

APPENDIX 9.2

Earth Science Partnership

Consulting Engineers | Geologists | Environmental Scientists

**Cosmeston Farm, Penarth
Proposed Residential Development
Preliminary Controlled Water Risk Assessment
Addendum Report**

Report Reference: ESP.7061b.3215

This page is left intentionally blank

Earth Science Partnership

Consulting Engineers | Geologists | Environmental Scientists

33 Cardiff Road, Taff's Well, CARDIFF, CF15 7RB ☎ 029 2081 3385
✉ enquiries@earthsciencepartnership.com www.earthsciencepartnership.com

Cosmeston Farm, Penarth Proposed Residential Development Preliminary Controlled Water Risk Assessment Addendum Report

Prepared for:
Welsh Government
Cathays Park
Cardiff
CF10 3NQ



Llywodraeth Cymru
Welsh Government

Cambria Consulting
Cambria House
16-17a Plas St. Pol de Leon
Penarth Marina
Cardiff
CF64 1TR

CAMBRIA
Constructive Thinking

Austin · Smith : Lord
One Dunleavy Drive
Cardiff
CF11 0SN

Austin·Smith:Lord

Report Reference: **ESP.7061b.3215**

Revision	Status	Date	Written by	Written and checked by	Approved by
1	Draft	October 2019	M Elcock BEng (Hons) FGS	D Bettosi BSc MSc CGeol CSci FGS RoGEP Professional	Giles Sommerwill BSc (Hons) MSc CGeol CL:AIRE QP SiLC FGS RoGEP Specialist
Signature:					
Notes:	<ol style="list-style-type: none">The status of this report is not final and is issued for comment only; as such, it is subject to change therefore it should not be relied up on. For a checked and authorised version please contact the Earth Science Partnership.Once issued this document is Uncontrolled, for the latest version and/or to confirm you have authorisation to use it please contact the Earth Science Partnership at enquiries@earthsciencepartnership.com or by telephone at 029 2081 3385.This document has been optimised for double sided printing and therefore may produce some blank pages when printed single sided.				

Contents

1	Introduction	5
1.1	Background	5
1.2	Report Format	6
1.3	Limitations of Report	6
2	Site Location and Areas	7
3	Summary of Previous Investigation	8
4	Additional Geo-environmental Monitoring and Testing	9
4.1	Leachate Samples	9
4.2	Groundwater Samples	9
5	Updated Ground Model	11
5.1	Geology	11
5.2	Evidence of Contamination	11
5.2	Hydrogeology	12
6	Preliminary Controlled Water Risk Assessment	15
6.1	Level One and Two Assessment.....	15
6.2	Level Three Assessment.....	23
7	Conclusions and Recommendations	28
7.1	Summary of Background Information.....	28
7.2	Summary of Results.....	28
7.3	Contamination Ground Model.....	29
7.4	Recommendations.....	30
8	References	32

Figures

- Figure 1 – Site Zonation Plan
- Figure 2 – Measured Groundwater Levels and Flow
- Figure 3 – Visit 1 Exceedances
- Figure 4 – Visit 2 Exceedances

Appendix A Geo-environmental Laboratory Test Results - Leachate

Appendix B Geo-environmental Laboratory Test Results – Groundwater

Appendix C Extracts of RTC Worksheet

General Notes

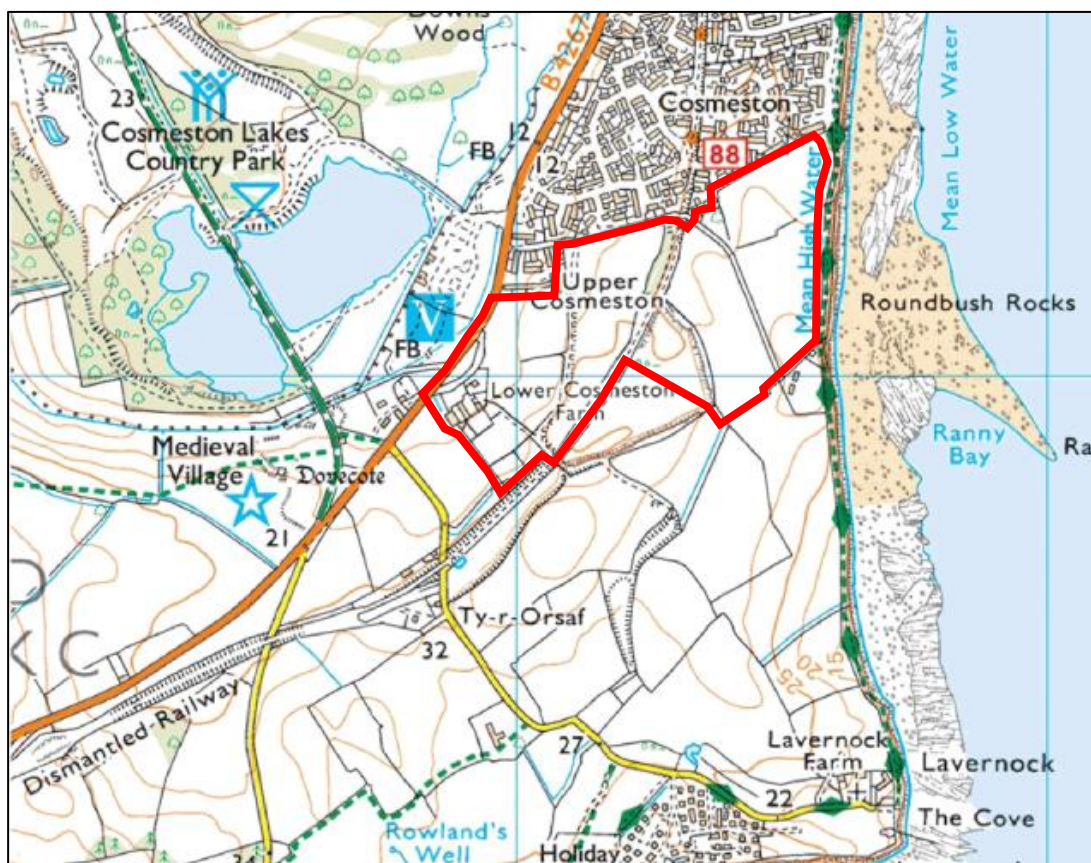
1 Introduction

1.1 Background

Further to our previous Geo-environmental and Geotechnical Assessment (ref. 7061b.3166 Rev 2) dated April 2019, we are pleased to present the results of our monitoring, assessment as per our revised proposal dated 26th November 2018 (Ref: 7061b.lt1).

The Welsh Government (hereafter known as the Client) are proposing to market the site for redevelopment, The Earth Science Partnership Ltd (ESP) were instructed on behalf of the Welsh Government via Austin-Smith:Lord and Cambria Consulting Ltd to undertake an integrated geotechnical and geo-environmental at the site, with the objective of the investigation, as provided by the Client, "To undertake a geo-environmental ground investigation and associated interpretive reporting to inform the masterplan and drainage strategy for the development of the site at Cosmeston Farm, Penarth for residential housing and a proposed primary school". The objectives and scope were altered on a number of occasions during discussions and meetings with the project team and details of this can be seen in our previous report.

This letter addendum report provides further assessment and recommendation in regard to a preliminary Controlled Waters Risk Assessment as part of the ongoing Master planning, and feasibility of development works for the site. The site location is shown on Insert 1.



Insert 1: Site Location Plan 1:25,000 (Ordnance Survey License No.: AL100015788).

1.2 Report Format

This report includes a brief summary of the site description and an overview of the different areas (Sections 2), a summary of the previous investigation (Section 3). Information on additional testing and monitoring is presented in Section 4 and updated Ground Model is presented using the new information in Section 6. The preliminary controlled water risk assessment is presented in Section 6 and recommendations and conclusions are provide as Section 7.

This report is issued as a digital version only.

1.3 Limitations of Report

This report represents the findings of the brief relating to the proposed end use and geotechnical category of structure(s) as detailed in Section 1.1 above. The brief did not require an assessment of the implications for any other end use or structures, nor is the report a comprehensive site characterisation and should not be construed as such. Should an alternative end use or structure be considered, the findings of the assessment should be re-examined relating to the new proposals.

Where preventative, ameliorative or remediation works are required, professional judgement will be used to make recommendations that satisfy the site-specific requirements in accordance with good practice guidance.

Consultation with regulatory authorities will be required with respect to proposed works as there may be overriding regional or policy requirements which demand additional work to be undertaken. It should be noted that both regulations and their interpretation by statutory authorities are continually changing.

This report represents the findings and opinions of experienced geo-environmental and geotechnical specialists. Earth Science Partnership does not provide legal advice and the advice of lawyers may also be required.

2 Site Location and Areas

The site is located within the boundaries of Lower Cosmeston Farm, Cosmeston, accessed from Lavernock Road (B4267) and entrance through the Livery Yard that occupies the west/south west portion of the site. Access to other areas is along trackways and through farm gates, once within the confines of the site boundary. Due to the overall size of the site and differing historical usages and geology, the site has been split into five areas which are discussed throughout our assessments and carried on in this letter report. These areas comprise the following and are shown on Enclosure 1:

- Area A – Comprising the West fields that make up the winter paddocks and fields associated with the livery;
- Area B – The historic former quarry/infilled land now used as summer paddocks;
- Area C – The historic former quarry and part of a former landfill;
- Area D – The North/North East fields that are currently used for crop growth.
- Area E - The “Old Quarry”. This area was not accessible during the investigation, due to ecological constraints.

A detailed description of these five areas and their boundaries can be read in our previous report (Ref. 7061b.3166 Rev 2 dated April 2019), and are shown on Figure 1.

3 Summary of Previous Investigation

As discussed above, the site has been split into five areas (see Section 2.0) which are discussed throughout this report, and shown in Figure 1. A brief summary of the history, ground conditions and hazards within the four areas that were accessible, are discussed below.

- **Area A**, comprises the west fields that make up the winter paddocks and fields associated with a livery business. The ground model here generally comprises topsoil over shallow bedrock, with limited to no Made Ground or contamination features identified. Soil contamination testing showed a single exceedance of naphthalene, compared to guidelines values for a residential, with plant uptake end use.
- **Area B**, a former and now infilled quarry. Here the ground model comprised up to 12m of reworked soils, with frequent occurrences of man made materials, such as brick, concrete and ash etc. Laboratory testing of soils indicated exceedances of some determinands, including arsenic, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene and naphthalene, compared to guidelines values for a residential, with plant uptake end use.
- **Area C**, comprises a former quarry and historic landfill. In this area, up to 7m of variable, domestic and commercial landfill waste has been identified, although it may be thicker in other areas. Laboratory testing of soil samples showed elevated concentrations of arsenic, benzo(a)pyrene, dibenzo(a,h)anthracene and several bands of aromatic hydrocarbons, EC 12 to EC35, compared to guidelines values for a residential, with plant uptake end use.

