

AtkinsRéalis



# Gravesend Shaft Groundwater Risk Assessment

Ferrovial Construction - Bemo Joint Venture

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100116608

# TILBURY TO GRAIN TUNNEL

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## Client signoff

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# Contents

|                    |                                            |           |
|--------------------|--------------------------------------------|-----------|
| <b>1.</b>          | <b>Introduction.....</b>                   | <b>5</b>  |
| 1.1                | Background .....                           | 5         |
| 1.2                | Scope .....                                | 5         |
| 1.2.1              | Need for groundwater risk assessment ..... | 6         |
| 1.3                | Information sources.....                   | 6         |
| 1.4                | Assumptions and limitations .....          | 6         |
| <b>2.</b>          | <b>Site summary .....</b>                  | <b>8</b>  |
| 2.1                | Site location and description .....        | 8         |
| 2.2                | Proposed shaft .....                       | 9         |
| <b>3.</b>          | <b>Shaft environmental setting .....</b>   | <b>10</b> |
| 3.1                | Introduction .....                         | 10        |
| 3.2                | Ground conditions .....                    | 10        |
| 3.2.1              | Published geology .....                    | 10        |
| 3.2.2              | Ground investigation .....                 | 10        |
| 3.3                | Hydrogeology .....                         | 12        |
| 3.4                | Hydrology .....                            | 13        |
| 3.5                | Environmental sensitivity .....            | 13        |
| 3.6                | Land contamination.....                    | 13        |
| 3.6.1              | PID monitoring .....                       | 14        |
| 3.6.2              | Geo-environmental Sampling .....           | 14        |
| 3.6.3              | Human health risk assessment.....          | 14        |
| 3.6.4              | Ground gas risk assessment .....           | 14        |
| 3.6.5              | Groundwater risk assessment .....          | 14        |
| 3.6.6              | Ground aggressivity .....                  | 14        |
| <b>4.</b>          | <b>Site conceptual model .....</b>         | <b>15</b> |
| 4.1                | Sources .....                              | 15        |
| 4.2                | Receptors.....                             | 15        |
| 4.3                | Pathways.....                              | 15        |
| <b>5.</b>          | <b>Qualitative risk assessment .....</b>   | <b>17</b> |
| 5.1                | Conceptual Site Model .....                | 18        |
| <b>6.</b>          | <b>Summary and recommendations.....</b>    | <b>23</b> |
| 6.1                | Summary .....                              | 23        |
| 6.2                | Recommendations .....                      | 23        |
| <b>7.</b>          | <b>References .....</b>                    | <b>24</b> |
| <b>Appendix A.</b> | <b>Site Drawing.....</b>                   | <b>27</b> |
| <b>Appendix B.</b> | <b>Design drawings.....</b>                | <b>29</b> |



Tables

Table 3-1 – SOCOTEC GI encountered ground conditions ..... 12

Table 3-2 – SOCOTEC GI encountered groundwater levels ..... 13

Table 5-1 – Qualitative Risk Matrix..... 17

Table 5-2 – Risk Classifications ..... 17

Table 5-3 – Preliminary CSM..... 19



# 1. Introduction

## 1.1 Background

AtkinsRéalis UK Limited (AtkinsRéalis) has been commissioned by Ferrovial Construction and Bemo joint Venture (FBJV) (the client) to provide geo-environmental consultancy support for the proposed Tilbury Shaft (the site), associated with the Tilbury Grain Kingsnorth Upgrade Project (TKRE) (Grain to Tilbury) for National Grid.

As part of the design, a groundwater risk assessment (GWRA) is required to assess the potential impact to groundwater, and receptors receiving groundwater flow, from the completion of the Gravesend Shaft. The GWRA is required as part of the submission of a groundwater activity permit. This assessment was undertaken in line with Environment Agency 'groundwater risk assessment for your environmental permit' guidance [1].

The study area for this report is located approximately 150 m south of the Eastcourt Marshes Electricity Substation.

The structure of the report includes:

- Section 2: a summary of the site and proposed shaft works and methodology;
- Section 3: a summary of the environmental baseline conditions;
- Section 4: risk assessment summarising the potential risk from contaminants, if present in soils, to migrate to surface water and groundwater in the underlying aquifer from the proposed works;
- Section 5: conceptual site model (CSM) and risk assessment; and
- Section 6: the conclusion of the assessment.

## 1.2 Scope

The Gravesend Shaft is proposed to be completed via Vertical Shaft Machine (VSM). This will involve interaction with groundwater and, therefore, a GWRA has been completed to assess the associated potential risks to groundwater and receptors of groundwater flow, in relation to the proposed works.

The assessment has been carried out in accordance with Environment Agency (EA) guidance 'groundwater risk assessment for your environmental permit' guidance [1].

The guidance sets out a tiered approach to risk assessment that consists of:

- Tier 1 – qualitative risk screening – investigate what the risks are, whether more detailed assessment is needed and what that would need to focus on (risk prioritisation);
- Tier 2 – generic quantitative risk assessment – to collect more information so you can make an informed decision on the risk posed by the site; and
- Tier 3 – detailed quantitative risk assessment – to collect more information and formulate a plan if there are clear source-pathway-receptor relationships.

Prior to the risk screening exercise, a CSM was developed to detail potential source-pathway-receptor (SPR) relationships introduced by the proposed discharge.

The assessment detailed herein has been progressed to Tier 1 - qualitative risk screening, only. This report provides recommendations for further work, where required.



## 1.2.1 Need for groundwater risk assessment

The EA approach to groundwater protection [2] includes position statements on infrastructure projects. The position statements have been reviewed, and the following were considered potentially relevant:

- C2 – Non-nationally significant infrastructure schemes: the EA will normally only agree to proposals for infrastructure within Source Protection Zone (SPZ) 1 to 2 where they do not have the potential to cause pollution or harmful disturbance to groundwater flow, or where these risks can be reduced to an acceptable level; and,
- C5 – Pipelines and high voltage fluid filled cables: the EA will normally object to pipelines or fluid filled cables that transport pollutants, particularly hazardous substances that pass through SPZ1 or SPZ2 where this is avoidable, or are below the water table in principal or secondary aquifers.

The Tilbury Tunnel scheme is associated with a high voltage transmission cable as part of National Grid's high voltage transmission network. It is understood that cross-linked polyethylene (XLPE) cables will be used, which are not fluid filled [3]. Position statement C5, above, is therefore not relevant.

The site is being progressed through the planning process, and is therefore considered a non-nationally significant infrastructure scheme.

## 1.3 Information sources

A list of the key sources of information for the proposed scheme are as follows:

- AECOM, Environmental Statement Volume VI Appendix 13.1 Water Framework Directive Assessment (Revision 1), 2024 [4];
- Ferrovial Construction, RAMs - shaft sinking with VSM, 2025 [5];
- SOCOTEC, Ground Investigation Report (Factual), 2023 [6];
- BakerHicks, Geotechnical Interpretive Report, 2023 [7]; and
- AtkinsRéalis, Gravesend Shaft Piling Risk Assessment, 2025 [8].

