AN APPLICATION TO VARY ENVIRONMENTAL PERMIT NO. RP3133PP FOR THE THORNHAUGH LANDFILL SITE OPERATED BY AUGEAN SOUTH LIMITED TO CHANGE THE RESTORATION PROFILE OF THE EXISTING PERMITTED SITE

ADDENDUM TO THE 2024 REVIEW OF THE HYDROGEOLOGICAL RISK ASSESSMENT FOR THORNHAUGH LANDFILL SITE

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1. Introduction

1.1 MJCA is commissioned by Augean South Limited (Augean) to undertake a hydrogeological risk assessment (HRA) for Thornhaugh Landfill Site in support of an application to vary Environmental Permit (EP) EPR/RP3133PP to change the restoration profile for the Thornhaugh Landfill Site (the site). This variation application is made in order to incorporate the changes to the consented restoration profile for the site as a result of the integration of the restoration proposals for the site with the former mineral extraction site at Cooks Hole Quarry immediately to the south of the site. As a result of the changes to the restoration profile, an additional depth of waste will be placed over some of the landfill area compared with that currently consented. The details of the changes to the restoration profile are presented in the Environmental Setting and Installation Design (ESID) report which accompanies this variation application and is provided at Appendix C to the Application Report. There are no changes to the types of wastes received at the site, the general principles of the site containment design, the principles of the site operations including leachate and landfill gas management and site monitoring. There are no changes to the boundary of the site. The variation will not add any additional activities to Table S1.1 of the EP.

1.2 A review of the hydrogeological risk assessment (HRA) for Thornhaugh Landfill Site (reference 1) was submitted to the Environment Agency (EA) in December 2024 in accordance with condition 3.1.5 of the EP (the 2024 HRAR) (reference 2). As such this HRA in support of the application to vary the EP comprises an addendum to the 2024 HRAR presenting the proposed changes to the site only and supporting HRA models. At the time of preparation of this report, the EA have not provided a response to the 2024 HRAR.

1.3 The site is operated by Augean and is permitted for the deposition of non-hazardous commercial and industrial waste, stable non-reactive hazardous waste (SNRHW), asbestos and gypsum together with other high sulphate bearing wastes. The site is centred approximately on National Grid Reference (NGR) TF 04876 00139 approximately 2km west north west of the village of Wansford, near Peterborough. The location of the site is shown on Figure 1 of the 2024 HRAR a copy of which is provided at Appendix HRA A for ease of reference.

1.4 Prior to landfilling the site was quarried for the ironstone of the Northampton Sand Formation by excavating the overlying Lincolnshire Limestone Formation and Grantham Formation. It is understood that the overlying materials removed during quarrying were used to backfill parts of the quarry. At a later date some of the overburden backfill was quarried and the remaining void was developed as a landfill. Landfilling commenced in 1984 with two phases (Phases 1 and 2) developed on the principal of disperse and attenuate and the remaining phases developed as containment landfill cells.

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1.5 Phases 1 and 2 previously comprised a closed landfill area the subject of a separate EP number EPR/FP3790NJ (EAWML 70119). An application for an EP for the development of Phases 3 to 7 on the principal of containment was prepared in 2004. The EP was issued based on documentation and risk assessments submitted with the EP application and in response to queries raised by the EA during the application process. Since the original EP was issued in 2005 a number of variations to the EP have been issued and additional documentation and risk assessments have been submitted with the applications to vary the EP. The supporting documentation and risk assessments for the 2024 HRAR include the most recent HRA (reference 1) and the most recent (at the time) Environmental Setting and Installation Design report (ESID) (reference 3) dated September 2014. All of the conditions of the original EP and subsequent variations to the EP were deleted and replaced by the issue of the EP variation reference EPR/RP3133PP/V006 issued in May 2016.

1.6 The 2014 HRA (reference 1) was prepared to support an application to vary the EP to extend the boundary of the EP landfill area to include an adjacent area of land known as the Bradshaw Land and to incorporate the closed landfill area comprising Phases 1 and 2. The application to vary the EP included limited screening and crushing activities necessary to recover materials from suitable inert waste such as construction, demolition and excavation wastes including such wastes that have been deposited in Phases 1, 2, 4 and 7 previously and which will be removed before the phases are engineered for landfill. The 2014 HRA included the development of a LandSim model for the site based on an HRA review prepared in March 2009 (reference 4) and the original EP application HRA prepared in November 2004 (reference 5).

1.7 During the determination period of the 2014 application to vary the EP various additions and amendments to the HRA were carried out. In response to the Schedule 5 Notice dated 19 March 2015 a revised version of Table HRA 6 presenting the proposals for the monitoring of leachate, groundwater and surface water at Thornhaugh Landfill was provided with an email dated 5 May 2015 (reference 6). Table HRA 6 (REVISED) was updated for consistency with the monitoring requirements specified in the EA Position Statement MWRP RPS 156 Version 1 dated September 2013 (RPS 156). Table HRA 6 (REVISED) is provided at Appendix A to the 2024 HRAR.

1.8 In a response dated 25 August 2015 to a Schedule 5 Notice dated 16 July 2015 the cap design for the site was reassessed in response to proposals for a geosynthetic clay liner (GCL) cap with an underlying drainage layer. Revised cap design infiltration rates were calculated using soil moisture deficit models. Further to the change in cap design infiltration rate the LandSim model was updated to include changes relating to the surface area of the landfill and changes to the source term for Phase 5 together with timescales for end of filling and off set times. An updated LandSim model and revised versions of Tables HRA 1 and HRA 3 with the updated source term and input parameters respectively were provided with the response dated 25 August 2015 (reference 7) together with the model results in a third revision to Table HRA 5. Tables HRA 1 (REVISED), Table HRA 3 (REVISED) and Table HRA 5 (THIRD REVISED) are provided at Appendix A of the 2024 HRAR. Further sensitivity analyses on the models were carried out in response to further requests for information from the Environment Agency in October 2015 and January 2016. For the purpose of this report where reference is made to the 2014 HRA this includes the further information provided during the EP determination period.

1.9 A further application to vary the EP to add five hazardous waste codes for deposit in the SNRHW cell was submitted to the EA in December 2023. No updates to the 2014 ESID or HRA were included with the application. When the EA issued the current EP variation number EPR/RP3133PP/V007 in July 2024, the varied EP included three additional improvement programme requirements into Table S1.3 of the EP in respect of the additional waste codes for deposit in the SNRHW cell. Improvement programme requirement IC8 is related to the HRA and is addressed in the 2024 HRAR. In addition, pursuant to improvement programme requirement IC7 the 2024 HRAR includes proposals for groundwater control and compliance levels for selected determinands together with a contingency action plan for groundwater quality at borehole TH26.

1.10 The 2024 HRAR comprises the third HRA review submitted pursuant to condition 3.1.5 of the EP since the original EP was issued in 2005 including the 2014 HRA and is the first HRA review for the site following the issue of EP variation reference EPR/RP3133PP/V006 in May 2016 with future HRA reviews due every six years. The 2024 HRAR includes a review of leachate and groundwater monitoring data for the period May 2014 to October 2024. The monitoring locations together with the key features of the site are shown on Figure 2 of the 2024 HRAR (Appendix HRA A). The 2024 HRAR includes a review of the CQA validation reports for the construction engineering carried out at the site since the 2014 HRA to confirm that the assumed values for the parameters used in the 2014 HRA are consistent with the phases constructed at the site. The data and information were compared with the assumptions made in the conceptual model presented in the 2014 ESID (reference 3) on which the HRA is based together with the values for the parameters used in the modelling in the HRA. An updated ESID report is included at Appendix C to the application to vary the EP the subject of this report (2025 ESID). It is concluded in the 2024 HRAR that Thornhaugh Landfill Site remains compliant with Schedule 22 to the Environmental Permitting (England and Wales) Regulations 2016. As stated above, a copy of the 2024 HRAR is provided at Appendix HRA A for ease of reference.

2025 HRAR Addendum

1.11 The site design parameters in the HRA models have been updated to reflect the proposed additional depth of waste that will be placed over some of the landfill area compared with that currently consented as a result of the changes to the restoration profile. In addition, the cap design for the site has been reassessed as it is proposed that a 1m clay cap will be used across the uncapped phases of the site. Revised cap design infiltration rates have been calculated using the soil moisture deficit models from the 2014 HRA. The results of the updated soil moisture deficit models are presented in this report and the updated infiltration rates have been used in the 2025 HRAR Addendum HRA models. This report comprises the updated HRA in support of the application to vary the EP to change the restoration profile for the site. The updated HRA presented in this 2025 HRAR Addendum comprises an assessment of the potential impacts of the change in design only.

1.12 For ease of reference for the Environment Agency in determining the application to include the change to the restoration profile and cap design, a sign posting document is included at Appendix HRA B in respect of the guidance/template for HRAs[1]. The document identifies where the information for each section of the guidance/template for HRAs relevant to Thornhaugh Landfill Site can be located in this document or the 2024 HRAR (Appendix HRA A) comprising the review of the 2014 HRA.

1 https://www.gov.uk/guidance/landfill-operators-environmental-permits/what-to-include-in-your-hydrogeological-risk-assessment accessed July 2025

2. Changes to the conceptual site model and the leachate management action plan

Sources

Leachate quality

2.1 The leachate source term for the 2025 HRAR Addendum models is presented in Table HRA 1 and is based on the 2014 HRA source term updated by the 2024 HRAR. An electronic copy of the leachate quality monitoring data was provided with the 2024 HRAR.

2.2 As reported in the 2024 HRAR, while there have been changes to the classification of some substances as hazardous substances or non-hazardous pollutants since the 2014 HRA was carried out for the site, it is assumed that the now non-hazardous pollutants cadmium and naphthalene remain as hazardous substances for the purpose of the HRA. The hazardous substance lead was added to the source term in the 2024 HRAR as part of the assessment of new waste codes permitted in the SNRHW cell carried out to address Improvement programme requirement IC8 in the EP. The source term for lead presented in Table HRA 1 has been updated to remove duplicates identified in the 2024 HRAR dataset. A sensitivity analysis LandSim model was run for the lead source term concentrations in the 2024 HRAR with the mean and maximum concentrations in Phases 1, 2, 4 and 7 set at the mean and maximum concentrations from the Waste Acceptance Criteria (WAC) testing results provided by Augean for the new waste codes which have had exceedances on one or more SNRHW WAC limits. This sensitivity analysis has been repeated in this 2025 HRAR Addendum and the results are presented in Section 4.

2.3 In this 2025 HRAR Addendum the now non-hazardous pollutant methyl tertiary butyl ether (MTBE) has been replaced with the hazardous substances xylene as xylene has been recorded at similar concentrations and within the range of those for MTBE modelled in the 2014 HRA and will behave similarly in the environment. The parameters relevant to the xylene leachate source term and the chemical and attenuation properties in the 2025 HRAR Addendum LandSim models are presented in Tables HRA 2A and HRA 2B.

2.4 The review period for the 2024 HRAR includes data for a 10 year period from 2014 up to 2024. The cadmium concentrations recorded in Phase 5 over the review period are significantly lower than those included in the 2014 HRA and the mean and maximum concentrations over the review period are an order of magnitude lower than cadmium concentrations in the other phases of the site. The cadmium source term in Phase 5 in the 2014 HRA included a statistical outlier. The source term for cadmium in Phase 5 has been updated in this 2025 HRAR Addendum based on the monitoring data for all phases over the 2024 HRAR review period.

2.5 Leachate levels at the site are reviewed in Section 3 of the 2024 HRAR "Review of essential and technical precautions" together with the leachate management action plan. It is considered that in general the leachate levels are managed and maintained below the compliance limits set in Table S3.1 'Leachate level limits and monitoring requirements' of the EP. The methods used to measure leachate levels are consistent with the Leachate Monitoring Action Plan (reference 8) for the site.

Pathways

2.6 The pathway input parameters used in the modelling in this 2025 HRAR Addendum are presented in Table HRA 3 and are based on the 2014 HRA models with the necessary updates to support the EP variation application. Based on the results of the 2024 HRAR, the pathway input parameters from the 2014 HRA remain valid. Amendments to the site design are set out in the 2025 ESID and parameters incorporating the design elements in the 2025 HRAR Addendum LandSim models are set out below. Comments on some of the input parameters reviewed in the 2024 HRAR are include below.

Waste porosity

2.7 The most recent landfill Environmental Permit variation application completed by Augean and approved by the EA comprises an application in 2021 for an extension to the nearby East Northants Resource Management Facility (ENRMF) hazardous waste landfill (EP EPR/TP3430GW). Consistent with the HRA presented in support of the 2021 ENRMF EP variation application (reference 9), the waste porosity input parameter has been updated in the 2025 HRAR Addendum LandSim model.