Although only a relatively limited number of exceedances were noted in samples tested, given the variability of the material, there is likely to other contaminants in the landfill that have not been measured.

- **Area D**, comprises the north/north-east fields which are predominantly used for crop growth. In this area, shallow bedrock was encountered, and no obvious sources of contamination were identified. Contamination testing of soils showed some elevated hydrocarbons in one of the samples tested, compared to guidelines values for a residential, with plant uptake end use.

4 Additional Geo-environmental Monitoring and Testing

Laboratory testing has been undertaken to identify the levels of selected contaminants within samples of leachate generated from shallow soils and groundwater on the site. The leachate samples were collected as part of the main investigation.

The geo-environmental analyses were carried out by a UKAS accredited testing laboratory with detection limits being generally compatible with the relevant guideline values adopted in the assessment.

4.1 Leachate Samples

In order to allow an assessment of the potential pollution risks to controlled waters, samples of leachate have been generated from six samples, three from Made Ground in Area B and three samples from the Landfill material in Area C. The leachate preparation was carried out in accordance with BS EN 12457, at a 10:1 eluate ratio.

The resulting leachate was analysed for the following determinants:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, copper, iron, lead, mercury, nickel, selenium, vanadium, zinc;
- Aluminium, antimony, cobalt, molybdenum manganese, silver, sodium, tin;
- US EPA 16 polycyclic aromatic hydrocarbon (PAH) compounds; and
- Total monohydric phenols, Cyanide.

The results of the leachate tests are presented in Appendix A.

Samples for leachate testing were not collected from Areas A and D given the lack of sources of contamination and limited number of soil exceedances measured in the soil testing.

4.2 Groundwater Samples

In order to establish the groundwater quality beneath the site, samples of groundwater were collected from the installed wells on 8th April 2019 (Visit 1), 26th April 2019 (Visit 2) and 19th August 2019 in general accordance with BS ISO 5667-11 (2009). Prior to sampling, the wells were purged by the removal of three well volumes where practical, to obtain a water sample representative of the groundwater in the vicinity. The third monitoring visit was carried out to obtain samples for dissolved iron only.

All groundwater samples taken for possible laboratory chemical analysis were collected in suitable clean containers provided by the testing laboratory for (e.g. clean polyethylene jars/bottles with fitted lids for routine soil testing, clear or amber glass bottles with screw on air-tight caps for organic contaminants, glass vials for volatile contaminants, etc.). Immediately after collection the samples were placed in sealed cool boxes with an ice pack where they remained during storage and transport to the laboratory.

In order to allow an assessment of the potential pollution risks to controlled waters, samples of groundwater recovered were analysed for the following determinands:

- Arsenic, barium, beryllium, boron, cadmium, total chromium, copper, iron, lead, mercury, nickel, selenium, vanadium, zinc;
- Aluminium, antimony, cobalt, molybdenum manganese, silver, sodium, tin;

- US EPA 16 polyaromatic hydrocarbon (PAH) compounds;
- Total monohydric phenols, Cyanide; and
- Petroleum hydrocarbons (CWG ali/aro carbon banded C₅ to C₃₅).

The results are presented in Appendices B1 (Visit 1), B2 (Visit 2) and B3 (Visit 3).

5 Updated Ground Model

5.1 Geology

As discussed in Section 3, our previous investigation showed a variable ground model for the different areas of the site.

- Areas A and D generally comprised a cover of topsoil over weathered rock.
- General Made Ground has been encountered in Area B to depths of 5.5m to 9m, comprising a generally gravelly, cobbly clay with cobbles consisting of Mudstone and Limestone. Some fragments of clinker, ash, coal and slag were noted.
- In Area C, markedly different ground conditions were encountered and comprised a highly variable landfill/refuse deposit. The material was primarily noted to comprise domestic and/or commercial refuse type materials and obviously “landfill”.

The ground conditions and typical depths encountered are summarised in Table 1 below.

Table 1: Summary of Ground Conditions Encountered

Strata	Area A (Fields)	Area B (Infilled Quarry)	Area C (Landfill)	Area D (Fields)
Topsoil	0.2 – 0.3m	(Placed Topsoil) 0.25m	(Placed Topsoil) 0.2m	0.2 – 0.45m
Made Ground	n/a	5.5 – 9m	0.5m	n/a
Landfill	n/a	n/a	7m	n/a
Bedrock (St Marys Well Bay)	From 0.3m	From 5.5 to 9m	From around 7m	From 0.5m
Bedrock (Probable Penarth Group)	n/a	n/a	n/a	From 0.5m

5.2 Evidence of Contamination

The former landfill, Area C was visually noted to contain a wide mixture of man made materials and is likely to be the main source of contamination at the site with regards to controlled waters. Whilst some evidence of ash, clinker, coal and slag were noted in soil within Area B, the quantities were relatively insignificant to those in Area C. It is therefore considered that the main source of contamination is Area C and for the purposes of this assessment was have assumed the entire extents of Area C is landfill materials and the source of contamination.

Anecdotal evidence from the tenant has suggested that burnt animal carcasses (associated with the foot and mouth outbreak) are present in the southern portion of Area B. No investigation was carried out in this area to confirm this information.

Geo-environmental soil testing has shown exceedances in other areas of the site, however these are considered to be relatively isolated occurrence and not as a result of widespread contamination, as such, any impact on groundwater water quality from these isolated occurrences is likely to be minimal to negligible.

It should be noted that the site boundary line that forms the southern boundary of Area C crosses the landfill and as such our site only encompasses about one third of the former landfill. There may be areas in the other two thirds of the former landfill that have significant evidence of contamination that were not identified by this investigation and it is worth reiterating here that the site boundary is just an arbitrary line, and is not a physical line of different areas and as such contamination just off site will be able to pass into our site relatively freely. Thus, contaminants measured in groundwater may be emanating off site in the other parts of the landfill.

5.2 Hydrogeology

The results of the groundwater depths, recorded during monitoring are presented in Table 2 below.

Table 2: Summary of Groundwater Monitoring

Investigation Point (Ground level mOD)	Base of install		Visit 1 5 th April 19		Visit 2 26 th April 19		Visit 3 15 th and 16 th May 19		Comments
	Depth (m)	Level (mOD)	Depth (m)	Level (mOD)	Depth (m)	Level (mOD)	Depth (m)	Level (mOD)	
E-BH1 (14)	7.35	6.65	2.05	11.95	*	*	1.9	12.1	Area A
E-BH2 (13)	7.44	5.56	1.3	11.7	1.83	11.17	1.94	11.06	Area A
E-BH3 (13)	7.2	5.8	1.2	11.8	1.48	11.52	1.93	11.07	Area A
E-BH4 (17)	6.9	10.1	5.8	11.2	DRY	-	6.5	10.5	Area A
E-BH5 S (24)	7.28	16.72	DRY	-	DRY	-	DRY	-	Area B
E-BH5 D (24)	12.57	11.43	DRY	-	DRY	-	DRY	-	Area B
E-BH6 S (23)	4.34	18.66	DRY	-	DRY	-	DRY	-	Area B
E-BH6 D (23)	15.15	7.85	10.22	12.78	10.24	12.76	10.11	12.89	Area B
E-BH7 S (21)	5.68	15.02	DRY	-	DRY	-	DRY	-	Area B
E-BH7 D (21)	13.98	7.02	8.96	12.04	8.85	12.15	8.85	12.15	Area B
E-BH8 S (29)	6.2	22.8	4.8	24.2	5.07	23.93	5.36	23.64	Area C
E-BH8 D (29)	12	17	5.45	23.55	5.74	23.26	5.9	23.1	Area C
E-BH9 S (33)	6.63	26.37	6.42	26.58	DRY	DRY	6.4	26.6	Area C
E-BH9 D (33)	12.4	20.6	8.1	24.9	8.3	24.7	8.34	24.66	Area C
E-BH10 S (34)	7	27	5.59	28.41	5.31	28.69	5.3	28.7	Area C
E-BH10 D (34)	12.5	21.5	5.1	28.9	5.3	28.7	5.3	28.7	Area C
E-BH11 (30)	7	23	5.35	24.65	6.8	23.2	6.3	23.7	Area D
E-BH12 (34)	6.7	27.1	1.3	32.7	4.2	29.8	4.37	29.63	Area D
E-BH13 (32)	10.5	21.5	8.8	23.2	9.24	22.76	9.2	22.8	Area D

Notes:

1. S = shallow installation.
2. D = deep installation.
3. *Not able to access borehole on monitoring visit.
4. All levels approximate.
5. Groundwater sampling undertaken on Visit 1 and Visit 2 and a specific visit to obtain samples for further testing 19th August 2019.

5.2.1 Groundwater Bodies

5.2.1.1 Whole Area

The groundwater monitoring presented above indicates that groundwater is at its highest on all three occasions in E-BH12 circa (27mAOD to 33mAOD). The levels of groundwater are considered to be relatively consistent and have been plotted, as shown on Figure 2.

A review of the groundwater levels indicate groundwater to generally flow toward the west, from Area D through Area C and Area B to Area A where it is at its lowest, of around 11mOD. The groundwater monitoring suggests that a single continuous body of water has been measured below the site, variations in this body of water are discussed below.

The groundwater level in E-BH13 suggests that there may be a component of groundwater flow toward the east in Area D, toward the sea cliffs near the eastern boundary of the site. The anticipated 'watershed' of this flow is shown on Figure 2.

Boreholes drilled in Area B and C received dual installations, one shallow installation with a response zone within either the infilled soils or landfill materials, and a deeper response zone, below a seal to understand any variation in groundwater conditions within the underlying weathered rock or bedrock.

5.2.1.2 Area B

The monitoring of shallow installations within Area B has generally shown that there is no persistent groundwater body within the reworked material. Groundwater has been measured in the deeper monitoring installations and suggest that groundwater is below the depth of Made Ground in this area. No water was measured in any of the visits in E-BH5, groundwater may therefore be deeper in this area and a component of flow toward the south could be possible, however, no monitoring points allow this possibility to be understood.

This former quarry is likely to act as a sink, or drain for groundwater and no lining was identified in the boreholes. It would in parts perhaps contain isolated pockets of water, but the monitoring has shown water to not be held within it and it may therefore allow water to pass through it freely.

5.2.1.3 Area C

The monitoring within Area C has shown that the groundwater level in both the shallow and deep installations are at a similar level, suggesting that any water within the landfill materials are directly connected to the general groundwater in the area. For example, the groundwater level in E-BH10 on the second and third monitoring visits was the same for both visits and levels within E-BH8 are within 0.5m of each other. No clay or other type of lining was noted in the base of the landfill, groundwater would therefore be able to flow/pass through the base of the landfill unhindered into the underlying bedrock and evidence of this has been seen in the monitoring.