## 1.4 Assumptions and limitations

This assessment has been carried out under current guidance and legislation, if these are revised in the future, then the assessment contained within this report may also need to be updated. This report does not advise on measures to manage risks associated with asbestos, where present. Detailed advice should be sought from a specialist contractor.

The findings, opinions and recommendations presented in this report are based on information obtained from a variety of third-party sources as detailed within this report. AtkinsRéalis has not independently verified third-party information and for the purposes of this assessment has assumed that such information is accurate and complete. Therefore, whilst this report and the opinions contained herein are accurate to the best of AtkinsRéalis' knowledge and belief, AtkinsRéalis cannot and does not guarantee the completeness, reliability or accuracy of the descriptions or conclusions based on supplied third-party information.

No responsibility can be accepted by AtkinsRéalis for the inaccuracies in the data supplied by any other party.



As with any physical ground investigation involving discrete sampling, test results will only be representative of the point sampled and further investigation and analysis may be required should ground conditions differ from those reported. Therefore, this report cannot guarantee against unexpected ground conditions occurring between the sampling points.

Constraints relating to geotechnical hazards, ecology, heritage, flooding/drainage, utilities, air quality and noise are beyond the remit of this report.

Ground gas and groundwater conditions are based on observations made at the time of the ground investigations and monitoring programmes, and may be subject to variation due to atmospheric, seasonal or other effects.

The report shall be read as one complete document. Sections (or figures/data/appendices) of the report cannot be used without full reference to other elements of the report and any previous works referenced within the report (and associated limitations).

The opinions given in this report are relevant only for the purpose for which the report was commissioned.



## 2. Site summary

### 2.1 Site location and description

The site is located in Gravesend, centred on approximate Ordnance Survey Grid Reference (OSGR) 567436, 174136. The site is part of the TKRE (Grain to Tilbury) Project for National Grid. The site is located to the south of the River Thames and comprises of Eastcourt Marshes Electricity Substation and area of land located south of substation and west of Milton Rifle Range.

The site dips with ground elevation across the site decreasing from approximately 6.0 (m) above ordnance datum (AOD) in the north to 2.0 m AOD in the south. A site layout plan is provided in Figure 2-1, extracted from GRR-FBJ-XX-GRRS4-DA-ZE-000002 (DRAFT), adapted, which presented in Appendix A.

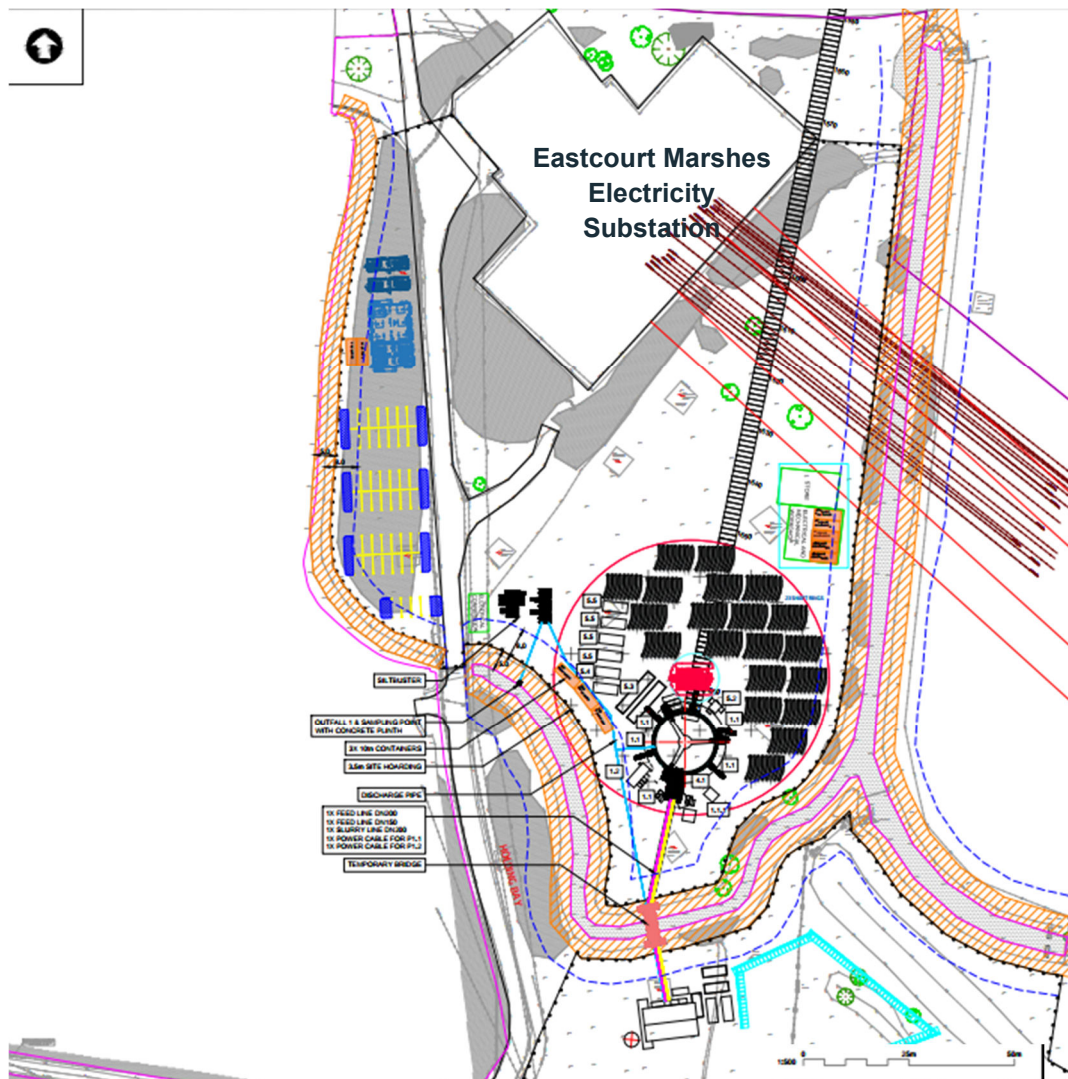


Figure 2-1 – Site layout plan

## 2.2 Proposed shaft

The development plans and pile design information are provided in Appendix B. The methodology for the VSM is presented in the VSM Risk Assessment Method Statement (RAMs) [5]. A high-level summary of the methodology is presented below.

The design comprises 35 cast in-situ concrete Continuous Flight Auger (CFA) piles of 750 millimetre (mm) diameter. The proposed lengths of the piles are 18.0 m which are likely to terminate near the base of the superficial deposits / top of the Chalk. These piles will be completed in a ring around the location of the shaft for geotechnical purposes.

Risk associated with the initial CFA piles have been assessed within a piling risk assessment [8] and so are not discussed further within this document, unless directly pertinent.

