REPORT

Sandsfield Gravel Company Ltd

Milegate Eastern Extension Landfill

Hydrogeological Risk Assessment

Submitted to:

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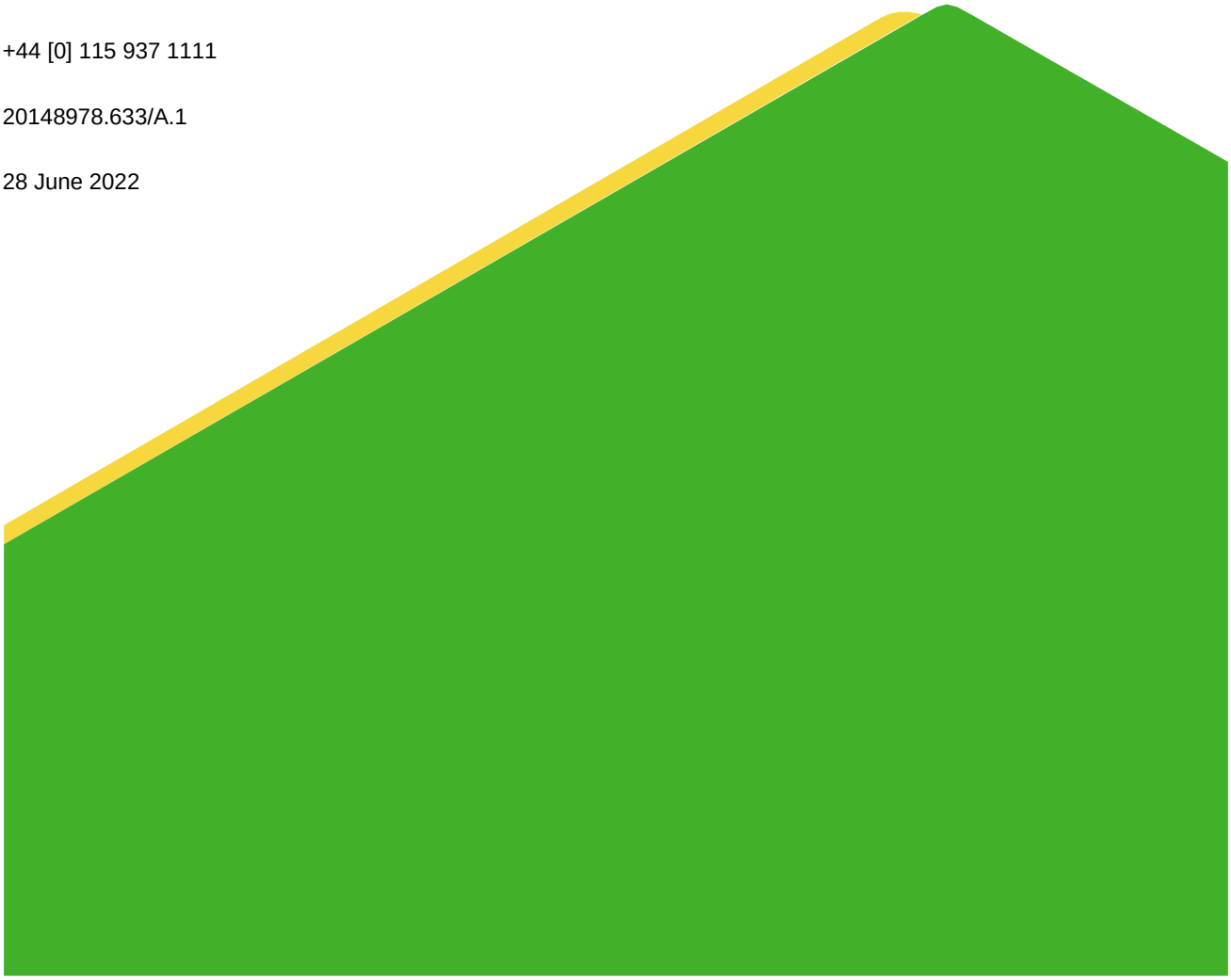

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1.0 INTRODUCTION

1.1 Report Context

Milegate Extension Landfill ('the Site') is located at Catwick Lane, Brandesburton, East Riding of Yorkshire, YO25 8SB and is operated by Sandsfield Gravel Company Ltd ('Sandsfield)'.

The existing Site is an active sand and gravel quarry and landfill for the disposal of non-hazardous waste. Landfilling takes place in accordance with Environmental Permit BX1942IX issued by the Environment Agency (EA) in 2006, and last varied and consolidated by the EA in February 2020 (EPR/BX1942IX/V003).

Sandsfield proposes to extend the existing Site into the neighbouring field to the east (the 'Eastern Extension') which is currently in agricultural use. Golder has been requested by Sandsfield to make a planning application with environmental impact assessment and an Environmental Permit variation application, to allow continued and uninterrupted mineral extraction and landfilling operations to extend into the Eastern Extension.

This document forms a hydrogeological risk assessment (HRA) to support the Eastern Extension planning and permit applications. The HRA aims to assess the potential impacts of extending the existing landfilled area as part of the proposed extension works. The report is prepared in accordance with the requirements of Schedules 10 and 22 of the Environmental Permitting Regulations, 2016.

This report draws upon information provided in previous HRAs for the existing Site. The HRA reference 03523539.502/A.0 was prepared by Golder in support of the application for this PPC Permit (Golder, 2004). Three responses to requests for further data from the Environment Agency (EA) were submitted in August 2005 (Golder 2005a), December 2005 (Golder, 2005b) and February 2006 (Golder, 2006a). These responses provided updated information, and a revised HRA was submitted as part of the December 2005 response. In accordance with condition 3.1.5 of the existing Permit further HRA reviews have been prepared in 2009 (Golder, 2009), 2015 (Golder, 2015) and most recently August 2021 (Golder, 2021). Further details regarding the site design and conceptual model development are presented in the *Environmental Setting and Installation Design Report* within the EP variation application.

The assistance of Sandsfield in the provision of data for this risk assessment review is gratefully acknowledged. Golder has not independently verified any of the information supplied.

1.1.1 Outline of Current Installation

The Site is located approximately 1 km southeast of Brandesburton village and 13 km northeast of the centre of Beverley, at National Grid Reference TA 1310 4750 (Drawing ESID1). The Site currently covers an area of approximately 12.5 ha and is bounded to the north and east by open fields, to the south by Milldam Beck and to the west by the closed Milegate Landfill.

Sand and gravel extraction has generally taken place in an east to west direction across the existing Site, and is almost complete in the Milegate Extension Landfill, aside from small areas around the base and sides of Cell 2 which will be removed as cell preparation takes place.

Landfilling at the Site has taken place continuously since waste acceptance commenced in 2007. Filling began in Cell 1 and proceeded in a westerly direction through Cells 3, 5 and 7. Cell 8 was constructed to the north of Cell 7 in 2016, and subsequently landfilling has continued in an easterly direction into Cells 6, 4A and 4B with Cells 2A and 2B to follow. Cells 1, 3, 5, 7 and 8 are filled and restored. Cell 6 has been recently filled and awaits restoration; Cells 4A ad 4B are currently operational.

In 2017, when most sand and gravel had been extracted, Cells 1, 3, 5 and 7 had been filled and Cell 8 had been recently constructed, Sandsfield also sought to amend the line of the northern boundary to include a purchased narrow strip of land, for both extraction and filling (the 'Northern Extension'). Planning permission was granted in June 2018, extending the period of landfilling to February 2038 and the Environmental Permit was varied in February 2020 to include the 'Northern Extension'.

1.1.2 Proposed Development

Sandsfield is proposing to extend mineral extraction and subsequent landfilling into the proposed 'Eastern Extension' to expand their future capacity. Development of the Eastern Extension is estimated to provide an additional landfill void space of 0.73 Mm^3 (post-settlement) or 0.82 Mm^3 (pre-settlement). Waste infilling of the proposed 'Eastern Extension' is expected to fall within the current permitted period of landfilling, therefore it is not proposed to extend this beyond the cessation year of 2038.

The direction of quarry working will be eastwards through the existing quarry sidewall in the area of Cells 2A and 2B and then Sandsfield will 'chase the mineral' clockwise around the north end of the site and then southwards once a working face has been established across the full, west to east, width of the site.

The Eastern Extension will comprise a further six landfill cells (Cells 9 to 14), as shown on **Drawing HRA1**. Non-hazardous waste will be deposited in areas of engineered containment at the Site. The waste types accepted at the existing Site for both disposal and restoration purposes are presented in Schedule 2 (Tables S2.1 and S2.2) of the current EP and are proposed to remain unchanged for the Eastern Extension development.

Mineral would be extracted at a typical rate of 100,000 tonnes/annum currently proposed to start in 2023 and finish in 2030 (seven years).

The total landfill void space for the existing site is estimated as 1,247,280 m^3. At the end of 2020 (the last annual site survey, dated 11 January 2021), the site had received 896,014 m^3 waste with therefore 351,266 m^3 remaining. At an input rate of 90,000 m^3/year, the existing site will be filled by end 2024. Landfilling is proposed to start in Cell 9 in 2025 and finish in 2034 (nine years), followed by capping and restoration.

1.2 Objectives

The main objective of this HRA is to support planning and permit applications for extension of the landfill to the east ('the Eastern Extension').

1.3 Report Structure

This report presents an update to the HRA for Milegate Extension Landfill, as follows:

- Section 2 summarises the conceptual hydrogeological site model for the Site;
- Section 3 summarises the modelling developed for the Site;
- Section 4 summarises the review of technical precautions in place for the Site; and
- Section 5 summarises the requisite surveillance in place for the Site.

2.0 CONCEPTUAL HYDROGEOLOGICAL SITE MODEL

2.1 Definitions

In the definition that has become accepted by the environmental and waste industries, there are three components to any risk assessment:

- The source is the potentially contaminative components of the leachate that will be generated by the percolation of infiltrating precipitation through the decomposing waste;
- The pathways are any routes linking the source with the receptors including the unsaturated zone and the saturated zone in which degradation processes may occur; and
- The receptors are groundwater and surface water bodies that are connected to the source by the pathways, such as surface watercourses, local supply boreholes, or springs.

These three components are linked within a hydrogeological conceptual model for a site. Should either one of the source, pathway, or receptor be absent from the site setting, negligible risk will be posed to the groundwater and surface water environment.

The three components of the risk posed from the disposal of waste at the Eastern Extension have been described in detail in the Environmental Setting and Installation Design (ref. 20148978.632) and are summarised in the following sections. Site conceptual model is also presented as **Drawing HRA2**.

2.2 Source

2.2.1 Proposed Design and Construction

The proposed layout for the Eastern Extension is shown on **Drawing HRA1**. Cells 9 and 10 will be progressed to the east of Cell 2B, and then Cells 11 to 14 in a north to south direction.

The mitigation measures incorporated into the landfill development include the nature of the Site's design and the management of any leachate that is produced. Cells within the existing Site have been constructed on a containment basis, and it is proposed that all future landfill cells within the Eastern Extension will also be constructed on a containment basis. Waste disposal will only take place in individual cells thus allowing for the containment and collection of any leachate produced.

The engineering details for the existing Site are summarised in the 2021 HRAR. It is proposed that the cell design principles, including liner, capping, leachate management and groundwater management, will follow those already adopted for the existing site.

