Kerdiffstown Landfill Remediation Project

Kildare County Council

Environmental Impact Assessment Report (EIAR) Volume 4 of 4: Appendices (Part 3)

32EW5604 DOC 0056 | Final

August 2017

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Appendix A12.2 Groundwater and Surface Water Monitoring Report - December 2016

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Kerdiffstown Landfill Remediation Project

Kildare County Council

Groundwater and Surface Water Monitoring Report - December 2016

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Kerdiffstown Landfill Remediation Project

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0	09/02/2017	Preliminary draft for comment	HF	MB	RR
1	03/05/2017	Final	HF	MB	RR

Contents

Executive Summary

This report presents the results and findings of a groundwater and surface water sampling exercise completed at Kerdiffstown Landfill (located near Naas in County Kildare) during December 2016 and has been completed by Jacobs on behalf of Kildare County Council (KCC). The landfill is situated within a sand and gravel overburden aquifer which overlies a limestone bedrock aquifer. The Morell River situated close to the site's eastern boundary has been identified as a sensitive surface water receptor.

This sampling round was a biannual round with more wells being sampled and a larger analytical suite than a normal monthly round. Therefore, during this sampling round, 34 groundwater samples (fourteen off-site, seven boundary and thirteen on-site) and sixteen surface water samples (five from the Morell River, six from waterbodies in Palmerstown Golf Course, four from the canal feeder and one from the site drainage discharge) were taken.

Rainfall during December was recorded at 49.2mm which is below the historical long term average for that month, noted to be 75.7mm. As five of the past six months were drier than average, groundwater levels fell between November and December in all but six groundwater wells.

As with previous monitoring rounds, concentrations of substances associated with landfill leachate such as ammoniacal nitrogen and chloride were found to be elevated in groundwater in the overburden deposits beneath the site and on the site's eastern boundary including in wells EMW03, EMW13 and BH26 where the highest concentrations are generally recorded. Lower concentrations of ammoniacal nitrogen and chloride were identified in boreholes installed between the site and the Morell River but with no discernible impact shown on the river water quality.

Key results, particularly exceedances of water quality standards (Interim Guideline Value (IGV) and/or Groundwater Threshold Value (GTV) for groundwater, and Environmental Quality Standards (EQS) for surface water), obtained during December 2016 are summarised in the table below.

Table 1: Summary of Groundwater Results recorded during December 2016

Locations	December 2016 Exceedances	Notable Results / Trends
On-Site Wells — Exceedances of water quality standards are seen for many key determinands in all wells located on-site, e.g. chloride, ammoniacal nitrogen, iron, manganese, sulphate and arsenic. The majority of results in on-site wells were within previously recorded ranges.		
EMW13 (north-east)	Exceedances in calcium, potassium, sodium, chloride, ammoniacal nitrogen, boron, iron, manganese, arsenic, barium, nickel and zinc.	Barium at lowest ever concentration recorded in this well. Toluene detected at this well for the first time since monitoring began.
EMW15 (west)	Exceedances in calcium, potassium, sulphate, chloride, ammoniacal nitrogen, iron, manganese, arsenic and barium.	Arsenic at highest ever recorded in this well (up slightly from November).
EMW16 (north)	Exceedances in calcium, potassium, sulphate, chloride, ammoniacal nitrogen, nitrite, iron, manganese, barium and nickel.	Alkalinity at lowest recorded in this well. Alkalinity generally trending downwards since June 2012.
EMW17 (south-east)	Exceedances in ammoniacal nitrogen and manganese.	Chloride, alkalinity and barium at lowest recorded concentrations in this well.
BH42 (centre south)	Exceedances in calcium, potassium, sulphate, ammoniacal nitrogen, iron, manganese, arsenic, barium, lead and nickel.	Sulphate and magnesium both at lowest recorded concentrations in this well.
BH36	Exceedances in chloride, ammoniacal	Ammoniacal nitrogen and sulphide at highest recorded

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Locations	December 2016 Exceedances	Notable Results / Trends
(centre north)	nitrogen, iron, manganese, arsenic, barium, copper, lead and nickel.	concentrations in this well; sulphate at lowest recorded concentration in this well.
BH6 (lower yard)	Exceedances in calcium, potassium, sulphate, boron, iron, manganese, arsenic, barium, chromium, copper, lead, mercury, nickel and zinc	Iron, manganese, alkalinity, arsenic, phosphate, boron, chromium, barium, nickel, copper, lead, mercury, zinc and vanadium at highest recorded concentrations in this well. However, the well dried up when taking the sample so silt within the sample is likely to account for the elevated concentrations.
BH7 (lower yard)	Exceedances in calcium, magnesium, potassium, chloride, ammoniacal nitrogen, boron, iron, manganese, arsenic, barium, cadmium, copper, lead, nickel and zinc.	Iron, manganese, sulphate, calcium, magnesium, phosphate, boron, barium, nickel, cadmium, copper, lead, zinc and sulphide at highest recorded concentrations in this well. However, the well had to be sampled using a bailer so additional silt within the sample is likely to account for the elevated concentrations.
GW1D (near site entrance)	Exceedances in chloride and manganese.	Chloride, alkalinity, chromium, barium, nickel and zinc at highest recorded concentrations in this well; iron, manganese, potassium, nitrate, sulphate and magnesium at lowest concentrations in this well.
GW2S (lower yard)	Exceedances in chloride, ammoniacal nitrogen, iron and manganese.	Ammoniacal nitrogen, manganese, potassium, sodium, alkalinity, arsenic, sulphate, calcium, magnesium and barium at lowest recorded concentrations in this well.
Boundary Wells EMW04, EMW07, EMW18 (all on the north-east and eastern boundary) and EMW24 (north) had results within normally observed ranges.		
EMW03 (north-east)	Exceedances in potassium, chloride, ammoniacal nitrogen, iron, manganese, arsenic, barium, lead and nickel.	Magnesium and boron at lowest recorded concentrations in this well; sulphide at highest recorded concentration. Calcium not exceeding IGV for the first time since December 2011.
EMW06 (north-east)	Exceedances in calcium, iron, manganese, barium, copper, lead and nickel.	This well continues to have lower concentrations in key determinands than nearby well EMW03. Sulphate, nickel, cadmium, lead, zinc and sulphide at highest recorded concentrations in this well.
EMW19 (east)	Exceedances in potassium, ammoniacal nitrogen, iron, manganese, arsenic and barium.	All elevated concentrations seen in previous months returning to more usually observed concentrations.
Off-Site Wells EMW05 (near Morell River), EMW08 (east), EMW21 (north-east), EMW22 (north), EMW28 (south) and EMW30 (Foley's Field) had results within normally observed ranges for all determinands.		
EMW02 (between site and Morell River)	Exceedances in nitrate, iron and manganese.	Sulphide at highest recorded concentration in this well.
EMW08 (between site and Morell River)	Exceedances in iron, manganese and barium.	Toluene detected at this well for the first time since monitoring began.
EMW20 (near Morell River)	Exceedances in ammoniacal nitrogen, iron, manganese and barium.	All major determinands have decreased further in December. The elevated results recorded in this well since late spring have now largely returned to more

Locations	December 2016 Exceedances	Notable Results / Trends
		"normal" concentrations for this well.
EMW23 (north)	Exceedances in potassium, iron, manganese and barium.	Chloride at lowest recorded concentration in this well.
EMW27 (Foley's Field)	Exceedances in calcium, ammoniacal nitrogen, iron, manganese, arsenic, barium, copper, mercury and nickel.	Chloride at lowest recorded concentration in this well; sulphide at highest recorded concentration in this well.
EMW29 (Foley's Field)	Exceedances in iron and manganese.	Ammoniacal nitrogen at highest recorded concentration in this well.
EMW31 (Palmerstown Golf Course)	Exceedances in ammoniacal nitrogen, iron, manganese and barium.	Sulphate at highest recorded concentration in this well.
EMW32 (Palmerstown Golf Course)	Exceedances in potassium, iron, manganese and barium.	Chloride and alkalinity at lowest recorded concentrations in this well; sulphate at highest recorded concentration in this well.
EMW33 (Palmerstown Golf Course)	Exceedances in ammoniacal nitrogen, iron, manganese, arsenic and barium.	Chloride at lowest recorded concentration in this well.

Table 2: Summary of Surface Water Results recorded during December 2016

Locations	December 2016 Exceedances	Notable Results / Trends
Morell River		
Upstream (SW01, SW02)	No exceedances	Chloride at SW01 at the highest concentration ever recorded here which is likely caused by road salt being washed in by rain on the day of sampling. Chloride reduced by SW02, after the Hartwell confluence.
Downstream (SW03-SW05)	No exceedances	The concentrations were generally within previously recorded ranges.
Canal Feeder		
Upstream (SW13)	Exceedance in copper	Previous higher exceedance in December 2015. Elevated chloride concentration due to road salt wash off.
Downstream (SW10-SW12)	Exceedances in cadmium, copper, lead and zinc.	Some similar exceedances seen in the past, except for lead.
Palmerstown Golf Course		
Lakes (SW06, SW07, SW14, SW15)	No exceedances	Results in the lake waterbodies were largely similar to previous monitoring rounds.
Hartwell (SW08, SW16)	No exceedances	Slightly elevated chloride concentrations were recorded, possibly caused by road runoff.

The following table highlights results which are particularly noteworthy due to detailed quantitative risk assessment (DQRA) trigger value exceedances, notable increasing pollutant trends, and/or unusual detections or IGV/GTV exceedances where they don't usually occur. Suggested actions to address these results are included in the table.

Table 3: Noteworthy Groundwater Observations and Actions

Location	Description	RAG	Actions
EMW19	The elevation in many determinands recorded from late spring to autumn have returned to or are returning to more usually seen concentrations for this well. Similar trends were recorded in the summer of 2014 suggesting a likely seasonal effect. See Section 2.2.2.1 for further detail.		Continue to closely monitor subsequent results to determine if this is a seasonal elevation as seen previously in this well.
EMW20	DQRA trigger values for both ammoniacal nitrogen and chloride were not exceeded for the first time in nine months. See Section 2.2.2.1 and 2.2.2.2 for further detail.		No further action required.

Table 4: Noteworthy Surface Water Observations and Actions

Location	Description	RAG	Actions
Morell River	There was a high concentration of chloride recorded upstream at SW01. This was elevated above normal results for this monitoring point. The field electrical conductivity was also elevated. It had been cold and wet prior to sampling suggesting that the elevation may have been caused by road salts being washed into the river. Further downstream at SW02, after the Hartwell flows into the Morell, the chloride concentration had returned to normal. There continues to be no significant impact seen in the Morell River as it flows past the site. See Section 2.2.3.1 for further detail.		Continued monthly monitoring to take place as scheduled.
Canal Feeder	During December 2016 the recent trend of higher downstream concentrations in some determinands has reversed. There were elevations and exceedances in some trace metals and organic compounds both upstream and downstream of the site. Similar elevations were not seen in nearby wells. This increase may have been caused by runoff from roads and fields from heavy rain before and during some of the sampling. See Section 2.2.3.1 for further detail.		Continue to closely monitor stream results and nearby groundwater results to determine a possible explanation for any adverse impacts.
Palmerstown Golf Course	The waterbodies within Palmerstown Golf Course show no evidence of impact from the landfill. In December, SW08 and SW16 both contained their highest concentrations of chloride recorded since monitoring began here (although below IGVs). Both locations are on the Hartwell River, and may have been impacted by salt runoff from the local roads, as seen in the Morell.		Continued biannual monitoring to take place as scheduled.

Exceedances mentioned above are to be considered as part of the current scope of works updating the conceptual site model (CSM) for the site and subsequently revisiting the trigger values when new data have been collected in relation to soils, water levels and water quality.

EPA Contaminated Land & Groundwater Risk Assessment Methodology		Report Reference	Report Date	Status
	STAGE 1: SITE CHARACTERISATION & ASSESSMENT			
1.1	**PRELIMINARY SITE ASSESSMENT**	Environmental Baseline Report Remedial Options Report	June 2013	Final
1.2	**DETAILED SITE ASSESSMENT**	Groundwater and Surface water Monitoring Reports	Monthly Reports from October 2013	Final
1.3	**QUANTITATIVE RISK ASSESSMENT**	Detailed Quantitative Risk Assessment	November 2014	Final
	STAGE 2: CORRECTIVE ACTION FEASIBILITY & DESIGN			
2.1	**OUTLINE CORRECTIVE ACTION STRATEGY**			
2.2	**FEASIBILITY STUDY & OUTLINE DESIGN**			
2.3	**DETAILED DESIGN**			
2.4	**FINAL STRATEGY & IMPLEMENTATION PLAN**			
	STAGE 3: CORRECTIVE ACTION IMPLEMENTATION & AFTERCARE			
3.1	**ENABLING WORKS**			
3.2	**CORRECTIVE ACTION IMPLEMENTATION & VERIFICATION**			
3.3	**AFTERCARE**			

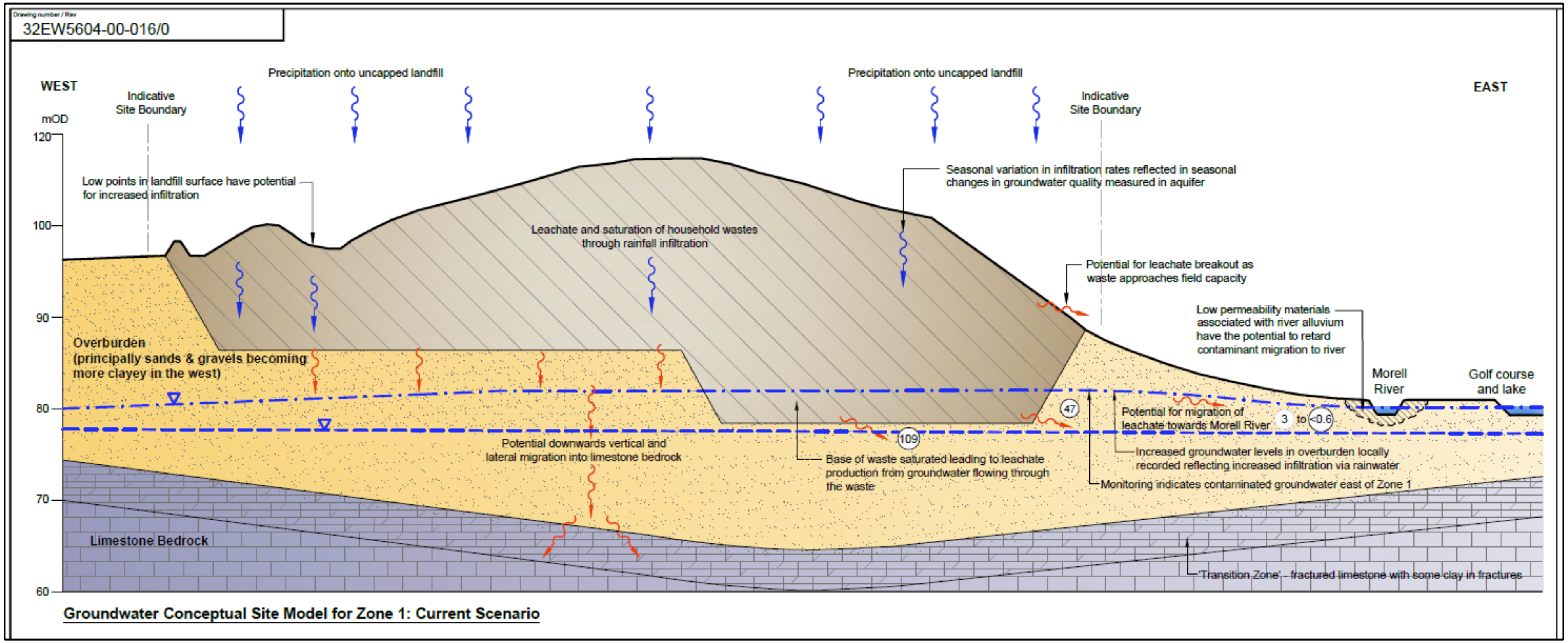


Diagram 1.1: Groundwater Conceptual Site Model (Version 4)

1. Introduction

1.1 Project Contractual Basis and Personnel Involved

In February 2013 SKM Enviros (now trading as Jacobs) was appointed as a framework contractor by the Environmental Protection Agency (EPA) to provide technical environmental support services in relation to the remediation of Kerdiffstown Landfill (hereafter referred to as the site). In June 2015 the control of the site was handed over to Kildare County Council (KCC) with the above mentioned framework contract being novated from the EPA to KCC.

Under the framework a Remedial Options Assessment was completed in July 2013. This assessment contained a number of key recommendations in relation to the future remediation of the site, which included a requirement to provide regular (monthly and six monthly[1]) on-going assessment of groundwater and surface water conditions in advance of remedial works using an existing network of groundwater monitoring wells installed on and around the site and pre-defined surface water monitoring locations.

This report presents the results and findings of groundwater and surface water monitoring completed by Jacobs in December 2016. The monitoring was completed at the request of KCC and was completed in accordance with Jacob's proposal to KCC dated 25th March 2016. The monitoring results presented in this report were preceded by monthly rounds of monitoring completed since October 2013 the results of which have been reported separately.

Monitoring included the collection and analysis of groundwater samples for a range of potential contaminants. Samples were collected from on-site, boundary and off-site monitoring wells installed within overburden deposits and underlying bedrock. In addition, for this round, sixteen surface water samples were collected from the Morell River (located north-east of the site), from the canal feeder (a surface water course located south-west of the site), from the site's surface water discharge, and from water bodies located on Palmerstown Golf Course (located east and north-east of the site). Analysis of the samples was completed by ALS Environmental.

1.2 Background Information

Waste operations ceased and the site was vacated during June 2010. Prior to this, Jacobs had been commissioned by the EPA to conduct an evaluation of potential environmental liabilities and related remedial costs associated with various closure scenarios for the landfill site. The results and findings of this study are presented in a previous report dated October 2010[2].

Since completion of the environmental liabilities assessment in 2010, Jacobs has been working with the EPA and as highlighted above was appointed as Framework Contractor in February 2013. Prior to this point Geosyntec Consultants (formerly Ford Consulting Group) had been commissioned by the EPA during 2011 to assess the condition of the site from the perspective of contaminated land and groundwater, and specifically to assess potential impacts from the site on sensitive environmental receptors. The results and findings of Geosyntec Consultants preliminary study are presented in a report dated April 2012[3].

Geosyntec subsequently completed groundwater and surface water monitoring rounds at the site in December 2011[4], May 2012[5], October 2012[6] and February 2013[7]. Jacobs has subsequently completed groundwater and surface water monitoring on a monthly basis since October 2013[8].

1 Monthly monitoring has been recommended from selected boreholes and for a reduced analytical suite. Six monthly sampling is recommended for all serviceable monitoring boreholes with analysis for an expanded suite. This report covers one monthly and one six-monthly rounds of sampling.

2 SKM Enviros, October 2010; Evaluation of Environmental Liabilities at Kerdiffstown Landfill.

3 Ford Consulting Group, April 2012; Preliminary Environmental Site Assessment – Kerdiffstown Landfill.

4 Ford Consulting Group, May 2012: Groundwater & Surface Water Monitoring at Kerdiffstown Landfill – December 2011 (Draft).

5 Ford Consulting Group, September 2012: Groundwater & Surface Water Monitoring at Kerdiffstown Landfill – May 2012 (Draft).

6 Geosyntec Consultants Ltd, January 2013: Groundwater & Surface water Monitoring at Kerdiffstown Landfill – October 2012 (Draft report).

7 Geosyntec Consultants Ltd, April 2013: Groundwater & Surface water Monitoring at Kerdiffstown Landfill – February 2013 (Draft report).

1.2.1 Physical Site Setting

The site is located c. 3.5km northeast of Naas and approximately 0.5km northwest of the N7 and Johnstown village as shown in Figure 1. To the northeast is parkland associated with Kerdiffstown House, to the north is a golf course and to the south west and south east are a mixture of land uses including residential, agriculture and worked out quarries.

The L2005 County Road from Sallins to Johnstown runs adjacent to the western and southern site boundaries, with the nearest residential property approximately 10m from the site boundary, with the boundary being interpreted as the former redline boundary for waste licence W0047-02.

It should be noted that the redline boundary as shown on all figures in this report is the boundary of the waste facility authorised by, and as specified in, waste license number W0047-02 granted to 'Neiphin Trading Limited'. This redline boundary is used for illustrative purposes only in this report to show the location and approximate outline of the former waste facility and does not imply any legal ownership boundaries or any limitation on the area within which any action is being or can be taken by the KCC under Section 56 of the Waste Management Act 1996 (as amended).

The closest surface water body to the site is the Morell River, which flows generally northwards within 50 m of the north-eastern site boundary to flow into the River Liffey. The River Liffey itself lies approximately 3km north-west of the site at its closest point, also flowing generally northwards, before following a more eastward flow direction some 5 to 6 km north of the landfill site. There is a major public water supply abstraction from the River Liffey at Leixlip, which serves Fingal, Kildare and north Dublin, located approximately 15 km north-east of the landfill site.

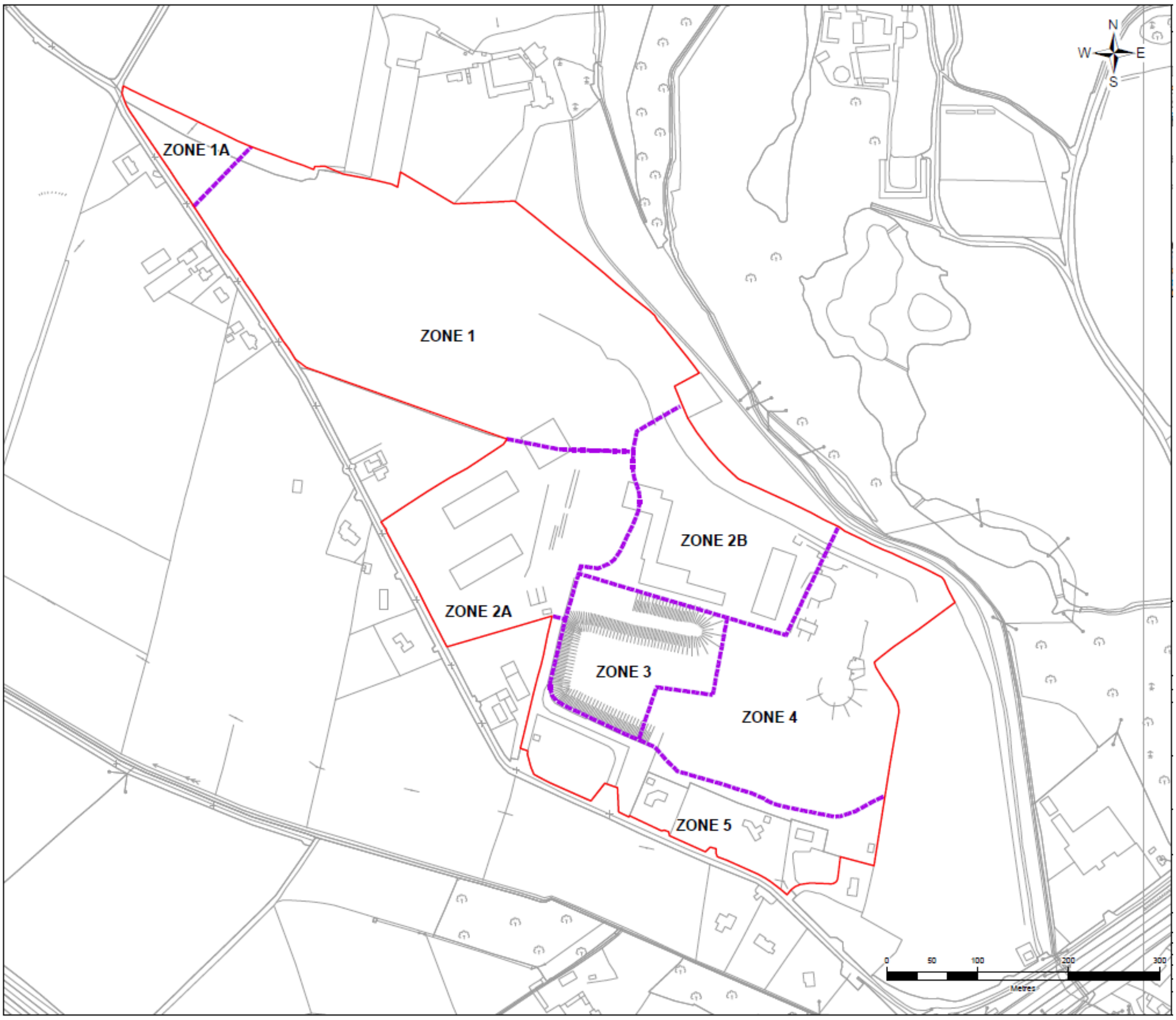
The canal feeder is an engineered feature that collects surface water run-off from lands generally to the south and south-west of the site. The canal feeder flows generally westward to the Grand Canal, which is located approximately 2 km west of the site.

1.2.2 Current Site Layout

The current site layout is attached in Figure 2. Plate 1 below which also shows the site sub-divided into a number of discrete geographical areas, or zones, each of which has their own unique characteristics. The layout of the various zones as shown below with information on the key characteristics of the materials within the zones summarised in the following table.

[8] Groundwater and Surface Water Monitoring Reports at Kerdiffstown Landfill October 2013 to December 2016.

Plate 1: Site Layout



Key Characteristics of the Landfill Zones

Zone	Zone Key Characteristics
1	Wastes deposited in the north-west area of the site which account for approximately 65% of the entire estimated volume of waste on site. The wastes in this area are typically unprocessed, highly odorous and principally comprise non-hazardous mixed construction and demolition (C & D) wastes and household wastes. C & D wastes noted to contain varying amounts of clay, gravel, concrete, brick, wood, textile, plastic, rubber and metal. Wastes in this area of the site are uncapped and unlined and localised areas of free leachate are likely to be present within the wastes. In the south and east of this zone, wastes are present beneath the groundwater table.
1A	Sub-zone of Zone 1 where waste appears to be absent.
2A	Much of this zone in the west-central portion of the site is covered by thick, reinforced concrete pads, which form a low permeability layer over the wastes and reduce direct rainwater ingress. Wastes noted to be domestic waste mixed in with C & D materials with varying amounts of clay, gravel, brick, concrete, wood, textile, paper, plastic, rubber and metal. . The smaller area of wastes not covered by concrete allows rainwater to infiltrate in a similar manner to Zone 1.
2B	Much of this zone in the east-central portion of the site is covered by thick, reinforced concrete pads, which form a low permeability layer over the wastes and reduce direct rainwater ingress. Wastes noted to be principally unprocessed non-hazardous mixed C & D waste with varying amounts of clay, gravel, brick, concrete, wood, textile, paper, plastic, rubber and metal. The smaller area of wastes not covered by concrete allows rainwater to infiltrate in a similar manner to Zone 1. Below much of this zone some wastes are present beneath the groundwater table.
3	This area is lined (the 'lined cell') with processed waste materials filling 60% of the existing void space. Wastes in this area comprise processed non-hazardous C & D materials with domestic waste mixed through. C & D wastes contain varying amounts of clay, gravel, concrete, brick, wood, textile, plastic, rubber and metal. The leachate generated within the lined cell is contained and removed for off-site treatment/disposal. There will be a long term requirement for removal and treatment of leachate from the lined cell.
4	Containing redundant infrastructure and concrete tanks/bays/walls in the lower yard area. The area also contains a surface water soakaway lagoon which is cut into waste deposits and into which water from the adjacent waste stockpiles drains. The bottom 1 to 2m of a small amount of the wastes is below the water table in this area.
5	No significant waste deposits are present in this area. This area also has a number of residential properties located on it which are within the site red line boundary.

1.2.3 Groundwater Monitoring Network

Following vacation of the site in 2010, the EPA has commissioned a number of site investigations to establish groundwater conditions as summarised in the Table 1.1 with the locations of installed monitoring wells shown in Figure 3.

Investigations involved installation of approximately 90 groundwater monitoring wells on and off site to collect data to define the hydrogeological site setting and provide groundwater monitoring points. Subsequent rounds of groundwater monitoring have been undertaken to establish the chemical quality of the groundwater with the most recent round prior to this report being undertaken by Jacobs in November 2016. Further details of the groundwater quality monitoring are provided in Chapter 2 of this report.

Table 1.1: Summary of Groundwater Site Investigations

	Dates of Site Investigation	No. of boreholes drilled	No. of monitoring wells installed	On / off site	Monitoring Well Numbers
EPA SI	10/05/10 to 12/05/10	10	9	Off site	EMW01* to EMW10
EPA SI	06/06/11 to 19/06/11	7	7	On site	EMW11 to EMW17
Phase 1 SI	09/01/12 to 06/02/12	24	4	On site	BH2, BH6, BH7, BH24
Phase 2 SI	14/08/12 to 21/09/12	61	21 (17 GW, 1 leachate (now dry), 2 Inclinometer, 1 Gas)	On and off site	BH26, BH36B, BH39B, BH40B, BH42, BH48, EMW18 to EMW24, BHEMW27 to EMW33.
Phase 3 SI	October 2016 (ongoing)	45	45	On and off site	RM01 to RM06, BB01 to BB04, DB01 to DB15 (excluding DB13), BH60 to BH80.
Former abstraction wells	Not relevant	2	2	On site	GW1D, GW2D

* EMW01 was backfilled due to health and safety concerns.

Figure 3 also shows a series of surface water monitoring locations, including the locations along the Morell River and the Canal Feeder where samples were collected during the December 2016 monitoring events.

1.3 Geological and Hydrogeological Conditions

1.3.1 Bedrock Geology

The majority of the site is underlain by bedrock in the Ballysteen Formation which is described as dark muddy limestone/shale. However, the far northwest corner of the site is underlain by the Waulsortian Limestone, which is described as a pale grey muddy limestone. The bedrock (both the Ballysteen Formation and Waulsortian Limestone) is classified by the Geological Survey of Ireland (GSI) as being a locally important aquifer which is moderately productive only in local zones.

The GSI's vulnerability classification for the bedrock aquifer in the vicinity of the site is 'high'. However, the limestone in this formation are stated to be quite 'muddy' and not susceptible to processes which would cause an increase in permeability such as karstification. As such groundwater abstractions from the bedrock are rare and have low yields where they are present. It is known, however, that there was an abstraction well on site which is described as being 'deep' although the details of it are not known and it is uncertain if this well did abstract from the limestone.

Investigations in 2012 reached the bedrock in four monitoring wells (EMW12, EMW19, EMW22 and EMW24) but at these locations no description of the rock type is provided in the borehole log. The recently undertaken investigation in 2016 installed a further eight boreholes which reached the bedrock. Cores recovered from the bedrock showed the limestone rock to be highly fractured near the surface with clay infilling some of the fractures. It is this upper fracture zone which will provide the principal pathways for groundwater movement in the bedrock.

The depth to bedrock has been recorded in the borehole logs as being between 6.7 and 26.8 m below ground level (mbgl).

1.3.2 Overburden Geology and Hydrogeology

On a regional scale the site is indicated to be in an area of glacio-fluvial sands and gravels which extend over an area of 2 km^2. However, the GSI overburden aquifer designation map does not show this deposit to be a recognised aquifer in the vicinity of the site.

In September 2010, Apex Geoservices provided a report which interpreted the geological data that was available at that time. They concluded that:

- To the west, northwest and south of the landfill, the upper 1.6 m comprised silt and clay type material overlying an average of 18.8 m of sand and gravel;
- To the east and northeast of the landfill the upper 1.5 m comprised dominantly alluvium, silt and clay overlying an average of 7.4m of silt/clay and sandy gravelly silt/clay overlying bedrock; and
- East and southeast of the landfill the rock levels generally range from 75 to 78mAOD. South and west of the landfill the rock levels generally range from 71 to 75mAOD.

Based on the information gained in previous site investigations, a greater thickness of glacial sands and gravels are found directly to the west, northwest and south of the landfill with a thickness in the region of 20 to 24m. In general, this glacial overburden is characterised by an initial, more silty, clayey sand and gravel horizon approximately 3m thick underlain by gravelly sands approximately 10m thick and then sandy gravels around 7m thick. To the east and northeast of the landfill the thickness of the sands and gravels decreases and in the Morell River valley, clayey alluvium is also present although the borehole logs do show that frequent sandy lenses are present in the clay-dominated alluvium.

Furthermore, it was noted that in monitoring wells located to the north-eastern site boundary within the grounds of Kerdiffstown House, significantly deeper superficial deposits were found and it appears that there is a buried channel in the bedrock surface.

The recently undertaken investigation in 2016 involved the drilling of over fifty boreholes at the site, with collection of data on the overburden geology. At the time of writing this report, the data from the boreholes are still being assessed, but will be considered in further assessments of groundwater and contaminant movement.

1.4 Project Objectives

The primary objectives of the December 2016 monitoring event were to collect data from existing monitoring wells and to use these data to update and refine the CSM developed from past investigations and monitoring events and to use the groundwater quality data set to observe if any emerging trends are notable in groundwater quality at the site and surrounding area.

1.5 Scope of Works

1.5.1 Rationale and Strategy

The scope of work completed for the December 2016 monitoring event is presented below:

December 2016 (Biannual Specification)
Collection of groundwater samples from 14 off-site monitoring wells EMW02, EMW05, EMW08, EMW20 to EMW23 and EMW27 to EMW33.
Collection of groundwater samples from seven boundary wells EMW03, EMW04, EMW06, EMW07, EMW18, EMW19 and EMW24.
Collection of groundwater samples from 13 on-site monitoring wells, BH6, BH7, GW1D, GW2S, EMW11 to EMW13, EMW15 to EMW17, BH26, BH36B, and BH42.
Collection of surface water samples from 16 monitoring locations SW01 to SW08 and SW10 to SW16 as well as a sample from the site discharge to the canal feeder.
Analysis of the collected groundwater and surface water samples for an expanded suite of inorganic parameters including major ions and metals/metalloids as well as a broad suite of organic compounds including polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), speciated phenols and pesticides.
Associated data assessment and reporting (i.e. this report).

Monitoring wells had been sampled previously by Geosyntec consultants in June 2011, September 2011, December 2011, May 2012, October 2012 and February 2013. Jacobs has completed monthly sampling of groundwater monitoring wells since October 2013. The results obtained from these monitoring rounds as well as previous rounds were reviewed to assess possible trends in groundwater levels and groundwater quality.

1.5.2 Meteorological Conditions

Weather conditions in December during the sampling period were as follows:

- 7th: Showery, mild (7-13°C), moderate breezes
- 8th: Showery, mild (7-13°C), moderate breezes
- 9th: Dry, mild (9-14°C), moderate breezes
- 12th: Dry, cold (4-10°C), gentle breezes
- 13th: Showery, mild (9-13°C), moderate breezes
- 14th: Heavy rainfall, cold (3-13°C), gentle breezes
- 15th: Dry, cold (2-11°C), moderate breezes

Details of rainfall during the month are presented below. December is shown to have received less than two-thirds of the average rainfall for the month.

Table 1.2: December 2016 Rainfall

	Casement Rainfall (mm)	Long Term Average Rainfall (1981 -2010) (mm)	% Above / Below Average
Dec-16	49.2	75.7	65%

1.5.3 Groundwater Monitoring Wells

Inertial lift foot-valves and tubing dedicated to each groundwater monitoring well were used to purge the wells prior to sample collection. Approximately three well volumes of water were purged from each monitoring well prior to sample collection. Monitoring well head parameters were monitored during purging and the samples collected for laboratory analysis were only collected once these parameters had stabilised. In the case of two wells (BH6 and BH7) bailers were used to purge and sample the groundwater due to a malfunction with the pump; while BH42 was hand-pumped as the well casing had been damaged preventing the pump from actuating. Samples collected for metals/metalloid analysis were filtered in the field into sample bottles containing dilute nitric acid preservative.

1.5.4 Surface Water

Surface water samples were collected either directly into laboratory-supplied sample bottles or through use of an extendable pole with a stainless steel sampling container.

1.6 Laboratory Analyses

The water samples were stored in cool boxes containing frozen ice packs following collection. They were dispatched from the site to the subcontracted laboratory via over-night courier on the day of sampling or by 14:00 the following day together with completed chain-of-custody documentation.

Table A.1 provides the sampling and analysis inventory for the December 2016 monitoring round.

2. Results and Discussion of Monitoring Programme

2.1 Site Hydrogeology and Groundwater Flow

2.1.1 Groundwater Levels and Rainfall

Groundwater elevations have been used to update groundwater contour plans for the superficial overburden deposits and the underlying bedrock recorded in December 2016. For the purpose of this report Figures 4 and 5 show indicative flow directions in December 2016 for the overburden and bedrock aquifers respectively. Table A.2 provides details of the groundwater level data recorded for December 2016.

The patterns of groundwater flow identified are similar to those observed during previous sampling visits. There were decreases in groundwater levels recorded in all but six wells (EMW03, EMW12, EMW16, EMW17, GW1D and BH2) when compared to data for the November 2016 round in both overburden and bedrock monitoring wells. Decreases of between 0.01 m and 0.69 m were recorded during December, the greatest of which was measured in EMW27. EMW14 was dry for the first time since December 2015. This continues a trend of decreasing water levels seen across the majority of wells for much of 2016.

Five wells showed marginal increases in December, ranging from 0.01 m to 0.03 m. The largest increase was seen in EMW12 and EMW16 (0.03 m), with GW1D increasing by 0.02 m and both EMW17 and BH2 increasing by 0.01 m. EMW03 had no change.

Graph 2.2 shows the temporal variation in groundwater levels in selected monitoring wells sampled for this report up to and including December 2016. These monitoring wells are completed within the overburden and are located in the north-eastern and south-eastern areas of the site within the known footprint of the landfill.

Monitoring commenced in May 2011. The graphs show that there has been a gradual increase in overall water levels up to January 2013, by between approximately 0.5m and 2m. This is likely to be the result of increased rainfall during 2012 (which was a wet year relative to 2011, with 861mm recorded at Casement weather station in 2012 compared to 429mm in the previous year).

The observed fall in groundwater levels visible on the chart from January 2013 onwards are as a result of the reduction in rainfall and therefore infiltration through the spring and summer months coupled with drier antecedent conditions in advance of the 2013 October and November monitoring and sampling visits.

Between December 2013 and March 2014 above average rainfall was experienced and as would be anticipated has led to an increase in groundwater levels. In subsequent months when recharge reduced, the groundwater levels responded to relatively dry conditions (June and July 2014). Notwithstanding that August 2014 was a wet month in comparison to the monthly historical average, groundwater levels at the end of 2014 were relatively low in comparison to previous winter levels. Little change was observed between August 2015 and December 2015 besides those expected from seasonal variation.

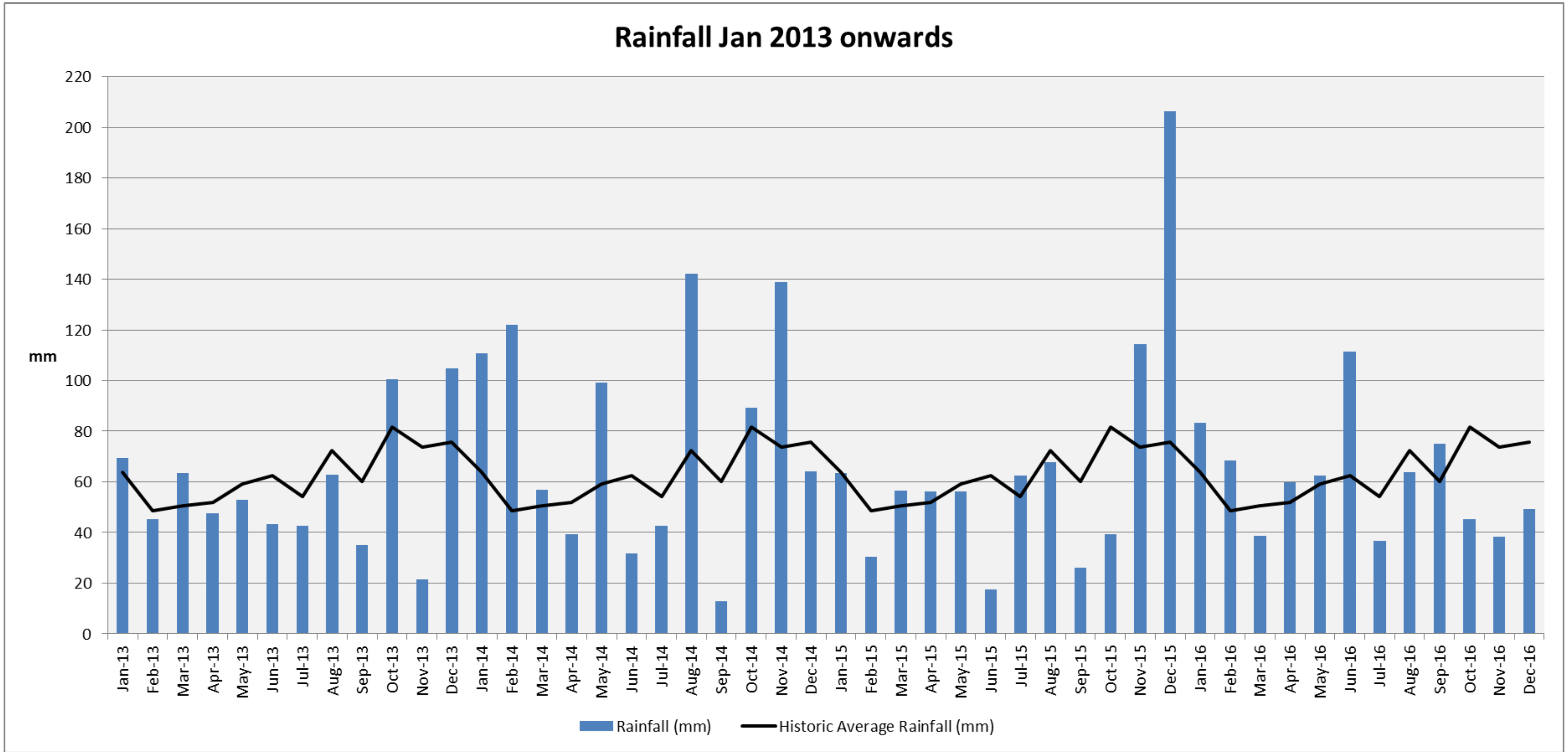
Between November 2015 and February 2016 there was a rise in water levels observed in the majority of the monitoring wells which is likely as a result of increased rainfall and groundwater recharge with above average rainfall being recorded. The levels have generally been decreasing from February to December 2016, with all but six monitoring wells showing a decrease in December compared to November 2016. This is due to the fact that rainfall reduced dramatically in March 2016 following four consecutive months of above average rainfall with April and May 2016 rainfall amounts being close to the long term average. Groundwater recharge (i.e. that rainwater which reaches the groundwater table) during the summer months usually falls to zero and the drop off in rainwater infiltration has caused decreases in water levels in the majority of monitoring wells. All but September 2016 had lower than average rainfall amounts in the second half of 2016.

