Pen y Glol Discharge
H1 Annex J Groundwater Risk Assessment Addendum

1. Introduction

1.1 Purpose of this Document

This note provides an addendum to the groundwater risk assessment ('GWRA') for the Pen y Glol caravan park's discharge of treated sewage effluent to ground prepared by Rukhydro (August 2021). This addendum provides a response to Natural Resources Wales ('NRW') Schedule 5 response dated 23 May 2024.

This note has been prepared by Rukhydro Limited for Pen y Glol Ltd as an extension to a scope of work for the preparation of a quantitative groundwater risk assessment for a discharge of treated sewage effluent as originally set out in Rukhydro Limited proposal (Ref 00095Cp018i1) dated 09 February 2021. **A *Non-Disclosure Notice*** and ***Third Party Disclaimer*** are provided at the end of this note. It is intended that this document will be shared with Natural Resources ("NRW").

1.2 Schedule 5 Requirement

The Schedule 5 notice refers to Pen-Y-Glol Ltd's application (PAN-020219) for a permit to discharge treated sewage effluent to ground under the *Environmental Permitting (England and Wales) Regulations 2016*.

The Schedule 5 notice requires Pen-Y-Glol Ltd to provide additional information on six bullet pointed items, but the one of relevance to this addendum reads:

- Provide a Detailed Quantitative Risk Assessment (DQRA) based on the final treatment system design as described in supporting information document titled: *Pen-y-Glol Proposed Effluent Treatment System* submitted 22/03/2023, using the Ffynnon Asaph spring as the groundwater receptor. Please see link for details Groundwater risk assessment for your environmental permit - GOV.UK (www.gov.uk).

In a clarification call[1] with NRW, it was agreed that an addendum or Appendix to the existing 2021 report should be acceptable, using information already gathered within that report. But that this addendum would be focussed on the what-if scenario that the Pen Y Glol discharge was in the catchment to Ffynnon Asaph spring. It was also communicated that the NRW geoscience team would wish to see use of the standard H1 Annex J5 spreadsheet.

1.3 Layout of this Addendum

A contents list is provided in Table 1.1. Following this introduction, Section 2 provides a short recap of the findings of the main groundwater risk assessment. Section 3 then provides an update on effluent treatment at the site and Section 4 reaffirms nitrate as the main contaminant of concern for the Ffynnon Asaph spring. Section 5 screens the risk to the spring using a dilution assessment and Section 6 models downgradient concentrations using the H1 Annex J5 workbook. Conclusions and recommendations are provided in Sections 7 and 8.

[1] Nick Rukin (Rukhydro Ltd) to James Wakeford (NRW) of 02 July 2024

Table 1.1 Table of Contents

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2. GWRA Summary Recap

The main findings of the Rukhydro (August 2021) GWRA regarding the Pen y Glol discharge were:

- The discharge is very likely to be outside the catchment and source protection zone (SPZ) to the Ffynnon Asaph spring, from which Welsh Water takes some water for public supply. Instead, groundwater is more likely to flow NNE towards the Dee Estuary.
- There are no licensed groundwater abstractions in this NNE flow direction and no private abstractions in that direction from the limestone. There is limited groundwater quality data in general, but a monitoring point (Tre Eden mine adit discharge) shows no clear evidence of impact from septic tanks over a likely agricultural signal.
- In terms of risk screening, the ≤15 m^3/day discharge to ground in an area of ash woodland is underlain by a circa 40-50 m thick unsaturated zone comprising gently (4°) northerly dipping limestones of the Carboniferous Loggerhead Limestone Formation. There is no protective layer of superficial deposits. Migration through the unsaturated zone will be via fractures in the limestone; there are no mapped sink holes in this area.
- The quantitative risk assessment to groundwater to the NNE focussed in on nitrate as likely being the main contaminant of concern, with ammoniacal nitrogen very likely being oxidised in the shallow discharge area or subsequent unsaturated zone.
- Travel times below the discharge to the water table were calculated to be between 4.3 and 4.8 days.
- Dilution of the discharged effluent in groundwater flowing (NNE) would lead to a dilution factor multiple of 0.29 to 0.32 (unitless) times.

3. Effluent Treatment Update

3.1 Effluent Treatment and Discharge in 2021

Section 2.2.4 of the Rukhydro (2021) risk assessment describes the foul drainage treatment at that time. Raw effluent was piped via site sewers to one of five separate septic tanks (each treating raw effluent) and then their treated effluent being treated through a sixth septic tank before discharge to ground in an area of ash woodland.

The discharge to ground takes place via three drainage runs comprising 4 inch (~102 mm) perforated pipes set in 20 mm size limestone pebble gravel filled infiltration trenches. 0.3m of gravel underlies each pipe. Each trench is circa 0.75-1 m deep and 0.8-0.9 m wide. A 50 m long feeder trench orientated southwards conveys treated effluent into three further 50 m long trenches spanning an orientation between 145° and 215° (~35° either side of south).

