Gwynedd Council

Llwyn Isaf Landfill- Area 3

Hydrogeological Risk Assessment Review

October 2023

Report for

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Executive summary

This report provides a review of the 2007 hydrogeological risk assessment (HRA) and the 2009 and 2015 re-assessments for Area 3 of the Llwyn Isaf Landfill (the site) using monitoring data up to March 2023. The review has been undertaken in accordance with the site's Environmental Permit (EP) requirement for six yearly reviews of the HRA (revised from four-yearly reviews by the Environmental Permitting Regulations in 2010).

The site, which comprises Areas 1, 2 and 3, is located 17 km southwest of Caernarfon, at National Grid Reference (NGR) SH450 488. Area 1 comprises the main elements of the site infrastructure and an anaerobic digestion (AD) facility, Area 2 is an unlined landfill in its aftercare phase and Area 3 is an engineered landfill, which is now restored and in definitive closure.

A hydrogeological risk assessment (HRA) was carried out for Area 3 of the site by WSP (formerly Amec Foster Wheeler) in 2007 (hereafter referred to as the 2007 HRA) in support of an Environmental Permit (EP) application for a non-hazardous landfill. Area 3 was issued with an EP (ref EPR/YP3138UJ) in October 2008. In 2009 WSP (formerly Amec Foster Wheeler) re-assessed the risks to groundwater in accordance with an EP Improvement Condition using additional information on groundwater levels and organic carbon content of the aquifer. In 2015 a further review was completed, which found that the site conceptual model developed in the previous HRAs is qualitatively unchanged, but the risks to receptors was re-assessed to take into account a higher leachate strength than originally assumed and additional leachate contaminants.

Since the 2015 HRA, leachate levels in Area 3 have remained below the EP compliance limit of 1.5 m above cell base except for isolated occurrences. Leachate strength (as defined by the concentration of chloride and ammoniacal-nitrogen) have shown an overall downwards trend since 2013, however there have been several spikes in concentration between May 2016 to November 2019.

Surface water drainage was reconfigured at the site during 2012. The new surface water management system comprises drainage pipework and an interceptor connected to an attenuation lagoon which discharges into the Afon Desach. Surface water collected from Area 3 drains to both the attenuation lagoon and an infiltration basin (soakaway located to the east of the site boundary). Most of Area 2 drains to the attenuation lagoon with the exception of the northernmost part which drains to one of two soakaways at the site, monitored at point Soakaway NS. Water quality in the Afon Desach, the site soakaways and discharge to the Afon Desach show no discernible impact from the site.

The geology at the site comprises re-worked silty sand and gravel 2 to 7 m thick underlain by vertically and laterally variable Glacial sand and gravel deposits (10 to 20 m thick), Glacial Till, and the Ordovician Arenig-Llandeilo Formation (slate, sandstone and siltstone bedrock). Groundwater in the sand and gravel deposits flows to the northwest, north, northeast.

Review of monitoring data since the 2015 HRA indicates no discernible impact in groundwater downgradient of Area 3. Some of the boreholes downgradient of Area 2 and 3 continue to exceed baseline quality and are likely to reflect some impact from the unlined landfill Area 2. EP groundwater compliance limits have not been exceeded except for isolated peaks for chloride, ammoniacal nitrogen and toluene. Proposals for revised limits are presented on the basis of water quality data collected since the 2015 HRA.

The site conceptual model developed in the previous HRAs is qualitatively unchanged but it was considered appropriate to re-assess the risks to receptors to take into account the higher leachate strength than originally assumed for some of the key parameters: ammoniacal nitrogen, chloride and zinc.

The risks to groundwater from Area 3 have been re-assessed using LandSim v 2.5.17 for these parameters. The modelling results for the EP leachate limit of 1.5 m above cell base indicate that there is no breakthrough above drinking water standard (DWS) of the non-hazardous substances chloride, ammoniacal-nitrogen, zinc and mecoprop. There is, therefore, no predicted impact on groundwater quality at the downgradient edge of Area 3.

There is therefore no predicted risk to the receptors to the northwest, north and northeast of the site, comprising the sand and gravel aquifer, Afon Desach and private water abstractions, as a consequence of the operation of Area 3.

Area 3 is therefore considered to comply with the relevant requirements of the Environmental Permitting Regulations 2010.

Contents

1. Introduction

1.1 Background

Llwyn Isaf Landfill site ('the site') is located approximately 17 km southwest of Caernarfon, at National Grid Reference (NGR) SH450 488 (Figure 1.1). The site includes Areas 1, 2 and 3. Area 1 comprises the main elements of the site infrastructure and anaerobic digestion (AD) facility, Area 2 is an unlined closed landfill and Area 3 is a closed engineered landfill. The site is operated by Gwynedd Council.

A hydrogeological risk assessment (HRA) was carried out for Area 3 of the site by WSP (formerly Entec) in 2007 (hereafter referred to as the 2007 HRA) in support of an Environmental Permit (EP) application for a non-hazardous landfill. Area 3 was issued with an EP (ref EPR/YP3138UJ) in October 2008. In 2009 WSP re-assessed the risks to groundwater in accordance with an EP Improvement Condition using additional information on groundwater levels and organic carbon content of the aquifer (Amec Foster Wheeler, 2009). The site entered 'definitive closure' on 18 July 2014 and is regulated under the conditions of a revised EP (ref. EPR/YP3138UJ/V006). Area 2 was regulated under the conditions of Waste Management Licence (WML) 37044 but the WML has since been superseded by an EP. In October 2015 a review of the HRA (hereafter referred to as the 2015 HRA) for Area 3 including proposals for revised groundwater compliance limits (Amec Foster Wheeler, 2015) was submitted to NRW in accordance with the requirements of Condition 4.2.2 of the EP. The proposed compliance limits were approved by NRW and incorporated in the latest EP Variation (EPR/YP3138UJ/V007 dated 22 February 2016).

1.2 Purpose of this Report

WSP has been appointed by Gwynedd Council to carry out a review of the 2007 HRA and the 2009 and 2015 re-assessments for Area 3 of the site in accordance with the EP requirements for six yearly reviews of the HRA. This report provides the HRA review.

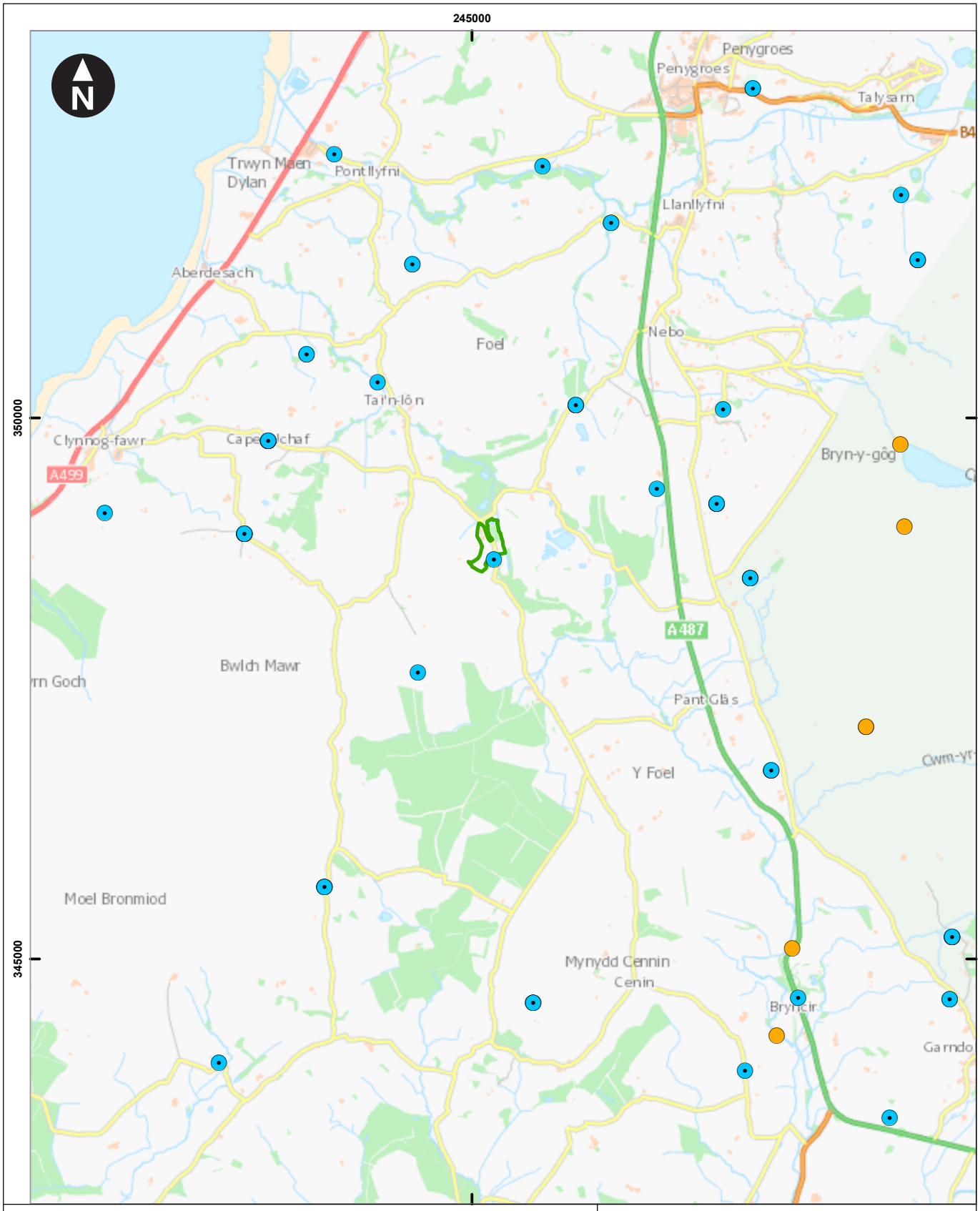
1.3 Sources of Information

Key sources of information used in the preparation of this report are:

- Entec, 2007. PPC Permit Application for Llwyn Isaf Landfill Site - Hydrogeological Risk Assessment. Entec ref. 18846rr095i1.
- Entec, 2009. Llwyn Isaf Landfill Site – Re-appraisal of Actual and Conceptual Hydrogeological Conditions. Report ref. 18846N665i2.
- Entec, 2013. Llwyn Isaf Landfill – Review of Groundwater Trigger Levels for Mercury. Report ref 28587N745i1.
- Entec, 2015. Llwyn Isaf Landfill Site Area 3 - Hydrogeological Risk Assessment Review. Entec ref. 18846rr970i2.

1.4 Layout of this Report

Following this introduction, the conceptual hydrogeological model for the site developed in the 2007/2009/2015 HRAs is updated using monitoring data up to March 2023 in Section 2. The quantitative re-assessment of the risks to groundwater is presented in Section 3. Section 4 reviews the adequacy of the monitoring network and Section 5 presents the conclusions. Data and calculations are summarised in the text and, where appropriate, more detailed information and charts are provided in the Appendices to this report.



Llwyn Isaf Landfill - Area 3
Hydrogeological Risk Assessment Review

Figure 1.1
Site location and local water abstractions

August 2023

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2. Review of Hydrogeological Conceptual Model

2.1 Introduction

This section of the report provides an update of the conceptual hydrogeological understanding of Area 3 of the site developed in the 2007/2009/2015 HRAs through incorporation of monitoring data up to March 2023. Where appropriate, the details in this section are drawn from the previous HRA's.

2.2 Site History and Design

The site is divided into 3 areas (Areas 1, 2 and 3).

- Area 1 comprises the main elements of the site infrastructure (disused pulveriser building, site offices, weighbridge, and storage bays) and an AD facility. Area 1 has not been subject to waste disposal.
- Area 2 received waste between 1986 and 2000 and is closed and capped. It was operated on the principle of "dilute and disperse" and has no engineered containment.
- Area 3 has been developed with engineered containment and leachate management facilities. The periods of filling in Area 3 were as follows:
  - Cell 1: filled between January 2009 and end of 2009;
  - Cell 2: filled between January 2010 and March 2011; and
  - Cell 3: filled between March 2011 and March 2012.

The engineered system in Area 3 cells comprises a Landfill Regulations-compliant composite liner on the base and sides consisting of a 2 mm HDPE geomembrane (artificial sealing layer) and a 0.5 m thick artificially established geological barrier of bentonite enhanced sands (BES). The cells were capped with a 1 mm Linear Low Density Polyethylene (LLDPE) double textured geomembrane overlain by a 300 mm thick drainage layer and a 1 m thick restoration soil layer. The site layout is shown on Figure 2.1.

2.3 Leachate Levels

EP Compliance Levels

The EP sets out a compliance limit for leachate levels of 1.5 m above the base of each cell in Area 3.

Leachate Management

Leachate extraction is carried out in Area 3 to manage leachate levels. The extracted leachate is stored on-site in the leachate collection tank prior to removal off-site by tanker for disposal. The leachate volume exported off-site was 976 m^3 in 2015, 958 m^3 in 2016, 812 m^3 in 2017, 702 m^3 in 2018, 648 m^3 in 2019, 852 m^3 in 2020, 516 m^3 in 2021 and 522 m^3 in 2022.

Leachate Level Data

The EP sets a requirement for monthly leachate level monitoring in Area 3 during the operational phase reducing to quarterly after the site entered definitive closure on 18th July 2014. Time-series plots of leachate levels for the period August 2015 to March 2023 (quarterly data) between are presented in Appendix A. Locations and details of the leachate monitoring wells/sumps are provided on Figure 2.1 together with the leachate levels across the site in January 2023.

The data show lower levels and dry conditions are generally recorded in Cell 1 than elsewhere. The EP limit was not exceeded at the site between August 2015 and March 2023. This suggests that the leachate extraction system is effective in controlling leachate levels and that the on-site leachate storage capacity is sufficient to ensure leachate level compliance in Area 3.

2.4 Leachate Quality

The leachate quality monitoring frequency in Area 3 was reduced from quarterly to six-monthly after the site entered definitive closure on 18 July 2014. Up to February 2013, leachate samples were generally taken from the leachate collection tank, with the cell source identified. From March 2013 onwards, samples of leachate have been collected individually from each of the three cells.

The monitoring locations are shown on Figure 2.1. Concentrations of ammoniacal-nitrogen and chloride (typical landfill leachate indicators) in leachate with time since August 2015 are presented in Appendix B. The data are summarised in Table 2.1 and show that:

- Leachate composition is within the range of compositions seen at other landfill sites receiving domestic and industrial wastes (as indicated by LandSim model default concentrations); and
- Chloride and ammoniacal-nitrogen concentrations have shown an overall downwards trend since 2013, however there have been several spikes in concentration between May 2016 to November 2019.

An extended analytical suite comprising hazardous organic substances was carried out on leachate from Area 3 in accordance with the EP in May 2016, May 2017, May 2018, May 2019, June 2020, May 2021 and May 2022. The results are summarised in Appendix B. The majority of determinands were below the laboratory detection limits (<0.000002 for pesticides to <0.1 mg/l for hydrocarbon bands). Substances recorded above the detection limits in the leachate included pesticides (mainly as mecoprop), extractable hydrocarbon bands (in particular EC10-EC16) and BTEX (mainly as toluene and xylene).

Table 2.1 Selected Leachate Quality Data for Llwyn Isaf Landfill Area 3

Substance	Concentrations January 2016 – November 2022 (mg/l)					LandSim Defaults (mg/l)			Water Quality Standard (mg/l)
	No	No >dl	Min	Mean	Max	Min	Mean	Max	
Ammoniacal Nitrogen	15	0	212	1131	2490	4	723	3640	0.39 (DWS)
Chloride	15	0	309	1325	2590	37	2270	7760	250 (DWS)
Zinc	7	1	<0.018	0.784	3.780	0.00225	0.165	208	5 (DWS)
Cadmium	15	11	0.001	0.001	0.004	0.0019	0.0101	0.105	0.0001 (MRV)

Substance	Concentrations January 2016 – November 2022 (mg/l)					LandSim Defaults (mg/l)			Water Quality Standard (mg/l)
	No	No >dl	Min	Mean	Max	Min	Mean	Max	
Mercury	6	6	-	-	-	0.0004	0.00009	0.00195	0.00001 (MRV)
Mecoprop	12	0	0.003	0.034	0.088	-	-	-	0.00004 (MRV) 0.0001 (DWS)

Notes: No- total number of samples; No>dl- number of samples above detection limit.
DWS- drinking water standard. MRV- minimum reporting value.

2.5 Geology Update

The geology at the site was described in detail in the 2007 HRA and was updated in the 2015 HRA with additional borehole information. In summary, the geology comprises a variable thickness of re-worked silty sand and gravel (made ground) 2 to 7 m thick underlain by vertically and laterally variable in composition Glacial sand and gravel deposits (10 to 20 m thick). The sand and gravel deposits are underlain by Boulder Clay (Glacial Till), which is in turn underlain by the Ordovician Arenig-Llandeilo Formation, comprising slate, sandstone and siltstone bedrock. The site boreholes did not prove the thickness of the Glacial Till and indicate that the upper surface slopes beneath the site at the southern site boundary towards the north and east.

No new boreholes have been commissioned at the site since the 2015 HRA.

2.6 Groundwater Level Update

Groundwater levels are monitored monthly at several boreholes around the site in accordance with the EP for Area 3 and former WML for Area 2. Boreholes M19, M20, M21 and M22 (under former WML for Area 2) have not been monitored since 2020 due to access issues which are currently being addressed. Monitoring data for the period August 2015 to February 2023 are plotted as hydrographs in Appendix D. Borehole details and groundwater level data for December 2022 and February 2023 are presented in Table 2.2. The data show that:

- The water table fluctuates within a range of around 1.5 to 3.0 m annually with higher levels recorded in winter compared to summer. Boreholes M19, M20, M21, M22 and DAS tend to show a lesser degree of fluctuation than other boreholes.
- The highest groundwater levels are recorded to the south of the site from where groundwater levels generally fall northwards towards Afon Desach. This is consistent with the previous HRAs. Groundwater level contour plots have been constructed for December 2022 data using the contouring software Surfer vs12 and are shown on Figure 2.1.
- Groundwater levels are below the base of Area 3 except for borehole DAS. This borehole is located within waste of Area 2 suggesting that levels are likely to represent perched leachate within the waste. This is supported by the poor water quality measured at this borehole.
- Between 2008 and 2015 there was a general downward trend in groundwater levels and a corresponding increase in thickness of the unsaturated zone at some downgradient locations (GW3, GW4 and M18). This is most likely associated with

reduced recharge to the sand and gravel aquifer due to periods of lower rainfall and the progressive engineering of Area 3 with a low permeability engineered liner and cap. Since 2015 groundwater levels stabilised once engineering of Area 3 was finished.

Table 2.2 Representative Recent Groundwater Level Data for Llwyn Isaf Landfill

Borehole	Borehole Datum	Groundwater Level December 2022/ February 2023	
	m AOD	m bgl	m AOD
BH1	132.64	6.7 / 6.3	125.94 / 126.34
GW3	134.42	6.25 / -	128.17 / -
GW4	138.07	9.72 / -	128.35 / -
GW5	134.21	-	-
M17	129.29	-	-
M10	134.91	9.04 / 8.6	125.87 / 126.31
M18	132.5	4.22 / 4.1	128.28 / 128.4
M19	127.41	Not monitored due to access issues	
M20	128.77	Not monitored due to access issues	
M21	130.98	Not monitored due to access issues	
M22	127.33	Not monitored due to access issues	
M31	128.9	5.05 / 4.9	123.85 / 124
M33	134.16	7.36 / 7.25	126.8 / 126.91
M34	131.18	5.68 / 5.42	125.5 / 125.76
M35	127.62	6.08 / 2.66	121.54 / 124.96
M36	138.29	8.6 / -	129.69 / -
M47	139.2	-	-
DAS	140.68	-	-

- Indicates no monitoring data available

2.7 Groundwater Quality Update

EP Compliance Limits

The 2015 HRA included proposals for revised groundwater compliance limits which were submitted to NRW on 19 October 2015 in accordance with the requirements of Condition 4.2.2 of the EP. The proposed compliance limits were approved by NRW and incorporated as an EP Variation (EPR/YP3138UJ/V007 dated 22nd February 2016).

The current EP groundwater compliance limits for Area 3 are summarised in Table 2.3. There are no compliance limits for Area 2.

Table 2.3 Current EP Groundwater Compliance Limits for Area 3

Borehole	Ammoniacal Nitrogen (mg/l)	Chloride (mg/l)	Zinc (mg/l)	Mercury (mg/l)	Mecoprop (mg/l)	Toluene (mg/l)
GW3	0.54	21	0.133	0.0001	0.00004	0.003
GW4	0.48	21	0.156	0.0001	0.00004	0.003
M36	0.49	22	0.094	0.0001	0.00004	0.003

Note: The EP does not specify if it is total or dissolved mercury.

Groundwater Quality Data

Groundwater quality at the site has been monitored at several locations since April 2008 and is currently monitored on a six-monthly basis. Between April 2008 and April 2009, samples were monitored on a monthly basis. This was reduced to quarterly sampling in 2009 and further reduced to 6-monthly following definitive closure of the site in July 2014. Some of these locations fall under the requirements of the EP for Area 3 and others under the requirements of the former WML for Area 2. Boreholes M19, M20, M21 and M22 (under former WML for Area 2) have not been monitored since 2020 due to access issues which are currently being addressed. Time-series plots for ammoniacal-nitrogen and chloride (key leachate contaminants) from August 2015 to February 2023 are provided in Appendix E. The data are summarised in Table 2.4 and compared to current EP compliance limits below. The analysis shows that:

- Ammoniacal-nitrogen and chloride: Baseline (boreholes upgradient of Area 2 - GW2, GW5 and M47):
  - Borehole GW2 has been dry since the start of sampling in 2008. Ammoniacal-nitrogen concentrations in boreholes GW5 and M47 were below detection limit (0.41 mg/l) in all samples. Chloride concentrations were low (<20 mg/l) and show no upward trend.
- Ammoniacal-nitrogen and chloride: Boreholes downgradient of Area 3 (GW3, GW4, M17, M18 and M36):
  - Concentrations of ammoniacal nitrogen and chloride have been low and most ammoniacal nitrogen concentrations were below detection limit.
  - EP compliance limits for chloride and ammoniacal-nitrogen have not been exceeded except for isolated peaks at boreholes GW4 and M36. There have been 2 ammoniacal nitrogen exceedances at GW4 (1.61 mg/l and 3.89 mg/l) and one at M36 (1.42 mg/l). Between August 2015 and March 2023, chloride exceedances only occurred in January 2016, just before the compliance limits were raised. These exceedances were only marginal and for GW3 and GW4 were below the new compliance limit.
- Ammoniacal-nitrogen and chloride: Borehole lateral to groundwater flow (DAS):
  - Prior to 2015, ammoniacal nitrogen and chloride concentrations were generally elevated and variable compared to other boreholes at the site reaching a peak value of 183 mg/l in May 2010. Since August 2015, concentrations have remained low, with 60% of ammoniacal nitrogen samples below detection limit.

