hafrenwater
environmental water management

Mr S Rees
Greenfield Enviro
1 Commercial Road
KEYWORTH
Nottingham
NG12 5JS

Project ref: 3174

24th January 2022

Dear Simon

**White Cross Farm Quarry; Comment on potential for impact on private water supply borehole at Windward House, Wallingford**

## Background

The proposed quarry at White Cross Farm, Wallingford, would extract sand and gravel from a shallow deposit located on the western bank of the River Thames. The submitted planning application was supported by a hydrogeological impact assessment (HIA) (Hafren Water, August 2021).

Subsequent to the submission of the Planning Application a response was received from the Environment Agency (EA) (22nd October 2021 EA ref WA/20201/129358) objecting to the proposals. One of the responses stated *'Insufficient information to determine risks to potable water supplies'.* (EA response quoted in italics) The Windward House domestic abstraction is located approximately 50m south of phases 2 and 3. The EA continue *'Our main concern is surrounding the groundwater supply to this abstraction, from our assessment of the groundwater environment, review of supplied information and the cumulative impact of the neighbouring New Barn Farm site, there is a risk of significantly reducing recharge and the direct lowering of groundwater levels into this area.'*

Hafren Water was commissioned to prepare a response to the comments and the outcome is given below.

## Proposed mitigation measures

The potential for impact upon the Windward House waterwell was identified during the HIA, consequently mitigation measures were proposed. These are discussed within Section 5.1 of the above referenced HIA report.

To mitigate the risk to the waterwell, mineral extraction within Phases 2 and 3, the closest to the waterwell, would begin in the south. This will allow the early placement of clay overburden against the southern face of the quarry void. This will create a low permeability barrier between the proposed extraction area and the private water supply. Laboratory testing of the overburden indicated that permeabilities of between 8x10-11 and 1x10-10m/s can be achieved.

The piezometers along the southern site boundary will be monitored weekly to allow the early identification of any adverse impact, in the unlikely event of its occurrence.

Notwithstanding the very small likelihood of impact due to the proposed mitigation measures, the issues have been assessed, as discussed below.

### Characterising the Windward House borehole

In order to meaningfully assess the potential for impact upon the waterwell its characteristics have to be known. These include the borehole depth, screened section, abstraction rates and drawdown during use. Simon Rees of Greenfield Enviro Limited attempted to find this information by contacting the property owner. (Telephone conversation 29th November 2021) However, the owner was 'not minded' to provide access to the waterwell. He added that he did not feel that he should provide any data relating to his well as it was 'clearly linked to the level of the Thames.' Consequently, it has not been possible to determine the characteristics of the waterwell.

Due to the non-co-operation of the site owner the potential for impact has had to be assessed by alternative means.

### Saturated thickness of the sand and gravel aquifer

Data shows that the groundwater level within the closest monitoring borehole to Windward House (GM 16/6) varies between 1.22 and 1.64m below ground level. (bgl) The base of the sand and gravel in the borehole was recorded at 2.4 m bgl. The saturated thickness of the aquifer in the vicinity within the Application Area at the closest point to Windward House is thus known to be extremely limited, varying being between 0.76m and 1.18m. It is difficult to envisage how an aquifer with such a limited saturated aquifer thickness could consistently supply the Windward House waterwell. For this reason, it is considered probable that the waterwell is installed into the chalk, which is situated at depth beneath the marly clay encountered beneath the mineral.

### Estimated water usage

Neither the pump specification nor the actual abstraction volumes from the Windward House waterwell are known, for the reasons stated above. Consequently, abstraction rates have had to be estimated. For supply planning in the UK daily water use per person is taken to be c150 litres. (Source: WaterUK) Therefore, assuming that there are 4 residents in the property the volume of abstraction from the waterwell may be expected to be c600l/day. For a worst-case situation, a volume of 1.2m3 (ie twice the likely volume) per day of abstraction has been used in this assessment. This equates to a very small equivalent constant demand of approximately 0.01 l/second.

### Groundwater flow direction

The inferred groundwater flow direction within the sand and gravel aquifer within the Application Area and its environs was previously determined and reported within the HIA referenced above. The contours are shown on Drawing 3174/HIA/07 within the HIA. It can be seen that the groundwater flow is broadly eastwards, towards the River Thames.

The source of supply to the waterwell would be groundwater flow, and would be replenished naturally from the west. ie From an area that would be un-affected by the proposed mineral extraction. It is noted that the New Barn Farm site is located well to the north of the Windward House waterwell.

### Recharge

An estimate of recharge / groundwater throughput in the sand and gravel can be made using the Darcy relationship, which is of the form:

$$Q = kiA$$

Where

$Q$ = groundwater flow (m3/day)

$k$ = hydraulic conductivity (m/d) conservatively estimated to be 10m/d

$i$ = hydraulic gradient = 0.004 (based on inferred groundwater contours)

$A$ = cross-sectional area of the saturated sand and gravel aquifer and assuming a 50m width = 50m2

The estimated groundwater throughflow is thus estimated to be 3.6 m3/d, which equates to 0.04 l/s.

It can be seen that the potential recharge to the waterwell, which will be supplied by groundwater flow from the west, is approximately 4 times the volume which may be abstracted.

Summary

The potential for impact to occur upon the Windward House waterwell was identified during the investigation for the HIA which supported the Planning Application. Robust mitigation measures, including the placement of a clay barrier and groundwater level monitoring are proposed.

It was not possible to determine the details of the waterwell due to the non-co-operation of the owner of Windward House.

The proven easterly groundwater flow within the sand and gravel aquifer is such that recharge to the Windward House waterwell will not be affected by either the White Cross Farm or New Barn proposed developments.

Recharge available to the aquifer in the vicinity of the waterwell is estimated to be approximately 4 times the volume which is considered likely to be abstracted.

On the basis of the above comments the potential for the proposed development to impact adversely upon the Windward House waterwell is considered to be insignificantly small.

Yours sincerely

C C Leake Bac MSc FGS
Director

# HYDROGEOLOGICAL AND HYDROLOGICAL ASSESSMENT FOR A PROPOSED SAND AND GRAVEL QUARRY AT WHITE CROSS FARM, WALLINGFORD

**Report Reference: 3174/HIA**
**Final F1**
**August 2021**

**Report prepared for**:

Greenfield Environmental
1 Commercial Road
Keyworth
Nottingham
NG12 5JS

## GENERAL NOTES

Title of report: Hydrogeological Impact Assessment
Site: White Cross Farm
Report ref: 3174/HIA
Date: August 2021

| Version | Date | Issued to |
|---|---|---|
| Draft D1 | 30th July 2021 | Simon Heaton |
| Final F1 | 5th August 2021 | Simon Heaton |
| | | |
| | | |

Author: Dylan Ingman MESci MSc FGS
Reviewer: Heather MacLeod BSc MSc FGS

This report has been prepared by Hafren Water Ltd for the named Client, with reasonable skill, care and diligence within the agreed scope and terms of contract. Hafren Water Ltd disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of work. This report has been prepared for use by the client and others acting on their behalf. The report may be passed to regulators. This report does not constitute legal advice or opinion.

This report does not represent advice to third parties and no reliance is offered to third parties. No liability is accepted with regard to third parties. Reliance required by any specific Third Party must be agreed in writing with Hafren Water Ltd.

*\\SERVER1\Public\Projects\White Cross Farm Quarry (3174)\Reports\HIA\Draft\3174_HIA F1 (Aug 21).docx*

## CONTENTS

## TABLES

## DRAWINGS

## APPENDICES

# 1 INTRODUCTION

## 1.1 Background

The proposed site at White Cross Farm ('the site') comprises agricultural land and grassland covering circa (c) 18.8 hectares (ha) adjacent to the River Thames. It is proposed to extract sand and gravel from the site down to bedrock. The restoration of the site will involve the importation of inert waste to return the site back to approximate original ground levels and to a mix of floodplain habitats and agricultural land. Planning Application P18/51641/CM has previously been submitted for the site but was refused by Oxfordshire County Council for reasons primarily relating to the previous marina end use element of the proposal. Following revision of the restoration plan it is proposed to resubmit the Planning Application.

Hafren Water has been commissioned to undertake an assessment of the extant water environment, including the potential for impact of the proposed development, and to ensure that any comments previously raised by the EA are addressed.

## 1.2 Location

White Cross Farm is located 1.2 km south of Wallingford town centre, and approximately 20 km southwest of Oxford. The site is centred on National Grid Reference (NGR) SU 460535 187753 as shown on *Drawing 3174/HIA/01*.

## 1.3 Scope of assessment

The objectives of the investigation are as below:

- Determination of baseline conditions of the water environment at the site and its environs
- Identification of potential impacts of the proposed mineral extraction and restoration
- Assessment of the magnitude and significance of potential impacts of mineral extraction and the proposed subsequent restoration
- Derivation of appropriate mitigation measures for any identified potential impacts

## 1.4 Comments from Oxfordshire County Council

A number of issues were raised by Oxfordshire County Council in their pre-application advice (PRE.0048/21, 6th May 2021) in particular drawing attention to the reason for the refusal of the originally proposed scheme. Of note to this hydrogeological impact assessment is their comment regarding the Environment Agency's objection relating to groundwater which stated:

> *"It has not been demonstrated that the development would not have an unacceptable impact on groundwater contrary to policies C4 of the Oxfordshire Minerals and Waste Local Plan – Part 1 Core Strategy and policy SP7 of the South Oxfordshire Local Plan 2011."*

It was also noted within the pre-application advice that the proposal for a clay barrier may still raise concerns with the EA about impacts on groundwater flow.

### 1.5 Comments from the Environment Agency

The Environment Agency issued two statements outlining their objections to the initial planning application on 6th March 2020 and 4th September 2020. These communications identified three issues relating to groundwater which will need to be addressed. These are:

- The emplacement of a clay barrier or the importation of low permeability inert fill may obstruct groundwater flow
- The cumulative impact of White Cross Farm and New Barn Farm on the water quality and resource would need to be assessed
- Assess the impact of the dewatering at the site on the abstraction licence at New Barn Farm (TH/039/0020/0008)

### 1.6 Data sources

The characteristics of the water environment have been investigated with the use of existing published data and reports, assessment of site data, and experience of other sites in broadly similar settings. The data sources used in the investigation are listed below:

Ordnance Survey (OS) mapping
- 1:25,000 scale

ESI
- Hydrogeological Impact Assessment, R65148R1, June 2017

Environment Agency
- WA/2018/125627/02-L01, 6th March 2020
- WA/2018/125627/03-L01, 3rd September 2020

Oxfordshire County Council
- Pre-Application advice, 6th May 2021

- Oxfordshire Minerals and Waste Local Plan (2017)

South Oxfordshire District Council

- South Oxfordshire Local Plan 2011 – 2035 (adopted 2020)

British Geological Survey (BGS)

- Allen DJ, Brewerton LJ, Coleby LM, Gibbs BR, Lewis MA, MacDonald M, Wagstaff SJ and Williams AT, 1997. The physical properties of major aquifers in England and Wales. BGS Technical Report WD/97/34
- Bricker SH and Bloomfield JP. Controls on the basin-scale distribution of hydraulic conductivity of superficial deposits: a case study from the Thames Basin, UK. Quarterly Journal of Engineering Geology and Hydrogeology, Vol 47, 2014
- Geological map, 1:50,000 (England & Wales), Sheet 254, Henley-on-Thames, Bedrock and superficial Edition
- GeoIndex (www.bgs.ac.uk/geoindex/)

### 1.7 Methodology

Baseline conditions of the water environment have been defined by the collation and analysis of existing data and field observations. The potential effects of the proposed development upon the extant water environment have been assessed by reference to the baseline data and a series of matrices (*Appendix 3174/HIA/A2*), developed to ensure a rigorous and consistent approach to the assessment of potential impacts. Mitigation measures have been proposed, where appropriate.

# 2 BASELINE CONDITIONS

## 2.1 Introduction

A review of the data sources presented in online databases and previous reports has been used to define the baseline conditions, which are described below.

## 2.2 Site description

The site covers an area of approximately 18.8 ha comprising agricultural land. A single barn is located in the west of the site. The site boundary is defined to the north and west by Nosworthy Road and Reading Road, respectively. The eastern boundary is defined by the River Thames and the southern boundary, by a bank of trees associated with a residential property.

The site is bisected by a drainage ditch that runs north to south through the centre. In the west the site falls from 45.7 metres Above Ordnance Datum (mAOD) to 44.3 mAOD at the ditch. In the east of the site the land is at approximately 43.5 mAOD and slopes very gently towards the Thames.

The land surrounding the site is generally level and falls gently towards the River Thames on both banks. Approximately 1 km east of the site the land rises relatively quickly to approximately 95 mAOD.

## 2.3 Hydrology

### 2.3.1 Rainfall

Rainfall data were obtained from the Environment Agency for the Benson rain gauge, located 3.4 km to the north of the site at NGR SU 61320 91235. Data are recorded between 31st October 1990 and 6th July 2021. The average monthly rainfall over these years is shown in *Table 3174/HIA/T1*.

**3174/HIA/T1: Rainfall data from the Benson rain gauge**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainfall (mm) | 53.5 | 38.8 | 34.9 | 44.5 | 48.8 | 39.2 | 40.0 | 46.8 | 47.3 | 62.9 | 66.9 | 54.2 |

During this period the total annual rainfall varied from a minimum of 404 mm (2005) to a maximum of 770 mm (2014) with a mean of 569 mm.

### 2.3.2 Watercourses

The ditch, which bisects the site, is reportedly frequently dry, only flowing following flooding from the Thames. This ditch is truncated in the north by Nosworthy Way.

A second drainage ditch crosses the northeastern corner of the site flowing generally west to east and joins the River Thames on the east boundary.

The largest watercourse in the vicinity of the site is the River Thames, which flows from north to south along the eastern boundary. Flow data for the river is available for the Days Weir (SU 568 936) from the National River Flow Archive. This gauge is located 9.8 km upstream of Wallingford where the Thames has a mean daily flow of 28.74 m$^3$/s.

Two tributaries of the Thames, comprising Bradford's Brook/Mill Brook (c700 m to the north of the site) and Cholsey Brook (c700 m to the south of the site), drain the western side of the river. Both watercourses are shown on *Drawing 3174/HIA/02*. Bradford's Brook and Cholsey Brook appear to be largely artificial and developed over a considerable period of time, as documented by Grayson, 2004[1].

No watercourses are present on the eastern bank of the River Thames in the vicinity of the site.

### 2.3.3 Waterbodies

There are a number of small waterbodies in the vicinity of the site boundary, as indicated on *Drawing 3174/HIA/02* and described below. Features to the east of the River Thames have not been considered as they are in a separate surface water catchment and hence are hydraulically isolated from the surface water regime around the site.

- A pond is located approximately 50 m south of the site. Based on LIDAR data and borehole logs this appears to be situated within a shallow clay layer. The groundwater level is anticipated to be close to the base of this feature
- Two ponds 480 m southwest of the site boundary at NGR SU 6015 8713. One pond is an in-line feature on Cholsey Brook, the other, larger, pond has an offtake from Cholsey Brook and has a discharge into a drain that flows back into Cholsey Brook

### 2.3.4 Springs

No springs are observed on OS mapping in the same surface water catchment as the site.

---

[1] Grayson AJ, 2004. Bradfords Brook, Wallingford. Oxoniensia, Volume 69 29-44 www.oxoniensia.org/volumes/2004/grayson.pdf (accessed 01/07/21)

### 2.3.5 Surface water abstractions

No surface water abstractions are present within 2 km of the site boundary.

### 2.3.6 Surface water discharge consents

Eight surface water discharge consents are present within 2 km of the site boundary, three of these are located on the opposite side of the Thames to the site. The nearest discharge points are located approximately 500 m south of the site at Bow Bridge and are indicated to be for sewage from a non-water-company source.

### 2.3.7 Flooding

The site is located primarily within an area designated as Flood Zone 3 by the Environment Agency, the western edge of the site is located within Flood Zone 2.

## 2.4 Sites of ecological and conservation interest

The MAGIC website (www.magic.gov.uk) indicates that the site is not located within 2 km of a Special Area of Conservation (SAC), Site of Special Scientific Interest (SSSI) or Special Protection Area (SPA). The Chilterns Area of Outstanding Natural Beauty (AONB) is located on the opposite side of the Thames to the site. North Wessex Downs AONB is located 1.5 km west of the site.

The eastern half of the site and the field adjacent and to the north are designated Priority Habitats comprising “coastal and floodplain grazing marsh”. Downstream of the site, along the banks of the Thames, there are numerous areas of “deciduous woodland” and “coastal and floodplain grazing marsh”.

None of the identified features are considered groundwater-supported.

The locations are presented on *Drawing 3174/HIA/03*.

## 2.5 Landfill facilities

There are no historic or licensed landfill facilities within 2 km of the site.

## 2.6 Geology

### 2.6.1 Regional

The geology of the area around the site is shown on *Drawing 3174/HIA/04*, taken from the 1:50,000-scale BGS geological map for Henley-on-Thames. The geological succession is summarised in *Table 3174/HIA/T2*.

**3174/HIA/T2: Geological succession**

| | | Formation | | Former name | Lithology |
|---|---|---|---|---|---|
| Superficial | | | Alluvium | *Alluvium* | Clay, silt sand and gravel |
| | | Thames Valley | Northmoor Sand and Gravel Member | *1st Terrace Deposits* | Sand and gravel |
| | | | Summertown-Radley Sand and Gravel Member | *2nd Terrace Deposits* | Sand and gravel |
| | | | Wolvercote Sand and Gravel Member | *3rd Terrace Deposits* | |
| Solid | White Chalk Subgroup | Lewis Nodular Chalk | (Chalk Rock Member at base) | *Upper Chalk* | Chalk with hard grounds |
| | | Holywell Nodular Chalk | (Melbourn Rock Member at base) | *Middle Chalk* | |
| | Grey Chalk Subgroup | Zig Zag Chalk | (Totenhoe Stone Member at base) | *Lower Chalk* | |
| | | West Melbury Marly Chalk | (Glauconitic Marl Member at base) | | |
| | Selbourne Group | Upper Greensand | | | |
| | | Gault | | | |

The Northmoor Sand and Gravel Member is indicated to be present across the site. These are described as a terrace of the River Thames comprising sandy limestone gravel. In the eastern half of the site the sand and gravel is indicated to be overlain by Alluvium associated with the River Thames. Alluvium generally comprises a mix of clay, silt, sand and gravel.

The regional bedrock geology comprises a sequence of Cretaceous chalk which dips shallowly towards the southeast. The site is directly underlain by the Glauconitic Marl Member of the West Melbury Marly Chalk Formation. The Member is between 2 m and 4 m thick and comprises calcareous sand and sandy silty chalk. In the southwest of the site the Glauconitic Marl is overlain by the rest of the West Melbury Marly Chalk Formation. The Glauconitic Marl is underlain by the Upper Greensand Formation (UGS), the upper horizons of which are similar to the Glauconitic Marl in composition and the exact boundary may be difficult to determine. The UGS can be from 25 m to 30 m thick.

### 2.6.2 Local

Thirty boreholes were drilled on-site between 2014 and 2016. The boreholes are located across the entirety of the site and drilled to depths of between 3.0 m and 7.7 metres below ground level (mbgl). Some of the boreholes were installed with permanent monitoring pipe and the locations of these are shown on *Drawing 3174/HIA/04*. The borehole logs are presented in *Appendix 3174/HIA/A1*.

The boreholes encountered a sandy clay between 0.3 m and 1.6 m thick beneath the topsoil. The clay overlies sand and gravel ranging in thickness between 1.6 m and 5.2 m, with the thickest deposit in the northwest of the site and it is gradually replaced by cohesive sediments as it approaches the River Thames. Directly beneath the sand and gravel is a weathered Chalk Marl (believed to be the Glauconitic Marl Member) which was encountered from between 2.2 m and 6.7 mbgl.

The BGS Geoindex records an additional 26 boreholes drilled within the site boundary during 1974. In general, the boreholes have a layer of clay approximately 2.7 m thick overlying the sand and gravel. The sand and gravel was encountered to a depth of between 2.7 m and 7.0 mbgl, with an average depth to the base of 4.6 m. Within all of the boreholes a 'stiff, off white clay' was encountered at the base, this is considered to be bedrock.

## 2.7 Hydrogeology

### 2.7.1 Aquifer status and regional context

The superficial deposits are classified by the Environment Agency as a Secondary A Aquifer. These are 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.

The bedrock beneath the site is designated as a Principal Aquifer, these are layers of rock that usually provide a high level of water storage and may support water supply and/or river base flow on a strategic scale. It is noted by Allen et al (1997) that the aquifer properties of the Chalk Marl (Glauconitic Marl) are poor due to high clay content, as such the unit is relatively impermeable and unproductive, and may define the base of the chalk aquifer.

The aquifer classifications are shown on *Drawing 3174/HIA/05*.

The Environment Agency data show that the site is not located in, or within 2 km of, a groundwater Source Protection Zone (SPZ).

### 2.7.2 Local hydrogeology

Water strikes were recorded in all of the site investigation boreholes during drilling. The groundwater strikes ranged between 44.00 m and 41.14 mAOD (0.19 m and 3.00 mbgl). A summary of the groundwater strikes is presented in *Table 3174/HIA/T3*. It should be noted that the water levels in this table represent groundwater level at the time of drilling, ie in the winter water levels will be higher, and in summer and early autumn levels will be lower.

**3174/HIA/T3: Groundwater strikes during drilling**

| Borehole | Date | Depth to water (mbgl) | Water elevation (mAOD) |
|---|---|---|---|
| WSA14/1 | 17/12/14 | 0.88 | 43.61 |
| WSA14/2 | 17/12/14 | 1.78 | 43.96 |
| WSA14/3 | 17/12/14 | 0.19 | 43.32 |
| WSA14/4 | 17/12/14 | 0.70 | 42.89 |
| WSA14/5 | 17/12/14 | 0.40 | 43.23 |
| WSA14/6 | 17/12/14 | 0.30 | 43.17 |
| WSA14/7 | 17/12/14 | 1.60 | 43.52 |
| WSA14/8 | 17/12/14 | 1.40 | 43.80 |
| WSA14/9 | 17/12/14 | 0.50 | 42.95 |
| WSA14/10 | 17/12/14 | 0.70 | 42.67 |
| WCF15/1 | 29/09/15 | 1.70 | 43.10 |
| WCF15/2 | 29/09/15 | 1.40 | 42.90 |
| WCF15/3 | 29/09/15 | 1.80 | 43.20 |
| WCF15/4 | 29/09/15 | 1.70 | 43.00 |
| WCF15/5 | 30/09/15 | 1.70 | 43.10 |
| WCF15/6 | 30/09/15 | 2.00 | 43.70 |
| WCF15/7 | 30/09/15 | 0.90 | 42.60 |
| WCF15/8 | 30/09/15 | 1.70 | 41.60 |
| WCF16/1 | 31/05/16 | 1.60 | 42.00 |
| WCF16/2 | 31/05/16 | 2.30 | 41.30 |
| WCF16/3 | 01/06/16 | 1.40 | 42.20 |
| WCF16/4 | 31/05/16 | 2.30 | 41.20 |
| GM16/1 | 18/11/16 | 2.00 | 41.71 |
| GM16/2 | 17/11/16 | 2.70 | 43.79 |
| GM16/3 | 17/11/16 | 2.50 (S&G)<br>7.40 (chalk) | 44.00<br>39.10 |

| **3174/HIA/T3: Groundwater strikes during drilling** | | | |
|---|---|---|---|
| **Borehole** | **Date** | **Depth to water (mbgl)** | **Water elevation (mAOD)** |
| GM16/4 | 16/11/16 | 2.80 | 43.23 |
| GM16/5 | 16/11/16 | 2.60 | 43.10 |
| GM16/6 | 15/11/16 | 1.70 | 42.83 |
| GM16/7 | 15/11/16 | 3.00 | 41.18 |
| GM16/8 | 18/11/16 | 2.10 | 41.14 |

The water strikes recorded within the BGS boreholes from 1974 give an average depth to groundwater of 2.4 mbgl. This is comparable to the boreholes drilled in June 2016 which were drilled at a similar time of year.

Piezometers were installed in twelve of the boreholes: WSA14/1 to WSA14/4 and GM16/1 to GM16/8. Monitoring of groundwater levels within these boreholes has been undertaken periodically since the piezometers were constructed. The groundwater levels are highest in the west and lowest in the southeast, indicating flow towards the River Thames. Seasonal fluctuations of the groundwater level are apparent within the data, with variations being between 0.5 m and 1.0 m, however these are not apparent in recent years due to a decrease in monitoring frequency. The groundwater levels within the piezometers during the monitoring period were between 42.40 m and 44.10 mAOD, which is consistent with the water strikes during drilling. Hydrographs of the monitoring data are presented on *Drawing 3174/HIA/06* and groundwater contours inferred for March 2021 are presented on *Drawing 3174/HIA/07*.

### 2.7.3 Groundwater vulnerability

The superficial and bedrock aquifers underlying the site and surrounding areas are classified as Medium to High vulnerability by the Environment Agency.

### 2.7.4 Aquifer properties

No site-specific data on the properties of the sand and gravel at the site have been determined, however, Bricker and Bloomfield (2014) analysed the results of grain size distributions for samples from the Northmoor Sand and Gravel using the Kozeny-Carmen method to estimate hydraulic conductivity. The results are shown in *Table 3174/HIA/T4*.

| 3174/HIA/T4: Estimated hydraulic properties for Northmoor Sand & Gravel | | | | | |
|---|---|---|---|---|---|
| **Unit** | **Count** | **Median** | **Average** | **Minimum** | **Maximum** |
| | | **m/d** | | | |
| Northmoor Sand & Gravel | 29 | 18.45 | 29.21 | 0.24 | 168.48 |
| Northmoor Sand & Gravel (U) | 40 | 8.81 | 10.46 | 0.26 | 42.71 |
| Northmoor Sand & Gravel (L) | 31 | 9.55 | 13.32 | 0.27 | 87.42 |
| U = Upper, L = Lower | | | | | |

### 2.7.5 Groundwater abstractions

Licensed abstractions

A freedom of information request was submitted to the Environment Agency to identify the currently licensed abstractions.

Seven licensed groundwater abstractions are located within 2 km of the site boundary. Six of these are on the opposite side of the River Thames and are, therefore, hydraulically isolated from the operations at the site.

The remaining abstraction is located 480 m northwest of the site within the boundary of New Barn Farm Quarry (Licence N° TH/039/0020/008). This abstraction licence relates to an area, which corresponds with a lagoon that appears to be being used as a source of water for mineral processing, with the water being returned to the lagoon for silt settlement. Based on the groundwater levels from White Cross Farm the water within the lagoons is likely to be in continuity with groundwater.

The location of the abstraction is shown on *Drawing 3174/HIA/04*.

Private abstractions

Private abstractions are those with an abstraction rate of less than 20 m$^3$/d. Data provided by South Oxfordshire County Council indicates eight private water supplies within 3 km of the site boundary. These were cross-referenced with borehole data available from the BGS. Details of the abstractions are summarised in *Table 3174/HIA/T5* and their locations are shown on *Drawing 3174/HIA/04*.

There are two private water supplies down-gradient of the site for Windward House (formerly Mead Furlong), these are located approximately 50 m and 200 m south of the site boundary. The remainder of the private water supplies are either up-gradient or on the opposite side of the River Thames.

