

**Quantitative Risk Assessment
Former Broadway PFS
Crowland
Lincolnshire
PE6 0BH**

Prepared for:

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FORMER BROADWAY PFS, CROWLAND

NON TECHNICAL SUMMARY

This report presents the findings of a groundwater risk assessment which was carried out to identify any outstanding risks to groundwater resources in the surrounding area. Where any risks have been identified appropriate mitigation measures or remedial action has been recommended in order to control them to a safe level.

- The ground beneath the property consists of sands and gravels which are a local resource for water supply and two boreholes, which are used for small scale irrigation, are known to exist at neighbouring properties.
- Recent groundwater sampling work carried out on site by EPS has shown that some petrol contamination remains in groundwater beneath the northern end of the former petrol station, in the vicinity of the former underground tank farm, (these were removed in 2003) and these impacts may pose a risk to the quality of groundwater beneath the surrounding area.
- To assess whether the levels of contaminant found do pose a potential risk, EPS has gathered some additional groundwater data for boreholes located in the neighbouring property, tested the mechanics of water movement beneath the site and then used a piece of modelling software to predict if the residual contamination could negatively affect the surrounding area over time.
- The results of this work show that the current concentrations of contaminant found in groundwater beneath the site do not pose a risk to groundwater in the surrounding area and this was supported by the results of groundwater tests on samples collected from the neighbouring property boreholes.
- EPS has therefore recommended that no remediation of groundwater is necessary for the site.

The above points represent a simplified summary of the findings of this assessment and should not form the basis for key decisions for the proposed development. A thorough review of the details contained within the following report, or discussion with EPS is recommended.

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1 INTRODUCTION

In March 2014, Environmental Protection Strategies Ltd (EPS) was commissioned by Mr Ian Ladds to complete a Remedial Strategy for the Former Broadway PFS, Crowland, Lincolnshire, PE6 0BH ('the site'); see Figure 1.

This report presents the findings of human health and groundwater risk assessment work, includes a revised Conceptual Site Model based on the work carried out at the site to date and presents a remedial strategy for the site.

Pre-application proposals for the site include the redevelopment of the site as residential properties. The proposed development plan is included as Appendix A.

1.1 Background and Previous Reports

Prior to the development of this report, several phases of investigations have been carried out but only two have been documented as follows:

- *Site Investigation Report – Former Broadway PFS, Crowland, Lincolnshire, PE6 0BH* (Applied Geology, Ref.: AG1031-08 – November 2008)
- *Supplementary Sampling Report – Former Broadway PFS, Crowland, Lincolnshire, PE6 0BH* (EPS Ltd, Ref.: UK14.01470 – 14th January 2014)

A brief summary of the work known to have been carried out is summarised below, however it is also recommended that the reader review the above reports prior to considering this document.

Previous Undocumented Investigations:

In 2000, the firm PEB Robson excavated three trial pits at the site to inspect the ground conditions and confirm the design and location of the on-site underground tanks. Subsequently, in 2001, Ground Engineering attended the site and drilled five boreholes to determine the conditions of the underlying soils at the site.

In June 2003, JP Chick & Partners attended the site to supervise the excavation and removal of underground tanks, which comprised several relatively small underground tanks used to store either petrol, diesel or waste oils at the northern end of the site. The excavations were reinstated with inert materials. JP Chick also excavated four trial pits in the surrounding area to determine the condition of the surrounding soils and groundwater but it is not clear what the results of this investigation were.

Applied Geology Report - November 2008

The report passed to EPS for review consists of a number of site plans with various notes appended to each to summarise various findings. Very little detail is included, however it appears Applied Geology attended the site in March 2008 to excavate several trial pits across the site and to install six on-site groundwater monitoring wells (BHA-F). In May 2008, Ground Engineering then installed one additional deeper ground monitoring well at the site (BH1A) and JP Chick & Partners Ltd subsequently undertook some groundwater testing of the seven on-site monitoring wells in June 2008. The results of the groundwater sampling identified elevated concentrations of hydrocarbons in several monitoring wells across the site, in particular BH1A situated in the central area of the site where up to 2mm of liquid hydrocarbon was found.

The monitoring wells were subsequently tested again in November 2008 by Applied Geology which indicated that the elevated concentrations of hydrocarbons were still present in the groundwater underlying the site, with the concentration of Total Petroleum Hydrocarbons detected in monitoring well BHA at a concentration of 72mg/l.

A very brief summary of some remediation activities, proposed for completion by Celtic Technologies Ltd, was also included in the report, which involved excavation of up to 3250m³ (6688 tonnes) of contaminated soil from the majority of the northern half of the property for subsequent off-site disposal. It is not clear if this work was ever completed.

EPS Report – January 2014

The supplementary sampling investigation consisted of the precision sampling of the seven existing groundwater monitoring wells at the site for subsequent laboratory analysis. In addition, seven trial pits were also excavated across the property to confirm the ground conditions and to determine if any of the former underground fuel storage tanks were still present at the site.

EPS did not find any remaining underground tanks and confirmed that ground conditions consisted predominantly of made ground overlying natural ground of Abbey Sands and Gravels and then Oxford Clay respectively; the last of which extended to beyond a depth of 3.0m. Groundwater was measured within the monitoring wells at depths of approximately 1.0m below the ground surface.

EPS found black and grey staining in the saturated subsurface soil in several of the trial pits it excavated, with some occasional hydrocarbon odours also evident. Evidence of dissolved hydrocarbon was found in the water samples that were submitted to the laboratory and these were found to exceed relevant basic screening criteria for some hydrocarbon compounds, (including benzene and xylene) at a few of the sampling locations. However, the concentrations identified were significantly lower than those identified during the last groundwater sampling in 2008.

EPS recommended that a detailed site-specific risk assessment for contaminants in groundwater was carried out to determine whether any remedial action would be necessary to protect the surrounding groundwater resources in the area.

Whilst no soil samples were collected for laboratory analysis, the report did make recommendations for future sampling and outlined work that may be necessary during the proposed development to protect the health of future site users from the presence of any hydrocarbon contaminants in the subsurface. These provisions included installation of a hydrocarbon-resistant membrane and drinking water pipework within proposed dwellings at the intended development to break linkages associated with direct and indirect contact with contaminated soil, as well as inhalation of vapours from soil into indoor air.

1.2 Objectives

In accordance with the recommendations made by EPS previous report, the objectives of this investigation are as follows:

- a) To quantify as far as possible the risks to groundwater resources in the surrounding area and therefore determine if existing concentrations in groundwater require control or reduction.
- b) To complete a revised Conceptual Site Model for the site based on this information.
- c) If necessary, to define a remedial strategy that ensures safe development in accordance with the Model Procedures for the Management of Land Contamination - Contaminated Land Report 11.

The work documented in this report to meet these objectives is presented in the following subsequent sections:

- 1) Groundwater Risk Assessment
- 2) Revised Conceptual Model
- 3) Remedial Strategy (if required)

1.3 Limitations and Constraints

The purpose of this report is to present the findings of a revised quantitative risk assessment and remedial options appraisal for treatment of contaminated soil and groundwater which may include a soil and water sampling investigation at the location(s) specified. When examining the data collected from the investigations made during these assessments, Environmental Protection Strategies Ltd (EPS) makes the following statements:

No investigation method is capable of completely identifying all of the contaminants that might be present in the soil or groundwater under a site. Where outlined in our report, we have examined the ground beneath a site by constructing a number of boreholes and / or trial pits to recover soil and / or groundwater samples. The locations of these excavations and sampling points are considered to be representative of the condition of the whole site subsurface. However, ground conditions are naturally variable and it may be possible that localised ground controls could influence the spread of contaminants within the site subsurface. For this reason it is possible that samples collected during the investigation may not represent the conditions across the entire site.

The investigation was carried out to assess the significance of contamination resulting from the use of the site as identified in this report. Unless EPS has otherwise indicated, no assessment of potential impact of any other previous uses has been made.

If third parties have been contracted / consulted during compilation of this report, the validity of any data they may have supplied, and which are included in the report, have been assessed as far as possible by EPS, however, EPS cannot guarantee the validity of these data.

The report has been prepared for the client(s) listed on the report title page and has been subject to standard internal EPS review procedures. EPS accepts no liability or responsibility for use of, or reliance upon, this report and / or the information contained within it by third parties.

2 GROUNDWATER RISK ASSESSMENT

The following plausible contaminant linkages to controlled waters have been identified associated with the site.

Source	Pathway	Receptor
Contaminated Groundwater	Lateral and vertical migration in permeable saturated aquifer material	Surrounding Groundwater Resources

Note:

The nearest surface watercourse to the site is a small drainage ditch situated at least 400m from the site, therefore groundwater has been identified as the primary receptor in this case.

2.1 Qualitative Risk Assessment

In the first instance the risks to groundwater both on-site and beyond the site boundary have been considered qualitatively, in the context of the tiered approach, presented within the EA's Groundwater Protection guidance (GP3).

2.1.1 Resource Potential

The underlying geology is classified by the EA as a Secondary (A) aquifer, (Abbey Sands and Gravels), which overlies unproductive strata, (Oxford Clay). Previous phases of site investigation have identified sands and gravels to depths of between 2.5m and 4-5m below ground level (m bgl) whereupon the underlying Oxford Clay was encountered. The site does not lie within a Source Protection Zone (SPZ) for local groundwater abstraction however there are two boreholes situated within the neighbouring properties which are used for watering gardens.

