Comhairle Contae Thiobraid Árann
Tipperary County Council

Report on Testing of

Proposed Groundwater and Leachate Management Regime

At Ballaghveny Landfill

June 2018

Prepared by:

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On behalf of

Tipperary County Council

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The Key Findings From the Report are:

- Managing the Phase 3 and Phase 4 leachate between March and May 2018 by allowing the leachate to rise up to 100 mOD in Phase 4, and to an elevation between 0.1 m and 0.2 m below the prevailing upgradient groundwater elevation at GW21 for Phase 3 led to a 70% reduction in leachate production for Phases 3 and 4 compared to the same period in 2016, when leachate elevations were generally kept below the 1 m threshold level for each phase.
- Phase 4 leachate elevations of 100 mOD resulted in leachate leakage at the downgradient boundary of Phase 4 near GW27 when the leachate elevation exceeded the downgradient groundwater elevation at GW27.
- The Phase 4 leachate management controls were manipulated to try and reverse the electrical conductivity trend indicating leachate contamination at GW27; however, lag times in the response of GW27 to changes in leachate conditions at Phase 4 mean that the effect of the manipulations has not yet been observed at GW27.
- The available data suggest that maintaining the Phase 3 leachate elevations 0.1 m lower than the prevailing groundwater elevation at GW21 did not result in leachate leakage from Phase 3 during the trial period.

EXECUTIVE SUMMARY

Following meeting with EPA in October 2017, Tipperary County Council received permission to carry out a leachate management trial allowing leachate levels at Phases 3 and 4 of the landfill to rise above the licensed 1 m-above-basal-liner threshold enshrined in Waste License W0078-03/C.

The objectives for the trial period were:

- To implement the proposed groundwater and leachate management regime for the duration of the test period;
- To monitor trends in groundwater and leachate levels and in groundwater and leachate quality for the duration of the test period in order to assess the impact (if any) of the testing on groundwater quality downgradient of Phases 3 and 4 of the landfill;
- If monitoring during the test period identified a potential impact on groundwater quality, to manipulate the test pumping setup to try and reverse any trends indicating a deterioration in groundwater quality; and,
- To assess the reduction in leachate pumping from Phases 3 & 4 of the landfill compared to the previous management regime, due to the implementation of the proposed new leachate management regime during the test period.

The leachate management trials were setup to maintain a constant level difference between the leachate level in the landfill and the prevailing groundwater elevation at a fixed reference point for each Phase. As such, if the leachate level were to rise too high and the level difference (i.e. "the differential") thereby drop below the set threshold, leachate would be pumped from the Phase in order to lower the leachate level and increase the differential to the required magnitude.

- For Phase 4, the leachate pumping chamber LS06 was linked to the upgradient groundwater well GW15 and the leachate pumping system programmed to maintain the LS06 leachate level 1 m below the GW15 groundwater level. Later in the test the differential was reduced to 0.2 m.
- For Phase 3, the leachate pumping chamber LS03 was linked to the upgradient groundwater well GW21 and the leachate pumping system programmed to maintain the LS03 leachate level 1 m below the GW21 groundwater level. Later in the test the differential was reduced to 0.2 m and then to 0.1 m.
- For each phase groundwater inflow was expected to drive the leachate level up to a level at equilibrium with the differential, after which leachate pumping would be required to balance the groundwater inflow and prevent further rise in the leachate level.

After the trial leachate management controls were setup at Phase 4 in mid-December 2017:

- The Phase 4 leachate level rose to 100 mOD and then plateaued. The 100 mOD leachate level was well below the maximum elevation allowed by the 0.2 m leachate control differential and no leachate pumping was occurring. As such, the hydraulic gradient was driving groundwater into Phase 4 and the leachate level was staying constant without pumping. This indicates that the groundwater inflow must have been balanced by leachate leaking out of Phase 4 through the basal liner.
- In mid-April 2018 after a lag time of approximately 63 days since the leachate reached 100 mOD, a groundwater electrical conductivity (EC) spike occurred at GW27 directly downgradient of Phase 4. EC at GW27 rose from 2,000 uS/cm to 3,000 uS/cm and then stayed above 3,000 uS/cm for the remainder of the test period.

- After the EC spike was recognised at GW27, the Phase 4 leachate level was progressively lowered in steps by pumping from LS06. Each step brought the leachate level below a potential leak elevation, such that the leak would be deactivated. This was intended to stop the leakage and reduce the EC at GW27 to its original levels. Following these manipulations the EC at GW27 did not reduce to its original levels during the trial period.
- The final manipulation carried out paired the LS06 leachate level with the downgradient groundwater monitoring location GW27, and by pumping LS06 lowered the Phase 4 leachate level to below the downgradient groundwater elevation at GW27. Conceptually, this final step should result in inward hydraulic gradients on all sides of Phase 4 and preclude any leachate leakage. Following this final manipulation the EC at GW27 did not reduce to its original levels during the trial period.
- Although the EC level at GW27 remains at approximately 3,000 uS/cm after the end of the trial period, based on the lag time of approximately 63 days between changes in leachate condition in Phase 4 and a response at GW27, it is expected that a downward trend should be observed at GW27 starting at some point between 07 July and 12 August 2018, depending on what leachate control manipulation caused the response.
- Depending on the final outcome of the trials following completion of the GW27 response lag times in August 2018, the LS06 leachate level controls should be programmed to maintain the leachate level 0.1 m below the downgradient groundwater elevation at GW27 (or other equivalent groundwater level monitoring location) in the long term.
- Since GW27 is intended to be decommissioned in due course with the filling of the Wedge Cell, GW21 is proposed as a replacement for determining the Phase 4 downgradient groundwater elevation.

After the trial leachate management controls were setup at Phase 3 in mid-December 2017:

- Over the course of the trial period, allowing the Phase 3 leachate level to rise to within 0.1 m of the GW21 groundwater level reduced the volume of leachate generated by the Phase, compared to keeping the leachate level below the 1 m threshold.
- The available data suggest that there was no leachate leakage from Phase 3 of the landfill during the implementation of the trial leachate management regime.
- The groundwater elevation contours and flowlines for the trial period show that there is no current groundwater monitoring location directly downgradient of Phase 3. The proposed monitoring well GW36 will fill this gap in the monitoring network.
- Further assessment of the Phase 3 trial leachate management regime should be carried out following the installation of monitoring well GW36, which is expected to be directly downgradient of Phase 3 and better positioned to detect potential Phase 3 leachate leakage than the current groundwater monitoring wells in the vicinity of Phase 3.

Table of Contents

List of Tables

List of Figures

Appendices

1 Introduction

1.1 Terms of Reference

Ballaghveny landfill is located in the townland of Ballaghveny, Ballymackey, Nenagh, Co. Tipperary (Figure 1). The landfill is owned by Tipperary County Council (TCC) and operates under Waste License W0078-03/C. The site layout is shown in Figure 2.

Hidrigeolaíocht Uí Chonaire Teoranta (HUCT) was appointed by TCC to carry out a series of leachate pumping tests at the landfill to determine the efficacy of the proposed leachate and groundwater control regime for the site.

1.2 Background to the Current Assessment

Tipperary County Council met with the Environment Protection Agency on the 10th of October 2017 to present a report on the hydrogeological aspects of the Specified Engineering Works carried out at the site between October 2016 and June 2017. A proposed new groundwater and leachate management regime was discussed at the meeting and it was decided to carry out testing to investigate the proposals.

In December 2017 Tipperary County Council submitted document LR032912 to the EPA outlining the pumping tests to be carried out. In January 2018 the EPA approved a period of testing to run between 01 January 2018 and 31 May 2018 and specified that a report on the testing carried out should be submitted to the EPA by 30 June 2018.

Prior to the test period the leachate management regime at the site required maintaining leachate levels within Phases 3 and 4 of the site at a level less than 1 m above the basal liner of the landfill. This was achieved by pumping leachate to the leachate lagoon to remove and excess leachate above the desired levels. During periods of leachate pumping and high groundwater levels, groundwater ingress through leaks in the basal liners of Phases 3 and 4 acted to maintain leachate levels against the leachate pumping effort. This resulted in the pumping of large volumes of groundwater-diluted leachate to meet the requirements of the leachate management regime. The pumped leachate was subsequently tankered offsite for treatment at wastewater treatment plants. The large volumes of leachate requiring tankering and treatment resulted in very high costs for Tipperary County Council.

The proposed new leachate management regime involves allowing the leachate levels within Phases 3 and 4 to rise up above the 1 m-above-the-basal-liner threshold to a level just below the prevailing groundwater level outside the phase. This maintains a hydraulic gradient from the aquifer into the landfill in order to prevent leachate escape, but the reduced hydraulic gradient minimises the volume of groundwater ingress. During the pumping tests the leachate level in each phase was allowed to rise to a maximum level of 0.1 m below the reference groundwater level outside the respective phase.

1.3 Key Objectives

The key objectives of the pumping test investigations were:

- To implement the proposed groundwater and leachate management regime for the duration of the test period;

- To monitor trends in groundwater and leachate levels and in groundwater and leachate quality for the duration of the test period in order to assess the impact (if any) of the testing on groundwater quality downgradient of Phases 3 and 4 of the landfill;
- If monitoring during the test period identified a potential impact on groundwater quality, to manipulate the test pumping setup to try and reverse any trends indicating a deterioration in groundwater quality; and,
- To assess the reduction in leachate pumping from Phases 3 & 4 of the landfill compared to the previous management regime, due to the implementation of the proposed new leachate management regime during the test period.

1.4 This Report

This report deals with the following topics:

- Preparatory work carried out to enable the leachate management trials to be carried out;
- The leachate management trials carried during the test period;
- Interpretation and discussion of the water level and quality trends observed during the test period;
- Updates to the site Hydrogeological Conceptual Model arising out of the work; and,
- Conclusions and recommendations arising from the pumping test investigations.

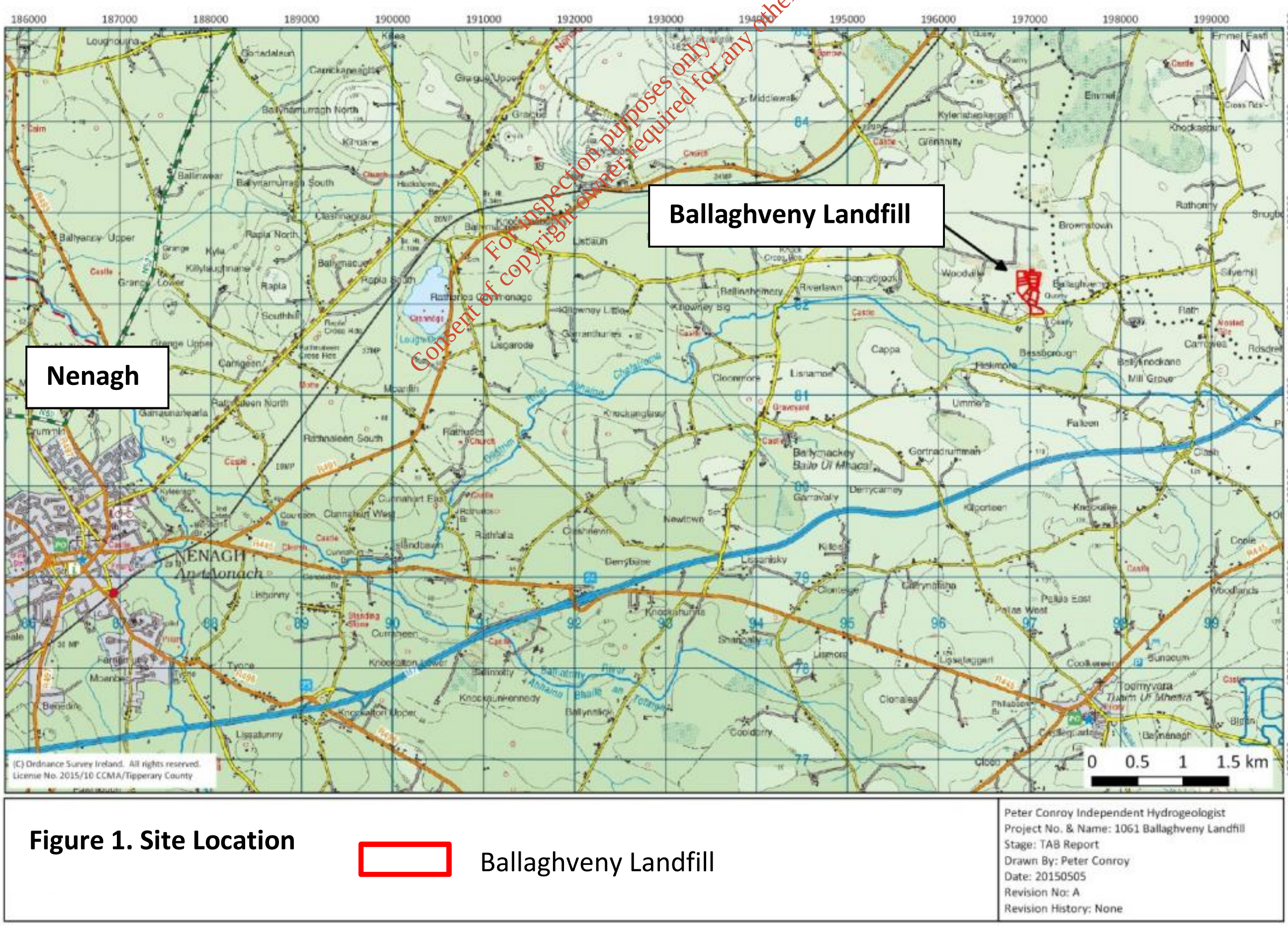

Figure 1. Site Location

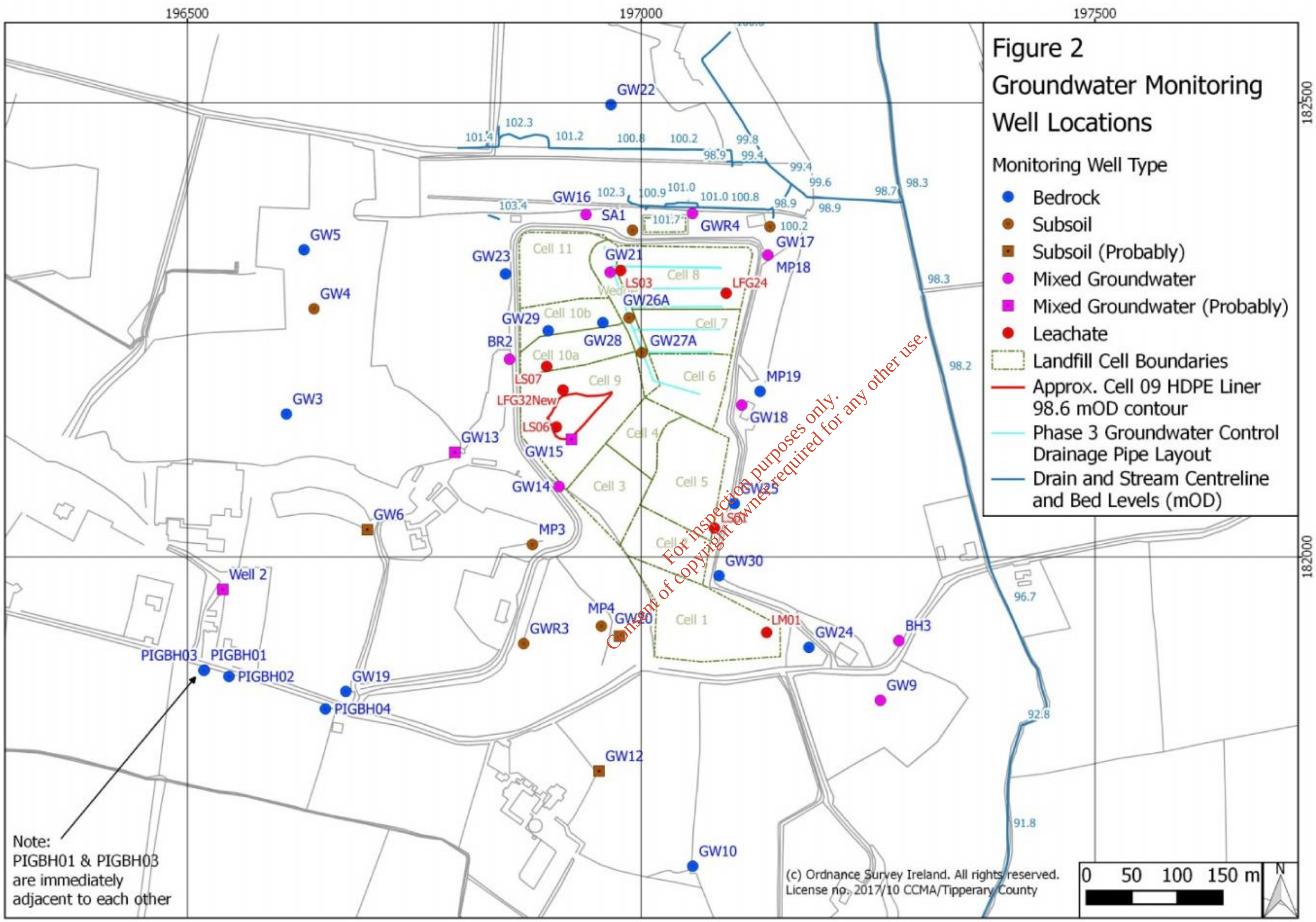

Figure 2. Site Layout

2 Factual Overview of the Testing Period

This section of the report includes tables, graphs and figures showing comprehensive collations of the available water level and water quality data.

A number of the graphs contain a large quantity of data which is difficult to interpret at first glance. The primary purpose of these graphs is to present the full scope of the monitoring data collected. Graphs showing targeted subsets of data are presented in Section 3 in support of particular aspects of the data interpretation.

2.1 Preparatory Work Ahead of the Pumping Tests

Table 1 summarises the preparatory works carried out ahead of the pumping tests.

Table 1. Preparatory Works Carried Out Ahead of the Pumping Tests

Location	Description
GW15	• New well head constructed: ○ Inclined Well casing and pipework extended forwards 2.16 m to new location such that well head is now positioned approximately 0.6 m above ground level supported by a headwall and over a concrete plinth.
LS06	• Lever valve fitted over top of dip tube to provide air-tight, easy-access to dip tube. • A slope survey was carried out on 20 December 2017 to determine the degree of inclination in the LS06 leachate well. The well was found to have a length of 18.8 m with a 3.9 m horizontal displacement between the well head and the base of the well, and a vertical displacement from the well head of 18.392 m. The calculated horizontal displacement assumes all lateral displacements are cumulative.
LS03	• Lever valve fitted over top of dip tube to provide air-tight, easy-access to dip tube.
Topographic Survey	• Topographic surveys of the well heads at GW15, GW21, LS03 and LS06 were carried out using Total Station to determine the elevation of the reference datum for water level dip-measurements at each location to an accuracy of +/- 2 mm. • The reference datum was taken as the invert of the top of the water level dip tube at GW15 and GW21, giving elevations of 108.52 mOD and 106.40 mOD respectively. • The reference datum was taken as the top rim of new dip-tube lever-valve access ports on the LS06 and LS03 well heads, giving elevations of 116.11 mOD and 101.00 mOD respectively. • The high accuracy topographic survey allowed potential errors in the comparison of water levels between GW15 and LS06, and between GW21 and LS03 to be minimised.
SCADACLOUD	• GW15 – LS06 and GW21 – LS03 were set up as paired wells on the SCADACLOUD pumping control system such that the leachate wells were set to remove leachate from the landfill by pumping in order to maintain the leachate level at a programmed level below the associated groundwater elevation.

2.2 Pumping Tests and Pumping Tests Timeline

The pumping tests carried out and the timeline of the pumping tests are detailed in Table 2.

Table 2. Pumping Tests Carried Out

Location	Date	Description
Scada cloud	13/12/2017	SCADACLOUD pumping system programmed to maintain leachate levels in LS06 and LS03 at an elevation 1.0 m below the prevailing groundwater level in GW15 and GW21 respectively. The very conservative 1.0 m differential was used to compensate for any potential inaccuracy in the topographic survey data relating the groundwater and leachate elevation data.
LS03	Baseline Info	• LS03 total depth measured at 4.05 m below the reference datum on 02/02/2018, i.e. base of LS03 is at 96.95 mOD. • Tender drawings for the Phase 3 construction contract show the design base of LS03 is positioned approximately 0.0 m below the adjacent HDPE liner for Phase 3 at the deepest part of the phase (i.e. adjacent to LS03). • On this basis the HDPE liner adjacent to LS03 is at approximately 96.95 mOD. • The 1 m leachate threshold corresponds to a leachate elevation of **97.95 mOD**.
LS03	13/12/2017 to 23/02/2018	Initial pumping period with pumping differential of 1.0 m maintained between the groundwater elevation in GW21 and the leachate elevation in LS03. • Leachate level in LS03 at 98.18 mOD on 13/12/2017 (i.e. already above the 1 m threshold). • LS03 level rises to 1 m below the GW21 groundwater level by 22/01/2018, i.e. LS03 = 99.26 mOD on 22/01/2018. • LS03 leachate level fluctuates at [GW21-1 m] mOD from 23/01/2018 onwards.
LS03	23/02/2018 to 25/042018	• New reference datum values from high accuracy topographic survey applied to calculation of GW21 and LS03 levels in mOD in SCADACLOUD. • SCADACLOUD programmed to maintain LS03 leachate elevation at a level 0.2 m lower than the prevailing groundwater elevation at GW21.
LS03	25/04/2018 onwards	• SCADACLOUD programmed to maintain LS03 leachate elevation at a level 0.1 m lower than the prevailing groundwater elevation at GW21.
LS06	Baseline Info	• Base of LS06 is 18.39 m below the reference datum, i.e. base of LS06 is at 97.72 mOD. • Tender drawings for the Phase 4 construction contract show the design base of LS06 is positioned 0.9 m below the adjacent HDPE liner for Phase 4 at the deepest part of the phase (i.e. adjacent to LS06). • On this basis the HDPE liner adjacent to LS06 is at approximately 98.62 mOD. • The 1 m leachate threshold corresponds to a leachate elevation of **99.62** mOD.
LS06	13/12/2017 to 23/02/2018	Initial pumping period with pumping differential of 1.0 m maintained between the groundwater elevation in GW15 and the leachate elevation in LS06. • Leachate level in LS06 at 98.07 mOD on 13/12/2017. • Rises to a level of 99.63 mOD by 22/01/2018 (i.e. the 1 m threshold). • Rises to a level 1 m below the GW15 groundwater level by 27/01/2018, i.e. LS06 = 99.73 mOD on 27/01/2018 (based on the estimated GW15 reference datum elevation in use at that time[1]). • LS06 leachate level fluctuates at [GW15 – 1 m] mOD from 27/01/2018 onwards. o Leachate pumping drops LS06 level to 99.52 mOD by end of period on 23/02/2018.

[1] Note that the GW15 level programmed in SCADACLOUD prior to 27/02/2018 was based on an estimated value for the GW15 reference datum elevation. The reference datum was surveyed accurately on 02/02/2018 and shown to be 0.55 m higher than previously estimated, such that the LS06 level on 27/01/2018 was actually 1.55 m below the GW15 groundwater elevation.

<table>
<tr><th>Location</th><th>Date</th><th>Description</th></tr>
<tr><td>LS06</td><td>23/02/2018 to 04/05/2018</td><td>

New reference datum values from high accuracy topographic survey applied to calculation of GW15 and LS06 levels in mOD in SCADACLOUD.
SCADACLOUD programmed to maintain LS06 leachate elevation at a level 0.2 m lower than the prevailing groundwater elevation at GW15 from 23/02/2018 onwards, allowing leachate levels to rise.

LS06 leachate elevation rises to 99.63 mOD on 27/02/2018.
LS06 leachate elevation rises to 99.67 mOD on 01/03/2018.

This is above the suspected leak threshold at 99.6 mOD discussed in previous reports (Conroy 2016 and HUCT 2017).
This is above the prevailing downgradient groundwater elevation of 99.65 mOD at GW27 at that time.

LS06 leachate level rises to 99.95 mOD between 01/03/2018 and 16/03/2018.
From 16/03/18 to 4/05/18 LS06 leachate level fluctuates between 99.93 mOD and 100.06 mOD.

This relatively steady level is between 0.85 m to 0.41 m below the prevailing level at GW15 and is maintained without leachate pumping.

The leachate level was expected to rise to 0.2 m below the GW15 level given the Scadacloud programming.

Interpretation is that the relatively steady level was possibly maintained by leachate leakage to the downgradient side of Phase 4.
Between 20 and 27/03/2018 the LS06 leachate level spikes up to 100.47 mOD then drops back to around 99.95 mOD again.

The spike is considered to relate to groundwater ingress in excess of the leakage rate during a groundwater elevation peak in response to prolonged heavy rainfall in March 2018.
The volume of leachate stored and then released in the generation and dissipation of the spike is estimated at 200 m^3 excluding any ongoing leakage for the duration of the peak.

Onset of rising trend in Electrical Conductivity (EC) at GW27 from 30/03/2018.

Considered to be due to leachate leakage deriving from the leak maintaining the steady leachate level at LS06 after 16/03/2018.

Suggests time lag between leakage and arrival of contamination at GW27.

Initial EC of 2,000 uS/cm rises to 3,000 uS/cm on 17/04/2018 and then remains steady at that level.
EC at GW27 remains steady above 3,000 uS/cm for two weeks between 18/04/2018 and 04/05/2018, suggesting a steady leachate leak rather than a short term slug of contamination.

As a result of the observed levels at LS06, GW15 and GW27 and the EC trend at GW27 it was decided to adapt the control settings at LS06 to try and reverse the observed EC trend at GW27.

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</table>

Location	Date	Description
LS06	04/05/2018 to 10/05/2018	New Settings at LS06 intended to bring the LS06 leachate elevation down to between the possible leak elevations of 99.95 mOD and 99.6 mOD, to see if this would reverse the EC trend at GW27 by deactivating the higher potential leak. • SCADACLOUD programmed to maintain LS06 leachate elevation at a level 0.6 m lower than the prevailing groundwater elevation at GW15 from 04/05/2018 onwards. o Pumping at LS06 dropped the leachate level to 99.93 mOD by 9 am on 05/05/2018. Historical pumping lockout then halted pumping until lockout removed on 06/05/2018. o The full 0.6m differential (LS06 leachate level at 99.7 mOD with GW15 groundwater elevation at 100.3 mOD) was achieved on 06/05/2018. o 0.6 m differential PLUS ongoing seasonal decline in GW15 groundwater elevation to 100.2 mOD, brought LS06 leachate elevation down to 99.6 mOD by 3 am on 10/05/2018. • EC at GW27 remained just above 3,000 uS/cm throughout the period.
LS06	10/05/2018 to 08/06/2018	New Settings at LS06 intended to bring the LS06 leachate elevation down to below the possible leak elevation of 99.6 mOD, to see if this would reverse the EC trend at GW27. • From 10/05/2018 the GW15 groundwater elevation was above 99.6 mOD, the LS06 leachate elevation was at or below 99.59 mOD , and the downgradient groundwater elevation at GW27 was less than the LS06 leachate elevation. o As such, the upgradient groundwater elevation exceeded the leachate elevation, which exceeded the downgradient groundwater elevation. o Ongoing leakage under these conditions would suggest that there are deeper leaks present in the Phase 4 liner below 99.6 mOD. o Note: LS06 leachate levels were below the 1 m threshold during this period. • The 0.6 m GW15-LS06 differential remained in place until 15/05/2018, with LS06 leachate elevation pumped down to 99.39 mOD by 3 am on that date. • On 15/05/2018 pumping at LS06 was locked out for leachate levels below 99.5 mOD, with pump cut-in when subsequent rising levels reach 99.53 mOD. o This was intended to keep leachate levels at about 99.5 mOD while GW15 groundwater elevation remained above 99.6 mOD; • By **25/05/2018** the LS06 leachate elevation had risen to between 99.50 mOD and 99.52 mOD in line with the pumping lockout window. o LS06 reached 99.52 mOD on 28/05/2018 and the LS06 pump cut in. • The GW27 EC rose from approximately 3,050 uS/cm to 3,370 uS/cm between **24/05/2018** and **27/05/2018**. o Then dropped steadily back to 3,185 uS/cm by 08/06/2018. o Remember that the EC trends at GW27 are affected by a time lag with respect to the occurrence of the leakage from Phase 4. • By **08/06/2018** the GW15 groundwater elevation had dropped to 99.60 mOD. o After approximately 1 month with steady settings, and o With the GW15 upgradient groundwater elevation dropping close to the LS06 leachate, and o With EC at GW27 remaining above 3,000 uS/cm, o It was decided to progress to a new setup to see if the EC trend at GW27 could be clearly reversed and EC levels returned to less than 2,000 uS/cm.

