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Hydrogeological and Foundation Works Risk Assessment Report

Land at Former Car Park, Dominion Way, Worthing, West Sussex

Prepared for Glenmore Holdings Ltd

By YES Engineering Group Limited

March 2023



Revision History

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Document Acceptance

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Statement of Competency

The above staff meet the definition of competent individuals as described in the Environment Agency's Land Contamination: Risk Management guidance since they have suitable qualifications, experience and training.

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1 Introduction

1.1 Terms of Reference

YES Engineering Group Ltd was appointed by Glenmore Holdings (the Client) to produce a Hydrogeological Risk Assessment Report to assess risks to controlled waters from foundation construction and operations at their proposed development, as described in our fee proposal dated 18th January 2023.

1.2 Objectives

Glenmore Holdings proposes to redevelop currently vacant land for five buildings that will provide Light Industrial, General Industrial, and Storage/ Distribution use, as well as associated carparking and an area of Open Storage use. An application for Town Planning consent has been made for the development under reference SWDM/0510/2022 dated May 2022, but no decision has been determined at the time of reporting. The objective is this report is to provide sufficient information to support the discharge of Town Planning conditions requested by Southern Water relating to hydrogeological risk assessment for the proposed development.

The site lies within a Source Protection Zone 1 (SPZ1) protective of a potable groundwater abstraction operated by Southern Water Ltd and as such Southern Water are a consultee under the Planning process. Following submission of a Preliminary Risk Assessment (PBA, 2022), groundwater gauging data (Your Environment, 2022) and Ground Condition Assessment ground investigation report (Ground CC, 2023) in support of the development, Southern Water has advised that they would not object to the application subject to a number of conditions (Southern Water, 2023). The requested conditions relevant to this report are:

- *A Hydrogeological Risk Assessment be completed, and this information is instilled within all. required design reports and CEMP. This should not be a contaminated land report.*
- *Piling is not permitted until turbidity water quality issues are fully mitigated. The adopted piling*
  methodology requires approval from Southern Water.
- *All other construction will take place at least 5m above the water table. Note this will need to account for seasonal groundwater level fluctuation and winter peaks. The only method to accurately collect this data is continuously. At least one winter season should be monitored, and this is defined as October to March of any given year.*
- *Southern Water require review and acceptance of the above listed and associated documents/assessments/reports to satisfy the risk to the Chalk aquifer has been appropriately mitigated.*

The letter also notes that '*All other comments in our response dated 30/05/2022 remain unchanged and valid*'. Further information on correspondence with Southern Water is presented in **Section 1.6** and the correspondence is presented in **Appendix A** – Consultation with Southern Water.

Another condition requested in the letters relate to submission of a Construction and Environmental Management Plan (CEMP) which will be completed in a separate report.

1.3 Report Tasks

The following tasks were undertaken during the preparation of this report:

- Review of current drawings for the site.
- Review the desk top study reporting provided.
- Review relevant monitoring and ground investigation reports provided.

- Site visit to complete groundwater gauging, aquifer permeability testing and install continuous groundwater level monitors.

1.4 Site Location and Description

The site is vacant land comprising a disused carpark located at Dominion Way, Worthing, West Sussex, BN14 8NT. It was formerly part of the Glaxo-Smith-Kline Ltd (GSK) pharmaceutical site adjacent to the north and west of the site. While in use by GSK the only structures shown on available plans were a contractors compounds in the west central area, a cold store in the north-west corner, an 'ATL transit waste area' in the south-east corner (ERM, 2020) and there is anecdotal evidence of light weight contractors buildings' present in the western area which is supported by features shown on Ordnance Survey mapping (PBA, 2022). The cold store is understood to have been demolished by GSK prior to divestment of the site to Glenmore Holdings. Historical mapping indicates that the site was undeveloped land until the 1980s.

The surrounding area comprises buildings associated with the current and former GSK site in all directions. The figure below illustrates the site boundary, SPZ1 boundary, Southern Water groundwater abstraction points and 250 metre (m) and 500 m search radii.

Figure 1.1 – Site Setting and SPZ1 Boundary

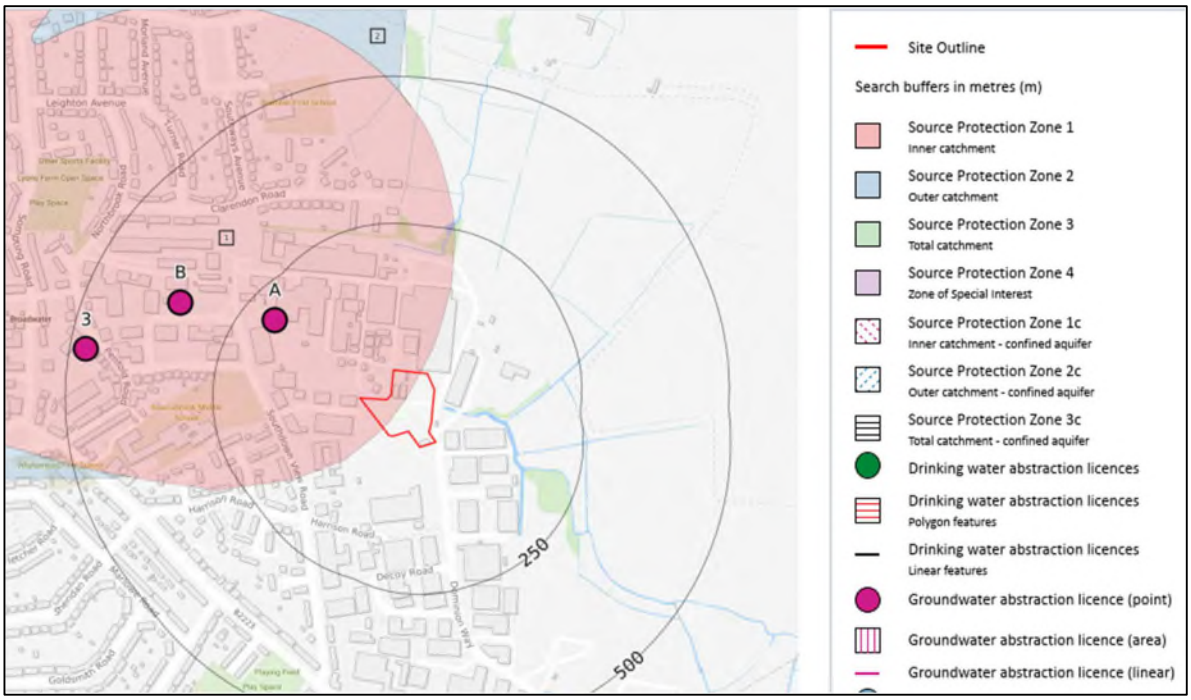


Figure reproduced from Groundsure Report GS7985865 presented in Phase 1 (PBA, 2022)

1.5 Information Sources

The information contained in the following reports has been used to prepare the Piling Risk Assessment:

- Draft Phase 2 Environmental Site Assessment GSK Worthing. Environmental Resources Management Ltd. 29th October 2020.
- Phase I Desk Study Land at Dominion Way. Pam Brown Associates Ltd. March 2022.

- Letter reporting groundwater gauging data, reference YEX2899. Your Environment Ltd. March 2022.
- Dominion Way, Worthing Ground Condition Assessment. Ground Condition Consultants Ltd. January 2023.