Monthly rainfall data are shown in Table 2.1 and Graph 2.1.

Table 2.1: Historical Rainfall Comparison

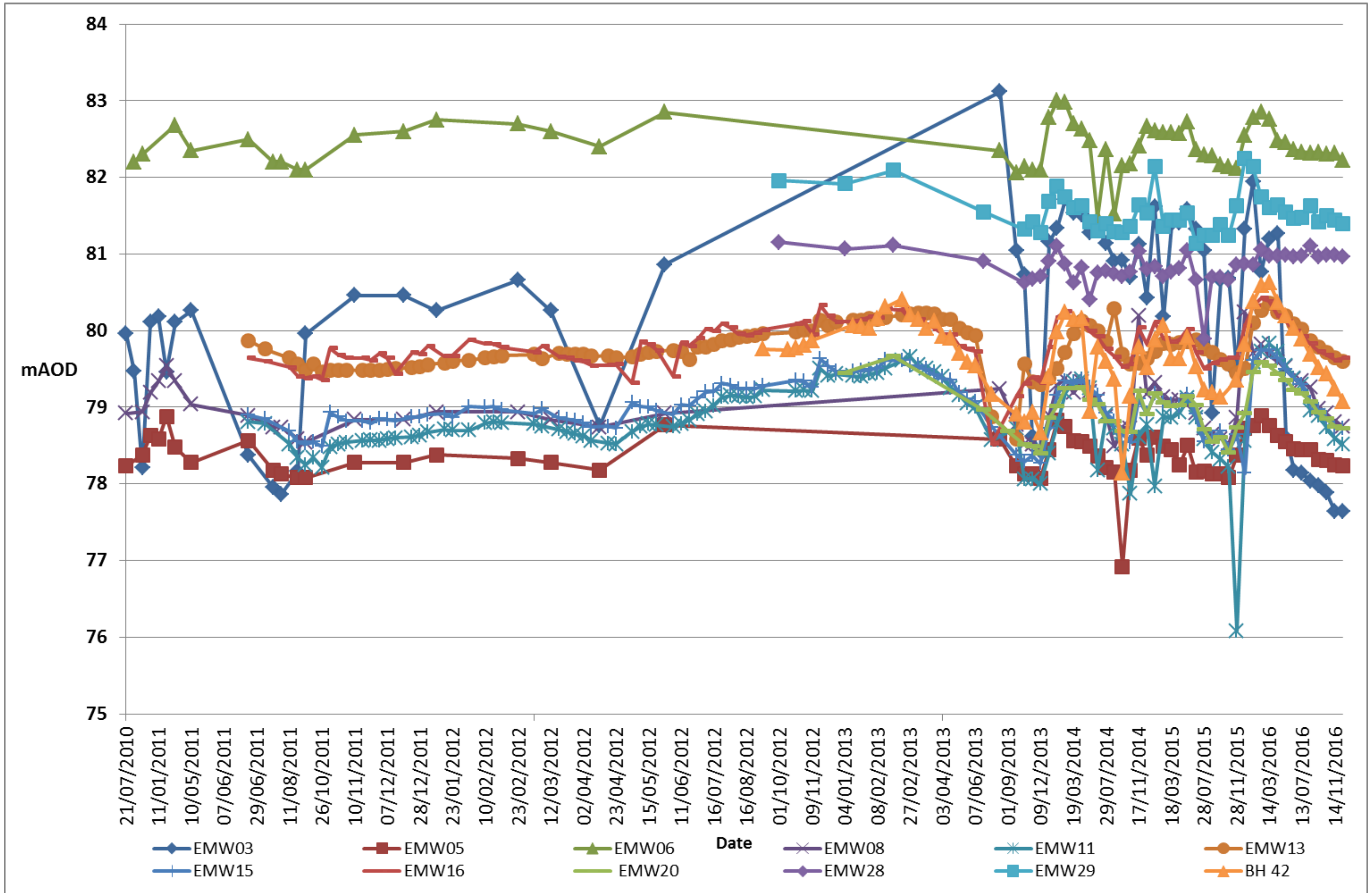
	Casement Rainfall (mm)	Long Term Average (mm) (1981 – 2010)	% of Average		Casement Rainfall (mm)	Long Term Average (mm) (1981 – 2010)	% of Average
Jan-13	69.5	63.8	109%	**Jan-15**	63.4	63.8	99%
Feb-13	45.2	48.5	93%	**Feb-15**	30.5	48.5	63%
Mar-13	63.3	50.7	125%	**Mar-15**	56.4	50.7	111%
Apr-13	47.5	51.9	92%	**Apr-15**	56.4	51.9	109%
May-13	52.8	59.1	89%	**May-15**	56.2	59.1	95%
Jun-13	43.2	62.5	69%	**Jun-15**	17.4	62.5	28%
Jul-13	42.7	54.2	79%	**Jul-15**	62.4	54.2	115%
Aug-13	62.9	72.3	87%	**Aug-15**	67.7	72.3	94%
Sep-13	35.1	60.3	58%	**Sep-15**	26.2	60.3	43%
Oct-13	100.4	81.6	123%	**Oct-15**	39.4	81.6	48%
Nov-13	21.6	73.7	29%	**Nov-15**	114.3	73.7	155%
Dec-13	104.7	75.7	138%	**Dec-15**	206.3	75.7	273%
Jan-14	110.7	63.8	174%	**Jan-16**	83.2	63.8	130%
Feb-14	122	48.5	252%	**Feb-16**	68.3	48.5	141%
Mar-14	56.7	50.7	112%	**Mar-16**	38.7	50.7	76%
Apr-14	39.3	51.9	76%	**Apr-16**	59.7	51.9	115%
May-14	99.1	59.1	168%	**May-16**	62.6	59.1	106%
Jun-14	31.7	62.5	51%	**Jun-16**	111.4	62.5	178%
Jul-14	42.6	54.2	79%	**Jul-16**	36.6	54.2	68%
Aug-14	142.2	72.3	197%	**Aug-16**	63.8	72.3	88%
Sep-14	12.8	60.3	21%	**Sep-16**	74.9	60.3	124%
Oct-14	89.1	81.6	109%	**Oct-16**	45.4	81.6	56%
Nov-14	138.9	73.7	188%	**Nov-16**	38.2	73.7	52%
Dec-14	64.9	75.7	86%	**Dec-16**	49.2	75.7	65%

Graph 2.1: Rainfall since January 2013 compared to the historical average



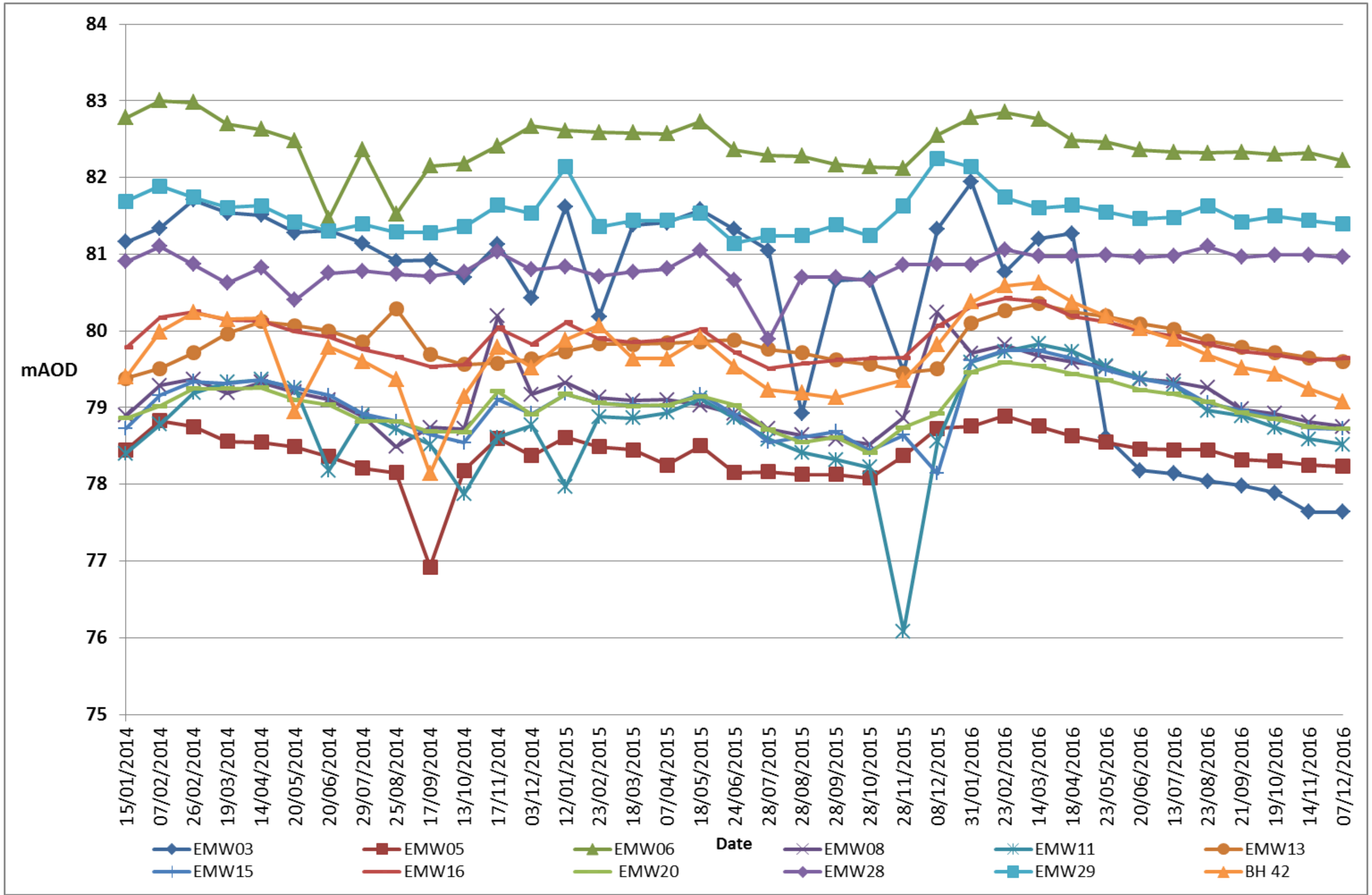
JACOBS

Graph 2.2a: Variations in Water Levels 2011 – Present (Monthly Overburden Wells)



Kildare County Council
Comhairle Contae Chill Dara

Graph 2.2b: Variations in Water Levels 2014 – Present (Monthly Overburden Wells)



With respect to groundwater levels recorded in overburden deposits during December 2016 relative to Ordnance Datum, these are shown in Figure 4. The pattern of groundwater contours indicate that in broad terms the water levels are similar to those observed in November 2016.

The groundwater levels in the overburden deposits show a similar pattern to those observed previously with a general fall from south to north indicating a broadly northerly flow. As with previous assessments the data also show a complex pattern of radial flow with an area of high groundwater levels across the northern area of the landfill (Zone 1) with the highest water level in this area being recorded in borehole EMW06 at 82.22 mAOD (albeit this appears to be monitoring a perched aquifer). The lowest groundwater level in the Zone 1 part of the site in December 2016 has been recorded in EMW03 at 77.64 mAOD and Figure 4 shows that this water level is a notable low point. This borehole has recorded the lowest groundwater level for the last seven months having previously shown fluctuations month-on-month.

A weir on the Morrell River adjacent to the site has an elevation of 79.79 mAOD indicating that groundwater to the east is likely to be in hydraulic connection with the river based upon the level and pattern of observed groundwater contours. EMW05 is closest in proximity to the Morrell River and in December 2016 EMW05 had a groundwater level of 78.23 mAOD.

To the south of the site, recorded groundwater levels in December 2016 were in the region of around 79 to 80 mAOD (BH2 does record a higher level (84.74 mAOD) although this is likely to be a perched water level). Previous spot measurement of the water level in the canal feeder drain has shown this feature to be at an elevation of around 80.6 mAOD adjacent to the site (monitoring point SW10). This suggests as previously that the canal feeder may be in hydraulic connection with groundwater, although the observed general groundwater flow direction (i.e. south to north) indicates that there is likely to be little groundwater input to this stream from the vicinity of the site. A very flat hydraulic gradient is observed in the south-east of the site in Zone 4.

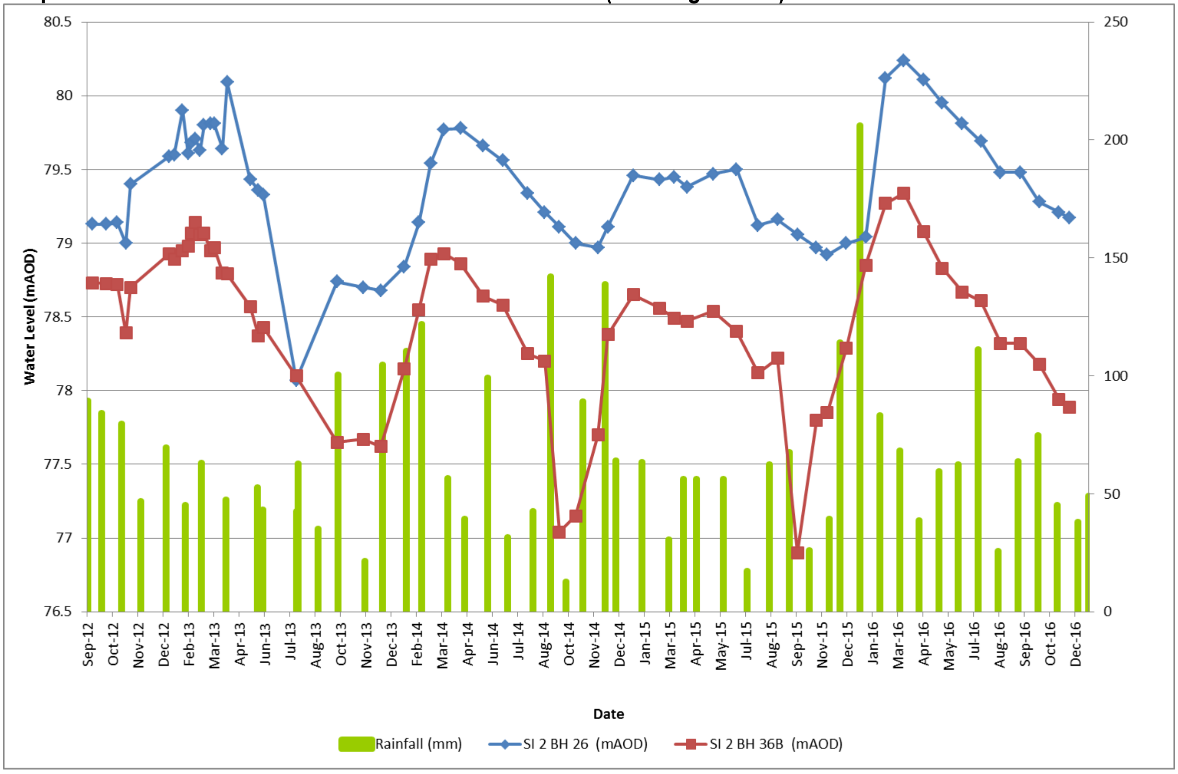
There are five monitoring wells in the bedrock aquifer from which water levels were obtained during the December 2016 sampling round (EMW12, EMW19, EMW22, EMW24 and GW1D). The pattern of inferred contours is shown in Figure 5 and as with previous monitoring rounds shows a generally south to north flow. Water levels measured in the bedrock in December 2016 had fallen slightly in all but two wells (EMW12 and GW1D) when compared to those measured in November 2016 with a drop of between 0.01 m and 0.05 m recorded. A slight increase of 0.03m was recorded in EMW12 and 0.02m in GW1D.

Comparison of measured water levels between the overburden and bedrock aquifers for December 2016 indicates higher water levels within the overburden across the site. This is consistent with previous observations and provides a mechanism for potential downward flow of groundwater (and potential contamination) from the wastes in the landfill into the bedrock aquifer.

With respect to groundwater levels and the base of the waste in Zone 1 (the unlined landfill), the data show that over much of the zone, the waste was above the groundwater level in December 2016. However, in a area in the north-east of Zone 1 (and parts of Zone 2B) as defined by the 80 mAOD contour on Figure 4, the waste is estimated to be at, or slightly deeper than 80 mAOD which would suggest that the wastes in these areas are below the groundwater table.

Graph 2.3 shows the groundwater levels recorded in BH26 and BH36B, situated in the north-eastern part of the site (Zone 1) since their installation in August 2012. It can be seen that the groundwater levels in December 2016 in both wells have continued to reduce since the highest levels recorded in March 2016. The above average rainfall from November 2015 to February 2016 (including almost three times the average in December 2015) is likely to have caused those high groundwater levels. The below average rainfall for the second half of 2016 has continued the downward trend in levels since March 2016.

Graph 2.3: Variations in Water Levels in BH26 and BH36B (showing rainfall)



2.1.2 Groundwater Flux

Previous estimates of the groundwater flux from Zone 1 to the Morell River have been made ranging from 160 to 640 m^3/day with the data used in the calculations shown below.

Approximate width of groundwater flow to Morell River	500 m
Sand/Gravel aquifer thickness	2.5-5 m
Hydraulic gradient beneath north-east boundary	0.005-0.02 (unitless)
Hydraulic conductivity (median for 2012 off-site wells)	25.4 m/day
Darcy velocity (calculated)	0.13-0.51 m/day
Actual velocity (calculated) assuming 25-30% porosity	0.4-1.7 m/day
Groundwater flux estimate	160-640 m^3/day

Estimated groundwater velocity is quite high at 0.4-1.7 m/day (146-620 m/year), even using the median hydraulic conductivity value. The sand and gravel aquifer seems to have high permeability and the hydraulic gradient is inevitably steep as the topographic gradient steeply falls away from the landfill to the river valley.

The resultant groundwater flux is therefore estimated at 160-640 m3/day. The mean flow in the Morell River adjacent to the site has been measured from 2009 to 2013 at 66,500 m3/day. Therefore, based on these data there is a dilution factor for any groundwater contaminants discharging to the river of between 415 and 104.

2.2 Groundwater Results

The following sections describe and relate observed groundwater parameters measured in the field and reported by the laboratory. The nature, magnitude and extent of contaminants of primary concern are discussed. Trend graphs are provided for key indicator parameters and the trends observed in each of the zones are discussed. The below section should be read in conjunction with Figure 3 Groundwater and Surface Water Monitoring Locations.

2.2.1 Field Measured Groundwater Parameters

Field-measured parameters comprising pH, dissolved oxygen, electrical conductivity (EC), temperature and redox potential, were recorded during purging and sample collection.

The measurements are presented in appended Table A.2 and summarised below.

Table 2.2: December 2016 Field Results

Parameter	Unit	Range	Location of min/max results	IGV
pH	-	6.6 to 8.5	EMW16, BH26 / GW2S	6.5-9.5
Dissolved Oxygen (DO)	mg/l	0.1 to 9.3	EMW19, EMW22, GW2S / EMW30	No abnormal change
Electrical conductivity (EC)	µS/cm	267 to 3515	GW2S / BH26	1,000
Redox potential (Eh)	mV	-148 to +302	GW2S/ EMW21	-
Temperature (T)	°C	9.5 to 28.2	BH6 / BH26	25

IGV –Interim Guideline Values

The following general observations are made in relation to the field-measured parameters. In common with earlier monitoring rounds, EC readings were generally above the IGV of 1,000 µS/cm in on-site monitoring wells and some boundary wells. In off-site monitoring wells the majority of readings were below the IGV.

Graph 2.4 shows the variation in EC readings for overburden monitoring wells that are monitored monthly. These include on-site locations in Zone 1 and near to the north-eastern site boundary. It can be seen that there are some seasonal variations in EC values, which is most pronounced in EMW03, EMW11, EMW13 and EMW15.

Electrical conductivity for the overburden monitoring wells were all within the range previously recorded for all overburden wells of 456 to 4581 µS/cm. As previously, BH26 recorded the highest EC value at 3,515 µS/cm which is a slight increase on November.

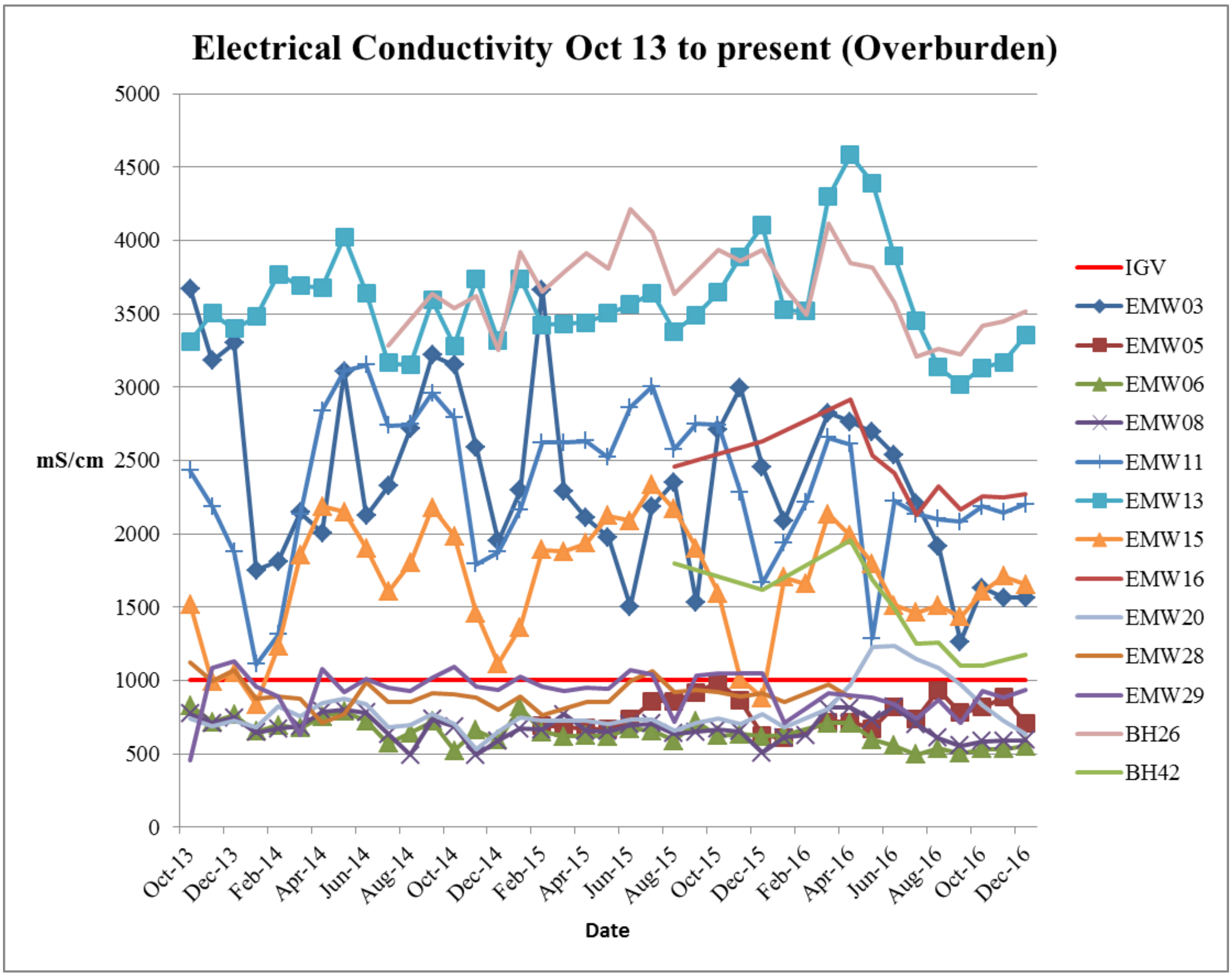
Some of the eastern and north-eastern boundary wells readings were above the IGV in some instances. The highest of these was recorded in boundary monitoring well EMW03 (1564 µS/cm in December 2016, almost identical to November's 1563 µS/cm). This monitoring well is very close to the north-east boundary of the landfill and the result is consistent with previous readings from earlier monitoring rounds (range from 1262 µS/cm to 3671 µS/cm). Similarly, boundary wells EMW04 (1408 µS/cm) and EMW07 (1162 µS/cm) had readings above the IGV. None of the 14 off-site wells had electrical conductivities above 1000 µS/cm.

The EMW04 result (1,408 µS/cm in December 2016) is down from the June 2016 result of 1995 µS/cm. The EMW07 reading is also down from 1576 µS/cm in June 2016 to 1162 µS/cm in December. The EMW20 readings have continued to fall, with the December 2016 reading of 632 µS/cm representing a return to the values seen prior to the elevated readings recorded between April and October 2016.

Graph 2.5 shows the EC values for samples from the bedrock. The value for the sample from EMW19D has decreased from November with the December 2016 reading of 952 µS/cm being the first time it has been below 1000 µS/cm since March 2016. The electrical conductivity measured at EMW12D has risen in December to

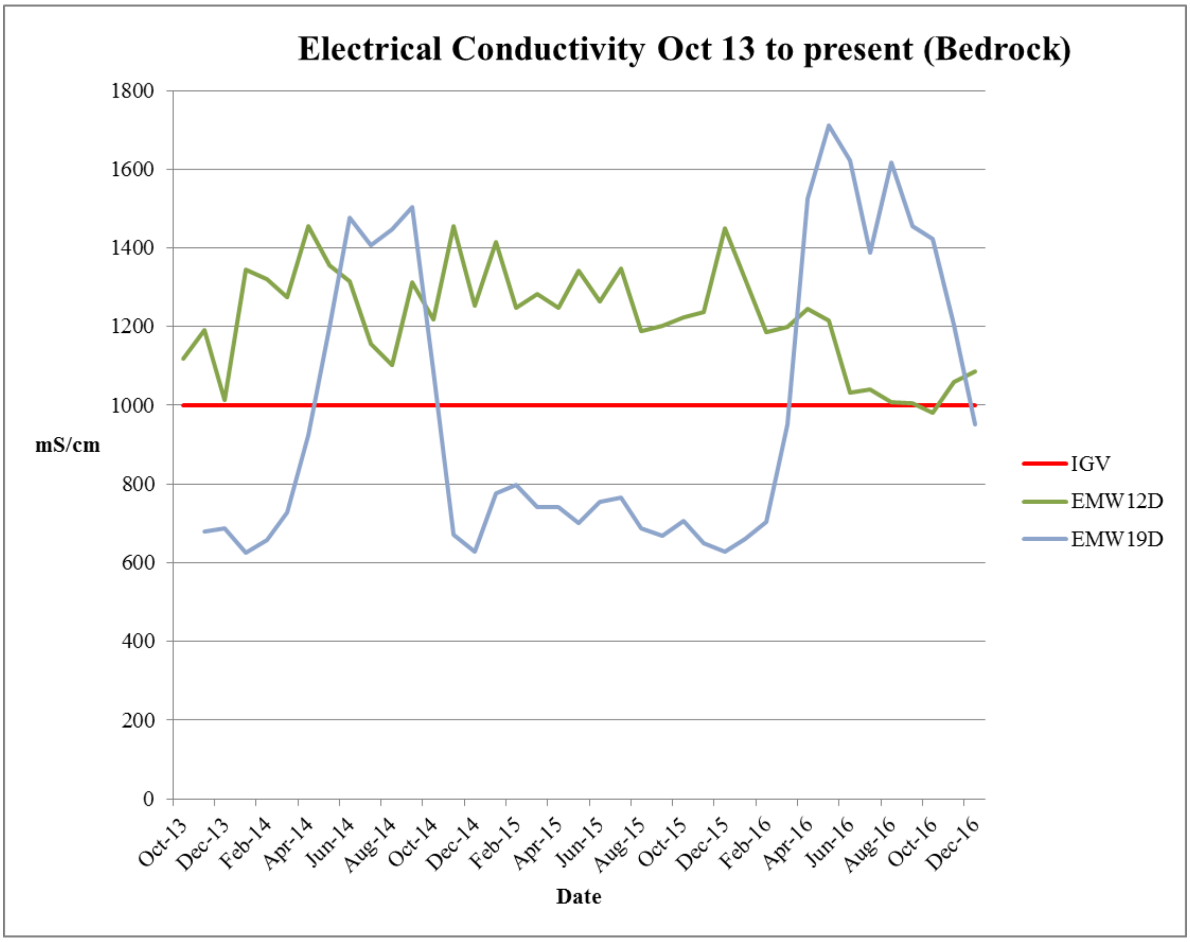
1085 µS/cm following the drop in October below the IGV to 982 µS/cm for the first time since monitoring began.

Graph 2.4: Overburden Electrical Conductivity Variations (Oct 2013 to present)



Note: Axes values are different between Graph 2.4 and 2.5

Graph 2.5: Bedrock Electrical Conductivity Variations (Oct 2013 to present)



Note: Axes values are different between Graph 2.4 and 2.5.

Groundwater redox potential was found to be significantly negative (reducing) in monitoring wells situated within Zone 1 of the site and also within monitoring wells close to the north-east and east of the site (e.g. EMW07, EMW15, EMW18). The on-site well EMW13 recorded a positive redox potential in June 2016. In December 2016 a negative redox potential was recorded which aligns with previous negative trends. Relatively low redox potential was also recorded in a number of overburden monitoring wells to the northeast of the landfill (e.g. boundary well EMW19, and off-site well EMW20). There were also negative redox potentials recorded in the wells located on Palmerstown Golf Course, namely EMW31 (-102.9 mV), EMW32 (-20.9 mV) and EMW33 (-96.7 mV). This aligns with previous results in these wells. Only occasional slight reducing-type odours were noted in monitoring wells where negative redox conditions were observed.

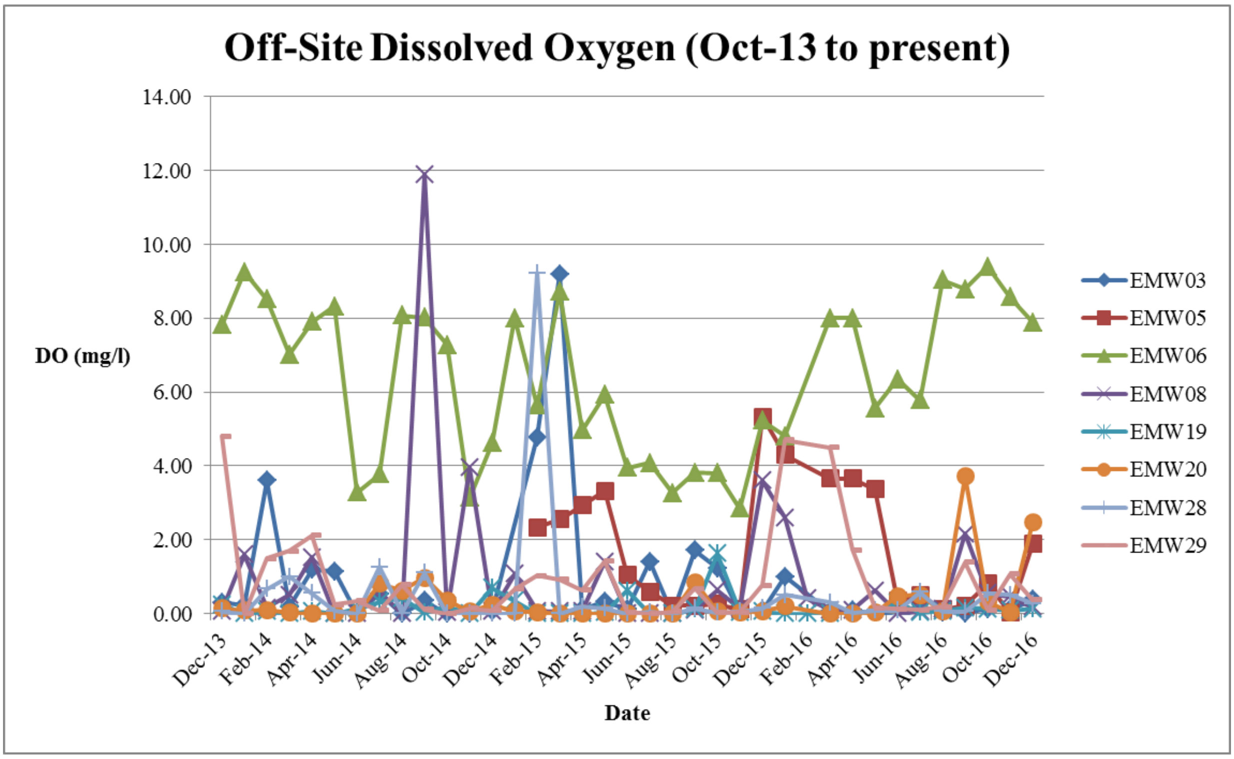
Dissolved oxygen (DO) readings show generally consistent concentrations month on month as shown in Graphs 2.6 and 2.7. The highest DO reading off-site was in EMW30 in a field to the south-east of the site, outside the site boundary (9.3 mg/l). This is almost identical to the concentration recorded in June 2016 (9.4 mg/l). As is typically the case, the highest DO reading of the boundary wells was EMW06 (7.9 mg/l). Many of the other off-site boreholes measured generally low DO concentrations (<3 mg/l) with the exception of EMW02 (3.3 mg/l), EMW04 (3.2 mg/l), EMW21 (6.9 mg/l) and EMW24 (5.9 mg/l). DO is generally low (<2mg/l) in off-site and boundary monitoring wells apart from EMW06 which has consistently had a higher DO.

In EMW05, adjacent to the Morell River, the DO has increased on November from 0.02 mg/l to 1.9 mg/l, after decreasing significantly between May and June 2016 (from 3.37 mg/l to 0.3 mg/l). This is likely a seasonal variation in this well, with higher DO in winter months than summer months.

On site, BH7 shows the highest concentration of DO (7.3 mg/l), a small increase on the previous biannual month of June 2016 (4.3 mg/l). EMW11 decreased slightly from 5.6 mg/l in November to 5.4 mg/l in December. Similarly EMW12 decreased slightly from 6.3 mg/l in November to 6.2 mg/l in December 2016. The remainder of the on-site wells show low DO concentrations, with all being below 2 mg/l, apart from wells BH6 (5.2 mg/l) and GW1D (6.5 mg/l).

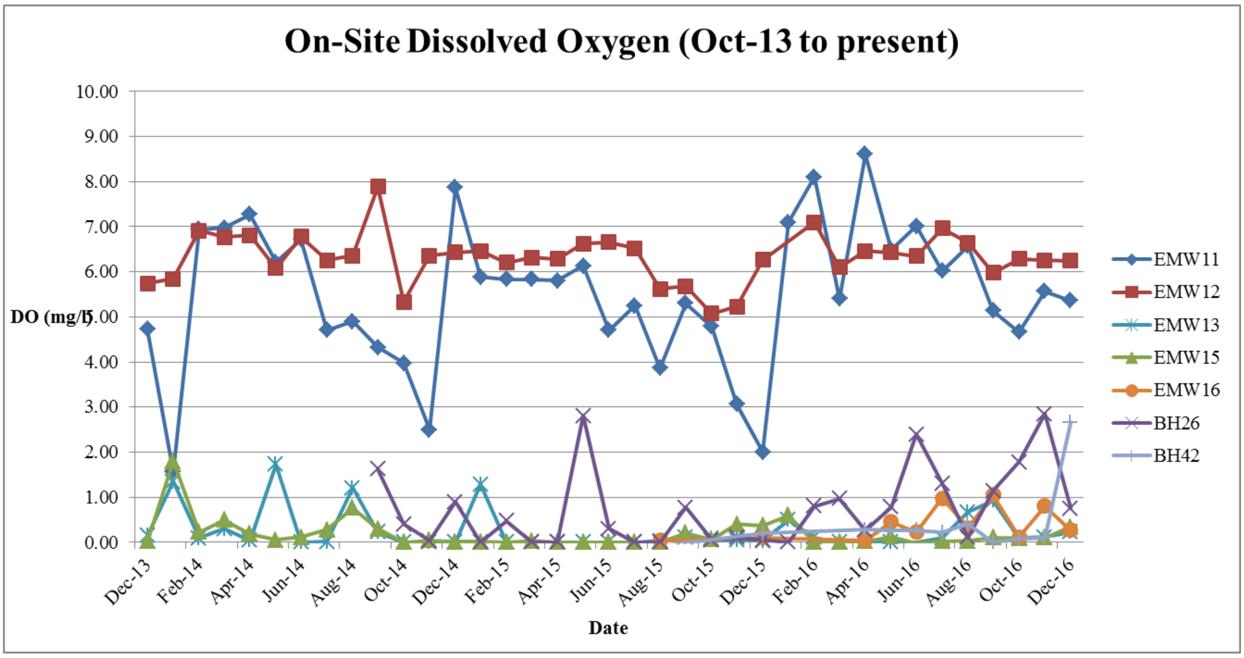
BH42 had a marked increase in DO from 0.1 in November to 2.7 mg/l in December. This is the highest DO recorded at this well. This is likely to be an inaccurate reading as the sampling method was changed during the December monitoring as the casing of the well was found to be damaged meaning that the pump could not be used and pumping through the low flow cell during purging was not possible. Instead, the well was hand pumped, with a number of grab samples taken during purging.

Graph 2.6: Field Recorded Dissolved Oxygen Readings – Off-Site



Note: Axes values are different between Graph 2.6 and 2.7

Graph 2.7: Field Recorded Dissolved Oxygen Readings – On-Site



Note: Axes values are different between Graph 2.6 and 2.7.

Groundwater temperatures in on and off-site monitoring wells were within the range of those recorded during previous sampling rounds. EMW13 (17.4°C in December 2016) has been noted as having a consistently high temperature previously. During sampling rounds completed since October 2013 high temperatures have also recorded in BH26 (28.2°C in December 2016) as well as BH36B (25.5°C in December 2016). These temperatures noted within Zone 1 are thought to be as a result of the microbial activity within the decomposing waste mass. The consistently elevated temperatures seen in EMW13 are likely being heated by groundwater flow from beneath the waste mass in the direction of EMW13.

pH displayed little variability when compared to previous sampling events recorded since October 2013.

2.2.2 Laboratory Analytical Results – Groundwater

During December 2016 samples were analysed for an expanded suite of determinands as outlined in Table A.1, including major ions, inorganic compounds and trace metals as key indicators of potential leachate impact at the site. The samples were also analysed for a broad range of organic compounds including VOCs, SVOCs, PAHs, phenols, formaldehyde, acid herbicides and organo-chlorine pesticides.

Summaries of the analytical results are presented in Tables A.3, A.5, A.6 and A.6a. For the organic compounds, only those compounds detected in at least one monitoring well are listed in the relevant table.

A summary of the December 2016 results is presented below. The laboratory reports containing the complete set of analytical data for the monitoring round are included in Appendix B.

In order to ensure consistency with previous monitoring rounds and in order to follow current best practice, analysis results for individual determinands have been screened against EPA Interim Guideline Values (IGVs)[9] and Groundwater Threshold Values (GTVs)[10] where they currently exist.

9 Environmental Protection Agency. Towards Setting Guideline Values for the Protection of Groundwater in Ireland. Interim Report.

10 Methodology for Establishing Groundwater Threshold Values and the Assessment of Chemical and Quantitative Status of Groundwater, Including an Assessment of Pollution Trends and Trend Reversal, EPA, 2010.

2.2.2.1 Ammoniacal Nitrogen, Major Ions, Alkalinity, COD and Chloride

Recovered groundwater samples have all been analysed for the following: ammoniacal nitrogen (as an indicator of ammonia presence), major ions, alkalinity, iron and manganese, TOC, BOD and COD. These determinands are often found to be elevated in groundwater which has mixed with landfill leachate and are therefore good indicators of potential leachate impact. Table A.3 includes major ion and ammoniacal nitrogen results. TOC, BOD and COD results are included in Table A.5. Trend graphs are provided for each of the determinands split between the overburden and bedrock monitoring wells (also refer to Figures 3, 7 and 8).

Ammoniacal Nitrogen

At sites such as Kerdiffstown where there is a history of disposal of municipal and commercial waste streams, ammoniacal nitrogen can typically be present at relatively high concentrations within leachate[11]. Important groundwater nitrogen species include ammoniacal nitrogen (linked to ammonia and ammonium from landfill leachate), nitrate (NO3) and nitrite (NO2). The latter is a transitional species and is usually present at relatively trace concentrations (as has been the case at Kerdiffstown). The IGV for ammoniacal nitrogen is set at 0.12 mg/l.

Graphs 2.8 and 2.9 show the variation in ammoniacal nitrogen concentrations for a select number of overburden and bedrock wells. Figure 7 and Figure 8 provide a graphical interpretation of the ammoniacal nitrogen distribution across the site.

