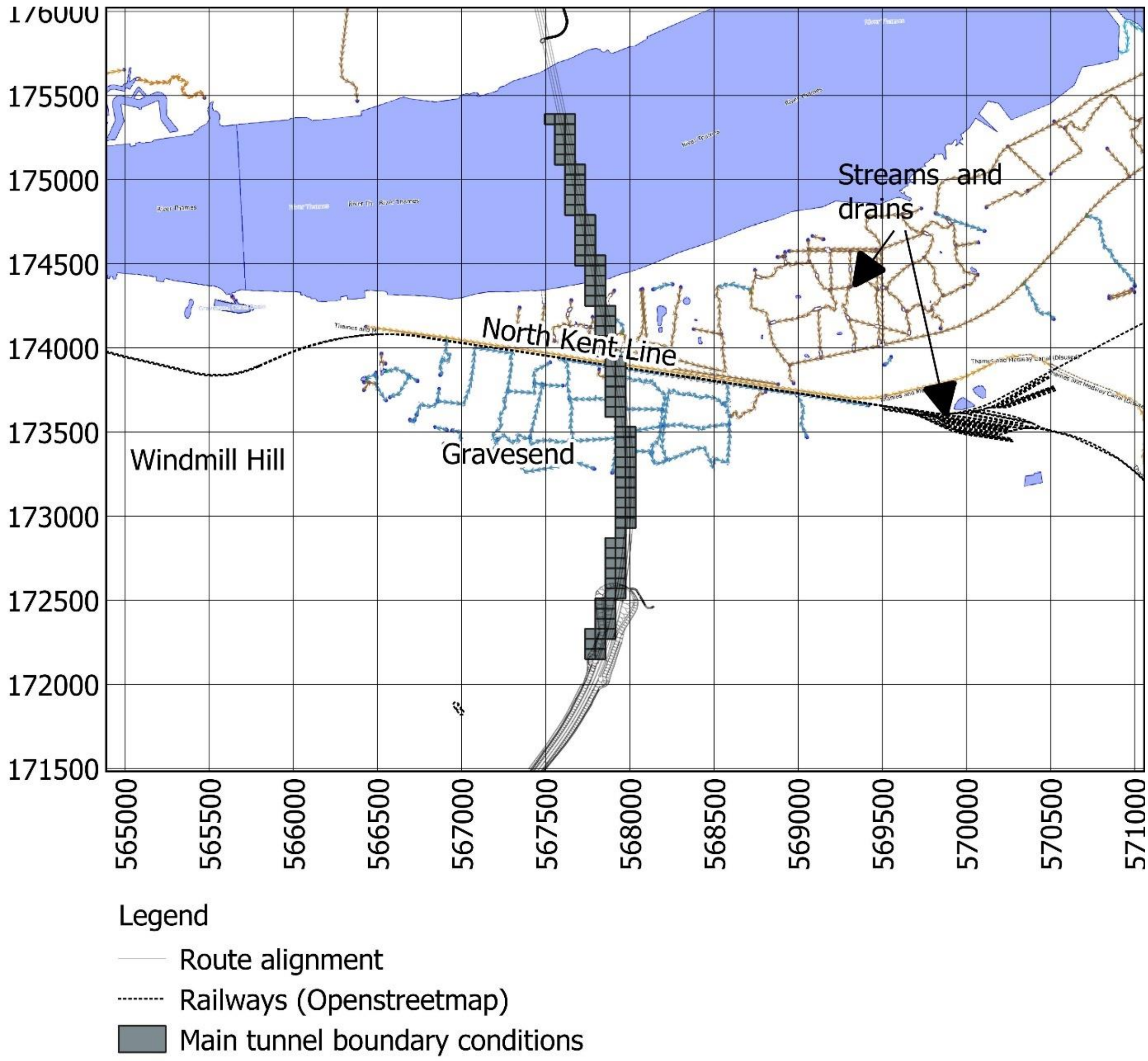


Figure 14 Main tunnel boundary conditions

2.4.4 Infrastructure – grout blocks

Figure 15 shows the location and elevation of the concrete plugs for the grout tunnel and LTC main tunnels. The grout block locations were provided by the Tunnel team as vertices coordinates with an elevation (Lower Thames Crossing - Cascade, 2019 (a)). The grout blocks span multiple layers of the groundwater and geological models. The purpose of the grout blocks is to provide a ‘dry’ zone in which maintenance of the tunnel boring machine or switching of parts or systems can occur. The assignment is done using the top and bottoms of the grout wall.

The hydraulic conductivity of the grout blocks is $1x10^{-7}$ m/s. The grout blocks for the grout tunnel are 20 m wide and therefore do not fill the entire 60 m wide model cell.

The grout plugs are included in the model as there is potential for groundwater mounding, but they also act to reduce drawdown.

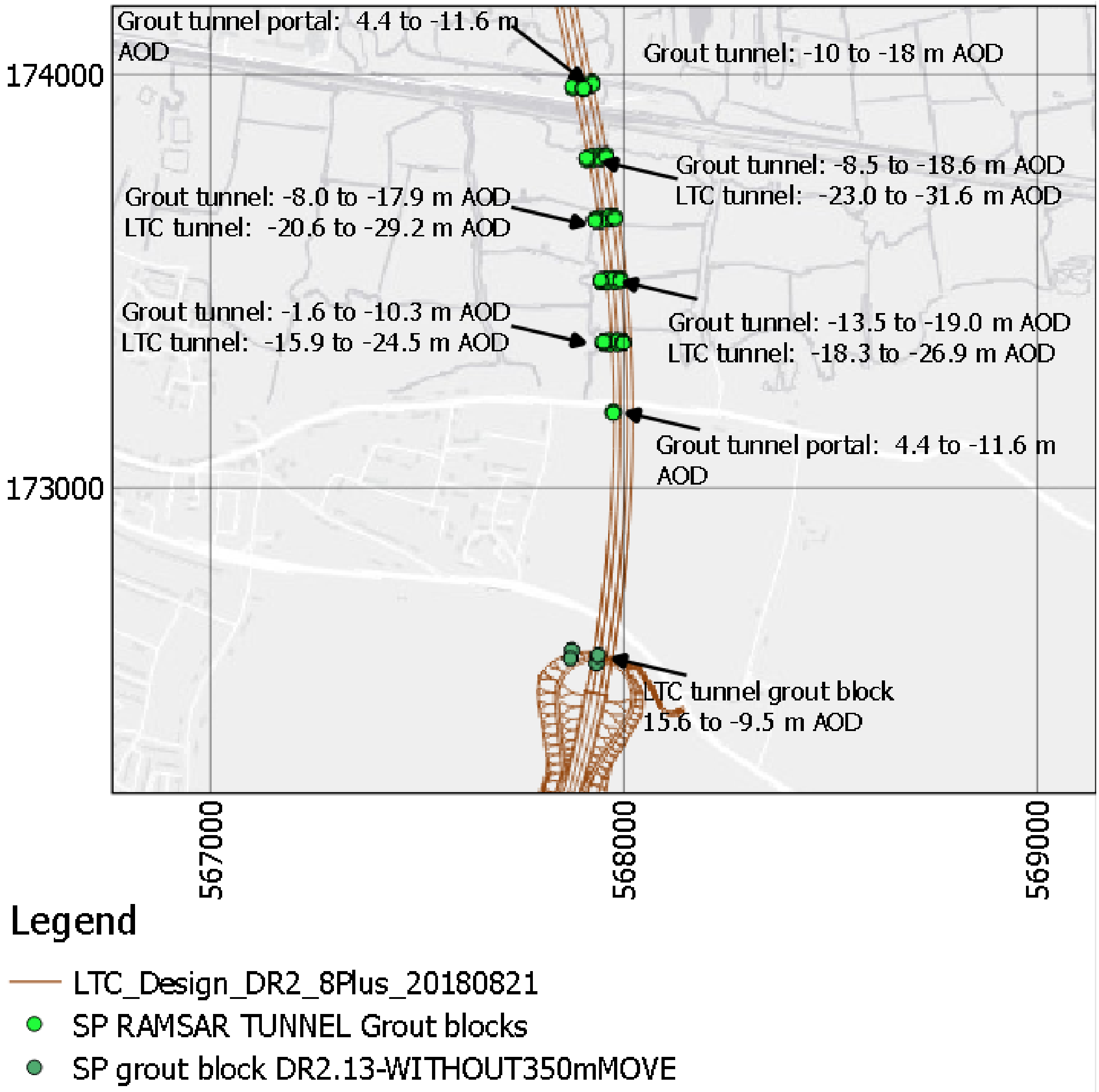


Figure 15 A location plan showing the Grout plugs for the grouting tunnel, cross tunnels and LTC tunnel, including their elevations

2.4.5 Aquifer Recharge

The BGS discuss that 'values (of aquifer recharge) of 100 mm/a were found for the north coast of Kent and values of over 280 m/a to central and southern Kent' (BGS, 2008). In the model, the recharge is applied to the top-most active model cell, excluding cells with river or drain boundary conditions.

Figure 16 and Table 8 describe the expected distribution of recharge in the groundwater model, with topographical change. The recharge rates are defined based on the material type as well as the topographical elevation.

Table 8 Aquifer Recharge values implemented in the groundwater model

Recharge rate (m/d)	Potential upper recharge rate (mm/a)	Distribution	Geological units	Conceptualisation
0.000767	280	Where the topography is above 100 m AOD	Harwich Formation Lambeth Group Lenham Formation Thanet Formation London Clay Chalk	Influenced by the amount of rainfall and the elevation. Recharge through lower permeability formations may be increased due to prolonged release from storage into unconfined Chalk
0.000384	140	Where the topography is between 70 m AOD and less than 100 m AOD		
0.000274	100	Where the topography is less than 70 m AOD		
0.000274	100	By outcrop type	Alluvium Tidal Flat Deposits Interglacial Deposits Head Deposits	Low elevation, with lower average rainfall and low hydraulic conductivity. Reasonable storage, but underlying Chalk is confined
0.001	365	River Terrace Deposits at outcrop	River Terrace Deposits Gravels (Boyn Hill; Black Park; Taplow; Lynch Hill, Kempton Park; Glacio-fluvial Deposits; Stanmore; Hackney.) Bagshot Formation	Highly permeable allowing for rapid infiltration of rainfall into the ground where these deposits are at ground surface.

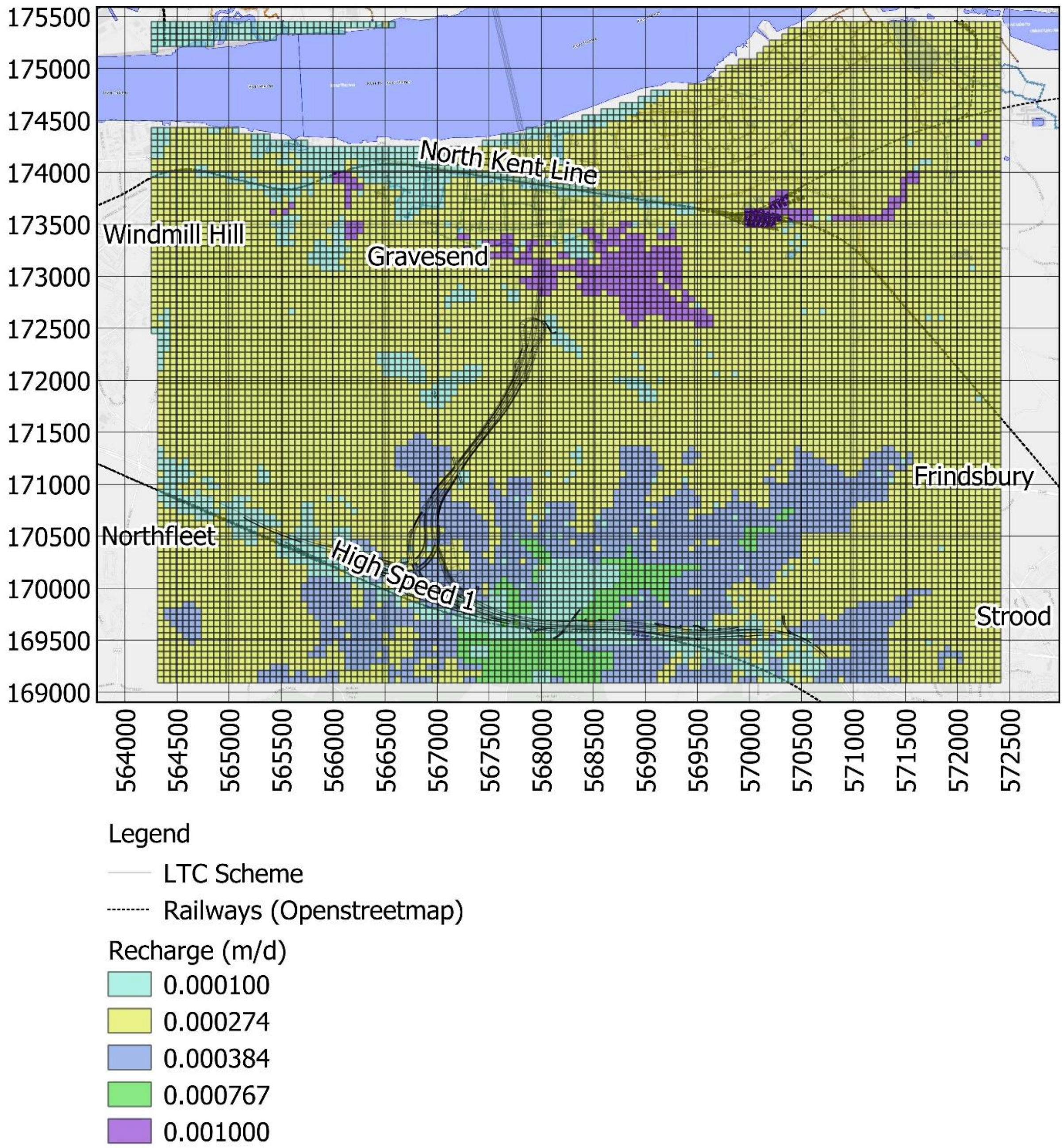


Figure 16 Recharge applied to the model based on elevation and material type

2.5 Calibration

2.5.1 Steady state calibration

The hydraulic head steady state model calibration was obtained by means of a manual iterative approach, by comparing the model output with:

- The February 2014 groundwater contours (baseline model) shown in Figure 17. These are interpolated from the Environment Agency (EA) regional monitoring network in the Chalk aquifer and provide a grid across the whole model domain for calibration; and

- The maximum observed water levels from selected LTC boreholes, also shown in Figure 17. The use of the maximum data is to be more compatible with the February 2014 water levels.

These are two very different datasets and are only partially compatible. There is quite poor correlation between the borehole data and EA gridded data, though the trends are similar. The borehole data shows a flatter hydraulic gradient within the chalk at low elevations and around the areas of outcrop alluvium and river terrace deposits. The contour data is more useful for calibrating the wider domain, whilst the borehole data is more useful for the scheme.

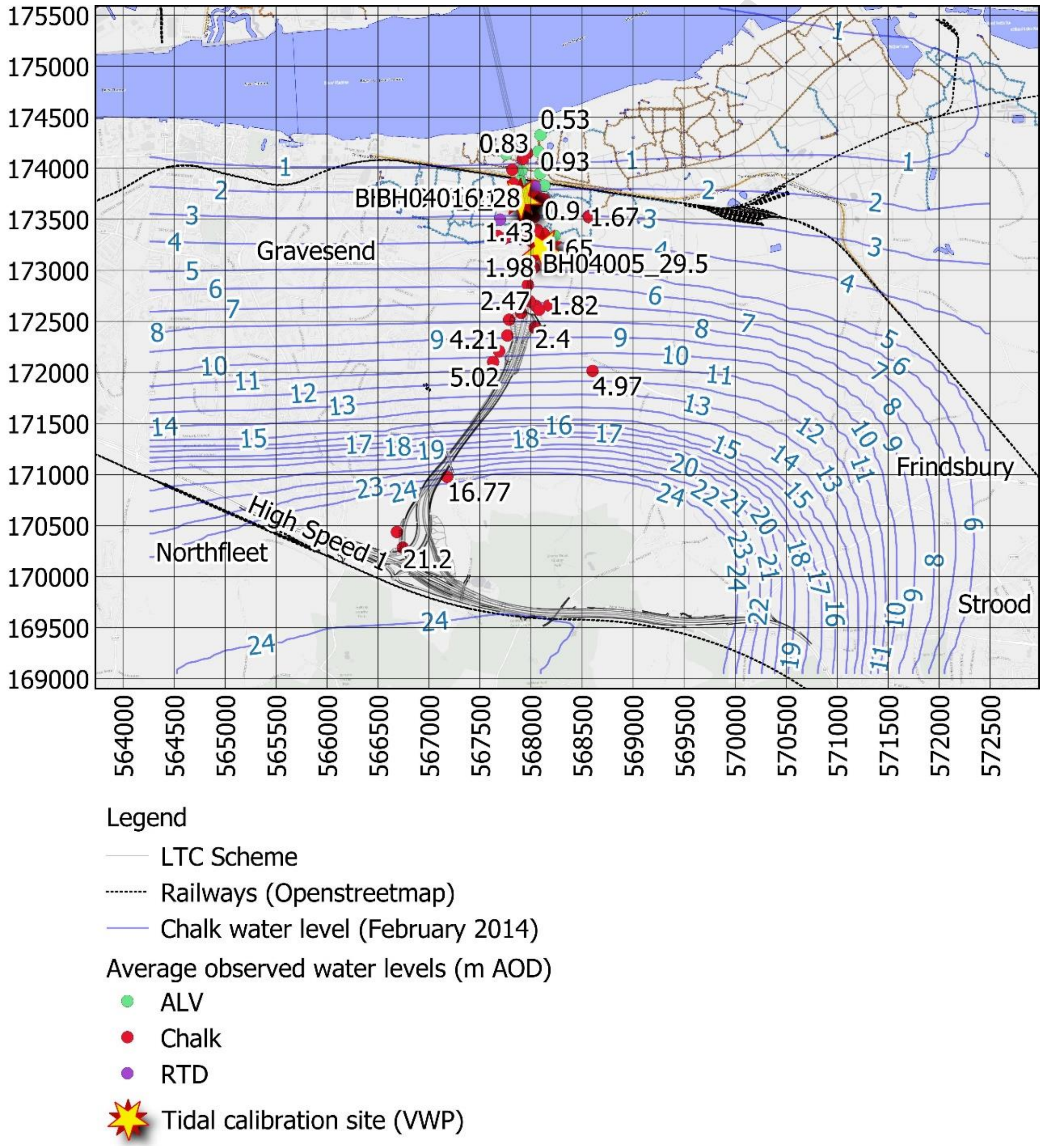


Figure 17 Water level data from boreholes used for calibration

The SRMS is calculated for the February 2014 grid compared to the model domain as well as for observations within subzones for the Alluvium, RTD and Chalk. Table 10 presents the quality criteria according to which the calibration has been obtained, i.e. the relative importance (weighting) assigned to the different zones of the modelled domain for the calculation of the SMRS.

Table 9 Weighting for steady state calibration

Subzone/Zone	Data	Weighting	Justification
Whole domain Chalk water level	February 2014	45%	Reflects wider water balance and recharge/transmissivity ratio. Compensating for fact LTC data is very linear in extent
Scheme – Chalk	LTC borehole water level monitoring data	45%	Important for controlling inflows in into the Scheme. Very sensitive to changes.
Scheme – RTD	LTC borehole water level monitoring data	8%	Potentially important to scheme inflows, but largely controlled by Chalk transmissivity
Scheme – Alluvium	LTC borehole water level monitoring data	2%	Low conductivity and largely insensitive in steady state. High scatter due to very local inhomogeneities and perching, land drainage.

2.5.2 Time-variant calibration

Figure 17 shows the locations of the Vibrating Wire Piezometers (VWP) sites BH04005 and BH0416 which were used for time-variant calibration. Figure 18 shows the water levels at these sites at various screen intervals. Of all the LTC VWP sites, these boreholes provided the best spatial distribution and had data over the same time-period.

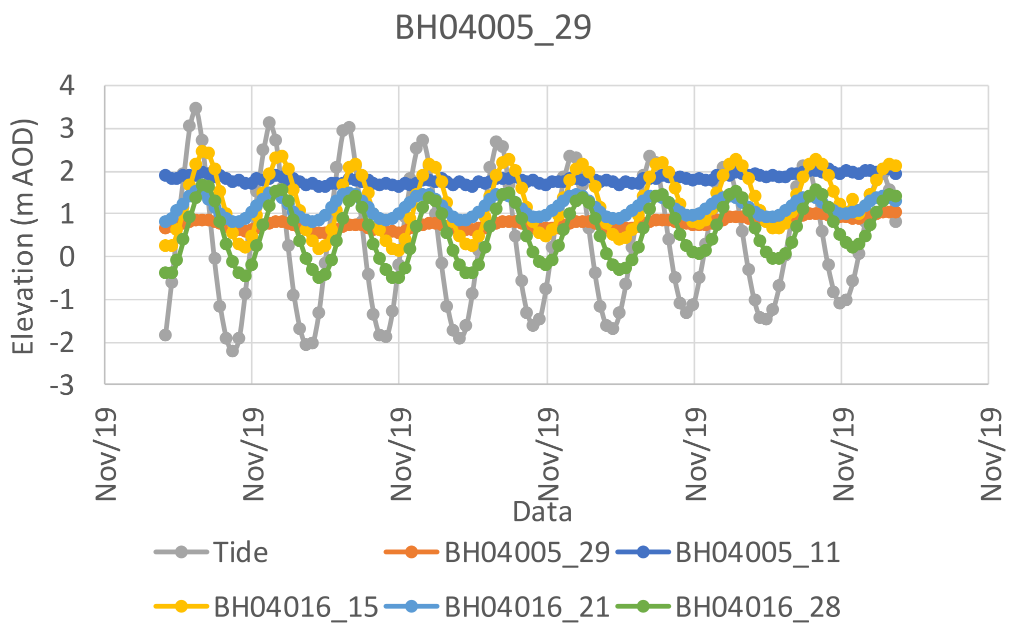


Figure 18 VWP observations of tidal response in the chalk (BH04005 and BH04016)

Name	Representative screen depth (m bgl)	Lithology
BH04005_11	11	Chalk
BH04005_29	29	Chalk
BH04016_15	15	RTD
BH04016_21	21	Chalk
BH04016_28	28	Chalk

The MODFLOW 'Hobs' package was used to extract data from the model at the right times, matching the observed data. A stress period of 1 hour was used to simulate the changing of the tide over a period of 5 days.

2.5.3 Manual calibration and changes to the conceptual model

A manual iterative approach to calibration was used to adjust the conceptual model to better fit the observed groundwater level data. Figure 19 shows plots of the predicted water level and the highest water level recorded from site boreholes. Figure 20 shows a plan view of the water table and the observed water level in the chalk for February 2014. The SRMS for the chalk boreholes is 8.19 % and for the February 2014 levels is 7.8 %. Findings from the calibration were:

- The observed tidal response is very large. Such a large tidal response can be achieved if there is a very high transmissivity, low storage and strongly confined aquifer with the Chalk. This aquifer must be well connected to the river Thames. Reviews of other schemes, such as the nearby CTRL scheme, showed that a thin but high transmissivity zone was present beneath RTD (Figure 9). After review of the AGS data for Chalk grade and core loss in the Chalk, this same zone of high transmissivity was included in the model. To obtain the high tidal response, the hydraulic conductivity of this area was calibrated to be in the order of 1x10^{-2} m/s and to be isotropic. Though the zone is only less than 5 m thick, this high hydraulic conductivity determines its large transmissivity. It was also necessary that the RTD vertical hydraulic conductivity (Kz) was low, even though the horizontal hydraulic conductivity (Kh) was high, so that the amplitude of the response was not dissipated.

- The BGS model of the Chalk does not match with site derived data well beneath the centre of the Thames. The BGS model has a layer of alluvium and RTD present, when the LTC borehole information shows the Chalk rising and outcropping at the river base. A modification was required beneath the Thames to improve the connectivity with the Chalk.
- A near surface layer of Chalk approximately 35 m thick allows for draining of the hinterlands through intersection of the water table with ‘dry’ streambeds. These streambeds are conceptualised to have increased transmissivity due to increased groundwater flows and dissolution effects. The location of the ‘dry’ channels can be approximated to topographical dips filled with head deposits, trending from south to north towards the Thames. This structure was built into the model by applying a layer with an elevation matching the Seaford Formation base (approximately 55 m bgl beneath the Thames) plus 20 m. This elevation approximately matches the Belle Tout beds. The calibration was found to be quite sensitive to the thickness of this high permeability layer, too deep and the groundwater levels would be too low in the hinterlands. This zone was found to have a calibrated horizontal hydraulic conductivity of about 5x10^{-4} m/s.
- The horizontal hydraulic conductivity of the deeper, ‘bulk’ chalk is lower than that of the shallow or weathered chalk. Mapping by the EA suggests that the transmissivity of the Chalk in the hinterland areas north of the Thames is between 20 to 100 m^2/d. This was assumed to be similar for the south side and a calibrated value of 35 m^2/d was found (a hydraulic conductivity of approximately 1x10^{-5} m/s to 5x10^{-6} m/s) when distributed across the saturated thickness beneath the Thames area and hinterlands respectively.
- The alluvium horizontal bulk hydraulic conductivity was calibrated to be 7x10^{-7} m/s and found not to be very sensitive. During time-variant simulations of the tidal effect, a cycling upwards and downwards gradient develops between the alluvium and Chalk. With such low hydraulic conductivity, recharge causes a local mounding of the water table.

This initial calibration was used to provide the starting point for a stochastic Monte Carlo assessment.

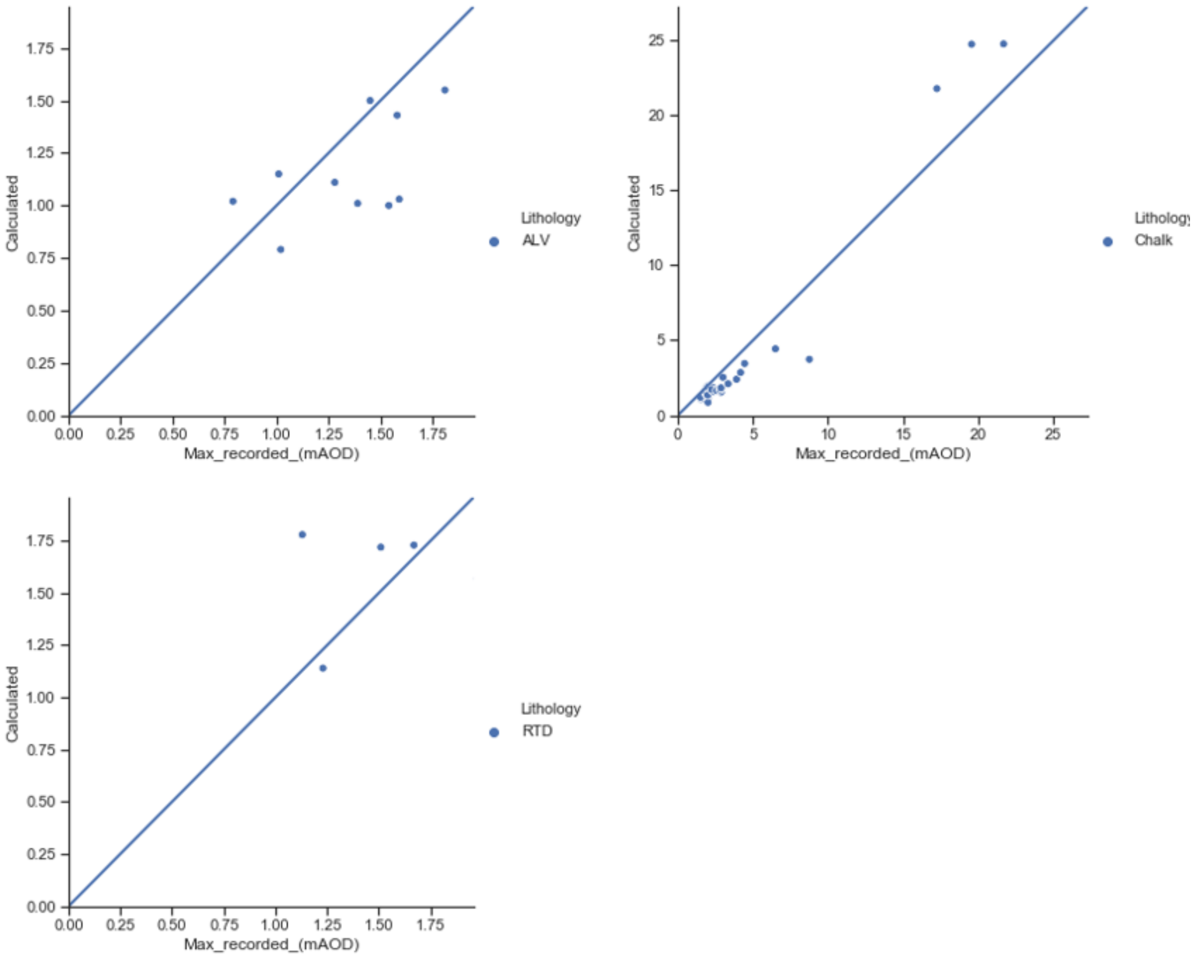


Figure 19 Steady state manual calibration with LTC boreholes: Calculated vs. Observed groundwater levels.

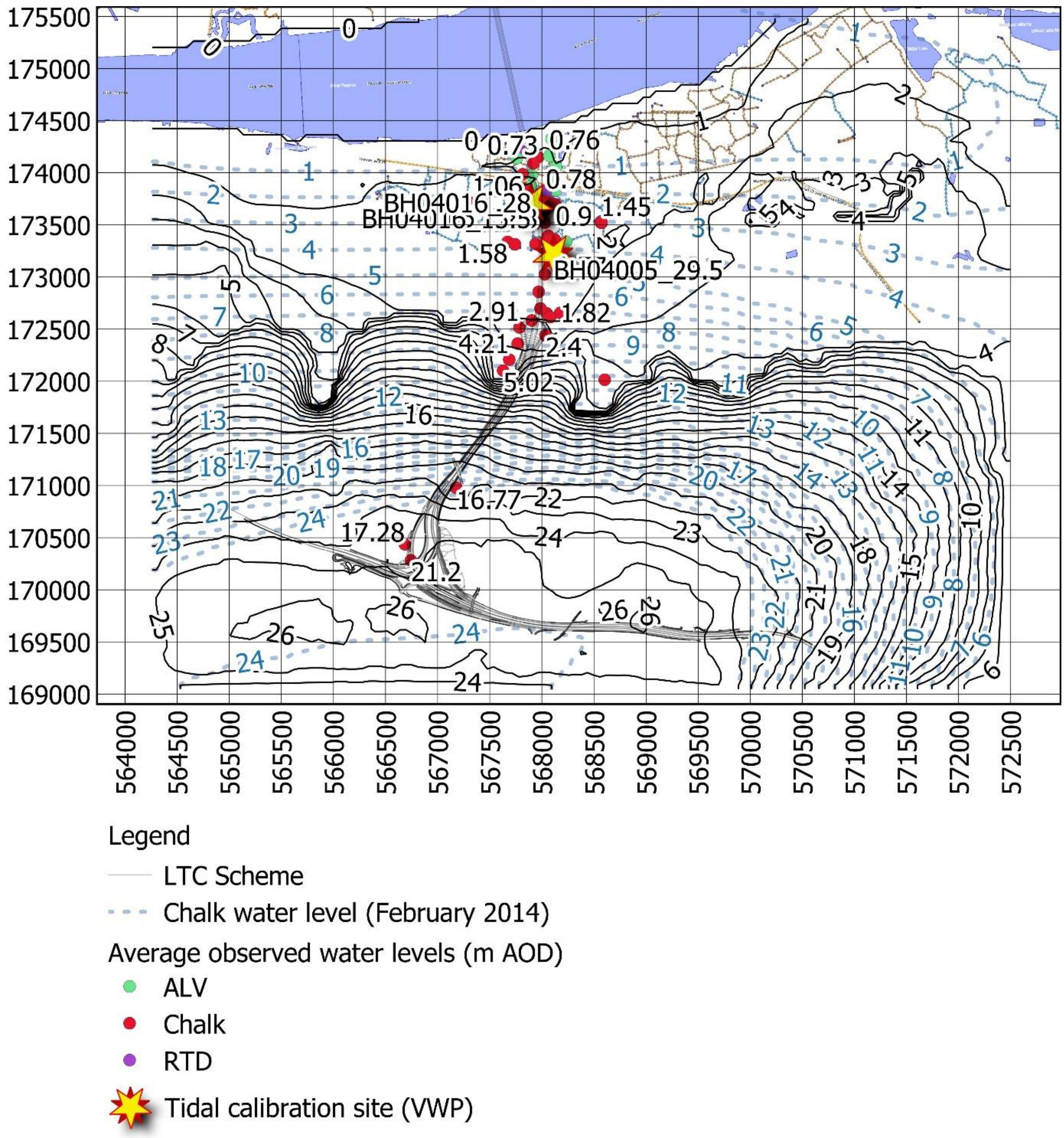


Figure 20 Steady state manual calibration: calibrated water table Monte Carlo assessment

It can be the case that a single calibration is fixed upon during groundwater modelling by manual iteration, when many may be available within the pre-defined parameter ranges. A Monte Carlo analysis tested 1600 model calibration parameters (horizontal and vertical hydraulic conductivities) combinations. Each simulation included a steady state and time-variant calibration assessment, followed by the scheme infrastructure scenario if the calibration was suitable. The assessment was completed using FloPy. For each simulation, the SRMS and parameters applied were recorded and assessed for the calibration data discussed in 2.5.1 to and 2.5.3.

The recharge was 'fixed' at the values discussed in paragraph 2.4.5. Parameters varied in the analysis included the horizontal and vertical hydraulic conductivity (in a pre-defined ratio) for:

- Alluvium (ratio of k_z(vertical)/k_h(horizontal)= 0.1)
- River terrace deposits (ratio of k_z(vertical)/k_h(horizontal)= 0.1)
- CKD (unstructured granular chalk/core loss zones (k_z=k_h)
- Belle Tout Chalk (a zone within approx. 35 m bgl, ratio of k_z(vertical)/k_h(horizontal)=0.02)
- Bulk Chalk – deeper chalk, making up the saturated chalk in the hinterlands (ratio of k_z(vertical)/k_h(horizontal)=0.02)

The parameters were selected at random from the following stochastic distributions, created after an initial manual calibration (Table 10):

Table 10 Log-normal distributions of hydraulic conductivity for the Monte Carlo simulations.

	Hydraulic conductivity (m/s)		
	Mean	Standard deviation	Max and min tested
Alluvium	$7x10^{-7}$	1.25	$1.29x10^{-8}$ to $9.95x10^{-5}$ m/s
RTD	$7.30x10^{-4}$	1	$5x10^{-5}$ to $2x10^{-3}$ m/s
Unstructured Chalk (CKD/AZCL)	$1x10^{-2}$	0.1	$6.93x10^{-3}$ to $1.39x10^{-2}$ m/s
Belle Tout formation	$5x10^{-4}$	0.25	$1.00x10^{-3}$ to $5.40x10^{-2}$ m/s
Bulk Chalk	35	0.25	[1]
[1]Bulk Chalk is matched to a transmissivity zone of between 20 m/d to 100 m/d (Figure 3.17 (Environment Agency, 2016))			

Figure 21 shows an example, randomly generated distribution with a mean of log($1x10^{-4}$ m/s) and standard deviation of log($0.5x10^{-4}$ m/s).

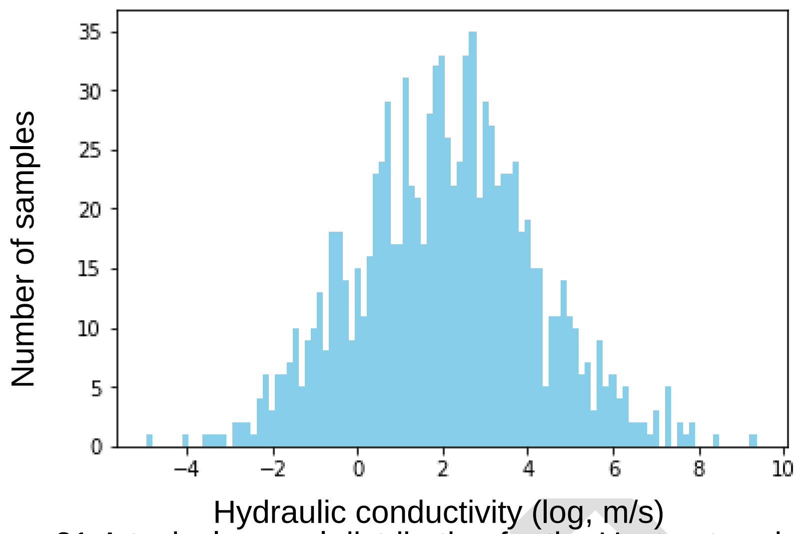


Figure 21 A typical normal distribution for the Unstructured Chalk with a mean of log(1x10^{-4} m/s) and standard deviation of log(0.5x10^{-4} m/s).

2.6 Results of the Monte Carlo simulations

2.6.1 Alluvium

Figure 22 shows a histogram for Alluvium Kh (horizontal hydraulic conductivity). The result shows that most calibrated Alluvium models have a low hydraulic conductivity. The hydraulic conductivity tends towards the lowest values simulated, in the order of 1x10^{-7} m/s.

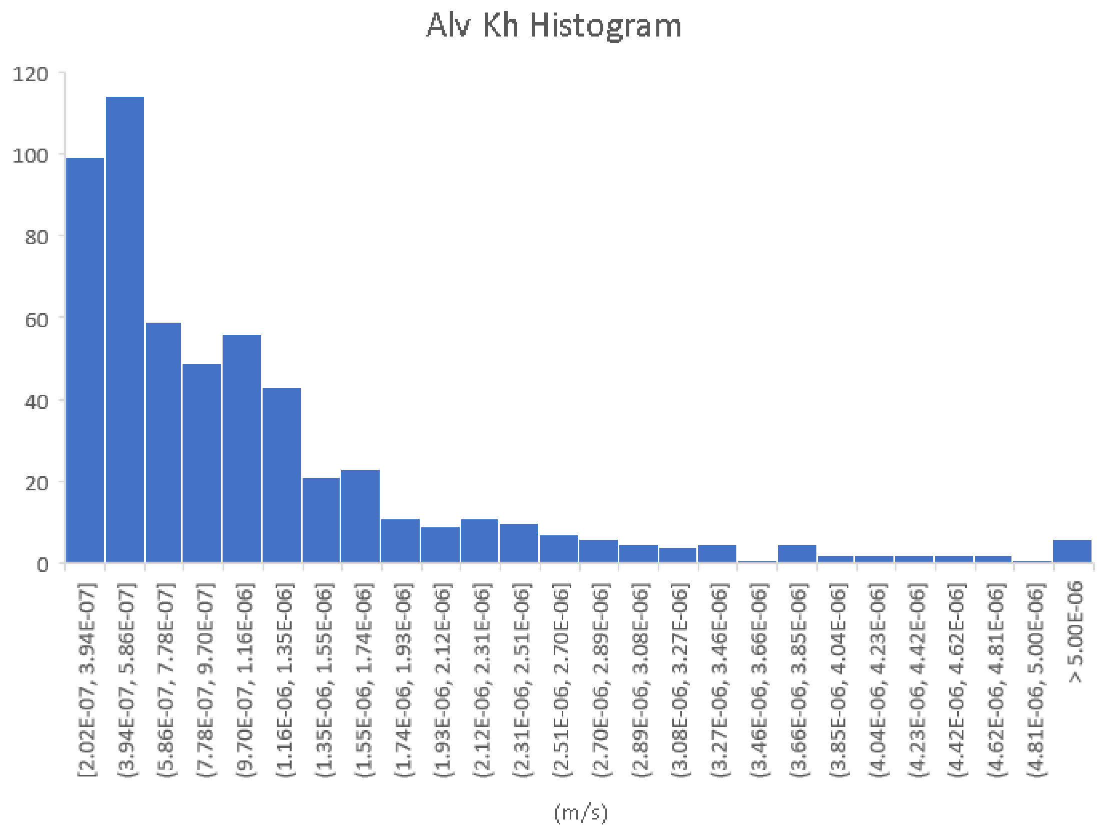


Figure 22 Alluvium kh

2.6.2 River Terrace Deposits (RTD)

Figure 23 shows a histogram of the results for the RTD. The results are skewed towards the lower end of the tested range, generally less than 7x10^{-4} m/s.

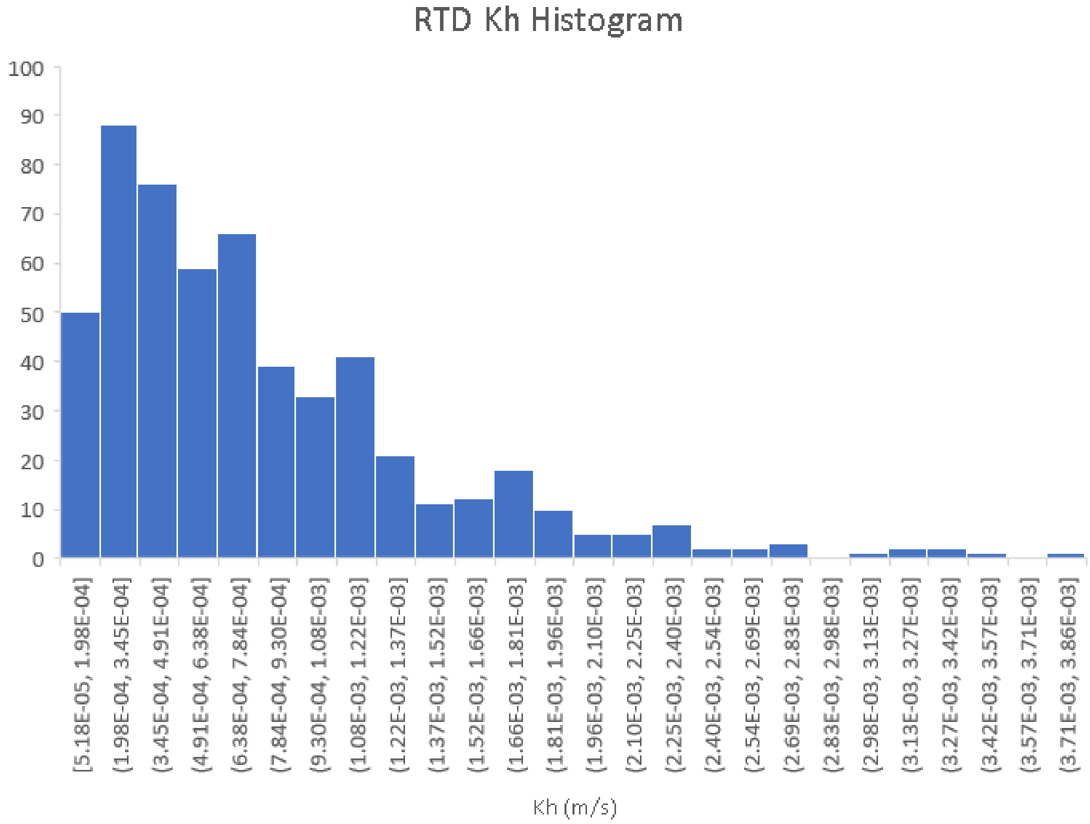


Figure 23 Monte Carlo results for the RTD

2.6.3 Unstructured chalk – (CKD, AZCL or RQD <0.1)

Figure 24 shows that the extremes of the range tested for the CKD (unstructured or karstic Chalk situated under the Thames or under RTD) are much less likely to occur than the central range of between 8.8x10^{-3} m/s and 1.12x10^{-3}. Once in the central range of parameters, there is little additional sensitivity. In practice:

- lower hydraulic conductivity values cause the tidal response to be too small;
- higher values cause both model instability and too much flattening of the water table in steady state.

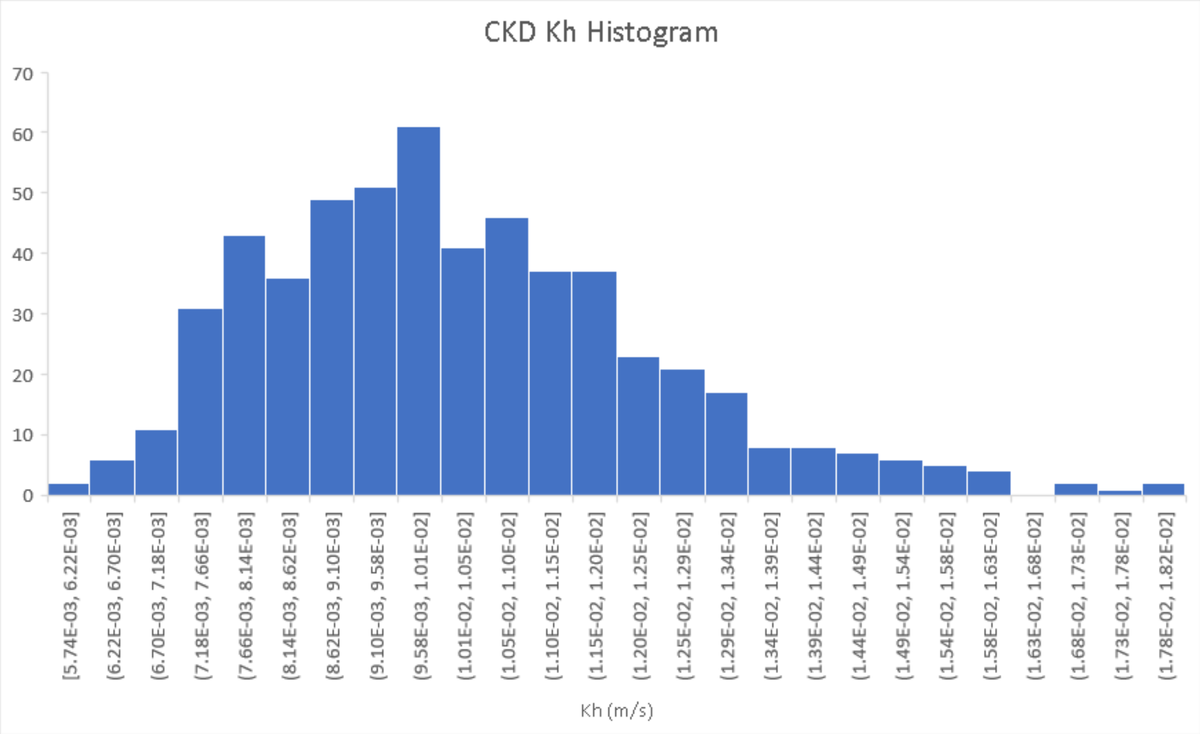


Figure 24 Monte Carlo results for the Unstructured chalk – (CKD, AZCL or RQD <0.1)

2.6.4 Belle Tout (upper part of Chalk)

Figure 25 shows that the calibrated values for the Belle Tout layer that forms the upper part of the Chalk, from a normal distribution with a skew to higher values. The peak bin is for a hydraulic conductivity of approximately 9 x10^{-4} m/s. Lower hydraulic conductivities cause hydraulic gradient between the Thames and the hinterlands to become too steep. This causes the calibration of the observed Chalk water levels in borehole to become poorer. Higher hydraulic conductivity values do not affect the LTC observed Chalk water levels but cause the hinterland regions to drain too freely. This causes the steady state calibration against the February 2014 regional water levels to fail.

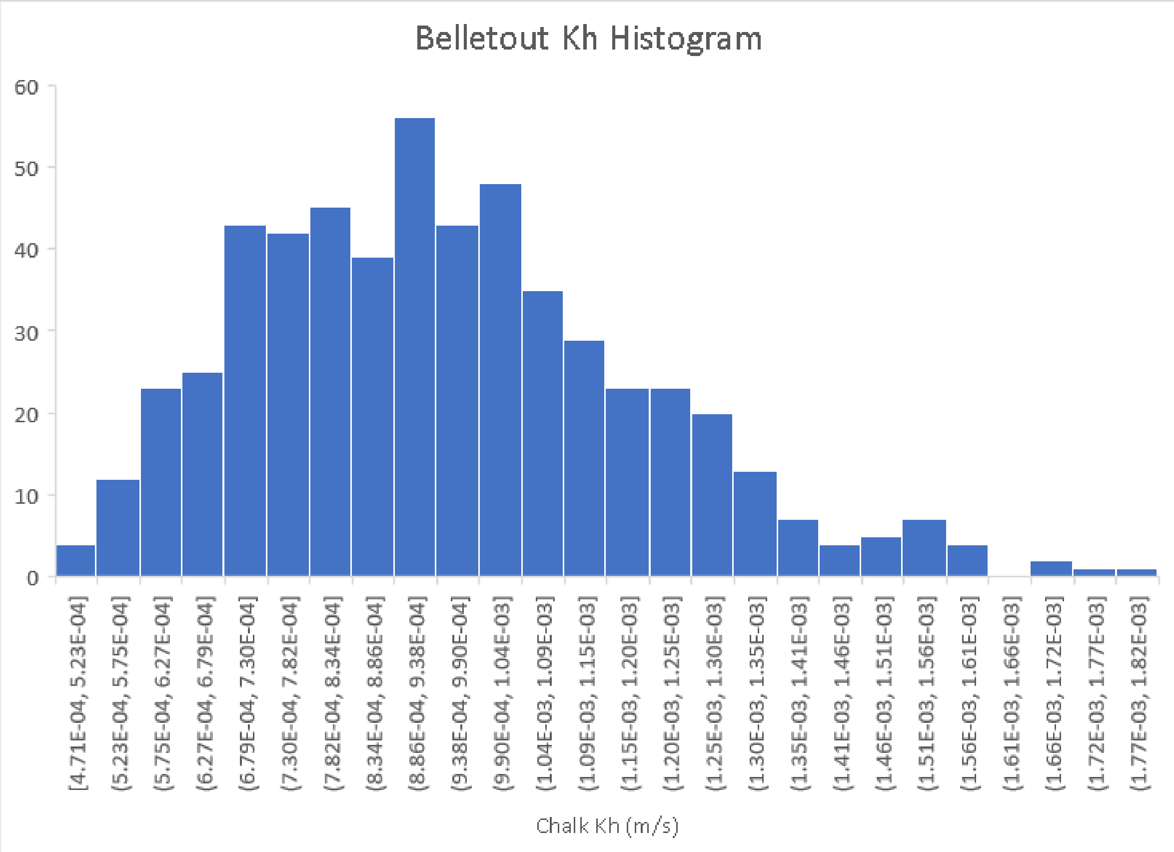


Figure 25 Monte Carlo results for the Belle Tout

2.6.5 Bulk Chalk (buried structured chalk)

Figure 26 shows that the calibrated values for the Chalk layer that forms the remaining aquifer beneath the Belle Tout layer (approx. 35 m bgl) to the base of the model (170 m bgl). This has been done by varying the transmissivity of the aquifer. If the base of the Belle Tout layer was above the water table then the February 2014 water table was used as the top of the aquifer to derive the thickness. The results showed a normal distribution with a mean of 37.6 m^2/d. This is within the expected range. And corresponds to a hydraulic conductivity of approximately $3x10^{-6}$ m/s for a 135 m thick aquifer.

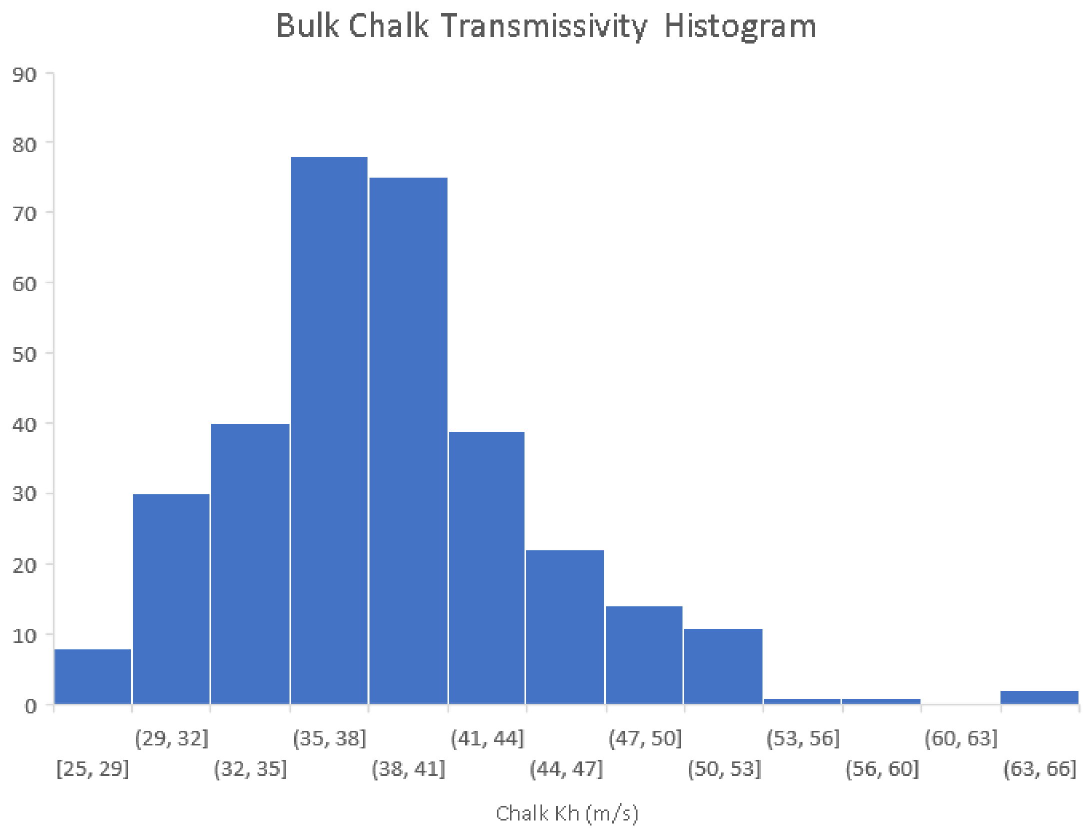


Figure 26 Monte Carlo results for the bulk Chalk rock

2.6.6 Representative 50th percentile model

Table 11 presents the results for the 50th and 95th percentile parameters from the Monte Carlo assessment.

Table 11 – Material Hydraulic conductivity for different percentiles.

Material	Hydraulic conductivity[2] 50th percentile (m/s)	Hydraulic conductivity[2] 5th percentile (m/s)	Hydraulic conductivity[2] 95th percentile (m/s)
[1]Made Ground		1.00×10^{-5}	
[1]Head Deposits		5.00×10^{-7}	
Alluvium	7.90×10^{-7}	2.83×10^{-7}	3.35×10^{-6}
River Terrace Deposits	6.55×10^{-4}	1.63×10^{-4}	2.0×10^{-3}
[1]London Clay		1.00×10^{-7}	
[1]Lambeth Group		1.00×10^{-7}	
[1]Harwich Formation		1.00×10^{-5}	
[1]Thanet Sands		1.00×10^{-4}	
CKD (Unstructured chalk, CTRL transition & HPZ zone)	1.00×10^{-2}	7.40×10^{-3}	1.39×10^{-2}
Belle Tout Chalk layer	9.30×10^{-4}	6.00×10^{-4}	1.39×10^{-3}

Material	Hydraulic conductivity[2] 50th percentile (m/s)	Hydraulic conductivity[2] 5th percentile (m/s)	Hydraulic conductivity[2] 95th percentile (m/s)
Bulk Chalk transmissivity (m^2/d)	37.61	29.46	49.84
[1]Manual calibration and not varied in assessment [2]Horizontal			

Figure 27 shows the prediction of the water table for the 50th percentile parameter set given in Table 11. The SRMS statistics for the simulation are:

- February 2014 water levels – 8.5%;
- Chalk observations – 6.9 %;
- Against all observations – 5.7 %; and
- Against tidal observations 15.8 %.

The calibration statistics for the February 2014 regional water levels reflects the difficulty in finding a solution that works for both data sets. The site-specific chalk observations from LTC boreholes have been prioritised. The February 2014 water levels have the following limitations:

- The February 2014 grid is produced from a relatively small number of water level observations distributed over a wide area (wider than the model);
- The February 2014 grid does not include information about the influence of local topography (valleys, interfluves);
- The February 2014 represents winter levels, rather than summer or average conditions. The LTC borehole monitoring data was obtained in summer and autumn conditions; and
- The February 2014 grid does not match well the observed data at LTC boreholes. It is still useful as a guide to the regional calibration.