- Ammoniacal-nitrogen and chloride: Boreholes downgradient of Areas 2 and 3 (M13, M19, M20, M21, M22, M30, M31, M34 and M35):
  - Ammoniacal nitrogen concentrations were generally below or close to detection limit except for boreholes M20, M21 and isolated spikes at BH1 and M35. Chloride concentrations were within baseline quality except for boreholes M20 and M21, where chloride was slightly elevated but showed a downwards trend between 2017 and May 2019. Since May 2019, these boreholes have not been monitored due to access issues before reinstatement in in March 2023. The slightly elevated concentrations above baseline quality prior to 2019 are likely to reflect some impact from the unlined landfill Area 2.
- Ammoniacal-nitrogen and chloride: Boreholes within Area 2 boundary (M10 and M33):
  - Chloride and ammoniacal-nitrogen were within baseline quality and showed no upward trend.
- Zinc: concentrations showed some variability before 2012 but have since remained below detection limit (<0.00018 mg/l) across the site, except for isolated spikes at GW5 and borehole DAS which appears to be located within Area 2 waste. The EP compliance limits for zinc have not been exceeded.
- Mecoprop: concentrations were generally below detection limit (<0.00004 mg/l) except for isolated spikes. Mecoprop at borehole DAS was mostly below detection limit but has been detected on a few occasions which is most likely to be the result of the borehole being located within waste deposits. However, concentrations remained low (<0.00004-0.00012-0.00033 mg/l as min-mean-max) and the EP compliance limits for mecoprop have not been exceeded.
- Mercury: total concentrations have occasionally exceeded the EP compliance limits. A review of mercury total/dissolved groundwater concentrations by Amec Foster Wheeler (2013) recommended that the compliance limit refers specifically to the dissolved (most mobile) form of mercury as this is the most relevant for assessing the risks to controlled waters. Dissolved mercury concentrations measured since July 2015 have generally been below detection limit (0.000015 mg/l) and below the EP limit.
- Toluene: concentrations remained below detection limits (<0.001 mg/l) until November 2019, when exceedances of the EP compliance limits were recorded at M36 (0.0123 mg/l in November 2019, 0.0056 mg/l in December 2020 and 0.0046 mg/l in March 2022). Concentrations were also recorded above detection limit at M17 in 2022 (0.0015 mg/l).

Table 2.4 Selected Groundwater Quality Data for Llwyn Isaf Landfill (August 2015 to February 2023)

Borehole	Ammoniacal-Nitrogen (mg/l)				Chloride (mg/l)			
	No	Min	Mean	Max	No	Min	Mean	Max
Upgradient								
M47	15	14	0.41	0.414	0.47	15	0	7.3
GW2	Dry							
GW5	15	15				15	0	6.9
Downgradient of Area 3								
GW3	16	16				15	0	9.4
M36	17	16	0.41	0.47	1.42	15	0	10.7
M17	15	15				15	0	15.1
GW4	16	14	0.41	0.70	3.89	15	0	9.9
M18	88	88				88	0	3.5
Lateral to groundwater flow (within Area 2 waste)								
DAS	15	9	0.41	1.07	4.82	15	0	4.8
Downgradient of Areas 2 and 3								
BH1	89	87	0.06	0.43	3.84	86	0	1.1
M13	Borehole removed August 2012							
M19*	46	44	0.27	0.42	0.8	46	0	6.7
M20*	41	0	0.54	4.09	8.11	46	0	7.9
M21*	34	11	0.41	0.61	2.84	34	0	15.2
M22*	44	32	0.40	0.49	1.88	44	0	12.4
M31	89	82	0.06	0.40	0.93	89	0	2.0
M34	87	86	0.06	0.39	0.53	87	0	2.6
M35	88	83	0.06	0.49	7.68	86	0	0.9

Within Area 2								
M10	88	81	0.08	0.45	1.78	86	0	3.1
M33	83	80	0.06	0.39	1.06	81	0	3.7

Notes: Data for August 2015 to February 2023. *Boreholes M19, M20, M21 and M22 were not monitored between May 2019 and February 2023 due to access issues. M19, M20 and M21 were reinstated in March 2023.

Analysis for an extended analytical suite for hazardous substances in groundwater was carried out at boreholes GW3, GW4, GW5, M17, M36, M47 and DAS in November 2016, May 2017, May 2018, May 2019, June 2020 and May 2022 BTEX compounds were also analysed on an annual basis. The results are summarised in Appendix E and show that most substances were not found above laboratory detection limits (<0.000002 mg/l for pesticides to <0.01 mg/l for hydrocarbon bands). The substances detected were generally present at low concentrations, in a small number of samples and both up and downgradient of the site (e.g. BTEX <0.001-0.0015 mg/l). Borehole DAS, which is likely to monitor perched leachate within Area 2, is the only point where mecoprop has been recorded above its detection limit at concentrations of 0.000019 to 0.00034 mg/l).

2.8 Surface Water Quality Update

EP Water Emission Limits

The EP originally set emission limits for a downstream location in the Afon Desach (location E) and the discharge from the surface water attenuation lagoon into the Afon Desach (location D). These locations are shown on Figure 2.1. Emission limits were set for pH (6.0-9.0), ammoniacal-nitrogen (<0.25 mg/l), dissolved oxygen (DO >80%), and biochemical oxygen demand (BOD <2.5 mg/l). The limits for location E were removed and those for location D were modified by an EP variation in September 2011 to: pH (6.0-9.0), ammoniacal-nitrogen (<0.3 mg/l), dissolved oxygen (DO >80%), suspended solids (<25 mg/l) and biochemical oxygen demand (BOD <4 mg/l).

Hydrology

The main watercourse in the vicinity of the site is the Afon Desach, the headwaters of which are located approximately 0.2 km to the east. Site visits and survey details undertaken previously showed that drainage in this watercourse and associated marshy areas and ponds is northwards and that the site lies within the catchment of the Afon Desach.

The groundwater level contour plot and the water elevation (128.67 m AOD) of the pond/marsh connected to the Afon Desach, about 0.15 km east of the site (Figure 2.1), indicate that the Afon Desach is likely to receive some baseflow from the sand and gravel aquifer at this location. The north-south cross section (Figure 2.2) indicates that the lake and tributary of the Afon Desach to the north of the site are perched above groundwater and unlikely to receive baseflow from the aquifer.

Site Drainage

Surface water drainage was reconfigured at the site during 2012 (Figure 2.1). Previously, surface water runoff from the site flowed into two soakaways which were formerly monitored monthly at locations SS and NS (Figure 2.1) in accordance with the EP requirements. The new surface water management system comprises drainage pipework and an interceptor connected to an attenuation lagoon which discharges into the Afon Desach at sample point D. Surface water collected from Area 3 drains to both the attenuation lagoon and the infiltration basin (soakaway located to the east of the site boundary). Most of Area 2 drains to the attenuation lagoon with the exception of the

northernmost part which drains to the soakaway NS. Soakaway SS was decommissioned during the development of the AD facility and replaced by the infiltration basin sampling location.

Surface Water Quality Data

Surface water quality was monitored at a monthly frequency during the operational phase for key determinands with an extended suite analysed at a quarterly frequency. When the site entered definitive closure on 18 July 2014 the monitoring frequency reduced to six monthly for key determinands and annually for the extended suite.

From 13th January 2023, NRW agreed to reduce both the point source emission sampling for surface water discharge (SWD Discharge) from every 2 months to quarterly (Appendix H).

Monitoring is undertaken at the following locations (Figure 2.1):

- Sample point B, which is located to the north of the site on a small tributary which feeds into the Afon Desach;
- Sample point C is located to the north east of the site in the Afon Desach and is the downstream sample point (approximately 330 m downstream of Area 3);
- Sample point D is the permitted discharge from the new surface water attenuation lagoon into the Afon Desach. Sampling commenced in September 2012 following commissioning of the attenuation lagoon;
- Sample point D2 is located in a lake to the north of the site;
- Sample point E is located approximately 300 m downstream from sample point C on Afon Desach (off the site plan Figure 2.1);
- Sample point W is located to the east of the site on the Afon Desach downgradient of the infiltration basin;
- Sample point Y is situated to the south east of the site in Afon Desach and is the upstream sample point;
- Infiltration basin is located to the east of the site and replaces the soakaway SS. Monitoring commenced in November 2012; and
- Soakaways NS and SS are located to the north of Area 3 and collect surface runoff. Soakaway SS was decommissioned in 2012.

Time series plots for ammoniacal-nitrogen and chloride (typical leachate indicators) since July 2015 are provided in Appendix F. Comparison of laboratory and on-site measurements of dissolved oxygen (DO) undertaken in May/June 2010 indicated that this parameter is sensitive to delays between sample collection and testing with lower levels recorded in the laboratory suggesting that degassing is occurring within the sampling vial prior to testing in the laboratory. DO measurements have since been undertaken on-site with a DO probe for the purposes of assessing compliance with the EP emission limits for locations D and E (Amec Foster Wheeler, 2010).

The monitoring data from July 2015 are summarised in Table 2.5 and show:

- <u>Afon Desach (locations B, C, E, Y and W):</u>
  - Concentrations upstream (location Y) and downstream (locations W, C and E) of the site and in the tributary (location B) were similar indicating no impact from Area 3.

- There was a peak in chloride concentrations at location C in November 2020 (101 mg/l). No other peaks in chloride or ammonicala nitrogen have been recorded at the Afon Desach locations.

- Lake (location D2): ammoniacal-nitrogen concentrations were variable with seasonal peaks (0.99 to 2 mg/l). Prior to 2015, these peaks occurred in February/March but more recently the peaks typically occur in November and appear to be showing a downwards trend. Seasonal peaks were not observed in 2015, 2016, 2018 and 2019. Chloride concentrations were between 12 and 30 mg/l but show no apparent seasonal variation.
- Discharge point (location D): no exceedance of the EP emission limits. In recent years suspended solids have shown less variability and have remained below 15 mg/l in all but one sample since July 2015 (17 mg/l recorded in May 2017).
- Infiltration basin: ammoniacal-nitrogen concentrations were generally below detection limit (<0.06 mg/l) and chloride concentrations were low (less than 15 mg/l) and show no upward trend. The data show no impact from Area 3.
- Soakaway NS: ammoniacal-nitrogen was generally below detection limit (various ranging from 0.06 mg/l) and chloride concentrations were less than 20 mg/l except for isolated peaks and show no upward trend. The data show no impact from Area 3.

In summary, the data show no discernible impact from Area 3 at the site's soakaways and infiltration basin and off-site in the Afon Desach.

Table 2.5 Selected Surface Water Quality Data for Llwyn Isaf Landfill

Sample Point	pH			Ammoniacal Nitrogen (mg/l)			Chloride (mg/l)			Dissolved Oxygen (mg/l)			Suspended Solids (mg/l)			Biological Oxygen Demand (mg/l)		
	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max
B	7.0	7.3	7.5	<0.06	0.06	0.06	7.3	9.4	12.0	<0.5	8.2	11.1	-	-	-	<1	1.0	1.0
C	7.3	9.4	12.0	<0.06	0.06	0.06	7.2	15.7	101.0	1.2	8.16	12.3	-	-	-	<1	1.3	4.0
D	7.0	7.8	8.8	<0.06	0.06	0.06	10.3	13.3	17.1	1.7 [55%]	8.83 [80%]	14.3 [93%]	1	3.8	17	<1	1.6	7.0
D2	7.4	7.8	8.1	<0.06	0.53	1.99	12.8	20.6	28.2	2.4	5.5	10.6	-	-	-	<1	2.6	11.0
E	7.1	7.6	7.9	<0.06	0.06	0.06	8.1	11.4	14.3	<0.5	7.6	11.4	-	-	-	<1	1.1	2.0
W	6.8	7.3	7.9	<0.06	0.06	0.07	6.3	9.7	13.2	2.9	7.94	12	-	-	-	<1	1.1	2.0
Y	6.7	7.3	7.7	<0.06	0.06	0.09	5.6	9.1	12.6	2	8.4	13.9	-	-	-	<1	1.0	1
Infiltration basin	7.5	7.8	8.2	<0.06	0.06	0.09	4.2	7.2	10.3	7.2	9.4	13.7						
NS	6.9	7.5	8.6	<0.06	0.08	0.41	3.7	8.6	32.4	0.5	7.7	12.6						
Emission Limits for sampling point D	6.0-9.0			0.3			-			80%			25			4		

Notes: Data for July 2015 to February 2023. Six-monthly monitoring for sample points B, C, D2, E, W and Y and monitoring every two months for sample point D after 18 July 2014 (definitive closure). Last monitoring round was November for sample points B, C, D2, E, W and Y and February for sample point D.
n.m.- not monitored under EP requirements.
Dissolved oxygen measurements in % as measured at the site are also presented for sample point D.

2.9 Groundwater and Surface Water Abstractions Update

Natural Resources Wales (NRW) have confirmed that there are no licensed surface water abstractions within 3 km of the site. The Environmental Health Officer of Gwynedd Council provided information on private water abstractions within 3 km of the site which are summarised in Table 2.6 and shown on Figure 1.1. Most private water abstractions are located upgradient or cross-gradient from the site and are therefore not considered to be at risk from it. The abstractions downgradient of the site are potential receptors and the closest is located approximately 1.1 km northeast.

Table 2.6 Private Water Abstractions in the Vicinity of Llwyn Isaf Landfill

NGR	Holder	Distance from Site Boundary (km)
SH 45202 48693	Mr Matt Swanbrick	0.03 – at southern boundary
SH 44499 47650	Unknown	1.1 to SW
SH 45958 50125	Unknown	1.3 to NE
SH 45958 50125	Unknown	1.3 to NE
SH 45958 50125	Unknown	1.3 to NE
SH 45958 50125	Mrs Heulwen Roberts	1.3 to NE
SH 46710 49345	Unknown	1.5 to NE
SH 44127 50331	Unknown	1.6 to NW
SH 47264 49211	Unknown	2 to E
SH 47264 49211	Unknown	2 to E
SH 47264 49211	Unknown	2 to E
SH 47264 49211	Unknown	2 to E
SH 42895 48934	Unknown	2.1 to W
SH 42895 48934	Unknown	2.1 to W
SH 42895 48934	Unknown	2.1 to W
SH 42895 48934	Unknown	2.1 to W
SH 42895 48934	Unknown	2.1 to W
SH 42895 48934	Richard Williams	2.1 to W
SH 42895 48934	Unknown	2.1 to W
SH 43116 49794	Unknown	2.1 to NW
SH 43116 49794	Unknown	2.1 to NW
SH 43116 49794	Unknown	2.1 to NW

NGR	Holder	Distance from Site Boundary (km)
SH 43116 49794	Unknown	2.1 to NW
SH 43116 49794	Unknown	2.1 to NW
SH 43116 49794	Unknown	2.1 to NW
SH 43116 49794	Unknown	2.1 to NW
SH 43471 50596	Unknown	2.2 to NW
SH 43471 50596	Unknown	2.2 to NW
SH 47571 48519	Unknown	2.3 to E
SH 47571 48519	Unknown	2.3 to E
SH 47571 48519	Unknown	2.3 to E
SH 47571 48519	Unknown	2.3 to E
SH 47322 50081	Unknown	2.3 to NE
SH 44446 51426	Unknown	2.5 to N
SH 44446 51426	Unknown	2.5 to NE
SH 46285 51805	Mr & Mrs Jones	2.9 to N
SH 46285 51805	Mr Michael Hallam	2.9 to NE

2.10 Site Hydrogeological Conceptual Model

The conceptual model for Area 3 of the site developed in the 2007 HRA and reviewed in the 2009 and 2015 HRAs has been updated using monitoring data up to March 2023 (summarised in Sections 2.3 to 2.8) and is summarised in Table 2.7.

Table 2.7 Updated Hydrogeological Conceptual Model for Area 3 of Llwyn Isaf Landfill

Source	Potential Pathways	Potential Receptors
Leachate derived from non-hazardous waste	Leakage through the engineered liner Migration through underlying unsaturated sands and gravels Lateral migration northwards within the sand and gravel aquifer	Groundwater within the sand and gravel deposits Local private water supplies downgradient of the site Local streams supported by baseflow

Source

The source at the site is landfill leachate, which typically comprises a complex range of contaminants. No leachate quality data was available for the 2007 HRA as it supported the EP application for a new non-hazardous landfill. However, a limited number of contaminants (Table 2.8) were selected for the 2007 HRA as representative of the range of substances which are typically present in leachate derived from non-hazardous waste (household, commercial and industrial wastes). The assumed contaminant concentrations were based on: (i) leachate quality data at the nearby Ffridd Rasus Landfill (NGR SH 577 338), which received pulverised wastes as was proposed at Llwyn Isaf, or where not available, (ii) the EA's LandSim model default or literature values. The 2007 HRA modelled a maximum leachate level at the site of 1.5 m above base consistent with the proposed leachate compliance level.

Table 2.8 Comparison of Leachate Data Modelled in 2007 and 2015 HRAs with Leachate Monitoring Data Area 3

Parameters Modelled		Parameter Values Modelled in 2007 and 2015 HRAs (mg/l) [a]			Parameter Values in August 2015 to March 2023 (mg/l) [b]			
Contaminant	**Type**	**Min**	**Mean**	**Max**	**Min**	**Mean**	**Max**	**No**
Ammoniacal-nitrogen	Non-hazardous inorganic pollutant, retarded	1.2 (0.5)	655 (196)	1510 (605)	**162**	**858**	**2490**	45
Chloride	Non-hazardous inorganic pollutant, conservative	235 (14)	970 (420)	1950 (3735)	**242**	**1062**	**2760**	15
Zinc	Non-hazardous metal, retarded	0.00113 (0.00003)	0.122 (0.105)	0.3 (0.91)	<0.018	**0.628**	**3.780**	7 (1 BDL [c])
Mecoprop	Non-hazardous organic, poorly retarded	0.00106 (-)	0.0222 (0.01)	0.06 (-)	**0.003**	**0.038**	**0.292**	12
Mercury	Hazardous metal, retarded	0.00005 (0.0000394)	0.000073 (0.0000891)	0.00013 (0.00195)	<0.0001		<0.0002	6 (All BDL)
Toluene	Hazardous organic, retarded	0.004 (not modelled)	0.103 (not modelled)	1.47 (not modelled)	<0.0001	0.007	0.041	12 (1 BDL)
Leachate Head (m above base)	-	0.75	-	1.5	0	0.57	1.46	

Notes: a) Parameter values modelled in the 2007 HRA that differ from those modelled in the 2015 HRA are shown in brackets and red text.
b) Cells in bold indicate increase from 2015 HRA assumptions.
c) BDL= below detection limit

Comparison of leachate monitoring data with the 2007 and 2015 HRAs' modelled parameters (Table 2.8 and Section 2.4) indicates that:

- Leachate levels have remained within the range previously modelled;
- Ammoniacal-nitrogen leachate concentrations exceed the range previously modelled by a factor of approximately 1.5 following an increase in ammoniacal-nitrogen concentrations between 2016 and 2019;
- Chloride maximum leachate concentrations exceed the range previously modelled, but only marginally (the mean value has increased by a factor of 1.09 and the maximum value by a factor of 1.4). Similar to ammoniacal-nitrogen, this follows high concentrations between 2016 and 2019;
- Zinc leachate concentrations exceed the range previously modelled by a factor of approximately 5 to 13;
- Mecoprop exceed the range previously modelled by a factor of approximately 2 to 5;
- Mercury and toluene leachate concentrations are within the range previously modelled; and
- Hazardous substances and non-hazardous pollutants modelled previously remain applicable in light of the leachate monitoring data (summarised in Section 2.4).

In summary, the leachate levels remained within the range modelled in the 2015 HRA but leachate quality exceeded the concentrations assumed in the 2015 HRA for some of the monitored parameters. These are: ammoniacal nitrogen, chloride and zinc, with zinc in particular showing a large increase. This is driven by elevated concentrations in these parameters between 2016 and 2019. Since then, concentrations have fallen, but the cause of these elevated levels is unclear. The risks posed by the higher leachate strength has been assessed in Section 3.

Pathways

There were no alterations to the operation, construction or management of the site proposed in the 2007 and 2015 HRAs. A lining system comprising 0.5 m thickness of BES, HDPE geomembrane and a leachate drainage blanket has been installed in Cells 1 to 3 as modelled in the 2007 HRA. The potential pathways for any contaminants from the landfill continue to be as identified in the 2007 and 2015 HRAs:

- Vertical leakage through the engineered liner;
- Vertical migration through the underlying unsaturated sand and gravel deposits; and
- Lateral migration northwards within the sand and gravel aquifer.

On this basis, it is concluded that the pathways modelled in the 2007 and 2015 HRAs remain valid but the updated unsaturated zone thickness has been re-assessed in Section 3.

Receptors

The key potential receptors to pollution from the site identified in the 2007 HRA comprises the following:

- Groundwater within the sand and gravel deposits (Secondary A aquifer);
- Local private water supplies located downgradient of the site (closest is 1.3 km northeast of the site);

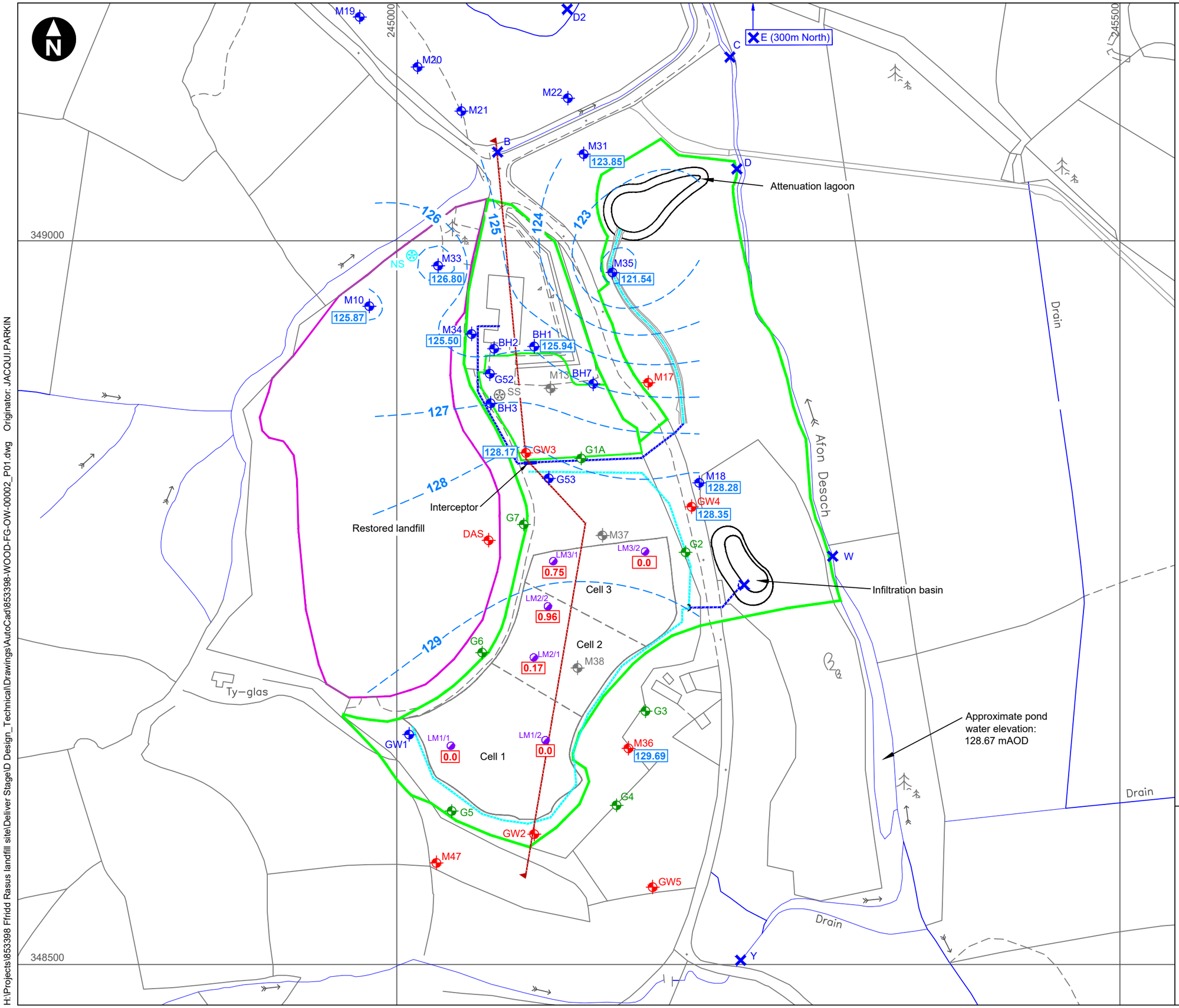
- Local streams supported by baseflow (Afon Desach 0.15 km east of the site as discussed in Section 2.8).

