



AMGEN
C y m r u

ALTERNATIVE SOLUTIONS
IN WASTE MANAGEMENT

BRYN PICA
LLWYDCOED
ABERDARE
CF44 0BX

Our Reference: LF/ljf/368

Date: 05.05.16

FAO Gwyn Jones
Environment Agency Wales
Rivers House
St. Mellons Business Park
St. Mellons
Cardiff
CF3 0EY

Dear Gwyn,

Re: Bryn Pica Landfill Site – PPC Permit No. DP3732SQ, 2015 Annual Report, Required Under Section 4.2 of the PPC Permit.

Section 4.2 of the Bryn Pica Landfill PPC Permit states:

A report or reports on the performance of the Activities over the previous year shall be submitted to the Agency by the 31st January (or other date agreed in writing by the Agency) each year.

Please find attached a report detailing those aspects requiring review under section 4.2 of the PPC Permit for the site.

With regards to item (f) no contamination or decontamination of the site has occurred during the reporting period. We have therefore not included any details relating to this matter in the report.

Should you have any queries with regards to the content of the report the please give me a call on 01685 870770.

Yours Sincerely,

Lee Foulkes
Technical Manager



Working in Partnership with
Rhondda Cynon Taf County Borough Council



Report No: AC2016/ENV/01
April 2016



**REVIEW OF ENVIRONMENTAL MONITORING
UNDERTAKEN AT THE
BRYN PICA LANDFILL SITE DURING THE PERIOD
JAN 15 – DEC 15**

**Amgen Cymru
Bryn Pica Landfill Site
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Executive Summary

Amgen Cymru has carried out a review of the results of environmental monitoring activities undertaken at the Bryn Pica landfill site, during 2016.

The submission to the Environment Agency (EA) of a periodic review of environmental monitoring results is required under Section 4.2 of the sites Environmental Permit. It is outlined in this document that such a review should include:

- a) A review of the results of the monitoring and assessment carried out in accordance with this permit against the relevant assumptions, parameters and results in the risk assessments submitted with the Application.*

The purpose of this report is to fulfil the above requirement of Section 4.2 Reporting to the Environmental Permit for the Bryn Pica Landfill Site, Rhondda – Cynon – Taff.

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REVIEW OF ENVIRONMENTAL MONITORING RESULTS COLLECTED DURING THE PERIOD JANUARY 2015 – DECEMBER 2015

1. INTRODUCTION

1.1 Terms of Reference and Context

- 1.1.1 Amgen Cymru (Amgen), [which is the trading name for the site licence holders Cynon Valley Waste Disposal Company Ltd] has carried out a review of the results of the environmental monitoring activities carried out at the Bryn Pica landfill site.
- 1.1.2 Amgen has operated the Bryn Pica Landfill Site since it began operating in 1993, when filling of the now restored Phase 1 began. The current EP Permit for the landfill area of the site (Number DP3732SQ) was issued by the Environment Agency initially on the 28th June 2006 as a PPC Permit, before transferring to an EP Permit on the 6th April 2008, which sets out the statutory requirements for the site's environmental management.
- 1.1.3 The site is currently active and accepting non-hazardous wastes. The site was operating under a Waste Management Licence (WML) until June of 2006 when the issue of the Permit superseded the WML for the landfill area of the site.
- 1.1.4 This document provides a review of leachate, groundwater and surface water monitoring carried out at the site during the period Jan 15 - Dec 15. This information has been reviewed in conjunction with previous monitoring results to provide for long term environmental trends.
- 1.1.5 Landfill Gas monitoring carried out at the Bryn Pica Landfill Site is reviewed separately in report no. AC2016/ENV/02 submitted in conjunction with this report.

1.2 Scope of Work

- 1.2.1 The submission to the Environment Agency (EA) of a periodic review of environmental monitoring results is required under Section 4.2 of the site permit conditions. It is outlined in this document that such a review should include:
- a) *A review of the results of the monitoring and assessment carried out in accordance with the Permit against the relevant assumptions, parameters and results in the risk assessments submitted with the Application;*
- 1.2.2 This report constitutes Amgen's submission under 4.2 (a) of the Environmental Permit for the Bryn Pica Landfill Site and includes analysis of:
- Leachate Monitoring
 - Surface Water Quality Monitoring
 - Groundwater Quality Monitoring

1.3 Environmental Assessment Criteria

- 1.3.1 As outlined in the Environment Agency's 'Guidance on monitoring of landfill leachate, groundwater and surface water', the results of Amgen's environmental monitoring exercises at the Bryn Pica site are compared to a series of assessment criteria.
- 1.3.2 These are intended to draw the attention of site management and the regulator (now NRW, formerly EA Wales) to the development of any adverse trends in environmental management at the site.

Environmental Assessment Limits

- 1.3.3 Environmental Assessment Limits (EAL's) are used in this report to quantify the potential impact the Bryn Pica landfill is having on proximal surface water and groundwater environments.
- 1.3.2 For those relevant leachate contamination determinands, monitoring results have been compared to EAL's, deemed to be the most appropriate Water Quality Standard (WQS), as published in Appendix A8 of the EA's guidance on Hydrogeological Risk Assessments for landfills (LFTGN01, April 2003), namely:
- **EQS-FWTR** Freshwater Environmental Quality Standards;
 - **WHO-GV** World Health Organisation (WHO) lifetime exposure guidelines;
 - **WHO-ATO** WHO Limits for effects on appearance, taste, or odour; or
 - **DWS-UK** UK Drinking Water Standards.
- 1.3.3 For the purpose of consistency the UK Drinking Water Standard (DWS-UK) values are used by this report as the default EAL, where specific contaminants are not represented in the DWS-UK standards, one of the alternative standards has been used.

Environmental Trends and Background Levels

- 1.3.4 Section 4 provides a consideration of long term trends of environmental monitoring results collected by Amgen at the Bryn Pica Landfill Site, during the period Feb 00 – Dec 15.

2. SITE DESCRIPTION

2.1 Site Location and Surroundings

- 2.1.1 The Bryn Pica Landfill Site is located approximately 4 km North of Aberdare at National Grid Reference (NGR) SO 010 047, at an elevation of between 260 – 350 mAOB, on the Northern slope of the Cynon Valley. The sites location in relation to its environmental setting is illustrated in Dwg. No. AC2015/ENV/01/001 (Site Location Plan).
- 2.1.2 The landfill waste disposal facility at the Bryn Pica site has been established in former opencast coal workings, with some mined coal seams beneath. The site also contains site offices, a Materials Recycling Facility (MRF), a Sorting Shed, a Landfill Gas Power Generation Scheme and a Leachate Treatment Plant (LTP).
- 2.1.3 In July 2011 the Company relocated the Community Recycling Centre (CRC Site) from Bryn Pica to the Ty Amgen Site. The Ty Amgen site is located approximately 1 mile down the road towards the village of Llwydcoed in the Waste Management Facility previously operated by Parle Skip Hire.

2.2 Environmental Setting

- 2.2.1 A detailed assessment of the Bryn Pica landfill site in relation to its environmental setting is provided in Report Number AM5458/ESID produced as part of the sites PPC Permit application. The main details of which are summarised below:

Hydrogeology:

- 2.2.2 The Bryn Pica landfill site overlies the North limb of the South Wales Coalfield Syncline, comprising Carboniferous middle and lower coal measure strata. These comprise cyclic deposits with aquifer forming rocks (i.e. sandstones) separated by non-aquifer forming rocks (i.e. siltstone, mudstone, coals and associated argillaceous horizons).
- 2.2.3 Typical for the area, coal seams are crossed with several faults, with a large fault system (Werfa Fault) running just North of the site.
- 2.2.4 The majority of coal seams underlying the Bryn Pica landfill site have under gone extensive deep mining, with the Nine Feet and Gellideg seams proving highly productive. Below the Gellideg seam, as well as interspersing higher seams extensive ironstone formations were identified and worked.
- 2.2.5 The Bryn Pica site was extensively opencast during the 1950's and 1960's. During that period it is reported that occasional worked coal seams (and their associated shafts / adits) were exposed at the base of the open cast excavations. Following completion of the opencast mining at the site, backfilling of the opencast void was undertaken using the opencast waste arising. In place of the natural geology, a heterogeneous mix of sandstones, siltstones and mudstones now exists. In places this is known to be up to 70m thick.
- 2.2.6 It is anticipated that groundwater infiltrating the opencast backfill material is intercepted by deep mine workings. Previous studies have shown that the most likely discharge point for this deep mine groundwater is at the location of the Watercourse Level, which exits the hillside within the industrial area known as the Prysmian Cable Works, national grid reference (NGR) SN 997040.
- 2.2.7 Groundwater issuing from the Watercourse Level is discharged to the Avon Cynon a

short distance away at NGR 001035.

Hydrology:

- 2.2.8 During the period 2001 – 2009 the Avon Cynon between NGR SN 968 053 and SO 004 027 has been classified by the Environment Agency as being of very good quality (Class A).
- 2.2.9 The Nant-y-Derlwyn watercourse discharges to the Avon Cynon at NGR SO 994041 flowing in a south westerly direction along Mynydd Aberdar (originating at NGR SO 015058). This watercourse is located approximately 500m away from the Bryn Pica landfill site in a westerly direction.
- 2.2.10 Adjacent to the south of the landfill site an unnamed stream flows in a south westerly direction, joining the Avon Cynon at NGR SO 003 034.

2.3 Environmental Management Systems

- 2.3.1 The Bryn Pica site consists of 4 phases of landfill waste disposal. These include the Phase 1 Dilute and Disperse cell (completed Jun 01) and the containment cells of Phase 2 (comprising cell divisions 2a, 2b and 2c) and Phase 3 (comprising cell divisions 3a, 3bi and 3bii). Each of these landfill cells has now been completed and remediated with a landfill cap. Final landfill capping was progressed over an area of the completed Phase 4a landfill cell in 2014.
- 2.3.2 At the time of writing landfill operations are ongoing within the Phase 4b landfill cell. The average monthly waste input rate for Bryn Pica (according in gate receipts taken in Jan 15) is around 6,150 Tonnes per month. This equated to an annual input of circa 74,000 Tonnes.
- 2.3.3 Leachate and Landfill Gas management systems at the site are managed by Amgen staff and Infinis (Landfill Gas to Energy Contractor). These systems protect local environmental receptors from the potentially harmful effects of leachate and landfill gas generation.

Phase 1 Leachate Management

Phase 1 of the Bryn Pica landfill consists of a 6 ha basal area of unlined waste, situated on a significant thickness of opencast backfill material. The cell contains approximately 1.5 million cubic metres of domestic, commercial and non-hazardous industrial waste.

A permanently engineered cap has been constructed over 5.3 ha of the western flank and top surface of the Phase 1 landform. This limits water infiltration in Phase 1 and is combined with a surface water drainage system that discharges clean surface water run off to a local water-course.

A large inert bund structure has been constructed around the base of the western flank of Phase 1 restricts leachate migration in this direction. Leachate drainage measures have been installed at the base of this bund, with leachate draining to a local lagoon, prior to it being pumped to the leachate containment system (attenuation lagoons located at the South Western margin of the site).

The eastern or 'internal' slope created by Phase 1 forms part of subsequent containment cells 2a – 3bii. An intermediate cap (consisting of 500 mm of opencast backfill) has been applied to this area to limit infiltration into the waste, with any contaminated run-off being directed to the contained leachate management system.

Phase 2a, 2b, 2c, 3a, 3bi and 3bii Leachate Management

Phases 2 and 3 of the Bryn Pica landfill are separated into 5 containment cells (cell 2a and 2b, cell 2c, cell 3a and cell 3b). Each cell consists of a composite basal liner (engineered barrier) and basal drainage system. Basal drainage is provided by a 300 mm thick, non-calcareous, clean stone blanket laid with slotted HDPE pipe acting as preferential drainage pathways. The basal drainage system in phase 2b and 3a consists of recycled whole tyres constructed as to provide a 300 mm drainage blanket on compaction. The basal drainage system in phase 3b consists of recycled, shredded tyres constructed to provide a 500mm drainage blanket on compaction.

Water entering areas of phase 2 and 3 through the working face (or area of intermediate capping) transgress through the waste profile towards the base of the cell. At this point it is captured by the basal liner and drainage system before being actively removed and disposed of to foul sewer.

Approximately 3.0 ha of cell 2a/b has been permanently covered with an engineered landfill cap. This intercepts precipitation prior to contact with waste materials. The resulting clean (uncontaminated) surface water drainage is directed to the surface water management system and discharged to a local water course.

Capping works undertaken in 2010 consisted of approximately 0.7 hectares of temporary (plastic) capping on the eastern flank of cell 3b.

Phase 4a Leachate Management

Leachate Management within the Phase 4a Landfill Containment Cell is facilitated through the use of a 300mm thick stone (aggregate) drainage blanket installed over the base of the cell. A Sidewall Riser type leachate extraction point is used to remove leachate from the base of the cell, which is then pumped to the Leachate Attenuation Lagoons via a dedicated pipeline.

Phase 4b Leachate Management

Similar to previous landfill cells at Bryn Pica, the base of Phase 4b is furnished with 300mm drainage blanket. The cell is equipped with 2 sidewall riser pipes for leachate extraction and 2 vertical leachate monitoring chambers. Pumping arrangement within the cell is made through the use of two submersible type pumps operating in a duty and standby arrangement.

Leachate Treatment Plant

The Bryn Pica Landfill is equipped with a Biological Leachate Treatment Plant able to treat high strength leachate at a rate of up to 200 m³ per day.

Throughout 2015 the plant effectively treated up to 200m³ of high strength leachate (700 – 1200mg/l NH₄ as N) per daily cycle, producing effluent with a NH₄ value of less than 5mg/l. In turn treated effluent is discharged to the foul sewer network via 1.5 km of underground pipeline.

Landfill Gas Management

Landfill gas (LFG) production at Bryn Pica is controlled using an active gas extraction and power generation system. This consists of a series of vertical gas extraction wells evenly spaced over the surface of the landfill. Fugitive LFG emissions are further limited through the presence of the engineered and intermediate cap. Further information relating to the landfill gas management system is provided in report AC2016/ENV/02, submitted in conjunction with this report.

3. LEACHATE, GROUNDWATER AND SURFACE WATER

3.1 Leachate, Groundwater and Surface Water Analysis Suites

3.1.1 The Bryn Pica Landfill Site – Environmental Management System (EMS) outlines the manner in which leachate, groundwater and surface water samples are obtained from the site along with a suggested suite of chemical analysis for each of these groups.

3.1.2 Laboratory analysis of a range of water chemistry determinants are required on a monthly, quarterly and annual frequency, depending on their association with leachate contamination, presence in waste materials deposited at the site, and the logistics involved in accurately quantifying their presence.

3.1.3 Tables 1a, 1b and 1c (Appendix B) reproduced from the EMS, detail the analysis required for leachate, groundwater and surface water monitoring (respectively). The timetable via which the operator implemented these analysis suites on leachate, groundwater and surface water is illustrated in Table 3.1, below.

Table 3.1: Amgen's implementation of the required chemical analysis suites for leachate, groundwater and surface water monitoring at the Bryn Pica site during the period January 2015 – December 2015.

Bryn Pica - Leachate Analysis 2015												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Analysis Suite	27.1	24.2	29.3	29.4	19.5	23.6	22.7	18.8	22.9	20.10	19.11	8.12
Date of Monitoring	Mon	Mon	Qtr	Mon	Mon	Qtr	Mon	Ann	Mon	Qtr	Mon	Mon
Bryn Pica - Groundwater Analysis 2015												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Analysis Suite	20.1	17.2	25.3	27.4	20.5	16.6	28.7	25.8	30.9	27.10	24.11	9.12
Date of Monitoring	Mon	Mon	Qtr	Mon	Mon	Qtr	Mon	Ann	Mon	Qtr	Mon	Mon
Bryn Pica - Surface Water Analysis 2015												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Analysis Suite	20.1	17.2	25.3	27.4	20.5	16.6	25.7	25.8	30.9	27.1	24.4	9.12
Date of Monitoring	Mon	Mon	Mon	Mon	Mon	Mon	Mon	Mon	Mon	Mon	Mon	Mon

3.2 Leachate Monitoring Results January 2013 – December 2015

3.2.1 Throughout the period Jan 15 – Dec 15 Amgen Cymru carried out leachate monitoring at 9 fixed points, representing various aspects of leachate generation at Bryn Pica. The location of these monitoring points is illustrated in Drg. No: AC2016/ENV/01/002 and a short description of each follows:

- **P1L2** (Phase 1 Leachate) – At this location leachate samples are obtained directly from the waste contained within Phase 1 via a redundant leachate re-circulation well.
- **L20** (Phase 1 Western flank Lagoon) – Leachate sampled from a storage lagoon situated at the base of the Phase 1 western flank. The direction of basal leachate drainage in phase 1 is westerly towards the retaining bund (inert). A system of drains within the retaining bund removes any basal leachate flow (as well as sub cap drainage) from the waste directing it to the western flank lagoon. Post capping of Phase 1, the volumes of leachate associated with this system has been significantly reduced, with no leachate flow available for sampling during the period Jan 15 – Dec 15.
- **P2aL1** (Phase 2 Leachate) – Samples representative of the leachate contained within Phase 2 are obtained from the Cell 2a pumping station. This consists of a leachate sump located directly within the Phase 2 waste mass connecting into the 300 mm basal leachate drainage blanket. Leachate level is also recorded at this point.
- **P2cL1** (Phase 2 Leachate) – Samples representative of the leachate contained within Phase 2c were attained from the Cell 2c pumping station during 2005. This consisted of the leachate sump located directly within the Phase 2 waste mass connected into the leachate drainage blanket.
- **P3aL1** (Phase 3a Leachate) – As Phase 3 of the landfill became operational in the first half of 2006 samples of leachate from Phase 3 were collected from the Cell 3a pumping station. This consists of the leachate sump located directly within the Phase 3 waste mass connected into the leachate drainage blanket. Leachate level is also recorded at this location.
- **P3bL1** (Phase 3b Leachate) – The second cell within Phase 3 became operational during the latter part of 2007. Phase 3a of the Bryn Pica Landfill is equipped with a side-slope riser leachate extraction point. Samples of leachate are gained from this location for chemical testing and leachate level recorded.
- **P4aL1** (Phase 4 Leachate) – Phase 4a of the Bryn Pica Landfill is equipped with a side-slope riser leachate extraction point. Samples of leachate are gained from this location for chemical testing and leachate level recorded. This phase is also equipped with vertical monitoring point identified by the monitoring ID's P4a(i) and P4a(ii). Leachate levels are recorded at this location; subject to the location of tipping operations and other access considerations.
- **LD1** (Leachate Attenuation Lagoon) – Leachate is sampled from the site's leachate attenuation lagoons prior to treatment within the Leachate Treatment Plant, followed by disposal to the foul sewer network. It represents leachate collected from all the above locations.

3.3 Leachate Level

- 3.3.1 Leachate levels within the containment landfill cells are required to be maintained below 1.0 m (i.e. 1.0 m above the basal lining system). Leachate levels are monitored monthly within leachate collection sumps located in Cell 2a, Cell 2c, Cell 3a, Cell 3b and Cell 4a. These facilities are in hydraulic continuity with the basal drainage system (consisting of 300mm layer of drainage aggregate or equivalent depth of recycled tyres).
- 3.3.2 Amgen Cymru staff have continued to undertake monthly dip measurement of the leachate level residing within the landfill containment cells at the Bryn Pica Landfill. The results show that the leachate levels within the landfill site continue to be maintained within the 1m (above the basal liner) required by the Environmental Permit for the site.

3.4 Leachate contaminants monitored by Amgen Cymru at the Bryn Pica landfill site during the period January 2011 – December 2015.

- 3.4.1 Table 3.3 presents a comparison of contaminant concentrations in leachate sampled at Bryn Pica (Phases 1,2,3 and 4) compared with those sampled at 28 other municipal landfills in the UK (DoE Research Report No. CWM 072/94 1995).
- 3.4.2 The data suggests that leachate sampled at Bryn Pica is consistent in comparison to the UK average values reported by the DoE in 1995, with a few exceptions e.g. sulphate and chromium values recorded in leachate sampled at all monitoring points Phase 1 (monitoring ID: P1L1), Phase 2 (monitoring ID: P2aL1 & P2cL1), Phase 3 (monitoring ID: P3aL1 & P3bL1) and the Attenuation Lagoons (monitoring ID: LD1). Within the Phase 4a landfill cells, several determinants actually exceed those reported by the DOE in 1995, this is typical of an immature leachate.

Phase 1

- 3.4.3 During the four year period Jan 11 to Dec 15, results of leachate sampling from within the Phase 1 landfill area have shown a good degree of consistency. The majority of parameters analysed are consistent with the DoE 1995 average values for landfill leachate. For example; the average value of Electrical Conductivity calculate for samples taken from Phase 1 in 2015 is calculated as being 12,964µS/cm compared to the 1995 DoE average of 11,502 µS /cm.
- 3.4.4 The average value of ammonia in leachate sampled from Phase 1 throughout 2015 is calculated as being 1,143mg/l NH₄ as N. This is slight reduction when compared with the value calculated for 2014 (1,152 mg/l NH₄ as N). These values are slightly above the DoE 1995 published average for non-hazardous landfill leachate (DoE, 1995 Average of 889 mg/l NH₄ as N). No significance has been drawn in relation to this observation. Concentrations of ammonia in leachate sampled from Phase 1 are similar in magnitude to those identified in leachate samples taken from other landfill cells at the site.

Phase 2

- 3.4.5 Throughout the period Jan-15 to Dec-15, Amgen staff collected a total of 12 samples from the Phase 2a landfill cell. Results of analysis on effluent captured from cell 2a suggest it to be slightly weaker in nature when compared to that produced in adjacent landfill cells. For example:

- The average ammonia concentration reported for Phase 2a in 2015 was 1,024 mg/l NH₄ as N compared to 1,167 mg/l and 2,440 mg/l for 2c and 3a respectively.
- This is also reflected in results of the analysis of electrical conductivity, averaging 11,454 uS/cm³ in samples taken from cell 2a throughout 2015, compared to 17,400 uS/cm³ in samples obtained from cell 2c.

3.4.6 Leachate sampled from within Landfill Cell 2c remains reasonably strong, with a number of key determinands illustrating average annual concentrations above those values report by the DoE in 1995. The Phase 2c Landfill Containment Cell is isolated from other cells within Phase 2 and therefore can be expected to produce leachate with a slightly differing characteristic.

3.4.7 Waste contained within Phase 2c is approximately 2 - 3 years younger than waste contained within Phase 2a and 2b. When compared with leachate sampled in Phase 2a, leachate samples taken from Phase 2c show higher concentrations of substances such as: Alkalinity, Ammonia and Electronic Conductivity. This observation is consistent with the comparative age of the wastes and indicates that leachate produced within Phase 2c is less mature in nature.

3.4.8 Previous reports have indicated that the strength of leachate sampled from within Phase 2c had been increasing year on year since 2010. However results from leachate samples taken during 2015 suggest that this has ceased to be the case. The average ammonia concentration in samples taken from Phase 2c during 2015 is reported as being 1,667 mg/l, compared to 1,907 mg/l in 2014.

Phase 3

3.4.9 Landfill leachate sampled within the Phase 3a and landfill cell has shown a slight increase in concentration throughout 2015. The effluent generated within the landfill at this location is the most concentrate of all of the leachate monitoring points at the site. Throughout 2015 sample of leachate from the cell 3a illustrated ammonia concentrations in the region of 2,440 mg/l NH₄ as N and electronic conductivity around 25,000 uS/cm³. This is accompanied by very high levels of other typical leachate contaminants such as chloride and potassium.

3.4.10 Tipping commenced in Phase 3a in August 2006; it can be noted that overtime the leachate sampled from this landfill cell is increasing in maturity. This is supported by the observation that the level of Ammoniacal Nitrogen, Alkalinity and Electrical Conductivity have increased at a steady rate over the previous 4 year period.

3.4.11 Previous monitoring results have indicated that the strength of leachate sampled from within Phase 3b had been steadily increasing year on year since 2011. However results from leachate samples taken during 2015 suggest that this has ceased to be the case. The average ammonia concentration in samples taken from Phase 3a during 2015 is reported as being 1,956 mg/l, compared to 1,906 mg/l in 2014.

Phase 4a

3.4.12 Landfill leachate sampled within the Phase 4a and landfill cell has increased in concentration throughout 2015. This trend is clearly illustrated in records of ammonia concentrations detected within sample taken from this area of the landfill. For example:

- Ammonia (NH₄ as N) concentration increased from 770 mg/l (annual average) in 2011 to 1,439 in 2015 mg/l.

- Electronic Conductivity recorded in samples taken throughout 2015 averaged 15,600 uS/cm³, compared to 13,747 uS/cm³ in 2013 and 9,190 uS/cm³ in 2011.
- This is accompanied by increasing levels of other typical leachate contaminants such as chloride and potassium.

Bulk Effluent

3.4.13 The leachate attenuation lagoons located at Bryn Pica can be seen to represent the bulk leachate produced from all the containment cells within the landfill (i.e. Phases 2, 3 and 4). The leachate is mixed and allowed to settle in the lagoons, before being transferred to the Leachate Treatment Plant. Leachate sampled at this location is identified as LD1 in the Company's leachate sampling program.

3.4.14 Overall the leachate sampled at LD1 continues to show a high degree of consistency with the average values reported by the DoE in 1995. Whilst values of individual determinands have fluctuated over the previous 5 year period, the baseline is fairly consistent around the DoE averages.

3.4.15 Time series plots for a range of leachate quality determinants monitored by AC during the period Aug 00 – Dec 15 have been produced (Appendix C).

Table 3.2: Annual average concentration of the principal leachate contaminants monitored by Amgen Cymru at the Bryn Pica landfill site during the period Jan 11 - Dec 15, compared with those national averages reported in DoE Research Report No. CWM 072/94 (DoE 1995).

Determinant	Units	DoE (1995)	BP – Phase 1					BP – Phase 2a					BP - Phase 2c				
			2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Alkalinity	mg/l	5,376	5,237	5,700	5,360	N/R	5,753	4,034	3,399	N/R	N/R	5,060	6,806	8,477	N/R	N/R	7,917
Ammonia	mg/l	889	483	1,163	1,142	1,152	1,143	711	652	689	756	1,024	1,276	1,477	1,672	1,907	1,667
Conductivity	uS/cm	11,502	6,323	12,000	12,212	12,667	12,964	6,667	7,263	7,614	8,707	11,454	13,345	15,733	17,380	18,767	17,400
BOD	mg/l	374	361	130	92	121	112	118	91	85	139	123	522	4,608	506	475	554
COD	mg/l	2,307	1,112	2,365	2,259	2047	2,045	1,273	995	1,002	1101	1,599	2,938	8,933	3,196	3,893	3,030
Cadmium	mg/l	0.015	<0.002	N/D	N/D	0.001	<0.001	<0.002	N/D	N/D	<0.002	0.121	<0.002	N/D	N/D	<0.002	N/D
Chloride	mg/l	2,074	658	1,288	1,323	1352	1,364	819	748	757	870	1,119	1,383	1,673	2,148	2,040	1,853
Chromium	mg/l	0.09	0.192	0.07	0.08	0.10	0.08	0.11	0.08	0.05	0.13	0.24	0.371	-	0.51	0.63	0.39
Iron	mg/l	27.4	3.3	8.7	18.3	34.6	18.9	3.9	3.7	3.3	6.5	11.4	2.8	-	6.8	43.9	1.6
Lead	mg/l	0.2	0.007	0.12	0.23	0.36	0.18	<0.002	0.008	0.006	0.007	0.013	0.007	-	0.016	0.017	0.003
pH	mg/l	7.52	7.5	8	8.0	7.8	7.9	7.6	7.8	7.8	7.8	7.9	7.7	7.8	8.0	8.0	7.7
Potassium	mg/l	854	352	463	469	446	446	289	249	273	302	404	585	761	882	750	672
Sodium	mg/l	1,480	684	1,170	1,255	1210	1,298	730	566	395	854	1,206	1,300	-	1,530	1810	1,590
Sulphate	mg/l	67	73	N/D	<200	6	10	79	N/D	<100	15	12	317	438	172	25	8.2
TOC	mg/l	733	479	1,154	698	636	588	627	491	398	327	437	1,284	2,650	1,328	1,157	1,077
TON	mg/l	0.86 – 1.03	<1	N/D	N/D	N/D	N/D	1.7	5.2	8.5	7.6	6.0	<1	0.4	N/D	N/D	N/D

Determinant	Units	DoE (1995)	BP - Leachate Discharge Lagoons (LD1)					BP - Phase 3a					BP - Phase 3b				
			2011	2012	2013	2014	2015	2011	2012	2013	2014	2015	2011	2012	2013	2014	2015
Alkalinity	mg/l	5,376	4,443	4,691	N/R	N/R	3,142	6,598	8,037	N/R	N/R	11,550	8,767	6,903	N/R	N/R	9,057
Ammonia	mg/l	889	722	812	859	758	550	1,082	1,597	N/R	2,632	2,440	1,637	1,303	N/R	1,906	1,956
Conductivity	uS/cm	11,502	8,631	9,515	9,468	9,342	8,523	11,564	17,067	N/R	24,450	25,000	16,357	13,286	N/R	18,171	17,682
BOD	mg/l	374	556	750	546	995	268	1,090	3,495	N/R	1,820	2,350	266	936	N/R	710	456
COD	mg/l	2,307	2,580	2,387	2,144	2812	1,434	3,545	7,247	N/R	7,660	8,365	3,744	3,334	N/R	3,984	3,922
Cadmium	mg/l	0.015	<0.0020	N/D	N/D	<0.002	<0.001	<0.002	N/D	N/R	<0.002	<0.001	<0.002	N/D	N/R	<0.002	<0.001
Chloride	mg/l	2,074	974	1,047	1,171	990	931	1,330	1,770	N/R	2,590	2,693	1,787	1,426	N/R	1,736	1,838
Chromium	mg/l	0.09	0.192	0.22	0.18	0.196	0.266	0.377	-	N/R	0.968	0.883	0.576	0.388	N/R	0.432	0.552
Iron	mg/l	27.4	3.29	4.2	3.9	3.7	5.6	5.3	-	N/R	4.3	2.8	6.16	8.63	N/R	10.35	11.2
Lead	mg/l	0.2	0.007	0.010	0.014	0.007	0.006	0.009	-	N/R	0.011	0.008	0.012	0.016	N/R	0.006	0.006
pH	mg/l	7.52	8.1	8.1	8	7.9	8.2	7.6	7.7	N/R	8.0	7.9	7.8	7.7	N/R	7.7	7.8
Potassium	mg/l	854	392	456	477	394	353	534	800	N/R	957	943	719	628	N/R	684	694
Sodium	mg/l	1,480	684	912	916	807	1,242	1,390	-	N/R	2,457	2,420	1,550	1,425	N/R	1,695	1,880
Sulphate	mg/l	67	93	26	<100	<10	24	245	108	N/R	19	N/D	128	67	N/R	53	N/D
TOC	mg/l	733	961	631	1,342	789	422	1,432	2,453	N/R	2,658	2,763	1,398	991	N/R	1,216	1,298
TON	mg/l	0.86 – 1.03	<1	N/D	N/D	N/D	85	<1	N/D	N/R	N/D	N/D	<1	N/D	N/R	1.1	0.6

Determinant	Units	DoE (1995)	BP – Phase 4a					BP – Phase 4b				
			2011	2012	2013	2014	2015	2015				
Alkalinity	mg/l	5,376	4,710	5,845	4,490	N/R	7,164	7,093				
Ammonia	mg/l	889	770	1,015	1,169	1,186	1,439	1,296				
Conductivity	uS/cm	11,502	9,190	11,351	13,747	13,643	15,680	15,767				
BOD	mg/l	374	548	1,031	644	223	234	213				
COD	mg/l	2,307	2,710	3,202	2,615	2,108	2,602	2,367				
Cadmium	mg/l	0.015	-	N/D	N/D	<0.002	<0.001	<0.001				
Chloride	mg/l	2,074	1,022	1,289	1,730	1,464	1,732	1,677				
Chromium	mg/l	0.09	-	0.254	0.344	0.402	0.577	0.514				
Iron	mg/l	27.4	-	7.1	3.6	1.6	1.9	13.9				
Lead	mg/l	0.2	-	0.006	0.011	0.006	0.010	0.013				
pH	mg/l	7.52	7.2	7.6	7.8	7.6	7.7	7.6				
Potassium	mg/l	854	417	570	638	681	607	736				
Sodium	mg/l	1,480	-	-	1,470	1,485	1,835	1,490				
Sulphate	mg/l	67	845	19	132	15	6.1	1.7				
TOC	mg/l	733	1,224	905	919	771	788	812				
TON	mg/l	0.86 – 1.03	4.1	N/D	N/D	N/D	N/D	0.0				

3.5 Groundwater quality monitored by Amgen at the Bryn Pica landfill site during the period January 2013 – December 2015

3.5.1 Amgen currently uses 17 groundwater monitoring installations for the purpose of observing groundwater water quality. The relative location of these monitoring points is illustrated in Drg. No. AC2016/ENV/01/003 and a description of them in relation to the hydrogeological risk assessment for the site is provided below.

3.5.2 Groundwater monitoring installations at the Bryn Pica landfill site can be divided into the following 3 groups according to their 'target' ground conditions:

- **Those borehole installations designed to monitor groundwater infiltration through the open cast backfill:** Namely GW 3 and GW 5. Monitoring borehole GW 3 is consistently dry indicating there is no standing groundwater table at this location. Within GW 5, a standing groundwater table is typically observed between 180 - 190 m AOD (See Document AM5458/ESID for further detail).
- **Those borehole installations designed to monitor groundwater present within the Middle Coal Measure Strata (MCM):** Namely GW 1, GW 2, GW 4, GW 6, GW07BH1, GW07BH2, GW07BH3, GW07BH4, GW07BH5, GW08BH9, GW08BH10, GW09BH01, GW09BH02 and GW09BH03. Monitoring boreholes GW1, GW 2, GW 4, GW07BH1, GW07BH2, GW07BH3, and GW08BH9 are consistently dry indicating there is no standing groundwater table at these locations.

Within GW 6, a standing groundwater level of 180 - 190 m AOD is typically observed.

GW07BH4 and GW07BH5 have standing groundwater level of 260-295 m AOD typically.

GW08BH10 was constructed in August 2008 and illustrated a standing groundwater head of approximately 12 m above the base of the installation. This would equate to approximately 130 – 140 m AOD.

