

wardell-armstrong.com

ENERGY AND CLIMATE CHANGE
ENVIRONMENT AND SUSTAINABILITY
INFRASTRUCTURE AND UTILITIES
LAND AND PROPERTY
MINING AND MINERAL PROCESSING
MINERAL ESTATES
WASTE RESOURCE MANAGEMENT



CHARLY45 LIMITED

FORMER GAS WORKS, GAS WORKS ROAD, READING

**DETAILED QUANTITATIVE RISK ASSESSMENT AND REMEDIATION STRATEGY
REPORT**

FEBRUARY 2018

your earth our world



DATE ISSUED: 23 February 2018
JOB NUMBER: LO10488
REPORT NUMBER: RPT003
VERSION: V0.1
STATUS: Final

CHARLY45 LIMITED

FORMER GAS WORKS, GAS WORKS ROAD, READING

DETAILED QUANTITATIVE RISK ASSESSMENT AND REMEDIATION STRATEGY REPORT

FEBRUARY 2018

PREPARED BY:

Emma Singleton Principal Engineering Geologist



Anna Saich Principal Geoscientist



REVIEWED BY:

Rob Reuter Associate Director



APPROVED BY:

Martin Hastie Technical Director



This report has been prepared by Wardell Armstrong LLP with all reasonable skill, care and diligence, within the terms of the Contract with the Client. The report is confidential to the Client and Wardell Armstrong LLP accepts no responsibility of whatever nature to third parties to whom this report may be made known. No part of this document may be reproduced without the prior written approval of Wardell Armstrong LLP.



Wardell Armstrong is the trading name of Wardell Armstrong LLP, Registered in England No. OC307138.

Registered office: Sir Henry Doulton House, Forge Lane, Etruria, Stoke-on-Trent, ST1 5BD, United Kingdom

UK Offices: Stoke-on-Trent, Birmingham, Cardiff, Carlisle, Edinburgh, Glasgow, Greater Manchester, Central Manchester
London, Newcastle upon Tyne, Sheffield, Truro. International Offices: Almaty, Moscow

ENERGY AND CLIMATE CHANGE
ENVIRONMENT AND SUSTAINABILITY
INFRASTRUCTURE AND UTILITIES
LAND AND PROPERTY
MINING AND MINERAL PROCESSING
MINERAL ESTATES
WASTE RESOURCE MANAGEMENT

CONTENTS

1	INTRODUCTION	1
2	BACKGROUND	5
3	CONCEPTUAL SITE MODEL	10
4	DETAILED QUANTITATIVE RISK ASSESSMENT – HUMAN HEALTH	13
5	DETAILED QUANTITATIVE RISK ASSESSMENT – CONTROLLED WATERS	22
6	GROUND GAS ASSESSMENT	28
7	DEVELOPMENT OF REMEDIATION STRATEGY	30
8	REMEDiation OPTIONS APPRAISAL	35
9	REMEDiation STRATEGY	44
10	REFERENCES	47

APPENDICES

Appendix 1	Planning Permission and Discharge of Conditions 5 and 9
Appendix 2	Human Health – SSAC
Appendix 3	Human Health – SSAC (Indoor and Outdoor Inhalation Pathways)
Appendix 4	Human Health – Wilson Modular Approach for Inhalation of Vapours in Indoor Air
Appendix 5	Human Health – SSAC (Outdoor Inhalation Pathways)
Appendix 6	Controlled Waters – DQRA Input Parameters
Appendix 7	Controlled Waters – Remedial Targets Worksheets
Appendix 8	Ground Gas Monitoring Results

1 INTRODUCTION

Instructions

- 1.1 This report is prepared in accordance with instructions from Dunthorne Parker Architects, on behalf of Charly45 Ltd. This follows a proposal dated 12 July 2017 by Wardell Armstrong LLP (WA).
- 1.2 The site is the Former Gas Works, Gas Works Road, Reading RG1 3EQ, and is located as shown on Figure 1. The site comprises approximately 0.07 hectares of land occupied by two disused buildings and a yard area and is bordered by residential buildings to the south and east, offices to the west and the main channel of the River Kennet to the north. There is a river wall along the northern boundary which separates the site from the river. There is another canalised branch of the River Kennet (referred to on historic plans as the Kennet and Avon Canal) approximately 60m to the south of the site. The site is located approximately 500m east of Reading town centre.

Figure 1: Aerial Image Showing Approximate Site Boundary



Reproduced from Landmark Information Group

Proposed Site Use

- 1.3 It is proposed to redevelop the site for residential use with gardens. The planning application (no. 160378) is for the creation of 20 residential units through the extension and conversion of the two existing buildings. The largest building, in the north along the river, will be extended to the west and upwards and will have flats on five levels. One flat is proposed to have a private garden. The ground floor level of the larger building (known as the River Kennet Building) will be reduced by up to 0.8m and the lowest level will now be used for cycle storage (not habitable dwellings). The smaller building, in the southwest of the site (known as Gas Works Road (GWR) Building), has an existing basement, although it will not be retained in the proposed development. The existing floors to both buildings have been removed and the proposed development includes beam and block floors with an underfloor void. A communal landscaped area is proposed between the two buildings. The single storey part of the largest building has been demolished as part of site clearance works. It is understood that no further demolition will be taking place.

Purpose of Report

- 1.4 This report provides a detailed quantitative risk assessment for soils and groundwater at the site. The report also proposes a remediation scheme for soil contamination at the site in order to satisfy planning condition 6 of the planning permission (no. 160378, Appendix 1). This report builds on the results of previous site investigations to enable assessment of the suitability of the site for residential development.
- 1.5 Remediation specification with details of the exact methods to be employed to remediate the soils and groundwater will be provided by specialist remediation contractor once the proposed remediation scheme has been agreed with the Local Authority.

Previous Reports

- 1.6 Atkins undertook desk study, site investigation and risk assessment work at the site on behalf of the former owners (National Grid Property). The following reports have been provided to WA for information:
- Factual Desk Study, Atkins, March 2010 (ref. Gas Works Road, Reading, Desk Study Factual Rev0). Referred to below as Atkins (2010a);
 - Environmental Investigation and Assessment, Final Factual Report, Atkins Ltd, October 2010 (ref. 5027279/GTG.20100598/Reading_2010/R002rev1) which

- includes details of a site investigation undertaken at the site in 2010. Referred to below as Atkins (2010b);
- Updated Controlled Waters Quantitative Risk Assessment, Atkins, May 2013. Referred to below as Atkins (2013);
 - Factual Desk Study, Final, Atkins Ltd, January 2014 (ref. GTG2000078/Reading/NGG Desk Study/R002v0). Referred to below as Atkins (2014).
- 1.7 Included as an appendix to the Atkins (2010a) report is a Factual Remediation Report by Waterman Environmental dated April 2001 (ref. R/EN997.HB.4.4.1; referred to below as Waterman, 2001) which describes remedial works undertaken at the site and the wider gas works.
- 1.8 WA prepared a Phase 1 Geo-Environmental Desk Study report dated August 2017 (ref. LO10488/RPT-001) and a Phase 2 Interpretative Site Investigation Report dated December 2017 (ref. LO10488/RPT-002) for the site. Section 2 of this report summarises the site history based on the Phase 1 Geo-Environmental Desk Study report. The geological, hydrogeological and hydrological setting of the site are also summarised in Section 2 with reference to the recent (2017) site investigation described in the Phase 2 Interpretative Site Investigation Report. However, the current report should be read in conjunction with the Phase 1 Geo-Environmental Desk Study Report and Phase 2 Interpretative Site Investigation Report.
- 1.9 Following receipt of the Phase 2 Interpretative Site Investigation Report, Reading Borough Council have confirmed that planning condition 5 (site investigation) and planning condition 9 (land gas) of the planning permission (no. 160378) are discharged (Appendix 1).

Limitations

- 1.10 This report has been prepared for the exclusive benefit of the Client for the purpose of providing geo-environmental recommendations for the site. The report contents shall only be used in that context. Furthermore, new information, changes in practice or new legislation may necessitate revised interpretation of the report after the date of its production.
- 1.11 Wardell Armstrong has used reasonable skill and care in the design of the site investigation work to comply with currently available industry guidance and to meet the requirements of the commission.

- 1.12 Whilst reasonable attempts have been made to identify the potential ground related constraints, it should be noted that the ground conditions encountered are representative only of the areas investigated at the time of investigation and may not be representative of the site as a whole. As part of the interpretation process reasonable inferences have been drawn between the investigation points, however, it should be recognised that ground and groundwater conditions can vary significantly both laterally and vertically over time due to changing conditions such as seasonal or climatic fluctuations etc. The potential for areas of loose/soft materials, contaminated materials and/or other potential problems cannot be completely discounted.
- 1.13 The positions of site investigation locations were restricted due to access, in ground obstructions, underground utilities and health and safety reasons. For example, boreholes that had been proposed to be undertaken within existing buildings could not be safely carried out due to the dilapidated condition of the structures and were therefore moved to external areas. A sixth proposed borehole (BH05) could not be undertaken in the east of the site due to access restrictions. Additionally trial pits were restricted to hand dug excavations due to access into the building and its dilapidated condition.

2 BACKGROUND

Site History

- 2.1 From the late 1800's the site formed part of larger gas works. Gas works buildings and equipment are recorded on historic maps in the north and west of site include pump room, boiler room, chimney, engine room and scrubbers. Tracks were shown to run across the middle of the site from west to east. Parts of workshop buildings and another chimney were located in the southwest corner of the site and part of a purifying house in northwest corner of the site. The larger gas works surrounded the site on the west, south and east sides (further details are provided in the Phase 1 Geo-Environmental Desk Study).
- 2.2 It is understood that part of the site, and larger areas of the wider gasworks, was remediated in 2000 by Waterman. Remedial works generally involved the excavation and offsite disposal of contaminated material (details are provided in Waterman, 2001). Records indicate that a total of 136 tonnes of contaminated material was excavated from the site and wider gas works and disposed of offsite. Treatment of groundwater was not undertaken as part of the remediation of the wider gasworks site, although groundwater that was pumped from excavations and from a below ground gasholder was removed from site during the works.
- 2.3 At the current site the extent of the remediation works in 2000 was restricted and two of the five validation samples collected reportedly recorded elevated concentrations of polycyclic aromatic hydrocarbon (PAHs) and ammonium. Both samples were from the base of the excavation.
- 2.4 Atkins (2013) report that some areas of the wider gasworks, specifically the area to the west of the site (the Prudential development), may have been redeveloped without the requirement for "*groundwater remediation or protection from the current site contamination*".

Geology

Made Ground

- 2.5 Made ground was present in all locations during the 2017 site investigation and ranged in thickness between 1.5m and 3.9m, with an average thickness of 2.15m. The full depth of made ground was not proved in all of the trial pit locations. The maximum

depth of made ground was encountered in BH01 in the northwest of the site, where it was present to 3.9mbgl. The made ground is generally described as soft to very soft dark grey/brown mottled black slightly sandy gravelly clay/slightly gravelly sandy silt with brick, concrete and rare flint, glass fragments and wood, and grey/brown sandy subangular and subrounded brick, sandstone and concrete coarse gravel/cobbles.

- 2.6 Where the made ground comprised a cohesive material (i.e. clay/silt) it was often described as being stained black and having a faint/strong hydrocarbon odour.
- 2.7 The description of the made ground encountered during the recent site investigation was similar to that encountered during the 2010 site investigation.

Superficial Deposits

- 2.8 Published geological mapping indicates that the site is underlain by natural superficial deposits comprising alluvium with a “basal gravel” which generally comprises sand and gravel. In the Kennet Valley the basal gravel is underlain by Quaternary River Terrace Deposits which are also described as sand and gravel. The site investigations undertaken at the site have not distinguished between the basal gravel and the River Terrace Deposits. The recent (2017) site investigation encountered alluvium in all boreholes at the site generally comprising clay and silt overlying sands and gravels. The clay and silt (shallow alluvium) ranged in thickness between 0m and 3.05m, with the average thickness being 1.7m. Clay and silt was absent under thick made ground at BH01 in the northwest of the site and was thickest in BH04B in the centre of the site (to 4.95m bgl). The clay and silt was generally described as soft to firm greenish grey mottled black silty clay/clayey silt with shell fragments and rare shells, gravelly/sandy in places. The clay and silt was noted to have a strong or faint hydrocarbon odour in all borehole locations and in some places was stained black.
- 2.9 The sand and gravel ranged in thickness between 2.20m and 3.95m thick, with the average thickness being 3.10m. The sands and gravels were generally described as medium dense to dense grey clayey sandy angular to rounded fine to coarse flint gravel, and medium dense to very dense grey slightly gravelly fine to coarse sand. The sands and gravels were noted to have a strong or faint hydrocarbon odour in all locations except BH04B. In BH03C a sheen and brown hydrocarbon staining was observed in the sand. The maximum depth of the sand and gravel was 7.8m bgl in BH04B in the centre of the site.

Bedrock Strata

- 2.10 Published mapping indicates the Seaford Chalk Formation and Newhaven Chalk Formation (undifferentiated) underlies the superficial deposits. Chalk was encountered underlying the sands and gravels of the alluvium in all borehole locations. The Chalk was described as structureless chalk composed of white/light brown slightly gravelly sandy silt. The minimum depth it was encountered was 6.1 bgl in BH01 and the maximum depth was at 7.8mbgl in BH04B. The full depth of the Chalk was not proven.

Hydrogeology

Superficial Aquifer

- 2.11 The Environment Agency classifies the superficial deposits (shallow alluvium and sand and gravel) as a Secondary A Aquifer. Secondary A aquifers are generally fractured or potentially fractured formations and do not have a high primary permeability. Although not producing large quantities of water for abstraction, they are important for local supplies and may supply base flow to rivers.
- 2.12 Four monitoring boreholes were installed within the alluvium during the 2017 site investigation. The boreholes are screened across both the shallow alluvium and the sand and gravel and record groundwater elevations between 35.97mAOD and 36.24mAOD (November 2017 to January 2018 monitoring rounds). Flow in the alluvium is to the north and east towards the main channel of the River Kennet which is adjacent to the northern boundary of the site. This direction is towards the River Kennet and also follows its downstream flow (towards the east), which suggests that the groundwater on site may potentially be in hydraulic continuity with the river. However, the river wall present along the northern boundary of the site may inhibit to a degree the continuity of groundwater at the site with the River Kennet.
- 2.13 Data from falling head tests undertaken in 2012 by Atkins indicated a variable hydraulic conductivity in the alluvium of between 1.0E-09 and 6.9E-09m/s, and in the made ground of 1.7E-09m/s.

Bedrock Aquifer

- 2.14 The Environment Agency classifies the solid strata (Chalk) as a Principal Aquifer and the site lies within Source Protection Zone (SPZ) III (Total Catchment) for a major public groundwater supply approximately 2km to the south of the site. Principal aquifers are highly permeable formations usually with a known or probable presence of significant fracturing. They are usually highly productive, strategic reserves able to support large abstractions, public water supply and river base flow.
- 2.15 At the site, one groundwater monitoring borehole has been installed within the Chalk and the December 2017 and January 2018 monitoring rounds recorded groundwater elevations between 35.86mAOD and 36.14mAOD. Hydrogeological mapping for the area indicates that groundwater flow in the Chalk in the Reading area is generally to the east (Institute of Geological Sciences, 1978) although it is influenced by the River Thames and groundwater abstractions.

Hydraulic Continuity

- 2.16 Borehole BH04B includes a dual installation with groundwater levels recorded in both the made ground and the alluvium (screened across both the shallow alluvium and the sand and gravel). Results from the recent groundwater monitoring (December 2017 and January 2018) at borehole BH04B suggest that the water in the made ground is likely to be perched.
- 2.17 Borehole BH06A includes a dual installation with groundwater levels recorded in both the alluvium (screened across both the shallow alluvium and the sand and gravel) and the Chalk. December 2017 and January 2018 monitoring results for borehole BH06A indicate that the groundwater levels in the alluvium are approximately 0.06 - 0.11m higher than the Chalk suggesting that the Chalk aquifer may not be in direct hydraulic continuity with the superficial aquifer.

Groundwater Abstractions

- 2.18 There are two active groundwater abstraction licences within 1km of the site. The closest is approximately 358m east of the site and is operated by M J Gleeson Group Plc which is licensed to abstract an undefined volume of groundwater per year for

pump and treat pollution remediation purposes. There is no information regarding the aquifer from which groundwater is abstracted; it could be from the shallow superficial aquifer or from the underlying Chalk. This abstraction is not considered to be a sensitive receptor in terms of the controlled waters assessment as it is used for remediation purposes.

- 2.19 The other groundwater abstraction is approximately 650m to the south of the site and is operated by Royal Berkshire Hospital. The licence is for 127,750m³ per year for drinking, cooking, sanitary and washing purposes. A BGS borehole (ref. SU77SW653) located at Royal Berkshire Hospital is recorded to be 83m deep and within the Chalk aquifer. This abstraction licence is therefore likely to relate to an abstraction from the Chalk.
- 2.20 The site lies within SPZ III for a major public groundwater supply approximately 2km to the south of the site. This supply is operated by the University of Reading and is licensed for the abstraction of groundwater from boreholes in the Chalk.

Hydrology

- 2.21 The nearest surface watercourse is the River Kennet, the main channel of which is adjacent to the northern boundary of the site. There is another canalised branch of the River Kennet (referred to on historic plans as the Kennet and Avon Canal) approximately 60m to the south of the site. The River Kennet flows to the east-northeast towards the River Thames, the confluence of the two rivers is approximately 800m downstream of the site.
- 2.22 There are two surface water abstraction licences within 1km of the site. The closest is approximately 750m north (NGR: 472072 174185) and is operated by The Reading Sustainability Centre, which is licensed to abstract an undefined amount of surface water per year for “other environmental improvements: transfer between sources” purposes. The abstraction is from the River Thames upstream of the confluence with the River Kennet. The other abstraction is from a lake/pond approximately 200m southwest of the site.

3 CONCEPTUAL SITE MODEL

- 3.1 Environment Agency guidance ('Model Procedures for the Management for Land Contamination – Contamination Land Report (CLR) 11) provides advice on the approach for the assessment of contamination on a site. This approach includes the production of a conceptual site model depicting the environmental processes that occur on and in the vicinity of the site and identifying the potential pollution linkages. The assessment of the significance of these pollution linkages can then be carried out through the risk assessment process.
- 3.2 The conceptual site model and the assessment of the associated risks is based upon the identification of the possible sources of contamination ("the sources"), the identification of who or what may be affected by the contaminants ("the receptors") and the possible pathways by which contaminants may migrate to one or more of the receptors ("the pathways").
- 3.3 The results from the WA site investigation and risk assessments have been used to assess the significance of these potential pollution linkages and identify the necessary remediation/risk management actions to be undertaken. The conceptual site model, as presented in the Phase 2 Interpretative Site Investigation Report, is shown in Table 1.

Table 1: Revised Conceptual Site Model			
Issue	Summary	Risk Category	
		Humans	Property/ Environment
Contamination Potential:			
Present site use	Disused former social club and governor house with yard area	Low	Moderate
Past site use	Gas works	High	High
Impact to site from past and present adjacent land uses	Past: surrounding gas works Present: offices, commercial, residential	High	High
Mining history	Historical shallow chalk/lime workings off site. No evidence on site.	Low	Low
Emissions, pollution incidents, discharges etc.	One revoked discharge consent 44m from site	Low	Low

Table 1: Revised Conceptual Site Model

Issue	Summary	Risk Category	
		Humans	Property/ Environment
Asbestos	Asbestos containing material (ACM) has tentatively been identified in the building. No ACM detected in made ground during site investigation but may still be encountered during site works.	Low/ Moderate	Low/ Moderate
Ground gas	Presence of made ground and organic materials in natural superficial deposits may give rise to ground gas	Moderate	Moderate
Waste management	No waste management facilities within 500m of the site	Low	Low
Past remediation	Contamination identified on site in the past and remediated on a statutory basis. Site may still be contaminated in terms of proposed residential use with gardens.	High	High
Environmental Sensitivity:			
Geology	Made ground overlying shallow alluvium (clay and silt) and sand and gravel which in turn overlies Chalk	n/a	n/a
Groundwater vulnerability	This site is situated on a Secondary A aquifer which overlies a Principal aquifer. The closest active groundwater abstraction licence is 358m east. Site is within a SPZ III for a public water supply 2km to south.	Moderate	High
Surface water vulnerability	The main channel of the River Kennet is adjacent to the northern boundary of the site. The nearest graded surface watercourse is a reach of the River Kennet, 284m north of site. The closest surface water abstraction licence is 750m north.	Low	Moderate
Geological constraints:			
Made ground / superficiales / solid geology	Made ground up to 3.9m proved at site (>5m recorded in 2010 investigation). Alluvium not indicated to contain peat layers.	Low	Low/ Moderate

Table 1: Revised Conceptual Site Model			
Issue	Summary	Risk Category	
		Humans	Property/ Environment
Mining setting	Historical shallow chalk/lime workings off site	Low	Low
Risks relating to other constraints (miscellaneous):			
Services	Pipework encountered during remediation in west of site. Pipework associated with governor building likely.	Low	Moderate
Flooding	Majority of site does not lie within a designated floodplain. The southern and northern edges of the site lie within Flood Zone 2 and 3 respectively. There is a very low chance of surface water flooding at the site. There is the potential for groundwater flooding to occur at the site.	Low	Low/ Moderate
Buried obstructions	Buried concrete encountered during remediation in west of site and during recent site investigation.	Low	Low/ Moderate
Unexploded ordnance	Site is within a low risk area for encountering unexploded ordnance.	Low	Low
Liability Issues:			
Risk of liability with past use of site.	Gas works	High	High
Risk of liability with current use of site	Disused former social club and governor house with yard area	Low	Low/ Moderate
Risk of liability for proposed use of site	Residential	Low	Low
Overall Risk for Site:	Moderate to High		

- 3.4 The Phase 2 Interpretative Site Investigation Report identified the need for detailed quantitative risk assessment (DQRA) for human health and controlled waters. The source-pathway-receptor pollution linkages for human health and controlled water receptors are described in more detail in Sections 4 and 5, respectively.

4 DETAILED QUANTITATIVE RISK ASSESSMENT – HUMAN HEALTH

Introduction

- 4.1 The Phase 2 Interpretative Site Investigation Report assessed the results of geochemical testing against published assessment criteria for residential land. The initial assessment identified Contaminants of Concern (COC) that exceeded the generic screening values and required further detailed quantitative risk assessment (DQRA) which are summarised in Table 2.

Table 2: Summary of Contaminants of Concern Identified in Soils		
Contaminant of Concern		Made ground
Chromium		✓
Lead		✓
Mercury		✓
TPHs	Aromatics EC10-EC12	✓
	Aromatics EC12-EC16	✓
	Aromatics EC16-EC21	✓
	Aromatics EC21-EC35	✓
Benzo(a)anthracene		✓
Benzo(a)pyrene		✓
Benzo(b)fluoranthene		✓
Benzo(k)fluoranthene		✓
Chrysene		✓
Dibenzo(ah)anthracene		✓
Fluoranthene		✓
Indeno(1,2,3-cd)pyrene		✓
Naphthalene		✓
Phenanthrene		✓
<i>Notes</i> ✓ Contaminant of concern identified from initial soils (human health) assessment at concentrations above generic screening criteria		

Conceptual Site Model – Human Health

- 4.2 The conceptual site model, in terms of human health is summarised in Table 3. The main receptors are future occupiers and site workers.

Table 3: Potential Pollutant Linkages for Human Health

Potential Pollutant Linkage (PPL)	Source	Pathway	Receptor
PPL HH1	Contaminated soils	Direct soil and indoor dust ingestion; skin contact with soils; consumption of homegrown produce; consumption of soil adhering to homegrown produce; and indoor dust and inhalation of indoor and outdoor dust and vapours	Future occupiers and site works
PPL HH2	Contaminated soils and organic materials in superficial deposits across the site (ground gas)	Gas migration	Future occupiers and site works

- 4.3 The following considers potential pollutant linkage PPL HH1. Section 6 (Ground Gas Assessment) considers pollutant linkage PPL HH2.
- 4.4 It is proposed to redevelop the site for residential use with at least one of the properties having access to a private garden. The planning application (no. 160378) is for the creation of 20 residential units through the extension and conversion of the two existing buildings (the former social club and governor house). The largest building will be extended to the west and upwards and will have flats on five levels. One flat is proposed to have a private garden. The ground floor level of the larger building will be reduced by up to 0.8m and the lowest level will now be used for cycle storage (not habitable dwellings). The smaller building has an existing basement, although it will not be retained in the proposed development and will be partially backfilled. A communal landscaped area is proposed between the two buildings. The single storey part of the larger building has been demolished as part of site clearance works. It is understood that no further demolition will be taking place.
- 4.5 Asbestos identification analysis undertaken on 22 samples taken from across the site did not record the presence of any asbestos containing material (ACM). Due to the nature of made ground encountered (demolition type material) and the historical uses of the site, the potential for asbestos to be present elsewhere on the site cannot be completely discounted. If unexpected or suspicious material is encountered during the redevelopment work, it is recommended that additional testing is undertaken.
- 4.6 It is understood that ACM has tentatively been identified in the fabric of the buildings that are to be retained on site. The management and / or potential risk of these materials (if present) is beyond the scope of this report which has only considered potential for asbestos fibres / ACM within the ground.

- 4.7 The assessment focuses on future occupiers of the site. During the construction works, there is a potential for site workers to come into contact with contaminated soils/waters. It will be necessary to adopt appropriate health and safety measures, including for the risks of gas in confined spaces, to mitigate the risks posed to construction workers. It is recommended that appropriate risk assessments are undertaken to identify safe working procedures and that these measures are included with the health and safety file and are passed to any future maintenance workers.
- 4.8 During the construction works, there is a potential for adjacent site users to be affected by contaminated dust. It will be necessary for the groundworks contractor to implement appropriate control measures to address this risk and these measures should be detailed in the Construction Environmental Management Plan to be produced by the contractors.

DQRA Methodology – Human Health

- 4.9 The Contaminated Land Exposure Assessment (CLEA) model v1.07 has been used to undertake DQRA to look at risk to human health through chronic exposure to potential contamination in soils. The CLEA model has been used in conjunction with alterations recommended by the Chartered Institute of Environmental Health/Land Quality Management (CIEH/LQM) Suitable for Use Levels (S4UL) publication to derive Site Specific Assessment Criteria (SSAC) for a residential end use.

Input Parameters

- 4.10 The critical receptor for a residential end use is a young female child and exposure duration is six years. As the proposed development includes a private garden consumption of homegrown produce and soil adhering to homegrown produce are considered as well as the following exposure pathways: direct soil and indoor dust ingestion; skin contact with soils; and indoor dust and inhalation of indoor and outdoor dust and vapours.
- 4.11 The buildings on site will be repurposed commercial buildings (a former governor house and social club). The former social club will be part four, five and six storeys and the former governor house will be three storeys, with each storey 2.7m high. The standard commercial “Office (pre-1970)” building type has been used to calculate the SSAC. The footprint of the buildings (approximately 250m² for the former social club and 100m² for the former governor house) is lower than the default value of 424m²

for the “Office (pre-1970)” building type so the assessment will be conservative in this regard. The default dust loading factor for the “Office (pre-1970)” building type ($100\mu\text{g}/\text{m}^3$) has been updated to reflect the residential end use, the recommended $50\mu\text{g}/\text{m}^3$ for residential end use has been used.

- 4.12 The made ground is generally described as being a matrix of slightly sandy gravelly clay or slightly gravelly sandy silt with brick, concrete and rare flint, glass fragments and wood, and brick, sandstone and concrete coarse gravel/cobbles. The superficial deposits underlying the made ground are clay and silt. Visual and olfactory evidence of hydrocarbon contamination was generally associated with cohesive material (i.e. clay/silt). The silty clay soil type has been used to calculate the SSAC.
- 4.13 Soil organic matter (SOM) results reported by Atkins (2010) were variable. During the 2017 site investigation three made ground and one alluvium sample identified as “clean” based on volatile organic compound (VOC) results were tested for Total Organic Carbon (TOC). Test results for TOC were converted to SOM and indicate an average SOM of 1.9% for the made ground materials.

Results

- 4.14 The results of this assessment are included in Appendix 2 and summarised in Table 4 together with the maximum concentration from the soil contamination testing results from the 2017 site investigation. Also included is the maximum concentration recorded from the combined 2017 and 2010 site investigation data. Where the maximum concentration exceeds a calculated SSAC it has been highlighted in bold for ease of reference. Either further DQRA or mitigation will be required where concentrations are above derived SSAC.

Table 4: Summary of SSAC and Soil Contamination Test Results					
Contaminant of Concern	Units	SSAC	Maximum Concentration (see Appendix 5 of Interpretative Site Investigation Report)		
			Made Ground (2017 data)	Made Ground (2010 and 2017 data)	Natural Materials (2017 data)
Chromium	mg/kg	6.05	22	24	17
Lead	mg/kg	200 ^a	330	1800	n/a ^b
Mercury	mg/kg	4.45	1.9	3	n/a ^b
Aromatics >EC10-EC12	mg/kg	156	180	180	350
Aromatics >EC12-EC16	mg/kg	272	600	600	1200
Aromatics >EC16-EC21	mg/kg	463	1,200	2,400	2600

Table 4: Summary of SSAC and Soil Contamination Test Results

Contaminant of Concern	Units	SSAC	Maximum Concentration (see Appendix 5 of Interpretative Site Investigation Report)		
			Made Ground (2017 data)	Made Ground (2010 and 2017 data)	Natural Materials (2017 data)
Aromatics >EC21-EC35	mg/kg	1,410	1,500	7,800	2900
Benzo(a)anthracene	mg/kg	11.4	180	180	190
Benzo(a)pyrene	mg/kg	2.64	90	90	70
Benzo(b)fluoranthene	mg/kg	3.18	140	260	140
Benzo(k)fluoranthene	mg/kg	90.0	140	150	130
Chrysene	mg/kg	20.6	140	150	130
Dibenzo(a,h)anthracene	mg/kg	0.28	24	24	13
Fluoranthene	mg/kg	483	340	490	460
Indeno(1,2,3-cd)pyrene	mg/kg	34.5	81	120	52
Naphthalene	mg/kg	58.8	150	150	490
Phenanthrene	mg/kg	181	300	300	680
Notes: a. Published C4SL for residential with home grown produce end use (CL:AIRE, 2014) b. No natural materials exceeded screening values so statistical analysis not undertaken.					

- 4.15 The results from the CLEA model indicate that the critical pathways (i.e. those pathways with the highest contributions to the total exposure) are dominated by direct ingestion and consumption of homegrown vegetables (Appendix 2). The critical pathways for lead are also direct ingestion and consumption of homegrown vegetables (CL:AIRE, 2014). Section 7 considers remediation options in detail. To support the options appraisal, further DQRA has been undertaken.
- 4.16 A clean cover pathway break, with imported clean soil used in all landscaped areas of the site and the single private garden, could be used to effectively sever the identified direct contact / ingestion and homegrown vegetables pathways. Details of the proposed clean cover pathway break are included in Section 7.
- 4.17 Additional SSAC have been produced for this clean cover scenario which consider the inhalation of vapours inside the proposed flats and outdoors only (referred to below as "SSAC (Indoor and Outdoor Inhalation Pathways)"). Placement of clean cover break will effectively sever the identified contamination linkages between future residents and non-volatile contamination (i.e. chromium and lead) and therefore SSAC have not been calculated for these COC.
- 4.18 The results of this assessment are included in Appendix 3 and summarised in Table 5 together with the maximum concentration from the soil contamination testing results from the 2017 site investigation. Also included is the maximum concentration from

the combined 2017 and 2010 site investigation data. Where the maximum concentration exceeds a calculated SSAC (Indoor and Outdoor Inhalation Pathways) it has been highlighted in bold for ease of reference. With the exception of naphthalene, the maximum concentration is below the calculated SSAC (Indoor and Outdoor Inhalation Pathways) for all COC. Therefore, this assessment demonstrates that provision of a suitable clean cover pathway break will effectively sever the identified pollutant linkage with all of the COC except naphthalene. Either additional mitigation of further DQRA will be necessary to address risk posed by naphthalene.

Table 5: Summary of SSAC for Indoor and Outdoor Inhalation Pathways and Soil Contamination Test Results

Contaminant of Concern	Units	SSAC (Indoor and Outdoor Inhalation Pathways)	Maximum Concentration (see Appendix 5 of Interpretative Site Investigation Report)		
			Made Ground (2017 data)	Made Ground (2010 and 2017 data)	Natural Materials (2017 data)
Chromium	mg/kg	n/a ^b	22	24	17
Lead	mg/kg	n/a ^b	330	1800	n/a ^a
Mercury	mg/kg	10.4	1.9	3	n/a ^a
Aromatics >EC10-EC12	mg/kg	11,400	180	180	350
Aromatics >EC12-EC16	mg/kg	82,500	600	600	1200
Aromatics >EC16-EC21	mg/kg	562,000	1200	2400	2600
Aromatics >EC21-EC35	mg/kg	26,600,000	1500	7800	2900
Benzo(a)anthracene	mg/kg	469	180	180	190
Benzo(a)pyrene	mg/kg	829	90	90	70
Benzo(b)fluoranthene	mg/kg	883	140	260	140
Benzo(k)fluoranthene	mg/kg	30,500	140	150	130
Chrysene	mg/kg	3,650	140	150	130
Dibenzo(a,h)anthracene	mg/kg	72.4	24	24	13
Fluoranthene	mg/kg	521,000	340	490	460
Indeno(1,2,3-cd)pyrene	mg/kg	8,910	81	120	52
Naphthalene	mg/kg	58.9	150	150	490
Phenanthrene	mg/kg	78,400	300	300	680
Notes:					
a. No natural materials exceeded screening values so statistical analysis not undertaken.					
b. Clean cover would effectively sever the pollutant linkages for chromium and lead.					

4.19 Naphthalene has been recorded at the site in excess of the calculated SSAC (Indoor and Outdoor Inhalation Pathways) with the critical pathway being indoor inhalation. Two samples exceed the calculated SSAC (Indoor and Outdoor Inhalation Pathways) of 59mg/kg:

- BH01 3.6-3.7mbgl (made ground) – 150mg/kg; and
- BH03C 3.5-3.6mbgl (natural sand and gravel) – 490mg/kg.

- 4.20 Further DQRA to assess the level of risk presented by the elevated levels of naphthalene identified at the site above the SSAC (Indoor and Outdoor Inhalation Pathways) calculated using the CLEA model has therefore been undertaken. The Johnson and Ettinger model used within the CLEA model is considered overly conservative for assessment of vapour intrusion into buildings where no basements will be constructed in the dwellings. The indoor inhalation and outdoor inhalation pathways have therefore been assessed separately.
- 4.21 Vapour flow from the ground into the building is modelled by Johnson and Ettinger through a pressure bearing slab and the retaining wall of the basement. Johnson and Ettinger use a pressure driven soil gas flow equation that models the effect of a basement constructed below ground level that is common in the United States. While this approach may yield a conservative estimate of vapour flow into a dwelling in many circumstances it is considered overly conservative for modelling situations where no basements will be constructed in the dwellings.
- 4.22 The ground floor level of the River Kennet Building will be reduced by up to 0.8m and the lowest level will now be used for cycle storage (not habitable dwellings). The GWR Building has an existing basement, although it will not be retained in the proposed development. The existing floors have been removed from both buildings and the proposed development includes beam and block floors with a ventilated sub-floor void. The potential for inhalation of vapours in indoor air has therefore been assessed utilising the Wilson Modular Approach (WMA) with reference to Wilson (2008).
- 4.23 In order to model the potential flow of vapour from the residual naphthalene contamination at the site to future dwellings site specific data regarding the soils and groundwater contamination as well as assumptions as to how a floor slab may be constructed have been used. The purpose of this exercise is to use reasonable assumptions to assess the potential need for a vapour barrier where a ventilated sub-floor void is incorporated into the design.
- 4.24 Physio-chemical data for naphthalene has been obtained from Environment Agency (2008). Building and soil parameters used in the modelling have been adopted from the CLEA model. The equations used to estimate vapour transfer from the source zone to indoor air are presented in full in Appendix 4 as a worked example with justification

of each of the parameters used within the equations together with worksheets for the COC (naphthalene). Table 6 below is a summary of the results of the modelling.