As stated by GP3, SPZs and the use of aquifer designation should not be taken as a substitute for site-specific risk assessment. In terms of vulnerability of groundwater, the EA's aim is to evaluate how susceptible groundwater resources are to pollution. In the case of this site, the classification of the underlying geology is designated by the EA as Secondary (A) Aquifer, however the site is located in a relatively small outcrop of the Abbey Sands and Gravel unit, which has been shown to be between 2 and 3m saturated thickness. The results of this risk assessment and the potential value of remediation should therefore be considered in context with the potential value of the resource in the immediate surrounding area.

2.1.2 Off-Site Migration

Measurement of groundwater elevations at the site has found a very flat groundwater surface within the ground which makes the prediction for any off-site migration difficult. However, laboratory testing of groundwater samples has provided some indicative evidence of groundwater flow through examination of the concentration and location of dissolved contaminants. The highest concentration of contaminants appears to be located within the central northern area of site, where the former underground storage tanks were originally located however, moderate impacts have also been found in samples collected from monitor wells located along the western boundary whilst no impact has been found in samples collected from the eastern boundary.

From this evidence, it would appear that contaminant migration is toward the west / southwest. Figure 2 provides an interpretation of the expected contaminant distribution across the site using results from EPS recent groundwater sampling results.

In addition to this, the current site owner advised EPS that previous investigations had found contamination in groundwater samples collected from the boreholes located in the neighbouring property to the southwest.

2.1.3 Conclusions

Whilst there are mitigating factors to consider alongside the results of any further assessment, the risk to groundwater resources at this site must be evaluated by means of a quantitative groundwater risk assessment. EPS has also concluded that groundwater within the boreholes at the adjacent properties must be resampled in order to provide a check on the predictions made by any quantitative risk assessment models.

2.2 Quantitative Risk Assessment

The following subsections provide an outline of the methodology used to carry out the quantitative risk assessment (QRA) modelling work and a summary of the various parameters used to develop the models.

2.2.1 Site Specific Aquifer Properties

In order to provide an indication of site specific values for the hydraulic conductivity of the underlying water bearing unit, rising head 'slug' tests were performed in February 2014, with water removed using a bailer and initial displacement and recovery of the groundwater levels measured using a dip meter. Tests were completed at BH1A, BHB and BHF.

On-site test results were analysed with the AQTESOLV pumping test software using the Bower & Rice straight line solution for unconfined units. The hydraulic conductivities were calculated as follows and are presented as Appendix B.

Location	Hydraulic Conductivity
BH1A	2.297m/day
BHB	0.629m/day
BHF	0.290m/day

2.2.2 Compliance Boreholes

In order to collect information to support the risk assessment process, EPS collected groundwater samples from the two boreholes situated within neighbouring properties at the site. In addition, it drilled a further borehole using a hand auger and installed a temporary monitor well at a distance of approximately 20m from the subject site so that an intermediary groundwater sample could be collected. The results of these laboratory tests found no evidence of dissolved hydrocarbons. A plan showing the location of the additional boreholes is presented as Figure 3 and full laboratory reports are provided in Appendix C.

2.2.3 Methodology

Potential risks to controlled waters have been further considered through quantitative groundwater risk assessment using the EA Guidance Document '*Methodology for the Derivation of Remedial Targets for Soil and Groundwater to Protect Water Resources*' – R&D P20.

The R&D P20 document outlines a methodology for predicting contaminant fate and transport in the unsaturated and saturated zone of the subsurface. Rather than generating true risk outputs, the methodology provides a framework for predicting contaminant concentrations at chosen “compliance points” relative to the source zone. Comparison of these predicted concentrations with established threshold criteria, (considered to be protective of environmental quality) forms the basis for developing on-site target concentrations.

The methodology follows a tiered approach incorporating progressively more sophisticated fate and transport models. If initial outputs (Tier 1) indicate that water resources will not be adversely impacted, progression to higher tiers should not be warranted. Site Specific Target Levels, (SSTL's - the theoretical maximum level that the contaminant may exist at the site without causing harm to the identified receptors) are calculated for each tier.

For the purposes of this assessment, potential SSTLs along with a consideration of travel times has been undertaken using the Remedial Targets Spreadsheet (RTS), which was also developed by the EA in line with R&D P20 methodology.

The variables for the model input parameters are outlined below and results for a variety of modelled scenarios are then presented and discussed.

2.2.4 Model Input Parameters

The following summarises the assumptions that have been made with regard to the source, pathways, and receptors that exist at the site and the parameters and values that have been used to model them with the RTW. The Remedial Targets Spreadsheet for benzene is included as Appendix D.

Contaminants of Concern	The contaminants of concern at this site have been determined to be derived from unleaded petrol. Although the impact is a mixture of petroleum hydrocarbon compounds, many of which represent environmental risks, for the purposes of this initial assessment the principal 'risk driver' for this group has been taken as Benzene, due to its high level of toxicity, (and associated low compliance targets) and relative high environmental mobility compared to other petrol range hydrocarbons. However, in order to provide some level of assurance the other hydrocarbon fractions are not ignored, the Aromatic C8-C10 group has also been assessed given its presence on site
Compliance Targets	The nearest main river, the River Welland, lies approximately 800m from the site and therefore has not been identified as a sensitive receptor to site derived contaminants, however other drainage ditches are located nearby.

	The closest continuous drainage ditch to the site lies approximately 400m to the southwest. Therefore, in the context of this site, groundwater should be considered as the principal risk receptor, making comparison to UK drinking water standards more relevant than Environmental Quality Standards for surface waters. The standard adopted for compliance is listed below:		
	CoC	Target Conc	Source
	Benzene	0.001mg/l	UK Drinking Water Standard (UKDWS)
	Aromatic Hydrocarbons C8-C10	0.01mg/l	
	In terms of distance to compliance, benzene has been taken as a List 1 / Hazardous substance present therefore in accordance with EA guidance (GP3), a distance to compliance of 50m has been adopted, which also coincides with the distance from the centre of the former tank farm at the northern end of the subject site. Plume distributions as shown in Figure 2 also indicate that the flow of contaminant is toward this borehole.		
Degradation of Contaminants	There are a range of approaches which can be taken to consider the role of degradation of contaminants in modelled fate and transport. The EA's preferred precautionary approach to the initial assessment of whether a site could pose a risk to the surrounding environment would be to assume degradation only occurs in the dissolved phase. However, to completely ignore the role of partition coefficients in the assessment of fate and transport of organic compounds, which would assume that once a contaminant has entered groundwater, it would never again sorb to aquifer media, does not represent a sound scientific basis on which to draw conclusions on unacceptable risks and any subsequent remedial requirements. Some evidence that degradation processes are active at the site, has been found during EPS investigations. The most simplistic evidence relates to the general reduction in dissolved hydrocarbon concentration in groundwater samples collected from monitor wells over time; the results from EPS recent sampling work and the previous investigation results are tabulated in Table 1 for comparison. In addition, groundwater parameters collected during the sampling process do provide supporting evidence of degradation, with measurable levels of dissolved oxygen and associated positive redox potentials recorded at sampling locations BHA, BHB and BHE, where groundwater samples were free of contamination, whilst contrasting reduced concentrations of dissolved oxygen and negative redox potentials in BHA1, BHC, BHD and BHF coincide with samples that contained dissolved hydrocarbon compounds. Given that sands and gravels typically contain little organic matter these parameters would indicate that the hydrocarbons are acting as a source of energy for naturally occurring aerobic bacteria.		

	However, with a lack of evidence concerning actual degree or rate of degradation, and assuming that aerobic degradation would be limited without a regular supply of oxygen, a precautionary approach has been taken of assuming the maximum anaerobic biotic half-lives as listed within the ConSim2 help files, (in turn taken from Environment Agency 2002 – ‘<i>The effects of contaminant concentration on the potential for natural attenuation.</i>’ R&D Technical Report P2-228/TR) and to initially consider degradation in the dissolved phase only. For benzene, the maximum anaerobic biotic half-life of 500 days has been used, however for Aromatic Hydrocarbons C8-C10, an arbitrarily conservative half-life of 5years has been selected.
Source Geometry	From the contaminant distribution within groundwater beneath the site, the source of contamination appears to be located within the central northern part of the site which is likely to be associated with back-fill material following removal of the old tank farm in this area. The source geometry for contaminants has therefore been taken as an area measuring 5m by 4m, the approximate extent of a large underground storage tank. A vertical extent of 4m has been used, the likely depth to the base of any former tank or interceptor. With respect to infiltration over the source zone, it has been assumed that approximately 30% of the property will be laid to free draining garden, therefore 30% of the national average rainfall has been used without any reduction (4.99×10^{-4} m/day).
Aquifer properties	Previous intrusive investigation carried out at the site has demonstrated that the Abbey Sands and Gravels are present up to approximately 4m bgl and groundwater has been identified at a rest level from around 1.0m bgl. On this basis the saturated aquifer thickness has been taken as 3m. Rising head slug tests gave hydraulic conductivity values of between 0.290m/day and 2.297m/day. The mean value has been used (1.07m/day). The hydraulic gradient has been calculated from groundwater elevations measured on site to be between 0.002 and 0.00125. Effective Porosity has been taken as 40%, which is considered representative of the nature of the Abbey Sands and Gravels using the median for the range of values listed for sand within the ConSim2 help files. Bulk density has been taken as 1.78 g/cm^3 which is the median value for sand in the Consim 2 help files. No information is available in respect of the Total Organic Carbon content of the aquifer. On this basis, an arbitrary value of 0.01% has been used for this assessment but it should be noted that no account is taken of this parameter if degradation is modelled in the dissolved phase only.
Dispersivity	Standard values of 10% longitudinal dispersivity along the plume length with 1% lateral and 0.1% vertical have been used

2.2.5 Model Outputs

The output from this modelling exercise has shown that the remedial target for benzene, based on the above input parameters would be 2.8mg/l, and for Aromatic hydrocarbons C8-C10, it would be 0.465mg/l. It is noted that the target concentrations for Aromatic hydrocarbons C8-C10 is marginally lower than the maximum dissolved concentration observed on site (0.64mg/l – BH1A) however the influence of the various input parameters is discussed in the section below.