Section 3.5.1 of the Rukhydro (2021) risk assessment calculates a drainage floor area of ([4 x 50m] x [0.8 to 0.9m] =) 160 to 180 m^2. If it was assumed the effluent spread out 0.5 to 1 m either side of each trench, the floor area would increase to ([4 x 50m] x [1.8 to 2.9m] =) 360 to 580m.

Pen-Y-Glol Ltd has communicated[2] that due to topographical limitations (an undulating rocky clay landscape) coupled with Flintshire Council insisting the mature woodlands are retained, that construction of further drainage trenches would be very challenging.

[2] Document: *Pen-y-Glol Proposed Effluent Treatment System.doc* (dated 19 December 2022)

3.2 Clenviro Package Treatment Plant

Pen-Y-Glol Ltd note that a new package treatment plant (PTP) was installed by Clenviro Ltd on 16 June 2023, with commissioning completed in October 2023.

On the PTP's standard performance certificate, it is described as a "*Small wastewater treatment system MATRIX CLF – submerged fixed film process*" with the performance efficiencies as shown in Table 3.1.

Table 3.1 Clenviro Package Treatment Plant Designed Effluent Quality

Parameter	Efficiency	Outflow Effluent Quality
Chemical Oxygen Demand (COD)	91.4%	56 mg/l
Biological Oxygen Demand (BOD_5)	96.2%	11 mg/l
Suspended Solids	95.5%	16 mg/l
Ammoniacal Nitrogen[2]	83.3%	5.9 mg/l

Notes:
1) Tested with an influent quality of ≥300 mg/l BOD_5.
2) Determined for temperatures ≥12°C in the bioreactor.

3.3 Clenviro PTP Treated Effluent Quality

Since the Clenviro PTP was commissioned in October 2023, influent and effluent water quality has been sampled on two occasions with results from analysis by accredited ALS laboratories provided in Table 3.2.

The sampled treated effluent quality is close to the performance certificate for BOD, but is higher for COD, suspended solids and ammoniacal nitrogen. The treated quality is, however, much better than assumed in Environment Agency (2020).

Table 3.2 also shows the calculated concentration of total inorganic nitrogen (T.I.N) as ranging between 42.2 and 50.4 mg/l N (average 46.3 mg/l N) in the treated effluent and 56.5 to 70.9 mg/l N (average 63.7 mg/l N) in the raw effluent. These concentrations compare to treated effluent average T.I.N concentrations of 64.0 and 48.3 mg/l N in a study (EPA, 2005) on two Irish PTPs. On the basis of these data the following T.I.N concentrations are assumed for the Pen y Glol PTP effluent:

- Minimum: 45 mg/l N;
- Average: 55 mg/l N;
- Maximum: 65 mg/l N.

When the residual ammoniacal nitrogen in the treated effluents is oxidised in the drainage field and unsaturated zone, these T.I.N would convert into nitrate-nitrogen in the underlying oxidised groundwater unless there was denitrification in the drainage field.

4. Substances of Concern

4.1 Guidance

Box 4.1 reproduces government guidance (Environment Agency, 2020) on substances of concern in groundwater risk assessments for discharges of treated sewage effluent to ground. The guidance notes that:

- ammoniacal nitrogen (which includes ammonium and ammonia), phosphates and microbiological contaminants are the main concerns.
- Ammoniacal nitrogen may be transformed into nitrate nitrogen in the drainage field or unsaturated zone unless there are losses through denitrification.
- Package treatment plant treated effluent should not contain hazardous substances above their minimum reporting values (MRVs; or limits of detection).

Table 3.2 Pen y Glol Clenviro PTP Influent and Effluent Water Quality

			Pen y Glol Raw Influent		Pen y Glol Treated Effluent		From Environment Agency (2020)[1]		PTP Treated Effluent from EPA (2005)					
									Site 2 (Puraflow®)			Site 4 (Puraflow®)[3]		
Parameter	**Method**	**Units**	30/11/2023	05/06/2024	30/11/2023	05/06/2024	**Septic Tank**	**PTP example**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**
ALS Test Number			2580277	2668215	2580277	2668215								
Laboratory Number			23481066	24102296	23481067	24102297								
pH	WAS039	pH units	6.9	10	7.5	6.9								
Conductivity- Electrical 20C	WAS039	µS/cm	742	920	669	769								
Ammoniacal Nitrogen as N	WAS036	mg/l	55.8	70.2	25.1	12.7	104	89	6.9	19.7	45.2		6.7	
Nitrogen, Total Oxidised as N	WAS036	mg/l	<0.7	<0.7	25.3	29.5				44.3			42.5	
Phosphorus , Total as P	WAS049	mg/l	10.2	12.3	11.2	12.6	15.8	10.5	16.8	33.6	85.6	3.9	8.0	12.4
Total Suspended Solids	WAS006	mg/l	74	103	38	7	Note 4	Note 4						
BOD + ATU (5 day)	WAS001	mg/l	142	319	13	8	368	20-55						
COD (Total)	WAS040	mg/l	566	448	90	67	677	210	98	188	316	68	199	370
TOC as C	WAS005	mg/l	64	72.5	21.7	22.7								
Chloride		mg/l					68.6	88.1	51.3	92.6	185.0	22.0	58.6	84.5
Boron		mg/l					0.84	0.37						
Arsenic		mg/l					<0.015	<0.015						
Cadmium		mg/l					<0.002	<0.002						
Copper		mg/l					0.015	0.007						
Iron		mg/l					0.130	0.040						
Lead		mg/l						<0.005						
Zinc		mg/l					0.030	0.010						
Total Inorganic Nitrogen[2]	Calculated	mg/l	56.5	70.9	50.4	42.2				64.0		27.3	48.3	65.6

