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Contaminated Land
and Hydrogeology

Glan Llyn, Llanwern: Soil Quality Verification Report, Phase 4C

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1. INTRODUCTION

Brighton STM Developments Ltd, on behalf of Revantage, has appointed H Fraser Consulting Ltd (HFCL) to assist with validating remediation works undertaken the former Llanwern Steelworks site at Glan Llyn.

The site has undergone remediation, comprising excavation of Made Ground materials, removal of materials unsuitable for re-use in the development platform, and recompaction of suitable Made Ground materials as an engineered fill. The remediation strategy for the site also requires a drainage layer to be installed above the engineered fill layer, to reduce infiltration to the Made Ground.

Two planning conditions (PC) apply to the site remediation work.

- PC 27 requires that, prior to commencement of each phase of development, a risk assessment, remediation strategy and verification plan are submitted to and approved in writing by the Local Authority.
- PC 28 requires that prior to commencement of each phase of development (excluding works required for the remediation strategy) a verification report is submitted to and approved in writing by the Local Authority, to demonstrate completion of the remediation strategy and the effectiveness of the remediation.

The site is being redeveloped in phases, and the current report relates to Phase 4C.

1.1 Remediation verification

Discussion between Revantage (and its predecessor St Modwen Developments), Natural Resources Wales (NRW), the designers of the remediation strategy Rodgers Leask Ltd (RLL) and HFCL resulted in an agreed process for the verification of phase-by-phase remediation of the site. This process is described in HFCL (2024a).

RLL has collected and processed the data relevant to verification of the remediation process and has provided the data used in this report. HFCL has reviewed and agreed RLL's data processing for Phase 4C.

1.2 Objective

The objective of this report is to demonstrate that the remediation criteria relating to controlled waters have been met. (RLL (2025) has separately reviewed the risks to human health.) This verification report is intended to be submitted alongside the human health assessment, to obtain discharge of Part 1 of PC 28 for Phase 4C.¹

1.3 Scope of works

The following work has been undertaken:

- RLL has reviewed and presented the data relevant to Phase 4C;

¹ Part 2 of PC 28 requires presentation of evidence of the placement of a drainage layer beneath the engineered fill material. This is the responsibility of the plot developers and will be signed off separately.

- HFCL has confirmed its agreement with the presented data and has checked that the data can be adequately mapped onto the agreed verification process;
- HFCL has produced this report to determine whether controlled waters risks related to Phase 4C have been adequately addressed.

2 BACKGROUND

2.1 Plot location

The location of Phase 4C is shown in the south-central part of Figure 2.1. Grid squares measure 50 m. At its northeast corner, the phase is less than 50 m from the nearest mapped surface water feature (Ellen Reen), which is part of the site reen system (still under development).



Figure 2.1 Plot Location

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2.2 Derivation of remediation criteria

Soil re-use values (SRVs) were derived by Atkins (2017) and amended by RLL (2019-22). A further minor correction for the residential development areas (including Phase 4C) was presented by HFCL (2024b). The derivation of SRVs assumes the following conceptual model.

- 60% of the site surface is impermeable, and 100% of incident rainfall on impermeable areas either evaporates or is routed via the drainage system directly to the reens
- 40% of the site has soft landscaping, and in these areas infiltration was calculated as 12.85 mm/a, by subtracting evapotranspiration and runoff from the total rainfall figure. Runoff from these areas also passes to the reens.
- 12.85 mm/a infiltrates the drainage layer overlying the engineered fill.
- In the soft landscaping areas, 60% of infiltration drains laterally through the drainage layer into a reen, and does not enter the engineered fill.
- 40% of infiltration drains into the engineered fill and migrates through the fill to a reen, dissolving potential contaminants from the fill materials.

- The infiltration that travels through the fill is diluted on reaching the reens by runoff and infiltration through the drainage layer. The relative fluxes of water passing through the fill to clean runoff provides the dilution factor.
- SRVs are calculated by multiplying the Environmental Quality Standard (EQS) by the dilution factor, and converting this water concentration into a soil concentration using a partition co-efficient.

This approach was set out originally by Atkins in 2017, modified by Rogers Leask in their Remediation Strategy report and approved by the Local Authority under discharge of Planning Condition 27.

Soil re-use values (SRVs) are set out HFCL (2024b) and values for selected contaminants of concern are reproduced here in Table 2.1.

Table 2.1 Selected soil re-use values

Determinand	Units	SRV
Iron (Total)	mg/kg	305,000
Fluoranthene	mg/kg	6.64
Benzo[b]fluoranthene	mg/kg	3.42

3 REMEDIATION ACTIVITIES AND VERIFICATION DATA

3.1 Remediation process

The remediation and verification work on Phase 4C has included the following:

- Complete excavation of Made Ground materials to the underlying Tidal Flat Deposits, screening and stockpiling;
- Sampling of stockpile materials;
- Removal of material unsuitable for use;
- Subdivision of the site into backfill zones;
- Placement of engineered fill in 300 mm layers, zone by zone;
- Sampling of surface materials, post-placement, to provide additional verification data.

3.2 Soil movements

All of the engineered fill used for Phase 4C derived from excavated site soils; various stockpiles of these soils were exploited to provide the required materials. No fill materials were brought from off site.

3.3 Soils validation data

In total 109 samples are available from fill materials for Phase 4C, and an additional 7 samples were taken from the near-surface, post-placement. Figure 3.1 shows the backfill zones for Phase 4C; each zone was backfilled in 300 mm layers, and the date label for each zone is the date that the backfill was completed. A materials management database was maintained so that there is a record of which stockpile was used for each layer in each backfill zone. Appendix A presents a full summary of the CoC data. Laboratory certificates are provided as an appendix to Rodgers Leask (2025).

