# Whitehall Landfill: Six Year Hydrogeological Risk Assessment Review

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## 60080ADR1. Final Report

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# 1 INTRODUCTION

## 1.1 Background

This report has been prepared by ESI Ltd. (ESI) at the request of CEMEX UK Materials Ltd (CEMEX). It presents the results of a review of the hydrogeological risk assessment (HRA) for the Whitehall Landfill site (the Site).

The original HRA for the Site was submitted as part of the PPC permit application in May 2005 (ESI, 2005a) (Table 1.1). A Schedule 4 notice was issued in August 2005, and responses to this and subsequent requests for information were provided in September 2005 (ESI, 2005b and ESI, 2005c). The Site was originally issued Permit Number MP3036SS on 17 March 2006 (Environment Agency, 2006) which was amended by Variation Notice number LP3630MR on 22 June 2007 (Environment Agency, 2007). The permit was varied again by Variation Notice number CP3334XQ in March 2008.

The objective of this study is to report and submit the findings of a current review of the HRA. At the time of the permit variation, HRA reviews were required every four years. This has now been changed to once every six years and therefore the next HRA review is due by 17 March 2016.

Permit regulation was taken over by National Resources Wales in 2013 following the merger of the Environment Agency Wales with other national resources bodies sponsored by the Welsh Government.

## 1.2 Scope of work

This review has been based on Environment Agency guidelines which were published in April 2009.

This report acts to provide:

- a review of the available site monitoring data;
- a review of the existing Site Conceptual Model;
- a review of the existing HRA; and
- recommendations for further work if necessary.

**Table 1.1 Permit and variation numbers**

| Detail | Date |
|---|---|
| Permit MP3036SS considered duly made | 09/05/2005 |
| Correspondence from applicant regarding company name | 20/07/2005 |
| Response to request for information | 31/08/2005 |
| Permit determined | 17/03/2006 |
| Variation Notice LP3630MR issued | 22/06/2007 |
| Variation Notice issued | 20/03/2008 |

## 1.3 Improvement conditions

There are no improvement conditions outstanding for the Site. Improvement Condition 2 of Permit LP3630MR related to the derivation of trigger levels for groundwater. This was completed in 2008 (ESI, 2008). This improvement condition also stated that once agreed, groundwater monitoring frequency could reduce to quarterly. However, this was not implemented at the Site until mid 2015 following discussion and agreement with National Resources Wales (NRW).

### 1.4 Site information

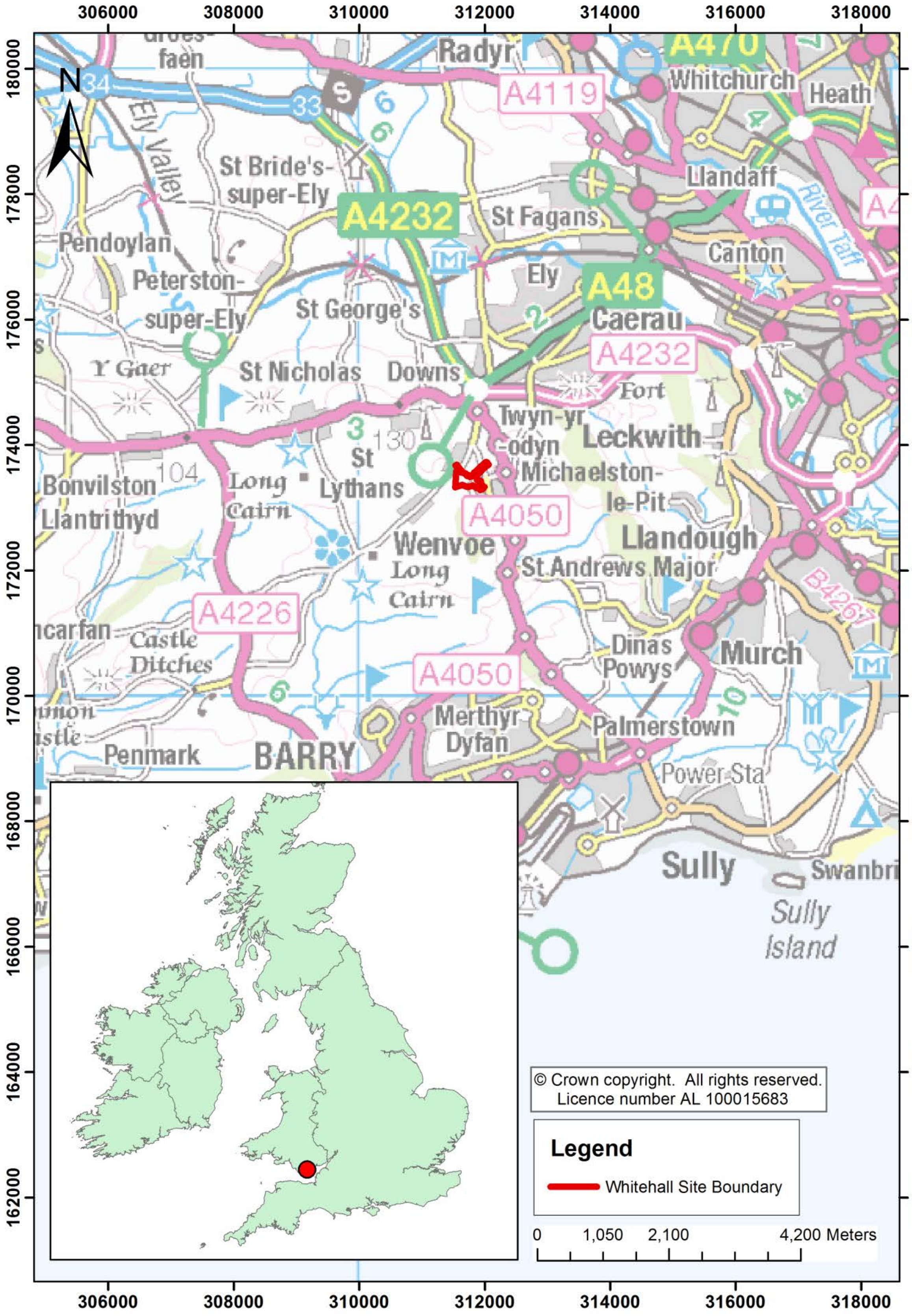
The Site covers an area of 5.2 ha and lies in a limestone quarry to the northwest of Wenvoe, approximately 6 miles southwest of Cardiff city centre, South Glamorgan, at NGR 311700, 173450 (Figure 1.1). It is currently licensed to accept inert waste only. Historically the Site accepted clean non-hazardous rubble and spoil and small quantities of organic materials. A site location plan, including the location of the monitoring locations is presented as Figure 1.2.

The Site lies on the eastern flank of a hill formed by the outcrop of the Friars Point Limestone (Ove Arup & ESI, 2005), the ground elevation around the Site perimeter falls sharply from 115 mAOD on the western boundary to 75 mAOD in the east.

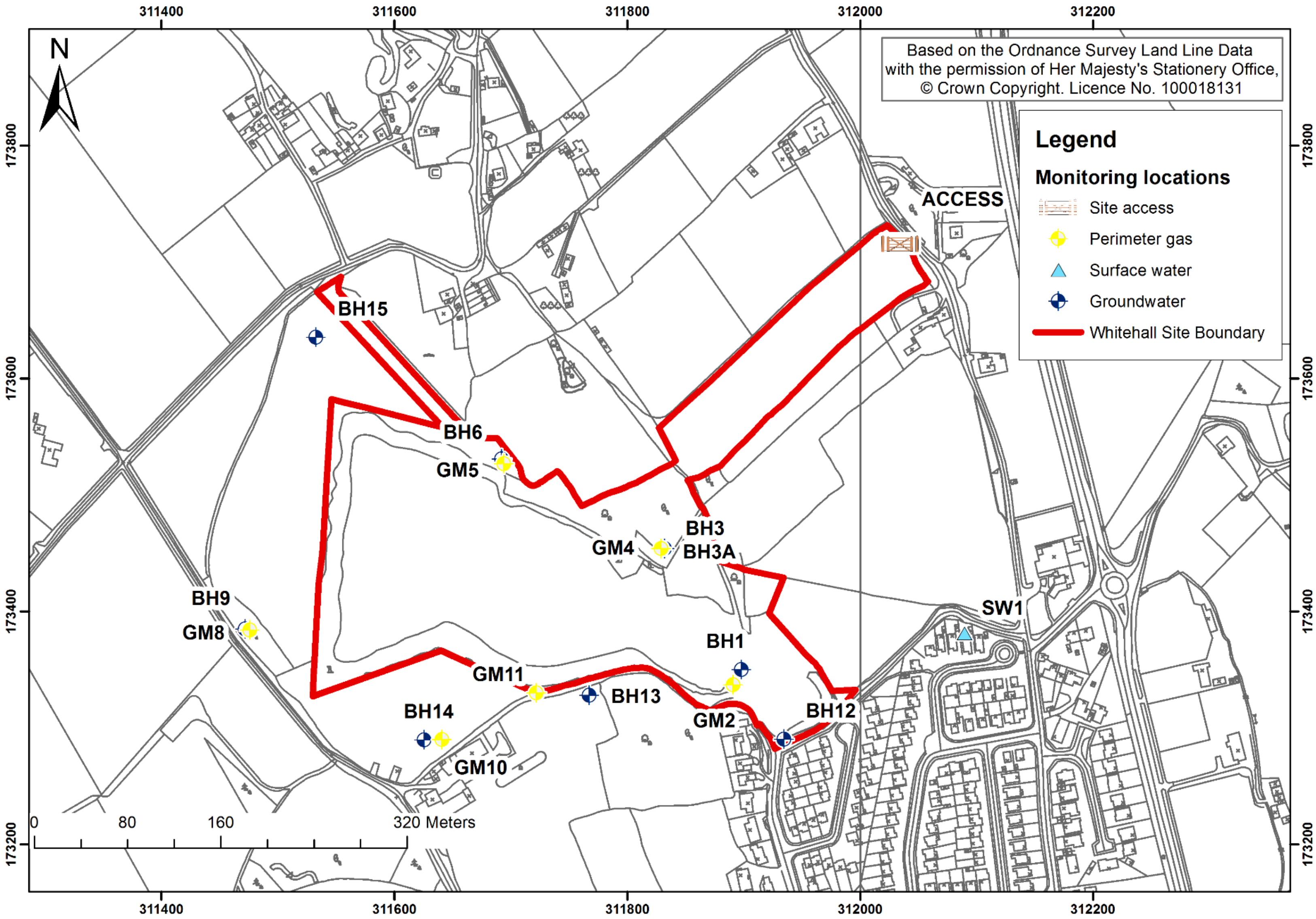
The Site is surrounded by fields and woodland to the north and woodland to the east. To the west of the Site are fields which are crossed by footpaths and contain a small pond. The southern part of the Site is mostly bounded by fields and a track, with woodland towards the eastern part. The south eastern tip of the Site is bounded by the houses and gardens along Wallston Road in Wallston which is at the north western edge of Wenvoe.