Location	Date	Description
LS06	08/06/2018 onwards	New Settings at LS06 intended to pump down the LS06 leachate elevation to below the downgradient groundwater elevation at GW27. • Under these conditions the hydraulic gradient should be inwards from the aquifer into Phase 4 both upgradient and downgradient of Phase 4 such that no leachate leakage should be possible. • With the potential for leachate leakage from Phase 4 eliminated, a clear decreasing trend in EC is expected to develop at GW27. • In order to create an inwards hydraulic gradient from the downgradient aquifer to Phase 4: o LS06 was paired with the downgradient groundwater monitoring well GW27 in Scadacloud and programmed to remove leachate by pumping to maintain a leachate elevation at LS06 that is 0.1 m lower than the prevailing groundwater elevation at GW27. o LS06 pumping lockout elevation set to 98.83 mOD to protect the pump against burn-out under low leachate level conditions. • The LS06 leachate elevation dropped below the GW27 groundwater elevation on 10/06/2018 and the 0.1 m differential was established by 11/06/2018 with LS06 at 98.94 mOD and GW27 at 99.04 mOD • The GW27 EC dropped steadily to 3,048 uS/cm by 19/06/2018. o GW27 groundwater elevation at 98.97 mOD o LS06 leachate elevation at 98.92 mOD • The GW27 EC dropped fairly steadily to 2,986 uS/cm by 27/06/2018. o GW27 groundwater elevation at 98.81 mOD o LS06 leachate elevation at 98.93 mOD

2.3 Water Quality Monitoring

The water quality monitoring locations referenced in the report are shown on Figure 2.

Laboratory analysis of groundwater samples was carried out routinely over the period July 2017 to May 2018 in line with the monitoring requirements of the site's Waste License. Additional sampling and analysis for a wider suite of parameters was carried out on a monthly basis between February and May 2018.

The sampling dates and the monitoring wells sampled are shown in Table 3. Table 3 also shows the analytical data for key water quality indicator parameters with respect to groundwater quality in the vicinity of a landfill. Table 3 is formatted for printing at A3 size.

Continuous electrical conductivity monitoring is ongoing at the following locations:

- At GW15, GW16, GW17, LS06 and LS03 since March 2016;
- At SA1, GW21, GW26, GW27, GW28 and GW29 since February 2017; and,
- At GW22 since March 2017.

EC data were also recorded manually in the field during water quality sampling events. When combined with the continuous data, the combined datasets provide a wider picture of EC spatial variation across the site compared to the EC logger data on their own. The combined EC datasets have been used to generate plots of the EC spatial distribution across the site for the water quality sampling events on 06 February, 06 March, 10 April and 01 May 2018. The EC distribution in each plot is based on interpolation of EC between the available data points using the Kriging interpolation technique. The interpolations do not take account of groundwater flow and associated contaminant migration. The EC spatial distribution plots are shown in Figures 03 to 06.

Table 3. Key Indicator Data for the Period July 2017 to May 2018

Bold red text indicates value exceeds SI366 of 2016 Threshold Value (TV)	Parameter	pH	Sulphate	Iron (Combined mg & ug data)	Manganese (Combined mg & ug data)	Ammonium NH4-N (rounded)	Nitrate N	Nitrite N	Conductivity @ 25°C (20C & 25C data combined)	Chloride	Alkalinity	Calcium	Magnesium	Potassium	Sodium	COD Chemical Oxygen Demand	BOD, 5 days with Inhibition (Carbonaceous)	Total Organic Carbon	Dissolved Oxygen	Dissolved Oxygen % Saturation	Temperature
	Units	pH units	mg/l	µg/l	µg/l	mg/l	mg/l	mg/l	µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	% O2	Degrees C
	SI 366 of 2016 TV	--	188	--	--	0.175	8.5	0.11	800	24	--	--	--	--	--	--	--	--	--	--	--
	Max Leachate	7.4	113	20156	2529	**643**	0	**0.4**	**10275**	**1369**	3908	283	128	505	988	848	51	858	8.4	80	16.1
	Max. Groundwater	7.9	98	33100	1470	**19**	**14.4**	0.0	**1703**	**182**	486	304	27	22	104	74	6	21	7.1	95	17.2
Location	Sample Date																				
Gw14	06/02/2018		< 20	450	150	< 0.2	4.3	< 0.02	**808**	**49.2**	326	135	13.4	3.0	23.1	< 8		1.89			
Gw14	06/03/2018		< 20	820	340	0.05	3.7	< 0.005	**831**	**46.6**	327	142	14.4	3.7	23.9						
Gw14	10/04/2018		< 20	3820	1470	**0.21**	3.9	0.03	791	**48.3**	333	150	15.3	2.7	23.8						
Gw14	01/05/2018		< 20	1390	510	0.13	4.3	< 0.005	**815**	**46.5**	352	169	14.1	2.6	24.5						
Gw15	18/07/2017	7.2	87			< 0.1			**932**	24.0										27	16.1
Gw15	09/08/2017	7.3	22			< 0.1			**974**	22.0										22	15.8
Gw15	20/09/2017	7.1	84			< 0.1			**959**	21.0										8	15.8
Gw15	18/10/2017	7.1	77			< 0.1			**954**	24.0										13	13.8
Gw15	21/11/2017	7.3	80			< 0.1			**955**	**25.0**										47	14.5
Gw15	06/12/2017	7.2	71			< 0.1			**937**	**28.0**										27	13.5
Gw15	24/01/2018	7.2	42			< 0.1			**866**	**34.0**										55.2	13.1
Gw15	06/02/2018		49.619	13	150	< 0.2	2.4	0.04	**873**	**44.3**	331	119	12.2	4.9	44.1	10		4.26			
Gw15	27/02/2018	7.3	48			< 0.1			590	**43.0**										49	9.8
Gw15	06/03/2018		45.11	11	80	< 0.01	< 2	0.01	**868**	**50.7**	320	115	11.9	4.4	39.7						
Gw15	27/03/2018	7.3	41			< 0.1			596	**50.0**										22	13.6
Gw15	10/04/2018		43.581	199	73.7	< 0.01	2.0	< 0.01	**908**	**50.8**	347	129	14.4	5.1	43.4						
Gw15	26/04/2018	7.3	37			< 0.1			596	**49.0**										28	13.8
Gw15	01/05/2018		42.288	9.6	42.8	0.03	< 2	0.01	**867**	**48.5**	360	141	12.8	4.7	41.5						
Gw16	18/07/2017	7.1	< 10			**5.8**			775	21.0										43	11.5
Gw16	09/08/2017	7.4	20			**5.3**			771	20.0										41	11.9
Gw16	20/09/2017	7.0	< 1			**4.9**			732	16.0										23	12
Gw16	18/10/2017	7.1	< 10			**4.8**			718	18.0										17	11.4
Gw16	21/11/2017	7.3	< 10			**4.4**			697	17.0										60	12.5
Gw16	06/12/2017	7.2	< 10			**4.2**			619	15.0										86	11.4
Gw16	24/01/2018	7.1	< 10			**4.7**			719	18.0										60.5	10
Gw16	27/02/2018	7.1	< 10			**4.7**			473	17.0										14	9.5
Gw16	27/03/2018	7.1	< 10			**4.8**			47	18.0										31	10
Gw16	26/04/2018	7.2	< 10			**4.6**			470	18.0										37	10.7
Gw17	18/07/2017	7.2	< 10			**4.8**			662	20.0										40	11.5
Gw17	09/08/2017	7.4	20			**4.6**			670	20.0										39	12.2
Gw17	20/09/2017	7.0	< 1			**4.6**			680	16.0										35	11.9
Gw17	25/10/2017	7.0	< 10			**4.5**			436	18.0										41	12.3
Gw17	21/11/2017	7.3	< 10			**4.6**			700	19.0										69	12.5
Gw17	06/12/2017	7.1	< 10			**5**			698	18.0										72	11.2
Gw17	24/01/2018	7.0	< 10			**4.9**			**854**	19.0										69.2	10.3
Gw17	06/02/2018		< 20	33100	310	**4.5**	< 2	0.02	750	18.8	358	142	6.7	2.4	13.3	74		15.23			
Gw17	27/02/2018	6.9	< 10			**4.5**			560	21.0										10	0.8
Gw17	06/03/2018		< 20	10500	210	**2.7**	< 2	< 0.005	752	19.2	350	128	6.2	2.1	14.4						
Gw17	27/03/2018	7.1	< 10			**4.9**			479	19.0										35	10.8
Gw17	10/04/2018		< 20	26300	230	**4.3**	< 2	0.01	619	19.0	352	135	6.0	2.1	12.6						
Gw17	26/04/2018	7.2	< 10			**4.7**			473	20.0										36	12.4
Gw17	01/05/2018		< 20	8620	170	**0.77**	< 2	< 0.005	706	19.3	347	143	5.2	1.7	12.4						
Gw18	18/07/2017	7.2	40			**2.5**			**1043**	**49.0**										36	12.2
Gw18	09/08/2017	7.3	12			**0.46**			789	12.0										28	13.2
Gw18	20/09/2017	7.0	39			**2.5**			**1003**	**32.0**										16	13
Gw18	18/10/2017	7.0	33			**3.7**			739	**36.0**										10	11.6
Gw18	21/11/2017	7.0	32			**7.6**			**1417**	**88.0**										15	12.4
Gw18	06/12/2017	7.0	34			**5.5**			**1327**	**77.0**										12	10.9
Gw18	24/01/2018	7.0	17			**0.9**			**979**	23.0										43.3	8.2
Gw18	24/01/2018	7.5	< 10			< 0.1			697	**45.0**										44.9	10.5
Gw18	07/02/2018		41.091	200	430	**3.5**	5.1	< 0.02	**1213**	**61.5**	487	167	20.7	16.6	42.0	11		5.73			
Gw18	27/02/2018	7.0	42			**5.8**			**987**	**97.0**										34	8.5
Gw18	06/03/2018		41.716	171	1160	**3.4**	4.4	0.04	**1416**	**100.8**	541	216	23.6	20.6	57.2						
Gw18	27/03/2018	7.0	37			**7.4**			**1102**	**154.0**										35	10
Gw18	10/04/2018		34.971	274	1000	**5.8**	< 2	0.07	**1427**	**237.2**	576	210	23.6	23.0	62.0						
Gw18	26/04/2018	7.0	27			**10**			**1244**	**171.0**										33	10.4
Gw18	01/05/2018		32.783	499	1640	**1.7**	< 2	0.01	**1494**	**163.7**	756	297	30.3	32.8	107.0						
Gw20	18/07/2017	7.4	45			**2.2**			**1299**	**175.0**										48	11.3
Gw20	20/09/2017	7.3	49			0.14			**1146**	**147.0**										28	11.5
Gw20	18/10/2017	7.2	48			< 0.1			765	**153.0**										17	10.9
Gw20	21/11/2017	7.5	43			**0.82**			**1215**	**141.0**										85	12.7
Gw20	06/12/2017	7.2	35			**1.7**			**1255**	**147.0**										21	10.9

Table 3. Key Indicator Data for the Period July 2017 to May 2018

Bold red text indicates value exceeds SI366 of 2016 Threshold Value (TV)	Parameter	pH	Sulphate	Iron (Combined mg & ug data)	Manganese (Combined mg & ug data)	Ammonium NH4-N (rounded)	Nitrate N	Nitrite N	Conductivity @ 25°C (20C & 25C data combined)	Chloride	Alkalinity	Calcium	Magnesium	Potassium	Sodium	COD Chemical Oxygen Demand	BOD, 5 days with Inhibition (Carbonaceous)	Total Organic Carbon	Dissolved Oxygen	Dissolved Oxygen % Saturation	Temperature
	Units	pH units	mg/l	µg/l	µg/l	mg/l	mg/l	mg/l	µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	% O2	Degrees C
	SI 366 of 2016 TV	--	188	--	--	0.175	8.5	0.11	800	24	--	--	--	--	--	--	--	--	--	--	--
	Max Leachate	7.4	113	20156	2529	**643**	0	**0.4**	**10275**	**1369**	3908	283	128	505	988	848	51	858	8.4	80	16.1
	Max. Groundwater	7.9	98	33100	1470	**19**	**14.4**	0.0	**1703**	**182**	486	304	27	22	104	74	6	21	7.1	95	17.2
Location	Sample Date																				
Gw20	24/01/2018	7.2	36			**4.3**			**1282**	**150.0**										22.4	10
Gw20	06/02/2018		36.116	930	310	**5.4**	**9.4**	0.02	**1231**	**144.6**	367	132	24.5	8.6	82.2	9		3.68			
Gw20	27/02/2018	7.3	41			**0.74**			**885**	**178.0**										34	9
Gw20	06/03/2018		45.332	510	370	**5.2**	**13.0**	0.06	**1429**	**178.7**	368	144	26.3	10.9	93.6						
Gw20	27/03/2018	7.2	44			**7.9**			**983**	**190.0**										35	9.7
Gw20	10/04/2018		46.718	920	330	**7.7**	**9.8**	0.05	**1407**	**300.5**	387	146	28.4	10.3	80.8						
Gw20	26/04/2018	7.3	36			**3**			**940**	**185.0**										46	10
Gw20	01/05/2018		50.254	108	335	**3**	**17.2**	0.04	**1450**	**189.8**	372	165	25.5	9.6	92.4						
GW21	06/02/2018		25.715	39900	690	< 0.2	< 2	0.08	785	15.9	353	160	7.9	4.2	23.6	39		10.69			
GW21	06/03/2018		< 20	25500	810	0.02	< 2	0.03	714	15.0	315	135	7.0	2.7	15.4						
GW21	10/04/2018		< 20	9330	560	**0.97**	< 2	< 0.01	693	13.4	339	132	7.1	2.4	12.4						
GW21	01/05/2018		< 20	5920	560	**0.56**	< 2	< 0.005	703	13.7	339	142	6.5	2.0	12.1						
GW22	06/02/2018		< 20	4450	190	**1.9**	< 2	< 0.02	526	11.8	273	103	3.0	< 0.4	8.3	33		13.14			
GW22	07/03/2018		< 20	4700	190		< 2	< 0.005	557	12.3	287	99	2.8	0.6	7.6						
GW22	10/04/2018		< 20	4960	210	**1.5**	< 2	< 0.01	549	11.5	275	110	3.2	0.7	6.9						
GW22	01/05/2018		< 20	4870	190	**0.53**	< 2	< 0.005	588	11.9	294	127	3.1	0.7	8.1						
GW23	06/02/2018		24.963	2930	220	< 0.2	< 2	0.04	749	19.8	343	240	23.6	4.3	17.9	< 8		2.5			
GW23	06/03/2018		27.329	3320	220	0.1	< 2	0.01	755	**29.9**	335	20	25.3	3.6	19.6						
GW23	10/04/2018		42.682	5220	160	0.07	< 2	0.06	743	**31.3**	353	207	24.3	4.3	18.7						
GW23	01/05/2018		24.086	3620	180	**0.29**	< 2	< 0.005	748	**33.1**	336	234	21.2	3.2	21.0						
GW24	07/02/2018		45.844	3540	520	**74.8**	< 2	0.03	**2444**	**236.8**	842	102	47.9	67.0	184.0	43		17.2			
GW24	06/03/2018		32.547	7050	940	**52**	< 2	0.03	**2455**	**263.7**	855	163	49.0	64.5	187.3						
GW24	10/04/2018		< 20	9010	880	**11.3**	< 2	0.03	**3838**	**574.4**	1324	149	93.3	116.6	276.9						
GW24	01/05/2018		< 20	9050	980	**15.8**	< 2	< 0.005	**4324**	**564.4**	1501	209	109.0	136.0	380.0						
GW28	06/02/2018		40.608	880	1650	**3.5**	< 2	< 0.02	**857**	18.4	393	138	12.6	3.3	34.3	8		4.06			
GW28	07/03/2018		37.323	3300	1530		< 2	< 0.005	783	17.9	354	136	11.4	3.1	28.1						
GW28	10/04/2018		37.276	850	1360	0.04	< 2	0.01	733	15.6	343	128	11.8	3.2	26.5						
GW28	01/05/2018		34.508	610	1270	0.11	< 2	< 0.005	779	15.1	372	148	10.9	3.2	27.4						
GW29	06/02/2018		20.148	136	2.2	< 0.2	< 2	< 0.02	662	14.9	307	117	9.3	1.3	11.5	8		4.33			
GW29	07/03/2018		21.293	480	69.2		< 2	< 0.005	670	14.6	293	112	9.0	1.3	11.3						
GW29	10/04/2018		21.662	181	37	0.02	< 2	< 0.01	657	12.7	318	124	10.5	1.4	12.3						
GW29	01/05/2018		20.329	56.1	15.9	**0.19**	< 2	< 0.005	711	11.9	324	141	9.5	1.4	12.3						
Gwr4	06/02/2018		< 20	10600	270	**4**	< 2	< 0.02	363	23.2	331	209	9.9	2.5	10.7	82		19.85			
Gwr4	06/03/2018		< 20	6450	180	**2.3**	< 2	< 0.005	678	20.4	317	141	6.5	1.4	10.8						
Gwr4	10/04/2018		< 20	19500	490	**3.7**	< 2	0.07	670	**30.5**	341	585	56.1	2.3	9.6						
Gwr4	01/05/2018		< 20	8370	190	**0.35**	< 2	< 0.005	659	23.7	327	166	7.8	1.7	11.2						
SA1	06/02/2018		< 20	16600	280	**4.1**	< 2	< 0.02	795	**25.0**	377	346	15.1	2.7	12.1	64		11.14			
SA1	06/03/2018		< 20	7760	180	**2.4**	< 2	< 0.005	743	21.0	340	161	7.4	1.9	11.9						
SA1	10/04/2018		< 20	11100	170	**4**	< 2	0.02	759	19.9	381	158	7.8	2.2	10.7						
SA1	01/05/2018		< 20	12300	270	**0.4**	< 2	< 0.005	**811**	23.1	427	269	8.4	2.5	12.6						

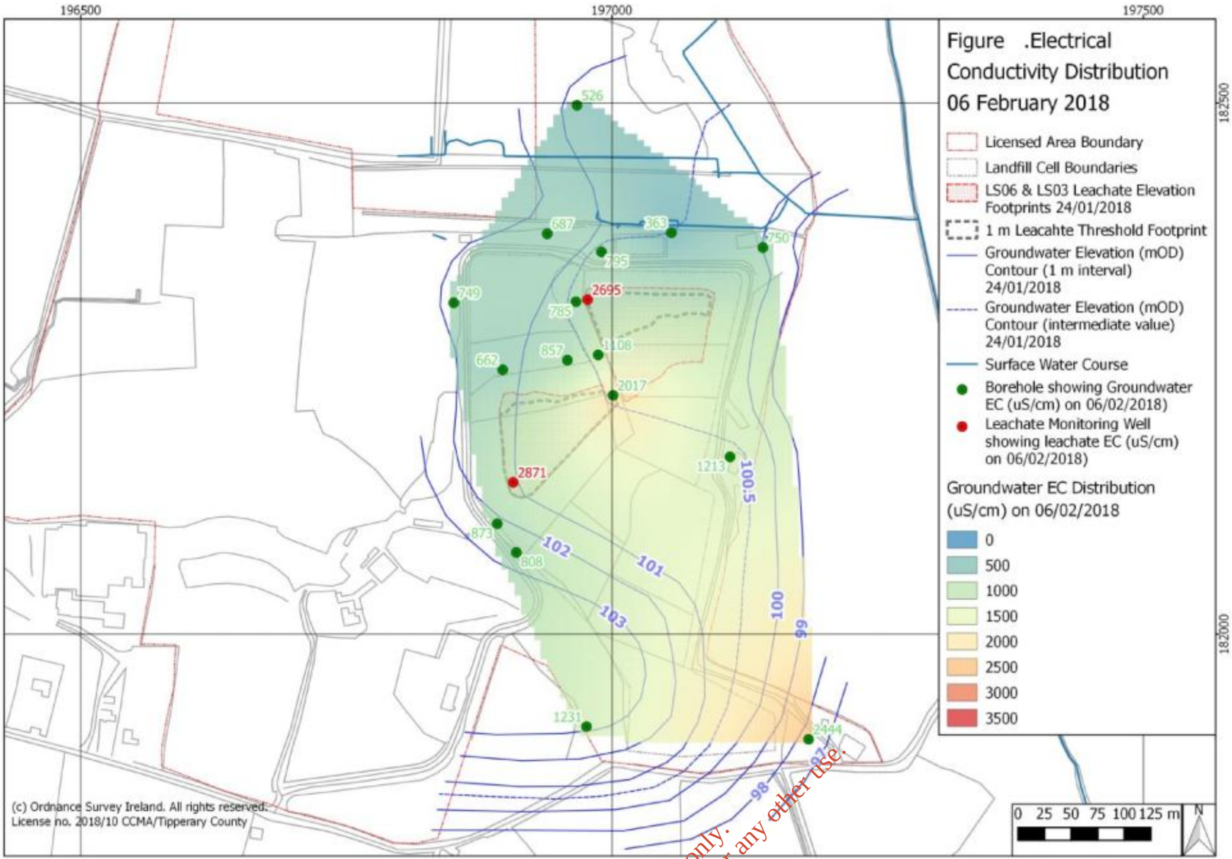

Figure 3. Electrical Conductivity Distribution 06 February 2018

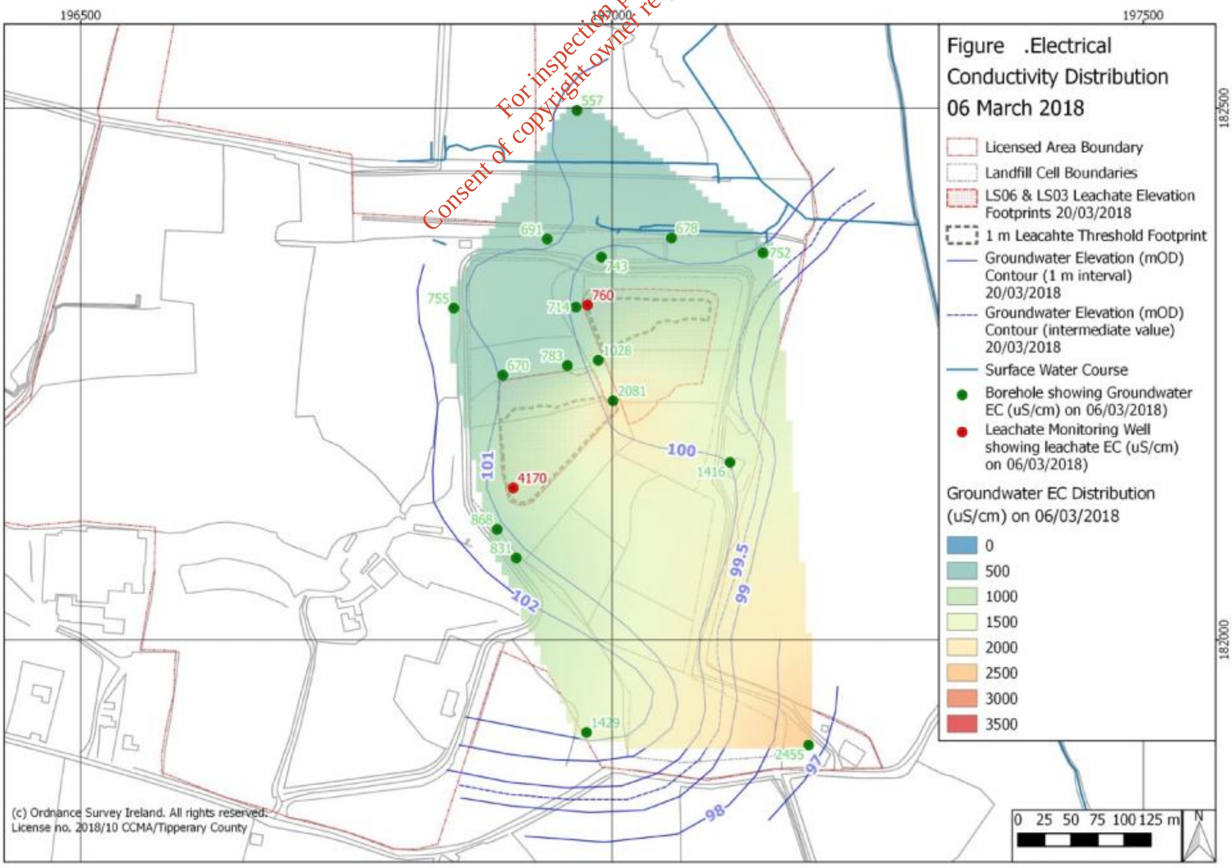

Figure 4. Electrical Conductivity Distribution 06 March 2018

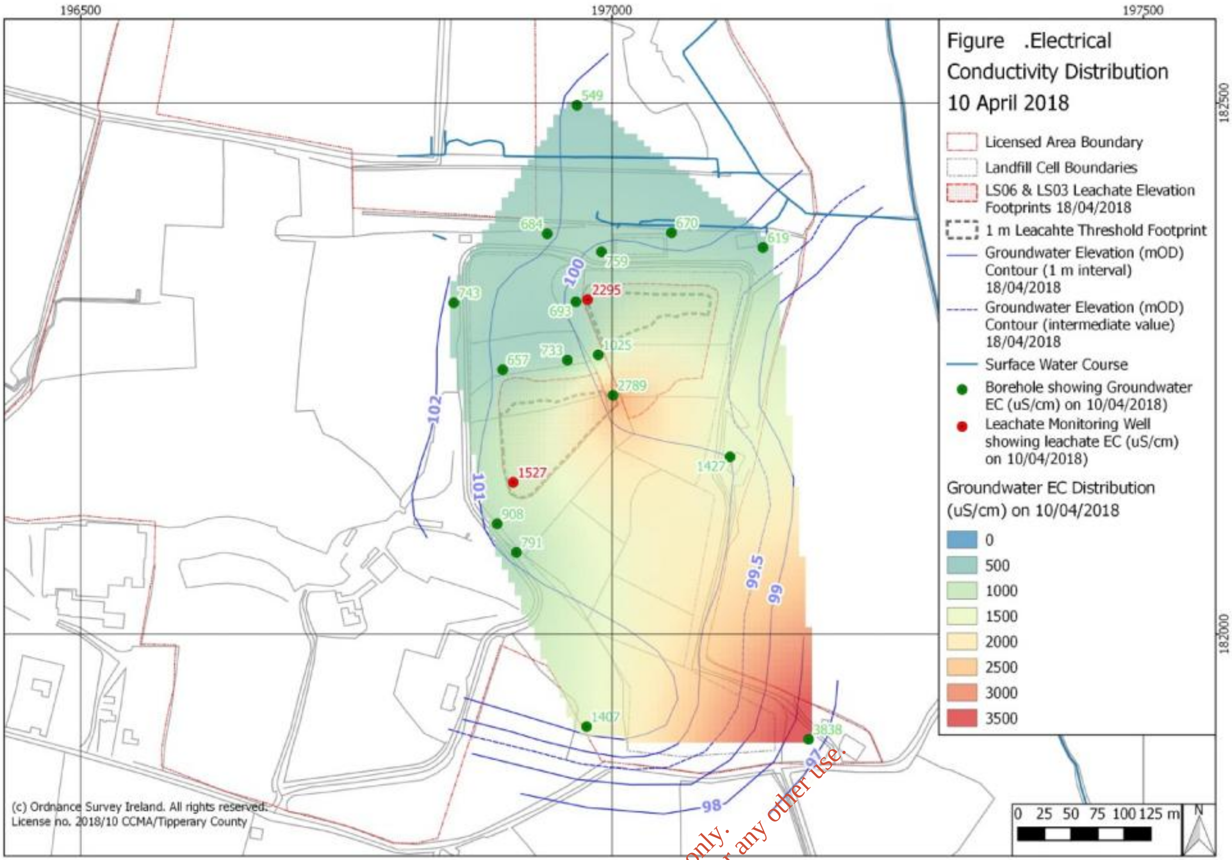

Figure 5. Electrical Conductivity Distribution 10 April 2018

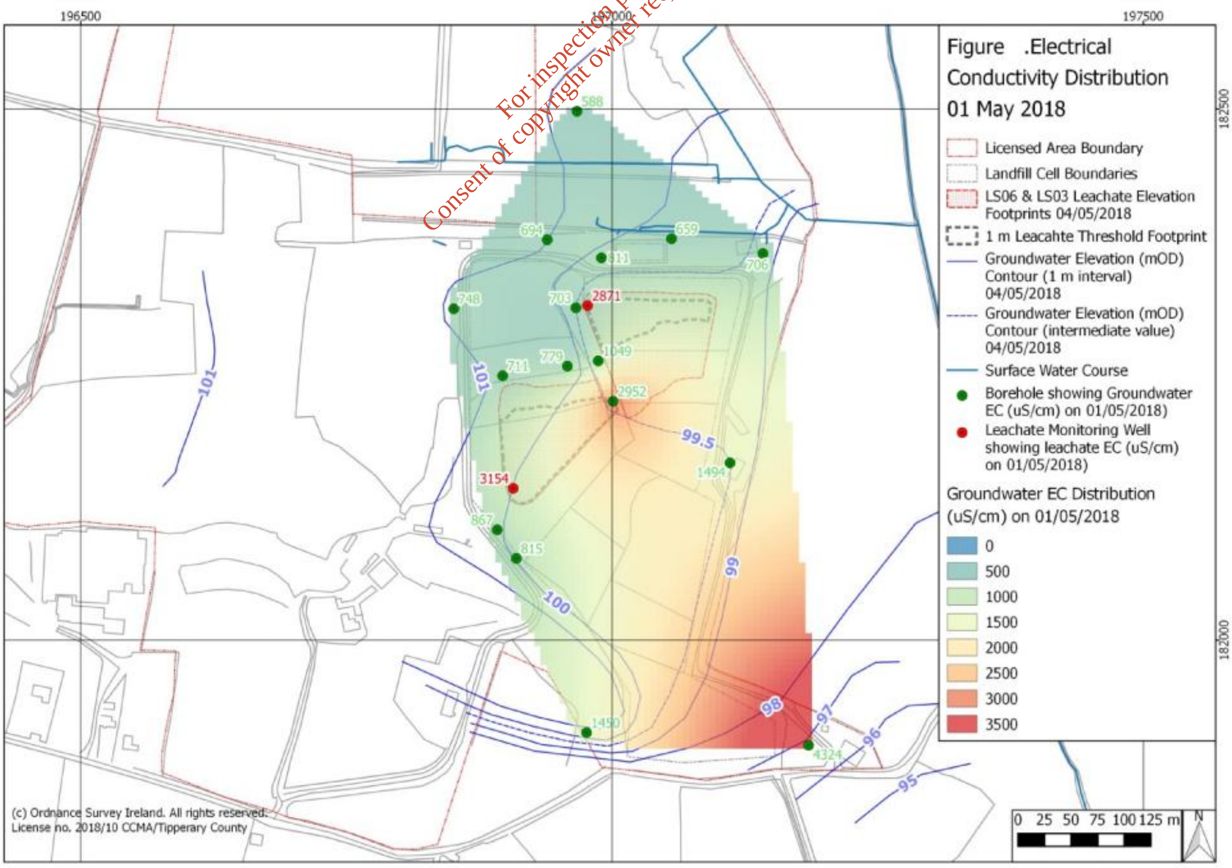

Figure 6. Electrical Conductivity Distribution 01 May 2018

The trends in electrical conductivity at the continuous EC monitoring locations between November 2017 and June 2018 are shown in Figure 7.