2.8 The waste porosity input parameter in LandSim is not clearly defined as total porosity and as such effective porosity or drainable porosity of waste values have been used in the 2014 and 2024 HRAR LandSim models for Thornhaugh Landfill. It does not state in the LandSim manual how waste porosity is used in the model calculations. Based on comments from the Environment Agency on other sites where this approach has been taken, the LandSim manual has been reviewed and it is assumed that waste porosity is used along with field capacity to calculate the "Free draining volume of leachate present in the waste mass (Vfd)" parameter presented in equation 4 of the LandSim 2.5 manual update (page XI) calculating leachate levels. It is assumed that the volume, Vfd, is calculated using a drainable porosity parameter calculated from (total) waste porosity minus field capacity which implies that the waste porosity used in LandSim is the total porosity of the waste rather than the effective porosity or drainable porosity assumed in the 2014 LandSim models. On this basis revised waste porosity values have been calculated and comprise the effective porosity or drainable porosity of waste values used as waste porosity in the 2014 and 2024 HRAR LandSim models added to the field capacity values in the models. This approach has been accepted by the Environment Agency for ENRMF and on other sites.

Cap design

2.9 The cap design for the site has been updated and it is now proposed that the cap comprises a 1m thick clay cap with a 0.3m granular layer formed from site derived sand placed over the cap to provide a drainage and protection layer at Phases 1, 2, 4, 5 and 7. Consistent with Table ESID 1 of the 2025 ESID report the 1m clay cap at Phases 1, 2, 4, 5 and 7 will be constructed over a 0.3m thick clay subgrade layer placed over the completed and profiled waste surface and restoration soils will be placed over the cap to a thickness of between 1m and 1.5m. The infiltration model presented in the approved 2014 HRA has been used to derive infiltration rates through the 1m thick clay cap. The model takes into account the soil moisture deficit in the overlying restoration soil, by-pass recharge through the soil and flow through the clay cap. The infiltration model includes the granular drainage layer above the clay cap consistent with the design of the cap. The methodology and model are presented at Appendices HRA C and HRA D respectively. The infiltration rates used in the 2025 HRAR Addendum model are presented in Table HRA 3. Phases 3 and 6 are capped hence there are no proposed changes to the approved infiltration parameters for theses phases in the 2025 HRAR Addendum models.

2.10 Pre-operational measure PO5 in Table S1.4 of the EP relates to capping in Phase 7A and states that:

> *Prior to commencement of capping in Phase 7A the operator shall submit to the Environment Agency detailed written proposals to monitor or verify through other measures which may include experimentation or calculation the cap infiltration in Phase 7A and obtain the Environment Agency's written approval to them.*

The pre-operational measure was included in the EP to reflect changes made in a previous EP Variation to allow a reduced basal liner system thickness formed from 0.5m of low permeability clay, a Geosynthetic Clay Liner (GCL) and a 2mm high density polyethylene (HDPE) geomembrane, rather than a 1m of low permeability clay and a 2mm HDPE geomembrane. This change relied on the site being capped with a GCL and having a long-term low cap infiltration rate reliant on the GCL, and PO5 was added to address EA concerns in respect of the potential for deterioration of a 6mm thick GCL cap over the lifetime of Phase 7A.

2.11 Subsequently the reduced basal liner thickness design was only constructed in Phase 7A and Phase 4B South, with all previous and subsequent phases employing the 1m of low permeability clay and 2mm HDPE geomembrane basal liner design. In addition, the design of the cap has changed to a 1m clay cap using materials that the operator has substantial experience working with and achieving low hydraulic conductivity conditions as detailed in extensive CQA testing providing significant confidence in the performance of the cap. As detailed above, the 1m clay cap will be constructed over a 0.3m thick clay subgrade layer placed over the completed and profiled waste surface and a 0.3m granular layer formed from site derived sand will be placed over the cap to provide a drainage and protection layer. Restoration soils will then be placed over the cap system to a thickness of between 1m and 1.5m. Due to the significant change to the cap design and confidence in the long-term performance of the capping material it is considered that the pre-operational measure is no longer relevant. Notwithstanding the lack of relevance of pre-operational measure PO5, it is wholly impractical to monitor infiltration through a low permeability 1m clay cap due to the very nature of the material; any measurable infiltration through the cap would take a disproportionately long time (decades) and there would be inherent difficulties determining the difference between condensation in or leakage due to monitoring equipment compared with infiltration. As a result it is considered that PO5 has been addressed and discharged and is no longer relevant or appropriate, and it is requested that pre-operational measure PO5 is removed from the varied EP.

Basal liner

2.12 In respect of the pathway through the basal liner, the CQA data for the site provided since the last HRA in 2014 are reviewed in the "Review of essential and technical precautions" section (Section 3) of the 2024 HRAR. While there have been no updates to the basal landfill liner as modelled in the 2014 HRA for Phase 1, Phase 2, Phase 4 and Phase 7 comprising a 0.5m thick clay liner with a single flexible membrane liner, this design has been used to construct Phase 4B South and Phase 7A only. A geosynthetic clay liner (GCL) is included between the 0.5m to 0.6m thick engineered clay liner and the 2mm thick high density polyethylene (HDPE) geomembrane in Phase 4B South and Phase 7A consistent with the approved design. Conservatively and consistent with the 2014 HRA, the GCL is not included in the 2025 HRAR Addendum models. The basal liner constructed for Phase 4B North, Phase 4C, Phase 7C and Phase 2 West comprises an approximately 1.1m to 1.2m thick engineered clay liner overlain by a 2mm HDPE geomembrane. Conservatively, the greater clay liner thickness has not been updated in the 2025 HRAR Addendum models.

2.13 The 2024 HRAR includes a sensitivity analysis on the hydraulic conductivity of the clay element of the basal liner showing that the model results are similar to those presented in the 2014 HRA and do not change the conclusions of the HRA. The sensitivity analysis has been repeated in this 2025 HRAR Addendum and is reported in Section 4.

Receptors

2.14 Consistent with the 2014 HRA, the compliance point for hazardous substances in groundwater will be at one or more boreholes down hydraulic gradient and directly adjacent to the landfill. For the purpose of the HRA the receptor for hazardous substances is at a monitoring borehole down hydraulic gradient of the phase boundary. No contaminant attenuation is assumed for hazardous substances in the groundwater pathways so that only the effect of immediate dilution after the discharge enters the groundwater is modelled.

2.15 Consistent with the 2014 HRA, the compliance point for non-hazardous pollutants in groundwater will be at one or more boreholes down hydraulic gradient and adjacent to the landfill. For the purpose of the HRA the receptor for non-hazardous pollutants is at a monitoring borehole at the site boundary. As confirmed in the 2024 HRAR, the secondary receptor closest to the site remains the Thornhaugh Beck which is down hydraulic gradient of the site and approximately 230m from the site boundary at its closest point (Figure 2 of the 2024 HRAR (Appendix HRA A)).

2.16 Environmental Assessment Levels (EALs) were proposed in the 2014 HRA based on minimum laboratory reporting values, laboratory detection limits, background groundwater quality, the Drinking Water Standard (DWS) or Environmental Quality Standards (EQS) depending on which was more appropriate at the time of the 2014 HRA. EALs are the concentrations of the substances above which there may be a discernible discharge of hazardous substances to groundwater and pollution of groundwater by non-hazardous pollutants at the respective receptors. The EALs are presented in Table HRA 1 and include the amendment to the EAL for Trichloroethene (TCE) and the addition of lead proposed in the 2024 HRAR. An EAL for xylene has been derived (Table HRA 1) based on the methodology used in the 2014 HRA. There are no other proposed revisions to the EALs presented in the 2014 HRA.

Summary of changes to the sources, pathways or receptors

2.17 In summary the changes to the conceptual site model since the 2024 HRAR was carried out are:

- Updates to the source term used in the 2024 HRAR for the hazardous substances lead, replacement of MTBE with the hazardous substance xylene and update to the to the source term for the hazardous substance cadmium in Phase 5 (Table HRA 1).
- The necessary updates to pathway input parameters in the 2025 HRAR Addendum to support the EP variation application comprise updates to the waste thickness and the infiltration to Phases 1, 2, 4, 5 and 7 based on the new cap design of 1m of clay.

- In addition to the items identified above, the 2025 HRAR Addendum models include updates to the timescales for end of filling of the landfill phases and off set times of the phases from the commencement of landfilling of the containment site in Phase 3 in 2003 and updates to the waste porosity.

The results of the 2025 HRAR Addendum models are presented in Section 4 and Table HRA 4.

3. Modelling approach

3.1 As detailed in Section 2 of the 2024 HRAR, in the HRA the lifecycle of the landfill is divided into three stages. The first stage comprises the operational phase of the landfill up to the completion of filling with waste where active leachate management is undertaken during active waste deposition. The second stage comprises the post closure managed phase of the landfill where all areas of the site are restored and active leachate management continues. The third stage comprises the point beyond which active management is necessary. During the third stage there will be no active leachate management. Thornhaugh Landfill Site is in the first stage of the lifecycle of the landfill.

3.2 The current approved 2014 HRA model for the site comprises a detailed quantitative HRA model using the probabilistic LandSim modelling tool developed by the Environment Agency. As there have been no significant changes to the conceptual site model for the site, LandSim comprises the most appropriate modelling tool to assess potential impacts to the water environment from Thornhaugh non-hazardous landfill site.

3.3 As detailed in Section 2, the proposed changes to the approved 2014 HRA model or additional changes to the input parameters in the 2024 HRAR model are presented in Tables HRA 1, HRA 2A, HRA 2B and HRA 3. The input parameters relevant to the sensitivity analyses are presented in Section 4.

3.4 A digital copy of the 2025 HRAR Addendum models is presented at Appendix HRA D together with an electronic copy of the revisions to the lead concentrations and details of the outlier in the cadmium concentrations in the leachate.

4. 2025 HRAR Addendum modelling

4.1 The 2025 HRAR Addendum model has been run in LandSim version 2.5.17. As set out in Section 2, the source term used in the 2024 HRAR for the hazardous substances lead, replacement of MTBE with the hazardous substance xylene and the source term for the hazardous substance cadmium in Phase 5 has been updated in the 2025 HRAR Addendum model (Table HRA 1). The pathway input parameter updates in the 2025 HRAR Addendum to support this EP variation application comprise updates to the waste thickness, waste porosity and infiltration to Phases 1, 2, 4, 5 and 7 based on the new cap design of 1m of clay together with timescales for end of filling and off set times.

Emissions to groundwater

4.2 The results of the 2025 HRAR Addendum LandSim model are summarised in Table HRA 4. An electronic copy of the 2025 HRAR Addendum LandSim model and result file are presented at Appendix HRA D.

Hazardous substances

4.3 The results of the 2025 HRAR Addendum LandSim model show that there will be no discernible concentration of hazardous substances at the 95th and the 50th percentiles in the groundwater at the assumed monitoring point adjacent to the boundary of the site during the operational and post closure managed phases of the landfill.

Non-hazardous pollutants

4.4 The results of the 2025 HRAR Addendum LandSim model show that there will be no exceedances of the groundwater EALs by non-hazardous pollutants at the 50th percentile or 95th percentile results at the non-hazardous pollutant receptor during the operational or the post closure managed phases of the landfill.

Warning messages

4.5 As reported in the HRA prepared in support of the 2021 ENRMF EP variation application, following completion of the model run an on-screen warning is displayed stating that during the current simulation "calculated leachate leakage exceeds 10%

of the aquifer flow on 168 iterations" It is understood that the 10% threshold is arbitrary. The calculated leachate leakage exceeds 10% of the aquifer flow in 168 model iterations out of a total of 1001 model iterations hence a small proportion of the model iterations only. It is reported in the LandSim manual that LandSim calculates an additional velocity due to leakage whenever the leakage is greater than 10% of the flow in the aquifer and takes into account the increase in groundwater velocity in the pathway resulting from displacement by leaking leachate. It is considered that this will result in a reduction in calculated travel times in the aquifer pathway for substances present in the leachate hence is conservative compared with the situation where the leakage is not greater than 10% of the flow in the aquifer.

4.6 It is likely that for model iterations where the leachate leakage exceeds 10% of the aquifer flow the aquifer flow is at the low end of the range of values calculated based on the hydraulic conductivity and hydraulic gradient model input parameters for the Northampton Sands Formation aquifer pathway. The area of the landfill is considered insignificant compared with the areal extent of the Northampton Sands Formation. On this basis it is considered likely that the rate of flow in the Northampton Sands Formation under the site generally will be greater than the aquifer flow rates calculated in the LandSim model. On this basis it is considered unlikely that the flow of leachate from the landfill will have a significant impact on the groundwater flow regime in the Northampton Sands Formation. The way in which the model has been parameterised with regard to parameter values affecting leachate leakage and aquifer flow is considered conservative generally. Notwithstanding the presence of the on-screen warning the model is considered appropriate based on the conceptual model that is the subject of the model.

4.7 As reported in the HRA prepared in support of the 2021 ENRMF EP variation application, following completion of the model run an on-screen warning is displayed stating that 'leakage rate decreasing' during the current simulation. The leachate level is fixed at 1.5m hence leakage should be consistent throughout the life of the model. From the hydraulics results of the model for the leakage from the landfill there is no detectable decrease in leakage rate shown during the life of the model. It is considered that any period over which the leakage rate decreases must be very short and very slight only hence will not have a significant impact on the overall results of the model and that the input parameters used are appropriate.