Drains exist 70 m east and 110 m northeast of the Site and a small pond is seen 20 m west of the Site. In addition, Wrinstone Brook is located ~400 m southeast of the Site.

**Figure 1.1 Site location**



## Figure 1.2 Site location plan



# 2 MONITORING DATA

## 2.1 Introduction

This section reviews the groundwater and surface water monitoring undertaken at the Site and compares the data with the relevant requirements set out in the permit. The monitoring points are displayed in Figure 1.2.

For clarity, this review focusses on data in the period between January 1 2009 and 29 February 2016. These data are compared to those which predates the previous HRA review, using all available monitoring data up to 31 December 2008.

## 2.2 Leachate monitoring

Leachate monitoring is not required as the Site has only accepted inert waste under the environmental permit.

## 2.3 Groundwater

Groundwater is required to be monitored for the parameters and at the locations and frequency specified in Table 2.1.

**Table 2.1 Groundwater monitoring requirements as specified in the permit**

| Location | Frequency | Parameters |
|---|---|---|
| BH1, BH12, BH13, BH14 | Quarterly[1] | Naphthalene |
| BH1, BH3, BH3A, BH6, BH9, BH12, BH13, BH14, BH15 | Quarterly[1] | Water level, pH, electrical conductivity, ammoniacal nitrogen, chloride, sulphate as SO4, alkalinity, total oxidised nitrogen, total organic carbon, sodium, potassium, calcium, magnesium, iron |
| | Annually | Manganese, cadmium, chromium, copper, nickel, lead, zinc, naphthalene |

Note 1: Following agreement of trigger levels, monitoring has reduced to quarterly as per Improvement Condition 2.

The requirements of the permit have been met, with the exception of minor exceptions as detailed in the annual monitoring reports.

### 2.3.1 Groundwater level

Historical groundwater elevation data for the Site is presented in Figure 2.1. There has been no significant change in groundwater elevation since the previous HRA review. Long term groundwater levels have risen slightly in BH6, which reached a new historical high of 94.55 mAOD in January 2011.

The highest water levels at the Site have been consistently recorded in BH06. It is noted that BH13, BH14 and BH15 were not monitored until summer 2007, as they were installed as part of an improvement condition.

Groundwater flow at the Site is likely to be heavily influenced by fissures within the Limestone strata. An indicative contour plot is presented in Figure 2.2 using the dataset from October 2014. This suggests that groundwater flow is broadly to the southeast, in the direction of Wrinstone Brook and in the direction of local topography. BH6 displays an anomalously high water level. It is most likely that this well intersects a specific fissure that has a higher piezometric head compared to fissures intersected by other locations.

There have been no significant changes to groundwater flow direction since the previous HRA review was undertaken.

### 2.3.2 Groundwater quality

A summary of groundwater quality data for the period December 2001 to December 2008 is presented in Table 2.3 and for the period January 2009 to February 2016 in Table 2.4. A discussion of these data is presented below.

Field parameters

For the period of this review, groundwater electrical conductivity has ranged between 254 and 1980 µS/cm for laboratory measurements, with a mean value of 723 µS/cm. This is slightly higher than the period prior to the last HRA review.

Part of the reason for the slight increase in groundwater conductivity is due to the increase in BH12 since 2009, although it is also noted that monitoring in this well only commenced in July 2007 (Figure 2.3). Nevertheless, the first six months of monitoring showed readings on average at around 567 µS/cm before they increased to up to 1000 µS/cm from February 2008. Readings have consistently been above 1000 µS/cm since around January 2009.

Average pH readings for the previous period were between 7.27 and 7.67 for field and laboratory readings respectively, whilst more recent data for the past six years shows average pH levels have varied little, being at 7.56 and 7.58 for field and laboratory readings respectively.

Ammoniacal nitrogen and major ions

Revised groundwater compliance limits were derived in ESI (2008), as summarised in Table 2.2.

**Table 2.2 Groundwater compliance limits**

| Determinand (mg/l) | BH1 | BH12 | BH13 | BH14 |
|---|---|---|---|---|
| Ammoniacal nitrogen | 0.39 | 0.39 | 0.39 | 0.39 |
| Chloride | 250 | 250 | 250 | 250 |
| Iron (µg/l) | 200 | 200 | 200 | 200 |
| Naphthalene | 0.05 | 0.05 | 0.05 | 0.05 |
| Potassium | 12 | 14.73 | 12 | 12 |

It is noted that the maximum ammoniacal nitrogen concentration shown on Table 2.3 is 215 mg/l. However the $95^{th}$ percentile result is 1.72 mg/l implying that the high maximum value is almost certainly an error. This result has not been changed here to maintain consistency with the previous HRA review.

Ammoniacal nitrogen concentrations have typically been below 0.5 mg/l for much of the past seven years, although there have been a few notable exceptions, as shown on Figure 2.4. Concentrations in BH6 were over 0.5 mg/l on two occasions since 2007, reaching a historical high of 2.45 mg/l before immediately dropping back to below the limit of detection. It is noted that BH6 is up hydraulic gradient of the Site and may be impacted by the landfills that lie to the north of the Site. There was also one occasion when concentrations reached 0.89 mg/l in BH3 and one occasion when concentrations reached 1.19 mg/l in BH3. Elevated ammoniacal nitrogen concentrations are not sustained and typically return to at or near the limit of detection following high readings. Ammoniacal nitrogen concentrations have on average decreased significantly since the previous HRA review, from an average of 1.33 mg/l between 2001 and 2008, to 0.05 mg/l between 2009 and 2015.

Significantly, ammoniacal nitrogen concentrations are also not elevated in down-gradient locations BH12 and BH13.

Historical groundwater chloride concentrations are presented in Figure 2.5. Concentrations have become more variable since the last HRA review, with concentrations increasing in BH12 and exhibiting high variability in BH3A and BH13 as well. Concentrations are broadly similar to the last HRA review, with average concentrations of 26.3 mg/l to 31.5 mg/l for the period prior to and post the last HRA review respectively. Concentrations are generally very low and are comfortably below the 250 mg/l UK DWS limit and the compliance limit.

Historical potassium concentrations are displayed in Figure 2.6. Since 2009, potassium concentrations have averaged 5.15 mg/l in all boreholes, with 86 out of 569 samples (15.1%) in excess of the UK DWS. Potassium concentrations are elevated in up-gradient borehole BH9, where they have been consistently above 20 mg/l. It is noted that 28 of the 86 exceedances occurred in BH9 i.e. there are also exceedances in the other boreholes as well.

It was established during a camera survey in May 2015 that borehole BH9 had been blocked at two separate depths, which was preventing routine sampling. The blockage higher up in the borehole was removed, allowing samples to be obtained during winter time when groundwater elevation in the Limestone is higher and above the deeper blockage (which is at 25.4 mbgl). Data collected during the winter of 2015 – 2016 shows that potassium remains close to 16 mg/l in BH9 and that up-gradient groundwater quality continues to be impacted. A sample of 0.18 mg/l was obtained in June 2015, but this is considered to be from water perched above the blockage and not indicative of the local groundwater quality in the aquifer at the time.

Figure 2.7 presents the spatial distribution of historical potassium concentrations, which shows that concentrations are also elevated in BH1 and BH12, which often are in exceedances of their 12 mg/l and 14.73 mg/l compliance limit, respectively. An increasing trend in potassium concentrations can be seen in BH1 and BH12. BH1 shows a large increase in December 2015 to 25.9 mg/l, but this is immediately followed by a significant drop to 11.5 mg/l which is below the compliance limit for this location. Concentrations at BH12 appear to have stabilised since 2012 and there was a significant drop in concentration in January 2016.

Concentrations might also be expected to be high in BH13 if a plume of contamination was migrating eastwards, but this is not the case as concentrations here have typically been around 1.2 mg/l for the past six years. A high potassium concentration of 25.9 mg/l was reported for BH1 in December 2015, but this was not sustained and concentrations immediately returned to their normal level. It is thus considered to be plausible that the elevated up-gradient potassium continues to impact upon some of the down-gradient locations.

The most likely explanation for this behaviour in potassium concentrations is that there has been a historical plume derived from the up-gradient landfills. This was passing across the up-gradient boundary of Whitehall Landfill from around 2000 and water quality is now improving up-gradient. The plume has passed under and around the Whitehall landfill which has resulted in potassium concentrations rising in some of the down-gradient wells since 2007. The data suggests that concentrations are close to peaking at the down-gradient locations and we may expect that the concentrations in the down-gradient wells will start decreasing as the plume moves away from Whitehall Landfill. BH3A is likely to be at the periphery of the plume. Recommendations are made in Section 5.2 to temporarily increase the potassium compliance limit.

Sulphate concentrations have been in excess of the DWS in 11% of samples. However, average concentrations are just 82.6 mg/l, and comfortably below the 250 mg/l UK DWS. As with other determinands, one of the main reasons for the increase since the previous HRA review is due to the fact that monitoring only commenced in BH12, BH13, BH14 and BH15 after the summer of 2007.

<u>Metals</u>

A variety of metals have been analysed on a quarterly basis. Only manganese was found to be in excess of the UK DWS, with 7 out of 56 samples (12.5 %) above the limit. Overall metal concentrations are all lower than at the time of the previous HRA review.

Iron has a trigger level of 200 µg/l set in the permit based on the UK drinking water standard. The control limit was set to 125 µg/l. In March 2012, the analytical laboratory raised the level of detection (LOD) for iron to 230 µg/l. As a result the LOD was higher than the control and trigger levels. Cemex discussed this matter with NRW via a letter dated 14 November 2014 (Cemex, 2014) where a request was made to increase the trigger limit to 250 µg/l. NRW refused this request by email and Cemex have had to change the analytical method for iron to achieve a lower LOD of 120 µg/l. Recommendations are made in Section 5.2 to increase the iron compliance limit.

Organic compounds

The only organic compound which has been monitored in groundwater since 2009 is naphthalene, in line with the permit requirements.

The maximum detected naphthalene concentration has risen slightly from 0.00013 mg/l prior to 2009, to 0.000147 mg/l between 2009 and 2015. Naphthalene is routinely monitored in groundwater, although only 29 out of 568 results between 2009 and 2015 were above the limit of detection and thus it is not statistically sound to calculate an average concentration.