GW09BH01 was constructed in July 2009 and illustrated a standing groundwater head of approximately 26 m above the base of the installation. Amgen staff have been unable to extract groundwater samples from this installation since June 12. It is suspected that the installation has suffered a degree of collapse, thus making it unserviceable.

GW09BH02 was constructed in July 2009 and illustrated a standing groundwater head of approximately 26 m above the base of the installation. Amgen staff have been unable to extract samples from this monitoring installation since Aug 12. It is suspected that the installation has suffered a degree of collapse, thus making it unserviceable.

GW09BH03 was constructed in July 2009 and illustrated a standing groundwater head of approximately 42 m above the base of the installation. Amgen staff have been unable to extract groundwater samples from this installation since April 2011. It is suspected that the installation has suffered a degree of collapse, thus making it unserviceable.

- **Location of known mine-water surface issues (i.e. mine adits, drift entries) used for the purpose of monitoring the significant mine drainage in the area:** Namely GW 7. A significant volume of discharge is consistently observed and sampled at GW 7; a location situated a short distance upstream of the River Cynon (See Document AM5458/ESID for further detail).

3.5.3 The current understanding of the hydrogeological model for the Bryn Pica landfill site can be summarised as follows as described by report number AM5458/ESID produced as part of the sites PPC Permit application:

- Precipitation and potentially leachate released from the base of the landfill filters vertically through the opencast backfill, which is between 20 and 30 m thick below the landfill base. Previously there has been little indication of groundwater accumulation within the opencast backfill and it is not considered to be a groundwater resource (aquifer).
- The EA's groundwater vulnerability map of the area around the Bryn Pica Landfill Site shows it as Unclassified due to its history of industrial activity. The natural stratum is of lower and middle coal measures, which predominantly consists of siltstones, mudstones and coal horizons. Typically these strata do not support significant groundwater resources.
- Historical reports indicate that various worked coal seams were encountered at the base of the opencast mining operation at the Bryn Pica site. Due to the nature of the UCM strata (i.e. predominantly mudstone, siltstone and coal horizons) it is reasonable to suggest that a large proportion of the groundwater generated in the area is intercepted by the extensive network of worked seams (now abandoned).
- Following the abandonment of the mining network, worked coal seams have continued to drain naturally (under gravity), with surface issues having previously been identified at lower levels of the Aberdare Mountain. One of which, the Watercourse Level has been identified as being significant in draining the area beneath the Bryn Pica landfill site. Previous calculations (based on water balance estimations and monitored discharge volumes, Aspinwalls 1998) have suggested that the majority of groundwater generated within the area surrounding the Bryn Pica site is drained to this location (i.e. groundwater monitoring location GW 7).

3.5.4 Annual averages have been calculated for the main groundwater quality determinands monitored at the site by Amgen Cymru during the period January 2013 to December 2015. These values have been summarised, below in Tables 3.4, 3.5 and 3.6, for 2013, 2014 and 2015 respectively. The identity and value of the chosen EAL is indicated, with any exceedances highlighted in **bold** type.

Table 3.3: Annual Average Groundwater Concentrations monitored at the Bryn Pica Landfill Site during the period Jan 13 – Dec 13.

Potential Contaminant	Units	EAL		GW 1	GW 2	GW 3	GW 4	GW 5	GW 6	GW 7	GW07 BH01	GW07 BH02	GW07 BH03	GW07 BH04	GW07 BH05	GW08 BH1	GW08 BH2	GW09 BH1	GW09 BH2	GW09 BH3
Ammoniacal Nitrogen (as N)	mg/l	DWS	0.5	-	-	-	-	N/D	0.02	N/D	-	-	-	-	0.14	-	-	-	-	-
Cadmium	mg/l	DWS	0.005	-	-	-	-	N/D	N/D	N/D	-	-	-	-	N/D	-	-	-	-	-
Calcium	mg/l	DWS	250	-	-	-	-	99	66	57	-	-	-	-	15	-	-	-	-	-
Chloride	mg/l	DWS	250	-	-	-	-	9.3	9.7	17.5	-	-	-	-	13.4	-	-	-	-	-
Chromium	mg/l	DWS	0.05	-	-	-	-	0.0005	N/D	N/D	-	-	-	-	N/D	-	-	-	-	-
Copper	mg/l	DWS	2	-	-	-	-	0.633	N/D	1.760	-	-	-	-	0.580	-	-	-	-	-
EC @ 20oC	µS/cm	DWS	1500	-	-	-	-	1425	540	718	-	-	-	-	222	-	-	-	-	-
Iron	mg/l	EQS	1	-	-	-	-	62.0	421.6	N/D	-	-	-	-	25.3	-	-	-	-	-
Lead	mg/l	DWS	0.01	-	-	-	-	N/D	N/D	N/D	-	-	-	-	N/D	-	-	-	-	-
Magnesium	mg/l	DWS	50	-	-	-	-	173	32	58	-	-	-	-	15	-	-	-	-	-
Nickel	mg/l	DWS	0.02	-	-	-	-	3.2	6.8	3.4	-	-	-	-	1.6	-	-	-	-	-
Nitrate (as NO3)	mg/l	DWS	50	-	-	-	-	N/D	N/D	0.75	-	-	-	-	0.02	-	-	-	-	-
Nitrite (as NO2)	mg/l	DWS	0.1	-	-	-	-	N/D	0.003	0.02	-	-	-	-	0.02	-	-	-	-	-
pH	-	DWS	5.5-9.5	-	-	-	-	6.9	7.0	7.3	-	-	-	-	6.9	-	-	-	-	-
Potassium	mg/l	DWS	12	-	-	-	-	32.0	7.3	20.9	-	-	-	-	8.5	-	-	-	-	-
Sodium	mg/l	DWS	200	-	-	-	-	10.0	5.8	21.2	-	-	-	-	8.1	-	-	-	-	-
Sulphate	mg/l	DWS	250	-	-	-	-	347	6	126	-	-	-	-	16	-	-	-	-	-
Zinc	mg/l	DWS	5	-	-	-	-	N/D	5.3	3.2	-	-	-	-	14.1	-	-	-	-	-

N / D - No actual values of substance identified at or above laboratory's minimum reporting value (MRV).

Table 3.4: Annual Average Groundwater Concentrations monitored at the Bryn Pica Landfill Site during the period Jan 14 – Dec 14.

Potential Contaminant	Units	EAL		GW 5	GW 6	GW 7	GW07 BH05	GW09 BH3
Ammoniacal Nitrogen (as N)	mg/l	DWS	0.5	<0.03	<0.03	0.05	0.03	0.33
Cadmium	mg/l	DWS	0.005	N/D	N/D	N/D	<0.0001	N/D
Calcium	mg/l	DWS	250	102	63	55	147	<u>263</u>
Chloride	mg/l	DWS	250	13	11	17	15	18
Chromium	mg/l	DWS	0.05	<0.005	<0.005	<0.005	<0.005	N/D
Copper	ug/l	DWS	2000	<0.001	N/D	0.002	N/D	0.002
EC @ 20oC	μS/cm	DWS	1500	1404	519	691	219	<u>2115</u>
Iron	mg/l	EQS	1	0.03	N/D	N/D	0.12	N/D
Lead	mg/l	DWS	0.01	N/D	N/D	N/D	N/D	N/D
Magnesium	mg/l	DWS	50	<u>166</u>	31	<u>54</u>	16	<u>194</u>
Nickel	ug/l	DWS	20.0	0.004	0.005	0.004	0.001	0.017
Nitrate (as NO3)	mg/l	DWS	50	N/D	N/D	<1	<1	N/D
Nitrite (as NO2)	mg/l	DWS	0.1	N/D	<0.004	<0.004	<0.004	N/D
pH	-	DWS	5.5-9.5	6.9	7.0	6.9	6.9	6.8
Potassium	mg/l	DWS	12	<u>31</u>	7	<u>20</u>	8	<u>27</u>
Sodium	mg/l	DWS	200	10	6	20	7	23
Sulphate	mg/l	DWS	250	<u>333</u>	21	118	21	<u>1070</u>
Zinc	mg/l	DWS	5	<0.005	0.006	0.007	0.010	0.085

N / D - No actual values of substance identified at or above laboratory's minimum reporting value (MRV).

Table 3.5: Annual Average Groundwater Concentrations monitored at the Bryn Pica Landfill Site during the period Jan 15 – Dec 15.

Potential Contaminant	Units	EAL		GW 5	GW 6	GW 7	GW07 BH05	GW09 BH3
Ammoniacal Nitrogen (as N)	mg/l	DWS	0.5	<0.03	<0.03	<0.03	<0.03	N/R
Cadmium	mg/l	DWS	0.005	N/D	N/D	N/D	N/D	N/R
Calcium	mg/l	DWS	250	100	66	58	16	N/R
Chloride	mg/l	DWS	250	11.3	8.8	18	14	N/R
Chromium	mg/l	DWS	0.05	N/D	<0.001	N/D	N/D	N/R
Copper	ug/l	DWS	2000	1.0	N/D	1.7	N/D	N/R
EC @ 20oC	µS/cm	DWS	1500	1,388	524	691	N/D	N/R
Iron	mg/l	EQS	1	0.05	N/D	N/D	0.04	N/R
Lead	mg/l	DWS	0.01	N/D	N/D	N/D	N/D	N/R
Magnesium	mg/l	DWS	50	<u>162</u>	32	<u>55</u>	15	N/R
Nickel	ug/l	DWS	20.0	3.2	1.8	N/D	N/D	N/R
Nitrate (as NO3)	mg/l	DWS	50	N/D	N/D	N/D	N/D	N/R
Nitrite (as NO2)	mg/l	DWS	0.1	N/D	N/D	N/D	N/D	N/R
pH	-	DWS	5.5-9.5	6.9	7.0	7.0	6.9	N/R
Potassium	mg/l	DWS	12	<u>30</u>	6	<u>20</u>	6	N/R
Sodium	mg/l	DWS	200	10	6	21	6	N/R
Sulphate	mg/l	DWS	250	<u>340</u>	23	125	17	N/R
Zinc	mg/l	DWS	5	0.005	0.002	0.006	0.002	N/R

N/D - No actual values of substance identified at or above laboratory's minimum reporting value (MRV).

- 3.5.5 The above comparison suggests that groundwater quality at the site has remained fairly static through the period Jan 13 – Dec 15. When comparing annual averages to the relevant water quality standards, groundwater sampled at the Bryn Pica landfill site, appears to be of good quality.
- 3.5.6 Time series plot for the range of groundwater quality determinants monitored by Amgen during the period Jan 00 – Dec 15 are provided in Appendix D. This information is summarised below in relation to the conceptual hydrogeological model for the site.

Ambient Groundwater Quality

- 3.5.7 Groundwater quality can vary significantly in the Middle and Lower Coal Measures throughout the South Wales area. Contamination of the groundwater occurs as mineral deposits exposed by mining are weathered and contaminants leached out. Typical water quality contaminants occurring in mining areas include iron, manganese, sulphate, potassium as well as high electrical conductivity.
- 3.5.8 Groundwater quality observed in GW07BH5, with updated information for 2015 in addition to previous years, provides a good set of data, showing ambient groundwater quality to be indicative of past mining activities and their associated contaminants. This is similar to results observed for many parameters of the groundwater sampled down-gradient of the site.

The Opencast Backfill Material

- 3.5.9 The opencast backfill material at Bryn Pica consists of a heterogeneous assemblage of mudstones, siltstones and sandstones, known to be up to 70 m thick in places across the site. This material is typically dry with little evidence of a standing groundwater table.
- 3.5.10 Given the free draining nature of the backfill material, it is thought that water entering from the surface (and potentially leachate discharge from the base) gravitates down towards the base of the opencast excavations. Thereafter entering abandoned mine workings that were intercepted by historic excavations.
- 3.5.11 Borehole installations GW 3 and GW 5 monitor potential groundwater contained within the opencast backfill at the Bryn Pica site. GW 3 is permanently dry, whilst GW 5 illustrated groundwater at a level between 180 - 190 m AOD. This demonstrates the variability of the opencast backfill material present at the site.

GW5

- 3.5.12 The groundwater monitoring installation GW5 is constructed to a depth of 22.5m and monitors groundwater quality within the opencast backfill at the Bryn Pica site. Groundwater sampled at GW5 is generally of a good quality, however there are a small number of determinants which have exceeded their associated EALs:
- Magnesium (Annual Average calculated for 2015: 162 mg/l)
 - Potassium (Annual Average calculated for 2015: 30 mg/l)
 - Sulphate (Annual Average calculated for 2015: 340 mg/l)
- 3.5.13 Those determinants exceeding their EALs have been identified as being associated with past mining activities as they are represented in both up-gradient and down-gradient groundwater samples. The levels of the referenced determinands identified at GW5 have been very consistent over the previous three years of monitoring. This would tend to indicate that they are not a result of any specific event but represent

the ambient water quality in groundwater contained within the Opencast Backfill material.

The Middle and Lower Coal Measures

- 3.5.14 Extensive mining of the middle and lower coal measures has removed the natural groundwater flow paths. These have most likely been replaced by preferential flow paths along old mineshafts and drainage adits.
- 3.5.15 The groundwater monitoring installations GW1, GW4, GW6, GW7, GW07BH1, GW07BH2, GW07BH3, GW07BH4, GW07BH5, GW08BH9, GW08BH10, GW09BH01, GW09BH02 and GW09BH03 all monitor groundwater quality in the coal measure strata beneath the site. GW1, GW07BH4 and GW07BH5 are considered to be up-gradient of the landfill. GW1, GW4, GW07BH1, GW07BH2, GW07BH3 and GW08BH9 are permanently dry; samples are taken from GW6, GW7, GW09BH01, GW09BH02 and GW09BH03, down-dip of the landfill site and GW07BH4 and GW07BH5 up-dip (these results were discussed above in the Ambient Groundwater Quality Section).

GW6

- 3.5.16 The groundwater monitoring installation GW6 is constructed to a depth of 82.5m. It monitors groundwater quality in the lower coal measure strata. Groundwater in GW6 is of good quality with only a small number of determinants averaging concentrations above their EAL's during the reporting period.
- 3.5.17 The results of groundwater monitoring undertaken during the period Jan 15 to Dec 15 indicates that groundwater in vicinity of GW 6 is of good quality. This is illustrated in Table 3.6 and it can be seen that there was no exceedance of the EALs presented.
- 3.5.18 Ammoniacal Nitrogen and Chloride levels detected in samples taken from groundwater monitoring installation GW6 are low, averaging <0.03 mg/l and 8.8 mg/l respectively. Given that these substances are key determinands in assessing the presence of landfill leachate, it is concluded that there is no indication that the landfill is having a detrimental impact on groundwater sampled at this location.

GW7

- 3.5.19 GW7 is an old mine drainage adit that drains the Gelli Deg and higher seams. The quality of the groundwater issuing from GW7 is good. During the reporting period the average concentrations calculated for the determinands analysed show the groundwater to generally be within UK-DWS.
- 3.5.20 Of the annual average concentration calculated for the groundwater monitoring installation GW 7 (as shown in table 3.6) it can be seen that the value for Potassium (2015 annual average value of 20 mg/l Potassium) is slightly above the EAL' adopted for this determinand (i.e. Drinking Water Standard of 12 mg/l). This was previously the case in corresponding monitoring results, reported in 2013 and 2014.
- 3.5.21 Given that the concentration of Ammoniacal Nitrogen and Chloride are both very low in samples taken from GW7, the above observation is not considered to be an indicative of any potential impact from the landfill site. Soluble metals such as Iron, Potassium and Magnesium are shown to present in up-gradient groundwater samples taken from within Middle Coal Measure Strata. It is likely that their elevated presence is a result of historical mining known to have occurred with the area.

GW14BH2

3.5.22 In 2014 Amgen Cymru progressed the installation of 3 new groundwater monitoring boreholes at locations down-gradient of the Bryn Pica Landfill. The location of these new ground monitoring installation was agreed to be closer to the edge of the landfill than the existing installation GW 5 and GW6. Of the 3 boreholes drilled only 1 (GW14BH2) return a standing head of water.

3.5.23 No samples have been obtained from these groundwater monitoring installations throughout 2015 due them being consistently dry. This observation is consistent with the conceptual hydrogeological model for the Bryn Pica Landfill Site. It is predicted that groundwater in the region of the site is drained by a large network of abandoned mine workings, essentially dewatering the ground around and beneath the landfill, reducing groundwater levels to depths beyond the reach of existing groundwater monitoring installation in this area.

Summary

3.5.24 In terms of its potential impact on groundwater resources, the Bryn Pica landfill site is considered to be low risk. The area surrounding the landfill has encountered both opencast and deep mining which has affected the hydrogeological regime at the site. The lower and middle coal measure strata beneath the site are not significant in terms of their potential to accommodate groundwater resources.

3.5.25 Given the history of deep mining at the site, it is likely that groundwater forms within the abandoned worked seams, from which it is drained to the surface via surface adits that exist in locations South West of the landfill.

3.5.26 Groundwater monitoring results for GW5, GW6, GW7, GW07BH05 show elevated levels of magnesium, potassium and iron concentrations. It is thought that these results are evidence of contamination from the coal and ironstone mining activities that occurred in the sites vicinity.

3.5.27 With regards to ambient groundwater quality at the Bryn Pica Landfill Site, results from GW07BH05 generally illustrated that groundwater is of a good quality. There are indications that ambient groundwater has been impacted by historic mining activities. These are represented by elevated level of Iron, Potassium and Magnesium all of which are typically associated with groundwater located in areas of historic coal mining.

3.5.28 In relation to potential leachate contamination derived from the Bryn Pica Landfill, monitoring of the principal leachate contaminants (i.e. ammonia NH_4 as N, chloride, nitrate, nitrite etc.) in groundwater suggests that the landfill is not having a determinable impact on groundwater quality.

3.6 Surface Water Quality Monitored by Amgen Cymru at the Bryn Pica Landfill Site during the Period January 2013 – December 2015

3.6.1 Amgen Cymru's surface water monitoring regime consists of 7 fixed monitoring points situated around the site. A description of the surface water monitoring regime is provided below, according to each relevant surface water course. The location of these monitoring points in relation to the landfill is illustrated in Drg. No. AC2016/ENV/01/004.

3.6.2 The surface water monitoring points along the Nant-y-Derlwyn stream are as follows:

- **SW1** (Upper Nant-y-Derlwyn) - Background surface water quality in the Nant-y-Derlwyn stream is monitored at SW1, which is located at NGR SO 0123 0575, approximately 550m north of the Installation. From this location, the stream flows down towards the site access road, at the northern end of the Installation.
- **SW 3** (Downstream of the old BPW landfill) – From the site access road, the stream is culverted beneath the old BPW landfill, for a distance of approximately 500m. Amgen continue to monitor any impact this old landfill has on the quality of surface water in the Nant-y-Derlwyn stream.
- **SW4a** (Lower Nant-y-Derlwyn) – Following its exit from beneath the old Bryn Pica West Landfill, the stream flows in a south westerly direction along the boundary of land owned by Amgen. Previously samples have been taken from SW4, on the downstream side of the abandoned railway line. However, since March 2005 samples have been taken from a point further down the Nant-y-Derlwyn due to health and safety concerns regarding access.

3.6.3 The surface water monitoring points located along the unnamed stream to the south of the Installation Boundary, which feeds the Ysguborwen Stream, are as follows:

- **SW 10** (Upstream of the Installation) – Since 2002 Amgen has carried out surface water monitoring of background surface water quality at a location directly east of the Bryn Pica Installation.
- **SW 11** (Old opencast settlement lagoon) – A surface water settlement lagoon exists on the site at a location within the control of Amgen. Surface water quality is sampled from the 750mm concrete pipe as it enters the lagoon. An unnamed stream to the south of the Installation enters this settlement lagoon, from where the overflow is directed beneath the disused railway line via a culvert.
- **SW 12** (tributary of the Ysguborwen Stream) – Overflow from the settlement lagoon described in SW11 above, combines with other small drainage features to form a small tributary to the Ysguborwen Stream. In March 2005, this additional monitoring point was added to gauge the quality of water therein. However, historically the surface water monitoring point identified as SW12 was located on the Nant-y-Wenalt (where it emerges from a culvert running beneath the old dismantled railway line).

3.6.4 Surface water monitoring points located in issues from the opencast backfill:

- **SW8** (Opencast Backfill Issue) – It is considered that the pond and associated unnamed watercourse to the south west of the site, represents perched groundwater issuing from near the base of the opencast backfill. This feature is located approximately 500m south west of the Installation.

3.6.5 Annual averages have been calculated for the main surface water quality determinands monitored at the site by Amgen during the period January 2013 to December 2015. This analysis has been summarised, below, in Tables 3.7, 3.8 and 3.9 for 2013, 2014 and 2015 respectively. The identity and value of the chosen EAL is indicated for each determinand, with any exceedances highlighted in **bold** type. The full data set is illustrated in a number of time-series plots (Appendix E).

Table 3.6: Annual Average Surface Water Concentrations for 2013.

Water Quality Determinand	Units	EAL		Surface Water Monitoring Point						
				SW1	SW3	SW4	SW8	SW10	SW11	SW12
Ammoniacal Nitrogen (NH ₄ as N)	mg/l	DWS	0.5	N/D	N/D	N/D	N/D	<0.03	1.49	N/D
Chloride	mg/l	DWS	250	5.5	26.7	22.5	6.9	6.9	9.6	7.3
COD	mg/l	-	-	N/D	7.2	5.2	1.1	N/D	34.5	1.3
DO	mg/l	-	-	10.3	9.5	9.6	9.1	15.2	12.7	8.3
EC @ 20°C	uS/cm	DWS	1500	206	409	595	1,229	90	170	979
PH	-	DWS	5.5-9.5	8.0	7.5	8.3	7.6	7.1	7.5	8.4

Table 3.7: Annual Average Surface Water Concentrations for 2014.

Water Quality Determinand	Units	EAL		Surface Water Monitoring Point						
				SW1	SW3	SW4	SW8	SW10	SW11	SW12
Ammoniacal Nitrogen (NH ₄ as N)	mg/l	DWS	0.5	<0.03	<0.03	<0.03	<0.03	<0.03	0.25	<0.03
Chloride	mg/l	DWS	250	8.1	16.0	18.6	10.9	7.2	8.5	11.5
COD	mg/l	-	-	<10	<10	<10	<10	<10	20.3	<10
DO	mg/l	-	-	9.6	9.0	9.9	8.5	9.8	9.9	9.9
EC @ 20°C	uS/cm	DWS	1500	221	363	569	1175	86	188	889
PH	-	DWS	5.5-9.5	8.0	7.4	8.4	7.6	7.0	7.5	8.2

Table 3.8: Annual Average Surface Water Concentrations for 2015.

Water Quality Determinand	Units	EAL		Surface Water Monitoring Point						
				SW1	SW3	SW4	SW8	SW10	SW11	SW12
Ammoniacal Nitrogen (NH ₄ as N)	mg/l	DWS	0.5	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Chloride	mg/l	DWS	250	6.9	18.6	40.2	9.6	7.3	25.1	10.3
COD	mg/l	-	-	<10	<10	<10	<10	<10	24.0	<10
DO	mg/l	-	-	8.46	8.62	8.41	8.50	9.18	8.63	8.69
EC @ 20°C	uS/cm	DWS	1500	223	403	640	1,166	93	209	860
PH	-	DWS	5.5-9.5	8.0	7.5	8.3	7.7	7.1	7.5	8.0

3.6.6 The above comparison illustrates that surface water sampled around the Bryn Pica Landfill during the period Jan 15 – Dec 15 is of a good quality. The high standard of water quality observed in surface water around the Bryn Pica Landfill in 2013 has been maintained throughout 2014 and 2014.

- 3.6.7 During the period Jan 15 to Dec 15, only 2 of the 68 (2.9%) surface water samples taken from around the site reported the presence of NH_4 as N, above the minimum reporting value of 0.03 mg/l. The maximum value recorded in any sample was 0.06 mg/l NH_4 as N (recorded in a surface water sample taken at location of SW8 in Aug-15). This demonstrates a very slight improvement in water quality when considering the 2.9% detection of ammonia above 0.03 mg/l in all surface water samples and the maximum value in any sample of 1.42 mg/l.
- 3.6.8 Appendix E presents time series plots for the surface water quality determinands above have been produced for the period Jan 00 – Dec 15. A summary of the results shown above and the time series plots is given below.

The Nant-y-Derlwyn Stream

- 3.6.9 Surface water quality in the Nant-y-Derlwyn stream (SW1, SW3 and SW4a) continues to show the water to be of very good quality with baseline, up-dip water quality comparing well with down-dip water quality.
- 3.6.10 Third party lab analysis of surface water samples taken during this reporting period (Jan 15 to Dec 15) show the water quality to be within UK Drinking Water Standards (UK-DWS). For example, Ammoniacal Nitrogen (NH_4 as N), a substance typically associated with leachate contamination, was not detected (above 0.03 mg/l) in any of the 30 samples obtained from locations both up-gradient and down-gradient of the landfill. This indicates that landfill / waste operations at Bryn Pica are not having a notable impact on the surface water environment at this location.

The Ysguborwen Stream

- 3.6.11 An unnamed tributary of the Ysguborwen Stream runs along the Bryn Pica site boundary and joins with several other small streams before eventually flowing into the Ysguborwen Stream. AC monitor the quality of this tributary at several places; SW10, SW11 and SW12, although due to the 'flashy nature' of this watercourse, sample yield at SW 11 is generally low. Throughout the current monitoring period AC staff only obtained 6 (of a possible 12) monthly samples from SW 11 due to the absence of flow.
- 3.6.12 Surface water monitored at SW12 throughout the period Jan 15 to Dec 15 has been recorded as being of good quality. There was no detection of Ammoniacal Nitrogen (NH_4 as N) in any of 8 surface water samples analysed during the reporting period (above the minimum reporting value of 0.03 mg/l). Furthermore, all other surface water quality determinands observed were below their relative Environmental Assessment Limits (EAL's); for example the highest concentration of Chloride observed during the referenced monitoring period was 11.5 mg/l. This is significantly lower than the UK-DWS of 250 mg/l.

Opencast Backfill Issues

- 3.6.13 Water issuing at SW8 is thought to be sourced from groundwater draining from the base of the opencast backfill material.
- 3.6.14 The quality of the water discharging at this point is very good, all water quality determinands sampled are were reported at levels below their associated EAL's, in particular Ammoniacal Nitrogen. Throughout 2015, Ammoniacal Nitrogen, a key determinant in potential landfill leachate contamination. Of the 12 samples obtained during the period Jan-15 to Dec-15 a single result was received above the minimum reporting value of 0.03 mg/l. This was reported as being 0.06 mg/l NH_4 as N in a sample taken in Aug-15. Electrical Conductivity readings at SW8 are representative of water

being filtered through the opencast backfill material and influenced by past mining activities; however concentrations have remained below the UK-DWS of 1500 us/cm.

4. CONCLUSIONS

4.1 Overview

- 4.1.1 Amgen Cymru has carried out environmental monitoring of leachate, groundwater and surface water at the Bryn Pica landfill site as specified in the site PPC Permit and Environmental Management Systems.
- 4.1.2 The information collected during these exercises has been reviewed in Section 3 of this document and forms part of the continual reporting of site activities to Natural Resources Wales (NRW – formerly EA Wales).

4.2 Landfill Leachate Levels and Composition

- 4.2.1 Leachate levels monitored within the Bryn Pica Landfill containment cells 2a, 2c, 3a, 3b, 4a and 4b illustrate compliance with the leachate levels specified in the site's Environmental Permit (i.e. <1m above the basal liner).
- 4.2.2 Amgen utilises 7 locations at Bryn Pica for the purpose of monitoring the concentrations of contaminants present within the landfill leachate. During this reporting period, Jan 15 – Dec 15, AC carried out laboratory analysis of 66 samples collected from these locations.
- 4.2.3 This report provides a comparison of Amgen's analysis of contaminant concentrations in leachate sampled at Bryn Pica with published average data for leachate in similar type UK landfills (see Table 3.3). The majority of contaminants illustrated as being present with the landfill leachate generated at Bryn Pica are report to be comparative with UK average values for non-hazardous landfills.
- 4.2.4 Levels of sulphate recorded in leachate sampled at the Bryn Pica Landfill have continues to decrease in 2015. This is apparent in a number of the landfill cells as follows:

Phase 2c -	2013 Annual Average Sulphate value was 172 mg/l, 25 mg/l in 2014 and reduced further in 2015 to less than 10 mg/l.
Phase 3a -	The Annual Average Sulphate value was 108 mg/l in 2012, 19 mg/l in 2014, with no detection in leachate samples taken in 2015.
Phase 4a -	2013 Annual Average Sulphate value was 132 mg/l compared to 15 mg/l in 2014. This reduced further to 6.1 mg/l in 2015.

The reason for this reduction is unclear, but may be related to the continued changing nature of landfill waste inputs.

- 4.2.5 The concentrations of Chromium recorded in Phase 1, Phase 2 and Phase 3 although elevated above the average values reported by the DoE in 1995 are not considered to pose an unacceptable risk to the environment (when considering water quality guidelines). The highest recorded value in any leachate sample taken at Bryn Pica during 2015 was reported to be 0.883 mg/l (taken from Phase 3a) compared to 1.02 mg/l in 2014.
- 4.2.6 The concentrations of Ammoniacal Nitrogen recorded in Phase 2 and Phase 3 although elevated above the average values reported by the DoE in 1995 are not considered to pose an unacceptable risk to the environment (when considering water quality guidelines).. The highest recorded value in 2015 was 2660 mg/l, in a sample taken from within the Phase 3a landfill cell. This landfill cell also yielded the highest level of ammonia in 2014 (2280 mg/l).

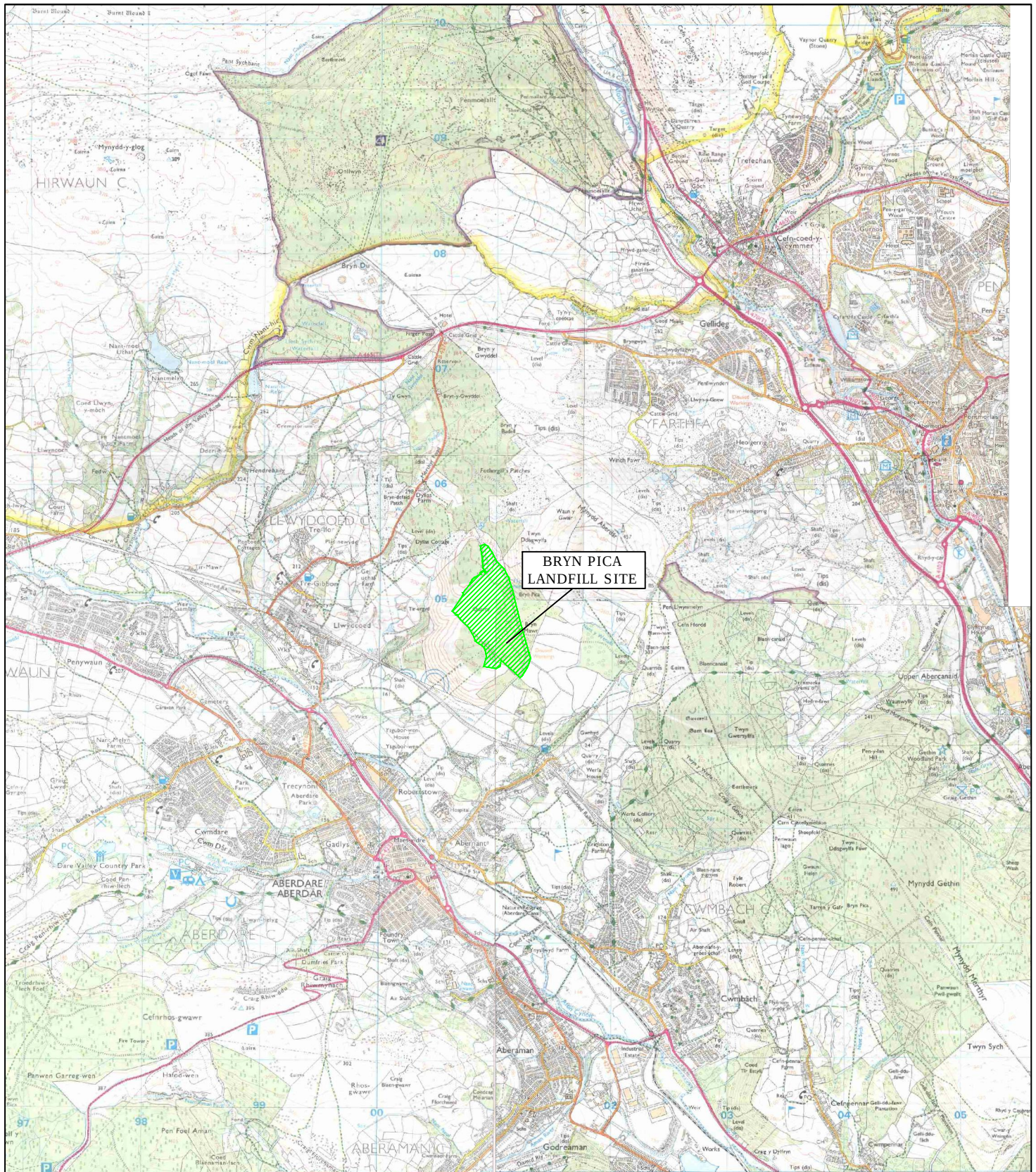
4.3 Groundwater Quality

- 4.3.1 The Bryn Pica landfill site is equipped with 16 groundwater monitoring points, 15 of which are situated 'down-dip' of the potential sources of leachate contamination. During this reporting period 12 of these points were permanently dry or did not hold sufficient water to yield a sample. Amgen Cymru carried out the agreed suite of laboratory analysis on samples from the remaining 4 boreholes with 48 groundwater samples obtained. This is a 4% increase when compared to the number of samples obtained in 2014.
- 4.3.2 Tables 3.4, 3.5 and 3.6 (section 3.5) provide a comparison of annual average groundwater quality monitored by Amgen Cymru during the period Jan 13– Dec 13, Jan 14 – Dec 14 and Jan 15 – Dec 15 with a series of recommended Environmental Assessment Limits (EAL's). Time-series plots are provided for those groundwater quality determinants included within the agreed monthly and quarterly groundwater analysis suites.
- 4.3.3 Average values calculated for key groundwater quality determinants (identified in relation to potential leachate contamination); illustrate that groundwater at the Bryn Pica site is generally of good quality. As can be seen from tables 3.4, 3.5 and 3.6 Section 3, a number of the annual average values calculated are consistently above their associated EAL. However, it is clear from the time series plots that these average values are generally elevated due to one or two higher anomalous values :
- **Ammoniacal Nitrogen (NH₄ as N)** – Ammoniacal Nitrogen concentrations recorded in groundwater sampled throughout 2015 illustrated very low concentrations of ammonia. Comparative monitoring between the up-dip and down-dip boreholes shows that during 2014, similar average annual NH₄ as N concentrations were present at levels below their respective EAL of 0.5mg/l.
 - A total of 48 groundwater samples were analysed for ammonia (NH₄ as N) during the period Jan 15 to Dec 15. Of these 2.1% reported concentrations in the range 0.04 mg/l to 0.10 mg/l. None of the 48 samples illustrated ammonia levels above the UK Drinking Water Standard of 0.5 mg/l. This gives a good indication that landfill leachate generated at Bryn Pica is not having a demonstrable impact on the quality of groundwater.
 - **Chloride** – AC completed chloride analysis on 48 groundwater samples obtained from the Bryn Pica landfill site during the period Jan 15 to Dec 15. The maximum recorded value was 19.4 mg/l, in a sample taken from GW 7 in Feb 15. The average chloride concentration in up gradient boreholes during this period was 14.3 mg/l. Comparing this with the down-gradient average of 12.6 mg/l suggests that landfill leachate is not have an impact on the quality of groundwater as it passes beneath the site.
 - **Lead** – During the monitoring period Jan 07 – Dec 10 lead average concentrations have appeared below the associated EAL; except within the up-gradient borehole GW07BH04 (during Oct 10, several 'heavy metal' determinants within GW07BH04 were reported as being abnormally high, which therefore skewed the annual averages for each of these determinants; to note a re-analysis of this borehole, following detection, reported results for each determinant below their associated EAL's). In 2011 there was no positive result for lead (lead not detected at or above a MRV of 0.002mg/l) in any of the sampled analysed. This was continued throughout 2012 – 2014 and no positive detection of lead was reported in any of the 16 samples tested in 2015.
- 4.3.4 Groundwater on and around the Bryn Pica Landfill Site is generally of a good quality. The results appear to be fairly static over the monitoring period, with no apparent detrimental changes in the concentrations of key contaminants associated with landfill leachate. The results of groundwater monitoring undertaken at Bryn Pica throughout 2015 have not provided any indication that the landfill is having a detrimental impact on groundwater beneath the site.