Notes:

1) Data from on-line Environment Agency (2020) guidance: https://www.gov.uk/government/publications/values-for-groundwater-risk-assessments/septic-tank-and-package-treatment-plants-liquid-effluent-pollutants-and-typical-concentrations
2) Total inorganic nitrogen is the sum of ammoniacal nitrogen and total oxidised nitrogen (TON). TON is the sum of nitrate-N and nitrite-N.
3) Min, max and average total nitrogen provided in a separate table to average ammoniacal nitrogen, nitrite and nitrate and there is minor inconsistency between them.
4) The guidance notes: "*For ammonium (as NH4+), ammonium may be transformed to nitrate in the drainage blanket or unsaturated zone and your risk assessment may need to consider the impact of nitrate on groundwater quality. In theory, 50mg per litre of ammonium (NH4+) could be converted to 172mg per litre of nitrate (NO3-) if there were no losses of nitrogen.*"

Box 4.1 – Substances of Concern (Environment Agency, 2024)

The main substances of concern (substances you must consider in your risk assessment) for sewage effluent discharges are:

- *ammoniacal nitrogen (the ammonium ion NH4+), a non-hazardous pollutant*
- *ammonia (NH3), also known as free ammonia or unionised ammonia*
- *microbiological contaminants – these are not substances in the definition of groundwater activities in the Environmental Permitting Regulations 2016, but can contain harmful contaminants (such as pathogens like bacteria, viruses or protozoa).*
- *phosphorus and phosphates, non-hazardous pollutants*
- *other contaminants – including hazardous organic compounds and household chemicals, such as cadmium and mercury, which are hazardous substances*

If you have a domestic septic tank or package treatment plant the discharge quality is likely to remain stable around these typical values [see Table 3.1] *and should not contain unusual substances. If so you should be able to use minimum reporting value (MRV) figures in your risk assessment.*

You will need to analyse the effluent as part of your quantitative risk assessment if:

- *this is not appropriate for you (for example, you have trade substances from your activity that is not domestic in nature)*
- *you will discharge over 50m^3 per day*

For both domestic and non-domestic systems you should try to prevent disposing of pharmaceuticals, pesticides, solvents, oils and greases.

Source: Environment Agency Guidance: https://www.gov.uk/guidance/infiltration-systems-groundwater-risk-assessments#assess-the-quality-of-the-treated-effluent (Substances of concern).

4.2 Attenuation in the Drainage Field

There is a broad consensus that in the drainage field, beneath the percolation pipes, a '*biomat*' typically forms and this helps even out infiltration through the length of the trenches and also leads to some attenuation of contaminants. For example, Knappe et al (2020) note:

> "*Studies on the long-term behavior of effluent infiltration in STUs showed that with time a microbial clogging zone, called the biomat or biozone, establishes in the upper few centimeters of the soil (Beal et al., 2006; McKinley and Siegrist, 2011; McKinley and Siegrist, 2010; Rainwater et al., 2005; Rice, 1974; Siegrist and Boyle, 1987). While the presence of this clogging zone was historically often linked to the hydraulic failure of STUs leading to insufficient effluent infiltration and potential ponding of effluent above ground (de Vries, 1972; McGauhey and Winneberger, 1964), the gradual formation of a biomat along the trench base is now understood to be crucial for facilitating effective effluent distribution over the entire design area and pollutant removal through adsorption, biodegradation, and filtration within the biomat itself and the unsaturated soil beneath (Amador and Loomis, 2018; Beal et al., 2005; McKinley and Siegrist, 2011; Siegrist et al., 2012).*"

Table 4.1 collates information on attenuation within 0.6m depth below infiltration trenches receiving package treatment plant discharges in Ireland as reported by EPA (2005). This shows:

- Ammoniacal nitrogen attenuation of 55 to 93%;
- Total Inorganic Nitrogen of 0 to 10%;
- Phosphate attenuation of 29 to 43%
- *E.coli* attenuation of circa 99%.

Work monitoring discharges to infiltration trenches from septic tanks in Canada over 30 years (Roberston et al, 2019) has reported average phosphate attenuation rates of 90% and 66% for sites with non-calcareous (<2 wt.% Ca) and calcareous substrates respectively.