1.6 Consultation with Southern Water

Correspondence with Southern Water is presented in **Appendix A** – Consultation with Southern Water. As noted in **Section 1.2**, following an initial objection to the proposed development (Letter dated 30th May 2022) further works were undertaken. In September 2022 the scope of works for the Phase 2 site investigation were submitted to Southern Water who responded by email on 28th September. The response included requests to undertake Piling and Hydrogeological Risk Assessments and that '*Any risk assessment should have separate pollutant pathway line items / individual assessments for each of the superficial aquifer, bedrock aquifer and potable groundwater abstractions*.'

Following submission of the Phase 2 report in January 2023 (Ground CC, 2023), Southern Water advised that they would not object to the development (Southern Water, 9th January 2023) subject to the application of the conditions summarised in **Section 1.2**. On 27th January 2023 YES Engineering requested clarification on some points raised in the Southern Water letter of 9th January 2023, specifically the requirements to undertake continuous groundwater level monitoring and to not excavate within 5 m of the water table. On 17th February 2023 YES Engineering submitted an Environmental Information Request for potentially sensitive information to support this risk assessment. A response had not been received at the time of reporting, however following subsequent correspondence with Southern Water the data requested is not considered critical to this assessment.

On 24th February 2023 Southern Water advised by email (presented in **Appendix A** – Consultation with Southern Water):

- The requirement to not excavate within 5 m of the water table can be updated to '5 m of the water table or 1 m of the Chalk aquifer'
- Continuous groundwater level monitoring 'is not required if groundwater levels are 1m of surface'
- Potentially sensitive information relating to Southern Water's abstraction could be obtained by EIR
- Comments in the Southern Water letter dated 30th May 2022 relating to site investigation did not relate to the study site.

On 24th February 2023 YES Engineering requested further confirmation that a full season of winter groundwater level monitoring was not required and sought to agree in principle the proposed use of vibro-stone column (VSC) piles. On 8th March 2023 Southern Water further advised by email (presented in **Appendix A** – Consultation with Southern Water):

- A full Winter season of groundwater level monitoring is not required.
- Southern Water require details of flood mitigation at the site and requested it be included within the Hydrogeological Risk Assessment.
- Noted that 'Foundations that do not enter the Chalk are preferred by Southern Water. SW will require review of the impact assessment to confirm if acceptable'.

- Regarding proposed daily monitoring during groundworks plus one week before and after 'This monitoring sounds sensible. The high risk time periods will be during the groundworks. Please include a more detailed programme of works and methodology in the HRA'.

1.7 Previous Investigations

1.7.1 ERM. Phase 2 Environmental Assessment. October 2020.

The report was prepared for GSK to support their divestiture of the subject site only. The investigation comprised of seven boreholes advanced to between 8m to 10m bgl using hollow stem auger (HSA), three handpits to 1.5m bgl and one groundwater gauging and sampling event. Borehole locations appear to have been selected to provide coverage across the site and to target the footprints of former buildings.

The intrusive works were completed in September 2020. Two soil samples per location were analysed for a suite of potential contaminants associated with GSK's use of the site including metals, VOCs, SVOCs, hydrocarbons, alcohols, PCBs and asbestos. Groundwater samples from six locations installed across both the Alluvium and Chalk were analysed for a similar suite.

The reported geology was up to 1.4m thickness of made ground (BH03) with alluvial silt encountered from depths between 1.1 and 1.4m bgl and up to 1.65m thick. Bedrock of Putty Chalk was reported between 1.5 and 3.7 m bgl and was 2.6m bgl or more in all locations except BH03 in the south-eastern corner.

Groundwater rest levels were between 0.96m and 1.05m aOD. The inferred groundwater flow direction from four boreholes installed in the Chalk is north-east to north under a hydraulic gradient of approximately 0.0001 m/m. Organic compounds were not detected in groundwater samples, the majority of metals were also below detection limits with the remainder below Drinking Water Standards (DWS) and Environmental Quality Standards (EQS). Made ground samples reported slightly elevated concentrations of some metals, hydrocarbons and polycyclic aromatic hydrocarbons (PAHs). The report concludes that for a commercial/industrial use the identified concentrations did not present a risk to health and that there was no evidence of residual impact to groundwater quality.

1.7.2 Phase I Desk Study Land at Dominion Way. Pam Brown Associates Ltd. March 2022.

The report was completed for Glenmore Holdings to support the planning application for the currently proposed development. The site history is reported as agricultural land until the 1980s and then part of the surrounding works. Units on site were reported to have been removed or changed configuration, with two remaining at the time of reporting. The report identified a Moderate risk from the former use to environmental receptors and recommended that ground investigation be undertaken to further assess the potential risks. No reference was made to the ERM report.

1.7.3 Letter reference YEX2899. Your Environment Ltd. March 2022.

Your Environment was commissioned by Glenmore Holdings to undertake groundwater gauging. The letter presents the results from gauging three boreholes referenced WS01 to WS03 which are located within the western third of the site. The gauging was completed at one to two week intervals over seven weeks between 26th November 2021 and 14th January 2022. The logs and installation details for these boreholes are not available, however the reported maximum measured base depth was 3.9m bgl, therefore it is inferred that they were installed at least partially within the Chalk. The depths to groundwater range from 0.37m to 2.16m bgl, borehole or groundwater elevations are not provided.

1.7.4 Ground Condition Assessment. Ground Condition Consultants Ltd. January 2023.

Ground Condition Consultants (Ground CC) undertook an investigation comprising of three windowless sampler boreholes drilled to a maximum of 5.45 m bgl (WS101 to WS107) and three cable percussion boreholes drilled to 15 m bgl (BH101 to BH103). The drilling was completed in November 2022 and groundwater gauging and gas monitoring were completed in December 2022. Made ground was present to a maximum depth of 1.4 m bgl, the silt Alluvium and then Chalk. Groundwater was struck at between 2.0 and 3.0 m bgl during drilling and rose to between 0.8 and 1.5 m bgl during subsequent monitoring. Ten soil samples were collected for total and leachable contaminants and seven groundwater samples were analysed for contaminants. The analytical suites included metals, inorganics, hydrocarbons, PAHs and VOCs. Further details from the investigation including geology and chemical analysis results are presented in Section 3 of this report. The report is presented in full in **Appendix H** - Ground CC Ground Condition Assessment Report. Ground CC concluded that '*No significant sources of contamination have been identified in the soil or groundwater on the site*' and '*The risks of impact to the proposed development or controlled waters from the site have therefore been assessed to be very low'*.

2 Field Work

2.1 Summary of Works

YES Environmental Ltd attended site on 24th January 2023 to undertake the following tasks:

- Gauging of all wells installed by Ground CC Ltd
- Permeability testing of BH102, BH102 and BH103
- Install continuous groundwater level monitors in BH102, BH102 and BH103

2.2 Groundwater Gauging and Groundwater Flow Direction

Depths to groundwater and base of monitoring wells were gauged using a water level meter. Gauging rounds were completed in the morning and evening. During the morning round it was found that most wells contained the tubing from inertial lift pumps previously used to sample the wells, this tubing had to be removed to enable insertion of the water level tape. Removal of the tubing was expected to slightly reduce the water level in the wells because of the water volume displaced by the tubing. For the 50mm diameter wells installed only in chalk it is expected that removal of the tubing would have had minimal effect on the water level given the larger well volume relative to the tubing volume and relatively high permeability of the Chalk. For the 32mm diameter wells installed only in the alluvium or in the alluvium and Chalk it is expected that water levels could have been more affected by removal of the tubing, therefore these narrow diameter wells were gauged only in the evening when groundwater levels had time to recover.