Table 6: Summary of WMA Modelling Results (Appendix 4)			
Contaminant of Concern	Maximum Concentration (mg/kg)	Inhalation Health Criteria Value – HCV_{inh} (µg/m³)	Worst Case Calculated Indoor Equilibrium Vapour Concentration – C_{building} (µg/m³)
Naphthalene	490	2.87	0.007

- 4.25 The further DQRA undertaken using the WMA indicates that maximum concentration of naphthalene recorded at the site is calculated to produce an equilibrium indoor air concentration below the relevant inhalation health criteria value. The WMA assessment has been undertaken on the basis that there is a minimum 150mm ventilated sub-floor void. If the foundation type varies from this assumption, the requirement for vapour protection measures will need to be reassessed to ensure that the assumptions used in the conceptual site model are appropriate to the alternative foundation type.
- 4.26 The outdoor inhalation pathway has been assessed using the CLEA model. The additional SSAC produced is referred to below as “SSAC (Outdoor Inhalation Pathway)”. The results of this assessment are included in Appendix 5 and summarised in Table 7 together with the statistical analysis of the soil contamination testing results from the 2017 site investigation. Also included are the statistical analysis which combines the 2017 and 2010 site investigation data. The maximum concentration from the statistical analysis is below the calculated SSAC (Outdoor Inhalation Pathway).

Table 7: Summary of SSAC Outdoor Inhalation Pathway and Soil Contamination Test Results					
Contaminant of Concern	Units	SSAC (Outdoor Inhalation Pathway)	Maximum Concentration from Statistical Analysis (see Appendix 5 of Interpretative Site Investigation Report)		
			Made Ground (2017 data)	Made Ground (2010 and 2017 data)	Natural Materials (2017 data)
Naphthalene	mg/kg	131,161	150	150	490

- 4.26 A clean cover pathway break, with imported clean soil used in all landscaped areas of the site and the single private garden, could be used to effectively sever the identified direct contact / ingestion and homegrown vegetables pathways. Details of the proposed clean cover pathway break are included in Section 7. The outdoor inhalation pathway has been assessed using the CLEA model and the indoor inhalation pathway has been assessed using the WMA. The assessment indicates that the inhalation pathways do not require any additional remediation measures based on the proposed building design.

5 DETAILED QUANTITATIVE RISK ASSESSMENT – CONTROLLED WATERS

Introduction

5.1 The Phase 2 Interpretative Site Investigation Report assessed the results of geochemical testing against published assessment criteria for groundwater and surface water. The initial assessment identified Contaminants of Concern (COC) that exceeded the conservative screening values and required further DQRA are summarised in Table 8.

Table 8: Summary of Contaminants of Concern Identified in Groundwater and Surface Water					
Contaminant of Concern	Groundwater			Surface Water	
	Made Ground (perched)	Shallow alluvium and sand and gravel	Chalk	Upstream	Downstream
Chromium				✓	
Mercury		✓			
Ammonium	✓	✓	✓		
Total cyanide	✓	✓	✓ ¹	✓ ²	✓ ²
Sulphur/ Sulphide	✓ ¹	✓ ¹	✓ ¹	✓ ²	✓ ²
Benzene		✓			
TPHs	✓	✓	✓	✓ ²	✓ ²
Acenaphthene	✓	✓			
Anthracene	✓	✓			
Benzo(a)pyrene	✓ ¹	✓ ¹	✓ ¹		
Benzo(b)fluoranthene	✓	✓			
Benzo(k)fluoranthene	✓	✓			
Fluoranthene	✓	✓	✓	✓ ²	✓ ²
Indeno(1,2,3-cd)pyrene	✓ ¹	✓ ¹	✓ ¹	✓ ²	✓ ²
Naphthalene		✓			
Notes ✓ Contaminant of concern identified from initial groundwater and/or surface water assessment at concentrations above Level 2 water quality criteria 1 Limit of detection higher than screening value for groundwater 2 Limit of detection higher than screening value for surface water					

Conceptual Site Model – Controlled Waters

5.2 The conceptual site model, in terms of controlled waters (surface water and groundwater) is summarised in Table 9. The main receptors are considered to be the River Kennet and the groundwater abstraction from the Chalk aquifer. Whilst the superficial deposits (shallow alluvium and sand and gravel) are classified as a Secondary A aquifer, there are no recorded groundwater abstractions from the

superficial aquifer in the vicinity of the site (with the possible exception of an abstraction for pump and treat pollution remediation purposes). Groundwater in the superficial aquifer is therefore not considered separately as a receptor as part of the DQRA.

Table 9: Potential Pollutant Linkages for Controlled Waters			
Potential Pollutant Linkage (PPL)	Source	Pathway	Receptor
PPL CW1	Contaminated soils	Leaching of soils and vertical migration of COC from the unsaturated soils into the underlying groundwater within the superficial aquifer (shallow alluvium and sands and gravels) and transport to the River Kennet	River Kennet
PPL CW2	Contaminated soils	Leaching of soils and vertical migration of COC from the unsaturated soils into the underlying groundwater within the superficial aquifer (shallow alluvium and sands and gravels), further migration in to the underlying Chalk aquifer and transport to the groundwater abstraction	Groundwater abstraction from the Chalk aquifer associated with the SPZ III
PPL CW3	Contaminated groundwater in the made ground and superficial aquifer	Migration of dissolved COC within groundwater in the superficial aquifer (shallow alluvium and sands and gravels) and transport to the River Kennet	River Kennet
PPL CW4	Contaminated groundwater in the made ground and superficial aquifer	Vertical migration of dissolved COC within groundwater in the superficial aquifer (shallow alluvium and sands and gravels) into the underlying Chalk aquifer and transport to the groundwater abstraction	Groundwater abstraction from the Chalk aquifer associated with the SPZ III

5.3 Leaching of soils and vertical migration of COC from the unsaturated soils into the underlying groundwater within the superficial aquifer (PPL CW1) is considered in the DQRA with the River Kennet considered as the key receptor due to the proximity to the site (adjacent to the site boundary). Further migration from the superficial aquifer into the underlying Chalk aquifer (PPL CW2) would result in additional dilution and therefore any remedial targets derived for the assessment of PPL CW1 would be conservative with respect to PPL CW2.

5.4 Whilst it is acknowledged that groundwater beneath the site has already been impacted by offsite contamination, it is considered that the most pragmatic approach

is to assess the potential for contamination to migrate from the primary source (i.e. contaminated soils) to the key receptor (the River Kennet, adjacent to the site boundary). The DQRA has not therefore been undertaken for the migration of dissolved COC within groundwater (i.e. potential pollutant linkages PPL CW3 and PPL CW4). This approach is considered appropriate as there has been no remediation of the adjacent properties which have reportedly been redeveloped without the need for remediation protective of controlled waters despite reportedly being grossly contaminated (see Section 2). It will ensure that any remedial targets derived will be protective of the surrounding environment without creating a situation that requires clean-up of material that is not having a significant impact on the environment.

DQRA Methodology – Controlled Waters

- 5.5 The Environment Agency Remedial Targets Worksheet Version 3.2 was utilised to assess the risk to Controlled Waters from contamination in soils and derive remedial targets. The methodology is based on a phased approach to risk assessment with four levels of assessment. The assessment levels for contaminated soils consider:
- Level 1 – ‘pore water’ concentrations;
 - Level 2 – effects of attenuation processes in the soil and unsaturated zones and predicts the effects of dilution by groundwater flow below the site;
 - Level 3 – effects of attenuation processes between the site and a downgradient receptor;
 - Level 4 – dilution in a receiving watercourse or abstraction.
- 5.6 A remedial target is derived at each level, in general the target becomes less stringent as the assessment level increases as additional processes such as dilution and attenuation are taken into account.
- 5.7 The Environment Agency consider Level 4 to represent a special case and any level 4 assessment must demonstrate that:
- Any impact on groundwater does not jeopardise future use of the resource; and
 - The cost of remediation is disproportionate in relation to the improvement of groundwater or surface water quality.
- 5.8 Assessment levels 1, 2 and 3 have been used to derive remedial targets for soils affected by the COC at the site. The assessment models the effects of attenuation,

dilution, dispersion and degradation of contamination between the source and the down-gradient receptor.

- 5.9 The Remedial Targets Worksheet assumes a single groundwater unit and models groundwater flow to a down hydraulic gradient compliance point. This is considered appropriate for modelling potential pollutant linkage PPL CW1.

Input Parameters

- 5.10 Input parameters for the soil and aquifer have been sourced from available site investigation data and from default literature values from the following sources:
- 2010 site investigation data including results of falling head tests;
 - 2017 site investigation data including results of laboratory analysis and groundwater level monitoring;
 - Updated technical background to the CLEA model (Environment Agency, 2009a);
 - ConSim manual; and
 - Hydrogeology: Principles and Practice (Hiscock, 2005).
- 5.11 Justification for the soil and aquifer parameters is provide in Appendix 6.
- 5.12 Physical properties for individual chemicals (Henry's Law constants, soil water partition coefficients and organic carbon partition coefficients) have been sourced from from the following sources:
- Atkins (2013);
 - LQM/CIEH (2015);
 - Petroleum Hydrocarbons in Groundwater: Supplementary Guidance for Hydrogeological Risk Assessment (Environment Agency, 2009b); and
 - Physical-Chemical Properties and Environmental Fate for Organic Chemicals (Mackay, 2006).
- 5.13 Justification for the chemical parameters is provide in Appendix 6.

Results

- 5.14 The Remedial Targets Worksheets are included in Appendix 7 and the results summarised in Table 10.

Table 10: Summary of Controlled Waters Remedial Targets

Determinand	Level 1 Soils SSAC (mg/kg)	Level 2 Soils SSAC (mg/kg)	Level 3 Soils SSAC (mg/kg)	Number of Samples Exceeding Level 3 Soils SSAC
Mercury	4.42E-01	6.88E-01	6.94E-01	1
Ammonium	3.32E+01	5.18E+01	5.18E+01	4
Cyanide (Total)	1.00E+00	1.06E+00	1.06E+00	5
Benzene	1.16E-02	1.56E+00	1.56E+00	0
Aliphatics >C12-C16	5.91E+02	9.21E+02	9.95E+02	0
Aliphatics >C16-C21	6.33E+04	9.87E+04	2.20E+07	0
Aliphatics >C21-C35	6.33E+04	9.87E+04	2.20E+07	0
Aromatics >EC5-EC7	1.16E-02	1.80E-02	2.15E+02	0
Aromatics >EC7-EC8	2.66E-02	4.14E-02	3.64E+43	0
Aromatics >EC8-EC10	1.79E-01	2.78E-01	1.86E+32	0
Aromatics >EC10-EC12	2.80E-01	4.37E-01	2.09E+49	0
Aromatics >EC12-EC16	5.55E-01	8.66E-01	8.02E+79	0
Aromatics >EC16-EC21	1.56E+00	2.43E+00	2.20E+28	0
Benzo(a)pyrene	2.41E-04	3.76E-04	1.98E+176	0
Benzo(b)fluoranthene	1.96E-04	3.05E-04	2.94E+147	0
Benzo(k)fluoranthene	2.77E-04	4.31E-04	4.54E+91	0
Fluoranthene	1.26E-03	1.97E-03	2.29E+70	0
Indeno(1,2,3-cd)pyrene	1.63E-04	2.54E-04	2.53E+28	0
Naphthalene	1.50E-02	2.34E-02	2.34E-02	0
Acenaphthene	4.45E-01	6.94E-01	1.03E+54	0
Anthracene	6.23E-03	9.70E-03	6.59E+36	0

- 5.15 The results of the controlled waters DQRA indicate that only mercury, ammonium and cyanide are present in soils at the site at concentrations that may represent a potential risk to identified receptors. However, the risk assessment undertaken is considered to be conservative for the site. The DQRA undertaken indicates that the majority of the COCs identified do not pose a significant risk to the identified controlled water receptor (i.e. the River Kennet adjacent to the site).
- 5.16 The risk assessment undertaken uses conservative input parameters and assumes steady state conditions are reached between soils, groundwater in the superficial Secondary A aquifer and the hypothetical borehole at the site boundary adjacent to the River Kennet. The assessment undertaken stops at Level 3 and does not allow for any dilution within the receiving water body. According to data in the UK Hydrometric Register, the Q95 flow in the River Kennet in the vicinity of the site (Kennet Theale Gauging Station) is 3.76m³/s. By comparison with the quantity of water estimated to flow from the site, calculated using Darcy's Law, the dilution offered by the River

Kennet adjacent to the site would be circa 13,000,000 times (Appendix 7). Dilution of only 0.00008% of that offered by the River Kennet in low flow conditions would be required to indicate that none of the COC included in the risk assessment represent a significant risk to the water quality of the river.

- 5.17 The risk assessments undertaken do not include reference to the river wall which runs along the entire length of the site adjacent to the river which will act to further restrict flow of groundwater from the site to the river. Additionally, as discussed in Section 2, redevelopment of the neighbouring sites which have also been developed on the former gasworks, have not included any remediation of groundwater, despite there being gross contamination of groundwater recorded during site investigations. It is therefore considered that the low levels of COCs which the conservative DQRA have highlighted are not a significant risk to identified controlled water receptors and that no further mitigation is required.
- 5.18 Considering that neighbouring sites already developed with known gross contamination in the groundwater have not been remediated, it is considered disproportionate to undertake remediation of soils at the site to Level 3 remedial targets. Instead, a strategy of betterment should be included in the remediation and redevelopment of the site. The redevelopment of the site will include provision of new drainage systems in association with areas of hardstanding that will reduce infiltration to the ground. Infiltration could be further reduced by incorporating a low permeability layer within soft landscaped areas which would help to significantly reduce the potential mobilisation of residual contamination in the soils to the underlying groundwater in the superficial Secondary A aquifer and River Kennet beyond.

6 GROUND GAS ASSESSMENT

- 6.1 The conceptual site model for human health (Table 3) identified a potential pollutant linkage for ground gas to future occupiers and site workers (PPL HH2). This section considers this potential pollutant linkage.
- 6.2 Guidance within CIRIA 665 “Assessing risks posed by hazardous ground gases to buildings” (2007) is used to calculate a Gas Screening Value (GSV) and generate a Characteristic Situation (CS) for the site. CS1 represents a very low risk and CS6 represents a very high risk from ground gas.
- 6.3 CIRIA 665 also provides some guidance on gas protection measures for each CS. Design of gas protection is also covered within BS8485:2015 “Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings”. Where the end use is residential the NHBC published guidance (traffic light system) can also be used as an alternative provided the construction of the buildings proposed is compliant with their guidance.
- 6.4 Ground gas monitoring was undertaken at the site by a technician from GE Ltd to provide an assessment of the ground gas regime at the site. Since the issue of the Phase 2 Interpretative Site Investigation Report in December 2017 additional gas monitoring visits have been carried out. The following updates the gas monitoring results and their interpretation to include the additional data.
- 6.5 Monitoring visits were carried out on four occasions for BH01, on 27 November 2017, 4 and 12 December 2017, and 18 January 2018. Monitoring was carried out on four occasions at BH02, BH03C and BH06A on 4 and 12 December 2017, and 4 and 18 January 2018. Monitoring was carried out on four occasions at BH04B on 7 and 12 December 2017, and 4 and 18 January 2018. WS001 was monitored on four occasions on 4 and 18 December 2017, and 4 and 18 January 2018. WS005 was monitored on three occasions on 4 December 2017, and 4 and 18 January 2018. The results are included in Appendix 8. A summary of monitoring results is shown in Table 11.

Table 11: Summary of Ground Gas Monitoring Results

Borehole	Response Zone, m bgl	Evidence of contamination	No. of monitoring rounds	Methane, %	Carbon dioxide, %	Oxygen, %	Flow rate, l/h ¹	Water level, m bgl	Range of atmospheric pressure during monitoring round, mb
BH01	0.9-4.0 Made ground	Yes	4	0-9.3	0-4.6	0.1-19.9	<0.1	1.49-1.67	975-1031
BH02	3.6-6.8 Alluvium	Yes	4	0	0-0.8	18.8-20.3	<0.1	1.53-1.76	978-1029
BH03C	2.6-6.8 Alluvium	Yes	4	0	0-0.4	18.6-20.3	<0.1-3.3	1.55-1.79	976-1029
BH04B	0.8-2.0 Made ground	Yes	4	0-1.4	0-2.0	17.8-20	<0.1	1.02-1.31	979-1003
	2.9-7.1 Alluvium	Yes	4	0	0-0.2	19.5-20.3	<0.1	1.73-1.97	979-998
BH06A	2.9-6.1 Alluvium	Yes	4	0	0-0.1	20-20.4	<0.1	1.72-1.95	978-1029
	7.6-9.15 Chalk	Yes	4	0	0-0.4	19.6-20.4	<0.1	1.78-2.06	978-1029
WS001	3.5-4.0 Made ground	Yes	4	0	0-0.4	19.6-20.3	<0.1	1.08-1.40	988-1024
WS005	3.5-4.5 Alluvium	Yes	3	0	0-0.3	19.9-20.4	<0.1	1.72-1.96	988-1029
Notes 1 Where a flow rate of 0l/hr was recorded on site the limit of detection of gas monitor has been assumed as 0.1l/hr									

- 6.6 In order to pose a risk to the end users of the site, the recorded concentrations of carbon dioxide and methane would need to migrate from the ground and accumulate in confined spaces within the development. A maximum gas flow of 3.3l/h has been assumed as a worst case.
- 6.7 In order to assess the potential risk posed by the recorded gas volumes at the site, as an initial screen, the methodology presented within CIRIA Report C665 “Assessing risk posed by hazardous ground gasses to buildings 2007” has been used.
- 6.8 BS8485 and CIRIA C665 requires the calculation of a Gas Screening Value (GSV) (Litres of gas per hour) using the formula below:

- Borehole flow rate (l/h) x gas concentration (%) = GSV (l/hr)

6.9 This calculation has been carried out for methane and carbon dioxide using the highest recorded concentration, therefore adapting the worst case volume.

Methane $GSV = 9.3\%/100\% \times 3.3\text{l/h} = 0.307\text{ l/hr}$

Carbon Dioxide $GSV = 4.6\%/100\% \times 3.3\text{l/h} = 0.152\text{ l/hr}$

6.10 CIRIA C665 have produced two models for qualitative analysis depending upon building type: NHBC's "Situation B – Low rise housing with a ventilated under floor void (min 150mm)" and the modified Wilson and Card Classification system "for all development types except situation B". Given the proposed development at the site, the Wilson and Card Classification Scheme is considered the most appropriate system for this site. The comparison of the calculated GSV with the classification tables show the site lies within Characterisation Situation 2 (CS2). This characteristic situation is typical of made ground, and will require low level gas protection measures. The composition and arrangement of the gas protection measures would be subject to detailed design by the foundation engineers and separate approval by the Local Authority.

7 DEVELOPMENT OF REMEDIATION STRATEGY

7.1 There are two main legislative drivers to dealing with contaminated land that are relevant to the proposed development at the site: Part 2A and the National Planning Policy Framework. Both are discussed in the context of the proposed development in the following text.

7.2 Contaminated land is defined within Part 2A of the Environmental Protection Act 1990. The Part 2A statutory guidance was revised in April 2012. The overarching objectives of the Government's policy on contaminated land and the Part 2A regime are:

- a) To identify and remove unacceptable risks to human health and the environment.
- b) To seek and ensure that contaminated land is made suitable for its current use.
- c) To ensure that the burdens faced by individuals, companies and society as a whole are proportionate, manageable and compatible with the principles of sustainable development.

7.3 The Environmental Protection Act 1990 introduced the concept of pollutant linkages (i.e. Contaminant-Pathway-Receptor) whereby:

Contaminant – a source or potential source of contamination.

Pathway – is one or more routes or means by which or through which a receptor is being exposed to or affected by a contaminant or could be exposed or affected.

Receptor – a living organism, a group of living organisms, an ecological system or a piece of property that is being or could be harmed by the contaminant or controlled waters which are being or could be polluted by a contaminant.

7.4 In order for contamination to pose a problem at a site all three components of the pollutant linkage must exist. The definition of contaminated land in accordance with the new statutory guidance within Section 78A (2) is in Paragraph 4.2, states:

“contaminated land is any land which appears to the local authority in whose area it is situated to be in such conditions, by reason of substances in, on or under the land that:

- a) Significant harm is being caused or there is significant possibility of such harm being caused, or
- b) Significant pollution of controlled waters is being or there is significant possibility of such pollution being caused.”

7.5 The National Planning Policy Framework (NPPF) 2012 comments on contaminated land with respect to the Planning Regime. The 12 core planning principles of the NPPF are set out in Paragraph 17 relevant extracts of which include the following statements that relate to the site and the proposed development:

- “contribute to conserving and enhancing the natural environment and reducing pollution. Allocation of land for development should prefer land of lesser environmental value, where consistent with other policies in the Framework;
- encourage the effective use of land by reusing land that has been previously developed (brownfield land), provided that it is not of high environmental value.”

7.6 Additional extracts from the NPPF that are considered particularly relevant to ground conditions and contamination at the site and the proposed development are:

- Paragraph 109 - “The Planning System should contribute to and enhance the natural and local environment by:
 - protecting and enhancing valued landscapes, geological conservation interests and soils;
 - preventing both new and existing development from contributing to or being put at unacceptable risk from, or being adversely affected by

- unacceptable levels of soil, air, water or noise pollution or land instability;
and
 - remediating and mitigating despoiled, degraded, derelict, contaminated and unstable land, where appropriate.”;
 - Paragraph 120 - “To prevent unacceptable risk from pollution and land instability, planning policies and decisions should ensure that new development is appropriate for its location. The effects (including cumulative effects) of pollution on health, the natural environment or general amenity, and the potential sensitivity of the area or proposed development to adverse effects from pollution, should be taken into account. Where a site is affected by contamination or land stability issues, responsibility for securing a safe development rests with the developer and/or landowner.”; and
 - Paragraph 121 - “Planning policies and decisions should also ensure that:
 - the site is suitable for its new use taking account of ground conditions and land instability, including from natural hazards or former activities such as mining, pollution arising from previous uses and any proposals for mitigation including land remediation or impacts on the natural environment arising from that remediation; and
 - after remediation, as a minimum, land should not be capable of being determined as contaminated land under Part IIA of the Environmental Protection Act 1990.”
- 7.7 The assessments undertaken to date (Sections 4, 5 and 6) identify a number of constraints to development at the site. These are addressed in the Remediation Strategy in Section 8. This strategy builds on the conceptual site model (CSM) developed for the site, the DQRA assessments for human health and controlled waters, and the ground gas risk assessment undertaken.
- 7.8 Each of these potential constraints is summarised in Table 12 and considered further together with an appraisal of the best available options to mitigate the identified pollutant linkage relative to the proposed development.

Table 12: Potential Pollutant Linkages

Potential Pollutant Linkage (PPL)	Source	Pathway	Receptor	Comments
PPL HH1	Chromium, lead, mercury, aromatics (>EC10-EC12, >EC12-EC16, >EC16-EC21, >EC21-EC35), benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene	Direct soil and indoor dust ingestion; skin contact with soils; consumption of homegrown produce; consumption of soil adhering to homegrown produce; and indoor dust and inhalation of indoor and outdoor dust and vapours	Future occupiers and site works	DQRA indicates that risk from the identified COC is from direct contact / ingestion pathways only (including consumption of homegrown produce) and that additional measures to address vapour inhalation are not necessary
PPL HH2	Organic material in the ground or methane/carbon dioxide	Gas migration	Future occupiers and site works	Gas risk assessment has identified a low risk to the proposed development from gas risk that will require mitigation
PPL CW1	Mercury, ammonium, cyanide, benzene, aliphatics (>C12-C16, >C16-C21, >C21-C35), aromatics (>EC5-EC7, >EC7-EC8, >EC8-EC10, >EC10-EC12, >EC12-EC16, >EC16-EC21), benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, acenaphthene, anthracene	Leaching of soils and vertical migration of COC from the unsaturated soils into the underlying groundwater within the superficial aquifer (shallow alluvium and sands and gravels) and transport to the River Kennet	River Kennet	DQRA indicates that there is only a potential for leaching of mercury, ammonium and cyanide from soils. Mitigation in the form of betterment is recommended
PPL CW2	Mercury, ammonium, cyanide, benzene, aliphatics (>C12-C16, >C16-C21, >C21-C35), aromatics (>EC5-EC7, >EC7-EC8, >EC8-EC10, >EC10-EC12, >EC12-EC16, >EC16-EC21), benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, acenaphthene, anthracene	Leaching of soils and vertical migration of COC from the unsaturated soils into the underlying groundwater within the superficial aquifer (shallow alluvium and sands and gravels), further migration in to the underlying Chalk	Groundwater abstraction from the Chalk aquifer associated with the SPZ III	

Table 12: Potential Pollutant Linkages

Potential Pollutant Linkage (PPL)	Source	Pathway	Receptor	Comments
		aquifer and transport to the groundwater abstraction		
PPL CW3	Mercury, ammonium, cyanide, benzene, aliphatics (>C12-C16, >C16-C21, >C21-C35), aromatics (>EC5-EC7, >EC7-EC8, >EC8-EC10, >EC10-EC12, >EC12-EC16, >EC16-EC21), benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, acenaphthene, anthracene	Migration of dissolved COC within groundwater in the superficial aquifer (shallow alluvium and sands and gravels) and transport to the River Kennet	River Kennet	Groundwater is understood not to have been remediated on adjacent sites also developed on the former gas works despite evidence of gross contamination. Therefore, remediation of groundwater is considered to be disproportionate for this site and is not considered further
PPL CW4	Mercury, ammonium, cyanide, benzene, aliphatics (>C12-C16, >C16-C21, >C21-C35), aromatics (>EC5-EC7, >EC7-EC8, >EC8-EC10, >EC10-EC12, >EC12-EC16, >EC16-EC21), benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene, acenaphthene, anthracene	Vertical migration of dissolved COC within groundwater in the superficial aquifer (shallow alluvium and sands and gravels) into the underlying Chalk aquifer and transport to the groundwater abstraction	Groundwater abstraction from the Chalk aquifer associated with the SPZ III	

Pollutant linkages identified as potentially significant in Table 12 must all be addressed in order for remediation of the site to be considered effective. However, the significance of these contaminant linkages should be reviewed if further information comes to light.

8 REMEDIATION OPTIONS APPRAISAL

8.1 Based on the results of desk study research and intrusive investigations listed in Section 1, along with the results of an investigation undertaken in 2017 a conceptual site model was developed and appropriate risk assessments have been undertaken with regards to identifying the most appropriate remediation strategy to deal with the soils contamination identified at the site.

8.2 In order to develop the Remediation Strategy for the site an options appraisal has been undertaken to review the various remedial techniques that may be applicable to the site and the proposed development. The various options available for consideration are classified into six categories of remedial methods as follows:

- Civil engineering methods;
- Biological treatment methods;
- Chemical treatment methods;
- Physical treatment methods;
- Stabilisation and solidification treatment methods; and / or
- Thermal treatment methods.

Civil engineering methods

8.3 Civil engineering methods use conventional civil engineering techniques by either removing the source or modifying contaminant pathways. Civil engineering methods include:

- *Excavation*

This involves the excavation of contaminated materials which can then be disposed of to a suitably licensed facility or re-disposed on site. However, the Landfill Directive sets out to limit landfilling of waste to a minimum as defined by EC legislation and can preclude the bulk landfilling of contaminated soils (depending on contaminant concentration) unless there is no other option. Even if landfilling is considered appropriate, pre-treatment would also be necessary. Overall, bulk excavation and landfilling alone are not considered practical, cost effective or the best available option. The site has limited access, the current building footprints are being retained and the size of the site means any excavation operations would be constrained. However, it is recognised that during construction works small unexpected areas of contamination may be

encountered and may need to be dealt with via excavation and disposal methods.

- *Cover systems*

This involves the placement of an uncontaminated material over the surface of the contaminated materials therefore breaking the pathway between the source and the site end-users and effectively mitigating against risks to end users from chromium, lead, mercury, TPH (aromatics >EC10-EC12, >EC12-EC16, >EC16-EC21, >EC21-EC35) and PAH (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, indeno(1,2,3-cd)pyrene, naphthalene) contamination within the soils. The cover system would comprise low permeability materials to reduce infiltration at the site providing additional protection to groundwater. However, the current river wall which is to be retained in the proposed development will act as a barrier and provide a level of protection to the adjacent River Kennet.

- *In ground barriers*

These physically isolate a contaminated mass of ground from surrounding media by the placement of barriers at the top, base and / or sides of the contamination. Vertical barriers can be installed by placing physical structures vertically into the ground. These may include sheet-piling, installation of bentonite walls (with or without membranes) or by grouting. This method is not considered appropriate at the site as no discrete area of gross contamination has been identified.

Biological Treatment Methods

- 8.4 Biological treatment methods use the natural physiological processes of micro-organisms such as bacteria and fungi to transform, fix, or immobilise contaminants. Biological remediation is potentially applicable to a wide range of organic contaminants and matrix types. Aerobic and anaerobic processes can be employed. Both ex-situ and in situ techniques are available. As biological methods rely on the activities of living organisms to be effective, they must have optimal process

conditions in terms of temperature, oxygen concentrations, nutrient balance, pH etc, Effectiveness can be inhibited by the presence of certain contaminants such as metals and pesticides. Treatment methods include:

- *Biopiles, landfarming, windrow turning;*

These are ex-situ techniques where solid phase contamination is treated biologically above ground in layers or piles of varying thicknesses. Biological activity can be stimulated by aeration and the addition of minerals, nutrients and moisture. This method is not considered appropriate for the site due to the lack of working areas that would be required.

- *Bioventing and biosparging;*

These are in situ treatments where oxygen is delivered to contaminated unsaturated soils by forced air movement by either extraction (bioventing) or injection of air (biosparging) to increase flow and oxygen concentrations in order to optimise biodegradation of aerobically degradable compounds. This method is not suitable at the site due to the types of contaminants determined by the DQRA to represent a potential risk that requires mitigation.

- *Bioinjection and bioaugmentation*

This involves the introduction of materials through a series of injection wells / boreholes which will either enhance the conditions within the media to encourage the growth of the natural microbial community which will break down the contaminants via respiration or adjust the redox conditions suitable for the growth of specific organisms. There are a number of patented compounds available such as oxygen release compound (ORC™) and hydrogen release compounds (HRC™). These are injected into the ground in liquid form and ORC enhances aerobic conditions suited to degradation of compounds such as TPH and BTEX. Bioaugmentation is in addition to chemical injection and involves the microbial injection of specific micro-organisms to target specific contaminants. These are generally only applicable below the water table and are therefore not considered appropriate to treat identified contamination in soils at the site. This method is not suitable at the site due to the types of

contaminants determined by the DQRA to represent a potential risk that requires mitigation.

- *Monitored natural attenuation*

This is the effect of naturally occurring physical, chemical and biological processes or any combination of these processes to reduce the load, concentration, flux or toxicity of polluting substances in groundwater. For this to be effective the rate at which these processes occur must be sufficient to prevent polluting substances impacting on identified receptors and to minimise expansion of contaminant plumes into unpolluted groundwater. Monitored natural attenuation (MNA) requires sufficient evidence to be collected to demonstrate that attenuation processes are occurring at a rate that protects the wider environment. This is particularly effective for treating groundwater plumes containing BTEX, phenols, PAH's (such as naphthalene) and petroleum hydrocarbons. This method is not considered appropriate at the site due to background concentrations of contaminants associated with the historic wider gas works site and the redevelopment of these areas without the need for remediation protective of controlled water. The proximity of the River Kennet adjacent to the northern boundary of the site, which is the identified receptor, also makes use of MNA difficult at the site. However, it may be suitable as part of remediation and validation works.

Chemical Treatment Methods

8.5 These involve chemical reactions that destroy or alter contaminants by the addition of reagents. Theoretically a wide range of contaminants are treatable since chemical processes can be formulated to address particular contaminants. There are a number of chemical processes that can be used including:

- *Chemical oxidation;*

Chemicals introduced into soil/groundwater to encourage redox reaction to convert hazardous contaminants to non-hazardous or less toxic compounds that are more stable, less mobile or inert. This in situ method has the advantage of a short treatment period however the chemical reagents, intermediates and by-products may have public health and environmental implications. Furthermore,

the effectiveness of the remediation will depend upon good contact between the reagents and contaminants. This method could be used in conjunction with excavation in the event of encountering unexpected areas of contamination.

- *Soil flushing;*

This involves flooding a zone of contamination with an appropriate solution to remove the contaminant from the soil. The contaminants are mobilised by a number of mechanisms including formation of emulsions or reacting chemically with the flushing solution. The contaminant bearing fluid is then collected and brought to the surface for disposal, recirculation or on-site treatment and reinjection. This method is potentially suitable to treat the capillary fringe just above the groundwater where high concentrations of contaminants are often found. This method is not considered suitable for the site.

Physical Treatment Methods

8.6 These methods involve the separation of contaminated and uncontaminated material by exploiting differences in physical properties to enable separation to occur. Physical treatment methods include:

- *Soil vapour extraction*

This is an in situ method used to treat the unsaturated zone and applies a vacuum to the soil to induce a controlled flow of air and remove volatile and some semi-volatile organic contaminants from the soil. The volatiles may then be released to the atmosphere or may require further treatment to eliminate possible harm to the public and environment. However, this will not remove heavy oils, tars or metals and may therefore need to be employed alongside other methods. This method is not considered appropriate for the site due to the constraints caused by the existing buildings and types of contaminants determined by the DQRA to represent a potential risk that requires mitigation.

- *Groundwater Pump and Treat*

This involves the collection of groundwater via abstraction wells utilising submersible pumps or alternatively groundwater can be diverted into a

collection lagoon system on site. Either way the water is pumped and treated through a treatment plant on site. Free phase product can be removed through a series of oil/water separation systems and dissolved contaminants can be removed from the water using filtration media or by chemical methods. The treated water could then be disposed of either to sewer or re-infiltrated into the ground. This method is not considered appropriate at the site due to background concentrations of contaminants associated with the historic wider gas works site and the redevelopment of these areas without need for remediation protective of controlled water. However, it may be practical for treatment of perched / shallow groundwater if encountered within excavations.

Stabilisation / Solidification Methods

- 8.7 These methods operate by solidifying contaminated soils and converting the contaminants to a less mobile form reducing the potential for leachate formation. Both ex-situ and in situ treatments are available; the former requiring a processing area for mixing plus an area for curing before re-use or replacement of stabilised material. The latter requires the cement to be injected into the ground and mixed with the soil using hollow stem rotary augers.