The local groundwater dependant terrestrial ecosystems (Corsydd Eifonydd SAC and Cors Gyfelog SSSI) are not considered to be affected by the site as these are fed by the southward draining watercourse to the southeast (upgradient) of the site and are within the catchment of the Afon Dwyfach.

The receptors modelled in the 2015 HRA are still considered to be appropriate and additional receptors have not been included in the updated conceptual model.

Summary

The site conceptual model is qualitatively unchanged from the 2015 HRA but it is considered appropriate to reassess the risks to receptors to take into account the higher leachate strength than originally assumed for certain parameters.



Key

- Installation boundary
- Groundwater monitoring borehole
- Perimeter landfill gas monitoring borehole
- Groundwater monitoring boreholes required by the Environmental Permit
- Former groundwater borehole
- Surface water quality sampling location
- Leachate monitoring point
- Notional related surface flow
- Approximate extent of closed landfill site (Area 2)
- Surface water drainage pipes
- Surface water drainage ditch
- Proposed surface water drainage ditch
- Full retention class 1 interceptor tank
- Soakaway monitored until August 2012
- Soakaway
- 122.68 — Groundwater level mAOD (December 2022) in Glacial sand and gravel
- Groundwater level contour mAOD (December 2022 in Glacial sand and gravel)
- 0.09 — Leachate level, metres above cell base (January 2023)
- Line of cross section

Note:
Boreholes M19, M20, M21 and M22 were not monitored after May 2019 due to access issues. M19, M20 and M21 were reinstated in March 2023.

0 m — 150 m

Scale 1:2500 @ A3

Llwyn Isaf Landfill - Area 3
Hydrogeological Risk Assessment Review

Figure 2.1
Site layout, leachate levels and groundwater levels

April 2023

SOUTH

NORTH

Cell Boundary

Cell Boundary

Installation Boundary

Small tributary of Afon Desach

Engineered cap

Engineered liner

M47

GW2

M36

M38

M37

GW3

BH1

M13

M31

mAOD

150

145

140

135

130

125

120

115

110

0

100

200

300

400

500

metres

?

?

?

?

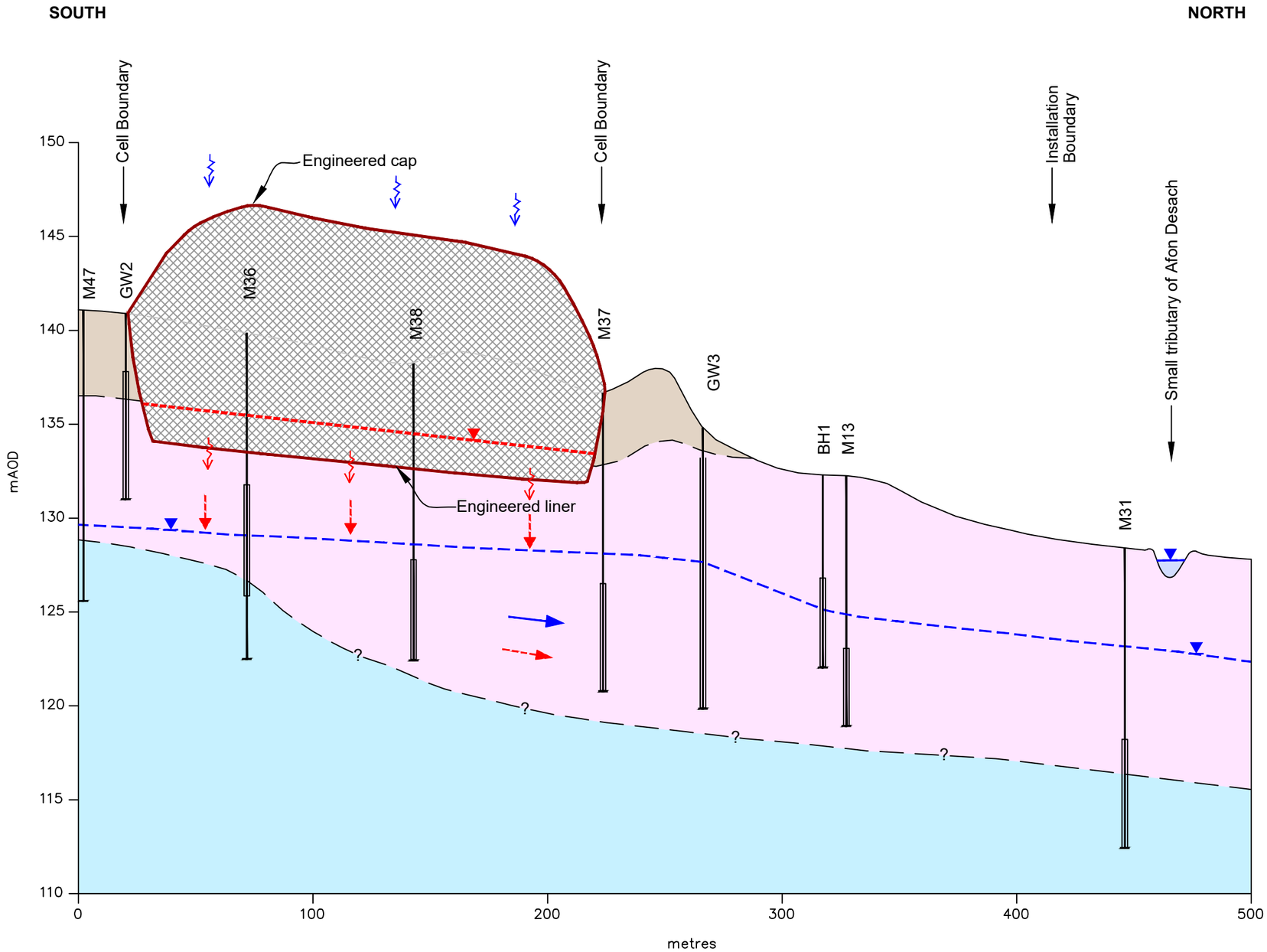
Key

- Waste
- Made Ground
- Glacial sand and gravel, silty near base
- Till
- Water table July 2015 in glacial sand and gravel
- Groundwater flow direction

Llwyn Isaf Landfill - Area 3
Hydrogeological Risk Assessment Review

Figure 2.2
North to South hydrogeological cross section

April 2023



Key

- Waste
- Made Ground
- Glacial sand and gravel, silty near base
- Till
- Water table July 2015 in glacial sand and gravel
- Groundwater flow direction
- EP compliance limit
- Basal leakage
- Contaminant vertical migration
- Contaminant lateral migration
- Rainfall

Llwyn Isaf Landfill - Area 3
Hydrogeological Risk Assessment Review

Figure 2.3
Site conceptual model

April 2023

3. Hydrogeological Risk Assessment Update

3.1 The Nature of the Hydrogeological Risk Assessment

Guidance for HRAs for landfills is given in Environment Agency (EA) (2010). This guidance takes into account the requirements of the Groundwater Directive and the Landfill Directive, as implemented by the Environmental Permitting Regulations 2010 (as amended).

Having developed a conceptual model for the site (Section 2.10), the guidance requires that a risk assessment be undertaken. The level of detail in a risk assessment should be proportionate to the nature and complexity of the risk being addressed, with the three tiers being Risk Screening, Simple Risk Assessment and Complex Risk Assessment. The more sensitive the environmental setting, the greater the level of confidence required. A Complex Risk Assessment is considered appropriate for Llwyn Isaf Landfill as the site is underlain by a Secondary A aquifer (sand and gravel deposits) aquifer which provide baseflow to the Afon Desach.

This section re-assesses the risks to groundwater quality from the site on the basis of the updated site conceptual model presented in Section 2.10.

3.2 Numerical Modelling Approach

Modelling Approach and Software

The 2007 HRA, 2009 partial update and 2015 HRA assessed the risks to groundwater from the site using the EA preferred landfill modelling package LandSim v2.5.17. The risks to groundwater from the increase in leachate strength of chloride, ammoniacal-nitrogen and zinc have been reassessed using the same model.

Model Parameterisation

The input parameters and sources of information for the LandSim model are listed in Appendix I. These are a combination of site-specific data and literature values as discussed in the previous HRAs. Parameters revised as part of this HRA review are noted in italic and include leachate concentrations and thickness of unsaturated zone.

Preliminary model runs undertaken without biodegradation showed time to peak concentrations at the base of the unsaturated zone to be in excess of 230 and 250 years (as 95th percentile) for ammonia and mecoprop, respectively, indicating relatively long travel. These long travel times suggest that there is sufficient time for biodegradation to occur. On this basis, and similar to the 2015 HRA, degradation has been modelled using the longest aerobic half-life values reported for ammonia (6 years) in EA (2003a), for toluene (0.5 year) in EA (2002) and for mecoprop (0.5 years) in EA (2004), Buss et al., (2006) and Howard et al (1991).

Sensitivity analysis

Sensitivity analysis is implicit in the selection of appropriate values for the parameters used in the risk assessment and the use of ranges of values. Where possible values have been checked for internal consistency. Where a choice of parameters was available, then more conservative values

were selected. In addition to this implicit sensitivity analysis, an explicit analysis of the leachate head has been undertaken.

The model base run considered the EP compliance leachate limit (1.5 m above base of cell) as the maximum leachate head. A maximum leachate head of 3 m above base of cell has been modelled to assess any increased risk to the receptors in the event that the leachate level control is temporarily unable to maintain levels below 1.5 m above base.

3.3 Emissions to Groundwater

Emissions to Groundwater: Hazardous Substances

Hazardous substances have not been remodelled in this HRA as leachate concentrations remain within the range modelled in the 2015 HRA (Section 2.4). Therefore, the results of the 2015 HRA, which predict no breakthrough of hazardous substances at the base of the unsaturated zone, remain valid,

Emissions to Groundwater: Non-Hazardous Pollutants

Table 3.3 shows the predicted concentrations of the non-hazardous pollutants ammoniacal-nitrogen, chloride, zinc and mecoprop in the sand and gravel deposits at the downgradient boundary of each cell. Predictions are shown for the 50th percentile (most likely) and 95th percentile (pessimistic assessment) for both the base run and sensitivity run and show that:

- For the EP leachate limit of 1.5 m above base (base run) chloride, ammoniacal-nitrogen, zinc and mecoprop groundwater concentrations at the downgradient edge of the site are not predicted to exceed their drinking water standards (DWS) or baseline concentrations; and
- For an increased leachate level of 3 m above base (sensitivity run) the predicted groundwater concentrations at the downgradient edge of the site are slightly higher than for 1.5 m head but remain below their DWS or baseline concentrations.

Table 3.1 LandSim Results for Base and Sensitivity Run: Non-Hazardous Substances

Substance	Max Groundwater Concentration at Downgradient Site Boundary in mg/l [travel time to downgradient site boundary][a]						DWS (mg/l)[b]	Baseline Quality (mg/l)[c]		
	Cell 1		Cell 2		Cell 3			Min	Mean	Max
	50%ile	95%ile	50%ile	95%ile	50%ile	95%ile				
Run 1 (Base Run)										
Ammoniacal-Nitrogen	0.002 [290]	0.041 [300]	NB	0.0034 [313]	0.0025 [280]	0.040 [277]	0.39	<0.041	0.74	4.82
Chloride	1.8 [144]	14.5 [138]	0.7 [235]	5.8 [154]	0.6 [156]	5.5 [157]	250	4.8	9.45	19.2
Zinc	NB	NB	NB	NB	NB	NB	5	0.018	0.11	0.61
Mecoprop	NB	NB	NB	NB	NB	NB	$1x10^{-4}$	<0.00004	0.00008	0.00033
Run 2 (Sensitivity Run for leachate head 3 m)										
Ammoniacal-Nitrogen	0.002 [282]	0.049 [257]	NB	0.0037 [283]	0.0026 [270]	0.038 [264]	0.39	<0.041	0.74	4.82
Chloride	2.0 [138]	16.0 [136]	0.8 [163]	6.2 [156]	0.7 [151]	5.5 [156]	250	4.8	9.45	19.2
Zinc	NB	NB	NB	NB	NB	NB	5	0.018	0.11	0.61
Mecoprop	NB	NB	NB	NB	NB	NB	$1x10^{-4}$	<0.00004	0.00008	0.00033

Notes: a) Predicted concentrations do not include baseline water quality
b) DWS- drinking water standard
c) Data for August 2015 to November 2022 (as min-mean-max) for upgradient boreholes M47 and GW5. The upgradient borehole GW2 continues to be dry.
NB- no breakthrough $<10^{-6}$ mg/l for mecoprop, $< 10^{-3}$ mg/l for ammoniacal-nitrogen and $<10^{-2}$ mg/l zinc (defined as 2 orders of magnitude below DWS)

3.4 Summary

The site conceptual model is qualitatively unchanged from the 2015 HRA but it has been considered appropriate to reassess the risks to groundwater taking into account the increase in leachate strength for a small number of non-hazardous substances since the 2015 HRA. Similar to the 2015 HRA, the risks to groundwater have been re-assessed using the EA's preferred landfill modelling package LandSim v 2.5.17.

The modelling results for the EP leachate limit of 1.5 m above cell base indicate that there is no breakthrough above DWS of the non-hazardous substances chloride, ammoniacal-nitrogen, zinc and mecoprop. There is, therefore, no predicted impact on groundwater quality from the Area 3 wastes at the downgradient edge of Area 3.

A sensitivity run with an increased leachate head of 3 m above cell base (reflecting potential temporary loss of leachate level control) indicates no additional risks to groundwater.

There is therefore no risk to receptors receiving groundwater baseflow (Afon Desach) and downgradient private water abstractions as a consequence of the operation of Area 3.

4. Requisite Surveillance

4.1 The Risk Based Monitoring Scheme

Under the Environmental Permitting Regulations, appropriate monitoring, or requisite surveillance, of a permitted site must be undertaken, typically consisting of leachate, groundwater and surface water monitoring. An appropriate level of monitoring is required to establish that site management requirements are being met and to provide warning of adverse impacts.

In addition to the monitoring locations and schedules, there are typically requirements for the establishment of control levels and compliance limits for groundwater and surface water quality (for surface water discharges) and leachate levels. These levels are used to ensure that the landfill is performing in line with its design (control levels) and as an indicator for potential impact from leachate and requirement for remedial actions (compliance limits).

4.2 Leachate Monitoring

Monitoring Regime

The leachate monitoring frequency in Area 3 was reviewed and reduced as part of the definitive closure of the site on 18 July 2014. Leachate level monitoring is currently undertaken quarterly and leachate samples are analysed on a six-monthly basis for key determinands, with annual extended analytical suite in accordance with the EP requirements (Table 4.1). Monitoring locations include two per cell for level measurements and one per cell for quality sampling. The current leachate monitoring requirements and the proposed changes are shown in Table 4.1

Table 4.1 Leachate Monitoring Regime for Area 3

Frequency	Monitoring Location	Measurement/determinands
Current monitoring		
Quarterly unless a reduced frequency is agreed in with NRW. Not less than six monthly.	All leachate monitoring points	Level
Six Monthly	All leachate wells /abstraction wells/ sumps identified on drawing ESID 7 of the permit application documents	Electrical conductivity (EC), Cl, NH4-N, pH, mecoprop, toluene, Chemical oxygen demand (COD), Biological oxygen demand (BOD), Ca, Mg, K, Na, Cd, Alk, Total organic carbon (TOC), SO4, total organic nitrogen (TON) and phenol.
Annually	All leachate wells /abstraction wells/ sumps identified on drawing ESID 7 of the permit application documents	As six-monthly plus: Cr, Cu, Fe, Pb, Mn, Ni, Zn and Hazardous substances
Proposed monitoring		

Frequency	Monitoring Location	Measurement/determinands
Six monthly	All leachate monitoring points	Level
Six Monthly	All leachate wells/ abstraction wells/ sumps identified on drawing ESID 7 of the permit application documents	Electrical conductivity (EC), pH, Cl, NH4-N, mecoprop, Zn, Hg, toluene, Chemical oxygen demand (COD) and Biological oxygen demand (BOD)
Annually		As six-monthly plus: Cr, Cu, Fe, Pb, Mn, Ni, Zn and Hazardous substances Ca, Mg, K, Na, Cd, Alk, Total organic carbon (TOC), SO4, total organic nitrogen (TON) and phenol.

It is proposed to reduce the leachate level monitoring frequency from quarterly to six-monthly. It is also proposed that the six-monthly leachate quality monitoring focus on the key substances modelled in the site's HRAs (plus field indicators) with a wider suite monitored annually. These proposals are based on:

- Leachate management infrastructure have maintained leachate levels below EP compliance limit.
- Filling and capping of the site is complete, which reduces the rate of leachate generation. It is therefore expected that leachate management will continue to maintain levels below the EP compliance limit.
- The HRA modelling presented in Section 3 predicts no future impact on water quality.

Compliance Leachate Limit

The HRA modelling presented in Section 3 has shown no impact from Area 3 on groundwater quality for the EP compliance leachate limit of 1.5 m above cell base. In addition, a sensitivity analysis modelling a maximum leachate level of 3 m above base representing temporary loss of leachate level control also showed no impact on groundwater quality. On this basis no changes are proposed to the EP limit.

4.3 Groundwater Monitoring

Monitoring Regime

Guidance published by the EA identifies a minimum requirement for three groundwater monitoring boreholes per groundwater system for a landfill site, comprising one upgradient and two downgradient (EA, 2003b). The monitoring requirements in the EP for Area 3 specifies the following locations:

- Upgradient: M47, GW2 and GW5;
- Lateral to groundwater flow and adjacent to unlined landfill Area 2: DAS (which is more likely to reflect leachate quality as it appears to be drilled in wastes): and
- Downgradient: M17, M36, GW3 and GW4.

In addition, the former WWL for Area 2 specifies groundwater monitoring at a number of boreholes to the north of Area 3 (Table 4.2). The number of monitoring boreholes for Area 3 meets the EA guidance (EA, 2003) requirements and so additional groundwater quality monitoring boreholes are

not recommended. It is noted that water levels and quality monitoring data for borehole DAS (no borehole log available) suggest that this borehole may be drilled within the wastes of Area 2 (Sections 2.6 and 2.7). The borehole should be decommissioned (and replaced, if required) if found to provide a potential vertical pathway for leachate into the aquifer.

The groundwater monitoring frequency in Area 3 was reviewed and reduced for the definitive closure of the site on 18 July 2014. Monitoring is currently undertaken six-monthly for key determinands, with annual extended analytical suite in accordance with the EP requirements (Table 4.2). The current groundwater monitoring requirements and the proposed changes are shown in Table 4.2.

Table 4.2 EP Groundwater Monitoring Requirement for Llwyn Isaf Landfill – Area 3

Frequency	Monitoring Location	Measurement/ Deteminand
Current monitoring – Area 3		
Six Monthly	GW2, GW3, GW4, GW5, M17, M36, M47 and DAS.	Level.
Six Monthly	GW2, GW3, GW4, GW5, M17, M36, M47 and DAS.	EC, DO, Cl, NH_4-N, Hg, Zn, mecoprop Ca, Mg, K, Na, Cd, Alk, TOC, SO_4, TON and phenol.
Annually	GW2, GW3, GW4, GW5, M17, M36, M47 and DAS.	Cr, Cu, Fe, Pb, Mn, Ni, Zn, hazardous substances suite
Proposed monitoring – Area 3		
Six Monthly	GW2, GW3, GW4, GW5, M17, M36, M47 and DAS.	Level.
Six Monthly	GW2, GW3, GW4, GW5, M17, M36, M47 and DAS.	Electrical conductivity (EC), DO, pH, Cl, NH4-N, mecoprop, Zn, Hg and toluene
Annually	GW2, GW3, GW4, GW5, M17, M36, M47 and DAS.	Ca, Mg, K, Na, Cd, Alk, TOC, SO_4, TON, phenol, Cr, Cu, Fe, Pb, Mn, Ni, Zn, hazardous substances suite

Notes: a) BH1 is a replacement for M13, which was lost to due to construction of the AD facility in July 2012.
b) Borehole M31 was reinstated and has been monitored since November 2011.
c) Soakaway SS was decommissioned in August 2012 following the construction of a new surface water drainage system.

It is proposed that the six-monthly groundwater quality monitoring for Area 3 targets the key substances modelled in the site's HRAs (plus field indicators) with the wider analytical suite monitored annually. These proposals are based on:

- Monitoring data shows no evidence of groundwater contamination by leachate from Area 3.
- Filling and capping of the site is complete, which reduces the rate of leachate generation. It is therefore expected that leachate management will continue to maintain levels below the EP compliance limit.
- The HRA modelling presented in Section 3 predicts no future impact on water quality.

Groundwater Control Levels and Compliance Limits

Control levels are intended to draw attention to any adverse or unanticipated trends in groundwater quality monitoring data or groundwater impacts. They are intended to provide an early warning system. They should allow for natural variations in groundwater quality and allow sufficient time for any necessary actions to be taken prior to compliance limits being exceeded. Compliance limits are specific compliance or regulatory standards.

The current EP groundwater compliance limits for Area 3 are summarised in Table 4.3. There are no compliance limits for Area 2. The compliance limits have been reviewed in this HRA using data from July 2015 to March 2023 (see Appendix G):

- Ammoniacal-nitrogen: the EP compliance limits have been exceeded on 2 occasions at GW4 (1.61 mg/l on 21/05/2019 and 3.89 mg/l on 17/11/2022) and on 1 occasion at M36 (1.42 mg/l on 18/06/2020). These are isolated spikes, with nearly all other results remaining below detection limit (<0.41 mg/l). On this basis no changes are proposed to the compliance limits.
- Chloride: EP compliance limits have only been marginally exceeded on one isolated occasion at M36 (22.1 mg/l on 20/01/2016). The compliance limits have not been exceeded at any of the other compliance points. On this basis no changes are proposed to the compliance limits.
- Zinc: the EP compliance limits have not been exceeded. On this basis no changes are proposed to the compliance limits.
- Mercury: as discussed in Section 2.7, the EP does not specify if the compliance limits refer to total or dissolved forms of mercury. Previous assessments (e.g. Amec Foster Wheeler, 2013) recommended that the compliance limit refers specifically to the dissolved (most mobile) form of mercury as this is the most relevant for assessing the risks to controlled waters. Dissolved mercury concentrations measured since July 2015 have generally been below detection limit (0.000015 mg/l) and have not risen above the EP compliance limit of 0.0001 mg/l. However, concentrations equal to the compliance limit have been observed, measured on two occasions at GW4 since January 2020. On this basis no changes are proposed to the compliance limits.
- Mecoprop: the EP compliance limits have not been exceeded in the observed monitoring period. On this basis no changes are proposed to the compliance limits.
- Toluene: Prior to 2015, there were no compliance limits for toluene in the EP. In 2016 a compliance limit of 0.0003 mg/l was brought into effect for GW3, GW4 and M36. The compliance limit has been exceeded on three isolated occasions at M36 but concentrations have otherwise mostly remained below detection limits. On this basis no changes are proposed to the compliance limits.