The investigation has not been able to ascertain the groundwater levels within the wider landfill area off site. It is reasonable to assume, based upon our findings, that the whole of the former landfill is unlined and any water (and contamination) within it, is directly connected to groundwater, as indicated by our monitoring.

The whole landfill in this instance will be acting as a 'bowl' or 'colander' as water will collect within it and form a preferential drainage pathway for water to flow into it, but it will also allow

groundwater to seep directly into the underlying strata. As such, it is possible that contaminants may be flowing out of the landfill in other areas, i.e. not just from Area C investigated but the wider landfill to the south of Area C.

Although we consider that the groundwater within the whole of the former landfill will form one body, there may be deeper or shallower areas within the landfill. As such, contaminants that lie at the base of aquifers, such as dense non-aqueous phase liquids (DNAPLs) may be present elsewhere in the landfill where there are deeper hollows/portions.

5.2.1.4 Groundwater linkage to Sully Brook

As discussed above, there is considered to be a continuous body of groundwater that flows toward the west, toward Sully Brook.

Online resources indicate that the ground level adjacent to Sully Brook is at approximately 12mOD, which is the same ground level in the western part of the site. Groundwater monitoring of boreholes in the western part of the site has shown levels of water at between 11mOD and 12mOD, i.e. near ground level.

A visual inspection of the water in Sully Brook showed that water was within about 1m from ground level, thus the groundwater level measured on site is similar to the level within Sully Brook. It is therefore reasonable to assume the stream is fed in part by groundwater and is effluent in form.

5.2.2 Hydraulic Gradient

Groundwater levels have been recorded as part of the ongoing monitoring and the results from all three visits have been reviewed individually. Hydraulic gradients of between 0.007 and 0.045 have been calculated for the site. The gradient of 0.045 has been found to be relatively consistent from east to west using levels in different boreholes across all three monitoring visits and this is thus likely to represent the 'steepest' hydraulic gradient for the site.

The levels within Area C have been considered separately, it is reasonable to assume that if the landfill were lined, and water was 'trapped' or confined within the landfill, the water level would be at a similar level in the three boreholes drilled in this area, similarly, there would be a noticeable difference in levels of the groundwater in the shallow installations, that have a response zone in the landfill materials, and the deeper wells, which have a response zone in the underlying bedrock. However, this has not been observed, the groundwater levels in the shallow and deeper standpipes are relatively similar and the levels show that groundwater is higher in the east of Area C than the west, and it is therefore connected to the wider groundwater body.

6 Preliminary Controlled Water Risk Assessment

6.1 Level One and Two Assessment

6.1.1 Methodology

The potential impact of contamination originating at the site on controlled waters in the area of the site (i.e. groundwater and surface water) has been initially evaluated in line with the Environment Agency guidance (Carey et al, 2006).

Levels of leachable contamination within the soil samples recovered at the site have been analysed, which represents a 'Level One' risk assessment (Carey et al, 2006). In addition, levels of contaminants within the groundwater beneath the site have also been analysed, which represents a 'Level Two' risk assessment (Carey et al, 2006).

6.1.2 Assessment Criteria

The results of the contamination testing have been compared to assessment criteria appropriate to the controlled water receptors in the area.

The Preliminary Risk Assessment (Section 3.1.5 in previous report) identified that the following controlled water receptors are potentially at risk from contamination originating at the site:

- The water quality in the Sully Brook, which is located some 40m west of the site; and
- The groundwater within the bedrock beneath the site classified as Secondary A and B Aquifers.
- The groundwater encountered within the shallow soils/weathered bedrock and bedrock beneath the site may be in hydraulic connection with the river water of Sully Brook.

Given the available information, we consider that the most vulnerable receptor with regards to leachable and mobile contamination would be the surface water within Sully Brook, and our assessment has concentrated on this receptor. However, for completeness, we have also extended the assessment to include the groundwater.

The monitoring of the groundwater levels, as discussed in Section 5.2.1, suggests that there is a component of groundwater flow toward the east, i.e. toward the coast. If contamination were to flow toward the east there would be additional theoretical receptors, however, the ground model suggest that this will not be realised and the watershed point is effectively protecting the coast. The component of groundwater flowing toward the east is likely to be small and contained within Area D. Thus, water in this area is effectively upgradient of the source of contamination (Area C) and contamination will not flow toward the east. The main flow of groundwater is toward the west as discussed above.

6.1.3 Assessment Rational

6.1.3.1 Surface Water Receptors

In order to assess the potential impact on the waters of the Sully Brook, the levels of contaminants have been compared to the Environmental Quality Standards (EQS) published within the Water Framework Directive Directions (WFD, 2015). For the purposes of this

assessment, the Annual Average (AA) or long term (mean) EQS have been adopted which represent the acceptable levels of a contaminant over an annual period. Given the most vulnerable receptor is considered an inland river, Sully Brook, the EQS published for fresh water have been adopted.

For cadmium, the EQS are dependent on the hardness of the receptor water body, we have used the most stringent EQS value.

For zinc the EQS is calculated from the Ambient Background Concentration (ABC) in the local river catchment (WFD, 2015). Given the site proximity to the coast, the site is considered to lie outside a traditional main river catchment area, therefore, for this assessment, the most stringent ABC of 1.4 µg/l has been used, which is likely to provide a conservative assessment.

6.1.3.2 Groundwater as a General Resource

In order to assess the potential risk to groundwater as a general resource beneath the site, we have adopted the 'concentrations of hazardous substances within groundwater below which the danger of deterioration of the groundwater quality is avoided' published by UK Technical Advisory Group (UKTAG) 2016 have been adopted as assessment criteria. These UKTAG concentrations have been calculated from thresholds designed to be protective of drinking water, so may be conservative in this instance. Therefore, an exceedance may not necessarily indicate an unacceptable risk.

6.1.3.3 Hazardous Substances

Some contaminants which can impact on controlled waters have been classed as hazardous substances (Joint agencies Groundwater Directive Advisory Group JAGDAG, 2019) and include arsenic, lead, mercury, and some of the polyaromatic and petroleum hydrocarbon compounds. Natural Resources Wales (NRW) require that the entry of hazardous substances into controlled waters is phased out, or at least any further entry should be minimised. The remaining contaminants are classed as non-hazardous.

6.1.3.4 Petroleum Hydrocarbons

There are currently no EU or UK guidelines for ethylbenzene and the World Health Organisation criteria (WHO, 2011) have been adopted for this compound. Similarly, with the exception of the BTEX compounds, there are no published assessment criteria for petroleum hydrocarbons within controlled waters. The Environment Agency/NRW have previously stipulated an assessment criteria of 10µg/l for all bands of petroleum hydrocarbons, and this has been used tentatively as the assessment criteria. However, it should be appreciated that this only represents a preliminary, broad-brush appraisal of the levels of contamination present and an exceedance does not necessarily define an unacceptable risk.

The actual assessment criteria adopted are shown in the following table(s), and further details on them can be found in the respective published documents.

6.1.3.5 Potable Groundwater

Although there are no groundwater receptors being considered as part of our assessment, the published Prescribed Concentration Values (PCV) of the Water Supply (Water Quality) Regulations

(WSR, 2016), which relate to the use of groundwater as a potable resource, have been shown in the below table as an indicator on the groundwater condition below the site in this regard.

Where no PCV is published, the 'concentrations of hazardous substances within groundwater below which the danger of deterioration of the groundwater quality is avoided' published by UKTAG (2016) have been shown. These UKTAG concentrations have been calculated from thresholds designed to be protective of drinking water.

6.1.4 Assessment of Leachate Test Results

The samples selected for leachate testing comprised Made Ground in Area B or Landfill materials from Area C.

The results of the leachate testing and their comparison to the relevant assessment criteria are presented in Table 3 below.

Table 3: Leachate Results – BASED UPON <50mg/l hardness

Compound	Range Recorded	EQS - AA	PCV ⁶	UKTAG ⁷	Exceedances
Metals and Semi-metals:					
Arsenic ¹	<1 - 1.6µg/l	50µg/l	-	5.0µg/l	None of 6
Boron ²	<20 - 69µg/l	-	1,000µg/l (PCV)	-	None of 6
Cadmium ^{1,10}	<0.08µg/l	<0.08µg/l	-	-	None of 6
Chromium ^{1,3}	<1µg/l	3.4µg/l	-	5.0µg/l	None of 6
Copper ^{2,6}	<1 - 4µg/l	1g/l	-	-	1 of 6 (EQS)
Lead ²	<1µg/l	1.2µg/l	-	5.0µg/l	None of 6
Iron ¹	39-620µg/l	1000µg/l	-	-	None of 6
Mercury ¹	<0.5µg/l	-	1µg/l (PCV)	0.5µg/l	None of 6
Nickel ²	<1 - 4.6µg/l	4µg/l	-	-	1 of 6 (EQS)
Selenium ²	<1µg/l	-	10µg/l (PCV)	-	None of 6
Zinc ⁹	<1 - 3.6µg/l	12.3µg/l	-	-	None of 6
Polyaromatic Hydrocarbon Compounds					
Anthracene ¹	<0.1µg/l	0.1µg/l	-	0.05µg/l	None of 6
Benzo[a]pyrene ¹	<0.1µg/l	0.00017µg/l	0.01µg/l (PCV)	0.005µg/l	None of 6*
BbF ⁴	<0.1µg/l	-	-	0.05µg/l	None of 6*
BghiP ⁴	<0.1µg/l	-	-	0.05µg/l	None of 6*
BkF ⁴	<0.1µg/l	-	-	0.05µg/l	None of 6*
IDP ⁴	<0.1µg/l	-	-	0.05µg/l	None of 6*
Sum BbF, BkF, BghiP & IDP	<0.4µg/l	-	0.1µg/l (PCV)	-	None of 6*
Naphthalene ²	<0.1µg/l	2.0µg/l	-	-	None of 6
Fluoranthene ³	<0.1µg/l	0.0063µg/l	-	-	None of 6*
Miscellaneous					
Cyanide ²	<50 - 70µg/l	1µg/l	50µg/l (PCV)	-	1 of 6 (EQS and PCV)*
Phenol ⁴	<30µg/l	7.7µg/l	-	-	None of 6*
pH	7.9- 9.1	-	6.5 - 9.5 (PCV)	-	None of 6
<p>Key:</p> <ol style="list-style-type: none"> Hazardous substance (JAGDAG, 2019). Non-hazardous substance (JAGDAG, 2019). All chromium present assumed to be chromium VI (conservative approach). All four PAH compounds classed as hazardous. Based on Sully Brook as main receptor. PCV – Prescribed Concentration Value, drinking water only – measured at consumers tap (WSR, 2016). UKTAG – UK TAG concentration below which the danger of deterioration in the groundwater quality is avoided. For hazardous substances only. Exceedances indicated in bold and red as shown. Zinc EQS based on worst case ambient background concentration. Cadmium EQS based on hardness of <40mg/l CaCO₃. Iron not classified by JAGDAG 2019 EQS-AA – Environmental Quality Standard (estuarine) - Annual Average. Test results presented in Appendix B. * indicates detection limit above guideline, however, no concentration recorded. <p>Key to PAH compounds: BbF: benzo[b]fluoranthene BghiP: benzo[ghi]perylene BkF: benzo[k]fluoranthene IDP: indeno[123-cd]pyrene</p>					

Three samples of leachates from Area B (infilled quarry) and Area C (Landfill) were tested and only in one location were exceedances noted, E-TP4, where exceedances of copper, nickel were above the EQS and cyanide is above the EQS and PCV.