Thermal Treatment Methods

- 8.8 These utilise heat to physically separate organic contamination from a soil matrix, the separated contamination is then disposed of and a cleaned soil or reduced volume of waste material is left. Thermal treatments are likely to be very expensive hence may not be appropriate for this reason. A number of thermal treatment methods are available including:

- *Thermal desorption*

This involves the application of heat to excavated wastes to volatilise organic contaminants and water. This therefore separates the organic contaminants out from waste using heat and the vapours are collected then oxidized, converting the contaminants to a less toxic form.

- *Steam / heat injection*

Steam can be injected via a series of wells into either the unsaturated or saturated zone to enhance the release of organic contaminants from the soil matrix by decreasing viscosity and accelerating volatilisation. The heat from the steam can destroy and volatilise organic chemicals which may otherwise remain recalcitrant. This method could potentially treat a wide variety of organic constituents although the breakdown of certain contaminants may produce more noxious daughter products so the chemistry of the area under treatment would need to be known in detail.

8.9 A summary of options is presented in Table 13, however it is likely that a combination of processes may be necessary to remediate the soils and groundwater at the site.

Table 13: Remediation Options

Remediation Technology	Technical Considerations for the Site	Practical Considerations	Assessment of Potential Suitability
Excavation and Disposal to Landfill	Waste will require classification for off-site disposal and be hazardous waste which will incur costs to dispose of to landfill which are likely to be high.	Can potentially result in large numbers of vehicle movements on/off site to haul the materials to landfill. Few suitable landfills currently available.	May be suitable for areas of unexpected contamination, but unlikely to be useful for addressing general contamination due to access restrictions, costs and sustainability issues.
Cover systems	Material needs to be chemically suitable and relatively stable with regards to leachate productions. Will not treat existing contamination but may reduce impact of residual contamination on site.	Well established method of providing remediation. Engineered cap can also provide enhanced geotechnical characteristics.	Likely to be suitable to break the human health pathways
Biopiles, windrows	Can be suitable for volatile contaminants within soils.	Excavation requirements limits the depth to which soils can be treated practically and requires space on site.	This method is not considered appropriate at the site due to the lack of working area that would be required.
Bioinjection / bioaugmentation	Can be suitable for contamination at depth that can be biodegraded.	Installation of appropriately located injection wells means the extent of any plume needs to be fully delineated.	Potentially suitable for deeper soils and groundwater but only suitable for organics and expensive.
Monitored Natural Attenuation	Suitable for long term monitoring and verification of remediation.	Access to monitoring wells needs to be maintained over potentially long periods of time.	Probably suitable as part of verification / validation works.
Chemical oxidation	Suitable for contaminants that can be oxidized but not generally suitable for free product.	Only small site area required for equipment but may require multiple applications.	Potentially suitable for soils and used in conjunction with

Table 13: Remediation Options			
Remediation Technology	Technical Considerations for the Site	Practical Considerations	Assessment of Potential Suitability
			excavations where unexpected areas of contamination are encountered.
Multi-phase vacuum extraction / Soil vapour extraction	Generally suitable for more volatile compounds but can be coupled with soil vapour extraction to treat soils above the capillary fringe. Suited to granular soils. Less volatile fractions could be difficult to treat.	Explosion hazards must be addressed.	This method is not considered suitable for the site due to the constraints caused by existing buildings.
Groundwater pump and treat	Unlikely to remediate dissolved phase to appropriate concentrations. Pumped water would require discharge to sewer or recycled on site after treatment.	Can require prolonged operation and is sometimes subject to rebound.	This method is not considered appropriate at the site due to background concentrations of contaminants associated with the historic wider gas works site and the redevelopment of these areas without need for remediation protective of controlled water. However, it could be useful for treating perched / shallow groundwater encountered in excavations.
In Situ Thermal Treatment	Could potentially be viable for the contamination present.	Very unlikely to be financially viable given the volumes of material to be treated and the likely cost of treatment.	Unlikely to be suitable due to financial reasons.

9 REMEDIATION STRATEGY

Setting Remedial Targets

- 9.1 In order to provide assurance that the remediation works have been undertaken to a standard that is acceptable to Regulators and that will provide a site that is suitable for the proposed development it is necessary to derive and set remedial targets that can be applied to the works at the site. The remedial targets can be used to determine where materials at the site require treatment/mitigation as well as for validation purposes.
- 9.2 The options appraisal indicates that a number of methods will in all likelihood need to be employed to mitigate the risk to the identified receptors (site users and the River Kennet).
- 9.3 It is generally accepted that the minimum required level of remediation is to remove free product (where identified). Observations during the site investigations works included hydrocarbon stained soils with strong hydrocarbon odour though no free product has been identified by either the site investigations or subsequent monitoring.
- 9.4 It is considered appropriate to set the remedial target for TPH at the SSACs defined in Table 10.

Remediation Strategy

- 9.5 The following main works elements will be required in order to remediate the site for redevelopment:
- Where applicable careful removal of buried floor slabs (including the floor slabs to buildings to be retained), areas of concrete hardstanding and substructures;
 - Processing by crushing with appropriate management controls of suitable materials generated from the removal of floor slabs etc. to a 6F1 / 6F2 grade aggregate for reuse during reinstatement and in the future development at the site;
 - Additional testing of materials beneath the former slab areas etc., as necessary, that exhibit olfactory or visual evidence of contamination;
 - Establishment of appropriate environmental monitoring;
 - Site controls and safe working procedures to limit release of contaminated dust that could include asbestos fibres during earthworks and minimise the risk to site workers and the wider public;

- Pumping out and treatment of any perched water within excavations required to remove sub-structures and / or contamination;
- Monitoring of existing boreholes during remediation works;
- Placement of a clean cover pathway break incorporating a low permeability layer to reduce infiltration in areas of landscaping and gardens.
- Installation of gas protection measures within the building footprint;
- Instigation of a watching brief to identify areas of previously unidentified contamination.

- 9.6 Details of the exact methods employed to remediate the soils will be provided in a remediation specification to be supplied by the remediation contractor. The contractor will be responsible for undertaking environmental monitoring throughout the works. Appropriate method statements and risk assessments for all potentially hazardous activities will be prepared by the contractor as necessary prior to undertaking works at the site. These method statements and risk assessments will detail procedures to be put in place to control the potential release of asbestos fibres during earthworks. It is considered likely that measures including use of appropriate PPE, good hygiene practices together with damping down of haul roads, temporary stockpiles and excavations within made ground will be required. As necessary, working methods will be adapted so that issues relating to dust or noise including statutory nuisance are minimised in accordance with good industry practice.
- 9.7 If as yet unidentified soils are encountered during the remedial works that are suspected of being grossly impacted, these materials will either be removed and treated as grossly impacted or tested so that they can be classified for appropriate re-use on the site.
- 9.8 Where identified, soils grossly impacted with TPH will be excavated under the supervision of a suitably experienced environmental engineer. Impacted soils will be excavated until the contamination has been removed based on visual / olfactory evidence which can be aided by the use of a PID (Photo-Ionisation Detector). Validation samples will then be collected to illustrate that the remedial targets have been achieved.
- 9.9 Treatments of excavations created where area of unexpected contamination may be encountered could include the application of chemical oxidation compounds.
- 9.10 If earthworks are required to reprofile the site, these will be carried out in accordance with the CL:AIRE The Definition of Waste: Development Industry Code of Practice and will require a Materials Management Plan (MMP). This will be prepared (if necessary)

by the contractor and audited by a Qualified Person as required prior to submission to the EA.

- 9.11 It will be necessary to reinstate all excavations completed as part of remediation works together with other voids created by the removal of sub-structures, obstructions etc. by backfilling works. Secondary aggregate, produced from the crushing of concrete, together with uncontaminated soils from reprofiling could be used for reinstatement of excavations and voids. Clean cohesive materials sourced from the reclamation works or from an off site source, will be used to construct a low permeability layer in the clean cover pathway break required in landscaped and garden areas to reduce future infiltration. Records of this work will be maintained for final verification purposes.
- 9.12 Records will need to be maintained for all of the environmental monitoring activities undertaken throughout the works.
- 9.13 Upon completion of the remediation works a validation report will be produced for the approval of the regulators.

10 REFERENCES

CL:AIRE (2014) Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination. Report reference SP1010

Environment Agency (2008) Compilation of data for priority organic pollutants for derivation of Soil Guideline Values. Science report: SC050021/SR7

Environment Agency (2009a) Updated technical background to the CLEA model. Science report: SC050021/SR3

Environment Agency (2009b) Petroleum Hydrocarbons in Groundwater: Supplementary Guidance for Hydrogeological Risk Assessment

Hiscock, K (2005) Hydrogeology: Principles and Practice. Cambridge University Press. 389pp

Natural Environment Research Council (2008) UK Hydrometric Register

USEPA (2005) Partition Coefficients for Metals in Surface Water, Soil and Waste

Wilson, S (2008) Modular approach to analysing vapour migration into buildings in the UK. Land Contamination & Reclamation, 16 (3), 223-236

APPENDICES

Appendix 1 Planning permission and discharge of conditions 5 and 9



Reading
Borough Council
Working better with you

**TOWN AND COUNTRY PLANNING ACT 1990
PLANNING AND COMPENSATION ACT 1991
THE TOWN & COUNTRY PLANNING
(DEVELOPMENT MANAGEMENT PROCEDURE) (ENGLAND) ORDER 2015**

APPLICATION FOR FULL PLANNING PERMISSION

To: e3 design limited
17 Dryburn Road
Stockton On Tees
Cleveland
TS19 8JN

Application No: 160378
Application type: Full Planning Approval

Applicant: Mulberry Park Investment (S.E.) Limited

READING BOROUGH COUNCIL as Local Planning Authority **GRANT FULL** planning permission for the following development in accordance with the plans and supporting information submitted in connection with this application.

Proposal: Change of use, conversion, extensions and various associated works to former Gas Works Buildings to create a part 4,5 and 6 storey building adjacent to the River Kennet and a 3 storey building fronting Gas Works Road, providing 20 (10x1, 9x2 and 1x3-bed) residential units (Class C3).

At: Former Gas Works Building Gas Works Road Reading

Subject to such conditions and for such reasons as may be attached

**OTHER STATUTORY CONSENTS MAY BE REQUIRED
PLEASE READ THE NOTES ISSUED WITH THIS DECISION NOTICE**

Date: 28th October 2016

Head of Planning, Development
& Regulatory Services

LEB



Application At: Former Gas Works Building Gas Works Road Reading

Application No: 160378

Application type: Full Planning Approval

CONDITIONS & REASONS

1. The development to which this permission relates must be begun not later than the expiration of three years beginning with the date on which the permission was granted.

Reason: To prevent an accumulation of unimplemented planning permissions, and in accordance with section 91 of the Town & Country Planning Act as amended by the Planning and Compulsory Purchase Act 2004.

2. The development hereby permitted shall not be carried out other than in accordance with the following drawings/documents;

Site Location Plan, as received 01/03/16

14/354/P01 Rev A - Existing Site Plan, as received 22/03/16

14/354/P100 Rev E - Proposed Site Plan, as received 15/06/16

14/354/P101 Rev A - Block Plan, as received 22/03/16

14/354/P02 Rev B - Existing Elevations & Sections Building 1, as received 31/03/16

14/354/P03 Rev B - Existing Elevations & Sections Building 2, as received 31/03/16

14/354/P04 Rev A - Existing Floor Plans Lower Level, as received 22/03/16

14/354/P05 Rev A - Existing Floor Plans Upper Level, as received 22/03/16

14/354/P06 Rev C - Proposed Elevations Building 1, as received 30/08/16

14/354/P07 Rev C - Proposed Elevations Building 2, as received 30/08/16

14/354/P08 Rev G - Proposed Floor Plans Level 1, as received 01/09/16

14/354/P09 Rev F - Proposed Floor Plans Level 2, as received 01/09/16

14/354/P10 Rev F - Proposed Second Floor Plans Level 3, as received 01/09/16

14/354/P11 Rev F - Proposed Third Floor Plans Level 4, as received 01/09/16

14/354/P12 Rev F - Proposed Floor Plans Level 5, as received 01/09/16

14/354/P13 Rev F - Proposed Fifth Floor Plans Level 6, as received 01/09/16

14/354/P15 Rev B - Proposed Sections Building 1, as received 14/06/16

14/354/P19 - Proposed Bin Store Enclosure, as received 31/03/16

Reason: To clarify which plans have been approved and in the interests of proper planning.

3. No development shall take place until details (including samples) of all materials (including brickwork, glazing / obscure glazing, window and dormer window frames/cills/copings/lintels/surrounds, roof, walls, doors, photovoltaics, railings, juliet balconies, guttering and downpipes) to be used in the construction of the

Date: 28th October 2016

Head of Planning, Development
& Regulatory Services

LEB



Reading

Borough Council

Working better with you

external surfaces of the development, have been submitted to and approved in writing by the local planning authority. The development shall not be carried out other than in full accordance with the approved details.

Reason: In the interests of safeguarding the character and appearance of the building and the wider immediate area, in accordance with Policies CS7 and CS33 of the Reading Borough LDF Core Strategy 2008 (Altered 2015) and Policy RC5 of the Reading Borough LDF Reading Central Area Action Plan 2009.

4. No development shall take place, including any works of demolition, until a Construction Method Statement has been submitted and approved in writing by the local planning authority to provide for:

- (A) The parking of vehicles and site operatives and visitors - to be shown on a Plan not less than 1.500.
- (B) Loading and unloading of plant and materials used in constructing the development - Areas to be shown on a plan not less than 1.500
- (C) Storage of plant and materials used in constructing the development - Areas to be shown on a plan not less than 1.500
- (D) The erection and maintenance of security hoarding / scaffolding if required.
- (E) Wheel washing facilities
- (F) Measures on site to control the deposition of dirt / mud on surrounding roads during construction.
- (G) Footpath Closures / Road Closures needed during construction
- (H) Traffic Management needed during construction
- (I) Times, routes and means of access into and from the site for construction traffic and delivery vehicles (including the removal of waste from the site and methods of preventing deposition of materials on the public highway)
- (J) A scheme specifying the provisions to be made for the control of noise and dust emanating from the site during the demolition and construction phase.

The approved Construction Method Statement shall be adhered to throughout the development process unless agreed otherwise in writing by the Local Planning Authority.

Reason: In the interests of safety, protecting the amenity of local land uses, neighbouring residents and highway safety in accordance with Policy CS20 of the Reading Borough LDF Core Strategy 2008 (Altered 2015), Policy RC9 of the Reading Borough LDF Reading Central Area Action Plan 2009 and Policies DM4 and DM12 of the Sites and Detailed Policies Document 2012 (Altered 2015).

Date: 25th October 2016

Head of Planning, Development
& Regulatory Services

LEB



5. No development shall take place until an assessment of the nature and extent of contamination has been submitted to and approved in writing by the Local Planning Authority. This assessment must be undertaken by a competent person, and shall assess any contamination on the site, whether or not it originates on the site. Moreover, it must include:

- (i) a survey of the extent, scale and nature of contamination;
- (ii) an assessment of the potential risks to:
 - a) human health,
 - b) property (existing or proposed) including buildings, crops, livestock, pets, woodland and service lines and pipes,
 - c) adjoining land,
 - d) groundwaters and surface waters,
 - e) ecological systems,
 - f) archaeological sites and ancient monuments;

Reason: To ensure the development is suitable for its end use and the wider environment and does not create undue risks to occupiers of the site or surrounding areas in terms of contaminated land, in accordance with Policy CS34 of the Reading Borough LDF Core Strategy 2008 (Altered 2015), Policy RC9 of the Reading Borough LDF Reading Central Area Action Plan 2009 and Policy DM4 of the Sites and Detailed Policies Document 2012 (Altered 2015).

6. No development shall take place until a detailed remediation scheme to bring the site to a condition suitable for the intended use by removing unacceptable risks to human health, buildings and other property and the natural and historical environment has been submitted to and approved in writing by the Local Planning Authority. The scheme must include all works to be undertaken, proposed remediation objectives and remediation criteria, an appraisal of remedial options, and proposal of the preferred option(s), and a timetable of works and site management procedures. The scheme must ensure that the site will not qualify as contaminated land under Part 2A of the Environmental Protection Act 1990 in relation to the intended use of the land after remediation.

Reason: To ensure the development is suitable for its end use and the wider environment and does not create undue risks to occupiers of the site or surrounding areas in terms of contaminated land, in accordance with Policy CS34 of the Reading Borough LDF Core Strategy 2008 (Altered 2015), Policy RC9 of the Reading Borough LDF Reading Central Area Action Plan 2009 and Policy DM4 of the Sites and Detailed Policies Document 2012 (Altered 2015).

Date: 28th October 2016

Head of Planning, Development
& Regulatory Services

LEB



Reading

Borough Council

Working better with you

7. The remediation scheme shall be implemented in accordance with the approved timetable of works. A validation report (that demonstrates the effectiveness of the remediation carried out) must be submitted to and approved by the Local Planning Authority prior to the first construction of the development.

Reason: To ensure the development is suitable for its end use and the wider environment and does not create undue risks to occupiers of the site or surrounding areas in terms of contaminated land, in accordance with Policy CS34 of the Reading Borough LDF Core Strategy 2008 (Altered 2015), Policy RC9 of the Reading Borough LDF Reading Central Area Action Plan 2009 and Policy DM4 of the Sites and Detailed Policies Document 2012 (Altered 2015).

8. In the event that contamination is found at any time when carrying out the approved development not previously identified, development must be halted on that part of the site and it must be reported in writing to the Local Planning Authority.

Following that an assessment of the nature and extent of contamination must be undertaken and where remediation is necessary a remediation scheme, together with a timetable for its implementation, must be submitted to and approved in writing by the Local Planning Authority.

The measures in the approved remediation scheme must then be implemented in accordance with the approved timetable. Following completion of measures identified in the approved remediation scheme a validation report must be submitted to and approved in writing by the Local Planning Authority.

Reason: To ensure the development is suitable for its end use and the wider environment and does not create undue risks to occupiers of the site or surrounding areas in terms of contaminated land, in accordance with Policy CS34 of the Reading Borough LDF Core Strategy 2008 (Altered 2015), Policy RC9 of the Reading Borough LDF Reading Central Area Action Plan 2009 and Policy DM4 of the Sites and Detailed Policies Document 2012 (Altered 2015).

9. No development shall take place until a detailed land gas site investigation has been carried out by a competent person to fully and effectively characterise the nature and extent of land gas and its implications. The method and extent of this site investigation shall be agreed in writing with the Local Planning Authority prior to commencement of the work and shall then proceed in strict accordance with the measures approved.

Reason: To ensure the development is suitable for its end use and the wider environment and does not create undue risks to occupiers of the site or surrounding areas due to the presence of land gas, in accordance with Policy CS34 of the Reading

Date: 25th October 2016

Head of Planning, Development
& Regulatory Services

LEB

Borough LDF Core Strategy 2008 (Altered 2015), Policy RC9 of the Reading Borough LDF Reading Central Area Action Plan 2009 and Policy DM4 of the Sites and Detailed Policies Document 2012 (Altered 2015).

10. No development shall take place until a scheme showing how the development is to be protected against the possibility of land gas has been submitted to and approved in writing by the Local Planning Authority. The scheme as approved shall be fully implemented and completed before the development is first occupied and those measures incorporated into the development shall thereafter be retained unless the Local Planning Authority agrees otherwise in writing.

Reason: To ensure the development is suitable for its end use and the wider environment and does not create undue risks to occupiers of the site or surrounding areas due to the presence of land gas, in accordance with Policy CS34 of the Reading Borough LDF Core Strategy 2008 (Altered 2015), Policy RC9 of the Reading Borough LDF Reading Central Area Action Plan 2009 and Policy DM4 of the Sites and Detailed Policies Document 2012 (Altered 2015).

11. The land gas remediation scheme shall be implemented in accordance with the approved timetable of works. A validation report (that demonstrates the effectiveness of the remediation carried out) must be submitted to and approved by the Local Planning Authority prior to any part of the accommodation hereby approved is occupied, unless the Local Planning Authority otherwise agrees in writing.

Reason: To ensure the development is suitable for its end use and the wider environment and does not create undue risks to occupiers of the site or surrounding areas due to the presence of land gas, in accordance with Policy CS34 of the Reading Borough LDF Core Strategy 2008 (Altered 2015), Policy RC9 of the Reading Borough LDF Reading Central Area Action Plan 2009 and Policy DM4 of the Sites and Detailed Policies Document 2012 (Altered 2015).

12. No development shall take place until a detailed scheme, informed by an assessment of the current noise environment, for protecting the dwellings from the external noise environment of the area has been submitted to and approved, in writing, by the Local Planning Authority. The scheme itself shall be designed, specified and constructed so that the sound insulation performance of the structure and the layout of the dwellings are such that the indoor ambient noise levels do not exceed the values detailed in Table 4 of BS 8233:2014. Thereafter, the development shall not be carried out other than in accordance with the approved scheme which shall be completed before any part of the accommodation hereby approved is occupied, unless the Local Planning Authority otherwise agrees in writing.

Reason: To safeguard the amenities of future occupiers and

Date: 28th October 2016



Head of Planning, Development
& Regulatory Services

LEB



Reading

Borough Council
Working better with you

existing/future nearby occupiers from noise and disturbance, in accordance with Policy CS34 of the Reading Borough LDF Core Strategy 2008 (Altered 2015), Policy RC9 of the Reading Borough LDF Reading Central Area Action Plan 2009 and Policy DM4 of the Reading Borough LDF Sites and Detailed Policies Document 2012 (Altered 2015).

13. i) No development shall take place until full details of both hard and soft landscaping have been submitted to and approved in writing by the local planning authority. The submitted details shall include:

- a) pedestrian access and circulation areas, hard surfacing materials (with the use of permeable materials wherever possible), any outdoor structures and ancillary objects (outdoor seating, raised planters, railings etc);
- b) plan showing the existing and proposed functional services above and below ground (e.g. drainage, power, communications cables and pipelines indicating lines, manholes etc);
- c) planting plans (including feature tree); written specifications (including cultivation, tree pits and other operations associated with plant establishment); schedules of plants, noting species (to include large canopy, native and wildlife friendly species, and species likely to prove adaptable to climate change), noting species, planting sizes and proposed numbers / densities, where appropriate.
- d) Biodiversity enhancements, including integral bird nesting and bat roosting opportunities on and around the extended building

ii) All hard landscaping works shall be carried out in accordance with the approved details prior to first occupation of any residential unit.

iii) All planting and other soft landscaping shall be provided before the end of the first planting season following the first occupation of any residential unit.

iv) Any trees or plants that within a period of five years after planting are removed, die, or in the opinion of the Local Planning Authority become seriously damaged or defective, shall be replaced as soon as is reasonably practicable with others of the species, size and number as originally approved.

Reason: To ensure provision and retention of suitable hard and soft landscaping in the interests of the appearance of the development and wider area and to provide biodiversity enhancements in accordance with Policies CS7, CS33, CS36 and CS38 of the Reading Borough LDF Core Strategy 2008 (Altered 2015) and Policy DM18 of the Sites and Detailed Policies Document 2012 (Altered 2015).

14. i) No development shall take place until a final design stage BREEAM (Domestic Refurbishment) assessment has been submitted to and approved, in writing, by the

Date: 25th october 2016

Head of Planning, Development
& Regulatory Services

LEB



Reading
Borough Council

Working better with you

Local Planning Authority, demonstrating that a minimum 50% of units achieve an 'Excellent' rating, and the remainder achieve a 'Very Good' rating.

(ii) Prior to the first occupation of any residential unit, a final BREEAM (Domestic Refurbishment) certificate shall be submitted to and approved, in writing, by the Local Planning Authority, demonstrating that a minimum 50% of units achieve an 'Excellent' rating, and the remainder achieve a 'Very Good' rating.

Reason: To ensure that the development contributes adequately towards environmental sustainability, in accordance with Policy CS1 of the Reading Borough LDF Core Strategy 2008 (Altered 2015) and Policy DM1 of the Sites and Detailed Policies Document 2012 (Altered 2015).

15. No development shall take place until details of an implementation, maintenance and management plan of the sustainable drainage scheme have been submitted to and approved by the Local Planning Authority. The scheme shall be implemented and thereafter managed and maintained in accordance with the approved plan. The plan shall include:

- i. a timetable for its implementation, and
- ii. a management and annual maintenance plan for the lifetime of the development which shall include the arrangements for adoption by any public body or statutory undertaker, or any other arrangements to secure the operation of the sustainable drainage scheme throughout its lifetime.

Reason: To ensure that the development contributions adequately towards environmental sustainable urban drainage, in accordance with Policy CS1 of the Reading Borough LDF Core Strategy 2008 (Altered 2015) and Policy DM1 of the Sites and Detailed Policies Document 2012 (Altered 2015).

16. No dwelling hereby permitted shall be occupied until the sustainable drainage scheme for the site has been completed in accordance with the approved details.

Reason: To ensure that the development contributions adequately towards environmental sustainable urban drainage, in accordance with Policy CS1 of the Reading Borough LDF Core Strategy 2008 (Altered 2015) and Policy DM1 of the Sites and Detailed Policies Document 2012 (Altered 2015).

17. The development permitted by this planning permission shall only be carried out in accordance with the approved Flood Risk Assessment (FRA) carried out by Weetwood dated February 2016 ref: 2969/FRA v1.0 and e-mail correspondence (and attached drawings/plans) dated 7 June 2016 to the Environment Agency from Mr Rhys Hughes and the following mitigation measures detailed within the FRA:

Date: 28th October 2016

Head of Planning, Development
& Regulatory Services

LEB



Reading
Borough Council

Working better with you

1. Finished floor levels of the northern building will be set no lower than 39.85 m AOD
2. Finished floor levels of the southern building will be set no lower than 38.92 m AOD

Reason: To reduce the risk of flooding to the proposed development and future occupants and to reduce the risk of flooding to the proposed development and future occupants, in accordance with Policy CS35 of the Reading Borough LDF Core Strategy 2008 (Altered 2015).

18. Prior to the first occupation of any residential unit hereby approved, the bicycle store and all bicycle storage spaces shall have been provided in accordance with approved plan 14/354/P08 Rev G - Proposed Floor Plans Level 1, as received 01/09/16. The bicycle store and spaces shall be retained, as approved, at all times thereafter solely for cycle storage purposes.

Reason: To ensure that adequate provision is made for travel to and from the site by sustainable alternatives to a motorcar, in accordance with Policies CS22 and CS24 of the Reading Borough LDF Core Strategy 2008 (Altered 2015) and Policy DM12 of the Reading Borough LDF Sites and Detailed Policies Document 2012 (Altered 2015).

19. Prior to the first occupation of any residential unit hereby approved, the waste and recycling storage shall be provided in accordance with approved plans 14/354/P08 Rev G - Proposed Floor Plans Level 1, as received 01/09/16 and 14/354/P19 - Proposed Bin Store Enclosure, as received 31/03/16. The waste and recycling storage shall be retained, as approved, at all times thereafter solely for waste and recycling storage and collection purposes.

Reason: To ensure that sufficient provision is made for the storage and collection of refuse and recyclables and to safeguard the amenity of existing nearby and future occupiers from potential disturbance and/or smells, in accordance with Policy CS2 of the Reading Borough LDF Core Strategy 2008 (Altered 2015) and Policy DM4 of the Sites and Detailed Policies Document 2012 (Altered 2015).

20. The residential flats hereby approved shall not be occupied until the Council has been notified in writing of the full postal address of the units. Such notification shall be addressed to the Council's Planning Manager (Implementation) quoting the planning application reference specified in this Decision Notice.

Reason: In order that the Council can update its records to ensure that parking permits are not issued to the occupiers of the new residential units hereby approved, and thus ensure that the development does not harm the existing amenities of the occupiers of neighbouring residential properties by adding to the already high level of on street car parking in the area, in accordance with Policy CS24 of the Reading Borough LDF Core

Date: 28th October 2016

Head of Planning, Development
& Regulatory Services

LEB



Strategy 2008 (Altered 2015) and Policy DM12 of the Sites and Detailed Policies Document 2012 (Altered 2015).

21. Prior to any agreement being entered into for a new occupation of, or transfer of any interest in, the residential flats hereby approved the prospective occupier/transferee shall be informed of the prohibition on entitlement to a car parking permit. All material utilised for advertising or marketing the residential flats for letting or sale shall make it clear to prospective tenants and occupiers that no parking permit will be issued by the Council to occupiers of the residential flats.

Reason: In order that the prospective occupiers are made aware of the fact that they will not be entitled to an on-street car parking permit, in the interests of the proper management of parking, and to ensure that the development does not harm the existing amenities of the occupiers of neighbouring residential properties by adding to the already high level of on street car parking in the area, in accordance with Policy CS24 of the Reading Borough LDF Core Strategy 2008 (Altered 2015) and Policy DM12 of the Sites and Detailed Policies Document 2012 (Altered 2015).

22. In connection with the implementation of this permission, no works shall take place outside the hours of 08:00hrs to 18:00hrs Mondays to Fridays, and 09:00hrs to 13:00hrs on Saturdays, and not at any time on Sundays and Bank or Statutory Holidays without prior approval from the Local Planning Authority.

Reason: To protect the amenity of occupiers of existing nearby properties from noise and disturbance from works connected with implementing this permission, in accordance with Policy CS34 of the Reading Borough LDF Core Strategy 2008 (Altered 2015) and Policy DM4 of the Sites and Detailed Policies Document 2012 (Altered 2015).

23. Prior to the first occupation of the relevant residential units, the windows annotated to be obscure glazed on approved plans 14/354/P08 Rev G - Proposed Floor Plans Level 1, as received 01/09/16; 14/354/P09 Rev F - Proposed Floor Plans Level 2, as received 01/09/16; 14/354/P10 Rev F - Proposed Second Floor Plans Level 3, as received 01/09/16; 14/354/P11 Rev F - Proposed Third Floor Plans Level 4, as received 01/09/16; 14/354/P12 Rev F - Proposed Floor Plans Level 5, as received 01/09/16; 14/354/P13 Rev F - Proposed Fifth Floor Plans Level 6, as received 01/09/16, shall be provided as such in full. All windows identified on the approved drawings as being obscure glazed shall be non-opening unless that part of the window which can be opened is a minimum of 1.7m above the internal floor level. These windows will be permanently retained and maintained thereafter as obscure glazed.

Reason: To protect the amenity of nearby occupiers from harmful overlooking and subsequent loss of privacy, in accordance with Policy DM4 of the Sites and Detailed Policies Document 2012 (Altered 2015).

Date: 28th October 2016

Head of Planning, Development
& Regulatory Services

LEB



Reading
Borough Council

Working better with you

24. Prior to the first occupation of any residential unit hereby approved, the energy measures hereby approved in the Energy & Sustainability Assessment By Sol Environment Ltd, Ref SOL1602ENT01, dated 29 February 2016, as received 01/03/16, shall be provided as such in full.

Reason: To ensure that the development contributions adequately towards environmental sustainability through energy measures, in accordance with Policy CS1 of the Reading Borough LDF Core Strategy 2008 (Altered 2015) and Policy DM1 of the Sites and Detailed Policies Document 2012 (Altered 2015).

INFORMATIVES

1. Officers have worked positively and proactively with the applicant to address and satisfactorily resolve various matters which have arisen as part of the assessment of the application, in order to provide a recommendation for approval in as expedient a timescale as has been possible in this instance.
2. The attention of the applicant is drawn to Section 59 of the Highways Act 1980, which enables the Highway Authority to recover expenses due to damage caused by extraordinary traffic.
3. The occupiers of the flats will not be entitled to an on-street car parking permit in the interests of the proper management of parking, and to ensure that the development does not harm the existing amenities of the occupiers of neighbouring residential properties by adding to the already high level of on street car parking in the area in accordance with adopted RBLP policy TRN12. The site is located close to local facilities, with frequent public transport services on nearby roads. The conditions attached place a requirement that the Council be notified of postal addresses of the residential units before occupation and that the occupiers/transferees to be informed of the prohibition on entitlement to a car parking permit.
4. Any works affecting the highway shall be in accordance with Reading Borough's Council's document "Guidance Notes for Activities on the Public Highway within the Borough of Reading". The applicant should be made aware that compliance with this document is mandatory and licences to work on the highway will only be issued if the requirements contained within it are met. A copy can be obtained within the Transport Strategy area of the Transport Section on the Reading Borough Web Site.

Date: 28th October 2016

Head of Planning, Development
& Regulatory Services

LEB



Reading

Borough Council
Working better with you

5. No materials or green waste produced as a result of the clearance of the site, demolition works or construction works associated with the development hereby approved shall be burnt on site.

6. A Unilateral Undertaking relates to this site, linked to this permission (LPA Ref No. 4255). A full copy of the unilateral undertaking is available on the Public Register held by Reading Borough Council.

7. Thames Water advises with regard to surface water drainage it is the responsibility of a developer to make proper provision for drainage to ground, water courses or a suitable sewer. In respect of surface water it is recommended that the applicant should ensure that storm flows are attenuated or regulated into the receiving public network through on or off site storage. When it is proposed to connect to a combined public sewer, the site drainage should be separate and combined at the final manhole nearest the boundary. Connections are not permitted for the removal of groundwater. Where the developer proposes to discharge to a public sewer, prior approval from Thames Water Developer Services will be required. They can be contacted on 0800 009 3921.

Thames Water requests that the Applicant should incorporate within their proposal, protection to the property by installing for example, a non-return valve or other suitable device to avoid the risk of backflow at a later date, on the assumption that the sewerage network may surcharge to ground level during storm conditions.

With regards to water, Thames Water will aim to provide customers with a minimum pressure of 10m head (approx 1 bar) and a flow rate of 9 litres/minute at the point where it leaves Thames Waters pipes. The developer should take account of this minimum pressure in the design of the proposed development.

8. The approved development is liable to pay the Community Infrastructure Levy (CIL) in line with the Council's CIL Charging Schedule. Upon permission or soon after, the Council will issue you with a CIL Liability Notice, which details the CIL amount payable.

CIL is not payable until commencement of the development, but before commencement you must submit a CIL Commencement Notice to the Council. Failure to submit a Commencement Notice before commencement may mean that a surcharge is imposed, and will mean that the liable party will not be able to benefit from the Council's Instalment Policy and that any claims for relief are void.

It is strongly advised that, before commencement, you submit an Assumption of Liability Form if you have not already done so. If at commencement no party has assumed liability to pay CIL, liability will default to the landowner(s), a surcharge may

Date: 28th October 2016

Head of Planning, Development
& Regulatory Services

LEB



Reading
Borough Council

Working better with you

be imposed, and the liable party will not be able to benefit from the Council's Instalment Policy.

If the development is eligible for a form of relief from CIL, a claim must be made prior to commencement. Claims made after commencement cannot be considered.

More information on CIL, including copies of the forms referred to above, are on the Planning Portal website:

(https://www.planningportal.co.uk/info/200126/applications/70/community_infrastructure_levy) and the Charging Schedule and Advice to Applicants are on the Council's website

(<http://www.reading.gov.uk/media/2594/Community-Infrastructure-Levy-Charging-Schedule/pdf/Community-Infrastructure-Levy-Charging-Schedule-20151.pdf> & http://www.reading.gov.uk/media/2791/Community-Infrastructure-Levy-Advice-to-Applicants/pdf/CIL_Advice_to_Applicants.pdf)

9. Your attention is drawn to the terms and conditions of this permission. Any development which is carried out but differs materially from the approved plans and details, or does not comply with any conditions attached to the permission may result in the Council taking action to remedy the breach of planning control. If you are in any doubt please contact the council.