It is therefore proposed that each cell in the Eastern Extension is constructed broadly as follows:

- Base and Side Slope Liner - 1 m of clay with a permeability of no greater than 1 x 10^{-9} m/s.
- Leachate Drainage – 300 mm crushed aggregate or 1 m shredded tyres leachate drainage blanket with underlying separation geotextile and overlying filter geotextile.
- Capping – 300 mm blinding layer, GCL, 900 mm subsoil and 100 mm topsoil.

2.2.2 Leachate Management

2.2.3 Leachate Levels

The Eastern Extension is to be hydraulically contained such that the level of leachate in the base of each proposed cell is maintained at a level lower than the surrounding groundwater level.

The Eastern Extension landfill will be operated under the principle of hydraulic containment. This means that leachate levels will need to be maintained at a level below external groundwater levels (in the surrounding Lower Sand and underlying Chalk) to achieve hydraulic containment. As the Eastern Extension is not yet developed, no leachate level data is currently available; however, monitoring wells are installed around the adjacent existing Site into the Lower Sand and Chalk to determine the groundwater levels in both formations. The future permitted leachate level will be specified with respect to the lowest seasonal groundwater levels in the Lower Sand and the Chalk. The lowest groundwater levels represent the period when the lowest degree of hydraulic containment will be present. Provided leachate levels are maintained below the groundwater level, no advective pathway exists for the migration of leachate from the Site. Each cell will have infrastructure installed to manage leachate at the required level.

2.2.4 Leachate Quality and Priority Contaminants

2.2.4.1 Leachate Quality

The Eastern Extension will be classified as a non-hazardous landfill. It is expected that it will receive the same range of wastes as the existing Site and the source term is therefore based on leachate concentrations from the existing Site. **Table HRA1** summarises the leachate quality taken from boreholes across the existing site from the last HRA review period, for priority contaminants defined in the HRAR (Golder 2021).

Table HRA1: Summary of leachate concentrations August 2015 to April 2021 (mg/l)

Determinand	Minimum	Median	Maximum	Count
Chloride	22	1620	3700	64
Ammoniacal Nitrogen	20	1095	2400	64
Nickel	0.011	0.137	0.5	64
Lead	0.00022	0.010	0.5	57
Benzene	<0.001	0.002	0.0078	32
Fluoranthene	0.00004	0.000285	0.00066	22
Mecoprop	<0.00002	<0.00002	0.0993	25

It is anticipated that the source term in the Eastern Extension will be broadly in line with the existing Site. Monitoring of leachate with a full suite of analysis including hazardous substances will allow the definition of a specific source term for the Eastern Extension in the future.

2.2.4.2 Priority Contaminants

Both hazardous substances and non-hazardous pollutants are anticipated to be present within the leachate to be produced in the Eastern Extension.

In accordance with the recently updated list for the existing Site (Golder, 2021), the priority contaminants to be assessed for the Eastern Extension are:

- Chloride: mobile inorganic anion, non-hazardous pollutant;
- Ammoniacal nitrogen: mobile inorganic cation, non-hazardous pollutant;
- Nickel: highly mobile metallic cation, non-hazardous pollutant;
- Lead: less mobile metallic ion, hazardous substance;
- Benzene: soluble, organic chemical, hazardous substance;

- Fluoranthene: less soluble, hydrophobic organic chemical, hazardous substance; and
- Mecoprop: acid herbicide, formerly a hazardous substance.

2.3 Pathways

2.3.1 Geology

2.3.1.1 Regional Geology

The regional geology has been obtained from the following published sources:

- 1:50,000 scale British Geological Survey geological map Sheet 72 for Beverley; and
- 1:50,000 scale British Geological Survey geological map Sheet 73 for Hornsea.

The published geological maps (**Figure HRA1**) indicate that much of the existing site and proposed Eastern Extension is underlain by drift deposits comprising undifferentiated glaciofluvial sands and gravels (shown in pink). In the northwest and northeast corners of the Eastern Extension and beyond the boundary to the north, the maps indicate that the sands and gravels are absent, and the area is underlain by Till (shown in blue). Chalk is present below the whole area at depth.

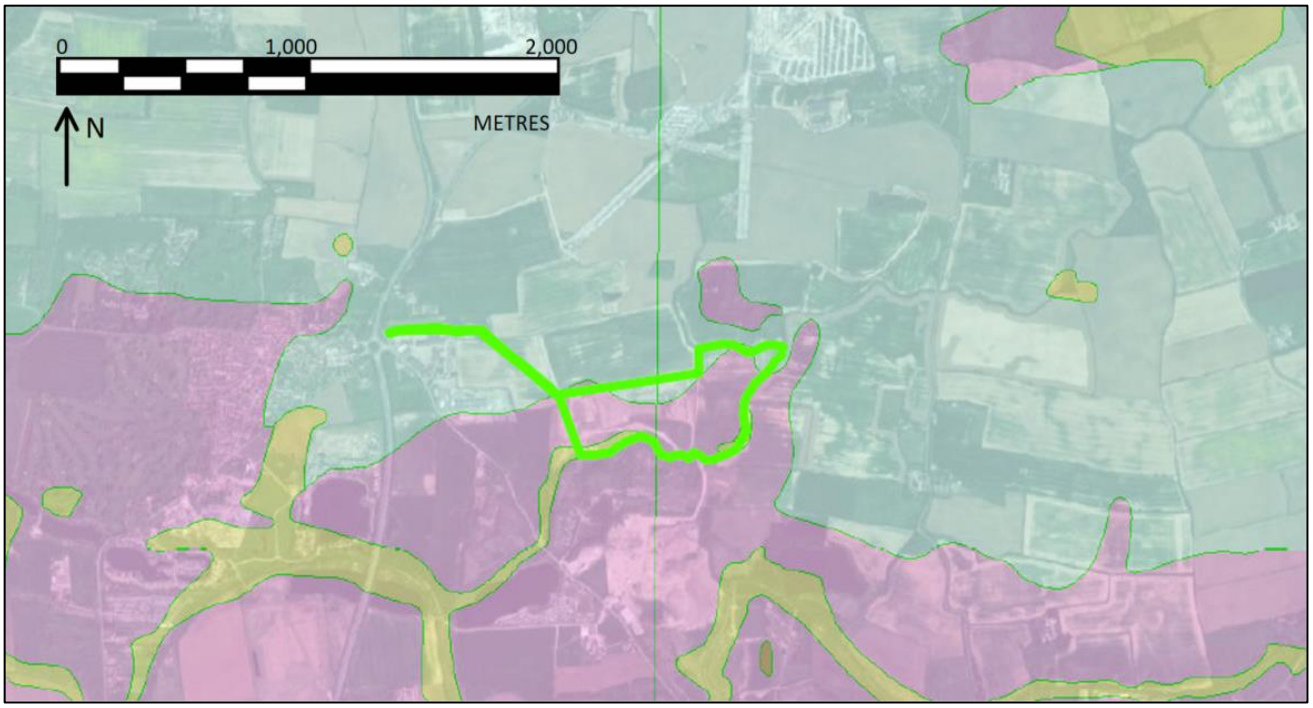


Figure HRA1: Extract from Geological Map (ESID9A) showing the existing landfill extended by the Eastern Extension.

The majority of the Site is underlain by glaciofluvial sand and gravel (the Lower Sand) which is designated as a Secondary B aquifer (MAGIC, 2021) with overlying soils of low leaching potential. The northern edge of the Site is underlain by Till, classified as a Secondary (undifferentiated) aquifer. In the footprint of the existing landfill, the sand and gravel deposits have been removed completely as part of the quarrying works that have taken place and it is proposed that they would also be removed in the Eastern Extension. The landfill therefore lies directly on the Secondary (undifferentiated) Till, which normally underlies the Lower Sand. Chalk, classified as a Principal aquifer, is present at depth beneath the Till.

2.3.1.2 Local Geology

Site investigation and monitoring boreholes, geological exposures within the existing quarry, and operational experience, indicate that the geology beneath the Site corresponds well with that indicated on the geological maps. Typically, the sand and gravel appears to be present in two layers, with a layer of clay between.

The local geology is described, as follows:

- **Till** (overburden);
- **Upper Sand and Gravel** (USG) - clayey or silty sand with some traces of fine gravel;
- **Middle Clay** - orange-brown and dark brown silty clay;
- **Lower Sand and Gravel** (LSG) - fine to coarse sand with fine to medium gravel;
- **Till** - Soft to stiff grey or grey brown silty sandy clay mixed with assorted gravel; and
- **Chalk**.

Deposits comprising undifferentiated glaciofluvial sands and gravels are exposed in the eastern side of the quarry, in which the Upper Sand & Gravel, Middle Clay and Lower Sand & Gravel can be readily distinguished. The published geological maps indicate that these extend below much of the proposed Eastern Extension. The published geological maps also indicate that the sand and gravel does not extend north of the existing site, and this, too, is confirmed by operational experience.

Four boreholes (BH01 to BH04) were drilled within the footprint of the proposed Eastern Extension, and a further two outside the eastern boundary across the Milldam Beck (BH05 and BH06), to prove the thickness of the geological units beneath.

Table HRA2: Geological Information from Boreholes adjacent to Eastern Extension and the existing site.

(m OD)	BH02	GWS03	GWC06	BHG06	BHG05	GWS02	BH04	BHG04	BHG03	GWC01	GWS01
Ground level	13.03	12.05	11.97	13.9	10.9	9.11	8.64	10.06	8.88	7.59	7.55
USG Top	10.03	Abs	Abs	10.1	7.9	8.31	8.24	9.46	8.88	6.09	7.55
USG Bottom	6.13	Abs	Abs	6.9	5.1	5.31	4.34	5.36	8.28	4.79	4.75
LSG Top	NR	-3.05	-3.63	NR	0.9	NR	-0.56	3.06	1.38	0.09	0.05
LSG Bottom	NR	-4.05	-4.56	NR	-1.1	NR	-2.86	0.66	-1.62	-4.21	-3.35
Chalk Top	NR	NR	-16.53	NR	NR	NR	NR	NR	NR	-16.11	NR
Bh Base	3.03	-5.05	-23.63	-1.1	-4.6	2.11	-11.36	-4.94	-2.12	-22.41	-4.05

**NR = Not Reached, Abs = Absent*

Table HRA2 confirms Sandsfield's experience of operating in this area in that the glaciofluvial deposits are undulatory and even discontinuous. Where present, extractable thickness ranges from typically 1.0 to 7.5 m.

The geological sequence penetrated by these boreholes is consistent with the conceptual model of the existing landfill.

2.3.2 Groundwater Levels and Hydraulic Containment

2.3.2.1 Groundwater Levels and Flow

The permit requires all boreholes on the MEPP to be monitored on a quarterly basis, although groundwater elevations are routinely monitored on a monthly basis at the Site.

Groundwater elevations for boreholes GWC01 and GWC06 which monitor the Chalk, and GWS01 to GWS03 which monitor the Lower Sand during the period August 2015 to April 2021 are presented as hydrographs in Appendix HRA3 of the 2021 HRA Review submitted for the variation application and summarised in **Table HRA4**. All of the presented boreholes are located along the eastern edge of the existing landfill and along the western boundary of the proposed Eastern Extension.

Borehole GWC06 was installed in November 2020 and borehole GWS02 is often dry. Fewer observations of the groundwater level are therefore available from these boreholes.