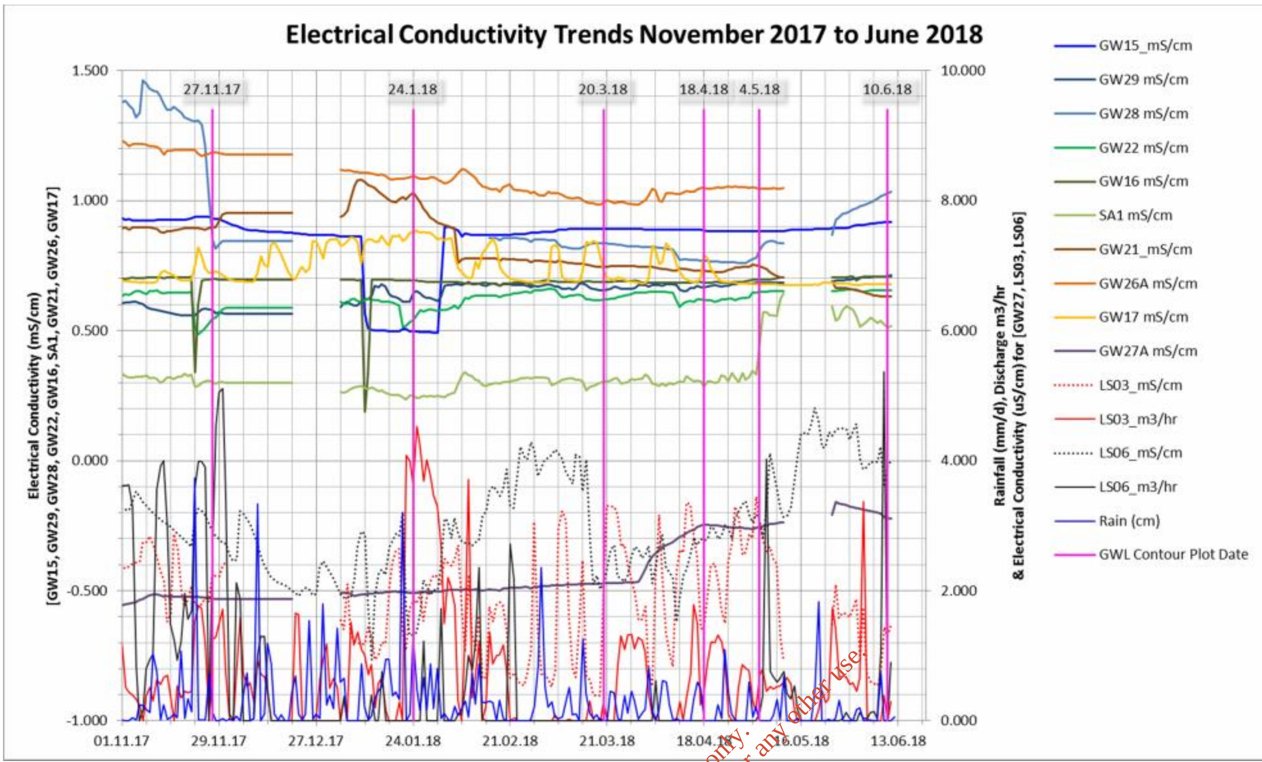

Figure 7. Electrical Conductivity Trends November 2017 to June 2018

Figures 8 to 14 show a series of graphs which illustrate the trends in laboratory measurements for a number of indicator parameters over time at a range of locations across the site.

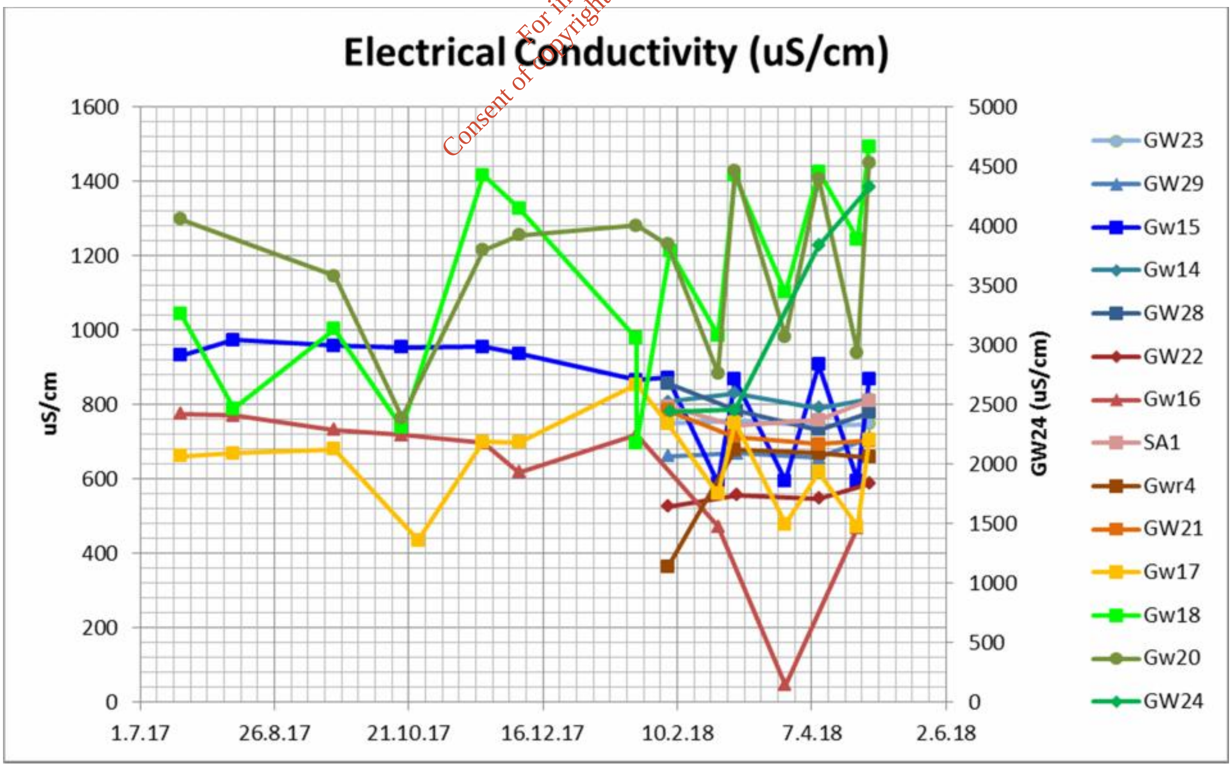

Figure 8. Electrical Conductivity Measurements in Groundwater Between July 2017 and June 2018

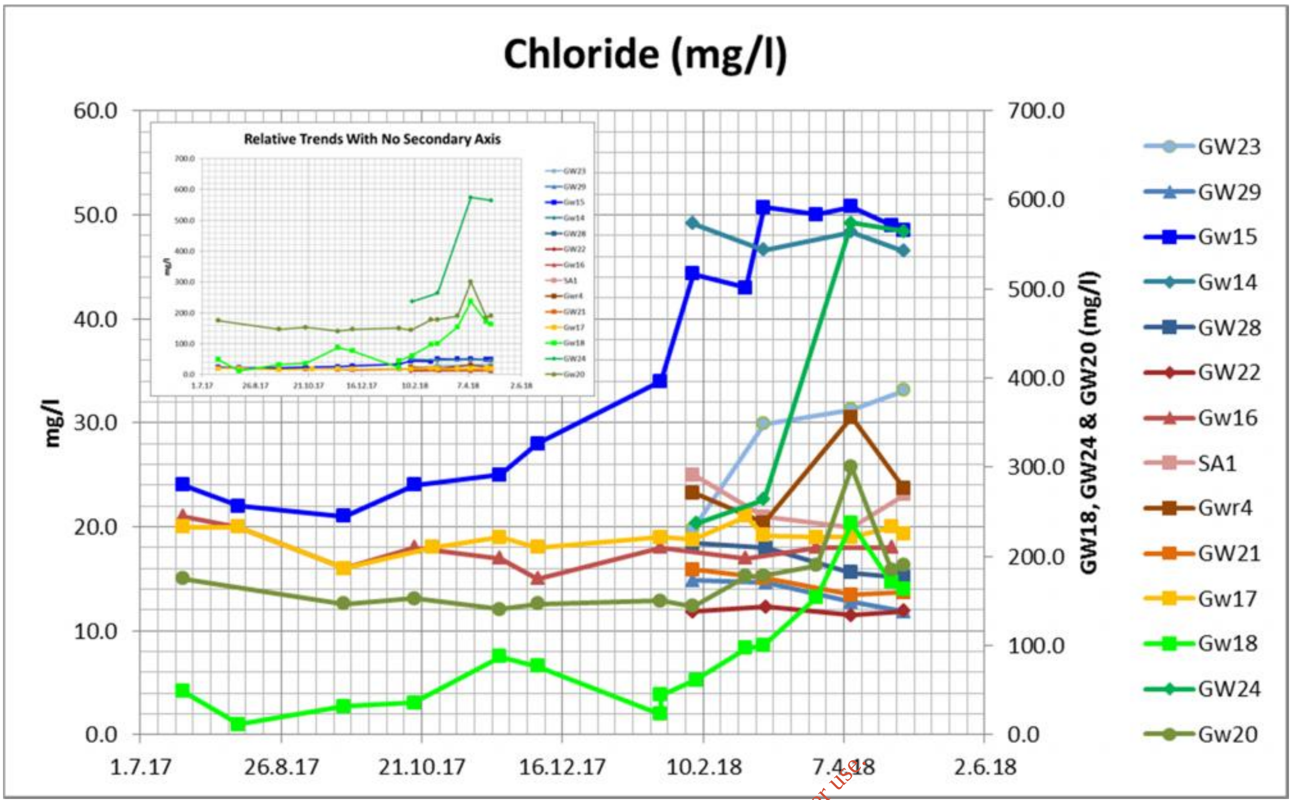

Figure 9. Chloride Concentration in Groundwater Between July 2017 and June 2018

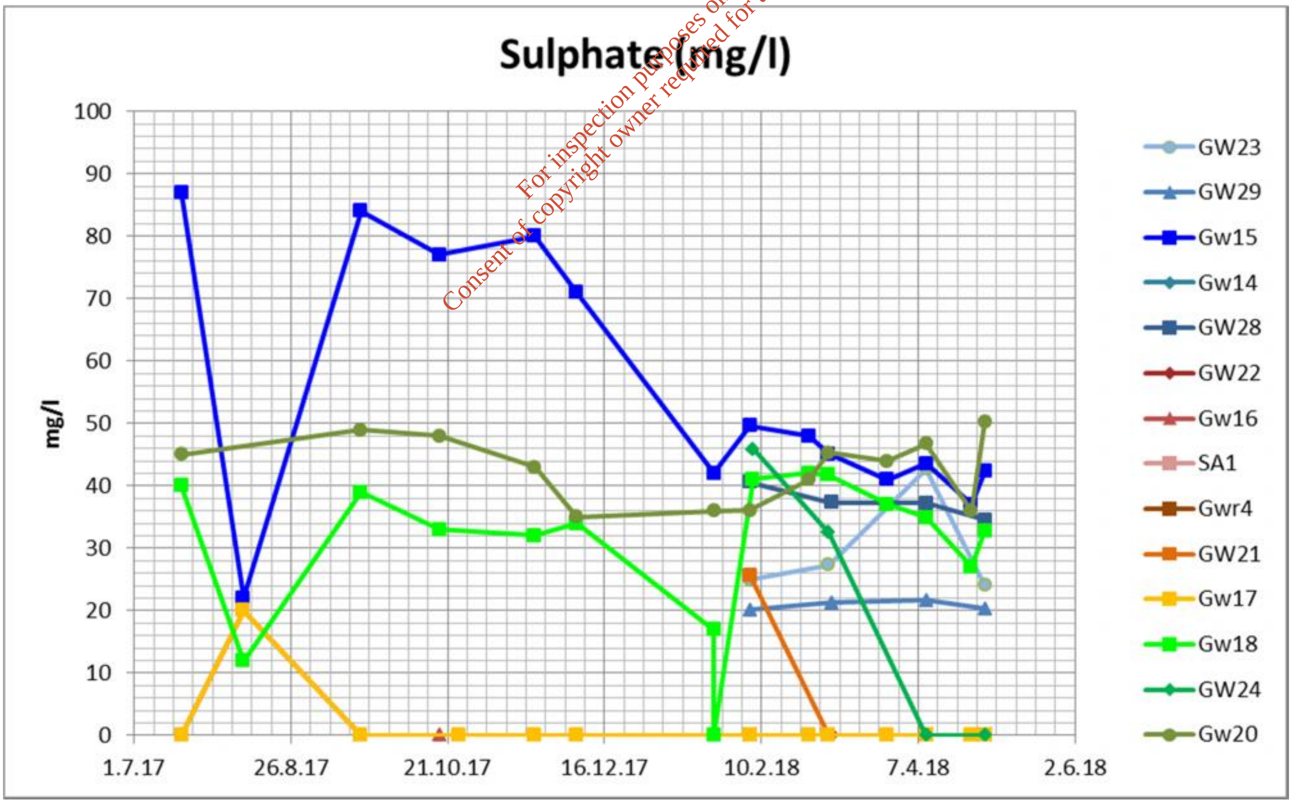

Figure 10. Sulphate Concentration in Groundwater Between July 2017 and June 2018

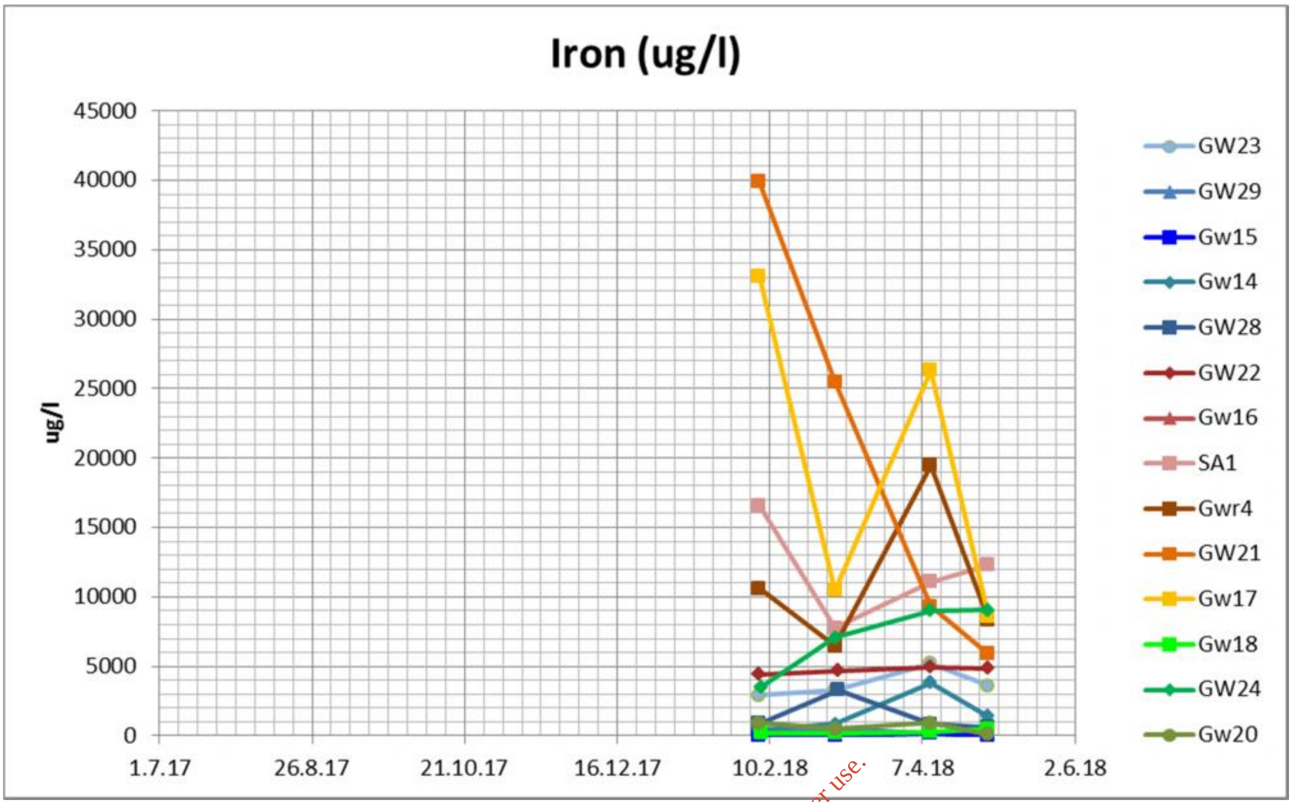

Figure 11. Iron Concentration in Groundwater Between July 2017 and June 2018

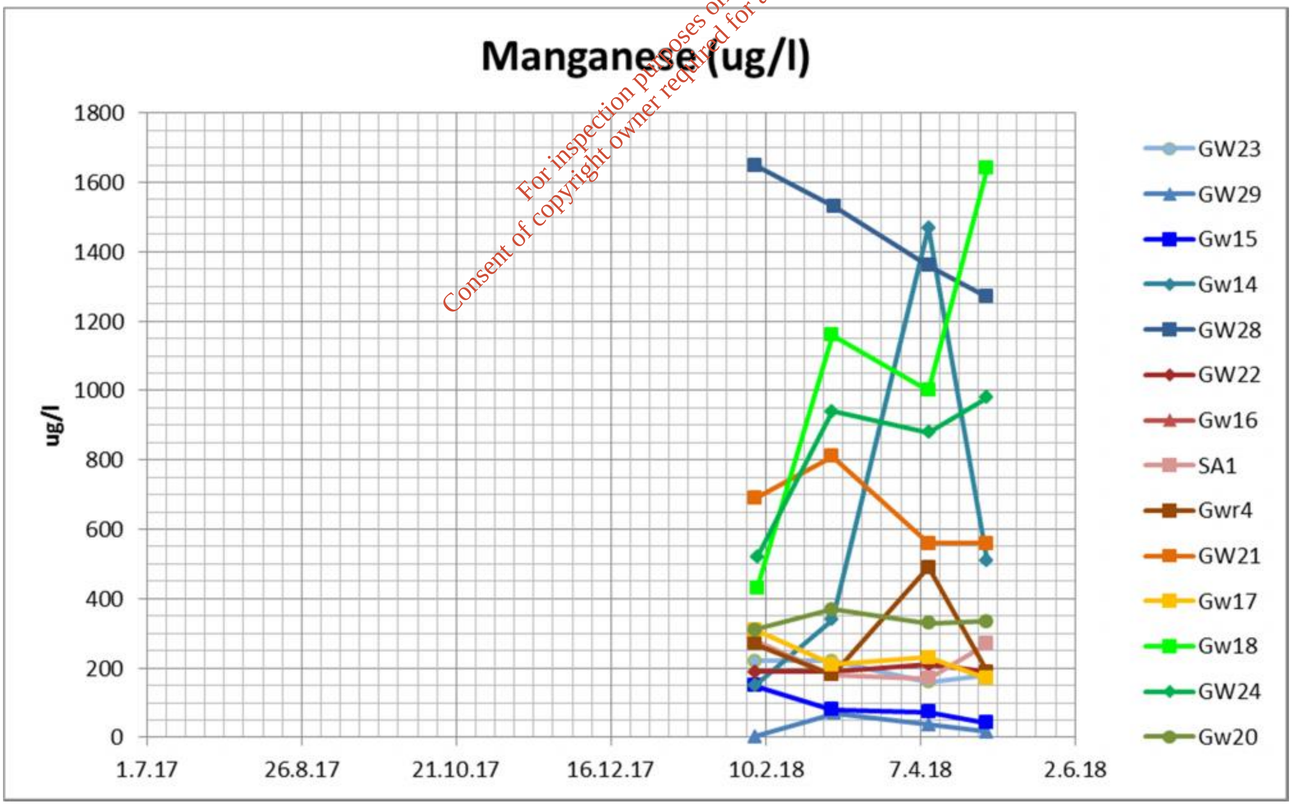

Figure 12. Manganese Concentration in Groundwater Between July 2017 and June 2018

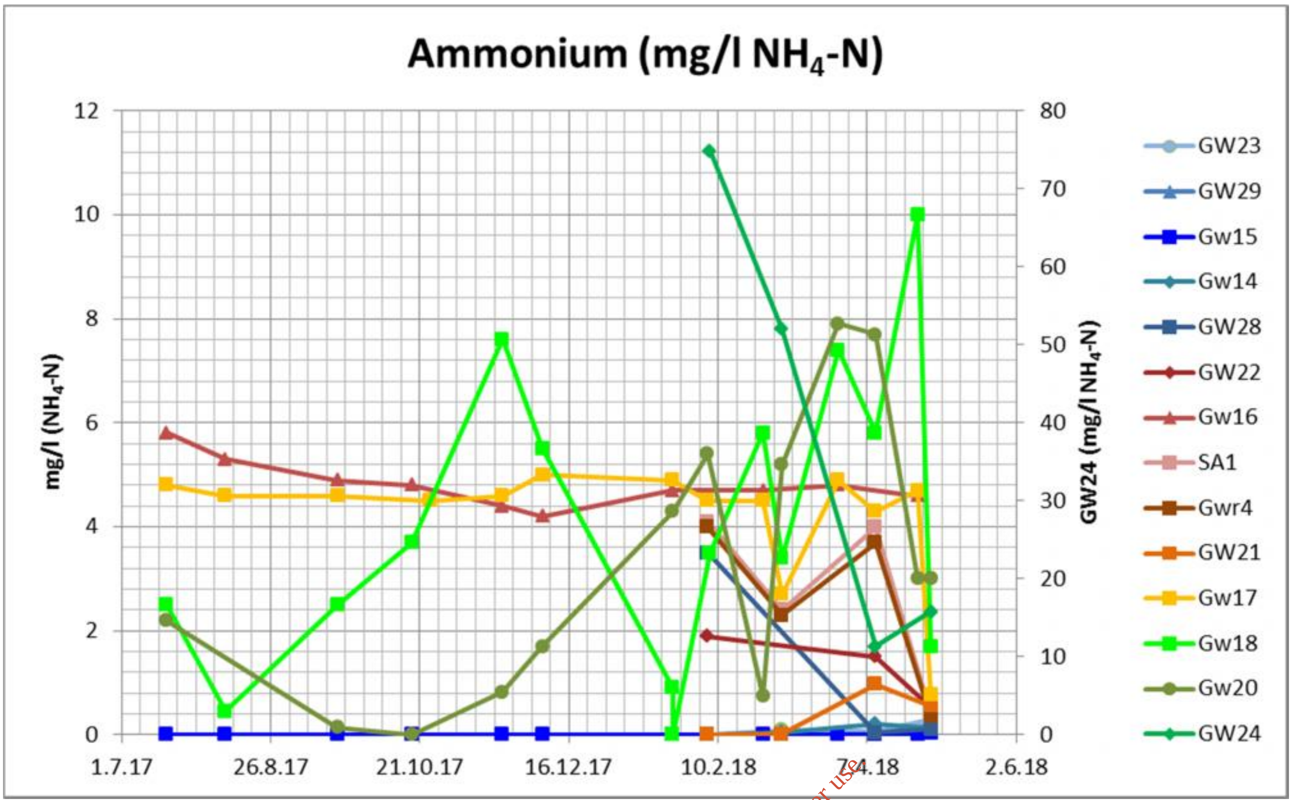

Figure 13. Ammonium Concentration in Groundwater Between July 2017 and June 2018

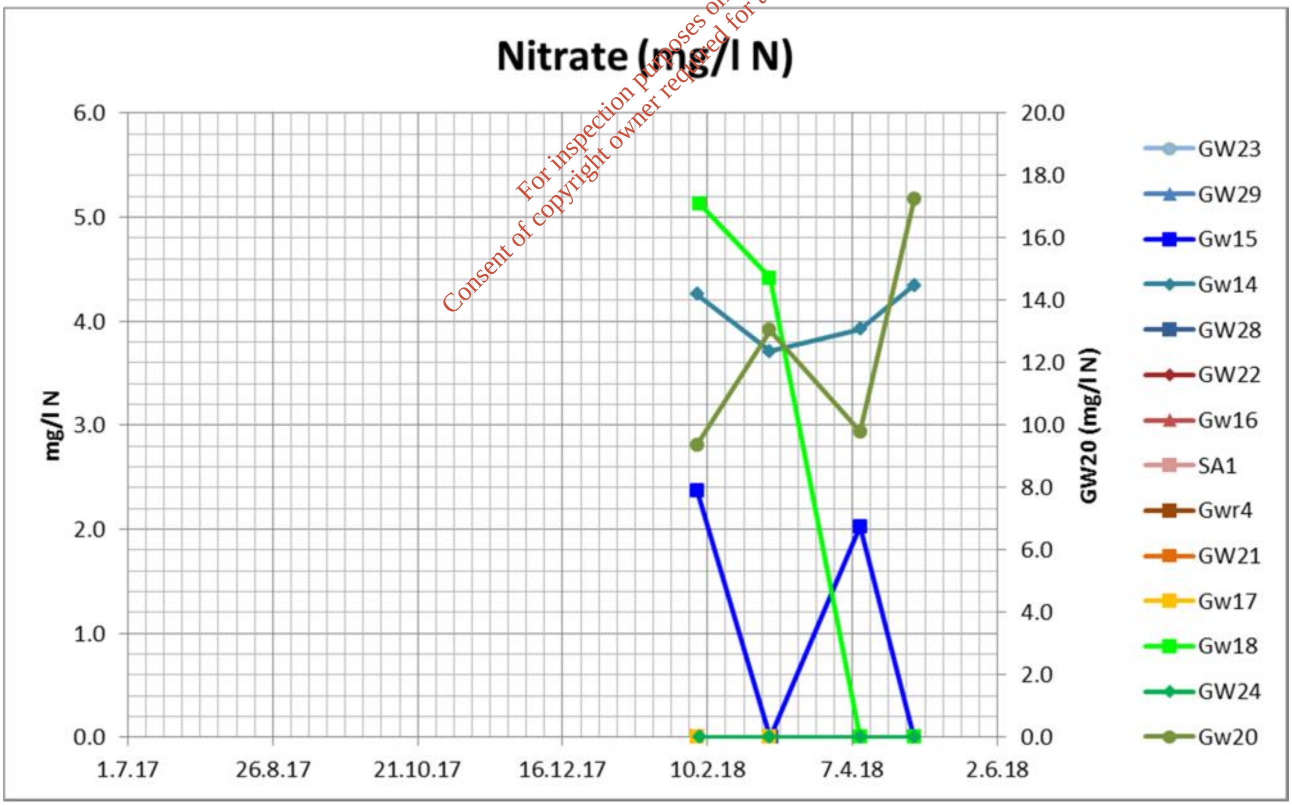

Figure 14. Ammonium Concentration in Groundwater Between July 2017 and June 2018

In addition, Table 4 shows the locations and sampling dates where organic compounds were detected in the samples, and the corresponding results. Only the detected organic compounds are shown in Table 4. The TCC Labworks database records the full list of additional organic compounds tested on each date but not detected in the samples.

Table 4. Organic Contaminants Detected in Groundwater Between July 2017 and June 2018

	Parameter	1,1-Dichloroethane	Phenols
	SI 366 of 2016 TV	2.25	-
Location	Date	µg/l	µg/l
Gw20	06/02/2018	**2.74**	< 1
GW24	07/02/2018	< 1	**17.1**

The full set of physico-chemical and inorganic parameter suites, as well as their analytical results, can be seen in Table A1.1 in Appendix 1.

2.4 Groundwater & Leachate Level Monitoring

The groundwater and leachate level monitoring locations referenced in the report are shown on Figure 2.

