# Hampshire Water Transfer and Water Recycling Project

## Outline Foundation Works Risk Assessment – 2 of 3 documents

## Proposed Water Recycling Plant and Trenchless Crossing to Budds Farm WTW Shaft Site


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WATER for LIFE

from Southern Water

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## Introduction

Southern Water Servies Limited (the Applicant) has commissioned this Outline Foundation Works Risk Assessment (Outline FWRA) to support the application for a Development Consent Order (DCO) for the construction of a new Water Recycling Plant (WRP) and water supply infrastructure. The purpose of the Project is to address the sustainability objectives of reduced abstractions on Hampshire's two main rivers – the River Test and the River Itchen - and ensure a resilient water supply for the Applicant's customers.

This Outline Foundation Works Risk Assessment (FWRA) is for the proposed Water Recycling Plant (WRP) piled foundations, associated launch shafts within the WRP site, a reception shaft at Budds Farm Wastewater Treatment Works (WTW) and the trenchless crossing between the WRP and Budds Farm Shaft.

The objective of the Outline FWRA is to demonstrate that the proposed foundation, shaft and trenchless crossing construction would not have an adverse impact by creating new pathways for the migration of contamination, considering the protection of water resources and human health. This assessment has been carried out in accordance with guidance published in March 2025, "Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution Prevention".

## Settings and Conditions

The WRP site is located on part of a former landfill which was created by enclosing an area of former estuary within a bund wall. The landfill was infilled between approximately 1969 and 1987 with domestic, commercial and industrial-type wastes. The Budds Farm shaft site is located in an area of historical landfill, formed by infilling of former WTW sludge pits. Neither landfill appears to benefit from an engineered impermeable liner or cap, with the waste materials being covered by a limited thickness of final cover soils. Both landfills therefore are understood to operate on the 'dilute and disperse' principle whereby contaminated leachate generated within the landfill can migrate out of the landfill and into the surrounding water environment. Beneath the landfill waste the natural ground conditions comprise Alluvium, Raised Marine Deposits and Tidal Flat Deposits (clay, silt, sand and gravel), which are in turn underlain by chalk bedrock.

The assessments undertaken have shown that during construction and in the proposed commercial / industrial end use scenario at the WRP site, the potential hazards to human health associated with the soils are limited to asbestos and to a much lesser extent, polycyclic aromatic hydrocarbons (PAHs). Potential hazards to human health associated with the soils at the Budds Farm Shaft site have not been identified.

The ground gas risk assessments undertaken have shown that the WRP site should be classified as Characteristic Situation (CS) 3, requiring ground gas mitigation for enclosed structures. The Budds Farm Shaft site should be classified as CS1, meaning that mitigation against ground gas ingress would not be required in new enclosed structures.

The assessment of potential hazards to aquatic ecology has identified potential hazards associated with leaching of metals, PAHs and ammoniacal nitrogen from the landfill waste masses at both the WRP site and the Budds Farm Shaft site into the shallow groundwater within the superficial deposits, the deeper groundwater in the chalk Principal Aquifer, and the adjacent Hermitage Stream. The potential for mobilisation of contamination and the creation of potential preferential pathways by which contamination could migrate is central to the Outline FWRA assessment process.

## Outline Foundation Works Risk Assessment

The seven pollution scenarios defined in the CL:AIRE, 2025 guidance have been assessed, as follows:

- Scenario 1 - Creation of preferential pathways, through a low permeability layer, to cause contamination of groundwater in an aquifer:
  - Piled Foundations – The risk has been assessed as Low based on the limited presence of low permeability layers beneath the landfill material, and the use of bored, cast in-situ Continuous Flight Auger (CFA) piles.
  - The risk has been assessed as Moderate on the basis of the limited presence of low permeability layers beneath the landfill material, and a shaft construction methodology that uses a deep soil mixing and a cast in-situ diaphragm wall.
  - Trenchless crossing – Not applicable. The trenchless crossing is to be constructed at depth entirely within the natural geology and therefore would not encounter solid contaminants.
- Scenario 2 - The driving of solid contaminants down into an aquifer during pile driving:
  - Piled Foundations – Not applicable, CFA piles are bored and therefore would not push soil down during pile installation.
  - Shafts – The risk has been assessed as Low on the basis that the shaft excavation will utilise a grab excavator, which extracts solid waste and brings it to the surface and does not push material downwards.
  - Trenchless crossing – Not applicable. The trenchless crossing is to be constructed at depth entirely within the natural geology and therefore would not encounter solid contaminants.
- Scenario 3 - Contamination of groundwater and subsequently surface waters by turbidity, support fluids, concrete, cement paste or grout:

  - Piled Foundations - The risks of increased turbidity, increased pH and increased chloride concentrations have been assessed as Moderate within the aquifers and Low within Langstone Harbour.

  - Shafts and trenchless crossing - The risks of increased turbidity, increased pH and increased chloride concentrations have been assessed as Moderate within the aquifers and Low within Langstone Harbour. The risk of fissure grout dispersal within the aquifers is assessed as Low, on the basis of use of a suitable grout mix and control of grout pressure and injection rate. The risk of bentonite support fluid break out is assessed as Moderate both within the aquifers and Langstone Harbour for the shafts, and Moderate within the aquifers and Low in Langstone Harbour for the trenchless crossing.

- Scenario 4 - Direct contact with contaminated soil or leachate causing degradation of pile materials:

  - Piled Foundations, shafts and trenchless crossing – The risk has been assessed as Low based on the conditions recorded during the ground investigations and use of an appropriate concrete design.

- Scenario 5 - Creation of preferential pathways to allow migration of landfill gas or contaminant vapours to surface:

  - Piled Foundations and shafts – The risk has been assessed as Low as the assessment undertaken has shown that construction of piled foundations and shafts does not alter the existing gassing regime whereby gases are expected to vent to atmosphere through the cover soils.

  - Trenchless crossing – Not applicable. The trenchless crossing is to be constructed at depth entirely within the natural geology and therefore would not encounter solid contaminants.

- Scenario 6 - Causing off-site migration of ground gas or increased vertical emissions as a result of vibration or other effects from the pile installation process:

  - Piled Foundations – Not applicable. CFA piles are a replacement-type pile and the CL:AIRE guidance states that "*replacement piling methods will not cause disturbance of the ground sufficient to cause off site migration of gas*".

  - Shafts - Not applicable. The shafts, like the CFA piles, are a replacement (i.e., not a displacement) technique and the associated ground improvement (deep soil mixing) is designed to densify the ground, resulting in a reduction in pore spaces and reduced permeability, meaning that gases are less able to migrate.

    - Trenchless crossing – Not applicable. The trenchless crossing is to be constructed at depth entirely within the natural geology and therefore would not encounter solid contaminants.

- Scenario 7 - Direct contact with contaminated soil arisings that have been brought to the surface:
  - Piled Foundations and Shafts – The risk has been assessed as Moderate given the assessed risks to human health associated with the on-site soils. Use of appropriate, good practice mitigation during construction will reduce this to Low.
  - Trenchless crossing – Not applicable. The trenchless crossing is to be constructed at depth entirely within the natural geology and therefore would not encounter solid contaminants.

## Mitigation Measures

Mitigation is embedded within the design and construction strategy and is assumed to include:

- Use of a Construction Environmental Management Plan (CEMP) to provide measures during the construction phase, such as the use of personal protective equipment, dust control measures and controls to prevent the release of new contamination.
- Management of construction wastes, including pile and shaft arisings.
- Suitable design of the Project, including the use of cast in-situ, replacement (vs. displacement) construction methodologies for the piled foundations and shafts, minimising penetration of piles into the chalk, specification of appropriate concrete classes to resist chemical attack and to limit bleeding into pore spaces, design of grout and fissure grouting methodology to limit excess dispersal through the chalk, etc.
- Use of an appropriate construction methodology developed by the Contractor to mitigate and remediate bentonite break outs.
- An Outline Water Monitoring Plan (ES Appendix 19.9 Outline Water Monitoring Plan, Volume II (Document reference 6.2, DCO Volume 6)) to identify significant changes in groundwater levels/ contamination levels in key locations during construction, and a Contingency Plan.

Overall, this assessment shows that with appropriate selection of piling, shaft construction and trenchless crossing techniques and associated control measures the potential risks associated with the construction of these elements of the Project are typically Low to Moderate. Given that the landfills operate on the 'dilute and disperse' principle, where migration of leachate out of the landfill into the surrounding groundwater is the expected behaviour, Moderate risks are not considered to represent an increased risk relative to the existing scenario.

The Outline FWRA demonstrates that technical solutions are feasible with mitigation measures that are protective of land quality and ground conditions receptors. The development of the Outline FWRAs follows an iterative process, which is dependent on detailed design and therefore the mitigation measures discussed in this Outline FWRA are subject to change.

The assessment is not intended to prescribe a definitive foundation design, nor to preclude alternative technical solutions. Instead, it demonstrates that a viable engineering solution is achievable in principle, subject to detailed design development and appropriate specification at the construction stage.

# 1 Introduction

## 1.1 Preamble

1.1.1 Southern Water Servies Limited (the Applicant) has commissioned this Outline Foundation Works Risk Assessment (Outline FWRA) to support the application for a Development Consent Order (DCO) for the construction of a new Water Recycling Plant (WRP) and water supply infrastructure. The purpose of the Project is to address the sustainability objectives of reduced abstractions on Hampshire's two main rivers – the River Test and the River Itchen - and ensure a resilient water supply for the Applicant's customers.

## 1.2 Assessment context

1.2.1 The purpose of this Outline FWRA is to demonstrate that the proposed foundation, shaft and trenchless crossing construction methods associated with the proposed WRP, associated shafts (including at Budds Farm Wastewater Treatment Works (WTW)) and trenchless crossings would not have an adverse impact by creating new pathways for the migration of contamination, considering the protection of both water resources and human health.

1.2.2 This Outline FWRA version has been produced in light of guidance published by CL:AIRE in March 2025, "*Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution Prevention"* [1].

1.2.3 The assessment is not intended to prescribe a definitive foundation design, nor to preclude alternative technical solutions. Instead, it demonstrates that a viable engineering solution is achievable in principle, subject to detailed design development and appropriate specification at the construction stage.

1.2.4 The information presented within this document is based upon an iterative design process, integrating available ground investigation data, conceptual site model development, and engineering judgement at the time of reporting.

1.2.5 It is acknowledged that foundation type, depth, geometry, and construction methodology would be dependent upon the detailed structural design chosen by the contractor.

1.2.6 This Outline FWRA is a dynamic documenting process which following additional site investigation data and detailed foundation design would be revised through the various stages of the Project.

## 1.3 Description of the project

1.3.1 The Project comprises the construction, operation and maintenance of the following components:

- WRP and associated pumping stations.
- Pipelines between Budds Farm WTW and the WRP site.

- Pipelines between the WRP site and Bedhampton Springs, connecting to pipelines being delivered by Portsmouth Water between Bedhampton Springs and Havant Thicket Reservoir.
- Pipeline between the WRP site and Otterbourne Water Supply Works (WSW).
- Above Ground Plant (AGP) comprising Intermediate Pumping Stations (IPS) and Break Pressure Tanks (BPT) located along the Pipeline between the WRP site and Otterbourne WSW.

1.3.2 The Project would also comprise the use of the following infrastructure:

- Havant Thicket Reservoir (which has been consented separately by Portsmouth Water and is currently under construction) for the storage of recycled water.
- The existing Eastney Long Sea Outfall (LSO), Eastney Pumping Station, and associated Eastney Transfer Tunnel for the release of reject water from the WRP site.
- Pipelines and other related works (which have been consented separately by Portsmouth Water) for the transfer of recycled water and source water between Bedhampton Springs and Havant Thicket Reservoir.

1.3.3 The construction and operation of the Project would be supported by other temporary and permanent works.

1.3.4 The Project will require the demolition, disassembly and/or temporary relocation of a number of small structures.

1.3.5 A detailed description of the Project can be found in Environmental Statement (ES) Chapter 3 Description of the Proposed Development, Volume I (Document reference 6.1, DCO Volume 6). The Application Glossary (Document reference 1.7, DCO Volume 1) sets out the abbreviations and definitions used in the DCO application for the Project.

## 1.4 Scope of work

1.4.1 The proposed WRP site is located approximately 1.4 km south-west of the centre of Havant and approximately 300 m west of Budds Farm Wastewater Treatment Works (WTW) and may be located by National Grid Reference (NGR) 470140E, 105670N. The current layout of the WRP site is shown on **Figure 1**. The land where the Budds Farm Shaft is to be constructed is referred to as “the Budds Farm Shaft site” and may be located by NGR 470645E, 105236N (**Figure 2**).

1.4.2 This report presents a summary description of the ground conditions and geoenvironmental conditions across the WRP site and the Budds Farm Shaft site and should be read in conjunction with the Geo-environmental Interpretative Report [2] for the proposed WRP site and Geo-environmental Interpretative Report [3] for the Budds Farm Shaft site.

1.4.3 This Outline FWRA relates solely to elements of the Project relating to the proposed WRP, including:

- New piled foundations at the WRP.

- The South Shaft – a launch shaft at the WRP for the Budds Farm trenchless crossing.
- The East Shaft - a launch shaft at the WRP for the Bedhampton Springs trenchless crossing (final route to be confirmed).
- The West Shaft – a launch shaft at the WRP for the Purbrook trenchless crossing.
- The Budds Farm Shaft – a reception shaft at Budds Farm WTW.
- Trenchless crossing between the Budds Farm Shaft and the WRP South Shaft.

1.4.4 Outline FWRAs for the elements not listed above are provided under separate cover (Document Reference 7.4, DCO Volume 7).

## 1.5 Limitations

1.5.1 This assessment is based upon information available at the DCO submission stage. Detailed design would be undertaken post-DCO consent, and this assessment should therefore be updated to a Detailed Foundation Works Risk Assessment by the contractor.

1.5.2 This report draws upon information presented in other studies prepared as part of submissions to support the ES submitted as part of the DCO application. Where referenced, the reports presenting this information should be read in conjunction with this report.

1.5.3 This document should be read as part of the wider ground risk and design information package and is not a substitute for detailed structural design, contractor-led method statements, or project-specific risk assessments required at later stages post-DCO consent.

# 2 Site setting

The text within this section is summarised in the Geoenvironmental Interpretative Report [4] and the Desk Study Report both contained within ES Appendix 11.2 Geotechnical and geo-environmental reports, Volume II (Document reference 6.2, DCO Volume 6), which should be read in conjunction with this Outline FWRA, and contains the Envirocheck Report and other drawings, documents, consultations etc. referenced throughout this section.

## 2.1 Site history – proposed WRP site

### Pre-Landfilling – Pre 1900s to 1960s

2.1.1 The earliest map available within the Envirocheck Report, dated 1866, indicates that the proposed WRP site comprised undeveloped marshy ground crossed by the Hermitage Stream.

2.1.2 Historical aerial photography available through Historic England's archives dated 1946 and 1948 ( [5] [6] [7] shows that the land within approximately 40 m of the proposed WRP site's northern boundary appears to be higher-lying and in use for agriculture. Historical mapping records that the western-most 100 m of the WRP site appears to be vegetated and crossed by streams and is labelled as "Broad Marsh". The remainder of the land within the WRP site appears to comprise marshland and the channel of the Hermitage Stream.

### Landfill construction and waste deposition – 1960s to 1980s

2.1.3 Planning application 14239/G proposed to develop the WRP site through the construction of a "*controlled refuse tip to level of surrounding area, with topsoil cove*r". The date of this application is unclear as the quality of the scanned document provided by HBC was limited and it was not possible to read all the information but appears to have been approved in April 1962, subject to conditions.

2.1.4 Planning permission HWU.14239/3G, dated September 1968 granted permission for "*use of land at Storehouse Lake, Bedhampton, as a controlled tip, quay, slip-way and dinghy park and construction of a channel diversion and road*". A 'red-line' plan showing the extent of this permission is not provided, however it is likely to apply to the area recorded by the EA as an historical landfill. Drawings submitted with this application show the location of a proposed bund wall, channel re-alignment works, proposed access road and indicate areas of "*level to be raised by controlled tipping*" (appears to be the higher-lying land in the west of the WRP site) and "*area to be reclaimed by controlled tipping*" (appears to be the lower lying coastal marshland).

2.1.5 Limited information relating to the landfill activities allowed by the planning permission is available within the Schedule of Conditions to the planning permission, as follows:

- "Refuse shall be tipped in layers not exceeding 6 ft. in depth.
- "All refuse exposed to the air shall be covered each day with at least 9 ins. of earth or other suitable inert material capable of forming an effective seal.

- “Deposits mainly of animal or fish waste shall be covered forthwith with at least 2 ft. of earth or other suitable inert material capable of forming an effective seal”.
- “No substance shall be deposited on the land other than the following: i) Soil, chalk, sand, gravel, hardcore and other earth spoil; ii) Trade refuse and domestic refuse.
- “No phenolic waste shall be deposited on the site without the prior consent of the Local Planning Authority”.

2.1.6 As described in [4], it appears that the bund was constructed with a sheet-piled wall on the seaward (southern / eastern) edge.

2.1.7 The EA has stated [4] that “the site is also recorded as being a dilute and disperse facility, so any engineering is likely to be minimal”.

2.1.8 Historical aerial photographs available through Cambridge University’s Air Photos Archive [8], [9], [10] taken on an unknown date show the progression of construction and filling of the landfill. Pertinent details shown on these photos include:

- Harts Farm Way has been constructed on an embankment along the WRP site’s southern boundary and a further haul/access road is present on an embankment approximately 60 m west of the edge of the new channel (extending northwards from what is now a small layby on Harts Farm Way near the south-eastern corner of the WRP site).
- The land in the western half of the WRP site appears to be reworked and potentially partially infilled.
- The land in the eastern half of the WRP site between the haul road embankment to the east, the Harts Farm Way embankment to the south and the higher lying/reworked/filled land to the west appears to have been reworked/filled to a lesser extent. The former channel of the Hermitage Stream appears to have been partially infilled in the WRP site’s north-eastern corner, and a possible culvert beneath Harts Farm Way is noted.
- To the south of Harts Farm Way and to the north of the bund, the former channel of the Hermitage Stream remains, and appears to contain water. A possible culvert/outfall in the bund wall at the southern end of the former channel is noted.
- The EA has stated [4] that “the site was infilled (or deposited as land raise) between around 1969 and 1987” and “the site is known to have taken household waste, as was as some commercial/industrial waste”. [11] states that wastes included “concrete waste, construction and demolition waste, household waste and incinerator residue”. A Local Authority incinerator being present approximately 200 m to the east, in the location of the present-day household waste recycling centre. Further aerial photos [12], [13] date unknown, show the filling in the western half of the WRP site to have been completed and this area to be grassed/vegetated whilst filling activities in the eastern half of the WRP site appear to be ongoing. The land

to the south of the WRP site appears to also have been infilled, with the former stream channel no longer visible.

*Landfill permit context*

2.1.9 As described in [4] the EA, Havant Borough Council (HBC) and Hampshire County Council (HCC) have been consulted to establish the context of the WRP site in relation to extant Waste Management Licences (WMLs) or Environmental Permits (EPs).

2.1.10 The EA has stated that "*Given that it ceased active operation in 1987, I don't think it was ever licenced/permitted by the Environment Agency, and was probably regulated by Hampshire County Council. As such I don't think we would have any waste licencing/permit files*".

2.1.11 The information provided by HBC does not indicate that a WML was issued, or if one was it does not appear to ever have been converted to an EP.

2.1.12 In relation to historical environmental management of the WRP site, HCC has stated "*The EA are correct to say that the site was never licensed or permitted by themselves and any activity from the mid-1970s would have been Licenced by the County Council (under the old Control of Pollution Act I think). However, that part of the County Council, the Waste Regulation Section, actually became the Environment Agency in 1996 (along with the old National Rivers Authority and HM Inspectorate of Pollution) and they took responsibility for the regulation and licencing/permitting of waste activities, and, consequently, took all the relevant files with them. From a Planning perspective this site has now been completed for such a long time that there are no outstanding planning requirements. In terms of Licences, as the EA commented there was no modern Permit for the site so no modern conditions or surrender requirements, so again I do not think there will be any outstanding matters*".

2.1.13 On this basis, it is considered that there is not an extant EP for the WRP site,

2.1.14 It is noted that [1] states "*this guidance is not applicable where a landfill operator, developer or landowner proposes to penetrate through the capping layer, base or sidewalls of a permitted landfill, where complex engineered lining systems are present including geomembranes and drainage layers*". Given the absence of an extant EP, it is considered appropriate to apply the CL:AIRE, 2025 guidance.

### Post-Landfilling – 1990s to present

2.1.15 Historical mapping dated 1987 and 1998 records the hard-surfaced area in the centre of the WRP site. The land in the west of the WRP site appears to be approximately level and is labelled as "Playing Field".

2.1.16 Planning permission 98/54097/2/HBC granted permission for "*Land raising by one metre*". Historical aerial imagery dated 1999 (available through Google Earth) appears to show these land-raising works being undertaken in the western half of the WRP site. These works were shown to be complete by the next photograph dated 2004.

2.1.17 The historical imagery dated 2005 shows vegetation cleared from the western half of the WRP site including the trees around the boundaries. Alterations to the junction between Harts Farm Way and the A27 are shown on the 2007 historical imagery, the south-western quadrant of the WRP site appears to have been used for stockpiling and as a construction compound.

2.1.18 Historical aerial imagery dated 2011 shows that the ground cover across the WRP site to be similar to the pre-2005 condition, with the exception of a limited area immediately west of the access road in the centre of the parcel. Cabins and vehicles can be seen on this image. During 2022 trees and vegetation were cleared from around the hard-surfaced area in the centre of the WRP site, from a triangular area to the north of the hard-surfaced area, and in the north-eastern corner of the WRP site. The proposed WRP site is shown in its existing configuration.

## 2.2 Site history – Budds Farm shaft site

2.2.1 The earliest map available within the Envirocheck Report, dated 1866, indicates that the land in the vicinity of the Budds Farm Shaft site comprised undeveloped marshy ground and areas of open water (Brockhampton Mill Lake). The land between the Budds Farm Shaft and the South Shaft was similarly marshy ground / open water.

2.2.2 Mapping dated 1939 records an area of refuse tip approximately 200 m to the south-east of the proposed Budds Farm Shaft location.

2.2.3 Historical aerial imagery dated 1960 [14] shows Budds Farm WTW to have been constructed, the image also records that the landfill to the south-east had been extended northwards, to approximately 130 m south of the Budds Farm Shaft site, with further landfilling taking place in an approximately 40 m wide strip parallel to the coastline, terminating immediately west of the proposed shaft location. It is noted that this land is recorded by the EA as an historical landfill named “Land South of Budds Farm Sewage Works” and is indicated to have received “household" wastes.

2.2.4 Mapping dated 1968 and 1974 and historical aerial imagery dated 1973 [15] record the existing coastline profile and shows the land to the west of the Budds Farm Shaft to be in use as a ‘sludge pit’ associated with Budd’s Farm WTW. Further ‘sludge pits’ are present in the surrounding area and an “L-shaped” mound is present immediately north of the proposed shaft. The ‘sludge pits’ appears to be formed by perimeter bunds, rather than being a ‘pit’ dug into the ground. The Hermitage Stream is also shown to have been re-aligned to its existing location.

2.2.5 Contemporary LIDAR imagery [16] indicates that the ‘sludge pits’ to the immediate west of the Budds Farm Shaft were not completely infilled, with the depressions of the former pits remaining visible. The LIDAR imagery indicates that further placement of material occurred to the north of the proposed shaft location, the shaft itself appears to be located on/adjacent to the fringe of the former landfill. Contemporary aerial imagery available within Google Earth shows the outline of the former ‘sludge pits’, which remain disused and overgrown.

## 2.3 Geology & ground conditions

### Published geology

2.3.1 The British Geological Survey (BGS) geological map of the area (BGS Sheet 316 – Fareham, Solid and Drift, 1998) [17] and the online GeoIndex Onshore Viewer [18] have been reviewed. A summary of the geological maps is discussed in this section.

*Artificial ground*

2.3.2 BGS mapping [17] [18] indicates that Made Ground is present across the entirety of the WRP site. This is consistent with the historical review and environmental searches, which indicate that the WRP site is located within an historical (now restored) landfill.

2.3.3 BGS does not record artificial ground in the area of the Budds Farm Shaft. An area of historical landfill located approximately 130 m to the south-east of the proposed shaft location is marked as such. BGS mapping [17] [18] indicates that Made Ground is present across the entirety of the WRP site. This is consistent with the historical review and environmental searches, which indicate that the WRP site is located within an historical (now restored) landfill.

*Superficial deposits*

2.3.4 The BGS indicate that the whole of the WRP site is underlain by Raised Marine Deposits, described by the BGS as "*Gravel (shingle), sand, silt and clay; commonly charged with organic debris (plant and shell).*" The area shown as underlain by these deposits is coincident with the area within the bund constructed in the 1960s (section 2.1).

2.3.5 Beneath the Raised Marine Deposits within the WRP site and to the south of the WRP site (including within the channel of the Hermitage Stream) the land is shown to be underlain by Tidal Flat Deposits, described by the BGS as "*commonly silt and clay with sand and gravel layers*."

2.3.6 The land immediately east of the WRP site, and the land in the vicinity of the Budds Farm Shaft site is shown to be underlain by Alluvium, described by the BGS as "*Normally soft to firm consolidated, compressible silty clay, but can contain layers of silt, sand, peat and basal gravel*". The Alluvium itself overlies the Tidal Flat Deposits.

2.3.7 The land immediately north of the WRP site is shown to be underlain by River Terrace Deposits described by the BGS as "*Sand and gravel, locally with lenses of silt, clay or peat*."

*Solid geology*

2.3.8 The WRP site, the land in the vicinity of the Budds Farm Shaft site, and the channel of the Hermitage Stream are shown to be underlain (beneath the overlying superficial deposits) entirely by the undifferentiated chalk deposits of the White Chalk Subgroup, described by the BGS as "*chalk with flints. With discrete marl seams, nodular chalk, sponge-rich and flint seams throughout*."

### Encountered ground conditions

2.3.9 The ground conditions at the WRP site, as encountered by the ground investigations undertaken at the WRP site to date are described in detail in the Geo-Environmental Interpretative Report [4] and are summarised in this section. The exploratory hole location plans from earlier ground investigations [11]are reproduced in the Figures (**Figures 3 and 4**) section.

2.3.10 The results of the ground investigations undertaken indicate that different types of waste have been deposited in different areas of the WRP site. Wastes of a more 'commercial' type appear to have been deposited in the west of the WRP site and wastes of a more 'domestic' type appear to have been deposited in the eastern half of the WRP site. For ease of reference these areas of waste deposition shall be referred to as the west cell and the east cell, noting that these 'cells' are not lined and do not appear to have an engineered cap. It is unknown if there is any structure (e.g., a bund) separating the western cell from the eastern cell in the centre of the WRP site.

