Havant Thicket Reservoir Project

Environmental Statement Volume 4 - Appendices
Appendix A10 Ground Conditions
A10.2 Havant Thicket Winter Storage Reservoir, Desk Study Report

Portsmouth Water Ltd.

21/08/20

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Introduction

Project Background

The need for additional water in the South East of England region is set out in the draft Water Resource Management Plans ("dWRMPs") prepared by Portsmouth Water and Southern Water, and in the Water Resources in the South East ("WRSE") studies. Many alternative options to meet these demands were considered, and the Havant Thicket Winter Storage Reservoir Project was selected through the WRMP process as a preferred option in both the Portsmouth Water's and Southern Water's dWRMPs.

Proposed Scheme

The proposed scheme, as described by the Portsmouth Water May 2009 plan (based on the Arup 2008/2009 outline plan), will involve the construction of a large reservoir capable of storing around 11.2 Mm^3 of water. This will be retained, partly by an embankment up to 20m high with a crest length of 3km, and partly by the topographical setting at the site. The proposed embankment has a crest level of +40.5 mOD and a maximum water level of +39.5 mOD and a minimum water level of +27.5 mOD. A wetlands habitat is proposed to the north of the site. The Arup scheme included for a pipe connecting the reservoir to Portsmouth Water's Bedhampton pumping station site. This report relates only to the reservoir site.

The reservoir, when constructed, will be filled with surplus drawn from the Havant and Bedhampton Springs when flows are at their highest in Winter via a new combined inlet/outline pipeline, and will provide water supplies to Portsmouth Water customers in the Summer months as required. The increase in water supplies available to Portsmouth Water on completion of the scheme will meet a deficit in water supplies to Southern Water created by Southern Water's imminent reduction of its abstraction licences on the River Itchen.

Complementary to its infrastructure resilience function, the reservoir will provide a new recreational facility/resource adjacent to one of the more deprived areas in south east Hampshire, in an area which the community can access on foot, by bike, or through existing bus routes. It offers further opportunities to improve the wider footpath, cycleway and bridleway networks in the area. More than 29,500 people live within reasonable walking distance of the site (1.5km) and 120,000 people live within reasonable cycling distance of the site (4.5km).

The development will provide a new wetland habitat and associated area for nature conservation. The proximity of the reservoir to the internationally important Langstone Harbour means that it can be used as a safe retreat for roosting birds when there is disturbance in the Harbour. The proposed pipeline will also be used as an emergency draw down pipeline if the reservoir needs to be drained down in emergency conditions in accordance with EA safety guidance (Guide to Drawdown Capacity for Reservoir Safety and Emergency Planning, 2017).

Objectives and approach

This document is part of a suite of 'Geology and Hydrogeology' documents being produced for Portsmouth Water to support the Havant Thicket Winter Storage Reservoir design. Previous documents include the Inception Report and this report builds on the available information reviewed by the Inception Report.

The information in the report identifies the baseline knowledge of the site that is to be used for scoping and strategy of further works. In particular, the desk study will assist in the following:

- Conduct a thorough desk study to synthesise all available information from publicly accessible information, historical ground investigations and planning studies.
- Inform the scoping and specification of the Phase 1 ground investigation.
- Identify potential contamination risks associated with the proposed development.
- Provide supplementary information to support preliminary design decisions for embankment design, borrow pit excavations and materials management plan.

Scope of Report

This desk study provides information on the topographic, geological, hydrogeological and geo-environmental conditions at the proposed HTWSR site.

This desk study considers the ground conditions only within footprint of the proposed Havant Thicket Winter Storage Reservoir site, as shown in Drawing 1 – the Study Area. It does not include the supporting infrastructure that includes the connecting pipeline to the Bedhampton treatment facilities, new pumping facilities, treatment facilities and additional pipelines downstream of Bedhampton.

Assumptions and Limitations

The conclusions and recommendations of this report are based on the data obtained and design details currently available at the time of writing (May 2019). This desk study considers the ground conditions only within footprint of the proposed Havant Thicket Winter Storage Reservoir site, as shown in Drawing 1 – the Study Area.

The findings and opinions conveyed via this report are based on information obtained from a variety of sources, as detailed within this report, including previous reports and ground investigations. Atkins cannot and does not guarantee the authenticity or reliability of the third-party information. It is not part of Atkins scope to independently verify any data collected by others. In addition, it is considered that this would not be appropriate to do so.

Exploratory holes sample or test a fraction of the ground being investigated and variation can occur between sampling points. Therefore, this report cannot guarantee against unexpected ground conditions occurring between the sampling points.

Executive Summary

Portsmouth Water's Water Resource Plan identified Havant Thicket Winter Storage Project as the principal strategic resource development in their supply area. The proposed scheme will involve the construction of a very large reservoir capable of storing surplus water of around 11Mm3. This will be retained, partly by an embankment up to 20m high and 1.5km long, and partly by the topographical setting at the Study Area. The reservoir, when constructed, will be filled with surplus water drawn from the Havant and Bedhampton Springs when flows are at their highest in Winter via a new combined inlet/outline pipeline, and will provide water supplies to Portsmouth Water customers in the Summer months as required.

This desk study presents the geology and hydrogeology for the proposed Havant Thicket Winter Storage Reservoir (HTWSR) site – the Study Area. The scope of the report is limited to the footprint and the immediate surrounding area of the proposed reservoir, as shown in Drawing 1 'Site Layout Plan'.

The Study Area is approximately 160 Hectares and lies within a shallow valley located between Havant, Leigh Park and Rowlands Castle, at approximate OS grid reference SU 715097. The Study Area gently dips to the south from +40mOD along the north boundary to +20mOD south of the reservoir site. Several watercourses and ditches flow across the site from the north to the south and west, converging on a main watercourse that flows south from Middle Clearing. A ditch near the eastern end of the site, running in an approximate north-south orientation, is independent of the main watercourse.

Sources of information provided by Portsmouth Water (detailed within the Geology and Hydrogeology Inception Report document ref: HTWSR-ATK-XX-XX-RP-Z-0007) and from independent search requests, were reviewed. The documents included (but not limited to) the following:

- Published sources from the BGS and literature.
- Ground Investigation assessments - historical ground investigations in the Study Area and the near field between 1962 and 2018.
- Engineering and options assessments – technical reports presenting the results from ground investigations in the Study Area.
- Draft Arup reports from the HTWSR scheme (2008 to 2009) – this included desk-based assessment (Geological and Hydrogeological), draft Aerial Photography Interpretation, proposed scheme drawings, draft Environmental Statement, and a draft Geotechnical Handover report.
- Professional service requests from landmark Group, PBA Associates and Historic England.

A summary of the published geological, hydrogeological and environmental conditions within the far field and near field is presented. This informed an interpretation of the general geology/hydrogeology and potential geological and environmental hazards that may be underlying the Study Area. The far field geology and other pertinent information, including the persistence of the Harwich Formation across the Hampshire basin, is presented in Drawing 2.

The geology of the site comprises Quaternary deposits of Head, underlain sequentially by the London Clay, Harwich and Reading Formations. The Culver Chalk Formation underlies the entire site; however, the depth has not yet been confirmed. Near field historical ground investigation 0.7km north of the Study Area and proven depths of the Reading Formation on the site, indicate that the Chalk may be encountered at approximately or below +7mOD within the Study Area [1] [2]. With exception to recent Quaternary deposits, all formations generally follow the regional structure of the Hampshire basin north of the Chichester Syncline and gently dip to the south-southwest between 1-2° (towards the syncline axis). The anticipated spatial extents and thicknesses of formations/units/sub-units are shown in Table A.

Table A - Expected ground conditions at the site

Formation	Unit / Sub-Unit	General Description	Expected thickness (m)	Spatial Extent
Head / Colluvium deposits		Sand and silty clays, locally gravelly with angular flints depending on upslope source and distance from source. Poorly sorted and poorly stratified deposits.	1 – 5m	Covers over 50% of the site in lower topographic regions and mostly in the west of site
London Clay Formation	Bognor Sand Member	Glauconitic bioturbated or cross-bedded fine- and medium-grained soils, partially cemented.	5 – 10m	Only present along a ridge to the southwest on Gammon's Hill
	Division A3	Bioturbated or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes Silt, with some layers of sandy clay.	15 – 20m	Absent in the northeast of site, increasing in thickness to the south
	Division A2	Clayey silts with sand partings and sandy silt beds.		Not proven
Harwich Formation	HWH1, HWH2 and HWH3	Previously referred to as the London Clay 'basal beds'. Pebbly glauconitic silts and sands and shelly clay with impure shelly limestone.	< 5m	Outcrops to the north and centre of the site, lateral extent across entire site to be confirmed
Lambeth Group	Reading Formation	Predominantly clay, mottled by pedogenetic processes in a humid environment. Red hues dominate with equal proportions of blue-grey and brown.	30 – 35m	Outcrops in the north of site
	Basal Beds	Glauconitic sand and clay basal bed.		
White Chalk		White chalk with numerous flint seams.	80 – 330m	Underlies entire site

Key findings from the Aerial Photography Interpretation (API) included identification of potential geological boundaries, areas of seepages/springs and potential areas of soil creep that are presented in Drawing 3. The geomorphology site walkover delineated some of these features identified within the API (seepages/springs), and the combined API and geomorphological findings are presented in Drawing 4.

Historical ground investigations and reports for the Study Area and those available in the near field are reviewed and presented in Section 7.2. All available historical exploratory hole locations in the Study Area, are presented in Appendix B Drawing 5, with geological cross sections within Drawings 6A to 6G. The anticipated ground profile for the Study Area is presented in Section 7.3. A key finding from the ground profile is the presence of shear surfaces recorded in Trial Pits undertaken in the MRM 1977-1979 ground investigation. The location and orientation of these are presented in Drawing 7.

Whilst key information pertinent to preliminary design of the embankment dam are reported in reviewed historical ground investigations, there are limitations in the lithostratigraphical/hydrogeological findings, which include (but not limited to):

- Depth to Chalk underlying the Study Area is not proven.
- The thickness of the Reading Formation is not proven.
- Continuity/persistence of the Harwich Formation across the site is not proven (although confirmed as present in the far field geology).
- The groundwater regime is poorly defined due to limited coverage of groundwater monitoring across the site.
- No in-situ permeability testing was undertaken.

An initial review of the geotechnical engineering issues are presented and specific hazards identified are shown in Drawings 8. This review includes a summary of parameters derived from available historical ground investigations in the Study Area (Table 9-1) followed by a review of the geotechnical hazards and geotechnical gap analysis, presented in Table 9-2 and Table 9-3 (respectively). The findings of the Geotechnical Gap Analysis within the desk study has indicated four key areas that will reduce residual risk of unknown ground and hydrogeological conditions, these are:

- **Robustness of ground model**: Target data gaps between historical Ground Investigation to delineate areas at risk of reservoir leakage and seepage primarily from the Harwich Formation, Bognor Sand Member and relic periglacial landforms (Pingos). Data gaps include leakage paths across the northern extent of the Study Area, along the proposed wetlands retaining structure. It should be noted that relic periglacial formations (Pingos) were not identified in the Study Area however a residual risk remains.
- **Groundwater regime**: Determine the local hydrogeological regime of the Harwich Formation and Chalk aquifers through additional groundwater monitoring and in-situ permeability testing that had previously not been conducted in historical ground investigations.
- **Evaluate Borrow pit area:** Target data gaps within the reservoir footprint to establish how each of the strata will be re-used. It is proposed that all excavated material from the excavations generally, and the borrow pit in particular, will be re-used on site, with testing to inform the suitability for each material e.g. for use in the embankment core, on the shoulder of the embankment, or for landscaping.
- **Stability of the embankment foundation and borrow pit slopes**: Conduct strength testing along the embankment and borrow pit slopes where data gaps remain. Investigate the shallow and deep shear surfaces encountered in historical trial pits and some borehole samples.

An outline for a Phase 1 ground investigation is been presented in Table 10-1 as a basis for reducing the risks of unknown ground and hydrogeological conditions outlined in Section 9.4.

A review of the environmental setting of the site was also undertaken to develop a Preliminary Conceptual Site Model (PCSM), which has identified and assessed the Potential Contamination Linkages (PCL). Potential on-site sources of contamination include reworked ground associated with historical construction, de-vegetation activities and the channelization of watercourses and potential spills / leaks associated with burnt out cars. Potential off-site contamination sources include Made Ground / contaminated ground and groundwater associated with a fuel station, historical landfills, infilled former brick, chalk and clay pits, allotments, a smithy and a former battery and military base.

Previous ground investigations undertaken at the site have not encountered Made Ground and potential on-site sources of contamination are considered to be localised with a limited likelihood of a pathway existing if present. Based on the PCSM, potential risks to human health, property, controlled waters and ecological receptors have been identified as very low to low risk, dependent on implementation of mitigation measures.

This study recommends that a Phase 1 ground investigation is undertaken to reduce the residual risk as identified in the Geotechnical Gap Analysis and PCSM.

1. Sources of Information

1.1. Summary of existing Data and Surveys

A review has been made of the existing information held by Portsmouth Water and in addition other accessible information has also been obtained and reviewed. The information has been established over several decades, since the project was first conceived in the early 1960's. Existing data and surveys available for the scheme, which are relevant to the ground conditions, geology and hydrogeology are summarised below:

- Ground investigation (GI) data – several previous ground investigations were undertaken between 1962 and 2008 to obtain information on the ground conditions underlying the scheme. The findings of the investigations are presented as factual reports, laboratory testing, borehole and trial pit records;
- Aerial photographs – there are a collection of aerial photographs which show the reservoir site history of the scheme;
- Water Resources Management Plan – the current plan was prepared in 2014 (with the 2019 version currently in draft) and provides information in relation to surface water and spring flows, abstraction borehole yields and annual groundwater levels; and
- Plans and drawings – there are several drawings for the scheme including geological plans and cross sections, details of historical boreholes, details of the reservoir layout, embankment contours and the pipeline route between the reservoir site and Bedhampton.

A full list of the existing data and surveys, with a commentary on suitability, is provided in Appendix D.

1.2. Summary of previous assessments and studies

The previous assessments and studies held by Portsmouth Water that are relevant to this desk study include:

- Desk-based assessments – a draft Desk Study by Arup was undertaken for the scheme in 2008 and included a summary of the previous investigations. A draft Hydrogeological Desk Study by Arup was also undertaken in 2009 and provides details in relation to the hydrogeology of the reservoir site and local area. Arup also undertook an interpretation (draft) of the aerial photographs in 2008 to provide information in relation to the history of the site. The Arup reports are contained in a geotechnical handover report; [3]
- Engineering and options assessments – several technical reports were prepared between 1962 and 2009 (Edgar Morton [4] [5], Mander, Raikes & Marshall [6] [7], Mouchel Parkman [8], Entec [9] and Arup [3]) which present the results from the ground investigations and discuss various options for the design and construction of the reservoir embankment.
- Ground investigation assessment – a draft Arup report was prepared in 2008 outlining the various phases of ground investigation, data gaps and the risks associated with the unknowns; and
- Draft Environmental Statement – A draft Environmental Statement was prepared by Arup for the scheme in 2008 and includes a geology and hydrogeology chapter.

Overall the relevant parts of the existing assessments and studies are suitable as a general background to the desk study assessment, noting that the draft Arup Reports need to be used in conjunction with the Portsmouth Water Feedback comments (Report No. 4 Geotechnical Engineering). A key omission from the Mouchel Parkman, Entec and Arup work in the latter part of the 2000's is the trial pits undertaken by Mander, Raikes and Marshall in the late 1970's.

A full list of the Portsmouth Water held previous assessments and studies that detail proposals for an earth embankment at the site is provided in Appendix D. References are provided within the document text.

The general sources of information that have been reviewed as part of this Desk Study are outlined in Table 1-1 below.

Table 1-1 – Sources of Information

Source Type	Data Observed	Information
Topography and Geographical information	Maps	• Envirocheck Report dated 29 April 2019 [10]. • Ordnance Survey (OS) Maps [10]: 1:25,000 1:50,000
	Aerial photography	• Historic England (Archives) • Portsmouth Water • Envirocheck Report [10] • Google Earth
Geological, Hydrogeological and Hydrological Data	British Geological Survey (BGS) Maps and memoirs	• BGS Sheet 316 (Fareham) at 1:50 000, 1998 [11] • BGS Sheet SU 70 NW and Sheet SU71 SW at 1:10 000 scale, 1983 • ESRI data at 1:10 000 (for Havant Thicket area) [12]
	BGS Borehole Records	• Summarised in Section 3.
	Historical ground investigations	• Edgar Morton and Partner, 1962-63 [4] • Hampshire Reservoirs Site 18 prepared by Mander, Raikes and Marshall, 1977-1978 [6] • Foundation Engineering Ltd, 1980 [13] • Soil Mechanics Ltd investigation, 2006 [14]
	Technical papers/reports	• Design and Construction of a 60 ft high earth embankment, Prof Peter Rowe, 1963 [5] • Mander, Raikes and Marshall (1977 – 1980) [6] • Mouchel Parkman (2006) [8] • Entec, 2007 [9] • Ove Arup & Partners, 2009 [3]
	BGS Geology of Britain Viewer	• Historical boreholes archive
	Data sheets and site context maps	• Envirocheck Report dated 29 April 2019. [10]
Site Use and Historical Development of Site	Historical maps and reports	Envirocheck Report dated 29 April 2019 including historic OS Maps at 1:2,000, 1:10,000 and 1:10,560 scale, dated 1870 to 2019. [10] • Site History Information Portsmouth Water, 2012 [15]
	Aerial photography	• Historic England (Archives) • Portsmouth Water • Envirocheck Report

Source Type	Data Observed	Information
		• Google Earth
Environmental Setting	Data sheets and site context maps	• Envirocheck Report by Landmark Information Group dated 29 April 2019. [10]
UXO	Risk Assessment and maps	• Preliminary Unexploded Ordnance (UXO) Threat Assessment Report undertaken by 6 Alpha Associates (part of Landmark Information Group), dated May 2019. [16]

2. Site Description

2.1. General

The following sections provide a summary of the available historical information gathered by Atkins from Portsmouth Water and other accessible public sources summarised in Appendix D.

Historical inception reports, desk studies, factual reports, geotechnical interpretative reports and feedback reports as detailed in Appendix D have been utilised to inform this desk study.

2.2. Site Description

The proposed HTWSR site, i.e., the Study Area, is presented in Drawing 1. The Study Area lies within a shallow valley located between Havant, Leigh Park and Rowlands Castle, at approximate OS grid reference SU 715 097. The Study Area has an area of approximately 160 Hectares and comprises predominantly open grassland, with some woodland, hedgerows and ditches. The Study Area is mostly utilised for animal grazing with public access retained via a bridleway across the middle of the Study Area, with permissive paths around most of the perimeter and along 'The Avenue'.

Planning permission for the construction of a reservoir was first granted in 1964. The land was acquired by Portsmouth Water in two blocks in 1965 and 1966 for the purpose of constructing a new reservoir to help meet the rising demand for water.

Figure 2-1 provides an aerial photograph to illustrate the current site layout, the key descriptors used in the Study Area history section and the proposed location of the Havant Thicket Winter Storage Reservoir. In order to evaluate key features within the footprint, the Study Area areas has been separated into four quadrants to assist the reader spatially as shown in the figure.

Figure 2-1 - Proposed reservoir site layout

2.2.1. Site Walkover

Site walkovers of the site were undertaken on 4th April 2019 and 24th April 2019. No potential sources of contamination or potentially contaminative processes were observed during the site walkover. However, it is noted that not all areas of the site were accessed during the site visits.

The walkover confirmed the general nature of the site as described above. In addition, the walkover helped to develop the geomorphological assessment presented in Section 5 herein.

2.3. Site History

A review of the historical development of the proposed HTWSR site and surrounding area (within 500m of the site) has been undertaken with reference to the following sources of information:

- OS mapping and historical aerial photographs included within the Envirocheck Report [17];
- Historical aerial photographs included as part of an Aerial Photograph Interpretation prepared by Arup in 2008 [18];
- Historical aerial photographs provided by Historic England [19]; and,
- A site history information document prepared by Portsmouth Water in 2012 [15].

The Envirocheck Report is included in Appendix F and other aerial photography sources are provided in Appendix D.

A summary of relevant features is provided in Table 2-1, comprising general development and potentially contaminative processes or features that may have affected the site from a geo-environmental perspective.

Table 2-1 – Summary of Historical Development

Date and Scale	On-site Development	Development in the surrounding area (within 500m of the site)
1870 1:10,560 1878 1:2,500	The site largely comprises woodland named as Havant Thicket. Open glades are also located within the wood. Three unnamed watercourses are present in the north of the site that converge into one unnamed watercourse in the southeast of the site. Areas within the site, are labelled as Thicket Bottom, Deerslaughter Plain, Gammons Hill and Bondfields Plain in the southeast and Parish Piece in the east of the site. A number of tracks are present throughout the site in various orientations. There were no common rights to the site in 1870 as it became part of the private Leigh Park Estate [15].	The woodland extends over 500m north of the site to the Forest of Bere and to approximately 500m to the west of the site, where it is bordered by open agricultural fields. The areas of woodland to the north is named Long Wood and to the west, Bells Copse. The unnamed watercourses within the north of the site extend further north for approximately 500m. The watercourse in the south of the site extends off-site in excess of 500m. An unnamed watercourse orientated north to south flows south from Bells Copse running parallel to the southwestern site boundary, approximately 400m away. The watercourse flows past Middle Park Farm, located approximately 400m southwest of the site. The settlement of Red Hill exists approximately 200m northeast of the site and comprises woodland, Redhill Farm and a Brick and Tileworks Clay Pit. St Johns Church, National School and Staunton Arms Public House are located approximately 225m east of the site, south of Red Hill. An area of woodland is present 500m east of the site boundary. A Brick Yard and Clay Pit are located approximately 100m to 200m southeast of the site with an additional Clay Pit 350m further southeast. This area is named The Durrants. There is also a

Date and Scale	On-site Development	Development in the surrounding area (within 500m of the site)
		road present that borders the southwest site boundary with potential residential properties adjacent. A Brick Kiln, Clay Pit and Drinking Well are located approximately 400m west of the site, north of the area of Dunsbury Hill. The area within 500m south of the site contains a number of coppices including Billys Coppice, Bondfields Coppice and Hammonds Coppice. 'The Lake' associated with Leigh Park Estate is located approximately 60m south of the site boundary and extends 200m further to the south. It is approximately 100m in width. A Battery is labelled within the boundary of The Lake. A group of cottages are also present approximately 200m south of the southwest corner of the site. A possible clay pit/cutting is present approximately 300m south of the site.
1897 – 1898 1:10,560 1897 1:2,500	A de-vegetated strip labelled 'The Avenue' is present running through the centre of the site, orientated from northwest to southeast. The Upper Lake and a Bathing House are now situated in the centre of The Avenue. A monument is also present on The Avenue within the southern site boundary. A sluice gate is present on the southern border of the Upper Lake A further de-vegetated rectangular area is located in the southwest of the site within Deerslaughter Plain.	Two Old Clay Pits are shown approximately 250m northwest and north of the site. Clay Pits and Brick Works are denoted 250m northeast of the site. Brick Field (Disused) is shown on the map, approximately 225m southeast of the site, west of the Durrants area. A Smithy is also located in this area. The claypit/cutting south of the site possibly infilled. An Old Chalk Pit is present approximately 200m northwest of the site A drain extends west from the northeast corner of the site towards to the unnamed watercourse to the west of the site.
1899 1:10,560 (Eastern half of the site available)	No significant changes.	No significant changes.
1909 – 1910 1:10,560 1909 1:2,500	The clearing in the southwest of the site, now named 'Middle Clearing' has been replanted in the northern section. The monument is now labelled as the 'George Canning Monument'. Gipsies Plain, located in the east of the site shows a square pattern, possibly being managed and is shown as heathland.	The Brick Works and Clay Pit located 250m northeast of the site are labelled 'Old Brick Works' and 'Old Clay Pit'. Residential development has taken place along Castle Road, east Red Hill, approximately 250m to 500m northeast of the site. The woodland running parallel to the unnamed watercourse to the west of the site is named The Warren.

Date and Scale	On-site Development	Development in the surrounding area (within 500m of the site)
1914 1:10,560 (Eastern half of the site available)	No significant changes.	No significant changes.
1931 – 1933 1:10,560	No significant changes.	The Smithy is no longer shown to be present 225m southeast of the site.
1938-1942 1:10,560 (North-western and southern half of the site available)	No significant changes.	Allotment Gardens are present approximately 250m southeast of the site.
1946 Aerial Photography	The aerial photograph shows woodland present across the majority of the site apart from the Gipsies Plain area in the east and a cleared square in the northwest of the site. The two sections of the Middle Clearing are shown, the southern section more sparsely planted with oak trees than the northern.	Previous reports referenced within the Portsmouth Water Site History Information report [15] suggest that a military establishment was present approximately 350m south of the site including a number of huts and football pitches.
1954 Aerial Photography	The photograph shows that the majority of woodland within the site has been cleared, leaving two small very young oak plantations (Middle Clearing and Round Wood) to the west of The Avenue. A thin row of trees bordering the Upper Lake and running south along The Avenue also remained. Tracks are present across the site.	Residential development named Leigh Park has taken place adjacent to the southwestern edge of the site.

Date and Scale	On-site Development	Development in the surrounding area (within 500m of the site)
1953 – 1972 1:2,500	No significant changes.	The residential development to the southwest of the site extends a further 500m southwest. A cutting is visible 50m north of Middle Park Farm to the west of the site and of the unnamed watercourse. A Pond is marked at Middle Park Farm and approximately 100m east of the farm. A pond is present approximately 150m southwest of the site. A Youth Hostel and Boys' Club has been constructed south of the cottages bordering the south of the site. A series of drains are present approximately 60m south of the site, possibly running either to or around The Lake.
1960 Aerial Photography	The majority of the site remains mostly cleared of trees with the exception of Middle Clearing and The Avenue. Scattered trees are visible across the site.	No significant changes.
1962 1:10,000	No significant changes.	No significant changes.
1966 1:10,000	No significant changes.	No significant changes.
1970 1:2,500	No significant changes.	Further residential development has taken place to the southwest of the site. Middle Park Farm no longer present. A weir exists in the place of the cutting intercepting the unnamed watercourse approximately 400m west of the site. Several ponds are present on the site of the Old Brick Works 250m northeast of the site. The Old Chalk Pit approximately 200m northwest of the site is no longer shown and potentially infilled.
1975 1:10,000 (Southern half of the site available)	The woodland to the east of The Avenue has been de-vegetated and regenerating scrub cleared. West of The Avenue the woodland key indicates 'Non-coniferous Trees-Scattered'. The George Canning Monument no longer shown to be present. A weir is present on the southern boundary of the Upper Lake.	No significant changes.

Date and Scale	On-site Development	Development in the surrounding area (within 500m of the site)
1980- 1982 1:10,000 (Northern half of the site available) 1981 1:2,500	The northern half of the site is largely de-vegetated excluding coniferous trees on the northern boundary of the Upper Lake and the northern site boundary.	No significant changes.
1992 1:10,000	The site is named the Sir George Staunton Country Park. The maps show all areas of the park have been de-vegetated apart from the Middle Clearing in the southwest of the site and the area within The Avenue. A section across the southern boundary of the site also remains vegetated and is still named as Havant Thicket.	The watercourses in the north of the site have been straightened. Further residential development has taken place approximately 150m to 500m northeast of the site.
2000 1:10,000	The site is now named Staunton Country Park.	No significant changes.
2003 Aerial Photography	No significant changes.	No significant changes.
2006 1:10,000	No significant changes.	No significant changes.
2019 1:10,000	No significant changes.	No significant changes.

3. Geology

3.1. Published Geological Information

The British Geological Survey map sheet 316 Fareham [11] was reviewed to determine the geological setting in the far field of the Study Area and is presented in Drawing 2.

The Hampshire basin[1] is located within a shallow E-W striking syncline known as the Bere Forest/Chichester syncline. The proposed reservoir site is on the northern limb of the syncline, approximately 4km from the axis. The geological map shows that the underlying formation of the syncline is cretaceous chalk deposits that outcrop to the north and south of the Study Area, within 1km and 3km (respectively). The chalk outcrop forms a regional high approximately 10km to the north of the reservoir site in the form of a large escarpment. From there, the topography decreases gently in a southerly direction, towards the Bere Forest/Chichester syncline axis.

Overlying the Cretaceous Culver Chalk Formation basement rocks are Palaeogene deposits that generally outcrop sequentially from north to south, towards the syncline axis. Quaternary deposits are present in variable amounts across the region.

3.1.1. Geological Nomenclature

The nomenclature used for lithological units has changed significantly within published geological literature and historical ground investigations. Table 3-1 outlines the nomenclature that will be used within this report and references the various terminology that has been previously used by others. Within the report text, any reference or direct quotes from historical text, will include '*sic*' after the reference and the formalised nomenclature in parentheses to aid clarification.

Table 3-1 - Nomenclature used for lithostratigraphical units

Period / Age	Group	Formation	Units with abbreviation used in this report		Terminology used by others / sub-units
Palaeogene / Eocene	Thames Group	London Clay Formation	Bognor Member	BM	Bognor Sand Member
			London Clay Division A3	LCA3	London Clay
			London Clay Division A2	LCA2	Walton Member, Harwich
		Harwich Formation		HWH1, HWH2, HWH3	London Clay Basal Beds, Oldhaven Formation, Blackheath Beds, Basement Bed, Tilehurst Member, Twyford Member, Herne Bay Member, Harfield Member
Palaeogene / Thantian - Ypresian	Lambeth Group	Reading Formation		RB	Reading Beds, Woolwich & Reading Beds,
Cretaceous / Campanian	White Chalk Sub-Group	Culver Chalk Formation		CHLK	Chalk, Upper Chalk, Tarrant Chalk, White Chalk Sub-Group

[1] The Hampshire Basin is a geological basin of Palaeogene age in southern England, underlying parts of Hampshire, the Isle of Wight, Dorset and Sussex

3.2. Far Field Geological Setting

Regionally, the Study Area is located within the Hampshire basin and more broadly, the Wessex basin[2]. The dominant geology and structures of the Wessex basin are dominated with deposits between the Permian and Cretaceous and are up to 3.5km thick in places. The Wessex basin-infilling is associated with massive tectonic extension and normal faulting, related to the opening up of Pangea in the Mesozoic age. Extension was followed by a phase of tectonic compression and reactivation of some of the faults within a reverse sense, principally of Miocene age [20].

The regional geological setting is heavily influenced by the depositional setting and tectonic history of the region. The key ages or periods and phases of tectonic and deposition are summarised here:

3.2.1. Palaeozoic Era

The region is underlain by Palaeozoic (or Variscan) bedrock. These strata were strongly deformed during the Variscan orogeny[3], a period of tectonic compression and mountain building that culminated at the end of the Carboniferous [20] and the formation of the supercontinent Pangea. There are no Palaeozoic deposits within 1.5km of ground surface beneath the Study Area.

3.2.2. Mesozoic Era

The Mesozoic period aligns to the break-up of supercontinent Pangea. Extension and early opening of the Atlantic led to reactivation of the deep-seated Variscan structures. These can be seen in BGS geological map cross sections on the 1:50,000 Fareham sheet [11] as a series of southward-throwing normal faults creating half-graben-like structures. Thick sedimentary sequences were laid down on the downthrown sides with a pattern of thinning sequences up the dip slope of the titled fault blocks [20].

A period of regional subsidence and relative sea-level rise in the late cretaceous resulted in a relatively uniform and thick chalk group deposited widely in the Hampshire basin [20]. Global seal level fall towards the end of the Cretaceous period that led to erosion in parts of the uppermost chalk and the development of a pre-Cenozoic unconformity.

3.2.3. Cenozoic Era

The Cenozoic is defined by three periods; the Palaeogene[4], Neogene[5] and Quaternary[6]. The early Cainozoic was characterised by intermittent deposition of Tertiary sediments (Lambeth Group) that took place about 58 Ma when a shallow sea extended from the deeper water of the North Sea Basin to cover the whole of southeast England [21] Increasing subsidence and relative sea level rise led to deposition of the London Clay, which tapered in thickness from a deeper depositional environment of London towards a shallower depositional environment of the Hampshire basin.

A phase of folding followed that was associated the collision of the African and Eurasia plates [20]. This N-S compressional event, *c.* 25 Ma, effectively separated the London and Hampshire Palaeogene basins onshore in southern England.

[2] A petroliferous geological area located along the southern coast of England and extending into the English Channel [54].
[3] A geologic mountain-building event caused by Late Palaeozoic continental collision between Euramerica and Gondwana to form the supercontinent of Pangaea
[4] Geological period spanning 43 million years from 66 million years ago to 23.03 million years ago
[5] Geological period spanning 20.45 million years from 23.03 million years ago to 2.59 million years ago
[6] Geological period spanning 2.58 million years ago to the present

The deposition of material in the Quaternary period was related to transgressional and regressional sea level cycles. During glacial periods, subaerial erosion was dominated by solifluction and an extensive river system to much lower base levels [20].

3.2.4. Regional Structure

Structurally, the area falls within the Wessex Basin which covered most of Southern England during Palaeozoic to Mesozoic Eras. It is underlain by highly deformed Devonian and Carboniferous strata [22]. The floor of the Wessex sedimentary basin within the region is divided by several major, shallow southward-dipping thrust zones and N-W oriented wrench faults, which formed during the Variscan orogeny at the end of the carboniferous [20]. The presence of these features affected not only the sedimentation in the Mesozoic and Cenozoic Eras, but also the position and alignment of folds and faults visible at the surface.

The 1:50,000 geological map has been used to infer the stress field which the rocks have experienced in the geological past. Within the outcrop of chalk, dry valleys are present which are likely to correspond to lines of weakness or jointing within the rock. The fracture sets inferred from the geological map can be broadly separated into two sets; those which trend in a NW-SE direction and those which trend in a NE-SW direction. The stresses which the rocks have experiences indicates a N-S primary stress axis. There are some E-W trending valleys which are thought to relate to tensional movement along deep basement faults rather than compressive forces.

3.3. Near Field

The proposed reservoir site is underlain by a sequence of Cretaceous, Palaeogene and Quaternary deposits that are presented in Table 3-2 below. The Lithostratigraphical units present are summarised in this section. The deepest stratum summarised within the Near Field is the cretaceous Chalk of Campanian age. The Campanian cretaceous and all older Chalk Formations are anticipated to be in Hydraulic connectivity, and underlain by the Gault Clay formation, an aquitard. For this reason, older Cretaceous deposits (including the Gault) have not been considered in this section as they are unlikely to have any further impact to the proposed design of the reservoir and supporting infrastructures.

Table 3-2 - Generalised geological sequence of the Near Field

Period	Epoch	Lithostratigraphical Units		Description	Depositional Environment	Potential Structures	Estimated Thickness [11]
Quaternary		**Pleistocene to Holocene**	**Head / Colluvium deposits**	Sand and silty clays, locally gravelly with angular flints. depending on upslope source and distance from source. Poorly sorted and poorly stratified deposits.	Superficial deposits that have accumulated by solifluction, hillwash and hillcreep.	Glacial terrain structures (mass movement deposits)	1 – 5m
Palaeogene	**Eocene**	**London Clay Formation**	**Bognor Sand Member**	Glauconitic bioturbated or cross-bedded fine- and medium-grained soils, partially cemented.	Broad open sea deposits affected by marine regression and transgression cycles. Clays deposited in deep marine setting with coarser deposits in upper cycle representing shallower conditions.	Shear zones Minor faults Joints and fissures Solifluction shears Pingos Sinkholes	5 – 10m
			Division A3	Bioturbated or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay.			15 - 20m
			Division A2	Clayey silts with sand partings and sandy silt beds			
		Harwich Formation		Previously referred to as the London Clay 'basal beds'. Pebbly glauconitic silts and sands and shelly clay with impure shelly limestone	Shallow marine shelf environment, with proximal 'facies' closer to shore, with relatively slow and interrupted sedimentation.	Shear Zones Joints and Fissures Pingos Sinkholes	< 5m
	Paleocene	**Lambeth Group**	**Reading Formation**	Predominantly clay, mottled by pedogenetic processes in a humid environment. Red hues dominate with equal proportions of blue-grey and brown.	Terrestrial deposits consisting of fresh or brackish water channels draining sandy flats. Flash flood deposition of clay deposits. Shallow inshore seas, deltas, estuaries and lagoons on the southern margins of low-lying hinterland.	Shear Zones Minor Faults Joints and fissures Solifluction shears Pingos Sinkholes	30 – 35m
			Basal Beds	Glauconitic sand and clay basal bed			
Cretaceous	**Late**	**White Chalk Group**		White chalk with numerous flint seams	Outer shelf of an epicontinental sea of normal salinity and little terriginous input	Joints and fissures Minor faults Sinkholes Buried valleys	80 – 330m

3.3.1. Chalk

Late Cretaceous deposits of Culver Chalk Formation outcrop to the north and northeast of the proposed reservoir site. The 1:50,000 BGS geological map [11] indicates that the Culver Chalk Formation gently dips to the south, with an increasing thickness of overlying deposits towards the south. The Culver Chalk Formation is characterised by white chalk with numerous flint seams.

3.3.2. Reading Formation (Lambeth Group)

The Reading Formation rests unconformably on the eroded surface of the Chalk Group and is between 30 and 35m thick. The formation consists of brightly coloured-mottled clays and silty clays; localised lenticular bodies of fine-to medium-grained well-sorted sand occur at various levels, particularly at the top and base [11]. The 1:10,000 BGS geological map indicates that only limited exposures of the Reading formation are present within the Study Area footprint, outcropping at the bottom of river valleys in the north of the Study Area.

The Reading Formation has been worked at numerous localities along the northern crop of the Bere Forest Syncline for both sand and for brick clay. According to historical mapping and aerial photography (PW), there is evidence to the east of the Study Area around Rowlands Castle of brickworks, with associated pits, within an outcrop of the Reading Formation (see Section 2.3 herein). Brick pits are still present in the wood to the south east of the reservoir site. There is no evidence from aerial photographs or historical maps that such extractive activity took place elsewhere on the reservoir site.

3.3.3. Harwich Formation

The Harwich Member directly overlies the Lambeth Group and comprises a highly glauconitic silty sand with clay layers and calcareous concretions. The sand is generally encountered as micaceous and bioturbated [23]. The formation is considered to have been deposited in a shallow marine shelf environment, with proximal 'facies' closer to shore, with relatively slow and interrupted sedimentation [24]. Spatially, the Harwich formation outcrops to the north and northeast of the Study Area.

As a consequence of the Harwich Formation's historical inclusion within the London Clay Formation as 'the basal beds' *sic*, historical geological mapping has not recorded all outcrops of the Harwich Formation in the Hampshire Basin as separate to the London Clay Formation. A review of Historical BGS boreholes was undertaken to identify the presence of the Harwich Formation in the far field of the Hampshire basin. Drawing 2 presents four far field historical BGS boreholes (SU 61SE44, 334, 294 and 295) and confirms the persistence of the Harwich Formation across the Hampshire Basin, either side of the Bere Forest/Chichester syncline. The boreholes generally record the Harwich Formation as medium dense light brown to dark grey silty clayey fine sand with occasional shell fragments. The persistence of the Harwich Formation in the Hampshire Basin is also described in King's paper [23].

3.3.4. London Clay Formation

The London Clay in the Hampshire Basin was deposited in near-shore or estuarine conditions, in contrast to the open marine depositional environment of the London Basin. The lithological units are therefore more diverse, and, in some instances, it is indistinguishable from the adjoining formations on the basis of lithology alone. The BGS geological mapping indicates that there are three distinct members of the London Clay group present underlying the Study Area [11]. The units dip to the southwest in correlation with the regional structure.

(1) The Walton Member *sic* (Division A2 of the London Clay Formation) overlying the Harwich Formation, a series of clayey silts with sand partings and sandy silt beds deposited within a transgressive marine environment. Within the Hampshire basin, Division A2 of the London Clay Formation has a similar lithological sequence to the top of the Harwich Formation. This follows a lithological change to silty clays, which forms the base of the A3 [23].

(2) The A3 division is more homogeneous and comprises bands rich in grey claystones [24].

(3) The Bognor Member, which overlies the A2 and A3, is defined by a coarsening-upwards sequence, culminating in a fine sand [23].

Division A1 of the London Clay formation, which would otherwise overlie the Harwich formation, is apparently absent from the depositional sequence. The division is however represented within the east Hampshire basin and would otherwise comprise a shelly silty clay. From the centre of the site and going southwest, the A3 and possibly A2 divisions of the London Clay outcrop, which increase in thickness towards the southwest of the Study Area. Finally, the Bognor Member that overlies the A3 division of the London clay is present along the southwest boundary [11].

3.3.5. Quaternary Deposits

BGS Geological mapping at 1:10 000 scale indicates that approximately half of the Study Area is covered by Quaternary Head (undifferentiated) deposits that have accumulated by solifluction, hillwash and hillcreep.

In general, the BGS geological map indicates that head local to the proposed reservoir site comprises variable sandy silty clay, locally gravelly; chalky and flinty in dry valleys. This would indicate that the source of the head is primarily from reworking and transport of in situ materials by solifluction rather than slope deposits.