Sensitivity analysis

4.8 A sensitivity analysis on the 2025 HRAR Addendum LandSim model has been run for the lead source term concentrations with the mean and maximum concentrations in Phases 1, 2, 4 and 7 set at the mean and maximum concentrations from the WAC testing results provided by Augean for the new waste codes which have had exceedances on one or more SNRHW WAC limits (Table 2B of the 2024 HRAR - Appendix HRA A). An electronic copy of the sensitivity analysis 2025 HRAR Addendum LandSim model for lead and the result file are presented at Appendix HRA D.

4.9 The results of the sensitivity analysis model for the lead source term concentrations show that there will be no discernible concentrations of the hazardous substance lead at the assumed monitoring point adjacent to the boundary of the site during the operational and post closure managed phases of the landfill with higher lead source term concentrations in Phases 1, 2, 4 and 7.

4.10 A sensitivity analysis on the 2025 HRAR Addendum LandSim model has been run to assess the hydraulic conductivity of the clay component of the landfill liner. As set out in the 2024 HRAR and consistent with the 2014 HRA, and the lowest quartile, the geometric mean and the 90th percentile of the CQA data for Phases 4B South, 4B North, 4C and 7A has been used for the minimum, most likely and maximum of the input values in Phases 1, 2, 4 and 7 of the model (Table 4 of the 2024 HRAR – Appendix HRA A). An electronic copy of the sensitivity analysis 2025 HRAR Addendum LandSim model for the hydraulic conductivity of the clay component of the landfill liner and the result file are presented at Appendix HRA D.

4.11 The results of the sensitivity analysis of the hydraulic conductivity of the clay component of the landfill liner in Phases 1, 2, 4 and 7 are summarised in the table below. The model results shows that there will be no discernible concentrations of hazardous substances at the assumed monitoring point adjacent to the boundary of the site during the operational and post closure managed phases of the landfill with higher hydraulic conductivity of the clay component of the landfill liner in Phases 1, 2, 4 and 7. The results of the model shows that the predicted concentrations of the non-hazardous pollutants in the groundwater at the 95th and 50th percentiles do not exceed the relevant EALs during the operational and post closure managed phases of the landfill with higher hydraulic conductivity of the clay component of the landfill liner in Phases 1, 2, 4 and 7.

4.12 The sensitivity analysis is highly conservative as the model does not take into account the additional GCL component of the landfill liner in Phase 4B South and Phase 7A or the increased thickness of the clay liner in Phase 4B North, Phase 4C, Phase 7C and Phase 2 West.

The results of the 2025 HRAR Addendum sensitivity analysis of the of the hydraulic conductivity of the clay component of the liner in Phases 1, 2, 4 and 7

Substance	Environmental Assessment Level (EAL) (mg/l)	Maximum concentration at the 95th percentile (mg/l)	Maximum concentration at the 50th percentile (mg/l)
Hazardous substances[a]			
Xylene	0.001		
Cadmium	0.00032		
Naphthalene	0.00045		
Trichloroethene	0.00002 (0.0002)		
Lead	0.051	6.9E-10	
Non-hazardous pollutants			
Ammoniacal N	0.39	0.18	0.011
Chloride	250	212	55
Manganese	0.22	0.19	0.0051
Phenol[b]	0.046		

NOTE: Where the maximum concentration is not shown there is no concentration reported in the results of the model above 1E-10mg/l

4.13 Setting the duration of management control in the LandSim model to 20,000 years in respect of each phase and specifying that the control of leachate levels will continue until the time approaching or at the point of completion is consistent with the principles set out in the Environment Agency memo to LandSim Users dated 3 March 2004 (Environment Agency reference Mgmt control v.2) in order to assess compliance with the regulations regarding the protection of groundwater in Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016 (EPR).

4.14 Consistent with the HRA prepared in support of the 2021 ENRMF EP variation application comprising the most recent landfill application completed by Augean and approved by the EA, a sensitivity analysis has been carried out on the period of management control. The 2025 HRAR Addendum model has been run deterministically with a period of management control of 60 years to assess the change in the “Expected Values” (50th percentile or most likely concentration). An electronic copy of the sensitivity analysis LandSim model and result file are presented at Appendix HRA D. A hard copy of the sensitivity analysis LandSim model is presented at Appendix HRA E.

4.15 The results of the sensitivity analysis of the management control period for the 2025 HRAR Addendum model show that with a duration of management control of 60 years the predicted “expected” or “most likely” concentrations do not exceed the groundwater EALs for hazardous substances or non-hazardous pollutants at the relevant receptors during the operational, post closure managed and post closure unmanaged phases of the landfill.

Conclusion of the 2025 HRAR Addendum

4.16 Based on the 2025 HRAR Addendum LandSim models undertaken using the updated leachate source term and site parameters to reflect the updated site design it is concluded that, consistent with the 2014 HRA and the 2024 HRAR, the site remains compliant with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016.

5. Monitoring

5.1 The monitoring of leachate, groundwater and surface water at Thornhaugh Landfill is the subject of conditions of the EP for the site and is set out in Table HRA 6 (REVISED) presented at Appendix A to the 2024 HRAR. The locations of the monitoring points are shown on Figure 2 of the 2024 HRAR. Changes to the monitoring network at the site since the 2014 HRA was prepared were summarised in section 6 of the 2024 HRAR.

Groundwater compliance limits

5.2 The groundwater quality compliance limits and control levels for the site are set out in Table HRA 9 of the 2014 HRA. The compliance limits are set at the Environmental Assessment Limits (EAL) from the 2014 HRA. The monitoring points at which the compliance limits and control levels should be applied are the down hydraulic gradient boreholes TH05, TH09, TH12, TH13, TH14, TH15, TH19A and TH26. For boreholes TH10, TH11, TH17A and TH18A located downgradient of Phases 1 and 2 comprising the disperse and attenuate landfill interim compliance limits are set out in Table HRA 10 of the 2014 HRA. The interim compliance limits apply for the period up until the completion of the excavation of waste from Phases 1 and 2. The groundwater compliance limits and the interim compliance limits are set out in Table S3.4 ‘Groundwater - emissions limits and monitoring requirements’ of the EP for the site.

5.3 The hazardous substance lead has been added to the LandSim models for the site in the 2024 HRAR to address improvement programme requirement IC8 in respect of new waste codes permitted at the site under the current EP and is included in the 2025 HRAR Addendum LandSim models. The EAL for lead is presented in the 2024 HRAR and in Table HRA 1. Lead is not the subject of compliance limits in the EP. It is requested that the EAL for lead is included as the compliance limit in Table S3.4 ‘Groundwater - emissions limits and monitoring requirements’ of the varied EP. Consistent with the other hazardous substances included in the HRA (Table HRA 9 of the 2014 HRA), the control level for lead in the groundwater is relevant to leachate quality and comprises the maximum leachate source term concentration in the leachate of 1.923mg/l.

5.4 MTBE has been replaced by the hazardous substance xylene in the 2025 HRAR Addendum LandSim models. The EAL for xylene is presented in Table HRA 1. It is requested that xylene replaces MTBE in Table S3.4 ‘Groundwater - emissions limits and monitoring requirements’ of the varied EP with the compliance limit for xylene set at the EAL. Consistent with the other hazardous substances included in the HRA (Table HRA 9 of the 2014 HRA), the control level for xylene in the groundwater is relevant to leachate quality and comprises the maximum leachate source term concentration in the leachate of 0.162mg/l.

5.5 The EAL for the hazardous substance TCE is updated in the 2024 HRAR as presented in Table HRA 1. It is requested that the compliance limit for TCE is updated in Table S3.4 ‘Groundwater - emissions limits and monitoring requirements’ of the varied EP to the EAL of 0.0002mg/l.

5.6 As stated in section 7 of the 2024 HRAR, in comments on the draft version of the EP provided for review in April 2016 it was requested that monitoring point reference TH09 was changed to TH08 in Table S3.4 ‘Groundwater - emissions limits and monitoring requirements’ as there typically is insufficient groundwater in borehole TH09 to collect a representative groundwater sample. The Environment Agency indicated that this change would be made in an e-mail dated 21 April 2016 but this was not then presented in the final version of the EP. Borehole TH05 is referenced in Table S3.4 ‘Groundwater - emissions limits and monitoring requirements’ of the EP. While comments on the draft version of the permit referred to inconsistencies in respect of reference to TH05 and TH06 in Tables HRA 6 and Table HRA 9 this item was not resolved and TH05 was left in the EP issued. It is requested that monitoring point reference TH09 is changed to TH08 and monitoring point reference TH05 is changed to TH06 in Table S3.4 ‘Groundwater - emissions limits and monitoring requirements’ as part of this EP variation.

5.7 It is considered in section 7 of the 2024 HRAR that the source of exceedance of compliance limits for ammoniacal nitrogen in the groundwater at boreholes TH12, TH13 and TH19A is the waste in disperse and attenuate Phases 1 and 2. It is considered in the 2024 HRAR that the source of exceedance of compliance limits for manganese in the groundwater at boreholes TH12, TH13 and TH14 is the waste in disperse and attenuate Phases 1 and 2. The exceedances coincide with material movements, excavation and engineering works associated with the development of

Phase 7A adjacent to Phase 1 and of Phase 2 West comprising part of the disperse and attenuate phases of the site. Concentrations and values of a number of determinands are elevated at boreholes down hydraulic gradient of Phases 1 and 2 with interim compliance limits applying to boreholes TH10, TH11, TH17A and TH18A until the excavation of the waste is complete in Phases 1 and 2. Electrical conductivity values recorded in the groundwater at down hydraulic gradient borehole TH11 frequently exceed the interim compliance limit of 2880µS/cm between July 2015 and August 2016 coinciding with Phase 7A construction works in 2015.

5.8 It is requested that scoring is suspended for the exceedances of groundwater quality compliance limits during material movements, excavation and engineering works which disturb the disperse and attenuate Phases 1 and 2 at the site. The exceedances are short lived during the campaigns of material movements, excavation and engineering works at and in the vicinity of Phases 1 and 2. The excavation of deposited waste from disperse and attenuate Phases 1 and 2 is for the purpose of environmental betterment and reducing the long-term contamination of groundwater from these phases. The temporary exceedance of compliance limits during these works are out of the control of the operator and scoring for the exceedances of groundwater quality compliance limits attributable to the development at and in the vicinity of Phases 1 and 2 during these remedial works is disproportionate and not reflective of the overall long-term benefits of the activities.

6. Conclusions

6.1 The results of the 2025 HRAR Addendum for Thornhaugh Landfill Site updating the 2014 HRA and 2024 HRAR models to reflect the changes to the restoration profile and the cap design for the site do not change significantly the results of the HRA. The 2014 HRA LandSim model as updated by the 2024 HRAR LandSim model has been re-run to include revisions to the concentration of the hazardous substances lead and cadmium (Phase 5) and replacement of MTBE with the hazardous substance xylene in the source term, the increase waste thickness and updated infiltration to Phases 1, 2, 4, 5 and 7 based on the new cap design of 1m of clay. Consistent with the 2024 HRAR, a sensitivity analysis on the concentration of lead in the source term in Phases 1, 2, 4 and 7 and on the hydraulic conductivity of the clay component of the landfill liner in Phases 1, 2, 4, 5 and 7 has been carried out together with a sensitivity analysis on the management control period of the landfill.

6.2 Based on the results of the re-run LandSim models and the sensitivity analyses, as discussed in Section 4, it is considered that the results of the models do not change the conclusions of the 2014 HRA or 2024 HRAR. Consequently, it is considered that the modelled impact of the site on groundwater as demonstrated in the 2014 HRA and 2024 HRAR complies with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016.

6.3 PO5 has been addressed and discharged in section 2 of this 2025 HRAR Addendum and is no longer relevant or appropriate. It is requested that pre-operational measure PO5 is removed from the varied EP.

6.4 The hazardous substance lead has been added to the LandSim models for the site in the 2024 HRAR. It is requested that the EAL for lead is included as the compliance limit in Table S3.4 'Groundwater - emissions limits and monitoring requirements' of the varied EP. MTBE has been replaced by the hazardous substance xylene in the 2025 HRAR Addendum LandSim models. It is requested that the EAL for xylene replaces the compliance limit for MTBE in Table S3.4 'Groundwater - emissions limits and monitoring requirements' of the varied EP. It is requested that the compliance limit for TCE is updated in Table S3.4 'Groundwater - emissions limits and monitoring requirements' of the varied EP to the EAL. The groundwater and surface water compliance limits set in 2014 have been compared with the concentrations of determinands recorded in the groundwater and surface water at the site in the 2024

HRAR (Appendix HRA A). It is requested that monitoring point reference TH09 is changed to TH08 and monitoring point reference TH05 is changed to TH06 Table S3.4 'Groundwater - emissions limits and monitoring requirements' as part of this EP variation to correct error in the current EP.