**3174/HIA/T5: Private groundwater abstractions**

| Location | NGR | Distance & Direction | Purpose | Type | Source |
|---|---|---|---|---|---|
| Organic Allotment | 462299,190405 | 2779 m NE | AD | Borehole | Unknown |
| Windward House (Mead Furlong) | 460510,187395 | 47 m S | D | Well | Unknown (suspected to be sand and gravel) |
| Windward House | 460466,187230 | 240 m S | D | Well | Unknown (suspected to be sand and gravel) |
| The Mill Barn | 461125,186470 | 1100 m SE | U | Borehole | Unknown |
| Ferry Cottage | 460220,185430 | 2069 m S | D | Borehole | Unknown |
| Little Stoke House | 460253,185340 | 2149 m S | D | Borehole | Chalk Group |
| 68 Wallingford Road | 459840,187588 | 498 m W | D | Borehole | Upper Greensand |
| Hithercroft Farm House | 458822,188750 | 1762 m NW | CDL | Borehole | Chalk Group |
| KEY:<br>AD – Allotment and drinking water D – Domestic U – unknown CDL – Commercial, domestic & livestock | | | | | |

Water availability

Abstraction of water at the site is regulated under the Thames Abstraction Licensing Strategy CAMS. The Thames bespoke licensing strategy applies to groundwater abstractions in direct hydraulic continuity with a river, therefore the proposed development would be governed by the restrictions put in place as part of the CAMS document.

The availability of water for abstraction at the site is dictated by the assessment point at River Thames Reading gauging station (AP4). For this assessment point it is indicated that water is not available for licensing and a Hands-Off Flow (HOF) limit has been set; "no abstraction will take place when the average of the daily mean flows of the preceding 5 days in the River Thames as gauged at Kingston is equal to or less than $Q_{50}$ (1780 Ml/d)". It is also indicated that abstraction would only be available for an average of 182 days per year.

For catchments that are designated as having water not available for licensing, licence trading would be required for a consumptive abstraction licence to be granted.

### 2.7.6 Conceptual hydrogeology

Based on the background information compiled above a hydrogeological conceptual model for the site has been constructed and is summarised below.

The site is underlain by sand and gravel deposits and the Glauconitic Marl Member, part of the lowest horizon of the Cretaceous Chalk. In the northeast of the site the marl is overlain by the West Marl Chalk Formation. Both of these chalk units are of low to moderate permeability.

The sand and gravel underlying the site is the main groundwater bearing unit and the underlying low hydraulic conductivity chalk marl is considered to act as the base of the aquifer restricting downward flow of groundwater to lower horizons. A shallow layer of clay is present across the site and likely locally restricts recharge from rainfall. Groundwater flow is towards the River Thames indicating that groundwater and the river are in hydraulic continuity.

An unsaturated zone exists within the sand and gravel and the saturated zone varies from 0.8 m to 4.0 m thick.

A summary of the conceptual model is presented as two schematic cross-sections for during extraction and following restoration in *Drawings 3174/HIA/08* and *3174/HIA/09*.

# 3 PROPOSED DEVELOPMENT

## 3.1 Mineral extraction

It is proposed to extract the full thickness of sand and gravel down and process the mineral on-site. This will produce up to 0.5 Mt of sand and gravel with the site being operational approximately for a five year period.

Phase A will be undertaken first, this will involve the stripping of topsoil, and the extraction and stockpiling of the sand and gravel from the area. The void will then be backfilled with inert imported engineered fill to allow the construction of access roads, mineral processing plant, weighbridge, site office and silt lagoon.

Mineral extraction will take place in four phases. This will begin in the northeast and continue clockwise around the site on a campaign basis. A 30 m standoff from the River Thames will be maintained. The treeline along the ditch that bisects the site will be retained.

Extraction will only be undertaken during the dry months to avoid the flooding season. Backfilling with imported inert fill will progressively follow material extraction and will take place throughout the year.

Due to the elevation of the groundwater, dewatering will be required in all phases to allow complete and safe mineral extraction and restoration.

The phasing plan is shown on *Drawing 3174/HIA/10*.

## 3.2 Restoration

Restoration will be concurrent with mineral extraction. Imported inert material will be used to return the land to within 0.6 m of the original topography, with the remainder of the ground being made up of topsoil and subsoil stripped from the site during the extraction phase.

The west of the site will be returned to arable land with the silt lagoon being converted into a permanent waterbody. The east of the site will be landscaped to form a damp meadow/ marshy wetland. The restored silt lagoon will be linked to the wetland through shallow scrapes, and the wetland will drain towards a permanent waterbody situated in the east of the site. The waterbody will include a high water overflow to the River Thames. The proposed restoration plan is presented in *Drawing 3174/HIA/11*.

## 3.3 Water management

### 3.3.1 During mineral extraction

Part of the mineral deposit is below the watertable, therefore it is proposed to dewater the deposit to allow complete mineral extraction. Encountered groundwater will be directed to a sump constructed at the lowest point of the quarry void. This point will move as the mineral extraction progresses to each phase in turn.

Water from the sump will be pumped to the lagoon in Phase A where it will be used in the mineral washing plant. The water from the plant will be passed back into the lagoon for settlement. Excess water will be discharged to the River Thames via the ditch in the northeast of the site. Water for welfare will be provided by an existing water main on-site.

An abstraction licence will be required for the transfer of groundwater from the quarry void to the River Thames prior to commencement of dewatering. Similarly an abstraction licence will be required for water used in mineral processing and any dust suppression or wheel washing activities if using water obtained on-site. An Environmental Permit will be required for the discharge of treated water off-site.

### 3.3.2 Post-restoration

Upon completion of infilling dewatering will cease and groundwater levels will be allowed to return to their pre-extraction state.

A new lagoon and the creation of a damp meadow will create additional long-term storage of surface water on the site. The final contours will result in run-off being towards the Thames, with some of this channelled in shallow scrapes towards a gravel face/ditch adjacent to the River Thames.

# 4 ASSESSMENT OF IMPACTS

## 4.1 Methodology

An assessment has been undertaken to determine the potential effects of the proposed mineral extraction and subsequent restoration on the water environment within and surrounding the site.

Potential impacts to the baseline and current conditions have been assessed for the short-term (operational) and long-term (post-restoration) phases of site development. The potential for unplanned incidents, such as spillage of hazardous substances, have also been taken into account. The following factors were considered:

- Magnitude of the impact
- Spatial extent of the impact
- Frequency of the impacts
- Timescale over which the impact may occur
- Cumulative impacts
- Sensitivity of the receiving environment

Mitigation measures and residual impacts have been considered as part of the assessment. The method of assessment is detailed in *Appendix 3174/HIA/A2* together with the matrices used to provide a robust method of assessment. Mitigation measures and residual impacts are discussed in Section 5.

## 4.2 Baseline sensitivity

The characteristics of the baseline water environment are used to form a basis from which the impact assessment can be undertaken. Details of how the baseline catchment sensitivity is assessed are provided in *Table 3174/HIA/A2.1* of *Appendix 3174/HIA/A2*.

Baseline sensitivities for various features surrounding the site are given in *Table 3174/HIA/T6.*

**3174/HIA/T6: Receptor sensitivity**

| Receptor | Sensitivity | Reasons |
|---|---|---|
| SURFACE WATER | | |
| On-site watercourses/ ditches | Low | The ditches are for field drainage and do not regularly contain water |
| River Thames & tributaries | Medium | Water availability along the length of the Thames is restricted. There is high connectivity between the river and surrounding superficial deposits. No water supported statutory sites of conservation or |

**3174/HIA/T6: Receptor sensitivity**

| Receptor | Sensitivity | Reasons |
|---|---|---|
| | | ecological interest are present within 2 km of the site |
| Down-gradient waterbodies | Low | The nearby waterbodies appear to be artificial and for recreational purposes |
| GROUNDWATER | | |
| Superficial Aquifer | Medium | The deposits are in hydraulic continuity with the River Thames, which has restricted water availability along its length. The deposits are a Secondary (A) Aquifer |
| Bedrock Aquifer | Low | The bedrock directly beneath the site is considered to have a low permeability |
| Windward House (Mead Furlong) Private supply | High | The supply is indicated to be for domestic use and is adjacent to the site. The target strata is unknown but suspected to be the sand and gravel |
| New Barn Farm Abstraction (TH/039/0020/008) | Medium | Groundwater supported lagoon used for mineral washing at the New Barn Farm Quarry |

### 4.3 Radius of influence

The proposed dewatering at the site will cause groundwater level lowering beyond the curtilage of the site. The extent of this lowering is referred to as the ‘radius of influence’ and it can be estimated using empirical formulae. The estimated radius of influence can then be used to identify the receptors that may be impacted by dewatering activities.

It should be noted that the degree of watertable lowering reduces exponentially from the centre of dewatering.

The saturated thickness of the sand and gravel has been determined from the borehole logs and monitoring data for the site, and is assumed to be 3 m in all phases. The median hydraulic conductivity for the Northmoor Sand and Gravel Group (*Table 3174/HIA/T4*) has been used throughout.

The Sichardt equation was used to attain an estimate for the radius of influence, giving a value of 120.6 m. This estimated radius of influence is lower than those previously predicted by ESI (2017) due to the use of a more relevant permeability value for the Northmoor Sand and Gravel Deposit.

The estimated radius of influence can be incorporated into the Dupuit-Forscheimer equation to calculate a groundwater inflow volume. Further refinement of the groundwater inflow was undertaken based on the specific geometry for each phase of working. Previously worked phases were assumed to represent areas of no-flow due to the presence of low permeability inert fill, and inflow from the river has been calculated based on reach transmissivity and aquifer properties. The volume of groundwater inflow from radial flow, backfilled phases (no-flow), and river inflow were weighted based on the proportion of the perimeter of the phase that they represent. The contribution from rainfall was based on the long-term averages. The water inflows ranged between 653.9 $m^3$/day and 130.6 $m^3$/day. Further details of the calculations are given in *Appendix 3174/HIA/A3*.

## 4.4 Potential impacts during mineral extraction

### 4.4.1 Water flow & level

Dewatering will be required for all phases of mineral extraction, however only one phase (or the equivalent area) will be open at any one time due to the progressive restoration. The effects of dewatering would therefore be time limited. The lowering of groundwater levels around the site may cause impacts to nearby receptors.

The site is adjacent to the River Thames and, whilst clay content increases towards the river, the groundwater monitoring data and levels from the Thames indicate that the groundwater is in hydraulic continuity with the Thames. The calculated radius of influence includes the river, indicating water will be drawn into the site from the river during dewatering. However, this volume would be minimal relative to flow in the river. Additionally, it is intended to discharge abstracted water back to the River Thames on the northern edge of Phase 1, upstream of the dewatering. Therefore, any water removed from the Thames would be returned, reducing the effects of drawdown.

The watercourses on-site do not regularly contain water and will be retained following completion of development. The watercourse in the northeast will be the discharge route for the site. There will, therefore, be no adverse impact on the flow in these watercourses from dewatering.

The groundwater table in the shallow superficial sand and gravel aquifer will temporarily be lowered during the operational phase (c5 years) of the development. During this time groundwater will flow into the site and be removed via dewatering activities. Estimates of the area surrounding the site where groundwater lowering may be experienced have been made and are small (up to 120 m from the site) compared with the size of the aquifer. Therefore the impact on the aquifer as a whole will be low.

The private water supply at Windward House is within the radius of influence for Phases 2 and 3. Any watertable lowering at the abstraction would only occur over a c2 year period and would be reversible. Due to it being a highly sensitivity receptor mitigation measures will be necessary. Details of the proposed mitigation measures are given in Section 5.

There is one waterbody within the radius of influence of dewatering, however this is likely to be situated within the shallow clay and not in continuity with the groundwater, therefore it would not be affected by dewatering.

The abstraction at the adjacent New Barn Farm Site (TH/039/0020/008) is a considerable distance outside the radius of influence, and therefore dewatering would have a negligible impact on this water supply.

**3174/HIA/T7: Water level impacts during development**

| Receptor | Sensitivity | Magnitude | Significance |
|---|---|---|---|
| SURFACE WATER | | | |
| On-site watercourses/ditches | Low | Negligible | None |
| River Thames & tributaries | Medium | Low | Minor |
| Down-gradient waterbodies | Low | Negligible | None |
| GROUNDWATER | | | |
| Windward House (Mead Furlong) Private supply | High | Medium | Major |
| Superficial Aquifer | Medium | Low | Minor |
| Bedrock Aquifer | Low | Negligible | None |
| New Barn Farm Abstraction (TH/039/0020/008) | Medium | Negligible | Minor |

### 4.4.2 Water quality

As with all quarry sites, their operation can pose a contaminant risk to the water environment through the accidental release of hydrocarbons from mobile and static plant, or from the off-site release of water with high suspended solid content.

Spill prevention practices and emergency spill procedures will be in place at the site during operation to reduce the likelihood of hydrocarbons being released into the environment. Further details are given in Section 5.

During the operational phase dewatering at the site would cause groundwater flow to be towards the centre of the site preventing any potential contamination from migrating off-site. In the unlikely event that contaminated water entered the water management system, off-site discharge would cease and the contamination dealt with in line with best practice.

Suspended solids will be produced during mineral washing and will only pose a risk to surface waters via the discharge route. Any sediment produced during dewatering will be able to settle out within the sump, the water would then be pumped to a lagoon which would promote further settlement. Water used for mineral processing would be returned to the lagoon to allow suspended solids to settle out prior to discharge.

Impacts associated with imported inert fill are discussed in Section 4.5 below.

| **3174/HIA/T8: Water quality impacts during development** | | | |
|---|---|---|---|
| **Receptor** | **Sensitivity** | **Magnitude** | **Significance** |
| SURFACE WATER | | | |
| On-site watercourses/ditches | Low | Negligible | None |
| River Thames & tributaries | Medium | Low | Minor |
| Down-gradient waterbodies | Low | Negligible | None |
| GROUNDWATER | | | |
| Windward House (Mead Furlong) Private supply | High | Low | Moderate |
| Superficial Aquifer | Medium | Low | Minor |
| Bedrock Aquifer | Low | Negligible | None |
| New Barn Farm Abstraction (TH/039/0020/008) | Medium | Negligible | Minor |

## 4.5 Potential impacts following restoration

### 4.5.1 Water flow & level

Restoration of the site will involve the importation of inert material that will likely be of a lower hydraulic conductivity than the superficial deposits. It was considered by the Environment Agency that this may obstruct groundwater flow and raise upstream groundwater levels. Groundwater flow is towards east-southeast. The adjacent New Barn Farm Quarry is located up-hydraulic gradient of the site. The proposed restoration of New Barn Farm also includes backfilling with imported inert material and this will result in groundwater flow being deflected to the north and south, as well as around the land occupied by White Cross Farm. Consequently, groundwater velocities in the intervening land, and directly up-gradient (adjacent to the western site boundary) of the site will be low and therefore the risk of raising groundwater levels upstream of White Cross Farm is minimal (<50 cm). As the superficial sand and gravel has a high hydraulic conductivity groundwater will readily flow around the site to the north and south. It should also be noted that no objection was raised by the Environment Agency in relation to the proposed restoration at New Barn Farm Quarry. The cumulative impact of backfilling with inert material on groundwater level is discussed further in Section 6.

Currently (pre-development), a clay layer is present across site directly beneath the topsoil, following restoration 600 mm of site won topsoil will be placed over the inert fill. The groundwater recharge characteristics will therefore be similar pre- and post-development. Additionally, the areal extent covered by the site is small compared to that of the aquifer, hence any changes in recharge would represent a minor change on the scale of the whole aquifer. Therefore, there would be no long-term reduction in groundwater levels due to changes in recharge.

**3174/HIA/T9: Water level impacts following restoration**

| **Receptor** | **Sensitivity** | **Magnitude** | **Significance** |
|---|---|---|---|
| SURFACE WATER | | | |
| On-site watercourses/ditches | Low | Negligible | None |
| River Thames & tributaries | Medium | Low | Minor |
| Down gradient water bodies | Low | Negligible | None |
| GROUNDWATER | | | |
| Windward House (Mead Furlong) Private supply | High | Negligible | Minor |
| Superficial Aquifer | Medium | Low | Minor |
| Bedrock Aquifer | Low | Negligible | None |
| New Barn Farm Abstraction (TH/039/0020/008) | Medium | Negligible | Minor |

### 4.5.2 Water quality

The backfilling of phases will be concurrent with mineral extraction and will be undertaken using imported inert material for which an Environmental Permit will be required. There are a number of receptors close to the site which could be impacted by the leaching of contaminants from this material. The base of the extraction will comprise the lower permeability Glauconitic Marl Member, which minimalises downward flow.

The material to be received at the site will be controlled by strict Waste Acceptance Criteria (WAC) and procedures, which will prevent any chemically unsuitable waste being placed at the site. The risk assessment undertaken as part of the permitting process for importing inert waste will fully assess the risk posed in the unlikely event that material exceeding the WAC limits is deposited at the site. Therefore the potential for receiving non-compliant waste and contamination as a result will be prevented by the permitting process.

**3174/HIA/T10: Water quality impacts following restoration**

| Receptor | Sensitivity | Magnitude | Significance |
|---|---|---|---|
| SURFACE WATER | | | |
| On-site watercourses/ditches | Low | Negligible | None |
| River Thames & tributaries | Medium | Negligible | Minor |
| Down-gradient waterbodies | Low | Negligible | None |
| GROUNDWATER | | | |
| Windward House (Mead Furlong) Private supply | High | Negligible | Minor |
| Superficial Aquifer | Medium | Negligible | Minor |
| Bedrock Aquifer | Low | Negligible | None |
| New Barn Farm Abstraction (TH/039/0020/008) | Medium | Negligible | Minor |

# 5 MITIGATION MEASURES AND RESIDUAL IMPACTS

## 5.1 During mineral extraction

### 5.1.1 Water flow & level

The private water supply of Windward House has been identified as potentially at risk during the dewatering of Phases 2 and 3. To mitigate the risk the extraction of these phases will begin in the south, which will allow clay overburden to be placed against the southern face to create a low permeability barrier between the extraction area and the private water supply. Laboratory testing of the overburden indicated permeabilities of between $8x10^{-11}$ and $1x10^{-10}$ m/s can be achieved.

The piezometers along the southern site boundary will be monitored on a weekly basis during dewatering of the southern phases, this will allow the effectiveness of the barrier to be monitored.

Measures to be undertaken in the event that derogation occurs will be confirmed and agreed as part of the process for obtaining a transfer licence. These measures may include the provision of a temporary alternate water supply.

### 5.1.2 Water quality

Hydrocarbons

Impacts due to the accidental spillages of hydrocarbons from plant will be mitigated by ensuring the following measures are taken:

i) All refuelling of mobile plant will take place on hardstanding in the plant area, minimising the risk of spillages reaching the sand and gravel aquifer.

ii) Fuel will be stored in a double skinned and/or bunded tank.

iii) All plant will be maintained in accordance with best practice and manufacturer's specification. Where possible, all maintenance will be carried out off-site or on areas of hardstanding.

iv) Written procedures will be in place for responding to an accidental spill of hydrocarbons, which will minimise the risk to the environment.

v) Spill kits will be available for use on site in the unlikely event that a spillage occurs.

By following the above measures the risk presented to receptors by accidental release of hydrocarbons during the site operation will be reduced as far as reasonably practicable and no further mitigation measures are considered necessary.

## 5.2 Post-restoration

### 5.2.1 Water quality

The risk of degrading general water quality by importing inert material will be mitigated by the implementation of strict Waste Acceptance Criteria, as well as other conditions that could be imposed by the Environmental Permit. No further mitigation measures are considered necessary at the site.

# 6 CUMULATIVE IMPACTS

The sand and gravel quarry at New Barn Farm is located between 150 m and 500 m west and up-gradient of the site. The mineral is being worked 'wet' and therefore no dewatering will occur. The site has an active abstraction licence which allows the abstraction of water from a lagoon for mineral processing, with water being returned to the lagoon for silt settlement. This abstraction is located a considerable distance outside the estimated radius of influence of the workings at White Cross Farm. Hence there would be no combined drawdown effect during the operational phase of the quarries.

The proposed restoration at both White Cross Farm and New Barn Farm comprises backfilling with material that will likely have a lower hydraulic conductivity than the superficial deposits. This will cause groundwater to flow around the restored sites, however as White Cross Farm is down-gradient of New Barn Farm, it is situated in an area of low flow created by New Barn Farm.

The groundwater level between the two sites may rise slightly due to obstruction of flow by the imported material at White Cross Farm, however this would be minimal due to low groundwater velocities between the two sites caused by water having to flow around the fill at New Barn Farm.

The redirecting of the groundwater flow by the placement of fill would result in water being directed towards the north and south of the site where it would discharge to the River Thames. The stretch of the River Thames adjacent to White Cross Farm is small in comparison to the length of the river, hence the effects on flow in the river will be negligible.

If chemically unsuitable material was placed at both sites, then leaching of the contaminants at both sites could result in concentrations within the surrounding groundwater exceeding relevant environmental standards. However, strict regulation of the type of materials imported and the controls placed on recovery sites by the environmental permitting system renders the accidental release of contaminants unlikely.

# 7 COMPLIANCE TO LOCAL POLICY

### 7.1.1 Oxfordshire Minerals and Waste Local Plan (2017)

The Oxfordshire Minerals and Waste Local Plan sets out the objectives and strategy for meeting the requirements for the supply of minerals and the management of waste within Oxfordshire. The plan set out a number of policies that relate to the water and are summarised below.

'Policy W6: Landfill and other permanent deposits of waste to land' states that the priority of the use of inert fill will be given to active or unrestored quarries, and that permission for filling will not be granted unless there would be an overall environmental benefit. The proposed development complies with this policy as the use of inert fill to restore the site will allow the creation of damp meadow/marshy wetland, returning the site to similar to pre-development conditions.

'Policy C4: water environment' requires developments demonstrate that there will be no unacceptable adverse risk to the quality or quantity of groundwater and surface water at nearby water supported habitats or abstractions, or impact the flow. 'Policy C5: Local environment, amenity and economy' states that the development must nor pose an unacceptable adverse impact on the local economy from surface or ground contamination. The proposed development will comply with these policies by implementing the mitigation measures outlined in Section 5.

### 7.1.2 South Oxfordshire Local Plan (2020)

The South Oxfordshire Local Plan sets out how developments will be planned and delivered within the county and contains a number of policies relating to the water environment.

'Policy INF4: Water resources' states that it must be demonstrated that the water requirements of the development can be met without detriment to existing abstractions, and other nearby water dependent receptors. The proposed development complies with this policy as the consumptive volume of water required operation of the site is low and measures have been proposed (Section 5.1) to mitigate the risk to the most sensitive receptor.

'Policy ENV4: Watercourses' sets out requirements for encouraging the enhancement of watercourses by leaving a buffer zone around watercourse and by removing culverts where possible. The proposed development provides a buffer zone along the River Thames in excess of that required by the policy. Whilst the extraction of mineral at the site will remove a field drain, the restoration will create new waterbodies and wetland therefore promoting and increase in biodiversity.

'Policy ENV12: Pollution' requires that the development does not result in an adverse impact to human health, the natural environment, or the amenity of neighbouring uses. The proposed development will comply with this policy by maintaining good site practice for pollution prevention and by following the environment permitting process for waste.

## 8 SUMMARY AND CONCLUSIONS

Greenfield Environmental is seeking to submit a revised scheme to obtain Planning Permission for a new sand and gravel extraction at White Cross Farm, located south of the town of Wallingford.

It is proposed to work the sand and gravel 'dry', which will require dewatering due to the depth of groundwater. The site will be progressively restored to original levels using inert fill and a mix of floodplain habitats and agricultural land.

The site is situated on the west bank of the River Thames. Two small tributaries to the Thames pass to the north and south of the site. Two drainage ditches are located on-site.

The proposed development is situated within superficial deposits of the Thames Valley Formation, comprising the sands and gravels of the Northmoor Sand and Gravel Member. Exploration boreholes show that the Northmoor Sand and Gravel Member is underlain by the Glauconitic Marl Member.

The sands and gravels form a locally important aquifer, classed by the Environment Agency as a Secondary A Aquifer. The Glauconitic Marl Member is part of the Cretaceous Chalk which is designated as a whole as a Principal Aquifer and is an important source for a variety of groundwater abstractions. However, the chalk marl is identified as being of low permeability and therefore acts as a barrier to flow. There is one licensed water abstraction and three private abstractions in the vicinity of the site.

There are no statutory sites of ecological interest within 2 km of the site boundary, which are considered as groundwater-supported.

Groundwater flow in the superficial sand and gravel is east-southeastwards, towards the River Thames, which it is considered to be in hydraulic conductivity with.

Dewatering at the site will require licensing and will be governed by the Thames Abstraction Licence Strategy. Water is indicated as not being available for licensing, however dewatering may be considered as a non-consumptive use.

An assessment of the impacts from the proposed site has been made with consideration of groundwater and surface water flows and quality, proximity of local areas of ecological interest, and water abstractions. Impacts of the proposed operation have been assessed against the current conditions around the site, whilst impacts following restoration have been assessed against the pre-development situation.

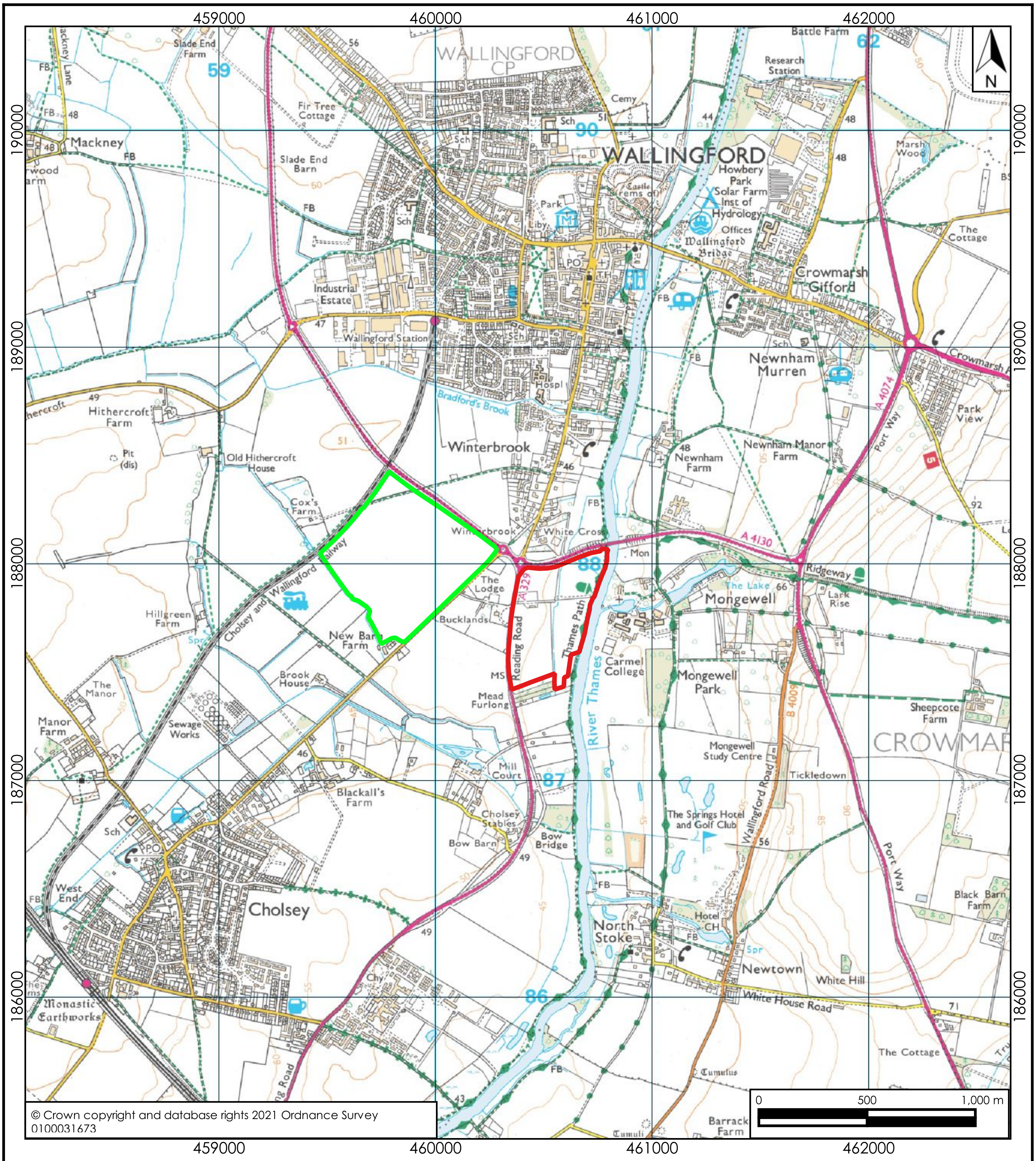
During the extraction phase the nearby private water supply at Windward House has been identified as being within the radius of influence of dewatering and mitigation measures have been proposed. The risk posed by dewatering to all other receptors is considered to be negligible.