3.4. Post depositional geological features

Post depositional geological features anticipated from the near field geology are presented in this section. Hazards are generally associated with regional changes to the tectonic regime in the Cenozoic Era and periglacial landforms in the Quaternary Period.

3.4.1. Bedding Slip

The Palaeogene deposits were subject to mild tectonic loading during the Alpine orogeny forming the syncline of the Hampshire basin. Bedding slip is likely to have occurred between cycles of deposition. Following extensive erosion and unloading of the overlying London Clay deposits in the order of 200m [25], shear zones formed by bedding slip are likely to have propagated further. Within the London Clay formation, sub-horizontal shear zones are reported in past studies that run parallel to the bedding and characterised by a continuous band of closely spaced, polished and lightly striated surfaces [26]. Although no evidence of these surfaces at the Study Area has been found to date, these types of shear zones may yet be underlying the Study Area.

The formation of shear zones from bedding slip may pose a potential hazard for the stability of the embankment and borrow pit slopes that will be intended to remain open in the long term.

3.4.2. Solifluction/relic shear zones

Solifluction was the predominant form of periglacial mass movement in Britain during glacial periods. The resultant slope deposits are often referred to as Head or Colluvium. The process occurs due to migration of water to the freezing zone that forms lenses of segregated ice. As a result, the overlying ground is heaved, and its structure dilated. Upon thawing, the lenses of water ensure saturated or near-saturated conditions prevail. Excess porewaters are generated from undrained or near-undrained self-loading from settlement of the loosened overlying soil structure back to its original denser packing [27]. Depending on the rate of thaw, material movement is possible on slopes down to inclinations of 1 to 2°.

The presence of relic shear zones within the London Clay Formation is well documented and has led to significant engineering problems in the past. Within high clay content materials, three types of solifluction shears tend to occur [28]: Type 1 and 2, are characterised by low angle laterally extensive

basal shears typically to a depth of 3.0m and dipping at angles of 0º to 40º; and type 3, are discrete extremely closely to closely spaced randomly orientated shears. Within the scope of this report, London Clay, that has undergone solifluction will be regarded and defined as Head.

A further four types of freeze-thaw shears associated with contraction, thaw-collapse and underthaw may result in the presence of deeper subvertical or sub-horizontal shear features [28]. These shear zones are likely to have propagated into the underlying Reading Formation where it outcrops in the north of the Study Area.

3.4.3. Pingos

During glacial maxima at the Study Area, pingos[7] of frost-shattered chalk, or frozen water bearing sand may have penetrated the overlying cohesive beds of the Reading Formation. Upon thaw, these features may have enabled a hydraulic pathway in the form of a chimney (or throat) through the cohesive beds of the Reading Formation, connecting surface waters / the permeable stratum of the Harwich Formation with the underlying Reading Formation basal beds / Chalk.

Pingos pose a concern for reservoir leakage. They also can be of concern for engineering projects as local settlement and stability problems can occur during excavation of materials and construction. However, the anticipated depth to chalk and porewater pressures of the chalk in the near field leads indicates that the presence of relic pingos underlying the site is unlikely. In addition, as noted later in Section 9.4, no evidence of Pingos has been found.

3.4.4. Natural Cavities

Fractures and joints are present within the chalk deposits associated with planes of weakness. In addition to this, fissures and karstic features are likely to be present due to the dissolution of chalk by groundwater flow. Sinkholes are present within the chalk and where the top of the Palaeogene Lambeth Formation tapers as indicated in the Peter Brett Associates (PBA) natural cavity search [29], presented in Appendix H. The features are related to acidic runoff from the overlying impermeable Palaeogene deposits which causes dissolution of Chalk.

No features were identified from within 500m of the Study Area boundary [29], however it does not preclude the presence of buried palaeochannels in the chalk that are likely to locally increase the thickness of overlying Palaeogene and Quaternary cover. However, linear solution features have been identified at the boundary of the Palaeogene and Cretaceous, between 500m to 1km away from the site's northern boundary.

3.4.5. Ground Stability Hazards

The Envirocheck report [17] indicates that the potential for collapsible ground, landslide, running sand and shrinking and swelling clay stability hazards within the site are predominantly very low to low. The northern end of the site is indicated to have a moderate risk of shrinking and swelling clay stability hazards. No hazards are identified for compressible ground or ground dissolution stability hazards.

3.5. Seismicity

The UK is located within an intraplate area on the north-western sector of the Eurasia plate far from any plate boundaries. The two closest boundaries are the Mid Atlantic Ridge to the west and the

[7] Active pingos are large, perennial conical shaped ice mounds which grow beneath the ground surface in periglacial environments. Pingos form when groundwater under artesian pressure forces its way to near the ground surface where it subsequently freezes to form an ice lens which heaves the ground upwards.

collision zone between Africa and Eurasia to the south. Levels of seismicity are therefore characteristically low [30]. Earthquake activity in the Hampshire Basin is lower than in many other parts of Britain. According to records held by the BGS, there is only 1 record of an earthquake with a magnitude of 4.0Mw or greater: the magnitude 4.4Mw Chichester earthquake of 1963. The epicentre was between Portsmouth and Chichester and it was felt across Sussex and Hampshire. Earthquakes with magnitudes of 4.2 and 4Mw occurred to the south of the region in the English Channel in 1734 and 1750 (respectively).

4. Hydrogeology

The Hampshire region contains a number of principal bedrock aquifers including the Chalk. There are some secondary bedrock aquifers within the Palaeogene deposits and to a lesser extent, unconfined secondary superficial aquifers within the Quaternary deposits. For further information, refer to the Environmental Hydrogeology presented in Section 6.2

4.1. Chalk

The Chalk in the Hampshire basin is most affected by the Alpine tectonics that has led to structural complexity including folds and faults within the unit. The Chalk outcrops along a large E-W escarpment in the Hampshire basin and so behaves mostly as an unconfined aquifer at higher ground. The Chalk aquifer becomes confined where it is overlain by Palaeogene deposits; these are present at lower elevations and towards the Chichester syncline axis. Seasonal springs can be formed along the northern edge of the Palaeogene-Chalk boundary during times of recharge, due to the build-up of groundwater behind the Palaeogene deposits.

In general, the groundwater flow direction is from north to south, with the hydraulic gradient following the topography of the region. The BGS 1:100 000 Hydrogeological map indicates that the potentiometric water levels within the chalk near to the Study Area are from +20mOD to 0mOD with the groundwater level generally decreasing from north-northeast to south-southwest [31].

Groundwater level data in the region has been obtained from Portsmouth Water and a request made to the Environment Agency. Groundwater hydrographs obtained/requested within the Chalk are listed below:

- Idsworth Well – SU - 1.5km north-northeast of reservoir)
- Pyle Farm Cottages – SU 712 124 – 2km north of reservoir (request made to the EA in April 2019)
- Cadlington House – SU 710 132 – 3km north of reservoir (request made to the EA in April 2019)
- Carpenters, Finchdean – SU 735 127 – 3km northeast of reservoir (request made to the EA in April 2019)

The nearest monitoring wells to the Study Area are Idsworth Well and Pyle Farm approximately located 1.5km and 2km north (respectively). Idsworth Well as on the Chalk outcrop at an approximate ground level of +63mOD with water levels in the monitoring well ranging from between +12.7mOD and +36.7mOD with an average of 20.0mOD between the years of 1932 and 2008 [32]. Pyle Farm, at an approximate ground level of +60mOD, is located directly on chalk outcrop and water levels in the monitoring well range from between +21mOD and +43mOD [33].

Note: The EA data has not been received or reviewed for this report.

The hydraulic properties of chalk are influenced by both micro and macro porosity within the unit. Groundwater flow within the saturated zone is primarily through fractures and therefore can be highly variable. Recharge in the unsaturated zone occurs rapidly through fractures or slowly through the matrix and thus permeability is significantly variable. Aquifer properties within chalk are laterally variable, largely associated with regional fracture networks described within Section 3.2.4. Pumping tests undertaken across the Hampshire basin within the chalk, have provided estimates of transmissivity that vary from 0.55m^2/d to 29,000m^2/d with a mean of 1,600m^2/d and median of 2,600m^2/d [34]. The highest transmissivities are located within the main valleys and the lowest along ridges between valleys where permeability is dictated by micro porosity.

4.2. Lambeth Group (Reading Formation)

The Reading Formation comprises interbedded layers of both high permeability sands and low permeability clays. In the northern part of the Hampshire basin, pumping yields are usually in the order of 100m^3/d and boreholes may be dry where sandy strata tapers or is absent [35] – this makes interpretation of piezometer profiles difficult. Pumping yields of up to 200m^3/d have been recorded north of Southampton and may partly be due to upward recharge to the basal sands from the underlying Chalk.

In the near field, the clays are dominant and act as an effective aquitard with respect to the overlying Harwich Formation and underlying Chalk. The basal beds of the Reading Formation may be present and if so, are expected to have the highest permeability and anticipated to be in hydraulic continuity with the underlying Chalk. Sandy channel deposits at the base of the stratum may also be present underlying the Study Area. These beds are likely to be confined by the overlying clay units of the Reading Formation. The sandy nature of the basal beds is important as this may lead to enhanced development of sinkholes and other solution features [35]. Furthermore, the presence of relic Pingo structures from glacial maxima may enhance the vertical permeability of the Reading Formation, providing a hydraulic pathway between the Harwich and the Chalk, although no such features have been identified to date.

The values of hydraulic conductivity for the clay rich deposits of the Reading Formation may range from 5x10^{-7} m/s to 5x10^{-9}m/s with the presence of fractures being the main control of permeability [21]. The presence of basal sands and infilled channel deposits are expected to have a horizontal hydraulic conductivity within the region of 1x10^{-3} to 1x10^{-5} m/s (with vertical hydraulic conductivity between 1x10^{-5}m/s and 1x10^{-8}m/s) [21].

4.3. Harwich Formation

The Harwich Formation is locally important to the near-field hydraulic regime of the proposed reservoir, where the unit outcrops to the north of the Study Area and then dips gently to the south. In general, the stratum comprises interbedded sands, silts and clays with large variations in thickness arising from an estuarine/shallow marine depositional environment. The permeability is therefore likely to be highly anisotropic with similar horizontal permeabilities as the basal beds of the Reading Formation [35] [33]. The presence of persistent calcareous concretions in the stratum may increase the permeability locally through fracture networks.

There is little information on the spatial extent and thicknesses of the Harwich formation in the Hampshire Basin, therefore, its persistence across the Study Area and hydraulic properties are not fully understood from published geological information.

4.4. London Clay Formation

The London Clay Formation is composed primarily of clay so is generally considered as unproductive strata with confining characteristics. Groundwater may be encountered within sandy layers/laminations within the unit although their persistence and thus yield is not significant. Horizontal hydraulic conductivity values are expected to be in the range of 5x10^{-8}m/s to 2x10^{-10}m/s [35]. The formation is highly anisotropic vertical permeability is significantly lower than horizontal permeability.

The Bognor Sand Member is present at the top of a coarsening up sequence of the London Clay Formation, and comprises silty and clayey sands. The stratum is anticipated to be water bearing with similar permeabilities to the basal beds of the Reading Formation and so considered as a perched aquifer.

5. Geomorphology

5.1. Site Geography and Topography

The proposed reservoir site gently dips to the south from 40mAD along the north boundary, to 20mAD south of the proposed embankment toe.

Three unnamed small watercourses flow from the north to the south across the Study Area. These converge in to one stream to the west of the Avenue before flowing off site in to the Riders Lane Stream. A small ditch traverses across the northeast of the Study Area at Gypsies Plain and flows off-site to the east. The alignment of the channels has been changed through time and associated with forestry operations and land drainage in the central and southwest area of the Study Area and have been straightened and moved since they were mapped by the Ordnance Survey in 1869.

To assess the geomorphology within this chapter, the Study Area has been separated into four areas as indicated below and aligns with the features presented:

- **Northeast**: Land to the north of the Havant Thicket Bridleway and to the east of the Avenue. Includes Upper Lake and part of forestry land known as Furzy Plain.
- **Southeast**: Land to the south of the Havant Thicket Bridleway and to the east of The Avenue. Includes that land known as Gipsies Plain to the east of the area and Hammond's Lands Coppice to the south.
- **Southwest**: Land to the south of the Havant Thicket Bridleway and west of The Avenue and includes the land known as Middle Clearing and Deerslaughter plain.
- **Northwest**: Land to the north of the Havant Thicket Bridleway / Middle Clearing and west of The Avenue and Upper Lake. The western boundary of the area is adjacent to the land known as Bell's Copse.

5.2. Aerial Photography Interpretation

Atkins undertook a review and interpretation of available aerial photographs to identify the geomorphological features and potential geohazards that might be present at and adjacent to the proposed Havant Thicket Winter Storage Reservoir (HTWSR) site – the Study Area. The study was to review and build upon a Draft Aerial Photograph Interpretation (API) undertaken by Arup in 2009 [36].

Atkins first undertook a review of aerial photographic prints made available by Portsmouth Water. These included oblique photographs from commissioned flyovers of the Havant site in 2006 (far field), 2007 (near field) and low to medium-resolution digital prints from the historical aerial photograph search undertaken by Arup and covering the period 1946 to 1996. All historic aerial photographs recorded within the Arup API were identified within the Historic England search. A complete list of the aerial photographs reviewed as part of the study is presented in Appendix D.

A total of 258 No. photographs were analysed within the footprint and near-field of the proposed HTWSR site and ranged in dates between 1946 and 2007. Where stereo pairs were available the prints were examined in 3D using a mirror stereoscope to amplify detail and depth of terrain features. Historical aerial photographs confirm that the majority of the proposed reservoir site was cleared of woodland between 1946 and 1954. Portsmouth Water obtained grants from the Ministry of Agriculture Food and Farming (MAFF) between 1967 and 1973 to improve the land for agriculture by removing scrub and enhancing the land drainage across the Study Area. This is reflected on the photographs during this time with straightening of fluvial routes in the Study Area and clearing overgrown land.

Whilst some natural geomorphological features are lost (i.e., wandering watercourses), the cleared land highlight other features that are summarised below.

It should be noted that aerial photography commissioned by Atkins was completed on 21st April 2019 was not reviewed for this report and will be presented in a separate technical note to be issued prior to the completion of the ground investigation.

The API technical note is presented in Appendix C with key findings summarised below. The locations of identified features are also in Appendix C1.

On-site

- **Soil Creep**: Presence of soil creep inferred from closely spaced undulating ground to the east of the 'The Avenue' and along the inferred Bognor Sand Member-London Clay Formation to the southwest in the land known as Deerslaughter Plain.
- **Wandering water courses**: To the west of The Avenue flowing northeast to southwest that confluence with the main watercourse. Streams to the north of the 'Middle Clearing' located.
- **Changes in stratum**: Possible identification of stratum boundary between the London Clay Formations of Bognor Sand Member and London Clay towards the southwest boundary in the land known as Deerslaughter Plain. Also, possible confirmation of boundary between London Clay and Harwich Formation in the land known as Gipsies Plain in the Study Area's southeast area.
- **Seepages / Springs**: Possible areas of seepage indicated along the Bognor Sand Member / London Clay boundary.
- **Relic Periglacial and post-depositional features:** The aerial photography did not identify the presence of pingos or sinkholes within the Study Area,

Near-field (Land within 1km of the Study Area boundary)

- **Surface depressions**: Surface depressions potentially indicating a Karst dominate terrain were noted at the golf course to the east and northeast between 0.25km and 1km outside of the site boundary. No evidence of similar features were observed within the site footprint.
- **Drainage lines**: Beyond the southwest site boundary at where Warren Park is located, depressions from past seasonal drainage and/or existing seasonal drainage is present within the Bognor Sand Member indicates the presence of past seasonal valleys that flow away from the site and confluence with a nearby north-south flowing stream. The north-south flowing stream extends further north along the western site boundary, incising into the higher ground to the north of the site along the boundary between Reading Formation and Harwich Sand Formation, and creating a river valley with relatively steep slopes on both sides. Note drainage lie features labelled on Figure C-3 in Appendix C.

5.3. Geomorphological Mapping

Following desk and aerial photography interpretation, geomorphological mapping of the Study Area was undertaken on 24th April 2019. These findings of the walkover are presented in Drawing 4.

The findings from geomorphology mapping are summarised below:

- **Southwest of the Study Area:** The southwest of the site is defined by a north-south trending valley between the land immediately west of Round Wood and the ridge of high ground across the west boundary of the Study Area. The west valley face is generally steeper than the

eastern side, with dips recorded between 11º to 15º compared to approximately 5º (respectively). Seepage is encountered along the west valley face immediately upstream to the inferred geological boundary (from 1:10,000 geological mapping) between the Bognor Sand Member and London Clay Formation. The base of the valley is defined by marshy / boggy conditions and the presence of hydrophilic vegetation.

- **Southeast of the Study Area:** Drainage channels intersect the site, following breaks in the grassland as seen in the geomorphological map. The topographic high is towards the southern boundary, west of Gipsies Plain and is approximately +34mOD. No significant geomorphological features were recorded within the southeast of the Study Area.
- **Northeast of the Study Area:** The land generally dips to the south-southwest between 1º to 3º. Drainage channels are present to the east and west of the area and form shallow north-south trending stream valleys that flow towards the southwest of the Study Area. No other significant geomorphological features were recorded within the northeast of the Study Area.
- **Northwest of the Study Area**: Undulating ground is recorded within land to the north of the Upper Lake that forms the east face of an incised stream valley. The 1:10,000 geological mapping indicates that the underlying geology is the Reading Formation. To the west of Upper Lake, another north-south stream s present. Seasonal drainage is recorded to in the northwest corner of the Study Area and indicates south-southeast flow towards Middle Clearing. Within seasonal drainage channels, the presence of shallow washout features were seen to incise into the underlying ground forming 500 to 600mm deep gullies. No other significant geomorphological features were recorded within the northwest of the Study Area.

6. Environmental Setting

A review of the environmental setting of the site and surrounding area (within 500m of the site) is provided in the following sections.

6.1. Environmental Geology

6.1.1. Potentially Infilled Land

No Made Ground / artificial ground is identified to be present on BGS geological maps underlying the site [12].

The Envirocheck report [17] indicates several areas of potentially infilled land (water and non-water) located within 500m of the site as summarised in Table 6-1 below, but none were identified on the Study Area.

Table 6-1 – Summary of Potentially Infilled Land

Distance and orientation from the site	Type	Use
19m southeast	Non-water	Unknown Filled Ground (Pit, quarry etc)
155m northeast	Non-water	Unknown Filled Ground (Pit, quarry etc)
179m northeast	Non-water	Unknown Filled Ground (Pit, quarry etc)
187m south	Water	Unknown Filled Ground (Pond, marsh, river, steam, dock etc)
198m north	Non-water	Unknown Filled Ground (Pit, quarry etc)
199m east	Water	Unknown Filled Ground (Pond, marsh, river, steam, dock etc)
288m northwest	Non-water	Unknown Filled Ground (Pit, quarry etc)
290m south	Water	Unknown Filled Ground (Pond, marsh, river, steam, dock etc)
375m northwest	Non-water	Unknown Filled Ground (Pit, quarry etc)
381m southeast	Non-water	Unknown Filled Ground (Pit, quarry etc)
426m west	Water	Unknown Filled Ground (Pond, marsh, river, steam, dock etc)

6.1.2. Radon

The Envirocheck report [17] indicates that the site is located within a lower probability radon area (less than 1% of homes are estimated to be at or above the Action Level). No radon protective measures are necessary in the construction of new dwellings or extensions.

6.1.3. Mineral Resources

The Envirocheck report [17] indicates that there are seven BGS recorded mineral sites located within 500m of the site as summarised in Table 6-2 below.

Table 6-2 – Summary of BGS Recorded Mineral Sites

Distance and orientation from the site	Site Name	Type / Commodity	Geology	Status
67m southeast	Durrants Brick Field	Opencast / Common Clay and Shale	London Clay Formation	Ceased
205m northeast	Red Hill Brick and Tile Works	Opencast / Common Clay and Shale	Lambeth Group	Ceased
215m north	Horsefoot Clay Pit	Opencast / Common Clay and Shale	London Clay Formation	Ceased
221m north	Long Wood Brick Works	Opencast / Common Clay and Shale	Lambeth Group	Ceased
296m northeast	Castle Road Clay Pit	Opencast / Common Clay and Shale	Lambeth Group	Ceased
394m southeast	North Lodge Clay Pit	Opencast / Common Clay and Shale	Bognor Sand Member	Ceased
408m west	Dunsbury Hill Brick Yard	Opencast / Common Clay and Shale	London Clay Formation	Ceased

Reference to the Envirocheck report [17] also indicates that quarrying of sand and clay and the operation of sand and gravel pits has historically been undertaken in several areas within 500m of the site. Former quarries / pits are indicated to be present 198m east, 288m west, 350m east and 375m northwest of the site. These are noted to be present on historical maps as outlined in Table 2-1. However, no activities were recorded on the site.

6.1.4. Mining Cavities

The Envirocheck report [17] indicates that the site is not located within a coal mining area. However, there is a man-made mining cavity located within 500m of the site as summarised in Table 6-3 below.

Table 6-3 – Summary of Man-made Mining Cavities

Distance and orientation from the site	Cavity Type	Commodity	Solid Geology
269m east	Historical Brick and Tile Works/Extensive Clay Pits – Potential Chalk Mining	Chalk	Lambeth Group, Culver Chalk Formation

6.2. Environmental Hydrogeology

6.2.1. Aquifer Classifications

The Envirocheck report [17] indicates that the Reading Formation / Lambeth Group underlying the north of the site and the Bognor Sand Member in the south of the site are classified as a Secondary

A aquifers[8]. The Harwich Formation is also classified as a Secondary A aquifer. The London Clay Formation underlying the centre of the site is classified as an Unproductive Strata[9]. The Chalk located 254m northwest of the site is classified as Principal aquifer[10]. The superficial Head deposits running where the outcrop is through the centre of the site are classified as a Secondary Undifferentiated aquifer[11].

6.2.2. Groundwater Vulnerability

The superficial aquifer is indicated to have a medium vulnerability and the Reading Formation / Lambeth Group and Bognor Sand Member bedrock aquifers are indicated to have a medium to high vulnerability. The London Clay is classified as an unproductive aquifer. The DEFRA Magic website [37] indicates that the northeast of the site is located within a groundwater drinking safeguard zone. The zone extends further north and east of the site in excess of 1km.

The Environment Agency catchment data explorer [38] indicates that the site is not located within Water Framework Directive (WFD) groundwater catchment body.

6.2.3. Source Protection Zones

The Envirocheck report [17] indicates that an Inner Zone (Zone 1)[12] Source Protection Zone (SPZ) is located approximately 254m northeast of the site, associated with the Chalk Principal aquifer. The site is located within an Inner Zone (Zone 1c)[13] SPZ with the northeast of the site being classified as an Outer Zone (Zone 2)[14] SPZ associated with regional principal aquifers.

6.2.4. Groundwater Abstractions

The Envirocheck report [17] indicates there are no groundwater abstraction licences within 1km of the site. One historic groundwater abstraction licence which was located approximately 824m north of the site which was operated by Borrow Investments Ltd between 1st April 2016 to 30th September 2016. No further information is available relating to the licence. It is noted that the Havant and Bedhampton Springs located approximately 3km to the south of the reservoir site will be the abstraction source for the reservoir.

6.2.5. Groundwater Flooding

The Envirocheck report [17] indicates that there is an area within the centre and south of the site that has the potential for groundwater flooding to occur at the surface and for groundwater flooding of property situated below ground level.

6.3. Hydrology

OS mapping within the Envirocheck report [17] indicates that there are a number of hydrological features present both on and off-site. Three unnamed watercourses flow from north to south entering the site along through the northern boundary. They converge into one stream to the west of The Avenue in Deerslaughter Plain. The alignment of the channels has been altered over time, which is reported to have been to improve the land for agricultural use [15].

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[8] The Environment Agency defines Secondary A Aquifers as 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.

[9] The Environment Agency defines Unproductive Strata as rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

[10] The Environment Agency defines a Principal aquifer as layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer.

[11] The Environment Agency defines Secondary Undifferentiated aquifers as those that have been assigned where it has not been possible to attribute either category A or B to a rock type. 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.

[12] The Environment Agency defines an Inner zone (Zone 1) as the 50-day travel time from any point below the water table to the source. This zone has a minimum radius of 50 metres.

[13] The Environment Agency defines an inner zone - subsurface activity only (Zone 1c) - as extending Zone 1 where the aquifer is confined and may be impacted by deep drilling activities.

[14] The Environment Agency defines an Outer zone (Zone 2) as a 400-day travel time from a point below the water table.

The western most watercourse originates in Havant Thicket approximately 400m north of the site before flowing south through Middle Clearing and joining the main stream in Deerslaughter Plain. The central watercourse flows south from beyond Havant Thicket, approximately 1.2km north of the site into the Upper Lake, which is located in the north of the site.

The Upper Lake covers an area of approximately 6,400 m^2. A weir is located on the southern edge of the lake. The damming of the central watercourse to form the lake was recorded to have been completed in 1869 [15].

A drain exits the lake flowing south along The Avenue for approximately 200m to a confluence. At this point the third watercourse, which flows from the northern boundary of the site, also joins the central watercourse. There is a drain present in the east of the site that connects to a series of drains that flow east from Gipsies Plain, west of The Durrants [15] that also joins at this point. An additional drain flows from east to west across The Avenue approximately 290m north of the southern boundary of the site towards the main confluence in Deerslaughter Plain. The combined watercourses and drains continue to flow south across the southwestern boundary of the site, flowing parallel to the residential development west of Thicket Lawn to a culvert below Middle Park Way Road approximately 500m south of the site.

A spring, well, and two additional drains are located within Hammonds Lands Copse and Hommick Copse. The drains are located approximately 70m and 170m south of the south of the site and flow west for approximately 220m and 500m towards The Lake. The Lake covers an area of approximately 16,700m^2 and is located 60m south of the site.

A further unnamed channel flows from north to south approximately 250m to 350m parallel to the western boundary of the site. The watercourse flows through Bells Copse and The Warren before being intercepted at a culvert located approximately 250m west of Warren Park Primary School in the north of Leigh Park.

There is a collection of small ponds located approximately 100m to 250m northeast of the site near Long Wood and Furzy Plain, as well as to the southeast of the site in the Hampshire County Council woodland. Historical maps show these areas as the sites of former brick works and clay pits.

The Environment Agency catchment data explorer [38] website indicates that the site falls within the Hermitage Stream WFD catchment. The stream is located approximately 1.32km west of the site. In 2016 the ecological classification for the stream was 'Moderate' and the chemical classification 'Good'.

6.3.1. Discharge Consents to Surface Water

The Envirocheck report [17] indicates there are two discharge consents located within 500m of the site which are summarised below:

- 362m northeast, related to the discharge of 'Other Matter-Surface Water' to a freshwater stream/river from domestic properties. The consent is dated March 1982, but is listed as lapsed; and
- 387m northeast, related to the discharge of 'Other Matter-Surface Water' to a freshwater stream/river from undefined property types. The consent is dated February 1988 but is listed as lapsed.

6.3.2. Discharge Consents to Groundwater

No discharges to groundwater are recorded within the Envirocheck report within 500m of the site.

6.3.3. Flood Risk

The Environment Agency flood map for planning website [39] shows that the majority of the site is located within a Flood Zone 1: low probability area of flooding from rivers and sea[15].

The land adjacent to the central watercourse flowing south from Deerslaughter Plain to Gammon's Hill and Thicket Lawn is classified as Flood Zone 2: medium probability[16] and Flood Zone 3: high probability of flooding from rivers and sea [17].

[15] Defined as land having a less than 1 in 1,000 annual probability of river or sea flooding.
[16] Defined as and having between a 1 in 100 and 1 in 1,000 annual probability of river flooding.
[17] Defined as and having a 1 in 100 or greater annual probability of river flooding.

The Rowlands Golf Course located approximately 370m northeast of the site is classified as a Flood Zone 3: high probability area.

6.3.4. Pollution Incidents to Controlled Waters

The Envirocheck report [17] indicates that four pollution incidents to controlled waters have occurred within 500m of the site, which are summarised in Table 6-4 below. No incidents are recorded for the site.

Table 6-4 – Summary of Pollution Incidents to Controlled Waters

Distance and orientation from the site	Date	Property Type / Location	Pollutant	Incident Severity	Receiving Water
259m northeast	July 1998	Unknown	Chemicals – Paints / Dyes	Category 3 – Minor Incident	Not Given
396m northeast	April 1992	Water Company Sewage / Castle Road	Oils – Diesel (Including Agricultural Pesticide/Fertilizer)	Category 3 – Minor Incident	Not Given
402m east	October 1996	Petrol Station / Shell Garage	Oils – Petrol	Category 3 – Minor Incident	Not Given
454m southwest	January 1994	Industrial / Dunsbury Way	Agricultural Pesticide/Fertilizer	Category 3 – Minor Incident	Not Given

6.4. Sensitive Land Uses

6.4.1. Ecological

The Envirocheck report [17] indicates that the area of the site to the west of The Avenue is a designated as Staunton Country Park. The Country Park continues south of the site and includes the areas of Thicket Lawn, Leigh Park, The Lake, Hommick Copse and Hammonds Land Copse. The South Downs National Park is situated approximately 448m east of the site.

There are also several Ancient Woodland designations located on-site and within 500m of the site, which include Ancient and Semi-Natural Ancient Woodland and Plantation on Ancient Woodland. Areas located on-site include the Forest of Bere, Hammonds Lands Copse, The Avenue, Middle Clearings, Thicket Bottom and Long Wood and other unnamed areas.

The site is located within a Nitrite Vulnerable Zone associated with the Chalk located 254m northeast of the site.

There are no further statutory designated sites within 500m of the site.

6.4.2. Heritage

The Envirocheck report [17] indicates there are nine Grade II Listed Buildings within 500m of the site. The closest to the site Rowlands Castle War Memorial located 64m east of the site. Staunton Country Park is also designated as a Grade II* Historic Park, Garden or Designated Landscape.

6.5. Waste Management Sites

6.5.1. Historical Landfills

The Envirocheck report [17] indicates that a historical landfill was present an estimated 327m west of the site. The licence was held by Gleeson Civil Engineering Limited in Cowplain, Hampshire. Specified waste included Inert Waste. No further information relating to the operation of the site is available.

6.5.2. Authorised Landfill and Waste Management Facilities

There are no records of current landfill or waste management facilities within 500m of the site [17].

6.6. Local Authority Pollution Prevention Control

The Envirocheck report [17] indicates there is one Local Authority Pollution Prevention Control (LAPPC) for PG1/14 petrol filling station registered to Shell UK Ltd located approximately 82m east of the site. The LAPPC is dated 31 December 1998 and is listed as permitted.

6.6.1. Contemporary Trade Directories

The Envirocheck report [17] indicates that there are three active contemporary trade directories located within 500m of the site. These are summarised in Table 6-5 below.

Table 6-5 - Summary of Contemporary Trade Directories

Distance and orientation from the site	Name	Classification	Status
169m northeast	A & J Grant UK Ltd	Printers	Active
310m northeast	Connells	Bags, Belts and Accessories – Manufacturers and Suppliers	Active
369m southwest	Mike Budgen Roadside Assistance	Car Breakdown and Recovery Services	Active
371m southwest	Regal Contract & Domestic Cleaning Co Ltd	Commercial Cleaning Services	Active

6.7. Unexploded Ordnance Risk

A preliminary unexploded ordnance (UXO) threat assessment, provided by Landmark [16] (Appendix G) indicates that the potential of a UXO hazard to occur at the site has been assessed as ‘Likely’. This is due to the site being located in the Petersfield Rural District, which recorded two High Explosive (HE) bomb strikes per 100 hectares and is classified as a low level of bombing. A military camp and battery were also located to the south of the site from 1870 and 1946 respectively. The report recommends that a detailed UXO risk assessment is undertaken to further assess the UXO risks at the site.

7. Ground Conditions

7.1. Introduction

Within this section, published geological information from BGS, desk-based studies and other literature sources are evaluated against historical site-specific and near-field information to develop a ground profile for the Study Area. The ground profile will form the basis to review the geotechnical issues at this initial stage and identify areas of uncertainty.

7.2. Historical Ground Investigations

A total of three historical ground investigations were undertaken between 1962 and 2007 at Havant Thicket to inform design proposals of an earth dam. The exploratory hole locations are presented on Drawing 5 which also includes information from the 1:10,000 BGS geological map, which includes the most recent design footprint for the dam and reservoir.

7.2.1. Edgar Morton & Partner with Embankment Design by Professor Rowe – 1962 to 1963

Portsmouth Water Company commissioned Edgar Morton and Partner in 1962 to undertake a feasibility study on site 18 (Havant Thicket). Pre-Piling Surveys Limited, on behalf of Edgar Morton and Partner carried out a site investigation comprising 20 boreholes, nine of which were located along the proposed embankment and 11 were located within the reservoir basin [4]. The proposed embankment footprint has since changed and therefore the boreholes do not align to the existing design, as shown on Drawing 5.

The majority of the boreholes range between 7m and 10m, with the deepest being 15.5m. The following main strata were identified in the investigation: Weathered London Clay, London Clay, London Clay Basal Beds *sic* (Harwich Formation) and Reading Beds *sic* (Reading Formation). No standpipes or piezometers were installed.

Geotechnical testing from Pre-Pilling Surveys Ltd comprised:

- 14No consolidated-undrained triaxial compression tests on samples from M03, M04 and M05;
- 11No consolidation tests on M03, M04, M05, M09, M12, M15, M16, M20;
- 3No Proctor compaction tests on samples from M09, M15 & M20;
- 5No index property tests on samples from M09, M12, M15, M16 & M20; and
- 5No particle size distribution tests on samples from M09, M12, M15, M16 & M20.

Additional laboratory soils testing was undertaken by the University of Manchester under the supervision of Professor Peter Rowe [5]. Geotechnical testing from University of Manchester comprised:

- 17No undrained triaxial compression (undrained shear strength) tests on samples from M01, M02 & M04;
- 3No consolidated undrained triaxial compression tests with pore water pressure measurement on 2No samples from M04 and remoulded sample from M10;
- 5No oedometer tests on sample from M02 & M04;
- 5No standard Proctor compaction tests on samples from M04 & M10; and
- 3No index property tests on samples from M10.

The factual report by Edgar Morton and Partner concluded that the geological sequence at the Study Area comprised superficial deposits underlain by London Clay and the Reading beds *sic (*Reading Formation) at depth. The superficial deposits are described as residual soils, stony and silty clays, and, in places, thin alluvial deposits and 'hillwash' *sic* (Colluvium).

The underlying London Clay was predominantly composed of laminated, 'grey silty clays' with 'thin layers of fine silt between laminae and with occasional beds of grey clayey silt'. Weathered London Clay was present up to 4.5 m below ground level and consisted of 'grey mottled silty clays'. The basal beds of the London Clay (Harwich Formation) were described as 'grey silty or sandy strata … with some silty clay or occasionally a silty clay with stones or gravel'. The Reading Beds (Reading Formation) were described as red and grey clays, sometimes silty and occasionally with sandy material within pockets or very thin beds.

Following the findings of the factual investigation report, Professor Peter Rowe summarised the results of soil laboratory testing by Pre-Piling Surveys Ltd and the University of Manchester to inform preliminary design and construction considerations of a 60 ft earth embankment dam.

7.2.2. Hampshire Reservoirs Site 18, Mander, Raikes & Marshall (MRM) – 1977-79

Mander, Raikes & Marshall (MRM) were commissioned by Southern Water Authority to produce a technical feasibility report on two groups of potential reservoir sites and resource allocation strategies. The report is split into three parts: Part 1 focuses on the feasibility studies and recommendations, Part 2 describes the Study Area investigation and evaluates each potential reservoir site and Part 3 investigates the possible development of the preferred sites, including the proposed reservoir known as East Hampshire Site 18 (Havant Thicket).

The aim of the Study Area investigation was to examine the feasibility of reservoir development, with attention paid to the potential water tightness of the proposed storage areas and the capability of the in-situ soils to support the future embankments or to be used as embankment construction material.

MRM undertook two phases of site investigation and included:

- An initial supplementary site investigation in 1977 that comprised four cable tool percussive boreholes that were sunk by Foundation Engineering Limited to confirm the geology reported in the 1962 investigations and to (a) investigate conditions in the extreme northern part of the Study Area; (b) to obtain additional information relating to the highest part of the proposed dam; (c) to investigation conditions relevant to an alternative embankment centre line. Two standpipe piezometers were installed. [6]
- A supplementary investigation in 1978/79 that comprises a further six cable tool percussive boreholes below the proposed embankment by Foundation Engineering Ltd and 42 trial pits by MRM within the Study Area. Eight standpipe piezometers were installed (four single, and two dual installations) [7]

Geotechnical testing from MRM were carried out in accordance to BS 1377 (1975) and included the following tests:

- 48No index property tests;
- 50No particle size distribution tests
- 14No consolidated undrained triaxial tests with pore pressure measurement on specimens of 38mm x 76mm in size and cell pressures of between 530 kPa and 1200 kPa
- 2No residual drained shear box tests from the London Clay Formation and the Reading Formation
- 5No permeability tests in a triaxial cell
- 8No standard compaction tests using a 2.5kg rammer

- 2No moisture condition values from clay samples from Borehole B6.

Close to the Study Area, a major highway embankment had slipped which was thought to be associated with shear surfaces in the London Clay, which MRM believed may also be present underlying the proposed reservoir site. As a result, 42 trial pits (A1-A13, E1-E2 & D1-D27) were dug between 3m and 5m with a Hymac backactor under the direct supervision of MRM. A and E series were dug along the line of the proposed embankment to investigate any shear planes within the foundation series, whilst D series were positioned to investigate the permeable basal beds of the London Clay *sic* (Harwich Formation).

The report concluded that superficial deposits generally lay on top of the London Clay. The London Clay was weathered, mottled brown near the surface and became greyer and stiffer with depth. The investigation confirmed the presence of much coarser stratum at the base of the London Clay that contains a greater proportion of sand, referred to as the 'basal beds' (Harwich Formation). The 'basal beds' are generally silty fine sand, but can contain pebble bands, coarse gravels and limestone. Succeeding the basal beds are the Reading Beds (Lambeth Group). The Reading Beds are generally stiff mottled red and brown silty clay. The strata were all dipping gently, at approximately 1.5°, to the south-southeast.

Site investigation results showed the artesian pressure within the 'Basal Beds' *sic* (Harwich Formation) was higher than anticipated, and the effective shear strength parameters were slightly lower on Site 18 than the other potential sites. All the trial pits located along the proposed embankment, showed shear planes of varying dimensions and orientation.

7.2.3. Entec UK Ltd with 2006 Soil Mechanics Ltd GI - 2007

Entec were commissioned on the behalf of Portsmouth Water Ltd to undertake a 'Phase 2' report that considered the engineering and environmental issues associated with the development of the HTWSR scheme [9]. Within a separate document, an assessment was made of the available volumes and material properties of the near surface formations within the basin of the proposed HTWSR and the assessment of these in the context of the likely requirements for the embankment construction.

In 2006, Soil Mechanics Ltd were commissioned by Entec to undertake a ground investigation comprising four cable percussion boreholes and four trial pits, with associated laboratory testing. The four boreholes ranged from 13m to 14m deep and were located specifically to investigate potential suitability of the London Clay and Reading Beds (Reading Formation) as embankment construction material. The trial pits were dug between 2.5 and 3.5m below the ground level and were located to the east of the Study Area onto the Reading Beds (Reading Formation). Additional trial pits were planned to be dug where London Clay outcrops to the west of the Study Area, however these were not excavated due to wet ground conditions. No standpipes or piezometers were installed.

Geotechnical laboratory testing on samples recovered from boreholes and trial pits comprised:

- 23No index property tests;
- 13No particle size distribution analyses;
- 7No heavy compaction tests;
- 4No undrained triaxial compression tests;
- 4No pH and sulphate content of soils tests;
- 3No dry density/moisture content relationship determination tests and
- 3No shear box tests.

The design approach for the proposed reservoir considered an undrained design that would not rely on consolidation of the foundation soils during the construction of the dam as Professor Peter Rowe advised in his 1963 report ([40]). The following suggestions were made by Entec Ltd:

- Both Reading Beds and London Clay form potentially suitable embanking material;

- Subject to confirmation by field compaction trials it is unlikely that a zoned embankment will be required;
- In view of the nature of the foundations and the dam location embankment slopes approaching 1v:7h are likely required; and
- There is little benefit to be obtained from substantial drainage within the embankment although basal drainage blankets are likely required.