Once this initial activity is complete, assembly of the VSM will be undertaken, allowing the excavation of the shaft itself. The shaft will have a 15 m internal diameter, and approximate 39 m depth [5]. The VSM requires initial excavation and temporary dewatering to allow the assembly of the launching and capping beam (shaft collar). These two initial shaft rings would require an excavation 2.5 m deep. Following completion of the initial excavation and set up of the VSM, the inside of the shaft will be filled with water to match the natural water table, therefore no dewatering will be required during this process. The shaft is excavated/dropped into the ground surrounded by a curtain of bentonite suspension, used as lubrication.

Following completion of the shaft sinking to the proposed target depth, -44 m AOD, the VSM excavation machinery is removed, the base of the shaft sealed via concrete and the internal water pumped out. The bentonite surrounding the shaft is also replaced with a cementitious grout. Groundwater was encountered during the 2023 GI between 0.80 m below ground level (bgl) to 2.18 m bgl at the site.

## 3. Shaft environmental setting

### 3.1 Introduction

The information presented in this section has been collated from the environmental information, ground investigations, and other sources listed in the sources of information, unless otherwise specifically cited.

### 3.2 Ground conditions

#### 3.2.1 Published geology

British Geological Survey (BGS) mapping [9] indicates that the site is underlain by superficial deposits of Alluvium. The Alluvium is reported as consisting of soft to firm consolidated silty clay, which may contain layers of silt, sand, peat and gravel. The bedrock underlying the site is mapped as chalk of the Lewes Nodular Chalk Formation, Seaford Chalk Formation and Newhaven Chalk Formation. Made Ground is not mapped at the site but may be present, related to historical development at the site and adjacent sites. Made Ground is mapped to the north and south of the site.

#### 3.2.2 Ground investigation

Ground investigation (GI) at the site was completed by SOCOTEC in 2023 [6]. The GI comprised 3 boreholes, 10 trial pits, and 7 Cone Penetration Tests (CPT). The maximum depth of the investigation was 72.00 m bgl. A borehole location plan is presented in Figure 3-1. Following the GI, BakerHicks completed an interpretive report [7] on the SOCOTEC data as well as available historical data for the site.

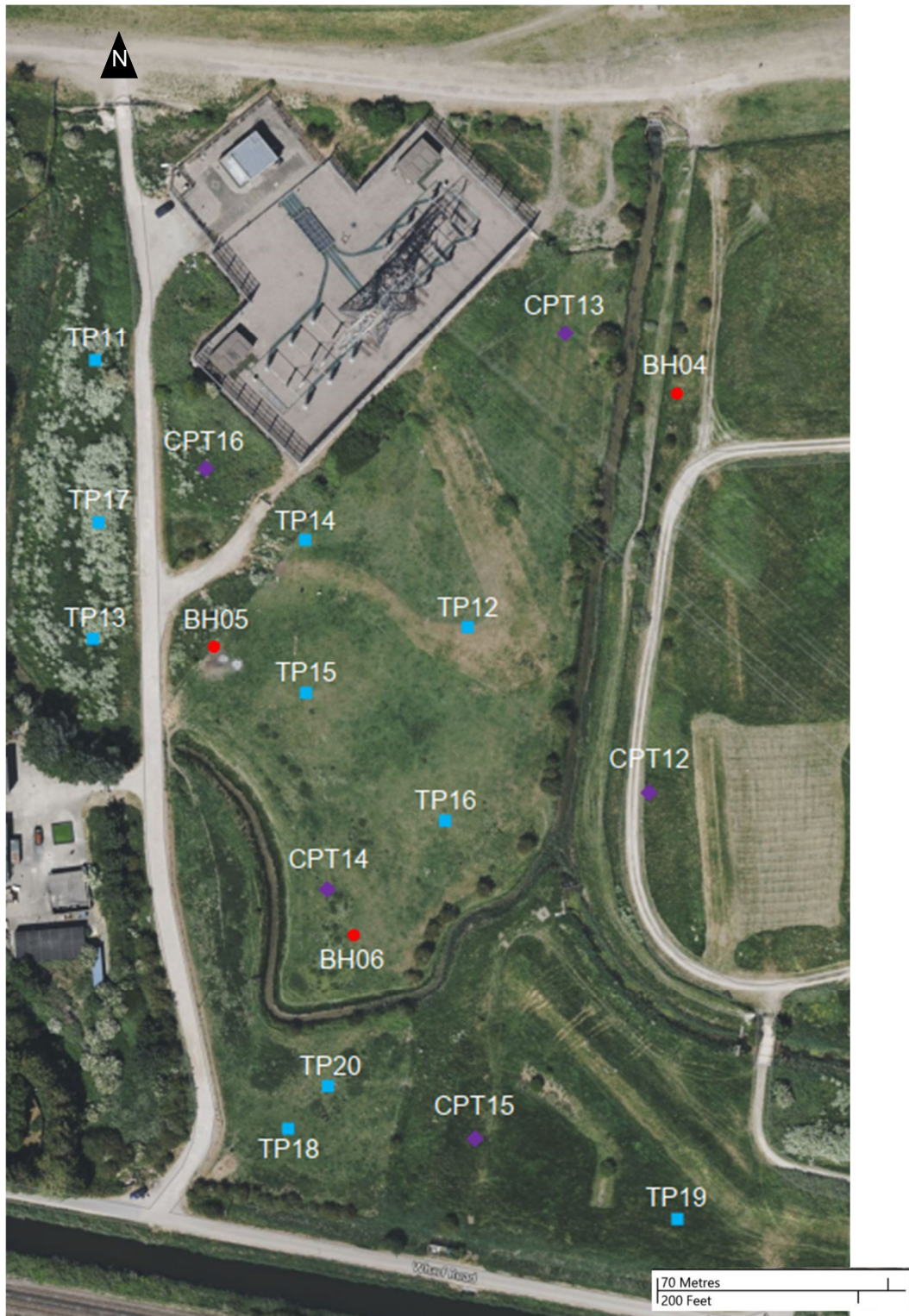


Figure 3-1 – SOCOTEC trail pit and borehole locations, extracted from SOCOTEC factual report [6].

The ground conditions identified during the SOCOTEC GI at the site as summarised in Table 3-1, below.

**Table 3-1 – SOCOTEC GI encountered ground conditions**

| Geology     | Strata                        | Elevation Range Encountered (mAOD) | Maximum Thickness (m) |
|-------------|-------------------------------|------------------------------------|-----------------------|
| -           | Topsoil                       | 0.00 to 0.50                       | 0.50                  |
| -           | Made Ground                   | 2.42 to -0.22                      | 2.30                  |
| Superficial | Alluvium                      | 2.10 to -14.40                     | 15.00                 |
|             | River Terrace Deposits        | -11.10 to -17.72                   | 6.00                  |
| Bedrock     | Seaford Chalk Formation       | -16.71 to -68.41                   | 51.70                 |
|             | Lewes Nodular Chalk Formation | -42.15, base unproven              | Unproven              |

Topsoil was identified as soft to firm, slightly sandy to gravelly clay with grass and occasional rootlets. Topsoil was identified at most locations across the site - BH04, BH06, CPT13, CPT14, CPT16 and all trial pits (TP11 to TP20).