Table 4.3 Current Groundwater Control Levels and Compliance Limits for Area 3

Substance	GW3		GW4		M36	
	Control Level	Compliance Limit	Control Level	Compliance Limit	Control Level	Compliance Limit
Ammoniacal Nitrogen (mg/l)	0.45	0.54	0.41	0.48	0.42	0.49
Chloride (mg/l)	19	21	19	21	20	22

Substance	GW3		GW4		M36	
	Control Level	Compliance Limit	Control Level	Compliance Limit	Control Level	Compliance Limit
Zinc (mg/l)	0.01	0.133	0.117	0.156	0.07	0.094
Mercury diss (mg/l)	-	0.0001	-	0.0001	-	0.0001
Mecoprop (mg/l)	-	0.00004	-	0.00004	-	0.00004
Toluene (mg/l)	-	0.003	-	0.003	-	0.003

4.4 Surface Water Monitoring

Monitoring Regime

Monitoring of sample point D (discharge from attenuation lagoon) has been recently reduced from every two months to quarterly (Gwynnedd Council letter ref SJF/YB3138UJ dated 05/12/22 and acceptance by NRW, email dated 11/01/23). Surface water monitoring at other locations is currently undertaken on a six-monthly basis for key determinands and annually for the extended suite in accordance with the EP requirements. Monitoring locations include on-site (infiltration lagoon and discharge) and off-site (Afon Desach and lake) locations. Monitoring requirements of the soakaway NS, which collects runoff from Area 2, is summarised in Table 4.2. The current surface water monitoring requirements for Area 3 are shown in Table 4.4. This level of monitoring is considered adequate and no changes are proposed.

Table 4.4 Current Surface Water Monitoring Regime

Frequency	Monitoring Location	Measurement/Determinand
Quarterly	D (discharge from attenuation lagoon)	NH4-N, DO, suspended solids, pH, BOD
Six Monthly	Infiltration Basin	EC, pH, Cl, NH4-N, Cd.
Six Monthly	W and Y (upstream) B, C, D2 and E (downstream) D (discharge from attenuation lagoon)	EC, pH, Alk, Cl, NH4-N, TOC, BOD, COD, DO.
Annually	W and Y (upstream) B, C, D2 and E (downstream) D (discharge from attenuation lagoon)	As six-monthly plus: Ca, Mg, K, Na, SO4, NO3, NO2, TON, Cd, Cu, Fe, Pb, Mn, Ni and Zn.

Surface Water Emission Limits

The EP sets emission limits for the discharge from the attenuation lagoon into the Afon Desach at location D (Table 2.5). The monitoring data indicate compliance with the emission limits and no changes are proposed to these.

5. Conclusions

This report provides an update to the 2007 HRA/2009 and 2015 re-assessments for Area 3 of Llwyn Isaf landfill using monitoring data up to July 2015 in accordance with the EP requirement for four yearly reviews of the HRA (now revised to six-yearly reviews by the Environmental Permitting Regulations 2010). The site conceptual model developed in the previous HRAs is qualitatively unchanged but it was considered appropriate to re-assess the risks to receptors to take into account the higher leachate strength than originally assumed and additional leachate contaminants.

Three leachate parameters from Area 3 (ammoniacal nitrogen, chloride and zinc) were identified as having increased in concentration between 2015 and 2020 and so have the potential to pose a risk to groundwater. These parameters were therefore re-assessed using LandSim. The results for the EP leachate limit of 1.5 m above cell base indicate that there is no breakthrough of these parameters.

A sensitivity run with an increased leachate head of 3 m above cell base (reflecting potential temporary loss of leachate level control) indicates no additional unacceptable risk to groundwater from Area 3.

Area 3 will continue to operate a comprehensive risk-based programme of leachate, surface water and groundwater monitoring and the implementation of compliance limits.

Area 3 is therefore considered to comply with the relevant requirements of the Environmental Permitting Regulations 2010.

6. References

Amec Foster Wheeler, 2013. Llwyn Isaf Landfill – Review of Groundwater Trigger Levels for Mercury. Report ref 28587N745i1.

Amec Foster Wheeler, 2010. Quarterly Environmental Monitoring Report: April to June 2010. Report ref 18846rr845i2.

Amec Foster Wheeler, 2015. Llwyn Isaf Landfill Site Area 3 - Hydrogeological Risk Assessment Review. Entec ref. 18846rr970i2.

Buss, S.R., Thrasher, J., Morgan, P. and Smith, J.W.N. 2006. A review of mecoprop attenuation in the subsurface. Quarterly Journal of Engineering Geology and Hydrogeology. Vol.39, pp. 283-292.

Environment Agency, 2002. The Effects of Contaminant Concentration on the Potential for Natural Attenuation. R&D Technical Report P2-228/TR.

Environment Agency, 2003a. Review of ammonium attenuation in soil and groundwater. Science Report NC/02/49. Environment Agency, Solihull.

Environment Agency, 2003b. Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water. Environment Agency, Solihull.

Environment Agency, 2004 Attenuation of mecoprop in the subsurface. Science Report NC/03/12. Environment Agency, Solihull.

Environment Agency, 2008a. Compilation of Data for Priority. Organic Pollutants for Derivation of Soil Guideline Values. Better regulation science programme, Science report SC050021/SR7. Bristol: Environment Agency.

Environment Agency, 2008b. Water resources in England and Wales - current state and future pressures. Environment Agency, Bristol.

Environment Agency, 2010. H1 - Technical Annex (j): Hydrogeological Risk Assessments for Landfills and the Derivation of Groundwater Control Levels and Compliance Limits. Environment Agency, Bristol, October 2010.

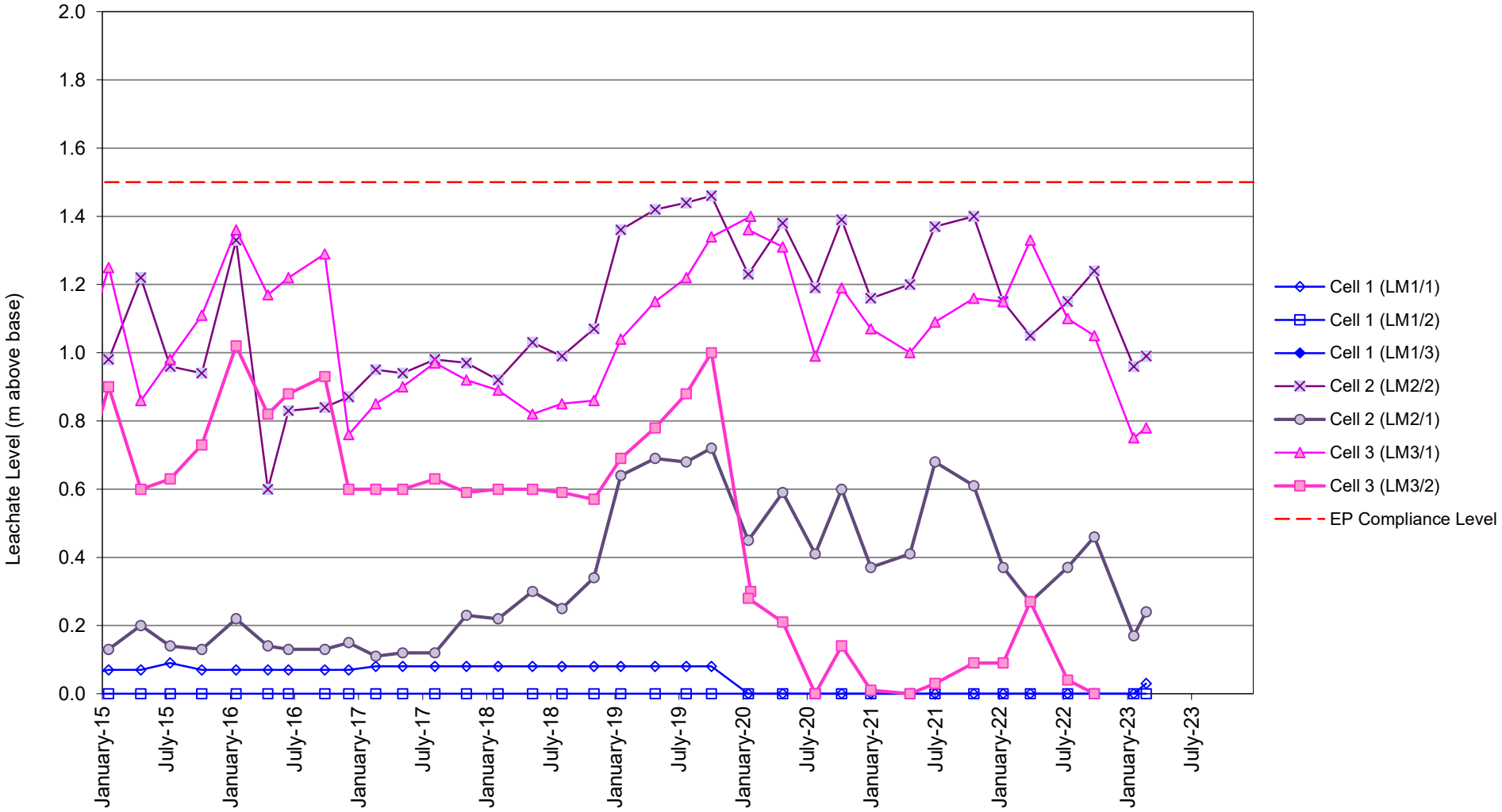
Howard, P.H., Boethling, R.S., Jarvis, W.F., Meylan, W.M. and Michalenko, E.M. 1991. Handbook of Environmental Degradation rates. Lewis Publishers. New York.

Joint Agencies Groundwater Directive Advisory Group (JAGDAG), 2013. Consolidated Response Report for Substance Determinations.

Powrie W and Beaven R P, 1999. Hydraulic Properties of Household Waste and Implications for Landfills. Proceedings of the Institute of Civil Engineers; Geotechnical Engineering, October 1999, pp235-247.

Appendix A
Leachate Level Chart

Llwyn Isaf Landfill: Leachate Levels

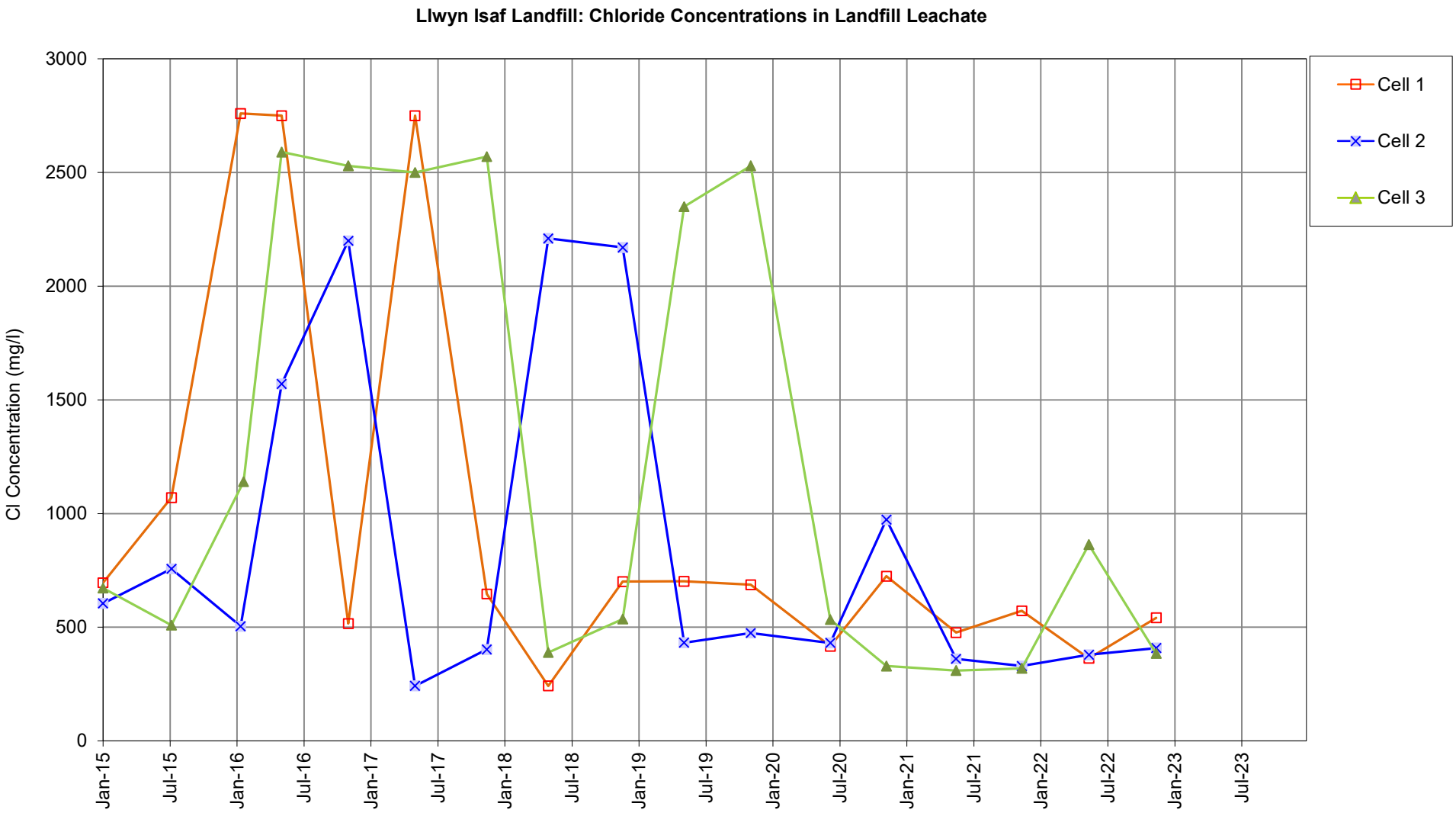


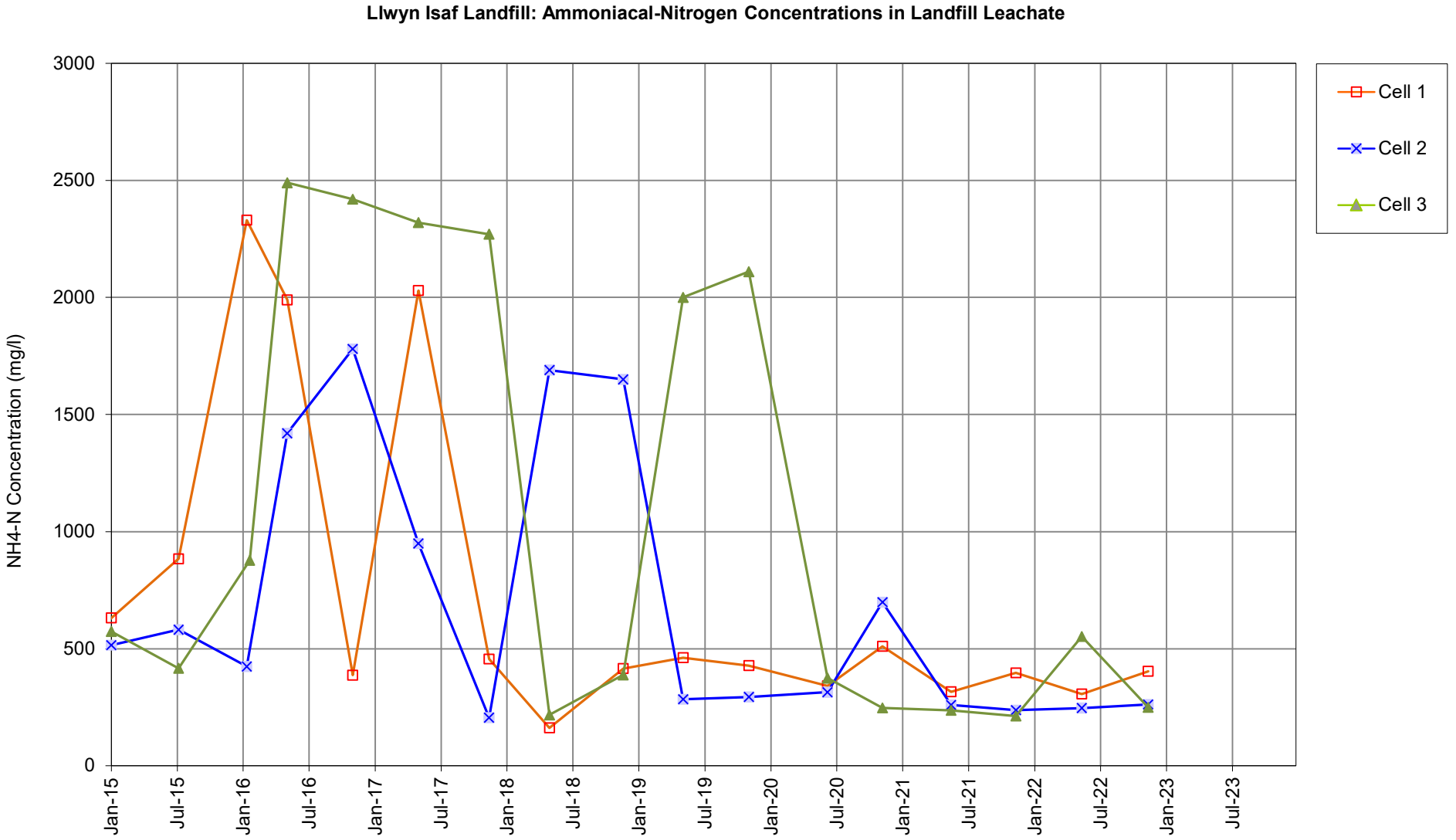
Appendix B
Leachate Quality Charts and Hazardous Suite Results

Table B1 Hazardous organic substances in leachate above detection limit (May 2016 to May 2022)

			Concentration	
	No	No >dl	Min (ug/l)	Max (ug/l)
Pesticides				
Dichloroprop	7	5	0.29	8.11
Mecoprop	7	0	2.59	81.9
Chlopyralid	7	3	0.12	13.4
BTEX				
Benzene	7	4	1.94	2.03
Ethyl benzene	7	6	0.78	0.78
Toluene	7	2	0.46	32.2
M&p-Xylene	5	2	1.1	1.96
o-Xylene	7	4	1.01	1.85
Hydrocarbon Bands				
EH >C6 - C40	7	0	47	2410
EH >C6 - C8	7	7		
EH >C8 - C10	7	4	151	176
EH >C10 - C16	7	0	47	1280
EH >C16 - C24	7	2	24	434
EH >C24 - C40	7	4	196	537
Others				
Cyanide, Total	7	3	0.022	0.054

Note: Annual data except for toluene and mecoprop (six-monthly).


Llwyn Isaf Landfill: Chloride Concentrations in Landfill Leachate
Cl Concentration (mg/l)
3000
2500
2000
1500
1000
500
0
Jan-15
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20
Jul-20
Jan-21
Jul-21
Jan-22
Jul-22
Jan-23
Jul-23
Cell 1
Cell 2
Cell 3


Llwyn Isaf Landfill: Ammoniacal-Nitrogen Concentrations in Landfill Leachate
NH4-N Concentration (mg/l)
3000
2500
2000
1500
1000
500
0
Jan-15
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20
Jul-20
Jan-21
Jul-21
Jan-22
Jul-22
Jan-23
Jul-23
Cell 1
Cell 2
Cell 3

Appendix C
Borehole Logs

BOREHOLE NUMBER BH1

AMEC AMEC E&I

CLIENT Gwynedd Council
PROJECT NAME Llwyn Isaf Landfill
PROJECT NUMBER 28587
CO-ORDINATES X: Y:
DATE STARTED 5/12/11 **COMPLETED** 6/12/11
GROUND ELEVATION 132.64 m **HOLE SIZE** 150mm
DRILLING CONTRACTOR Soil Mechanics
GROUND WATER LEVELS:
DRILLING METHOD Cable Percussion
AT TIME OF DRILLING 1.00 m / Elev 131.64 m
LOGGED BY Simon Howard
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)	ENVIRONMENTAL DATA	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
					0.30 (132.34) MADE GROUND: Tarmacadam surface (broken out).	
					0.60 (132.04) MADE GROUND: Damp bluish-grey fine to coarse angular to subangular slate gravel.	
					Dense brown gravelly SAND. Gravel is fine to very coarse, occasionally cobble-sized, subangular to rounded of mixed lithology including probable sandstone and mudstone. No odour.	
2						
4						
					5.40 (127.24) Wet greenish brown slightly gravelly sandy SILT. Gravel is fine to coarse saubangular to subrounded. No odour.	
6						
					7.20 (125.44) Wet grey/brown gravelly sandy SILT. Gravel is fine to very coarse, occasionally conbble-sized, subangular to rounded. No odour.	
8						
					9.50 (123.14) Wet greyish brown gravelly SAND. Gravel is fine to very coarse, angular to subrounded of mixed lithology. No odour.	
10					10.50 (122.14)	

Borehole terminated at 10.5 m bgl.

Bottom of borehole at 10.50 meters.

BOREHOLE NUMBER BH2

AMEC AMEC E&I

CLIENT Gwynedd Council
PROJECT NAME Llwyn Isaf Landfill
PROJECT NUMBER 28587
CO-ORDINATES X: Y:
DATE STARTED 1/12/11 **COMPLETED** 2/12/11
GROUND ELEVATION 131.04 m **HOLE SIZE** 150mm
DRILLING CONTRACTOR Soil Mechanics
GROUND WATER LEVELS:
DRILLING METHOD Cable Percussion
AT TIME OF DRILLING 1.00 m / Elev 130.04 m
LOGGED BY Simon Howard
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)	ENVIRONMENTAL DATA	GRAPHIC LOG	MATERIAL DESCRIPTION		WELL DIAGRAM
					MADE GROUND: Damp greyish brown sand and gravel. Gravel is fine to very coarse, occasionally cobble sized, subrounded to subangular of mixed lithology including probable slate and sandstone. No odour.		
					1.00	130.04	
					MADE GROUND: Damp brown and occasionally mottled orange gravelly silty sand. Gravel is fine to coarse angular to subrounded of mixed lithology including probable mudstone and sandstone. No odour.		
2					2.00	129.04	
					Wet dense slightly sandy angular to subangular fine to coarse GRAVEL of mixed lithology.		
4							
					5.50	125.54	
					Wet medium dense grey brown fine SAND with rare medium subangular gravel. No odour.		
6							
					7.40	123.64	
					Wet dense greyish brown gravelly SAND. Gravel is fine to very corse, angular to subrounded of mixed lithology. No odour.		
8							
10					10.00	121.04	

Borehole terminated at 10.0 m bgl.
Bottom of borehole at 10.00 meters.

BOREHOLE NUMBER BH3

AMEC AMEC E&I

CLIENT Gwynedd Council
PROJECT NAME Llwyn Isaf Landfill
PROJECT NUMBER 28587
CO-ORDINATES X: Y:
DATE STARTED 8/12/11 **COMPLETED** 9/12/11
GROUND ELEVATION 131.64 m **HOLE SIZE** 150mm
DRILLING CONTRACTOR Soil Mechanics
GROUND WATER LEVELS:
DRILLING METHOD Cable Percussion
AT TIME OF DRILLING 1.00 m / Elev 130.64 m
LOGGED BY Simon Howard
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)	ENVIRONMENTAL DATA	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
					0.30 (131.34) MADE GROUND: Fine to coarse angular to subangular slate gravel.	
					Dense brown silty gravelly SAND. Gravel is fine to very coarse, occasionally cobble-sized, subangular to subrounded of mixed lithology. No odour.	
2						
4					3.80 (127.84) Grey and brown fine to very coarse occasionally cobble-sized slightly sandy GRAVEL. Gravel is angular to subrounded of mixed lithology. No odour.	
6						
8					... with silty clay lenses beyond 8.5 m bgl.	
10					10.00 (121.64)	

Borehole terminated at 10.0 m bgl.
Bottom of borehole at 10.00 meters.