2.2.6 Sensitivity Analysis

Sensitivity analysis was performed using the RTW for the contaminant of concern Aromatic C8-C10, which found the lowest remedial target and also amongst the highest dissolved concentrations on site (maximum of 0.640mg/l). Each input parameter was multiplied by a factor of 0.1, 0.5, 2 and 10, (i.e. varying input parameters by both plus and minus 100% and then an order of magnitude) and the resultant remedial target recorded. The output is presented as Appendix E.

The results of this work show that the most sensitive parameters are the distance to the compliance point, the degradation half-life for the contaminant, the hydraulic conductivity and gradient.

The selection of input parameters for target concentration and distance was relatively straight forward given the nature of the contaminants as List I / Hazardous substances within geology classified by the EA as Secondary (A) Aquifer. Although the underlying geology is considered to have a relatively limited resource potential, a distance of 50m represented an appropriate option in line with GP3 and coincidentally, the nearest of the neighbouring boreholes also lies at a distance of approximately 50m from the central site area as shown in Figure 3.

Depleted levels of dissolved oxygen and negative redox potentials can be considered as an indicator to the environment under which degradation of contaminants is occurring at the site. Whilst some of the groundwater surrounding the contaminant plume did show aerobic conditions, anaerobic conditions have been assumed within the plume itself and associated degradation rates have been taken as the most conservative limit of the range suggested within the ConSim 2 help files (ConSim 2 being an Environment Agency endorsed modelling package, within which ranges of degradation rates are taken from Environment Agency Publication from 2002. *The effects of contaminant concentration on the potential for natural attenuation. R&D Technical Report P2-228/TR*). Degradation has also been considered within the dissolved phase only, therefore EPS is satisfied that the input parameter is conservative.

Using the half-life adopted within the model for Aromatic C8-C10 (1625days), it would not be unreasonable to expect contaminant concentrations to have reduced appropriately between the monitoring work carried out by Ground Engineering in November 2008 and the recent groundwater sampling exercise carried out by EPS in February 2014. The Ground Engineering report identified benzene to be present at a concentration of 2.8mg/l within BH1A, compared to a concentration of 0.64mg/l reported by EPS 5years later. These data would suggest that a half-life of around 900days would be more appropriate, therefore the parameter in the model is considered reasonably precautionous.

The sensitivity surrounding degradation and hydraulic properties of the aquifer, (which effectively dictates travel time and therefore the level of degradation that can take place,) show that its role is extremely important to the assessment of this site. Both of these parameters were measured on site and therefore EPS is satisfied that these are realistic for use in the model.

On this basis, and also examining the model plot for potential decrease in concentration over distance from the source, it is concluded that the model outputs are appropriate for use for this site, and reflective of what has been observed during recent sampling work.

2.3 Sustainable Remediation

While it is recognised that some technically feasible groundwater remedial approaches could potentially be implemented at the site, their likely effectiveness in terms of successful delivery of remedial objectives and the wider economic and environmental benefits which could reasonably be expected to be achieved are limited.

Both statutory and industry guidance present the need for reasonableness of remediation, whereby the enforcing authority should have particular regard to the practicability, effectiveness and durability of remediation, the health and environmental impacts of the chosen remedial options, the financial cost which is likely to be involved and the benefits of remediation with regards to the seriousness of the harm or pollution of controlled water in question.

In financial cost benefit terms this essentially comes down to the level of Total Economic Value (TEV) that could reasonably be achieved by remediation. On the basis of the information included in this report, the ground conditions beneath the site have a relatively low economic value in terms of exploitable resource potential and the reduction in concentration required at the site is marginal, therefore it has been concluded that the TEV could not outweigh the cost of remedial action.

Based on the information and discussions presented above, it is concluded that the delivery of a groundwater remediation scheme at the former Broadway petrol station in Crowland, on the basis of reducing risks to controlled waters could not pass such for a test of 'reasonableness' and therefore is not recommended.

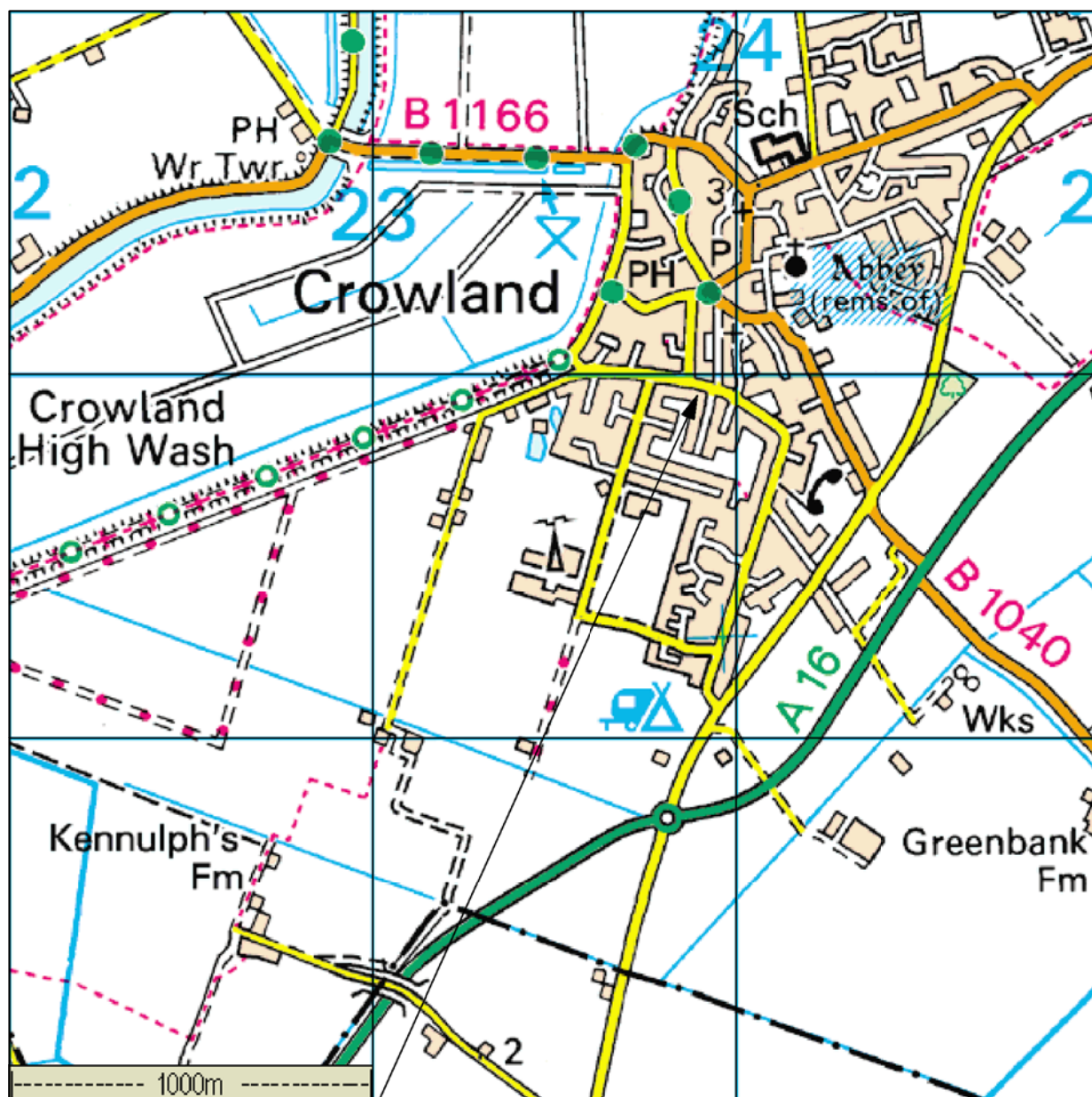
3 CONCLUSIONS AND RECOMMENDATIONS

Based upon the results of this assessment EPS does not consider remediation of groundwater at this site to be necessary.

The remedial measures needed to control the potential risks to human health do however, need to be carried out and validated to ensure that the proposed residential development does not pose an unacceptable risk to future site residents.

A copy of this report should also be submitted to the local planning department in support of discharging any relevant planning conditions.