Made Ground was identified in all SOCOTEC boreholes and was identified as orange, grey and bluish soft to firm, slightly sandy to gravelly sandy silt or clay. Alluvium was reported as soft to firm slightly sandy clayey silts with some fine to medium sand towards the base. Sand towards the base was described as brownish grey silt and dark orangish brown gravelly fine to medium sand with occasional sandy silty clay. Peat was reported in BH04 with a thickness of 0.98 m and was identified as plastic dark brown amorphous peat. River Terrace Deposits (RTD) were identified below the Alluvium in the three deep boreholes, reported as brown speckled black or brownish grey fine to coarse sand and subangular to subrounded fine to coarse gravel of flint.

Bedrock of Seaford Chalk Formation was identified in the three deep boreholes, reported as between 1.30 m and 3.00 m of structureless chalk, recovered as sandy gravelly clay or sandy silty gravel, over 27.9 m to 48.7 m of CIRIA grade B4 to A1 structured chalk described as extremely weak to weak medium density chalk. Some fracture sets were reported in the structured chalk. Bedrock of Lewes Nodular Chalk Formation was identified below the Seaford Chalk Formation in boreholes BH04, BH05 and BH06. The Lewes Nodular Chalk Formation was reported as very weak to weak medium density white chalk, CIRIA grade A2 to fractureless with frequent black nodular flint. No notable layers of flint were reported.

### 3.3 Hydrogeology

The superficial RTD and Alluvium are classified as a secondary A aquifer. The Seaford Chalk Formation and Lewes Nodular Chalk Formation are classified by the Environment Agency as principal aquifers.

Online information [10] indicates that there are no groundwater source protection zones (SPZ) on or within 500 m of the site.

The SOCOTEC 2023 investigation installed monitoring boreholes at locations BH04, BH05 and BH06. The boreholes were installed with dual installs in superficial and bedrock geology. No groundwater strikes were reported due to the use of water flush during drilling.



The reported groundwater monitoring results from the SOCOTEC GI at the site as summarised in Table 3-2, below.

**Table 3-2 – SOCOTEC GI encountered groundwater levels**

| Borehole ID | Base of borehole (m bgl) | Response zone depth range (m bgl) | Response zone strata    | Groundwater level range (m bgl / m AOD) |
|-------------|--------------------------|-----------------------------------|-------------------------|-----------------------------------------|
| BH04        | 48.00                    | 15.00 to 16.00                    | Alluvium                | 1.33 to 2.07 /<br>0.87 to 0.13          |
|             |                          | 42.00 to 44.00                    | Seaford Chalk Formation | 1.76 to 2.18 /<br>0.44 to 0.02          |
| BH05        | 68.02                    | 16.00 to 19.00                    | RTD                     | 0.81 to 1.87 /<br>1.67 to 0.61          |
|             |                          | 50.00 to 53.00                    | Seaford Chalk Formation | 0.80 to 1.96 /<br>1.68 to 0.52          |
| BH06        | 69.51                    | 5.00 to 7.50                      | Alluvium                | 1.05 to 1.30 /<br>1.44 to 1.19          |
|             |                          | 34.50 to 27.50                    | Seaford Chalk Formation | 1.09 to 1.66 /<br>1.40 to 0.83          |

The groundwater elevation data suggests that the superficial and bedrock aquifers are in hydraulic continuity.

## 3.4 Hydrology

The estuarine River Thames is located approximately 50 m to the north, flowing in an easterly direction. A number of drainage ditches are present adjacent and in the vicinity of the site however these are understood not to directly connect to the River Thames [4].

## 3.5 Environmental sensitivity

Online information [10] indicates presence of RAMSAR sites and Sites of Special Scientific Interest (SSSI) approximately 50 m to the south of the site and 450 m to the east of the site. There is also a Special Protection Areas (SPA) located approximately 600 m to the north-east of the site. There are no Special Areas of Conservation (SAC), or Local Nature Reserves (LNR) present within 1 km of the site.

## 3.6 Land contamination

Data from the 2023 SOCOTEC GI was assessed by BakerHicks and reported in their Interpretive Report [7]. The report presented human health, ground gas and controlled waters risk assessments on available data from the 2023 GI at the site.



### 3.6.1 PID monitoring

Photo-ionisation detector (PID) headspace testing was undertaken on 64no. samples across the site. All reported values were between 0.1 to 0.3 ppm. No visual or olfactory evidence of contamination were reported at the site.

### 3.6.2 Geo-environmental Sampling

SOCOTEC completed geo-environmental sampling which included 12 soil samples and three groundwater samples [6].

### 3.6.3 Human health risk assessment

The BakerHicks report completed a human health assessment on available site data (34 samples). No exceedances of selected screening criteria were reported.

### 3.6.4 Ground gas risk assessment

The BakerHicks report discussed ground gas at the site and reported that monitoring identified elevated ground gas levels for methane, carbon monoxide and carbon dioxide. It was also noted that the data collected did not represent an assessment of the Made Ground materials. A theoretical high risk was reported and it was noted that migration of gas off-site through preferential pathways (underground services, trenches, pipelines) is possible and appropriate mitigation measures for asphyxiation or explosion in below ground excavations should be implemented. The reported high risk was specifically associated with the data gap and lack of representative data from Made Ground.

### 3.6.5 Groundwater risk assessment

The BakerHicks report completed a controlled waters risk assessment on the three groundwater samples collected during the GI. Samples were screened against Environmental Quality Standards (EQS) and Drinking Water Standards (DWS). Screening of the available data reported exceeding concentrations of chloride (3,200 mg/l, DWS+EQS 250 mg/l), boron (1.99 mg/l, DWS of 1.99 mg/l) and arsenic (0.014 mg/l, DWS of 0.01 mg/l) above DWS. Additionally, chromium (0.002 mg/l, EQS of 0.0006 mg/l), zinc (0.017 mg/l, EQS of 0.0079 mg/l) and fluoranthene (0.01 µg/l, EQS of 0.0063) was detected above EQS. The identified exceedances of chloride, maximum concentration 3200 mg/l, was inferred to be related to the proximity of the site to the estuarine River Thames. The majority of the rest of the concentrations were marginal exceedances above the criteria.

The BakerHicks report states that no soil-leachate laboratory analysis was completed during the GI and so no soil-leachate data was available for screening.

The BakerHicks report concluded that the potential leaching and downward migration of contaminants represented an active pollutant linkage at the site. Based on the screening undertaken, BakerHicks reported that the superficial deposits and chalk were likely to be in hydraulic continuity. Overall, BakerHicks assessed the risk from leaching of contaminants into groundwater as moderate/low. Recommendations comprised monitoring of groundwater during the works to ensure no deterioration of quality, appropriate treatment and/or disposal of any water derived from dewatering activities alongside an environmental watching brief during the works.

### 3.6.6 Ground aggressivity

Ground aggressivity was also assessed in the 2023 BakerHicks report, reported as design sulphate (DS) class 2 and ACEC (AC) class 2 for the Alluvium, and DS-1 and AC-1 for Made Ground, RTD, Seaford Chalk Formation and Lewes Nodular Chalk Formation.