BOREHOLE NUMBER BH6

AMEC AMEC E&I

CLIENT Gwynedd Council
PROJECT NAME Llwyn Isaf Landfill
PROJECT NUMBER 28587
CO-ORDINATES X: Y:
DATE STARTED 6/12/11 **COMPLETED** 7/12/11
GROUND ELEVATION 132.55 m **HOLE SIZE** 150mm
DRILLING CONTRACTOR Soil Mechanics
GROUND WATER LEVELS:
DRILLING METHOD Cable Percussion
AT TIME OF DRILLING 1.00 m / Elev 131.55 m
LOGGED BY Simon Howard
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)	ENVIRONMENTAL DATA	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
					0.20 (132.35) MADE GROUND: Clay and stone fill (drillers description). Fine orange/brown SAND with some fine to coarse angular to subrounded gravel. No odour.	
					1.30 (131.25) Dense orange/brown gravelly SAND. Gravel is fine to very coarse, angular to subrounded of mixed lithology including probable sandstoner and slate. No odour.	
2						
					2.40 (130.15) Damp dense slightly gravelly SAND. Gravel is fine to very coarse, subangular to rounded. No odour.	
4						
					5.50 (127.05) Wet grey/brown slightly sandy GRAVEL. Gravel is fine to very coarse, subangular to subrounded of mixed lithology. No odour.	
6						
8						
10					10.00 (122.55)	

Borehole terminated at 10.0 m bgl.
Bottom of borehole at 10.00 meters.

BOREHOLE NUMBER BH7

AMEC AMEC E&I

CLIENT Gwynedd Council
PROJECT NAME Llwyn Isaf Landfill
PROJECT NUMBER 28587
CO-ORDINATES X: Y:
DATE STARTED 7/12/11 **COMPLETED** 8/12/11
GROUND ELEVATION 132.39 m **HOLE SIZE** 150mm
DRILLING CONTRACTOR Soil Mechanics
GROUND WATER LEVELS:
DRILLING METHOD Cable Percussion
AT TIME OF DRILLING 1.00 m / Elev 131.39 m
LOGGED BY Simon Howard
AT END OF DRILLING ---
NOTES
AFTER DRILLING ---

DEPTH (m)	SAMPLE TYPE NUMBER	BLOW COUNTS (N VALUE)	ENVIRONMENTAL DATA	GRAPHIC LOG	MATERIAL DESCRIPTION	WELL DIAGRAM
					MADE GROUND: Grass over soft brown slightly gravelly sandy clay with some fine rootlets. Gravel is fine to very coarse, occasionally cobble-sized, angular to subrounded. No odour.	
					0.90 131.49	
					MADE GROUND: Grey and brown gravelly sandy clay with some fine rootlets. Gravel is fine to coarse angular to subangular. No odour.	
					1.40 130.99	
2					Dense grey/brown silty gravelly SAND. Gravel is fine to very coarse, occasionally coblle-sized, angular to subrounded. No odour.	
4						
					5.10 127.29	
6					Wet dense grey and brown sandy GRAVEL. Gravel is fine to very coarse, occasionally cobble sized, angular to subrounded of mixed lithology. No odour.	
8					8.80 123.59	
					Wed medium dense fine orange/brown silty SAND. No odour.	
10					10.00 122.39	

Borehole terminated at 10.0 m bgl.
Bottom of borehole at 10.00 meters.

3 0003

DRILLING LOG

DRAGON DRILLING LIMITED
154 MWROG STREET
RUTHIN
LL15 1LG
TEL: 01824 707777

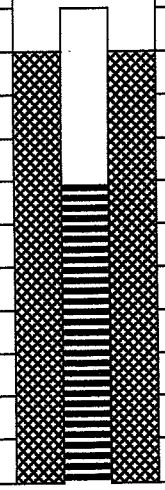
SITE: Llwyn Isaf

BOREHOLE NO: 3(G5)

DATE: 23/09/2008

OPERATION	SIZE (MM)	FROM DEPTH (M)	TO DEPTH (M)	TOTAL
Set up				1
Drilling	167	GL	7.0	7.0
MDPE Casing	110	0.5	7.0	7.5

DEPTH (M)	DESCRIPTION
GL	Soil
0.5	Sand, gravel and groundwater



MATERIAL & DEPTH (M)

0.5 Plain casing
0.0 Bentonite
1.5 Gravel
7.0 Gravel

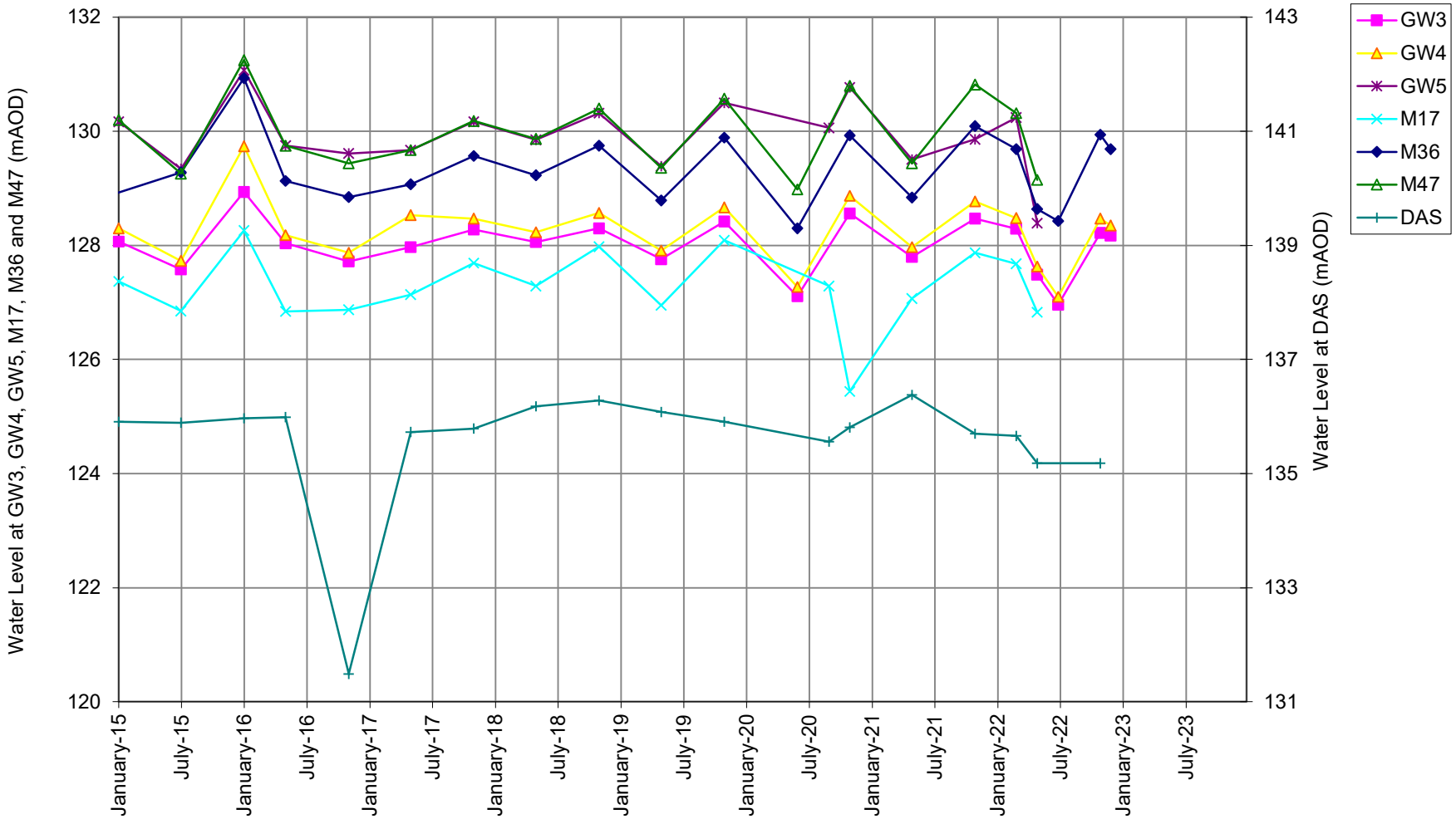
PREDICTED DEPTH (M)	ACTUAL DEPTH (M)	LEACHATE (MBGL)	END CAP	SLOTTED (M)	PLAIN (M)	CASING HEIGHT (MAGL)	STONE (MBGL)	BENTONITE (MBGL)
7.0	7.0	0.0	Yes	4.0	3.5	0.5	1.5	0.0

SIGNED: (CLIENT)

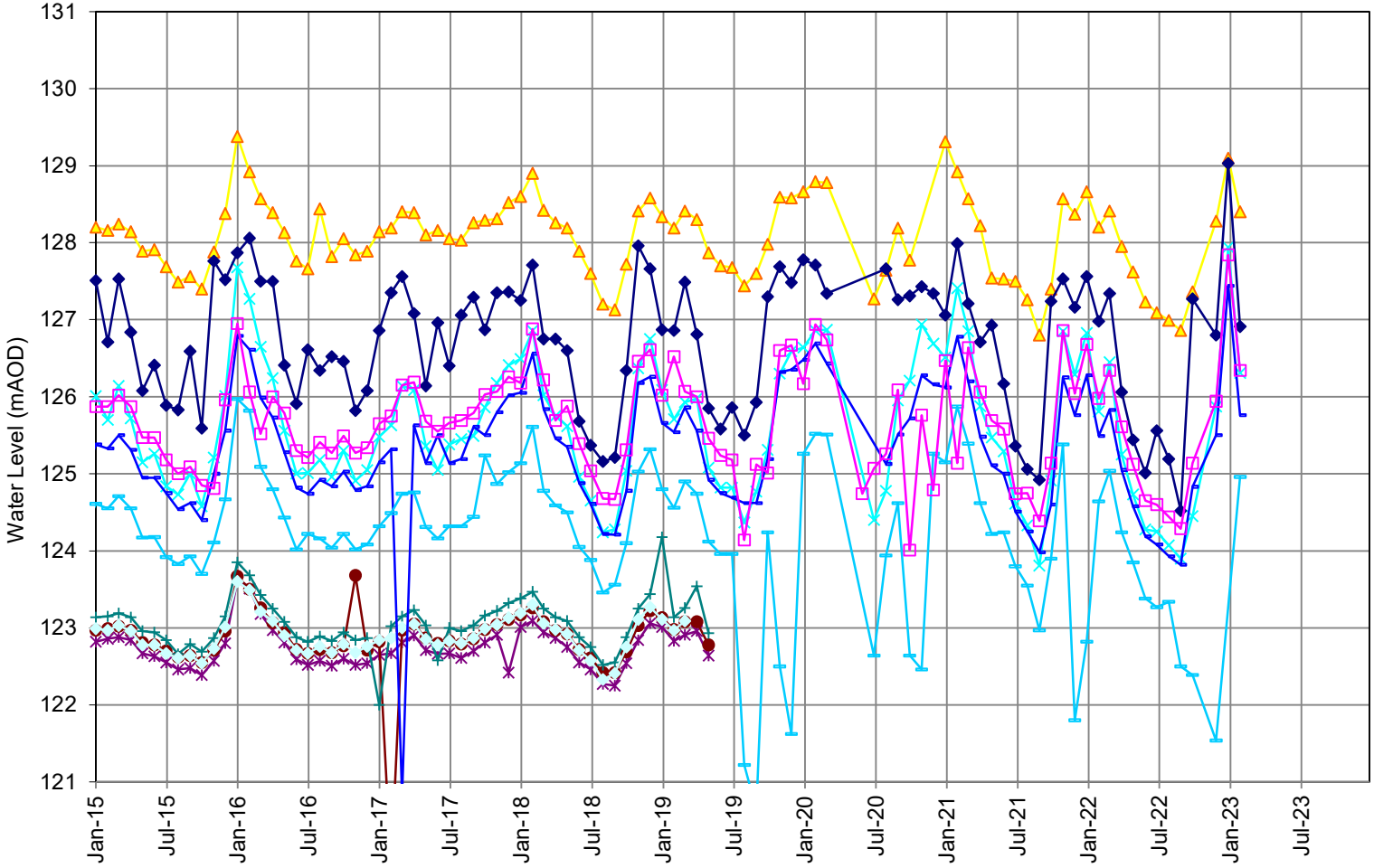
SIGNED: Francis Hay (LEAD DRILLER)

Appendix D
Groundwater Hydrographs

Llwyn Isaf Landfill: Groundwater Levels (Area 3)



Llwyn Isaf Landfill: Groundwater Levels (Area 2)



* Borehole M13 was lost to construction work for the new AD plant. The replacement borehole (BH1) has been monitored since September 2012.

Appendix E
Groundwater Quality Charts and Hazardous Suite Results

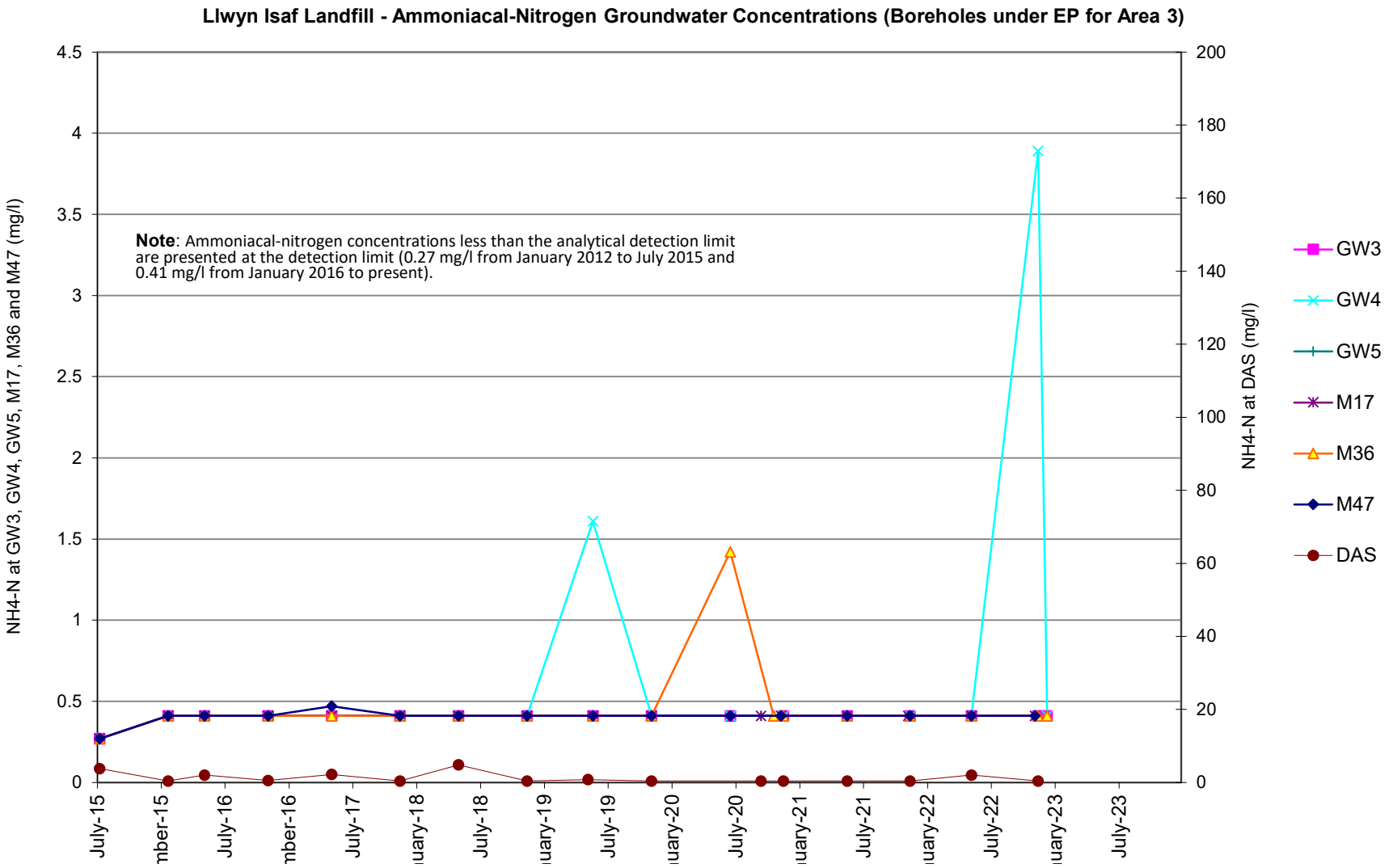
Table E1 Hazardous organic substances in groundwater above detection limit (May 2016 to May 2022)

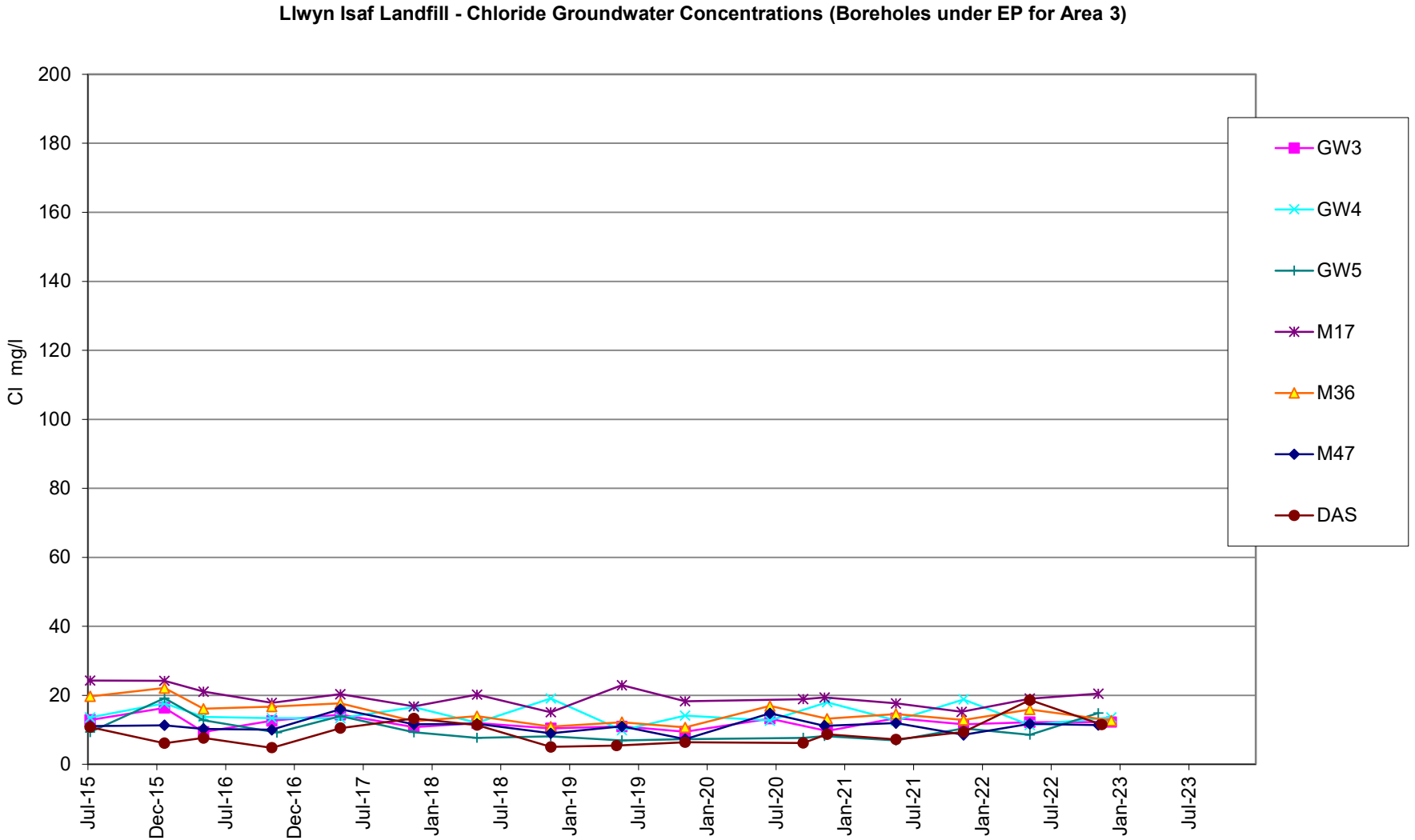
Hazardous Substance	Concentration (ug/l)	Date
M47		
EH >C6 - C40	17	05/11/2016
EH >C24 - C40	17	05/11/2016
EH >C6 - C40	84	02/05/2017
EH >C16 - C24	20	02/05/2017
EH >C24 - C40	64	02/05/2017
Mercury, Filtered as Hg	0.018	10/05/2022
M36		
EH >C6 - C40	13	05/11/2016
EH >C24 - C40	13	05/11/2016
EH >C6 - C40	73	06/06/2020
EH >C24 - C40	73	06/06/2020
Phenol	6.3	06/06/2020
3&4-Methylphenol	20.4	06/06/2020
Mercury, Total as Hg	0.04	08/03/2022
EH >C6 - C40	25	08/03/2022
EH >C24 - C40	25	08/03/2022
Toluene	4.57	08/03/2022
Mercury, Total as Hg	0.05	10/05/2022
EH >C6 - C40	52	10/05/2022
EH >C24 - C40	52	10/05/2022

M36		
Toluene	2.2	10/05/2022
Mercury, Filtered as Hg	0.01	17/11/2022
M17		
EH >C6 - C40	12	14/09/2020
EH >C24 - C40	12	14/09/2020
Toluene	1.46	08/11/2022
DAS		
Chlorfenvinphos	0.003	02/05/2017
Mecoprop	0.43	02/05/2017
EH >C6 - C40	87	02/05/2017
EH >C16 - C24	27	02/05/2017
EH >C24 - C40	14	02/05/2017
EH >C10 - C16	47	02/05/2017
Mecoprop	0.34	01/05/2018
Mecoprop	0.19	07/05/2019
GW3		
Mercury, Filtered as Hg	0.02	17/11/2022
alpha-Chlordane	17.4	17/11/2022
Dieldrin	5.6	17/11/2022
gamma-HCH	9.9	17/11/2022
GW4		
EH >C6 - C40	10	02/05/2017
EH >C24 - C40	10	02/05/2017
EH >C6 - C40	2500	21/05/2019
EH >C16 - C24	1560	21/05/2019
EH >C24 - C40	903	21/05/2019
EH >C10 - C16	40	21/05/2019