Following restoration, raising of the upstream groundwater level due to the placement of low permeability materials will be minimal due to the presence of the adjacent New Barn Farm quarry, which will deflect groundwater flow around the upstream boundary of the site. The risk of the imported material degrading water quality surrounding the site is considered minor due to the utilisation of Waste Acceptance Criteria to regulate the waste placed at the site. Any further mitigation measures will be determined during the permitting process.

The cumulative impacts associated with the development of the adjacent New Barn Farm are considered negligible in regards to groundwater flow and quality.

It is considered that the proposed development complies with the policies relating to water quality and supply as set out in the Oxfordshire Minerals and Waste Local Plan and the South Oxfordshire Local Plan.

# DRAWINGS



© Crown copyright and database rights 2021 Ordnance Survey 0100031673

Legend

🟥 White Cross Farm Site Boundary

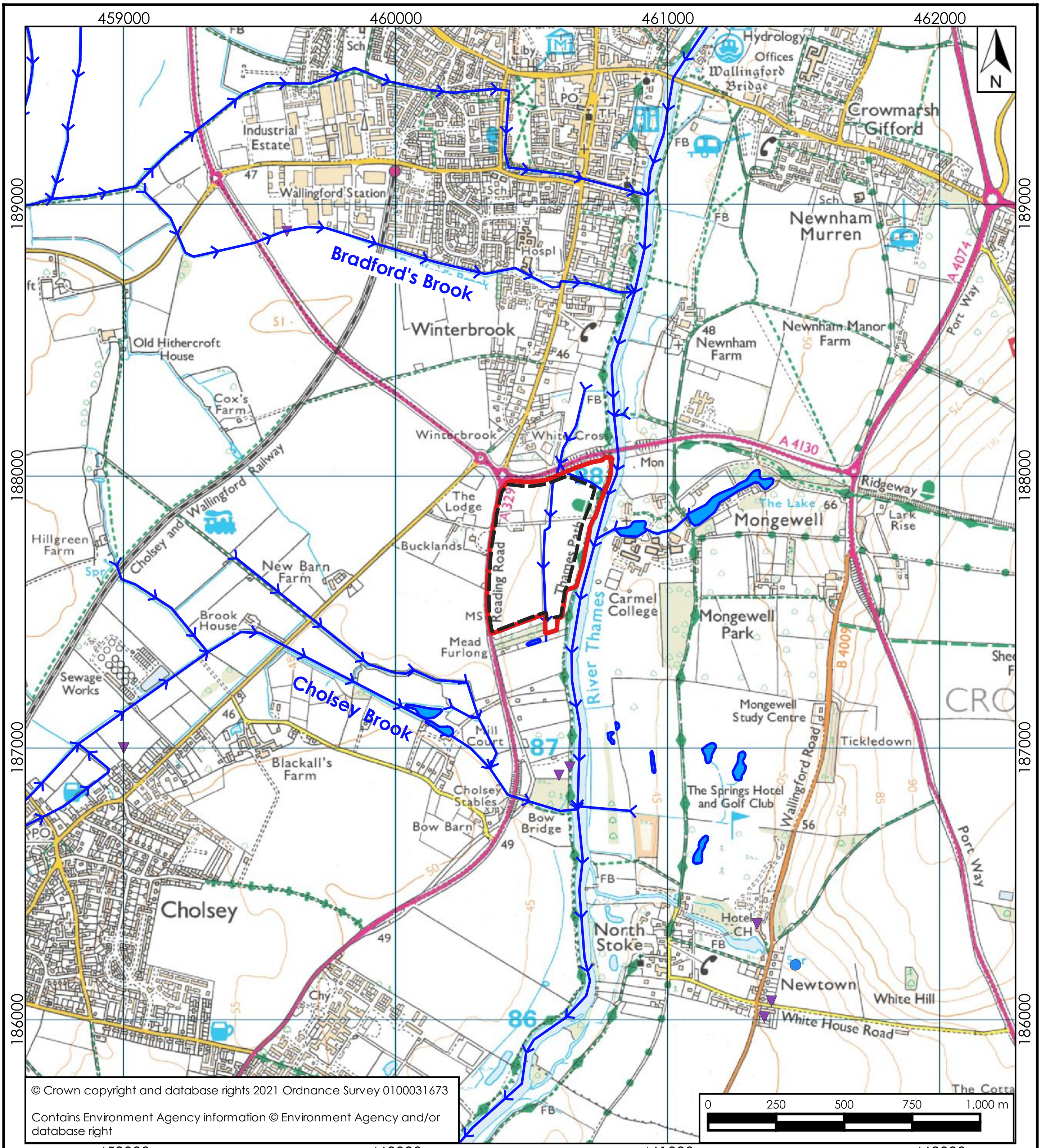
🟩 New Barn Farm Site Boundary

Scale correct at A4

**hafrenwater**
environmental water management

Barkers Chambers • Barker Street • Shrewsbury •
Shropshire • SY1 1SB
www.hafrenwater.com • Tel. 01743 355 770

| | |
|---|---|
| Client | Greenfields Environmental<br>1 Commercial Road<br>Keyworth<br>Nottingham<br>NG12 5JS |
| Title | Site Location |
| Project | White Cross Farm |
| Drawing | 3174/HIA/01 |
| Version | 1 |
| Date | June 21 |
| Scale | 1:25,000 |



Legend

- ▭ Site Boundary
- ▭ Extent of Extraction
- ■ Waterbody
- ⟩— Watercourse
- ▼ Surface Water Discharge Consent
- ● Spring

Scale correct at A4

hafrenwater
environmental water management

Barkers Chambers • Barker Street • Shrewsbury • Shropshire • SY1 1SB
www.hafrenwater.com • Tel. 01743 355 770

Client
Greenfields Environmental
1 Commercial Road
Keyworth
Nottingham
NG12 5JS

Title: Water Features

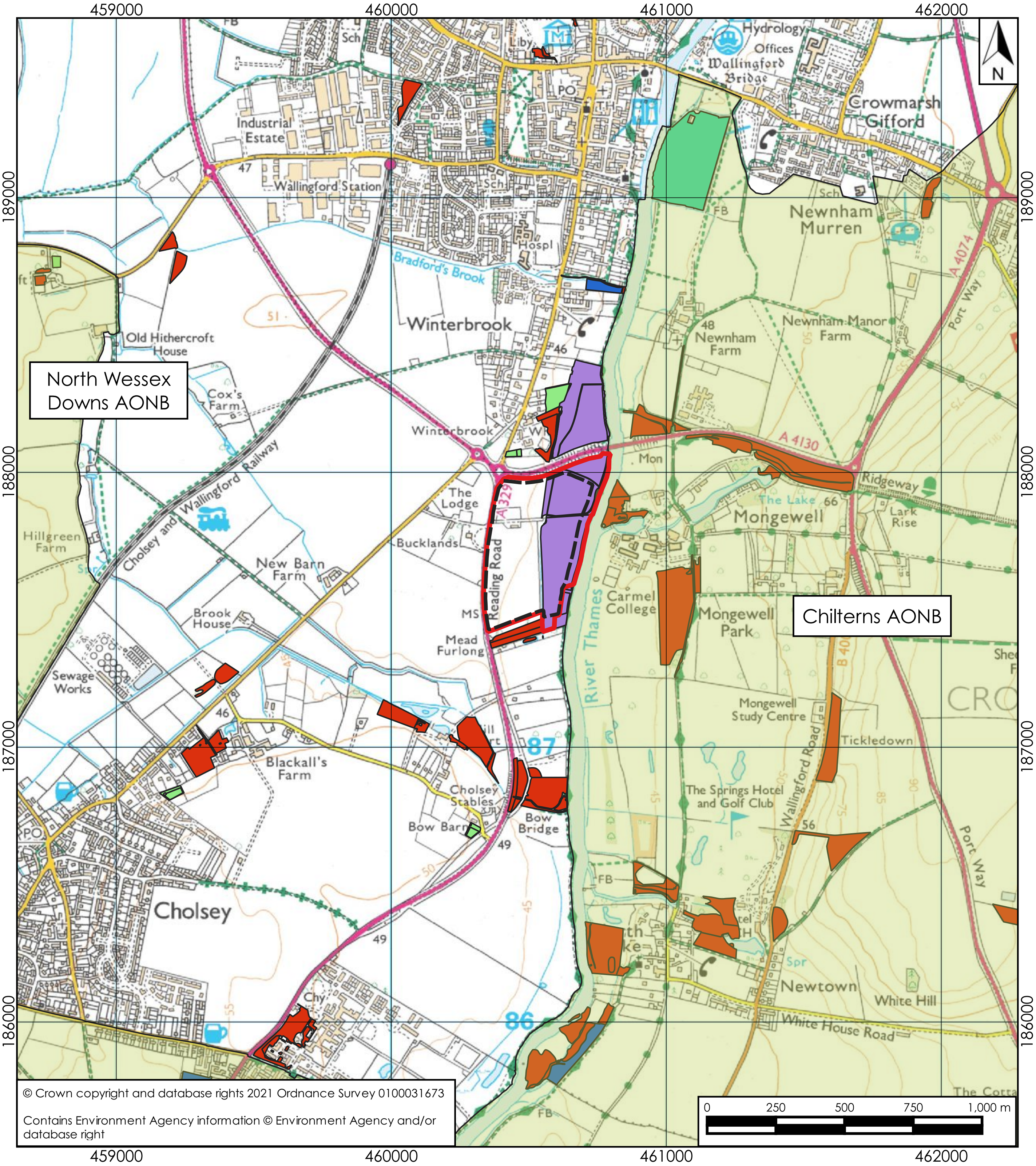
Project: White Cross Farm

Drawing: 3174/HIA/02

Version: 1

Date: July 21

Scale: 1:20,000



## Legend

| | |
|---|---|
| 🟥 | Site Boundary |
| ⬚ | Extent of Extraction |
| 🟨 | AONB |

Priority Habitat

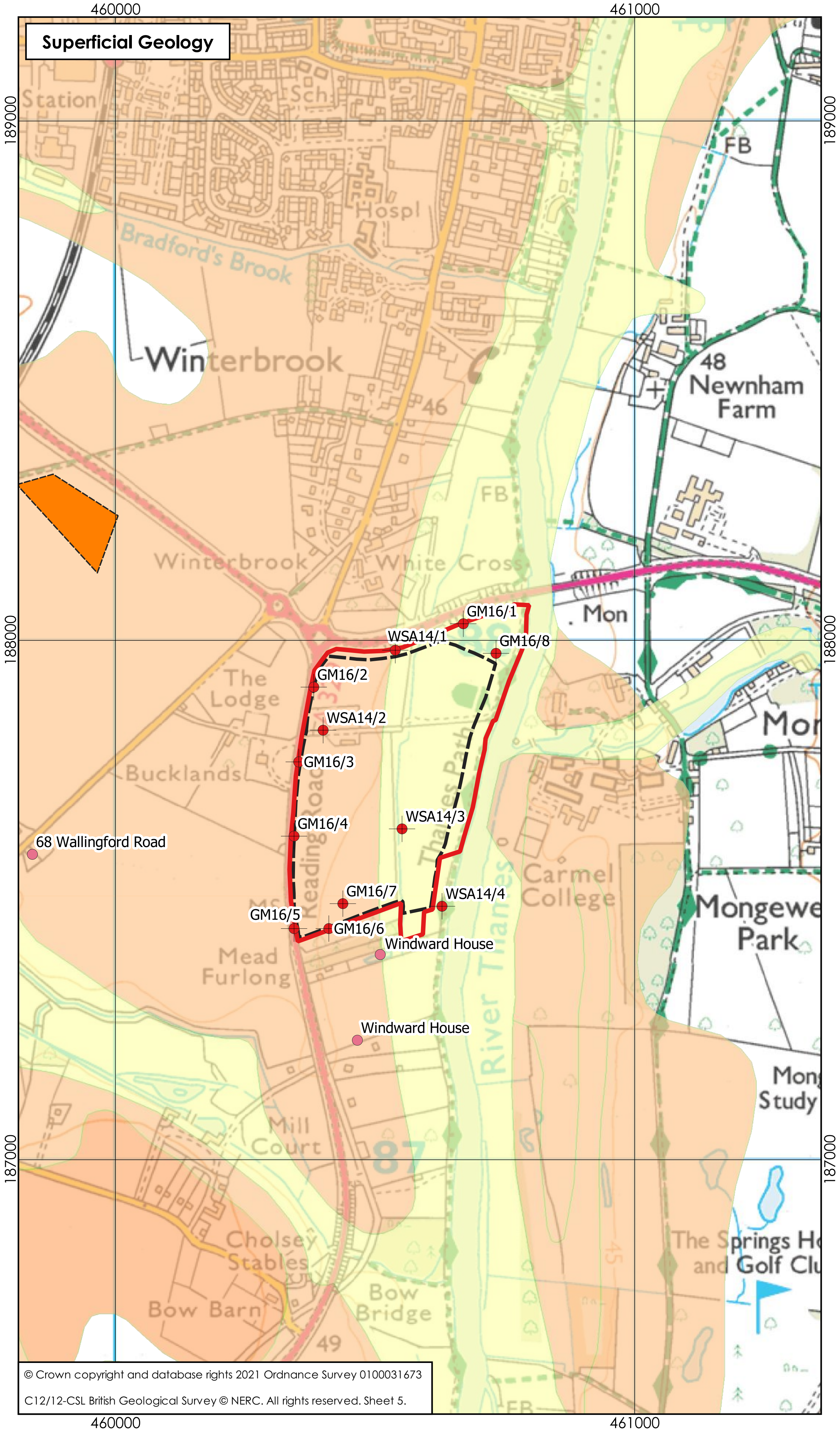
| | |
|---|---|
| 🟪 | Coastal and floodplain grazing marsh |
| 🟥 | Deciduous woodland |
| 🟦 | No main habitat but additional habitats present |
| 🟩 | Traditional orchard |

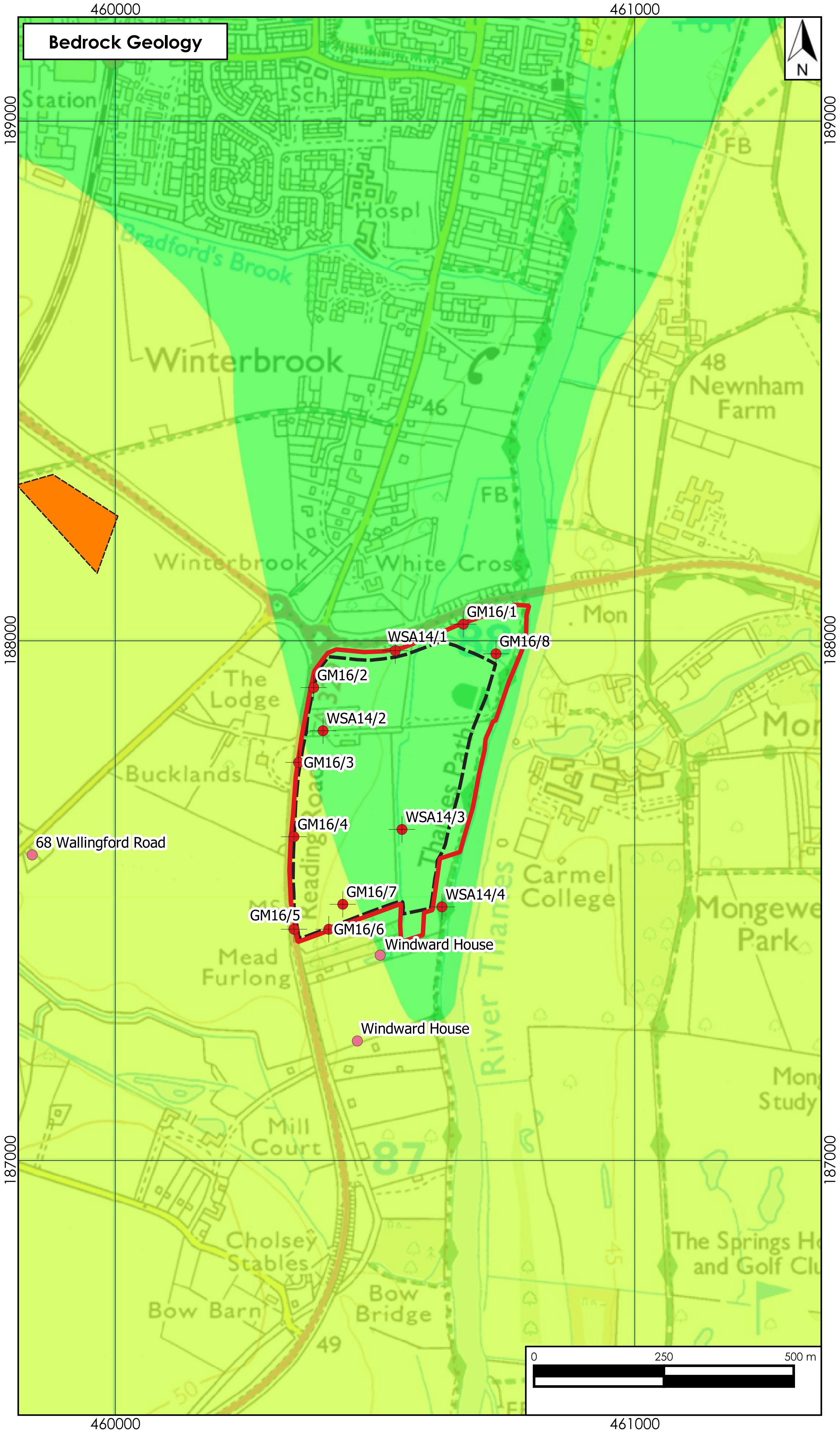
Scale correct at A4

hafrenwater
environmental water management
Barkers Chambers • Barker Street • Shrewsbury • Shropshire • SY1 1SB
www.hafrenwater.com • Tel. 01743 355 770

Client
Greenfields Environmental
1 Commercial Road
Keyworth
Nottingham
NG12 5JS

| | | | |
|---|---|---|---|
| Title | Ecological Sites | | |
| Project | White Cross Farm | | |
| Drawing | 3174/HIA/03 | Version | 1 |
| Date | July 21 | Scale | 1:20,000 |





Legend

🟥 Site Boundary

⬚ Extent of Excavation

● Monitoring Borehole

🟧 New Barn Farm Licenced Abstraction Area

● Private Water Supply

Superficial Deposits

🟨 Alluvium

🟧 Northmoor Sand & Gravel Member

Bedrock

🟩 West Melbury Marly Chalk Formation

🟩 Glauconitic Marl Member

🟩 Upper Greensand Formation

Scale correct at A3

Client
Greenfields Environmental
1 Commercial Road
Keyworth
Nottingham
NG12 5JS

Title Geology

Project White Cross Farm

Drawing 3174/HIA/04

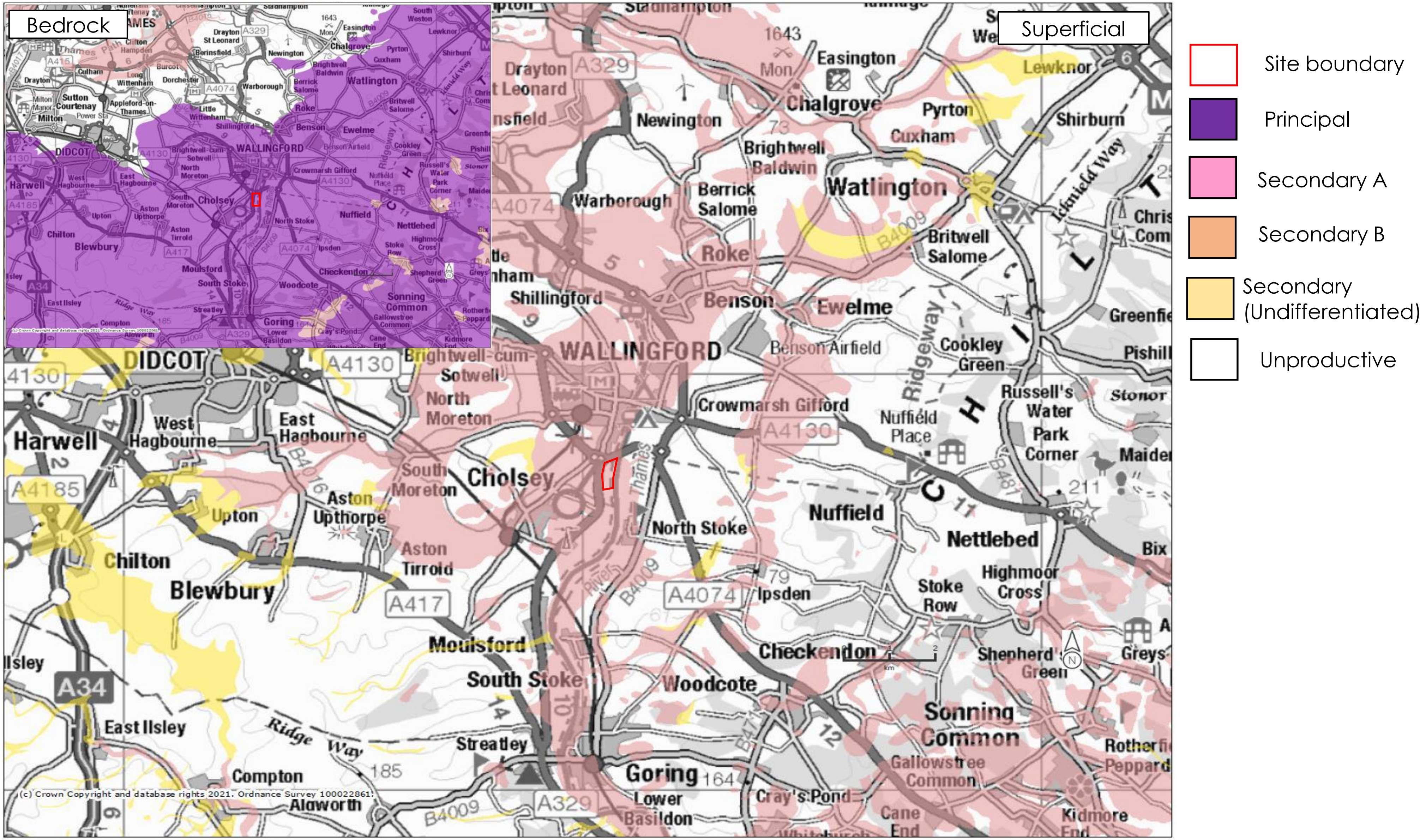
Version 1

Date July 21

Scale 1:10,000

hafrenwater
environmental water management

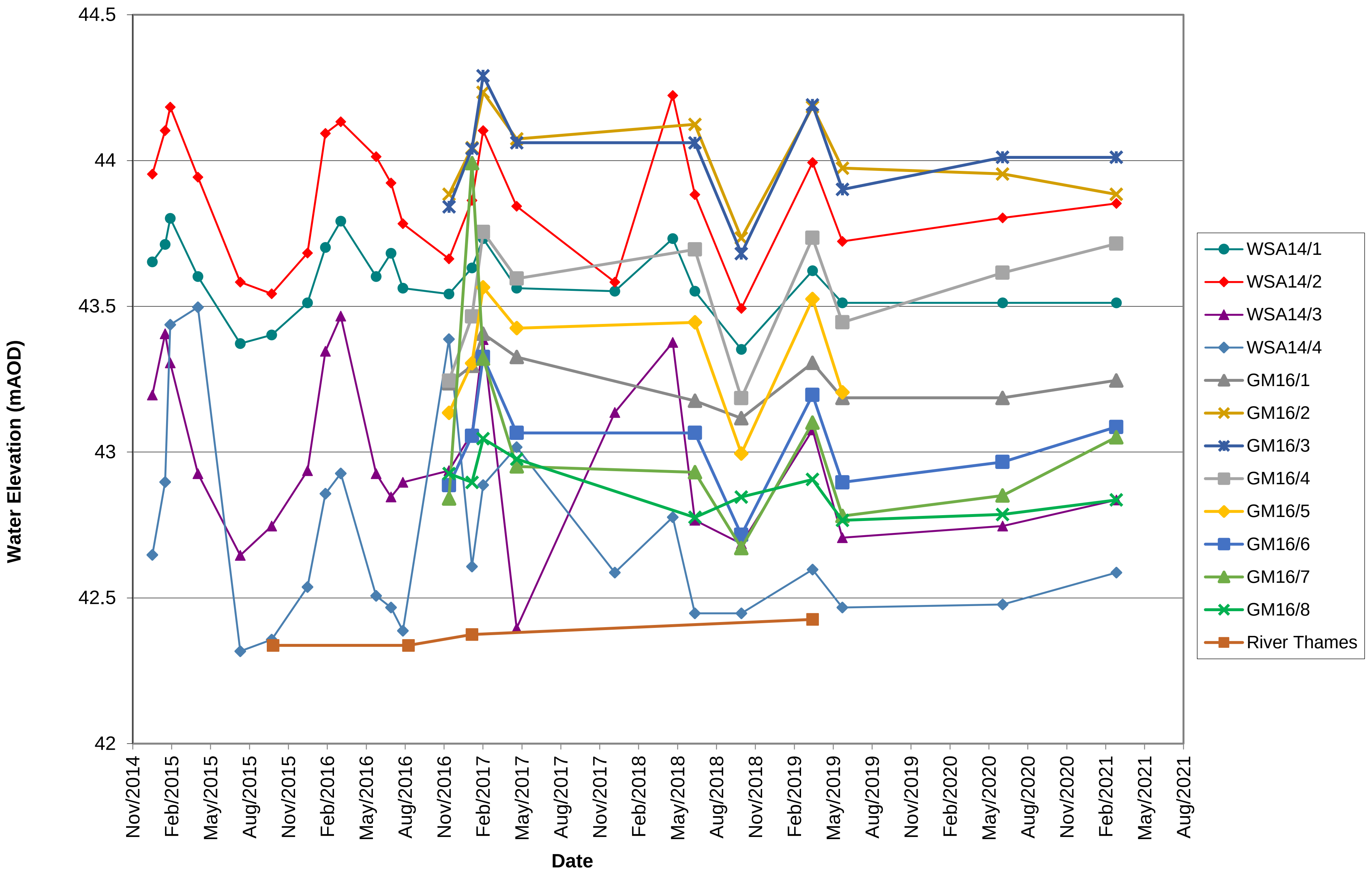
Barkers Chambers • Barker Street • Shrewsbury •
Shropshire • SY1 1SB
www.hafrenwater.com • Tel. 01743 355 770