## 4. Site conceptual model

Land contamination is evaluated through the identification and assessment of SPR contaminant linkages, and the risk is assessed in accordance with recent guidance [11]. A CSM has been developed based on the available information, including the 2023 BakerHicks interpretive report [7], to enable the assessment of the potential sources of contamination. The CSM has been developed to specifically assess SPR contaminant linkages relating to the proposed works to construct Gravesend Shaft (as per Section 2.2), with a focus on risks to groundwater related receptors such as groundwater aquifers and recipients of groundwater flow.

The CSM describes the relationship between the sources of contamination and receptors to the potential contamination. As part of the CSM development, three elements are identified and assessed:

- Sources of contamination and contaminants interacting with or derived from the proposed construction works;
- Groundwater receptors of contamination, including groundwater aquifers and recipients of groundwater flow; and
- Pathways between the sources and receptors.

The following section presents the preliminary CSM pertaining to groundwater, and receptors receiving groundwater flow, for the site.

### 4.1 Sources

The following sources of contamination were identified at site, or identified as part of the construction methodology:

- **S1:** Potentially contaminated Made Ground across the site;
- **S2:** Bentonite lubrication surrounding the shaft;
- **S3:** Cementitious grout surrounding the final shaft;
- **S4:** Water within the shaft, poured into the shaft prior to advancing the VSM to control groundwater levels; and
- **S5:** Potentially contaminated groundwater at the site, from on and off-site sources (including substation and historical rifle range).

Due to the historical land use in the area, it is considered likely that contaminants derived from off-site sources may be present in the groundwater.

### 4.2 Receptors

The identified receptors are as follows:

- **R1:** Secondary aquifers – Alluvium (secondary undifferentiated aquifer), and RTD (secondary A aquifer);
- **R2:** Principal aquifers – Lewes Nodular Chalk Formation and Seaford Chalk Formation; and
- **R3:** Surface Waters (drainage ditches to east, south and west and River Thames to the north).

### 4.3 Pathways

The following pathways have been identified:



- **P1:** Leaching/dissolution from contaminated soil;
- **P2:** Vertical migration within the unsaturated zone and groundwater;
- **P3:** Horizontal migration within the aquifer; and
- **P4:** Migration via surface water/drainage.



## 5. Qualitative risk assessment

Table 5-1 below provides the qualitative risk matrix, based on CIRIA guidance [12], in which the likelihood or probability of each contaminant linkage being realised is ranked against the severity of the consequences. The result is the relative risk classification, the results of which can inform the due diligence process and allow prioritisation of any further assessments or the implementation of risk management measures.

**Table 5-1 – Qualitative Risk Matrix**

| Risk Matrix                        |                 | Severity of Consequence |                   |                   |                   |
|------------------------------------|-----------------|-------------------------|-------------------|-------------------|-------------------|
|                                    |                 | Severe                  | Medium            | Mild              | Minor             |
| Probability of Contaminant linkage | High Likelihood | Very High Risk          | High Risk         | Moderate Risk     | Moderate/Low Risk |
|                                    | Likely          | High Risk               | Moderate Risk     | Moderate/Low Risk | Low Risk          |
|                                    | Low Likelihood  | Moderate Risk           | Moderate/Low Risk | Low Risk          | Very Low Risk     |
|                                    | Unlikely        | Moderate/Low Risk       | Low Risk          | Very Low Risk     | Very Low Risk     |

Definitions of the risk classifications presented in the guidance are given in Table 5-2 below.

**Table 5-2 – Risk Classifications**

| Risk Classification | Definition                                                                                                                                                                                                                                             |
|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Very High Risk      | There is a high probability that severe harm could arise to a designated receptor from an identified source, or there is evidence that severe harm to a designated receptor is currently happening.                                                    |
| High Risk           | Harm is likely to arise to a designated receptor from an identified source.                                                                                                                                                                            |
| Moderate Risk       | It is possible that harm could arise to a designated receptor from an identified source. However, it is relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild. |
| Low Risk            | It is possible that harm could arise to a designated receptor from an identified source, but it is likely that this harm, if realised, would at worst normally be mild.                                                                                |
| Very Low Risk       | There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe.                                                                                                                |

The individual sources, pathways and receptors identified in previous sections are judged against this risk matrix and professional judgement has been used to estimate the combination of probability of a contaminant linkage being realised and the consequence of the harm that might result in line with CIRIA C552 [12]. Details of the potential contaminant linkages and associated risks are recorded in Table 5-2.



## 5.1 Conceptual Site Model

Based on the sources identified, a CSM with associated risk is shown below in Table 5-3 to understand the potential contaminant linkages.

Furthermore, it has been identified that groundwater will be temporarily dewatered during the initial excavation required for the assembly of the launching and capping beam [5]. Shallow groundwater has been identified on site, although the excavation will only be to 2.5 m bgl, and temporary. The dewatering will be within Made Ground and Alluvium which has a low permeability. Therefore, there will be a negligible impact to groundwater levels and flow. Water pumped out during the temporary dewatering will be treated and discharged in line with relevant assessments and legislation.

The steady state radius of influence from the proposed dewatering is calculated to be approximately 20.0 m from the edge of the excavation. This assumes dewatering to approximately 1.0 m below the required excavation (2.5 m in depth), for a conservative total of 3.0 m of drawdown, and a conservative hydraulic conductivity of the Made Ground of  $5.0\text{E-}06$  metres per second (m/s) [7]. Given the heterogenous nature of the shallow geology at the site, the proposed duration of the dewatering for excavation and conductivity of the strata, it is considered unlikely that the radius of influence will reach this distance within the time that dewatering is occurring.

Further review of the proposed dewatering is presented in the Dewatering Technical Note [13].



**Table 5-3 – Preliminary CSM**

| Source Description                                     | Pathway                                                                                                      | Receptor                                                                                | Consequence | Likelihood     | Risk Category      | Comment/mitigation                                                                                                                                                                                                                      |
|--------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------|----------------|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>S1:</b> Made Ground across the site                 | <b>P1 and P2:</b> Leaching/ dissolution from contaminated soil followed by vertical migration to groundwater | <b>R1:</b> Secondary undifferentiated aquifer – Alluvium, and secondary A aquifer - RTD | Mild        | Likely         | Moderate/ Low Risk | Leaching of contaminants identified within Made Ground, which will be exposed temporarily during initial excavations. Vertical migration of contaminants to underlying shallow groundwater.                                             |
|                                                        |                                                                                                              | <b>R2:</b> Principal aquifer – Chalk*                                                   | Mild        | Likely         | Moderate/ Low Risk | Strata expected to be in hydraulic continuity [7] and so completion of piling and VSM activities is expected to result in a reduction of migration in groundwater in the vicinity of the shaft due to the lower hydraulic conductivity. |
|                                                        | <b>P3:</b> Horizontal migration within the aquifer                                                           | <b>R3:</b> Surface Waters                                                               | Mild        | Low likelihood | Low Risk           | Lateral migration of contaminants within the underlying aquifer, providing baseflow to surface waters. Drainage ditches not in direct contact to River Thames. River Thames 50 m north of site.                                         |
| <b>S2:</b> Bentonite lubrication surrounding the shaft | <b>P2:</b> Vertical migration within unsaturated zone and groundwater                                        | <b>R1:</b> Secondary undifferentiated aquifer – Alluvium, and secondary A aquifer - RTD | Medium      | Unlikely       | Low Risk           | Potential loss of bentonite lubrication surrounding the shaft during shaft progression, and transport within the underlying aquifer. Bentonite is not classified as a hazardous substance [14]. Use of practicable low slump            |
|                                                        |                                                                                                              | <b>R2:</b> Principal aquifer – Chalk*                                                   | Medium      | Unlikely       | Low Risk           |                                                                                                                                                                                                                                         |