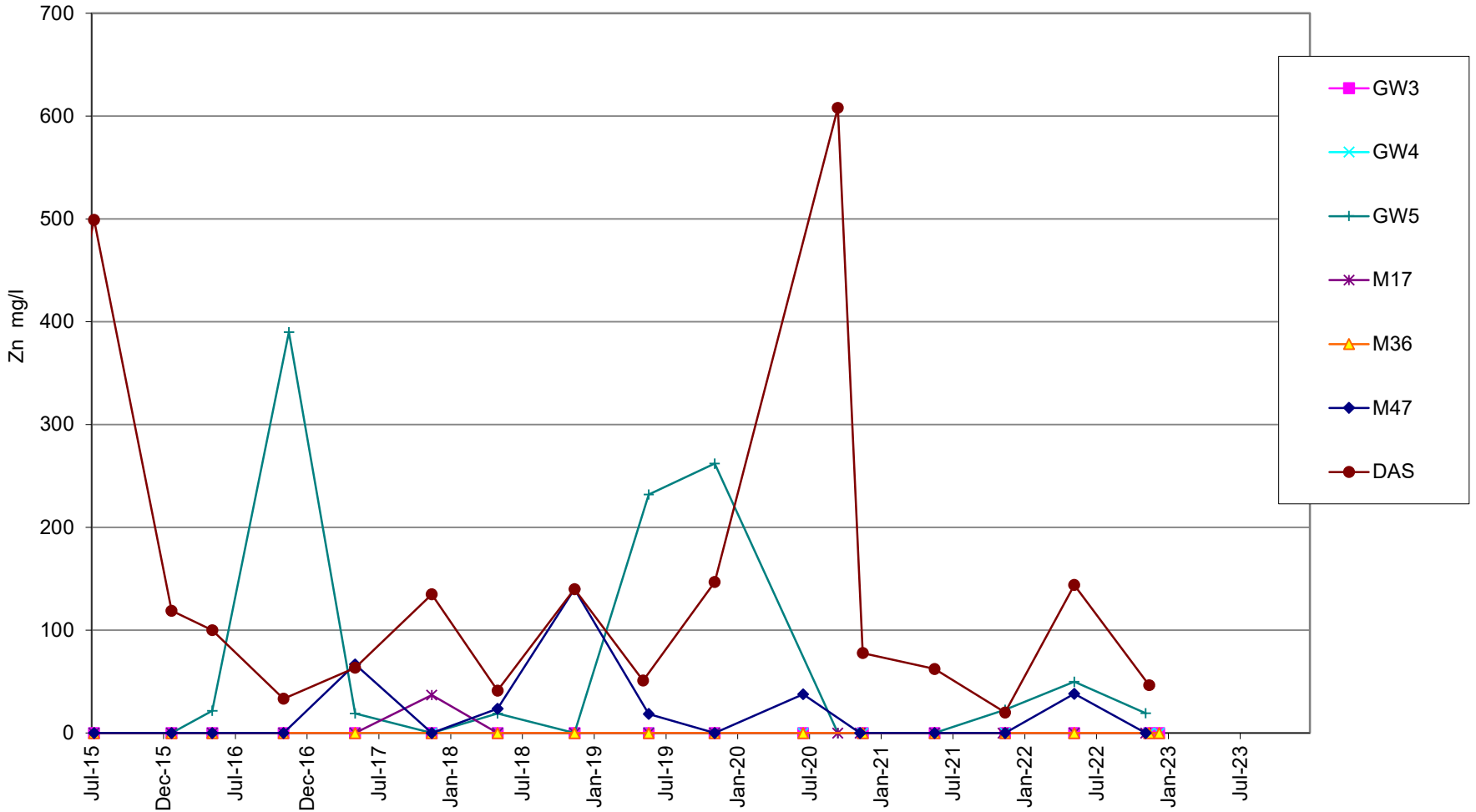
GW4		
EH >C6 - C40	79	06/06/2020
EH >C24 - C40	79	06/06/2020
Mercury, Total as Hg	0.08	08/03/2022
Mercury, Total as Hg	0.04	10/05/2022
EH >C6 - C40	21	10/05/2022
EH >C24 - C40	21	10/05/2022
Mercury, Filtered as Hg	0.1	17/11/2022
alpha-Chlordane	15.4	17/11/2022
gamma-HCH	2.6	17/11/2022
Hexachlorobutadiene	1.9	17/11/2022
o,p - TDE	0.13	17/11/2022

GW5		
EH >C6 - C40	39	02/05/2017
EH >C16 - C24	16	02/05/2017
EH >C24 - C40	23	02/05/2017
EH >C6 - C40	11	01/05/2018
EH >C16 - C24	11	01/05/2018
Mercury, Total as Hg	0.11	08/03/2022
Mercury, Filtered as Hg	0.053	10/05/2022
Mercury, Total as Hg	0.06	08/11/2022
Phenol	26.8	08/11/2022

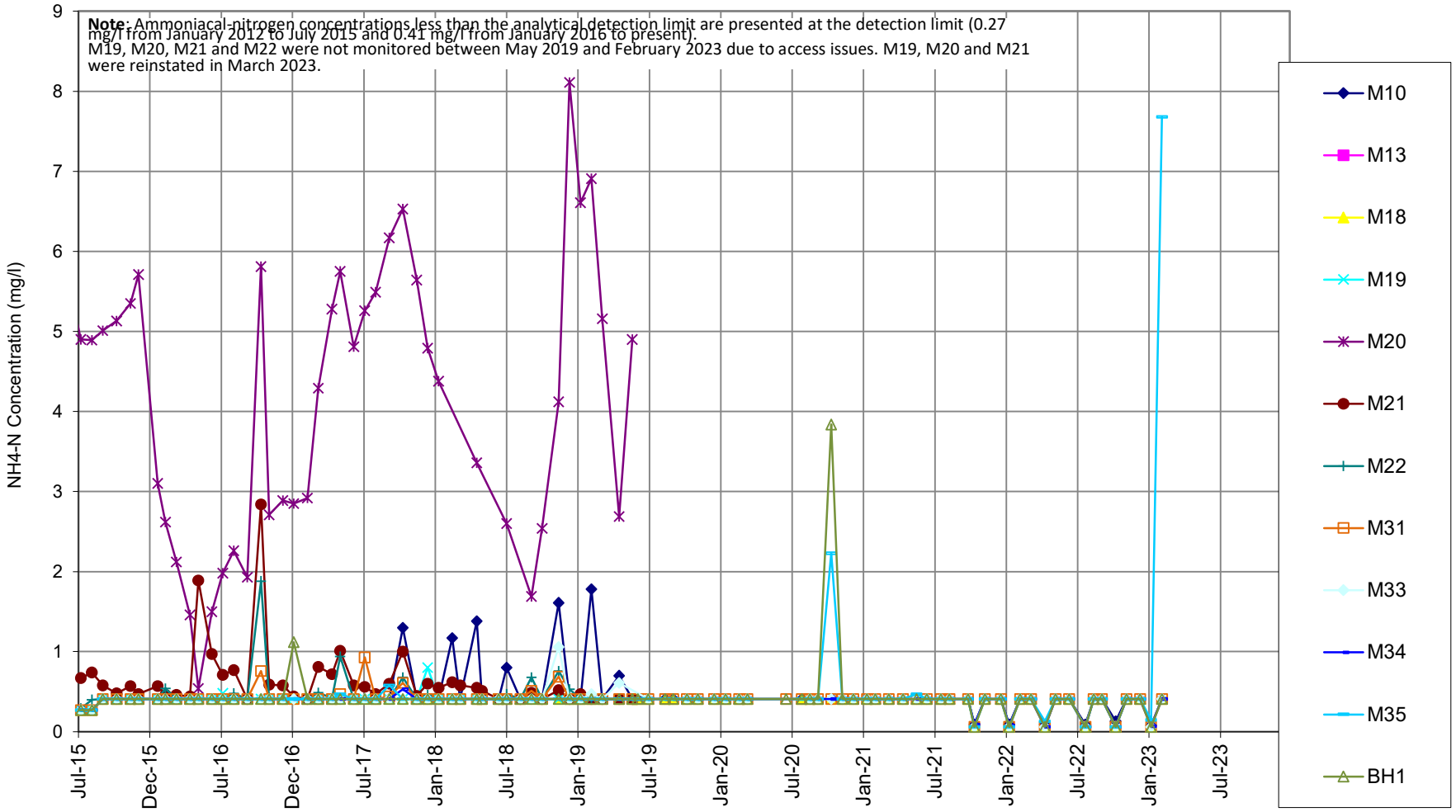

Llwyn Isaf Landfill - Ammoniacal-Nitrogen Groundwater Concentrations (Boreholes under EP for Area 3)
Note: Ammoniacal-nitrogen concentrations less than the analytical detection limit are presented at the detection limit (0.27 mg/l from January 2012 to July 2015 and 0.41 mg/l from January 2016 to present).
NH4-N at GW3, GW4, GW5, M17, M36 and M47 (mg/l)
NH4-N at DAS (mg/l)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
200
180
160
140
120
100
80
60
40
20
0
July-15
nber-15
July-16
nber-16
July-17
uary-18
July-18
uary-19
July-19
uary-20
July-20
uary-21
July-21
uary-22
July-22
uary-23
July-23
GW3
GW4
GW5
M17
M36
M47
DAS

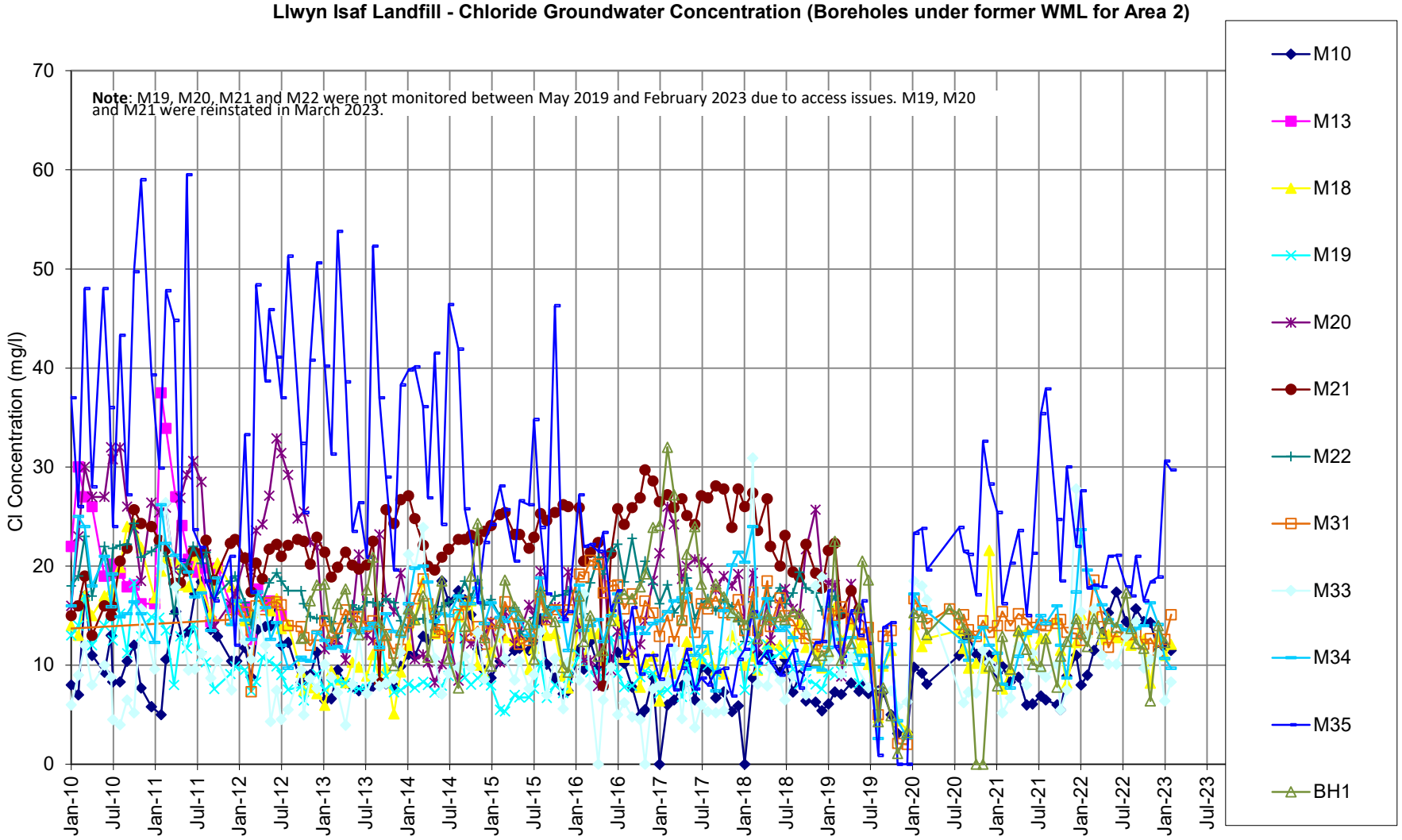

Llwyn Isaf Landfill - Chloride Groundwater Concentrations (Boreholes under EP for Area 3)
Cl mg/l
200
180
160
140
120
100
80
60
40
20
0
Jul-15
Dec-15
Jul-16
Dec-16
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20
Jul-20
Jan-21
Jul-21
Jan-22
Jul-22
Jan-23
Jul-23
GW3
GW4
GW5
M17
M36
M47
DAS

Llwyn Isaf Landfill - Zinc Groundwater Concentrations (Boreholes under EP for Area 3)

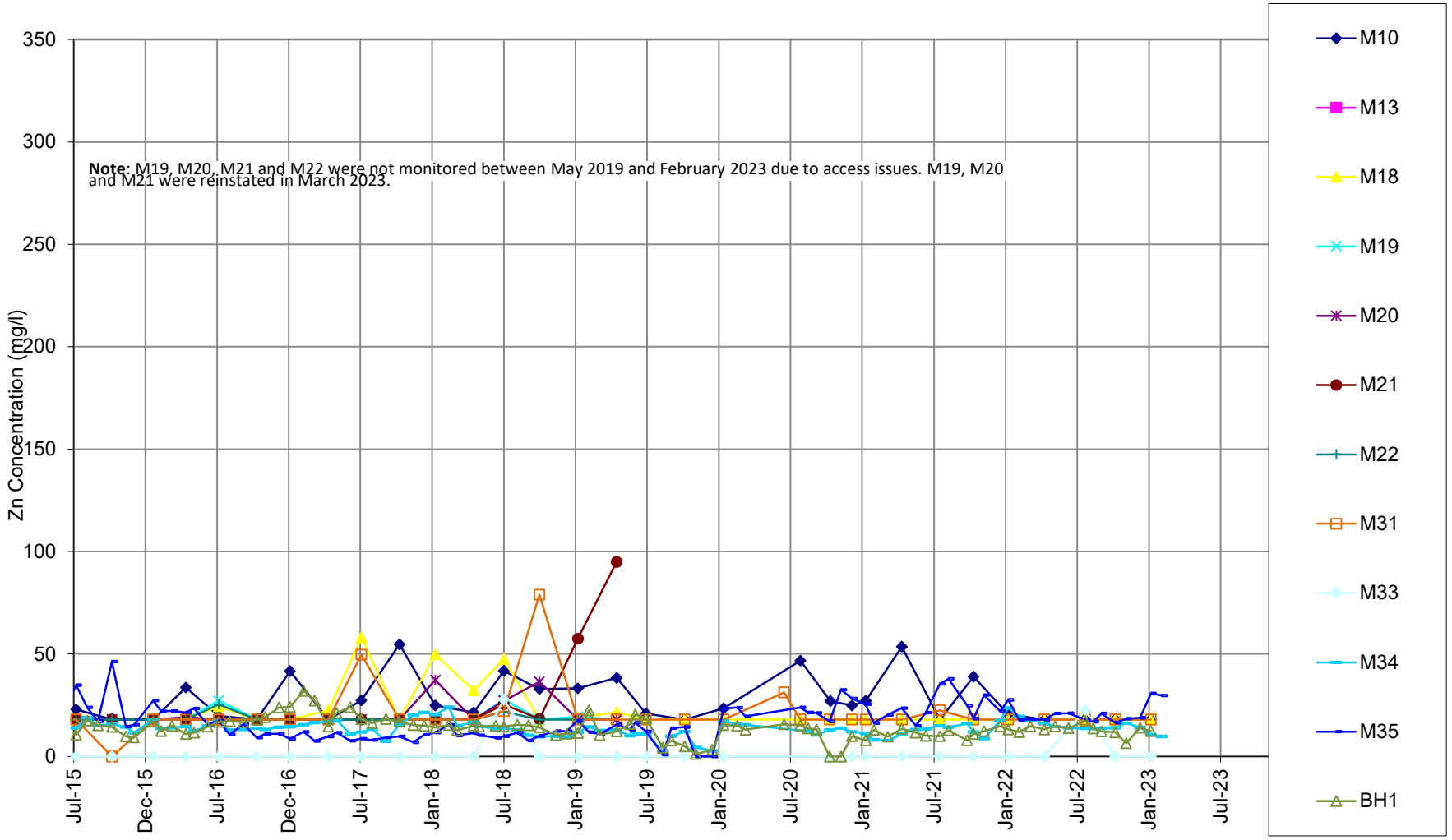


Llwyn Isaf Landfill - Ammoniacal-Nitrogen Groundwater Concentrations (Boreholes under former WML for Area 2)



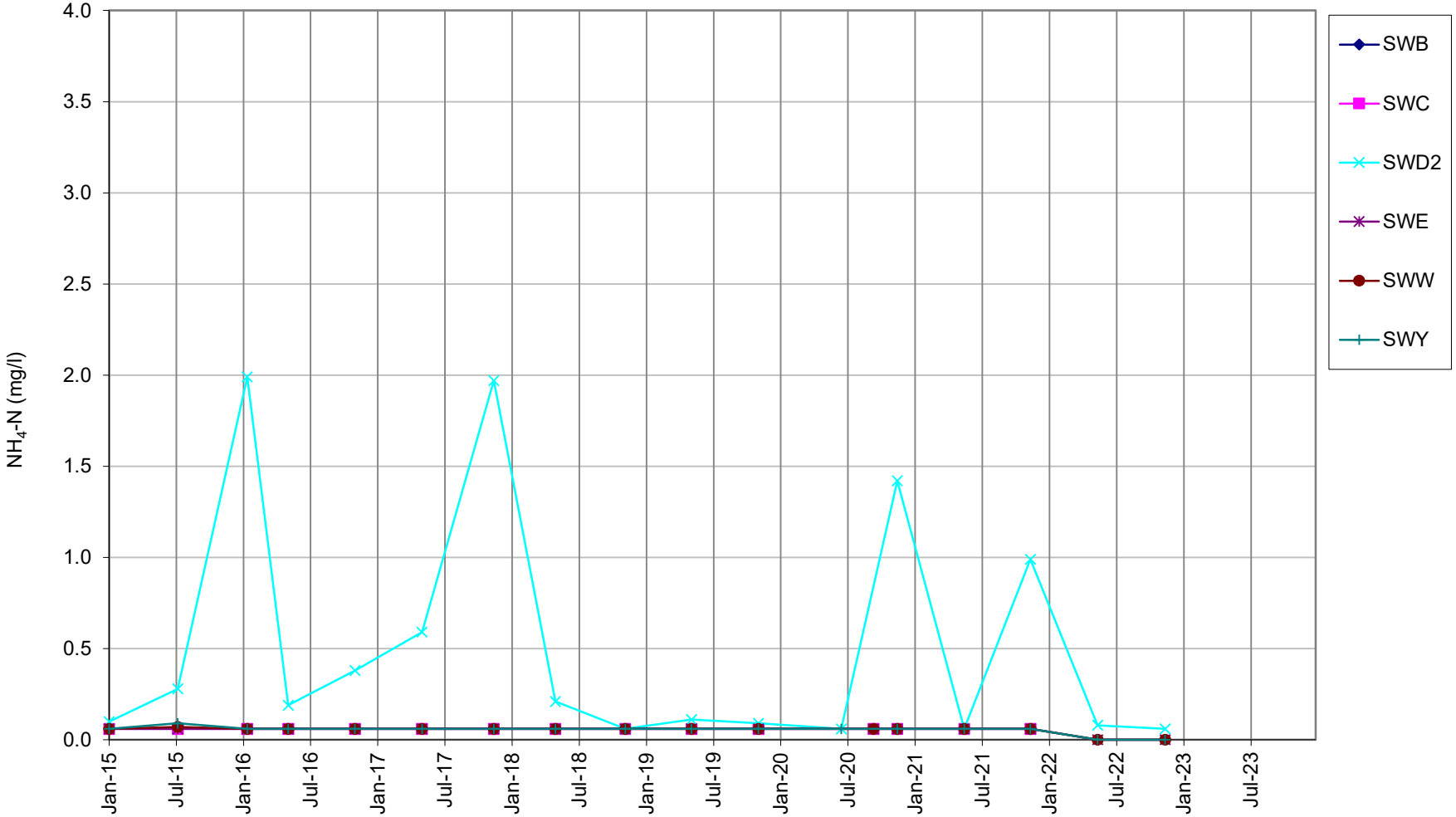

Llwyn Isaf Landfill - Chloride Groundwater Concentration (Boreholes under former WML for Area 2)
Note: M19, M20, M21 and M22 were not monitored between May 2019 and February 2023 due to access issues. M19, M20 and M21 were reinstated in March 2023.
Cl Concentration (mg/l)
0
10
20
30
40
50
60
70
Jan-10
Jul-10
Jan-11
Jul-11
Jan-12
Jul-12
Jan-13
Jul-13
Jan-14
Jul-14
Jan-15
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20
Jul-20
Jan-21
Jul-21
Jan-22
Jul-22
Jan-23
Jul-23
M10
M13
M18
M19
M20
M21
M22
M31
M33
M34
M35
BH1

Llwyn Isaf Landfill - Zinc Groundwater Concentration (Boreholes under former WML for Area 2)