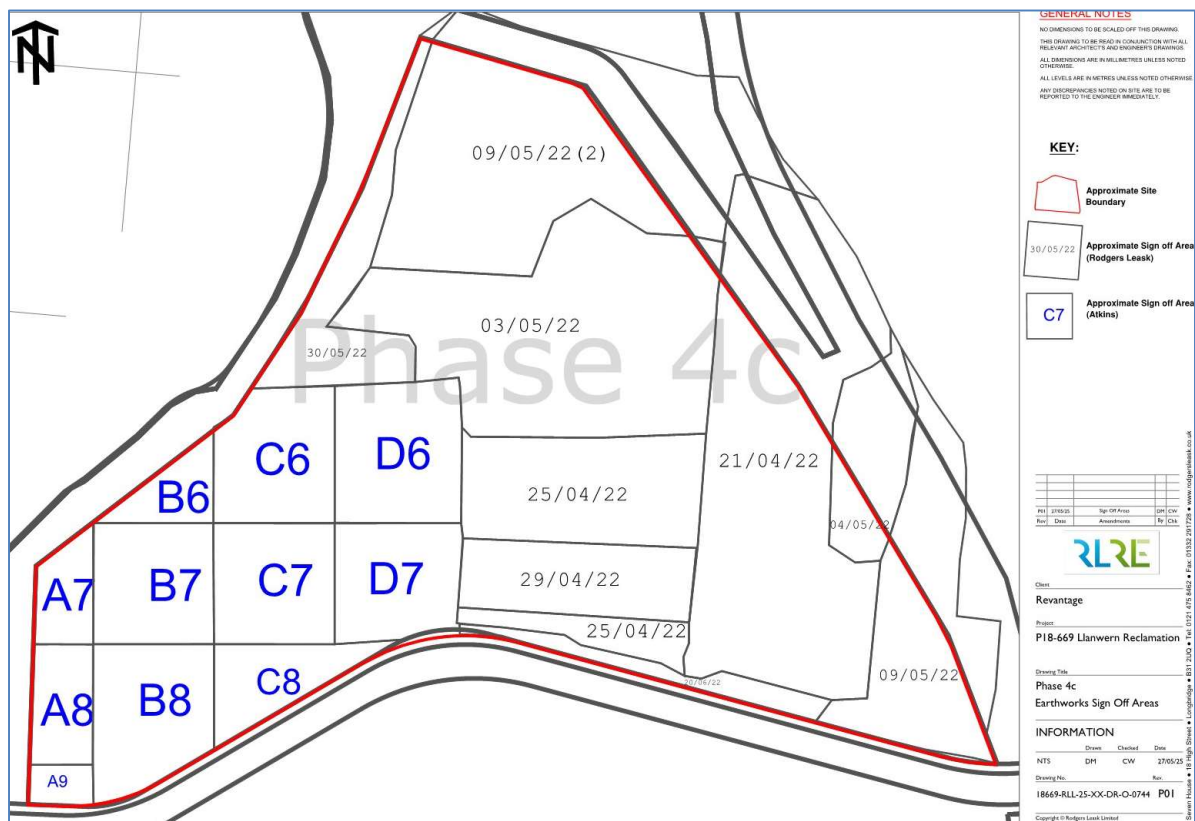


Figure 3.1 Backfill zones

4 ASSESSMENT OF CONTAMINANTS OF CONCERN

4.1 Assessment stages

HFCL (2024a) sets out the verification process that has been agreed. This proceeds through three stages, as follows.

4.1.1 Identification of Contaminants of Concern

The verification data for the phase are screened against the SRVs. Contaminants of Concern (CoCs) are defined as determinands for which the 95thile of the analytical results from the fill materials exceeded the SRV. Some CoCs have such slow travel times that they cannot be expected to travel the minimum 12.5 m assessment distance within a 1,000-year assessment period and therefore present no significant risk. Those that have a 95thile exceeding the SRV and that are mobile enough to travel more than 12.5 m in the assessment period are taken forward for further evaluation.

4.1.2 Statistical assessment

At this stage a thorough statistical and spatial analysis is carried out. This includes presentation of the entire data set for each CoC as a box plot, presentation of the same data sets as histograms; and spatial assessment of the data, with an average concentration and the upper confidence limit of the mean value (UCLmean) concentration calculated for each backfill zone in the phase. If the UCLmean concentration for any CoC in any backfill zone exceeds the SRV this is taken to the next stage.

4.1.3 Screening against Reference Values

The average and UCLmean concentrations for the different backfill zones are then compared against the Reference Values that are relevant, considering the distance of each backfill zone from the nearest surface water (the travel distance required for contaminants to move from the backfill zone to the receptor).

Any UCLmean concentration that exceeds the relevant Reference Value requires additional justified mitigation, or fails the validation method.

4.1.4 Review of hydraulic conductivity data for engineered fill

Because the derivation of the SRVs assumes a hydraulic conductivity no higher than 1×10^{-6} m/d for the engineered fill, hydraulic conductivity data need to be presented to show that this has been achieved.

4.2 Stage 1 – Identification of Contaminants of Concern

The verification data for Phase 4C have been screened against the SRVs. Results are summarised in Table 4.1 and detailed in Appendix A. This includes the samples taken from stockpiles prior to backfilling and the surface verification samples taken after placement. In both the table and the appendix any value exceeding the SRV is highlighted in red. (Values below the relevant SRV are highlighted in green in the appendix.)

The analysis shows that most of the assessed determinands were detected in a significant number of soil samples. However, maximum values only exceeded the SRV in six cases, and 95th percentile values are below the SRV for every determinand.

Table 4.1 Summary of soil quality results

Determinand	Units	SRV	N Detects*	Mean	Max	95%ile
Inorganics						
Cyanide (Free)	mg/kg	2.02	8	1.02	2.60	1.04
Ammoniacal Nitrogen	mg/kg	154	9	8.55	27.8	12
Iron (Total)	mg/kg	305,000	113	137,627	639,000	329,800
Arsenic	mg/kg	2,533	107	12.2	89.2	25.9
Cadmium	mg/kg	73	74	0.51	3.38	1.80
Chromium	mg/kg	9,431	98	125.57	592	328.8
Manganese	mg/kg	33,300	104	13,986.54	59,800	28,425
Copper	mg/kg	451	106	23.94	165	50.62
Mercury	mg/kg	132	11	0.53	1.33	1.40
Nickel	mg/kg	11,500	113	18.96	64	37.82
Lead	mg/kg	15,700	112	61.68	369	122
Selenium	mg/kg	702	78	7.09	26.2	12.96
Vanadium	mg/kg	1,606	113	223.46	894	518.2
Zinc	mg/kg	138,000	111	246.79	1380	485
Speciated TPH						
Aliphatic VPH >C5-C6	mg/kg	73	1	0.04	0.01	0.05
Aliphatic VPH >C6-C8	mg/kg	359	31	0.04	0.07	0.05
Aliphatic VPH >C8-C10	mg/kg	2,841	29	0.05	0.44	0.34
Aliphatic EPH >C10-C12	mg/kg	22,500	18	0.71	3.80	2.20
Aliphatic EPH >C12-C16	mg/kg	450,000	83	5.68	165	17.56
Aliphatic EPH >C16-C21	mg/kg	56,600,000	104	19.70	400	58.16
Aliphatic EPH >C21-C35	mg/kg	56,600,000	108	71.24	320	177.8
Aliphatic EPH >C35-C44	mg/kg	56,600,000	99	26.75	84.9	65.88
Aromatic VPH >C5-C7	mg/kg	8.51	0	0.04	0.00	0.05
Aromatic VPH >C7-C8	mg/kg	177	0	0.04	0.00	0.05
Aromatic VPH >C8-C10	mg/kg	144	11	0.04	0.04	0.05
Aromatic EPH >C10-C12	mg/kg	227	25	0.80	7.9	2.0
Aromatic EPH >C12-C16	mg/kg	451	72	3.26	93.00	6.85
Aromatic EPH >C16-C21	mg/kg	1,424	106	17.49	740	32.76
Aromatic EPH >C21-C35	mg/kg	11,300	110	55.27	970	110.80
Aromatic EPH >C35-C44	mg/kg	11,300	95	18.22	93	62.74
PAH						
Naphthalene	mg/kg	27	97	0.33	2.90	1.72
Acenaphthylene	mg/kg	16.7	78	0.20	1.73	0.81
Acenaphthene	mg/kg	30	75	0.04	0.29	0.10
Fluorene	mg/kg	27	85	0.14	1.50	0.50
Phenanthrene	mg/kg	27	105	1.08	10.10	3.54
Anthracene	mg/kg	34	91	0.35	4.64	1.14
Fluoranthene	mg/kg	6.64	113	2.05	23.30	7.16
Pyrene	mg/kg	76	113	1.63	15.30	6.24
Benzo[a]anthracene	mg/kg	607	112	1.11	10.10	4.94
Chrysene	mg/kg	621	112	1.06	8.60	4.66
Benzo[b]fluoranthene	mg/kg	3.42	112	1.61	11.70	6.93

Determinand	Units	SRV	N Detects*	Mean	Max	95%ile
Benzo[k]fluoranthene	mg/kg	5.05	112	0.54	4.12	2.32
Benzo[a]pyrene	mg/kg	34	112	1.15	7.85	4.72
Indeno(1,2,3-c,d)pyrene	mg/kg	25	112	0.90	5.70	3.55
Dibenz(a,h)anthracene	mg/kg	838	89	0.22	1.39	0.77
Benzo[g,h,i]perylene	mg/kg	13	112	0.82	5.23	3.11
Other organics						
Phenol	mg/kg	3.05	20	0.05	0.60	0
Benzene	µg/kg	3,800	1	82.91	0.01	180
Toluene	µg/kg	128,000	0	70.09	0	140
Ethylbenzene	µg/kg	80,000	0	40.09	0	80
m & p-Xylene	µg/kg	74,000	0	100.09	0	200
o-Xylene	µg/kg	74,000	0	100.09	0	200

* 116 samples were analysed for all determinands.