Table 4.1 Drainage Field Attenuation of Substances of Concern (after EPA, 2005)

		Site 2 PTP Discharge				Site 4 PTP Discharge			
Parameter	**Units**	**Effl-uent**	**At 0.3m**	**At 0.6m**	**Removal[1] at 0.6m**	**Effl-uent**	**At 0.3m**	**At 0.6m**	**Removal[1] at 0.6m**
COD	mg/l O_2	188.1	107.5	76.2	59.5%	215.8	109.3	89.5	58.5%
Ammoniacal Nitrogen	mg/l N	20.5	5.8	1.5	92.7%	6.7	3.8	3.0	55.2%
Total (Inorganic) Nitrogen	mg/l N	64.0	59.2	57.9	9.5%	49.2	53.7	50.5	-2.6%
Orthophosphate	mg/l P	33.6	23.9	23.8	29.2%	8.4	6.8	4.8	42.9%
E. coli[2]	cfu/100ml	>1000	<10	<10	99.0%	10-1000	<10	<10	Up to 99.0%

Notes:
1) Calculated as (Effluent – at 0.6m)/Effluent.
2) Original data show number of samples with different bands of *E.coli* concentrations (e.g. <10, 10-100, 100-1000).

4.3 Conclusion

The combination of the Environment Agency guidance (Box 4.1), which notes to assume hazardous substances at their minimum reporting values (below detection), and the attenuation factors above means that total inorganic nitrogen, present primarily as nitrate-nitrogen, is the main contaminant of concern. Nitrate was the contaminant of concern evaluated in the Rukhydro (2021) risk assessment.

5. Dilution Only Risk Screening for Ffynnon Asaph Spring

5.1 Purpose of this Section

Before undertaking a more detailed quantitative risk assessment in Section 6, this section calculates the dilution factor for any contaminants leaving the base of the drainage field arriving in Ffynnon Asaph spring.

As noted in Section 2, the Rukhydro (2021) report provided evidence to indicate that the Pen y Glol discharge is outside the catchment to the Ffynnon Asaph spring, with groundwater from beneath the site more likely flowing NNE towards the Dee Estuary. So this dilution factor assessment is for the what-if scenario that the Pen y Glol discharge is within the catchment to the Ffynnon Asaph spring.

5.2 Ffynnon Asaph Spring Flows

By correlating spot measurements of flows at the spring with daily measured flows on the River Wheeler at Bodfari, Section 2.3.5 of Rukhydro (2021) derived flow statistics for the Ffynnon Asaph spring as shown in Table 5.1.

Table 5.1 shows flows at the spring are likely to range between ~4700 m^3/day at low (95^{th} percentile) flows and ~29340 m^3/day at high (5^{th} percentile) flows, with a median (50^{th} percentile) of ~11040 m^3/day and average (mean) of ~13500 m^3/day.

5.3 Dilution Factors for Pen Y Glol in Ffynnon Asaph Spring

Table 5.1 also calculates dilution factors for the Pen y Glol discharge (assumed at a maximum of 15 m^3/day) in the Ffynnon Asaph spring. This shows on average the Pen y Glol discharge would be ~$1/900^{th}$ of the spring's flows; the range being between $1/313^{th}$ and $1/1956^{th}$.

5.4 Calculated Increase in Ffynnon Asaph Nitrate Concentration

Table 5.1 also shows the calculated increase in nitrate concentration in the spring assuming T.I.N concentrations in the Pen y Glol discharge of 45 to 65 mg/l N (see Section 3.3). The increase is between 0.02 and 0.21 mg/l N, with an average of 0.06 mg/l N.

Table 5.1 FFynnon Asaph Flows and Pen y Glol Discharge Dilution Assessment

			Flow or Dilution Statistic					
Item	**Parameter**	**Units**	**95%ile**	**70%ile**	**50%ile**	**Mean**	**10%ile**	**5%ile**
1a	Ffynnon Asaph spring[1]	m^3/s	0.054	0.089	0.128	0.156	0.282	0.340
1b	"	m^3/day	4697	7692	11042	13508	24349	29338
2	Pen y Glol assumed discharge	m^3/day				15		
3a	Dilution factor multiple[2]	fraction	0.0032	0.0019	0.0014	0.0011	0.0006	0.0005
3b	Dilution factor divisor[3]	integer	313	513	736	901	1623	1956
4	Pen y Glol assumed T.I.N[4]	mg/l N	45			55		65
5	Calculated increase in Ffynnon Asaph nitrate due to dilution of Pen Y Glol discharge[5]	mg/l N	0.02			0.06		0.21

Notes:

1. Based on correlation between measured spot flows for the Ffynnon Asaph spring and daily measured flows on the River Wheeler at Bodfari (se Rukhydro, 2021, Table 2.2). Flows converted from units of m^3/s to m^3/day.
2. Calculated as Pen y Glol discharge fixed at a maximum of $15m^3/day$ divided by Ffynnon Asaph spring flows. This assumes that the small discharge from Pen y Glol would already be part of the measured flows at the spring.
3. The inverse of the dilution factor multiple.
4. Total inorganic nitrogen (T.I.N) is the sum of ammoniacal nitrogen, nitrite-N and nitrate-N but in the Carboniferous Limestone groundwater this will be all as nitrate-N.
5. For the 95th percentile, the calculation is the minimum T.I.N in the discharge (45 mg/l N) divided by the 5th percentile dilution factor (1956) to give the lowest likely concentration increase (0.02 mg/l N). Conversely, for the 5th percentile, the calculation is the maximum T.I.N in the discharge (65 mg/l N) divided by the 95th percentile dilution factor (313) to give the highest likely concentration increase (0.21 mg/l N).

5.5 Impact on Ffynnon Asaph Spring

Calculated increases in nitrate in the spring of 0.02 to 0.21 mg/l N (average of 0.06 mg/l N) compare to the following nitrate concentrations:

- drinking water standard of 11.3 mg/l N (=50 mg/l NO_3);
- mean of 6.87 mg/l N and 95th percentile (high) of 8.08 mg/l N for 535 samples of the spring between June 1980 and December 2020 (see Table 2.8 of Rukhydro, 2021).

The predicted increases in nitrate in the spring due to the Pen y Glol discharge are therefore very small e.g. 0.21/6.87 = 3% at worst and 0.06/6.87 = 0.9% on average.

6. Assessing Impact on Downgradient Groundwater

6.1 Approach

To assess the impact on downgradient groundwater, assuming flow is towards the Ffynnon Asaph spring, then the H1 Annex J5 Excel workbook[3] (Release 3, March 2022) has been used to model the effects of dispersion and dilution of nitrate in downgradient groundwater.

[3] https://www.gov.uk/government/publications/h1-annex-j5-infiltration-worksheet

6.2 Inputs

The H1 Annex J5 workbook has five separate worksheets and these have been populated as set out in Table 6.1.

Table 6.1 H1 Annex J5 Worksheet Inputs for Pen y Glol Discharge (1 of 2)

Parameter	Units	Value	Basis	Further detail in	
				This addendum	Rukhydro (2021)
Introduction sheet					
Substance		Nitrate			
Environmental Standard (C_T)	mg/l NO_3	50	Drinking water standard.		
Infiltration System sheet					
Concentration of substance in discharge (entering infiltration system)	mg/l NO_3	199-244-288	Assume min-mean-max of 45-55-65 mg/l N = 199-244-288 mg/l NO_3.	Section 3.3	
Type of Treatment		Package Treatment Plant	Clenviro PTP	Section 3.2	
Specify discharge (Q1) or calculate based on use (Q2)		Specified discharge Q1	Option selected.		
Discharge rate	m^3/day	15	As per permit application. Conservative assumption.		
Specify area of drainage field or calculate based on percolation rate		Specify	Option selected.		
Area of drainage field	m^2	170	4 No 50m long trenches each 0.8 to 0.9m wide (assumed 0.85m)	Section 3.1	Section 2.2.4
Attenuation_unsatzone worksheet					
Drainage Layer					
Thickness of drainage layer	m	0.3	Pipes sit on 0.3m gravel	Section 3.1	
Water filled porosity	fraction	0.3	LandSim manual Table 5.5 range for coarse gravel[1] is 0.24 to 0.36.	Section 3.1	
Bulk density	g/cm^3		Assume mineral density of 2.3g/cm^3 and then calculate with porosity.		
Option to select degradation		No degradation occurs	Option selected. Conservative assumption.	Section 4.2	
Method of defining partition co-efficient		User specified value	Option selected.		
Soil water partition coefficient	l/kg	0	No retardation assumed for nitrate.		
Unsaturated Zone					
Thickness of unsaturated zone below drainage field	m	41.5	Range 41.5 to 50.5m. Conservative assumption.		Section 3.5.4
Water filled porosity	fraction	0.01	Fracture porosity		Section 3.5.4
Bulk density of unsaturated zone	g/cm^3	2.28	Assume mineral density of 2.3g/cm^3 and then calculate with porosity.		
Option to select degradation		No degradation occurs	Option selected.		
Method of defining partition co-efficient		User specified value	Option selected.		
Soil water partition coefficient	l/kg	0	No retardation assumed for nitrate.		

Notes: (continued on next page)

1. Rukhydro (2021) Fig 2.3 notes 20-50mm gravel. This is coarse gravel as defined by ISO14688 (https://en.wikipedia.org/wiki/Gravel).