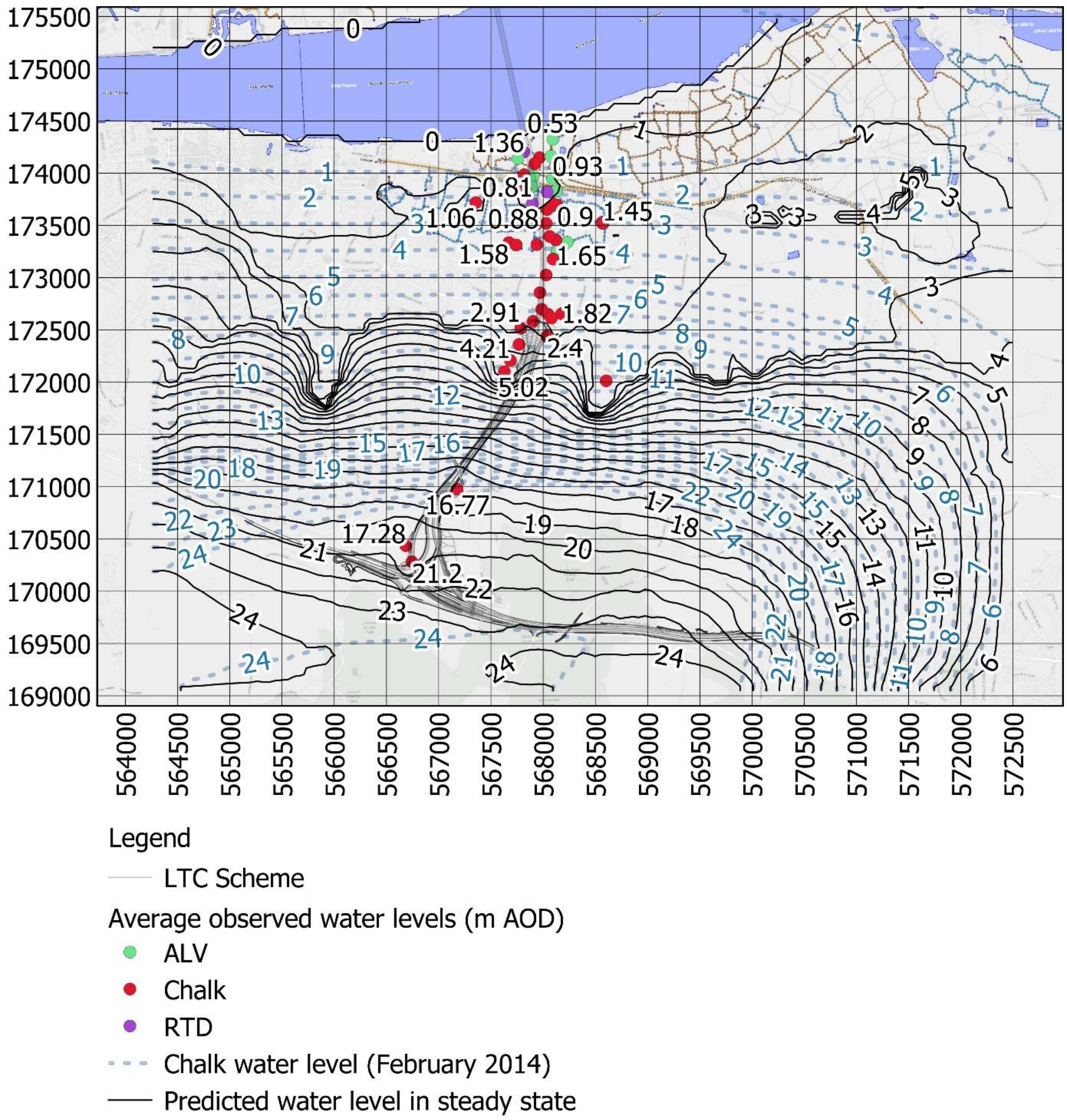


Figure 27 Predicted water table from the steady state baseline model using the 50th percentile parameter setup.

The SRMS of the calculated and observed tidal variation of the 50th percentile scenario is calculated to be 16 %, however a good fit is observed with the data. Achieving the full range of tidal variation in the model is difficult with parameters within the expected ranges of hydraulic conductivity. The observed tidal range at BH04016 is from +2 m AOD to -0.2 m AOD. This borehole is approximately 450 m from the River Thames. The tidal range within the Chalk causes an alternating upwards and downwards gradient between the Chalk in which it is measured, the underlying Chalk and overlying RTD and Alluvium. The response is indicative of:

- a level of confinement that is not achievable in the model;
- a lower storage than the expected range allows;

- a very direct hydraulic connection to the River Thames.

To obtain the degree of hydraulic response observed (Figure 28 and Figure 29), the following modifications were necessary :

- Inclusion of Clay layers from AGS data within the bulk alluvium is necessary to confine the RTD. The clay was assigned a hydraulic conductivity of 1/10th the bulk alluvium.
- A zone with a hydraulic conductivity of at least $1x10^{-3}$ m/s (Kh=Kz) was required beneath the Thames to connect the river with the Chalk.
- RTD gravel and Chalk storage coefficient set to $1x10^{-6}$ (equivalent to aquifer compressibility of approximately $1x10^{-10}$ m^2/N.

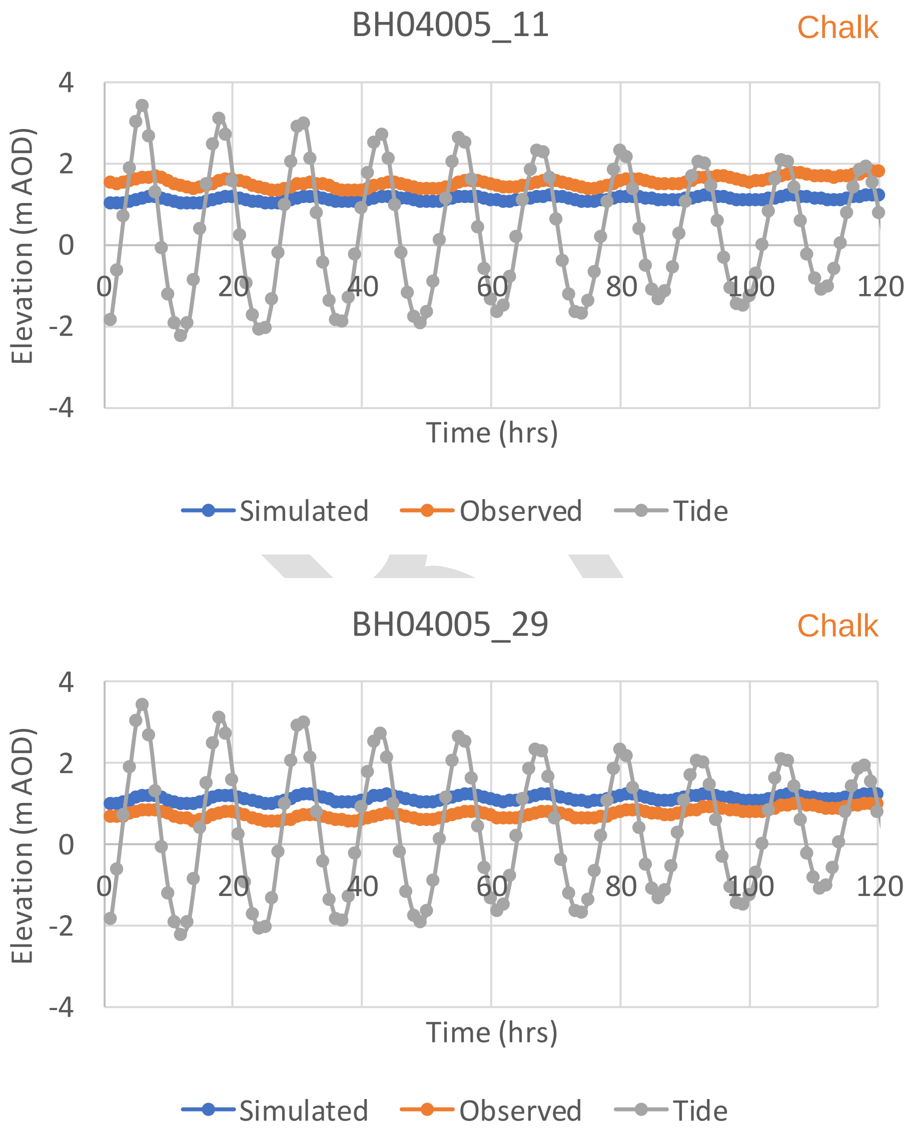
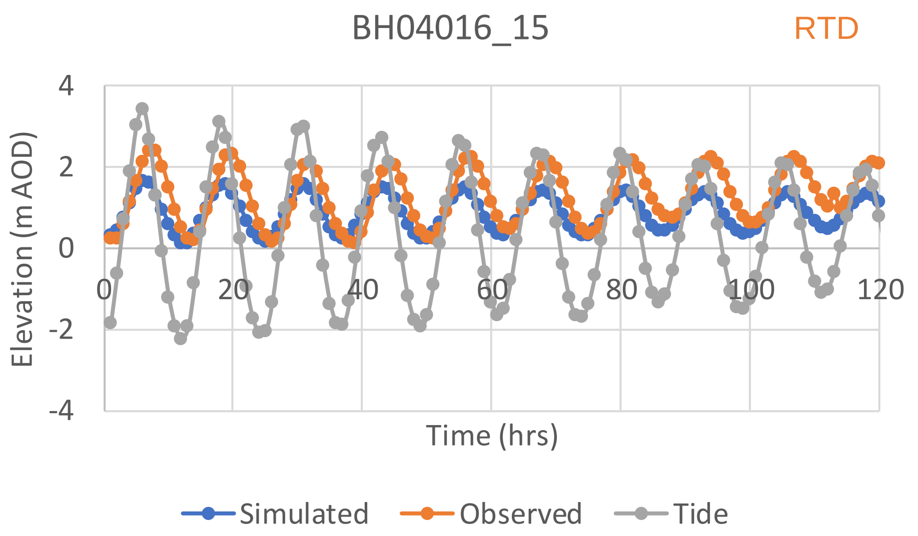
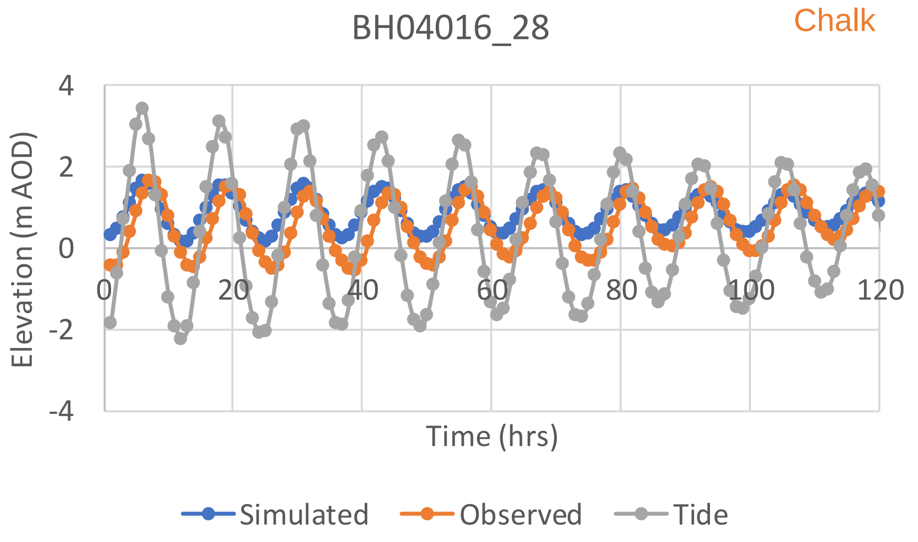


Figure 28 Predicted and observed tidal variation for BH04005





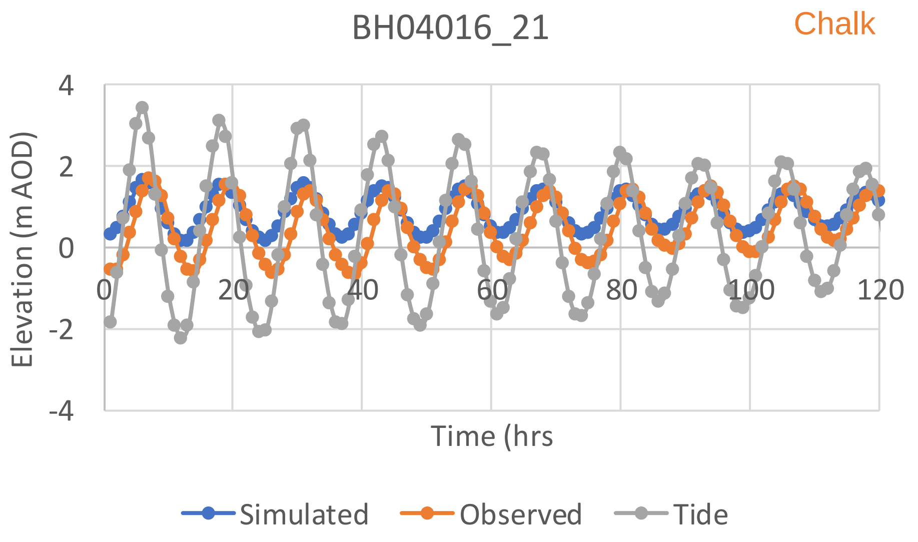


Figure 29 Predicted and observed groundwater levels for BH04016

3 Results with the LTC scheme

3.1 Grout tunnel shafts only (construction)

The grouting tunnel shafts are modelled using a drain with a low conductance. This simulates the pre-drilled sheet piles and clutch sheet piles, forming a relatively water-tight cylindrical column. Excavation is to be performed by a grab excavator within this column. As such, the shaft inflow is dependent on the conductance and the geological formation parameters.

The predicted combined flow rate to the two grouting tunnel shafts for the 50th percentile scenario is 3.3 L/s (284 m^3/d).

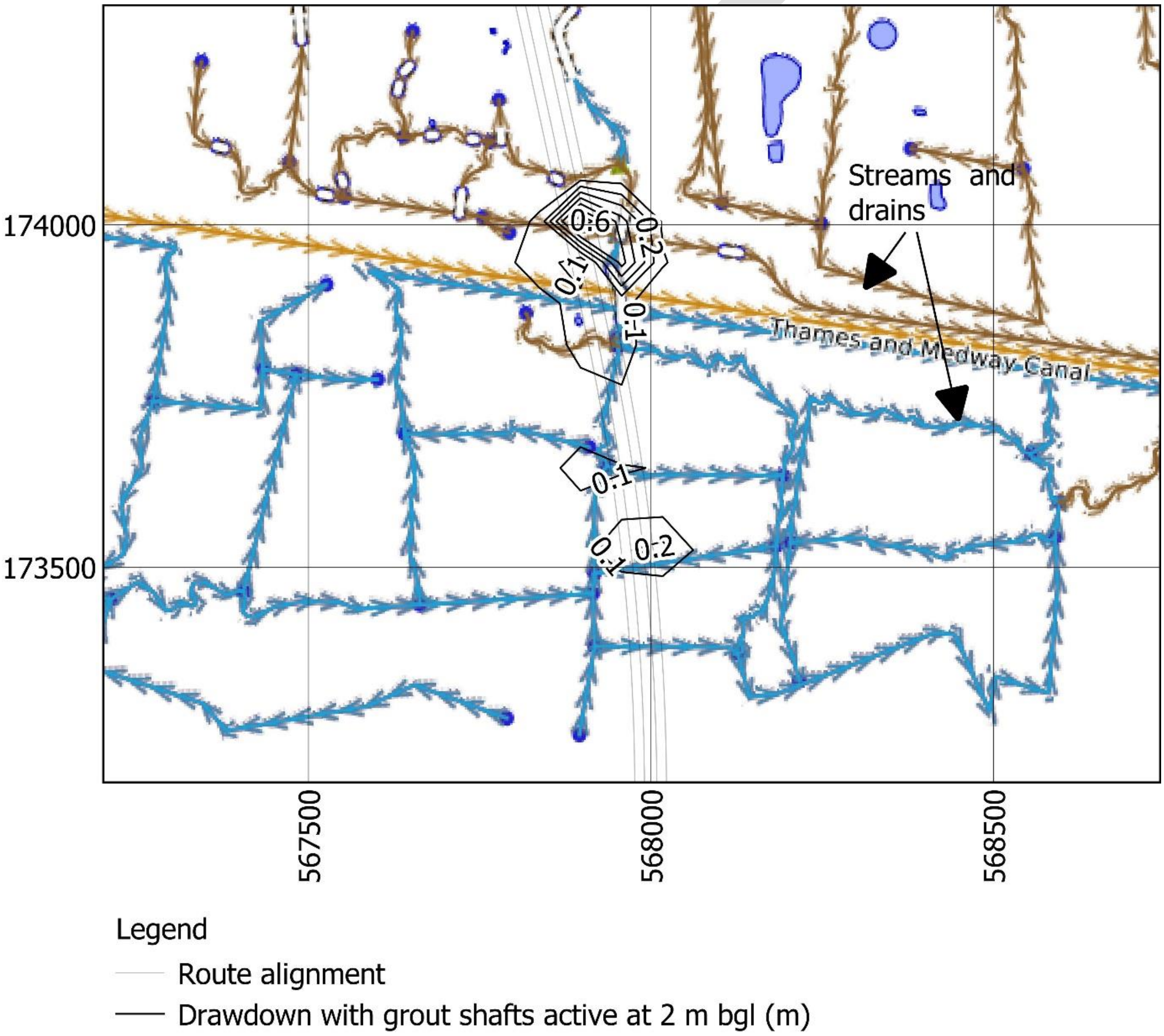


Figure 30 Drawdown with grout shafts active

The extent and magnitude of drawdown is quite limited as the inflows are restricted by the low conductance of the drains making up the shafts (Figure 30). Because of this, the water level in the cell with the shaft inside does not drawdown to the base of the shaft and represents the water level in the aquifer immediately adjacent to the sheet piles. Appendix E shows that the extent of drawdown decreases within the RTD. In the RTD the flow rate is so small that drawdown is negligible. Drawdown is larger in magnitude within the alluvium as recharge and hydraulic conductivity is low, however the extent is very limited.

The Monte Carlo assessment included a steady state simulation for inflow to the shafts for each calibrated parameter set. Figure 31 shows the inflow rate to the shafts from the Monte Carlo assessment. The inflow rate does not vary significantly as it is well controlled by the low conductivity sheet piles and grout portal base.

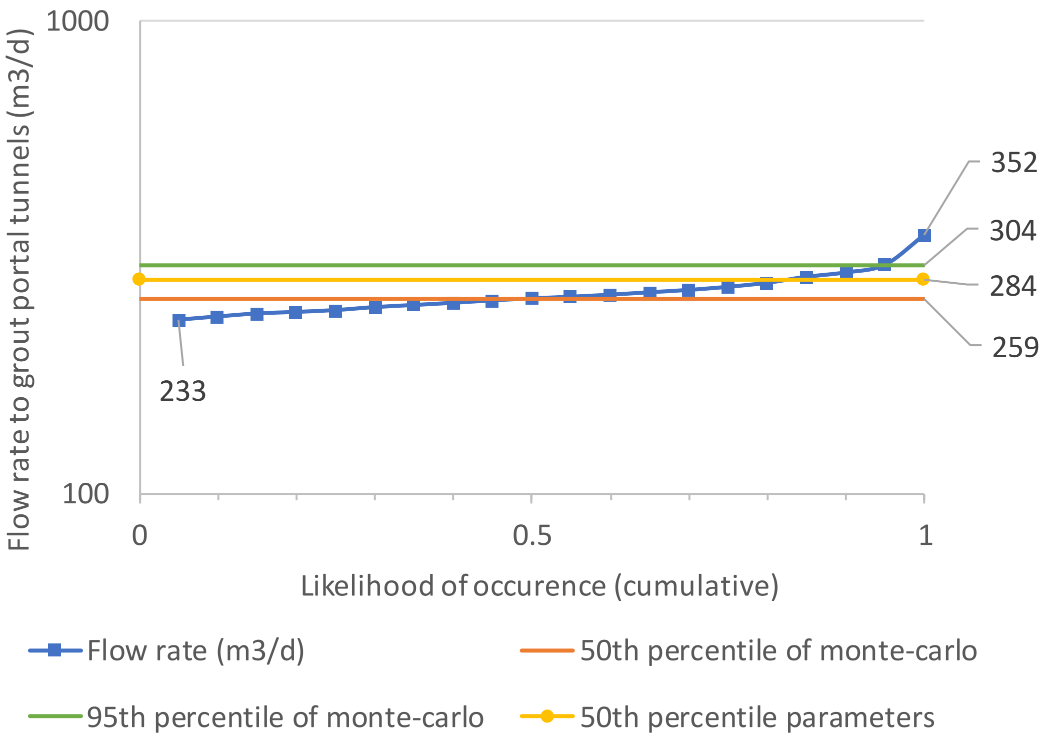


Figure 31 Monte Carlo assessment of inflow to grouting tunnel shafts

3.2 Shafts and grouting tunnel

The calculated inflow for the advanced grouting tunnel is 0.013 L/s (1.16 m^3/d). This is low because the prescribed flow rate is restricted to 0.1 L/d/m^2. Figure 32 shows the predicted drawdown of the water table. There is little additional drawdown. As the total inflow rate to the grouting tunnel is very low the drawdown is mainly caused by the shafts. The presence of the grouting tunnel has caused the drawdown cone to be extended across the top of the grouting tunnel. This is because the grouting tunnel acts as a local flow barrier and drawdown increases when there is a flow barrier close to an abstraction. Appendix F illustrates the extent of the drawdown at different depths. The drawdown from the tunnel reduces to zero with depth. This is because the seepage is supported by the high transmissivity RTD rather than the low hydraulic conductivity Alluvium.

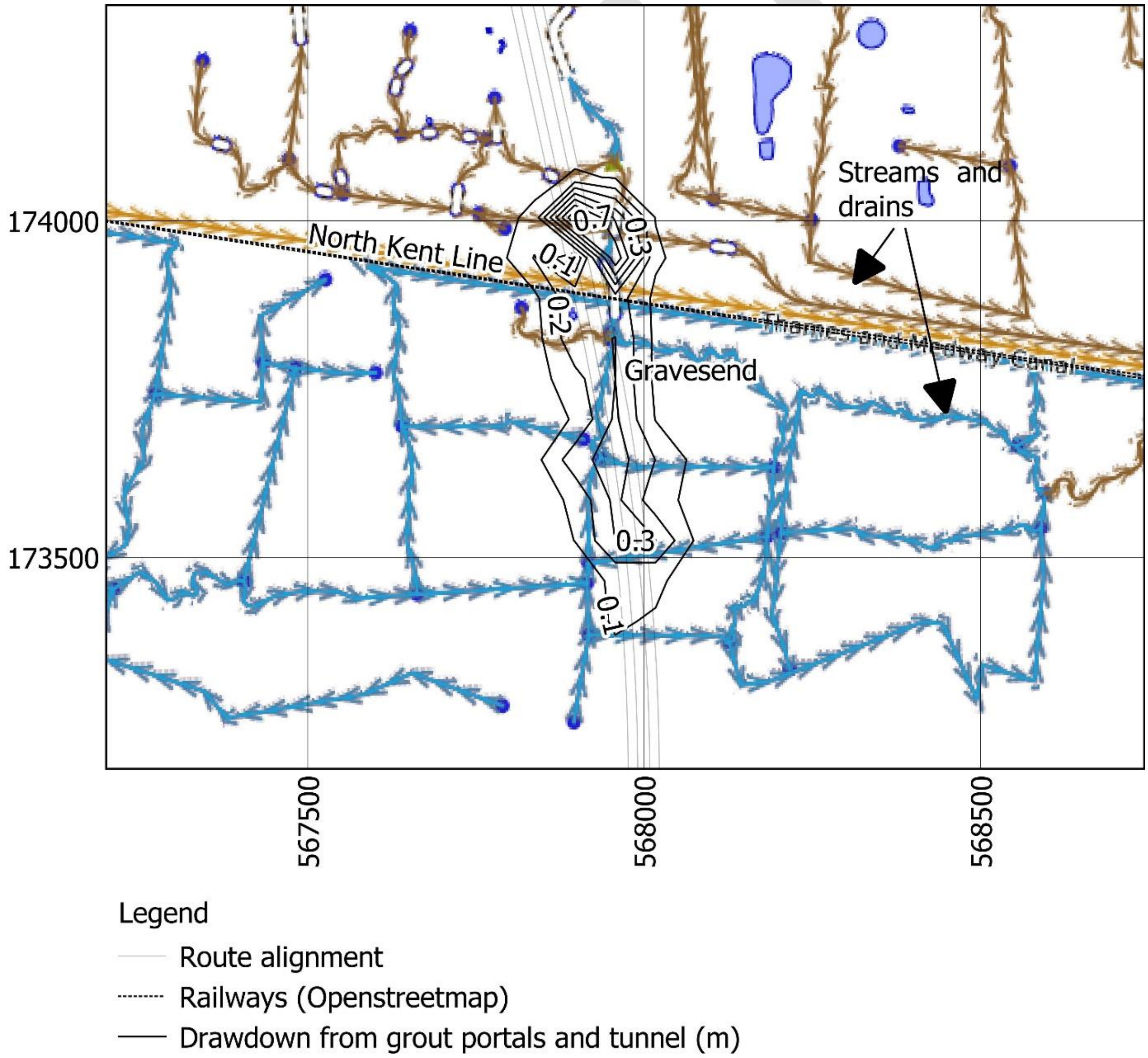


Figure 32 Drawdown of the water table from the grouting tunnel with inflow rate of 0.1 L/s/m^2

In a worst-case scenario, the inflow rate to the tunnel could be 0.5 L/d/m^2 of tunnel surface area. Figure 33 shows the drawdown predicted in this scenario at 2 m bgl. The calculated drawdown remains very small, this is because the prescribed flow rate into the tunnel remains very small.

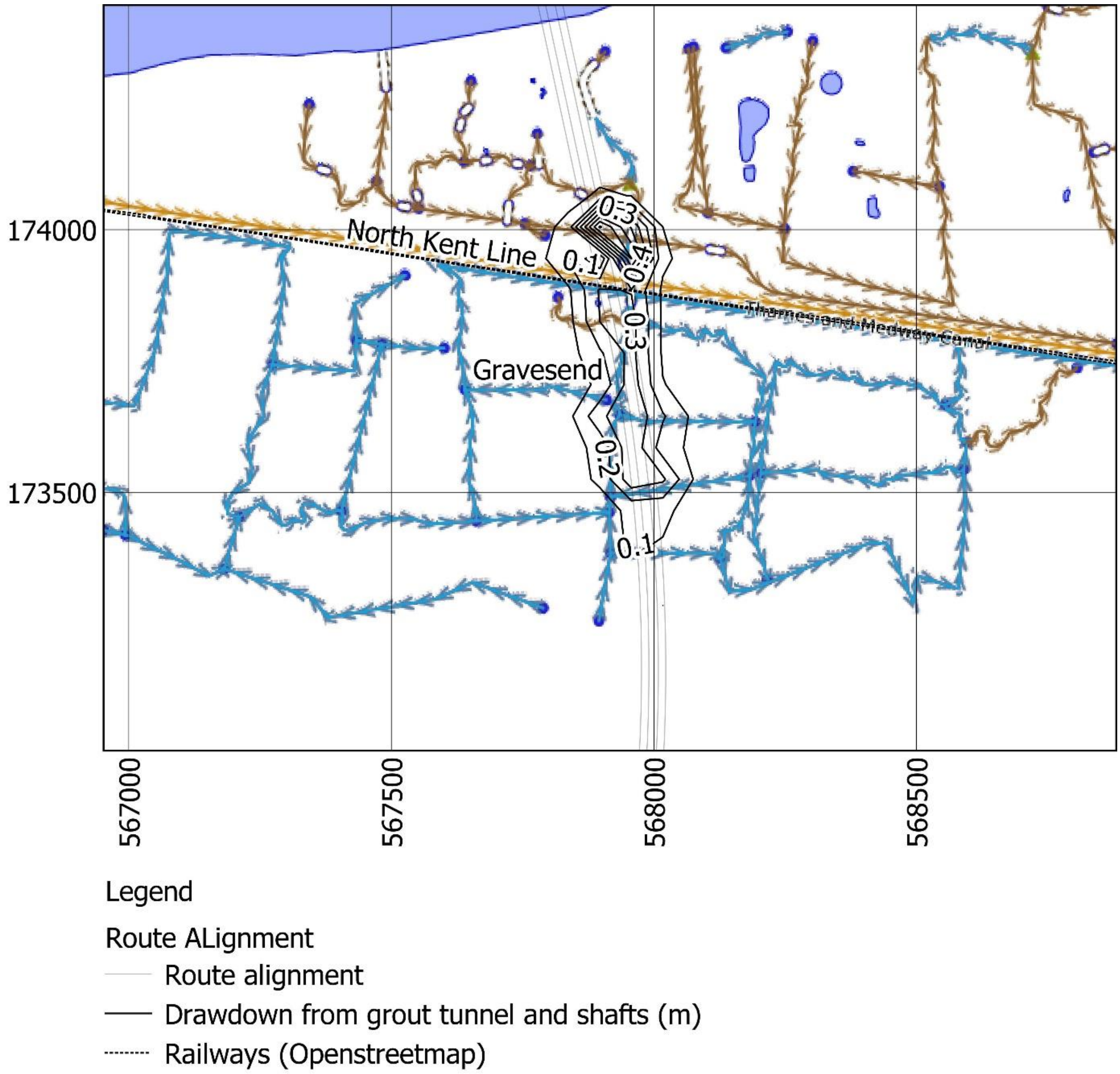


Figure 33 Drawdown from the grout tunnel with inflow rate of 0.5 L/s/m^2

3.3 Main tunnels (operation)

A separate scenario was completed that included the main tunnels only. In operation, the grout tunnel will no longer be drained of groundwater. The main tunnels boundary conditions are shown in Appendix D. The scenario included the following features:

- Main tunnel concrete TBM maintenance blocks; and
- Main tunnels prescribed drainage.

The water extracted from the main tunnels in the model was 0.2 L/s (18.4 m^3/d). Figure 34 shows the predicted drawdown for this scenario.

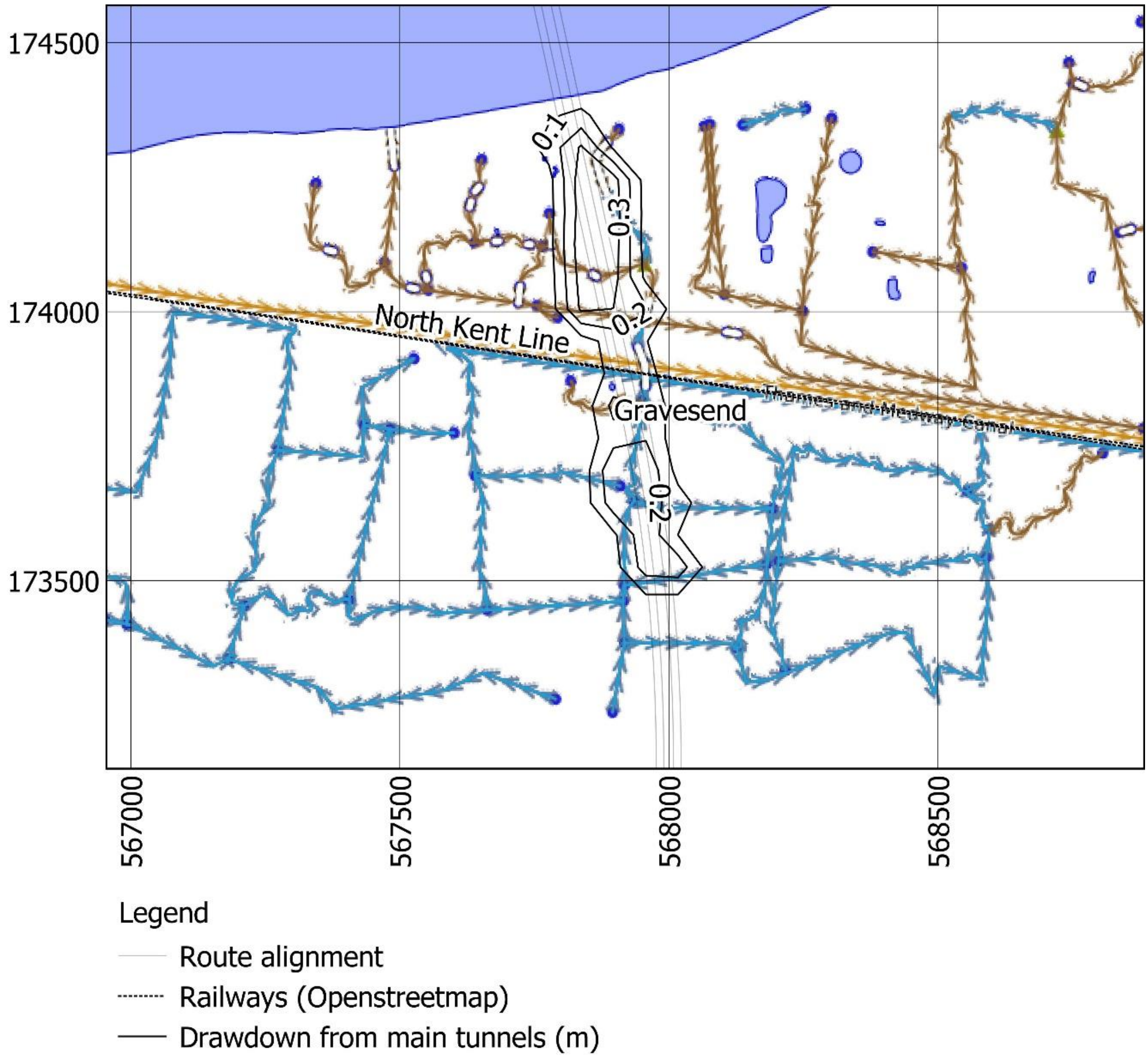


Figure 34 Drawdown from the main LTC tunnels with an inflow rate of 0.1 L/s/m^2

In the worst-case scenario, the inflow rate to the main tunnels could be 0.5 L/d/m^2 of tunnel surface area. Figure 35 shows the drawdown predicted in this scenario at 2 m bgl. The difference between the two scenarios is negligible. This is because the total inflow rate is very low in comparison to the aquifer hydraulic conductivities. The predicted drawdown of the water table caused by the main tunnels is slightly broader in extent than that of the grout tunnel, but less in magnitude. This is because the main tunnels are deeper than the grout tunnels.

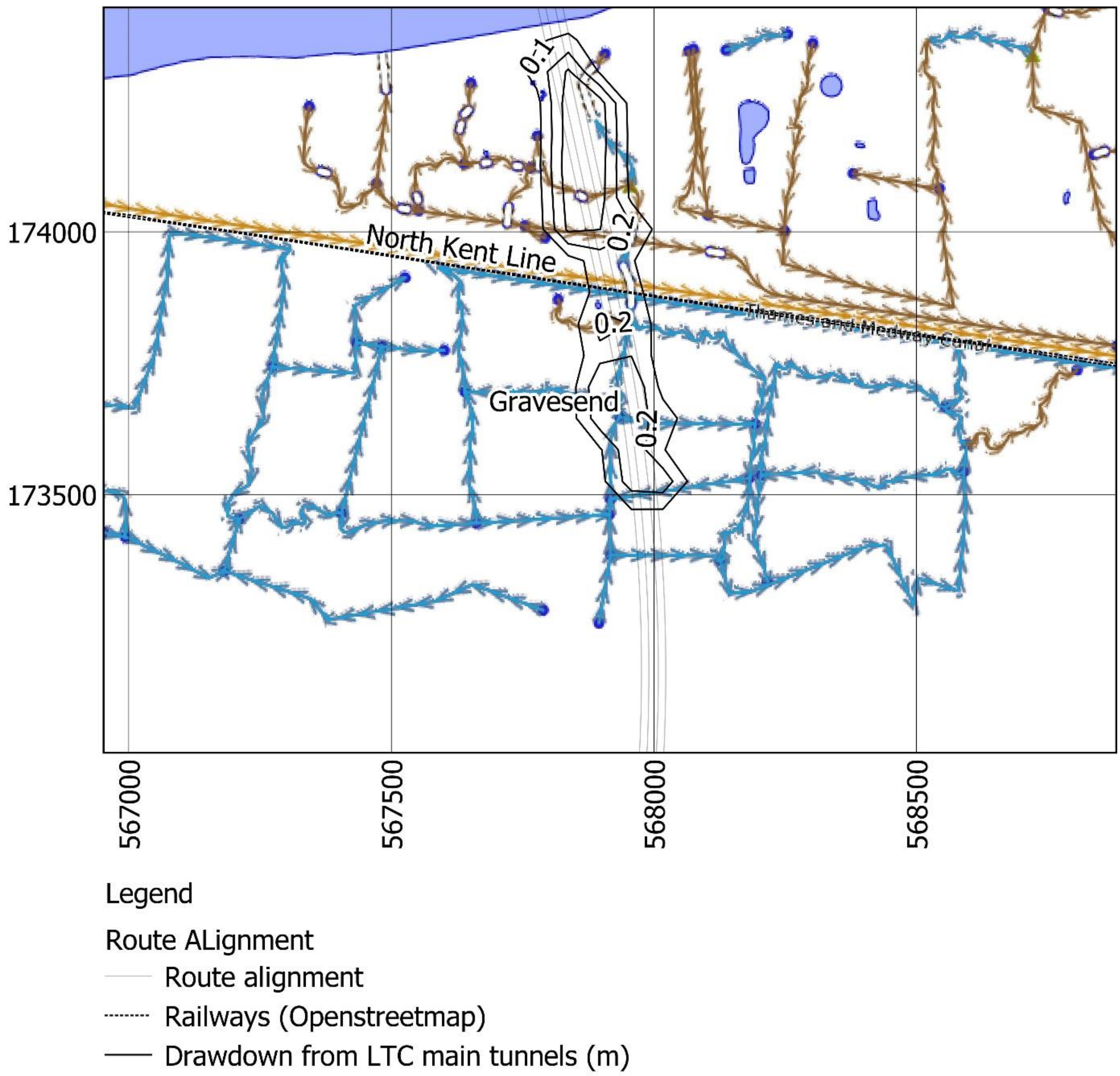


Figure 35 Drawdown of the water table from the main LTC tunnels with an inflow rate of 0.5 L/s/m^2

4 Movement of the fresh- saline interface

4.1 Method

SEAWAT V4 (USGS (United States Geological Survey), 2007) is used via the FloPy interface to carry out the saline interface modelling. SEAWAT is a coupled version of MODFLOW and MT3DMS designed to simulate three-dimensional, variable density, saturated ground-water flow. The model is solved using a finite difference approximation similar to the one solved by MODFLOW-2000.

The SEAWAT models have been completed in steady state.

Table 12 provides the additional parameters that are implemented for SEAWAT for the baseline model.

Table 12 SEAWAT specific parameters

Applied to all models	**Parameter**	**Value**	**Unit**
Dt0	Timestep length	Unspecified (determined by solver)	d
dmcoef	Molecular diffusion coefficient	0.57	m^2/d From Henry Problem
al	Longitudinal Dispersivity	Kh*3	m
trpt	Transverse Dispersivity	0.1*Longitudinal Dispersivity	m
trpv	Vertical Dispersivity	0.05*Longitudinal Dispersivity	m
River boundary concentration		20	g/l
denseref	Reference density of water	1000	g/l
denseslp	The slope of the linear equation of state that relates fluid density to solute concentration	0.7143	From Henry Problem
iwtable	Flag	0	Water table correction for density not applied
densemin densemax	Flag	0	No limitation
Sconc	Initial concentration	Initial distribution concentration calculated based on Ghyben-Herzberg approximation, with a maximum of 20 g/l	g/l
InitHds	Initial Heads	Topography	m AOD

Perlen	Length of simulation	Steady state	d
nstp	Number of stress periods	1	
dt0		5000	days per time period

4.2 Results of SEAWAT modelling

Figure 36, Figure 37 and Figure 38 provide a cross section through model column 62 (Easting 567856) for the baseline, grouting tunnel and main tunnels scenarios. This is the cross section through which the conceptual model was drawn (section 2.2.5).

Figure 39 and Figure 40 show the concentration change at 20 m bgl in the Chalk between the baseline, grouting tunnel and main tunnel scenarios, respectively. The concentration change is less than 0.2 g/l. The figures show that there is a small increase where the LTC route crosses beneath the Thames, as expected. Similar magnitude changes occur elsewhere in the layer, at considerable distance from the scheme. This suggests that the changes are potentially within the error of the model solution accuracy and can be considered as negligible. This is to be expected as the volume of groundwater drained to the scheme is very small.

The steady state solution does not include the natural impacts of the tidal flushing of the upper part of the Chalk aquifer with saline water from the Thames. The impact of this is likely to be significantly larger that the impact of the scheme.

Overall, the modelling results indicates that there will be no measurable movement of the saline interface due to the scheme. This is due to the construction methodology and materials used in construction, which together cause the inflow to the scheme be negligible in terms of the wider water balance, as well as the existing large scale impact of the River Thames tidal fluctuation.

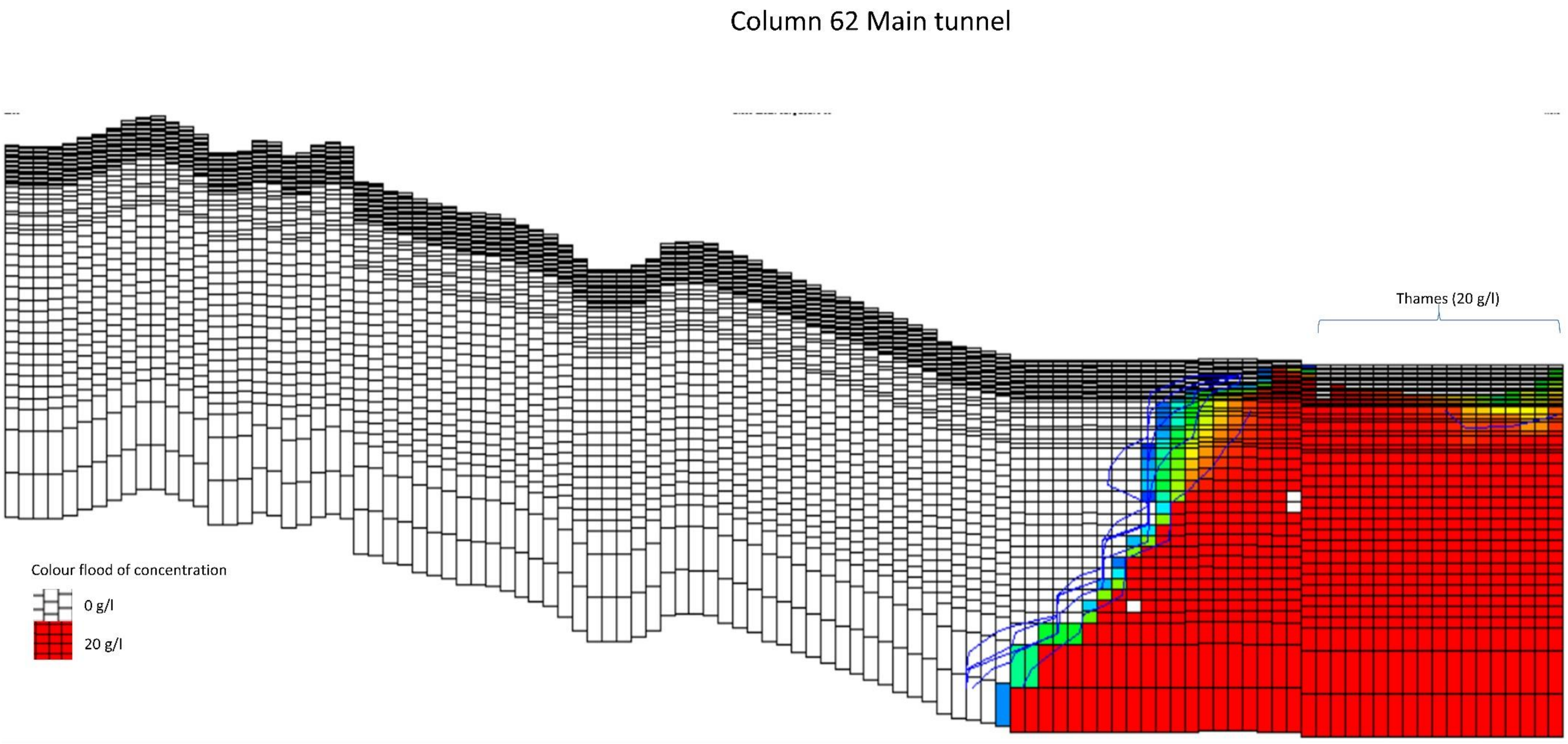


Figure 36 Position of the saline interface in the baseline scenario. Vertical exaggeration approximately 10x.

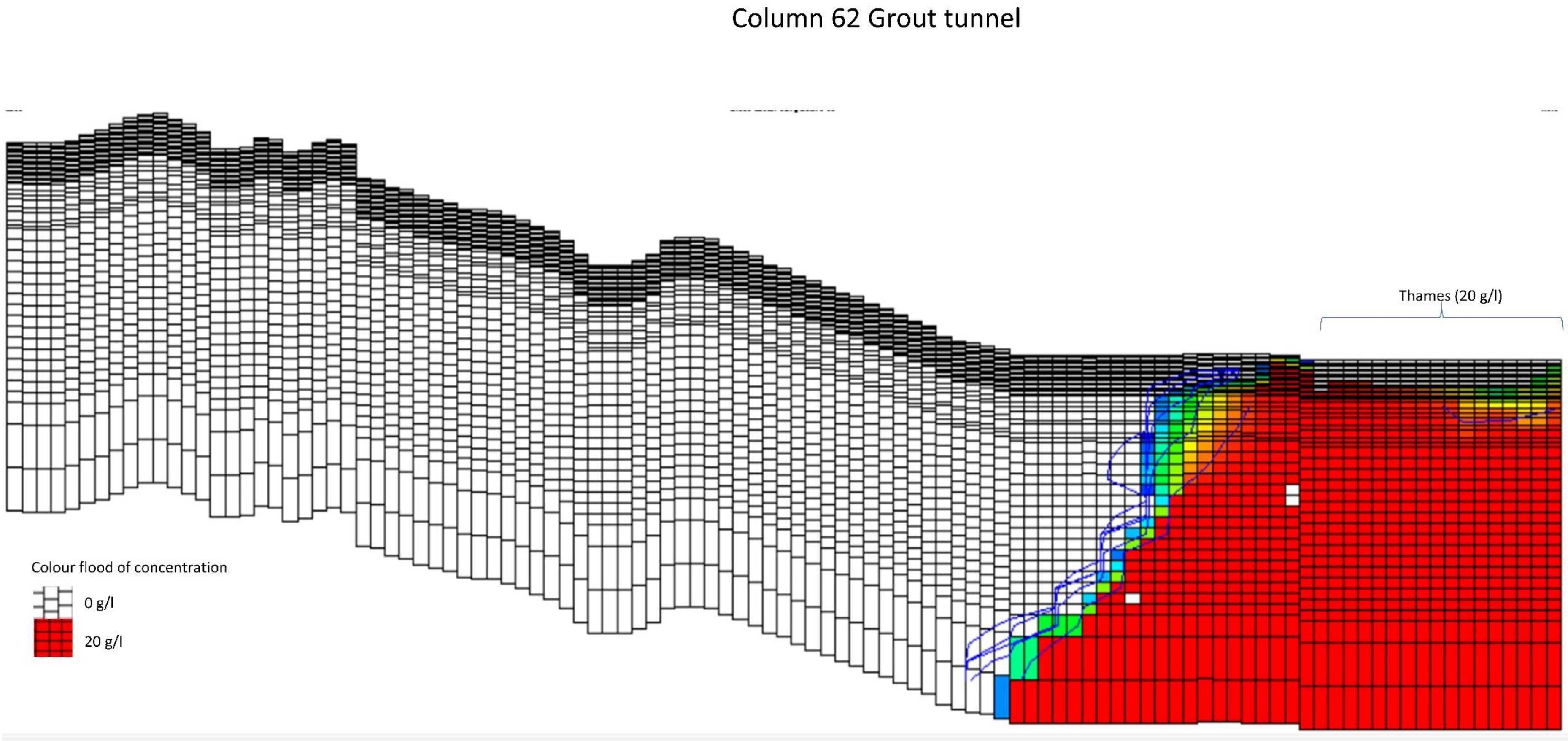


Figure 37 Position of the saline interface in the grouting shafts and grouting tunnel scenario. Vertical exaggeration approximately 10x.

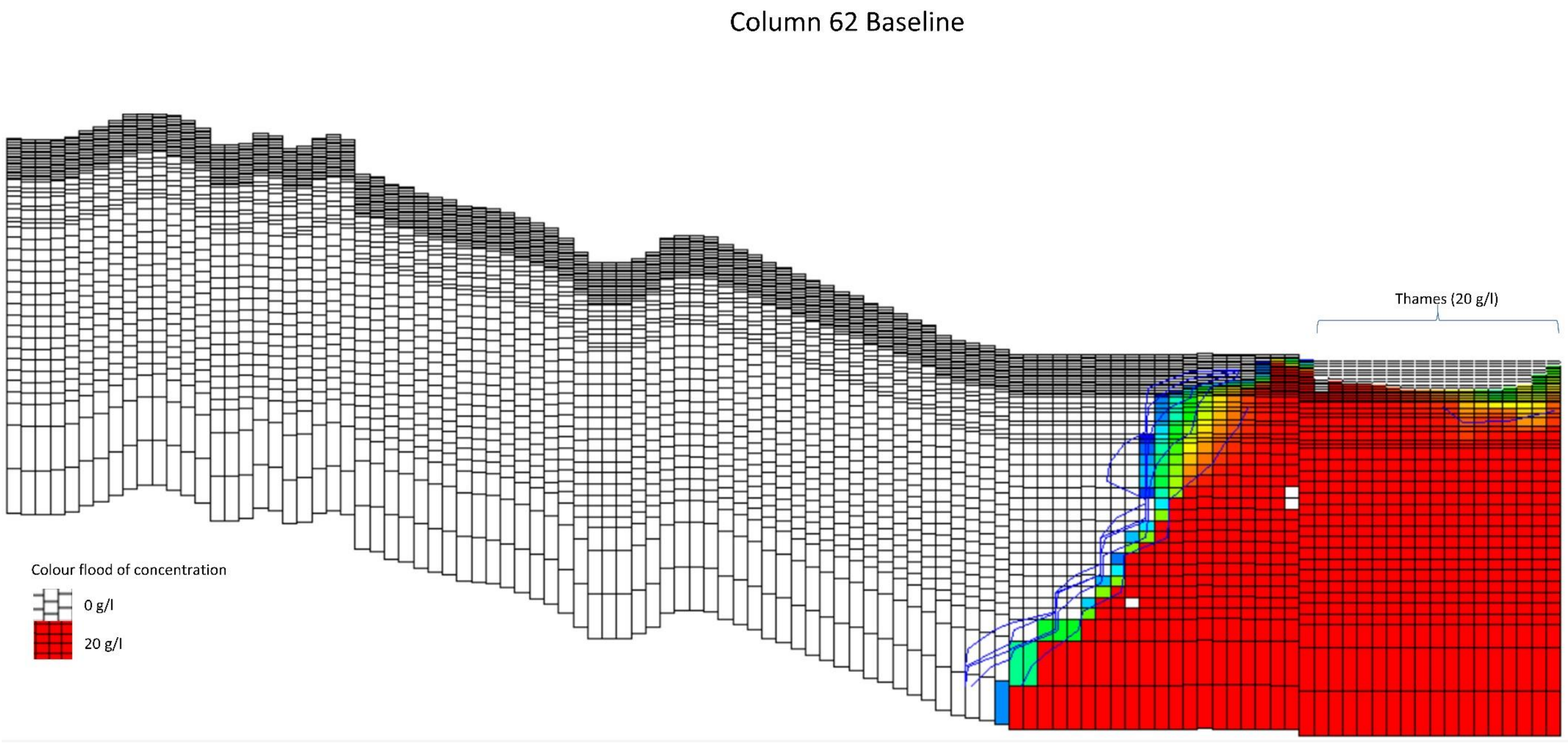


Figure 38 Position of the saline interface in the main tunnels scenario. Vertical exaggeration approximately 10 x.

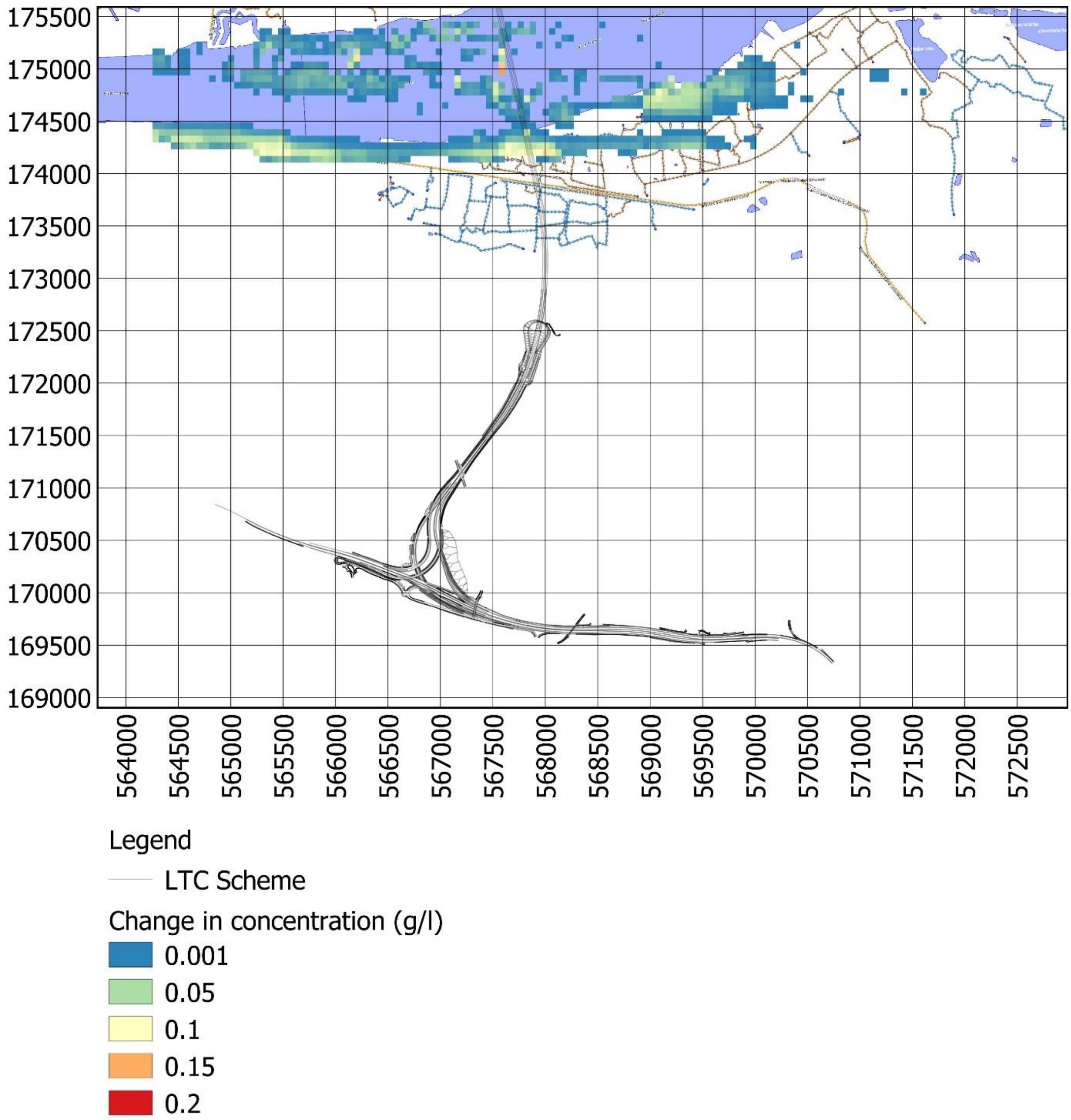


Figure 39 Concentration change between baseline and grouting tunnel scenario at 20 m bgl

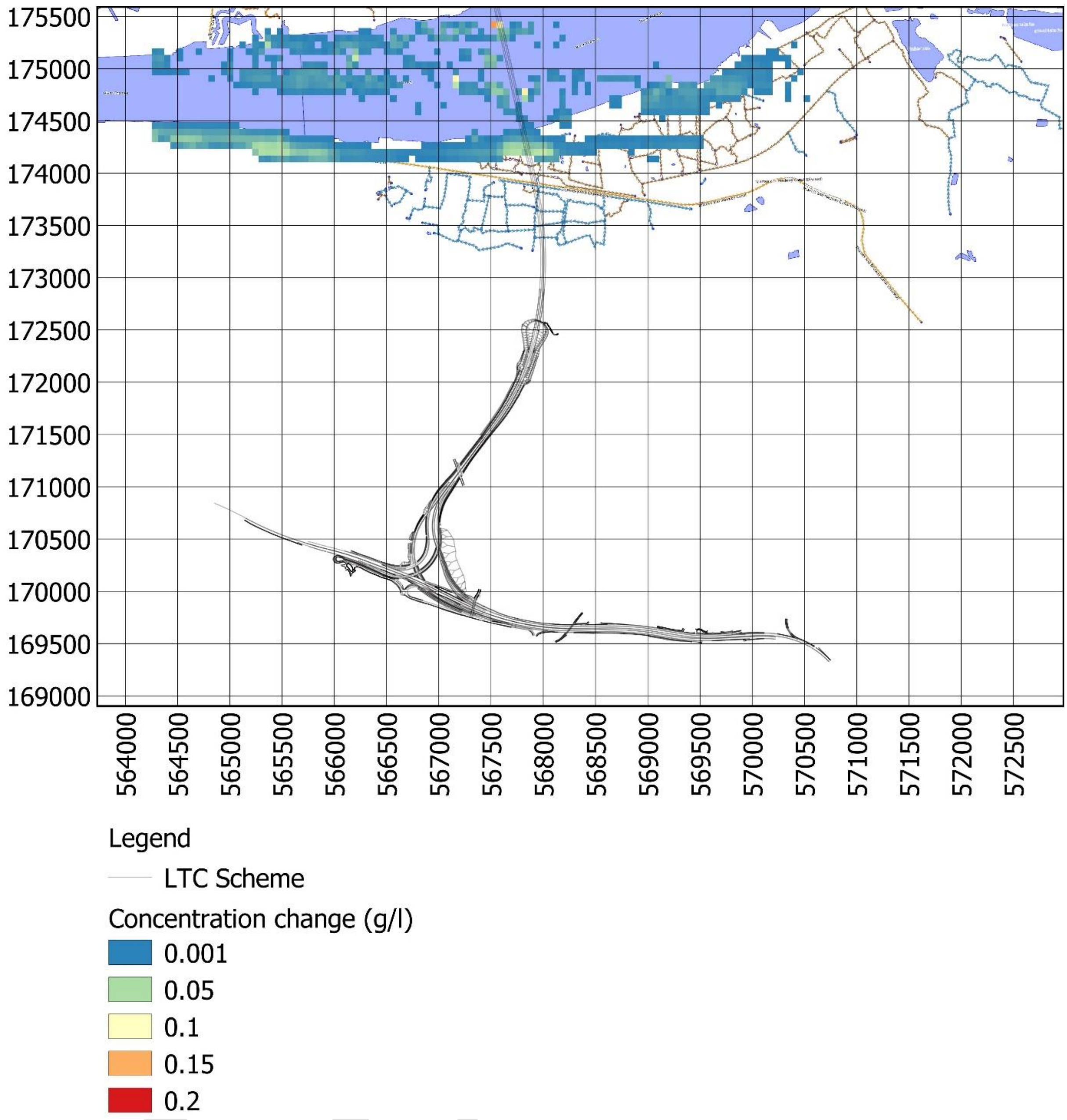


Figure 40 Concentration change between baseline and LTC main tunnels scenario at 20 m bgl

5 Summary

Groundwater modelling has been completed for the proposed advanced grouting tunnel and LTC main tunnels in the Ramsar site area, south of the River Thames.