It was found that there are numerous monitoring wells on site in addition to those installed by Ground CC Ltd or those gauged by Your Environment Ltd. Some of the additional wells are at similar locations to the Ground CC wells and two of them were inadvertently gauged in the morning round rather than the intended Ground CC well. Therefore only the results from the evening round have been used for interpretation of groundwater flow direction.

The gauging results are presented in **Appendix B** – Groundwater Gauging Results and a potentiometric surface plot is presented in **Figures**.

Within wells installed only in the Chalk the groundwater depths were between 0.877m and 1.054m bgl (elevations 1.813m to 2.039m aOD). Within wells installed only in the Alluvium the groundwater depths were between 0.800m and 1.115m bgl (elevations 1.650m to 1.805m aOD). Ground CC Ltd noted in their report that there were no groundwater strikes within the Alluvium during drilling and concluded that the groundwater gauged in these wells may represent groundwater that has leaked through the base seal in these wells.

The potentiometric surface plot indicates that at the time of gauging groundwater was flowing towards the east-north-east under a gradient of 0.004 m/m.

2.3 Aquifer Hydraulic Conductivity Testing

Aquifer permeability testing was undertaken on boreholes BH101, BH102 and BH103 that were installed by Ground CC Ltd with response zones set in the Chalk only. Water levels were recorded using an electronic pressure transducer known as a 'Troll™' set to record at one second intervals, with additional readings taken from the water level meter. Change in head was initiated with a solid 'slug' with two or three part slug used as required to achieve sufficient change in head. Up to eight rising and falling head tests were completed on each well.

Prior to interpretation of the tests the normalised response curves within each well were plotted on to a single graph to identify the most consistent, and therefore representative, tests for interpretation, and to exclude poor quality data from analysis. The test results were analysed using the United States Geological Survey (USGS) Bouwer-Rice excel workbook (USGS, 2004). A summary of the test results is presented in the table below and the interpretation sheets are presented in **Appendix C** – Hydraulic Conductivity Test Interpretation.

Table 2.1 – Summary of Hydraulic Conductivity Test Results

Borehole	Representative Hydraulic Conductivity $m.d^{-1}$	Geological Unit	Response Zone m bgl	Tests
BH101	Geomean – 12.8 Min – 11.0 Max – 17.0	Tarrant Chalk	3.5 – 10.1	4 rising head, 4 falling head. Two and three part slugs used. Two tests not interpretable.
BH102	Geomean – 1.2 Min – 1.4 Max – 1.4	Tarrant Chalk	3.0 – 10.0	3 rising head and 4 falling head. Two part slugs used. Three tests not interpretable.
BH103	Geomean – 5.0 Min – 4.3 Max – 6.0	Tarrant Chalk	3.5 – 10.0	3 rising head, 3 falling head. Two and three part slugs used. Two tests not interpretable.

2.4 Continuous Groundwater Level Monitoring

Three Trolls™ were left installed in BH101, BH102 and BH103, and a barometric pressure Troll™ within the well chamber at BH101. These boreholes have a suitable layout to infer changes in groundwater flow direction as well as groundwater levels at each location. The Trolls™ were set to record at two hour intervals and were left monitoring until agreement on the duration of winter monitoring had been agreed with Southern Water (See **Section 1.6**).

Since the monitors were installed, Southern Water has advised that continuous level monitoring is not required. Therefore the loggers were therefore scheduled to be removed on 13th March 2023, the data can be presented if requested by Southern Water, and would be provided in a separate report.

3 Hydrogeological Site Setting

3.1 Topography

The site is relatively flat lying with a gentle slope downward from approximately 3.2m aOD in the western area to 2.5m aOD in the north-eastern area. The immediately surrounding area is also relatively flat lying.

3.2 Geology

The typical downward sequence, as determined from the exploratory holes undertaken as part of the ground investigation by Ground CC is presented in the table below and scale cross sections showing the geology on regional scale as well as on site scale with the proposed buildings and pile depths are presented in **Appendix D** – Geological Cross-Sections:

Table 3.1 – Summary of Geology Encountered On-Site

Unit	Description	Range of Depth to Top of Unit (m bgl)	Range of Thicknesses (m)
Hard standing	Concrete or tarmac - absent at BH102 and WS107.	Ground level	Tarmac – 0.1 Concrete – 0.3
Made Ground	Engineered fill of fine to coarse GRAVEL over reworked sandy gravelly SILT with occasional brick fragments.	Ground level to 0.3	0.50 to 1.3
Alluvium	Soft grey SILT and CLAY with varying sand and gravel content and occasional peat pockets	0.4 to 1.4	1.3 to 2.4
White Chalk Subgroup	Grade DM 'Structureless or remoulded melange' Chalk 'Possible Grade C' Chalk (typical discontinuity aperture >3mm, spacing 60 – 200mm) reported between 11.5 and 15.0m bgl in BH101 and BH102. Hydrogeological mapping indicates that the Chalk may be approximately 250m thick in the vicinity of the site. BGS borehole TQ10SE70 located approximately 600m west of the site reports over 187.5m thickness of Chalk (base not proven).	2.2 to 3.5	>11.0, base not proven

The logged Made Ground and Alluvium strata descriptions presented in the Ground CC report are supported by particle size distribution (PSD) analysis of selected samples. The Ground CC encountered geology is consistent with that reported by ERM (ERM, 2020) who

reported up to 1.4m thickness of made ground underlain by Alluvium of 'silty sandy clay' then 'silt' up to 1.65m thick underlain by 'Putty Chalk' at between 1.5 and 3.7m bgl.

The encountered geology is consistent with BGS mapping for the site which shows that the site is underlain by superficial deposits of 'Alluvium - Clay, Silt, Sand And Peat'. 'Head - Clay, Silt, Sand And Gravel' is shown over 200m from the site but is not likely to underlie the Alluvium on site given the logged descriptions. Bedrock is shown as 'Tarrant Chalk Member – Chalk' which is further described as 'Soft white chalk with relatively widely spaced but large flint seams.' The unit is reported to be between 35 – 40m thick and the parent material is the Culver Chalk.

The nearest available BGS borehole log is TQ10SE31/B approximately 300 m west of site which relates to Northbrook Pumping Station and was drilled to 38.1 m bgl in 1893. A file note dated 1963 states that the borehole is no longer used (presumed to have previously been used for potable abstraction). The log reports Drift of gravels and clays to 7.9 m bgl underlain by 11.6 m thickness of 'plastic chalk' which was underlain by 'chalk with flints' to a depth of 61.0 m bgl. The description of plastic Chalk is consistent with the description of structureless Chalk on site, and the thickness is also similar.

The BGS GeoIndex does not identify water wells near the site other than those reported in the PRA. All water level data held by BGS at locations near the site is over 60 years old and therefore of limited relevance compared to recent readings. The nearest groundwater level data available from www.gaugemap.co.uk (accessed 13 February 2023) is for a well at Whitelot Bottom which is approximately 8.5 km north-east of site, however as the groundwater level ranges between approximately 25 and 125 m aOD then the levels are not considered suitable to infer data for the study site where the range in groundwater levels will be restricted by the low site elevation and proximity to the sea.

3.3 Hydrogeological Information

3.3.1 Groundwater Level and Flow regime

Made Ground – groundwater was not encountered during drilling in the made ground in either the Ground CC or ERM ground investigations.