Table HRA3: Summary of Relevant Groundwater Elevations August 2015 to April 2021 (m AOD)

Borehole	Minimum (m AOD)	Median (m AOD)	Maximum (m AOD)	Range (m)	5th Percentile (m AOD)	Count
Boreholes installed in the Chalk						
GWC01	2.03	2.43	2.68	0.65	2.04	38
GWC06	3.27	3.27	3.27	0	3.27	1
Boreholes installed in the Lower Sand						
GWS01	0.01	1.98	3.10	3.08	0.085	38
GWS02	4.62	4.74	5.83	1.2	4.63	12
GWS03	-1.94	-1.60	-1.22	0.72	-1.7	38

Note: Data excludes occasions when the borehole was reported as dry. The count is number of occasions water is in the borehole.

The hydrographs presented in Appendix HRA3 of the 2021 HRA Review indicate no clear trend in groundwater elevation over the last six years and the water elevations remain similar to previous interpretations.

The original HRA concluded that the groundwater flow in the Lower Sand was towards the excavation. This is expected to remain the case until the voids are filled and the groundwater level returns to pre-excavation levels.

The original HRA stated that the groundwater flow in the Chalk appeared to be generally southwest although the regional groundwater flow in the Chalk shown on a hydrogeological map for the area was towards the east and southeast. Groundwater contours for the Chalk presented on Drawing HRA2 of the 2021 HRA Review are consistent with the original HRA, indicating a south westerly direction of flow.

Groundwater level trends observed beneath the existing landfill are expected to continue into the Eastern Extension as the geology remains consistent.

2.3.2.2 Hydraulic Containment Assessment

Under normal operating conditions the existing landfill is operated under the principle of hydraulic containment and this principle will be extended to the Eastern Extension. The previous HRAs state that where leachate elevations are at least 0.4 m lower than external groundwater elevations, the site is considered to pose a negligible risk to groundwater quality.

Plots of leachate elevation against groundwater elevations in boreholes adjacent to the relevant cells are provided in Appendix HRA4 of the 2021 HRA Review. These indicate that hydraulic containment has been maintained between August 2015 and April 2021. Leachate elevations in the Eastern Extension will also be kept below the surrounding groundwater elevations. The efficiency of this methodology at the existing landfill provides confidence that it will perform equally well in the Eastern Extension.

2.4 Receptors

The following potential receptors to leachate at Milegate Extension Landfill were identified in the 2021 HRA review and are considered valid for the proposed Eastern Extension:

- Groundwater in the Lower Sand when leachate is elevated above the interface between the Till and the Lower Sand but lower than the elevation of groundwater in the Lower Sand; and
- Groundwater in the Lower Sand and Chalk should leachate heads become elevated above external groundwater elevations.

The Milldam Beck, the Moor Main Drain, and surface water ponds to the south of the Site are not considered to be receptors of contamination from the existing landfill since no groundwater pathway exists between the Site and these surface water features. This assumption remains valid for the Eastern Extension.

The permit requires groundwater quality to be monitored on a quarterly or annual basis according to the schedules listed in Tables S3.4 and S3.7. A summary of groundwater concentrations for priority contaminants in the Chalk for the period August 2015 to April 2021 is presented in **Table HRA4** and for the Lower Sand in **Table HRA5**. Time-series plots for chloride, ammoniacal nitrogen and nickel in samples of groundwater collected from boreholes adjacent to the Eastern Extension are presented in Appendix HRA5 of the 2021 HRA Review.

Fewer results are available from Borehole GWC06 because it was installed in November 2020 and has not had sufficient amount of water available for representative sample collection and borehole GWS02 that often has insufficient water to purge and sample.

Table HRA4: Groundwater Quality in the Chalk (mg/l), Priority Contaminants, August 2015 to April 2021

Borehole	Minimum	Median	Maximum	Count	Permit Compliance Limit
Chloride					
GWC01	19	94	132	26	250
GWC02	25	145	170	26	250
GWC05	17	66	140	25	250
Ammoniacal Nitrogen					
GWC01	<0.01	0.065	2.1	26	5.4
GWC02	<0.01	0.015	2.3	25	5.4
GWC05	<0.01	0.02	2.4	25	5.4

Borehole	Minimum	Median	Maximum	Count	Permit Compliance Limit
Nickel					
GWC01	<0.0001	0.001	0.011	26	0.02
GWC02	0.0002	0.001	0.0061	25	0.02
GWC05	0.002	0.006	0.011	25	0.02
Lead					
GWC01	<0.00009	0.00021	0.036	13	No limit (0.00063[a])
GWC02	<0.00009	0.0005	0.003	12	No limit (0.00076[a])
GWC05	<0.00009	0.000325	0.012	12	No limit (0.00044[a])
Benzene					
GWC01	<0.0002	<0.001	<0.001	26	0.001
GWC02	<0.00002	<0.001	<0.001	26	0.001
GWC05	<0.0002	<0.001	<0.001	25	0.001
Fluoranthene					
GWC01	<0.00001	0.000035	0.00006	4	No limit (0.0006[a])
GWC02	<0.00001	0.00001	0.00001	4	No limit (0.0006[a])
GWC05	<0.00001	0.00001	0.00001	4	No limit (0.0006[a])
Mecoprop					
GWC01	<0.00002	<0.00002	<0.00002	4	No limit (0.018[a])
GWC02	<0.00002	<0.00002	<0.00002	4	No limit (0.018[a])
GWC05	<0.00002	0.00002	0.00002	4	No limit (0.018[a])

Note a) Value proposed in Golder (2021).

Table HRA5: Groundwater Quality in the Lower Sand (mg/l) August 2015 to April 2021

Borehole	Minimum	Median	Maximum	Count	Permit Compliance Limit
Chloride					
GWS01	33	**435**	**720**	26	415
GWS03	21	44	110	25	250
Ammoniacal Nitrogen					
GWS01	0.2	2.2	5.1	26	6.9
GWS03	<0.01	0.03	**12**	25	5.4
Nickel					
GWS01	0.0018	0.008	**0.082**	26	0.02
GWS03	<0.0005	0.004	**0.055**	25	0.02

Borehole	Minimum	Median	Maximum	Count	Permit Compliance Limit
Lead					
GWS01	<0.00009	0.00015	0.035	13	No limit (0.00036[a])
GWS03	<0.00009	0.00011	0.122	13	No limit (0.0002[a])
Benzene					
GWS01	<0.0002	<0.001	<0.001	26	0.001
GWS03	<0.0002	<0.001	<0.001	25	0.001
Fluoranthene					
GWS01	<0.00001	0.00001	0.00005	4	No limit (0.0006[a])
GWS03	<0.00001	0.00001	0.00001	4	No limit (0.0006[a])
Mecoprop					
GWS01	<0.00002	0.000055	0.00013	4	No limit (0.018[a])
GWS03	<0.00002	0.00002	0.00003	4	No limit (0.018[a])

Bold *values indicate exceedance of the compliance limit.*
Note a) Value proposed in Golder (2021).

Similar groundwater chemistry is expected to be encountered in the deposits underlying the Eastern Extension as the aquifers are continuous west to east. The collected data shows that the compliance limits have not been exceeded within the Chalk and only occasionally in the shallow aquifer.

The groundwater quality in the Chalk has remained satisfactory throughout the duration of the landfilling operations and this situation is expected to continue in the future provided hydraulic containment is maintained as planned.

2.5 Compliance Points

Current EA guidance[1] states that '*for predictive modelling of hazardous substances, your compliance point will normally be set immediately downgradient of the discharge, at a point just below the water table adjacent to the edge of the discharge area and within the expected vertical mixing depth. Practically, compliance with control levels and compliance limits for hazardous substances are assessed at monitoring points which are normally one or more boreholes directly adjacent to the landfill. This reflects the practical problems in collecting samples from beneath a landfill.*

For non-hazardous pollutants the compliance point will also normally be the monitoring boreholes adjacent to the landfill. Where groundwater has no current or potential future resource value, boreholes for monitoring non-hazardous pollutants further from the site may be appropriate.'

[1] https://www.gov.uk/guidance/landfill-developments-groundwater-risk-assessment-for-leachate#compliance-points.

In light of this guidance compliance points for assessing the risk posed by contamination originating at the Eastern Extension are as follows:

- For hazardous substances, the compliance points are just below the water table immediately post dilution in the Lower Sand adjacent to the Site, or in Chalk beneath the Site; and
- For non-hazardous pollutants, the compliance point is the down-gradient boundary of the Site within groundwater within the Lower Sand and Chalk following dilution.

2.6 Environmental Assessment Levels

Receptor sensitivity can be gauged by the specification of Environmental Assessment Levels (EALs). EALs may be used to benchmark the results of predictive modelling. The modelling approach taken for this Site is not borehole/ location specific. EALs, therefore, differ from compliance limits, which are borehole/ location specific and, therefore reflect potential spatial variation in groundwater concentrations from off-Site sources.

An input of a hazardous substance is considered to have been prevented if the substance concerned is not discernible in the groundwater above natural background conditions or a relevant minimum reporting value (MRV) after the immediate dilution as the leachate enters the groundwater. Therefore, to be protective of groundwater as a potential resource, EALs for hazardous substances have been set at the EA's MRV[2]. If no MRV has been developed a Limit of Quantification (LoQ) has been used, which is either defined by the UK Technical Advisory Group (UK TAG) on the Water Framework Directive[3], or in a commercial laboratory is defined as being three times a commercially available limit of reporting. Review of the reliably available limit of detection for fluoranthene from commercial laboratories since the 2021 HRA review provided in Appendix C of the Supporting Statement (ref. 20148979.631) finds it is equal to 0.00002 mg/l, which yields a LOQ of 0.00006 mg/l. It is therefore proposed that the fluoranthene EAL is adjusted to 0.00006 mg/l.

For non-hazardous pollutants, the EALs have been set at the UK Drinking Water Standard (DWS) or Environmental Quality Standard (EQS).

The EALS for the Eastern Extension are the same as those the existing landfill and are presented in **Table HRA6**.

Table HRA6: Environmental Assessment Levels (EALs)

Determinand	EAL (mg/l)	Justification
Chloride	250	UK DWS
Ammoniacal Nitrogen	0.39	UK DWS
Nickel	0.02	UK DWS
Lead	0.0002	UK TAG LOQ
Benzene	0.001	MRV
Fluoranthene	0.00006	Laboratory LOQ
Mecoprop	0.018	Annual average freshwater EQS

[2] https://www.gov.uk/government/publications/values-for-groundwater-risk-assessments/hazardous-substances-to-groundwater-minimum-reporting-values

[3] Technical report on Groundwater Hazardous Substances, working paper 11b(iii) v12, dated September 2016 - available at https://www.wfduk.org/sites/default/files/Media/UKTAG_Technical%20report_GW_Haz-Subs_ForWebfinal.pdf

2.7 Summary of Conceptual Model

A summary review of the hydrogeological conceptual model has identified only minor and expected differences between the existing landfill, last reviewed in 2021, and the Eastern Extension.

The planned extension is to be constructed eastwards of the existing landfill and divided into six cells numbered from 9 to 14. All cells are planned to be designed and constructed similar to previous cells at the existing landfill albeit with different geometry.

The same type of waste is expected to be deposited at the proposed Eastern Extension as at the existing landfill and the leachate quality is therefore expected to be the same as that in the existing landfill. As such, the list of priority contaminants is identical to that formulated for the existing landfill.

Boreholes drilled with the Eastern Extension prove geology consistent with that on the eastern periphery of the existing landfill. Pathways for contaminant migration from the Eastern Extension are therefore the same as from the existing landfill. There are no long-term changes in groundwater levels across the Site, and as such the Eastern Extension will, like the existing landfill, be managed using the principle of hydraulic containment.

The receptors for leachate from the Eastern Extension are the same as those from the existing landfill. They are groundwater in the glacial deposits and chalk.