Continuous groundwater level monitoring is ongoing at the following locations:

- At LS06, LS03, GW14, GW15, GW16, SA1, GW17, GW18, and GW20 since March 2016;
- At GW13, GWR4, MP18, and MP19 since October 2016;
- At GW21, GW22, GW23, GW24, GW26, GW27, GW28, and GW29 since February 2017; and,
- At GWR3 since July 2017.

The level data have been converted to metres above Ordnance Datum (mOD) and the trends in groundwater elevation can be seen in Figures 15 and 16 for key locations relating to Phases 4 and 3 respectively.

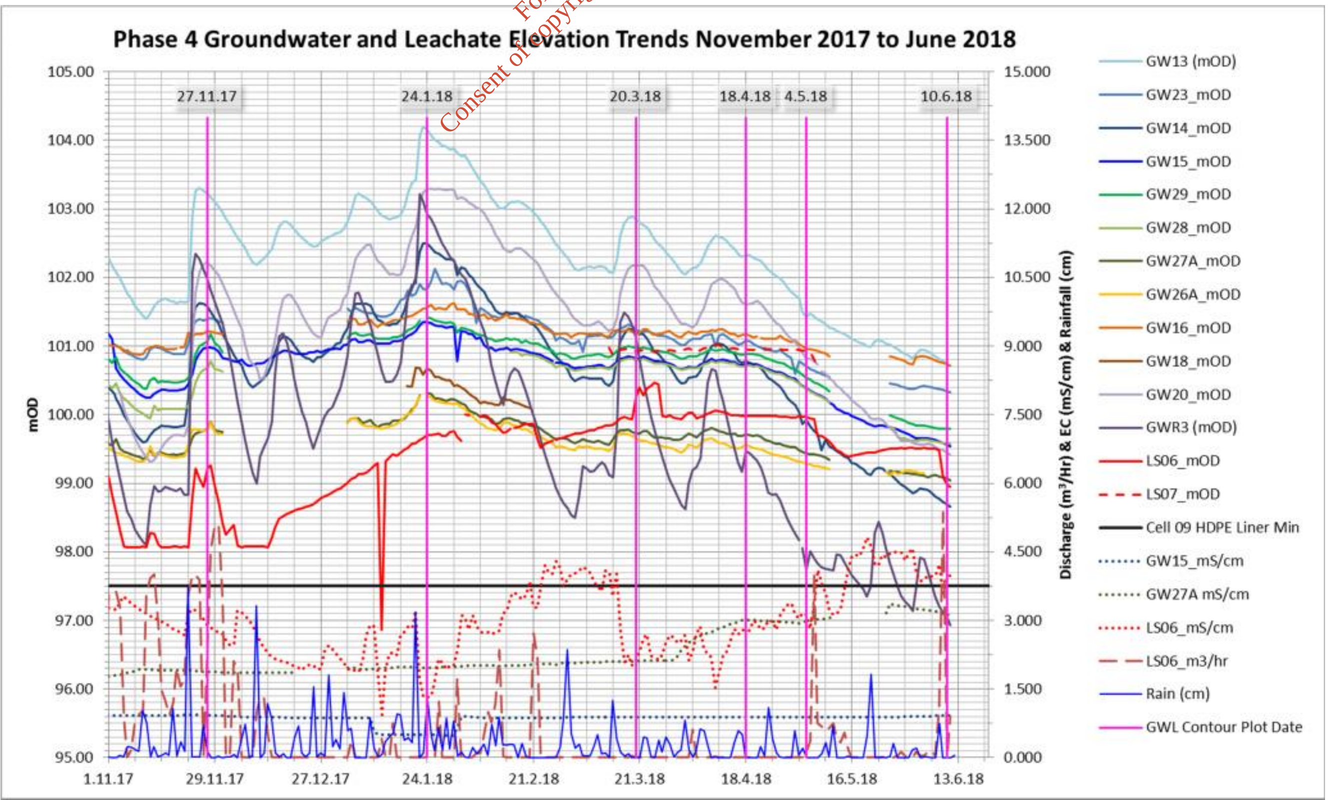

Figure 15. Phase 4 Groundwater and Leachate Elevation Trends November 2017 to June 2018

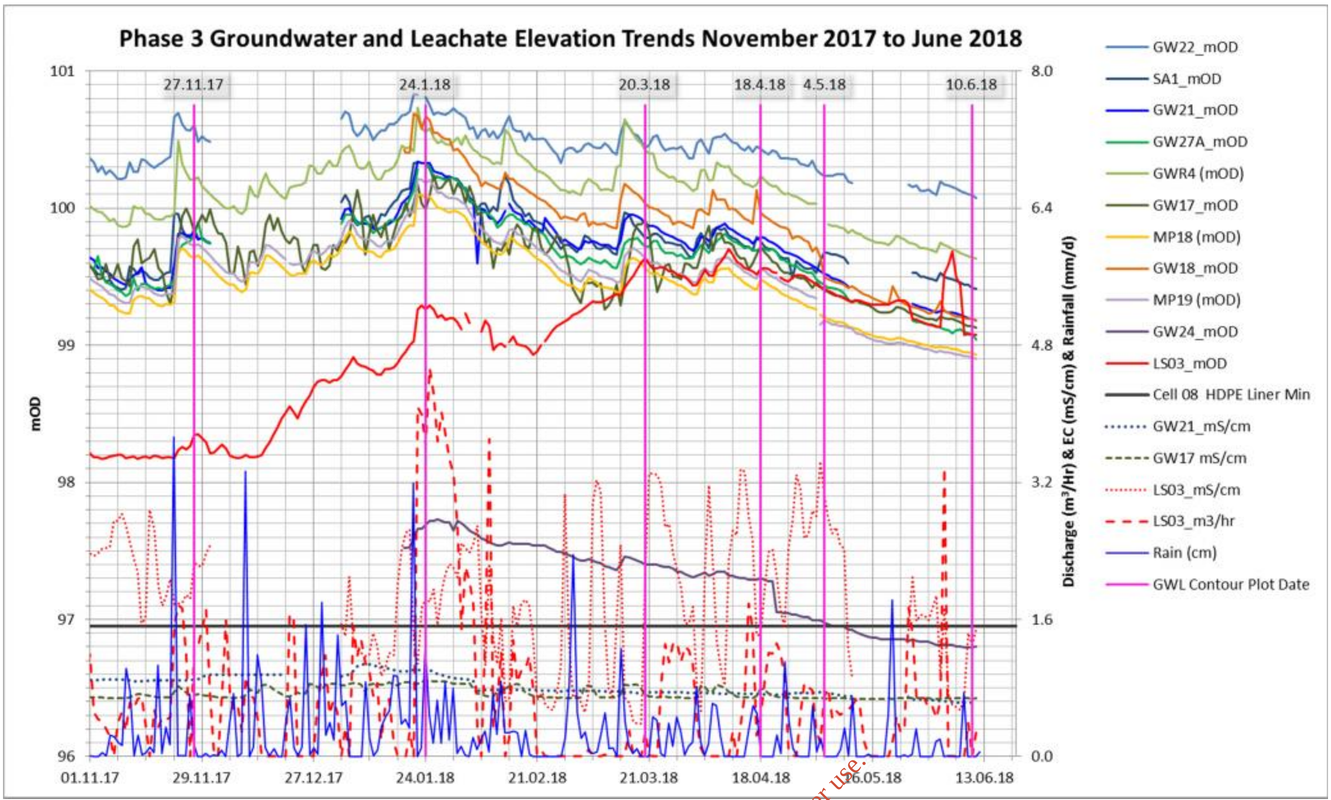

Figure 16. Phase 3 Groundwater and Leachate Elevation Trends November 2017 to June 2018

The available logger data, supplemented by manual spot measurements of water level, have been used to delineate interpretative groundwater elevation contours across the site for key dates between November 2017 and June 2018. The contour maps are shown in Figures 17 to 22. The graphs in Figures 15 and 16 indicate where each groundwater contour plot occurs along the graph timeline.

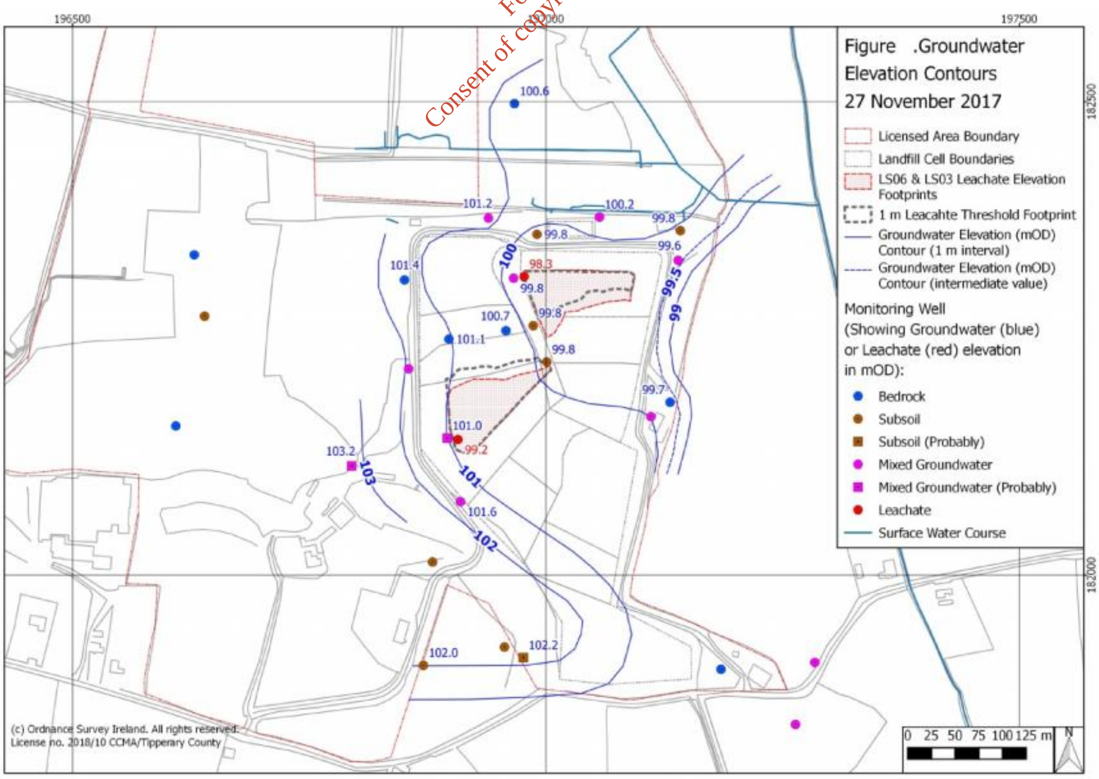

Figure 17. Groundwater Elevation Contours 27 November 2017

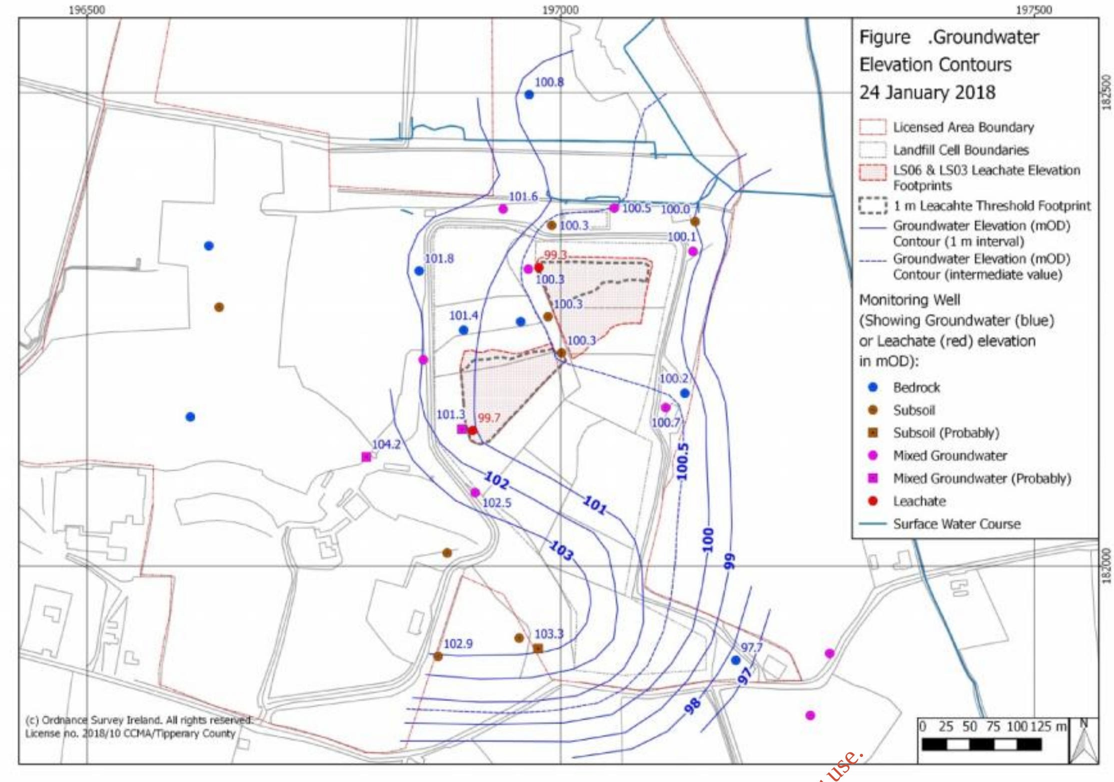

Figure 18. Groundwater Elevation Contours 24 January 2018

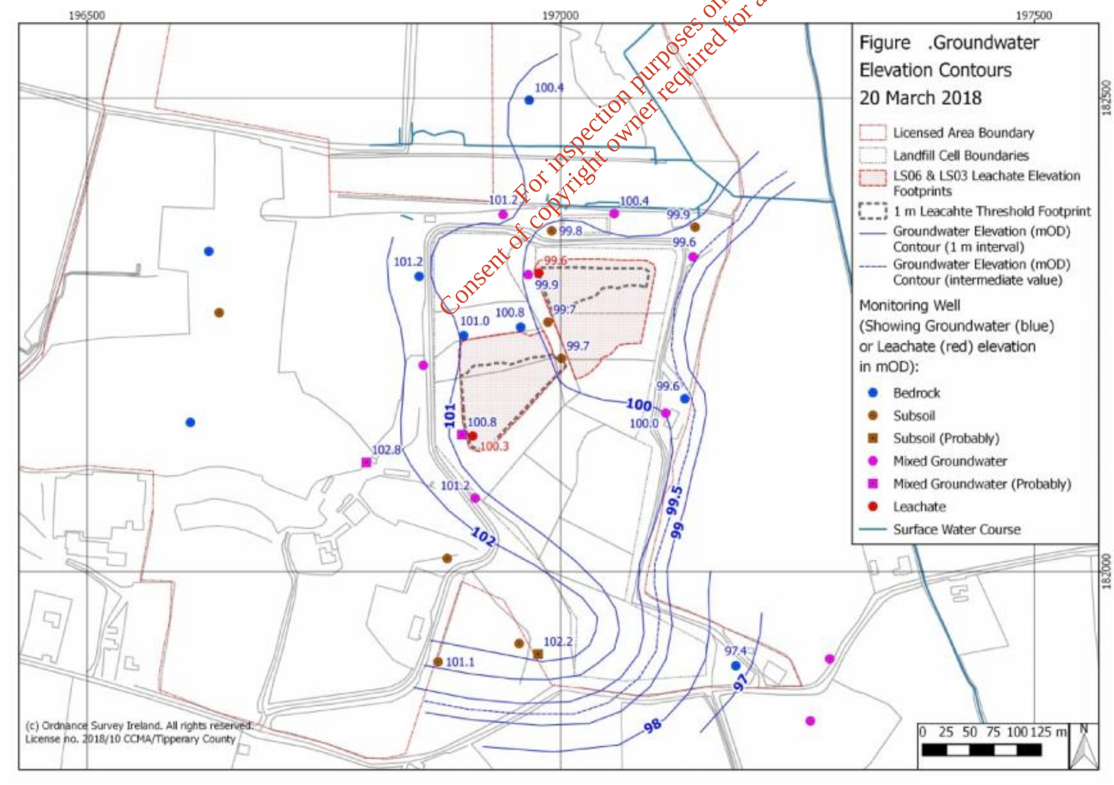

Figure 19. Groundwater Elevation Contours 20 March 2018

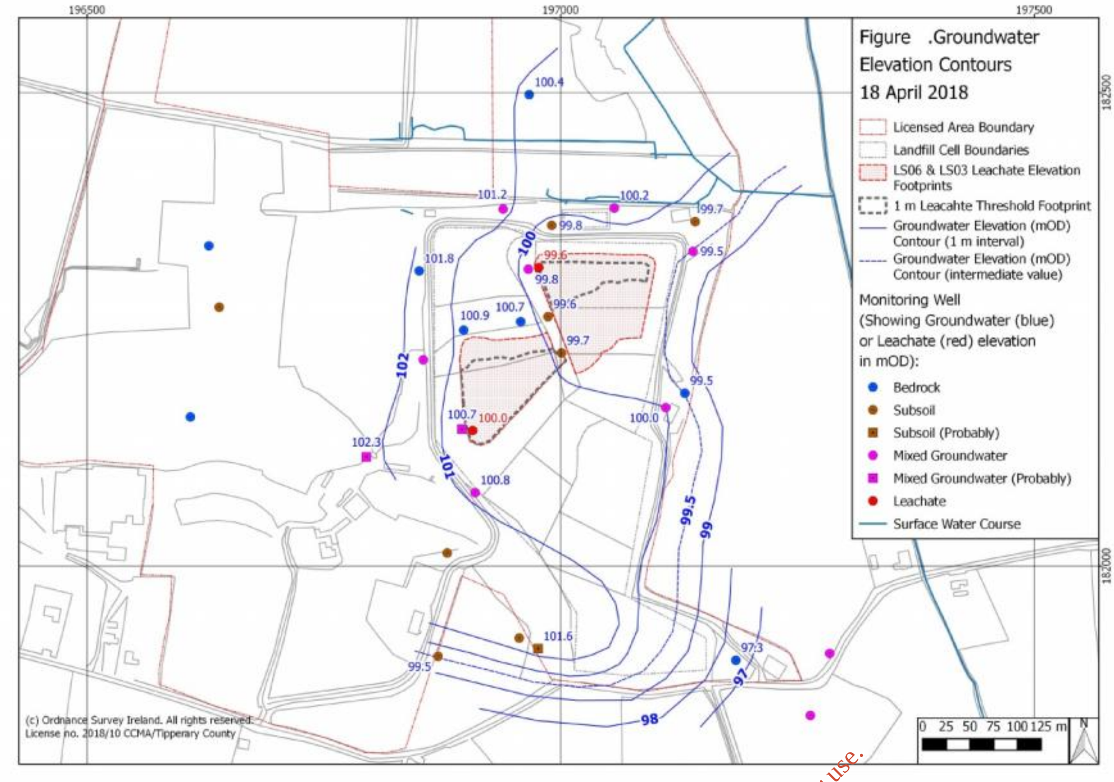

Figure 20. Groundwater Elevation Contours 18 April 2018

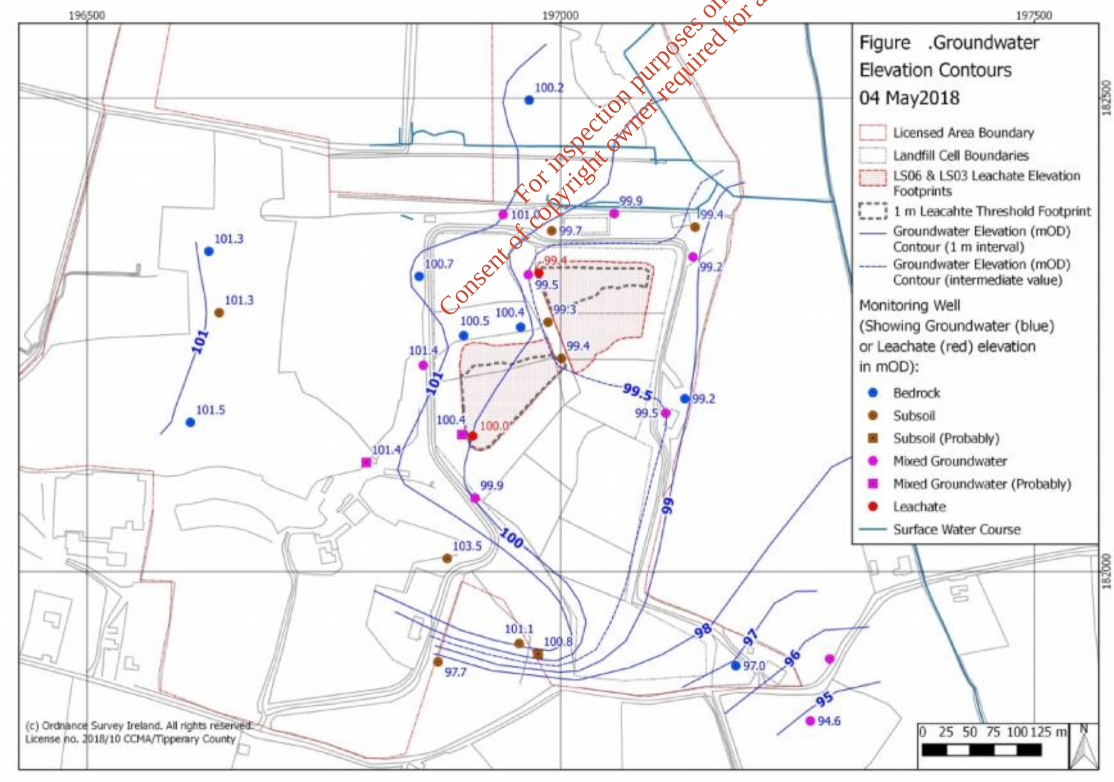

Figure 21. Groundwater Elevation Contours 04 May 2018

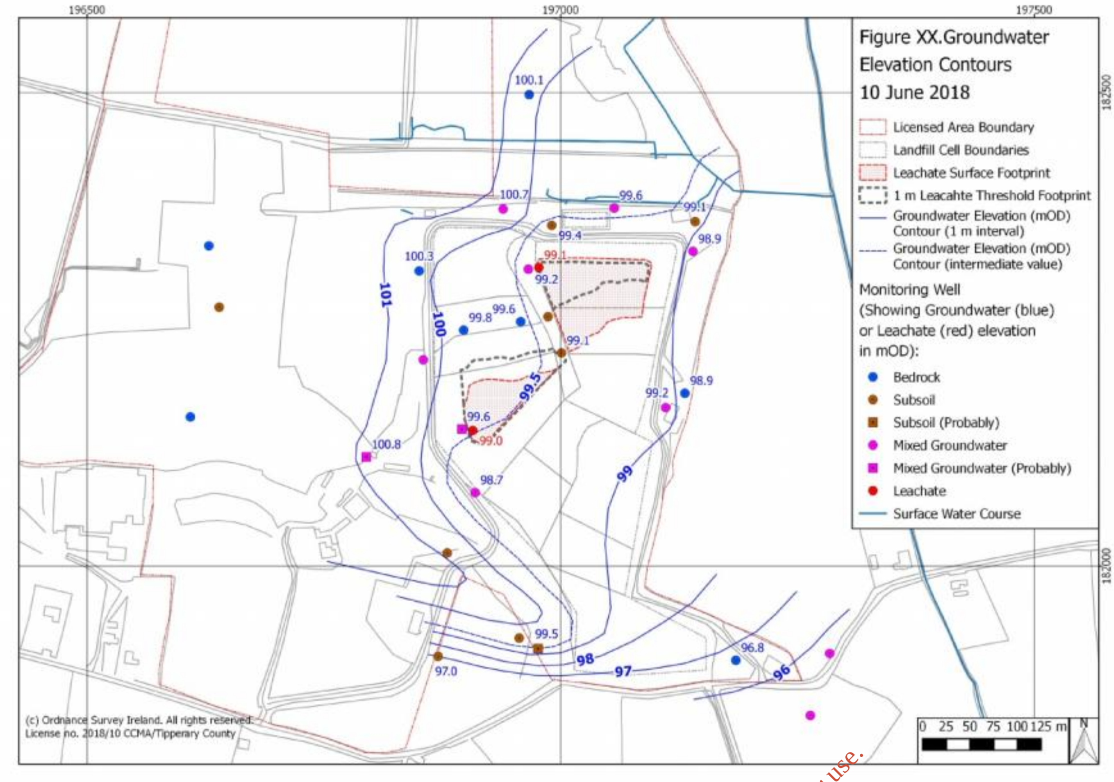

Figure 22. Groundwater Elevation Contours 10 June 2018

2.5 Additional Work Since October 2017

2.5.1 Well Remediation and Camera Surveys

A number of groundwater monitoring wells on site was considered to have a build up of sediment in the screened sections of the wells. The wells were cleaned out using a Jet-Vacuum procedure on 3 and 4 May 2018. The remediated wells were as follows:

- MP3, GW14, GW13, GW3, GW4, GW5, GWR4, SA1, GW18, MP19, GWR3, GW20, MP4, BR2 and GW10.

A number of groundwater monitoring wells had no borehole log or the borehole log had no record of the depth of the screened interval at the well. These wells were subjected to a downhole camera survey on 08 May 2018 to determine the depth of the screened interval in each well. The wells surveyed were as follows:

- GW13, GW3, BR2, GW14, GW20, GWR3, GW9, and GW10.

The new data on the monitoring wells acquired during the works are summarised in Table A2.1 in Appendix 2.

2.5.2 Geophysics Procurement

A geophysical contractor has been procured to carry out a geophysical investigation at the site including ground conductivity, ground penetrating radar, electrical resistivity, and seismic surveys. The investigations are expected to be carried out in July 2018.

2.5.3 Monitoring Well Drilling Procurement

A drilling contractor is currently being procured to drill eight new groundwater monitoring wells around the landfill footprint. The proposed drilling locations were detailed in the SEW Report on the proposed drilling submitted to the EPA in December 2017.

2.5.4 Low Flow Sampling Equipment Procurement for 24 Month Water Quality Monitoring Programme

Equipment is currently being procured to setup a low-flow groundwater sampling regime at the site in support of the 24 month detailed water quality monitoring programme agreed as one of the outcomes from the meeting between Tipperary County Council and the EPA on 10 October 2017. Currently equipment has been procured to trial on 7 no. boreholes during sampling in August 2018. Following a successful trial of the equipment it is intended to proceed to procure additional equipment to extend the regime across the full compliment of 33 no. boreholes included in the 24 month detailed water quality monitoring programme.

In addition, the well remediation and camera surveys detailed in Section 2.5.1 were primarily carried out to facilitate setup of a low-flow sampling regime at the remediated and surveyed wells.

2.5.5 Equipment Failure

It is noted here that the pair of buried water level and conductivity sensors at groundwater monitoring location GW26 malfunctioned on 11 May 2018. The location is buried and sealed under the Wedge Cell basal liner and it is not currently possible to access the location to repair the sensors. As such, data has not been available for that location since 11 May 2018.

3 Assessment of Hydrogeological Data

3.1 Trial Leachate Management Regime Conceptual Model

This section provides a brief overview of the conceptual model for the leachate management regime implemented during the trial period.