The groundwater model included a 3D geological model supplied by the BGS, supplemented with site specific information obtained from ground investigations completed by LTC. This data included material type, stratigraphy and RQD information from boreholes, packer test, variable head test and pumping test data.

Groundwater level data from LTC boreholes was used for calibration of the steady state model and a time-variant tidal response model. As a result of calibration to the new data, adjustments were made to the conceptual model. These included a zone of high transmissivity associated with RQD of less than 0.1, zones of core loss and Chalk Ciria weathering grade D. This zone enables a strong hydraulic, confined response within the Chalk to the River Thames tide. These high transmissivities exist at a shallow elevation within the Chalk, in a relatively thin layer beneath the River Terrace Deposits as well as a thicker zone at the edge of the alluvium. Their position is similar to those found in other projects local to this area.

A manual calibration was completed, followed by a Monte Carlo assessment. In both parameters were varied within suitable ranges to determine the ranges that maintain a reasonable calibration.

Prediction of drawdown was completed using the 50^{th} percentile results of the Monte Carlo assessment. These are the most realistic parameter set.

The modelling scenarios completed included:

- Advanced grouting tunnel shafts only
- Shafts and advanced grouting tunnel
- Main tunnels (operation).

The mitigations embedded in the design cause the inflow rates to the tunnels to be very low. These mitigations include:

- Use of pressurised TBM method that inhibits groundwater inflow during drilling;
- Stopping the TBM within grout blocks for TBM maintenance;
- Use of caisson methods and pre-grouting of ingress and egress shafts to inhibit groundwater inflow; and
- Specification of the maximum leakage rates based on the British Tunnelling Society prescribed leakage rates for tunnels and advice from the LTC-CASCADE Tunnels Portal team.

The inflow to the LTC grouting and main tunnels was simulated at both prescribed inflow rates of 0.1 $L/d/m^2$ and 0.5 $L/d/m^2$, the latter being considered the worst case. Both sets of simulations gave a very similar result. The results for the worst case were:

- Advanced grouting tunnel shafts

  - The predicted total inflow to the shafts, simulated as drains in the model, is 3.2 L/s (284 m^3/d). This prediction assumes that shafts are fully surrounded by a hydraulic barrier 0.5 m thick with a hydraulic conductivity of $1x10^{-7}$ m/s.
- Advanced grouting tunnel
  - The 0.1 m contour extends from northing 173374 to northing 174081;
  - Drawdown extends 60 m or less from the grouting tunnel and reaches a maximum of 0.3 m above the tunnel;
  - The southern shaft is not predicted to cause drawdown of more than 0.1 m;
  - The northern shaft is predicted to cause drawdown of 0.7 m immediately adjacent to it. This reduces to less than 0.1 m at a distance of 120 m from the shaft.
- Main tunnels
  - the 0.1 m contour extends from northing 176465 to northing 174377;
  - The extent of the drawdown is limited to the model cells above the main tunnels, forming a channel approximately 120 m wide;
  - Maximum drawdown is predicted to be 0.3 m along a line immediately above the main tunnels within this area.

The SEAWAT models show that there would be no increase in salinity below the Ramsar site, as a result of the underground infrastructure. The model predicts no significant movement of the saline/fresh water interface, either during construction or operation. This is the same for both prescribed leakage rates.

Overall, the model indicates that the mitigations built into the scheme are effective at minimising the groundwater drainage to the below groundwater level infrastructure and so also at minimising the amount of drawdown caused by the scheme.

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Appendix A: Packer and variable head tests included in the model

BH2322	2.28	-13.32	2.40E-06	567883.4	173842.1	0.5	60	562289_V9-Final AGS2-Phase1A	Rising head	15.6	15.6
BH2322	2.28	-13.32	2.80E-05	567883.4	173842.1	0.5	60	562289_V9-Final AGS2-Phase1A	Falling head	15.6	15.6
BH2384	8.79	-18.11	8.00E-07	567348.3	176334.8	0.5	60	562289_V9-Final AGS2-Phase1A	Falling head	27.15	26.65
BH2384	8.79	-24.19	1.50E-06	567348.3	176334.8	0.5	60	562289_V9-Final AGS2-Phase1A	Falling head	33.23	32.73
BH2384	8.79	-22.86	2.00E-06	567348.3	176334.8	0.5	60	562289_V9-Final AGS2-Phase1A	Falling head	31.9	31.4
BH2385	7.14	-18.28	9.70E-07	567407.8	176463.1	0.5	60	562289_V9-Final AGS2-Phase1A	Falling head	25.67	25.17
BH2392A	5.36	-16.64	4.90E-06	567363.5	176631.4	0.5	60	562289_V9-Final AGS2-Phase1A	Falling head	22	22
BH2392A	5.36	-16.64	5.60E-04	567363.5	176631.4	0.5	60	562289_V9-Final AGS2-Phase1A	Rising head	22	22

BH2384	8.79	-2.61	2.20E-06	567348.3	176334.8	0.6	60	562289_V9-Final AGS2-Phase1A	Falling head	11.7	11.1
BH2385	7.14	-20.46	3.50E-07	567407.8	176463.1	0.6	60	562289_V9-Final AGS2-Phase1A	Falling head	27.9	27.3
BH2385	7.14	-22.81	6.50E-07	567407.8	176463.1	0.6	60	562289_V9-Final AGS2-Phase1A	Falling head	30.25	29.65
BH2308	2.2	-1.7	6.00E-06	568082.9	173268.7	1	60	562289_V9-Final AGS2-Phase1A	Rising head	4.4	3.4
BH2308	2.2	-6.8	2.70E-05	568082.9	173268.7	1	60	562289_V9-Final AGS2-Phase1A	Rising head	9.5	8.5
BH02002	48.6	-6.9	5.08E-07	567807.4	171508.1	1.5	120		Packer		
BH02002	48.6	29.1	1.63E-06	567807.4	171508.1	1.5	120		Packer		
BH02002	48.6	38.35	1.73E-06	567807.4	171508.1	1.5	120		Packer		
BH2301	9.17	-39.28	4.97E-06	568028	173026.3	1.5	120		Packer		
BH2301	9.17	-9.28	1.00E-05	568028	173026.3	1.5	120		Packer		
BH2301	9.17	-27.28	2.02E-05	568028	173026.3	1.5	120		Packer		

BH2301	9.17	-21.28	3.27E-05	568028	173026.3	1.5	120		Packer		
BH2301	9.17	-13.28	3.89E-05	568028	173026.3	1.5	120		Packer		
BH04009	5.8	-12.2	1.20E-05	567926	173142.8	1.5	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	18.75	17.25
BH04009	5.8	-12.2	1.25E-05	567926	173142.8	1.5	120		Packer		
BH04009	5.8	-12.2	1.30E-05	567926	173142.8	1.5	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	18.75	17.25
BH04009	5.8	-12.2	1.40E-05	567926	173142.8	1.5	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	18.75	17.25
BH04009	5.8	-12.2	1.50E-05	567926	173142.8	1.5	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	18.75	17.25
BH04009	5.8	-12.2	1.60E-05	567926	173142.8	1.5	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	18.75	17.25

BH04009	5.8	-12.2	1.80E-05	567926	173142.8	1.5	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	18.75	17.25
BH04009	5.8	-15.2	2.40E-05	567926	173142.8	1.5	120		Packer		
BH04009	5.8	-15.2	2.40E-05	567926	173142.8	1.5	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	21.75	20.25
BH04009	5.8	-15.2	3.00E-05	567926	173142.8	1.5	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	21.75	20.25
BH04009	5.8	-15.2	3.10E-05	567926	173142.8	1.5	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	21.75	20.25
BH04009	5.8	-15.2	3.20E-05	567926	173142.8	1.5	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	21.75	20.25
OH07022	7.24	-36.01	9.30E-06	567341	176009	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012083	Water Pressure	44	42.5
OH07022	7.24	-36.01	9.70E-06	567341	176009	1.5	60	B-AGSF-X-X-X-D-X-X-	Water Pressure	44	42.5

								X-0003-02012082			
OH07022	2.33	-36.01	1.00E-05	567341	176009	1.5	120		Packer		
OH07022	7.24	-36.01	1.00E-05	567341	176009	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012081	Water Pressure	44	42.5
OH07022	7.24	-36.01	1.00E-05	567341	176009	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012084	Water Pressure	44	42.5
OH07022	7.24	-36.01	1.10E-05	567341	176009	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012080	Water Pressure	44	42.5
OH07022	7.24	-29.01	3.00E-05	567341	176009	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012075	Water Pressure	37	35.5
OH07022	7.24	-29.01	3.30E-05	567341	176009	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012076	Water Pressure	37	35.5
OH07022	7.24	-29.01	4.40E-05	567341	176009	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012077	Water Pressure	37	35.5

OH07022	7.24	-29.01	4.50E-05	567341	176009	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012078	Water Pressure	37	35.5
OH07022	2.33	-29.01	4.73E-05	567341	176009	1.5	120		Packer		
OH07022	7.24	-29.01	5.30E-05	567341	176009	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012079	Water Pressure	37	35.5
OH07022	2.33	-32.51	5.48E-05	567341	176009	1.5	120		Packer		
OH07021	7.64	-57.86	1.60E-07	567530	176062	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012072	Water Pressure	66.25	64.75
OH07021	7.64	-57.86	1.60E-07	567530	176062	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012074	Water Pressure	66.25	64.75
OH07021	7.64	-57.86	2.30E-07	567530	176062	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012073	Water Pressure	66.25	64.75
OH07021	2.33	-57.86	2.40E-07	567530	176062	1.5	120		Packer		
OH07021	7.64	-57.86	3.30E-07	567530	176062	1.5	60	B-AGSF-X-X-X-D-X-X-	Water Pressure	66.25	64.75

								X-0003-02012070			
OH07021	7.64	-57.86	4.90E-07	567530	176062	1.5	60	B-AGSF-X-X-X-D-X-X-X-0003-02012071	Water Pressure	66.25	64.75
OH07040	2.33	-35.52	7.24E-06	567379	176105	1.5	120		Packer		
OH07040	2.33	-32.02	9.00E-06	567379	176105	1.5	120		Packer		
OH07040	2.33	-28.52	4.24E-05	567379	176105	1.5	120		Packer		
BH1306	7.4	-27.8	3.61E-06	567449.8	175700.3	1.6	120		Packer		
BH1306	7.4	-33.8	4.89E-06	567449.8	175700.3	1.6	120		Packer		
BH1306	7.4	-39.8	2.27E-05	567449.8	175700.3	1.6	120		Packer		
OW06016	26.21	-45.7	2.65E-06	567608.5	175545.6	2	120		Packer		
OW06016	26.21	-41.7	2.76E-06	567608.5	175545.6	2	120		Packer		
OW06016	26.21	-33.7	1.52E-05	567608.5	175545.6	2	120		Packer		
BH13002	23.66	9.16	4.20E-07	564805.2	180074.9	2	60	C-AGSF-X-X-X-D-X-X-	Falling Head	15.5	13.5

								X-0004-02012064			
BH01003	68.85	-1.15	2.60E-07	570033	169729.1	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	71.5	68.5
BH01003	68.85	-1.15	2.70E-07	570033	169729.1	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	71.5	68.5
BH01003	68.85	-1.15	2.72E-07	570033	169729.1	3	120		Packer		
BH01003	68.85	-1.15	2.80E-07	570033	169729.1	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	71.5	68.5
BH01003	68.85	-1.15	2.90E-07	570033	169729.1	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	71.5	68.5
BH01003	68.85	2.85	5.40E-07	570033	169729.1	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	67.5	64.5
BH01003	68.85	2.85	5.60E-07	570033	169729.1	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	67.5	64.5

BH01003	68.85	2.85	5.86E-07	570033	169729.1	3	120		Packer		
BH01003	68.85	2.85	5.90E-07	570033	169729.1	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	67.5	64.5
BH01003	68.85	2.85	6.00E-07	570033	169729.1	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	67.5	64.5
BH01003	68.85	2.85	6.40E-07	570033	169729.1	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	67.5	64.5
BH01003	68.85	6.85	8.90E-07	570033	169729.1	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63.5	60.5
BH01003	68.85	6.85	9.90E-07	570033	169729.1	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63.5	60.5
BH01003	68.85	6.85	1.04E-06	570033	169729.1	3	120		Packer		
BH01003	68.85	6.85	1.10E-06	570033	169729.1	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63.5	60.5

BH01025	70.9	9.4	1.20E-07	567177.8	170977.2	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63	60
BH01025	70.9	15.4	1.20E-07	567177.8	170977.2	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	57	54
BH01025	70.9	9.4	1.65E-07	567177.8	170977.2	3	120		Packer		
BH01025	70.9	9.4	2.10E-07	567177.8	170977.2	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63	60
BH01025	70.9	15.4	2.60E-07	567177.8	170977.2	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	57	54
BH01025	70.9	9.4	2.70E-07	567177.8	170977.2	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63	60
BH01025	70.9	15.4	2.70E-07	567177.8	170977.2	3	120		Packer		
BH01025	70.9	9.4	2.90E-07	567177.8	170977.2	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	63	60

BH01025	70.9	15.4	2.90E-07	567177.8	170977.2	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	57	54
BH01025	70.9	15.4	3.10E-07	567177.8	170977.2	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	57	54
BH01025	70.9	12.4	4.10E-07	567177.8	170977.2	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	60	57
BH01025	70.9	12.4	4.30E-07	567177.8	170977.2	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	60	57
BH01025	70.9	12.4	4.40E-07	567177.8	170977.2	3	120		Packer		
BH01025	70.9	12.4	4.60E-07	567177.8	170977.2	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	60	57
BH01025	70.9	12.4	4.70E-07	567177.8	170977.2	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	60	57
BH02002	48.6	20.1	3.30E-07	567807.4	171508.1	3	120		Packer		

BH02002	48.6	7.1	4.20E-07	567807.4	171508.1	3	120		Packer		
BH02002	48.6	0.1	6.90E-07	567807.4	171508.1	3	120		Packer		
BH02002	48.6	14.1	8.65E-07	567807.4	171508.1	3	120		Packer		
BH04009	5.8	-25.2	2.30E-06	567926	173142.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	32.5	29.5
BH04009	5.8	-25.2	2.50E-06	567926	173142.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	32.5	29.5
BH04009	5.8	-25.2	2.52E-06	567926	173142.8	3	120		Packer		
BH04009	5.8	-25.2	2.60E-06	567926	173142.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	32.5	29.5
BH04009	5.8	-25.2	2.70E-06	567926	173142.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	32.5	29.5
BH04009	5.8	-20.2	7.50E-06	567926	173142.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	27.5	24.5

BH04009	5.8	-20.2	8.00E-06	567926	173142.8	3	120		Packer		
BH04009	5.8	-20.2	8.50E-06	567926	173142.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	27.5	24.5
BH04009	5.8	-20.2	8.60E-06	567926	173142.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	27.5	24.5
BH04009	5.8	-20.2	9.20E-06	567926	173142.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	27.5	24.5
BH04009	5.8	-20.2	9.60E-06	567926	173142.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	27.5	24.5
BH04015	1.95	-42.05	2.10E-07	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	45.5	42.5
BH04015	1.95	-42.05	2.15E-07	568028.6	173521.8	3	120		Packer		
BH04015	1.95	-42.05	2.20E-07	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	45.5	42.5

BH04015	1.95	-42.05	2.40E-07	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	45.5	42.5
BH04015	1.95	-42.05	2.60E-07	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	45.5	42.5
BH04015	1.95	-42.05	2.90E-07	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	45.5	42.5
BH04015	1.95	-34.85	3.90E-06	568028.6	173521.8	3	120		Packer		
BH04015	1.95	-34.85	3.90E-06	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	38.3	35.3
BH04015	1.95	-30.05	3.90E-06	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	33.5	30.5
BH04015	1.95	-30.05	4.10E-06	568028.6	173521.8	3	120		Packer		
BH04015	1.95	-30.05	4.30E-06	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	33.5	30.5

BH04015	1.95	-34.85	4.40E-06	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	38.3	35.3
BH04015	1.95	-30.05	4.80E-06	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	33.5	30.5
BH04015	1.95	-30.05	5.00E-06	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	33.5	30.5
BH04015	1.95	-34.85	5.20E-06	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	38.3	35.3
BH04015	1.95	-30.05	5.90E-06	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	33.5	30.5
BH04015	1.95	-34.85	6.60E-06	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	38.3	35.3
BH04015	1.95	-34.85	7.90E-06	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	38.3	35.3

BH04015	1.95	-25.25	8.80E-06	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	28.7	25.7
BH04015	1.95	-25.25	1.10E-05	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	28.7	25.7
BH04015	1.95	-25.25	1.14E-05	568028.6	173521.8	3	120		Packer		
BH04015	1.95	-25.25	1.20E-05	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	28.7	25.7
BH04015	1.95	-25.25	1.30E-05	568028.6	173521.8	3	120	A-AGSF-X-X-X-D-X-X-X-0001-02012020	Double packer test	28.7	25.7
BH2316	2.18	-16.32	7.00E-07	568038.2	173653.4	3	60	562289_V9-Final AGS2-Phase1A	Falling head	20	17
BH2316	2.18	-29.82	1.70E-06	568038.2	173653.4	3	60	562289_V9-Final AGS2-Phase1A	Falling head	33.5	30.5
BH2316	2.18	-37.97	7.78E-06	568038.2	173653.4	3	120		Packer		
BH2316	2.18	-31.97	1.53E-05	568038.2	173653.4	3	120		Packer		

BH2316	2.18	-25.97	1.54E-05	568038.2	173653.4	3	120		Packer		
OW05002	-7.72	-29.02	6.70E-06	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.8	19.8
OW05002	-7.72	-29.02	6.90E-06	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.8	19.8
OW05002	-7.72	-29.02	7.10E-06	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.8	19.8
OW05002	26.21	-29.02	7.12E-06	567742.3	174496.4	3	120		Packer		
OW05002	-7.72	-29.02	7.30E-06	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.8	19.8
OW05002	-7.72	-47.32	7.40E-06	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	41.1	38.1
OW05002	26.21	-47.32	7.40E-06	567742.3	174496.4	3	120		Packer		
OW05002	-7.72	-29.02	7.60E-06	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-	Packer Test	22.8	19.8

								X-0002-02012020			
OW05002	-7.72	-41.32	8.30E-06	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	35.1	32.1
OW05002	-7.72	-47.32	8.40E-06	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	41.1	38.1
OW05002	-7.72	-47.32	9.10E-06	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	41.1	38.1
OW05002	-7.72	-41.32	9.50E-06	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	35.1	32.1
OW05002	-7.72	-47.32	1.00E-05	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	41.1	38.1
OW05002	-7.72	-41.32	1.10E-05	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	35.1	32.1
OW05002	26.21	-41.32	1.10E-05	567742.3	174496.4	3	120		Packer		

OW05002	-7.72	-47.32	1.20E-05	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	41.1	38.1
OW05002	-7.72	-35.32	1.90E-05	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	29.1	26.1
OW05002	26.21	-35.32	1.90E-05	567742.3	174496.4	3	120		Packer		
OW05002	-7.72	-35.32	2.20E-05	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	29.1	26.1
OW05002	-7.72	-35.32	2.50E-05	567742.3	174496.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	29.1	26.1
OW05007	-12.22	-54.12	1.10E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	43.4	40.4
OW05007	-12.22	-54.12	1.30E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	43.4	40.4
OW05007	-12.22	-54.12	1.50E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-	Packer Test	43.4	40.4

								X-0002-02012020			
OW05007	-12.22	-54.12	1.60E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	43.4	40.4
OW05007	26.21	-54.12	1.60E-06	567781.6	174776.4	3	120		Packer		
OW05007	-12.22	-39.26	1.80E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	28.54	25.54
OW05007	-12.22	-54.12	1.90E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	43.4	40.4
OW05007	-12.22	-39.26	1.90E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	28.54	25.54
OW05007	-12.22	-32.96	1.90E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	26.21	-39.26	1.98E-06	567781.6	174776.4	3	120		Packer		
OW05007	-12.22	-39.26	2.00E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-	Packer Test	28.54	25.54

								X-0002-02012020			
OW05007	-12.22	-32.96	2.10E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	-12.22	-39.26	2.30E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	28.54	25.54
OW05007	-12.22	-32.96	2.30E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	-12.22	-32.96	2.50E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	26.21	-32.96	2.53E-06	567781.6	174776.4	3	120		Packer		
OW05007	-12.22	-32.96	2.80E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	-12.22	-48.12	4.60E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	37.4	34.4

OW05007	26.21	-48.12	4.60E-06	567781.6	174776.4	3	120		Packer		
OW05007	-12.22	-48.12	4.90E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	37.4	34.4
OW05007	-12.22	-48.12	5.40E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	37.4	34.4
OW05007	-12.22	-48.12	5.50E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	37.4	34.4
OW05007	-12.22	-32.96	6.30E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	26.21	-32.96	6.30E-06	567781.6	174776.4	3	120		Packer		
OW05007	-12.22	-48.12	6.80E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	37.4	34.4
OW05007	-12.22	-32.96	9.70E-06	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24

OW05007	-12.22	-32.96	1.10E-05	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	-12.22	-32.96	1.30E-05	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW05007	-12.22	-32.96	1.50E-05	567781.6	174776.4	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	22.24	19.24
OW06001	-13.15	-32.99	3.90E-07	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	21.34	18.34
OW06001	-13.15	-32.99	4.10E-07	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	21.34	18.34
OW06001	-13.15	-32.99	4.30E-07	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	21.34	18.34
OW06001	-13.15	-32.99	4.70E-07	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	21.34	18.34

OW06001	-13.15	-32.99	4.80E-07	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	21.34	18.34
OW06001	26.21	-32.99	9.00E-06	567659.3	174856.3	3	120		Packer		
OW06001	-13.15	-39.55	9.30E-06	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	27.9	24.9
OW06001	-13.15	-39.55	9.90E-06	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	27.9	24.9
OW06001	-13.15	-39.55	1.00E-05	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	27.9	24.9
OW06001	26.21	-39.55	1.00E-05	567659.3	174856.3	3	120		Packer		
OW06001	-13.15	-45.55	1.10E-05	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	33.9	30.9
OW06001	-13.15	-39.55	1.10E-05	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	27.9	24.9

OW06001	-13.15	-51.55	1.40E-05	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	39.9	36.9
OW06001	-13.15	-45.55	1.40E-05	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	33.9	30.9
OW06001	-13.15	-51.55	1.50E-05	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	39.9	36.9
OW06001	26.21	-51.55	1.52E-05	567659.3	174856.3	3	120		Packer		
OW06001	-13.15	-51.55	1.60E-05	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	39.9	36.9
OW06001	-13.15	-45.55	1.60E-05	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	33.9	30.9
OW06001	-13.15	-51.55	1.70E-05	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	39.9	36.9
OW06001	-13.15	-45.55	1.70E-05	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-	Packer Test	33.9	30.9

								X-0002-02012020			
OW06001	26.21	-45.55	1.70E-05	567659.3	174856.3	3	120		Packer		
OW06001	-13.15	-45.55	1.80E-05	567659.3	174856.3	3	120	E-AGSF-X-X-X-D-X-X-X-0002-02012020	Packer Test	33.9	30.9
OW06006	26.21	-41.8	3.76E-06	567692.3	175144	3	120		Packer		
OW06006	26.21	-47.84	4.72E-06	567692.3	175144	3	120		Packer		
OW06006	26.21	-41.8	5.48E-06	567692.3	175144	3	120		Packer		
OW06006	26.21	-35.8	7.43E-06	567692.3	175144	3	120		Packer		
OW06016	26.21	-37.7	9.18E-06	567608.5	175545.6	3	120		Packer		
OH07022	7.24	-40.26	1.10E-06	567341	176009	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012086	Water Pressure	49	46
OH07022	7.24	-40.26	1.10E-06	567341	176009	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012087	Water Pressure	49	46

OH07022	7.24	-40.26	1.20E-06	567341	176009	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012088	Water Pressure	49	46
OH07022	7.24	-40.26	1.20E-06	567341	176009	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012089	Water Pressure	49	46
OH07022	2.33	-40.26	1.22E-06	567341	176009	3	120		Packer		
OH07022	7.24	-40.26	1.50E-06	567341	176009	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012085	Water Pressure	49	46
OH07021	7.64	-52.86	3.10E-07	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012066	Water Pressure	62	59
OH07021	7.64	-52.86	3.30E-07	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012065	Water Pressure	62	59
OH07021	7.64	-47.86	1.30E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012060	Water Pressure	57	54
OH07021	7.64	-47.86	1.80E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-	Water Pressure	57	54

								X-0003-02012061			
OH07021	7.64	-47.86	2.30E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012062	Water Pressure	57	54
OH07021	7.64	-47.86	2.40E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012063	Water Pressure	57	54
OH07021	7.64	-47.86	2.60E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012064	Water Pressure	57	54
OH07021	2.33	-47.86	2.83E-06	567530	176062	3	120		Packer		
OH07021	7.64	-52.86	3.20E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012067	Water Pressure	62	59
OH07021	7.64	-52.86	3.20E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012068	Water Pressure	62	59
OH07021	7.64	-38.86	3.50E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012058	Water Pressure	48	45

OH07021	7.64	-38.86	3.60E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012057	Water Pressure	48	45
OH07021	7.64	-38.86	3.60E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012059	Water Pressure	48	45
OH07021	2.33	-38.86	3.65E-06	567530	176062	3	120		Packer		
OH07021	7.64	-38.86	3.90E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012056	Water Pressure	48	45
OH07021	2.33	-52.86	4.00E-06	567530	176062	3	120		Packer		
OH07021	7.64	-52.86	4.00E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012069	Water Pressure	62	59
OH07021	7.64	-34.86	4.00E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012052	Water Pressure	44	41
OH07021	7.64	-34.86	4.10E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012051	Water Pressure	44	41

OH07021	7.64	-34.86	4.50E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012050	Water Pressure	44	41
OH07021	7.64	-34.86	4.50E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012053	Water Pressure	44	41
OH07021	2.33	-42.86	4.58E-06	567530	176062	3	120		Packer		
OH07021	7.64	-34.86	5.20E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012054	Water Pressure	44	41
OH07021	7.64	-38.86	5.50E-06	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012055	Water Pressure	48	45
OH07021	7.64	-30.86	4.70E-05	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012045	Water Pressure	40	37
OH07021	7.64	-30.86	4.90E-05	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012048	Water Pressure	40	37
OH07021	7.64	-30.86	5.00E-05	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-	Water Pressure	40	37

								X-0003-02012047			
OH07021	7.64	-30.86	5.10E-05	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012046	Water Pressure	40	37
OH07021	2.33	-30.86	5.12E-05	567530	176062	3	120		Packer		
OH07021	7.64	-30.86	5.90E-05	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012049	Water Pressure	40	37
OH07021	7.64	-26.86	8.00E-05	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012041	Water Pressure	36	33
OH07021	7.64	-26.86	8.40E-05	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012040	Water Pressure	36	33
OH07021	7.64	-26.86	8.40E-05	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012042	Water Pressure	36	33
OH07021	2.33	-26.86	8.70E-05	567530	176062	3	120		Packer		
OH07021	7.64	-26.86	8.80E-05	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-	Water Pressure	36	33

								X-0003-02012043			
OH07021	7.64	-26.86	9.90E-05	567530	176062	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012044	Water Pressure	36	33
OH07040	2.33	-38.77	3.88E-06	567379	176105	3	120		Packer		
OH07012	7.45	-34.05	1.10E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012033	KPO	43	40
OH07012	7.45	-34.05	1.40E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012032	KPO	43	40
OH07012	7.45	-34.05	1.60E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012034	KPO	43	40
OH07012	7.45	-38.05	1.70E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012039	KPO	47	44
OH07012	2.33	-38.05	1.75E-07	567559	176233	3	120		Packer		
OH07012	7.45	-38.05	1.80E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-	KPO	47	44

								X-0003-02012035			
OH07012	7.45	-34.05	1.80E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012031	KPO	43	40
OH07012	7.45	-34.05	1.90E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012030	KPO	43	40
OH07012	7.45	-30.05	3.40E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012027	KPO	39	36
OH07012	2.33	-30.05	3.60E-07	567559	176233	3	120		Packer		
OH07012	7.45	-30.05	3.60E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012028	KPO	39	36
OH07012	7.45	-30.05	3.80E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012026	KPO	39	36
OH07012	7.45	-30.05	4.80E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012025	KPO	39	36

OH07012	7.45	-30.05	4.90E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012029	KPO	39	36
OH07012	7.45	-38.05	6.60E-07	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012036	KPO	47	44
OH07012	7.45	-38.05	1.20E-06	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012038	KPO	47	44
OH07012	7.45	-38.05	1.50E-06	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012037	KPO	47	44
OH07012	7.45	-26.05	7.40E-06	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012023	Water Pressure	35	32
OH07012	2.33	-26.05	7.97E-06	567559	176233	3	120		Packer		
OH07012	7.45	-26.05	8.00E-06	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012021	Water Pressure	35	32
OH07012	7.45	-26.05	8.50E-06	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-	Water Pressure	35	32

								X-0003-02012022			
OH07012	7.45	-26.05	1.10E-05	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012020	Water Pressure	35	32
OH07012	7.45	-26.05	1.10E-05	567559	176233	3	60	B-AGSF-X-X-X-D-X-X-X-0003-02012024	Water Pressure	35	32
BH09002	3.38	-1.62	1.20E-04	567046.2	177958.1	3	60	C-AGSF-X-X-X-D-X-X-X-0004-02012021	Falling Head	6.5	3.5
BH09002	3.38	-1.62	6.60E-04	567046.2	177958.1	3	60	C-AGSF-X-X-X-D-X-X-X-0004-02012020	Rising Head	6.5	3.5
BH09006	12.37	-2.63	1.60E-06	566928	178336.7	3	60	C-AGSF-X-X-X-D-X-X-X-0004-02012023	Rising Head	16.5	13.5
BH09006	12.37	-2.63	1.70E-06	566928	178336.7	3	60	C-AGSF-X-X-X-D-X-X-X-0004-02012022	Falling Head	16.5	13.5
BH10003	6.64	-33.86	1.40E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-	Packer	42	39

								X-0004-02012046			
BH10003	6.64	-33.86	1.40E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012047	Packer	42	39
BH10003	6.64	-33.86	1.60E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012048	Packer	42	39
BH10003	6.64	-26.86	1.60E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012042	Packer	35	32
BH10003	6.64	-26.86	1.60E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012043	Packer	35	32
BH10003	6.64	-33.86	1.70E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012045	Packer	42	39
BH10003	6.64	-26.86	1.70E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012041	Packer	35	32
BH10003	6.64	-26.86	1.70E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-	Packer	35	32

								X-0004-02012044			
BH10003	6.64	-26.86	1.80E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012040	Packer	35	32
BH10003	6.64	-33.86	2.00E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012049	Packer	42	39
BH10003	6.64	-20.86	2.70E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012036	Packer	29	26
BH10003	6.64	-20.86	2.70E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012037	Packer	29	26
BH10003	6.64	-20.86	2.70E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012038	Packer	29	26
BH10003	6.64	-20.86	2.80E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012035	Packer	29	26
BH10003	6.64	-20.86	2.80E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-	Packer	29	26

								X-0004-02012039			
BH10003	6.64	-15.86	5.70E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012032	Packer	24	21
BH10003	6.64	-15.86	6.00E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012033	Packer	24	21
BH10003	6.64	-39.86	6.10E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012050	Packer	48	45
BH10003	6.64	-39.86	6.10E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012051	Packer	48	45
BH10003	6.64	-15.86	6.20E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012031	Packer	24	21
BH10003	6.64	-15.86	6.50E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012034	Packer	24	21
BH10003	6.64	-15.86	6.70E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-	Packer	24	21

								X-0004-02012030			
BH10003	6.64	-39.86	6.90E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012052	Packer	48	45
BH10003	6.64	-39.86	7.30E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012053	Packer	48	45
BH10003	6.64	-39.86	8.30E-06	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012054	Packer	48	45
BH10003	6.64	-10.86	1.80E-05	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012026	Packer	19	16
BH10003	6.64	-10.86	1.90E-05	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012025	Packer	19	16
BH10003	6.64	-10.86	1.90E-05	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-X-0004-02012027	Packer	19	16
BH10003	6.64	-10.86	2.00E-05	566824.3	179204.7	3	120	C-AGSF-X-X-X-D-X-X-	Packer	19	16

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BH10004	7.63	2.13	2.70E-07	566645.5	179312.2	3	60	C-AGSF-X-X-X-D-X-X-X-0004-02012056	Rising Head	7	4
BH10004	7.63	2.13	2.80E-07	566645.5	179312.2	3	60	C-AGSF-X-X-X-D-X-X-X-0004-02012055	Falling Head	7	4
BH11004	20.3	2.3	2.50E-07	566276	179707	3	60	C-AGSF-X-X-X-D-X-X-X-0004-02012058	Rising Head	19.5	16.5
BH11004	20.3	2.3	2.60E-07	566276	179707	3	60	C-AGSF-X-X-X-D-X-X-X-0004-02012057	Falling Head	19.5	16.5
BH11007	17.88	4.38	1.00E-07	565801.6	179927.6	3	60	C-AGSF-X-X-X-D-X-X-X-0004-02012060	Rising Head	15	12
BH11007	17.88	4.38	4.10E-07	565801.6	179927.6	3	60	C-AGSF-X-X-X-D-X-X-	Falling Head	15	12

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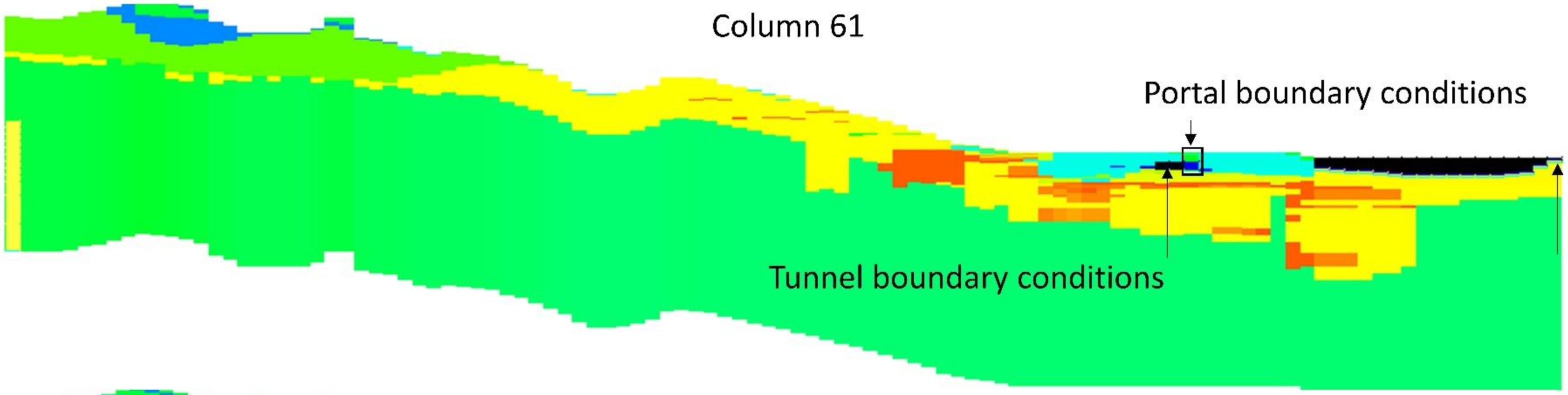
OH07012	2.33	-34.05	1.35E-07	567559	176233	4	120		Packer		
BH12005	23.82	-3.18	2.50E-06	564462.1	180123.4	6	60	C-AGSF-X-X-X-D-X-X-X-0004-02012062	Rising Head	30	24
BH12005	23.82	-3.18	4.30E-06	564462.1	180123.4	6	60	C-AGSF-X-X-X-D-X-X-X-0004-02012061	Falling Head	30	24

Appendix B Additional model parameters

Unit	Hydraulic conductivity (Kh, m/s)	Hydraulic conductivity (factor of Kh)	Sy	Ss
Boyn Hill Gravel	$6.55X10^{-4}$	0.1	0.15	0.00001
Black Park Gravel	$6.55X10^{-4}$	0.1	0.15	0.00001
Taplow Gravel	$1.00X10^{-4}$	0.1	0.15	0.00001
Lynch Hill Gravel	$6.55X10^{-4}$	0.1	0.15	0.00001
Kempton Park Gravel	$6.55X10^{-4}$	0.1	0.15	0.00001
Bagshot Fm	$6.55X10^{-4}$	0.1	0.15	0.00001
Claygate Member	$1.00X10^{-7}$	0.3	0.01	$5.00X10^{-4}$
Clay With Flints	$1.00X10^{-7}$	0.1	0.01	$5.00X10^{-4}$
Glacio Fluvial Deposits	$6.55X10^{-4}$	0.1	0.1	$1.00X10^{-5}$
Glacio Fluvial Silts and Clays	$5.00X10^{-6}$	0.1	0.03	$1.00X10^{-5}$
Harwich Formation	$1.00X10^{-5}$	0.1	0.08	$1.00X10^{-5}$
Lowestoft Fm	$1.00X10^{-7}$	1.0	0.01	$1.00X10^{-5}$
Lambeth Group	$1.00X10^{-7}$	0.5	0.01	$1.00X10^{-5}$
Lenham Fm	$1.00X10^{-5}$	0.3	0.1	$1.00X10^{-5}$
Stanmore Gravel	$6.55X10^{-4}$	0.1	0.15	$1.00X10^{-5}$
Worked Ground	$1.00X10^{-5}$	0.1	0.5	0.005
Infilled Ground	$1.00X10^{-5}$	0.1	0.5	0.005
Head	$5.00X10^{-7}$	1.0	0.1	0.005
Tidal Flat	$7.90X10^{-6}$	0.1	0.05	0.0005
Hackney Gravel	$6.55X10^{-4}$	0.1	0.15	$1.00X10^{-5}$
Interglacial Deposits	$1.00X10^{-5}$	0.1	0.05	$1.00X10^{-4}$
Ilford Silt	$1.00X10^{-6}$	0.1	0.05	0.0005
RTD	$6.55X10^{-4}$	0.1	0.05	$1.00X10^{-5}$
Thanet Formation	$1.00X10^{-4}$	0.1	0.1	$1.00X10^{-5}$
London Clay	$1.00X10^{-7}$	0.1	0.02	$1.00X10^{-5}$
Belle Tout Chalk	$9.30X10^{-4}$	0.02	0.005	$1.00X10^{-6}$

Appendix C Grout tunnel boundary conditions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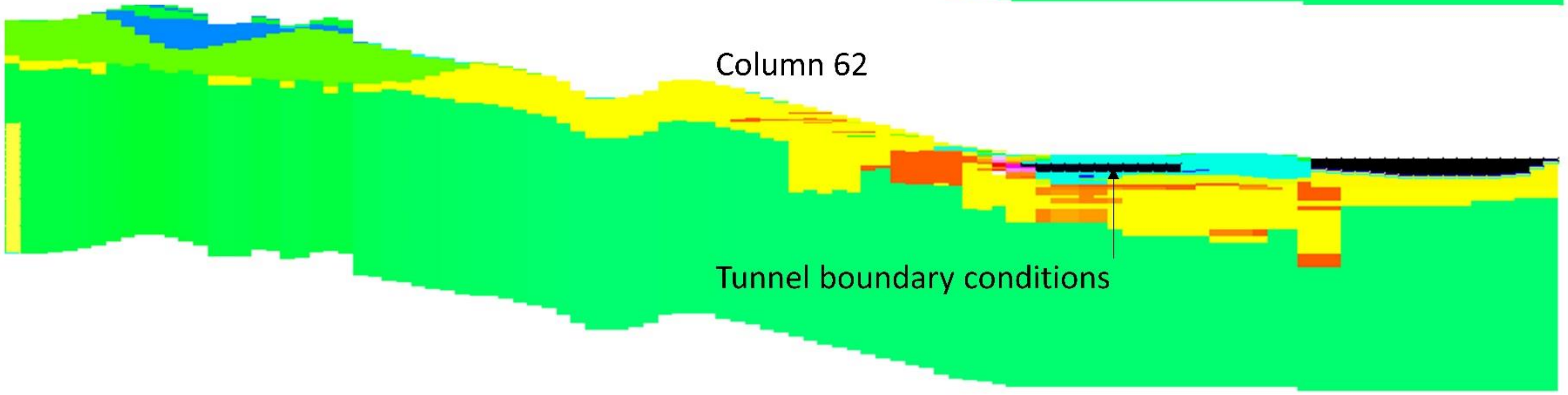
Portal boundary conditions
Tunnel boundary conditions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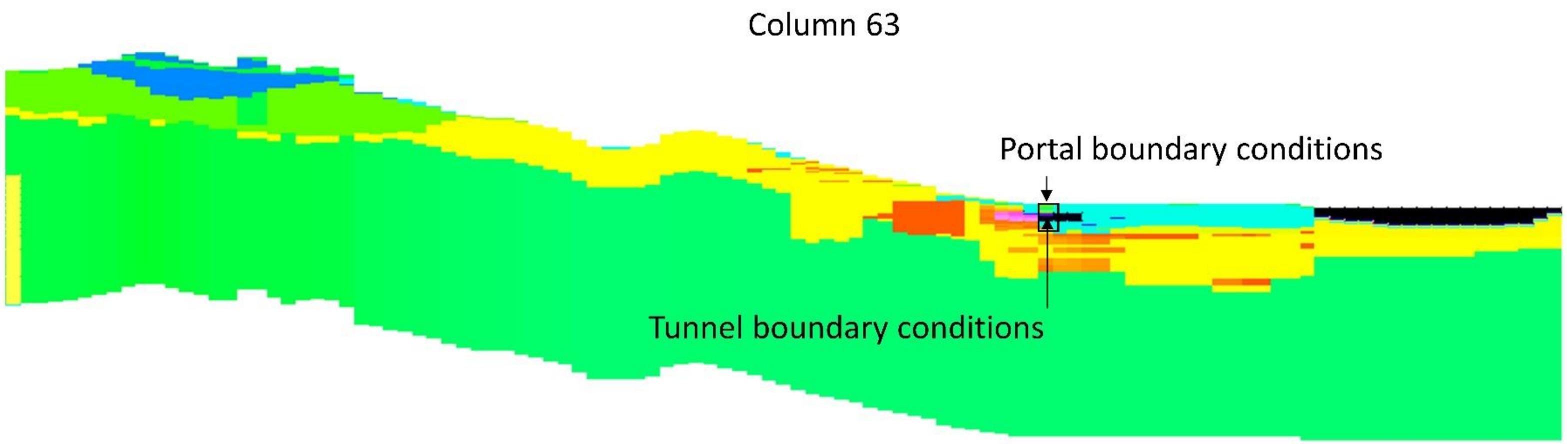
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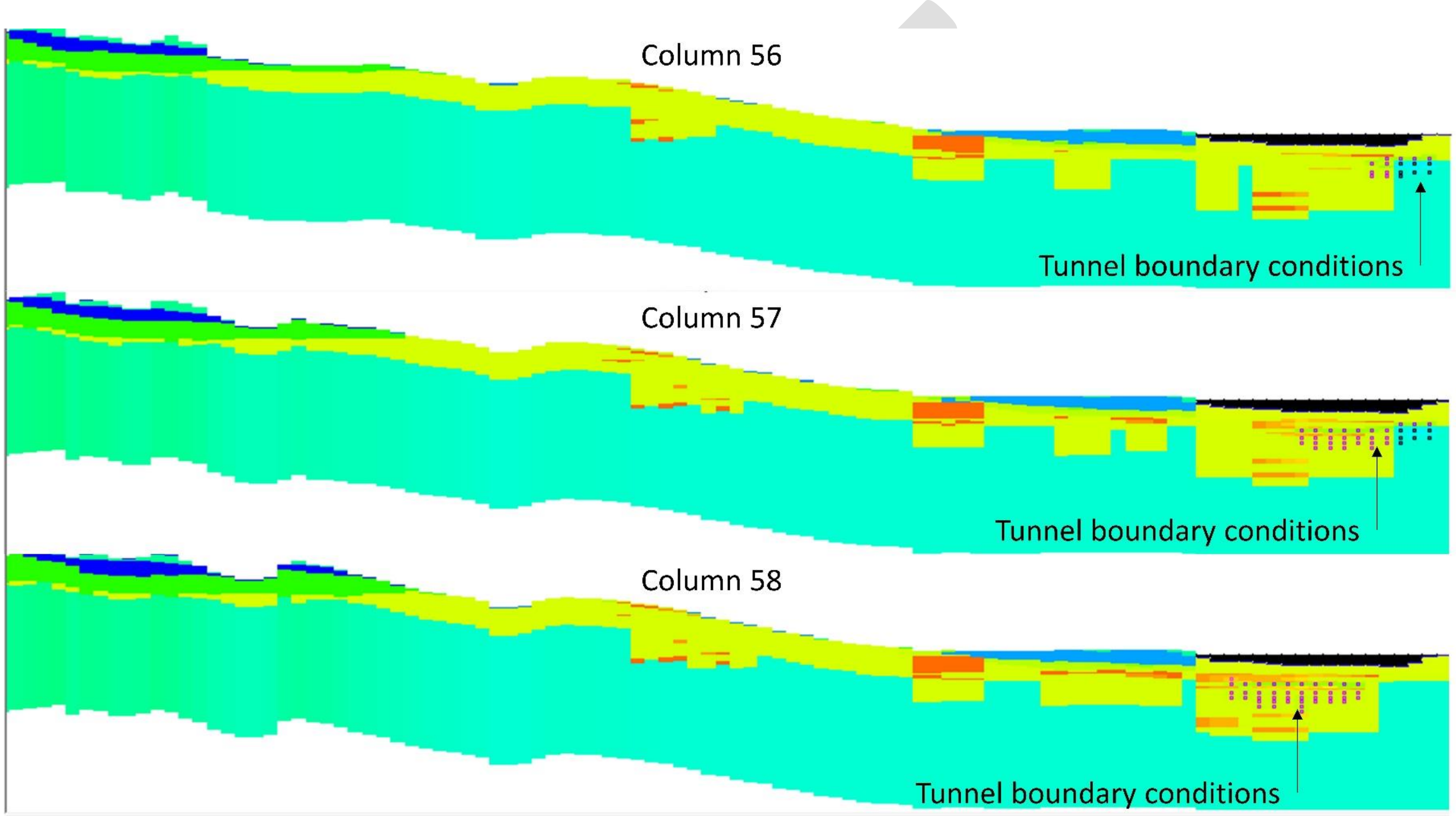
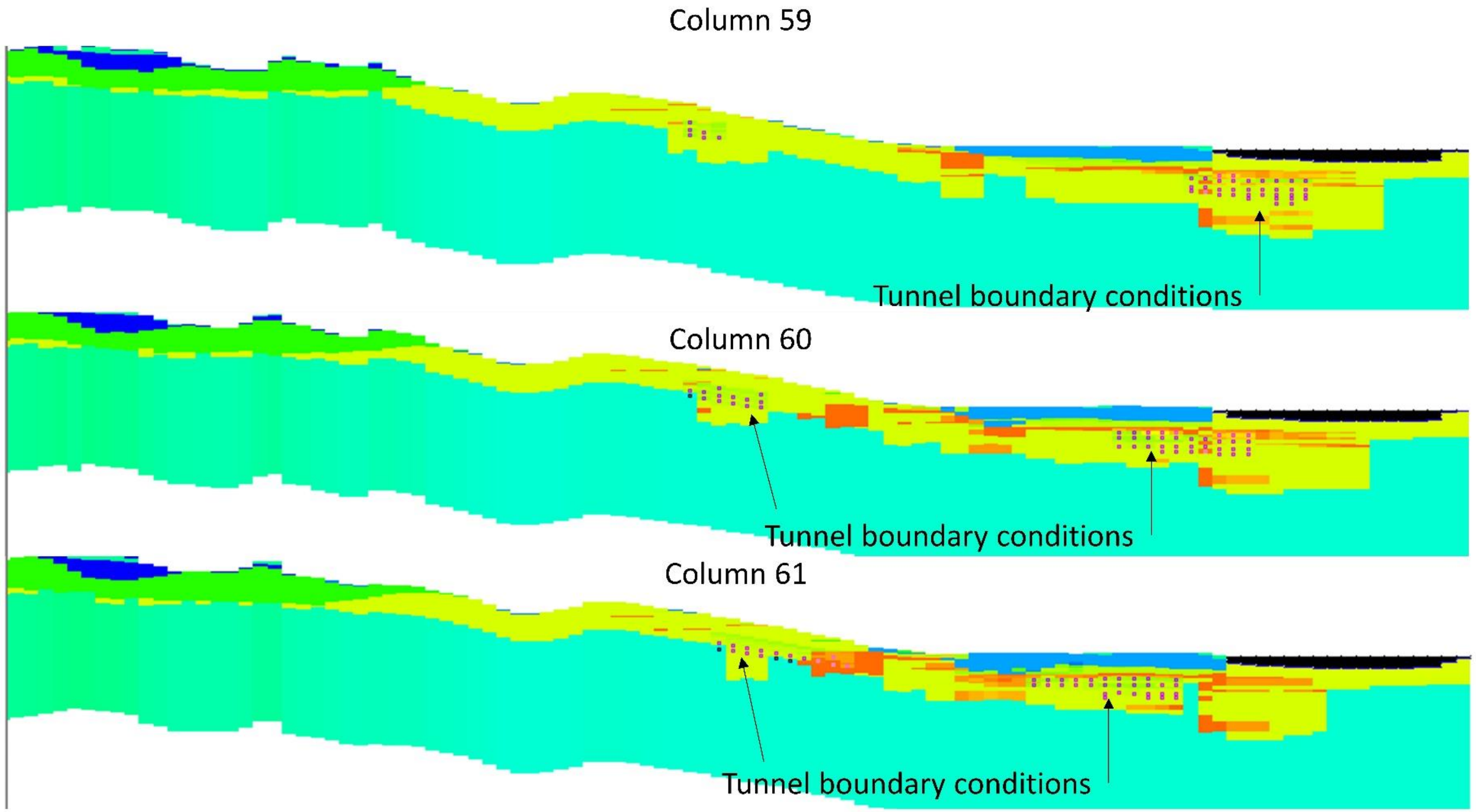
Tunnel boundary conditions

Appendix D Main tunnel boundary conditions

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Column 60
Tunnel boundary conditions
Column 61
Tunnel boundary conditions