Groundwater compliance points and EALs are the same as for the existing landfill and reflect EA guidance.

3.0 HYDROGEOLOGICAL RISK ASSESSMENT

3.1 Justification for Modelling Approach and Software

Golder adopted a complex risk assessment methodology for the existing landfill (Golder, 2021) and proposes to extend it to the Eastern Extension. This approach recognises the leachate concentrations within the site, the aquifer status outside the sidewall lining systems, and the location of the site beneath the water table.

A quantitative risk assessment of the Eastern Extension has been carried out using probabilistic simulation with a Golder developed Monte Carlo spreadsheet within excel and LandSim Version 2.5. The probabilistic approach allows uncertainties to be addressed by assigning a probability distribution to the parameter range based on site-specific data. The models and software are considered to be applicable to the scenarios (see below) and the hydrogeological conditions.

Three scenarios have been considered for the Eastern Extension as part of this application:

- The normal operating condition of the Eastern Extension will be hydraulic containment, whereby leachate within the Eastern Extension will be maintained at an elevation that is lower than the surrounding groundwater elevation. An inward hydraulic gradient will exist under these conditions, which will not support the advective flow of leachate out of the site. This situation assumes leachate elevations below the base of the Lower Sand.
- In the normal operating condition diffusion could occur through the sidewall if leachate levels are above the base of the Lower Sand but are maintained at an elevation below the piezometric elevation of groundwater in the Chalk and the water level in the Lower Sand. An inward hydraulic gradient will exist that will not support the advective flow of leachate out of the site. Nevertheless, diffusive movement of contaminants through the sidewall could occur under this situation. This situation is modelled using a probabilistic spreadsheet model (Crystal Ball).

- Leakage through the sidewall and landfill base ('Failure Scenario') - leachate levels exceeding the groundwater level in the Lower Sand and the piezometric elevation of groundwater in the Chalk, leading to a loss of hydraulic containment in the long-term. In this circumstance, advective migration from the Eastern Extension laterally into the Lower Sand and downwards into the Chalk could occur resulting in a potential effect on groundwater quality. Sidewall leakage is modelled using a probabilistic spreadsheet model (Crystal Ball); basal leakage to the Chalk is modelled using LandSim v2.5.

The same scenarios have been considered by the original HRA for the existing landfill and in subsequent HRA reviews. The most recent review of the HRA is in Appendix C of the Supporting Statement (ref. 20148979.631) submitted for the variation application.

3.2 Model Parametrisation

It is only the geometry of the Eastern Extension that means the parameterisation of the existing models is not appropriate. The model parameter values for the geometry of the proposed Eastern Extension are presented in **Table HRA7**.

Table HRA7: Geometry Model Inputs

Cell	Base Area (m^2)	Surface Area (m^2)
Cell 9	5291	9499
Cell 10	5749	8535
Cell 11	2838	13528
Cell 12	2934	5418
Cell 13	2713	5598
Cell 14	2978	11194
Total Landfill Area	**44273**	**11463**
Length of Site Perimeter (m) (Sidewall)	720	

The priority contaminants for the existing landfill were last updated in the 2021 HRA review (Golder, 2021) and are applicable to the Eastern Extension. The leachate concentrations and probability density functions (PDFs) were also updated as a part of the 2021 HRA review and are considered appropriate to the Eastern Extension. The priority contaminants, their concentrations, and PDFs are presented in Table HRA8.

Table HRA8: Eastern Extension Leachate Quality PDFs

Determinand	Units	PDF	Minimum	Most Likely	Maximum
Chloride*	mg/l	Log Triangular	171	1914	3700
Ammoniacal Nitrogen	mg/l	Log Triangular	20	978	2,400
Nickel	mg/l	Log Triangular	0.011	0.15	0.5
Lead	mg/l	Log Triangular	0.00022	0.0105	0.5
Benzene	mg/l	Uniform	0.001		0.017
Fluoranthene	mg/l	Log Triangular	0.00004	0.00057	0.00076
Mecoprop	mg/l	Log Uniform	0.00002		0.0993

** The sample taken in January 2021 had an unusually low concentration of 22 mg/l – concentrations of other major ions are also unusually low, and the ionic balance is outside the expected range. For conservatism, this value has been removed from the dataset.*

3.3 Emissions to Groundwater

3.3.1 Diffusion through the Sidewall (Normal Operating Conditions)

The rate of diffusion of contaminants through the sidewall into the Lower Sand has been compared with the rate of advection into the landfill in the circumstance of leachate levels being higher than the base of the Lower Sand.

The comparison assumes the distance across the sidewall liner between leachate and groundwater is 1 m and the elevation of groundwater is 1 m higher than the elevation of leachate. A printout of the spreadsheet model is in Appendix HRA1, and an electronic copy is in Appendix HRA4.

The predicted advective travel time into the landfill and the predicted diffusive time out of the landfill are shown in **Table HRA9**.

Table HRA9: Comparison of Advective Inward Travel Time with the time for Diffusion out through the Sidewall Liner

	Advective Inward Travel Time (year)	Diffusive Outward Travel Time (year)
5th percentile	16.78	158.55
50th percentile	30.35	158.55
95th percentile	66.20	158.55

The diffusive travel time for a (non-retarded) contaminant out through the sidewall liner is greater than the inward rate of migration by advection. There is therefore confidence that under normal operating conditions contaminants cannot migrate to the Lower Sand even if the leachate elevation is not lower than the elevation of the top of the Till.

3.3.2 Sidewall Leakage (Failure Scenario)

A printout of the spreadsheet model for sidewall leakage is presented in Appendix HRA2, and an electronic copy contained in Appendix HRA4. The predicted travel times through the sidewall liner for the priority determinands under these conditions are presented in **Table HRA10**.

Chloride is unretarded but the travel time for all other species includes for retardation. These values have only changed from those presented in the existing site HRA due to the probabilistic nature of the model, since the change to leachate concentrations and geometry will not affect these results.

Table HRA10: Predicted Travel Times through the Sidewall Liner

Determinant	Predicted Travel Time (years)		
	5th percentile	50th percentile	95th percentile
Chloride	682	1231	2763
Ammoniacal Nitrogen	2662	$1.16x10^{4}$	$3.25x10^{4}$
Nickel	$2.65x10^{5}$	$4.44x10^{5}$	$9.70x10^{5}$
Lead	$3.34x10^{5}$	$2.80x10^{6}$	$4.35x10^{7}$
Benzene	1989	3677	8297
Fluoranthene	$5.95x10^{5}$	$1.01x10^{6}$	$2.20x10^{6}$
Mecoprop	$1.77x10^{3}$	$2.99x10^{3}$	$6.56x10^{3}$

At the 5th percentile, it can be seen that lead, fluoranthene, and nickel are predicted to take in excess of 10,000 years to migrate through the sidewall and therefore it is considered these species do not pose a significant risk to groundwater in the Lower Sand adjacent to the Eastern Extension.

The predicted impact from the remaining determinands, i.e. ammoniacal nitrogen, benzene, chloride, and mecoprop on groundwater in the Lower Sand surrounding the Eastern Extension is summarised in **Table HRA11**. The results are after dilution in the aquifer, and biodegradation for benzene and mecoprop.

Table HRA11: Predicted Impact from Sidewall Leakage on Groundwater Quality

Determinand	Predicted Impact (mg/l)			EAL
	5th percentile	50th percentile	95th percentile	
Chloride	152	716	2175	250
Ammoniacal Nitrogen	28	253	1,179	0.39
Benzene	0^	0^	0^	0.001
Mecoprop	0^	0^	0^	0.018

^ *Biodegradation in the liner is calculated to reduce the concentrations to effectively zero*

At the 95th percentile, indefinite failure of the leachate management systems at the Eastern Extension is predicted to result in concentrations of ammoniacal nitrogen and chloride in excess of the respective EALs. The unretarded travel time for chloride through the sidewall liner is greater than 682 years at the 95th percent confidence level, and this is considered a sufficient length of time to implement remedial measures at the Site and to effectively enable leachate heads to be reduced to compliance levels before an impact on the surrounding groundwater occurs.

3.3.3 Basal Leakage (Failure Scenario)

The results of the updated LandSim v2.5 simulation, which are presented in Appendix HRA4, indicate the predicted impact on groundwater within the Chalk as shown in **Table HRA12**.

Table HRA12: Predicted Impact from Basal Leakage on Groundwater Quality.

Contaminant	Unit	Predicted Impact (95th Percentile)	EAL
Chloride	mg/l	91.1	150
Ammoniacal Nitrogen	mg/l	17.6	0.39
Nickel	mg/l	0.0	0.02
Lead	mg/l	0.0	0.0002
Benzene	mg/l	$7.1x10^{-6}$	0.001
Fluoranthene	mg/l	0.0	0.0006
Mecoprop	mg/l	0.0013	0.018

At the 95th percentile, indefinite failure of the leachate management systems at the Eastern Extension is predicted to result in concentrations of ammoniacal nitrogen in excess of the established EAL. The predicted time of the peak concentration of ammoniacal nitrogen is approximately 3982 years, and this is considered a sufficient length of time to implement remedial measures at the Site and to effectively enable leachate heads to be reduced to compliance levels before an impact on the chalk groundwater occurs.

3.4 Sensitivity Analysis

The purpose of a sensitivity analysis is to quantify the variation in the model output caused by uncertainty in the input parameters. The impact assessment has been undertaken using a probabilistic spreadsheet model and LandSim. These allow the uncertainty in the input parameters to be addressed directly by inputting a range of values for each parameter. The models select the input values randomly from the probability density functions applied for each iteration and a stochastic output is produced that enables the probability of each result to be assessed.

4.0 REVIEW OF TECHNICAL PRECAUTIONS

A series of essential and technical precautions were identified as part of the original HRA. These are detailed below and are considered to remain applicable for the Eastern Extension.

4.1 Capping

All non-operational cells in the Eastern Extension will be temporarily or permanently capped when appropriate. Subsequently, all cells will undergo restoration.

4.2 Lining Design

All cells are designed to operate under the principle of hydraulic containment. Cells will be lined with a minimum of 1 m clay with a permeability no greater than 1 x 10^{-9} m/s.

The risk assessment demonstrates that the basal lining design provides sufficient environmental protection for compliance with the Groundwater Directive and Landfill Directive as implemented by the Environmental Permitting Regulations.

4.3 Leachate Management

Leachate will be managed in accordance with the Leachate Management Plan [ref. 20148978.638] and Environmental Permit in order to maintain hydraulic containment as for the existing landfill.

4.4 Groundwater Management

Groundwater is currently being removed from the worked out sand and gravel void in the northeast corner of the Site. To facilitate working of sand and gravel in the Eastern Extension, groundwater removal will be required. Groundwater should continue to be managed in accordance with the Groundwater Management Plan [ref. 20148978.639]. In the future once landfilling is complete and pumping ceased, rebound of the surrounding groundwater will occur increasing the degree of hydraulic containment at the Site.

4.5 Surface Water Management

Surface water management practices at the Site continue generally as outlined in the first request for further information [Golder, 2005a] with minor variations as agreed with the Agency. The surface water management plan has been updated [ref. 20148978.640].

5.0 REQUISITE SURVEILLANCE

The purpose of this section is to present monitoring infrastructure for the planned Eastern Extension.

Drawing HRA1 shows the location of current groundwater and surface water monitoring points and leachate extraction and monitoring points for the Eastern Extension.

The requisite surveillance has been reviewed with reference to EA landfill monitoring guidance[4].