As the analysis shows, the backfill in Phase 4C was not of good enough chemical quality as iron, fluoranthene and benzo[b]fluoranthene were flagged as CoCs.

4.3 Stage 2 – Statistical assessment

4.3.1 Stockpile samples – box plots and histograms

Box plots are used to show the minimum value of the data set, the range of data falling between the 25th and 75th percentile, the mean value and the maximum value. They are useful to visually assess whether the data points are evenly distributed throughout the range. Histograms show the data distributed by the number of data points within specific ranges and are useful for identifying the distribution of data across the range, and also for identifying whether higher values are common or rare in the data set. Box plots and histograms are presented in Figure 4.1 to Figure 4.6.



Figure 4.1 Box plot for iron (mg/kg)

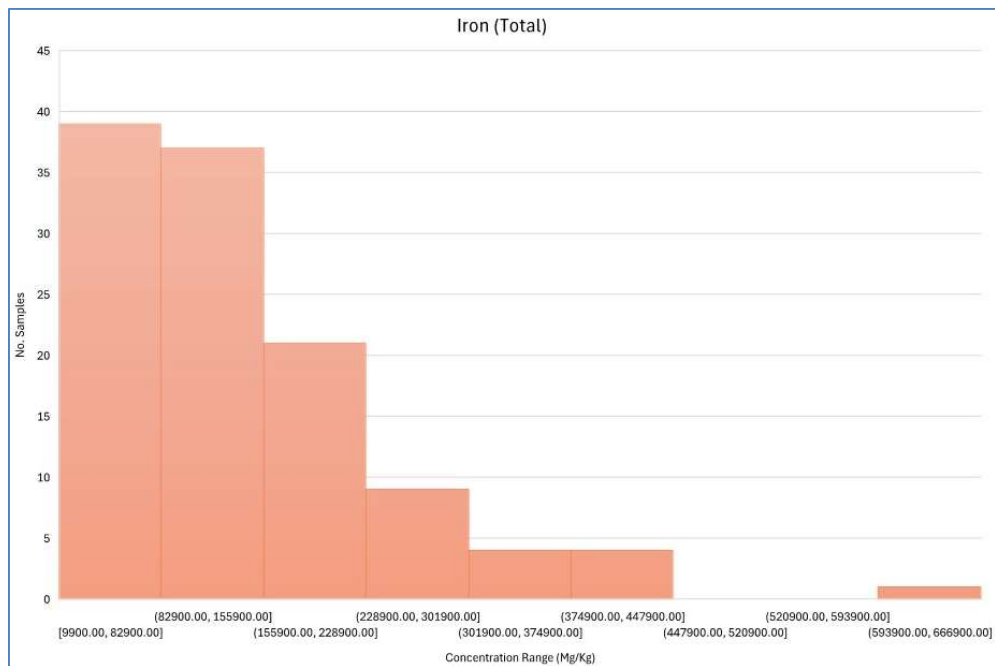


Figure 4.2 Histogram for iron (mg/kg)

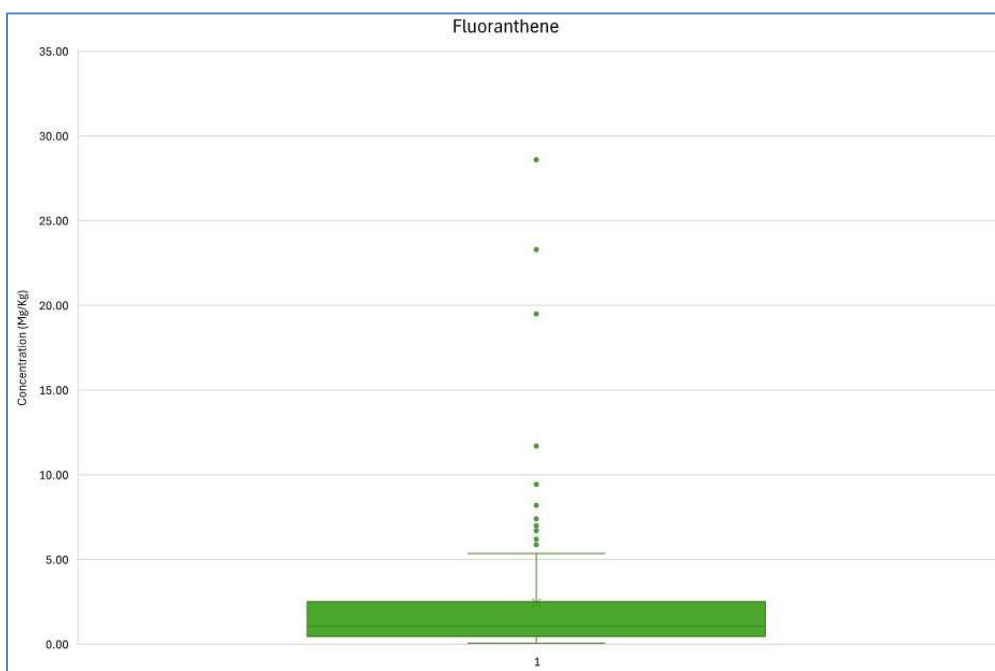


Figure 4.3 Box plot for fluoranthene (mg/kg)

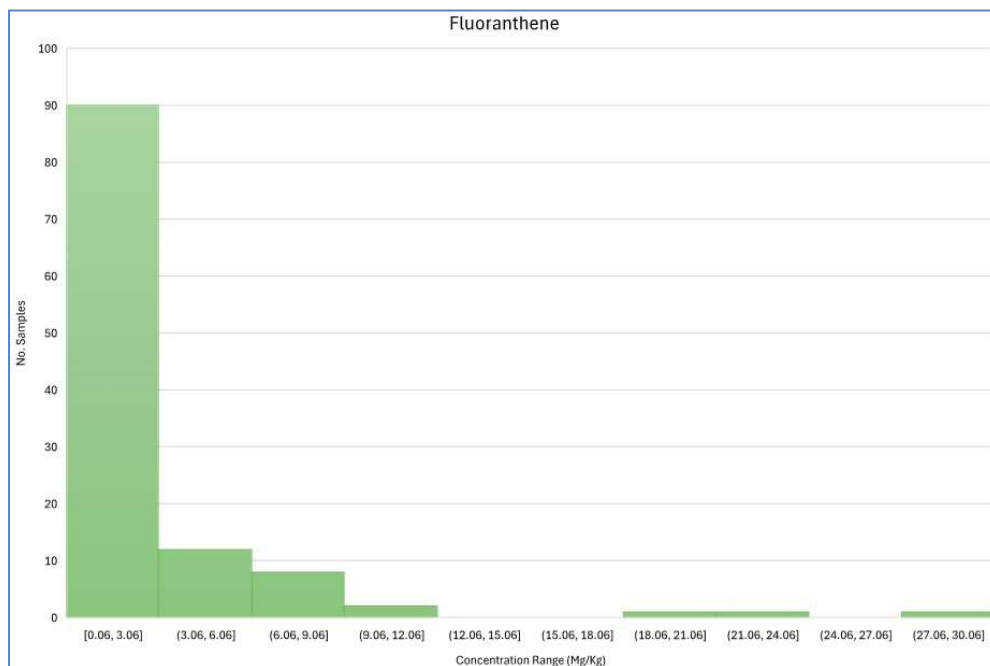


Figure 4.4 Histogram for fluoranthene (mg/kg)