FIGURES



Approximate Site Location

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Title: Site Location Plan

Project: Former Broadway PFS, Crowland

Client: Mr Ian Ladds

Fig No: 1

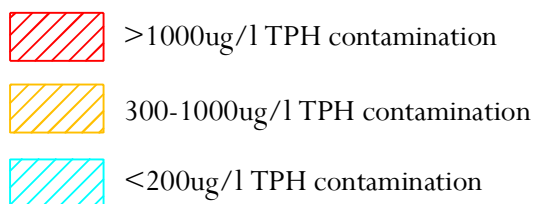
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Drawn By: TJ **Approved By:** WE

Job No: UK14.1470

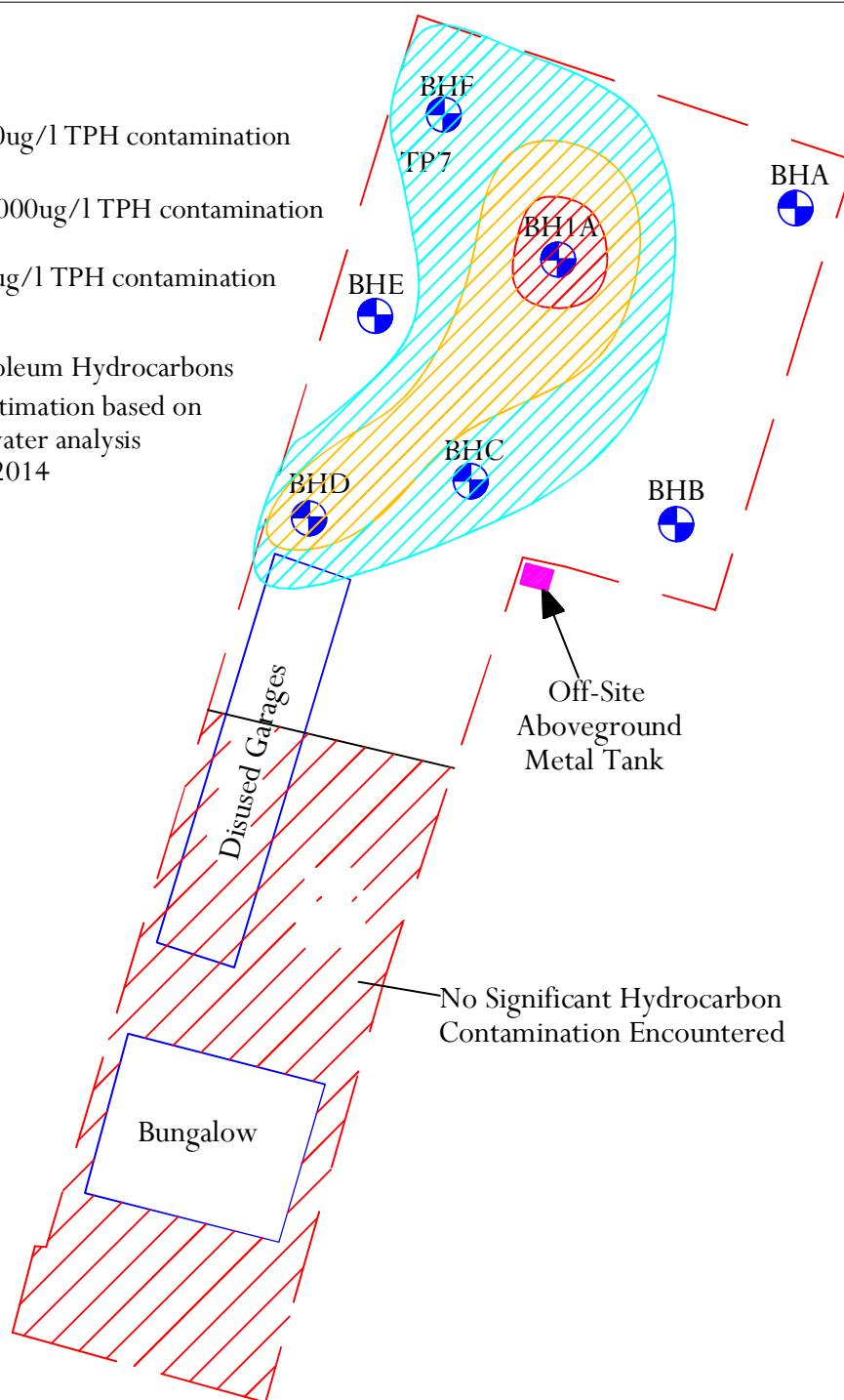
Dwg No: Ladds/Broadway/0214/01

Date: February 2014

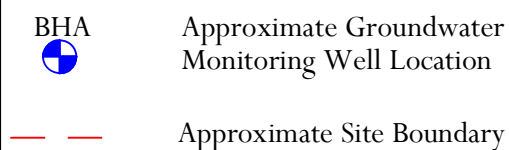


TPH = Total Petroleum Hydrocarbons

Note: This is an estimation based on results of groundwater analysis conducted in Feb 2014



Key



Title: Estimated Contaminant Distribution

Project: Former Broadway PFS, Crowland

Client: Mr Ian Ladds

Fig No: 2

Scale: Not to Scale

Drawn By: GL Approved By: GL

Job No: UK14.1470

Dwg No: Ladds/Broadway/0414/02

Date: April 2014



BH2



CHAPEL STREET

existing bungalow

existing bungalow
5existing bungalow
3a

3 existing 2 storey cottage

existing 2 storey
cottagesproposed two storey town houses
approved under application H02/0048/0715841
proposed 2 m high
close boarded fenceexisting 2 m high
boundary wall

parking area

9870

existing right of way to garages at rear

BH1



HA1

**Key:**

Temporary Monitoring Well



Neighbouring Abstraction Well Location

0m

25m

**Title:** Location of Neighbouring Abstraction Wells and Monitoring Well**Project:** Former Broadway PFS, Crowland**Scale:** Approximately As Shown**Client:** Mr Ian Ladds**Drawn By:** TJ **Approved By:** WE**Fig No:** 3**Job No:** UK14.1470**Dwg No:** Ladds/Broadway/0214/03**Date:** February 2014

TABLES

Table 1 – Groundwater Monitoring Results (2008 and 2014)

Summary Results Collected in November 2008

Contaminant	No. of Samples	No of Detections	Range of Detections (µg/l)		Highest Location
			Min	Max	
TPH	7	4	22	72,000	BH1A
Benzene	7	4	79	2,700	BH1A
Toluene	7	3	3.3	820	BH1A
Ethyl-Benzene	7	4	1.5	840	BHD
Xylenes	7	4	6.8	2,560	BHD
MTBE	7	n/a	n/a	n/a	n/a

Summary Results Collected in November 2014

Contaminant	No. of Samples	No of Detections	Range of Detections (µg/l)		Highest Location
			Min	Max	
TPH	7	4	34	1000	BH1A
Benzene	7	4	40	560	BH1A
Toluene	7	3	6.5	28	BH1A
Ethyl-Benzene	7	2	6.4	120	BHD
Xylenes	7	3	16.5	64	BHD
MTBE	7	3	11	24	BH1A

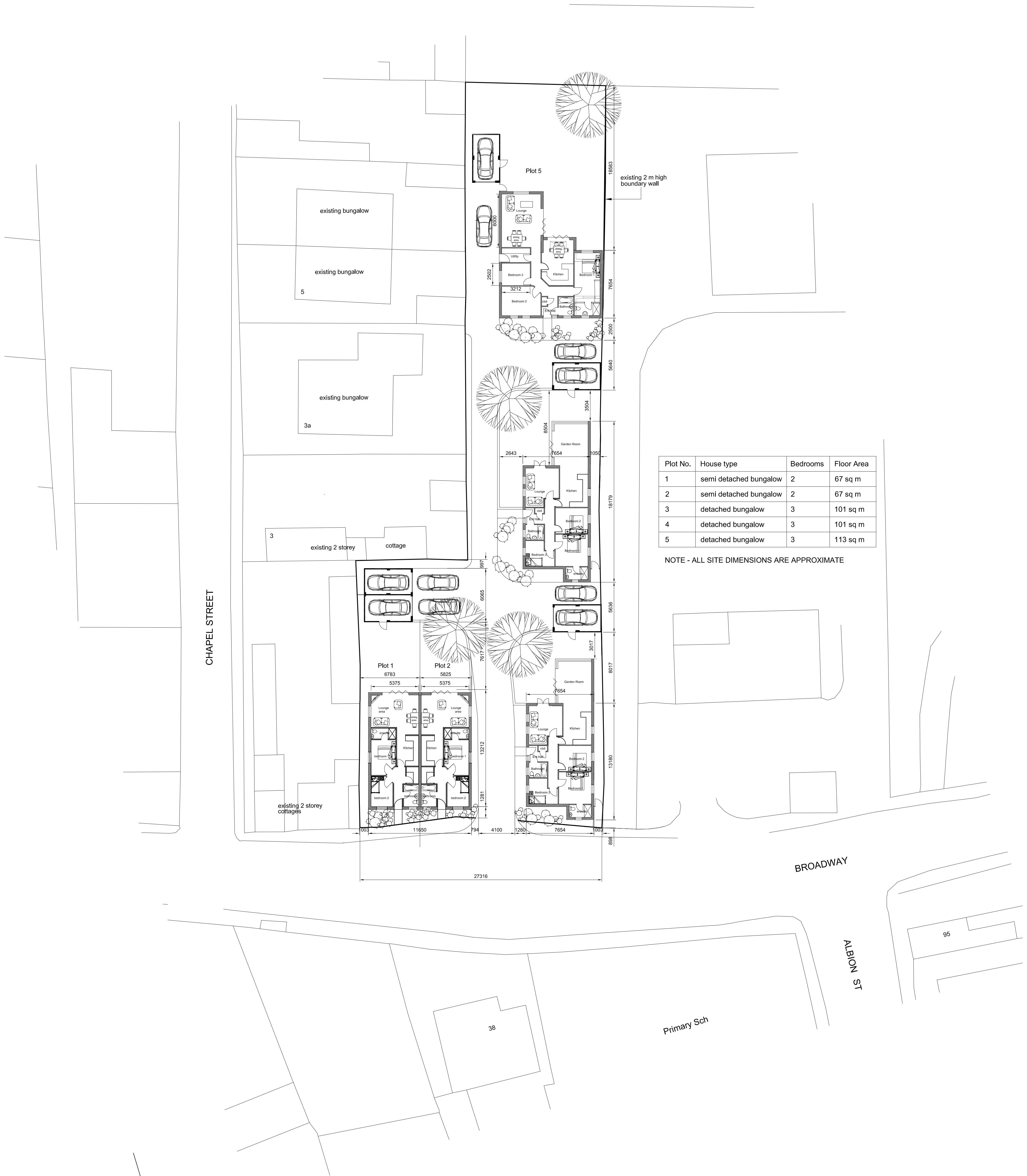
Notes:

n/a = Analyte not measured by laboratory analysis

APPENDICES

APPENDIX A

Proposed Development Plan



Plot No.	House type	Bedrooms	Floor Area
1	semi detached bungalow	2	67 sq m
2	semi detached bungalow	2	67 sq m
3	detached bungalow	3	101 sq m
4	detached bungalow	3	101 sq m
5	detached bungalow	3	113 sq m