On-Site Wells

Graph 2.8 shows that EMW13, in Zone 1, consistently contains the highest ammoniacal nitrogen concentrations of all monthly wells. In December 2016 the concentration was 165 mg/l, identical to the November 2016 concentration.

BH26, also in Zone 1, consistently shows elevated concentrations of ammoniacal nitrogen well above the IGV of 0.12 mg/l. During December 2016 the result from BH26 was recorded as 129 mg/l, almost identical to the previous month's concentration of 130 mg/l. The concentrations in BH26 have steadily increased since monitoring began in October 2012 (29.7 mg/l) until June 2015 (142 mg/l). The concentrations were then seen to gradually decrease until April 2016 (100 mg/l), after which ammoniacal nitrogen concentrations were noted to increase gradually, possibly indicating a seasonal fluctuation.

As with EMW13 and BH26, there was no change in ammoniacal nitrogen concentration in EMW15 during December 2016, maintaining a concentration of 14.4 mg/l. Ammoniacal nitrogen concentrations in EMW15 have remained relatively steady since January 2016, with very little change month on month through the whole of 2016. Ammoniacal nitrogen has been similarly stable since June 2016 in nearby well EMW16. In December it decreased slightly from 6.08 mg/l in November to 5.18 mg/l in December. As with EMW15 and EMW16, BH42 has also remained relatively stable, with little change in concentration since April 2016. In December 2016 the ammoniacal nitrogen concentration here was detected at 3.42 mg/l, a slight increase on November's 3.08 mg/l.

EMW11 and EMW12 have continued to record concentrations below the limit of detection (0.06 mg/l), while wells BH6 and GW1D also had concentrations below the limit of detection, with this representing a large decrease for BH6 from a high of 6.06 mg/l during the previous round in June 2016.

Of the rest of the monitoring wells, the highest concentration was recorded in EMW17 at 1.39 mg/l. This represents a decrease on the June 2016 concentration of 3.81 mg/l, the highest ever recorded in this well. The rest of the ammoniacal nitrogen concentrations in the south and west of the site were less than 1mg/l. BH36 in Zone 1, at 1.65 mg/l in December 2016, continued to contain a higher concentration than previously seen in this well. Between October 2012 and December 2015 there was little change in the ammoniacal nitrogen concentration, staying between 0.23 mg/l and 0.39 mg/l. The concentration then increased in June 2016 to 1.59 mg/l. The December 2016 concentration is the highest ever recorded in this well.

11 This is evidenced by routine chemical analysis of the leachate which is currently collected and removed from the lined cell in Zone 3 of the site where ammonia is detected.

It should be noted that in the past the highest ammoniacal nitrogen concentration of the monitoring wells sampled six monthly has been in EMW14 (ranging from 110mg/l to 273mg/l) but this monitoring well could not be sampled in December 2016 as it was found to be dry.

Boundary Wells

Ammoniacal nitrogen concentrations remained elevated above the IGV at some monitoring boreholes along the north-eastern boundary area of Zone 1 (observed in previous monitoring rounds). At EMW03, the ammoniacal nitrogen concentration reduced slightly from 26.3 mg/l to 23.8 mg/l in December 2016. This represents the fifth month in a row where the concentration has fallen in this well from a peak concentration of 47mg/l in the summer of 2016. The concentration in EMW03 tends to fluctuate a great deal which may reflect seasonal fluctuations with higher concentrations generally observed when rainfall and groundwater recharge are lower.

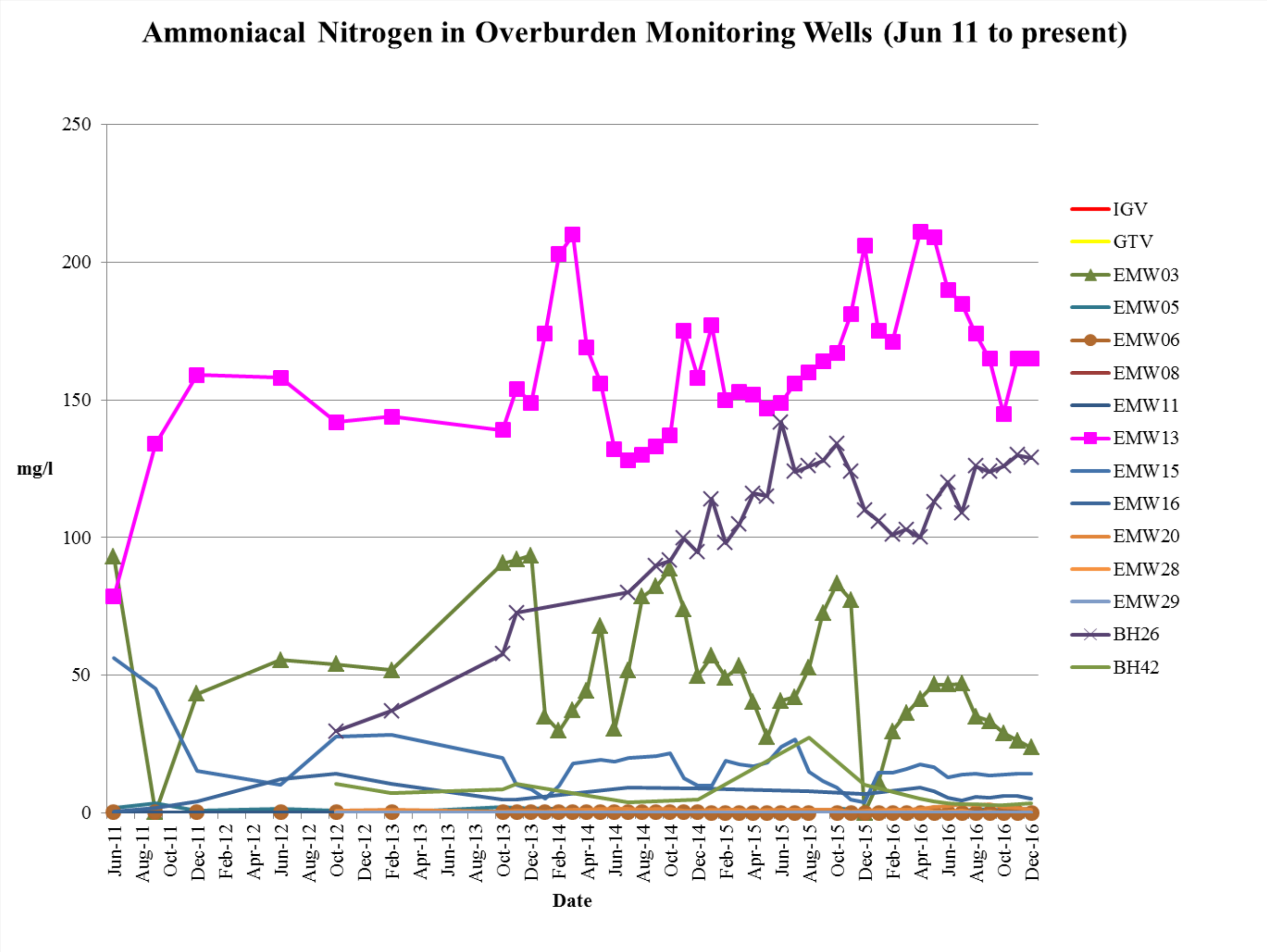
Ammoniacal nitrogen coupled with the presence of other analytes such as chloride (discussed later in this report) is indicative of the presence of landfill leachate in groundwater at EMW03 and is consistent with results obtained during earlier monitoring rounds. It is noted, however, that the ammoniacal nitrogen concentration recorded within EMW06, also located close to the north-eastern site boundary, continues to record concentrations below the detection limit (0.27 mg/l or 0.06 mg/l) since June 2011, suggesting that the off-site impact remains localised at present. However, EMW06 is relatively shallow and it is possible that the groundwater measured in this well is a perched aquifer and not representative of groundwater as a whole.

At EMW19 on the eastern boundary of the site the ammoniacal nitrogen concentration recorded during December 2016 was 3.83 mg/l, a marked decrease on November's 4.98 mg/l, and a continuation of the downward trend seen since concentrations peaked in October 2016 at 5.84 mg/l. This is still well above the IGV of 0.12 mg/l as has been consistently the case since monitoring began here. This reflects a trend recorded during the summer of 2014, where the peak concentration was 3.71 mg/l in July 2014 reducing to 1.11 mg/l by December 2014, and suggests a seasonal variation in this well.

As with nearby EMW03, there is a likely seasonal influence on ammoniacal nitrogen concentrations in EMW04, with concentrations tending to be higher in the summer and lower in the winter. This trend has continued to this round where the concentration fell from 14 mg/l in June 2016 to 0.27 mg/l in December 2016.

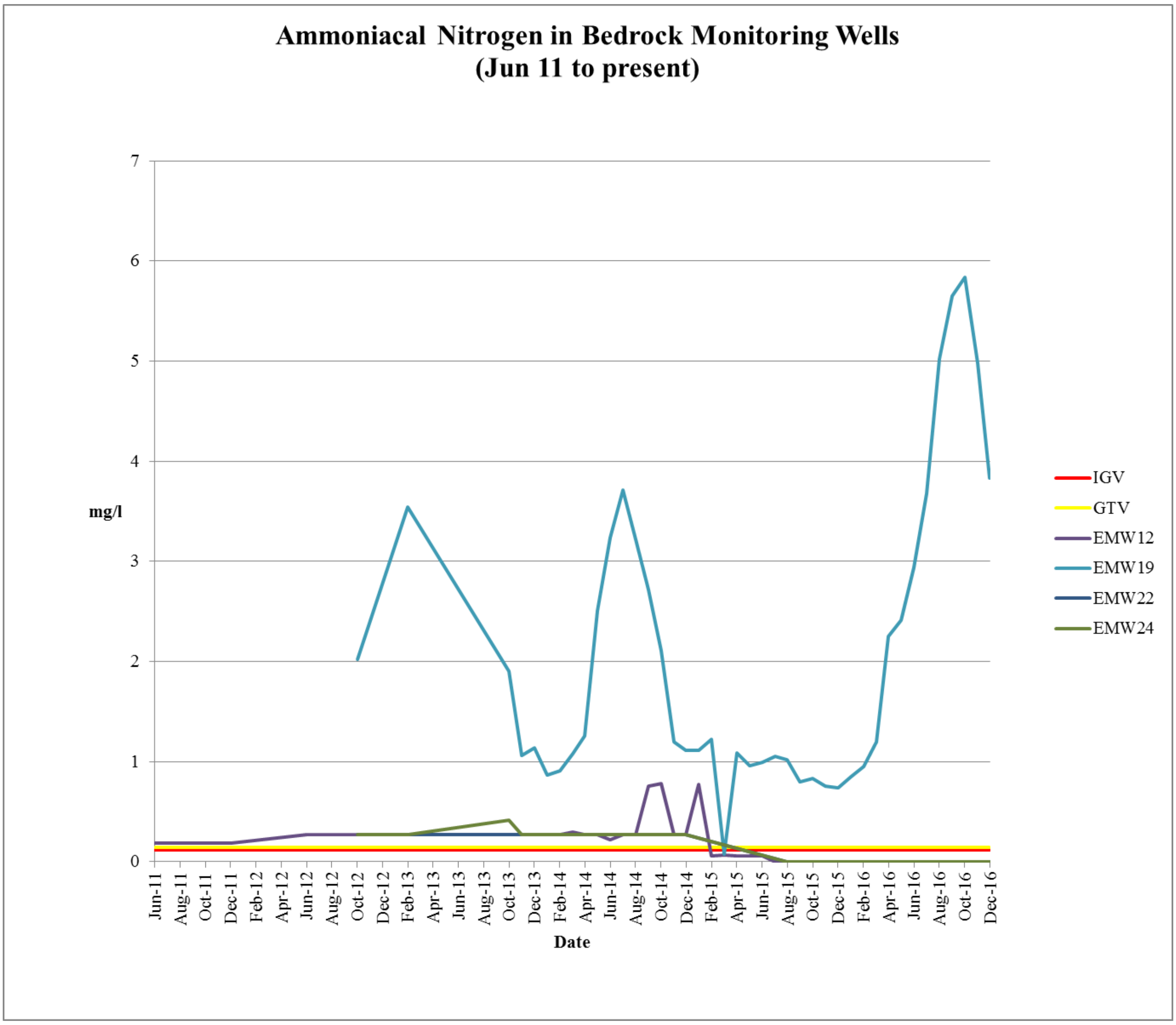
EMW07 and EMW18 showed similar decreases in ammoniacal nitrogen concentration from 8.63 mg/l in June 2016 to 4.89 mg/l in December 2016; and from 0.67 mg/l in June 2016 to 0.44 mg/l in December 2016 respectively. The decrease in EMW18 brings the ammoniacal nitrogen concentration close to the historical low of 0.41 mg/l recorded for this borehole in October 2012. EMW24, at the north-west site boundary, was again found to be below the limit of detection for ammoniacal nitrogen.

Graph 2.8: Ammoniacal Nitrogen in Overburden Monitoring Wells (June 2011 to present)



Note: Axes values are different between Graph 2.8 and 2.9

Graph 2.9: Ammoniacal Nitrogen in Bedrock Monitoring Wells (June 2011 to present)



Note: Axes values are different between Graphs 2.8 and 2.9.

Off-Site Wells

Reported ammoniacal nitrogen concentrations in all but one of the 14 off-site monitoring wells (EMW31) were less than 2 mg/l, with all but six wells having concentrations below the IGV of 0.12 mg/l. The discussion below looks at the offsite wells by location.

Kerdiffstown House

At EMW05, the ammoniacal nitrogen concentration in December 2016 was 1.45 mg/l, a slight reduction on November's 1.58 mg/l. During the summer of 2015, concentrations of ammoniacal nitrogen were observed to rise in this well to 1.95 mg/l by October 2015. However, the concentration subsequently fell back to below the limit of detection of 0.06 mg/l in December 2015. Similarly, in May 2016 the concentration at EMW05 rose from 0.07 mg/l to 1.58 mg/l in November 2016. Results recorded during December 2016 represent the seventh consecutive month in which the IGV of 0.12 mg/l has been exceeded in EMW05.

At EMW20, adjacent to the Morell River, the ammoniacal nitrogen concentration decreased again for the third consecutive month to 1.06 mg/l in December 2016, down from 1.87 mg/l in November. This represents a return to the concentrations normally recorded in this well (~ 1mg/l) prior to the increases which began in April 2016 (1.5 mg/l) and peaked at 3.06 mg/l in July 2016.

EMW08 is generally seen to fluctuate in ammoniacal nitrogen concentration from a high of 0.62 mg/l in April of 2016 to below the limit of detection (0.06 mg/l) on multiple occasions. The December concentration fell to a concentration below the limit of detection from 0.11 mg/l in November 2016.

Of the biannual wells in the grounds of Kerdiffstown House, all four wells recorded concentrations under the limit of detection (0.06 mg/l). These were EMW02 located about half way between the site boundary and the Morell River, EMW21 located north-east of the site, and EMW22 (bedrock) and EMW23 to the north of the site at the rear of Kerdiffstown House. Ammoniacal nitrogen has typically not been detected in these wells during past monitoring rounds.

Foley's Fields

In the field to the south and west of the site, EMW28 recorded the highest concentration of ammoniacal nitrogen at 0.23 mg/l, up very slightly on the previous round of 0.22 mg/l (IGV of 0.12 mg/l). The concentration of ammoniacal nitrogen in this well has fluctuated a lot in the past. The December result was within the range normally seen here (0.14 mg/l to 0.7 mg/l).

EMW29, located directly south of the site, recorded a concentration of 0.12 mg/l, an increase on November noted below the limit of detection (0.06 mg/l). This is the highest concentration recorded here since monitoring began, and the first time ammoniacal nitrogen has been detected above the limit of detection since August 2015.

EMW27 (adjacent to EMW28) recorded a concentration above the IGV at 0.38 mg/l. However, this is down from the June 2016 result of 0.52 mg/l. This is the second consecutive round in which a decrease in concentration has been recorded here. At EMW30 near the south-eastern site boundary ammoniacal nitrogen was not found above the limit of detection, as has been the case during past monitoring rounds.

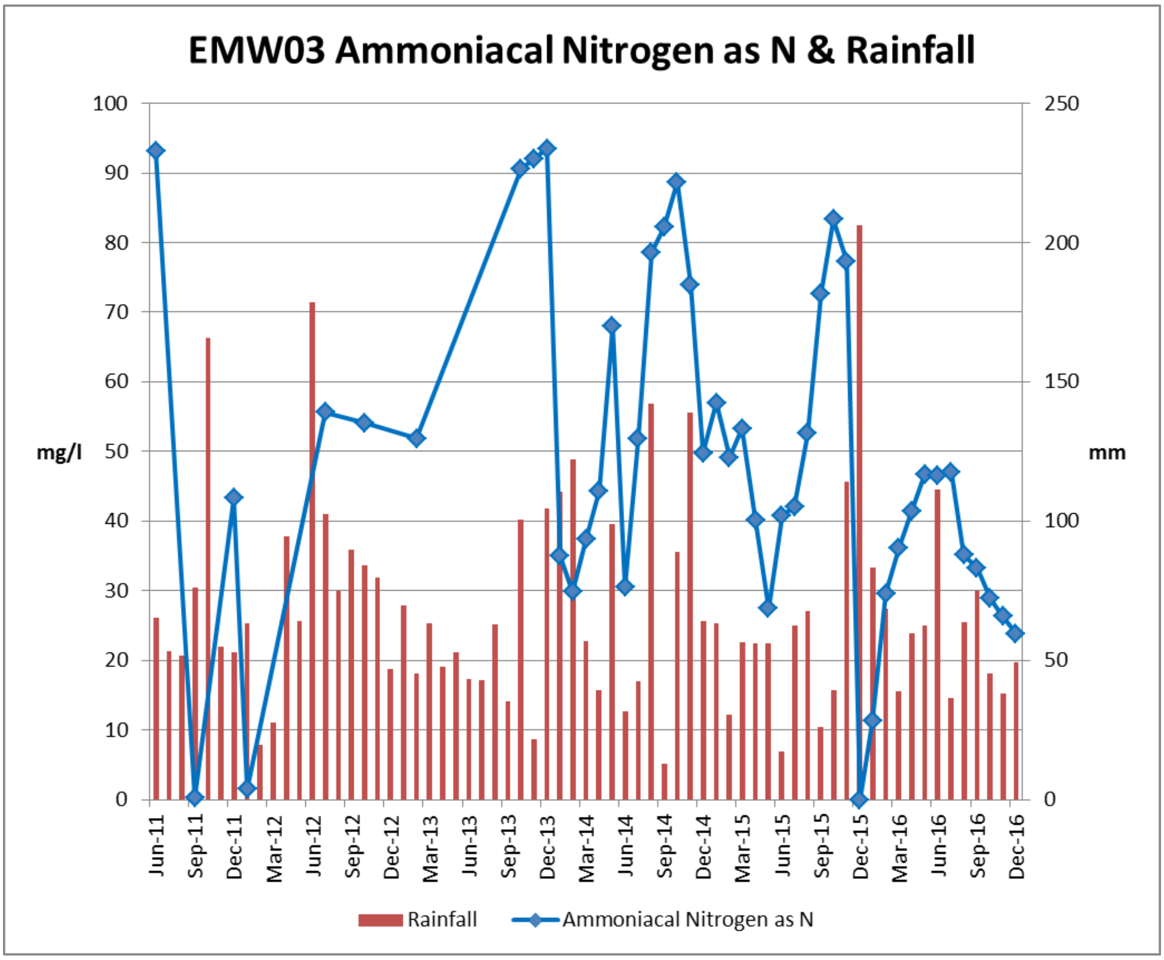
Palmerstown Golf Course

EMW31 and EMW33 recorded ammoniacal nitrogen concentrations at 2.82 mg/l and 0.20 mg/l respectively. The concentration recorded in EMW32 was noted to be 0.12 mg/l and at the IGV. The results represent increases at all three wells when compared to the previous sampling round in June 2016 but below maximum levels previously recorded at these locations.

Evidence of Seasonal Variation

At EMW03 (Graph 2.10) the concentration of ammoniacal nitrogen can be seen fluctuating with higher concentrations observed during drier periods (e.g. Q4 2013) followed by lower concentrations after increases in rainfall and groundwater recharge in Q1, 2014. In December 2015 rainfall was recorded at 206 mm, the highest monthly total since monitoring commenced by the EPA in 2011 and almost three times the historical monthly average of 76 mm (1981 to 2010). This followed a relatively wet November in 2015 (with 155% of the monthly average). The corresponding ammoniacal nitrogen concentration recorded in EMW03 during December 2015 was below the limit of detection (0.06 mg/l) for the first time since monitoring commenced. Given that the average concentration of ammoniacal nitrogen is approximately 52 mg/l this shows the diluting effect of rainfall on the observed concentrations. In 2016, concentrations again increased, peaking in June and have subsequently decreased, even though the rainfall following June has been below the long term average and groundwater levels have continued to fall.

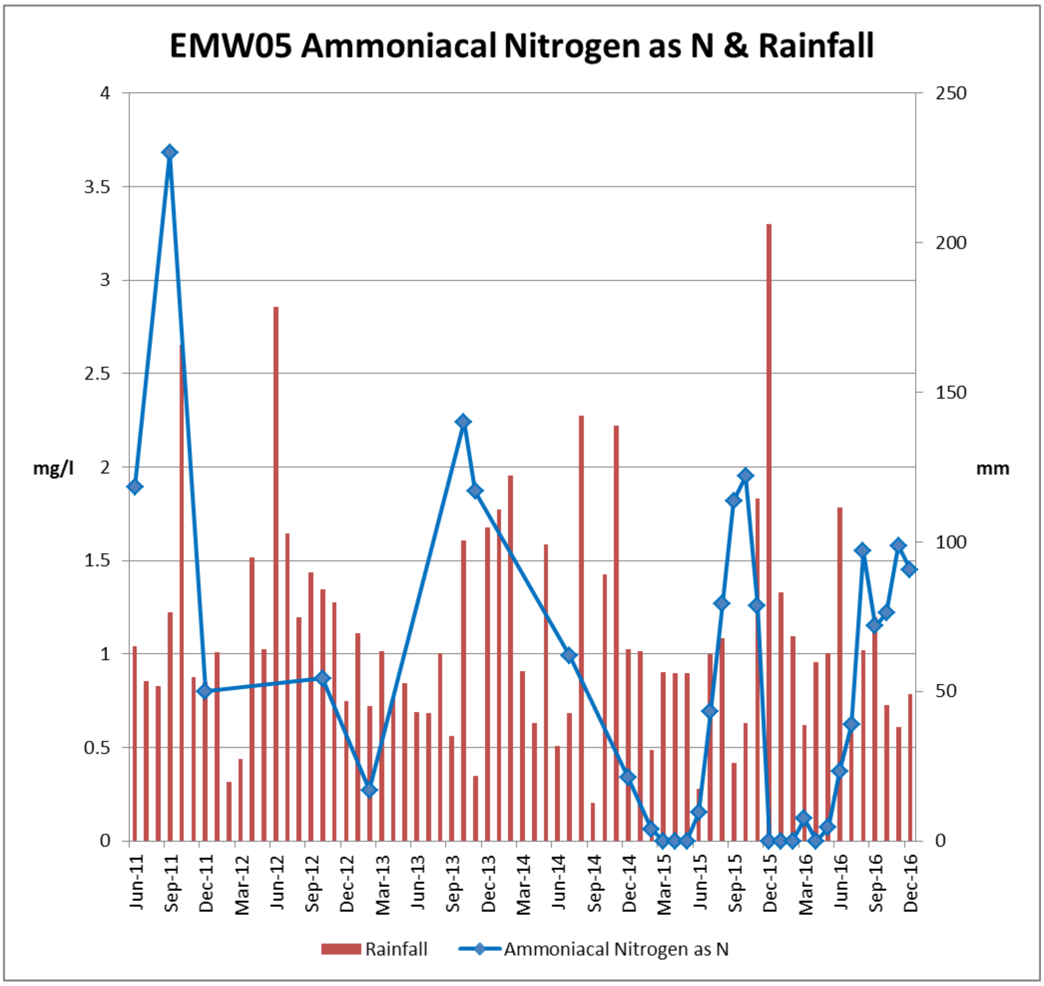
Graph 2.10: EMW03 Ammoniacal Nitrogen and Rainfall



Note: Axes values are different between Graphs 2.10, 2.11 and 2.12.

In EMW05 (Graph 2.11), a monitoring well completed relatively close to the Morell River, an ammoniacal nitrogen concentration of 1.45 mg/l was recorded in December 2016 which represents the seventh month in a row in which the IGV (0.12 mg/l) has been breached. Seasonal variation has been observed in this borehole previously with the IGV breached from June to November 2015 when concentrations were 0.15 mg/l to 1.95 mg/l, following which there were six months where ammoniacal nitrogen concentrations were recorded below the IGV.

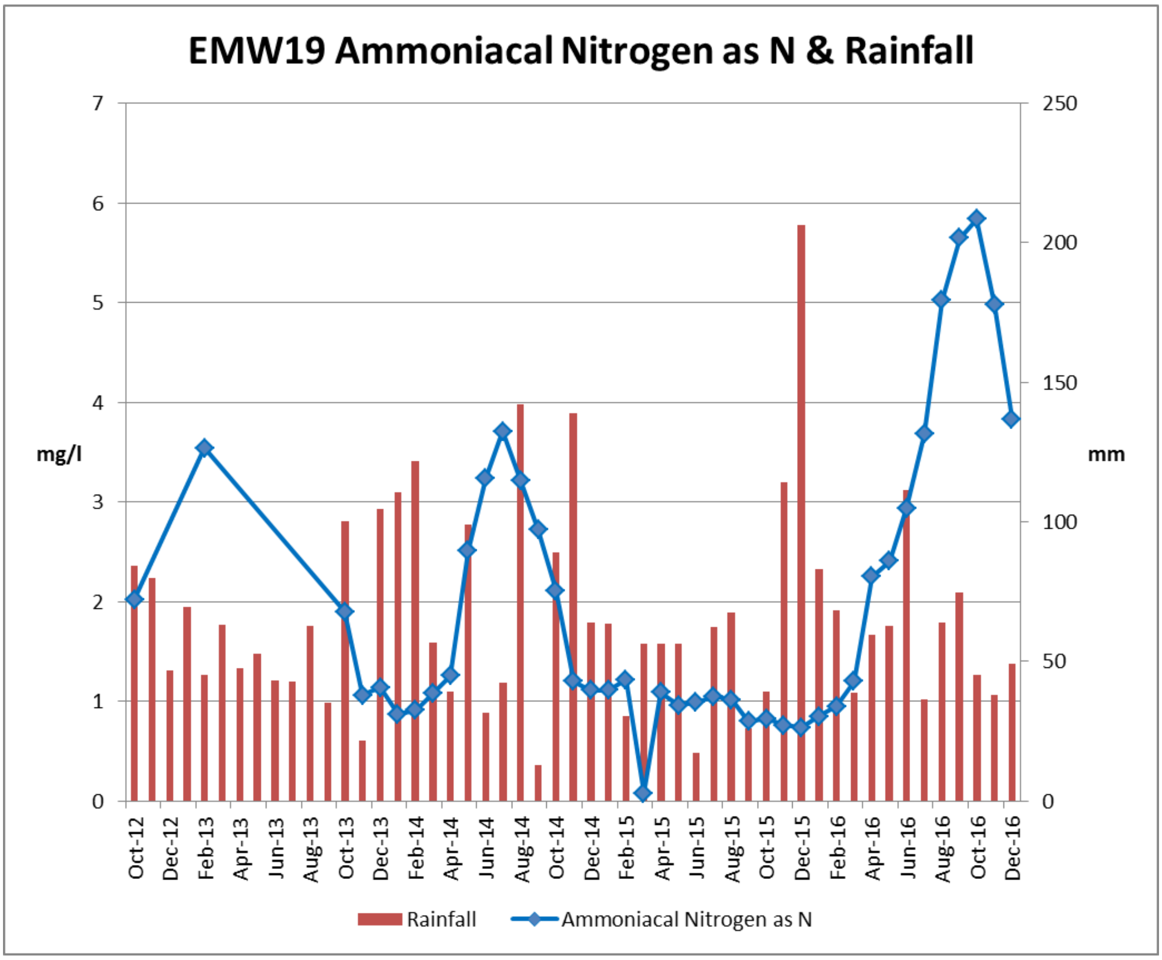
Graph 2.11: EMW05 Ammoniacal Nitrogen and Rainfall



Note: Axes values are different between Graphs 2.10, 2.11 and 2.12.

In December 2016, EMW19 recorded an ammoniacal nitrogen concentration of 3.83 mg/l which is a decrease from the November concentration of 4.98 mg/l. It is the only bedrock well to record ammoniacal nitrogen above the limit of detection and above the IGV (0.12 mg/l). The ammoniacal nitrogen concentration at EMW19 was noted to increase from December 2015 to October 2016 however in recent months the levels have decreased. This may be due to seasonal fluctuation as recorded during the spring-summer of 2014 when an increase in ammoniacal concentration was noted. Graph 2.12 shows ammoniacal nitrogen concentrations against rainfall since October 2012 when the well was installed. Decreasing amounts of rainfall and groundwater recharge since December 2015 have resulted in a gradual increase in concentrations up until October 2016. Although groundwater levels have continued to fall in November and December 2016, the ammoniacal nitrogen concentrations have also fallen.

Graph 2.12: EMW19 Ammoniacal Nitrogen and Rainfall



Note: Axes values are different between Graphs 2.10, 2.11 and 2.12.

Nitrate

The IGV for nitrate is 25 mg/l, while the limit of detection is 3.1 mg/l. Graphs 2.13 and 2.14 show nitrate concentrations in overburden and bedrock wells respectively.

On-Site Wells

Nitrate concentrations in on-site monitoring wells during December 2016 ranged from below the limit of detection (3.1 mg/l) to 71.3 mg/l. Nitrate was only detected above the limit of detection in four of the on-site wells during December 2016, namely EMW11, EMW12, EMW13 and GW1D. Of these, only EMW11 and EMW12 exceeded the IGV, a trend seen on-site since monitoring began.

At EMW11, nitrate concentrations were noted to be 71.3 mg/l during December 2016, representing a slight decrease from November 2016 (75.1 mg/l). This well almost consistently contains the highest nitrate concentrations of all on-site wells. There is a pattern of rise and fall seen in this well (from 16.7 mg/l at its lowest in February 2014 to its peak of 88.4 mg/l in October 2016) representing a seasonal variation, with a general rise in the summer and fall in the winter.

Bedrock well EMW12 (Graph 2.14) recorded a decrease in nitrate concentration from 39 mg/l in November to 29.2 mg/l in December 2016. This well typically fluctuates around the GTV of 37.5 mg/l, with the lowest recorded concentration at 23.7 mg/l in March 2016 and the highest at 47 mg/l in March 2015. As is usually the case, most of the other on-site wells were found to have nitrate concentrations below the limit of detection (3.1 mg/l), namely EMW15, EMW16, BH26 and BH42.

The nitrate concentration increased at EMW13 from below the limit of detection in November 2016 to 5.9 mg/l in December. Nitrate concentrations at this well tend to fluctuate, with the highest concentration recorded at 10 mg/l in August 2016.

The nitrate concentration in GW1D decreased from 7.6 mg/l in December 2015 (the last round in which a sample was taken), to 4.5 mg/l in December 2016. This is the lowest concentration recorded here since monitoring began.

Boundary Wells

In December 2016 all boundary wells had nitrate concentrations below the IGV of 25 mg/l with the exception of EMW04. EMW03 and EMW06 near the north-eastern boundary, as well as EMW07 and EMW18, had nitrate concentrations below the limit of detection of 3.1 mg/l. In the case of EMW06, EMW07 and EMW18 the nitrate concentrations have always tended to be below the limit of detection.

In EMW03, there was a decrease in the nitrate concentration in December 2016 from 3.4 mg/l to below the limit of detection (3.1mg/l). Nitrate concentrations are seen to fluctuate in EMW03 and a pattern of seasonality is emerging as more data are gathered (Graph 2.13). The nitrate concentration in EMW03 peaked in December 2015 at 185 mg/l, and has dramatically decreased since to be below the limit of detection (3.1 mg/l) between May and October 2016. No other monitoring wells show evidence of such a marked change in nitrate during the monitoring period. An adjacent monitoring well, EMW02, has also shown some variability but not to the same extent (<3.1 mg/l to 83.3 mg/l), although this borehole is only sampled every six months so trends will not be as apparent.

At EMW04, situated along the boundary to the south of EMW03, contained the highest concentration of nitrate of all of the wells sampled in December 2016. The concentration has increased slightly since June 2016, up from 121 mg/l to 129 mg/l. The nitrate concentration has been found to fluctuate greatly in the past, with the December 2016 concentration within the previously recorded range for this well (between 6.64 mg/l and 176 mg/l).

At bedrock well EMW19 nitrate was detected above the limit of detection for the first time since March 2015 at 21.4 mg/l. As can be seen in Graph 2.14, this is the highest concentration ever recorded in this well. It is however still below the IGV of 25 mg/l.

Off-Site Wells

Nitrate was above the limit of detection in eight of the fourteen off-site wells in December 2016. All but one of these eight wells were below the IGV (EMW05, EMW20, EMW22, EMW23, EMW29, EMW30 and EMW32), with only EMW02 exceeding the IGV at 26.9 mg/l. EMW08, EMW21, EMW27, EMW28, EMW31 and EMW33 were below the limit of detection in December 2016. This is generally found to be the case in all of these wells.

Kerdiffstown House

The concentration of nitrate in EMW02 was 26.9 mg/l in December 2016, marginally exceeding the IGV of 25 mg/l. This was a reduction in nitrate compared to the June 2016 round of sampling at 41.5 mg/l. Nitrate concentrations in this well are found to fluctuate largely, with a range from below the limit of detection up to a maximum of 83.3 mg/l as recorded in November 2013. As with nearby boundary well EMW03, there is likely a seasonal component to the concentrations seen in this well.

At EMW05, near the Morell River, nitrate continues to remain below the IGV and was recorded at 9.7 mg/l, down from 13.1 mg/l during November 2016, and within the range previously recorded at this location from below the limit of detection in May 2015 and February 2016 up to 18.15 mg/l in June 2012.

In EMW20, located further upstream of the Morell River, nitrate was detected at 5.7 mg/l. This is the first time that nitrate has been detected above the limit of detection in this well since December 2014, and is the highest concentration ever recorded here.

EMW22 and EMW23, located north of the site, recorded a decrease in their respective nitrate concentrations when compared to June 2016. Bedrock well EMW22 recorded a slight decrease from 9 mg/l in June 2016 to 7.6 mg/l in December, below the peak of 43.6 mg/l recorded in December 2015. Adjacent overburden well EMW23 similarly showed a slight decrease from 19 mg/l to 15.6 mg/l, below the peak recorded in December 2015 of 33.7 mg/l.

Foley's Fields

Concentrations of nitrate remained below the IGV of 25 mg/l during December 2016 in all four monitoring wells located in Foley's fields.

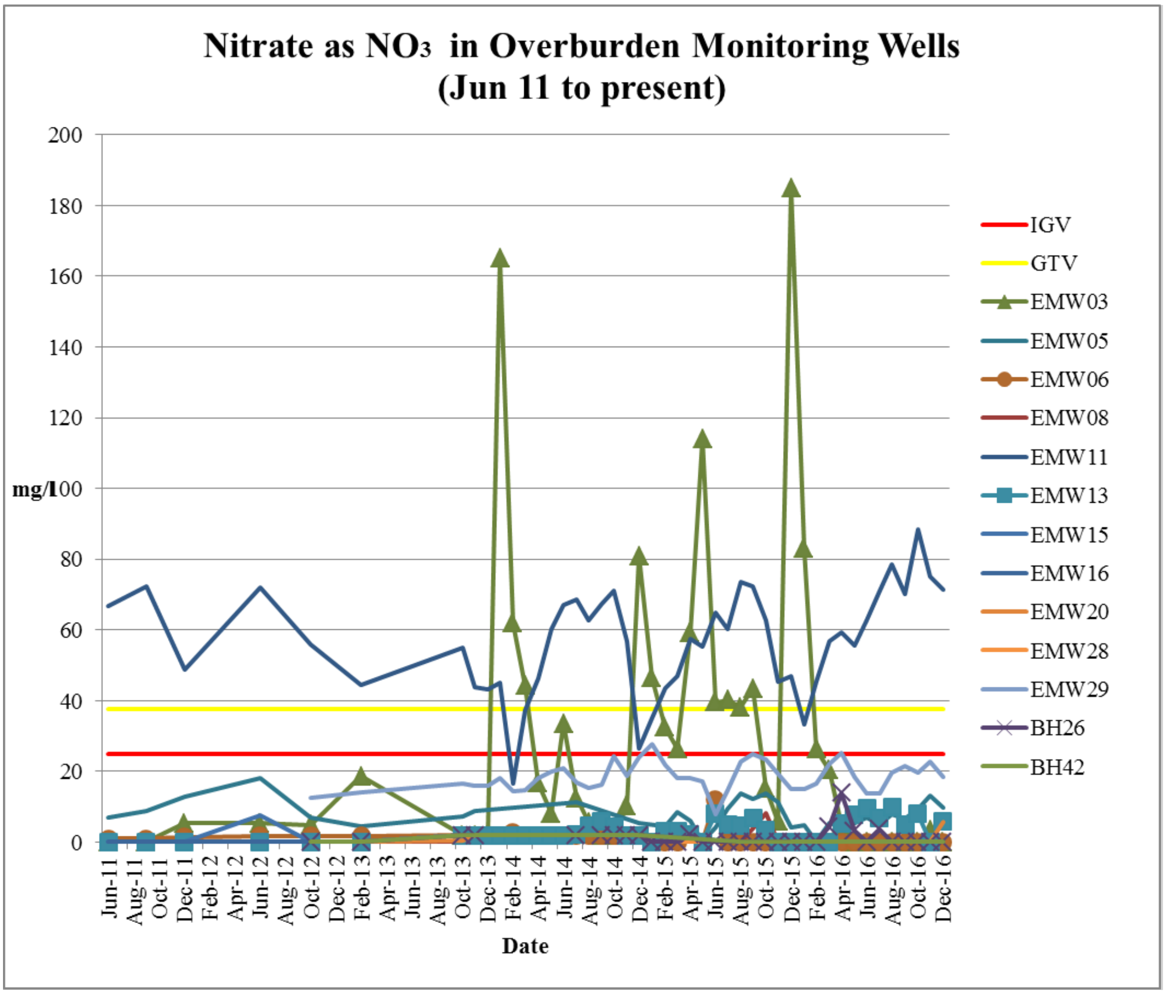
EMW29 had a nitrate concentration of 18.3 mg/l in December 2016, a decrease on November's 22.8 mg/l and within the range normally recorded here (7.8 mg/l recorded in June 2015 to 27.7 mg/l recorded in January 2015). At EMW28 nitrate was below the limit of detection of 3.1 mg/l, as has always been the case.

EMW30 had a nitrate concentration of 10.1 mg/l in December, a decrease on the previous monitoring round of 14.4 mg/l in June 2016, and well below the peak of 31.9 mg/l as recorded in October 2012. The nitrate concentration at EMW27 was also below 3.1 mg/l as has always been the case in this well since monitoring began.

Palmerstown Golf Course

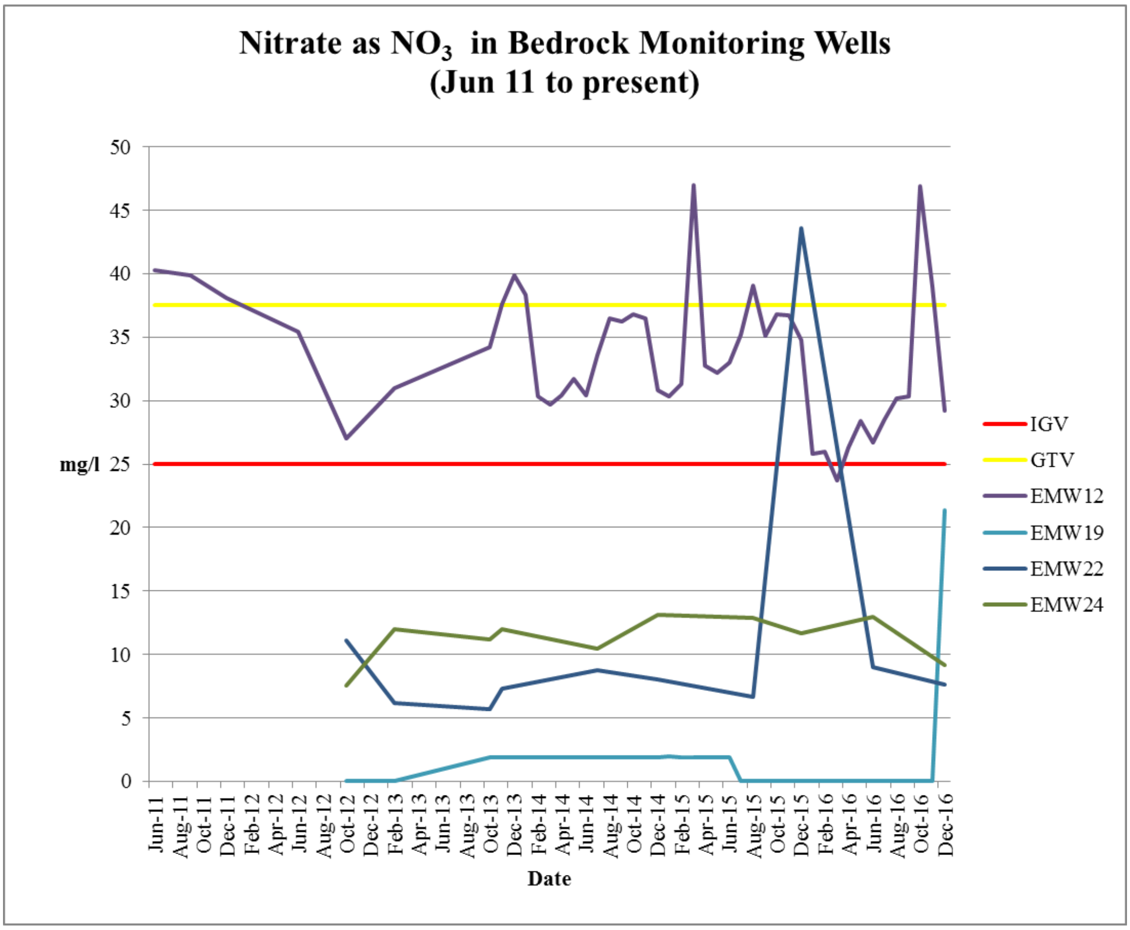
EMW31 and EMW33 located at the golf course were found to have a nitrate concentration below the limit of detection of 3.1 mg/l. This has been consistently the case with these wells since monitoring began here in October 2012. EMW32 recorded an increase in nitrate from below the limit of detection (3.1 mg/l) in June 2016 to 10.1 mg/l in December and represents the highest nitrate concentration ever recorded in this well.