6.1.5 Assessment of Groundwater Test Results

The groundwater beneath the site has been analysed on two occasions, with samples collected from installed wells on 8th April 2019 (Visit 1) and 26th April 2019 (Visit 2). The results are also presented in Appendix B.

6.1.5.1 Visit 1

During Visit 1, the 13no. installed wells, of which six have dual installs were all monitored, of the total 19no. standpipes, six were dry (all shallow). Thus 13 water samples recovered were analysed for the same range of contaminants as the leachate. The results of the groundwater testing on samples collected during Visit 1 and their comparison to the relevant assessment criteria are summarised in Table 4 overleaf.

Table 4: Groundwater Results, Visit 1

Compound	Range Recorded	EQS - AA	PCV	UKTAG ⁵	Exceedances
Metals and Semi-metals:					
Arsenic ⁴	0.33-4µg/l	50µg/l	-	5.0µg/l	None of 13
Boron ⁴	21-420µg/l	-	1,000µg/l (PCV)	-	None of 13
Cadmium ^{1,6}	<0.03- 0.12 µg/l	<0.08µg/l	-	-	2 over EQS BH6D, BH7D)
Chromium ^{4,5}	<0.25- 49 µg/l	3.4µg/l	-	5.0µg/l	1 over EQS and UKTAG (BH9D)
Copper ^{4,6}	<0.4- 8 µg/l	1µg/l	-	-	11 over EQS, none over TV
Lead ²	<0.09-1µg/l	1.2µg/l	-	5.0µg/l	None of 13
Mercury ¹	<0.01µg/l	-	1µg/l (PCV)	0.5µg/l	None of 13
Nickel ³	<1.1- 25 µg/l	4µg/l	-	-	4 over EQS (BH6D, BH7D, BH8S, BH9D)
Selenium ⁴	<0.25-6.6µg/l	-	10µg/l (PCV)	-	None of 13
Zinc ^{4,6}	<1.3- 650 µg/l	12.3µg/l	-	-	4 over EQS (BH6D, BH8D, BH9D, BH10D)
Polyaromatic Hydrocarbon Compounds					
Anthracene ¹	<0.01- 0.12 µg/l	0.1µg/l	-	0.05µg/l	1 over both EQS and UKTAG, BH8 S
Benzo[a]pyrene ¹	<0.01µg/l	0.00017µg/l	0.01µg/l (PCV)	0.005µg/l	None of 13*
BbF ¹	<0.01µg/l	-	-	0.05µg/l	None of 13
BghiP ¹	<0.01-0.01µg/l	-	-	0.05µg/l	None of 13
BkF ¹	<0.01µg/l	-	-	0.05µg/l	None of 13
IDP ¹	<0.01µg/l	-	-	0.05µg/l	None of 13
Sum BbF, BkF, BghiP & IDP	<0.04-0.04µg/l	-	0.1µg/l (PCV)	-	None of 13
Naphthalene ²	<0.05-0.14µg/l	2.0µg/l	-	-	None of 13
Fluoranthene ³	<0.01- 0.24 µg/l	0.0063µg/l	-	-	5 above EQS (BH2, BH3, BH8S&D, BH10D)
Petroleum Hydrocarbon Compounds					
Benzene ³	<1µg/l	10µg/l	-	0.05µg/l	None of 13
Toluene ⁴	<1µg/l	74µg/l	-	350µg/l	None of 13
Ethylbenzene ⁴	<1µg/l	-	300µg/l (WHO)	-	None of 13
TPH C ₅ -C ₁₀ ^{4, 9}	<0.6µg/l	-	10µg/l (EA)	-	None of 13
TPH C ₁₀ -C ₂₁ ^{4, 9}	<6µg/l	-	10µg/l (EA)	-	None of 13
TPH C ₂₁ -C ₃₅ ^{4, 9}	<22µg/l	-	10µg/l (EA)	-	None of 13*
Miscellaneous					
Cyanide ⁴	<40µg/l	1µg/l	50µg/l (PCV)	-	None of 13*
Phenol ⁴	<1.5-1.8µg/l	7.7µg/l	-	-	None of 13

Key:

1. Hazardous substance (JAGDAG, 2019).
2. Non-hazardous substance (JAGDAG, 2019).
3. All chromium present assumed to be chromium VI (conservative approach).
4. All four PAH compounds classed as hazardous.
5. Based on Sully Brook as main receptor.
6. PCV – Prescribed Concentration Value, drinking water only – measured at consumers tap (WSR, 2016).
7. UKTAG – UK TAG concentration below which the danger of deterioration in the groundwater quality is avoided. For hazardous substances only.
8. Exceedances indicated in bold and red as shown.
9. Zinc EQS based on worst case ambient background concentration.
10. Cadmium EQS based on hardness of <40mg/l CaCO₃.
11. EQS-AA – Environmental Quality Standard (estuarine) - Annual Average.
12. Test results presented in Appendix B.
13. * indicates detection limit above guideline, however, no concentration recorded.

Key to PAH compounds:

BbF: benzo[b]fluoranthene
BghiP: benzo[ghi]perylene

BkF: benzo[k]fluoranthene
IDP: indeno[123-cd]pyrene

The groundwater results show levels of dissolved copper above its EQS in all areas across much of the site. There appears to be no obvious trend to the copper concentrations.

Metals including nickel, cadmium, zinc and chromium are elevated in samples taken from Areas B and C, and generally appear to be higher in Area C. These metals are not noted in any other water samples taken from Area A or D in Visit 1.

Elevated concentrations (against EQS) of Fluoranthene were as noted in Area C, with it being noted in EBH-8 and EBH-10; the highest value was noted in EBH-8. The concentration in EBH-10 was lower and it was also elevated in two boreholes in Area A, EBH2 and EBH3.

Anthracene was also elevated (EQS and UKTAG) in EBH-8, but not elevated elsewhere.

Figure 3 shows the distribution of exceedances across the site.

6.1.5.2 Visit 2

During Visit 2, the 13 installed wells, of which six have double installs were all monitored, of the total 19 standpipes, 8 were dry. Thus 11 water samples were recovered and analysed for the same range of contaminants as the leachate. The results of the groundwater testing on samples collected during Visit 2 and their comparison to the relevant assessment criteria are summarised in Table 5 overleaf.

Table 5: Groundwater Results, Visit 2

Compound	Range Recorded	EQS - AA	PCV	UKTAG	Exceedances
Metals and Semi-metals:					
Arsenic ⁴	0.31- 5.4 µg/l	50µg/l		5.0µg/l	1 over UKTAG (BH9D)
Boron ⁴	41-460µg/l	-	1,000µg/l (PCV)	-	None of 11
Cadmium ^{1,6}	<0.03- 0.15 µg/l	<0.08µg/l		-	2 over EQS BH7D, BH10D)
Chromium ^{4,5}	<0.25- 3.9 µg/l	3.4µg/l		5.0µg/l	1 over EQS (BH6D)
Copper ^{4,6}	<0.4- 4.8 µg/l	1µg/l		-	7 over EQS
Lead ²	<0.09µg/l	1.2µg/l		5.0µg/l	None of 11
Mercury ¹	<0.01µg/l	0.05µg/l	1µg/l (PCV)	0.5µg/l	None of 11
Nickel ³	<1.1- 29 µg/l	4µg/l		-	4 over EQS (BH6D, BH7D, BH8S&D, BH9D)
Selenium ⁴	<0.25-0.63µg/l	-	10µg/l (PCV)	-	None of 11
Zinc ^{4,6}	<1.3- 46 µg/l	12.3µg/l		-	3 over EQS (BH8D, BH9D, BH10D)
Polyaromatic Hydrocarbon Compounds					
Anthracene ¹	<0.01- 0.19 µg/l	0.1µg/l		0.05µg/l	1 over both EQS and UKTAG (BH8S)
Benzo[a]pyrene ¹	<0.01- 0.02 µg/l	0.00017µg/l	0.01µg/l (PCV)	0.005µg/l	1 over EQS, PCV and UKTAG (BH2)
BbF	<0.01-0.04µg/l	-		0.05µg/l	None of 11
BghiP	<0.01-0.03µg/l	-		0.05µg/l	None of 11
BkF	<0.01-0.01µg/l	-		0.05µg/l	None of 11
IDP	<0.01-0.03µg/l	-		0.05µg/l	None of 11
Sum BbF, BkF, BghiP & IDP	<0.04- 0.11 µg/l	-	0.1µg/l (PCV)	-	1 over PCV, BH2.
Naphthalene ²	<0.05-0.2µg/l	2.0µg/l		-	None of 11
Fluoranthene ³	<0.01- 0.31 µg/l	0.0063µg/l		-	6 above EQS (BH2, BH8S, BH8D, BH9D, BH10S, BH13)
Petroleum Hydrocarbon Compounds					
Benzene ³	<1µg/l	10µg/l		0.05µg/l	None of 11*
Toluene ⁴	<1µg/l	74µg/l		350µg/l	None of 11
Ethylbenzene ⁴	<1µg/l	-	300µg/l (WHO)	-	None of 11
TPH C ₅ -C ₁₀ ^{4,9}	<0.6µg/l	10µg/l (EA)	10µg/l (EA)	-	None of 11
TPH C ₁₀ -C ₂₁ ^{4,9}	<6µg/l	10µg/l (EA)	10µg/l (EA)	-	None of 11
TPH C ₂₁ -C ₃₅ ^{4,9}	<22µg/l	10µg/l (EA)	10µg/l (EA)	-	None of 11*
Miscellaneous					
Cyanide ⁴	<40µg/l	1µg/l	50µg/l (PCV)	-	None of 11*
Phenol ⁴	<1.5µg/l	7.7µg/l		-	None of 11

Key:	
1. Hazardous substance (JAGDAG, 2019).	
2. Non-hazardous substance (JAGDAG, 2019).	
3. All chromium present assumed to be chromium VI (conservative approach).	
4. All four PAH compounds classed as hazardous.	
5. Based on Sully Brook as main receptor.	
6. PCV – Prescribed Concentration Value, drinking water only – measured at consumers tap (WSR, 2016).	
7. UKTAG – UK TAG concentration below which the danger of deterioration in the groundwater quality is avoided. For hazardous substances only.	
8. Exceedances indicated in bold and red as shown.	
9. Zinc EQS based on worst case ambient background concentration.	
10. Cadmium EQS based on hardness of <40mg/l CaCO ₃ .	
11. EQS-AA – Environmental Quality Standard (estuarine) - Annual Average.	
12. Test results presented in Appendix B.	
13. * indicates detection limit above guideline, however, no concentration recorded.	
Key to PAH compounds:	
BbF: benzo[b]fluoranthene	BkF: benzo[k]fluoranthene
BghiP: benzo[ghi]perylene	IDP: indeno[123-cd]pyrene

Again, the groundwater results show levels of copper above its EQS across much of the site. The evidence for copper concentration to reduce in Areas A and D compared to B and C is less prominent in this round.