6.5 It is requested that scoring is suspended for the exceedances of groundwater quality compliance limits during material movements, excavation and engineering works which disturb the disperse and attenuate Phases 1 and 2 at the site. The excavation of disperse and attenuate Phases 1 and 2 is for the purpose of environmental betterment and reducing the long-term contamination of groundwater from these phases.

6.6 Based on the results of the 2025 HRAR Addendum presented in this report it is considered that Thornhaugh Landfill Site remains compliant with Schedule 22 to the Environmental Permitting (England and Wales) Regulations 2016.

7. References

1. MJCA, 2014. An application to vary Environmental Permit No RP3133PP for the Thornhaugh Landfill Site operated by Augean South Limited to extend the area of the existing permitted site. Hydrogeological Risk Assessment Report. Report reference: AU/TH/JRC/2826/01/HRA.

2. MJCA, 2024. Review of the Hydrogeological Risk Assessment for Thornhaugh Landfill Site. Report reference: AU/TH/JRC/20127/01.

3. MJCA, 2014. An application to vary Environmental Permit No RP3133PP for the Thornhaugh Landfill Site operated by Augean South Limited to extend the area of the existing permitted site. Environmental Setting and Installation Design Report. Report reference: AU/TH/MAS/5477/01/ESID.

4. Environmental Simulations International Limited, 2009. Thornhaugh Landfill: 4 yearly HRA review and response to Improvement Condition 16. Report reference 60194R1 dated March 2009.

5. Environmental Simulations International Limited, 2004. Hydrogeological risk assessment report Thornhaugh Quarry. Report reference 6453HRA1 dated November 2004.

6. MJCA, 2015. Application number: EPR/RP3133PP/V006 – Response to the notice of request for further information dated 19 March 2015 for Thornhaugh Landfill Site. Email to Päivi Porali-Perrell of the EA dated 5 May 2015. Response to a request for further information.

7. MJCA, 2015. Application Number: EPR/RP3133PP/V006 – Response to the notice of request for further information dated 16 July 2015 for Thornhaugh Landfill Site. Email to Päivi Porali-Perrell of the EA dated 25 August 2015. Response to a request for further information.

8. Augean South Limited. 2024. Leachate Monitoring Action Plan Thornhaugh (TH) to complement permit EPR/RP3133P. Document dated December 2024.

9. MJCA, 2021. An application to vary Environmental Permit Number EPR/TP3430GW for the hazardous waste landfill site operated by Augean South Limited at East

Northants Resource Management Facility. Review of the Hydrogeological Risk Assessment for East Northants Resource Management Facility and Hydrogeological Risk Assessment for the proposed western extension. Report reference: AU/KCW/JRC/2991/01HRAR.

TABLES

Table HRA 1

Leachate source term used in the 2025 HRA Addendum LandSim models

Determinand	Unit	Phase	Environmental Assessment level (EAL) in 2014 HRA	2014 HRA source term concentration (mg/l)			Leachate concentration recorded between May 2014 and June 2024			
				Minimum	Most likely	Maximum	Minimum	Mean	Maximum	Count
Hazardous substances										
Xylene [a] (MTBE)	mg/l	All	0.003	(0.0078)	(0.034)	(0.35)	**0.003**	**0.016**	**0.162**	78 (<LOD)
Cadmium[b]	mg/l	All except 5	0.00032	**0.003**	**0.0065**	**0.035**	0.00003	0.0012	0.0530	197
		5		0.003	0.0083	0.36	0.00003 (**0.00003**)	0.00046 (**0.0012**)	0.0054 (**0.0636**)	169
Naphthalene	mg/l	All	0.00045	**0.00087**	**0.028**	**2**	0.00005	0.0056	**0.29**	156
Trichloroethene[c]	mg/l	All	0.0002	0.00029	**0.027**	**0.27**	**0.001**	0.001	0.001	All results <LOD
Lead[d]	mg/l	All	0.051				**0.00783**	**0.082**	**1.923**	358
Non-hazardous pollutants										
Ammoniacal nitrogen[e]	mg/l	All except 5	0.39	**51**	200	600	0.5	**309**	**1,601**	283
		5		**51**	260	1,300	0.7	**273**	**2,320**	274
Chloride[f]	mg/l	All except 5	250	**440**	1,100	4,500	3.1	**1,870**	**8,900**	270
		5		**440**	5,800	54,000	2.5	**9,679**	**72,000**	264
Manganese[g]	mg/l	All	0.22	**0.16**	1.2	17	0.002	**4.6**	**272.85**	369
Phenol	mg/l	All	0.046	**0.01**	**0.24**	**15**	0.00001	0.12	3.4	140

Notes:

While cadmium, MTBE and naphthalene have been reclassified as non-hazardous pollutants, it is assumed that cadmium and naphthalene are hazardous substances for the purpose of this HRA review. MTBE has been replaced by the hazardous substance xylene (see note a below).

BOLD denotes the concentrations used in the 2025 HRAR Addendum model runs.

[a] MTBE has not been recorded in the leachate since 2021. As Xylene is recorded in the leachate at similar concentrations to those modelled in the HRA, MTBE has been replaced by Xylene in the 2025 HRAR Addendum model. Consistent with the 2014 HRA, the minimum source term concentration comprises the 25th percentile of the available leachate data for xylene. The most likely comprise the average value of the data. The maximum concentration comprises the maximum value from the data plus 20%. The EAL for xylene is based on the laboratory detection limits for m and p-xylene plus o-xylene.

[b] Based on the 2024 HRAR, the concentration of cadmium in the leachate in Phase 5 are not higher than in the rest of the landfill with the mean and maximum concentrations an order of magnitude lower than in the rest of the site. The cadmium source term in Phase 5 in the 2014 HRA included a statistical outlier. The source term in Phase 5 has been updated using the data for all phases over the 2024 HRAR review period. The minimum source term concentration comprises the 25th percentile of the cadmium data over the 2024 HRAR review period. The most likely comprise the average value of the data over the 2024 HRAR review period. The maximum concentration comprises the maximum value from the data over the 2024 HRAR review period plus 20%. The source term concentrations used in Phase 5 in the 2025 HRAR Addendum is shown in parenthesis in the table above. An electronic copy of the details of the outlier in the cadmium concentrations in the leachate in Phase 5 are provided at Appendix HRA D.

[c] The 2024 HRAR comparison data for trichloroethene from May 2014 to June 2024 comprise annual hazardous substances suites for 2015, 2017, 2018, 2019, 2020, 2021, 2022, 2023, and 2024. All results were recorded as <LOD. The EAL for TCE should be amended to 0.0002mg/l consistent with the UKTAG limit of quantification (see section 7 of the 2024 HRA Review).

[d] Lead was added to the 2024 updated HRAR model runs to address improvement programme requirement IC8. Consistent with the 2014 HRA, the minimum source term concentration comprises the 25th percentile of the available leachate data for lead. The most likely comprise the average value of the data. The maximum concentration comprises the maximum value from the data plus 20%. The EAL is set at the mean concentration recorded in groundwater up hydraulic gradient of the site (in boreholes TH1, TH2, TH3, TH4 and TH25) plus two standard deviations as the typical concentration in the groundwater is recorded above the detection limit. The lead source term in the 2025 HRAR Addendum model has been updated to remove duplicates identified in the 2024 HRAR dataset. An electronic copy of the revisions to the lead concentrations in the leachate are provided at Appendix HRA D.

[e] The 2024 HRAR comparison data for ammoniacal nitrogen from May 2014 to June 2024 excludes data for August 2020 which comprised elevated concentrations at the majority of locations with concentrations recorded before and after August 2020 within the range recorded previously.

[f] The 2024 HRAR comparison data for chloride from May 2014 to June 2024 excludes data Phase 4C for May 2020 and data for Phases 4B north and 4B South for August 2022 which comprised elevated concentrations with all concentrations recorded before, where relevant, and after within the range recorded previously.

[g] The 2024 HRAR comparison data for manganese from May 2014 to June 2024 excludes data for May 2018 and February 2021 which comprised elevated concentrations at the majority of locations with concentrations recorded before and after these dates within the range recorded previously.

Table HRA 2A
Parameters relevant to the determinands in the leachate source term

Determinand	Kappa value constants		Reference / justification
	m (kg/l)	c (kg/l)	
Hazardous substances			
Xylene	0.0298	0.2919	Conservatively the value for chloride has been used

Table HRA 2B
Input parameters for the LandSim hydrogeological risk assessment model – chemical and attenuation properties

Parameter	Pathway (CL = clay liner, NSF=Northampton sand Formation)	K_{oc} (l/kg)			Half life (years)	
		Minimum	Most likely	Maximum	Minimum	Maximum
Hazardous substances						
Xylene	**CL**[1]		*260*		*0.5*	*1*
	NSF				*0.038*	*1*

Notes:
Probability density functions key:

- Unshaded: single value
- Numbers in italics: log distributions (triangular or uniform).

Derivation of parameter values:
The Koc value for xylene taken from Golder Associates. ConSim 2.5 help file
The half life values for xylene are derived from P.H. Howard, R.S. Boethling, W.F. Jarvis, W.M. Meylan & E.M. Michalenko, H. Taub Printup (Ed), 1991. Handbook of Environmental Degradation Rates. Lewis publishers. 1 For the purpose of this assessment it is assumed conservatively that the clay liner is anaerobic.

Table HRA 3
Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Landfill parameters							
Time offset	nearest whole year	1 (West and East) and 7A		18		Single	Start of waste disposal in 2015 (7A) and 2028 used to calculate offset in relation to Phase 3 - mean of offset times used for Phases 1 (West and East) and 7A
		2 (West and East)		22		Single	Start of waste disposal in 2024 (2 (West)) and 2026 (2 (East)) used to calculate offset in relation to Phase 3 - mean of offset times used for Phase 2 (West and East)
		3		0		Single	From 2014 HRA
		4B (North and South), 4C, 7B and 7C		20		Single	Start of waste disposal in 2020 (4B (North)), 2021 (4C), 2023 (7C) and 2033 (7B) used to calculate offset in relation to Phase 3 - mean of offset times used for Phases 4B (South), 4C, 7B and 7C
		5 (North, South and the extension)		5		Single	From 2014 HRA
		6 (A and B)		1		Single	From 2014 HRA
Infiltration to waste	mm/year	All phases		587.7		Normal with a 10% standard deviation	From 2014 HRA
Cap design infiltration	mm/year	All phases except 3 and 6 (A and B)	0.32	0.60	1.9	Log triangular	1m Clay cap. Values derived from infiltration model at Appendix HRA D.

Table HRA 3
Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Cap design infiltration	mm/year	3 and 6 (A and B)		0.0001		Single	From 2014 HRA
End of filling	years from start of waste disposal to nearest whole year	1 (West and East) and 7A		18		Single	1 (West and East) not constructed (assume 2028) 7A 2015 to 2017
		2 (West and East)		4		Single	2W 2024 to 2025 2E not constructed (assume 2026)
		3		1		Single	From 2014 HRA
		4B (North and South), 4C, 7B and 7C		19		Single	4B North 2020 to 2021 4B South 2017 to 2018 4C 2021 to 2025 7C 2023 to 2026 7B not constructed (assume 2033)
		5 (North, South and the extension)		8		Single	From 2014 HRA
		6 (A and B)		2		Single	From 2014 HRA
Infiltration to grassland	mm/year	3 and 6 (A and B)		0.48		Single	From 2014 HRA
Start of PE cap degradation	years	3 and 6 (A and B)		250		Single	LandSim default
End of PE cap degradation	years	3 and 6 (A and B)		1000		Single	LandSim default

Table HRA 3
Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Length of the base of the landfill in the direction of groundwater flow	m	1 (West and East) and 7A		290		Single	From 2014 HRA
		2 (West and East)		165		Single	
		3		180		Single	
		4B (North and South), 4C, 7B and 7C		245		Single	
		5 (North, South and the extension)		105		Single	
		6 (A and B)		220		Single	
Width of the base of the landfill perpendicular to groundwater flow	m	1 (West and East) and 7A		140		Single	From 2014 HRA
		2 (West and East)		85		Single	
		3		70		Single	
		4B (North and South), 4C, 7B and 7C		290		Single	
		5 (North, South and the extension)		170		Single	
		6 (A and B)		80		Single	

Table HRA 3
Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Surface area of the landfill	m^2	1 (West and East) and 7A		57340		Single	Minor amendments from 2014 HRA to Phases 2 (West and East), 4B (North and South), 4C, 7B, 7C and 5 (North, South and the extension) based on as built Phase 2 (West), 4C and 7C.
		2 (West and East)		23320		Single	
		3		24415		Single	
		4B (North and South), 4C, 7B and 7C		104120		Single	
		5 (North, South and the extension)		27940		Single	
		6 (A and B)		35275		Single	
Waste thickness	m	1 (West and East) and 7A		13.9		Single	Average waste thickness based on the waste volume divided by the surface area (Phases 3 and 6 (A and B) as 2014 HRA)
		2 (West and East)		18.8		Single	
		3		10.2		Single	
		4B (North and South), 4C, 7B and 7C		12.6		Single	
		5 (North, South and the extension)		11.2		Single	
		6 (A and B)		8.8		Single	