Table 6.1 H1 Annex J5 Worksheet Inputs for Pen y Glol Discharge (2 of 2)

Parameter	Units	Value	Basis	Further detail in	
				This addendum	Rukhydro (2021)
Dilution worksheet					
Length of drainage field in direction of groundwater flow	m	91.0[2]	50m + 50mcos(35°) to 50m+50m. Conservative assumption.	See Note 3	
Saturated aquifer thickness	m	200	Range 200 to 300m. Conservative assumption[4].		Section 2.6.5
Hydraulic Conductivity of aquifer in which dilution occurs	m/d	0.215	Range 0.14 to 0.25. Conservative assumption[4].		Section 2.6.5
Hydraulic gradient of water table	fraction	0.0148			Section 2.6.3
Width of drainage field perpendicular to groundwater flow	m	57.4[2]	Trenches splay 35° each side of south, so the furthest tip is 50m x Sin(35°) from south.	Section 3.1	
Background concentration of substance in groundwater up-gradient of site	mg/l NO_3	24.5	Ffynnon Asaph Spring mean 6.873mg/l N = 24.5mg/l NO_3. (See Note 5).		Table 2.8
Option to define mixing zone thickness		Calculate	Option selected.		
Attenuation_satzone worksheet					
Option to select degradation		No degradation occurs	Option selected.		
Bulk density of aquifer materials	g/cm^3	2.28	Assume mineral density of 2.3g/cm^3 and then calculate with porosity.		
Effective porosity of aquifer	fraction	0.01	Fracture porosity		Section 3.5.4
Distance to compliance point	m	1000	See Note 6.		
Option to select time		Steady state	Option selected.		
Method of defining partition co-efficient		User specified value	Option selected.		
Soil water partition coefficient	l/kg	0	No retardation assumed for nitrate.		
Define dispersivity option		Dispersivities 10%, 1%, 0.1% of pathway length	User manual (Environment Agency, 2014; Sn 5.0 bullet 6) recommended option for fractured aquifers		

Notes:

1. Rukhydro (2021) Fig 2.3 notes 20-50mm gravel. This is coarse gravel as defined by ISO14688 (https://en.wikipedia.org/wiki/Gravel).
2. It is noted that the combination of the length of drainage field in the direction of groundwater flow and the width of the drainage field perpendicular flow multiplied together produce an area much greater than the drainage field area. But that is just a function of the layout of the site.
3. The drainage field is laid out with a 50m initial pipe/ trench then splaying into 3 No additional 50m trenches at an angle of 35° each side of south. Taking a groundwater flow direction approximately south to north, then the length of the outer trenches is (50m x cosine(35°)=) 40.96m main the total length including the initial 50m as ~91.0m. The length of the central trench is (50m + 50m=) 100m, so use of 91 m is pessimistic.
4. Saturated hydraulic conductivity and saturated aquifer thickness are interrelated through their product = transmissivity. Rukhydro (2021; Section 2.6.5) calculated a transmissivity range of 43 to 50 m^2/day based on a catchment water balance based flow (Q) and hydraulic gradient (i) of 0.0148. The average transmissivity is 46.5 m^2/day. This combination of a saturated aquifer thickness of 200m and hydraulic conductivity of 0.215 m/day gives the lowest transmissivity of 43 m^2/day and is considered the most conservative.
5. There are no monitoring data in the area of the discharge to define background water quality in the Carboniferous Limestone so this average for the Ffynnon Asaph spring is used. The Pen y Glo discharge is in an area with significant woodland and is in the upper parts of the catchment (to the Dee Estuary or in this scenario to the Ffynnon Asaph spring). It would be plausible to assume that background nitrate concentrations are therefore lower than assumed here.
6. Distance from discharge site to Hendre Fawr sink hole is 3km from which point tracer tests have shown connection to the Ffynnon Asaph spring. 1 km distance nominally used to show change in concentrations at 50m distance intervals.

6.3 Conservative Assumptions

Table 6.1 shows that conservative (pessimistic assumptions) have been assumed with respect to options of no degradation (denitrification) or retardation of nitrate and to options where there is uncertainty in several parameters. The discharge is also assumed to be at 15 m^3/day at all times.

6.4 Sensitivity Analysis

As neither nitrate degradation nor retardation is being modelled the main factors affecting the predicted concentration are:

- Assumed concentration of total inorganic nitrogen (= nitrate after nitrification of ammoniacal nitrogen) in the discharge.
- The combination of hydraulic conductivity and saturated aquifer thickness which affects dilution, dispersion and mixing zone thickness.

Table 6.2 shows the values assumed for three versions of the H1 Annex J5 workbook.

Table 6.2 Variables assumed for Sensitivity Analysis

Parameter	Units	Optimistic	Likely	Pessimistic
Varied Inputs				
Concentration of substance in discharge (entering infiltration system)	mg/l NO_3	177.14 (45 mg/l N)	221.43 (55 mg/l N)	287.86 (65 mg/l N)
Transmissivity	m^2/day	50	46.5	43
Saturated aquifer thickness	m	300	250	200
Hydraulic Conductivity of aquifer in which dilution occurs	m/d		0.186	0.215
Calculated Outputs[1]				
Mixing Zone Thickness	m	300	250	200
Groundwater flow (mixing zone) below drainage field	m^3/d	42.44	39.47	36.50
Groundwater velocity	m/d	0.334	0.380	0.449
Concentration of nitrate at:	mg/l NO_3			
50m		58.5	67.7	78.1
250m		44.3	48.9	54.1
Distance at which drinking water standard of 50m met (to nearest 50m)	m	150	250	400

Notes:
1. These shown to illustrate that the changes to the assumed transmissivity produce less diluting groundwater and faster velocities for the pessimistic option.