Alluvium – groundwater was not encountered during drilling within the Alluvium in any of the Ground CC locations and in only two out of ten of the ERM locations, indicating that where present it is perched and isolated. Some Ground CC wells were installed only in the Alluvium which reported rest groundwater levels similar to those in the Chalk. However as noted in Section 2.2, this may reflect groundwater in the Chalk leaking through the bentonite seal at the base of the wells. Given the perched nature of the groundwater in these wells and the uncertainty over whether the groundwater is from this unit, a groundwater flow direction has not been calculated for the alluvium. Silt typically has relatively low permeability and any flow would be intergranular. The following notes were drawn from the Ground CC Interpretive Report (January 2023) regarding permeability of the Alluvium:

'*The monitoring wells screened within the Alluvium were purged dry during the sampling round and were allowed to recharge to enable sampling during the same monitoring round. As no groundwater was recorded within the upper strata of the Alluvium or the Made Ground during the investigation, the ability of these wells to recharge and the relatively slow rate at which they did so, suggests that there is either a slow seepage of groundwater from the Alluvium or the seals at the base of the wells were not entirely successful and some confined groundwater from the Chalk bypassed the seal and recharged the wells.*'

Chalk – groundwater was encountered during drilling at all locations that encountered the Chalk, with groundwater strikes at or near the top of the unit. Rest water levels were all above the strike levels, typically by over 1m, indicating that the groundwater is confined by the overlying Alluvium which in turn supports the above assessment that the Alluvium has low permeability.

Hydrogeological mapping for the area (NERC, 1978) indicates that in 1973 the regional groundwater flow direction was likely towards the south or south-east towards the sea and the groundwater elevation was between 5m and 0 m aOD. The map shows that more locally to the site groundwater flow direction was towards the north, and that a 0 m aOD ring contour is located between three groundwater abstractions all north of the site that comprise the Northbrook PWS.

The potentiometric surface plot presented by ERM indicates a flow direction towards the north-east or north under a gradient of 0.0001 m/m. The potentiometric surface plot of groundwater elevations recorded on 24th February by YES Environmental Ltd (See **Figures 1**) shows a groundwater flow direction towards the east-northeast under a gradient of 0.004 m/m. Given that part of the site is located within a Source Protection Zone (SPZ1) for an abstraction well 195 m north-west then a north-westerly flow direction would be anticipated. The difference between observed and expected flow direction may reflect:

- SPZs are modelled using conservative assumptions in order to be protective. Considering the site's location on the down regional hydraulic gradient side of the abstraction then the model is likely to be more sensitive to differences between assumed aquifer parameters applied to the model and actual conditions. Therefore, therefore the catchment of the well may not be as large as indicated by the SPZ1.

- SPZs are modelled based on maximum licensed abstraction rates. Abstraction rates usually vary seasonally with demand. If the abstraction rate was lower at the time of gauging, for example due to seasonal variation, or there are other limitations on the abstraction rate, then the observed well catchment may have been smaller at the time of gauging than that predicted by the SPZ model.

- The observed flow directions are based on levels from wells installed in the upper 10m of the Chalk whereas the modelled flow directions are likely to be based on the properties of deeper Chalk. There may be variation with depth whereby flow direction in the top of the unit is locally influenced by surface water features such as those adjacent to the western and eastern site boundaries (see below), whereas the deeper flow would not be.

The Chalk typically exhibits dual porosity with the majority of flow volumes occurring within fractures or solution features, and a much smaller proportion via intergranular flow since Chalk is microporous with low intrinsic permeability. Where the Chalk is structureless then flow is expected to be dominated by intergranular flow, but where it becomes competent rock within which fractures can form then the groundwater flow will be dominated by fracture-flow. Based on the logged descriptions of the Chalk beneath the site then it is expected the flow will be predominately intergranular to approximately 10 m bgl (minimum reported depth to structured Chalk is 11.5 m bgl), then fracture-flow potentially becoming more important. Due to the drilling method (cable percussion) there is some uncertainty over the logged descriptions from the Ground CC report. The ERM investigation used Hollow Stem Auger with windowless sampling which is less destructive to samples than cable percussion, however some uncertainty remains. With both methods it is possible that structured chalk was not identified during drilling and therefore fractures could have been present that were not identified.

The geometric means of measured hydraulic conductivity of wells installed in the Chalk on site is 1.2 $m.d^{-1}$, 5.0 $m.d^{-1}$ and 12.8 $m.d^{-1}$. The fastest conductivity was in BH101 where potentially structured Chalk was identified, however the test results do not show a dual-response curve that might be expected for a well installed in a well with both intergranular and fracture flow. Fracture flow may occur within the tested interval at BH101, if so then it is expected that this would apply to the deeper part of the response zone where less weathered Chalk may be present.

A review was completed of transmissivity data for nearby boreholes installed within the chalk. This identified:

- Links Road Golf Club, 2.9 km north-west. 370 $m^2.d^{-1}$. Based on tested interval of approximately 35 m this equates to approximately 11 $m.d^{-1}$ hydraulic conductivity. Logged description of chalk not available in the relevant BGS log.
- Tolmare Farm, 6.4 km north-west. 6,500 $m^2.d^{-1}$. Based on tested interval of approximately 130 m this equates to approximately 50 $m.d^{-1}$ hydraulic conductivity. The BGS log reports 'soft chalk', 'soft and hard layers of chalk' and 'sticky chalk' within the tested interval.

These data indicate that conductivity is variable on a regional as well as local scale and that fracture flow is present in the deeper strata encountered at Tolmare Farm.

3.3.2 Aquifer Designations

The 'Alluvium – Silt' aquifer is designated by the Environment Agency as a Secondary - Undifferentiated aquifer, these aquifers are described as '*these layers have previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type'*. Based on the logged descriptions of the unit on site it is considered unlikely that the aquifer on site could either support an abstraction or provide significant baseflow to local surface waters.

The Chalk is designated by the Environment Agency as a Principal aquifer, these are described as '*Geology of high intergranular and/or fracture permeability, usually providing a high level of water storage and may support water supply/river base flow on a strategic scale*.'

The Groundwater Vulnerability map and associated information presented in the Phase 1 report shows the site to be in an area of Medium vulnerability for the Silt Secondary A aquifer which is noted as 3 m to 10 m thick, and Low vulnerability for the Chalk Principal aquifer which is noted as having 'well connected fractures'. The Low rating for the Chalk likely reflects the presence of overlying low permeability drift deposits.

3.4 Groundwater Abstractions

The GroundSure report presented in the PRA (PBA, 2022) identifies the 'Active' groundwater abstractions within 2 km of the site as presented in the table below.

Table 3.2 – Summary of Local Groundwater Abstraction Licences

Distance (m) / Direction	Type	Point / Licence	Name	Licenced Annual Volume (Daily Maximum) m^3
195 North-west	Potable - Direct	Northbrook PS Point 1 10/41/310210	Southern Water Services Ltd	

Distance (m) / Direction	Type	Point / Licence	Name	Licenced Annual Volume (Daily Maximum) m^3
345 North-west	Potable – Direct	Northbrook PS Point 2 10/41/310210	Southern Water Services Ltd	26,000,000 (111,000)
1,615 North-west	Potable – Direct	Broadwater PS Borehole 3 10/41/310210	Southern Water Services Ltd	
1,615 North-west	Potable – Direct	Broadwater PS Well 10/41/310210	Southern Water Services Ltd	
1,628 North-west	Potable – Direct	Broadwater PS Borehole 1 10/41/310210	Southern Water Services Ltd	
1,628 North-west	Potable – Direct	Broadwater PS Borehole 2 10/41/310210	Southern Water Services Ltd	

In addition to the above, the hydrogeological map for the area (NERC, 1978) notes that in 1976 the nearest abstraction was licensed for 2M $m^3.yr^{-1}$.