*WRP site – West 'Cell'*

2.3.11 A summary of the ground conditions encountered in the west 'cell' is presented in Table 2-1.

**Table 2-1 Summary of ground conditions encountered – West 'Cell'**

| Stratum | Depth to Top (m bgl) | Depth to Bottom (m bgl) | Thickness (m) | Typical Description |
|---|---|---|---|---|
| Cover Soils | Ground Level | 1.3 to 3.5. Typically, between 2.0 and 3.0. | 1.5 to 3.5 | A limited thickness of TOPSOIL, overlying:<br><br>Soft to firm, light grey to dark grey to brown slightly sandy to sandy variably gravelly CLAY with a low cobble content. Gravel is fine to coarse, subrounded to angular of brick, concrete, sandstone, chalk, limestone, and flint, rarely with pieces of plastic and clinker. Cobbles are brick and concrete. Occasional organic odour. |
| Landfill Waste | 1.3 to 3.5 | 8.2 to 11.5 (Where full thickness proved) | 4.7 to 9.0 (Where full thickness proved) | Landfill waste comprising glass, paper, wood, plastic, metal, brick, concrete, occasional fabric, rubber, ceramics, ash, and sponge and rarely carpet and steel in a matrix of very soft to soft, black slightly sandy, slightly gravelly clay or grey silty sand. Tyres recorded in TP105 and TP106. Matrix proportion varies from 95% to 10%. 'Waste' odour commonly recorded, occasional hydrocarbon odour. |
| Alluvium | 8.2 to 10.7 | 9.7 to 11.1 (Where full thickness proved) | 0.4 to 3.5 (Where full thickness proved) | Encountered in RO101, RO107, CP02A, CP04 only. Soft to very soft brown and mottled grey, occasionally gravelly SILT. Gravel is subangular to rounded, fine to medium of chalk. |
| River Terrace / Raised Marine Deposits | 5.5 to 11.5 | 11.1 to 14.0 (Where full thickness proved) | 1.6 to 3.3 (Where full thickness proved) | Encountered in RO102, RO103, RO108 and CP01 only.<br>Yellowish-brown to orangish-brown, sandy to slightly sandy and occasionally slightly clayey angular to subangular fine to medium GRAVEL of flint. |
| Lewes Nodular Chalk Formation | 11.1 to 13.0 | Proved to a maximum of 35.0 in CP01 and CPO2A | Proved to a maximum of 22.0 in CP01 and CP02A | Encountered in all exploratory holes where the full thickness of superficial deposits was proved. Recovered as gravel or silt of cream to white, very weak to weak, low to medium density structureless CHALK. With occasional fine to coarse subrounded |

| Stratum | Depth to Top (m bgl) | Depth to Bottom (m bgl) | Thickness (m) | Typical Description |
|---|---|---|---|---|
| | | | | flints. Typically grades Dm to Dc, becoming C2 – B2 with depth. |

Notes:
1) “m bgl” denoted metres below ground level.
2) Depths presented in this table are in metres below ground level, and it should be recognised that the topography within the WRP site has been artificially altered by historical landfilling activities.
3) Alluvium was not encountered in every exploratory hole, with the waste mass directly overlying the River Terrace Deposits in certain locations.
4) The combination of the above factors results in apparent ‘crossover’ between the depth to the base of the Alluvium and the top of the River Terrace Deposits.

### *WRP site – East ‘Cell’*

2.3.12 A summary the ground conditions encountered in the east ‘cell’ is presented in Table 2-2.

**Table 2-2 Summary of ground conditions encountered – East 'Cell'**

| Stratum | Depth to Top (m bgl) | Depth to Bottom (m bgl) | Thickness (m) | Typical Description |
|---|---|---|---|---|
| Cover Soils | Ground Level | 0.9 to more than 4.0. Typically between 0.9 and 1.5. | 0.9 to more than 4.0. Typically between 0.9 and 1.5. | Encountered in all exploratory holes except TP05 (WYG).<br><br>A limited thickness of TOPSOIL, overlying layers of:<br><br>Soft to firm brown to orangish brown slightly sandy and occasionally slightly gravelly CLAY. Gravel is subrounded to subangular, fine to coarse of “natural lithologies”, sandstone, chalk, limestone, flint and brick, rarely with fragments of glass.<br><br>Greenish brown to yellowish brown, gravelly fine to coarse SAND. Gravel is fine to coarse of brick, flint, limestone.<br><br>Potential asbestos containing material (ACM) fragment noted in RO104 between 0.0 m and 0.39 m bgl. |
| Landfill Waste | 0.0 to 4.0 | 8.2 to 16.65 (Where full thickness proved) | 6.8 to 15.15 (Where full thickness proved) | Typically, paper, plastic, wood, glass, ceramics, Styrofoam, textiles, newspaper (1986), cardboard, with occasional “organic material”, wool, metal, aluminium, concrete, leather, “possible animal fur” and rarely with brick and ash, carpet, rubber, cobbles of concrete.<br><br>Within a matrix of very soft to soft, dark grey to black slightly sandy, slightly gravelly clay or grey silty sand. Matrix proportion |

| Stratum | Depth to Top (m bgl) | Depth to Bottom (m bgl) | Thickness (m) | Typical Description |
|---|---|---|---|---|
| | | | | varies from 10% to 90%. 'Waste' odour commonly recorded, occasional solvent and hydrocarbon odour. |
| Alluvium / River Terrace / Raised Marine Deposits | 8.2 to 10.7 | 10.5 to 14.0 (Where full thickness proved) | 0.9 to 5.8 (Where full thickness proved) | Encountered in RO104, RO105, RO109, CP03, CP06, DS101, DS102 and DS103 only.<br><br>Medium dense to dense brown to cream sandy, slightly clayey subangular to angular, fine to coarse GRAVEL of flint and occasional chalk. |
| Lewes Nodular Chalk Formation | 10.5 to 16.6 | Proved to a maximum of 65.25 in BHRP01 | Proved to a maximum of 48.6 in BHRP01 | Encountered in all exploratory holes where the full thickness of superficial deposits was proved.<br><br>Recovered as gravel or silt of cream to white, very weak to weak, low to medium density structureless CHALK. With occasional fine to coarse subrounded flints. Typically grades Dm to Dc increasing to B3 to C3 with depth. |

### *Budds Farm shaft site*

2.3.13 A summary the ground conditions encountered in BHW005, WSW001 and WSW002, located proximal to the location of the Budds Farm Shaft (as presented in **Figure 5**), are presented in Table 2-3.

2.3.14 WSW001 and WSW002 were located on higher ground approximately 10 m to the west and south-west of the proposed shaft location. The ground level at these exploratory holes (7.07 m Above Ordnance Datum [m AOD], and 6.53 m AOD) was approximately 3.5 m above the ground level at BHW005 (3.42 m AOD), located approximately 15 m north-east of the proposed shaft. This change in elevation is considered to represent the former landfill and the historical 'sludge pits'.

**Table 2-3 Summary of ground conditions encountered – Budds Farm shaft site**

| Stratum | Depth to Top (m bgl) / [m AOD] | Depth to Bottom (m bgl) / [m AOD] | Thickness (m) | Typical Description |
|---|---|---|---|---|
| Made Ground | 0.00 [3.42 to 7.07] | 2.18 to 5.00<br><br>[1.24 to 1.53] | 2.18 (BHW005 in lower-level area) to 5.0 (WSW002 – within raised area) | In WSW001 and WSW002 comprised between 1.3 m and 1.6 m thickness of soft to firm grey and brown sandy, gravelly CLAY. Gravel is fine to coarse of chert, concrete and brick.<br><br>Beneath upper clayey layer comprises loose dark brown, mottled black and orange very gravelly SAND. Gravel is chert, slag, coal, tile, wood and glass. |

| Stratum | Depth to Top (m bgl) / [m AOD] | Depth to Bottom (m bgl) / [m AOD] | Thickness (m) | Typical Description |
|---|---|---|---|---|
| | | | | Beneath middle sand layer is firm greyish brown or brownish grey gravelly CLAY. Gravel is of chert with occasional glass, brick and concrete.<br><br>In BHW005, beneath 0.2 m thickness of gravel surfacing, comprised reddish brown to brownish grey silty and sandy GRAVEL, gravelly SAND and sandy, gravelly CLAY. Gravel is fine to coarse of quartzite, limestone and chert, brick, concrete and occasional asphalt. This layer is considered to be analogous to the basal clay layer encountered within WSW001. |
| Alluvium (cohesive) | 2.18 to 5.00 [1.24 to 1.53] | 2.98 [0.44] (BHW005) (base not proven in WSW002 | 0.80 (BHW005)<br><br>At least 1.45 (WSW002) | Firm to stiff bluish grey, mottled dark grey and light brown sandy, slightly gravelly CLAY. Gravel is medium and subrounded of chert. |
| Alluvium (granular) / Raised Marine Deposits | 2.98 [0.44] | 7.20 [3.78] | 4.22 | Medium dense grey slightly sandy and silty GRAVEL of fine to coarse flint. |
| Lewes Nodular Chalk Formation | 7.20 [-3.78] | Proved to 45.8 m (BHW005) (base not proved) | Proved to a maximum of 38.6m (BHW005) | Initially, light brownish-white structureless CHALK recovered as gravelly SILT. Gravel is angular to subangular very weak medium-density chalk.<br><br>With depth becoming very weak low to medium density white CHALK with occasional brown, black and orange staining. |

## 2.4 Hydrogeology

2.4.1 The superficial Alluvium and River Terrace Deposits are classified as Secondary A Aquifers. Secondary A aquifers are defined by the Environment Agency (EA) as "permeable layers that can support local water supplies and may form an important source of base flow to rivers.

2.4.2 The superficial Tidal Flat Deposits and Raised Marine Deposits are classified as Secondary Undifferentiated Aquifers. Secondary Undifferentiated aquifers are applied by the EA "where it is not possible to apply either a Secondary A or B definition because of the variable characteristics of the rock type. These have only a minor value". The EA define a Secondary B aquifer as "mainly lower permeability layers that may store and yield limited amounts of groundwater through characteristics like thin cracks (called fissures) and openings or eroded layers".

2.4.3 The chalk bedrock is classified as a Principal Aquifer. Principal aquifers are defined by the EA as layers that "provide significant quantities of drinking water, and water for business needs. They may also support rivers, lakes and wetlands". Such strata typically have high intergranular and/or fracture permeability capable of a high level of water storage.

2.4.4 The EA's Catchment Data Explorer indicates that the groundwater within the chalk underlying the WRP and Budds Farm Shaft sites is part of the "*East Hants Chalk Water Body*". The East Hants Chalk Water Body does not extend beneath the Hermitage Stream, or out into Langstone Harbour. This water body received an Overall Water Framework Directive (WFD) classification of Poor in 2019. This can be further broken down to classifications of Poor for both quantitative supply and chemical quality.

2.4.5 Groundwater flow within the aquifers beneath the WRP site and Budds Farm Shaft site, is anticipated to be towards the south, following the topography and leading towards Langstone Harbour. Locally to the coastline there may be daily reversals in groundwater flow direction due to tidal influences.

2.4.6 The WRP site and Budds Farm Shaft site are not located within a groundwater Source Protection Zone (SPZ). The nearest such zone, an SPZ 1, is located approximately 400 m to the north of the WRP site.

2.4.7 The WRP site and Budds Farm Shaft site are not located within a groundwater Drinking Water Safeguard Zone. Such a zone is present approximately 400 m north of the WRP site, coincident with the groundwater SPZ 1.

2.4.8 There are three licenced groundwater abstractions within 1.0 km of the WRP site and Budds Farm Shaft site. The nearest of these is an abstraction of groundwater for potable water supply by Portsmouth Water Ltd, located approximately 500 m north of the WRP site.

2.4.9 Groundwater within the aquifers beneath the WRP site and Budds Farm Shaft site is indicated to be at High vulnerability to a pollutant released at ground level based on the hydrological, geological, hydrogeological and soil properties within a single square kilometre. High vulnerability is defined by the EA as "Areas able to easily transmit pollution to groundwater. They are likely to be characterised by high leaching soils and the absence of low permeability superficial deposits.

2.4.10 The WRP site and Budds Farm Shaft site are located within groundwater Nitrate Vulnerable Zone (NVZ), Ref: 2 – Chichester, Langstone and Portsmouth Harbours Eutrophic NVZ.

2.4.11 The WRP site and the Budds Farm Shaft site are both located within areas of reclaimed former marine / estuary land where saline groundwater conditions are likely to be prevalent. It is therefore considered that potable abstraction is highly unlikely to be a future consideration and on this basis hydrogeology (resource) will not be taken forwards as a receptor for consideration in this assessment. This is consistent with the EA's view in an earlier consultation [4] where the EA stated, in regard to the chalk "*While it is notionally a principal aquifer, we recognise that given the site setting, it is unlikely to have significant resource potential*".

## 2.5 Geoenvironmental conditions

## Potential hazards to human health – WRP site

2.5.1 In the cover soils, the identified human health hazards in the solid phase are limited to asbestos, which was visually identified in one exploratory hole and detected by the laboratory in 2 out of 33 samples, and marginally elevated (vs. the generic assessment criteria (GAC) for a commercial / industrial end use) concentrations of benzo(a)pyrene and dibenzo(a,h)anthracene, which were recorded in one sample of the cover soils only.

2.5.2 In the waste mass, the identified human health hazards in the solid phase are principally limited to asbestos, which was detected by the laboratory in 14 of the 50 samples analysed. Concentrations of metals, petroleum hydrocarbons, benzene, toluene, ethylbenzene and xylenes (BTEX), volatile organic compounds (VOCs) and semi volatile organic compounds (SVOCs) were below the adopted GAC in all samples analysed. Concentrations of polycyclic aromatic hydrocarbons (PAHs) were below the adopted GAC in all samples with the exception of BHW001 at 2.1 m bgl, which recorded concentrations of dibenzo(a,h)anthracene in excess of the GAC.

2.5.3 There were no exceedances of the commercial/industrial GAC within the natural soils.

2.5.4 The ground gas risk assessment undertaken based on the landfill gas spot monitoring and continuous monitoring results shows whilst the boreholes typically exhibit ‘Characteristic Situation’ (CS) CS2 conditions, CS3 conditions have been recorded in four boreholes, and within one of these borehole CS3 conditions were prevalent for approximately 15% of the monitoring period. It is considered that a classification of CS3 is appropriate and suitably (but not overly) precautionary.

2.5.5 Measures would be required to mitigate the risk from the identified asbestos and PAH hazards to human health within the cover soils and landfill waste. Ground gas protection measures would be required in the construction of any proposed enclosed buildings.

## Potential hazards to human health – Budds Farm shaft site

2.5.6 The results of the laboratory analyses undertaken on samples of the materials encountered in boreholes BHW005, WSW001 and WSW002 have been compared against the adopted GAC for a commercial / industrial end use. Exceedances of these GAC were not recorded. Asbestos was not encountered. On the basis of the information available, it is not anticipated that additional mitigation (beyond any embedded, standard practice) measures would be required for the protection of human health.

2.5.7 Ground gas monitoring undertaken within borehole BHW005 (screened within the chalk) recorded maximum steady state methane and carbon dioxide concentrations of 0.1 %v/v and 0.2 %v/v respectively, with a minimum oxygen concentration of 21.3 %v/v. Ground gas flow was not detected in excess of the instrument limit of detection of 0.1 L/hr.

2.5.8 Ground gas monitoring undertaken within boreholes WSW001 (screened within the Made Ground) and WSW002 (screened within the cohesive Alluvium) recorded maximum steady state methane and carbon dioxide concentrations of 0.1 %v/v and 7.3 %v/v respectively, with a minimum oxygen concentration of 12.3 %v/v. Ground gas flow was not detected in excess of the instrument limit of detection of 0.1 L/hr.

2.5.9 Worst-case Gas Screening Values (GSVs) of 0.0001 L/hr for methane and 0.0073 L/hr for carbon dioxide have been calculated, corresponding to CS1 conditions. In such situations, ground gas protection measures for new enclosed structures are not typically required.

### Potential hazards to controlled waters (including aquatic ecology) – WRP site and Hermitage Stream

2.5.10 Elevated concentrations (vs. the saltwater Environmental Quality Standards [EQS] of metals (copper, nickel, lead, zinc, and mercury) and ammonia were identified in the groundwater within the shallow superficial deposits and the chalk.

2.5.11 Elevated concentrations of ammonia, copper and zinc were identified in the surface waters within the Hermitage Stream. These elevated concentrations present a potential hazard to aquatic ecology within both the groundwater, surface water and within the adjacent Langstone Harbour.

2.5.12 Ammonia concentrations are significantly elevated in the waste mass and also highly elevated within the groundwater recovered from both the chalk and the superficial deposits. The surface water within the Hermitage Stream appears to be slightly impacted with ammonia and it is suggested that leachate from the WRP site and the other 'dilute and disperse' type landfills within the nearby area is entering these waters. It should be noted that release of leachate to the surrounding environment is the expected behaviour for an unlined 'dilute and disperse' type landfill.

2.5.13 Elevated concentrations of certain PAHs have been recorded within the waters recovered from boreholes screened within the waste mass. Groundwater within the underlying River Terrace Deposits / Raised Marine Deposits Secondary A Aquifer appears to be marginally impacted by PAHs, with two of the twelve samples analysed recording elevated concentrations. One of the 38 samples of groundwater from the chalk recorded a single marginally elevated PAH concentration, suggesting that groundwater within the Principal Aquifer is not significantly impacted by PAHs.

### Potential hazards to controlled waters (including aquatic ecology) – Budds Farm site

2.5.14 Elevated concentrations (vs. the saltwater EQS) within the groundwater recovered from the Alluvium immediately beneath the Made Ground beneath WSW002 included metals (cadmium, copper, lead, nickel and zinc), ammonia and PAHs (anthracene, fluoranthene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene and benzo(g,h,i)perylene). Concentrations of petroleum hydrocarbons remained close to or below the laboratory method detection limit, with a maximum concentration of 1.19 mg/l (vs. 0.4 mg/l detection limit) recorded in WSW002.

2.5.15 Elevated concentrations (vs. the saltwater EQS) within the groundwater recovered from the chalk at depth beneath BHW005 were limited to a single marginally elevated concentration of zinc (7.0 µg/l, vs EQS of 6.8 µg/l).

2.5.16 The absence of elevated concentrations in the groundwater within the chalk, compared to the elevated concentrations within the overlying superficial deposits, suggests that vertical migration of water between the shallow superficial deposits and the chalk at depth is limited.

2.5.17 As described above, the surface water within the Hermitage Stream appears to be slightly impacted with ammonia and it is suggested that leachate from the landfill at Budds Farm WTW, and the other 'dilute and disperse' type landfills within nearby area is entering these waters. It should be noted that release of leachate to the surrounding environment is the expected behaviour for an unlined 'dilute and disperse' type landfill.

## 2.6 Groundwater Conditions

### Perched water / landfill leachate – WRP site

2.6.1 Perched water/landfill leachate strikes during drilling and perched water/landfill leachate levels monitoring during the ground investigations to date are summarised in Table 2-4.

**Table 2-4 Summary of perched water / landfill leachate strikes and spot monitoring records – WRP site**

| Exploratory Hole | Strike During Drilling – Depth and Elevation | Stratum Within Which Strike Was Recorded | Spot Monitoring – Depth and Elevation (as recorded in in-waste response zones) |
|---|---|---|---|
| RO101 | No strike recorded | n/a | 7.93 to 8.25 m bgl<br>2.78 to 3.10 m AOD |
| RO102 | 1.00 m bgl<br>9.04 m AOD | Cover Soils | 7.25 to 7.95 m bgl<br>2.50 to 3.20 m AOD |
| RO103 | 7.60 m bgl<br>2.85 m AOD | Landfill Waste | 2.54 to 8.50 m bgl<br>1.89 to 7.85 m AOD |
| TP104 | 1.80 m bgl<br>8.19 m AOD | Cover Soils | n/a |
| CP01 | No strike recorded | n/a | 7.07 to 8.02 m bgl<br>2.52 to 2.87 m AOD |
| CP02A | No strike recorded | n/a | 7.98 to 8.79 m bgl<br>2.00 to 2.81 m AOD |
| CP05 | 5.90 m bgl<br>3.66 m AOD | Landfill Waste | 6.72 to 7.63 m bgl<br>1.93 to 2.84 m AOD |
| TP09 | 3.9 m bgl<br>4.27 m AOD | Landfill Waste | n/a |
| RO104 | No strike recorded | n/a | 8.78 to 9.92 m bgl<br>1.11 to 2.25 m AOD |
| RO105 | 2.5 m bgl (fast inflow)<br>7.89 m AOD | Landfill Waste | 8.72 to 9.6 m bgl<br>0.76 to 1.73 m AOD |
| RO106 | No strike recorded | n/a | 8.72 to 9.70 m bgl<br>0.69 to 1.67 m AOD |
| RO109 | No strike recorded | n/a | 8.71 to 8.84 m bgl<br>0.95 to 1.08 m AOD |
| TP112 | 3.50 m bgl<br>5.44 m AOD | Landfill Waste | n/a |
| TP117 | 2.4 m bgl (fast inflow) | Landfill Waste | n/a |

| Exploratory Hole | Strike During Drilling – Depth and Elevation | Stratum Within Which Strike Was Recorded | Spot Monitoring – Depth and Elevation (as recorded in in-waste response zones) |
|---|---|---|---|
| | 7.91 m AOD | | |
| TP119 | 2.75 m bgl<br>6.63 m AOD | Landfill Waste | n/a |
| CP03 | 10.5 m bgl<br>-1.83 m AOD | Landfill Waste | 5.19 to 7.34 m bgl<br>1.33 to 3.48 m AOD |
| CP06 | 4.3 m bgl<br>8.1 m AOD | Landfill Waste | n/a |
| BHRP01 | 13.60 m bgl<br>-0.20 m AOD | Landfill Waste | 10.58 to 12.02 m bgl<br>1.38 to 2.82 m AOD |
| BHW001 | 7.20 m bgl<br>0.92 m AOD | Landfill Waste | 5.75 to 6.98 m bgl<br>1.14 to 2.37 m AOD |
| BHW002 | 7.30 m bgl<br>1.13 m AOD | Landfill Waste | 6.41 to 7.20 m bgl<br>1.23 to 2.02 m AOD |

2.6.2 It is evident from Table 2-4 that a perched water / landfill leachate table is present within the landfill waste. Following the initial strike, the water / leachate level often rose, showing that pockets of leachate may be confined by the waste mass itself. The resting level of the perched water / landfill leachate was typically between 1.0 m and 3.0 m AOD.

2.6.3 Perched water / landfill leachate levels at the WRP site were also monitored with a datalogger as summarised in Table 2-5.

**Table 2-5 Summary of perched water / landfill leachate levels as monitored by datalogger - WRP site**

| Exploratory Hole | Maximum Groundwater Elevation (m AOD) | Minimum Groundwater Elevation (m AOD) |
|---|---|---|
| RO101 (S) (West Cell) | 1.935 | 0.343 |
| RO108 (West Cell) | 2.207 | 0.728 |
| RO104 (S) (East Cell) | 2.840 | 2.820 |
| RO105 (S) (East Cell) | 5.470 | 4.740 |
| RO106 (S) (East Cell) | 2.500 | 2.150 |

2.6.4 It is evident from measurements recorded in RO101 in the north-western corner of the western cell, and RO108 in the south-eastern corner of the western cell, that groundwater within the west ‘cell’ is tidally influenced. A review of the perched water / landfill leachate levels in the eastern cell, recorded by datalogger, indicates that that the perched water / landfill leachate levels within the eastern cell do not vary across / are not influenced by tidal cycles.

## Groundwater – WRP site

2.6.5 Groundwater strikes during drilling and groundwater levels monitored during the ground investigations undertaken to date are summarised in Table 2-6.

**Table 2-6 Summary of groundwater strikes and spot monitoring records - WRP site**

| Exploratory Hole | Strike During Drilling – Depth and Elevation | Stratum Within Which Strike Was Recorded | Spot Monitoring – Depth and Elevation (as recorded in response zones in chalk) |
|---|---|---|---|
| CP02A | 9.6 m bgl<br>1.19 m AOD | Alluvium | 9.25 to 9.54 m bgl<br>1.25 to 1.54 m AOD |
| RO102 | 9.00 m bgl<br>1.04 m AOD | River Terrace Deposits | 8.38 to 8.40 m bgl<br>2.48 to 2.50 m AOD |
| CP01 | 11.5 m bgl<br>-0.96 m AOD | River Terrace Deposits | 8.56 to 9.29 m bgl<br>1.25 to 1.98 m AOD |
| RO105 | 17.00 m bgl (fast inflow)<br>- 6.61 m AOD | Chalk | 9.32 to 9.63 m bgl<br>1.25 to 1.56 m AOD |
| RO101 | 11.50 m bgl<br>-0.47 m AOD | Chalk | 7.57 to 8.15 m bgl<br>1.89 to 2.47 m AOD |
| RO103 | No groundwater strike | n/a | 10.54 to 11.05 m bgl<br>1.63 to 2.14 m AOD |
| RO107 | No groundwater strike | n/a | 9.57 to 9.72 m bgl<br>1.02 to 1.17 m AOD |
| RO108 | No groundwater strike | n/a | 7.43 to 7.94 m bgl<br>1.06 to 1.57 m AOD |
| BHRP02 | No groundwater strike | n/a | 7.46 to 9.32 m bgl<br>0.94 to 2.81 m AOD |

2.6.6 It is considered that groundwater in the River Terrace Deposits and chalk is at least partially confined by the overlying Alluvium. The River Terrace Deposits and chalk are likely to be hydraulically connected and appear to have an unconfined piezometric surface typically between 1.0 m and 2.5 m AOD.

2.6.7 Groundwater levels were also monitored with a datalogger / continuous gas monitoring equipment across several tidal cycles, as summarised in Table 2-7.

**Table 2-7 Summary of groundwater datalogger levels - WRP site**

| Exploratory Hole | Maximum Groundwater Elevation (m AOD) | Minimum Groundwater Elevation (m AOD) | Average Tidal Range (m) |
|---|---|---|---|
| DS101<br>(response zone in River Terrace Deposits) | 1.836 | 0.725 | 0.90 |
| DS103<br>(response zone in River Terrace Deposits) | 1.009 | 0.657 | 0.10 |
| RO108<br>(response zone in chalk) | 2.207 | 0.728 | 1.30 |
| RO105<br>(response zone in chalk) | 2.473 | 1.031 | 1.30 |
| RO109<br>(response zone in chalk) | 2.129 | 0.528 | 1.50 |

2.6.8 On the basis of the above, it is evident that groundwater levels in the chalk and River Terrace Deposits are tidally influenced.

### Perched water – Budds Farm shaft site

2.6.9 Perched water was not encountered whilst drilling. Borehole WSW001, installed to 4.0 m bgl within the Made Ground, remained dry during the monitoring period.

### Groundwater – Budds Farm shaft site

2.6.10 Groundwater strikes during drilling and groundwater levels monitored during the ground investigations undertaken to date are summarised in Table 2-8.

**Table 2-8 Summary of groundwater strikes and spot monitoring records – Budds Farm shaft site**

| Exploratory Hole | Strike During Drilling – Depth and Elevation | Stratum Within Which Strike Was Recorded | Spot Monitoring – Depth and Elevation |
|---|---|---|---|
| WSW002 | 5.80 m bgl<br>0.73 m AOD | Alluvium | 4.37 to 4.68 m bgl (response zone in Alluvium)<br>2.16 to 1.86 m AOD |
| BHW005 | 26.4 m bgl<br>-22.98 m AOD | Chalk | Response zone in chalk between 10.5 and 15 m bgl - 1.93 to 2.36 m bgl<br>1,49 to 1.06 m AOD<br><br>Response zone in chalk between 21.5 and 26.5 m bgl - 1.12 to 2.49 m bgl<br>2.30 to 0.93 m AOD |

2.6.11 The Alluvium in WSW002, at the depth of the strike was recorded is described as "*slightly sandy, gravelly CLAY*". Water within this Alluvium appears to be slightly confined and may be limited to smaller pockets of water within more granular areas.

# 3 Conceptual site model

The Conceptual Site Model (CSM) for the WRP site and Budds Farm Shaft site is described in detail in the Geo-environmental Interpretative Report [4] and is summarised in this section.

## 3.1 Potential sources of contamination (PSC)

**Table 3-1 Potential sources of contamination**

| PSC Reference | Description | Potential Contaminants of Concern (PCOC) |
|---|---|---|
| 1 | Landfill waste deposited on and adjacent to Budds Farm Shaft site between c. 1960s to 1980s,<br><br>Landfill waste within former (now closed and restored) landfill that received domestic, commercial, and industrial wastes between 1969 and 1987 before being restored to grassland.<br><br>PSC is both an on-Site and off-Site source. | Landfill leachate containing elevated concentrations of inorganic compounds including ammoniacal nitrogen.<br><br>The landfill waste mass could include a variety of materials, with PCOC including asbestos, metals and metalloids, hydrocarbons (total petroleum hydrocarbons (TPH) and polycyclic aromatic hydrocarbons (PAHs), volatile and semi-volatile organic compounds (VOCs and SVOCs), poly- and per-fluoroalkyl substances (PFAS).<br><br>Whilst there is potential for hydrocarbons present within the fill to migrate via the groundwater to the adjacent surface waters, there is no evidence to date that this is the case (e.g., hydrocarbon plumes have not been recorded).<br><br>Landfill gases (methane, carbon dioxide, hydrogen sulphide, carbon monoxide, depleted oxygen concentrations) |
| 2 | Made Ground (restoration soils and soils imported to the western half of the WRP site in the late 1990s as part of land raising works to create playing fields.<br>(On-Site source) | Asbestos, metals, and metalloids, TPH, PAHs. |
| 3 | Budds Farm WTW located immediately north-east of Budds Farm Shaft site and former sewage works located approximately 50 m north of the WRP site. Constructed by 1930, demolished by 1972.<br>(Off-Site source) | Metals, TPH, PAHs, VOCs, SVOCs, pathogens, phenols, ammonia, asbestos, cyanide, PFAS and ground gas (from infilled former tanks). |

## 3.2 Identification of potential pathways

3.2.1 To determine whether the identified hazards pose a risk it is necessary to identify the presence of potential receptors and pathways by which these receptors can be exposed to the hazard.