Metals such as cadmium, nickel, copper, zinc and chromium are elevated in Areas B and C only, the concentrations of such metals are generally higher in Area C. Arsenic is elevated (UKTAG) in Area C only.

Fluoranthene concentrations again appear higher in Area C, non was measured in Area B and low concentrations, although still exceedances, were measured in E-BH2 and E-BH3 as last time, in addition however, fluoranthene was also measured in E-BH13, in Area D.

Anthracene is elevated in Area C (EGS and UKTAG) only. Other polyaromatic hydrocarbons (PAH), such as benzo(a)pyrene is elevated (against EQS, PCV, UKTAG) in Area A, E-BH2, and Sum PAH is elevated (PCV) in E-BH2. Figure 4 shows the distribution of exceedances across the site.

6.1.5.3 Visit 3

A third visit was undertaken to obtain samples from all the installation to be tested for dissolved iron. The results of the testing is presented below.

Table 6: Groundwater Results, Visit 3

Compound	Range Recorded	EQS - AA	PCV	UKTAG	Exceedances
Metals and Semi-metals:					
Iron	65-920µg/l	1000µg/l	-	-	None of 8
Key:					
1. Hazardous substance (JAGDAG, 2019).					
2. QS-AA – Environmental Quality Standard (estuarine) - Annual Average.					
3. Test results presented in Appendix B.					

None of the samples tested for dissolved iron exceeded the EQS level of 1000µg/l.

6.2 Level Three Assessment

6.2.1 Methodology

The Level Two assessment in the previous section has identified a potential risk to groundwater beneath the site and water within Sully Brook from:

- Copper, Nickel, Zinc, Cadmium, Chromium, Arsenic;
- Anthracene, Benzo(a)pyrene, Fluoranthene, Sum PAH; and
- Cyanide.

The Level One and Two assessments assume that the receptor lies immediately adjacent to the site and do not allow for the attenuation of contaminants as they travel between the site and the main receptor of concern (Sully Brook), which is located some 40m from the site, but further from Areas B and C. A Level Three assessment of risks to controlled waters allows for this effect to be modelled from further information on the hydrogeology of the area.

The methodology adopted is as published by the Environment Agency guidance (Carey et al, 2006), and the data inputs used are discussed further in the following sections, before the results of the assessment presented in Section 6.2.4.

6.2.2 Assessment Criteria

The assessment criteria adopted in the Level Three assessment are the same as those used in the Level One/Two assessment.

6.2.3 Level Three Assessment Inputs

Elevated levels of some metals and polyaromatic hydrocarbons have been recorded on water samples collected from the site. In order to assess the impact of these measured levels within the context of the site environment, they have been subjected to a Remedial Target Assessment.

The framework detailed in the Environment Agency publication *Remedial Targets Methodology: Hydrogeological Risk Assessment for Land Contamination (RTM 2006)* has been used to determine Remedial Target Concentrations (RTCs) for the groundwater, against which the measured contaminant levels can be measured.

Section 2.4 of the RTM discusses the timescale of any remedial actions and essentially assess the sensitivity of the site area to potential impact from contamination. The four categories detailed range from a site within a *Source Protection Zone 1* (possible urgent remedial action required) to a site over unproductive strata with no nearby surface water receptors (action by remedial target assessment). The study-site setting approximates to the third scenario as there are no particularly sensitive aquifers (high vulnerability or Source Protection Zone II) or sensitive dependant ecosystem in close proximity of the site. The need for remedial action being determined by derivation of remedial targets is considered appropriate at this stage.

The anticipated primary source of the contamination at the site, Landfill (Area C) and infilled land (Area B) will remain, and their whole scale removal is not proposed. This risk assessment assumes that the landfill material and infilled land will not be removed and will remain, suggesting that the source of contamination will remain at the site (constant source term).

It is therefore considered appropriate to begin the derivation of RTCs at *Groundwater – Level 3*. Assuming the above, it is conservative to assume that the contaminant plume identified will be stable, however, given the time that has elapsed and finite amount of material within the landfill and made ground, it is possible that the plume may indeed be shrinking.

The Methodology provides a Microsoft Excel spreadsheet (Remedial Target Worksheet: Release 3.1 – October 2006) that performs the calculations for the derivation of RTCs. Relevant extracts of the sheets are presented within Appendix C.

In order to assess the sensitivity of the site within its environmental context, “Level 3” calculations have been undertaken for the site. This analysis allows for minor dispersion and sorption as the contaminated water moves off-site and can also calculate for contaminant decay, essentially allowing for a degree of *Attenuation*. The derived remedial target has then been compared with measured groundwater concentrations below the site.

For simplicity, a constant source term has been assumed and as no further contamination will occur, owing to the absence of a clearly defined remaining source, the measured levels will continue to breakdown naturally, which makes it a conservative assumption.

The preliminary sensitivity assessment was completed using measurements and realistic, justified assumptions, summarised in the table below. Where parameters were obtained using experience and judgement, to ensure accuracy further reference was made to a number of sources, predominantly from Technical References, CONSIM, Environment Agency guidance documents and other reference books listed in Section 9.0.

The site exists in a moderately sensitivity setting as Sully Brook is located some 40m west, or down gradient of the site. For sensitivity assessment purposes, Sully Book has been set as the compliance point. This location is considered robust as it is conservative, and therefore protective.

Table 7: Input Parameters for ‘Level 3’ Remedial Target Assessment

Parameter	Value	Source
Source Width	160m	Width of Area C for our site.
Saturated Aquifer Thickness	7m	Maximum measured thickness of Landfill material from our boreholes, water within this material.
Plume Thickness	3.5m	Assume half of the saturated aquifer to be contaminated.
Hydraulic Conductivity	3.3m/day	Obtained from a review of on site soakaway and permeability tests.
Hydraulic Gradient	0.045	Typical hydraulic gradient measured on site from measured groundwater levels, as shown on Figure 2.
Porosity	0.2	Typical value selected from CONSIM recommended parameters.
Bulk Density	2	Typical value selected from CONSIM recommended parameters.
Aquifer FOC	0.003	Typical value selected from CONSIM recommended parameters.
Dispersivities		Used calculated values within worksheet.

6.2.4 RTM 2006 'Level 3' – Contaminants in Groundwater

As discussed in previous sections, although the level of copper exceed its guidelines values, the distribution suggests that it may be naturally occurring and no assessment has been carried out for copper.

Table 8: Chemical Specific Factors for Elevated Contaminants

Contaminant	Half Life	Source and Comment
Nickel	9.99x10 ⁹⁹	Metal – no degradation
Zinc	9.99x10 ⁹⁹	Metal – no degradation
Cadmium	9.99x10 ⁹⁹	Metal - no degradation Remedial Targets Methodology
Chromium	9.99x10 ⁹⁹	Metal – no degradation
Anthracene	300	Based upon half life of Naphthalene EAP228/Koc:1288 – Consim)-assumption ¹
Benzo(a)pyrene	9.99x10 ⁹⁹	No degradation - Remedial Targets Methodology
Sum PAH	300	Based upon half life of Naphthalene EAP228/Koc:1288 – Consim)-assumption ¹
Fluoranthene	300	Based upon half life of Naphthalene EAP228/Koc:1288 – Consim)-assumption ¹
Notes: 1, Half life for polyaromatic hydrocarbons; anthracene, fluoranthene and Sum PAHs based upon known half life of naphthalene.		

The findings of the calculations are presented in the following table.

Table 9: Measured Levels against Level 3 RTCs – Compliance Point 40m – Sully Brook

Compound	RTC (mg/l)	Max Measured Level (mg/l)	Comment
Nickel	0.00934	0.029	Max concentration above RTC, Further consideration required
Zinc	0.028	0.65	Max concentration above RTC, Further consideration required
Cadmium	0.000187	0.00015	Max concentration below RTC
Chromium	0.00794	0.049	Max concentration above RTC, Further consideration required
Anthracene	RTC not generated by model due to anticipated degradation	0.00012	Anthracene expected to degrade prior to reaching compliance point.
Benzo(a)pyrene	0.000000397	0.00002	Max concentration above RTC, Further consideration required
Sum PAH	RTC not generated by model due to anticipated degradation	0.00011	Sum PAH expected to degrade prior to reaching compliance point.
Fluoranthene	RTC not generated by model due to anticipated degradation	0.00031	Fluoranthene expected to degrade prior to reaching compliance point.
Notes: RTC – Remedial Target Concentrations			

The RTCs derived show that nickel, zinc, chromium and benzo(a)pyrene present a theoretical risk to Sully Brook, whilst cadmium, anthracene, sum PAH and fluoranthene do not pose a risk to Sully Brook.

In order to assess the sensitivity of the key input parameters for which assumptions were required, a sensitivity analysis has been performed by running the model with alternative options, summarised on the table below.

Table 10: Sensitivity Analysis on Key Input Parameters – Compliance Point 40m – Sully Brook

Compound	Revised RTC			Max Measured Level (mg/l)
	Gradient doubled to 0.09 (no change)	Permeability doubled to 6.6m/d (no change)	Combined (no change)	
Nickel	0.00934 (no change)	0.00934 (no change)	0.00934 (no change)	0.029
Zinc	0.028 (no change)	0.028 (no impact)	0.028 (no change)	0.65
Cadmium	0.000187 (no change)	0.000187 (no change)	0.000187 (no change)	0.00015
Chromium	0.00794 (no change)	0.00794 (no change)	0.00794 (no change)	0.049
Anthracene	4.28x10 ²³³	2.28x10 ²³³	6.53x10 ¹⁶⁵	0.00012
Benzo(a)pyrene	0.000000397 (no change)	0.000000397 (no change)	0.000000397 (no change)	0.00002
Sum PAH	2.28x10 ²³³	4.28x10 ²³³	6.53x10 ¹⁶¹	0.00011
Fluoranthene	2.7x10 ²³²	2.78x10 ²³²	4.11x10 ¹⁶⁰	0.00031

The sensitivity analysis has shown that doubling the gradient, and permeability, has no impact on the remediation target concentrations for Nickel, Zinc, Cadmium, Chromium and benzo(a)pyrene. Remediation target concentrations for anthracene, sum PAH and fluoranthene are now calculable, however, they are in magnitudes far greater than concentrations measured on site.