Figure 4.5 Box plot for benzo(b)fluoranthene (mg/kg)

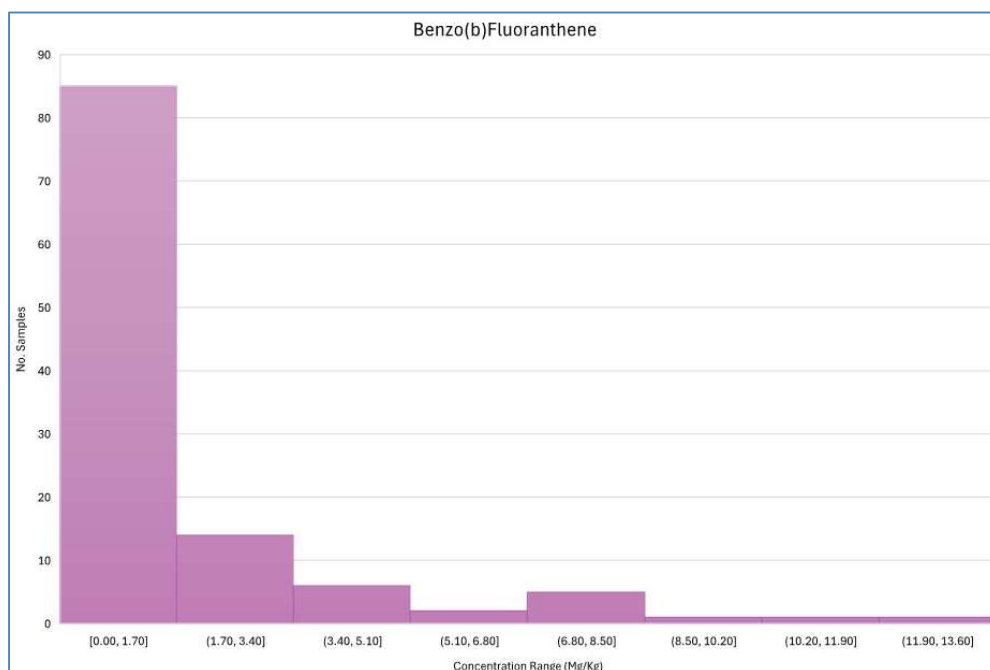


Figure 4.6 Histogram for benzo(b)Fluoranthene (mg/kg)

The following points can be seen from the plots.

- For iron the data range from c. 20,000 mg/kg to c. 639,000 mg/kg. The average value is 137,627 mg/kg and the SRV of 305,000 mg/kg is close to the 95th percentile (Figure 4.1). There are 5 data points that exceed the SRV. The histogram confirms that the data have a long-tailed distribution, with lower values being relatively common.
- For fluoranthene the data range from c. 0.01 mg/kg to c. 5.5 mg/kg. The average value is 2.05 mg/kg and 75% of the data points are below 5 mg/kg. There are 11 data points that exceed the screening criteria of 7.16 mg/kg. The histogram confirms that the data have a long-tailed distribution, with lower values being relatively common.
- For benzo(b)fluoranthene the data range from c. 0 mg/kg to c. 4.6 mg/kg. The average value is 1.61 mg/kg and 75% of the data points are below 2.5 mg/kg. There are 8 data points that exceed the screening criteria of 6.93 mg/kg. Again, the histogram confirms that the data have a long-tailed distribution, with lower values being relatively common.

4.3.2 Stockpile samples – spatial plots

The verification data have been plotted spatially as follows.

An average concentration has been derived from each stockpile location. Each 300 mm layer of backfill was sourced from a specific stockpile and the average stockpile concentration was therefore, ascribed to the layer. Each backfill zone was typically backfilled with seven layers, and an average concentration derived for each zone. The plots, drawn up by Rodgers Leask, are presented in Figure 4.7, Figure 4.8 and Figure 4.9. In each plot, the highest colour category represents values exceeding the SRV.

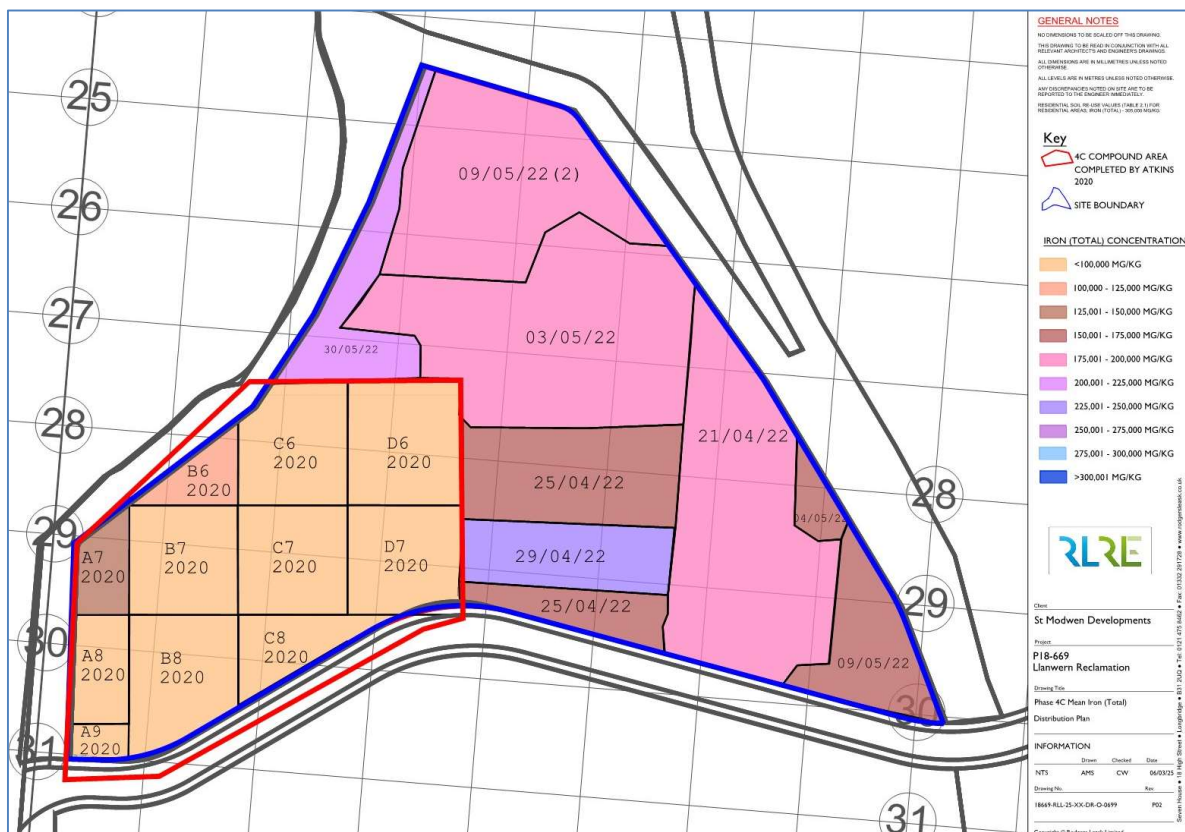


Figure 4.7 Iron distribution (mean values)