3.2.2 Potential hazards require a pathway connecting the source (if present) to potential receptors to impact upon the receptors. These pathways are capable of conveying the potential contaminants identified. Pathways may be anthropogenic (artificial) or natural.

3.2.3 Anthropogenic pathways are artificial routes capable of conveying contaminants and include such routes as surface water drains, high permeability backfill materials, poorly consolidated Made Ground, mine workings, mining induced fissures from subsidence, foundations, and persons disturbing contamination sources in such a way as to liberate contaminants.

3.2.4 Natural pathways are naturally occurring routes capable of conveying contaminants such as permeable strata, fractures and fissures, wind-blown material etc.

3.2.5 The pathways considered relevant to this assessment are described in Table 3-2.

**Table 3-2 Relevant pathways**

| Receptor | Details |
|---|---|
| **Human health** | Ingestion of soil / dust indoors, e.g., in site cabins or in completed structures. |
| | Ingestion of soil / dust outdoors. |
| | Inhalation of particles (dust / soil) – outdoor. |
| | Inhalation of particles (dust / soil) – indoor. |
| | Vapours – outdoor – migration via natural or anthropogenic pathways. |
| | Vapours – indoor – migration via natural or anthropogenic pathways. |
| | Dermal absorption via direct contact with soil. |
| **Groundwater** | Groundwater within permeable natural strata as a pathway allowing migration of mobile contamination leached from contaminated soils. |
| | Groundwater migrating via anthropogenic routes e.g., boreholes, landfill waste mass etc. |
| **Surface Water** | Runoff or discharges to surface water via existing drainage network, e.g., historical land drains, highway drainage. |
| | Recharge of surface water in Langstone Harbour via contaminated groundwater within the shallow unconfined aquifer. The boundary, or interface, between the groundwater and surface water is in a state of dynamic equilibrium, moving with the seasonal variations of the water table and daily tidal fluctuations. |
| | Deposition of wind-blown dust. |
| **Buildings** | Direct contact – Sulphate attack on concrete, hydrocarbon corrosion / permeation of plastic pipes. |
| | Migration of gases / vapours through permeable natural strata, fissures or fractures etc. Migration of gases / vapours through permeable backfill materials, buried service corridors, cracks in floor slabs. |
| **Ecologically Sensitive Sites** | Runoff or discharges to surface water via existing drainage network, e.g., historical land drains, highway drainage and uptake by flora and fauna either by roots, ingestion or inhalation. |

| Receptor | Details |
|---|---|
| | Deposition of wind-blown dust and uptake by flora and fauna either by roots, ingestion or inhalation. |
| | Recharge of surface water via contaminated groundwater and uptake by flora and fauna either by roots, ingestion or inhalation. |

## 3.3 Receptor identification

3.3.1 Potential receptors identified by this assessment are presented in Table 3-3. Receptors are identified at the baseline phase (i.e., the current situation, pre-construction), the construction phase of the development, and the operational phase of the development.

**Table 3-3 Potential receptors**

| Receptor | Comment |
|---|---|
| **Human Health – On-site** | Baseline – Not Applicable. Site is vacant with no public footpaths.<br>Construction – Ground workers constructing the Project.<br>Operation – Workers at proposed WRP. Maintenance workers undertaking in-ground works. |
| **Human Health – Off-site** | Baseline, Construction and Operation – Workers at adjacent business park, yard, aggregates wharf etc. |
| **Groundwater (resource)** | Baseline, Construction and Operation – Eliminated.<br>Potable abstractions have not been identified within 250 m of either the WRP site or the Budds Farm shaft site. Both sites are located within reclaimed former marine land where saline groundwater conditions are likely to be prevalent and potable abstraction is unlikely to be viable. |
| **Groundwater (biodiversity)** | Baseline, Construction and Operation – The EA's Catchment Data Explorer indicates that the groundwater beneath both sites received an WFD classification of Poor in 2019 for chemical quality. |
| **Surface Water (resource)** | Baseline, Construction and Operation – Eliminated.<br>Surface water abstractions have not been identified within 250 m of either the WRP site or the Budds Farm shaft. Both Langstone Harbour and Hermitage Stream are tidal (saline). |
| **Surface Water (biodiversity)** | Baseline, Construction and Operation - The Hermitage Stream received a WFD classification of Moderate for Ecological Quality in 2019. |
| **Ecologically Sensitive Sites** | Baseline, Construction and Operation - Langstone Harbour, is a designated Site of Special Scientific Interest (SSSI), Special Area of Conservation (SAC), Special Protection Area (SPA), wetland of international importance designated under the Ramsar Convention and a WFD safeguarded Groundwater Dependent Terrestrial Ecosystem (GWDTE). |
| **Geodiversity** | Neither the WRP site or the Budds Farm shaft site are located within 1.0 km of any geologically designated SSSI or geologically designated Local Site or Regionally Important Geological Site . |
| **Property – Buildings** | A single listed structure (Old Mill House) is present, approximately 190 m north (i.e., hydraulically upgradient) of the WRP site. |

| Receptor | Comment |
|---|---|
| | It is considered highly unlikely that this property would experience impacts due to the construction of the Project, e.g., migration of contamination.<br>A safeguarded mineral wharf is present between the WRP site and the Budds Farm Shaft site.<br>Assorted commercial / light industrial properties are also present within 250 m of both sites.<br>Archaeological receptors, e.g., scheduled monuments etc., have not been identified within 500 m of either site. |

3.3.2 A schematic conceptual site model sketch is provided in the Figures (**Figure 6**) section at the back of this report.

# 4 Outline foundation works risk assessment

## 4.1 Purpose

4.1.1 The purpose of this Outline FWRA is to ensure that the construction of the shafts and tunnels would not have an adverse impact on the environment by creating new pathways for the migration of contamination, considering the protection of both water resources and human health. The need for an Outline FWRA is set out in ES Chapter 11 Land quality and ground conditions, Volume II (Document reference 6.1, DCO Volume 6) as a risk reduction measure.

## 4.2 Proposed construction

4.2.1 The WRP site would consist of a main process building, three pumping stations, kiosks for control equipment, administration buildings and parking facilities. Several large holding tanks and chemical storage units would also be constructed above ground. These would either be pre-cast concrete tanks or glass fused to steel construction.

4.2.2 It is proposed to locate the WRP in the western half of the WRP site where the ground levels are more low lying and are broadly level. This reduces the quantum of earthworks required and, as a result the amount of off-site disposal of surplus soils and materials.

### Selection of piling and ground improvement methodology

4.2.3 The WRP would be supported on piled foundations. For lightly loaded slabs or hardstanding, piles would be socketed approximately 2 m into the top of the Chalk (approximately 15 m depth). For heavier structures piles would be extended approximately 10.5 m into the Chalk (approximately 23.5 m depth). These details are based upon information at the DCO submission stage. Detailed design would be undertaken post-DCO consent, and this assessment would therefore be revised by the contractor.

4.2.4 Continuous Flight Auger (CFA) piles are the preferred piling option. CFA piles are a type of bored ‘replacement’ pile. The choice of piling methodology is principally geo-environmentally driven, with cast in-situ CFA piles selected as this method allows ‘intimate contact’ between the pile and the surrounding landfill waste, minimising the risk of creating pathways for contamination to migrate into the underlying chalk and adjacent surface waters. The recommendation for the use of CFA piles was made at an early stage of the design of the proposed WRP, with the need to minimise creation of migration pathways being the principal objective. Geotechnical, structural, noise and vibration considerations have been secondary to the geo-environmental considerations, and therefore the geotechnical and structural design has responded to the geo-environmental requirements.

*4.2.5* As described in [1], *“this method uses a hollow stemmed CFA to excavate the pile bore and fill the bore with cement or grout. The auger is introduced into the ground by rotary methods at a speed and pitch that minimises soil displacement. The soil retained on the auger flights supports the sides of the pile shaft during drilling.*

*4.2.6 On achieving the required depth, cementitious grout or concrete is introduced under pressure via the hollow stem into the base of the borehole. The auger is withdrawn at a controlled rate whilst maintaining the concrete or grout at a positive pressure. Spoil is withdrawn from the hole on the auger flights and the concrete fills the hole under the auger head, the positive pressure forcing it into contact with the surrounding soil".*

*4.2.7 Once the auger is fully withdrawn, the positive hydrostatic pressure from the concrete supports the hole during the time taken for the concrete to cure. Once the complete auger string has been removed from the hole, the spoil arisings are cleared away, a reinforcing cage can, if required, be introduced into the concrete in the pile, assisted by vibration".*

*4.2.8* [1] also states "*the concrete that is placed in the pile forms a close contact with the surrounding soil. The irregular interface between the pile and the soil improves load transfer and the difference in skin friction between the two types is small. It will also minimise the risk of contaminant or ground gas migration down or up the pile/soil interface*".

4.2.9 It is recognised that there are particular difficulties associated with installing CFA piles within a landfill. These could include:

- If the landfill is very incompetent (i.e. undrained shear strength less than 30kPa) there is a risk that the material surrounding the pile may collapse into the concrete mix before the concrete is set. It is possible to use a casing to support the bore, and as described in [1] this uses a specialist rig with double rotary drive units for the auger and casing. These rotate in opposite directions, simultaneously drilling the auger and casing into the ground. Following withdrawal of the casing, it is imperative that the material surrounding the pile does not collapse into the wet concrete. To combat this the concrete mix would be thickened, however there is a limit to how thick the mix can be made due to the requirement to insert the steel reinforcement prior to setting.
- There is the potential for obstructions to be present within the landfill waste, which could be difficult to overcome with CFA. If the challenges cannot be resolved, an alternate boring method might instead be used. Regardless of boring method, a cast in-situ pile would be used.
- Design Sulphate (DS) Class and Aggressive Chemical Environment for Concrete (ACEC) conditions might impact the decision on whether CFA is feasible. Should the waste materials be classified to be AC-4 or above, challenges might arise around the concrete coverage required around the reinforcement cage. If this is the case, the pile diameter can be increased to allow for sacrificial concrete.

## Shaft construction

4.2.10 Three launch shafts would be constructed within the WRP site to enable pipeline construction by Tunnel Boring Machine (TBM) or pipe-jacking:

- WRP East shaft – Bedhampton Pipe Jack
- Shaft internal diameter 12.5 m
- Invert level 16.8 m bgl
- WRP West shaft – Purbrook Tunnel (excavated by TBM)

- Shaft internal diameter 15.0 m
- Invert level 24.6 m bgl
- WRP South shaft – for Budds Farm Pipe Jack
- Shaft internal diameter 9.0 m
- Invert level 20.4 m bgl

4.2.11 A reception shaft (the Budds Farm Shaft) would be constructed at the Budds Farm end of the Budds Farm Pipe-Jack, with an internal diameter of 5.5 m and the invert level at 17.6 m bgl.

4.2.12 All shafts would descend through landfill waste, then Quaternary superficial deposits including Alluvium, Raised Marine Beach Deposits and River Terrace Deposits (one or more of these) and reach their full depth in the underlying chalk, which may be structured/structureless.

4.2.13 According to the current proposed designs, all shafts would be constructed using non-displacement methods, which limits the opportunity for waste to be pushed into the surrounding natural deposits/aquifers. The shafts would comprise a diaphragm wall (primary lining) with a cast-in-situ, reinforced concrete secondary lining, constructed using the following methodology:

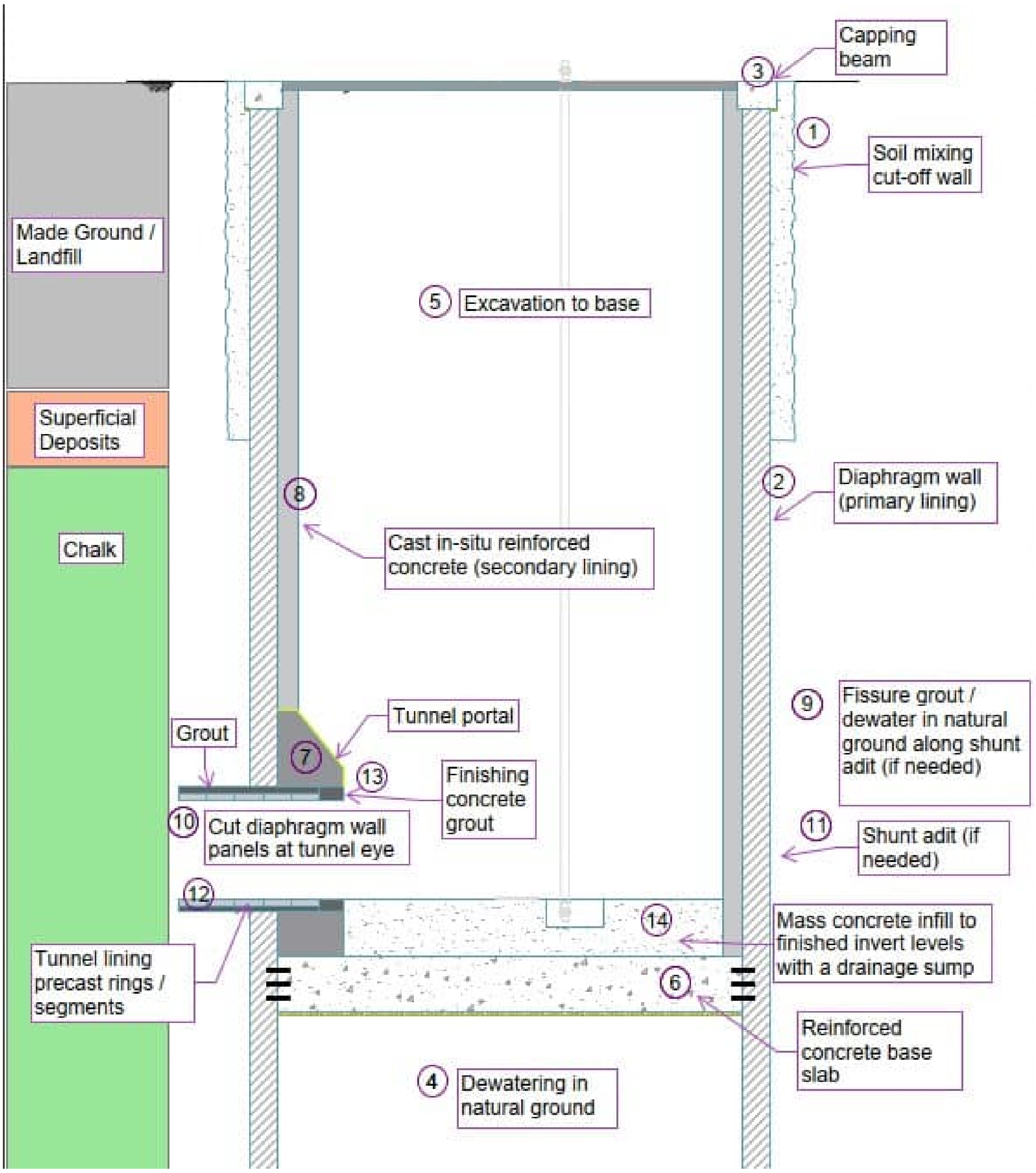
- First, deep soil mixing would be used within the Made Ground and landfill waste to stabilise the ground around the proposed diaphragm wall and prevent instability of the trench, as well as substantially lowering the permeability of the soils, preventing migrating of contamination. A more stable trench would lead to smooth-sided diaphragm walls, thus ensuring intimate contact between the poured concrete and the surrounding soils. This intimate contact prevents new contamination pathways forming at the soil-concrete interface.
- Deep soil mixing is an in-situ ground improvement technique that enhances the characteristics of weak soils by mechanically mixing them with a cementitious binder injected into the soil. The action of mixing materials such as cement or bentonite with soil causes the properties of the soil to become more like soft rock. It is anticipated that this would be achieved using a wet binder from an on-site temporary batching plant, to create a series of overlapping soil mixed columns. By this method two concentric, stabilised cut-off walls would be formed either side of the proposed diaphragm wall. The inner wall is temporary and is excavated later, with the shaft.
- Within the deep soil mixing cut off wall a diaphragm wall (primary lining) would be constructed down to the base depth of the shaft (i.e., through the natural soils). A grab excavator would be used to form the excavation for each wall ‘panel’, with a bentonite slurry used to keep the excavation open, again ensuring smooth-sided diaphragm walls and good contact of the poured concrete with surrounding soil. Once a panel has been excavated, reinforcement cages are lowered into the excavation, after which concrete for that panel is poured.
- Following the completion of all panels, a capping beam would be cast to control displacements and provide structural continuity between panels.
- The shaft and inner cut-off wall would then be excavated to the full depth, including temporary dewatering prior to casting the base slab. Groundwater inflow would be

minimised by embedding diaphragm walls into competent chalk and fissure grouting (if required) the chalk beneath the final excavation level. Pump tests would be carried out to monitor the hydrogeological regime and determine the measures necessary for groundwater control.

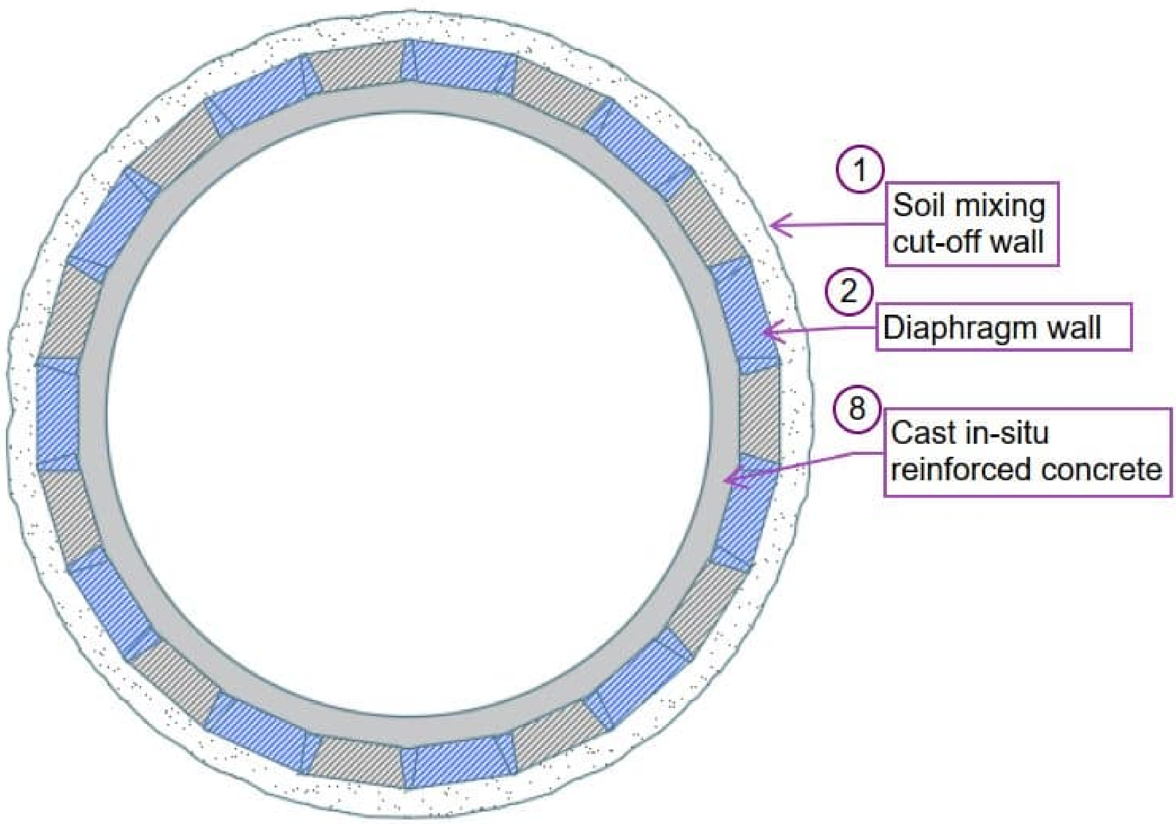
- The reinforced concrete base slab is then cast in place.
- A portal is constructed from reinforced concrete followed by a secondary lining of reinforced concrete around the diaphragm walls to provide additional water tightness (diaphragm wall panels would be cut later at the tunnel eye as construction proceeds).

4.2.14 Graphics 4-1 and 4-2 show a cross section and plan view of the completed shaft. The circled numbers show the order of operations.

**Graphic 4-1 Schematic cross section of completed shaft**



**Graphic 4-2 Schematic plan view of completed shaft**




## 4.3 Climate change

4.3.1 The EA's Land Contamination Risk Management guidance (Environment Agency, 2025) recommends the incorporation of climate change considerations into land contamination risk assessment and the options appraisal process so that site works and long-term remediation are sustainably robust and endure future climate change events.

4.3.2 Climate change requires the design and implementation of land contamination risk management reduction measures to account for Extreme Weather Events (EWE). EWE considers not just the general increase in magnitude such as temperature but also the intensity such as increasingly intense precipitation causing run-off or short-term groundwater level rise or surface flooding.

4.3.3 In relation to this Outline FWRA, the baseline hydrogeological conditions identified in the ground investigation could evolve through changes to long term groundwater levels, increased tidal variability due to rising sea levels, and increased seasonal variations of groundwater levels potentially affecting structures and other elements of the Project that interact with the ground. EWEs leading to more frequent and higher intensity precipitation, or hotter drier conditions could lead to increased erosion/deterioration of unprotected natural surfaces.

4.3.4 Consideration of the potential effects of climate change have been conducted during the design of the Project, and suitable design parameters have been adopted to account for potential adverse impacts from climate change.

## 4.4 Hazard identification: potential adverse environmental impacts and risk assessment

4.4.1 Discussion of the potential adverse environmental impacts that could occur as a result of construction of the Project and a Generic Quantitative Risk Assessment of the WRP site are provided within the GIR for the WRP site [4] within ES Appendix 11.2 Geotechnical and geo-environmental reports, Volume II (Document reference 6.2, DCO Volume 6).

### Initial Risk Screening

4.4.2 [1] presents a risk assessment matrix for groundwater that can be used at the outset of a project to provide a high-level initial screening of risk to groundwater. The outcome from this matrix can then be used to guide the assessment and design processes. It is recognised that the project has progressed well beyond the initial stages where this matrix would be used, however it has been completed to provide a 'baseline' assessment of risk.

**Table 4-1 Outline Foundation works risk assessment matrix for groundwater – initial screening** (after CL:AIRE, 2025)

| Factor | Risk Ranking | | | | Assessed Risk Ranking at WRP Site |
|---|---|---|---|---|---|
| | Negligible Risk | Low Risk | Moderate Risk | High Risk | |
| Aquifer designation | Unproductive strata | Groundwater resource | Secondary | Principal | High |
| Receptor | No credible receptor | Groundwater outside SPZs (that contamination could credibly reach) | SPZ 3/ total catchment zone Surface watercourse | SPZ 1 and 2<br><br>Site of Special Scientific Interest (SSSI) | High |
| Flow regime | | Matrix intergranular flow | | Fracture flow | High |
| Permeability | Very low permeability | Low permeability | High permeability | Very high permeability | Low |
| Contamination | No significant contamination present | Low leachability (compare to suitable standards, | Dissolved phase in perched water | Dissolved phase in perched water | Moderate |

| Factor | Risk Ranking | | | | Assessed Risk Ranking at WRP Site |
|---|---|---|---|---|---|
| | Negligible Risk | Low Risk | Moderate Risk | High Risk | |
| | | EQS or Drinking Water Standards, DWS) | | Non-aqueous phase liquids (NAPL) | |
| Piling / ground improvement depth | Pile to more than 10 m above bottom of aquiclude | Pile to between 5 m and 10 m from bottom of aquiclude | Pile to less than 5 m above bottom of aquiclude | Pile extends into aquifer | High |

4.4.3 The overall risk to groundwater, on the basis of the initial screening, is assessed to be High.

4.4.4 For a site assessed as High groundwater risk, [1] states:

*4.4.5 "FWRA required possibly with remedial targets assessment to determine if piling is acceptable at all and if so what mitigation and monitoring is required. Specific FWRA report required. This should be started at the desk study stage (RIBA Stage 1) and should then be developed as further site investigation is completed and the design progressed".*

4.4.6 In relation to ground gas and vapour hazards [1] states:

- "In most cases the use of piled foundations or ground improvement will not increase risk posed by ground gas and neither bored pile, driven precast concrete or open tube (with infill) piles or vibro concrete columns will form preferential pathways unless through a thin layer of stiff clay that is confining a gas source that is under pressure or of large volume in an open void [19]. Therefore most scenarios are low risk and do not need assessment...
- "In most cases the use of piled foundations or ground improvement will not increase risk posed by ground gas and neither bored pile, driven precast concrete or open tube (with infill) piles or vibro concrete columns will form preferential pathways unless through a thin layer of stiff clay that is confining a gas source that is under pressure or of large volume in an open void [19]. Therefore most scenarios are low risk and do not need assessment...The only high risk scenarios are:

  Thin or engineered capping layer over high pressure source (e.g. recent landfill sites) or large volume gas source in an open void (mine workings); and
- Driven steel H or I section piles that are driven through a confining layer and link a gas source under pressure or of large volume to the surface".

4.4.7 The landfill within the WRP site does not benefit from a low permeability capping layer and is not a recent landfill. The landfill is not assessed to be a high-pressure source as borehole pressures recorded during the continuous monitoring closely tracked the atmospheric pressure, indicating that the cover soils are suitably permeable such that pressure changes are rapidly conveyed through the cover and into the fill. Driven piles are not utilised as part of the Project.

4.4.8 CFA piles are therefore not considered to increase the risks posed by landfill gas and would not form preferential pathways for gas migration.

## Risk management – mitigation by design

4.4.9 As discussed in Section 4.2 the location of the WRP within the western area and the selection of construction methodologies (e.g., the use of CFA piles) has been guided by the assessment of the potential environmental risks.

4.4.10 The project is currently at indicative design with progression to more developed and detailed technical design to be undertaken post DCO consent. As described in Figure 6.1 of the [1] for a project at this stage, this outline FWRA would be kept under review, subject to the completion of detailed design.

## Risk management – relevant contaminant linkages

4.4.11 As summarised in Table 10.1 of the GIR [4] (see ES Appendix 11.2 Geotechnical and geo-environmental reports, Volume II (Document reference 6.2, DCO Volume 6) (reproduced in part below as Table 4-2) the potential contaminant linkages considered to require risk management comprise:

**Table 4-2 Summary of contaminant linkages requiring risk management, and relevance to construction of piled foundations and shafts**

| Contaminant Linkage (CL) | Hazard | Receptor & Pathway | Relevant to Construction of Piled Foundations and Shafts? |
|---|---|---|---|
| CL1 | Cover soils and landfill waste – Asbestos, PAHs, Landfill Gases | Construction workers, workers at adjacent commercial development, members of the public using the footpath adjacent to the Hermitage Stream / nearby green spaces - Inhalation | Yes – via creation of pile and shaft arisings. |
| CL2 | Unforeseen Ground Conditions | Human Health - Construction Workers & Neighbouring - Dermal contact, inhalation, ingestion | Yes – but managed separately and not within the scope of this FWRA. |
| CL3 | Made Ground – Asbestos, PAHs. | Future Maintenance/Service workers - Dermal contact, inhalation, ingestion | No. |
| CL4 | Made Ground – Asbestos, PAHs, Landfill gases | Future Users – Dermal contact, inhalation, ingestion | No. |
| CL5 | Made Ground - Hydrocarbons | Future Users<br>Permeation of Water Supply Pipe | No. |
| CL6 | Made Ground – aggressive ground conditions | Concrete<br>Direct Contact | Yes – degradation of pile/shaft leading to formation of preferential migration pathways. |
| CL7 | Metals, ammonia | Controlled Waters & Ecologically Sensitive Sites – Migration of | Yes (see below). |

| Contaminant Linkage (CL) | Hazard | Receptor & Pathway | Relevant to Construction of Piled Foundations and Shafts? |
|---|---|---|---|
| | | leachate to groundwater and surface water via natural and anthropogenic routes. | |

4.4.12 In relation to CL7, the limited thickness of silty and occasionally gravelly Alluvium that underlies that waste mass and separates it from the underlying sandy gravel River Terrace Deposits or Raised Marine Deposits (where present) or otherwise, the chalk bedrock, is not considered to function as an aquiclude.