The leachate management regime in place under Waste License W0078-03/C requires that the leachate levels in Phases 3 and 4 of the landfill be maintained at a level less than 1 m above the basal liner of each phase. Due to basal liner leaks, groundwater inflow into a phase occurs when the groundwater level outside a leak exceeds the leachate level inside. The groundwater inflow causes the leachate level to rise above the 1 m threshold for large parts of the year. This requires leachate to be pumped from the phases to try and keep the level below the 1 m threshold, which in turn induces further groundwater inflow. This results in the production of very large quantities of dilute leachate at the site, which must subsequently be tankered off site for treatment. Figure 23 shows a diagrammatic representation of the licensed leachate management regime. The ongoing, annual cost of maintaining this leachate management regime is very high. In addition**, the licensed regime may still lead to groundwater contamination if a leak is in a location where the licensed leachate elevation exceeds the downgradient groundwater elevation outside the leak (e.g. "Leak 2" in Figure 23).**

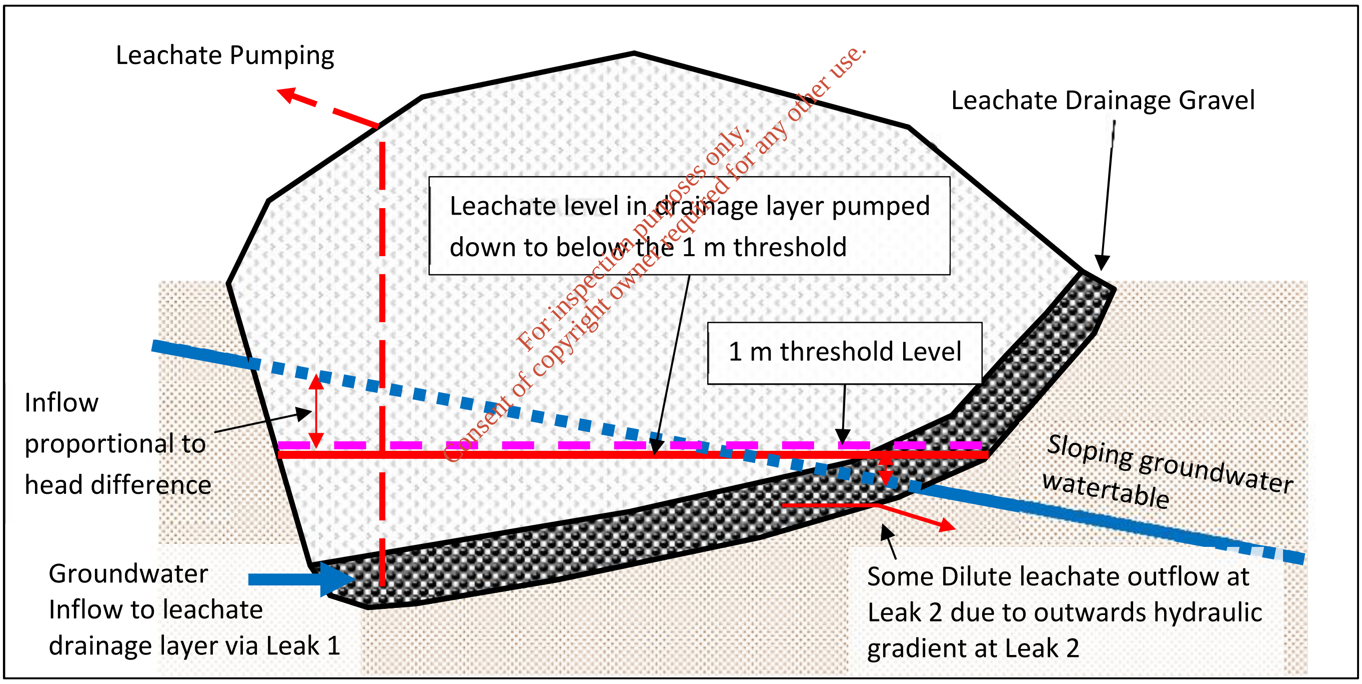

Figure 23. Diagram of Licensed Leachate Management Regime

During the testing period an alternative leachate management regime was trialled. This involved allowing the leachate level to rise above the 1 m threshold such that the leachate level came close to equilibrium with the external groundwater level. The leachate level was maintained slightly below the external groundwater level reference at all times to ensure the hydraulic gradient remained inwards from the aquifer to the landfill, in order to prevent leachate escape. The reduced hydraulic gradient under these conditions resulted in a reduction in the quantity of groundwater inflow into the phases, such that there was a reduction in the volume of leachate produced by the site during the test period. This approach works best where the groundwater table has minimal gradient as shown in Figure 24. Where there is a significant groundwater hydraulic gradient across the landfill and leaks present on the upgradient and down gradient sides of the landfill, there may be significant leakage out the downgradient leak where the leachate level is equilibrated to the upgradient groundwater level

(Figure 25). In such cases the leachate level needs to be kept below the lowest downgradient leak (Figure 26) or equilibrated to the downgradient groundwater level (Figure 27) to prevent leachate leakage.

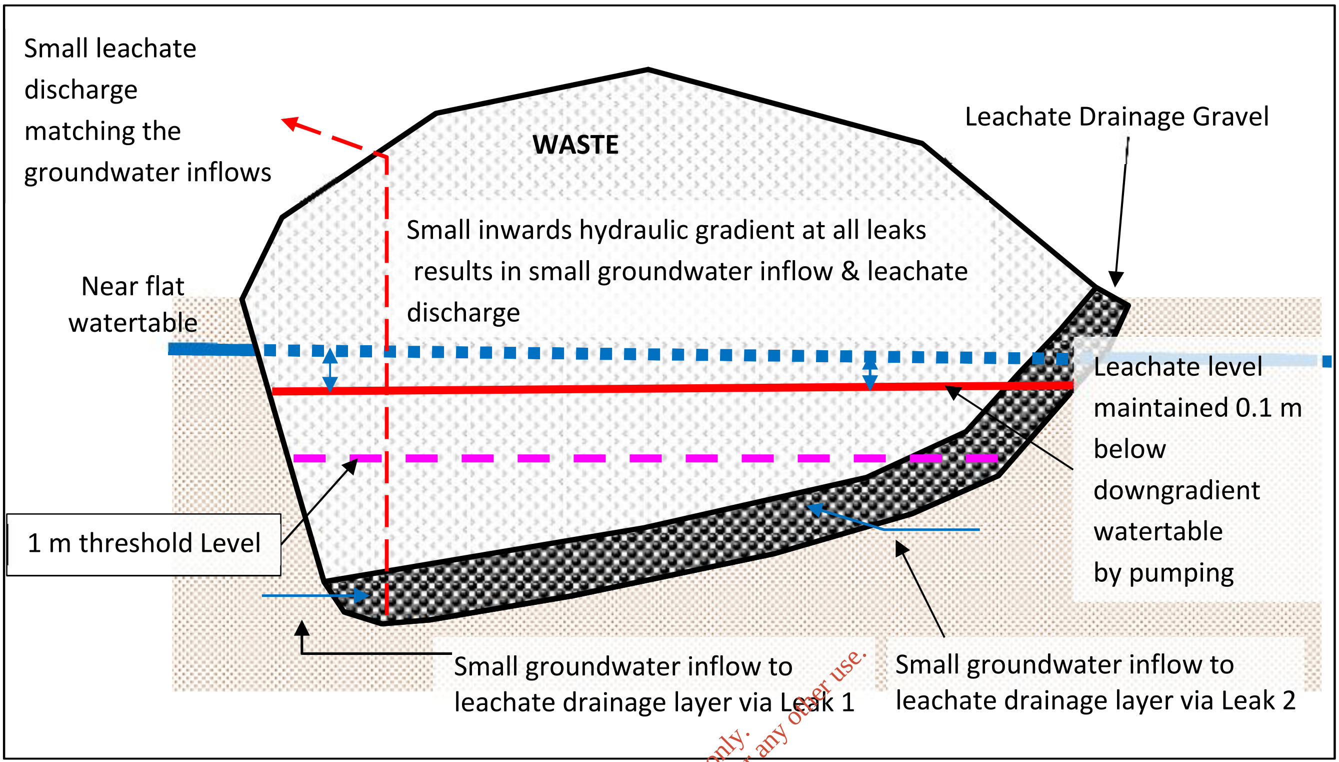

Figure 24. Diagram of Trial Leachate Management Regime in scenario with near-flat watertable

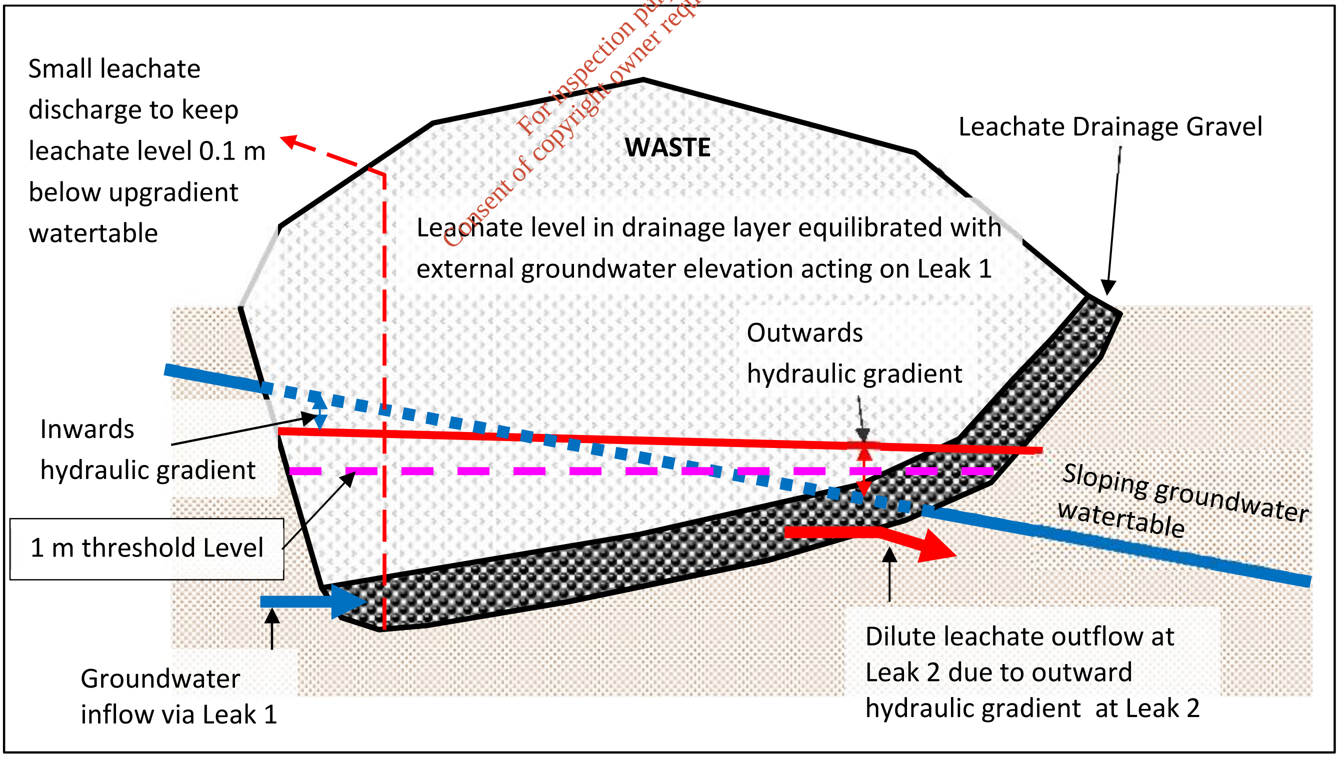

Figure 25. Diagram of Trial Leachate Management Regime in scenario with strongly sloping watertable

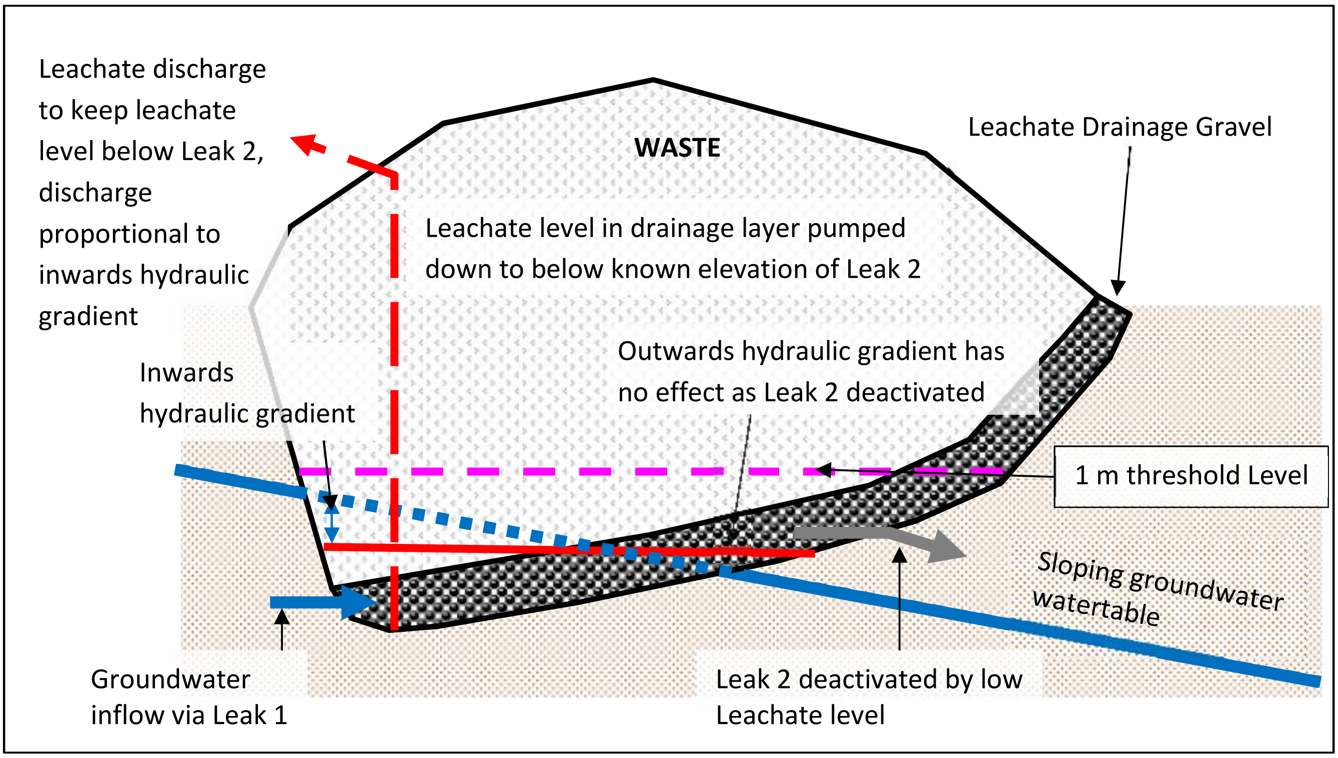

Figure 26. Diagram of Trial Leachate Management Regime in scenario with leachate level below lowest downgradient leak

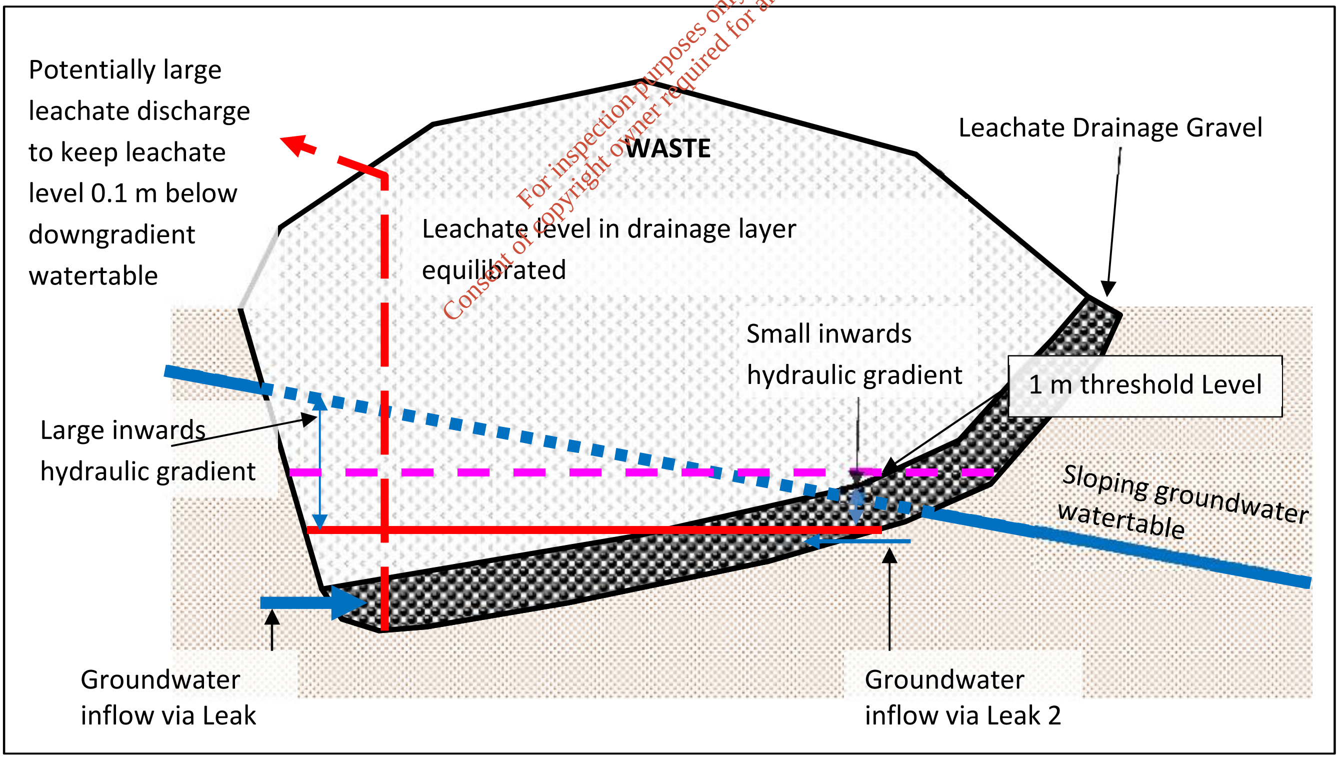

Figure 27. Diagram of Trial Leachate Management Regime in scenario with leachate level below downgradient Watertable

3.2 Leachate Discharge Volumes

A key objective for testing of the proposed groundwater and leachate management regime was:

- To assess the reduction in leachate pumping from Phases 3 & 4 of the landfill compared to the licensed management regime, due to the implementation of the proposed new leachate management regime during the test period.

Figures 28 and 29 show the monthly volumes of leachate pumped from Phases 3 and 4 between March 2016 and May 2018. The monthly totals are shown in Table A2.2 in Appendix 2.

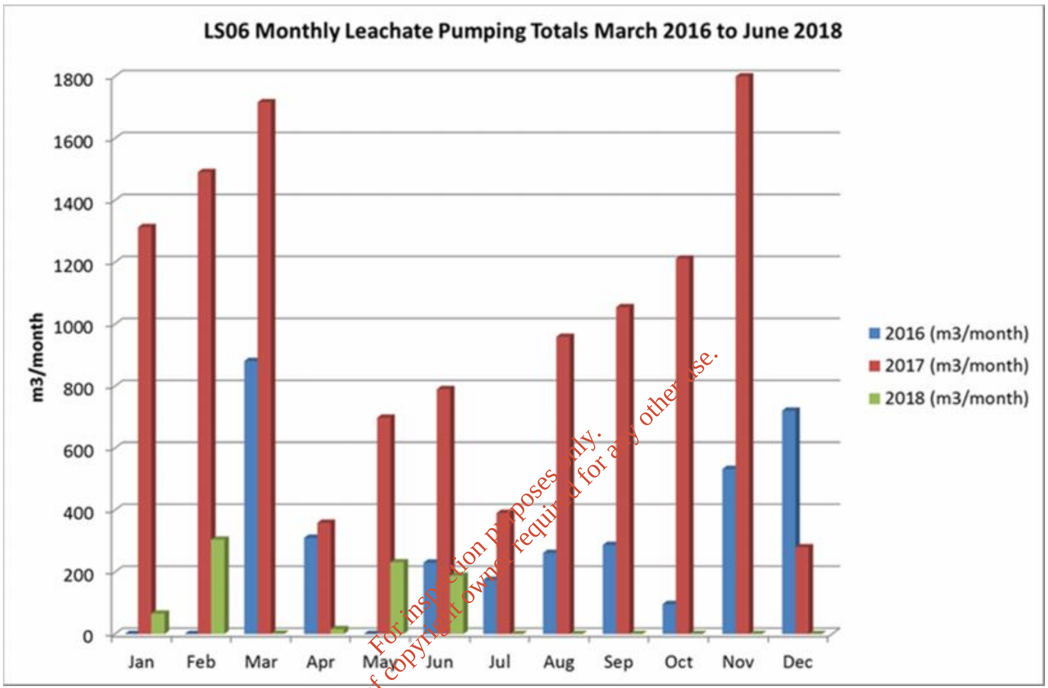

Figure 28. Phase 4 (LS06) Monthly Leachate Volumes

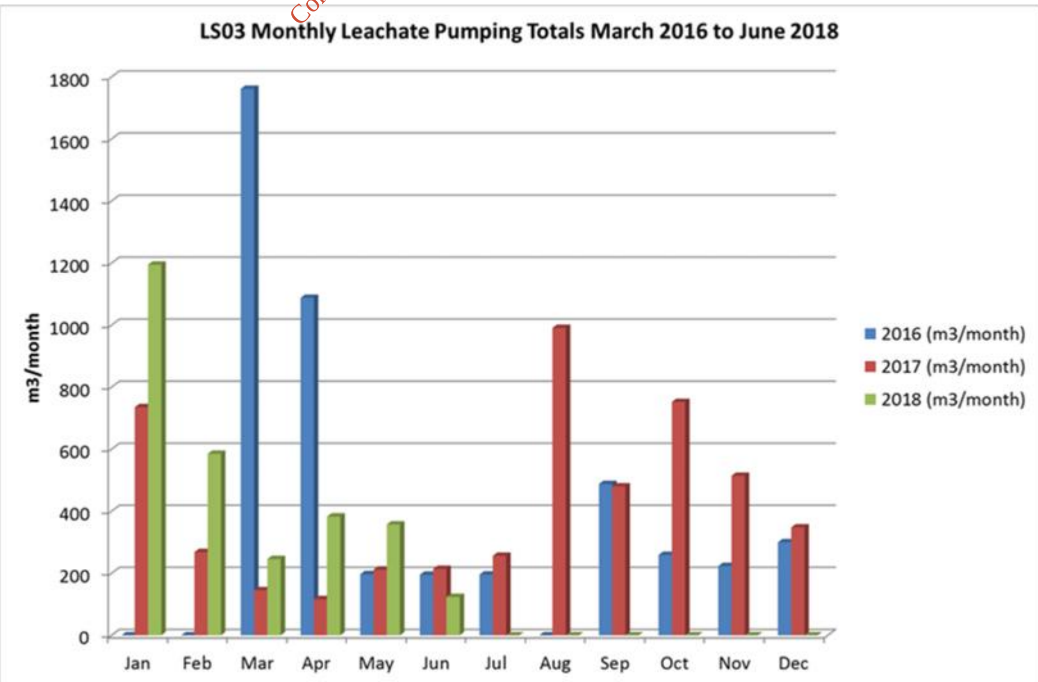

Figure 29. Phase 3 (LS03) Monthly Leachate Volumes

Figure 28 shows that the leachate volumes pumped from LS06 during the test period January to May in 2018 (green columns) are significantly lower than the volumes recorded for those months in 2016 and 2017, where data are available. The total volumes pumped for Phase 4 (LS06) during the period March to May in each year from 2016 to 2018 were 1,192 m^3, 2,774 m^3 and 248 m^3. The Phase 4 2017 totals (red columns) were particularly high due to rainfall ingress in addition to groundwater inflow. **Overall the trial period shows a significant reduction in leachate production compared to the licensed management regime which requires leachate levels below the 1 m threshold.**

Figure 29 shows a more complicated outcome regarding the leachate volumes pumped from LS03. During the test period January to May in 2018 (green columns) the monthly totals exceed the values for the same months in 2017 (red columns). It is considered that the low volumes of leachate produced by the licensed leachate management system in 2017 are due to the combined effect of the very dry winter period from November 2016 through to April 2017, and the large scale dewatering of the aquifer in the vicinity of Phase 3 during the construction and subsequent testing of the abstraction well GW21 during the same period. Comparison of the March to May data for 2016 (blue columns) and 2018 shows the total volumes of leachate pumped from LS03 during the two periods were 3,046 m^3 and 986 m^3. This again shows a **significant reduction in leachate production under the trial leachate management regime compared to the licensed management regime, during typical groundwater conditions.**

The 2018 data in Figure 29 also show that the volume of leachate pumped from LS03 dropped significantly in March to May of 2018 compared to January and February of 2018, after the pumping-maintained level difference between the external groundwater reference (GW21) and LS03 was reduced from 1 m to 0.2 m and subsequently to 0.1 m.

The combined totals for LS03 and LS06 for the period March to May in 2016 and 2018 are 4,238 m^3 and 1,234 m^3, which suggests **the trial leachate management regime may reduce leachate production by approximately 70% under typical groundwater conditions, compared to maintaining leachate levels below the 1 m threshold.**

3.3 Interpretation of Groundwater and Leachate Levels Data & Groundwater Electrical Conductivity Data

3.3.1 Groundwater Flow Direction

Figures 17 to 22 show ground water elevations, leachate elevations, the leachate footprint corresponding to the prevailing leachate level in Phases 3 and 4, and the interpreted groundwater elevation contours for the site for key dates between November 2017 and June 2018. The groundwater elevation contours indicate that throughout the trial period the following conditions prevailed:

- The morainic ridge west and south west of Phase 4 and the bog to the north of Phases 3 and 4 are upgradient of the landfill.
- The area east of Phase 3 is downgradient of the landfill.
- Groundwater flow is roughly from southwest, west and northwest to east beneath Phases 4 and 3 with the flow generally converging on the groundwater drainage layer underlying Phase 3 and the contiguous naturally high transmissivity zone present immediately east of Phase 3.
    - Figures 30 and 31 show the interpreted groundwater flowlines on 18 April and 10 June 2018.
    - The flowlines indicate that depending on the configuration of the contours, the proportion of the upgradient groundwater flow directed towards the high transmissivity zone east of Phase 3 is variable; and,
    - That the downgradient monitoring wells GW18 and MP19 may lie on a flowline moving northeast beneath Phase 1 Cell 2 in one configuration (Figure 30) and on flowline moving east from Phase 4 Cell 9 in another configuration (Figure 31).
- Following the high accuracy topographic survey of the GW15 well head, the GW15 datum elevation was revised upwards by 0.55 m. All GW15 groundwater elevation data were re-calculated in line with the revised datum elevation. This had the effect of simplifying the groundwater elevation contour interpretations compared to interpretations in previous reports.
    - Prior to the datum revision the calculated groundwater elevations suggested a cone of depression around GW15, which was attributed to drawdown owing to leakage of groundwater into Phase 4.
    - With the revised elevation data based on the new datum the cone of depression around GW15 does not occur at the scale of the drawings.
    - The groundwater elevation contour plots in this report show groundwater elevations based on the new GW15 datum elevation.
    - Historical groundwater plots in previous reports will be checked and revised as necessary as part of the MODFLOW groundwater flow model for the site being developed as part of the Phase 1 Tier 3 risk assessment.

3.3.2 Interpretation of Phase 4 Data

Electrical conductivity levels at GW27 are shown on Figures 7, 15 and 32. GW27 is located directly downgradient of Phase 4 in the south end of the Wedge Cell.

Figure 32 shows that the baseline electrical conductivity (EC) beneath Phase 4 between November 2017 and June 2018 was approximately 900 uS/cm, as represented by GW15. For the same period EC at GW27 was initially at 1,800 uS/cm and rose slowly to 2,100 uS/cm by 30 March 2018, as shown at Point 1 on Figure 32. After 30 March 2018 the EC at GW27 rose to 3,000 uS/cm by 18 April 2018 and remained approximately steady at that level until 10 May 2018. A short data loss occurred between 11 and 24 May. By 25 May 2018 EC at GW27 was rising sharply and reached 3,300 uS/cm by 27 May 2018. Since 27 May 2018 the level has dropped steadily and reached 2,986 uS/cm on 27 June**. It is likely that these EC trends at GW27 are related to leachate leakage along the Cell 9 & 10a/ Wedge Cell boundary on the east side of Phase 4, which is immediately upgradient of GW27.** Figures 17 to 22 show that the leachate footprint within Phase 4 extended to the cell boundaries immediately adjacent to GW27 between at least 24 January and 05 May 2018.