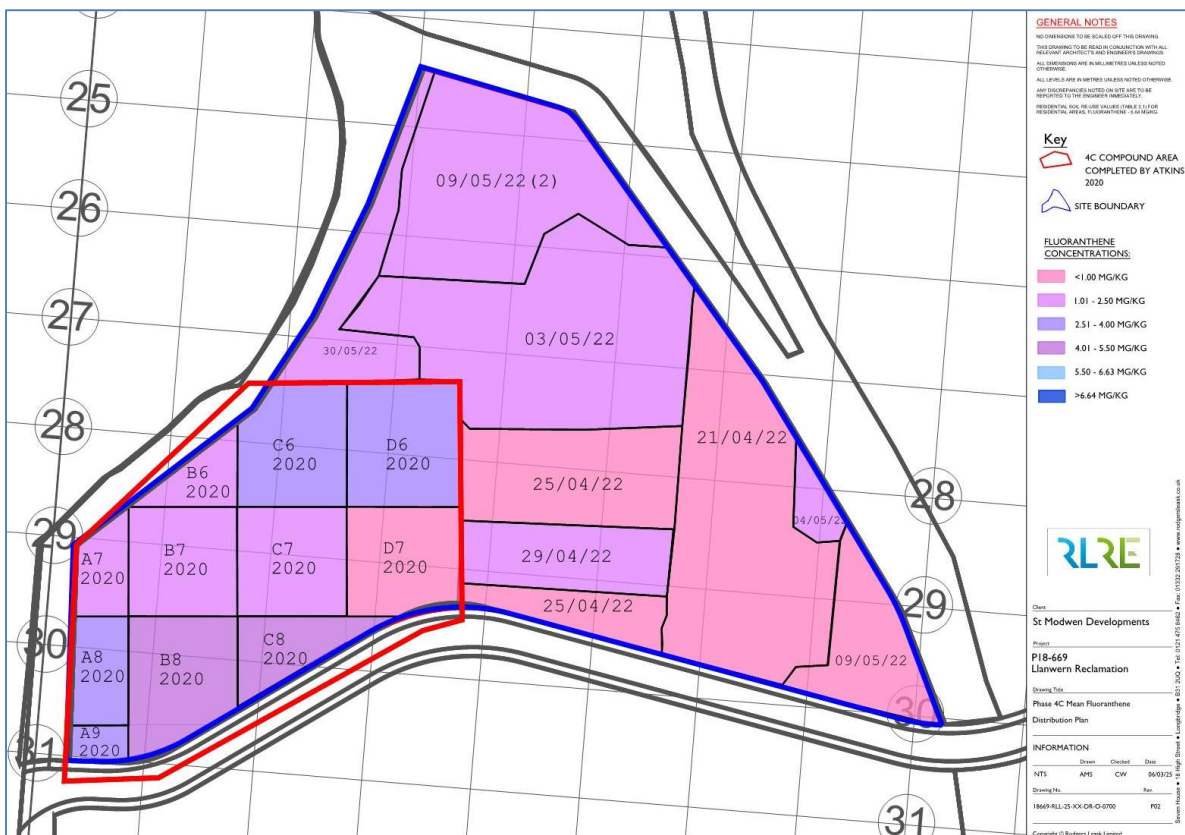


Figure 4.8 Fluoranthene distribution (mean values)

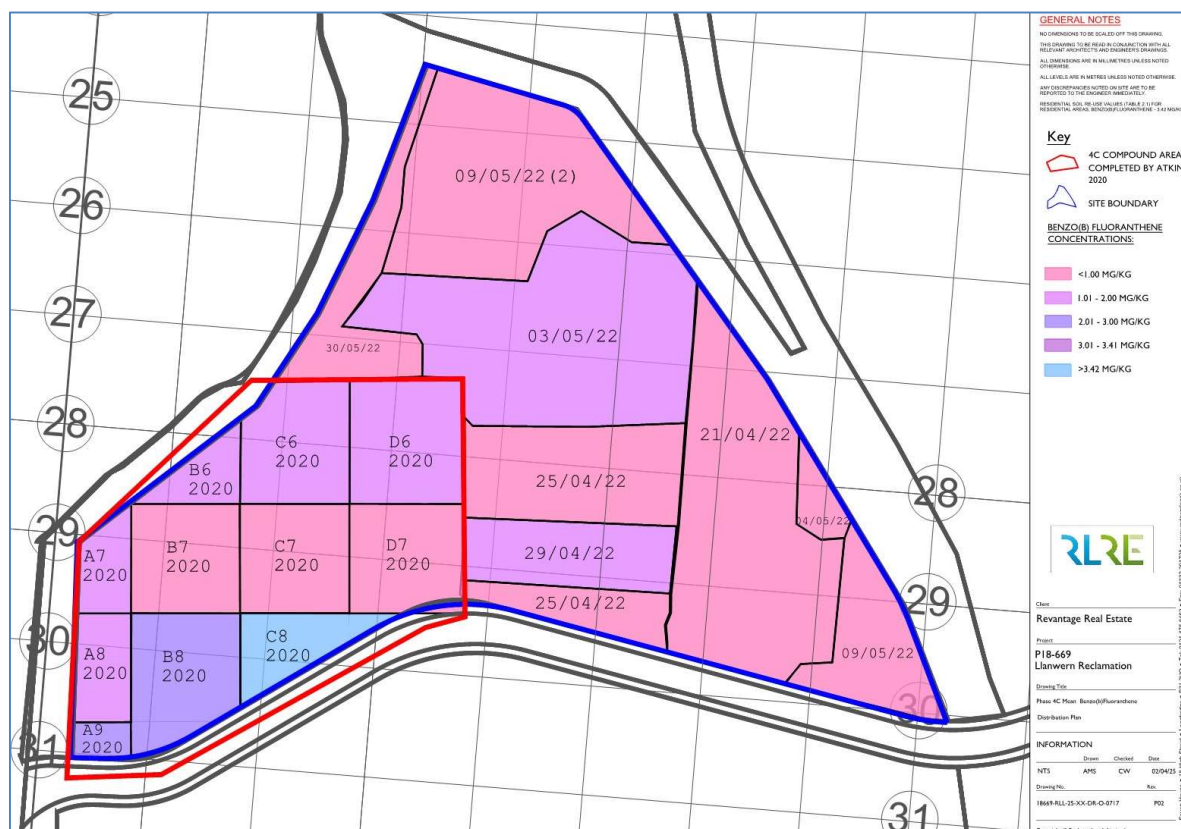


Figure 4.9 Benzo(b)fluoranthene (mean values)

For any data set, there is uncertainty associated with the estimate of the mean value, a conservative assessment of the mean value can be made by calculating an Upper Confidence Limit (UCL) in the mean. This has been done using Student's t-distribution method (likely to be more appropriate for the distribution of analytical results seen in Section 4.1), resulting in a slightly higher estimate of the average concentration for each backfill zone. This report refers to the 95th percentile UCLmean, which have been plotted spatially and are presented in Figure 4.10, Figure 4.11, and Figure 4.12.