| Source Description                                  | Pathway                                                               | Receptor                                                                                | Consequence | Likelihood | Risk Category | Comment/mitigation                                                                                                                                                                                                                                                                                                 |
|-----------------------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------|-------------|------------|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                     | <b>P3:</b> Horizontal migration within the aquifer                    | <b>R1:</b> Secondary undifferentiated aquifer – Alluvium, and secondary A aquifer - RTD | Medium      | Unlikely   | Low Risk      | bentonite to reduce likelihood of migration. Lubrication pumping rates and total volumes used should be monitored to provide an early indication of potential loss/migration.                                                                                                                                      |
|                                                     |                                                                       | <b>R2:</b> Principal aquifer – Chalk*                                                   | Medium      | Unlikely   | Low Risk      |                                                                                                                                                                                                                                                                                                                    |
| <b>S3:</b> Cementitious grout surrounding the shaft | <b>P2:</b> Vertical migration within unsaturated zone and groundwater | <b>R1:</b> Secondary undifferentiated aquifer – Alluvium, and secondary A aquifer - RTD | Medium      | Unlikely   | Low Risk      | Potential loss of cementitious grout injected when excavation is complete, and transport within the underlying aquifer. Use of practicable low slump grout to reduce likelihood of migration. Pumping rates and total volumes used should be monitored to provide an early indication of potential loss/migration. |
|                                                     |                                                                       | <b>R2:</b> Principal aquifer – Chalk*                                                   | Medium      | Unlikely   | Low Risk      |                                                                                                                                                                                                                                                                                                                    |
|                                                     | <b>P3:</b> Horizontal migration within the aquifer                    | <b>R1:</b> Secondary undifferentiated aquifer – Alluvium, and secondary A aquifer - RTD | Medium      | Unlikely   | Low Risk      |                                                                                                                                                                                                                                                                                                                    |
|                                                     |                                                                       | <b>R2:</b> Principal aquifer – Chalk*                                                   | Medium      | Unlikely   | Low Risk      |                                                                                                                                                                                                                                                                                                                    |
| <b>S4:</b> Water within the shaft                   | <b>P2:</b> Vertical migration within unsaturated zone and groundwater | <b>R1:</b> Secondary undifferentiated aquifer – Alluvium, and secondary A aquifer - RTD | Minor       | Likely     | Low Risk      | Water poured into the shaft is to comply with the EQS and DWS, and therefore not contain harmful or hazardous substances. Groundwater will mix with water within the shaft. Migration of this water into and within                                                                                                |
|                                                     |                                                                       | <b>R2:</b> Principal aquifer – Chalk*                                                   | Minor       | Likely     | Low Risk      |                                                                                                                                                                                                                                                                                                                    |



| Source Description                     | Pathway                                            | Receptor                              | Consequence | Likelihood | Risk Category | Comment/mitigation                                                                                                                                                                                                                                                                                    |
|----------------------------------------|----------------------------------------------------|---------------------------------------|-------------|------------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                        | <b>P3:</b> Horizontal migration within the aquifer | <b>R3:</b> Surface Waters             | Minor       | Likely     | Low Risk      | the underlying aquifer will be limited by balancing internal and external water levels, reducing the differential water pressure at the base of the shaft. Once the cementitious grout is cured/base of shaft is in place, the groundwater and the interior of the shaft are no longer in continuity. |
| <b>S5:</b> Groundwater on and off site | <b>P3:</b> Horizontal migration within the aquifer | <b>R2:</b> Principal aquifer – Chalk* | Medium      | Likely     | Moderate      | Lateral migration of groundwater within the underlying aquifer, providing baseflow to surface waters.                                                                                                                                                                                                 |
|                                        |                                                    | <b>R3:</b> Surface Waters             | Medium      | Likely     | Moderate      |                                                                                                                                                                                                                                                                                                       |



| Source Description | Pathway                                         | Receptor                  | Consequence | Likelihood | Risk Category | Comment/mitigation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|--------------------|-------------------------------------------------|---------------------------|-------------|------------|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                    | <b>P4:</b> Migration via surface water/drainage | <b>R3:</b> Surface Waters | Medium      | Unlikely   | Low Risk      | <p>The shaft should have limited impact on groundwater.</p> <p>Changes to the groundwater regime around the shaft will be minimal. Temporary dewatering will have negligible impact on the shallow groundwater at the site and is unlikely to draw in potential contamination from outside of the site (maximum 20.0 m area of influence from edge of excavation). The impact of the VSM will be limited by balancing internal and external water levels, reducing the differential water pressure at the base of the shaft.</p> <p>Management of spoil to reduce likelihood of potential runoff will manage risk of migration via surface water and drainage.</p> |

\* Lewes Nodular Chalk Formation and Seaford Chalk Formation



## 6. Summary and recommendations

### 6.1 Summary

The GWRA undertaken has determined that the construction of Gravesend shaft using VSM poses a low to moderate risk to the superficial alluvium aquifer, Seaford Chalk Formation and Lewes Nodular Chalk Formation principal aquifers, and surface waters (the River Thames). Potential contamination sources include Made Ground on site, groundwater, bentonite lubrication and cementitious grout surrounding the shaft and water in the shaft during the works.

The low to moderate risk are associated with Made Ground and groundwater present on site, and the potential increased risk of mobilising contamination during works.

The use of bentonite lubrication and the cementitious grout surrounding the shaft is not expected to migrate significantly within the aquifer, with an overall low risk. Use of low slump bentonite lubrication and cementitious grout is recommended to further reduce the likelihood of migration. The proposed fissure grouting of the chalk will reduce the likely migration of bentonite and grout. Pumping rates and total volumes used should be monitored during works to provide an early indication of potential migration.

The water poured into the shaft during the works shall comply with DWS and EQS, and therefore will not contain substances which could pose a contamination risk to receptors, resulting in a low risk. Migration of this water into and within the underlying aquifer will be limited by balancing internal and external water levels, reducing the differential water pressure at the base of the shaft.

Shallow groundwater will also be temporarily dewatered during the initial excavation to 2.5 m bgl. The excavation will be temporary, resulting in a negligible impact to groundwater levels and flow.