For the avoidance of doubt, the following conditions requires details to be submitted and approved in writing by the local planning authority prior to any development taking place (pre-commencement conditions):

Conditions 3, 4, 5, 6, 7, 9, 10, 12, 13i), 14i), 15

For the avoidance of doubt, the following conditions require details to be submitted and approved in writing by the local planning authority prior to the first occupation of any unit (pre- occupation conditions):

Conditions 11, 14ii), 20

For the avoidance of doubt, the following conditions do not require details to be submitted /approved, but are required to be complied with prior to the first occupation of any unit (compliance conditions):

Conditions 13ii), 16, 17, 18, 19, 21, 22, 23, 24

10. These works will require separate approval under the Building Regulations. Please contact the Council's Building Control service for further advice on (0118) 937 2449.

Date: 28th October 2016

Head of Planning, Development
& Regulatory Services

LEB

NOTES

APPEALS TO THE SECRETARY OF STATE

If you are aggrieved by the decision of the Council to refuse permission for the proposed development or to grant it subject to conditions, then you can appeal to the Secretary of State under section 78 of the Town and Country Planning Act 1990.

If this is a decision on a planning application relating to the same or substantially the same land and development as is already the subject of an enforcement notice, if you want to appeal against the Council's decision on the application you must do so within 28 days of the date of this notice.

If an enforcement notice is served relating to the same or substantially the same land and development as in your application and you want to appeal against the Council's decision on your application, you must do so within 28 days of the date of service of the enforcement notice, or within 6 months (or 12 weeks in the case of a householder appeal) of the date of this notice, whichever period expires earlier.

If the above circumstances do not apply, any appeal must be made within the following time limits.

If this is a householder application and you want to appeal against the Council's decision then you must do so within 12 weeks of the date of this notice. If this is an advertisement application and you want to appeal against your local planning authority's decision then you must do so within 8 weeks of the date of this notice. If you want to appeal against your local planning authority's decision for any other type of application (which is not a householder or advertisement application, or an application for a Certificate of Lawfulness) then you must do so within 6 months of the date of this notice.

The Secretary of State can allow a longer period for giving notice of an appeal, but he will not normally be prepared to use this power unless there are special circumstances which excuse the delay in giving notice of appeal. The Secretary of State need not consider an appeal if it seems to him that the Local Planning Authority could not have granted planning permission for the proposed development or could not have granted it without the conditions they imposed, having regard to the statutory requirements, to the provisions of any development order and to any directions given under a development order. In practice, the Secretary of State does not refuse to consider appeals solely because the Local Planning Authority based their decision on a direction given by him.

Appeals must be made using a form which you can get from the Planning Inspectorate at Temple Quay House, 2 The Square, Temple Quay, Bristol BS1 6PN, tel. 0303 444 5000, or online at www.planningportal.gov.uk/pcs.

Purchase Notices

If either the Local Planning Authority or the Secretary of State refuses permission to develop land or grants it subject to conditions, the owner may claim that he can neither put the land to a reasonably beneficial use in its existing state nor render the land capable of a reasonably beneficial use by the carrying out of any development which has been or would be permitted. In these circumstances, the owner may serve a purchase notice on the Council in whose area the land is situated. This notice will require the Council to purchase his interest in the land in accordance with the provisions of Part VI of the Town and Country Planning Act 1990.

Street Naming & Numbering

You must contact Reading Borough Council to:

- Name or number a new development
- Name a new street
- Get addresses for flat conversions
- Name or rename an existing building

Otherwise the following may occur:

- You will not have an official address or postcode. When your property goes through the official process it may be given a different address and Postcode than you are currently using.
- You may have difficulty receiving mail
- You may have problems when buying goods or services such as utilities and telecommunications
- The emergency services may have difficulty locating you.
- You may have problems accessing Council services such as Education, Parking Services and Electoral Registration.

The Council is responsible for assigning house names and numbers and street names. It is also responsible for updating the National Land and Property Gazetteer (NLPG) which is a list of addresses which meet a common standard (BS7666) used throughout the country.

When a new address or change of address is requested, the Council contacts Royal Mail who check the address on behalf of the Emergency Services, assign a postcode and add it to their Postal Address File (PAF). The PAF list is used by many companies and services to check addresses, authenticate transactions and order goods, as well as deliver mail, so it is in your interest for your address to be on that list. Royal Mail will not create an address until requested to do so by the Council.

How to apply:

Email us using streetnamingnumbering@reading.gov.uk

Or telephone us on 0118 9373737

What we need to complete your request:

For new addresses or flat conversions:

- Site layout plan containing plot numbers
- Location plan - No bigger than A3 size (hard copy, PDF, JPEG or AutoCAD) showing the site boundary, including the new development, together with surrounding buildings for reference
- Anticipated completion and occupation dates

For change of address:

- You must be, or have authorisation from, the owner to request a change of address.
- Floor plan of the existing property
- Reason for change

Once created, the Council informs various bodies of your new address including the Emergency Services, Council Tax, Land Registry and utility companies as well as adding it to the National Land and Property Gazetteer.

Please be advised that companies and services using the PAF file only update the addresses monthly, quarterly or even less frequently, therefore it may take a while for your address to be listed in some places. It will, however, appear on the Royal Mail website within a few days once it has been added to the live address file.

Reading Borough Council has no control over the frequency by which other organisations update their address files.

Dunthorne Parker Architects
Unit 22 The Artworks
Elephant Road
London
SE17 1AY

Giorgio Framalicco
Head of Planning, Development
& Regulatory Services

Civic Offices, Bridge Street,
Reading, RG1 2LU

☎ 0118 9373787

Our Ref: 172304

Your Ref: PP-06623031

Direct ☎:

e-mail: Jonathan.Markwell@reading.gov.uk

8 February 2018

Your contact is: Mr Jonathan Markwell, Planning

Dear Dunthorne Parker Architects,

TOWN AND COUNTRY PLANNING ACT 1990

Application Reference: 172304

Application type: Approval of Conditions

Address: Former Gas Works Buildings Gas Works Road Reading

Proposal: Partial discharge of condition 4 (Construction Method Statement) and discharge of conditions 5 (Contaminated Land) & 9 (Land Gas) of planning permission 160378.

I refer to the above application to partially discharge the remaining element of condition 4 (Construction Method Statement) and the discharge of conditions 5 (Contaminated Land) & 9 (Land Gas) of planning permission 160378 and respond as follows:

Condition 4

The construction method statement details, as shown on the following:

Construction Method Statement Rev A by DPA, as received 06/02/18

208 - Parking Plan, as received 06/02/18

are approved pursuant to condition 4.

In conjunction with approval of details 171160 (Construction Method Statement details for initial demolition works only) granted on 21/09/17 it is confirmed that condition 4 is now discharged in full.

Condition 5

The Senior Environmental Health Officer has commented as follows: A site investigation satisfying the requirements of the condition has been carried out. Elevated levels of chromium, lead, mercury, PAHs and TPHs associated with the former use of the site have been identified, it will therefore be

necessary for a DQRA to be carried out and a remediation scheme to be submitted. I can recommend discharge of condition 5.

Accordingly the contaminated land details, as shown in the following document:

Phase 2 Interpretative Site Investigation Report by Wardell Armstrong, Ref RPT002 V1.0, dated December 2017, as received 20/12/17

are approved pursuant to condition 5.

Condition 9

The Senior Environmental Health Officer has commented as follows: A land gas investigation has been carried out. It has identified elevated levels of methane which result in the site being considered characteristic situation 2. The details of how the development will be protected to this level must now be submitted. I can recommend that condition 9 is discharged.

Accordingly the land gas details, as shown in the following document:

Phase 2 Interpretative Site Investigation Report by Wardell Armstrong, Ref RPT002 V1.0, dated December 2017, as received 20/12/17

are approved pursuant to condition 9.

The above conditions, where a submission is required and has been provided, shall have been considered to have been discharged, providing that the development is undertaken in accordance with the approved details.

Please note that it is the responsibility of the developer to ensure that all relevant conditions are complied with during the construction and/or subsequent use of the development.

Should you wish to discuss this matter further, please contact me by email or the direct line as above.

Yours sincerely

Jonathan Markwell

Mr Jonathan Markwell

Appendix 2 Human Health – SSAC

CLEA Software Version 1.071

Page 1 of 11

Report generated 12-Feb-18

Report title Gas Works Road, Reading

Created by AS at Wardell Armstrong



RESULTS

[illegible]



Environment
Agency

[illegible]

Environment Agency		Soil Distribution				Media Concentrations													
		Sorbed	Dissolved	Vapour	Total	Soil	Soil gas	Indoor Dust	Outdoor dust at 0.8m	Outdoor dust at 1.6m	Indoor Vapour	Outdoor vapour at 0.8m	Outdoor vapour at 1.6m	Green vegetables	Root vegetables	Tuber vegetables	Herbaceous fruit	Shrub fruit	Tree fruit
		%	%	%	%	mg kg ⁻¹	mg m ⁻³	mg kg ⁻¹	mg m ⁻³	mg m ⁻³	mg m ⁻³	mg m ⁻³	mg m ⁻³	mg kg ⁻¹ FW	mg kg ⁻¹ FW	mg kg ⁻¹ FW	mg kg ⁻¹ FW	mg kg ⁻¹ FW	mg kg ⁻¹ FW
1	Chromium (VI) (S4UL)	97.0	3.0	0.0	100.0	6.05E+00	NR	3.02E+00	2.57E-09	0.00E+00	0.00E+00	0.00E+00	1.21E-03	6.05E-04	6.05E-04	5.44E-01	1.81E-03	5.44E-01	
2	Mercury-elemental (S4UL)	99.7	0.3	0.0	100.0	4.45E+00	3.09E+00	2.22E+00	1.89E-09	0.00E+00	3.84E-05	5.26E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
3	Aromatic EC >10-12 (S4UL)	98.1	1.8	0.0	100.0	1.56E+02	3.80E+02	7.81E+01	6.65E-08	0.00E+00	6.31E-04	4.06E-05	0.00E+00	3.05E+01	4.12E+01	1.18E+01	0.00E+00	0.00E+00	
4	Aromatic EC >12-16 (S4UL)	99.1	0.9	0.0	100.0	2.72E+02	5.84E+01	1.36E+02	1.16E-07	0.00E+00	1.51E-04	2.74E-05	0.00E+00	2.94E+01	4.03E+01	1.52E+01	0.00E+00	0.00E+00	
5	Aromatic EC >16-21 (S4UL)	99.7	0.3	0.0	100.0	4.63E+02	1.96E+00	2.32E+02	1.97E-07	0.00E+00	1.81E-05	2.01E-05	0.00E+00	1.70E+01	2.66E+01	1.59E+01	0.00E+00	0.00E+00	
6	Aromatic EC >21-35 (S4UL)	100.0	0.0	0.0	100.0	1.41E+03	2.40E-02	7.06E+02	6.01E-07	0.00E+00	3.13E-07	2.00E-05	0.00E+00	2.45E+00	9.58E+00	1.43E+01	0.00E+00	0.00E+00	
7	Benzo(a)anthracene (S4UL)	99.9	0.1	0.0	100.0	1.14E+01	4.00E-04	5.70E+00	4.85E-09	0.00E+00	5.03E-08	1.27E-07	0.00E+00	3.37E-02	1.25E-01	8.68E-02	0.00E+00	0.00E+00	
8	Benzo(a)pyrene (S4UL)	100.0	0.0	0.0	100.0	2.64E+00	3.11E-06	1.32E+00	1.12E-09	0.00E+00	4.50E-10	2.24E-08	0.00E+00	3.30E-03	1.76E-02	1.25E-02	0.00E+00	0.00E+00	
9	Benzo(b)fluoranthene (S4UL)	100.0	0.0	0.0	100.0	3.18E+00	5.37E-06	1.59E+00	1.35E-09	0.00E+00	7.51E-10	2.98E-08	0.00E+00	5.62E-03	2.60E-02	1.79E-02	0.00E+00	0.00E+00	
10	Benzo(k)fluoranthene (S4UL)	100.0	0.0	0.0	100.0	9.01E+01	9.13E-05	4.50E+01	3.83E-08	0.00E+00	1.32E-08	7.09E-07	0.00E+00	8.74E-02	5.22E-01	3.70E-01	0.00E+00	0.00E+00	
11	Chrysene (S4UL)	99.9	0.1	0.0	100.0	2.06E+01	1.03E-04	1.03E+01	8.78E-09	0.00E+00	1.37E-08	2.72E-07	0.00E+00	1.05E-01	3.19E-01	2.09E-01	0.00E+00	0.00E+00	
12	Dibenzo(ah)anthracene (S4UL)	100.0	0.0	0.0	100.0	2.81E-01	7.02E-07	1.40E-01	1.20E-10	0.00E+00	9.22E-11	1.91E-09	0.00E+00	1.80E-04	1.29E-03	8.79E-04	0.00E+00	0.00E+00	
13	Fluoranthene (S4UL)	99.7	0.3	0.0	100.0	4.83E+02	1.44E-01	2.42E+02	2.06E-07	0.00E+00	1.73E-05	1.16E-05	0.00E+00	1.21E+01	2.21E+01	1.17E+01	0.00E+00	0.00E+00	
14	Indeno(123-cd)pyrene (S4UL)	99.9	0.1	0.0	100.0	3.45E+01	7.01E-05	1.73E+01	1.47E-08	0.00E+00	9.75E-09	3.49E-07	0.00E+00	8.44E-02	3.39E-01	2.22E-01	0.00E+00	0.00E+00	
15	Naphthalene (S4UL)	93.2	6.8	0.0	100.0	5.32E+01	4.39E+01	2.66E+01	2.27E-08	0.00E+00	9.61E-04	9.47E-06	0.00E+00	2.70E+01	3.92E+01	9.58E+00	0.00E+00	0.00E+00	
16	Phenanthrene (S4UL)	99.2	0.8	0.0	100.0	1.82E+02	4.04E-01	9.09E+01	7.74E-08	0.00E+00	4.41E-05	8.14E-06	0.00E+00	1.81E+01	2.57E+01	9.14E+00	0.00E+00	0.00E+00	
17																			
18																			
19																			
20																			

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Appendix 3 Human Health – SSAC (Indoor and Outdoor Inhalation Pathways)

CLEA Software Version 1.071

Page 1 of 11

Report generated 15-Feb-18

Report title Gas Works Road, Reading

Created by AS at Wardell Armstrong



RESULTS

[illegible]



Environment
Agency

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Environment Agency		Oral Health Criteria Value ($\mu\text{g kg}^{-1}$ BW day ⁻¹)		Inhalation Health Criteria Value ($\mu\text{g kg}^{-1}$ BW day ⁻¹)		Oral Mean Daily Intake ($\mu\text{g day}^{-1}$)		Inhalation Mean Daily Intake ($\mu\text{g day}^{-1}$)		Air-water partition coefficient (K_{ow}) ($\text{cm}^3 \text{cm}^{-3}$)		Coefficient of Diffusion in Air ($\text{m}^2 \text{s}^{-1}$)		Coefficient of Diffusion in Water ($\text{m}^2 \text{s}^{-1}$)		$\log K_{ow}$ ($\text{cm}^3 \text{g}^{-1}$)		$\log K_{ow}$ (dimensionless)		Dermal Absorption Fraction (dimensionless)		Soil-to-dust transport factor (g g^{-1} DW)		Sub-surface soil to indoor air correction factor (dimensionless)		Relative bioavailability via soil ingestion (unitless)		Relative bioavailability via dust inhalation (unitless)		
1	Chromium (VI) (S4UL)	TDI	0.9	ID	0.0001	6.7	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
2	Mercury-elemental (S4UL)	NR	0	TDI	0.06	0	0.026	1.17E-01	6.34E-06	2.00E-09	4.16	0.62	0	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	Aromatic EC >10-12 (S4UL)	TDI	40	TDI	60	9.99E+99	9.99E+99	7.22E-02	1.00E-05	1.00E-09	3.4	3.93	0.1	0.5	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	Aromatic EC >12-16 (S4UL)	TDI	40	TDI	60	9.99E+99	9.99E+99	1.26E-02	1.00E-05	1.00E-09	3.7	4.29	0.1	0.5	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	Aromatic EC >16-21 (S4UL)	TDI	30	NR	0	9.99E+99	0	6.95E-04	1.00E-05	1.00E-09	4.15	4.82	0.1	0.5	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	Aromatic EC >21-35 (S4UL)	TDI	30	NR	0	9.99E+99	0	2.48E-05	1.00E-05	1.00E-09	5.1	5.95	0.1	0.5	10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	Benzo(a)anthracene (S4UL)	ID	0.155	ID	0.0015	0.06	0.011	3.16E-05	4.60E-06	3.80E-10	4.89	5.91	0.13	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	Benzo(a)pyrene (S4UL)	ID	0.031	ID	0.0003	0.11	0.006	1.76E-06	4.38E-06	3.67E-10	5.11	6.18	0.13	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	Benzo(b)fluoranthene (S4UL)	ID	0.039	ID	0.00038	0.11	0.013	2.05E-06	4.36E-06	3.62E-10	5.02	6.08	0.13	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	Benzo(k)fluoranthene (S4UL)	ID	1.03	ID	0.01	0.09	0.007	1.74E-06	4.36E-06	3.62E-10	5.17	6.26	0.13	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	Chrysene (S4UL)	ID	0.31	ID	0.003	0.11	0.017	3.18E-06	4.57E-06	3.77E-10	4.74	5.73	0.13	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	Dibenzo(ah)anthracene (S4UL)	ID	0.0031	ID	0.00003	0.04	0.033	5.40E-06	4.08E-06	3.40E-10	5.27	6.38	0.13	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	Fluoranthene (S4UL)	TDI	12.5	TDI	12.5	0.35	0.084	6.29E-05	5.01E-06	4.11E-10	4.26	5.13	0.13	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	Indeno(123-cd)pyrene (S4UL)	ID	0.443	ID	0.0043	0.1	0.009	2.05E-06	4.17E-06	3.51E-10	4.94	5.97	0.13	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	Naphthalene (S4UL)	TDI	20	TDI	0.86	7	2.8	6.62E-03	6.52E-06	5.16E-10	2.81	3.34	0.13	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	Phenanthrene (S4UL)	TDI	12.5	TDI	12.5	1.54	0.518	1.43E-04	5.34E-06	4.32E-10	3.74	4.5	0.13	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17																														
18																														
19																														
20																														

[illegible]

Appendix 4 Human Health – Wilson Modular Approach for Inhalation of Vapours in Indoor Air

		Contaminant:	Naphthalene					Building Type:	Pre-1970 office						
		HCV _{inh} (ID or TDSI):	0.82	=	2.87			Soil Type:	Silty clay						
			µg/kg-d		µg/m³										
		Calculated Indoor Vapour Concentration from Equation 10 below for comparison with HCV _{inh}	C _{building}	7.02E-03	µg/m³										
Wilson eq			Input Parameters		units			Calculated Variables		units		Outputs		units	
Source Vapour Concentration in Soil Air from Soil Contamination															
(2)	Soil Concentration	C _R	490	mg/kg				C _R	0.00049	g/g					
	Soil dry bulk density	ρ _b	0.94	g/cm³											
	Dimensionless Henry's Law constant (or K _{aw})	H' _{TS}	0.00662	-											
	Soil air filled porosity	θ _a	0.12	cm³/cm³											
	Soil water filled porosity	θ _w	0.51	cm³/cm³				θ _t	0.63	cm³/cm³					
	Octanol-water partition coefficient	K _{oc}	645.6542	cm³/g											
	Soil fraction organic carbon	f _{oc}	0.019	-				K _d	12.26743	cm³/g		C _{source}	2.53E-07	g/cm³	
Source Vapour Concentration in Soil Air from Groundwater Contamination															
(3)	Groundwater concentration	C _w	19.1	µg/l				C _w	1.91E-08	g/cm³					
	Dimensionless Henry's Law constant (or K _{aw})	H' _{TS}	0.00662	-								C _{source}	1.26E-10	g/cm³	
Source Vapour Concentration in Soil Air from NAPL															
(4)	NAPL Mole fraction	X _i		-											
	Vapour Pressure	P _i	2.28E-05	atm											
	Moelcular Weight	MW	128.17	g/mol											
	Universal Gas Constant	R	8.21E-05	m³atm/molK											
	Soil Temperature	T	283.15	K								C _{source}	0.00E+00	g/cm³	
Combined Vapour Concentration from Soil, Groundwater and / or NAPL															
	Sum of C _{source} calculated individually for soil, groundwater and NAPL.											C _{source}	2.53E-07	g/cm³	
Diffusive Flow from Ground to Void															
(5)	Floor Area	A _b	4.24E+06	cm²											
	Soil (S), Water (W), NAPL (N) or (C) combined	Source Type	C	-											
	Vapour concentration at top of soil	C _{so}	0.00E+00	g/cm³											
	Diffusion coefficient in air	D _{air}	6.52E-02	cm²/s											
	Diffusion coefficient in water	D _{water}	5.16E-06	cm²/s				D _{eff}	3.50E-04	cm²/s					
	Depth to Source	L	50	cm								E	7.51E-06	g/s	
Concentration in Void after Dilution by Fresh Air in Void															
(7)	Air Exchanges in Void	V _{ex}		1/day				T _{exchange}	#DIV/0!	s					
	Void Height	H _{void}	15	cm				Q _{void}	4782.54	cm³/s					
	Vapour concentration in outdoor air	C _e	0.00E+00	g/cm³											
	Use Air exchange/day (1) or BS5925 (2)	1 or 2	2	-								C _{void}	1.57E-09	g/cm³	
Advective Flow from Void (Ground) Through Cracks into Building															
(9)	Pressure difference	ΔP	4.4	Pa											
	Intrinsic permeability of floor slab	k _v	2.00E-07	cm²											
	Area of cracks in floor slab	A _{crack}	1647.3	cm²											
	Viscosity of air	μ	1.80E-05	Pa s											
	Thickness of floor slab	D _{crack}	15	cm								Q _{entry}	8.43E-09	g/s	
Diffusive Flow from Void through slab/barrier into building															
	Floor Area	A _b	4.24E+06	cm²											
	Vapour concentration in building	C _{so}		g/cm³											
	Effective Diffusion coefficient for whole slab (barrier)	D _{eff}		cm²/s											
	Slab/barrier thickness	L		cm								Q _{entry}	#DIV/0!	g/s	
Concentration in Building after Dilution by Fresh Air in Void (Advective flow - no Barrier)															
(10)	Air exchange rate in building	B _{ex}	1	1/hr											
	Vapour concentration in outdoor air	C _e	0.00E+00	g/cm³											
	Building height	H	1020	cm				Q _{building}	1.20E+06	cm³/s		C _{building}	7.02E-15	g/cm³	
													7.02E-03	µg/m³	
Concentration in Building after Dilution by Fresh Air in Void (Diffusive Flow - Vapour Barrier)															
(10)	Air exchange rate in building	B _{ex}	1	1/hr											
	Buiding height	H	1020	cm				Q _{building}	1.20E+06	cm³/s		C _{building}	#DIV/0!	g/cm³	
													#DIV/0!	µg/m³	

Appendix 5 Human Health – SSAC (Outdoor Inhalation Pathways)

CLEA Software Version 1.071

Page 1 of 11

Report generated 15-Feb-18

Report title Gas Works Road, Reading



Created by AS at Wardell Armstrong

RESULTS

[illegible]



Environment
Agency

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Appendix 6 Controlled Waters – DQRA Input Parameters

Source:**Made Ground**

Parameter	Variable	Value	Units	Data Source
Natural Moisture Content		24	% wt	From 2010 SI and 2017 SI.
Particle Density		2.78	tonnes/m3	Default value
Dry Bulk Density		1.59	tonnes/m3	From Atkins (2013), representative value to gravelly sand. Checked (ConSim manual)
Water filled soil porosity	qW	0.38	fraction	Calculated using porosity calculator
Air filled soil porosity	qa	0.05	fraction	Calculated using porosity calculator
Bulk density of soil zone material	r	0.94	g/cm ³	Default value for Silty Clay from Environment Agency (2009)
Infiltration	Inf	0.001	m/d	Assumed 20% infiltration of average annual effective rainfall (rainfall - MORECS AE) plus 30mm/a leakage from drains
Area of contaminant source	A	464	m ²	Based on site width (16m) and length (29m) from Atkins (2013) (measured from site plan). Checked (site plan)
Length of contaminant source in direction of groundwater flow	L	29	m	From Atkins (2013), based on site length (measured from site plan) in direction of groundwater flow (to E). Checked (site plan)
Width of contaminant source perpendicular to groundwater flow	w	16	m	Based on site width (16m) from Atkins (2013) (measured from site plan). Checked (site plan)
Fraction of organic carbon (in soil)	foc	0.011	fraction	From 2017 SI (average of made ground values)

Potential Pollutant Linkage (PPL):**CW1****Shallow Superficial Aquifer**

Parameter	Variable	Value	Units	Data Source
Saturated aquifer thickness	da	5.3	m	Calculated from average thickness of Alluvium and Sand and Gravel and average groundwater level from 2017 SI
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.00E-02	m/d	Falling head tests carried out in 2012 indicate 2.76E-04m/d (Atkins, 2013) but sand and gravels will be higher
Hydraulic gradient of water table	i	0.03	fraction	From 12/12/2017 monitoring round
Enter mixing zone thickness	Mz	5.4	m	Assumed equal to saturated aquifer thickness
Bulk density of aquifer materials	r	1.59	g/cm3	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	0.4	fraction	Glacial deposits (Hiscock, 2005)
Distance to compliance point	x	10	m	Nominal 10m (river adjacent to site)
Time since pollutant entered groundwater	t	1E+99	days	Steady state conditions
Fraction of organic carbon in aquifer	foc	4.35E-03	fraction	Average value for glacio-fluvial silty sand (Consim manual)

Dispersivities 10%, 1%, 0.1% of pathway length

Parameter	Target concentration		Henry's Law constant		Soil water partition coefficient		Organic carbon partition	
Variable	CT		H		Kd		Koc	
Units	mg/l		dimensionless		l/kg		l/kg	
Mercury	0.00007	EQS Freshwater (The Water Fra	0.117	LQM/CIEH (2015)	6310	USEPA (2005)	n/a	n/a
Ammonium	0.5	EQS Freshwater (The Water Fra	0	-	66	From Atkins (2013)	n/a	n/a
Cyanide (Total)	0.001	EQS Freshwater (The Water Fra	0	-	1.00E+03	From Atkins (2013)	n/a	n/a
Benzene	0.01	EQS Freshwater (The Water Fra	1.16E-01	LQM/CIEH (2015)	n/a	n/a	6.76E+01	LQM/CIEH (2015)
Aliphatics >C12-C16	0.01	UKDWS for hydrocarbons	1.71E+02	LQM/CIEH (2015)	n/a	n/a	5.37E+06	LQM/CIEH (2015)
Aliphatics >C16-C21	0.01	UKDWS for hydrocarbons	1.07E+03	LQM/CIEH (2015)	n/a	n/a	5.75E+08	LQM/CIEH (2015)
Aliphatics >C21-C35	0.01	UKDWS for hydrocarbons	1.07E+03	LQM/CIEH (2015)	n/a	n/a	5.75E+08	LQM/CIEH (2015)
Aromatics >EC5-EC7	0.01	UKDWS for hydrocarbons	1.16E-01	LQM/CIEH (2015)	n/a	n/a	6.76E+01	LQM/CIEH (2015)
Aromatics >EC7-EC8	0.01	UKDWS for hydrocarbons	1.15E-01	LQM/CIEH (2015)	n/a	n/a	2.04E+02	LQM/CIEH (2015)
Aromatics >EC8-EC10	0.01	UKDWS for hydrocarbons	2.53E-01	LQM/CIEH (2015)	n/a	n/a	1.58E+03	LQM/CIEH (2015)
Aromatics >EC10-EC12	0.01	UKDWS for hydrocarbons	7.22E-02	LQM/CIEH (2015)	n/a	n/a	2.51E+03	LQM/CIEH (2015)
Aromatics >EC12-EC16	0.01	UKDWS for hydrocarbons	1.26E-02	LQM/CIEH (2015)	n/a	n/a	5.01E+03	LQM/CIEH (2015)
Aromatics >EC16-EC21	0.01	UKDWS for hydrocarbons	6.95E-04	LQM/CIEH (2015)	n/a	n/a	1.41E+04	LQM/CIEH (2015)
Benzo(a)pyrene	0.00000017	EQS Freshwater (The Water Fra	1.76E-06	LQM/CIEH (2015)	n/a	n/a	1.29E+05	LQM/CIEH (2015)
Benzo(b)fluoranthene	0.00000017	Benzo(a)pyrene EQS Freshwater	2.05E-06	LQM/CIEH (2015)	n/a	n/a	1.05E+05	LQM/CIEH (2015)
Benzo(k)fluoranthene	0.00000017	Benzo(a)pyrene EQS Freshwater	1.74E-06	LQM/CIEH (2015)	n/a	n/a	1.48E+05	LQM/CIEH (2015)
Fluoranthene	0.0000063	EQS Freshwater (The Water Fra	6.29E-05	LQM/CIEH (2015)	n/a	n/a	1.82E+04	LQM/CIEH (2015)
Indeno(1,2,3-cd)pyrene	0.00000017	Benzo(a)pyrene EQS Freshwater	2.05E-06	LQM/CIEH (2015)	n/a	n/a	8.71E+04	LQM/CIEH (2015)
Naphthalene	0.002	EQS Freshwater (The Water Fra	6.62E-03	LQM/CIEH (2015)	n/a	n/a	6.46E+02	LQM/CIEH (2015)
Acenaphthene	0.017	Freshwater Chronic Screening V	7.59E-04	LQM/CIEH (2015)	n/a	n/a	2.34E+03	LQM/CIEH (2015)
Anthracene	0.0001	EQS Freshwater (The Water Fra	1.81E-04	LQM/CIEH (2015)	n/a	n/a	5.62E+03	LQM/CIEH (2015)

Parameter	Enter soil concentration	
Variable	Co	
Units	mg/kg	
Mercury	0.46	From 2017 SI (average of made ground concentrations)
Ammonium	7.6	From 2017 SI (average of made ground concentrations)
Cyanide (Total)	1.5	From 2017 SI (average of made ground concentrations)
Benzene	0.0021	From 2017 SI (average of made ground concentrations)
Aliphatics >C12-C16	21	From 2017 SI (average of made ground concentrations)
Aliphatics >C16-C21	25	From 2017 SI (average of made ground concentrations)
Aliphatics >C21-C35	40	From 2017 SI (average of made ground concentrations)
Aromatics >EC5-EC7	0.002	From 2017 SI (average of made ground concentrations)
Aromatics >EC7-EC8	0.001	From 2017 SI (average of made ground concentrations)
Aromatics >EC8-EC10	0.038	From 2017 SI (average of made ground concentrations)
Aromatics >EC10-EC12	32	From 2017 SI (average of made ground concentrations)
Aromatics >EC12-EC16	118	From 2017 SI (average of made ground concentrations)
Aromatics >EC16-EC21	390	From 2017 SI (average of made ground concentrations)
Benzo(a)pyrene	34	From 2017 SI (average of made ground concentrations)
Benzo(b)fluoranthene	34	From 2017 SI (average of made ground concentrations)
Benzo(k)fluoranthene	21	From 2017 SI (average of made ground concentrations)
Fluoranthene	87	From 2017 SI (average of made ground concentrations)
Indeno(1,2,3-cd)pyrene	17	From 2017 SI (average of made ground concentrations)
Naphthalene	24	From 2017 SI (average of made ground concentrations)
Acenaphthene	15	From 2017 SI (average of made ground concentrations)
Anthracene	21	From 2017 SI (average of made ground concentrations)

Parameter	Half life for degradation of contaminant in water	
Variable	t1/2	
Units	days	
Mercury	1.00E+10	
Ammonium	1.00E+10	
Cyanide (Total)	1.00E+10	
Benzene	720	Mackay (2006)
Aliphatics >C12-C16	1.00E+10	
Aliphatics >C16-C21	1.00E+10	
Aliphatics >C21-C35	1.00E+10	
Aromatics >EC5-EC7	720	Half-life for benzene Mackay (2006). Benzene used as indicator compound as per Environment Agency (2009b)
Aromatics >EC7-EC8	28	Half-life for toluene Mackay (2006). Toluene used as indicator compound as per Environment Agency (2009b)
Aromatics >EC8-EC10	360	Half-life for xylene Mackay (2006). Xylene used as indicator compound as per Environment Agency (2009b)
Aromatics >EC10-EC12	258	Half-life for naphthalene Mackay (2006). Naphthalene used as indicator compound as per Environment Agency (2009b)
Aromatics >EC12-EC16	204	Half-life for acenaphthene Mackay (2006). Acenaphthene used as indicator compound as per Environment Agency (2009b)
Aromatics >EC16-EC21	4280	Half-life for benzo(k)fluoranthene Mackay (2006). Benzo(k)fluoranthene used as indicator compound as per Environment Agency (2009b)
Benzo(a)pyrene	1064	Mackay (2006)
Benzo(b)fluoranthene	1220	Mackay (2006)
Benzo(k)fluoranthene	4280	Mackay (2006)
Fluoranthene	880	Mackay (2006)
Indeno(1,2,3-cd)pyrene	4280	Half-life for benzo(k)fluoranthene Mackay (2006). Benzo(k)fluoranthene used as indicator compound as per Environment Agency (2009b)
Naphthalene	258	Mackay (2006)
Acenaphthene	204	Mackay (2006)
Anthracene	920	Mackay (2006)

Appendix 7 Controlled Waters – Remedial Targets Worksheets



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Mercury		
Target Concentration (C _T)	0.00007	mg/l	Origin of C _T : EQS Freshwater (The Water Framework Directive 2015)

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant
Target concentration

C_T Mercury 0.00007 mg/l

Input Parameters

Standard entry

Variable	Value	Unit
Water filled soil porosity	0.382E-01	fraction
Air filled soil porosity	0.465E-02	fraction
Bulk density of soil zone material	0.940E-01	g/cm ³
Henry's Law constant	0.117E-01	dimensionless

Source of parameter value
Calculated using porosity calculator
Calculated using porosity calculator
From Atkins (2013), representative value to gravelly
LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d 0.631E+03 l/kg

USEPA (2005)

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

foc

fraction

Organic carbon partition coefficient

K_{oc}

l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pKa

Fraction of organic carbon (in soil)

foc

fraction

Soil water partition coefficient used in Level Assessment

K_d 0.631E+03 l/kg

Specified value

Level 1 Remedial Target

Level 1 Remedial Target 0.442E-01 mg/kg (for comparison with soil analyses)

or

0.00007 mg/l (for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Mercury
0.00007 mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.09E-04

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or

6.88E-01

mg/kg

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Mercury		from Level 1
Target Concentration	C _T	0.00007	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration			
Enter soil concentration	0.46	mg/kg	
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	l/kg	see options
Longitudinal dispersivity	ax	m	see options
Transverse dispersivity	az	m	see options
Vertical dispersivity	av	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Groundwater flow velocity	V	2.09E-03	m/d
Retardation factor	Rf	2.51E+04	fraction
Decay rate used	λ	6.93E-11	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02	fraction
Rate of contaminant flow due to retardation	u	8.34E-08	m/d
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	9.92E-01	fraction
Attenuation factor (C _{CP} /C _{TP})	AF	1.01E+00	fraction
Calculated soil leachate concentration	Co	7.29E-05	mg/l