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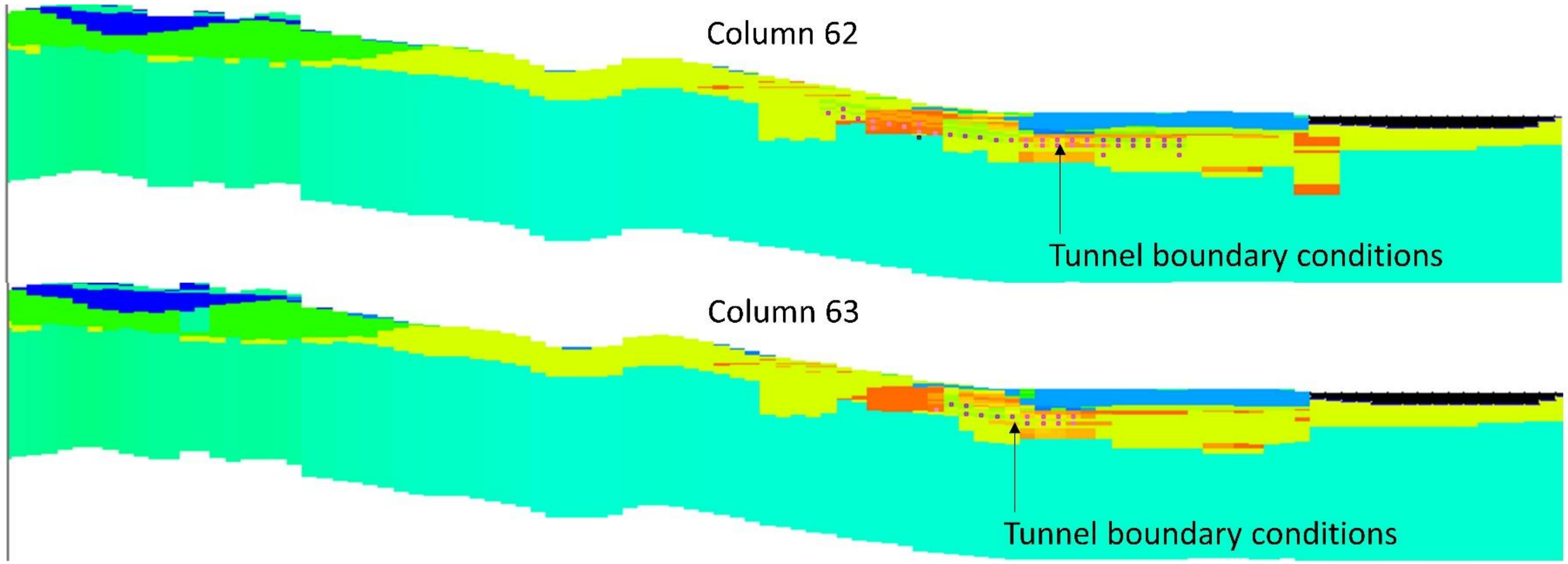
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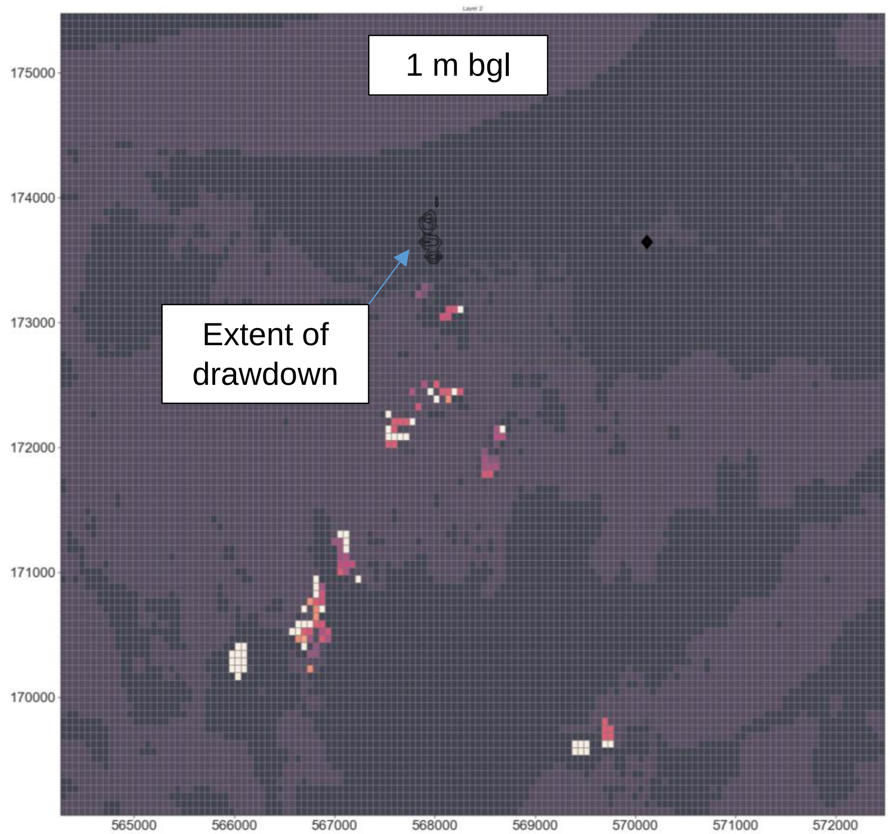
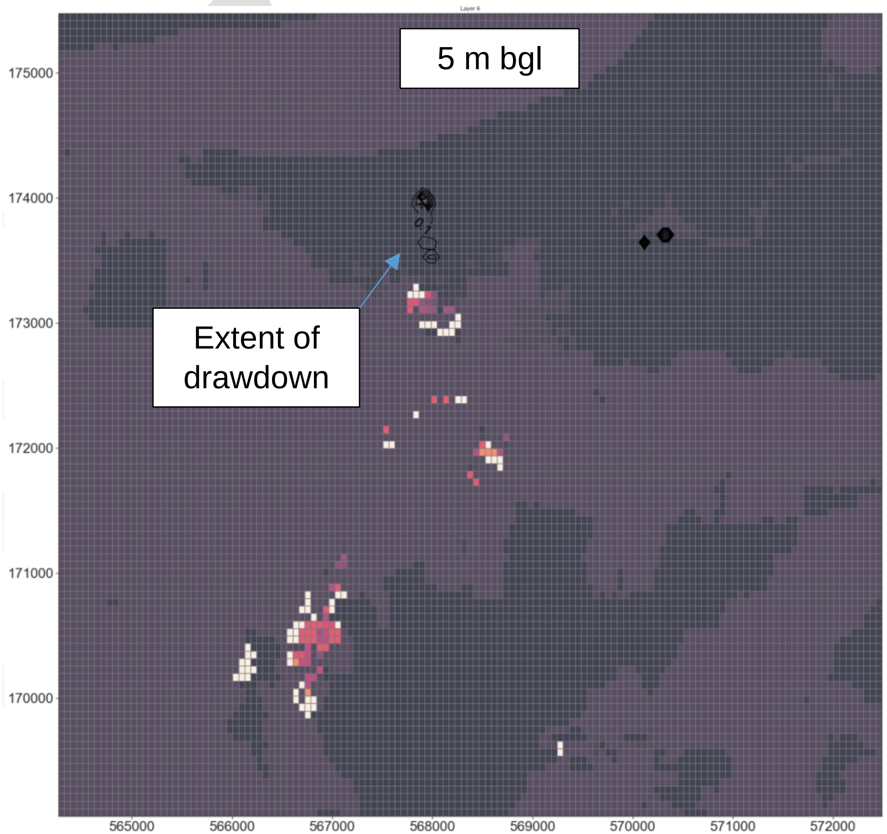
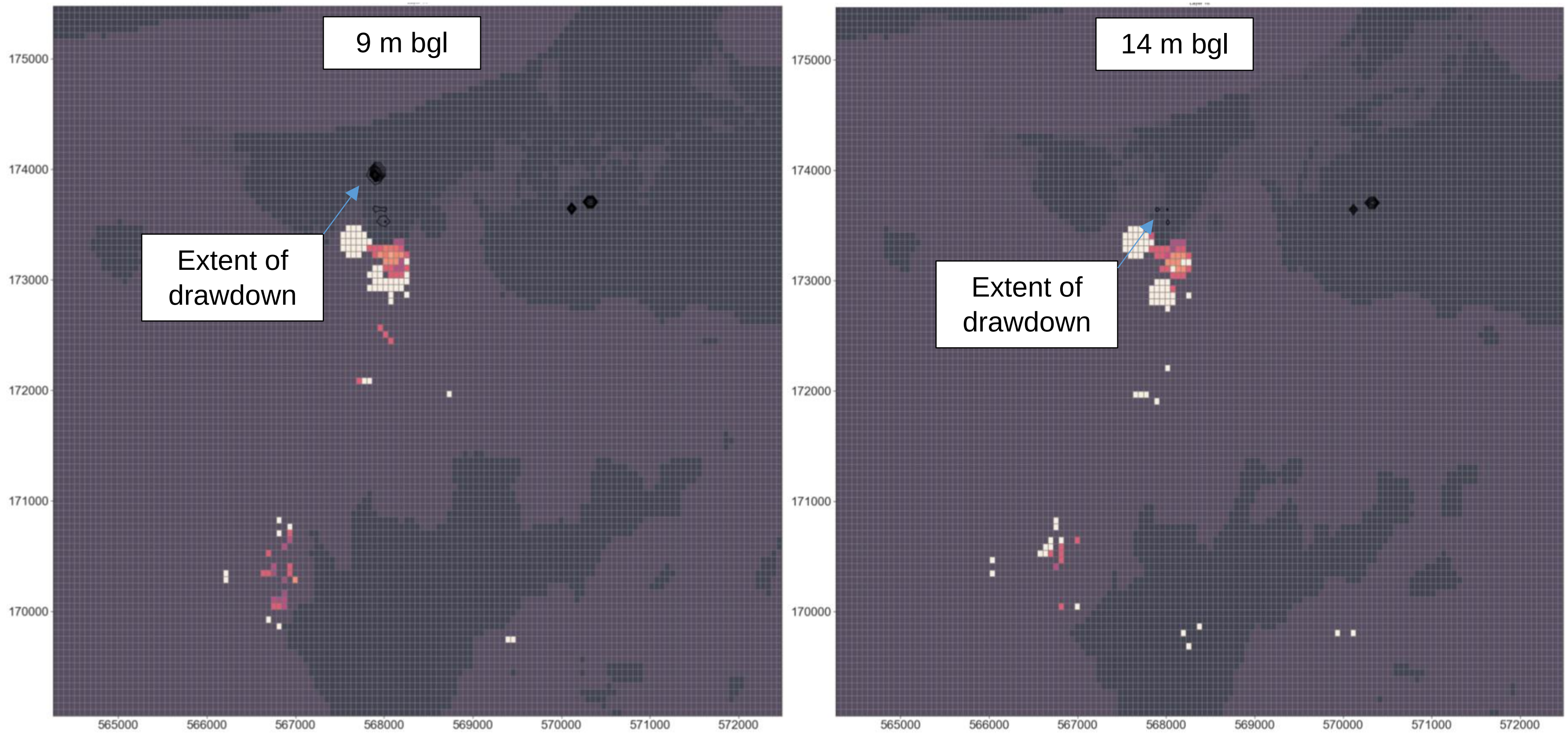
Tunnel boundary conditions
Column 63
Tunnel boundary conditions

Appendix E Drawdown for grout tunnel portals



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Extent of drawdown
14 m bgl
Extent of drawdown
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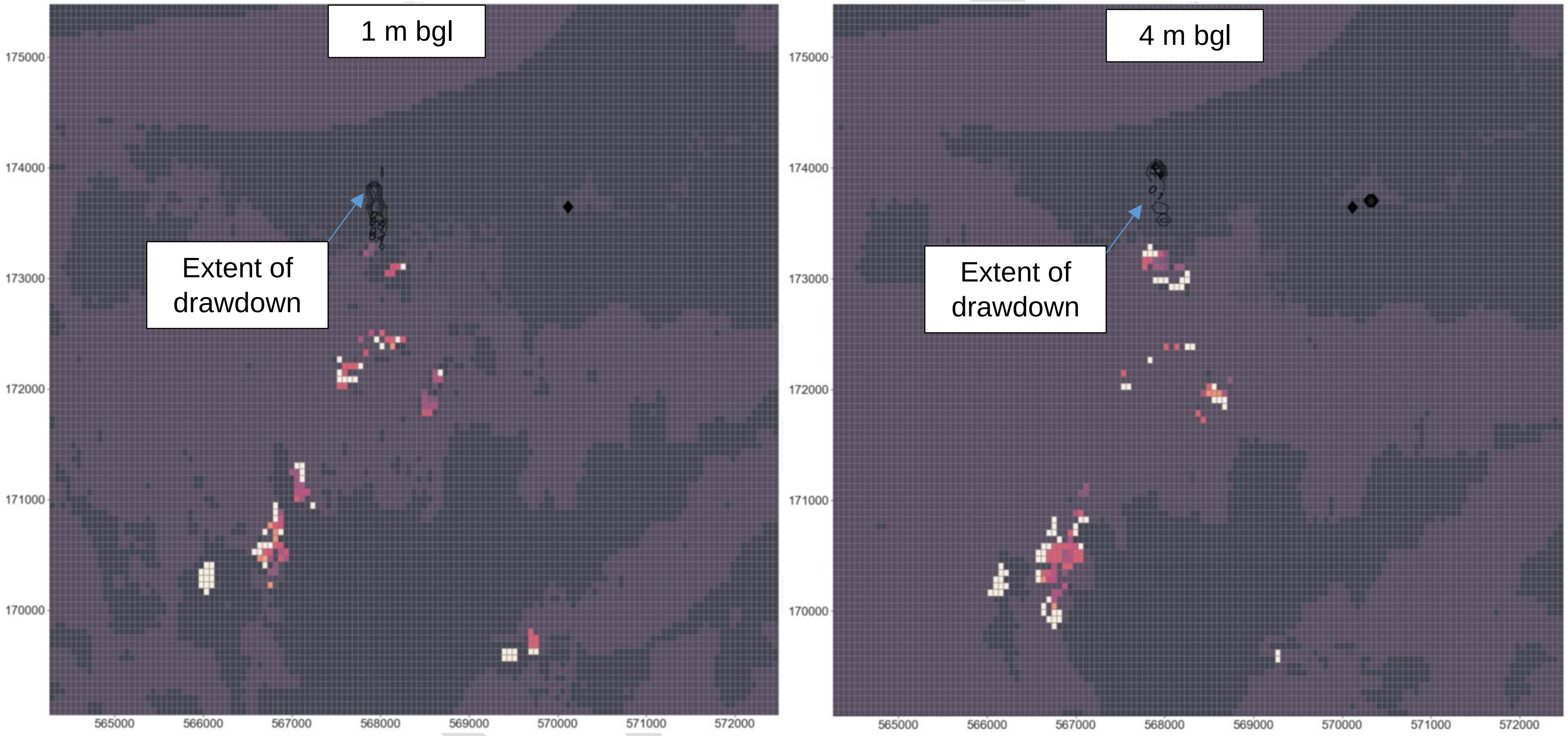
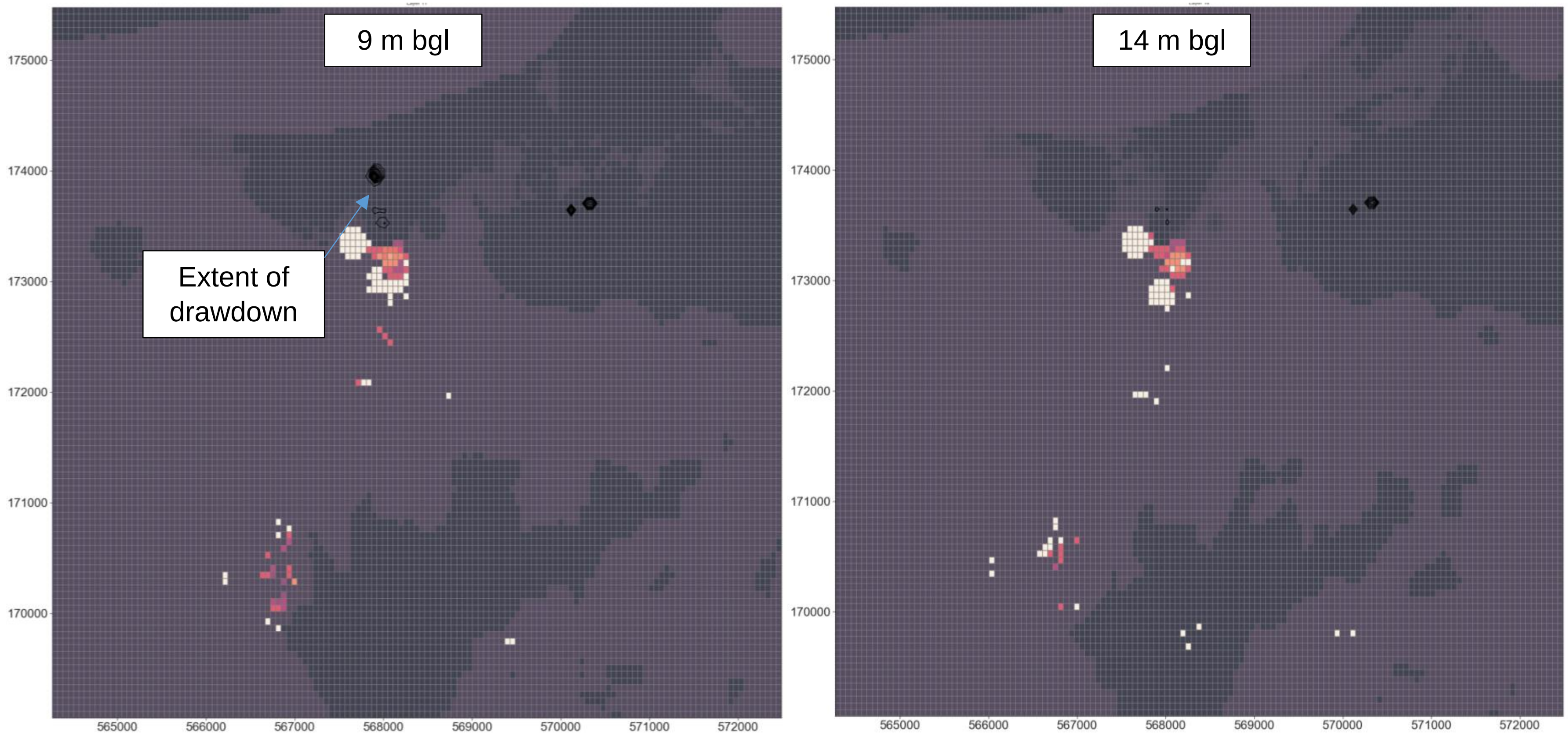
174000
173000
172000
171000
170000
565000
566000
567000
568000
569000
570000
571000
572000

Appendix F Drawdown for grout tunnel portals and tunnel




9 m bgl
Extent of drawdown
14 m bgl
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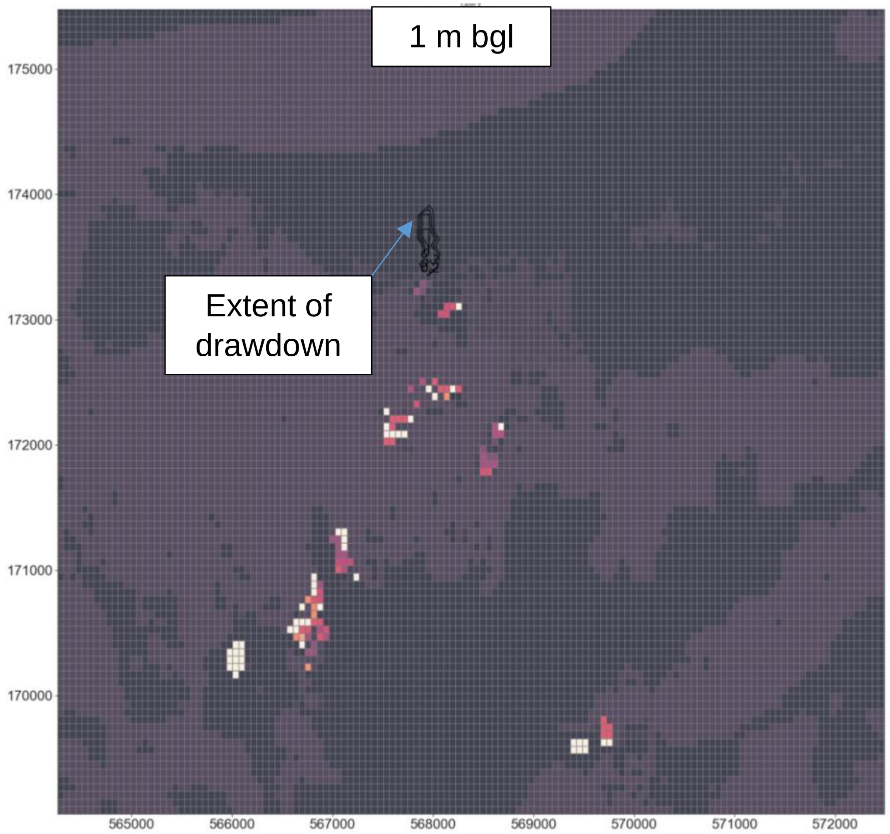
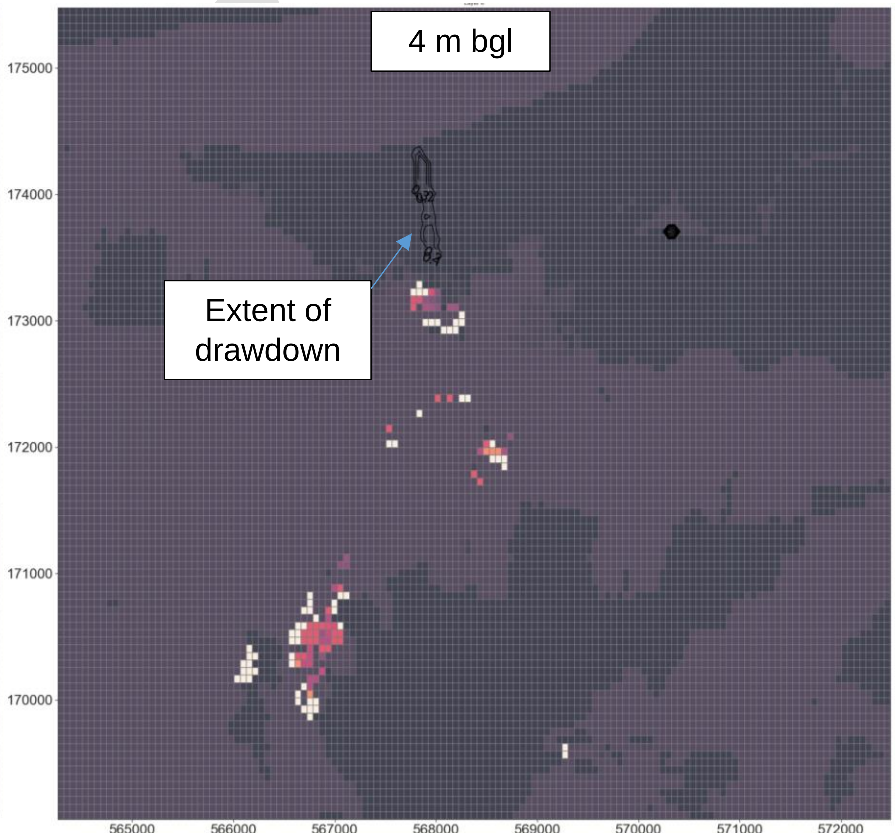
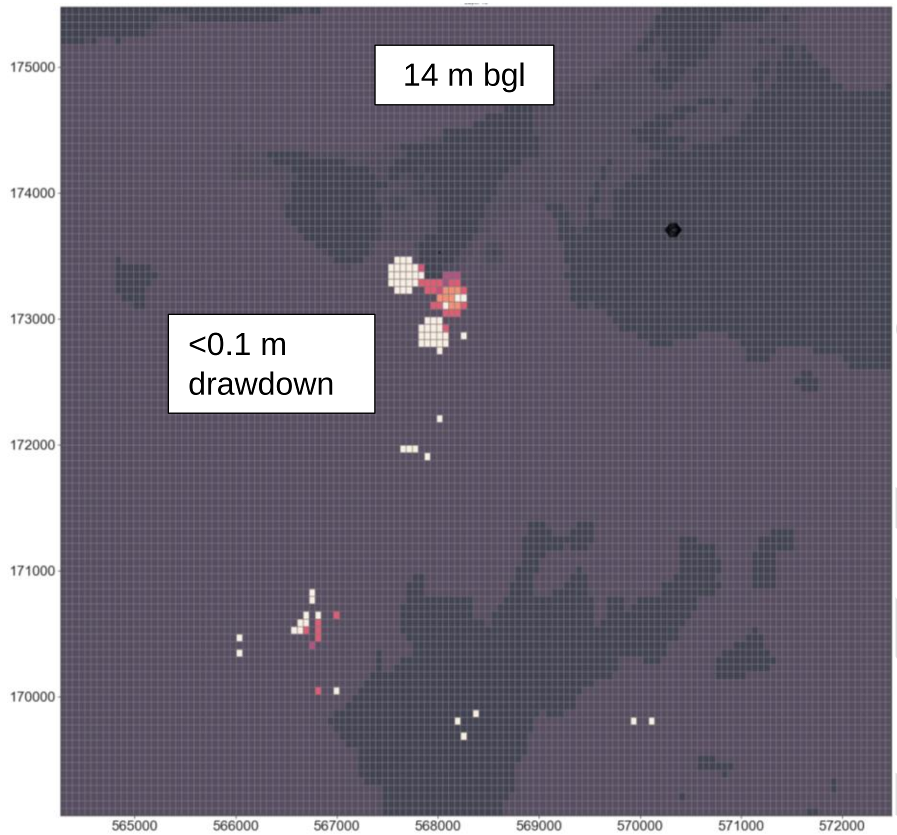
174000
173000
172000
171000
170000
565000
566000
567000
568000
569000
570000
571000
572000

Appendix G Drawdown for Main tunnels






14 m bgl
<0.1 m drawdown
175000
174000
173000
172000
171000
170000
565000
566000
567000
568000
569000
570000
571000
572000

Annex AA2 Technical Note Baseline Water Balance for the Ramsar site (Filborough Marshes)

Lower Thames Crossing

Baseline Water Balance for the Ramsar Site (Filborough Marshes) – Technical Note

HE540039-CJV-GEN-GEN-TNT-GEO-00118v2

DATE: 05/06/2020

Baseline Water Balance for the Ramsar Site (Filborough Marshes) – Technical Note

VERSION: 2.0

Lower Thames Crossing

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1 Executive summary

An assessment of the current and historical baseline water conditions within the internationally protected Ramsar site is required to determine the potential impact of Lower Thames Crossing works.

This assessment has been conducted by the Lower Thames Crossing hydrogeology team; part of the tunnels and systems group, to present a hydrogeological summary of the baseline water balance for part of the Thames Estuary and Marshes Ramsar site and SSSI.

2 Introduction

2.1 Background

This technical note has been prepared by CASCADE on behalf of Highways England to present an initial hydrogeological summary of the baseline water balance for part of the Thames Estuary and Marshes Ramsar site and SSSI (herein described as the Ramsar site). The water balance study area is the area of the Filborough Marshes within and slightly beyond the Order Limits.

The Ramsar site, comprises internationally protected wetlands, and is located along the River Thames. The proposed Lower Thames Crossing Project involves construction of tunnels beneath the Ramsar site. Therefore, an assessment of the current baseline conditions within the Ramsar site is required. A more detailed conceptual site model, potential impact and mitigation, if required, will also be presented in separate documents.

2.2 Objectives

The objectives of this Technical Note are:

- To estimate water inflows and outflows and determine the overall annual change in storage within the shallow water system at the water balance study area, within the Ramsar site.
- To provide a preliminary baseline assessment of interactions between groundwater and surface water.
- To qualitatively identify potential connectivity which may be impacted by the Lower Thames Crossing Project construction and operation.

2.3 Assumptions and Limitations

The following assumptions and limitations have been factored in this assessment:

- The control volume for the water balance is the area shown in Figure 2 and has an area of approximately 350 000 m^2 and thickness of approximately 2 m. This is considered as appropriate to analyse the shallow water conditions at the Ramsar site within and surrounding the Order of Limits.
- The default calculation period of this preliminary water balance is the calendar month. All water components enter or leave the control volume within this time interval.
- Daily rainfall, actual evapotranspiration (AE) and soil moisture deficit (SMD) data covering the period between 2000 and 2019 have been purchased from the Meteorological Office rainfall and evaporation calculation system (MORECS, [1] or provided by the Environmental Agency [2] and then grouped over the calendar month.
- Evaporation has been calculated based on freely available public information combining daily data (2000 – 2012) from the UK Centre for Ecology and Hydrology (CHESS; [3] or monthly average historical weather data from world weather online [4].

- The horizontal and vertical hydraulic conductivity values of the shallow Alluvium are based on the "Ramsar Advanced Grouting Tunnel and Main Tunnels Numerical Model – Technical Note" [5].
- The assessment covered within this technical note is based on LTC ground investigation data available to April 2020.
- The Lower Thames Crossing design release, DR2.14 development boundary has been used as the Order Limits are currently being finalised. It has been assumed that the Order Limits will be of similar extent in vicinity of the Ramsar site.
- Does not include any effects which may be introduced by works including the proposed advanced grout tunnel [6].

3 Water Balance Assessment

3.1 Filborough Marshes Water Balance Area

The Lower Thames Crossing route alignment crosses the Filborough Marshes area of the Ramsar site (Figure 3.1). This area of the Ramsar site is therefore considered to have the greatest potential to be impacted by the Lower Thames Crossing Project construction and operation.

Figure 3.1 – Ramsar England (green) and designated environmentally sensitive areas (pink) in relation to the DR2.14 route alignment (red line boundary)

The water balance study area (herein described as the study area) is shown in Figure 3.2. The water balance assessment accounts for water movement into and out of the shallow water system within part of the Filborough Marshes immediately adjacent to the Lower Thames Crossing route alignment. The study area comprises an area of approximately 350 000 m^2 and is relatively flat lying with an average elevation of 2.2 mAOD. It is bounded by the railway line to the north and Lower Higham Road to the south. The east-west extent is defined by drainage ditches running roughly parallel to the route alignment approximately 100-200 m outside of the DR2.14 development boundary.

The shallow water system examined in the water balance calculation includes the soil, subsurface strata and surface water ditches that lie within this area from the ground surface down to 0 mOD. The shallow water system is assumed to be approximately 2 m thick.

Figure 3.2 – Water balance study area (yellow) covers the area of the Filborough Marshes alongside the Development Boundary (red) that lies within the larger Ramsar area (green)

3.2 Water Balance conceptual model

The water balance approach has considered site specific, potential inflows and outflows which can be described generally in the form:

Input – Output = Change in Storage

Water balance assessments are used to help manage water supply and predict where there may be shortages. Figure 3.3 shows a conceptual summary of the significant inflows to and outflows from the Filborough Marshes shallow water system.

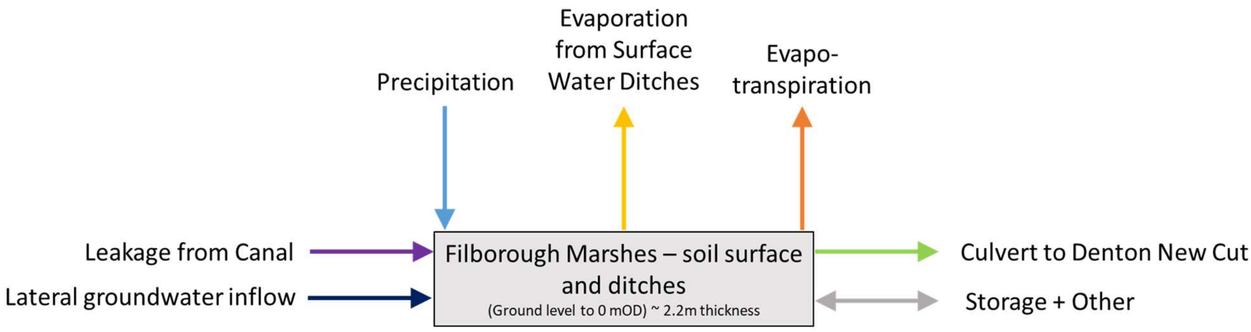

Figure 3.3 – conceptual diagram of water inflows, outflows and storage within the study area

3.3 Water Balance components and estimated values

3.3.1 Inflows

Table 3.1 lists the potential inputs of water to the study area and considers the potential magnitude and sources of available data related to each factor.

Table 3.1 – Summary of potential inputs to the water balance study area

Type of input	Nature of Water input	Estimated input per month	Data Sources
Precipitation	Precipitation directly onto the land surface area	5 – 170 mm Up to 60000 m^3	Site-specific precipitation data purchased from MORECS – 5km grid square and specified “rough grazing” land use [1]
Recharge from surface water – ditches	Ditches within the study area are considered as part of the surface water system and therefore do not contribute to the overall water balance equation	Not applicable Ditches act as water storage bodies rather than a source. Water balance calculates change of storage	
Recharge from surface water – Thames and Medway Canal	Although historical reports maintain that the Thames and Medway Canal (herein described as the Canal) has an impermeable lining, no field evidence was found indicating the presence of an impermeable barrier. Evidence from 2018 when no manual top-up occurred suggests that leakage from the canal to the north edge of site is occurring (see discussion in Section 3.4.3)	~400 – 3000 m^3 These estimates are based on a canal lined with material with an average permeability of	Assuming a constant water level of 3.72 mAOD for Canal water level [7] Calculated using a representative average permeability derived from the volume of water required to fully top up the canal following 126 days of no manual top-up in 2018.

Type of input	Nature of Water input	Estimated input per month	Data Sources
		4 x10^{-8} m/s with all leakage directed towards the study area and are therefore considered a low estimate of possible inflows.	For discussion of canal leakage refer to Section 3.4.3
Seawater intrusion	Conductivity data from surface water ditches across the study area suggests that there is no significant input of saltwater into the shallow water system at this location	Insignificant	Lower Thames Crossing field data [8]
Lateral groundwater inflow and leakage from other aquifers	Any movement of groundwater into this location is likely to occur by diffuse seepage horizontally from the chalk aquifer to the alluvium underlying the surface water system. Vertical groundwater inflow not considered in the water balance because similar groundwater levels in alluvium and chalk (i.e. no driving vertical hydraulic gradient), based on the information analysed to date (Appendix A). Groundwater modelling at the Ramsar site [9] suggests groundwater flow is mainly horizontal, towards the river Thames, the main discharge point. No springs have been identified during Lower Thames Crossing water features surveys and the RSPB Reserve manager stated no springs are observed on site.	~50 - 150 m^3	Calculated using modelled mean conductivity of the underlying and surrounding alluvium. Kh = 7.9 x10^{-7} m/s and Kv = 0.1*Kh [5] For discussion of alluvium conductivity refer to Section 3.4.2 Calculation also uses hydraulic head of groundwater interpolated from Church Lane borehole [10]. This record ends on 20/04/2018 with a level of 7.17 mAOD and has been extrapolated to remain constant at this level for calculations later than this date. Nearby Lower Thames Crossing wells indicate actual water levels several meters lower than this static level from the start of monitoring in November 2018.
Discharge	One Environment Agency discharge consent has been identified at Filborough Farm Barn (P09544) near the southeast corner of the study area. This is described as an outlet for sewage into the land, however no further information related to the nature and volume of this discharge consent is available.	Unknown – assumed to be insignificant	Environment Agency data

3.3.2 Outflows

Table 3.2 lists the potential outflows of water from the study area and considers the potential magnitude and sources of available data related to each factor.

Table 3.2 – Summary of potential outflows from the water balance study area

Outflow type	Nature of Water outflow	Estimated flow per month	Data Sources
Abstraction	No current or historical abstractions have been identified within the study area. There are two abstractions downgradient of the study area from Denton New Cut (see Figure 2). The closest to site is managed by the RSPB to top up Shorne marshes, and the abstraction further downstream is licensed by Gravesham Council and is used to top-up the Thames and Medway Canal to maintain the water level. These abstractions are therefore limited by flow from the study area to Denton New Cut and not applicable to the water balance model	Not applicable	Lower Thames Crossing communications with Thames and Medway Canal Association Chairman [7]
Baseline flow in rivers	No rivers have been identified outflowing from the study area. The surface water system (ditches) is considered separately below.	Not applicable	
Surface water flow	Site observations indicate that surface water within the study area is contained in a network of drainage ditches which ultimately outflows via a culvert (Figure 3.2) into Denton New Cut. The outflow is understood to be adjusted by the landowner by manual removal of a stopper board from the culvert opening.	Source of uncertainty – not included in calculations. Forms part of "Storage + Other" system	Lower Thames Crossing Water features survey [11] and Lower Thames Crossing communications with Thames and Medway Canal Association Chairman [7]
Discharge to the sea	No direct discharge from the study area to the sea or to the Thames Estuary is anticipated.	Not applicable	
Flows to other aquifers	Seepage of water from the study area downwards into lower strata. Groundwater level data from boreholes within the Ramsar show similar water levels in the Alluvium, Chalk and RTD. This suggests that there is insufficient hydraulic head difference to drive quantifiable net flow from the study area to lower strata.	Not applicable	See Appendix 1
Evapo-transpiration	Evapotranspiration from the soil surface – estimated as total surface area minus area of surface water ditches. The topsoil and alluvium have been considered to be covered with rough	10 to 90 mm Up to 30 000 m^3	Site-specific potential and actual evaporation (PE and AE) data purchased from MORECS [1]

Outflow type	Nature of Water outflow	Estimated flow per month	Data Sources
	grass based on information from the water features survey [11]		Additional PE and AE have been provided by the Environment Agency [2] for comparison
Open Water Evaporation	Evaporation from the surface of shallow drainage ditches. The salinity of the ditches has been considered to be <1% for the purposes of calculations. This is in line with conductivity and geochemical data collected from ditches on site by Lower Thames Crossing [8] [12]	20 – 250 mm 500 – 6500 m^3 based on a total ditch surface area of approximately 26 000 m^2 (from GIS polygon, and an average channel width of 3 m [12].	Calculated using daily air temperature, air pressure and specific humidity data [3] between 2000 – 2012 Calculated using monthly average temperature and humidity data [4] between 2013 - 2019
Change of storage and other	Field data relating to water storage could not be collected. As a result, this has been assumed from the difference between total inflows and outflows on a monthly basis. Storage occurs in autumn and winter and is released during periods of low rainfall. This variable potentially includes unquantifiable surface water outflow as discussed above.	Up to 45000 m^3 (from water balance) Capacity of ditches likely to be up to 50000 m^3 based on ~2m depth [12]. Storage in excess of this is likely to cause surface water flooding.	Water balance assessment.

3.4 Water Balance Results

3.4.1 Balance of inputs and outputs

Figure 3.4 shows the balance of input and output volumes and expected change in storage or unquantifiable flows between 2000 and 2019.

3.4.2 Alluvium Permeability

Alluvium permeability affects the calculated magnitude of inflows from groundwater and canal leakage. Following recommendations from the preliminary baseline water balance (Version 1 of this document), data collected from Lower Thames Crossing Phase 2 Ground Investigation were used to assess the likely permeability of the Alluvium. Following recommendations from the preliminary baseline water balance (Version 1 of this document), data collected from Lower Thames Crossing Phase 2 Ground Investigation (GI) were used to assess the likely permeability of the Alluvium. Results are summarised in Table 3.3. Full results are presented in (Appendix B)

Table 3.3 – Summary of alluvium permeabilities from analysis of Lower Thames Crossing GI data from locations around the proposed grout tunnel below the Ramsar Study area. For further details refer to Appendix B

	Launch Shaft (South of the Ramsar Study Area)	Mid Tunnel (Within the Ramsar Study Area)	Reception Shaft (North of the Ramsar Study Area)
Conductivity used for Water balance calculations (this report)	Kh = 7.9 x 10^{-7} m/s; Kv = 0.1 * Kh [5]		
Conductivity used for V1 preliminary water balance calculations	Kh = 1.14 x 10^{-6} m/s Kv = 0.3 * Kh [9]		
Values interpreted from Lower Thames Crossing Cone Penetrometer Test Data	K = 1 x 10^{-10} to 1 x 10^{-8} Surface layer (top 2 m) has a higher K (~1 x 10^{-6} to 1 x 10^{-8} m/s)	K = 1 x 10^{-9} m/s Surface layer (top 0.8 m) has a higher K (~1 x 10^{-6} to 1 x 10^{-8} m/s)	K < 1 x 10^{-10} m/s Surface layer (top 0.5 m) has higher K (~1 x 10^{-7} m/s)
Values interpreted from Lower Thames Crossing Variable Head Tests	-	K = 8.0 x 10^{-8} m/s	-

This assessment indicates that the values for Kh and Kv used in this report are within the range given by a variety of testing approaches from the GI data. Cone Penetrometer Test (CPT) data indicates that the topmost layer of the Alluvium may have a slightly higher permeability but that the bulk hydraulic conductivity is similar or lower than the hydraulic conductivity used in the water balance calculations presented in this report. Using values towards the high conductivity end of the range of values indicated by modelling and GI work ensures that the water balance makes a conservative estimate of the groundwater dependency of the surface water system.

3.4.3 Canal Leakage

The inflow from the Thames and Medway Canal to the surface water system has also been estimated with some uncertainty. Although historical reports maintain that the Thames and Medway canal has an impermeable lining, no field evidence was found during water features surveys to indicate the presence of an impermeable barrier [11]. Data from a period in 2018 during which no manual top-up of the canal occurred does suggest that leakage from the canal is occurring, as the volume of water required to top up the canal following this period was greater than expected had the only output been to evaporation [14]. Initial calculations indicate an average permeability of between 8.5 x 10^{-8} and 4.0 x10^{-8} m/s for the canal lining. However, it is unknown whether this leakage is localised to cracks or degraded areas in a less permeable barrier or occurs uniformly across the entire canal.

For the purpose of this baseline water balance report we have assumed a lined canal which leaks into the study area both horizontally and vertically at 4.0 x10^{-8} m/s as a conservative scenario to produce a low estimate of the expected inflow from a leaking canal.

3.4.4 Storage Depletion

Figure 3.5 shows the seasonal water budget based on the major water inflow (precipitation) and major outflow (evapotranspiration). Potential storage depletion is indicated when graphs of evapotranspiration (yellow line) exceeds the rainfall graph (blue line).

The role of soil moisture deficit (SMD) in water balance calculations is important. Recharge into the soil system is assumed possible only if the soil moisture is replenished. Additionally evapotranspiration can, theoretically, only occur in soils with a soil moisture deficit of less than a maximum, here estimated as 110 mm [15] and progressively decreases with increasing soil moisture deficit.

SMD datasets from MORECS and the Environment Agency record a similar seasonal pattern with low SMD throughout the winter increasing to a summer peak – typically in August or September. The MORECS data is considered to be most representative of conditions in the Ramsar, as it uses a smaller 5 km grid square and specified “rough grazing” land use type across the square to represent vegetation specific to the Ramsar, which is grazed by animals and not mown extensively. The SMD dataset from MORECS indicates that high summer SMD does not become a limiting factor to evapotranspiration from the Ramsar.

Visual analysis of imagery from Sentinel-2 optical satellite [16] indicates that there is no sign of moisture stress during extended dry conditions during two representative years with low summer precipitation (Appendix C). This supports the MORECS interpretation of a lower soil moisture deficit which reduces but does not limit evapotranspiration during dry periods.

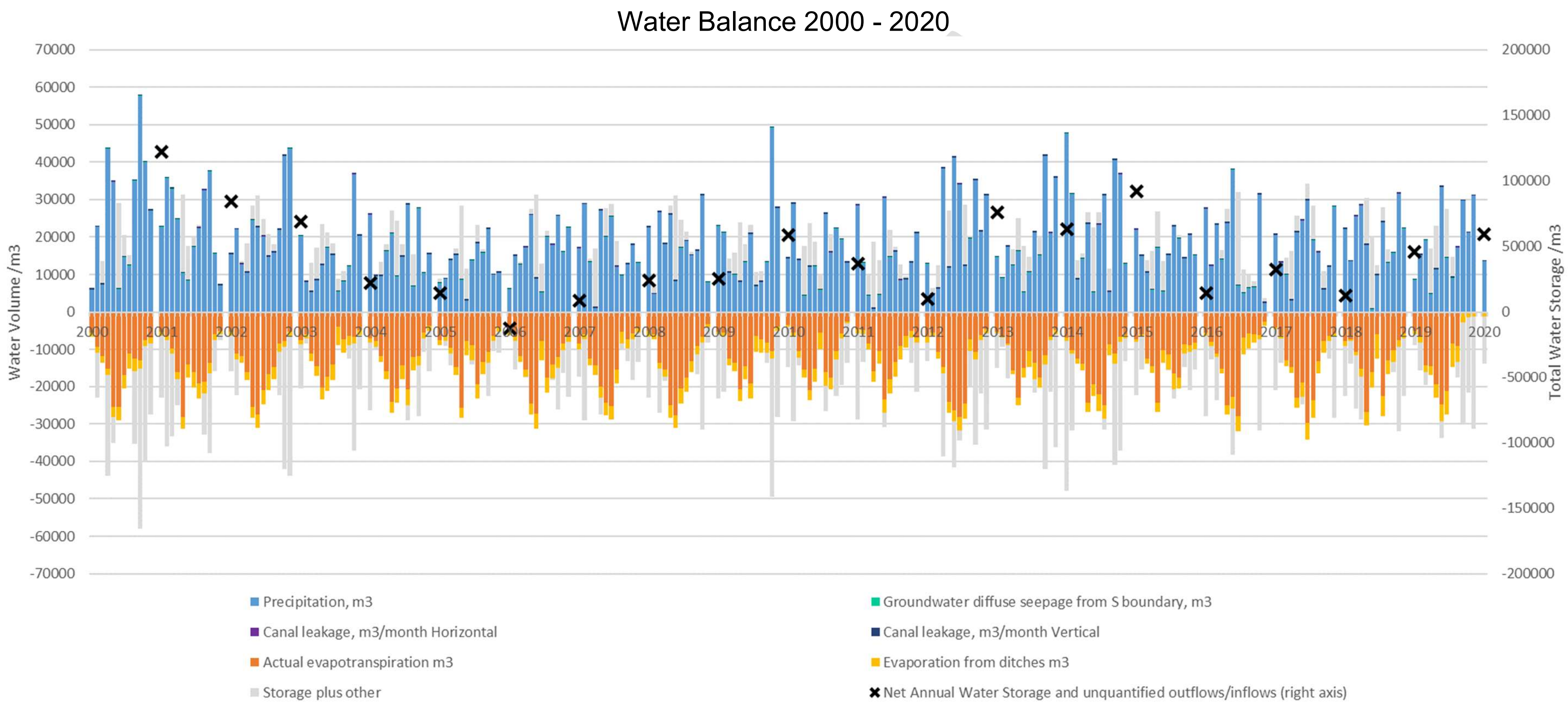

Figure 3.4 – Histograms representing total monthly water volume change within the study area (histogram bars on left axis) and net annual water to storage and unknown outflows or inflows at the end of each year (black crosses on right axis)

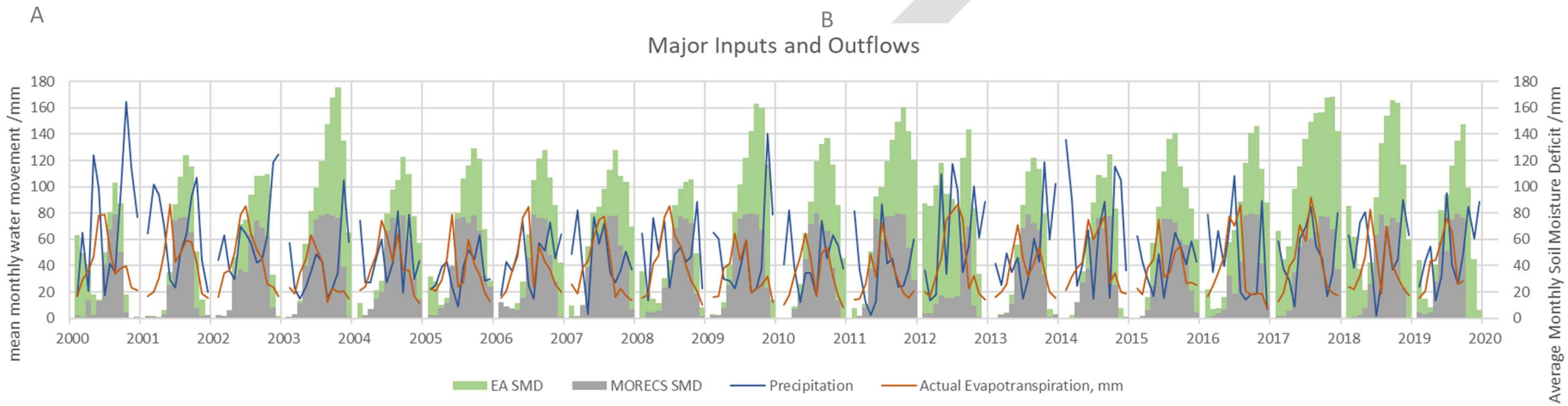

Figure 3.5 – Major inflows - precipitation (blue) vs major water outflows - evapotranspiration (orange) and the effect of soil moisture deficit (SMD) on water loss through actual evapotranspiration. Peak SMD during summer corresponds to a drop in actual evapotranspiration rates.

3.5 Summary of Results

The assumed low permeability of alluvium appears to impede significant inflow of water to the Ramsar site from other aquifers and water sources. Of these flows, the dominant input is rainfall, which makes up between 95 and 98% of the total annual water inputs. Minor inputs may come from leakage from the Canal and from diffuse shallow groundwater seepage. Monthly calculations indicate that the groundwater body does not contribute significantly to the total surface water system inflows. Groundwater inflow is likely to be limited to horizontal flow due to a lack of a driving vertical head through the system (Figure A.1) the horizontal inflow driven by the hydraulic gradient from the southern boundary of the study area and typically contributes <2% of the total inflows per month (Figure 3.6). Of the 237 months analysed for the water balance calculations, only 3 required more than 5% of the monthly total inflows from groundwater. These months have anomalously low precipitation (less than 2.7 mm over the month) and are considered extreme scenarios.

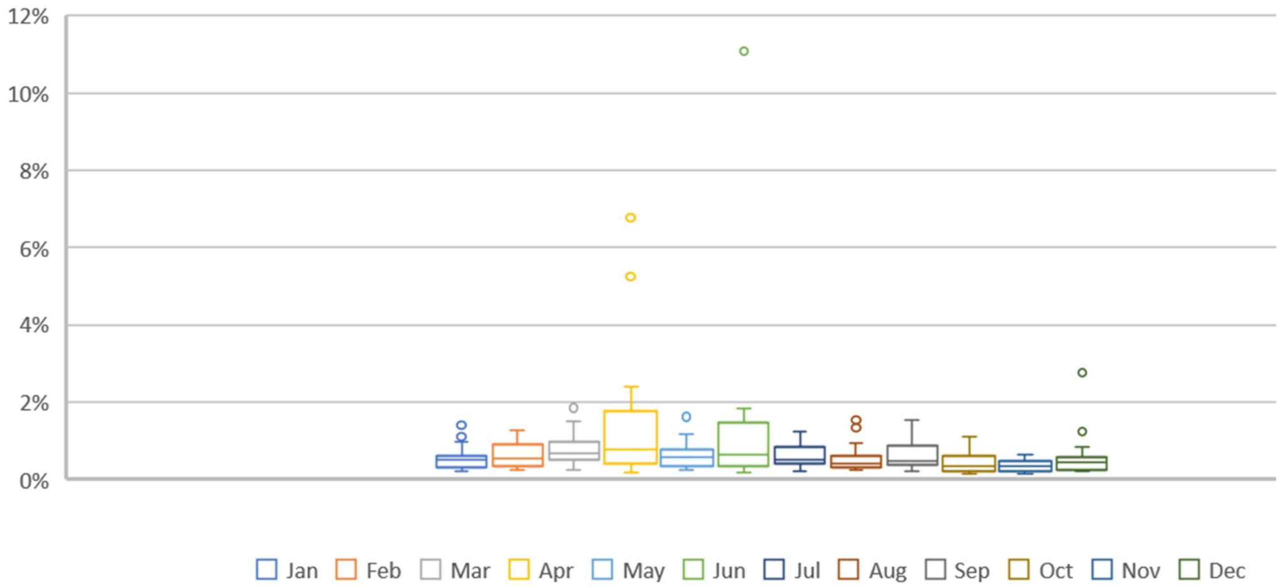

Figure 3.6 – Box plots of calculated percentage contribution of groundwater to total inflows to the study area by month between 2000 and 2020.

Evapotranspiration and evaporation are the major outflows with vertical groundwater seepage assumed to be negligible given the results from modelling and groundwater levels. Evapotranspiration has been assumed to occur across the entire soil surface area of the Ramsar site (taken as 92.6% by area) and accounts for approximately 77 to 86% of the annual outflows. Evaporation has been taken to occur across the remaining water covered area of the Ramsar site (7.4% by area assuming a 3 m ditch width) and accounts for the remaining 14 to 23% of annual outflow.

The greatest source of uncertainty in the water balance is surface water outflow from the system. Surface water outflow to Denton New Cut is manually adjusted by use of a stopper board by the landowner and historical data are not available. The water from Denton New Cut is used to top up the Thames and Medway Canal to maintain water levels of 3.72 mAOD [7]. Historical data of monthly pump operation from 2014 – 2019 is available [7] and allows the potential magnitude of this abstraction to be estimated.

However it is inappropriate to include data from the abstraction directly in the water balance as it lies outside the boundaries of the study area and the volume of water available to pump into Denton New Cut will include other sources than surface water runoff from the culverted outflow.

The water balance indicates that up to 120 000 m^3 of water is transmitted to storage or unquantifiable outflows annually. Therefore without additional outflow, flooding is likely to occur during times of high precipitation as storage requirements exceed the expected storage capacity of the drainage ditches within the site (estimated to be approximately 50000 m^3 based on a < 2 m ditch depth).

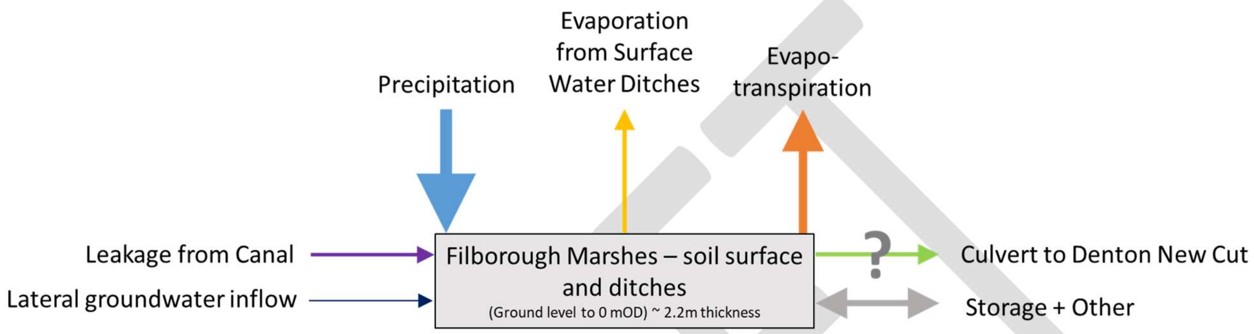

Figure 3.7 – Conceptual diagram of assessed main water inflows, outflows and storage within the study area (width of arrows indicates proportional magnitude)

4 Conclusions

4.1 Conclusions

A water balance assessment has been conducted of the shallow water system within part of the Filborough Marshes, immediately adjacent to the Lower Thames Crossing route alignment (the study area). This is part of the Ramsar site that overlies proposed Lower Thames Crossing tunnels. The preliminary water balance calculations suggest the following:

- The major source of water to the study area is precipitation and provides between 95 and 98% of the total annual water inputs.
- Groundwater flow is mostly horizontal and contribution to the system is small with typically <2% of the total water input per month from diffuse shallow groundwater seepage.
- The Thames and Medway Canal is likely to be a minor contributor to total water inflows as the rate of leakage is generally lower than the conductivity of the surrounding Alluvium
- The major outflows of water from the study area are evapotranspiration from the soil and evaporation from surface water ditches.
- The major uncertainty in the system is the amount of surface water drained by manual removal of the stopper board between the ditches and the culvert to Denton New Cut. Water pumped from Denton New Cut to the Thames and Medwater Canal is not an appropriate proxy for the magnitude of this outflow as it is outside the study area and is likely to include additional unquantified water sources.
- Without additional surface water outflow to Denton New Cut, flooding is likely to occur during times of high precipitation as storage requirements exceed the calculated storage capacity of surface ditches.
- Water storage depletion (of the soils and ditches) occurs when rainfall is low and is exceeded by evaporation plus evapotranspiration.
- Evaporation volume calculation is sensitive to the surface area of ditches. These calculations assume a width of 3 m.
- The water balance indicates that up to 120 000 m^3 of water is transmitted to storage or unquantifiable outflows annually.
- In prolonged dry periods where soil moisture deficit is high, the amount of water lost to evapotranspiration is reduced, but remote imaging of vegetation indicates no signs of significant water stress during representative dry periods.
- Magnitude of lateral groundwater inflow and leakages are based on vertical hydraulic conductivity (Kv) and horizontal hydraulic conductivity (Kh) of alluvium, from numerical modelling, geometric averages of Lower Thames Crossing Phase 1 and Phase 2 ground investigation and published sources. Significant continuous peat or sand layers could represent potential pathways for increased water movement.

5 References

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Appendices

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Appendix A – Additional Figures

A.1 Preliminary Groundwater Data

Figure A.1 shows preliminary manual dip data collected between Oct 2017 and Feb 2020 during Lower Thames Crossing Phase 1 and Phase 2 GI monitoring rounds. This shows that the alluvium, river terrace deposits and chalk aquifer all have a similar piezometric head and there appears to be no hydraulic pressure difference to drive significant flow from the surface alluvium to lower strata.

Figure A.1 - Groundwater levels from manual dips of Environment Agency boreholes (black crosses), Phase 1 and Phase 2A boreholes installed in chalk (green) river terrace deposits (red) and alluvium (light brown) south of the Thames. Vertical and lateral extent of study area is outlined (black box).

Figure A.2 shows water levels from the Environment Agency borehole on Church Lane. This record ends on 20/04/2018 with a level of 7.17 mAOD and has been extrapolated to remain constant at this level for calculations later than this date. Nearby Lower Thames Crossing wells OH03001 and OH03003 show actual water levels several meters lower than this static level from the start of monitoring in November 2018. Extrapolation assuming a linear gradient from the locations of these boreholes to the Church Lane monitoring point indicates lower water levels of between 4 to 5 mAOD between 2018 and 2019.

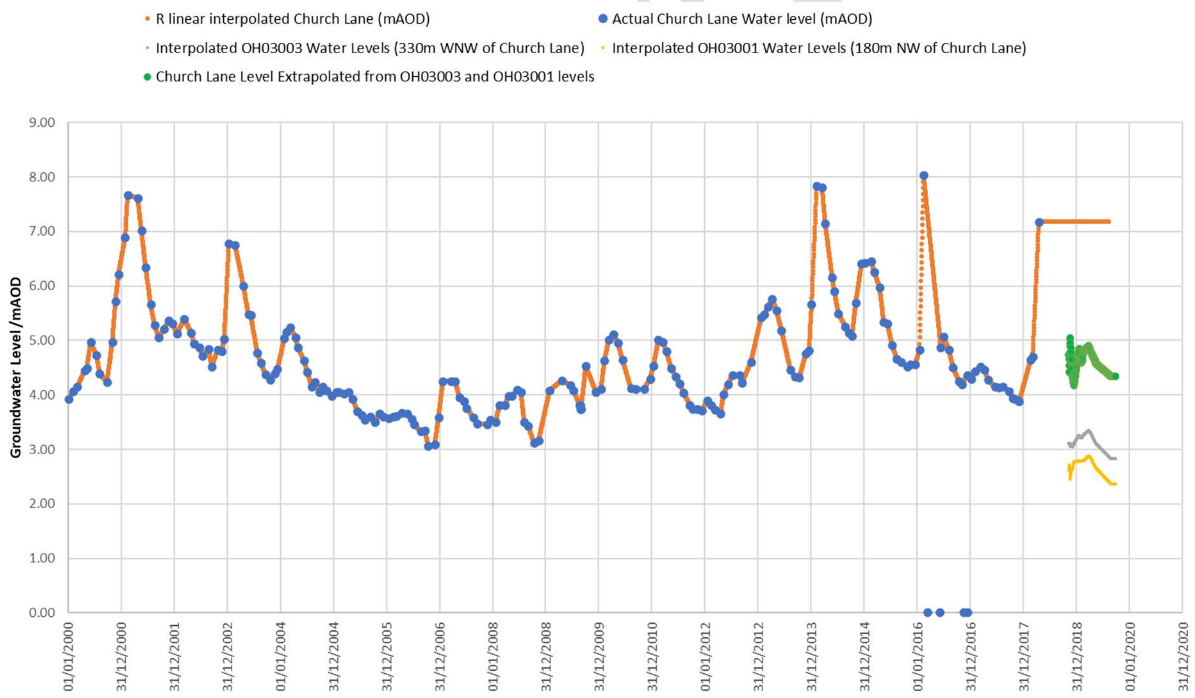


Figure A.2 - Groundwater levels from the Environment Agency's Church Lane monitoring borehole (blue) and interpolated series (orange) used to calculate horizontal groundwater movement. Manual dip data from nearby Lower Thames Crossing wells (yellow and grey) have been used to extrapolate water levels at the Church Lane monitoring borehole location (green) for comparison.