3.5 Discharges to Groundwater

No licenced discharges to groundwater were reported within the 500 m search radius of the GroundSure report presented in the Phase 1 report (PBA, 2022).

3.6 Hydrology

Based on the GroundSure report (PBA, 2022) the following information on surface waters and drains located on or adjacent to the site has been identified:

- A culverted un-named stream flows from north-west to south-east along part of the north-eastern site boundary. An outfall of the culvert is present approximately 15 m east of the site (ERM, 2020). The drain is noted as containing water all year round (PBA, 2022). Another un-named watercourse at a confluence approximately 120m east of the site.
- The site is currently drained by gully drains present across the hardstanding areas. During the YES Environmental site visit of 24th January 2023 water could be see standing at less than 1 m bgl in some of the drains.
- An un-named drain is present along part of the south-west boundary, no flow direction is shown on OS mapping and no flow was evident within the drain during the YES Environmental site visit, however based on topography it is assumed to flow south-east towards the Teville Stream.

- The site lies within the Teville Stream Water Body catchment and the Adur and Ouse Management Catchment. Based on information from the Catchment Data Explorer (https://environment.data.gov.uk/catchment-planning/WaterBody/GB107041011940 accessed 15th February, 2023) the ecological quality of the River Teville when last assessed in 2019 was Bad and chemical quality was Bad. Specific issues were fish and invertebrate indicators, dissolved oxygen, 'mercury and its compounds' and polybrominated diphenylethers (PBDE)

3.7 Surface Water Abstractions

No licenced surface water abstractions were reported by GroundSure within 2 km of the site.

3.8 Discharges to Surface Water

The Phase 1 report identifies 30 discharges to surface water within 500 m of the site (PBA, 2022), the majority of which were revoked in or before 1997. None are considered relevant to hydrogeological risks at the site.

Smithkline Beecham holds a permit for trade effluent discharge to surface waters located 205 m north (permit number AUO393). The trade effluent type is 'pharmaceutical products', including Red List substances.

3.9 Flood Risk and Mitigation

The site is within an area classified as having 'high' risk of pluvial, fluvial and groundwater flooding. Detailed assessment of flood risk is presented in the Flood Risk Assessment for the site (AGAEA, 2022). The risk from pluvial and fluvial flooding relates to the northern area of site which is classified by the Environment Agency as Flood Zones 2 and 3, whereas the groundwater flood risk applies to the majority of site. It is understood that there have been no incidents of groundwater flooding on site recorded by the Environment Agency.

Proposed flood mitigation measures include designation of the northern area of site as parking/open storage to reduce hazards in that area, raising of finished floor levels beneath the proposed buildings and roadways to list them above the groundwater flood risk, and the use of underground attenuation tanks to attenuate stormwater flow which will discharge via a Hydrobrake. Limited porous paving areas are also proposed, water from these will be collected and discharged via the attenuation tanks rather than infiltrating to soil.

3.10 Chemical Impacts Relevant to Controlled Waters Risks, Soil and Groundwater

3.10.1 Soil

Ground CC Ltd

Ground CC Ltd collected ten soil samples for chemical analysis between 21st and 25th November 2022. The majority of samples were collected between 0.3 and 0.7 m bgl, with one between 0.8 and 1.0 m bgl. Six samples were of Made Ground, four of Chalk and one of Silt. The samples were analysed for a suite of metals, polycyclic aromatic hydrocarbons (PAHS), fractionated total petroleum hydrocarbons (TPH), volatile organic compounds (VOCs) and several inorganic parameters including cyanide and ammonia.

The majority of analyses returned results below detection limits or commensurate with background concentrations. Slightly elevated concentrations of mercury (1 to 4 $mg.kg^{-1}$), PAHs (up to 26 $mg.kg^{-1}$ total of 16 compounds) and >C10 hydrocarbons (up to 307 mg/kg)

were reported in some samples. The only VOCs detected were carbon disulphide, 1,3,5-trimethylbenzene, and 1,2,4-trimethylbenzene, all as 2 to 8 µg.kg^{-1}.

Of the soil concentrations detected, only mercury and hydrocarbons are considered to present potentially unacceptable risk to groundwater. The soil concentrations were not compared to generic assessment criteria (GAC) protective of groundwater, risks were assessed based on soil leachate and groundwater concentrations.

ERM

ERM collected 20 soil samples from ten locations and analysed for a more extensive analytical suite as described in Section 1.7.1. At each location one shallow sample was collected, typically <1 m bgl and one deeper one typically from natural ground between 1 – 3 m bgl. The results were similar to those reported by Ground CC and no contamination considered by YES Environmental to present significant risk to groundwater was reported.. Concentrations in the natural soils were generally below detection limits and detections were typically representative of background concentrations.

3.10.2 Leachate

Ground CC

Ground CC analysed ten shallow samples for leachate analysis, for same suite as the soils. The samples were generally collected between 1 – 2.2 m bgl, with one from 0.4 – 0.6 m bgl. Two were of Made Ground, four of Silt and four of Chalk. The samples were analysed for the same suite as soils, except for VOCs which would be lost during leachate preparation.

The leachate results were compared to GAC which were Drinking Water Standards (DWS) and, where available. The only parameters reported to exceed DWS were lead in four samples (Made Ground and Silt) and carcinogenic PAHs in one sample (Chalk). The lead exceeded by factor of up to 5.2 and the PAHs by a factor of 1.4. These minor exceedances are considered unlikely to result in unacceptable impacts to groundwater given the aggressive nature of the leachate test, this assessment is supported by groundwater data from wells installed in shallow groundwater (see below).

Hydrocarbon and mercury concentrations were below detection limits, indicating that the concentrations of these contaminants detected in overlying soils have not resulted in unacceptable leachable concentrations within the underlying soils.

ERM

ERM did not undertake leachate analysis.

3.10.3 Groundwater

Ground CC Ltd

Seven groundwater samples were collected on 1 December 2022, one from BH101 to BH103 which are installed only in the Chalk and the remainder from WS101, WS103, WS104 and WS106. WS103 is installed across Made Ground and Alluvium while WS101, WS104 and WS106 are installed in Alluvium only. The samples were analysed for a similar suite to the soils and compared to DWS GAC.

No concentrations exceeded GAC indicating low risk to groundwater from contamination on and up-hydraulic gradient of the site. Mercury, lead and VOCs were all below detection limits, indicating that the elevated concentrations of these detected in soil or leachate are not impacting groundwater. Slightly elevated TPH was reported in WS101, with a total of 60 $\mu g.L^{-1}$.

ERM

Six samples of groundwater were collected on 8th September 2020, all from wells installed in Alluvium and Chalk. The samples were analysed for a similar suite to the soils.

The only concentrations to exceed DWS GAC were selenium in one well which exceeded by a factor of 1.2 and manganese in five wells including up-hydraulic gradient wells and is therefore attributed to background concentrations.

3.10.4 Aggressive Ground

Ground CC analysed six samples of soil between 0.3 and 2.0 m bgl for sulphate and pH. Aggressive conditions were not reported, with concrete design class AC-1S recommended.

3.10.5 Waste Classification

The results have not been previously screened for waste classification and no Waste Acceptance Criteria (WAC) analysis has been completed.