**hafrenwater**
environmental water management
Barkers Chambers • Barker Street • Shrewsbury • United Kingdom • SY1 1SB
E: info@hafrenwater.com • T: 01743 355 770

Client
Greenfields Environmental
1 Commercial Road
Keyworth
Nottingham, NG12 5JS

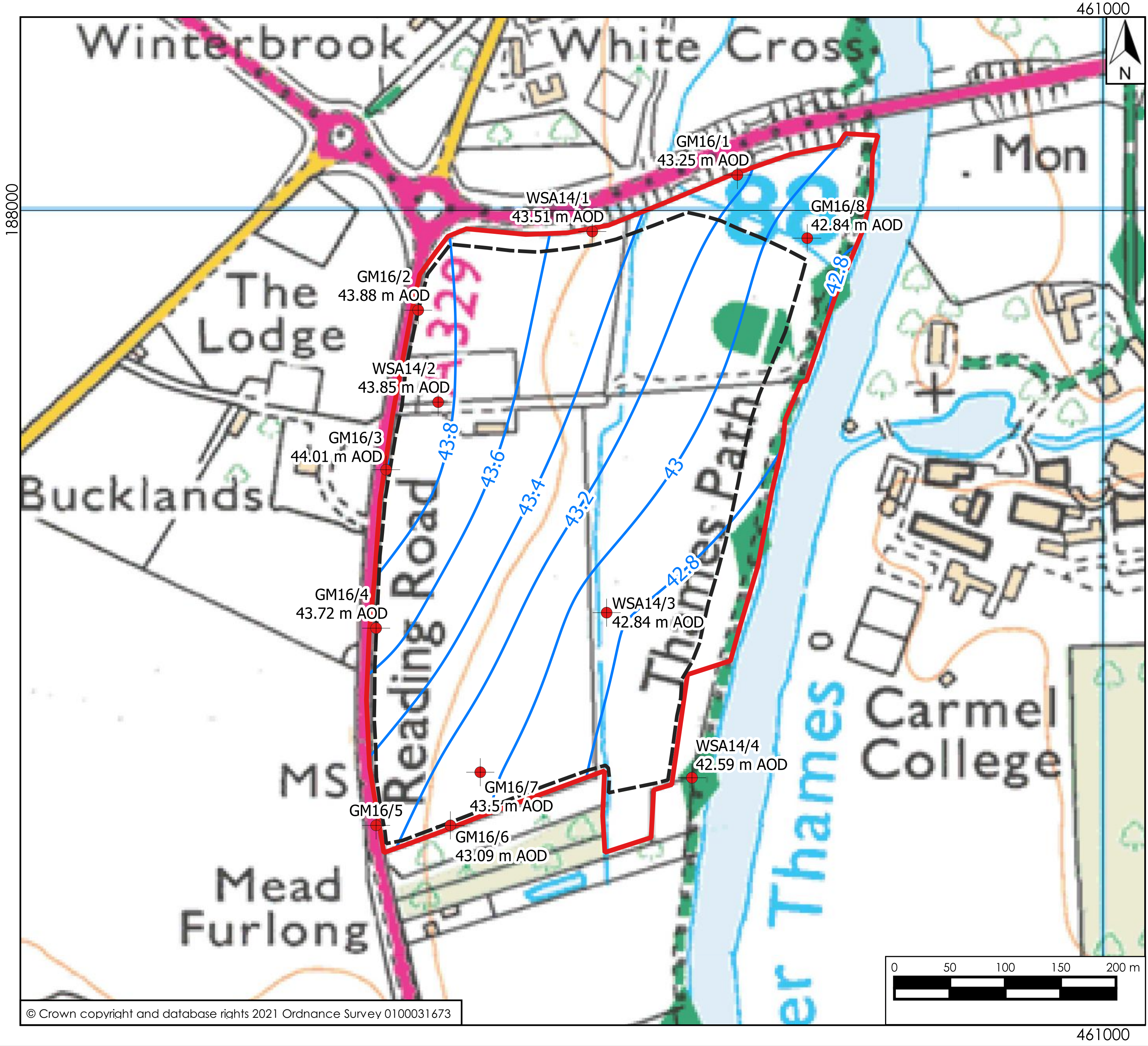
| | | | |
|---|---|---|---|
| Title | Aquifer Designations | | |
| Project | White Cross Farm | | |
| Drawing | 3174/HIA/05 | Version | 1 |
| Date | Jul-21 | Scale | n/a |



**hafrenwater**
environmental water management
Barkers Chambers • Barker Street • Shrewsbury • United Kingdom • SY1 1SB
*E:* info@hafrenwater.com • *T:* 01743 355 770

| | |
|---|---|
| Client | Greenfields Environmental<br>1 Commercial Road<br>Keyworth<br>Nottingham, NG12 5JS |

| | | | |
|---|---|---|---|
| Title | Groundwater Hydrographs | | |
| Project | White Cross Farm | | |
| Drawing | 3174/HIA/06 | Version | 1 |
| Date | Jul-21 | Scale | n/a |



Legend

🟥 Site Boundary

▭ Extent of Excavation

― Groundwater Elevation Contour March 21 (m AOD)

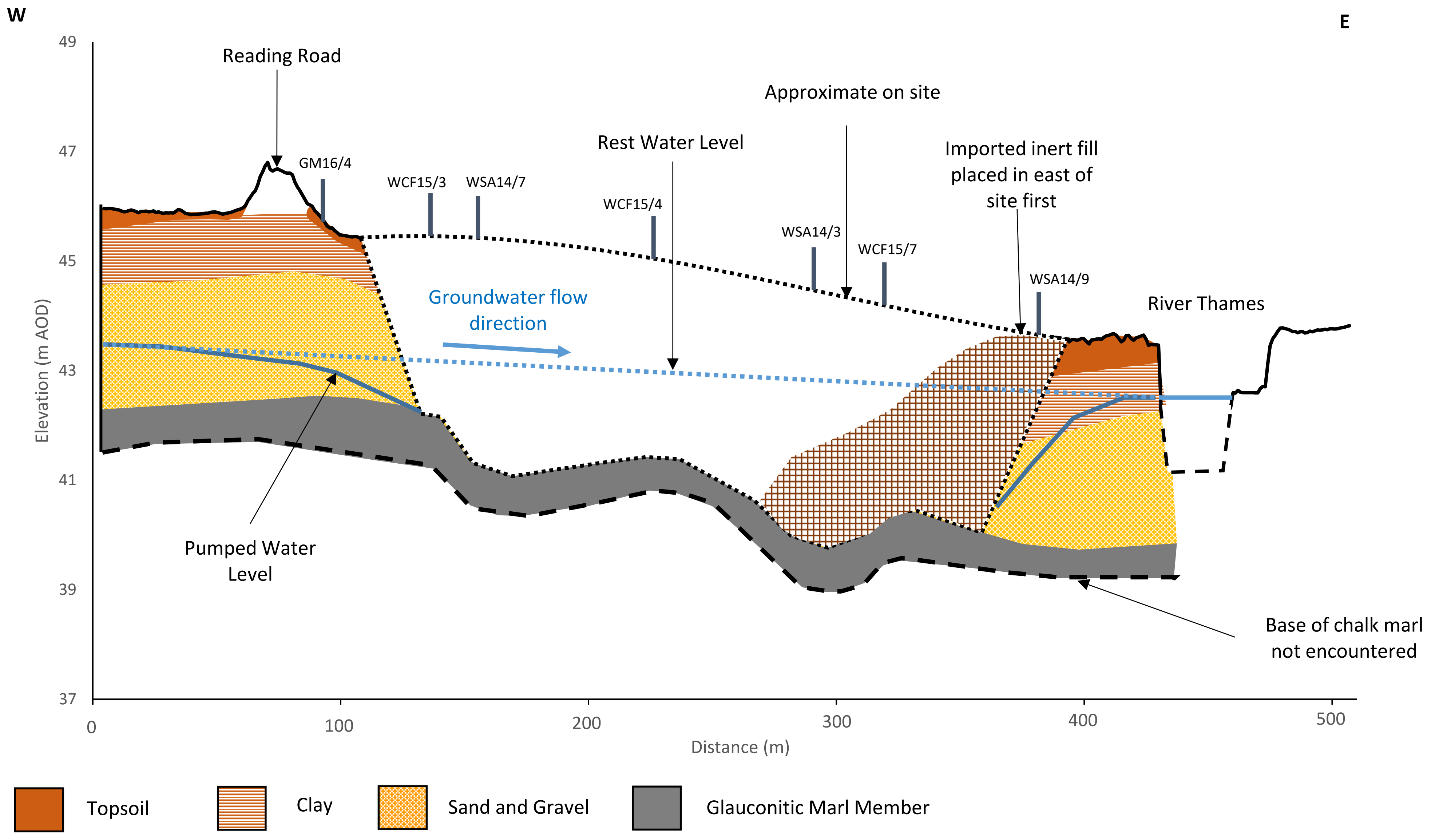
● Monitoring Borehole & Groundwater Elevation

Scale correct at A4

| | |
|---|---|
| Client | Greenfield Environmental |
| Title | Inferred Groundwater Contours |
| Project | White Cross Farm |
| Drawing | 3174/HIA/07 |
| Version | 1 |
| Date | July 21 |
| Scale | 1:5,000 |

hafrenwater
environmental water management

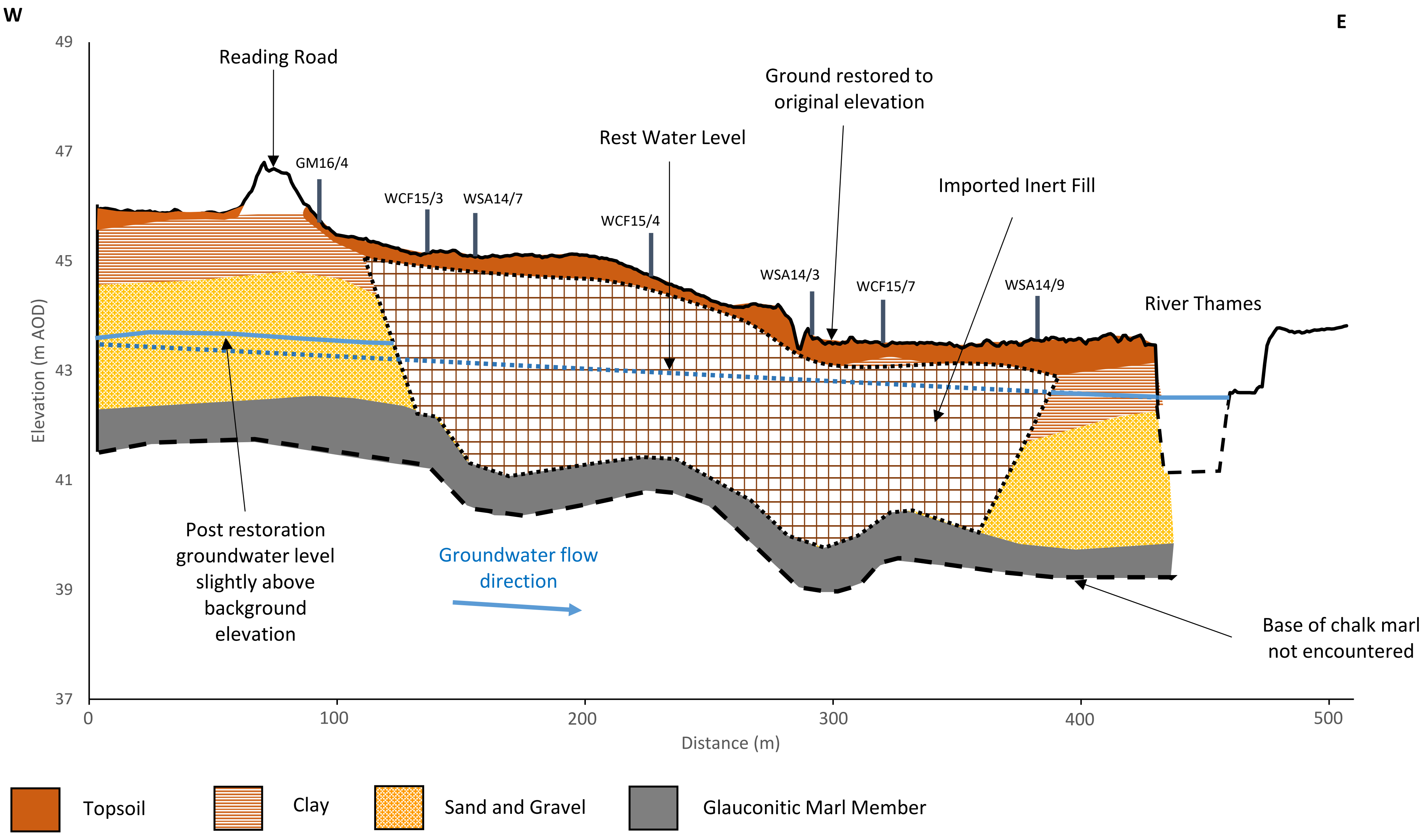
Barkers Chambers • Barker Street • Shrewsbury •
Shropshire • SY1 1SB
www.hafrenwater.com • Tel. 01743 355 770



**hafrenwater**
environmental water management
Barkers Chambers • Barker Street • Shrewsbury • United Kingdom • SY1 1SB
E: info@hafrenwater.com • T: 01743 355 770

Client
Greenfields Environmental
1 Commercial Road
Keyworth
Nottingham, NG12 5JS

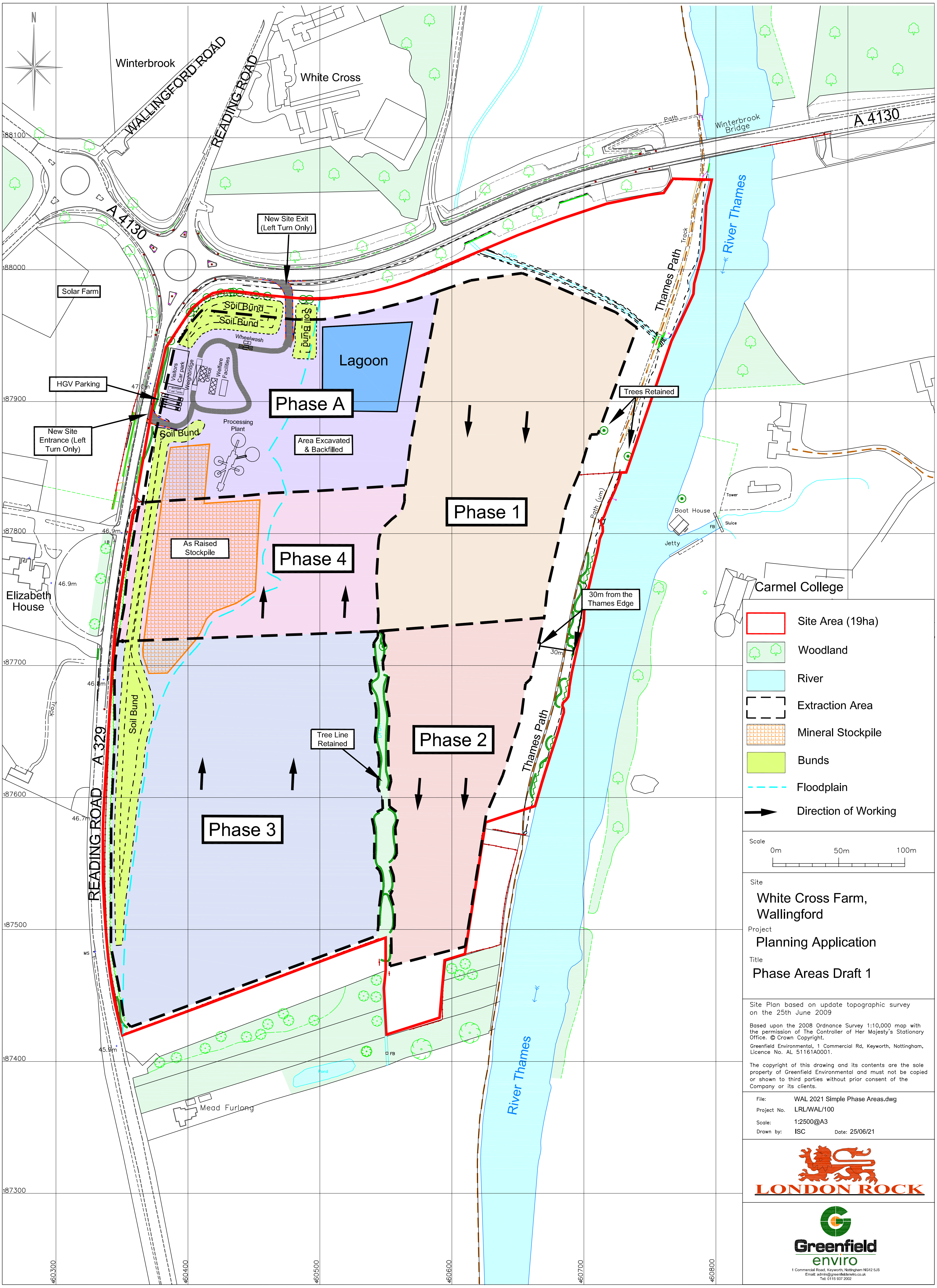
Title: Schematic Cross Section - During Extraction
Project: White Cross Farm
Drawing: 3174/HIA/08
Version: 1
Date: Jul-21
Scale: n/a



**hafrenwater**
environmental water management
Barkers Chambers • Barker Street • Shrewsbury • United Kingdom • SY1 1SB
*E:* info@hafrenwater.com • *T:* 01743 355 770

Client
Greenfields Environmental
1 Commercial Road
Keyworth
Nottingham, NG12 5JS

| | | | |
|---|---|---|---|
| Title | Schematic Cross Section - Post Restoration | | |
| Project | White Cross Farm | | |
| Drawing | 3174/HIA/09 | Version | 1 |
| Date | Jul-21 | Scale | n/a |



Site
White Cross Farm, Wallingford

Project
Planning Application

Title
Phase Areas Draft 1

Site Plan based on update topographic survey on the 25th June 2009

Based upon the 2008 Ordnance Survey 1:10,000 map with the permission of The Controller of Her Majesty's Stationary Office. © Crown Copyright.

Greenfield Environmental, 1 Commercial Rd, Keyworth, Nottingham, Licence No. AL 51161A0001.

File: WAL 2021 Simple Phase Areas.dwg
Project No. LRL/WAL/100
Scale: 1:2500@A3
Drawn by: ISC Date: 25/06/21

LONDON ROCK

Greenfield enviro
1 Commercial Road, Keyworth, Nottingham NG12 5JS
Email: admin@greenfieldenviro.co.uk
Tel: 0115 937 2002

LEGEND

| | |
|---|---|
| 🟥 | Planning Application Boundary |
| 🟩 | Agricultural Land within the Application Boundary |
| 🟩 | Existing Woodland / Hedgerows / Scrub |
| 🟦 | Existing Water Bodies / Courses |
| ▬ | Buildings, Roads & Tracks |
| 80.0 | Existing Contours (1m intervals) & Spot Heights m aOD |
| ● ● | Thames Path |
| 🟩 | Enhanced Amenity Experience along the Thames Path |
| ● ● | Additional Section of Permissive Public Pathway away from the A4130 to Wallingford |
| 🟩 | Creation of Damp Meadow Habitat |
| 🟦 | Creation of Lagoon |
| 🟩 | Strengtheing and New Native Planting of Hedge between Agriculture and Damp Meadow |
| 🟩 | Reinstatement of all Best & Most Versatile Agricultural Land |
| 🟩 | Beat up / Strengthening of Existing Hedgerow / New Planting - Native Species Rich |
| ▬ | Proposed Barn |

KEDD Limited

PROJECT:
White Cross Farm, Wallingford

TITLE:
Concept Restoration

REF NO:
KD.WLF.D.010

DATE:
July 2021

SCALE:
1:2,500 @ A3

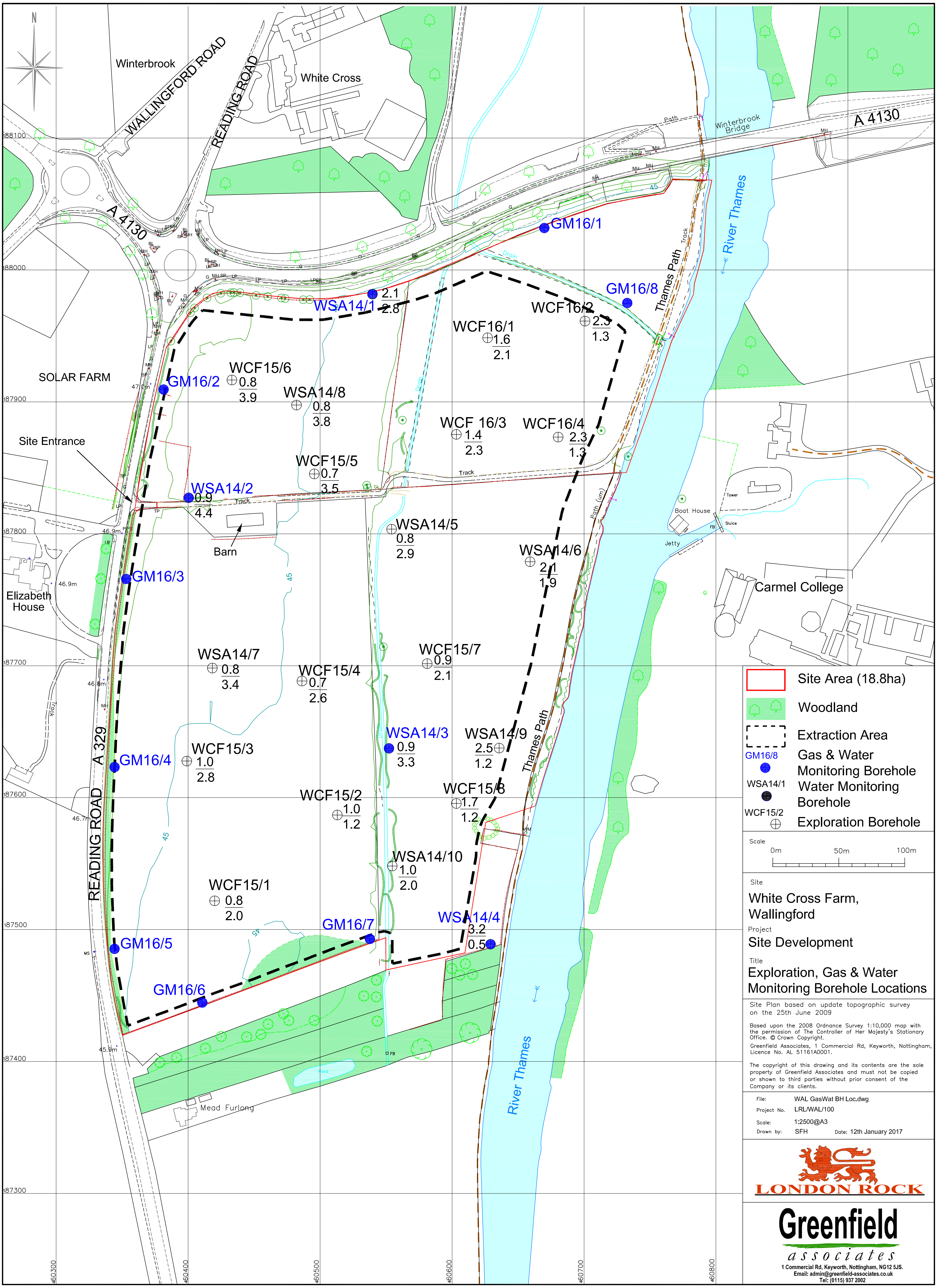
N

STATUS:
1st DRAFT

Fox Studio, Much Wenlock, Shropshire TF13 6BL

# APPENDIX 3174/HIA/A1

## Borehole logs



Site
White Cross Farm, Wallingford

Project
Site Development

Title
Exploration, Gas & Water Monitoring Borehole Locations

Site Plan based on update topographic survey on the 25th June 2009

Based upon the 2008 Ordnance Survey 1:10,000 map with the permission of The Controller of Her Majesty's Stationary Office. © Crown Copyright.

Greenfield Associates, 1 Commercial Rd, Keyworth, Nottingham, Licence No. AL 51161A0001.