4.4 Surface Water Quality

- 4.4.1 Throughout the period Jan 15 – Dec 15 Amgen have carried out the required surface water monitoring at 7 locations on and around the Bryn Pica landfill site, with 72 samples being collected for laboratory analysis. The results of a series of laboratory analyses carried out on the surface water samples collected at the site are presented, along with a comparison of associated EAL's.
- 4.4.2 Tables 3.7, 3.8 and 3.9 (Section 3.6) provide a comparison of annual average surface water quality monitored by AC during the period Jan 13 – Dec 13, Jan 14 – Dec 14 and Jan 15 – Dec 15, with a series of recommended Environmental Assessment Limits (EAL's).
- 4.4.3 Average annual values calculated for key surface water quality determinands (identified in relation to potential leachate contamination), suggest that surface water; on and around the Bryn Pica site is of a good quality. There has been indication of elevated Ammoniacal Nitrogen (NH_4) when compared to the UK-DWS of 0.5 mg/l in previous years monitoring, which were equally distributed in upstream and downstream monitoring locations and as such have not been related to landfill operations at the site.
- 4.4.4 Over the previous 16 years AC has continued to collect data regarding the levels of ammonia in surface water on and around the Bryn Pica Landfill Site. Monthly analysis of this key leachate contaminant has resulted in a total of 1083 samples analysis over the period Nov 99 to Dec 15. The results of this analysis are illustrated in the time series plot provided in Appendix E. Observation of this data suggest that there are four distinct periods of water quality at site as follows:
- | | |
|----------------|---|
| 1999 to 2003 - | Surface water sampled during this period illustrate a baseline of 0.6 mg/l NH_4 as N, with frequent peak readings in the range 1 – 10 mg/l. |
| 2004 to 2008 - | Surface water sampled during this period had a slightly lower baseline, around 0.3 mg/l with frequent peak results in the range 1 – 10 mg/l (occasionally higher). |
| 2009 to 2011 - | A much lower baseline was recorded in surface water sampled during this period. This relates to improvements in the Minimum Reporting Value (MRV) provided by third party laboratory analysis services. During this period of operation, occasional peak results occur in the range 0.1 mg/l to 0.4 mg/l NH_4 as N. Nevertheless, there is clear indication that the quality of surface water around the landfill site has improved. |
| 2012 to 2015 - | The low baseline achieved in 2009 continued through this period of operation, with very low rates of positive detection (i.e. values of ammonia at or above the MRV of 0.03mg/l NH_4 as N). Peak results are very rare and do not typically occur at levels that exceed the UK Drinking Water Standard (DWS) of 0.5 mg/l. |

Appendix A - Drawings



REPRODUCED FROM ORDNANCE SURVEY 1:50,000 MAP WITH THE PERMISSION OF THE CONTROLLER OF HER MAJESTY'S STATIONERY OFFICE. © CROWN COPYRIGHT, LICENCE NUMBER AL50604A.



AMGEN CYMRU
BRYN PICA
LLWYDGOED
ABERDARE
CF44 0BX

JOB TITLE

BRYN PICA WASTE MANAGEMENT FACILITY ANNUAL REPORT 2015

DRAWING TITLE

SITE LOCATION PLAN

REV.	DESCRIPTION	DATE
DRAWN	A.P.W.	DATE 05/01/16
APPROVED	L.F.	DATE 05/01/16
SCALE	1:50,000	SHEET A4
DRAWING NO.	AC2016/ENV/01/001	
STATUS FOR COMMENT ☐ FOR APPROVAL ☐ DRAFT ☐ FINAL ☒		

BRYN PICA - SITE PLAN

NOTES

1. ALL LEVELS TO mAOD

LEGEND

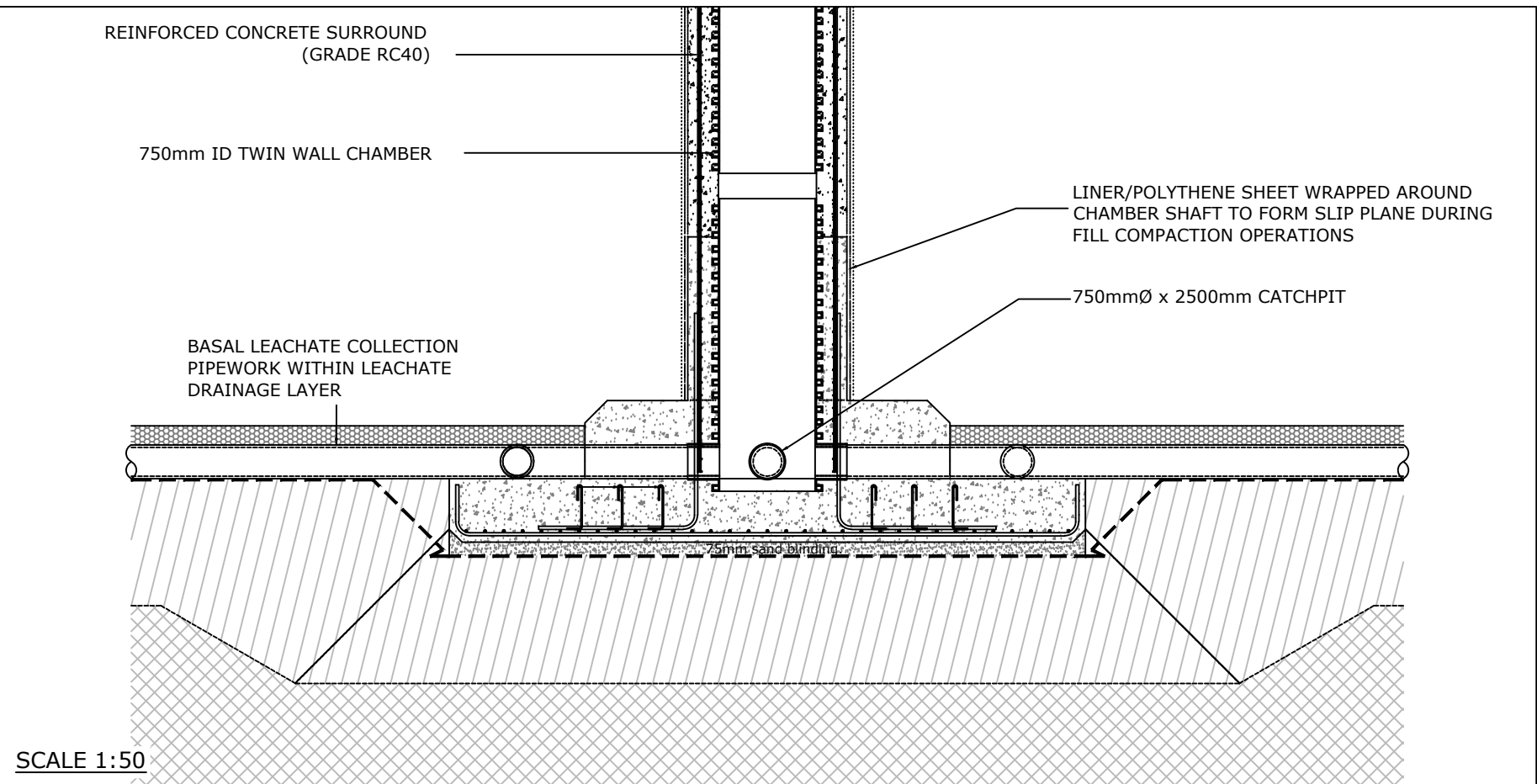
INSTALLATION BOUNDARY

PHASE BOUNDARIES (EXISTING)

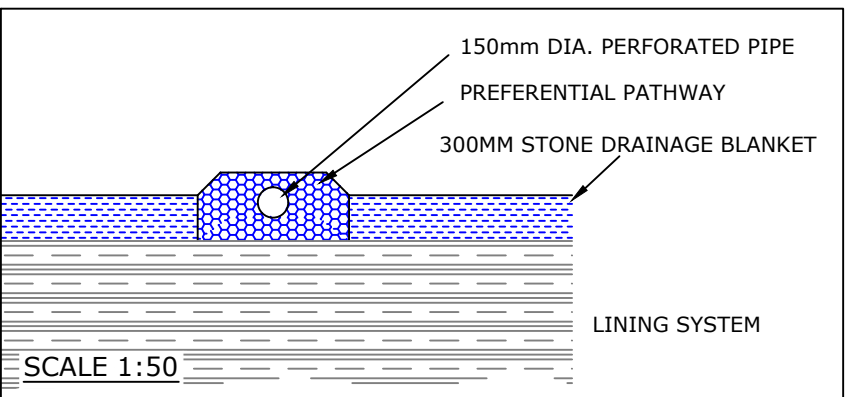
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LE1

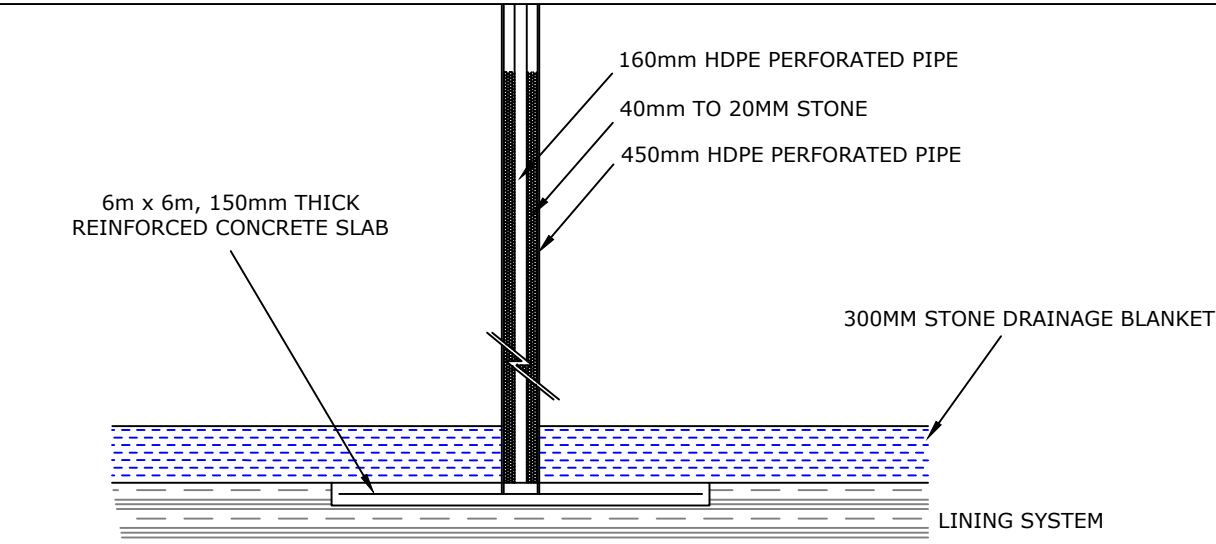
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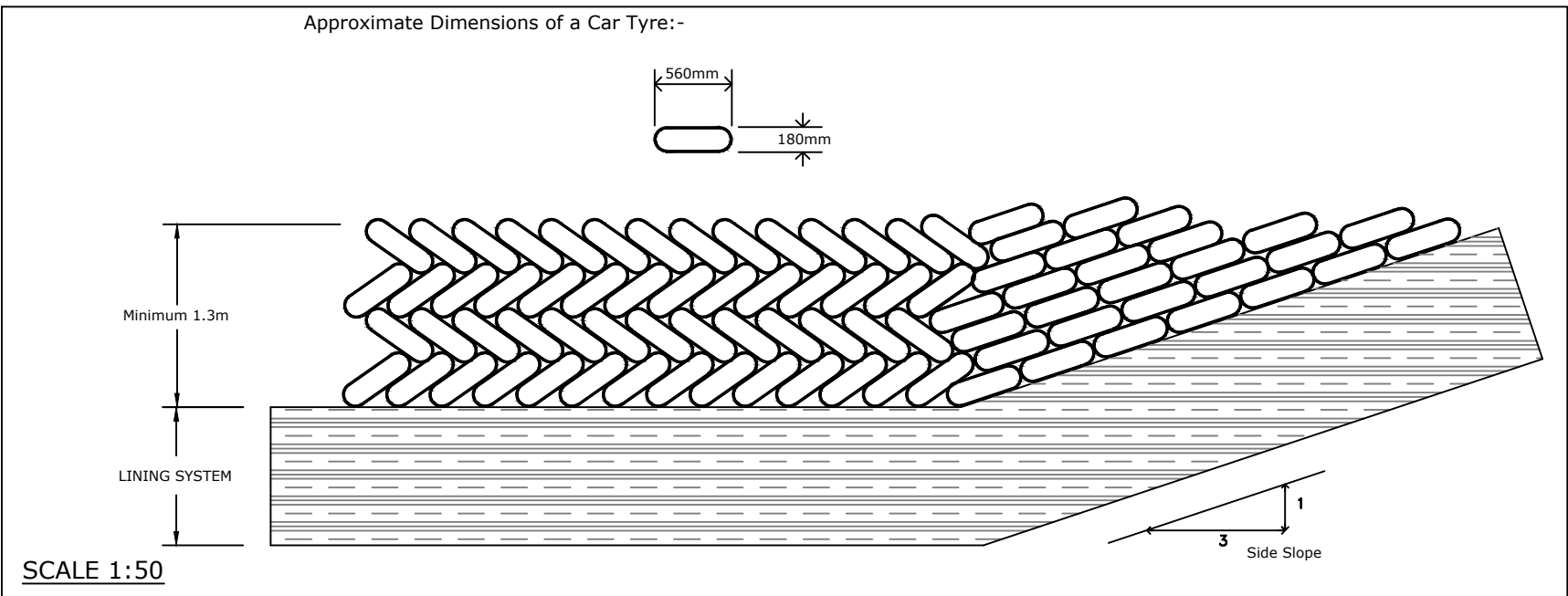
TYPICAL SECTION THROUGH LEACHATE COLLECTION WELL



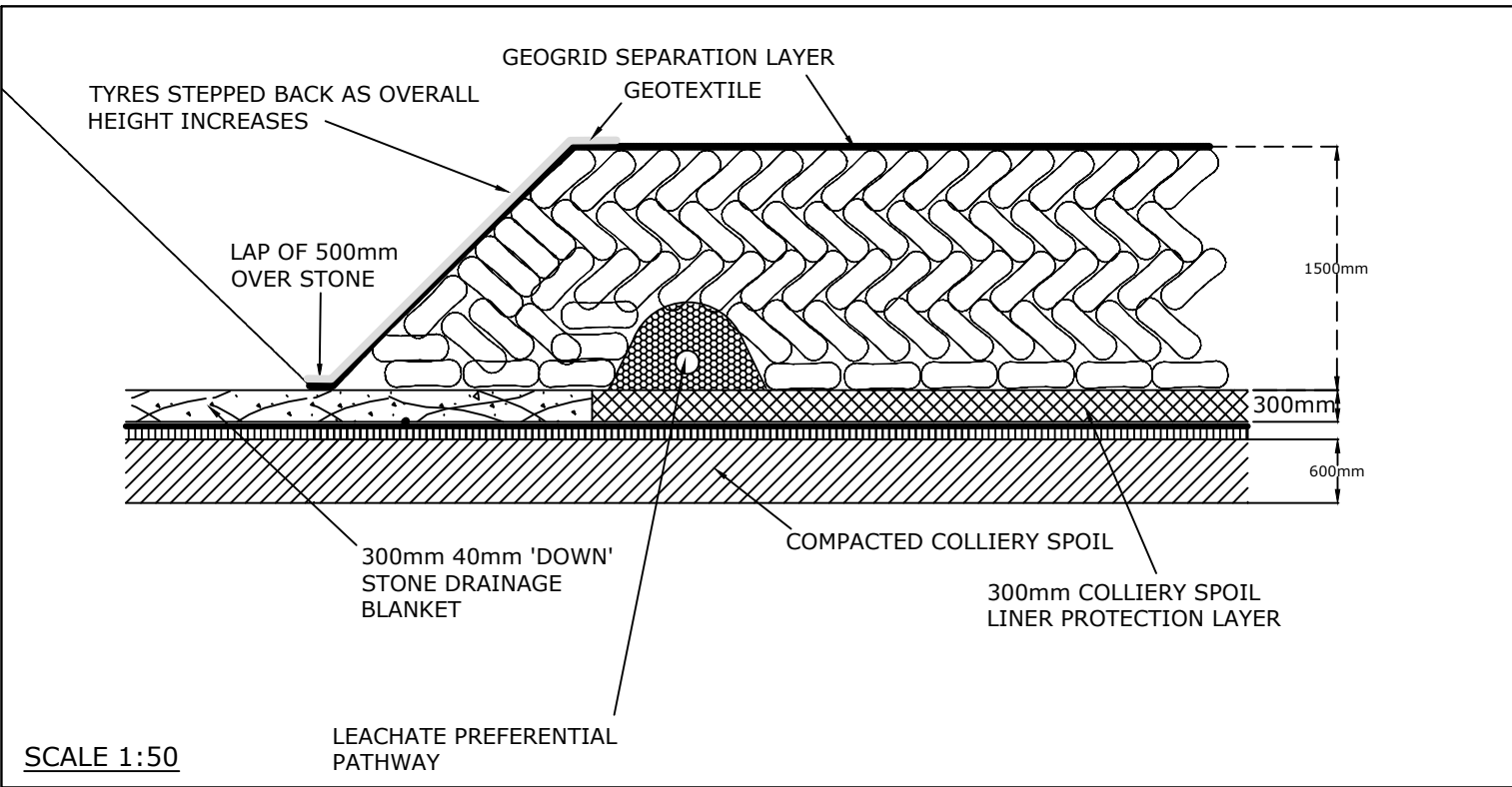
TYPICAL DETAIL THROUGH STONE DRAINAGE LAYER



TYPICAL LEACHATE MONITORING POINT



TYPICAL DETAIL THROUGH WHOLE TYRE LEACHATE DRAINAGE LAYER



	PROJECT TITLE BRYN PICA WASTE MANAGEMENT FACILITY ANNUAL REPORT 2015			
	DRAWING TITLE LEACHATE MANAGEMENT			
	DRAWN BY APW	DATE 16.02.2015	CHECKED BY LF	16.02.2015
	SCALE AS SHOWN	SHEET SIZE A1	DRAWING No: AC2016/ENV/01/002	REVISION 0
NOTES	REV	DESCRIPTION		DATE BY

Appendix B – Table 1a, 1b and 1c showing the Monitoring Suites used by Amgen for Leachate, Groundwater and Surface Water.

Appendix C – Time Series Plots Illustrating the Results of Amgen'
Laboratory Analysis of Leachate Sampled at the Bryn Pica Landfill
Site during the period Jan 00 – Dec 15.

Table 1A - Leachate Monitoring Suites for Bryn Pica

Determinant	Frequency
Field Measurements	
pH	M/Q/A
Temperature	M/Q/A
Conductivity	M/Q/A
Laboratory Measurements	
Ammonical Nitrogen	W/M/Q/A
COD	W/M/Q/A
Suspended Solids	W/M/Q/A
Dissolved Methane	W/M/Q/A
Calcium, Total as Ca	Q/A
Chloride as Cl	Q/A
Magnesium as Mg	Q/A
pH	Q/A
Sodium, Total as Na	Q/A
TOC as C	Q/A
BOD + ATU (5 day)	Q/A
Conductivity - Electrical 20°C	Q/A
Alkalinity as CaCO ₃	Q/A
Potassium, Total as K	Q/A
Sulphate as SO ₄	Q/A
Nitrogen, Total Oxidised as N	Q/A
Iron, Total as Fe	A
Nickel, Total as Ni	A
Cadmium, Total as Cd	A
Chromium, Total as Cr	A
Copper, Total as Cu	A
Lead, Total as Pb	A
Manganese, Total as Mn	A
Zinc, Total as Zn	A
List I / II Annual Suite	
Tellurium by ICP-MS	A
Uranium by ICP-MS	A
Silver, Total as Ag	A
Fluoride as F	A
Arsenic, Total as As	A
Boron, Total as B	A
Selenium, Total as Se	A
Vanadium, Total as V	A
Tin, Total as Sn	A
Cobalt, Total as Co	A
Barium, Total as Ba	A
Antimony, Total as Sb	A
Molybdenum, Total as Mo	A
Titanium, Total as Ti	A
Beryllium, Total as Be	A
Thallium, Total as Tl	A
Total Inorganic Phosphorus	A
Nitrate as N	A

Mercury, Total as Hg	A
Mecoprop	A
TPH>C6-C40	A
VOC with TICs	A
SVOC with Tics	A
Triphenyltin	A
Tributyltin	A
Monuron	A
Bromoxynil	A
Triazophos	A
2,3,6 - TBA	A
2,4 - D	A
2,4 - DB	A
2,4,5, - T	A
Dicamba	A
MCPA	A
Dichlorprop	A
MCPB	A
Ioxynil	A
Phorate	A
Propetamphos	A
Pirimiphos-methyl	A
Fenthion	A
Dichlorvos	A
Mevinphos	A
Demeton-s-methyl	A
Dimethoate	A
Diazinon	A
Parathion-methyl	A
Disulphoton	A
Fenitrothion	A
Malathion	A
Parathion ethyl	A
Chlorfenvinphos	A
Carbophenothion	A
Azinphos-methyl	A
Diuron	A
Isoproturon	A
Chlortoluron	A
Linuron	A
Aldrin	A
Dieldrin	A
Heptachlor Epoxide	A
Chlordane - alpha	A
Dichlobenil	A
Chlordane gamma	A
Endosulphan alpha	A
Endrin	A
HCH - alpha	A
HCH - beta	A
HCH - gamma	A
Hexachlorobutadiene	A
Hexachlorobenzene	A
Isodrin	A
o,p - DDE	A
o,p - DDT	A

o,p - TDE	A
p,p - DDE	A
p,p - DDT	A
p,p - TDE	A
Tecazene	A
Triallate	A
1,2,4 - Trichlorobenzene	A
Trifluralin	A
TPH>C6 -C8	A
TPH>C8 -C10	A
TPH>C10 -C16	A
TPH>C16 -C24	A
TPH>C24 -C40	A
Dibromofluoromethane	A
Toluene-d8	A
4-bromofluorobenzene	A
Dichlorodifluoromethane	A
Chloromethane	A
Chloroethane	A
Bromomethane	A
Vinyl Chloride	A
Trichlorofluoromethane	A
1,1-Dichloroethane	A
Dichloromethane	A
Trans-1,2-dichloroethene	A
1,1-Dichloroethane	A
Cis-1,2-dichloroethene	A
2,2-Dichloropropane	A
Chloroform	A
Bromochloromethane	A
1,1,1-Trichloroethane	A
1,1-Dichloropropene	A
1,2-Dichloroethane	A
Benzene	A
Carbon Tetrachloride	A
1,2-Dichloropropane	A
Trichloroethene	A
Bromodichloromethane	A
Dibromomethane	A
Cis-1,3-dichloropropene	A
Cyanide, Total as CN	A
Naphthalene	A
Toluene	A
Trans-1,3-dichloropropene	A
1,1,2-trichloroethane	A
1,3-dichloropropane	A
Tetrachloroethene	A
Dibromochloromethane	A
1,2-dibromoethane	A
Chlorobenzene	A
1,1,1,2-tetrachloroethane	A
Ethyl Benzene	A
m,p-xylene	A
o-xylene	A
Styrene	A
Bromoform	A

Isopropylbenzene	A
1,1,2,2-tetrachloroethane	A
1,2,3-trichloropropane	A
n-propylbenzene	A
Bromobenzene	A
2-chlorotoluene	A
1,3,5-trimethylbenzene	A
4-chlorotoluene	A
tert-butylbenzene	A
1,2,4-trimethylbenzene	A
sec-butylbenzene	A
p-isopropyltoluene	A
1,3-dichlorobenzene	A
1,4-dichlorobenzene	A
n-butylbenzene	A
1,2-dichlorobenzene	A
1,2-dibromo-3-chloropropane	A
1,2,4-trichlorobenzene	A
Hexachlorobutadiene	A
1,2,3-trichlorobenzene	A
2-Fluorobiphenyl	A
MTBE	A
Terphenyl-d14	A
2-Methylphenol	A
4-Methylphenol	A
Dibenzofuran	A
bis(2-Chloroisopropyl) ether	A
N-nitrosodi-n-propylamine	A
Hexachloroethane	A
Nitrobenzene	A
Isophorone	A
2,4-dimethylphenol	A
2-nitrophenol	A
bis(2-chloroethoxy)methane	A
2,4-Dichlorophenol	A
Hexachlorobutadiene	A
4-Chloro-3-methylphenol	A
2-Methylnaphthalene	A
2,4,6-Trichlorophenol	A
2,4,5-Trichlorophenol	A
2-Chloronaphthalene	A
Dimethyl phthalate	A
2,6-Dinitrotoluene	A
Acenaphthylene	A
Acenaphthene	A
2,4-Dinitrotoluene	A
Diethyl phthalate	A
4-Nitrophenol	A
4-Chlorophenyl phenylether	A
Fluorene	A
Carbazole	A
n-Nitrosodiphenylamine	A
4-Bromophenyl phenyl ether	A
Hexachlorobenzene	A
Pentachlorophenol	A
Phenanthrene	A

Anthracene	A
di-n-Butyl phthalate	A
Fluoranthene	A
Pyrene	A
Butyl benzyl phthalate	A
Benzo(a)anthracene	A
Chrysene	A
bis(2-ethylhexyl)phthalate	A
di-n-octyl phthalate	A
Benzo(b)fluoranthene	A
Benzo(k)fluoranthene	A
Benzo(a)pyrene	A
Indeno(1,2,3-cd)pyrene	A
Dibenz(a,h)anthracene	A
Benzo(ghi)perylene	A
Phenol	A
Bis(2-chloroethyl) ether	A
2-chlorophenol	A
2-Fluorophenol	A
Phenol-d6	A
Nitrobenzene-d5	A
2,4,6-Tribromophenol	A

W = Weekly, M = Monthly, Q = Quarterly, A = Annually

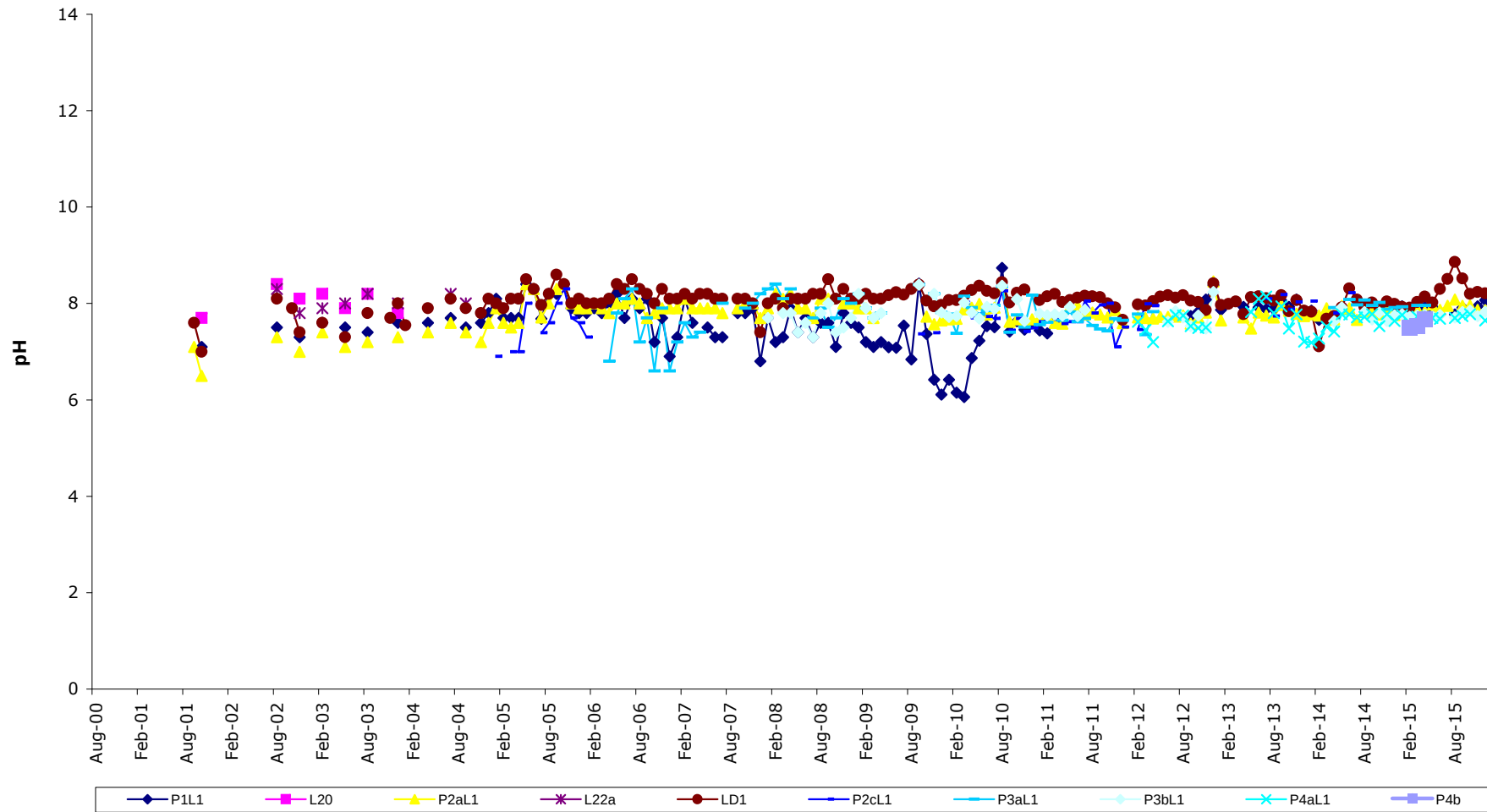
Table 1A - Leachate Monitoring Suites for Bryn Pica

Determinant	Frequency
Field Measurements	
pH	M/Q/A
Temperature	M/Q/A
Conductivity	M/Q/A
Laboratory Measurements	
Ammonical Nitrogen	W/M/Q/A
COD	W/M/Q/A
Suspended Solids	W/M/Q/A
Dissolved Methane	W/M/Q/A
Calcium, Total as Ca	Q/A
Chloride as Cl	Q/A
Magnesium as Mg	Q/A
pH	Q/A
Sodium, Total as Na	Q/A
TOC as C	Q/A
BOD + ATU (5 day)	Q/A
Conductivity - Electrical 20°C	Q/A
Alkalinity as CaCO ₃	Q/A
Potassium, Total as K	Q/A
Sulphate as SO ₄	Q/A
Nitrogen, Total Oxidised as N	Q/A
Iron, Total as Fe	A
Nickel, Total as Ni	A
Cadmium, Total as Cd	A
Chromium, Total as Cr	A
Copper, Total as Cu	A
Lead, Total as Pb	A
Manganese, Total as Mn	A
Zinc, Total as Zn	A
List I / II Annual Suite	
Tellurium by ICP-MS	A
Uranium by ICP-MS	A
Silver, Total as Ag	A
Fluoride as F	A
Arsenic, Total as As	A
Boron, Total as B	A
Selenium, Total as Se	A
Vanadium, Total as V	A
Tin, Total as Sn	A
Cobalt, Total as Co	A
Barium, Total as Ba	A
Antimony, Total as Sb	A
Molybdenum, Total as Mo	A
Titanium, Total as Ti	A
Beryllium, Total as Be	A
Thallium, Total as Tl	A
Total Inorganic Phosphorus	A
Nitrate as N	A