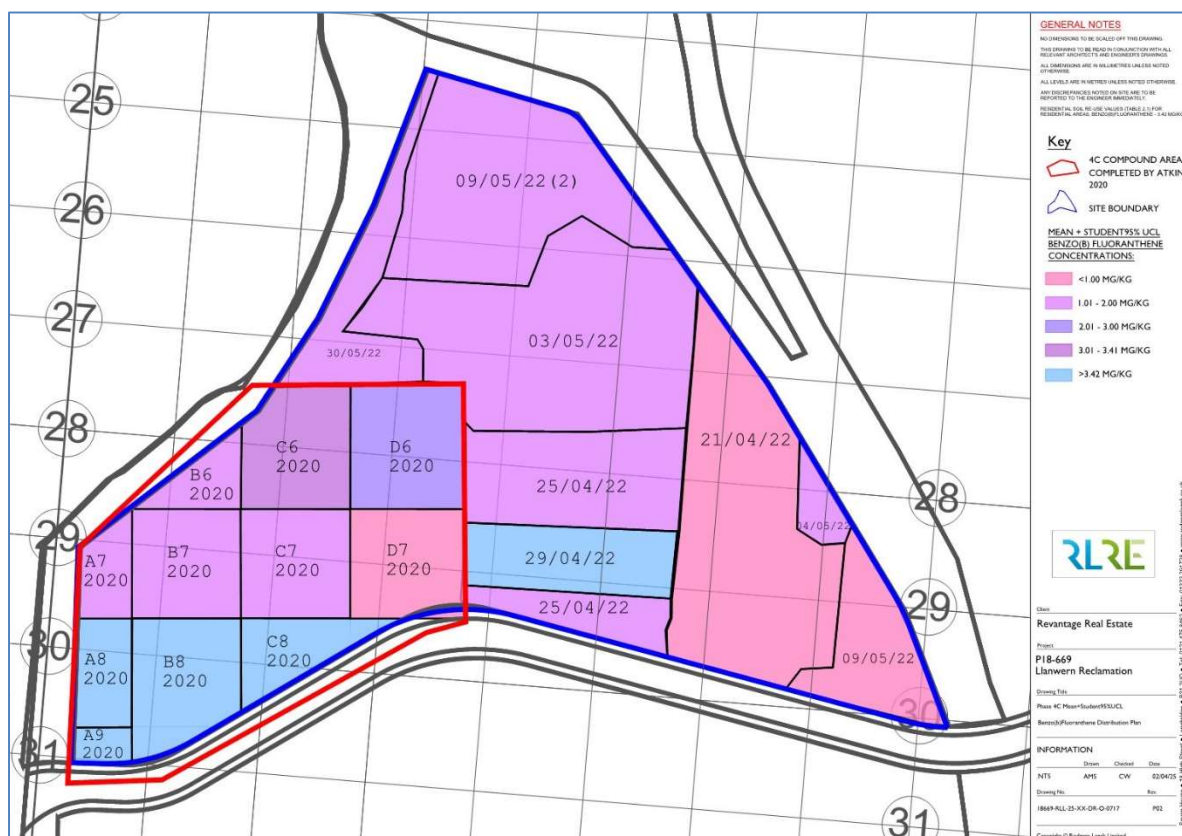


Figure 4.12 Benzo(b)fluoranthene (UCL Mean values)

4.3.3 Surface verification samples

The surface verification samples are included in the statistical presentation (Table 4.1 and subsequent graphs). For completeness we have summarised them separately in Table 4.2 for the identified CoC.

Table 4.2 Summary of surface verification samples

Determinand	No	No exceeding	Min	Max	Mean	UCLMean	SRV
Benzo[b]fluoranthene	7	3	<0.1	8.70	4.51	7.17	3.42
Fluoranthene	7	2	0.72	7.40	4.53	6.81	6.64
Iron (Total)	7	0	9,900	69,000	40,414	59,920	305,000

Table 4.2 shows that the UCLmean value for iron is below the SRV; no further review of iron concentrations in the surface verification samples is therefore required. For benzo(b)fluoranthene and fluoranthene the UCLmean value is higher than the SRV.

Closer examination of the individual sample results shows that three surface verification samples, taken from three different backfill zones, showed exceedances of the SRV for benzo(b)fluoranthene. Two of the same samples also showed exceedances for fluoranthene.

Table 4.3 Table 4.2 shows the locations where the SRV was exceeded for fluoranthene or benzo(b)fluoranthene. (For the relevant backfill zone locations, see Figure 3.1.) A conservative estimate of the average value for the relevant fill areas, incorporating the surface sample as well

as the fill samples, is calculated by weighting the UCLmean of the stockpile samples by the thickness of fill, and the surface sample value by a thickness of 0.1 m². The values in the table that exceed the SRV are shown in bold.

Table 4.3 Combining surface sample and fill concentrations (mg/kg)

Determinand	Fluoranthene		Benzo(b)fluoranthene		
SRV	6.64		3.42		
Validation sample point	4C-SV2	4C-SV6	4C-SV2	4C-SV4	4C-SV6
Backfill zone	30/05/22	21/04/22	30/05/22	B7	21/04/22
Validation sample value	7.40	7.40	8.40	5.60	8.70
Backfill mean value	1.28	0.40	0.95	0.97	0.37
Backfill and validation mean*	1.56	0.84	1.29	1.26	0.89
Weighted UCLmean*	2.18	1.77	2.00	1.88	1.98

* Backfill and surface sample combined, with weighting

4.3.4 Summary of sample results

For iron, it can be seen from Figure 4.7 and Figure 4.10 that the average and UCLmean concentrations in all backfill zones except one (29/04/22) are lower than the SRVs. The surface validation samples provided no exceedances of the SRV for iron. We conclude therefore that the engineered fill meets the Stage 2 assessment criteria with respect to iron, with the exception of one backfill zone 29/04/22. Consequently, backfill zone 29/04/22 is taken forward for further assessment for iron.

For fluoranthene, it can be seen from Figure 4.8 and Figure 4.11 that the average and UCLmean concentrations for all backfill zones are below the SRV of 6.64 mg/kg. Surface validation samples from two backfill zones did show exceedances of the SRV, but, as shown in Table 4.2, incorporating these results explicitly did not raise the backfill zone UCLmean above the SRV. Therefore, fluoranthene is not taken forward for further assessment.

For benzo(b)fluoranthene the average concentration of one backfill zone (C8 2020) exceeds the SRV of 3.42 mg/kg (Figure 4.9). If the UCL estimate of the mean is used, the average concentration of five backfill zones exceeds the SRV (Figure 4.12). Three surface verification samples also exceeded the SRV; however, when weighted UCLmean values were calculated for the relevant zones (including the surface samples), they did not exceed the SRV. Benzo(b)fluoranthene is therefore taken forward for further assessment of five backfill zones.

4.4 Stage 3 – Screening against Reference Values

The results of the RTM assessment are presented in Table 4.4. It can be seen that over a 1,000-year period, none of the modelled contaminants is predicted to reach a distance of 12.5 m. We examined the effect of modelling for even longer periods, and neither of the organic contaminants is shown

² Surface verification samples are taken by hand with a trowel from the top 100 mm of the backfill. This is a different sample set to the stockpile samples. Additionally, due to the grain size bias resulting from the sample method, it is likely that the average of the surface samples is not representative of the whole top 300 mm layer, but rather selected fine-grained material from the top 100 mm.

to break through even after 10,000 years. Iron does break through within that time, but at very low concentrations (several orders of magnitude below the SRV). Relevant RTM spreadsheet calculations were provided electronically in Appendix C to HFCL (2024a). Print-outs of the relevant spreadsheet tabs for 10,000-year runs are in Appendix B to the current report.