NOTE - ALL SITE DIMENSIONS ARE APPROXIMATE



Revision Date Drawn Description

Client Wilcox Group Ltd

Project Residential Development at Rear of 59-61 Broadway, Crowland

Drawing Feasibility Layout

Scale 1:200 Drawn AWM Checked TAC Date 21/07/2014

Trevor A Clay RIBA Ltd, 14 Old Fendike Road, Weston Hills, Spalding, Lincs. PE126DD
01406 380027 07778 597975 trevor@tacarchitects.co.uk

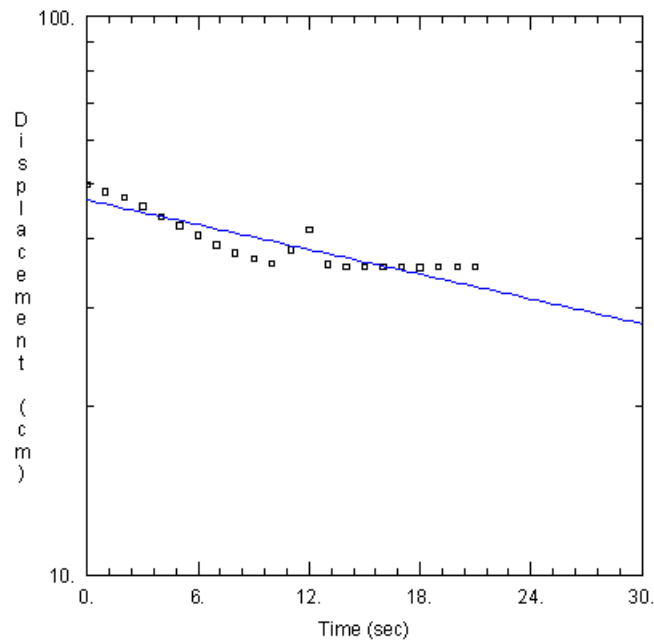


Drawing No. 14/387/PA/003

www.tacarchitects.co.uk

APPENDIX B

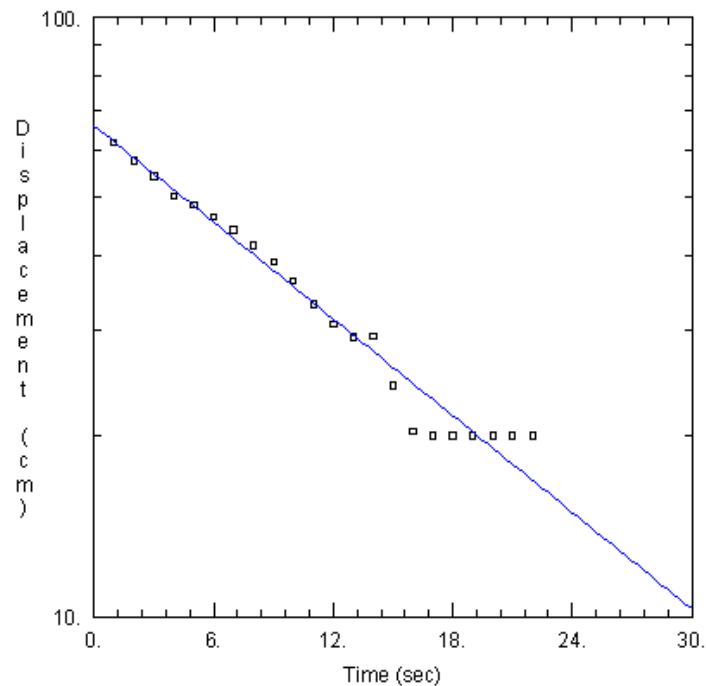
AQTESOLV Outputs: Hydraulic Conductivity Tests

WELL TEST ANALYSIS

Data Set:

Date: 04/15/14Time: 15:45:45PROJECT INFORMATIONCompany: EPS LtdClient: Ian LaddsProject: UK14.1470Location: CrowlandsTest Well: BHBTest Date: 09.04.14AQUIFER DATASaturated Thickness: 340 cmAnisotropy Ratio (K_z/K_r): 1WELL DATA (New Well)Initial Displacement: 161 cmStatic Water Column Height: 179 cmTotal Well Penetration Depth: 179 cmScreen Length: 179 cmCasing Radius: 2.5 cmWell Radius: 2.5 cmSOLUTIONAquifer Model: UnconfinedSolution Method: Bouwer-Rice $K = 0.6269$ m/day $y_0 = 46.89$ cm

BH1A



WELL TEST ANALYSIS

Data Set:

Date: 04/15/14

Time: 16:04:45

PROJECT INFORMATION

Company: EPS Ltd

Client: Ian Ladds

Project: UK14.1470

Location: Crowlands

Test Well: BH1A

Test Date: 09.04.14

AQUIFER DATA

Saturated Thickness: 350 cm

Anisotropy Ratio (K_z/K_r): 1

WELL DATA (New Well)

Initial Displacement: 173 cm

Static Water Column Height: 177 cm

Total Well Penetration Depth: 177 cm

Screen Length: 177 cm

Casing Radius: 2.5 cm

Well Radius: 2.5 cm

SOLUTION

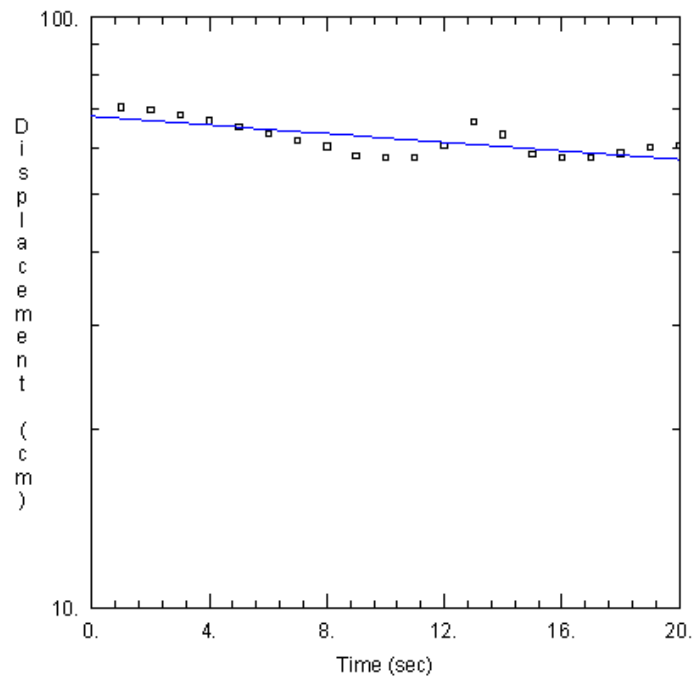
Aquifer Model: Unconfined

Solution Method: Bouwer-Rice

$K = 2.297$ m/day

$y_0 = 65.95$ cm

BHF



<u>WELL TEST ANALYSIS</u>	
Data Set:	
Date: <u>04/15/14</u>	Time: <u>15:58:50</u>
<u>PROJECT INFORMATION</u>	
Company: <u>EPS Ltd</u>	
Client: <u>Ian Ladds</u>	
Project: <u>UK14.1470</u>	
Location: <u>Crowlands</u>	
Test Well: <u>BHF</u>	
Test Date: <u>09.04.14</u>	
<u>AQUIFER DATA</u>	
Saturated Thickness: <u>350</u> cm	Anisotropy Ratio (Kz/Kr): <u>1</u>
<u>WELL DATA (New Well)</u>	
Initial Displacement: <u>184</u> cm	Static Water Column Height: <u>196</u> cm
Total Well Penetration Depth: <u>196</u> cm	Screen Length: <u>196</u> cm
Casing Radius: <u>2.5</u> cm	Well Radius: <u>2.5</u> cm
<u>SOLUTION</u>	
Aquifer Model: <u>Unconfined</u>	Solution Method: <u>Bouwer-Rice</u>
K = <u>0.2903</u> m/day	y0 = <u>67.89</u> cm

APPENDIX C

Laboratory Report for Off-Site Groundwater Sample Analysis



Chemtest Ltd
Depot Road
Newmarket
CB8 0AL

Tel: 01638 606070

Email: info@chemtest.co.uk

Final Report

Test Report Number: 14-00364

Issue: 0

Date of Issue: 05/01/2014

Contact: Giles Lock
Glock

Customer Details: Environmental Protection Strategies Ltd
Unit 7B Caxton House
Broad Street
Cambourne
Cambridgeshire

Quotation No:

Order No:

Customer Reference: UK14.1470

Date Received: 25/04/2014

Date Approved: 01/05/2014

Details:

Approved by:

Phil Hellier, Project Director

Results Summary

Report No.: 14-00364_0

Customer Sample ID	BH1	BH2	HA1
Customer Sample Reference	BH1	BH2	HA1
Chemtest Sample ID	1898	1899	1900
Sample Type	WATER	WATER	WATER
Sample Depth (m)	0 - 0	0 - 0	0 - 0
Sampling Date	25/04/2014	25/04/2014	25/04/2014