5.1 Leachate Monitoring

Leachate monitoring is essential to develop an understanding of the quality of leachate present at the site and how it evolves with time. It is important that leachate levels are monitored regularly across the Eastern Extension to ensure the site remains in compliance in respect of leachate levels. In the event that leachate levels approach or exceed compliance limits then emergency measures can be implemented e.g. increased active leachate abstraction, in order to bring the Eastern Extension back into compliance.

Each new cell will have two leachate monitoring points to allow monitoring of leachate levels remote to the leachate abstraction point. Leachate levels in 'LMP' series monitoring points are determined in addition to those in 'LCP' series points. Leachate monitoring infrastructure is described as a part of the Environmental Setting and Installation Details (ESID) report (ref. 20148978.632) and presented in Drawing ESID7A.

Leachate levels are currently required to be monitored on a monthly basis for operational cells, and quarterly for capped cells, at the existing site in accordance with Table S3.1 of the Permit. This is considered also appropriate for the Eastern Extension.

The leachate level compliance limit will be set to 1 m above base of cell unless otherwise agreed as a part of pre-operational conditions[5]. These should be regularly reviewed and amended to reflect ongoing groundwater monitoring.

Leachate quality monitoring is required at the existing site on a quarterly basis in accordance with Table S3.9 of the Permit. An annual hazardous substance screen is required for operational cells, and once every four years for non-operational cells. This practice should be continued for the Eastern Extension.

5.2 Groundwater Monitoring

It is essential to monitor groundwater adjacent to the Eastern Extension for groundwater elevation and quality. This is because an increase in contaminant concentrations beyond compliance limit concentrations may indicate that leachate is migrating from the landfill in a fashion that is not consistent with the predicted landfill behaviour. In such an instance, remedial steps can be taken rapidly and effectively to minimise any further detrimental effects on the groundwater environment.

New groundwater monitoring wells will be drilled around the Eastern Extension into both the shallow and deep aquifers. Following the methods applied at the existing site, the shallow and deep aquifer monitoring points will be located in pairs. They will be evenly spaced along the eastern edge of the proposed extension. The proposed monitoring points are presented in the revised MEPP (Drawing HRA1).

Groundwater levels are currently required to be monitored at the existing site quarterly in accordance with Table S3.7 of the Permit, and this is also considered appropriate for the Eastern Extension, since it will operate under hydraulic containment principles.

[4] https://www.gov.uk/guidance/landfill-operators-environmental-permits/monitor-and-report-your-performance

[5] It is requested that the varied Permit includes pre-operational conditions for Cells 9 to 14 similar to pre-operational conditions 2 and 3 for Cells 4A/B and Cell2A/b, respectively.

Similarly, groundwater quality monitoring should be conducted in accordance with Tables S3.4 and S3.7 of the Permit.

5.2.1 Groundwater Compliance Limits

Schedule 10 of the Environmental Permitting Regulations requires that groundwater compliance limits are set for potentially polluting substances.

Due to variable water quality observed in the Lower Sand at the existing site as presented in Appendix 5 of the 2021 HRA Review provided in Appendix C of the Supporting Statement (ref. 20148979.631), it is suggested that monitoring of this aquifer around the Eastern Extension will be carried out prior to setting appropriate compliance levels. It is requested that a pre-operational condition requires Lower Sand groundwater monitoring for at least one year prior to onset of the landfilling.

The recently installed borehole GWC06 monitoring the chalk is upgradient of the existing landfill but will become downgradient of part of the Eastern Extension. Compliance limits have therefore been established for GWC06.

Groundwater compliance limits for borehole GWS05 installed in late 2020 were intended to be set following collection of a minimum of 12 months of data. To date no groundwater quality data has been collected for GWS05 due to low water yield of the borehole resulting in insufficient water volume to collect representative samples for analysis. Compliance limits will be set following collection and analysis of 12 samples from GWS05.

Table S3.4 of the Environmental Permit lists groundwater compliance limits. This table needs varying to account for the findings of the 2021 HRA review provided in Appendix C of the Supporting Statement (ref. 20148979.631) as well as the Eastern Extension. **Table HRA13** presents Table S3.4 as it is proposed it appears in the varied Permit.

Table HRA13: Proposed Table S3.4 of the Varied Permit

Table S3.4 Groundwater – emission limits and monitoring requirements					
Monitoring point reference	**Parameter**	**Limit (incl. unit)**	**Reference Period**	**Monitoring frequency**	**Monitoring standard or method**
Chalk Wells GWC01, GWC02, GWC03, GWC05 and GWC06 and Eastern Extension Chalk Wells as shown on the MEPP	Chloride	250 mg/l	Spot Sample	Quarterly	As specified in Environment Agency Guidance TGN02 'Monitoring of Landfill Leachate, Groundwater and Surface Water' (February 2003), risk assessments for your environmental permit (www.gov.uk) or such other subsequent guidance as may be agreed in writing with the Environment Agency
	Ammoniacal Nitrogen	5.4 mg/l			
	Nickel	20 µg/l			
	Benzene	1 µg/l			
	Fluoranthene	0.06 µg/l			
	Mecoprop	18 µg/l			
GWC01	Lead	0.63 µg/l			
GWC02		0.76 µg/l			
GWC03		0.2 µg/l			

GWC05		0.44 µg/l			
GWC06 and Eastern Extension Chalk Wells as shown on the MEPP		To be set following collection of 12 months of data			
Sand and Gravel Wells GWS02, GWS03, GWS04, GWS07, GWS08, GWS09, GWS10, MB3 and MB04/03	Chloride	250 mg/l	Spot Sample	Quarterly	As specified in Environment Agency Guidance TGN02 'Monitoring of Landfill Leachate, Groundwater and Surface Water' (February 2003), risk assessments for your environmental permit (www.gov.uk) or such other subsequent guidance as may be agreed in writing with the Environment Agency
GWS01		415 mg/l			
GWS03, GWS10	Ammoniacal Nitrogen	5.4 mg/l			
GWS04, MB04/3		5.5 mg/l			
GWS01		6.9 mg/l			
GWS02		4.6 mg/l			
GWS07		10.75 mg/l			
GWS08		1.8 mg/l			
GWS09		2.0 mg/l			
MB3		4.3 mg/l			
GWS01, GWS02, GWS03, GWS04, GWS08, GWS09, GWS10 and MB04/03	Nickel	20 µg/l			
GWS07		50 µg/l			
MB3		37 µg/l			
GWS01, GWS02, GWS03, GWS04, GWS07, GWS08, GWS09, GWS10, MB3 and MB04/03	Mecoprop	18 µg/l			

GWS02, GWS03, GWS07, GWS10, MB3 and MB04/3	Lead	0.25 µg/l			
GWS01		0.36 µg/l			
GWS04		0.4 µg/l			
GWS08		3.75 µg/l			
GWS09		0.43 µg/l			
GWS01, GWS02, GWS03, GWS04, GWS07, GWS08, GWS09, GWS10, MB3 and MB04/03	Benzene	1 µg/l			
GWS01, GWS02, GWS03, GWS04, GWS07, GWS08, GWS09, GWS10, MB3 and MB04/03	Fluoranthene	0.06 µg/l			
GWS05 and EE S&G Wells as shown on the MEPP	To be set following collection of 12 months of data				
GWS06	To be set following collection and analysis of 12 samples				

5.3 Surface Water Monitoring

The existing surface water quality monitoring points remain appropriate although the current upgradient monitoring point will become downgradient of the Eastern Extension. Two new monitoring points will be established upgradient: one on Milldam Beck (SW5) and another on Moor Main Drain (SW4). The surface water monitoring points locations are presented in Drawing HRA1.

All else remains the same as at the existing landfill; the water will be monitored on a monthly basis for the list of determinands given in Tables S3.3 and S3.10 of the Permit. **Table HRA14** presents the proposed surface water compliance limits for monitoring points in the form of Table S3.3 of the Environmental Permit.

Table HRA14: Updated Compliance Limits for Table S3.3 of the Permit

Table S3.3 Point source emissions to water (other than sewer) – emission limits and monitoring requirements						
Emission point Ref. & Location	**Parameter**	**Source**	**Limit (incl. unit)**	**Reference Period**	**Monitoring Frequency**	**Monitoring Standard or Method**
SW2 – Milldam Beck	BOD	Surface water	20 mg/l*	Spot sample	Monthly	As specified in Environment Agency Guidance TGN02 ‘Monitoring of Landfill Leachate,
	pH		<9 >6			
	Chloride		250 mg/l			
	Ammoniacal Nitrogen		1.0 mg/l*			

	Suspended solids		50 mg/l*			Groundwater and Surface Water' (February 2003), risk assessments for your environmental permit (www.gov.uk) or such other subsequent guidance as may be agreed in writing withthe Environment Agency
SW3 – Surface Water Settlement Pond	BOD		20 mg/l			
	pH		<9 >6			
	Chloride		250 mg/l			
	Ammoniacal Nitrogen		5.4 mg/l			
	Suspended solids		125 mg/l			
SW1 – Milldam Beck As identified on the MEPP	BOD		20 mg/l*			
	pH		<9 >6			
	Chloride		250 mg/l			
	Ammoniacal Nitrogen		1.0 mg/l*			
	Suspended solids		50 mg/l*			

** Emission limits for BOD, Ammoniacal Nitrogen and Suspended Solids are applicable only where concentrations at SW1 and SW2 exceed those concentrations within SW4 and SW5 - as identified on the MEPP.*

6.0 CONCLUSIONS

In accordance with Schedule 22 of the Environmental Permitting Regulations, necessary measures will be taken to prevent the input of hazardous substances to groundwater. Discharges of hazardous substances will not be discernible in groundwater immediately downgradient of the landfill. Both hazardous substances and non-hazardous pollutants are present within the leachate produced at the existing site and are expected to also be present in leachate that will be generated in the Eastern Extension. There is potential for this leachate to migrate through the liner system, and it therefore poses a hazard to groundwater and surface water quality. Consequently, arrangements must be made to continue to collect the contaminated water and leachate that is generated by the site.

The proposed technical precautions including the liner system, capping, and management of leachate and groundwater, will prevent unacceptable discernible discharge of hazardous substances and non-hazardous pollutants to groundwater throughout the site's lifecycle and are therefore considered compliant with Schedule 22 of the Environmental Permitting Regulations.

The provision of suitable requisite surveillance of groundwater is a requirement of Schedule 22 of the Environmental Permitting Regulations. The requisite surveillance for the site has been reviewed and amended to accommodate the Eastern Extension in accordance with EA guidance.

7.0 REFERENCES

1) MAGIC, 2021. www.magic.defra.gov.uk accessed on 11 May 2021.

2) Golder Associates (UK) Ltd, 2004. Section B – Hydrogeological Risk Assessment Milegate Extension Landfill Site, Report Number 03523539.502/A.0, November 2004.

3) Golder Associates (UK) Ltd, 2005a. Response to request for further information (July 2005) Milegate Extension Landfill Site, Report Number 03523539.500/B.0, August 2005.

4) Golder Associates (UK) Ltd, 2005b. Response to request for further information (October 2005) Milegate Extension Landfill Site, Report Number 03523539.500/B.0, December 2005.

5) Golder Associates (UK) Ltd, 2006a. Milegate Extension Landfill (Application Reference BX1942IX), letter issued to Mr Gavin Waite, Reference 03523539.250, February 2006.

6) Golder Associates (UK) Ltd, 2006b. Groundwater Management and Monitoring Plan, Milegate Extension Landfill, Report Number 06529180.503/A.0 dated December 2006.