7.2.4. Near Field Historical Ground Investigations

Several Ground Investigations for proposed developments within the vicinity of the Study Area were made available by Portsmouth Water for review for this report. A brief summary of these investigations and key findings are provided below:

- **Proposed Landfill at Hazleton Farm, Horndean (0.7 km north of site)**: Aspinwall & Company Ltd was commissioned by Hughes Waste Management Ltd to undertake a geophysical and intrusive investigation to assess the suitability of the Hazelton Farm site for a Landfill. Top of chalk and Lambeth Group contour plots are presented in the documents. Within 1 km of the proposed reservoir site, the chalk is encountered between 30mAD and 26mAD and indicates a southerly dip of approximately 1.3°. A contour plot for the bottom of Made Ground is also provided however not for the base of the Harwich formation, which outcrops immediately south of the Hazelton Farm footprint according to the 1:10,000 BGS Geological Map. The combined thickness of the Lambeth Group and Harwich formation was therefore anticipated to be approximately 24m along the Hazleton Farm site's southern boundary [41].
- **Horndean (Borrow Land), Portsmouth (1.5 km north of site)**: Desk study, multidisciplinary ground investigation and ground condition assessment undertaken by PBA (the Engineer), TerraDat (the Geophysical Survey Contractor) and CC Ground Investigations (the Ground Investigation Contractor) on behalf of Bloor Homes. The desk study phase reported that the potential for natural solution features to be present on the Study Area is assessed to be very high. A Geophysical survey carried out identified the presence of a broad resistive linear channel oriented E-W. The geophysical report suggests that this may be a sand and gravel infilled palaeochannel, carved into the Reading Formation and possibly the underlying chalk [42]. The field investigation comprised trial pits, windowless sample boreholes and rotary cored boreholes to a maximum investigation depth of 37.76mOD. In general, the geological conditions encountered were Made Ground / Topsoil underlain by fine and/or coarse grained Head deposits which were immediately underlain by the Lambeth Group (Reading Formation). Tarrant Chalk *sic* (Culver Chalk Formation) was encountered at 8 locations below the Lambeth Group. In BH1006, the exploratory hole closest to the footprint of the proposed reservoir site, the Lambeth Group is encountered from is 59.56mAD to 46.26mAD (13.3m thickness) [43] [44].
- **Land off Redhill Road, Rowlands Castle (1 Km east of site)**: Structa LLP was instructed by Explore Living plc to undertake an additional ground investigation at Land off Redhill Road, Rowlands Castle. The supplementary investigation followed two previous phases of investigation completed by Structa LLP. The Study Area covers an approximate area of 2.3 Ha, 400m south of Rowlands Castle. Underlying Made Ground, Structa inferred that the geological sequence comprised possible Reading Formation (recovered as sandy clay) underlain by Possible Culver Chalk Formation (recovered as chalk with flint). Exploratory hole WS104 indicated the presence of a solution features interpreted as a pipe type feature more than 10m deep and up to 5m in diameter [45].
- **Padnall Grange, Padnall Road, Cowplain (1.3 Km northwest of site)**: Soils Limited was commissioned by Bellway Homes (Wessex) to undertake a Phase 2 ground investigation. The investigation included 4 No. windowless sampler boreholes 5 No. trial pits to a maximum depth of 6m below the ground level. The levels above ordinance datum were not recorded. The Study Area investigation does not provide pertinent information to the proposed reservoir site and corresponds to the underlying geological sequence that is indicated on the 1:50,000 BGS geological map [11] [46].

- **Southleigh Landfill Site, Havant (1.5 km southeast of site)**: The information provided includes sections of a working draft for a ground investigation report undertaken by MJ Carter Associates on behalf of Onyx UK Limited for a proposed extension of the Southleigh Landfill site in Havant. Whilst there are no records of exploratory holes, the working draft texts refers to the presence of the Bognor Member, London Clay and Reading Beds (Reading Formation), that is in accordance to the geological sequence indication on the 1:50,000 BGS geological map [11]. An ephemeral spring line is recorded in the western corner of the Study Area between the Bognor Member and the London Clay.

7.3. Ground Profile

The ground profile for the proposed reservoir site has been developed based on the historical ground investigations on site, the near field, and published Geological data. Drawing 5 which presents the 1:10,000 BGS geology overlain with the historical exploratory hole locations within or close to the proposed reservoir site. Geological cross sections along the alignment of the embankment, through the reservoir in N-S and E-W orientations, and E-W section along the northern boundary of the Study Area are presented in Drawings 6A to 6D.

Attempts were not made by others in the historical reports to refine and interpret sub-units of the London Clay, Harwich Formation and Reading Formation. However, an initial interpretation has been made here, derived upon historical descriptions and is to provide a basis for further investigation.

7.3.1. Possible Made Ground

A thin layer of topsoil / reworked ground was encountered across the majority of the site that is associated with ploughing and reworking of agricultural fields and historical forestry plantations. The thickness is generally no more than 0.3m. The thickness may be greater surrounding Upper Lake where earthworks were undertaken to form the pond.

7.3.2. Shear Surfaces

Shear surfaces recorded within the A and E series of the MRM Trial pits are presented in Drawing 7 and also listed within Table 7-1 and Table 7-2, below. The trial pits were originally along the proposed line of the embankment. In the most recent update to the embankment design by Arup (2009) [3], trial pits concentrated to the south and southwest of the reservoir are no longer situated along the dam crest or southern shoulder but instead are either inside the proposed reservoir or under the proposed upstream shoulder.

Shear planes were recorded in the MRM investigation A series and E series trial pits and also within extruded and split U100 (102mm diameter) undisturbed samples in Head, London Clay and Reading Formations. Of the A and E series, all trial pits reported shear planes of varying dimensions with the exception of the three most westerly pits, A1 to A3 and the most easterly, A13. Shear planes were most developed along the lower part of the valley side to the west of the central watercourse. To the west of the central watercourse (trial pits E1, E2, A4 and A5), the shearing is reported to a zone extending from below the topsoil layer to a depth of 2.5m to 5.0m (Trial pits were advanced to a maximum depth of 5.2m). Along the eastern side of the north-south trending valley between Deerslaughter plain and The Avenue, the zone of shearing is thinner extending to only about 1.5m below ground level, and the planes are generally smaller and less extensive.

Deeper shears described within split U100 samples of London Clay and Reading Formations appear to be mostly associated with bedding slip from N-S compression during the early Palaeogene and stress-relief during erosion of the London Clay Formation that has led to over-consolidation of the formations. The shears are generally described as discontinuous, sub-horizontal to sub-vertical and randomly oriented which is not indicative of post-depositional mass movement or soil creep.

7.3.3. Quaternary Deposits (Head / Colluvium)

Descriptions of the Quaternary deposits from historical exploratory descriptions were variable with the distinction between topsoil, reworked land for agriculture and material characteristically defined as head not always distinguishable. Where head deposits are indicated in the 1:10,000 BGS geological mapping they appear to extend along valley floors. the MRM trial pit descriptions indicate that the material generally comprises flint gravel within a matrix of fine sandy silty clay [6].

In general, the thickness of the Head underlying topsoil was between 0.1m and 2.85m, with an average thickness of 0.92m.

Head deposits recorded at the Study Area are associated with soliflucted Palaeogene deposits of London Clay and Reading Formations that were altered during Quaternary glacial periods.

Shear surfaces associated with movement (i.e., solifluction shears) were generally recorded within the top 1.5m in Quaternary Head deposits that comprise soliflucted London Clay Formation within MRM trial pits but were occasionally up to 3.1m.

Table 7-1 - Shear surfaces recorded within Quaternary Head Deposits / soliflucted London Clay Formation

Trial Pit	Shear Surface Dip / Orientation	Depth mbgl	Notes
A4	25-30/090	1.5	Stiff-very stiff grey and brown mottled silty CLAY with many interleaved and overlapping shiny surfaced slightly striated shear planes, most prominent around 1.5m and to a slightly lesser extent 2.2m but present to base of pit, can be traced for 400mm but overlap with adjacent planes.
A4	30-40/180	1.5	
A4	50-60/180	2.2	
A5	±30/025	0.7 - 1.4	Shiny shear planes with striations parallel to dip trending in approximate downslope directions with undulating surfaces. Most common between 0.7 and 1.4m but can be found at all depths to 4m, also most continuous and extensive 0.7 and 1.4m.
A5	±30/110	0.7 - 1.4	
A6	26/160	1.1	Few shiny striated shear surfaces which can be traced laterally 400mm.
A6	29/119	1.1	
A7	Sub-vertical	0.5 - 0.9	Well-developed shear surfaces present approximately 100mm spacing vertically. A well-defined plane which can be traced across the south face at 0.95m seems to mark the lower limit of the shear planes which dip generally northwards.
A8	- / -	0.4 - 1.6	Variously orientated shiny shear surfaces with striations parallel to dip extend to 1.5m. Surfaces mainly grey in colour.
A9	- / -	0.5 -1.0	Non-pervasive shear surfaces
A10	20-45/230	<1.2	Extensive curving of shear planes exposed on the south face, striations parallel to dip.
A11	- / -	0.4 - 1.4	Shiny striated shear surfaces dipping mainly northeast at approximately 30°.
A12	- / -	1.0	Some shiny striated mainly grey shear planes.
E1	00?/090	0.25 - 0.9	Many interleaved and overlapping shear planes strongly developed.
E1	42/090	1.7 - 3.1 (1.7)	Major shear surface starts at 1.7m extends to 3.1m over full width of pit.
E1	56/090	1.7 - 3.1 (3.1)	
E2	27/270	0.25 - 2.1	Variously orientated grey shear surfaces with striations parallel to dip and overlapping.
E2	22/045	0.25 - 2.1	
E2	10/315	0.25 - 2.1	
E2	20/200	0.25 - 2.1	
E2	20/270	0.25 - 2.1	
E2	18/270	0.25 - 2.1	

7.3.4. London Clay Formation (Bognor Sand Member)

The London Clay Formation exhibits both lateral and vertical variation. In general, the thickness of the London Clay Formation increases to the south and southwest and tapers to the north and northeast (towards the boundary with the Harwich Formation).

The Bognor Sand Member on site generally comprises a silty fine sand. The historical exploratory holes M01, M10, BGS18/B1, and A1 to A3 indicate that the Bognor Sand Member is present towards the southwest boundary of the Study Area. It is on a ridge-like topographical feature, that will form the western flank of the reservoir.

The thickness of the Bognor Sand Member was between 1.75m and 5.3m. The spatial extent of the Bognor Sand Member may also be smaller than indicated on the 1:10,000 BGS Geological Mapping and presence in historical exploratory holes due to the process of solifluction advancing materials of the Bognor Sand Member downslope.

7.3.5. London Clay Formation (Division A3)

The historical exploratory hole descriptions indicate that Division A3 of the London Clay comprises a stiff to very stiff grey/brown fissured occasionally laminated silty clay or clayey silt with ferruginous claystones of up to 100mm thick and lenses/partings of fine sand and silt. Below claystone and mudstone bands, ‘sugary’ selenite and/or gypsum crystals are noted as present along fissures and shear surfaces. Fissures are recorded in several trial pits, this generally corresponds to the description of the A3 division provided by C. King (1981) for the Hampshire basin.

A weathered layer of the London Clay is present within most historical exploratory holes and is between a minimum of 0.3m and maximum of 3.32m thick in exploratory holes D12 and 18/B6 (respectively). It is generally described as firm to stiff orange to brown / grey mottled silty clay.

Overall thickness of Division A3 ranges from a minimum of 0.8m thick in exploratory hole D4 (in the north of the Study Area) to a maximum of 28.2m in exploratory hole 18/B1 (in the south of the study Area).

7.3.6. London Clay Formation (Division A2)

There is no significant evidence from historical exploratory holes to indicate the Division A2 of the London Clay is present. In some areas of the Study Area, the boundary between the London Clay Formation and the Harwich Formation is poorly defined and is variably described in trial pits as: ‘concentrated layer of flint gravel’ (D12); ‘medium and coarse flint in a stiff clay matrix’ (D19) and ‘stiff silty clay with flint gravel and some fossiliferous limestone slabs (up to 600mm across)’.

7.3.6.1. London Clay Shear Surfaces

Shear surfaces within the in-situ London Clay Formation that have been derived from descriptions of extruded 102mm undisturbed samples in the MRM investigation and trial pit logs are presented in Table 7-2 below. It is possible that the material in Head is derived from the London Clay.

Table 7-2 - Shear surfaces recorded within the London Clay Formation

Borehole / Trial Pit	Shear Surface Dip / Orientation	Depth mbgl	Notes
A4	50-60/180	2.2	Stiff-very stiff grey and brown mottled silty CLAY with many interleaved and overlapping shiny surfaced slightly striated shear planes, most prominent around 1.5m and to a slightly lesser extent 2.2m but present to base of pit, can be traced for 400m but overlap with adjacent planes.
A6	- / -	1.8 – 3.9	Some planes slightly shiny but do not appear to be sheared surfaces and are very small in extent.

Borehole / Trial Pit	Shear Surface Dip / Orientation	Depth mbgl	Notes
E1	42/090	1.7 - 3.1 (1.7)	Major shear surface starts at 1.7m extends to 3.1m over full width of pit.
E1	56/090	1.7 - 3.1 (3.1)	Many interleaved and overlapping shear planes strongly developed.
18/4 (Sample 41)	- / -	12.50-12.80	Slight evidence of slightly shiny small infrequent lineated shear surfaces.
18/B3 (Sample 13)	- / -	2.70 – 3.15	Evidence of occasional sub-horizontal smooth shiny very slightly lineated shear surfaces.
18/B3 (Sample 42)	- / -	8.20 – 8.65	Weakly developed slightly shiny shear planes
18/B5 (Sample 20)	- / -	3.85 – 4.3	Some evidence for subvertical semi-planar discontinuities with occasional smooth slightly shiny shear surfaces

7.3.7. Harwich Formation

The Harwich formation is recorded in most historical exploratory holes. The stratum has a thickness of up to 3.1m (identified within Trial Pit D17) but recorded between 1.5m (D7 and D11) in the west and 2.4m (D17 and D19) in the east of the Study Area. Historical exploratory trial pits indicate that there are typically three layers of the Harwich Formation present across the Study Area and comprises a sequence of:

(1) Light brown and grey fine sand (HWH1), underlain by;
(2) Fossiliferous layer, variably recovered as a grey limestone, Mudstone, conglomerate or stiff dark grey to grey green clayey silt / compact silty clayey fine sand (HWH2), underlain by;
(3) Grey silty fine sand or sandy silt with variable clay content (HWH3).

The MRM trial pits indicate that seepages are encountered below the conglomerate layer and at the interface with the Reading Formation. Seepage is variable and with some trial pits (D6 and D12) indicating significant seepage. Boreholes encountering the Harwich Formation recorded groundwater strikes, see Section 7.4 for further detail.

The Harwich formation is generally overlain by the London Clay formation with exception to the north of the Study Area where it outcrops. The Harwich is absent locally where streams have incised into the Reading Formation stratum. It has not clear whether the formation is present across the entirety of the Study Area. Historical BHs, M1, M10, M12 and SM BH01 do not extend below the London Clay to confirm whether the Harwich formation is present towards the western boundary.

7.3.8. Lambeth Group (Reading Formation)

The Reading Formation (within the Lambeth Group) is encountered in the majority of boreholes. The maximum thickness of the Reading Formation was not proven from historical ground investigation undertaken within the Study Area. A thickness of at least 23.8m was recorded in MRM BH 18/4 in the south of the site. Near field BH BGS ‘Staunton Arms’ to the west of the Study Area indicates a combined thickness of the London Clay Formation and Reading Formation (‘Red green brown clay and sand’) of 31.0m.

The Reading Formation outcrops in the northern zone of the Study Area and along various small streams that cross the Study Area. The strata dips gently to the south-southwest at an angle of approximately 1.5° [7]; however locally this may be steeper due to variable weathering of the Reading Formation prior to deposition of the overlying Harwich Formation and/or London Clay.

Descriptions of the Reading Formation from historical site investigations indicates that the stratum comprises a firm to very stiff mottled red, grey/blue and brown silty locally sandy clay. Moderately weak thinly laminated mudstone, sandstone and cemented nodules are present in several boreholes. Fissures are recorded as extremely closely spaced, randomly oriented and matt. A weathered layer

of the Reading Formation was encountered in some trial pits (D1, D9 and D14) and was recovered as gravel within a red mottled brown and grey silty clay matrix, generally less than 0.3m in thickness. The MRM 'D' series Trial Pits, which encountered the Reading Formation, did not indicate the presence of shear surfaces however it is unclear within the report whether man-entry to examine the ground fabric was or was not undertaken.

In boreholes 18/1, 18/B2, SM BH102, SM BH103 and trial pits D1, D14, D19, SM TP103; a weathered layer of the Reading Formation approximately 0.5m thick is present. This layer generally comprises a soft becoming firm red yellow brown, locally mottled orange brown sandy silty Clay. Localised softening of the Reading Formation may be associated with seepage from groundwater confined to the overlying Harwich Formation.

Shear surfaces within the Reading Formation were encountered within extruded 102mm diameter undisturbed samples from the MRM ground investigation. The shear surfaces were generally recorded as smooth, shiny lineated or striated surfaces inclined by between 30 and 45 degrees with occasional slickensided shear surfaces[18]. BGS BH18/3 indicates that a series of slickensided surfaces are present at 15.00mbgl (+7.75mOD).

There has been no historical laboratory strength testing on Reading Formation material within the Study Area made available. This would be required to develop and confirm design parameters to perform geotechnical checks on preliminary design, and could be determined with laboratory triaxial testing UU and CU. The Reading Formation material may be a good source of clay material and should not yet be discounted.

7.3.9. Chalk

There is minimal information regarding the Chalk beneath the Study Area as only one borehole east and adjacent to the Study Area, BGS BH 'Staunton Arms', recorded chalk at a depth of 33.5mbgl (a level of approximately +7mOD from review of DEFRA LiDAR data in the near field). Historical ground investigations to about 1km north of the Study Area indicate that the Chalk surface is at approximately +26mOD, and dips gently to the south at approximately 1.3° [41]. The depth of Chalk is expected to be typically around 35m below ground level (in the north part of the site) to 25m (in the south part of the site).

Descriptions of the chalk from the investigations within or adjacent to the proposed reservoir are limited, i.e., 'Chalk and Flints' (BGS Staunton Arms). The PBA [44] near field GI undertaken 1.5 km north of the Study Area generally describes the chalk as 'off-white or cream sandy gravelly SILT or angular to sub-rounded clayey fine to coarse GRAVEL and COBBLES. The clasts are extremely weak to weak low to medium density white CHALK'.

The spatial extent of dissolution features in the Hampshire basin generally follows the Palaeogene and Cretaceous boundary. A large number of solution features are present within the chalk around Horndean and Rowland's Castle to the north and northeast of the proposed reservoir (respectively), with the nearest mapped feature to the boundary of the site being 600m to the northeast; see Section 3.4.4 for further information. Additionally, an infilled E-W oriented palaeochannel was possibly identified within a near-field ground investigation 1.5km north of the proposed reservoir site boundary [44].

7.3.10. Previous Evidence of Contamination

Dumped and burnt out cars which may be a potential source of contamination were noted to be present on site during previous site walkovers [47]. However, none were seen during the most recent walkover undertaken in 2019.

[18] Slickensides are polished surfaces on the face of a fissure that indicate historical movement and may reduce the in-situ shear strength of the stratum.

Previous site investigations [9] [13] have not encountered Made Ground at the site or indicated any visual or olfactory evidence of contamination at the site, as outlined in the Entec 2007 [9] report. A thin layer of topsoil / reworked ground was encountered across the majority of the site that is associated with ploughing and reworking of agricultural fields and historical forestry plantations. The thickness is generally no more than 0.3m.

Previous investigations were also undertaken for geotechnical purposes and no contamination testing was undertaken to confirm the contamination status of the site or to verify the suitability of material for re-use as part of the proposed development.

7.4. Groundwater

7.4.1. Groundwater Conditions

Hydrogeological properties of the strata, as encountered from historical ground investigations and laboratory testing is presented in Table 7-3 below.

Table 7-3 - Summary of Hydrogeological Properties in the Study Area

Stratum	Hydrogeological Properties
London Clay (Bognor Sand Member)	The Bognor Sand Member is a persistent sandy member of the London Clay Formation and has the potential to contain an elevated groundwater body towards the southwest boundary of the Study Area. Evidence from the aerial photograph interpretation and geomorphological survey indicates that spring lines are present along the base of the Bognor Sand Member, above Division A2/A3 of the London Clay. No in situ permeability testing was conducted within this formation however 1 No permeability laboratory test was undertaken that recorded a value of $1x10^{-6}$ m/s.
London Clay (Division A2 and A3)	Whilst the London Clay is characterised as predominantly a low permeability material, historical investigation has indicated minor seepage along fissures, shears and fractures of the mudstone bands. Persistent mudstone bands may provide an enhanced pathway of surface waters towards the underlying stratum. In the historical ground investigations, there were a number of water strikes (Refer to Appendix A), indicating the ability of the formation to transmit water. No in-situ permeability testing was conducted within this formation; however, it is anticipated to be in the region of $5x10^{-8}$ m/s to $2x10^{-10}$ m/s [35].
Harwich Formation	Groundwater has been encountered in the Harwich Formation during ground investigations. Water strikes were reported in the 1962 Edgar Morton & Partners ground investigation with free-flowing water under artesian pressure found in boreholes M03, M05, and M06. In M03, in the centre of the valley, water rose to 1.6m above ground level and in M05, on higher ground, sub-artesian pressures were encountered with water rising to within 5.2m of ground level, which correspond to +23.5mOD and +24.5mOD (respectively). Artesian conditions were reported during drilling in the 1977-1979 MRM investigation as indicated in Table 7-4. In general, where the Harwich is confined by the overlying London Clay Formation, artesian or sub-artesian water was encountered. No in-situ or laboratory permeability testing was conducted within this formation however is anticipated to be similar to the basal sands of the Reading Formation i.e., from $1x10^{-3}$m/s to $1x10^{-5}$m/s [35] [33].
Lambeth Group (Reading Formation)	Water strikes were recorded in several boreholes (Refer to Appendix A) within the Reading Formation, however, they often did not align to any changes within strata on the logs. These water strikes are most likely to tie in where the saturated zone is intercepted or with isolated water bearing sand lenses which were not described accurately during logging. The Reading Formation is not expected to hold significant quantities of water. However, it is possible that water bearing channel fill deposits may be present that may have significantly greater permeability than the other

Stratum	Hydrogeological Properties
	lithologies within the formation. Such channel fill deposits were inferred in a geophysical survey conducted 1.5km to the north of the site [44]. The permeability of the Reading Formation is anticipated to be from $5x10^{-7}$m/s to $5x10^{-9}$m/s in clay deposits and $1x10^{-3}$m/s to $1x10^{-6}$m/s in basal sand deposits (if present on site) [21].
Tarrant Chalk	The historical ground investigations did not extend into the Culver Chalk Formation, with exception to a near-field BGS borehole 'Staunton Arms'. Groundwater contours taken from the East Hampshire groundwater monitoring report suggest that the water level in the Chalk beneath the Havant Thicket site typically varies between 0mOD and +20mOD [31].

Historical ground investigation data related to groundwater encountered on site is presented in Table 7-4 and includes strike/rise data from boreholes and seepage within trial pits. See Figure 7-1, Figure 7-2 and Figure 7-3 for excerpts of historical report with tables presenting the piezometer reading programme and results.

Table 7-4 - Groundwater encountered from historical ground investigations in the Study Area

Strata		No. of exploratory Holes	Strike Range mOD (mbgl)	Comments	No. of trial pits	Seepage Range mOD (mbgl)
Bognor Sand Member		0	None recorded		2	+36.2 to +32.8 (2.5 - 4.0)
London Clay A2/A3		9	10.7 - 32.97 (1.30 - 9.60)		4	+30.6 to +18.25 - (1.75 - 3.90)
Harwich Formation	**HWH1**	1	+33.66 (1.68)		2	+31.20 to +31.14 - (2.6 - 2.9)
	HWH2	4	+18.61 to +10.1 (11.50 to 13.72)	Artesian conditions 18/B3, 18/B6 & 18/B5	0	None Recorded
	HWH3	1	+7.1 (12.5)	Artesian conditions 18/4, M03*[1]	12	+33.64 to +21.69 - (1.5 - 5.2)
Lambeth Group (Reading Formation)		4	+23.1 - +15.4 (11.30 - 13.72)	Artesian Conditions indicated in SMBH103, SMBH102 & M05	2	+33.04 to +29.1 (2.95 - 3.6)

*[1] Free-flowing water under pressure recorded in the basal beds *sic* (Harwich Formation), not possible to define sub-unit of Harwich Formation from M03 borehole log.

TABLE I.8

PIEZOMETER READINGS

EAST HAMPSHIRE

Borehole Number	Depth of Tip	Date of Installation	1977 16.9	1977 21.10	1977 26.10	1977 2.11	1977 9.11	1977 16.11	1977 9.12	1978 11.1	1978 27.1	1978 9.2
15/3	36.5	23.9.77		3.90	3.89	3.84	3.73		3.67	3.63		3.63
15/5	9.75	14.9.77	5.80	6.40	6.29	6.35	6.33		6.23	5.86		5.62
17/1	11.50	13.10.77			0.88	0.67	0.42		0.36	0.44	0.44	0.51
17/2	23.50	21.10.77			1.65	1.20	0.97			0.84	0.73	0.72
17/3	9.30	3.10.77			7.15	7.27	7.20			5.96	6.13	5.75
17/6	3.0	6.10.77			0.62	0.53	0.52	0.64	0.10	0.44	0.52	0.67
17/9	12.5	11.10.77							+0.20	+0.08	+0.10	+0.10
17/10	4.4	11.10.77			3.29	3.16	3.03		2.67	2.15	1.93	1.70
18/3	24.0	28.10.77					6.72	3.00	0.60		0.14	+0.06
18/4	12.2	24.10.77										
19/1	5.0	7.11.77						1.00	0.89	0.94	0.93	0.92
19/3	13.0	4.11.77					5.37	5.17	4.98	4.41	4.39	4.27
19/4	9.0	15.11.77						4.90	3.17	2.46	2.72	2.80
19/5	15.3	16.11.77										
19/6	8.5	14.11.77						Dry	5.71	5.17	5.27	5.62
19/8	6.8	15.11.77						3.51	3.35	5.25	3.47	5.08
20/1	13.0	21.11.77							1.44	1.34		1.27
20/2	21.0	3.11.77						0.91	0.80	0.76		1.13
20/3	4.7	1.11.77						1.02	0.68			0.90
20/4	32.5	9.11.77										

NOTE: Piezometric levels in metres below GL, but
+ve values signify head in metres above ground level

Sheet 1 of 2

Figure 7-1 – Extract of historical groundwater readings, from MRM 1977-79 Table I.8 Sheet 1 of 2 [6]

TABLE I.8

PIEZOMETER READINGS

EAST HAMPSHIRE

Borehole Number	Depth of Tip	Date Of Installation	1979 14.2	1979 28.3	1979 26.4	1979 14.5	1979 28.6	1979 26.7	1979 30.8	1979 12.9	1979 12.10	1979 26.11
18/3	24.0	28.10.77	0.20	0.25	0.36		0.61	1.35	1.09	1.05	1.05	1.00
18/4	12.2	24.10.77	+6.8	+7.0	+7.0	+6.5	+6.8	+7.0	+7.0	+7.0	+6.9	+6.9
18/B1	9.6	14.12.78	7.41		7.48	7.63	7.79	7.59	8.78	7.73	7.38	7.43
18/B2	17.5	17.11.78	0.61	0.83	0.84	0.89	0.81	0.82	0.85	0.91	0.91	1.00
18/B3	13.75	5. 9.79										+2.8
18/B4	13.0	9. 1.79		1.49	2.65	2.64	2.69	2.94	2.97	3.06	3.07	
18/B6	11.75	11. 9.79									4.01	

NOTE Piezometric levels in metres below GL, but
+ve values signify head in metres above ground level.

Sheet 2 of 2

Figure 7-2 – Extract of historical groundwater readings, from MRM 1977-79 Table I.8 Sheet 2 of 2 [6]

RECORD OF PIEZOMETER READINGS

Date 1979	Boreholes B1	B2	18/3	18/4*	B4	B3*	B6
30 Jan	10.87		0.34	6.2			
14 Feb	7.41	0.61	0.20	6.8			
28 Feb	7.48	0.91	0.36	6.8			
28 Mar		0.83	0.25	7.0	1.49		
26 Apr	7.48	0.84	0.36	7.0	2.65		
14 May	7.63	0.89		6.5	2.64		
28 Jun	7.79	0.81	0.61	6.8	2.69		
11 Jul	7.68	0.82	1.04	7.1	2.81		
26 Jul	7.59	0.82	1.35	7.0	2.93		
15 Aug	7.65	0.84	1.27	7.0	2.95		
30 Aug	8.78	0.85	1.09	7.0	2.97		
12 Sep	7.73	0.91	1.05	7.0	3.06		
12 Oct	7.38	0.90	1.05	6.9	3.07		4.01
08 Nov	9.06	0.95	0.78	6.8	2.85	3.75	3.63
16 Nov	7.48	0.93		6.8		3.25	
23 Nov	7.43	1.00		6.8		2.80	

*Note: The values represent depth of water level below ground level for all boreholes except numbers 18/4 and B3, for which the values recorded are in metres above ground level.

TABLE III.4.1

Figure 7-3 – Extract of historical groundwater readings, from MRM 1980 Table III.4.1 [7]

7.4.2. Groundwater Regime

Limited historical groundwater monitoring was undertaken by MRM in seven boreholes installed with piezometers between 1977 and 1979. The response zones of the piezometers were mostly in the Harwich Formation but also in the London Clay (18/B1 and 18/B3) and the Reading Formation (18/3). The data from the monitoring rounds is summarised within Appendix A1. The monitoring wells were mostly concentrated along the proposed embankment alignment from the south to the southeast of site and is on average between +24.0 and +26.1mOD. In the southwest of the site the average monitored groundwater level was +31.4mOD. however, this did not include groundwater response within the Bognor Sand Member as no installations were made within the formation. Towards the centre of the site, the only groundwater level recorded is at BGS Borehole 18/3 and ranges from +25.5 to +26.5mOD in the year of 1979.

The groundwater regime on site is surmised to be composed of:

- An elevated groundwater body within the Bognor Sand Member in the southwest of the site.
- A semi-confined aquifer within the Harwich Formation that is inferred to be confined by the overlying London Clay Formation and underlying Reading Formation. The aquifer is reported with sub-artesian and artesian pressures beneath the proposed embankment.

- A chalk aquifer where the historic groundwater regime has not been confirmed within the site footprint.

The Idsworth well monitoring data is plotted with monthly groundwater monitoring data obtained from the MRM ground investigation in Figure 7-4. The readings do not indicate that there is hydraulic continuity between Palaeogene deposits / Harwich Formation and the underlying Chalk. However, groundwater monitoring wells installed in the MRM investigation have not been verified by Atkins and information from near field groundwater monitoring in the Chalk is sparse. Additional groundwater monitoring is required to confirm the groundwater regime underlying the Study Area.

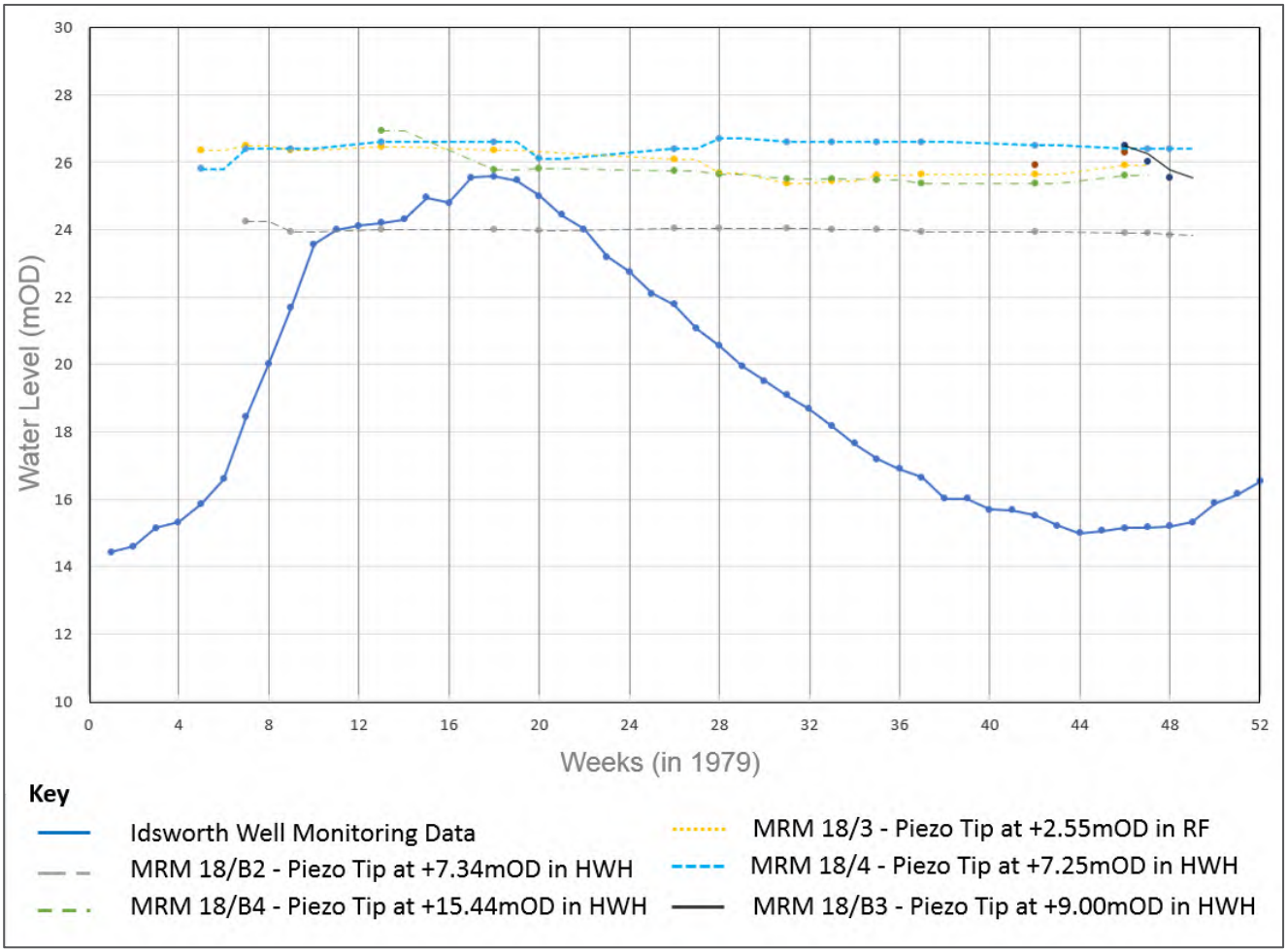

Figure 7-4 - Selected historical groundwater monitoring from MRM Ground Investigation plotted with Idsworth Well Monitoring Data in 1979

7.4.3. Strata Permeability

No in-situ testing was undertaken in historical ground investigations at the Study Area. Direct permeability testing in triaxial cells was undertaken by Foundations Engineering on behalf of MRM in 1979. Table 7-5 below provides a summary of the permeability ranges that were inferred by MRM. The anticipated regional permeability ranges for all stratum encountered on site from published literature is provided in Table 7-3 above.

Table 7-5 - Results of historical permeability tests

Stratum	Direct Permeability Test in Triaxial Cell (m/s)	Inferred Permeability from Historical Ground Investigations
Bognor Sand Member	1×10^{-6} (1 result)	No results
London Clay Formation	2×10^{-8} to 1×10^{-8} (2 results)	No results
Harwich Formation	7×10^{-5} to 1×10^{-7} (2 results)	10×10^{-5} to 4×10^{-5} (3 results from GI)*
Reading Formation	No results	No results
Chalk	Historical Ground Investigation in the Study Area did not reach Chalk outcrop	

*Results interpreted from the Foundations Engineering Ltd report whereby permeability values were derived from the rise in boreholes 18/4, B3 and B5 during drilling.

8. Land Contamination Assessment

8.1. Summary

A Preliminary Conceptual Site Model (PCSM) has been prepared for HTWSR and is provided in Appendix E. A summary of the findings is presented below.

Based on the PCSM, potential risks to human health, property, controlled waters and ecological receptors have been identified as very low to low risk, dependent on implementation of mitigation measures. Previous ground investigations undertaken at the site have not encountered Made Ground and potential on-site sources of contamination are considered to be localised with a limited likelihood of a pathway existing if present.

Potential on-site sources of contamination include reworked ground associated with historical construction, de-vegetation activities and the channelization of watercourses and potential spills / leaks associated with burnt out cars. Potential off-site contamination sources include Made Ground / contaminated ground and groundwater associated with a fuel station, historical landfills, infilled former brick, chalk and clay pits, allotments, a smithy and a former battery and military base at Leigh Park.

Although previous ground investigations undertaken at the site have not identified the presence of Made Ground, no chemical testing has been undertaken to date. In order to provide information on the baseline conditions at the site and to inform soil re-use / materials management for outline design, it is recommended that an additional ground investigation is undertaken at the site to include environmental testing. The ground investigation should be designed to provide a broad coverage of exploratory holes across the site and to target localised areas of potential contamination to confirm the contamination status of the site and to verify the suitability of material for re-use as part of the proposed development.

The proposed ground investigation should include environmental sampling of soil and groundwater, groundwater monitoring and chemical laboratory analysis. The resulting data should then be used to undertake a generic quantitative risk assessment (GQRA). Laboratory testing should comprise a range of metals, metalloids, inorganic and organic determinants relevant to the contaminants likely to be associated with identified current and historical land uses. Asbestos should also be included within shallow samples. In the event that soils are to be removed off-site as waste, appropriate waste classification should be undertaken. Material to be re-used on-site as part of the development, should be managed under an appropriate scheme such as the CL:AIRE Definition of Waste: Code of Practice to demonstrate its suitability for re-use.

9. Geotechnical Engineering Issues – Initial Review

9.1. Strata Characteristics and Preliminary Geotechnical Design Parameters

Ranges of geotechnical parameters are presented in Table 9-1 for the Head, London Clay Formation, Harwich Formation and the Reading Formation underlying the Study Area. Data presented is from historical ground investigations undertaken between 1962 and 2007 [4] [5] [6] [7] [9]. There are some key differences in the test methodology between the different investigations that impact test results for earthworks i.e. compaction testing and Atterberg testing:

1. Compaction testing: The compactive effort (weight) used is different in the 2007 testing versus the 1963 and 1977 testing – this results in a different dry density and optimum moisture content value for the same material.
2. Atterberg testing: Either a Casagrande bowl or a falling cone test is used to derive the liquid limit – there are significant differences in the testing results between the two methods. Whilst the falling cone is now industry standard, the Casagrande bowl was predominantly adopted in historical investigations. However, the methodology adopted for each campaign is unknown.

The ranges of parameters presented have been derived from available historical ground investigations from the Study Area and are therefore indicative only and are not intended for use in design at this initial stage. Preliminary design parameters, outlined in Section 9.5, are to be validated through further GI. The prior data set is useful for the basis for design, but it is incomplete (i.e. there are key data gaps) and large assumptions would need to be made without further GI. This supplementary investigation would inform design parameters to be adopted for the following strata:

- Bognor Sand Member: to determine how it will behave when a cut-off wall is constructed through it and into the London clay, and if the excavated material would be suitable embankment shoulder material.
- Harwich Formation: to determine design and earthwork parameters, and if the excavated material would be suitable embankment shoulder material.
- Reading Formation: to determine undrained shear strength parameters for use in the assessment of borrow pit cutting slope stability.
- London Clay: to improve compaction testing data, and to undertake testing in the main areas proposed for the borrow pit (for earthworks design, plant required, materials management etc) where suitable information is not available.

Drawing 8 presents the key geotechnical engineering issues within the footprint of the reservoir site that require further consideration at this initial stage.

Stratum	Unit	Moisture content (Max, Min, Avg) (%)	Liquid Limit & Plastic Limit (Max, Min, Avg)	Particle Size Distribution (Min – Max) (%)	Compaction Testing Mg/m³ and % (Max, Min, Avg)	Density Mg/m³ (Max, Min, Avg)	Drained Parameters (Max, Min, Avg)	Undrained Parameters (Max, Min, Avg)	No. of BHs/TPs stratum present
Quaternary Deposits (Head)		1 Result (31)	1 result LL = 67% PL = 22%	1 result Clay =47; Silt = 44; Clay & Silt = 91 Sand = 9; Gravel = 0	1 Result ρ_b (dry) = (1.71)	1 result bulk density = 2.06	1 Result φ' = 25°	No Lab Data Available	10
London Clay	**Bognor Sand Member**		No Lab Data Available						1
	London Clay Division A3	19 results (39, 25, 30)	17 results LL = (98, 63, 75) PL = (31, 19, 26) PI = (67, 37, 49)	11 results Clay =26 to 66 Silt = 30 to 47 Clay & Silt = 92 to 99 Sand = 1 to 5 Gravel = 0	2 Results (2007) ρ_b (dry) = (1.82, 1.68, 1.75) OMC = (14,13, 13.5): 2 Results (1963) ρ_b (dry) =(1.6, 1.5, 1.55) OMC = (20, 18.7, 19.4):	14 results bulk density = (2.01, 1.79, 1.93)	17 Results φ' = (34,13, 24)° 5 Results c' = (55, 7, 27)	17 Results C_u = (108, 40, 75)	20
	London Clay Division A2		No Lab Data Available / formation may not be present.						0
Harwich Formation		2 results (28, 27, 28)	1 result LL = 43 PL = 18 PI = 25	2 results Clay =5 Silt = 37 Clay & Silt = 42 to 87 Sand = 13 to 58 Gravel = 0	No Results	No Results	No lab data available		22
Lambeth Group	**Reading Formation**	31 results (30, 14, 18)	30 results LL = (66, 32, 50) PL = (23, 12, 18) PI = (43, 20, 32)	22 results Clay =23 to 61 Silt = 33 to 65 Clay & Silt = 71 to 99 Sand = 1 to 29 Gravel = 0	8 Results (2007) ρ_b (dry) = (2.08, 1.82 1.96) OMC = (13, 10.9, 11.7) 8 Results (1963 and 1977) ρ_b (dry) = (1.84, 1.64, 1.74[1]) OMC = (22.5, 13, 18[1]):	3 Results bulk density = (2.25, 2.18, 2.21)	3 Results φ' = (34,13, 24)°	No results	29
	Basal Beds		No Lab Data. Tentatively identified in the BGS Staunton Arms borehole.						1
Chalk	**Culver Chalk Formation**		No Lab Data available in vicinity of the Study Area						1

LL = Liquid Limit; PL = Plasticity Limit; PI = Plasticity Index; ρ_b = Bulk Density; OMC = Optimum Moisture Content 2.5kg rammer used in the 1963 and 1977, 4.5 kg rammer used in the 2007. 1. Average value from 1977 MRM report

Table 9-1 – Strata Characteristics and Indicative Geotechnical Parameters

9.2. Geotechnical Hazards

A summary of the anticipated geotechnical hazards and engineering considerations is presented in Table 9-2 below.