Graph 2.13: Nitrate as NO_3 in Overburden Monitoring Wells (June 2011 to present)



Note: Axes values are different between Graphs 2.13 and 2.14.

Graph 2.14: Nitrate as NO_3 in Bedrock Monitoring Wells (June 2011 to present)



Note: Axes values are different between Graphs 2.13 and 2.14.

Phosphate

Phosphates (analysed as total phosphate) can be elevated in landfill leachates compared to background groundwater or surface water concentrations. There is currently no IGV for total phosphate, with 0.03 mg/l being the IGV for orthophosphate only. The limit of detection is 0.37 mg/l. Phosphate was detected above the limit of detection in 24 of the 34 wells sampled in December 2016.

On-Site Wells

Phosphate was detected in eight of the wells sampled on site. The highest concentration was recorded in BH7 in the lower yard of the site at 12.56 mg/l in December 2016. This is a large increase over the June 2016 concentration of 3.98 mg/l, and is the highest concentration ever recorded at this well. Nearby well BH6 was also at its highest concentration at 5.82 mg/l, a large increase on June 2016 which was below the limit of detection. In both cases bailers were used to sample, which may have impacted the results.

BH42 also increased in phosphate since June 2016, increasing from 0.46 mg/l to 0.92 mg/l. This is marginally lower than the well’s highest phosphate concentration of 0.98 mg/l. All other wells showed little change in phosphate concentration when compared to June 2016.

Boundary Wells

Phosphate was detected above the limit of detection in all boundary wells located on the east and north-east boundary of the site. There was no phosphate detected at the northern boundary well EMW24, as has often been the case in the past.

EMW07 contained the highest concentration of phosphate of all the boundary wells at 6.44 mg/l. This is an increase on the June 2016 concentration (4.29 mg/l) but is below the peak for this well of 8.27 mg/l recorded in February 2013.

EMW06 similarly recorded an increase in phosphate concentration, increasing from below the limit of detection in June 2016 to 1.53 mg/l in December. This is below the peak for this well of 2.19 mg/l recorded in September 2011.

EMW04 recorded a significant decrease in phosphate when compare to June 2016, decreasing from 4.9 mg/l to 0.86 mg/l in December. Large fluctuations have been seen previously in this well.

There was little change in the other boundary wells when compared to June 2016, with phosphate concentrations remaining largely stable.

Off-Site Wells

Ten of the fourteen wells located away from the site had phosphate concentrations above the limit of detection in December 2016. The highest phosphate concentration of all of the off-site wells was recorded at EMW33 in Palmerstown Golf Course at 3.68 mg/l. This equals the previous peak of 3.68 mg/l at this well in August 2015 and is an increase on 2.48 mg/l recorded in June 2016. The other golf course wells, EMW31 and EMW32 recorded 1.35 mg/l and 0.52 mg/l respectively. The concentration in EMW31 increased slightly on the June concentration of 1.16 mg/l, while the EMW32 concentration decreased slightly from 0.86 mg/l.

The three wells in Foley's fields located south of the site all had phosphate concentrations below the limit of detection. This has often been the case in the past in these wells, with EMW27 and EMW29 being below the detection limit in June 2016 also. EMW28 tends to fluctuate more, with the range recorded here between the detection limit and 15.94 mg/l. In June 2016 EMW28 had a phosphate concentration of 4.29 mg/l.

There was very little change in concentration noted in the wells located within the grounds of Kerdiffstown House, with EMW02, EMW05, EMW20, EMW21, EMW22 and EMW23 all remaining stable when compared to June 2016. An exception was EMW08, which had the highest concentration of the Kerdiffstown House wells at 2.33 mg/l, an increase from the June concentration of 1.53 mg/l, but remaining below the peak for this well of 4.29 mg/l recorded in December 2014.

Major ions

In a landfill that received a mixture of municipal and commercial waste such as Kerdiffstown, leachate may be characterised by the presence of inorganic macro components which include commonly occurring cations and anions (including calcium, sodium, sulphate etc.).

The results for major ions were generally consistent with the field monitoring well head parameters summarised above, with key indicators of leachate impact being elevated in on-site overburden monitoring wells. As previously recorded, monitoring wells located close to the north-eastern site boundary (i.e. on-site well EMW13 and boundary well EMW03) contained relatively elevated concentrations of major ions. Key leachate indicators in monitoring wells to the north-east of the site (EMW06, EMW08, EMW19 and EMW20) were generally low relative to the results for most of the on-site monitoring wells. This indicates that the amount of leachate migration off-site has been low and remains localised.

Alkalinity

Where dissolved organic matter derived from decomposing waste is present in leachate this can lead to removal of oxygen and nitrate from groundwater following mixing with leachate, which in turn can lead to increased concentrations of carbon dioxide in the groundwater and increased concentrations of alkalinity (a measure of carbonate and bicarbonate ion presence) due to dissolution of carbonate minerals in the aquifer, where they are present.

On-Site Wells

During December there was little to no fluctuation in alkalinity concentrations in any of the sampled wells when compared with previous rounds. EMW11 increased slightly in November from 523 mg/l to 538 mg/l, well below the peak of 1380 mg/l recorded in June 2012.

EMW12 decreased slightly from 295 in November 2016 to 272 mg/l in December, with the alkalinity in this bedrock well remaining stable since monitoring began here in June 2011. EMW13 contained the highest concentration of alkalinity of all of the on-site wells, as is often the case, at 1630 mg/l in December, up slightly from 1580 mg/l recorded the previous month. As with EMW12, the alkalinity concentrations at EMW13have remained generally stable since monitoring began, with very little fluctuation seen. BH26 recorded a marginal decrease when compared to November 2016 from 1440 mg/l to 1410 mg/l. The alkalinity at BH26 decreased from 2500 mg/l in October 2012 to 1260 mg/l in July 2014, but has remained very stable since then with very little fluctuation in concentrations.

The on-site wells located in the south-east of the site, EMW15 and EMW16 also recorded very similar alkalinity concentrations to the previous months, with EMW15 decreasing slightly from 642 mg/l in November to 606 mg/l in December 2016; while further south-east EMW16 also recorded a slight decrease from 859 mg/l to 803 mg/l over the same period. As with other on-site wells there has been very little fluctuation recorded in either of these wells over recent years. The alkalinity concentration in EMW15 fell from the peak of 1570 mg/l in June 2011 to 467 mg/l in December 2011, followed by general stability since then. EMW16 peaked in early monitoring rounds at 2190 mg/l in June 2012 and following a large reduction by the next monitoring round at 1480 mg/l in October 2012, there has been a very gradual decrease recorded in this well since with the December 2016 concentration the lowest ever recorded here.

BH42, towards the centre of the southern half of the site, has shown very little fluctuation in recent monitoring rounds, with a slight decrease recorded in December 2016 from 333 mg/l in November 2016 to 320 mg/l. Unlike the other on-site wells, there has been more fluctuation in alkalinity recorded in the past, with the concentrations ranging from a peak of 547 mg/l in October 2013 to a low of 295 mg/l in October 2016.

EMW17 in the south-east corner of the site has similarly shown very little fluctuation in alkalinity since late 2013, with a slight decrease recorded between June 2016 and December from 326 mg/l to 264 mg/l. Similarly BH26 has fluctuated very little since November 2013, with a slight decrease recorded from 581 mg/l in June 2016 to 419 mg/l in December.

Two of the three wells in the lower yard of the site, BH6 and BH7, recorded large increases in alkalinity since June 2016, with fluctuations in these wells generally more pronounced than many of the other on-site wells. BH6 increased from 495 mg/l in June 2016 (the lowest ever recorded here) to 965 mg/l in December (the highest ever recorded here). In contrast, GW2S in the lower yard, recorded a very large decrease from 349 mg/l in June 2016 to 104 mg/l in December, by far the lowest concentration ever recorded in this well.

Bedrock well GW1D in the south of the site recorded a slight increase in alkalinity since the last time it was sampled, increasing from 318 mg/l in December 2015 to 327 mg/l in this round. This is the highest concentration ever recorded here.

Boundary Wells

The alkalinity concentration was found to have decreased in all boundary wells in December 2016, except for at EMW03. EMW03, located on the boundary with Zone 1, had the highest alkalinity concentration of all boundary wells in December at 835 mg/l. This is typically the case. It increased very slightly from 806 mg/l in November 2016 to 835 mg/l in December. The alkalinity concentration fluctuates greatly at this well with concentrations recorded between the low of 75.7 mg/l (January 2015) and the high of 1780 mg/l (October 2013). Nearby well, EMW06, recorded a slight decrease in alkalinity from 696 mg/l in November to 486 mg/l in December 2016, with concentrations in this well remaining largely stable in this well since monitoring began in June 2011.

Bedrock well EMW19 has continued to decrease in alkalinity concentration since the recent summer high of 606 mg/l (July 2016), with it decreasing from 500 mg/l in November to 438 mg/l in December. This represents a continuation of the downward trend towards concentrations normally seen in this well of around 300 mg/l since the increase during the summer. A similar, albeit more pronounced increase was seen in the summer of 2014, with the alkalinity concentration peaking at 1100 mg/l in September 2014. This is likely a seasonal variation as seen in a number of other determinands in this well.

There were decreases in alkalinity recorded in all boundary wells. At EMW04, located south-east of EMW03, alkalinity decreased from 1410 mg/l in June 2016 to 626 mg/l in December. Fluctuations in this well have been far less pronounced in the past when compared to EMW03, with the December concentration within the range recorded since December 2011 of 379 mg/l to 1410 mg/l, and well below the peak here of 3460 mg/l recorded in September 2011.

EMW07, further to the south along the boundary, recorded a decrease from 587 mg/l in June 2016 to 470 mg/l in December. This is within the previously recorded range of between 136 mg/l and 667 mg/l. In EMW18, to the south-east along the site boundary, alkalinity decreased from 302 mg/l in June 2016 to 279 mg/l, with the alkalinity in this well being largely stable since monitoring began here in October 2012.

Bedrock well EMW24 on the northern boundary also decreased slightly in alkalinity concentration from 342 mg/l in June 2016 to 323 mg/l in December. This is the lowest concentration ever recorded in this well.

<u>Off-Site Wells</u>

There was little to no change noted in alkalinity concentrations in any of the off-site monitoring wells in December of 2016 with all being between 300 mg/l and 600 mg/l, lower than many of the on-site and boundary wells which show evidence of leachate contamination.

<u>Iron and Manganese</u>

Iron and manganese oxides which may be present within the matrix of the overburden and bedrock aquifers can also be reduced within leachate impacted groundwater where oxygen concentrations are low leading to increased concentrations of total iron and manganese.

The IGV of 0.2 mg/l for iron and 0.05 mg/l for manganese is consistently exceeded in the majority of wells, both on-site and off-site, and in the overburden and bedrock. During the December 2016 round of monitoring there were only three wells where the iron concentration was below the IGV, namely on-site bedrock well EMW12 and on-site wells EMW17 located to the south-east, and GW1D to the south-west section of the site, all being below the limit of detection of 0.23 mg/l. There was only one exception when it came to manganese concentrations, namely at EMW12 where a concentration of 0.007 mg/l was recorded.

<u>On-Site Wells</u>

In December all wells with the exception of bedrock well EMW12 recorded iron and manganese concentrations above the IGV reflecting little to no change in both iron and manganese concentrations when compared to the November 2016 results.

The highest concentration of manganese was observed at BH7 (10.3 mg/l), while nearby BH6 recorded the highest iron concentration at 48.7 mg/l, the highest concentrations ever recorded in these wells. Both wells, located in the lower yard of the site, recorded large increases in iron and manganese since the previous monitoring round in June 2016.,. BH6 increased from 1.34 mg/l to 48.7 mg/l in iron, and from 1.96 mg/l to 8.81 mg/l in manganese. BH7 increased from 13.5 mg/l to 27 mg/l in iron, and from 3.63 mg/l to 10.3 mg/l in manganese. In contrast, nearby well GW2S recorded a pronounced decrease from 5.05 mg/l to 0.6 mg/l in iron (equalling the previous low in October 2013), and from 0.99 mg/l to 0.06 mg/l in manganese (the lowest ever recorded in this well).

The bedrock well GW1D also recorded pronounced decreases in both determinands, with iron falling from 0.58 mg/l to a low of <0.23 mg/l, and similarly manganese falling from 0.59 mg/l to the low of 0.06 mg/l in December 2016.

EMW17 and BH36 recorded iron and manganese concentrations on a par with previous results. In the case of EMW17, iron was below the limit of detection (0.23 mg/l), down from 0.38 mg/l in June, while manganese similarly reduced slightly from 1.5 mg/l in June to 1.37 mg/l. There were similarly slight reductions in both determinands at BH36, with iron decreasing from 7.97 mg/l in June 2016 to 7.54 mg/l, and manganese reducing from 3.57 mg/l in June 2016 to 2.94 mg/l.

Boundary Wells

As with previous monitoring rounds, dissolved iron was elevated (>5mg/l) in monitoring wells located close to the north-eastern site boundary (e.g. EMW03 59.8 mg/l, EMW06 8.55 mg/l, EMW07 18.2 mg/l and EMW19 14.4 mg/l in December 2016).

Some variability in dissolved iron concentrations has been observed in several monitoring wells. In EMW03 close to the north-eastern site boundary, iron concentrations have been shown to fluctuate month on month. The concentration peaked in January 2015 (523 mg/l) as shown in Graph 2.15. The record high iron concentration in January 2015 was followed by a marked decrease in February 2015 followed by fluctuating concentrations in subsequent months, with a concentration of 59.8 mg/l recorded in December 2016, up slightly from 42.9 mg/l in November. Manganese has also fluctuated in this well between a low of 0.62 mg/l recorded in September 2011 and peak of 2.69 mg/l recorded in February 2013. As with iron the concentration fell slightly from 1.87 mg/l in November 2016 to 1.82 in December.

Iron and manganese concentrations in EMW06 further increased in December 2016. Iron increased from 6.37 mg/l in November 2016 to 8.55 mg/l in December 2016, the highest concentration recorded here since the peak of 15.9 mg/l in September 2011. Similarly the manganese concentration increased from 1.25 mg/l in November to 2.08 mg/l in December, the highest since the peak of 2.24 in January 2015.

In the eastern boundary well EMW19, the iron concentration fell further from 16 mg/l in November 2016 to 14.4 mg/l in December, reflecting a decreasing trend in recent months. Manganese concentrations in EMW19 have also followed a decreasing trend following a high of 2.33 mg/l in June 2016 to 1.89 mg/l in December.

Manganese concentrations in the eastern boundary wells EMW04 and EMW07 showed a decrease in December 2016 to 0.427 mg/l and 1.32 mg/l respectively following the highest ever manganese concentrations at 4.31 mg/l and 1.9 mg/l respectively, recorded in June 2016. Iron concentrations in EMW04 decreased from 16.2 mg/l in June 2016 to 1.81 mg/l in December; while in EMW07 it increased slightly from 18.1 mg/l to 18.2 mg/l.

Bedrock well EMW24 at the northern site boundary recorded decreases in both iron and manganese. Iron reduced from 13.1 mg/l in June 2016 to 3.43 mg/l in December, the lowest concentration recorded here since November 2013 at 1.53 mg/l. Manganese reduced marginally from 0.83 mg/l in June to 0.76 mg/l in December.

Off-Site Wells

Kerdiffstown House

In EMW20, located between the site boundary and the Morell River, both iron and manganese have largely returned to the concentrations generally recorded before May 2016. In both cases the concentrations have been falling since their peaks in May 2016 (16.8 mg/l iron and 2.19 mg/l manganese), with iron reducing further from 9.63 mg/l in November to 7.39 mg/l in December, and manganese reducing further from 1.29 mg/l in November to 1.06 mg/l in December. This is the lowest ever recorded manganese concentration at this well.

EMW05 and EMW08 both recorded concentrations within normally recorded ranges in both iron and manganese. At EMW05 concentrations increased slightly in both determinands, with iron increasing from 4.03 mg/l in November to 4.53 mg/l in December; and manganese increasing from 0.84 mg/l to 0.93 mg/l. These concentrations are well below their respective peaks in February 2015 of 8.74 mg/l in iron and 2.09 mg/l in manganese. The concentration of iron in EMW08 increased slightly from 3.87 mg/l in November to 4.31 mg/l in December, still well below the peak of 70.8 mg/l in January 2015. Manganese fell slightly in EMW08 from 0.79 mg/l to 0.76 mg/l, and remained below the peak of 1.06 mg/l recorded in February 2013 and again in June 2014.

Results from all of the Kerdiffstown House wells were within previously recorded ranges in both iron and manganese. EMW02 recorded an increase in both iron and manganese concentrations, with iron increasing from the low of 0.35 mg/l in June 2016 to 1.89 mg/l in December; and manganese increasing from its low of 0.03 mg/l in June to 0.2 mg/l in December. Both concentrations are well below their respective peaks of 4.02 mg/l in iron and 0.69 mg/l in manganese. EMW22 and EMW23 to the north of the site, behind Kerdiffstown House recorded little change on recent results. Bedrock well EMW22 decreased in iron from 1.42 mg/l in June to 0.91 mg/l in December, and in manganese from 0.7 mg/l in June to 0.66 mg/l in December. Adjacent well EMW23 recorded slight increases in both determinands with iron increasing from 1.75 mg/l in June to 2.04 mg/l in December and manganese increasing from 0.36 mg/l in June to 0.39 mg/l in December.

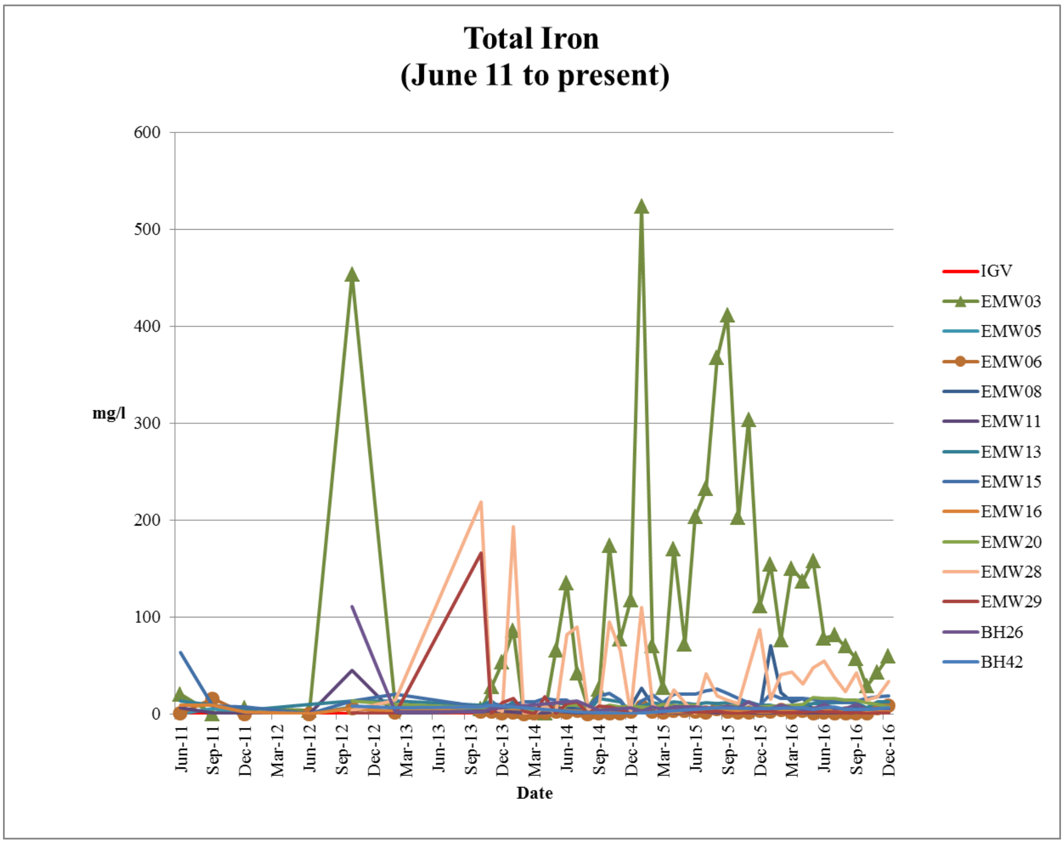
Foley's Fields

During December 2016, by far the highest off-site concentration of both iron and manganese was observed at EMW27 (56.4 mg/l and 13.7 mg/l respectively), located in the field to the south of the site. These are both the highest concentrations recorded in this well since October 2013. EMW28, located adjacent to EMW27, shows fluctuation in results with an increase in iron concentration to 33.4 mg/l in December 2016 from 17.6 mg/l recorded in November. Manganese similarly increased from 1.48 mg/l in November to 2.59 mg/l in December. Both results are well below their respective peaks of 219 mg/l in iron and 16 mg/l in manganese, both recorded in October 2013. The other well in the field, EMW29, recorded no significant change over concentrations recorded over the past two years, remaining in and around 2mg/l in iron and 0.16 mg/l in manganese.

Palmerstown Golf Course

There was little change in iron and manganese concentrations in the three wells in Palmerstown Golf Course. EMW31 increased slightly in both determinands compared to June 2016, from 21.1 mg/l to 22 mg/l in iron, and 1.99 mg/l to 2.13 mg/l in manganese. EMW32 decreased slightly in both determinands, from 3.88 mg/l to 1.9 mg/l in iron, and from 1.71 mg/l to 1.25 mg/l in manganese. EMW33 recorded an increase in iron concentration from 7.62 mg/l in June 2016 to 9.09 mg/l in December. This is the highest concentration here since the peak in August 2015 of 10.5 mg/l. In contrast, the manganese concentration decreased in EMW33 from 0.52 mg/l to 0.46 mg/l.

Graph 2.15: Total Iron in Selected Overburden Monitoring Wells (June 2011 to present)



Chemical Oxygen Demand (COD)

COD is a broad measure of the concentration of oxidizable organic contaminants present in the groundwater and therefore can be a useful indicator of the presence of landfill leachate.

On-Site Wells

BH26, generally the well with the highest COD, previously recorded a peak concentration of 4,160 mg/l in September 2015. COD values have since fallen, although there was a slight increase in December 2016 to 458 mg/l from November's concentration of 420 mg/l.

The COD concentration at EMW13 in the north of the site increased from 312 mg/l in November to 325 mg/l in December 2016. This is the second increase following six consecutive reductions since April 2016 when a high of 444 mg/l was recorded. Bedrock well EMW12 recorded a decrease from 20 mg/l in November to 18 mg/l in December. Prior to November, COD hadn't been detected in this well above the limit of detection of 11 mg/l since May 2016.

EMW11 in the west of the site recorded a concentration of 56 mg/l COD in December, an increase from 44 mg/l in November 2016.

COD in both EMW15 and EMW16 increased in December 2016 compared to November, with EMW15 up from 34 mg/l to 50 mg/l and EMW16 up slightly from 82 mg/l to 86 mg/l. However these concentrations are below both October 2016 concentrations of 64 mg/l in EMW15 and 11 mg/l in EMW16. Similarly BH42 increased from 45 mg/l in November to 49 mg/l, a concentration below the October result of 50 mg/l.

EMW17, GW1D and GW2S did not record COD above the limit of detection of 11 mg/l. The COD in BH36 decreased from 177 mg/l in June 2016 to 110 mg/l in December. There were large changes in both BH6 and

BH7 located in the lower yard, with BH6 increasing dramatically from 64 mg/l in June to 207 mg/l in December, and BH7 falling dramatically from 400 mg/l to 21 mg/l in the same period.

Boundary Wells

EMW03, the well with the highest COD concentration outside of the site, recorded a concentration of 186 mg/l in December 2016, an increase from November's result of 122 mg/l. These concentrations are well below the January 2016 peak concentration of 1,069 mg/l.

Nearby well EMW06 recorded a significant increase in the COD concentration to 153 mg/l in December, from 11 mg/l in November 2016. This is the highest concentration recorded for this well, although a concentration of 125 ml/l was recorded in December 2015.

In bedrock boundary well EMW19, a further decrease in COD was detected down to 20 mg/l in December 2016 from 27 mg/l in November from a high of 52 mg/l in October 2016.

EMW04 showed a decrease in COD concentration from 228 mg/l in June 2016 to 57 mg/l in December. Further south along the boundary, EMW07 decreased from 50 mg/l to 37 mg/l; and EMW18 decreased from 18 mg/l to 12 mg/l. The only biannual well to increase in COD was EMW24 to the north of the site, which increased slightly from 79 mg/l in June 2016 to 83 mg/l in December.

Off-Site Wells

In December 2016, the off-site wells generally had COD concentrations ranging from 14 mg/l to 62 mg/l which are within previously recorded ranges. Exceptions to this are the two adjacent wells in Foley's Field, south of the site, namely EMW27 and EMW28. EMW28 continued to have a high COD concentration compared to other off-site wells at 163 mg/l, up from 121 mg/l in November. In addition EMW27 recorded a notably elevated COD of 480 mg/l in December 2016 which is an increase from 172 mg/l recorded in June 2016 and is the highest concentration at this well since February 2013 when the concentration was recorded at 1440 mg/l.

Chloride

Chloride is also a common key indicator of landfill leachate presence. Graph 2.16 shows the variation in chloride concentrations for selected monitoring wells within the overburden. A very similar pattern of variation in chloride concentrations is shown for EC and ammoniacal nitrogen for the corresponding monitoring wells with decreased concentrations generally observed in those samples collected during the winter / spring months. As with EC and ammoniacal nitrogen this is particularly pronounced within EMW03.

Chloride concentrations recorded within bedrock monitoring wells are shown in Graph 2.17.

On-Site Wells

Chloride was found during December 2016 to be highest in the on-site monitoring wells BH26 (412 mg/l) and EMW13 (221 mg/l) in Zone 1 of the site, similar to concentrations recorded in November. The chloride concentration recorded at EMW11 was also above the IGV (30 mg/l) at 51.7 mg/l, and the concentration in bedrock well EMW12 increased marginally to above the IGV at 31 mg/l.

Towards the south-east of the site, EMW15 recorded a chloride concentration of 50.3 mg/l in December, a slight decrease from 51.6 mg/l in November 2016, while EMW16 recorded the highest concentration in the southern half of the site at 153 mg/l, a slight decrease from the November concentration (165 mg/l). Chloride concentrations in BH42 remained below the IGV at 25.1 mg/l.

BH36, also in Zone 1 of the site, recorded a concentration of 139 mg/l in December, a decrease in concentration from 189 mg/l in June 2016. The chloride concentration at BH7 in the south-east of the site increased to 64.7 mg/l in December 2016 following the lowest ever concentration of 50 mg/l recorded in June.

The chloride concentration in GW1D was 170 mg/l; the previous monitored concentration at this well was 21 mg/l in December 2015.

Boundary Wells

The concentration of chloride in EMW03 in December 2016 showed a slight further reduction to 59.3 mg/l compared to 60.4 mg/l during November 2016 which was the highest chloride concentration recorded in all boundary wells during that period. At EMW19, the bedrock well on the eastern boundary, the chloride concentration continued to decrease, decreasing to 27.5 mg/l in December from 32 mg/l in November which is below the IGV of 30 mg/l following eight months of exceedances. As with some of the overburden monitoring wells, EMW19 potentially shows seasonal fluctuation with lower chloride concentrations recorded during the winter months. The concentration in EMW06 was 5.7 mg/l in December having been below the limit of detection in November (3.7 mg/l).

Of the biannually monitored wells, chloride concentrations in the monitoring wells located near to the site boundary were relatively elevated and above the IGV. A concentration of 40.5 mg/l was recorded in EMW04 in December, which is a slight decrease from 47.5 mg/l in June 2016. A concentration slightly above the IGV of 31.1 mg/l was recorded in EMW07 during December, a decrease from 50.6 mg/l in June.

Off-Site Wells

All off-site monitoring wells remained below the IGV of 30 mg/l, with the exception of EMW22 located north of the site behind Kerdiffstown House (35 mg/l).

Kerdiffstown House

Chloride concentrations remained relatively low in off-site monitoring wells to the north-east e.g. EMW05 at 24.8 mg/l and EMW08 at 8.6 mg/l. EMW20 recorded a concentration of 19.5 mg/l, a further slight fall from November's 22.9 mg/l and the fifth consecutive month the concentration has been below the IGV of 30 mg/l following a rise in concentration over the summer.

Of the biannually monitored wells, EMW22 recorded a concentration of 35 mg/l, a decrease from 37.9 mg/l recorded in June 2016. This is the second lowest result ever recorded in this well, the lowest being 34.2 mg/l in October 2012. Adjacent well EMW23 had its lowest ever recorded chloride concentration at 11.4 mg/l.

Foley's Fields

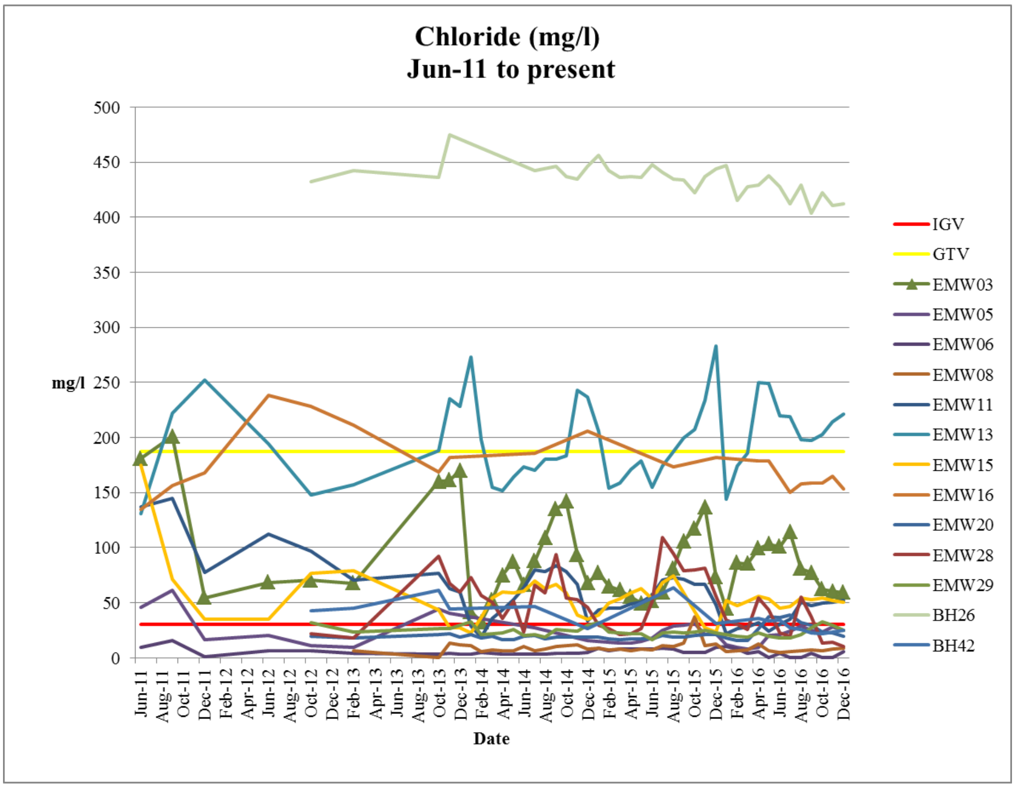
In other off-site wells to the south of the site in Foley's Field, EMW28 showed a concentration of 9.9 mg/l in December 2016 which is a decrease from 14.4 mg/l in November and the lowest concentration ever recorded at this well. Adjacent well EMW27 also recorded its lowest ever chloride concentration at 15.1 mg/l.

EMW29 recorded a further decrease in chloride concentration from 29.4 mg/l to 25.2 mg/l, remaining below the IGV of 30 mg/l. Chloride concentrations in this well have fluctuated between 16.6 mg/l and 33 mg/l in the past.

Palmerstown Golf Course

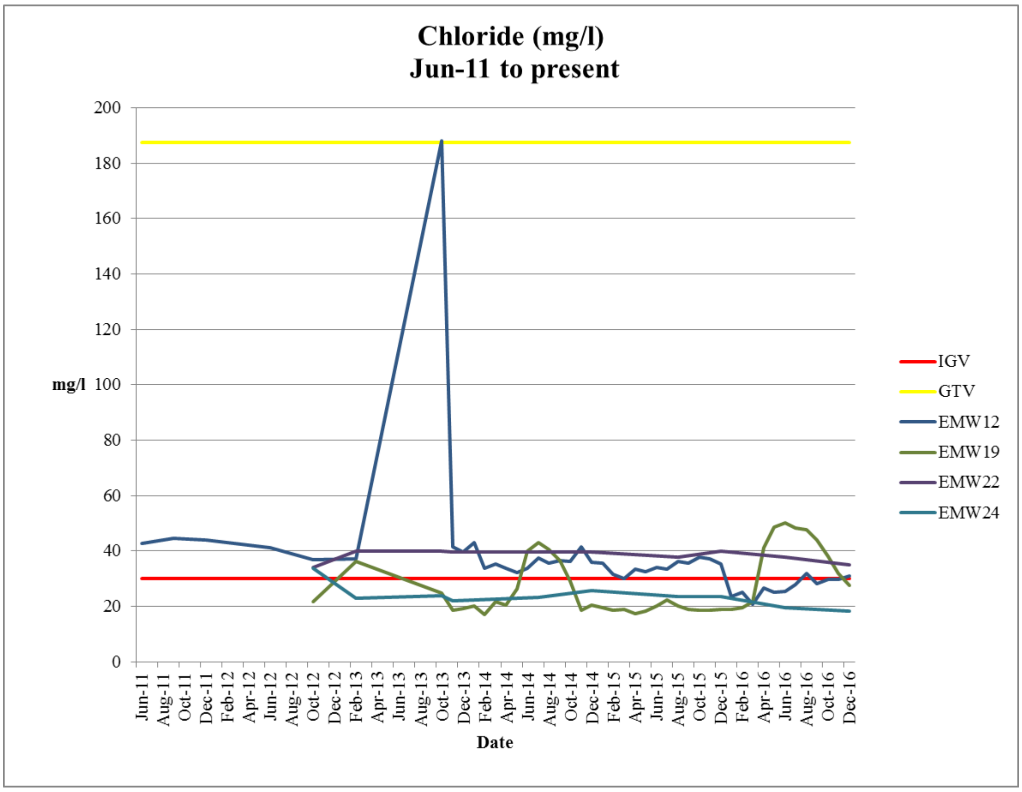
Chloride concentrations in all of the wells on the golf course remained below the IGV of 30 mg/l, as has always been the case with EMW31 at 19.9 mg/l (down from June's 21.7 mg/l), EMW32 at 18.2 mg/l (down from 19 mg/l in June and the lowest ever recorded in this well), and EMW33 at 16.1 mg/l (down from 20.1 mg/l in June and also the lowest ever for this well).

Graph 2.16: Chloride in Overburden Monitoring Wells (June 2011 to present)



Note: Axes values are different between Graph 2.16 and 2.17

Graph 2.17: Chloride in Bedrock Monitoring Wells (June 2011 to present)

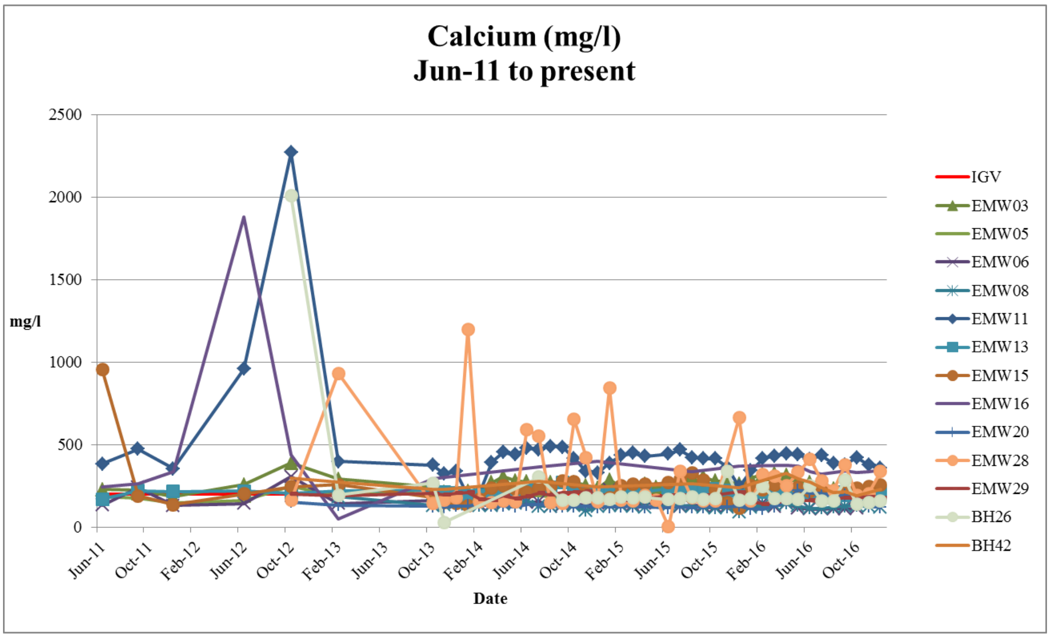


Note: Axes values are different between Graphs 2.16 and 2.17.

Calcium

Where geology of limestone bedrock and limestone dominated subsoils are common, groundwater is often hard, containing high concentrations of calcium, magnesium and bicarbonate. The IGV for calcium is set at 200mg/l. Eleven of the 34 calcium concentrations observed during December 2016 were above the IGV. Graph 2.18 shows calcium concentrations in selected wells.

Graph 2.18: Calcium in Selected Overburden Monitoring Wells (June 2011 to present)



On-Site Wells

The highest calcium concentration in December 2016 was recorded in on-site well BH7 at 1290 mg/l. This is an increase from the previously recorded concentration of 402 mg/l in June 2016 and the highest recorded at this well. Of the other on-site biannually monitored wells only BH6 recorded a concentration above the IGV of 200mg/l at 360 mg/l, an increase from 319 mg/l in June 2016.

The calcium concentration at EMW11 in December 2016 was 360 mg/l which has decreased further from 376 mg/l in November 2016. EMW11 had shown an increase in calcium concentrations during previous monitoring, peaking at 469 mg/l in July 2015 but concentrations reduced to 246 mg/l in December 2015. However, concentrations were noted to rise again to 342 mg/l in January 2016, with further increases to 445 mg/l in April 2016. This variation relates to seasonal fluctuations and greatly elevated concentrations for calcium have previously been observed at EMW11 with the highest recorded concentration of 2,200 mg/l measured during October 2012.

The calcium concentration at EMW13 increased in December to 216 mg/l from just below the IGV at 196 mg/l in November. Concentrations have fluctuated around the IGV since April 2016 with concentrations recorded being between 192 mg/l and 211 mg/l. Prior to July 2016, calcium concentrations were last recorded below the IGV in December 2015. As with EMW13, BH26 also tends to remain near the IGV of 200 mg/l, with a slight increase recorded in December from 152 mg/l in November to 158 mg/l.

As is generally the case, in December 2016, EMW15 and EMW16 in the east of the site recorded concentrations exceeding the IGV at 255 mg/l and 349 mg/l respectively. These represent slight reductions from November in both wells. BH42 near the centre of the site showed a slight increase in concentration to 232 mg/l, up from 211 mg/l in November 2016. Calcium has been gradually increasing in this well since October, when the concentration was recorded below the IGV for the first time in this well.

Bedrock well EMW12 had a calcium concentration marginally below the IGV at 195 mg/l in December 2016, a slight decrease from November's result of 200 mg/l. The calcium concentration in this well tends to fluctuate around the IGV of 200 mg/l.

Boundary Wells

Of the boundary wells, the highest calcium concentration was recorded in EMW04 (239 mg/l), at the eastern site boundary to the south of EMW03. This is a decrease from the highest calcium concentration recorded in this well of 615 mg/l.

Of the other six boundary wells, only EMW06 recorded calcium concentration above the IGV at 211 mg/l, an increase from 176 mg/l and the first time the IGV has been exceeded for this well since January 2015 when a concentration of 228 mg/l was recorded.

The calcium concentration at EMW19 decreased to 169 mg/l following a concentration above the IGV for the eighth consecutive month at 298 mg/l in November. This is a continuation of the decreases in calcium concentration recorded in this well since elevated results were recorded during late spring to early autumn, with calcium concentrations appearing to reduce towards more usual concentrations for this well, i.e. averaging approximately 120 mg/l. During the summer of 2014, EMW19 also showed similarly elevated concentrations and the elevation therefore may be related to seasonal fluctuations.