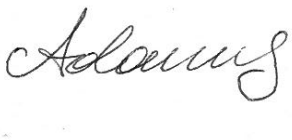
7) Golder Associates (UK) Ltd, 2009. Hydrogeological Risk Assessment Review – Milegate Extension Landfill Site, Report Number 07514290324.508/A.0, September 2009.

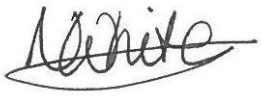
8) Golder Associates (UK) Limited, 2015. Milegate Extension Landfill Site. Hydrogeological Risk Assessment Six-Yearly Review. 07514290324.508/A.0. September 2015.

9) Golder Associates (UK) Limited, 2021. Sandsfield Gravel Company Ltd. Hydrogeological Risk Assessment Review – Milegate Extension Landfill. 07514290324.508/A.0. August 2021.

Signature Page

Golder WSP





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Date: 28 June 2022

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DRAWINGS

Drawing HRA1 – Monitoring and Extraction Point Plan

Drawing HRA2 – Conceptual Site Model

LEACHATE DISCHARGE PIPELINE
LEACHATE HOLDING TANKS
LANDFILL GAS COMPOUND (PROPOSED)
LANDFILL GAS FLARE (EXISTING)

512 800 E
513 000 E
513 200 E
513 400 E
513 600 E
447 600 N
447 400 N
447 200 N

SW4
SW5
Moor Main Drain
BHG39
BHG38
BHG40
BHG37
BHG36
BHG35
BHG41
BHG34
FB
BHG33
Drain
BHG32
BHG31
Scrub
BHG30
BHG29
BHG28
BHG27
BHG26
BHG25
BHG24
BHG23
GWS01
SW1
MB04/01
BHG42
GWS03
GWC06
BHG07
GWC02
GWS04
BHG08
BHG09
GWS05
BHG10
BHG11
BHG12
BHG13
GWS06
GWC04
BHG14
BHG15
GWS07
BHG16
BHG17
SW3
MB3
GWS08
GWC03
BHG18
SW2
MB04/03
BHG19
Mildam Beck
GWC05
BHG20
BHG21
GWS09
BHG22
Mildam Beck Drain
BHG01
GWS10
BHG02
GWC01
BHG03
BHG04
BHG05
GWS02
BHG06
LMP11A
LCP11
CELL 11
LMP11B
LCP12
LMP12A
LMP10A
LCP10
LCP9
LMP9A
CELL 12
LMP12B
LMP13A
CELL 13
LMP13B
LCP13
LCP14
LMP14A
CELL 14
LMP14B
LCP2A
LCP2B
LMP2C
LCP4B
LMP2A
LMP4C
CELL 4B
LMP4D
LMP4B
CELL 4A
LMP4A
CELL 2A
CELL 2B
LMP9B
LMP10B
CELL 9
CELL 10
LCP4A
LMP2B
LMP2D
LCP1
LMP1A
CELL 1
LMP1B
LCP3
LMP3A
LMP3B
CELL 3
LMP5A
LCP5
LMP5B
CELL 5
LMP7A
LMP7B
CELL 7
LCP7
LMP8B
LCP8
LMP8A
CELL 8
LMP6B
CELL 6
LMP6A
MB5
LCP6
MB4
LMP1
LCP1
10
5
0
Sandfield
Scrub
Nc

LEGEND

- PERMIT BOUNDARY
- CELL BOUNDARY
- CLAY LINER CONTOUR
- EXISTING SURFACE WATER MONITORING BOREHOLE - DEEP
- EXISTING SURFACE WATER MONITORING BOREHOLE - SHALLOW
- EXISTING GROUNDWATER MONITORING BOREHOLE
- EXISTING SURFACE WATER MONITORING POINT
- PROPOSED SURFACE WATER MONITORING POINT
- PROPOSED SAND AND GRAVEL MONITORING BOREHOLE
- PROPOSED CHALK MONITORING BOREHOLE
- EXISTING PERIMETER GAS MONITORING WELL
- PROPOSED PERIMETER GAS MONITORING WELL
- EXISTING LEACHATE EXTRACTION WELL
- EXISTING LEACHATE MONITORING WELL
- PROPOSED LEACHATE EXTRACTION WELL
- PROPOSED LEACHATE MONITORING WELL

NOTES

1. ALL LEVELS RELATIVE TO NEWLYN ORDNANCE DATUM.
2. GENERALISED LAYOUT OF EXISTING INFRASTRUCTURE SHOWN.

REFERENCE(S)

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0 50 100
1:2,500 METRES

CLIENT
SANDSFIELD GRAVEL COMPANY LTD

PROJECT
EASTERN EXTENSION PERMIT VARIATION APPLICATION

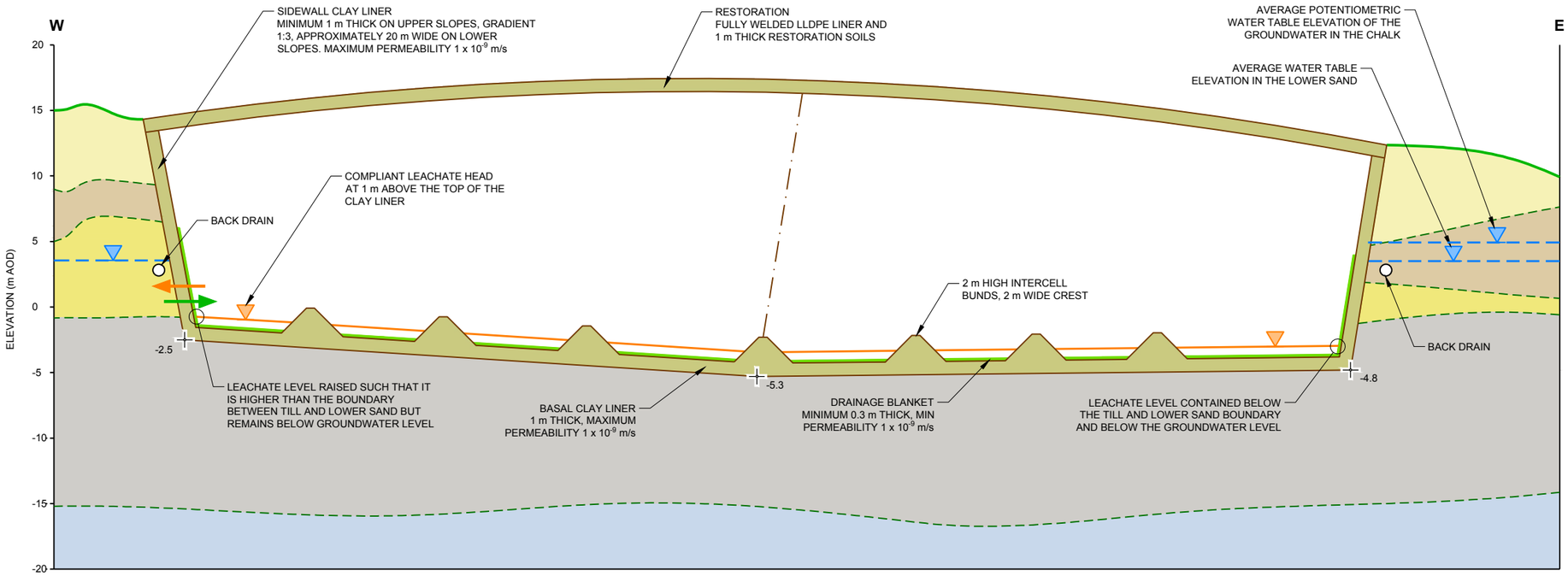
TITLE
MONITORING AND EXTRACTION POINT PLAN

CONSULTANT
WSP GOLDER

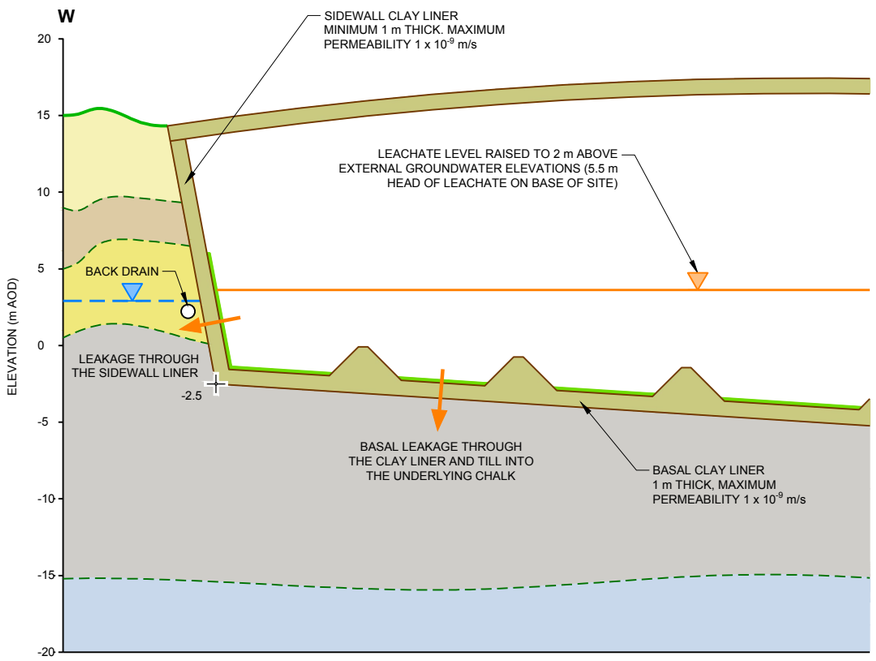
YYYY-MM-DD	2022-06-15
DESIGNED	AA
PREPARED	ECS
REVIEWED	AA
APPROVED	CM

PROJECT NO.	CONTROL	REV.	DRAWING
20148978	1005-HR-0001	B	HRA1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ISO A3
25 mm
0



NORMAL OPERATING CONDITIONS
SCALE 1:400 V, NTS H



FAILURE SCENARIO
SCALE 1:400 V, NTS H

LEGEND

- GROUND LEVEL
- INFERRED BOUNDARY
- UPPER SAND
- CLAY
- LOWER SAND
- TILL
- CHALK
- DIFFUSION OF CONTAMINANTS THROUGH SIDEWALL
- ADVECTIVE MOVEMENT OF GROUNDWATER INTO SITE

CLIENT
SANDSFIELD GRAVEL COMPANY LTD

PROJECT
EASTERN EXTENSION PERMIT VARIATION APPLICATION

TITLE
CONCEPTUAL SITE MODEL

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2021-11-15
DESIGNED	AA
PREPARED	ECS
REVIEWED	AA
APPROVED	CM

PROJECT NO.	CONTROL	REV.	DRAWING
20148978	1005-HR-0002	A	HRA2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

0 25 mm

APPENDIX HRA1

Sidewall Diffusion Model Printout

Diffusion Assessment - Milegate Extension Landfill (Eastern Extension)