Table 9-2 - Potential geotechnical hazards in the Study Area

Hazard Category	Engineering Considerations	Comment on Ground Conditions
Low bearing capacity soils	Ground that is soft of compressible may cause excessive settlement and affect the serviceability limit state of the proposed embankment.	Head deposits encountered across approximately 50% of the site and along the alignment of the proposed embankment dam.
Soil creep	Undermining foundation soils of the proposed embankment.	The API has indicated possible areas of soil creep in the southwest of the site (along the alignment of the proposed embankment dam).
Shear surfaces	Global stability failure of reservoir embankment due to embankment loading and re-activation of pre-existing shear surfaces.	Shear surfaces encountered within boreholes and trial pits as described in Section 7.3. Some shear surfaces are likely associated with soil creep.
Instability of excavations	Difficulty in excavation for materials during construction phase of embankment.	Instability of trial pits were encountered in some of the historical trial pits where sandy strata was encountered.
Adverse ground chemistry	Naturally occurring sulphates, sulphides, acids and chlorides may be damaging to buried steel and concrete on proposed supporting infrastructure.	Reading Formation deposits naturally have a higher acidity and high sulphate content in the London Clay Formation.
High groundwater table (including waterlogged ground/flooding)	Difficulty in excavation for materials during construction phase of embankment.	Waterlogged conditions identified along seepage lines between the Bognor Sand Member and the London Clay Formation. To the west and southeast of the Study Area where the London Clay Formation outcrops, low permeability of formation expected to increase flooding of low-lying ground and excavations through the Harwich Formation in borrow pit area.
Artesian groundwater	Artesian Groundwater conditions may cause internal erosion (piping) of an embankment or floodwall structure, and uplift of excavation floor.	Artesian groundwater from the Harwich Formation encountered immediately downstream of proposed embankment dam in historical boreholes. It may also be present in the borrow pit area.

Hazard Category	Engineering Considerations	Comment on Ground Conditions
Relic periglacial landforms	Presence of leakage paths during filling of proposed reservoir.	Relic Pingo formations – see technical discussion in Section 9.4. None identified to date.
Natural Cavities	Presence of leakage paths during filling of proposed reservoir.	Dissolution features not encountered within 500m of the site boundary
Seepage under embankment dam when filling the proposed reservoir. Seepage from the reservoir basin.	Presence of leakage paths during filling and operation of proposed reservoir.	Historical ground investigation and published geological information indicate that the Bognor Sand Member and the Harwich Formation is present in the Study Area – see technical discussion in Section 9.4.
Leakage pathway from proposed wetlands	Presence of leakage paths during filling and operation of proposed wetlands, particularly during periods where the reservoir water level is low.	Historical ground investigation and published geological information indicate that the Harwich Formation is present in this area – see technical discussion in Section 9.4.
Changes to watercourses	Construction of embankment dam may influence local hydrology. Susceptibility of dam to flooding and erosion of downstream embankment toe.	API and geomorphological mapping indicated seasonal drainage into the proposed reservoir from high ground to west of the Study Area.
Unexploded Ordnance (UXO)	Encountering UXO during Ground investigation phases, earthworks and construction.	The potential of a UXO hazard to occur at the site has been assessed as 'Likely'
Earthworks	Sufficient materials on site for the embankment	See technical discussion in Section 9.4.

9.3. Geotechnical Gap Analysis

A geotechnical gap analysis has been carried out using information from historical ground investigations and technical reports within the Study Area and near field. The following data gaps have been identified (Table 9-3), and methods of reducing this uncertainty have been proposed. A review has also been made and is presented in the Ground Investigation rationale document reference: HTWSR-ATK-ZZ-ZZ-RP-C-0002.

Table 9-3 - Geotechnical gap analysis

Data Gap	Reason Required	Recommendations
Ground Model: Lithostratigraphy	To enable baseline interpretation of the lithostratigraphy that is absent from historical ground investigation records. To provide implications for excavation and construction of proposed reservoir.	Undertake ground investigation and detailed logging of deep cored boreholes.
Ground Model: Extent and persistence of the Harwich Formation.	Historical exploratory boreholes do not confirm the presence of the Harwich Formation (a leakage	Undertake ground investigation to confirm the persistence of the Harwich Formation across the site.

Data Gap	Reason Required	Recommendations
	pathway) to the west of the proposed reservoir.	
Ground Model: Periglacial landforms / presence of leakage paths.	Develop and confirm ground model to perform geotechnical checks on preliminary design.	Geophysical profiling with Electrical Resistivity Tomography (ERT) to be incorporated into the ground investigation.
Ground Model: Depth of Chalk below the Study Area.	Develop and confirm ground model to perform geotechnical checks on preliminary design.	Undertake ground investigation to confirm depth of chalk underlying the site.
The local hydrogeological regime of the Palaeogene and Chalk aquifers.	To understand the seasonal changes of groundwater underlying the site to inform design of temporary works (borrow pit excavation) and permanent (reservoir and supporting infrastructure) and establish baseline conditions (level, chemical composition). Develop and confirm ground model to perform geotechnical checks on detailed design.	Installation of standpipe piezometers and/or vibrating wire piezometers targeted in anticipated water bearing stratum of the Harwich Formation, Basal Reading Formation beds and Chalk.
Permeability of foundation soils.	To undertake seepage calculations to confirm water tightness of the foundation soils	Undertake in-situ and laboratory permeability tests to evaluate permeabilities of the foundation soils.
Sufficient materials on site for the embankment and their composition for use on embankment foundation.	Establish the available materials for re-use and how they can be used. Information is lacking to the southwest of the site that is an area with the greatest thickness of London Clay.	Ground investigation to delineate extent of suitable embankment materials and their composition.
Stability of dam foundation and shoulder slopes.	Historical ground investigation undertaken along outdated embankment dam alignment.	Targeted ground investigation along sections of the proposed embankment dam.
Characteristic geotechnical parameters: Strength, deformation and permeability parameters of fill and foundation.	Develop and confirm design parameters to perform geotechnical checks on preliminary design.	Field testing for strength and permeability and geotechnical laboratory testing.
Unexploded Ordnance (UXO)	To alleviate risk during excavation of borrow pit and foundation.	Following recommendations of the preliminary UXO desk study, a detailed UXO risk assessment is advised.
No historical laboratory strength testing on Reading Formation.	To develop and confirm design parameters to perform geotechnical checks on preliminary design.	Undertake laboratory triaxial testing UU and CU.

9.4. Discussion

This section evaluates the geotechnical hazards and data gaps that have been identified for the proposed reservoir. The key areas to which additional data needs to be gathered can be categorised

as follows: ground model; earthworks; reservoir leakage; and, stability of dam foundation and slopes. A technical discussion for each category is presented here:

9.4.1. Ground model

A key input for preliminary design is the development of a 3D ground model to reduce the risk of unforeseen ground conditions. The ground model can be developed from the existing information present on site and would provide an outline to geological boundaries, depths of materials and some geotechnical hazards. However, the existing information provides little information for the depth to chalk and spatial extent of the Harwich Formation. There are a number of historical exploratory holes in the location of proposed borrow pit (excluding the southwest area) and embankment. However, there is a lack of testing and the historical exploratory holes do not extend to the expected depth of the borrow pit.

Further ground investigation would comprise targeted boreholes supplemented by non-intrusive Electrical Resistivity Tomography (ERT). The ERT would be used to increase the spatial extent of the inferred ground model whilst the shallow and deep boreholes would enable ground truthing and assist with the interpretation of the groundwater regime.

Detailed logging of core samples from deep boreholes will reduce the uncertainty of unidentified lithostratigraphic changes in units. This includes the following:

- Confirming the presence of permeable basal beds of the Reading Formation that have been identified within the regional geology of the Hampshire basin [23] and that may influence the groundwater regime underlying the Study Area, if present.
- Confirming the presence of the London Clay Formation (Division A2) and its spatial extent across the Study Area to design for water tightness of the reservoir and material suitability for earthworks.
- Reduce uncertainty of the 3D ground model with respect to geological boundaries between formations and sub-unit formations.

9.4.2. Earthworks

It is proposed that material for the embankment dam will be sourced exclusively from within the proposed reservoir footprint. This will help develop a sustainable solution. Therefore, confirmation of sufficient and suitable materials on site to build the embankment is required.

Upon initial review of historical ground investigation data, the London Clay, Reading Formation and possibly Harwich Formation would provide suitable materials for earthworks. The near-surface strata within the Study Area varies from silty clay of the London Clay or Reading Beds to a slightly silty sand from the Harwich Formation. The results of the Atterberg limit determinations and the compaction tests show that generally the natural moisture content of the clay is above its optimum moisture content and its plastic limit. This indicates that clay deposits of the London Clay and Reading Formation should have the ability to deform without excessive crack formation during re-working.

The moisture condition value (MCV) calibration tests were performed on a London Clay sample and Reading Formation sample. For both tests the average moisture content fell within the typical MCV values of 8 to 12 for earthworks suitability. The slope of the Reading Formation calibration test suggests the Reading Formation material is also sensitive to small moisture content changes and therefore will be a more weather dependent material for reuse.

Table 9-1 indicates some key limitations with existing historical laboratory testing that is summarised as follows:

- There is no Laboratory data within the Bognor Sand Formation to confirm suitability of re-use for embankment shoulders.

- Although not confirmed to be present on site, there is no Laboratory Test data for London Clay Division A2, this may reflect the lack of interpretation of formation sub-units in historical ground investigation.
- Compaction test results for dry density and optimum water content in the 1963 investigation are significantly different, this may be due to several reasons: (i) variability of the London Clay and Reading Formation across the site, (ii) quality control of the testing; and, (iii) Compaction tests included for amalgamated samples.
- Of the two particle size distribution test results reported from within the Harwich Formation, the material has a sand content of between 13% and 58%.Confirming characteristics of the Harwich Formation is key in the confirmation of re-use for embankment shoulders, filters and/or drains.

Information from trial pits is lacking to the southwest of the Study Area where only one trial pit was dug within a potential borrow pit area. Further ground investigation is required to confirm the spatial extent and thicknesses of both the London Clay, Reading Formation and their sub-units.

In addition to volumes and suitability of the materials on site for earthworks, further consideration is required for the excavation of and temporary works for the borrow pit. This includes installation of piezometers within the chalk and basal beds of the Reading Formation (if present) to indicate the presence of artesian pressures below any proposed borrow pit excavations. This will inform the safe level of borrow pit excavation into the Reading Formation and prevent the occurrence of basal heave. Also, whilst some information regarding shear surfaces within the Reading Formation is recorded, it is not documented within Trial Pits. Considerations to temporary slopes during excavation of material and long-term stability of borrow pit slopes need to be investigated.

9.4.3. Reservoir Leakage and Seepage

There are three primary concerns associated with leakage from the proposed reservoir highlighted in historical reports [3] and review of historical ground investigation within this desk study, these are (i) the presence of relic pingo formations (past periglacial landforms);(ii) the persistence of the Harwich Formation underlying the Study Area (respectively); and, (iii) the detail of the Bognor Sand Member / London Clay Division A3 boundary and groundwater conditions in the Bognor Sand Member.

The expert panel, commissioned by Portsmouth Water, identified that a key concern to reservoir leakage is whether relic pingoes are present on site. Pingo features would be most likely to form within the Chalk and granular basal beds, or water bearing channel deposits within the Reading Formation. Although the head of water within the Chalk and overlying minor aquifers of the Palaeogene increases to the South, so does the thickness of cohesive deposits of the Reading Formation and London Clay. In glacial periods, the depth of sub-artesian, or artesian water within the Chalk and Reading Formation is unlikely to be within the near-surface layers susceptible to freezing.

Relic periglacial features were not noted within the Aerial Photography Interpretation, and a relationship between the chalk aquifer water levels and those of the secondary Palaeogene aquifers (Harwich and Reading Formation) in the MRM historical ground water monitoring was not identified, for further information see Section 7.4.2. In addition, none of the previous studies gave any evidence of the existence of Pingos. The preliminary findings imply that relic pingo formations and thus hydraulic conductivity between the Palaeogene deposits (namely the Harwich Formation) and the Culver Chalk Formation is unlikely to be present on site. Installation of piezometers into the underlying chalk formation will be required to reduce uncertainty as to whether or not there is hydraulic conductivity with the Harwich formation.

Leakage from the reservoir is likely to proceed mainly from the Harwich Formation and the Bognor Sand Member. Two groundwater scenarios are currently possible based upon existing site information for the Harwich Formation. (1) The Harwich Formation is not laterally persistent to the south and thins out. If this is the case, then groundwater would be unable to flow southwards. Groundwater would rise to a maximum level in the unit defined by the topography of the outcrop area,

from this point water will run off at the surface. (2) The Harwich Formation is laterally persistent to the south and re-outcrops south of the Chichester syncline axis. Drawing 2 presents four boreholes in the far field that indicate the presence of the Harwich formation, to the north and south of the Chichester syncline axis. The groundwater is therefore likely to flow through the unit in a southerly direction. Whilst the lateral persistence of the Harwich Formation in the far field was confirmed, the persistence and design parameters in the near field are still required, specifically across the west of the Study Area as shown in Drawing 8.

Seepage along the geological boundary between the Bognor Sand Member and London Clay Formation was noted in the API (see Section 5.2 and Drawing 3) and the Geomorphological Mapping (see Section 5.3 and Drawing 4). The Bognor Sand Member is likely to pose a potential leakage pathway across the western boundary of the proposed reservoir.

The wetlands structure is likely to be a minor embankment to retain water north of the reservoir during maximum drawdown of the reservoir to +27.5mOD (maximum water level is +39.5mOD). The embankment will require suitable cut-off to avoid leakage of wetlands through the underlying Harwich formation. Drawing 6B presents a cross section along the northern boundary of the reservoir area and indicated minimal information to inform the ground model and hydrogeological conditions underlying the wetlands structure. Exploratory holes from further ground investigation should target this area of the site to confirm the extent of the Harwich formation and characteristic strength of the foundation soils for the retaining structure.

There is currently limited information regarding porewater pressures of in-situ materials and their permeabilities. Whilst laboratory permeability testing was carried out, further in-situ permeability testing within boreholes and preferably trials pits should be carried out to determine stratum permeabilities within the reservoir and underlying the embankment dam.

9.4.4. Stability of dam foundation, slopes and borrow pits

The Ground Profile, summarised in Section 7.3, indicates the presence of pre-existing solifluction, freeze-thaw and/or bedding plane shears within Quaternary (Head) deposits, London Clay Formation and Reading Formation. Drawing 7 shows the dip and orientation of shear surfaces from historical trial pit records. The presence of ground that contains pre-existing slip surfaces and if left in place beneath an earth dam may result in the reactivation of slipping along these planes. This will mean the earth structure will be less stable than if the soil had been removed and replaced with compacted fill [48]. The failure of Carsington Dam is an example of this [49].

The thickness of Head deposits encountered in the Study Area is typically between 1.0 to 2.0m and increases in thickness towards the lower reaches of the valley in the south of the site. Deeper zones of head deposits with solifluction shears at the bottom of this valley extend to 2.7m and 3.1m in trial pits E2 and E1 (respectively). Under the proposed reservoir alignment, the 1:10,000 BGS Geological Map indicates that superficial Head deposits are only present to the south and along a thick finger stretching eastwards past The Avenue. However, there is a lack of historical ground investigation along the proposed reservoir alignment to confirm the presence and thickness of Head deposits. Additional ground investigation will assist in delineating the extent and thickness of head deposits that would need to be stripped from the embankment foundation, if required.

The API has indicated that there is potential for soil creep as shown in Drawing 3. Similarly, to soliflucted head layers, areas of suspected soil creep along the proposed reservoir alignment may need to be stripped from the embankment foundation.

Shear surfaces associated with bedding slip are present in the underling London Clay Formation and in the Reading Formation, where it outcrops along the eastern flank of the proposed reservoir alignment. Whilst these shear surfaces are not expected to be laterally persistent, derivation of

characteristic strength parameters should reflect a reduced value in consideration of their presence. In general, there is a good amount of strength testing of the London Clay Formation and the undrained shear strength profile, developed by Peter Rowe in 1963 - Cu of 35 kPa, increasing to 70 kPa at 18m depth - provides a good baseline to validate any further laboratory strength testing [3]. Sample recovery within the Reading Formation from U100 sampling in historical boreholes was poor and thus there is limited drained and undrained parameters derived from laboratory tested carried out. The Lambeth outcrops under proposed dam foundation to the west and east.

Triaxial testing (historical) indicate significant cohesion (c') values that might not be reasonable and be a function of the test quality and sample size.

10. Areas of Uncertainty

10.1. Ground Investigation

The geotechnical Gap Analysis in Section 9.3 has identified the following ground related issues that will require greater definition from the current position of understanding:

- General profile and lithology,
- Shallow (up to 5mbgl) shear surface features associated with past ground instability during periglacial periods of geological history,
- Leakage from the reservoir basin and through the embankment fill and foundations,
- The hydrogeological regime,
- Re-use of materials in general and the identification of low permeability (clay rich) fill materials.
- Geo-environmental sampling to determine the environmental baseline condition of the Study Area,

10.1.1. General Objectives of Ground Investigation

The overall objectives of the ground investigation are being developed and detailed in a separate report but in general will be as follows:

- To provide enough ground conditions information to develop a robust design that can demonstrate that the viability and details of the scheme have been established sufficiently to grant Planning Permission (HTWSR Phase 1a), and
- To provide enough ground information to enable a design and build contract to be tendered, and implemented, with confidence that the risks have been identified, and can be managed within the cost constraints (HTWSR Phase 1b).

10.1.2. Phase 1 Ground Investigation

The phase 1 of the ground investigation will concentrate on the first bullet point in section 10.1.1above, while establishing the position regarding the second bullet point. The ground investigation has considered the existing data that has been provided by Portsmouth Water.

Once the first phase of the ground investigation has been completed and interpreted, the information will be fed into the design for planning. At this stage the adequacy of the information for detailed design will be reviewed and the second phase of the investigation planned.

It is planned that the following topics will be resolved by the Phase 1 ground investigation, or as a minimum any uncertainty will be reduced to the extent that a robust design for the planning application can be prepared. It is considered that these topics generally cover the Milestones considered to be an appropriate by the safety panel.

- Establish the lithology and stratification of the relevant strata.
- Establish the available materials for the earthworks and how they can be re-used.
- Establish the presence and distribution of the features of ground instability associated with past periglacial conditions.

- Collection and testing of environmental samples to confirm the contamination status of the site, to refine the PCSM and to verify the suitability of material for re-use as part of the proposed development.
- Installation of ground water monitoring points to establish the piezometric head in the various strata across the site.

The following outline ground investigation is considered appropriate for the Phase 1 Ground Investigation (Table 10-1).

Table 10-1 - Outline of Phase 1 Ground Investigation

Investigation Item	Detail	Commentary
Deep Rotary Cored Boreholes to Reading Beds/Chalk	• Three rotary cored BH's to between 35 and 60 metres depth • To extend knowledge and understanding of geological column across the site • Field testing for strength and permeability • Sample recovery for strength testing • A piezometer in each hole to provide a long-term monitoring position at depth	This will be spread around the site, and together with earlier information will enable the detailed geological conditions to be confirmed. They will also enable the long-term ground water conditions in the Chalk and Reading Formation to be confirmed.
Shallow cable tool boreholes	• 17 shallow boreholes at depths between 10 to 15 metres • Enable sample recovery for borrow pit evaluation • Field testing for strength and permeability • Enable installation of shallow piezometers in each hole, to provide long term monitoring at shallow depth to complement the deep piezometers noted above	These will enable large samples to be recovered for laboratory testing. Sampling to be nearly continuous in the upper 5 or so metres, to help identification of shear surfaces.
Machine excavated trial pits	• 15 machine excavated trial pits • Target around 3m to 6.5m deep. • These will focus on shallow materials a) to help identify shear surfaces, shallow superficial geology b) to gain material for earthworks testing • Selected pits, (around half) will be shored to enable logging by person entry. These will be focus of investigation for shallow shear surfaces	These will permit the detailed investigation of geology at shallow depth, and shallow shear surface. In addition, they will enable large samples to be recovered for earthworks testing.
Laboratory Testing	Testing of samples record from the investigation, including • Classification testing • Undrained and effective stress testing for strength • Earthworks testing, including relationship testing over a range of parameters affecting earthworks	These will enable a detailed assessment of stability, and the establishment of a materials management plan.
Geophysical profiling.	Electrical resistivity Tomography Carried out on around 5 to 10 two sets of orthogonal arrays	These will complement the BH's to provide a detailed 3 D mapping exercise to be carried out across the site.

10.2. Further Studies

It is recommended that the following studies are undertaken:

- Ground investigation rationale document to support the findings of this desk study.
- Ground investigation specification for the purposes of minimising the geotechnical, hydrogeological and geo-environmental data gaps identified within this desk study.

11. Conclusions and Recommendations

This desk study has presented the geology and hydrogeology of the proposed Havant Thicket Winter storage Reservoir. The scope of the report was limited to the proposed reservoir footprint and the immediate surrounding area (generally within 500m of the site).

The findings of the Geotechnical Gap Analysis within the desk study has indicated four key areas that will reduce residual risk of unknown ground and hydrogeological conditions, these are:

- **Robustness of ground model**: Target data gaps between historical Ground Investigation to delineate areas at risk of reservoir leakage and seepage primarily from the Harwich Formation, Bognor Sand Member and relic periglacial landforms (Pingos). Data gaps include leakage paths across the northern extent of the Study Area, along the proposed wetlands retaining structure. It should be noted that relic periglacial formations (Pingos) were not identified in the Study Area however a residual risk remains.
- **Groundwater regime**: Determine the local hydrogeological regime of the Harwich Formation, Bognor Sand Member and Chalk aquifers through additional groundwater monitoring and in-situ permeability testing that had previously not been conducted in historical ground investigations.
- **Evaluate Borrow pit area**: Target data gaps within the reservoir footprint to establish how each of the strata will be re-used. It is proposed that all excavated material from the excavations generally, and the borrow pit in particular, will be re-used on site, with testing to inform the suitability for each material e.g. for use in the embankment core, on the shoulder of the embankment, or for landscaping. But if material on site is insufficient to form the structural section of the embankment and drainage materials, import of fill may be needed.
- **Stability of the dam and borrow pit foundation**: Conducted further strength testing along the embankment and borrow pit slopes where data gaps remain. Investigate the shallow and deep shear surfaces encountered in historical trial pits and some borehole samples.

A review of the environmental setting of the site was also undertaken to develop a PCSM, which has identified and assessed PCL. Based on the PCSM, potential risks to human health, property and ecological receptors have been identified as low to very low, with the potential risks to controlled waters identified as moderate / low, dependent on the implementation of mitigation measures.

It recommended that that a Phase 1 ground investigation is undertaken to reduce the residual risk as identified in the Geotechnical Gap Analysis and PCSM.

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Appendices to A10.2 Desk Study Report

ATKINS BASELINE - LOW RISK

Appendix A10.2 Desk Study Report

Appendix A.1 Historical Ground Investigation Records and Groundwater Monitoring

A.1. Historical Ground Investigation Records and Groundwater Monitoring

Source	Year	Location ID	TP/BH	Easting (m)	Northing (m)	Ground Level +mOD	Final Depth +mOD	Groundwater encountered +mOD (mbgl)	Groundwater Monitoring +mOD	Piezometer Depth, +mOD	Seepage mOD (mbgl)
Morton	1962	M01	BH	471035	109337	35.41	15.24	32.97 (2.44)			
Morton	1962	M02	BH	471182	109356	26.85	15.24	23.19 (3.66) 17.4 (9.45)			
Morton	1962	M03	BH	471320	109373	21.74	12.8				
Morton	1962	M04	BH	471561	109384	27.6	16.31	27.14 (0.46)			
Morton	1962	M05	BH	471816	109410	29.87	15.24	16.15 (13.72)			
Morton	1962	M06	BH	471980	109504	32.61	15.24				
Morton	1962	M07	BH	472106	109610	34.57	9.14				
Morton	1962	M08	BH	472115	109773	33.96	7.82				
Morton	1962	M09	BH	472121	109884	35.81	7.62				
Morton	1962	M10	BH	470921	109498	36.21	9.14				
Morton	1962	M11	BH	471975	110000	36.09	5.94				
Morton	1962	M12	BH	470820	109798	35.02	9.14				
Morton	1962	M13	BH	471080	110078	32.75	7.62				
Morton	1962	M14	BH	471342	110085	35.34	7.62	33.62 (1.68)			
Morton	1962	M15	BH	471654	110124	37.73	6.1				
Morton	1962	M16	BH	471130	109815	28.23	7.92				
Morton	1962	M17	BH	471342	109963	32.17	7.62				
Morton	1962	M18	BH	471836	109988	35.52	7.62				
Morton	1962	M19	BH	471212	109955	29.96	7.62				
Morton	1962	M20	BH	471616	109837	29.36	7.62				

Source	Year	Location ID	TP/BH	Easting (m)	Northing (m)	Ground Level +mOD	Final Depth +mOD	Groundwater encountered +mOD (mbgl)	Groundwater Monitoring +mOD	Piezometer Depth, +mOD	Seepage mOD (mbgl)
MRM	1977	BGS18/1	BH	471150	110350	36.55	23.55				
MRM	1977	BGS18/2	BH	471410	110330	36.65	26.65				
MRM	1977	BGS18/3	BH	471590	109750	26.7	0.6	15.40 (11.30)	25.35 - 26.50	2.55 (Lambeth Group)	
MRM	1977	BGS18/4	BH	471350	109150	19.6	-14.6	10.70 (8.90) 7.10 (12.50)	25.80 - 26.70	7.25 (Harwich Formation)	
MRM	1978	BGS18/B1	BH	471040	109230	39.36	4.96	29.76 (9.6)	28.49 - 31.98	29.76 (London Clay) 5.46 (Harwich Formation)*	
MRM	1978	BGS18/B2	BH	471200	109250	24.84	3.34	23.14 (1.7) 20.79 (4.05)	23.84 - 24.23	7.34 (Harwich Formation)	
MRM	1978	BGS18/B3	BH	471320	109260	22.75	2.75	10.1 (12.65)	25.55 - 26.50	14.59 (London Clay)* 9.00 (Harwich Formation)	
MRM	1978	BGS18/B4	BH	471600	109400	28.44	13.44	26.34 (2.10)	25.37 - 26.95	15.44 (Harwich Formation)	
MRM	1978	BGS18/B5	BH	471370	109300	23.62	3.62	22.32 (1.3) 11.17 (12.45)		9.87 (Harwich Formation)*	
MRM	1978	BGS18/B6	BH	471900	109460	29.91	11.91	18.61 (11.30)	25.90 – 26.28	18.16 (Harwich Formation)	
MRM	1978	A1	TP	471054	109213	39.2	5.1				36.2 – 35.2 (3.0- 4.0)
MRM	1978	A2	TP	471110	109217	35.3	5.1				32.8 - 30.2 (2.5 - 5.1)

Source	Year	Location ID	TP/BH	Easting (m)	Northing (m)	Ground Level +mOD	Final Depth +mOD	Groundwater encountered +mOD (mbgl)	Groundwater Monitoring +mOD	Piezometer Depth, +mOD	Seepage mOD (mbgl)
MRM	1978	A3	TP	471148	109223	30.9	5.4				27.1 - 26.6 (3.8 - 3.85)
MRM	1978	A4	TP	471195	109268	27.4	5				
MRM	1978	A5	TP	471261	109252	24.5	4.9				
MRM	1978	A6	TP	471328	109298	22	3.9				20.25 (1.75)
MRM	1978	A7	TP	471358	109276	23.5	4				
MRM	1978	A8	TP	471465	109298	25.2	3.5				
MRM	1978	A9	TP	471715	109412	29.2	3.5				
MRM	1978	A10	TP	471928	109473	31.3	4				
MRM	1978	A11	TP	472055	109602	34.5	3.4				
MRM	1978	A12	TP	472164	109698	33.5	4.6				30.6 (2.9)
MRM	1978	A13	TP	472223	109829	33.8	4.3				31.2 - 31.05 (2.6 - 2.75)
MRM	1978	D1	TP	471390	110149	33.13	2.2				
MRM	1978	D2	TP	471361	110137	35.54	3.4				33.64 (1.9)
MRM	1978	D3	TP	471308	110116	36.4	3.1				34.1 (2.3)
MRM	1978	D4	TP	471417	109883	32.5	3.9				29.1 - 28.9 (3.4 - 3.6)
MRM	1978	D5	TP	471480	109749	27.71	4.6				24.41 - 24.31 (3.3 - 3.4)
MRM	1978	D6	TP	471287	109701	26.49	5.4				21.69 - 21.49 (4.8 - 5.0)
MRM	1978	D7	TP	471277	109867	28.43	3.8				26.43 - 24.43 (2.0 - 4.0)
MRM	1978	D8	TP	471221	109991	30.33	2.5				
MRM	1978	D9	TP	471151	110121	32.44	1.3				

MRM	1978	D10	TP	471360	109985	31.93	2.5				
Source	**Year**	**Location ID**	**TP/BH**	**Easting (m)**	**Northing (m)**	**Ground Level +mOD**	**Final Depth +mOD**	**Groundwater encountered +mOD (mbgl)**	**Groundwater Monitoring +mOD**	**Piezometer Depth, +mOD**	**Seepage mOD (mbgl)**
MRM	1978	D11	TP	471045	110117	34.9	3.2				
MRM	1978	D12	TP	471093	109944	31.22	4.9				28.62 - 26.72 (2.6 - 4.5)
MRM	1978	D13	TP	471187	109855	27.73	3.9				25.88 - 23.83 (1.85 - 3.9)
MRM	1978	D14	TP	471478	110207	37.52	1				
MRM	1978	D15	TP	471362	109823	30.75	5.2				25.85 - 25.55 (4.9 - 5.2)
MRM	1978	D16	TP	472166	109879	35.3	4.5				32.1 - 30.8 (3.2 - 4.5)
MRM	1978	D17	TP	472018	109870	33.84	4.2				31.14 - 30.94 (2.7 - 2.9)
MRM	1978	D18	TP	471881	109852	31.44	3.2				29.44 - 29.24 (2.0 - 2.2)
MRM	1978	D19	TP	471766	109745	29.92	4.5				26.77 (3.15)
MRM	1978	D20	TP	471757	109928	33	3.3				30.85 (2.15)
MRM	1978	D21	TP	471656	109794	28.94	3.3				
MRM	1978	D22	TP	471642	109897	30.5	2.3				
MRM	1978	D23	TP	471598	110042	33.57	1.3				
MRM	1978	D24	TP	471902	110008	35.99	3.4				33.04 (2.95)
MRM	1978	D25	TP	471849	110132	39.27	3				
MRM	1978	D26	TP	472055	110008	36.83	3.3				
MRM	1978	D27	TP	472199	110031	40.3	3				
MRM	1978	E1	TP	471226	109273	26.86	4.6				
MRM	1978	E2	TP	471295	109297	22.15	4.4				18.25 (3.9)

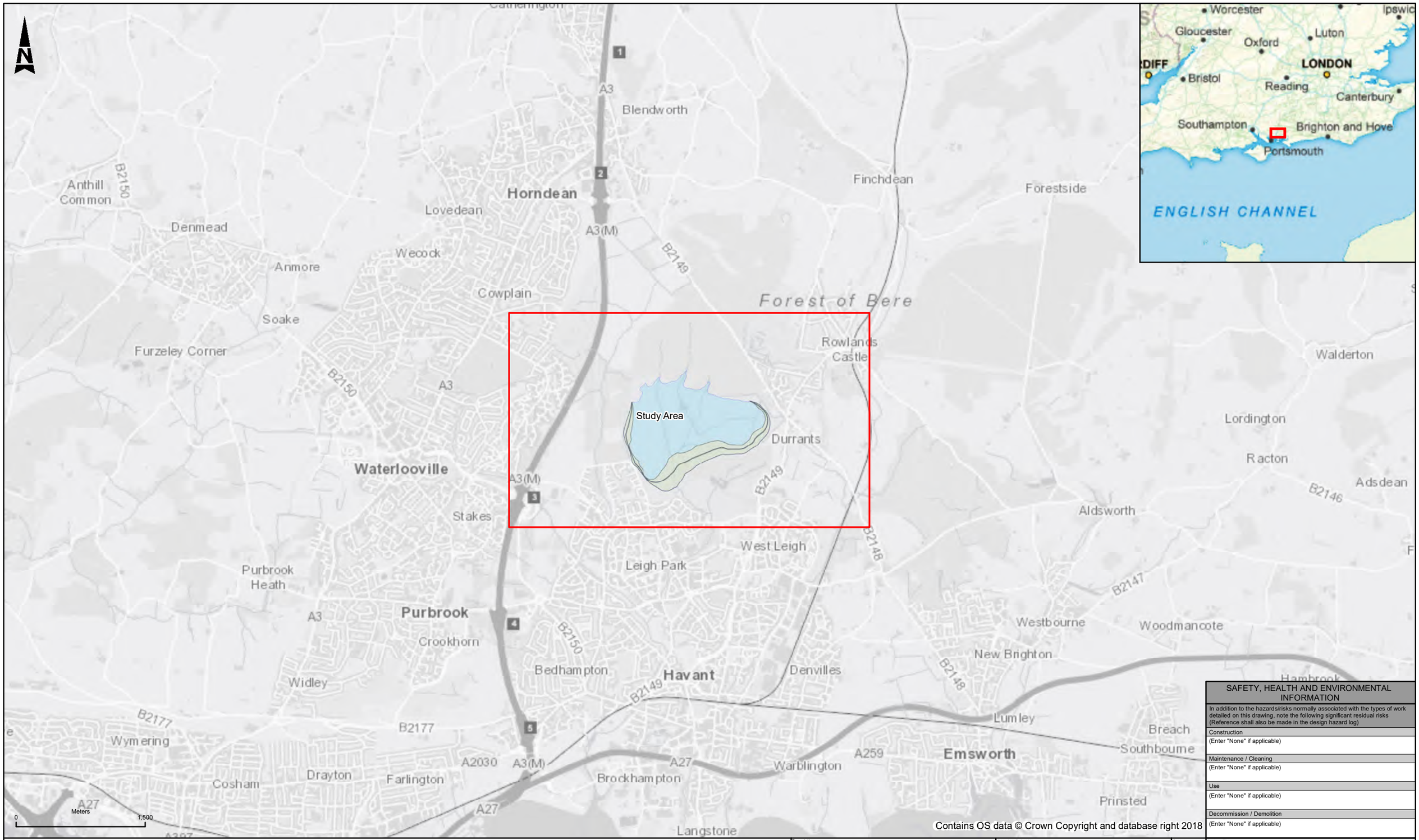
Soil Mechanics	2006	SM BH101	BH	472025	109825	33.5	14.45				
Source	**Year**	**Location ID**	**TP/BH**	**Easting (m)**	**Northing (m)**	**Ground Level +mOD**	**Final Depth +mOD**	**Groundwater encountered +mOD (mbgl)**	**Groundwater Monitoring +mOD**	**Piezometer Depth, +mOD**	**Seepage mOD (mbgl)**
Soil Mechanics	2006	SM BH102	BH	471750	109950	33	14.45	19.60 (13.40)			
Soil Mechanics	2006	SM BH103	BH	471275	110025	33	13.45	20.50 (12.50)			
Soil Mechanics	2006	SM BH104	BH	471025	109600	29.5	14.55				
Soil Mechanics	2006	SM TP101	TP	471975	109830	32.5	2.5				
Soil Mechanics	2006	SM TP102	TP	471875	110060	36.5	2.5				
Soil Mechanics	2006	SM TP103	TP	471675	109925	31.5	3.4				
Soil Mechanics	2006	SM TP104	TP	471550	110050	34.5	3				

*Standpipe piezometer installation not monitored

Appendix A10.2 Desk Study

Appendix B Drawings

B.1 Site Location Plan
B.2 Farfield Geology and Geological Structures
B.3 Aerial Photography Interpretation
B.4 Geomorphology Map
B.5 Geology and Historical Exploratory Hole Location Plan
B.6 Historical Ground Investigation Cross-section Plan and Sections (8 sheets)
B.7 Shear Surfaces Identified in Historical Ground Investigations
B.8 Geotechnical Engineering Issues - Initial Review



Reservoir Footprint (Arup 2009)

Reservoir Embankment (Arup 2009)

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SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION
In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)
Construction
(Enter "None" if applicable)
Maintenance / Cleaning
(Enter "None" if applicable)
Use
(Enter "None" if applicable)
Decommission / Demolition
(Enter "None" if applicable)

Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description: Site Location Plan						
S0	P01	NW	FD	---	---	16/05/2019

Drawing Suitability: WORK IN PROGRESS

Status: S0

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Client: Portsmouth Water

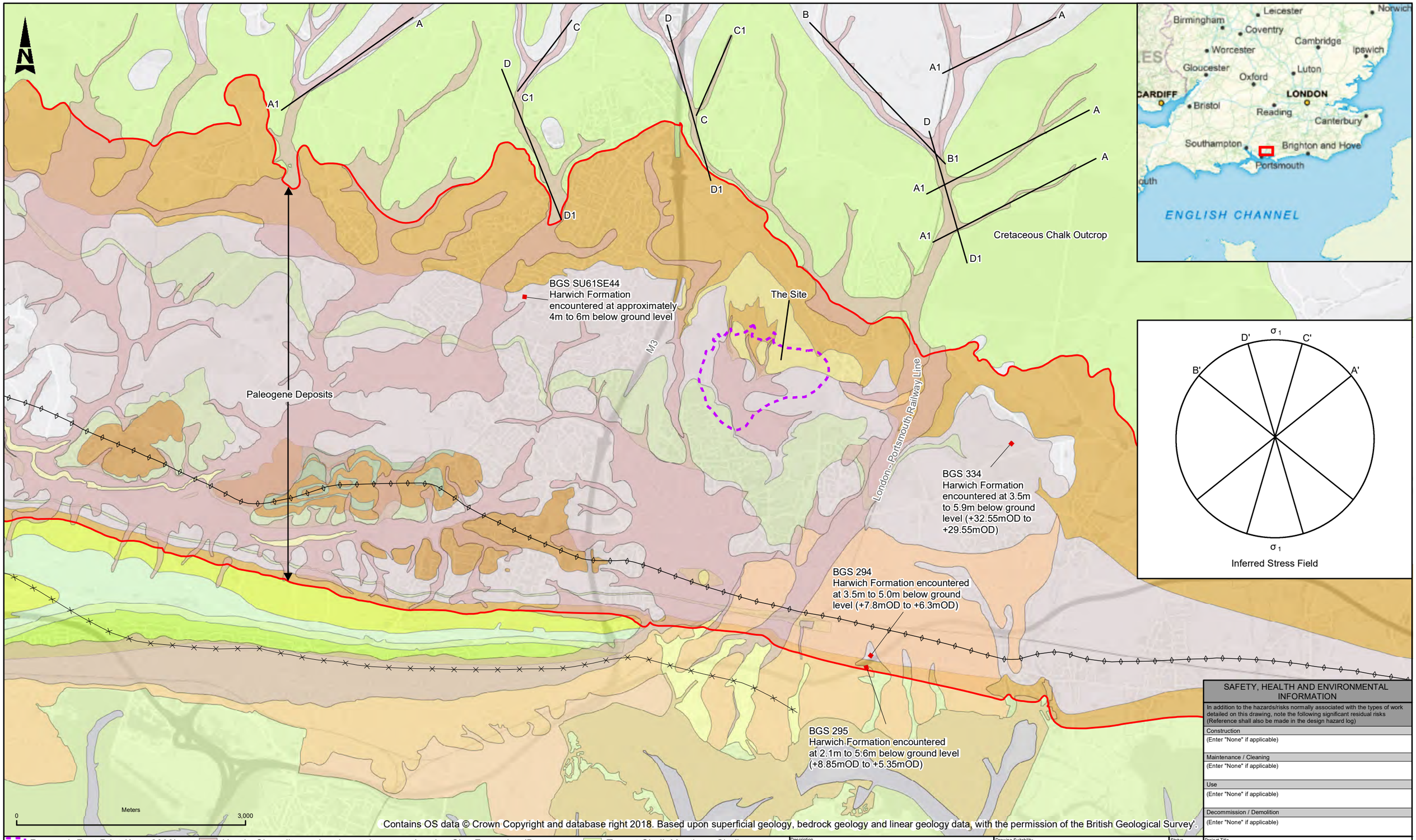
Project Title: Havant Thicket Winter Storage Project