4.4.13 As the landfill is unlined and operates on the ‘dilute and disperse’ principle, leachate generated within the landfill is able to migrate out of the landfill (of which the WRP site occupies one part only) via the underlying superficial deposits, to enter the underlying groundwater and subsequently the surrounding surface water environment where the groundwater and surface water are in hydraulic continuity.

4.4.14 The baseline condition is therefore that there is an active contaminant linkage by which adverse environmental impacts are already occurring, with the groundwater and surface water shown to be impacted by contamination likely to have originated within the landfill (of which the WRP site is one part only).

## 4.5 Assessment methodology

4.5.1 The adopted methodology for assessing land contamination and estimating risk is described below.

4.5.2 Table 4-3 below presents the criteria for assessment of **source significance**. A value between 1 (Very Low) and 5 (Very High) is assigned, based upon professional judgement and taking into account factors such as historical land use, gas generation potential, and the results of the ground investigation.

**Table 4-3 Criteria for classifying source significance**

| Classification/Score | Potential for generating contamination/gas based on land use |
|---|---|
| Very Low<br><br>1 | Land use: Residential, retail or office use, agriculture<br>Contamination: Limited<br>Gas generation potential: Soils with low organic content |
| Low<br><br>2 | Land use: Recent small scale industrial and light industry<br>Contamination: locally slightly elevated concentrations<br>Gas generation potential: Soils with high organic content (limited thickness) |
| Moderate<br><br>3 | Land use: Railway yards, collieries, scrap yards, engineering works<br>Contamination: Possible widespread slightly elevated concentrations and locally elevated concentrations<br>Gas generation potential: Dock silt and substantial thickness of organic alluvium/peat |
| High<br><br>4 | Land use: Heavy industry, non-hazardous landfills<br>Contamination: Possible widespread elevated concentrations<br>Gas generation potential: Shallow mine workings Pre 1960s landfill |
| Very High<br><br>5 | Land use: Hazardous waste landfills, gas works, chemical works<br>Contamination: Likely widespread elevated concentrations<br>Gas generation potential: Landfill post 1960 |

4.5.3 Table 4-4 below presents the criteria for assessment of **receptor sensitivity**, showing how for various receptors, a sensitivity value between 1 (Very Low) to 5 (Very High) is assigned using professional judgement.

**Table 4-4 Criteria for classifying receptor sensitivity**

| Classification | Definition |
|---|---|
| Very Low<br><br>1 | Receptor of limited importance<br>• Groundwater: Unproductive strata (strata with negligible significance for water supply or river baseflow) (previously non-aquifer), Secondary B (water-bearing parts of non-aquifers), Secondary undifferentiated (previously minor or non-aquifer, but information insufficient to classify as Secondary A or B)<br>• Surface water: WFD Surface Water status Bad<br>• Ecology: No local designation<br>• Buildings: Replaceable<br>• Human health: Unoccupied/limited access |
| Low<br><br>2 | Receptor of local or county importance with potential for replacement<br>• Groundwater: Secondary A aquifer<br>• Surface water: WFD Surface Water status Poor<br>• Ecology: Local habitat resources<br>• Buildings: Local value<br>• Human health: Minimum score 4 where human health identified as potential receptor |
| Moderate<br><br>3 | Receptor of local or county importance with potential for replacement<br>• Groundwater: Principal aquifer<br>• Surface water: WFD Surface Water status Moderate<br>• Ecology: County wildlife sites, Areas of Outstanding Natural Beauty (AONB)<br>• Buildings: Area of Historic Character<br>• Human health: Minimum score 4 where human health identified as potential receptor |
| High<br><br>4 | Receptor of county or regional importance with limited potential for replacement<br>• Groundwater: Source Protection Zone 2 or 3<br>• Surface water: WFD Surface Water status Good<br>• Ecology: SSSI, National or Marine Nature Reserve (NNR or MNR)<br>• Buildings: Conservation Area<br>• Human health: Minimum score 4 where human health identified as potential receptor |
| Very High | • Receptor of national or international importance<br>• Groundwater: Source Protection Zone (SPZ) 1<br>• Surface water: WFD Surface Water status High<br>• Ecology: Special Areas of Conservation (SAC and candidates), Special Protection Areas (SPA and potentials) or wetlands of international importance (Ramsar)<br>• Buildings: World Heritage site<br>Human health: Residential, open spaces and uses where children are present |

4.5.4 The assigned numerical values for source significance and receptor sensitivity are multiplied together to give a classification of **consequence**, as summarised below:

- Severe – 17 to 25
- Medium – 10 to 16
- Mild – 5 to 9
- Minor – 1 to 4

4.5.5 Probability is assigned a value between Unlikely and High Likelihood. Definitions of likelihood are provided in [20].

4.5.6 The matrix presented below as Table 4-5 is then used to combine the assessed values for probability and consequence.

**Table 4-5 Matrix for classifying risk (combination of probability and consequence)**

| Probability | Consequence | | | |
|---|---|---|---|---|
| | ***Severe*** | ***Medium*** | ***Mild*** | ***Minor*** |
| ***High likelihood*** | Very high | High | Moderate | Moderate/Low |
| ***Likely*** | High | Moderate | Moderate/Low | Low |
| ***Low likelihood*** | Moderate | Moderate/Low | Low | Very low |
| ***Unlikely*** | Moderate/Low | Low | Very low | Very low |
| Note: Where a classification of Moderate/Low is given, professional judgement may be used to assign either a Moderate or Low classification | | | | |

4.5.7 The pathways presented within the below scenario tables do not have a significance assigned to them, instead the pathway is used to inform the professional judgement of the probability.

4.5.8 The Outline FWRA has been conducted for the piling, shaft and trenchless crossing construction methods described in Section 4.2.

## 4.6 Pollution scenarios

4.6.1 The guidance [1] considers the following pollution scenarios with respect to piling and penetrative ground improvement methods:

- Creation of preferential pathways, through a low permeability layer, to cause contamination of groundwater in an aquifer.
- The driving of solid contaminants down into an aquifer during pile driving.
- Contamination of groundwater and subsequently surface waters by turbidity, support fluids, concrete, cement paste or grout.
- Direct contact with contaminated soil or leachate causing degradation of pile materials.
- Creation of preferential pathways to allow migration of landfill gas or contaminant vapours to surface.
- Causing off-site migration of ground gas or increased vertical emissions as a result of vibration or other effects from the pile installation process.
- Direct contact with contaminated soil arisings that have been bought to the surface.

4.6.2 In addition, the potential changes to groundwater flows and levels as a result of construction of the Project, including temporary changes due to dewatering within the proposed shafts during construction have been assessed.

4.6.3 The potential risks associated with each pollution scenario have been assessed utilising a Conceptual Site Model to identify 'source-pathway-receptor' linkages. The assessed risks associated with each pollution scenario are presented in the following sections.

## 4.7 Risk assessment – CFA or other bored cast in-situ piled foundations

### Pollution scenario 1

4.7.1 Pollution Scenario 1 considers the creation of preferential pathways, through a low permeability layer, to cause contamination of groundwater in an aquifer.

4.7.2 The contaminant linkage assessed and the assessed significance of the potential source, pathway and the assessed receptor sensitivity are summarised in Table 4-6.

**Table 4-6 Pollution scenario 1 (piled foundations) - significance of potential contaminant linkage**

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| Source | Landfill Waste | The landfill waste beneath the area within which the WRP is to be constructed extends to a depth of between 8.2 m and 11.5 m bgl (thickness of between 4.7 m and 9.0 m).<br><br>The landfill waste typically comprises glass, paper, wood, plastic, metal, brick, concrete, occasional fabric, rubber, ceramics, ash, and sponge and rarely carpet and steel in a matrix of very soft to soft, black slightly sandy, slightly gravelly clay or grey silty sand. Tyres recorded in TP105 and TP106. Matrix proportion varies from 95% to 10%. 'Waste' odour commonly recorded, occasional hydrocarbon odour. | High (4) |
| Pathway | Pile / soil interface | It is proposed to utilise cast in-situ CFA piles or other form of cast in-situ bored pile. These pile types all form an intimate contact with the surrounding soils, significantly reducing the likelihood (vs., a driven or displacement pile) of the creation of preferential pathways for the migration of contaminants. | - |
| Receptor | Secondary A Aquifer (River Terrace Deposits)<br><br>Principal Aquifer (Chalk)<br><br>Hermitage Stream<br><br>Langstone Harbour | The WRP site is underlain by River Terrace Deposits, designated as a Secondary A Aquifer and chalk, which is designated as a Principal Aquifer. The piled foundations would pass through the River Terrace Deposits and would be socketed within the chalk.<br><br>Langstone Harbour located approximately 200 m south of the WRP site is a tidal inlet of the English Channel. Langstone Harbour is a designated Site of Special Scientific Interest (SSSI), Special Area of Conservation (SAC), Special Protection Area (SPA), a wetland of international importance designated under the Ramsar Convention and a WFD safeguarded Groundwater Dependent Terrestrial Ecosystem (GWDTE). Hermitage Stream is present immediately east of the WRP site and flows south-east into Langstone Harbour. | Secondary A Aquifer – Low (2)<br><br>Principal Aquifer – Moderate (3)<br><br>Hermitage Stream, Langstone Harbour – Very High (5) |

4.7.3 As discussed in Section 2, the limited thickness of silty and occasionally gravelly Alluvium that underlies that waste mass and separates it from the underlying natural deposits is not considered to function as an aquiclude. The landfill is unlined, and therefore piling through the waste mass and into the underlying natural soils is not anticipated to puncture either an artificial or natural low permeability layer.

4.7.4 As the landfill is unlined and operates on the 'dilute and disperse' principle, leachate generated within the landfill retained by the bund wall (of which the WRP site is only one part) is able to migrate out of the landfill via the underlying superficial deposits, to enter the underlying groundwater and subsequently the surrounding water environment. This being the case, the construction of the piles through the landfill waste and into the underlying natural strata is not considered to represent the creation of new preferential pathways for contaminant migration as this pathway is already active across the whole landfill.

4.7.5 The landfill does not benefit from any basal liner or engineering and operates on the 'dilute and disperse' principle. On this basis the proposed piling would not breach a basal liner.

4.7.6 Displacement piles, such as driven or screw piles induce radial or vertical movement or densification of the material surrounding the pile. Replacement piling methods such as CFA piles do not induce these movements and/or densification. CFA techniques also minimise the creation of preferential pathways along the sides of the pile by providing a tight seal to the surrounding soil and reducing permeability at the soil-pile interface due to the placement method of the concrete under pressure.

4.7.7 As stated in [1], "avoidance of disturbance to the surrounding soil requires a high standard of workmanship in the construction process. Reduced support due to poor working practices, however short term, during boring or augering could lead to collapse of soil or piping into the hole, leading to loss of density in the surrounding soil and possibly void formation". Appropriate QA/QC methods would be incorporated into the works to enable workmanship to be monitored and verified.

4.7.8 During CFA piling the boring and placement of concrete is a continuous process meaning that an open, unsupported void is not created as soil is retained on the auger flights to provide support to the surrounding soil until the auger is withdrawn. Following the completion of drilling, the auger is withdrawn and concrete is placed at a rate consistent with the rate of withdrawal of the auger so that the hole is supported. CFA rigs are fully instrumented, meaning that voids, obstructions and resistance caused by the bore interacting with certain waste types (e.g. fabrics) can be identified. 'Flighting' of the auger (i.e. rotation without progress), which may give rise to loss of ground creating potential voids would be addressed within the piling specification with requirements to limit this.

4.7.9 [1] notes that: "*Where a pile is installed through a body of contaminated groundwater or leachate, it is important that free water cannot flow to the aquifer during pile construction … The action of the auger in CFA piles should maintain support of the soil. The short construction period for the piles means the risk is normally low, unless the auger is bored in and left stationary whilst large volumes of contaminated water flow down it*".

4.7.10 Rotary bored piling techniques such as CFA can also use temporary casings to provide stability to the material surrounding the pile bore, as well as acting as a seal pending placement of concrete. This further reduces the risk of creating a preferential pathway to the underlying aquifer. If leachate is identified during drilling this can be removed and disposed of prior to advancing the bore further, reducing the risk of downhole contaminant transport. The bores can be advanced incrementally, to allow a visual check of arisings.

4.7.11 The consequence of contamination, given the nature of the source (landfill waste – High (4)) and sensitivity of the receptor (Langstone Harbour – Very High (5)) is assessed in absence of mitigation measures as **Severe**. Assuming the use of CFA or other cast in-situ piles, a likelihood of Unlikely has been assigned. On this basis, combining a Severe consequence and Unlikely probability as per Table 4-5, the risk of pollution of groundwater with regards to the creation of preferential pathways through low permeability layers is assessed to be **Moderate/Low** and on the basis of the limited presence of low permeability layers beneath the landfill material, and the choice of piling methodology, has been assigned as **Low**.

### Pollution scenario 2

4.7.12 Pollution Scenario 2 considers the driving of solid contaminants down into an aquifer during pile driving.

4.7.13 CFA piles are not a blunt-ended solid or closed-end type of pile, or an open-ended tubular pile that could become 'plugged' and therefore would not push soil down during pile installation.

4.7.14 During CFA piling the ground is supported initially by the auger bore and subsequently by the injected concrete. The placement of the concrete and the withdrawal of the auger are undertaken as a single operation and there is typically no need drilling fluids to support the excavation. In lower competency ground (less than 30 kPa) a casing may be required. As stated in [1] "*Replacement methods, which involve the extraction of the soil prior to placing the pile, will not in normal circumstances lead to soil being dragged downwards. With CFA piling techniques drag down cannot occur as the soil is constantly moved up the auger flights*".

4.7.15 On this basis, further assessment of Pollution Scenario 2 is not required.

### Pollution scenario 3

4.7.16 Pollution Scenario 3 considers the contamination of groundwater and, subsequently, surface water by turbidity, support fluids, concrete, cement paste, or grout.

4.7.17 The contaminant linkage assessed, and the assessed significance of the potential source, pathway and receptor are summarised in Table 4-7 below and the text that follows.

**Table 4-7 Pollution scenario 3 (piled foundations) - significance of potential pollution linkage**

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| Source | Increased turbidity due to drilling and casting of piles – includes particulates from formation and concrete/grout particulates washed into groundwater. | Analysis of settled turbidity production by tunnel boring machines in chalk reported 80% of particles to be less than10.5 µm and 20%, less than 0.1 µm [21], which was attributed to the size of intact coccoliths in the chalk (approximately 10 µm) and fragmentary material, respectively [22] The main particle size of cement is in the range 5 to 30 µm [23]. | High (4) |

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| | Water bleeding from concrete. | Additives are added to concrete to reduce the amount of water used in the mix and reduce the amount of concrete loss and bleed. Mix is to be designed according to appropriate technical guidance. Bleed waters typically have high pH and chloride concentrations. | Low (2) |
| Pathway | Migration within the River Terrace Deposits towards receptors | The River Terrace Deposits typically comprise sandy, slightly clayey, fine to coarse gravel of flint and occasional chalk. These deposits are expected to be highly permeable. | - |
| | Migration within the chalk towards receptors | Chalk is a dual porosity aquifer; the majority of transport occurs within the fractures and fissures. Transport within fractures and fissures is likely to be rapid and can occur over long distances. | |
| Receptor | Secondary A Aquifer (River Terrace Deposits)<br><br>Principal Aquifer (Chalk)<br><br>Hermitage Stream<br><br>Langstone Harbour | The WRP site is underlain by River Terrace Deposits, designated as a Secondary A Aquifer and chalk, which is designated as a Principal Aquifer. The piled foundations would pass through the River Terrace Deposits and would be socketed within the chalk.<br><br>Langstone Harbour located approximately 200 m south of the WRP site is a tidal inlet of the English Channel. Langstone Harbour is a designated SSSI, SAC, SPA, a wetland of international importance designated under the Ramsar Convention and a WFD safeguarded GWDTE (DEFRA, 2023). Hermitage Stream is present immediately east of the WRP site and flows south-east into Langstone Harbour. | Secondary A Aquifer – Low (2)<br><br>Principal Aquifer – Moderate (3)<br><br>Hermitage Stream, Langstone Harbour – Very High (5) |

*Risk assessment – turbidity*

4.7.18 As stated in [1] "By development of a robust conceptual site model (CSM) similar to those used for land contamination risk assessment, the potential risks can be qualitatively assessed. The principles of source, pathway and receptor creating a potential pollutant linkage are similar to those set out in the LCRM guidance [24]. For the piling CSM the greatest emphasis is on the pathways and the source".

4.7.19 The impacts of increased turbidity principally relate to potable water abstractions. As stated in [22] "abstractors of groundwater are required by the Drinking Water Inspectorate to regularly test groundwater for turbidity. The turbidity results are used as a marker for risks from pathogens such as Cryptosporidium and E. coli, which the turbidity test does not differentiate from mineral particles. Therefore, if increased turbidity is detected the operator has to shut down the abstraction until mitigation has been implemented… Additionally, increased turbidity can compromise the disinfection process, and where the abstracted water is treated using membrane filters then the filters can become fouled by the turbidity".

4.7.20 The WRP site is not located within a groundwater SPZ. The nearest such zone, an SPZ 1, is located approximately 400 m to the north, associated with Portsmouth

Water's Bedhampton Springs abstractions. The nearest abstraction point (based upon information provided by Portsmouth Water) is indicated to be located approximately 490 m to the north of the WRP site.

4.7.21 Regional groundwater flow within the chalk bedrock is generally southerly from the elevated chalk hills of the South Downs in the north towards the shallow Langstone Harbour and Solent in the south. The hydraulic heads from the groundwater source in the north result in groundwater flowing beneath the Palaeogene deposits of the Chichester syncline and emerging as springs (such as Bedhampton Springs) to the south of the Chichester syncline. The springs at Bedhampton are located immediately south of the geological boundary between the chalk, and the overlying Lambeth Ground and London Clay Formation, which confine groundwater within the chalk. As stated in [25] "there is rapid and substantial movement of groundwater from the north under the Palaeogene deposits of the Chichester–Bere Forest Syncline to major springs at … Bedhampton".

4.7.22 As described in the Hydrogeological Impact Assessment [26] for the Project:

4.7.23 As described in the Hydrogeological Impact Assessment [26] for the Project:"Chalk is an unusual karst aquifer in that cave development can be limited, but extensive networks of smaller solutional conduits and fissures that enable rapid groundwater flow are present.

4.7.24 Dolines, stream sinks, dissolution pipes and springs are common in chalk bedrock with the Bedhampton and Havant spring complex in Hampshire (within our study area) being one of the best examples of karstic springs in the UK, producing a combined flow rate in the order of 600 – 2,000 l/s [25].

4.7.25 Up to 45 stream sinks have been mapped to the north of the study area in the Horndean and Rowlands Castle areas. These are found in the area close to the boundary between the chalk and Palaeogene formations and are critical point sources of recharge for the aquifer, as there are no permanent streams in the area.

4.7.26 The water that enters the stream sinks is considered to flow through the chalk beneath the Chichester Syncline and then emerge in the Bedhampton and Havant spring complex to the south (circa 5-6 km distance) (Matheson et al, 2019). Tracer testing undertaken in the 1970s indicated significant groundwater velocities in the order of 2-3 km/d and supported the presence of a well-developed conduit system linking the stream sinks north of the Chichester Syncline to the spring complex, with low attenuation and dilution.

4.7.27 Rapid flow has also been detected at Otterbourne [27]. Rapid flow supports the presence of karst features, which has implications for pollution and groundwater quality risks (such as turbidity)"

4.7.28 Information provided by Portsmouth Water shows that the abstractions at Bedhampton Springs are all from springs, which discharge into collection chambers. There are no abstractions from boreholes at Bedhampton Springs. Water required for supply is subsequently pumped to Farlington, whilst excess water flows into the adjacent watercourses.

4.7.29 This is of particular note as, because groundwater naturally flows to the surface and is not pumped from an aquifer at depth, a cone of drawdown around the abstractions would not be present. The WRP site is located some 490 m down hydraulic gradient of Bedhampton Springs. In absence of a cone of drawdown to reverse the groundwater flow direction it is considered highly unlikely that an increase in turbidity of the groundwater in the chalk at the WRP site would be realised at the Bedhampton Springs.

4.7.30 The proposed CFA piles would be socketed into the chalk at depth beneath the WRP site and would therefore be installed beneath the groundwater table. Chalk generally comprises coccoliths, foraminifera and other shell debris, cemented together to lesser or greater degrees. The coccoliths are particularly small, being several micrometres across. Any construction work can result in disintegration of the chalk mass into these fine particles which, when the work is below or close to the groundwater level, has the potential to induce turbidity in groundwater. Due to their small size these particles do not settle quickly and can rapidly migrate through fissures in the aquifer.

4.7.31 CFA and other rotary boring methods are likely to generate turbidity. Rolfe and Speed [22] states "*CFA and other rotary methods are likely to generate turbidity, particularly when operating in rock or fine-grained strata, due to the mechanical action of the rotating parts abrading the rock or soil*". Finer particles would migrate further in an aquifer as they are held in suspension at lower velocities and migrate through smaller pore sizes.

4.7.32 The Lewes Nodular Chalk Formation is a dual porosity aquifer with rapid flow occurring through fracture networks and slower flow through the less porous matrix. The chalk usually has high storage although not always high permeability due to the narrow apertures of the fractures [27]. Numerous fractures were identified in the chalk in the boreholes drilled within the WRP site [28]. It is this stratum from which groundwater is abstracted approximately 490 m to the north-east of the WRP site at Bedhampton Springs.

4.7.33 The River Terrace Deposits typically comprise sandy, slightly clayey, fine to coarse gravel of flint and occasional chalk; these deposits are expected to be highly permeable.

4.7.34 As discussed in Section 2, it is considered that groundwater in the River Terrace Deposits and chalk is only partially confined by the overlying Alluvium. The River Terrace Deposits and chalk are likely to be hydraulically connected and appear to have an unconfined piezometric surface typically between 1.0 m and 2.5 m AOD, i.e., approximately the same as the water level in Langstone Harbour across a tidal cycle.

4.7.35 It is considered likely that the groundwater in the superficial and bedrock aquifers is in at least partial hydraulic connectivity with the surface water in Langstone Harbour. A geophysical investigation of Langstone Harbour undertaken in 1998 [29] concluded that *"the … observed motion of saline intrusion within an area of coastal wetland has been shown to be out of phase with the tidal cycle in some places and in phase in others. The main areas of in-phase influx are within buried channels, surface inlets and at the coastal front. Out-of-phase influx has been identified in several locations and is attributed to relatively low lateral permeability along shallow conduits*".

4.7.36 It is considered to be Likely that an increase in turbidity within the groundwater beneath the WRP site would occur as a result of the construction of the proposed CFA piles. However, it is considered Unlikely that this increase in turbidity would be realised, to a measurable extent, within Langstone Harbour or at Bedhampton Springs. By combining a Medium consequence and Likely probability, as per Table

4.5, the associated risk of increasing turbidity in the aquifers beneath the WRP site is assessed to be **Moderate**.

4.7.37 The consequence of contamination, given the nature of the source (increased turbidity due to drilling and casting of piles – High (4)) and sensitivity of the receptor (Secondary A and Principal Aquifers and Bedhampton Springs public water supply abstractions, Langstone Harbour SSSI, SPA, SAC, Ramsar site etc. - Very High (5)) is assessed as Severe. By combining a Severe consequence and Unlikely probability, as per Table 4-5, the associated risk of increasing turbidity within Langstone Harbour is assessed to be **Moderate/Low** and on the basis of the almost negligible likelihood of the potential turbidity increases being realised at the Bedhampton Springs abstractions, has been assigned as **Low**. It is considered likely that the groundwater in the superficial and bedrock aquifers is in at least partial hydraulic connectivity with the surface water in Langstone Harbour. A geophysical investigation of Langstone Harbour undertaken in 1998 [29] concluded that "the … observed motion of saline intrusion within an area of coastal wetland has been shown to be out of phase with the tidal cycle in some places and in phase in others. The main areas of in-phase influx are within buried channels, surface inlets and at the coastal front. Out-of-phase influx has been identified in several locations and is attributed to relatively low lateral permeability along shallow conduits".

*Risk assessment – loss of high pH and high chloride water from concrete*

4.7.38 The piles would be socketed into the chalk at depth beneath the WRP site and would therefore be installed beneath the groundwater table. Concrete bleeding in bored piles occurs as the fresh concrete is subject to high head pressures resulting in high pore-water pressures inside the fresh concrete matrix, which can be much higher than the pore-water pressures in the surrounding soil, which can cause water to be forced out of the fresh concrete matrix into the soil matrix and vertically upwards within the bore itself (Martin D. Larisch, September 2019) with the area of bleed often located at the bottom of the pile.

4.7.39 The concrete mix composition has not yet been designed, however Clause 1604.7 of the Specification for Highway Works [30] requires that "*the concrete shall be designed so that segregation does not occur during the placing process, and bleeding of the concrete shall be minimised*". There are currently no specific requirements in the specification to control bleed but Clause B21.5.4 of the ICE Pile Specification allows for determination of bleed in accordance with the test recommended by the Concrete Institute of Australia (CIA). The CIA recommended practice [31] gives an acceptance criterion of 15 L/$m^3$. The preliminary pile design assumes a pile diameter of 450 mm, giving a potential concrete volume (for an assumed 20 m pile) of approximately 3.2 $m^3$ and a corresponding bleed volume of about 48 L per pile (~3.2 x 15). Approximately 3,200 piles are indicated to be required, giving a total potential bleed volume of 150,000 L or 150 $m^3$.

4.7.40 [32] indicates that a suitable specification of the fine/medium sand content, water/cement ratio and admixtures would effectively restrict bleeding. The suitability of any additives added to the concrete mix to promote fast-curing should be confirmed with the EA.

4.7.41 The piling contractor would also be required to specify the concrete mix to prevent bleed as far as is reasonably practicable. It is anticipated that this would be done by default as the piling contractor would (for cost reasons) wish to minimise concrete loss.

4.7.42 As discussed above, saline intrusion into the chalk aquifer beneath the WRP site is likely to be occurring within Langstone Harbour. Saline waters are, by their nature, enriched in sodium and chloride and Langstone Harbour is a saline tidal inlet.

4.7.43 It is considered to be Likely that an increase in pH and chloride concentrations within the groundwater beneath the WRP site would occur as a result of drilling or casting of piles. It is considered Unlikely, however, that this increase in pH and chloride concentrations would be realised within Langstone Harbour.

4.7.44 Whilst there is assessed to be a likely partial connectivity between Langstone Harbour and the chalk aquifer, it is likely that the migration pathway is predominantly one-directional, with saline water entering the aquifer. On this basis, it is considered Unlikely that an increase in chloride concentrations or pH within Langstone Harbour would result from the drilling activities.

4.7.45 For the aquifers beneath the WRP site, the consequence of contamination, given the nature of the source (increased pH and chloride concentrations resulting from concrete bleed – Low (2)) and sensitivity of the receptor (Secondary A and Principal Aquifers (Moderate - 3) is assessed as Mild. By combining a Mild consequence and Likely probability, as per Table 4-5, the associated risk of increased pH and chloride concentrations within the aquifers beneath the WRP site is assessed to be **Moderate/Low** and on the basis of the use of cast-in site CFA piles that piles would be purposefully extended into the chalk aquifer, has been assigned as **Moderate**.

4.7.46 For Langstone Harbour, the consequence of contamination, given the nature of the source (increased pH and chloride concentrations resulting from concrete bleed – Low (2)) and sensitivity of the receptor (Langstone Harbour SSSI, SPA, SAC, Ramsar site etc. - Very High (5) is assessed as Medium. By combining a Medium consequence and Unlikely probability, as per Table 4-5, the associated risk of increased pH and chloride concentrations within the Langstone Harbour is assessed to be **Low**.

## Pollution scenario 4

4.7.47 Pollution Scenario 4 considers the direct contact of the piles or engineered structures with contaminated soil or leachate causing degradation of pile materials (where the secondary effects are to increase the potential for contaminant migration).

4.7.48 The contaminant linkage assessed, and the assessed significance of the potential source, pathway and receptor are summarised in Table 4-8.