Input Parameters and Results

Parameter		Units	Distribution	Min	Likely	Max	Selected	Justification
Travel Time by Advection								
Hydraulic head	H	m	Single		1		1.0E+00	Assumed head difference where leachate is adjacent to the Lower Sand aquifer (see explanation in text)
Thickness of pathway	TCY	m	Uniform		1		1.0E+00	Sidewall liner thickness.
Hydraulic conductivity of clay	KCY	m/s	Log Triangular	1.60E-10	6.30E-10	1.00E-09	6.3E-10	Minimum and average hydraulic conductivity from recompacted samples of the Till obtained at the site (data provided by the applicant). Maximum value set to equal to 1E-9 m/s in accordance with the design requirement
Effective porosity of clay	PCY	Fraction by Vol	Uniform	0.34		0.6	4.7E-01	Typical range for clay as suggested in ConSim Help files
Head gradient across liner	I	-	Single				1.0E+00	Calculated: I = H/TCY
Unretarded velocity across basal liner and Till	UV	m/yr	Single				4.2E-02	Calculated: UV = KCY x I / PCY
Travel time across pathway	ATT	y	Single				2.4E+01	Calculated: ATT = TCY/UV
Travel Time by Diffusion								
Distance through sidewall liner	X	m	Uniform		1		1.0E+00	Sidewall liner thickness.
Free water diffusion coefficient	FW-D	m2/s	Single		2E-09		2.0E-09	Conservative worst case estimate of free water diffusion coefficient
Effective diffusion coefficient	F-D	m2/s	Single		2E-10		2.0E-10	Incorporating tortuosity (Appelo and Postma, 1996)
Diffusion coefficient for chloride	D-cl	m2/s	Single		2E-10		2.0E-10	Free water diffusion coefficient (incorporating tortuosity) / RF
Travel time for chloride	DTT-cl	s	Single				5.0E+09	Calculated from DTT-cl = TCY^2/D-cl
Travel time for chloride	DTT-cl	y	Single				1.6E+02	Calculated: DTT-cl/(365*86400)
Head difference where advective travel time equals diffusive travel time								
Approximate diffusive flow rate	Qd	m/yr	Single				6.3E-03	Calculated from Qd =x/DTT-cl
Minimum hydraulic gradient	Imin	-	Single				1.5E-01	Calculated from Imin = (Qd x PCY)/(KCYx3600x24x365)
Minimum hydraulic head	Hmin	m	Single				1.5E-01	Calculated from Hmin = Imin x TCY

Percentiles	Advective Travel Time (years)	Diffusive Travel Time (years)	Minimum Head Required (m)
5.0%	16.78	158.55	0.11
50.0%	30.35	158.55	0.19
95.0%	66.20	158.55	0.42

APPENDIX HRA2

Sidewall Leakage Model Printout

Milegate Extension Landfill Site (Eastern Extension) - Effect from Sidewall Leakage

Data Sheet

Parameter	Units	Symbol	Distribution	Min	Likely	Max	Selected	Justification
Source Term								
Entire Site								
Lead	mg/l	C-Pb	Log Triangular	2.20E-04	1.05E-02	5.00E-01	1.05E-02	Range observed in results of monitoring from the current site
Ammoniacal Nitrogen	mg/l	C-Amm	Log Triangular	2.00E+01	9.78E+02	2.40E+03	9.78E+02	Range observed in results of monitoring from the current site
Benzene	mg/l	C-Cd	Uniform	1.00E-03		1.70E-02	9.00E-03	Range observed in results of monitoring from the current site
Chloride	mg/l	C-Cl	Log Triangular	1.71E+02	1.91E+03	3.70E+03	1.91E+03	Range observed in results of monitoring from the current site
Fluoranthene	mg/l	C-Fant	Log Triangular	4.00E-05	5.70E-04	7.60E-04	5.70E-04	Range observed in results of monitoring from the current site
Nickel	mg/l	C-Ni	Log Triangular	1.10E-02	1.50E-01	5.00E-01	1.50E-01	Range observed in results of monitoring from the current site
Mecoprop	mg/l	C-Mcp	Log Uniform	2.00E-05		9.93E-02	1.41E-03	Range observed in results of monitoring from the current site
Clay Liner Properties								
Sidewall liner thickness	m	TCY	Single		9.00E+00		9.00E+00	Minimum pathway thickness at the upper side slopes of the site adjacent to a leachate head of 2.0 m above external groundwater elevations (i.e. 8.0 m above the base of the site)
Clay liner permeability	m/s	KCY	Log Triangular	1.60E-10	6.30E-10	1.00E-09	6.3E-10	Minimum and average hydraulic conductivity from recompacted samples of the Till obtained at the site (data provided by the applicant). Maximum value set equal to 1E-9 m/s in accordance with the design requirement
Effective porosity of clay liner all cells	Fraction by Vol	PCY	Uniform	3.40E-01		6.00E-01	4.70E-01	Suggested values from ConSim help files
Dry density	g/cm^3	DCY	Uniform	1.81E+00		2.14E+00	1.98E+00	Minimum and maximum recorded during permeability testing of the clay.
Fraction organic carbon	Fraction	FOC	Log Uniform	6.10E-03		8.00E-03	6.99E-03	Minimum and maximum recorded during testing of the clay.
Minor Aquifer Properties								
Permeability	m/s	K	Log Uniform	1.00E-07		1.00E-05	1.00E-06	Golder judgement for poorly sorted silty sands and gravels
Hydraulic gradient	-	I	Uniform	1.00E-05		1.00E-04	5.50E-05	Conservative low hydraulic gradient used in the absence of site specific data
Width of aquifer perpendicular to direction of flow	m	L	Single		5.00E+02		5.00E+02	Assumed that groundwater under natural conditions flows from the east towards the west down the valley
Thickness of aquifer	m	T	Single		2.00E+00		2.00E+00	Average saturated thickness of Lower Sand aquifer outside sidewall liner
Retardation								
Kd Lead	l/kg	Kd	Log Triangular	2.70E+01	2.70E+02	2.70E+04	2.70E+02	Suggested value from ConSim Help files
Kd Ammoniacal Nitrogen	l/kg	Kd	Uniform	1.00E-01		4.00E+00	2.05E+00	Suggested value from National Groundwater and Contaminated Land Centre Report NC/02/49 for glacial till and engineered clay liners
Koc Benzene	l/kg	Koc	Uniform	3.80E+01		9.70E+01	6.75E+01	Suggested value from ConSim Help files
Kd Chloride	l/kg	Kd	Single		0.00E+00		0.00E+00	Suggested value from ConSim Help files
Koc Fluoranthene	l/kg	Koc	Single		2.78E+04		2.78E+04	From TPH CWG Vol. 3 Selection of Representative TPH Fractions Based on Fate and Transport Considerations
Kd Nickel	l/kg	Kd	Single		8.57E+01		8.57E+01	Suggested value from ConSim Help files
Koc Mecoprop	l/kg	Koc	Single		4.85E+01		4.85E+01	Suggested value from USEPA
Half Lives for Organic Species								
Benzene	years	t½	Uniform	2.70E-01		1.37E+00	8.20E-01	Suggested value from ConSim Help files for anaerobic biotic half life (100 to 500 days)
Fluoranthene	years	t½	Uniform	7.34E-01		1.03E+00	8.84E-01	Suggested value from Review of the Fate and Transport of Selected Contaminants in the Soil Environment (2003)
Mecoprop	years	t½	Uniform	2.70E-02		2.50E-01	1.39E-01	Suggested value from Howard et al, 1991

Milegate Extension Landfill Site (Eastern Extension) - Effect from Sidewall Leakage

Wetted Area Calculation

Cell	Length of Exposed Sidewall (m)	Leachate Head Difference (m)	Wetted Area (m^2)
Entire Site	720.24	2	1440.48

Assumptions

(1) Length of exposed sidewall assumes that the sidewall is vertical

(2) Length of sidewall measured from site design drawings

Milegate Extension Landfill Site (Eastern Extension) - Effect from Sidewall Leakage

Leakage Calculation

Parameter	Units	Symbol	Selected	Justification	
Eastern Extension					
Head difference between leachate and groundwater	mg/l	HD	2	Assumed head difference	
Head gradient across liner	-	I	2.22E-01	Calculated: I = HD/TCY	
Unretarded velocity across liner	UV	m/yr	9.39E-03	Calculated: UV = KCY x I/PCY	
Effective wetted area	A	m2	1440.48	Calculated: Sheet 'Wetted Area'	
Unretarded travel time	UTT	years	9.58E+02	Calculated: UTT = TCY/UV	795.16996
Leakage rate through liner	LR	m3/day	1.74E-02	Calculated: LR = KCY*I*A	0.0075675

Milegate Extension Landfill Site (Eastern Extension) - Effect from Sidewall Leakage

Non-hazardous substances Effect on Aquifer

Parameter	Units	Symbol	Value	Justification	
Aquifer Properties					
Leakage rate	m3/day	LR	1.74E-02	From Sheet 'Sidewall Leakage'	
Area of aquifer	m2	AR	1.00E+03	Calculated: AR = L*T	
Flow in the aquifer	m3/day	QD	4.75E-03	Calculated: QD = K*I*AR*86400	
Dilution of Chloride					
Mass flux of chloride	mg/day	m-Cl	3.33E+04	Calculated: m-Cl = LR*C-Cl*1000	
Concentration after dilution	mg/l	C-Cl-D	1.50E+03	Calculated: C-Cl-D = m-Cl/(QD+LR)*0.001	2468.9268
Dilution of Ammoniacal Nitrogen					
Mass flux of ammoniacal nitrogen	mg/day	m-Amm	1.70E+04	Calculated: m-Amm = LR*C-Amm*1000	
Concentration after dilution	mg/l	C-Amm-D	7.68E+02	Calculated: C-Amm-D = m-Amm/(QD+LR)*0.001	49.535322
Dilution of Nickel					
Mass flux of nickel	mg/day	m-Ni	2.61E+00	Calculated: m-Ni = LR*C-Ni*1000	
Concentration after dilution	mg/l	C-Ni-D	1.18E-01	Calculated: C-Ni-D = m-Ni/QD*0.001	0.015488
Degradation and Dilution of Mecoprop					
Degradation of Mecoprop	mg/l		0.00E+00	Calculated: CCY = C EXP - (0.693 x RTT / T½)	0
Mass flux of Mecoprop	mg/day	m-Mcp	0.00E+00	Calculated: m-Mcp = LR*C-Mcp*1000	
Concentration after dilution	mg/l	C-Mcp-D	0.00E+00	Calculated: C-Mcp-D = m-Mcp/(QD+LR)*0.001	0

Milegate Extension Landfill Site (Eastern Extension) - Effect from Sidewall Leakage