6.3 Preliminary Lines of Evidence for Natural Attenuation

Natural Attenuation (NA) is the effect of naturally occurring processes that reduce the load, concentration, flux, or toxicity of polluting substances in groundwater. The Environment Agency document *Guidance on the Assessment and Monitoring of Natural Attenuation of Contaminants in Groundwater* (RD95 - 2000) has been used to describe “lines of evidence” that support the indication that Natural Attenuation of the organic compounds identified at the site is occurring.

6.2.5 Primary Lines of Evidence

Primary lines of evidence are based on a demonstration of the reduction of contaminant concentrations down-gradient of a source, or over time.

Groundwater sampling down gradient (in area A) from what is anticipated to be the main source of contamination Area C and to some extent Area B, has shown significantly lower levels of metals such that they decrease within the boundary of the site. Further monitoring would be required to confirm the consistency of the decline in levels. However, the Phase three modelling suggests that nickel, zinc and chromium would potentially represent a risk to Sully Brook and no elevated concentrations of these metals have been found in E-BH1, E-BH2 and BH-3. This is either because such concentrations are below detection limits or possibly because successful natural attenuation, in any case concentration recorded in Area B and C are not present in Area A, this is considered a primary line of evidence of natural attenuation.

7 Conclusions and Recommendations

7.1 Summary of Background Information

As discussed in Section 2.0, the site has been split into five areas which have different histories and site usages.

- **Area A**, comprises the west fields where the ground model comprises topsoil over shallow bedrock, with limited to no Made Ground or contamination. A single exceedance of naphthalene was measured in soil samples tested.
- **Area B**, a former and now infilled quarry where up to 12m of Made Ground was encountered. Laboratory testing of soils indicated exceedances of arsenic, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene and naphthalene.
- **Area C**, comprises approximately one third of a former quarry and historic landfill. In this area, up to 7m of variable, domestic and commercial landfill waste was identified. Laboratory testing of soil samples showed elevated concentrations of arsenic, benzo(a)pyrene, dibenzo(a,h)anthracene and several bands of aromatic hydrocarbons, EC12 to EC35.

The variability of this material suggests that there is likely to be other contaminants in the landfill that have not been measured. An important consideration is that only (approximately) one third of the landfill has been investigated, as the other two thirds are off site.

- **Area D**, comprises fields which generally have no made ground and shallow bedrock. Some elevated hydrocarbons were encountered in one of the samples tested, however, there is not considered to be a widespread source of contamination in this area.

7.2 Summary of Results

Three samples of leachates from Area B (infilled quarry) and Area C (Landfill) were tested and only in one location were exceedances noted, E-TP4, where exceedances of copper, nickel were above the EQS and cyanide is above the EQS and PCV.

Groundwater testing has shown levels of copper in all Areas (A to D) and these are considered to be natural or background concentrations. The levels of copper show no obvious decrease in concentration further from Areas B and C and they have been recorded up gradient of the anticipated source.

Visit 1 monitoring showed metals including nickel, cadmium, zinc and chromium to be elevated in samples taken from Areas B and C, and generally appear to be higher in Area C. These metals are not noted in any other water samples taken from Area A or D, in Visit 1. Visit 2 showed metals such as cadmium, nickel, copper, zinc and chromium to be elevated in Areas B and C only, the concentrations of such metals are generally higher in Area C. Arsenic is elevated (UKTAG) in Area C only.

Elevated concentrations (against EQS) of Fluoranthene were noted in Area C in both rounds of monitoring, where it was generally at its highest concentration. Fluoranthene was also noted in

two boreholes in Area A (EBH2 and EBH3) during both visits. Fluoranthene was also noted in E-BH13 in Area D on the second monitoring visit.

Anthracene was elevated (EQS and UKTAG) in Area C in both visits, but not elevated elsewhere.

Other polyaromatic hydrocarbons (PAH), such as benzo(a)pyrene is elevated (against EQS, PCV, UKTAG) in Area A, E-BH2, and Sum PAH is elevated (PCV) in E-BH2 during visit 2.

The groundwater testing showed that elevated concentrations of nickel, zinc, cadmium, chromium, benzo(a)pyrene, anthracene, fluoranthene and Sum PAH needed further consideration and a level 3 controlled groundwater risk assessment was undertaken to understand these risks better to the receptor for the assessment, water in Sully Brook.

The remedial target concentrations (RTCs) derived from the Level three assessment show that nickel, zinc, chromium and benzo(a)pyrene present a theoretical risk to Sully Brook, whilst cadmium, anthracene, fluoranthene and sum PAH do not pose a risk to Sully Brook.

The sensitivity analysis has shown that doubling the gradient, and permeability, has no impact on the remediation target concentrations for nickel, cadmium, zinc, chromium and benzo(a)pyrene. However, the sensitivity analysis did show the remedial target concentrations for anthracene, fluoranthene and sum PAH to alter, however, these were to very high concentrations which have not been measured in the investigation.

7.3 Contamination Ground Model

The investigation and contamination sampling has shown that the former landfill, which is in part covered by Area C of the site, is likely to be the main source of contamination at Cosmeston Farm; some contamination may also arise from Area B.

Groundwater monitoring has shown that water in the landfill (Area C) and underlying bedrock is at a similar level, suggesting it is in continuity with the nearby groundwater within the bedrock. The landfill was found to have no lining and water (with contamination loading) will therefore be able to pass from the landfill into the surrounding bedrock, and thus, the local groundwater body. As discussed in Section 5.2.1.3, the landfill will essentially act as a 'bowl', or 'colander' and if it is unlined, groundwater level within the landfill will be similar to that in the surrounding soils or rock.

Groundwater monitoring has shown that groundwater is expected to flow from the eastern parts of the site, through the landfill toward the western parts of the site, eventually on to Sully Brook, which is likely to be an effluent stream. Thus, contamination in the groundwater will flow toward the west, toward Sully Brook.

The groundwater table in the far eastern parts of the site is anticipated to fall toward the east, toward the sea cliffs and away from contamination sources.

Contamination testing within the groundwater has shown that samples collected from Area C are more elevated than those elsewhere on site, although a significant number of elevations are also encountered immediately down gradient, in Area B. The boreholes in Area A showed no measurable concentrations of metals previously elevated in Area B and C, such as nickel, zinc, chromium and arsenic.

Some polyaromatic hydrocarbons were measured in Area C, and in Area A too. Apart from fluoranthene which was measured in both Area A and C, benzo(a)pyrene and sum PAHs were noted only in Area A. We do not consider a source of these contaminants in Area A and are more

likely to be from a source in Area C or possibly Area B. The results suggests polyaromatic hydrocarbons within the groundwater potentially flowing toward the Sully Brook.

An unexplained elevated concentration of fluoranthene was encountered in E-BH13 in the far east of the site. It is possible that this has arisen due to sampling error, laboratory error, or perhaps due to some component of the groundwater flowing east, perhaps for a short period of time if not at a constant rate.

The level three assessment provided Remediation Target Concentrations for the contaminants that exceeded assessment criteria and show that nickel, zinc, chromium and benzo(a)pyrene present a theoretical risk to Sully Brook, whilst cadmium, anthracene, fluoranthene and sum polyaromatic hydrocarbons (PAH) do not pose a risk to Sully Brook.

Three boreholes, E-BH1, E-BH2 and E-BH3 are located along the western boundary of the site and are downgradient of Areas B and C and no exceedances of nickel, zinc or chromium were noted in these boreholes, possibly suggesting that the natural attenuation being realised at the site is higher than we have modelled.

Benzo(a)pyrene was measured in E-BH2 and may be entering Sully Brook. The concentration potentially entering Sully Brook is relatively low, and remediation, or costly removal of the source (Area C) is unlikely to be feasible or economically viable.

A large unknown in the Ground Model is the remainder of the off site landfill materials, it is possible that contamination off site, but within the landfill is impact the site and wider environs. It may be prudent to explore this further with additional investigation if considered warranted.

As discussed above, groundwater testing has shown levels of dissolved copper in all Areas (A to D) and is considered to be natural or representative of background concentrations. The levels of copper show no obvious decrease in concentration further from Areas B and C and they have been recorded up gradient of the anticipated source which suggests that they are naturally occurring.

7.4 Conclusions and Recommendations

The investigation and monitoring programme has enabled us to develop a confident ground model such that the risks posed to receptors is well understood, and essentially quantifiable.

Although the groundwater testing has shown slightly elevated levels of contaminants at the site, these have generally been observed to decrease down gradient such that risks to receptors are generally considered to be low. The concentrations of contaminants anticipated to be leaving site are at such a low levels, no current technology exists that could provide significant or meaningful betterment or treatment. The removal of the source, thought to be Area C and the wider landfill (off site) is unlikely to be economically viable for the development.

If further confidence on the above is required, then further monitoring could be carried out in due course, which could coincide with investigation of nearby land, including the landfill and the quarry (Area E).

Due care in construction and site clearance activities should be maintained throughout the development of the site and as more detailed investigations are carried out for separate parcels of land, this risk assessment should be reviewed and updated as necessary.