Determinand	Accred	SOP	Units	LOD			
Aliphatic TPH >C5-C6	N	1675	µg/l	0.1	< 0.10	< 0.10	
Aliphatic TPH >C6-C8	N	1675	µg/l	0.1	< 0.10	< 0.10	
Aliphatic TPH >C8-C10	U	1675	µg/l	0.1	< 0.10	< 0.10	
Aliphatic TPH >C10-C12	U	1675	µg/l	0.1	< 0.10	< 0.10	
Aliphatic TPH >C12-C16	U	1675	µg/l	0.1	< 0.10	< 0.10	
Aliphatic TPH >C16-C21	U	1675	µg/l	0.1	< 0.10	< 0.10	
Aliphatic TPH >C21-C35	U	1675	µg/l	0.1	< 0.10	< 0.10	
Aliphatic TPH >C35-C44	U	1675	µg/l	0.1	< 0.10	< 0.10	
Total Aliphatic Hydrocarbons	U	1675	µg/l	5	< 5.0	< 5.0	
Aromatic TPH >C5-C7	N	1675	µg/l	0.1	< 0.10	< 0.10	
Aromatic TPH >C7-C8	N	1675	µg/l	0.1	< 0.10	< 0.10	
Aromatic TPH >C8-C10	U	1675	µg/l	0.1	< 0.10	< 0.10	
Aromatic TPH >C10-C12	M	1675	µg/l	0.1	< 0.10	< 0.10	
Aromatic TPH >C12-C16	U	1675	µg/l	0.1	< 0.10	< 0.10	
Aromatic TPH >C16-C21	U	1675	µg/l	0.1	< 0.10	< 0.10	
Aromatic TPH >C21-C35	M	1675	µg/l	0.1	< 0.10	< 0.10	
Aromatic TPH >C35-C44	N	1675	µg/l	0.1	< 0.10	< 0.10	
Total Aromatic Hydrocarbons	U	1675	µg/l	5	< 5.0	< 5.0	
Total Petroleum Hydrocarbons	U	1675	µg/l	10	< 10	< 10	
Benzene	U	1760	µg/l	1	< 1.0	< 1.0	< 1.0
Toluene	U	1760	µg/l	1	< 1.0	< 1.0	< 1.0
Ethylbenzene	U	1760	µg/l	1	< 1.0	< 1.0	< 1.0
m & p-Xylene	U	1760	µg/l	1	< 1.0	< 1.0	< 1.0
o-Xylene	U	1760	µg/l	1	< 1.0	< 1.0	< 1.0

Report Information

Key

U	hold UKAS accreditation
M	hold MCERTS and UKAS accreditation
N	do not currently hold UKAS accreditation
S	This analysis has been subcontracted to a UKAS accredited laboratory that is accredited for this analysis
SM	This analysis has been subcontracted to a UKAS accredited laboratory that is not accredited for this analysis
T	This analysis has been subcontracted to an unaccredited laboratory
I/S	Insufficient Sample
U/S	Unsuitable sample
N/E	not evaluated
<	means "less than"
>	means "greater than"

Comments or interpretations are beyond the scope of UKAS accreditation

The results relate only to the items tested

Uncertainty of measurement for the determinands tested are available upon request

None of the results in this report have been recovery corrected

Sample Deviation Codes

- a - No date of sampling supplied
- b - Sample age exceeds stability time (sampling to extraction)
- c - Sample not received in appropriate containers

Sample Retention and Disposal

All soil samples will be retained for a period of one month

All water samples will be retained for 7 days following the date of the test report

Charges may apply to extended sample storage

If you require extended retention of samples, please email your requirements to:

customerservices@chemtest.co.uk

APPENDIX D

Remedial Targets Worksheet Output - Groundwater



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: February 2006

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.

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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:	Broadway PFS		
Site Address:	Crowland		
Completed by:	Giles Lock		
Date:	16-Apr-14	Version:	1.01
Contaminant	Benzene		
Target Concentration (C_T)	0.001	mg/l	Origin of C_T: Resource Protection Value

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 3.1



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

0.001 mg/l

Input Parameters

Standard entry

Water filled soil porosity

θ_w

2.40E-01

fraction

Literature value from CLEA Science report 3 (sand)

Air filled soil porosity

θ_a

3.00E-01

fraction

Literature value from CLEA Science report 3 (sand)

Bulk density of soil zone material

ρ

1.78E+00

g/cm³

Median of Consim files

Henry's Law constant

H

2.25E-01

dimensionless

TPHCWG

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}

1.00E-03

fraction

Arbitrary low value in absence of site data

Organic carbon partition coefficient

K_{oc}

6.76E+01

l/kg

TPHCWG

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

6.76E-02

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

2.40E-04

mg/kg

(for comparison with soil analyses)

or

0.001

mg/l

(for comparison with leachate test results)

Site being assessed: Broadway PFS

Completed by: Giles Lock

Date: 16-Apr-14

Version: 1.01

Remedial Targets Worksheet , Release 3.1



Level 2 - Soil

Contaminant
Target concentration

C_T

Benzene
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

4.99E-04 m/d
2.00E+01 m²

Standing - 30% of mean for 1981-2011 daily rainfall for
Assume source measures 4m by 5m

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

4.00E+00 m
3.50E+00 m
1.61E+00 m/d
1.63E-03 fraction
5.00E+00 m
0.00E+00 mg/l

Assume tank lies perpendicular to gw flow
Observed
Average of site data
Mean of site data
Assume tank lies perpendicular to gw flow
Assumed upgradient to be non-detect

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

Calculate
1.11E+00 m

Calculated Parameters

Dilution Factor

DF

2.45E+00

Level 2 Remedial Target

2.45E-03 mg/l
or
5.89E-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)

Cc

0.00E+00 mg/l

Calculated concentration within receptor (dilution only)

0.00E+00 mg/l

0

Site being assessed: Broadway PFS
Completed by: Giles Lock
Date: 16-Apr-14
Version: 1.01

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Benzene		from Level 1
Target Concentration	C _T	0.001	mg/l	from Level 1
Dilution Factor	DF	2.45E+00		from Level 2

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

Ogata Banks	Equations in R&D Pub. 20
-------------	--------------------------

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 dissolved pollutants only

Enter source concentration

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter soil concentration	1	mg/kg	
Half life for degradation of contaminant in water	5.00E+02	days	Maximum anaerobic half life
Calculated decay rate	1.39E-03	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	1.11E+00	m	from Level 2
Bulk density of aquifer materials	1.78E+00	g/cm ³	Median from Consim
Effective porosity of aquifer	4.00E-01	fraction	Median from Consim
Hydraulic gradient	2.74E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	1.61E+00	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Based on GP3 to protect gw resource
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+100	days	time variant options only
Parameters values determined from options			
Partition coefficient	K _d	1.76E-01	l/kg see options
Longitudinal dispersivity	ax	5.000	m see options
Transverse dispersivity	az	0.500	m see options
Vertical dispersivity	ay	0.050	m see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters

Variable		
Groundwater flow velocity	v	1.10E-02 m/d
Retardation factor	R _f	1.78E+00 fraction
Decay rate used	λ	7.78E-04 d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	2.74E-03 fraction
Rate of contaminant flow due to retardation	u	6.19E-03 m/d
Ratio of Compliance Point to Source Concentration	C _{EO} /C ₀	1.32E-03 fraction
Attenuation factor (C ₀ /C _{EO})	AF	7.55E+02 fraction
Calculated soil leachate concentration	Co	4.16E+00 mg/l

Remedial Targets

Level 3 Remedial Target	1.85E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	4.45E-01	mg/kg	For comparison with measured soil concentration. This assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Distance to compliance point	50	m	
Ratio of Compliance Point to Source Concentration	C _{EO} /C ₀	1.32E-03 fraction	Ogata Banks

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 l/kg

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer f_{oc} 2.60E-03 fraction

Organic carbon partition coefficient K_{oc} 6.76E+01 l/kg

Entry for ionic organic 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 f_{oc} fraction

Soil water partition coefficient K_d 1.76E-01 l/kg

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

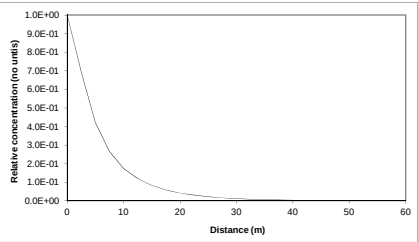
Dispersivities 10%, 1%, 0.1% of pathway length

Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	m
Transverse dispersivity	az	0.00E+00	5.00E+00	2.98E+00	m
Vertical dispersivity	ay	0.00E+00	5.00E-01	2.98E-01	m
		0.00E+00	5.00E-02	2.98E-02	m

Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{2.414}; 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 the separate Corona Solution spreadsheet 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 (No units)	Concentration mg/l
0	1.0E+00	4.16E+00
2.5	6.93E-01	2.88E+00
5.0	4.20E-01	1.75E+00
7.5	2.65E-01	1.10E+00
10.0	1.74E-01	7.26E-01
12.5	1.18E-01	4.93E-01
15.0	8.23E-02	3.42E-01
17.5	5.83E-02	2.42E-01
20.0	4.18E-02	1.74E-01
22.5	3.03E-02	1.26E-01
25.0	2.22E-02	9.25E-02
27.5	1.64E-02	6.83E-02
30.0	1.22E-02	5.08E-02
32.5	9.12E-03	3.79E-02
35.0	6.85E-03	2.85E-02
37.5	5.17E-03	2.15E-02
40.0	3.91E-03	1.63E-02
42.5	2.97E-03	1.24E-02
45.0	2.26E-03	9.42E-03
47.5	1.73E-03	7.19E-03
50.0	1.32E-03	5.51E-03

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:	Broadway PFS
Completed by:	Giles Lock
Date:	16/4/2014
Version:	1.01

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

R&D Publication 20 Remedial Targets Worksheet, Release 3.1



Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

Contaminant	Benzene	from Level 1
Target Concentration	C _T 1.00E-03	mg/l from Level 1