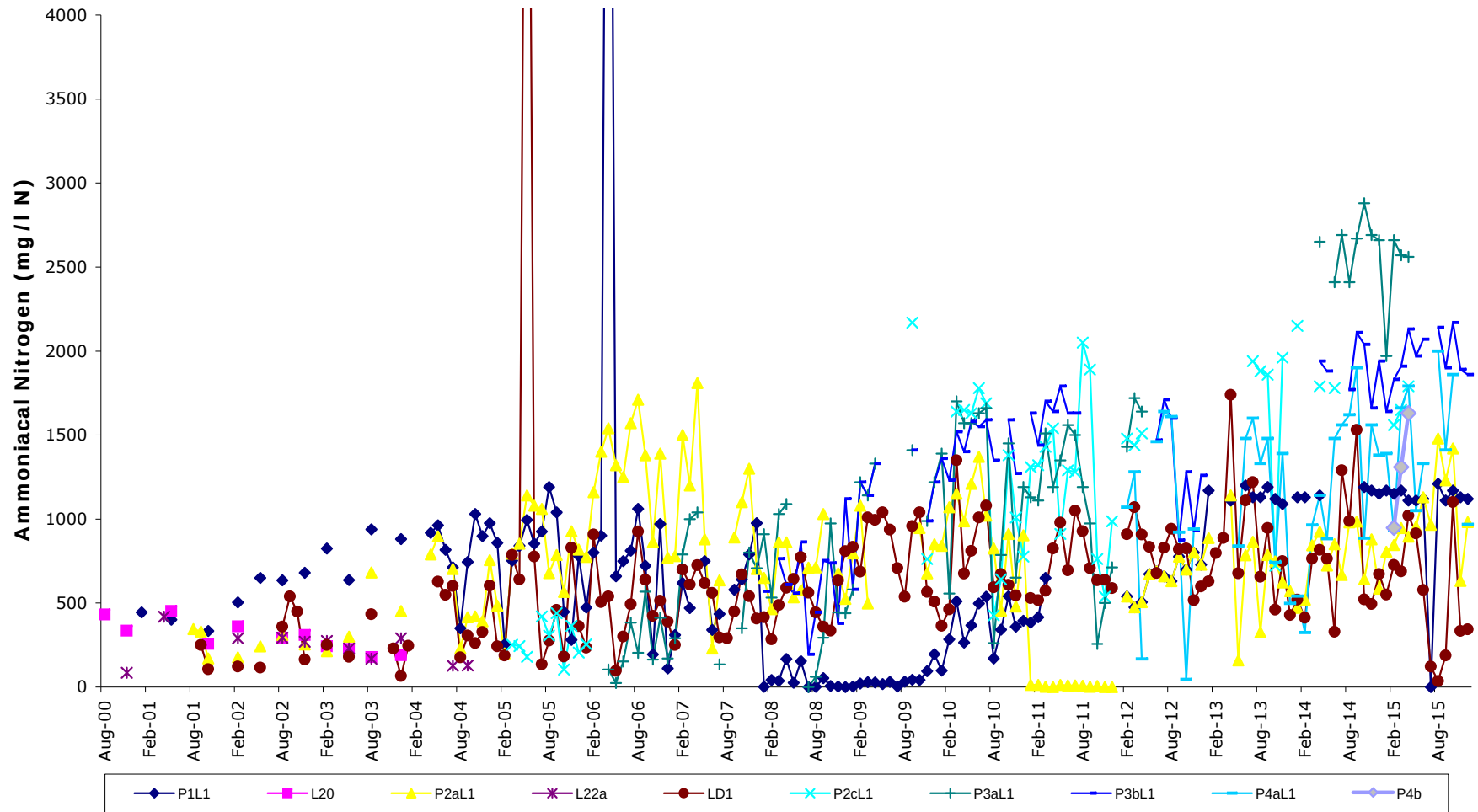
Mercury, Total as Hg	A
Mecoprop	A
TPH>C6-C40	A
VOC with TICs	A
SVOC with Tics	A
Triphenyltin	A
Tributyltin	A
Monuron	A
Bromoxynil	A
Triazophos	A
2,3,6 - TBA	A
2,4 - D	A
2,4 - DB	A
2,4,5, - T	A
Dicamba	A
MCPA	A
Dichlorprop	A
MCPB	A
Ioxynil	A
Phorate	A
Propetamphos	A
Pirimiphos-methyl	A
Fenthion	A
Dichlorvos	A
Mevinphos	A
Demeton-s-methyl	A
Dimethoate	A
Diazinon	A
Parathion-methyl	A
Disulphoton	A
Fenitrothion	A
Malathion	A
Parathion ethyl	A
Chlorfenvinphos	A
Carbophenothion	A
Azinphos-methyl	A
Diuron	A
Isoproturon	A
Chlortoluron	A
Linuron	A
Aldrin	A
Dieldrin	A
Heptachlor Epoxide	A
Chlordane - alpha	A
Dichlobenil	A
Chlordane gamma	A
Endosulphan alpha	A
Endrin	A
HCH - alpha	A
HCH - beta	A
HCH - gamma	A
Hexachlorobutadiene	A
Hexachlorobenzene	A
Isodrin	A
o,p - DDE	A
o,p - DDT	A

o,p - TDE	A
p,p - DDE	A
p,p - DDT	A
p,p - TDE	A
Tecazene	A
Triallate	A
1,2,4 - Trichlorobenzene	A
Trifluralin	A
TPH>C6 -C8	A
TPH>C8 -C10	A
TPH>C10 -C16	A
TPH>C16 -C24	A
TPH>C24 -C40	A
Dibromofluoromethane	A
Toluene-d8	A
4-bromofluorobenzene	A
Dichlorodifluoromethane	A
Chloromethane	A
Chloroethane	A
Bromomethane	A
Vinyl Chloride	A
Trichlorofluoromethane	A
1,1-Dichloroethane	A
Dichloromethane	A
Trans-1,2-dichloroethene	A
1,1-Dichloroethane	A
Cis-1,2-dichloroethene	A
2,2-Dichloropropane	A
Chloroform	A
Bromochloromethane	A
1,1,1-Trichloroethane	A
1,1-Dichloropropene	A
1,2-Dichloroethane	A
Benzene	A
Carbon Tetrachloride	A
1,2-Dichloropropane	A
Trichloroethene	A
Bromodichloromethane	A
Dibromomethane	A
Cis-1,3-dichloropropene	A
Cyanide, Total as CN	A
Naphthalene	A
Toluene	A
Trans-1,3-dichloropropene	A
1,1,2-trichloroethane	A
1,3-dichloropropane	A
Tetrachloroethene	A
Dibromochloromethane	A
1,2-dibromoethane	A
Chlorobenzene	A
1,1,1,2-tetrachloroethane	A
Ethyl Benzene	A
m,p-xylene	A
o-xylene	A
Styrene	A
Bromoform	A

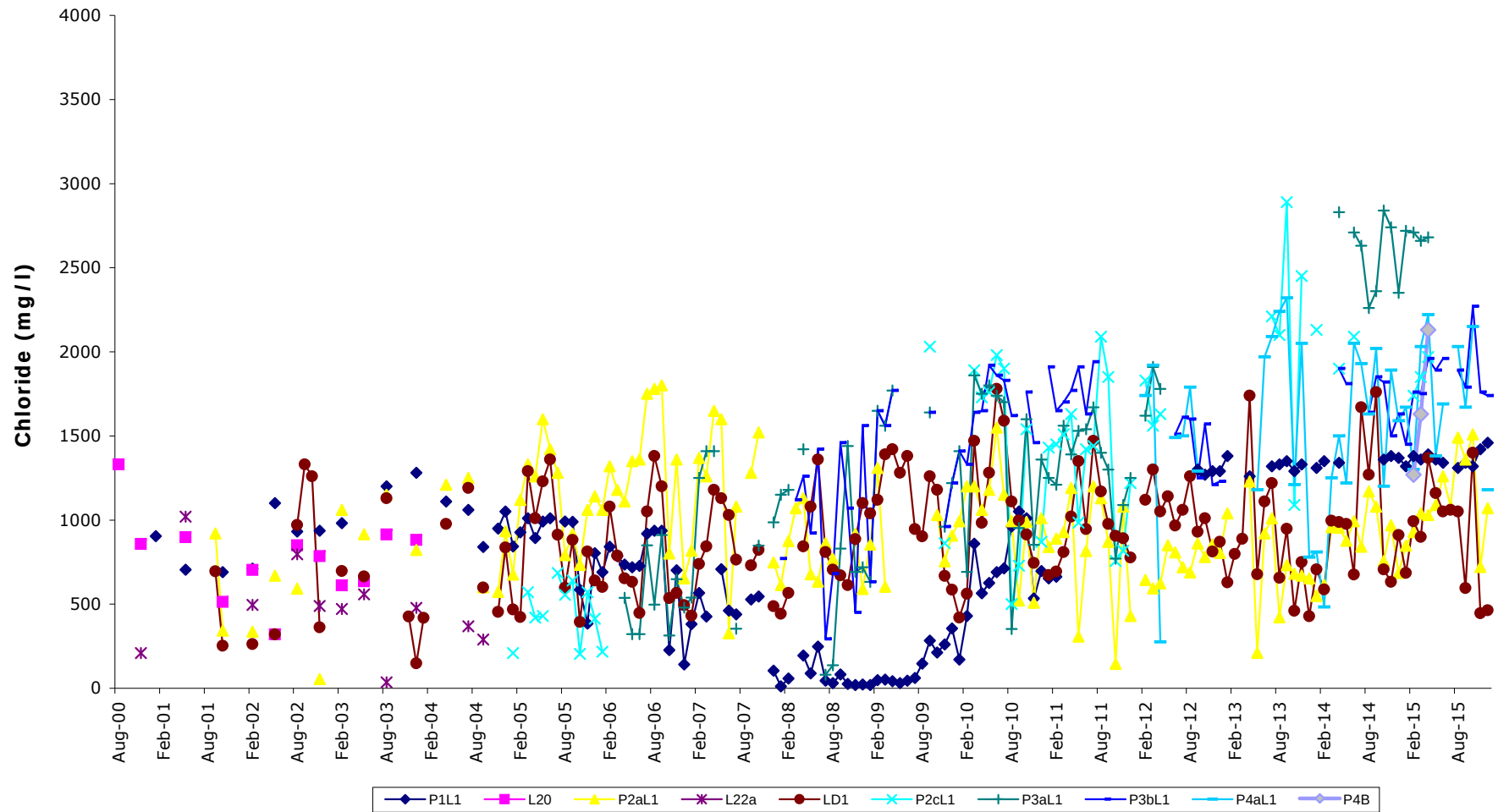
Lab analysis of pH levels in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2000 - Dec 2015.



Lab analysis of Ammoniacal Nitrogen (as N) concentrations in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2000 - Dec 2015.



Lab analysis of Chloride concentrations in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2000 - Dec 2015



Landfill Site during the period Jan 2000 - Dec 2015



Aug-00

—◆— P1L1

—■— L20

—▲— P2aL1

—*— L22a

—●— LD1

—✕— P2cL1

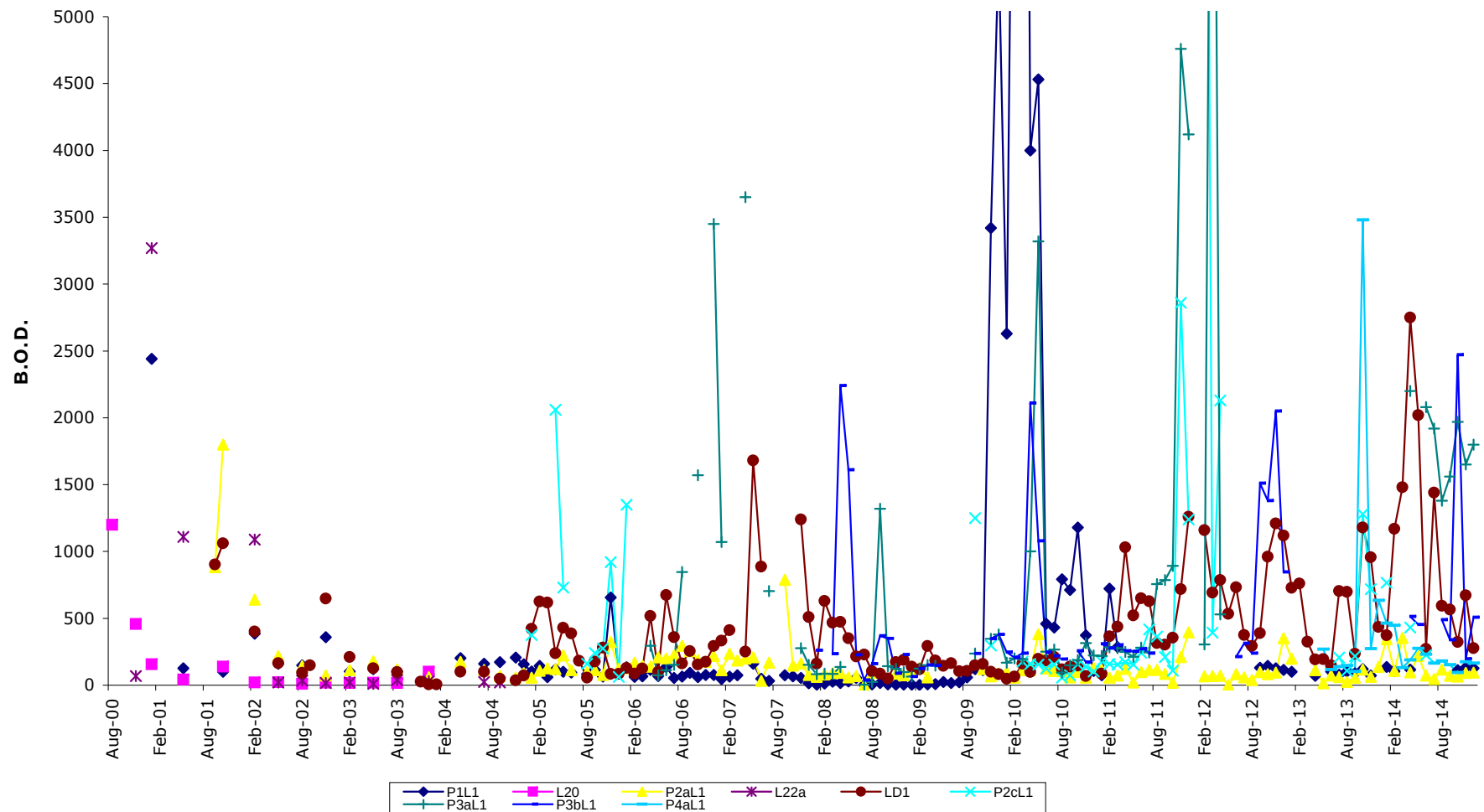
—+ P3aL:

— P3b

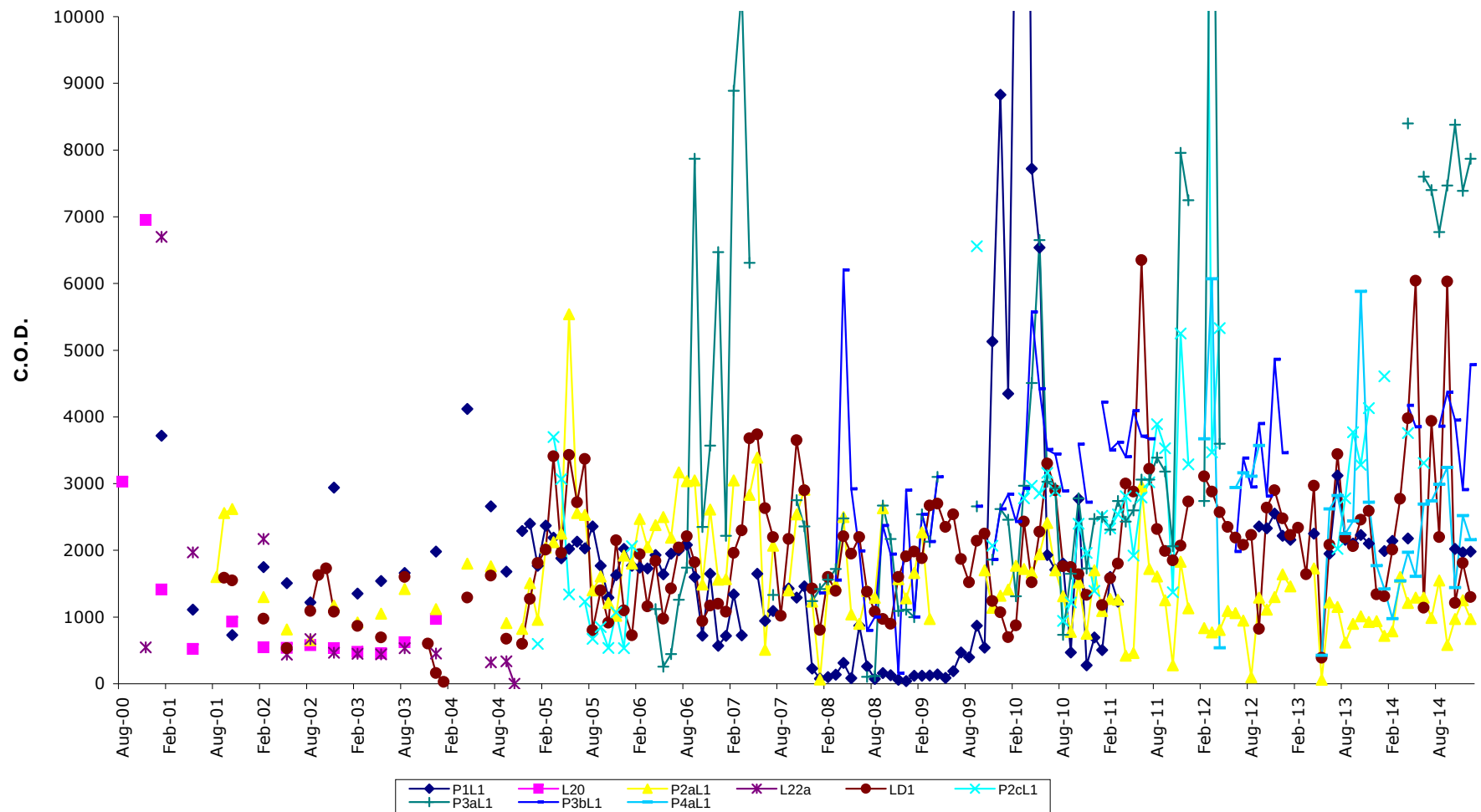
— P4

—◆— P

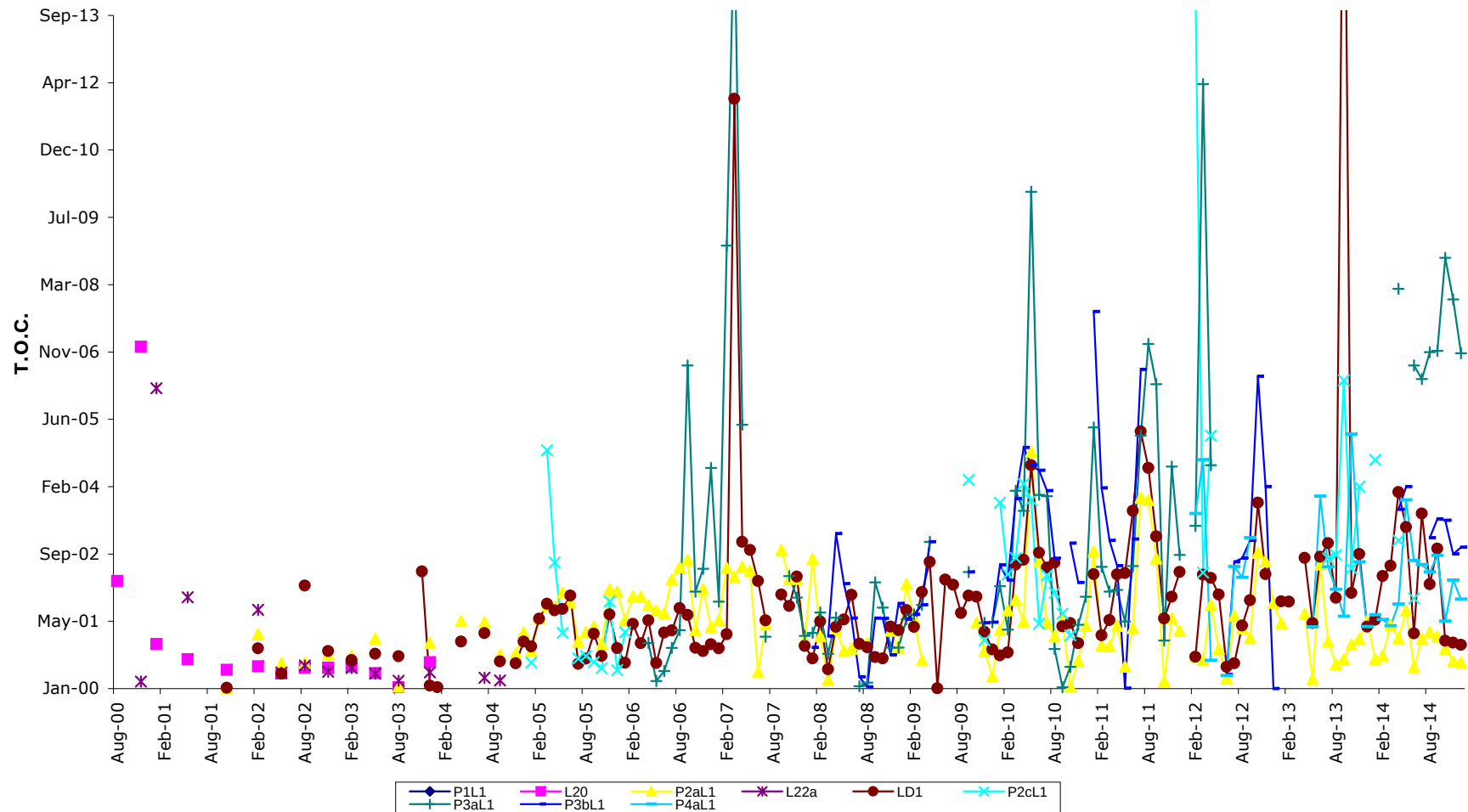
Lab analysis of B.O.D. in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Aug 2000 - Dec 2014.



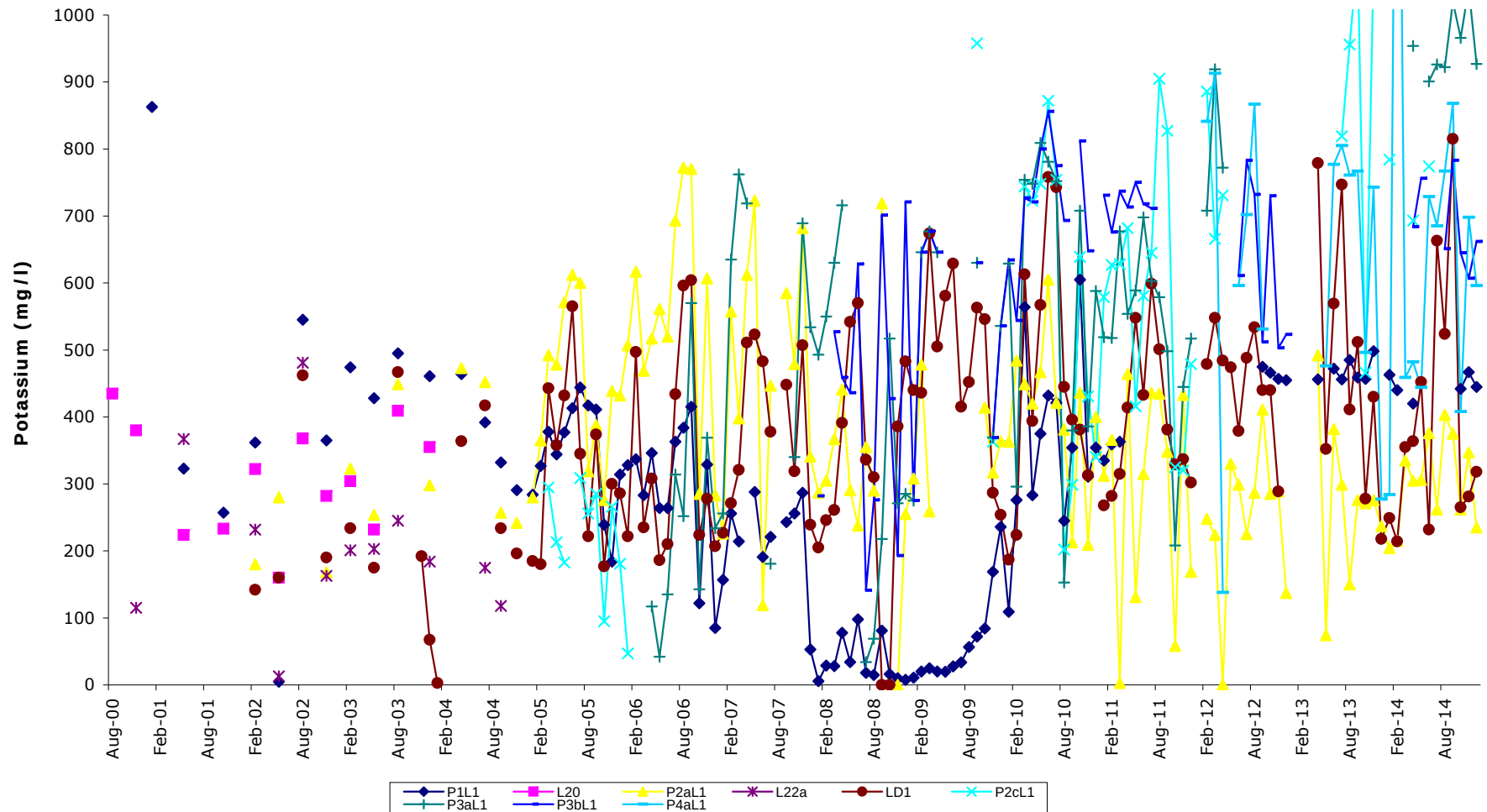
Lab analysis of C.O.D. in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Aug 2000 - Dec 2014.



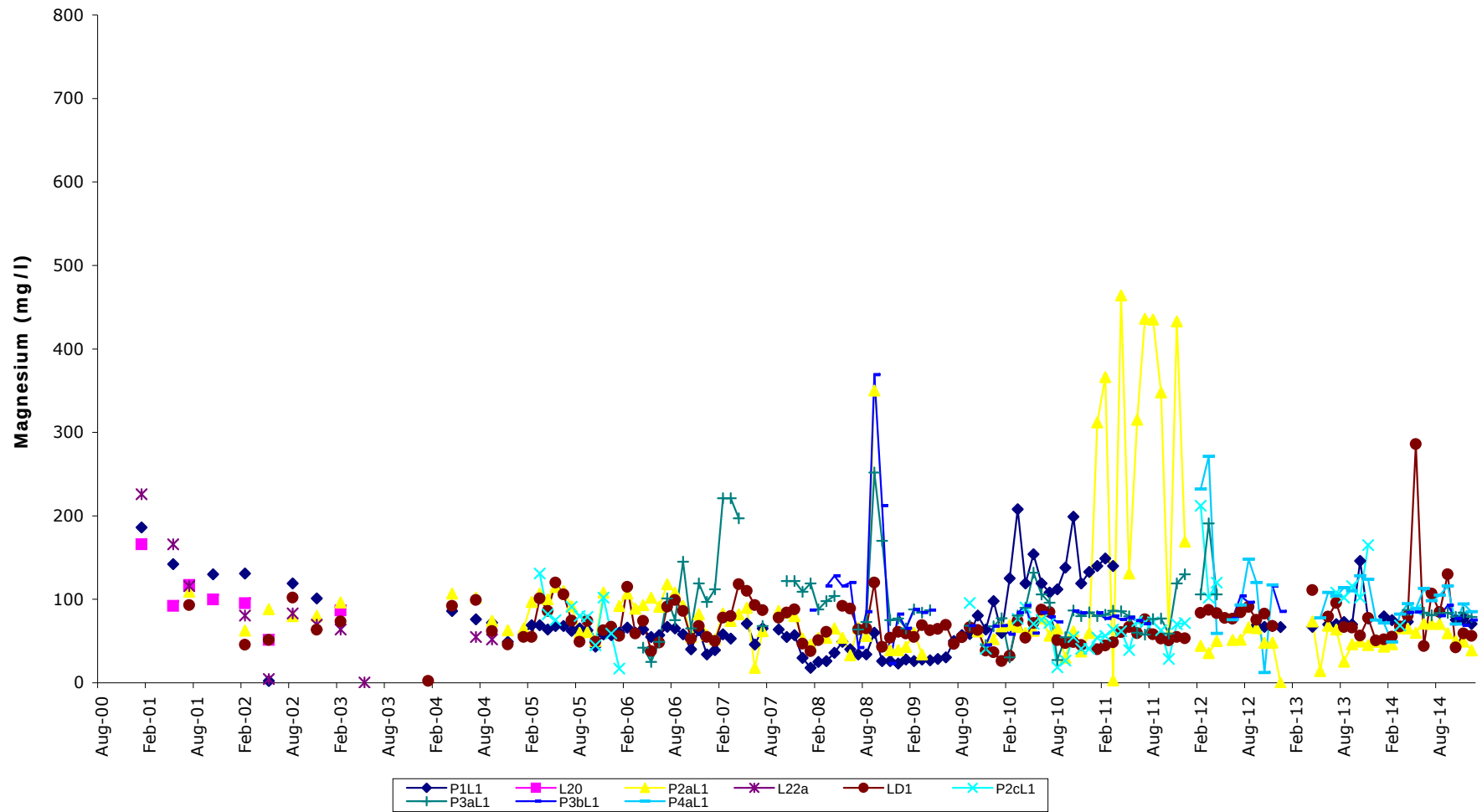
Lab analysis of T.O.C. in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Aug 2000 - Dec 2014.



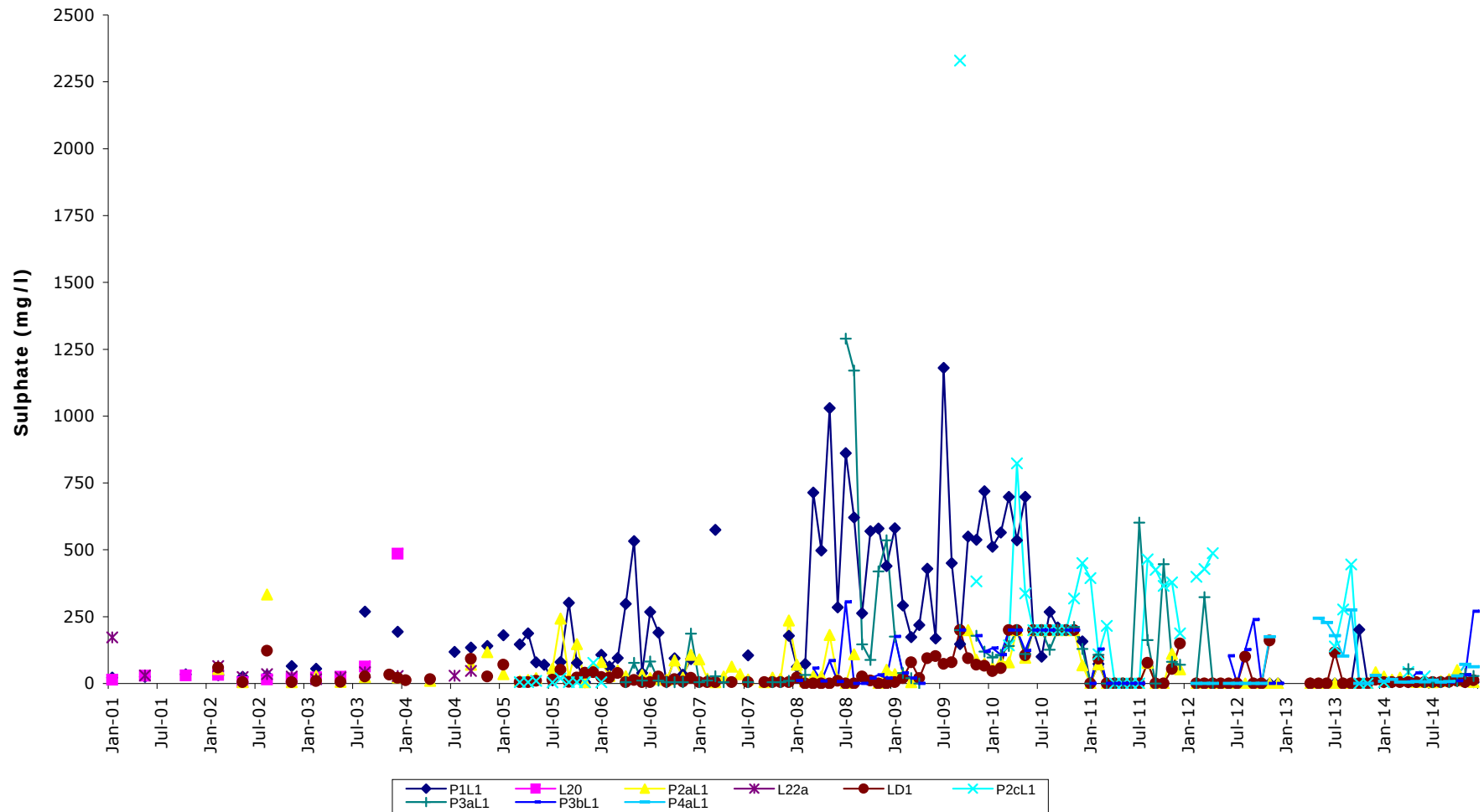
**Lab analysis of Potassium concentrations in leachate sampled by Amgen Cymru at the Bryn Pica
Landfill Site during the period Aug 2000 - Dec 2014.**



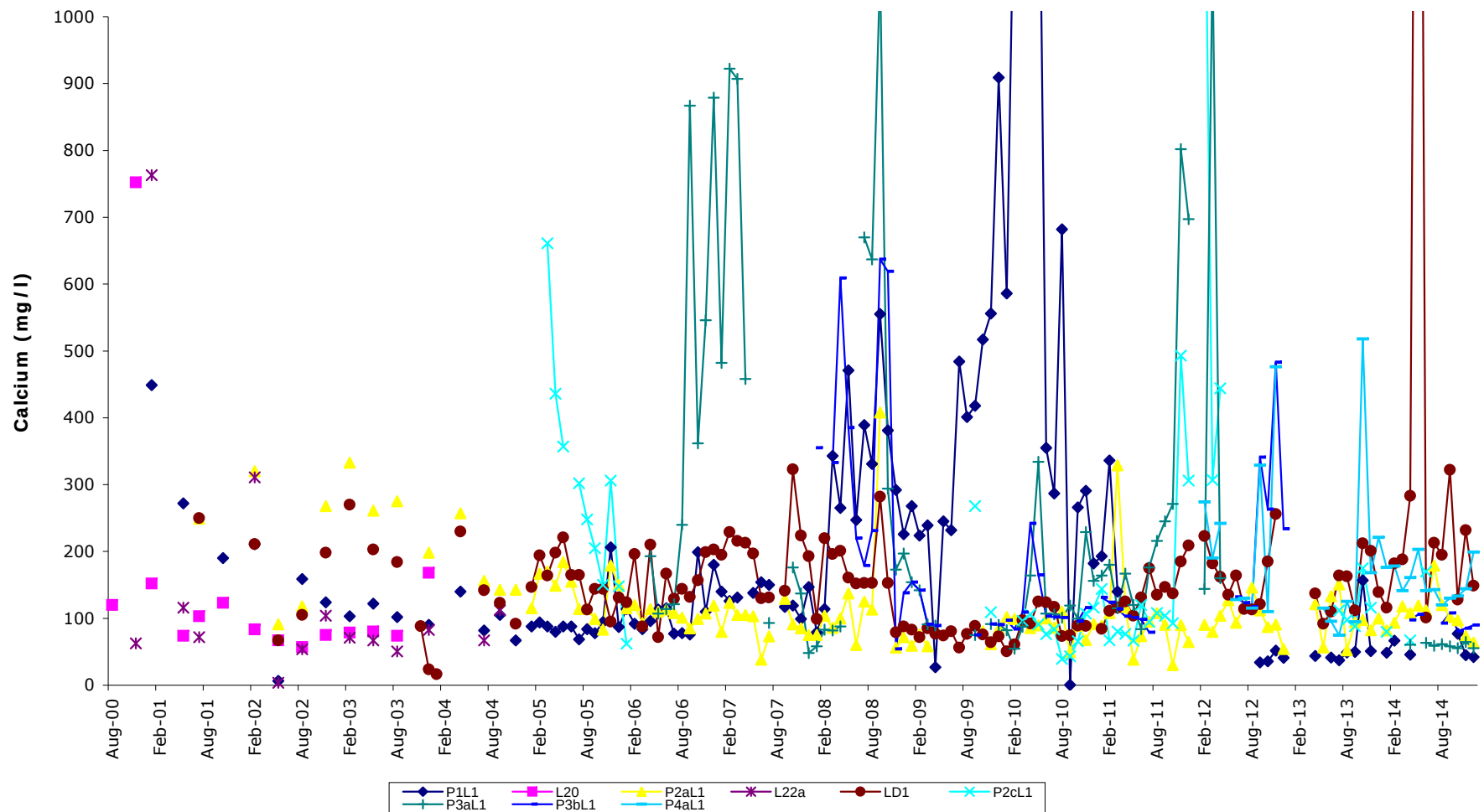
Lab analysis of Magnesium concentration in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period January 2001 - Dec 2014.