Table 4-8 Pollution scenario 4 (piled foundations) - significance of potential contaminant linkage

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| Source | Landfill waste and landfill leachate.<br><br>Sulphate-rich groundwater | 47 No. chloride concentrations in groundwater samples (carried out as part of the geo-environmental testing suites) gave values between 28 and 2900 mg/l. Six tests were carried out on samples of water obtained directly from the Hermitage Stream; five of these gave values between 120 and 740 mg/l, and one during high tide | High (4) |

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| | | gave a more extreme value of 11,000 mg/l (although this is unlikely to be characteristic of the WRP site, which is in-land and separated from the Hermitage Stream by a sheet piled wall). This information indicates that groundwater below the WRP site is not strongly saline and therefore BRE SD1 guidance applies (valid for freshwater and brackish conditions up to around 12,000 to 17,000 mg/l chloride content).<br><br>The preliminary concrete design classifications are as follows:<br><br>Made Ground – Cover Soils – DS-2, ACEC-2<br>Made Ground – Landfill Waste – DS-4, ACEC-4<br>Alluvium, DS-4, ACEC-4<br>Raised Marine / River Terrace Deposits – DS-1, ACEC-1<br>Chalk – DS-1, ACEC-1<br><br>Free phase hydrocarbons were not encountered. | |
| Pathway | Direct pile/soil contact | Direct contact with surrounding soils, landfill leachate and groundwater. Cast in-situ piles form an intimate contact with the surrounding soils. | - |
| Receptor | Foundation piles | To be designed using an appropriate concrete class as per the findings of the ground investigations. | High (4) |

4.7.49 The principal implications of aggressive ground conditions affecting piling at the WRP site are as follows:

- Limitation in the choice of piling methods (including for any remedial works to replace damaged piles during the operational phase).
- Degradation of pile materials leading to an increase in permeability of the piles, creating migration pathways.
- Reaction with pile materials causing a failure to cure, affecting both structural and environmental performance.

*Piling methodology choice*

4.7.50 As previously stated, cast in-situ CFA piles are the preferred choice as this method allows ‘intimate contact’ between the pile and the surrounding landfill waste, minimising the risk of creating pathways for contamination to migrate into the underlying chalk and adjacent surface waters.

*Degradation of pile materials*

4.7.51 Concrete in contact with contaminated soils, leachate or groundwater may be subject to chemical attack, resulting in degradation of the concrete. Such degradation could reduce the effectiveness of the seal between the pile and surrounding ground resulting in pathways to open along the soil/pile interface, increasing the risk of pollution scenarios 1 and 5. In particularly aggressive scenarios, degradation of concrete can cause structural weakness leading to long term settlement or eventual collapse of structures.

4.7.52 An assessment of measured concentrations of naturally occurring sulphates and acids is presented in [4]. Overall, it is recommended that a Design Sulphate Class DS-2 and ACEC class AC-2 is likely to be appropriate for the majority of the buried concrete, noting that the recommendations of BRE (2017) should be followed in the design of mixes for buried concrete for the classifications given.

4.7.53 BS EN 206:2013 + A2:2021 notes that water with a dissolved ammonium content of between 60 mg/l and 100 mg/l is classified as a "*highly aggressive chemical environment*", also referred to as XA 3 conditions. The results of testing undertaken on groundwater and landfill leachate samples recovered from the WRP site boreholes indicated ammonium concentrations of up to 240 mg/l. An appropriate concrete design for XA 3 conditions, in accordance with the limiting value for composition and properties of concrete as shown in Table F.1 of BS EN 206:2013 + A2:2021, should be adopted. It is noted that these results are those from the geo-environmental laboratory analyses undertaken as part of the ground investigations at the WRP site. Whilst the laboratory analyses of ammonium is UKAS and MCERTS accredited, it was via an in-house method based on "*Examination of Water and Wastewater – 20$^{th}$ Edition, Clesceri, Greenberg and Eaton*" not the method specified in ISO 7150-1 as specified by Table 2 of BS EN 206:2013 + A2:2021.

4.7.54 In relation to chloride attack BRE SD1 [33] states "*the levels of chloride found in the ground are generally chemically innocuous; indeed, they may be beneficial since there is considerable evidence, from seawater studies, that the presence of chloride generally reduces sulphate attack … high chloride concentrations in the ground will increase the risk of corrosion since chloride ions may migrate into the concrete and lead to a reduction in passivity at the metal surface. The recommendations for the protection of steel reinforcement in BS 8500-1 should be followed*". Given the WRP site's coastal location and the presence of tidally influenced groundwater, the design of the concrete and reinforcement would also be undertaken with reference to BS 6349-1 (Maritime Works) and BS 8500-1 (Concrete. Complementary British Standard to BS EN 206 - Method of specifying and guidance for the specifier) as recommended by [33].

4.7.55 As stated in [1] "*Wilson et. al, (2001) conducted tests to investigate the effect of* hydrocarbon contamination on foundation concrete. The results indicate that petroleum hydrocarbons reduce the long term strength gain of concrete by up to 25%. This can be allowed for in design, thus avoiding the need for expensive sleeving or surface protection systems. Available evidence suggests that the effects of petroleum hydrocarbons on hardened concrete, which has achieved its design strength, are of limited concern". On this basis and given the typically limited petroleum hydrocarbon concentrations encountered within the landfill (with the exception of two samples of the landfill material with petroleum hydrocarbon concentrations of 11,589 mg/kg and 9,850 mg/kg), it is considered that degradation of pile materials due to hydrocarbon attack is unlikely.

*Inhibition of curing*

4.7.56 Organic compounds, notably phenols, can affect the setting of concrete through an inhibition or medication of the hydration of the cement [33] and [34]. BRE report BR

255 [35] states that "*hydrocarbons such as petrol, petroleum distillates in general, and lubricating oils that are entirely of mineral origin, do not attack concrete*". In relation to phenols [34] states the main effect of phenol upon concrete may be "*inhibition or modification of the hydration process*" rather than chemical attack on the hardened cement paste.

*4.7.57* [34] further notes that "*it is difficult to say what the relationship might be between a concentration in soil and the concentration in groundwater in contact with the soil, but it should be noted that phenol is soluble and, in general, a given soil-concentration implies a higher concentration in the liquid phase. Concentrations of up to 250 mg/l have been reported in groundwater from gasworks*".

4.7.58 The concentrations of the majority of phenol compounds analysed (as recorded in [28]) within the groundwater were below the laboratory method detection limit (148 out of 164 analyses), and where concentrations in excess of the laboratory method detection limit were recorded (16 out of 164 analyses), the concentrations ranged between 1.3 µg/l and 36 µg/l, with a maximum concentration of total monohydric phenols of 63 µg/l.

4.7.59 The literature reviewed does not provide any indication of the phenol concentrations required to initiate inhibitory effects upon concrete curing. The tests upon freshly cured concrete presented in [34] used phenol solutions of concentrations between 1000 mg/l and 25,000 mg/l to provide conditions analogous to gasworks sites, i.e., an environment where adverse effects upon concrete foundations have historically been recognised. Over a period of two years, concrete immersed in the strongest phenol solutions showed reductions in strength of up to 20% relative to a control sample. The dissolved phenol concentrations at the WRP site are approximately five to six orders of magnitude lower than the concentrations used by [34], and on this basis it is anticipated that significant inhibition of curing or attack by phenol is Unlikely.

*Risk assessment*

4.7.60 The consequence of contamination, given the nature of the source (High - 4) and sensitivity of the receptor (High - 4) is assessed as Medium. Assuming the use of an appropriate concrete mix, the probability of degradation of in-ground concrete due to attack by aggressive chemicals, hydrocarbons or naturally occurring sulphates and acids is assessed to be Unlikely.

4.7.61 By combining a Medium consequence and Unlikely probability, as per Table 4-5, the associated risk of degradation of pile materials and the associated creation of new pathways is assessed to be **Low**.

### Pollution scenario 5

4.7.62 Pollution Scenario 5 considers the potential for creation of preferential pathways to allow upward migration of landfill gas or contaminant vapours to the surface.

4.7.63 The contaminant linkage assessed, and the assessed significance of the potential source, pathway and receptor are summarised in Table 4-9.

**Table 4-9 Pollution scenario 5 (piled foundations) - significance of potential contaminant linkage**

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| Source | Potentially hazardous ground gases | The assessment undertaken [4] shows that the ground gas regime at the WRP site should be classified as Characteristic Situation (CS) 3. Whilst CS2 conditions are typically prevalent, CS3 conditions have been recorded in four boreholes, and within one of these borehole CS3 conditions were prevalent for approximately 15% of the monitoring period.<br><br>It is considered that a classification of CS3 is appropriate and suitably (but not overly) precautionary. | High (4) |
| Pathway | Pile / oil interface | The landfill does not benefit from an engineered cap.<br><br>In the existing scenario landfill gases vent directly to the atmosphere.<br><br>The proposed piled foundations do not therefore alter the existing pathway. | - |
| Receptor | End Users Construction Workers | The critical receptor is workers constructing or working at the proposed WRP. | High (4) |

4.7.64 Pollution Scenario 5 relates specifically to the creation of preferential pathways for gas migration as a result of piling.

4.7.65 As stated in [1]:

4.7.66 "*The only situation where gas migration may potentially be enhanced by piles other than H or I piles is where driven or bored piles penetrate a stiff over consolidated clay layer that is very thin (thickness less than two pile diameters) at shallow depth and that covers a gas source under pressure*".

*4.7.67* "*In most sites in the UK where diffusive flow of gas through the ground will be dominant (i.e. the gas source is not recent landfill or mine workings), large displacement-driven piles or replacement piles will not cause preferential pathways for ground gas migration. This assumes the piles are constructed with reasonable standards of workmanship and quality assurance in appropriate ground conditions (e.g. obstructions will not damage driven tube piles).* [19] *advised that there is no reason to increase the category of risk associated with ground gas, or the characteristic situation (CS) in BS 8485 … because piled foundations are being used.*"

4.7.68 The landfill within the WRP site does not benefit from a low permeability capping layer and is not a recent landfill. The landfill within the WRP site is not assessed to be a high-pressure source as the borehole pressure, as recorded during the continuous monitoring, closely tracked the atmospheric pressure indicating that the cover soils are suitably permeable such that pressure changes are rapidly conveyed through the cover and into the fill. In this regard, construction of piled foundations does not alter the existing gassing regime whereby gases are expected to vent to atmosphere through the cover soils.

*4.7.69* [1] further notes: "*replacement piles installed to reasonable standards of workmanship should not cause disturbance of the surrounding soil and provided that the pile is formed or placed in intimate contact with the surrounding soil, there should be no formation of preferential pathways for upward gas migration, except where the clay layer is less than two pile diameters in thickness and the gas below is under pressure*"*.*

4.7.70 During piling works, there is an increased risk of site workers being exposed to landfill gases, which can migrate to the surface via the pile bore prior to placement of concrete. As on all potentially contaminated sites, extra precautions should be taken to comply with the relevant health and safety legislation and guidance. The piling contractor's risk assessment and method statement would need to address all issues in relation to potential exposure to ground gases during construction.

4.7.71 The consequence of contamination, given the nature of the source (landfill gases – High (4)) and sensitivity of the receptor (human health – end users – High (4)) is assessed as Medium. Assuming the use of CFA (or other cast-in situ bored pile), the likelihood of gas migration along a preferential pathway at the pile/soil interface is assigned as Unlikely. By combining a Medium consequence and Unlikely probability, as per Table 4-5, the associated risk of creation of preferential pathways to allow upward migration of landfill gas to the surface is assessed to be **Low.**

4.7.72 It is noted that the risk assessed above relates specifically to migration along a preferential pathway created by piling. A wider gas hazard exists where gases currently migrate upwards through the cover soils. Mitigation of the assessed landfill gas hazard is described in the outline remediation strategy presented in [4].

4.7.73 As described in [4], gas protection measures suitable for a site characterised as Characteristic Situation (CS) 3 should be constructed as part of the Project where enclosed habitable spaces are to be constructed. The protection measures should comprise at least two of the three elements below:

- The structural barrier of the floor slab, or of the basement slab and walls if a basement is present.
- Ventilation measures.
- Gas resistant membrane.

4.7.74 During construction it is anticipated that landfill gases are only likely to present a hazard to human health in areas where gases could accumulate, e.g., in trenches or excavations. Appropriate health and safety management during construction, e.g., managing gaseous hazards through the use of safe methods of working in confined spaces, would provide mitigation against the construction phase human health hazard.

## Pollution scenario 6

4.7.75 Pollution Scenario 6 considers causing of off-site migration of ground gas or increased vertical emissions as a result of vibration or other effects from the pile installation process.

*4.7.76* As stated in [1] "*Replacement piling methods will not cause disturbance of the ground sufficient to cause off site migration of gas*"*.*

4.7.77 On this basis, further assessment of Pollution Scenario 6 is not required.

## Pollution scenario 7

4.7.78 Pollution Scenario 7 considers direct contact of site workers and others with contaminated soil arisings, which have been brought to the surface.

4.7.79 CFA and other bored piles would generate arisings at the surface, which would include potentially contaminated landfill waste.

4.7.80 The contaminant linkage assessed, and the assessed significance of the potential source, pathway and receptor are summarised in Table 4-10.

**Table 4-10 Pollution Scenario 7 (Piled Foundations) - Significance of Potential Contaminant Linkage**

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| Source | Contaminated soil arisings | The landfill waste beneath the area within which the WRP is to be constructed extends to a depth of between 8.2 m and 11.5 m bgl (thickness of between 4.7 m and 9.0 m).<br><br>The landfill waste typically comprises glass, paper, wood, plastic, metal, brick, concrete, occasional fabric, rubber, ceramics, ash, and sponge and rarely carpet and steel in a matrix of very soft to soft, black slightly sandy, slightly gravelly clay or grey silty sand. Tyres recorded in TP105 and TP106. Matrix proportion varies from 95% to 10%. ‘Waste’ odour commonly recorded, occasional hydrocarbon odour.<br><br>In the cover soils, the identified human health hazards in the solid phase are limited to asbestos, which was visually identified in one exploratory hole and detected by the laboratory in 2 out of 33 samples, and marginally elevated (vs. the GAC for a commercial / industrial end use) concentrations of PAHs, which were recorded in one sample only.<br><br>In the waste mass, the identified human health hazards in the solid phase are principally limited to asbestos, which was detected by the laboratory in 14 of the 50 samples analysed. Concentrations of metals, petroleum hydrocarbons, BTEX, VOCs and SVOCs were below the adopted GAC in all samples analysed. Concentrations of PAHs were below the adopted GAC in all but one of the samples analysed.<br><br>There were no recorded exceedances of the commercial/industrial GAC within the natural soils. | High (4) |
| Pathway | Contact with excavated arisings | It is proposed to utilise cast in-situ CFA piles (or other form of cast in-situ bored pile. These pile types bring to the surface a volume of soil and there is a potential for contact with the excavated arisings. | - |
| Receptor | Construction Workers | The critical receptor is construction workers undertaking the piling works. | High (4) |

4.7.81 The identified hazards to human health [4] comprise asbestos and PAHs. The GAC used to define these hazards relate to a commercial / industrial end use scenario.

These criteria are used to assess chronic risk to a worker's health over a period of multiple years and are not strictly applicable to the acute, short-term risk associated with exposure to pile arisings over a period of weeks.

4.7.82 The identified hazards to human health [4] comprise asbestos and PAHs. The GAC used to define these hazards relate to a commercial / industrial end use scenario. These criteria are used to assess chronic risk to a worker's health over a period of multiple years and are not strictly applicable to the acute, short-term risk associated with exposure to pile arisings over a period of weeks.The Society of Brownfield Risk Assessment (SoBRA) has prepared acute GAC (AGAC) for the assessment of acute risks of exposure to arsenic, benzene, cadmium, free cyanide, phenol, trichloroethylene (TCE) and vinyl chloride. The AGAC for Adult (construction worker) scenario, lower of either oral or inhalation criteria presented: arsenic = 7,000 mg/kg, benzene = 370 mg/kg, cadmium = 12,000 mg/kg, free cyanide = 1,400 mg/kg, phenol = 175,000 mg/kg, TCE = 33,000 mg/kg, vinyl chloride = 220 mg/kg. The AGAC consider "*occupational exposure during construction, remediation or site investigation"* and focus on "*a worker coming into direct contact with soil contaminants or inhaling dusts or vapours arising from the excavation of contaminated soils"*…"*with exposure over the working day as the duration"*. A review of the results of the geo-environmental laboratory results indicates that there are no exceedances of the AGAC.

4.7.83 Asbestos was encountered in approximately 20% of the samples of the cover soils and landfill waste analysed. On this basis the consequence of contamination, given the nature of the source (landfill waste – High (4)) and sensitivity of the receptor (construction workers – High (4)) is assessed as Medium, with a likelihood of realising this linkage (in absence of mitigation) being Likely. By combining a Medium consequence and Likely probability as per Table 4-5, The associated risk is assessed to be **Moderate**.

4.7.84 It is noted that this risk is assessed in absence of any mitigation. Mitigation of the assessed hazards to human health during the construction phase is described in the outline remediation strategy presented in [4].

4.7.85 In line with current regulations (such as the Construction (Design and Management) Regulations, 2015) and best practice, appropriate protective clothing and equipment would be worn by site workers; and good standards of hygiene adopted to prevent prolonged skin contact, inhalation and ingestion of soils during construction, whilst appropriate methods of working would be selected to limit the potential for air-borne dust to arise associated with the excavation and disturbance of the soils present on the WRP site.

4.7.86 The inclusion of mitigation measures does not alter the sensitivity of the receptor or the magnitude of the hazard (i.e., the consequence) but does reduce the likelihood of the risk being realised to Unlikely. Including mitigation measures, the associated risk is assessed to be **Low**.

## Additional considerations

4.7.87 In addition to the pollution scenarios considered above, the potential changes to groundwater flows and levels as a result of construction of the proposed piled foundations have been considered.

4.7.88 On the basis that the volume of piles to be introduced into the ground is relatively low and there are no continuous ‘barriers’ to groundwater flow proposed, changes to the groundwater regime are expected to be negligible. Therefore, no further assessment for piled foundations is required.

## 4.8 Risk assessment – shafts

### Pollution scenario 1

4.8.1 Pollution Scenario 1 considers the creation of preferential pathways, through a low permeability layer, to cause contamination of groundwater in an aquifer.

4.8.2 The contaminant linkage assessed and the assessed significance of the potential source, pathway and receptor are summarised in the Table 4-11. The assessment has been undertaken on a ‘worst-case’ basis and applies to both the WRP site and the Budds Farm Shaft site.

**Table 4-11 Pollution scenario 1 (shafts) - significance of potential contaminant linkage**

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| Source | Landfill Waste (WRP site) and Made Ground (Budds Farm Shaft site) | The landfill waste beneath the area within which the WRP is to be constructed extends to a depth of between 8.2 m and 11.5 m bgl (thickness of between 4.7 m and 9.0 m).<br><br>The landfill waste typically comprises glass, paper, wood, plastic, metal, brick, concrete, occasional fabric, rubber, ceramics, ash, and sponge and rarely carpet and steel in a matrix of very soft to soft, black slightly sandy, slightly gravelly clay or grey silty sand. Tyres recorded in TP105 and TP106. Matrix proportion varies from 95% to 10%. ‘Waste’ odour commonly recorded, occasional hydrocarbon odour.<br><br>The Made Ground at the Budds Farm Shaft site extends to between approximately 2.2 m and 5.0 m bgl and comprises an upper gravelly clay (gravel of chert, concrete and brick) overlying a gravelly sand (gravel of chert, slag, coal, tile, wood and glass) overlying a basal gravelly clay (gravel of chert with occasional glass, brick and concrete).<br><br>It is anticipated that the shaft would be sunk from the ‘lower’ ground level in the area and would therefore seek to avoid disturbance of the majority of the Made Ground that sits above this level. | High (4) |
| Pathway | Shaft / soil interface | All proposed shafts extend down through the Landfill Waste and Made Ground, Quaternary Superficial Deposits and into the chalk bedrock below.<br><br>The current proposed construction method promotes intimate contact between the shaft and the surrounding soil, preventing the creation of preferential pathways for | |

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| | | contaminant migration. | |
| Receptor | Secondary A Aquifer (Alluvium and River Terrace Deposits/Raised Marine Deposits)<br><br>Principal Aquifer (Chalk)<br><br>Hermitage Stream<br><br>Langstone Harbour | The WRP site is underlain by River Terrace / Raised Marine Deposits, designated as a Secondary A Aquifer.<br><br>The Budds Farm Shaft site is underlain by Alluvium and River Terrace Deposits, also designated as Secondary A Aquifer. The chalk at depth beneath both the WRP site and the Budds Farm Shaft site is designated as a Principal Aquifer.<br><br>The piled foundations would pass through the River Terrace Deposits and would be socketed within the chalk.<br><br>Langstone Harbour is located approximately 200 m south of the WRP site and approximately 70 m west of the Budds Farm Shaft site and is a tidal inlet of the English Channel. Langstone Harbour is a designated SSSI, SAC, SPA, a wetland of international importance designated under the Ramsar Convention and a WFD safeguarded GWDTE.<br><br>Hermitage Stream is present between the WRP site and the Budds Farm Shaft site and flows south-east into Langstone Harbour. | Secondary A Aquifer – Low (2)<br><br>Principal Aquifer – Moderate (3)<br><br>Hermitage Stream, Langstone Harbour – Very High (5) |

4.8.3 As discussed in Section 2, the limited thickness of silty and occasionally gravelly Alluvium that underlies that waste mass and separates it from the underlying natural deposits is not considered to function as an aquiclude. The landfill is unlined, and therefore construction of the shafts through the waste mass and into the underlying natural soils is not anticipated to penetrate either an artificial or natural low permeability layer.

4.8.4 As the landfill is unlined and operates on the ‘dilute and disperse’ principle, leachate generated within the landfill (of which the WRP site occupies only one part) is able to migrate out of the landfill via the underlying superficial deposits, to enter the underlying groundwater and subsequently the surrounding water environment.

4.8.5 Details of the proposed shaft construction method are included in Section 4.2. Factors relevant to this Pollution Scenario are summarised in this section.

4.8.6 All proposed shafts would extend down through the Landfill Waste, Quaternary Superficial Deposits and into the chalk bedrock below. Theoretically there is potential for new contamination pathways to form along the shaft/ soil interface: however, the proposed construction methods result in intimate contact between the shaft walls and surrounding soil, preventing pathways from forming.

4.8.7 The proposed cut-off walls are formed by deep, mechanical mixing of soil with cement and water that is injected in situ, therefore preventing void formation. They also stabilise the ground around the proposed diaphragm wall and would prevent instability of the trench. A stable trench would lead to smooth-sided diaphragm walls, thus enabling close contact between the poured concrete and the surrounding soils.

4.8.8 Within the deep soil mixing cut off wall, the main diaphragm wall (primary lining) would be constructed down to the base depth of the shaft (i.e., through the natural soils). A grab excavator would be used to form the trench for each wall 'panel', with bentonite slurry used to keep the excavation open and stable prior to concrete pouring, again ensuring smooth-sided diaphragm walls. Reinforcement cages would also be installed prior to concrete pouring, limiting the possibility of post-construction movement and void creation. Finally concrete would be poured into the excavation, filling voids and forming intimate contact with the surrounding soil.

4.8.9 The consequence of contamination, given the nature of the source (landfill waste – High (4)) and sensitivity of the receptor (Langstone Harbour – Very High (5)) is assessed in absence of mitigation measures as Severe. On the basis of the proposed outline construction methodology, a likelihood of Low has been assigned.

4.8.10 By combining a Severe consequence and Low probability as per Table 4-5, the risk of pollution of groundwater with regards to the creation of preferential pathways through low permeability layers is assessed to be **Moderate**.

4.8.11 The 'low permeability' layer between the landfill waste and the underlying aquifers comprises Alluvium described as "gravelly silt". The boundaries between the Alluvium and the underlying River Terrace / Raised Marine Deposits are also poorly defined, with regular mixing / grading between the strata recorded. Whilst the Alluvium is undoubtedly of lower permeability than the River Terrace / Raised Marine Deposits, it is not considered to be 'low permeability' in the sense that it is functioning as an aquiclude, preventing the downwards migration of water into the underlying strata.

4.8.12 Whilst a **Moderate** risk of pollution of groundwater with regards to the creation of preferential pathways has been identified, it should be remembered that the landfills beneath (and to the south and west of) the WRP site and to the south and west of the Budds Farm Shaft site operate on the 'dilute and disperse' principle, where migration of leachate out of the landfill into the surrounding groundwater is the expected behaviour. On this basis, a **Moderate** risk is not considered to represent an increased risk relative to the existing condition (i.e., negligible impact beyond the existing scenario).

## Pollution scenario 2

4.8.13 Pollution Scenario 2 considers the driving of solid contaminants down into an aquifer during construction.

4.8.14 The contaminant linkage assessed, and the assessed significance of the potential source, pathway and receptor are summarised in Table 4-12. The assessment has been undertaken on a 'worst-case' basis and applies to both the WRP site and the Budds Farm Shaft site.

**Table 4-12 Pollution scenario 2 (shafts) - significance of potential contaminant linkage**

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| Source | Landfill Waste | The landfill waste beneath the area within which the | High (4) |

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| | | WRP is to be constructed extends to a depth of between 8.2 m and 11.5 m bgl (thickness of between 4.7 m and 9.0 m).<br><br>The landfill waste typically comprises glass, paper, wood, plastic, metal, brick, concrete, occasional fabric, rubber, ceramics, ash, and sponge and rarely carpet and steel in a matrix of very soft to soft, black slightly sandy, slightly gravelly clay or grey silty sand. Tyres recorded in TP105 and TP106. Matrix proportion varies from 95% to 10%. 'Waste' odour commonly recorded, occasional hydrocarbon odour.<br><br>The Made Ground at the Budds Farm Shaft site extends to between approximately 2.2 m and 5.0 m bgl and comprises an upper gravelly clay (gravel of chert, concrete and brick) overlying a gravelly sand (gravel of chert, slag, coal, tile, wood and glass) overlying a basal gravelly clay (gravel of chert with occasional glass, brick and concrete).<br><br>It is anticipated that the shaft would be sunk from the 'lower' ground level in the area and would therefore seek to avoid disturbance of the majority of the Made Ground that sits above this level. | |
| Pathway | Physical driving downwards of material during construction works. | All proposed shafts extend down through the Landfill Waste and Made Ground into the chalk bedrock below.<br><br>The current proposed construction method for shafts is a non-displacement method, preventing solid contaminants from being pushed down into the aquifer. | - |
| Receptor | Secondary A Aquifer (Alluvium and River Terrace Deposits/Raised Marine Deposits)<br><br>Principal Aquifer (Chalk) | The WRP site is underlain by River Terrace/Raised Marine Deposits, designated as a Secondary A Aquifer. The Budds Farm Shaft site is underlain by Alluvium and River Terrace Deposits, also designated as Secondary A Aquifers. The chalk at depth beneath both the WRP site and the Budds Farm Shaft site is designated as a Principal Aquifer. The shafts would extend into the chalk. | Secondary A Aquifer – Low (2)<br><br>Principal Aquifer – Moderate (3) |

4.8.15 All proposed shafts extend down through the Landfill Waste into the chalk bedrock below; however, the proposed shaft construction is by non-displacement methods, which eliminate the downwards displacement of solid landfill waste and Made Ground. As noted in [1] "*penetrative ground improvement methods involve horizontal displacement and densification of the soil through which the column is constructed. In normal circumstances this will not lead to soil being dragged downwards*".

4.8.16 The proposed shafts include two cut-off walls; a diaphragm wall and a secondary lining. The cut off walls reach the base of the landfill waste and are formed by mechanical mixing of soil with a cementitious binder, which is injected in situ. The mechanical rotor mixes soils laterally and would not force material downwards towards the aquifer.

4.8.17 The proposed diaphragm walls would be formed using a grab excavator, which extracts solid waste and brings it to the surface and does not push material downwards.

4.8.18 The shaft and inner cut-off wall inside the diaphragm wall are excavated by mechanical means, again bringing solid waste to the surface and not pushing material deeper.

4.8.19 Finally, the secondary lining would be cast-in-situ and only be formed after the shaft has been excavated.

4.8.20 The consequence of contamination, given the nature of the source (landfill waste (4)) and sensitivity of the receptor (Secondary A and Principal Aquifers, maximum (3)) is assessed as Medium.