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

Ogata Banks Equations in R&D Pub. 20

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

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 dissolved pollutants only

Source of parameter value			
Initial contaminant concentration in groundwater at plume core	C ₀	1.00E+01	mg/l
Half life for degradation of contaminant in water	t _{1/2}	5.00E+02	days
Calculated decay rate	λ	1.39E-03	days ⁻¹
Width of plume in aquifer at source (perpendicular to flow)	Sz	5.00E+00	m
Plume thickness at source	Sy	3.00E+00	m
Saturated aquifer thickness	da	3.50E+00	m
Bulk density of aquifer materials	ρ	1.78E+00	g/cm ³
Effective porosity of aquifer	n	4.00E-01	fraction
Hydraulic gradient	i	1.63E-03	fraction
Hydraulic conductivity of aquifer	K	1.61E+00	m/d
Distance to compliance point	x	5.00E+01	m
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m
Time since pollutant entered groundwater	t	1.00E+100	days
Parameters values determined from options			
Partition coefficient	Kd	6.76E-02	l/kg
Longitudinal dispersivity	ax	5.00E+00	m
Transverse dispersivity	az	5.00E-01	m
Vertical dispersivity	ay	5.00E-02	m

Calculated Parameters

Groundwater flow velocity	v	6.53E-03	m/d
Retardation factor	Rf	1.30E+00	fraction
Decay rate used	λ	1.07E-03	d ⁻¹
Rate of contaminant flow due to retardation	u	5.02E-03	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C _{ED}	3.57E-03	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	AF	2.80E+03	

Remedial Targets

Remedial Target	2.80E+00	mg/l	For comparison with measured groundwater concentration.
Ogata Banks			
Distance to compliance point	50	m	
Concentration of contaminant at compliance point	C _{ED} /C ₀	3.57E-03	mg/l
after	1.0E+100	days	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.

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

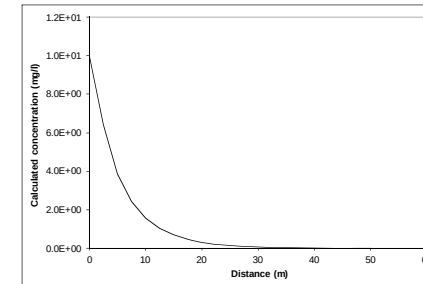
Entry if specify partition coefficient (option)		
Soil water partition coefficient	Kd	l/kg
Entry for non-polar organic chemicals (option)		
Fraction of organic carbon in aquifer	foc	1.00E-03 fraction
Organic carbon partition coefficient	Koc	6.76E+01 l/kg
Entry for ionic organic chemicals (option)		
Sorption 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	6.76E-02 l/kg

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

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

Longitudinal dispersivity	ax	Enter value	Calc value	Xu & Eckstein	m
Transverse dispersivity	az	1.00E+01	5.00E+00	2.80E+00	m
Vertical dispersivity	ay	1.00E+00	5.00E-01	2.80E-01	m
		0.90E-01	5.00E-02	2.80E-02	

For calculated value, assumes ax = 0.1 * x, az = 0.01 * x, ay = 0.001 * x
Xu & Eckstein (1995) report ax = 0.83(log₁₀x)^{0.414}; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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 the separate Corona Solution spreadsheet should be used

Site being assessed:	Broadway PFS
Completed by:	Giles Lock
Date:	16/4/2014
Version:	1.01

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet
Distance Concentration

	mg/l
0	1.0E+01
2.5	6.42E+00
5.0	3.86E+00
7.5	2.42E+00
10.0	1.57E+00
12.5	1.03E+00
15.0	6.85E-01
17.5	4.59E-01
20.0	3.10E-01
22.5	2.10E-01
25.0	1.43E-01
27.5	9.79E-02
30.0	6.72E-02
32.5	4.62E-02
35.0	3.19E-02
37.5	2.20E-02
40.0	1.52E-02
42.5	1.06E-02
45.0	7.36E-03
47.5	5.12E-03
50.0	3.57E-03



Hydrogeological risk assessment for land contamination

Remedial Targets Worksheet , Release 3.1

Date of Workbook Issue: February 2006

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.

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

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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:	Broadway PFS		
Site Address:	Crowland		
Completed by:	Giles Lock		
Date:	16-Apr-14	Version:	1.01
Contaminant	Aro 8-10		
Target Concentration (C_T)	0.01	mg/l	Origin of C_T: Drinking Water Standard

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 3.1



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

Aro 8-10

0.01 mg/l

Input Parameters

Standard entry

Water filled soil porosity

θ_w

2.40E-01

fraction

Literature value from CLEA Science report 3 (sand)

Air filled soil porosity

θ_a

3.00E-01

fraction

Literature value from CLEA Science report 3 (sand)

Bulk density of soil zone material

ρ

1.78E+00

g/cm³

Median Consim2 range for sand

Henry's Law constant

H

4.80E-01

dimensionless

TPHCWG

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}

1.00E-03

fraction

Arbitrary low value in absence of site data

Organic carbon partition coefficient

K_{oc}

1.59E+03

l/kg

TPHCWG

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

1.59E+00

l/kg

Calculated value

Level 1 Remedial Target

Level 1 Remedial Target

1.80E-02

mg/kg

(for comparison with soil analyses)

or

0.01

mg/l

(for comparison with leachate test results)

Site being assessed: Broadway PFS

Completed by: Giles Lock

Date: 16-Apr-14

Version: 1.01

Remedial Targets Worksheet , Release 3.1



Level 2 - Soil

Contaminant
Target concentration

C_T

Aro 8-10
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

Inf

4.99E-04

m/d

Standing - 30% of mean for 1981-2011 daily rainfall for

Area of contaminant source

A

2.00E+01

m²

Assume source measures 4m by 5m

Not used in calculation

Entry for groundwater flow below site

Length of contaminant source in direction of groundwater flow

L

4.00E+00

m

Assume tank lies perpendicular to gw flow

Saturated aquifer thickness

da

3.50E+00

m

Observed

Hydraulic Conductivity of aquifer in which dilution occurs

K

1.61E+00

m/d

Average of site data

Hydraulic gradient of water table

i

1.63E-03

fraction

Mean of site data

Width of contaminant source perpendicular to groundwater flow

w

5.00E+00

m

Assume tank lies perpendicular to gw flow

Not used in calculation

Background concentration of contaminant in groundwater beneath site

Cu

0.00E+00

mg/l

Assumed upgradient to be non-detect

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

Calculate

Enter mixing zone thickness

Mz

m

Calculated mixing zone thickness

Mz

1.11E+00

m

Calculated Parameters

Dilution Factor

DF

2.45E+00

Level 2 Remedial Target

2.45E-02

mg/l

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

or

4.42E-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)

Cc

0.00E+00

mg/l

Calculated concentration within receptor (dilution only)

0.00E+00

mg/l

0

Site being assessed: Broadway PFS

Completed by: Giles Lock

Date: 16-Apr-14

Version: 1.01

Level 3 - Soil

See Note



Input Parameters	Variable	Value	Unit	Source
Contaminant		Aro 8-10		from Level 1
Target Concentration	Ct	0.01	mg/l	from Level 1
Dilution Factor	DF	2.45E+00		from Level 2

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

Ogata Banks	Equations in R&D Pub. 20
-------------	--------------------------

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 dissolved pollutants only

Variable	Value	Unit	Source of parameter value
Soil concentration as mg/kg			
Enter soil concentration	0	mg/kg	
Half life for degradation of contaminant in water	1.83E+03	days	Arbitrary 5yr half life
Calculated decay rate	3.80E-04	days ⁻¹	calculated
Width of plume in aquifer at source	5.00E+00	m	from Level 2
Plume thickness in aquifer at source	1.11E+00	m	from Level 2
Bulk density of aquifer materials	1.78E+00	g/cm ³	Median for sand from Consim2
Effective porosity of aquifer	4.00E-01	fraction	Mid Consim2 range for sand
Hydraulic gradient	2.74E-03	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	1.61E+00	m/d	from Level 2
Distance to compliance point	5.00E+01	m	Based on GP3 to protect gw resource
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+100	days	time variant options only
Parameters values determined from options			
Partition coefficient	4.12E+00	l/kg	see options
Longitudinal dispersivity	5.000	m	see options
Transverse dispersivity	0.500	m	see options
Vertical dispersivity	0.050	m	see options

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable	Value	Unit
Groundwater flow velocity	v	1.10E-02	m/d
Retardation factor	Rf	1.93E+01	fraction
Decay rate used	λ	1.96E-05	d ⁻¹
Hydraulic gradient used in aquifer flow down-gradient	i	2.74E-03	fraction
Rate of contaminant flow due to retardation	u	5.70E-04	m/d
Ratio of Compliance Point to Source Concentration	C _{EP} /C ₀	2.35E-02	fraction
Attenuation factor (C ₀ /C _{EP})	AF	4.26E+01	fraction
Calculated soil leachate concentration	Co	0.00E+00	mg/l

Remedial Targets

Level 3 Remedial Target	1.04E+00	mg/l	For comparison with measured pore water concentration.
Ogata Banks	or		This assumes Level 1 Remedial Target is based on Target Concentration.
	1.88E+00	mg/kg	For comparison with measured soil concentration. This
Distance to compliance point	50	m	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C _{EP} /C ₀	2.35E-02	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

Soil water partition coefficient	Kd		l/kg
Fraction of organic carbon in aquifer	foc	2.60E-03	fraction
Organic carbon partition coefficient	Koc	1.59E+03	l/kg
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	4.12E+00	l/kg