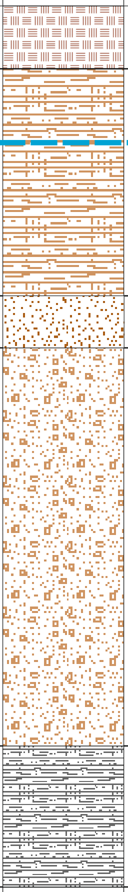
File: WAL GasWat BH Loc.dwg
Project No. LRL/WAL/100
Scale: 1:2500@A3
Drawn by: SFH
Date: 12th January 2017

LONDON ROCK

Greenfield
associates
1 Commercial Rd, Keyworth, Nottingham, NG12 5JS.
Email: admin@greenfield-associates.co.uk
Tel: (0115) 937 2002

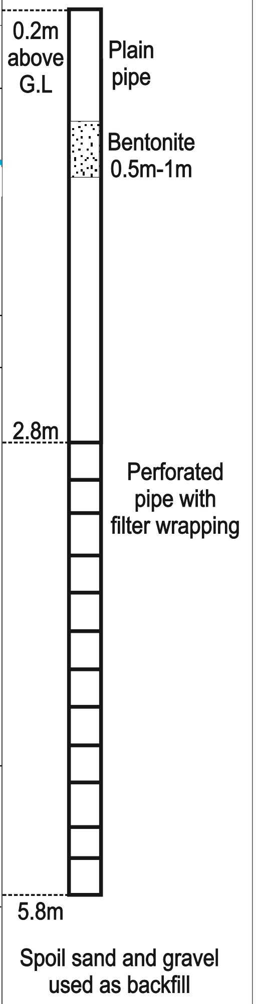
# *White Cross Farm, Wallingford*

## Shell & Auger Borehole Log: Borehole No. WSA 14/1



| Depth (m) | Lithological Description | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) Grading (F: S: G) |
|---|---|---|---|---|
| 0.4 | ***Soil and Subsoil***<br>Clayey dark soil | 0.4 | 44.09 | |
| 1.9 | ***Clay***<br>Yellowish, stiff clay | 1.5 | 42.59 | Water strike at 0.88 m/ 43.61m AOD |
| 2.1 | ***Sand***<br>Brown, very silty, fine sand. | 0.2 | 42.39 | |
| 4.9 | ***Sand and gravel***<br>Yellowish-brown sand and gravel. 60% gravel, 40% sand. G: fine-medium, angular-rounded flint gravel.<br>S: fine-medium, slightly silty.<br>Occasional small cobbles. | 2.8 | 39.59 | |
| 5.9 | ***Clay***<br>Grey clay, stiff, silty, turning to weak shale. | 1.0 | 38.59 | |
| | End of Borehole - 5.90m | | | |

Installation diagram



Spoil sand and gravel used as backfill

| | | |
|---|---|---|
| Borehole No.<br>WSA 14/1 | Contractor<br>Metcalfe Bros | Client<br>London Rock |
| Date<br>17/12/14 | BH Diameter<br>150 mm | Project<br>Geological Investigation |
| Grid Ref:<br>SU 460539 187981 | Surface Level<br>44.49 mAOD | Site White Cross Farm, Wallingford |

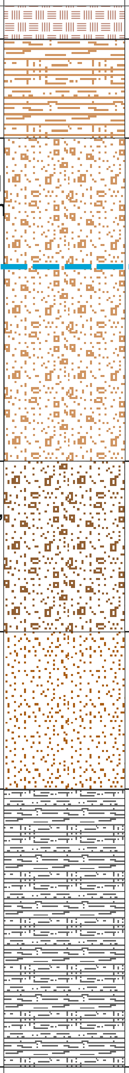
Greenfield
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

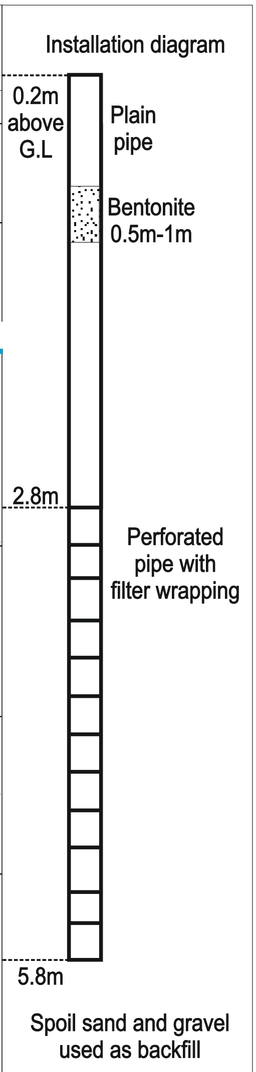
# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WSA 14/2

| Depth (m) | Lithological Description | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) Grading (F: S: G) |
|---|---|---|---|---|
| 0.3 | ***Soil and Subsoil*** Sandy dark soil | 0.3 | 45.44 | |
| 0.9 | ***Clay***<br>Brown to yellow clay, firm, pebbly | 0.6 | 44.84 | |
| | ***Sand and Gravel***<br>Light orangey brown sand & gravel (50-50 mix). Gravel, fine to medium sand: fine-coarse. Gravel, angular to rounded. Slightly silty. Some clay lumps. | 2.1 | 42.74 | 8: 50: 42<br>Water strike at 1.78 m/ 43.96m AOD<br>10: 53: 37 |
| 4.2 | ***Sand and Gravel***<br>Brown sand and gravel. 60-70% gravel, with sand. Fine to medium gravel, fine to coarse sand. G: Angular-sub rounded. | 1.2 | 41.54 | 5: 66: 29 |
| 5.3 | ***Pebbly Sand***<br>Brown, pebbbly sand. Fine to coarse, slightly silty. | 1.1 | 40.44 | |
| | ***Clay***<br>Grey clay, stiff. Silty clay, turning to weak grey shale with depth. | 1.7 | 38.74 | |

End of Borehole - 7.00m





Borehole No.
WSA 14/2

Date
17/12/14

Grid Ref:
SU 460400 187827

Contractor
Metcalfe Bros

BH Diameter
150 mm

Surface Level
45.74 mAOD

Client
London Rock

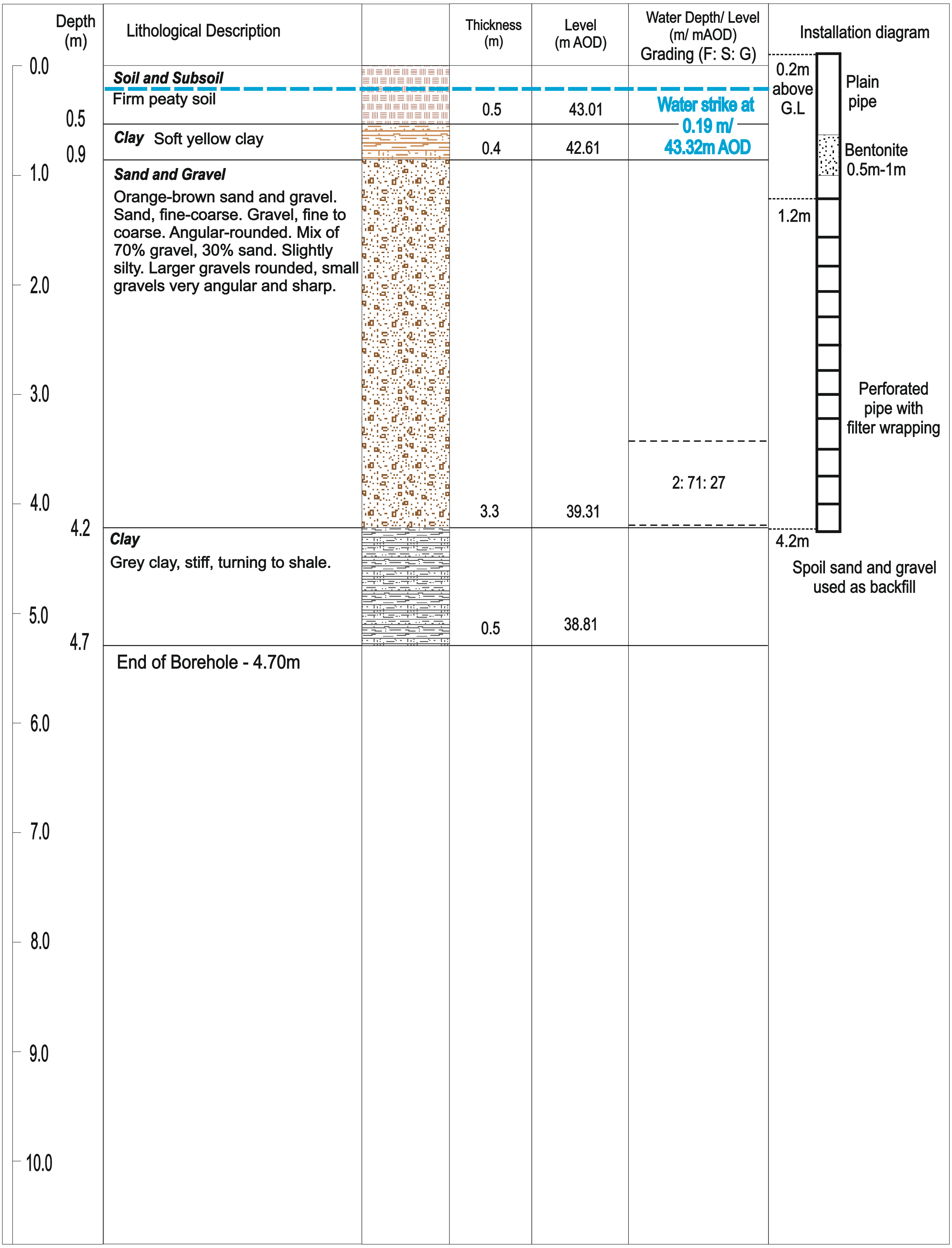
Project
Geological Investigation

Site
White Cross Farm, Wallingford

**Greenfield**
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# *White Cross Farm, Wallingford*

## Shell & Auger Borehole Log: Borehole No. WSA 14/3



| Depth (m) | Lithological Description | | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) Grading (F: S: G) |
|---|---|---|---|---|---|
| 0.5 | ***Soil and Subsoil***<br>Firm peaty soil | ▨ | 0.5 | 43.01 | Water strike at 0.19 m/ 43.32m AOD |
| 0.9 | ***Clay*** Soft yellow clay | ▨ | 0.4 | 42.61 | |
| 4.2 | ***Sand and Gravel***<br>Orange-brown sand and gravel. Sand, fine-coarse. Gravel, fine to coarse. Angular-rounded. Mix of 70% gravel, 30% sand. Slightly silty. Larger gravels rounded, small gravels very angular and sharp. | ▨ | 3.3 | 39.31 | 2: 71: 27 |
| 4.7 | ***Clay***<br>Grey clay, stiff, turning to shale. | ▨ | 0.5 | 38.81 | |
| | End of Borehole - 4.70m | | | | |

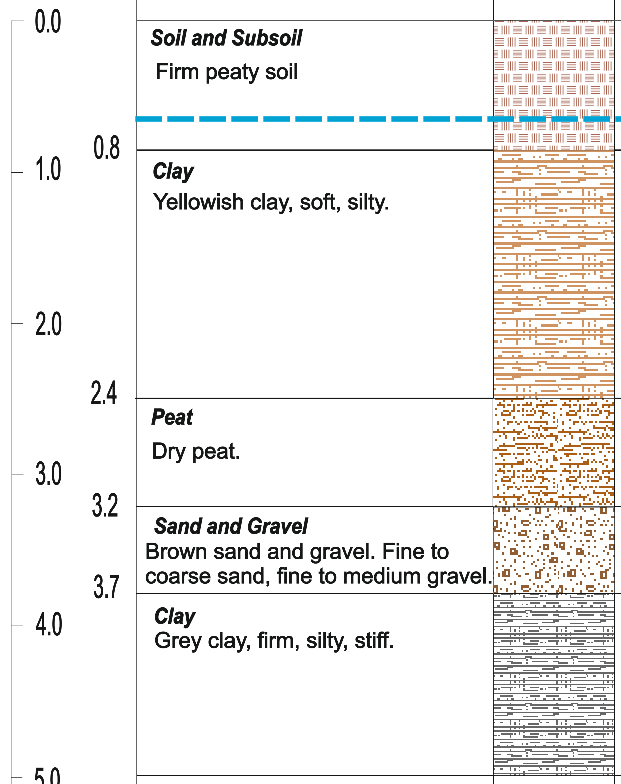
| | | |
|---|---|---|
| Borehole No.<br>WSA 14/3 | Contractor<br>Metcalfe Bros | Client<br>London Rock |
| Date<br>17/12/14 | BH Diameter<br>150 mm | Project<br>Geological Investigation |
| Grid Ref:<br>SU 460552 187637 | Surface Level<br>43.51 mAOD | Site White Cross Farm, Wallingford |

**Greenfield**
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

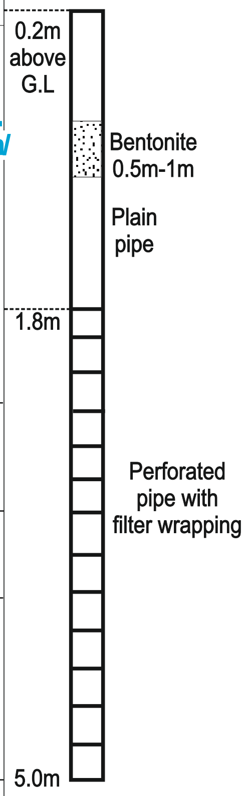
# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WSA 14/4

| Depth (m) | Lithological Description | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) Grading (F: S: G) |
|---|---|---|---|---|
| 0.8 | ***Soil and Subsoil***<br>Firm peaty soil | 0.8 | 42.79 | Water strike at 0.7m/ 42.89m AOD |
| 2.4 | ***Clay***<br>Yellowish clay, soft, silty. | 1.6 | 41.19 | |
| 3.2 | ***Peat***<br>Dry peat. | 0.8 | 40.39 | |
| 3.7 | ***Sand and Gravel***<br>Brown sand and gravel. Fine to coarse sand, fine to medium gravel. | 0.5 | 39.89 | |
| | ***Clay***<br>Grey clay, firm, silty, stiff. | 1.3 | 38.59 | |
| | End of Borehole - 5.00m | | | |



Installation diagram



Spoil sand and gravel used as backfill

Borehole No. WSA 14/4

Date 17/12/14

Grid Ref: SU 460629 187488

Contractor Metcalfe Bros

BH Diameter 150 mm

Surface Level 43.59 mAOD

Client London Rock

Project Geological Investigation

Site White Cross Farm, Wallingford

Greenfield
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WSA 14/5

| Depth (m) | Lithological Description | | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) | Grading F: S: G |
|---|---|---|---|---|---|---|
| 0.4 | ***Soil and Subsoil***<br>Peaty soil | | 0.4 | 43.23 | | |
| 0.8 | ***Clay***<br>Yellowish clay, soft, silty, turns grey. | | 0.4 | 42.83 | Water strike at 0.4m/ 43.23m AOD | |
| 3.7 | ***Sand and Gravel***<br>Orange-brown sand and gravel. Coarse mix (80% G, 20% S). Gravel, fine to coarse, angular to sub-angular. Sand, fine-coarse. Gravel, hard flint and sandstone. | | 2.9 | 39.93 | 2: 38: 60 | |
| 4.2 | ***Clay***<br>Grey clay, firm, silty, stiff. | | 0.5 | 39.43 | | |

End of Borehole - 4.20m

0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

| | | |
|---|---|---|
| Borehole No.<br>WSA 14/5 | Contractor<br>Metcalfe Bros | Client<br>London Rock |
| Date<br>17/12/14 | BH Diameter<br>150 mm | Project<br>Geological Investigation |
| Grid Ref:<br>SU 460554 187803 | Surface Level<br>43.63 mAOD | Site White Cross Farm, Wallingford |

**Greenfield**
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WSA 14/6

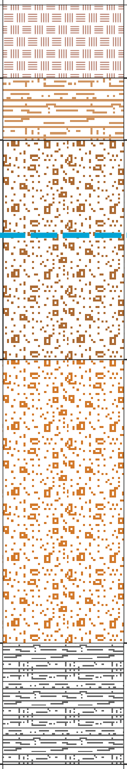
| Depth (m) | Lithological Description | | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) | Grading F: S: G |
|---|---|---|---|---|---|---|
| 0.0<br>0.5 | ***Soil and Subsoil***<br>Peaty soil | | 0.5 | 42.97 | Water strike at 0.3m/ 43.17m AOD | |
| 1.0<br>1.4 | ***Clay***<br>Yellowish clay, soft. | | 0.9 | 42.07 | | |
| 2.0<br>2.1 | ***Clay***<br>Dark grey clay, soft, turning to silty peat. | | 0.7 | 41.37 | | |
| 3.0<br>4.0 | ***Sand and Gravel***<br>Brown-dark brown sand and gravel. 60-70% gravel, 30-40% sand. Sand, coarse. Gravel, fine to medium. Angular-rounded. Occasional small clay bound lumps Gravel is flint and sanstone. | | 1.9 | 39.47 | | |
| 4.5 | ***Clay***<br>Light grey clay, stiff. | | 0.5 | 38.97 | | |
| 5.0<br>6.0<br>7.0<br>8.0<br>9.0<br>10.0 | End of Borehole - 4.50m | | | | | |

| | | |
|---|---|---|
| Borehole No.<br>WSA 14/6 | Contractor<br>Metcalfe Bros | Client<br>London Rock |
| Date<br>17/12/14 | BH Diameter<br>150 mm | Project<br>Geological Investigation |
| Grid Ref:<br>SU 460659 187778 | Surface Level<br>43.47 mAOD | Site White Cross Farm, Wallingford |

**Greenfield**
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WSA 14/7



| Depth (m) | Lithological Description | | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) | Grading F: S: G |
|---|---|---|---|---|---|---|
| 0.0<br>0.4 | ***Soil and Subsoil*** | | 0.4 | 44.72 | | |
| 0.8 | ***Clay***<br>Brown clay, stiff, pebbly | | 0.4 | 44.32 | | |
| 1.0 | ***Sand and gravel***<br>Brown to orange-brown sand and gravel. 60% sand, 40% gravel. | | | | 3: 44: 53 | |
| 2.0<br>2.3 | Sand: Fine-medium, G: Fine-med. Sub-rounded to rounded. | | 1.5 | 42.82 | Water strike at 1.60m/ 43.52m AOD | |
| 3.0<br>4.0<br>4.2 | ***Sand and gravel***<br>Orange-brown sand and gravel. 80% gravel, 20% sand. Gravel, fine-coarse, angular- sub-angular.<br>Occasional cobbles. Sand: Fine to medium. | | 1.9 | 40.92 | | |
| 5.0 | ***Shale***<br>Light grey shale, stiff. | | 0.8 | 40.12 | | |
| 6.0<br>7.0<br>8.0<br>9.0<br>10.0 | End of Borehole - 5.00m | | | | | |

Borehole No.
WSA 14/7

Date
17/12/14

Grid Ref:
SU 460418 187698

Contractor
Metcalfe Bros

BH Diameter
150 mm

Surface Level
45.12 mAOD

Client
London Rock

Project
Geological Investigation

Site
White Cross Farm, Wallingford

**Greenfield**
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WSA 14/8

| Depth (m) | Lithological Description | | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) | Grading F: S: G |
|---|---|---|---|---|---|---|
| 0.0<br>0.4 | ***Soil and Subsoil*** | | 0.4 | 44.8 | | |
| 0.8 | ***Clay***<br>Yellow clay, pebbley, firm. | | 0.4 | 44.4 | | |
| 1.0 | ***Sand and Gravel***<br>Orange to brown sand and gravel. 80% gravel, 20% sand mix. | | | | | |
| 2.0<br>3.0<br>3.7 | Sand, fine to coarse. Gravel, fine to coarse, angular to sub-angular. | | 2.9 | 41.5 | Water strike at 1.4m/ 43.8m AOD<br>4: 46: 50 | |
| 4.0<br>4.6 | ***Sand and Gravel***<br>Brown sand and gravel, 50-50 mix. Sand, fine to medium. Gravel, fine to medium, angular to rounded. Slightly silty. Occasional clay bound lumps. Few rounded cobbles. | | 0.9 | 40.6 | | |
| 5.0<br>5.1 | ***Clay***<br>Light grey clay, stiff | | 0.5 | 40.1 | | |
| 6.0<br>7.0<br>8.0<br>9.0<br>10.0 | End of Borehole - 5.10m | | | | | |

| | | |
|---|---|---|
| Borehole No.<br>WSA 14/8 | Contractor<br>Metcalfe Bros | Client<br>London Rock |
| Date<br>17/12/14 | BH Diameter<br>150 mm | Project<br>Geological Investigation |
| Grid Ref:<br>SU 460482 187897 | Surface Level<br>45.2mAOD | Site White Cross Farm, Wallingford |

**Greenfield**
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WSA 14/9

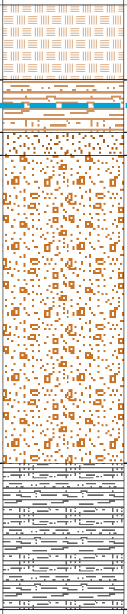
| Depth (m) | Lithological Description | | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) | Grading F: S: G |
|---|---|---|---|---|---|---|
| 0.0 | ***Soil and Subsoil***<br>Firm, peaty soil mix. | | 0.9 | 42.55 | | |
| 0.9 | ***Clay***<br>Yellow clay, silty, soft. | | 0.9 | 41.65 | Water strike at 0.5m/ 42.95m AOD | |
| 1.8 | ***Clay and peat***<br>Dark grey clay peat, soft mix. | | 0.7 | 40.95 | | |
| 2.5 | ***Sand and Gravel***<br>Brown sand and gravel, fine to medium flint and sandstone gravel, fine to coarse sand. Slightly silty. | | 1.2 | 39.75 | | |
| 3.7 | ***Clay***<br>Light grey, stiff clay. | | 0.5 | 39.25 | | |
| 4.2 | End of Borehole - 4.20m | | | | | |

0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

| | | | |
|---|---|---|---|
| Borehole No.<br>WSA 14/9 | Contractor<br>Metcalfe Bros | Client<br>London Rock | Greenfield associates<br>1 Commercial Rd, Keyworth, Nottingham NG12 5JS<br>E-mail: admin@greenfield-associates.co.uk<br>Tel: 0115 9372002 |
| Date<br>17/12/14 | BH Diameter<br>150 mm | Project<br>Geological Investigation | |
| Grid Ref:<br>SU 460635 187637 | Surface Level<br>43.45 mAOD | Site White Cross Farm, Wallingford | |

# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WSA 14/10



| Depth (m) | Lithological Description | | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) | Grading F: S: G |
|---|---|---|---|---|---|---|
| 0.0 | ***Soil and Subsoil***<br>Peat soil mix | | 0.4 | 42.97 | | |
| 0.6 | ***Clay***<br>Yellow clay, firm | | 0.3 | 42.67 | Water strike at 0.7m/ 42.67m AOD | |
| 0.9 | ***Sand*** Yellow silty, firm sand | | 0.1 | 42.57 | | |
| 1.0<br>2.0 | ***Sand and gravel***<br>Orange-brown sand and gravel. 50-50 mix of sand and gravel. Sand, fine to medium. Gravel, fine to medium, angular to rounded. Slightly silty.<br>Occasional clay bound lumps. Occasional larger rounded pebbles. | | 2.0 | 40.57 | 5: 56: 39 | |
| 3.0 | ***Clay***<br>Light grey clay, turning to weak shale. | | 1.0 | 39.57 | | |
| 4.0 | End of Borehole - 4.00m | | | | | |
| 5.0 | | | | | | |
| 6.0 | | | | | | |
| 7.0 | | | | | | |
| 8.0 | | | | | | |
| 9.0 | | | | | | |
| 10.0 | | | | | | |

Borehole No. WSA 14/10

Date 17/12/14

Grid Ref: SU 460554 187548

Contractor Metcalfe Bros

BH Diameter 150 mm

Surface Level 43.37 mAOD

Client London Rock

Project Geological Investigation

Site White Cross Farm, Wallingford

Greenfield
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# ***White Cross Farm, Wallingford***

## Shell & Auger Borehole Log: Borehole No. WCF 15/1

| Depth (m) | Lithological Description | | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) | Grading F: S: G |
|---|---|---|---|---|---|---|
| 0.0 | | | | 44.8 | | |
| 0.4 | ***Soil and Subsoil***<br>Stoney soil | | 0.4 | 44.4 | | |
| 0.8 | ***Clay***<br>Yellow-brown firm clay, occasional pebbles. | | 0.4 | 44.0 | | |
| | ***Sand and gravel***<br>Brown slightly silty sand & gravel, fine-medium sand, fine-medium, angular-rounded flint gravel. Occasional clay bound lumps. | | 1.2 | 42.8 | Water strike at 1.7 m/ 43.1m AOD | |
| 2.8 | ***Sand and gravel***<br>Brown sand & gravel, fine-coarse sand fine-medium, angular to rounded flint gravel. Occasional cobbles. | | 0.8 | 42.0 | | 2: 27: 72 |
| | ***Clay***<br>Light grey chalky clay. | | 1.2 | 40.8 | | |
| | End of Borehole - 4.00m | | | | | |

0.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0

| | | |
|---|---|---|
| Borehole No.<br>WCF 15/1 | Contractor<br>Metcalfe Bros | Client<br>London Rock |
| Date<br>29/09/2015 | BH Diameter<br>150 mm | Project<br>Geological Investigation |
| Grid Ref:<br>SU 460420 187521 | Surface Level<br>44.75 mAOD | Site White Cross Farm, Wallingford |

**Greenfield**
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# *White Cross Farm, Wallingford*

## Shell & Auger Borehole Log: Borehole No. WCF 15/2

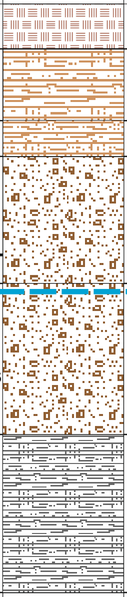
| Depth (m) | Lithological Description | | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) | |
|---|---|---|---|---|---|---|
| 0.0 | | | | 44.3 | | |
| 0.25 | ***Soil*** Stoney dark clayey soil | ▨ | 0.25 | 44.1 | | |
| 1.0 | ***Clay***<br>Brown stiff clay with occasional cobbles. | ▨ | 0.75 | 43.4 | | |
| 2.0<br>2.2 | ***Sand and Gravel***<br>Orange-brown sand & gravel, sand fine-coarse, fine-medium sub angular to sub rounded flint gravel. | ▨ | 1.2 | 42.2 | Water strike at 1.4 m/ 42.9m AOD | 3: 57: 40 |
| 3.0<br>3.2 | ***Clay***<br>Light grey, firm chalky clay. | ▨ | 1.0 | 41.2 | | |
| 4.0<br>5.0<br>6.0<br>7.0<br>8.0<br>9.0<br>10.0 | End of Borehole - 3.20m | | | | | |

| | | |
|---|---|---|
| Borehole No.<br>WCF 15/2 | Contractor<br>Metcalfe Bros | Client<br>London Rock |
| Date<br>29/09/2015 | BH Diameter<br>150 mm | Project<br>Geological Investigation |
| Grid Ref:<br>SU 460513 187586 | Surface Level<br>44.29 mAOD | Site White Cross Farm, Wallingford |

**Greenfield**
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WCF 15/3



| Depth (m) | Lithological Description | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) | |
|---|---|---|---|---|---|
| 0.0 | | | 45.0 | | |
| 0.3 | ***Soil and Subsoil*** Stoney soil | 0.3 | 44.7 | | |
| 0.9 | ***Clay***<br>Brown firm clay. | 0.6 | 44.1 | | |
| | ***Clayey Sand*** | 0.1 | 44.0 | | |
| 1.7 | ***Sand and Gravel***<br>Brown slightly silty sand & gravel, fine-medium sand, fine-coarse angular to sub angular flint gravels. Occasional clay lumps. | 0.7 | 43.3 | | |
| 2.8 | ***Sand and Gravel***<br>Brown- grey brown sand & gravel, fine-coarse sand, fine-medium, sub angular to rounded flint gravels | 1.1 | 42.2 | Water strike at 1.8 m/ 43.2m AOD | 3: 39: 58 |
| 3.8 | ***Clay***<br>Light grey firm chalky clay. | 1.0 | 41.2 | | |
| | End of Borehole - 3.80m | | | | |

0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

Borehole No.
WCF 15/3

Date
29/09/15

Grid Ref:
SU 460398 187627

Contractor
Metcalfe Bros

BH Diameter
150 mm

Surface Level
44.97 mAOD

Client
London Rock

Project
Geological Investigation

Site White Cross Farm, Wallingford

**Greenfield**
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WCF 15/4

| Depth (m) | Lithological Description | | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) Grading (F: S: G) |
|---|---|---|---|---|---|
| 0.0 | | | | 44.7 | |
| 0.25 | ***Soil and Subsoil*** Clayey dark soil | | 0.25 | 44.5 | |
| 0.6 | ***Clay***<br>Brown stiff clay with odd pebbles | | 0.35 | 44.2 | |
| 0.7 | ***Sandy Clay*** | | 0.1 | 44.1 | |
| 1.0 | ***Sand and Gravel***<br>Orange-brown sand & gravel, fine to coarse sand, fine-medium rounded to sub-angular flint gravels. Occasional silt bound lumps. | | 1.3 | 42.8 | Water strike at 1.7m/ 43.0m AOD |
| 2.0<br>3.0<br>3.3 | ***Sand and Gravel***<br>Orange-brown sand & gravel, fine to coarse sand with fine-medium, angular to sub-rounded flint and quartzite gravels. Occasional coarse gravel. | | 1.3 | 41.5 | |
| 4.0 | ***Clay***<br>Light grey firm chalky clay | | 0.7 | 40.8 | |
| 5.0<br>6.0<br>7.0<br>8.0<br>9.0<br>10.0 | End of Borehole - 4.00m | | | | |

| | | | |
|---|---|---|---|
| Borehole No.<br>WCF 15/4 | Contractor<br>Metcalfe Bros | Client<br>London Rock | **Greenfield**<br>*associates*<br>1 Commercial Rd, Keyworth, Nottingham NG12 5JS<br>E-mail: admin@greenfield-associates.co.uk<br>Tel: 0115 9372002 |
| Date<br>29/09/2015 | BH Diameter<br>150 mm | Project<br>Geological Investigation | |
| Grid Ref:<br>SU 460486 187688 | Surface Level<br>44.73 mAOD | Site White Cross Farm, Wallingford | |

# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WCF 15/5

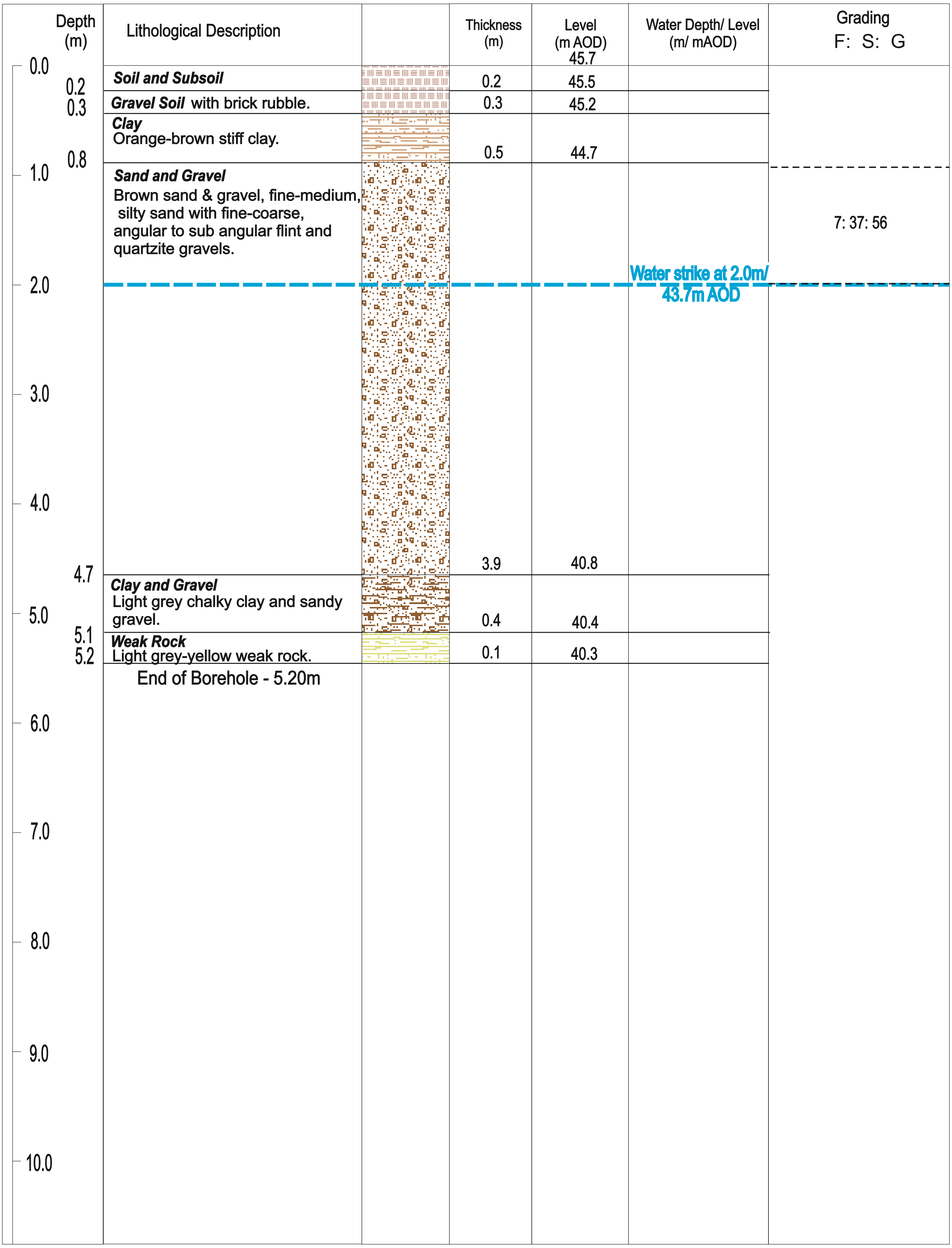
| Depth (m) | Lithological Description | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) | Grading F: S: G |
|---|---|---|---|---|---|
| 0.0 | | | 44.8 | | |
| 0.25 | ***Soil and Subsoil*** | 0.25 | 44.6 | | |
| 0.6 | ***Clay***<br>Brown firm-stiff clay. | 0.35 | 44.2 | | |
| 0.7 | ***Clayey Sand*** | 0.1 | 44.1 | | |
| | ***Sand and Gravel***<br>Orange-brown sand & gravel, fine to medium sand, slightly silty with fine to medium, sub angular to rounded, flint gravels. Occasional clay lumps. | 1.3 | 42.8 | Water strike at 1.7m/ 43.1m AOD | |
| 4.2 | ***Sand and Gravel***<br>Orange-brown sand & gravel, fine to coarse sand, fine to coarse angular to sub angular flint and quartzite gravels. | 2.2 | 40.6 | | 2: 56: 42 |
| | ***Clay***<br>Light grey firm clay. | 0.8 | 39.8 | | |
| | End of Borehole - 5.00m | | | | |

| | | | |
|---|---|---|---|
| Borehole No.<br>WCF 15/5 | Contractor<br>Metcalfe Bros | Client<br>London Rock | |
| Date<br>17/12/14 | BH Diameter<br>150 mm | Project<br>Geological Investigation | |
| Grid Ref:<br>SU 460495 187845 | Surface Level<br>44.83 mAOD | Site White Cross Farm, Wallingford | |

**Greenfield**
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WCF 15/6



| Depth (m) | Lithological Description | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) | Grading F: S: G |
|---|---|---|---|---|---|
| 0.0 | | | 45.7 | | |
| 0.2 | ***Soil and Subsoil*** | 0.2 | 45.5 | | |
| 0.3 | ***Gravel Soil*** with brick rubble. | 0.3 | 45.2 | | |
| 0.8 | ***Clay***<br>Orange-brown stiff clay. | 0.5 | 44.7 | | |
| 4.7 | ***Sand and Gravel***<br>Brown sand & gravel, fine-medium, silty sand with fine-coarse, angular to sub angular flint and quartzite gravels. | 3.9 | 40.8 | Water strike at 2.0m/ 43.7m AOD | 7: 37: 56 |
| 5.1 | ***Clay and Gravel***<br>Light grey chalky clay and sandy gravel. | 0.4 | 40.4 | | |
| 5.2 | ***Weak Rock***<br>Light grey-yellow weak rock. | 0.1 | 40.3 | | |

End of Borehole - 5.20m

| | | |
|---|---|---|
| Borehole No.<br>WCF 15/6 | Contractor<br>Metcalfe Bros | Client<br>London Rock |
| Date<br>30/09/2015 | BH Diameter<br>150 mm | Project<br>Geological Investigation |
| Grid Ref:<br>SU 460433 187916 | Surface Level<br>45.72 mAOD | Site<br>White Cross Farm, Wallingford |

Greenfield
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WCF 15/7

| Depth (m) | Lithological Description | | Thickness (m) | Level (m AOD)<br>43.5 | Water Depth/ Level (m/ mAOD) | Grading F: S: G |
|---|---|---|---|---|---|---|
| 0.0 | | | | | | |
| 0.2 | ***Soil and Subsoil*** | ▨ | 0.2 | 43.3 | | |
| 0.9 | ***Clay***<br>Soft yellow clay turning to soft grey clay. | ▨ | 0.7 | 42.6 | Water strike at 0.9m/ 42.6m AOD | |
| | ***Sand and gravel***<br>Brown sand & gravel, fine-coarse sand, fine-medium, sub angular to rounded gravels. | ▨ | 2.1 | 40.5 | | 2: 60: 38<br>1: 49: 50 |
| 3.8 | ***Clay***<br>Light grey firm chalky clay. | ▨ | 0.8 | 39.7 | | |
| | End of Borehole - 3.80m | | | | | |

Depth scale: 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

Borehole No. WCF 15/7

Date 30/09/2015

Grid Ref: SU 460581 187701

Contractor Metcalfe Bros

BH Diameter 150 mm

Surface Level 43.49 mAOD

Client London Rock

Project Geological Investigation

Site White Cross Farm, Wallingford

**Greenfield**
associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# White Cross Farm, Wallingford

## Shell & Auger Borehole Log: Borehole No. WCF 15/8

| Depth (m) | Lithological Description | Thickness (m) | Level (m AOD) | Water Depth/ Level (m/ mAOD) | Grading F: S: G |
|---|---|---|---|---|---|
| 0.0 | | | 43.3 | | |
| 0.2 | ***Soil and Subsoil*** | 0.2 | 43.1 | | |
| 0.8 | ***Clay***<br>Brown firm clay. | 0.6 | 42.5 | | |
| 1.7 | ***Clay***<br>Soft grey blue clay. | 0.9 | 41.6 | Water strike at 1.7m/ 41.6m AOD | |
| 2.9 | ***Sand & Gravel***<br>Brown sand & gravel, fine to coarse sand, fine-coarse angular to sub angular flint gravels with occasional cobbles. | 1.2 | 40.4 | | |
| 3.5 | ***Clay***<br>Light grey firm chalky clay. | 0.6 | 39.8 | | |
| | End of Borehole - 3.50m | | | | |
| 5.1 | | | | | |

Depth scale: 0.0, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0

| | |
|---|---|
| Borehole No. | WCF 15/8 |
| Date | 30/09/2015 |
| Grid Ref: | SU 460603 187595 |
| Contractor | Metcalfe Bros |
| BH Diameter | 150 mm |
| Surface Level | 43.27 mAOD |
| Client | London Rock |
| Project | Geological Investigation |
| Site | White Cross Farm, Wallingford |

Greenfield associates
1 Commercial Rd, Keyworth, Nottingham NG12 5JS
E-mail: admin@greenfield-associates.co.uk
Tel: 0115 9372002

# White Cross Farm, Wallingford

## **Borehole ID**: GM16/1

LONDON ROCK SUPPLIES LTD

## Geological Log

## Installation Details

**Headworks Level:** 44.246m AOD

**Ground Level:** 43.706m AOD

0.0 - 0.2 Clayey dark topsoil

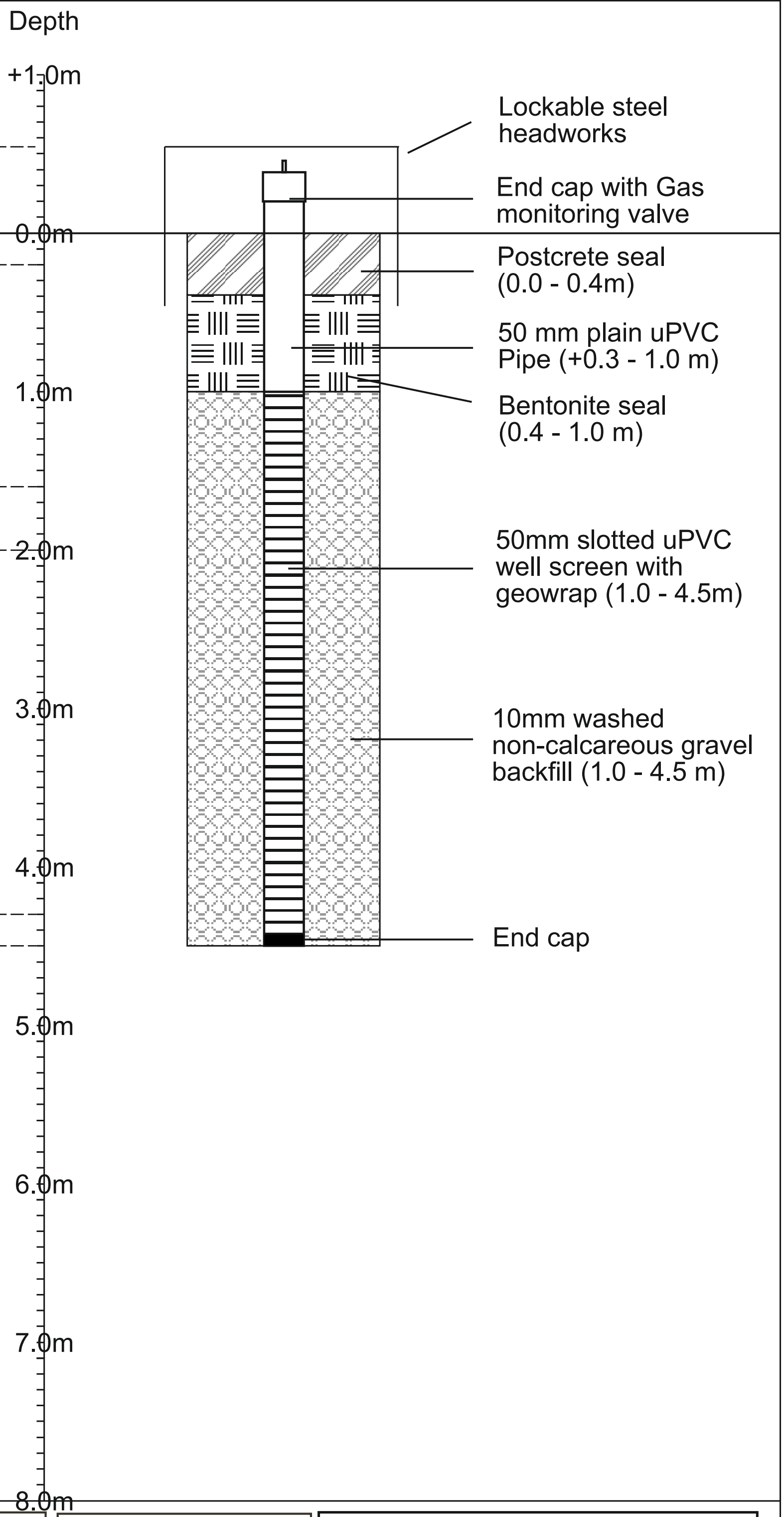
0.2 - 1.6 Brown becoming grey slightly sandy Clay

1.6 - 2.0 Dark gray slightly sandy organic Clay (Peat)

2.0 - 4.3 Brown Sand & Gravel, fine to coarse sand and fine occasionally medium flint gravel

4.3 - 4.5 Light grey extremely weak silty Chalk Marl

**Base of Borehole:** 39.206m AOD



**Client**
London Rock Ltd

**Project**
Site Development

**Location**
White Cross Farm
Wallingford

**Contractor**
Metcalfe Bros Ltd

**Drilling Method**
150mm Shell & Auger

**Water Struck at**
2.00 m

**Date Drilled**
18/11/2016

**Casing Depth**
4.40m

**Grid Ref.**
SU 60670 88032

Greenfield associates
1 Commercial Road, Keyworth, Ng12 5JS
Tel/fax: 0115 9372002
email: admin@greenfield-associates.co.uk

# White Cross Farm, Wallingford

## **Borehole ID**: GM16/2

LONDON ROCK
SUPPLIES LTD

## Geological Log

**Headworks Level:** 47.174 m AOD

**Ground Level:** 46.488 m AOD

0.0 - 0.2 Topsoil

0.2 - 1.7 Stiff brown slightly clayey sandy Silt

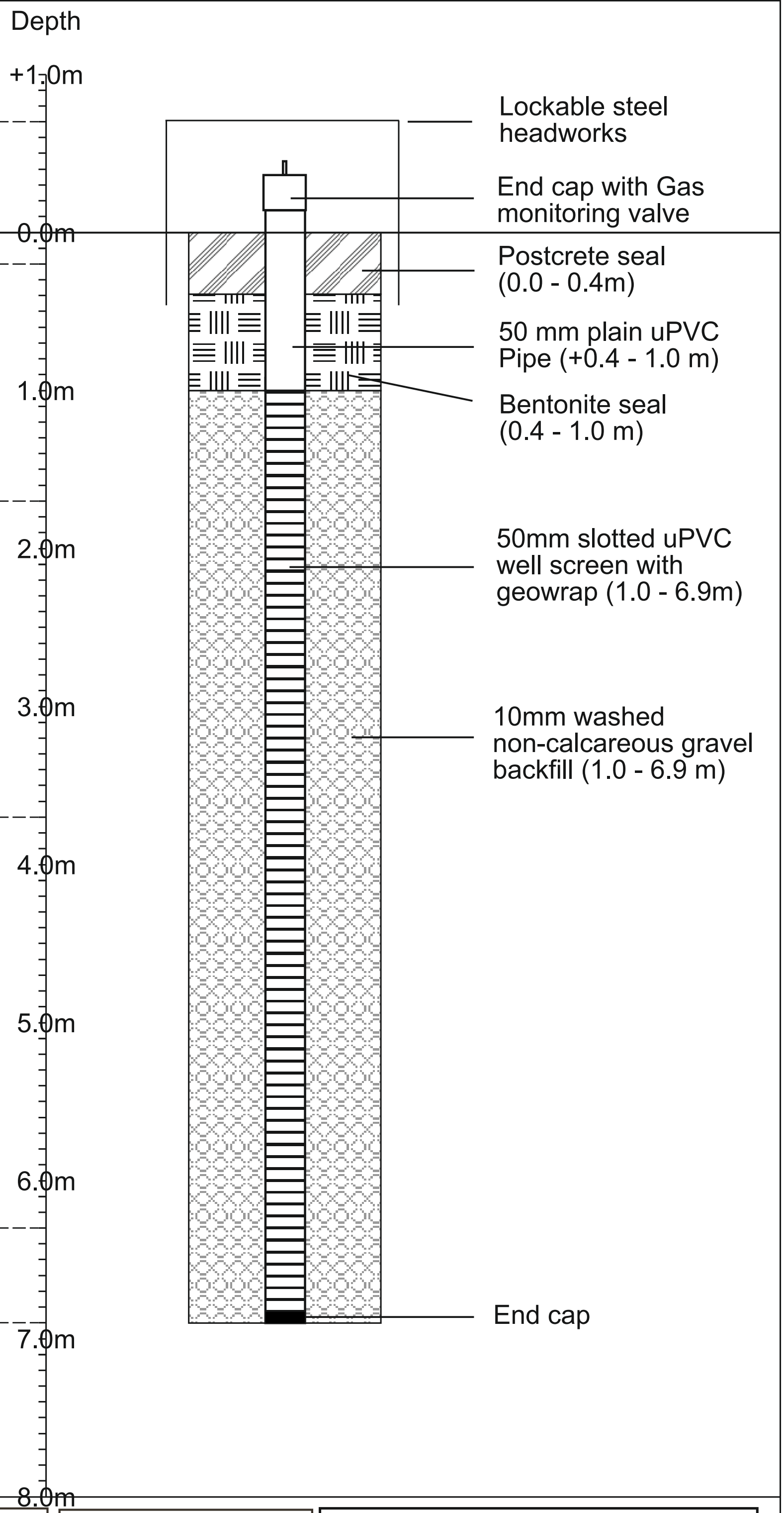
1.7 - 3.7 Brown Sand & Gravel

3.7 - 6.3 Brown slightly silty Sand & Gravel

6.3 - 6.9 Cream/grey stiff locally extremely weak Chalk Marl

**Base of Borehole:** 35.588 m AOD

## Installation Details



| | | |
|---|---|---|
| **Client**<br>London Rock Ltd | **Contractor**<br>Metcalfe Bros Ltd | **Date Drilled**<br>17/11/2016 |
| **Project**<br>Site Development | **Drilling Method**<br>150mm Shell & Auger | **Casing Depth**<br>3.00m |
| **Location**<br>White Cross Farm<br>Wallingford | **Water Struck at**<br>2.70 m | **Grid Ref.**<br>SU 60382 87910 |

Greenfield
associates
1 Commercial Road, Keyworth, Ng12 5JS
Tel/fax: 0115 9372002
email: admin@greenfield-associates.co.uk

# White Cross Farm, Wallingford

## Borehole ID: GM16/3

### Geological Log

**Headworks Level:** 47.111m AOD

**Ground Level:** 46.495m AOD

0.0 - 0.3 Dark stoney soil

0.3 - 1.5 Dark brown firm to stiff Sandy Clay

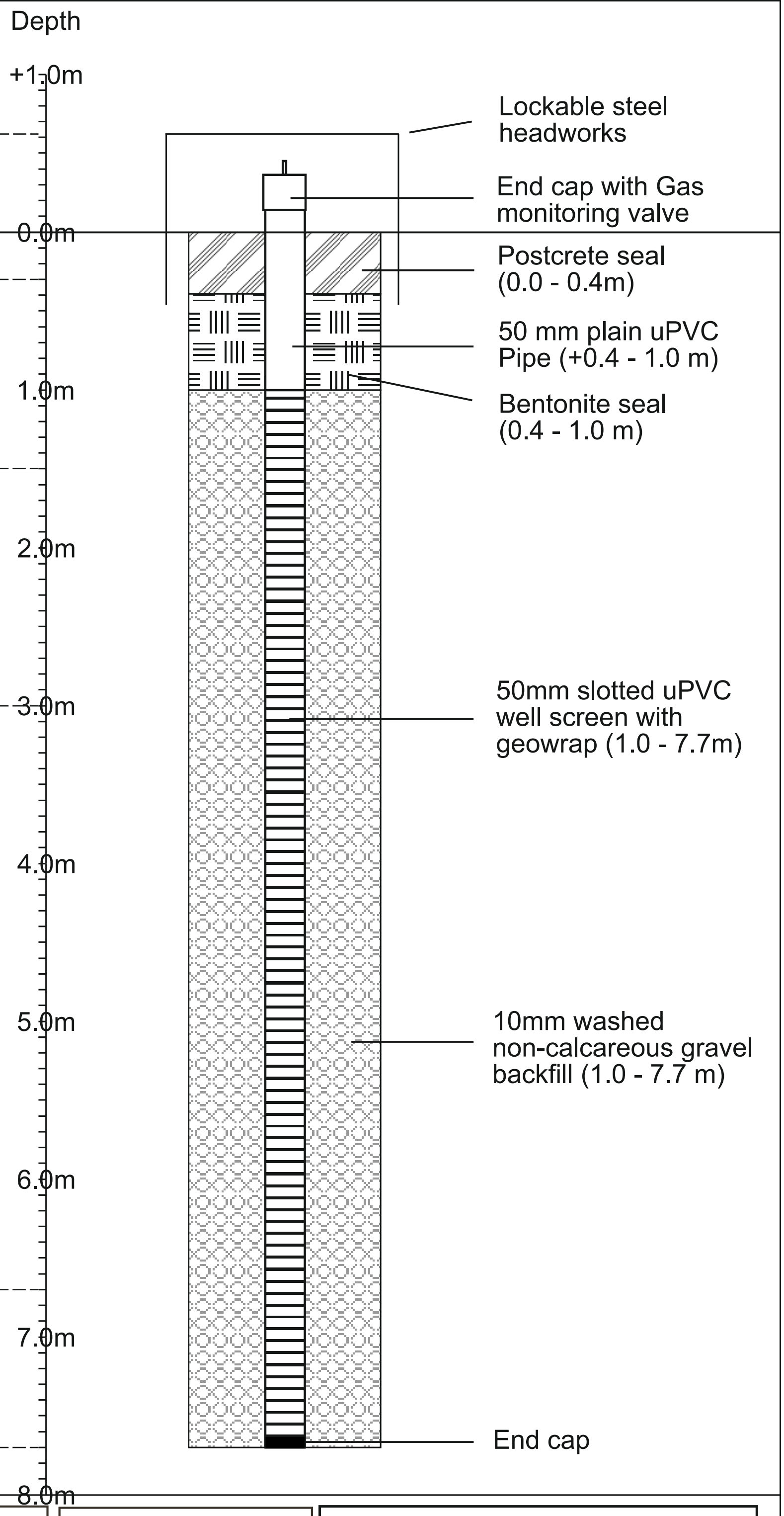
1.5 - 3.0 Light brown fine to coarse Sand with much fine to medium gravel

3.0 - 6.7 Brown Sand & Gravel, medium to coarse sand and fine to medium flint gravel

6.7 - 7.7 Cream/grey extremely weak to weak silty Chalk Marl

**Base of Borehole:** 38.795m AOD

### Installation Details



**Client**
London Rock Ltd

**Project**
Site Development

**Location**
White Cross Farm
Wallingford

**Contractor**
Metcalfe Bros Ltd

**Drilling Method**
150mm Shell & Auger

**Water Struck at**
2.5 m + 7.4m

**Date Drilled**
17/11/2016

**Casing Depth**
6.20m

**Grid Ref.**
SU 60353 87766

Greenfield associates
1 Commercial Road, Keyworth, Ng12 5JS
Tel/fax: 0115 9372002
email: admin@greenfield-associates.co.uk