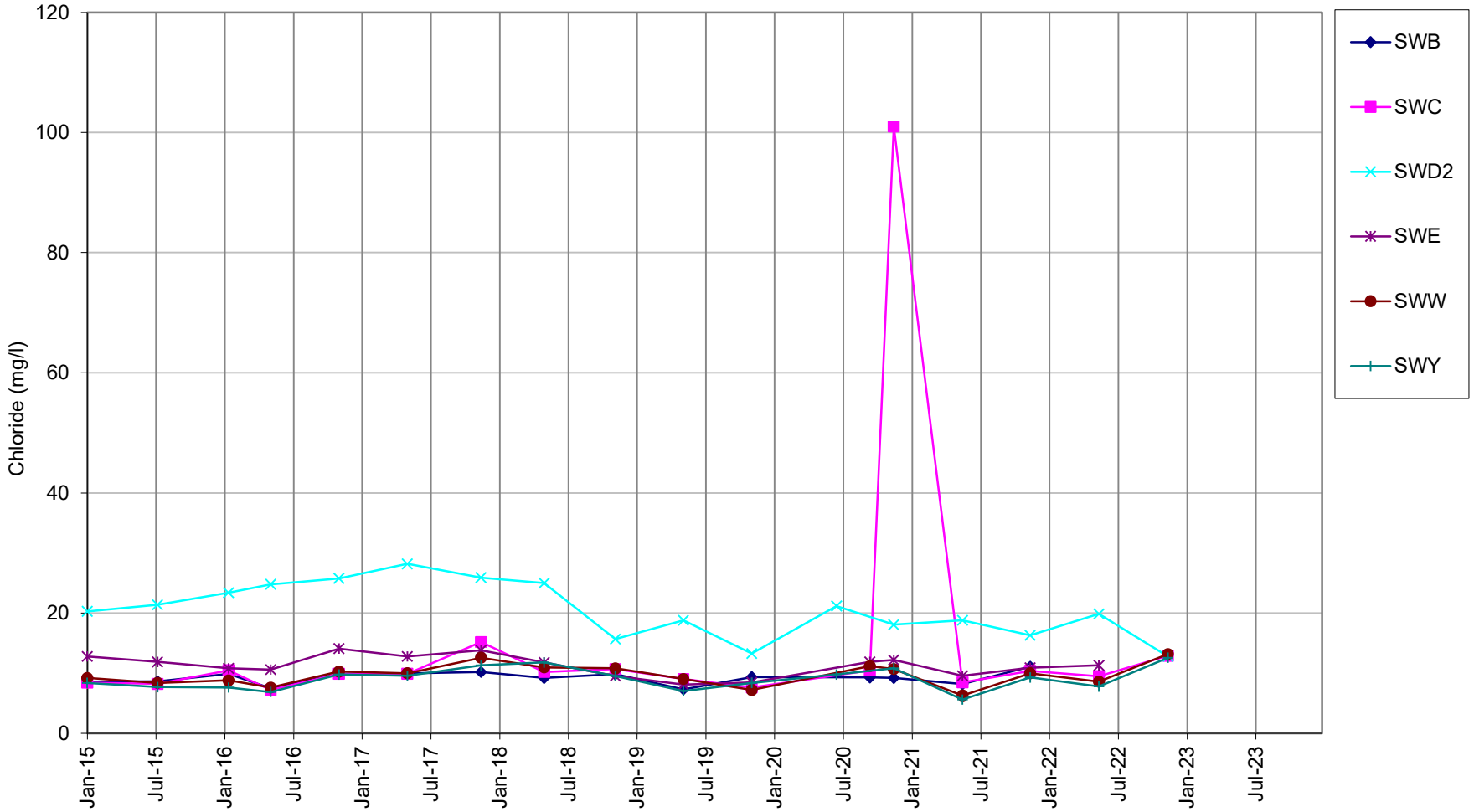


Appendix F
Surface Water Quality Charts

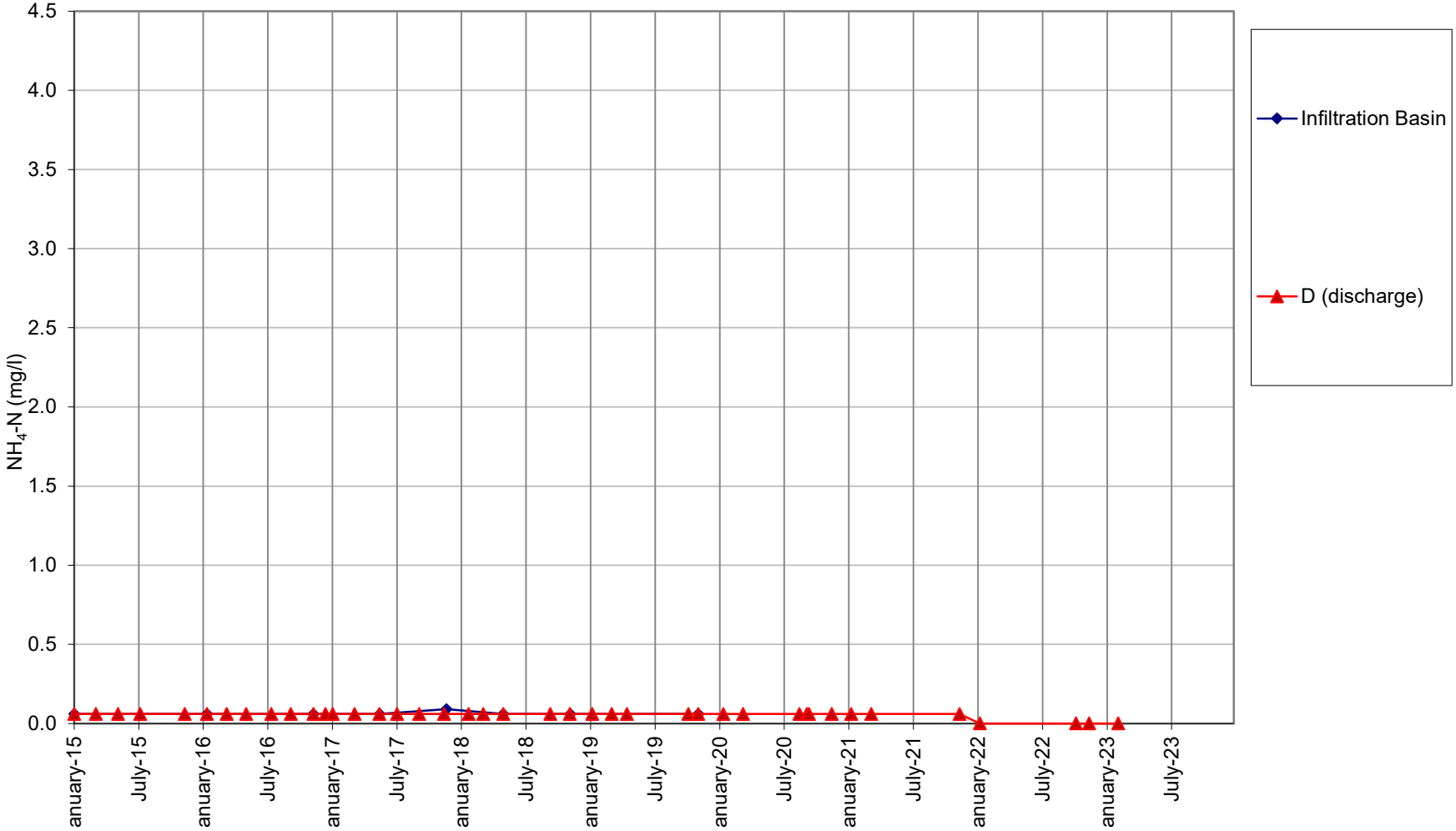
Llwyn Isaf Landfill: Ammoniacal Nitrogen Concentrations in Afon Desach and Lake to the North of Site



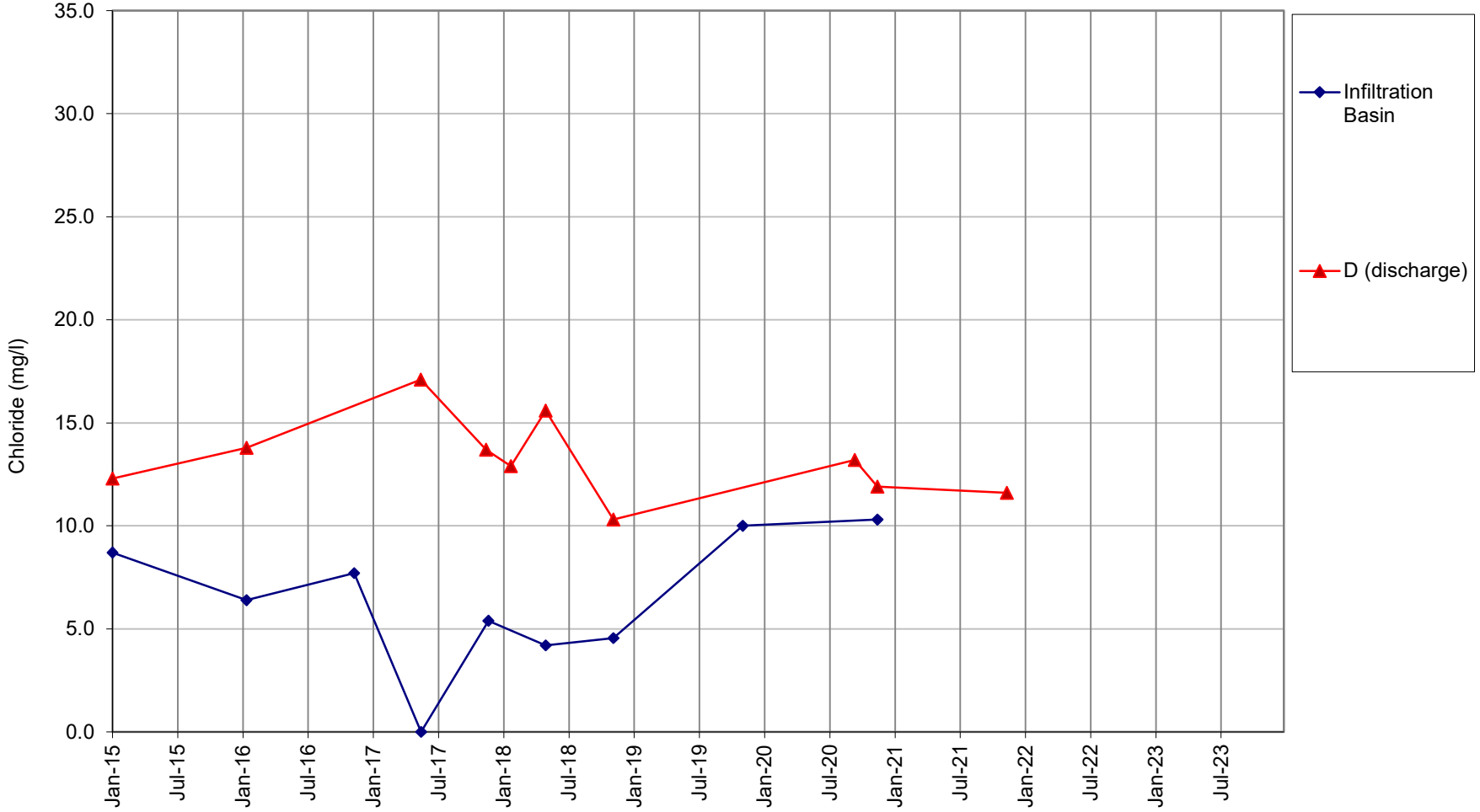
Llwyn Isaf Landfill: Chloride Concentrations in Afon Desach and Lake to the North of Site



Llwyn Isaf Landfill: Ammoniacal Nitrogen Concentrations in Site Discharge and Infiltration Basin

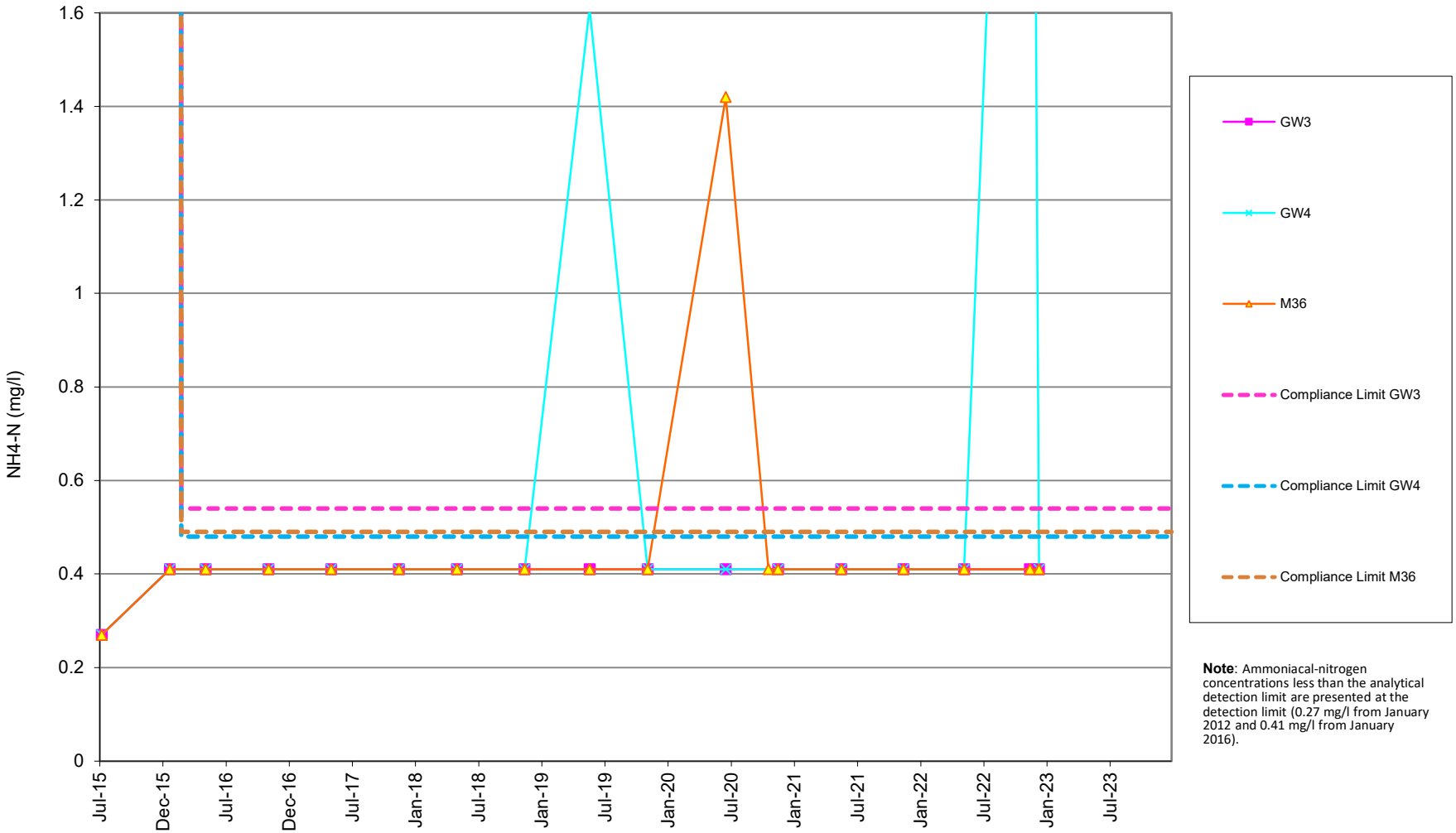


Llwyn Isaf Landfill: Chloride Concentrations in Site Discharge and Infiltration Basin

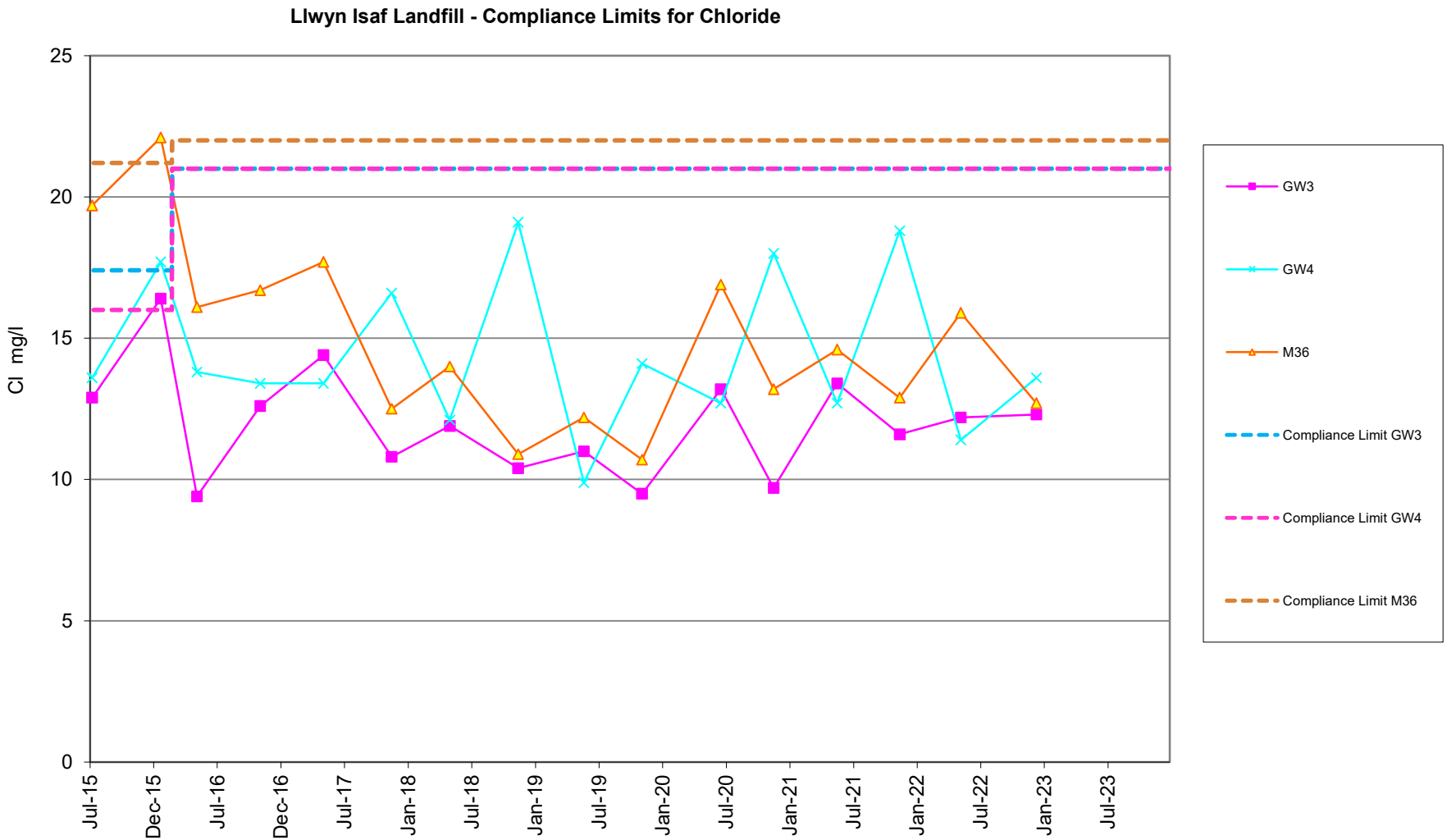


Appendix G
Groundwater EP Compliance Limits

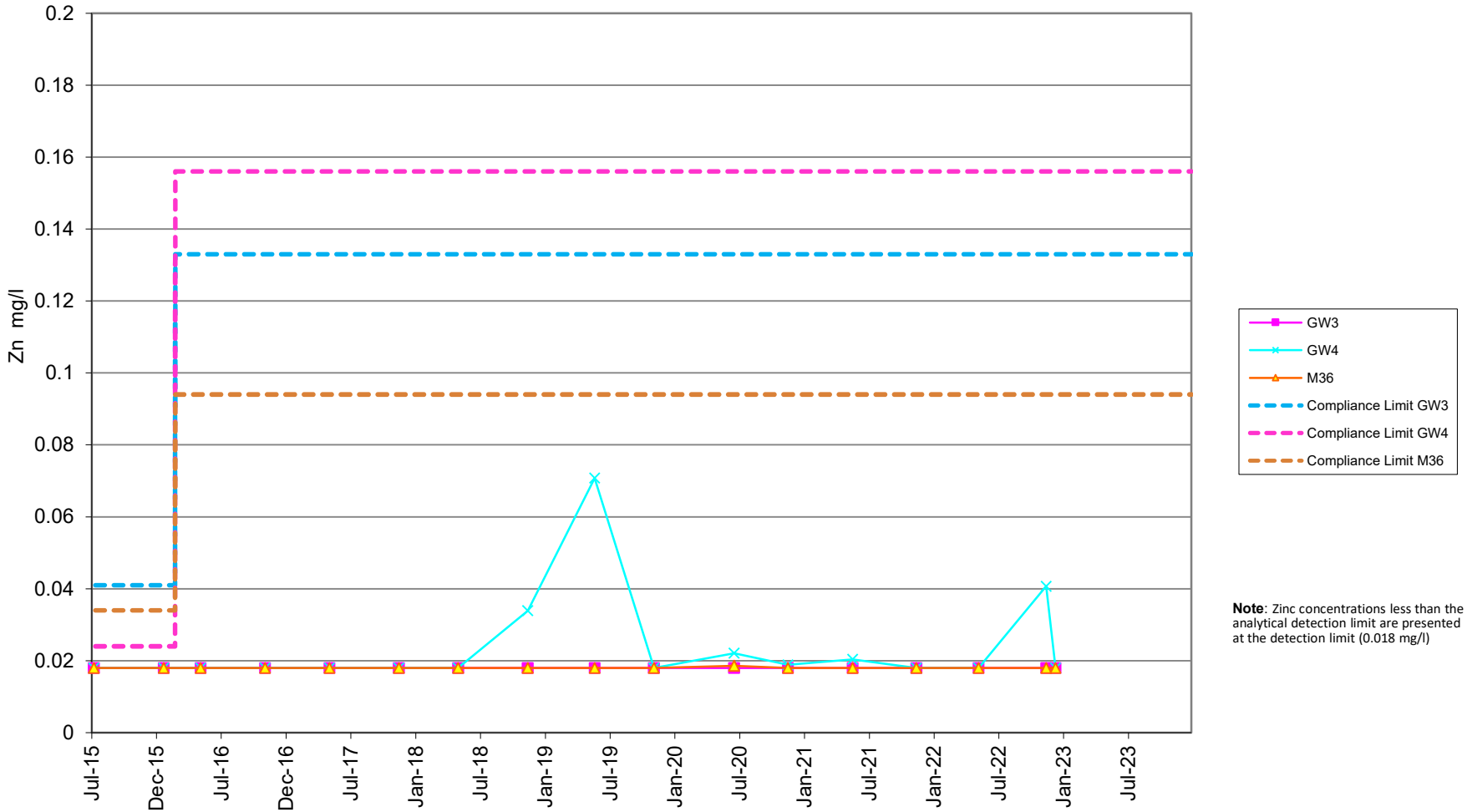
Llwyn Isaf Landfill - Compliance Limits for Ammoniacal-Nitrogen



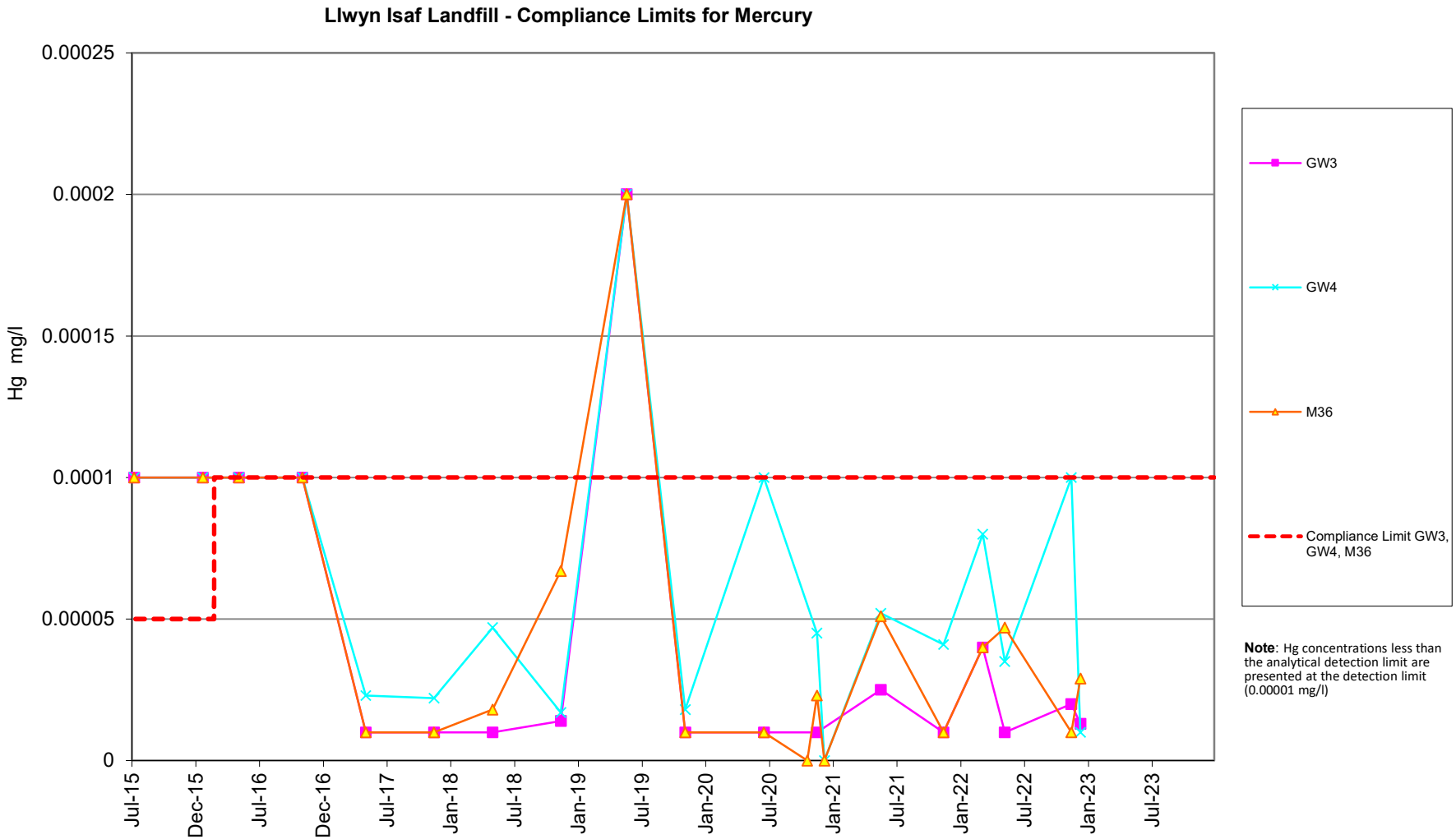
Note: Ammoniacal-nitrogen concentrations less than the analytical detection limit are presented at the detection limit (0.27 mg/l from January 2012 and 0.41 mg/l from January 2016).