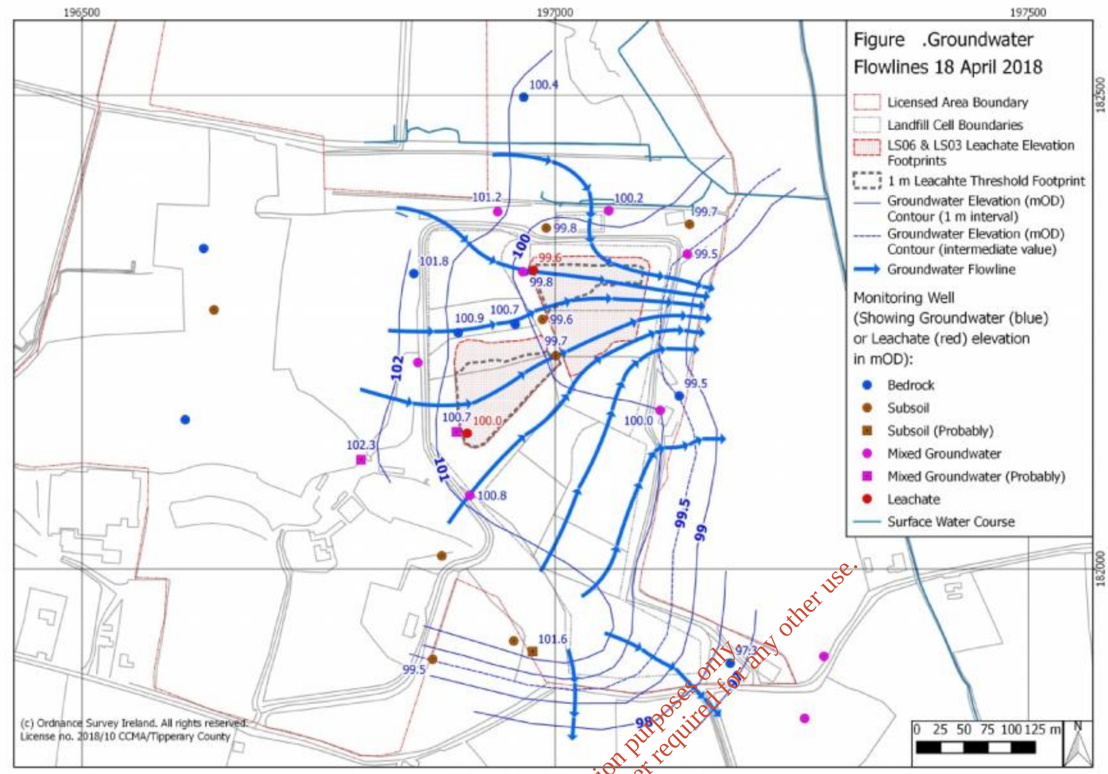

Figure 30. Interpreted Groundwater Flowlines on 18 April 2018

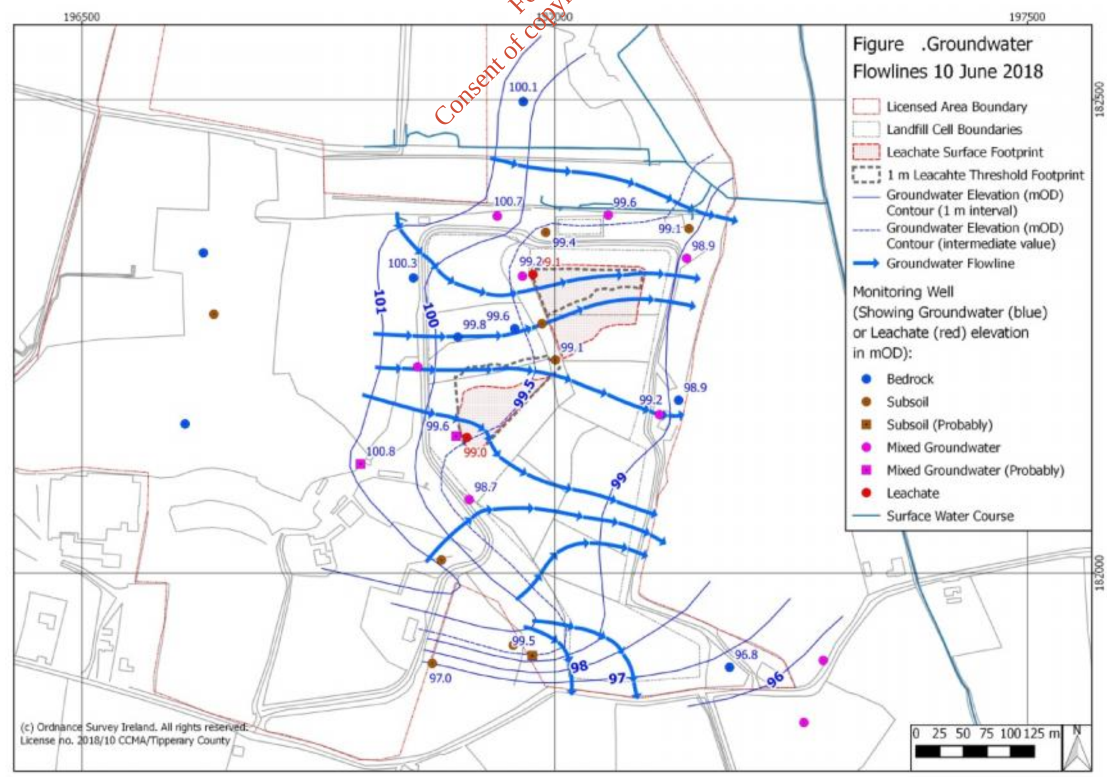

Figure 31. Interpreted Groundwater Flowlines on 10 June 2018

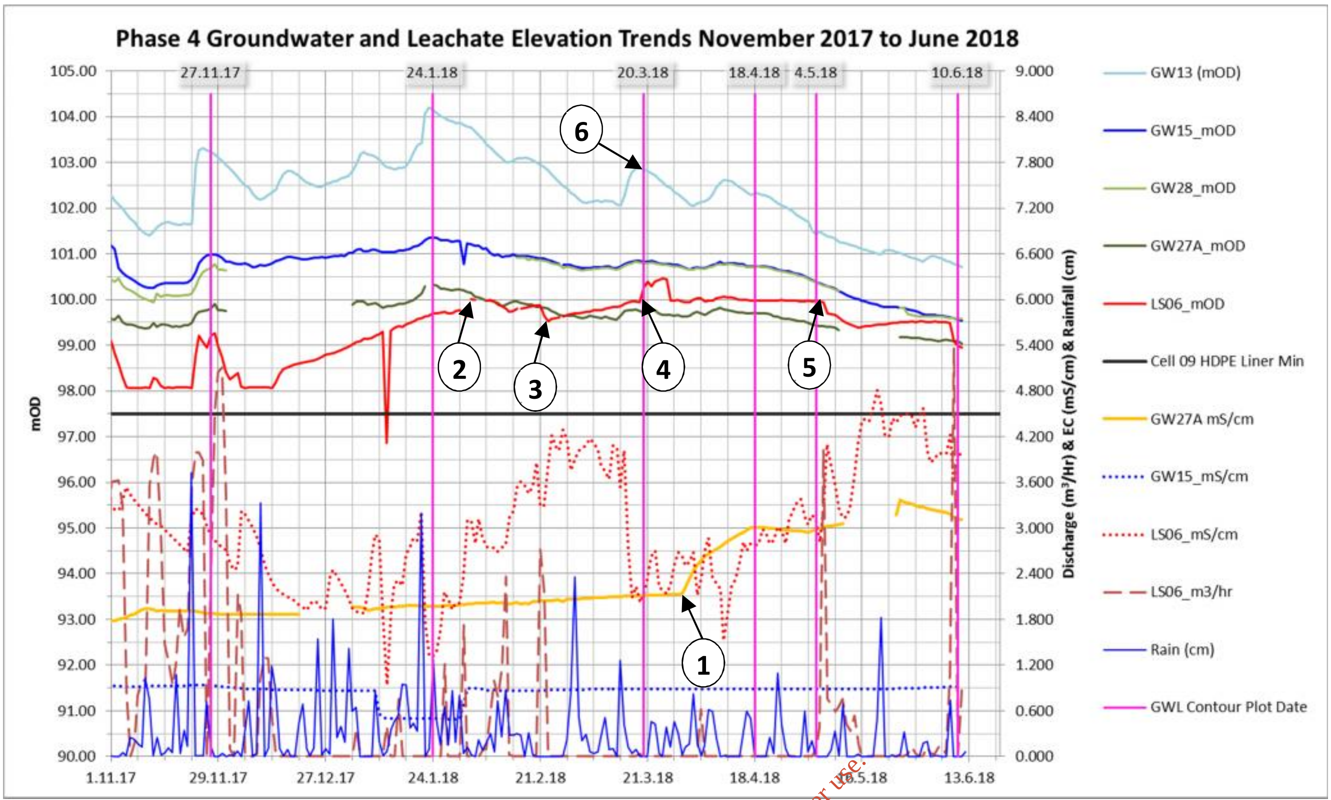

Figure 32. Selected Phase 4 Groundwater and Leachate Level and Electrical Conductivity Trends

3.3.2.1 Data supporting the interpretation that Phase 4 leachate leakage occurs near GW27

The following paragraphs examine the supporting data for this conclusion.

Figure 32 shows the leachate elevation trend for the Phase 4 leachate chamber LS06. On 13 December 2016 the LS06 level controls were programmed to allow the LS06 level to rise within 1 m of GW15, which at the time was approximately 2.5 m above the leachate level. By 03 February 2018 (Point 2 on Figure 32) the LS06 leachate level had reached an elevation of approximately 100 mOD and 1 m below the GW15 groundwater elevation. From 03 February to 23 February 2018 pumping at LS06 maintained LS06 at a level 1 m below GW15 as the GW15 groundwater level dropped slowly. On 23 February 2018 (Point 3 on Figure 32) the LS06 level controls were adjusted to allow the LS06 level to rise within 0.2 m of GW15. After this the LS06 level rose to 99.95 mOD on 17 March 2018 (Point 4 on Figure 32). From 17 March to 06 May 2018 (Point 5 on Figure 3) the LS06 level remained largely steady at approximately 100 mOD, with no leachate pumping from LS06 even though there was a strong inwards, upgradient hydraulic gradient (the LS06 level was continuously between 0.35 m and 0.75 m below the GW15 groundwater level). Furthermore, briefly after 03 February (Point 2) and continuously after 28 February (shortly after Point 3) the leachate level at LS06 exceeded the downgradient groundwater elevation at GW27.

It is considered that possibly briefly after Point 2 and then steadily after Point 4:

- Groundwater inflow to Phase 4 took place via an upgradient leak under the inwards upgradient hydraulic gradient.
- The influent groundwater flowed along the leachate drainage layer and leaked out through a downgradient leak in the vicinity of GW27 under the outwards hydraulic gradient on the downgradient side of the landfill.
- Upgradient groundwater inflow and downgradient leachate leakage were roughly balanced such that the **leachate level remained approximately steady at 100 mOD without any leachate pumping**.

- This is equivalent to the diagram presented in Figure 25, except that no leachate pumping took place.
- For a brief period after Point 4 the leachate level rose rapidly to 100.45 mOD before dropping back to 100 mOD by 28 March 2018.
    - This leachate level spike coincides with an upgradient groundwater level spike which occurred after prolonged heavy rainfall between 27 February and 17 March. The groundwater spike is evident at GW13 on 20 March 2018 (Point 6 on Figure 32). The same spike is much more subdued at GW15. Taken together the data indicate a short period of increased upgradient hydraulic gradient which would have driven an increased volume of groundwater through the system, supplied by rainfall recharge.
    - The leachate level spike at LS06 suggests that the under the increased hydraulic gradient conditions, additional groundwater was driven into Phase 4. This increased inflow overloaded the capacity of the downgradient leakage to balance the upgradient inflow, such that the excess inflow was stored in the leachate gravels and resulted in a spike in the leachate level.
    - The volume of leachate required to increase the Phase 4 leachate level from 100 mOD to 100.45 mOD is estimated at 200 m^3 based on the Leachate Volume Model for Ballaghveny Landfill presented in the Report on Pumping Tests Carried Out in Q1 & Q2 of 2016 At Ballaghveny Landfill (Conroy 2016).
    - On the dissipation of the leachate level spike on 27 March 2018 an approximately 200 m^3 slug of leachate was leaked from storage, in addition to the ongoing steady leakage, in order to reduce the LS06 leachate level back to 100 mOD by 28 March 2018.

A key factor in this interpretation of the groundwater and leachate level trends is that leachate leakage occurs on the downgradient side of Phase 4. The groundwater monitoring wells immediately downgradient of part or all of Phase 4 in order of increasing downgradient position are GW15, GW29, GW28, and GW26 and GW27. Figures 3 to 7 show that out of these wells only GW27 exhibits a significant electrical conductivity rising trend during the interpreted leachate leakage period. The nearby location GW26 does show a small rise in EC from 980 uS/cm to 1,050 uS/cm between 30 March and 18 April (Figure 7), which is likely to be due to lateral dispersion of the leachate leakage occurring in the vicinity of GW27.

By 06 May 2018 (Point 5 on Figure 32) the steady EC plateau at 3,000 uS/cm at GW27 was interpreted to be a steady leachate leak and the LS06 leachate controls were manipulated to progressively lower the LS06 leachate level such that it was dropped below elevations that are considered to be potential leak elevations, i.e. the 100 mOD level maintained by LS06 between Points 4 and 5 on Figure 32, and the 99.6 mOD level interpreted from previous reports[2]. The details of the manipulations are provided in Table 2. Between 06 May and 15 May the LS06 leachate level was pumped down to below 99.5 mOD. It was then held steady at approximately 99.5 mOD until 08 June 2016. The manipulations were hoped to reduce the EC levels at GW27 to 2,000 uS/cm or less on the basis that lowering the leachate level below the likely level of the downgradient leak would stop the leachate leakage, as shown in Figure 26. The EC level at GW27 did not drop below 3,000 uS/cm during this period of manipulations.

Given the possibility that the interpreted leakage levels of 100 mOD and 99.6 mOD may not be correct and that leachate leakage may have been ongoing in spite of the leachate control manipulations, it was decided to pump

[2] The GW15 datum elevation was revised upwards by 0.55 m following the high accuracy survey of the well head on 02 February 2018. It is possible that the potential leakage threshold of 99.6 mOD interpreted in previous reports based on data from step pumping tests at GW15 also needs to be revised upwards by 0.55 m, i.e. to 100.15 mOD. This revised value is close to 100 mOD level at LS06 interpreted to be controlling leakage from Phase 4 during the investigations discussed in this report. This point will be considered fully as part of the future Phase 1 Tier 3 risk assessment work.

down the leachate level to below the downgradient groundwater level. This conservative final manipulation of the leachate controls is expected to preclude the possibility of further leakage in line with the diagram shown in Figure 27.

The LS06 leachate level dropped below the downgradient groundwater elevation at GW27 on 10 June 2018. Between 10 June and 21 June the EC level at GW27 dropped from 3,120 uS/cm to 3,000 uS/cm, i.e. the EC level is currently still at the levels associated with ongoing leachate leakage after all of the potential leachate control manipulations have been exhausted.

In spite of this it is still possible that the leachate control manipulations carried out have successfully curtailed the leachate leakage**. It is likely that there is a lag time between changes at the actual leak location and the expression of those changes at GW27.** As such, it is possible that the current gradual downwards EC trend at GW27 will accelerate after the conclusion of the lag time and bring the GW27 EC level back down to its original level.

3.3.2.2 Potential Lag Times between the Occurrence of Phase 4 Leachate Leakage and its Expression at GW27

In assessing potential lag times it has been assumed that the Phase 4 leakage started on 03 February 2018 (Point 2 on Figure 32), when the LS06 leachate elevation first, briefly reached the 100 mOD threshold[3].

On this basis:

- The onset of the steep rising trend at GW27 on 30 March 2018 corresponds to a 55 day time lag.
- The steep rising trend at GW27 between 30 March and 18 April after which the EC plateaus at 3,000 uS/cm reflects dispersion and potentially retardation of the advancing leachate plume. Adding these 18 days to the breakthrough time gives a very conservative lag time of 73 days.
- Correlating the dissipation of the LS06 leachate peak at 100.45 mOD on 26 March 2018 with the secondary spike in EC at GW27 from 3,100 uS/cm up to 3,300 uS/cm between 25 and 27 May 2018 suggests a lag time of 61 days.
- The average of these three estimates is 63 days.
- Applying a lag time of 63 days to the LS06 leachate control manipulations suggests that the onset of a steep downward trend in EC from 3,000 uS/cm to 2,000 uS/cm in response to the stopping of leachate leakage could be expected at GW27 as follows:
    - If dropping the LS06 leachate level below 99.95 mOD on 05 May 2018 stopped the leakage, then a steep downward trend could be expected at GW27 from 07 July onwards.
    - If dropping the LS06 leachate level below 99.6 mOD on 10 May 2018 stopped the leakage, then a steep downward trend could be expected at GW27 from 12 July onwards.
    - If dropping the LS06 leachate level below the GW27 downgradient groundwater elevation on 10 June 2018 stopped the leakage, then a steep downward trend could be expected at GW27 from 12 August onwards.
- Unless the future EC data for GW27 clearly indicate that the manipulations related to the 100 mOD or 99.6 mOD leakage thresholds stopped the leakage, the LS06 leachate level controls should be programmed to maintain the leachate level 0.1 m below the downgradient groundwater elevation at GW27 (or other equivalent groundwater level monitoring location) in the long term.

[3] Nonetheless it is noted that just prior to this between 26 January and 03 February 2018 the leachate level is steady at about 99.7 mOD, such that the leakage may have started on the 26 of January and the elevation differences are a related to revisions of the well head datum elevations after the high accuracy well head survey on 02 February 2018.

- Since GW27 is intended to be decommissioned in due course with the filling of the Wedge Cell, GW21 is proposed as a potential replacement for determining the Phase 4 downgradient groundwater elevation. Figures 17 to 22 show that groundwater elevations at GW27 and GW21 were generally either the same or within 0.1 m of each other during the trial period. Figure 16 shows that the largest difference between GW27 and GW21 during the trial period occurred on 12 March 2018 and amounts to 0.15 m.

3.3.2.3 Where does the leachate plume migrate to downgradient of GW27?

- Figures 17 to 21 and Figure 30 suggest the contaminated flowpaths in the vicinity of GW27 are likely to flow into the high transmissivity zone beneath and to the east of Phase 3 after moving downgradient of GW27. This appears to be the most likely plume migration direction. If this proves to be the case the proposed groundwater monitoring well GW36 is likely to be in a good position to detect a contaminant plume in the area. The proposed location for GW36 is shown on Figure 33.
- The plume does not appear to impact on GW17.
    - The fluctuating EC trend at GW17 shown in Figure 7 indicates that the EC at GW27 flips back and forth between:
        - the baseline EC of the Bog-Type groundwater flow that approaches GW17 from the northwest from GW22 (EC of approximately 700 uS/cm); and,
        - the baseline EC of the Gravel-Type groundwater flow that approaches GW17 from the west from GW23 and GW29 (EC of approximately 850 uS/cm).
    - This would suggest that GW17 is at a location that intercepts different non-contaminated baseline flowlines (Bog-Type or Gravel-Type) depending on the prevailing groundwater elevation.
    - Note: A recap of the water quality Water-Types at the site is provided in Section 3.4.1.
- The delineated contours and groundwater flowlines in Figures 22 and 31 respectively suggest that contamination could migrate from GW27 to GW18 under favourable groundwater elevation conditions. Figures 17 to 21 and Figure 30 suggest that GW18 typically intersects flowlines passing north-eastwards from beneath Cell 2 of Phase 1, which would be another potential source for any evidence of contamination at GW18.

3.3.2.4 Licensed leachate threshold of 1 m above basal liner

It is noted that during the trial period the LS06 leachate level was below the 1 m threshold of 99.62 mOD prior to 21 January 2018 and from 10 May 2018 onwards.

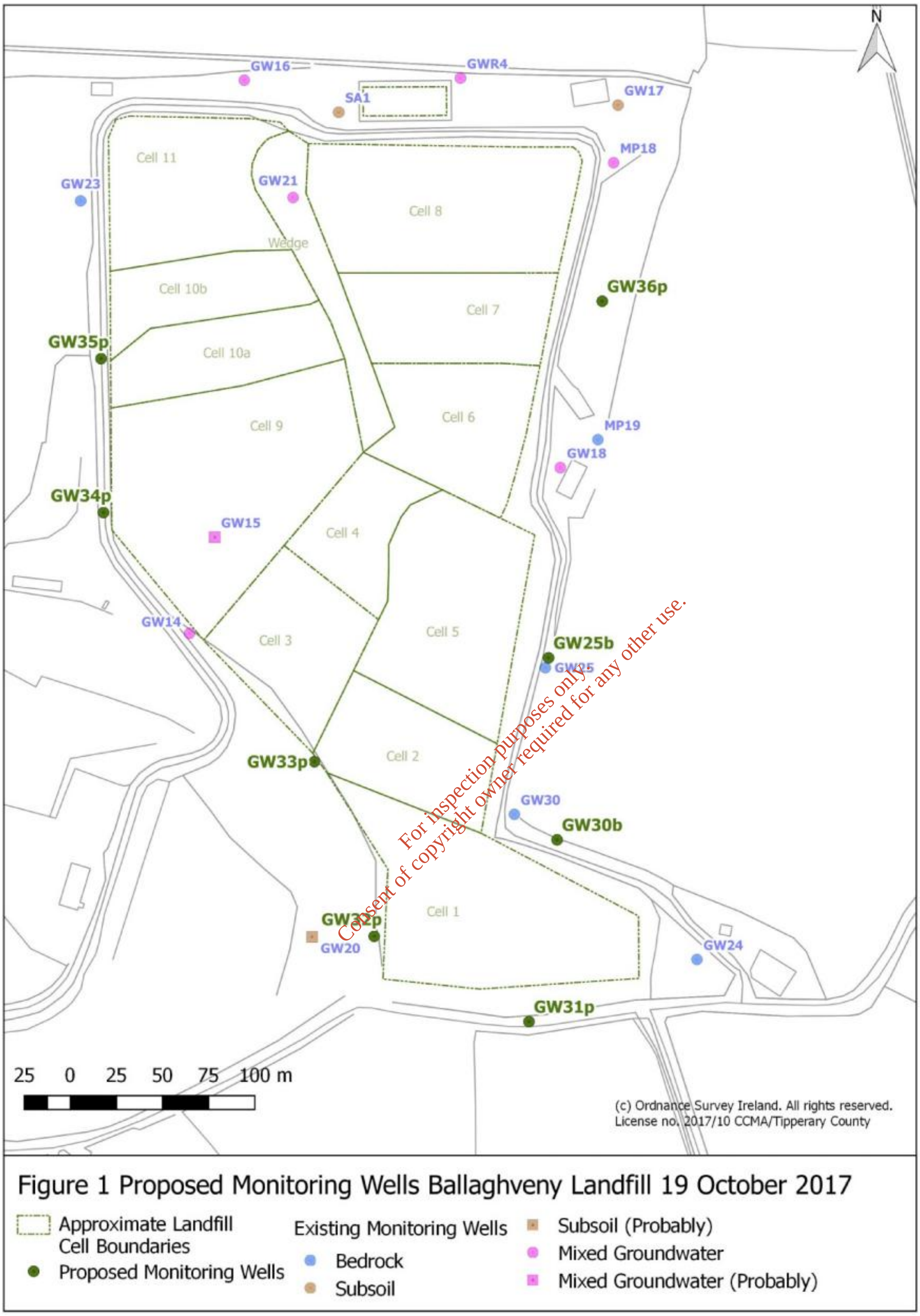

Figure 33. Proposed Groundwater Monitoring Well Locations

3.3.3 Interpretation of Phase 3 Data

The groundwater elevation contours shown in Figures 17 to 22 and the groundwater flowlines shown in Figures 30 and 31 suggest that there is generally no groundwater monitoring well that directly intercepts groundwater flowlines passing beneath Phase 3 of the landfill. The proposed monitoring well GW36 shown in Figure 33 will bridge this data gap.

It may be that under favourable groundwater elevation conditions groundwater flowlines beneath Cell 6 (the southern-most cell of Phase 3) may be intercepted by GW18 (Figure 31). The Phase 3 leachate footprint does not generally extend into Cell 6 (Figures 17 to 22), such that any leachate leakage from Phase 3 is more likely to be from Cells 7 or 8 and would not be intercepted by GW18. Under conditions where the flowlines beneath Cell 6 go to GW18, they would also pass beneath Phase 4 and GW27 prior to Cell 6, and any contamination of the flowline would be more likely to derive from Phase 4 than from Cell 6.

Although none of the current monitoring wells directly intercept flowlines passing beneath Phase 3, it is possible that lateral dispersion of the contaminant plume could lead to the detection of contamination at the monitoring wells peripheral to the downgradient side of Phase 3, i.e. GW17, MP18, MP19 and GW18. Of these GW17 has continuous electrical conductivity monitoring, and GW17 and GW18 were included in the groundwater monitoring regimes undertaken during the trial period.

As discussed in Section 3.3.2.3 there is no evidence of leachate contamination in the continuous EC data for monitoring well GW17. Figure 9 shows that the Chloride data for GW17 between July 2017 and May 2018 are all less than the SI 366 of 2016 Groundwater Regulations chloride threshold of 24 mg/l, which further suggests that no leachate contamination from potential lateral dispersion of leachate leakage occurred at GW17.

As discussed in Section 3.3.2.3 GW18 generally intercepts groundwater flowlines that pass beneath Phase 1 Cell 2 to the southwest of the borehole. The laboratory water quality data for GW18 for chloride and electrical conductivity show the GW18 trends for these parameters correlate very strongly with the trends for boreholes GW24 and GW20 in the southern part of the site adjacent to Phase 1 of the landfill. This suggests that evidence of contamination in the groundwater quality data for GW18 during the trial period derives from Phase 1 of the landfill rather than from leachate leakage from Phases 3 and 4 during the trial period.

As such the available water quality data show no evidence of leachate leakage from Phase 3 during the trial investigation period.

3.3.3.1 Groundwater and Leachate Level and Leachate Pumping Data

Figure 34 shows a selection of key groundwater and leachate level trends relevant to the trial leachate management regime at Phase 3. Additional trends are shown in Figure 16.

The trends in Figure 34 illustrate the following points:

- The horizontal hydraulic gradient across Phase 3 of the landfill between GW21 on the upgradient side and GW17 and MP18 on the downgradient side is small, with the head difference ranging from approximately 0.2 m to 0.3 m during the trial period.
- During the trial period the groundwater elevation at MP18 generally represented the lowest groundwater elevation adjacent to Phase 3.
- As discussed in Section 3.2 the volume of leachate pumped from Phase 3 in 2018 decreased as the the differential maintained between the GW21 groundwater elevation and the LS03 leachate elevation was initiated at 1 m on 13 December 2017 (Point 1 on Figure 34), and then reduced from 1 m to 0.2 m to 0.1 m on 23 February and 24 April respectively (Points 2 and 3 on Figure 34 respectively).

- After the implementation of each differential the LS03 leachate level increased to the extent allowed by the programmed pumping differential and was subsequently maintained at the appropriate elevation by leachate pumping from LS03.
- There was no plateauing of the leachate level due to leakage as discussed with respect to Phase 4 in Section 3.3.2.

- Figure 34 shows that:
  - The LS03 leachate elevation was generally below the downgradient groundwater elevation at GW17; and,
  - The LS03 leachate elevation was above the downgradient elevation at MP18 from 20 March 2018 onwards (Point 4 on Figure 34).
  - This indicates that there may have been an outwards hydraulic gradient acting on the downgradient Phase 3 boundary after 20 March 2018.
  - There is no evidence that any leachate escaped from Phase 3 during the period of the outward hydraulic gradient.
- Figure 34 shows that during the 0.1 m differential period after Point 3 on Figure 34, the GW21-LS03 head difference dropped below the 0.1 m threshold on one occasion:
  - During the period 10 to 24 May a malfunction on POD 2 of the telemetry system at the site caused a data loss for GW21. Point 5 on Figure 34 shows that towards the end of this period the LS03 leachate elevation may have risen to equal the GW21 groundwater elevation.
  - There is no evidence that any leachate escaped from Phase 3 during the period of increased outward hydraulic gradient.
- The LS03 leachate level was between 1.1 m and 2.7 m above the 1 m leachate threshold during the trial period.

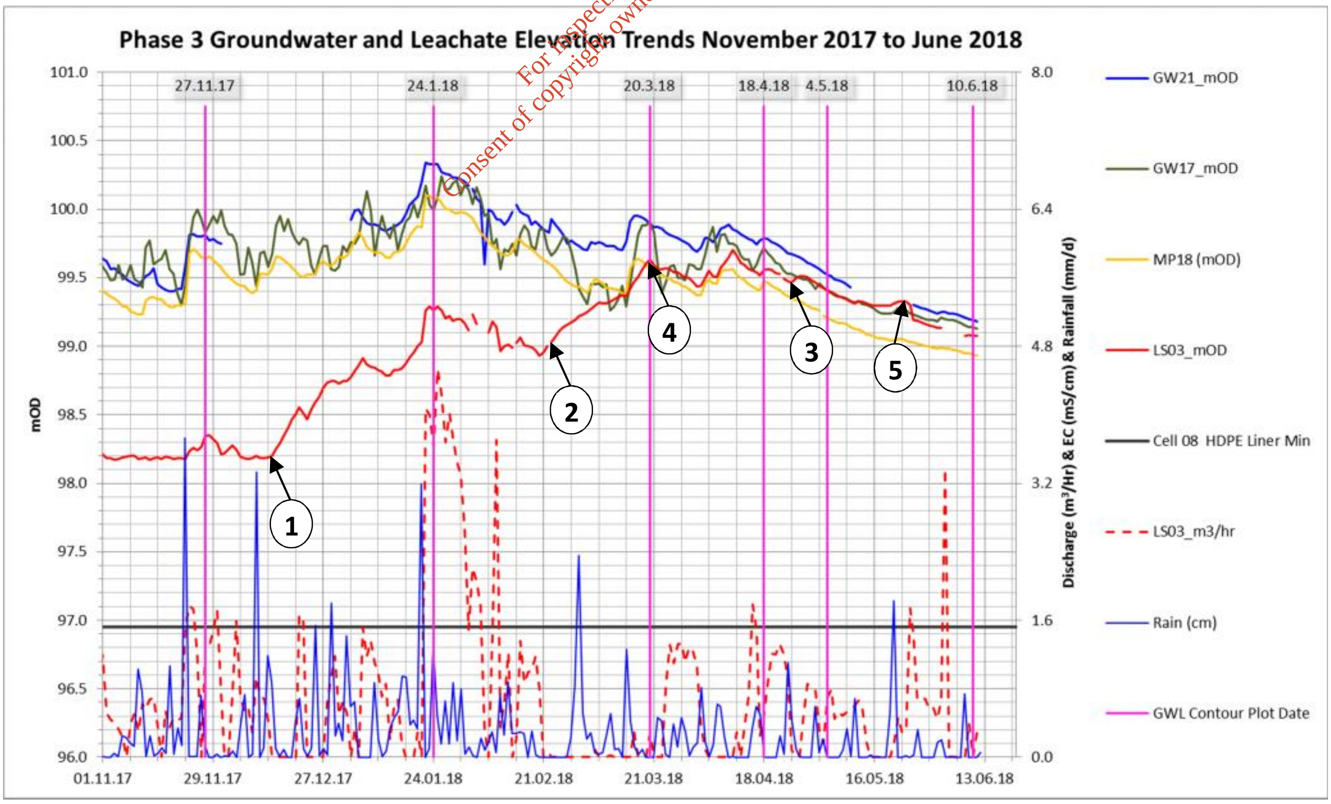

Figure 34. Selected Phase 3 Groundwater and Leachate Level and Electrical Conductivity Trends

Overall the available data for Phase 3 suggest that:

- Over the course of the trial period allowing the Phase 3 leachate level to rise to within 0.1 m of the GW21 groundwater level reduced the volume of leachate generated by the Phase compared to keeping the leachate level below the 1 m threshold; and,
- The available data suggest that there was no leachate leakage from Phase 3 of the landfill during the implementation of the trial leachate management regime.
- Further assessment of the Phase 3 trial leachate management regime should be carried out following the installation of monitoring well GW36, which is expected to be directly downgradient of Phase 3 and better positioned to detect potential Phase 3 leachate leakage than the current groundwater monitoring wells in the vicinity of Phase 3.