Table 4.4 Model results (mg/l)

Contaminant	Remedial Target (Residential) mg/kg *		
	12.5 m	37.5 m	62.5 m
Iron	No impact	No impact	No impact
Fluoranthene	No impact	No impact	No impact
Benzo(b)fluoranthene	No impact	No impact	No impact

We therefore conclude that concentrations of these three CoC in the fill for Phase 4C do not pose a significant risk to controlled waters at Glan Llyn.

4.5 Hydraulic conductivity data

RLL (2025) reports hydraulic conductivity data for Phase 4C and includes detailed appendices showing the derivation of the hydraulic conductivity results. They are summarised here for ease of reference.

Table 4.5 Hydraulic conductivity testing at Phase 4C

Method	N tests	Hydraulic conductivity (m/s)		
		Min	Max	Mean
Infiltration test	10	2.78E-07	9.72E-07	8.12E-07
Falling head test	3	4.91E-07	9.95E-07	8.23E-07
Rising head test	3	4.99E-07	7.40E-07	6.01E-07
Aggregate	16	3.6926E-13	9.95E-07	6.72E-07

As the table demonstrates, all measured hydraulic conductivity values were smaller than the assumed value of 10^{-6} m/s and the mean value of all tests was 6.7×10^{-7} m/s. The assumption used in the derivation of the SRVs is therefore valid.

5 CONCLUSIONS

Remediation has been undertaken on Phase 4C of the Glan Llyn development site, comprising excavation of Made Ground materials, stockpiling, and placement of suitable materials as a compacted engineered fill. The plot is subdivided into backfill zones, which were sequentially backfilled in layers.

The data set was screened against Soil Re-use Values (SRVs) by comparing the 95th percentile value for each contaminant against the SRV. For Phase 4C, the 95th percentile concentration of iron, fluoranthene and benzo(b)fluoranthene was above the SRV for assessed contaminants. Further statistical presentation of data and comparison to Reference Values was therefore required for these three contaminants of concern (CoC).

Box plots and histograms show that the data sets for the CoC were affected by a small number of high concentrations. Spatial plots indicated that average concentrations across the majority of the site area were below SRVs.

Verification samples comprise stockpile sampling, with materials tracking such that average concentrations of potential contaminants can be calculated for each backfill zone. Surface samples were also taken after the backfill was placed, which enhance the verification sample data set. Review of the verification samples for the three CoC for Phase 4C indicated that they did not alter the conclusions of the statistical assessment.

Screening against Reference Values from the modelling of transport processes through the engineered fill has been undertaken to understand the significance of the higher concentrations of the three CoC.

Reference Value screening shows that over a 1,000-year period, iron, fluoranthene and benzo(b)fluoranthene would not be detected 12.5 m from the source area, owing to attenuation processes along the groundwater transport pathway.

It can be concluded that the concentrations of potential contaminants within the fill materials meet the remediation requirements for Phase 4C. We conclude that the data presented are sufficient to allow the sign-off of PC28 Part 1 for Phase 4C.

REFERENCES

Atkins, 2017, Glan Llyn, Llanwern: Llanwern Controlled Waters Detailed Quantitative Risk Assessment, report no. 5111373-LLA-OUT-0257.

HFCL, 2024a, Glan Llyn: Soils validation strategy for protection of controlled waters, report no. 30937 R2.

HFCL, 2024b, Glan Llyn, Llanwern: Soil quality verification – Correction to calculated re-use criteria for soils at Glan Llyn (residential), technical note no. 30937 TN1.

Rodgers Leask, 2019-2022: Glan Llyn Llanwern Sitewide: Controlled Waters DQRA 2019 Update, report no. 18669-RLE-19-RP-O-0006.

Rodgers Leask, 2025: Phase 4C Chemical Validation Report - 18669-RLL-23-XX-RP-O-0434-P02.

APPENDIX A

Summary data for Contaminants of Concern (spreadsheet file)

APPENDIX B

Selected Remedial Targets Methodology spreadsheets

R&D Publication 20 Remedial Targets Worksheet, Release 3.2



Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)	Variable	Value	Unit	Source
Contaminant Target Concentration	C _T	Benzo(b)fluoranthene 6.36E-05	mg/l	from Level 1

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

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

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+00	mg/l	
Half life for degradation of contaminant in water	t _{1/2}	1.22E+03	days	
Calculated decay rate	λ	5.69E-04	days ⁻¹	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+02	m	
Plume thickness at source	Sy	1.98E+00	m	
Saturated aquifer thickness	da	2.10E+00	m	
Bulk density of aquifer materials	ρ	1.36E+00	g/cm ³	
Effective porosity of aquifer	n	8.00E-02	fraction	
Hydraulic gradient	i	1.33E-02	fraction	
Hydraulic conductivity of aquifer	K	8.64E-02	m/d	
Distance to compliance point	x	1.25E+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	3.65E+07	days	time variant options only

Parameters values determined from options

Partition coefficient	Kd	5.34E+04	l/kg	see options
Longitudinal dispersivity	ax	1.25E+00	m	see options
Transverse dispersivity	az	1.25E-01	m	see options
Vertical dispersivity	ay	1.25E-02	m	see options

Calculated Parameters Variable

Groundwater flow velocity	v	1.44E-02	m/d	
Retardation factor	Rf	9.09E+05	fraction	
Decay rate used	λ	6.26E-10	d ⁻¹	
Rate of contaminant flow due to retardation	u	1.58E-08	m/d	
Contaminant concentration at distance x, assuming one-way vertical dispersion	C _{ED}	0.00E+00	mg/l	
Attenuation factor (one way vertical dispersion, CO/CED)	AF	breakthrough at compliance point		

Remedial Targets

Remedial Target	No impact	mg/l	For comparison with measured groundwater concentration.
Ogata Banks			
Distance to compliance point	12.5	m	
Concentration of contaminant at compliance point after	C _{ED} /C ₀	0.00E+00 3.7E+07	mg/l 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.

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

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer

Organic carbon partition coefficient

Entry for ionic organic chemicals (option)

Sorption coefficient for related species

Sorption coefficient for ionised species

pH value

acid dissociation constant

Fraction of organic carbon in aquifer

Soil water partition coefficient

Kd

foc

Koc

K_{oc,ion}K_{oc,ion}

pH

pKa

foc

Kd

5.34E+04

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

For calculated value, assumes ax = 0.1 * x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = 0.83(log₁₀)^{2.414}; az = ax/10, ay = ax/100 are assumed

Enter value

Calc value Xu & Eckstein

0.00E+00

1.25E+00

0.00E+00

1.25E-01

0.00E+00

1.25E-02

1.04E+00

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R&D Publication 20 Remedial Targets Worksheet, Release 3.2



Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)	Variable	Value	Unit	Source
Contaminant		Fluoranthene		from Level 1
Target Concentration	C _T	2.35E-03	mg/l	from Level 1