4.8.21 By combining a Medium consequence and Low probability, as per Table 4-5, the associated risk of driving of solid contaminants down into an aquifer during shaft construction is assessed to be **Moderate/Low** and on the basis that the underlying aquifer materials would themselves be removed to progress the shaft construction, this risk has been assigned as **Low**.

### Pollution scenario 3

4.8.22 Pollution Scenario 3 considers the contamination of groundwater and subsequently surface waters by turbidity, support fluids, concrete, cement paste, or grout.

4.8.23 The contaminant linkages assessed, and the assessed significance of the potential source, pathway and receptor are summarised in Table 4-13 and the text that follows. The assessment has been undertaken on a ‘worst-case’ basis and applies to both the WRP site and the Budds Farm Shaft site.

**Table 4-13 Pollution scenario 3 (shafts) - significance of potential contaminant linkage**

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| Source | Increased turbidity due to cut off wall and diaphragm wall installation. | The use of deep soil mixing would be limited to the Made Ground (cover soils) and landfill waste only. Increased turbidity of the perched water / landfill leachate may result from the mixing and stabilisation processes. It is anticipated that the majority of increased turbidity would be limited to the perched water / landfill leachate in the waste mass, noting that this could migrate laterally to surface waters and vertically to the underlying superficial and bedrock aquifers.<br><br>Further turbidity increases could occur as a result of physical disturbance of soils during the vertical grab excavation process undertaken as part of the diaphragm wall installation as well as any losses of | High (4) |
| | Water bleeding from concrete. | | Low (2) |
| | Excess dispersal of fissure grout and leaching of contaminants into groundwater. | | High (4) |

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| | Bentonite breakout from excavation trench and leaching of contaminants into groundwater. | bentonite mud used to maintain excavation stability beneath the base of the cut-off wall. These impacts are anticipated to be limited to groundwater within the Alluvium / Raised Marine / River Terrace Deposits, and the underlying chalk.<br><br>Water with a high pH and chloride content may bleed from concrete in the cut off wall/ diaphragm wall into groundwater. Additives can be added to concrete to reduce amount of water used in the mix and thereby reduce the amount of concrete loss and bleed. The concrete mix is to be designed according to appropriate technical guidance and with the agreement of the EA.<br><br>Grout may be injected into the chalk aquifer at the base of the shaft prior to dewatering to prevent ingress of groundwater through the base of the shaft. Where required, a high-density grout mix (cement, gravel and bentonite) would be utilised to prevent dispersal through the rock. Grout volume to be minimised with careful preparation and methodology, including injection pressure control. The methodology for this would be agreed with the EA following detailed design. | High (4) |
| | Slurry/concrete/grout additives | | High (4) |
| Pathway | Migration within the River Terrace Deposits towards receptors | The River Terrace Deposits typically comprise sandy, slightly clayey, fine to coarse gravel of flint and occasional chalk. These deposits are expected to be highly permeable. | - |
| | Migration within the chalk towards receptors | Chalk is a dual porosity aquifer; the majority of transport occurs within the fractures and fissures. Transport within fractures and fissures is likely to be rapid and can occur over long distances. | |
| Receptor | Secondary A Aquifer (River Terrace Deposits)<br><br>Principal Aquifer (Chalk)<br><br>Hermitage Stream<br><br>Langstone Harbour | The WRP site is underlain by River Terrace/Raised Marine Deposits, designated as a Secondary A Aquifer. The Budds Farm Shaft site is underlain by Alluvium and River Terrace Deposits, also designated as Secondary A Aquifers. The shafts would extend into the chalk.<br><br>Langstone Harbour is located approximately 200 m south of the WRP site and approximately 70 m west of the Budds Farm Shaft site and is a tidal inlet of the English Channel. Langstone Harbour is a designated SSSI, SAC, SPA, a wetland of international importance designated under the Ramsar Convention and a WFD safeguarded GWDTE.<br><br>Hermitage Stream is present between the WRP site and the Budds Farm Shaft site and flows south-east into Langstone Harbour. | Secondary A Aquifer – Low (2)<br><br>Principal Aquifer – Moderate (3)<br><br>Hermitage Stream, Langstone Harbour – Very High (5) |

*Risk assessment – turbidity*

4.8.24 As described in Section 4.7 the impacts of increased turbidity principally relate to potable water abstractions, with the principal receptor being the potable supply groundwater abstractions at Bedhampton Springs, approximately 530 m to the north of the WRP site.

4.8.25 Turbidity could be generated from cut off wall construction, through the mechanical mixing and cement/water injection, as well as the excavation and casting of the diaphragm walls. It includes particulates from formation and concrete/grout particulates washed into groundwater.

4.8.26 It is considered to be Likely that an increase in turbidity within the groundwater beneath both the WRP site and the Budds Farm Shaft site would occur as a result of the excavation and casting of the shafts. It is considered Unlikely, however, that this increase in turbidity would be realised within Langstone Harbour to a measurable extent.

4.8.27 Information provided by Portsmouth Water shows that the abstractions at Bedhampton Springs are all from springs, which discharge into collection chambers. There are no abstractions from boreholes at Bedhampton Springs. Water required for supply is subsequently pumped to Farlington, whilst excess water flows into the adjacent watercourses.

4.8.28 This is of particular note as, because groundwater naturally flows to the surface and is not pumped from an aquifer at depth, a cone of drawdown around the abstractions would not be present. The proposed shafts at the WRP site and Budds Farm Shaft site are located, at most proximal, some 490 m down hydraulic gradient of Bedhampton Springs. In the absence of a cone of drawdown to reverse the groundwater flow direction it is considered highly unlikely that an increase in turbidity of the groundwater in the chalk at the WRP site and Budds Farm Shaft site would be realised at Bedhampton Springs.

4.8.29 For the aquifers beneath both the WRP site and the Budds Farm Shaft site, the consequence of contamination, given the nature of the source (increased turbidity due to construction of shafts – High (4)) and sensitivity of the receptor (Secondary A and Principal Aquifers – Moderate (3) is assessed as Medium.

4.8.30 For Langstone Harbour, the consequence of contamination, given the nature of the source (increased turbidity due to construction of shafts – High (4)) and sensitivity of the receptor (Langstone Harbour SSSI, SPA, SAC, Ramsar site, etc. – Very High (5)) is assessed as Severe.

4.8.31 By combining a Medium consequence and Likely probability, as per Table 4-5, the associated risk of increasing turbidity in the aquifers beneath both the WRP site and the Budds Farm Shaft site is assessed to be **Moderate**, noting that (as previously discussed) it is highly unlikely that this increase in turbidity would be realised at the Bedhampton Springs abstractions.

4.8.32 By combining a Severe consequence and Unlikely probability, as per Table 4-5, the associated risk of increasing turbidity within Langstone Harbour is assessed to be **Moderate**/**Low** and on the basis of the saline nature of the harbour, has been assessed as **Low**. It should also be noted that the Harbour is tidal, and therefore an already turbid environment within which an increase in turbidity may be difficult to discern.

4.8.33 As an additional precaution, the contractor undertaking the piling and excavation works should prepare a Water Monitoring Plan. The aim of this plan would be to identify significant changes to groundwater / contamination levels in key locations during construction and establish the Contingency Plan to be enacted if adverse impacts are identified. The Water Monitoring Plan should include the following:

- Groundwater level and quality should be monitored prior to construction to establish baseline conditions. This may include monitoring at abstractions, including turbidity.
- Groundwater level and quality should be monitored during and post construction, including turbidity measurements.
- Alert and trigger levels should be identified.
- A Contingency Plan should be presented, establishing the actions that would be taken to mitigate adverse impacts. This approach should be agreed with potable supply providers and the EA.

*Risk assessment – loss of high pH and high chloride water from concrete*

4.8.34 Concrete bleeding can occur from newly-formed diaphragm walls, as the fresh concrete is subject to high head pressures resulting in high pore-water pressures inside the fresh concrete matrix. This can be much higher than the pore-water pressures in the surrounding soil and thus cause water to be forced out of the fresh concrete matrix into the soil matrix (Martin D. Larisch, September 2019) with the area of bleed often located at the bottom of the shaft.

4.8.35 The concrete mix composition has not yet been designed, however Clause 1604.7 of the Specification for Highway Works [30] requires that "*the concrete shall be designed so that segregation does not occur during the placing process, and bleeding of the concrete shall be minimised*". There are currently no specific requirements in the specification to control bleed but Clause B21.5.4 of the ICE Pile Specification allows for determination of bleed in accordance with the test recommended by the Concrete Institute of Australia (CIA). The CIA recommended practice [31] gives an acceptance criterion of 15 $l/m^3$.

4.8.36 [32] indicates that a suitable specification of the fine/medium sand content, water/cement ratio and admixtures would effectively restrict bleeding. The suitability of any additives added to the concrete mix to promote fast-curing should be confirmed with the EA.

4.8.37 The contractor would be required to specify the concrete mix to prevent bleed as far as is reasonably practicable. It is anticipated that this would be done by default as the contractor would (for cost reasons) wish to minimise concrete loss.

4.8.38 As discussed above, saline intrusion into the chalk aquifer beneath both the WRP site and the Budds Farm Shaft site is known to be occurring within Langstone Harbour. Saline waters are, by their nature, enriched in sodium and chloride. Langstone Harbour is itself a saline tidal inlet.

4.8.39 It is considered to be Likely that an increase in pH and chloride concentrations within the groundwater beneath both the WRP site and the Budds Farm Shaft site would occur as a result of the excavation and casting of the shafts. It is considered Unlikely, however, that this increase in pH and chloride concentrations would be realised within Langstone Harbour.

4.8.40 As per the above, it is considered Unlikely that groundwater within the chalk aquifer enters Langstone Harbour, and the migration pathway is predominantly one-directional, with saline water entering the aquifer. On this basis, it is considered Unlikely that an increase in chloride concentrations or pH within Langstone Harbour would result from the drilling activities.

4.8.41 The consequence of contamination, given the nature of the source (increased pH and chloride concentrations resulting from concrete bleed – Moderate (3)) and sensitivity of the receptor (Secondary A and Principal Aquifers, Langstone Harbour SSSI, SPA, SAC, Ramsar site etc. - Very High (5)) is assessed as Medium.

4.8.42 By combining a Medium consequence and Likely probability, as per Table 4-5, the associated risk of increased pH and chloride concentrations within the aquifers beneath both the WRP site and the Budds Farm Shaft site is assessed to be **Moderate**.

4.8.43 By combining a Medium consequence and Unlikely probability, as per Table 4-5, the associated risk of increased pH and chloride concentrations within Langstone Harbour is assessed to be **Low**.

*Risk assessment – fissure grout dispersal*

4.8.44 Fissure grouting may be required around the base of the shafts within the chalk, in order to reduce transmissivity rates and control the dewatering process. Grout is injected into the ground at relatively high pressure, which can cause it to disperse widely, especially where in the area of open fissures or particularly weak rock. Grout contains some potential contaminants that can leach into the groundwater so volumes injected should be kept to a minimum by avoiding wide dispersal beyond the target area.

4.8.45 Dispersal of grout can be minimised in a number of ways, for instance by altering its consistency with additives that make it more resistant to washout. A thixotropic grout can be selected, i.e. one that is fluidised upon action by vibration and pumping, and becomes stiff as pressure releases, and would prevent wide dispersal of grout into the surrounding chalk. Grout should be properly mixed and injection pressures can be carefully administered and monitored, to allow suitability for the ground conditions.

4.8.46 Assuming the adoption of the above, it is considered that the risk of significant dispersal of fissure grout (if required) is **Low**.

*Risk assessment – bentonite support fluid break out*

4.8.47 Bentonite is a dense and viscous, thixotropic material, which stabilises the diaphragm wall trench, and lines the excavation with a low permeability layer (or ‘filter cake’). These properties prevent it from dispersing widely beyond the excavation walls.

4.8.48 Bentonite mud is formed from inert, non-toxic clays, that are not damaging to land surfaces and quickly break down in salt water. Break out of bentonite mud occurs when the mud pressure in the trench exceeds the strength of the overlying / surrounding ground resulting in mud being forced out into the surrounding formation.

4.8.49 Research published in April 2024 [36] states that “*NaCl and $CaCl_2$ salt negatively influence bentonite-based drilling mud's rheological and filtration properties. … As the concentration of salt is elevated, there is a decrease in the extent of hydration and dispersion. The phenomenon described is a result of the presence of cations in solution, which exert a force that drives the exchange cations to migrate towards the* *surface of the clay particle. As a result, the viscosity will be reduced*". On this basis, break outs in saltwater are considered to be highly unlikely to be environmentally damaging as the viscosity of the fluid reduces and the natural clay materials are dispersed.

4.8.50 The contractor should, during detailed design, consider developing their construction methodology to mitigate and remediate break outs during excavation and should consider the mitigation and responses outlined in the following points:

- **Limiting the volume of the break out**. The contractor would be monitoring fluid pressure and the volume of fluid returns to allow losses to be quickly identified if they occur. When fluid losses are identified the contractor would cease excavation and investigate if the losses are visible at surface and, if so, the location of the break out. During the excavation a watching brief would be maintained for any signs of break out.
- **Containing the break out**. When a surface break out has been identified, it would be contained with appropriate methods. The most appropriate methods would depend on the location of the break out. Sandbags arranged to form a bund around the break out are the most common method.
- **Removing the break out fluid.** Typically, hand carried pumps and hoses are used to pump the fluid from the break out location to either the entry or exit pits, or a holding tank or bowser for transfer back to the excavation.
- **Sealing the break out.** Most break outs seal themselves after either a period of time to allow the bentonite mud to gel in the fracture, or when the excavation advances, reducing the pressure of the fluid passing the fracture. In some cases, environmentally friendly additives, termed Lost Circulation Materials (LCM) are added to the drilling fluid to assist in sealing the fracture.
- **Remediating the break out.** When the break out is deemed to have been sealed, any remaining bentonite mud would be removed as far as possible, with the proviso that the cleaning process does not cause more harm or damage to the environment than leaving the fluid to dissipate and break down naturally.

4.8.51 With the adoption of the measures described above (and noting the rapid breakdown of bentonite in saline conditions) it is considered that:

- Within the Secondary A and Principal Aquifers there is a Low likelihood of either a break-out of bentonite occurring, or harm occurring to the aquifers in the event of a break-out occurring.
- Within Langstone Harbour there is an Unlikely likelihood of either a break-out of bentonite occurring, or harm occurring to Langstone Harbour in the event of a break-out occurring.

4.8.52 Within the aquifers, the consequence of contamination, given the nature of the source (High – 4) and the sensitivity of the receptor (Secondary A and Principal Aquifers – Moderate (3) is assessed as Medium. By combining a Medium consequence and Low probability, as per Table 4-5, the associated risk of bentonite support fluid breakout within the aquifers beneath both the WRP site and the Budds Farm Shaft site is assessed to be **Low/Moderate** and on the basis of the likely large quantum of support fluids required for the construction of the shafts has been assigned as **Moderate**.

4.8.53 Within Langstone Harbour, the consequence of contamination, given the nature of the source (High – 4) and the sensitivity of the receptor (SSSI, SPA, SAC, Ramsar site, etc. – Very High (5)) is assessed as Severe. By combining a Severe consequence and Low probability, as per Table 4-5, the associated risk of bentonite support fluid breakout within Langstone Harbour is assessed to be **Moderate**.

*Risk assessment – contamination of groundwater by additives in slurry / concrete / grout*

4.8.54 Additives may be used to enhance the performance of the bentonite slurry, concrete or grout and may include polymers, clay, cement, foaming agents, thickening agents, etc. These contaminants may have potential to leach into groundwater and disperse through the aquifer.

4.8.55 Additives and conditioning agents should be appropriately selected with the exclusion of substances that could be hazardous to the environment. The EA should be consulted by the contractor should any potentially hazardous additives be proposed for use.

4.8.56 As discussed above, additives and conditioning agents would be appropriately selected with the exclusion of substances that could be hazardous to the environment. The EA would be consulted during the additive selection process. On this basis, it is considered that the risk of contamination of groundwater by additives is **Very Low**.

## Pollution scenario 4

4.8.57 Pollution Scenario 4 considers the direct contact of engineered structures with contaminated soil or leachate causing degradation of construction materials (where the secondary effects are to increase the potential for contaminant migration).

4.8.58 The assessment for Pollution Scenario 4 for the shafts at both the WRP site and the Budds Farm Shaft site is the same as the assessment for the construction of piled foundations.

4.8.59 The consequence of contamination, given the nature of the source (High - 4) and sensitivity of the receptor (Moderate - 3) is assessed as Medium. Assuming the use of an appropriate concrete mix, the probability of degradation of in-ground concrete due to attack by aggressive chemicals or naturally occurring sulphates and acids is assessed to be Unlikely.

4.8.60 By combining a Medium consequence and Unlikely probability, as per Table 4-5, the associated risk of degradation of concrete and the associated creation of new pathways is assessed to be **Low**.

## Pollution scenario 5

4.8.61 Pollution Scenario 5 considers the potential for creation of preferential pathways to allow migration of landfill gas or contaminant vapours to the surface.

4.8.62 The contaminant linkage assessed, and the assessed significance of the potential source, pathway and receptor are summarised in the following table. The assessment has been undertaken on a ‘worst-case’ basis and applies to both the WRP site and the Budds Farm Shaft site.

**Table 4-14 Pollution scenario 5 (shafts) - significance of potential contaminant linkage**

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| Source | Potentially hazardous ground gases | The assessment undertaken for the WRP site [4] shows that the ground gas regime at this part of the WRP site should be classified as Characteristic Situation (CS) 3. Whilst CS2 conditions are typically prevalent, CS3 conditions have been recorded in four boreholes, and within one of these borehole CS3 conditions were prevalent for approximately 15% of the monitoring period.<br><br>It is considered that a classification of CS3 is appropriate and suitably (but not overly) precautionary.<br><br>The assessment undertaken for the Budds Farm Shaft site shows that the ground gas regime at this part of the Budds Farm Shaft site should be classified as CS1. | High (4) |
| Pathway | Shaft / soil interface | The landfill does not benefit from an engineered cap.<br><br>In the existing scenario landfill gases vent directly to the atmosphere.<br><br>The proposed shafts do not therefore alter the existing pathway. | |
| Receptor | End Users Construction Workers | The critical receptor is workers constructing or working at the proposed WRP. | High (4) |

4.8.63 The landfill waste beneath the WRP site and (to a lesser degree) the Budds Farm Shaft site is a recognised source of potentially hazardous landfill gases. The landfills do not benefit from an engineered cap. There is no lower permeability surface layer which would be punctured by shaft excavation or trenchless crossing construction and in this regard, construction of the trenchless crossings and shafts does not alter the existing gassing regime whereby gases and vent to atmosphere through the cover soils.

4.8.64 The use of a cast in-situ soil-mixed wall, and a cast-in-situ diaphragm wall would minimise the creation of preferential migration pathways for gas along the sides of the shaft by providing 'intimate contact' between the concrete / cement stabilised soils, and the surrounding material.

4.8.65 During shaft excavation works there is an increased risk of site workers being exposed to landfill gases. As on all contaminated sites, extra precautions should be taken to comply with the relevant health and safety legislation and guidance. The shaft excavation and construction contractor's risk assessment and method statement would need to address all issues in relation to potential exposure to ground gases during construction.

4.8.66 The consequence of contamination, given the nature of the source (landfill gases – High (4)) and sensitivity of the receptor (human health – end users (High - 4)) is assessed as Medium.

4.8.67 The likelihood of gas migration along a preferential pathway at the shaft or trenchless crossing / soil interface is assigned as Unlikely.

4.8.68 By combining a Medium consequence and Unlikely probability, as per Table 4-5, the associated risk of creation of preferential pathways to allow upward migration of landfill gas to the surface is assessed to be **Low**.

### Pollution scenario 6

4.8.69 Pollution Scenario 6 considers causing of off-site migration of ground gas or increased vertical emissions as a result of vibration or other effects from the ground improvement processes associated with shaft construction.

4.8.70 As stated in [1] "*Replacement piling methods will not cause disturbance of the ground sufficient to cause off site migration of gas*". In relation to ground improvement, e.g., deep soil mixing, [1] states "*ground improvement is designed to densify the ground and therefore there is the risk of reduced volume of space for gas. The gas is far more likely to migrate up the stone columns than any distance horizontally. Therefore gas migration off site is not considered to be a significant risk when installing stone columns. For other types of improvement, the vibration is not sufficient or prolonged enough to cause significant volumes of gas to migrate off site*".

4.8.71 On this basis, further assessment of Pollution Scenario 6 is not required.

### Pollution scenario 7

4.8.72 Pollution Scenario 7 considers direct contact of site workers and others with contaminated soil arisings, which have been brought to the surface.

4.8.73 The shaft excavations would generate arisings, which would include potentially contaminated landfill waste.

4.8.74 The assessment for Pollution Scenario 7 for the shafts at both the WRP site and the Budds Farm Shaft site is the same as the assessment for the construction of piled foundations, i.e. **Moderate** risks that can be mitigated to **Low**.

### Additional considerations

4.8.75 In addition to the pollution scenarios considered above, the potential changes to groundwater flows and levels as a result of construction of the Project, including temporary changes due to dewatering within the proposed shafts during construction have been considered, as follows.

- Normal, historical migration pathways of contaminants in groundwater may be locally altered by the construction of shafts, which form an impermeable barrier around which groundwater must flow.
- Dewatering works would be carried out as part of shaft excavation and would temporarily alter the hydrogeological regime, drawing water towards the shaft in a cone of depression, and then pumping it out from inside the shaft to be disposed of at the surface to a licenced facility or via a permitted discharge.

*Flow barriers – shaft construction*

4.8.76 The combined diameter of the three shafts proposed at the WRP site is 40 m, while the length of the land package is circa 400 m. This is not deemed a significant enough barrier to bring material changes to the hydrogeological regime and the flow path of contaminants through the landfill. Similarly, at Budds Farm where the proposed reception shaft is 6 m diameter, it is considered a minor and insignificant barrier to groundwater flow. Construction of the shafts themselves may remove potential contaminant sources in the landfill and slightly decrease the flux of contaminants downgradient of the shafts.

*Dewatering during shaft construction*

4.8.77 Prior to excavation of soil and waste materials within the diaphragm wall, the groundwater level within the shaft would be reduced in order to prevent ingress of groundwater into the shaft excavation. This would involve pumping from inside the base of the shaft. Where transmissivity of the strata around the shaft foundations is low, groundwater levels can be reduced quickly without drawing in large volumes of water from around the shaft. However, if transmissivity is high, larger volumes of water may be drawn in from around the shaft across a large cone of depression, in order to reduce groundwater levels sufficiently for excavation to proceed. The localised change in flow direction and the potential localised increase in flow rates through the landfill waste may lead to temporary, localised mobilisation of contamination / leachate within the waste towards the dewatering point. It should again be noted that the landfill beneath (and to the south and west of) the WRP site operates on the 'dilute and disperse' principle, where migration of leachate out of the landfill into the surrounding groundwater is the expected behaviour. On this basis, any temporary and localised changes in flow patterns of leachate within the landfill is not considered to represent an increased risk relative to the existing scenario (i.e., negligible impact).

4.8.78 Furthermore there are many controls to dewatering that can be adopted. Pumping tests carried out in boreholes in the intended pumping area prior to shaft construction would indicate the transmissivity of the rock, and observation wells used during pump tests in the area surrounding the proposed shaft would indicate the impact that dewatering might have on the hydrogeological regime, including the cone of depression and changes to flow rates through the landfill. If the transmissivity is deemed too high then fissure grouting can be used to target the ground surrounding the base of the shaft, to infill the largest fissures/open discontinuities.

4.8.79 It should also be noted that the dewatering process would remove contaminants from the ground that may otherwise have continued following a path out of the landfill into surrounding aquifers.

## 4.9 Risk assessment – WRP to Budds Farm shaft Trenchless Crossing

### Pollution scenario 1

4.9.1 Pollution Scenario 1 considers the creation of preferential pathways through a low permeability layer, to cause contamination of groundwater in an aquifer.

4.9.2 On the basis that the WRP to Budds Farm Shaft Trenchless Crossing is to be constructed entirely within the natural geology at depth, i.e., the construction does not penetrate an aquitard, an assessment of this Pollution Scenario is not required.

### Pollution scenario 2

4.9.3 Pollution Scenario 2 considers the driving of solid contaminants down into an aquifer during construction.

4.9.4 On the basis that the WRP to Budds Farm Shaft Trenchless Crossing is to be constructed at depth entirely within the natural geology, and therefore would not encounter solid contaminants, an assessment of this Pollution Scenario is not required.

## Pollution scenario 3

4.9.5 Pollution Scenario 3 considers the contamination of groundwater and, subsequently, surface waters by wet concrete, cement paste, or grout.

4.9.6 The contaminant linkages assessed, and the assessed significance of the potential source, pathway and receptor are summarised in Table 4-15 and the text that follows.

**Table 4-15 Pollution scenario 3 (trenchless crossing) - significance of potential contaminant linkage**

<table>
<tr><th>Link</th><th>Description</th><th>Comment</th><th>Source Significance / Receptor Sensitivity</th></tr>
<tr><td rowspan="4">Source</td><td>Increased turbidity due to trenchless crossing construction.</td><td rowspan="4">Turbidity increases could occur at depth within the chalk as a result of physical disturbance of the chalk during drilling/boring, as well as any losses of drilling mud (e.g., bentonite) used to maintain excavation stability at the drill head. These impacts are anticipated to be limited to groundwater within the chalk. It is anticipated that either an Earth Pressure Balance (EPB) micro-Tunnel Boring Machine (TBM), or a slurry micro-TBM would be utilised.<br><br>EPB micro-TBMs maintain pressure at the excavation face by pressurising the excavation chamber with a slurry formed (within the excavation chamber by injection of conditioners) from the excavated materials.<br><br>Slurry micro-TBMs maintain pressure at the excavation face using a (typically) bentonite slurry, which is produced at a slurry plant on the surface and is pumped into the excavation chamber where it reaches the excavation face and penetrates into the ground, forming a filter cake, which guarantees the transfer of counter-pressure to the excavation face.<br><br>Grouting may be undertaken on completion of boring/drilling (if required) to provide a grouted annulus around the trenchless crossing, to prevent the creation of permanent preferential flow paths.<br><br>The trenchless crossing lining would be installed by pipe-jacking, which may involve the injection of a bentonite mud around the lining to improve lubrication against the surrounding rock.<br><br>The volume of bentonite mud and grout to be injected is to be minimised with careful preparation and</td><td>High (4)</td></tr>
<tr><td>Excess dispersal of grout and leaching of contaminants into groundwater.</td><td>High (4)</td></tr>
<tr><td>Bentonite breakout either at cutting face, or from annulus, and leaching of contaminants into groundwater.</td><td>High (4)</td></tr>
<tr><td>Slurry/grout additives</td><td>High (4)</td></tr>
</table>



from Southern Water

| Link | Description | Comment | Source Significance / Receptor Sensitivity |
|---|---|---|---|
| | | methodology, including injection pressure control. The methodology for this would be agreed with the EA following detailed design. | |
| Pathway | Migration within the chalk towards receptors | Chalk is a dual porosity aquifer; the majority of transport occurs within the fractures and fissures. Transport within fractures and fissures is likely to be rapid and can occur over long distances. | - |
| Receptor | Principal Aquifer (Chalk)<br><br>Hermitage Stream<br><br>Langstone Harbour | The trenchless crossing would be constructed at depth within the chalk which is designated as a Principal Aquifer.<br><br>Langstone Harbour is located approximately 200 m south of the WRP site and approximately 70 m south-west of the Budds Farm Shaft site. Langstone Harbour is a tidal inlet of the English Channel and is a designated SSSI, SAC, SPA, a wetland of international importance designated under the Ramsar Convention and a WFD safeguarded GWDTE (DEFRA, 2023).<br><br>Hermitage Stream is present between the WRP site and the Budds Farm Shaft site and flows south-east into Langstone Harbour. | Principal Aquifer – Moderate (3)<br><br>Hermitage Stream, Langstone Harbour – Very High (5) |

## *Trenchless crossing techniques*

### *EPB micro-TBM*

4.9.7 In an EPB micro-TBM, a screw conveyor controls the rate of spoil extraction, with the aim of balancing the rates of excavation and extraction such that the external pressure, and the pressure within the excavation chamber are balanced.