Considering the limited risks identified, further assessment is not deemed necessary.

### 6.2 Recommendations

The following recommendations should be followed during the proposed works:

- Contractors are to be made aware of potential for contamination to be present in Made Ground, across the entire site. Take a 'watching brief' approach. Monitor the composition of arisings. Seek advice if contaminated material encountered. Implement appropriate health and safety measures (e.g. use of personal protection equipment).
- Risks to groundwater and surface water are to be managed through the measures outlined within the Construction Environmental Management Plan (CEMP);
- All arisings shall be removed from the site. The arisings shall be appropriately classified and treated/disposed off-site at a suitable waste management facility under an appropriate duty of care. If arisings are to be re-used on site, then they must be assessed appropriately and re-use done under a relevant materials management plan or permit; and
- Further recommendations associated with the proposed piling are present within the piling risk assessment [8].



## 7. References

- [1] Environment Agency, "Groundwater risk assessment for your environmental permit," 03 04 2018. [Online]. Available: <https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit>.
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- [5] Ferrovial Construction, RAMS - Shaft sinking with VSM, 2025.
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- [9] British Geological Survey, "Geoindex (Onshore)," 2025. [Online]. Available: [https://mapapps2.bgs.ac.uk/geoindex/home.html?\\_ga=2.110293255.307195702.1709628913-1519560593.1709628912](https://mapapps2.bgs.ac.uk/geoindex/home.html?_ga=2.110293255.307195702.1709628913-1519560593.1709628912). [Accessed 05 2025].
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- [12] Construction Industry Research and Information Association (CIRIA), "Contaminated Land Risk Assessment: A guide to good practice (C552)," 2001.
- [13] AtkinsRéalis, "Tilbury to Grain Tunnel, Tilbury and Gravesend Flow Rate Technical Note, 100116608\_DewateringTN\_P01," 2025.
- [14] Joint Agencies Groundwater Directive Advisory Group, "Appendix 3 Confirmed List I and List II Substances," Water Framework Directive UK TAG, [Online]. Available: <https://www.wfduk.org/sites/default/files/Media/Substances%20transferred%20from%20List%20I%20%26%20II%20to%20hazardous%20or%20non%20hazardous.pdf>. [Accessed 04 02 2023].



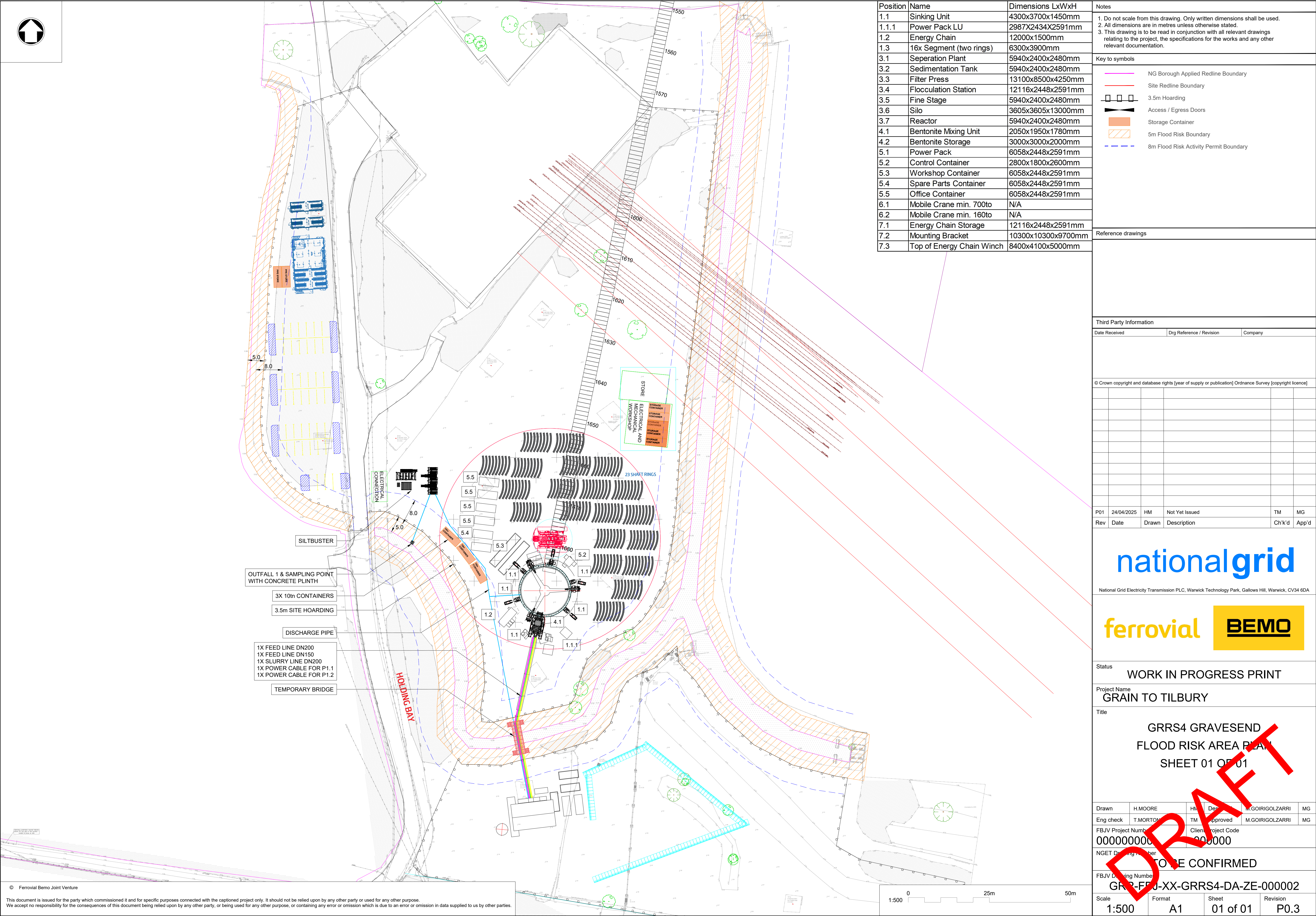


# APPENDICES



# Appendix A. Site Drawing





| Position | Name                      | Dimensions LxWxH   |
|----------|---------------------------|--------------------|
| 1.1      | Sinking Unit              | 4300x3700x1450mm   |
| 1.1.1    | Power Pack LU             | 2987X2434X2591mm   |
| 1.2      | Energy Chain              | 12000x1500mm       |
| 1.3      | 16x Segment (two rings)   | 6300x3900mm        |
| 3.1      | Seperation Plant          | 5940x2400x2480mm   |
| 3.2      | Sedimentation Tank        | 5940x2400x2480mm   |
| 3.3      | Filter Press              | 13100x8500x4250mm  |
| 3.4      | Flocculation Station      | 12116x2448x2591mm  |
| 3.5      | Fine Stage                | 5940x2400x2480mm   |
| 3.6      | Silo                      | 3605x3605x13000mm  |
| 3.7      | Reactor                   | 5940x2400x2480mm   |
| 4.1      | Bentonite Mixing Unit     | 2050x1950x1780mm   |
| 4.2      | Bentonite Storage         | 3000x3000x2000mm   |
| 5.1      | Power Pack                | 6058x2448x2591mm   |
| 5.2      | Control Container         | 2800x1800x2600mm   |
| 5.3      | Workshop Container        | 6058x2448x2591mm   |
| 5.4      | Spare Parts Container     | 6058x2448x2591mm   |
| 5.5      | Office Container          | 6058x2448x2591mm   |
| 6.1      | Mobile Crane min. 700to   | N/A                |
| 6.2      | Mobile Crane min. 160to   | N/A                |
| 7.1      | Energy Chain Storage      | 12116x2448x2591mm  |
| 7.2      | Mounting Bracket          | 10300x10300x9700mm |
| 7.3      | Top of Energy Chain Winch | 8400x4100x5000mm   |