Off-Site Wells

Two of the fourteen off-site wells exceeded the IGV for calcium in December 2016. These were both adjacent to each other and located in Foley's Field, south of the site. At EMW28 a calcium concentration of 337 mg/l was recorded, a further increase from 204 mg/l in November but consistent with previous large concentration fluctuations at this location (concentrations range from 144 mg/l to 1200 mg/l). In the adjacent well, EMW27, a concentration above the IGV at 359 mg/l was recorded. This is an increase from 159 mg/l recorded in June 2016 and the first time the IGV of 200 mg/l has been exceeded since concentrations of 670 and 663 mg/l were recorded in October and November 2013.

EMW20 recorded a calcium concentration of 119 mg/l, the fifth consecutive month the IGV has not been exceeded here since being above the IGV from May to July 2016. This is the lowest concentration since 111 mg/l was recorded in February 2016, and represents a return to the more usual concentrations recorded in this well prior to the elevation during the summer months, i.e. averaging around 130 mg/l.

Sodium

Sodium is naturally present in groundwater and is also present in landfill leachate. Concentrations measured during December 2016 were similar to those recorded previously and all but two results were below the IGV of 150 mg/l. As with November, the exceptions were BH26 in Zone 1 with an elevated concentration of 306 mg/l compared to 302 mg/l in November and within the range previously observed in this well (211 mg/l to 2430 mg/l). EMW13, also in Zone 1, recorded a concentration of 204 mg/l compared to 222 mg/l in November. This too is within the previously recorded range for this well (86.4 mg/l to 270 mg/l).

The sodium concentration recorded in bedrock boundary well EMW19 in December 2016 decreased further to 25.2 mg/l from 33.6 mg/l in November. The highest concentration ever recorded in this well was 51.7 mg/l in September 2016. This concentration is still well below the IGV.

All of the biannually monitored wells recorded concentrations below the IGV consistent with previous results with the highest concentration recorded in boundary well EMW04 at 45 mg/l, a decrease from 63.6 mg/l in June 2016.

Sulphate

Sulphates exist in nearly all natural waters, the concentrations varying according to the nature of the terrain through which they flow. In polluted waters in which the dissolved oxygen is low, sulphate is readily reduced to sulphide causing noxious odours. The IGV for sulphate is 200 mg/l.

On-Site Wells

The highest concentration of sulphate on-site in December 2016 was detected in EMW11 at 805 mg/l, a slight increase from 790 mg/l in November. This well consistently has the highest concentration of all of the wells monitored, both on and off-site. EMW12 (321 mg/l), EMW15 (395 mg/l), EMW16 (410 mg/l) and BH42 (337 mg/l) were also noted to have sulphate concentrations above the IGV of 200 mg/l during December 2016, as is typical for all of these wells. In the case of BH42, the sulphate concentration reduced slightly from 342 mg/l in November, making it the lowest concentration of sulphate recorded in this well since monitoring began here.

For the on-site monitoring wells sampled six monthly, all but BH6 recorded concentrations below the IGV of 200 mg/l. BH6 recorded a concentration of 237 mg/l in December 2016. This is down from 544 mg/l in June 2016 and the lowest concentration ever recorded in this well. In the case of GW2S and BH36, they both recorded their lowest sulphate concentrations at below the limit of detection (4.4 mg/l) in GW2S and 25.6 mg/l in BH36. In contrast, BH7, in the lower yard near BH6 and GW2S, recorded its highest sulphate concentration at 167 mg/l although only marginally higher than the previous peak of 165 mg/l recorded in December 2015.

Boundary Wells

Eastern boundary well EMW07, has the highest sulphate concentration of any of the wells situated outside of the site. The concentration recorded during December 2016 was 188 mg/l, down from 231 mg/l in June 2016. This well tends to fluctuate greatly, with it previously breaching the IGV in summer 2014. All other biannual boundary wells continued to have sulphate concentrations below the IGV as has always been the case since monitoring began.

Of the other boundary wells, EMW19 recorded the highest sulphate concentration in December 2016. The concentration recorded during December 2016 was 142 mg/l down from 216 mg/l in November, a further decrease on the August highest ever concentration of 335 mg/l. This represents the first time that the sulphate concentration has been below the IGV in this well since March 2016. The other monthly monitored boundary wells had concentrations below the IGV of 200 mg/l, with EMW03 at 66.2 mg/l and EMW06 at 14.9 mg/l. In the case of EMW06, the December sulphate concentration was the highest ever for this well after increasing from November's 11.3 mg/l. This is still well below the IGV of 200 mg/l.

Off-Site Wells

All off-site wells recorded sulphate concentrations below the IGV. The sulphate concentration at EMW05, near the Morell River, decreased slightly from 24.1 mg/l in November 2016 to 23.5 mg/l in December. The sulphate concentration at EMW08 remained below the limit of detection of 8.6 mg/l. EMW20 recorded a relatively pronounced further decrease in sulphate concentration in December at 17.5 mg/l down from 43.5 mg/l in November. All other wells in Kerdiffstown House remained well below the IGV with little or no change when compared to the June 2016 concentrations.

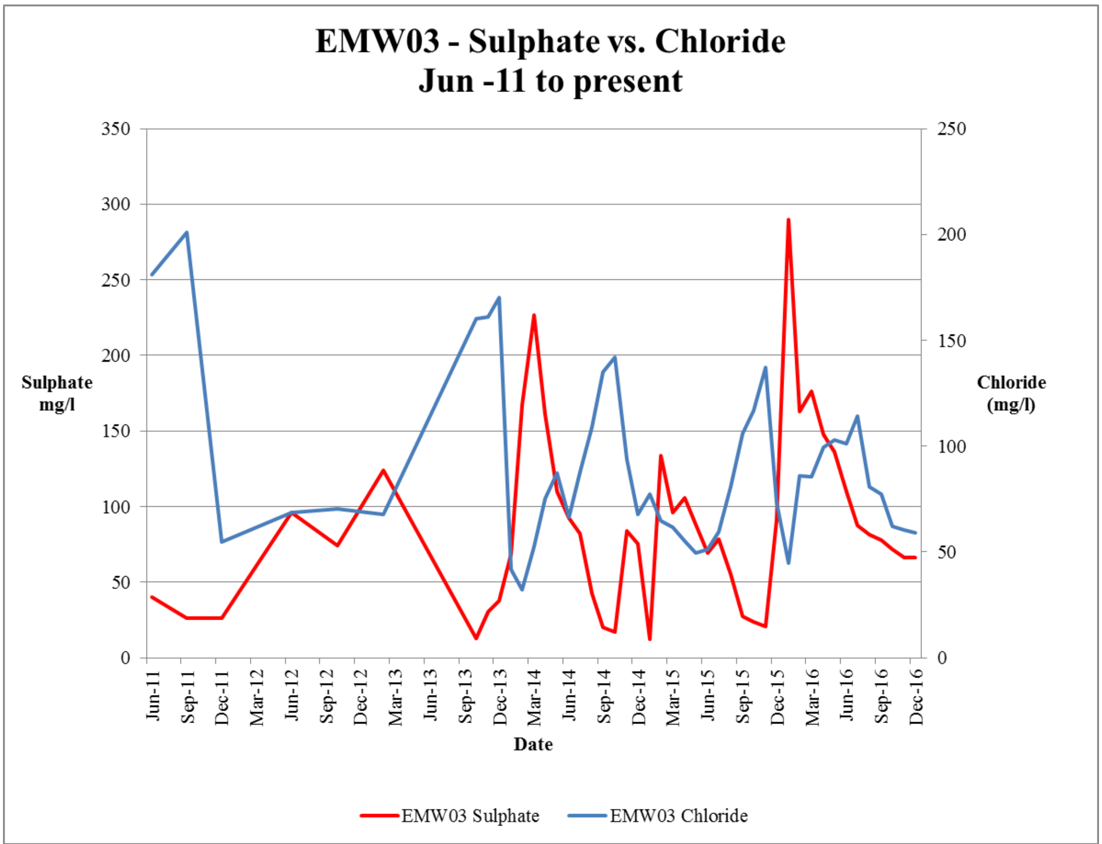
There was a slight increase in the sulphate concentration recorded in Foley's Field well EMW29, with the concentration increasing to 88.3 mg/l in December 2016 from 79.9 mg/l in November. In the other Foley's Field well, EMW28, the sulphate concentration also increased slightly to 18.1 mg/l from 17.2 mg/l. The other wells in Foley's fields both had sulphate concentrations significantly below the IGV, as has always been the case. There was very little change when compared to the previous round of sampling in June 2016.

In Palmerstown Golf Course all three wells had sulphate concentrations significantly below the IGV, as has always been the case here since monitoring began. Both EMW31 and EMW32 however recorded their highest ever sulphate concentrations in December 2016, at 30.8 mg/l (up from less than 4.4 mg/l in June) and 24.6 mg/l (up from 15.2 mg/l in June) respectively.

Sulphate v Chloride

As noted above, low sulphate concentrations may be indicative of landfill leachate as sulphate is reduced to sulphide. As such, an increase in parameters such as chloride and a reduction in sulphate concentrations may indicate the presence of landfill leachate and comparing the two determinands may show impacts from leachate. In EMW03 and EMW13, there has been an observed seasonal change when concentrations of sulphate are compared to chloride as can be seen in Graphs 2.19 and 2.20.

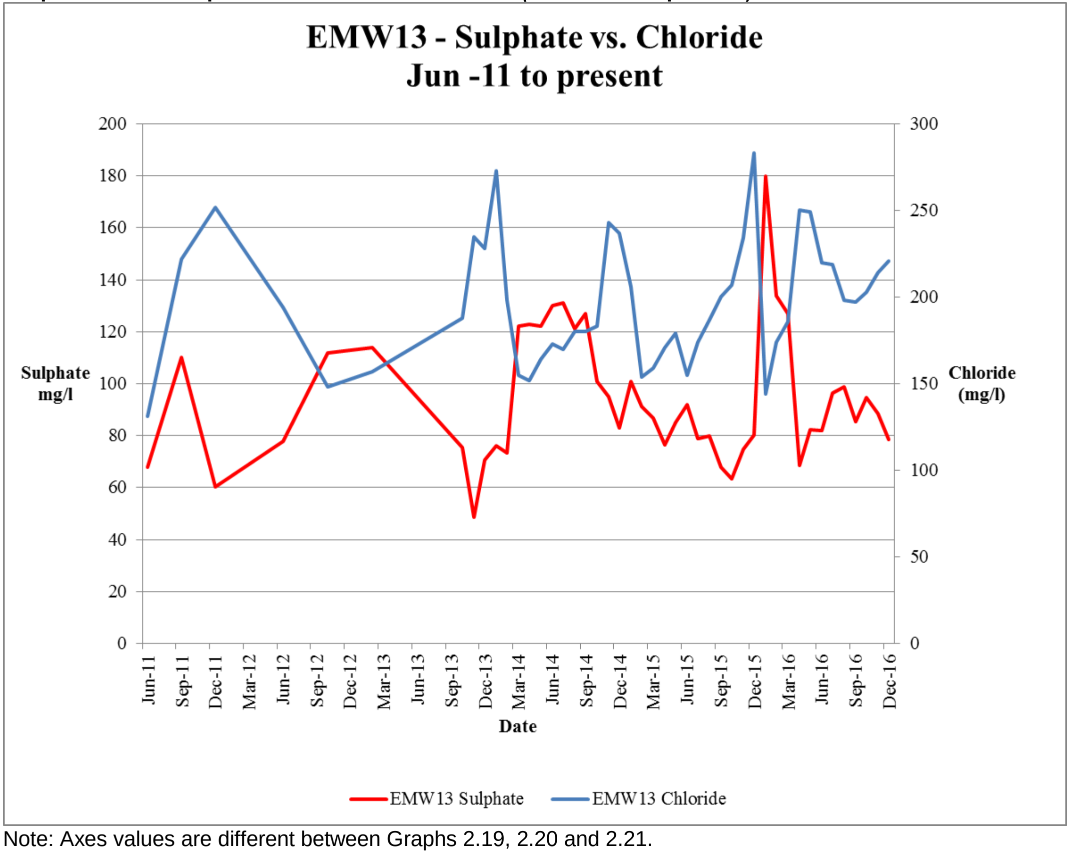
Graph 2.19: Sulphate and Chloride in EMW03 (June 2011 to present)



Note: Axes values are different between Graphs 2.19, 2.20 and 2.21.

In EMW03 during December 2016, there was little variation in both chloride and sulphate concentrations from November as shown below in Graph 2.19. However, on most occasions, as chloride concentrations increase, sulphate concentrations do decrease indicating impacts from landfill leachate at this location. The relationship is most pronounced from 2013 to 2015 and in 2016, both chloride and sulphate concentrations have shown a general decrease since June (this may relate to the relatively low rainfall that has occurred in the second half of 2016). However, the relative difference has decreased and it is likely that into 2017 sulphate concentrations will show an increase as has been observed in previous winters whilst chloride concentrations continue to decline.

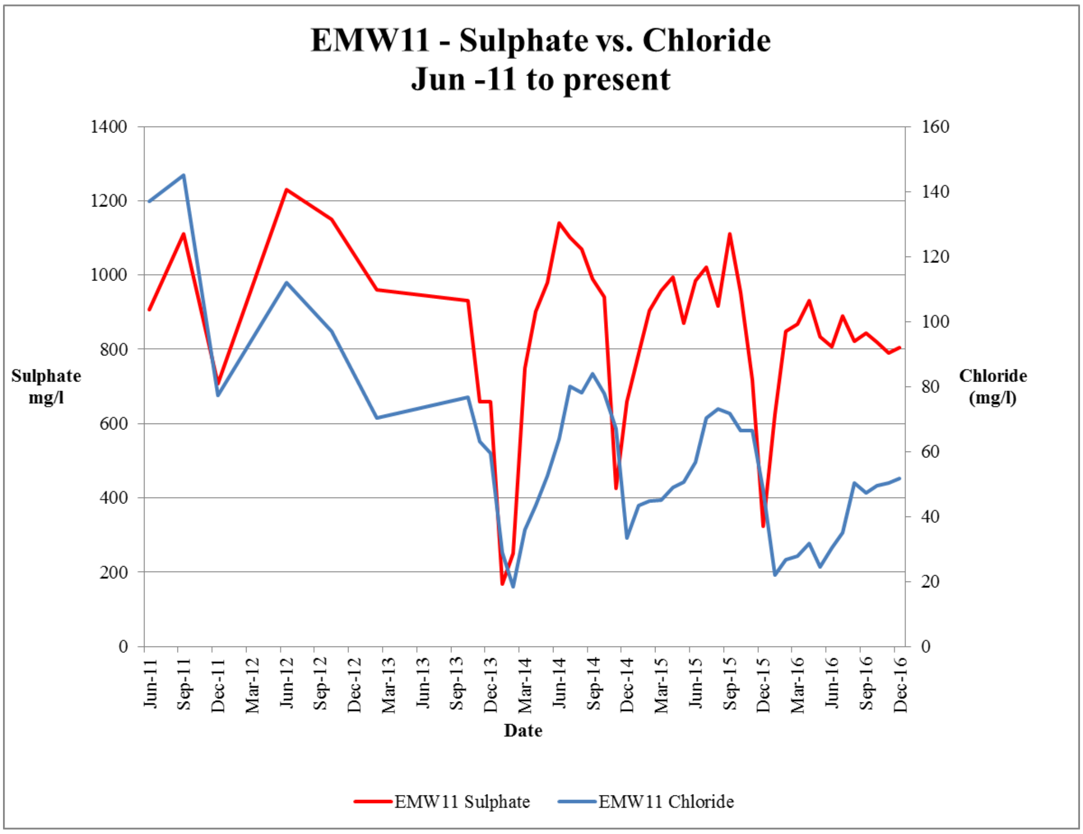
Graph 2.20: Sulphate and Chloride in EMW13 (June 2011 to present)



Note: Axes values are different between Graphs 2.19, 2.20 and 2.21.

In EMW13 a similar pattern to EMW03 is seen although not as pronounced. In December 2016 in EMW13 it is seen that the concentration of sulphate decreased whilst chloride increased as seen in Graph 2.20. This is a continuation of the trend in November which was a return to the inverse relationship normally seen in this well which wasn't so apparent earlier in the year.

Graph 2.21: Sulphate and Chloride in EMW11 (June 2011 to present)



Note: Axes values are different between Graphs 2.19, 2.20 and 2.21.

In EMW11 there is normally no observed 'inverse' seasonal fluctuation between chloride and sulphate concentrations with concentrations generally showing the same relative increase/decrease over the monitoring period as shown in Graph 2.21. Both chloride and sulphate show the lowest concentrations during the winter when groundwater recharge (and dilution) is higher. EMW11 is unusual for the site as the groundwater from this well has very low chloride concentrations (for a groundwater affected by landfill leachate) but high sulphate concentrations. This would suggest that the source of contamination in this well is different from elsewhere on site, possibly due to different waste types in Zone 2A to the rest of the site (high sulphate concentrations can be associated with construction-type wastes such as gypsum-based plasterboard).

Sulphide

As noted above, under reducing conditions, sulphate may be reduced to sulphide. Sulphide analysis is undertaken as part of the six monthly testing and in December 2016, sulphide was detected in nineteen boreholes.

On-Site Wells

Six boreholes where sulphide was detected were situated on site, with the highest concentrations detected in the southern part of the site. BH7 recorded a very high concentration of 9.9 mg/l, the highest ever in this well and of any of the wells monitored in December and a significant increase on the June result of 0.503 mg/l. BH42 also recorded an increase in sulphide concentration, albeit much less pronounced, from 0.076 mg/l in June 2016 to 0.14 mg/l. This was slightly below the peak for this well of 0.145 mg/l.

There was also sulphide detected in the eastern part of the site in EMW16 and EMW17 (0.112 mg/l and 0.024 mg/l respectively). This is the first time that sulphide has been detected in EMW17. Sulphide was also detected in two wells near the centre of Zone 1, at BH26 and BH36 (0.026 mg/l and 0.274 mg/l respectively).

Sulphide detection is not unusual in either well, however in the case of BH36, the sulphide concentration was at its highest concentration ever recorded here, up from 0.149 mg/l in June 2016.

Boundary Wells

Four of the boundary wells had sulphide detections, with three of these located near each other along the eastern site boundary with Kerdiffstown House; namely EMW03 (0.241 mg/l), EMW04 (0.103 mg/l) and EMW06 (0.067 mg/l). In the case of EMW03, there has been an increasing trend in sulphide concentration following on from 0.199 mg/l in June 2016 up to the new high for this well of 0.241 mg/l. EMW06, north of EMW03, also recorded its highest ever sulphide concentration in December 2016, the first time that sulphide has been detected above the limit of detection of 0.02 mg/l in this well since monitoring began. In contrast, the EMW04 sulphide concentration dropped from June's 0.435 mg/l.

The boundary well EMW24, at the northernmost site boundary, had a sulphide concentration of 0.3 mg/l, an increase on June 2016 (less than 0.2 mg/l), but significantly below the peak for this well of 1.06 mg/l.

Off-Site Wells

Four boreholes within the grounds of Kerdiffstown House had sulphide detections as follows: EMW02 (0.107 mg/l); EMW05 (0.04 mg/l), located between the site and the Morell River; the bedrock well EMW22 (0.059 mg/l) and the overburden well EMW23 (0.02 mg/l) located behind the house, north of the site. In the case of EMW02, December's recorded concentration was the highest ever for this well, increasing from below the limit of detection of 0.02 mg/l in June 2016. Concentrations in this well have been seen to fluctuate between the limit of detection and 0.089 mg/l in the past, with the previous peak recorded in August 2015.

The other five boreholes in which sulphide was detected were located off-site and away from Kerdiffstown House, with the highest detection in off-site wells being in EMW27 south-west of the site at 4.34 mg/l. EMW27 had the highest concentration in the previous round in June 2016, with this December result being the highest ever recorded in this well, up from June's 0.88 mg/l. Adjacent well, EMW28, also recorded an increase in sulphide from below 0.02 mg/l in June 2016 to 0.097 mg/l, the highest concentration here since 0.619 mg/l was detected in October 2012. In the other Foley's field, to the south-east of the site, sulphide was detected in EMW30 at 0.064 mg/l, an increase on June's less than 0.02 mg/l but significantly below the peak concentration of 0.247 mg/l in October 2012.

Two of the Palmerstown Golf Course wells recorded sulphide concentrations, these being EMW32 and EMW33, at 0.026 mg/l and 0.023 mg/l respectively. EMW32 recorded a decrease on the previous round's peak of 0.283 mg/l, while EMW33 saw an increase in concentration from below the limit of detection although still remaining below the peak for this well of 0.049 mg/l recorded in August 2015. Sulphide was not detected at EMW31 following the highest concentration recorded at this well in June 2016.

Arsenic

In certain types of wastes when the pH is low the solubility of many metal and metalloid ions increases and they can become mobilised into the developing leachate. As such, elevated concentrations of trace metals can be indicative of leachate contamination within groundwater. Arsenic has previously been identified in the groundwater above the IGV concentration and is therefore included in the monthly analytical suite. In December 2016 there were a number of exceedances of the IGV (10 µg/l) and GTV (7.5 µg/l) for arsenic as shown in Table 2.3.

Table 2.3: December 2016 Arsenic Exceedances

	GTV	IGV	November 2016
On-Site Wells			
EMW13	7.5 µg/l	10 µg/l	13 µg/l
EMW15			31 µg/l
BH6			35 µg/l
BH7			15 µg/l
BH26			22 µg/l
BH36			23 µg/l
BH42			11 µg/l
Boundary Wells			
EMW03	7.5 µg/l	10 µg/l	15 µg/l
EMW07			16 µg/l
EMW19			14 µg/l
Off-Site Wells			
EMW27	7.5 µg/l	10 µg/l	56 µg/l
EMW28			27 µg/l
EMW33			27 µg/l

Exceedance of the IGV is common for the wells listed in Table 2.3. The concentration in EMW08 has continued to decrease since the all-time high of 84 µg/l in January 2016 and is now at 2.5 µg/l staying below the IGV and GTV for an eighth consecutive month. The concentration in EMW15 has been gradually increasing over the past six months, with the December 2016 concentration of 31 µg/l an all-time high for this well (the previous high concentration though was only marginally below this at 30 µg/l). On-site well BH42 exceeded the IGV for the first time since April 2016, when the value was also 11 µg/l. However, this is still below the peak for this well of 14.2 µg/l in October 2012. The arsenic concentration in EMW03 has increased slightly to 15 µg/l, following a decrease in November to 10 µg/l. A pattern of rise and fall has been observed previously in relation to arsenic concentrations in EMW03.

One exception however is BH6, where the IGV was exceeded for the first time ever in this well since monitoring began here. The December concentration of 35 µg/l was the highest ever recorded in this well and represents a 33.3 µg/l increase on June 2016 when the lowest ever concentration for the well was recorded.

Potassium

Potassium occurs naturally in groundwater but is also a constituent of landfill leachate. The IGV for potassium has been established at 5mg/l. Graph 2.22 illustrates the concentrations that have been recorded in the overburden monitoring wells.

On-Site Wells

In December 2016, the highest concentration of potassium was observed in on-site boundary well EMW13 with a result of 82.4 mg/l, significantly above the IGV of 5 mg/l. This compares to a concentration of 82.9 mg/l recorded during November 2016. Elevated concentrations have been consistently observed in this location since June 2011.

Concentrations of potassium also exceeded the IGV in on-site monitoring wells EMW11 (44.1 mg/l), EMW15 (30.2 mg/l), EMW16 (15.8 mg/l), BH26 (53.6 mg/l) and BH42 (16.1 mg/l). In all of these wells IGV exceedances in potassium are regularly recorded. In EMW12, fluctuating potassium concentrations have been observed since monitoring began ranging from 1.92 mg/l to 6.95 mg/l. Potassium concentrations had been trending upwards since November 2015, when concentrations rose from 3.3 mg/l to the high of 6.95 mg/l in February 2016. Potassium concentrations have since fallen, but in December 2016 the concentration increased slightly over the previous month to 4.47 mg/l, from 3.71 mg/l while still remaining below the IGV.

Of the biannually monitored on-site wells, both BH6 and BH7 recorded potassium concentrations above the IGV at 13.7 mg/l and 21 mg/l respectively. Both of these wells have consistently recorded concentrations above the IGV. For BH6, a reduction in concentration has been observed from the previous result of 36.6 mg/l in June 2016, with December's concentration being the lowest ever recorded in this well. The concentration in well BH7 is consistent with previous results; in June 2016 a concentration of 19.5 mg/l was recorded, with the range previously recorded here between 11.2 mg/l and 25 mg/l.

Boundary Wells

Concentrations of potassium also exceeded the IGV (5 mg/l) in boundary monitoring wells EMW03 (18.5 mg/l), EMW19 (6.74 mg/l), EMW04 (15.3 mg/l) and EMW07 (11.3 mg/l). Concentrations in EMW03 have consistently exceeded the IGV and there has been a generally decreasing trend following a high of 50.1 mg/l in November 2015. The December 2016 concentration is the lowest for this well since monitoring began here.

For the bedrock monitoring well EMW19, the concentration fell for the third consecutive month decreasing from 9.07 mg/l in November 2016. The concentration of potassium at EMW19 had been observed to rise month on month to above the IGV of 5 mg/l in September 2014 at 6.72 mg/l (Graph 2.23). Concentrations subsequently fell to below the IGV. However, concentrations had been increasing again from 1.48 mg/l in December 2015 and in April 2016 the concentration rose above the IGV to 5.64 mg/l, with the rise continuing to 11.3 mg/l in September 2016, the highest level recorded in this well since monitoring began. With concentrations falling again, this pattern of rise and fall is likely an example of a seasonal fluctuation.

Concentrations in EMW04 are consistently above the IGV and show a fluctuating trend, the previous recorded concentration was 21 mg/l in June 2016. For EMW07, the June 2016 result of 16.5 mg/l was the first time the IGV had been exceeded in this well since July 2014 (16.7 mg/l). The December result was a slight decrease from June 2016.

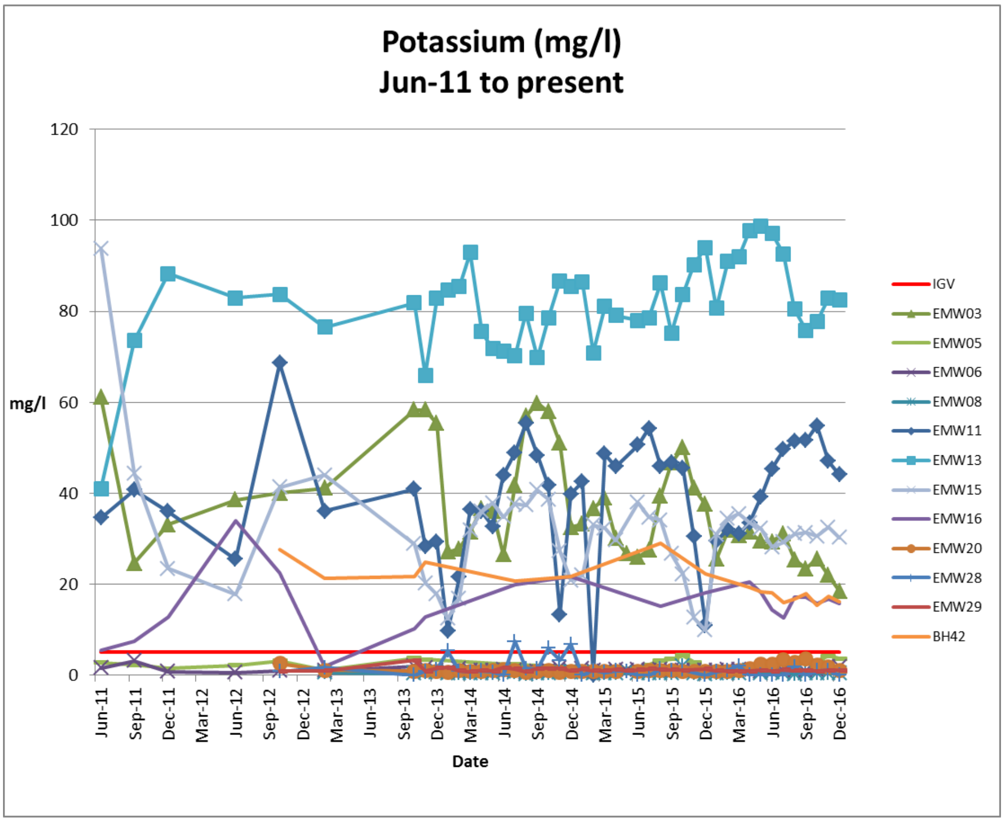
At EMW24, at the northern boundary, potassium was not detected above the limit of detection of 1.8 mg/l, a significant decrease on the June 2016 concentration of 7.83 mg/l, which was the first time the IGV of 5 mg/l had been exceeded in this well.

Off-Site Wells

The IGV was exceeded in two of the off-site wells consistent with previous results in June 2016. These were Kerdiffstown House well EMW23 at 11.7 mg/l, a slight increase from 10.9 mg/l in June, and a similar slight increase at Palmerstown Golf Course well EMW32, up to 6.73 mg/l from 5.55 mg/l recorded in June. In both cases they were within their previously recorded ranges of 10.9 mg/l to 14.2 mg/l and 1.86 mg/l to 45.7 mg/l respectively.

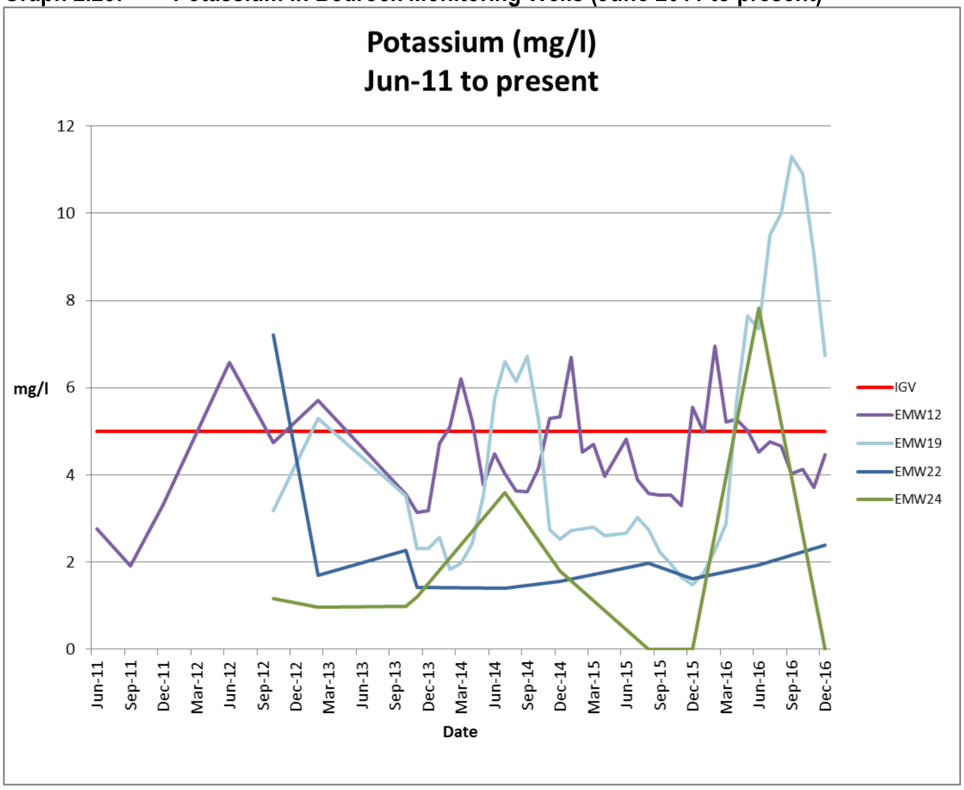
As was the case in November, and has generally been the case in past monitoring rounds, there were no other off-site wells where the potassium concentration exceeded the IGV in December 2016, with the highest value being 3.68 mg/l in EMW05 which is a decrease from November's concentration of 4.23 mg/l.

Graph 2.22: Potassium in Overburden Monitoring Wells (June 2011 to present)



Note: Axes values are different between Graphs 2.22 and 2.23.

Graph 2.23: Potassium in Bedrock Monitoring Wells (June 2011 to present)



Note: Axes values are different between Graphs 2.22 and 2.23.

Total Organic Carbon (TOC)

Total organic carbon (TOC) is one of the key parameters that are tested on landfill sites such as Kerdiffstown to establish the overall organic content of leachates and groundwater. There is no guideline value assigned for TOC other than 'there should be no abnormal change in recorded concentrations'. The results are presented in Table A.5.

In December 2016, BH26 in Zone 1 again recorded the highest TOC concentration at 103 mg/l. This is consistent with previous high TOC results for this well with a concentration of 106 mg/l recorded in November. High TOC concentrations have also been observed at on-site well EMW13 which is situated close to BH26 to the north west of the site. A TOC concentration of 80 mg/l was recorded in December 2016 which is within the typical range for this well which has fluctuated between 30.9 mg/l and 124 mg/l in the past. These would be viewed as abnormal given the likely background concentrations of <10 mg/l as recorded in several other boreholes.

The TOC value recorded at boundary well EMW03 during December was noted to be 12.3 mg/l. At EMW03, the TOC concentration tends to fluctuate with a marked decrease observed in January 2014 (11.6 mg/l); concentrations subsequently increased up to October 2014 (49.1 mg/l) albeit with a small fall recorded in June 2014. Since June 2015 there was a rise in concentration from around 14 mg/l with the concentration in November 2015 observed at 56 mg/l. From November 2015 to January 2016 the concentration fell again to 14 mg/l. However, the TOC concentration was largely stable from February to July 2016 (range of 25.5 to 30 mg/l) before falling to the current concentration.

TOC concentrations in bedrock monitoring wells EMW12 and EMW19 recorded during December 2016 were relatively low at 2.4 mg/l and 5.1 mg/l respectively, both slight reductions on November's concentrations.

TOC concentrations in the biannually monitored wells were all relatively low at between 0.8 mg/l (GW1D and EMW22) and 12.7 mg/l (BH36B), which are typical of the biannually monitored wells.

Biochemical Oxygen Demand (BOD)

When biodegradable organic matter (including organic waste) is present in waters it provides nutrients for the growth of bacteria and other microorganisms causing them to multiply and, where bacterial numbers are sufficient causing a depletion of dissolved oxygen in the water. The BOD (5 day) test is a measure of the amount of oxygen consumed by microorganisms in breaking down the organic matter.

All of the results are presented in Table A.5. BOD values in the monitoring wells are presented in Table 2.4 for those wells that were above the applicable[12] LOD. 19 of the 34 wells sampled recorded BOD values above the LOD in December 2016.

In December 2016 the highest concentration was recorded in EMW33 at 54 mg/l. This is unusual for this well, having recorded BOD concentrations of 3 mg/l or less during the past sampling rounds. All other wells had concentrations of 10 mg/l or less, as has generally been seen in the past.

[12] The laboratory adjusts the applicable LOD depending on the dilution factor required as a result of interference in the sample such as silt of high chloride.

Table 2.4: December 2016 BOD Detections

Monitoring Well	December 2016
On-Site Wells	
EMW11	2 mg/l
EMW13	10 mg/l
EMW15	1 mg/l
EMW16	1 mg/l
EMW17	1 mg/l
BH6	2 mg/l
BH7	1 mg/l
BH26	10 mg/l
BH36	2 mg/l
BH42	2 mg/l
GW2S	1 mg/l

Monitoring Well	December 2016
Boundary Wells	
EMW24	2 mg/l

Monitoring Well	December 2016
Off-Site Wells	
EMW05	3 mg/l
EMW21	1 mg/l
EMW22	2 mg/l
EMW23	2 mg/l
EMW28	2 mg/l
EMW31	4 mg/l
EMW33	54 mg/l

Cyanide

Cyanide is a reactive, highly toxic entity which in excessive amount will cause mortality rapidly to humans and to fish. Cyanide was not detected above the limit of detection (0.009 mg/l) in any of the monitoring wells in December 2016. In most cases the cyanide concentration has been below the limit of detection. It has, however, in the past been detected above the limit of detection in BH26 at concentrations of 0.012 mg/l in December 2014 and at 0.01mg/l in July 2015, in EMW11 at concentrations of 0.135 mg/l in June 2014 and 0.016 mg/l in February 2015, and in EMW03 at 0.027 mg/l in April 2016.

Trace Metals/Elements

In certain types of wastes when the pH is low the solubility of many metal ions increases and therefore they can become mobilised into the developing leachate. As such, elevated concentrations of trace metals can be indicative of leachate contamination within groundwater.

Results for trace metals and metalloids during December 2016 are presented in Table A.3. There were a number of exceedances of the respective IGVs/GTVs for these metals, which are summarised in Table 2.5 below.

Table 2.5: Trace Metal and Metalloid Exceedances in December 2016

Parameter	Lower of IGV/GTV (mg/l)	Number of exceedances	Maximum result (mg/l)	Location of maximum result
Arsenic	0.0075	13	0.056	EMW27 (off-site, Foley's Field))
Barium	0.1	21	2.32	BH6 (on-site)
Boron	0.75	5	5.04	BH7 (on-site)
Cadmium	0.00375	1	0.0217	BH7 (on-site)
Chromium	0.03	1	0.052	BH6 (on-site)
Copper	0.03	6	0.646	BH6 (on-site)
Lead	0.01	8	0.621	BH6 (on-site)
Mercury	0.0001	3	0.00123	EMW27 (off-site, Foley's Field)
Nickel	0.015	14	0.543	EMW27 (off-site, Foley's Field)
Zinc	0.1	4	1.860	BH6 (on-site)

Analytical results for dissolved metals in groundwater were broadly similar to those recorded in previous monitoring rounds, both in terms of the number of exceedances against IGVs and GTVs and the location of the exceedances.

The principal exception to this is BH6 and BH7, which accounted for seven of the ten highest results in Table 2.5. There were large increases in the concentrations in a number of metals in these wells in December2016 compared to the June monitoring round. They are both located in the lower yard in the south east of the site, where there were demolition works taking place at the time. These demolition works may account for some of the increases recorded in December. However, it should be noted that the boreholes had to be sampled with a bailer on this occasion rather than by low-flow pumping. Using a bailer is likely to create more sediment in the sample and even with filtering the finest particles will remain which would result in higher than normal metal concentrations.

As with the June 2016 results, EMW27 was the location for three of the maximum values recorded. The source of this contamination is unknown. Given the groundwater flow direction and metal concentrations identified elsewhere around the site the source does not appear to be landfill leachate and further detailed sampling on a regular basis may provide more data to determine the source.

Organic Compounds

Groundwater samples from all the monitoring wells included in the current monitoring round were analysed for a suite of VOCs, SVOCs, PAHs, TPH, phenols, formaldehyde, acid herbicides and organo-chlorine pesticides.

The results for organic compounds are summarised below and the data are shown in Table A.6.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAH results are shown in Table A.6a. In common with previous monitoring results, PAHs were detected at low to trace concentrations in a small number of monitoring wells including on-site monitoring wells EMW11, EMW12, BH6, BH36 and BH42. As with the June 2016 monitoring, no PAHs were detected in BH26 which is only the second time since November 2013. The highest total PAH concentration reported was 3.71 µg/l in EMW29 located in Foley's Field, south of the site. PAHs are consistently detected at this well, with this being the highest total PAH concentration ever recorded here and representing an increase over the June 2016 concentration of 0.077 µg/l.

In overall terms, concentrations of PAHs detected in groundwater in on and off-site monitoring wells were similar to those in previous monitoring rounds. There are some exceptions, namely off-site and boundary wells EMW05, EMW06, EMW21, EMW22 and EMW24; and on-site well EMW17, all of which recorded their first detections of PAHs during December 2016.

PAHs were detected in the following monitoring wells:

Total PAHs (µg/l) December 2016								
On-Site Wells			***Boundary Wells***			***Off-Site Wells***		
EMW11	0.03		EMW03	0.034		EMW02	0.07
EMW12	0.173		EMW04	0.02		EMW05	0.072
BH6	0.01		EMW06	0.203		EMW08	0.32
BH36	0.422		EMW24	0.031		EMW21	0.023
BH42	0.469					EMW22	0.014
						EMW27	0.143
						EMW28	0.162
						EMW29	3.71
						EMW30	0.042
						EMW32	0.084

Total Petroleum Hydrocarbons (TPH)

TPH (as measured by the VPH/EPH C5-C44 analysis) is reported in the majority of monitoring boreholes to be below the limit of detection. TPH was detected in only one sample, namely EMW28 (off-site in Foley's Field) at 17 µg/l.

Semi Volatile Organic Compounds (SVOCs)

Excluding phenols (see below for consideration of phenolic compounds), SVOCs were absent in the groundwater samples.

Trace concentrations of target list compounds have been detected in past monitoring rounds in on-site monitoring wells. However, in all cases they have been reported close to the limit of detection and to date no compounds have been reported consistently at elevated concentrations in any of the monitoring wells monitored.

Volatile Organic Compounds (VOCs)

As with the SVOCs, VOCs were generally absent in the groundwater samples. Chloroform was detected in northern boundary well EMW24 at a concentration of 1.44 µg/l. Chloroform has previously been detected at this monitoring well at similar trace concentrations. Toluene was detected in two wells; EMW08 at 0.59 µg/l and EMW13 at 0.51 µg/l. This is the first time that toluene has been detected in both wells. Previously toluene was detected at Kerdiffstown House wells EMW02 at 1 µg/l, and EMW07 at 1.6 µg/l, but no toluene was detected in these wells for this monitoring round.