8 References








- ALLEN D J, BREWERTON L J, COLEBY L M, GIBBS B R, LEWIS M A, MacDONALD A M, WAGSTAFF S J and WILLIAMS A T. 1997. The Physical Properties of Major Aquifers in England & Wales. BGS Technical Report WD/97/34 - EA R&D Publication 8. BGS and Environment Agency.
- BRITISH STANDARDS INSTITUTION (BSI). 2011. Investigation of Potentially Contaminated Sites – Code of Practice. BS10175, HMSO, London.
- CAREY M A, FINNAMORE J R, MORREY M J and MARSLAND P A. 2000. Guidance on the Assessment and Monitoring of Natural Attenuation of Contaminants in Groundwater.
- CAREY M A, MARSLAND P A and SMITH J W N. 2006. Remedial Targets Methodology – Hydrogeological Risk Assessment for Land Contamination. Environment Agency.
- CONTAMINATED LAND: APPLICATIONS IN REAL ENVIRONMENTS (CL:AIRE). 2013. Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination. CL:AIRE Report SP1010.
- ENVIRONMENT AGENCY. 2001a. Benchmarking and Guidance on the Comparison of selected Groundwater Risk-Assessment Models. National Groundwater & Contaminated Land Centre Report NC/00/14.
- ENVIRONMENT AGENCY. 2001b. Guidance on Assigning Values to Uncertain Parameters in Subsurface Contaminant Fate and Transport Modelling. National Groundwater & Contaminated Land Centre Report NC/99/38/3.
- ENVIRONMENT AGENCY. 2001c. Guide to Good practice for the Development of Conceptual Models and the Selection and Application of Mathematical Models of Contaminant Transport Processes in the Subsurface. National Groundwater & Contaminated Land Centre Report NC/99/38/2.
- ENVIRONMENT AGENCY. 2002. The Effects of Contaminant Concentration on the Potential for Natural Attenuation. R&D Technical Report P2-228/TR.
- JONES H K, MORRIS B L, CHENEY C S, BREWERTON L J, MERRIN P D, LEWIS M A, MacDONALD A M, COLEBY L M, TALBOT J C, McKENZIE A A, BIRD M J, CUNNINGHAM J and ROBINSON V K. 2000. The Physical Properties of Minor Aquifers in England & Wales. BGS Technical Report WD/00/4 - EA R&D Publication 68. BGS and Environment Agency.
- SMITH J W N and CAREY M A. 2006. Remedial Targets Worksheet v3.1: User Manual. Hydrogeological Risk Assessment for Land Contamination. Environment Agency.
- EUROPEAN UNION. 2000. The Protection of Groundwater against Pollution and Deterioration. Directive 2000/60/EC of the European Parliament and of the Council. (Water Framework Directive)
- EUROPEAN UNION. 2006. The Protection of Groundwater against Pollution and Deterioration. Directive 2006/118/EC of the European Parliament and of the Council. (Groundwater Daughter Directive).
- EUROPEAN UNION. 2008. Environmental Quality Standards in the Field of Water Policy. Directive 2008/105/EC of the European Parliament and of the Council.
- UK TECHNICAL ADVISORY GROUP ON THE WATER FRAMEWORK DIRECTIVE (WFD UK TAG). 2012. Updated Recommendations on Environmental Standards, River Basin Management (2015-2021). SR3-2012, Draft.

WELSH GOVERNMENT. 2009a. The Groundwater (England and Wales) Regulations. Statutory Instrument No. 2902, 2009.

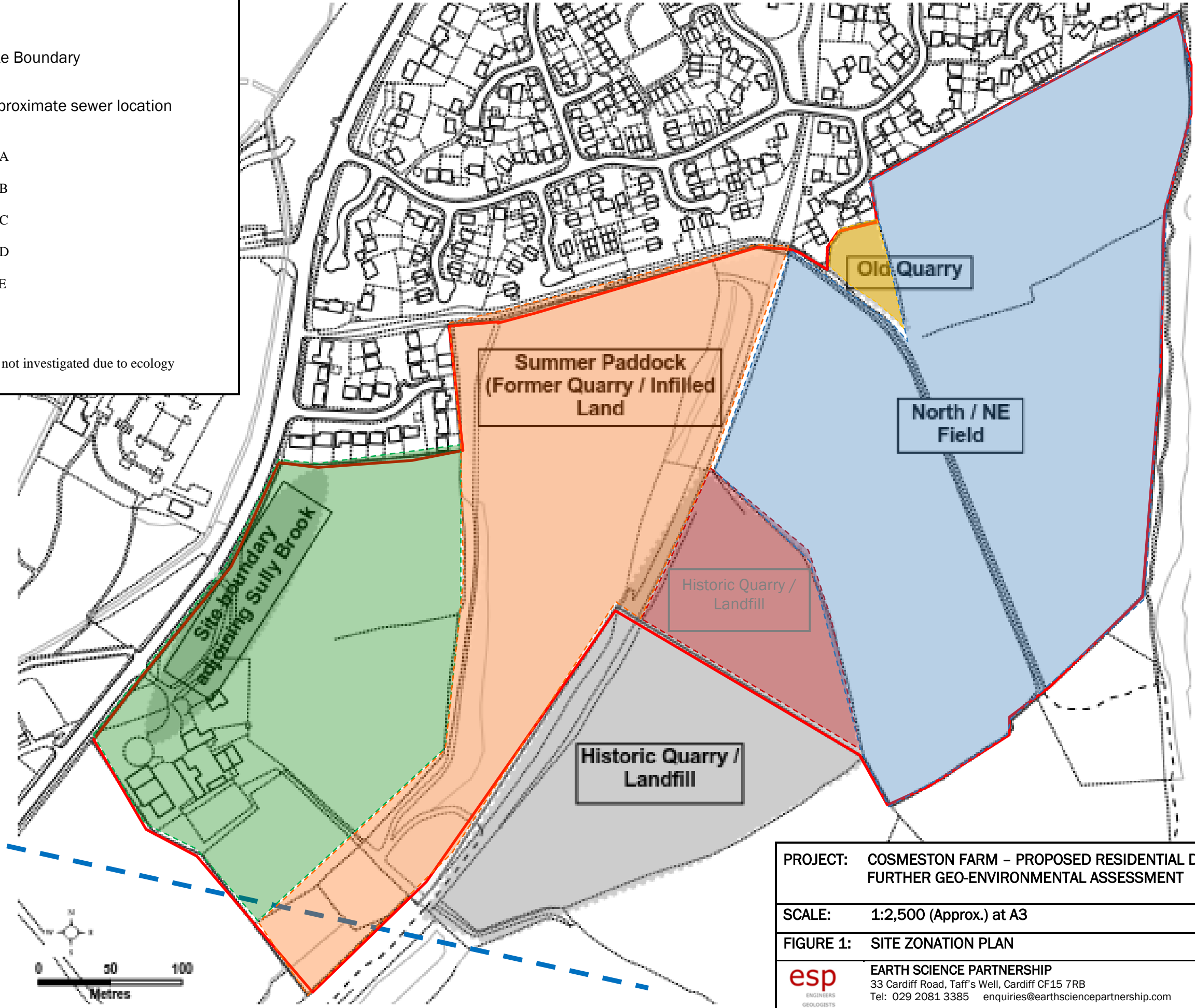
WELSH GOVERNMENT. 2009b. River Basin Districts Surface Water and Groundwater Classification (Water Framework Directive) (England and Wales) Direction 2009.

WELSH GOVERNMENT. 2010b. The River Basin Districts Typology, Standards and Groundwater Threshold Values (Water Framework Directive) (England and Wales) Directions 2010.

Key:

-  Site Boundary
-  Approximate sewer location
-  AREA A
-  AREA B
-  AREA C
-  AREA D
-  AREA E

Notes:
Old Quarry area not investigated due to ecology



PROJECT: COSMESTON FARM – PROPOSED RESIDENTIAL DEVELOPMENT
FURTHER GEO-ENVIRONMENTAL ASSESSMENT

SCALE: 1:2,500 (Approx.) at A3

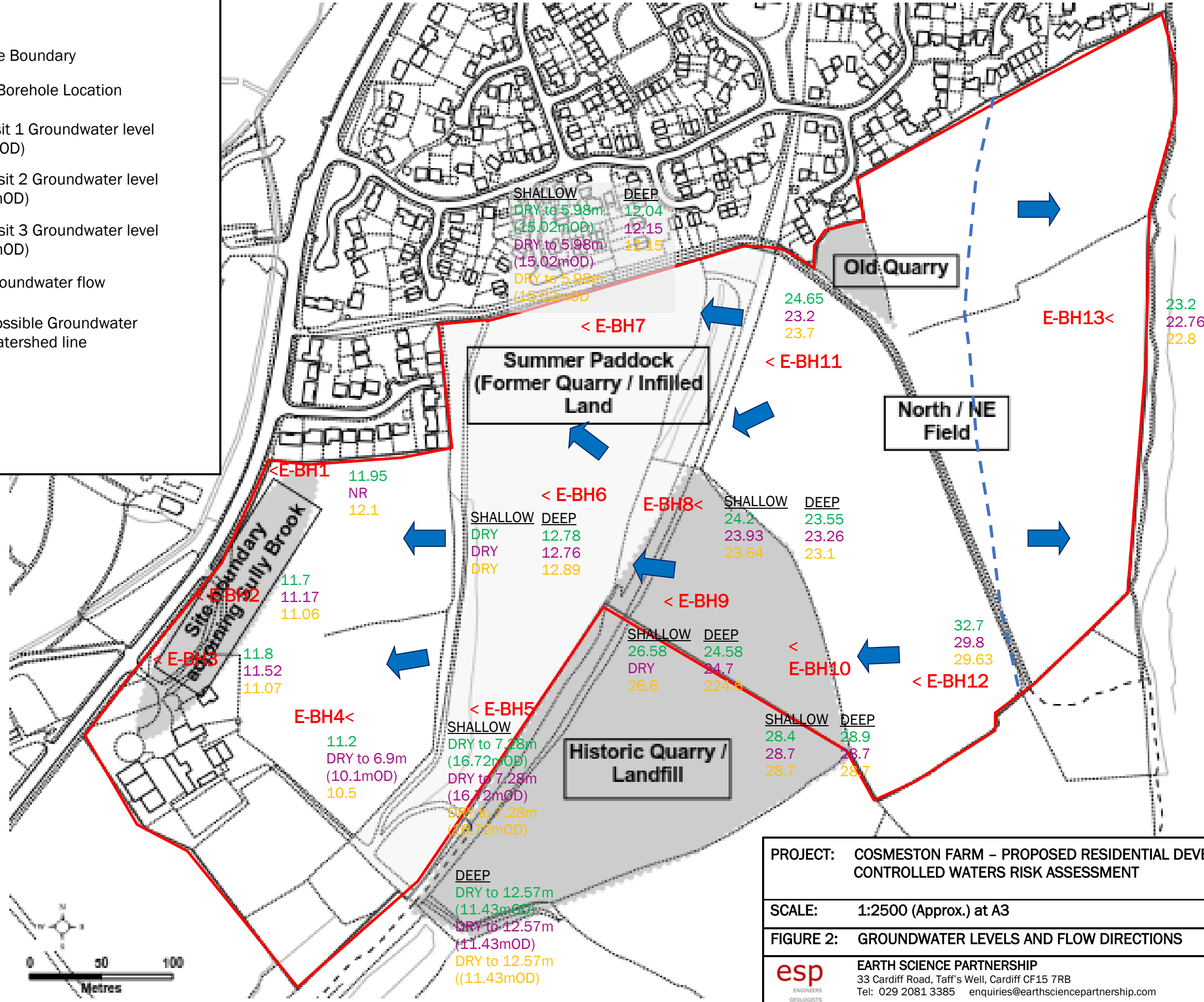
FIGURE 1: SITE ZONATION PLAN

esp
ENGINEERS
GEOLOGISTS
SCIENTISTS
EARTH SCIENCE PARTNERSHIP
33 Cardiff Road, Taff's Well, Cardiff CF15 7RB
Tel: 029 2081 3385 enquiries@earthsciencepartnership.com

Key:

- - Site Boundary
- < E-BH1 - ESP Borehole Location
- 15.5 - Visit 1 Groundwater level (mOD)
- 15.5 - Visit 2 Groundwater level (mOD)
- 15.5 - Visit 3 Groundwater level (mOD)
- ↓ - Groundwater flow
- - - - Possible Groundwater watershed line

Notes:

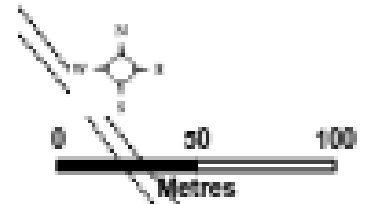


PROJECT: COSMESTON FARM – PROPOSED RESIDENTIAL DEVELOPMENT
CONTROLLED WATERS RISK ASSESSMENT

SCALE: 1:2500 (Approx.) at A3

FIGURE 2: GROUNDWATER LEVELS AND FLOW DIRECTIONS

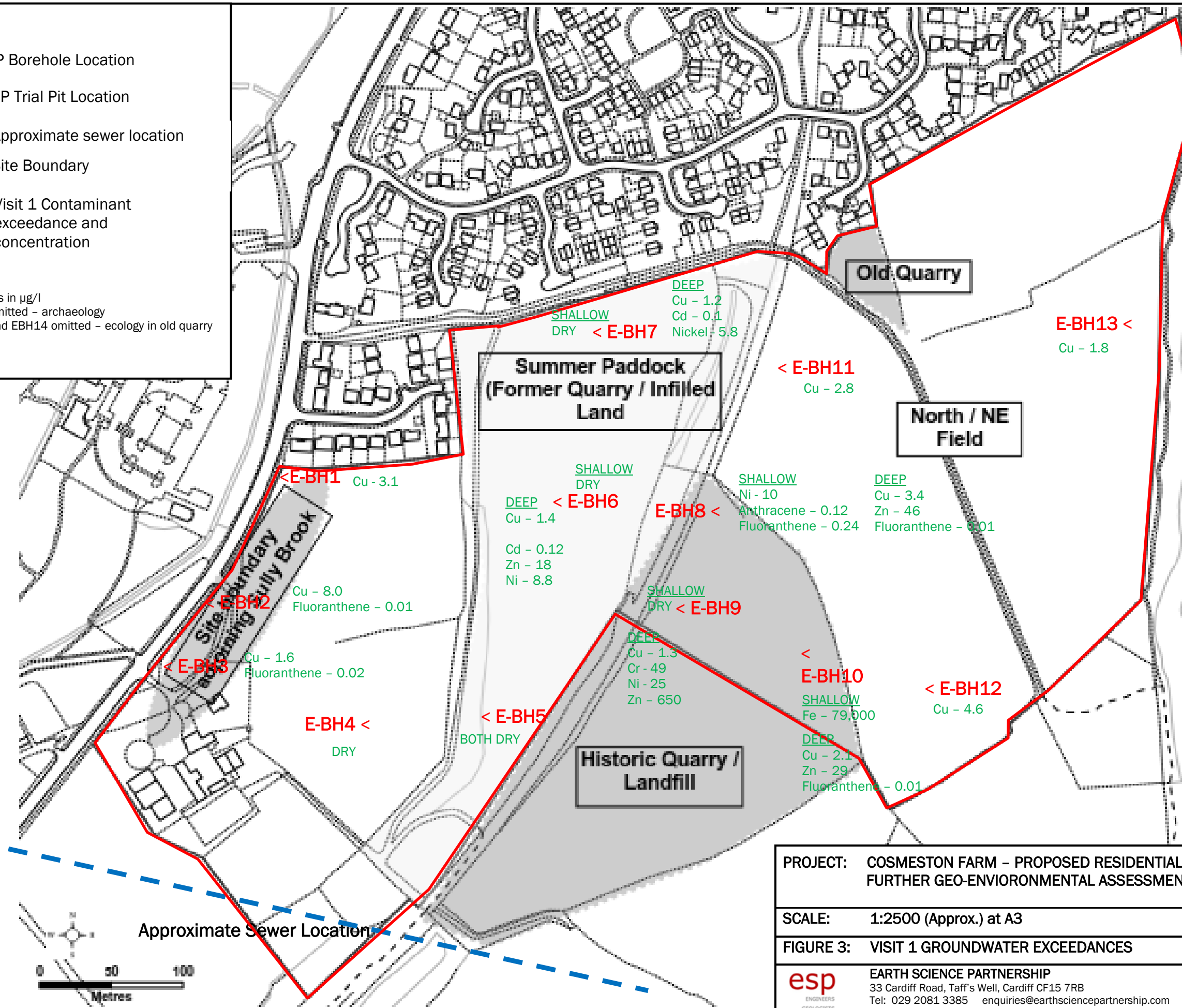
esp EARTH SCIENCE PARTNERSHIP
33 Cardiff Road, Taff's Well, Cardiff CF15 7RB
Tel: 029 2081 3385 enquiries@earthsciencepartnership.com



Key:

- < E-BH1 - ESP Borehole Location
- D E-TP1 - ESP Trial Pit Location
- - - - - Approximate sewer location
- - - - - Site Boundary
- DEEP
Cu - 1.4 - Visit 1 Contaminant exceedance and concentration

Notes:
 All concentrations in µg/l
 ETP14, ETP16 omitted - archaeology
 ETP27, ETP28 and EBH14 omitted - ecology in old quarry



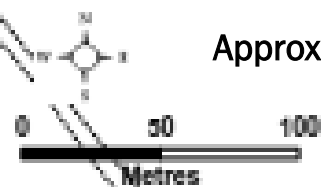
PROJECT: COSMESTON FARM – PROPOSED RESIDENTIAL DEVELOPMENT
 FURTHER GEO-ENVIRONMENTAL ASSESSMENT

SCALE: 1:2500 (Approx.) at A3

FIGURE 3: VISIT 1 GROUNDWATER EXCEEDANCES



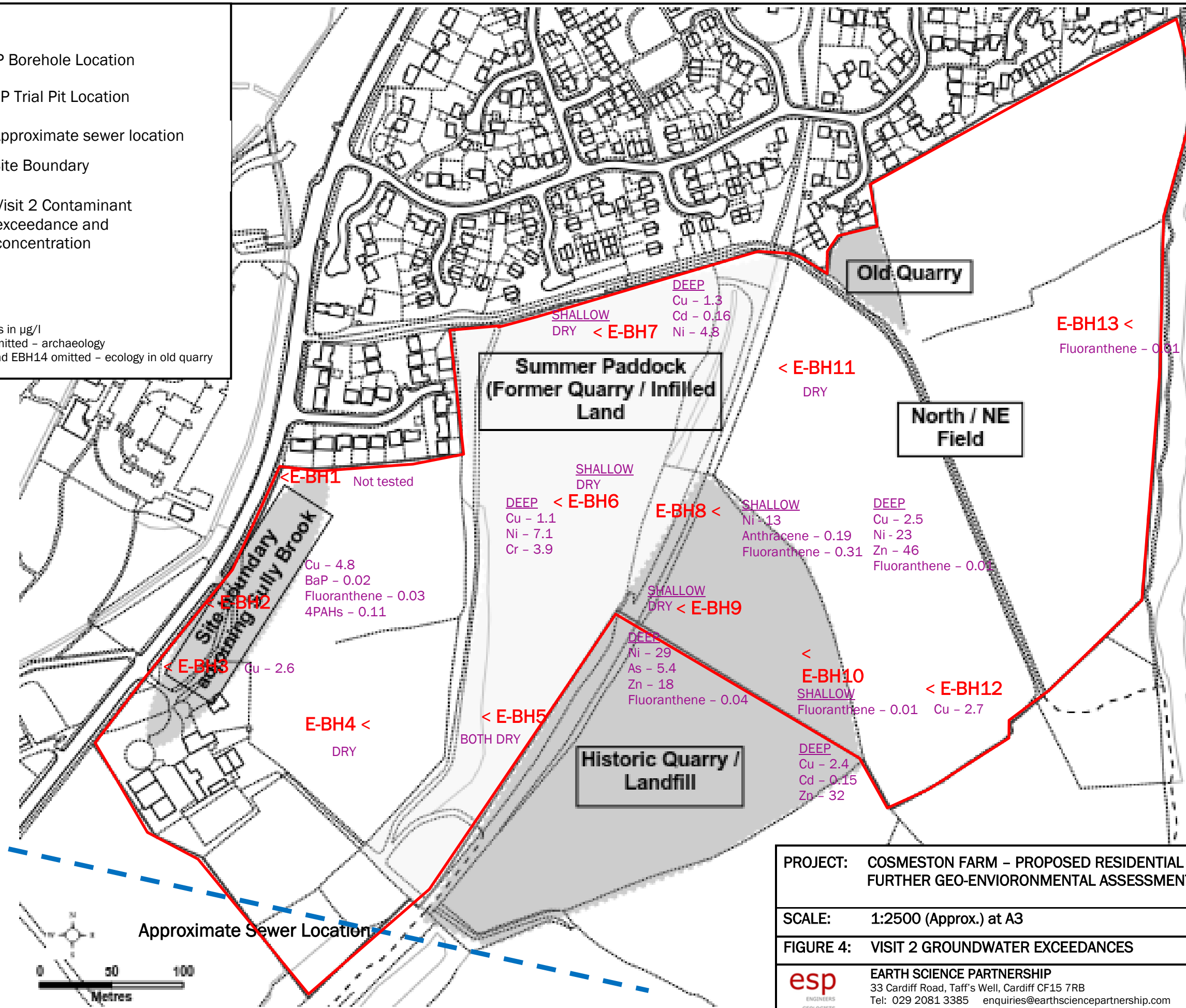
EARTH SCIENCE PARTNERSHIP
 33 Cardiff Road, Taff's Well, Cardiff CF15 7RB
 Tel: 029 2081 3385 enquiries@earthsciencepartnership.com



Key:

- < E-BH1 - ESP Borehole Location
- D E-TP1 - ESP Trial Pit Location
- - - - - Approximate sewer location
- - - - - Site Boundary
- Cu - 2.6 - Visit 2 Contaminant exceedance and concentration

Notes:
 All concentrations in µg/l
 ETP14, ETP16 omitted - archaeology
 ETP27, ETP28 and EBH14 omitted - ecology in old quarry



PROJECT: COSMESTON FARM - PROPOSED RESIDENTIAL DEVELOPMENT
 FURTHER GEO-ENVIRONMENTAL ASSESSMENT

SCALE: 1:2500 (Approx.) at A3

FIGURE 4: VISIT 2 GROUNDWATER EXCEEDANCES

esp
 ENGINEERS
 GEOLOGISTS
 SCIENTISTS
 EARTH SCIENCE PARTNERSHIP
 33 Cardiff Road, Taff's Well, Cardiff CF15 7RB
 Tel: 029 2081 3385 enquiries@earthsciencepartnership.com