**Figure 2.1 Historical groundwater elevation in all requisite boreholes**

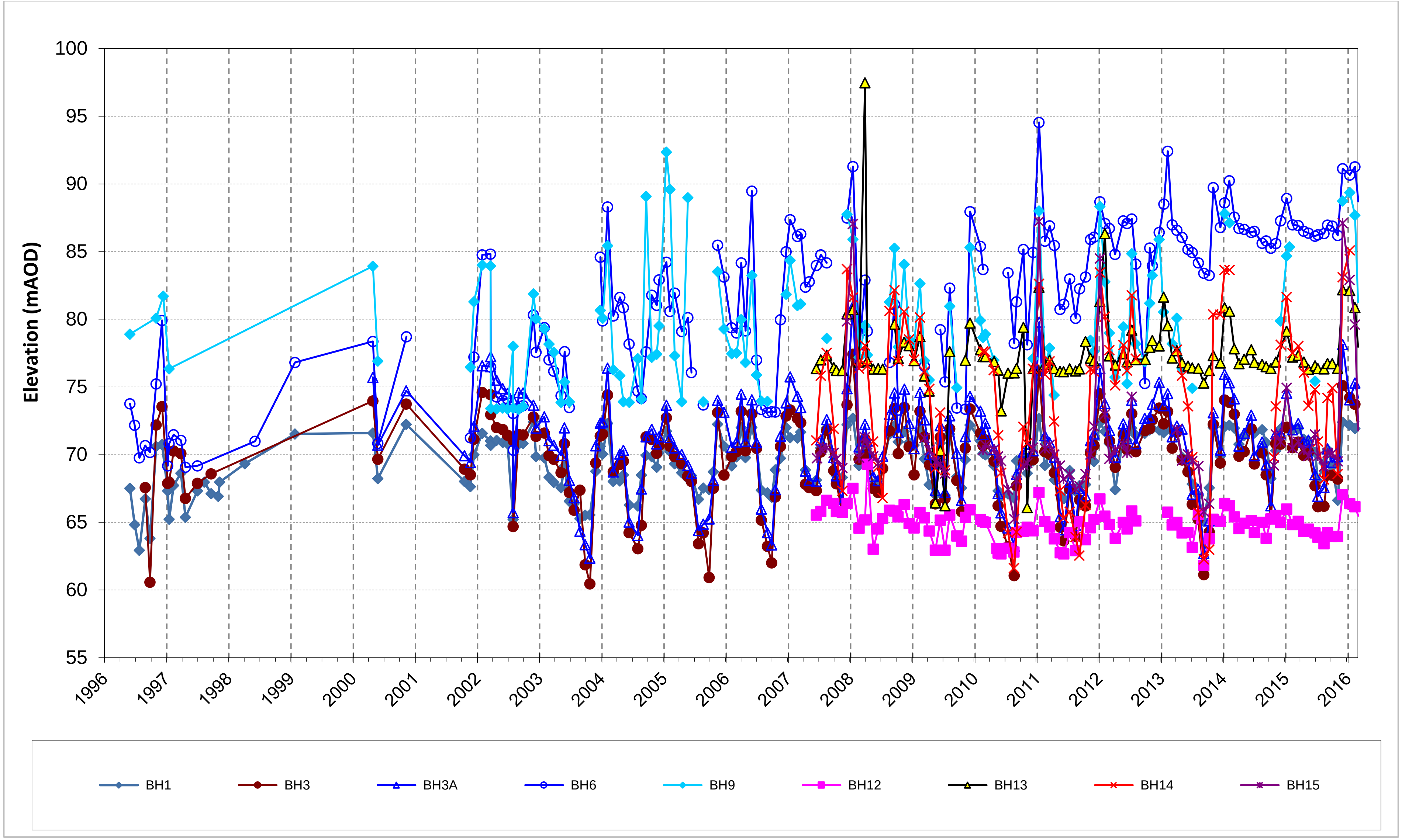
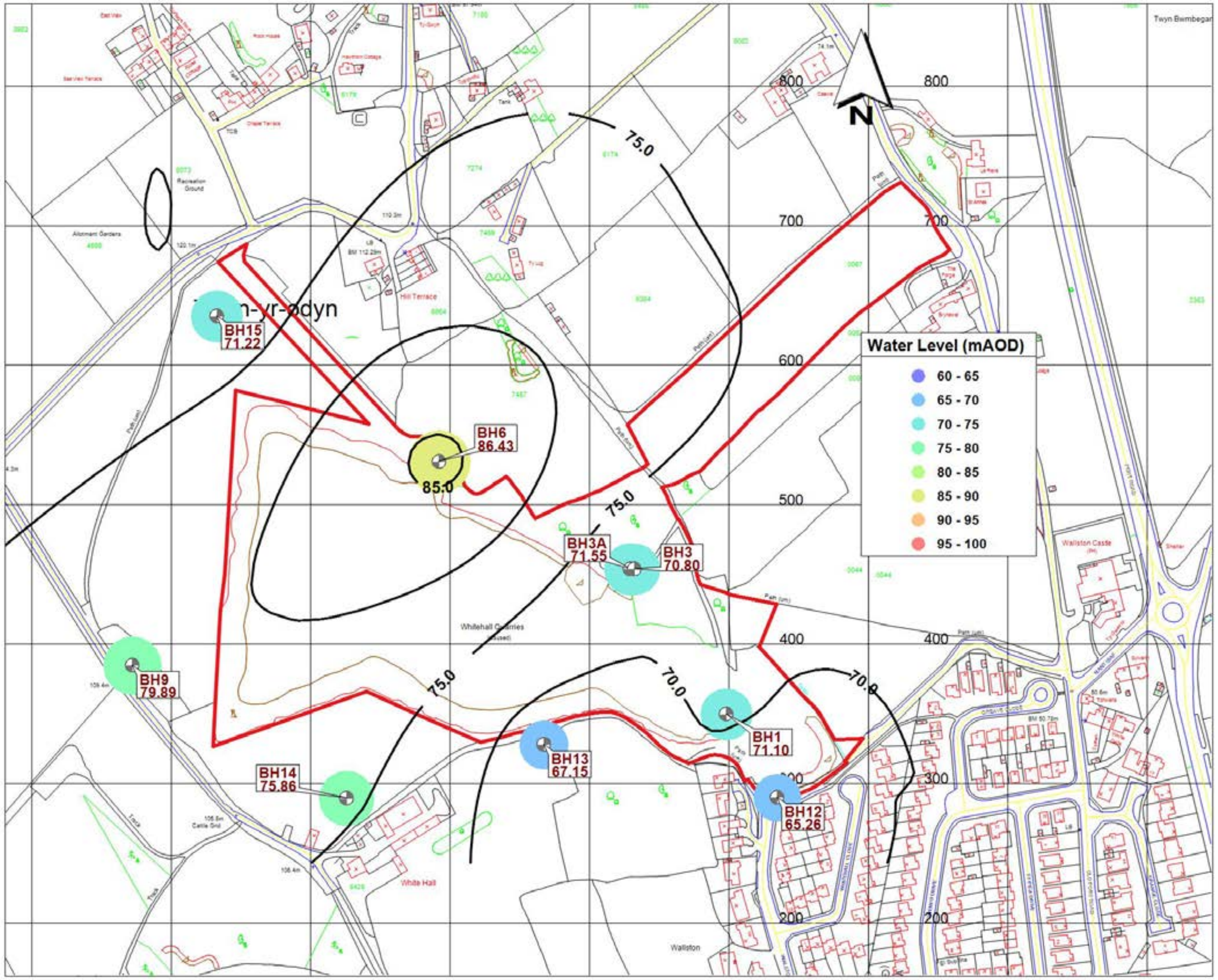


**Figure 2.2 Indicative groundwater elevation contours (October 2014)**




Note: contours based upon average of November and December 2014 dataset.

**Table 2.3 Statistical summary of groundwater quality between December 2001 and December 2008**

| | | | | | | | | | | UKDWS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Determinand** | **No. of Results** | **Unit** | **Min** | **Max** | **Mean** | **Standard Deviation** | **95th Percentile** | **# > LOD** | **% > LOD** | **No. Exceeding** | **% Exceeding** | **Action Level** |
| **Field and laboratory parameters** | | | | | | | | | | | | |
| Conductivity- Electrical (Field) | 87 | µS/cm | 192 | 1498 | 709 | 280 | 1360 | 87 | 100 | - | - | - |
| Conductivity- Electrical 20deg | 428 | µS/cm | 305 | 18000 | 686 | 854 | 913 | 428 | 100 | - | - | - |
| pH | 481 | pH | 6.51 | 10.7 | 7.67 | 0.42 | 8.4 | 481 | 100 | - | - | - |
| pH (Field) | 48 | pH | 4.87 | 8.37 | 7.27 | 0.732 | 8.17 | 48 | 100 | - | - | - |
| **Major ions** | | | | | | | | | | | | |
| Alkalinity as CaCO3 | 232 | mg/l | 0 | 1230 | 287 | 119 | 404 | 232 | 100 | - | - | - |
| Calcium | 232 | mg/l | 55 | 5500 | 178 | 505 | 208 | 232 | 100 | 10 | 4.31 | 250 |
| Chloride | 497 | mg/l | <2 | 212 | 26.3 | 14.6 | 49 | 496 | 99.8 | 0 | 0 | 250 |
| Magnesium | 228 | mg/l | 5.7 | 615 | 34.6 | 48.2 | 54 | 228 | 100 | 19 | 8.33 | 50 |
| Nitrate as N | 176 | mg/l | <0.3 | 43 | 3.61 | 6.52 | 19 | 124 | 70.5 | 18 | 10.2 | 11 |
| Nitrogen (total oxidised) as N | 224 | mg/l | <0.3 | 43 | 3.77 | 6.48 | 19 | 160 | 71.4 | - | - | - |
| Potassium | 319 | mg/l | <1 | 65 | 6.41 | 8.51 | 26 | 307 | 96.2 | 37 | 11.6 | 12 |
| Sodium | 232 | mg/l | 4.8 | 57 | 16.6 | 8.7 | 32 | 232 | 100 | 0 | 0 | 200 |
| Sulphate as SO4 | 262 | mg/l | <5 | 279 | 44.7 | 50.9 | 141 | 248 | 94.7 | 2 | 0.763 | 250 |
| **Metals** | | | | | | | | | | | | |
| Cadmium | 176 | mg/l | <0.0005 | 0.01 | n.d. | n.d. | 0.005 | 13 | 7.39 | 6 | 3.41 | 0.005 |
| Chromium | 176 | mg/l | <0.005 | 0.22 | n.d. | n.d. | 0.0525 | 22 | 12.5 | 9 | 5.11 | 0.05 |
| Copper | 176 | mg/l | <0.005 | 0.063 | 0.00894 | 0.00933 | 0.03 | 60 | 34.1 | 0 | 0 | 2 |
| Iron | 311 | mg/l | <0.03 | 8.4 | 0.232 | 0.827 | 0.994 | 62 | 19.9 | 49 | 15.8 | 0.2 |
| Lead | 176 | mg/l | <0.005 | 0.08 | n.d. | n.d. | 0.0425 | 25 | 14.2 | 18 | 10.2 | 0.025 |
| Manganese | 176 | mg/l | <0.04 | 3 | 0.298 | 1.54 | 0.7 | 147 | 83.5 | 84 | 47.7 | 0.05 |
| Nickel | 176 | mg/l | <0.005 | 0.1 | 0.00992 | 0.0126 | 0.0308 | 52 | 29.5 | 15 | 8.52 | 0.02 |
| Zinc | 176 | mg/l | <0.005 | 0.16 | 0.0219 | 0.0185 | 0.05 | 127 | 72.2 | 0 | 0 | 5 |
| **Nitrogen species** | | | | | | | | | | | | |
| Ammoniacal Nitrogen as N | 485 | mg/l | <0.04 | 215 | 1.33 | 12 | 1.72 | 195 | 40.2 | 67 | 13.8 | 0.39 |

| Determinand | No. of Results | Unit | Min | Max | Mean | Standard Deviation | 95th Percentile | # > LOD | % > LOD | UKDWS No. Exceeding | UKDWS % Exceeding | UKDWS Action Level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ammonium as NH4 | 14 | mg/l | <0.3 | 525 | 86.8 | 180 | 467 | 11 | 78.6 | - | - | - |
| **Nitrite as N** | **43** | **mg/l** | **<0.003** | **0.011** | **n.d.** | **n.d.** | **0.05** | **4** | **9.3** | **35** | **81.4** | **0.03** |
| **Other parameters** | | | | | | | | | | | | |
| Bicarbonate Alkalinity | 176 | mg/l | 154 | 1230 | 304 | 118 | 414 | 176 | 100 | - | - | - |
| COD (Total) | 441 | mg/l | <20 | 366 | 18.4 | 27 | 45 | 145 | 32.9 | - | - | - |
| Hardness as CaC03 | 138 | mg/l | 188 | 711 | 378 | 95.1 | 514 | 138 | 100 | - | - | - |
| Naphthalene | 181 | mg/l | <1E-05 | 0.00013 | n.d. | n.d. | 0.00003 | 10 | 5.52 | - | - | - |
| TOC (filtered) | 223 | mg/l | 0.8 | 20 | 5.24 | 3 | 11 | 223 | 100 | - | - | - |