Drawing Title: SITE LOCATION PLAN

Drawing Number

Project	Originator	Volume	Location	Type	Role	Number
HTWSR	ATK	ZZ	ZZ	DR	Z	0001

Original Size:	Scale	Project Ref. No:	Sheet:	Rev.
A3	1:40,000	---	1 of 1	P0 1.1



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DRAFT

- Reservoir Foot Print (Arup 2009)
- Portsdown Anticline
- Bere Forest/Chichester Syncline Axis
- Alluvium - Clay, silt, sand and gravel
- Beach And Tidal Flat Deposits (Undifferentiated) - Clay, silt, sand and gravel
- Head - Clay and gravel
- Head - Clay, silt, sand and gravel
- Raised Marine Deposits - Sand and gravel
- River Terrace Deposits (Undifferentiated) - Sand, silt and clay
- Wittering Formation - Sand [UDCS]
- Wittering Formation - Sand, silt and clay
- Whitecliffe Sand Member - Sand
- London Clay Formation (Bognor Sand Member)
- London Clay Formation - Clay, silt and sand
- Harwich Formation (London Clay Formation – Sand)
- Lambeth Group - Clay, Silt and Sand
- Portsdown Chalk Formation - Chalk
- Spetisbury Chalk Member - Chalk
- Tarrant Chalk Member - Chalk
- Newhaven Chalk Formation - Chalk
- Lewes Nodular Chalk Formation, Seaford Chalk Formation, Newhaven Chalk Formation, Culver Chalk Formation And Portsdown Chalk Formation (Undifferentiated) - Chalk
- Boundary of Paleogene / Cretaceous
- Dry Valleys

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

Construction
(Enter "None" if applicable)

Maintenance / Cleaning
(Enter "None" if applicable)

Use
(Enter "None" if applicable)

Decommission / Demolition
(Enter "None" if applicable)

Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description: Farfield Geology and Regional Geological Structures						
S0	P01	NW	FD	---	---	16/05/2019

Drawing Suitability: WORK IN PROGRESS

Status: S0

Project Title: Havant Thicket Winter Storage Project

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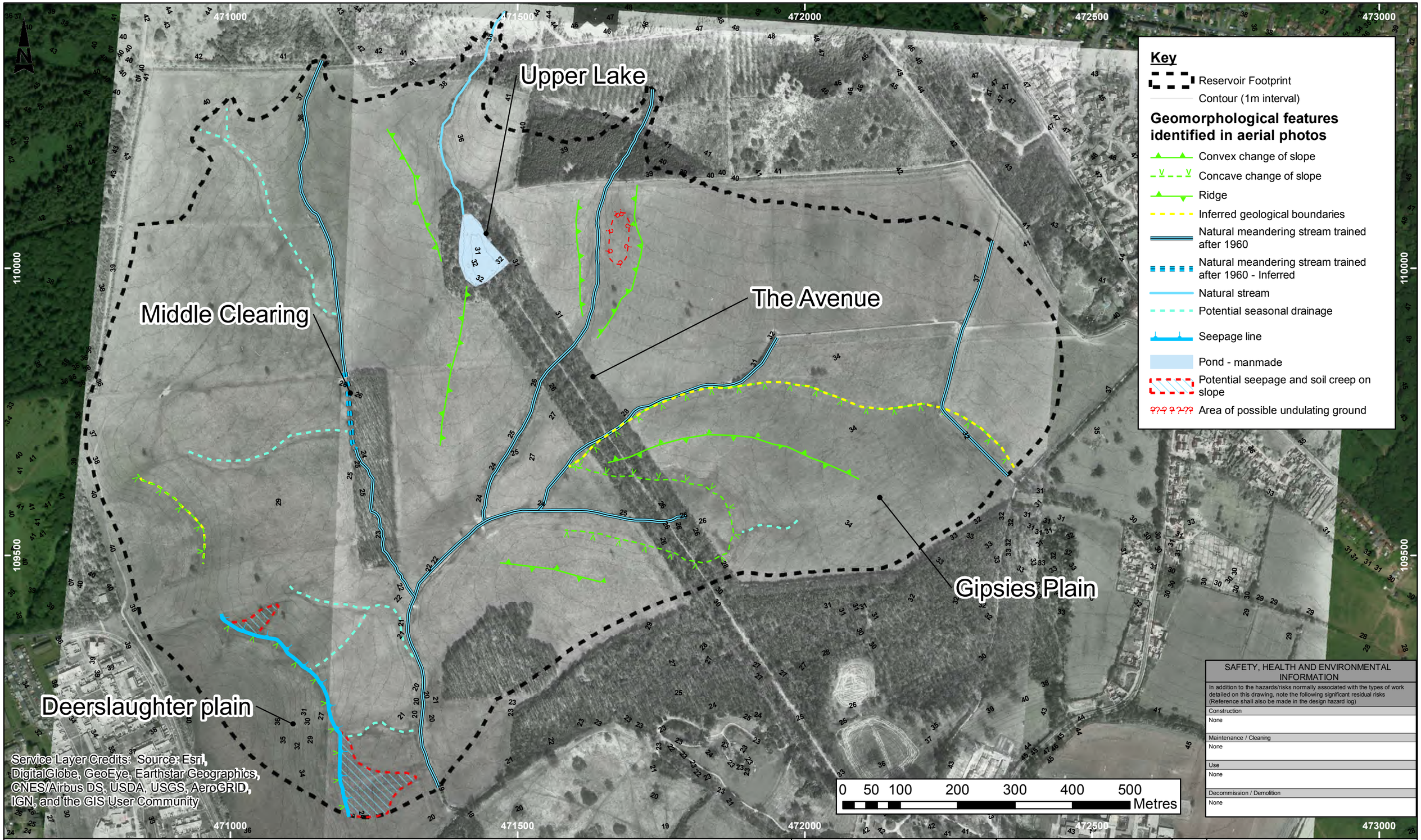
Client: Portsmouth Water

Drawing Title: FARFIELD GEOLOGY AND REGIONAL GEOLOGICAL STRUCTURES

Drawing Number: HTWSR - ATK - ZZ - ZZ - DR - C - 0001
(Project | Originator | Volume | Location | Type | Role | Number)

Original Size: A3 | Scale: 1:45,000 | Project Ref. No: --- | Sheet: 1 of 1 | Rev: P0 1.1



SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION
In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)
Construction
None
Maintenance / Cleaning
None
Use
None
Decommission / Demolition
None

Notes

1. Proposed reservoir layout based on GIS data provided to Atkins by Portsmouth Water on the 1st April 2019.
2. Selected aerial photos between 1946 - 1996 have been reviewed in producing this aerial photographic interpretation.
3. Geomorphological features interpreted on this drawing are based on the 1996 aerial photos (OS/96535 - 025 and OS/96535 - 026), which is displayed as the drawing background.
4. Where applicable, aerial photos have been reviewed in stereopairs using a mirror stereoscope.
5. Coordinates projected in British National Grid.

DRAFT

Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description Aerial Photography Interpretation - Geomorphology						
S0	P0 1.1	CKMT	OJP	ABH	JPA	---

Drawing Suitability: FOR INFORMATION

Status: S0

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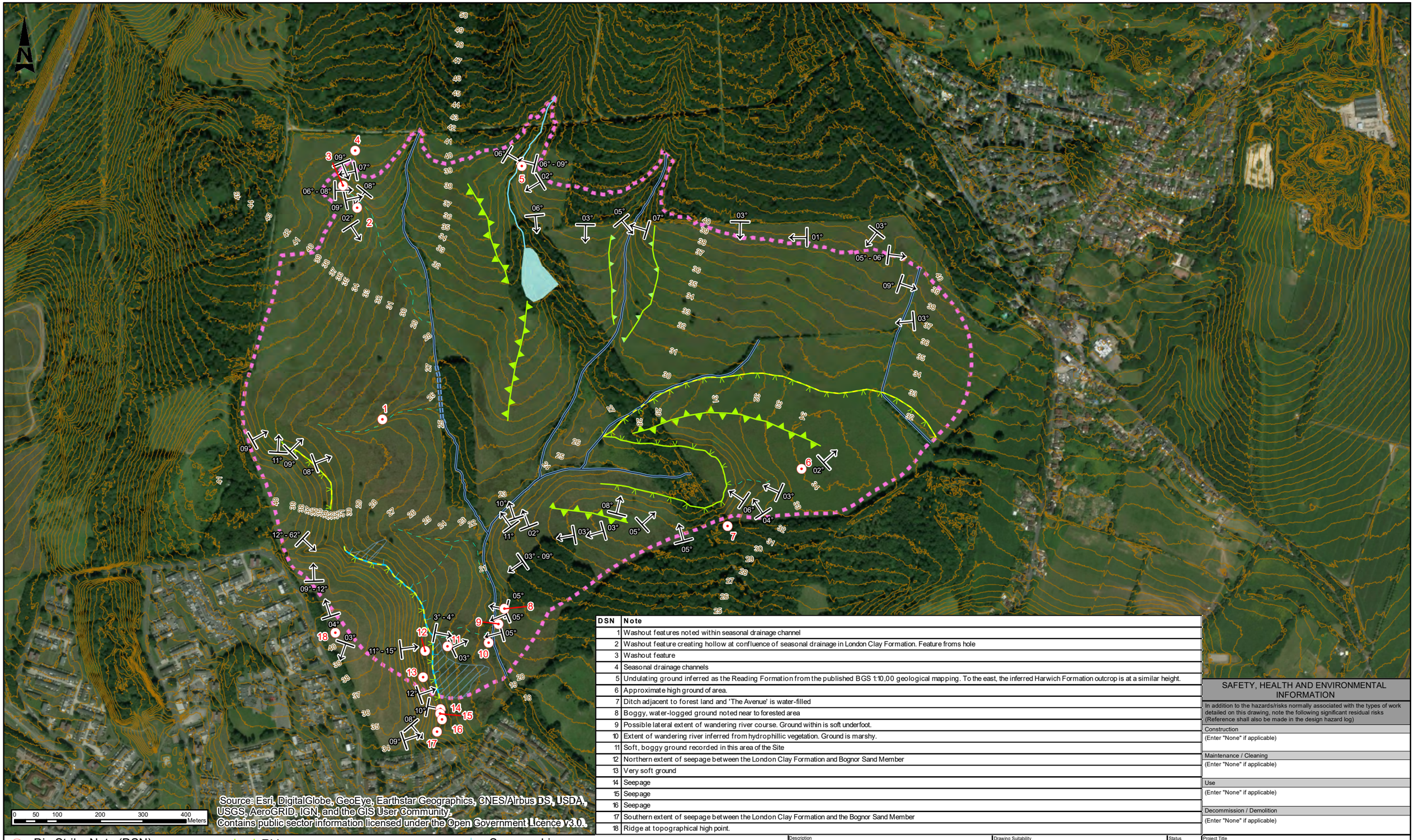
Client: Portsmouth Water

Project Title: Havant Thicket Winter Storage Project

Drawing Title: Aerial Photography Interpretation - Geomorphological Mapping of Proposed Site

Drawing Number: Project HTWSR | Originator ATK | Volume - | Location | Type | Role | Number

Original Size: A3 | Scale 1:6,000 | Project Ref. No: --- | Sheet: 1 of 1 | Rev: P0 1.1



DSN	Note
1	Washout features noted within seasonal drainage channel
2	Washout feature creating hollow at confluence of seasonal drainage in London Clay Formation. Feature froms hole
3	Washout feature
4	Seasonal drainage channels
5	Undulating ground inferred as the Reading Formation from the published BGS 1:10,00 geological mapping. To the east, the inferred Harwich Formation outcrop is at a similar height.
6	Approximate high ground of area.
7	Ditch adjacent to forest land and 'The Avenue' is water-filled
8	Boggy, water-logged ground noted near to forested area
9	Possible lateral extent of wandering river course. Ground within is soft underfoot.
10	Extent of wandering river inferred from hydrophillic vegetation. Ground is marshy.
11	Soft, boggy ground recorded in this area of the Site
12	Northern extent of seepage between the London Clay Formation and Bognor Sand Member
13	Very soft ground
14	Seepage
15	Seepage
16	Seepage
17	Southern extent of seepage between the London Clay Formation and the Bognor Sand Member
18	Ridge at topographical high point.

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

Construction
(Enter "None" if applicable)

Maintenance / Cleaning
(Enter "None" if applicable)

Use
(Enter "None" if applicable)

Decommission / Demolition
(Enter "None" if applicable)

- Dip Strike Note (DSN)
- Reservoir Footprint (Arup 2009)
- Recorded Strike and Dip of Ground Surface
- 1m Contours
- Concave
- Convex
- Ridge
- Inferred Geological Boundaries
- Natural Meandering Stream Trained After 1960
- Natural Meandering Stream Trained After 1960 - Inferred
- Natural Stream
- Potential Seasonal Drainage
- Seepage Line
- Pond - manmade
- Potential seepage on slope

DRAFT

Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description Geomorphological Map						
Status S0	Revision P01	Drawn NW	Checked FD	Reviewed ---	Authorised ---	Issue Date 16/05/2019

Drawing Suitability: WORK IN PROGRESS

Status: S0

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Client: Portsmouth Water

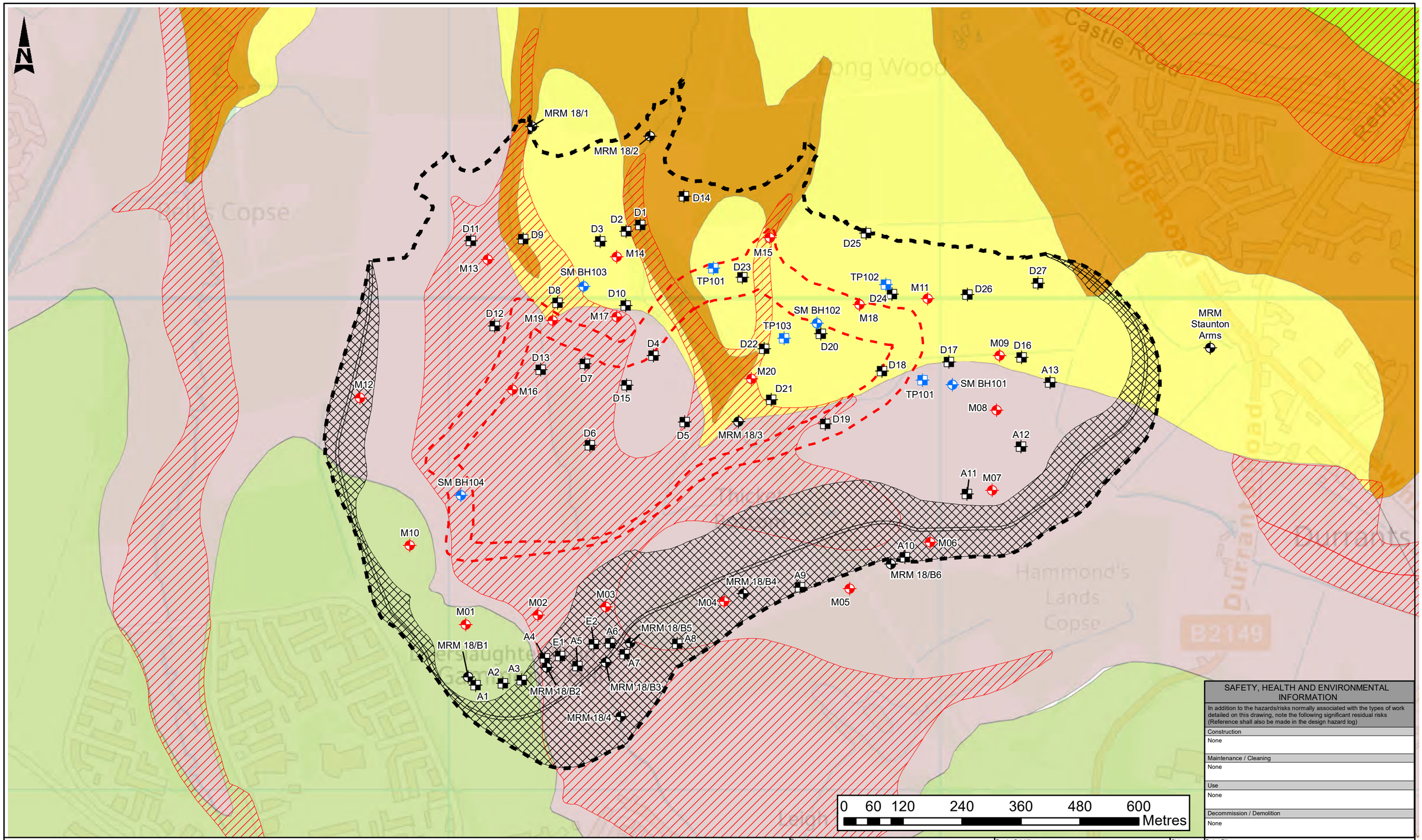
Project Title: Havant Thicket Winter Storage Project

Drawing Title: GEOMORPHOLOGICAL MAP

Drawing Number

Project	Originator	Volume	Location	Type	Role	Number
HTWSR	ATK	ZZ	ZZ	DR	C	0002

Original Size:	Scale	Project Ref. No:	Sheet:	Rev:
A3	1:8,000	---	1 of 1	P0 1.1



SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

Construction
None

Maintenance / Cleaning
None

Use
None

Decommission / Demolition
None

Notes

1. Historical boreholes, geology and proposed reservoir layout based on GIS data provided to Atkins by Portsmouth Water on the 1st April 2019.
2. Soil Mechanics 2006 and MRM 1979 trial pit locations digitised by Atkins based on georeferenced plans. Trial pit locations shown are approximate, and accurate to approximately +/- 15m of the positions shown.
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4. This drawing contains British Geological Survey materials ©NERC 2019

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Key

Historic Ground Investigation Exploratory Positions
- BGS (MRM) 1977 - 1979
- Morton 1963
- Soil Mechanics 2006

Historical Trial Pit Locations
- MRM 1979
- Soil Mechanics 2006
- Borrow pit (Arup 2009)

- Resevoir Embankment (Arup 2009)
- Reservoir Footprint (Arup 2009)
- Superficial Deposits
- London Clay (Bognor Member)
- London Clay
- London Clay (Harwich Formation)
- Reading Formation
- Chalk

Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description Sketch for Information						
Status S0	Revision P0 1.1	Drawn JRG	Checked OJP	Reviewed RL	Authorised JPA	Issue Date ---

Drawing Suitability: FOR INFORMATION

Status: S0

Project Title: Havant Thicket Winter Storage Project

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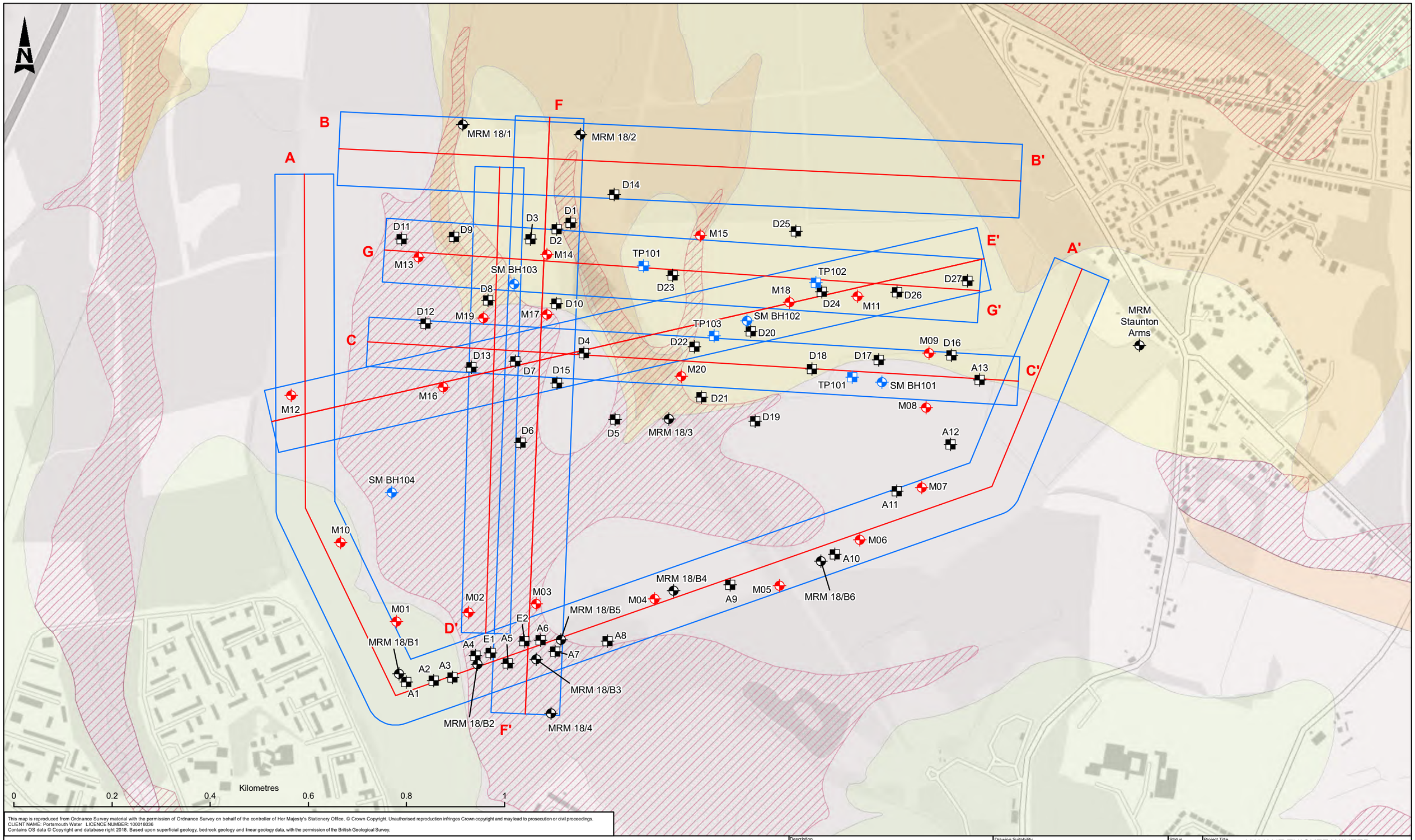
Client: Portsmouth Water

Drawing Title: GEOLOGY AND HISTORICAL BOREHOLE LOCATION PLAN

Drawing Number

Project	Originator	Volume	Location	Type	Role	Number
HTWSR	ATK	-				

Original Size:	Scale	Project Ref. No:	Sheet:	Rev:
A3	1:7,000	---	1 of 1	P0 1.1



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CLIENT NAME: Portsmouth Water LICENCE NUMBER: 100018036
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Cross Section

Cross Section Extent

Historic Ground Investigation Exploratory Positions

- BGS (MRM) 1977 - 1979
- Morton 1963
- Soil Mechanics 2006
- MRM 1979
- Soil Mechanics 2006
- Superficial Deposits
- London Clay Formation (Bognor Sand Member)
- London Clay Formation - Clay, silt and sand
- Harwich Formation (London Clay Formation – Sand)
- Lambeth Group - Clay, Silt and Sand
- Tarrant Chalk Member - Chalk

Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description FOR INFORMATION						
Status S2	Revision P01.1	Drawn FD	Checked GR	Reviewed RL	Authorised KO	Issue Date 29/11/2019

Drawing Suitability: **FOR INFORMATION**

Status: **S2**

Project Title: HAVANT THICKET WINTER STORAGE RESERVOIR PROJECT

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Fax: +44 (0) 1372 740055
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Drawing Title: CROSS SECTION PLAN

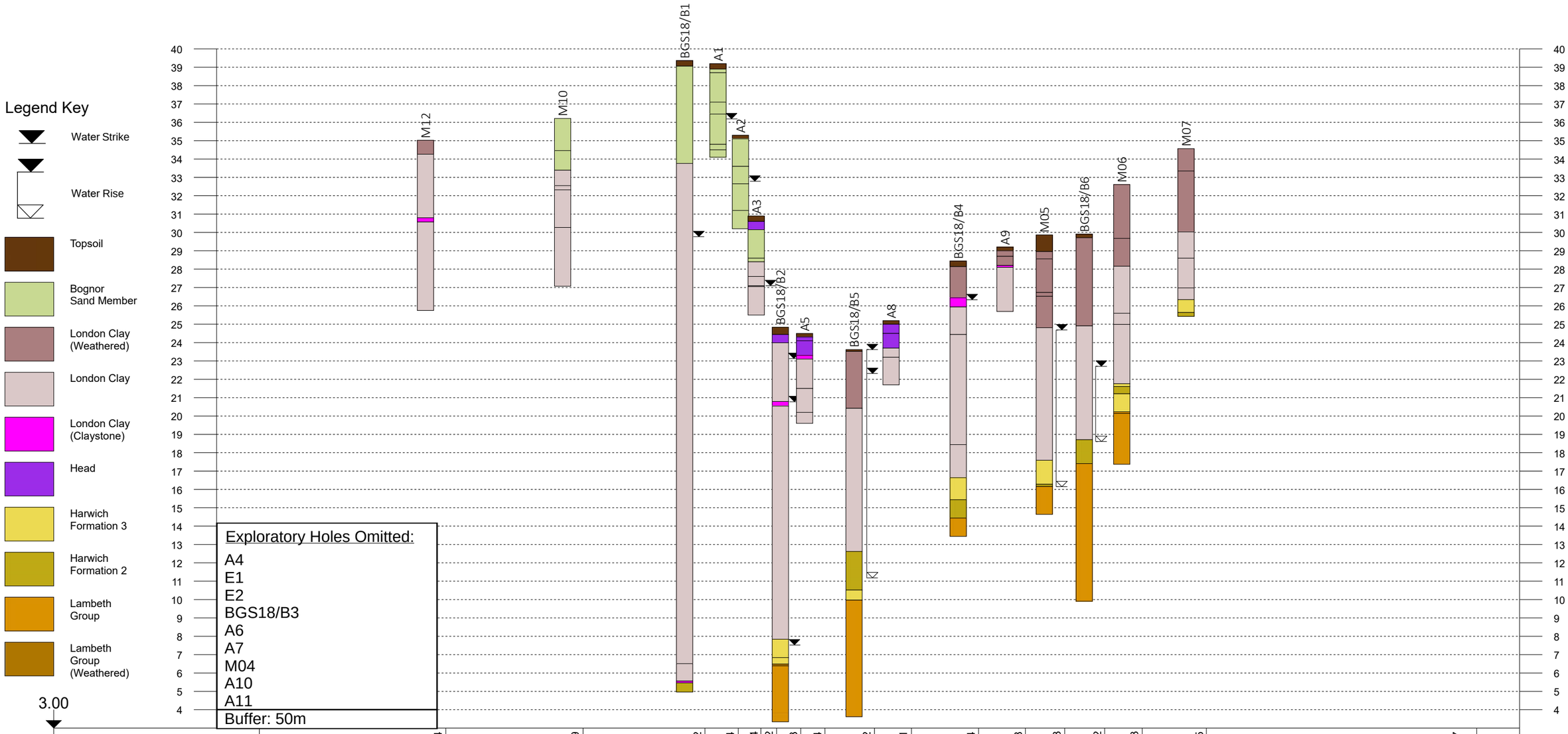
Client: Portsmouth Water

Drawing Number

Project	Originator	Volume	Location	Type	Role	Number
HTWSR	ATK	ZZ	ZZ	DR	C	0004

Original Size:	Scale	Project Ref. No:	Sheet:	Rev:
A3	1:7,000	---	1 of 1	P01.1

Project ID	Client	Section Line A	ATKINS Member of the SNC-Lavalin Group	
20181923	Portsmouth Water			
Project Title	**Engineer**		**Vertical Scale**	**Horizontal Scale**
Havant Thicket Storage Reservoir	Atkins		As shown	As shown



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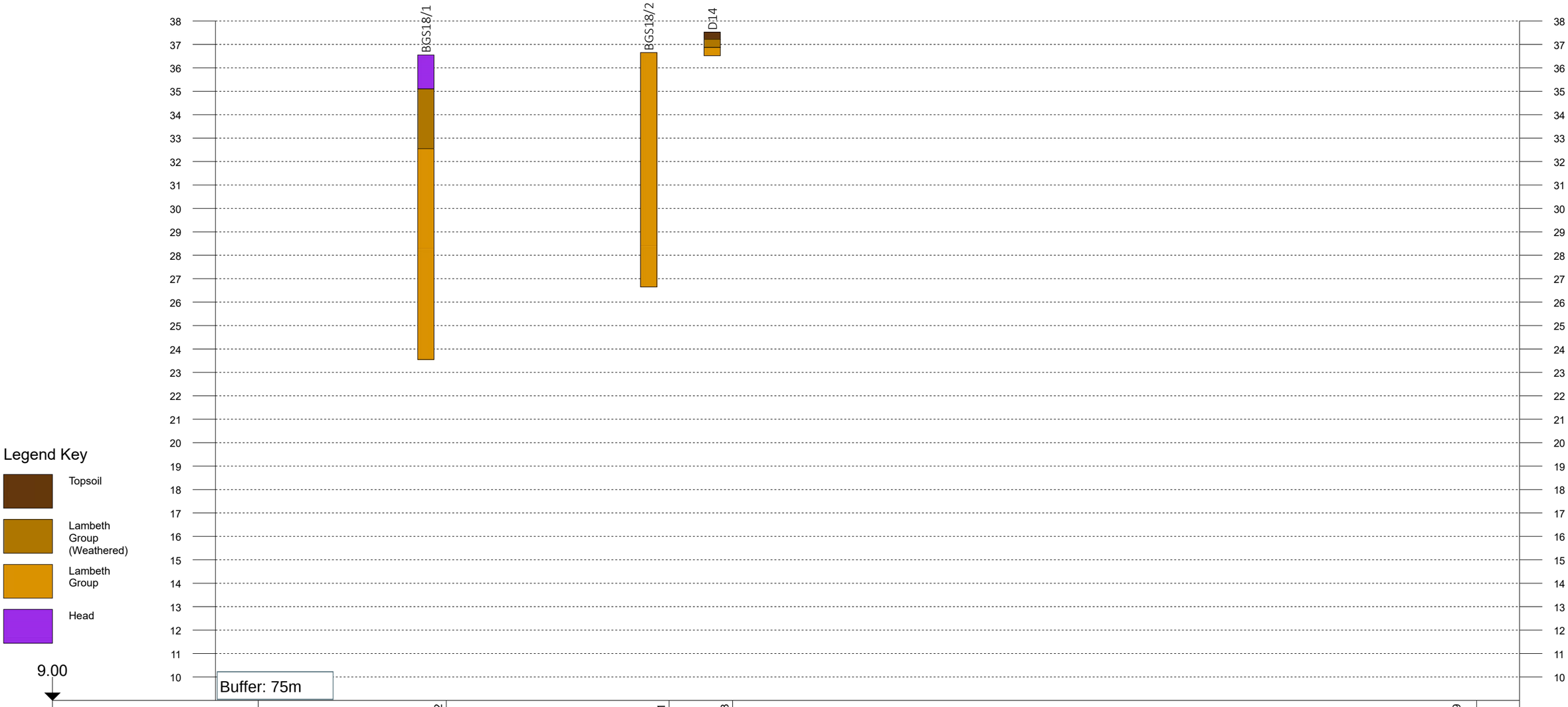
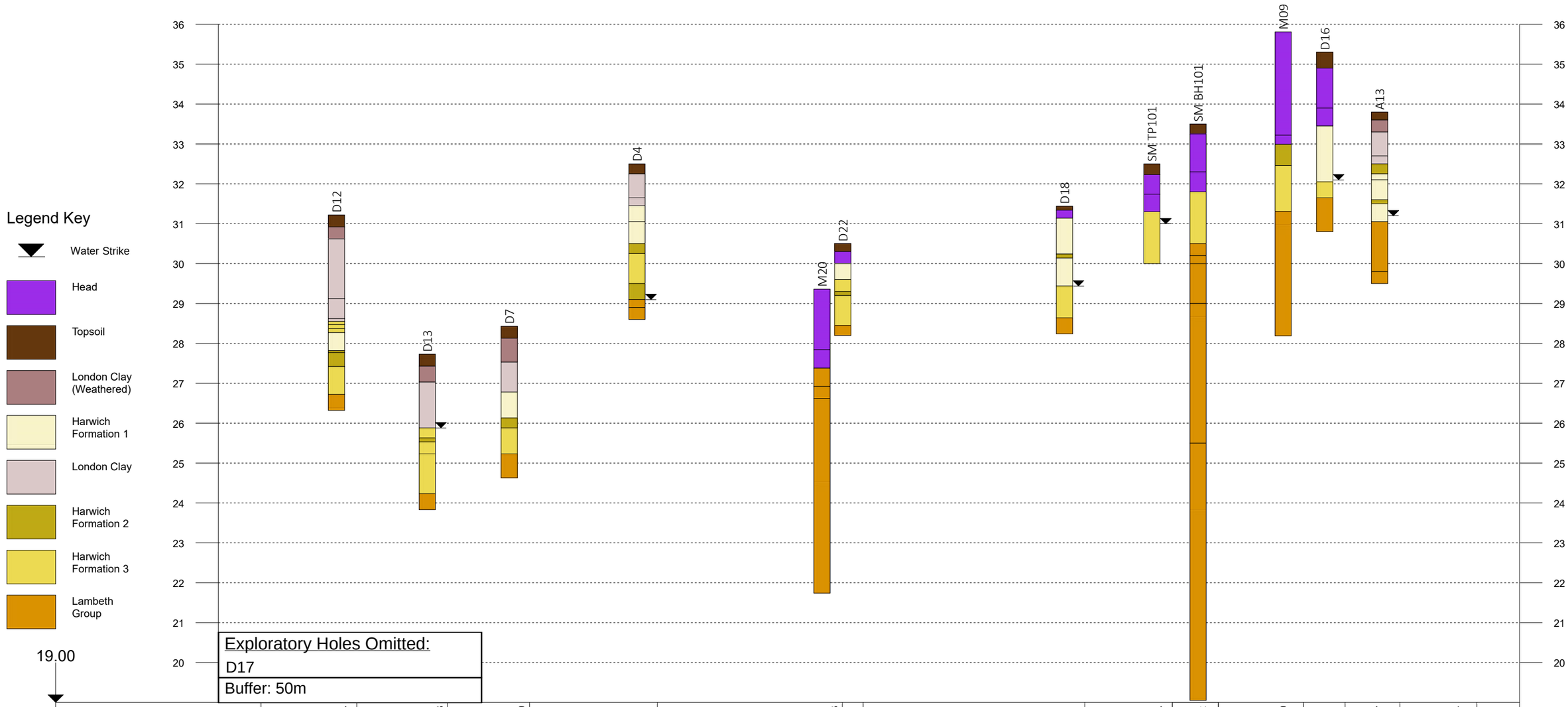
447.84	42.73	36.21
777.29	29.45	39.36
1070.2	31.86	39.20
1150.4	16.85	35.30
1204.4	9.76	30.90
1242.2	17.75	24.84
1300.3	0.82	24.50
1358.4	7.85	23.62
1477.2	25.90	25.20
1566.1	24.92	28.44
1727.4	2.34	29.20
1839.8	38.10	29.87
1934.3	19.17	29.91
2030.2	4.55	32.61
2120.3	53.06	34.57
2274.5		
2923.79		

Project ID	Client	Section Line B	ATKINS Member of the SNC-Lavalin Group	
20181923	Portsmouth Water			
Project Title	**Engineer**		**Vertical Scale**	**Horizontal Scale**
Havant Thicket Storage Reservoir	Atkins		As shown	As shown



Chainage (m)	0.00	219.82	480.51	554.78	1424.97
Offset (m)		70.04	63.52	55.79	
Elevation (mAOD)		36.55	36.65	37.52	

Project ID	Client	Section Line C	ATKINS Member of the SNC-Lavalin Group	
20181923	Portsmouth Water			
Project Title	**Engineer**		**Vertical Scale**	**Horizontal Scale**
Havant Thicket Storage Reservoir	Atkins		As shown	As shown



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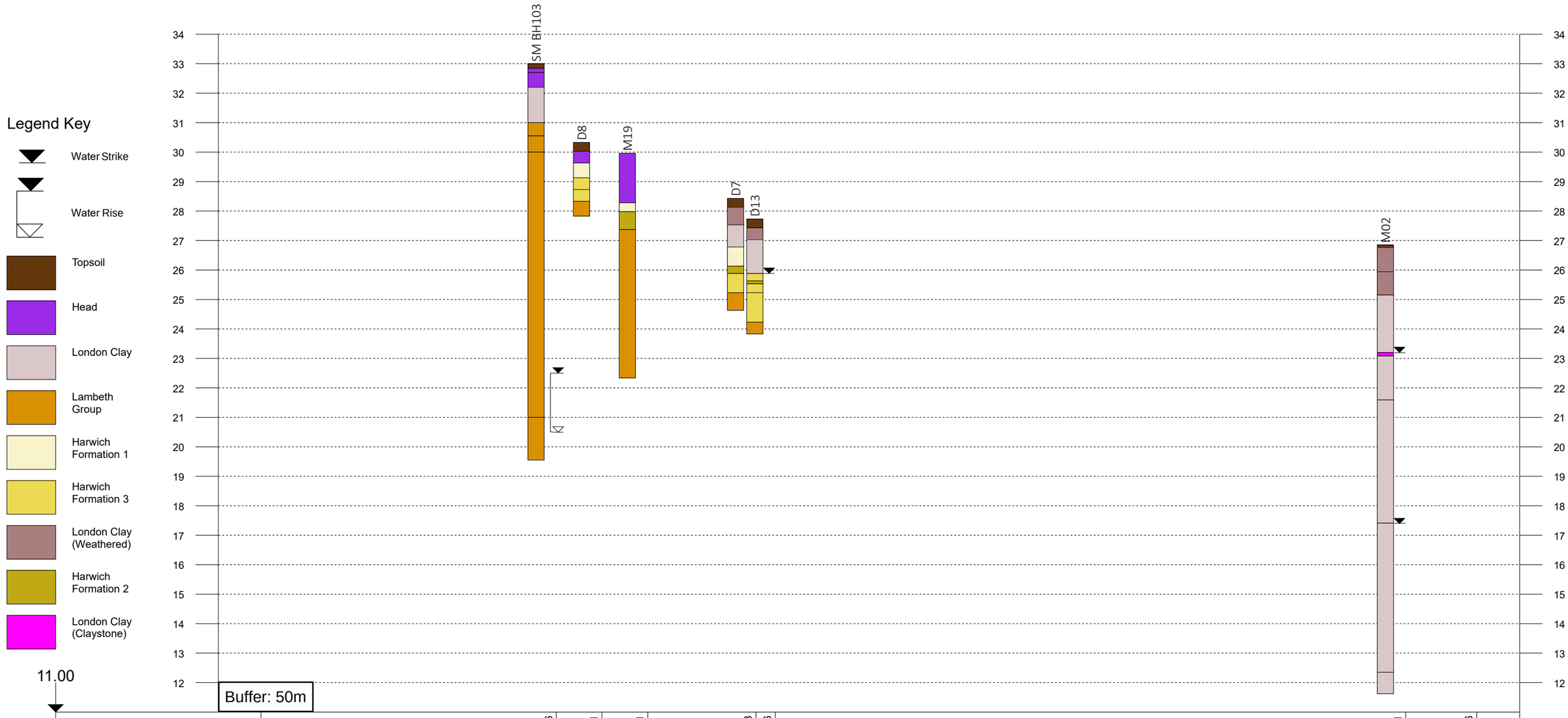
Offset (m)		45.95	37.79	20.89	2.72	32.35	28.98	2.91	19.75	22.02	42.13	39.60	7.22		
Elevation (mAOD)		31.22	27.73	28.43	32.50	29.36	30.50	31.44	32.50	33.50	35.81	35.30	33.80		

Project ID	Client	Section Line D	ATKINS Member of the SNC-Lavalin Group	
20181923	Portsmouth Water			
Project Title	**Engineer**		**Vertical Scale**	**Horizontal Scale**
Havant Thicket Storage Reservoir	Atkins		As shown	As shown



Chainage (m)	0.00	233.66	269.61	305.91	391.48	406.76	905.61	961.76	
Offset (m)		33.23	19.49	27.17	41.00	48.50	35.26		
Elevation (mAOD)		33.00	30.33	29.96	28.43	27.73	26.85		

Project ID	Client		
20181923	Portsmouth Water		
Project Title	**Engineer**	**Vertical Scale**	**Horizontal Scale**
Havant Thicket Storage Reservoir	Atkins	1:202	1:6756