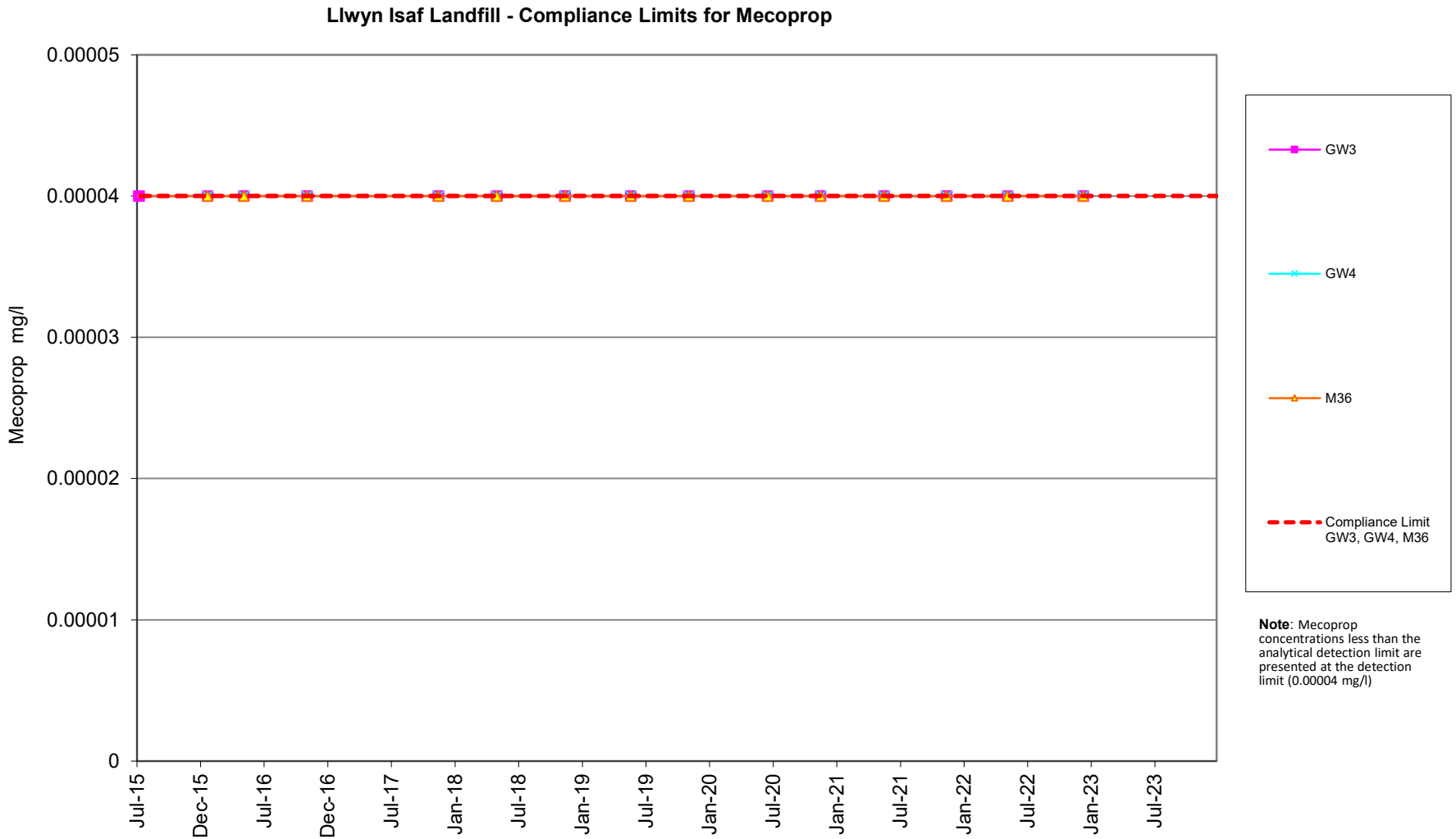

Llwyn Isaf Landfill - Compliance Limits for Chloride
Cl mg/l
25
20
15
10
5
0
Jul-15
Dec-15
Jul-16
Dec-16
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20
Jul-20
Jan-21
Jul-21
Jan-22
Jul-22
Jan-23
Jul-23
GW3
GW4
M36
Compliance Limit GW3
Compliance Limit GW4
Compliance Limit M36

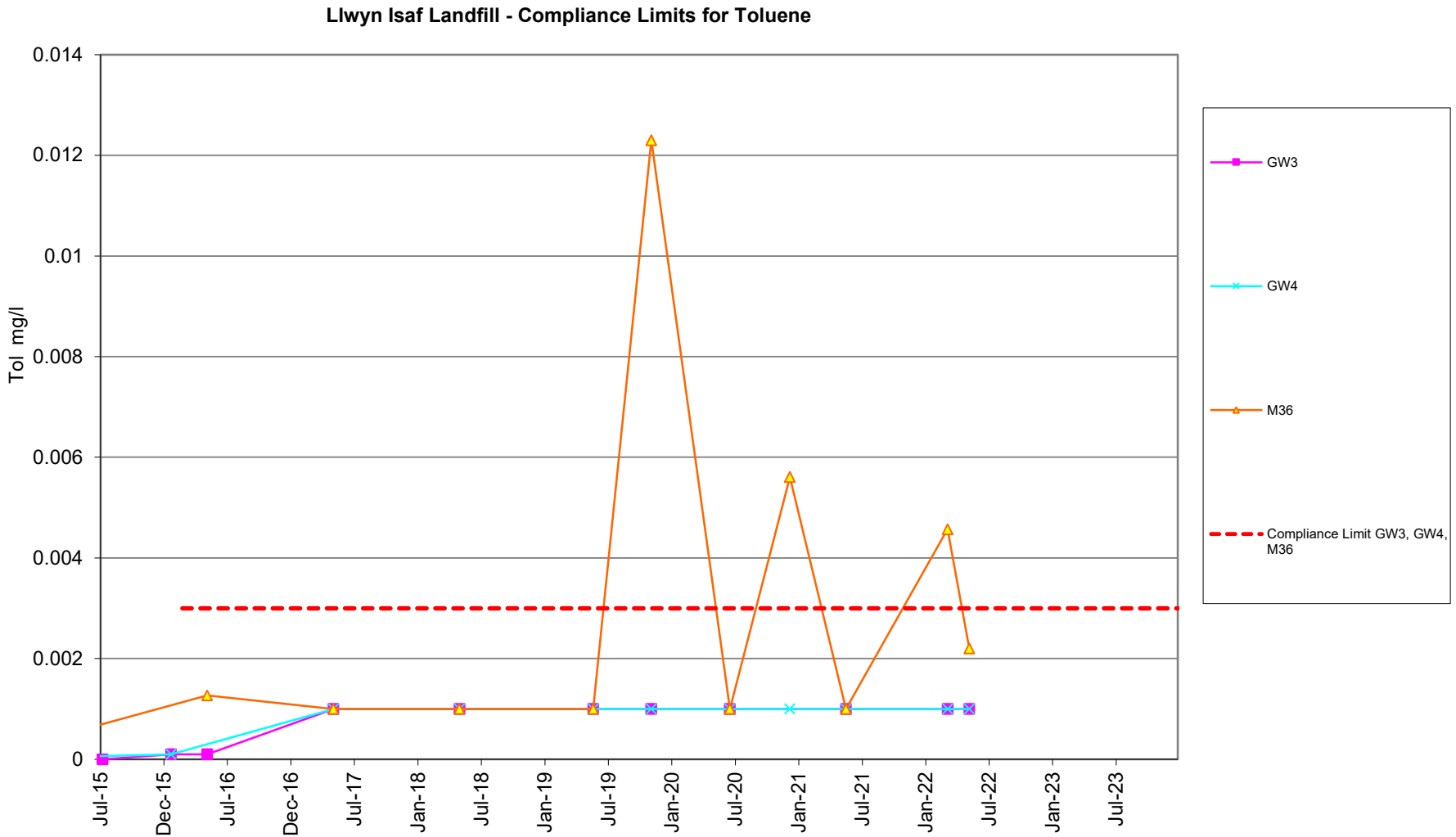
Llwyn Isaf Landfill - Compliance Limits for Zinc



Note: Zinc concentrations less than the analytical detection limit are presented at the detection limit (0.018 mg/l)


Llwyn Isaf Landfill - Compliance Limits for Mercury
Hg mg/l
0.00025
0.0002
0.00015
0.0001
0.00005
0
Jul-15
Dec-15
Jul-16
Dec-16
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20
Jul-20
Jan-21
Jul-21
Jan-22
Jul-22
Jan-23
Jul-23
GW3
GW4
M36
Compliance Limit GW3, GW4, M36
Note: Hg concentrations less than the analytical detection limit are presented at the detection limit (0.00001 mg/l)


Llwyn Isaf Landfill - Compliance Limits for Mecoprop
Mecoprop mg/l
0.00005
0.00004
0.00003
0.00002
0.00001
0
Jul-15
Dec-15
Jul-16
Dec-16
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20
Jul-20
Jan-21
Jul-21
Jan-22
Jul-22
Jan-23
Jul-23
GW3
GW4
M36
Compliance Limit GW3, GW4, M36
Note: Mecoprop concentrations less than the analytical detection limit are presented at the detection limit (0.00004 mg/l)


Llwyn Isaf Landfill - Compliance Limits for Toluene
Tol mg/l
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Jul-15
Dec-15
Jul-16
Dec-16
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20
Jul-20
Jan-21
Jul-21
Jan-22
Jul-22
Jan-23
Jul-23
GW3
GW4
M36
Compliance Limit GW3, GW4, M36

Appendix H
Reduction in Sampling Variance

Schofield, Becky

From: Roberts, Anthony <Anthony.Roberts@cyfoethnaturiolcymru.gov.uk>
Sent: 11 January 2023 11:17
To: Susan Jane Francis (PP/YGC); Bradford, Julie
Cc: Steven Edwards (PP/YGC); John Alun Thomas (PP/YGC)
Subject: Re: Llwyn Isaf - Reduction in sampling - Variance By Letter
Attachments: YP3138UJ letter to NRW (05.12.22).doc

HI Sue/Steve,

I have had a look at the proposals for reduced sampling in the attached letter and agree that these changes are reasonable in the context of the historical sampling data and evidence provided.

As the permit allows for this to be agreed in writing rather than through the traditional variation route, these changes can be initiated from the end of this week. 13th January 2023.

If you have any further queries, please do not hesitate to contact me.

Julie, please can you place this on the DMS/PR as it is an official written agreement.

Best wishes

Tony

Tony Roberts
Cyfoeth Naturiol Cymru / Natural Resources Wales
Senior Officer/SMNR and SynBiogas Programme Project Manager
Waste and Industry Regulation Team, Maes Y Fynnon,
Bangor. LL57 2DW
Ffôn/Tel: 03000 653752
Ffôn symudol / Mobile: 07468 742602

E-Bost/E-mail

Anthony.Roberts@naturalresourceswales.gov.uk

From: Susan Jane Francis (PAB) <susanjanefrancis@gwynedd.llyw.cymru>
Sent: 05 December 2022 12:44
To: Roberts, Anthony <Anthony.Roberts@cyfoethnaturiolcymru.gov.uk>
Cc: Steven Edwards (PAB) <stevenedwards@gwynedd.llyw.cymru>; John Alun Thomas (PAB)

<johnalunthomas@gwynedd.llyw.cymru>
Subject: Llwyn Isaf - Reduction in sampling

Llwyn Isaf Landfill (YP3138UJ)

Hi Tony,

Hope you are well.

I've prepared a letter for your consideration outlining our proposal to reduce both the surface water discharge consent and the surface emissions monitoring frequency.
Hope these meet with yor approval.

Kind regards
Sue

Susan Francis
Assistant Engineer/Peiriannydd Cynorthwyol
Tel : 01286 679508

Adran Amgylchedd
Environment Department

Gwasanaethau Gwastraff ac Ailgylchu
Waste and Recycling Services

Gofynnwch am/Ask for: Susan Francis
☎07879494360
susanjanefrancis@gwynedd.llyw.cymru

Ein Cyf / Our Ref: **SJF/YB3138UJ (05/12/22)**
Eich Cyf / Your Ref:

Gwynedd Council Offices
Cibyn Industrial Estate
Caernarfon
Gwynedd
LL55 2BD

05/12/22

Proposal to reduce the sampling frequency at Llwyn Isaf Landfill
Permit YB3138UJ

Dear Tony,

Gwynedd Council would like to propose a reduction in the frequency of monitoring from the following two tables as detailed in permit YB3138UJ Llwyn Isaf Landfill :-

- *Table S3.3 – Point source emissions to water (other than sewer) – emissions limits and monitoring requirements*
- *Table S3.6 - Landfill gas from capped surfaces – limits and monitoring requirements*

Under the permit conditions for both table S3.3 and S3.6 a review of the monitoring frequency may be agreed in writing with the NRW.

Table S3.3 Point source emissions to water (other than sewer) – emissions limits and monitoring requirements

Sampling point D (SWD (Discharge)), is a discharge point, from the surface water attenuation lagoon, into the River Desach.
Gwynedd Council would like to propose a reduction in the sampling frequency at this location, from every two months to quarterly monitoring. Emission limits have been set at this location for pH, Ammoniacal nitrogen, suspended solids and BOD and these limits will remain in place.

Parameters	Limit	Monitoring frequency	
		Current	Proposed
Ammoniacal nitrogen	0.3 mg/l	Every 2 months	Every 3 months
Dissolved oxygen	80 %		
BOD	4 mg/l		
Suspended Solids	25 mg/l		
pH	6.0 – 9.0		

Swyddfa'r Cyngor
Caernarfon
Gwynedd. LL55 1SH
01766 771000
www.gwynedd.llyw.cymru

A total of 11 sampling rounds at SWD (discharge) were taken between January 2020 – November 2022. The results have been tabulated below.

SWD (discharge)	LIMITS	15/1/2020	11/3/2020	18/08/20	08/09/20	17/11/20	12/01/21
pH	6.0 to 9.0	7.9	7.9	7.5	8	7.6	7.9
NH4 (mg/l)	0.3	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
BOD (mg/l)	4	<1	<1	2	<1	<1	<1
suspended solids (mg/l)	25	1	2	2	1	3	<1

Results summary

SWD (discharge)	LIMITS
pH	6.0 to 9.0
NH4 (mg/l)	0.3
BOD (mg/l)	4
suspended solids (mg/l)	25

Location was dry in
2020 – June and July
2021 – May, July and September
2022 – April, May and July

Very little variance is seen in these results and there have been no breaches of the set limits for any of the specified parameters during this three-year period.

Table S3.6 Landfill gas from capped surfaces – limits and monitoring requirements

Measurements of the fugitive emissions emitted from the permanent cap is undertaken in-house using a hired analyser, the INFICON IRwin SXT. Currently monitoring is carried out yearly in accordance with Table S3.6 of the permit.

Results of the walk over are summarised as follows :-

Date	Emissions
05/11/20	The maximum result for methane emissions during the survey was 10ppm
11/11/21	The maximum result for methane emissions during the survey was 13ppm
28/09/22	3 isolated occurrences of methane detected up to 4ppm

None of the surface emission results recorded levels of methane above the action threshold of 100ppm.
Gwynedd Council propose that monitoring be reduced from yearly to monitoring every 2 years.

In summary

Both proposals have presented data over a three - year period, monitoring as per the permit requirements.

No impact on the environment can be detected from either of these activities, with all results below any set limits. Based on the data collected, a reduction in the sampling frequency with no change to the measured parameters would continue to provide sufficient information to monitor any potential impact on the local environment emanating from the closed landfill.

The proposals are summarised as follows

Sampling details	Current permit requirement	Proposed frequency
(S3.3) SW D Discharge	Every 2 months	Every quarter
(S3.6) Fugitive emissions	Yearly	Every 2 years

We hope that both proposals meet with your approval and we look forward to hearing from you in due course.

Yours Sincerely,

Susan Francis
Assistant Engineer

Appendix I
LandSim Input Parameters

Table I.1 LandSim Input Parameters: Leachate Source Term

Description Unit	Unit	Concentration			Kd (l/kg)	Koc (l/kg)	Half Life (yrs)	Justification
		Min	Mean	Max				
Ammoniacal-N	mg/l	*162*	*858*	*2490*	0.5-2	-	6*	Conc- Table 2.8 Kd – LandSim default Half life – longest value in EA (2003a)
Chloride	mg/l	*242*	*1062*	*2760*	0	-	10^9	Conc- Table 2.8 Kd & Half life – conservative substance so no sorption or biodegradation.
Zinc	mg/l	*<0.018*	*0.628*	*3.780*	1-600	-	10^9	Conc- Table 2.8 Kd – LandSim default Half life – no degradation
Mecoprop	mg/l	0.003	0.038	0.292	-	0-50-5700	0.5	Conc- Table 2.8 Koc – EA (2004). Kd calculated by LandSim. Half life – 2007 HRA
Leachate Head Above Liner	m	0.75	-	1.5	-		-	EP Compliance Level (max)

Notes: * Values for unsaturated zone and aquifer. No biodegradation modelled in the engineered liner.
Parameters in italic indicate change from 2015 HRA LandSim model.
Where two input values are given this indicates that a uniform distribution was used for probabilistic modelling; where three input values are presented then a triangular distribution was used. Where the range of values was more than 2 orders of magnitude a log uniform or log-triangular distribution was used.
LandSim default kappa values used for ammoniacal-nitrogen, chloride andzinc). Kappa value for mecoprop was assumed to be the same as that for ammoniacal-nitrogen.

Table I2 LandSim Input Parameters: Infiltration, Site Geometry, Engineered Barrier and Unsaturated and Aquifer Pathways

Description	Distribution				Justification
	Unit	Min	Mean	Max	
Infiltration					
Infiltration Uncapped	mm/yr	500	650	800	Effective rainfall from EA (2008b)
Infiltration Capped	mm/yr	50 (mean) 5 (standard deviation)			LandSim default. Normal distribution assumed with a 10% standard deviation from mean.
Site Geometry					
Top area	Ha	0.83 Cell 1, 0.56 Cell 2, 0.31 Cell3			Site plans
Base area	Ha	0.49 Cell 1, 0.36 Cell 2, 0.21 Cell 3			Site plans
Head of leachate when surface water breakout occurs	m	-	7	-	Measured from cell base contours and ground level
Waste thickness	m	7	-	13	2007 HRA (measured from cross sections)
Waste porosity	-	0.51	-	0.56	Powrie & Beaven (1999)
Waste Dry density	kg/l	0.43	-	0.50	Powrie & Beaven (1999)
Waste field capacity	-	0.3	0.35	0.4	Assumed
Engineered Barrier System					
Type	Composite				
Geomembrane liner					
Pin holes		0	-	25	2007 HRA (LandSim default)
Holes		0	-	5	2007 HRA (LandSim default)
Tears		0	0.1	2	2007 HRA (LandSim default)
Offset of FML degradation	years		150		2007 HRA (LandSim default)

Description	Distribution				Justification
	Unit	Min	Mean	Max	
Time for area of defects to double[a]	years		100		2007 HRA (LandSim default)
Mineral Liner (BES)					
Hydraulic Conductivity	m/s	$1.3x10^{-10}$ $5.8x10^{-11}$ $3.0x10^{-10}$	$2.8x10^{-10}$ $1.2x10^{-10}$ $3.9x10^{-10}$	$4.1x10^{-10}$ Cell1 $3.2x10^{-10}$ Cell2 $4.8x10^{-10}$ Cell 3	CQA data
Mineral Liner (BES)					
Thickness	m		0.5		2007 HRA (site design)
Moisture Content Cell1 Cell2 Cell3	-	0.07 0.08 0.08	0.09 0.12 0.10	0.11 0.16 0.11	CQA data
Longitudinal Dispersivity	m		0.05		2007 HRA (10% pathway length)
Dry density Cell1 Cell2 Cell3	kg/l	1.88 1.48 2.05	2.00 1.91 2.06	2.09 2.05 2.06	CQA data
Organic carbon content	-	0.0001	0.00085	0.006	2007 HRA (assumed)
Unsaturated Pathway (Glacial Sands and Gravels)					
Flow Model	Porous medium				
Pathway length Cell1 Cell2 Cell3	m	*2.8* *2.1* *1.6*	*4.2* *4.2* *3.9*	*5.7* *5.9* *5.5*	Estimated from groundwater levels in the vicinity of each cell for the period August 2015 to March 2023 and top of formation levels.
Matrix Hydraulic conductivity	m/s	$1.0x10^{-5}$	$1.0x10^{-4}$	$1.0x10^{-3}$	2007 HRA (calculated from PSD data)
Moisture Content	-	0.15	-	0.30	2007 HRA (assumed)
Density	kg/l		1.8		2007 HRA (typical value for gravelly sands)
Organic carbon content	-	0.0002	0.0006	0.001	2009 HRA (based on site measurements)
Longitudinal Dispersivity	m	10% of pathway length			LandSim default
Aquifer Pathway (Glacial Sands and Gravels)					

Description	Distribution				Justification
	Unit	Min	Mean	Max	
Mixing zone thickness	m	5		15	Estimated from site data
Hydraulic gradient	-	0.003	0.006	0.01	Measured from groundwater levels across the site (2009-2015).
Hydraulic conductivity	m/s	$1.0x10^{-5}$	$1.0x10^{-4}$	$1.0x10^{-3}$	2007 HRA (calculated from PSD data)
Porosity	-	0.25	-	0.4	2007 HRA (typical value for gravelly sands from Consim manual)
Density	kg/l	-	1.8		2009 HRA (typical value for gravelly sands)
Organic carbon content	-	0.0002	0.0006	0.001	2009 HRA (based on site measurements)
Longitudinal Dispersivity	m	10% of pathway length			LandSim default
Transverse Dispersivity	m	10% of longitudinal dispersivity			LandSim default

Notes: Parameters in italic indicate change from 2015 HRA LandSim model. Where two input values are given this indicates that a uniform distribution was used for probabilistic modelling; where three input values are presented then a triangular distribution was used. Where the range of values was more than 2 orders of magnitude a log uniform or log-triangular distribution was used.

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