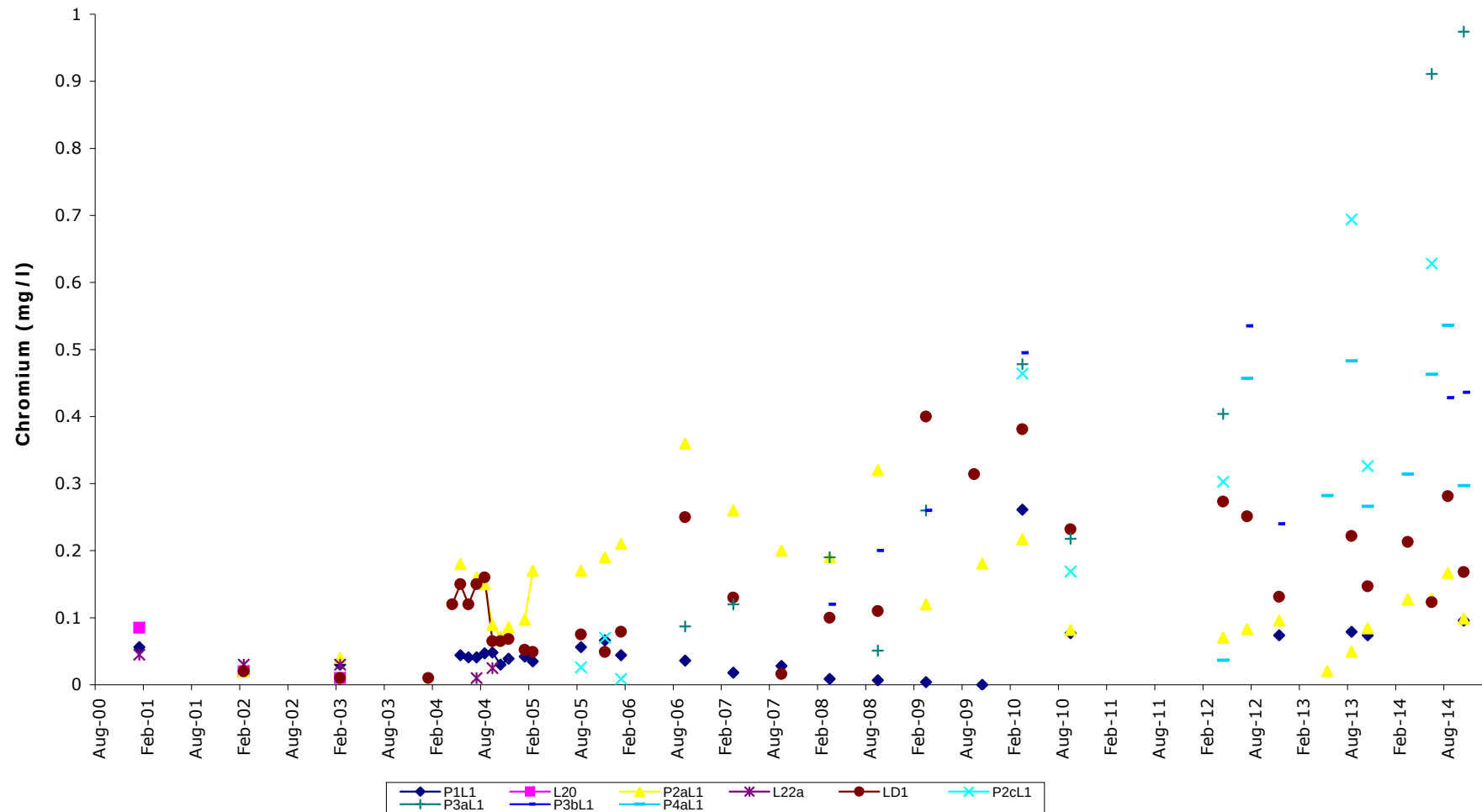
Lab analysis of Sulphate concentration in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2001 - Dec 2014.



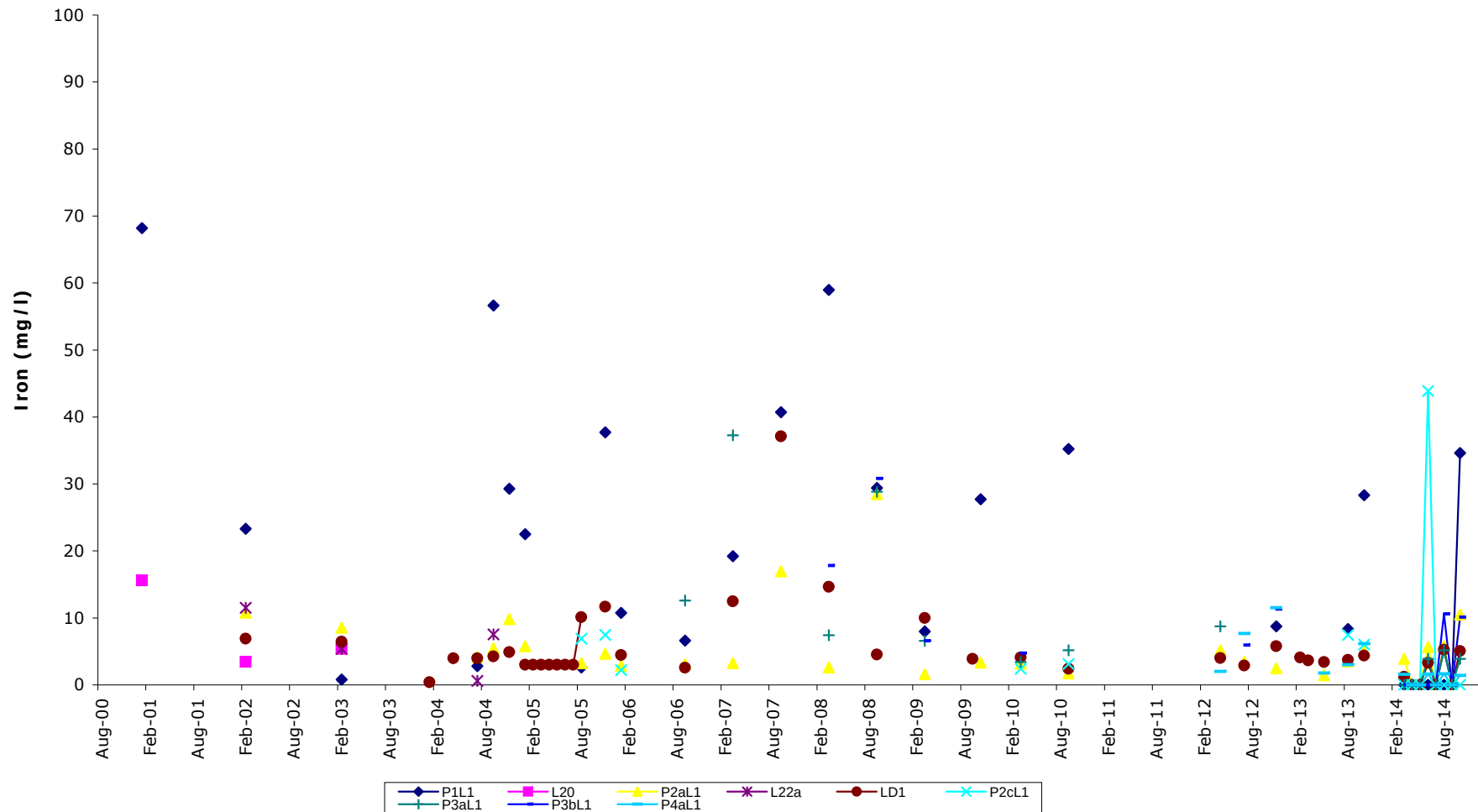
Lab analysis of Calcium concentration in leachate sampled by Amgen Cymru at the Bryn Pica Landfill
Site during the period Aug 2000 - Dec 2014.



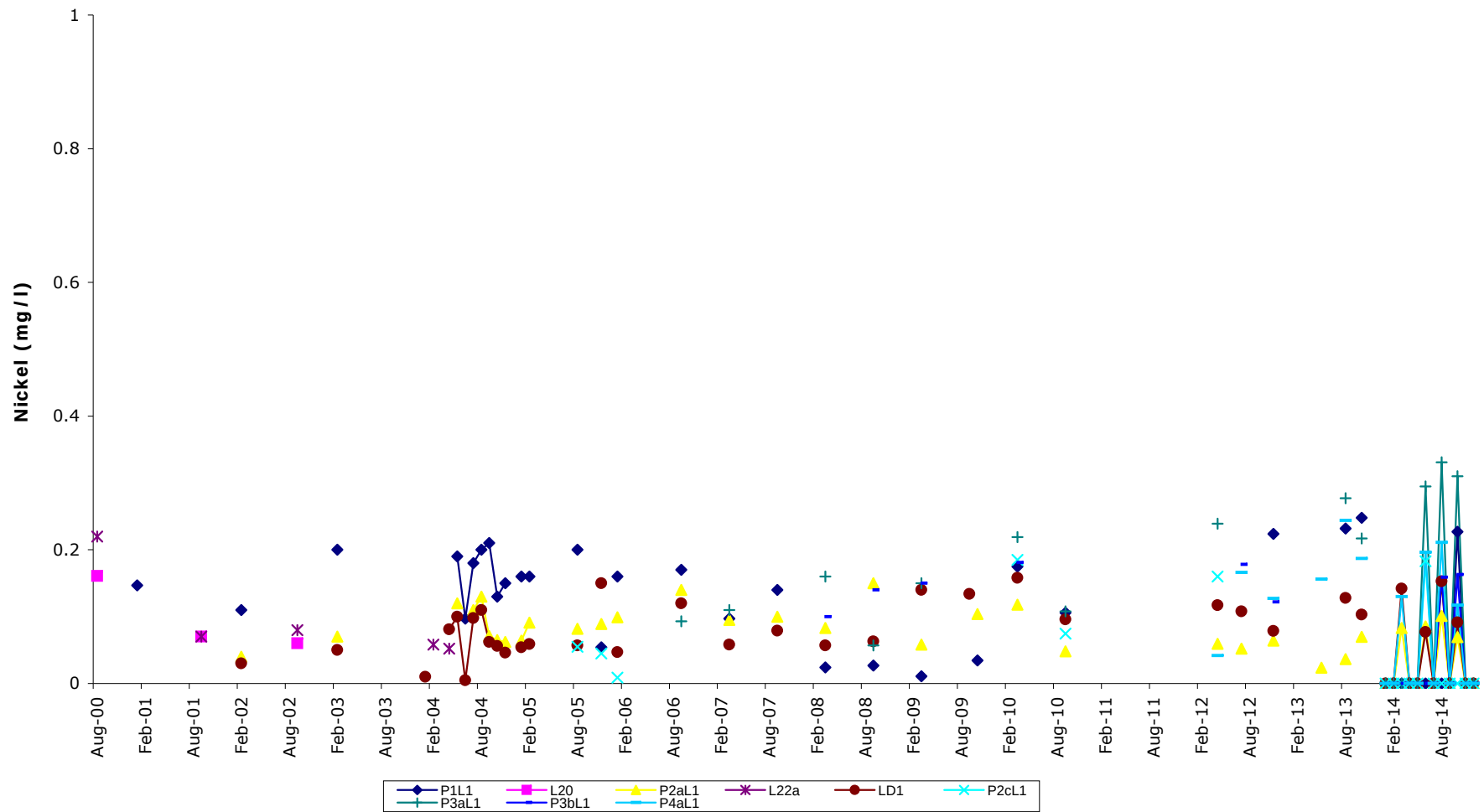
Lab analysis of Chromium concentration in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2001 - Dec 2014.



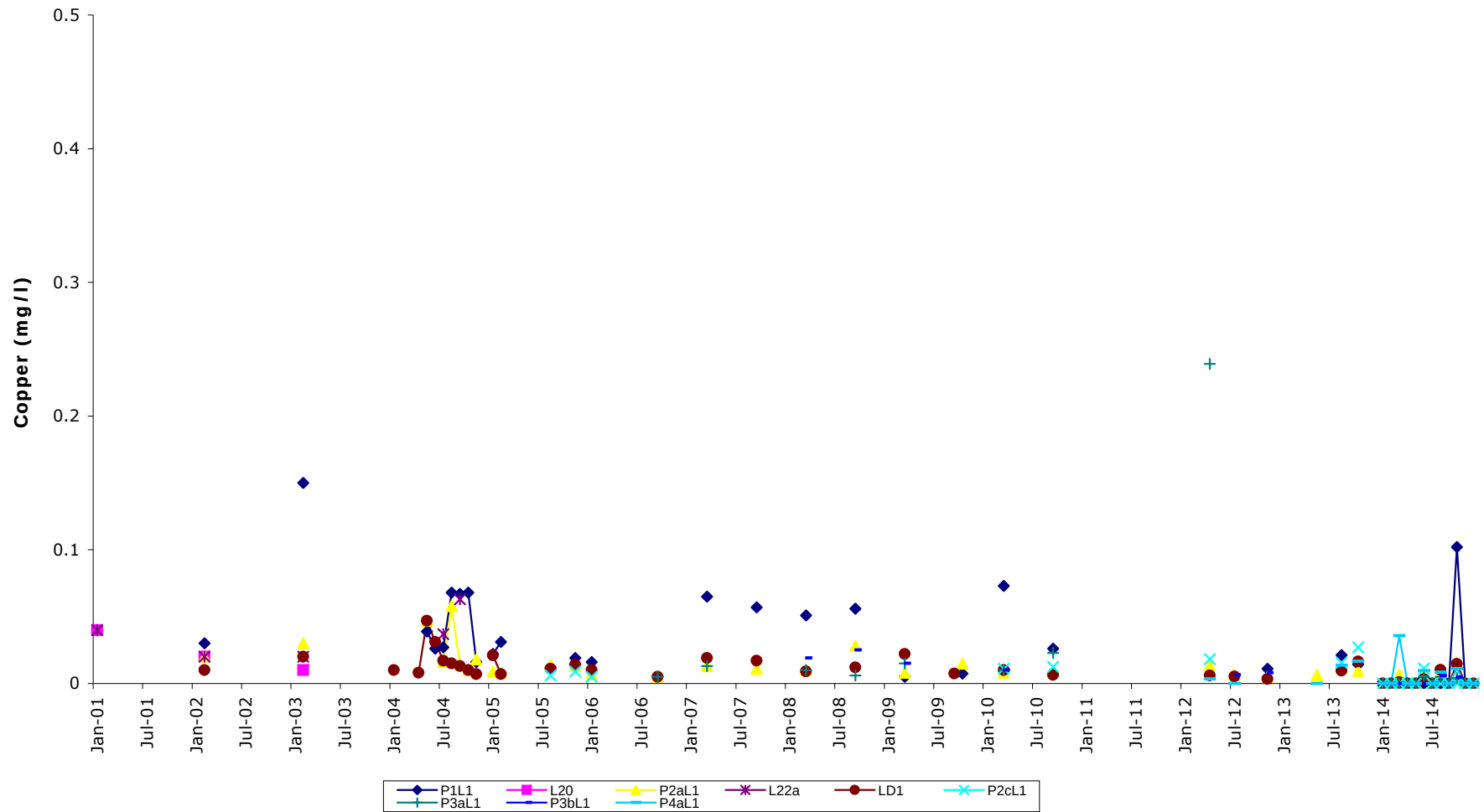
Lab analysis of Iron concentration in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2001 - Dec 2014.



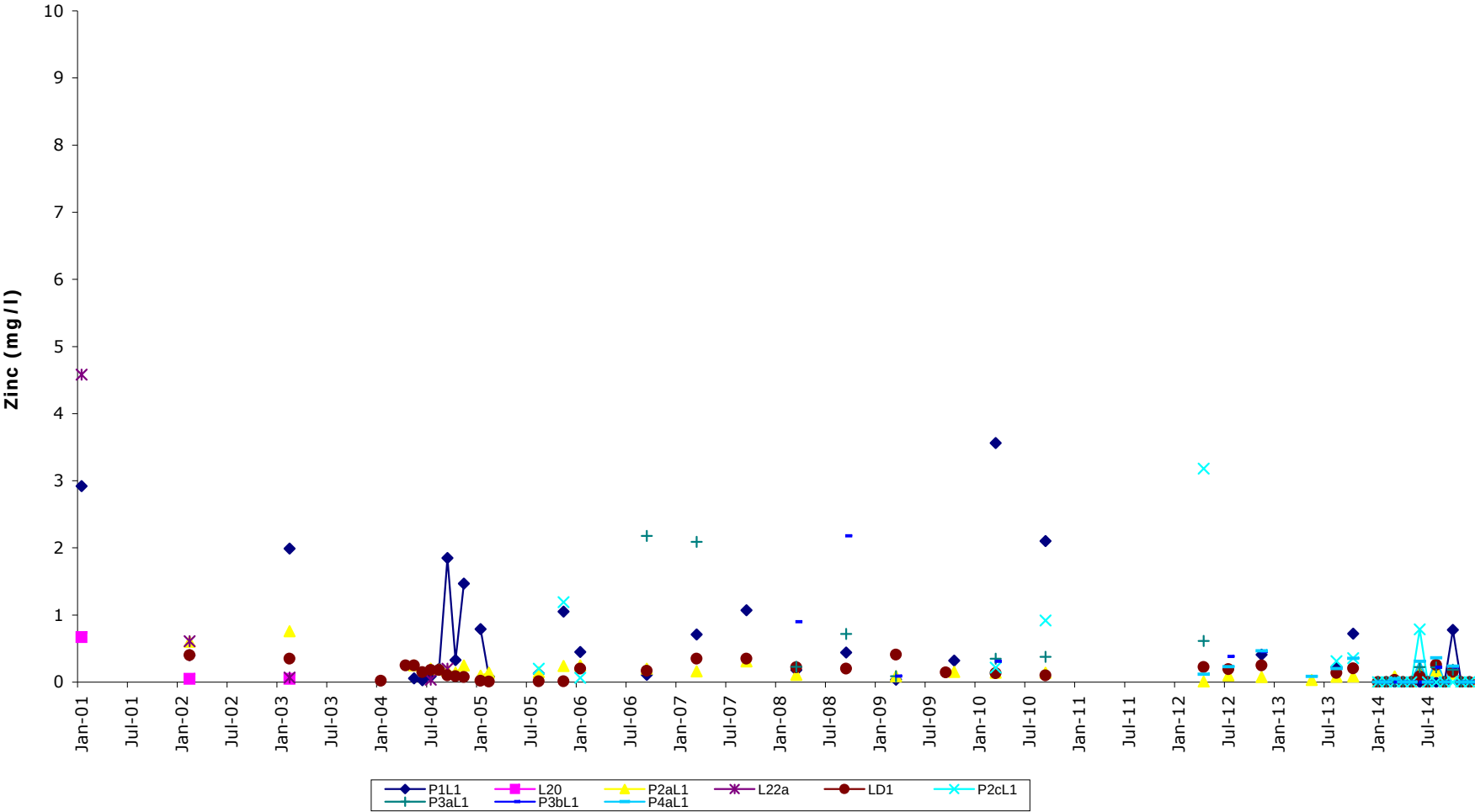
Lab analysis of Nickel concentration in leachate sampled by Amgen Cymru at the Bryn Pica Landfill
Site during the period Jan 2001 - Dec 2014.



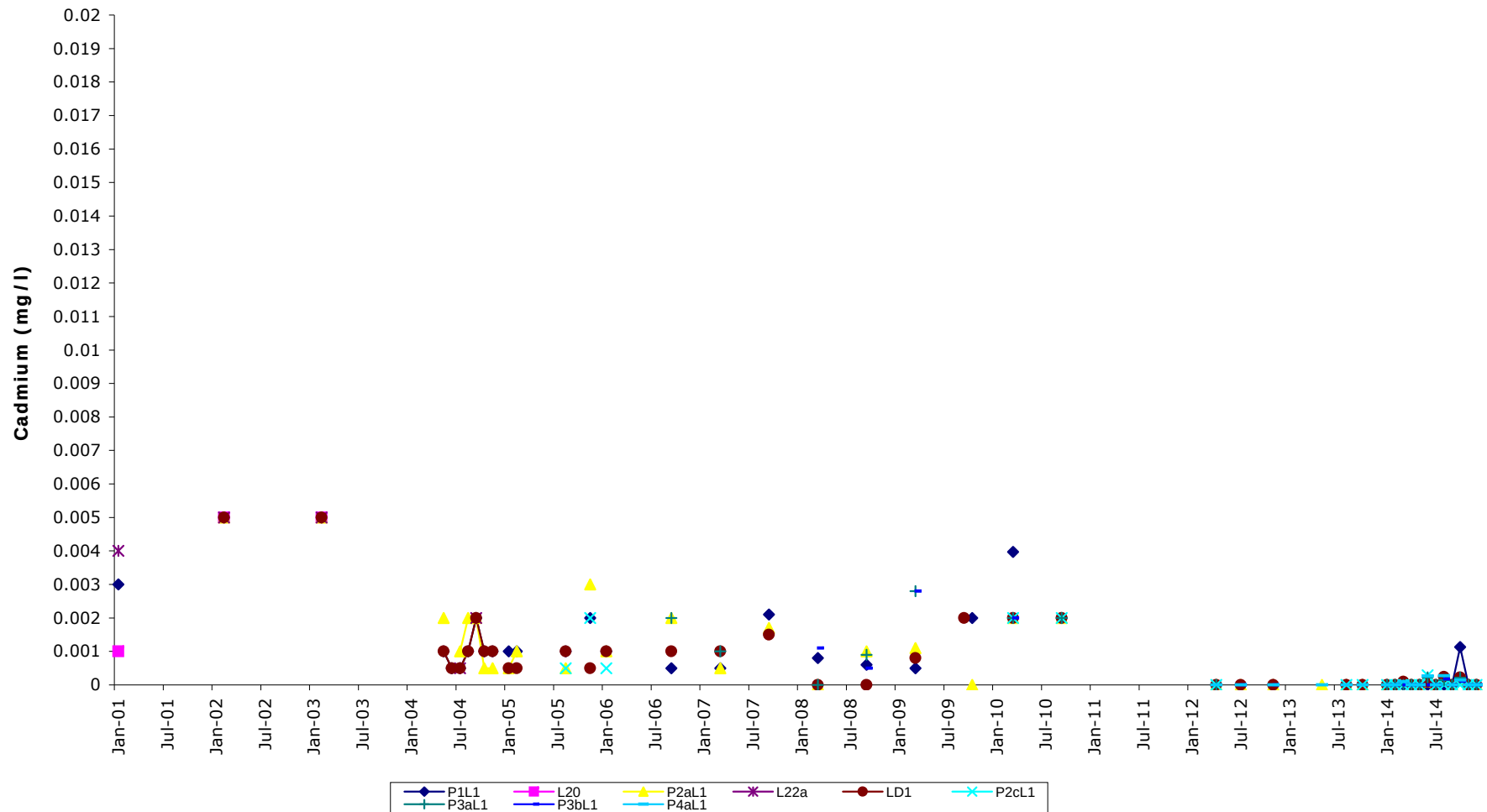
Lab analysis of Copper concentration in leachate sampled by Amgen Cymru at the Bryn Pica Landfill
Site during the period Jan 2001 - Dec 2014.



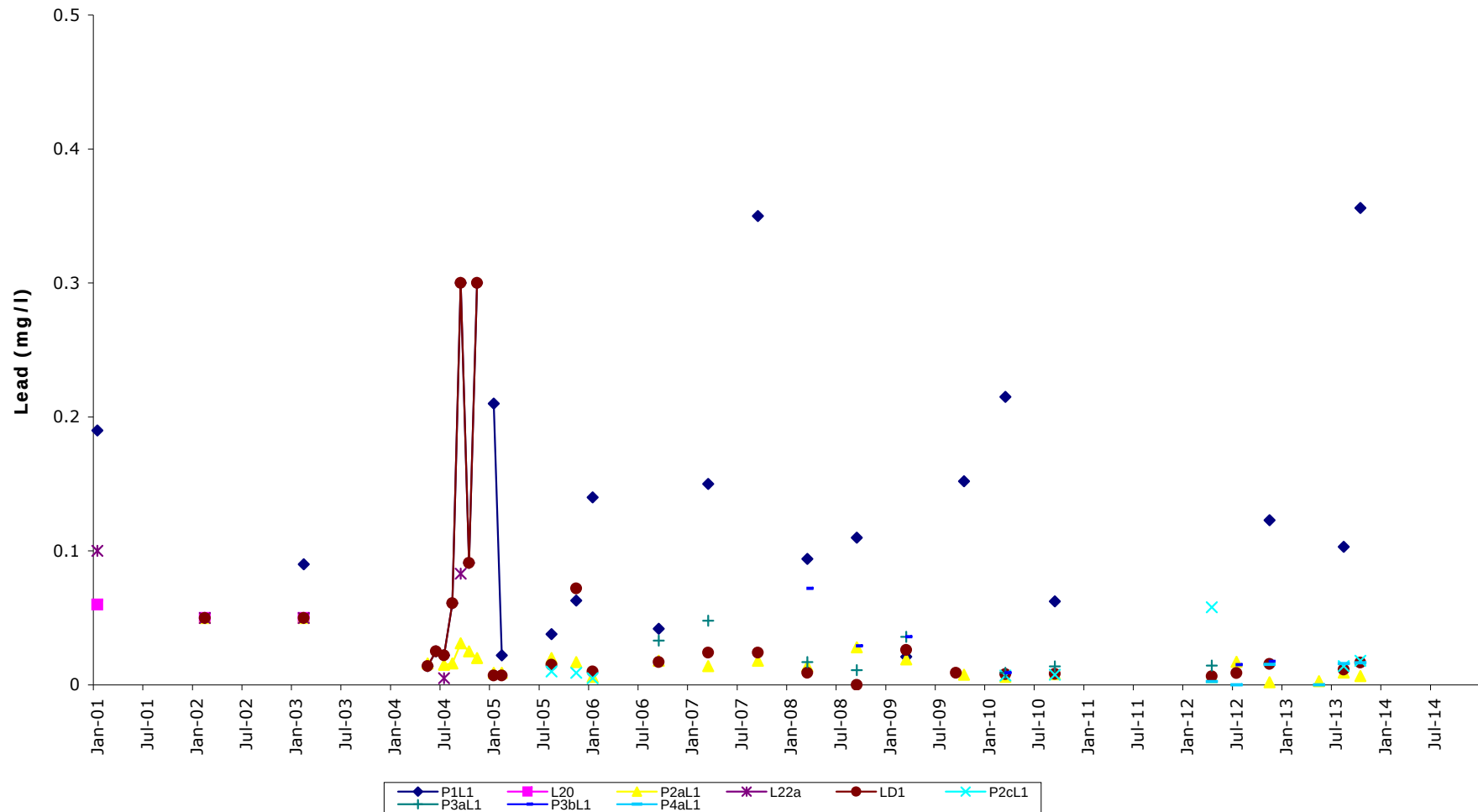
**Lab analysis of Zinc concentration in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site
during the period Jan 2001 - Dec 2014.**



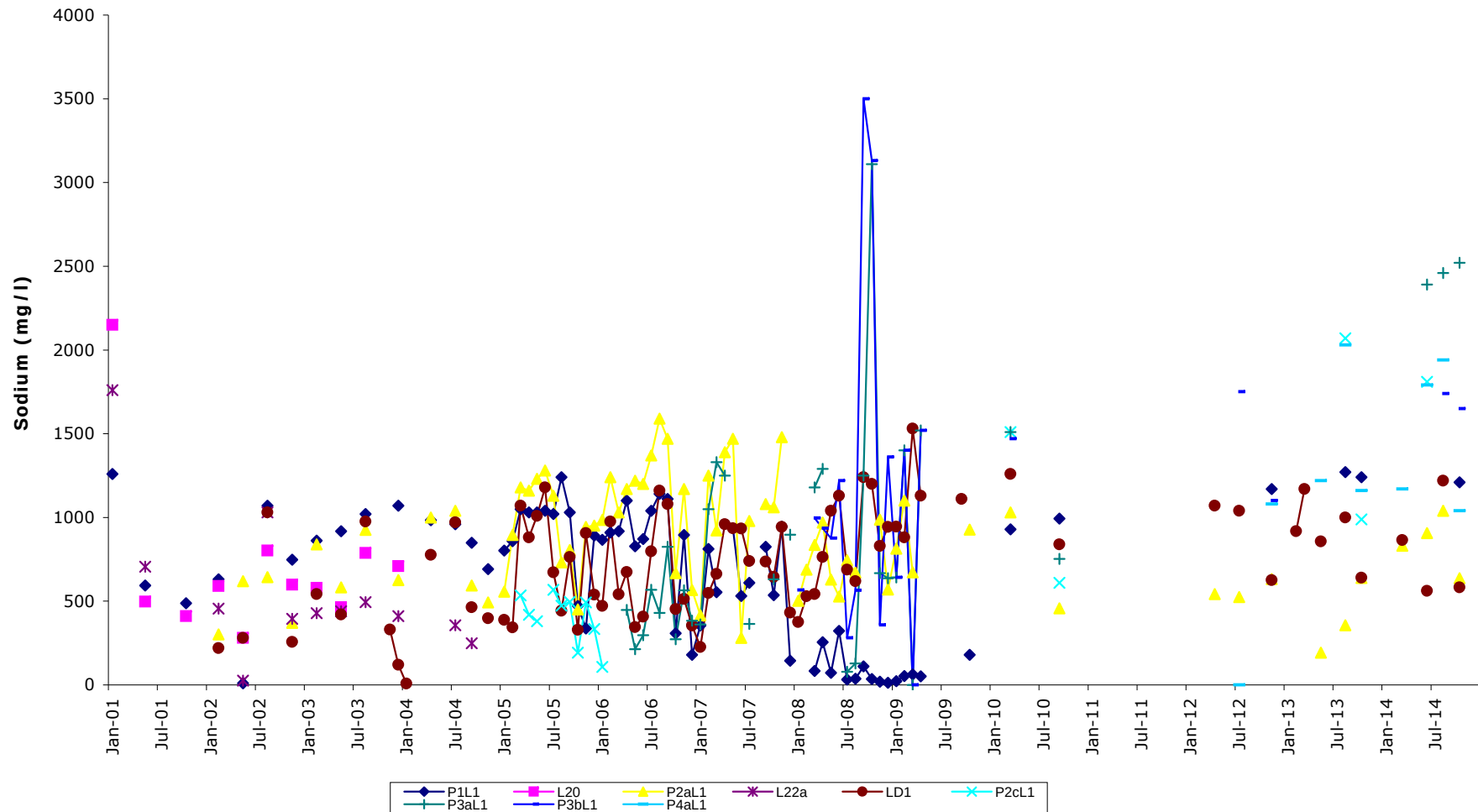
Lab analysis of Cadmium concentration in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2001 - Dec 2014.