Remedial Targets

Level 3 Remedial Target	1.10E-04	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	6.94E-01	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	9.92E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)
User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	6.31E+03	l/kg
----------------------------------	----	----------	------

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer	foc		fraction
Organic carbon partition coefficient	Koc		l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species	K _{oc,li}		l/kg
Sorption coefficient for ionised species	K _{oc,i}		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction

Soil water partition coefficient	Kd	6.31E+03	l/kg
----------------------------------	----	----------	------

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity

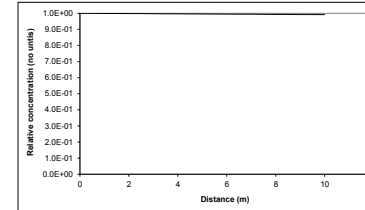
Transverse dispersivity

Vertical dispersivity

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀)^{2.4+1.4}; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.00E+00	4.68E-05
0.5	1.00E+00	4.67E-05
1.0	9.99E-01	4.67E-05
1.5	9.99E-01	4.67E-05
2.0	9.98E-01	4.67E-05
2.5	9.98E-01	4.67E-05
3.0	9.98E-01	4.67E-05
3.5	9.97E-01	4.66E-05
4.0	9.97E-01	4.66E-05
4.5	9.96E-01	4.66E-05
5.0	9.96E-01	4.66E-05
5.5	9.95E-01	4.66E-05
6.0	9.95E-01	4.65E-05
6.5	9.95E-01	4.65E-05
7.0	9.94E-01	4.65E-05
7.5	9.94E-01	4.65E-05
8.0	9.93E-01	4.65E-05
8.5	9.93E-01	4.64E-05
9.0	9.93E-01	4.64E-05
9.5	9.92E-01	4.64E-05
10.0	9.92E-01	4.64E-05

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed: Former Gas Works
Completed by: AS
Date: #####
Version: 1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Ammonium		
Target Concentration (C _T)	0.5	mg/l	Origin of C _T : EQS Freshwater (The Water Framework Directive 2015)

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant	Ammonium
Target concentration	C _T 0.5 mg/l

Input Parameters

Standard entry

Water filled soil porosity	θ _w	3.82E-01	fraction
Air filled soil porosity	θ _a	4.65E-02	fraction
Bulk density of soil zone material	ρ	9.40E-01	g/cm ³
Henry's Law constant	H	0.00E+00	dimensionless

Calculated using porosity calculator
Calculated using porosity calculator
From Atkins (2013), representative value to gravelly

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient	K _d	6.60E+01	l/kg
----------------------------------	----------------	----------	------

From Atkins (2013)

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	f _{oc}		fraction
Organic carbon partition coefficient	K _{oc}		l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species	K _{oc,n}		l/kg
Sorption coefficient for ionised species	K _{oc,i}		l/kg
pH value	pH		pH units
Acid dissociation constant	pK _a		
Fraction of organic carbon (in soil)	f _{oc}		fraction

Soil water partition coefficient used in Level Assessment	K _d	6.60E+01	l/kg	Specified value
---	----------------	----------	------	-----------------

Level 1 Remedial Target

Level 1 Remedial Target	3.32E+01	mg/kg	(for comparison with soil analyses)
	or		
	0.5	mg/l	(for comparison with leachate test results)

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	12-Feb-18
Version:	1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Ammonium
0.5 mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

7.79E-01

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or

5.18E+01

mg/kg

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Ammonium		from Level 1
Target Concentration	C _T	0.5	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration	7.6	mg/kg	
Enter soil concentration	1.00E+10	days	
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	l/kg	see options
Longitudinal dispersivity	ax	m	see options
Transverse dispersivity	az	m	see options
Vertical dispersivity	av	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Groundwater flow velocity	V	2.09E-03	m/d
Retardation factor	Rf	1.99E+03	fraction
Decay rate used	λ	6.93E-11	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02	fraction
Rate of contaminant flow due to retardation	u	1.05E-06	m/d
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	9.99E-01	fraction
Attenuation factor (C _{CP} /C ₀)	AF	1.00E+00	fraction
Calculated soil leachate concentration	Co	1.14E-01	mg/l

Remedial Targets

Level 3 Remedial Target	7.80E-01	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	5.18E+01	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	9.99E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd 5.00E+02 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc fraction

Organic carbon partition coefficient Koc l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,ri} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc fraction

Soil water partition coefficient Kd 5.00E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity

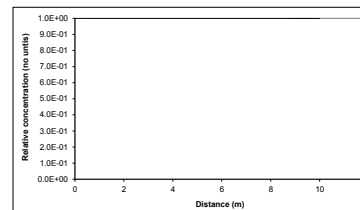
Transverse dispersivity

Vertical dispersivity

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.4+1.4}$; $az = ax/10$, $ay = ax/100$ are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.00E+00	7.34E-02
0.5	1.00E+00	7.34E-02
1.0	1.00E+00	7.34E-02
1.5	1.00E+00	7.34E-02
2.0	1.00E+00	7.34E-02
2.5	1.00E+00	7.34E-02
3.0	1.00E+00	7.34E-02
3.5	1.00E+00	7.34E-02
4.0	1.00E+00	7.34E-02
4.5	1.00E+00	7.34E-02
5.0	1.00E+00	7.34E-02
5.5	1.00E+00	7.34E-02
6.0	1.00E+00	7.34E-02
6.5	1.00E+00	7.34E-02
7.0	1.00E+00	7.34E-02
7.5	1.00E+00	7.34E-02
8.0	9.99E-01	7.34E-02
8.5	9.99E-01	7.34E-02
9.0	9.99E-01	7.34E-02
9.5	9.99E-01	7.34E-02
10.0	9.99E-01	7.34E-02

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed: Former Gas Works

Completed by: AS

Date: #####

Version: 1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Cyanide (Total)		
Target Concentration (C _T)	0.001 mg/l	Origin of C _T :	EQS Freshwater (The Water Framework Directive 2015)

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

User specified value for partition coefficient

Contaminant
Target concentration
 C_T

Cyanide (Total)
0.001 mg/l

Input Parameters

Standard entry

Variable	Value	Unit
Water filled soil porosity θ_w	3.82E-01	fraction
Air filled soil porosity θ_a	4.65E-02	fraction
Bulk density of soil zone material ρ	9.40E-01	g/cm ³
Henry's Law constant H	0.00E+00	dimensionless

Source of parameter value
Calculated using porosity calculator
Calculated using porosity calculator
From Atkins (2013), representative value to gravelly

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Variable	Value	Unit
Soil water partition coefficient K_d	1.00E+03	l/kg

From Atkins (2013)

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil) f_{oc}		fraction
Organic carbon partition coefficient K_{oc}		l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species $K_{oc,n}$		l/kg
Sorption coefficient for ionised species $K_{oc,i}$		l/kg
pH value pH		pH units
Acid dissociation constant pK_a		
Fraction of organic carbon (in soil) f_{oc}		fraction

Soil water partition coefficient used in Level Assessment	K_d	1.00E+03	l/kg	Specified value
---	-------	----------	------	-----------------

Level 1 Remedial Target

Level 1 Remedial Target	1.00E+00	mg/kg	(for comparison with soil analyses)
	or		
	0.001	mg/l	(for comparison with leachate test results)

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	12-Feb-18
Version:	1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Cyanide (Total)
0.001

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.56E-03

mg/l

or

1.56E+00

mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

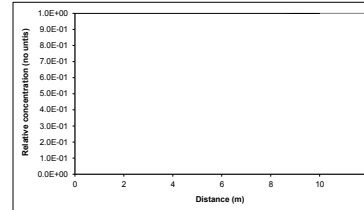
See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Cyanide (Total)		from Level 1
Target Concentration	C _T	0.001	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Enter method of defining partition co-efficient (using pull down list)
User specified value for partition coefficient

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd	5.00E+02	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc		fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	K _{oc,li}		l/kg
Sorption coefficient for ionised species	K _{oc,i}		l/kg
pH value	pH		
Acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	5.00E+02	l/kg



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks	Relative concentration	Concentration
Distance	(No units)	mg/l
0	1.00E+00	9.62E-04
0.5	1.00E+00	9.62E-04
1.0	1.00E+00	9.62E-04
1.5	1.00E+00	9.62E-04
2.0	1.00E+00	9.62E-04
2.5	1.00E+00	9.62E-04
3.0	1.00E+00	9.62E-04
3.5	1.00E+00	9.62E-04
4.0	1.00E+00	9.62E-04
4.5	1.00E+00	9.62E-04
5.0	1.00E+00	9.62E-04
5.5	1.00E+00	9.62E-04
6.0	1.00E+00	9.62E-04
6.5	1.00E+00	9.62E-04
7.0	1.00E+00	9.62E-04
7.5	1.00E+00	9.62E-04
8.0	9.99E-01	9.61E-04
8.5	9.99E-01	9.61E-04
9.0	9.99E-01	9.61E-04
9.5	9.99E-01	9.61E-04
10.0	9.99E-01	9.61E-04

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value, k)

Variable	Value	Unit	Source of parameter value
Enter source concentration			
Enter soil concentration			
Half life for degradation of contaminant in water	t _{1/2}	1.5 days	mg/kg
Calculated decay rate	λ	6.93E-11 days ⁻¹	calculated
Width of plume in aquifer at source	Sz	1.60E+01 m	from Level 2
Plume thickness in aquifer at source	Sy	5.40E+00 m	from Level 2
Bulk density of aquifer materials	ρ	1.59E+00 g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	4.00E-01 fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	8.37E-02 fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	1.00E-02 m/d	from Level 2
Distance to compliance point	x	1.00E+01 m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z		
Distance (depth) to compliance point perpendicular to flow direction	y		
Time since pollutant entered groundwater	t	1.00E+99 days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	5.00E+02 l/kg	see options
Longitudinal dispersivity	ax	1.000 m	see options
Transverse dispersivity	az	0.100 m	see options
Vertical dispersivity	av	0.010 m	see options

Parameter values should be checked against Level 1 and 2

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity	ax	0.00E+00	1.00E+00	8.50E-01	m
Transverse dispersivity	az	0.00E+00	1.00E-01	8.50E-02	m
Vertical dispersivity	ay	0.00E+00	1.00E-02	8.50E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2+1/4}; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	2.09E-03 m/d
Retardation factor	Rf	1.99E+03 fraction
Decay rate used	λ	6.93E-11 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02 fraction
Rate of contaminant flow due to retardation	u	1.05E-06 m/d
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	9.99E-01 fraction
Attenuation factor (C _{CP} /C ₀)	AF	1.00E+00 fraction
Calculated soil leachate concentration	Co	1.50E-03 mg/l

Remedial Targets

Level 3 Remedial Target	1.56E-03	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	1.56E+00	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point	10	m	
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	9.99E-01	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	#####
Version:	1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	0.1
Contaminant	Benzene		
Target Concentration (C _T)	0.01	mg/l	Origin of C _T : EQS Freshwater (The Water Framework Directive 2015)

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Benzene
0.01 mg/l

Input Parameters

Standard entry

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

1.16E-01

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

6.76E+01

l/kg

From 2017 SI (average of made ground values)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

7.44E-01

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

1.16E-02

mg/kg

(for comparison with soil analyses)

or

0.01

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 0.1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Benzene
0.01

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.56E-02

mg/l

or

1.80E-02

mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 0.1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Benzene		from Level 1
Target Concentration	C _T	0.01	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration	0.0021	mg/kg	
Enter soil concentration	7.20E+02	days	
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	l/kg	see options
Longitudinal dispersivity	ax	m	see options
Transverse dispersivity	az	m	see options
Vertical dispersivity	av	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Groundwater flow velocity	V	2.09E-03	m/d
Retardation factor	Rf	3.96E+00	fraction
Decay rate used	λ	9.63E-04	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02	fraction
Rate of contaminant flow due to retardation	u	5.29E-04	m/d
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	8.38E-05	fraction
Attenuation factor (C _{CP} /C _{TP})	AF	1.19E+04	fraction
Calculated soil leachate concentration	Co	1.82E-03	mg/l

Remedial Targets

Level 3 Remedial Target	1.86E+02	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	2.15E+02	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	8.38E-05	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)
Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.10E-02 fractionOrganic carbon partition coefficient K_{oc} 6.76E+01 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,ri} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer f_{oc} fraction

Soil water partition coefficient Kd 7.44E-01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity

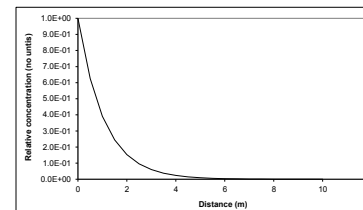
Transverse dispersivity

Vertical dispersivity

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.4+14}; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	1.17E-03
0.5	6.25E-01	7.29E-04
1.0	3.91E-01	4.56E-04
1.5	2.45E-01	2.85E-04
2.0	1.53E-01	1.78E-04
2.5	9.57E-02	1.12E-04
3.0	5.98E-02	6.98E-05
3.5	3.74E-02	4.36E-05
4.0	2.34E-02	2.73E-05
4.5	1.46E-02	1.71E-05
5.0	9.15E-03	1.07E-05
5.5	5.72E-03	6.67E-06
6.0	3.58E-03	4.17E-06
6.5	2.24E-03	2.61E-06
7.0	1.40E-03	1.63E-06
7.5	8.75E-04	1.02E-06
8.0	5.48E-04	6.38E-07
8.5	3.42E-04	3.99E-07
9.0	2.14E-04	2.50E-07
9.5	1.34E-04	1.56E-07
10.0	8.38E-05	9.77E-08

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	#####
Version:	0.1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Aliphatics >C12-C16		
Target Concentration (C _T)	0.01	mg/l	Origin of C _T : UKDWS for hydrocarbons

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Aliphatics >C12-C16
0.01 mg/l

Input Parameters

Standard entry

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

1.71E+02

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

5.37E+06

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

5.91E+04

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

5.91E+02

mg/kg

(for comparison with soil analyses)

or

0.01

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Aliphatics >C12-C16
0.01

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.56E-02

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or

9.21E+02

mg/kg

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

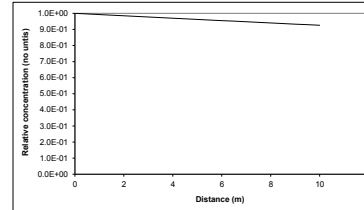
See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Aliphatics >C12-C16		from Level 1
Target Concentration	C _T	0.01	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Enter method of defining partition co-efficient (using pull down list)
Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)		
Soil water partition coefficient	Kd	
Entry for non-polar organic chemicals (option)		
Fraction of organic carbon in aquifer	foc	1.10E-02 fraction
Organic carbon partition coefficient	Koc	5.37E+06 l/kg
Entry for ionic organic chemicals (option)		
Sorption coefficient for related species	K _{oc,li}	
Sorption coefficient for ionised species	K _{oc,i}	
pH value	pH	
Acid dissociation constant	pKa	
Fraction of organic carbon in aquifer	foc	
Soil water partition coefficient	Kd	5.91E+04 l/kg



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks	Relative concentration	Concentration
Distance	(No units)	mg/l
0	1.0E+00	2.25E-04
0.5	9.96E-01	2.24E-04
1.0	9.92E-01	2.23E-04
1.5	9.88E-01	2.22E-04
2.0	9.85E-01	2.21E-04
2.5	9.81E-01	2.20E-04
3.0	9.77E-01	2.20E-04
3.5	9.73E-01	2.19E-04
4.0	9.70E-01	2.18E-04
4.5	9.66E-01	2.17E-04
5.0	9.62E-01	2.16E-04
5.5	9.58E-01	2.15E-04
6.0	9.55E-01	2.15E-04
6.5	9.51E-01	2.14E-04
7.0	9.47E-01	2.13E-04
7.5	9.44E-01	2.12E-04
8.0	9.40E-01	2.11E-04
8.5	9.36E-01	2.11E-04
9.0	9.33E-01	2.10E-04
9.5	9.29E-01	2.09E-04
10.0	9.26E-01	2.08E-04

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Enter source concentration			
Enter soil concentration	20.7	mg/kg	Soil concentration as mg/kg
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	l/kg	see options
Longitudinal dispersivity	ax	m	see options
Transverse dispersivity	az	m	see options
Vertical dispersivity	av	m	see options

Parameter values should be checked against Level 1 and 2

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity	ax	0.00E+00	1.00E+00	0.00E-01	m
Transverse dispersivity	az	0.00E+00	1.00E-01	0.00E-02	m
Vertical dispersivity	ay	0.00E+00	1.00E-02	0.00E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{0.4+1.4}; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	2.09E-03 m/d
Retardation factor	Rf	2.35E+05 fraction
Decay rate used	λ	6.93E-11 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02 fraction
Rate of contaminant flow due to retardation	u	8.91E-09 m/d
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	9.26E-01 fraction
Attenuation factor (C ₁₀ /C ₁₀₀)	AF	1.08E+00 fraction
Calculated soil leachate concentration	Co	3.50E-04 mg/l

Remedial Targets

Level 3 Remedial Target	1.68E-02	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	9.95E+02	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	9.26E-01	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	#####
Version:	1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Aliphatics >C16-C21		
Target Concentration (C _T)	0.01	mg/l	Origin of C _T : UKDWS for hydrocarbons

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Aliphatics >C16-C21
0.01 mg/l

Input Parameters

Standard entry

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

1.07E+03

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

5.75E+08

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

6.33E+06

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

6.33E+04

mg/kg

(for comparison with soil analyses)

or

0.01

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Aliphatics >C16-C21
0.01

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.56E-02

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or

9.87E+04

mg/kg

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Contaminant	Aliphatics >C16-C21	from Level 1
Target Concentration	C _T 0.01	mg/l from Level 1
Dilution Factor	DF 1.56E+00	from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration	25	mg/kg	
Enter soil concentration	1.00E+10	days	
Half life for degradation of contaminant in water	t _{1/2} 6.93E-11	days ⁻¹	calculated
Width of plume in aquifer at source	Sz 1.60E+01	m	from Level 2
Plume thickness in aquifer at source	Sy 5.40E+00	m	from Level 2
Bulk density of aquifer materials	ρ 1.59E+00	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n 4.00E-01	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i 8.37E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K 1.00E-02	m/d	from Level 2
Distance to compliance point	x 1.00E+01	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t 1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd 6.33E+06	l/kg	see options
Longitudinal dispersivity	ax 1.000	m	see options
Transverse dispersivity	az 0.100	m	see options
Vertical dispersivity	av 0.010	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Groundwater flow velocity	V	2.09E-03	m/d
Retardation factor	Rf	2.52E+07	fraction
Decay rate used	λ	6.93E-11	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02	fraction
Rate of contaminant flow due to retardation	u	8.32E-11	m/d
Ratio of Compliance Point to Source Concentration	C _{EP} /C ₀	4.48E-03	fraction
Attenuation factor (C ₀ /C _{EP})	AF	2.23E+02	fraction
Calculated soil leachate concentration	Co	3.95E-06	mg/l

Remedial Targets

Level 3 Remedial Target	3.48E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	2.20E+07	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{EP} /C ₀	4.48E-03	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.10E-02 fractionOrganic carbon partition coefficient K_{oc} 5.75E+08 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,li} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH l/kg

Acid dissociation constant pKa fraction

Fraction of organic carbon in aquifer f_{oc} fraction

Soil water partition coefficient Kd 6.33E+06 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity

Transverse dispersivity

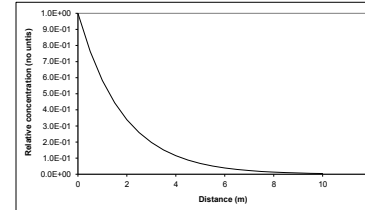
Vertical dispersivity

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.4+1.4}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	2.53E-06
0.5	7.63E-01	1.93E-06
1.0	5.82E-01	1.48E-06
1.5	4.44E-01	1.13E-06
2.0	3.39E-01	8.59E-07
2.5	2.59E-01	6.55E-07
3.0	1.97E-01	5.00E-07
3.5	1.51E-01	3.82E-07
4.0	1.15E-01	2.91E-07
4.5	8.77E-02	2.22E-07
5.0	6.69E-02	1.70E-07
5.5	5.11E-02	1.29E-07
6.0	3.90E-02	9.87E-08
6.5	2.97E-02	7.53E-08
7.0	2.27E-02	5.75E-08
7.5	1.73E-02	4.39E-08
8.0	1.32E-02	3.35E-08
8.5	1.01E-02	2.55E-08
9.0	7.69E-03	1.95E-08
9.5	5.87E-03	1.49E-08
10.0	4.48E-03	1.13E-08

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed: Former Gas Works

Completed by: AS

Date: #####

Version: 1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment			
Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Aliphatics >C21-C35		
Target Concentration (C_T)	0.01	mg/l	Origin of C_T: UKDWS for hydrocarbons

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Aliphatics >C21-C35
0.01 mg/l

Input Parameters

Standard entry

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

1.07E+03

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

5.75E+08

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

6.33E+06

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

6.33E+04

mg/kg

(for comparison with soil analyses)

or

0.01

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Aliphatics >C21-C35
0.01

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.56E-02

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or

9.87E+04

mg/kg

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Contaminant	Aliphatics >C21-C35	from Level 1
Target Concentration	C _T 0.01	mg/l from Level 1
Dilution Factor	DF 1.56E+00	from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d I/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.10E-02 fractionOrganic carbon partition coefficient K_{oc} 5.75E+08 I/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,ri} I/kgSorption coefficient for ionised species K_{oc,i} I/kg

pH value pH I/kg

Acid dissociation constant pK_a fractionFraction of organic carbon in aquifer f_{oc} fractionSoil water partition coefficient K_d 6.33E+06 I/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Enter value Calc value Xu & Eckstein

Longitudinal dispersivity ax 0.00E+00 1.00E+00 8.30E-01 m

Transverse dispersivity az 0.00E+00 1.00E-01 8.30E-02 m

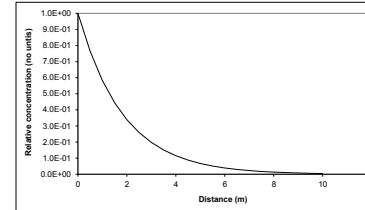
Vertical dispersivity ay 0.00E+00 1.00E-02 8.30E-03 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀)^{2.4+1.4}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	4.05E-06
0.5	7.63E-01	3.09E-06
1.0	5.82E-01	2.36E-06
1.5	4.44E-01	1.80E-06
2.0	3.39E-01	1.37E-06
2.5	2.59E-01	1.05E-06
3.0	1.97E-01	8.00E-07
3.5	1.51E-01	6.11E-07
4.0	1.15E-01	4.66E-07
4.5	8.77E-02	3.56E-07
5.0	6.69E-02	2.71E-07
5.5	5.11E-02	2.07E-07
6.0	3.90E-02	1.58E-07
6.5	2.97E-02	1.21E-07
7.0	2.27E-02	9.20E-08
7.5	1.73E-02	7.02E-08
8.0	1.32E-02	5.35E-08
8.5	1.01E-02	4.09E-08
9.0	7.69E-03	3.12E-08
9.5	5.87E-03	2.38E-08
10.0	4.48E-03	1.82E-08

Calculated Parameters

Groundwater flow velocity	V	2.09E-03	m/d
Retardation factor	Rf	2.52E+07	fraction
Decay rate used	λ	6.93E-11	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02	fraction
Rate of contaminant flow due to retardation	u	8.32E-11	m/d
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	4.48E-03	fraction
Attenuation factor (C _{CP} /C _{TP})	AF	2.23E+02	fraction
Calculated soil leachate concentration	Co	6.32E-06	mg/l

Remedial Targets

Level 3 Remedial Target	3.48E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	2.20E+07	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	4.48E-03	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	#####
Version:	1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment			
Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Aromatics >EC5-EC7		
Target Concentration (C_T)	0.01	mg/l	Origin of C_T: UKDWS for hydrocarbons

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Aromatics >EC5-EC7
0.01 mg/l

Input Parameters
Standard entry

Variable

Value

Unit

Source of parameter value

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

1.16E-01

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

6.76E+01

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

7.44E-01

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

1.16E-02

mg/kg

(for comparison with soil analyses)

or

0.01

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Aromatics >EC5-EC7
0.01

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.56E-02

mg/l

or

1.80E-02

mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Aromatics >EC5-EC7		from Level 1
Target Concentration	C _T	0.01	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Enter method of defining partition co-efficient (using pull down list)
Calculate for non-polar organic chemicals

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration	0.002	mg/kg	
Enter soil concentration	7.20E+02	days	
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	l/kg	see options
Longitudinal dispersivity	ax	m	see options
Transverse dispersivity	az	m	see options
Vertical dispersivity	av	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	2.09E-03 m/d
Retardation factor	Rf	3.96E+00 fraction
Decay rate used	λ	9.63E-04 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02 fraction
Rate of contaminant flow due to retardation	u	5.29E-04 m/d
Ratio of Compliance Point to Source Concentration	C _{EP} /C ₀	8.38E-05 fraction
Attenuation factor (C ₀ /C _{EP})	AF	1.19E+04 fraction
Calculated soil leachate concentration	Co	1.73E-03 mg/l

Remedial Targets

Level 3 Remedial Target	1.86E+02	mg/l	For comparison with measured pore water concentration.
Ogata Banks	2.15E+02	mg/kg	This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	10	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{EP} /C ₀	8.38E-05	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Entry if specify partition coefficient (option)		
Soil water partition coefficient	Kd	l/kg
Entry for non-polar organic chemicals (option)		
Fraction of organic carbon in aquifer	foc	1.10E-02 fraction
Organic carbon partition coefficient	Koc	6.76E+01 l/kg
Entry for ionic organic chemicals (option)		
Sorption coefficient for related species	K _{oc,li}	l/kg
Sorption coefficient for ionised species	K _{oc,i}	l/kg
pH value	pH	
Acid dissociation constant	pKa	
Fraction of organic carbon in aquifer	foc	fraction
Soil water partition coefficient	Kd	7.44E-01 l/kg

Define dispersivity (click brown cell and use pull down list)

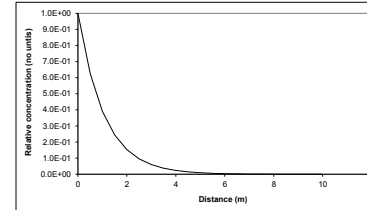
Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity	ax	0.00E+00	1.00E+00	8.30E-01	m
Transverse dispersivity	az	0.00E+00	1.00E-01	8.30E-02	m
Vertical dispersivity	ay	0.00E+00	1.00E-02	8.30E-03	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.4+14}; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	1.11E-03
0.5	6.25E-01	6.95E-04
1.0	3.91E-01	4.34E-04
1.5	2.45E-01	2.72E-04
2.0	1.63E-01	1.70E-04
2.5	9.57E-02	1.06E-04
3.0	5.98E-02	6.64E-05
3.5	3.74E-02	4.16E-05
4.0	2.34E-02	2.60E-05
4.5	1.46E-02	1.63E-05
5.0	9.15E-03	1.02E-05
5.5	5.72E-03	6.36E-06
6.0	3.58E-03	3.98E-06
6.5	2.24E-03	2.49E-06
7.0	1.40E-03	1.55E-06
7.5	8.75E-04	9.72E-07
8.0	5.48E-04	6.08E-07
8.5	3.42E-04	3.80E-07
9.0	2.14E-04	2.38E-07
9.5	1.34E-04	1.49E-07
10.0	8.38E-05	9.30E-08

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	#####
Version:	1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Aromatics >EC7-EC8		
Target Concentration (C _T)	0.01	mg/l	Origin of C _T : UKDWS for hydrocarbons

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Aromatics >EC7-EC8
0.01 mg/l

Input Parameters Standard entry

Variable

Value

Unit

Source of parameter value

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

1.15E-01

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

2.04E+02

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

2.25E+00

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

2.66E-02

mg/kg

(for comparison with soil analyses)

or

0.01

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Aromatics >EC7-EC8
0.01

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.56E-02

mg/l

or

4.14E-02

mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Aromatics >EC7-EC8		from Level 1
Target Concentration	C _t	0.01	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Enter method of defining partition co-efficient (using pull down list)
Calculate for non-polar organic chemicals

Select analytical solution (click on brown cell below, then on pull-down menu)

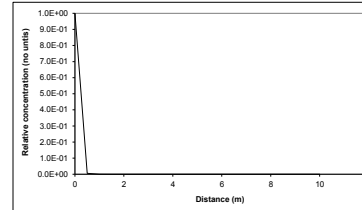
Ogata Banks Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Entry if specify partition coefficient (option)		
Soil water partition coefficient	Kd	
Entry for non-polar organic chemicals (option)		
Fraction of organic carbon in aquifer	foc	1.10E-02 fraction
Organic carbon partition coefficient	Koc	2.04E+02 l/kg
Entry for ionic organic chemicals (option)		
Sorption coefficient for related species	K _{oc,li}	
Sorption coefficient for ionised species	K _{oc,i}	
pH value	pH	
Acid dissociation constant	pKa	
Fraction of organic carbon in aquifer	foc	
Soil water partition coefficient	Kd	2.25E+00 l/kg



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	2.41E-04
0.5	5.66E-03	1.37E-06
1.0	3.20E-05	7.73E-09
1.5	1.81E-07	4.38E-11
2.0	1.03E-09	2.48E-13
2.5	5.81E-12	1.40E-15
3.0	3.29E-14	7.94E-18
3.5	1.86E-16	4.49E-20
4.0	1.05E-18	2.54E-22
4.5	5.96E-21	1.44E-24
5.0	3.38E-23	8.15E-27
5.5	1.91E-25	4.61E-29
6.0	1.08E-27	2.61E-31
6.5	6.12E-30	1.48E-33
7.0	3.46E-32	8.36E-36
7.5	1.96E-34	4.73E-38
8.0	1.11E-36	2.68E-40
8.5	6.28E-39	1.52E-42
9.0	3.56E-41	8.59E-45
9.5	2.01E-43	4.86E-47
10.0	1.14E-45	2.75E-49

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration	0.001	mg/kg	
Enter soil concentration	2.80E+01	days	
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	2.25E+00	l/kg see options
Longitudinal dispersivity	ax	1.000	m see options
Transverse dispersivity	az	0.100	m see options
Vertical dispersivity	av	0.010	m see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	2.09E-03 m/d
Retardation factor	Rf	9.93E+00 fraction
Decay rate used	λ	2.48E-02 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02 fraction
Rate of contaminant flow due to retardation	u	2.11E-04 m/d
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	1.14E-45 fraction
Attenuation factor (C _{CP} /C ₀)	AF	8.78E+44 fraction
Calculated soil leachate concentration	Co	3.76E-04 mg/l

Remedial Targets

Level 3 Remedial Target	1.37E+43	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	3.64E+43	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	1.14E-45	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99.

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used

Xu & Eckstein (1995) report ax = 0.83/(log₁₀x)^{2+1/4}; az = ax/10, ay = ax/100 are assumed

Enter value	Calc value	Xu & Eckstein
ax	0.00E+00	1.00E+00 8.30E-01 m
az	0.00E+00	1.00E-01 8.30E-02 m
ay	0.00E+00	1.00E-02 8.30E-03 m

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed: Former Gas Works
Completed by: AS
Date: #####
Version: 1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment			
Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Aromatics >EC8-EC10		
Target Concentration (C_T)	0.01	mg/l	Origin of C_T: UKDWS for hydrocarbons

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Aromatics >EC8-EC10
0.01 mg/l

Input Parameters Standard entry

Variable

Value

Unit

Source of parameter value

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravelly

Henry's Law constant

H

2.53E-01

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

1.58E+03

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

1.74E+01

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

1.79E-01

mg/kg

(for comparison with soil analyses)

or

0.01

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Aromatics >EC8-EC10
0.01

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.56E-02

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or
2.78E-01
mg/kg
For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Level 3 - Soil

See Note



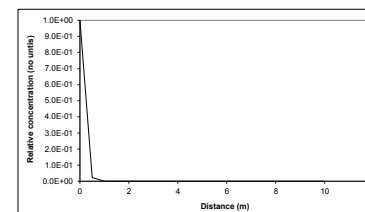
	Input Parameters	Variable	Value	Unit	Source
	Contaminant	C _T	Aromatics >EC8-EC10		from Level 1
	Target Concentration	DF	0.01	mg/l	from Level 1
	Dilution Factor		1.56E+00		from Level 2
Select analytical solution (click on brown cell below, then on pull-down menu)	Ogata Banks	Equations in HRA publication			
Select nature of decay rate (click on brown cell below, then on pull-down menu)					
Approach for simulating degradation of pollutants:					
	Enter source concentration	Soil concentration as mg/kg			
	Enter soil concentration	t _{1/2}	0.037857143	days	
	Half life for degradation of contaminant in water	λ	3.60E+02	days	
	Calculated decay rate	Sz	1.93E-03	days ⁻¹	calculated
	Width of plume in aquifer at source	Sy	1.60E+01	m	from Level 2
	Plume thickness in aquifer at source	p	5.40E+00	m	from Level 2
	Bulk density of aquifer materials	n	1.59E+00	g/cm ³	Average value for gravely sand (ConSim manual)
	Effective porosity of aquifer	i	4.00E-01	fraction	Glacial deposits (Hiscock, 2005)
	Hydraulic gradient	K	8.37E-02	fraction	from Level 2 (adjusted)
	Hydraulic conductivity of saturated aquifer	x	1.00E-02	m/d	from Level 2
	Distance to compliance point	y	1.00E+01	m	Nominal 10m (river adjacent to site)
	Distance (lateral) to compliance point perpendicular to flow direction	z		m	
	Distance (depth) to compliance point perpendicular to flow direction	t		s	
	Time since pollutant entered groundwater		1.00E+99	days	time variant options only
	Parameters values determined from options				
	Partition coefficient	Kd	1.74E+01	l/kg	see options
	Longitudinal dispersivity	ax	1.000	m	see options
	Transverse dispersivity	ay	0.100	m	see options
	Vertical dispersivity	az	0.010	m	see options

Define dispersivity (click brown cell and use pull down list)

	Enter value	Calc value
Longitudinal dispersivity	ax	0.99E+00 1.00E+00
Transverse dispersivity	ay	0.99E+00 1.00E-01
Vertical dispersivity	az	0.99E+00 1.00E-02

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log(x/y))^{+1.4}; az = ax/10, ay = ax/100 are assumed



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for
distance-concentration graph

Ogata Banks		
From calculation sheet		
Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	1.36E-03
0.5	2.28E-02	1.31E-05
1.5	5.22E-04	7.10E-07
1.5	1.19E-05	1.62E-08
2.0	2.72E-07	3.71E-10
2.5	6.22E-09	8.46E-12
3.0	1.42E-10	1.93E-13
3.5	3.25E-12	4.42E-15
4.0	7.42E-14	1.01E-16
4.5	1.69E-15	2.31E-18
5.0	3.87E-17	5.27E-20
5.5	8.84E-19	1.20E-21
6.0	2.02E-20	2.75E-23
6.5	4.61E-22	6.28E-25
7.0	1.05E-23	1.43E-26
7.5	2.41E-25	3.28E-28
8.0	5.50E-27	7.48E-30
8.5	1.26E-28	1.71E-31
9.0	2.87E-30	3.91E-33
9.5	6.56E-32	8.92E-35
10.0	1.50E-33	2.04E-36

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	#####
Version:	1

Remedial Targets			
Calculated soil leachate concentration	Co	2.12E-03	mg/l
Level 3 Remedial Target Ogata Banks		1.04E+31 or 1.86E+32	mg/l mg/kg
Distance to compliance point		10	m
Ratio of Compliance Point to Source Concentration	C _{cp} /C _s	1.50E-33	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O_2 , NO_3^- , SO_4^{2-} etc than an alternative solution should be used.