4.9.8 The cutter head breaks up the ground, and conditioners are injected into the excavated soil within the excavation chamber to create a paste of a selected consistency. This paste needs to be sufficiently liquid enough to be removed by the screw conveyor but sufficiently solid enough to form a plug between the atmospheric pressure at the exit end of screw conveyor and the entrance end of the screw conveyor within the excavation chamber, which is maintained at pressure to support the ground ahead of the face. A slight negative pressure is maintained in the excavation chamber to encourage consistent inward movement of excavated materials.

4.9.9 This technique minimises mobilisation of chalk ‘flour’, which would otherwise contribute to increases in turbidity within the aquifer.

### *Slurry micro-TBM*

4.9.10 Slurry micro-TBMs maintain pressure at the excavation face through the use of a slurry (typically bentonite), which is produced at a slurry plant on the surface and is pumped into the excavation chamber where it reaches the excavation face and penetrates into the ground, forming a filter cake, which guarantees the transfer of counterpressure to the excavation face. The cutter head then excavates the natural materials and the bentonite slurry, which is then pumped from the excavation chamber to a separation plant, to allow the arisings to be removed and the slurry to be recycled.

4.9.11 When using a slurry micro-TBM it is important to manage the pressures such that excessive pressures are avoided in the excavation chamber, which could force the excavation slurry away from the cutting face and avoid low pressure in the excavation chamber, which would allow increased water flow. The pressure should be maintained always slightly lower than the groundwater pressure to maintain consistent inward movement of groundwater and slurry into the micro-TBM.

4.9.12 The additional logistics requirements of connecting and disconnecting slurry feed and return lines when adding new lining segments means it is less likely that a slurry micro-TBM would be utilised, however this option has been retained, pending detailed design.

### *Installation of lining*

4.9.13 In both of the above cases, the micro-TBM serves to create the bore but does not install the lining. The lining would be installed through pipe-jacking, i.e., the driving of (typically) concrete rings into the bore using hydraulic jacks.

4.9.14 Ring 1 would be placed immediately behind the micro-TBM as it is launched, with rings 2, 3, 4 etc., placed behind from the launch shaft and progressively jacked into the ground. Ring 1 therefore ends up being jacked the full length of the trenchless crossing and forms the connection with the reception shaft.

4.9.15 A (typically) bentonite mud may be injected around the segmental linings during pipe-jacking to provide lubrication for the lining against the surrounding rock (requirement subject to drive length and the conditions encountered) and to seal flow paths along the length of the trenchless crossing annulus in the temporary case.

4.9.16 Once the full lining is in place it can then be grouted in place to secure it in its permanent position and seal potential preferential flow paths around the annulus. Grout is injected through the rings, displacing the bentonite and sealing flow paths around the annulus.

4.9.17 The bentonite/grout mix would be thixotropic (i.e., fluidised upon action by vibration and pumping, and becomes stiff and remains in place when pressure releases), to prevent excess dispersal into the surrounding ground.

### *Risk assessment – increased turbidity due to trenchless crossing construction*

4.9.18 For the aquifers beneath the WRP site and the Budds Farm Shaft site (i.e., the aquifers within which the trenchless crossing would be constructed) , the consequence of contamination, given the nature of the source (increased turbidity due to construction/tunnelling – High (4)) and sensitivity of the receptor (Principal Aquifer – Moderate (3) is assessed as Medium. It is considered to be Likely that an increase in turbidity within the groundwater beneath WRP to Budds Farm Shaft site would occur as a result of the excavation of the WRP to Budds Farm trenchless crossing. By combining a Medium consequence and Likely probability, as per Table 4-5, the associated risk of increasing turbidity in the chalk aquifer beneath the WRP to Budds Farm Shaft site is assessed to be **Moderate**.

4.9.19 Information provided by Portsmouth Water shows that the abstractions at Bedhampton Springs are all from springs, which discharge into collection chambers. There are no abstractions from boreholes at Bedhampton Springs. Water required for supply is subsequently pumped to Farlington, whilst excess water flows into the adjacent watercourses.

4.9.20 This is of particular note as because groundwater naturally flows to the surface and is not pumped from an aquifer at depth, a cone of drawdown around the abstractions would not be present. The proposed trenchless crossing between the WRP site and Budds Farm is located some 800 m down hydraulic gradient of Bedhampton Springs. In absence of a cone of drawdown to reverse the groundwater flow direction it is considered highly unlikely that an increase in turbidity of the groundwater in the chalk at the WRP site would be realised at the springs at Bedhampton Springs.

4.9.21 For the aquifers beneath the WRP site and Budds Farm Shaft site (i.e., the aquifers within which the trenchless crossing would be constructed), the consequence of contamination, given the nature of the source (increased turbidity due to construction of the trenchless crossing – High (4)) and sensitivity of the receptor (Secondary A and Principal Aquifers – Moderate (3) is assessed as Medium. By combining a Medium consequence and Likely probability, as per Table 4-5, the associated risk of increasing turbidity in the aquifers within which the trenchless crossing would be constructed is assessed to be **Moderate**, noting that (as previously discussed) it is highly unlikely that this increase in turbidity would be realised at the Bedhampton Springs abstractions.

4.9.22 For Langstone Harbour, the consequence of contamination, given the nature of the source (increased turbidity due to construction of the trenchless crossing – High (4)) and sensitivity of the receptor (Langstone Harbour SSSI, SPA, SAC, Ramsar site, etc. – Very High (5)) is assessed as Severe. It is considered Unlikely, that an increase in turbidity would be realised within Langstone Harbour or the Hermitage Stream to a measurable extent. By combining a Severe consequence and Unlikely probability, as per Table 4-5, the associated risk of increasing turbidity within Langstone Harbour is assessed to be **Low/Moderate** and on the basis of the likely partial connectivity between Langstone Harbour and the chalk aquifer but likely predominantly one-directional migration pathway, with saline water entering the aquifer, has been assigned as **Low**. It should be noted that the Harbour is tidal, and therefore an already turbid environment within which an increase in turbidity may be difficult to discern.

*Risk assessment – grout dispersal*

4.9.23 Grouting of the annulus may be undertaken upon completion of trenchless crossing construction, to provide a grouted annulus around the lining to prevent creation of permanent preferential flow paths.

4.9.24 Grout is injected into the ground at relatively high pressure, which can cause it to disperse widely, especially where in the area of open fissures or particularly weak rock. Grout contains some potential contaminants that can leach into the groundwater so volumes injected should be kept to a minimum by avoiding wide dispersal beyond the target area. The grout mix would be thixotropic (i.e., fluidised upon action by vibration and pumping, and becomes stiff and remains in place when pressure releases), to prevent excess dispersal into the surrounding ground.

4.9.25 Dispersal of grout can be minimised in a number of ways, for instance by altering its consistency with additives that make it more resistant to washout. A thixotropic grout would be selected, i.e. one that is fluidised upon action by vibration and pumping, and becomes stiff as pressure releases, and would prevent wide dispersal of grout into the surrounding chalk. Grout should be properly mixed and injection pressures can be carefully administered and monitored, to allow suitability for the ground conditions.

4.9.26 The consequence of contamination, given the nature of the source (Low – 2) and sensitivity of the receptor (Very High – 5) is assessed as Medium.

4.9.27 Assuming the adoption of the above, it is considered that the likelihood of excess grout dispersal is Unlikely.

4.9.28 By combining a Medium consequence and Unlikely probability, as per Table 4-5, the risk to waters associated with dispersal of grout during annulus grouting in either the temporary or permanent case is assessed to be **Low**.

*Risk assessment – bentonite support fluid break out*

4.9.29 Bentonite is a dense, viscous, thixotropic material, which in the use of a slurry TBM would be injected into the excavation chamber at pressure to penetrate into the ground a short distance ahead of the cutter head to form a low permeability layer (or ‘filter cake’). These properties prevent it from dispersing widely beyond the excavation walls. A bentonite mud may also be injected around the segmental linings during pipe-jacking to provide lubrication for the lining against the surrounding rock and to seal the annulus between the lining and the surrounding rock in the temporary case.

4.9.30 As previously discussed bentonite support fluid break outs in saltwater or saline groundwater are considered to be highly unlikely to be environmentally damaging as the viscosity of the fluid reduces and the natural clay materials are dispersed.

4.9.31 As previously discussed the trenchless crossing construction contractor should develop their construction methodology to mitigate and remediate break outs during construction.

4.9.32 With the adoption of the measures described above (and noting the rapid breakdown of bentonite in saline conditions) it is considered that:

- Within the Secondary A and Principal Aquifers there is a Low likelihood of either a break-out of bentonite occurring, or harm occurring to the aquifers in the event of a break-out occurring.
- Within Langstone Harbour there is an Unlikely likelihood of either a break-out of bentonite occurring, or harm occurring to Langstone Harbour in the event of a break-out occurring.

4.9.33 Within the aquifers, the consequence of contamination, given the nature of the source (High – 4) and the sensitivity of the receptor (Secondary A and Principal Aquifers – Moderate (3) is assessed as Medium. By combining a Medium consequence and Low probability, as per Table 4-5, the associated risk of bentonite support fluid breakout within the aquifers beneath the WRP to Budds Farm Shaft site is assessed to be **Moderate/Low** and on the basis that the whole of the trenchless crossing construction is located within the chalk, has been assigned as **Moderate**.

4.9.34 Within Langstone Harbour, the consequence of contamination, given the nature of the source (High – 4) and the sensitivity of the receptor (SSSI, SPA, SAC, Ramsar site, etc. – Very High (5)) is assessed as Severe. By combining a Severe consequence and Unlikely probability, as per Table 4-5, the associated risk of bentonite support fluid breakout within Langstone Harbour is assessed to be **Moderate/Low** and on the basis of the saline nature of the Harbour, has been assigned as **Low**.

*Risk assessment – contamination of groundwater by additives in slurry / concrete / grout*

4.9.35 Additives may be used to enhance the performance of the bentonite slurry, concrete or grout and may include polymers, clay, cement, foaming agents, thickening agents, etc. These contaminants may have potential to leach into groundwater and disperse through the aquifer.

4.9.36 Additives and conditioning agents should be appropriately selected with the exclusion of substances that could be hazardous to the environment. The EA should be consulted by the contractor should any potentially hazardous additives be proposed for use.

4.9.37 As discussed above, additives and conditioning agents would be appropriately selected with the exclusion of substances that could be hazardous to the environment. The EA would be consulted during the additive selection process. On this basis, it is considered that the risk of contamination of groundwater by additives is **Very Low**.

### Pollution scenario 4

4.9.38 Pollution Scenario 4 considers the direct contact of engineered structures with contaminated soil or leachate causing degradation of construction materials (where the secondary effects are to increase the potential for contaminant migration).

4.9.39 The WRP site to Budds Farm Shaft trenchless crossing is to be constructed entirely within the natural geology at depth and therefore would not encounter contaminated soil. The presence of two separate overlying landfills that operate on the ‘dilute and disperse’ principle means that there is potential that landfill leachate could be encountered (albeit diluted by groundwater within the chalk). To provide a conservative assessment, the assessment for Pollution Scenario 4 for the WRP site to Budds Farm Shaft trenchless crossing is assessed to be the same as the assessment for the construction of piled foundations.

4.9.40 The consequence of contamination, given the nature of the source (High - 4) and sensitivity of the receptor (Moderate - 3) is assessed as Medium. Assuming the use of an appropriate concrete mix, the probability of degradation of in-ground concrete due to attack by aggressive chemicals or naturally occurring sulphates and acids is assessed to be Unlikely.

4.9.41 By combining a Medium consequence and Unlikely probability, as per Table 4-5, the associated risk of degradation of concrete and the associated creation of new pathways is assessed to be **Low**.

### Pollution scenario 5

4.9.42 Pollution Scenario 5 considers the potential for creation of preferential pathways through a low permeability surface layer to allow upward migration of landfill gas, soil gas or contaminant vapours to the surface.

4.9.43 On the basis that the WRP site to Budds Farm Shaft trenchless crossing is to be constructed entirely within the natural geology at depth, i.e., the construction does not penetrate a low permeability surface layer, an assessment of this Pollution Scenario is not required.

### Pollution scenario 6

4.9.44 Pollution Scenario 6 considers causing of off-site migration of ground gas or increased vertical emissions as a result of vibration or other effects from the construction processes involved with trenchless crossing construction.

4.9.45 On the basis that the WRP site to Budds Farm Shaft trenchless crossing is to be constructed entirely within the natural geology at depth, an assessment of this Pollution Scenario is not required.

### Pollution scenario 7

4.9.46 Pollution Scenario 7 considers direct contact of site workers and others with contaminated soil arisings which have been brought to the surface.

4.9.47 On the basis that the WRP to Budds Farm Shaft trenchless crossing is to be constructed at depth entirely within the natural geology, an assessment of this Pollution Scenario is not required.

# 5 Mitigation measures

## 5.1 General

5.1.1 Remediation measures to mitigate potential risks to the groundwater are not deemed necessary. However, the following general mitigation measures are assumed as part of this assessment:

- Construction Environmental Management Plan (CEMP) presenting construction and operational good practice measures (prevention of the creation of new pollution, personal protective equipment, safe methods of work).
- Assurance of a high standard of work by selecting a competent contractor(s) to carry out the piling, shaft construction and trenchless crossing construction works, ideally with prior experience in similar conditions.
- Appropriate risk assessment and method statements (RAMS) as required by the Construction (Design and Management) Regulations 2015.
- Cleaning down equipment if any obvious smearing or contaminated materials is observed to be adhering to the piling machinery, with any contaminated water resulting from this contained and disposed of appropriately as per the piling method statement.
- Appropriate personal protection and dust control measures during site works to minimise exposure for construction workers.
- Collection and appropriate disposal of waste concrete and other arisings at the surface.
- Protocol for dealing with unexpected contamination.
- Appropriate concrete mix/metal selection and appropriate design life of the development.
- A watching brief on Langstone Harbour and Hermitage Stream should be put in place to identify any visual indication of increased turbidity and should this occur a stop placed on the works, until visual impact dispersed and piling method and rates reviewed.

5.1.2 In addition to the above, the storage of materials e.g., cement, grout, additives, diesel, cleaning chemicals etc. would all require control. Controls for materials storage would be provided within the CEMP.

## 5.2 CFA piles

5.2.1 Mitigation measures specifically relating to CFA piles (or other bored cast in-situ piles) are as follows:

- Design of piles to try to minimise penetration into the chalk e.g. by considering larger pile groups with shorter piles.
- Placement of concrete at a rate consistent with the withdrawal of the auger to ensure support of the soil during CFA piling.
- A risk assessment in accordance with BRE Special Digest 1:2005 conducted at detailed design stage in order to verify the concrete class. This would result in the risks of pile degradation being negligible.
- Design of the concrete mix for the piles to limit bleeding into pore spaces.

### Shafts and trenchless crossing

5.2.2 In addition to the general mitigation measures, the mitigation measures specifically relating to shaft and trenchless crossing construction are as follows:

- Design of shafts to try to minimise penetration into the chalk by tailoring to local ground conditions.
- Cut off walls to be designed to optimise stability of the diaphragm wall trench by tailoring to local ground conditions.
- Design of the concrete mix for the diaphragm walls and piles to limit bleeding into pore spaces.
- Design of grout and fissure grouting methodology to limit excess dispersal through the chalk.
- Additives and conditioning agents should be appropriately selected with the exclusion of substances that could be hazardous to the environment. The EA should be consulted by the contractor should any potentially hazardous additives be proposed for use.
- A risk assessment in accordance with BRE Special Digest 1:2005 conducted at detailed design state in order to verify the concrete class. This would result in the risks of pile degradation being negligible.
- An Outline Water Monitoring Plan (ES Appendix 19.9 Outline Water Monitoring Plan, Volume II (Document reference 6.2, DCO Volume 6)) to identify significant changes in groundwater levels/ contamination levels in key locations during construction, and a Contingency Plan.
- The contractor would develop their construction methodology to mitigate and remediate bentonite break outs that could occur during the works.
- Appropriate storage/ treatment of potentially contaminated water pumped out during dewatering to inhibit contamination of ground or surface water bodies.

## 5.3 Considerations

5.3.1 Following completion of the detailed design a detailed FWRA would be prepared, replacing this outline FWRA. The detailed FWRA, prepared following completion of the detailed design process, would specify quality assurance and quality control (QA/QC) procedures suitable for the adopted methods of construction.

5.3.2 Engagement and consultation with the EA, Havant Borough Council, Portsmouth Water and other relevant consultees would be continued in order to address relevant concerns and clarify regulatory requirements for the works as above including any required licences, permits and consents, e.g., for dewatering, and treatment of contaminated waters pumped from the excavations.

# 6 Conclusion

6.1.1 This Outline FWRA has followed the approach recommended in the prevailing guidance [1].

6.1.2 The results of the risk assessment presented in Section 4 indicates that with appropriate selection of piling techniques and associated control measures the potential risks associated with the construction of the proposed piled foundations are considered to be **Low** to **Moderate**.

6.1.3 The results of the risk assessment presented in Section 4 indicates that with appropriate selection of shaft and trenchless crossing construction techniques and associated control measures, the potential risks associated with the construction of the proposed shafts are considered to be **Very Low to Moderate**, noting that the landfills beneath (and to the south and west of) the WRP site and to the south and west of the Budds Farm Shaft site operate on the 'dilute and disperse' principle, where migration of leachate out of the landfill into the surrounding groundwater is the expected behaviour. On this basis, Moderate risks are not considered to represent an increased risk relative to the existing scenario (i.e., negligible impact beyond the existing scenario).

6.1.4 The Outline FWRA demonstrates that technical solutions are feasible with mitigation measures that are protective of land quality and ground conditions receptors. The development of the Outline FWRAs follows an iterative process, which is dependent on detailed design and therefore the mitigation measures discussed in this Outline FWRA are subject to change.

# Glossary

| Term | Definition |
|---|---|
| Above Ground Plant (AGP) | This collectively refers to the Intermediate Pumping Stations and Break Pressure Tanks. |
| As Low As Reasonably Practicable (ALARP) | Involves weighing a risk against the trouble, time and money needed to control it. Thus, ALARP describes the level to which we expect to see risks controlled. |
| Amenity | Refers to the qualities of a place that make it enjoyable and attractive to users of an area. |
| Ancient woodland | Woodland that has existed continuously since 1600 in England, Wales and Northern Ireland and is defined as an irreplaceable habitat. |
| Anthropogenic | Caused by humans or their activities. |
| Applicant | Southern Water Services Limited. |
| Aquitard | Geological formations that have low permeability and restrict the flow of water. They are often made up of clay, shale, or other fine-grained materials, and can act as barriers that prevent or restrict the movement of water between aquifers or between groundwater and surface water. |
| Baseline | The current environmental and social conditions within the Order Limits or within a study area. This provides a benchmark against which changes arising from the Proposed Development are assessed for each relevant assessment. |
| Break Pressure Tank (BPT) | BPT are anticipated to be required at high points along the pipeline route. Water is pumped to BPTs, where it then flows onwards using gravity from the tank. This reduces the amount of energy required to transfer water. BPTs reduce the overall maximum pressure in the pipeline system associated with changes in flow rate as a result of topography. |
| Budds Farm pumping station | A pumping station located at Budds Farm Wastewater Treatment Works to support the transfer of treated wastewater to the Water Recycling Plant site. |
| Budds Farm Wastewater Treatment Works (WTW) | An existing Southern Water site that treats wastewater from the Applicant's customers prior to release into the Solent from the Eastney Long Sea Outfall. The Proposed Development would utilise highly treated wastewater from the Budds Farm WTW to produce recycled water at the Water Recycling Plant site. Reject water would be transferred from the Water Recycling Plant back to Budds Farm WTW where a connection would be made for onwards transfer to the existing Eastney Transfer Tunnel, Eastney Pumping Station and Eastney Long Sea Outfall for discharge into the Solent.<br>Chemical filter washing at the Water Recycling Plant site would generate process waste that would be discharged via the foul sewer network to Budds Farm WTW for treatment. |
| Carbon dioxide ($CO_2$) | A naturally occurring gas, also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning biomass, of land use changes and of industrial processes (e.g. cement production). It is the principal anthropogenic greenhouse gas that affects the earth's radiative balance. |

| Term | Definition |
|---|---|
| Climate | The general weather conditions prevailing over a long period of time. Climate change will see trends in the climate conditions changing (seasonal averages and extremes). |
| The Contractor | The Applicant or a person appointed by the Applicant or by anyone else having the benefit of part or all of the Development Consent Order to carry out any construction element of the Proposed Development or to operate the Proposed Development. |
| Development Consent Order (DCO) | A statutory order which provides consent for a project and means that a range of other consents, such as planning permission and listed building consent, will not be required. A DCO can also include powers authorising the compulsory acquisition and temporary possession of land and rights over land which is the subject of an application. A draft DCO (Document reference 3.1, DCO Volume 3) is submitted by the applicant as part of its application [37]. |
| Drinking water | Water that has been treated to strict regulatory standards, ready for supply to domestic and non-domestic customers as drinking water. |
| Drought conditions | Droughts are naturally occurring events and are typically characterised by a prolonged period of abnormally low rainfall, leading to a shortage of water. |
| Eastney Long Sea Outfall (LSO) | An existing Southern Water infrastructure component used to release treated wastewater from Budds Farm Wastewater Treatment Works. No works to the Eastney LSO are proposed as part of the Proposed Development; however, reject water produced from the Water Recycling Plant will be released from the Eastney LSO using the Eastney Transfer Tunnel and Eastney Pumping Station. |
| Environmental Permit | A legal requirement under the Environmental Permitting (England and Wales) Regulations 2016 [38] that allows certain activities which could impact the environment or human health to be carried out, subject to conditions that control and reduce those impacts. |
| Environmental Statement (ES)<br><br>(DCO Volume 7.4) | A document reporting the findings of the Environmental Impact Assessment which describes the likely significant effects arising from the Proposed Development on the environment and measures proposed to mitigate likely significant effects. |
| Extreme drought | A drought event that occurs every 1-in-500 years, or a 0.2% chance of occurring in any given year . |
| Flood Risk Assessment (FRA)<br><br>(Environmental Statement Appendix 19.1 Flood Risk Assessment, Volume II (Document reference 6.2, DCO Volume 6)) | A technical report that evaluates the potential for flooding from all sources (e.g. fluvial, coastal, surface water, groundwater, reservoir and sewers) on a development site and proposes measures to manage and mitigate those risks. It is a crucial part of the planning process, ensuring that new developments are located and designed in a way that minimises the potential for flood damage and protects people and property both on the site and in the wider area.<br>A FRA (Environmental Statement Appendix 19.1 Flood Risk Assessment, Volume II (Document reference 6.2, DCO Volume 6)) is submitted by the Applicant as part of the Development Consent Order application. |

| Term | Definition |
|---|---|
| Flood Zone 1 | Land having a less than 0.1% annual probability of river or sea flooding. |
| Flood Zone 2 | Land having between a 1% and 0.1% annual probability of river flooding; or land having between a 0.5% and 0.1% annual probability of sea flooding. |
| Flood Zone 3a | Land having a 1% or greater annual probability of river flooding; or land having a 0.5% or greater annual probability of sea flooding. |
| Flood Zone 3b | Comprises land where water from rivers or sea has to flow or be stored in times of flood. Functional floodplain will normally compromise:<br>Normally land having a 3.3% or greater annual probability of flooding, with any existing flood risk management infrastructure operating effectively, or<br>Land that is designed to flood, even I it would only food in more extreme events (such as 0.1% annual probability of flooding). |
| Geophysical survey | The means of non-intrusive survey by systematic collection of measurements of physical properties of the earth to provide spatial information allowing interpretation of site formation processes and/or the potential presence of archaeologically significant remains. |
| Hampshire Water Transfer and Water Recycling Project | This is the name of the Proposed Development, that is the Strategic Resource Option being delivered as part of the Water For Life Hampshire programme. A water supply scheme comprising a combination of both water transfer and water recycling technology that would play a major role in making up the shortfall in water supply across the Hampshire supply area, especially in a drought. |
| Havant Thicket Reservoir | The Havant Thicket Reservoir is a development under construction by Portsmouth Water that has planning permission granted by the relevant local planning authorities. Following the transfer of recycled water from the Water Recycling Plant site, the recycled water would be combined with water contained within the Havant Thicket Reservoir. The Proposed Development would use the Havant Thicket Reservoir for the storage of recycled water, before transfer to Otterbourne Water Supply Works. |
| Hazardous waste | Waste, or the material or substances it contains, which is harmful to humans or the environment, and is classified as hazardous in The Hazardous Waste (England and Wales) Regulations 2005 (SI 2005/894) . |
| Inert Waste | According to Directive 2008/98/EC [39] which is Retained European Union Legislation under the European Union (Withdrawal) Act 2018, inert waste is waste that:<br>• Will not undergo any significant physical, chemical or biological transformations.<br>• Will not dissolve.<br>• Will not burn.<br>• Will not physically or chemically react.<br>• Will not biodegrade. |

| Term | Definition |
|---|---|
| | • Will not adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to human health.<br>• Has insignificant total leachability and pollutant content.<br>• Produces a leachate with an ecotoxicity that is insignificant (if it produces leachate). |
| Light Detection and Ranging (LiDAR) | A survey detection system based on radar principles using light. It makes 3-dimensional representations of areas of the Earth's surface. |
| Made Ground | Areas where natural deposits have been replaced or altered by the introduction of artificial deposits and/or imported natural materials. |
| Main River | Watercourses designated under the Water Resources Act 1991 [40] as 'main' are usually larger rivers and streams that are shown on the Environment Agency's Statutory Main River map. The Environment Agency has permissive powers, but not a duty, to carry out maintenance, improvement or construction work on designated Main Rivers to manage flood risk. |
| Mitigation | Measures intended to avoid, prevent, reduce and, where possible, offset likely significant adverse environmental effects. Measures follow the mitigation hierarchy as described in section 5.3 of Environmental Statement Chapter 5 EIA approach and methodology, Volume I (Document reference 6.1, DCO Volume 6). |
| Monitoring | Measures to ensure the systematic and ongoing collection, analysis and evaluation of data related to the implementation and performance of a development. Monitoring can be undertaken to monitor conditions in the future to verify any environmental effects identified by the Environmental Impact Assessment, the effectiveness of mitigation or enhancement measures or ensure remedial action are taken should adverse effects above a set threshold occur. All monitoring measures adopted by the Proposed Development are reflected in Environmental Statement Appendix 5.5 Commitments Register, Volume II (Document reference 6.2, DCO Volume 6). |
| Otterbourne Water Supply Works (WSW) | An existing Southern Water site which abstracts water from river Itchen and ground sources and will continue to do in certain circumstances after the Proposed Development. The Proposed Development would transfer source water from Havant Thicket Reservoir to Otterbourne WSW. The source water would be treated to strict regulatory standards at Otterbourne WSW prior to being supplied to customers. |
| Outline Construction Environmental Management Plan (CEMP)<br><br>(Document reference 7.1, DCO Volume 7) | Contains identified topic specific mitigation measures to be adopted during construction and specifies plans and method statements to be produced by the Contractor to avoid and reduce environmental effects. Mitigation measures are generally tertiary mitigation, although some secondary mitigation measures are also included.<br>The measures contained in the Outline CEMP are secured by a requirement in Schedule 2 to the Development Consent Order. Detailed CEMP(s) will be produced and submitted for approval in accordance with the corresponding requirement in Schedule 2 to |