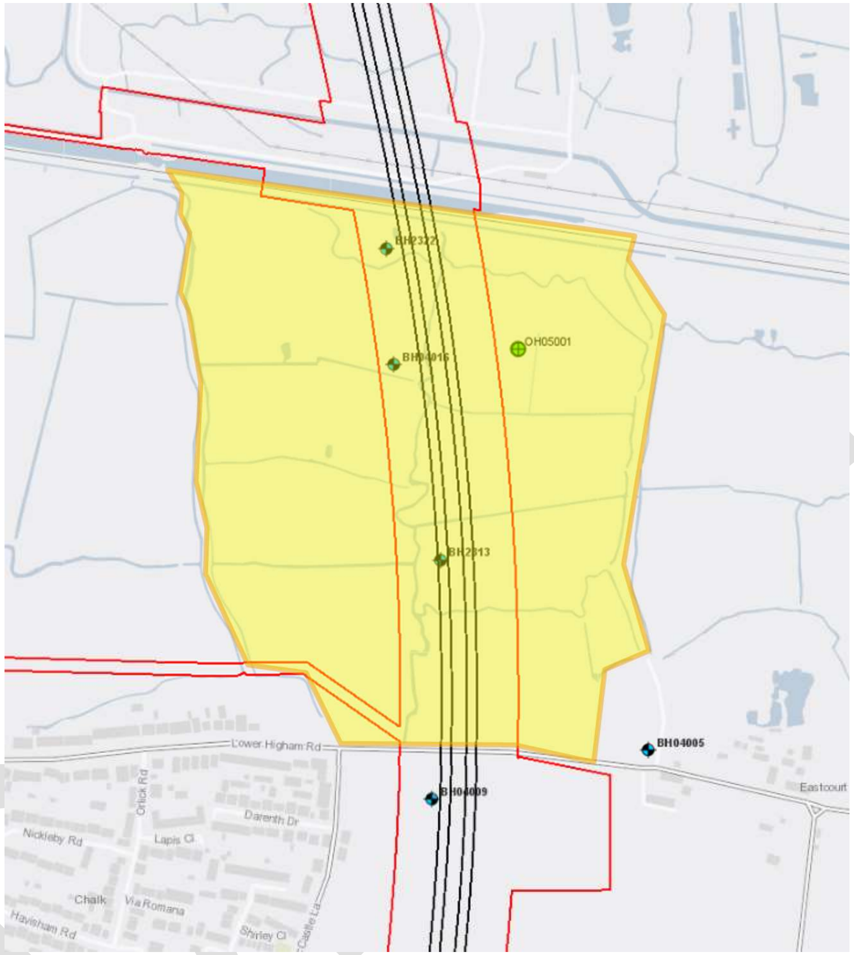


Figure A.3 – Locations of GI within or close to the Ramsar study area with VWP installations or dataloggers. BH2322, OH05001, BH04016 and BH2313 lie within the boundary.

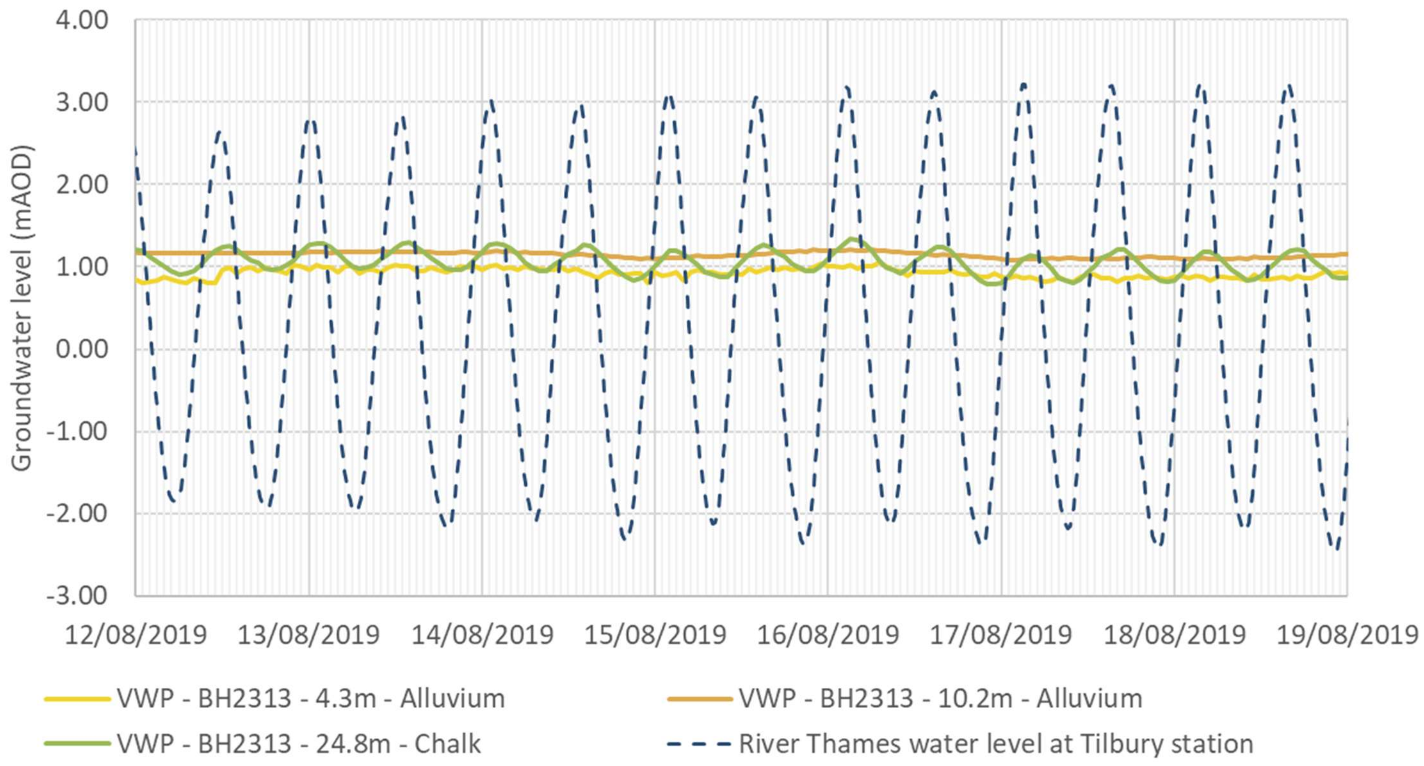


Figure A.4 – Representative hydrograph from VWP installation in BH2313 within the Ramsar. BH04016. OH05001 not included due to suspected faulty installation, BH04016 not included due to suspected data channel errors which have been queried with the contractor. BH2322 only has a chalk response zone and is not relevant to include.

Figure A.4 shows groundwater levels from multiple vibrating wire piezometers recently installed as part of Lower Thames Crossing Phase 2 Ground Investigation. These confirm observations from manual dip data (Figure A.1) that Chalk and RTD water levels are similar to in the Alluvium but with an increased tidal response due to higher hydraulic conductivity. This supports the assumption that there is no significant head difference driving a vertical inflow to the Ramsar.

Appendix B - Vertical hydraulic connectivity around the Ramsar Site

B.1 Background

This Appendix reports the assessment on the hydraulic vertical connectivity between the Ramsar site, the advanced grouting tunnel and deeper aquifer system, based on field and laboratory data from the Phase 2 Ground Investigations (Lower Thames Crossing Document n. HE540039-PCI-GEN-GEN-REP-GEO-00043.pdf currently in DRAFT form), as detailed in the following Section 1.3.

B.2 Sources of information

The sources of information used in the preparation of this note include published literature and site-specific data collected during various phases of ground investigation; these are listed in Section 5 of the main report.

B.3 Methodology

This assessment is mainly based on the Package A Phase 2 ground investigation results (see location of these GIs in Figure B.1, Lower Thames Crossing Document n. HE540039-PCI-GEN-GEN-REP-GEO-00043.pdf currently in DRAFT form), comprising the following field and laboratory data:

- Lithology (borehole logs)
- Variable head tests (VHT)
- Cone Penetration Tests (CPTs)
- Groundwater levels monitoring

The areal extent of this assessment is determined based on the influence zone of the grouting tunnel where the natural groundwater regime is predicted (see Figure B.2 to Figure B.5) to show some level of adverse impact.

Cone Penetration Tests (CPTs) data is processed using the methods outlined in Robertson (2010) [17]

Variable head tests from Phase 2 ground investigations are also considered.

A comparison of the K ranges for the relevant lithologies obtained using the VHT and CPT data with the K values previously used in the groundwater numerical model and the water balance (this report) is additionally carried out. This will enable a consistency check and (potentially) highlights significant discrepancies for further investigation.

The obtained K data (outlined above) is then interpreted together with the new Phase 2 borehole logs and the groundwater levels data, within three main areas of the grouting tunnel: the Launch Shaft, the Reception Shaft, and the area in between (Mid Tunnel), as detailed in the following Sections.

The Launch Shaft and Reception Shaft are both outside the limits of the protected Ramsar site (Figure B.2) and outside of the water balance volume. Properties of the Alluvium around the launch and reception site have been assessed in order to gauge the amount of lateral variation in conductivity that may be present across the Ramsar.

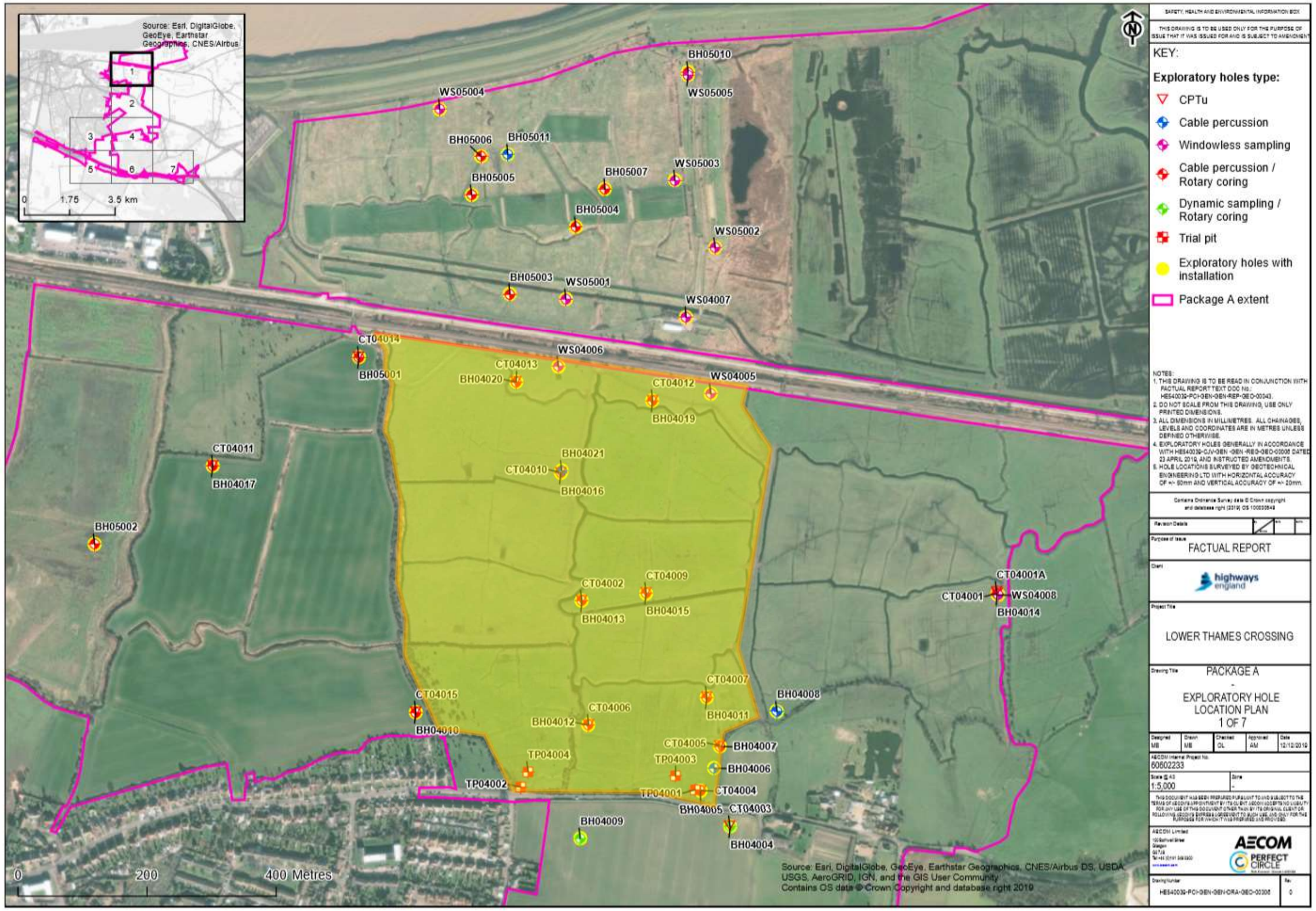


Figure B.1 - Southern area of the Lower Thames Crossing project and location of Phase 2A ground investigations

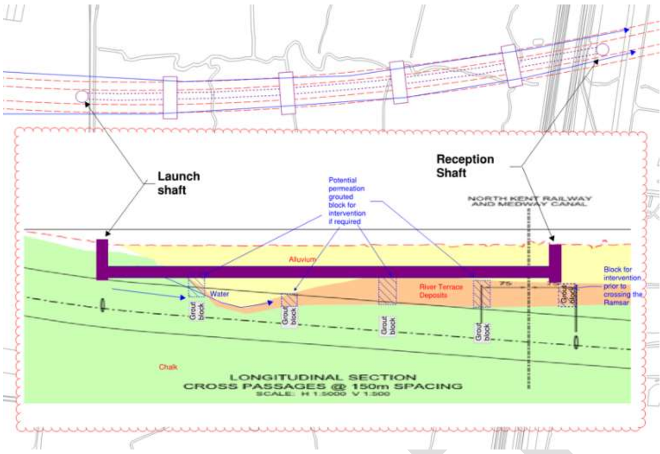


Figure B.2 - Cross section showing the grouting tunnel and grout blocks.

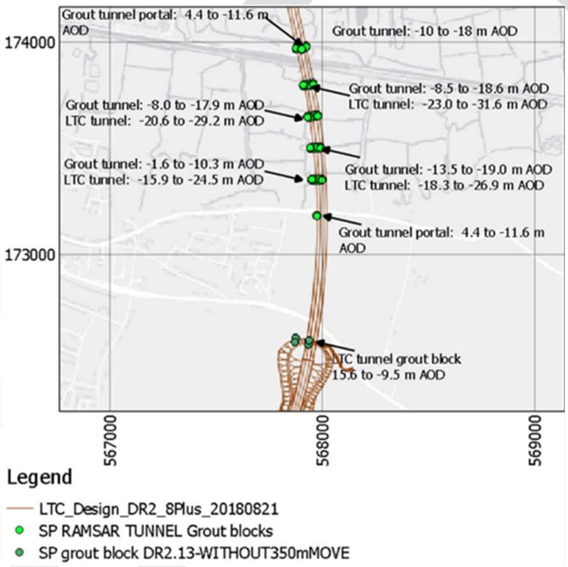


Figure B.3 - Grout tunnel and Lower Thames Crossing main tunnels alignment showing portals and grouting blocks.

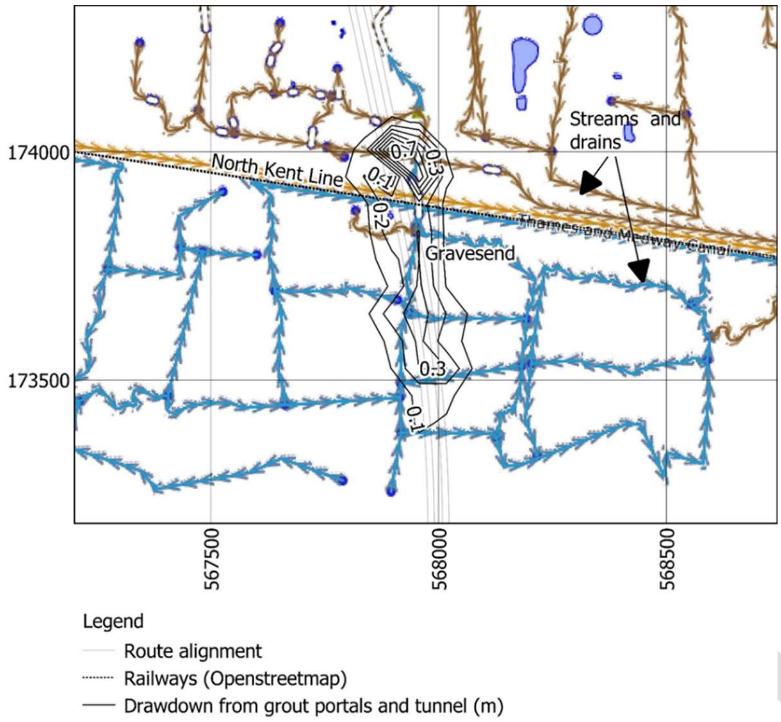


Figure B.4 - Drawdown from the grout tunnel with inflow rate of 0.1 L/s/m²

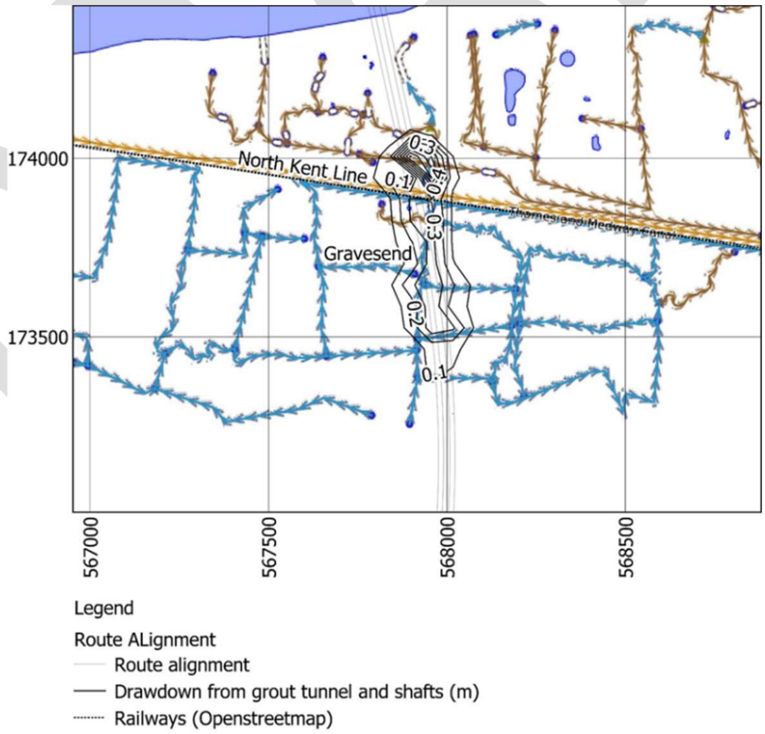


Figure B.5 - Drawdown from the grout tunnel with inflow rate of 0.5 L/s/m²

B.4 Hydraulic conductivity estimates

Hydraulic conductivity estimates from CPTs

CPT tests were used to estimate the hydraulic conductivity according to two methods, as outlined in the following Sections.

B.4.1 Permeability estimates based on CPTu dissipation test

The dissipation of pore pressures during a CPTu dissipation test is controlled by the coefficient of consolidation in the horizontal direction which is directly proportional to the hydraulic conductivity. Various methods allow estimation of soil permeability (k) using the time for 50% dissipation (t50) from a CPTu dissipation test [13].

Only a few dissipation tests were available for the Alluvium. The corresponding K values are presented in Table B.1 below:

Table B.1 Permeability estimates based on CPTu dissipation test

Borehole ID	CPT test ID	Depth of dissipation test (mbgl)	Strata ID	Lithology	Area of proposed grout tunnel	Hydraulic Conductivity (m/s)
BH04004	CT04003	1.50	ALV	sandy gravelly SILT	Launch shaft	1.5E-08
BH04005	CT04004	2.00	ALV	silty gravelly SAND.	Launch shaft	1.50E-08
BH04015	CT04009	10.29	ALV	Silty CLAY	Mid Tunnel	1.20E-08

These limited dissipation tests results confirm the Alluvium in the Launch Shaft area to be very low permeability in its shallower portion (0-2 mbgl).

B.4.2 Permeability estimates based on soil type

While detailed explanation of this method is included in [13], in brief, the hydraulic conductivity is estimated as a function of the Soil Behaviour Type (SBT) Index, Ic, which is directly proportional to the Normalised cone resistance (Qtn) and the Normalised friction ratio (Fr) which are determined with the CPTu tests.

- $Ic = [(3.47 - \log Qtn)^2 + (\log Fr + 1.22)^2]^{0.5}$

The proposed relationship between soil permeability (k) and SBT Ic, shown in Figure B.6, can be represented by:

- When 1.0 < Ic ≤ 3.27 $k = 10^{(0.952 – 3.04 Ic)}$ m/s
- When 3.27 < Ic < 4.0 $k = 10^{(-4.52 – 1.37 Ic)}$ m/s

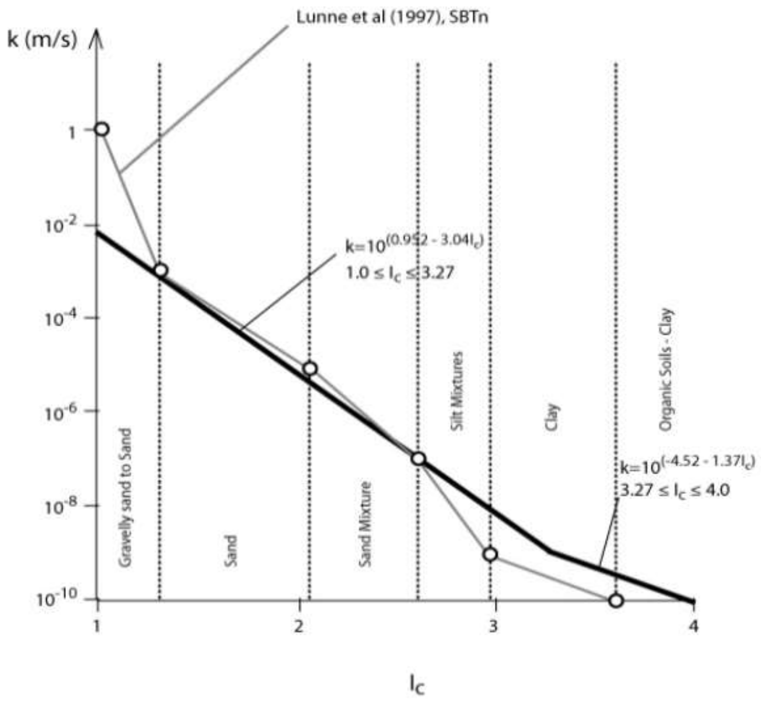


Figure B.6 Variation of soil permeability (k) as a function of SBT Ic. [17].

Equations above can be used to provide an estimate of soil permeability (k) and to show the variation of soil permeability with depth from a CPT sounding. Since the normalized CPT parameters (Qtn and Fr) respond to the mechanical behaviour of the soil and depend on many soil variables, the suggested relationship between k and Ic is approximate and should only be used as a guide.

Table B.2 summarises the available K estimates from a selection of CPT tests carried out in the three grouting tunnel areas, together with explanation and interpretation notes. It should be noted that, according to Figure 3.6, where Ic is greater or equal to 4, the corresponding estimated K value is assumed to be lower or equal to 1E-10 m/s (very low permeability); estimates of K using values of Ic greater than 4 are unrealistically low.

Table B.2 Summary of K estimates results in Alluvium (from CPT tests)

CPT ID	BH ID	AREA	GEOLOGY	Layer depth (mbgl)	Layer Thick ness (m)	CPTu test extent	Interval(s) where Ic<=4 (K>= 1E-10) (mbgl)	Hydraulic Conductivity K (m/s) Geometric mean	Notes
CT04003	BH04004	Launch Shaft	TOPSOIL/ALV	0.0-2.20	0.20	0.0-15.0	0 – 0.20 CLAY	6.5E-08	For most of their layer thickness, ALV and Ks are relatively low.
					1.46		0.74 – 2.2 SAND and SILT	4.5E-06	
CT04004	BH04005	Launch Shaft	HEAD/ALV	0.0-7.8	7.80	0.0-13.52	0.0 – 0.70 CLAY	7.2E-07	ALV is of low K for the majority of the layer.
							1.00 – 1.84 SAND	2.7E-06	
							1.92 – 5.14 SAND, GRAVEL, CLAY	3.4E-10	
							7.48 – 7.62 CLAY	1.8E-08	
CT04001	BH04014	Mid Tunnel East	TOPSOIL/ALV	0.0-21.90	21.90	0.0-4.04	0.0-0.30 CLAY	5.4E-08	Alluvium generally of very low permeability
							3.20-3.94 CLAY and GRAVEL	1.1E-05	
CT04011	BH04017	Mid Tunnel West	TOPSIL/ALV	0.0-15.10	15.10	0.0-14.76	0.0-0.2 CLAY	5.6E-08	Alluvium generally very low permeability
							14.42-14.68 CLAY	1.1E-08	
CT04002	BH04013	Mid Tunnel	TOPSOIL/ALV	0.0-17.90	17.90	0.0-17.92	0.0-0.8 CLAY	6.0E-07	The thick alluvium at this location is of relatively low permeability

CPT ID	BH ID	AREA	GEOLOGY	Layer depth (mbgl)	Layer Thick ness (m)	CPTu test extent	Interval(s) where Ic<=4 (K>= 1E-10) (mbgl)	Hydraulic Conductivity K (m/s) Geometric mean	Notes
CT04010	BH04016	Mid Tunnel	TOPSOIL/ALV	0.0-13.0	13.00	0.0-15.0	0.0-0.58 CLAY	3.2E-06	Alluvium generally very low permeability (K less than 1E-10m/s) apart from the top portion;
							10.3-10.72 Clayey GRAVEL	3.9E-09	
CT04013	BH04020	Reception Shaft	TOPSOIL/ALV	0.0-14.10	14.10	0.0-15.36	0.0-0.34 CLAY	4.8E-07	Alluvium generally very low permeability (K less than 1E-10), apart from very superficial portion;
CT04012	BH04019	Reception Shaft	TOPSOIL/ALV	0.0-10.15	10.15	0.0-14.58	1.2-10.12 organic CLAY	<1E-10	CPT test failed up to 1.2mbgl. Alluvium generally very low permeability (K less than 1E-10m/s)
CT04014	BH05001	Reception Shaft	TOPSOIL/ALV	0.0-13.80	13.80	0.0-13.76	0.0-0.76 CLAY	2.9E-07	Alluvium generally very low permeability (K less than 1E-10), apart from very superficial portion, slightly more permeable but still low K.
							13.64-13.64 CLAY	4.80E-10	

The overall summary of Alluvium K estimated results based on CPT tests is as follows:

- Launch Shaft - The top portion (up to 2 m) shows relatively low K values of 1E-06 to 1E-08 m/s; however, where the strata has significant thickness, K values decrease significantly (1E10-8 to less than 1E-10 m/s).
- Mid Tunnel - generally very low permeability (K less than 1E-9 m/s), with a superficial portion (up to 0.8 m) with K values in the order of 1E-06 to 1E-08 m/s and one lens with K values in the order of 1E-05 m/s.
- Reception Shaft - generally, very low permeability (K less than 1E-10m/s) apart from the top portion (less than 0.5m) with K ~ 1E-07 m/s.

B.4.3 **Permeability estimates from variable head tests**

Only one variable head test is available in the grouting tunnel area at BH05002, located at the Mid Tunnel (West) area in the alluvium (Figure B.1). The hydraulic conductivity was measured to be 8.06E-08 m/s between 8.0 and 10.0mbgl in a silty CLAY with frequent pockets of peat.

B.5 Discussion

Considered all together, the K estimates from the CPTs and VHT presented in the previous Sections, for the three grout tunnels areas can be summarised as follows:

Launch Shaft: in this area, the Alluvium appears to be very heterogeneous, with a wide range of K between 1E-06 m/s to less than 1E-10 m/s. This supports use of the literature values (1E-08 to 1E-07 m/s); the initial assumption for K in the groundwater model [5].

Mid Tunnel: in this area the Alluvium overall confirms its fairly low conductivity of between 1E-10 and 1E-08 m/s and it appears to be less heterogeneous and of lower conductivity than in the Launch Shaft area.

Reception Shaft: In this area, the Alluvium K values is overall of low hydraulic conductivity. CPT tests suggest very low K (1E-10 m/s). Borehole logs confirm the presence of abundant very low permeability deposits (silt, clay), confirming the suitability of CPT tests estimates. K values support the suitability of the values used in the numerical model and water balance.

Appendix C – Remote Imaging Data

C.1 Methodology

Visual analysis of imagery from Sentinel-2 optical satellite [16] for two representative years with extended dry periods was used to qualitatively determine whether vegetation across the Ramsar shows signs of moisture stress during dry conditions. Datasets with a resolution of 10 to 20m were analysed using NDVI (Normalized Difference Vegetation Index) and MSI (Moisture Stress Index) [21] during pre-dry (May to July), driest period (July to August) and post-dry conditions (September to November) for 2016 and 2018.

C.2 Normalized Difference Vegetation Index

NDVI is the most widely used vegetation index and normalises green leaf scattering (Near Infra-red) and chlorophyll absorption (red) and can be used to indicate the presence of grassland as opposed to barren rock or soil. In both dry years (Figure C.1 and Figure C.2) the NDVI index indicates a reduction in chlorophyll content between the pre-dry and dry period, but continued shrub or grassland coverage throughout the driest period with no evidence for barren conditions in areas of the Ramsar within 3 km of the proposed route alignment. Recovery from dry period conditions is slow with post-dry period NDVI values notably lower than pre-dry conditions.

C.3 Moisture Stress Index

MSI is a measurement of reflectance which is sensitive to increasing leaf water content where higher values indicate greater water stress. In both dry years (Figure C.3 and Figure C.4) the data from pre-dry conditions indicates low water stress across the Ramsar within 3km of the proposed route alignment. MSI generally increases during the driest period but remains within typical values for green vegetation and in both years the MSI is highest during the post dry period.

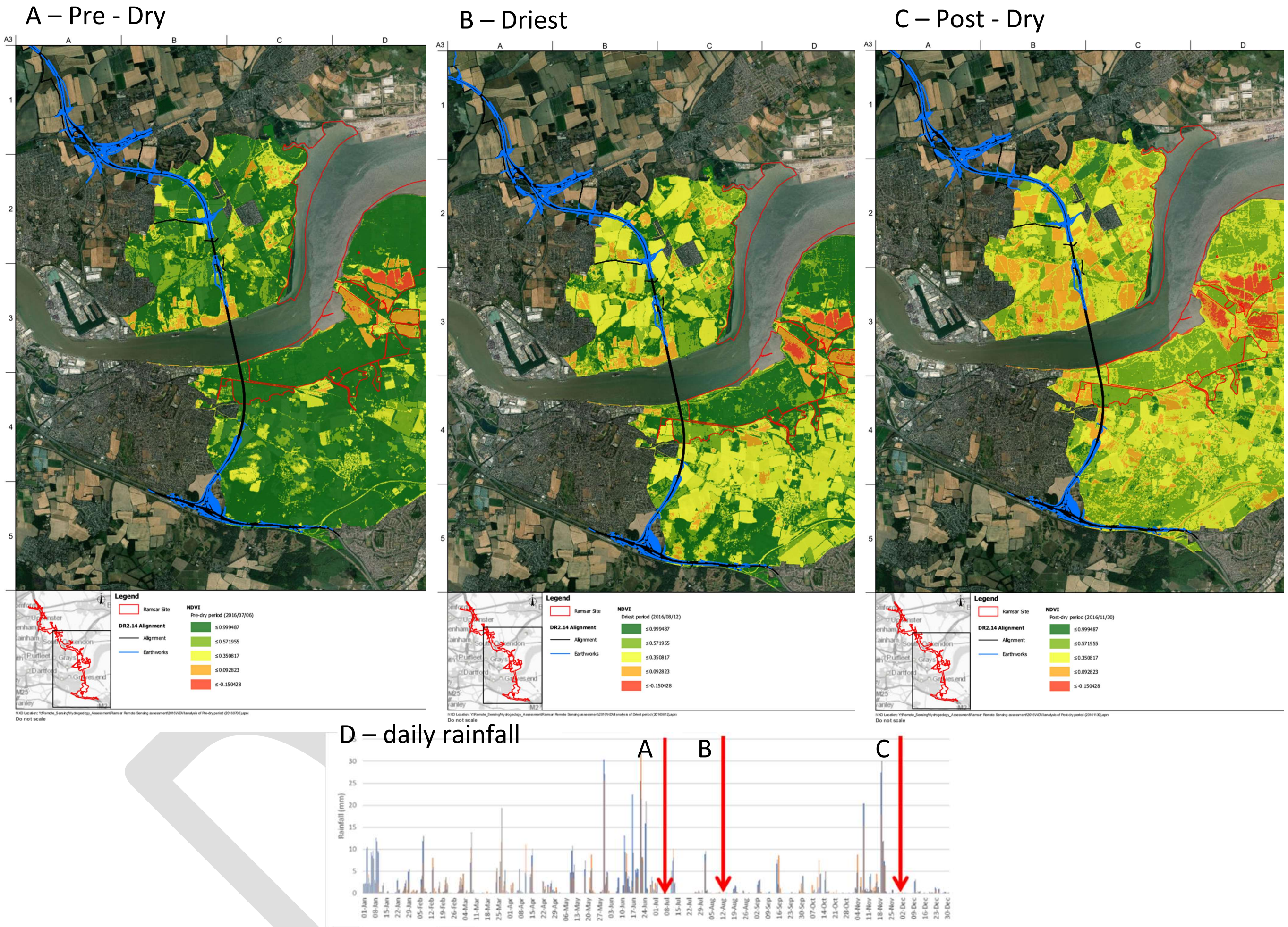


Figure C.1 – NDVI imagery from 2016 dry period. (A) Pre-dry period - 06/07/2016; (B) Driest period - 08/12/2016; (C) Post-dry period - 30/11/2016; (D) 2016 daily rainfall records with arrows indicating date of each image

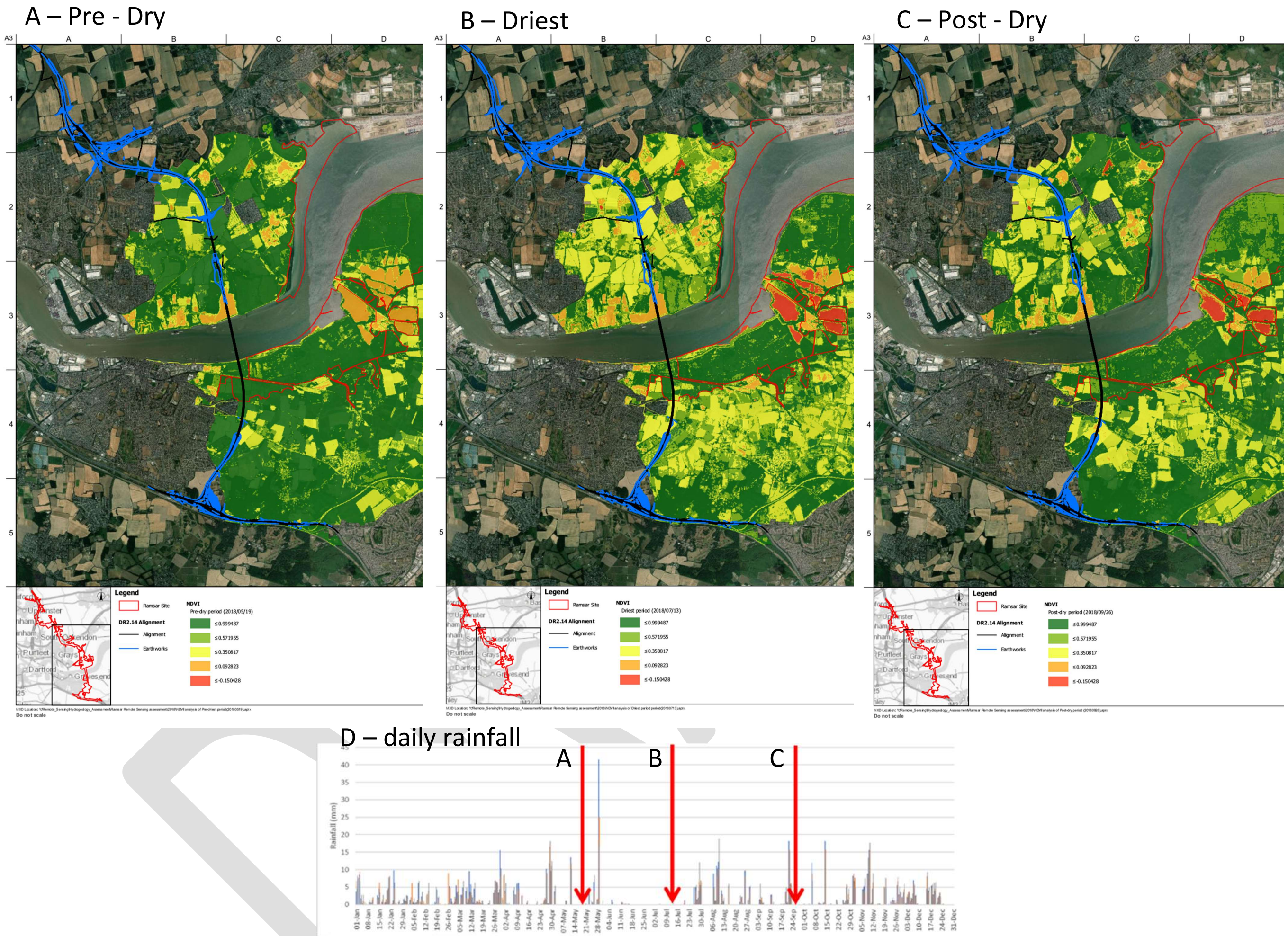


Figure C.2 – NDVI imagery from 2018 dry period. (A) Pre-dry period - 19/05/2018; (B) Driest period - 13/07/2018; (C) Post-dry period - 26/09/2018; (D) 2018 daily rainfall records with arrows indicating date of each image

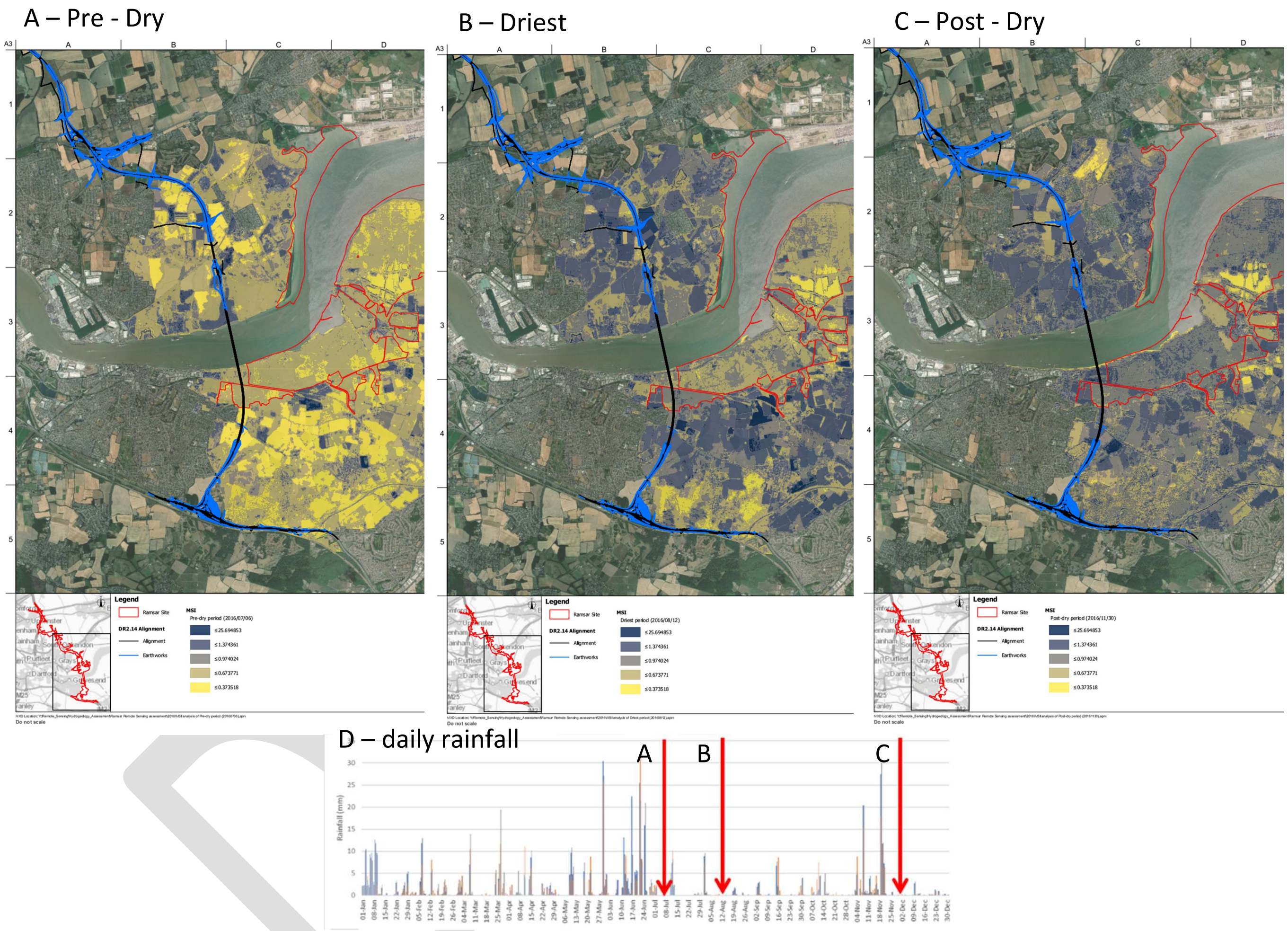


Figure C.3 – MSI imagery from 2016 dry period. (A) Pre-dry period - 06/07/2016; (B) Driest period - 08/12/2016; (C) Post-dry period - 30/11/2016; (D) 2016 daily rainfall records with arrows indicating date of each image

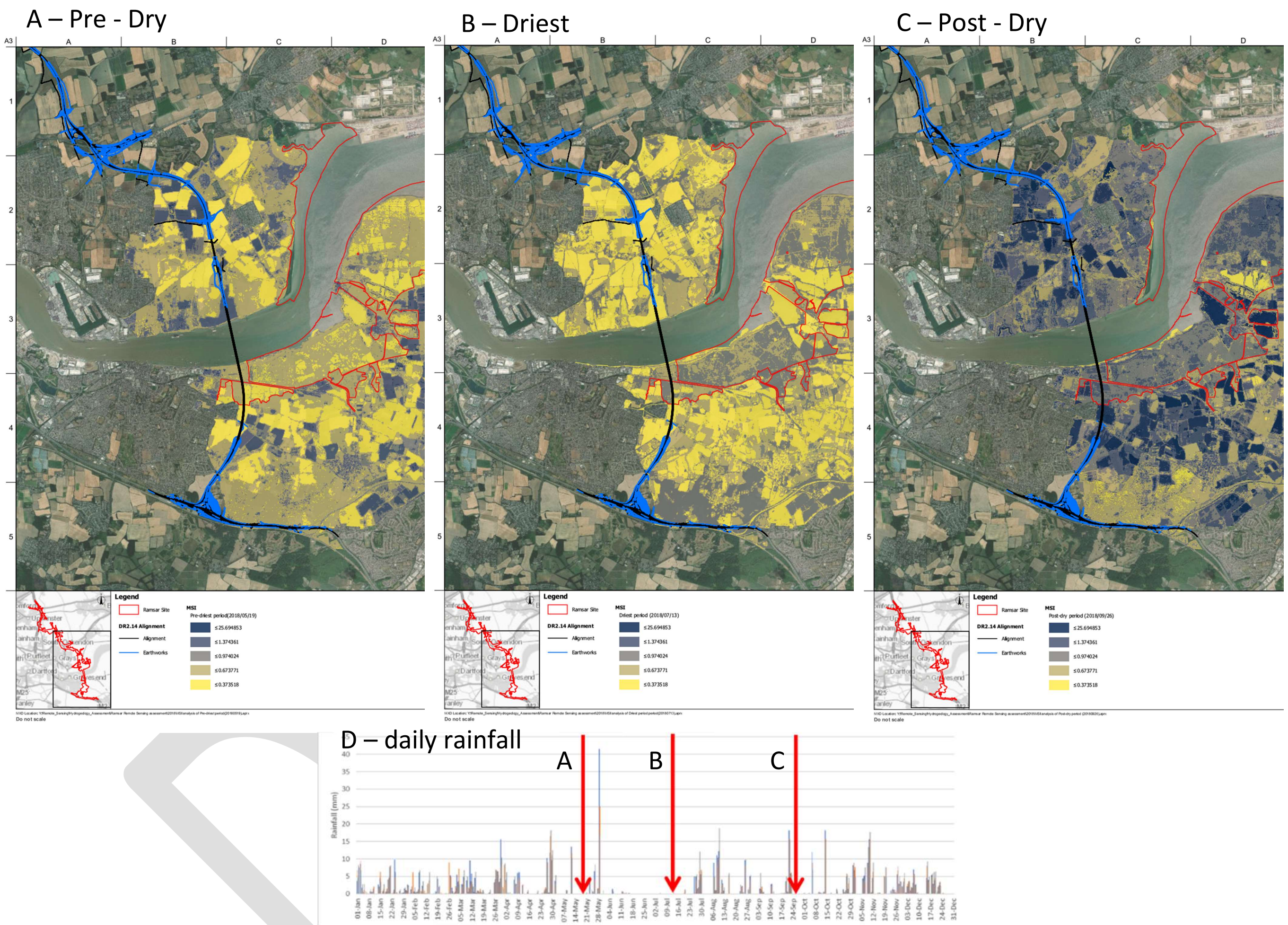
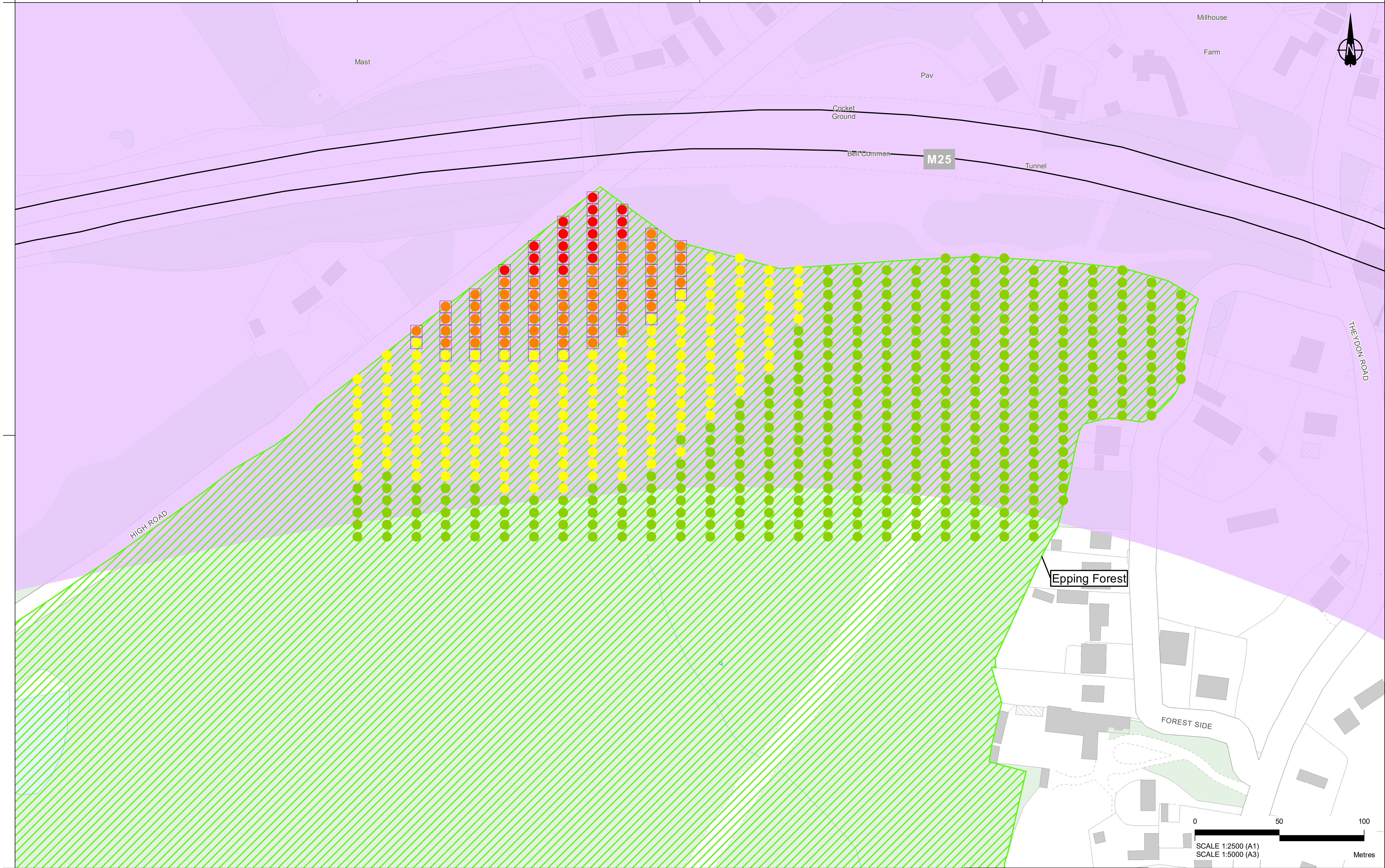


Figure C.4 – MSI imagery from 2018 dry period. (A) Pre-dry period - 19/05/2018; (B) Driest period - 13/07/2018; (C) Post-dry period - 26/09/2018; (D) 2018 daily rainfall records with arrows indicating date of each image

Annex BB 22 July 2020 Stage 1 Screening Figure 31 – Predicted change in nitrogen deposition at European sites



Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	15/07/2020	For Information	LK	IP	RC

LEGEND

- Affected Road Network (ARN)
- Area with 200m of the ARN - Operation (2027)
- Special Protection Area
- Ramsar site
- Special Area of Conservation
- Predicted change in N deposition between Do Something (DS) and Do Minimum (DM)

N kg/ha/yr

- -0.13 - 0.02
- 0.03 - 0.05
- 0.06 - 0.10
- 0.11 - 0.19
- 0.20 - 0.41
- N deposition change (DS-DM) > 1% of LCL

Client

highways england

Project

5TH FLOOR BEAUFORT HOUSE
15 ST BOTOLPH STREET
LONDON EC3A 7DT

Status

For Information

Original Size: A3
Revision: P01
Scale: 1:2,000

Drawing title

Predicted change in nitrogen deposition at European sites
Epping Forest SAC

Drawing number

FIGURE 31A

MXD Location: G:\678379CH_LTC_HRA\GIS\MXDs for July Submission\HRA_Fig31.mxd

Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	15/07/2020	For Information	LK	IP	RC

LEGEND

- Affected Road Network (ARN)
- Area with 200m of the ARN - Operation (2027)
- Special Protection Area
- Ramsar site
- Special Area of Conservation
- Predicted change in N deposition between Do Something (DS) and Do Minimum (DM)
  N kg/ha/yr
  - -0.13 - 0.02
  - 0.03 - 0.05
  - 0.06 - 0.10
  - 0.11 - 0.19
  - 0.20 - 0.41
- N deposition change (DS-DM) > 1% of LCL

Client
highways england

Project
5TH FLOOR BEAUFORT HOUSE
15 ST BOTOLPH STREET
LONDON EC3A 7DT

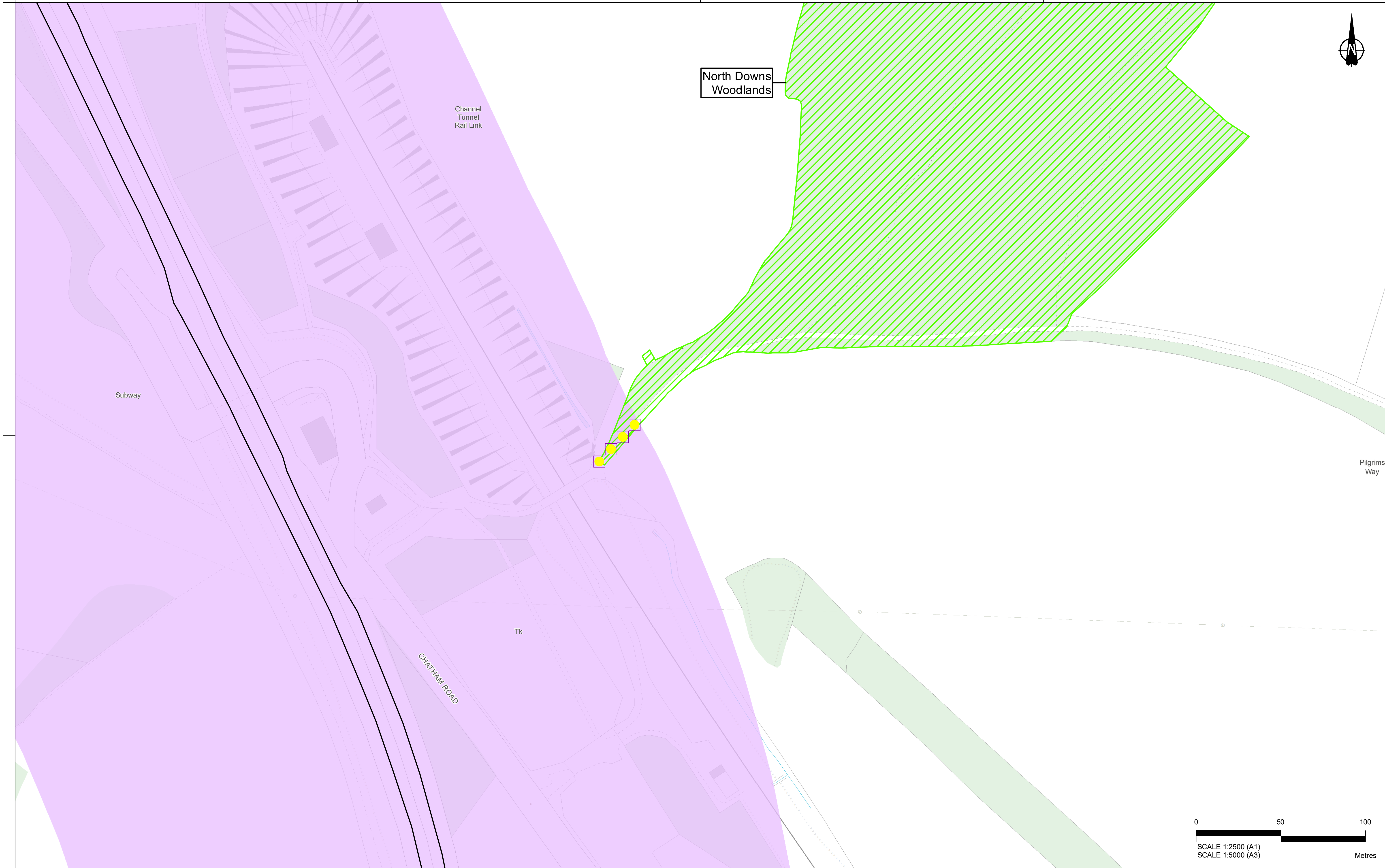
Status
For Information

Original Size: A3
Revision: P01
Scale: 1:2,000

Drawing title
Predicted change in nitrogen deposition at European sites
Medway Estuary & Marshes Ramsar and SPA

Drawing number
FIGURE 31B

MXD Location: G:\678379CH_LTC_HRA\GIS\MXDs for July Submission\HRA_Fig31.mxd



Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	15/07/2020	For Information	LK	IP	RC