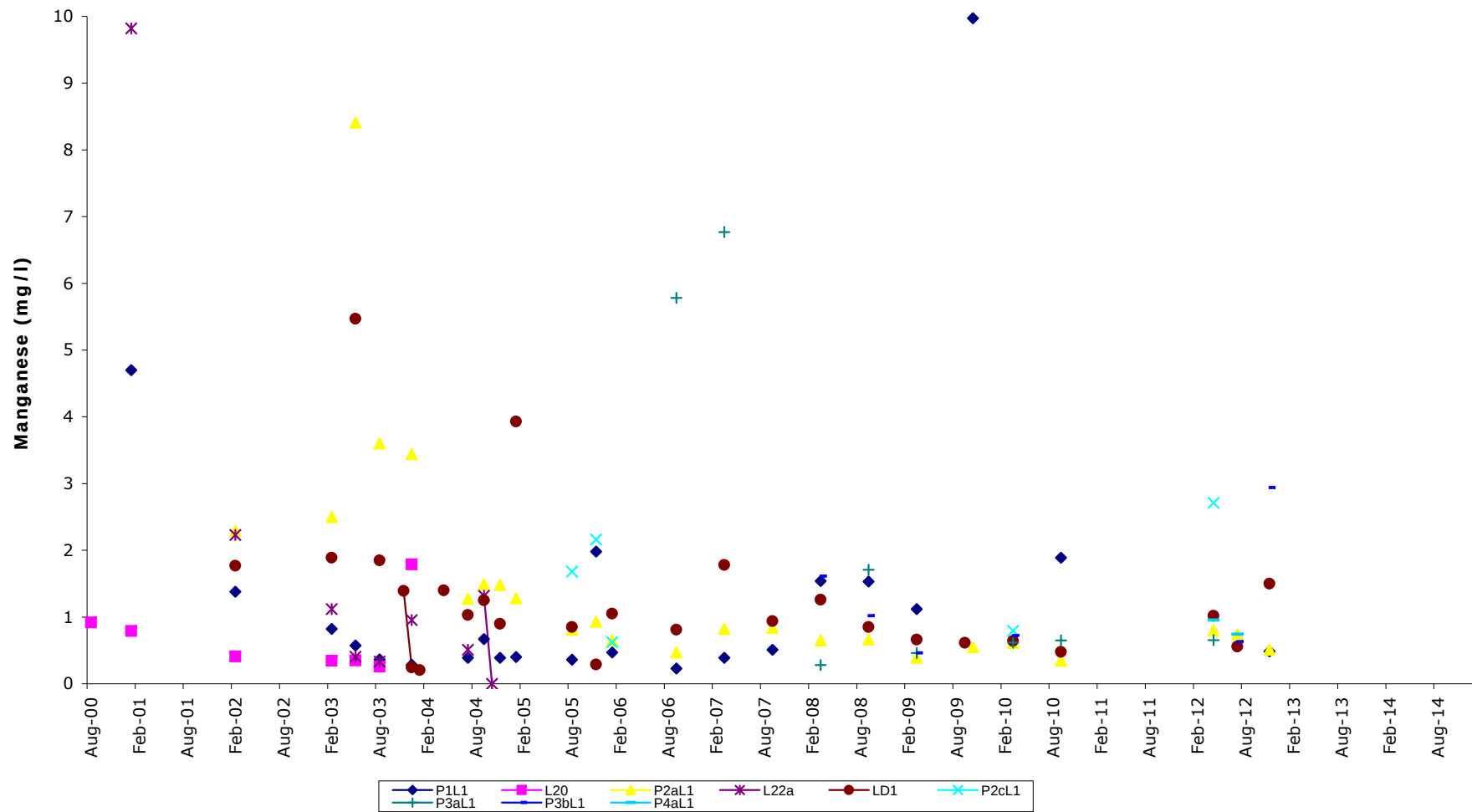
Lab analysis of Lead concentration in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2001 - Dec 2014.



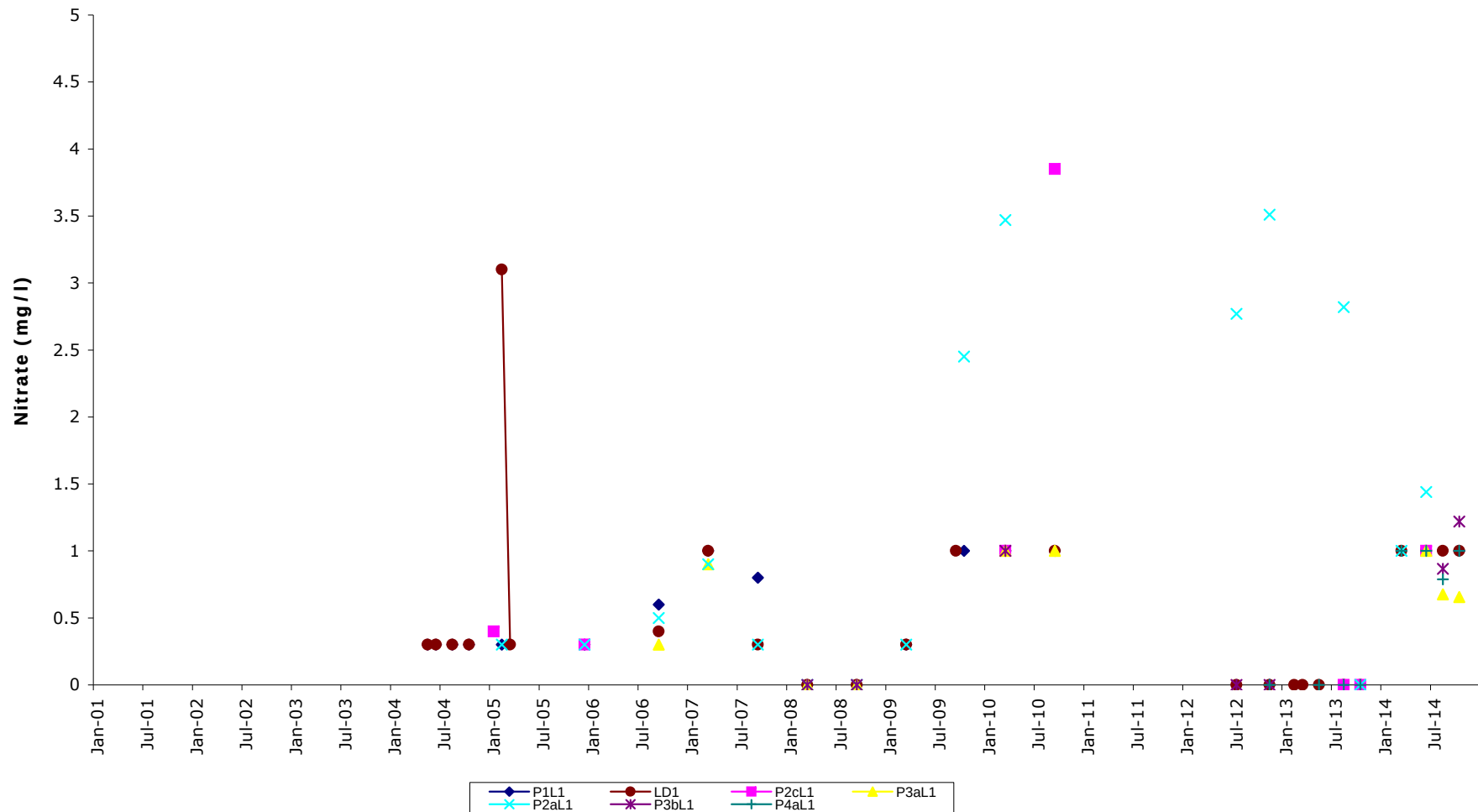
Lab analysis of Sodium concentration in leachate sampled by Amgen Cymru at the Bryn Pica Landfill
Site during the period Jan 2001 - Dec 2014.



Lab analysis of Manganese concentrations in leachate sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Aug 2000 - Dec 2014.

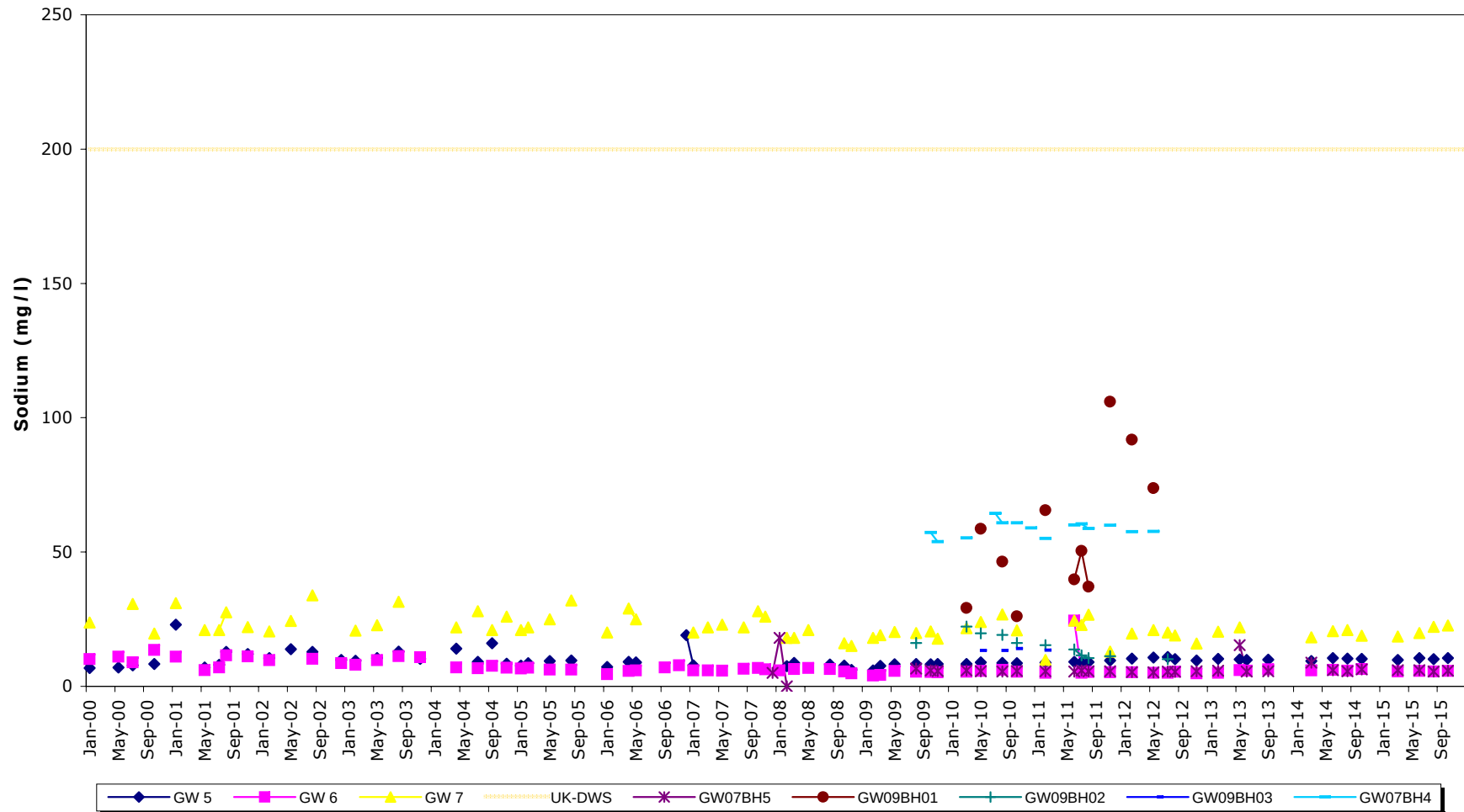


Lab analysis of Nitrate concentration in leachate sampled by Amgen Cymru at the Bryn Pica Landfill
Site during the period Jan 2004 - Dec 2014.

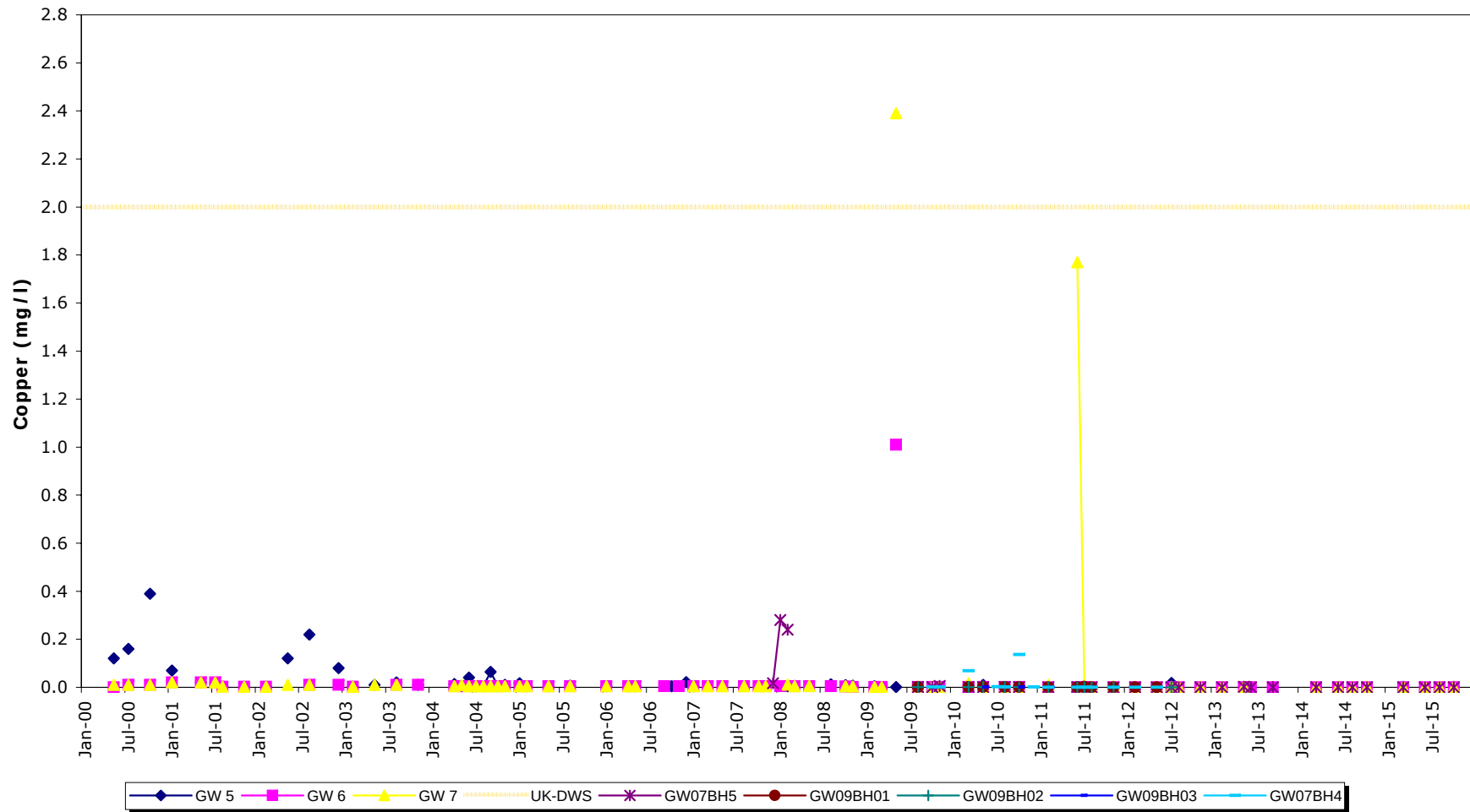


Appendix D – Time Series Plots Illustrating the Results of Amgen'
Laboratory Analysis of Groundwater Sampled at the Bryn Pica
Landfill Site during the period Jan 00 – Dec 15.

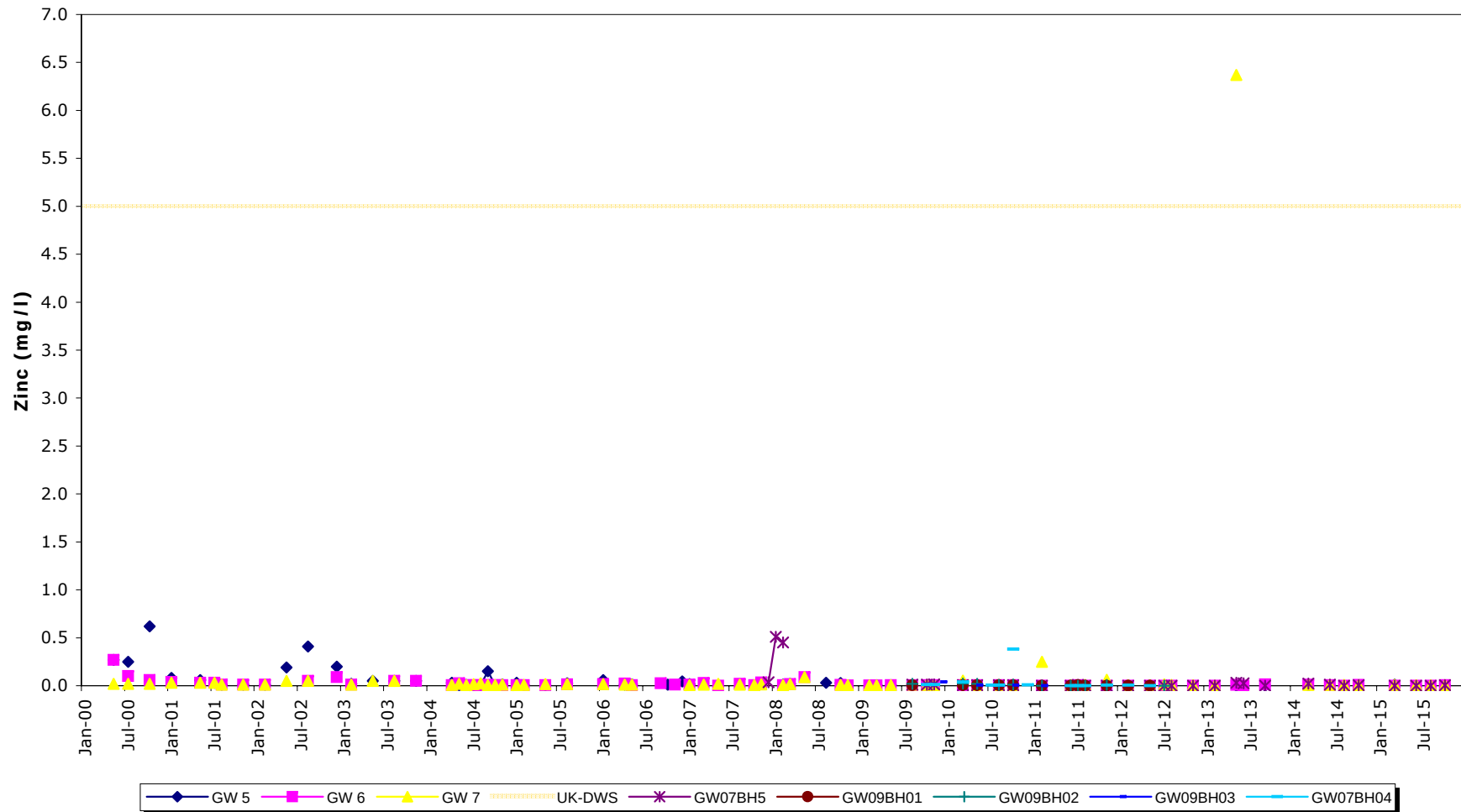
**Lab analysis of Sodium concentration in groundwater sampled by Amgen Cymru at the Bryn Pica
Landfill Site during the period Jan 2000 - Dec 2015.**



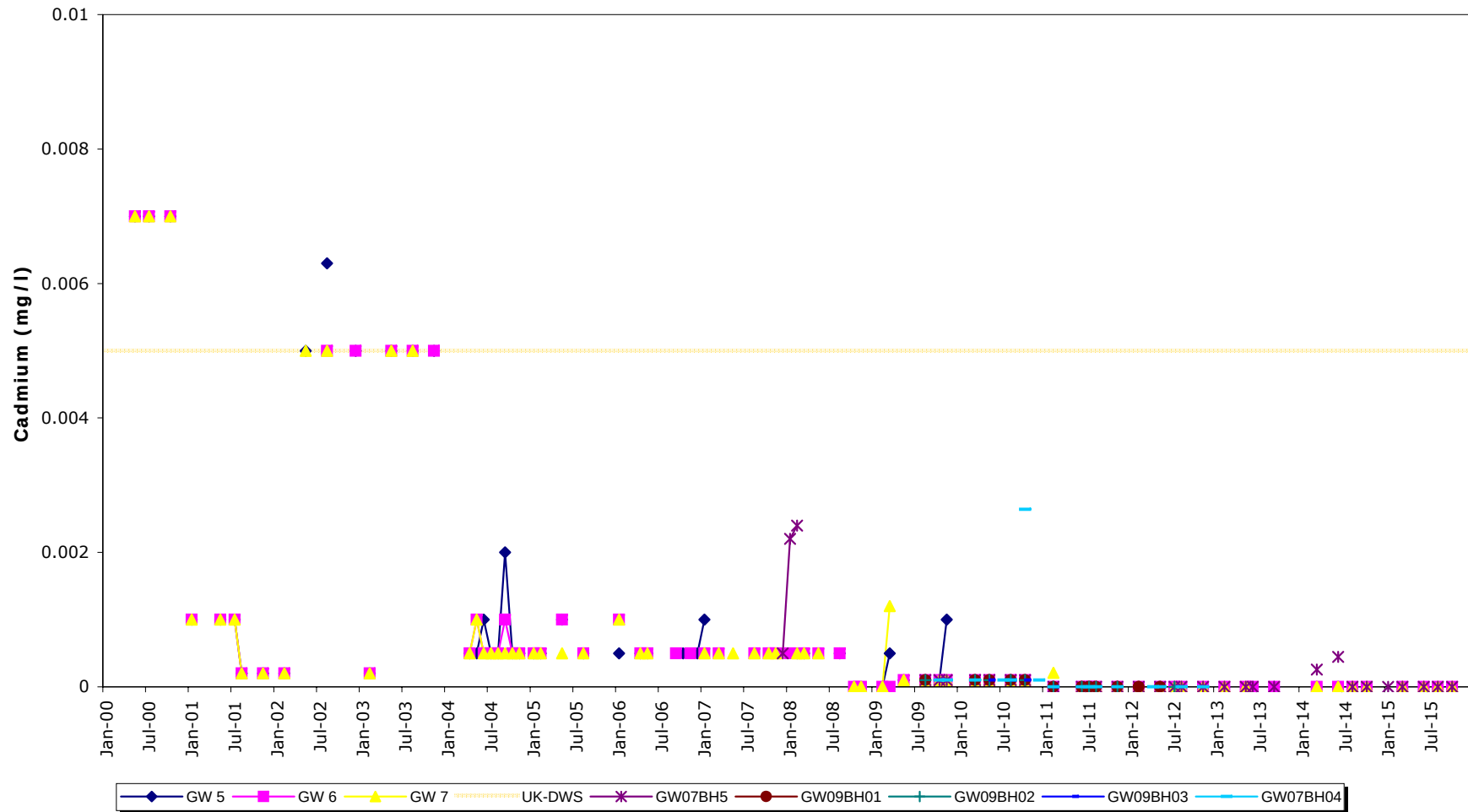
**Lab analysis of Copper concentration in groundwater sampled by Amgen Cymru at the Bryn Pica
Landfill Site during the period Jan 2000 - Dec 2015.**



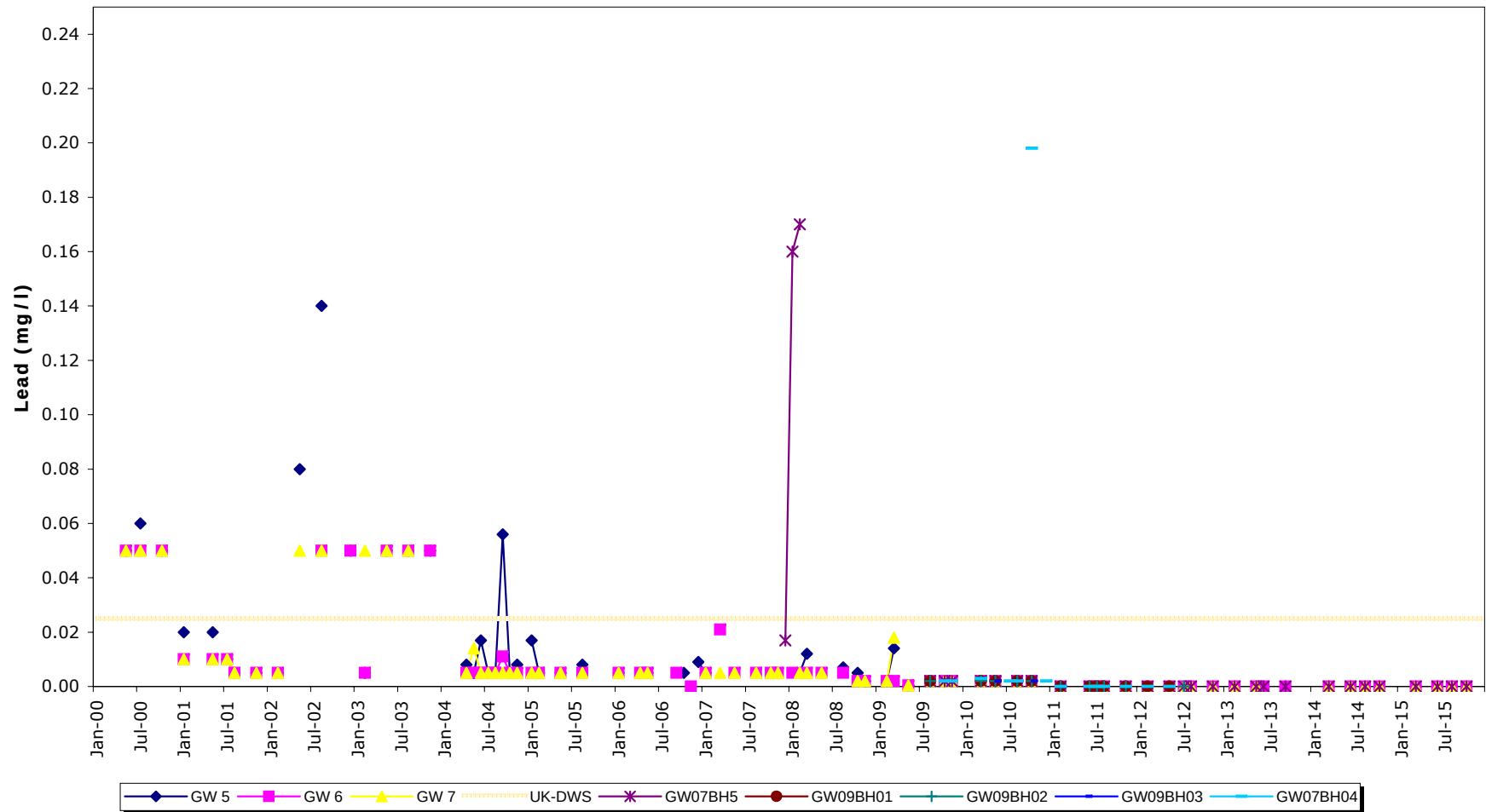
Lab analysis of Zinc concentration in groundwater sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2000 - Dec 2015.



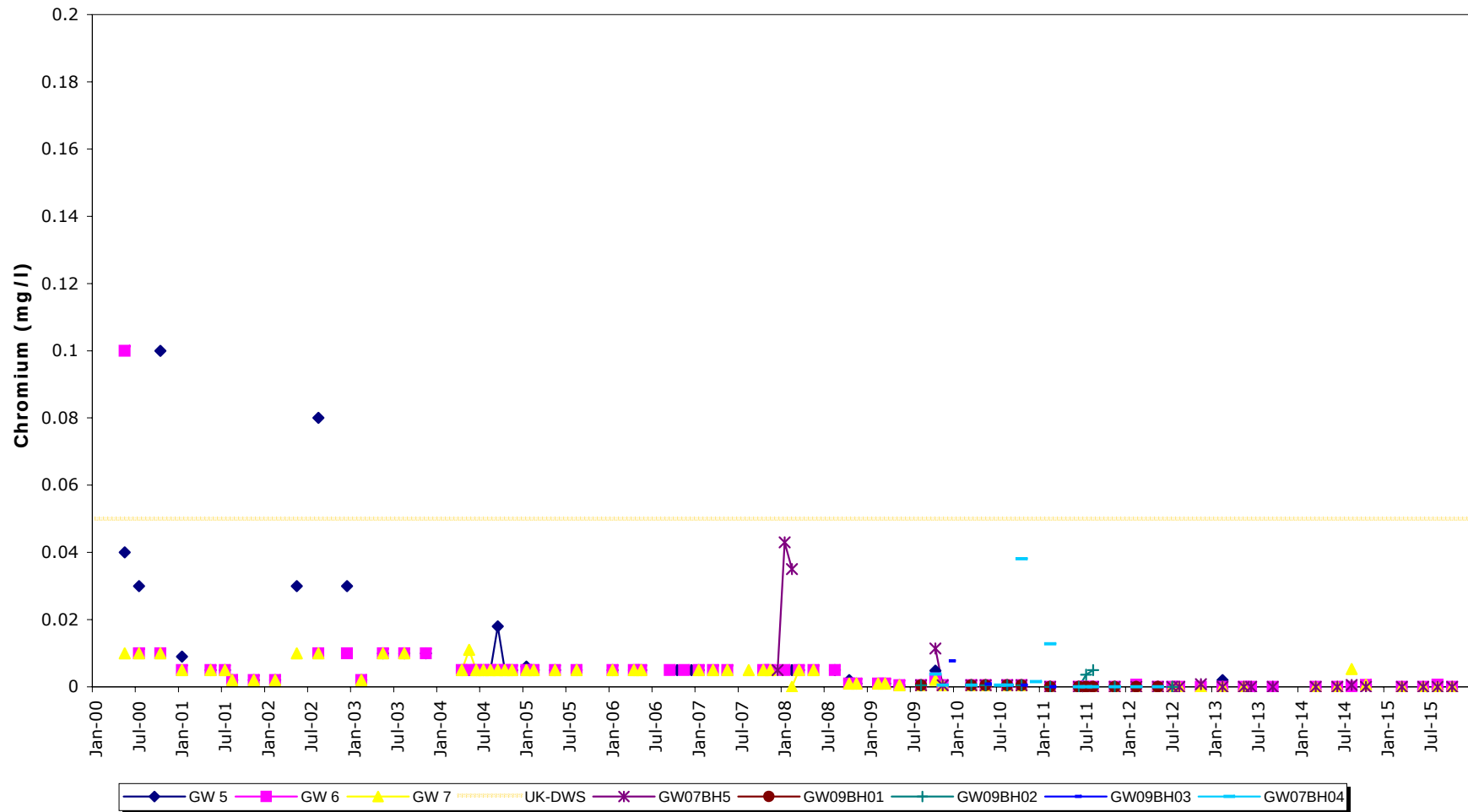
**Lab analysis of Cadmium concentration in groundwater sampled by Amgen Cymru at the Bryn Pica
Landfill Site during the period Jan 2000 - Dec 2015.**



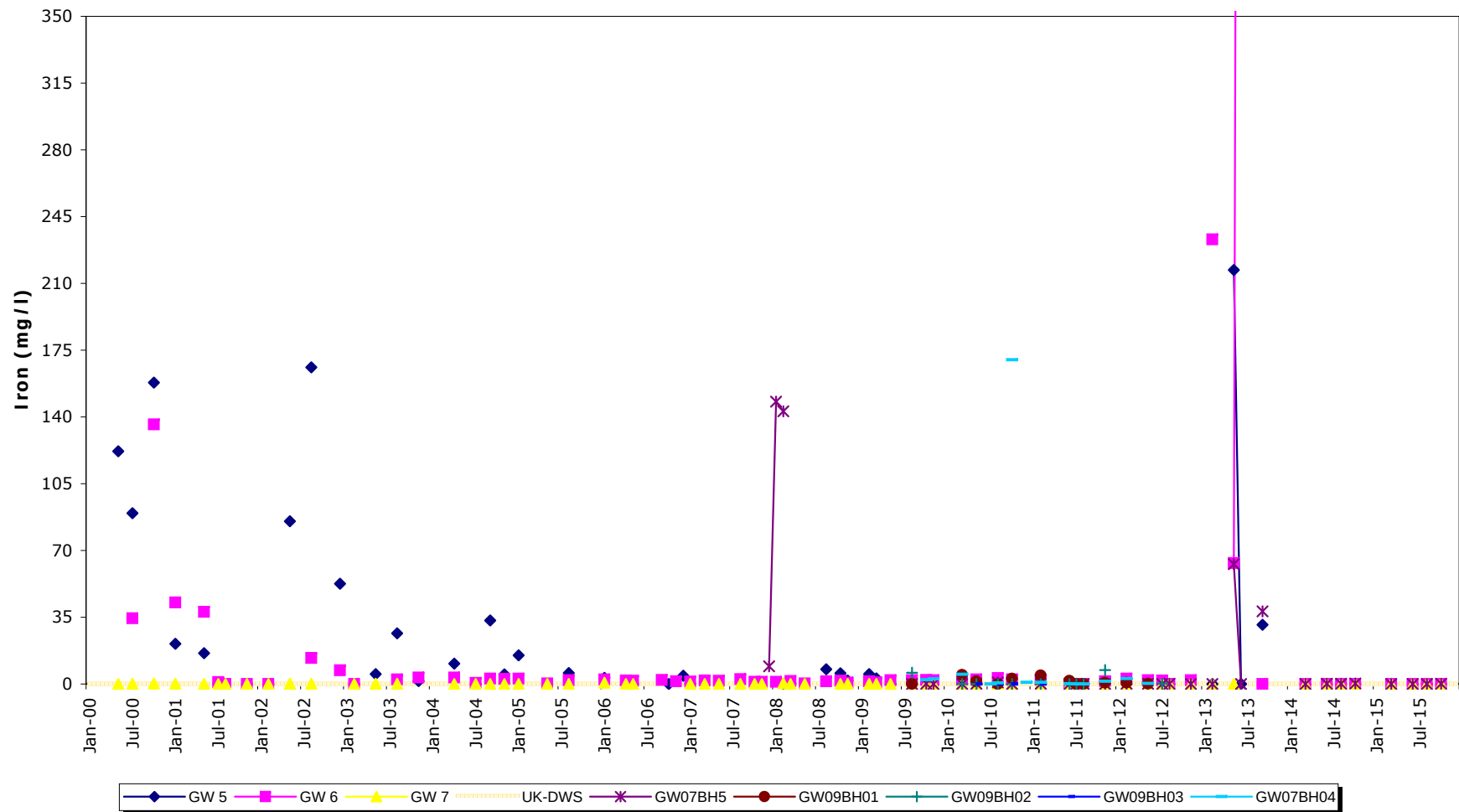
Lab analysis of Lead concentration in groundwater sampled by Amgen Cymru at the Bryn Pica Landfill
Site during the period Jan 2000 - Dec 2015.