| Term | Definition |
|---|---|
| | the draft Development Consent Order (Document reference 3.1, DCO Volume 3). |
| Outline Foundation Works Risk Assessment (FWRA)<br><br>(Document reference 7.4, DCO Volume 7) | A preliminary assessment prepared during the design phase that identifies potential risks associated with foundation works, such as piling or ground improvement, particularly in areas of contamination or sensitive ground conditions. It sets out initial mitigation measures and informs the development of detailed risk assessments post-consent. |
| Pipeline between the Water Recycling Plant site and Otterbourne Water Supply Works | An underground pipeline approximately 35 kilometres long would transfer up to approximately 90 megalitres per day of source water at maximum operation, from the Water Recycling Plant site to Otterbourne Water Supply Works. Above Ground Plant would support the transfer of water from the Water Recycling Plant site to Otterbourne Water Supply Works.<br>Due to the length of the pipeline, it has been divided into sections:<br>Section D: The Water Recycling Plant site to Portsdown Hill<br>Section E: Portsdown Hill to Boarhunt<br>Section F: Boarhunt to Crockerhill<br>Section G: Crockerhill to Wickham<br>Section H: Wickham to Shedfield<br>Section J: Shedfield to the River Hamble<br>Section K: The River Hamble to Lower Upham<br>Section L: Lower Upham to Brambridge<br>Section M: Brambridge to Otterbourne Water Supply Works |
| Pipelines between Budds Farm Wastewater Treatment Works and the Water Recycling Plant site | Two pipelines between Budds Farm Wastewater Treatment Works and the Water Recycling Plant site: one to transfer treated wastewater from Budds Farm Wastewater Treatment Works to the Water Recycling Plant site and the other to transfer reject water from the Water Recycling Plant site to Budds Farm Wastewater Treatment Works. The Pipelines would connect to the existing treated wastewater release infrastructure and the reject water would be released via the existing Eastney Long Sea Outfall using the existing Eastney Transfer Tunnel and Eastney Pumping Station. The development required to connect into the existing treated wastewater infrastructure would form part of this component of the Proposed Development.<br>The Pipelines between Budds Farm Wastewater Treatment works and the Water Recycling Plant site would be installed on the same route under the Hermitage Stream and Harts Farm Way and would be approximately 700m in length.<br>The Pipelines between Budds Farm Wastewater Treatment works and the Water Recycling Plant site would transfer a maximum flow of approximately 82 Mega litres per day (Ml/d) of treated wastewater to the Water Recycling Plant site. The pipeline from the Water Recycling Plant site to Budds Farm Wastewater Treatment Works would be sized for the same transfer capacity of approximately 82Ml/d as it may be necessary to return the maximum volume of water being treated back to Budds Farm Wastewater Treatment Works. |

| Term | Definition |
|---|---|
| Pipelines between the Water Recycling Plant site and Bedhampton Springs | The Pipelines would transfer recycled water from the Water Recycling Plant site to Bedhampton Springs, and source water from Bedhampton Springs back to the Water Recycling Plant site (before transfer to Otterbourne Water Supply Works).<br>The Pipelines, connecting to pipelines being delivered by Portsmouth Water between Bedhampton Springs and Havant Thicket Reservoir, would enable the transfer at maximum operation of approximately 60 megalitres per day (Ml/d) of recycled water from the Water Recycling Plant site to Havant Thicket Reservoir and approximately 90Ml/d of source water from Havant Thicket Reservoir to the Water Recycling Plant site, for onward transfer to Otterbourne Water Supply Works. |
| Preliminary Environmental Information (PEI) Report | The PEI Report sets out the information that "*is reasonably required for the consultation bodies to develop an informed view of the likely significant environmental effects of the development*" (Regulation 12(2)(b) of the Environmental Impact Assessment Regulations 2017 [41] as set out in Planning Inspectorate (2025) Nationally Significant Infrastructure Projects - Advice Note Seven: Environmental Impact Assessment: process, preliminary environmental information and environmental statements, Section 8.3 [42]). The PEI Report was consulted on at the Summer 2024 Consultation. |
| Principal Aquifer | Rocks or soils that provide significant quantities of water and can support water supply and/or baseflow to rivers, lakes and wetlands on a strategic scale. They typically have a high intergranular and/or fracture permeability, meaning they usually provide a high level of water storage. |
| Project | This refers to the Hampshire Water Transfer and Water Recycling Project, as described in Environmental Statement Chapter 3 Description of the Proposed Development, Volume I (Document reference 6.1, DCO Volume 6). |
| Ramsar site | A Ramsar site is the land listed as a Wetland of International Importance under The Convention on Wetlands of International Importance Especially as Waterfowl Habitat (the Ramsar Convention) established in 1971 and came into force in 1975. |
| Receptor | An individual, group or asset that receives an impact of effect. |
| Recycled water | Purified water that has been produced by taking treated wastewater and removing remaining impurities using advanced treatment techniques. |
| Reject water | During the water recycling process, reject water is produced. Reject water is water containing impurities removed from the treated wastewater and released using the existing Eastney Transfer Tunnel and Eastney Long Sea Outfall. |
| Release from the Eastney Long Sea Outfall (LSO) | The existing Eastney LSO releases treated wastewater from Budds Farm Wastewater Treatment Works via the existing Eastney Transfer Tunnel and Eastney Pumping Station. The Proposed Development would utilise the Eastney LSO for the release of reject water produced by the Water Recycling Plant site. During maximum operation approximately 22 Mega litres per day (Ml/d) of reject water would be released from the Eastney LSO. During minimum flow operation approximately 4Ml/d of reject water would be released from the Eastney LSO. |

| Term | Definition |
|---|---|
| Remediation | An action taken to break or modify the source-pathway-receptor (contaminant) linkage so that the risks are removed or reduced to an acceptable level for the land use under consideration [43]. |
| Secondary A aquifer | These are permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers. |
| Secondary B aquifer | These are mainly lower permeability layers that may store and yield limited amounts of groundwater through characteristics like thin cracks (called fissures) and openings or eroded layers. |
| Secondary undifferentiated aquifer | This has been assigned in cases where it has not been possible to attribute either a Secondary A or B aquifer to the soil type due to the variable characteristics. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type. |
| Site of Special Scientific Interest (SSSI) | A nationally site designated by Natural England as an area of special interest by reason of any of its flora, fauna, geological or physiographical features. SSSI are legally protected under the Wildlife and Countryside Act 1981 (as amended) [44]. |
| Source Protection Zone 1 (SPZ1) | Inner protection zone - defined as the 50-day travel time from any point below the water table to the abstraction source. This zone has a minimum radius of 50m radius from the source, whichever is larger. |
| Source Protection Zone 1c (SPZ1c) | Inner protection zone - defined as the 50-day travel time from any point below the water table to the abstraction source. This zone has a minimum radius of 50m and is where there is protective geology cover, such as clay. |
| Source Protection Zone 2 (SPZ2) | Outer protection zone - defined by a 400-day travel time. The zone will default to a minimum radius of 250m or 500m, depending on the size of the abstraction, if the 400-day travel time zone is smaller. |
| Source Protection Zone 2c (SPZ2c) | Outer protection zone – defined by a 400-day travel time. The zone will default to a minimum radius of 250m or 500m, depending on the size of the abstraction, if the 400-day travel time zone is smaller, and is where there is a protective geology cover of low permeability sat above a unit of high permeability. |
| Source Protection Zone 3 (SPZ3) | Source catchment protection zone - defined as the area around an abstraction source within which all groundwater recharge is presumed to be discharged at the abstraction source. |
| Source water | Water that is used as a source for drinking water. For the Proposed Development, this water is treated to strict regulatory standards at the Otterbourne Water Supply Works before being supplied to customers. |
| Source-pathway-receptor linkage | For a risk to arise there must be hazard that consists of a ‘source’ (e.g. high rainfall); a ‘receptor’ (e.g. people, environment); and a pathway between the source and the receptor (e.g. flooding). |
| Special Area of Conservation (SAC) | Area(s) of protected habitat(s) and species as defined in the European Union Habitats Directive (92/43/EEC) [45]. |

| Term | Definition |
|---|---|
| Special Protection Area (SPA) | A designated area for birds under the European Union Directive on the Conservation of Wild Birds (2009/147/EC) [46]. |
| Summer 2024 Consultation | The statutory consultation held in 2024 which consulted on the Proposed Development, including the draft Order Limits, the proposed pipeline routes, proposed sites for the Above Ground Plant and Water Recycling Plant, temporary construction compounds and any temporary or permanent access routes. |
| Trenchless crossings | Crossings where trenchless installation techniques will be used during construction of the Proposed Development. |
| Unproductive strata | These are predominantly rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow. |
| Waste | Any substance or object which the holder discards or intends to or is required to discard – unusable or unwanted. |
| Wastewater | A combination of water from kitchens, bathrooms, sinks and taps (in domestic and non-domestic properties) and rainwater from roads and roofs, that is transported to, and cleaned at, a wastewater treatment works. |
| Water for Life Hampshire | This is the programme being progressed by the Applicant to address the sustainability objectives of to meet demand following a reduction in abstractions on Hampshire's two main rivers - The Test and Itchen - and ensuring a resilient water supply for the Applicant's customers, especially during times of drought. |
| Water Recycling Plant (WRP) | The WRP would receive a total maximum volume of approximately 82 Mega litres per day (Ml/d) of treated wastewater from Budds Farm Wastewater Treatment Works. This would provide a maximum output of approximately 60Ml/d of recycled water. Approximately 22Ml/d of reject water is produced from the water recycling process and would be combined with the existing Budds Farm Wastewater Treatment Works treated wastewater flows (that are generated by the existing operation of Budds Farm Wastewater Treatment Works), and released via the existing Eastney Transfer Tunnel, Eastney Pumping Station, and Eastney Long Sea Outfall operated by the Applicant. |
| Water Recycling Plant (WRP) site | The site containing the WRP, three pumping stations, a main process building, kiosks, administrative buildings and parking facilities. Located at a site north-west of Budds Farm Wastewater Treatment Works. |
| The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 (WER) | The WER [47] transpose the European Water Framework Directive 2000/60/EC into law in England and Wales. |
| The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015 (WFD Direction) | The WFD Direction [48] establish a series of thresholds that are used in the classification of water body status under the Water Environment (Water Framework Directive) England and Wales) Regulation 2017. |

# Abbreviations

| Term | Definition |
|---|---|
| AA | Annual Average |
| ACM | Asbestos Containing Material |
| AGP | Above Ground Plant |
| AOD | Above Ordnance Datum |
| AONB | Area of Outstanding Natural Beauty |
| APFP | Application Form for Development Consent |
| AQS | Air Quality Standards |
| BaP | Benzo(a)pyrene |
| BGS | British Geological Survey |
| BLM | Biotic Ligand Model |
| BPT | Break Pressure Tank |
| BS | British Standards |
| BSI | British Standards Institution |
| BTEX | Benzene, Toluene, Ethylbenzene, and Xylene |
| bgl | Below Ground Level |
| CEMP | Construction Environmental Management Plan |
| $CH_4$ | Methane |
| CFA | Continuous Flight Auger |
| CL:AIRE | Contaminated Land: Applications in Real Environments |
| $CO_2$ | Carbon dioxide |
| $CO_2e$ | Carbon dioxide equivalent |
| COD | Chemical Oxygen Demand |
| CSM | Conceptual Site Model |
| DCO | Development Consent Order |
| DEFRA | Department for Environment, Food and Rural Affairs |
| DWS | Drinking Water Standards |
| EA | Environment Agency |
| EPS | European Protected Species |
| EQS | Environmental Quality Standards |
| EQS-AA | Environmental Quality Standard – Annual Average |
| ES | Environmental Statement |
| FGL | Finished Ground Level |
| FWRA | Foundation Works Risk Assessment |
| GAC | Generic Assessment Criteria |
| GI | Ground Investigation |
| GIR | Geo-Environmental Interpretative Report |
| GL | Ground Level |
| GWDTE | Groundwater Dependent Terrestrial Ecosystem |
| HBC | Havant Borough Council |
| IPS | Intermediate Pumping Station |
| LiDAR | Light Detection and Ranging |

| | |
|---|---|
| km | Kilometre |
| LSO | Long Sea Outfall |
| MAGIC | Multi-Agency Geographic Information for the Countryside |
| mbgl | Metres Below Ground Level |
| mAOD | Metres Above Ordnance Datum |
| Ml/d | Megalitres per Day |
| NVZ | Nitrate Vulnerable Zone |
| $NH_3$ | Ammonia |
| $NH_4$ | Ammonium |
| $NO_2$ | Nitrogen dioxide |
| $NO_3$ | Nitrate |
| PCOC | Potential Contaminant of Concern |
| OD | Ordnance Datum |
| OS | Ordnance Survey |
| PAH | Polycyclic aromatic hydrocarbons |
| PFAS | Poly- and per-fluoroalkyl substances |
| PPE | Personal Protective Equipment |
| PSC | Potential Source of Contamination |
| SAC | Special Area of Conservation |
| SPA | Special Protection Area |
| SPZ | Source Protection Zone |
| SSSI | Site of Special Scientific Interest |
| SVOCs | Semi-volatile organic compounds |
| TBM | Tunnel Boring Machine |
| TPH | Total petroleum hydrocarbons |
| UK | United Kingdom |
| WFD | Water Framework Directive |
| WMP | Water Monitoring Plan |
| WRP | Water Recycling Plant |
| WSW | Water Supply Works |
| WTW | Wastewater Treatment Works |

# References

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[3] Phase 0 GIR, 6.2 Vol2 ES Appendix 11.2, "Geo-environmental Interpretative Report for the Phase 0 Ground Investigation (Tunnels and Shafts)," Stantec.

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[6] Historic England 2, "Aerial Photo - raf_3g_tud_uk_156_v_5043," 2025. [Online]. Available: https://historicengland.org.uk/images-books/archive/collections/aerial-photos/record/raf_3g_tud_uk_156_v_5043.

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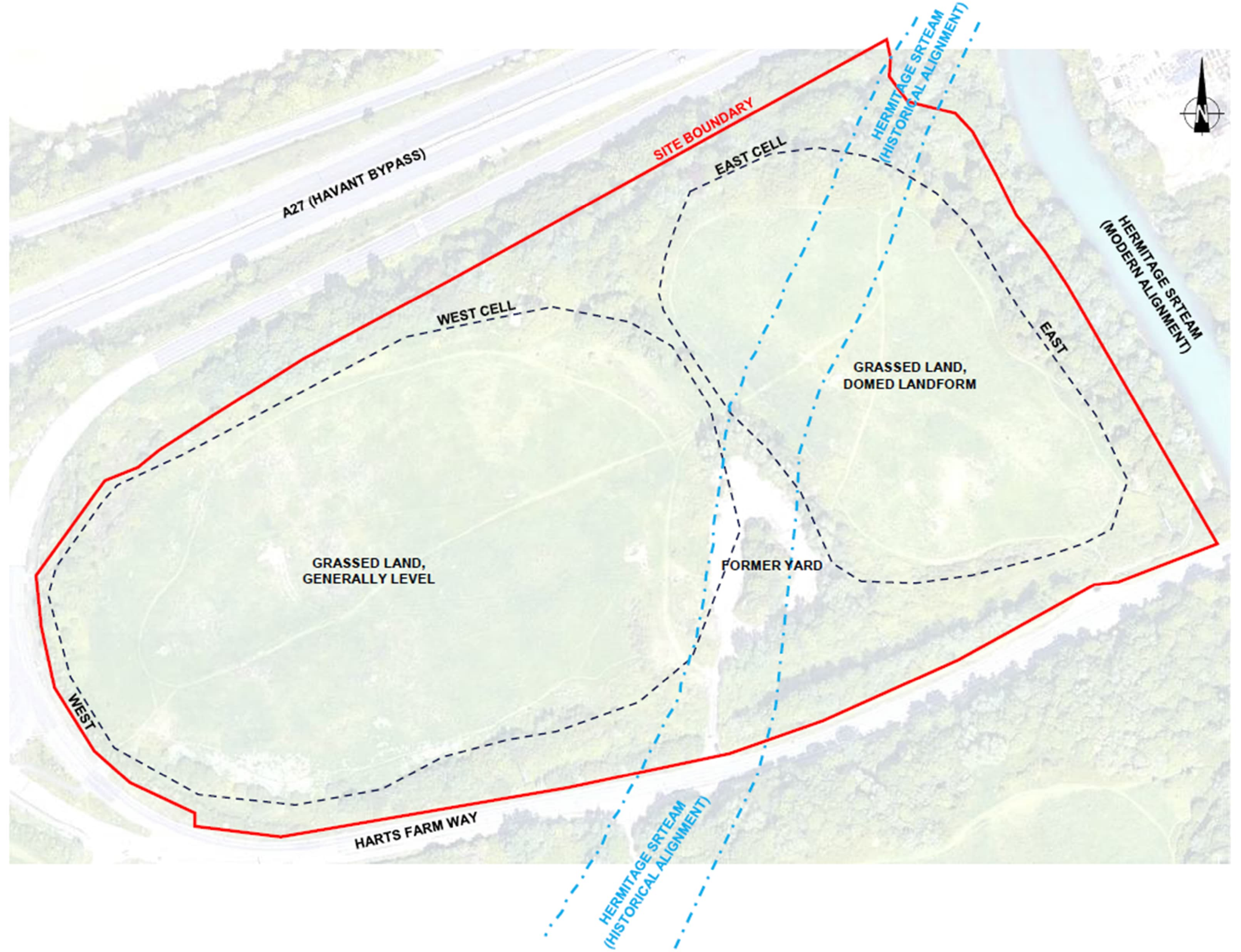
# Figures

Figure 1 – Current Layout of Proposed WRP Site

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**Scaling Note**: Do not scale from this drawing – any errors or omissions shall be reported to Stantec without delay.
**Utilities Note**: The position of any existing public or private sewers, utility services, plant or apparatus shown on this drawing is believed to be correct, but no warranty to this is expressed or implied. Other such plant or apparatus may also be present but not shown. Persons referring to this drawing are therefore advised to undertake their own investigation where the presence of any existing sewers, services, plant or apparatus may affect their operations.

Southern Water

Client/Project:
Southern Water
Havant Water Transfer Water Recycling Project - Water Recycling Plant

| Prepared: | Checked: | Date: |
|---|---|---|
| JAH | SD | 04/2026 |

Title
Current Layout of Proposed WRP Site

Not to Scale

| Revision: | Figure: |
|---|---|
| 1 | 1 |

**Figure 2 – Current Location of the Proposed Area for the Budds Farm Shaft Site**

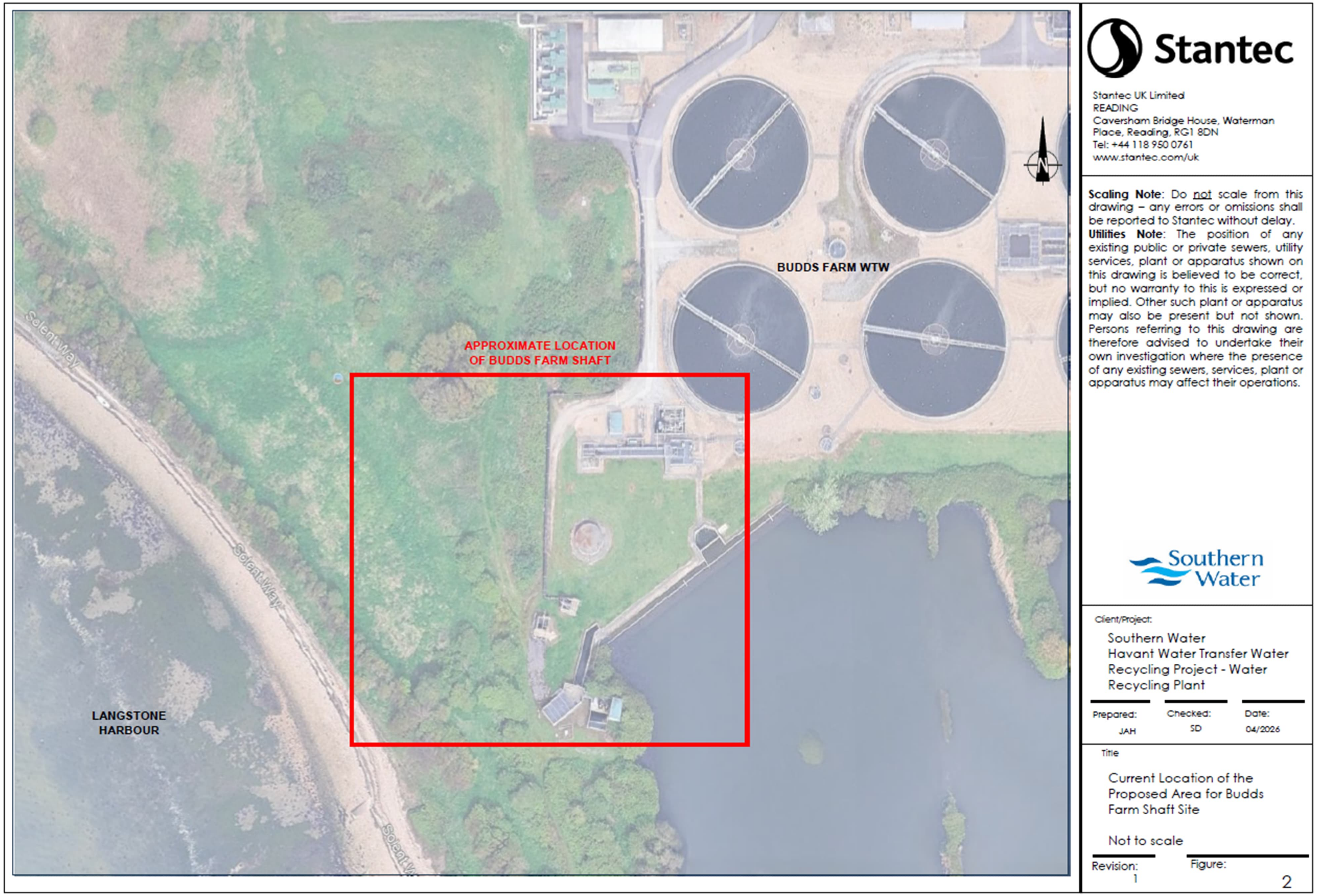


**Figure 3 - Exploratory Hole Locations (DS, 2022)**

**Figure 4 - Exploratory Hole Locations (WYG, 2017)**

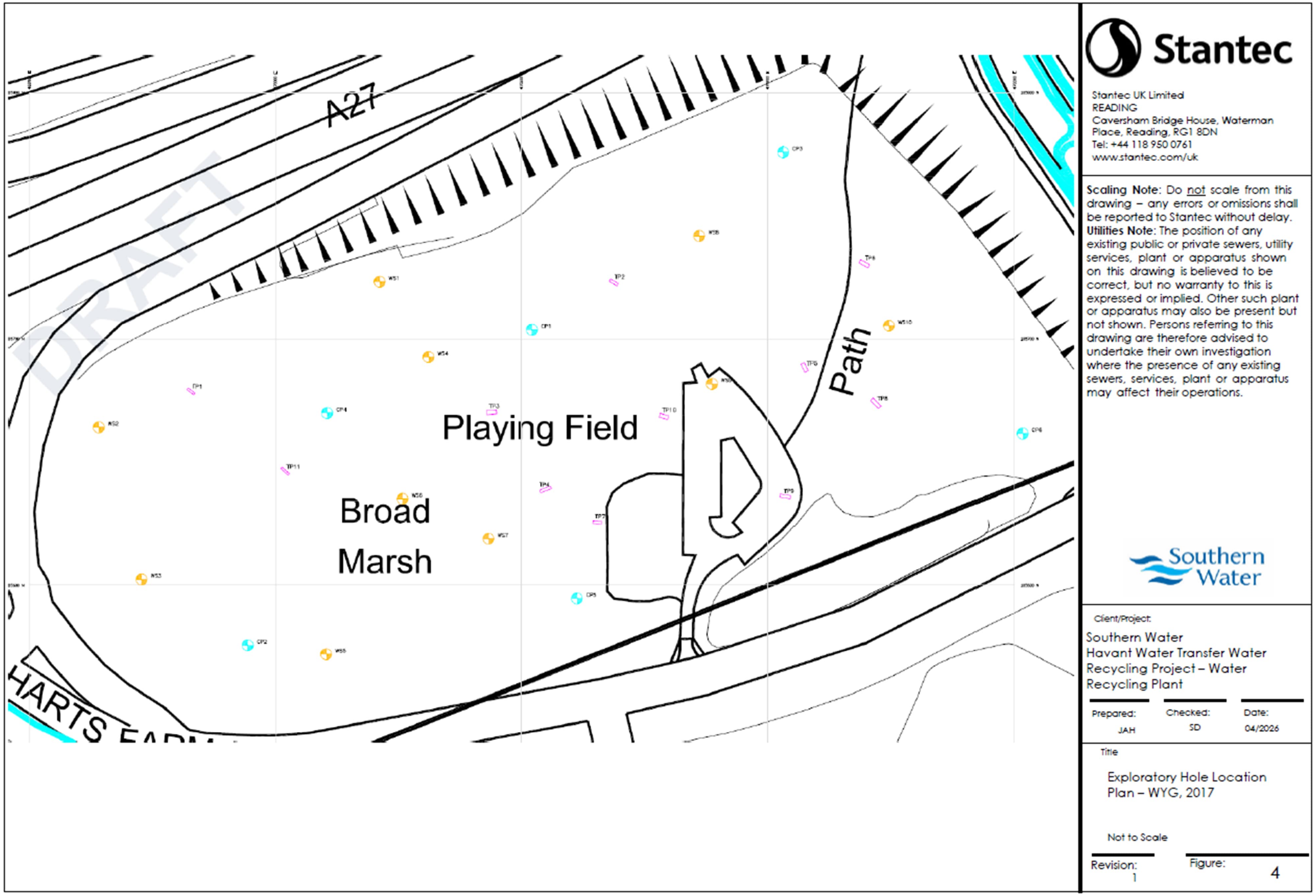
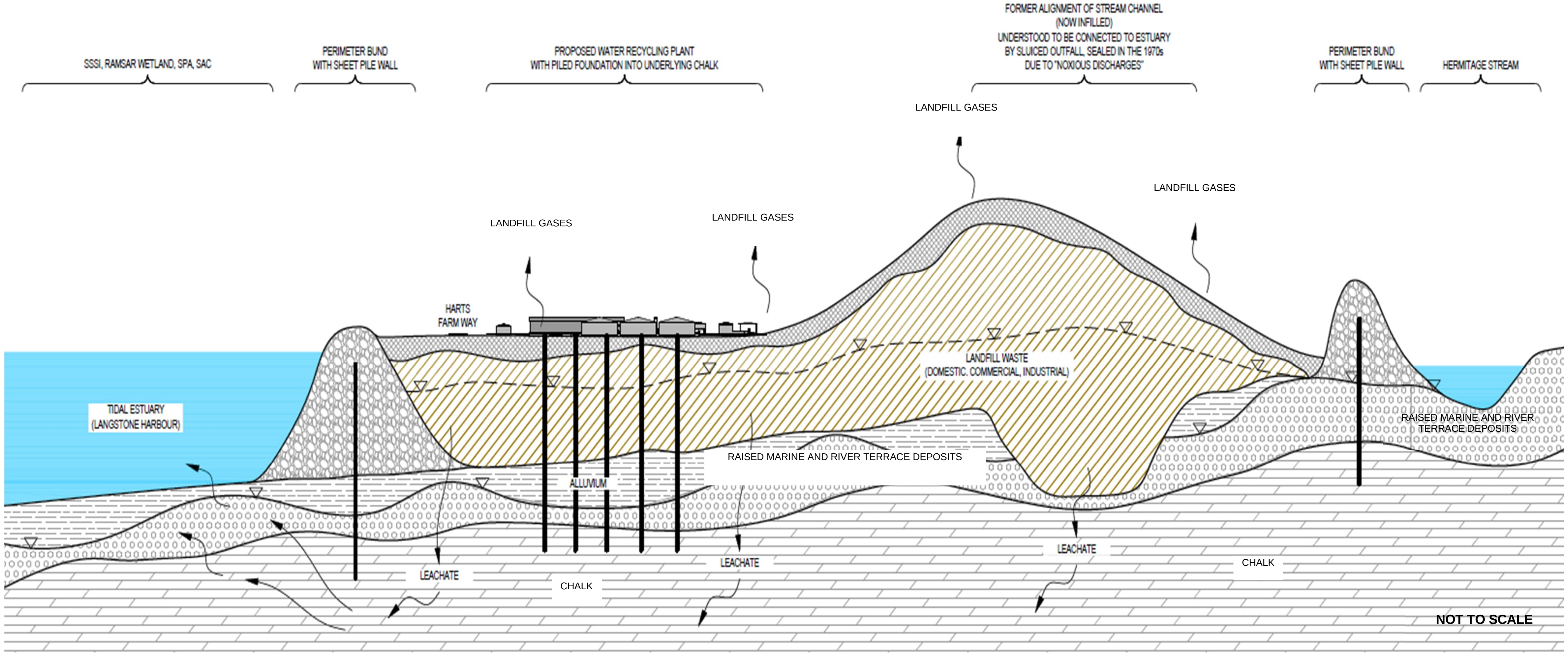


**Figure 5 Exploratory Hole Locations (SSP, 2023)**

**Figure 6 – Schematic Conceptual Site Model (Cross Section)**




NOTES:

The dashed line and triangles within the landfill waste denotes the indicative landfill leachate level.
The solid line and triangles within the raised marine and river terrace deposits denote the indicative groundwater level.

**Figure 7 - Extract of Schematic Conceptual Site Model (Location Plan)**