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Aromatics >EC10-EC12		
Target Concentration (C _T)	0.01	mg/l	Origin of C _T : UKDWS for hydrocarbons

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Aromatics >EC10-EC12
0.01 mg/l

Input Parameters

Standard entry

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

7.22E-02

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

2.51E+03

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

2.76E+01

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

2.80E-01

mg/kg

(for comparison with soil analyses)

or

0.01

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Aromatics >EC10-EC12
0.01

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.56E-02

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or
4.37E-01
mg/kg
For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Aromatics >EC10-EC12		from Level 1
Target Concentration	C _T	0.01	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Enter method of defining partition co-efficient (using pull down list)
Calculate for non-polar organic chemicals

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Enter source concentration			
Enter soil concentration			
Half life for degradation of contaminant in water	t _{1/2}	31.51428571	mg/kg
Calculated decay rate	λ	2.58E+02	days
Width of plume in aquifer at source	Sz	2.69E-03	days ⁻¹
Plume thickness in aquifer at source	Sy	1.60E+01	m
Bulk density of aquifer materials	ρ	5.40E+00	m
Effective porosity of aquifer	n	1.59E+00	g/cm ³
Hydraulic gradient	i	4.00E-01	fraction
Hydraulic conductivity of saturated aquifer	K	8.37E-02	fraction
Distance to compliance point	x	1.00E-02	m/d
Distance (lateral) to compliance point perpendicular to flow direction	z	1.00E+01	m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days
Parameters values determined from options			time variant options only
Partition coefficient	Kd	2.76E+01	l/kg
Longitudinal dispersivity	ax	1.000	m
Transverse dispersivity	az	0.100	m
Vertical dispersivity	av	0.010	m

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Groundwater flow velocity	v	2.09E-03	m/d
Retardation factor	Rf	1.11E+02	fraction
Decay rate used	λ	2.69E-03	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02	fraction
Rate of contaminant flow due to retardation	u	1.89E-05	m/d
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	2.09E-50	fraction
Attenuation factor (C _{CP} /C ₀)	AF	4.78E+49	fraction
Calculated soil leachate concentration	Co	1.12E+00	mg/l

Remedial Targets

Level 3 Remedial Target	7.46E+47	mg/l	For comparison with measured pore water concentration.
Ogata Banks	2.09E+49	mg/kg	This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	10	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	2.09E-50	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

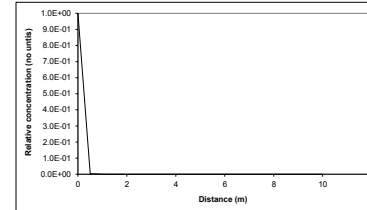
Entry if specify partition coefficient (option)		
Soil water partition coefficient	Kd	l/kg
Entry for non-polar organic chemicals (option)		
Fraction of organic carbon in aquifer	foc	1.10E-02 fraction
Organic carbon partition coefficient	Koc	2.51E+03 l/kg
Entry for ionic organic chemicals (option)		
Sorption coefficient for related species	K _{oc,li}	l/kg
Sorption coefficient for ionised species	K _{oc,li}	l/kg
pH value	pH	
Acid dissociation constant	pKa	
Fraction of organic carbon in aquifer	foc	fraction
Soil water partition coefficient	Kd	2.76E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity	ax	0.00E+00	1.00E+00	8.30E-01	m
Transverse dispersivity	az	0.00E+00	1.00E-01	8.30E-02	m
Vertical dispersivity	ay	0.00E+00	1.00E-02	8.30E-03	m
Note values of dispersivity must be > 0					
Xu & Eckstein (1995) report ax = 0.83/(log ₁₀ x) ^{2+1/4} ; az = ax/10, ay = ax/100 are assumed					

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	7.21E-01
0.5	3.28E-03	2.37E-03
1.0	1.08E-05	7.76E-06
1.5	3.53E-08	2.55E-08
2.0	1.16E-10	8.36E-11
2.5	3.80E-13	2.74E-13
3.0	1.25E-15	9.00E-16
3.5	4.09E-18	2.95E-18
4.0	1.34E-20	9.68E-21
4.5	4.41E-23	3.18E-23
5.0	1.45E-25	1.04E-25
5.5	4.74E-28	3.42E-28
6.0	1.56E-30	1.12E-30
6.5	5.11E-33	3.68E-33
7.0	1.68E-35	1.21E-35
7.5	5.50E-38	3.96E-38
8.0	1.80E-40	1.30E-40
8.5	5.82E-43	4.27E-43
9.0	1.94E-45	1.40E-45
9.5	6.37E-48	4.59E-48
10.0	2.09E-50	1.51E-50

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	#####
Version:	1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment			
Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Aromatics >EC12-EC16		
Target Concentration (C_T)	0.01	mg/l	Origin of C_T: UKDWS for hydrocarbons

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Aromatics >EC12-EC16
0.01 mg/l

Input Parameters
Standard entry

Variable

Value

Unit

Source of parameter value

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

1.26E-02

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

5.01E+03

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

5.51E+01

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

5.55E-01

mg/kg

(for comparison with soil analyses)

or

0.01

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Aromatics >EC12-EC16
0.01

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.56E-02

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or

8.66E-01

mg/kg

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Aromatics >EC12-EC16		from Level 1
Target Concentration	C _t	0.01	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration	118	mg/kg	
Enter soil concentration	2.04E+02	days	
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	5.51E+01	l/kg see options
Longitudinal dispersivity	ax	1.000	m see options
Transverse dispersivity	az	0.100	m see options
Vertical dispersivity	av	0.010	m see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	V	2.09E-03 m/d
Retardation factor	Rf	2.20E+02 fraction
Decay rate used	λ	3.40E-03 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02 fraction
Rate of contaminant flow due to retardation	u	9.51E-06 m/d
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	1.08E-80 fraction
Attenuation factor (C ₁₀ /C ₀)	AF	9.26E+79 fraction
Calculated soil leachate concentration	Co	2.12E+00 mg/l

Remedial Targets

Level 3 Remedial Target	1.44E+78	mg/l	For comparison with measured pore water concentration.
Ogata Banks	8.02E+79	mg/kg	This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	10	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	1.08E-80	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)
Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.10E-02 fractionOrganic carbon partition coefficient K_{oc} 5.01E+03 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,ri} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH l/kg

Acid dissociation constant pKa fraction

Fraction of organic carbon in aquifer f_{oc} fraction

Soil water partition coefficient Kd 5.51E+01 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity

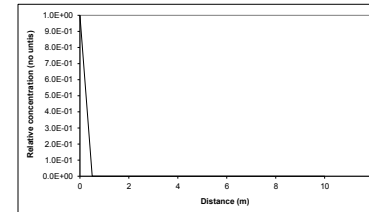
Transverse dispersivity

Vertical dispersivity

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.4+1.4}; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.00E+00	1.36E+00
0.5	1.00E-04	1.37E-04
1.0	1.01E-08	1.37E-08
1.5	1.01E-12	1.38E-12
2.0	1.02E-16	1.38E-16
2.5	1.02E-20	1.39E-20
3.0	1.02E-24	1.39E-24
3.5	1.03E-28	1.40E-28
4.0	1.03E-32	1.41E-32
4.5	1.04E-36	1.41E-36
5.0	1.04E-40	1.42E-40
5.5	1.04E-44	1.42E-44
6.0	1.05E-48	1.43E-48
6.5	1.05E-52	1.43E-52
7.0	1.06E-56	1.44E-56
7.5	1.06E-60	1.44E-60
8.0	1.06E-64	1.45E-64
8.5	1.07E-68	1.46E-68
9.0	1.07E-72	1.46E-72
9.5	1.08E-76	1.47E-76
10.0	1.08E-80	1.47E-80

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed: Former Gas Works

Completed by: AS

Date: #####

Version: 1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment			
Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Aromatics >EC16-EC21		
Target Concentration (C_T)	0.01	mg/l	Origin of C_T: UKDWS for hydrocarbons

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Aromatics >EC16-EC21
0.01 mg/l

Input Parameters

Standard entry

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

6.95E-04

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

1.41E+04

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

1.55E+02

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

1.56E+00

mg/kg

(for comparison with soil analyses)

or

0.01

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Aromatics >EC16-EC21
0.01

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.56E-02

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or

2.43E+00

mg/kg

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Aromatics >EC16-EC21		from Level 1
Target Concentration	C _t	0.01	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration			
Enter soil concentration	390	mg/kg	
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	l/kg	see options
Longitudinal dispersivity	ax	m	see options
Transverse dispersivity	az	m	see options
Vertical dispersivity	av	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Groundwater flow velocity	V	2.09E-03	m/d
Retardation factor	Rf	6.19E+02	fraction
Decay rate used	λ	1.62E-04	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02	fraction
Rate of contaminant flow due to retardation	u	3.38E-06	m/d
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	1.10E-28	fraction
Attenuation factor (C ₁₀ /C ₁₀₀)	AF	9.06E+27	fraction
Calculated soil leachate concentration	Co	2.50E+00	mg/l

Remedial Targets

Level 3 Remedial Target	1.41E+26	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	2.20E+28	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	1.10E-28	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Enter method of defining partition co-efficient (using pull down list)
Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.10E-02 fractionOrganic carbon partition coefficient K_{oc} 1.41E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,ri} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH l/kg

Acid dissociation constant pKa fraction

Fraction of organic carbon in aquifer f_{oc} fraction

Soil water partition coefficient Kd 1.55E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity

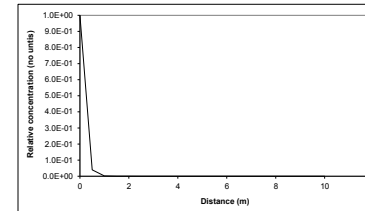
Transverse dispersivity

Vertical dispersivity

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.4+1.4}; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	1.61E+00
0.5	4.00E-02	6.43E-02
1.0	1.60E-03	2.57E-03
1.5	6.40E-05	1.03E-04
2.0	2.56E-06	4.11E-06
2.5	1.02E-07	1.65E-07
3.0	4.10E-09	6.59E-09
3.5	1.64E-10	2.64E-10
4.0	6.56E-12	1.05E-11
4.5	2.63E-13	4.22E-13
5.0	1.05E-14	1.69E-14
5.5	4.20E-16	6.75E-16
6.0	1.68E-17	2.70E-17
6.5	6.73E-19	1.08E-18
7.0	2.69E-20	4.32E-20
7.5	1.08E-21	1.73E-21
8.0	4.31E-23	6.92E-23
8.5	1.72E-24	2.77E-24
9.0	6.89E-26	1.11E-25
9.5	2.76E-27	4.43E-27
10.0	1.10E-28	1.77E-28

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed: Former Gas Works

Completed by: AS

Date: #####

Version: 1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Benzo(a)pyrene		
Target Concentration (C _T)	0.00000017 mg/l	Origin of C _T :	EQS Freshwater (The Water Framework Directive 2015)

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration
 C_T

Benzo(a)pyrene
0.00000017 mg/l

Input Parameters

Standard entry

Variable	Value	Unit
Water filled soil porosity θ_w	3.82E-01	fraction
Air filled soil porosity θ_a	4.65E-02	fraction
Bulk density of soil zone material ρ	9.40E-01	g/cm ³
Henry's Law constant H	1.76E-06	dimensionless

Source of parameter value
Calculated using porosity calculator
Calculated using porosity calculator
From Atkins (2013), representative value to gravely
LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil) f_{oc}

1.10E-02 fraction

Organic carbon partition coefficient K_{oc}

1.29E+05 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species $K_{oc,n}$

l/kg

Sorption coefficient for ionised species $K_{oc,i}$

l/kg

pH value pH

pH units

Acid dissociation constant pK_a

Fraction of organic carbon (in soil) f_{oc}

fraction

Soil water partition coefficient used in Level Assessment K_d 1.42E+03 l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target	2.41E-04	mg/kg	(for comparison with soil analyses)
	or		
	0.00000017	mg/l	(for comparison with leachate test results)

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	12-Feb-18
Version:	1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Benzo(a)pyrene
0.00000017

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

2.65E-07

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or

3.76E-04

mg/kg

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Benzol(a)pyrene		from Level 1
Target Concentration	C _T	0.00000017	mg/l	from Level 1
Dilution Factor	DF	1.99E+00		from Level 2

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d I/kg

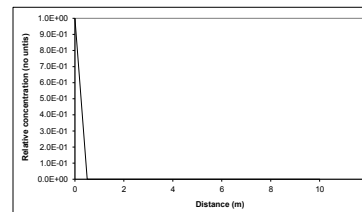
Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.10E-02 fractionOrganic carbon partition coefficient K_{oc} 1.29E+05 I/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,ri} I/kgSorption coefficient for ionised species K_{oc,i} I/kg

pH value pH

Acid dissociation constant pK_a fractionFraction of organic carbon in aquifer f_{oc} I/kgSoil water partition coefficient K_d 1.42E+03 I/kg

Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks	Distance	Relative concentration	Concentration
		(No units)	mg/l
	0	1.0E+00	1.54E-02
	0.5	1.03E-09	1.59E-11
	1.0	1.07E-18	1.64E-20
	1.5	1.10E-27	1.69E-29
	2.0	1.14E-36	1.75E-38
	2.5	1.17E-45	1.81E-47
	3.0	1.21E-54	1.86E-56
	3.5	1.25E-63	1.92E-65
	4.0	1.29E-72	1.99E-74
	4.5	1.33E-81	2.05E-83
	5.0	1.38E-90	2.12E-92
	5.5	1.42E-99	2.19E-101
	6.0	1.47E-108	2.26E-110
	6.5	1.51E-117	2.33E-119
	7.0	1.56E-126	2.41E-128
	7.5	1.61E-135	2.49E-137
	8.0	1.67E-144	2.57E-146
	8.5	1.72E-153	2.65E-155
	9.0	1.78E-162	2.74E-164
	9.5	1.84E-171	2.82E-173
	10.0	1.89E-180	2.92E-182

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	#####
Version:	1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration			
Enter soil concentration	34	mg/kg	
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	K _d	I/kg	see options
Longitudinal dispersivity	ax	m	see options
Transverse dispersivity	az	m	see options
Vertical dispersivity	av	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	2.09E-03 m/d
Retardation factor	Rf	5.63E+03 fraction
Decay rate used	λ	6.51E-04 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02 fraction
Rate of contaminant flow due to retardation	u	3.71E-07 m/d
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	1.89E-180 fraction
Attenuation factor (C _{CP} /C ₀)	AF	5.28E+179 fraction
Calculated soil leachate concentration	Co	2.40E-02 mg/l

Remedial Targets

Level 3 Remedial Target	1.40E+173	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	1.98E+176	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	1.89E-180	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Benzo(b)fluoranthene		
Target Concentration (C _T)	0.00000017	mg/l	Origin of C _T : Benzo(a)pyrene EQS Freshwater (The Water Framework)

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Benzo(b)fluoranthene
0.00000017 mg/l

Input Parameters

Standard entry

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

2.05E-06

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

1.05E+05

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

1.15E+03

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

1.96E-04

mg/kg

(for comparison with soil analyses)

or

0.00000017

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Benzo(b)fluoranthene
0.00000017

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

2.65E-07

mg/l

or

3.05E-04

mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters

Variable	Value	Unit	Source
Contaminant	Benzobifluoranthene		from Level 1
Target Concentration	C _T 0.00000017	mg/l	from Level 1
Dilution Factor	DF 1.56E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d I/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.10E-02 fractionOrganic carbon partition coefficient K_{oc} 1.05E+05 I/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,ri} I/kgSorption coefficient for ionised species K_{oc,i} I/kg

pH value pH I/kg

Acid dissociation constant pK_a fractionFraction of organic carbon in aquifer f_{oc} I/kgSoil water partition coefficient K_d 1.15E+03 I/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Enter value Calc value Xu & Eckstein

Longitudinal dispersivity ax 0.00E+00 1.00E+00 8.30E-01 m

Transverse dispersivity az 0.00E+00 1.00E-01 8.30E-02 m

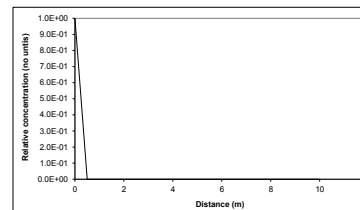
Vertical dispersivity ay 0.00E+00 1.00E-02 8.30E-03 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2+1/4}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	1.89E-02
0.5	2.82E-08	5.35E-10
1.0	7.97E-16	1.51E-17
1.5	2.25E-23	4.26E-25
2.0	6.36E-31	1.20E-32
2.5	1.80E-38	3.40E-40
3.0	5.07E-46	9.60E-48
3.5	1.43E-53	2.71E-55
4.0	4.04E-61	7.65E-63
4.5	1.14E-68	2.16E-70
5.0	3.22E-76	6.10E-78
5.5	9.10E-84	1.72E-85
6.0	2.57E-91	4.87E-93
6.5	7.26E-99	1.37E-100
7.0	2.05E-106	3.88E-108
7.5	5.79E-114	1.10E-115
8.0	1.63E-121	3.09E-123
8.5	4.61E-129	8.74E-131
9.0	1.30E-136	2.47E-138
9.5	3.68E-144	6.97E-146
10.0	1.04E-151	1.97E-153

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	#####
Version:	1

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration			
Enter soil concentration	34	mg/kg	
Half life for degradation of contaminant in water	t _{1/2} 1.22E+03	days	
Calculated decay rate	λ 5.68E-04	days ⁻¹	calculated
Width of plume in aquifer at source	Sz 1.60E+01	m	from Level 2
Plume thickness in aquifer at source	Sy 5.40E+00	m	from Level 2
Bulk density of aquifer materials	ρ 1.59E+00	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n 4.00E-01	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i 8.37E-02	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K 1.00E-02	m/d	from Level 2
Distance to compliance point	x 1.00E+01	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t 1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	K _d 1.15E+03	I/kg	see options
Longitudinal dispersivity	ax 1.000	m	see options
Transverse dispersivity	az 0.100	m	see options
Vertical dispersivity	ay 0.010	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v 2.09E-03	m/d
Retardation factor	Rf 4.58E+03	fraction
Decay rate used	λ 5.68E-04	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i 8.37E-02	fraction
Rate of contaminant flow due to retardation	u 4.57E-07	m/d
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀ 1.04E-151	fraction
Attenuation factor (C _{CP} /C ₀)	AF 9.62E+150	fraction
Calculated soil leachate concentration	Co 2.95E-02	mg/l

Remedial Targets

Level 3 Remedial Target	2.55E+144	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	2.94E+147	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀ 1.04E-151	fraction	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment			
Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Benzo(k)fluoranthene		
Target Concentration (C _T)	0.00000017	mg/l	Origin of C _T : Benzo(a)pyrene EQS Freshwater (The Water Framework)

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Benzo(k)fluoranthene
0.00000017 mg/l

Input Parameters

Standard entry

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravelly

Henry's Law constant

H

1.74E-06

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

1.48E+05

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

1.63E+03

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

2.77E-04

mg/kg

(for comparison with soil analyses)

or

0.00000017

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Benzo(k)fluoranthene
0.00000017

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

2.65E-07

mg/l

or

4.31E-04

mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Benzok(h)fluoranthene		from Level 1
Target Concentration	C _T	0.00000017	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Enter method of defining partition co-efficient (using pull down list)

Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d I/kg

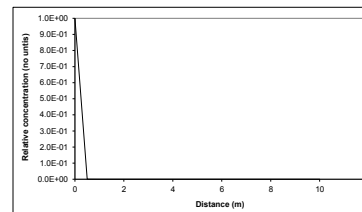
Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.10E-02 fractionOrganic carbon partition coefficient K_{oc} 1.48E+05 I/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,ri} I/kgSorption coefficient for ionised species K_{oc,i} I/kg

pH value pH I/kg

Acid dissociation constant pK_a fractionFraction of organic carbon in aquifer f_{oc} I/kgSoil water partition coefficient K_d 1.63E+03 I/kg

Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks	Relative concentration	Concentration
Distance	(No units)	mg/l
0	1.0E+00	8.28E-03
0.5	1.77E-05	1.47E-07
1.0	3.15E-10	2.60E-12
1.5	5.58E-15	4.62E-17
2.0	9.90E-20	8.19E-22
2.5	1.76E-24	1.45E-26
3.0	3.11E-29	2.58E-31
3.5	5.52E-34	4.57E-36
4.0	9.79E-39	8.11E-41
4.5	1.74E-43	1.44E-45
5.0	3.08E-48	2.55E-50
5.5	5.46E-53	4.52E-55
6.0	9.69E-58	8.02E-60
6.5	1.72E-62	1.42E-64
7.0	3.05E-67	2.52E-69
7.5	5.41E-72	4.48E-74
8.0	9.59E-77	7.94E-79
8.5	1.70E-81	1.41E-83
9.0	3.02E-86	2.50E-88
9.5	5.35E-91	4.43E-93
10.0	9.49E-96	7.86E-98

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	#####
Version:	1

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration			
Enter soil concentration	21	mg/kg	
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	K _d	I/kg	see options
Longitudinal dispersivity	ax	m	see options
Transverse dispersivity	az	m	see options
Vertical dispersivity	ay	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Groundwater flow velocity	v	2.09E-03	m/d
Retardation factor	Rf	6.47E+03	fraction
Decay rate used	λ	1.62E-04	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02	fraction
Rate of contaminant flow due to retardation	u	3.24E-07	m/d
Ratio of Compliance Point to Source Concentration	C _{EP} /C ₀	9.49E-96	fraction
Attenuation factor (C ₀ /C _{EP})	AF	1.05E+95	fraction
Calculated soil leachate concentration	Co	1.29E-02	mg/l

Remedial Targets

Level 3 Remedial Target	2.79E+88	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	4.54E+91	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{EP} /C ₀	9.49E-96	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Fluoranthene		
Target Concentration (C _T)	0.0000063 mg/l	Origin of C _T :	EQS Freshwater (The Water Framework Directive 2015)

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water Partition Co-efficient by using the pull down menu below

Calculate for non-polar organic chemicals

Contaminant	Fluoranthene	
Target concentration	C _T	0.000063 mg/l

Input Parameters

Standard entry

Water filled soil porosity	θ_w	3.82E-01	fraction
Air filled soil porosity	θ_a	4.65E-02	fraction
Bulk density of soil zone material	ρ	9.40E-01	g/cm ³
Henry's Law constant	H	6.29E-05	dimensionless

Calculated using porosity calculator
Calculated using porosity calculator
From Atkins (2013), representative value to gravel
LQM/CIEH (2015)

	This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient.
ly	The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd		l/kg
----------------------------------	----	--	------

--	--

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)	foc	1.10E-02	fraction
--------------------------------------	-----	----------	----------

From 2017 SI (average of made ground values)

Organic carbon partition coefficient	Koc	1.82E+04	l/kg
--------------------------------------	-----	----------	------

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species $K_{oc,n}$ l/kg

Sorption coefficient for ionised species	$K_{oc,i}$	l/kg
--	------------	------

pH value	pH	pH units
1	1	1
2	2	2
3	3	3
4	4	4
5	5	5
6	6	6
7	7	7
8	8	8
9	9	9
10	10	10
11	11	11
12	12	12

Acid dissociation constant	pKa	
----------------------------	-----	--

Fraction of organic carbon (in soil) foc fraction

Soil water partition coefficient used in Level Assessment	Kd	2.00E+02	l/kg	Calculated value
---	----	----------	------	------------------

Level 1 Remedial Target

Level 1 Remedial Target	1.26E-03	mg/kg	(for comparison with soil analyses)
	or		
	0.0000063	mg/l	(for comparison with leachate test results)

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	12-Feb-18
Version:	1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Fluoranthene
0.0000063

mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

9.82E-06

mg/l

or

1.97E-03

mg/kg

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Fluoranthene		from Level 1
Target Concentration	C _T	0.0000063	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Enter method of defining partition co-efficient (using pull down list)
Calculate for non-polar organic chemicals

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration			
Enter soil concentration	87	mg/kg	
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	l/kg	see options
Longitudinal dispersivity	ax	m	see options
Transverse dispersivity	az	m	see options
Vertical dispersivity	av	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	2.09E-03 m/d
Retardation factor	Rf	7.97E+02 fraction
Decay rate used	λ	7.88E-04 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02 fraction
Rate of contaminant flow due to retardation	u	2.63E-06 m/d
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	8.60E-74 fraction
Attenuation factor (C ₁₀ /C ₁₀₀)	AF	1.16E+73 fraction
Calculated soil leachate concentration	Co	4.34E-01 mg/l

Remedial Targets

Level 3 Remedial Target	1.14E+68	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	2.29E+70	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C ₁₀ /C ₀	8.60E-74	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.10E-02 fractionOrganic carbon partition coefficient K_{oc} 1.82E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,ri} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer f_{oc} fraction

Soil water partition coefficient Kd 2.00E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity

ax 0.00E+00 1.00E+00 8.50E-01 m

Transverse dispersivity

az 0.00E+00 1.00E-01 8.50E-02 m

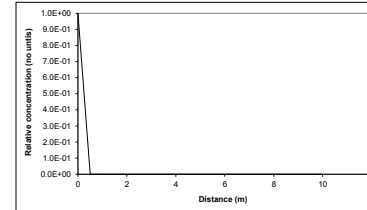
Vertical dispersivity

ay 0.00E+00 1.00E-02 8.50E-03 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2+1/4}; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	2.78E-01
0.5	2.22E-04	6.18E-05
1.0	4.94E-08	1.37E-08
1.5	1.10E-11	3.05E-12
2.0	2.44E-15	6.78E-16
2.5	5.42E-19	1.51E-19
3.0	1.20E-22	3.35E-23
3.5	2.67E-26	7.44E-27
4.0	5.94E-30	1.65E-30
4.5	1.32E-33	3.67E-34
5.0	2.93E-37	8.16E-38
5.5	6.52E-41	1.81E-41
6.0	1.45E-44	4.03E-45
6.5	3.22E-48	8.95E-49
7.0	7.15E-52	1.99E-52
7.5	1.59E-55	4.42E-56
8.0	3.53E-59	9.62E-60
8.5	7.84E-63	2.16E-63
9.0	1.74E-66	4.85E-67
9.5	3.87E-70	1.08E-70
10.0	8.60E-74	2.39E-74

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed: Former Gas Works

Completed by: AS

Date: #####

Version: 1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Indeno(1,2,3-cd)pyrene		
Target Concentration (C _T)	0.00000017	mg/l	Origin of C _T : Benzo(a)pyrene EQS Freshwater (The Water Framework)

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Indeno(1,2,3-cd)pyrene
0.00000017 mg/l

Input Parameters

Standard entry

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

2.05E-06

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

8.71E+04

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

9.58E+02

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

1.63E-04

mg/kg

(for comparison with soil analyses)

or

0.00000017

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Indeno(1,2,3-cd)pyrene
0.00000017 mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

2.65E-07

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or

2.54E-04

mg/kg

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Indeno(1,2,3-cd)pyrene		from Level 1
Target Concentration	C _T	0.00000017	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Enter method of defining partition co-efficient (using pull down list)
Calculate for non-polar organic chemicals

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration	17	mg/kg	
Enter soil concentration	4.28E+03	days	
Half life for degradation of contaminant in water	1.62E-04	days ⁻¹	calculated
Calculated decay rate	1.60E+01	m	from Level 2
Width of plume in aquifer at source	5.40E+00	m	from Level 2
Plume thickness in aquifer at source	1.59E+00	g/cm ³	Average value for gravelly sand (ConSim manual)
Bulk density of aquifer materials	4.00E-01	fraction	Glacial deposits (Hiscock, 2005)
Effective porosity of aquifer	8.37E-02	fraction	from Level 2 (adjusted)
Hydraulic gradient	1.00E-02	m/d	from Level 2
Hydraulic conductivity of saturated aquifer	1.00E+01	m	Nominal 10m (river adjacent to site)
Distance to compliance point		m	
Distance (lateral) to compliance point perpendicular to flow direction		m	
Distance (depth) to compliance point perpendicular to flow direction		m	
Time since pollutant entered groundwater	1.00E+99	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	2.00E+02	l/kg see options
Longitudinal dispersivity	ax	1.000	m see options
Transverse dispersivity	az	0.100	m see options
Vertical dispersivity	av	0.010	m see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Groundwater flow velocity	V	2.09E-03	m/d
Retardation factor	Rf	7.97E+02	fraction
Decay rate used	λ	1.62E-04	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02	fraction
Rate of contaminant flow due to retardation	u	2.63E-06	m/d
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	1.00E-32	fraction
Attenuation factor (C _{CP} /C ₀)	AF	9.97E+31	fraction
Calculated soil leachate concentration	Co	1.77E-02	mg/l

Remedial Targets

Level 3 Remedial Target	2.64E+25	mg/l	For comparison with measured pore water concentration.
Ogata Banks	2.53E+28	mg/kg	This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	10	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	1.00E-32	Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.10E-02 fractionOrganic carbon partition coefficient K_{oc} 1.82E+04 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,ri} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer f_{oc} fraction

Soil water partition coefficient Kd 2.00E+02 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity

Transverse dispersivity

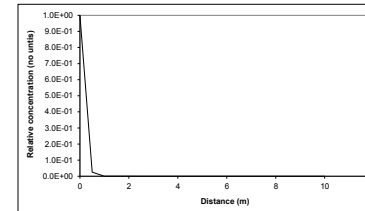
Vertical dispersivity

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2+1/4}; az = ax/10, ay = ax/100 are assumed

Note

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	1.14E-02
0.5	2.51E-02	2.86E-04
1.0	6.31E-04	7.18E-06
1.5	1.59E-05	1.80E-07
2.0	3.98E-07	4.53E-09
2.5	1.00E-08	1.14E-10
3.0	2.51E-10	2.86E-12
3.5	6.32E-12	7.19E-14
4.0	1.59E-13	1.81E-15
4.5	3.99E-15	4.54E-17
5.0	1.00E-16	1.14E-18
5.5	2.52E-18	2.86E-20
6.0	6.32E-20	7.19E-22
6.5	1.59E-21	1.81E-23
7.0	3.99E-23	4.54E-25
7.5	1.00E-24	1.14E-26
8.0	2.52E-26	2.86E-28
8.5	6.32E-28	7.20E-30
9.0	1.59E-29	1.81E-31
9.5	3.99E-31	4.54E-33
10.0	1.00E-32	1.14E-34

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed: Former Gas Works

Completed by: AS

Date: #####

Version: 1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Naphthalene		
Target Concentration (C _T)	0.002	mg/l	Origin of C _T : EQS Freshwater (The Water Framework Directive 2015)

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Naphthalene
0.002 mg/l

Input Parameters Standard entry

Variable

Value

Unit

Source of parameter value

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

6.62E-03

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

6.46E+02

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

7.10E+00

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

1.50E-02

mg/kg

(for comparison with soil analyses)

or

0.002

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Naphthalene
0.002

mg/l

from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

3.12E-03

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or

2.34E-02

mg/kg

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Naphthalene		from Level 1
Target Concentration	C _T	0.002	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Enter method of defining partition co-efficient (using pull down list)
Calculate for non-polar organic chemicals

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration			
Enter soil concentration	24	mg/kg	
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	Kd	l/kg	see options
Longitudinal dispersivity	ax	m	see options
Transverse dispersivity	az	m	see options
Vertical dispersivity	av	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable	Value	Unit
Groundwater flow velocity	v	2.09E-03 m/d
Retardation factor	Rf	2.92E+01 fraction
Decay rate used	λ	2.69E-03 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02 fraction
Rate of contaminant flow due to retardation	u	7.16E-05 m/d
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	3.00E-25 fraction
Attenuation factor (C _{CP} /C ₀)	AF	3.33E+24 fraction
Calculated soil leachate concentration	Co	3.20E+00 mg/l

Remedial Targets

Level 3 Remedial Target	1.04E+22	mg/l	For comparison with measured pore water concentration.
Ogata Banks	7.79E+22	mg/kg	This assumes Level 1 Remedial Target is based on Target Concentration.
Distance to compliance point	10	m	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	3.00E-25	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99

Entry if specify partition coefficient (option)

Soil water partition coefficient Kd l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer foc 1.10E-02 fraction

Organic carbon partition coefficient Koc 6.46E+02 l/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,ri} l/kgSorption coefficient for ionised species K_{oc,i} l/kg

pH value pH

Acid dissociation constant pKa

Fraction of organic carbon in aquifer foc

Soil water partition coefficient Kd 7.10E+00 l/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity

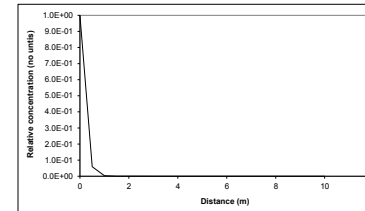
Transverse dispersivity

Vertical dispersivity

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.4+1.4}; az = ax/10, ay = ax/100 are assumed

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O₂, NO₃, SO₄ etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	2.05E+00
0.5	5.94E-02	1.22E-01
1.0	3.53E-03	7.24E-03
1.5	2.10E-04	4.30E-04
2.0	1.25E-05	2.56E-05
2.5	7.40E-07	1.52E-06
3.0	4.40E-08	9.02E-08
3.5	2.61E-09	5.36E-09
4.0	1.55E-10	3.18E-10
4.5	9.22E-12	1.89E-11
5.0	5.48E-13	1.12E-12
5.5	3.26E-14	6.68E-14
6.0	1.93E-15	3.97E-15
6.5	1.15E-16	2.36E-16
7.0	6.83E-18	1.40E-17
7.5	4.06E-19	8.32E-19
8.0	2.41E-20	4.94E-20
8.5	1.43E-21	2.94E-21
9.0	8.51E-23	1.75E-22
9.5	5.06E-24	1.04E-23
10.0	3.00E-25	6.16E-25

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99.