Table HRA 3
Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Waste porosity	fraction	All phases	0.45		0.67	Uniform	Effective porosity or drainable porosity of waste values used as *waste porosity* in the 2014 LandSim models added to the *field capacity* values in the models (see section 2.6 of this report).
Waste dry density	kg/l	All phases		1.02		Single	From 2014 HRA
Waste field capacity	fraction	All phases		0.4		Single	From 2014 HRA
Specified head of leachate on liner	m	All phases		1.5		Single	Compliance limit set in EP number EPR/3133PP
Flexible membrane liner							
Pin holes	ha^{-1}	All phases except Phase 3	0		25	Triangular	From 2014 HRA
Holes	ha^{-1}	All phases except Phase 3	0		5	Triangular	
Tears	ha^{-1}	All phases except Phase 3	0	0.1	2	Triangular	
Onset of degradation	years	All phases except Phase 3		150		Single	
Time for defects to double	years	All phases except Phase 3		100		Single	

Table HRA 3
Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Clay liner							
Clay liner thickness	m	1 (West and East), 2 (West and East), 4B (North and South), 4C, and 7 (A, B and C)		0.5		Single	From 2014 HRA
		3, 5 (North, South and the extension) and 6 (A and B)		1		Single	
Hydraulic conductivity	m/s	1 (West and East), 2 (West and East), 4B (North and South), 4C, 7 (A, B and C)	5.1×10^{-11}	6.9×10^{-11}	1.6×10^{-10}	Log triangular	From 2014 HRA
		3	1.5×10^{-11}		4.0×10^{-11}	Log uniform	
		5 (North, South and the extension)	8.0×10^{-11}	1.2×10^{-10}	3.1×10^{-10}	Log triangular	
		6 (A and B)	6.4×10^{-11}	8.4×10^{-11}	1.5×10^{-10}	Log triangular	

Table HRA 3
Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Clay liner							
Fraction of organic carbon	fraction	All phases	0.002	0.004	0.01	Triangular	From 2014 HRA
Dry bulk density	g/cm^3	All phases	1.55	1.68	1.77	Triangular	From 2014 HRA
Moisture content	fraction	All phases	0.14		0.25	Uniform	From 2014 HRA
Longitudinal pathway dispersivity	m	1 (West and East), 2 (West and East), 4B (North and South), 4C, 7 (A, B and C)		0.05		Single	From 2014 HRA
		3, 5 (North, South and the extension) and 6 (A & B)		0.1		Single	
Unsaturated zone – Northampton Sands Formation							
Unsaturated zone thickness	m	Phases 3, 5 & 6		0		Single	From 2014 HRA
		Phases 1, 2, 4 & 7		1		Single	From 2014 HRA
Hydraulic conductivity	m/s	All phases	4.3×10^{-6}	1.1×10^{-5}	1.0×10^{-4}	Log triangular	From 2014 HRA

Table HRA 3
Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Unsaturated zone – Northampton Sands Formation							
Moisture Content	fraction	All phases	0.1		0.3	Uniform	From 2014 HRA
Pathway density	kg/l	All phases		2		Single	From 2014 HRA
Pathway dispersivity	m	Phases 3, 5 & 6		0		Single	From 2014 HRA
		Phases 1, 2, 4 & 7		0.1		Single	From 2014 HRA
Pathway fraction of organic carbon	fraction	All phases	0.0001	0.0012	0.026	Log triangular	From 2014 HRA
Aquifer pathway – Northampton Sands Formation							
Hydraulic conductivity	m/s	All phases	4.3×10^{-6}	1.1×10^{-5}	1.0×10^{-4}	Log triangular	From 2014 HRA.
Pathway density	kg/l	All phases		2		Single	From 2014 HRA
Pathway fraction of organic carbon	fraction	All phases	0.0001	0.0012	0.026	Log triangular	From 2014 HRA

Table HRA 3
Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Aquifer pathway – Northampton Sands Formation							
Aquifer pathway length	m	1 (West and East) and 7A	18		308	Uniform	Calculated in LandSim
		2 (West and East)	308		473	Uniform	
		3	310.5		490.5	Uniform	
		4B (North and South), 4C, 7B and 7C	18		263	Uniform	
		5 (North, South and the extension)	473		578	Uniform	
		6 (A and B)	490		710.5	Uniform	
Regional gradient	none	All phases		0.0062		Normal with a standard deviation of 0.0008	From 2014 HRA
Aquifer thickness	m	All phases		2.92		Normal with a standard deviation of 0.38m	From 2014 HRA

Table HRA 3
Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Aquifer pathway – Northampton Sands Formation							
Aquifer pathway width	m	1 (West and East) and 7A		140		Single	From 2014 HRA
		2 (West and East)		85		Single	
		3		70		Single	
		4B (North and South), 4C, 7B and 7C		290		Single	
		5 (North, South and the extension)		170		Single	
		6 (A and B)		80		Single	
Pathway porosity	fraction	All phases	0.1		0.3	Uniform	From 2014 HRA
Longitudinal pathway dispersivity	m	All phases	1.8		64.55	Uniform	From 2014 HRA
Transverse dispersivity	m	All phases	0.18		6.455	Uniform	From 2014 HRA

Table HRA 4

Results of the 2025 HRAR Addendum LandSim modelling for Thornhaugh Landfill Site [UPDATE ONCE FINAL MODEL DECIDED]

Determinand	Phases contributing to the predicted receptor concentration	Environmental Assessment Level (EAL) (mg/l)	Time taken for breakthrough at the 95th percentile (years)[2]	Time taken to exceed the EAL at the 95th percentile (years)[3]	Maximum concentration at the 95th percentile [4] (mg/l)	Time taken for breakthrough at the 50th percentile (years)[2]	Time taken to exceed the EAL at the 50th percentile (years)[3]	Maximum concentration at the 50th percentile [4] (mg/l)
Hazardous substances								
Xylene	1 (West and East) and 7A	0.003 (3×10^{-3})						
	2 (West and East)							
	3							
	4B (North and South), 4C (North and South), 7B and 7C							
	5 (North, South and the extension)							
	6 (A and B)							
Cadmium	1 (West and East) and 7A	0.00032 (3.2×10^{-4})						
	2 (West and East)							
	3		13,500		1.8×10^{-9}			
	4B (North and South), 4C (North and South), 7B and 7C							
	5 (North, South and the extension)		1,500		3.5×10^{-5}	14,000		1.7×10^{-9}
	6 (A and B)		5,500		8.5×10^{-5}			
Napthalene	1 (West and East) and 7A	0.00045 (4.5×10^{-4})						
	2 (West and East)							
	3							
	4B (North and South), 4C (North and South), 7B and 7C							
	5 (North, South and the extension)							
	6 (A and B)							
Trichloroethene	1 (West and East) and 7A	0.0002 (2×10^{-4})						
	2 (West and East)							
	3							
	4B (North and South), 4C (North and South), 7B and 7C							
	5 (North, South and the extension)		30		1.0×10^{-9}			
	6 (A and B)							
Lead	1 (west and East) and 7A	0.051 (5.1×10^{-2})						
	2 (West and East)							
	3							
	4B (North and South), 4c (North and South), 7B and 7C							
	5 (North, South and the extension)		7,700		3.7×10^{-6}	14,000		2.5×10^{-9}
	6 (A and B)		14,000		2.4×10^{-9}			
Non-hazardous pollutants								
Ammoniacal N	All	0.39	90		0.17	250		0.009
Chloride	All	250	25		208	40		54
Manganese	All	0.22	3,000		0.14	11,000		0.0025
Phenol	All	0.046						

Notes:
The concentrations for hazardous substances are those predicted at the monitoring point adjacent to the boundary of the phase.
The concentrations for non-hazardous pollutants are those predicted at the site boundary from the cumulative impact of all cells

[1] The EALs are explained in section 1.2 of the 2014 report, in Table HRA 1 (REVISED) (Appendix HRA A) and in Table HRA 1.
[2] Where the time taken for the breakthrough of a contaminant is not shown there is no breakthrough of the contaminant over the 19,999 years modelled.
[3] Where the time taken to exceed the EAL is not shown there is no exceedance of the EAL over the 19,999 years modelled.
[4] Where the maximum concentration is not shown there is no concentration reported in the results of the model above 1×10^{-10}mg/l

APPENDICES

APPENDIX HRA A

A COPY OF THE REPORT ENTITLED "REVIEW OF THE HYDROGEOLOGICAL RISK ASSESSMENT FOR THORNHAUGH LANDFILL SITE." REPORT REFERENCE: AU/TH/JRC/20127/01 (2024 HRAR) (REFERENCE 2)

REVIEW OF THE HYDROGEOLOGICAL RISK ASSESSMENT FOR THORNHAUGH LANDFILL SITE

Report reference: AU/TH/JRC/20127/01
December 2024

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This report has been prepared by MJCA with all reasonable skill, care and diligence, and taking account of the Services and the Terms agreed between MJCA and the Client. This report is confidential to the client and MJCA accepts no responsibility whatsoever to third parties to whom this report, or any part thereof, is made known, unless formally agreed by MJCA beforehand. Any such party relies upon the report at their own risk.

1. Introduction

1.1 MJCA is commissioned by Augean South Limited (Augean) to undertake a review of the hydrogeological risk assessment (HRA) for Thornhaugh Landfill Site (reference 1). The review of the HRA has been undertaken in accordance with condition 3.1.5 of Environmental Permit (EP) variation number EPR/RP3133PP/V007 for the non-hazardous landfill issued in July 2024 (reference 2). The site is operated by Augean for the deposition of non-hazardous commercial and industrial waste, stable non-reactive hazardous waste (SNRHW), asbestos and gypsum together with other high sulphate bearing wastes. The site is centred approximately on National Grid Reference (NGR) TF 04876 00139 approximately 2km west north west of the village of Wansford, near Peterborough. The location of the site is shown on Figure 1.

1.2 Prior to landfilling the site was quarried for the ironstone of the Northampton Sand Formation by excavating the overlying Lincolnshire Limestone Formation and Grantham Formation. It is understood that the overlying materials removed during quarrying were used to backfill parts of the quarry. At a later date some of the overburden backfill was quarried and the remaining void was developed as a landfill. Landfilling commenced in 1984 with two phases (Phases 1 and 2) developed on the principal of disperse and attenuate and the remaining phases developed as containment landfill cells.

HRA Review

1.3 Phases 1 and 2 previously comprised a closed landfill area the subject of a separate EP number EPR/FP3790NJ (EAWML 70119). An application for an EP for the development of Phases 3 to 7 on the principal of containment was prepared in 2004. The EP was issued based on documentation and risk assessments submitted with the EP application and in response to queries raised by the Environment Agency (EA) during the application process. Since the original EP was issued in 2005 a number of variations to the EP have been issued and additional documentation and risk assessments have been submitted with the applications to vary the EP. The supporting documentation and risk assessments include the most recent HRA (reference 1) and the most recent Environmental Setting and Installation Design report (ESID) (reference 3) dated September 2014. All of the conditions of the original EP and subsequent variations to the EP were deleted and replaced by the issue of the EP variation reference EPR/RP3133PP/V006 issued in May 2016.

1.4 The 2014 HRA (reference 1) was prepared to support an application to vary the EP to extend the boundary of the EP landfill area to include an adjacent area of land known as the Bradshaw Land and to incorporate the closed landfill area comprising Phases 1 and 2. The application to vary the EP included limited screening and crushing activities necessary to recover materials from suitable inert waste such as construction, demolition and excavation wastes including such wastes that have been deposited in Phases 1, 2, 4 and 7 previously and which will be removed before the phases are engineered for landfill. The 2014 HRA included the development of a LandSim model for the site based on an HRA review prepared in March 2009 (reference 4) and the original EP application HRA prepared in November 2004 (reference 5).

1.5 During the determination period of the 2014 application to vary the EP various additions and amendments to the HRA were carried out. In response to the Schedule 5 Notice dated 19 March 2015 a revised version of Table HRA 6 presenting the proposals for the monitoring of leachate, groundwater and surface water at Thornhaugh Landfill was provided with an email dated 5 May 2015 (reference 6). Table HRA 6 (REVISED) was updated for consistency with the monitoring requirements specified in the EA Position Statement MWRP RPS 156 Version 1 dated September 2013 (RPS 156). Table HRA 6 (REVISED) is provided at Appendix A for ease of reference.

1.6 In a response dated 25 August 2015 to a Schedule 5 Notice dated 16 July 2015 the cap design for the site was reassessed in response to proposals for a geosynthetic clay liner (GCL) cap with an underlying drainage layer. Revised cap design infiltration rates were calculated using soil moisture deficit models. Further to the change in cap design infiltration rate the LandSim model was updated to include changes relating to the surface area of the landfill and changes to the source term for Phase 5 together with timescales for end of filling and off set times. An updated LandSim model and revised versions of Tables HRA 1 and HRA 3 with the updated source term and input parameters respectively were provided with the response dated 25 August 2015 (reference 7) together with the model results in a third revision to Table HRA5. Tables HRA 1 (REVISED), Table HRA 3 (REVISED) and Table HRA 5 (THIRD REVISED) are provided at Appendix A for ease of reference. Further sensitivity analyses on the models were carried out in response to further requests for information from the Environment Agency in October 2015 and January 2016. For the purpose of this report where reference is made to the 2014 HRA this includes the further information provided during the EP determination period.