Based on the available data it is expected that if excavated then the majority of Made Ground would be classified as Non-Hazardous waste suitable for disposal to a landfill licenced to accept Non-Hazardous waste, while the Alluvium and Chalk would likely be classified as Non-Hazardous waste suitable for disposal to a landfill licenced to accept Inert waste. These anticipated classifications must be confirmed by quantitative assessment before any excavated material is sent off-site. It is noted that the proposed piling method of ground improvement would not generate arisings.

4 Proposed Development

4.1 Proposed Ground Levels

Prior to the foundation works a piling mat formed of 6F2 material in compacted layers will be installed within building footprints to a minimum thickness of 350 mm. It is proposed that this will be retained upon completion of the works, and that ground beneath all buildings will be raised by between 350 – 600 mm above current ground levels to ensure they are the required height above potential flood levels. Ground levels beneath roads and parking areas are also proposed to be raised by 350 mm above current levels to provide sufficient cover to protect proposed stormwater attenuation 'crates' beneath hardstanding. Outside of the building and road footprints the ground will slope gently downwards.

4.2 Summary of Piling Works

The proposed foundation solution is to use 'vibro' stone columns that would extend to 2.5 m below finished floor levels (maximum 2.1 m below current levels) within building footprints to support 750 mm wide reinforced strip foundations and floor slab and 2.0 m x 2.0 m pad foundations. The stone columns would be 350 mm wide and placed at 1.0 m centres beneath each building footprint. Approximately 2,714 piles will be installed in total. A drawing presenting a section through the proposed floor design is presented in **Appendix E** – Pile Design Information. They would be installed using a vibrating 'poker' to create the hole and then backfilled with stone through the centre of the poker. The vibration is sideways rather than vertical motion, so as to stiffen the adjacent soils. The contractor's Pilling Method Statement is presented as **Appendix F** – Piling Contractor's Method Statement. This methodology primarily improves the strength of shallow ground rather than transferring loads to deeper ground as with more traditional piling.

As illustrated in **Figures 2** the current depth to Chalk across the site in twenty locations across the site was between 2.5 and 5.0 m bgl in fourteen of the seventeen locations where Chalk was encountered. Shallower depths were reported at Ground CC borehole WS103 towards the centre of site (2.2 m bgl), WS106 in the south-eastern corner (2.4 m bgl) and at ERM borehole BH03 in the south-west corner (1.5m bgl). Borehole BH03 is further from the nearest proposed building than WS107 at which the depth to Chalk is 3.4 m bgl, therefore it is evident that the piling works in the footprint of that building are unlikely to penetrate the Chalk, and the majority of piles will terminate one metre or more above it.

4.3 Selected Piling Method

Glenmore Holdings Ltd has confirmed that the vibro stone columns (VSC) method has been selected for use at this site. This follows a piling options appraisal by their engineer RP Allen Consulting Ltd who noted that driven piles would be required to reach 16 - 20 m bgl and could well cause turbidity, and that Continuous Flight Auger (CFA) piles would be required to reach 24 m bgl which would also be likely to generate turbidity. For both driven or CFA piles the Chalk is likely to be highly fractured within the target depth which would increase the risk of turbidity migrating to the abstraction well.

The Environment Agency guidance Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution Prevention (EA, 2001) notes in Table 5.1 the following advantages with respect to VSC, which they classify as Penetrative Ground Improvement.

- The risk of soil arisings being brought to the surface is not likely

- Risks of pile degradation due to aggressive conditions (if present) are likely to be acceptable provided there is appropriate workmanship and quality control
- The risk of driving solid contaminants down into the aquifer during piling not likely
- The risk of contaminating groundwater or surface water with cement paste or grout is not likely

The EA guidance (EA, 2001) advises that potential disadvantages of VSC include:

- There is a risk of creating pathways from contamination (if present) through a low permeability surface layer to underlying groundwater
- They can create a preferential pathway for ground gas or vapour (if present) to reach the surface

5 Hydrogeological, Piling and Foundation Works Risk Assessment

5.1 Hydrogeological Risk Assessment

Risks to the potable abstraction from turbidity created during piling, changes in groundwater flow regime, material imported to site during development, run-off from the site during development have been assessed as well as relevant pathways from the Environment Agency document 'Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution Prevention' (EA, 2001). The detailed assessment is presented below and a summary of this assessment is presented in tabular form in **Appendix G** – Summary Of Piling Risk Assessment:

1. **Risks to potable abstraction from increased turbidity**

<u>During Development</u>

The principal mitigation against this risk is that the proposed method will not penetrate into the Chalk. Therefore, although there is a potential pathway for turbidity created on site within fractured Chalk, there is no source. The EA does not advise on turbidity risks from different piling methods (EA, 2001). However, since the vibration of the vibro rig is in the lateral plane then it is considered that there should not be significant transmission of vibration vertically down into the Chalk. Additionally, the Chalk is described as being structureless or 'putty' or 'plastic' to at least 11.5 m bgl on site, suggesting there would be over 8 m thickness of this material below the base of the VSC piles after the ground level has been raised based on the maximum depth to Chalk of 3.5 m bgl. Based on the logged descriptions, this structureless Chalk is considered unlikely to support transport of silt particles to deeper fractured strata due to the high fines content of structureless Chalk.

<u>During Operation</u>

This pathway does not apply to the operational phase, and same points as above apply.

The risk from VSC piles via this pathway during both development and operational phases is therefore considered to be low.

2. **Risks of changes to groundwater flow regime**

<u>During Development</u>

The proposed method will not penetrate into the Chalk, and therefore the VSC piling will not alter the groundwater flow regime in the Chalk in terms of quantity or flow direction. Since the Alluvium is low permeability then it does not support a continuous water body so the installation of piles will not interfere with groundwater flow within the Alluvium. Temporary removal of hardstanding during development will expose the Alluvium however it is expected that there will be little infiltration into the low permeability Alluvium and that the water will be managed and disposed to surface water following suitable treatment, if required.

<u>During Operation</u>

The same points as above apply regarding the VSC piles. The entire site will be covered by buildings and hardstanding and the resulting roof and surface water collected and discharged

to surface water. This should result in slight reduction of recharge to the Alluvium compared to the current baseline, but is unlikely to significantly alter recharge to the Chalk aquifer.

The risk from the development during construction and operational phases to groundwater flow regime is therefore considered to be low.

3. Creation of preferential pathways, through a low permeability layer (an aquitard), to allow potential contamination of an underlying aquifer

The Alluvial Silt has relatively low permeability compared to the underlying Chalk and is reported to be between 1.3 and 2.4 m thick (Ground CC, 2023). Ground CC reported that there were no groundwater strikes within the Alluvium during drilling and water in the Chalk appears to be confined by this layer, indicating that it could reduce infiltration reaching the Chalk and also attenuate overlying contamination by sorption and supporting degradation.

<u>During Development</u>

As described in Section 4.2, the VSC piles have been designed so that they will not fully penetrate the Alluvium therefore they would not create complete pathways to the underlying Chalk. Additionally, analysis of groundwater samples from wells installed in the Made Ground and Alluvium has not identified contaminants at concentrations that exceed DWS target values, indicating acceptable risks if a pathway was inadvertently created that allowed perched water to enter Chalk. Any water present in the Made Ground and Alluvium is perched (where present) therefore volumes are small. Furthermore, it is noted that based on the size of structures on neighbouring sites, the Alluvium must have already been penetrated near to the site in which case any pathways created during the proposed development would not be new pathways. Analysis of groundwater samples from the Chalk has not identified contaminant concentrations above DWS, indicating that any existing connections between perched and deeper groundwater have not resulted in unacceptable impact to the Chalk aquifer.