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

Ogata Banks Equations in HRA publication

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+00	mg/l	
Half life for degradation of contaminant in water	t _{1/2}	8.80E+02	days	
Calculated decay rate	λ	7.88E-04	days ⁻¹	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+02	m	
Plume thickness at source	Sy	1.98E+00	m	
Saturated aquifer thickness	da	2.10E+00	m	
Bulk density of aquifer materials	ρ	1.36E+00	g/cm ³	
Effective porosity of aquifer	n	8.00E-02	fraction	
Hydraulic gradient	i	1.33E-02	fraction	
Hydraulic conductivity of aquifer	K	8.64E-02	m/d	
Distance to compliance point	x	1.25E+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	3.65E+06	days	time variant options only

Parameters values determined from options

Partition coefficient	Kd	2.81E+03	l/kg	see options
Longitudinal dispersivity	ax	1.25E+00	m	see options
Transverse dispersivity	az	1.25E-01	m	see options
Vertical dispersivity	ay	1.25E-02	m	see options

Calculated Parameters Variable

Groundwater flow velocity	v	1.44E-02	m/d	
Retardation factor	Rf	4.77E+04	fraction	
Decay rate used	λ	1.65E-08	d ⁻¹	
Rate of contaminant flow due to retardation	u	3.01E-07	m/d	
Contaminant concentration at distance x, assuming one-way vertical dispersion	C _{ED}	0.00E+00	mg/l	
Attenuation factor (one way vertical dispersion, CO/CED)	AF	breakthrough at compliance point		

Remedial Targets

Remedial Target	No impact	mg/l	For comparison with measured groundwater concentration.
Ogata Banks			
Distance to compliance point	12.5	m	
Concentration of contaminant at compliance point	C _{ED} /C ₀	0.00E+00	mg/l
after		3.7E+06	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.

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

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer

Organic carbon partition coefficient

Entry for ionic organic chemicals (option)

Sorption coefficient for related species

Sorption coefficient for ionised species

pH value

acid dissociation constant

Fraction of organic carbon in aquifer

Soil water partition coefficient

Kd 2.81E+03 l/kg

foc fraction

Koc l/kg

K_{oc,i} l/kgK_{oc,i} l/kg

pH

pKa

foc fraction

Kd 2.81E+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

For calculated value, assumes ax = 0.1 * x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = 0.83(log₁₀)^{2.414}; az = ax/10, ay = ax/100 are assumed

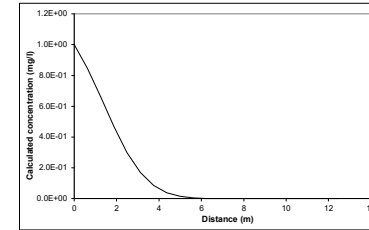
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Calc value Xu & Eckstein

0.00E+00 1.25E+00 1.04E+00

0.00E+00 1.25E-01 1.04E-01

0.00E+00 1.25E-02 1.04E-02



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 then an alternative solution should be used.

Site being assessed: Llanwern reference tables

Completed by: XMBB/JWG

Date: #####

Version: 2

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
	mg/l
0	1.0E+00
0.6	8.46E-01
1.3	6.80E-01
1.9	4.67E-01
2.5	2.98E-01
3.1	1.69E-01
3.8	8.54E-02
4.4	3.81E-02
5.0	1.49E-02
5.6	5.14E-03
6.3	1.55E-03
6.9	4.09E-04
7.5	9.43E-05
8.1	1.90E-05
8.8	1.89E-06
9.4	2.86E-07
10.0	3.79E-08
10.6	0.00E+00
11.3	0.00E+00
11.9	0.00E+00
12.5	0.00E+00

R&D Publication 20 Remedial Targets Worksheet, Release 3.2



Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

Contaminant	Variable	Value	Unit	Source
Target Concentration	C _T	3.76E+02	mg/l	from Level 1

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

Ogata Banks Equations in HRA publication

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	1.00E+00	mg/l	
Half life for degradation of contaminant in water	t _{1/2}	1.00E+99	days	
Calculated decay rate	λ	6.93E-100	days ⁻¹	
Width of plume in aquifer at source (perpendicular to flow)	Sz	1.00E+02	m	
Plume thickness at source	Sy	1.98E+00	m	
Saturated aquifer thickness	da	2.10E+00	m	
Bulk density of aquifer materials	ρ	1.36E+00	g/cm ³	
Effective porosity of aquifer	n	8.00E-02	fraction	
Hydraulic gradient	i	1.33E-02	fraction	
Hydraulic conductivity of aquifer	K	8.64E-02	m/d	
Distance to compliance point	x	1.25E+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	3.65E+06	days	time variant options only

Parameters values determined from options

Partition coefficient	Kd	8.10E+02	l/kg	see options
Longitudinal dispersivity	ax	1.25E+00	m	see options
Transverse dispersivity	az	1.25E-01	m	see options
Vertical dispersivity	ay	1.25E-02	m	see options

Calculated Parameters

Groundwater flow velocity	v	1.44E-02	m/d	
Retardation factor	Rf	1.38E+04	fraction	
Decay rate used	λ	5.03E-104	d ⁻¹	
Rate of contaminant flow due to retardation	u	1.04E-06	m/d	
Contaminant concentration at distance x, assuming one-way vertical dispersion	C _{ED}	3.80E-03	mg/l	
Attenuation factor (one way vertical dispersion, CO/CED)	AF	2.63E+02		

Remedial Targets

Remedial Target	9.91E+04	mg/l	For comparison with measured groundwater concentration.
Ogata Banks			
Distance to compliance point	12.5	m	
Concentration of contaminant at compliance point after	C _{ED} /C ₀	3.80E-03	mg/l
		3.7E+06	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.

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

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient

Entry for non-polar organic chemicals (option)

Fraction of organic carbon in aquifer

Organic carbon partition coefficient

Entry for ionic organic chemicals (option)

Sorption coefficient for related species

Sorption coefficient for ionised species

pH value

acid dissociation constant

Fraction of organic carbon in aquifer

Soil water partition coefficient

Kd 8.10E+02 l/kg

foc fraction

Koc l/kg

K_{oc,i} l/kg

K_{oc,i} l/kg

pH

pKa

foc fraction

Kd 8.10E+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

For calculated value, assumes ax = 0.1 * x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report ax = 0.83(log₁₀)^{2.414}; az = ax/10, ay = ax/100 are assumed

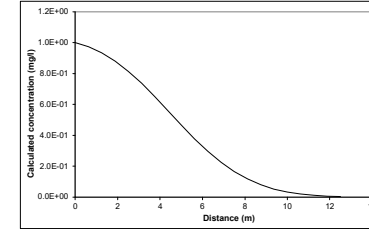
Enter value

Calc value Xu & Eckstein

0.00E+00 1.25E+00 1.04E+00

0.00E+00 1.25E-01 1.04E-01

0.00E+00 1.25E-02 1.04E-02



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 then an alternative solution should be used

Site being assessed: Llanwern reference tables
Completed by: XMBB/JWG
Date: #####
Version: 2

Calculated concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Concentration
0	1.0E+00
0.6	9.73E-01
1.3	9.34E-01
1.9	8.81E-01
2.5	8.15E-01
3.1	7.38E-01
3.8	6.51E-01
4.4	5.59E-01
5.0	4.67E-01
5.6	3.78E-01
6.3	2.97E-01
6.9	2.25E-01
7.5	1.66E-01
8.1	1.17E-01
8.8	8.03E-02
9.4	5.30E-02
10.0	3.37E-02
10.6	2.07E-02
11.3	1.22E-02
11.9	6.94E-03
12.5	3.80E-03