* Mean statistics for non-detects are calculated at half the limit of detection. n.d. – statistic not determinable due to insufficient positive detections.

**Table 2.4 Statistical summary of groundwater quality between January 2009 and February 2016**

| Determinand | No. of Results | Unit | Min | Max | Mean | Median | Standard Deviation | 5th Percentile | 95th Percentile | # > LOD | % > LOD | UKDWS No. Exceeding | UKDWS % Exceeding | UKDWS Action Level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Field / lab parameters** | | | | | | | | | | | | | | |
| Conductivity- Electrical (Field) | 195 | µS/cm | 0.68 | 1764 | 745 | 743 | 286 | 71.2 | 1276 | 195 | 100 | 0 | 0 | - |
| Conductivity- Electrical 20deg | 590 | µS/cm | 254 | 1980 | 723 | 671 | 235 | 444 | 1280 | 590 | 100 | 0 | 0 | - |
| D.O. concentration | 55 | mg/l | 0.6 | 9.2 | 4.63 | 4.4 | 2.18 | 0.87 | 8.05 | 55 | 100 | 0 | 0 | - |
| Dissolved Oxygen Unfixed | 1 | mg/l | 8.7 | 8.7 | 8.7 | 8.7 | - | 8.7 | 8.7 | 1 | 100 | 0 | 0 | - |
| pH | 590 | pH | 7.1 | 8.6 | 7.6 | 7.6 | 0.261 | 7.3 | 8.1 | 590 | 100 | 0 | 0 | - |
| pH (Field) | 414 | pH | 6.1 | 11 | 7.56 | 7.58 | 0.531 | 6.7 | 8.3 | 414 | 100 | 0 | 0 | - |
| **Major ions** | | | | | | | | | | | | | | |
| Alkalinity as CaCO3 | 590 | mg/l | 28 | 482 | 310 | 309 | 69.8 | 198 | 432 | 590 | 100 | 0 | 0 | - |
| Calcium | 590 | mg/l | 51.4 | 686 | 122 | 105 | 56.4 | 67.8 | 239 | 590 | 100 | 20 | 3.39 | 250 |
| Chloride | 590 | mg/l | 2.6 | 109 | 31.7 | 26.6 | 18.7 | 8.68 | 71 | 590 | 100 | 0 | 0 | 250 |
| Magnesium | 598 | mg/l | <0.25 | 192 | 29.3 | 28 | 14.6 | 11.3 | 45.8 | 590 | 98.7 | 11 | 1.84 | 50 |
| Nitrate as N | 21 | mg/l | <0.42 | 6.72 | 1.17 | n.d. | 1.85 | n.d. | 5.93 | 9 | 42.9 | 0 | 0 | 11 |
| Nitrogen (total oxidised) as N | 590 | mg/l | <0.42 | 19.5 | 2.37 | 1.06 | 3.64 | n.d. | 9.79 | 429 | 72.7 | 0 | 0 | - |
| Potassium | 602 | mg/l | 0.27 | 29 | 5.25 | 2.04 | 5.79 | 0.751 | 16.6 | 602 | 100 | 94 | 15.6 | 12 |
| Potassium (exc. BH9) | 571 | mg/l | 0.27 | 25.9 | 4.44 | 1.96 | 4.68 | 0.75 | 14.7 | 571 | 100 | 63 | 11 | 12 |
| Sodium | 590 | mg/l | 2.39 | 74.9 | 18.1 | 13.8 | 14 | 5.14 | 53.3 | 590 | 100 | 0 | 0 | 200 |
| Sulphate as SO4 | 590 | mg/l | <1.3 | 586 | 82.3 | 19 | 126 | 3 | 415 | 573 | 97.1 | 65 | 11 | 250 |
| **Metals** | | | | | | | | | | | | | | |
| Cadmium | 56 | mg/l | <0.0006 | 0.0019 | 0.000368 | n.d. | 0.000254 | n.d. | 0.000675 | 11 | 19.6 | 0 | 0 | 0.005 |
| Chromium | 56 | mg/l | <0.002 | 0.0011 | n.d. | n.d. | n.d. | n.d. | 0.001 | 5 | 8.93 | 0 | 0 | 0.05 |
| Copper | 56 | mg/l | <0.009 | 0.017 | 0.00557 | n.d. | 0.00322 | n.d. | 0.0128 | 27 | 48.2 | 0 | 0 | 2 |
| Iron | 604 | mg/l | <0.12 | 8.85 | n.d. | n.d. | n.d. | n.d. | 0.206 | 64 | 10.6 | 31 | 5.13 | 0.2 |
| Lead | 56 | mg/l | <0.006 | 0.021 | 0.00411 | n.d. | 0.00368 | n.d. | 0.012 | 10 | 17.9 | 0 | 0 | 0.025 |
| Manganese | 56 | mg/l | 0.014 | 0.23 | 0.0401 | 0.0325 | 0.0336 | 0.0188 | 0.0828 | 56 | 100 | 7 | 12.5 | 0.05 |

| | | | | | | | | | | | | UKDWS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Determinand** | **No. of Results** | **Unit** | **Min** | **Max** | **Mean** | **Median** | **Standard Deviation** | **5th Percentile** | **95th Percentile** | **# > LOD** | **% > LOD** | **No. Exceeding** | **% Exceeding** | **Action Level** |
| Nickel | 56 | mg/l | <0.003 | 0.0066 | 0.00203 | n.d. | 0.00139 | n.d. | 0.00465 | 15 | 26.8 | 0 | 0 | 0.02 |
| Zinc | 56 | mg/l | <0.018 | 0.05 | 0.0101 | n.d. | 0.0078 | n.d. | 0.0233 | 25 | 44.6 | 0 | 0 | 5 |
| **Nitrogen species** | | | | | | | | | | | | | | |
| Ammoniacal Nitrogen as N | 593 | mg/l | <0.06 | 2.45 | 0.0548 | n.d. | 0.142 | n.d. | 0.17 | 102 | 17.2 | 10 | 1.69 | 0.39 |
| **Other parameters** | | | | | | | | | | | | | | |
| Bicarbonate Alkalinity | 21 | mg/l | 186 | 419 | 303 | 295 | 69.1 | 190 | 419 | 21 | 100 | 0 | 0 | - |
| COD (Total) | 21 | mg/l | <11 | 27 | 13.8 | 14 | 6.64 | n.d. | 25 | 15 | 71.4 | 0 | 0 | - |
| Napthalene | 593 | mg/l | <1E-05 | 0.000147 | n.d. | n.d. | n.d. | n.d. | n.d. | 29 | 4.89 | 0 | 0 | - |
| TOC (filtered) | 590 | mg/l | <0.7 | 38.7 | 4.15 | 3.46 | 3.48 | 1.1 | 8.6 | 585 | 99.2 | 0 | 0 | - |