Phenolic Compounds

Phenol (identified within the SVOC suite) was reported above analysis detection limits in the following four on-site/boundary monitoring wells:

EMW04 Phenol = 4.3 µg/l EMW07 Phenol = 2.3 µg/l

EMW15 Phenol = 1.2 µg/l EMW12 Phenol = 2.5 µg/l

With respect to the speciated phenol analysis which is undertaken during the biannual sampling, phenolic compounds were identified in 7 of the 33 samples. Figure 10 shows an overview of the distribution of speciated phenols during December 2016. The highest total phenol concentration from the speciated analysis was for monitoring well EMW13 within the Zone 1 landfill at 98 µg/l. Phenols have been detected in this borehole on all sampling occasions and this well also recorded the highest phenol concentration in the June 2016 sampling round at 90 µg/l. The speciated analysis showed that trimethylphenols were the dominant species at 78 µg/l in this monitoring well.

Analysis results from earlier monitoring rounds have indicated the presence of phenolic compounds in on-site monitoring wells at similar concentrations to those identified in December 2016. However, in December 2016, the total speciated phenol concentration in BH26, while up on June's 5.2 µg/l to 36 µg/l, is still significantly lower than the high recorded here at 230 µg/l in August 2015. As with the June monitoring, no phenols were detected above the limit of detection at BH42. There were no phenols detected in BH36 in December after detection in June 2016 for the first time since July 2014. There was no phenol detected in off-site well EMW08 in December 2016, following detection for the first time in June 2016. The only off-site well where phenol was detected was in EMW27, in Foley's Field at a concentration of 3.2 µg/l. This was the first time that phenol has been detected above the limit of detection of 0.5 µg/l in this well.

Formaldehyde

During the current round of monitoring, formaldehyde was detected in a total of seven monitoring wells: on site in the following four wells; EMW13 (0.053 mg/l), EMW15 (0.143 mg/l), BH6 (0.136 mg/l) and BH26 (0.103 mg/l); at the site boundary in EMW07 (0.063 mg/l) only; and off-site in the following two wells; EMW28 (0.035 mg/l) and EMW31 (0.857). In this round EMW31 has the highest concentration, which is consistent with previous results, although no formaldehyde was detected in this well in June 2016.

Herbicides & Pesticides

The groundwater samples were analysed for a standard suite of acid herbicides and organo-chlorine pesticides. In December, three of the four compounds typically detected were detected above the respective laboratory detection limits. These are shown below and Figure 11 provides an overview of the distribution of mecoprop on and off site during December 2016.

Mecoprop is an active ingredient in many broadleaf weed killers and has previously been detected in past monitoring events. For the December 2016 monitoring round, concentrations in excess of the IGV of 10 µg/l are reported at two locations (EMW13 at 14.4 µg/l and BH26 at 28.6 µg/l) with concentrations above analysis detection limits in 15 of the groundwater samples analysed, including some from the off-site monitoring wells close to the north-eastern site boundary.

Off-site and in boundary wells, mecoprop was not detected above the IGV in any samples with the highest concentration being 1.62 µg/l in EMW03 along the north eastern boundary. Mecoprop was also detected in monitoring well EMW05 and EMW20, both adjacent to the Morell River. EMW05 had a concentration of 0.5 µg/l, an increase on 0.35 µg/l recorded in June 2016, and the highest concentration since July 2014 (0.63 µg/l). EMW20 had a mecoprop concentration of 0.04 µg/l, a decrease on the June 2016 concentration of 0.33 µg/l (the highest ever recorded at this well).

Dichlobenil is also used for weed control. Consistent with previous results, it was reported at trace concentration in four groundwater samples; specifically off site monitoring well EMW04 recorded a concentration 2 ng/l. On site in near boundary monitoring well EMW13 a concentration of 27 ng/l was recorded (below the IGV/GTV of 100ng/l). Also on site in Zone 1, BH26 recorded a concentration of 4 ng/l and in Zone 4 BH6 recorded a concentration of 56 ng/l.

Another compound, dieldrin, was detected in BH6 at a concentration of 7 µg/l during December 2016 (this compound has been detected in this monitoring well on previous occasions). A common use of dieldrin was as a soil insecticide prior to 1970. There is no IGV associated with dieldrin.

It should be noted that chlopyralid was not detected in any well during December 2016 having been detected in June 2016 at on-site borehole BH2 at a concentration of 0.06 µg/l, below the IGV of 0.1 µg/l. This broadleaf weed killer had been detected previously in this well.

2.2.2.2 Comparison of Results against Proposed DQRA Trigger Levels

The analytical results collected over the past 12 months have been compared to the trigger levels presented in the November 2014 groundwater DQRA report. Trigger levels were proposed in the DQRA for a small number of determinands in a small number of wells. These trigger levels have not been formally adopted in any licence or other regulatory document. Trigger levels were not exceeded in any of the wells as shown in Table 2.6. This is the first month since March 2016 that trigger levels for chloride and ammoniacal nitrogen were not exceeded in EMW20.

Table 2.6: Comparison of December 2016 Results against DQRA Trigger Levels

Determinand	Concentration (Last 12 months) (mg/l)		Concentration (mg/l) (December 2016)	Trigger Level (mg/l)	Comment
	Min	Max			
EMW02					
Chloride	<3.7	14.1	7.6	50.5	Monitored three times since December 2015; no exceedances
Ammoniacal nitrogen	<0.06	<0.06	<0.06	1.3	Monitored three times since December 2015; no exceedances
Phenol	<0.0001	**0.00015**	<1e-4	0.0001	Monitored three times since December 2015; one exceedance in **December 2015**
Mecoprop	<4e-5	<4e-5	<4e-5	0.00018	Monitored three times since December 2015; not detected above limit of detection
EMW03					
Chloride	44.6	114	59.3	237.7	Monitored monthly; no exceedances
Ammoniacal nitrogen	<0.06	47	23.8	130.7	Monitored monthly; no exceedances
Phenol	<0.0001	**0.00078**	<0.0001	0.0001	Monitored three times since December 2015; one exceedance in **December 2015**
Mecoprop	0.00162	0.00306	0.00162	0.032	Monitored three times since December 2015; no exceedances
EMW05					
Chloride	7.6	29.1	24.8	57.3	Monitored monthly, no exceedances
Ammoniacal nitrogen	<0.06	1.58	1.45	3.7	Monitored monthly, no exceedances
Phenol	<1e-4	<1e-4	<1e-4	0.00028	Monitored three times since December 2015; not detected above limit of detection

Determinand	Concentration (Last 12 months) (mg/l)		Concentration (mg/l) (December 2016)	Trigger Level (mg/l)	Comment
	Min	Max			
Mecoprop	5e-5	0.0005	0.0005	0.00153	Monitored three times since December 2015; no exceedances
EMW08					
Chloride	4.8	12.3	8.6	15.4	Monitored monthly; no exceedances
Ammoniacal nitrogen	<0.06	**0.62**	<0.06	0.4	Monitored monthly; one exceedance: **April 2016**
Phenol	<1e-4	**0.00053**	<1e-4	0.0001	Monitored three times since December 2015, one exceedance in **June 2016**
Mecoprop	<4e-5	<4e-5	<4e-5	0.00004	Monitored three times since December 2015, not detected above limit of detection
EMW20					
Chloride	15.5	**39.1**	19.5	22.6	Monitored monthly; 8 exceedances: **April, May, June, July, August, September, October, November 2016**
Ammoniacal nitrogen	0.94	**3.06**	1.06	1.4	Monitored monthly; 7 exceedances: **April, May, June, July, August, September, October, November 2016**
Phenol	<1e-4	<1e-4	<1e-4	0.0001	Monitored three times since December 2015; no exceedances.
Mecoprop	<4e-5	**0.00033**	4e-5	0.00023	Monitored three times since December 2015; one exceedance in **June 2016**
EMW21					
Chloride	<3.7	7.1	4.1	32.4	Monitored three times since December 2015; no exceedances
Ammoniacal nitrogen	<0.06	<0.06	<0.06	0.3	Monitored three times since December 2015; no exceedances
Phenol	<1e-4	<1e-4	<1e-4	0.0119	Monitored three times since December 2015; not detected above limit of detection
Mecoprop	<4e-5	<4e-5	<4e-5	0.00014	Monitored three times since December 2015; not detected above limit of detection

2.2.3 Laboratory Analytical Results – Surface Water

In December 2016, grab water samples were collected from the Morell River, canal feeder and Palmerstown Golf Club estate at a total of fifteen locations upstream and downstream of the landfill (as shown on Figure 3) in order to assess any changes in water quality as a result of leachate generated from the waste materials on site. A sample of water from the site's surface water runoff discharge pipe was also collected.

The samples were analysed for the same suite of analytes as the groundwater samples including major ions, metals/metalloids and organic compounds. The inorganic results are presented in Table A.4. Results of analysis of COD, BOD and TOC are presented in Table A.5. The majority of the organic determinands are presented in Table A.6 whilst Table A.6a presents the results from analyses of PAHs detected in surface water samples.

Data obtained from the EPA's HydroNet shows that on the day of sampling, the flow in the Morell River was 0.329 m^3/s. On the basis of the historical data (2009 to 2016), this is equivalent to a Q94 flow (i.e. the flow that is exceeded 94% of the time), indicating a low flow in the river at the time of sampling.

Ammoniacal Nitrogen

Morell River

As seen in Table 2.7, ammoniacal nitrogen was not detected above the limit of detection (LOD) (0.06 mg/l) in any sample taken from the Morell River during December 2016. This has consistently been the case since monitoring began here.

Canal Feeder

Ammoniacal nitrogen levels have been elevated at SW13 since monitoring commenced in October 2013. A concentration of 3.48 mg/l was detected in December 2016, an increase from 0.06 mg/l in November. This is the highest concentration seen here since July 2015. Ammoniacal nitrogen was below the LOD in all other canal feeder samples except for SW10 (downstream of the site discharge pipe) where 0.38 mg/l was detected which is within the typical range of fluctuation at this location. In June 2016 the sample from SW10 was below the LOD but in December 2015 the concentration was 0.37 mg/l. The site discharge sample was below the LOD, where concentrations tend to fluctuate month on month. Downstream locations SW11 and SW12 were below the LOD as is generally the case at these monitoring locations.

Palmerstown Golf Course

Samples taken from the watercourses on the PGC, namely two golf course lakes and the Hartwell River, showed low concentrations in the two downstream samples (maximum of 0.2 mg/l). The results at these two locations were similar to the June 2016 round of monitoring, with both being well below their respective peaks of December 2014 (0.5 mg/l in SW07 and 0.6 mg/l in SW14). Ammoniacal nitrogen was not detected above the limit of detection (0.06mg/l) in the upstream samples or samples taken from adjacent to the site.

Table 2.7: December 2016 Surface Water Ammoniacal Nitrogen Results

Water Body	Sampling Location	Ammoniacal Nitrogen (mg/l) December 2016	Orientation from site
Morell River	SW01	<0.06	Upstream SE
	SW02	<0.06	Upstream E
	SW03	<0.06	Adjacent E
	SW04	<0.06	Adjacent E
	SW05	<0.06	Downstream NE
Canal Feeder	SW13	**3.48**	Upstream S
	Site Discharge	<0.06	Adjacent to S
	SW10	**0.38**	Downstream S
	SW11	<0.06	Downstream SW
	SW12	<0.06	Downstream SW
Watercourse on PGC	SW16	<0.06	Upstream SE (Hartwell)
	SW08	<0.06	Upstream SE (Hartwell)
	SW06	<0.06	Adjacent E (Lake)
	SW15	<0.06	Adjacent E (Lake)
Watercourse on PGC	SW14	**0.19**	Downstream NE (Lake)
	SW07	**0.2**	Downstream NE (Lake)

Major Ions

As discussed above, in terms of major ions, the presence of inorganic macro components which include commonly occurring cations and anions may be indicative of leachate generated from a landfill such as Kerdiffstown. The results for major ions in surface water samples were generally consistent with those observed since October 2013 with no indication of significant impact of leachate on the river quality.

Phosphate

Phosphates in surface waters can be from natural sources such as soils, but also man-made such as agricultural run-off and fertilisers. There is currently no EQS for total phosphate in surface waters.

Morell River

The Morell River continued to have phosphate concentrations below the limit of detection of 0.37 mg/l. Phosphate has never been detected at any of the monitoring points in the Morell River.

Canal Feeder

Phosphate was detected in the canal feeder during December 2016. Phosphate has been detected in all of the canal feeder monitoring points in the past. However, the concentrations measured in December were the highest ever for SW11, SW12 and SW13. The highest concentration was detected in SW13 where phosphate was measured at 2.45 mg/l, a large increase from the June 2016 concentration which was below the limit of detection, and marginally higher than the previous peak of 2.21 mg/l in August 2015.

Phosphate was also found downstream of the site in SW11 (at 0.64 mg/l) and SW12 (at 0.58 mg/l). In both cases this represents a large increase on the June round of monitoring with both having been below the limit of detection during that round. The phosphate concentration is also significantly above the previous peaks at both points, with both having previously peaked in December 2015 (SW11 at 0.16 mg/l and SW12 at 0.18 mg/l).

The large increase in phosphate here during this monitoring round may have been due to the weather conditions before and during the sampling. There had been a period of dry weather followed by heavy and persistent rain. This rain may have washed in pollutants which had built up on the surrounding roads and fields during the dry period.

Palmerstown Golf Course

All of the waterbodies sampled in the golf course had phosphate concentrations below the limit of detection. This has generally always been the case in these waterbodies.

TOC, COD and BOD

Results of TOC analysis are presented in Table A.5 and summarised below in Table 2.8.

The determination of TOC is complementary to the oxygen demand analyses (biochemical and chemical) discussed below and, in strict terms, it is a better indicator of organic content in that it is a direct measurement of carbon.

Morell River

TOC results were noted to vary slightly between 1 mg/l and 1.3 mg/l as the river passes the site as shown in Table 2.8. In December the TOC concentration upstream at SW01 was the highest at 1.3 mg/l, while the lowest was at SW05, downstream of the site at 1 mg/l. There is therefore a tentative indication of decreasing TOC concentrations from upstream to downstream, although all TOC concentrations were low as has been the case in previous monitoring rounds.

Canal Feeder

A particularly high TOC reading of 8.4 mg/l was detected at SW13 upstream of the site in December 2016. This compares with a more typical result of 2.5 mg/l as recorded in November 2016. This is the highest TOC in SW13 since November 2015 when a concentration of 10 mg/l was detected. The sample from SW13 was taken on December 13th, following a spell of rainfall the night/morning before which may have washed in organic matter from the nearby roads and fields and increased the TOC. This is similarly seen with other determinands such as chloride, which is often elevated at SW13 during the summer due to road salt being washed in to the canal feeder.

TOC in the canal feeder is usually found to rise between SW13 to SW10 past the outflow from the site. A TOC in December 2016 at SW10 of 4 mg/l is similar to that recorded at SW10 in June 2016 (4.4 mg/l), but is a decrease on the upstream value at SW13. In December the TOC concentration generally falls as the stream flows past the site, with SW11 at 4.2 mg/l and SW12 (the furthest downstream sample) having the lowest concentration at 2.6 mg/l.

Palmerstown Golf Course

TOC concentrations were consistent with previous monitoring rounds on the PGC Estate at between 1.5 and 3.5 mg/l.

Table 2.8: December 2016 Surface Water TOC Results

Water Body	Sampling Location	TOC (mg/l) December 2016	Orientation from site
Morell River	SW01	1.3	Upstream SE
	SW02	1.1	Upstream E
	SW03	1.1	Adjacent E
	SW04	1.1	Adjacent E
	SW05	1	Downstream NE
Canal Feeder	SW13	8.4	Upstream S
	Site Discharge	1.8	Adjacent to S
	SW10	4	Downstream S
	SW11	4.2	Downstream SW
	SW12	2.6	Downstream SW
Watercourse on PGC	SW16	3.5	Upstream SE (Hartwell)
	SW08	1.5	Upstream SE (Hartwell)
	SW06	2.8	Adjacent E (Lake)
	SW15	3.5	Adjacent E (Lake)
Watercourse on PGC	SW14	3.3	Downstream NE (Lake)
	SW07	3.4	Downstream NE (Lake)

BOD and COD

Results of BOD and COD analysis are presented in Table A.5 and summarised below in Table 2.9. The BOD concentrations in rivers often increase during periods of heavy rain and high river flows as organic matter is washed in from the land and farmyards.

Morell River

Results for the samples obtained from the Morell River in December 2016 were below the limit of detection of 1 mg/l, which is similar to the previous round. With respect to COD, and unlike the previous four rounds, the concentrations generally fell as the river flowed past the site. SW01 had a COD concentration of 13 mg/l, which increased to 18 mg/l at SW02, shortly after the inflow of the Hartwell. From SW03 to SW05 there was no COD detected above the LOD of 11 mg/l. This trend had more typically been seen in the Morell River prior to August 2016, with SW05 generally not having a COD above the applicable LOD.

Canal Feeder

The highest concentration of BOD (6 mg/l) in the canal feeder was recorded at SW13, upstream of the site discharge point. As with TOC, this was the highest at SW13 since November 2015. BOD was recorded as below the limit of detection (1 mg/l) in November 2016. The BOD was lower downstream of the site discharge with all results the same or reduced on the previous monitoring rounds.

Notably high COD concentrations were recorded at all monitoring points other that at the site discharge. At SW13, a concentration of 67 mg/l was recorded in December 2016 compared to 27 mg/l recorded in November. Elevated concentrations were also recorded at other locations. In all cases the COD concentrations were higher than the previous round of sampling. As with the TOC, this may be explained by relatively heavy rainfall the morning before and during sampling in the canal feeder.

Palmerstown Golf Course

All six PGC samples contained BOD concentrations at or below the limit of detection. COD results in the PGC samples were above the limit of detection (11 mg/l) except at SW07 at the most northerly sampling point in one of the lakes in PGC. This contrasts with the previous monitoring results in June 2016, where SW07 was the only site in PGC where a COD above the limit of detection was recorded.

Table 2.9: December 2016 Surface Water BOD & COD Results

Water Body	Sampling Location	BOD (mg/l)	COD (mg/l)	Orientation from site
		Dec-16	Dec-16	
Morell River	SW01	<1	13	Upstream SE
	SW02	<1	18	Upstream E
	SW03	<1	<11	Adjacent E
	SW04	<1	<11	Adjacent E
	SW05	<1	<11	Downstream NE
Canal Feeder	SW13	6	67	Upstream S
	Site Discharge	<1	<11	Adjacent to S
	SW10	<1	23	Downstream S
	SW11	2	32	Downstream SW
	SW12	2	41	Downstream SW
Watercourse on PGC	SW16	<1	12	Upstream SE (Hartwell)
	SW08	1	13	Upstream SE (Hartwell)
	SW06	<1	17	Adjacent E (Lake)
	SW15	1	21	Adjacent E (Lake)
Watercourse on PGC	SW14	<1	24	Downstream NE (Lake)
	SW07	<1	<11	Downstream NE (Lake)

Chloride

Morell River

An unusually elevated chloride concentration of 33.5 mg/l was detected at upstream location SW01 in December 2016 as shown in Table 2.10. This is the highest chloride concentration ever recorded at this location or at any of the Morell River locations. There had been cold conditions and some rain previous to the sampling in the river and the elevated chloride concentration may therefore be attributed to road salt being washed into the river. The chloride had reduced to more typical concentrations in SW02, just upstream of the site and shortly after the inlet of the Hartwell tributary.

There is typically very little variation in chloride concentrations in the Morell River when comparing upstream to downstream concentrations as indicated in Graph 2.24, and concentrations at the other sampling sites are similar to previous monitoring rounds. On most occasions the chloride concentration is marginally higher downstream than upstream, although this wasn't observed in December 2016.

Canal Feeder

Similar to the TOC and COD concentrations, the December results show some particularly elevated chloride concentrations at locations in the canal feeder. In particular, a chloride concentration of 70.2 mg/l at SW13 upstream of the site was recorded in December compared with 23.3 mg/l in November. This is likely to be caused by road salt being washed into the stream upstream of the site as has been seen in past winters.

In a reverse to the trend seen in recent months, the chloride concentration at SW13 was higher than downstream concentrations, with the concentration falling from 70.2 mg/l at SW13, to 56mg/l at SW10, to 52.6 mg/l at SW11 and 25 mg/l at SW12. This is the first time since April 2016 that the chloride concentration has been lower at SW11 than at SW13.

Palmerstown Golf Course

Concentrations of chloride for samples obtained from watercourses on the PGC Estate ranged from 18.6 mg/l to 22.9 mg/l which is approximately similar to previous rounds of sampling although slightly higher than the June 2016 results which ranged from 16.2 mg/l to 18.2 mg/l.

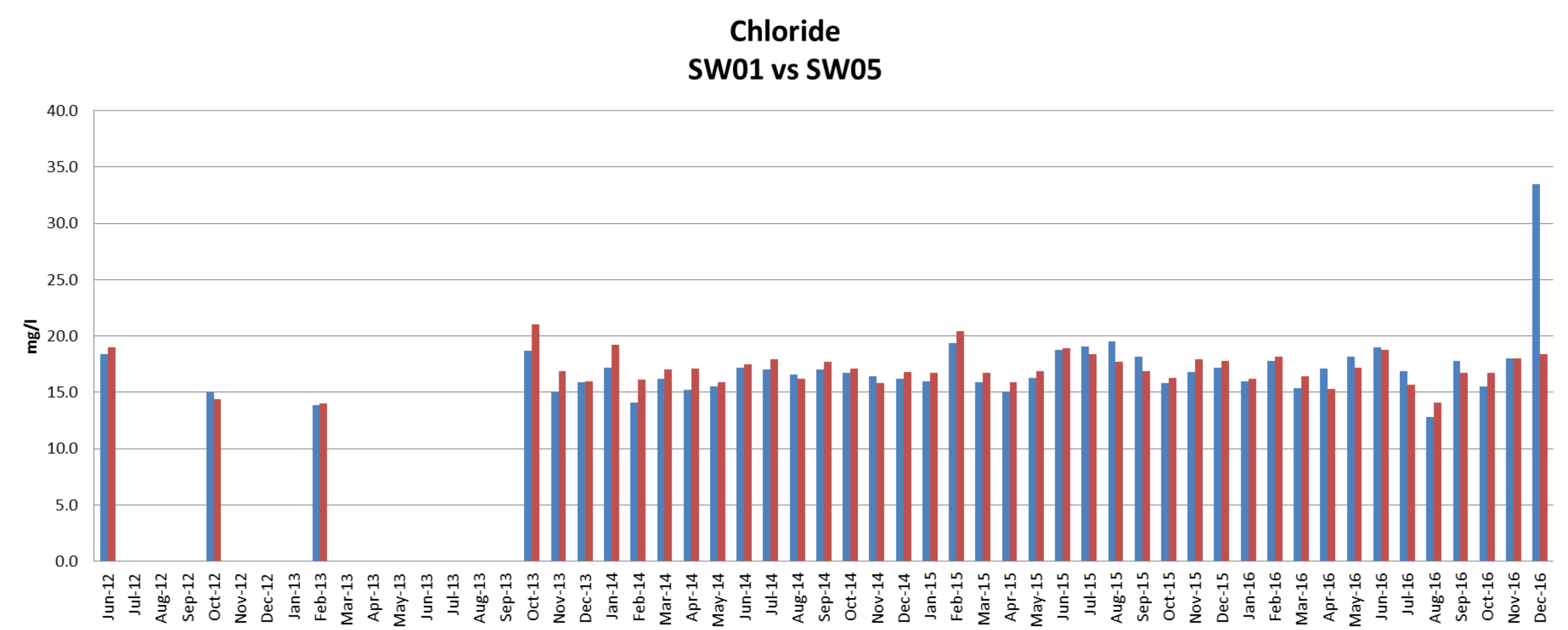
At two sampling points, namely SW08 and SW16, the highest chloride concentrations since monitoring began were recorded. The concentration at SW08 increased in December 2016 to 21.9 mg/l from 16.4 mg/l in June 2016, while SW16 increased to 22.2 mg/l from 18.2 mg/l. Both of these monitoring points are located in the Hartwell, the Morell River tributary flowing through the southern end of the golf course.

Table 2.10:December 2016 Surface Water Chloride Results

Water Body	Sampling Location	Chloride (mg/l)	Orientation from site
		December 2016	
Morell River	SW01	33.5	Upstream SE
	SW02	17.3	Upstream E
	SW03	18.9	Adjacent E
	SW04	18.3	Adjacent E
	SW05	18.4	Downstream NE
Canal Feeder	SW13	70.2	Upstream S
	Site Discharge	<3.7	Adjacent to S
	SW10	56	Downstream S
	SW11	52.6	Downstream SW
	SW12	25	Downstream SW
Watercourse on PGC	SW16	22.2	Upstream SE (Hartwell)
	SW08	21.9	Upstream SE (Hartwell)
	SW06	18.7	Adjacent E (Lake)
	SW15	18.6	Adjacent E (Lake)
Watercourse on PGC	SW14	18.8	Downstream NE (Lake)
	SW07	21.9	Downstream NE (Lake)

In comparison to the data from the Morell River, the data collected from the surface water features on the PGC show very similar chloride concentrations with no indication that there is significant impact of runoff from the golf course affecting the river quality in the Morell River.

Graph 2.24: Chloride in Morell River – Upstream (SW01) vs downstream (SW05) (June 2012 to Present)



	Jun-12	Oct-12	Feb-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15
SW01	18.	15.	13.	18.	15.	15.	17.	14.	16.	15.	15.	17.	17.	16.	17.	16.	16.	16.	16.	19.	15.
SW05	19.	14.	14.	21.	16.	16.	19.	16.	17.	17.	15.	17.	17.	16.	17.	17.	15.	16.	16.	20.	16.

	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16
SW01	15	16	19	19	20	18	16	17	17	16	18	15	17	18	19	17	13	18	16	18	34
SW05	16	17	19	18	18	17	16	18	18	16	18	16	15	17	19	16	14	17	17	18	18

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Trace Metals/Elements

Results for trace metals and metalloids are presented in Table 4. There were exceedances of a small number of the respective surface water quality EQSs during December 2016 in the canal feeder. There were no exceedances recorded in any of the other waterbodies sampled, as has largely been the case since monitoring began. There were no trace metals detected in the site discharge.

The EQS for cadmium of 0.2 µg/l was exceeded at SW12, downstream of the site, with a concentration of 0.7 µg/l recorded. Cadmium is very rarely detected in the surface water samples around the landfill site, with this being the first time it has been detected at SW12. Sources of cadmium can include runoff from soils and agricultural runoff. The day in which SW12 was sampled was extremely wet, with persistent rain throughout the day, and so runoff from the surrounding fields may have been the source of this cadmium.

The EQS for copper of 5 µg/l was exceeded in samples from upstream (SW13 at 7.6 µg/l) and downstream (SW11 at 16 µg/l and SW12 at 17 µg/l) in the canal feeder. With the exception of SW10 just downstream of the site discharge outfall where copper was not detected above the limit of detection (1.9 µg/l), the copper concentrations increased from upstream to downstream. Copper has been detected in the canal feeder during previous sampling rounds, with both SW13 and SW10 exceeding the EQS in December 2015, and SW12 exceeding it in June 2016. Sources of copper, like cadmium, are both natural and anthropogenic, with it occurring naturally in soils but also in agricultural runoff and pesticides.

The EQS for lead of 7.2 µg/l was exceeded downstream in the canal feeder at SW11 (9 µg/l) and SW12 (10 µg/l). There was no lead detected upstream. This represents the first time that lead has been detected in the canal feeder since monitoring of it began in 2012.

The EQS for zinc (50 µg/l) was also substantially exceeded at the canal feeder downstream points SW11 (202 µg/l) and SW12 (184 µg/l). Zinc has been detected above the limit of detection (18 µg/l) at all locations in the canal feeder on occasion in the past monitoring rounds. This includes exceedances both upstream and downstream, with SW13 and SW10 recording exceedances in December 2015 (50 µg/l and 70 µg/l respectively), and SW11 and SW12 recording exceedances in October 2013 (60 µg/l and 80 µg/l respectively). The December 2016 concentrations are higher than recorded in this waterbody previously.

Organic Compounds

Surface water samples from the sixteen sampling locations included in the December 2016 monitoring round were analysed for a suite of VOCs, SVOCs, PAHs, phenols, formaldehyde, acid herbicides and organo-chlorine pesticides.

The results for organic compounds (where detected) are summarised below, and also in Table A.6 and Table A.6a.

There were a number of VOCs and SVOCs detected in December 2016, many for the first time. These are summarised in Table 2.11 below. They were predominantly found in the canal feeder, both upstream and downstream of the site.

Table 2.11: VOCs and SVOCs detected in December 2016

Parameter	IGV (µg/l)	Result (µg/l)	Location of result
Benzene	1.0	0.8	SW13 (Canal Feeder)
Chloroform	-	0.36	SW13 (Canal Feeder)
Bromoform	-	0.82	SW04 (Morell River)
		0.6	SW08 (PGC - Hartwell)
		0.26	SW10 (Canal Feeder)
		0.31	SW11 (Canal Feeder
		0.25	SW12 (Canal Feeder)
1,2,4-Trimethylbenzene	-	28.2	SW13 (Canal Feeder)
1,3,5-Trimethylbenzene	-	5.2	SW13 (Canal Feeder)
Dichloromethane	10	**16.4**	SW11 (Canal Feeder)
		18.5	SW12 (Canal Feeder)
Toluene	10	0.62	SW13 (Canal Feeder)
Ethyl Benzene	10	**11.4**	SW13 (Canal Feeder)
m&p-Xylene	10	**14.9**	SW13 (Canal Feeder)
Isopropylbenzene	-	2.6	SW13 (Canal Feeder)
Naphthalene	1	**8.3**	SW13 (Canal Feeder)
n-Propylbenzene	-	2.5	SW13 (Canal Feeder)
o-Xylene	10	3.58	SW13 (Canal Feeder)

TPH (as measured by the VPH/EPH C5-C44 analysis) was above the limit of detection in a small number of samples, with detections mainly in the canal feeder. The following detections were made in December 2016:

- SW01 (upstream in the Morell River) = 11 µg/l
- SW13 (upstream in the canal feeder) = 220 µg/l
- SW11 (downstream in the canal feeder) = 93 µg/l
- SW12 (downstream in the canal feeder) = 58 µg/l

Polycyclic aromatic hydrocarbons (PAHs)

Trace concentrations of PAHs were recorded in the surface water samples as shown in the following table (Table 2.12). Please refer to Table A.6a for the breakdown of PAH results.

Table 2.12:December 2016 Surface Water Total PAH Results

Parameter	LOD (µg/l)	Result (µg/l)	Location of result
Total PAH	<0.01	0.153	SW01 (Morell)
		0.064	SW02 (Morell)
		0.024	SW08 (PGC)
		0.035	SW10 (Canal Feeder)
		0.74	SW13 (Canal Feeder)
		0.01	SW14 (PGC - Lake)
		0.01	SW15 (PGC - Lake)
		0.01	SW16 (PGC - Hartwell)

Formaldehyde, Herbicides & Pesticides

Formaldehyde was not detected in any of the surface water samples. Pesticides were recorded in two surface water samples as shown in Table 2.13, with both being downstream of the site in the canal feeder.

Table 2.13:December 2016 Surface Water Pesticide Results

Parameter	LOD	Result	Location of result
Diazinon	<0.003 µg/l	0.006 µg/l	SW11
		0.005 µg/l	SW12

The canal feeder (downstream of the site) was the only location in which any pesticides were found during December 2016. Only one compound was identified, namely Diazinon, at a concentration just above the limit of detection at two of monitoring points. There were no pesticides or herbicides detected in any of the other waterbodies.

Overall, the results indicate good surface water quality in all of the surface water samples with no indications of significant leachate impact (as evidenced by ammoniacal nitrogen, chloride, alkalinity, COD) in any of the samples. However, it is noted that there were trace metals and organic compounds detected in the canal feeder, both upstream and downstream, at higher concentrations than recorded previously. This has potentially occurred due to road runoff as it is noted that prior to sampling the weather had been relatively dry (as indicated by the low flow in the Morell River) with rain at the time of sampling washing off pollutants from roads.

2.3 Potential Pollutant Linkages

The groundwater CSM for Zone 1, considering contaminant sources, pathways and receptors is presented in Figure 6 and summarised below.

Overall the CSM remains the same to that identified during previous groundwater monitoring rounds as well as the DQRA.

Source

The ultimate source for contamination observed at the site is the waste that has been deposited across the site. As water percolates through waste in the uncapped areas of the landfill, leachate will be produced and monitoring of on-site monitoring wells (current and previous) shows clear evidence of leachate impacted groundwater within the overburden deposits beneath the site. However, on-site observations and earlier calculations of leachate generation would indicate that the wastes are currently not fully saturated and a large proportion of rainfall that enters the waste soaks into the waste rather than generates leachate. However, this may change in the future and as the wastes become saturated more leachate will be produced.

A further source of leachate generation will be groundwater flowing through the wastes. Assessment of site investigation data shows that an area of waste in the north-western area is likely to be up to 5m below the groundwater table. There will be leaching directly from this waste into groundwater. Level data indicates a clear increase in groundwater levels within the overburden during the period from November 2013 through to March 2014 (acknowledging that levels drop again in March) as increased infiltration occurs across the site. More recent groundwater level data indicates a relatively stable level within the overburden. It is also noted that while an increase in groundwater levels increases the potential for direct leaching of contaminants from the waste mass into shallow groundwater, the increased flow of groundwater through the shallow aquifer caused by higher infiltration rates also has the effect of “diluting” leachate strength as evidenced by the decrease in chloride concentrations in monitoring wells installed along or near the north-eastern boundary during the period of higher water levels.

Pathways

The groundwater quality data collected in December 2016 show that leachate contaminated groundwater is present on the site’s north-eastern boundary and groundwater level data indicates that groundwater is flowing from the site towards the Morell River. This is consistent with previous observations at the site. The pathway for leachate migration is via the landfill base and any subsequent natural routes connected to the receptor. These routes are considered to be movement of contaminants through the unsaturated zone to the groundwater underlying the site and subsequent movement of the contaminants within groundwater.

The pattern of groundwater flow between the site and the canal feeder suggest there is limited potential for leachate migration from the site through shallow groundwater although it should be noted that there is a direct connection to the site via a surface water drain. The groundwater therefore presents a pathway from the site to the river. If contamination were to enter the river, then the river could also act as a pathway with the water being diverted from the river to the Grand Canal or flowing into the River Liffey.

It is noted, however, greatly elevated contaminant concentrations are not observed in groundwater samples from off-site monitoring wells closer to the river and it is possible that attenuation processes are reducing the concentrations of contaminants as they migrate from the site.

Receptors

Based on the groundwater flow direction and contaminant distribution, the principal receptor being considered for the identified contamination is the Morell River, situated to the west of the site. Other surface water features to the east of the site associated with the Palmerstown Golf Club and the canal feeder ditch may also be receptors for groundwater. If contamination were to enter the Morell River then receptors downstream of the river, including abstractions from the River Liffey, may be at risk.

The groundwater itself should also be considered as a receptor although to the east of the site where there is limited potential for use of the groundwater due to the relatively narrow strip of land between the site and the river, this may be considered more a pathway than a receptor. Groundwater can be regarded as potential receptors as future users of groundwater may seek to use this resource (while some of the golf courses in the area have abstraction wells for irrigation there are no known users of drinking water wells locally). It should be noted that while there is clearly impacted groundwater within the overburden deposits directly beneath the site, there is limited evidence of impact in the underlying bedrock.

Current monitoring has shown that while there is contamination in the groundwater beneath the site and near to the north-east site boundary, to date this has not migrated to the river to result in significant impacts on any surface waters as observed through the comparison of upstream and downstream samples collected from an extended network of monitoring points.

3. Summary, Conclusions and Recommendations

3.1 Summary and Conclusions

3.1.1 Groundwater Results

The conceptual model for the site shown in Figure 6 suggests dilution from winter rainfall and that the associated increased recharge is diluting leachate. The model also shows a general increase in groundwater levels within the overburden and bedrock aquifers in response to (likely) increased rates of infiltration.

Water levels recorded in both aquifer units in December 2016 show similar results to November. In summary, overall flow directions within the overburden are similar to those seen previously with a complex pattern of recharge evident over the footprint of the landfill. The bedrock flow directions have also maintained the previously observed direction of flow in a north or north-easterly direction. There is currently limited evidence of off-site movement of contamination through migration of leachate impacted groundwater though it is recommended that monitoring is continued in accordance with the strategy presented within the Groundwater Management Plan.

Groundwater quality data for December 2016 is largely consistent with results obtained during previous sampling rounds completed between June 2011 and November 2016. As with previous monitoring there is evidence of leachate impact in the north and north-eastern boundary areas of the site within the overburden aquifer beneath Zone 1 of the landfill and north of Zone 2B. The highest concentrations of key leachate indicators (EC, ammoniacal nitrogen and chloride) were recorded in monitoring wells close to the north-eastern boundary of Zone 1, rather than under the central area of this zone.

There were no abnormal results recorded in on-site wells during December 2016. As is normally seen, overburden wells recorded generally elevated concentrations of chloride and ammoniacal nitrogen, with EMW13 and BH26 in the northern part of the site being the most pronounced.

BH6 and BH7 in the lower yard to the south-east of the site were noteworthy in that they had elevated concentrations in a number of parameters on this occasion, particularly metals. However, these elevated concentrations were likely to have been caused by the sampling methods as in BH7 a bailer had to be used and in the case of BH6, the water level was very low and the well dried up during sampling resulting in the sample containing a considerable amount of silt.

As previously stated there is evidence of localised leachate impact along the north-eastern boundary of the site, with ammoniacal nitrogen and chloride concentrations in EMW03 being consistently above the IGV. Nearby boundary wells EMW04 and EMW07 show less evidence of contamination than EMW03, with the IGV exceeded in both chloride and ammoniacal nitrogen, but to a much lesser extent than in EMW03. This indicates that much of the leachate movement from Zone 1 along this boundary is localised.

At eastern boundary well EMW19 the determinands for the key leachate indicators have decreased in concentration over the past number of sampling rounds, with this being the case again in December. In the case of chloride it is back below the IGV while for ammoniacal nitrogen it remains above the IGV. Similar trends were seen in the summer of 2014 when many determinands were elevated during the summer months suggesting a possible seasonal effect (although such an effect was not seen in the summer of 2015).

As with previous sampling rounds, elevated ammoniacal nitrogen and chloride concentrations were present in some off-site groundwater monitoring wells located between the site and the Morell River such as EMW05 and EMW20. However the concentrations noted are low when compared to the concentrations recorded in a number of boundary and on-site wells with ammoniacal nitrogen in both wells being only slightly above the IGV.

At EMW20, trigger values for both ammoniacal nitrogen and chloride established as part of a detailed DQRA were not exceeded for first time in nine months. Decreases continued to be recorded in most determinands in EMW20 in December 2016, with determinands largely back to more ‘normal’ concentrations for this well, with chloride below the IGV and ammoniacal nitrogen slightly above. EMW21, located further north along the Morell

River, consistently remains below the IGV for the key determinands of ammoniacal nitrogen and chloride indicating that leachate migration from the north-eastern boundary is not making it to the river.

Elsewhere, there is currently little evidence to suggest significant off-site movement of contaminated groundwater towards the Morell River based on the results obtained in December 2016. The results obtained in December continue to suggest that while there is leachate contaminated groundwater flowing from the site, this is localised to the north-eastern boundary and is not impacting on the water quality in the Morell River. There are no indications of leachate impact to the north, west and south of the site. The inferred groundwater flow regime for the overburden groundwater shown on Figure 4 indicates an overall south to north or north-east movement of groundwater within the overburden and bedrock aquifer, which suggests that increased concentrations of certain substances in selected monitoring wells to the south and west are not linked to the landfill.

3.1.2 Surface Water Results

Monitoring of surface water samples from the Morell River and canal feeder has been undertaken at key strategic locations during the monthly monitoring rounds to assess whether the landfill is having an adverse impact upon water quality within these water bodies. For this biannual monitoring round additional surface water samples were collected, including samples from water courses on Palmerstown Golf Course.

Morell River

The analytical results from the surface water samples collected during the December 2016 monitoring indicate that water quality in the Morell River is generally good. This has also been the case during previous monitoring rounds since 2011. Water quality in the downstream samples was very similar to water quality in the respective upstream samples. The exception during December was in chloride concentrations. Chloride was elevated upstream of the site at SW01 above the concentrations normally recorded here. However, the chloride concentration was back to normal further downstream at SW02, past the confluence with the Hartwell. It had been cold and wet prior to sampling so it is possible that salt from the road had been washed in by the recent rainfall.

There was no significant increase in the key leachate indicators (ammoniacal nitrogen, chloride and alkalinity) between the respective upstream and downstream samples. For the first time since October, there was no significant fluctuation in COD recorded, with COD decreasing from SW02 to SW03 and remaining below the limit of detection from there.

Canal Feeder

During December 2016 the recent trend of higher downstream concentrations in some determinands has reversed. There were elevations and exceedances in some trace metals and organic compounds both upstream and downstream of the site. Similar elevations were not seen in nearby groundwater wells and this increase may have been caused by runoff from roads and fields from heavy rain shortly before and during the sampling.

Palmerstown Golf Course

The waterbodies within Palmerstown Golf Course show little evidence of impact from the landfill. In December, SW08 and SW16 both contained their highest concentrations of chloride recorded since monitoring began here. Both locations are on the Hartwell River, and may have been impacted by salt runoff from the local roads, as seen in the Morell River.

3.2 Recommended Way Forward

The observations from the monitoring indicate broadly similar conditions to those encountered previously and the previously defined groundwater CSM remains valid. It should be noted that the waste materials in the northern area of the site remain uncapped (and unlined) while the site remains in its current state. Therefore, increased leachate generation within this area of the site can be reasonably anticipated in the future as the wastes become increasingly saturated through progressive rainfall infiltration. This may in turn lead to increased potential for off-site migration of a plume of groundwater contaminated by landfill leachate towards the Morell River.