LEGEND

- Affected Road Network (ARN)
- Area with 200m of the ARN - Operation (2027)
- Special Protection Area
- Ramsar site
- Special Area of Conservation
- Predicted change in N deposition between Do Something (DS) and Do Minimum (DM)
  - N kg/ha/yr
  - -0.13 - 0.02
  - 0.03 - 0.05
  - 0.06 - 0.10
  - 0.11 - 0.19
  - 0.20 - 0.41
- N deposition change (DS-DM) > 1% of LCL

Client

highways england

Project

5TH FLOOR BEAUFORT HOUSE
15 ST BOTOLPH STREET
LONDON EC3A 7DT

Status: For Information

Original Size: A3 | Revision: P01

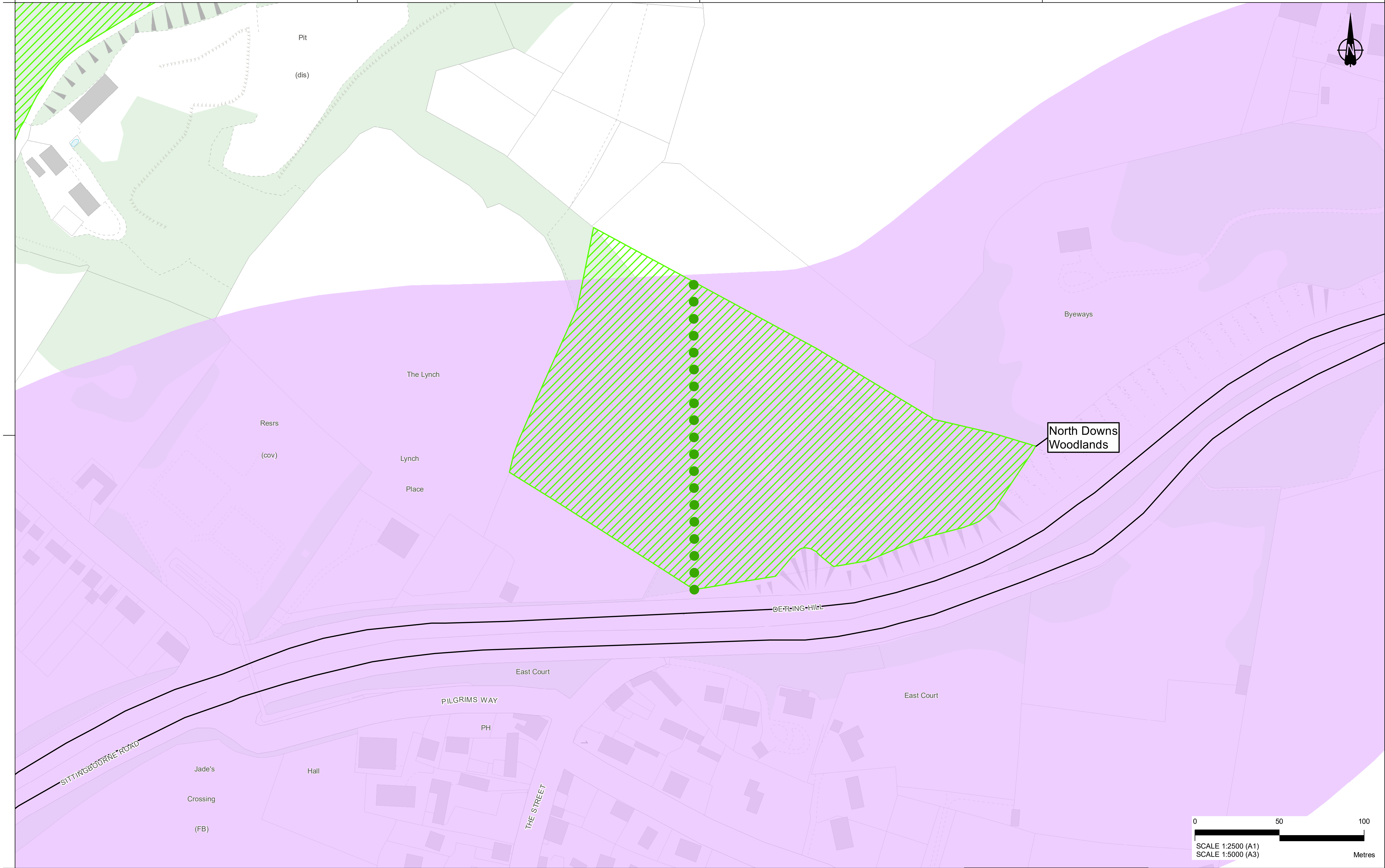
Scale: 1:2,000

Drawing title

Predicted change in nitrogen deposition at European sites
North Downs Woodland SAC

Drawing number: FIGURE 31C

MXD Location: G:\678379CH_LTC_HRA\GIS\MXDs for July Submission\HRA_Fig31.mxd



Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	15/07/2020	For Information	LK	IP	RC

LEGEND

- Affected Road Network (ARN)
- Area with 200m of the ARN - Operation (2027)
- Special Protection Area
- Ramsar site
- Special Area of Conservation
- Predicted change in N deposition between Do Something (DS) and Do Minimum (DM)

N kg/ha/yr

- -0.13 - 0.02
- 0.03 - 0.05
- 0.06 - 0.10
- 0.11 - 0.19
- 0.20 - 0.41
- N deposition change (DS-DM) > 1% of LCL

Client

highways england

Project

5TH FLOOR BEAUFORT HOUSE
15 ST BOTOLPH STREET
LONDON EC3A 7DT

Status

For Information

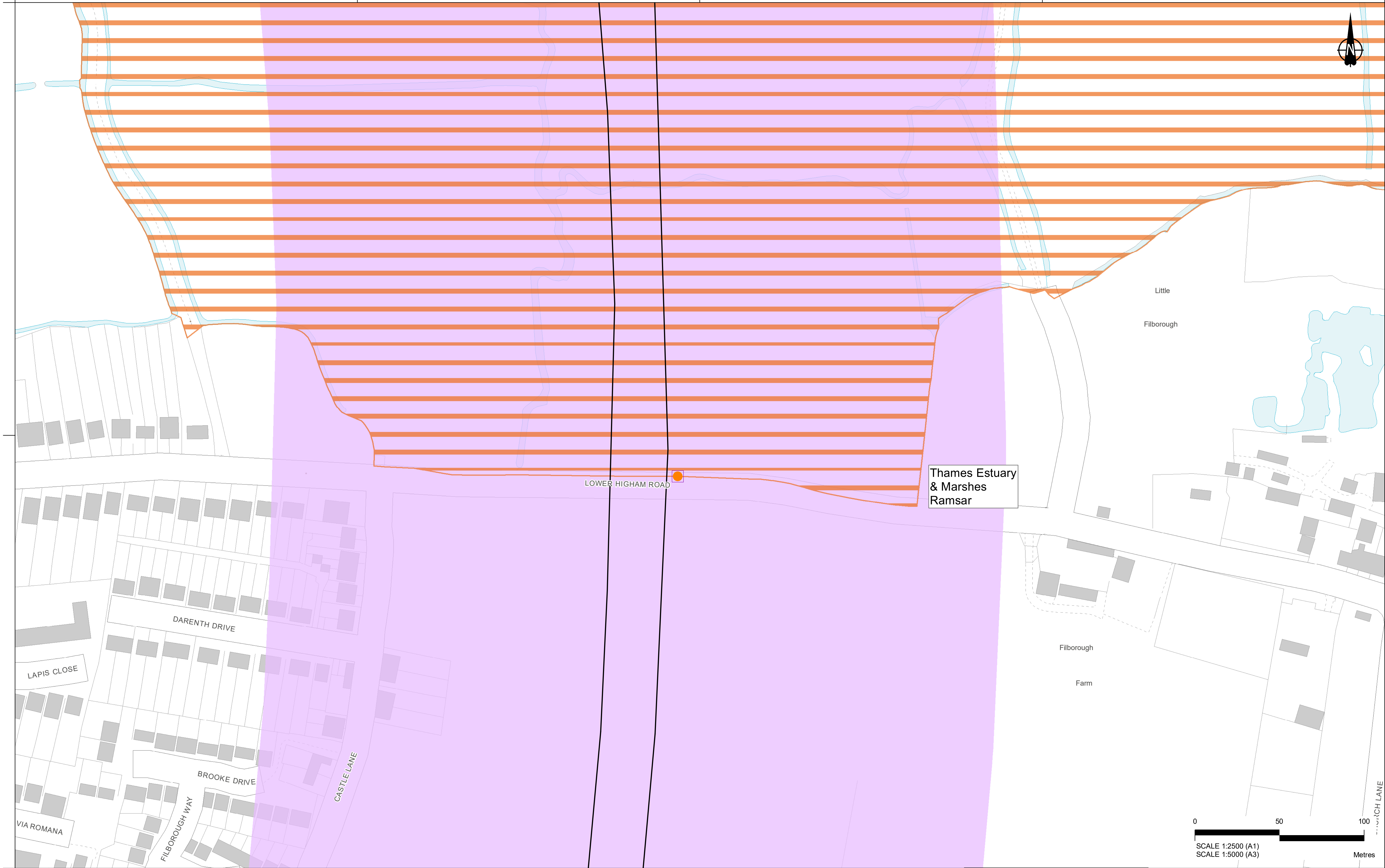
Original Size: A3
Revision: P01
Scale: 1:2,000

Drawing title

Predicted change in nitrogen deposition at European sites North Downs Woodland SAC

Drawing number: FIGURE 31D

MXD Location: G:\678379CH_LTC_HRA\GIS\MXDs for July Submission\HRA_Fig31.mxd



Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	15/07/2020	For Information	LK	IP	RC

LEGEND

- Affected Road Network (ARN)
- Area with 200m of the ARN - Operation (2027)
- Special Protection Area
- Ramsar site
- Special Area of Conservation
- Predicted change in N deposition between Do Something (DS) and Do Minimum (DM)

N kg/ha/yr

- -0.13 - 0.02
- 0.03 - 0.05
- 0.06 - 0.10
- 0.11 - 0.19
- 0.20 - 0.41
- N deposition change (DS-DM) > 1% of LCL

Client: highways england

Project

5TH FLOOR BEAUFORT HOUSE
15 ST BOTOLPH STREET
LONDON EC3A 7DT

Status: For Information

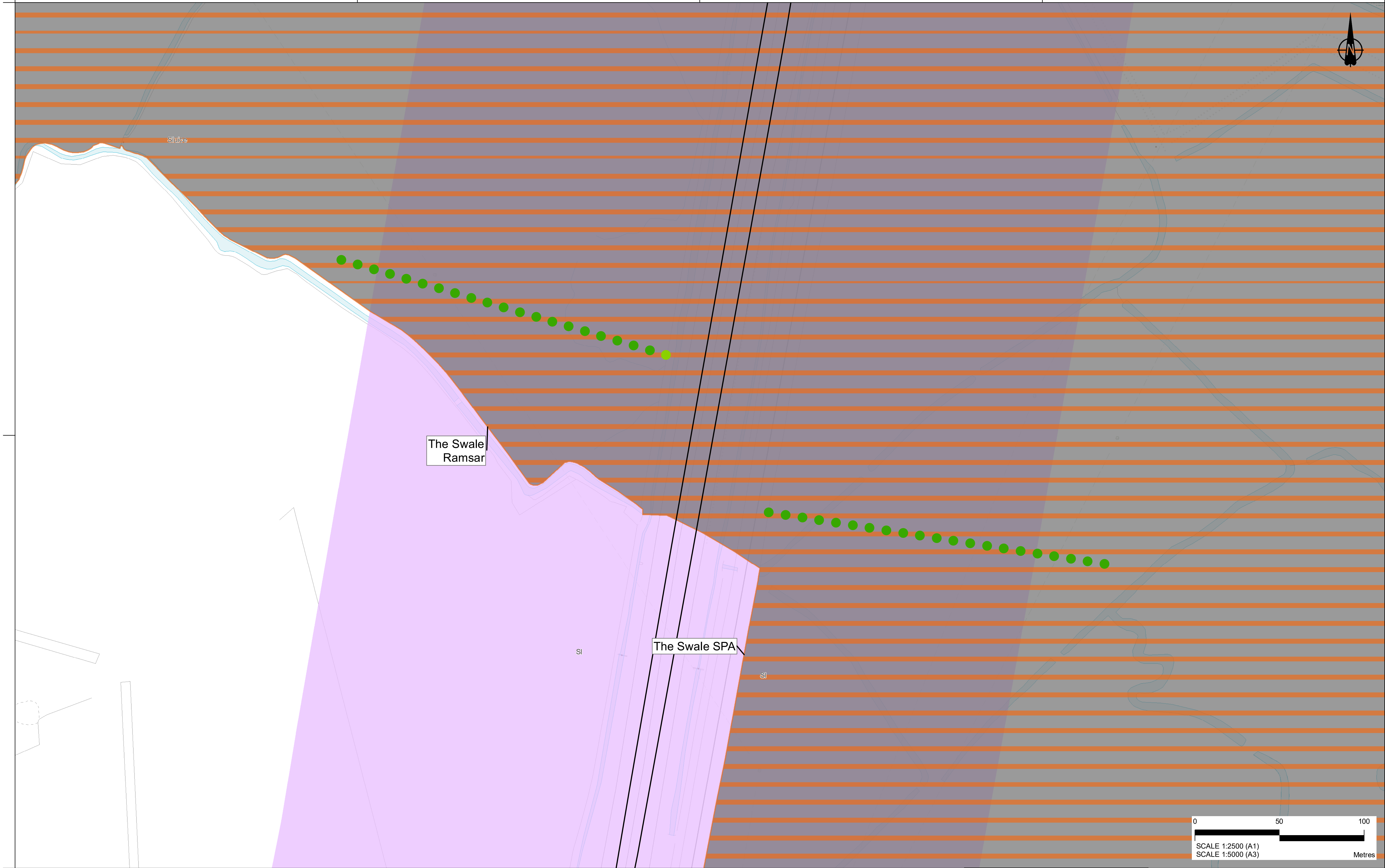
Original Size: A3 | Revision: P01 | Scale: 1:2,000

Drawing title

Predicted change in nitrogen deposition at European sites Thames Estuary & Marshes Ramsar

Drawing number: FIGURE 31E

MXD Location: G:\678379CH_LTC_HRA\GIS\MXDs for July Submission\HRA_Fig31.mxd



Rev	Status	Rev. Date	Purpose of revision	Drawn	Chck'd	Apprv'd
P01	S8	15/07/2020	For Information	LK	IP	RC

LEGEND

- Affected Road Network (ARN)
- Area with 200m of the ARN - Operation (2027)
- Special Protection Area
- Ramsar site
- Special Area of Conservation

Predicted change in N deposition between Do Something (DS) and Do Minimum (DM)

N kg/ha/yr

- -0.13 - 0.02
- 0.03 - 0.05
- 0.06 - 0.10
- 0.11 - 0.19
- 0.20 - 0.41

- N deposition change (DS-DM) > 1% of LCL

Client: highways england

Project

5TH FLOOR BEAUFORT HOUSE
15 ST BOTOLPH STREET
LONDON EC3A 7DT

Status: For Information

Original Size: A3 | Revision: P01 | Scale: 1:2,000

Drawing title: Predicted change in nitrogen deposition at European sites The Swale Ramsar and SPA

Drawing number: FIGURE 31F

MXD Location: G:\678379CH_LTC_HRA\GIS\MXDs for July Submission\HRA_Fig31.mxd

Annex CC 10 September 2020 DCO1.0 Stage 1 Screening – Appendix H – LA 105 NEA001 Comparison

Appendix H Comparison of DMRB LA105 with NEA001

H.1.1 This Appendix provides a comparison of the methodology used in the assessment of the effects of changes in air quality on European sites (based on DMRB LA105 (Highways England, et al., 2019)) with the advice within NEA001 (Natural England, 2018) (which is the approach suggested by Natural England during consultation) to show whether:

a. the LA105 methodology includes all elements of the NEA001 advice to demonstrate no Adverse Effects on Integrity (AEI), albeit as evidence of the absence of Likely Significant Effects (LSE)

b. the LA105 approach provides a specific methodology to assess effects for the 'considerations' provided for the assessment in NEA001

c. the LA105 methodology provides objective evidence for the absence of a likely significant effect (LSE), and therefore Appropriate Assessment in not required.

H.1.2 This Appendix compares LA105 and NEA001 approaches through two comparisons, based on:

a. The summary of the approach in Appendix A of NEA001 (Table H.1)

b. The sub headings of sections 4 to 6 of NEA001

H.1.3 The comparison demonstrates that all methodological elements of, or considerations within NEA001 are incorporated into the assessment, other than that NEA001 advises that an approach concluding LSE cannot be discounted based on NEA001 step 4 (application of screening thresholds). However, NEA001 has little methodological advice on how to carry out an appropriate assessment, whereas LA105 screening does have a clear method.

H.1.4 NEA001 states:

4.3 In undertaking an assessment of 'likely significant effects' under the Habitats Regulations, authoritative case law has established that:

An effect is likely if it 'cannot be excluded on the basis of objective information'

An effect is significant if it 'is likely to undermine the conservation objectives'

In undertaking a screening assessment for likely significant effects 'it is not that significant effects are probable, a risk is sufficient'…. but there must be credible evidence that there is 'a real, rather than a hypothetical, risk''.

4.4 The Advocate General's opinion in Sweetman also offers some simple guidance that the screening step 'operates merely as a trigger' which asks 'should we bother to check?''.

H.1.5 It is arguable that use of the LA105 methodology in the Screening assessment of the Project demonstrates through the use of objective information that there is no credible evidence that a real risk exists of undermining the Conservation Objectives on any European sites. It is therefore not necessary to "bother to check" any further level of detail to be able to discount adverse effects on the integrity of the sites.

H.1.6 Notwithstanding the issue of Screening vs Appropriate Assessment, it is concluded that applying the methodology in LA105 provides the same assessment steps as advised by Natural England in NEA001, and therefore come to the same overall conclusion as to whether an acceptable level of effect on European sites would occur.

Table H.1 Comparison based on the summary of the approach in Appendix A of NEA001

NEA001 Appendix A headings				LTC approach through LA105
Stage	**Step ref**	**Flowchart step**	**Supplemental evidence/ basis for judgment**	
Initial screening for credible risk of an effect	1	Check Distance criteria - could significant emissions reach a protected site? Yes = move to Step 2 No = no further HRA required	Industry standards based on likely distance for modelled emissions (scoping model); often related back to significance threshold Distance Criteria – 200m for roads and available upon request; note this is currently under review APIS Introduction to Air Pollution [redacted]	200m from Affected Road Network (ARN) used. See below information for definition of the ARN.
	2	Check the sensitivity of qualifying habitats or supporting habitat of qualifying species. Are habitats in proximity sensitive to the emission type? Yes = move to Step 3 No = no further HRA required	APIS Site relevant Critical Loads and Levels (based on literature and professional judgement) [redacted]	Analysis of all qualifying features of relevant European sites within the 200m zone by reference to web-based data and survey results Sensitivity of habitats identified through APIS Site Relevant Critical Loads and Levels
Detailed screening for determining whether screening	3	Check habitat likelihood to be exposed to emissions Are the sensitive habitats where	Use application documents to understand predicted emissions (magnitude and location if available). If not available, assume emissions reach entire site in proximity.	AQ modelling used to identify predicted N deposition and zone where predicted increase was >1% of the critical load

NEA001 Appendix A headings				LTC approach through LA105
Stage	**Step ref**	**Flowchart step**	**Supplemental evidence/ basis for judgment**	
thresholds are appropriate		emissions are predicted to be? Yes or Unsure = move to Step 4a No = no further HRA required	Investigate location of habitats determined as sensitive in Step 2. Use MAGIC priority habitat layers (internal staff: if necessary contact Site Responsible Officer for advice to understand if sensitive habitats are present).	GIS analysis of overlap of qualifying features with AQ modelled predicted N deposition
Applying screening thresholds	4a	Apply Screening Threshold Alone If below threshold alone = move to step 4b. If above = move straight to step 5.	Ascertain the Process Contribution (PC) or proxy increase in traffic from the plan or project (emissions and predicted deposition or AADT flow). This can be determined through application document, screening model results, detailed model results and information from APIS. Apply Screening threshold (1% of critical level or load or 1000AADT) alone.	The ARN was defined based on the following criteria being met: 1) annual average daily traffic (AADT) >=1,000; or 2) heavy duty vehicle (HDV) AADT >=200; or 3) a change in speed band; or 4) a change in carriageway alignment by >=5m. The AQ modelling was completed for transects where European sites were within 200m of the ARN and used to identify predicted N deposition and zone with >1% critical load. For Epping Forest SAC, the ARN was in tunnel, so plumes from the portals were modelled as a matrix rather than transects perpendicular to the ARN road.
	4b	Apply Screening Threshold In-combination with other traffic/roads	Use information from competent authority to determine if there are plans or projects in the pipeline (not in background pollution) that should be considered in-combination for emission from roads/ increase in traffic.	The traffic model that underpins the AQ modelling was “in combination” as it used the data provided by the Office of National Statistics to consider the future traffic growth. This is the same data that underpins the development growth requirements for Local Plans etc.

NEA001 Appendix A headings				LTC approach through LA105
Stage	**Step ref**	**Flowchart step**	**Supplemental evidence/ basis for judgment**	
		If below threshold in-combination = move to step 4c. If above = move straight to step 5.	For instance, add traffic increases/ emissions & deposition from other Local Plans together and apply 1000 AADT/ 1% to that sum.	
	4c	Apply screening threshold in-combination across sectors If below threshold in-combination = no likely significant effect can be advised, and no further assessment is required. If above = move to step 5.	Use information from other competent authorities (Planning Portal or Environmental Permitting register) to determine if there are nearby permissions that would have an in-combination effect with the roads being assessed. When all relevant proposals together (in-combination) fall below the 1% or 1000 AADT level of change, there is reasonable rationale to consider the proposal unlikely to have a significant effect.	This has been completed within the assessment of In-combination effects for air quality and includes other contributors (industrial and agricultural) to nitrogen deposition as well as the traffic already included.
Advise Appropriate Assessment is required and contribute scoping advice	5	Provide supporting evidence to Competent Authority (scoped as appropriate) Proceed to Step 6 when requested by competent authority and sufficient information is available to provide advice	Check distance of sensitive habitats from emissions	The assessment demonstrates through the use of objective information that there is no credible evidence that a real risk of undermining the Conservation Objectives on any European sites exists. It is therefore not necessary to "*bother to check*" any further level of detail to be able to discount adverse effects on the integrity of the sites. Objective information has been used to demonstrate that likely significant effects can be discounted and so Appropriate Assessment is not required.

NEA001 Appendix A headings				LTC approach through LA105
Stage	**Step ref**	**Flowchart step**	**Supplemental evidence/ basis for judgment**	
				Web based data and field survey results were used to check overlap of sensitive habitats with predicted increases in N deposition.
			Check European Site Conservation Objectives	Conservation objectives checked from NE's supplementary advice.
			Check environmental benchmark (critical level and load) Check background concentrations and exceedance Check APIS Trends Tab for reasonable expectation that background pollution is decreasing	APIS used to check critical loads.
			Assess likely scale and duration of impacts on habitats from emissions	AQ modelling included background concentrations and exceedances. AQ modelling used DEFRA data for predicted future levels plus a correction factor to ensure precautionary data used. AQ modelling and GIS used to identify scale of effect in terms of N deposition and area of habitat affected.
			Check strategic initiatives in area (if would be undermined if project or plan was allowed)	No strategic initiatives identified.
			Check mitigation options and whether detailed modelling may be needed (up to competent authority)	No mitigation possible as potential effects out with Order Limits. AQ modelling provided and detailed sensitivity of potentially affected habitats identified through survey of habitats and analysis

NEA001 Appendix A headings				LTC approach through LA105
Stage	**Step ref**	**Flowchart step**	**Supplemental evidence/ basis for judgment**	
				of nitrogen sensitivity of species present through consideration of Ellenberg indicator values for fertility.
			Consider any residual effects (after mitigation where practicable) and check for in-combination effects with other plans/projects	Residual effect considered within the detailed assessment step in the LA105 screening method (Fig 2.98 in LA105), using the scale of effects and sensitivity of receiving habitats. In combination assessment of other sources (Industrial and Agricultural) of N deposition carried out.
Advice on the appropriate assessment	6	Competent Authority has provided an Appropriate Assessment conclusion When requested by competent authority and information is available to provide advice	Give formal advice on appropriate assessment – provide reasoning for our advice	Objective information has been used to demonstrate that likely significant effects can be discounted and so Appropriate Assessment is not required. LA105 provides a specific methodology for undertaking the assessment. NEA001 does not provide a specific methodology.

H.2 Comparison based on the sub headings of sections 4 to 6 of NEA001

NEA001 Section 4: Advice on Screening for Likely Significant Effects

H.2.1 **Step 1:** Does the proposal give rise to emissions which are likely to reach a European site?
NE and HE in agreement with the 200m from the ARN methodology used.

H.2.2 **Step 2:** Are the qualifying features of sites within 200m of a road sensitive to air pollution?
NE and HE in agreement with the APIS methodology used.

H.2.3 **Step 3:** Could the sensitive qualifying features of the site be exposed to emissions?
GIS and survey data have been used to identify what qualifying habitats are present within areas where increases in N deposition are predicted. This method is not contested by NE.

H.2.4 **Step 4:** Application of screening thresholds
NE and HE in agreement with the use of AADT as proxy for emissions and 1% of critical load methodology. No mitigation is taken into account in the assessment.

H.2.5 **Step 4a:** apply the threshold alone
NE and HE in agreement as LA105 and NEA001 indistinguishable on this step.

H.2.6 **Step 4b:** apply the threshold in-combination with emissions from other road traffic plans and projects
The Traffic modelling and LA105 inherently include in-combination effects from all traffic sources of N deposition. However, NE dispute the model is adequate as it does not include allocations from completed Local Plans. LTC response is that the ONS data used both in the model and in Local Plans provides the same outputs. This issue from NE has not been mentioned since January.

H.2.7 **Step 4c:** apply the threshold in-combination with emissions from other non-road plans and projects
An in-combination assessment methodology has been developed considering non-traffic sources such as industrial and agricultural sources. The methodology is consistent with the scope of in-combination assessment described in NEA001 and has been issued to NE for consultation (18 March), but no responses yet received.

H.2.8 **Step 5:** Advise on the need for Appropriate Assessment where thresholds are exceeded, either alone or in-combination

NEA001 advises that if any of the thresholds in steps 1 to 4 are exceeded then Appropriate Assessment is required. It is considered in LA105 that objective evidence is available to conclude there is no credible evidence that a real risk exists of undermining the Conservation Objectives on any European sites and so Appropriate Assessment is not required.
NEA001 does not provide a methodology for what is considers should be scoped into an Appropriate Assessment or "a definitive or exhaustive checklist of factors to consider". The considerations it does advise are included are included in the LA105 methodology.

NEA001 Section 5: Advising competent authorities on the scope and content of an Appropriate Assessment

H.2.9 NEA001 states that:

It should not be assumed that appropriate assessment will necessarily involve detailed and complex monitoring or modelling work. Whilst complex work might be necessary in fully understanding what will happen to a site if the plan or project goes ahead and asking whether that would be consistent with maintaining or restoring a site's integrity, it is equally possible that a fairly concise and straightforward assessment might be entirely 'appropriate'.

H.2.10 The assessment considers that sufficient (and appropriate) evidence has been provided to fully understand what would happen to the sites being assessed.

H.2.11 NEA001 states that the impacts resulting from a change in the atmospheric concentration or deposition of pollutants as a result of the plan or project might include:

- Changes in the species composition of a designated or supporting habitat

H.2.12 The likelihood of changes in species composition from the effects of the Project are considered in the final step of the Screening through identification of whether the species present were sensitive to N deposition. Existing species composition was identified by detailed botanical surveys through a survey methodology consulted on with NE. Each species was allocated a N sensitivity score using a recognised method. No N sensitive species are present within the affected area or an area considered to be at least twice the area that would be significantly affected by road traffic generated N deposition. It can be concluded therefore a small increase of N deposition over a small area would be highly unlikely to cause a change in species composition.

- Reduction in the species richness of designated habitat

H.2.13 The lack of N sensitive species in the baseline condition indicates that it is highly unlikely that there would be a reduction in species richness. A reduction in species richness would only be expected if some species present were to be sensitive to N deposition and therefore might be expected to be lost if such an effect were high enough and extensive enough to prevent survival of such species in the area.

- Damage or loss of sensitive lichens and bryophytes

H.2.14 The bryophyte survey identified a low diversity of species present within the affected area or an area considered to be at least twice the area that would be significantly affected by road traffic generated N deposition. No N sensitive species were recorded and therefore no damage or loss would be expected.

H.2.15 Lichens have not been specifically surveyed as such survey is seasonally constrained. However, the absence of any higher plants or bryophytes that are N sensitive within the survey is considered to be sufficient and appropriate information to reasonably exclude the likelihood of other species (including lichens) being damaged or lost. It is extremely unlikely that N sensitive lichens would be present when no N sensitive bryophytes are.

- Increases in nitrate leaching and changes in soil nutrient status

H.2.16 The botanical survey results show that there was no discernible difference in the habitat structure or quality between the affected area, an area within 200m of the road and the area within twice the distance of the road that would be expected to be significantly affected by road traffic generated N deposition. It is considered therefore that even if background N deposition had changed soil nutrient status, it has not been to an appreciable level that can be measured through habitat quality. In this circumstance, it is highly unlikely that the Project’s contribution would do so, therefore it is not required to provide detailed survey and analysis for soil chemistry.

Issues recommended for further consideration by an appropriate assessment

H.2.17 Consider whether the sensitive qualifying features of the site would be exposed to emissions

Assessment of this is an agreed matter in steps 1-4.

H.2.18 Consider the European Site’s Conservation Objectives

Assessment includes consideration of the Conservation Objective of ‘Restore’ where greater than nugatory N deposition effects are predicted. The assessment therefore considers whether the scale of N deposition in terms of quantity and geographical scale would be likely to prevent the restoration of AQ within critical loads.

H.2.19 Consider background pollution: a) Review the Environmental Benchmarks (‘critical loads and levels’) and feature sensitivity to nitrogen; b) Check for exceedance of Environmental Benchmarks; c) Consider trends and whether there is evidence to indicate that background levels are decreasing

The assessment is consistent with all the advice on sources of information and benchmarks within NEA001. The traffic and AQ modelling carried out indicates that national measures to reduce pollution (such as cleaner cars) is likely to reduce the N deposition load on the site as evidenced that the total N load post construction of the project would be less than existing, albeit that reduction would be slightly more without the project.

H.2.20 Consider the designated site in its national context

Natural England report Natural England Commissioned Report (NECR) 200 provides the relative categorisation of SAC site exposure to road traffic NOx in a national context and a relative risk categorisation of SACs based on exposure and site sensitivity. Epping Forest SAC would be categorised as at high risk of air quality effects. This is accepted within the screening through consideration of background levels and the exceedances of critical loads outlined in the assessment.

H.2.21 Consider the best available evidence on small incremental impacts from nitrogen deposition

NEA001 states that “habitats that have already been subject to high background nitrogen deposition can develop an effective tolerance to the effects of further deposition. However, this evidence is not appropriate for use to justify further exceedance on designated sites alone.” It goes on to suggest that how much additional nitrogen might lead to a loss of one species on the habitat might inform a more precise assessment of the likely effect, using the analysis of the likely loss of one species as outlined in the NECR210: Assessing the effects of small increments of atmospheric nitrogen deposition (above the critical load) on semi-natural habitats of conservation importance. This is considered within the methodological screening step in LA105 of ”Does the change in N deposition associated with the Project lead to the loss of 1 species?”, which refers to the same NE report.

H.2.22 Consider the spatial scale and duration of the predicted impact and the ecological functionality of the affected area

Spatial sale has been considered in the screening assessment by identification of the extent of the area predicted to be subject to exceedances of the screening criteria. This is shown to be a very small area and very small proportion of the SAC as a whole or extent of the affected qualifying feature habitat.

H.2.23 The duration of the effect is considered as effectively permanent as it is assessed as an operational effect. This is assessed in the context of predicted reductions in overall N deposition by the opening year and through the lifetime of the road. The predicted reduction in N deposition would not bring the background effect to below the critical loads but would show an improvement of the situation towards the recovery of the site and achievement of the Conservation Objective of restoring the site. Whilst the Project would lead to a slightly lesser improvement than the do minimum case, that reduced improvement would be nugatory and not significantly slow achieving the restore objective.

H.2.24 The risk to the integrity of the site has been “approached in a reasonable and proportionate manner”. The “relative importance of the area affected in terms of the rarity, location, distribution, vulnerability to change and ecological structure” has been considered by reference to the survey information collected and analysis against the habitats within the SAC and N deposition sensitivity.

H.2.25 Consider site survey information

Walkover surveys were carried out in February 2020 to identify broad habitat types within the areas predicted to have increased N deposition, to inform steps 1-4 in NEA001.

A detailed botanical survey was carried out in May 2020 to inform assessment of the likelihood of damage or loss to N sensitive species.

H.2.26 Consider national, regional and local initiatives or measures which can be relied upon to reduce background levels at the site

No initiatives or measures specific to the area /site have been identified. National policy and practice are leading to a reduction in N deposition on the site as evidenced by the traffic and AQ modelling showing a predicted reduction in N loading post construction.

H.2.27 Consider measures to avoid or reduce the harmful effects of the plan or project on site integrity

No mitigation measures are considered necessary to reduce harmful effects and none are proposed.

H.2.28 Consider any likely in-combination effects with other live plans and projects from other sectors

An in-combination assessment methodology has been used that considers industrial and agricultural sources and is consistent with NEA001 scoping advice on in-combination assessment.

NEA001 Section 6: Giving Natural England's advice to the competent authority for the purposes of the appropriate assessment

H.2.29 The Project has sought advice through consultation with NE since 2013, including latterly with draft methodologies and draft HRA Screening reports. Regular calls have also been organised to discuss the AQ assessment and NE's concerns.

H.2.30 NEA001 states the following:

Natural England's advice on an appropriate assessment is not binding and it does not have to be given such weight if cogent reasons can be given by a competent authority for departing from it.

and

Natural England should advise on the competent authority's conclusion reached by its appropriate assessment. Where we do not agree with the conclusions of the assessment, we should explain why not with clear and credible reasoning.

H.2.31 It is considered that the methodology in LA105 provides cogent reason why the assessment can depart from the advice within NEA001.

H.2.32 It is considered that no specific (i.e. clear and credible) reasons have been provided during consultation that the LA105 methodology and the subsequent conclusions of the assessment are not sufficient for the purposes of HRA by the Competent Authority.

Annex DD1 28 January 2021 Technical Note: Recreational disturbance - Additional analysis to support HRA screening

LTC HRA Technical Note: Recreational disturbance - Additional analysis to support HRA screening

Reference (HRA Conclusion 74 in the draft SoCG between LTC and Natural England)

Introduction

The HRA DCO application 1.0 concluded that there would be no LSE from Recreational pressure, but no agreement was made with Natural England as there was insufficient evidence to demonstrate no LSE, only reasoned arguments. Through consultation, it was agreed to undertake additional analysis of travel distances and populations to demonstrate the change of populations (if any) likely to visit European sites (within defined zones of influence (ZoI)) when the new road scheme was operational.

Analysis/ test completed

An analysis has been undertaken to test the hypothesis that the scheme would provide "better access" (i.e., be available for more people to visit within a certain distance/drive time) to the European sites, as the distance to parking facilities within or adjacent to the site via a new river crossing has been shortened for a number of people.

1. Identify ZoIs (distances people are considered likely to visit)
2. Identify key visitor access points to European sites
3. Check if road system with the new scheme layout would be within the ZoI (in terms of distance along the road network) of each European site access point.

IF the distance to cross the river on the new road and travel to a site access point is less than the ZOI then:

4. Compare an estimate of the population (either with population or residential units (numbers of) data) within the ZoIs for Kent and Essex with and without the scheme; so providing a measure of the potential change in visitor numbers potentially visiting and therefore potentially disturbing the SPA / Ramsar.

Using these data, for each European site, answer the following questions:

1. Is there any increase in population within the ZoI following the scheme? If no, there would be no effect. If yes:
    2. Is the change significant? If no, then no LSE. If yes:
        3. What is the population change that needs mitigating?
        4. Calculate the payments to the relevant third party (Birdwise or Birdaware)
            i. The Thames, Medway and Swale Estuaries Strategic Access Management and Monitoring Strategy (BIRDWISE) sets the contribution at £223.58 per dwelling[1].
            ii. The RAMS (BIRDAWARE) sets a tariff of £125.58, which applies to all residential development within the ZoI[2].

[1] https://northkent.birdwise.org.uk/wp-content/uploads/2018/02/Mitigation-Strategy.pdf
[2] https://www.thurrock.gov.uk/make-planning-application/natural-habitat-sites

Background information

Identifying ZoIs

Key information on zones of influence relating to recreational disturbance has been gathered from:

1. Essex Coast Recreational disturbance Avoidance & Mitigation Strategy (RAMS) Habitats Regulations Assessment Strategy document 2018-2038
   Delivery of strategy managed by Birdaware
2. North Kent Strategic Access Management and Monitoring Scheme (SAMMS) Board (Birdwise)

The ZoIs for recreational disturbance recorded within these strategy documents were as follows and are shown on Figure 1:

- Benfleet and Southend SPA/Ramsar 4.3km
- Thames Estuary and Marshes SPA/Ramsar – Essex 8.1km
- Thames Estuary and Marshes SPA/Ramsar – Kent 6km
- Medway Estuary and Marshes SPA/Ramsar 6km
- The Swale SPA/Ramsar 6km

Visitor access point locations

Sources of information for site access points

- Essex side - Essex Coast Recreational disturbance Avoidance & Mitigation Strategy (RAMS) Habitats Regulations Assessment Strategy document 2018-2038 – January 2019
- Kent side - Fearnley, H. & Liley, D. (2011). North Kent Visitor Survey Results. Footprint Ecology.

Figure 1 illustrates the visitor access points that had been identified within the strategy documents and were "nearest" to the proposed Project. Table 1 sets out the drive distances from the new Project junctions to the visitor access points within the Thames Estuary and Marshes SPA/Ramsar north and south of the River Thames. These distances were taken from google maps using the "directions" function.

Table 1: The drive distance between the visitor access points and the Project junctions with the existing road network.

European site	Access on which side of river	Access point	Recreational disturbance ZoI	Approx. driving distance from access point to new junction
Thames Estuary & Marshes	North	Coalhouse Fort	8.1km	A13 (Jct 29) 9.2km
		Thurrock Thameside Nature Park	8.1km	A13 (Jct 29) 6.8km
	South	Shornmead/ Gravesend access to Saxon Shore Way Nearest car park – Ship & Lobster Pub, Gravesend	6km	A2 Junction 7km
		Cliff Creek RSPB Cliff Pools car park	6km	A2 junction 13.6km

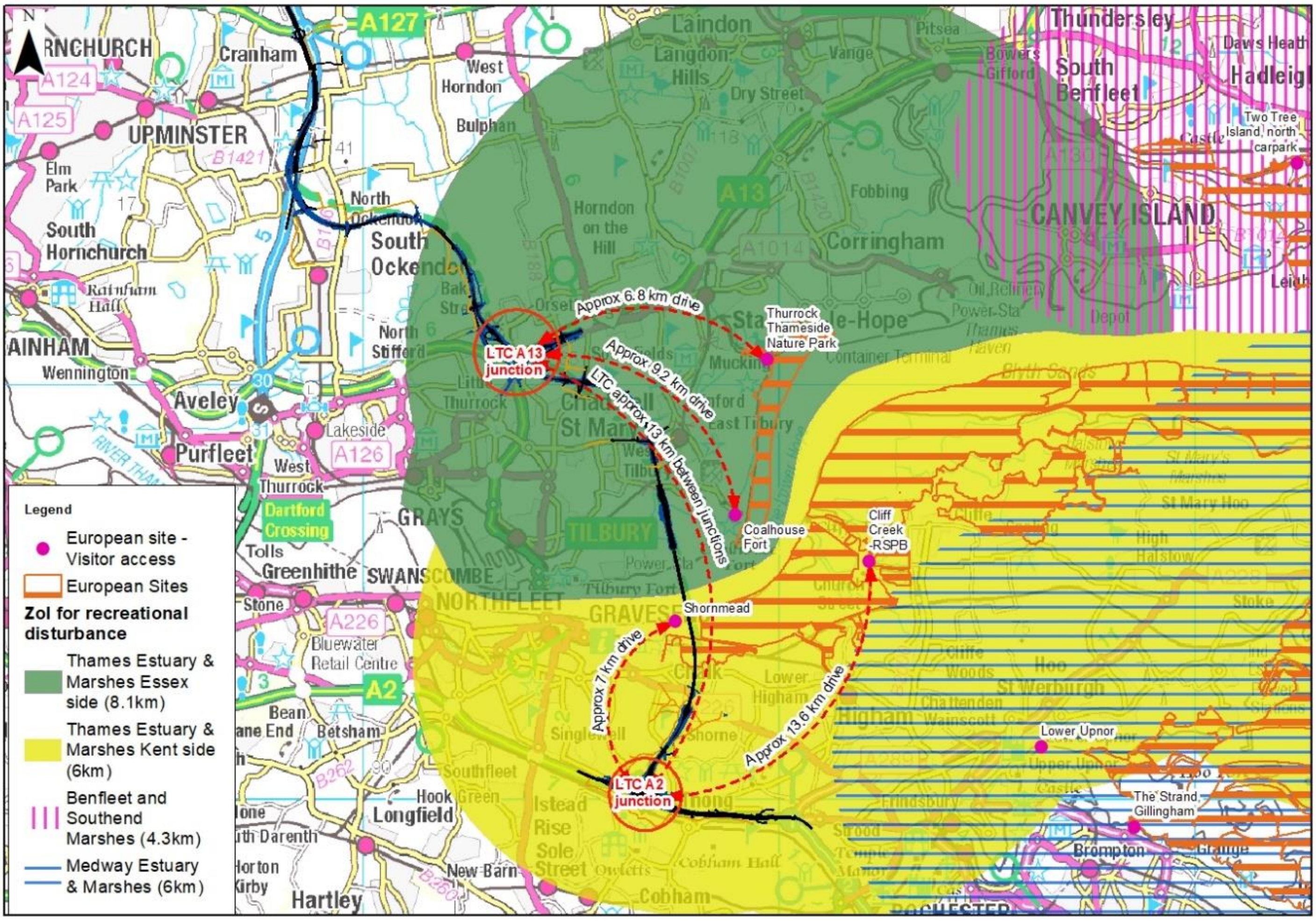
Site specific analyses

The scheme and its junctions on to the existing road network are only within the ZoI of the Thames Estuary and Marshes SPA/Ramsar north and south of the River Thames. Therefore, no LSE on the other European sites identified will occur as they are too distant from the scheme based on the ZoIs developed for recreational disturbance and land use planning.

The ZoI for recreational disturbance is 8.1 and 6km north and south of the River respectively and any visitor from residential development within that ZoI is expected to visit the European site of the ZoI they are within, i.e., visitors are expected to drive the ZoI distance to reach that site.

Figure 1 illustrates the recreational disturbance ZoIs, the visitor access points and the drive distances to the new scheme junctions from those access points as well as between the new scheme junctions.

Figure 1: Illustration of the proximity of the Project to the recreational disturbance ZoIs and the distances by road any prospective visitors would need to drive if using the new tunnel



The visitor data used to determine the ZoIs indicated that visitors to the sites were generally from the local residential area. The distances from the new junctions (to use the new crossing) exceed the ZoIs in all cases other than access from Thurrock Thameside Nature Park to the A13 junction (6.8km).

The Project only provides access to the new crossing at the junctions with the A13 and A2. The distance between these junctions (13km) exceeds all the ZoIs described in the strategy documents, which means that visitors would not be expected to travel across the river to visit the sites as the distance would be too great/ not perceived as a local trip. This is irrespective of the travel distances to or from the residential area to the junctions.

Even in the Thurrock Thameside Nature Park case therefore, once the 13km between the two new crossing junctions is added to that drive distance to the new junction, it is clear that the total driving distance far exceeds the ZoI for a journey likely to be made to the site.

Conclusion

The Project would not change the population of people within the ZoI of recreational pressures of any European site and therefore no LSE on the Thames Estuary and Marshes Ramsar/SPA or any other European site would occur.

Annex DD2 24 June 2021 Feedback received from Natural England

Date: 24 June 2021
Our ref: DAS/2566
Your ref: -

NATURAL ENGLAND

Customer Services
Hornbeam House
Crewe Business Park
Electra Way
Crewe
Cheshire
CW1 6GJ

0300 060 3900

[redacted]

By email only, no hard copy to follow

Dear [redacted]

Discretionary Advice Service (Charged Advice)
Contract Ref: DAS2566
Development proposal and location: Lower Thames Crossing NSIP: review of various HRA Technical Notes

Thank you for your seeking Natural England's advice on a number of draft Technical Notes accompanying the revised Habitats Regulations Assessment for the Lower Thames Crossing project.

This advice is being provided as part of Natural England's Discretionary Advice Service. The Lower Thames Crossing project has asked Natural England to provide the following advice:

- Review of various Habitats Regulations Assessment Technical Notes

This advice is provided in accordance with the Quotation (5461/205152) and Agreement dated 17th January 2017.

There may be examples where there are points of detail that we may not be able to agree however we may still be able to agree with the overall conclusion. We have tried to indicate where this may be the case.

Recreational Disturbance – dated 28th January 2021
Natural England is satisfied that the Lower Thames Crossing's Habitats Regulations Assessment (HRA) conclusions are now robustly evidenced, in particular that the travel distances required to reach European 'Habitats' sites are greater than the known zones of influences for sites both north and south of the river (based on junction locations and the need to double back to reach the sites). Based on the information provided, we concur with the conclusion of no likely significant effect (LSE).

Dust – dated 11th May 2021
Overall, whilst the control measures all seem appropriate (but see below), they are as yet unevidenced. This may be because no evidence exists that the industry best practice measures are effective (noting your observation that they have never been updated or changed). We appreciate the position here, and we accept the measures outlined are considered to be most effective, and that the most appropriate measures will be selected for any given circumstance. We have some specific additional comments:

- We agree that the revised note dated 11th May 2021 appropriately reflects the European sites at risk from dust effects (compared to the 9th March 2021 version), i.e. limited to the

Thames Estuary & Marshes Special Protection Area (SPA) and Ramsar site.

- The use of vegetating or seeding of stockpiles for stabilisation purposes may carry the risk of introducing undesirable or non-target species into the seed bank. The final selection of the measures to be used to suppress dust in any given location should be mindful of this risk and should attempt to be 'ecologically inert' if possible, so as not to undermine any future habitat restoration proposals for the site.
- The note is written as if the measures will entirely disrupt the pathway and so concludes 'no likely significant effect' (i.e. reducing the pathway from 200m to effectively 0m from source). Given the scale and duration of the project, a very high degree of confidence is required in the measures, and so it is important that the measures (along with suitable monitoring) are appropriately secured and transferred through the various stages of the Construction Environmental Management Plan (CEMP) and equivalent documents.

Operational Noise & Visual Disturbance – dated 9th March 2021
Natural England is satisfied that there are no unlikely to be any operational noise or visual disturbance impacts on the Kent side since the southern portal is outside the 600 metres zone of influence for noise and vibration and 300 metres for visual disturbance detailed within the HRA Screening Report.

In Essex, there may be some concerns in areas of functionally linked land, but the note does not present any noise modelling to indicate the effectiveness of the proposed noise barriers. There will also be short to medium term visual impacts before the woodland screening matures. Our advice is that the aim should be to reduce the area affected to the minimum possible.

We note and agree that likely significant effects cannot be ruled out, and that these pathways are to be taken forward to Appropriate Assessment. We also note the provision of mitigation land for these impacts at Coalhouse Fort and will comment on this via the separate Technical Note provided shortly. Whilst we have some concerns that the mitigation land is proposed to 'add certainty' only, overall Natural England agrees with these HRA screening conclusions.

Construction & Operation Lighting – dated 12th May 2021
During the construction phase, we have concerns that the REAC commitments and embedded mitigation measures do not provide a sufficient degree of certainty that impacts to the designated sites and functionally linked land will be avoided or fully mitigated. For example:

'Construction compounds and worksites (which includes compounds CA5, CA3A and CA3B) would be lit for safety, security and working requirements, with a lux (lighting) level appropriate to the task and in line with industry best practice…' (section 4.5.27)

'…Contractors would assess the required lux level to ensure visual intrusion and light spillage are kept to a minimum, particularly in close proximity to residential properties and busy roads…' (section 4.5.28)

Natural England advises that a REAC commitment not to increase light above a certain level within European 'Habitats' sites or functionally linked land would be required to give the certainty required in order to conclude no LSE. Our advice on other proposals affecting European sites has been to accept a 0.5 lux level (equivalent of a moonlit night) as a sensitivity threshold.

During the operation phase, given that the southern portal is outside the 300 metres for visual disturbance detailed within the HRA Screening Report for the SSSI, Ramsar site and functional land, we would agree that an LSE from lighting impacts can be ruled out. For the northern portal, we advise that light contour modelling should be provided to evidence the conclusions reached. It may be that a conclusion of no LSE can be justified, although we note the proposed provision of mitigation land for the Essex side (on which we will comment separately) should it not be possible to support this conclusion.

Construction Surface Water Discharge – dated 11th May 2021
It is important that the surface water discharge from the southern construction compounds into the

Ramsar and SSSI ditch remains within an appropriate range of chemical parameters. This will ensure that pollution incidents are avoided and impacts to the Ramsar ditch and associated species are avoided through the Environment Agency consenting process. Without this degree of certainty Natural England cannot agree with the conclusions.

As we have discussed and agreed verbally, the chemical parameters that need to be referenced are: turbidity; cover of filamentous algae (Enteromorpha); total phosphorous; dissolved oxygen; biochemical oxygen; total ammonia; water levels and salinity. Following our recent discussion, we welcome the inclusion of phosphorous and ammonia within the list of parameters to be monitored.

We note the proposed REAC commitment details that 'The water quality standards of the discharge would not exceed the standards recorded for each of the parameters during the pre-construction surveys'. Whilst achieving a water quality standard that is no worse than a pre-construction baseline is welcomed in principle, we consider that, if the baseline water quality is below that required to achieve or maintain favourable condition of the site, the project should aim to improve water quality (i.e. betterment). This would be consistent with Highways England's role as a 28G body under the Wildlife & Countryside Act 1981 (as amended) and its duty as a public body to both conserve <u>and enhance</u> SSSIs. This would also align with the Water Framework Directive to achieve 'good ecological status.'

There is a list of characteristic species for brackish and freshwater ditches which may be helpful in monitoring any salinity gradient:

Brackish species:

- *Potamogeton pectinatus*
- *Ceratophyllum submersum*
- *Myriophyllum spicatum*
- *Ranunculus baudotii*
- *Zannichelia palustris*
- *Chenopodium chenopodioides*
- *Bulboschoenus maritimus*
- *Juncus gerardii*
- *Schoenoplectus tabernaemontani*

Freshwater species:

- *Sparganium erectum*
- *Ceratophyllum demersum*
- *Hydrocharis morsus-ranae*

Construction Noise & Mitigation Measures – dated 13th April 2021

In terms of the wintering birds associated with the Thames Estuary and Marshes SPA and Ramsar Site, and subject to the provision of the alternative functionally linked land (separate advice to follow), we acknowledge the efforts made to reduce noise disturbance towards achieving a conclusion of no adverse effects on integrity. However, it is noted that much of the work giving rise to noise that has the potential to disturb birds will be undertaken from April-July. In Kent the underpinning South Thames Estuary and Marshes SSSI is also notified for its breeding birds. Whilst outside of the scope of the HRA, the mitigation measures need to be achievable, and the Environmental Statement will need to ensure that impacts to wintering and breeding birds associated with the SSSI are avoided or fully mitigated.

In Essex, we note that the area of suitable habitat affected by construction noise has been reduced from 328ha to 106ha with the introduction of mitigation measures. Whilst this is welcomed in principle, the aim should be to reduce the area affected to the minimum possible, and we have provided further advice on the proposed measures below.

In terms of REAC commitment HR004, the wording does not commit to specific decibel levels, only to ensure they 'do not result in noise levels… that would cause disturbance to the wintering bird qualifying interests'. Whilst the REAC commitment is underpinned by technical background, in our view this wording does not give sufficient certainty in its current form.

Our assumption is that the acoustic barrier arrangements at compound CA5 are aligned to achieve the most effective reduction, but it would be helpful to have confirmation of this.

The 3m earth bund running parallel with the river is significant in that it attempts to address noise impacts to the especially important area of functionally linked land in the inter-tidal zone. REAC commitment HR005 indicates that the 3m high bund will be 'substantially started during April, May, June and July…' however we advise that these works should ideally be 'substantially completed' during that window whilst also bearing in mind the need to avoid impacts to breeding birds including any associated with the designated sites. It would be helpful if greater clarity and certainty on the measures (for example what is meant by 'substantially') were provided. Similarly, it is not clear how long such a bund might take to be constructed, whether 3m is the maximum feasible or whether further reductions could be achieved with a taller structure.

REAC commitment HR006 provides more certainty around when construction of noise attenuation bunds should be scheduled, so there seems to be some inconsistency between the proposed REAC commitments. Arguably it is the earthworks nearer the river that are more sensitive than the compound boundaries (for Essex).

It should be noted that – strictly speaking – the SPA seasonality tables indicate some presence of qualifying species within both April and July during the spring and autumn passage periods respectively. We appreciate that complete avoidance may not be possible, so we highlight this for completeness only. The Lower Thames Crossing and other relevant third party surveys could be used to provide additional analysis, but we appreciate that the note does not attempt to conclude 'no LSE'. It would be a useful exercise for the Lower Thames Crossing to review available third party data & consider any implications that may arise from this.

There remains some limited exceedance of LSE triggers levels along the foreshore area for the general works and (as might be expected) noise disturbance will be more considerable for the north portal outfall pipeline construction directly within the inter-tidal area. Therefore we cannot at this stage rule out LSE and the need for Appropriate Assessment would still be our conclusion for the northern section.

Overall the note is to be viewed alongside the Technical Note on provision of mitigation land at Coalhouse Fort in making the case for 'no adverse effect on integrity'. Natural England therefore agrees that construction noise is likely to have a significant effect, and that mitigation (both noise reduction measures and additional land) would be required. We will provide our review of mitigation.

☒ The advice provided in this letter has been through Natural England's Quality Assurance process

The advice provided within the Discretionary Advice Service is the professional advice of the Natural England adviser named below. It is the best advice that can be given based on the information provided so far. Its quality and detail is dependent upon the quality and depth of the information which has been provided. It does not constitute a statutory response or decision, which will be made by Natural England acting corporately in its role as statutory consultee to the competent authority after an application has been submitted. The advice given is therefore not binding in any way and is provided without prejudice to the consideration of any statutory consultation response or decision which may be made by Natural England in due course. The final judgement on any proposals by Natural England is reserved until an application is made and will be made on the information then available, including any modifications to the proposal made after receipt of discretionary advice. All pre-application advice is subject to review and revision in the light of changes in relevant considerations, including changes in relation to the facts, scientific knowledge/evidence, policy, guidance or law. Natural England will not accept any liability for the accuracy, adequacy or completeness of, nor will any express or implied warranty be given for, the advice. This exclusion does not extend to any fraudulent misrepresentation made by or on behalf of Natural England.

Yours sincerely

[redacted]

Annex EE 12 February 2021 Technical Note - Habitat enhancement to maintain baseline functionality of functionally linked land

LTC HRA Technical Note: Habitat enhancement to maintain baseline functionality of functionally linked land

The following mitigation measures will be included in DCO 2.0 application that are additional to the proposal at DCO 1.0.

- Permanent enhancement of land adjacent to Coalhouse Fort
- Temporary enhancement of 3 arable fields to the south of the firing range
- Reinstatement of compound 3b to an enhanced habitat type
- Increased monitoring

In addition to definition and assessment of these measures within the HRA SIAA report, securing of the proposals will be achieved variously through the following:

- Environmental Principles
- Environmental Masterplan (EMP)
- Outline landscape and ecology management plan (OLEMP)
- REAC commitments

Appropriate securing mechanisms for proposed mitigation measures are summarised in the table below.

Measure	Duration Temp / Perm	Env. Principles	Masterplan	OLEMP	REAC
Coalhouse Fort	Perm	YES	YES	YES	n/a
3 arable fields	Temp	n/a	n/a	n/a	YES
Compound 3b	Perm	YES	YES	YES	n/a
Monitoring	Temp	n/a	n/a	YES	YES

1 Proposed amendments to the Environmental Principles

The Environmental Principles are to be amended with the following additions:

1.1 Permanent enhancement of land adjacent to Coalhouse Fort

Insert ref number	Enhancement of functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar	The land parcel adjacent to Coalhouse Fort shall be used for habitat enhancement to maintain baseline functionality of functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar. The land will be used to create a series of shallow scrape habitats, high tide roost features and coastal grazing marsh habitat suitable for use by the qualifying features of the SPA/Ramsar (LE6.2 Banks and ditches, LE6.1 Water bodies and associated plants, LE6.4 Marsh and wet grassland).