<u>During Site Operation</u>

The same points as above will apply, no additional pathways would be created during the operational phase. Following development the site will be completely surfaced with impermeable hardstanding and buildings and the resulting surface and roof water collected and discharged via storm water attenuation tanks to surface water. Therefore infiltration will be reduced compared to the baseline scenario and potential for a linkage between perched water and groundwater in the Chalk further reduced.

Therefore, although this is identified as a potential pathway for VSC piles (EA, 2001) they will not fully penetrate the Alluvium and there is no known contamination source, therefore the risk during both the development and operational phases is considered to be Low.

4. The driving of solid contaminants down into an aquifer during pile driving

<u>During Development</u>

According to the Environment Agency "*Penetrative ground improvement methods involve horizontal displacement and densification of the soil through which the column is constructed. In normal circumstances this will not lead to soil being dragged downwards" (EA, 2001).*

The proposed VSC piles have been designed so that they will not penetrate the Chalk which further reduces such risks. Site investigations have not identified contamination in shallow soils considered likely to impact the groundwater in Chalk if it was driven downwards.

During Operation

The same points as above apply, there would be no additional risks during operation.

The risk from VSC piles via this pathway during both development and operational phases is therefore considered to be low.

5. Contamination of groundwater and subsequently, surface waters by concrete, cement paste or grout

During Development

The proposed VSC method uses stone rather than concrete or grout. According to the EA "*The installation of stone columns will not lead to the leaching of wet concrete, cement paste or grout into fast flowing groundwater*" (EA, 2001).

During Operation

This pathway does not apply to the operational phase, and same points as above apply.

The risk from VSC piles via this pathway during both development and operational phases is therefore considered to be low.

6. Contamination of shallow groundwater or adjacent surface waters by arisings

During Development

As noted above the VSC piling method will not generate arisings. Limited arisings will be generated by excavations for shallow strip foundations. Excavations are not expected to require dewatering. Risks from the arisings formed by strip foundations should be managed as standard good practice through the implementation of a Materials Management Plan (MMP).

During Operation

This pathway does not apply to the operational phase, and same points as above apply.

The risk from VSC piles via this pathway during both development and operational phases is therefore considered to be low.

7. Risks to aquifer from material imported to site

During Development

As described in Section 4.1 there is a requirement to import material to site to create a piling mat and to raise ground levels within the building footprints and beneath hardstanding to above potential flood levels.

Material imported to site will be natural stone for the piles and certified 6F2 for the piling mat. The piling mat material will be placed above the permanent water table and would be exposed for a relatively short period before being covered over by buildings or hardstanding, therefore risks from direct leaching or infiltration would be low.

During Operation

The material will be placed above the permanent water table and covered over by buildings or hardstanding, therefore risks from direct leaching or infiltration would be low.

The risk to the aquifer from this pathway during both development and operational phases is therefore considered to be low.

8. Risks from Site Surface Water Run-off/ Infiltration

During Development

During development the hardstanding will be temporarily removed, creating the risk that, following rainfall, silt-laden surface water could flow into the drain adjacent to the south-western boundary, or to enter existing gully drains across the site that are assumed to discharge to the culverted stream at the north-eastern boundary of site. The vibro piling may displace trapped porewater from the silt Alluvium and if so this is expected to emerge at the ground surface. The majority of the site falls gently from north-east to south-east which will reduce risks to the adjacent drain.

Prior to removal of hardstanding, gully drains in those areas will be grubbed up and blocked to prevent discharge of silt contaminated water from entering nearby water courses. If necessary a sump will be created to contain surface run-off and the resulting water discharged to the stream, via a treatment system if required.

During Operation

The entire site will be covered by buildings and hardstanding and the resulting roof and surface water collected and discharged to surface water, via treatment system if required which would be agreed with the Environment Agency. No infiltration of surface water is proposed. There would therefore be no unacceptable risk from surface water runoff during operation of the development.

The risk to the aquifer from this pathway during both development and operational phases is therefore considered to be low.

5.2 Other Environmental Risks Associated with Piling & Foundation Works

Risks to the other environmental receptors identified in the Environment Agency guidance (EA, 2001) are assessed below.

1. Creation of preferential pathways, through a low permeability surface layer, to allow upward migration of landfill gas, soil gas or contaminant vapours to the surface

During Development

No significant sources of ground gas (including dissolved phase ground gas) or contaminant vapours have been identified on or near site, therefore the creation of such pathways would not result in a risk. Additionally the shallow water table precludes permeable strata or the VSC piles from acting as pathways by saturating the pore spaces.

During Operation

The same points as above will apply with no additional pathways created.

The risk from VSC piles via this pathway during both development and operational phases is therefore considered to be low.

2. Direct contact of site workers and others with contaminated soil arisings which have been brought to the surface

During Development

As described in Section 4.3, an advantage of the VSC method is that it does not bring arisings to the surface. As described in Section 3.9.1, significant soil contamination was not identified. As noted by the EA, 'the risk from contaminated soil arisings in the case of vibro replacement and vibro concrete columns is in general considered to be negligible' (EA, 2001), however they are unlikely to contain contamination that would present a risk to health of workers and standard precautions and use of personal protective equipment (PPE) should mitigate any unexpected contamination.

During Operation

The site will be covered in hardstanding therefore there will be no risks from this pathway.

The risk from VSC piles via this pathway during both development and operational phases is therefore considered to be low.

3. Direct contact of the piles or engineered structures with contaminated soil or leachate causing degradation of pile materials (where the secondary effects are to increase the potential for contaminant migration)

During Development

The VSC piles will be constructed using natural stone that is not susceptible to degradation from aggressive ground. As noted in Section 3.9.4, aggressive ground conditions have not been identified on site.

During Operation

The same points as above will apply with no additional pathways created.

The risk from VSC piles via this pathway during both development and operational phases is therefore considered to be low.

5.3 Summary of Hydrogeological, Piling and Foundation Works Risk Assessment

No risks greater than Low were identified, provided that the recommended mitigation measures are implemented.

5.4 Piling and Foundation Mitigation Measures

Although risks to the aquifers and surface waters from the proposed development are relatively low, the following mitigation measures are proposed:

5.4.1 Groundwater Monitoring

Baseline

Before vibro-piling works commence, baseline conditions will be assessed by taking daily turbidity readings from three wells installed in the Chalk, located down-hydraulic gradient and up-hydraulic gradient of the building footprints. The boreholes monitored will be BH101, BH103 and ERM borehole BH02. Ground CC borehole BH102 is within the footprint of a proposed unit so will be decommissioned before works commence.

The readings will be recorded in nephelometric turbidity units (NTU) using a calibrated field meter. Readings will be taken by the contractor's nominated staff who will be trained in groundwater sampling and use of the instrument. Groundwater levels will also be recorded. Given the shallow depth of the piles, the upper part of the water column in the borehole will be sampled, using either a pump with the intake set at the top of the screened section which is between 3.0 and 3.5 m bgl in the above wells, just below the surface of the Chalk.

At the end of the baseline monitoring the average and maximum reading in each well will be recorded and set as the baseline for each well.

During Piling

The piling programme is estimated to take one month. Southern Water will be informed of the start date at least one week in advance, and of any subsequent changes to programme.

During piling monitoring will be completed at the end of each working day at all three wells, the data plotted on a chart and compared to the baseline readings to determine whether there has been variation from baseline conditions or if an upward trend is emerging.