Exceedances mentioned in this report are to be considered as part of the current scope of works updating the conceptual site model (CSM) for the site and subsequently revisiting the trigger values when new data have been collected in the on-going ground investigation and groundwater sampling in relation to soils, water levels and water quality.

On the above basis and whilst remediation proposals are being developed it is recommended that regular monthly groundwater sampling and analysis is continued in line with the recommendations made within the Groundwater Management Plan.

4. Glossary of Abbreviations

BOD	Biochemical Oxygen Demand (mg/l)
C&D	Construction & Demolition
COD	Chemical Oxygen Demand (mg/l)
COPC	Contaminants of Potential Concern
CSM	Conceptual Site Model
DO	Dissolved Oxygen (mg/l)
DQRA	Detailed Quantitative Risk Assessment
EC	Electrical Conductivity (µS/cm)
Eh	Redox potential or oxidation reduction potential (mV)
EIS	Environmental Impact Statement
Fe	Iron
GTV	Groundwater Threshold Value (S.I No. 9 of 2010)
HDPE	High Density Polyethylene
IGV	Interim Groundwater Value
LOD	Limit of Detection
mAOD	metres above Ordnance Datum
Mn	Manganese
N	Nitrogen
NO_2	Nitrite
NO_3	Nitrate
PAH	Polycyclic Aromatic Hydrocarbon
SVOC	Semi volatile Organic Compound
TIC	Tentatively Identified Compound
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
VOC	Volatile Organic Compound

Appendix A. Tables

Table A.1: Sampling and Analysis Inventory December 2016

Table 1 - Sample Inventory

Analytical Suite	EMW02	EMW03	EMW04	EMW05	EMW 06	EMW07	EMW08	EMW11	EMW12	EMW13	EMW 15	EMW 16	EMW 17	EMW18	EMW19	EMW20	EMW21	EMW22	EMW23	EMW24	EMW27	EMW28	EMW29	EMW30	EMW31	EMW32	EMW33	BH6	BH7	GW1D	GW2S	BH26	BH36B	BH42	Samples
pH, conductivity	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34
Anions & Cations	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34
Metals	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34
Free, total cyanide	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34
VPH/EPH >C5 - C44	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34
Alkalinity	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34
COD, BOD, TOC	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34
SVOCs with TICs	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34
VOCs with TICs	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34
Formaldehyde	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34
Pesticides	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34
PAHs	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34
Speciated phenols	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	34

Analytical Suite	SW01	SW02	SW03	SW04	SW05	SW06	SW07	SW8	Site Discharge	SW10	SW11	SW12	SW13	SW14	SW15	SW16	Total
pH, conductivity	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
Anions & Cations	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
Metals (incl. Fe, Mn)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
Free, total cyanide	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
VPH/EPH >C5 - C44	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
Alkalinity	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
COD, BOD, TOC	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
SVOCs with TICs	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
VOCs with TICs	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
Formaldehyde	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
Pesticides	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
PAHs	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16
Speciated phenols	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	16

Major Ions: Ca, Mg, K, Na, SO_4, Cl, F, PO_4, NO_3, NO_2, Alkalinity, Ammoniacal Nitrogen
Metals: Fe, Mn, As, Ba, Be, B, Cd, Cr, Cu, Pb, Se, Hg, Ni, V, Zn, Al, Sb
SVOC - Semi-Volatile Organic Compound
VOC - Volatile Organic Compound
TICs - Tentatively Identified Compounds
TPH - Total Petroleum Hydrocarbons
Pesticides comprises acid herbicides and organo-chlorine pesticides
Speciated phenols - Catechol,Total Cresol, Total Xylenol, Naphthol, Phenol

Table A.2: Field-Based Measurements and Readings December 2016

Table 2 - Groundwater Field Parameters and Observations

Piezometer	DTGW (mbct) - 2016	Depth to Base (mbct)	Casing Top Elevation (mAOD)	Groundwater Elevation (mAOD) November 2016	Temp (°C)	DO (mg/l)	Specific Conductivity (µS/cm)	Field pH (-)	Eh (mV)	Comment / Purged Volume
EMW02	1.61	5.90	81.06	79.45	10.4	3.3	728.7	7.0	+184.1	
EMW03	8.62	16.20	86.26	77.64	11.2	0.4	1563.7	6.8	-19.0	
EMW04	3.39	7.25	83.72	80.33	11.3	3.2	1408.0	6.8	+203.3	
EMW05	1.55	5.82	79.78	78.23	10.2	1.9	708.4	7.0	+257.9	
EMW06	4.98	7.23	87.20	82.22	11.3	7.9	549.7	7.1	+228.1	
EMW07	2.19	5.65	81.02	78.83	12.1	0.3	1162.0	7.0	-142.1	
EMW08	1.49	4.91	80.24	78.75	11.1	0.2	591.8	7.0	-55.4	
EMW11	19.41	22.42	97.93	78.52	11.6	5.4	2201.0	6.8	+272.1	
EMW12	15.14	19.42	91.88	76.74	13.8	6.2	1085.0	7.0	+225.4	
EMW13	15.83	19.60	95.43	79.60	17.4	0.2	3352.5	6.8	-87.7	
EMW14	Dry	22.73	100.81	Dry						Well dry - no sample possible
EMW15	13.37	17.89	92.09	78.72	15.9	0.3	1651.9	7.0	-109.3	
EMW16	12.60	17.98	92.24	79.64	13.9	0.3	2268.1	6.6	+47.1	
EMW17	12.96	20.72	92.93	79.97	11.4	0.3	558.1	7.3	+21.7	
EMW18	2.43	6.14	81.01	78.58	11.7	0.2	515.8	7.3	-119.0	
EMW19	2.71	15.85	80.75	78.04	11.7	0.1	951.7	6.9	-84.4	
EMW20	1.80	6.34	80.52	78.72	11.2	2.5	631.9	7.1	-83.1	
EMW21	4.60	6.82	82.36	77.76	11.0	6.9	563.1	7.0	+302.3	
EMW22	12.23	23.65	88.19	75.96	10.1	0.1	766.0	7.1	+224.5	
EMW23	9.21	14.76	88.51	79.30	10.2	1.9	708.0	7.0	+257.5	
EMW24	16.48	26.11	93.24	76.76	10.2	5.9	595.5	7.2	+269.0	
EMW27	1.90	15.20	82.21	80.31	10.6	0.2	736.0	6.9	-66.3	
EMW28	1.56	8.14	82.52	80.96	11.1	0.3	816.7	6.8	-44.0	
EMW29	0.75	7.83	82.14	81.39	10.5	0.4	933.4	6.9	+29.6	
EMW30	12.02	11.81	91.25	79.23	10.2	9.3	656.9	7.0	+231.4	
EMW31	1.65	6.39	80.30	78.65	11.3	0.2	915.2	6.9	-102.9	
EMW32	3.08	11.45	81.53	78.45	10.7	0.5	713.7	7.0	-20.9	
EMW33	1.81	5.71	81.53	79.72	10.2	0.8	585.0	7.4	-96.7	
BH26	27.42	36.28	106.59	79.17	28.2	0.8	3514.6	6.6	-70.4	
BH36B	35.51	39.02	113.40	77.89	25.5	1.6	1103.7	6.8	-79.1	
BH39B	Dry	13.84	97.58	Dry						Well dry - no sample possible
BH40B	Dry	16.30	94.76	Dry						Well dry - no sample possible
BH42	3.69	10.10	82.77	79.08	11.7	2.7	1172.0	7.3	-66.3	Hand pumped due to damaged casing
BH2	8.15	8.42	92.89	84.74						Insufficient water in well for sampling
BH6	1.84	2.38	81.13	79.29	9.5	5.2	1162.5	7.3	+127.9	Well dried during sampling - silty
BH7	2.11	5.04	81.11	79.00	11.6	7.3	837.9	7.5	+10.8	Bailer used - pump unavailable
GW1D	14.36	18.90	92.20	77.84	10.6	6.5	771.3	7.5	+63.0	
GW2S	2.23	11.28	80.98	78.75	10.9	0.1	267.2	8.5	-147.7	

Notes:
µS/cm - micro Siemens per centimetre
mAOD 0 metres above ordnance datum
DTGW - Depth to ground water **mbct** - metres below casing top
EMW18-EMW42 inclusive top of casing height is ground surface +0.3m

Table A.3: Inorganic Compounds in Groundwater

Table 3 - Results of Laboratory Analysis of Groundwater for Inorganic Compounds

Analyte	Frequency	Units	IGV	GTV	IGV / GTV	EMW02	EMW03	EMW04	EMW05	EMW06	EMW07	EMW08	EMW11	EMW12	EMW13	EMW15	EMW16	EMW17	EMW18	EMW19	EMW20	EMW21	EMW22
						Biannual	Monthly	Biannual	Monthly	Monthly	Biannual	Monthly	Monthly	Monthly	Monthly	Monthly	Monthly (as of April 2016)	Biannual	Biannual	Monthly	Monthly	Biannual	Biannual
Sampling Date					Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16
Calcium , Total as Ca	M	mg/l	200	-	200	155	200	239	185	211	187	122	360	195	216	255	349	95.1	89.3	169	119	122	106
Magnesium, Total as Mg	B	mg/l	50	-	50	10	31.3	33.5	12.5	11.6	18.8	7	61.7	18.8		35.3	39.9	10.9	7.7	18	8.3	4.3	19.7
Potassium , Total as K	M	mg/l	5	-	5	1.74	18.5	15.3	3.68	1.9	11.3	0.53	44.1	4.47	82.4	30.2	15.8	3.6	1.06	6.74	1.09	0.61	2.38
Sodium , Total as Na	M	mg/l	150	150	150	11.2	38.5	45	21.4	2.1	29.2	4.09	74.8	23.2	204	54.5	110	11.2	8.74	25.2	10.1	3.08	15.5
Alkalinity as CaCO3	M	mg/l	-	-	-	399	835	626	470	486	470	333	538	272	1630	606	803	264	279	438	332	322	322
Sulphate as SO4	M	mg/l	200	187.5	200	32.2	66.2	135	23.5	14.9	188	8.6	805	321	78.6	295	410	8.8	10.5	142	17.5	6.1	84.1
					187.5																		
Chloride as Cl	M	mg/l	30	24-187.5	30	7.6	59.3	40.5	24.8	5.7	31.1	8.6	51.7	31	221	50.3	153	19.5	17.4	27.5	19.5	4.1	35
					187.5																		
Nitrate as NO3*	M	mg/l	25	37.5	25	26.9	<3.1	129	9.7	<3.1	<3.1	<3.1	71.3	29.2	5.9	<3.1	<3.1	<3.1	<3.1	21.4	5.7	<3.1	7.6
					37.5																		
Ammoniacal Nitrogen as N#	M	mg/l	0.12	0.05-0.14	0.12	<0.06	23.8	0.27	1.45	<0.06	4.89	<0.06	<0.06	<0.06	165	14.4	5.18	1.39	0.44	3.83	1.06	<0.06	<0.06
					0.14																		
Nitrite as NO2*	B	mg/l	0.10	0.38	0.10	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	1.09	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28
					0.38																		
Phosphates , Total as PO4*	B	mg/l	0.03	0.035	0.03	0.80	0.98	0.86	0.80	1.53	6.44	2.33	<0.37	<0.37	0.89	2.60	1.04	<0.37	0.86	2.20645161	1.23	<0.37	0.74
					0.035																		
Boron, Total as B	B	mg/l	1	0.75	1	0.26	0.42	0.84	0.29	<0.23	0.32	<0.23	1.09	<0.23	2.01	0.6	0.34	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23
					0.75																		
Sulphide as S	B	mg/l	-	-	-	0.107	0.241	0.103	0.04	0.067	<0.020	<0.020	<0.02	<0.020	<0.020	<0.020	0.112	0.024	<0.020	<0.020	<0.020	<0.020	0.059
Iron , Total as Fe	M	mg/l	0.2	-	0.2	1.89	59.8	1.81	4.53	8.55	18.2	4.31	0.66	<0.23	12.5	18.9	2.9	<0.23	3.55	14.4	7.39	0.28	0.91
Manganese , Total as Mn	M	mg/l	0.05	-	0.05	0.199	1.82	0.427	0.933	2.08	1.32	0.756	0.059	0.007	1.17	6.4	4.01	1.37	0.824	1.53	1.06	0.075	0.657
Arsenic, Total as As	M	µg/l	10	7.5	10	2.2	15	2.5	4.4	5.4	16	2.5	<1	<1	13	31	3.8	1.1	7.2	14	3.4	<1	<1
					7.5																		
Barium, Total as Ba	B	µg/l	100	-	100	34	610	148	74	111	290	108	35	49	495	289	170	54	82	264	120	23	80
Beryllium, Total as Be	B	µg/l	-	-	-	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1
Cadmium , Total as Cd	B	µg/l	5	3.75	5	0.8	1.7	1.2	<0.6	3.3	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	1.4	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
					3.75																		
Chromium , Total as Cr	B	µg/l	30	37.5	30	2	7	2	3	7	3	<2	4	2	8	<2	3	<2	<2	<2	<2	<2	<2
					37.5																		
Copper, Total as Cu	B	µg/l	30	1500	30	6.5	24	9.3	5.9	31	8.6	4.8	5.8	2.1	9.1	2.2	23	<1.9	<1.9	<1.9	<1.9	<1.9	8.2
					1500																		
Lead , Total as Pb	B	µg/l	10	18.75	10	8	20	8	10	38	10	<6	<6	<6	10	<6	10	<6	<6	<6	<6	<6	7
					18.75																		
Mercury, Total as Hg	B	µg/l	0.1	0.75	0.1	<0.10	<0.10	<0.10	<0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
					0.75																		
Nickel , Total as Ni	B	µg/l	20	15	20	10	53	21	11	46	8	5	27	31	38	7	33	5	5	4	4	<3	8
					15																		
Selenium, Total as Se	B	µg/l	-	-	-	0.8	<0.8	<0.8	1.2	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	2	<0.8
Vanadium , Total as V	B	µg/l	-	-	-	4	9	<4	5	15	4	<4	<4	<4	6	<4	4	<4	<4	<4	<4	<4	<4
Zinc, Total as Zn	B	µg/l	100	-	100	30	80	40	20	100	40	<18	30	30	127	<18	30	<18	<18	<18	<18	<18	30
Cyanide, Total	M	µg/l	-	-	-	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9

49 Concentration exceeds IGV

35 | 35 Concentration exceeds GTV

* Concentration converted into concentration to correspond with IGV and GTV concentrations:

IGV is for ammonia (as ammonium, reported as NH3 and this has been compared to ammonical-N results. IGV/GTVs converted to appear as N in this table

Phosphate as P → Phosphate as PO4 [Conversion Factor = 95/31]

Freq* = Monthly or bi annual Parameter

LOD VALUE symbol removed for graphs

Table 3 - Results of Laboratory Analysis of Groundwater for Inorganic Compounds

Analyte	Frequency	Units	IGV	GTV	EMW23	EMW24	EMW27	EMW28	EMW29	EMW30	EMW31	EMW32	EMW33	BH26	BH36	BH42	GW1D	GW2S	BH6
					Biannual	Biannual	Biannual	Monthly	Monthly	Biannual	Biannual	Biannual	Biannual	Monthly (as of September 2014)	Biannual	Monthly (as of April 2016)	Biannual	Biannual	Biannual
Sampling Date					**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**
Calcium , Total as Ca	M	mg/l	200	-	**141**	**153**	**359**	**337**	**178**	**175**	**172**	**149**	**113**	**158**	**185**	**232**	**145**	**21.4**	**360**
Magnesium, Total as Mg	B	mg/l	50	-	**11.8**	**17.4**	<60.0	**8.2**	**12**	**10.1**	**10.6**	**15.7**	**11.3**	**34.2**	**18.9**	**21.7**	**21**	**10.7**	**38**
Potassium , Total as K	M	mg/l	5	-	**11.7**	<1.8	<18.0	<1.80	**1.1**	**1.17**	**1.49**	**6.73**	**1.4**	**53.6**	**4.85**	**16.1**	**1.81**	**2.15**	**13.7**
Sodium , Total as Na	M	mg/l	150	150	**7.79**	**7.39**	<30.0	**6.48**	**15.3**	**5.42**	**12.2**	**9.75**	**9.18**	**306**	**38.4**	**28.5**	**14.2**	**15.6**	**18.6**
Alkalinity as CaCO3	M	mg/l	-	-	**389**	**323**	**533**	**571**	**423**	**446**	**467**	**408**	**310**	**1410**	**419**	**320**	**327**	**104**	**965**
Sulphate as SO4	M	mg/l	200	187.5	**26.8**	**36.6**	**26**	**18.1**	**88.3**	**8**	**30.8**	**24.6**	**11.1**	**23.3**	**25.6**	**337**	**108**	<4.4	**237**
Chloride as Cl	M	mg/l	30	24-187.5	**11.4**	**18.4**	**15.1**	**9.9**	**25.2**	**12.1**	**19.9**	**18.2**	**16.1**	**412**	**139**	**25.1**	**170**	**31.8**	**26**
Nitrate as NO3*	M	mg/l	25	37.5	**15.6**	**9.2**	<3.1	<3.1	**18.3**	**10.1**	<3.1	**10.1**	<3.1	<3.1	<3.1	<3.1	**4.5**	<3.1	<3.1
Ammoniacal Nitrogen as N#	M	mg/l	0.12	0.05-0.14	<0.06	<0.06	**0.38**	**0.23**	**0.12**	<0.06	**2.82**	**0.12**	**0.2**	**129**	**1.65**	**3.42**	<0.06	**0.32**	<0.06
Nitrite as NO2*	B	mg/l	0.10	0.38	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28
Phosphates , Total as PO4*	B	mg/l	0.03	0.035	**0.58**	<3.7	<36.77	<3.68	<0.37	**0.77**	**1.35**	**0.52**	**3.68**	**0.77**	**1.35**	**0.92**	<0.37	<0.37	**1.90**
Boron, Total as B	B	mg/l	1	0.75	<0.23	<2.3	<23.0	<2.3	<0.23	<0.23	<0.23	<0.23	<0.23	**2.46**	<0.23	**0.4**	<0.23	<0.23	**3.94**
Sulphide as S	B	mg/l	-	-	**0.02**	**0.3**	**4.34**	**0.097**	<0.020	**0.064**	<0.020	**0.026**	**0.023**	**0.026**	**0.274**	**0.14**	<0.020	<0.020	<0.020
Iron , Total as Fe	M	mg/l	0.2	-	**2.04**	**3.43**	**56.4**	**33.4**	**0.99**	**4.2**	**22**	**1.9**	**9.09**	**5.42**	**7.54**	**6.36**	<0.23	**0.6**	**48.7**
Manganese , Total as Mn	M	mg/l	0.05	-	**0.389**	**0.763**	**13.7**	**2.59**	**0.075**	**0.728**	**2.13**	**1.25**	**0.459**	**1.78**	**2.94**	**4.39**	**0.06**	**0.061**	**8.81**
Arsenic, Total as As	M	µg/l	10	7.5	<1	**2.2**	**56**	**27**	<1	<1	**2.6**	<1	**27**	**22**	**23**	**11**	<1	<1	**35**
Barium, Total as Ba	B	µg/l	100	-	**107**	**0.102**	**1210**	**328**	**46**	**0.104**	**229**	**189**	**120**	**698**	**330**	**113**	**96**	**16**	**2320**
Beryllium, Total as Be	B	µg/l	-	-	<2.1	<21	<210	<21	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1
Cadmium , Total as Cd	B	µg/l	5	3.75	<0.6	<6	<60	<6	<0.6	**0.8**	<0.6	<0.6	<0.6	<0.6	**2.7**	**1.3**	<0.6	<0.6	<0.6
Chromium , Total as Cr	B	µg/l	30	37.5	**3**	<20	<200	**25**	<2	**5**	<2	**3**	<2	**6**	**6**	**5**	<2	<2	**52**
Copper, Total as Cu	B	µg/l	30	1500	**7.7**	**16**	**187**	**66**	**5.3**	**8.7**	**10**	**9.8**	**2.8**	**13**	**38**	**19**	**2.2**	<1.9	**646**
Lead , Total as Pb	B	µg/l	10	18.75	**7**	<60	<600	**110**	<6	**26**	**7**	<6	<6	**9**	**23**	**21**	<6	<6	**621**
Mercury, Total as Hg	B	µg/l	0.1	0.75	<0.10	**0.2**	**1.23**	<0.10	<0.10	<0.1	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	**0.59**
Nickel , Total as Ni	B	µg/l	20	15	**9**	<30	**543**	**117**	**6**	**15**	**4**	**11**	**3**	**79**	**37**	**21**	**5**	**3**	**107**
Selenium, Total as Se	B	µg/l	-	-	**2.6**	**1.6**	<0.8	**1**	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	**1**	<0.8	**1.2**
Vanadium , Total as V	B	µg/l	-	-	**5**	<40	<400	<40	<4	**7**	<4	**5**	**4**	<4	**9**	**5**	<4	<4	**93**
Zinc, Total as Zn	B	µg/l	100	-	**30**	<180	<1800	**339**	**20**	**60**	<18	**30**	<18	**60**	**80**	**60**	<18	<18	**1860**
Cyanide, Total	M	µg/l	-	-	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9

	49	Concentration exceeds IGV
35	35	Concentration exceeds GTV

* Concentration converted into concentration to correspond with IGV and GTV concentrations:

IGV is for ammonia (as ammonium, reported as NH3 and this has been compared to ammonical-

Phosphate as P → Phosphate as PO4 [Conversion Factor = 95/31]

Freq* = Monthly or bi annual Parameter

LOD VALUE symbol removed for graphs

Table A.4: Inorganic Compounds in Surface Water

Table 4 - Inorganic Compounds in Surface Water

Analyte	Freq	Units	Fresh Water EQS (AA)	SW01	SW02	SW03	SW04	SW05	SW06	SW07	SW08	Site Discharge	SW10 (Canal Feeder upstream)	SW11
Sampling Date				**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**
Calcium , Total as Ca	M	mg/l	-	**108**	**99.9**	**99.5**	**101**	**99.1**	**96.2**	**102**	**102**	**31.9**	**118**	**43**
Magnesium, Total as Mg	B	mg/l	-	**12.5**	**10.8**	**10.9**	**10.9**	**10.6**	**8.7**	**8.8**	**9.1**	**0.9**	**7.6**	**2.7**
Potassium , Total as K	M	mg/l	-	**1.48**	**1.47**	**1.61**	**1.5**	**1.41**	**1.94**	**2.4**	**2.04**	**2.09**	**3.9**	**2.25**
Sodium , Total as Na	M	mg/l	-	**15**	**9.3**	**9.11**	**8.1**	**8.46**	**8.85**	**9.7**	**11.8**	**3.22**	**34.9**	**27.2**
Alkalinity as CaCO3	M	mg/l	-	**301**	**287**	**286**	**286**	**286**	**271**	**283**	**274**	**76**	**346**	**96.8**
Sulphate as SO4	M	mg/l	-	**11.6**	**11.6**	**11.6**	**11.8**	**11.8**	**18.3**	**18.8**	**19.2**	**6.9**	**27.3**	**8.5**
Chloride as Cl	M	mg/l	-	**33.5**	**17.3**	**18.9**	**18.3**	**18.4**	**18.7**	**18.3**	**21.9**	<3.7	**56**	**52.6**
Nitrate as NO3*	M	mg/l	-	**13.9**	**12.6**	**12.9**	**12.9**	**12.7**	<3.1	<3.1	**9.3**	<3.1	<3.1	<3.1
Ammoniacal Nitrogen as N[#]	M	mg/l	-	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	**0.2**	<0.06	<0.06	**0.38**	<0.06
Nitrite as NO2*	B	mg/l	-	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28	<0.28
Phosphates , Total as PO4*	B	mg/l	-	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	<0.37	**0.643548387**
Boron, Total as B	B	mg/l	-	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23
Fluoride as F	B	mg/l	-	**0.114**	<1	**0.107**	**0.1**	**0.067**	**0.113**	**0.1**	**0.063**	**0.1**	**0.242**	**0.075**
Iron , Total as Fe	M	mg/l	-	<0.23	<0.23	<0.23	<0.23	<0.23	<0.23	**0.7**	<0.23	<0.23	<0.23	**1.61**
Manganese , Total as Mn	M	mg/l	-	<0.007	**0.007**	**0.01**	**0.01**	**0.016**	**0.162**	**0.43**	<0.007	<0.007	**0.37**	**0.325**
Arsenic, Total as As	M	µg/l	25	<1	<1	<1	<1	<1	<1	**1.1**	<1	**1.7**	<1	**2.3**
Barium, Total as Ba	B	µg/l	-	**74**	**68**	**69**	**69**	**67**	**55**	**75**	**64**	**19**	**63**	**47**
Beryllium, Total as Be	B	µg/l	-	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1	<2.1
Cadmium , Total as Cd	B	µg/l	0.2	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Chromium , Total as Cr	B	µg/l	5	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	**3**
Copper, Total as Cu	B	µg/l	5	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	<1.9	**2**	<1.9	**16**
Lead , Total as Pb	B	µg/l	7.2	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	**9**
Nickel , Total as Ni	B	µg/l	20	<3	<3	**10**	**5**	**4**	<3	**6**	<3	**4**	**3**	**8**
Selenium, Total as Se	B	µg/l	-	**1.3**	**1.2**	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8
Vanadium , Total as V	B	µg/l	-	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Zinc, Total as Zn	B	µg/l	50	<18	<18	**20**	<18	<18	<18	<18	<18	<18	<18	**202**
Cyanide, Total	M	µg/l	-	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9	<9

Table 4 - Inorganic Compounds in Surface Water

Analyte	Freq	Units	Fresh Water EQS (AA)	SW12	SW13	SW14	SW15	SW16
Sampling Date				**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**
Calcium , Total as Ca	M	mg/l	-	**38.7**	**141**	**97.7**	**91.7**	**99.2**
Magnesium, Total as Mg	B	mg/l	-	**2.9**	**7.6**	**8.6**	**8.5**	**8.9**
Potassium , Total as K	M	mg/l	-	**1.49**	**3.52**	**2.05**	**2.14**	**2.05**
Sodium , Total as Na	M	mg/l	-	**13.6**	**36.7**	**8.21**	**8.47**	**10.7**
Alkalinity as CaCO3	M	mg/l	-	**85.6**	**402**	**282**	**261**	**279**
Sulphate as SO4	M	mg/l	-	**5**	**20.3**	**19.3**	**18.2**	**24.6**
Chloride as Cl	M	mg/l	-	**25**	**70.2**	**18.8**	**18.6**	**22.2**
Nitrate as NO3*	M	mg/l	-	<3.1	<3.1	<3.1	<3.1	**9.4**
Ammoniacal Nitrogen as N[#]	M	mg/l	-	<0.06	**3.48**	**0.19**	<0.06	<0.06
Nitrite as NO2*	B	mg/l	-	<0.28	<0.28	<0.28	<0.28	<0.28
Phosphates , Total as PO4*	B	mg/l	-	**0.582258**	**2.4516129**	<0.37	<0.37	<0.37
Boron, Total as B	B	mg/l	-	<0.23	<0.23	<0.23	<0.23	<0.23
Fluoride as F	B	mg/l	-	**0.041**	**0.23**	**0.075**	**0.068**	<1
Iron , Total as Fe	M	mg/l	-	**1.29**	**7.41**	**0.62**	<0.23	<0.23
Manganese , Total as Mn	M	mg/l	-	**0.143**	**1.9**	**0.229**	**0.035**	<0.007
Arsenic, Total as As	M	µg/l	25	**1.4**	**10**	<1	<1	<1
Barium, Total as Ba	B	µg/l	-	**37**	**127**	**64**	**51**	**62**
Beryllium, Total as Be	B	µg/l	-	<2.1	<2.1	<2.1	<2.1	<2.1
Cadmium , Total as Cd	B	µg/l	0.2	**0.7**	<0.6	<0.6	<0.6	<0.6
Chromium , Total as Cr	B	µg/l	5	**3**	<2	<2	<2	<2
Copper, Total as Cu	B	µg/l	5	**17**	**7.6**	<1.9	<1.9	<1.9
Lead , Total as Pb	B	µg/l	7.2	**10**	<6	<6	<6	<6
Nickel , Total as Ni	B	µg/l	20	**8**	**4**	<3	**3**	<3
Selenium, Total as Se	B	µg/l	-	<0.8	<0.8	<0.8	<0.8	**0.8**
Vanadium , Total as V	B	µg/l	-	<4	<4	<4	<4	<4
Zinc, Total as Zn	B	µg/l	50	**184**	**30**	<18	<18	<18
Cyanide, Total	M	µg/l	-	<9	<9	<9	<9	<9

Table A.5: TOC, COD and BOD in Groundwater and Surface Water

Table 5 - TOC & COD in Groundwater & Surface Water

Analyte	Units	IGV	GTV	EMW02
				Dec-16
TOC (Filtered)	mg/l	-	-	2.1
COD (Total)	mg/l	-	-	36
BODS + ATU				<1

Analyte	Units	IGV	GTV	EWM03
				Dec-16
TOC (Filtered)	mg/l	-	-	12.3
COD (Total)	mg/l	-	-	186
BODS + ATU	mg/l			<1

Analyte	Units	IGV	GTV	EMW04
				Dec-16
TOC (Filtered)	mg/l	-	-	10.8
COD (Total)	mg/l	-	-	57
BODS + ATU				<1

Analyte	Units	IGV	GTV	EMW05
				Dec-16
TOC (Filtered)	mg/l	-	-	4
COD (Total)	mg/l	-	-	44
BODS + ATU	mg/l			3

Analyte	Units	IGV	GTV	EMW06
				Dec-16
TOC (Filtered)	mg/l	-	-	1
COD (Total)	mg/l	-	-	153
BODS + ATU	mg/l			<1

Analyte	Units	IGV	GTV	EMW07
				Dec-16
TOC (Filtered)	mg/l	-	-	5.6
COD (Total)	mg/l	-	-	37
BODS + ATU				<1

Analyte	Units	IGV	GTV	EMW08
				Dec-16
TOC (Filtered)	mg/l	-	-	1.3
COD (Total)	mg/l	-	-	33
BODS + ATU	mg/l			<1

Analyte	Units	IGV	GTV	EMW11
				Dec-16
TOC (Filtered)	mg/l	-	-	10.6
COD (Total)	mg/l	-	-	56
BODS + ATU	mg/l			2

Table 5 - TOC & COD in Groundwater & Surface Water

Analyte	Units	IGV	GTV	EMW12D
				Dec-16
TOC (Filtered)	mg/l	-	-	2.4
COD (Total)	mg/l	-	-	18
BODS + ATU	mg/l			<1

Analyte	Units	IGV	GTV	EMW13
				Dec-16
TOC (Filtered)	mg/l	-	-	80
COD (Total)	mg/l	-	-	325
BODS + ATU	mg/l			10

Analyte	Units	IGV	GTV	EMW15
				Dec-16
TOC (Filtered)	mg/l	-	-	11.3
COD (Total)	mg/l	-	-	50
BODS + ATU	mg/l			1

Analyte	Units	IGV	GTV	EMW16
				Dec-16
TOC (Filtered)	mg/l	-	-	18.4
COD (Total)	mg/l	-	-	86
BODS + ATU				1

Analyte	Units	IGV	GTV	EMW17
				Dec-16
TOC (Filtered)	mg/l	-	-	1.8
COD (Total)	mg/l	-	-	<11
BODS + ATU				1

Analyte	Units	IGV	GTV	EMW18
				Dec-16
TOC (Filtered)	mg/l	-	-	2.3
COD (Total)	mg/l	-	-	12
BODS + ATU				<1

Analyte	Units	IGV	GTV	EMW19
				Dec-16
TOC (Filtered)	mg/l	-	-	5.1
COD (Total)	mg/l	-	-	20
BODS + ATU	mg/l			<1

Table 5 - TOC & COD in Groundwater & Surface Water

Analyte	Units	IGV	GTV	EMW20
				Dec-16
TOC (Filtered)	mg/l	-	-	2.5
COD (Total)	mg/l	-	-	14
BODS + ATU	mg/l			<1

Analyte	Units	IGV	GTV	EMW21
				Dec-16
TOC (Filtered)	mg/l	-	-	0.9
COD (Total)	mg/l	-	-	18
BODS + ATU				1

Analyte	Units	IGV	GTV	EMW22
				Dec-16
TOC (Filtered)	mg/l	-	-	0.8
COD (Total)	mg/l	-	-	18
BODS + ATU				2

Analyte	Units	IGV	GTV	EMW23
				Dec-16
TOC (Filtered)	mg/l	-	-	1.1
COD (Total)	mg/l	-	-	48
BODS + ATU				2

Analyte	Units	IGV	GTV	EMW24
				Dec-16
TOC (Filtered)	mg/l	-	-	1.6
COD (Total)	mg/l	-	-	83
BODS + ATU				2

Analyte	Units	IGV	GTV	EMW27
				Dec-16
TOC (Filtered)	mg/l	-	-	6
COD (Total)	mg/l	-	-	480
BODS + ATU				<1

Analyte	Units	IGV	GTV	EMW28
				Dec-16
TOC (Filtered)	mg/l	-	-	13.4
COD (Total)	mg/l	-	-	163
BODS + ATU	mg/l			2

Analyte	Units	IGV	GTV	EMW29
				Dec-16
TOC (Filtered)	mg/l	-	-	2.6
COD (Total)	mg/l	-	-	16
BODS + ATU	mg/l			<1

Table 5 - TOC & COD in Groundwater & Surface Water

Analyte	Units	IGV	GTV	EMW30
				Dec-16
TOC (Filtered)	mg/l	-	-	0.9
COD (Total)	mg/l	-	-	62
BODS + ATU				<1

Analyte	Units	IGV	GTV	EMW31
				Dec-16
TOC (Filtered)	mg/l	-	-	5.2
COD (Total)	mg/l	-	-	31
BODS + ATU				4

Analyte	Units	IGV	GTV	EMW32
				Dec-16
TOC (Filtered)	mg/l	-	-	1.2
COD (Total)	mg/l	-	-	52
BODS + ATU				<1

Analyte	Units	IGV	GTV	EMW33
				Dec-16
TOC (Filtered)	mg/l	-	-	1.6
COD (Total)	mg/l	-	-	<11
BODS + ATU				54

Analyte	Units	IGV	GTV	BH6
				Dec-16
TOC (Filtered)	mg/l	-	-	6.6
COD (Total)	mg/l	-	-	207
BODS + ATU				2

Analyte	Units	IGV	GTV	BH7
				Dec-16
TOC (Filtered)	mg/l	-	-	5.8
COD (Total)	mg/l	-	-	21
BODS + ATU				1

Analyte	Units	IGV	GTV	BH26
				Dec-16
TOC (Filtered)	mg/l	-	-	103
COD (Total)	mg/l	-	-	458
BODS + ATU	mg/l			10

Analyte	Units	IGV	GTV	BH36B
				Dec-16
TOC (Filtered)	mg/l	-	-	12.7
COD (Total)	mg/l	-	-	110
BODS + ATU				2

Table 5 - TOC & COD in Groundwater & Surface Water

Analyte	Units	IGV	GTV	BH42
				Dec-16
TOC (Filtered)	mg/l	-	-	8.2
COD (Total)	mg/l	-	-	49
BODS + ATU	mg/l			2

Analyte	Units	IGV	GTV	GW1D
				Dec-16
TOC (Filtered)	mg/l	-	-	0.8
COD (Total)	mg/l	-	-	<11
BODS + ATU				<1

Analyte	Units	IGV	GTV	GW2S
				Dec-16
TOC (Filtered)	mg/l	-	-	1.9
COD (Total)	mg/l	-	-	<11
BODS + ATU				1

Analyte	Units	IGV	GTV	SW01
				Dec-16
TOC (Filtered)	mg/l	-	-	1.3
COD (Total)	mg/l	-	-	13
BODS + ATU	mg/l			<1

Analyte	Units	IGV	GTV	SW02
				Dec-16
TOC (Filtered)	mg/l	-	-	1.1
COD (Total)	mg/l	-	-	18
BODS + ATU	mg/l			<1

Analyte	Units	IGV	GTV	SW03
				Dec-16
TOC (Filtered)	mg/l	-	-	1.1
COD (Total)	mg/l	-	-	<11
BODS + ATU	mg/l			<1

Analyte	Units	IGV	GTV	SW04
				Dec-16
TOC (Filtered)	mg/l	-	-	1.1
COD (Total)	mg/l	-	-	<11
BODS + ATU				<1

Analyte	Units	IGV	GTV	SW05
				Dec-16
TOC (Filtered)	mg/l	-	-	1
COD (Total)	mg/l	-	-	<11
BODS + ATU	mg/l			<1

Table 5 - TOC & COD in Groundwater & Surface Water

Analyte	Units	IGV	GTV	SW06
				Dec-16
TOC (Filtered)	mg/l	-	-	2.8
COD (Total)	mg/l	-	-	17
BODS + ATU				<1

Analyte	Units	IGV	GTV	SW07
				Dec-16
TOC (Filtered)	mg/l	-	-	3.4
COD (Total)	mg/l	-	-	<11
BODS + ATU				<1

Analyte	Units	IGV	GTV	SW08
				Dec-16
TOC (Filtered)	mg/l	-	-	1.5
COD (Total)	mg/l	-	-	13
BODS + ATU				1

Analyte	Units	IGV	GTV	Site Discharge
				Dec-16
TOC (Filtered)	mg/l	-	-	1.8
COD (Total)	mg/l	-	-	<11
BODS + ATU	mg/l			<1

Analyte	Units	IGV	GTV	SW10
				Dec-16
TOC (Filtered)	mg/l	-	-	4
COD (Total)	mg/l	-	-	23
BODS + ATU				<1

Analyte	Units	IGV	GTV	SW11
				Dec-16
TOC (Filtered)	mg/l	-	-	4.2
COD (Total)	mg/l	-	-	32
BODS + ATU	mg/l			2

Analyte	Units	IGV	GTV	SW12
				Dec-16
TOC (Filtered)	mg/l	-	-	2.6
COD (Total)	mg/l	-	-	41
BODS + ATU				2

Analyte	Units	IGV	GTV	SW13
				Dec-16
TOC (Filtered)	mg/l	-	-	8.4
COD (Total)	mg/l	-	-	67
BODS + ATU	mg/l			6

Table 5 - TOC & COD in Groundwater & Surface Water

Analyte	Units	IGV	GTV	SW14
				Dec-16
TOC (Filtered)	mg/l	-	-	3.3
COD (Total)	mg/l	-	-	24
BODS + ATU				<1

Analyte	Units	IGV	GTV	SW15
				Dec-16
TOC (Filtered)	mg/l	-	-	3.5
COD (Total)	mg/l	-	-	21
BODS + ATU				1

Analyte	Units	IGV	GTV	SW16
				Dec-16
TOC (Filtered)	mg/l	-	-	1.6
COD (Total)	mg/l	-	-	12
BODS + ATU				<1

Table A.6: Organic Compounds in Groundwater and Surface Water

Table 6 - Organic Compounds in Groundwater & Surface Water

Analyte	Units	IGV	GTV	EMW02	EMW03	EMW04	EMW05	EMW06	EMW07	EMW08	EMW11	EMW12	EMW13	EMW15	EMW16	EMW18	EMW19D	EMW20	EMW21	EMW22	EMW23	EMW24	EMW27	EMW28	EMW29	EMW30	EMW31	EMW33	BH36B	BH26	BH6
Sampling Date				**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**
Benzene	ug/l	1.0	0.75	<0.2	**0.43**	<0.2	<0.2	<0.2	<0.2	<0.2	<1.0	<1.0	**1.18**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<1.0	<0.2
Chlorobenzene*	ug/l	1.0	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<1.0	**0.12**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1
Chloroform	ug/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**1.44**	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1
Chloromethane*	ug/l	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**1.5**	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromoform*	ug/l	-	-	**0.39**	<0.2	<0.2	<0.2	**0.36**	<0.2	<0.2	<1.0	<1.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**0.87**	<0.2	**6.86**	<0.2	<0.2	<0.2	**1.11**	**0.25**	<0.2	<0.2	<0.2	<1.0	<0.2
1,1-Dichloroethane	ug/l	-	-	<0.1	<0.1	<0.1	<0.5	<0.1	<0.1	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1
1,2,4-Trimethylbenzene	ug/l	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
1,3,5-Trimethylbenzene*	ug/l	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromodichloromethane*	ug/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.14**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1
Dibromochloromethane*	ug/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.43**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1
Dichloromethane*	ug/l	10	-	**11.7**	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<1.0	<1.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<6.0	<1.0	<6.0
cis-1,2-Dichloroethene*	ug/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<1.0	**0.12**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1
Hexachlorobutadiene	ng/l	-	-	<7	<7	<7	<7	<7	<7	<7	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<7	<7	<7	<1.0	<1.0	<1.0	<7	<2.0	<1.0
1,4-Dichlorobenzene	ug/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<2.0	<0.1
Bis (2-chloroisopropyl) ether	ug/l	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<2.0	<1.0	<1.0	<2.0	<1.0	<1.0	<2.0	<1.0
1,2,4-Trichlorobenzene	ng/l	0.4	-	<0.1	<0.1	<0.1	<10	<0.1	<0.1	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1	<0.1	<2.0	<0.1
Toluene	ug/l	10	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	**0.59**	<1.0	<1.0	**0.51**	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5
Ethyl Benzene	ug/l	10	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.16**	<1.0	<0.1
m&p-Xylene	ug/l	10	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<1.0	<1.0	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**0.22**	<1.0	<0.2
Isopropylbenzene*	ug/l	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Naphthalene*	ug/l	1		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
n-Propylbenzene*	ug/l	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
o-Xylene*	ug/l	10	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1
Vinyl Chloride*	ug/l	-	0.375	<0.1	**0.17**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.5	**0.18**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.5	<0.1
Dieldrin	ug/l	-	-	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	**7**
Azinphos-methyl*	ug/l	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	**0.006**	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Diazinon*	ug/l	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
2,3,6 - TBA	ug/l	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<5.0	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.5	<0.05	<0.05	<0.05	<0.05	<0.05	<5.0	<0.05
Bentazone	ug/l	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<5.0	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.5	<0.05	<0.05	<0.05	<0.05	<0.05	<5.0	<0.05
Dicamba	ug/l	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<5.0	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.5	<0.05	<0.05	<0.05	<0.05	<0.05	<5.0	<0.05
Formaldehyde	mg/l	-	-	<0.029	<0.029	<0.029	<0.029	<0.029	**0.063**	<0.029	<0.029	<0.029	**0.053**	**0.143**	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	**0.035**	<0.029	<0.029	**0.857**	<0.029	<0.029	**0.103**	**0.136**
Chlopyralid	ug/l	0.1	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<5.0	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.5	<0.05	<0.05	<0.05	<0.05	<0.05	<5.0	<0.05
Dichlobenil	ng/l	100	100	<2	<2	**2**	<2	<2	<2	<2	<2	<2	**27**			<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	**4**	**56**
Dichlorprop	ug/l	0.1	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<5.0	**0.06**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1	<0.5	<0.05	<0.05	<0.05	<0.05	<0.05	<5.0	<0.05
Mecoprop	ug/l	10	0.075	<0.04	**1.62**	**0.4**	**0.5**	<0.04	**0.16**	<0.04	<0.04	<0.04	**14.4**	**0.42**	**0.74**	<0.04	**0.27**	**0.04**	<0.04	**0.05**	<0.04	<0.04	<0.08	<0.4	<0.04	<0.04	<0.04	<0.04	**0.25**	**28.6**	**0.11**
Phenol	ug/l	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	**1.2**	**1.5**	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	**2.2**	<0.10
Total Cresols	ug/l	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	**0.48**	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.1	<0.10
Total Phenols	ug/l	0.5	-	<0.50	**11**	<0.50	<0.50	**1.3**	<0.50	<0.50	<0.50	**1.2**	**98**	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	**3.2**	<0.50	<0.50	<0.50	<0.50	**0.67**	<0.50	**36**	<0.50
Xylenol, Total	ug/l	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	**18**	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	**12**	<0.10
Total Trimethylphenol	ug/l	-	-	<0.10	**11**	<0.10	<0.10	**1.3**	<0.10	<0.10	<0.10	<0.10	**78**	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	**3.2**	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	**22**	<0.10
Naphthol	ug/l	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.1	<0.10

*	Newly detected in December 2016
13.6	Concentration exceeds I(
0.31	Concentration exceeds GTV

Note: Only samples where there was at least one positive detection of the compounds listed are included in this table, and only compounds detected in at least one sample are listed. Refer to the laboratory reports for the full set of results.