Notes

1. Do not scale from this drawing. Only written dimensions shall be used.

2. All dimensions are in metres unless otherwise stated.

3. This drawing is to be read in conjunction with all relevant drawings relating to the project, the specifications for the works and any other relevant documentation.

| Key to symbols |                                        |
|----------------|----------------------------------------|
|                | NG Borough Applied Redline Boundary    |
|                | Site Redline Boundary                  |
|                | 3.5m Hoarding                          |
|                | Access / Egress Doors                  |
|                | Storage Container                      |
|                | 5m Flood Risk Boundary                 |
|                | 8m Flood Risk Activity Permit Boundary |

Reference drawings

| Third Party Information |                          |         |
|-------------------------|--------------------------|---------|
| Date Received           | Drg Reference / Revision | Company |

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|     |            |       |                |        |       |
|-----|------------|-------|----------------|--------|-------|
| P01 | 24/04/2025 | HM    | Not Yet Issued | TM     | MG    |
| Rev | Date       | Drawn | Description    | Ch'k'd | App'd |

National Grid Electricity Transmission PLC, Warwick Technology Park, Gallows Hill, Warwick, CV34 6DA

Status

WORK IN PROGRESS PRINT

Project Name

GRAIN TO TILBURY

Title

GRRS4 GRAVESEND  
FLOOD RISK AREA PLAN  
SHEET 01 OF 01

|                     |                               |          |          |                 |    |
|---------------------|-------------------------------|----------|----------|-----------------|----|
| Drawn               | H.MOORE                       | HM       | Des      | M.GOIRIGOLZARRI | MG |
| Eng check           | T.MORTON                      | TM       | approved | M.GOIRIGOLZARRI | MG |
| FBJV Project Number | Client Project Code           |          |          |                 |    |
| 000000000           | 000000                        |          |          |                 |    |
| NGET Drawing Number | TO BE CONFIRMED               |          |          |                 |    |
| FBJV Drawing Number | GRR-FBV-XX-GRRS4-DA-ZE-000002 |          |          |                 |    |
| Scale               | Format                        | Sheet    |          | Revision        |    |
| 1:500               | A1                            | 01 of 01 |          | P0.3            |    |

# Appendix B. Design drawings

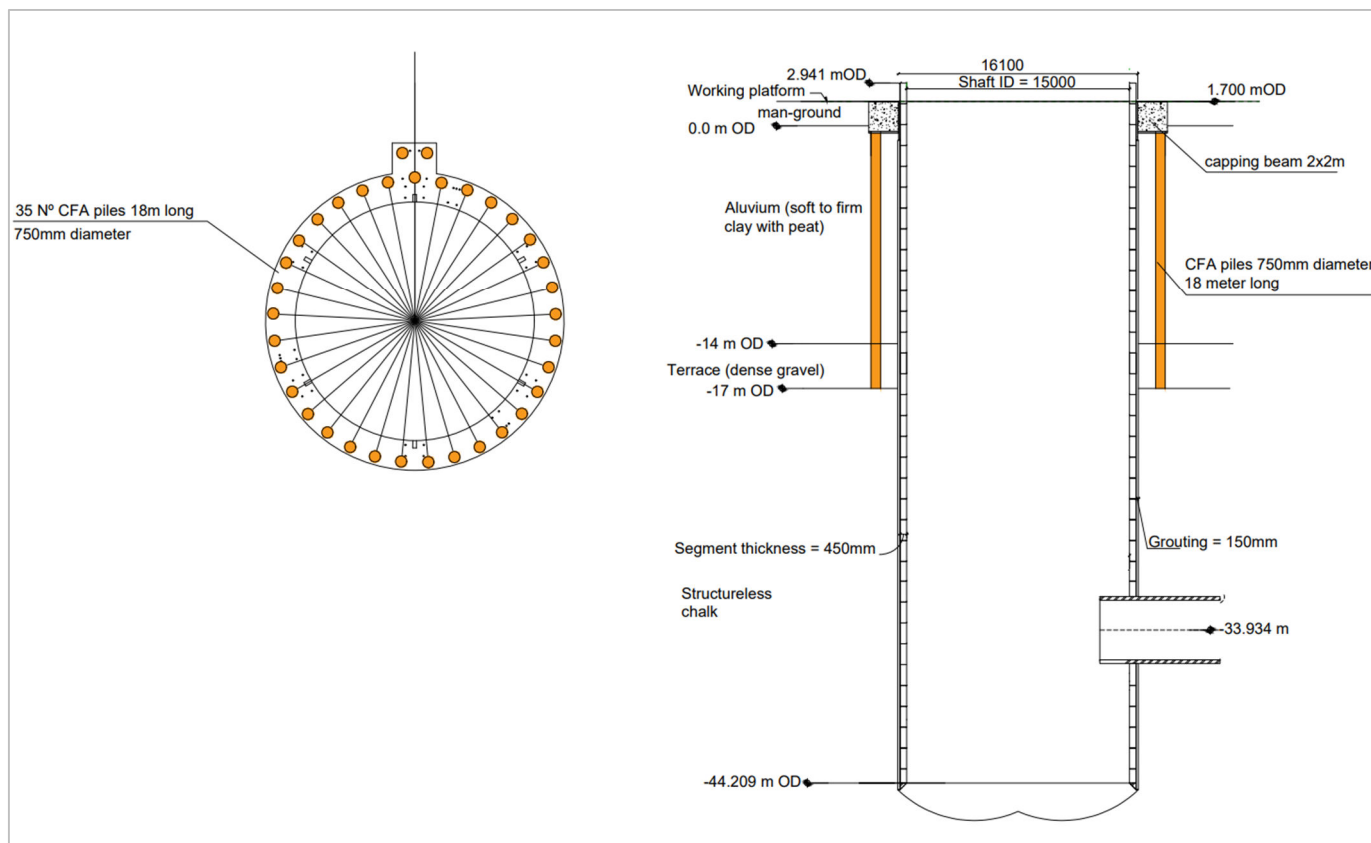


Figure B-1 – VSM Development and pile design drawing

AtkinsRéalis