1.7 A further application to vary the EP to add five hazardous waste codes for deposit in the SNRHW cell was submitted to the EA in December 2023. No updates to the 2014 ESID or HRA were included with the application. When the EA issued the current EP variation number EPR/RP3133PP/V007 in July 2024, the varied EP included three additional improvement programme requirements into Table S1.3 of the permit in respect of the additional waste codes for deposit in the SNRHW cell. It is stated in improvement programme requirement IC8 that:

> *"The Operator shall submit a Hydrogeological Risk Assessment Review (HRAR) to the Environment Agency in writing for approval in accordance with condition 3.1.5 which takes into consideration the properties of the new waste types:10 01 14*, 12 01 16*, 16 07 09*, 16 11 03*, 19 01 11* (as referenced in table S2.4) in any cell for Stable Non-Reactive Hazardous Waste"*

1.8 This HRA review includes consideration of the properties of the new waste types:10 01 14*, 12 01 16*, 16 07 09*, 16 11 03*, 19 01 11* in any cell for SNRHW consistent with improvement programme requirement IC8.

1.9 It is stated in condition 3.1.5 of EP variation number EPR/RP3133PP/V007 for Thornhaugh Landfill Site that:

> *"The operator shall submit to the Environment Agency a review of the Hydrogeological Risk Assessment:*
>
> *(a) between nine and six months prior to the fourth anniversary of the granting of the permit; and*
>
> *(b) between nine and six months prior to every subsequent six years after the fourth anniversary of the granting of the permit.*

1.10 This report comprises the third HRA review since the original EP was issued in 2005 including the 2014 HRA and the first HRA review for the site following the issue of EP variation reference EPR/RP3133PP/V006 in May 2016 with future HRA reviews due every six years.

1.11 Leachate and groundwater monitoring data for the period May 2014 to October 2024 have been reviewed. The monitoring locations together with the key features of the site are shown on Figure 2. The CQA validation reports for the construction of Phase 4B South (reference 8), Phase 4B North (reference 9), Phase 4C (reference 10), Phase 7A (reference 11), Phase 7C (reference 12), and Phase 2 West (reference 13) comprising the engineering carried out at the site since the 2014 HRA have been reviewed to confirm that the assumed values for the parameters used in the 2014 HRA are consistent with the phases constructed at the site. The data and information have been compared with the assumptions made in the conceptual model presented in the ESID (reference 3) on which the HRA is based together with the values for the parameters used in the modelling in the HRA.

1.12 Groundwater and landfill gas monitoring borehole TH26 was installed at the site in November 2019. The groundwater quality monitoring data collected at borehole TH26 since November 2019 is the subject of improvement programme requirement IC7 of the EP and a review of the data is included in this HRA review. Pursuant to improvement programme requirement IC7 this HRA review includes proposals for groundwater control and compliance levels for selected determinands together with a contingency action plan for groundwater quality at borehole TH26.

1.13 The purpose of the HRA review is to demonstrate that the impact of the site on groundwater remains compliant with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016 which have replaced the 2010 regulations referred to in the 2014 HRA. Where necessary the HRA models have been updated to demonstrate that the potential impact of the site on groundwater remains compliant with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016. The results of the HRA review are presented in this report. This report has been prepared with reference to the guidance provided by the Environment Agency at www.gov.uk.

2. Review of the conceptual site model and the leachate management action plan

Sources

2.1 In the HRA the lifecycle of the landfill is divided into three stages. The first stage comprises the operational phase of the landfill up to the completion of filling with waste where active leachate management is undertaken during active waste deposition. The second stage comprises the post closure managed phase of the landfill where all areas of the site are restored and active leachate management continues. The third stage comprises the point beyond which active management is necessary. During the third stage there will be no active leachate management. Thornhaugh Landfill Site is in the first stage of the lifecycle of the landfill.

2.2 Since the issue of EP variation reference EPR/RP3133PP/V006 in May 2016 there have been no significant changes to the permitted site operations with the exception of the additional hazardous waste codes permitted in the SNRHW cells since the issue of EP variation reference EPR/RP3133PP/V007 in July 2024. Since the preparation of the 2014 HRA the main changes at the site with respect to the development of the landfill comprise the construction and filling of Phase 4B South, Phase 4B North, Phase 4C, Phase 7A, Phase 7C and Phase 2 West. Landfilling is currently ongoing in Phase 7C and Phase 2 West. Phases 3 and 6 were capped prior to the 2014 HRA and so remain unchanged.

2.3 Leachate levels at the site are reviewed in Section 3 of this HRA review “Review of essential and technical precautions” together with the leachate management action plan.

Leachate quality

2.4 The leachate source term used for the modelling in the 2014 HRA is presented in Table HRA 1 (REVISED) reproduced at Appendix A. Leachate concentrations for each determinand have been reviewed over the monitoring period May 2014 to June 2024 comprising the period of monitoring following that reviewed in the 2014 HRA. The leachate concentrations have been compared with the values used in the 2014 HRA. The results of the comparison of the leachate quality data with the 2014 HRA source term are presented in Table 1. An electronic copy of the leachate quality monitoring data reviewed is presented at Appendix B.

2.5 There have been changes to the classification of some substances as hazardous substances or non-hazardous pollutants since the 2014 HRA was carried out for the site with some hazardous substances for groundwater being reclassified as non-hazardous pollutants and some non-hazardous pollutants being reclassified as hazardous substances. Cadmium, MTBE, and naphthalene which are included in the hazardous substance leachate source term, have been reclassified as non-hazardous pollutants. All of the non-hazardous pollutants included in the 2014 HRA have remained non-hazardous pollutants. It is assumed that the hazardous substances modelled in the 2014 HRA remain as hazardous substances for the purpose of this HRA review and the re-classification of substances as hazardous substances or non-hazardous pollutants has not been taken into account.

2.6 In general, the concentrations of hazardous substances recorded in the leachate over the review period are within the range modelled in the 2014 HRA. The maximum cadmium concentration of 0.053mg/l recorded in all cells except Phase 5 is marginally higher than the maximum concentration modelled in the 2014 HRA of 0.035mg/l. It is considered that the marginal increase in the maximum cadmium concentration would not significantly change the results of the HRA and it is not necessary to re-model cadmium. While MTBE has not been recorded consistently in the leachate, the hazardous substances xylene has been recorded at similar concentrations and within the range of those for MTBE modelled in the 2014 HRA hence the model for MTBE could be a proxy for xylene.

2.7 The mean concentrations of ammoniacal nitrogen recorded over the review period are marginally higher than the most likely concentrations modelled in the 2014 HRA. The maximum concentration of ammoniacal nitrogen recorded over the review period in all cells except Phase 5 is nearly 3 times greater and the maximum concentration in Phase 5 is nearly 2 times greater than those modelled in the 2014 HRA. The mean and maximum concentrations of chloride recorded over the review period in all cells except Phase 5 are nearly double the most likely and double the maximum concentrations modelled in the 2014 HRA. The mean and maximum concentrations of chloride recorded over the review period in Phase 5 are approximately double the most likely and a third higher than the maximum concentrations modelled in the 2014 HRA. The mean and maximum concentrations of manganese recorded over the review period in all cells are approximately four times higher than the most likely and an order of magnitude higher than the maximum concentrations modelled in the 2014

HRA. The phenol concentrations recorded in the leachate over the review period are within the range modelled in the 2014 HRA.

2.8 Due to the potentially significant increases in the concentrations in the leachate of the non-hazardous pollutants ammoniacal nitrogen, chloride and manganese the source term for these substances has been updated and the approved 2014 HRA model has been re-run. The minimum concentrations remain unchanged and the most likely and maximum concentrations have been updated consistent with the mean and maximum concentrations recorded between May 2015 and June 2024 (Table 1). The results of the LandSim model run with the updated source term are presented in Section 5 of this HRA review "HRA review modelling".

Improvement programme requirement IC8

2.9 It is understood that Augean are using the Waste Acceptance Criteria (WAC) for Stable Non-reactive hazardous waste (SNR) accepted at landfills for non-hazardous waste for the acceptance of the new waste stream/ waste codes. Augean have provided data comprising WAC data for waste streams which have had exceedances on one or more SNR WAC limits only. In general, the data provided is for the substances where exceedances have been recorded only and not the full set of WAC testing data.

2.10 As part of this review the liquid to solid ratio 10 l/kg leaching limit values for SNR expressed in mg/l have been compared with the source term used in the current approved version of the HRA models for the site. Not all substances with WAC limits are modelled in the HRA. The SNR WAC and the WAC testing results are compared with source term values comprising substances that are classified in a similar manner and behave similarly in the environment. The HRA source term values used for the comparison are presented in Table 2A. The results of the comparison of the SNR WAC and the WAC testing results with the HRA source term values are presented in Table 2B.

2.11 As can be seen in Tables 2A and 2B, the SNR WAC limit for arsenic is in the range for the HRA source term modelled for a Hazardous substance – metal in Phase 5 only. If it is assumed that chromium comprises chromium VI and is classified as a hazardous substance, then the SNR WAC limit for chromium is higher than the HRA source term modelled for a Hazardous substance – metal. The SNR WAC limit for lead is higher than the HRA source term modelled for a Hazardous substance – metal. All other SNR WAC limits are within the range of the comparative HRA source term concentrations modelled.

2.12 The maximum and mean concentrations for chromium exceed the maximum HRA source term modelled for a Hazardous substance – metal. The maximum concentration only for lead exceeds the maximum HRA source term modelled for a Hazardous substance – metal. The maximum concentration for cadmium, is within the range for the HRA source term modelled for Phase 5 only but exceeds that for all phases except Phase 5. The maximum concentrations only for total chromium and zinc exceed the maximum HRA source term modelled for a Non-hazardous pollutant – metal. While there are some exceedances of the HRA source term modelled in the WAC testing results data for the new waste steam/ waste codes a full set of WAC testing data has not been provided. It is understood that for HRA purposes all the data meet the SNR WAC limits based on the statistical methods in WM3.

2.13 As the SNR WAC limits for the hazardous substances arsenic, chromium (assuming chromium comprises chromium VI) and lead are higher than the HRA source term modelled for a Hazardous substance – metal (cadmium) in the majority of the phases at the site the 2014 HRA model results (Appendix A – Table HRA 5 (THIRD REVISION)) have been reviewed to assess whether it may be necessary to carry out further HRA modelling.

2.14 The HRA model results for cadmium are marginally lower than the Environmental Assessment Level (EAL) for Phase 5 of the landfill and less than an order of magnitude below the EAL for Phase 6. However, the results for cadmium are orders of magnitude lower than the EAL for all other phases of the landfill modelled. The SNR WAC limits for arsenic, chromium and lead are between 2 and 3 orders of magnitude higher than the most likely cadmium source term concentration used in the 2014 HRA models. On this basis, as the new waste steam/ waste codes are not included in Phases 5 and 6 it is not necessary to carry out further HRA modelling.

2.15 Although it has been determined that further HRA modelling is not necessary, as a precaution lead has been added to the source term and the approved 2014 HRA model has been re-run. Lead has been selected as it has the highest concentration of the hazardous substance metals recorded in the WAC testing results provided by Augean for the new waste codes. The source term concentrations are presented in

Table 1. The other determinand specific input parameters for lead are presented in Tables 3A and 3B. The maximum source term concentration is above the SNR WAC limit for lead. The results of the LandSim model run are presented in Section 5 of this HRA review "HRA review modelling".

2.16 A sensitivity analysis LandSim model has been run for the lead source term concentrations with the mean and maximum concentrations in Phases 1, 2, 4 and 7 set at the mean and maximum concentrations from the WAC testing results provided by Augean for the new waste codes which have had exceedances on one or more SNR WAC limits (Table 2B). The results of the sensitivity analysis are presented in Section 5.

Pathways

2.17 The pathway input parameters used in the modelling in the 2014 HRA is presented in Table HRA 3 (REVISED) reproduced at Appendix A. In respect of the pathway through the basal liner, the CQA data for the site provided since the last HRA in 2014 are reviewed in the "Review of essential and technical precautions" section (Section 3) of this HRA review.

2.18 The conceptual site model for the site on which the HRA is based is described in the ESID (reference 3) and is summarised in the 2014 HRA. In summary, the geology in the vicinity of the site comprises the Lincolnshire Limestone Formation which in turn is underlain by the Grantham Formation and Northampton Sand Formation. In parts of the site the sequence has been replaced partly with backfilled material comprising reworked material of the Lincolnshire Limestone Formation and Grantham Formation. The Northampton Sand Formation is underlain by the Whitby Mudstone Formation. The Lincolnshire Limestone Formation is unsaturated across the majority of the site with groundwater present in the Grantham Formation and the Northampton Sand. Generally, the groundwater flow direction beneath the site is to the east towards and in the direction of flow of the Thornhaugh Beck. The Lincolnshire Limestone Formation is designated by the Environment Agency as a Principal Aquifer, the Grantham Formation is designated a Secondary Aquifer (undifferentiated), the Northampton Sand Formation is designated a Secondary A Aquifer and the Whitby Mudstone Formation is designated unproductive strata.