Table 6 - Organic Compounds in Groundwater & Surface Water

Analyte	Units	IGV	GTV	BH7	GW1D	GW2S	BH42	SW04	SW08	SW10	SW11	SW12	SW13
Sampling Date				**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**	**Dec-16**
Benzene	ug/l	1.0	0.75	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**0.8**
Chlorobenzene*	ug/l	1.0	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chloroform	ug/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**0.36**
Chloromethane*	ug/l	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Bromoform*	ug/l	-	-	<0.2	<0.2	<0.2	<0.2	**0.82**	**0.6**	**0.26**	**0.31**	**0.25**	<0.2
1,1-Dichloroethane	ug/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
1,2,4-Trimethylbenzene	ug/l	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**28.2**
1,3,5-Trimethylbenzene*	ug/l	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**5.2**
Bromodichloromethane*	ug/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dibromochloromethane*	ug/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dichloromethane*	ug/l	10	-	<6.0	**9.3**	<6.0	<6.0	<6.0	<6.0	<6.0	**16.4**	**18.5**	<0.1
cis-1,2-Dichloroethene*	ug/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Hexachlorobutadiene	ng/l	-	-	<1.0	<7	<1.0	<1.0	<1.0	<7	<7	<7	<7	<7
1,4-Dichlorobenzene	ug/l	-	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bis (2-chloroisopropyl) ether	ug/l	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<2.0	<1.0	<2.0
1,2,4-Trichlorobenzene	ng/l	0.4	-	<0.1	<0.1	<0.1	<0.1	<1.0	<0.1	<0.1	<0.1	<0.1	<0.1
Toluene	ug/l	10	-	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	**0.62**
Ethyl Benzene	ug/l	10	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**11.4**
m&p-Xylene	ug/l	10	-	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	**14.9**
Isopropylbenzene*	ug/l	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**2.6**
Naphthalene*	ug/l	1		<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**8.3**
n-Propylbenzene*	ug/l	-	-	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	**2.5**
o-Xylene*	ug/l	10	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	**3.58**
Vinyl Chloride*	ug/l	-	0.375	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dieldrin	ug/l	-	-	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Azinphos-methyl*	ug/l	-	-	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Diazinon*	ug/l	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	**0.006**	**0.005**	<0.003
2,3,6 - TBA	ug/l	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1
Bentazone	ug/l	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1
Dicamba	ug/l	-	-	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1
Formaldehyde	mg/l	-	-	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029	<0.029
Chlopyralid	ug/l	0.1	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1
Dichlobenil	ng/l	100	100	<2	<2	<2		<2	<2	<2	<2	<2	<2
Dichlorprop	ug/l	0.1	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.1
Mecoprop	ug/l	10	0.075	**0.05**	<0.04	**0.05**	**0.25**	<0.04	<0.04	<0.04	<0.04	<0.04	<0.08
Phenol	ug/l	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Cresols	ug/l	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Phenols	ug/l	0.5	-	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Xylenol, Total	ug/l	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Total Trimethylphenol	ug/l	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Naphthol	ug/l	-	-	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10

*	Newly detected in Decem
13.6	Concentration exceeds I
0.31	Concentration exceeds G
Note:	Only samples where there compounds listed are incl at least one sample are lis of results.

Table A.6a: PAHs in Groundwater and Surface Water

Table 6a - PAHs in
Groundwater & Surface Water

Analyte	Units	EMW02	EMW03	EMW04	EMW05	EMW06	EMW07	EMW08	EMW11	EMW12	EMW13	EMW21	EMW22	EMW24	BH6	EMW 27
		Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Jun-16	Dec-16	Jun-16	Dec-16	Dec-16
Acenaphthene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Acenaphthylene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Anthracene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo (a) anthracene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo (g,h,i) perylene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo (a) pyrene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo (b) fluoranthene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo (k) fluoranthene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Chrysene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenz (a,h) anthracene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoranthene	ug/l	0.04	0.034	0.02	0.043	0.084	<0.01	0.148	0.016	0.089	<0.04	0.011	0.014	0.015	<0.01	0.062
Fluorene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Indeno (1,2,3) cd pyrene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Naphthalene	ug/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.04	<0.01	<0.01	<0.01	<0.01	<0.01
Phenanthrene	ug/l	0.013	<0.01	<0.01	0.015	0.097	<0.01	0.128	0.014	0.05	<0.04	0.012	<0.01	0.016	<0.01	0.058
Pyrene	ug/l	0.016	<0.01	<0.01	0.014	0.022	<0.01	0.045	<0.01	0.033	<0.04	<0.01	<0.01	<0.01	0.01	0.023
Total PAHs	ug/l	0.07	0.034	0.02	0.072	0.203	<0.01	0.32	0.03	0.173	<0.04	0.023	0.014	0.031	0.01	0.143

Table 6a - PAHs in Groundwater & Surface Water

Analyte	Units	EMW 28	EMW 29	EMW 30	EMW 32	BH 26	BH 36	BH 42	SW01	SW02	SW08	SW10	SW 13	SW14	SW 15	SW16
		Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16	Dec-16
Acenaphthene	ug/l	<0.02	0.041	<0.01	<0.01	<0.04	0.037	<0.01	0.013	<0.01	<0.01	<0.01	0.102	<0.01	<0.01	<0.01
Acenaphthylene	ug/l	<0.02	<0.01	<0.01	<0.01	<0.04	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01
Anthracene	ug/l	<0.02	<0.01	<0.01	<0.01	<0.04	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01
Benzo (a) anthracene	ug/l	<0.02	<0.01	<0.01	<0.01	<0.04	<0.10	0.032	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01
Benzo (g,h,i) perylene	ug/l	<0.02	<0.01	<0.01	<0.01	<0.04	<0.10	0.051	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01
Benzo (a) pyrene	ug/l	<0.02	<0.01	<0.01	<0.01	<0.04	<0.10	0.049	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01
Benzo (b) fluoranthene	ug/l	<0.02	<0.01	<0.01	<0.01	<0.04	<0.10	0.053	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01
Benzo (k) fluoranthene	ug/l	<0.02	<0.01	<0.01	<0.05	<0.04	<0.10	0.026	<0.01	<0.01	<0.01	<0.01	0.032	<0.01	<0.01	<0.01
Chrysene	ug/l	<0.02	0.011	<0.01	<0.01	<0.04	<0.10	0.036	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01
Dibenz (a,h) anthracene	ug/l	<0.02	<0.01	<0.01	<0.01	<0.04	<0.10	0.012	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01
Fluoranthene	ug/l	0.065	1.65	0.022	0.022	<0.04	<0.10	0.067	0.041	0.032	0.011	0.012	0.03	<0.01	<0.01	<0.01
Fluorene	ug/l	<0.02	0.043	<0.01	<0.01	<0.04	0.022	<0.01	0.016	<0.01	<0.01	<0.01	0.084	<0.01	<0.01	<0.01
Indeno (1,2,3) cd pyrene	ug/l	<0.02	<0.01	<0.01	<0.01	<0.04	<0.10	0.041	<0.01	<0.01	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01
Naphthalene	ug/l	<0.02	0.029	<0.01	<0.01	<0.04	0.363	<0.01	0.038	<0.01	<0.01	<0.01	0.45	<0.01	<0.01	<0.01
Phenanthrene	ug/l	0.072	1.29	0.02	0.028	<0.04	<0.10	0.034	0.033	0.019	0.013	0.023	0.042	0.01	0.01	0.01
Pyrene	ug/l	0.025	0.652	<0.01	0.034	<0.04	<0.10	0.068	0.016	0.014	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01
Total PAHs	ug/l	0.162	3.71	0.042	0.084	<0.04	0.422	0.469	0.156	0.064	0.024	0.035	0.74	0.01	0.01	0.01

Only samples where there was at least one positive detection of the compounds listed are included in this table, and only

Appendix B. Figures

Figure 1: **Site Location**

Drawing number / Rev

32EW5602-009_1/0

KEY:

Former W0047-02 Waste Licence Boundary

0 200 400 600 800

METRES

Rev	Rev. Date	Purpose of revision	Drawn	Check'd	Rev'd	Apprv'd
0	11/03/2016	FIRST ISSUE	AR	UD	DM	SJM

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Comhairle Contae Chill Dara

Project

KERDIFFSTOWN LANDFILL
SITE REMEDIATION PROJECT

Drawing title

FIGURE 1
SITE LOCATION

Drawing status

FIRST ISSUE

Scale: 1:20,000 @ A3 — DO NOT SCALE

Jacobs No.: 32EW5602

Client no.:

Drawing number: 32EW5602-008_9 — Rev: 0

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I:\Enviros\Design\PROJECTS\UK\32EW5602\Figures\Task 8\March 2016\32EW5602-008_9.dwg - 11/03/2016 10:07:34 - Figure 1 - atroberts

Figure 2: Site Layout

Drawing number / Rev
32EW5602-008_10/0

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KEY:

- Former W0047-02 Waste Licence Boundary
- Site Buildings
- Site Structures
- Dwellings

0 50 100 150
METRES

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
0	11/03/2016	FIRST ISSUE	AR	RK	DM	SJM

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Project
KERDIFFSTOWN LANDFILL
SITE REMEDIATION PROJECT

Drawing title
FIGURE 2
SITE LAYOUT

Drawing status
FIRST ISSUE

Scale	AS SHOWN
Jacobs No.	32EW5602
Client no.	

Drawing number: 32EW5602-008_10 Rev: 0

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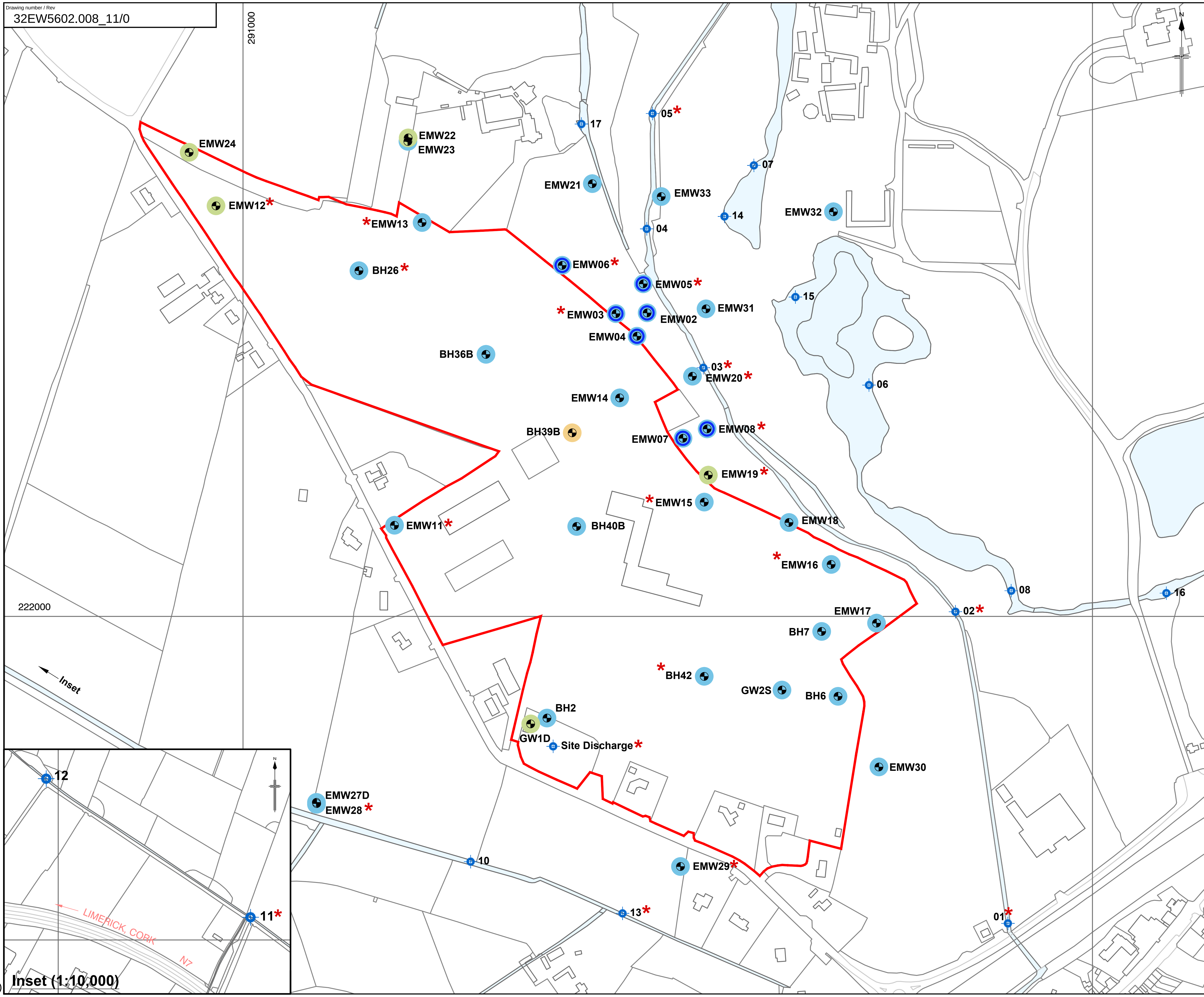
\\Enviros\Design\PROJECTS\KU32EW5602\Figures\Task 8\March 2016\32EW5602-008_10.dwg - 11/03/2016 10:30:56 - Figure 2 - alroberts

Figure 3: Groundwater and Surface Water Monitoring Locations

Drawing number / Rev
32EW5602.008_11/0



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KEY:

- Former WA0047-02 Waste Licence Boundary
- Surface Water Monitoring Point
- Groundwater Monitoring Point
- Gas/Groundwater Monitoring
- Overburden GW
- Bedrock
- Leachate

Proposed Sampling Frequency

- * Monthly Only

0 50 100 150
METRES

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
0	11/03/2016	FIRST ISSUE	AR	UD	DM	SJM

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Project
KERDIFFSTOWN LANDFILL
SITE REMEDIATION PROJECT

Drawing title
FIGURE 3
GROUNDWATER, SURFACE WATER AND OFF-SITE GAS MONITORING LOCATIONS

Drawing status
FIRST ISSUE

Scale: AS SHOWN — DO NOT SCALE
Jacobs No.: 32EW5602
Client no.:
Drawing number: 32EW5602.008_11
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Figure 4: Inferred Shallow Groundwater Flow Regime

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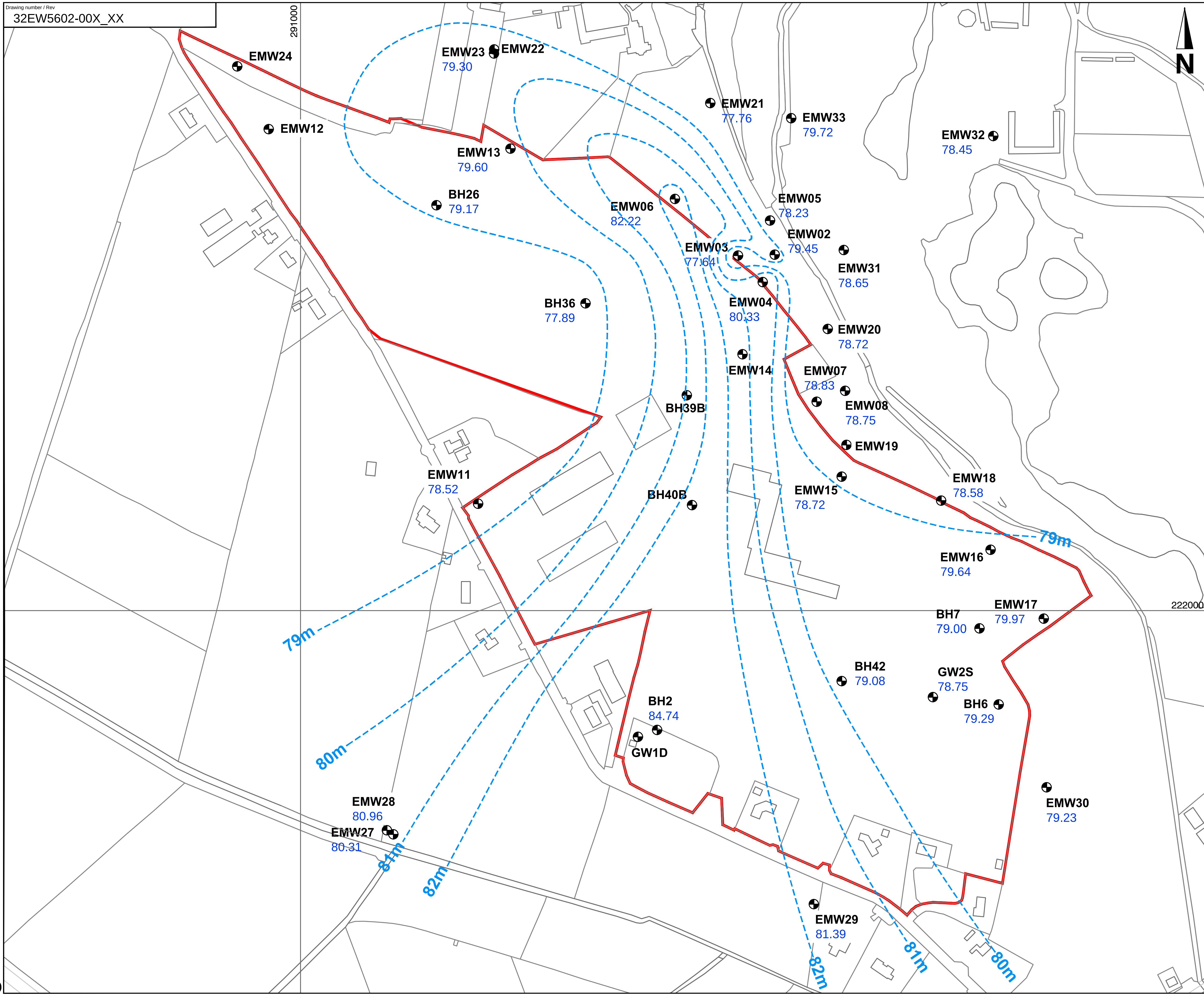

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KEY:

- Former WA0047-02 Waste Licence Boundary
- Surface Water Monitoring Point
- Groundwater Monitoring Point
- Leachate Monitoring Point
- Landfill Gas Monitoring Well
- Inferred Groundwater Contour (mAOD)

0 50 100 150
METRES

Rev	Rev. Date	Purpose of revision	Drawn	Checkd	Rev'd	Apprv'd
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Drawing title
FIGURE 4
INFERRED SHALLOW GROUNDWATER FLOW REGIME. DECEMBER 2016

Drawing status

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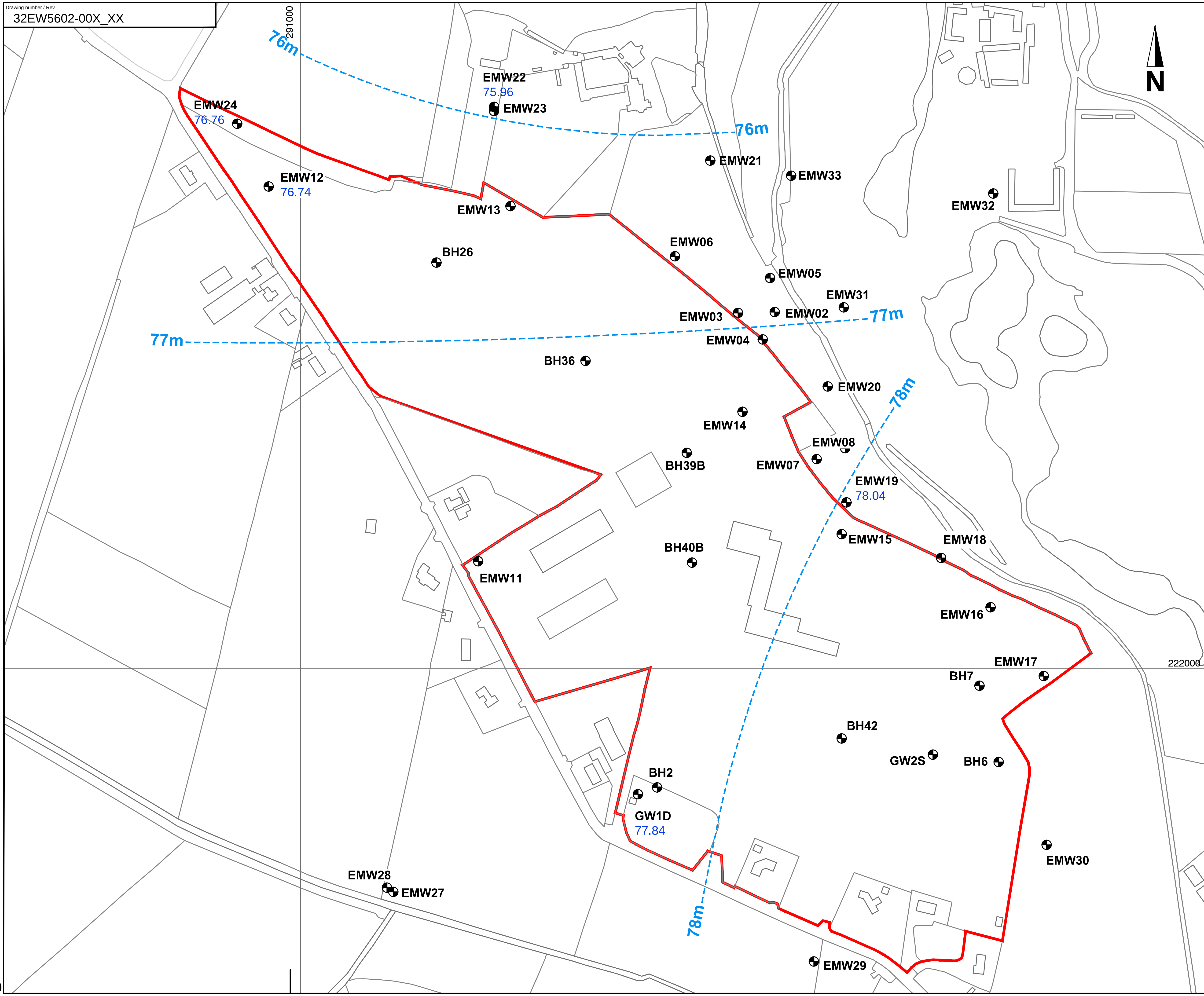
Figure 5: Inferred Groundwater Flow Regime in Bedrock



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- Leachate Monitoring Point
- Landfill Gas Monitoring Well
- Inferred Groundwater Contour (mAOD)

0 50 100 150
METRES

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FIGURE 5
INFERRED BEDROCK GROUNDWATER
FLOW REGIME. DECEMBER 2016

Drawing status

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Figure 6: Updated Conceptual Site Model (Version 4)

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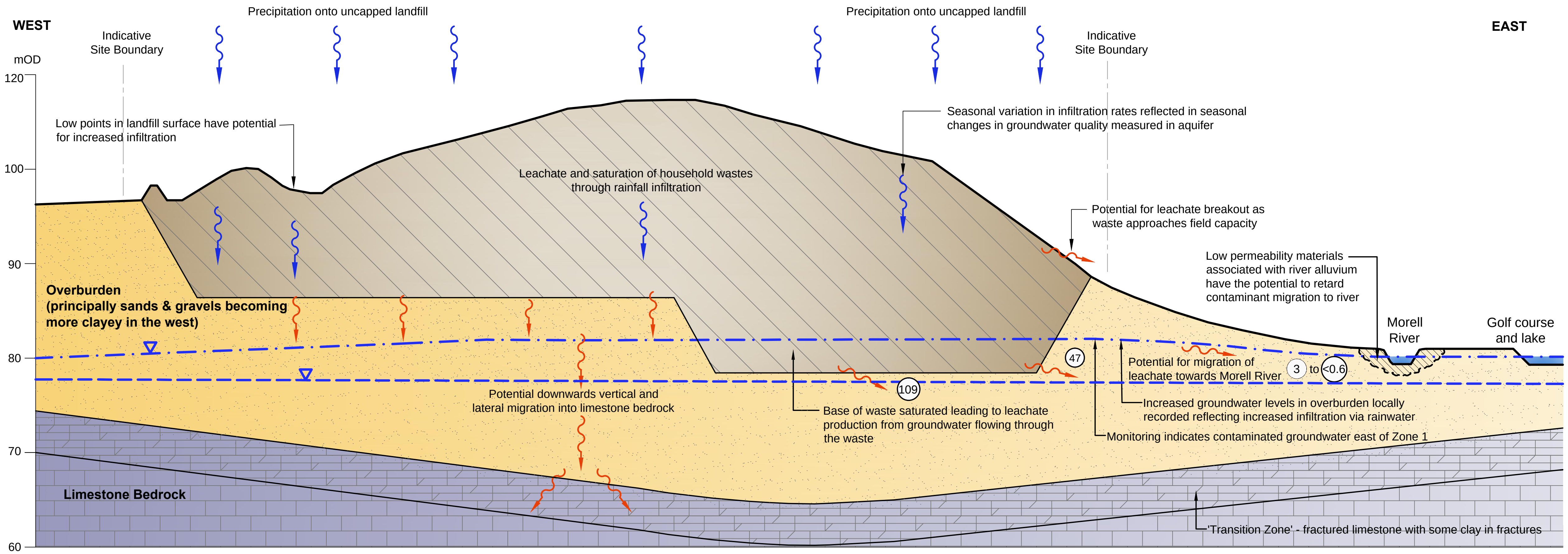
32EW5604-00-016/0



Groundwater Conceptual Site Model for Zone 1: Current Scenario

KEY:

- Groundwater Level in the Overburden
- Groundwater Head in the Limestone Bedrock
- Migrating Leachate
- (47) Ammoniacal Nitrogen Concentration July 2016 (mg/l)

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FIGURE 6
HYDROGEOLOGY CONCEPTUAL
SITE MODEL (ZONE 1)

Drawing status

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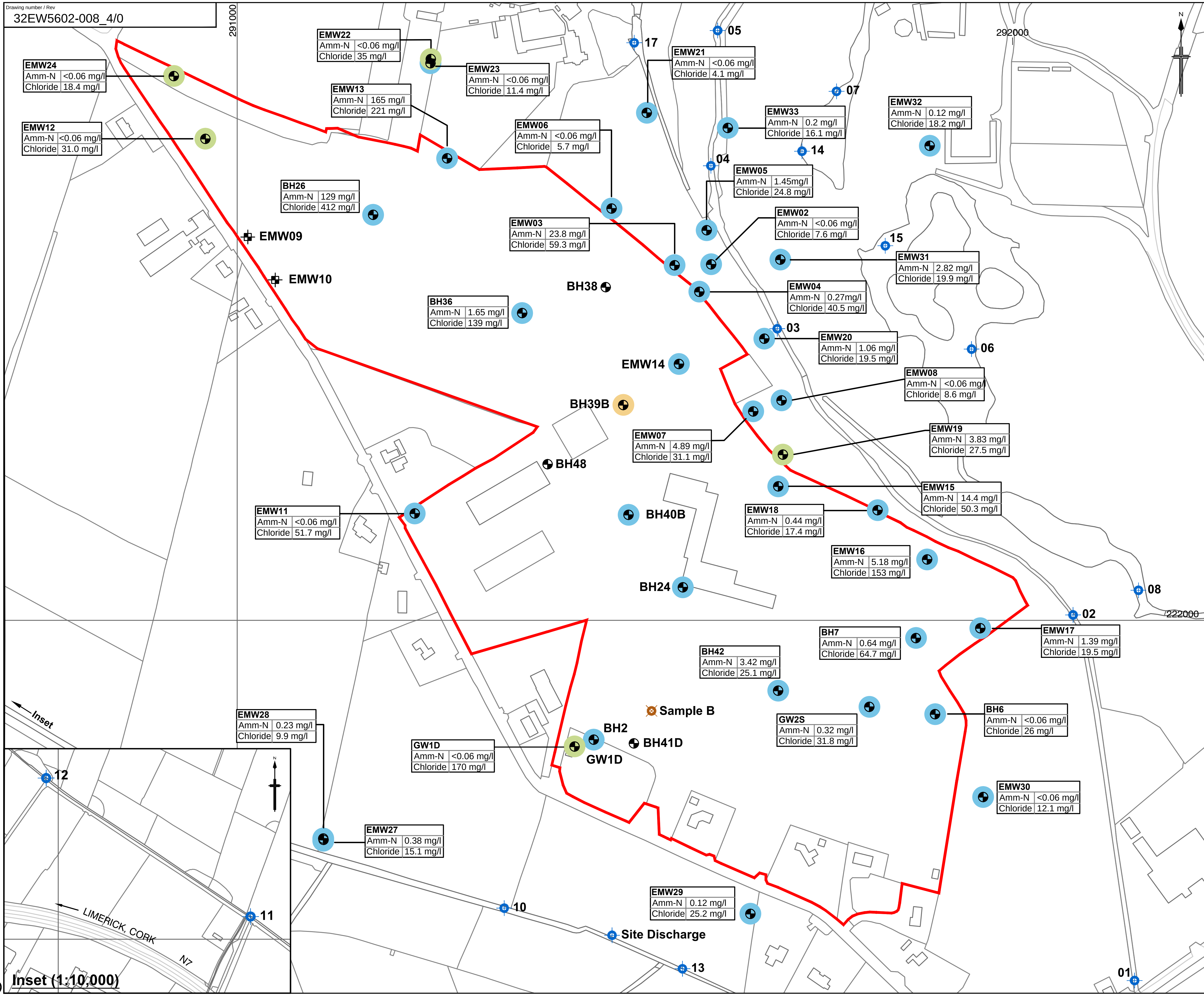
\\ledub1-fil001\ji\Sustainable Solutions\Kerdiffstown Landfill\5 - Drawings\CAD\Engineering Design - EIS\32EW5604-00-016.dwg - 05/05/2017 09:23:59 - FIGURE 6 GW - alrobets

Figure 7: Groundwater Ammoniacal Nitrogen and Chloride Concentrations (December 2016)



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- Surface Water Monitoring Point
- Groundwater Monitoring Point
- Landfill Gas Monitoring Well
- Leachate Monitoring Point
- Overburden GW
- Bedrock
- Leachate (Currently Dry)

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FIGURE 7
GROUNDWATER AMMONIACAL N,
CHLORIDE RESULTS. DECEMBER 2016

Drawing status

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Figure 8: Groundwater Ammoniacal Nitrogen Distribution (December 2016)

Drawing number / Rev
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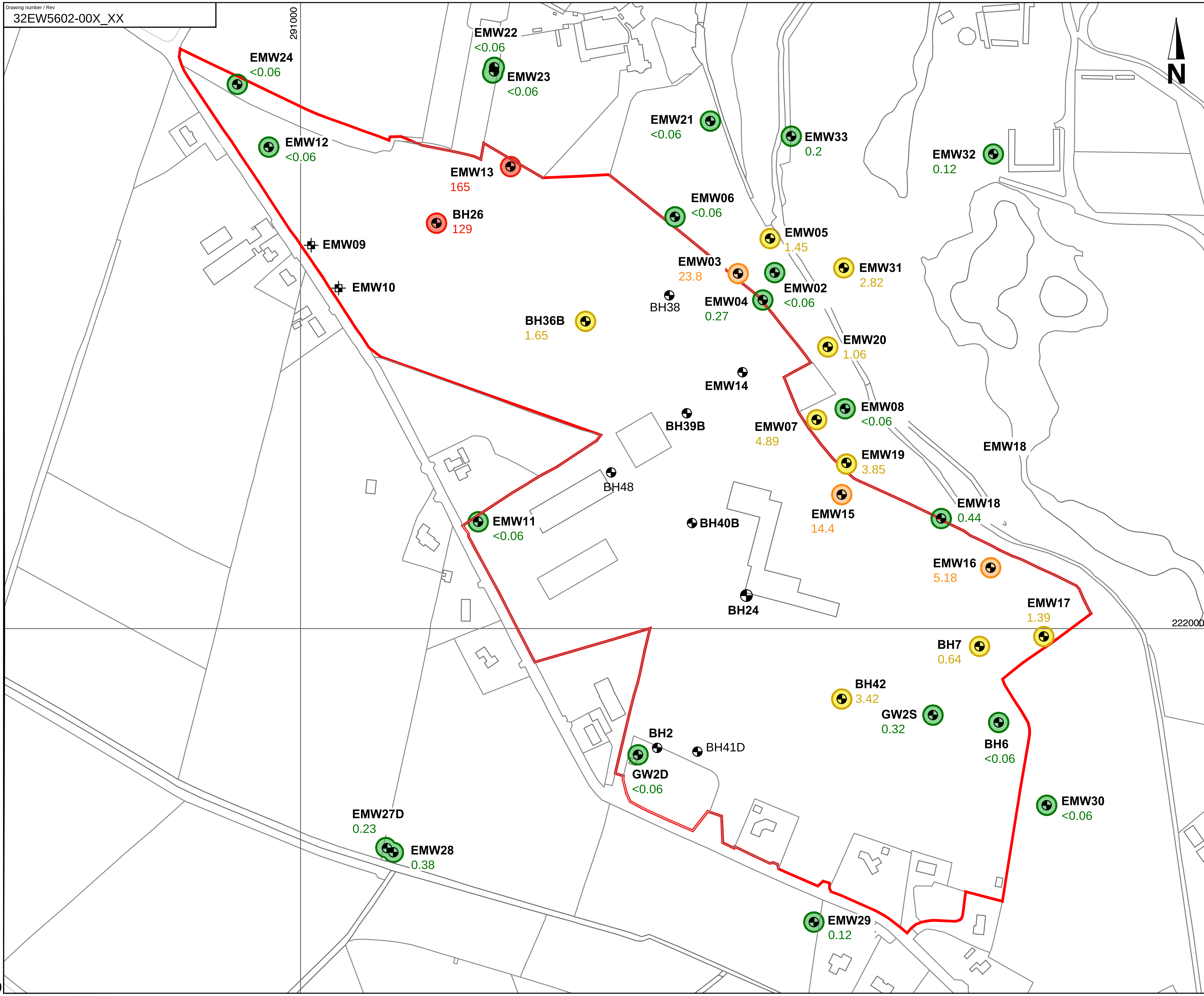

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KEY:

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- Inferred Groundwater Contour (mAOD)

Ammoniacal Nitrogen Concentrations

- <0.5mg/l
- 0.5 - 5mg/l
- 5 - 50mg/l
- >50mg/l

0 50 100 150
METRES

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Drawing title
FIGURE 8
AMMONIACAL NITROGEN
DISTRIBUTION. DECEMBER 2016

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Figure 9: Groundwater Chloride Concentrations (December 2016)

Drawing number / Rev
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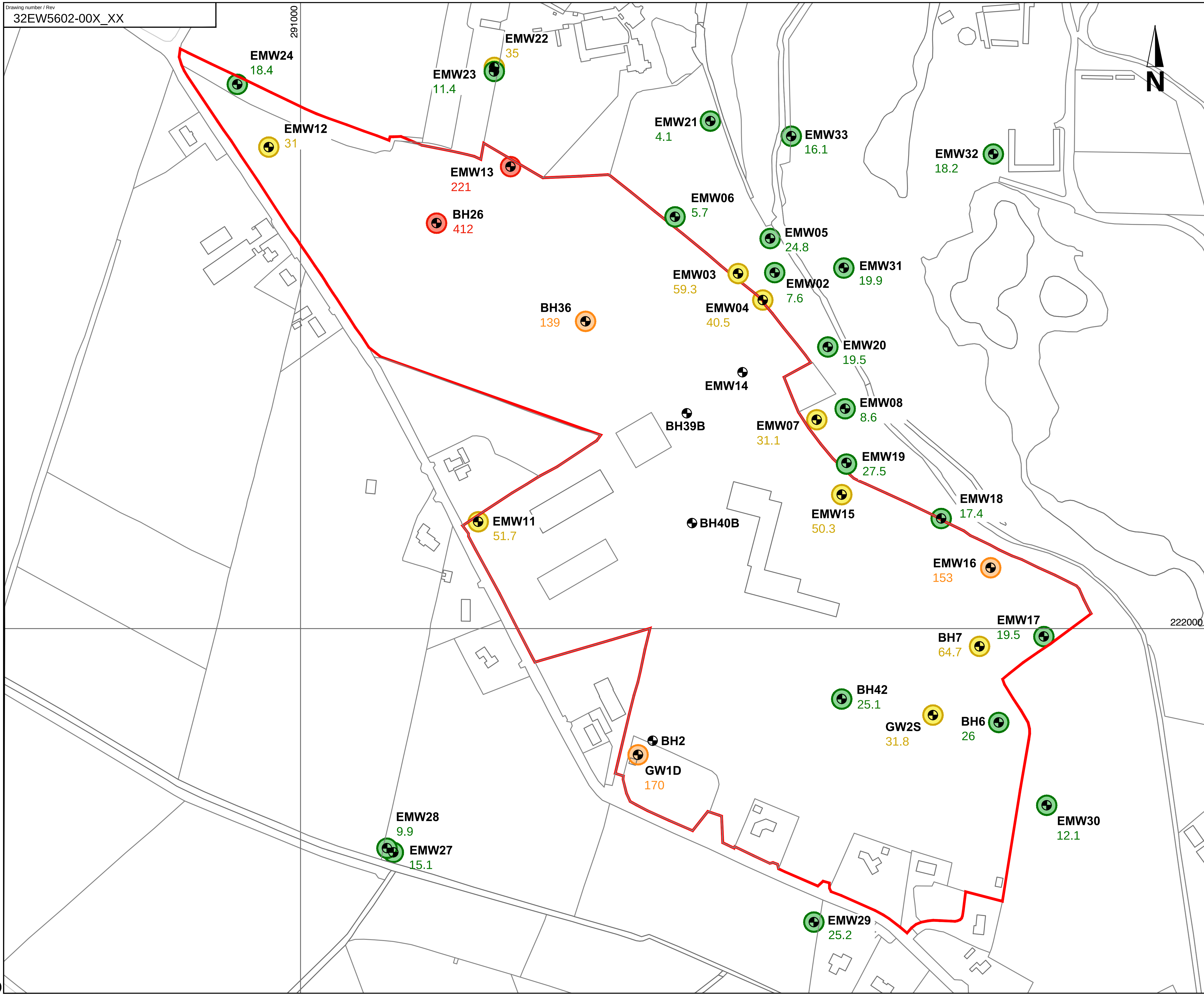

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KEY:

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Chloride

- <30mg/l
- 30mg/l - 100mg/l
- 100mg/l - 200mg/l
- >200mg/l

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FIGURE 9
GROUNDWATER CHLORIDE
DISTRIBUTION. DECEMBER 2016

Drawing status

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Drawing number: 32EW5602-00X_XX — Rev: 0

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