3.4 Interpretation of Hydrochemistry and Water Quality

3.4.1 Recap on Groundwater Water-Types at the Site

The report on the 2016 Pumping Tests at Ballaghveny Landfill (Conroy, 2016) identified three water types in the groundwater in the vicinity of the landfill:

- GRAVEL-TYPE groundwater characterised by background concentrations of EC, Ammonia, Iron, Manganese, Chloride, Potassium and COD, and detectable sulphate and nitrate.
- BOG-TYPE groundwater characterised by elevated Iron and Manganese, elevated Ammonia (<7 mg/l), high COD, low EC, Chloride and Potassium.
- ~~LEACHATE-TYPE groundwater~~ (name retired and replaced by….)
- GROUNDWATER-POLLUTED-BY-LEACHATE-TYPE (GPBL-TYPE):
    - In hindsight, the name LEACHATE-TYPE used in Conroy (2016) may lead to confusion with actual leachate;
    - In this report this water type is called GROUNDWATER-POLLUTED-BY-LEACHATE-TYPE groundwater (GPBL-TYPE);
    - This water type is characterised by elevated EC, Ammonia (>7 mg/l), Iron, Manganese, Chloride, Potassium and COD, with negligible Nitrate or Sulphate. The major ion concentrations may also be much higher than the typical baseline levels in this water type.
    - Two-way and three-way mixing of these water types across the site leads to intermediate chemical compositions spatially and temporally, with large changes in individual parameters over short spaces and/or time periods due to changes in redox conditions and/or cation exchange reactions.

3.4.2 Detection of Organic Compounds in Groundwater

Table 5 shows the organic contaminants detected in samples from groundwater monitoring boreholes around the site between July 2017 and May 2018.

Table 5. Organic Compounds Detected in Groundwater

	Parameter	1,1-Dichloroethane	Phenols
	SI 366 of 2016 TV	-	-
Location	Date	µg/l	µg/l
GW20	06/02/2018	2.74	< 1
GW24	07/02/2018	< 1	17.1

The table shows that 1,1-Dichloroethane was detected at GW20 and Phenols were detected at GW24, both in early February 2018. GW20 and GW24 are downgradient of Phase 1 of the landfill and do not intersect groundwater flowlines passing beneath Phases 3 and 4 of the landfill. As such, these detections are not considered to be related to leachate leakage from Phases 3 and 4 during the trial period. They are likely to derive from leachate leakage from Phase 1 of the landfill, which is unlined.

Water quality issues associated with Phase 1 of the landfill will be assessed as part of the Phase 1 Tier 3 quantitative risk assessment.

3.4.3 Trends in Hydrochemistry Indicator Parameters

Electrical conductivity data for GW27 (and to a much lesser extent GW26) suggest that groundwater at GW27 was contaminated by leachate leakage from Phase 4 during the trial period. The data and interpretation are discussed in detail in Section 3.3.2.

Monitoring wells GW26 and GW27 are buried beneath the Wedge Cell and are not accessible for collection of groundwater samples. As a result there are no laboratory groundwater water quality data for these locations to compare to the electrical conductivity trends for the locations.

Graphs of laboratory water quality data versus time for the trial period for the indicator parameters electrical conductivity, chloride, sulphate, iron, manganese, ammonium and nitrate are shown in Figures 8 to 14 respectively.

For GW18, GW24 and GW20 the graphs show highly elevated concentrations of chloride, ammonium, and electrical conductivity; high to very high concentrations of iron and manganese; nitrate concentrations below the detection limit, and high to very high concentrations of other major ions. The three wells show very similar trends for electrical conductivity and for chloride concentration. The data suggest the three wells are contaminated by the same leachate source. As discussed in Section 3.3.3 the three wells are on groundwater flowlines deriving from beneath Phase 1 of the landfill. As such the observed leachate contamination is considered to be related to leachate leakage from Phase 1, which is unlined, rather than to leakage from Phase 3 or 4 during the trial period.

Chloride concentrations for the other monitoring wells are less than 24 mg/l, except for GW23, SA1 and GWR4 which had occasional concentrations between 24 mg/l and 33 mg/l, and GW14 and GW15 which had concentrations between 34 mg/l and 35 mg/l during the trial period. Elevated concentrations of chloride adjacent to a landfill are a strong indicator of leachate contamination. The low chloride concentrations at GW22, GW16, SA1, GWR4, GW21, GW17, GW23, GW29, and GW28 suggest these locations were not contaminated by leachate during the trial period. Figure 9 shows that the rising trend in chloride concentrations at GW15 began in September 2017, rising from 21 mg/l on 20 September 2017 to 28 mg/l by 06 December 2017, which is prior to the start of the trial period. The rising trend in chloride at GW15 correlates roughly with the rising and subsequent high groundwater levels at the site from September 2017 onwards. The exact source for the slight rising trend in chloride at GW15 is not obvious based on the available data. The chloride trend was not initiated by the trial leachate management period and the other indicator parameters at GW15 and GW14 (see below) suggest the locations represent GRAVEL-TYPE groundwater, and were not subject to significant leachate contamination during the trial period such as occurred at GW27.

High concentrations of iron, manganese and ammonia, and sulphate and nitrate concentrations below the detection limit at GW22, GW16, GW21, SA1, GWR4, and GW17 suggest that BOG-TYPE groundwater dominated the northern site boundary in the vicinity of these monitoring wells during the trial period. This is in keeping with the groundwater flow direction in this area during the trial period which was from the bog area north of the site southeast towards the landfill (Figures 30 and 31).

Generally low concentrations of iron, manganese and ammonia, and detectable sulphate and nitrate at GW15 and GW14 suggest that GRAVEL-TYPE groundwater dominated the western upgradient boundary of Phase 4 in the vicinity of these monitoring wells during the trial period. This is in keeping with the groundwater flow direction in this area during the trial period which was from the west of the site east towards the landfill (Figures 30 and 31).

Monitoring wells GW23, GW29, and GW28 are between the two extremes and are likely to reflect a mixture of BOG-TYPE and GRAVEL-TYPE groundwater types. This is in keeping with the groundwater flow direction in this area during the trial period. Figures 30 and 31 show flowlines from west of the site and northwest of the site converging in this area, which would be expected to result in mixing of BOG-TYPE and GRAVEL-TYPE groundwater.

3.4.4 Phase 3 and 4 Leachate Electrical Conductivity Data

Electrical conductivity trends at LS06 and LS03 during the trial period are shown on Figures 15 and 16 respectively. The trends suggest that the leachate electrical conductivity fluctuates roughly in proportion to the magnitude of the groundwater inflow to the phase.

As such, when the inwards hydraulic gradient driving groundwater into the phase is large the leachate electrical conductivity goes on a downward trend. As the leachate level increases in response to the groundwater inflow, the inwards hydraulic gradient decreases leading to a reduction in the inflow rate such that the leachate electrical conductivity reverts to a rising trend.

4 Updated Hydrogeological Conceptual Model

The monitoring and site investigation work completed at the landfill during the trial period have confirmed the broad framework of the hydrogeological conceptual model (HCM) developed in the Technical Ammendment B Hydrogeological Assessment Report (Conroy, 2015) and refined in the reports on the spring 2016 pumping tests (Conroy, 2016) and the report on the SEW construction of GW21 (HUCT 2017).

The Technical Ammendment B Hydrogeological Assessment Report HCM cross section diagram for the site is re-produced in Figure 35.

The data and interpretation from the ongoing monitoring, SEW works, and subsequent pumping trials have led to the following refinements to the conceptual model:

- The lateral hydraulic gradient across Phase 4 of the landfill causes groundwater inflow into Phase 4 when the upgradient groundwater elevation exceeds the leachate elevation inside the Phase.
- The leachate elevation inside the phase rises in response to the groundwater inflow.
- Once the leachate level reaches an elevation of 100 mOD and when the downgradient groundwater elevation is less than the leachate elevation, leachate leaks out the downgradient side of the landfill in the vicinity of GW27.
- Except for times of peak groundwater inflow, the magnitude of the leachate leakage is approximately equal to the groundwater inflow.
- Potentially the leakage is viable at leachate elevations below 100 mOD as long as the downgradient groundwater elevation is lower than the leachate elevation.
- The groundwater elevation and trend at GW21 is approximately equal to the Phase 4 downgradient groundwater elevation and trend at GW27.
- Phase 4 leachate leakage in the vicinity of GW27 is likely to migrate northeast into the high transmissivity zone beneath and to the east of Phase 3.
- The lateral hydraulic gradient across Phase 3 of the landfill is small and of the order of 0.2 m to 0.3 m.
- Groundwater inflow to Phase 3 occurs and causes the leachate level to rise in response to the inflow.
- As long as the leachate elevation is maintained below the upgradient groundwater elevation at GW21 the data from the existing monitoring network suggest that leachate leakage does not occur from Phase 3.
- Trends indicating leachate contamination at GW18 correlate with similar trends at GW20 and GW24 and suggest that leachate contamination at GW18 derives from Phase 1 of the landfill.
- Electrical conductivity levels at GW17 fluctuate between the baseline levels for BOG-TYPE groundwater and GRAVEL-TYPE groundwater. This suggests that GW17 is at a location that intersects either groundwater flowpaths from the bog to the northwest or the gravel aquifer to the west, depending on the prevailing groundwater elevation distribution in the area.

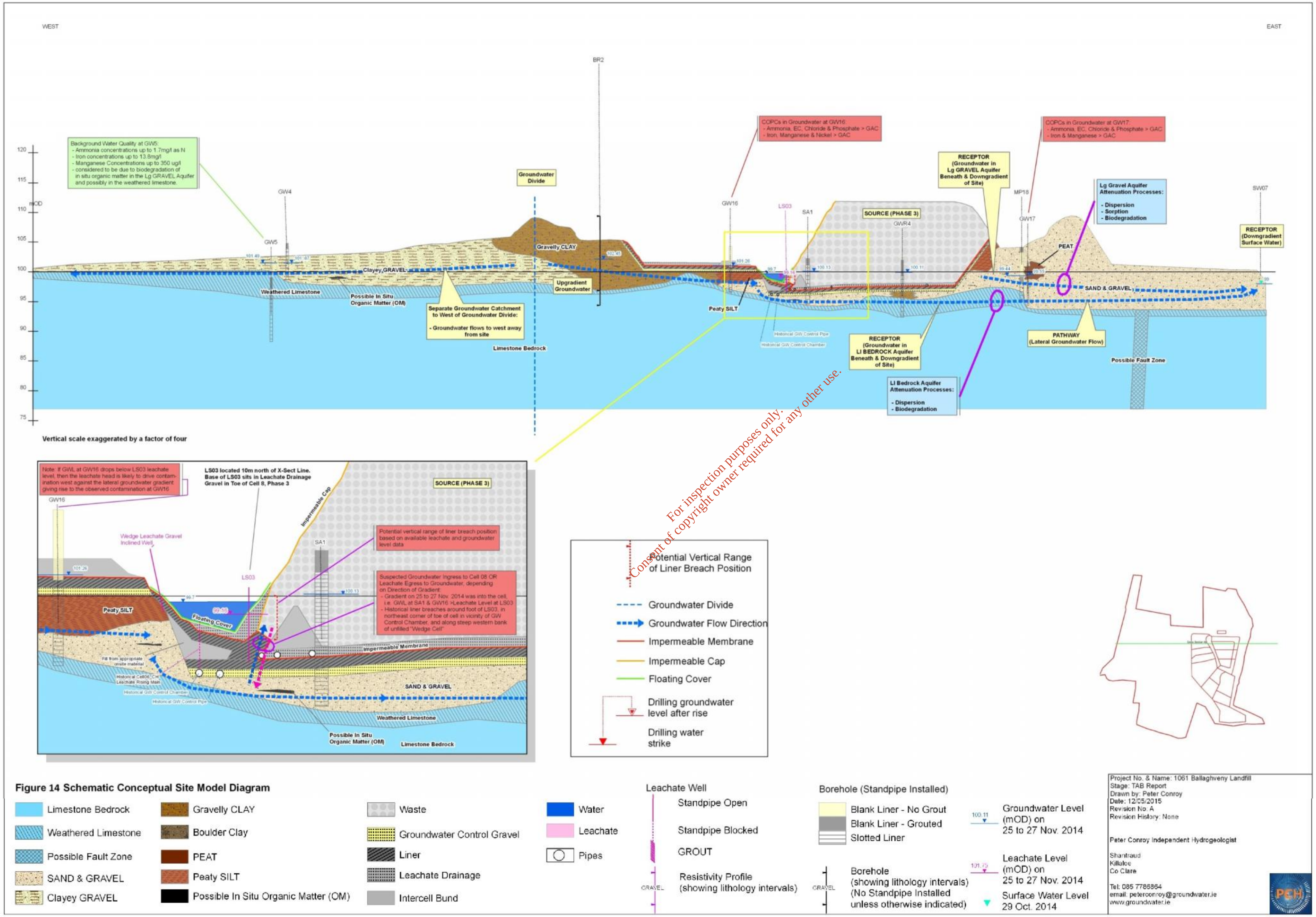

Figure 35 .Hydrogeological Conceptual Model Cross Section Diagram

5 Groundwater Management Strategy

5.1 Phase 4

- Over the course of the trial period allowing the Phase 4 leachate level to rise to 100 mOD reduced the volume of leachate generated by the Phase compared to keeping the leachate level below the 1 m threshold.
    - Leachate leakage also contributed to the reduction in the leachate volume pumped from Phase 4 once the leachate level stabilised at 100 mOD.
- Due to lag times in the groundwater response at GW27 to changes in the Phase 4 leachate management regime the effect of the leachate level manipulations during the trial period are not yet fully apparent. The effect of the leachate level manipulations during the trial period are expected to manifest in the form of the onset of a steep downward trend in EC from 3,000 uS/cm to 2,000 uS/cm at GW27, in line with the following timescales:
    - If dropping the LS06 leachate level below 99.95 mOD on 05 May 2018 stopped the leakage, then a steep downward trend could be expected at GW27 from 07 July onwards.
    - If dropping the LS06 leachate level below 99.6 mOD on 10 May 2018 stopped the leakage, then a steep downward trend could be expected at GW27 from 12 July onwards.
    - If dropping the LS06 leachate level below the GW27 downgradient groundwater elevation on 10 June 2018 stopped the leakage, then a steep downward trend could be expected at GW27 from 12 August onwards.
- Unless the future EC data for GW27 in line with the above timescales clearly indicate that the manipulations related to the 100 mOD or 99.6 mOD leakage thresholds stopped the leakage, the LS06 leachate level controls should be programmed to maintain the leachate level 0.1 m below the downgradient groundwater elevation at GW27 (or other equivalent groundwater level monitoring location) in the long term.
- Since GW27 is intended to be decommissioned in due course with the filling of the Wedge Cell, GW21 is proposed as a potential replacement for determining the Phase 4 downgradient groundwater elevation.
    - Figures 17 to 22 show that groundwater elevations at GW27 and GW21 were generally either the same or within 0.1 m of each other during the trial period.
    - Figure 16 shows that the largest difference between GW27 and GW21 during the trial period occurred on 12 March 2018 and amounts to 0.15 m.

5.2 Phase 3

- Over the course of the trial period allowing the Phase 3 leachate level to rise to within 0.1 m of the GW21 groundwater level reduced the volume of leachate generated by the Phase compared to keeping the leachate level below the 1 m threshold.
- The available data suggest that the implementation of this leachate management regime did not result in leachate leakage from Phase 3 during the trial period.
- Phase 3 leachate levels should be managed to minimise leachate production by keeping the LS03 leachate elevation 0.1 m lower than the groundwater elevation at GW21.
- Further assessment of the Phase 3 trial leachate management regime should be carried out following the installation of monitoring well GW36, which is expected to be directly downgradient of Phase 3, and better position to detect potential Phase 3 leachate leakage than the current groundwater monitoring wells in the vicinity of Phase 3.

6 Conclusions

The following conclusions have been drawn from the results of the investigations carried out during the trial period:

- Managing the Phase 3 and Phase 4 leachate between March and May 2018 by allowing the leachate to rise up to 100 mOD in Phase 4, and to an elevation between 0.1 m and 0.2 m below the prevailing upgradient groundwater elevation at GW21 for Phase 3 led to a 70% reduction in leachate production for Phases 3 and 4 compared to the same period in 2016, when leachate elevations were generally kept below the 1 m threshold level for each phase.
- Phase 4 leachate elevations of 100 mOD resulted in leachate leakage at the downgradient boundary of Phase 4 near GW27 when the leachate elevation exceeded the downgradient groundwater elevation at GW27.
- The Phase 4 leachate management controls were manipulated to try and reverse the electrical conductivity trend indicating leachate contamination at GW27; however lag times in the response of GW27 to changes in leachate conditions at Phase 4 mean that the effect of the manipulations has not yet been observed at GW27.
- The available data suggest that maintaining the Phase 3 leachate elevations 0.1 m lower than the prevailing groundwater elevation at GW21 did not result in leachate leakage from Phase 3 during the trial period.

7 Recommendations for further work

- Unless the future EC data in July and August 2018 for GW27 clearly indicate that the manipulations related to the 100 mOD or 99.6 mOD leakage thresholds stopped the leachate leakage from Phase 4, the LS06 leachate level controls should be programmed to maintain the leachate level 0.1 m below the downgradient groundwater elevation at GW27 (or other equivalent groundwater level monitoring location) in the long term.
- Since GW27 is intended to be decommissioned in due course with the filling of the Wedge Cell, GW21 is proposed as a replacement for determining the Phase 4 downgradient groundwater elevation.
- Phase 3 leachate levels should be managed to minimise leachate production by keeping the LS03 leachate elevation 0.1 m lower than the groundwater elevation at GW21.
- Further assessment of the Phase 3 trial leachate management regime should be carried out following the installation of monitoring well GW36, which is expected to be directly downgradient of Phase 3 and better positioned to detect potential Phase 3 leachate leakage than the current groundwater monitoring wells in the vicinity of Phase 3.

8 Comment on Engineering Options

Engineering options to raise the downgradient groundwater elevation for Phases 3 and 4 shall be examined.

9 References

Conroy, P., 2015. Ballaghveny Landfill (W0078-03/B) Technical Ammendment B - Hydrogeological Assessment Report. Peter Conroy Independent Hydrogeologist, Shantraud, Killaloe, Co. Clare. June 2015. On behalf of Tipperary County Council.

Conroy, P., 2016. Report on Pumping Tests Carried Out During Quarter 1 and Quarter 2 of 2016 At Ballaghveny Landfill. Peter Conroy Independent Hydrogeologist, Shantraud, Killaloe, Co. Clare. August 2016. On behalf of Tipperary County Council.

HUCT 2017. Hydrogeological Report on the Groundwater Monitoring, Specified Engineering Works and associated Pumping Trials carried out at Ballaghveny Landfill in the Period June 2016 to June 2017. Hidrigeolaíocht Uí Chonaire Teoranta (HUCT). On behalf of Tipperary County Council.

Appendix 1

Water Quality Data

Table A1.1. Water Quality Data for the Period July 2017 to May 2018

Bold red text indicates value exceeds SI366 of 2016 Threshold Value (TV)	Parameter	pH	Sulphate	Iron (Combined mg & ug data)	Manganese (Combined mg & ug data)	Ammonia N (rounded)	Nitrate N	Nitrite N	Conductivity @ 25°C (20C & 25C data combined)	Chloride	Alkalinity	Calcium	Magnesium	Potassium	Sodium	COD Chemical Oxygen Demand	BOD, 5 days with Inhibition (Carbonaceous)	Ortho-Phosphate P	Arsenic	Boron	Cadmium (Combined mg & ug data)	Chromium (Combined mg & ug data)	Copper (Combined mg & ug data)	Lead (Combined mg & ug data)	Mercury (Combined mg & ug data)	Nickel (Combined mg & ug data)	Zinc (Combined mg & ug data)	Coliform Bacteria	E Coli	Total Organic Carbon	Dissolved Oxygen	Dissolved Oxygen % Saturation	Temperature
	Units	pH units	mg/l	µg/l	µg/l	mg/l	mg/l	mg/l	µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	no./100mls	MPN/100mls	mg/l	mg/l	% O2	Degrees C
	SI 366 of 2016 TV	--	188	--	--	0.175	8.5	0.11	800	24	--	--	--	--	--	--	--	0.035	7.5	--	--	37.5	--	7.5	0.75	--	75	--	--	--	--	--	--
	Max Leachate	7.4	113	20156	2529	**643**	0	**0.4**	**10275**	**1369**	3908	283	128	505	988	848	51	**2.0**	0.0	2546	0.0	**48**	0	0	0	187	0	24196	20	858	8.4	80	16.1
	Max. Groundwater	7.9	98	33100	1470	**19**	**14.4**	0.0	**1703**	**182**	486	304	27	22	104	74	6	**0.1**	1.0	156	4.1	10	36	**40**	**1**	16	**309**	727	0	21	7.1	95	17.2
Location	Sample Date																																
GW14	26/01/2017		< 20	3340	940	0.02	4.005	< 0.005	**906**	**34**	338	241	14.5	3.0	22.5	< 8	2	< 0.025	0.0025	< 50	2	5.9	9.8	**40**	< 0.01	10.3	**87.8**	6	< 1	1.4			
GW14	18/04/2017	7.6	< 20		< 0.7	< 0.01	4.554	< 0.005	**820**	**41**	369	118	12.7	2.3	20.9	< 8	< 2	< 0.025				< 0.9			< 0	1.09				2.0	5.92	58.9	14.9
Gw14	06/02/2018		< 20	450	150	< 0.2	4.3	< 0.02	**808**	**49.2**	326	135	13.4	3.0	23.1	< 8			< 0.5	21	< 0.1	< 1	6.77	< 0.2	< 0.01	0.6	41.2	< 1	< 1	1.89			
Gw14	06/03/2018		< 20	820	340	0.05	3.7	< 0.005	**831**	**46.6**	327	142	14.4	3.7	23.9			<0.01		< 50	< 0.2	< 0.9	7.6	**10**	**1**	< 0.5	20						
Gw14	10/04/2018		< 20	3820	1470	**0.21**	3.9	0.03	791	**48.3**	333	150	15.3	2.7	23.8			**0.08**		< 50	2.8	4.3	15.2	**15.5**	**1**	7.3	57.1						
Gw14	01/05/2018		< 20	1390	510	0.13	4.3	< 0.005	**815**	**46.5**	352	169	14.1	2.6	24.5			<0.01		< 50	2.4	3.4	36	**14**	**1**	6.7	52.8						
GW15	13/09/2016	7.2	71			< 0.1			**896**	**25**																						32	15.5
GW15	07/04/2017		49	16	660	0.02	< 2	0.008	**964**	23	387	128	12.7	4.5	42.5	< 8	3	< 0.025				< 0.9			< 0	5.77				2.8			
GW15	22/06/2016	7.2	97			< 0.1			**843**	**32**																						25	16.9
GW15	19/07/2016	7.2	75			< 0.1			**876**	**30**																						14	16.6
GW15	16/08/2016	7.6	87			< 0.1			**914**	**31**																						38	16.7
GW15	11/10/2016	7.4	85			< 0.1			**898**	**28**																						27	14.8
GW15	15/11/2016	7.0	98			< 0.1			**955**	**28**																						54	15.1
GW15	17/01/2017	7.1	89			< 0.1			**935**	24																						51	15.3
GW15	26/01/2017		89	80	1050	0.07	< 2	< 0.005	**1108**	23	393	117	13.3	6.4	103.6	< 8	< 2	< 0.025	< 0.0001	< 50	1.3	1.8	9.2	3.7	< 0.01	6.4	**160**	< 1	< 1	1.9			
GW15	14/02/2017	6.8	75			< 0.1			**981**	23																						50	13.9
GW15	14/03/2017	7.5	26			< 0.1			**933**	**26**																						31	15.1
GW15	28/03/2017		53	< 7.2	751	0.03	< 2	< 0.005	**823**	**24**	382	304	12.7	4.6	45.5	< 8	< 2	< 0.025				1.8			< 0.01	5.5		< 1	< 1	1.7			
GW15	04/04/2017	7.4	51	24	762	0.03	< 2	0.007	**935**	23	384	135	13.1	4.4	44.5	< 8	< 2	< 0.025				2.3			< 0	4.65				2.2	2.94	30.7	17.2
GW15	12/04/2017	7.3	49			< 0.1			**861**	23																						37	16.9
GW15	19/04/2017	6.8	50	< 7.2	790	0.13	< 2	0.006	**895**	23	436	125	12.9	4.8	43.6	9	3	< 0.025				< 0.9			< 0	3.59				1.6	2	20	17.2
GW15	13/06/2017	7.4	77			< 0.1			39	23																						49	15.7
Gw15	18/07/2017	7.2	87			< 0.1			**932**	24.0																						27	16.1
Gw15	09/08/2017	7.3	22			< 0.1			**974**	22.0																						22	15.8
Gw15	20/09/2017	7.1	84			< 0.1			**959**	21.0																						8	15.8
Gw15	18/10/2017	7.1	77			< 0.1			**954**	24.0																						13	13.8
Gw15	21/11/2017	7.3	80			< 0.1			**955**	**25.0**																						47	14.5
Gw15	06/12/2017	7.2	71			< 0.1			**937**	**28.0**																						27	13.5
Gw15	24/01/2018	7.2	42			< 0.1			**866**	**34.0**																						55.2	13.1
Gw15	06/02/2018		49.619	13	150	< 0.2	2.4	0.04	**873**	**44.3**	331	119	12.2	4.9	44.1	10			< 0.5	23	< 0.1	< 1	3.31	< 0.2	< 0.01	1.43	48.7	2	< 1	4.26			
Gw15	27/02/2018	7.3	48			< 0.1			590	**43.0**																						49	9.8
Gw15	06/03/2018		45.11	11	80	< 0.01	< 2	0.01	**868**	**50.7**	320	115	11.9	4.4	39.7			<0.01		< 50	< 0.2	< 0.9	5.5	< 1.7	**1**	< 0.5	20						
Gw15	27/03/2018	7.3	41			< 0.1			596	**50.0**																						22	13.6
Gw15	10/04/2018		43.581	199	73.7	< 0.01	2.0	< 0.01	**908**	**50.8**	347	129	14.4	5.1	43.4			< 0.025		< 50	2.5	< 0.9	28.3	3.1	**1**	2.5	50.7						
Gw15	26/04/2018	7.3	37			< 0.1			596	**49.0**																						28	13.8
Gw15	01/05/2018		42.288	9.6	42.8	0.03	< 2	0.01	**867**	**48.5**	360	141	12.8	4.7	41.5			<0.01		< 50	2.4	1.4	23.8	< 1.7	**1**	1.3	34.4						
GW16	22/06/2016	7.2	15			**4**			577	17																						20	11.7
GW16	19/07/2016	7.4	< 10			**5.2**			702	23																						51	12
GW16	16/08/2016	7.4	12			**4.6**			724	19																						38	11.9
GW16	13/09/2016	7.5	5			**4.2**			624	14																						35	12.1
GW16	11/10/2016	7.4	< 10			**4**			605	17																						35	11.7
GW16	15/11/2016	7.3	25			**2.5**			555	16																						61	12
GW16	17/01/2017	7.2	< 10			**4.4**			673	21																						54	11.2
GW16	26/01/2017		< 20	11300	160	**5.2**	< 2	< 0.005	**824**	20	329	144	4.2	1.4	14.5	46	2	< 0.025	0.018	< 50	1.2	3	4.6	**7.6**	< 0.01	7.6	**117**	< 1	< 1	18.7			
GW16	14/02/2017	6.5	< 10			**5**			683	20																						46	10.9
GW16	14/03/2017	7.5	20			**5.4**			722	20																						37	11
GW16	12/04/2017	7.2	< 10			**4.6**			676	19																						57	10.4
GW16	19/04/2017	6.7	< 20	1400	130	**5.7**	< 2	< 0.005	780	21	391	130	4.1	1.3	13.9	56		< 0.025				< 0.9			< 0	3.2				17.3	7.1	64	11.1
GW16	17/05/2017	7.0	< 10			**4.9**			732	18																						66	11.1
GW16	13/06/2017	7.2	< 10			**4.8**			39	18																						56	11.2
Gw16	18/07/2017	7.1	< 10			**5.8**			775	21.0																						43	11.5
Gw16	09/08/2017	7.4	20			**5.3**			771	20.0																						41	11.9
Gw16	20/09/2017	7.0	< 1			**4.9**			732	16.0																						23	12
Gw16	18/10/2017	7.1	< 10			**4.8**			718	18.0																						17	11.4
Gw16	21/11/2017	7.3	< 10			**4.4**			697	17.0																						60	12.5
Gw16	06/12/2017	7.2	< 10			**4.2**			619	15.0																						86	11.4
Gw16	24/01/2018	7.1	< 10			**4.7**			719	18.0																						60.5	10
Gw16	27/02/2018	7.1	< 10			**4.7**			473	17.0																						14	9.5
Gw16	27/03/2018	7.1	< 10			**4.8**			47	18.0																						31	10
Gw16	26/04/2018	7.2	< 10			**4.6**			470	18.0																						37	10.7
GW17	22/06/2016	7.2	< 10			**4.8**			674	20																						14	12.4
GW17	19/07/2016	7.3	< 10			**4.9**			671	21																						28	12.4
GW17	16/08/2016	7.7	< 10			**4.6**			679	20																						34	12
GW17	13/09/2016	7.2	< 1			**4.7**			750	17																						27	11.7
GW17	11/10/2016	7.1	< 10			**5.3**			675	21																						25	11.1
GW17	15/11/2016	7.2	< 10			**5**			718	21																						62	11.7
GW17	17/01/2017	7.2	< 10			**4.6**			653	19																						71	11.2
GW17	26/01/2017		< 20	7280	140	**4.9**	< 2	< 0.005	797	20	312	130	5.2	1.6	13.5	45	2	**0.042**	0.0015	< 50	0.9	2.7	3.5	3.4	< 0.01	2.7	25	29	< 1	16.0			
GW17	14/02/2017	6.7	< 10			**5**			670	20																						55	10
GW17	14/03/2017	7.4	19			**5**			683	19																						36	11.5
GW17	12/04/2017	7.2	< 10			**4.9**			677	20																						61	11.2
GW17	25/04/2017	7.2	< 20	2020	90	**5.1**	< 2	< 0.005	718	20	339	121	4.8	1.3	10.9	42	3	0.028				9.7			< 0	15.64				20.9	3.62	32.5	10.5
GW17	13/06/2017	6.9	< 10			**4.8**			39	19																						49	11.8
Gw17	18/07/2017	7.2	< 10			**4.8**			662	20.0																						40	11.5
Gw17	09/08/2017	7.4	20			**4.6**			670	20.0																						39	12.2
Gw17	20/09/2017	7.0	< 1			**4.6**			680	16.0																						35	11.9
Gw17	25/10/2017	7.0	< 10			**4.5**			436	18.0																						41	12.3
Gw17	21/11/2017	7.3	< 10			**4.6**			700	19.0																						69	12.5
Gw17	06/12/2017	7.1	< 10			**5**			698	18.0																						72	11.2
Gw17	24/01/2018	7.0	< 10			**4.9**			**854**	19.0																						69.2	10.3
Gw17	06/02/2018		< 20	33100	310	**4.5**	< 2	0.02	750	18.8	358	142	6.7	2.4	13.3	74			1.02	17	< 0.1	1.49	11	< 0.2	**1.12**	10.4	**309**	57.1	< 1	15.23			
Gw17	27/02/2018	6.9	< 10			**4.5**			560	21.0																						10	0.8
Gw17	06/03/2018		< 20	10500	210	**2.7**	< 2	< 0.005	752	19.2	350	128	6.2	2.1	14.4			**0.10**		< 50	< 0.2	< 0.9	7.6	< 1.7	**1**	< 0.5	20						
Gw17	27/03/2018	7.1	< 10			**4.9**			479	19.0																						35	10.8
Gw17	10/04/2018		< 20	26300	230	**4.3**	< 2	0.01	619	19.0	352	135	6.0	2.1	12.6			**0.07**		< 50	< 0.2	< 0.9	10	5.2	0	3.9	**225**						
Gw17	26/04/2018	7.2	< 10			**4.7**			473	20.0																						36	12.4
Gw17	01/05/2018		< 20	8620	170	**0.77**	< 2	< 0.005	706	19.3	347	143	5.2	1.7	12.4			**0.09**		< 50	0.9	3.3	< 2	3.7	**1**	3.3	**101**						
GW18	22/06/2016	7.2	35			**3.6**			**983**	**55**																						18	12.4
GW18	19/07/2016	7.4	37			**4**			**1187**	**62**																						19	12.8
GW18	16/08/2016	7.9	36			**3.3**			**1030**	**65**																						26	14.1
GW18	13/09/2016	7.3	42			**1.3**			**877**	19																						31	12.7
GW18	11/10/2016	7.1	42			**2.2**			**990**	**43**																						21	11.8
GW18	15/11/2016	7.2	51			**0.99**			**947**	**26**																						50	12.1
GW18	13/12/2016	7.4	47			**0.89**			**1008**	**33**																						48	11.6
GW18	17/01/2017	7.2	53			**0.87**			**895**	**27**																						61	11.6
GW18	26/01/2017		39	3960	1380	**1.5**	< 2	< 0.005	**1396**	**73**	495	28	24.4	16.7	45.0	18	2	< 0.025	0.0034	74	2.5	7.1	20.2	**20.9**	< 0.01	40.9	**207**	2	< 1	4.6			
GW18	14/02/2017	6.6	42			**1.8**			**1152**	**62**																						53	10.4
GW18	14/03/2017	7.3	87			**6.5**			**1324**	**87**																						38	11.2
GW18	12/04/2017	7.1	35			**8.1**			**1523**	**107**																						34	11.2
GW18	19/04/2017	7.2	35	40	730	**7.6**	**17.307**	0.073	**1536**	**111**	635	230	26.1	24.6	71.3	28	3	< 0.025				< 0.9			< 0	19.5				6.6	4.89	46.1	12.4
GW18	13/06/2017	7.3	48			**0.33**			39	12																						26	13
Gw18	18/07/2017	7.2	40			**2.5**			**1043**	**49.0**																						36	12.2