**Figure 2.3 Historical groundwater electrical conductivity**

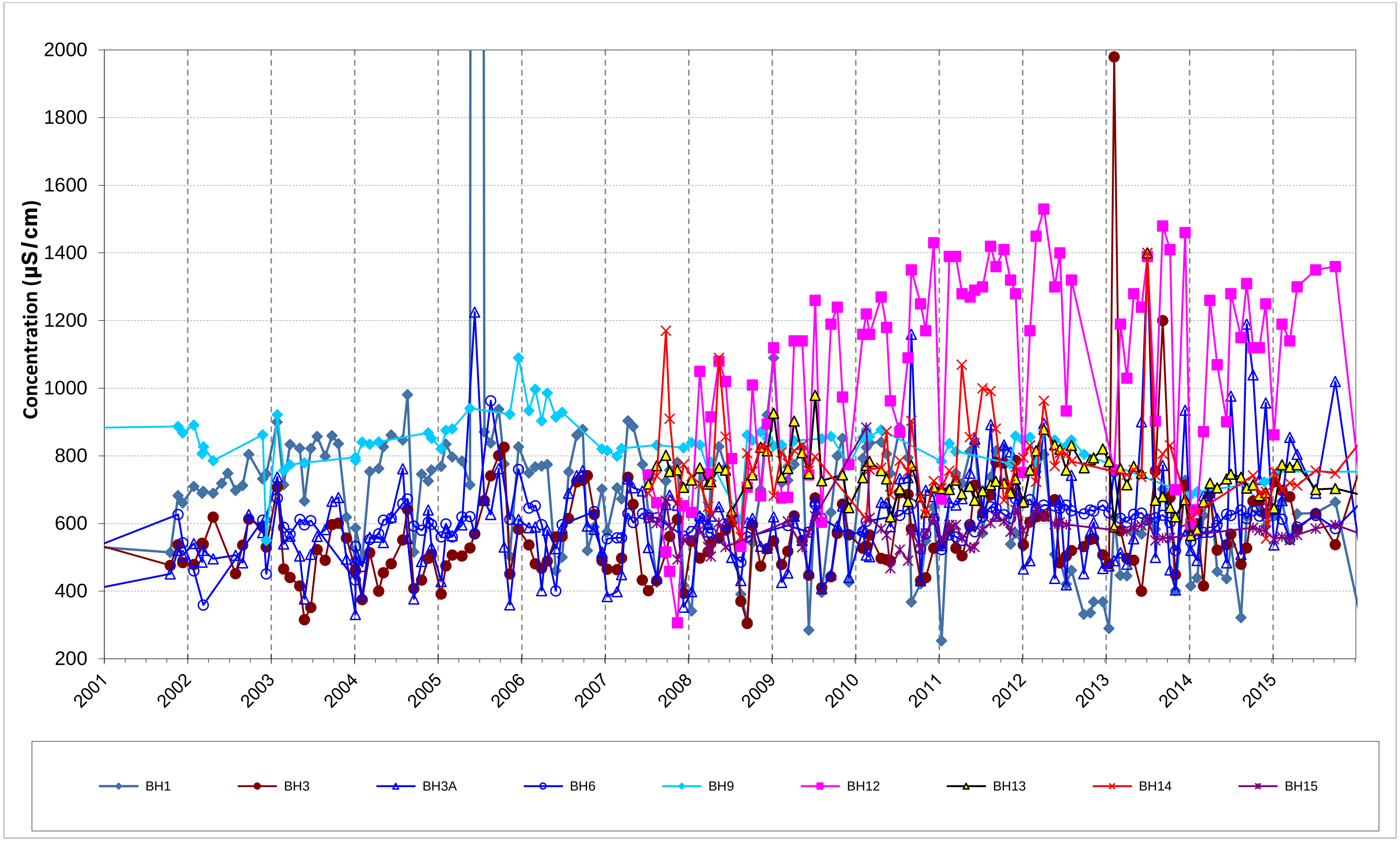


**Figure 2.4 Historical groundwater ammoniacal nitrogen concentrations**

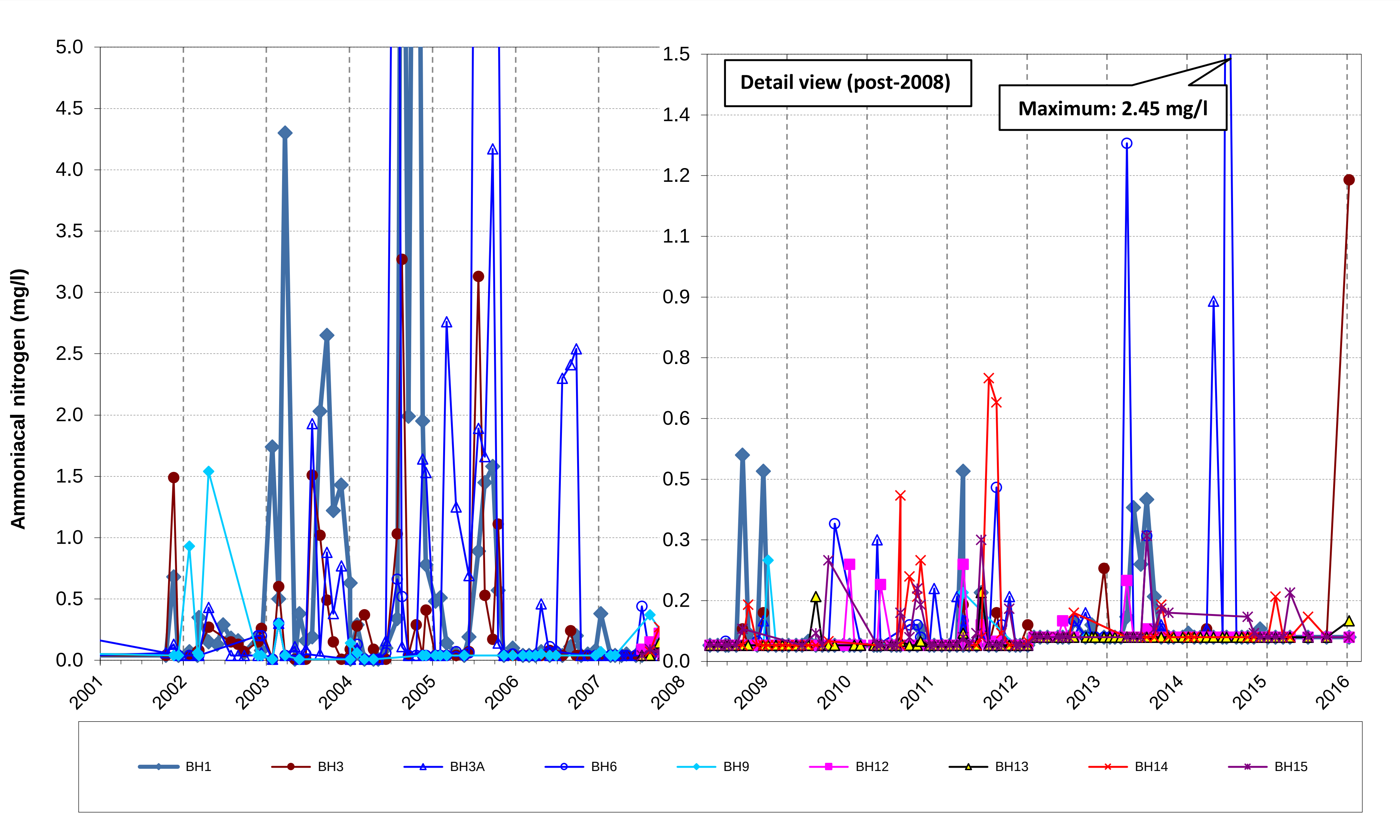


**Figure 2.5 Historical groundwater chloride concentrations**

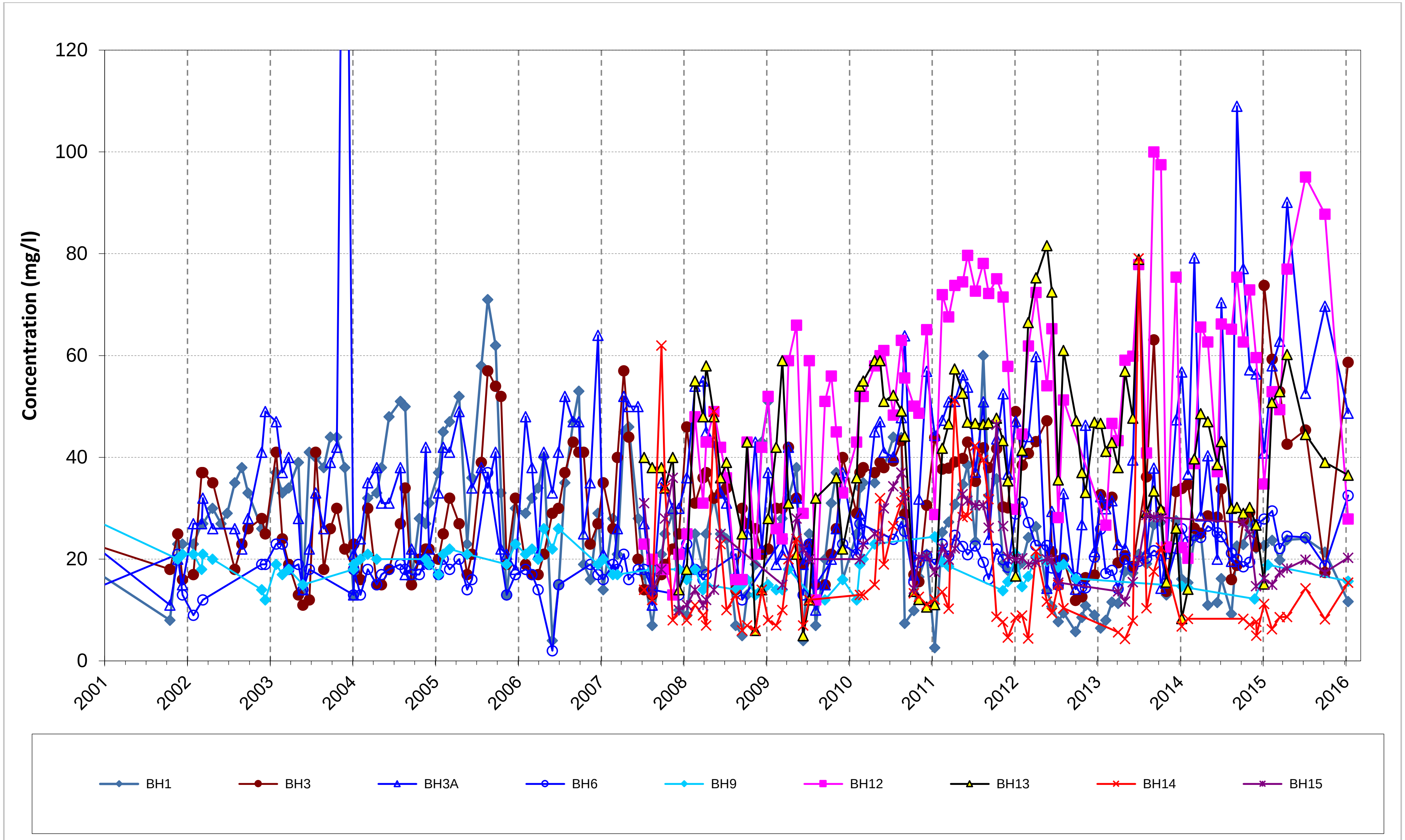


**Figure 2.6 Historical groundwater potassium concentrations**

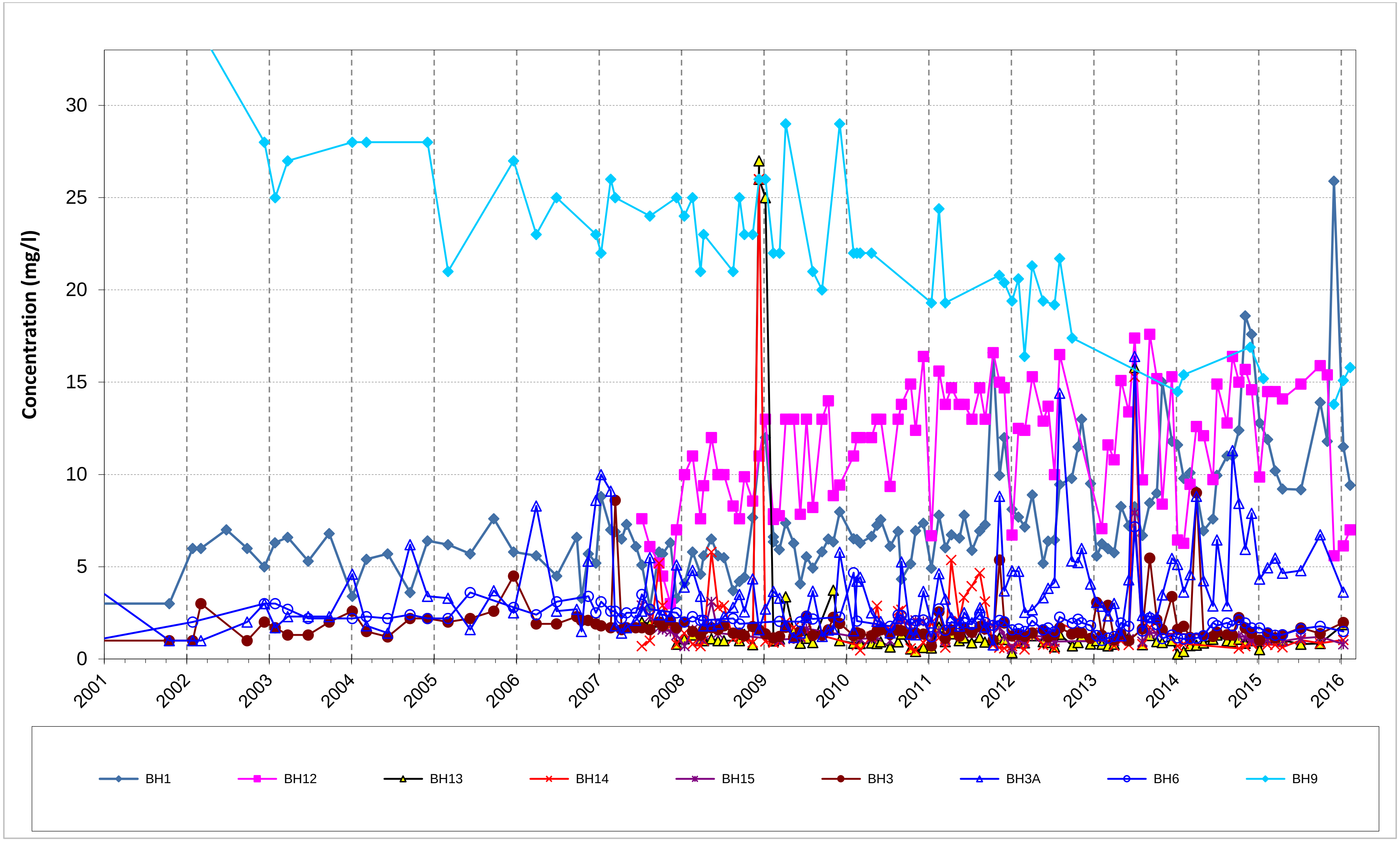


**Figure 2.7 Historical spatial distribution of groundwater potassium concentrations**

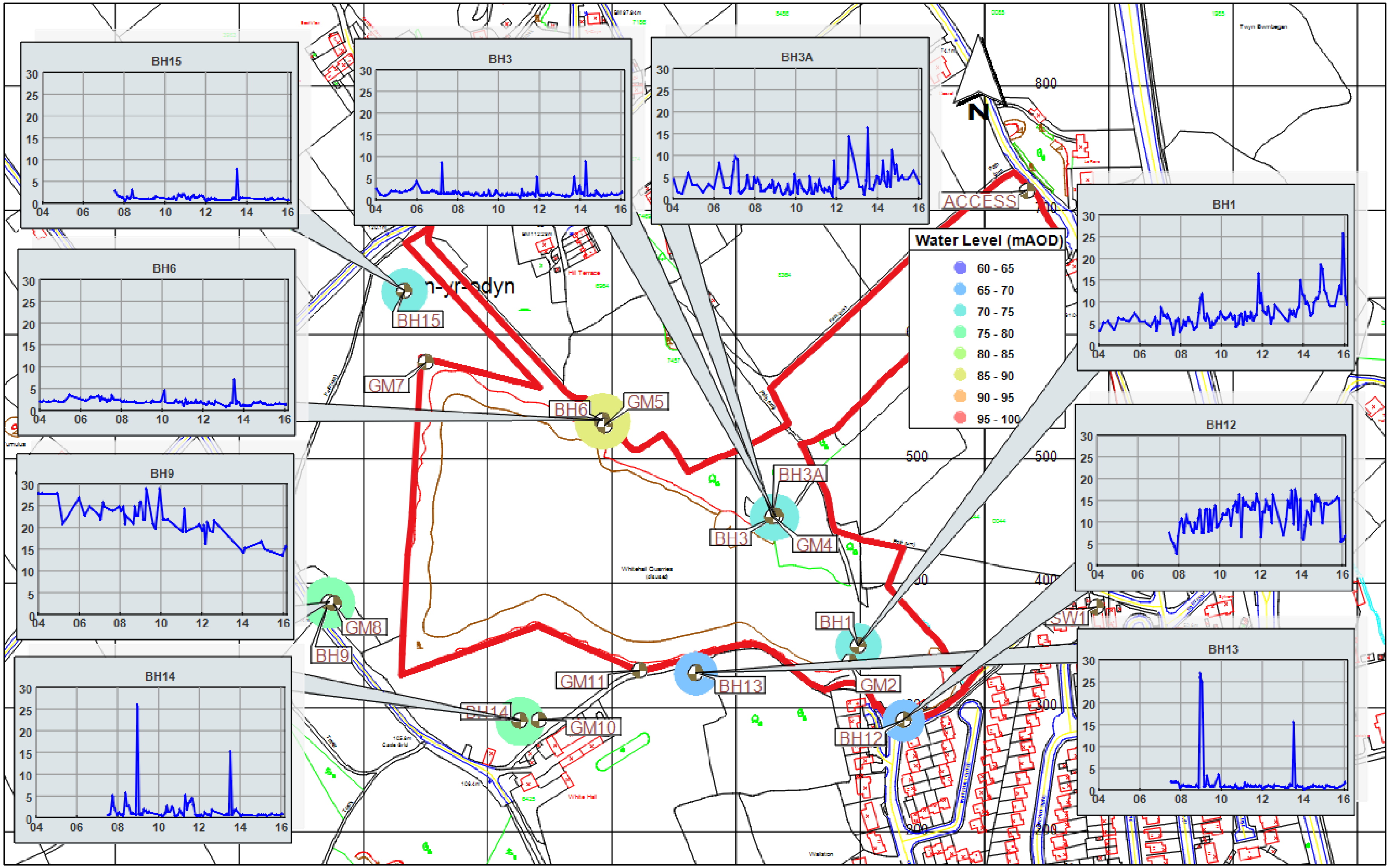
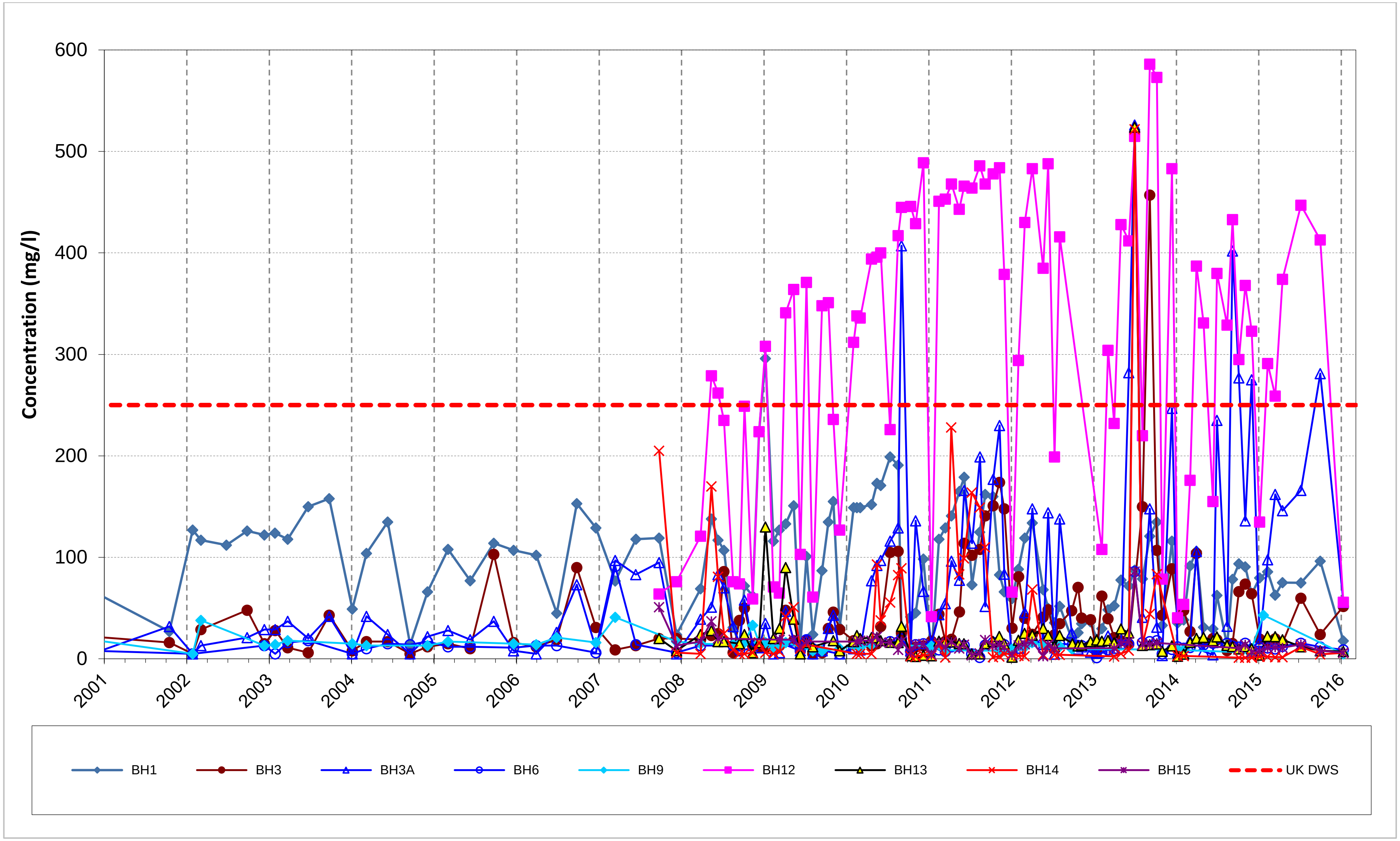


**Figure 2.8 Historical groundwater sulphate concentrations**



# 3 REVIEW OF ORIGINAL SITE CONCEPTUAL HYDROGEOLOGICAL MODEL

In this section the original site conceptual model for Whitehall Landfill, as described in ESI (2005a) is compared against the site data that was reviewed in Section 2 of this report.

## 3.1 Source-pathway-receptor linkages

### 3.1.1 Sources

The original HRA source term considered the total volume of waste in Whitehall Landfill on its completion.

For an inert landfill, it is stated in Environment Agency (2011) that "a discharge that would result in or might lead to the direct or indirect input of a pollutant into groundwater is not a groundwater activity if the input of the pollutant is of a quantity and concentration so small as to obviate any present or future danger of deterioration in the quality of the receiving groundwater. If the discharge is deemed to not be a groundwater activity by the Environment Agency then further assessment of the risk to groundwater would not be required."

The source of contamination is taken to be the inert waste disposed of in the landfill. It is stated in ESI (2009) that although the installation is used for the disposal of inert waste only, it is reported that wastes deposited at the Site in the past have included small amounts of topsoil, bituminous material and wood (including tree trunks), which were previously considered to be inert (ESI, 2005a). These were formerly acceptable in accordance with the Site's Waste Management Licence but are no longer acceptable as inert wastes in accordance with the Landfill Regulations. The source term in the original model accounted for this by means of a more representative concentration of ammoniacal nitrogen and by modelling naphthalene as a representative substance for the bituminous materials. As these materials are no longer imported under the current permit, the modelled source term is considered to be conservative.