2.19 The pathway for the migration of leachate from the site will be through the basal liner of the landfill, vertically through the unsaturated zone and to the groundwater in the Northampton Sand Formation and/or backfilled materials. The migration of leachate from the site may continue laterally in the saturated zone of the Northampton Sand Formation and/or backfilled materials generally to the east towards and in the direction of flow of the Thornhaugh Beck.

2.20 Groundwater levels recorded at boreholes at the site between December 2000 and October 2024 are presented on Figures 3a and 3b. As can be seen on Figures 3a and 3b groundwater levels at the site fluctuate within similar ranges between May 2014 and October 2024 compared with between December 2000 and April 2014. The saturated thicknesses and hydraulic gradients calculated based on the groundwater monitoring data recorded between May 2014 and October 2024 are similar to those used in the 2014 HRA as shown in the table below.

Parameter	2014 HRA		Calculated from May 2014 to October 2024 data	
	Most likely	Probability density function	Average	Standard deviation
Saturated thickness	2.92	Normal with a standard deviation of 0.38m	2.75	0.49
Hydraulic gradient (unitless)	0.0062	Normal with a standard deviation of 0.0008	0.0067	0.0007

NOTE: As presented in the 2014 HRA, hydraulic gradients calculated between borehole TH1 up hydraulic gradient and the down hydraulic gradient boreholes TH12, TH13, TH14, TH18, TH18A, TH19 and TH19A. Saturated thickness calculations exclude boreholes TH07, TH20, TH21, TH22 and TH23.

2.21 For the purpose of providing a minimum 1m thick unsaturated zone beneath the base of the engineered liner, the elevation level on which the engineered barrier will be constructed has been designed based on a maximum groundwater level. For phases constructed since the 2014 HRA which comprise Phase 4B South, Phase 4B North, Phase 4C, Phase 7A, Phase 7C and Phase 2 West the maximum groundwater level used to inform the design of cells and the elevation level of the base of the engineered liner was that recorded in March 2013 and presented at Figure ESID 11 (reference 3).

2.22 The highest groundwater levels recorded at boreholes at the site between May 2014 and October 2024 are generally those recorded in February 2021 along the western boundary of the site and to the south of Phase 4 (TH01 to TH04, TH15 and TH25), in March 2021 to the south and north east (TH14 and TH18A) and May 2021 in the east (TH12). The groundwater levels recorded at the site in February 2021 are presented as interpolated groundwater contours on Figure 4. Consistent with the 2014 HRA, for the purpose of conservatively interpolating the groundwater levels across the site, groundwater levels recorded in a number of boreholes located in the north of the site have not been relied on as it is uncertain if the response zone in the monitoring wells is intersecting the groundwater levels in the Northampton Sand Formation.

2.23 Comparison of the interpolated groundwater contours for February 2021 with those for March 2013 show that in general the groundwater levels in February 2021 are similar to or lower than in March 2013 across the site with the exception of the western margins of the site. The groundwater levels in February 2021 are approximately 1m higher than in March 2013 at borehole TH01 to the west of the site and between approximately 0.4m and 0.5m higher than in March 2013 along the rest of the western boundary of the site (boreholes TH02, TH03, TH04 and TH25) and to the south of Phase 4 (borehole TH15). The only cells where the unsaturated zone thickness may be influenced by these higher groundwater levels are those in Phase 4. No unsaturated zone is included beneath Phases 3, 5 and 6 in the 2014 HRA model. The assumption in 2014 HRA that the unsaturated zone thickness beneath Phases 1, 2 and 7 is 1m remains valid.

2.24 Comparison of the interpolated groundwater contours for February 2021 with the as built topographic survey of the top formation level from the CQA verification reports for Phase 4B South (reference 8), Phase 4B North (reference 9) and Phase 4C show that the minimum unsaturated zone thickness ranges between approximately 1.5m and 0.5m beneath Phase 4B South, between approximately 1.0m and 0.5m beneath Phase 4B North and between approximately 2.0m and 0.5m beneath Phase 4C in February 2021. On all other occasions over the review period the minimum unsaturated zone thickness is approximately 1m or greater beneath Phase 4B South, 4B North and 4C. It is considered that the assumption in the 2014 HRA that the unsaturated zone thickness beneath Phase 4B South, Phase 4B North and Phase 4C is 1m is valid and generally is highly conservative.

Receptors

2.25 As described in the 2014 HRA, the compliance point for hazardous substances in groundwater will be at one or more boreholes down hydraulic gradient and directly adjacent to the landfill. For the purpose of the HRA the receptor for hazardous substances is at a monitoring borehole down hydraulic gradient of the phase boundary. No contaminant attenuation is assumed for hazardous substances in the groundwater pathways so that only the effect of immediate dilution after the discharge enters the groundwater is modelled.

2.26 As described in the 2014 HRA, the compliance point for non-hazardous pollutants in groundwater will be at one or more boreholes down hydraulic gradient and adjacent to the landfill. For the purpose of the HRA the receptor for non-hazardous pollutants is at a monitoring borehole at the site boundary. The secondary receptor closest to the site remains the Thornhaugh Beck which is down hydraulic gradient of the site and approximately 230m from the site boundary at its closest point (Figure 2). Based on information provided by the Environment Agency and the Local Authorities in November 2024 there are no further licensed, deregulated or private water abstractions located within 2km of the site in addition to those identified in the 2014 HRA and 2014 ESID.

2.27 Environmental Assessment Levels (EALs) were proposed in the 2014 HRA based on minimum laboratory reporting values, laboratory detection limits, background groundwater quality, the Drinking Water Standard (DWS) or Environmental Quality Standards (EQS) depending on which was more appropriate at the time of the 2014 HRA. EALs are the concentrations of the substances above which there may be a discernible discharge of hazardous substances to groundwater and pollution of groundwater by non-hazardous pollutants at the respective receptors. The EALs are presented in Table 1. The EALs have been reviewed as part of the monitoring section (Section 7) of this HRA review.

Summary of changes to the sources, pathways or receptors

2.28 In summary the changes to the conceptual site model since the 2014 HRA was carried out are:

- updates to the source term used in the 2014 HRA based on the leachate quality recorded over the review period for the non-hazardous pollutants ammoniacal nitrogen, chloride and manganese (Table 1).

- Precautionary addition of hazardous substance lead to the source term (Table 1) in the 2014 HRA based on the leachate quality recorded over the review period to address improvement programme requirement IC8.

The results of the HRA review re-run model is presented in Section 5 and Table 5.

3. Review of the essential and technical precautions

3.1 For the purpose of reviewing the essential and technical precautions the leachate level monitoring data and available CQA reports for the construction of Phases 4B South, Phase 4B North, Phase 4C, Phase 7A, Phase 7C and Phase 2 West have been reviewed and compared with the assumptions and values for the parameters used in the 2014 HRA (reference 1).

CQA data

3.2 The results of the comparison of landfill liner data from the CQA reports for Phase 4B South (reference 8), Phase 4B North (refence 9), Phase 4C (reference 10), Phase 7A (reference 11), Phase 7C (reference 12) and Phase 2 West (reference 13) with the values for the parameters used in the 2014 HRA (reference 1) are presented in Table 4. The basal landfill liner constructed for Phase 4B South and Phase 7A comprises an approximately 0.5m to 0.6m thick engineered clay liner overlain in turn by a geosynthetic clay liner (GCL) and a 2mm thick high density polyethylene (HDPE) geomembrane. The basal liner constructed for Phase 4B North, Phase 4C, Phase 7C and Phase 2 West comprises an approximately 1.1m to 1.2m thick engineered clay liner overlain by a 2mm HDPE geomembrane. The basal landfill liner as modelled in the 2014 HRA for Phase 4, Phase 7 and Phase 2 comprises a 0.5m thick clay liner with a single flexible membrane liner.

3.3 Based on a review of the available landfill liner data from the CQA reports the data generally are within the range of or similar to the values for dry bulk density and moisture content used in the 2014 HRA. The hydraulic conductivity testing results for Phase 4B South, Phase 4B North, Phase 4C and Phase 7A show that while the minimum hydraulic conductivity values are similar to the minimum value used in the 2014 HRA, the geometric mean and maximum hydraulic conductivity values are higher than the most likely and maximum values used in the 2014 HRA. The hydraulic conductivity testing results for Phase 7C and Phase 2 West generally are within the ranged used in the 2014 HRA although the maximum hydraulic conductivity value from Phase 7C is higher than the maximum value used in the 2014 HRA. Notwithstanding the higher geometric mean and maximum hydraulic conductivity values it is considered that the landfill phases constructed at the site since the 2014 HRA incorporate significant design redundancy when compared to the 2014 HRA LandSim models. It is therefore considered that the 2014 HRA is conservative owing to the absence of a GCL in the model with respect to Phase 4B South and Phase 7A and owing to the increased thickness of the clay liner with respect to Phase 4B North, Phase 4C, Phase 7C and Phase 2 West.

3.4 Irrespective of the design redundancy when compared to the 2014 HRA LandSim models with respect to Phases 4B South, Phase 4B North, Phase 4C, Phase 7A, Phase 7C and Phase 2 West a sensitivity analysis LandSim model has been run for the hydraulic conductivity of the liner. Consistent with the 2014 HRA the lowest quartile, the geometric mean and the 90th percentile of the CQA data for Phases 4B South, Phase 4B North, Phase 4C, and Phase7A has been used for the minimum, most likely and maximum of the input values in Phases 1, 2, 4 and 7 of the model. The results of the sensitivity analysis are presented in Section 5.

Leachate level

3.5 A leachate level compliance limit of 1.5m above the top of the basal landfill liner is set in Table S3.1 'Leachate level limits and monitoring requirements' of the EP for the site (reference 2). The leachate level limit of 1.5m is set for both operational cells and non operational cells. As described in Table HRA 7 (reference 1) the compliance limit of 1.5m above the top of the mineral liner applies to the leachate monitoring boreholes only and the compliance limit with respect to the leachate extraction wells is 2.5m above the top of the mineral liner. The methods used to measure leachate levels are consistent with the Leachate Monitoring Action Plan (reference 14) for the site.

3.6 Leachate levels recorded at the site between January 2014 and September 2024 are shown on Figures 5a and 5b. Generally, leachate levels are below the leachate level limit of 1.5m with respect to the leachate monitoring wells with exceedances of the leachate level limit recorded on a number of occasions in leachate monitoring wells THL5A12, THLW5A13, THLW5B12, THLW5B13, THLW6A3 and THLW6B22 over the monitoring period reviewed. Generally, leachate levels are below the leachate level limit of 2.5m with respect to the leachate extraction wells with exceedances of the leachate level limit recorded on a number of occasions in leachate extraction wells THLW5A11 and THLW5B21. Figures 5a and 5b show that in general these exceedances were recorded on or before March 2018 and that since April 2018 there have been only sporadic exceedances of the leachate level limit. It is considered that in general the leachate levels are managed and maintained below the compliance limit.

4. Modelling approach

4.1 As detailed in Section 2, in the HRA the lifecycle of the landfill is divided into three stages. The first stage comprises the operational phase of the landfill up to the completion of filling with waste where active leachate management is undertaken during active waste deposition. The second stage comprises the post closure managed phase of the landfill where all areas of the site are restored and active leachate management continues. The third stage comprises the point beyond which active management is necessary. During the third stage there will be no active leachate management. Thornhaugh Landfill Site is in the first stage of the lifecycle of the landfill.

4.2 The current approved 2014 HRA model for the site comprises a detailed quantitative HRA model using the probabilistic LandSim modelling tool developed by the Environment Agency. As there have been no significant changes to the conceptual site model for the site, LandSim comprises the most appropriate modelling tool to assess potential impacts to the water environment from Thornhaugh non-hazardous landfill site.

4.3 As detailed in Sections 2 and 3, the proposed changes to the approved 2014 HRA model or additions to the input parameters in the 2024 HRA Review model are presented in Table 1 and Tables 3A and 3B. The input parameters relevant to the sensitivity analyses are presented in Table 2B and Table 4.

4.4 A digital copy of the 2024 HRA Review models is presented at Appendix B together with an electronic copy of the leachate, groundwater and surface water monitoring data.

5. HRA review modelling

5.1 As set out in Section 2, the source term concentrations have been updated where the concentrations recorded in the leachate over the review period exceed the concentrations in the source term used in the 2014 HRA model. The 2024 HRA Review model has been run in LandSim version 2.5.17. The hazardous substance lead has been added to the source term. There have been revisions to the concentrations for the non-hazardous pollutants ammoniacal nitrogen, chloride and manganese compared with the 2014 HRA model.