Section Line E

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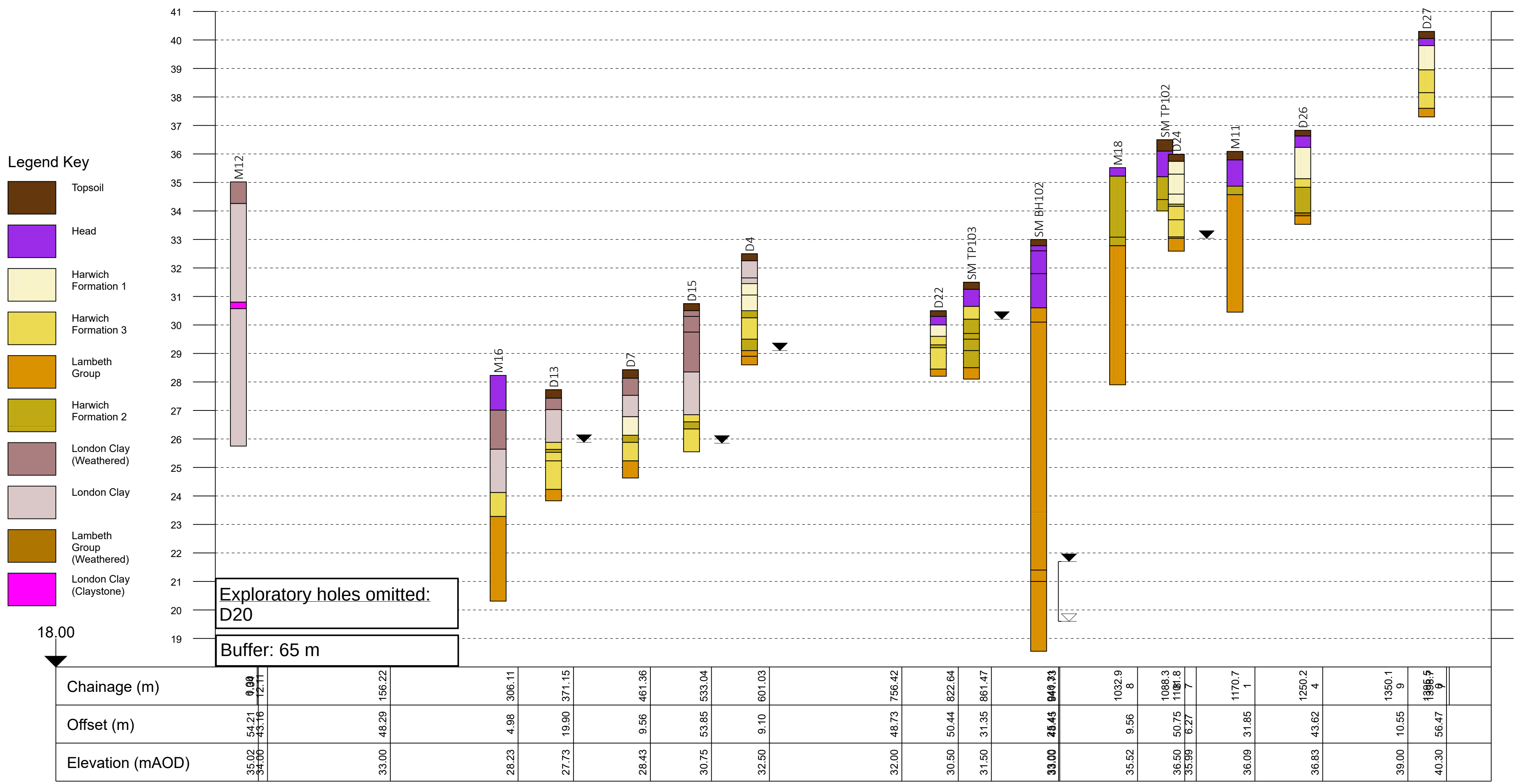
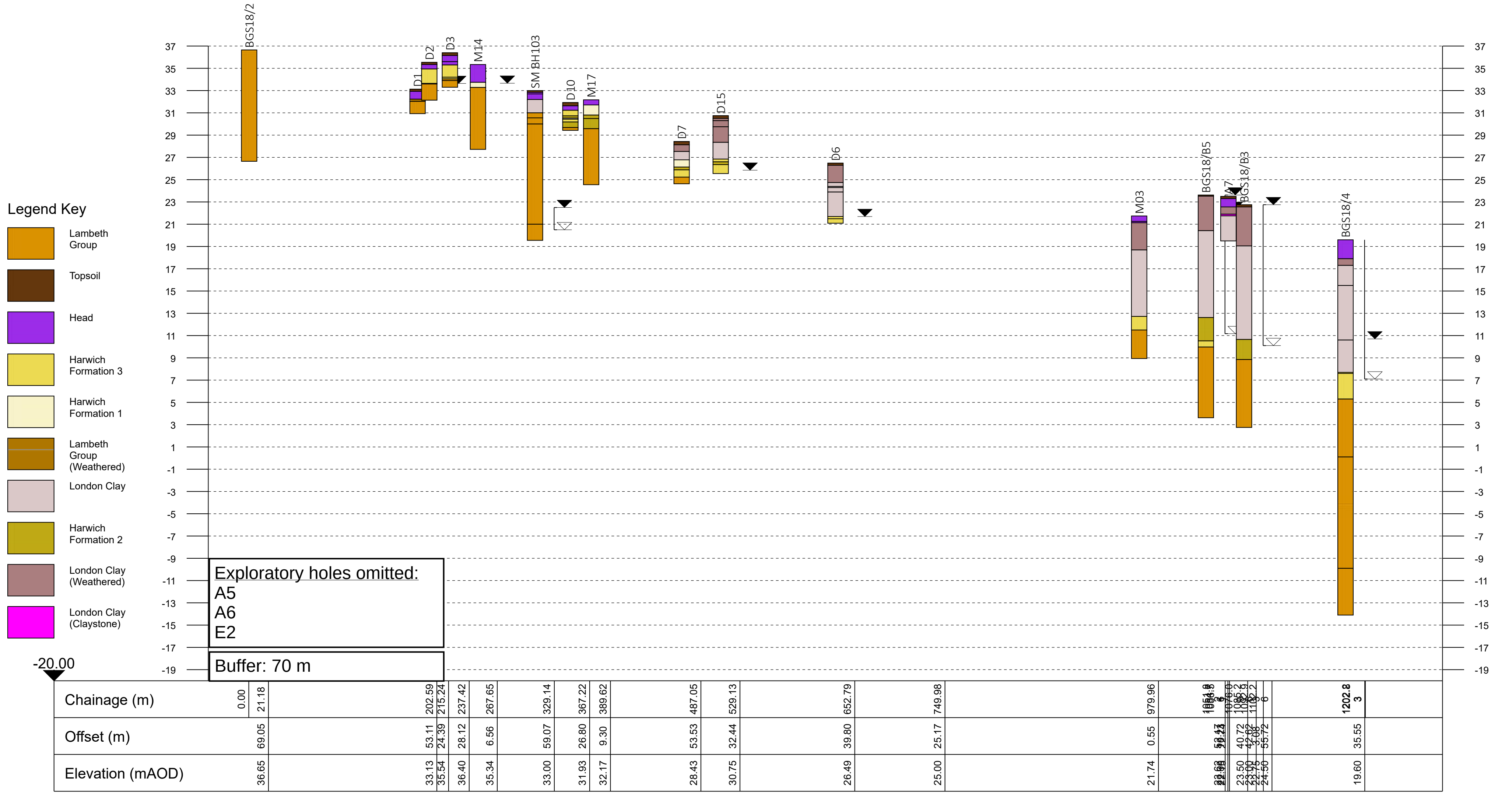
Member of the SNC-Lavalin Group

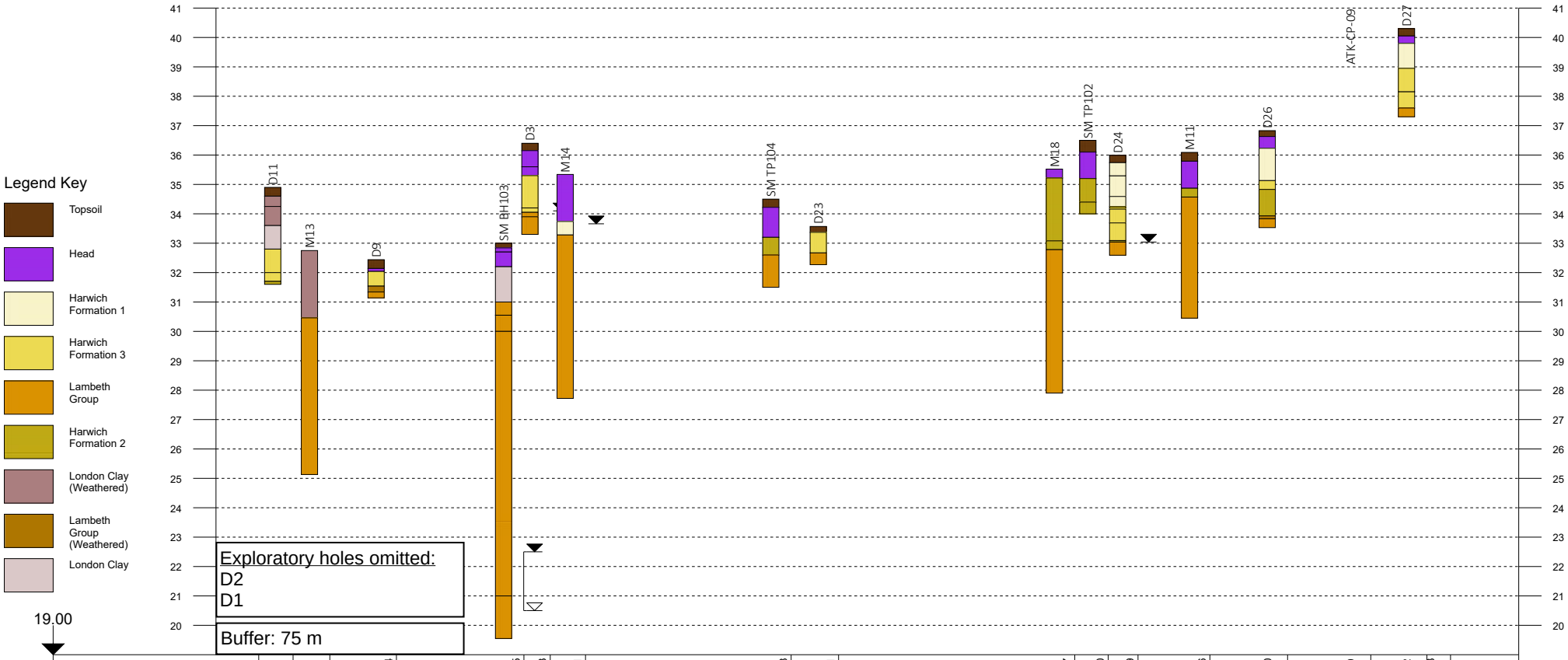


Project ID	Client	Section Line F	ATKINS
20181923	Portsmouth Water		Member of the SNC-Lavalin Group

Project Title	Engineer	Vertical Scale	Horizontal Scale
Havant Thicket Storage Reservoir	Atkins	1:500	1:6000



Project ID	Client	Section Line G	ATKINS Member of the SNC-Lavalin Group	
5169117	Portsmouth Water			
Project Title	**Engineer**		**Vertical Scale**	**Horizontal Scale**
Havant Thicket Storage Reservoir	Atkins		1:200	1:6000



Chainage (m)	Offset (m)	Elevation (mAOD)
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72.56	7.38	32.75
140.54	40.24	32.44
270.65	47.30	33.00
297.53	45.69	36.40
333.51	17.02	35.34
543.38	4.08	34.50
591.81	8.87	33.57
832.87	46.93	35.52
867.00	27.50	36.50
897.39	22.59	35.99
970.76	25.72	36.09
1050.06	12.41	36.83
1134.96	49.83	39.00
1192.21	20.11	40.30
1216.36		

A series of slickensided surfaces are present at 15.00mbgl

Shiney striated grey shear surfaces

30°

20°-45°

Non-pervasive shear surfaces

42°-56°

30°-40°

50°-60°

25°-30°

50°-60°

56°

27°

26°

29°

42°

30°

30°

Randomly oriented shiney shear surfaces parallel to dip

Well developed sub-vertical shear surfaces

Meters

0

600

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SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

Construction
(Enter "None" if applicable)
Maintenance / Cleaning
(Enter "None" if applicable)
Use
(Enter "None" if applicable)
Decommission / Demolition
(Enter "None" if applicable)

- Reservoir Embankment (Arup 2009)
- Reservoir Footprint (Arup 2009)
- Orientation of Shear Surfaces within the London Clay Formation
- Orientation of Shear Surfaces in Head Deposits
- Shear Surfaces in the Head Deposits (Orientation Not Defined)
- Shear Surfaces in Reading Formation
- 1m Contours
- Head - Clay and gravel
- Head - Clay, silt, sand and gravel
- River Terrace Deposits (Undifferentiated) - Sand, silt and clay
- Wittering Formation - Sand [UDCS]
- Wittering Formation - Sand, silt and clay
- Whitecliffe Sand Member - Sand
- London Clay Formation (Bognor Sand Member)
- London Clay Formation - Clay, silt and sand
- Harwich Formation (London Clay Formation – Sand)
- Lambeth Group - Clay, Silt and Sand
- Portsdown Chalk Formation - Chalk
- Spetisbury Chalk Member - Chalk
- Tarrant Chalk Member - Chalk
- Newhaven Chalk Formation - Chalk

DRAFT

Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description						
Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date
Description: Shear Surfaces Identified in Historical Ground Investigations						
S0	P01	NW	FD	---	---	16/05/2019

Drawing Suitability: WORK IN PROGRESS

Status: S0

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Client: Portsmouth Water

Project Title: Havant Thicket Winter Storage Project

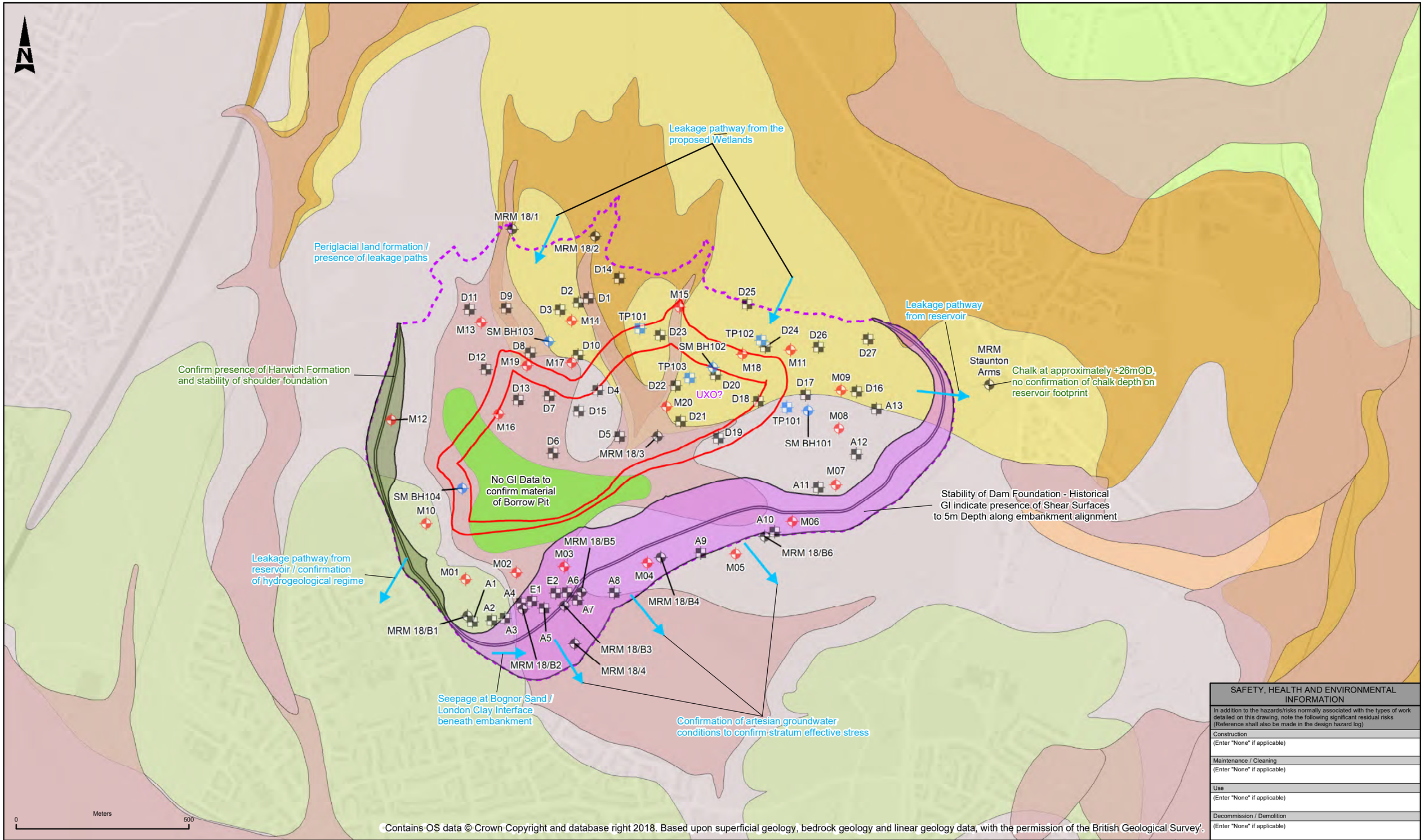
Drawing Title: SHEAR SURFACES IDENTIFIED IN HISTORICAL GROUND INVESTIGATIONS

Drawing Number

Project	Originator	Volume
HTWSR	ATK	ZZ

Location	Type	Role	Number
ZZ	DR	C	0005

Original Size:	Scale	Project Ref. No:	Sheet:	Rev:
A3	1:8,000	---	1 of 1	P0 1.1



(MRM) 1977 - 1979
Morton 1963
Soil Mechanics 2006
MRM 1979
Soil Mechanics 2006
Borrow Pit (Arup 2009)
Reservoir Embankment (Arup 2009)
Reservoir Footprint (Arup 2009)

Wittering Formation - Sand [UDCS]
Wittering Formation - Sand, silt and clay
Whitecliffe Sand Member - Sand
London Clay Formation (Bognor Sand Member)
London Clay Formation - Clay, silt and sand

Harwich Formation (London Clay Formation – Sand)
Lambeth Group - Clay, Silt and Sand
Portsdown Chalk Formation - Chalk
Spetisbury Chalk Member - Chalk
Tarrant Chalk Member - Chalk
Newhaven Chalk Formation - Chalk

Lewes Nodular Chalk Formation, Seaford Chalk Formation, Newhaven Chalk Formation, Culver Chalk Formation And Portsdown Chalk Formation (Undifferentiated) - Chalk

DRAFT

Status	Revision	Drawn	Checked	Reviewed	Authorised	Issue Date	Description
S0	P01	NW	FD	---	---	---	Geotechnical Engineering Issues

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following significant residual risks (Reference shall also be made in the design hazard log)

Construction
(Enter "None" if applicable)

Maintenance / Cleaning
(Enter "None" if applicable)

Use
(Enter "None" if applicable)

Decommission / Demolition
(Enter "None" if applicable)

Drawing Suitability: WORK IN PROGRESS
Status: S0

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Client: Portsmouth Water

Project Title: Havant Thicket Winter Storage Project

Drawing Title: GEOTECHNICAL ENGINEERING ISSUES

Drawing Number

Project	Originator	Volume	Location	Type	Role	Number
HTWSR	ATK	ZZ	ZZ	DR	C	0006

Original Size:	Scale	Project Ref. No:	Sheet:	Rev:
A3	1:10,000	---	1 of 1	P0 1.1

Appendix A10.2 Desk Study Report

Appendix C.1 Aerial Photography Interpretation

Technical Note

Project:	Havant Thicket Reservoir		
Subject:	Aerial Photography Interpretation (API)		
Author:	Clement Tam		
Check:	Oliver Pengilly	Review	Andrew Hart
Date:	28 November 2019	Project No.:	<project no>
Atkins No.:	20181923		

Introduction

Atkins undertook a review and interpretation of available aerial photographs to identify the geomorphological features and potential geohazards that might be present at and adjacent to the proposed Havant Thicket Winter Storage Reservoir (HTWSR) site – the Study Area. The study was to review and build upon a Draft Aerial Photograph Interpretation (API) undertaken by Arup in 2008 [50].

A search request was made to Historic England for all aerial photographs within the area bounded by OS grid references SU 69902 11495, SU 73286 11552, SU 73339 08674 and SU 69956 08639. The search identified 237 vertical and four specialist oblique aerial photographs.

Atkins first undertook a review of aerial photographic prints made available by Portsmouth Water. These included oblique photographs from commissioned flyovers of the Havant site in 2006 (far field), 2007 (near field) and low to medium-resolution digital prints from the historical aerial photograph search undertaken by Arup and covering the period 1946 to 1996. All historic aerial photographs recorded within the Arup API were identified within the Historic England search. A complete list of the aerial photographs reviewed as part of the study is presented in Appendix C2.

Methodology

A review of all aerial photographs identified within the Historic England archive search was undertaken on 4th April 2019. Where the aerial photograph stereo pairs were available, the prints were examined in 3D using a mirror stereoscope to amplify detail and depth of the terrain features. The inspection was first performed on those photographs that were taken at a higher altitude, were older and have good coverage of the Study Area. This allowed the interpreter to gain a general overview of the Study Area, before progressing to a closer inspection of the more recent aerial photographs, which were taken at lower altitudes. Undertaking the API in chronological order allows for the development of geomorphological features identified in earlier aerial photographs to be followed over time.

Since the aerial photographs taken in 1996 have the best quality and coverage of the proposed site (Photo ID: OS/96535 - 025 and OS/96535 – 026), this stereopair has been used as the layer to record the geomorphological interpretation of the Study Area.

The findings from the API undertaken here have been digitised using ESRI ArcGIS software so that the data is available for use within the project's Geographic Information System (GIS). Each of the interpreted features was assigned a description and the corresponding photograph year were recorded within the attribute data. An output map including all the interpreted features is presented in Drawing 3 in Appendix B.3.

The findings of this API are to be supplemented by recent aerial photography including infrared imaging, collected on 21st April 2019.

API Observations

On-site

The observations from the API are discussed in this section and also summarised in Drawing 3 in Appendix B.3.

1946 – 1949

The majority of the Study Area is wooded in the available aerial photographs (Figure C-1 - Aerial photograph taken on 19 Apr 1946 (Photo ID: RAF/3G/TUD/UK/156 - 5127)Figure C-1 - Aerial photograph taken on 19 Apr 1946 (Photo ID: RAF/3G/TUD/UK/156 - 5127)

-). Prominent open areas included: Open grassland northeast of Gipsies Plain (east of the Study Area); area with bare landcover south of Middle Clearing (west of the Study Area); open grassland at Thicket Lawn (south of Study Area). The woodland in the Middle Clearing area was also partially cleared in 1946.
- The site is situated in a gentle valley bounded by lower altitude mounds at all sides. There is a north-south trending river valley on the western boundary to the Study Area.

A meandering stream is present flowing from the stream valleys to the north of the Study Area, through a trapezoidal pond at the end of 'The Avenue' known as 'Upper Lake', into the area of open fields to the south of the Study Area (Figure C-1 - Aerial photograph taken on 19 Apr 1946 (Photo ID: RAF/3G/TUD/UK/156 - 5127)Figure C-1 - Aerial photograph taken on 19 Apr 1946 (Photo ID: RAF/3G/TUD/UK/156 - 5127)

- Vegetation appears to be relatively sparse to the north of the Study Area and becomes gradually denser further into the gentle valley.
- Dense vegetation and the relatively poor quality of the early photos prevent the delineation of geomorphological features.
- No discernible evidence for slope movements could be identified as affecting the Study Area.

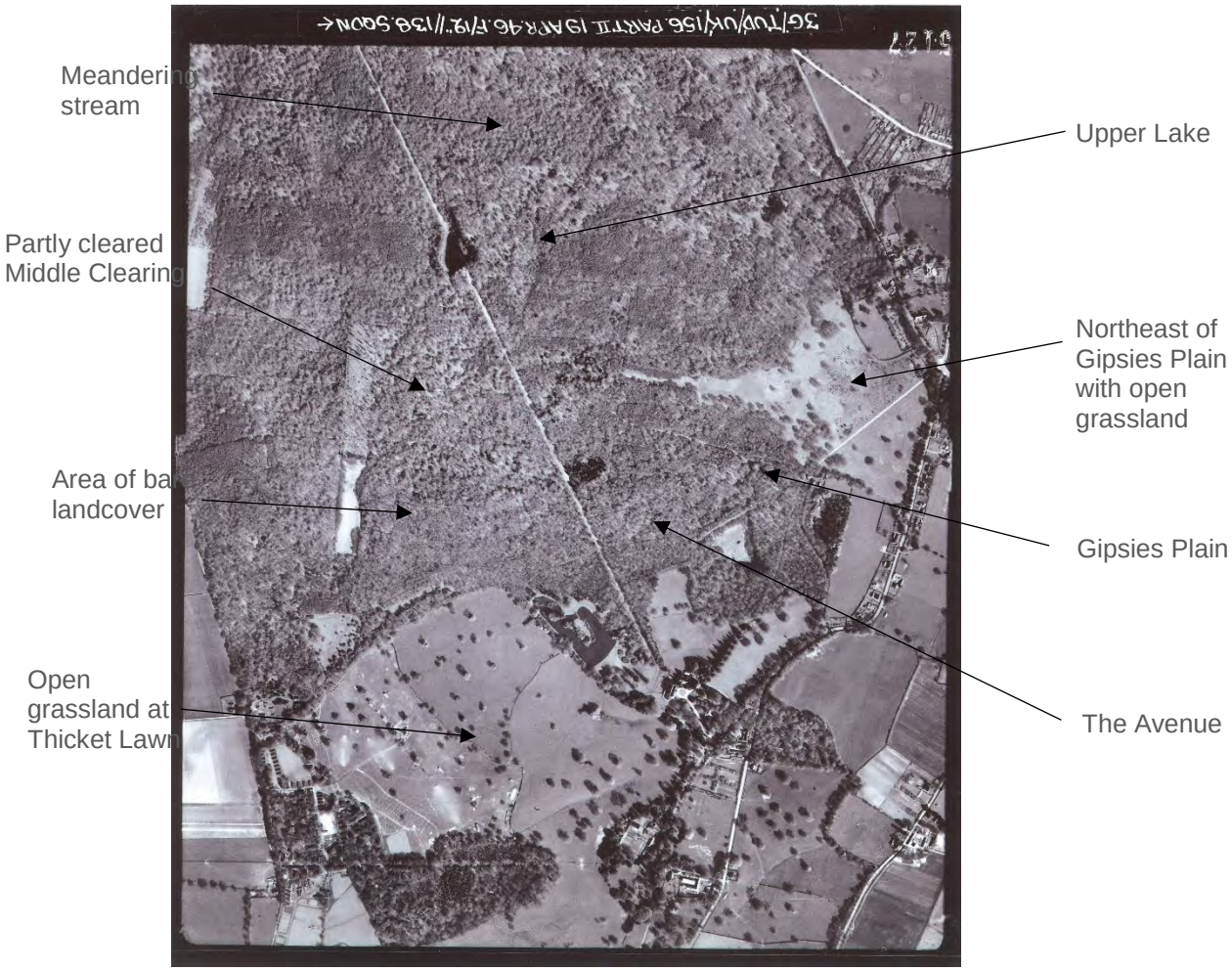

Figure C-1 - Aerial photograph taken on 19 Apr 1946 (Photo ID: RAF/3G/TUD/UK/156 - 5127)

<u>1950 – 1959</u>

- The majority of the woodland across the Study Area has been cleared, with the exception of isolated small areas including the Middle Clearing, the heart-shaped woodland southeast of the Middle Clearing, and a narrow strip of woodland along the Avenue. Sporadic individual trees can also be observed across the Study Area.
- A number of north-south flowing meandering streams can be seen to the north and southeast of the 'Middle clearing', and in the centre of the Study Area cutting across the Avenue (Figure C-2).
- An area of undulating ground either side of a water course can be seen in some of the aerial photographs as affecting the slopes to the northeast of 'The Avenue'. This could indicate an area of possible soil creep (Figure C-2). However, it is also noted that the quality of the aerial photographs was relatively poor, and this could not be confirmed during the site walkover.
- No discernible evidence for slope movements could be identified as affecting the relatively gentle slopes elsewhere in the Study Area.

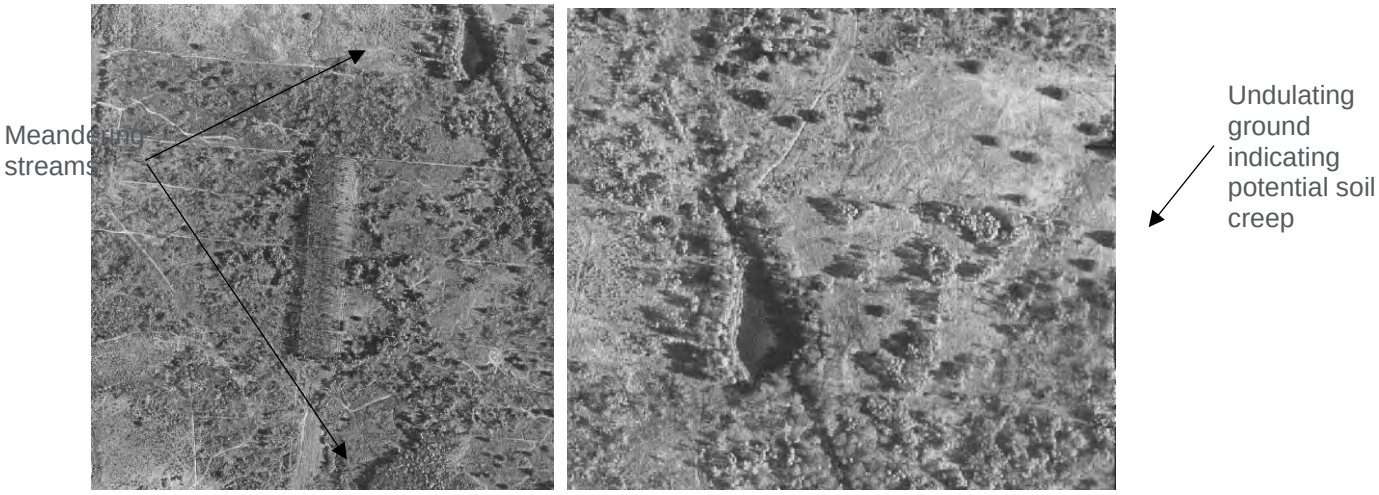

Figure C-2 –Aerial photographs taken on 07 May 1954 (Left - Photo ID: RAF/82/914 – 013. Right - Photo ID: RAF/82/914 – 014)

<u>1960 - 1969</u>

- The majority of the woodland across the Study Area has been cleared, with forestry access tracks now also clearly visible in the aerial photographs (Figure C-3).
- The meandering streams visible in earlier aerial photographs across the Study Area (Figure C-3), appears to have been straightened in 1960 (Figure C-3), possibly to improve drainage of the Study Area, which (anecdotally) can become very water-logged.
- No discernible evidence for slope movements could be identified as affecting the Study Area.

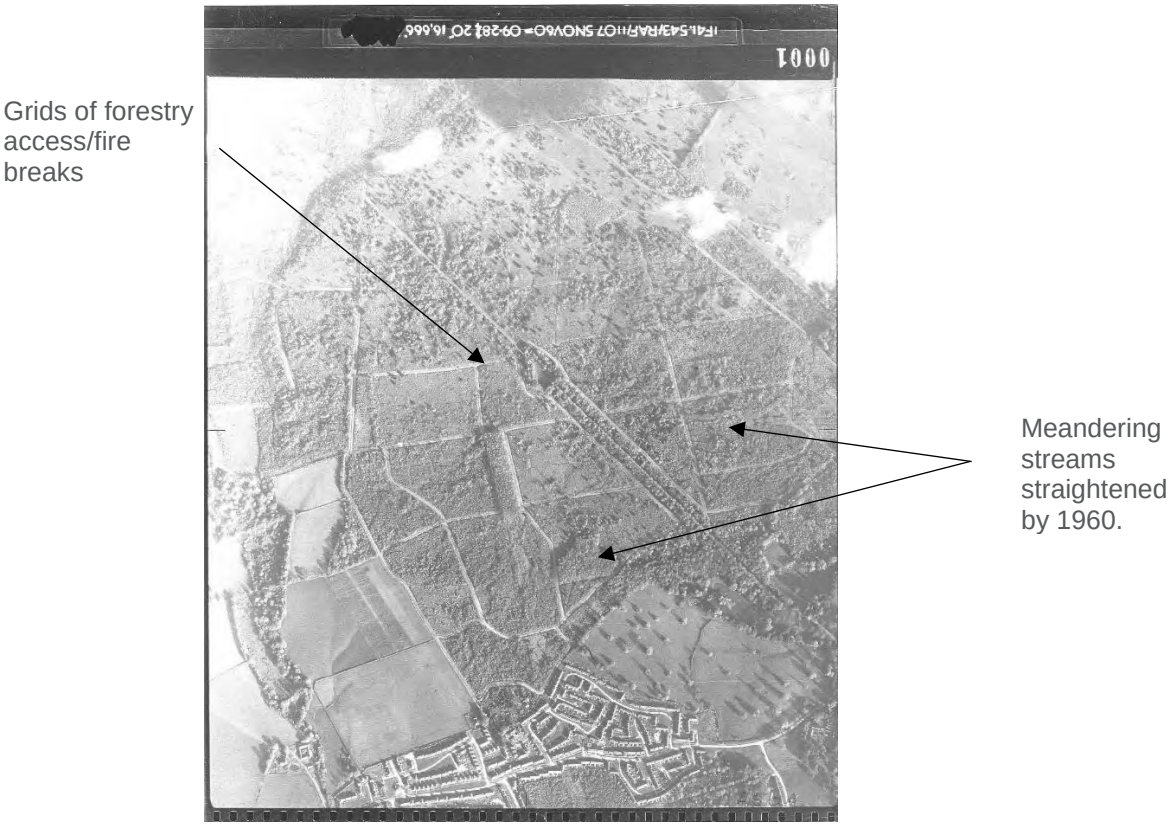

Figure C-3 - Aerial photograph taken on 05 Nov 1960 (Photo ID: RAF/543/1107 - 0001)

1970 – 1979

- The poor quality and coverage of the available aerial photographs have prevented the identification of any relevant geomorphological features pertinent to this work.

1980 – 1989

- Trees have been cleared with open grassland observed across the majority of the Study Area
- An area can be observed to the east of the Upper Lake (Figure C-4) that has a mottled ground surface, possibly due to soil disturbance by forestry, deforestation or agricultural activities.
- No discernible evidence for slope movements could be identified as affecting the Study Area.

Figure C-4 - Aerial photograph taken on 07 May 1981. (Photo ID: MAL/81012 - 212)

1990 – 1996

- The aerial photographs from this period had the best quality and coverage of all those used during the API.
- Trees have remained cleared from much of the Study Area with grass fields being the dominant land cover across the Study Area, allowing better observation of the surface features present in the area.
- This means that the valley that will be used for the HTWSR site can be clearly seen.

- The northern part of this valley area contains several small stream channels that converge towards south of the Study Area via the straightened watercourse noted above, before exiting the Study Area into the drainage south of the Thicket Lawn (Figure C-5).
- It appears that the majority of stream channels within the Study Area have now been straightened (Figure C-5). It is understood that this may have been undertaken to ease the drainage of the area as (anecdotally) much of the area can become very water-logged. This land drainage work across the site, including straightening, is understood to have been undertaken with funding from the Ministry of Agriculture Farming and Food (MAFF) in 1973.
- Seasonal drainage valleys can also be observed branching into the west of the Study Area (Figure C-5). These valleys have been highlighted on Appendix B Drawing 3, indicating the connection to the western-most stream, flowing in a north-south orientation. The seasonal drainage valleys in the southwest corner of the site are indicated as originating from the seepage line along the break in the slope (Figure C-5).
- Evidence for seepage lines can be seen on some of the slopes in the southwest of the Study Area (Figure C-5). Their location is nearly always coincident with a relatively distinct break of slope. It is possible that the location for these seepage lines corresponds to the geological boundary between the Bognor Sand Member and the London Clay Formation.
- The seepage lines appear to be accompanied by areas of soil creep based on aerial photograph interpretation (Figure C-5), however this could not be confirmed during the site walkover.
- Other possible geological boundaries between the London Clay and Harwich Formation in the eastern part of the Study Area have also been inferred based on the presence of relatively distinct changes in slope angle due to breaks of slope.

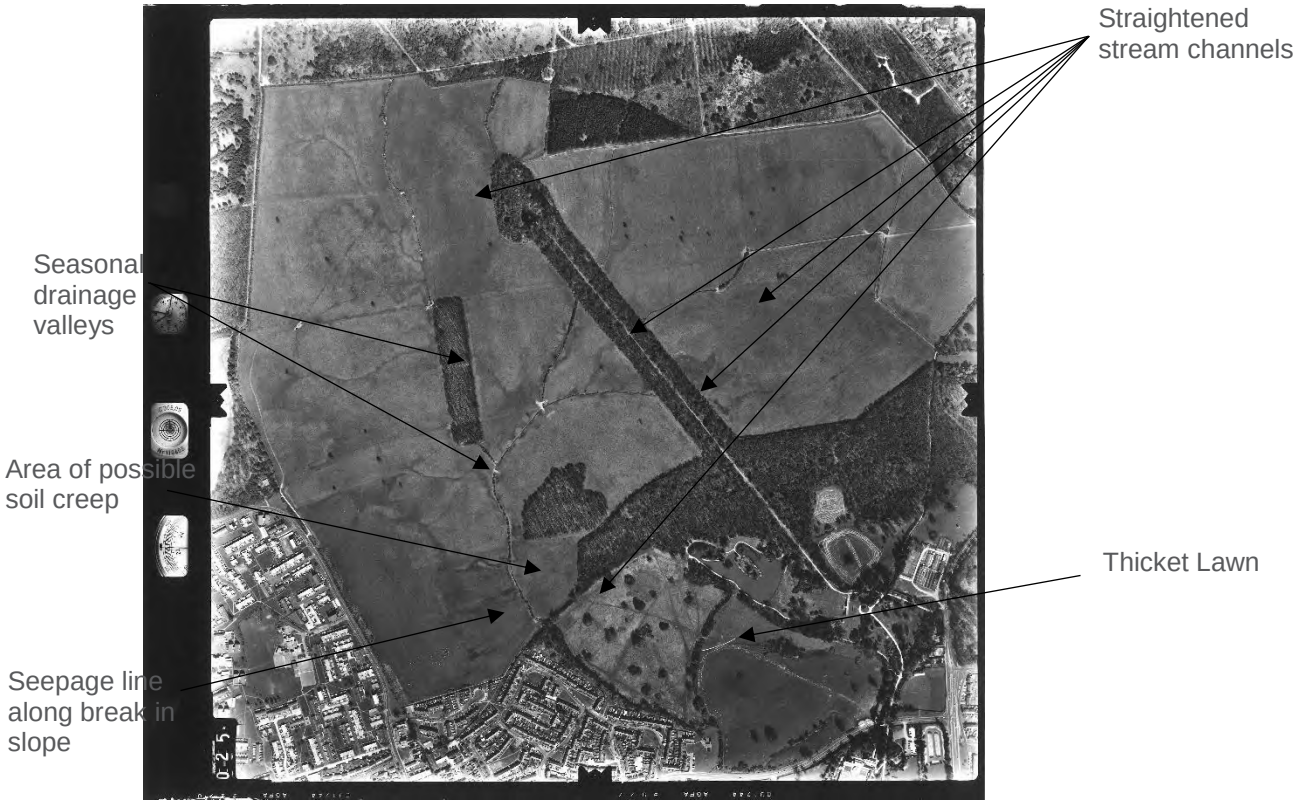

Figure C-5 - Aerial photograph taken on 20 Apr 1996. (Photo ID: OS/96535 - 025)

Near-field (within 1km of the site boundary)

Whilst the review of the aerial photographs primarily focused within the site boundaries of the proposed reservoir, some major geomorphological features have been identified in the near-field of the Study Area:

- Surface depressions: An area of surface depressions, possibly relating to the presence of karst were noted at the golf course approximately between 0.25km and 1km to the east and north east of the Study Area (i.e., outside of the Study Area boundary). No evidence of similar features were observed within the Study Area. Depressions identified in historical aerial photographs are to be confirmed with recent imagery flown on 21st April 2019.
- Drainage lines: Beyond the south west Study Area, where Warren Park is located, depressions within the Bognor Sand Member potentially indicates the presence of past seasonal valleys that flow away from the site and confluence with a nearby north-south flowing stream. The north-south flowing stream extends further north along the western side of the Study Area, incising into the higher ground to the north of the Study Area, possibly along the boundary between the Reading Formation and the Harwich Sand Formation, thereby creating a river valley with relatively steep slopes on both sides.