Site being assessed: Former Gas Works

Completed by: AS

Date: #####

Version: 1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment

Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Acenaphthene		
Target Concentration (C _T)	0.017	mg/l	Origin of C _T : Freshwater Chronic Screening Value, Region 4 USEPA

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Acenaphthene
0.017 mg/l

Input Parameters
Standard entry

Variable

Value

Unit

Source of parameter value

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravely

Henry's Law constant

H

7.59E-04

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

2.34E+03

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

2.58E+01

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

4.45E-01

mg/kg

(for comparison with soil analyses)

or

0.017

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Acenaphthene
0.017

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

2.65E-02

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or

6.94E-01

mg/kg

For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Acenaphthene		from Level 1
Target Concentration	C _T	0.017	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Ogata Banks	Equations in HRA publication
-------------	------------------------------

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants:

Apply degradation rate to pollutants in all phases (e.g. field derived value, 4

Enter method of defining partition co-efficient (using pull down list)
Calculate for non-polar organic chemicals

Entry if specify partition coefficient (option)

Soil water partition coefficient K_d I/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 1.10E-02 fractionOrganic carbon partition coefficient K_{oc} 2.34E+03 I/kg

Entry for ionic organic chemicals (option)

Sorption coefficient for related species K_{oc,ri} I/kgSorption coefficient for ionised species K_{oc,i} I/kg

pH value pH I/kg

Acid dissociation constant pK_a fractionFraction of organic carbon in aquifer f_{oc} I/kgSoil water partition coefficient K_d 2.58E+01 I/kg

Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

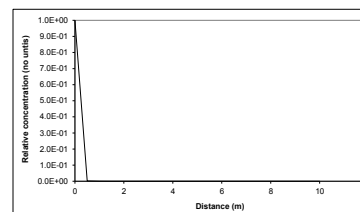
Enter value Calc value Xu & Eckstein

Longitudinal dispersivity ax 0.00E+00 1.00E+00 8.30E-01 m

Transverse dispersivity az 0.00E+00 1.00E-01 8.30E-02 m

Vertical dispersivity ay 0.00E+00 1.00E-02 8.30E-03 m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2+1/4}; az = ax/10, ay = ax/100 are assumed

Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Distance	Relative concentration	Concentration
	(No units)	mg/l
0	1.0E+00	3.67E-01
0.5	1.96E-03	7.19E-04
1.0	3.63E-06	1.41E-06
1.5	7.49E-09	2.75E-09
2.0	1.46E-11	5.38E-12
2.5	2.87E-14	1.05E-14
3.0	5.61E-17	2.06E-17
3.5	1.10E-19	4.03E-20
4.0	2.15E-22	7.88E-23
4.5	4.20E-25	1.54E-25
5.0	8.21E-28	3.02E-28
5.5	1.61E-30	5.90E-31
6.0	3.14E-33	1.16E-33
6.5	6.15E-36	2.26E-36
7.0	1.20E-38	4.42E-39
7.5	2.35E-41	8.65E-42
8.0	4.61E-44	1.69E-44
8.5	9.01E-47	3.31E-47
9.0	1.76E-49	6.48E-50
9.5	3.45E-52	1.27E-52
10.0	6.75E-55	2.48E-55

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter source concentration			
Enter soil concentration	15	mg/kg	
Half life for degradation of contaminant in water	t _{1/2}	days	
Calculated decay rate	λ	days ⁻¹	calculated
Width of plume in aquifer at source	Sz	m	from Level 2
Plume thickness in aquifer at source	Sy	m	from Level 2
Bulk density of aquifer materials	ρ	g/cm ³	Average value for gravelly sand (ConSim manual)
Effective porosity of aquifer	n	fraction	Glacial deposits (Hiscock, 2005)
Hydraulic gradient	i	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	m/d	from Level 2
Distance to compliance point	x	m	Nominal 10m (river adjacent to site)
Distance (lateral) to compliance point perpendicular to flow direction	z	m	
Distance (depth) to compliance point perpendicular to flow direction	y	m	
Time since pollutant entered groundwater	t	days	time variant options only
Parameters values determined from options			
Partition coefficient	K _d	I/kg	see options
Longitudinal dispersivity	ax	m	see options
Transverse dispersivity	az	m	see options
Vertical dispersivity	ay	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Groundwater flow velocity	V	2.09E-03	m/d
Retardation factor	Rf	1.04E+02	fraction
Decay rate used	λ	3.40E-03	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	8.37E-02	fraction
Rate of contaminant flow due to retardation	u	2.02E-05	m/d
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	6.75E-55	fraction
Attenuation factor (C _{CP} /C ₀)	AF	1.48E+54	fraction
Calculated soil leachate concentration	Co	5.73E-01	mg/l

Remedial Targets

Level 3 Remedial Target	3.93E+52	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	1.03E+54	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	10	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{CP} /C ₀	6.75E-55	fraction

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99.

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	#####
Version:	1



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.2

First released: 2006. Version 3.2: January 2013

This worksheet has been produced in combination with the document 'Remedial Targets Methodology: Hydrogeological risk assessment for land contamination (Environment Agency 2006).

Users of this worksheet should always refer to the User Manual to the Remedial Targets Methodology and to relevant guidance on UK legislation and policy, in order to understand how this procedure should be applied in an appropriate context.

© Environment Agency, 2006. (Produced by the Environment Agency's Science Group)

The calculation of equations in this worksheet has been independently checked by Entec (UK) Ltd on behalf of the Environment Agency.

All rights reserved. You will not modify, reverse compile or otherwise dis-assemble the worksheet.

Liability: The Environment Agency does not promise that the worksheet will provide any particular facilities or functions. You must ensure that the worksheet meets your needs and you remain solely responsible for the competent use of the worksheet. You are entirely responsible for the consequences of any use of the worksheet and the Agency provides no warranty about the fitness for purpose or performance of any part of the worksheet. We do not promise that the media will always be free from defects, computer viruses, software locks or other similar code or that the operation of the worksheet will be uninterrupted or error free. You should carry out all necessary virus checks prior to installing on your computing system.

IMPORTANT: To enable MS Excel worksheet, click Tools, Add -Ins, Analysis Tool Pak and Analysis Tool Pak-VBA (to calculate error functions).

Details to be completed for each assessment			
Site Name:	Former Gas Works		
Site Address:	Gas Works Road, Reading		
Completed by:	AS		
Date:	12-Feb-18	Version:	1
Contaminant	Anthracene		
Target Concentration (C _T)	0.0001	mg/l	Origin of C _T : EQS Freshwater (The Water Framework Directive 2015)

This worksheet can be used to determine remedial targets for soils (Worksheets Level 1 Soil, Level 2 and Level 3 Soil) or to determine remedial targets for groundwater (Level 3 Groundwater). For Level 3, parameter values must be entered separately dependent on whether the assessment is for soil or groundwater. For soil, remedial targets are calculated as either mg/kg (for comparison with soil measurements) or mg/l (for comparison with leaching tests or pore water concentrations).

Site details entered on this page are automatically copied to Level 1, 2 and 3 Worksheets.

Worksheet options are identified by brown background and employ a pull-down menus. Data entry are identified as blue background.

Data origin / justification should be noted in cells coloured yellow and fully documented in subsequent reports.

Data carried forward from an earlier worksheet are identified by a light green background

It is recommended that a copy of the original worksheet is saved (all data fields in the original copy are blank).

The spreadsheet also includes a porosity calculation worksheet, a soil impact calculation worksheet and a worksheet that performs some simple hydrogeological calculations.

Remedial Targets Worksheet , Release 3.2

Level 1 - Soil



Select the method of calculating the soil water
Partition Co-efficient by using the pull down menu
below

Calculate for non-polar organic chemicals

Contaminant
Target concentration

C_T

Anthracene
0.0001 mg/l

Input Parameters

Standard entry

Water filled soil porosity

θ_w

3.82E-01

fraction

Calculated using porosity calculator

Air filled soil porosity

θ_a

4.65E-02

fraction

Calculated using porosity calculator

Bulk density of soil zone material

ρ

9.40E-01

g/cm³

From Atkins (2013), representative value to gravelly

Henry's Law constant

H

1.81E-04

dimensionless

LQM/CIEH (2015)

This sheet calculates the Level 1 remedial target for soils(mg/kg) based on a selected target concentration and theoretical calculation of soil water partitioning. Three options are included for determining the partition coefficient. The measured soil concentration as mg/kg should be compared with the Level 1 remedial target to determine the need for further action.

Entry if specify partition coefficient (option)

Soil water partition coefficient

K_d

l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon (in soil)

f_{oc}

1.10E-02

fraction

From 2017 SI (average of made ground values)

Organic carbon partition coefficient

K_{oc}

5.62E+03

l/kg

LQM/CIEH (2015)

Entry for ionic organic chemicals (option)

Sorption coefficient for neutral species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

pH units

Acid dissociation constant

pK_a

Fraction of organic carbon (in soil)

f_{oc}

fraction

Soil water partition coefficient used in Level Assessment

K_d

6.19E+01

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

6.23E-03

mg/kg

(for comparison with soil analyses)

or

0.0001

mg/l

(for comparison with leachate test results)

Site being assessed: Former Gas Works

Completed by: AS

Date: 12-Feb-18

Version: 1

Remedial Targets Worksheet , Release 3.2



Level 2 - Soil

Contaminant
Target concentration

C_T

Anthracene
0.0001

mg/l
from Level 1
from Level 1

This sheet calculates the Level 2 remedial target for soils (mg/kg) or for pore water (mg/l).

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 2 remedial target to determine the need for further action. Equations presented in 'Hydrogeological risk assessment for land contamination' (Environment Agency 2006)

Input Parameters

Variable

Value

Unit

Source of parameter value

Standard entry

Infiltration
Area of contaminant source

Inf
A

1.00E-04
4.64E+02

m/d
m²

Calculated infiltration
m and length (29m) from Atkins (2013) (measured from site plan)

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow
Saturated aquifer thickness
Hydraulic Conductivity of aquifer in which dilution occurs
Hydraulic gradient of water table
Width of contaminant source perpendicular to groundwater flow
Background concentration of contaminant in groundwater beneath site

L
da
K
i
w
Cu

2.90E+01
5.40E+00
1.00E-02
3.00E-02
1.60E+01
0.00E+00

m
m
m/d
fraction
m
mg/l

Site length (measured from site plan) in direction of groundwater flow
Thickness of Alluvium and Sand and Gravel and average groundwater velocity
From 12/12/2017 monitoring round
width (16m) from Atkins (2013) (measured from site plan)

Not used in calculation

Define mixing zone depth by specifying or calculating depth (using pull down list)

Enter mixing zone thickness
Calculated mixing zone thickness

Mz
Mz

Specify
5.40E+00

m
m

Assumed equal to saturated aquifer thickness

Calculated Parameters

Dilution Factor

DF

1.56E+00

Level 2 Remedial Target

1.56E-04

mg/l

For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration

or
9.70E-03
mg/kg
For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water

Additional option

Calculation of impact on receptor

Concentration of contaminant in contaminated discharge (entering receptor)

C_c

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Former Gas Works
Completed by: AS
Date: 12-Feb-18
Version: 1

Level 3 - Soil

See Note



Input Parameter	Variable	Value	Unit	Source
Contaminant		Anthracene		from Level 1
Target Concentration	C_T	0.0001	mg/l	from Level 1
Dilution Factor	DF	1.56E+00		from Level 2

Select analytical solution (click on brown cell below, then on pull-down menu)

Variable	Value	Unit	Source
Ogata Banks			Equations in HRA publication

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for sequential degradation of pollutants: **Apply degradation rate to pollutants in all phases (e.g. field derived value, R)**

Variable	Value	Unit	Source of parameter value
Enter source concentration			Soil concentration as mg/kg
Enter soil concentration	21	mg/kg	
Half life for degradation of contaminant in water	$t_{1/2}$	9.20E+02	days
Calculated decay rate	λ	7.53E-04	days ⁻¹
Width of plume in aquifer at source	Sz	1.60E+01	m
Plume thickness in aquifer at source	Sy	5.40E+00	m
Bulk density of aquifer materials	ρ	1.59E+00	g/cm ³
Effective porosity of aquifer	n	4.00E-01	fraction
Hydraulic gradient	i	8.37E-02	fraction
Hydraulic conductivity of saturated aquifer	K	1.00E-02	m/d
Distance to compliance point	x	1.00E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z		m
Distance (depth) to compliance point perpendicular to flow direction	y		m
Time since pollutant entered groundwater	t	1.00E+99	days

Parameters values determined from options

Variable	Value	Unit	Source
Partition coefficient	Kd	6.19E+01	l/kg
Longitudinal dispersivity	ax	1.000	m
Transverse dispersivity	ay	0.100	m
Vertical dispersivity	az	0.010	m

Enter method of defining partition coefficient (using pull down list)

Calculate for non-polar organic chemicals

Enter if specify partition coefficient (option)

Soil water partition coefficient

Kd

6.19E+01

l/kg

Enter for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer

foc

1.10E-02

fraction

Organic carbon partition coefficient

Koc

5.62E+03

l/kg

Enter for ionic chemicals (option)

Sorption coefficient for related species

K_{oc,n}

l/kg

Sorption coefficient for ionised species

K_{oc,i}

l/kg

pH value

pH

Acid dissociation constant

pKa

Fraction of organic carbon in aquifer

foc

fraction

Soil water partition coefficient

Kd

6.19E+01

l/kg

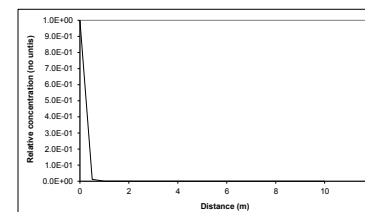
Define dispersivity (click brown cell and use pull down list)

Dispersivities 10%, 1%, 0.1% of pathway length

Variable	Value	Unit	Source
Longitudinal dispersivity	ax	1.00E+00	m
Transverse dispersivity	ay	0.10E+00	m
Vertical dispersivity	az	0.01E+00	m

Note values of dispersivity must be > 0

Xu & Eckstein (1995) report $ax = 0.83(\log_{10} x)^{-1.416}$; $ay = ax/10$, $az = ax/100$ are assumed



Note: 'Relative concentration' is the ratio of calculated concentration at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks		
From calculation sheet		
Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	2.16E-01
0.5	1.14E-02	2.48E-03
1.0	1.31E-04	2.83E-05
1.5	1.50E-06	3.24E-07
2.0	1.71E-08	3.71E-09
2.5	1.96E-10	4.24E-11
3.0	2.24E-12	4.85E-13
3.5	2.56E-14	5.55E-15
4.0	2.93E-16	6.35E-17
4.5	3.36E-18	7.26E-19
5.0	3.84E-20	8.31E-21
5.5	4.39E-22	9.50E-23
6.0	5.02E-24	1.09E-24
6.5	5.75E-26	1.24E-26
7.0	6.57E-28	1.42E-28
7.5	7.52E-30	1.63E-30
8.0	8.60E-32	1.86E-32
8.5	9.84E-34	2.19E-34
9.0	1.13E-35	2.44E-36
9.5	1.29E-37	2.79E-38
10.0	1.47E-39	3.19E-40

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), based on the distance to the receptor or compliance located down hydraulic gradient of the source Three solution methods are included, the preferred option is Ogata Banks. By setting a long travel time (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.9E+99

Site being assessed:	Former Gas Works
Completed by:	AS
Date:	#####
Version:	1

Remedial Targets			
Calculated soil reagent concentration	Co	3.37E-01	mg/l
Level 3 Remedial Target Ogata Banks	1.06E+35 or 6.59E+36	mg/l mg/kg	For comparison with measured pore water concentration. This assumes Level 1 Remedial Target is based on Target Concentration. For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point	10	m	
Ratio of Compliance Point to Source Concentration	C _{cp} /C _s	1.47E-39	fraction Ogata Banks

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target. The recommended value for time when calculating the remedial target is 9.9E+99

Note
This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best described by an electron limited degradation such as oxidation by O_2 , NO_3 , SO_4 etc than an alternative solution should be used.

Dilution in River Kennet

Parameter	Variable	Value	Units
Hydraulic Conductivity of aquifer in which dilution occurs	K	1.00E-02	m/d
Hydraulic gradient of water table	i	0.03	fraction
Width of contaminant source perpendicular to groundwater flow	w	16	m
Saturated aquifer thickness	da	5.3	m
Cross-sectional area	A	84.8	m ²
Flow from site to River (calculated using Dracy's Law)	Q	0.025	m ³ /d
Flow in River Kennet at Theale (Q95 flow from Natural Environment Research Council, 2008)	Q	3.76	m ³ /s
		324,864	m ³ /d
Dilution factor	DF	12,769,811	unitless

Appendix 8 Ground Gas Monitoring Results

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
BH01	27/11/17 13:20:00	1009	0.00								0.0	10		
BH01	27/11/17 13:21:00										0.0			
BH01	27/11/17 13:22:00										0.0			
BH01	27/11/17 13:23:00										0.0			
BH01	27/11/17 13:24:00										0.0			
BH01	27/11/17 13:25:00			3.5	9.1	0.6	0.0	0	0	2.5				
BH01	27/11/17 13:26:00			3.5	9.2	0.4	0.0	0	0	3.2				
BH01	27/11/17 13:27:00			3.5	9.2	0.4	0.0	0	0	3.7				
BH01	27/11/17 13:28:00			3.5	9.3	0.4	0.0	0	0	4.1				
BH01	27/11/17 13:29:00			3.5	9.3	0.3	0.0	0	0	4.3				
BH01	27/11/17 13:30:00			3.5	9.3	0.3	0.0	0	0	4.7				
BH01	27/11/17 13:31:00			3.5	9.3	0.3	0.0	0	0	5.0				
BH01	27/11/17 13:32:00			3.5	9.3	0.4	0.0	0	0	5.4				
BH01	27/11/17 13:33:00			3.5	9.1	0.7	0.0	0	0	5.9				
BH01	27/11/17 13:34:00			3.6	8.8	1.2	0.0	0	0	6.4				
BH01	27/11/17 13:35:00	1031	0.00									9	1.64	
BH01	04/12/17 09:50:00										0.0			
BH01	04/12/17 09:51:00										0.0			

remarks

denotes result exceeding capacity of gas monitoring equipment

VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.

CONTRACT

33572

CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lit/hr)	temperature (°C)	water level (m - bgl)	remarks
BH01	04/12/17 09:52:00										0.0			
BH01	04/12/17 09:53:00										0.0			
BH01	04/12/17 09:54:00										0.0			
BH01	04/12/17 09:55:00			4.0	4.7	0.3	0.0	0	0	9.1				
BH01	04/12/17 09:56:00			4.1	4.7	2.0	0.0	0	0	10.6				
BH01	04/12/17 09:57:00			4.1	4.7	0.1	0.0	0	0	11.9				
BH01	04/12/17 09:58:00			4.1	4.7	0.1	0.0	0	0	12.6				
BH01	04/12/17 09:59:00			4.1	4.7	0.1	0.0	0	0	13.4				
BH01	04/12/17 10:00:00			4.1	4.7	0.1	0.0	0	0	14.6				
BH01	04/12/17 10:01:00			4.2	4.7	0.2	0.0	0	0	15.7				
BH01	04/12/17 10:02:00			4.3	4.5	0.4	0.0	0	0	17.0				
BH01	04/12/17 10:03:00			4.4	4.4	0.6	0.0	0	0	18.5				
BH01	04/12/17 10:04:00			4.6	4.2	1.4	0.0	0	0	20.7				
BH01	04/12/17 10:05:00												1.67	
BH01	12/12/17 10:15:00	975	0.00								0.0	3		
BH01	12/12/17 10:16:00										0.0			
BH01	12/12/17 10:17:00										0.0			
BH01	12/12/17 10:18:00										0.0			
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.													CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
BH01	12/12/17 10:19:00										0.0			
BH01	12/12/17 10:20:00			1.3	6.0	12.7	0.0	0	0	4.6				
BH01	12/12/17 10:21:00			1.1	4.6	13.9	0.0	0	0	5.8				
BH01	12/12/17 10:22:00			0.9	4.3	14.5	0.0	0	0	6.4				
BH01	12/12/17 10:23:00			0.8	3.9	15.2	0.0	0	0	8.1				
BH01	12/12/17 10:24:00			0.7	3.4	15.8	0.0	0	0	8.7				
BH01	12/12/17 10:25:00			0.7	3.2	16.0	0.0	0	0	8.9				
BH01	12/12/17 10:26:00			0.6	2.9	16.2	0.0	0	0	8.9				
BH01	12/12/17 10:27:00			0.6	2.7	16.7	0.0	0	0	8.8				
BH01	12/12/17 10:28:00			0.6	2.6	16.6	0.0	0	0	8.7				
BH01	12/12/17 10:29:00			0.5	2.5	16.8	0.0	0	0	8.8				
BH01	12/12/17 10:30:00												1.49	
BH01	04/01/18 10:55:00													Cover and surrounding area under water. No monitoring possible.
BH01	18/01/18 09:00:00	997	0.00								0.0	8		
BH01	18/01/18 09:01:00										0.0			
BH01	18/01/18 09:02:00										0.0			
BH01	18/01/18 09:03:00										0.0			
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.													CONTRACT 33572	CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
BH01	18/01/18 09:04:00										0.0			
BH01	18/01/18 09:05:00			0.1	0.1	19.8	1.7	0	0	0.4				
BH01	18/01/18 09:06:00			0.0	0.0	19.9	2.2	0	0	0.4				
BH01	18/01/18 09:07:00			0.0	0.0	19.9	1.9	0	0	0.4				
BH01	18/01/18 09:08:00			0.0	0.0	19.9	1.7	0	0	0.4				
BH01	18/01/18 09:09:00			0.0	0.0	19.9	2.2	0	0	0.5				
BH01	18/01/18 09:10:00			0.0	0.0	19.9	1.6	0	0	0.5				
BH01	18/01/18 09:11:00			0.0	0.0	19.9	1.5	0	0	0.5				
BH01	18/01/18 09:12:00			0.0	0.0	19.9	1.5	0	0	0.5				
BH01	18/01/18 09:13:00			0.0	0.0	19.9	2.2	0	0	0.5				
BH01	18/01/18 09:14:00			0.0	0.0	19.9	1.7	0	0	0.0				
BH01	18/01/18 09:15:00												1.58	
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.													CONTRACT 33572	CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lit/hr)	temperature (°C)	water level (m - bgl)	remarks
BH02	04/12/17 10:15:00	1029	0.00								0.0	9		
BH02	04/12/17 10:16:00										0.0			
BH02	04/12/17 10:17:00										0.0			
BH02	04/12/17 10:18:00										0.0			
BH02	04/12/17 10:19:00										0.0			
BH02	04/12/17 10:20:00			0.2	0.0	19.3	0.0	0	0	18.2				
BH02	04/12/17 10:21:00			0.0	0.0	20.2	0.0	0	0	15.5				
BH02	04/12/17 10:22:00			0.0	0.0	20.3	0.0	0	0	13.4				
BH02	04/12/17 10:23:00			0.0	0.0	20.3	0.0	0	0	12.4				
BH02	04/12/17 10:24:00			0.0	0.0	20.3	0.0	0	0	11.5				
BH02	04/12/17 10:25:00			0.0	0.0	20.3	0.0	0	0	10.8				
BH02	04/12/17 10:26:00			0.0	0.0	20.3	0.0	0	0	10.3				
BH02	04/12/17 10:27:00			0.0	0.0	20.3	0.0	0	0	10.0				
BH02	04/12/17 10:28:00			0.0	0.0	20.3	0.0	0	0	9.5				
BH02	04/12/17 10:29:00			0.0	0.0	20.3	0.0	0	0	9.2				
BH02	04/12/17 10:30:00	978	0.00									3	1.76	
BH02	12/12/17 09:50:00										0.0			
BH02	12/12/17 09:51:00										0.0			

remarks

denotes result exceeding capacity of gas monitoring equipment

VOC - Photolionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.

CONTRACT
33572

CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
BH02	12/12/17 09:52:00										0.0			
BH02	12/12/17 09:53:00										0.0			
BH02	12/12/17 09:54:00										0.0			
BH02	12/12/17 09:55:00			0.7	0.0	19.3	0.0	0	0	2.9				
BH02	12/12/17 09:56:00			0.7	0.0	19.4	0.0	0	0	2.9				
BH02	12/12/17 09:57:00			0.7	0.0	19.3	0.0	0	0	2.5				
BH02	12/12/17 09:58:00			0.7	0.0	19.2	0.0	0	0	2.3				
BH02	12/12/17 09:59:00			0.7	0.0	19.1	0.0	0	0	1.9				
BH02	12/12/17 10:00:00			0.7	0.0	19.0	0.0	0	0	1.7				
BH02	12/12/17 10:01:00			0.7	0.0	19.0	0.0	0	0	1.5				
BH02	12/12/17 10:02:00			0.7	0.0	19.0	0.0	0	0	1.4				
BH02	12/12/17 10:03:00			0.7	0.0	19.0	0.0	0	0	1.3				
BH02	12/12/17 10:04:00			0.7	0.0	18.9	0.0	0	0	1.2				
BH02	12/12/17 10:05:00												1.61	
BH02	04/01/18 07:40:00	996	0.00								0.0	8		
BH02	04/01/18 07:41:00										0.0			
BH02	04/01/18 07:42:00										0.0			
BH02	04/01/18 07:43:00										0.0			
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.													CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole /trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgt)	remarks	
BH02	04/01/18 07:44:00	997	0.00								0.0	8	1.53		
BH02	04/01/18 07:45:00			0.8	0.0	18.9	0.0	0	0	1.1					
BH02	04/01/18 07:46:00			0.5	0.0	19.2	0.0	0	0	1.6					
BH02	04/01/18 07:47:00			0.5	0.0	19.4	0.0	0	0	1.5					
BH02	04/01/18 07:48:00			0.4	0.0	19.4	0.0	0	0	1.4					
BH02	04/01/18 07:49:00			0.4	0.0	19.5	0.0	0	0	1.3					
BH02	04/01/18 07:50:00			0.3	0.0	19.6	0.0	0	0	1.2					
BH02	04/01/18 07:51:00			0.3	0.0	19.6	0.0	0	0	1.2					
BH02	04/01/18 07:52:00			0.3	0.0	19.7	0.0	0	0	1.1					
BH02	04/01/18 07:53:00			0.3	0.0	19.7	0.0	0	0	1.0					
BH02	04/01/18 07:54:00			0.3	0.0	19.7	0.0	0	0	0.9					
BH02	04/01/18 07:55:00														
BH02	18/01/18 09:00:00	997	0.00								0.0	8	1.53		
BH02	18/01/18 09:01:00										0.0				
BH02	18/01/18 09:02:00										0.0				
BH02	18/01/18 09:03:00										0.0				
BH02	18/01/18 09:04:00										0.0				
BH02	18/01/18 09:05:00			0.1	0.1	19.8	1.7	0	0	0.4					
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.														CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lit/hr)	temperature (°C)	water level (m - bgl)	remarks
BH02	18/01/18 09:06:00			0.0	0.0	19.9	2.2	0	0	0.4				
BH02	18/01/18 09:07:00			0.0	0.0	19.9	1.9	0	0	0.4				
BH02	18/01/18 09:08:00			0.0	0.0	19.9	1.7	0	0	0.4				
BH02	18/01/18 09:09:00			0.0	0.0	19.9	2.2	0	0	0.5				
BH02	18/01/18 09:10:00			0.0	0.0	19.9	1.6	0	0	0.5				
BH02	18/01/18 09:11:00			0.0	0.0	19.9	1.5	0	0	0.5				
BH02	18/01/18 09:12:00			0.0	0.0	19.9	1.5	0	0	0.5				
BH02	18/01/18 09:13:00			0.0	0.0	19.9	2.2	0	0	0.5				
BH02	18/01/18 09:14:00			0.0	0.0	19.9	1.7	0	0	0.0				
BH02	18/01/18 09:15:00												1.67	
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.													CONTRACT 33572	CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole /trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks	
BH03C	04/12/17 10:40:00	1029	0.00								0.0	9			
BH03C	04/12/17 10:41:00										0.0				
BH03C	04/12/17 10:42:00										0.0				
BH03C	04/12/17 10:43:00										0.0				
BH03C	04/12/17 10:44:00										0.0				
BH03C	04/12/17 10:45:00			0.4	0.0	19.7	0.0	0	0	11.3					
BH03C	04/12/17 10:46:00			0.4	0.0	19.7	0.0	0	0	10.7					
BH03C	04/12/17 10:47:00			0.4	0.0	19.7	0.0	0	0	10.5					
BH03C	04/12/17 10:48:00			0.3	0.0	19.7	0.0	0	0	10.3					
BH03C	04/12/17 10:49:00			0.3	0.0	19.7	0.0	0	0	10.3					
BH03C	04/12/17 10:50:00			0.3	0.0	19.7	0.0	0	0	10.3					
BH03C	04/12/17 10:51:00			0.3	0.0	19.7	0.0	0	0	10.2					
BH03C	04/12/17 10:52:00			0.3	0.0	19.7	0.0	0	0	10.2					
BH03C	04/12/17 10:53:00			0.3	0.0	19.7	0.0	0	0	10.3					
BH03C	04/12/17 10:54:00			0.3	0.0	19.7	0.0	0	0	10.3					
BH03C	04/12/17 10:55:00	976	14.00									3	1.79		
BH03C	12/12/17 10:40:00										0.0				
BH03C	12/12/17 10:41:00										0.0				
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photolionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against Isobutylene.														CONTRACT 33572	CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
BH03C	12/12/17 10:42:00										0.0			
BH03C	12/12/17 10:43:00										0.0			
BH03C	12/12/17 10:44:00										0.0			
BH03C	12/12/17 10:45:00			0.3	0.0	18.7	0.0	0	0	34.9				
BH03C	12/12/17 10:46:00			0.3	0.0	18.7	0.0	0	0	35.6				
BH03C	12/12/17 10:47:00			0.3	0.0	18.6	0.0	0	0	37.6				
BH03C	12/12/17 10:48:00			0.3	0.0	18.7	0.0	0	0	38.5				
BH03C	12/12/17 10:49:00			0.3	0.0	18.7	0.0	0	0	39.8				
BH03C	12/12/17 10:50:00			0.3	0.0	18.7	0.0	0	0	40.4				
BH03C	12/12/17 10:51:00			0.3	0.0	18.8	0.0	0	0	40.6				
BH03C	12/12/17 10:52:00			0.3	0.0	18.8	0.0	0	0	40.7				
BH03C	12/12/17 10:53:00			0.3	0.0	18.8	0.0	0	0	40.9				
BH03C	12/12/17 10:54:00			0.3	0.0	18.8	0.0	0	0	40.2				
BH03C	12/12/17 10:55:00												1.79	
BH03C	04/01/18 08:10:00	987	21.00								3.3	8		
BH03C	04/01/18 08:11:00										0.0			
BH03C	04/01/18 08:12:00										0.0			
BH03C	04/01/18 08:13:00										0.0			
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.													CONTRACT 33572	CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lit/hr)	temperature (°C)	water level (m - bgl)	remarks
BH03C	04/01/18 08:14:00	997	-114.00								0.0			
BH03C	04/01/18 08:15:00			0.4	0.0	19.0	0.0	0	0	3.5				
BH03C	04/01/18 08:16:00			0.1	0.0	19.6	0.0	0	0	3.4				
BH03C	04/01/18 08:17:00			0.0	0.0	19.8	0.0	0	0	3.3				
BH03C	04/01/18 08:18:00			0.0	0.0	19.9	0.0	0	0	3.1				
BH03C	04/01/18 08:19:00			0.0	0.0	20.0	0.0	0	0	3.1				
BH03C	04/01/18 08:20:00			0.0	0.0	20.0	0.0	0	0	2.9				
BH03C	04/01/18 08:21:00			0.0	0.0	20.1	0.0	0	0	2.7				
BH03C	04/01/18 08:22:00			0.0	0.0	20.1	0.0	0	0	2.4				
BH03C	04/01/18 08:23:00			0.0	0.0	20.1	0.0	0	0	2.3				
BH03C	04/01/18 08:24:00			0.0	0.0	20.1	0.0	0	0	2.2				
BH03C	04/01/18 08:25:00												1.55	
BH03C	18/01/18 09:40:00										-2.7	8		
BH03C	18/01/18 09:41:00										-2.7			
BH03C	18/01/18 09:42:00										-0.9			
BH03C	18/01/18 09:43:00										-0.9			
BH03C	18/01/18 09:44:00										-1.5			
BH03C	18/01/18 09:45:00			0.0	0.0	19.8	1.1	0	0	0.4				
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.													CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole /trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks	
BH03C	18/01/18 09:46:00			0.0	0.0	20.0	0.0	0	0	0.2					
BH03C	18/01/18 09:47:00			0.0	0.0	20.2	0.0	0	0	0.1					
BH03C	18/01/18 09:48:00			0.0	0.0	20.2	0.0	0	0	0.1					
BH03C	18/01/18 09:49:00			0.0	0.0	20.2	0.0	0	0	0.1					
BH03C	18/01/18 09:50:00			0.0	0.0	20.2	0.0	0	0	0.1					
BH03C	18/01/18 09:51:00			0.0	0.0	20.3	0.0	0	0	0.1					
BH03C	18/01/18 09:52:00			0.0	0.0	20.3	0.0	0	0	0.1					
BH03C	18/01/18 09:53:00			0.0	0.0	20.3	0.0	0	0	0.1					
BH03C	18/01/18 09:54:00			0.0	0.0	20.3	0.0	0	0	0.1					
BH03C	18/01/18 09:55:00												1.70		
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.														CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole /trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks	
BH04B	07/12/17 09:05:00	1003	0.00								0.0	12		19mm standpipe	
BH04B	07/12/17 09:06:00										0.0				
BH04B	07/12/17 09:07:00										0.0				
BH04B	07/12/17 09:08:00										0.0				
BH04B	07/12/17 09:09:00										0.0				
BH04B	07/12/17 09:10:00			1.0	1.4	18.0	0.0	0	0	5.0					
BH04B	07/12/17 09:11:00			1.0	1.4	18.0	0.0	0	0	5.4					
BH04B	07/12/17 09:12:00			1.6	1.4	18.0	0.0	0	0	5.5					
BH04B	07/12/17 09:13:00			1.6	1.4	18.0	0.0	0	0	5.3					
BH04B	07/12/17 09:14:00			1.5	1.3	18.0	0.0	0	0	5.3					
BH04B	07/12/17 09:15:00			1.5	1.3	18.7	0.0	0	0	5.3					
BH04B	07/12/17 09:16:00			1.5	1.3	18.1	0.0	0	0	5.4					
BH04B	07/12/17 09:17:00			1.5	1.3	18.2	0.0	0	0	5.5					
BH04B	07/12/17 09:18:00			1.4	1.3	18.2	0.0	0	0	5.4					
BH04B	07/12/17 09:19:00			1.4	1.3	18.2	0.0	0	0	5.4					
BH04B	07/12/17 09:21:00	979	-5.00									3	1.30	19mm standpipe	
BH04B	12/12/17 12:16:00														
BH04B	12/12/17 12:17:00									0.0					
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 19mm													CONTRACT 33572		CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING

Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lit/hr)	temperature (°C)	water level (m - bgl)	remarks
BH04B	12/12/17 12:18:00										0.0			
BH04B	12/12/17 12:19:00										0.0			
BH04B	12/12/17 12:20:00										0.0			
BH04B	12/12/17 12:21:00										0.0			
BH04B	12/12/17 12:22:00			0.0	0.0	19.8	0.0	0	0	0.5				
BH04B	12/12/17 12:23:00			0.0	0.0	20.0	0.0	0	0	0.4				
BH04B	12/12/17 12:24:00			0.0	0.0	20.0	0.0	0	0	0.4				
BH04B	12/12/17 12:25:00			0.0	0.0	20.0	0.0	0	0	0.4				
BH04B	12/12/17 12:26:00			0.0	0.0	20.0	0.0	0	0	0.4				
BH04B	12/12/17 12:27:00			0.0	0.0	20.0	0.0	0	0	0.4				
BH04B	12/12/17 12:28:00			0.0	0.0	20.0	0.0	0	0	0.4				
BH04B	12/12/17 12:29:00			0.0	0.0	20.0	0.0	0	0	0.4				
BH04B	12/12/17 12:30:00			0.0	0.0	20.0	0.0	0	0	0.4				
BH04B	12/12/17 12:31:00			0.0	0.0	20.0	0.0	0	0	0.4				
BH04B	12/12/17 12:32:00												1.31	
BH04B	04/01/18 09:36:00	987	0.00									8		19mm standpipe
BH04B	04/01/18 09:37:00										0.0			
BH04B	04/01/18 09:38:00										0.0			
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 19mm													CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
BH04B	04/01/18 09:39:00										0.0			
BH04B	04/01/18 09:40:00										0.0			
BH04B	04/01/18 09:41:00										0.0			
BH04B	04/01/18 09:42:00			2.0	0.0	18.0	0.0	0	0	1.0				
BH04B	04/01/18 09:43:00			2.0	0.0	17.9	0.0	0	0	1.1				
BH04B	04/01/18 09:44:00			2.0	0.0	17.8	0.0	0	0	1.2				
BH04B	04/01/18 09:45:00			2.0	0.0	17.9	0.0	0	0	1.2				
BH04B	04/01/18 09:46:00			2.0	0.0	17.8	0.0	0	0	1.2				
BH04B	04/01/18 09:47:00			2.0	0.0	17.8	0.0	0	0	1.2				
BH04B	04/01/18 09:48:00			2.0	0.0	17.8	0.0	0	0	1.2				
BH04B	04/01/18 09:49:00			2.0	0.0	17.8	0.0	0	0	1.1				
BH04B	04/01/18 09:50:00			2.0	0.0	17.8	0.0	0	0	1.0				
BH04B	04/01/18 09:51:00			2.0	0.0	17.8	0.0	0	0	1.0				
BH04B	04/01/18 09:52:00												1.02	
BH04B	18/01/18 11:01:00	998	-1.00									8		19mm standpipe
BH04B	18/01/18 11:02:00										0.0			
BH04B	18/01/18 11:03:00										0.0			
BH04B	18/01/18 11:04:00										0.0			
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 19mm													CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
BH04B	18/01/18 11:05:00										0.0			
BH04B	18/01/18 11:06:00										0.0			
BH04B	18/01/18 11:07:00			1.6	0.0	19.1	0.0	0	0	0.3				
BH04B	18/01/18 11:08:00			1.6	0.0	19.1	0.0	0	0	0.3				
BH04B	18/01/18 11:09:00			1.6	0.0	19.1	0.0	0	0	0.3				
BH04B	18/01/18 11:10:00			1.6	0.0	19.1	0.0	0	0	0.3				
BH04B	18/01/18 11:11:00			1.6	0.0	19.1	0.0	0	0	0.3				
BH04B	18/01/18 11:12:00			1.6	0.0	19.1	0.0	0	0	0.3				
BH04B	18/01/18 11:13:00			1.6	0.0	19.1	0.0	0	0	0.3				
BH04B	18/01/18 11:14:00			1.6	0.0	19.1	0.0	0	0	0.3				
BH04B	18/01/18 11:15:00			1.6	0.0	19.1	0.0	0	0	0.3				
BH04B	18/01/18 11:16:00			1.6	0.0	19.1	0.0	0	0	0.3				
BH04B	18/01/18 11:17:00												1.19	
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 19mm													CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks	
BH04B	12/12/17 12:00:00	979	-5.00								0.0	3		50mm standpipe	
BH04B	12/12/17 12:01:00										0.0				
BH04B	12/12/17 12:02:00										0.0				
BH04B	12/12/17 12:03:00										0.0				
BH04B	12/12/17 12:04:00										0.0				
BH04B	12/12/17 12:05:00			0.0	0.0	19.5	0.0	0	0	1.2					
BH04B	12/12/17 12:06:00			0.0	0.0	19.5	0.0	0	0	1.3					
BH04B	12/12/17 12:07:00			0.0	0.0	19.7	0.0	0	0	1.3					
BH04B	12/12/17 12:08:00			0.0	0.0	19.8	0.0	0	0	1.2					
BH04B	12/12/17 12:09:00			0.0	0.0	19.7	0.0	0	0	1.3					
BH04B	12/12/17 12:10:00			0.0	0.0	19.7	0.0	0	0	1.3					
BH04B	12/12/17 12:11:00			0.0	0.0	19.8	0.0	0	0	1.3					
BH04B	12/12/17 12:12:00			0.0	0.0	19.8	0.0	0	0	1.2					
BH04B	12/12/17 12:13:00			0.0	0.0	19.8	0.0	0	0	1.2					
BH04B	12/12/17 12:14:00			0.0	0.0	19.8	0.0	0	0	1.2					
BH04B	12/12/17 12:15:00	987	0.00									8	1.97	50mm standpipe	
BH04B	04/01/18 09:20:00										0.0				
BH04B	04/01/18 09:21:00										0.0				
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mint RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 50mm														CONTRACT 33572	CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
BH04B	04/01/18 09:22:00										0.0			
BH04B	04/01/18 09:23:00										0.0			
BH04B	04/01/18 09:24:00										0.0			
BH04B	04/01/18 09:25:00			0.2	0.0	19.9	0.0	0	0	2.5				
BH04B	04/01/18 09:26:00			0.0	0.0	20.1	0.0	0	0	2.1				
BH04B	04/01/18 09:27:00			0.0	0.0	20.3	0.0	0	0	1.5				
BH04B	04/01/18 09:28:00			0.0	0.0	20.3	0.0	0	0	1.4				
BH04B	04/01/18 09:29:00			0.0	0.0	20.3	0.0	0	0	1.2				
BH04B	04/01/18 09:30:00			0.0	0.0	20.3	0.0	0	0	1.0				
BH04B	04/01/18 09:31:00			0.0	0.0	20.3	0.0	0	0	0.8				
BH04B	04/01/18 09:32:00			0.0	0.0	20.3	0.0	0	0	0.7				
BH04B	04/01/18 09:33:00			0.0	0.0	20.3	0.0	0	0	0.7				
BH04B	04/01/18 09:34:00			0.0	0.0	20.3	0.0	0	0	0.7				
BH04B	04/01/18 09:35:00												1.73	
BH04B	18/01/18 10:45:00	998	-2.00								0.0	8		50mm standpipe
BH04B	18/01/18 10:46:00										0.0			
BH04B	18/01/18 10:47:00										0.0			
BH04B	18/01/18 10:48:00										0.0			
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 50mm													CONTRACT 33572	CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lt/hr)	temperature (°C)	water level (m - bgl)	remarks
BH04B	18/01/18 10:49:00										0.0			
BH04B	18/01/18 10:50:00			0.0	0.0	20.1	0.0	0	0	0.7				
BH04B	18/01/18 10:51:00			0.0	0.0	20.2	0.0	0	0	0.5				
BH04B	18/01/18 10:52:00			0.0	0.0	20.2	0.0	0	0	0.5				
BH04B	18/01/18 10:53:00			0.0	0.0	20.2	0.0	0	0	0.4				
BH04B	18/01/18 10:54:00			0.0	0.0	20.2	0.0	0	0	0.4				
BH04B	18/01/18 10:55:00			0.0	0.0	20.2	0.0	0	0	0.4				
BH04B	18/01/18 10:56:00			0.0	0.0	20.2	0.0	0	0	0.4				
BH04B	18/01/18 10:57:00			0.0	0.0	20.2	0.0	0	0	0.4				
BH04B	18/01/18 10:58:00			0.0	0.0	20.2	0.0	0	0	0.4				
BH04B	18/01/18 10:59:00			0.0	0.0	20.2	0.0	0	0	0.3				
BH04B	18/01/18 11:00:00												1.88	
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 50mm													CONTRACT 33572	CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole /trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks	
BH06A	04/12/17 11:16:00	1029	0.00								0.0	9		19mm standpipe	
BH06A	04/12/17 11:17:00										0.0				
BH06A	04/12/17 11:18:00										0.0				
BH06A	04/12/17 11:19:00										0.0				
BH06A	04/12/17 11:20:00										0.0				
BH06A	04/12/17 11:21:00			0.1	0.0	20.1	0.0	0	0	10.4					
BH06A	04/12/17 11:22:00			0.0	0.0	20.4	0.0	0	0	9.4					
BH06A	04/12/17 11:23:00			0.0	0.0	20.4	0.0	0	0	5.2					
BH06A	04/12/17 11:24:00			0.0	0.0	20.4	0.0	0	0	5.0					
BH06A	04/12/17 11:25:00			0.0	0.0	20.4	0.0	0	0	0.4					
BH06A	04/12/17 11:26:00			0.0	0.0	20.4	0.0	0	0	0.4					
BH06A	04/12/17 11:27:00			0.0	0.0	20.4	0.0	0	0	0.4					
BH06A	04/12/17 11:28:00			0.0	0.0	20.4	0.0	0	0	0.3					
BH06A	04/12/17 11:29:00			0.0	0.0	20.4	0.0	0	0	0.3					
BH06A	04/12/17 11:30:00			0.0	0.0	20.4	0.0	0	0	0.3					
BH06A	04/12/17 11:31:00											1.95			
BH06A	12/12/17 11:41:00	978	6.00								0.0	3		19mm standpipe	
BH06A	12/12/17 11:42:00										0.0				
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 19mm														CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lir/hr)	temperature (°C)	water level (m - bgl)	remarks
BH06A	12/12/17 11:43:00										0.0			
BH06A	12/12/17 11:44:00										0.0			
BH06A	12/12/17 11:45:00										0.0			
BH06A	12/12/17 11:46:00			0.0	0.0	20.0	0.0	0	0	0.6				
BH06A	12/12/17 11:47:00			0.0	0.0	20.0	0.0	0	0	0.6				
BH06A	12/12/17 11:48:00			0.0	0.0	20.0	0.0	0	0	0.6				
BH06A	12/12/17 11:49:00			0.0	0.0	20.0	0.0	0	0	0.5				
BH06A	12/12/17 11:50:00			0.0	0.0	20.0	0.0	0	0	0.5				
BH06A	12/12/17 11:51:00			0.0	0.0	20.0	0.0	0	0	0.5				
BH06A	12/12/17 11:52:00			0.0	0.0	20.0	0.0	0	0	0.5				
BH06A	12/12/17 11:53:00			0.0	0.0	20.0	0.0	0	0	0.5				
BH06A	12/12/17 11:54:00			0.0	0.0	20.0	0.0	0	0	0.5				
BH06A	12/12/17 11:55:00			0.0	0.0	20.0	0.0	0	0	0.5				
BH06A	12/12/17 11:56:00													
BH06A	04/01/18 08:51:00	987	0.00								0.0	8	1.95	19mm standpipe
BH06A	04/01/18 08:52:00										0.0			
BH06A	04/01/18 08:53:00										0.0			
BH06A	04/01/18 08:54:00										0.0			
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 19mm													CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING

Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differential (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lit/hr)	temperature (°C)	water level (m - bgl)	remarks
BH06A	04/01/18 08:55:00	997	-2.00								0.0			
BH06A	04/01/18 08:56:00			0.0	0.0	20.2	0.0	0	0	0.1				
BH06A	04/01/18 08:57:00			0.0	0.0	20.3	0.0	0	0	0.0				
BH06A	04/01/18 08:58:00			0.0	0.0	20.3	0.0	0	0	0.0				
BH06A	04/01/18 08:59:00			0.0	0.0	20.3	0.0	0	0	0.0				
BH06A	04/01/18 09:00:00			0.0	0.0	20.3	0.0	0	0	0.0				
BH06A	04/01/18 09:01:00			0.0	0.0	20.3	0.0	0	0	0.0				
BH06A	04/01/18 09:02:00			0.0	0.0	20.3	0.0	0	0	0.0				
BH06A	04/01/18 09:03:00			0.0	0.0	20.3	0.0	0	0	0.0				
BH06A	04/01/18 09:04:00			0.0	0.0	20.3	0.0	0	0	0.0				
BH06A	04/01/18 09:05:00			0.0	0.0	20.3	0.0	0	0	0.0				
BH06A	04/01/18 09:06:00												1.72	
BH06A	18/01/18 10:21:00										0.0	8		19mm standpipe
BH06A	18/01/18 10:22:00										0.0			
BH06A	18/01/18 10:23:00										0.0			
BH06A	18/01/18 10:24:00										0.0			
BH06A	18/01/18 10:25:00										0.0			
BH06A	18/01/18 10:26:00			0.0	0.0	20.3	0.0	0	0	0.3				
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 19mm													CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
BH06A	18/01/18 10:27:00			0.0	0.0	20.3	0.0	0	0	0.3				
BH06A	18/01/18 10:28:00			0.0	0.0	20.2	0.0	0	0	0.3				
BH06A	18/01/18 10:29:00			0.0	0.0	20.2	0.0	0	0	0.3				
BH06A	18/01/18 10:30:00			0.0	0.0	20.2	0.0	0	0	0.3				
BH06A	18/01/18 10:31:00			0.0	0.0	20.3	0.0	0	0	0.3				
BH06A	18/01/18 10:32:00			0.0	0.0	20.3	0.0	0	0	0.3				
BH06A	18/01/18 10:33:00			0.0	0.0	20.3	0.0	0	0	0.3				
BH06A	18/01/18 10:34:00			0.0	0.0	20.3	0.0	0	0	0.3				
BH06A	18/01/18 10:35:00			0.0	0.0	20.3	0.0	0	0	0.3				
BH06A	18/01/18 10:36:00												1.86	19mm standpipe
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 19mm													CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING

Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
BH06A	04/12/17 11:00:00	1029	0.00								0.0	9		50mm standpipe
BH06A	04/12/17 11:01:00										0.0			
BH06A	04/12/17 11:02:00										0.0			
BH06A	04/12/17 11:03:00										0.0			
BH06A	04/12/17 11:04:00										0.0			
BH06A	04/12/17 11:05:00			0.1	0.0	20.1	0.0	0	0	9.9				
BH06A	04/12/17 11:06:00			0.0	0.0	20.1	0.0	0	0	9.2				
BH06A	04/12/17 11:07:00			0.0	0.0	20.2	0.0	0	0	9.1				
BH06A	04/12/17 11:08:00			0.0	0.0	20.2	0.0	0	0	9.5				
BH06A	04/12/17 11:09:00			0.0	0.0	20.3	0.0	0	0	7.9				
BH06A	04/12/17 11:10:00			0.0	0.0	20.3	0.0	0	0	7.4				
BH06A	04/12/17 11:11:00			0.0	0.0	20.3	0.0	0	0	7.1				
BH06A	04/12/17 11:12:00			0.0	0.0	20.3	0.0	0	0	6.8				
BH06A	04/12/17 11:13:00			0.0	0.0	20.3	0.0	0	0	6.5				
BH06A	04/12/17 11:14:00			0.0	0.0	20.4	0.0	0	0	6.1				
BH06A	04/12/17 11:15:00	978	0.00									3	2.08	50mm standpipe
BH06A	12/12/17 11:25:00										0.0			
BH06A	12/12/17 11:26:00										0.0			

remarks

denotes result exceeding capacity of gas monitoring equipment

VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.

50mm

CONTRACT
33572

CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



borehole /trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lit/hr)	temperature (°C)	water level (m - bgl)	remarks		
BH06A	12/12/17 11:27:00	968	0.00								0.0					
BH06A	12/12/17 11:28:00										0.0					
BH06A	12/12/17 11:29:00										0.0					
BH06A	12/12/17 11:30:00			0.0	0.0	20.0	0.0	0	0	2.6						
BH06A	12/12/17 11:31:00			0.0	0.0	19.9	0.0	0	0	2.5						
BH06A	12/12/17 11:32:00			0.0	0.0	20.0	0.0	0	0	2.5						
BH06A	12/12/17 11:33:00			0.0	0.0	20.0	0.0	0	0	2.3						
BH06A	12/12/17 11:34:00			0.0	0.0	20.0	0.0	0	0	2.2						
BH06A	12/12/17 11:35:00			0.0	0.0	20.0	0.0	0	0	2.1						
BH06A	12/12/17 11:36:00			0.0	0.0	20.0	0.0	0	0	2.1						
BH06A	12/12/17 11:37:00			0.0	0.0	20.0	0.0	0	0	2.0						
BH06A	12/12/17 11:38:00			0.0	0.0	20.0	0.0	0	0	1.9						
BH06A	12/12/17 11:39:00			0.0	0.0	20.0	0.0	0	0	1.9						
BH06A	12/12/17 11:40:00													2.06		
BH06A	04/01/18 08:35:00												0.0	8		50mm standpipe
BH06A	04/01/18 08:36:00												0.0			
BH06A	04/01/18 08:37:00												0.0			
BH06A	04/01/18 08:38:00												0.0			
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 50mm													CONTRACT 33572		CHECKED	

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
BH06A	04/01/18 08:39:00	997	-2.00								0.0			
BH06A	04/01/18 08:40:00			0.4	0.0	19.6	0.0	0	0	4.5				
BH06A	04/01/18 08:41:00			0.1	0.0	19.9	0.0	0	0	4.0				
BH06A	04/01/18 08:42:00			0.0	0.0	20.0	0.0	0	0	3.5				
BH06A	04/01/18 08:43:00			0.0	0.0	20.0	0.0	0	0	2.9				
BH06A	04/01/18 08:44:00			0.0	0.0	20.1	0.0	0	0	2.4				
BH06A	04/01/18 08:45:00			0.0	0.0	20.2	0.0	0	0	2.2				
BH06A	04/01/18 08:46:00			0.0	0.0	20.2	0.0	0	0	1.9				
BH06A	04/01/18 08:47:00			0.0	0.0	20.2	0.0	0	0	1.8				
BH06A	04/01/18 08:48:00			0.0	0.0	20.2	0.0	0	0	1.7				
BH06A	04/01/18 08:49:00			0.0	0.0	20.2	0.0	0	0	1.7				
BH06A	04/01/18 08:50:00												1.78	
BH06A	18/01/18 10:05:00										0.0	8		50mm standpipe
BH06A	18/01/18 10:06:00										0.0			
BH06A	18/01/18 10:07:00										0.0			
BH06A	18/01/18 10:08:00										0.0			
BH06A	18/01/18 10:09:00										0.0			
BH06A	18/01/18 10:10:00			0.1	0.0	19.7	0.0	0	0	1.8				
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 50mm													CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lt/hr)	temperature (°C)	water level (m - bgl)	remarks
BH06A	18/01/18 10:11:00			0.1	0.0	19.8	0.0	0	0	1.7				
BH06A	18/01/18 10:12:00			0.0	0.0	20.1	0.0	0	0	0.9				
BH06A	18/01/18 10:13:00			0.0	0.0	20.1	0.0	0	0	0.9				
BH06A	18/01/18 10:14:00			0.0	0.0	20.1	0.0	0	0	0.8				
BH06A	18/01/18 10:15:00			0.0	0.0	20.1	0.0	0	0	0.7				
BH06A	18/01/18 10:16:00			0.0	0.0	20.1	0.0	0	0	0.7				
BH06A	18/01/18 10:17:00			0.0	0.0	20.2	0.0	0	0	0.6				
BH06A	18/01/18 10:18:00			0.0	0.0	20.2	0.0	0	0	0.6				
BH06A	18/01/18 10:19:00			0.0	0.0	20.2	0.0	0	0	0.6				
BH06A	18/01/18 10:20:00												1.94	
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene. 50mm													CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole /trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks	
WS001	04/12/17 11:40:00	1009	0								0.0	9			
WS001	04/12/17 11:41:00										0.0				
WS001	04/12/17 11:42:00										0.0				
WS001	04/12/17 11:43:00										0.0				
WS001	04/12/17 11:44:00										0.0				
WS001	04/12/17 11:45:00			0.0	0.0	20.2	0.0	0	0	0.7					
WS001	04/12/17 11:46:00			0.0	0.0	20.2	0.0	0	0	0.7					
WS001	04/12/17 11:47:00			0.0	0.0	20.2	0.0	0	0	0.6					
WS001	04/12/17 11:48:00			0.0	0.0	20.3	0.0	0	0	0.6					
WS001	04/12/17 11:49:00			0.0	0.0	20.3	0.0	0	0	0.6					
WS001	04/12/17 11:50:00			0.0	0.0	20.3	0.0	0	0	0.6					
WS001	04/12/17 11:51:00			0.0	0.0	20.3	0.0	0	0	0.6					
WS001	04/12/17 11:52:00			0.0	0.0	20.3	0.0	0	0	0.6					
WS001	04/12/17 11:53:00			0.0	0.0	20.3	0.0	0	0	0.6					
WS001	04/12/17 11:54:00			0.0	0.0	20.3	0.0	0	0	0.6					
WS001	04/12/17 11:55:00	1024	-6.00									7	1.40		
WS001	18/12/17 10:15:00										-1.5				
WS001	18/12/17 10:16:00										-1.5				
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.														CONTRACT 33572	CHECKED

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole /trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (l/hr)	temperature (°C)	water level (m - bgl)	remarks	
WS001	18/12/17 10:17:00	988	0.00								-1.2	8	1.21		
WS001	18/12/17 10:18:00										-1.5				
WS001	18/12/17 10:19:00										-1.5				
WS001	18/12/17 10:20:00			0.4	0.0	19.6	0.0	0	0	10.1					
WS001	18/12/17 10:21:00			0.1	0.0	19.8	0.0	0	0	9.7					
WS001	18/12/17 10:22:00			0.0	0.0	19.9	0.0	0	0	9.2					
WS001	18/12/17 10:23:00			0.0	0.0	20.0	0.0	0	0	8.6					
WS001	18/12/17 10:24:00			0.0	0.0	20.0	0.0	0	0	8.1					
WS001	18/12/17 10:25:00			0.0	0.0	20.0	0.0	0	0	7.7					
WS001	18/12/17 10:26:00			0.0	0.0	20.0	0.0	0	0	7.3					
WS001	18/12/17 10:27:00			0.0	0.0	20.0	0.0	0	0	6.8					
WS001	18/12/17 10:28:00			0.0	0.0	20.0	0.0	0	0	6.4					
WS001	18/12/17 10:29:00			0.0	0.0	20.0	0.0	0	0	6.2					
WS001	18/12/17 10:30:00														
WS001	04/01/18 08:35:00														0.0
WS001	04/01/18 08:36:00									0.0					
WS001	04/01/18 08:37:00									0.0					
WS001	04/01/18 08:38:00									0.0					
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against Isobutylene.														CONTRACT 33572	CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lir/hr)	temperature (°C)	water level (m - bgl)	remarks
WS001	04/01/18 08:39:00	997	-1.00								0.0			
WS001	04/01/18 08:40:00			0.3	0.0	19.8	0.0	0	0	1.3				
WS001	04/01/18 08:41:00			0.0	0.0	20.0	0.0	0	0	1.2				
WS001	04/01/18 08:42:00			0.0	0.0	20.1	0.0	0	0	1.1				
WS001	04/01/18 08:43:00			0.0	0.0	20.2	0.0	0	0	1.0				
WS001	04/01/18 08:44:00			0.0	0.0	20.2	0.0	0	0	0.9				
WS001	04/01/18 08:45:00			0.0	0.0	20.2	0.0	0	0	0.9				
WS001	04/01/18 08:46:00			0.0	0.0	20.2	0.0	0	0	0.8				
WS001	04/01/18 08:47:00			0.0	0.0	20.2	0.0	0	0	0.8				
WS001	04/01/18 08:48:00			0.0	0.0	20.2	0.0	0	0	0.8				
WS001	04/01/18 08:49:00			0.0	0.0	20.2	0.0	0	0	0.8				
WS001	04/01/18 08:50:00												1.08	
WS001	18/01/18 09:20:00										0.0	8		
WS001	18/01/18 09:21:00										0.0			
WS001	18/01/18 09:22:00										0.0			
WS001	18/01/18 09:23:00										0.0			
WS001	18/01/18 09:24:00										0.0			
WS001	18/01/18 09:25:00			0.0	0.0	20.1	0.0	0	0	0.2				
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.													CONTRACT 33572	CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole /trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks	
WS001	18/01/18 09:26:00			0.0	0.0	20.1	0.0	0	0	0.2					
WS001	18/01/18 09:27:00			0.0	0.0	20.2	0.0	0	0	0.2					
WS001	18/01/18 09:28:00			0.0	0.0	20.2	0.0	0	0	0.2					
WS001	18/01/18 09:29:00			0.0	0.0	20.2	0.0	0	0	0.2					
WS001	18/01/18 09:30:00			0.0	0.0	20.2	0.0	0	0	0.2					
WS001	18/01/18 09:31:00			0.0	0.0	20.2	0.0	0	0	0.2					
WS001	18/01/18 09:32:00			0.0	0.0	20.2	0.0	0	0	0.2					
WS001	18/01/18 09:33:00			0.0	0.0	20.2	0.0	0	0	0.2					
WS001	18/01/18 09:34:00			0.0	0.0	20.2	0.0	0	0	0.2					
WS001	18/01/18 09:35:00												1.27		
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.														CONTRACT 33572	CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
WS005	04/12/17 12:05:00	1029	-1								0.0	9		
WS005	04/12/17 12:06:00										0.0			
WS005	04/12/17 12:07:00										0.0			
WS005	04/12/17 12:08:00										0.0			
WS005	04/12/17 12:09:00										0.0			
WS005	04/12/17 12:10:00			0.1	0.0	20.2	0.0	0	0	0.7				
WS005	04/12/17 12:11:00			0.0	0.0	20.3	0.0	0	0	0.6				
WS005	04/12/17 12:12:00			0.0	0.0	20.3	0.0	0	0	0.6				
WS005	04/12/17 12:13:00			0.0	0.0	20.3	0.0	0	0	0.6				
WS005	04/12/17 12:14:00			0.0	0.0	20.3	0.0	0	0	0.6				
WS005	04/12/17 12:15:00			0.0	0.0	20.3	0.0	0	0	0.6				
WS005	04/12/17 12:16:00			0.0	0.0	20.3	0.0	0	0	0.6				
WS005	04/12/17 12:17:00			0.0	0.0	20.3	0.0	0	0	0.6				
WS005	04/12/17 12:18:00			0.0	0.0	20.3	0.0	0	0	0.6				
WS005	04/12/17 12:19:00			0.0	0.0	20.3	0.0	0	0	0.6				
WS005	04/12/17 12:20:00	1026	-4									7	1.96	
WS005	18/12/17 11:45:00										-1.5			
WS005	18/12/17 11:46:00										-1.2			

remarks

denotes result exceeding capacity of gas monitoring equipment

VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.

CONTRACT
33572

CHECKED

GAS AND GROUNDWATER LEVELS

SITE: GAS WORKS ROAD, READING



Borehole /trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (ltr/hr)	temperature (°C)	water level (m - bgl)	remarks
WS005	18/12/17 11:47:00										-1.2			
WS005	18/12/17 11:48:00										-1.2			
WS005	18/12/17 11:49:00										-1.2			
WS005	18/12/17 11:50:00			0.3	0.0	20.0	0.0	0	0	2.0				
WS005	18/12/17 11:51:00			0.3	0.0	19.9	0.0	0	0	1.9				
WS005	18/12/17 11:52:00			0.1	0.0	20.0	0.0	0	0	1.8				
WS005	18/12/17 11:53:00			0.1	0.0	20.0	0.0	0	0	1.7				
WS005	18/12/17 11:54:00			0.0	0.0	20.0	0.0	0	0	1.7				
WS005	18/12/17 11:55:00			0.0	0.0	20.0	0.0	0	0	1.6				
WS005	18/12/17 11:56:00			0.0	0.0	20.1	0.0	0	0	1.6				
WS005	18/12/17 11:57:00			0.0	0.0	20.1	0.0	0	0	1.6				
WS005	18/12/17 11:58:00			0.0	0.0	20.1	0.0	0	0	1.6				
WS005	18/12/17 11:59:00			0.0	0.0	20.1	0.0	0	0	1.6				
WS005	18/12/17 12:00:00												1.89	
WS005	04/01/18 10:30:00	988	0.00								0.0	8		
WS005	04/01/18 10:31:00										0.0			
WS005	04/01/18 10:32:00										0.0			
WS005	04/01/18 10:33:00										0.0			

remarks
 # denotes result exceeding capacity of gas monitoring equipment
 VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.

CONTRACT
33572

CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole / trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lt/hr)	temperature (°C)	water level (m - bgl)	remarks
WS005	04/01/18 10:34:00	999	-2.00								0.0	8	1.72	
WS005	04/01/18 10:35:00			0.1	0.0	20.2	0.0	0	0	0.7				
WS005	04/01/18 10:36:00			0.0	0.0	20.1	0.0	0	0	0.8				
WS005	04/01/18 10:37:00			0.0	0.0	20.3	0.0	0	0	0.8				
WS005	04/01/18 10:38:00			0.0	0.0	20.3	0.0	0	0	0.7				
WS005	04/01/18 10:39:00			0.0	0.0	20.3	0.0	0	0	0.7				
WS005	04/01/18 10:40:00			0.0	0.0	20.3	0.0	0	0	0.7				
WS005	04/01/18 10:41:00			0.0	0.0	20.3	0.0	0	0	0.7				
WS005	04/01/18 10:42:00			0.0	0.0	20.4	0.0	0	0	0.6				
WS005	04/01/18 10:43:00			0.0	0.0	20.4	0.0	0	0	0.6				
WS005	04/01/18 10:44:00			0.0	0.0	20.4	0.0	0	0	0.6				
WS005	04/01/18 10:45:00													
WS005	18/01/18 11:20:00										0.0			
WS005	18/01/18 11:21:00										0.0			
WS005	18/01/18 11:22:00										0.0			
WS005	18/01/18 11:23:00										0.0			
WS005	18/01/18 11:24:00										0.0			
WS005	18/01/18 11:25:00			0.3	0.0	20.0	0.0	0	0	0.3				
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photolionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.													CONTRACT 33572	CHECKED

Geotechnical Engineering Limited

GAS AND GROUNDWATER LEVELS

CLIENT: WARDELL ARMSTRONG LLP

SITE: GAS WORKS ROAD, READING



Borehole /trial pit no.	date and time	barometric pressure (mb)	pressure differentiation (mm H ₂ O)	carbon dioxide (%)	methane (%)	oxygen (%)	LEL (%)	hydrogen sulphide (ppm)	carbon monoxide (ppm)	VOC (ppm)	gas flow (lit/hr)	temperature (°C)	water level (m - bgl)	remarks	
WS005	18/01/18 11:26:00			0.0	0.0	20.1	0.0	0	0	0.3					
WS005	18/01/18 11:27:00			0.0	0.0	20.1	0.0	0	0	0.3					
WS005	18/01/18 11:28:00			0.0	0.0	20.2	0.0	0	0	0.3					
WS005	18/01/18 11:29:00			0.0	0.0	20.2	0.0	0	0	0.3					
WS005	18/01/18 11:30:00			0.0	0.0	20.2	0.0	0	0	0.3					
WS005	18/01/18 11:31:00			0.0	0.0	20.2	0.0	0	0	0.3					
WS005	18/01/18 11:32:00			0.0	0.0	20.2	0.0	0	0	0.3					
WS005	18/01/18 11:33:00			0.0	0.0	20.2	0.0	0	0	0.3					
WS005	18/01/18 11:34:00			0.0	0.0	20.2	0.0	0	0	0.3					
WS005	18/01/18 11:35:00												1.72		
remarks # denotes result exceeding capacity of gas monitoring equipment VOC - Photoionisation Detector Mini RAE 2000 measures VOC vapours with 10.6eV lamp calibrated against isobutylene.														CONTRACT 33572	CHECKED

STOKE-ON-TRENT

Sir Henry Doulton House
Forge Lane
Etruria
Stoke-on-Trent
ST1 5BD
Tel: +44 (0)178 227 6700

BIRMINGHAM

Two Devon Way
Longbridge Technology Park
Longbridge
Birmingham
B31 2TS
Tel: +44 (0)121 580 0909

CARDIFF

22 Windsor Place
Cardiff
CF10 3BY
Tel: +44 (0)292 072 9191

CUMBRIA

Marconi Road
Burgh Road Industrial Estate
Carlisle
Cumbria
CA2 7NA
Tel: +44 (0)122 856 4820

EDINBURGH

Great Michael House
14 Links Place
Edinburgh
EH6 7EZ
Tel: +44 (0)131 555 3311

GLASGOW

2 West Regent Street
Glasgow
G2 1RW
Tel: +44 (0)141 433 7210

LONDON

46 Chancery Lane
London
WC2A 1JE
Tel: +44 (0)207 242 3243

MANCHESTER (City Centre)

76 King Street
Manchester
M2 4NH
Tel: +44 (0)161 817 5038

MANCHESTER (Greater)

2 The Avenue
Leigh
Greater Manchester
WN7 1ES
Tel: +44 (0)194 226 0101

NEWCASTLE UPON TYNE

City Quadrant
11 Waterloo Square
Newcastle Upon Tyne
NE1 4DP
Tel: +44 (0)191 232 0943

SHEFFIELD

Unit 5
Newton Business Centre
Newton Chambers Road
Thornccliffe Park
Chapelton
Sheffield
S35 2PH
Tel: +44 (0)114 245 6244

TRURO

Baldhu House
Wheal Jane Earth Science Park
Baldhu
Truro
TR3 6EH
Tel: +44 (0)187 256 0738

International offices:

ALMATY
29/6 Satpaev Avenue
Regency Hotel Office Tower
Almaty Kazakhstan
050040
Tel: +7(727) 334 1310

MOSCOW

21/5 Kuznetskiy Most St.
Moscow
Russia
Tel: +7(495) 626 07 67

wardell-armstrong.com

STOKE-ON-TRENT

Sir Henry Doulton House
Forge Lane
Etruria
Stoke-on-Trent
ST1 5BD
Tel: +44 (0)178 227 6700

BIRMINGHAM

Two Devon Way
Longbridge Technology Park
Longbridge
Birmingham
B31 2TS
Tel: +44 (0)121 580 0909

CARDIFF

22 Windsor Place
Cardiff
CF10 3BY
Tel: +44 (0)292 072 9191

CUMBRIA

Marconi Road
Burgh Road Industrial Estate
Carlisle
Cumbria
CA2 7NA
Tel: +44 (0)122 856 4820

EDINBURGH

Great Michael House
14 Links Place
Edinburgh
EH6 7EZ
Tel: +44 (0)131 555 3311

GLASGOW

2 West Regent Street
Glasgow
G2 1RW
Tel: +44 (0)141 433 7210

LONDON

46 Chancery Lane
London
WC2A 1JE
Tel: +44 (0)207 242 3243

MANCHESTER (City Centre)

76 King Street
Manchester
M2 4NH
Tel: +44 (0)161 817 5038

MANCHESTER (Greater)

2 The Avenue
Leigh
Greater Manchester
WN7 1ES
Tel: +44 (0)194 226 0101

NEWCASTLE UPON TYNE

City Quadrant
11 Waterloo Square
Newcastle Upon Tyne
NE1 4DP
Tel: +44 (0)191 232 0943

SHEFFIELD

Unit 5
Newton Business Centre
Newton Chambers Road
Thornccliffe Park
Chapelton
Sheffield
S35 2PH
Tel: +44 (0)114 245 6244

TRURO

Baldhu House
Wheal Jane Earth Science Park
Baldhu
Truro
TR3 6EH
Tel: +44 (0)187 256 0738

International offices:

ALMATY
29/6 Satpaev Avenue
Regency Hotel Office Tower
Almaty Kazakhstan
050040
Tel: +7(727) 334 1310

MOSCOW

21/5 Kuznetskiy Most St.
Moscow
Russia
Tel: +7(495) 626 07 67

your earth our world