Retarded Travel Time Calculation

Parameter	Units	Symbol	Selected	Justification	
General					
Fraction organic carbon	Fraction	Foc	6.99E-03	From 'data sheet'	
Unretarded travel time	year	UTT	9.58E+02		
Kd Values					
Koc Benzene	l/kg	Koc	6.75E+01	Suggested value from ConSim Help files	
Kd Benzene	l/kg	Kd	4.72E-01	Calculated: Koc*Foc	
Kd Ammoniacal Nitrogen	l/kg	Kd	2.05E+00	Suggested value from National Groundwater and Contaminated Land Centre Report NC/02/49	
Kd Lead	1/kg	Kd	2.70E+02	Suggested value from ConSim Help files	
Kd Chloride	l/kg	Kd	0.00E+00	Suggested value from ConSim Help files	
Koc Fluoranthene	l/kg	Koc	2.78E+04	From TPH CWG Vol. 3 Selection of Representative TPH Fractions Based on Fate and Transport Considerations	
Kd Fluoranthene	l/kg	Kd	1.94E+02	Calculated: Koc*Foc	
Kd Nickel	l/kg	Kd	8.57E+01	Suggested value from ConSim Help files	
Koc Mecoprop	l/kg	Koc	4.85E+01	Suggested value from USEPA	
Kd Mecoprop	l/kg	Kd	3.39E-01	Calculated: Koc*Foc	
Retardation Factors					
Rf Benzene	-	Rf	2.98E+00	Calculated: 1+((DCY*Kd)/PCY)	
Rf Ammoniacal Nitrogen	-	Rf	9.61E+00	Calculated: 1+((DCY*Kd)/PCY)	
Rf Lead	-	Rf	1.14E+03	Calculated: 1+((DCY*Kd)/PCY)	
Rf Chloride	-	Rf	1.00E+00	Calculated: 1+((DCY*Kd)/PCY)	
Rf Fluoranthene	-	Rf	8.17E+02	Calculated: 1+((DCY*Kd)/PCY)	
Rf Nickel	-	Rf	3.61E+02	Calculated: 1+((DCY*Kd)/PCY)	
Rf Mecoprop	-	Rf	2.42E+00	Calculated: 1+((DCY*Kd)/PCY)	
Retarded Travel Time					
Benzene	-	RTT	2.86E+03	Calculated: RTT = UTT*Rf	7143.0432
Ammoniacal Nitrogen	-	RTT	9.21E+03	Calculated: RTT = UTT*Rf	12300.134
Lead	-	RTT	1.09E+06	Calculated: RTT = UTT*Rf	546316.9
Chloride	-	RTT	9.58E+02	Calculated: RTT = UTT*Rf	1205.1381
Fluoranthene	-	RTT	7.83E+05	Calculated: RTT = UTT*Rf	1019223.7
Nickel	-	RTT	3.46E+05	Calculated: RTT = UTT*Rf	323246.65
Mecoprop	-	RTT	2.32E+03	Calculated: RTT = UTT*Rf	4019.2469

Milegate Extension Landfill Site (Eastern Extension) - Effect from Sidewall Leakage

Hazardous substances Effect on Secondary Aquifer

Parameter	Units	Selected	Justification	
Eastern Extension				
Fluoranthene	mg/l	0.00E+00	Calculated: CCY = C EXP - (0.693 x RTT / T½)	0
Benzene	mg/l	0.00E+00	Calculated: CCY = C EXP - (0.693 x RTT / T½)	0
Lead	mg/l	1.05E-02	Calculated: CCY = C EXP - (0.693 x RTT / T½)	0.0151031

Milegate Extension Landfill Site (Eastern Extension) - Effect from Sidewall Leakage

Results

Percentiles	Unretarded Travel Time (years)	Leakage Rate (m^3 per day)
0.0%	448.82	4.43E-03
2.5%	619.66	5.61E-03
5.0%	682.38	6.25E-03
50.0%	1230.79	1.36E-02
95.0%	2762.88	2.25E-02
97.5%	3116.92	2.39E-02
100.0%	4572.85	2.73E-02

	Retarded Travel Times (years)						
Percentiles	Benzene	Ammoniacal Nitrogen	Lead	Chloride	Fluoranthene	Nickel	Mecoprop
0.0%	1198	862	7.63E+04	449	4.32E+05	2.10E+05	1.24E+03
2.5%	1803	2085	2.44E+05	620	5.52E+05	2.48E+05	1.64E+03
5.0%	1989	2662	3.34E+05	682	5.95E+05	2.65E+05	1.77E+03
50.0%	3677	1.16E+04	2.80E+06	1231	1.01E+06	4.44E+05	2.99E+03
95.0%	8297	3.25E+04	4.35E+07	2763	2.20E+06	9.70E+05	6.56E+03
97.5%	9.38E+03	3.80E+04	6.47E+07	3117	2.44E+06	1.08E+06	7.35E+03
100.0%	1.60E+04	6.56E+04	2.54E+08	4573	3.56E+06	1.41E+06	1.06E+04

	Concentration after Degradation (mg/l)			Concentration after Degradation and Dilution (mg/l)	Concentration After Dilution (mg/l)		
Percentiles	Fluoranthene	Benzene	Lead	Mecoprop	Chloride	Ammoniacal Nitrogen	Nickel
0.0%	0.000	0.000	0.000	0.000	14	5	0.002
2.5%	0.000	0.000	0.001	0.000	106	20	0.008
5.0%	0.000	0.000	0.001	0.000	152	28	0.011
50.0%	0.000	0.000	0.010	0.000	716	253	0.062
95.0%	0.000	0.000	0.146	0.000	2175	1179	0.232
97.5%	0.000	0.000	0.207	0.000	2455	1414	0.274
100.0%	0.000	0.000	0.480	0.000	3436	2314	0.441

APPENDIX HRA3

Landsim Model Printout

Project: Milegate Extension Landfill - Eastern Extension

Project Number: 20148978.633

Customer: Sandsfield Gravel Company

Failure Scenario - assuming head difference between leachate and chalk groundwater elevation is 2m. Updated for HRA Review November 2021 to include site-specific leachate data.

Calculation Settings

Number of iterations: 201

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Unretarded values used for simulation

No Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

No Biodegradation

Saturated Vertical Pathway:

No Vertical Pathway

Aquifer Pathway:

Retarded values used for simulation

Biodegradation

Timeslices at: 30, 100, 300, 1000

Decline in Contaminant Concentration in Leachate

Ammoniacal_N	Non-Volatile
c (kg/l): 0.59	m (kg/l): 0
Benzene	Volatile
Half life (years): 10	
Chloride	Non-Volatile
c (kg/l): 0.2919	m (kg/l): 0.0298
Lead	Non-Volatile
c (kg/l): 0.0171	m (kg/l): 0.0443
Mecoprop	Non-Volatile
c (kg/l): 0	m (kg/l): 0
Nickel	Non-Volatile
c (kg/l): -0.1479	m (kg/l): 0.0987
Fluoranthene	Non-Volatile
c (kg/l): 0	m (kg/l): 0

Project: Milegate Extension Landfill - Eastern Extension

Project Number: 20148978.633

Customer: Sandsfield Gravel Company

Failure Scenario - assuming head difference between leachate and chalk groundwater elevation is 2m. Updated for HRA Review November 2021 to include site-specific leachate data.

Contaminant Half-lives (years)

Aquifer Pathway:

Ammoniacal_N	UNIFORM(5,10)
Benzene	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Lead	SINGLE(1e+009)
Mecoprop	SINGLE(1e+009)
Nickel	SINGLE(1e+009)
Fluoranthene	SINGLE(1e+009)

Background Concentrations of Contaminants

Justification for Contaminant Properties

Justifications as per the HRA report (ref. 20148978.633)

All units in milligrams per litre

Phase: Phase 1

Infiltration Information

Cap design infiltration (mm/year):	TRIANGULAR(0.35,1.1,5.04)
Infiltration to waste (mm/year):	SINGLE(50)
End of filling (years from start of waste deposit):	0

Justification for Specified Infiltration

Infiltration has been selected based on Eastern Extension and previous ESID reports findings (Ref. 20148978.632 Section 2.3.1)

Duration of management control (years from the start of waste disposal): 25000

Cell dimensions

Cell width (m):	61.2
Cell length (m):	61.2
Cell top area (ha):	0.898906
Cell base area (ha):	0.374544
Number of cells:	6
Total base area (ha):	2.24726
Total top area (ha):	5.39343
Head of Leachate when surface water breakout occurs (m)	SINGLE(13)
Waste porosity (fraction)	SINGLE(0.4)
Final waste thickness (m):	SINGLE(20.7)
Field capacity (fraction):	SINGLE(0.3)
Waste dry density (kg/l)	SINGLE(0.7)

Justification for Landfill Geometry

Design geometry of the Eastern Extension as outlined in ESID report (Ref. 20148978.632).

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(20,978,2400)
	Data are spot measurements of Leachate Quality
Benzene	UNIFORM(0.001,0.017)
	Data are spot measurements of Leachate Quality
Chloride	LOGTRIANGULAR(171,1914,3700)
	Data are spot measurements of Leachate Quality
Lead	LOGTRIANGULAR(0.00022,0.0105,0.5)
	Data are spot measurements of Leachate Quality
Mecoprop	LOGUNIFORM(2e-005,0.0993)
	Data are spot measurements of Leachate Quality
Nickel	LOGTRIANGULAR(0.011,0.15,0.5)
	Data are spot measurements of Leachate Quality
Fluoranthene	LOGTRIANGULAR(4e-005,0.00057,0.00076)
	Data are spot measurements of Leachate Quality

Justification for Species Concentration in Leachate

Concentrations observed in leachate from existing Site as summarised in HRA report (ref. 20148978.633).

Drainage Information

Fixed Head.

Head on EBS is given as (m): SINGLE(2000)

Justification for Specified Head

In order to achieve a leakage equivalent to that predicted by the spreadsheet model, leakage has been forced to the prescribed infiltration by forcing the calculated leakage to be excessively high. This is achieved by setting the fixed head to 2,000 m.

Barrier Information

There is no barrier

Justification for Engineered Barrier Type

The landfill has been modelled with no engineered barrier system.

pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	UNIFORM(9,13)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.34,0.6)
Pathway Density (kg/l):	UNIFORM(1.81,2.14)

Justification for Unsat Zone Geometry

Justifications as per the HRA report (ref. 20148978.633)

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(1.6e-010,6.3e-010,2.1e-009)

Justification for Unsat Zone Hydraulics Properties

Justifications as per the current HRA report (ref. 20148978.633)

Pathway longitudinal dispersivity (m):	UNIFORM(0.9,1.3)

Justification for Unsat Zone Dispersion Properties

Set as 10% of the pathway length.

Retardation parameters for pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	UNIFORM(0.1,4)
Benzene: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(38,97)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Mecoprop: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(48.51)
Nickel	SINGLE(85.7)
Fluoranthene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(27800)
Fraction of Organic Carbon (fraction)	UNIFORM(0.0061,0.008)

Justification for Kd Values by Species

Justifications as per HRA report (ref. 20148978) and the Sidewall Leakage calculations presented in thereof.

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(450,650)
Pathway width (m):	SINGLE(200)

pathway parameters

No Vertical Pathway

pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	SINGLE(5)

Justification for Aquifer Geometry

Width of aquifer equal to the length of the base of the landfill perpendicular to the direction of groundwater flow.

Pathway regional gradient (-):	UNIFORM(0.0004,0.0006)
Pathway hydraulic conductivity values (m/s):	UNIFORM(0.00011,0.00028)
Pathway porosity (fraction):	UNIFORM(0.01,0.03)

Justification for Aquifer Hydraulics Properties

The hydarulic properties of the aquifer are as described in ESID report (ref. 20148978.632)

Pathway longitudinal dispersivity (m):	SINGLE(10)
Pathway transverse dispersivity (m):	SINGLE(3)

Justification for Aquifer Dispersion Details

Set at 1% and 0.3% of path length for longitudinal and transverse dispersivity, respectively.

Retardation parameters for pathway

Modelled as aquifer pathway.

Uncertainty in Kd (l/kg):

Ammoniacal_N	UNIFORM(0,0.03)
Benzene: Calculated kd	
Partition to Organic Carbon ml/g	UNIFORM(38,97)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,2700)
Mecoprop: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(48.51)
Nickel	SINGLE(0)
Fluoranthene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(27800)
Fraction of Organic Carbon (fraction)	TRIANGULAR(9.6e-005,0.00036,0.00065)

Justification for Aquifer Kd Values by Species

Please refer to the HRA (ref. 20148978.633) and appendices of thereof. foc values from Attenuation of mecoprop in the subsurface (EA report NC/03/12, 2004)

Pathway Density (kg/l):	NORMAL(1.79,0.22)

APPENDIX HRA4

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