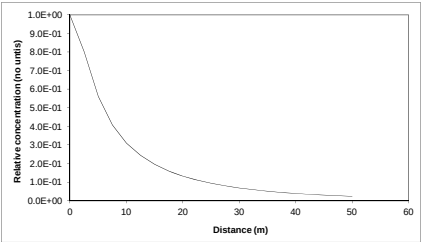
Define dispersivity (click brown cell and use pull down list)

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

Longitudinal dispersivity	ax	0.00E+00	5.00E+00	2.98E+00	m
Transverse dispersivity	az	0.00E+00	5.00E-01	2.98E-01	m
Vertical dispersivity	ay	0.00E+00	5.00E-02	2.98E-02	m

Xu & Eckstein (1995) report ax = 0.83(log₁₀ax)^{2.414}; 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 the separate Corona Solution spreadsheet 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	0.00E+00
2.5	8.00E-01	0.00E+00
5.0	5.60E-01	0.00E+00
7.5	4.08E-01	0.00E+00
10.0	3.10E-01	0.00E+00
12.5	2.43E-01	0.00E+00
15.0	1.95E-01	0.00E+00
17.5	1.59E-01	0.00E+00
20.0	1.32E-01	0.00E+00
22.5	1.11E-01	0.00E+00
25.0	9.37E-02	0.00E+00
27.5	7.98E-02	0.00E+00
30.0	6.85E-02	0.00E+00
32.5	5.91E-02	0.00E+00
35.0	5.13E-02	0.00E+00
37.5	4.47E-02	0.00E+00
40.0	3.90E-02	0.00E+00
42.5	3.42E-02	0.00E+00
45.0	3.01E-02	0.00E+00
47.5	2.66E-02	0.00E+00
50.0	2.35E-02	0.00E+00

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:	Broadway PFS
Completed by:	Giles Lock
Date:	16/4/2014
Version:	1.01

R&D Publication 20 Remedial Targets Worksheet, Release 3.1



Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

Contaminant	Aro 8-10	from Level 1
Target Concentration	C _T 1.00E-02	mg/l from Level 1

Select Method for deriving Partition Co-efficient (using pull down menu)

Calculate for non-polar organic chemicals

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 aquifer	f _{oc}	fraction
Organic carbon partition coefficient	K _{oc}	l/kg
Entry for ionic organic 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	pK _a	
Fraction of organic carbon in aquifer	f _{oc}	fraction
Soil water partition coefficient	K _d	4.12E+00 l/kg

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

Ogata Banks

Equations in R&D Pub. 20

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

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 dissolved pollutants only

Initial contaminant concentration in groundwater at plume core	C ₀	2.70E-01	mg/l	Source of parameter value
Half life for degradation of contaminant in water	t _{1/2}	1.83E+03	days	Max Site Conc
Calculated decay rate	λ	3.80E-04	days ⁻¹	Arbitrary 5yr half life
Width of plume in aquifer at source (perpendicular to flow)	Sz	5.00E+00	m	Assume tank is perpendicular to flow
Plume thickness at source	Sy	3.00E+00	m	Assume full depth of former tank farm
Saturated aquifer thickness	da	3.50E+00	m	Max observed saturated thickness
Bulk density of aquifer materials	ρ	1.78E+00	g/cm ³	Median from Consim
Effective porosity of aquifer	n	4.00E-01	fraction	Median from Consim
Hydraulic gradient	i	1.63E-03	fraction	Field Data
Hydraulic conductivity of aquifer	K	1.61E+00	m/d	Average of site data
Distance to compliance point	x	5.00E+01	m	GP3 protective of groundwater resource
Distance (lateral) to compliance point perpendicular to flow direction	z	0.00E+00	m	EA Recommended Value
Distance (depth) to compliance point perpendicular to flow direction	y	0.00E+00	m	EA Recommended Value
Time since pollutant entered groundwater	t	1.00E+100	days	time variant options only
Parameters values determined from options				
Partition coefficient	K _d	4.12E+00	l/kg	see options
Longitudinal dispersivity	ax	5.00E+00	m	see options
Transverse dispersivity	az	5.00E-01	m	see options
Vertical dispersivity	ay	5.00E-02	m	see options

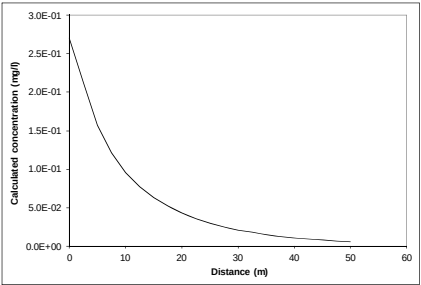
Calculated Parameters

Groundwater flow velocity	v	6.53E-03	m/d
Retardation factor	R _f	1.93E+01	fraction
Decay rate used	λ	1.96E-05	d ⁻¹
Rate of contaminant flow due to retardation	u	3.38E-04	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C _{ED}	5.81E-03	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	AF	4.65E+01	

Remedial Targets

Remedial Target	4.65E-01	mg/l	For comparison with measured groundwater concentration.
Ogata Banks			
Distance to compliance point	50	m	
Concentration of contaminant at compliance point	C _{ED} /C ₀	5.81E-03	mg/l Ogata Banks
after	1.0E+100	days	

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 graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, 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 it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater 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 9.0E+99.

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 the separate Corona Solution spreadsheet should be used

Site being assessed: Broadway PFS
Completed by: Giles Lock
Date: 16/4/2014
Version: 1.01

Calculated concentrations for distance-concentration graph

Ogata Banks

From calculation sheet

Distance	Concentration
	mg/l
0	2.7E-01
2.5	2.13E-01
5.0	1.57E-01
7.5	1.21E-01
10.0	9.60E-02
12.5	7.74E-02
15.0	6.32E-02
17.5	5.20E-02
20.0	4.31E-02
22.5	3.59E-02
25.0	3.00E-02
27.5	2.52E-02
30.0	2.12E-02
32.5	1.79E-02
35.0	1.52E-02
37.5	1.29E-02
40.0	1.09E-02
42.5	9.31E-03
45.0	7.94E-03
47.5	6.79E-03
50.0	5.81E-03

APPENDIX E

Sensitivity Analysis

Sensitivity Analysis - Remedial Target for Groundwater

Project Name: Former Broadway Petrol Station, Crowland
Project Ref: UK14.1470
Contaminant of Concern: Aromatics C8-C10
Calculated Tier 3 Remedial Target: 0.0357mg/l

Remedial Target Values

Parameter		Unit
Target Concentration	C _T	mg/l
Half life for degradation of contaminant in water	t _{1/2}	days
Width of plume in aquifer at source (perpendicular to flow)	Sz	m
Plume thickness at source	Sy	m
Saturated aquifer thickness	da	m
Bulk density of aquifer materials	ρ	g/cm ³
Effective porosity of aquifer	n	fraction
Hydraulic gradient	i	fraction
Hydraulic conductivity of aquifer	K	m/d
Distance to compliance point	x	m
Fraction of organic carbon in aquifer	foc	fraction

Input Parameter Value				
0.1	0.5	Value Used	2	10
0.0010	0.005	0.010	0.020	0.100
183	913	1.83E+03	3.65E+03	1.83E+04
0.5	2.5	5	10	50
0.30	1.5	3	6	30
0.35	1.8	3.5	7	35
0.18	0.89	1.78	3.56	17.8
0.04	0.2	0.4	0.8	0.95
1.63E-04	8.13E-04	0.00163	3.25E-03	1.63E-02
0.16	0.804	1.607	3.214	16.07
5	25	50	100	500
0.0001	0.0005	0.001	0.002	DAP

Tier 3 Remedial Target (mg/l)				
0.1	0.5	Value Used	2	10
4.65	0.929	0.465	0.232	0.0465
1.56E+04	2.71	0.465	0.16	0.0465
4.55	0.915	0.465	0.247	0.128
3.57	0.77	0.465	0.465	0.465
0.465	0.465	0.465	0.465	0.465
0.465	0.465	0.465	0.465	0.465
0.0585	0.160	0.465	2.72	4.85
1.56E+04	2.71	0.465	0.16	0.0465
1.56E+04	2.71	0.465	0.16	0.0465
0.013	0.0702	0.465	8.82	1.17E+06
0.465	0.465	0.465	0.465	1.00E+07

Percent Difference

Parameter		Unit
Target Concentration	C _T	% Diff
Half life for degradation of contaminant in water	t _{1/2}	% Diff
Width of plume in aquifer at source (perpendicular to flow)	Sz	% Diff
Plume thickness at source	Sy	% Diff
Saturated aquifer thickness	da	% Diff
Bulk density of aquifer materials	ρ	% Diff
Effective porosity of aquifer	n	% Diff
Hydraulic gradient	i	% Diff
Hydraulic conductivity of aquifer	K	% Diff
Distance to compliance point	x	% Diff
Fraction of organic carbon in aquifer	foc	% Diff

% Change in Input Parameter Value				
0.1	0.5	Value Used	2	10
-90	-50	0	100	900
-90	-50	0	100	900
-90	-50	0	100	900
-90	-50	0	100	900
-90	-50	0	100	900
-90	-50	0	100	900
-90	-50	0	100	138
-90	-50	0	100	900
-90	-50	0	100	900
-90	-50	0	100	900
-90	-50	0	100	n/a

% Change in Tier 3 Remedial Target				
0.1	0.5	Value Used	2	10
900	100	0	-50	-90
3.35E+06	483	0	-66	-90
878	97	0	-47	-72
668	65	0	0	0
0	0	0	0	0
0	0	0	0	0
-87	-66	0	485	943
3.35E+06	483	0	-66	-90
3.35E+06	483	0	-66	-90
-97	-85	0	1797	2.52E+08
0	0	0	0	2.15E+09

n/a - not applicable

(DAP = Degradation in All Phases wt 0.001 foc)