Appendix A10.2 Desk Study Report

Appendix C.2 List of Historical Aerial Photopgraphy Reviewed

Sortie number	Frame number	Centre point (in OS National Grid)	Date	Scale 1:	Film details (in inches)	Reviewed by Atkins?	Reviewed by Arup?	Area of Site (NW/SW/NE/SE)
RAF/3G/TUD/UK/156	5125	SU 702 093	19 APR 1946	10400	Black and White 8.25 x 7.5	Yes	No	NW, SW
RAF/3G/TUD/UK/156	5126	SU 710 094	19 APR 1946	10400	Black and White 8.25 x 7.5	Yes	Yes	SW, NW, SE, NE
RAF/3G/TUD/UK/156	5127	SU 717 094	19 APR 1946	10400	Black and White 8.25 x 7.5	Yes	Yes	SW, NW, SE, NE
RAF/3G/TUD/UK/156	5128	SU 725 094	19 APR 1946	10400	Black and White 8.25 x 7.5	Yes	No	NE, SE
RAF/3G/TUD/UK/156	5153	SU 701 109	19 APR 1946	10400	Black and White 8.25 x 7.5	Yes	No	NW
RAF/3G/TUD/UK/156	5154	SU 709 109	19 APR 1946	10400	Black and White 8.25 x 7.5	Yes	Yes	NW, NE
RAF/3G/TUD/UK/156	5155	SU 716 109	19 APR 1946	10400	Black and White 8.25 x 7.5	Yes	Yes	NE
RAF/3G/TUD/UK/156	5156	SU 724 110	19 APR 1946	10400	Black and White 8.25 x 7.5	Yes	No	NE
RAF/CPE/UK/2478	5308	SU 710 090	10 MAR 1948	5500	Black and White 8.25 x 7.5	Yes	Yes	SW
RAF/CPE/UK/2478	5309	SU 706 090	10 MAR 1948	5500	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/CPE/UK/2478	5310	SU 703 090	10 MAR 1948	5500	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/CPE/UK/2478	5329	SU 701 097	10 MAR 1948	5500	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/CPE/UK/2478	5330	SU 705 097	10 MAR 1948	5500	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/CPE/UK/2478	5331	SU 708 097	10 MAR 1948	5500	Black and White 8.25 x 7.5	Yes	No	NW
RAF/540/1286	68	SU 735 105	14 APR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1286	69	SU 735 101	14 APR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1286	70	SU 734 097	14 APR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1286	71	SU 734 093	14 APR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1286	72	SU 734 089	14 APR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1286	105	SU 725 089	14 APR 1954	5000	Black and White 8.25 x 7.5	YES	No	N/A
RAF/540/1286	106	SU 715 089	14 APR 1954	5000	Black and White 8.25 x 7.5	YES	No	SE
RAF/540/1286	106	SU 724 092	14 APR 1954	5000	Black and White 8.25 x 7.5	YES	No	SE
RAF/540/1286	107	SU 715 092	14 APR 1954	5000	Black and White 8.25 x 7.5	Yes	No	SE
RAF/540/1286	107	SU 724 094	14 APR 1954	5000	Black and White 8.25 x 7.5	Yes	No	SW
RAF/540/1286	108	SU 714 095	14 APR 1954	5000	Black and White 8.25 x 7.5	Yes	No	SE
RAF/540/1286	108	SU 724 097	14 APR 1954	5000	Black and White 8.25 x 7.5	Yes	No	SW
RAF/82/914	11	SU 713 088	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	12	SU 714 091	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	Yes	SE
RAF/82/914	12	SU 724 092	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	Yes	SW
RAF/82/914	13	SU 713 096	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	Yes	SE, NE
RAF/82/914	13	SU 723 097	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	Yes	SW & NW
RAF/82/914	14	SU 712 101	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	Yes	NE
RAF/82/914	14	SU 722 102	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	Yes	NW, NE
RAF/82/914	15	SU 711 107	07 MAY 1954	5000	Black and White 8.25 x 7.5	YEs	No	N/A
RAF/82/914	15	SU 721 108	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	
RAF/82/914	16	SU 711 112	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	16	SU 721 113	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	30	SU 697 088	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	30	SU 708 089	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	SW
RAF/82/914	31	SU 697 093	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	31	SU 707 093	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	SW, NW
RAF/82/914	32	SU 696 098	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	32	SU 707 098	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	SW, NW
RAF/82/914	33	SU 696 102	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	33	SU 707 103	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	NW
RAF/82/914	34	SU 696 107	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A

Sortie number	Frame number	Centre point (in OS National Grid)	Date	Scale 1:	Film details (in inches)	Reviewed by Atkins?	Reviewed by Arup?	Area of Site (NW/SW/NE/SE)
RAF/82/914	34	SU 706 108	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	35	SU 696 112	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	35	SU 707 113	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	37	SU 729 089	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	38	SU 729 094	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	39	SU 730 099	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	40	SU 730 105	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/82/914	41	SU 731 110	07 MAY 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	129	SU 705 090	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	130	SU 705 098	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	131	SU 705 100	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	132	SU 705 103	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	SW
RAF/58/1343	133	SU 705 105	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	SW
RAF/58/1343	134	SU 704 107	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	NW
RAF/58/1343	135	SU 704 109	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	136	SU 704 112	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	148	SU 710 112	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	149	SU 710 110	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	166	SU 725 112	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	166	SU 717 112	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	167	SU 725 109	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	167	SU 717 110	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	168	SU 725 107	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	168	SU 717 107	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	169	SU 725 104	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	169	SU 717 104	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	170	SU 725 101	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	Yes	NE
RAF/58/1343	170	SU 717 101	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	Yes	NE
RAF/58/1343	171	SU 725 098	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	NE, SE
RAF/58/1343	171	SU 717 098	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	NE
RAF/58/1343	172	SU 725 095	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	NE, SE
RAF/58/1343	172	SU 717 096	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	SE, NE
RAF/58/1343	173	SU 725 093	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	NE, SE
RAF/58/1343	173	SU 717 093	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	SE
RAF/58/1343	174	SU 725 090	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/1343	174	SU 717 090	18 JAN 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	182	SU 697 089	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	182	SU 706 088	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	SW
RAF/540/1266	183	SU 697 092	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	183	SU 706 091	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	SW
RAF/540/1266	184	SU 697 094	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	184	SU 706 094	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	SW
RAF/540/1266	185	SU 697 097	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	185	SU 706 097	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	SW, NW
RAF/540/1266	186	SU 697 100	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	186	SU 705 100	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	NW

Sortie number	Frame number	Centre point (in OS National Grid)	Date	Scale 1:	Film details (in inches)	Reviewed by Atkins?	Reviewed by Arup?	Area of Site (NW/SW/NE/SE)
RAF/540/1266	187	SU 697 103	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	187	SU 705 103	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	NW
RAF/540/1266	193	SU 729 113	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	193	SU 720 112	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	NW
RAF/540/1266	194	SU 729 110	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	194	SU 720 109	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	195	SU 729 106	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	195	SU 720 106	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	Yes	N/A
RAF/540/1266	196	SU 729 103	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	196	SU 721 103	08 MAR 1954	5000	Black and White 8.25 x 7.5	No	Yes	
RAF/540/1266	197	SU 730 100	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	197	SU 721 100	08 MAR 1954	5000	Black and White 8.25 x 7.5	No	Yes	
RAF/540/1266	198	SU 730 096	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	198	SU 722 097	08 MAR 1954	5000	Black and White 8.25 x 7.5	No	Yes	
RAF/540/1266	199	SU 730 094	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	199	SU 721 094	08 MAR 1954	5000	Black and White 8.25 x 7.5	No	Yes	
RAF/540/1266	200	SU 730 091	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/540/1266	200	SU 721 091	08 MAR 1954	5000	Black and White 8.25 x 7.5	Yes	Yes	SW, SE
RAF/58/2480	134	SU 707 090	16 JUN 1958	10000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/2480	134	SU 726 087	16 JUN 1958	10000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/2480	135	SU 709 099	16 JUN 1958	10000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/2480	135	SU 728 099	16 JUN 1958	10000	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/543/328	151	SU 722 094	09 JUL 1958	10750	Black and White 8.25 x 7.5	Yes	Yes	SE, NE, SW, NW
RAF/543/328	152	SU 723 100	09 JUL 1958	10750	Black and White 8.25 x 7.5	Yes	Yes	SE, NE, SW, NW
RAF/543/328	153	SU 723 106	09 JUL 1958	10750	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/543/328	155	SU 706 083	09 JUL 1958	10750	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/2860	76	SU 704 086	14 MAY 1959	11200	Black and White 8.25 x 7.5	Yes	No	SW, SE
RAF/58/2860	77	SU 712 087	14 MAY 1959	11200	Black and White 8.25 x 7.5	Yes	No	SW, SE
RAF/58/2860	78	SU 720 087	14 MAY 1959	11200	Black and White 8.25 x 7.5	Yes	No	SW, SE
RAF/58/2860	79	SU 727 087	14 MAY 1959	11200	Black and White 8.25 x 7.5	Yes	No	SE, SW
RAF/58/2860	227	SU 723 113	14 MAY 1959	11200	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/2860	228	SU 716 114	14 MAY 1959	11200	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/58/2860	229	SU 709 115	14 MAY 1959	11200	Black and White 8.25 x 7.5	Yes	No	N/A
RAF/543/1107	1	SU 712 097	05 NOV 1960	10000	Black and White 8.25 x 7.5	Yes	No	ALL
RAF/543/1107	2	SU 719 096	05 NOV 1960	10000	Black and White 8.25 x 7.5	Yes	No	ALL
RAF/543/1107	3	SU 725 095	05 NOV 1960	10000	Black and White 8.25 x 7.5	Yes	No	ALL
MAL/60444	85381	SU 701 091	14 OCT 1960	6000	Black and White 9 x 9	Yes	No	N/A
MAL/60444	85382	SU 703 096	14 OCT 1960	6000	Black and White 9 x 9	Yes	No	N/A
MAL/60444	85383	SU 705 101	14 OCT 1960	6000	Black and White 9 x 9	Yes	No	N/A
MAL/60444	85384	SU 707 106	14 OCT 1960	6000	Black and White 9 x 9	Yes	No	N/A
MAL/60444	85385	SU 709 111	14 OCT 1960	6000	Black and White 9 x 9	Yes	No	N/A
MAL/60444	85392	SU 722 115	14 OCT 1960	6000	Black and White 9 x 9	Yes	No	N/A
OS/63016	70	SU 702 108	12 APR 1963	7500	Black and White 9 x 9	Yes	No	N/A
OS/63016	71	SU 701 102	12 APR 1963	7500	Black and White 9 x 9	Yes	No	N/A
OS/63016	72	SU 699 095	12 APR 1963	7500	Black and White 9 x 9	Yes	No	N/A
OS/63016	106	SU 711 092	12 APR 1963	7500	Black and White 9 x 9	Yes	Yes	SW, NW, SE, NE

Sortie number	Frame number	Centre point (in OS National Grid)	Date	Scale 1:	Film details (in inches)	Reviewed by Atkins?	Reviewed by Arup?	Area of Site (NW/SW/NE/SE)
OS/63016	107	SU 712 099	12 APR 1963	7500	Black and White 9 x 9	Yes	Yes	SW, NW, SE, NE
OS/63016	108	SU 713 105	12 APR 1963	7500	Black and White 9 x 9	Yes	Yes	NW, NE
OS/63016	109	SU 714 111	12 APR 1963	7500	Black and White 9 x 9	Yes	No	N/A
OS/63016	124	SU 725 107	12 APR 1963	7500	Black and White 9 x 9	Yes	No	N/A
OS/63016	125	SU 724 100	12 APR 1963	7500	Black and White 9 x 9	Yes	No	N/A
OS/63016	126	SU 723 094	12 APR 1963	7500	Black and White 9 x 9	Yes	No	N/A
MAL/63568	107758	SU 712 090	27 FEB 1963	11300	Black and White 9 x 9	Yes	Yes	SW, SE, NE, NW
MAL/63568	107759	SU 723 090	27 FEB 1963	11300	Black and White 9 x 9	Yes	Yes	SW, SE, NE, NW
MAL/63568	107760	SU 733 090	27 FEB 1963	11300	Black and White 9 x 9	Yes	Yes	SE
MAL/65008	177	SU 725 084	12 MAR 1965	11000	Black and White 9 x 9	No	Yes	
MAL/65009	5	SU 707 091	12 MAR 1965	11000	Black and White 9 x 9	Yes	Yes	NW, SW
MAL/65009	6	SU 717 091	12 MAR 1965	11000	Black and White 9 x 9	Yes	Yes	NW, SW, SE, NE
MAL/65009	7	SU 728 091	12 MAR 1965	11000	Black and White 9 x 9	Yes	Yes	NW, SW, SE, NE
MAL/66076	17	SU 699 089	29 NOV 1966	3000	Black and White 9 x 9	Yes	No	N/A
MAL/66076	24	SU 699 090	29 NOV 1966	3000	Black and White 9 x 9	Yes	No	N/A
MAL/66076	39	SU 701 104	29 NOV 1966	3000	Black and White 9 x 9	Yes	No	N/A
MAL/67081	73	SU 725 088	26 AUG 1967	11000	Black and White 9 x 9	Yes	Yes	
MAL/67081	74	SU 716 088	26 AUG 1967	11000	Black and White 9 x 9	Yes	Yes	
MAL/67081	75	SU 707 089	26 AUG 1967	11000	Black and White 9 x 9	Yes	Yes	
MAL/67082	97	SU 709 088	26 AUG 1967	11000	Black and White 9 x 9	Yes	Yes	NW, SW
MAL/67082	98	SU 719 088	26 AUG 1967	11000	Black and White 9 x 9	Yes	Yes	NW, SW, SE, NE
MAL/67082	99	SU 729 088	26 AUG 1967	11000	Black and White 9 x 9	Yes	Yes	NW, SW, SE, NE
OS/69258	419	SU 709 105	11 JUN 1969	7200	Black and White 9 x 9	Yes	Yes	NW, SW
OS/69258	420	SU 707 114	11 JUN 1969	7200	Black and White 9 x 9	Yes	No	N/A
OS/70122	89	SU 704 089	20 MAY 1970	5000	Black and White 9 x 9	Yes	No	N/A
OS/70122	90	SU 704 093	20 MAY 1970	5000	Black and White 9 x 9	Yes	No	N/A
OS/70122	91	SU 704 097	20 MAY 1970	5000	Black and White 9 x 9	Yes	No	N/A
OS/70122	92	SU 704 100	20 MAY 1970	5000	Black and White 9 x 9	Yes	No	N/A
OS/70122	93	SU 704 104	20 MAY 1970	5000	Black and White 9 x 9	Yes	No	N/A
OS/70122	94	SU 703 109	20 MAY 1970	5000	Black and White 9 x 9	Yes	No	N/A
MAL/81016	159	SU 716 111	03 JUN 1981	10000	Black and White 9 x 9	Yes	No	NE, NW
MAL/81016	160	SU 725 112	03 JUN 1981	10000	Black and White 9 x 9	Yes	No	N/A
MAL/81012	73	SU 714 081	07 MAY 1981	10000	Black and White 9 x 9	Yes	No	N/A
MAL/81012	74	SU 723 081	07 MAY 1981	10000	Black and White 9 x 9	Yes	No	N/A
MAL/81012	211	SU 722 100	07 MAY 1981	10000	Black and White 9 x 9	Yes	Yes	
MAL/81012	212	SU 713 100	07 MAY 1981	10000	Black and White 9 x 9	Yes	Yes	
OS/96535	23	SU 705 095	20 APR 1996	7700	Black and White 9 x 9	Yes	No	NW, SW
OS/96535	24	SU 710 095	20 APR 1996	7700	Black and White 9 x 9	Yes	Yes	
OS/96535	25	SU 715 094	20 APR 1996	7700	Black and White 9 x 9	Yes	Yes	
OS/96535	26	SU 720 094	20 APR 1996	7700	Black and White 9 x 9	Yes	Yes	
OS/96535	27	SU 725 094	20 APR 1996	7700	Black and White 9 x 9	Yes	No	
SU 7109 / 1	2					YES	No	SW/SE
SU 7208 / 1						YES	No	-
SU 7209 / 1	3					YES	No	SW
SU 7209 / 2						YES	No	

Appendix A10.2 Desk Study Report.

Appendix D Sources of Information

Appendix D.1 Data and Surveys

Data set / Survey	Date published / prepared	Revision	Author	Description	Purpose	Suitability
Pre-Pilling Surveys Ltd - Soil Sample Results Etc.pdf	1962?	-	Pre-Piling Surveys Ltd	Borehole records.	Borehole records (20 no.).	Survey relevant to the ongoing evaluation of the geology and hydrogeology of the reservoir site. Strata descriptions are variable and based on the standard of the time and by several persons (based on the handwriting). No geological designation. Limited / variable reporting of groundwater during drilling and no monitoring instruments installed.
Site Investigation for Havant Thicket for Portsmouth & Gosport Water Company	1962?	-	Pre-Piling Surveys Ltd	Results of tests as follows: Consolidation tests on undisturbed and compacted samples, Standard Proctor compaction tests, Index property tests, Grading Analyses	General parameters of the ground.	Suitable but subject to reassessment
Results of Triaxial Tests for Proposed Reservoir, Havant Thicket, Hampshire	1962?	-	Pre-Piling Surveys Ltd	Summary and results of Triaxial tests	Strength parameters of the ground.	Suitable but subject to reassessment
Technical Report on Reservoir Investigation, East Hampshire 1977 - 78	1979?	-	Mander, Raikes and Marshall (MRM)	To present the results of the site investigations carried out in connection to Sites 15, 17, 18, 19 & 20, and to discuss the technical and economic problems associated with each development.	Havant Thicket is Site 18. Report contains: trial pit records (42 no.) by MRM, sample descriptions by MRM, laboratory testing summaries and groundwater monitoring for 1977 to 1979 (includes additional monitoring by MRM).	Survey relevant to the ongoing evaluation of the geology and hydrogeology of the reservoir site. Sample description is by MRM and may be at variance with the FEL borehole description as by splitting the sample more strata fabric detail can be recorded. Strata description are very detailed (dip/strike and persistence of shear planes) in some of the trial pits. This detail can only be achieved by man-entry but the records do not state this. Therefore, it is unknown if strata which is described with no shear planes was because there was no man-entry and hence the extent of shearing is unknown.
Southern Water Authority, East Hampshire Reservoir Contract Nos 3, 3A, 3B, Havant Thicket, site 18, Factual Report on Site Investigation (CF869/1640/1766)	Feb 1980	-	Foundation Engineering Limited (FEL)	Factual ground investigation report carried out for Southern Water Authority on the instructions of Mander, Raikes and Marshall, consulting Engineers and Hydrogeologists.	Report contains borehole records (10 no.): 18/1 to 18/4 (1977 and 18/B1 to 18/B6 (1978-79) with laboratory tests as follows: index property tests, grading analyses, specific gravity, consolidated undrained triaxial compression tests, shear box tests, Standard Proctor compaction tests and MCV tests.	Survey relevant to the ongoing evaluation of the geology and hydrogeology of the reservoir site. Strata descriptions are based on the standard at the time: CP 2001:1957[19] and laboratory testing on BS 1377:1967[20]. No geological designation. Variable reporting of groundwater during drilling. Monitoring instruments were installed; but no groundwater monitoring data is included in this report.
Havant Thicket, Hampshire, **Factual Report on Ground Investigation**	Mar 2007	D6072, Issue 1	Soil Mechanics Ltd	Factual ground investigation report carried out for Portsmouth Water with Entec UK Ltd as the 'Engineer'. The aim of the site investigation was to obtain geotechnical information on the ground conditions across the site for the reservoir construction. This report presents the factual records of the field work and laboratory testing.	Report contains borehole records (4 no.) and trial pit records (4 no.) with laboratory testing as follows: index property tests, grading analyses, particle density, undrained triaxial compression tests, shear box tests, 'heavy' compaction tests.	Survey relevant to the ongoing evaluation of the geology and hydrogeology of the reservoir site. Strata descriptions are based on the standard at the time: BS 5930:1999[21] and laboratory testing on BS 1377:1990[22]. No geological designation or groundwater monitoring instruments installed. Band of soft clay and water strikes found within the Reading Formation which shall be investigated further.

[19] BS CP 2001 (1957) Site Investigation. BSI, London, 1957
[20] BS 1377:1967, Methods of test for soils for civil engineering purposes, BSI, London, 1967
[21] BS 5930:1999, Code of practice for site investigations, BSI, London, 1999
[22] BS 1377:1990, Methods of test for soils for civil engineering purposes, BSI, London, 1990

Data set / Survey	Date published / prepared	Revision	Author	Description	Purpose	Suitability
Geotechnical Handover Appendix B - Item 15 TN 7. Appendix B - Desk Study. Historical Boreholes Drawing 123755-20_001	01/02/08	P1	ARUP	Drawing showing Havant Thicket Winter Storage Reservoir Historical Boreholes.	Information drawing to show the historical borehole locations.	Suitable for use but need to verify the position of the boreholes shown.
Idsworth Well	2008	-	Portsmouth Water	Weekly water level monitoring data for 1932-2008. Also includes abstraction information.	To check for that groundwater movements in chalk mirror those during the1977-79 piezometer monitoring of the Harwich Formation	Suitable but data needs to be concurrent for the desk study and future design work. No units for the data is provided – needs to be confirmed with Portsmouth Water.
Geotechnical Handover Appendix B - Item 15 TN 7. Appendix D - Aerial Photographs	19/01/09	-	ARUP	Series of historical aerial photographs.	Package of aerial photographs.	Suitable as a starting point - more recent aerial photographs would need to be obtained.
Geotechnical Handover Appendix B - Item 15 TN 7. Appendix C - Geotechnical Information. Geology and Historic Boreholes Drawing 123755-20 Figure C1	13/02/09	Draft 1	ARUP	GINT overlay of historical borehole locations.	GINT overlay of historical borehole locations.	Suitable as a starting point - to be updated with current geological maps and available historical borehole locations.
Geotechnical Handover Appendix B - Item 15 TN 7. Appendix C - Geotechnical Information. Table C1	13/02/09	Draft 1	ARUP	Table C1 - Digest of soil properties.	Summary table of soil properties.	Suitable as a starting point - to be updated following completion of proposed GI.
Geotechnical Handover Appendix B - Item 15 TN 7. Appendix C - Geotechnical Information. Figures C2 to C9	13/02/09	Draft 1	ARUP	Figures showing geotechnical test data.	Summary figures of soil properties.	Suitable as a starting point - to be updated following completion of proposed GI.
Geotechnical Handover Appendix B - Item 15 TN 7. Appendix C - Geotechnical Information. Geology and Historic Boreholes Drawing 123755-20 Figure C1	16/02/09	P1	ARUP	Drawing showing Havant Thicket Winter Storage Reservoir Geology and Historical Boreholes.	Information drawing to show the geology and historical borehole locations.	Suitable as a starting point - to be updated with current geological maps and available historical borehole locations.
Geotechnical Handover Appendix C - Item 15 TN 8. Appendix B - Hydrogeological Desk Study. Hydrogeological Report, Figures	16/02/09	Draft 11	ARUP	Series of four figures showing borehole location, geology plan, schematic geological cross-section and EA hydrograph data	Illustration figures for the hydrogeological desk study.	Suitable as an initial starting point – Figure 4 will need updating with recent monitoring.
Geotechnical Handover Appendix B - Item 15 TN 7. Appendix E - Geological Plans and Sections	Feb 2009	-	ARUP	Series of hand-drawn geological cross sections.	Series of hand-drawn geological cross sections.	Suitable as an initial starting point - will need updating with proper geological cross section drawings, including response zones, location of proposed structures and groundwater level information where available.
Havant Thicket Winter Storage Reservoir, Outline Plan	May 2009	V9	Portsmouth Water	Plan showing anticipated leisure activities at the reservoir site.	Identifies potential structures and wetlands zone where ground conditions are required to be known.	Suitable as starting point of proposed works for geological and hydrogeological assessment.
Reservoir Auxiliary Structures Layout, DWG_123755-WC-1000	1609/09	P3	ARUP	Plan showing ground level contours, embankment contours and location of reservoir ancillary structures.	Identifies potential structures where ground conditions are required to be known.	Suitable as starting point of proposed works for geological and hydrogeological assessment.
Havant Thicket Winter Storage Reservoir, Proposed Pipeline Route	21/05/12	-	Portsmouth Water	Plan showing current pipeline route from Bedhampton to reservoir site.	Shows where ground conditions are required to be known.	Suitable as starting point of proposed works for geological and hydrogeological assessment.
Aerial photographs	Various	-	Supplied by Portsmouth Water from various original sources	Collection of aerial photographs provided in digital format (jpeg, tif, bmp) including Sealand Aerial 2006 and Commission Air 2007	To identify ground features that may relate to geological features	Variable quality but suitable for review for desk study report.
Reservoir Embankment Contour Plan DRG_123755-WC-1002	Undated-	A1	ARUP	Plan showing reservoir embankment contours and borrow pit contours.	Identifies potential position of embankment and borrow pit where	Suitable as starting point of proposed works for geological and hydrogeological assessment. Contour height values are not shown.

Data set / Survey	Date published / prepared	Revision	Author	Description	Purpose	Suitability
					ground conditions are required to be known.	
Public Consultation Report (Arup Item 25). Groundwater diagram 3	-	-	ARUP	Regional groundwater contour map for the area, showing the location of the reservoir.	Regional groundwater level and flow direction.	Not suitable as a starting point - no source references, age of image etc has been provided.
Previous ground investigation information near to reservoir site (supplied by Portsmouth Water)						
Borrow Land SI				Ground investigation information near to the reservoir site.	Back ground information on geology and hydrogeology to the north.	Suitable for providing geological context near the reservoir.
Factual Report (C6028)	18/07/18	01	CC Ground Investigations Ltd			
Ground Condition & Ground Investigation Report (42208/3501 R001 (GIR))	15/11/18	2	Peter Brett as part of Stantec			
Geophysical Survey Report (5708)	Dec 2017	2	Terra Dat			
Hazleton Farm SI info						
Various extracts from documents relating to the inquiry into the 'Proposed Landfill and Waste Recycling Facility, Hazleton Farm, Horndean	Aug 1997	-	Various			
Keyline – Land at Redhill Road, Rowlands Castle						
Site Investigation (2037-R100)	06/08/10	-	Structa			
Supplementary Site Investigation (2037-R101)	12/04/11	-	Structa			
Letter report on Additional Ground Investigation (2037-005)	05/05/11	-	Structa			
Land East of Horndean						
Geophysical Survey Report (J6794)	July 2014	-	StratsScan			
Contaminated Land & Geotechnical Desk Study	03/10/14	P02	Ramboll			
Geophysical Survey Report (5708)	Dec 17	2	Terra Dat			
Letter report on Geophysical Survey (42208/3501/CBH/RP/CE/AD/CW)	02/01/18	-	Peter Brett			
Factual Report (C6028)	18/07/18	01	CC Ground Investigations Ltd			
Ground Condition & Ground Investigation Report (42208/3501 R001 (GIR))	15/11/18	2	Peter Brett as part of Stantec			
Phase 1 Ground Condition Assessment	08/03/19	1	Peter Brett as part of Stantec			
Padnell Grange		-				
Phase II Ground investigation Report (16362/GIR)	Aug 2017		Soils Ltd			
Land east of Southleigh Forest SI						
Letter with extract from MJ Carter Associates report (ON/SO/MW/1191/01, July 2003)	23/07/03		Onyx UK Ltd			
Letter with extract from MJ Carter report (ON/SO/MW/1191/01a, July 2003)	25/11/05		Onyx UK Ltd			

Appendix A10.2 Desk Study Report.

Appendix D Sources of Information

Appendix D.2 Previous Assessments and Studies

Document	Date published / prepared	Revision	Author	Description	Purpose	Suitability
Geological Report on the proposed storage reservoir at Havant Thicket	18/12/62	-	Edgar Morton & Partner	Letter report on the results of the boreholes	Provides summary of the basic geology and problems caused by the London Clay Basal Beds (aka Harwich Formation).	Suitable as background data for geological and hydrogeological assessment. Reports bedrock strata dipping at ~1.5° to the south-southwest. Identifies London clay Basal Beds as an issue for seepage and embankment stability. No reporting of groundwater levels.
Proposed Storage Reservoir at Havant Thicket	30/03/63	-	Professor Peter W. Rowe	To present the results of their soil mechanics tests and their influence on the design and construction of a 60 ft high earth embankment.	Provides a summary of the strength testing undertaken on the London Clay, an outline design and construction of the embankment.	Suitable as background data for understanding the issues with design and construction of the embankment. Identifies the low strength of the near surface London Clay and silt laminations beneath the embankment foundation as design and construction issues.
Technical Report on Reservoir Investigation, East Hampshire 1977 - 78	Feb 1978?	-	Mander, Raikes & Marshall (MRM)	To present the results of the site investigations carried out in connection to Sites 15, 17, 18, 19 & 20, and to discuss the technical and economic problems associated with each development.	Engineering report on five sites in East Hampshire around Havant including Site 18 (Havant Thicket) and reports on the 1977 ground investigation (boreholes 18/1 to 18/4) methodology. Includes summaries of the laboratory data. sample descriptions by MRM and groundwater monitoring for 1977.	Suitable as general background to the geology and hydrogeology assessment. As it is a comparison report a standard embankment cross-section is used across the five sites but noting the two issues (low strength material and the London Clay Basal Beds) at Site 18 may influence the result.
Southern Water Authority, General Report on Reservoir Investigations, Hampshire 1975-78 (Draft Copy)	Feb 1978	-	Mander, Raikes & Marshall	To summarise and correlate the results of two inter-related studies of potential reservoir sites, one group in the Test and Itchen Valleys and the other in the Portsmouth area of supply in East Hampshire.	Summary Engineering Report of two engineering reports for different areas, one of which includes Site 18 (Havant Thicket).	Suitable as general background to the geology and hydrogeology assessment. Acknowledges Prof Rowe's report of low strength London Clay and states that some of 1977 strength tests may also be suspiciously low. Unable to state if the low values are typical or sufficiently orientated to cause an embankment stability issue. Identifies the London Clay Basal Beds (Harwich Formation) as a second design problem being water bearing and artesian in the valley base beneath the embankment. Recommends both design issues to be part of a supplementary exercise.
Technical Report on Reservoir Investigation, East Hampshire 1977 – 78 (Extracts)	1979?	-	Mander, Raikes & Marshall (MRM)	To present the results of the site investigations carried out in connection to Sites 15, 17, 18, 19 & 20, and to discuss the technical and economic problems associated with each development.	Engineering report on five sites in East Hampshire around Havant including Site 18 (Havant Thicket) and reports on the 1977 ground investigation (boreholes 18/1 to 18/4) and the 1978-79 ground investigation (18/B1 to 18/B6). Includes trial pits and sample descriptions by MRM. Includes summaries of the laboratory data and groundwater monitoring for 1977-79. Note this report has same title as the report (possibly dated Feb 1978 and inferred from the MRM General Report of Feb 1978) but contains additional ground investigation results for Site 18. Only Site 18 data has been provided	Suitable as general background to the geology and hydrogeology assessment. As it is a comparison report a standard embankment cross-section is used across the five sites but based on the Site 18 additional ground investigation data the low strength material extent has not been confirmed as a design limitation and the cut-off required for the Basal Beds (Harwich Formation) is deemed a localised issue.

Document	Date published / prepared	Revision	Author	Description	Purpose	Suitability
Southern Water Authority, Reservoir Investigation – Hampshire, Report on Engineering Studies	Jan 1980	-	Mander, Raikes & Marshall	To compare and summarise the results of technical feasibility studies of potential reservoir sites, undertaken in conjunction with separate, but related work by the Southern Water Authority to study the implications of various resource allocation strategies.	The report compares two areas of potential reservoir sites and provides a self-contained summary of the feasibility studies and recommendations, describes the site investigation methods and a site by site evaluation as a potential reservoir site. Possible development, programme and costs of preferred sites is given. Includes groundwater monitoring for 1979 from the installed piezometer instruments. Note: provided with extracts from report – Part I, Part II, Part III.4, Figs III 4.1 to III 4.6	Suitable as general background to the geology and hydrogeology assessment. Asserts that the findings agree with the geological map of the reservoir site area. Provides more description of the ground conditions especially in the trial pits of the shear zones and planes. States no evidence of valley bulging present beneath the embankment. Also states that any permeable material between the low permeability London Clay and Reading Beds is described in the report as Basal Beds.
Details of pumping test interruptions and their effect on analysis	13/03/06	-	Entec	Technical note on the pumping test interruptions for the Newtown Constant Rate Test; Lowe Upham Step Test and Constant Rate Test and Aldingbourne Constant Rate Test.	To present technical information to support additional cost requirements.	Suitable for information on the historical pumping tests.
Havant Thicket Reservoir, Winter Storage Reservoir, Engineering Study – Options Review & Initial Engineering Assessment (Draft Final)	03/04/06	005	Mouchel Parkman	To summarise the key engineering and geotechnical issues associated with the location and design of the Havant Thicket Winter Storage Reservoir and associated pipeline, identify additional investigation and survey work and to update the outline scheme costs. Report produced on behalf of Entec for Portsmouth Water.	The report indicates that the Havant Thicket site appears to be the most suitable location for a reservoir in the area. However, the geotechnical review concluded that the data is incomplete and further investigation work is required.	Suitable as it contains information relating to geology and laboratory testing summary data subject to noting the Portsmouth Water comments and observations. The MRM Report containing the trial pit records is not a document recorded as being reviewed. Reports lists key geotechnical problems as: (1) low strength and slickensided material with shear surfaces in the embankment foundation, (2) presence of higher permeability London Clay Basal Beds beneath the embankment and within the reservoir basin, (3) uplift pressures from localised artesian groundwater conditions and (4) variable fill material properties noting that the insitu water content is greater than the optimum water content form the Proctor compaction test.
Portsmouth Water Limited, Havant Thicket Winter Storage Reservoir, Comments on Mouchel Parkman Report 3rd April 2006, Revision 005	12/05/06 File last modified date	-	Portsmouth Water	Comments on the Mouchel Parkman April 2006 report on options and engineering assessment.		To be used in conjunction with the Mouchel Parkman 'Engineering Study – Options Review & Initial Engineering Assessment' report, dated 03/04/06.
Portsmouth Water Limited, Havant Thicket Winter Storage, Engineering Study, Phase 1 Final Report	Aug 2006	5	Entec UK Limited	Comprises a review of the Company's water resources plan; to ensure that there is a clear and robust 'statement of need' for the Havant Thicket scheme, and that this particular scheme forms part of the least cost solution.	The key output from this work is an update to Portsmouth Water's 'baseline' and 'final plan' AMP4 supply-demand balance estimates for the period 2005-2030.	Not suitable. Contains no geology or hydrogeology information.
Portsmouth Water Limited, Havant Thicket Winter Storage, Engineering Study, Final Phase Two Report	Oct 2006	-	Entec UK Limited	Comprises a range of engineering and environmental investigations of the Havant Thicket proposals that are necessary now to ensure the scheme can be delivered on time, assuming	Engineering review of the past proposals for the Havant Thicket reservoir with minor adjustments for more detailed topography data and environmental constraints.	Suitable as general background to the geology and hydrogeology assessment. Reports lists key geotechnical problems as per the Mouchel Parkman report (dated 03/04/06) but includes seismic hazard study. Recommends a staged ground investigation, the first in relation to the EIA

Document	Date published / prepared	Revision	Author	Description	Purpose	Suitability
				Havant Thicket is part of the preferred solution.		to determine the material characteristics and available volume of material to construct the embankments. The second stage is to support the design of the reservoir in relation to the identified key geotechnical problems.
Portsmouth Water Limited, Havant Thicket Winter Storage, Embankment Material Investigations	10/04/07	-	Entec UK Limited	To review the available volumes and material properties of the near surface formations within the basin of the proposed Havant Thicket Reservoir and the assessment of these in the context of the likely requirements for embankment construction.	Review of various options for the Havant Thicket reservoir based on available material from an on-site borrow pit. Note: document is missing Figure 2.1.	Suitable as general background to the material characteristics of the London Clay and Reading Formation and provides a listing of the principles that future ground investigations are to address.
Entec 2007 Fig2.1 borrow pit DEST40023	2007	-	Entec UK Limited	Location of borrow pit Figure 2.1 which is missing from the Entec report 'Embankment Material Investigations'.	Entec's borrow pit location used to generate volume of materials.	Suitable as general background to the geology and hydrogeology assessment.
Geotechnical Handover Appendix B - Item 15 TN 7. Geological Setting	17/10/08		ARUP	Summary of desk study and previous investigations.	Summarise the regional and local geological setting of the reservoir site and includes a desk study on the available information and aerial photograph interpretation.	Suitable as a starting point for the geology and hydrogeology assessment of the reservoir, however it will require updating with currently available information, noting the Portsmouth Water Feedback comments and observations. Key updates may include: • The inclusion of the trial pits (42 no) excavated by Mander, Raikes and Marshall. • Assessing the existing geotechnical data and providing preliminary design parameters. • Consideration of sinkholes. • Outlining a conceptual site model ((CSM) in relation to contamination issues.
Geotechnical Handover Appendix E - Item 15 TN 10. Phases of ground investigation	02/12/08 Unfinished	Draft 1	ARUP	This report describes the risk of unknowns not being resolved prior to planning.	Highlights further GI that is required to answer the list of unknowns.	Suitable as a starting point to highlight the unknowns. Table compares Arup GI design with unknowns and whether information will be achieved to solve each.
Geotechnical Handover Appendix B - Item 15 TN 7. Geological Setting Appendix D - Aerial Photograph Interpretation	19/01/09	-	ARUP	Havant Reservoir Aerial Photography Interpretation.	An aerial photographic interpretation (API) was undertaken to determine the site history and assess potential features of engineering geological concern.	Suitable as a starting point for understanding the site history for geomorphological features and contamination purposes. Key updates may include: • Any identified feature being marked on a plan. • View all available photographs from Portsmouth Water and Historic England.
Geotechnical Handover Appendix F - Item 15 TN 11. Preliminary Specification for Work	10/02/09 Unfinished	Draft 1	ARUP	Preliminary specification of works with costings.	Summarising and pricing GI that would address unknowns for detailed design highlighted in TN9 and TN10.	Not suitable for use. Numerous incomplete documents. Will need to be re-drafted for any proposed and agreed additional GI.
Geotechnical Handover Appendix C - Item 15 TN 8. Groundwater in the Area	16/02/09	Draft 1	ARUP	Report summarising the hydrogeological setting of the reservoir.	The aim of the report is to provide a summary of groundwater levels and potential water tightness of the	Suitable as a starting point. Information contained within will require updating for use.

Document	Date published / prepared	Revision	Author	Description	Purpose	Suitability
					geological strata beneath the reservoir site.	
Geotechnical Handover Appendix D - Item 15 TN 9. Geological and Geotechnical Unknowns	02/03/09	Draft 3	ARUP	Technical note listing and briefly describing all unknowns relative to design of the reservoir. Water tightness & availability of materials.	This technical note seeks to identify the unknowns relating to the water tightness, availability and nature of material for the embankment and the near-surface ground conditions beneath the embankment.	Suitable as a starting point to highlight the unknowns. Describes the design principles (as an overview), then lists the unknowns (29 no.) with some details on each. Good summary.
Geotechnical Handover Appendix C - Item 15 TN 8. Appendix B - Hydrogeological Desk Study. Hydrogeological Report	07/04/09	Issue	ARUP	Reviews the regional and local hydrogeological regime.	The aims of this study are to provide an understanding of the hydrogeological system at Havant Thicket to inform design of the embankment dam and reservoir.	Suitable as a starting point - needs to be updated, taking account of the comments made in the Portsmouth Water handover responses. Key updates may include: • All necessary drawings required to support the information presented in desk study, including cross sections and groundwater contour maps. • Consideration of sinkholes. • Consideration of the Idsworth Well monitoring data. • Discussion of gradients in the chalk is outdated (1979 and 1997 report referenced), this could be updated with Portsmouth Water info or a review of regional models if available. • Interpretation of pumping test results. • Further seepage analysis. • Assessment of leakage from potential pingos (or other geological features).
Portsmouth Water, HTWSR, Geotechnical Handover Report, DRAFT 1	29/09/09	Draft 1	Ove Arup & Partners Ltd	Includes: TN7 – Geological Setting, TN8 – Groundwater in the Area, TN9 – Geological and Geotechnical Unknowns, TN10 – Phases of Ground Investigation & TN11 – Design of Ground Investigation.	To provide information for the re-commencement of the scheme at some point in the future.	Suitable as a starting point for the geology and hydrogeology assessment of the reservoir subject to noting the Portsmouth Water Feedback Report 4 comments and observations. Further observations on TN7 to TN11 are included below.
Portsmouth Water Ltd Havant Thicket Winter Storage Reservoir Environmental Impact Assessment	October 2009 - unfinished	2	ARUP	This report provides a draft Environmental Statement.	ES draft.	Suitable as a starting point for understanding the ground contamination and hydrogeology of the reservoir site. This will require updating, noting the feedback from Portsmouth Water.
Havant Thicket Winter Storage, Reservoir Project, Portsmouth Water Feedback, Report 4, Geotechnical Engineering	Oct 2010	-	Portsmouth Water	Review and comments of the geotechnical engineering work submitted by Arup in the 'Geotechnical Handover Reports	Notes for future project restart.	To be used in conjunction with the Arup Geotechnical Handover Report
Havant Thicket Winter Storage Reservoir Site, Site History Information	14/03/12	Final Version	Portsmouth Water	Collation of the history of the HTWSR site.	To illustrate: (a) the history of the reservoir development site, and (b) the extent to which the habitat has changed through time.	Suitable as starting point for identification of geological and hydrogeological features as shown on historical maps. Understanding of site history will require updating using historical maps from an Envirocheck and available aerial photographs.