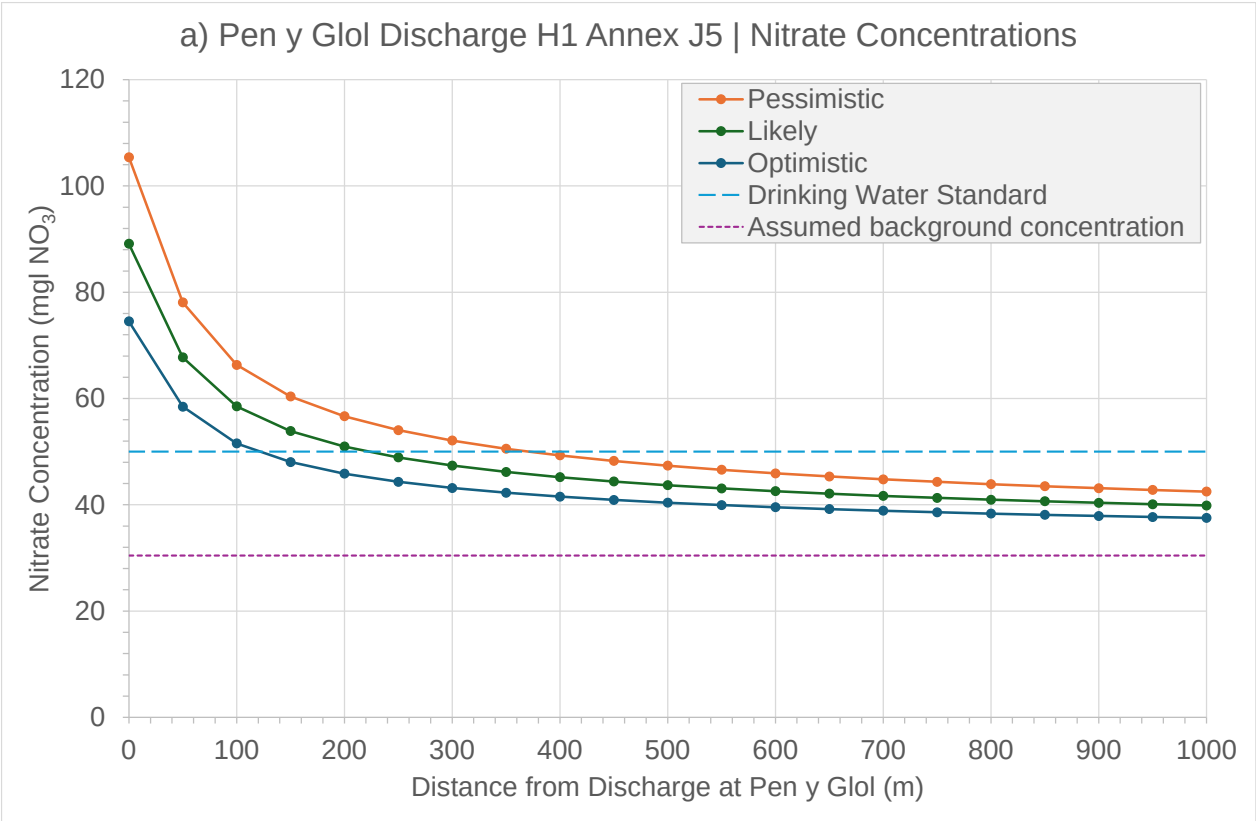
6.5 Outputs

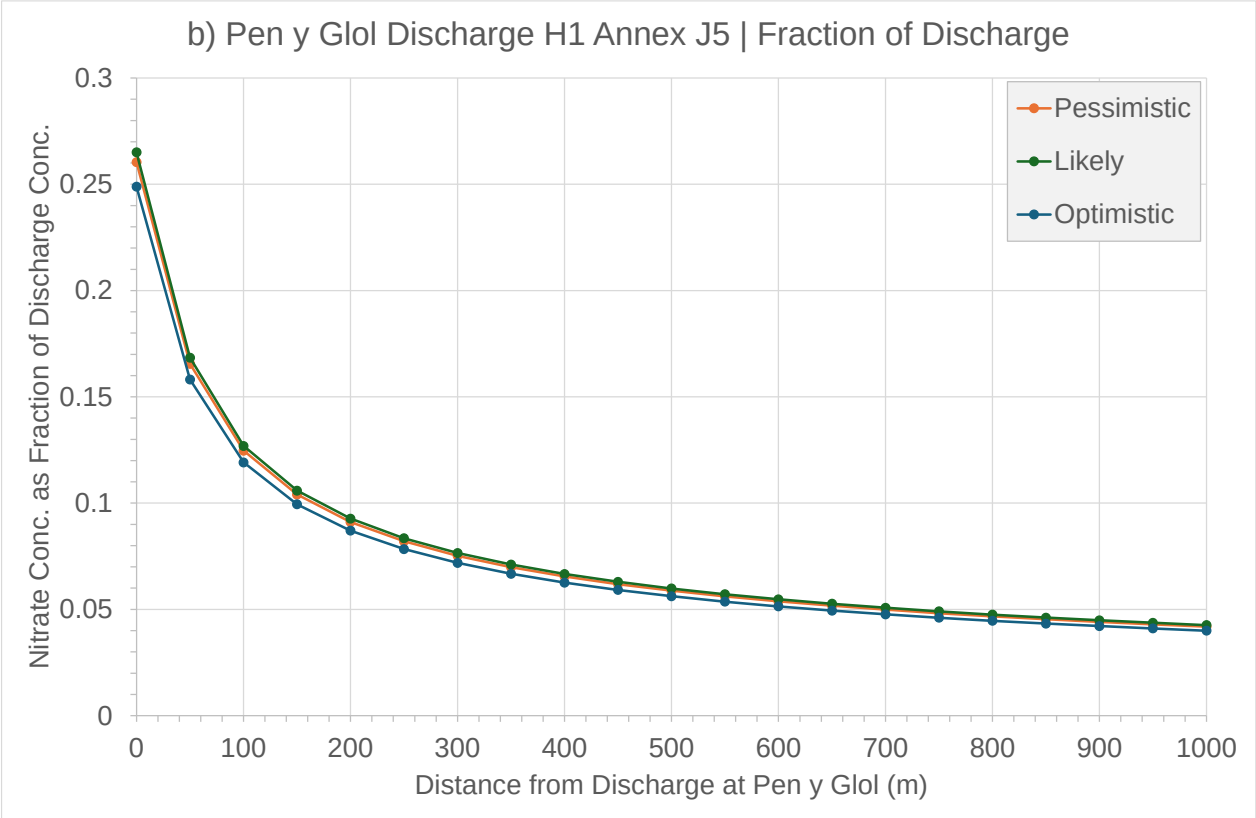
Figure 6.1 provides charts illustrating:

a) Change in modelled nitrate concentration downgradient of the Pen y Glol discharge;
b) That change expressed a fraction of the assumed discharge concentration.

The charts show the modelled significant decrease in nitrate concentration within a few hundred metres of the discharge. Background concentrations are plausibly lower than assumed given the amount of woodland in nearby areas. The main variation in the modelled outputs is related to the assumed input concentration.

Figure 6.1 – Results of Modelling using H1 Annex J5 Workbook





Note: See Tables 6.1 and 6.2 for assumed values. The Pen y Glol discharge is circa 5.2 km ('as the crow flies') from the Ffynnon Asaph spring and circa 3 km from the Hendre Fawr sink hole from which point tracer tests have shown connection to the spring.

7. Conclusions

Notwithstanding that the Pen y Glol discharge is more likely to be within the catchment to the River Dee than to the Ffynnon Asaph spring, the conclusions from this assessment are:

- Nitrate is likely to be the main contaminant of concern to the spring;
- For risk screening, based on dilution of the Pen y Glol discharge in the spring, the increase in nitrate nitrogen is between 0.02 and 0.21 mg/l N, with an average of 0.06 mg/l N (assuming discharge concentrations of nitrate of 45, 55 and 65 mg/l N). These concentration increases are very small (<3%) compared to the average concentration in the spring of 6.87 mg/l N.
- The downgradient impact of the Pen y Glol discharge has also been modelled in H1 Annex J5 workbooks. An optimistic, likely and pessimistic version has been created. These show that the drinking water standard (50 mg/l NO_3 = 11.3 mg/l N) would be met within distances of 150 m, 250 m and 400 m respectively. This assumes that background concentrations are as measured at the spring but they are plausibly lower given the amount of woodland in this upper catchment area.

8. Recommendations

In undertaking this assessment, the following recommendations are made:

- Pen y Glol Ltd should discuss with Clenviro Ltd the current performance of the package treatment plant with respect to higher output concentrations of COD, suspended solids and ammoniacal nitrogen than stated on the systems expected concentrations (see Section 3.3).
- Further samples of treated effluent should be collected, with analysis as in November 2023 and June 2024 to help better constrain variability in effluent quality and in particular in concentrations of ammoniacal nitrogen and total oxidised nitrogen. Sampling should include measurement of temperature of the effluent at the time of sampling and should be undertaken under a range of site occupancy (e.g. peak holiday season as well as quieter times). Flow at the time of sampling should also be recorded.

9. References

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.....Date…8th July 2024……

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