If monitoring identifies a significant change from baseline, for example a 25% increase above the maximum, or an upward trend that indicates that the baseline maximum concentration is likely to be exceeded then further investigation will be triggered, to be completed within 48 hours of the exceedance (excluding weekends) and Southern Water will be informed of the findings by email. If the investigation confirms that there has been, or is likely to be, significant exceedance then a mitigation plan will be developed and implemented. Mitigation would depend on the circumstances, but could include additional confirmatory monitoring at higher frequency, reduction in the rate of piling works or relocating the piling rig to another area of site to allow conditions to settle.

After Piling

The monitoring will continue for one week after piling to confirm that there is no residual upward trend.

5.4.2 Surface Water Monitoring

A culverted stream runs along part of the north-eastern boundary of site and there is a drain along part of the south-western site boundary. No buildings are proposed in that area of site. Subject to access being made available by the site owner (GSK), the culverted drain outfall approximately 15 m downstream of the site boundary will be assessed for presence of increased sediment, by visual inspection only to ensure safety of the workers. Similarly, the drain at the south-western boundary will also be inspected for presence of increased sediment. Inspections will be carried out to the same schedule as the groundwater monitoring.

If increased sediment is noted then investigation will be triggered to confirm the cause. If the cause is confirmed to be the piling works then a mitigation plan will be developed and implemented.

5.4.3 Construction and Environmental Management Plan (CEMP)

The contractor shall develop a CEMP to ensure that risks to environmental receptors are controlled, and then implement it. The CEMP shall include a specific section on controlling risks to controlled waters from piling or foundation works. This section shall be submitted to Southern Water for approval to support the removal of their objection related to this point.

The CEMP shall include a requirement to implement a Watching Brief for unexpected contamination and set out how it would be assessed and subsequent actions.

5.4.4 Materials Management Plan (MMP)

Before below ground works an MMP will be developed and implemented to ensure that any soil arisings generated during construction are suitably managed to prevent risks to the aquifers, surface waters or workers. The MMP will also be used to control the quality of materials imported to site and their storage to prevent risks to these receptors.

5.4.5 Personal Protective Equipment (PPE)

The contractor will assess risks from contamination and ensure that their workers use appropriate PPE to protect themselves from contamination, if encountered.

5.5 Change Management

If changes to the piling approach are required, such as their layout or depth, then these will be assessed by Glenmore Holdings and if they are considered to have the potential to affect risk to controlled waters (e.g. piles extended to greater depths or outside currently proposed footprints) then the Southern Water will be informed by email with the updated details attached to the email.

5.6 Risk Assessment Conclusions

The proposed penetrative ground improvement method of VSC piles is the most appropriate foundation solution to minimise risks to the Chalk aquifer because unlike displacement or non-displacement methods it does not require penetration of the Chalk and turbidity created should be minimal.

Provided the recommended mitigation measures are employed, the placement of piles at the site is not considered to pose unacceptable risk to the nearby groundwater abstractions or surface waters.

6 Conclusions and Mitigation Measures

6.1 Conclusions

YES Engineering was requested by Glenmore Holdings Ltd to undertake a Hydrogeological and Foundation Works Risk Assessment for risks to controlled waters from piling for the proposed redevelopment of currently vacant land for five buildings that will provide Light Industrial, General Industrial, and Storage/ Distribution use, and an area of Open Storage use. The proposals are currently subject to a decision for Town Planning consent. Southern Water has requested that conditions be applied to any consent, such that a hydrogeological risk assessment, foundation works risk assessment and relevant information be included in a Construction and Environmental Management Plan (CEMP) for the works.

The site is in a relatively sensitive groundwater setting, within an SPZ1 that is protective of a potable water abstractions owned by Southern Water which is 195 m north east of the site and abstracts from the Chalk Principal Aquifer present beneath the site. During two ground investigations onsite (2020 by ERM Ltd and 2022 by Ground CC Ltd), groundwater was not encountered within shallow Made Ground or the Alluvium (Silt), but was encountered as a confined body within the Tarrant Chalk. The depth to Chalk was between 1.5 and 3.7m bgl, and was over 2.2 m bgl in fourteen of seventeen locations including at all proposed building footprints). Rest groundwater levels were between 0.96 and 1.05 m bgl during those investigations. Additional groundwater gauging was completed over six visits between November and January 2021 which reported depths between 0.37 to 2.16 m bgl, response zones of the borehole monitored are not known, but they were of sufficient depth to reach the Chalk. Groundwater flow direction reported by ERM was towards the north-east to north in September 2020, and Ground CC confirmed an easterly to north-easterly flow direction in December 2022. Reported groundwater gradients were between 0.0001 and 0.0004. A culverted stream flows along part of the north-eastern boundary of site and there is an open drain along part of the south-western boundary. The site is within an area at high risk of pluvial, fluvial and groundwater flooding.

Neither investigation identified soil, soil leachate or groundwater contamination considered to present unacceptable risk to controlled waters. In total, there were 20 sample locations with analysis of 30 soil samples, ten leachate samples and thirteen groundwater samples. A summary of the analytical results is presented in Section 3.9. Soil samples and groundwater well response zones were targeted on Made Ground, Alluvium and three only within the Chalk. The investigation reported Made Ground of variable composition to up to 1.4 mbgl then Alluvium of silt with varying sand and gravel content and then Chalk which was structureless to at least 11.5 m bgl and was proven to a thickness of 11.0 m. The maximum drilled depth was 15 m bgl.

In January 2023, YES Environmental undertook groundwater level gauging, aquifer permeability testing of three Ground CC boreholes installed within the Chalk and installed continuous water level monitors in the three boreholes set to record every two hours. The permeability testing reported permeabilities of between 1 and 13 m d^{-1}, indicating that the tested depths are not within highly fractured Chalk.

Given the low ground strength of the silt Alluvium, raft foundations are not suitable for the proposed buildings. Following review of piling options, vibro stone column piling (VSC) penetrative ground improvement was selected as the lowest risk method because the required bearings can be achieved without penetrating the Chalk aquifer and has low risk of

pushing material vertically downwards. A risk assessment has been completed for risks to hydrogeological receptors (and other receptors that could be impacted from the piling works) from the proposed works during the development and operational phases. The assessment considered eleven risk types which included risks of turbidity impacting the abstraction well. The assessment identified Low risk from all types subject to mitigation measures being implemented.

6.2 Recommendations

Mitigation measures are recommended to further reduce risks during piling. These comprise:

- Groundwater monitoring of three wells installed in the Chalk (BH101, BH103 and ERM borehole BH02) using a field water quality meter to assess turbidity and water levels before, during and after the piling works. The wells are located down and up-hydraulic gradient of the areas to be piled, comprising BH102 between the piling footprints and the abstraction well, BH101 to the east of the piling footprints and BH103 which is up/cross-hydraulic gradient of the majority of the site apart from Block A.
- Surface water monitoring of the drain and culverted stream outfall by visual inspection for sediment ingress.
- Implementation of a CEMP including a specific section on risks to controlled waters from piling or foundations works. This shall include implementation of a Watching Brief for unexpected contamination.
- Implementation of an MMP to ensure that arisings and materials brought to site are correctly managed.
- Use of PPE as required to ensure groundworkers are protected from contamination, if present.
- Southern Water will be informed if there are changes to the planned works that could impact the assessed risks.

7 References

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Figures

Figure 1 – Potentiometric Surface Plot for Chalk Aquifer, 24 January 2023

Figure 2 – Depths to Chalk (metres below current ground level)