1.2 Temporary enhancement of 3 arable fields to the south of the firing range

This enhancement is only required on a temporary basis, for the duration of the construction period and will be defined and secured through a REAC commitment. Therefore, it is not appropriate to define Environmental Principles.

1.3 Reinstatement of compound 3b to an enhanced habitat type

Insert ref number	Enhancement of functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar	The land parcel within/ adjacent to the south of the Metropolitan Police firing range shall be used for habitat enhancement, post construction, to maintain baseline functionality of functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar. The land will be used to create <<INSERT habitats agreed with RSPB (expected mid-March)>> suitable for use by the qualifying features of the SPA/Ramsar (LE6.2 Banks and ditches, LE6.1 Water bodies and associated plants, LE6.4 Marsh and wet grassland <<UPDATE when agreed habitats agreed with RSPB>>).

1.4 Monitoring

Monitoring is included as specific REAC commitments and/or included within the prescriptions in the OLEMP for each enhancement measure, and so a separate monitoring principle is not required.

2 Proposed amendments to the Environmental Masterplan (EMP)

The EMP is to be amended as follows:

2.1 Permanent enhancement of land adjacent to Coalhouse Fort

Reference to Coalhouse Fort water vole habitat to be removed and replaced with the following proposals:

2.1.1 Environmental function codes (From LD 117 Landscape design. Table 4.2a)

- For all elements - EFD Nature conservation and biodiversity

2.1.2 Landscape element codes (From LD 117 Landscape design. Table 4.2b)

- For wet scrape features - LE6.1 Water bodies and associated plants
- For high tide roost features – LE6.2 Banks and ditches
- For grassland (coastal grazing marsh) features - LE6.4 Marsh and wet grassland

2.2 Temporary enhancement of 3 arable fields to the south of the firing range

This enhancement is only required on a temporary basis, for the duration of the construction period and will be defined and secured through a REAC commitment. Therefore, it will not be included on the EMP.

2.3 Reinstatement of compound 3b to an enhanced habitat type

Additional area to be included in the EMP, relating to compound 3b's reinstatement.

<<INSERT figure of the reinstated area for the EMP when we have agreement with RSPB>>

2.3.1 Environmental function codes (From LD 117 Landscape design. Table 4.2a)

- For all elements - EFD Nature conservation and biodiversity

2.3.2 Landscape element codes (From LD 117 Landscape design. Table 4.2b)

- E.g. <<Update when habitats agreed with RSPB>>
- For wet scrape features - LE6.1 Water bodies and associated plants
- For grassland (coastal grazing marsh) features - LE6.4 Marsh and wet grassland

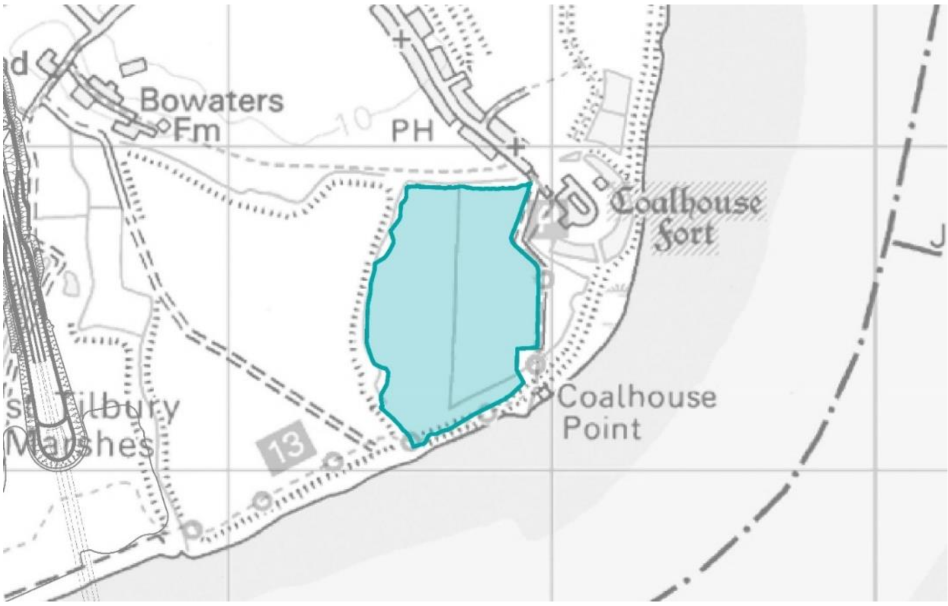
3 Proposed amendments to the OLEMP

The draft OLEMP is to be amended as follows:

3.1 Permanent enhancement of land adjacent to Coalhouse Fort as wintering bird habitat

Reference to Coalhouse Fort water vole habitat to be removed but location figure below to be retained.

3.1.1 Description of Management Area



This management area is located to the west of Coalhouse Fort just to the North of the River Thames.

The management area extends west to a drainage ditch on the boundary to the East Tilbury landfill.

The existing landscape is comprised of arable, agricultural land, and is low-lying at its natural level in contrast to the surrounding land which has been raised as part of landfill activities.

An existing ditch runs through the middle of the management area, bisecting the area as it runs in a north-south alignment.

The management area is approximately 34ha in size.

This management area is shown in the Environmental Masterplan (Application Document 6.2, Figure 2.4) Section 9 Sheets 15, 16, 19, & 20

3.1.2 Management Aims and Objectives

The management aim and objectives of this area are:

- To provide a series of shallow scrape habitats, high tide roost features and coastal grazing marsh habitat suitable for use by the qualifying features of the Thames Estuary and Marshes SPA/Ramsar.
- To provide habitats similar to those immediately north of Tilbury Fort that currently support foraging and roosting qualifying features of the SPA/Ramsar and in line with guidance from Natural England.

3.1.3 Typologies Present

The planting and habitat typologies present within this area are listed below:

- LE6.1 Water bodies and associated plants – Shallow scrape habitat
- LE6.2 Banks and ditches – High tide roost features
- LE6.4 Marsh and wet grassland – Coastal grazing marsh

3.1.4 Outline management prescriptions

The outline management prescriptions and programmes for the typologies listed above will be detailed in the OLEMP as follows:

3.1.4.1 LE6.1 Water Bodies and associated plants – Shallow scrape habitat

3.1.4.1.1 Description

Shallow scrape habitats are proposed within the Project design, their primary function being to maintain the functionality of functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar. They do not form part of the Project drainage design and would be designed to maximise their value to the qualifying features of the SPA/Ramsar, following good practice guidance such as RSPB's 'Scrape creation for wildlife' and 'Creating wader scrapes and flashes on farmland - Information and advice note (2003). Evidence of efficacy can be found at https://www.conservationevidence.com/actions/153

3.1.4.1.2 Outline Aims and Objectives

The following outline aims and objectives are for all shallow scrape habitats.

- To provide enhanced functionality within functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar by providing foraging habitat for a range of bird qualifying features of the SPA/Ramsar.
- Scrapes to be managed to provide optimum habitat for foraging waterfowl.

3.1.4.1.3 Outline Prescriptions

The work activities to complete the enhancement of the land adjacent to Coalhouse Fort will be completed before the compounds 5, 3A and 3B are set up.

The exact details of the work activities will be developed between all parties during the development of the LEMP and subsequent work-specific method statements.

This will be based on the Highways England's Manual of Contract Documents for Highways Works, Series 3000 unless otherwise agreed with Highways England. The table below describes the programme of work for establishment and initial maintenance (first five years).

Action			**Years 1-5 of the Construction Period**				
Task	Responsibility	Season	1	2	3	4	5
Excavation of wet scrape habitats for foraging waterfowl features of the Thames Estuary and Marshes SPA/Ramsar Excavated material to be used for construction of high tide roost features.	Principal Contractor (PC)	Summer	Y	-	-	-	-
Removal of all trees, shrubs, fencing posts, etc. that could act as predator observation points within 300m of scrapes.	PC	Summer	Y	-	-	-	-
Enable grazing management of the surrounding coastal grazing marsh and high tide roost features to include scrape edges / margins	PC	Summer	Y	Y	Y	Y	Y
Attendance of quarterly site inspections with the Ecological Clerk of Works	Ecological Clerk of Works (EcCOW) appointed by PC	Quarterly	Y	Y	Y	Y	Y
Removal from scrapes of floating litter, debris, or other contaminants – weekly as part of general litter maintenance	EcCOW appointed by PC	As required	Y	Y	Y	Y	Y
Annual removal of unwanted vegetation from scrapes including edges / margins	EcCOW appointed by PC	Summer	Y	Y	Y	Y	Y
Annual removal of shrubs within 300m of scrapes that	EcCOW appointed by PC	Summer	Y	Y	Y	Y	Y

Action			Years 1-5 of the Construction Period				
could act as predator observation points and reduce overall sightlines for foraging waterfowl.							

3.1.4.1.4 Outline Measure of Success

To ensure that the management objectives are achieved, the following monitoring targets have been devised to measure success:

- Shallow water and exposed mud habitats available for foraging by qualifying waterfowl features of the Thames Estuary and Marshes SPA/Ramsar.
- Vegetation largely absent and not interfering with foraging of waterfowl.
- Absence of obstructions to sightlines of waterfowl or predator observation points within 300m of scrapes.

3.1.4.1.5 Outline Monitoring Frequency and Methods

The aim of the suggested monitoring programme is to ascertain whether the outline measures of success listed above have been achieved.

The monitoring will commence in the first year after the habitats are created and will comprise:

- Habitat establishment and suitability.
- Bird use.

Frequency of monitoring visits to record the habitat establishment and suitability will be determined by the success of establishment and the frequency of monitoring adjusted accordingly to ensure relevant follow up operations are undertaken. At this stage an annual visit for the first 5 years following creation is proposed and carried out in late summer.

During construction and for five years post construction, annual surveys will be undertaken of use of scrapes by passage and wintering waterfowl, with monthly visits August to March inclusive. Surveys will record:

- Waterfowl species and numbers at both low and high tide during daylight.
- Waterfowl species and numbers at high tide nocturnally.
- Distribution of waterfowl in relation to the scrape habitats.
- Disturbing stimuli and waterfowl behaviours in response to them (including where no response).
- Management requirements such as vegetation removal.

Highways England’s appointed monitoring party will carry out the monitoring visits and feed back to the steering group as part of annual monitoring reporting.

Action			All construction years and post construction years 1-5				
Task	Responsibility	Season	1	2	3	4	5
Annual check of habitat suitability	Highways England's appointed monitoring party	Late summer	Y	Y	Y	Y	Y
Annual survey of waterfowl	Highways England's appointed monitoring party	August to March	Y	Y	Y	Y	Y

3.1.4.2 LE6.2 Banks and Ditches – High tide roost features

3.1.4.2.1 Description

This typology includes raised ground or bank features within or adjacent to wet scrape habitats that are suitable for roosting of waterfowl feature species of the Thames Estuary and Marshes SPA / Ramsar during high tides.

The form of high tide roost features may vary, but vegetation would be absent or short / sparse between August and March inclusive to facilitate roosting by waterfowl.

3.1.4.2.2 Outline Aims and Objectives

The following outline aims and objectives are for all high tide roost features.

- To provide enhanced functionality within functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar by providing high tide roosting habitat for a range of bird qualifying features of the SPA/Ramsar.
- Areas to be managed to provide optimum habitat for roosting waterfowl.

3.1.4.2.3 Outline Prescriptions

The work activities to complete the enhancement of the land adjacent to Coalhouse Fort will be completed before the compounds 5, 3A and 3B are set up.

The exact details of the work activities will be developed between all parties during the development of the LEMP and subsequent work-specific method statements.

This will be based on the Highways England's Manual of Contract Documents for Highways Works, Series 3000 unless otherwise agreed with Highways England. The table below describes the programme of work for establishment and initial maintenance (first five years).

Action			Years 1-5 of the Construction Period				
Task	Responsibility	Season	1	2	3	4	5
Spreading of material excavated during creation of wet scrape habitats to form raised ground and banks suitable for roosting waterfowl	Principal Contractor (PC)	Summer	Y	-	-	-	-

Action			Years 1-5 of the Construction Period				
Attendance of quarterly site inspections with the Project Ecological Clerk of Works	Ecological Clerk of Works (EcCOW) appointed by PC	Quarterly	Y	Y	Y	Y	Y
High tide roost features to be grazed during the summer and mown / strimmed in late summer where necessary to provide a short / sparse vegetation between August and March.	PC	Summer	Y	Y	Y	Y	Y
Selective spot treatment of herbicide as required for larger pernicious weeds	EcCOW appointed by PC	Twice yearly - May and September	Y	Y	Y	Y	Y
Injurious weeds are to be eradicated, removed and disposed of off-site, as per the latest DEFRA / Natural England guidance.	EcCOW appointed by PC	As required	Y	Y	Y	Y	Y
All litter / foreign debris to be removed and taken off site	EcCOW appointed by PC	As required	Y	Y	Y	Y	Y

3.1.4.2.4 Outline Measure of Success

To ensure that the management objectives outlined previously are achieved, the following monitoring targets have been devised to measure the success of the management objectives:

- High tide roosting features available for roosting qualifying waterfowl features of the Thames Estuary and Marshes SPA/Ramsar.
- High tide roost features sufficiently elevated, so they are available for roosting waterfowl at spring high tides.
- Vegetation of high tide roost features sufficiently low / sparse between August and March inclusive to not deter roosting by waterfowl.
- Absence of obstructions to sightlines of waterfowl or predator observation points within 300m of high tide roost features.

3.1.4.2.5 Outline Monitoring Frequency and Methods

The aim of the suggested monitoring programme is to ascertain whether the outline measures of success listed above have been achieved.

Monitoring will commence in the first year after the habitats are created and will comprise:

- Habitat establishment and suitability.
- Bird use.

Frequency of monitoring visits to record the habitat establishment and suitability will be determined by the success of establishment and the frequency of monitoring adjusted accordingly to ensure relevant follow up operations are undertaken. At this stage an annual visit for the first 5 years following creation is proposed and carried out in late summer.

During construction and for five years post construction, annual surveys will be undertaken of use of high tide roosting features by passage and wintering waterfowl, with monthly visits August to March inclusive. Surveys will record:

- Waterfowl species and numbers at both low and high tide during daylight.
- Waterfowl species and numbers at high tide nocturnally.
- Distribution of waterfowl in relation to the high tide roost features.
- Disturbing stimuli and waterfowl behaviours in response to them (including where no response.
- Management requirements such as vegetation removal.

Highways England's appointed monitoring party will carry out the monitoring visits and feed back to the steering group as part of annual monitoring reporting.

Action			All construction years and post construction years 1-5				
Task	Responsibility	Season	1	2	3	4	5
Annual check of habitat suitability	Highways England's appointed monitoring party	Late summer	Y	Y	Y	Y	Y
Annual survey of waterfowl	Highways England's appointed monitoring party	August to March	Y	Y	Y	Y	Y

3.1.4.3 LE6.4 Marsh and Wet Grassland – Coastal grazing marsh

3.1.4.3.1 Description

The coastal grazing marsh typology is located within the areas of enhanced functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar and includes areas of seasonally wet grassland and shallow edged ditches.

3.1.4.3.2 Outline Aims and Objectives

- To create and maintain coastal grazing marsh habitat suitable for foraging of passage and wintering waterfowl features of the Thames Estuary and Marshes SPA/Ramsar.
- To maintain a grassland sward between August and March inclusive at a height of approximately 10cm or below through summer grazing and late summer mowing where necessary.
- To maintain the ditch network as open ditches with shallow profiled banks through ditch clearance and bank profiling on a ten-year rotational management regime. Ditch management to be carried out only on one bank with one fifth of ditches being managed each year.

3.1.4.3.3 Outline Prescriptions

The work activities to complete the enhancement of the land adjacent to Coalhouse Fort will be completed before the compounds 5, 3A and 3B are set up.

The exact details of the work activities will be developed between all parties during the development of the LEMP and subsequent work-specific method statements.

This will be based on the Highways England's Manual of Contract Documents for Highways Works, Series 3000 unless otherwise agreed with Highways England. The table below describes the programme of work for establishment and initial maintenance (first five years).

Action			**Years 1-5 of the Construction Period**				
Task	Responsibility	Season	1	2	3	4	5
Sow suitable coastal grazing marsh grassland mix.	Principal Contractor (PC)	Spring / summer	Y	-	-	-	-
Clear one side of one fifth of ditches and reprofile banks to shallow gradient.	PC	Spring / summer	Y	Y	Y	Y	Y
Instigate grazing regime and late summer mowing where required to maintain sward height of approximately 10cm or below between August and March inclusive.	PC	Summer	Y	Y	Y	Y	Y
Attendance of quarterly site inspections with the Project Ecological Clerk of Works	Ecological Clerk of Works (EcCOW) appointed by PC	Quarterly	Y	Y	Y	Y	Y
Removal from water bodies of floating litter, debris, fly tipping, surface weeds, contaminants and animal carcasses – weekly as part of general litter maintenance	EcCOW appointed by PC	As required	Y	Y	Y	Y	Y
Any unsuccessful grassland sowing to be replaced annually.	EcCOW appointed by PC	Spring / summer	N	Y	Y	Y	Y
Injurious weeds are to be eradicated, removed and disposed of off-site, as per the latest DEFRA / Natural England guidance.	EcCOW appointed by PC	As required	Y	Y	Y	Y	Y

3.1.4.3.4 Outline Measure of Success

To ensure that the management objectives outlined previously are achieved, the following monitoring targets have been devised to measure the success of the management objectives:

- Coastal grazing marsh available for foraging by qualifying waterfowl features of the Thames Estuary and Marshes SPA/Ramsar.
- The sward height is maintained at approximately 10cm or below between August and March inclusive.
- The grassland supports species typical of coastal grazing marsh with no scrub.
- Ditch habitats provide diversity of habitat without interfering with foraging of waterfowl.
- Absence of obstructions to sightlines of waterfowl or predator observation points.

3.1.4.3.5 Outline Monitoring frequency and methods

The aim of the suggested monitoring programme is to ascertain whether the outline measures of success listed above have been achieved.

Monitoring will commence in the first year after the habitats are created and will comprise:

- Habitat establishment and suitability
- Bird use

Frequency of monitoring visits to record the habitat establishment and suitability will be determined by the success of establishment and the frequency of monitoring adjusted accordingly to ensure relevant follow up operations are undertaken. At this stage an annual visit for the first 5 years following creation is proposed and carried out in late summer.

During construction and for five years post construction, annual surveys will be undertaken of use of coastal grazing marsh created through the project by passage and wintering waterfowl, with monthly visits August to March inclusive. Surveys will record:

- Waterfowl species and numbers at both low and high tide during daylight.
- Waterfowl species and numbers at high tide nocturnally.
- Distribution of waterfowl in relation to the coastal grazing marsh habitats.
- Disturbing stimuli and waterfowl behaviours in response to them (including where no response).
- Management requirements such as vegetation mowing or weed eradication.

Highways England's appointed monitoring party will carry out the monitoring visits and feed back to the steering group as part of annual monitoring reporting.

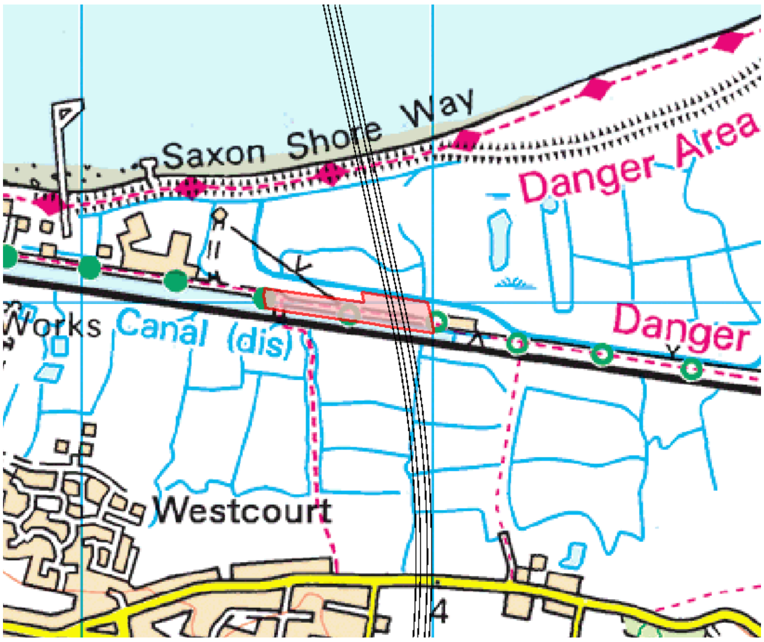
Action			All construction years and post construction Years 1-5				
Task	Responsibility	Season	1	2	3	4	5
Annual check of habitat suitability	Highways England's appointed monitoring party	Late summer	Y	Y	Y	Y	Y
Annual survey of waterfowl	Highways England's appointed monitoring party	August to March	Y	Y	Y	Y	Y

3.2 Temporary enhancement of 3 arable fields to the south of the firing range

As these works will be temporary construction works, these will not be referenced within the OLEMP. These will be defined and secured through a REAC commitment.

3.3 Reinstatement of Compound 3b to enhanced wintering bird habitat

3.3.1 Description of Management Area



This management area is located to the south of the Metropolitan Police firing range, just to the North of the Thames and Medway canal.

The existing landscape is comprised of ditch, rough grassland, scrub, hardstanding and access roads.

The management area is approximately 3ha in size.

There will be a new management area shown in the Environmental Masterplan (Application Document 6.2, Figure 2.4) Section TBC Sheets TBC

3.3.2 Management Aims and Objectives

The management aim and objectives of this area are:

- To provide a series of shallow scrape habitats, high tide roost features and coastal grazing marsh <<to be updated when habitats agreed with RSPB>> habitat suitable for use by the qualifying features of the Thames Estuary and Marshes SPA/Ramsar in line with guidance from RSPB.

3.3.3 Typologies Present

The planting and habitat typologies present within this area are listed below:

- E.g. <<to be updated when habitats agreed with RSPB>>
- LE6.1 Water bodies and associated plants – Shallow scrape habitat
- LE6.2 Banks and ditches – High tide roost features
- LE6.4 Marsh and wet grassland – Coastal grazing marsh

3.3.4 Outline management prescriptions and programmes

For the typologies listed above these will be detailed in the OLEMP. <<update when habitats agreed with RSPB>>

4 Proposed amendments to the REAC commitments

REAC commitments will be added and amended as follows:

4.1 Permanent enhancement of land adjacent to Coalhouse Fort

No additional or changes to commitments made at DCO Application 1.0 are required as the measures necessary are secured through the Environmental Principles, EMP and OLEMP.

4.2 Temporary enhancement of 3 arable fields to the south of the firing range

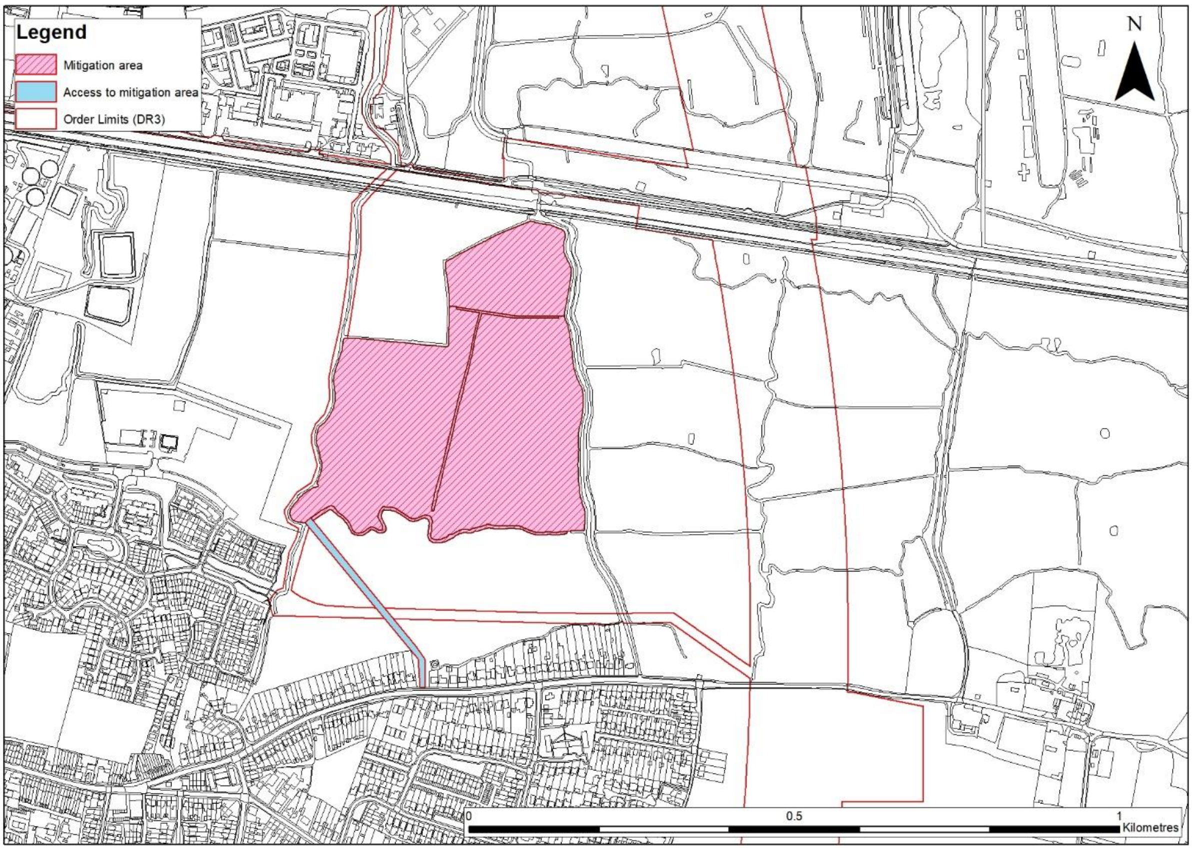


Figure 1: Location of the 3 arable field (Plot XXXX)

Issue	REAC commitment at DCO Application 1.0	New REAC commitment for DCO Application 2.0
Change of management of	N/A – new Commitment	HR005

arable land for the construction period		To provide temporarily enhanced functionality of functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar, the management of the three fields in plot XXXX to the south of the Metropolitan Police firing range and adjacent to the SPA/Ramsar will consist of grassland and/or spring sown crops and winter stubbles throughout the construction period of compounds CA3A and CA3B.

4.3 Reinstatement of compound 3b to an enhanced habitat type

No additional, or changes to, commitments made at DCO Application 1.0 are required as the measures necessary are secured through the Environmental Principles, EMP and OLEMP.

4.4 Monitoring

Issue	REAC commitment at DCO Application 1.0 (To be retained in the REAC)	Additional REAC commitment for DCO Application 2.0
Inclusion of recording of behaviours in response to disturbing stimuli as well as numbers of birds Plus Recording of use of mitigation areas by target bird species	MB004 An annual bird survey will be undertaken whilst works are being carried out in the area below mean high water springs. The survey will be undertaken between 01 September and 31 March inclusive and to a specification submitted to the MMO.	HR007 Between 01 September and 31 March inclusive during each year of the LTC construction period, complete monthly surveillance visits from fixed vantage points to observe functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar as identified in the HRA (<<insert reference to suitable figure in the HRA>>) within 300m of Order limits of the Project. The survey will record numbers of waterfowl present and any behaviours in response to disturbance stimuli to a specification developed in consultation with Natural England.

5 Efficacy of the proposed enhanced habitats

The evidence to demonstrate that the proposed enhancements of functionally linked land would provide additional functionality from their exiting state is as follows:

5.1 Land near Coalhouse Fort

The proposed change from arable farmland to a mosaic of coastal grazing marsh, shallow scrapes and high tide roost features is designed to create a similar mosaic of habitats as currently found in the area around Tilbury Fort. The surveys have shown that the existing use of the land near Coalhouse Fort is very low and limited to lapwing occasional use, see figure 2. The surveys also showed that the Tilbury Fort area supports a range of SPA/Ramsar qualifying features at all times and states of tide, see figure 3. The proposed habitats are therefore demonstrably more suitable than the existing habitats for use by qualifying feature species.

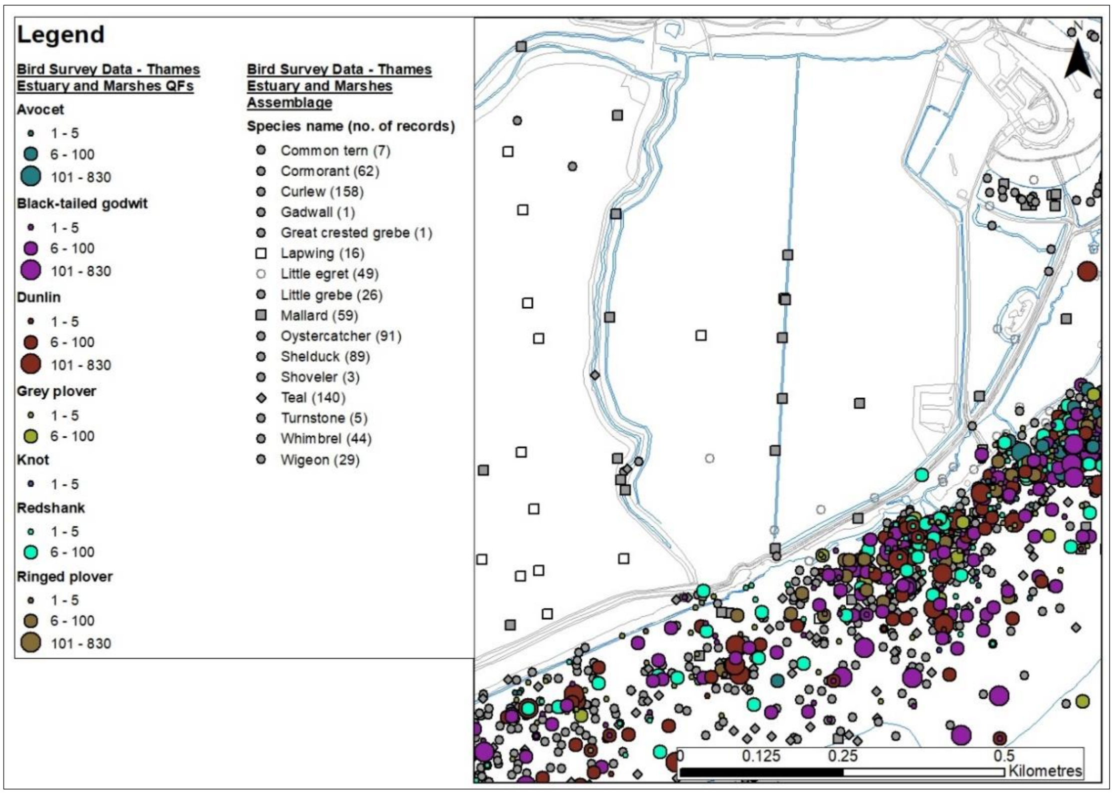


Figure 2 Distribution of Thames Estuary and Marshes QFs and assemblage at the land near Coalhouse Fort

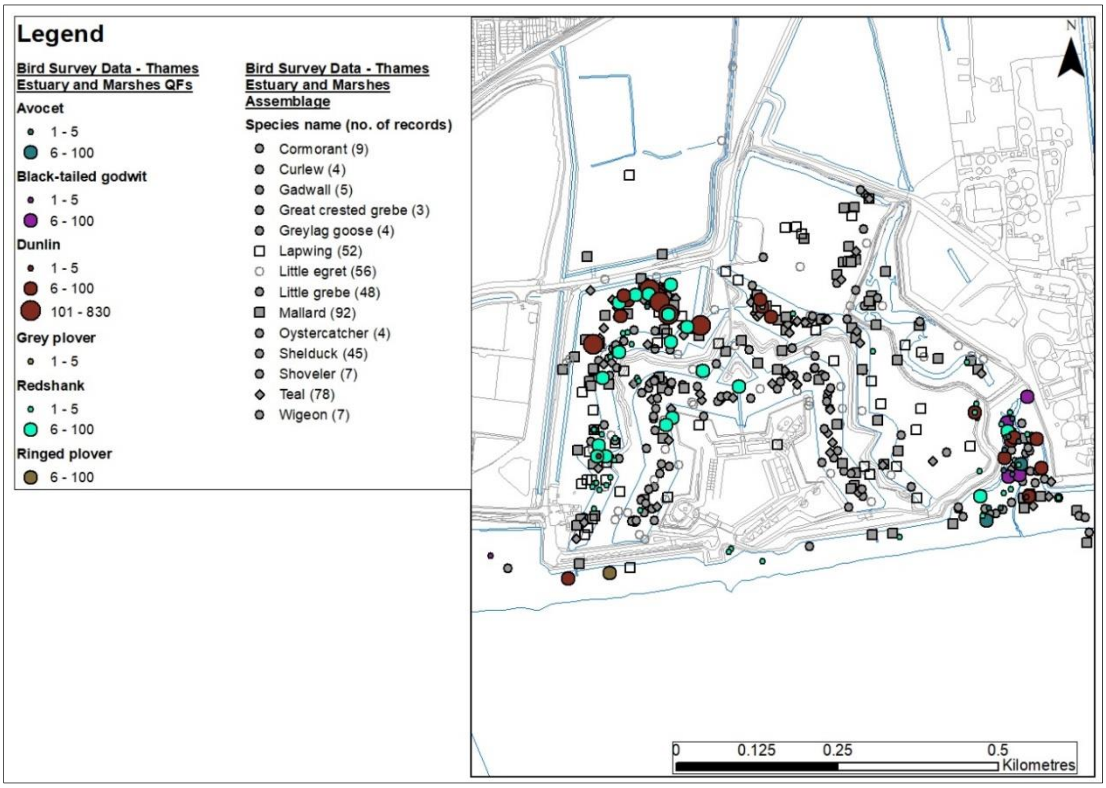


Figure 3: Distribution of Thames Estuary and Marshes QFs and assemblage at Tilbury Fort habitat mosaic

In addition, the geographical location of the proposed habitat creation is adjacent to intertidal mud and saltmarsh habitat that has also been shown by surveys to support relatively high concentrations of a range of qualifying species. It would therefore be certain that these birds would be able to find the new habitat easily and there would be no barriers between where the birds are currently using and the new habitats.

The habitat creation would be carried out as soon as possible after award of the DCO and prior to any significant construction effects and would be managed permanently by Highways England or it appointed contractors. Therefore, these enhanced habitats would provide additional functionality of the functionally linked land in both construction and operation of the Project.

5.2 Three arable fields to the south of the firing range

The surveys of this area showed no use by qualifying feature species and limited use of the fields by assemblage species such as lapwing and mallard when the management of the fields was under winter cereal crops, see figure 4. Noting that the surrounding fields are grassland.

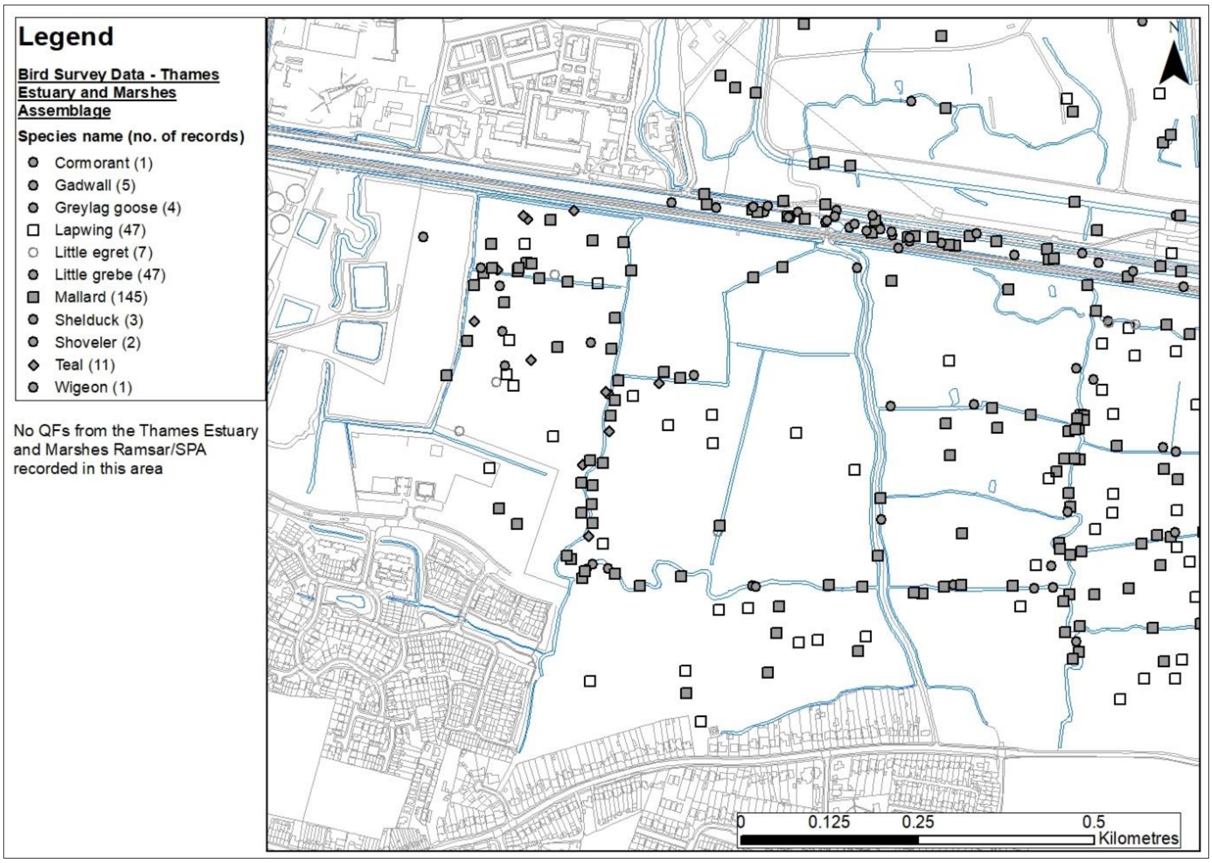


Figure 4: Distribution of Thames Estuary and Marshes QFs and assemblage at the 3 arable fields

Whilst winter cereal crops are used by qualifying feature species from time to time, it is generally understood that these species use grassland or winter stubbles from spring sown crops preferentially, notwithstanding other variables such as wetness and recent ploughing that can increase earthworm availability temporarily.

Earthworm availability is thought to be a key food resource for wintering waterfowl using functionally linked land. This would be increased during the winter if the land is managed either under grassland or spring crop management regimes. Grassland management has increased earthworm availability because it is generally a long-term management with absent or only occasional ploughing, which would increase biomass. Spring cropping has increased earthworm availability because the worm biomass developed during the summer months would not be reduced by autumn ploughing.

The Project would enforce management of these fields as either grassland or spring sown crops throughout the construction period to provide short grass or stubble during the passage and wintering season, which would be of higher value to wintering qualifying feature species than the existing management which has developing cereal crops during the passage/winter season.

The effects on functionally linked land south of the river are only associated with the construction period as there is no permanent land requirement. Therefore, this enhancement will be for the duration of the construction period only (prior to return to arable production post construction) and would be effective at increasing the functionality of the functionally linked land during the period when effects reducing potential functionality have been predicted.

5.3 Reinstatement of compound 3b

The proposed restoration of compound 3b would entail changing the existing habitats of hardstanding, path, ditch and rough grassland into <<Insert habitats agreed with RSPB>>. Very little activity of qualifying species was recorded in this area during surveys as it is considered as little more than an access corridor to the firing range, see figure 5.

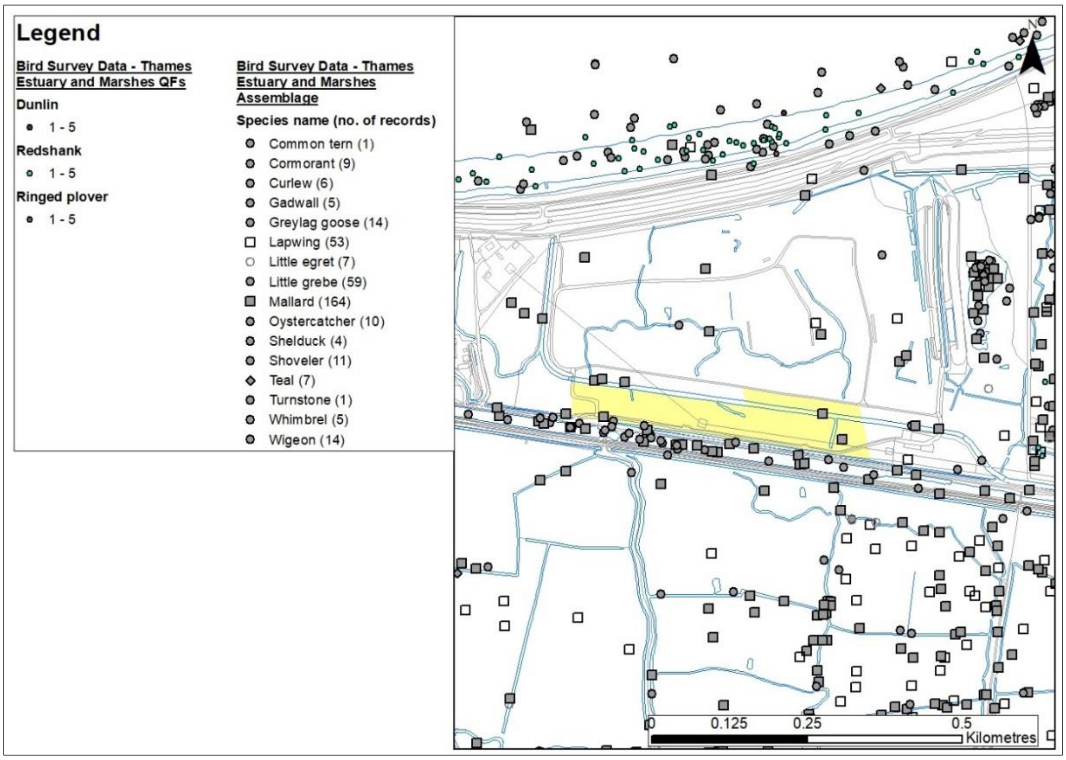


Figure 5: Distribution of Thames Estuary and Marshes QFs and assemblage at compound 3B (shaded yellow)

The access to the firing range will be improved as part of the construction programme and will run to the north of this area. Therefore, once the compound is decommissioned it can be enhanced to habitats suitable for the qualifying species and assemblage features.

The land is owned currently by RSPB and it is proposed that it will be managed by them post construction. RSPB has provided advice in developing the optimum habitats for enhancing the area for qualifying species and assemblage features. The created habitats are designed to be attractive to birds and so would be demonstrably higher functionality for the SPA/Ramsar.

The use of compound 3b is relatively short in duration (no more than three years) and so the habitat enhancement could be undertaken with four or so years remaining in the main construction programme. The habitats would therefore add functionality within the construction period, albeit not for all of that period. As RSPB would be the long-term managers of the land post construction, the area will also provide permanent enhancement of the functionality of functionally linked land.

Annex FF 23 February 2021 Technical Note - Habitat enhancement to maintain baseline functionality of functionally linked land (Revision 1)

LTC HRA Technical Note: Habitat enhancement to maintain baseline functionality of functionally linked land

1 Introduction

The following mitigation measures will be included in DCO 2.0 application that are additional to the proposal at DCO 1.0.

- Permanent enhancement of land adjacent to Coalhouse Fort
- Temporary enhancement of 3 arable fields to the south of the firing range
- Reinstatement of compound 3b to an enhanced habitat type
- Increased monitoring

In addition to definition and assessment of these measures within the HRA SIAA report, securing of the proposals will be achieved variously through the following:

- Environmental Principles
- Environmental Masterplan (EMP)
- Outline landscape and ecology management plan (OLEMP)
- REAC commitments

Appropriate securing mechanisms for proposed mitigation measures are summarised in the table below.

Measure	Duration Temp / Perm	Env. Principles	Masterplan	OLEMP	REAC
Coalhouse Fort	Perm	YES	YES	YES	n/a
3 arable fields	Temp	n/a	n/a	n/a	YES
Compound 3b	Perm	YES	YES	YES	n/a
Monitoring	Temp	n/a	n/a	YES	YES

2 Proposed amendments to the Environmental Principles

The Environmental Principles are to be amended with the following additions:

2.4 Permanent enhancement of land adjacent to Coalhouse Fort

Insert ref number	Enhancement of functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar	The land parcel adjacent to Coalhouse Fort shall be used for habitat enhancement to maintain baseline functionality of functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar. The land will be used to create a series of shallow scrape habitats, high tide roost features and coastal grazing marsh habitat suitable for use by the qualifying features of the SPA/Ramsar (LE6.2 Banks and ditches, LE6.1 Water bodies and associated plants, LE6.4 Marsh and wet grassland).

2.5 Temporary enhancement of 3 arable fields to the south of the firing range

This enhancement is only required on a temporary basis, for the duration of the construction period and will be defined and secured through a REAC commitment. Therefore, it is not appropriate to define Environmental Principles.

2.6 Reinstatement of compound 3b to an enhanced habitat type

Insert ref number	Enhancement of functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar	The land parcel within/ adjacent to the south of the Metropolitan Police firing range shall be used for habitat enhancement, post construction, to maintain baseline functionality of functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar. The land will be used to create <<INSERT habitats agreed with RSPB (expected mid-March)>> suitable for use by the qualifying features of the SPA/Ramsar (LE6.2 Banks and ditches, LE6.1 Water bodies and associated plants, LE6.4 Marsh and wet grassland <<UPDATE when agreed habitats agreed with RSPB>>).

2.7 Monitoring

Monitoring is included as specific REAC commitments and/or included within the prescriptions in the OLEMP for each enhancement measure, and so a separate monitoring principle is not required.

3 Proposed amendments to the Environmental Masterplan (EMP)

The EMP is to be amended as follows:

3.4 Permanent enhancement of land adjacent to Coalhouse Fort

Reference to Coalhouse Fort water vole habitat to be removed and replaced with the following proposals:

3.4.1 Environmental function codes (From LD 117 Landscape design. Table 4.2a)

- For all elements - EFD Nature conservation and biodiversity

3.4.2 Landscape element codes (From LD 117 Landscape design. Table 4.2b)

- For wet scrape features - LE6.1 Water bodies and associated plants
- For high tide roost features – LE6.2 Banks and ditches
- For grassland (coastal grazing marsh) features - LE6.4 Marsh and wet grassland

3.5 Temporary enhancement of 3 arable fields to the south of the firing range

This enhancement is only required on a temporary basis, for the duration of the construction period and will be defined and secured through a REAC commitment. Therefore, it will not be included on the EMP.

3.6 Reinstatement of compound 3b to an enhanced habitat type

Additional area to be included in the EMP, relating to compound 3b's reinstatement.

<<INSERT figure of the reinstated area for the EMP when we have agreement with RSPB>>

3.6.1 Environmental function codes (From LD 117 Landscape design. Table 4.2a)

- For all elements - EFD Nature conservation and biodiversity

3.6.2 Landscape element codes (From LD 117 Landscape design. Table 4.2b)

- E.g. <<Update when habitats agreed with RSPB>>
- For wet scrape features - LE6.1 Water bodies and associated plants
- For grassland (coastal grazing marsh) features - LE6.4 Marsh and wet grassland

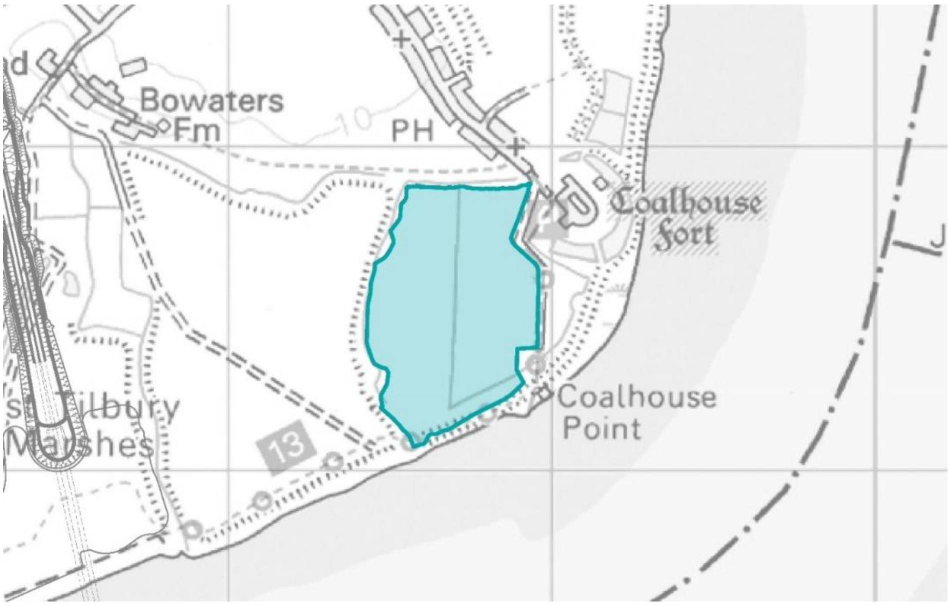
4 Proposed amendments to the OLEMP

The draft OLEMP is to be amended as follows:

4.4 Permanent enhancement of land adjacent to Coalhouse Fort as wintering bird habitat

Reference to Coalhouse Fort water vole habitat to be removed but location figure below to be retained.

4.4.1 Description of Management Area



This management area is located to the west of Coalhouse Fort just to the North of the River Thames.

The management area extends west to a drainage ditch on the boundary to the East Tilbury landfill.

The existing landscape is comprised of arable, agricultural land, and is low-lying at its natural level in contrast to the surrounding land which has been raised as part of landfill activities.

An existing ditch runs through the middle of the management area, bisecting the area as it runs in a north-south alignment.

The management area is approximately 34ha in size.

This management area is shown in the Environmental Masterplan (Application Document 6.2, Figure 2.4) Section 9 Sheets 15, 16, 19, & 20

4.4.2 Management Aims and Objectives

The management aim and objectives of this area are:

- To provide a series of shallow scrape habitats, high tide roost features and coastal grazing marsh habitat suitable for use by the qualifying features of the Thames Estuary and Marshes SPA/Ramsar.

- To provide habitats similar to those immediately north of Tilbury Fort that currently support foraging and roosting qualifying features of the SPA/Ramsar and in line with guidance from Natural England.

4.4.3 Typologies Present

The planting and habitat typologies present within this area are listed below:

- LE6.1 Water bodies and associated plants – Shallow scrape habitat
- LE6.2 Banks and ditches – High tide roost features
- LE6.4 Marsh and wet grassland – Coastal grazing marsh

4.4.4 Outline management prescriptions

The outline management prescriptions and programmes for the typologies listed above will be detailed in the OLEMP as follows:

4.4.4.1 LE6.1 Water Bodies and associated plants – Shallow scrape habitat

4.4.4.1.1 Description

Shallow scrape habitats are proposed within the Project design, their primary function being to maintain the functionality of functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar. They do not form part of the Project drainage design and would be designed to maximise their value to the qualifying features of the SPA/Ramsar, following good practice guidance such as RSPB's 'Scrape creation for wildlife' and 'Creating wader scrapes and flashes on farmland - Information and advice note (2003). Evidence of efficacy can be found at https://www.conservationevidence.com/actions/153

4.4.4.1.2 Outline Aims and Objectives

The following outline aims and objectives are for all shallow scrape habitats.

- To provide enhanced functionality within functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar by providing foraging habitat for a range of bird qualifying features of the SPA/Ramsar.
- Scrapes to be managed to provide optimum habitat for foraging waterfowl.

4.4.4.1.3 Outline Prescriptions

The work activities to complete the enhancement of the land adjacent to Coalhouse Fort will be completed before the compounds 5, 3A and 3B are set up.

The exact details of the work activities will be developed between all parties during the development of the LEMP and subsequent work-specific method statements.

This will be based on the Highways England's Manual of Contract Documents for Highways Works, Series 3000 unless otherwise agreed with Highways England. The table below describes the programme of work for establishment and initial maintenance (first five years).

Action			**Years 1-5 of the Construction Period**				
Task	Responsibility	Season	1	2	3	4	5
Excavation of wet scrape habitats for foraging waterfowl features of the	Principal Contractor (PC)	Summer	Y	-	-	-	-

Action			Years 1-5 of the Construction Period				
Thames Estuary and Marshes SPA/Ramsar Excavated material to be used for construction of high tide roost features.							
Removal of all trees, shrubs, fencing posts, etc. that could act as predator observation points within 300m of scrapes.	PC	Summer	Y	-	-	-	-
Enable grazing management of the surrounding coastal grazing marsh and high tide roost features to include scrape edges / margins	PC	Summer	Y	Y	Y	Y	Y
Attendance of quarterly site inspections with the Ecological Clerk of Works	Ecological Clerk of Works (EcCOW) appointed by PC	Quarterly	Y	Y	Y	Y	Y
Removal from scrapes of floating litter, debris, or other contaminants – weekly as part of general litter maintenance	EcCOW appointed by PC	As required	Y	Y	Y	Y	Y
Annual removal of unwanted vegetation from scrapes including edges / margins	EcCOW appointed by PC	Summer	Y	Y	Y	Y	Y
Annual removal of shrubs within 300m of scrapes that could act as predator observation points and reduce overall sightlines for foraging waterfowl.	EcCOW appointed by PC	Summer	Y	Y	Y	Y	Y

4.4.4.1.4 Outline Measure of Success

To ensure that the management objectives are achieved, the following monitoring targets have been devised to measure success:

- Shallow water and exposed mud habitats available for foraging by qualifying waterfowl features of the Thames Estuary and Marshes SPA/Ramsar.
- Vegetation largely absent and not interfering with foraging of waterfowl.
- Absence of obstructions to sightlines of waterfowl or predator observation points within 300m of scrapes.

4.4.4.1.5 Outline Monitoring Frequency and Methods

The aim of the suggested monitoring programme is to ascertain whether the outline measures of success listed above have been achieved.

The monitoring will commence in the first year after the habitats are created and will comprise:

- Habitat establishment and suitability.
- Bird use.

Frequency of monitoring visits to record the habitat establishment and suitability will be determined by the success of establishment and the frequency of monitoring adjusted accordingly to ensure relevant follow up operations are undertaken. At this stage an annual visit for the first 5 years following creation is proposed and carried out in late summer.

During construction and for five years post construction, annual surveys will be undertaken of use of scrapes by passage and wintering waterfowl, with monthly visits August to March inclusive. Surveys will record:

- Waterfowl species and numbers at both low and high tide during daylight.
- Waterfowl species and numbers at high tide nocturnally.
- Distribution of waterfowl in relation to the scrape habitats.
- Disturbing stimuli and waterfowl behaviours in response to them (including where no response).
- Management requirements such as vegetation removal.

Highways England's appointed monitoring party will carry out the monitoring visits and feed back to the steering group as part of annual monitoring reporting.

Action			All construction years and post construction years 1-5				
Task	Responsibility	Season	1	2	3	4	5
Annual check of habitat suitability	Highways England's appointed monitoring party	Late summer	Y	Y	Y	Y	Y
Annual survey of waterfowl	Highways England's appointed monitoring party	August to March	Y	Y	Y	Y	Y

4.4.4.2 LE6.2 Banks and Ditches – High tide roost features

4.4.4.2.1 Description

This typology includes raised ground or bank features within or adjacent to wet scrape habitats that are suitable for roosting of waterfowl feature species of the Thames Estuary and Marshes SPA / Ramsar during high tides.

The form of high tide roost features may vary, but vegetation would be absent or short / sparse between August and March inclusive to facilitate roosting by waterfowl.

4.4.4.2.2 Outline Aims and Objectives

The following outline aims and objectives are for all high tide roost features.

- To provide enhanced functionality within functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar by providing high tide roosting habitat for a range of bird qualifying features of the SPA/Ramsar.
- Areas to be managed to provide optimum habitat for roosting waterfowl.

4.4.4.2.3 Outline Prescriptions

The work activities to complete the enhancement of the land adjacent to Coalhouse Fort will be completed before the compounds 5, 3A and 3B are set up.

The exact details of the work activities will be developed between all parties during the development of the LEMP and subsequent work-specific method statements.

This will be based on the Highways England's Manual of Contract Documents for Highways Works, Series 3000 unless otherwise agreed with Highways England. The table below describes the programme of work for establishment and initial maintenance (first five years).