Appendix A10.2 Desk Study Report.

Appendix E Preliminary Conceptual Site Model

Preliminary Conceptual Site Model

Introduction

Land contamination has been assessed through the identification and assessment of Potential Contaminant Linkages (PCLs). The approach adopted by Atkins is in accordance with the Contaminated Land Exposure Assessment (CLEA) model produced by Defra and the Environment Agency and as outlined in Contaminated Land Report (CLR) 11 [51].

CLR11 provides a technical framework for identifying and remediating contamination through the application of a risk management process. The question of whether risk is unacceptable in any particular case involves not only scientific and technical assessments, but also appropriate criteria by which to judge the risk and conclude the level of risk which would be unacceptable based on current guidance documents.

This assessment involves the development of a conceptual site model which describes the source-pathway-receptor relationship between potential sources of contamination and associated contaminants. This includes contaminants from both on-site and off-site sources, receptors to such contamination (humans, controlled water (groundwater/surface water), ecological systems (flora and fauna of conservation designations) and property, as well as potential pathways between the sources and receptors. If all three are present or considered likely to be present, they are described as potential contaminant linkages which can be subject to the risk assessment process.

A Preliminary Risk Assessment has been completed in accordance with CLR11 and has been based on the desk study information described in the preceding sections.

It should be noted that under current health and safety legislation, construction and maintenance workers are required to carry out appropriate risk assessments and instigate appropriate mitigating measures to protect themselves, other human receptors and the environment from contamination that may be present. Such risks must be adequately mitigated by the measures required under current legislation, specifically the Construction Design Management (CDM) Regulations [52], which requires that potential risks to human health and the environment from construction activities are appropriately identified and all necessary steps taken to eliminate / manage that risk. On this basis, it been assumed that personal protective equipment (PPE) and health and safety best practices will be adopted during the construction works and acute risks to construction workers / site visitors during construction have therefore not been considered as part of this assessment.

Risk Estimation

Through consideration of the potential consequence and likelihood of exposure occurring, a potential risk rating for each PCL has been assigned and is presented in Section 8.1. The purpose of this assessment is to focus upon the potential risks present based on the proposed development, post construction with no mitigation measures. The definitions of estimated risk are taken from CIRIA report C552 [53] and have been summarised in Table E-1 below.

Table E-1 - Definitions of Estimate Risk

Risk Level	Definition
Very High Risk	There is a high probability that severe harm could arise to a designated receptor or there is evidence that severe harm to a designated receptor is currently happening. This risk, if realised, is likely to result in a substantial liability. Urgent investigation (if not already undertaken) and remediation are likely to be required.
High Risk	Harm is likely to arise to a designated receptor. Realisation of the risk is likely to present a substantial liability. Urgent investigation (if not already undertaken) is required and remedial works may be necessary in the short term and are likely over the long term.
Moderate Risk	It is possible that harm could arise to a designated receptor. However, it is either relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild. Investigation (if not already undertaken) is normally required to clarify the risk and to determine the potential liability. Some remedial works may be required in the long term.

Risk Level	Definition
Low Risk	It is possible that harm could arise to a designated receptor, but it is likely that this harm, if realised, would be mild. Further investigation is not necessarily required, however should be considered to confirm that there is no unanticipated contamination present.
Very Low Risk	The possibility of harm to the designated receptor is either not plausible or, if the possibility of harm is plausible, risk is considered to be very unlikely with attenuation along the exposure pathway. Further investigation is not necessarily required, however may be considered to confirm that there is no unanticipated contamination present.

The risk is evaluated through the probability matrix presented in Table E-2 below.

Table E-2 - Estimation of the level of risk by comparison of consequence and probability

	Consequence[23]				
Probability[24]		**Severe**	**Medium**	**Mild**	**Minor**
	High Likelihood	Very High Risk	High Risk	Moderate Risk	Moderate / Low Risk
	Likely	High Risk	Moderate Risk	Moderate / Low Risk	Low Risk
	Low Likelihood	Moderate Risk	Moderate / Low Risk	Low Risk	Very Low Risk
	Unlikely	Moderate / Low Risk	Low Risk	Very Low Risk	Very Low Risk

Preliminary Conceptual Site Model (PCSM)

Based upon the historical and present land uses identified in Section 2.3 and Section 6, a PCSM has been produced, identifying potential sources of contamination, migration or exposure pathways and receptors for the site.

The following sections are described in terms of the potential source – pathway – receptor PCLs, which are defined by interpretation of the information contained within this desk study and the details of the proposed development, correct at the time of writing.

Potential Contamination Sources

Based on the historical maps and the desk study information summarised in this report, the following potential sources of contamination have been identified as summarised in Table E-3. The list of activities and contaminants of concern listed in the table below should not be considered exhaustive and provides a guide to the likely range of contaminants that may be present at or around the site.

Table E-3 - Potential Contamination Sources

Location	Potential Source of Contamination	Potential Contaminants
On-site	Re-worked clay from pond excavation used in the construction of the Upper Lake and Upper Lake Weir. Re-worked site won material used during the construction of the Boat House and the George Canning Monument.	A range of inorganic and organic contaminants.
	Re-worked site won material used during the channelization of unnamed watercourses.	A range of inorganic and organic contaminants.
	Potentially contaminated ground from localised spills / leaks of hydrocarbons during past mechanical de-vegetation.	A range of inorganic and organic contaminants including heavy metals,

[23] Consequence – The result or effect of an event occurring
[24] Probability – The likelihood or frequency of an event occurring

Location	Potential Source of Contamination	Potential Contaminants
		hydrocarbons and Polyaromatic Hydrocarbons (PAHs).
	Potentially contaminated natural superficial strata from localised spills / leaks of hydrocarbons from previously observed dumped and burnt out cars or known motorbike use [47].	A range of inorganic and organic contaminants including heavy metals, hydrocarbons and PAHs including the potential for asbestos.
Off-site	Potentially contaminated ground and groundwater associated with the fuel station located 82m east of the site.	A range of inorganic and organic contaminants including heavy metals, hydrocarbons and PAHs.
	Made Ground of unknown provenance used for the infilling of surrounding brick, chalk and clay pits located between 100m and 350m to the south east of the site as well as potentially contaminated ground associated with the operation of the pits, brickfields and associated brickworks.	A range of inorganic and organic contaminants including the potential for asbestos and ground gas.
	Made Ground and potentially contaminated groundwater associated with the historical landfill located approximately 327m west of the site.	A range of inorganic and organic contaminants including heavy metals, hydrocarbons, PAHs, Polychlorinated Biphenyls (PCBs) including the potential for asbestos, leachate and ground gas.
	Made Ground of unknown provenance used in construction of housing estates to the east and south of the site.	A range of inorganic and organic contaminants including the potential for asbestos.
	Made Ground and potentially contaminated ground associated with the former Leigh Park battery located approximately 60m south of the site and the military base located 350m south of the site.	A range of inorganic and organic contaminants including heavy metals, hydrocarbons.
	Made Ground and potentially contaminated ground associated with the former allotments located approximately 250m southeast of the site.	A range of inorganic and organic contaminants including heavy metals, hydrocarbons, herbicides and pesticides.
	Made Ground and potentially contaminated ground associated with the Smithy located approximately 225m southeast of the site.	A range of inorganic and organic contaminants including heavy metals, hydrocarbons.

Potential Receptors and Pathways

The following potential receptors which are relevant to the current and future site use and potential contaminant exposure and migration pathways have been identified as outlined in Table E-4 below:

Table E-4 - Potential Receptors and Pathways

Receptor Group	Receptor	Potential Contaminant Migration Pathways
Human Health (on-site)	Current on-site users including members of the public using footpaths and trails.	Dermal contact / ingestion / inhalation of contaminants in soil and soil-derived dust; and Dermal contact / ingestion of contaminants in groundwater within excavations; and Inhalation of ground gas / vapours which may have migrated onto site from off-site sources.
	Future on-site users including reservoir operatives, maintenance workers and members of the public visiting the reservoir.	

Receptor Group	Receptor	Potential Contaminant Migration Pathways
Human Health (off-site)	Off-site workers and residents in surrounding commercial and residential areas.	Dermal contact with and ingestion of contaminants in soil-derived dusts and water that may have migrated off-site; and Inhalation of soil-derived dust and fibres which may have migrated off-site.
	Off-site visitors using the surrounding footpaths and parks.	
Controlled Waters: Surface Water	The proposed reservoir, unnamed watercourses, drains and the Upper Lake located on-site.	Leaching or dissolution of contaminants in soils and subsequent migration of contaminants; Lateral migration of dissolved phase contaminants via preferential pathways such as drains and low permeability strata horizons in the Harwich Formation and Bognor Sands; Lateral migration of dissolved phase contaminants in groundwater to surface water; and Migration of contaminants entrained in surface water runoff.
	Off-site watercourses, drains, ponds and The Lake within 500m of the site.	
Controlled Waters: Groundwater	Superficial Undifferentiated aquifer and bedrock Secondary A aquifers (on-site and off-site).	Leaching or dissolution of contaminants in soils and subsequent migration of contaminants in groundwater; Vertical migration of dissolved phase contaminants to the underlying groundwater; and Lateral migration of dissolved phase contaminants via preferential pathways such as drains and low permeability strata horizons in the London Clay / Harwich Formation and Bognor Sands.
	Chalk Principal aquifer (on-site and off-site).	
Property	Future below ground on-site infrastructure.	Direct contact of contaminated soils/water with infrastructure, services and structures and subsequent chemical attack; and Direct contact of migrating contaminated groundwater within infrastructure, services and structures.
	Off-site residential / commercial properties within surrounding 500m.	Migration of contaminated groundwater along strata and preferential pathways such as service routes or differentially permeable strata and subsequent chemical attack.
Ecological	Woodland (on-site and off-site) and County Park on-site.	Uptake of contaminants in soil and soil-derived dust; and Leaching / dissolution of contaminants from unsaturated soils followed by migration in groundwater / perched water.

Preliminary Conceptual Site Model (PCSM)

Table E-5 below presents the key information included in the PCSM prepared for the site in its current land use and for the future proposed development. The assessment has been undertaken using the following assumptions:

- Construction has been carried out in accordance with appropriate Health and Safety and environmental protection requirements.

Table E-5 - Preliminary Conceptual Site Model

Source	Receptor		Contaminant Exposure / Migration Pathway	Potential Consequence	Probability	Risk Classification	Comments
On-site • Re-worked site won material used during the construction of the Upper Lake, Upper Lake Weir, Boat House and the George Canning Monument • Re-worked site won material used during the channelization of unnamed watercourses • Potentially contaminated natural superficial strata from localised spills / leaks during past mechanical de-vegetation • Potentially contaminated natural superficial strata from localised spills / leaks from previously observed dumped and burnt out cars or motorbike use. Off-site • Potentially contaminated ground and groundwater associated with the fuel station located approximately 84m east of the site • Made Ground of unknown provenance	Human Health: On-site	Current on-site users including members of the public using footpaths and trails and future members of the public visiting the reservoir	Dermal contact / ingestion / inhalation of contaminants in soil and soil-derived dust Dermal contact / ingestion / of contaminants in groundwater within excavations Inhalation of ground gas / vapours which may have migrated onto site	Mild	Unlikely	Very Low Risk	Previous ground investigations undertaken at the site have not encountered Made Ground and potential on-site sources of contamination are considered to be localised with a limited likelihood of a pathway existing if present. No evidence of contamination or peat derived ground gas sources on site. Potential landfill ground gas sources off-site (former clay pits). However, risk to on-site receptors is very low due to impermeable strata in proximity to off-site sources and long distances (>100s m) to any proposed buildings. The site is predominately grassed / vegetated / wooded which reduces the risk of direct contact / ingestion of loose soils during normal use as the soil matrix is bound by vegetation roots. The area of the proposed development will be excavated, exposing bare soils and subsequently increasing the short-term risk of ingestion / inhalation of soil derived dust. However, off-site receptors are located significant distance from planned earthworks and the tree screening will remain in place in the west of the site (where the closest residential receptors are located), which reduces the risk from site derived dust reaching the residents. It is anticipated post construction vegetated areas with be returned to pre-construction condition and the reservoir lining materials will act as a barrier. Future visitors to the site may be frequent through transient movement across the site via public footpaths. Landscaped areas are presumed to be covered in grass / vegetation. It is unlikely that site users would routinely come into contact with bare soils.
		Future on-site users including reservoir operatives and maintenance workers		Mild	Low Likelihood[21] [25]	Low Risk	
	Human Health: Off-site	Off-site workers and residents in surrounding commercial and residential areas	Dermal contact with and ingestion of contaminants in soil-derived dusts and water that may have migrated off-site Inhalation of soil-derived dust and fibres which may have migrated off-site	Mild	Unlikely	Very Low Risk	
		Off-site visitors to surrounding footpaths and parks		Mild	Unlikely	Very Low Risk	

25 It has been assumed that risks to future site users including reservoir operatives and maintenance workers will be mitigated by the implementation of appropriate PPE.

Source	Receptor		Contaminant Exposure / Migration Pathway	Potential Consequence	Probability	Risk Classification	Comments
used for the infilling of surrounding brick, chalk and clay pits located between 100m and 350m to the south east of the site as well as potentially contaminated ground associated with the operation of the pits, brickfields and associated brickworks • Made Ground and potentially contaminated groundwater associated with the historical landfill located approximately 327m west of the site • Made Ground of unknown provenance used in construction of housing estates to the east and south of the site • Made Ground and potentially contaminated ground associated with the former Leigh Park Estate battery located approximately 60m south of the site and military base located approximately 350m south of the site • Made Ground and potentially contaminated ground associated with							Vegetated or hardcovered surfaced areas across the site means that off-site migration of dusts and soils are unlikely to occur. In addition, the surrounding area comprises either hardstanding or vegetation, which will reduce dust generation and therefore the limit the potential for ingestion and inhalation pathways to on-site receptors from off-site sources. Previous ground investigations undertaken at the site have not encountered Made Ground and the potential for ground gas generation from on-site sources is considered to be very low. In addition, the presence of the London Clay formation and the Lambeth Group clay will reduce the likelihood of lateral migration of ground gas / vapours from potential off-site sources (infilled clay, brick and clay pits) to occur. There is the potential for site users to come into contact with soils while operating the site or carrying out maintenance (e.g. vegetation clearance, maintenance of the reservoir and below ground infrastructure). Considering the likely hardstanding and vegetated cover and infrequent short-term access, the risk of direct contact and potential generation of dust is low. It is also assumed that any potential risks to ground workers would be managed through robust risk assessments to identify appropriate PPE and working methods.
	Controlled Waters: Surface water	The proposed reservoir, watercourses, drains and the Upper Lake located on-site.	Leaching or dissolution of contaminants in soils and subsequent migration of contaminants	Medium	Unlikely	Low Risk	The proposed works could result in the mobilisation of contamination in unsaturated soils, if present, through leaching/dissolution of, and subsequent migration into, the surface

Source	Receptor		Contaminant Exposure / Migration Pathway	Potential Consequence	Probability	Risk Classification	Comments
the former allotments located approximately 250m southeast of the site • Made Ground and potentially contaminated ground associated with the Smithy located approximately 225m southeast of the site		Off-site watercourses, drains, ponds and The Lake	Lateral migration of dissolved phase contaminants via preferential pathways such as drains and low permeability strata horizons in the Harwich Formation and Bognor Sands. Lateral migration of dissolved phase contaminants in groundwater to surface water. Migration of contaminants entrained in surface water runoff.				water features via migration in drainage and groundwater. It is assumed that engineered drainage will be present on the site which would intercept surface water runoff and reduce migration and infiltration of potential contaminants into the underlying soils although this is likely to be localised to hardstanding areas. Where excavation is required, consideration should be given to the potential for generation of preferential pathways during the works where contaminants may potentially leach from unsaturated soils into surface water. Controls should be implemented to mitigate this risk as far as is practicable. The presence of the London Clay formation and the Lambeth Group clay will reduce the likelihood of lateral migration of contaminated groundwater to occur. However, the installation of underground services as part of the development including access tunnels and shafts may create preferential pathways for migration. The superficial Secondary Undifferentiated aquifer and bedrock Secondary A aquifers directly underly the site and consideration should be given to the potential for generation of preferential pathways. However, it is noted that the geological units underlying the site dip towards the south, reducing the risk of contamination migrating onto site from potential off-site sources. However, controls should be implemented to mitigate this risk as far as is practicable.
	Controlled Waters Groundwater	Superficial Secondary Undifferentiated aquifer and bedrock Secondary A aquifers (on-site and off-site)	Leaching or dissolution of contaminants in soils and subsequent migration of contaminants in groundwater	Medium	Unlikely	Low Risk	
		Chalk Principal aquifer (on-site and off-site)	Vertical migration of dissolved phase contaminants to the underlying groundwater Lateral migration of dissolved phase contaminants via preferential pathways such as drains and low permeability strata horizons in the Harwich Formation and Bognor Sands	Medium	Unlikely	Low Risk	
	Property	On-site future below ground infrastructure	Direct contact of contaminated soils/water with infrastructure, services and structures and subsequent chemical attack	Minor	Unlikely	Very Low Risk	It is assumed that appropriate concrete classifications will be adopted for proposed underground structures and infrastructure as part of the design of the works.

Source	Receptor		Contaminant Exposure / Migration Pathway	Potential Consequence	Probability	Risk Classification	Comments
			Direct contact of migrating contaminated groundwater within infrastructure, services and structures				
		Off-site residential / commercial properties	Migration of contaminated groundwater along strata and preferential pathways such as service routes or differentially permeable strata and subsequent chemical attack.	Minor	Unlikely	Very Low Risk	
	Ecological	Woodland (on-site and off-site) and County Park on-site	Uptake of contaminants in soil and soil-derived dust Leaching / dissolution of contaminants from unsaturated soils followed by migration in groundwater / perched water	Minor	Unlikely	Very Low Risk	The site is predominately grassed / vegetated / wooded, which reduces the risk of direct contact / ingestion of loose soils during normal use as the soil matrix is bound by vegetation roots.

Summary

Based on the PCSM, potential risks to human health, property, controlled waters and ecological receptors have been identified as very low to low risk, dependent on implementation of mitigation measures. Previous ground investigations undertaken at the site have not encountered Made Ground and potential on-site sources of contamination are considered to be localised with a limited likelihood of a pathway existing if present.

Potential on-site sources of contamination include reworked ground associated with historic construction, de-vegetation activities and the channelization of watercourses and potential spills / leaks associated with burnt out cars. Potential off-site contamination sources include Made Ground / contaminated ground and groundwater associated with a fuel station, historical landfills, infilled former brick, chalk and clay pits, allotments, a smithy and a former battery and military base.

Although previous ground investigations undertaken at the site have not identified the presence of Made Ground, no chemical testing has been undertaken to date. In order to provide information on the baseline conditions at the site and to inform soil re-use / materials management for detailed design, it is recommended that an additional ground investigation is undertaken at the site to include environmental testing. The ground investigation should be designed to provide a broad coverage of exploratory holes across the site and to target localised areas of potential contamination to confirm the contamination status of the site and to verify the suitability of material for re-use as part of the proposed development.

The proposed ground investigation should include environmental sampling of soil and groundwater, groundwater monitoring and chemical laboratory analysis. The resulting data should then be used to undertake a generic quantitative risk assessment (GQRA). Laboratory testing should comprise a range of metals, metalloids, asbestos, inorganic and organic determinants relevant to the contaminants likely to be associated with identified current and historical land uses. In the event that soils are to be removed off-site as waste, appropriate waste classification should be undertaken. Material to be reused on-site as part of the development, should be managed under an appropriate scheme such as the CL:AIRE Definition of Waste: Code of Practice to demonstrate its suitability for reuse.

Appendix A10.2 Desk Study Report.

Appendix F Reservoir Envirocheck Report

Refer to:

ES_Volume_4_Appendix A10.2_Appendix_F

Appendix A10.2 Desk Study Report.

Appendix G Preliminary Unexploded Ordnance (UXO) Threat Assessment

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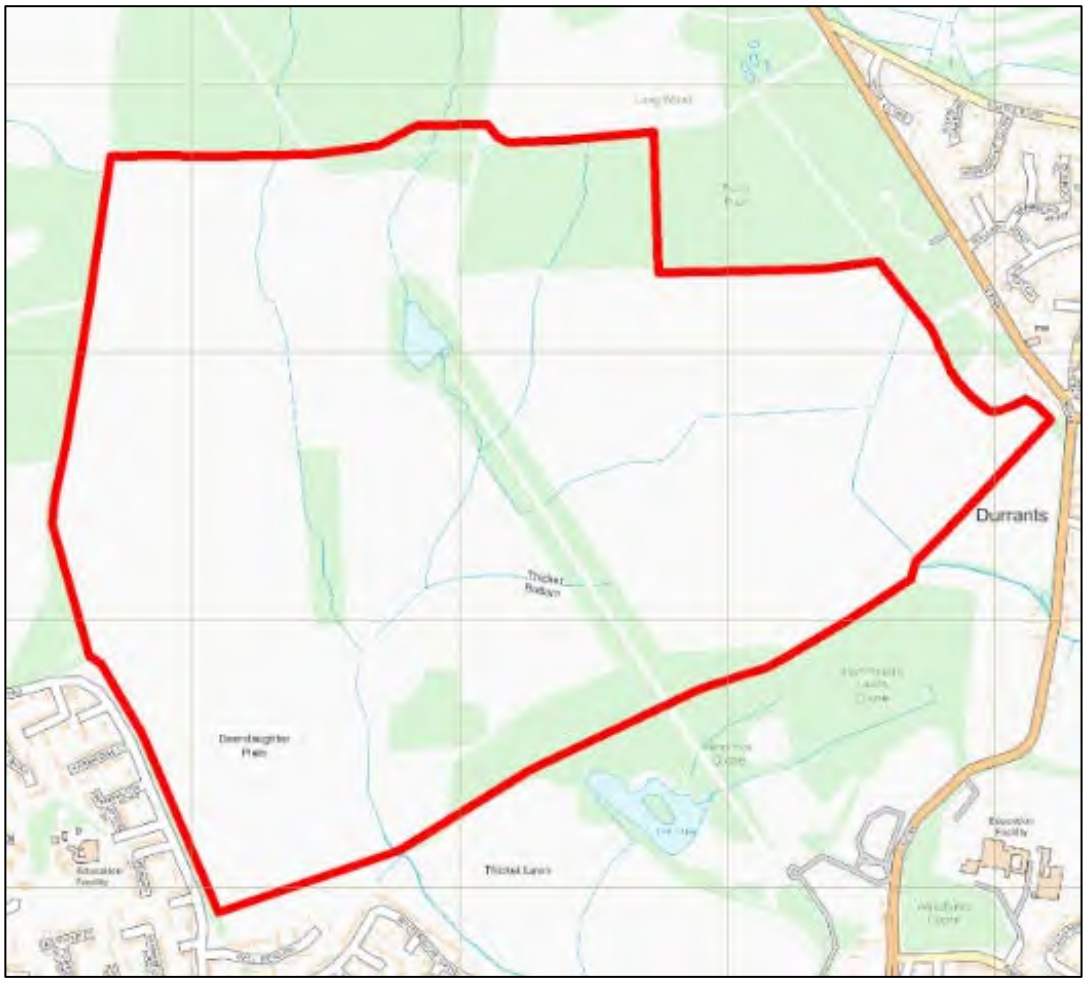
PRELIMINARY UNEXPLODED ORDNANCE (UXO) THREAT ASSESSMENT

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



6 ALPHA PROJECT NUMBER	P7345	**ORIGINATOR**	S. Barratt
LANDMARK ORDER NUMBER	202758520_1	**REVIEWED BY**	C. Cole (7th May 2019)
CLIENT REFERENCE	5169117	**RELEASED BY**	R. Bullock (7th May 2019)
SITE	Site at 472000, 110000		
RECOMMENDATION	This Site requires a Detailed UXO Threat and Risk Assessment		

STUDY SITE

The Study Site is described as "Site at 472000, 110000" and it is centred on National Grid Reference 471510, 109770.

THREAT POTENTIAL AND RECOMMENDATIONS

The potential for a UXO hazard to occur, and more specifically, the potential for unexploded WWI and WWII ordnance to exist at this site is assessed as being LIKELY (*Figure 2*).

In accordance with *CIRIA* C681 Chapter 5 on managing UXO risks, *6 Alpha* recommends that the next stage in the risk management framework is:

DETAILED UXO THREAT & RISK ASSESSMENT

We would be pleased to provide this service, please contact *Envirocheck* for further details:

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REPORT SUMMARY

During WWII, the Study Site was situated within *Petersfield Rural District*, which recorded two High Explosive (HE) bomb strikes per 100 hectares; a very low level of bombing.

Luftwaffe aerial reconnaissance photography associated with the Site did not identify any primary bombing targets within 1,000m of the Site boundary.

Neither *Air Raid Precaution* (ARP) records nor official bomb damage mapping were available. Nonetheless, further research identified that a total of six HE bomb strikes were identified within *Havant Thicket* (potentially on-site).

Further research identified that *Havant Thicket* forest (located on-site) was used by the army to house troops, equipment, vehicles and tanks before the invasion of Europe during WWII.

Given that a military camp was identified on-site and bomb strikes were identified potentially on-site during WWII; it would suggest that further action is warranted to address the potential for UXO encounter.

USING THIS REPORT

This Preliminary Assessment is designed to inform environmental and construction professionals of the potential threat of military related explosives and/or ordnance on, or in, the vicinity of the Study Site.

This assessment is designed to be employed as a site-screening tool to meet with the requirement of Phase One of the *CIRIA UXO Risk Management Framework*; there are two broad prospective outcomes; either the threat level requires a detailed threat & risk assessment; or no further action is required. In the former instance we can provide a report within 10 working days (or more quickly upon application).

Two figures accompany the report, the *Second World War* (WWII) High Explosive (HE) Bomb Density and the final Probability of UXO Encounter. The purpose of this approach is to demonstrate that whilst bomb density statistics give an indication for WWII bombing, they should not be relied upon exclusively to generate a holistic assessment.

For further information, please contact *Envirocheck*:

Website: http://www.envirocheck.co.uk

Telephone: +44 (0)844 844 9952

Email: customerservice@envirocheck.co.uk

DATA FINDINGS

Threat Source (within 1,000m)		Detail	
		Identified	Comments
	Airfields/Military Facilities	✗	*D-Day Marshalling Camp* (on-site).
	Ordnance Manufacture/Storage	✗	None recorded within 1,000m.
	WWII Decoy Bombing Sites	✗	None recorded within 1,000m.
	WWII Defensive Features	✓	A heavy anti-aircraft battery (660m south-east).
	WWII *Luftwaffe* Designated Bombing Targets	✗	*Luftwaffe* aerial photography did not identify any primary bombing targets within 1,000m.
	WWII Bomb Strikes Within Site Boundary	✓	Further research identified that a total of 6 HE bomb strikes fell within *Havant Thicket* (potentially on-site).
	WWII Bomb Strikes Near Site Boundary	✗	ARP records were not available.
	WWII Bomb Damage	✗	Official bomb damage mapping was not available.
	Abandoned Bomb Register	✗	The official abandoned bomb list did not identify any abandoned bombs within 1,000m.
	Potential Threat Sources	✓	The most probable UXO threat is posed by LSA/SAA/AXO and WWII *German* HE bombs.
	WWII Bombing Density Per 100 Hectares	✓	The Site was located within *Petersfield Rural District*, which recorded two HE bomb strikes per 100 hectares.

IMPORTANT NOTES

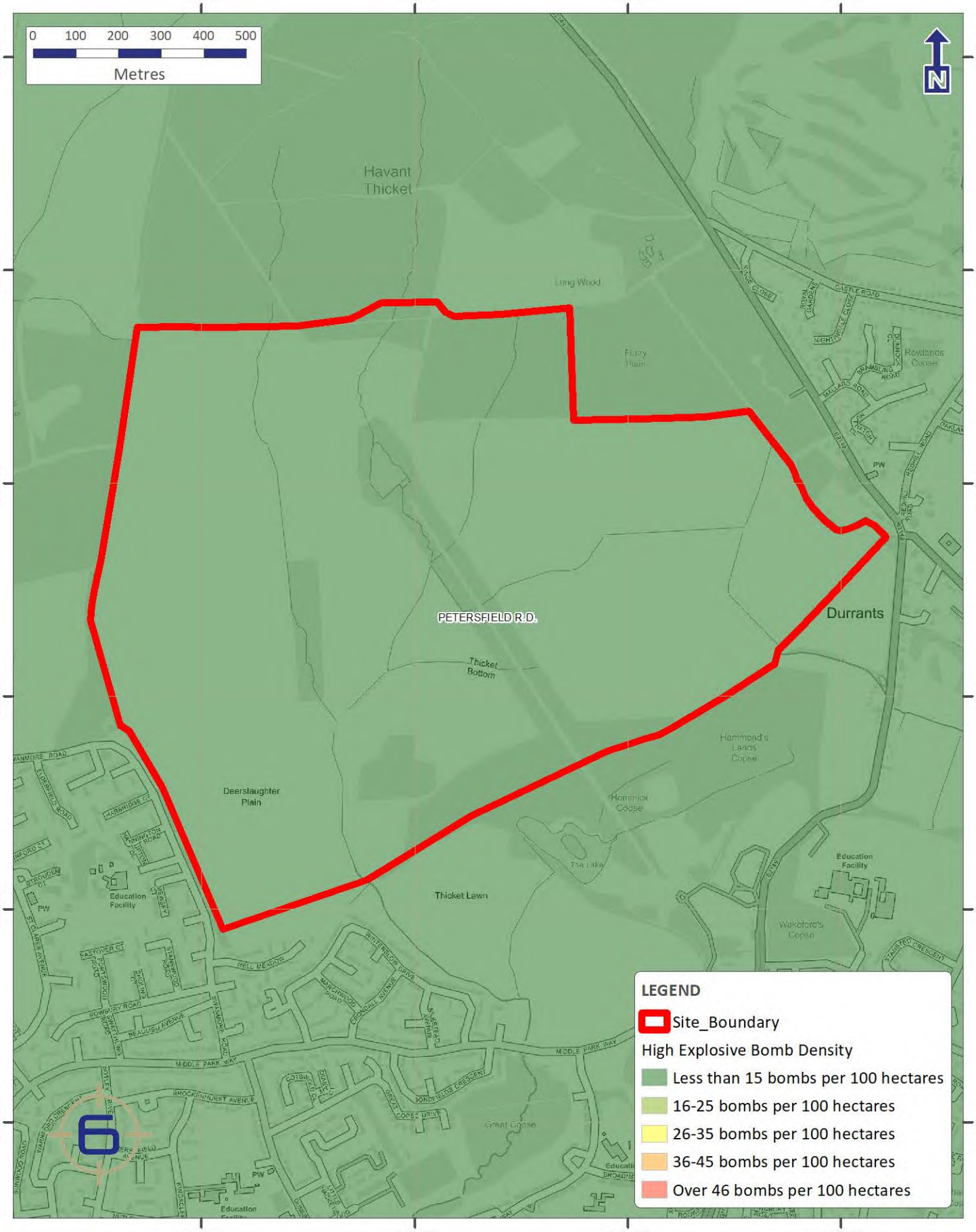
1. The term 'Preliminary UXO Threat Assessment' has been used to describe this report, to fall in line with the *CIRIA* C681 guidelines. Whilst the term 'Risk' can be justifiably used at this stage, the reader should note that the 'Consequence' function of 'Risk' is not considered. Should it be required, this would be addressed in the 'Detailed UXO Threat & Risk Assessment' (Stages 2 and 3).
2. This report is accurate and up to date at the time of writing.
3. The assessment levels have been generated from historical data and third party sources. Where possible *6 Alpha* have sought to verify the accuracy of such data, but cannot be held accountable for inherent errors that may be in third party data sets (e.g. *National Archives* or library sources).
4. *6 Alpha* have exercised all reasonable care, skill and due diligence in producing this service.
5. Whilst every effort has been used to identify all potential UXO/explosive threats, there were a number of private facilities, which may not have released privately recorded information concerning UXO/explosive threats into the public domain. It is therefore possible that some of the aforementioned sites may not be included within the database.

BRITISH NATIONAL GRID

SITE AT 472000, 110000

WWII High Explosive Bomb Density

BOMB SEARCH
WWW.6ALPHA.COM



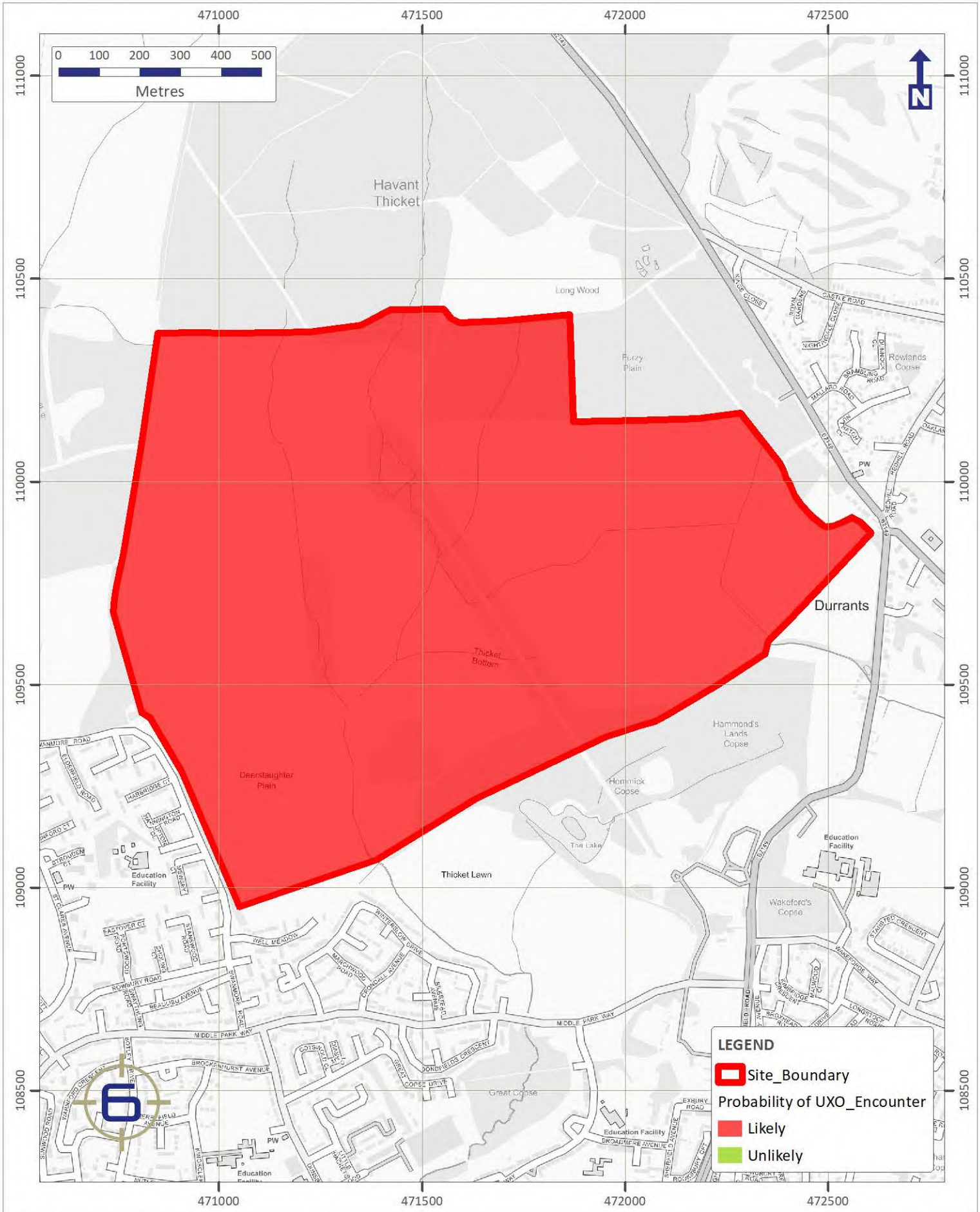
PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE			
P7345	1	SB	CC	03 May 2019	Contains Ordnance Survey data © Crown copyright and database right 2017	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.	alpha ASSOCIATES

BRITISH NATIONAL GRID

SITE AT 472000, 110000

Probability of UXO Encounter

BOMB SEARCH
WWW.6ALPHA.COM



PROJECT NO.	FIGURE	DRAWN	CHECKED	DATE		
P7345	2	SB	CC	07 May 2019	Contains Ordnance Survey data © Crown copyright and database right 2017	Produced by and Copyright to 6 Alpha Associates Ltd. Users noting any errors please notify 6 Alpha.

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Appendix A10.2 Desk Study Report.

Appendix H Natural Cavaties Database Search Results

now part of

Stantec

PBA, now part of Stantec
Caversham Bridge House
Waterman Place, Reading
Berkshire RG1 8DN
T: +44 (0)118 950 0761
E: reading@peterbrett.com

Your ref: 5169117-013

Our ref: 46335/CBH/SC/TT

18 April 2019

Atkins Ltd
Woodcote Grove
Ashley Road
Epsom
Surrey
KT18 5BW

Attn: Oliver Pengilly

Dear Mr Pengilly,

RE: PBA NATURAL CAVITIES DATABASE SEARCH FOR THE SITE AT HAVANT THICKET WINTER STORAGE RESERVIOR.

We refer to your email dated 16 April 2019, regarding the above. We thank you for your instructions to carry out a natural cavities database search for the above-named site.

The cavities database search has been carried out at four points around the site boundary due to the size of the site. The National Grid References were determined from the site plan provided and are as follows:

- SU 7117 1037
- SU 7185 1017
- SU 7245 0992
- SU 7126 0913

NATURAL CAVITY RECORDS

A search of the PBA Natural Cavities Database indicated that there are no recorded natural cavity locations within 500m of the site boundary.

Despite the absence of natural cavity records within the site boundary or a 500m radius of the site boundary, it should be noted that there are a significant number recorded beyond this radius. Cavities involving swallow holes, sinkholes and solution pipes are located within the vicinity of Rowlands Castle golf course, approximately 650-800m north east of the site. Furthermore, natural cavities are densely distributed to the north of the site, with the closest located approximately 600m away and extending towards Junction 2 of the A3(M). Similarly, these records comprise sinkholes and swallow holes.

It is noted that the cavity distribution is most dense where the Palaeogene Lambeth Group and Cretaceous Chalk Group interface exists; with swallow holes appearing to trace the feathering boundary of the Lambeth. The Palaeogene/Chalk interface produces a prominent karstic horizon, and with reference to the published BGS geological map of Fareham (Sheet 316, 1998 – 1:50,000), similar geological conditions are present in areas within the site boundary.

Registered Office: Peter Brett Associates LLP, Buckingham Court, Kingsmead Business Park, London Road, High Wycombe, Bucks HP11 1JU
Peter Brett Associates LLP is a limited liability partnership and is registered in England and Wales with registered number OC334398.
A list of members' names is open to inspection at our registered office.

Subject to the following note, according to PBA Cavities Databases, no records pertaining to natural cavities appear to be present within the site footprint. We draw your attention to the fact that the absence of, or the presence of, existing records for the site should not be considered conclusive – the information provided is indicative only. For any decision on investment, construction or any other actions relating to the project, further investigations will be required to confirm ground conditions.

Yours sincerely,

Stuart Chandler
Associate
For and on behalf of
PBA, NOW PART OF STANTEC

The work undertaken by PBA was carried out on a fixed fee basis and in accordance with our Standard Terms and Conditions, a copy of which is attached to this report. ACE Agreement 2 Advisory, Investigatory and Other Service shall also apply where appropriate.

We draw your attention to the fact that the absence of, or the presence of, existing records for the site should not be considered conclusive – the information provided is indicative only. For any decision on investment, construction or any other actions relating to the project, further investigations will be required to confirm ground conditions. IN NO EVENT SHALL PBA BE LIABLE FOR ANY LOSS OR DAMAGE INCLUDING, WITHOUT LIMITATION, INDIRECT OR CONSEQUENTIAL LOSS OR DAMAGE ARISING FROM THE USE OF THE DATA FROM THE PBA CAVITIES DATABASES.

The Natural Cavities & Mining Cavities Databases have been compiled by Peter Brett Associates LLP (PBA Cavities Databases). They contain information collected since the 1980s from multiple sources including: academic publications, public/business organisations, online resources and commercial project experience. The databases are managed and updated with new records at regular intervals. The PBA Cavities Databases provide information to aid further assessment and should not be used alone to make final decisions on investment or construction on a site as further investigation may be necessary. Given the challenges of source data diversity, quality and age the PBA Cavities Databases cannot guarantee to contain a complete set of information relevant to a site, sometimes records may have been inaccurately positioned, incorrectly interpreted or missed. The data is not intended to be used in place of obtaining professional advice for a specific project. The PBA Cavities Databases are copyrighted and shall be treated as confidential information and must not, without the prior written consent of PBA, be disclosed to a third party. PBA is now part of Stantec.