Table A1.1. Water Quality Data for the Period July 2017 to May 2018

Bold red text indicates value exceeds SI366 of 2016 Threshold Value (TV)	Parameter	pH	Sulphate	Iron (Combined mg & ug data)	Manganese (Combined mg & ug data)	Ammonia N (rounded)	Nitrate N	Nitrite N	Conductivity @ 25°C (20C & 25C data combined)	Chloride	Alkalinity	Calcium	Magnesium	Potassium	Sodium	COD Chemical Oxygen Demand	BOD, 5 days with Inhibition (Carbonaceous)	Ortho-Phosphate P	Arsenic	Boron	Cadmium (Combined mg & ug data)	Chromium (Combined mg & ug data)	Copper (Combined mg & ug data)	Lead (Combined mg & ug data)	Mercury (Combined mg & ug data)	Nickel (Combined mg & ug data)	Zinc (Combined mg & ug data)	Coliform Bacteria	E Coli	Total Organic Carbon	Dissolved Oxygen	Dissolved Oxygen % Saturation	Temperature
	Units	pH units	mg/l	µg/l	µg/l	mg/l	mg/l	mg/l	µS/cm	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	no./100mls	MPN/100mls	mg/l	mg/l	% O2	Degrees C
	SI 366 of 2016 TV	--	188	--	--	0.175	8.5	0.11	800	24	--	--	--	--	--	--	--	0.035	7.5	--	--	37.5	--	7.5	0.75	--	75	--	--	--	--	--	--
	Max Leachate	7.4	113	20156	2529	643	0	0.4	10275	1369	3908	283	128	505	988	848	51	2.0	0.0	2546	0.0	48	0	0	0	187	0	24196	20	858	8.4	80	16.1
	Max. Groundwater	7.9	98	33100	1470	19	14.4	0.0	1703	182	486	304	27	22	104	74	6	0.1	1.0	156	4.1	10	36	40	1	16	309	727	0	21	7.1	95	17.2
Location	Sample Date																																
Gw18	09/08/2017	7.3	12			0.46			789	12.0																						28	13.2
Gw18	20/09/2017	7.0	39			2.5			1003	32.0																						16	13
Gw18	18/10/2017	7.0	33			3.7			739	36.0																						10	11.6
Gw18	21/11/2017	7.0	32			7.6			1417	88.0																						15	12.4
Gw18	06/12/2017	7.0	34			5.5			1327	77.0																						12	10.9
Gw18	24/01/2018	7.0	17			0.9			979	23.0																						43.3	8.2
Gw18	24/01/2018	7.5	< 10			< 0.1			697	45.0																						44.9	10.5
Gw18	07/02/2018		41.091	200	430	3.5	5.1	< 0.02	1213	61.5	487	167	20.7	16.6	42.0	11			1.21	107	0.19	< 1	2.08	0.28	< 0.01	16	33.8	27.2	3.1	5.73			
Gw18	27/02/2018	7.0	42			5.8			987	97.0																						34	8.5
Gw18	06/03/2018		41.716	171	1160	3.4	4.4	0.04	1416	100.8	541	216	23.6	20.6	57.2			<0.01		124	< 0.2	< 0.9	7.3	< 1.7	1	30	20						
Gw18	27/03/2018	7.0	37			7.4			1102	154.0																						35	10
Gw18	10/04/2018		34.971	274	1000	5.8	< 2	0.07	1427	237.2	576	210	23.6	23.0	62.0			0.03		74	6.4	3.2	16.9	5.8	1	31.8	53.8						
Gw18	26/04/2018	7.0	27			10			1244	171.0																						33	10.4
Gw18	01/05/2018		32.783	499	1640	1.7	< 2	0.01	1494	163.7	756	297	30.3	32.8	107.0			<0.01		126	15.8	2.4	21.9	9.3	1	55.2	81.8						
GW18	17/05/2017	7.0	46			4.9			1183	62																						68	12.1
GW20	22/06/2016	7.4	13			< 0.1			1076	131																						19	11.6
GW20	19/07/2016	7.3	39			0.54			1157	146																						27	11.9
GW20	16/08/2016	7.7	42			1.9			1270	173																						38	12.4
GW20	13/09/2016	7.3	25			0.48			1302	71																						29	11.5
GW20	11/10/2016	7.5	40			< 0.1			1198	154																						31	10.5
GW20	15/11/2016	7.2	44			2.3			1309	171																						62	10.9
GW20	13/12/2016	7.3	52			1.7			1282	167																						43	10.2
GW20	17/01/2017	7.2	36			4.2			1281	151																						67	10.4
GW20	26/01/2017		45	200	435	8.5	8.148	0.063	936	156	413	153	29.7	12.2	7.9	12	2	< 0.025	0.0006	81	4.3	2.5	3.7	6.1	< 0.01	32.3	13.2	4	< 1	5.0			
GW20	14/02/2017	7.0	37			4.9			694	150																						52	10.3
GW20	14/03/2017	7.4	138			3.6			1196	138																						25	10.7
GW20	12/04/2017	7.2	34			2.7			1294	156																						54	10.3
GW20	17/05/2017	7.1	40			0.76			1269	159																						87	10.6
GW20	13/06/2017	7.2	44			0.94			39	183																						32	11.4
Gw20	18/07/2017	7.4	45			2.2			1299	175.0																						48	11.3
Gw20	20/09/2017	7.3	49			0.14			1146	147.0																						28	11.5
Gw20	18/10/2017	7.2	48			< 0.1			765	153.0																						17	10.9
Gw20	21/11/2017	7.5	43			0.82			1215	141.0																						85	12.7
Gw20	06/12/2017	7.2	35			1.7			1255	147.0																						21	10.9
Gw20	24/01/2018	7.2	36			4.3			1282	150.0																						22.4	10
Gw20	06/02/2018		36.116	930	310	5.4	9.4	0.02	1231	144.6	367	132	24.5	8.6	82.2	9		<0.02	< 0.5	88	0.1	1.33	5.65	0.63	< 0.01	26.1	60	3.1	2	3.68			
Gw20	27/02/2018	7.3	41			0.74			885	178.0																						34	9
Gw20	06/03/2018		45.332	510	370	5.2	13.0	0.06	1429	178.7	368	144	26.3	10.9	93.6			0.01		65	< 0.2	470	8.2	< 1.7	1	40	< 2.8						
Gw20	27/03/2018	7.2	44			7.9			983	190.0																						35	9.7
Gw20	10/04/2018		46.718	920	330	7.7	9.8	0.05	1407	300.5	387	146	28.4	10.3	80.8			0.03		< 50	< 0.2	600	12.6	7.2	1	35.3	27.2						
Gw20	26/04/2018	7.3	36			3			940	185.0																						46	10
Gw20	01/05/2018		50.254	108	335	3	17.2	0.04	1450	189.8	372	165	25.5	9.6	92.4			<0.01		< 50	13.7	88.7	28.5	5.4	1	26.2	43.5						
GW21	01/02/2017		< 20	11600	780	1.2	< 2	< 0.005	763	17	388	157	7.6	4.1	17.2	41	3	< 0.025	0.0094	< 50	0.8	2.7	5	4.1	< 0.01	9.3	58.2	31	< 1	10.7			
GW21	25/04/2017	7.5	< 20	210	410	1.6	< 2	0.097	650	16	312	108	5.2	4.7	13.8	30	3	< 0.025				6.8			< 0	11.7				< 0.5	7.94	74.8	12.5
GW21	06/02/2018		25.715	39900	690	< 0.2	< 2	0.08	785	15.9	353	160	7.9	4.2	23.6	39		<0.02	1.91	26	< 0.1	< 1	< 0.85	< 0.2	< 0.01	10.2	270	7.5	< 1	10.69			
GW21	06/03/2018		< 20	25500	810	0.02	< 2	0.03	714	15.0	315	135	7.0	2.7	15.4			<0.01		53	< 0.2	< 0.9	31.8	10	0	20	570						
GW21	10/04/2018		< 20	9330	560	0.97	< 2	< 0.01	693	13.4	339	132	7.1	2.4	12.4			< 0.025		< 50	0.7	1.2	24.6	4.4	1	6.5	66						
GW21	01/05/2018		< 20	5920	560	0.56	< 2	< 0.005	703	13.7	339	142	6.5	2.0	12.1			<0.01		< 50	0.7	1.8	29.3	2.2	1	5	29.8						
GW22	26/01/2017		< 20	3390	230	2	< 2	< 0.005	639	16	268	125	3.6	0.8	9.1	29	3	< 0.025	0.014	< 50	1.1	4.3	15.5	12.1	< 0.01	10.2	21.8	19	< 1	11.5			
GW22	18/04/2017	7.2	< 20		190	2.1	< 2	< 0.005	593	20	351	110	3.4	0.8	9.0	[illegible]	3	< 0.025				< 0.9			< 0	2.2				14.4	3.28	31.2	12.9
GW22	06/02/2018		< 20	4450	190	1.9	< 2	< 0.02	526	11.8	273	103	3.0	< 0.4	8.3	33		<0.02	2.02	< 9.4	< 0.1	< 1	35.1	< 0.2	< 0.1	2.75	27.7	< 1	< 1	13.14			
GW22	07/03/2018		< 20	4700	190		< 2	< 0.005	557	12.3	287	99	2.8	0.6	7.6			0.02		< 50	0.8	3.5	5.6	2.8	1	4.3	6.1						
GW22	10/04/2018		< 20	4960	210	1.5	< 2	< 0.01	549	11.5	275	110	3.2	0.7	6.9			0.04		< 50	0.2	1	29.1	3.5	1	4.2	7.2						
GW22	01/05/2018		< 20	4870	190	0.53	< 2	< 0.005	588	11.9	294	127	3.1	0.7	8.1			0.05		< 50	0.5	2.9	28.7	4.5	1	4.6	7.1						
GW23	27/01/2017		21	33200	840	< 0.01	< 2	< 0.005	726	27	314	72	28.8	6.7	30.2	< 8	3	< 0.025	0.0048	53	2.5	20.2	115	130	< 0.01	53.4	180	4	< 1	2.0			
GW23	18/04/2017	7.5	< 20		< 0.7	< 0.01	< 2	< 0.005	754	27	360	102	18.8	1.8	18.8	< 8	< 2	< 0.025				< 0.9			< 0	2.67				3.0	4.92	48	14.1
GW23	06/02/2018		24.963	2930	220	< 0.2	< 2	0.04	749	19.8	343	240	23.6	4.3	[illegible]	< 8		<0.02	< 0.5	44	< 0.1	< 1	< 0.85	< 0.2	< 0.01	1.46	122	< 1	< 1	2.5			
GW23	06/03/2018		27.329	3320	220	0.1	< 2	0.01	755	29.9	335	20	25.3	3.6	19.6			<0.01		< 50	< 0.2	10	135	40	1	20	60						
GW23	10/04/2018		42.682	5220	160	0.07	< 2	0.06	743	31.3	353	207	24.3	4.3	18.7			0.12		< 50	1	11.5	118	27.3	1	12	68						
GW23	01/05/2018		24.086	3620	180	0.29	< 2	< 0.005	748	33.1	336	234	21.2	3.2	21.0			<0.01		< 50	1.1	11.2	158	31.8	1	12.9	67.7						
GW24	26/01/2017		< 20	6920	770	191.4	< 2	< 0.005	5696	721	1611	161	13.8	13.6	44.9	122	5	0.119	0.028	1071	10.1	6.9	13.3	21.1	< 0.01	55.3	74.5	30	< 1	46.4			
GW24	19/04/2017	7.2	< 20	126	590	197.2	< 2	< 0.005	4302	637	1658	119	121.5	172.7	440.2	112	6	0.122				2.9			< 0	37.2				41.3	6.09	56.6	11.45
GW24	07/02/2018		45.844	3540	520	74.8	< 2	0.03	2444	236.8	842	102	47.9	67.0	184.0	43		<0.02	7.89	433	< 0.1	< 1	20.5	0.21	< 0.01	28.7	23.8	< 1	< 1	17.2			
GW24	06/03/2018		32.547	7050	940	52	< 2	0.03	2455	263.7	855	163	49.0	64.5	187.3			0.14		470	< 0.2	< 0.9	11.9	10	1	30	10						
GW24	10/04/2018		< 20	9010	880	11.3	< 2	0.03	3838	574.4	1324	149	93.3	116.6	276.9			0.11		741	< 0.2	6.5	22.6	17.2	1	41	101						
GW24	01/05/2018		< 20	9050	980	15.8	< 2	< 0.005	4324	564.4	1501	209	109.0	136.0	380.0			0.07		860	< 0.2	5.9	26.8	19.5	1	37.4	251						
GW28	27/01/2017		45	1630	1120	0.05	< 2	< 0.005	1105	19	438	250	14.9	4.4	42.3	21	7	< 0.025	0.0018	< 50	0.8	1.9	5.4	7.8	< 0.01	12.2	13.9	47	< 1	4.5			
GW28	18/04/2017	7.2	< 20		4980	< 0.01	< 2	< 0.005	943	21	536	143	15.0	2.0	40.9	132	81	< 0.025				< 0.9			< 0	16.64				41.6	4.76	43.7	11.5
GW28	06/02/2018		40.608	880	1650	3.5	< 2	< 0.02	857	18.4	393	138	12.6	3.3	34.3	8		<0.02	0.52	34	< 0.1	< 1	< 0.85	< 0.2	< 0.01	6.89	33	1	< 1	4.06			
GW28	07/03/2018		37.323	3300	1530		< 2	< 0.005	783	17.9	354	136	11.4	3.1	28.1			0.02		< 50	0.9	3.7	11.2	9.4	1	12.3	30.6						
GW28	10/04/2018		37.276	850	1360	0.04	< 2	0.01	733	15.6	343	128	11.8	3.2	26.5			0.03		< 50	< 0.2	< 0.9	10	< 1.7	1	5.3	7.4						
GW28	01/05/2018		34.508	610	1270	0.11	< 2	< 0.005	779	15.1	372	148	10.9	3.2	27.4			<0.01		< 50	0.6	1.1	26.7	2.6	1	6.4	12.2						
GW29	27/01/2017		25	250	21	0.03	< 2	< 0.005	864	14	327	144	10.9	1.4	14.6	11	7	< 0.025	< 0.0001	< 50	0.6	0.9	3.9	< 1.7	< 0.01	2.7	5.1	19	< 1	3.8			
GW29	18/04/2017	7.2	24	261	12	< 0.01	< 2	< 0.005	747	16	380	124	10.4	1.1	12.6	8	< 2	< 0.025				< 0.9			< 0	2.11				2.3	2.8	25.7	11.4
GW29	06/02/2018		20.148	136	2.2	< 0.2	< 2	< 0.02	662	14.9	307	117	9.3	1.3	11.5	8		<0.02	0.71	20	< 0.1	< 1	< 0.85	< 0.2	< 0.01	1.23	30	62.4	< 1	4.33			
GW29	07/03/2018		21.293	480	69.2		< 2	< 0.005	670	14.6	293	112	9.0	1.3	11.3			<0.01		< 50	0.5	2.2	3.8	2.4	90000	2.9	4.4						
GW29	10/04/2018		21.662	181	37	0.02	< 2	< 0.01	657	12.7	318	124	10.5	1.4	12.3			< 0.025		< 50	< 0.2	< 0.9	21.6	2.8	1	2.8	6.3						
GW29	01/05/2018		20.329	56.1	15.9	0.19	< 2	< 0.005	711	11.9	324	141	9.5	1.4	12.3			<0.01		< 50	0.8	0.9	34.9	2.4	1	1.3	9.5						
GWR4	27/01/2017		< 20	10500	233	4.1	< 2	< 0.005	769	21	307	30	9.2	1.3	10.3	73	7	< 0.025	0.015	< 50	1.6	8.9	18.3	45.4	< 0.01	11.9	70.7	3	< 1	15.5			
GWR4	19/04/2017	7.1	< 20	340	110	3.9	< 2	< 0.005	666	28	336	110	5.8	1.4	13.0	350	3	0.104				1.1			< 0	2.13				28.4		4.86	12.7
Gwr4	06/02/2018		< 20	10600	270	4	< 2	< 0.02	363	23.2	331	209	9.9	2.5	10.7	82		<0.02	4.59	21	< 0.1	1.06	< 0.85	0.7	1.09	0.7	85.3	< 1	< 1	19.85			
Gwr4	06/03/2018		< 20	6450	180	2.3	< 2	< 0.005	678	20.4	317	141	6.5	1.4	10.8			0.03		< 50	< 0.2	< 0.9	7.5	20	1	10	30						
Gwr4	10/04/2018		< 20	19500	490	3.7	< 2	0.07	670	30.5	341	585	56.1	2.3	9.6			0.88		< 50	4	14.3	25.6	49.6	1	19.6	147						
Gwr4	01/05/2018		< 20	8370	190	0.35	< 2	< 0.005	659	23.7	327	166	7.8	1.7	11.2			0.20		< 50	1.4	5.4	< 2	18.6	1	8.8	55.9						
SA1	26/01/2017		< 20	10200	318	2.8	< 2	0.02	1584	24	249	34	10.3	2.3	14.0	68	2	< 0.025	0.012	< 50	2.3	10	24.8	49.3	< 0.01	32.6	86.5	41	3	14.2			
SA1	18/04/2017	7.0	< 20		110	3.3	< 2	< 0.005	766	20	409	139	7.1	2.0	11.6	63	6	0.055				< 0.9			< 0	7.62				20.8	2.79	26.9	13.4
SA1	06/02/2018		< 20	16600	280	4.1	< 2	< 0.02	795	25.0	377	346	15.1	2.7	12.1	64		<0.02	2.71	17	< 0.1	< 1	< 0.85	< 0.2	< 0.01	10.6	49.7	310	< 1	11.14			
SA1	06/03/2018		< 20	7760	180	2.4	< 2	< 0.005	743	21.0	340	161	7.4	1.9	11.9			<0.01		< 50	< 0.2	< 0.9	8.8	10	1	10	30						
SA1	10/04/2018		< 20	11100	170	4	< 2	0.02	759	19.9	381	158	7.8	2.2	10.7			0.06		< 50	0.7	3.7	25.5	10.2	1	13	42.7						
SA1	01/05/2018		< 20	12300	270	0.4	< 2	< 0.005	811	23.1	427	269	8.4	2.5	12.6			<0.01		< 50	1.6	7.4	19.1	23.3	1	21.6	80.5						

Appendix 2

Monitoring Well & Leachate Data

Monitoring Well Jet-Vacuum and Downhole Camera Survey Results

Leachate Discharge Volumes Data 2016 to 2018

Table A2.1. Jet-Vac Well Remediation and Downhole Camera Survey Data

Current Name	Type	BH Log	Datum (D)	Datum (magl)	Recorded Original Depth from Log or Driller (mbD)	Total Depth Dip Prior to Jet-Vac (mbD)	Total Depth Dip After to Jet-Vac (mbD)	Infill Removed (m)	Predicted Infill (m)	Difference between recorded original depth and post Jet-Vac depth (m)	Comment on Jet Vac &/or Camera Survey Results	Camera Survey Screen Top (mbD)	Camera Survey Screen Bottom (mbD)
MP3	Borehole	Yes	Top of 2" HDPE.	0.24	10.2	8.66	9.68	1.02	1.6	0.6			
GW14	Borehole	Yes	Top of 6" SC (well cover).	0.10	20.8	19.59	20.14	0.55	1.2	0.7	0.2 m of new infill 24 hrs after Jet-Vac. Pipe widely unscrewed at 6.4 mbD.		
GW13	Borehole	Data from Driller	Top of 2" HDPE.	0.65	18.2	16.96	17.11	0.15	1.2	1.0		14.3	17.1
GW3	Borehole	Yes	Top of yellow 2" pipe.	0.32	17.6	17.28	17.3	0.02	0.3	0.3	Vertical slots	11.5	17.3
GW4	Borehole	Yes	Top of yellow 2" pipe.	0.04	6.3	4.92	5.96	1.04	1.4	0.4	0.05 m of new infill 24 hrs after Jet-Vac		
GW5	Borehole	Yes	Top of yellow 2" pipe.	0.33	14.5	13.63	13.75	0.12	0.9	0.8	Pipe diameter to small for camera survey		
GWR4	Borehole	Yes	Temp Datum = top of 2" HDPE	0.53	10.5	7.94	9.1	1.16	2.6	1.4	0.42 m of new infill 24 hrs after Jet-Vac		
SA1	Borehole	Yes	Top of yellow 2" pipe at highest point.	0.05	7.4	5.48	6.58	1.1	2.0	0.9	0.32 m of new infill 24 hrs after Jet-Vac		
GW18	Borehole	Yes	Top of 2" HDPE.	0.06	11.9	10.78	10.78	0	1.1	1.1			
MP19	Borehole	Yes	Top of 2" Liner.	0.19	10.1	9.41	9.42	0.01	0.7	0.7			
GWR3	Borehole	Yes	Top of 2" HDPE.	-0.02	21.0	17.56	18	0.44	3.4	3.0	0.07 m of new infill 72 hrs after Jet-Vac. Pipe joint at 5.9mbD broken inwards partially blocking pipe and preventing further camera survey.	6.0	-
GW20	Borehole	Data from Driller	Top of 2" HDPE.	0.81	12.4	11.29	11.32	0.03	1.1	1.1		8.8	11.3
MP4	Borehole	Yes	Top of 2" HDPE.	0.23	10.2	9.14	9.98	0.84	1.1	0.2			
BR2	Borehole	Yes	Temp Datum = top of 2"	0.59	15.6	7.25	13.37	6.12	8.3	2.2	0.86 m length of standpipe found in scrub adjacent to well head likely to have been original top of pipe prior to slope re-grading during Phase 4 construction	5.9	13.1
GW10	Borehole	Yes	Top of 2" HDPE.	0.64	13.7	13	13.48	0.48	0.7	0.3	Pipe diameter to small for camera survey		
GW9	Borehole	Yes	Top of 2" HDPE.	0.38	12.8	-	-	-	-	-	Pipe joint at 1.0 mbD very unscrewed.	4	12.7

Table A2.2 Monthly Leachate Volumes for LS03 and LS06

	LS06	LS06	LS06	LS03	LS03	LS03
	2016 (m3/month)	2017 (m3/month)	2018 (m3/month)	2016 (m3/month)	2017 (m3/month)	2018 (m3/month)
Jan	*no data*	1314	66	*no data*	735	1195
Feb	*no data*	1491	305	*no data*	268	585
Mar	882	1716	1	1762	145	246
Apr	310	359	16	1088	116	383
May	0	698	231	197	212	357
Jun	230	791	*no data*	195	214	*no data*
Jul	175	391	*no data*	196	256	*no data*
Aug	262	960	*no data*	0	991	*no data*
Sep	288	1055	*no data*	488	480	*no data*
Oct	96	1212	*no data*	259	752	*no data*
Nov	533	1800	*no data*	223	514	*no data*
Dec	721	280	*no data*	300	348	*no data*
Total March to May	1192	2774	248	3046	474	986
Total January to December	3497	12066	618	4707	5033	2766
Haulage cost @ €10/m3	34966	120660	6185	47071	50326	27658
Treatment Cost @ €7/m3	24476	84462	4329	32950	35228	19360
Total Cost (€)	59442	205122	10514	80021	85554	47018
Potential 70% Saving (€)	41609	143585	7360	56015	59887	32913

	2016	2017	2018
Total Volume (m3)	8204	17099	3384
Total Cost (€)	€ 139,463	€ 290,676	€ 57,532
Potential 70% Saving (€)	€ 97,624	€ 203,473	€ 40,272