The original HRA modelled the site without the presence of a landfill cap or basal barrier system, and waste placement prior to the 2005 PPC application did not require engineered containment. However, the since the issue of the environmental permit subsequent phases have required the construction of an enhanced geological barrier on all future phases. As a result the model can be considered a conservative representation of the real system.

In the absence of a landfill cap or complete basal barrier system, effective rainfall is able to infiltrate into the waste, permeate downwards through the waste and pass into the underlying sand and gravel. Waste materials at the Site have not been placed below groundwater levels.

The determinands that were used to model contaminant transport in the original HRA were:

- Ammoniacal nitrogen - although bio-degradable material will not be deliberately disposed of at Whitehall, it is possible that some residual biodegradable material may historically have been placed or may be accidentally placed in the landfill in the future. Therefore, it is possible that some degradation products, such as ammonium may be produced. The purpose of including ammonium in the risk model was to demonstrate that, even if it were present in the leachate, it does not pose a risk to groundwater.
- Chloride – inorganic conservative contaminant.
- Calcium – inorganic conservative contaminant.
- Potassium – inorganic conservative contaminant.
- Iron – a mobile metal observed in groundwater at Whitehall.
- Naphthalene – a relatively soluble polycyclic aromatic hydrocarbon compound included to represent historical bitumen wastes.

These are representative of different groups of contaminants which exhibit similar behaviour.

The source used for the leachate source term for Whitehall Landfill is AEA (1991), which presents data from six demolition and inert waste sites. The exception to this is for ammoniacal nitrogen and naphthalene. Ammoniacal nitrogen concentrations presented in AEA (1991) are high for an inert source which does not contain any biodegradable material, but reasonable for a non-hazardous site. The model thus used a weighted average concentration for ammoniacal nitrogen to represent the mixture of wastes that may be present.

For naphthalene, the non-hazardous component of the waste was represented using a concentration that was two orders of magnitude higher than the detection limit.

Cemex also undertakes its own Duty of Care testing on random samples of incoming waste. These samples are quarantined and then subjected to the testing regime outlined in the Site Operating Plan; if the results are above the criteria in the Site Operating Plan the tested loads are rejected and the associated job is terminated.

As water passes through the Site and leachate is removed, the total mass of contaminant present in the landfill will decline. It is assumed that this rate of decline is proportional to the total water flux through the landfill.

### 3.1.2 Pathways

Inflows to the landfill are due to rainfall water and water table mound (only in the western end). In the absence of a landfill cap or basal barrier system, effective rainfall / groundwater inflow is able to infiltrate the waste, permeate downwards through the waste and pass downwards into the underlying Friars Point Limestone aquifer.

The pathway by which contamination may reach a key receptor is via downward flux through the landfill base. The infiltrating rainfall water passes into the Limestone and reaches the water table. Along this pathway, dispersion and retardation occurs, although the opportunity for retardation may be limited due to water being transported through fissures.

The strata surrounding the landfill form the principal geological barrier between the landfill and the non-hazardous receptor. The principal pathway considered in the original HRA was via the saturated Friars Point Limestone. The transport processes considered along the pathway were advection, retardation, decay, dispersion and dilution, although the opportunity for retardation may be limited due to water being transported through fissures.

The pathways described above are considered to remain applicable to Whitehall landfill.

### 3.1.3 Receptors

The receptors assessed in the original modelling were as follows:

<u>Hazardous substances</u>

The water table beneath the Site – with no dilution or any other process occurring.

<u>Non-hazardous substances</u>

Two down-hydraulic gradient receptors were modelled. These were the down-hydraulic gradient site boundary and the Wrinstone Brook, which are 200 m and 680 m from the centre of the Site respectively. At the Wrinstone Brook, the receptor to be considered is the groundwater adjacent to the brook.

Appropriate environmental Acceptance Levels (EALs) of the modelled contaminants were considered to be the minimum Reporting Values (MRVs) for hazardous substances, and the UK Drinking Water Standards (UK DWS) for non-hazardous substances.

Based on the conceptual modelling and a review of the site monitoring data, the receptors described above are considered to remain applicable to Whitehall Landfill.

## 3.2 Summary of changes to the conceptual model

It is considered that there have been no significant changes to the Site conceptual model which would warrant a review of the modelling approach undertaken in the original model developed for Whitehall Landfill.

# 4 HYDROGEOLOGICAL RISK ASSESSMENT

In this section we have reviewed the original hydrogeological risk assessment and assessed its ongoing validity.

## 4.1 Numerical modelling

In the original HRA a generic quantitative modelling approach (as defined in Environment Agency, 2011) was undertaken. This approach is considered to remain valid.

### 4.1.1 Justification for modelling approach and software

In the original HRA, ESI's RAM software modelling tool was used. This tool is considered to remain appropriate for an above water table inert landfill.

### 4.1.2 Model parameterisation

A number of inputs were required for the source, pathway and receptor terms.

Initially, modelling considered source terms for ammoniacal nitrogen, calcium, chloride, iron and potassium based on typical values for inert waste obtained from previous studies. A lower value than that suggested by the literature was utilised for ammoniacal nitrogen, as the literature value did not represent modern landfill directive compliant waste. The mean value of the literature values was considered appropriate to represent the non-hazardous element of the source term. Source dimensions were derived from known information about current and future landfill geometry.

Naphthalene was also included in the source term as a representative substance for the bituminous materials which were previously deposited.

Pathway parameters for the Site were obtained from MORECS data for infiltration and from expected values for runoff based on the on-site gradient. Up-hydraulic-gradient and down-hydraulic-gradient heads measured at the Site were used as model inputs. There has been no significant variation in water levels at the site and this input remains appropriate.

Receptor distances were obtained from Site plans and MRVs and DWS were used as the environmental assessment levels (EAL) for modelling.

Modelling considered advection, retardation, decay, dispersion and dilution within the saturated Friars Point Limestone. The input parameters are considered to remain a conservative modeling scenario.

In light of the monitoring data acquired over the last six years, the mathematical model remains appropriate for the site conceptual model.

# 5 REQUISITE SURVEILLANCE

This section reviews the requirements for on-going surveillance.

## 5.1 Groundwater monitoring

Groundwater is currently monitored at the locations and frequency given in Table 2.1. Groundwater monitoring frequency reduced to quarterly (with an additional annual suite) in mid-2015 in line with Improvement Condition 2 and current Environment Agency guidance on landfill monitoring. The frequency and determinand suites are considered to remain appropriate for an inert landfill.

## 5.2 Groundwater compliance limits

Groundwater compliance limits have been set for ammoniacal nitrogen, chloride, iron, naphthalene and potassium at boreholes BH1, BH12, BH13 and BH14. These locations are located down hydraulic gradient of the landfill and are therefore considered to remain appropriate for compliance monitoring purposes.

Iron compliance limit

The current iron compliance limit of 200 µg/l is currently giving cause for concern. Historically the analytical laboratory, ALS, have used analytical method WAS049 which had a level of detection (LOD) of 190 µg/l. However, in March 2012 the LOD was increased to 230 µg/l. This increase in the LOD was instigated by the laboratory, ALS, following a review of best practice within the industry. As a result CEMEX have had to change the analytical method in order to get the LOD below 200 µg/l.

Iron was selected as a determinand for the HRA and as a compliance limit determinand on the basis that baseline concentrations in groundwater at the Site are low and that iron may have formed a component of historical waste placed at the Site in the form of reinforcing rods, containers, etc. Such materials are unlikely to be placed in the Site under the current regime as they would be recycled.

It is difficult to determine an appropriate source term for inert landfills as there is no requirement to collect or monitor leachate. The source term selected for the HRA was based on a literature search and an iron concentration of 7.98 mg/l was selected. The model predicted a maximum iron concentration at the edge of Site receptor of 1.4 µg/l. Using the model, it was determined that a source term concentration of 1,160 mg/l would be required in order to get receptor concentrations equal to the selected environmental assessment level (EAL) of 200 µg/l. It is thus considered quite unlikely that a breach of the iron compliance limit will occur in practise.

Following Environment Agency guidance at the time, the iron EAL was set to be the drinking water standard (DWS) for iron. However, we note that this DWS has been set as high iron concentrations cause discolouration of drinking water; iron does not cause health problems. It is therefore questionable as to whether the DWS is the most appropriate EAL for this determinand.

According to the ESID report (Ove Arup & ESI, 2005), there is one licensed groundwater abstraction (licence number 21/58/11/0008) within a 1 km radius of the site. This is located at Whitehall Farm (NGR ST 1141 7314), to the south west of the site, and is used for direct spray irrigation. As this is not used for drinking water, a higher iron concentration in this source would not be of concern.

Whilst no information could be obtained for private supplies, given the rural landscape around the Site, it is likely that any private supplies would also be for agricultural supply rather than drinking water.

The HRA also considered a second receptor; groundwater adjacent to Wrinstone Brook. This receptor was selected on the basis that groundwater may discharge to surface water at this point. The edge of site receptor has a travel distance of 200 m from the centre of the Site whilst the Wrinstone Brook receptor has a travel distance of 680 m. The predicted iron concentration at Wrinstone Brook is 0.14 µg/l; i.e. an order of magnitude lower concentration that the edge of site receptor. Therefore, in order to ensure that concentrations at Wrinstone Brook do not exceed the EAL, concentrations at the edge of site receptor could be as high as 2,000 µg/l.

On this basis, it is considered that increasing the edge of site compliance limit from its current level of 200 µg/l to 250 µg/l would not cause any significant issue in terms of determining a pollution event from the landfill and should concentrations above 250 µg/l be observed in the edge of site groundwater monitoring wells, that could be attributed to the Site, there would be sufficient time to take remedial action before the DWS is exceeded at Wrinstone Brook or actual groundwater abstractions that are used for drinking water supply.

<u>Potassium compliance limit</u>

As discussed in Section 2.3.2 the potassium compliance limit is sometimes exceeded in BH1 and BH12. Whilst the increasing trend at BH12 appears to have stabilised, the trend appears to be continuing at BH1. Superimposed on the longer term trend is a shorter term annual trend such that concentrations are often below the compliance limit during the wetter winter months when there is more dilution and above it during the summer months when there is less dilution.

The cause of the increasing potassium trend is believed to be historical landfills located up hydraulic gradient of the Site. Elevated potassium is also observed at the up hydraulic gradient monitoring well BH9, although this now has a declining trend. This suggests that the peak in the plume currently lies between BH9 and BH1 / BH12.

Given this situation, it is recommended that the compliance limit is temporarily increased to a level that is above the maximum expected for the plume. The revised limit should then be reviewed at the next HRA review (i.e. in 6 years' time) to assess whether it is appropriate to revert to the current limit.

On this basis, updated compliance limits for potassium at BH1 and BH12 are proposed.