Action			**Years 1-5 of the Construction Period**				
Task	Responsibility	Season	1	2	3	4	5
Spreading of material excavated during creation of wet scrape habitats to form raised ground and banks suitable for roosting waterfowl	Principal Contractor (PC)	Summer	Y	-	-	-	-
Attendance of quarterly site inspections with the Project Ecological Clerk of Works	Ecological Clerk of Works (EcCOW) appointed by PC	Quarterly	Y	Y	Y	Y	Y
High tide roost features to be grazed during the summer and mown / strimmed in late summer where necessary to provide a short / sparse vegetation between August and March.	PC	Summer	Y	Y	Y	Y	Y
Selective spot treatment of herbicide as required for larger pernicious weeds	EcCOW appointed by PC	Twice yearly - May and September	Y	Y	Y	Y	Y
Injurious weeds are to be eradicated, removed and disposed of off-site, as per the latest DEFRA / Natural England guidance.	EcCOW appointed by PC	As required	Y	Y	Y	Y	Y
All litter / foreign debris to be removed and taken off site	EcCOW appointed by PC	As required	Y	Y	Y	Y	Y

4.4.4.2.4 Outline Measure of Success

To ensure that the management objectives outlined previously are achieved, the following monitoring targets have been devised to measure the success of the management objectives:

- High tide roosting features available for roosting qualifying waterfowl features of the Thames Estuary and Marshes SPA/Ramsar.
- High tide roost features sufficiently elevated, so they are available for roosting waterfowl at spring high tides.
- Vegetation of high tide roost features sufficiently low / sparse between August and March inclusive to not deter roosting by waterfowl.
- Absence of obstructions to sightlines of waterfowl or predator observation points within 300m of high tide roost features.

4.4.4.2.5 Outline Monitoring Frequency and Methods

The aim of the suggested monitoring programme is to ascertain whether the outline measures of success listed above have been achieved.

Monitoring will commence in the first year after the habitats are created and will comprise:

- Habitat establishment and suitability.
- Bird use.

Frequency of monitoring visits to record the habitat establishment and suitability will be determined by the success of establishment and the frequency of monitoring adjusted accordingly to ensure relevant follow up operations are undertaken. At this stage an annual visit for the first 5 years following creation is proposed and carried out in late summer.

During construction and for five years post construction, annual surveys will be undertaken of use of high tide roosting features by passage and wintering waterfowl, with monthly visits August to March inclusive. Surveys will record:

- Waterfowl species and numbers at both low and high tide during daylight.
- Waterfowl species and numbers at high tide nocturnally.
- Distribution of waterfowl in relation to the high tide roost features.
- Disturbing stimuli and waterfowl behaviours in response to them (including where no response.
- Management requirements such as vegetation removal.

Highways England's appointed monitoring party will carry out the monitoring visits and feed back to the steering group as part of annual monitoring reporting.

Action			All construction years and post construction years 1-5				
Task	Responsibility	Season	1	2	3	4	5
Annual check of habitat suitability	Highways England's appointed monitoring party	Late summer	Y	Y	Y	Y	Y
Annual survey of waterfowl	Highways England's appointed monitoring party	August to March	Y	Y	Y	Y	Y

4.4.4.3 LE6.4 Marsh and Wet Grassland – Coastal grazing marsh

4.4.4.3.1 Description

The coastal grazing marsh typology is located within the areas of enhanced functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar and includes areas of seasonally wet grassland and shallow edged ditches.

4.4.4.3.2 Outline Aims and Objectives

- To create and maintain coastal grazing marsh habitat suitable for foraging of passage and wintering waterfowl features of the Thames Estuary and Marshes SPA/Ramsar.
- To maintain a grassland sward between August and March inclusive at a height of approximately 10cm or below through summer grazing and late summer mowing where necessary.
- To maintain the ditch network as open ditches with shallow profiled banks through ditch clearance and bank profiling on a ten-year rotational management regime. Ditch management to be carried out only on one bank with one fifth of ditches being managed each year.

4.4.4.3.3 Outline Prescriptions

The work activities to complete the enhancement of the land adjacent to Coalhouse Fort will be completed before the compounds 5, 3A and 3B are set up.

The exact details of the work activities will be developed between all parties during the development of the LEMP and subsequent work-specific method statements.

This will be based on the Highways England's Manual of Contract Documents for Highways Works, Series 3000 unless otherwise agreed with Highways England. The table below describes the programme of work for establishment and initial maintenance (first five years).

Action			Years 1-5 of the Construction Period				
Task	Responsibility	Season	1	2	3	4	5
Sow suitable coastal grazing marsh grassland mix.	Principal Contractor (PC)	Spring / summer	Y	-	-	-	-
Clear one side of one fifth of ditches and reprofile banks to shallow gradient.	PC	Spring / summer	Y	Y	Y	Y	Y
Instigate grazing regime and late summer mowing where required to maintain sward height of approximately 10cm or below between August and March inclusive.	PC	Summer	Y	Y	Y	Y	Y
Attendance of quarterly site inspections with the Project Ecological Clerk of Works	Ecological Clerk of Works (EcCOW) appointed by PC	Quarterly	Y	Y	Y	Y	Y
Removal from water bodies of floating litter, debris, fly tipping, surface weeds, contaminants and animal carcasses – weekly as part of general litter maintenance	EcCOW appointed by PC	As required	Y	Y	Y	Y	Y
Any unsuccessful grassland sowing to be replaced annually.	EcCOW appointed by PC	Spring / summer	N	Y	Y	Y	Y
Injurious weeds are to be eradicated, removed and disposed of off-site, as per the latest DEFRA / Natural England guidance.	EcCOW appointed by PC	As required	Y	Y	Y	Y	Y

4.4.4.3.4 Outline Measure of Success

To ensure that the management objectives outlined previously are achieved, the following monitoring targets have been devised to measure the success of the management objectives:

- Coastal grazing marsh available for foraging by qualifying waterfowl features of the Thames Estuary and Marshes SPA/Ramsar.
- The sward height is maintained at approximately 10cm or below between August and March inclusive.
- The grassland supports species typical of coastal grazing marsh with no scrub.
- Ditch habitats provide diversity of habitat without interfering with foraging of waterfowl.
- Absence of obstructions to sightlines of waterfowl or predator observation points.

4.4.4.3.5 Outline Monitoring frequency and methods

The aim of the suggested monitoring programme is to ascertain whether the outline measures of success listed above have been achieved.

Monitoring will commence in the first year after the habitats are created and will comprise:

- Habitat establishment and suitability
- Bird use

Frequency of monitoring visits to record the habitat establishment and suitability will be determined by the success of establishment and the frequency of monitoring adjusted accordingly to ensure relevant follow up operations are undertaken. At this stage an annual visit for the first 5 years following creation is proposed and carried out in late summer.

During construction and for five years post construction, annual surveys will be undertaken of use of coastal grazing marsh created through the project by passage and wintering waterfowl, with monthly visits August to March inclusive. Surveys will record:

- Waterfowl species and numbers at both low and high tide during daylight.
- Waterfowl species and numbers at high tide nocturnally.
- Distribution of waterfowl in relation to the coastal grazing marsh habitats.
- Disturbing stimuli and waterfowl behaviours in response to them (including where no response).
- Management requirements such as vegetation mowing or weed eradication.

Highways England's appointed monitoring party will carry out the monitoring visits and feed back to the steering group as part of annual monitoring reporting.

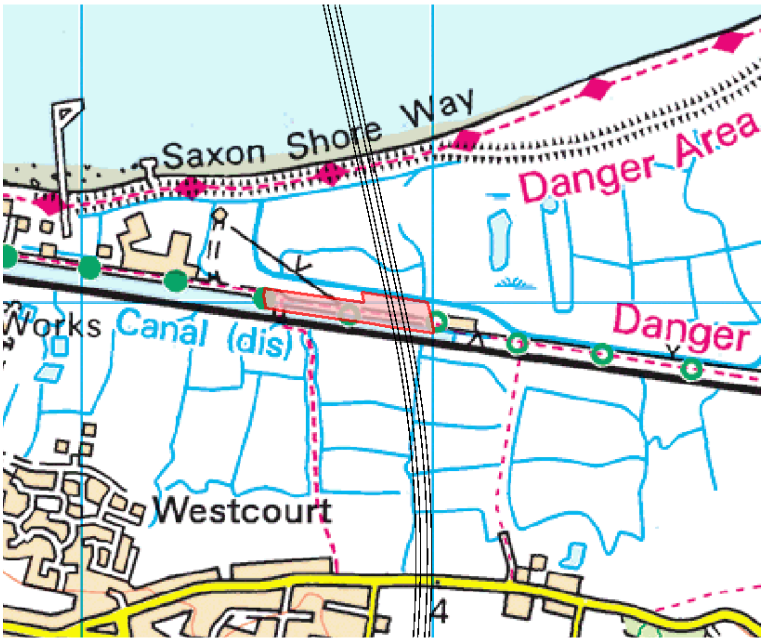
Action			All construction years and post construction Years 1-5				
Task	Responsibility	Season	1	2	3	4	5
Annual check of habitat suitability	Highways England's appointed monitoring party	Late summer	Y	Y	Y	Y	Y
Annual survey of waterfowl	Highways England's appointed monitoring party	August to March	Y	Y	Y	Y	Y

4.5 Temporary enhancement of 3 arable fields to the south of the firing range

As these works will be temporary construction works, these will not be referenced within the OLEMP. These will be defined and secured through a REAC commitment.

4.6 Reinstatement of Compound 3b to enhanced wintering bird habitat

4.6.1 Description of Management Area



This management area is located to the south of the Metropolitan Police firing range, just to the North of the Thames and Medway canal.

The existing landscape is comprised of ditch, rough grassland, scrub, hardstanding and access roads.

The management area is approximately 3ha in size.

There will be a new management area shown in the Environmental Masterplan (Application Document 6.2, Figure 2.4) Section TBC Sheets TBC

4.6.2 Management Aims and Objectives

The management aim and objectives of this area are:

- To provide a series of shallow scrape habitats, high tide roost features and coastal grazing marsh <<to be updated when habitats agreed with RSPB>> habitat suitable for use by the qualifying features of the Thames Estuary and Marshes SPA/Ramsar in line with guidance from RSPB.

4.6.3 Typologies Present

The planting and habitat typologies present within this area are listed below:

- E.g. <<to be updated when habitats agreed with RSPB>>
- LE6.1 Water bodies and associated plants – Shallow scrape habitat
- LE6.2 Banks and ditches – High tide roost features
- LE6.4 Marsh and wet grassland – Coastal grazing marsh

4.6.4 Outline management prescriptions and programmes

For the typologies listed above these will be detailed in the OLEMP. <<update when habitats agreed with RSPB>>

5 Proposed amendments to the REAC commitments

REAC commitments will be added and amended as follows:

5.4 Permanent enhancement of land adjacent to Coalhouse Fort

No additional or changes to commitments made at DCO Application 1.0 are required as the measures necessary are secured through the Environmental Principles, EMP and OLEMP.

5.5 Temporary enhancement of 3 arable fields to the south of the firing range

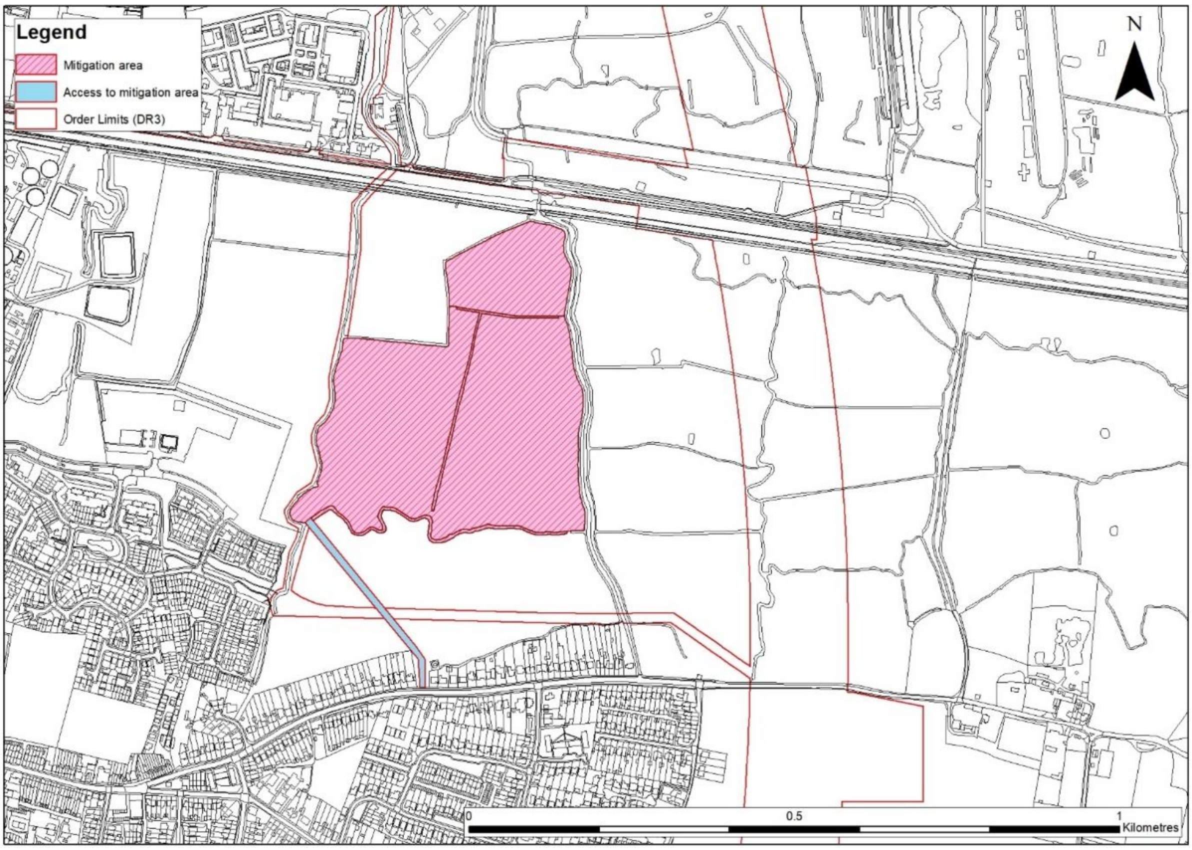


Figure 1: Location of the 3 arable field (Plot XXXX)

Issue	REAC commitment at DCO Application 1.0	New REAC commitment for DCO Application 2.0
Change of management of arable land for the construction period	N/A – new Commitment	HR005 To provide temporarily enhanced functionality of functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar, the management of the three fields in plot XXXX to the south of the Metropolitan Police firing range and adjacent to the SPA/Ramsar will consist of grassland and/or spring sown crops and winter stubbles throughout the construction period of compounds CA3A and CA3B.

5.6 Reinstatement of compound 3b to an enhanced habitat type

No additional, or changes to, commitments made at DCO Application 1.0 are required as the measures necessary are secured through the Environmental Principles, EMP and OLEMP.

5.7 Monitoring

Issue	REAC commitment at DCO Application 1.0 (To be retained in the REAC)	Additional REAC commitment for DCO Application 2.0
Inclusion of recording of behaviours in response to disturbing stimuli as well as numbers of birds Plus Recording of use of mitigation areas by target bird species	MB004 An annual bird survey will be undertaken whilst works are being carried out in the area below mean high water springs. The survey will be undertaken between 01 September and 31 March inclusive and to a specification submitted to the MMO.	HR007 Between 01 September and 31 March inclusive during each year of the LTC construction period, complete monthly surveillance visits from fixed vantage points to observe functionally linked land associated with the Thames Estuary and Marshes SPA/Ramsar as identified in the HRA (<<insert reference to suitable figure in the HRA>>) within 300m of Order limits of the Project. The survey will record numbers of waterfowl present and any behaviours in response to disturbance stimuli to a specification developed in consultation with Natural England.

6 Efficacy of the proposed enhanced habitats

The evidence to demonstrate that the proposed enhancements of functionally linked land would provide additional functionality from their exiting state is as follows:

6.4 Land near Coalhouse Fort

The proposed change from arable farmland to a mosaic of coastal grazing marsh, shallow scrapes and high tide roost features is designed to create a similar mosaic of habitats as currently found in the area around Tilbury Fort. The surveys have shown that the existing use of the land near Coalhouse Fort is very low and limited to lapwing occasional use, see figure 2. The surveys also showed that the Tilbury Fort area supports a range of SPA/Ramsar qualifying features at all times and states of tide, see figure 3. The proposed habitats are therefore demonstrably more suitable than the existing habitats for use by qualifying feature species.

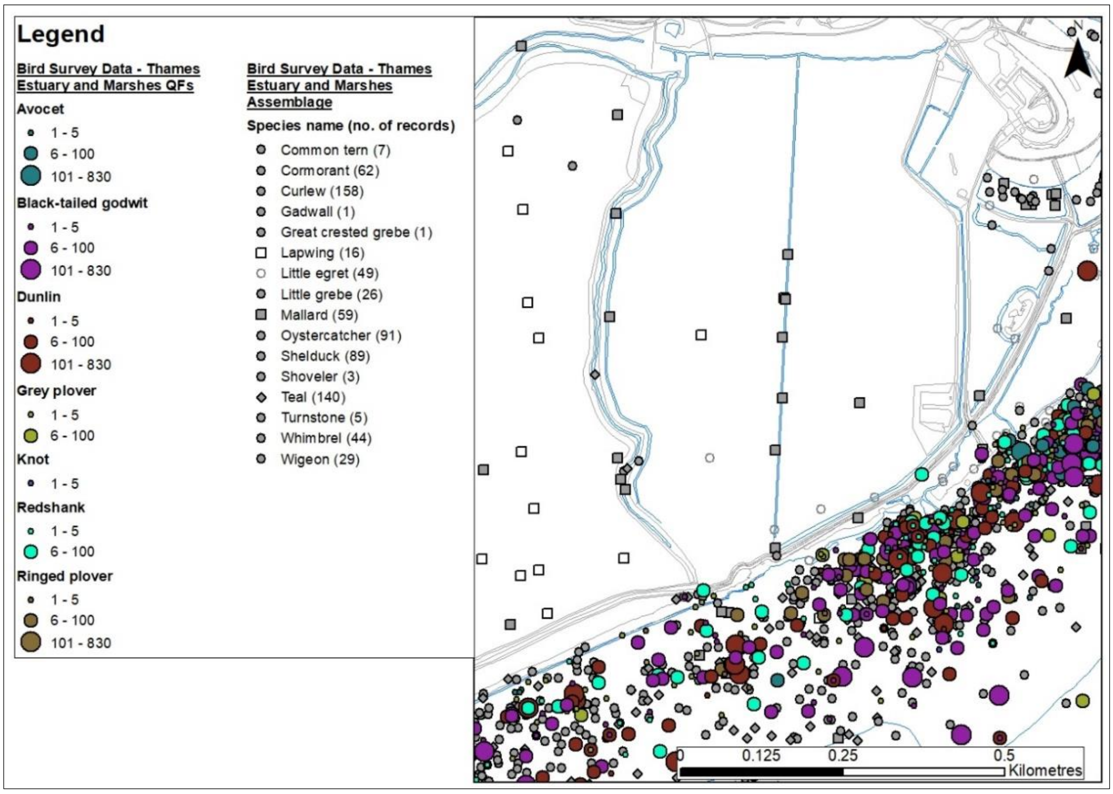


Figure 2 Distribution of Thames Estuary and Marshes QFs and Assemblage at the land near Coalhouse Fort

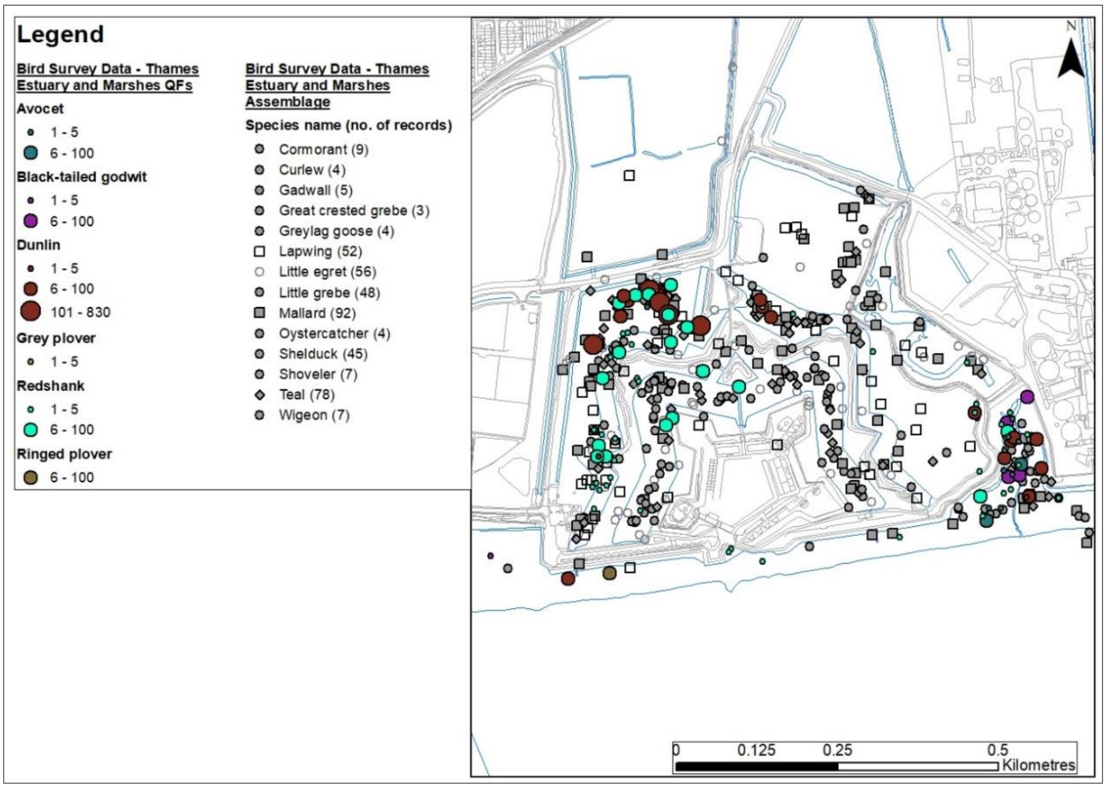


Figure 3: Distribution of Thames Estuary and Marshes QFs and Assemblage at Tilbury Fort habitat mosaic

In addition, the geographical location of the proposed habitat creation is adjacent to intertidal mud and saltmarsh habitat that has also been shown by surveys to support relatively high concentrations of a range of qualifying species. It would therefore be certain that these birds would be able to find the new habitat easily and there would be no barriers between where the birds are currently using and the new habitats.

The habitat creation would be carried out as soon as possible after award of the DCO and prior to any significant construction effects and would be managed permanently by Highways England or it appointed contractors. Therefore, these enhanced habitats would provide additional functionality of the functionally linked land in both construction and operation of the Project.

6.5 Three arable fields to the south of the firing range

The surveys of this area showed no use by qualifying feature species and limited use of the fields by Assemblage species such as lapwing and mallard when the management of the fields was under winter cereal crops, see figure 4. Noting that the surrounding fields are grassland.

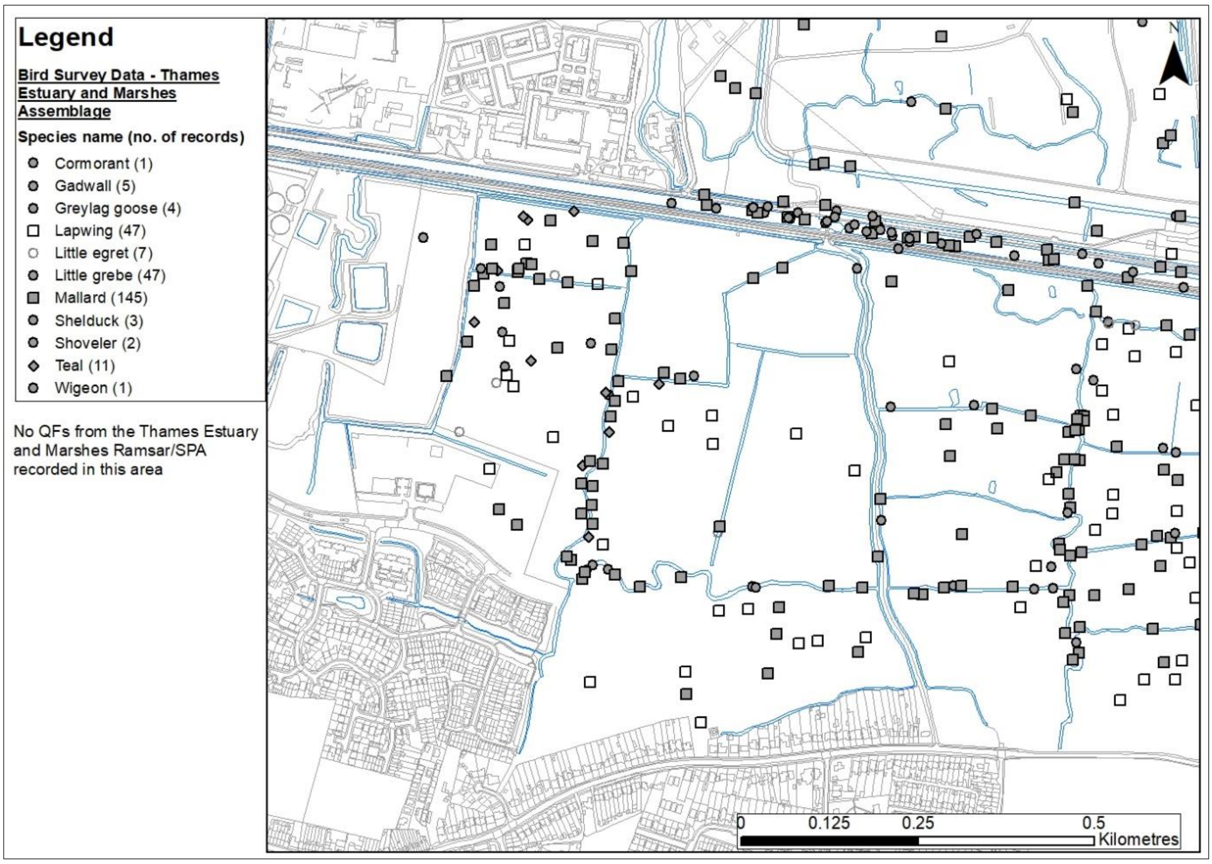


Figure 4: Distribution of Thames Estuary and Marshes QFs and Assemblage at the 3 arable fields

Whilst winter cereal crops are used by qualifying feature species from time to time, it is generally understood that these species use grassland or winter stubbles from spring sown crops preferentially, notwithstanding other variables such as wetness and recent ploughing that can increase earthworm availability temporarily.

Earthworm availability is thought to be a key food resource for wintering waterfowl using functionally linked land. This would be increased during the winter if the land is managed either under grassland or spring crop management regimes. Grassland management has increased earthworm availability because it is generally a long-term management with absent or only occasional ploughing, which would increase biomass. Spring cropping has increased earthworm availability because the worm biomass developed during the summer months would not be reduced by autumn ploughing.

The Project would enforce management of these fields as either grassland or spring sown crops throughout the construction period to provide short grass or stubble during the passage and wintering season, which would be of higher value to wintering qualifying feature species than the existing management which has developing cereal crops during the passage/winter season.

The effects on functionally linked land south of the river are only associated with the construction period as there is no permanent land requirement. Therefore, this enhancement will be for the duration of the construction period only (prior to return to arable production post construction) and would be effective at increasing the functionality of the functionally linked land during the period when effects reducing potential functionality have been predicted.

6.6 Reinstatement of compound 3b

The proposed restoration of compound 3b would entail changing the existing habitats of hardstanding, path, ditch and rough grassland into <<Insert habitats agreed with RSPB>>. Very little activity of qualifying species was recorded in this area during surveys as it is considered as little more than an access corridor to the firing range, see figure 5.

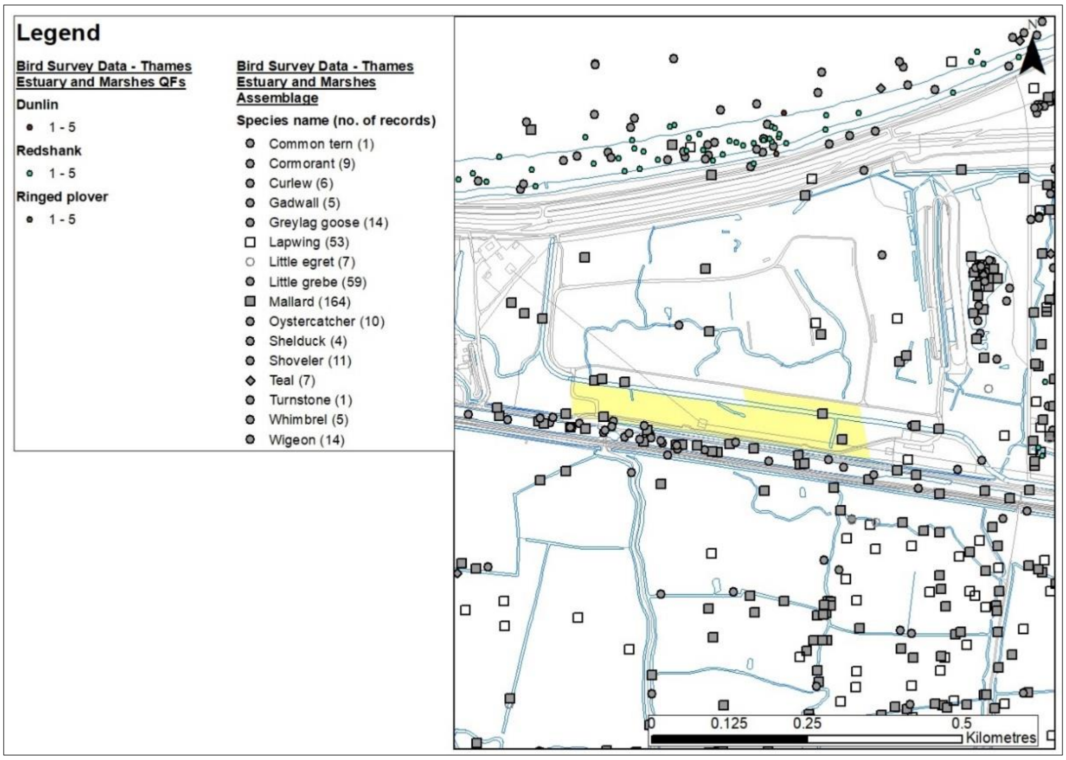


Figure 5: Distribution of Thames Estuary and Marshes QFs and Assemblage at compound 3B (shaded yellow)

The access to the firing range will be improved as part of the construction programme and will run to the north of this area. Therefore, once the compound is decommissioned it can be enhanced to habitats suitable for the qualifying species and Assemblage features.

The land is owned currently by RSPB and it is proposed that it will be managed by them post construction. RSPB has provided advice in developing the optimum habitats for enhancing the area for qualifying species and Assemblage features. The created habitats are designed to be attractive to birds and so would be demonstrably higher functionality for the SPA/Ramsar.

The use of compound 3b is relatively short in duration (no more than three years) and so the habitat enhancement could be undertaken with four or so years remaining in the main construction programme. The habitats would therefore add functionality within the construction period, albeit not for all of that period. As RSPB would be the long-term managers of the land post construction, the area will also provide permanent enhancement of the functionality of functionally linked land.

6.7 Quantification to illustrate no net loss of function of FLL

The abundance of birds within the habitat provides a measure of its functionality and we have used this measure to illustrate how the Project mitigates the loss of FLL during the construction and operation phases.

To evidence the predicted increase in function of enhanced habitat on the mitigation areas we have assessed the abundance of birds on a number of exemplar[1] habitat plots. Based on the survey data of bird use of existing exemplar habitats, it is expected that the new habitats created in the mitigation areas would attract similar numbers of birds. The increase in functionality of the mitigation areas can therefore be identified by comparing existing use (from survey data) and expected future use (from survey data of existing exemplar habitat) in the habitat to be created).

Using field data collected during Project survey work 2017 – 2019, the winter/passage months (Aug-Apr Incl.) data has been used in the analysis as it is effects on FLL for overwintering birds that requires mitigation.

The exemplar plots have been chosen as they reflect the habitat objectives of the mitigation plots as follows:

- Tilbury Fort – the mosaic of scrapes, open water and grassland which would be created within the mitigation plot adjacent to Coalhouse Fort
- RSPB Plot – the mosaic of managed grassland and ponds which would be created <<update when habitats agreed with RSPB>> when reinstating Compound 3b
- Ramsar grass – the agricultural grassland types within the Ramsar which would be created within the 3 arable fields mitigation plot

The exemplar plots are all terrestrial FLL (above MHW) and no intertidal areas have been used, as likely significant effects are only on terrestrial FLL.

The following data (see Table 6.1 to Table 6.4) has been compiled for each of the exemplar plots, the mitigation areas and the areas affected by land take:

- Species diversity – total number of species recorded in plot (including split Thames Estuary and Marches SAC/Ramsar QFs or Assemblage)
- Species abundance - Total number of individuals recorded (all surveys)
- Plot size in hectares
- Calculated the species abundance per hectare
- The expected future abundance on mitigation plots has been calculated by multiplying the plot size by the abundance per hectare of the equivalent exemplar plot

The functionality of the habitat has been calculated for the baseline (existing habitat within the Order Limits), during construction and during operation.

[1] Exemplar – Habitat types include features that would be created in the new mitigation areas for example scrapes, grassland etc.

Table 6.1 Exemplar plots – Existing habitat functionality

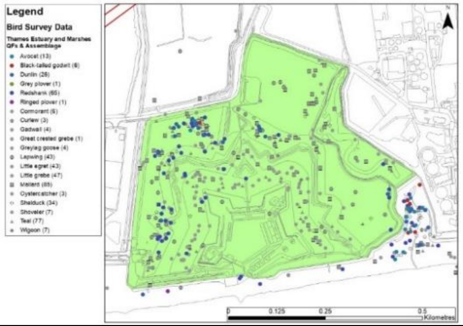
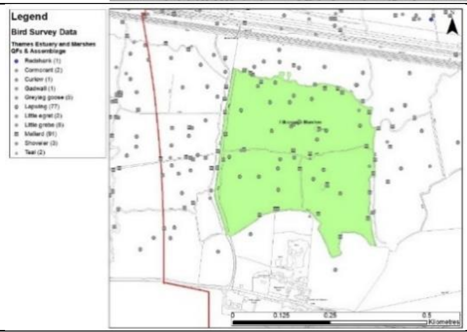
Name	**Location**	**Species diversity**	**Species abundance**	**Plot size (ha)**	**Abundance /ha**
Tilbury Fort plot Exemplar for Coalhouse Fort enhancement to identify expected abundance / ha		16 QFs: 4 Assemblage: 12	5181	31.4	165.0
RSPB plot Exemplar for reinstatement of Compound 3b to identify expected abundance / ha		9 QFs: 0 Assemblage: 9	349	4.9	189.7
Ramsar grass plot Filborough Marshes Exemplar for management of arable fields to identify expected abundance / ha		6 QFs: 0 Assemblage:	270	14.5	18.62

Table 6.2 Mitigation Plots – Existing and expected functionality

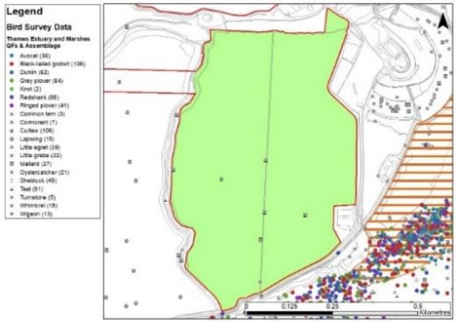
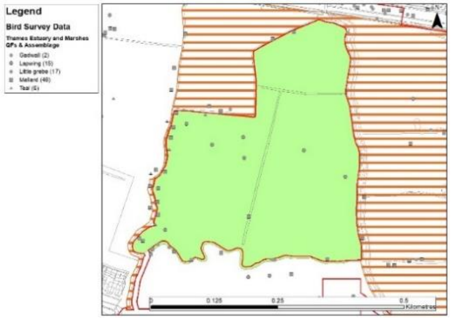
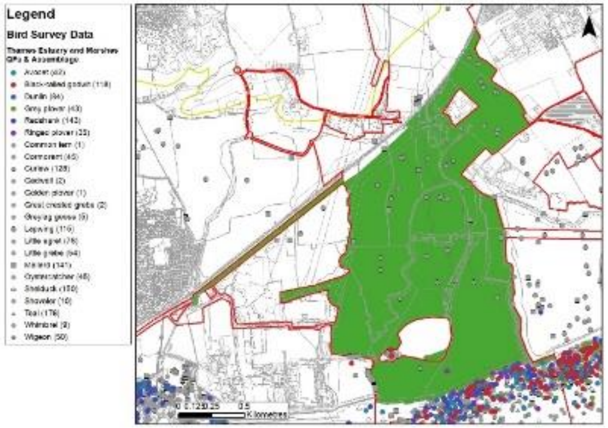
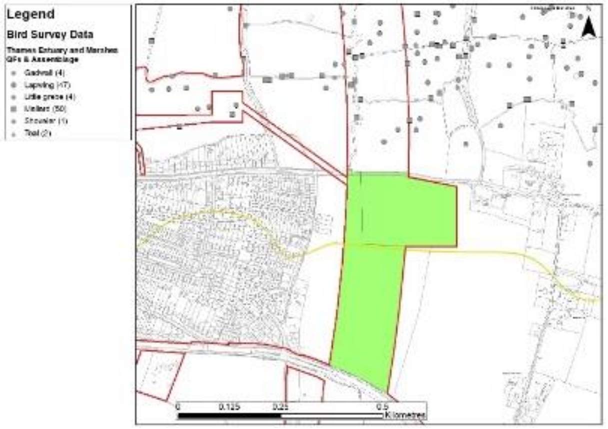
Name	Location	Species diversity	Species abundance for the plot	Plot size (ha)	Existing Abundance /ha	Expected abundance /ha	Expected abundance for the plot
Coalhouse Fort – existing plot		3 QFs: 0 Assemblage: 3	88	34.4	2.6	165	5,676
Reinstatement 3b – existing plot		2 QFs: 0 Assemblage: 2	3	3.24	0.93	189	612
3 Arable fields – existing plot		5 QFs: 0 Assemblage: 5	88	14.3	6.2	19	272

Table 6.3 Construction land take - Existing habitat functionality

Name	Location	Species diversity	Species abundance	Plot size (ha)	Abundance /ha
Compound 5		13 QFs: 4 Assemblage: 9	490	260	1.88
Compound 3a		0	0	4.5	0

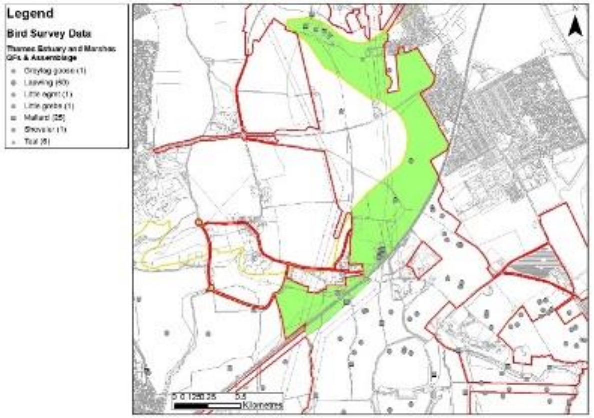
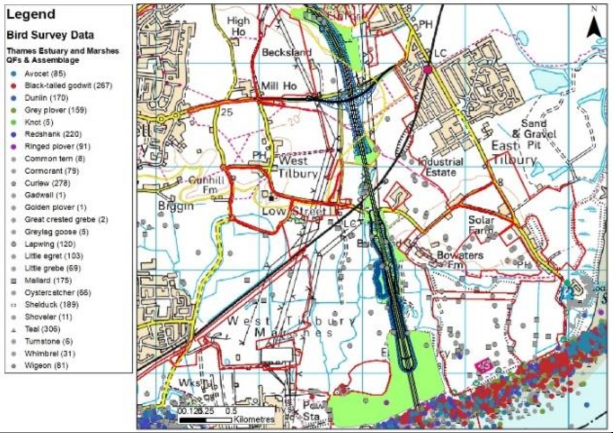
Name	**Location**	**Species diversity**	**Species abundance**	**Plot size (ha)**	**Abundance /ha**
Compound 3b		2 QFs: 0 Assemblage: 2	3	3.24	0.93
Land take north of Tilbury Rail		4 QFs: 0 Assemblage: 4	778	98	7.94

Table 6.4 Permanent land take – Existing habitat functionality

Name	Location	Species diversity	Species abundance	Plot size (ha)	Abundance /ha
North Portal		5 QF: 1 Assemblage: 4	176	99.8	1.76

6.7.1 Summary of impact assessment using functionality

The table below illustrates the change in functionality of the FLL affected by the Project and with the provision of the proposed habitat enhancement plots in which the functionally would be expected to increase.

Table 6.5 Summary of existing and predicted functionality

	Functionality (species abundance)		
	Existing	**Construction**	**Operation**
FLL within Order limits (not including mitigation areas)	1271	0	1095[2]
Mitigation area adjacent to Coalhouse Fort	88	5,676	5,676
Mitigation area Compound 3b reinstatement	3	0	612
Mitigation area 3 arable fields	88	272	0
Total	**1450**	**5948**	**7383**
Ratio to existing		**4:1**	**5:1**

[2] Calculated: Total of abundance of construction land take minus total abundance in permanent land take

Annex GG 09 March 2021 Technical Note – Dust measures

HRA Technical Note: Efficacy of measures to avoid and reduce dust emissions.

Introduction

Following discussion within meeting 2/12/2020 & 9/12/2020 Natural England requested that the HRA screening report included evidence of the efficacy of the measures to avoid and reduce dust emissions. This technical note provides extracts from the screening report to illustrate how the assessment of effects on dust has been updated – to facilitate agreement on the conclusion in the SoCG prior to Natural England seeing the final resubmission draft of the Screening report.

Proposed text in the Screening Report

The zone of influence for dust emissions is described in Table 4.3. It is defined in DMRB LA 105 (Highways England, et al., 2019) as the Area within the 200m of the Order Limits where dust effects could occur in absence of mitigation.

Section 5.2 describes the European sites that could be affected by dust emissions (without any measures in place) are those:

1. within 200m of the Order Limits - Thames Estuary and Marshes Ramsar; and,
2. where functionally linked land is within 200m of the Order Limits - Benfleet and Southend SPA/Ramsar, Thames Estuary and Marshes SPA/Ramsar, Medway Estuary and Marshes SPA/Ramsar and The Swale SPA/Ramsar.

The measures that are relied upon in the screening report are set out within Section 4.5 Assumptions, Project design and environmental measures as follows:

"Change in air quality – dust emissions – construction

Construction

The following good practice measures would be implemented to reduce and manage dust during the construction phase. These measures are considered to be effective, at containing dust, when used at source and are defined in many industry standards for use on construction sites, for example the "Environmental good practice on site guide (CIRIA C741)" (Charles & Edwards, 2015).

Implement good practice measures to reduce dust during demolition works such as [AQ002]:

a. *Soft strip inside buildings before demolition (i.e. retain external walls and windows where safe and practicable to provide a screen against dust).*
b. *Use water suppression where practicable for dust control, during demolition operations.*
c. *Avoid explosive blasting, using appropriate manual or mechanical alternatives.*
d. *Bag and remove any biological debris or damp down such material before demolition.*

Implement good practice controls to reduce dust during works, such as [AQ0003]:

a. *Cover with topsoil and re-vegetate earthworks and exposed areas including soil stockpiles to stabilise surfaces.*
b. *Use a cover such as hessian, mulches or tackifiers where it is not possible to re-vegetate or cover with topsoil.*
c. *Remove the cover systematically during work to reduce exposure of areas that are not being worked on.*
d. *Ensure sand and other aggregates are stored in bunded areas and are not allowed to dry out, unless required for a particular process, in which case ensure that appropriate additional control measures are in place to prevent escape.*
e. *Ensure bulk cement and other fine powder materials are delivered in enclosed tankers and stored with suitable emission control systems to prevent escape.*
f. *For small supplies of fine powder materials ensure bags are sealed after use and stored appropriately to prevent dust.*

Implement good practice controls to reduce track-out during works such as [AQ0004]:

a. *Use of water-assisted dust sweepers on the access and local roads to remove any material tracked out of the site.*
b. *Avoid dry sweeping of large areas.*
c. *Ensure vehicles entering and leaving worksites are securely covered to prevent escape of materials during transport.*
d. *Inspect haul routes for integrity, instigate necessary repairs and record in site log book.*
e. *Access gates to be sited at least 10m from receptors e.g. residential properties where practicable.*
f. *Apply dust suppressants to locations where large volume of vehicles enter and exit the construction site.*

Implement good practice controls to manage dust during construction such as [AQ0005]:

a. *Undertake onsite and offsite inspections to monitor dust.*
b. *Plan site layout so that machinery and dust-causing activities are located away from receptors, as far as this is reasonably practicable.*
c. *Erect suitable solid screens or barriers around dusty activities or the site boundary.*
d. *Avoid site runoff of water or mud.*
e. *Remove waste materials that have a potential to produce dust from site as soon as reasonably practicable.*
f. *Cover, seed or fence stockpiles to prevent wind whipping.*
g. *Cutting/grinding/sawing equipment to use water as dust suppressant or suitable local extract ventilation.*
h. *Ensure an adequate water supply on the site for effective dust/particulate matter suppression, using recycled water where reasonably practicable.*
i. *Use enclosed chutes, conveyors and covered skips to reduce escape of dust.*
j. *Reduce drop heights from conveyors, loading shoves, hoppers and other loading or handling equipment to a practical minimum; and use fine water sprays on such equipment where appropriate.*

k. *Ensure equipment is readily available onsite to clean any spillages and clean up spillages as soon as the spill is identified.*
l. *Reuse and recycle waste to reduce dust from waste materials."*

The assessment of LSE is carried out in Section 6.2. The text explaining the reliance and efficacy of the good practice measures reads as follows.

Efficacy of good practice measures

Whilst no studies of the efficacy of the good practice measures are available in the literature to specifically demonstrate their effectiveness in preventing significant effects on nearby receptors, the measures have been developed over many years by the industry and there is very high confidence in their efficacy. The construction industry standards have been in place for many years and there has been no call or need for updating it in recent years, suggesting that they represent a mature and successful set of guidelines. There is no reason to suppose that measures that have proved successful on multiple projects in the past; protecting multiple habitat types and people without significant complaint; would not be equally successful at mitigating dust effects on European site habitats.

The effect in the Thames Estuary and Marshes Ramsar

Alone

"Good practice measures that reflect the construction dust risk, have been proposed to minimise the dust effects at receptors, as outlined in paragraphs 4.5.18 to 4.5.22 (this is the text within the assumptions section above). These measures are integral to the Project and are considered to be effective, at containing dust, when used at source and are defined in industry standards for use on construction sites, for example the "Environmental good practice on site guide (CIRIA C741)" (Charles & Edwards, 2015). The impact of construction dust is not expected to trigger a significant air quality effect because the measures reduce and avoid dust emissions at source, disrupting any pathway to effect. Therefore, the risk of LSE within the Thames Estuary and Marshes Ramsar is considered de minimis as a result of the Project alone.

In-combination

The pathway to effect has been disrupted at source therefore there cannot be a feasible risk of this effect acting in combination with other plans and projects and the Project itself has a nugatory de minimis effect so could not contribute to any in combination effect.

Therefore, a conclusion is reached of no LSE on the Thames Estuary and Marshes Ramsar due to construction dust as a result of the Project alone or in-combination with other plans and projects."

The effect on functionally linked land

Alone

"Good practice measures that reflect the construction dust risk, have been proposed to minimise the dust effects at receptors, as outlined in paragraphs 4.5.18 to 4.5.22 (note this is the text within the assumptions section above). These measures are integral to the Project and are considered to be effective, at containing dust, when used at source and are defined in industry standards for use on construction sites, for example the "Environmental good practice on site guide (CIRIA C741)" (Charles & Edwards, 2015). The impact of construction dust is not expected

to trigger a significant air quality effect because the measures reduce and avoid dust emissions at source, disrupting any pathway to effect. Therefore, the risk of LSE within the functionally linked land is considered de minimis as a result of the Project alone."

In-combination

"The pathway to effect has been disrupted at source therefore there cannot be a feasible risk of this effect acting in combination with other plans and projects and the Project itself has a de minimis effect so could not contribute to any in combination effect.

Therefore, a conclusion is reached of no LSE on the functionally linked land of the following European Sites due to construction dust as a result of the Project alone or in-combination with other plans and projects, namely:

a. Benfleet and Southend Marshes SPA and Ramsar

b. Medway Estuary and Marshes SPA and Ramsar

c. Thames Estuary and Marshes SPA and Ramsar

d. The Swale SPA and Ramsar"

Annex HH 09 March 2021 Technical Note - Operational Noise & Visual Disturbance

HRA Technical Note: Operational Noise and Visual Disturbance

Introduction

During the consultation meeting 3 Feb 2021, when reviewing the rationale for potential operational effects of the new road through the functionally linked land (FLL) north of the River Thames, NE suggested that given the provision of mitigation land adjacent to Coalhouse Fort it would be logical to consider the following effects at SIAA:

- Changes in noise and vibration – operation
- Changes in visual disturbance (vehicles in eyeline) – operation

This note has been produced to facilitate agreement on the HRA conclusions on operational noise and visual disturbance pathways in the SoCG prior to Natural England seeing the final resubmission draft of the Screening and Appropriate Assessment reports.

Background

At DCO 1.0 we concluded no LSE because of these changes, which was predicated on the assumption that the construction phase land take and disturbance of FLL that could conceivably be affected during operation resulted in it being not used for the entirety of the construction period. Therefore, use of the "re-provisioned" FLL by qualifying birds would be as a result of them "moving back" into the area affected by operational noise and visual disturbance and so would not perceive changes but consider it "the normal environment".

The conclusion of no LSE as a result of operational changes in noise and vibration has been agreed by NE for the following European sites:

- Benfleet and Southend SPA/Ramsar
- Medway Estuary and Marshes SPA/Ramsar
- Thames Estuary and Marshes SPA/Ramsar
- The Swale SPA/Ramsar

At DCO 1.0, the conclusion of no LSE as a result of operational changes in visual disturbance (vehicles in eyeline) has had been agreed by NE for the following European sites:

- Benfleet and Southend SPA/Ramsar

Since DCO 1.0, the conclusion of no LSE as a result of operational changes in visual disturbance (vehicles in eyeline) has been agreed by NE for the following European sites:

- Medway Estuary and Marshes SPA/Ramsar (30/09/2020)
- The Swale SPA/Ramsar (30/09/2020)
- Thames Estuary and Marshes SPA/Ramsar (19/02/2021)

NE had agreed all of the conclusions of no LSE based on the pre-submission draft of the DCO 1.0 Screening Report. However, following discussions in the NE consultation meeting 3 February (and in light of the comments received from PINS) indicated that the rationale associated with the no LSE conclusion was difficult to quantify and could be open to challenge.

In light of these discussions, we are amending some of the HRA assessment / conclusions to ensure that the HRA is definitively compliant with case law and the expectation of PINS. To that end, the operational noise and visual disturbance effects will be concluded as "LSE uncertain" in the screening report and will be assessed in more detail in the SIAA with the proposed rationale for concluding no AEoI described below.

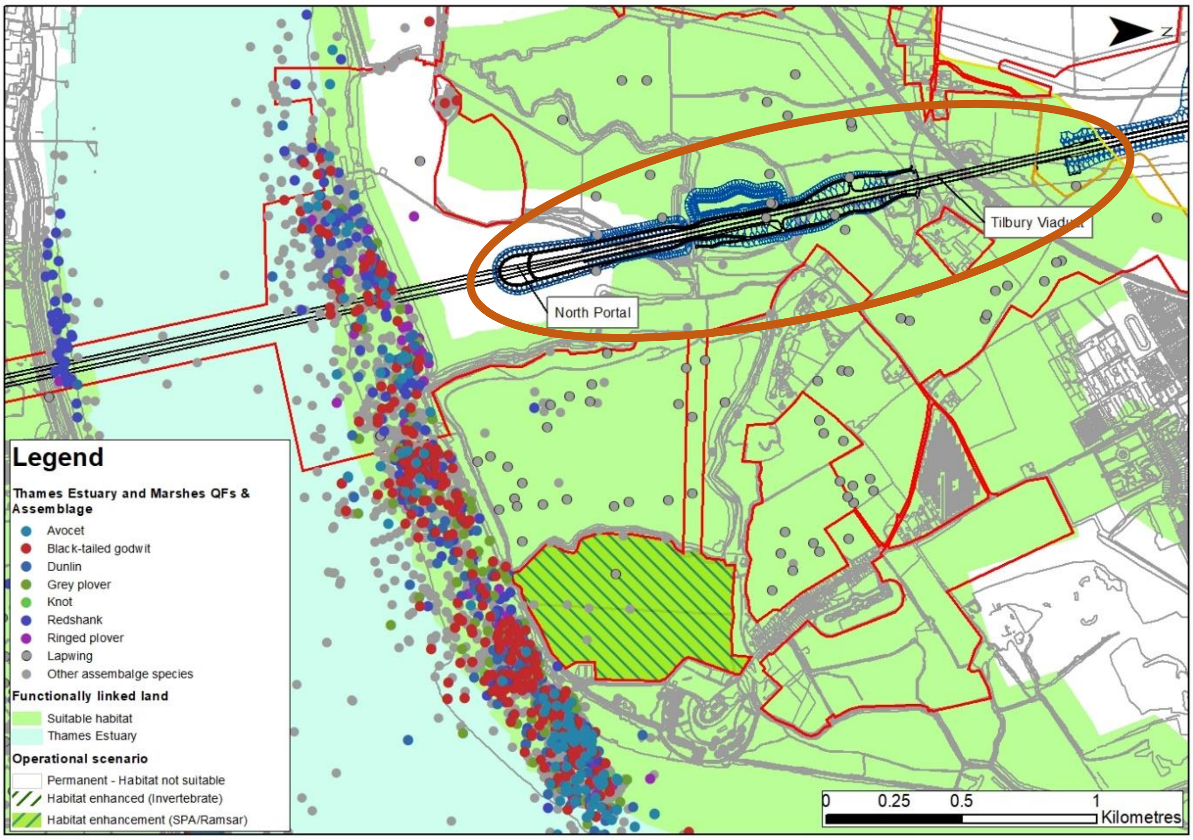
The list of issues within the HRA SoCG has been updated to change the screening conclusions from "no LSE" to "LSE uncertain" and new SIAA conclusions have been added accordingly with conclusions of No AEoI

Proposed rationale to be presented within the SIAA

Zone of influence

The potential pathway to effect for operational noise and vibration and visual (vehicles in eyeline) disturbance is limited to the habitat either side of the new road north of the River Thames between the north portal and the new Tilbury Viaduct. Figure 1 illustrates the area potentially affected by these changes.

Figure 1: Bird records within the FLL in the approx. operational zone of influence, as indicated by the orange line



Sites identified with potential LSE

FLL could be affected and is potentially associated with the following European sites (when the extent of sensitivity methodology for identifying FLL has been used in screening sites for consideration):

- Benfleet and Southend SPA/Ramsar
- Medway Estuary and Marshes SPA/Ramsar

- Thames Estuary and Marshes SPA/Ramsar
- The Swale SPA/Ramsar

It should be noted that using the more detailed method of identifying FLL used in the SIAA would only identify the Thames Estuary and Marshes SPA/Ramsar as having affected FLL.

Measures that reduce or avoid

Noise barriers (Acoustic barrier locations shown on sheet 17 and 20 in vol 2.5 general arrangement) are proposed on the Tilbury Viaduct as it crosses the Tilbury Rail Line and on the east side of the approach to the Viaduct from the north portal. These will reduce noise and avoid visual disturbance of birds using the FLL within 300m of the new road.

The embankment on the approach to Tilbury Viaduct would be planted (woodland) and would screen the road and reduce disturbance to birds in the long term, once the planting matures (within approx.10-15 years).

Any uncertainty of residual effects resulting in reduced bird use of that area of FLL is mitigated by provision of enhanced undisturbed habitat adjacent to Coalhouse Fort.

Figure 2 illustrates where the Project avoids visual disturbance, through being in cutting, provision of noise barriers and woodland planting, and reduces traffic noise through the provision of noise barriers.

Figure 2: Project design and mitigation measures that avoid/reduce disturbance effects

Assessment of no AEoI

The risk of birds being disturbed is limited to the areas where the road is on embankment and in these locations both the woodland planting and noise barriers are considered to reduce noise and visual stimuli. Therefore, the risk of significant disturbance in functionally linked land is considered to be avoided or reduced to the extent that no effect on the integrity of the associated European sites. The provision of the land adjacent to Coalhouse Fort means that the baseline of FLL is maintained permanently, further adding to the certainty that any detriment to the birds caused by operational disturbance would be avoided. Understanding the scale of risk of detrimental effects on the birds should also include that birds using the area are very small in number (less than 1% of the SPA population); and would in all likelihood either not perceive a change or will quickly become accustomed to the new “environment”. Therefore, the habitat will continue to act as FLL for the associated European sites and no AEOI is predicted to occur.

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