# White Cross Farm, Wallingford

## **Borehole ID**: GM16/4

LONDON ROCK
SUPPLIES LTD

| **Geological Log** | **Installation Details** |
|---|---|

**Headworks Level:** 46.695m AOD

**Ground Level:** 46.035m AOD

0.0 - 0.25  Dark stoney soil

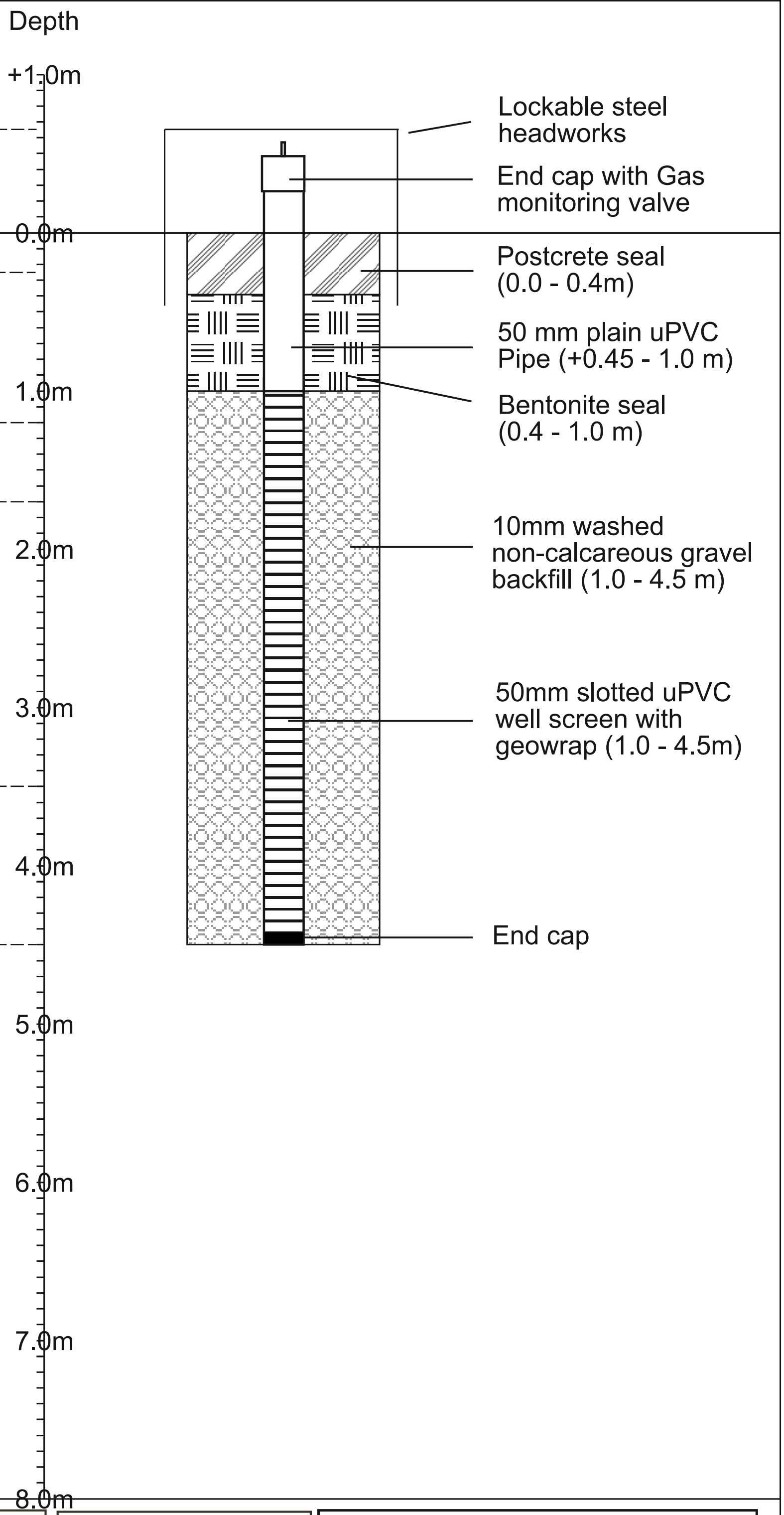
0.25 - 1.2  Stiff brown Sandy Clay

1.2 - 1.7  Light brown to brown slightly sandy Silt, becoming clayey and pebbly in bottom 0.2m

1.7 - 3.5  Brown Sand & Gravel, fine to coarse sand and fine to medium flint gravel

3.5 - 4.5  Light grey/cream weathered Chalk Marl

**Base of Borehole:** 41.535m AOD



| | | | |
|---|---|---|---|
| **Client**<br>London Rock Ltd | **Contractor**<br>Metcalfe Bros Ltd | **Date Drilled**<br>16/11/2016 | Greenfield associates<br>1 Commercial Road, Keyworth, Ng12 5JS<br>Tel/fax: 0115 9372002<br>email: admin@greenfield-associates.co.uk |
| **Project**<br>Site Development | **Drilling Method**<br>150mm Shell & Auger | **Casing Depth**<br>4.00m | |
| **Location**<br>White Cross Farm<br>Wallingford | **Water Struck at**<br>2.8m | **Grid Ref.**<br>SU 60344 87623 | |

# White Cross Farm, Wallingford

## **Borehole ID**: GM16/5

LONDON ROCK
SUPPLIES LTD

## Geological Log

## Installation Details

**Headworks Level:** 46.285m AOD

**Ground Level:** 45.698m AOD

0.0 - 0.3 Dark clayey soil

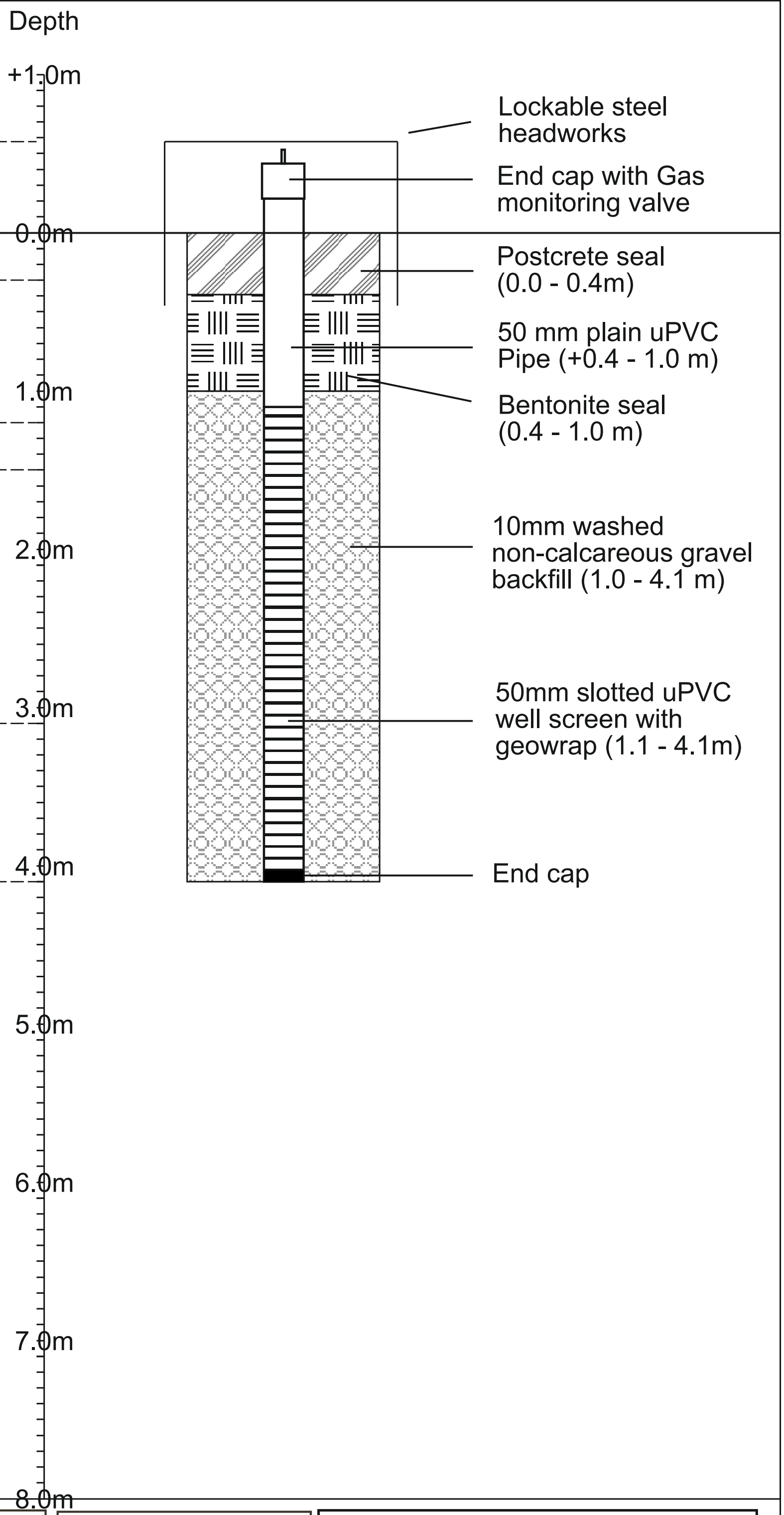
0.3 - 1.2 Dark brown firm to stiff sandy Clay

1.2 - 1.5 Light brown fine to medium Sand

1.5 - 3.1 Light brown fine to coarse Sand with much fine to medium flint gravel

3.1 - 4.1 Light grey/cream firm to extremely weak weathered Chalk Marl

**Base of Borehole:** 41.598m AOD



**Client**
London Rock Ltd

**Project**
Site Development

**Location**
White Cross Farm
Wallingford

**Contractor**
Metcalfe Bros Ltd

**Drilling Method**
150mm Shell & Auger

**Water Struck at**
2.6m

**Date Drilled**
16/11/2016

**Casing Depth**
3.50m

**Grid Ref.**
SU 60344 87445

Greenfield
associates
1 Commercial Road, Keyworth, Ng12 5JS
Tel/fax: 0115 9372002
email: admin@greenfield-associates.co.uk

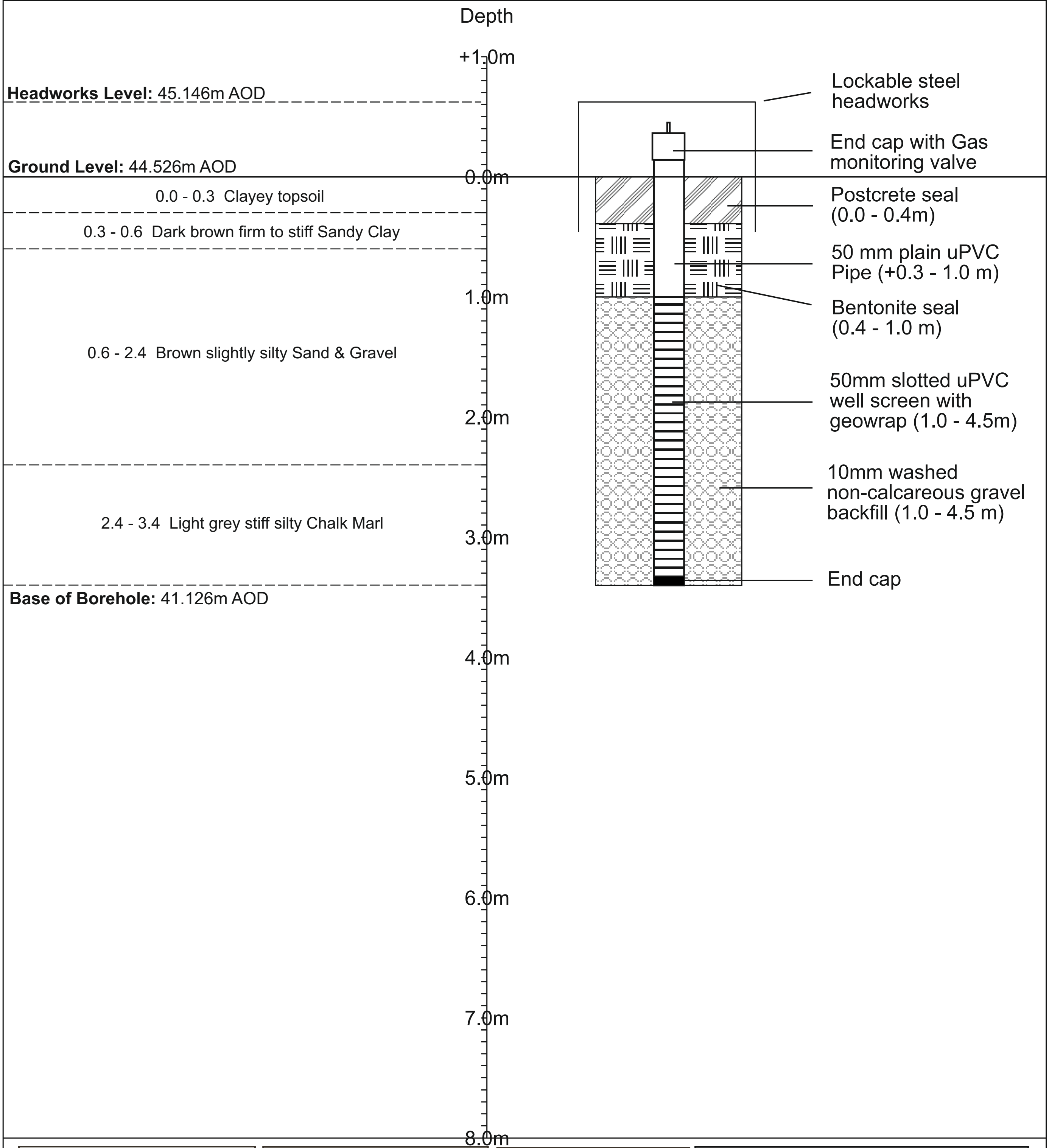
# White Cross Farm, Wallingford

## **Borehole ID**: GM16/6

LONDON ROCK SUPPLIES LTD

### Geological Log

### Installation Details



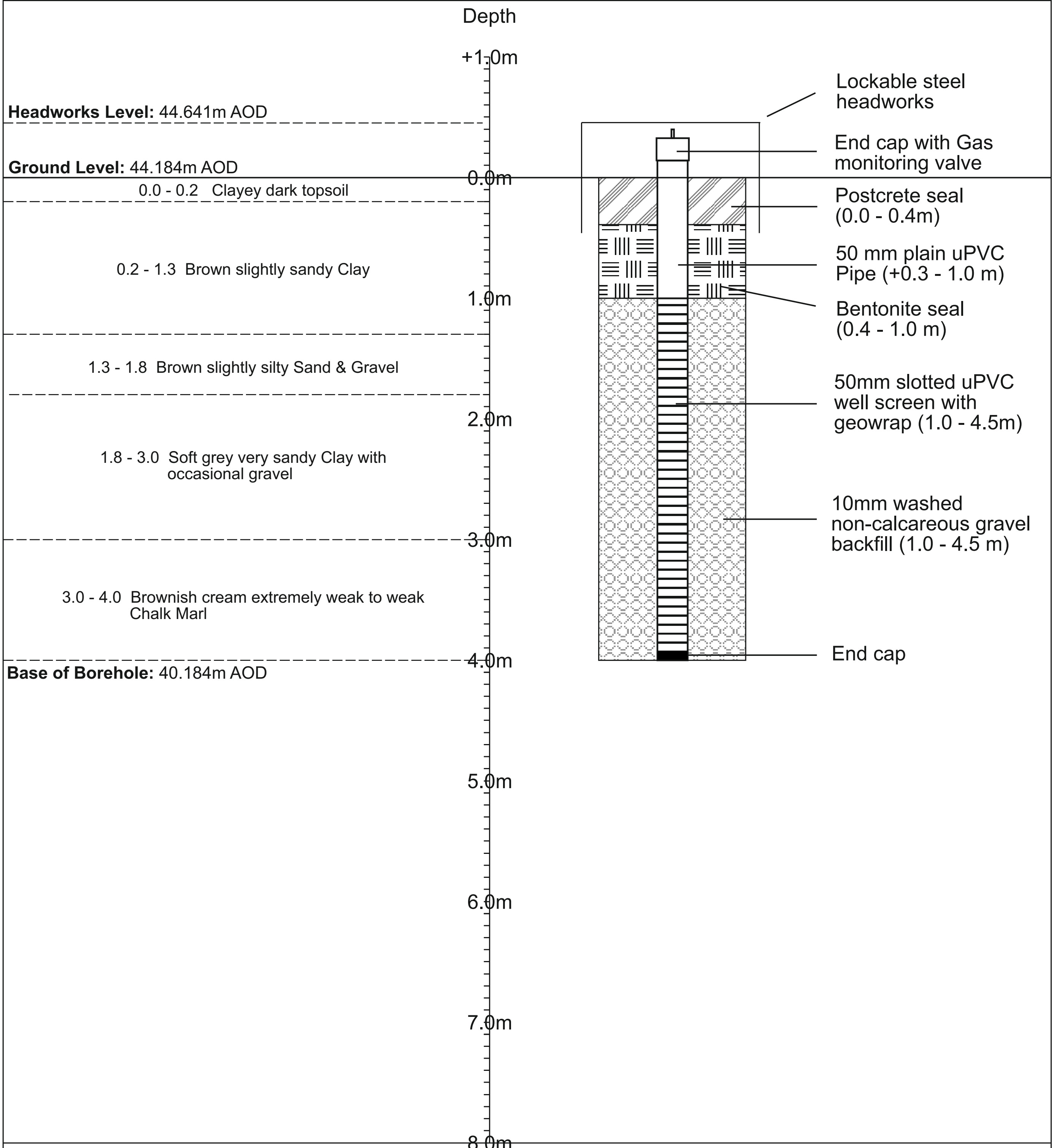
| | | |
|---|---|---|
| **Client**<br>London Rock Ltd | **Contractor**<br>Metcalfe Bros Ltd | **Date Drilled**<br>15/11/2016 |
| **Project**<br>Site Development | **Drilling Method**<br>150mm Shell & Auger | **Casing Depth**<br>3.00m |
| **Location**<br>White Cross Farm<br>Wallingford | **Water Struck at**<br>1.70 m | **Grid Ref.**<br>SU 60411 87445 |

Greenfield associates
1 Commercial Road, Keyworth, Ng12 5JS
Tel/fax: 0115 9372002
email: admin@greenfield-associates.co.uk

# White Cross Farm, Wallingford

## **Borehole ID**: GM16/7

| Geological Log | Installation Details |
|---|---|



**Headworks Level:** 44.641m AOD

**Ground Level:** 44.184m AOD

0.0 - 0.2 Clayey dark topsoil

0.2 - 1.3 Brown slightly sandy Clay

1.3 - 1.8 Brown slightly silty Sand & Gravel

1.8 - 3.0 Soft grey very sandy Clay with occasional gravel

3.0 - 4.0 Brownish cream extremely weak to weak Chalk Marl

**Base of Borehole:** 40.184m AOD

| | | |
|---|---|---|
| **Client**<br>London Rock Ltd | **Contractor**<br>Metcalfe Bros Ltd | **Date Drilled**<br>15/11/2016 |
| **Project**<br>Site Development | **Drilling Method**<br>150mm Shell & Auger | **Casing Depth**<br>3.00m |
| **Location**<br>White Cross Farm<br>Wallingford | **Water Struck at**<br>3.00 m | **Grid Ref.**<br>SU 60438 87493 |

Greenfield associates
1 Commercial Road, Keyworth, Ng12 5JS
Tel/fax: 0115 9372002
email: admin@greenfield-associates.co.uk

# White Cross Farm, Wallingford

## **Borehole ID**: GM16/8

| Geological Log | Installation Details |
|---|---|

Depth

+1.0m

**Headworks Level:** 43.856m AOD

**Ground Level:** 43.240m AOD

0.0m

0.0 - 0.15 Clayey topsoil

1.3 - 2.1 Grey slightly sandy Clay

0.4 - 1.3 Dark brown sandy Clay with much organic material (Peat)

1.0m

1.3 - 2.1 Dark brown very clayey organic Silt

2.0m

2.1 - 2.9 Brown Sand & Gravel, fine to coarse sand and fine to medium flint gravel

3.0m

2.9 - 3.9 Cream/grey clayey sandy weathered Chalk Marl

**Base of Borehole:** 39.340m AOD

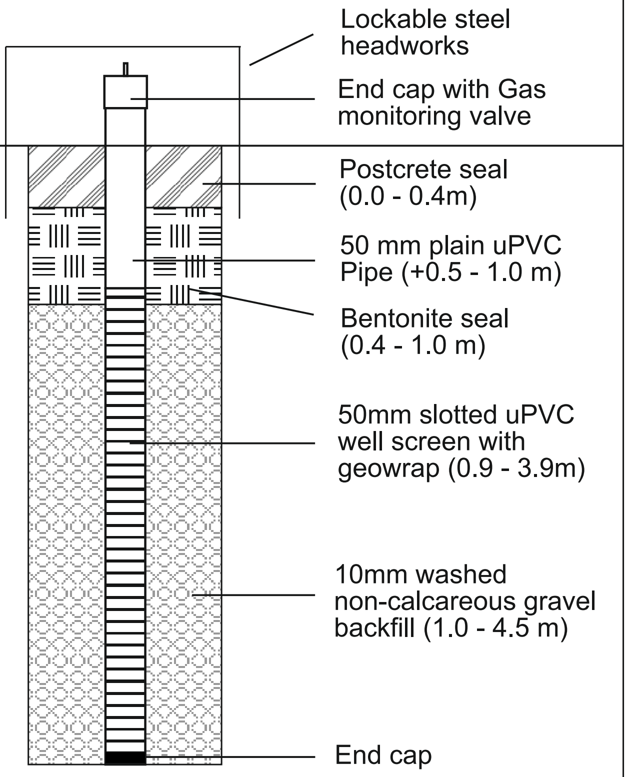
4.0m

5.0m

6.0m

7.0m

8.0m



| | | |
|---|---|---|
| **Client**<br>London Rock Ltd | **Contractor**<br>Metcalfe Bros Ltd | **Date Drilled**<br>18/11/2016 |
| **Project**<br>Site Development | **Drilling Method**<br>150mm Shell & Auger | **Casing Depth**<br>3.30m |
| **Location**<br>White Cross Farm<br>Wallingford | **Water Struck at**<br>2.10 m | **Grid Ref.**<br>SU 60733 87975 |

Greenfield
associates
1 Commercial Road, Keyworth, Ng12 5JS
Tel/fax: 0115 9372002
email: admin@greenfield-associates.co.uk

## APPENDIX 3174/HIA/A2

## Assessment methodology

## Method of assessment

The method of assessment of hydrological and aquatic effects has involved:

- Characterisation of the baseline environment
- Determination of the sensitivity of key catchments and watercourses
- Evaluation of the significance of predicted effects taking account of the magnitude of effects (before and after mitigation)
- Evaluation of the sensitivity of the baseline environment affected

A rigorous and consistent approach to the assessment has been adopted using matrices to help classify sensitivity of the resource, and determine the scale and significance of effects.

### Baseline sensitivity

The characterisation of the baseline water environment has involved the review of data and identification of sensitivities. The characterisation of catchment sensitivities has been guided by the matrix presented in *Table 3174/HIA/A2.1* which lists indicative criteria.

The criteria for sensitivity are based approximately on hierarchy of factors relating to the quality of the aquatic environment. The criteria have been used to guide the analysis of the sensitivity of the baseline hydrological, hydrogeological and water quality environment.

**Table 3174/HIA/A2.1: Catchment sensitivity classification**

| **Sensitivity category** | **Sensitivity criteria** | |
|---|---|---|
| | **Adjacent to Application Area** | **Downstream/in catchment** |
| High sensitivity | SSSI or Aquatic Natura 2000 site<br>Wetland/watercourse habitat of particular ecological importance<br>Highly vulnerable groundwater<br>Significant peat deposits on sloping ground | Aquatic Natura 2000 site or SSSI immediately downstream/ adjacent to site |
| Medium sensitivity | Wetland watercourse habitat of particular ecological importance<br>Moderately vulnerable groundwater<br>Significant peat deposits | Aquatic Natura 2000 site or SSSI further downstream of the catchment.<br>Sensitive locally designated site of ecological interest |
| Low sensitivity | Low vulnerability groundwater<br>Superficial peat deposits | |
| Not sensitive | No aquatic habitats or watercourses present<br>No significant groundwater present | |

Impact prediction and evaluation

The prediction and assessment of effects on hydrology, hydrogeology and other aquatic resources has been undertaken using a series of tables to document the various potential impacts from aspects of the proposed project. Impacts have been predicted for the proposed development based on the guideline criteria for impact magnitudes set out in *Table 3174/HIA/A2.2*.

**Table 3174/HIA/A2.2: Impact magnitude**

| Impact magnitude | Guideline criteria |
|---|---|
| High | Total loss of, or alteration to, key features of the baseline resource such that post-development characteristics or quality would be fundamentally and irreversibly changed, eg watercourse realignment |
| Medium | Total loss of, or alteration to, key features of the baseline resource such that post-development characteristics or quality would be partially changed, eg in-stream permanent bridge works |
| Low | Small changes to the baseline resource which are detectable but the underlying characteristics or quality of the baseline situation would be similar to pre-development conditions, eg culverting of very small watercourses |
| Negligible | A very slight change from baseline conditions, which is barely distinguishable and approximates to the ‘no change’ situation, eg short-term compaction from plant movements |

Using these criteria a series of generic impacts have been predicted for the proposed development. Residual effects have been predicted taking into account site-specific mitigation.

The significance of the predicted effects has been assessed in relation to the sensitivities of the baseline resource. A matrix of significance was developed to provide a consistent framework for evaluation and is presented in *Table 3174/HIA/A2.3*. Guideline criteria for the various categories of effect are included in *Table 3174/HIA/A2.4*.

**Table 3174/HIA/A2.3: Significance matrix**

| Magnitude | Sensitivity | | | |
|---|---|---|---|---|
| | High | Medium | Low | Negligible |
| High | Major | Major | Moderate | Minor |
| Medium | Major | Moderate | Minor | Minor |
| Low | Moderate | Minor | Minor | None |
| Negligible | Minor | Minor | None | None |

**Table 3174/HIA/A2.4: Significance of effects categories**

| Significance | Definition | Guideline criteria |
|---|---|---|
| None | No detectable change to the environment | No effects on drainage patterns, surface and groundwater quality or aquatic habitat |

**Table 3174/HIA/A2.4: Significance of effects categories**

| Significance | Definition | Guideline criteria |
|---|---|---|
| Minor | A small but detectable change to the environment | Localised changes in drainage patterns or groundwater flows, or changes resulting in minor and reversible effects on surface and groundwater quality or aquatic habitats |
| Moderate | A larger, but non-fundamental change to the environment | Changes in water quality or quantity affecting part of a catchment or groundwaters of moderate vulnerability, or changes resulting in loss of conservation value to aquatic habitats or designated areas |
| Major | A fundamental change to the environment | Changes in water quality or quantity affecting widespread catchments or groundwater reserves of strategic significance, or changes resulting in substantial loss of conservation value to aquatic habitats and designations |

In the above classification, fundamental changes are those which are permanent, detrimental and would result in widespread change to the baseline environment.

The matrices used to guide the assessment have been applied with a degree of flexibility since the evaluation of effects would always be subject to particular location-specific characteristics which need to be taken into account. For this reason, the evaluation of impact significance, in particular, would not always correlate exactly with the cells in the relevant matrix where professional judgement and knowledge of local conditions may result in a slightly different interpretation of the impact concerned. Cumulative effects have been taken into account through prediction and evaluation of effects at a catchment-wide level.