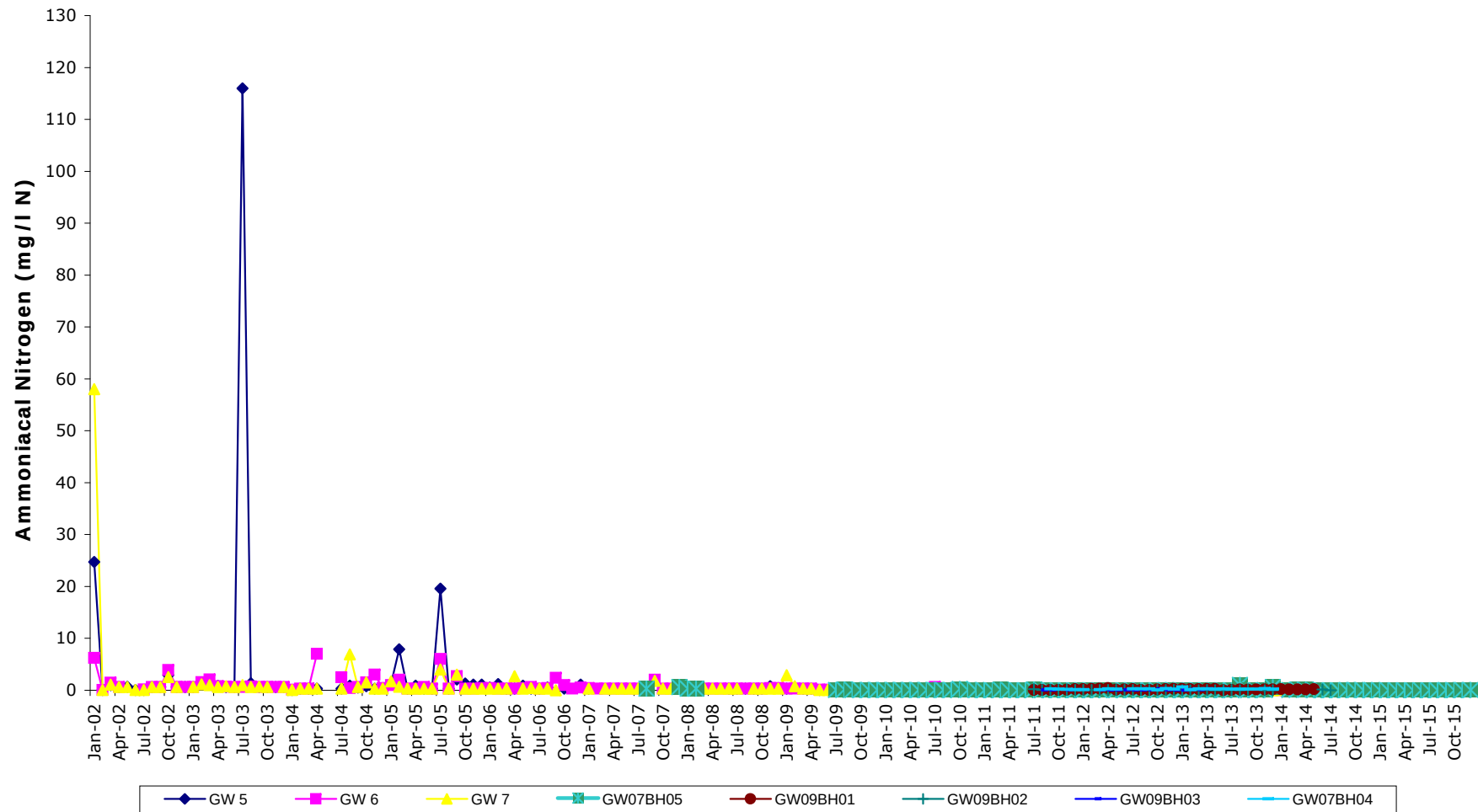
Lab analysis of Chromium concentration in groundwater sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2000 - Dec 2015.



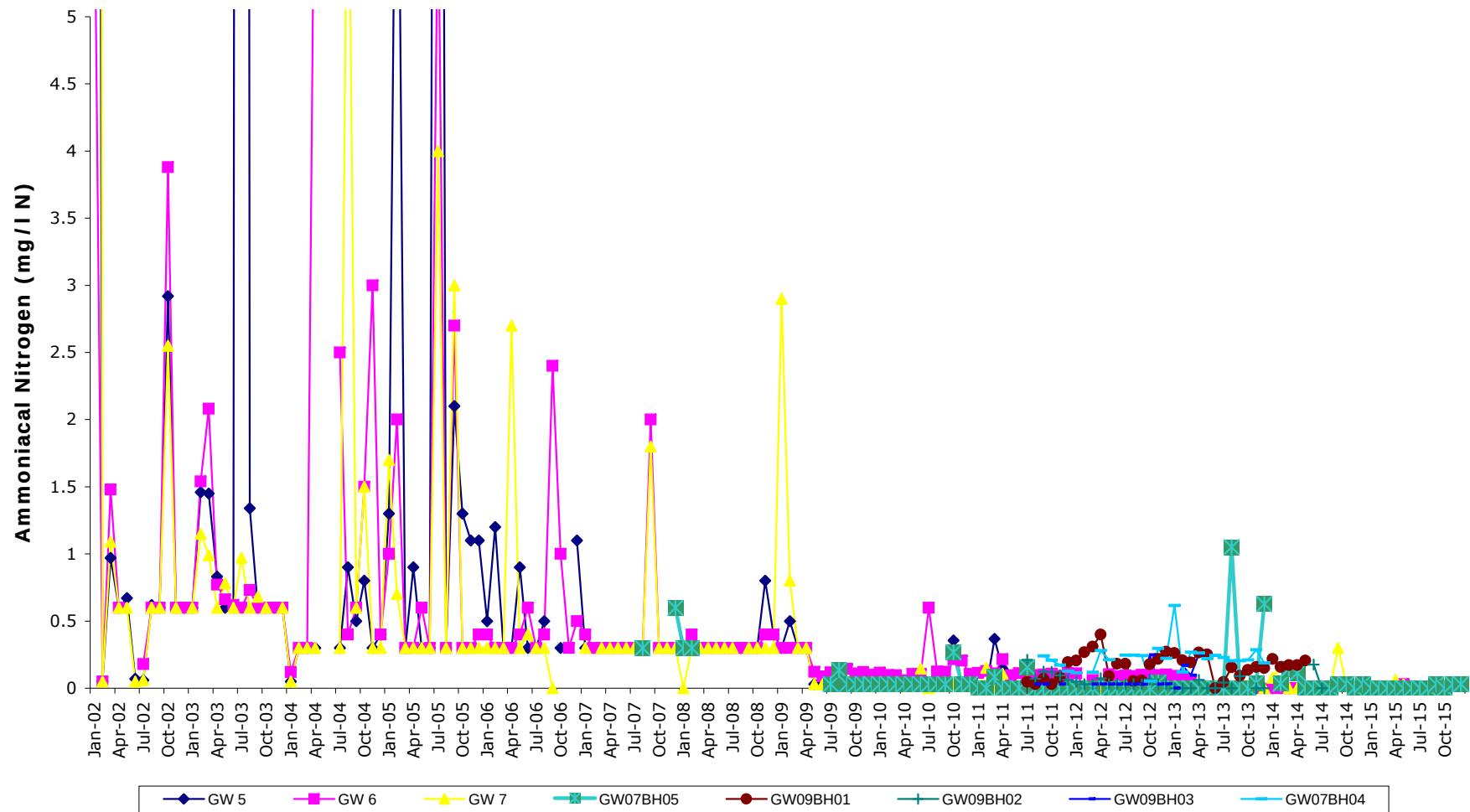
Lab analysis of Iron concentration in groundwater sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2000 - Dec 2015.



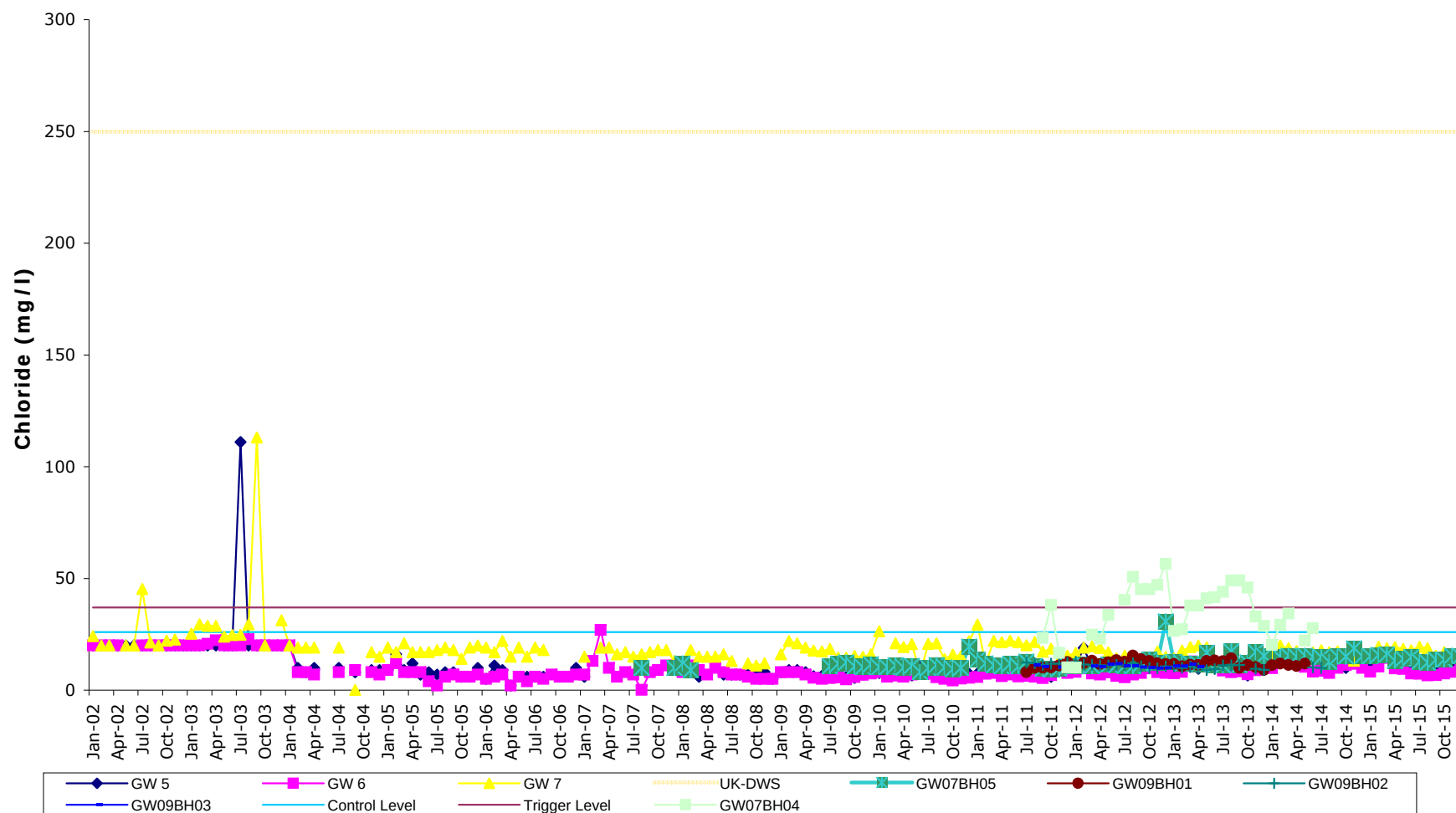
Lab analysis of Ammoniacal Nitrogen (as N) concentrations in groundwater sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2002 - Dec 2015 (Scale 1).



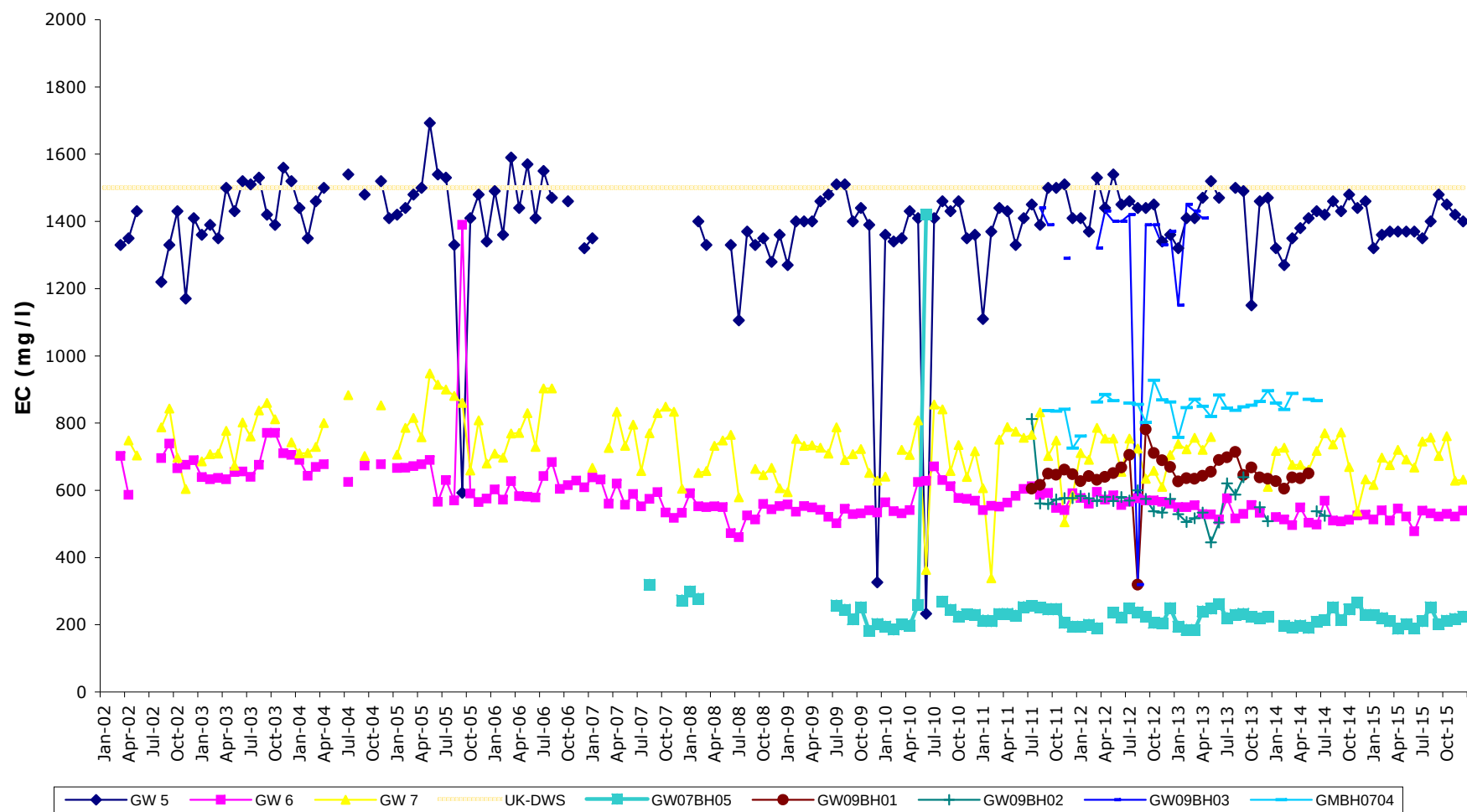
Lab analysis of Ammoniacal Nitrogen (as N) concentrations in groundwater sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2002 - Dec 2015 (Scale 2).



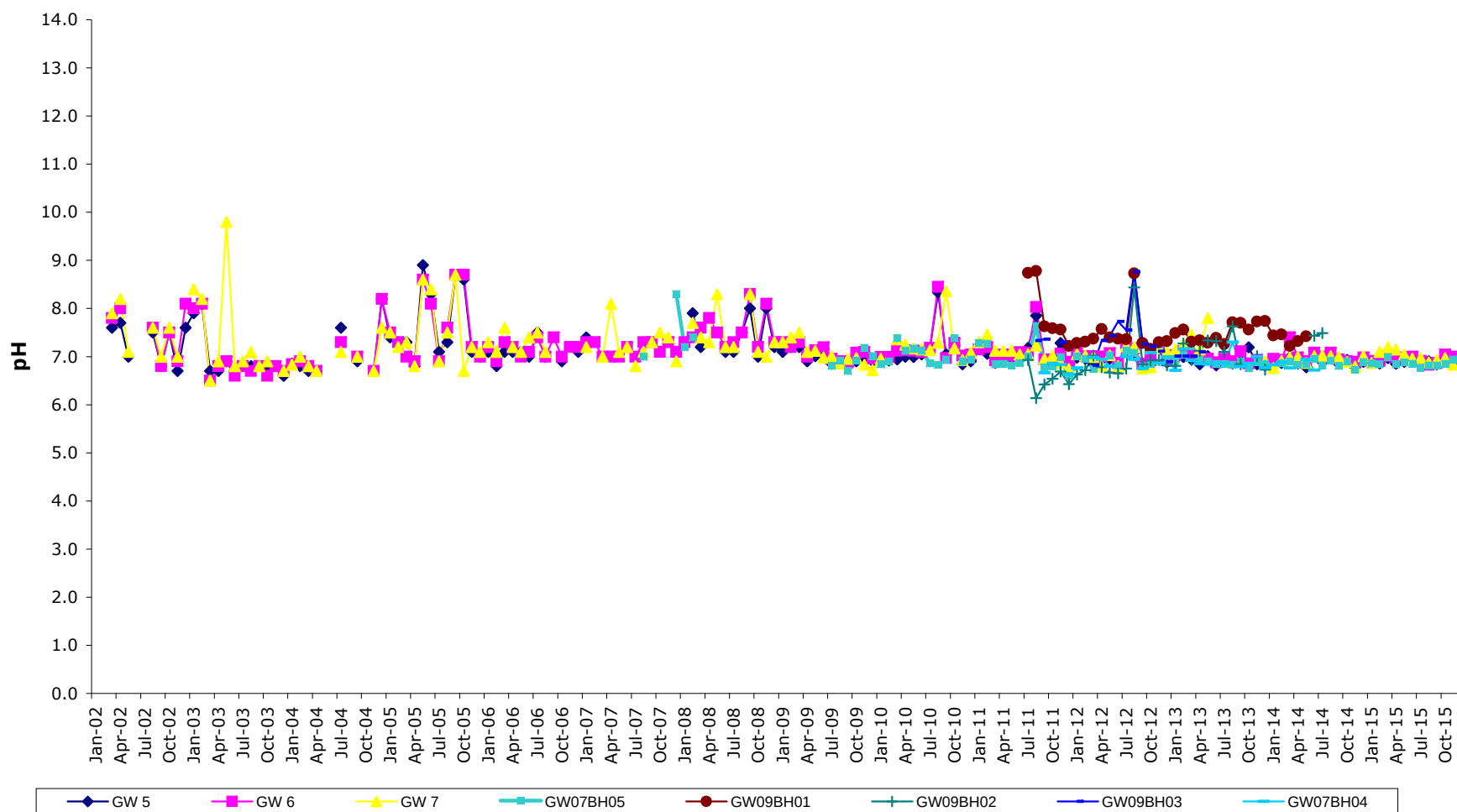
**Lab analysis of Chloride concentrations in groundwater sampled by Amgen Cymru at the Bryn Pica
Landfill Site during the period Jan 2002 - Dec 2015.**



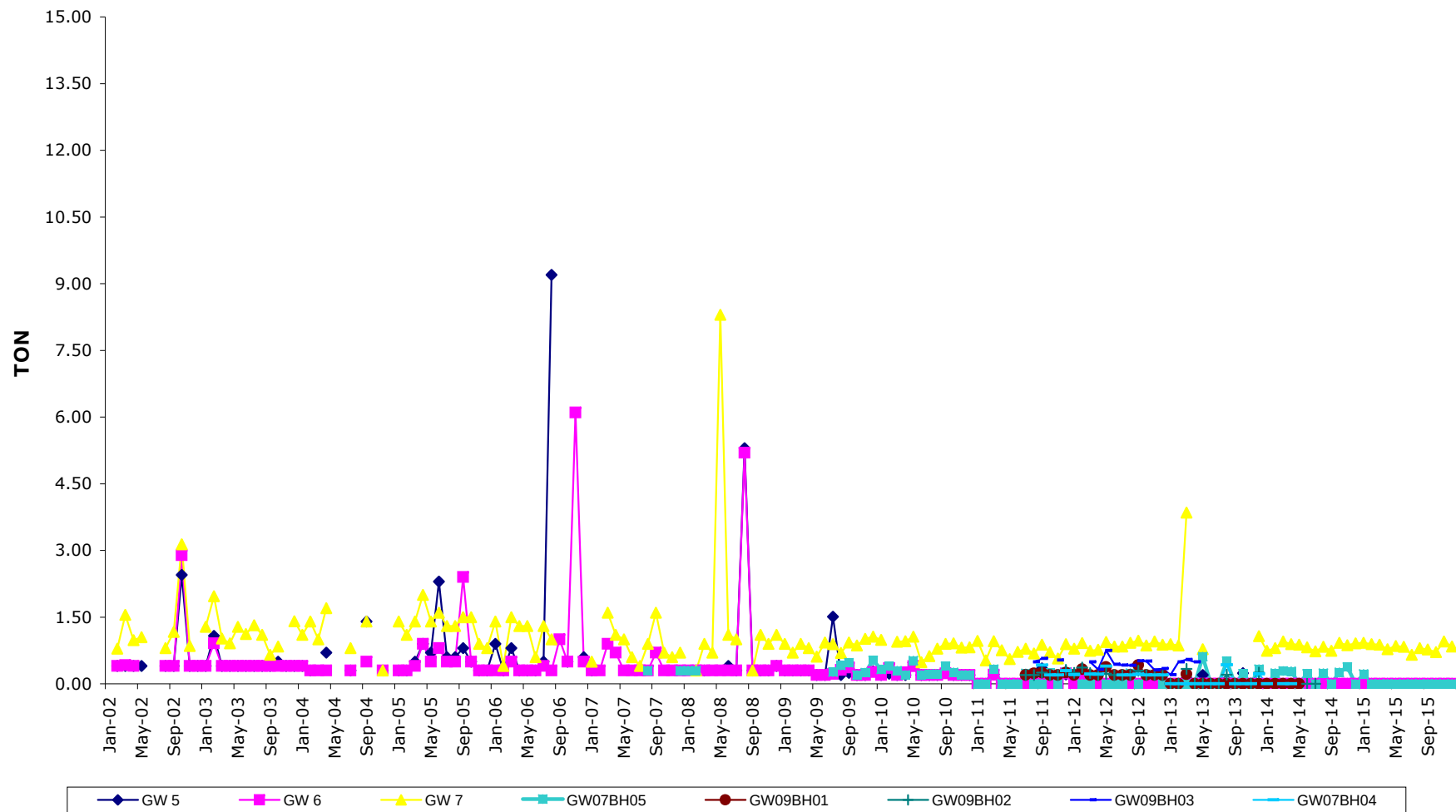
**Lab analysis of Electric Conductivity levels in groundwater sampled by Amgen Cymru at the Bryn Pica
Landfill Site during the period Jan 2002 - Dec 2015.**



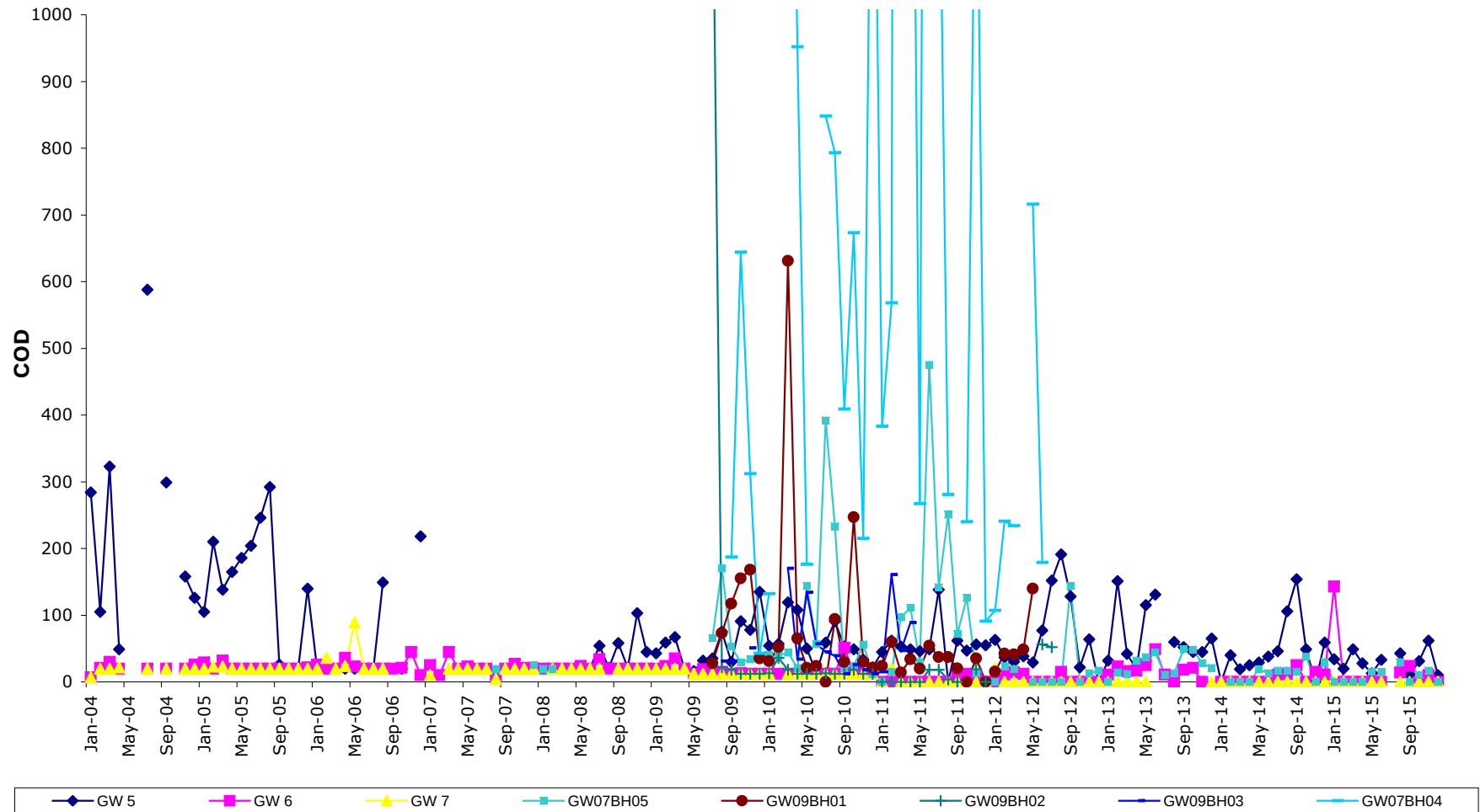
**Lab analysis of pH levels in groundwater sampled by Amgen Cymru at the Bryn Pica Landfill Site
during the period Jan 2002 - Dec 2015.**



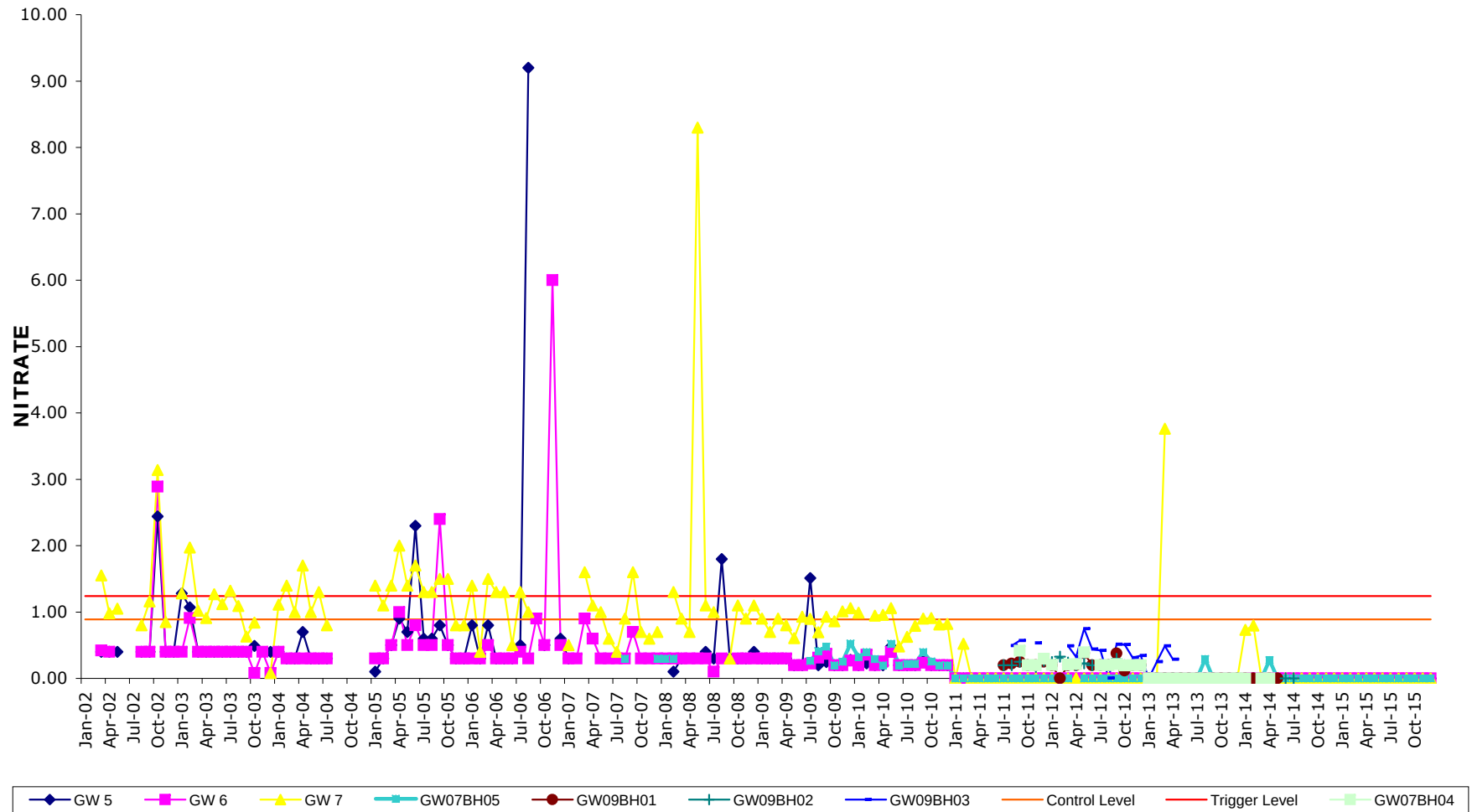
**Lab analysis of Total Oxidisable Nitrogen (TON) concentrations in groundwater sampled by Amgen
Cymru at the Bryn Pica Landfill Site during the period Jan 2002 - Dec 2015.**



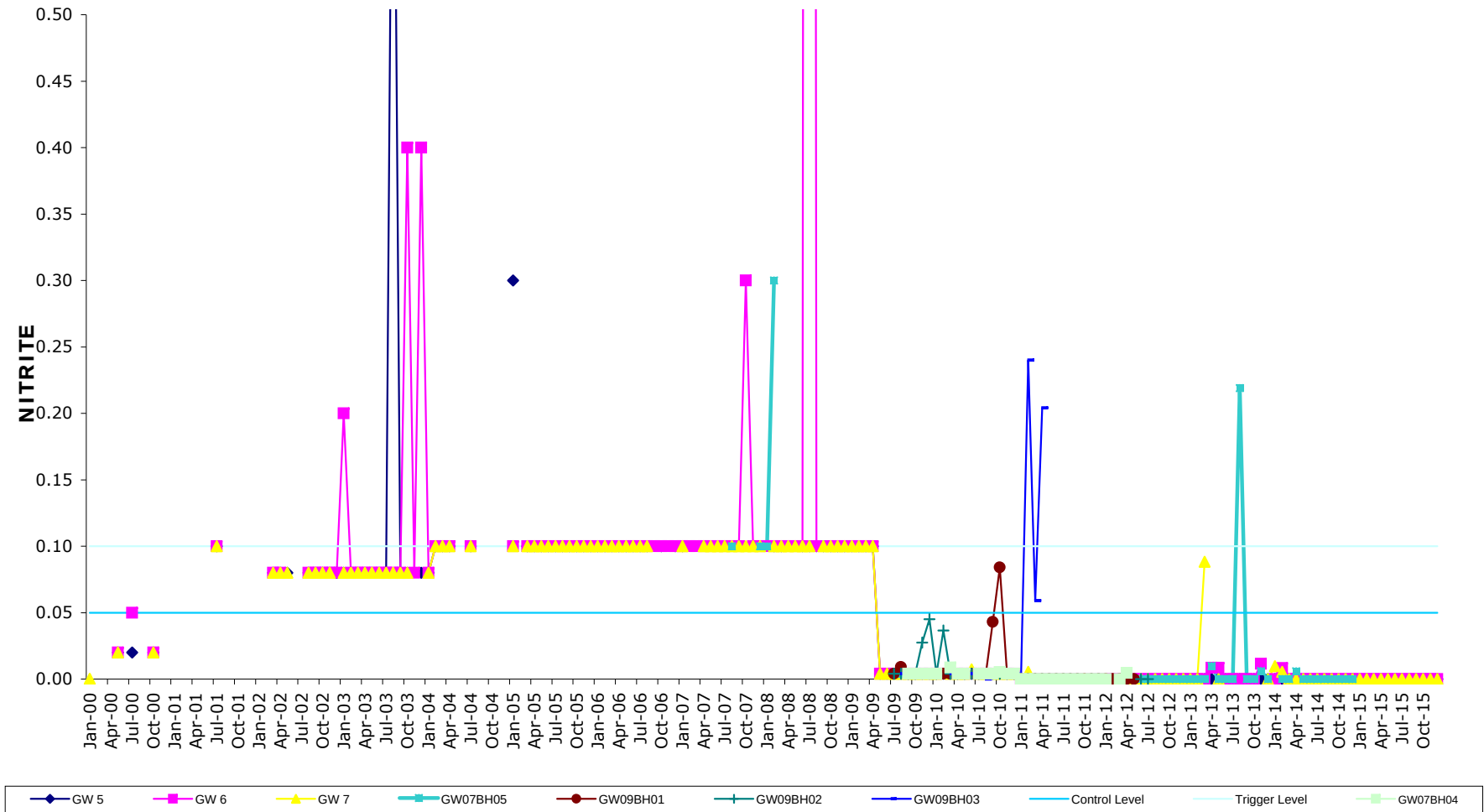
**Lab analysis of Chemical Oxygen Demand (COD) concentrations in groundwater sampled by Amgen
Cymru at the Bryn Pica Landfill Site during the period Jan 2004 - Dec 2015.**



**Lab analysis of Nitrate concentrations in groundwater sampled by Amgen Cymru at the Bryn Pica
Landfill Site during the period Jan 2002 - Dec 2015.**

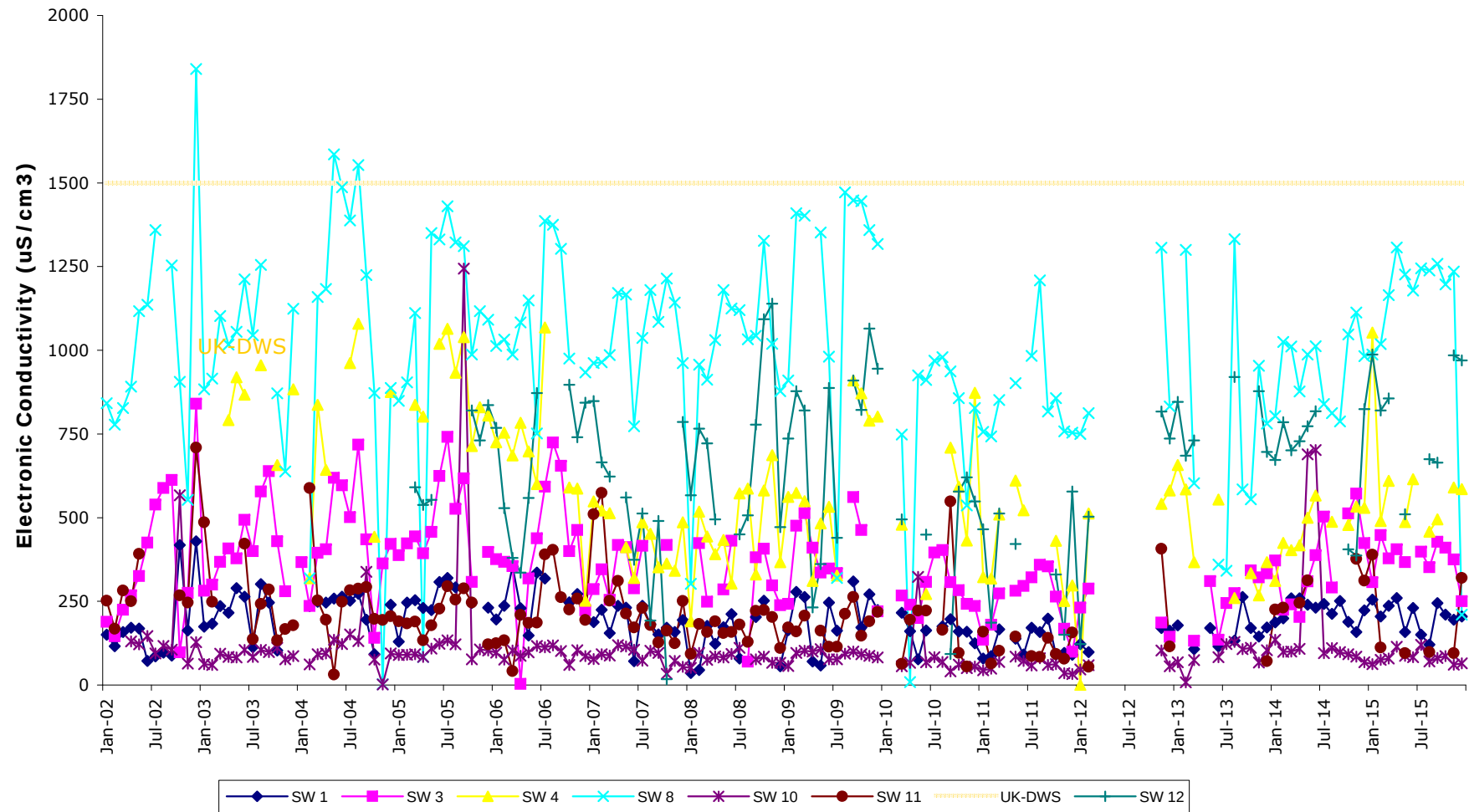


Lab analysis of Nitrite concentrations in groundwater sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2000 - Dec 2015.