- As BH12 appears to have reached its peak, the proposed compliance limit is based on the mean result plus three standard deviations using the data from January 2012 to March 2016 (i.e. the dataset since concentrations have levelled off). The proposed control level is defined based on mean value plus two standard deviations. The concentrations and the proposed control level and compliance limit are presented on Figure 5.1. The proposed control level is 19 mg/l and the compliance limit is 23 mg/l.
- As concentrations are still rising at BH1 it is not appropriate to use the mean concentration plus three standard deviations approach. On the basis that we believe we have reached, or are close to reaching, peak concentrations, the compliance limit has been set at the maximum concentration plus 1 mg/l. The control level has been set at a concentration that should allow early warning of an acceleration of the increase. We note that if this control level had been adopted earlier there would have been two exceedances of it during the autumn of 2014 and 2015 when concentrations increased sharply due to low groundwater level and dilution. The concentrations and the proposed control level and compliance limit are presented on Figure 5.2. The proposed control level is 18 mg/l and the compliance limit is 27 mg/l.

**Figure 5.1 Potassium data for BH12, including proposed revised control level and compliance limit**

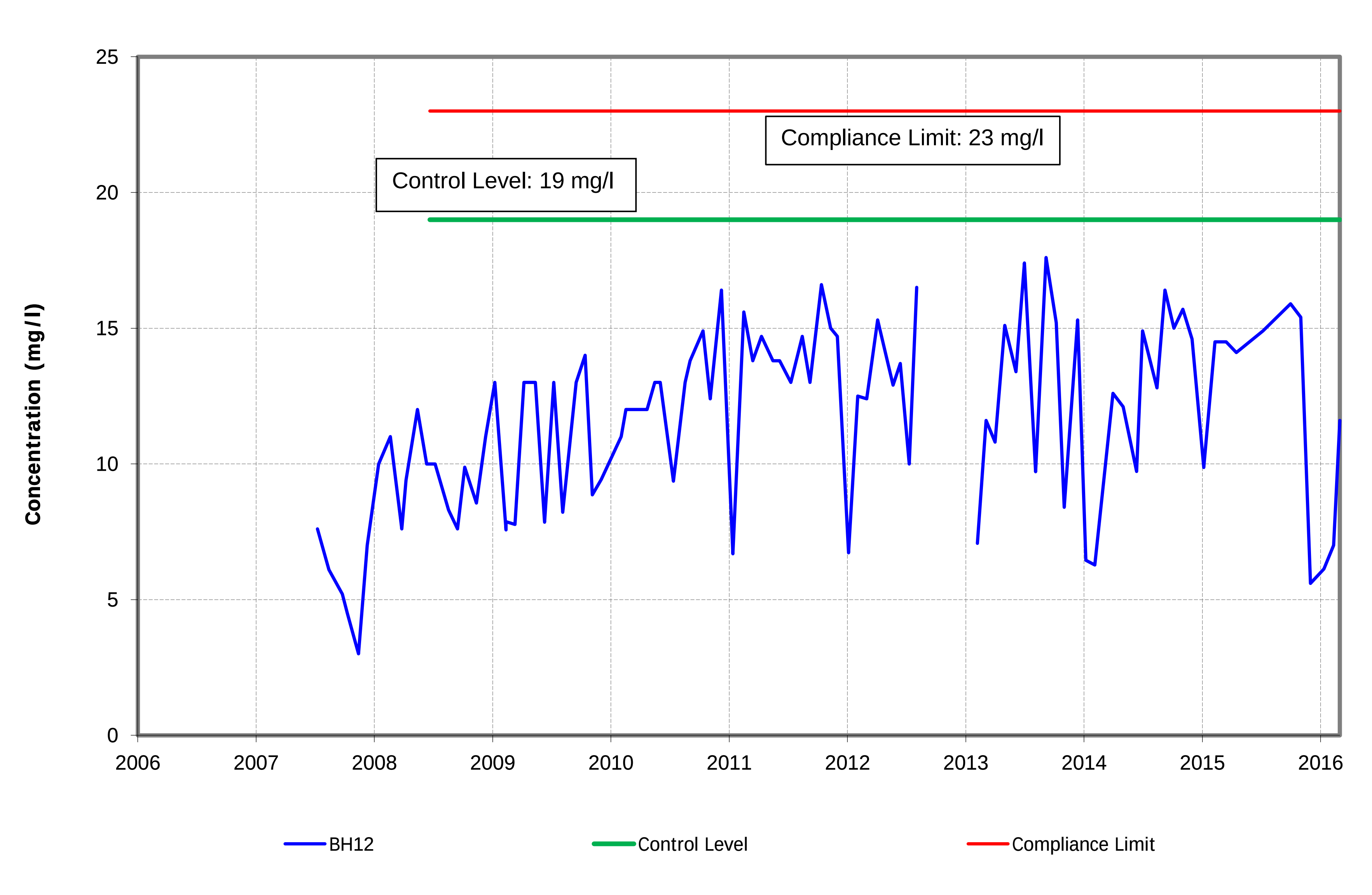
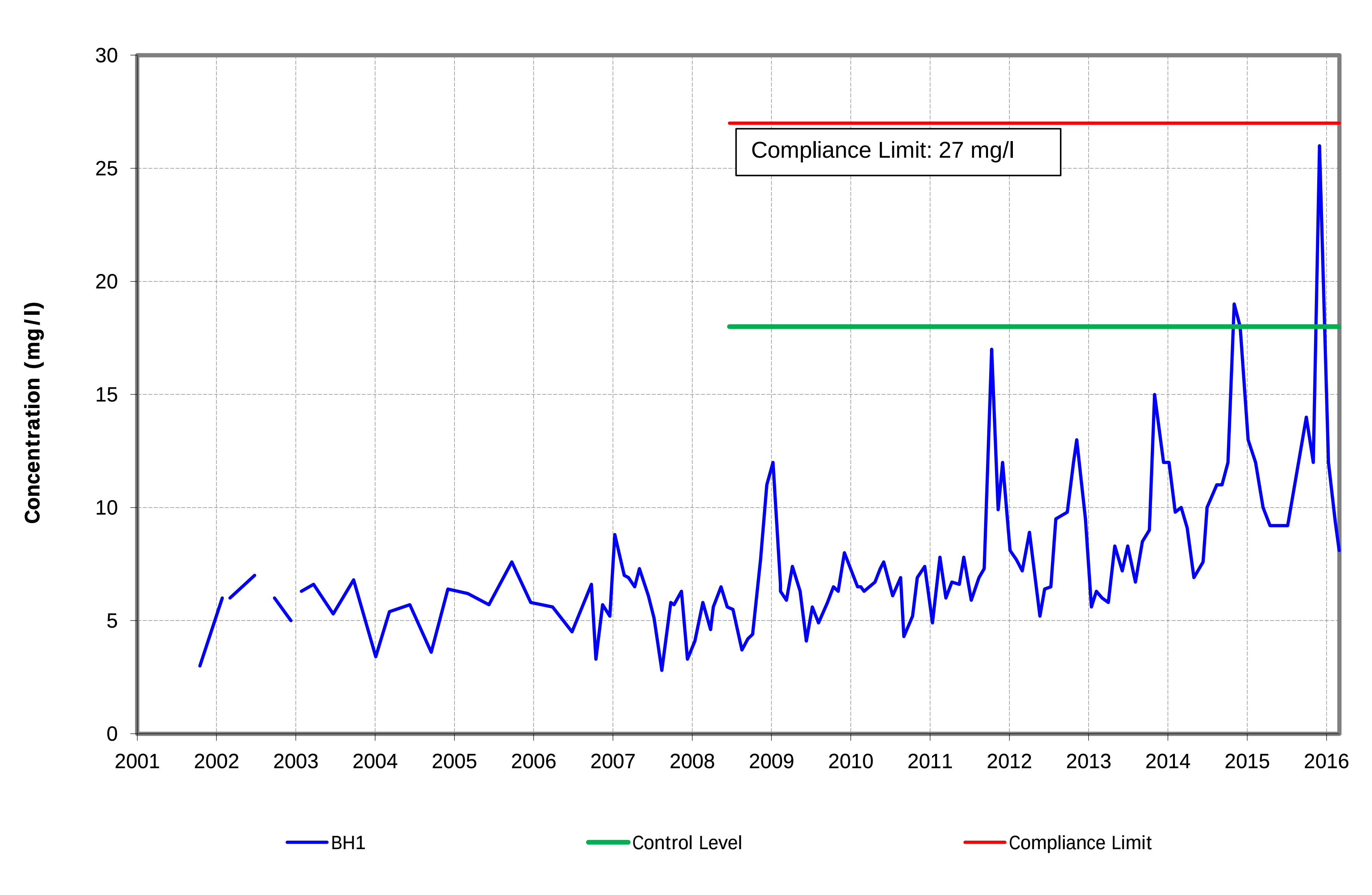


**Figure 5.2 Potassium data for BH1, including proposed revised control level and compliance limit**



# 6 CONCLUSIONS

Schedule 10 of the Environmental Permitting Regulations implements the Landfill Directive with the objective of preventing or reducing as far as practical negative effects on the environment, in particular the pollution of controlled waters during the whole life cycle of the landfill. This is achieved through stringent operational and technical requirements on the waste and landfills.

Requisite monitoring at the Site has in general been carried out according to the requirements of the permit.

Groundwater level and quality monitoring data have been reviewed and it is concluded that there has not been any significant change to the groundwater flow regime or groundwater quality.

The conceptual model, modelling methodology and mathematical model used in the previous HRA have all been reviewed. It is concluded that these models remain fit for purpose.

Small changes to the Site compliance limits are recommended as follows:

- the compliance limit for iron should be raised to 250 µg/l at all locations and
- the compliance limit for potassium at BH1 and BH12 should be temporarily increased whilst the potassium plume migrates under the Site. It is proposed that these compliance limits will be reviewed again at the next HRA review in 6 years' time to determine whether they can revert back to the current limits.

The Site is concluded to remain in compliance with the Environmental Permitting (England and Wales) Regulations 2010.

# 7 REFERENCES

**AEA, 1991.** A study of the type and scale of environmental impacts from landfills accepting predominantly wastes other than domestic. Report ref. AEA-EE-0240.

**Environment Agency 2006**. PPC Permit for Whitehall Landfill, MP3036SS. 17 March 2006.

**Environment Agency 2007**. Variation Notice for Whitehall Landfill, LP3630MR 22 June 2007.

**Environment Agency, 2011.** Additional guidance for hydrogeological risk assessments for landfills and the derivation of groundwater control levels and compliance limits. Horizontal guidance note H1 – Annex J 3.

**ESI, 2005a.** Whitehall Landfill Hydrogeological Risk Assessment Report. April 2005. Report Number: 116073. Report Status: Final.

**ESI 2005b.** Response to Schedule 4 notice: Whitehall Landfill. App. No. EA/PPC/MP3036SS. 13 September 2005.

**ESI 2005c.** Response to Schedule 4 notice: Whitehall Landfill. App. No. EA/PPC/MP3036SS. 20 September 2005.

**ESI, 2008.** Whitehall control and trigger level review, May 2008. Report reference: 6496HR2.

**Ove Arup & ESI 2005.** Whitehall Landfill Conceptual Model, ESID Report. April 2005. Report Number: 116073.