# APPENDIX 3174/HIA/A3

# Groundwater inflow and radius of influence calculations

# White Cross Farm
Phase A

hafrenwater

| | |
|---|---|
| Calc sheet by: | DI |
| Version number: | 1 |
| Date: | 07/07/2021 |

## Hydraulic parameters

| | min | most likely | max |
|---|---|---|---|
| Hydraulic conductivity, K (m/day) | 0.24 | 18.45 | 168.48 |

## Dupiut-Forcheimer formula for inflows

| | | | |
|---|---|---|---|
| Initial saturated thickness, $h_0$ (m) | 3 | | |
| Seepage face, $h_s$ (m) | 0.25 | | |
| Drawdown, $\Delta h$ (m) | 2.75 | | |
| Saturated thickness, $h_w$ (m) | 0.5 | | |
| Radius of working area choice | Circular | ← select result from box 1 | |
| Radius of working area, $r_w$ (m) | 92.0 | | |
| | min | most likely | max |
| Groundwater inflow, Q ($m^3$/day) | 47.4 | 605.7 | 2892.4 |
| Groundwater inflow, Q (L/s) | 0.55 | 7.01 | 33.48 |

## Box 1: CIRIA formula for effective radius of working area

| | | |
|---|---|---|
| Length (m) | 163.1 | |
| Width (m) | 163.1 | |
| | Circular | Rectangular |
| Effective radius (m) | 92.0 | 103.8 |

## Box 2: Sichardt formula for radius of influence

| | | | |
|---|---|---|---|
| Sichardt factor, Cs | 3000 | (3000 for radial flow, 1500-2000 for linear flow) | |
| Drawdown (m) | 2.75 | | |
| | min | most likely | max |
| Radius of influence, $R_0$ (m) | 13.8 | 120.6 | 364.3 |

## Total ingress (groundwater + rainfall)

| | | | |
|---|---|---|---|
| Groundwater inflow choice | most likely | ← select result from Theim calcs | |
| Groundwater inflow (m3/day) | 605.7 | | |
| Runoff catchment (m2) | 26626 | | |
| | min | most likely | max |
| Fraction of rainfall forming runoff | 60% | 80% | 100% |
| Fraction of rainfall choice | max | ← select proportion from table above | |

| | Avg. rainfall per month (mm) | Runoff rate (m3/day) | Runoff rate (L/s) | Runoff + GW inflow (m3/day) | Runoff + GW inflow (L/s) |
|---|---|---|---|---|---|
| January | 53.50 | 46.0 | 0.53 | 651.7 | 7.54 |
| February | 38.80 | 36.9 | 0.43 | 642.6 | 7.44 |
| March | 34.90 | 30.0 | 0.35 | 635.7 | 7.36 |
| April | 44.50 | 39.5 | 0.46 | 645.2 | 7.47 |
| May | 48.80 | 41.9 | 0.49 | 647.6 | 7.50 |
| June | 39.20 | 34.8 | 0.40 | 640.5 | 7.41 |
| July | 40.00 | 34.4 | 0.40 | 640.1 | 7.41 |
| August | 46.80 | 40.2 | 0.47 | 645.9 | 7.48 |
| September | 47.30 | 42.0 | 0.49 | 647.7 | 7.50 |
| October | 62.90 | 54.0 | 0.63 | 659.7 | 7.64 |
| November | 66.90 | 59.4 | 0.69 | 665.1 | 7.70 |
| December | 54.20 | 46.6 | 0.54 | 652.3 | 7.55 |
| Annual average | | 42.1 | 0.5 | 647.8 | 7.5 |
| Annual maximum | | 59.4 | 0.7 | 665.1 | 7.7 |

## EXPLANATION OF CELL COLOURS

| | |
|---|---|
| Yellow | Data entry |
| Green | Formulae |
| Blue | Select from list |

## EXPLANATION OF DUPUIT-FORCHEIMER FORMULA

Dupiut-Forcheimer is valid for unconfined flow (i.e. variable saturated thickness) CIRIA 2000: Eq 6.7.

This is called the Theim-Dupiut equation by the Environment Agency 2007: box 3.2.

$$Q = \pi k\left[\left(h_o^2 - h_w^2\right)/\ln\left(r_o / r_w\right)\right]$$

Where
Q = groundwater ingress rate (m3/d)
k = hydraulic conductivity (m/d)
h0 = sat'd thickness before drawdown (m)
hs = height of seepage face in workings (m)
hw = sat'd aquifer thickness after drawdown + hs (m)
rw = radius of working area (m)
r0 = rw + radius of influence (m)

Effective radius of the working area estimate is based on CIRIA 2000: equation 6.5

## EXPLANATION OF SICHARDT FORMULA

Cited as equation 6.8 in CIRIA 2000, and equation 3.4 by Cashman and Preene 2001.

$$r = Ch\sqrt{k}$$

Where
r = radius of influence (m)
C = constant
h = drawdown (m)
k = hydraulic conductivity (m/s)
rw = radius of working area (m)

## REFERENCES

Cashman and Preene, 2001. Groundwater Lowering in Construction: A Practical Guide. Spon Press. (Superseded by Cashman and Preene, 2020. Groundwater Lowering in Construction: A Practical Guide to Dewatering (3rd edition). CRC Press)

CIRIA, 2000. Groundwater control - design and practice. Report C515 (Superseded by CIRIA, 2007. Groundwater control - design and practice (second edition). Report C750.)

Environment Agency, 2007. Hydrogeological impact appraisal for dewatering abstractions. Science Report SC040020/SR1

White Cross Farm
Phase 1

hafrenwater

| | |
|---|---|
| Calc sheet by: | DI |
| Version number: | 1 |
| Date: | 07/07/2021 |

## Hydraulic parameters

| | *min* | *most likely* | *max* |
|---|---|---|---|
| Hydraulic conductivity, K (m/day) | 0.24 | 18.45 | 168.48 |

## Dupiut-Forcheimer formula for inflows

| | | | |
|---|---|---|---|
| Initial saturated thickness, $h_0$ (m) | 3 | | |
| Seepage face, $h_s$ (m) | 0.25 | | |
| Drawdown, Δh (m) | 2.75 | | |
| Saturated thickness, $h_w$ (m) | 0.5 | | |
| Radius of working area choice | Circular | ← select result from box 1 | |
| Radius of working area, $r_w$ (m) | 105.8 | | |
| | *min* | *most likely* | *max* |
| Groundwater inflow, Q ($m^3$/day) | 54.0 | 667.0 | 3106.0 |
| Groundwater inflow, Q (L/s) | 0.63 | 7.72 | 35.95 |

## Box 1: CIRIA formula for effective radius of working area

| | | |
|---|---|---|
| Length (m) | 187.6 | |
| Width (m) | 187.6 | |
| | *Circular* | *Rectangular* |
| Effective radius (m) | 105.8 | 119.4 |

## Box 2: Sichardt formula for radius of influence

| | | | |
|---|---|---|---|
| Sichardt factor, Cs | 3000 | (3000 for radial flow, 1500-2000 for linear flow) | |
| Drawdown (m) | 2.75 | | |
| | *min* | *most likely* | *max* |
| Radius of influence, $R_0$ (m) | 13.8 | 120.6 | 364.3 |

## Total ingress (groundwater + rainfall)

| | | | |
|---|---|---|---|
| Groundwater inflow choice | most likely | ← select result from Theim calcs | |
| Groundwater inflow (m3/day) | 667.0 | | |
| Runoff catchment (m2) | 35201 | | |
| | *min* | *most likely* | *max* |
| Fraction of rainfall forming runoff | 60% | 80% | 100% |
| Fraction of rainfall choice | max | ← select proportion from table above | |

| | Avg. rainfall per month (mm) | Runoff rate (m3/day) | Runoff rate (L/s) | Runoff + GW inflow (m3/day) | Runoff + GW inflow (L/s) |
|---|---|---|---|---|---|
| January | 53.50 | 60.8 | 0.70 | 727.8 | 8.42 |
| February | 38.80 | 48.8 | 0.56 | 715.8 | 8.28 |
| March | 34.90 | 39.6 | 0.46 | 706.6 | 8.18 |
| April | 44.50 | 52.2 | 0.60 | 719.2 | 8.32 |
| May | 48.80 | 55.4 | 0.64 | 722.4 | 8.36 |
| June | 39.20 | 46.0 | 0.53 | 713.0 | 8.25 |
| July | 40.00 | 45.4 | 0.53 | 712.4 | 8.25 |
| August | 46.80 | 53.1 | 0.62 | 720.2 | 8.34 |
| September | 47.30 | 55.5 | 0.64 | 722.5 | 8.36 |
| October | 62.90 | 71.4 | 0.83 | 738.4 | 8.55 |
| November | 66.90 | 78.5 | 0.91 | 745.5 | 8.63 |
| December | 54.20 | 61.5 | 0.71 | 728.6 | 8.43 |
| Annual average | | 55.7 | 0.6 | 722.7 | 8.4 |
| Annual maximum | | 78.5 | 0.9 | 745.5 | 8.6 |

## EXPLANATION OF CELL COLOURS

| | |
|---|---|
| Yellow | Data entry |
| Green | Formulae |
| Blue | Select from list |

## EXPLANATION OF DUPUIT-FORCHEIMER FORMULA

Dupiut-Forcheimer is valid for unconfined flow (i.e. variable saturated thickness) CIRIA 2000: Eq 6.7.

This is called the Theim-Dupiut equation by the Environment Agency 2007: box 3.2.

$$Q = \pi k\left[\left(h_o^2 - h_w^2\right) / \ln\left(r_o / r_w\right)\right]$$

Where
Q = groundwater ingress rate (m3/d)
k = hydraulic conductivity (m/d)
h0 = sat'd thickness before drawdown (m)
hs =  height of seepage face in workings (m)
hw = sat'd aquifer thickness after drawdown + hs (m)
rw = radius of working area (m)
r0 = rw + radius of influence (m)

Effective radius of the working area estimate is based on CIRIA 2000: equation 6.5

## EXPLANATION OF SICHARDT FORMULA

Cited as equation 6.8 in CIRIA 2000, and equation 3.4 by Cashman and Preene 2001.

$$r = Ch\sqrt{k}$$

Where
r = radius of influence (m)
C = constant
h = drawdown (m)
k = hydraulic conductivity (m/s)
rw = radius of working area (m)

## REFERENCES

Cashman and Preene, 2001. Groundwater Lowering in Construction: A Practical Guide. Spon Press. (Superseded by Cashman and Preene, 2020. Groundwater Lowering in Construction: A Practical Guide to Dewatering (3rd edition). CRC Press)

CIRIA, 2000. Groundwater control - design and practice. Report C515 (Superseded by CIRIA, 2007. Groundwater control - design and practice (second edition). Report C750.)

Environment Agency, 2007. Hydrogeological impact appraisal for dewatering abstractions. Science Report SC040020/SR1

White Cross Farm
Phase 2

| | |
|---|---|
| Calc sheet by: | DI |
| Version number: | 1 |
| Date: | 07/07/2021 |

hafrenwater

## Hydraulic parameters

| | min | most likely | max |
|---|---|---|---|
| Hydraulic conductivity, K (m/day) | 0.24 | 18.45 | 168.48 |

## Dupiut-Forcheimer formula for inflows

| | | |
|---|---|---|
| Initial saturated thickness, $h_0$ (m) | 3 | |
| Seepage face, $h_s$ (m) | 0.25 | |
| Drawdown, $\Delta h$ (m) | 2.75 | |
| Saturated thickness, $h_w$ (m) | 0.5 | |
| Radius of working area choice | Circular | ← select result from box 1 |
| Radius of working area, $r_w$ (m) | 81.6 | |

| | min | most likely | max |
|---|---|---|---|
| Groundwater inflow, Q ($m^3$/day) | 42.4 | 559.0 | 2726.8 |
| Groundwater inflow, Q (L/s) | 0.49 | 6.47 | 31.56 |

## Box 1: CIRIA formula for effective radius of working area

| | |
|---|---|
| Length (m) | 144.6 |
| Width (m) | 144.6 |

| | Circular | Rectangular |
|---|---|---|
| Effective radius (m) | 81.6 | 92.1 |

## Box 2: Sichardt formula for radius of influence

| | | |
|---|---|---|
| Sichardt factor, Cs | 3000 | (3000 for radial flow, 1500-2000 for linear flow) |
| Drawdown (m) | 2.75 | |

| | min | most likely | max |
|---|---|---|---|
| Radius of influence, $R_0$ (m) | 13.8 | 120.6 | 364.3 |

## Total ingress (groundwater + rainfall)

| | | |
|---|---|---|
| Groundwater inflow choice | most likely | ← select result from Theim calcs |
| Groundwater inflow (m3/day) | 559.0 | |
| Runoff catchment (m2) | 20923 | |

| | min | most likely | max |
|---|---|---|---|
| Fraction of rainfall forming runoff | 60% | 80% | 100% |
| Fraction of rainfall choice | max | ← select proportion from table above | |

| | Avg. rainfall per month (mm) | Runoff rate (m3/day) | Runoff rate (L/s) | Runoff + GW inflow (m3/day) | Runoff + GW inflow (L/s) |
|---|---|---|---|---|---|
| January | 53.50 | 36.1 | 0.42 | 595.1 | 6.89 |
| February | 38.80 | 29.0 | 0.34 | 588.0 | 6.80 |
| March | 34.90 | 23.6 | 0.27 | 582.5 | 6.74 |
| April | 44.50 | 31.0 | 0.36 | 590.0 | 6.83 |
| May | 48.80 | 32.9 | 0.38 | 591.9 | 6.85 |
| June | 39.20 | 27.3 | 0.32 | 586.3 | 6.79 |
| July | 40.00 | 27.0 | 0.31 | 586.0 | 6.78 |
| August | 46.80 | 31.6 | 0.37 | 590.5 | 6.83 |
| September | 47.30 | 33.0 | 0.38 | 591.9 | 6.85 |
| October | 62.90 | 42.5 | 0.49 | 601.4 | 6.96 |
| November | 66.90 | 46.7 | 0.54 | 605.6 | 7.01 |
| December | 54.20 | 36.6 | 0.42 | 595.5 | 6.89 |
| Annual average | | 33.1 | 0.4 | 592.1 | 6.9 |
| Annual maximum | | 46.7 | 0.5 | 605.6 | 7.0 |

## EXPLANATION OF CELL COLOURS

| | |
|---|---|
| Yellow | Data entry |
| Green | Formulae |
| Blue | Select from list |

## EXPLANATION OF DUPUIT-FORCHEIMER FORMULA

Dupiut-Forcheimer is valid for unconfined flow (i.e. variable saturated thickness) CIRIA 2000: Eq 6.7.

This is called the Theim-Dupiut equation by the Environment Agency 2007: box 3.2.

$$Q = \pi k\left[\left(h_o^2 - h_w^2\right)/\ln\left(r_o / r_w\right)\right]$$

Where
Q = groundwater ingress rate (m3/d)
k = hydraulic conductivity (m/d)
h0 = sat'd thickness before drawdown (m)
hs = height of seepage face in workings (m)
hw = sat'd aquifer thickness after drawdown + hs (m)
rw = radius of working area (m)
r0 = rw + radius of influence (m)

Effective radius of the working area estimate is based on CIRIA 2000: equation 6.5

## EXPLANATION OF SICHARDT FORMULA

Cited as equation 6.8 in CIRIA 2000, and equation 3.4 by Cashman and Preene 2001.

$$r = Ch\sqrt{k}$$

Where
r = radius of influence (m)
C = constant
h = drawdown (m)
k = hydraulic conductivity (m/s)
rw = radius of working area (m)

## REFERENCES

Cashman and Preene, 2001. Groundwater Lowering in Construction: A Practical Guide. Spon Press. (Superseded by Cashman and Preene, 2020. Groundwater Lowering in Construction: A Practical Guide to Dewatering (3rd edition). CRC Press)

CIRIA, 2000. Groundwater control - design and practice. Report C515 (Superseded by CIRIA, 2007. Groundwater control - design and practice (second edition). Report C750.)

Environment Agency, 2007. Hydrogeological impact appraisal for dewatering abstractions. Science Report SC040020/SR1

White Cross Farm
Phase 3

hafrenwater

| | |
|---|---|
| Calc sheet by: | DI |
| Version number: | 1 |
| Date: | 07/07/2021 |

## Hydraulic parameters

| | min | most likely | max |
|---|---|---|---|
| Hydraulic conductivity, K (m/day) | 0.24 | 18.45 | 168.48 |

## Dupiut-Forcheimer formula for inflows

| | | |
|---|---|---|
| Initial saturated thickness, $h_0$ (m) | 3 | |
| Seepage face, $h_s$ (m) | 0.25 | |
| Drawdown, $\Delta h$ (m) | 2.75 | |
| Saturated thickness, $h_w$ (m) | 0.5 | |
| Radius of working area choice | Circular | ← select result from box 1 |
| Radius of working area, $r_w$ (m) | 129.1 | |

| | min | most likely | max |
|---|---|---|---|
| Groundwater inflow, Q ($m^3$/day) | 65.2 | 769.0 | 3454.1 |
| Groundwater inflow, Q (L/s) | 0.75 | 8.90 | 39.98 |

## Box 1: CIRIA formula for effective radius of working area

| | |
|---|---|
| Length (m) | 228.8 |
| Width (m) | 228.8 |

| | Circular | Rectangular |
|---|---|---|
| Effective radius (m) | 129.1 | 145.7 |

## Box 2: Sichardt formula for radius of influence

| | | |
|---|---|---|
| Sichardt factor, Cs | 3000 | (3000 for radial flow, 1500-2000 for linear flow) |
| Drawdown (m) | 2.75 | |

| | min | most likely | max |
|---|---|---|---|
| Radius of influence, $R_0$ (m) | 13.8 | 120.6 | 364.3 |

## Total ingress (groundwater + rainfall)

| | | |
|---|---|---|
| Groundwater inflow choice | most likely | ← select result from Theim calcs |
| Groundwater inflow (m3/day) | 769.0 | |
| Runoff catchment (m2) | 52350 | |

| | min | most likely | max |
|---|---|---|---|
| Fraction of rainfall forming runoff | 60% | 80% | 100% |
| Fraction of rainfall choice | max | ← select proportion from table above | |

| | Avg. rainfall per month (mm) | Runoff rate (m3/day) | Runoff rate (L/s) | Runoff + GW inflow (m3/day) | Runoff + GW inflow (L/s) |
|---|---|---|---|---|---|
| January | 53.50 | 90.3 | 1.05 | 859.3 | 9.95 |
| February | 38.80 | 72.5 | 0.84 | 841.5 | 9.74 |
| March | 34.90 | 58.9 | 0.68 | 827.9 | 9.58 |
| April | 44.50 | 77.7 | 0.90 | 846.6 | 9.80 |
| May | 48.80 | 82.4 | 0.95 | 851.4 | 9.85 |
| June | 39.20 | 68.4 | 0.79 | 837.4 | 9.69 |
| July | 40.00 | 67.5 | 0.78 | 836.5 | 9.68 |
| August | 46.80 | 79.0 | 0.91 | 848.0 | 9.81 |
| September | 47.30 | 82.5 | 0.96 | 851.5 | 9.86 |
| October | 62.90 | 106.2 | 1.23 | 875.2 | 10.13 |
| November | 66.90 | 116.7 | 1.35 | 885.7 | 10.25 |
| December | 54.20 | 91.5 | 1.06 | 860.5 | 9.96 |
| Annual average | | 82.8 | 1.0 | 851.8 | 9.9 |
| Annual maximum | | 116.7 | 1.4 | 885.7 | 10.3 |

## EXPLANATION OF CELL COLOURS

| | |
|---|---|
| Yellow | Data entry |
| Green | Formulae |
| Blue | Select from list |

## EXPLANATION OF DUPUIT-FORCHEIMER FORMULA

Dupiut-Forcheimer is valid for unconfined flow (i.e. variable saturated thickness) CIRIA 2000: Eq 6.7.

This is called the Theim-Dupiut equation by the Environment Agency 2007: box 3.2.

$$Q = \pi k\left[\left(h_o^2 - h_w^2\right)/\ln\left(r_o / r_w\right)\right]$$

Where
Q = groundwater ingress rate (m3/d)
k = hydraulic conductivity (m/d)
h0 = sat'd thickness before drawdown (m)
hs = height of seepage face in workings (m)
hw = sat'd aquifer thickness after drawdown + hs (m)
rw = radius of working area (m)
r0 = rw + radius of influence (m)

Effective radius of the working area estimate is based on CIRIA 2000: equation 6.5

## EXPLANATION OF SICHARDT FORMULA

Cited as equation 6.8 in CIRIA 2000, and equation 3.4 by Cashman and Preene 2001.

$$r = Ch\sqrt{k}$$

Where
r = radius of influence (m)
C = constant
h = drawdown (m)
k = hydraulic conductivity (m/s)
rw = radius of working area (m)

## REFERENCES

Cashman and Preene, 2001. Groundwater Lowering in Construction: A Practical Guide. Spon Press. (Superseded by Cashman and Preene, 2020. Groundwater Lowering in Construction: A Practical Guide to Dewatering (3rd edition). CRC Press)

CIRIA, 2000. Groundwater control - design and practice. Report C515 (Superseded by CIRIA, 2007. Groundwater control - design and practice (second edition). Report C750.)

Environment Agency, 2007. Hydrogeological impact appraisal for dewatering abstractions. Science Report SC040020/SR1

White Cross Farm
Phase 4

hafrenwater

| | |
|---|---|
| Calc sheet by: | DI |
| Version number: | 1 |
| Date: | 07/07/2021 |

### Hydraulic parameters

| | min | most likely | max |
|---|---|---|---|
| Hydraulic conductivity, K (m/day) | 0.24 | 18.45 | 168.48 |

### Dupiut-Forcheimer formula for inflows

| | | |
|---|---|---|
| Initial saturated thickness, $h_0$ (m) | 3 | |
| Seepage face, $h_s$ (m) | 0.25 | |
| Drawdown, $\Delta h$ (m) | 2.75 | |
| Saturated thickness, $h_w$ (m) | 0.5 | |
| Radius of working area choice | Circular | ← select result from box 1 |
| Radius of working area, $r_w$ (m) | 81.3 | |

| | min | most likely | max |
|---|---|---|---|
| Groundwater inflow, Q ($m^3$/day) | 42.2 | 557.7 | 2722.2 |
| Groundwater inflow, Q (L/s) | 0.49 | 6.45 | 31.51 |

### Box 1: CIRIA formula for effective radius of working area

| | | |
|---|---|---|
| Length (m) | 144.1 | |
| Width (m) | 144.1 | |
| | Circular | Rectangular |
| Effective radius (m) | 81.3 | 91.7 |

### Box 2: Sichardt formula for radius of influence

| | | |
|---|---|---|
| Sichardt factor, Cs | 3000 | (3000 for radial flow, 1500-2000 for linear flow) |
| Drawdown (m) | 2.75 | |

| | min | most likely | max |
|---|---|---|---|
| Radius of influence, $R_0$ (m) | 13.8 | 120.6 | 364.3 |

### Total ingress (groundwater + rainfall)

| | | |
|---|---|---|
| Groundwater inflow choice | most likely | ← select result from Theim calcs |
| Groundwater inflow (m3/day) | 557.7 | |
| Runoff catchment (m2) | 20778 | |

| | min | most likely | max |
|---|---|---|---|
| Fraction of rainfall forming runoff | 60% | 80% | 100% |
| Fraction of rainfall choice | max | ← select proportion from table above | |

| | Avg. rainfall per month (mm) | Runoff rate (m3/day) | Runoff rate (L/s) | Runoff + GW inflow (m3/day) | Runoff + GW inflow (L/s) |
|---|---|---|---|---|---|
| January | 53.50 | 35.9 | 0.42 | 593.5 | 6.87 |
| February | 38.80 | 28.8 | 0.33 | 586.5 | 6.79 |
| March | 34.90 | 23.4 | 0.27 | 581.1 | 6.73 |
| April | 44.50 | 30.8 | 0.36 | 588.5 | 6.81 |
| May | 48.80 | 32.7 | 0.38 | 590.4 | 6.83 |
| June | 39.20 | 27.1 | 0.31 | 584.8 | 6.77 |
| July | 40.00 | 26.8 | 0.31 | 584.5 | 6.77 |
| August | 46.80 | 31.4 | 0.36 | 589.1 | 6.82 |
| September | 47.30 | 32.8 | 0.38 | 590.4 | 6.83 |
| October | 62.90 | 42.2 | 0.49 | 599.8 | 6.94 |
| November | 66.90 | 46.3 | 0.54 | 604.0 | 6.99 |
| December | 54.20 | 36.3 | 0.42 | 594.0 | 6.88 |
| Annual average | | 32.9 | 0.4 | 590.6 | 6.8 |
| Annual maximum | | 46.3 | 0.5 | 604.0 | 7.0 |

## EXPLANATION OF CELL COLOURS

| | |
|---|---|
| Yellow | Data entry |
| Green | Formulae |
| Blue | Select from list |

## EXPLANATION OF DUPUIT-FORCHEIMER FORMULA

Dupiut-Forcheimer is valid for unconfined flow (i.e. variable saturated thickness) CIRIA 2000: Eq 6.7.

This is called the Theim-Dupiut equation by the Environment Agency 2007: box 3.2.

$$Q = \pi k\left[\left(h_o^2 - h_w^2\right) / \ln\left(r_o / r_w\right)\right]$$

Where
Q = groundwater ingress rate (m3/d)
k = hydraulic conductivity (m/d)
h0 = sat'd thickness before drawdown (m)
hs = height of seepage face in workings (m)
hw = sat'd aquifer thickness after drawdown + hs (m)
rw = radius of working area (m)
r0 = rw + radius of influence (m)

Effective radius of the working area estimate is based on CIRIA 2000: equation 6.5

## EXPLANATION OF SICHARDT FORMULA

Cited as equation 6.8 in CIRIA 2000, and equation 3.4 by Cashman and Preene 2001.

$$r = Ch\sqrt{k}$$

Where
r = radius of influence (m)
C = constant
h = drawdown (m)
k = hydraulic conductivity (m/s)
rw = radius of working area (m)

## REFERENCES

Cashman and Preene, 2001. Groundwater Lowering in Construction: A Practical Guide. Spon Press. (Superseded by Cashman and Preene, 2020. Groundwater Lowering in Construction: A Practical Guide to Dewatering (3rd edition). CRC Press)

CIRIA, 2000. Groundwater control - design and practice. Report C515 (Superseded by CIRIA, 2007. Groundwater control - design and practice (second edition). Report C750.)

Environment Agency, 2007. Hydrogeological impact appraisal for dewatering abstractions. Science Report SC040020/SR1

## River-Aquifer Leakage

Inflow from the river was calculated using the equation based on reach transmisivity and aquifer properties, as defined by the Environment Agency (2007)

$$q = \frac{T\,(Z\ - h)}{L\ - (\frac{B}{2})}$$

q = Leakage to the aquifer from the channel
T = Transmisivity of channel bank
Z = Surface water elevation in channel
h = Elevation of water table
B = Width of channel

Environment Agency, 2007. Hydrogeological impact appraisal for dewatering abstractions. Science Report SC040020/SR1

## Groundwater Inflow

**Phase A**

| | |
|---|---|
| Radial groundwater inflow (m3/day) | 605.7 |
| Groundwater and Rainfall inflow (m3/day) | 647.8 |

**Phase 1**

| | |
|---|---|
| Radial groundwater inflow (m3/day) | 667 |
| Inflow from river (m3/day) | 129.8 |
| Inflow from Sand & Gravel (m3/day)* | 467.7 |
| Average Rainfall Runoff (m3 /day) | 55.7 |
| Inflow from S&G, river, and rainfall (m3/day) | 653.2 |

**Phase 2**

| | |
|---|---|
| Radial groundwater inflow (m3/day) | 559 |
| Inflow from river (m3/day) | 142.3 |
| Inflow from Sand & Gravel (m3/day)* | 254.6 |
| Average Rainfall Runoff (m3 /day) | 33.1 |
| Inflow from S&G, river, and rainfall (m3/day) | 430 |

**Phase 3**

| | |
|---|---|
| Radial groundwater inflow (m3/day) | 769 |
| Inflow from river (m3/day)[†] | - |
| Inflow from Sand & Gravel (m3/day)* | 571.1 |
| Average Rainfall Runoff (m3 /day) | 82.8 |
| Inflow from S&G, river, and rainfall (m3/day) | 653.9 |

**Phase 4**

| | |
|---|---|
| Radial groundwater inflow (m3/day) | 557.7 |
| Inflow from river (m3/day)[†] | - |
| Inflow from Sand & Gravel (m3/day)* | 97.7 |
| Average Rainfall Runoff (m3 /day) | 32.9 |
| Inflow from S&G, river, and rainfall (m3/day) | 130.6 |

*Inflow determined by reducing the calculated radial flow by the proportion of the perimited occupied by a river or backfilled phase (assumed to be no-flow) e.g. if an previous phase occupies 1/3 of the perimiter then the sand and gravel inflow would be assumed to be 2/3 of the radial flow value.

[†] No inflow from the river is assumed for these phases as the backfilling of the previous phases will reduce interaction with the river.