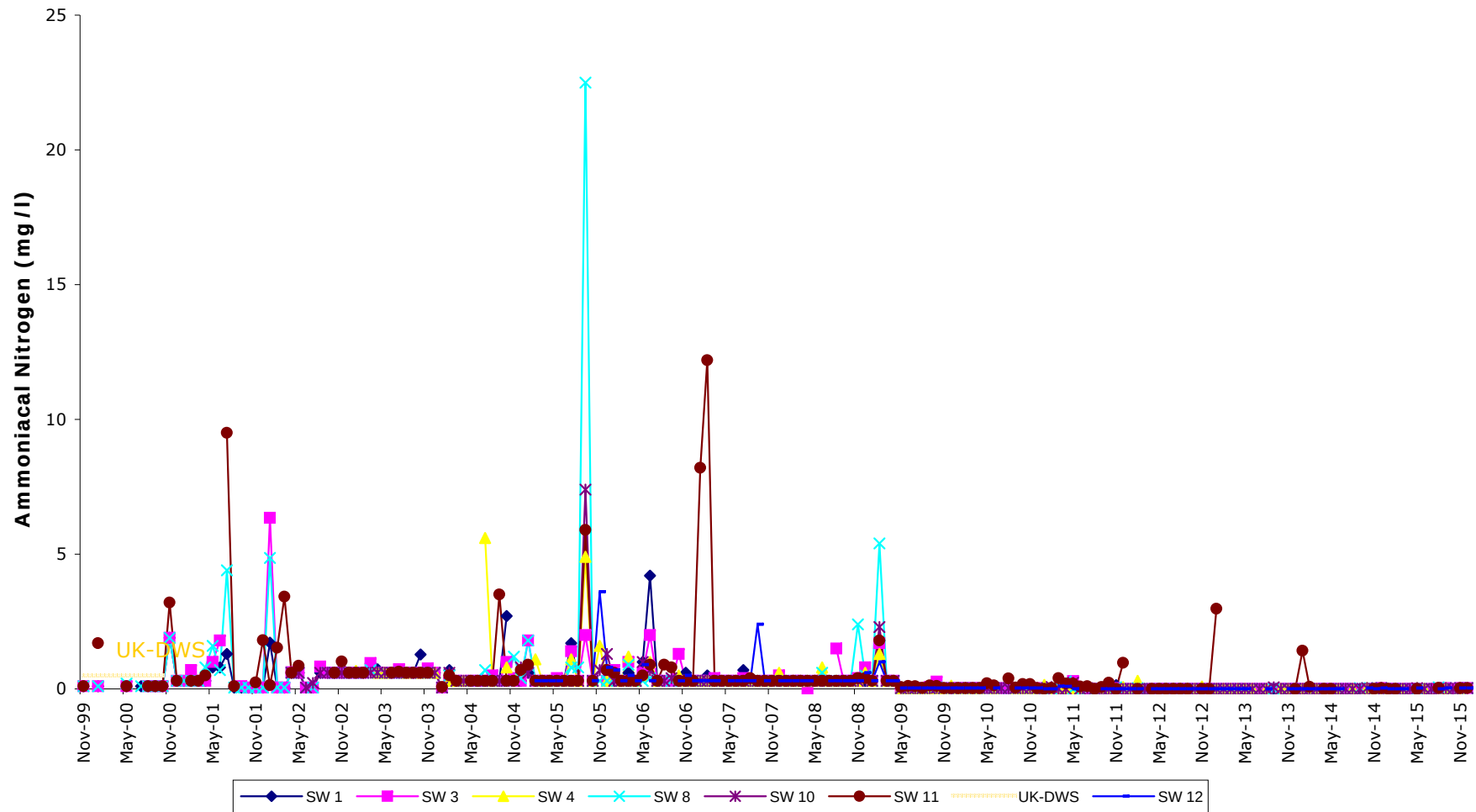


Appendix E – Time Series Plots Illustrating the Results of Amgen'
Laboratory Analysis of Surface Water Sampled at the Bryn Pica
Landfill Site during the period Jan 00 – Dec 15.

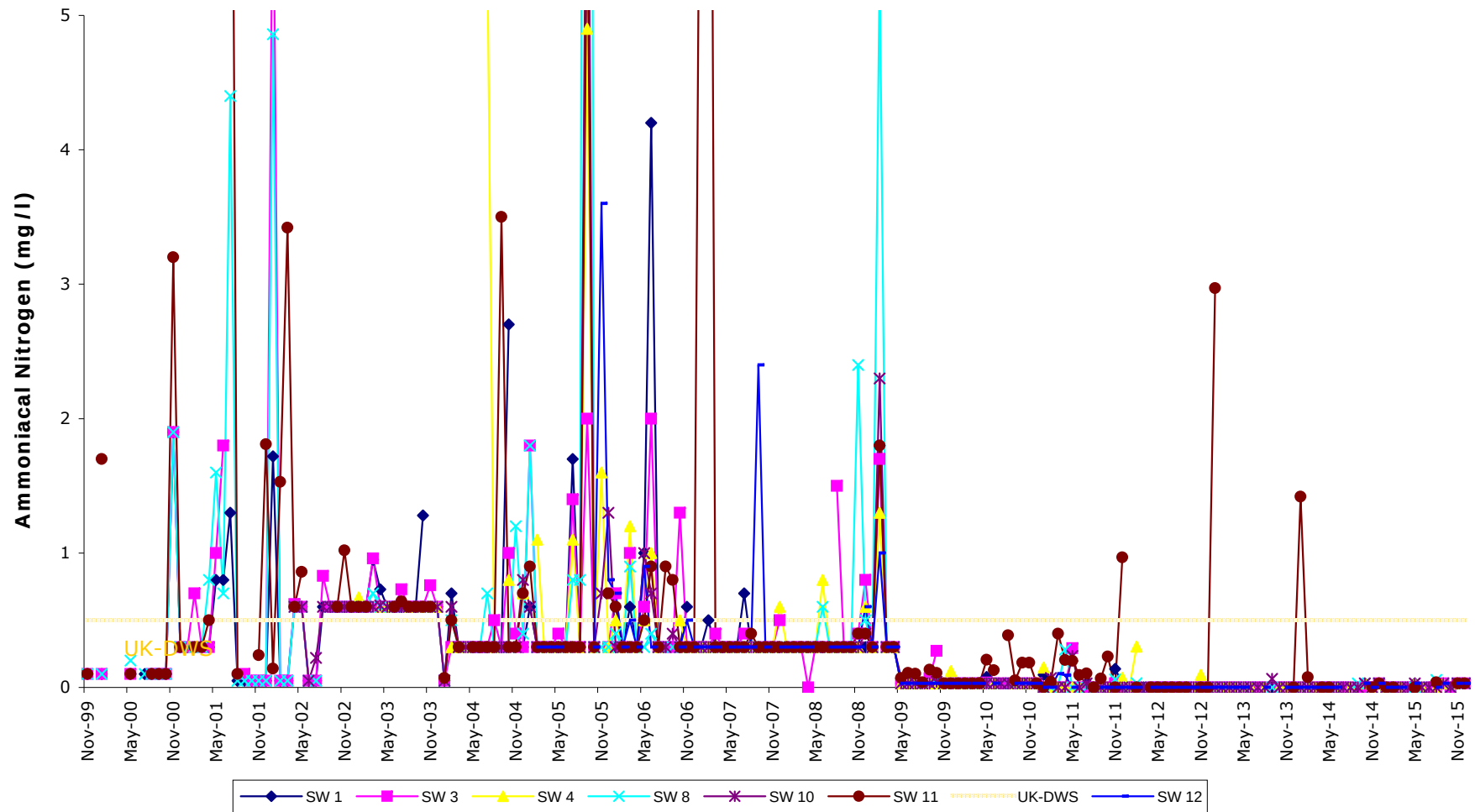
In-Situ analysis of Electronic Conductivity levels in surface water sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period August 2002 - Dec 2015.



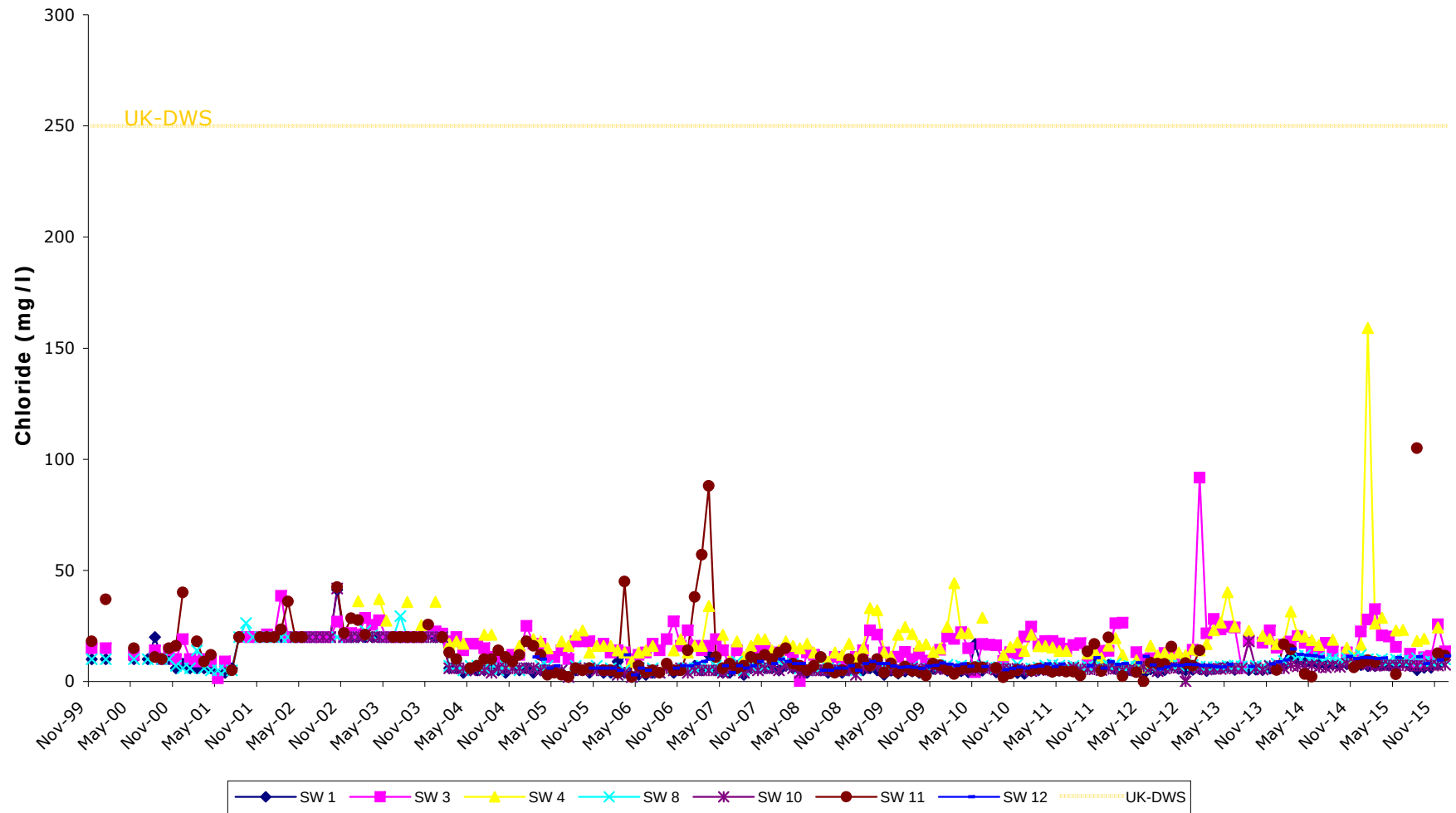
Lab analysis of Ammoniacal Nitrogen (as N) concentrations in surface water sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period November 1999 - Dec 2015.



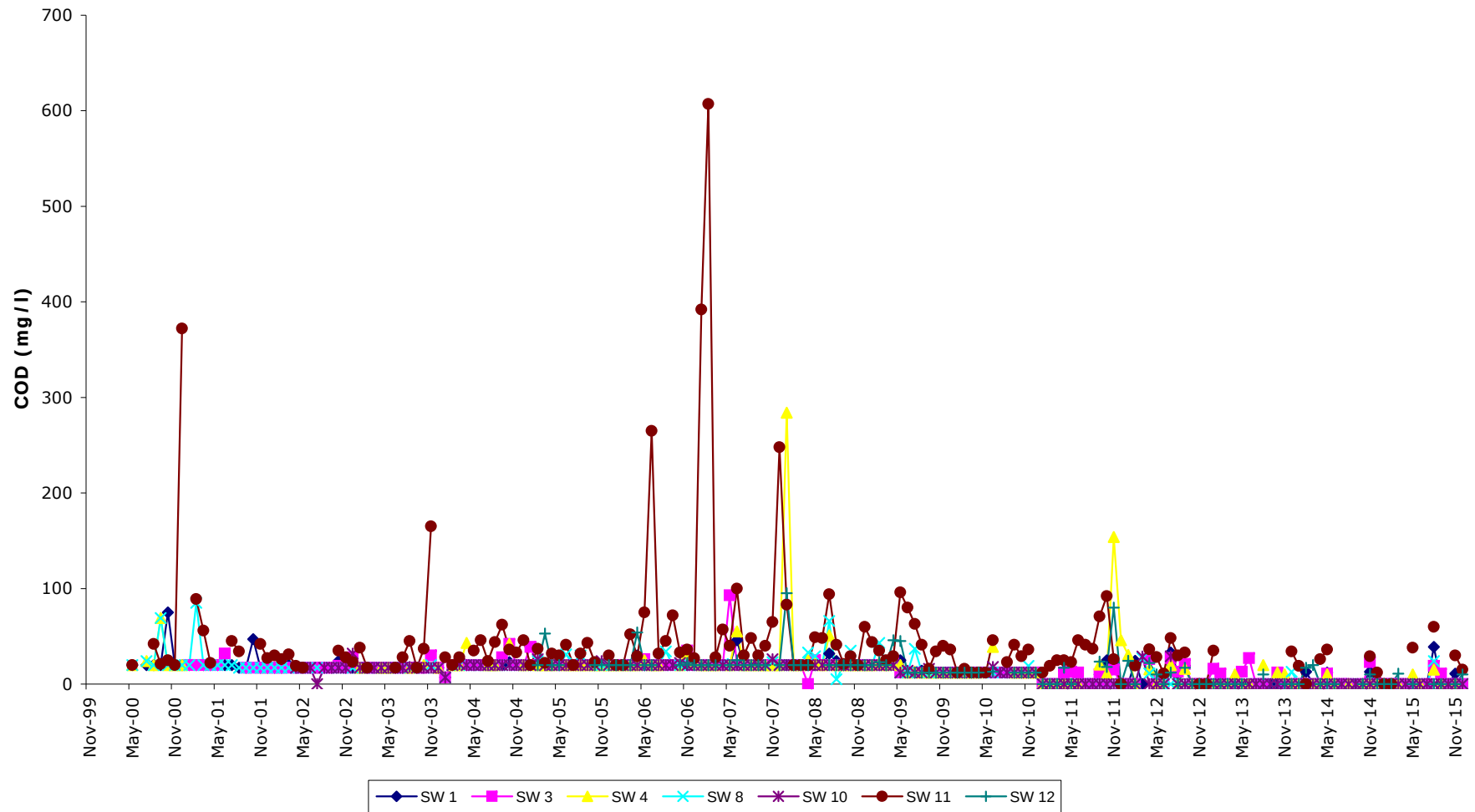
Lab analysis of Ammoniacal Nitrogen (as N) concentrations in surface water sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period November 1999 - Dec 2015 (Alternative Scale).



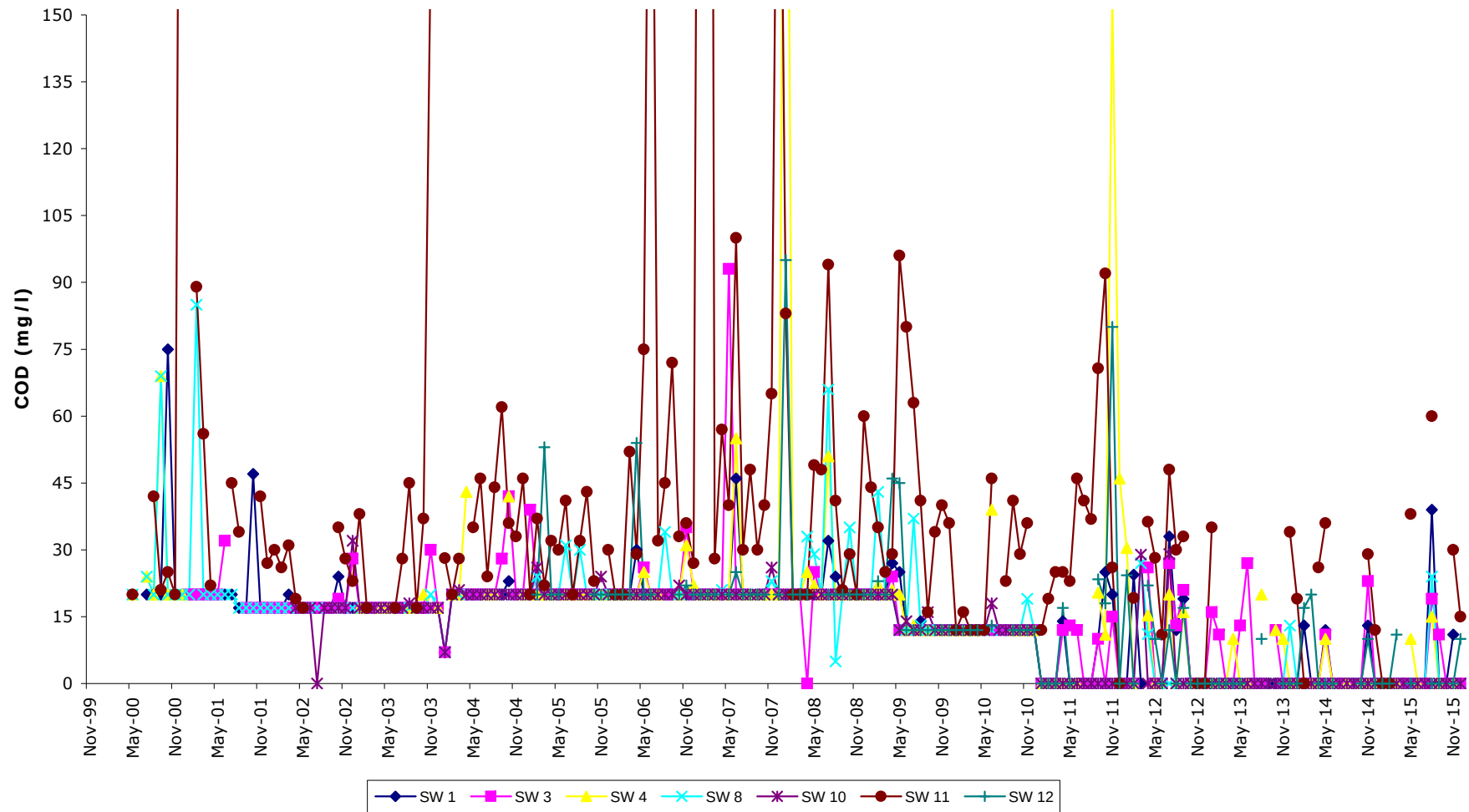
Lab analysis of Chloride concentrations in surface water sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period November 1999 - December 2015.



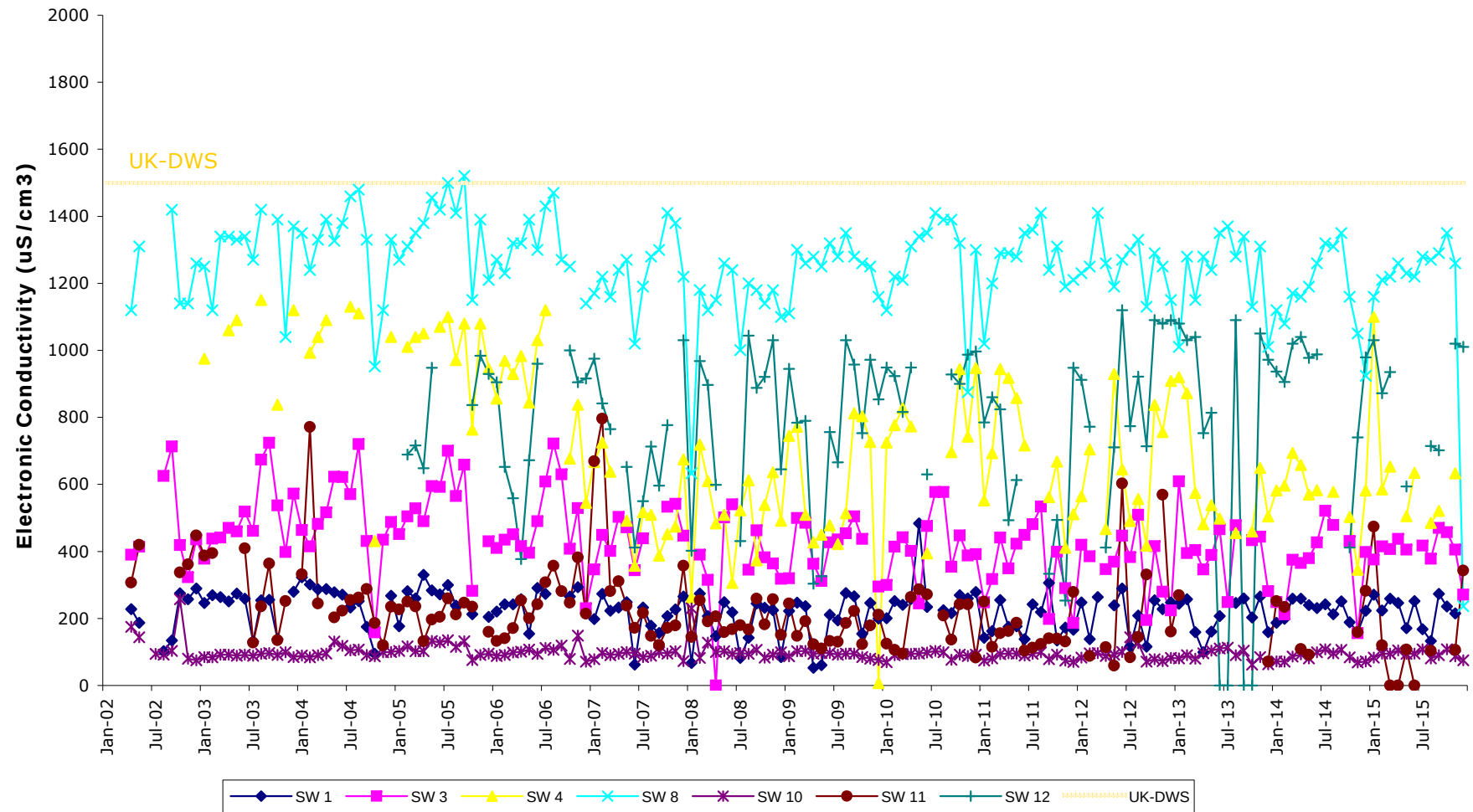
**Lab analysis of Chemical Oxygen Demand (COD) concentrations in surface water sampled by Amgen
Cymru at the Bryn Pica Landfill Site during the period Jan 2000 - Dec 2015.**



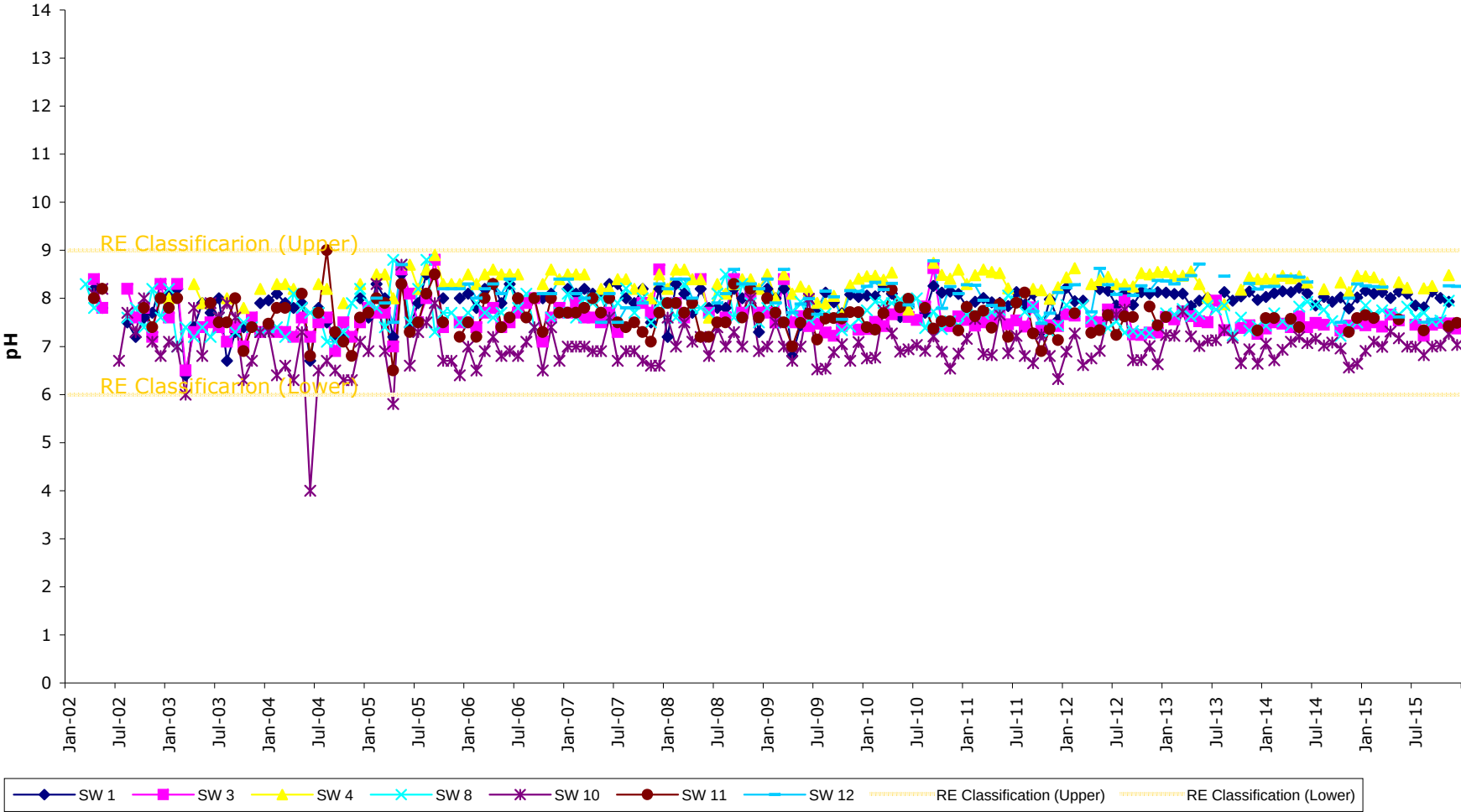
Lab analysis of Chemical Oxygen Demand (COD) concentrations in surface water sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2000 - Dec 2015 (Alternative Scale).



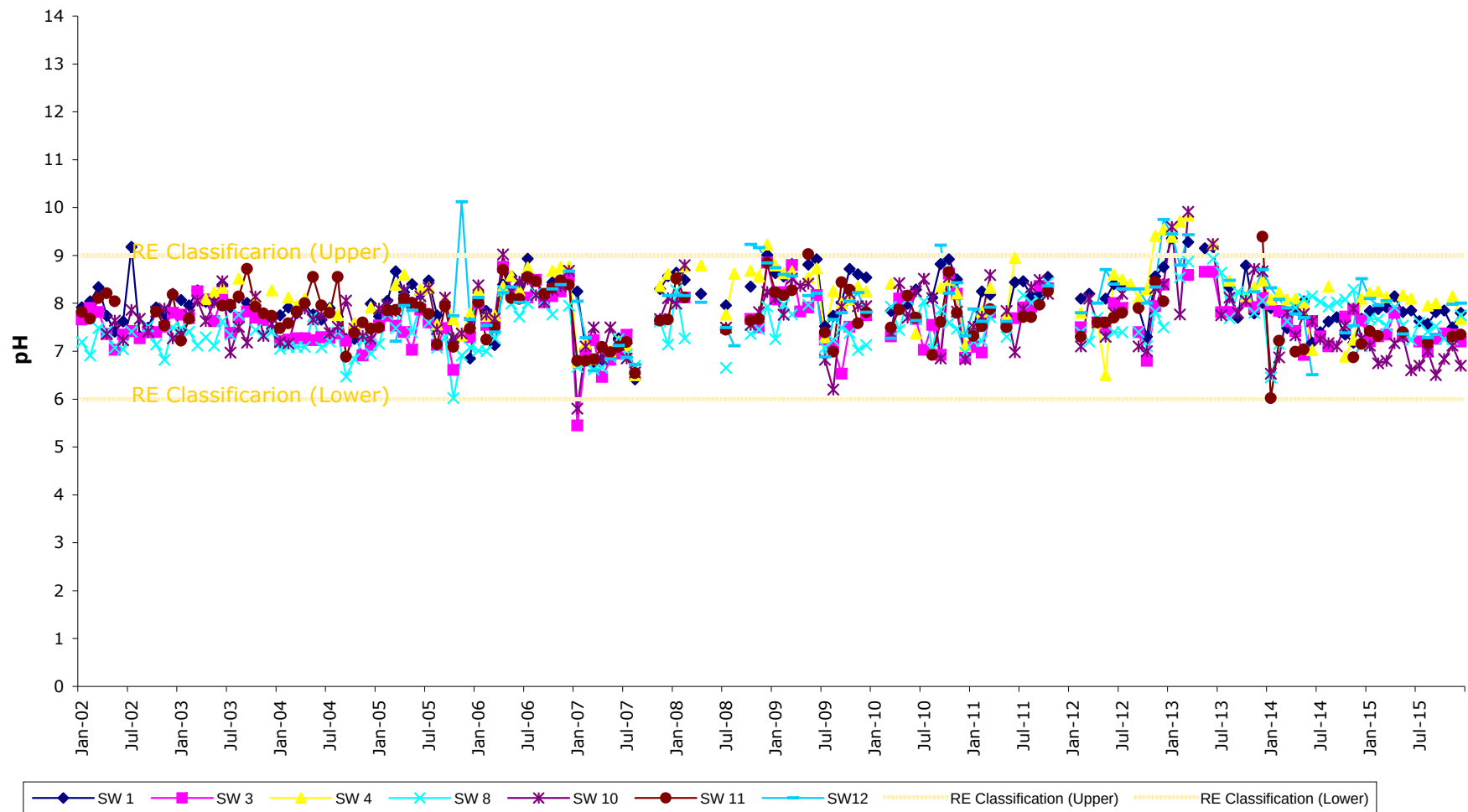
Lab analysis of Electronic Conductivity levels in surface water sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2002 - Dec 2015.



Lab analysis of pH in surface water sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period Jan 2002 - Dec 2015.



In-Situ analysis of pH in surface water sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period August 2002 - Dec 2015.



In-Situ analysis of Temperature in surface water sampled by Amgen Cymru at the Bryn Pica Landfill Site during the period August 2002 - Dec 2015.