Emissions to groundwater

5.2 The results of the 2024 HRA Review LandSim model are summarised in Table 5. An electronic copy of the 2024 HRA Review LandSim model and result file are presented at Appendix B. A hard copy of the 2024 HRA Review LandSim model is presented at Appendix C.

Hazardous substances

5.3 The concentrations of the hazardous substances modelled in the 2014 HRA remain valid for Cadmium, MTBE, naphthalene and Trichloroethene (TCE) and no updates have been carried out as part of the 2024 HRA review. The hazardous substance lead has been added to the 2024 HRA Review LandSim model to assess the potential concentrations of hazardous metals in the new waste codes permitted under the current version of the EP issued in July 2024 consistent with improvement programme requirement IC8 of the EP. The results of the 2024 HRA Review LandSim model show that there will be no discernible concentration of lead at the 95th and the 50th percentiles in the groundwater at the assumed monitoring point adjacent to the boundary of the site during the operational and post closure managed phases of the landfill.

Non-hazardous pollutants

5.4 The results of the 2024 HRA Review LandSim model show that there will be no exceedances of the groundwater EALs by non-hazardous pollutants at the 50th percentile or 95th percentile results at the non-hazardous pollutant receptor during the operational or the post closure managed phases of the landfill.

Sensitivity analysis

5.5 A sensitivity analysis on the 2024 HRA review LandSim model has been run for the lead source term concentrations with the mean and maximum concentrations in in Phases 1, 2, 4 and 7 set at the mean and maximum concentrations from the WAC testing results provided by Augean for the new waste codes which have had exceedances on one or more SNR WAC limits (Table 2B). An electronic copy of the sensitivity analysis 2024 HRA review LandSim model for lead and the result file are presented at Appendix B.

5.6 The results of the sensitivity analysis model for the lead source term concentrations show that there will be no discernible concentrations of the hazardous substance lead at the assumed monitoring point adjacent to the boundary of the site during the operational and post closure managed phases of the landfill with higher lead source term concentrations in Phases 1, 2, 4 and 7.

5.7 A sensitivity analysis on the 2024 HRA review LandSim model has been run to assess the hydraulic conductivity of the clay component of the landfill liner. Consistent with the 2014 HRA the lowest quartile, the geometric mean and the 90th percentile of the CQA data for Phases 4B South, 4B North, 4C and 7A has been used for the minimum, most likely and maximum of the input values in Phases 1, 2, 4 and 7 of the model (Table 4). An electronic copy of the updated LandSim model and result file are presented at Appendix B.

5.8 The results of the sensitivity analysis of the hydraulic conductivity of the clay component of the landfill liner in Phases 1, 2, 4 and 7 are summarised in the table below. The model results shows that there will be no discernible concentrations of hazardous substances at the assumed monitoring point adjacent to the boundary of the site during the operational and post closure managed phases of the landfill with higher hydraulic conductivity of the clay component of the landfill liner in Phases 1, 2, 4 and 7. The results of the model shows that the predicted concentrations of the non-hazardous pollutants in the groundwater at the 95th and 50th percentiles do not exceed the relevant EALs during the operational and post closure managed phases of the landfill with higher hydraulic conductivity of the clay component of the landfill liner in Phases 1, 2, 4 and 7.

5.9 The sensitivity analysis is highly conservative as the model does not take into account the additional GCL component of the landfill liner in Phase 4B South and Phase 7A or the increased thickness of the clay liner in Phase 4B North, Phase 4C, Phase 7C and Phase 2 West.

The results of the HRA review sensitivity analysis of the hydraulic conductivity of the clay component of the liner in Phases 1, 2, 4 and 7

Substance	Environmental Assessment Level (EAL) (mg/l)	Maximum concentration at the 95th percentile	Maximum concentration at the 50th percentile
Hazardous substances[a]			
MTBE	0.001		
Cadmium	0.00032		
Naphthalene	0.00045		
Trichloroethene	0.00002 (0.0002)		
Lead	0.051		
Non-hazardous pollutants			
Ammoniacal N	0.39	0.133	0.009
Chloride	250	164	46
Manganese	0.22	0.120	0.003
Phenol[b]	0.046		

[a] No breakthrough of hazardous substances at the assumed monitoring point adjacent to the boundary of Phases 1, 2, 4 and 7 over the 20,000year period modelled.
[b.] No breakthrough of non-hazardous pollutant phenol at the compliance point over the 20,000year period modelled.

Conclusion of the 2024 HRA review

5.10 Based on the 2024 HRA Review LandSim models undertaken using the updated leachate source term concentrations and the sensitivity analyses of the hydraulic conductivity of the clay component of the liner in Phases 1, 2, 4 and 7, it is concluded that the results are similar to those presented in the 2014 HRA and do not change the conclusions of the HRA. The 2024 HRA Review LandSim models undertaken include lead in the leachate source term with a sensitivity analysis of the concentrations of lead to address improvement programme requirement IC8 of the EP. The site remains compliant with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016.

6. Infrastructure integrity

6.1 The monitoring of leachate, groundwater and surface water at Thornhaugh Landfill is the subject of conditions of the EP for the site and is set out in Table HRA 6 (REVISED) presented at Appendix A. The locations of the monitoring points are shown on Figure 2. Changes to the monitoring network at the site since the 2014 HRA was prepared are summarised in this section of the report.

6.2 Groundwater and landfill gas monitoring borehole TH26 was installed at the site in November 2019 pursuant to Improvement Programme Requirement IC6 in Table S1.3 of Schedule 1 to the EP. The borehole was the subject of CQA verification (reference 15). A copy of the Environment Agency approval dated February 2020 of the CQA verification of borehole TH26 is provided at Appendix D.

6.3 Groundwater monitoring borehole TH21 was decommissioned as part of the Phase 7A construction works details of which are included in the CQA verification report for Phase 7A (reference 11). Groundwater monitoring borehole TH22 was decommissioned as part of the Phase 7C construction works details of which are included in the CQA verification report for Phase 7C (reference 12). Groundwater monitoring boreholes TH23 and TH24 were decommissioned as part of the Phase 4C construction works details of which are included in the CQA verification report for Phase 4C (reference 10). It is understood that groundwater monitoring borehole TH20 has been lost. Groundwater monitoring borehole TH20 will be decommissioned as part of the engineering works of Phase 1 East.

6.4 Further comments on the monitoring network at the site are included in section 7 of this report comprising the review of water quality monitoring.

7. Monitoring

Groundwater compliance limits

7.1 The groundwater quality compliance limits and control levels for the site are set out in Table HRA 9 of the 2014 HRA. The compliance limits are set at the Environmental Assessment Limits (EAL) from the 2014 HRA. The monitoring points at which the compliance limits and control levels should be applied are the down hydraulic gradient boreholes TH05, TH09, TH12, TH13, TH14, TH15, TH19A and TH26. For boreholes TH10, TH11, TH17A and TH18A located downgradient of Phases 1 and 2 comprising the disperse and attenuate landfill interim compliance limits are set out in Table HRA 10 of the 2014 HRA. The interim compliance limits apply for the period up until the completion of the excavation of waste from Phases 1 and 2. The groundwater compliance limits and the interim compliance limits are set out in Table S3.4 'Groundwater - emissions limits and monitoring requirements' of the EP for the site (reference 2).

7.2 As reported in Section 6, groundwater and landfill gas monitoring borehole TH26 was installed at the site in November 2019 pursuant to Improvement Programme Requirement IC6 in Table S1.3 of Schedule 1 to the EP. It is stated in Improvement Programme Requirement IC7 in Table S1.3 of Schedule 1 to the EP that:

> *"The operator shall submit a written report to the Environment Agency for approval. The report shall include a review of at least 12 months of groundwater quality data from monitoring borehole TH26, proposals for groundwater control and compliance levels for selected determinands, and a contingency action plan. The control and compliance levels shall be adopted upon receipt of written agreement from the date stipulated by the Environment Agency."*

Groundwater quality monitoring commenced in February 2020 at borehole TH26. The groundwater quality compliance limits and control levels for the site are set out in Table HRA 9 of the 2014 HRA and include borehole TH26. Pursuant to Improvement Programme Requirement IC7 the groundwater quality compliance limits and control levels for borehole TH26 are reviewed as part of this 2024 HRA Review with the other monitoring boreholes the subject of compliance limits.

7.3 The groundwater quality monitoring data collected between May 2014 and September 2024 have been reviewed and compared with the compliance limits set in 2014. An electronic copy of the groundwater quality monitoring data reviewed is presented at Appendix B. A comparison of groundwater quality data collected between May 2014 and September 2024 at the relevant monitoring boreholes with the compliance limits set in 2014 is presented on the chemographs provided at Appendix E. As reported in Section 6, groundwater monitoring boreholes TH21, TH22, TH23 and TH24 have been decommissioned as part of the ongoing development of the site. Borehole TH20 has been lost. Boreholes TH20 to TH24 are not the subject of groundwater compliance limits.

7.4 In comments on the draft version of the permit provided for review in April 2016 it was requested that monitoring point reference TH09 was changed to TH08 as there typically is insufficient groundwater in borehole TH09 to collect a representative groundwater sample. The Environment Agency indicated that this change would be made in an e-mail dated 21 April 2016 but this was not then presented in the final version of the EP. Groundwater samples have been taken occasionally from borehole TH09 over the review period. Based on the inconsistency of monitoring at borehole TH09 and the comments on the draft permit the groundwater quality at the adjacent borehole TH08 has been reviewed and compared with the compliance limits as well as the limited data for borehole TH09.

7.5 Borehole TH06 is referenced in Table HRA 9 in respect of the boreholes to which compliance limits should apply. Borehole TH05 is referenced in Table S3.4 'Groundwater - emissions limits and monitoring requirements' of the EP. While comments on the draft version of the permit referred to inconsistencies in respect of reference to TH05 and TH06 in Tables HRA 6 and Table HRA 9 this item was not resolved and TH05 was left in the EP issued. Groundwater quality at the adjacent boreholes TH05 and TH06 has been reviewed and compared with the compliance limits.

Hazardous substances

7.6 MTBE concentrations in the groundwater at the down hydraulic gradient boreholes TH05, TH06, TH08, TH12, TH13, TH14 and TH15 exceeded the compliance limit of 0.001mg/l on one occasion in 2014 and on two occasions in 2014 at borehole TH19A. MTBE concentrations in the groundwater at the up hydraulic gradient boreholes TH01 to TH04 and TH25 exceeded the compliance limit of 0.001mg/l in May 2014. No other exceedances of the compliance limit for MTBE were recorded over the review period at the down hydraulic gradient boreholes the subject of the compliance limit.

7.7 Cadmium concentrations in the groundwater at the down hydraulic gradient boreholes TH05, TH06, TH08, TH09, TH12, TH13, TH14, TH15, TH19A and TH26 are recorded at concentrations below the compliance limit of 0.00032mg/l on all occasions during the review period with the exception of at borehole TH12 in April 2023. Cadmium in the groundwater at borehole TH12 in April 2023 was recorded at a concentration of 0.00064mg/l. A cadmium concentration at the compliance limit was recorded in the groundwater at borehole TH12 in May 2024.

7.8 The limit of detection (LOD) of the analytical method used for naphthalene concentrations recorded in the groundwater in all boreholes at the site exceed the compliance limit of 0.00045mg/l for the down hydraulic gradient boreholes TH05, TH06, TH08, TH09, TH12, TH13, TH14, TH15, TH19A and TH26 between May 2015 and February 2021 and between May to September 2024. The LOD of the analytical method used for naphthalene concentrations recorded in the groundwater in all boreholes at the site exceeds the interim compliance limit of 0.00014mg/l for the down hydraulic gradient borehole TH10 between May 2015 and February 2021 and between May to September 2024. There are no naphthalene concentrations recorded in the groundwater at the down hydraulic gradient boreholes above the analytical method detection limit used of 0.001mg/l over the period May 2015 and February 2021 and between May to September 2024. No naphthalene concentrations recorded in the groundwater at down hydraulic gradient borehole TH11 exceed the interim compliance limit of 0.0268mg/l over the review period.

7.9 Naphthalene concentrations recorded in the groundwater at down hydraulic gradient boreholes TH05, TH06, TH08, TH09, TH12, TH13, TH14, TH15, TH19A and TH26 between April 2021 and March 2024 are all below the LOD of the analytical method of 0.00005mg/l or 0.0001mg/l hence below the compliance limit of 0.00045mg/l. Naphthalene concentrations recorded in the groundwater at down hydraulic gradient borehole TH10 between April 2021 and March 2024 are all below the LOD of the analytical method of 0.00005mg/l or 0.0001mg/l hence below the compliance limit of 0.00014mg/l. Going forward groundwater samples for naphthalene analysis will be sent to an analytical laboratory that can achieve a LOD at or below the compliance limits.

7.10 The LOD of the analytical method used for Trichloroethene (TCE) concentrations recorded in the groundwater in all boreholes at the site exceed the compliance limit of 0.00002mg/l for the down hydraulic gradient boreholes TH05, TH06, TH08, TH09, TH12, TH13, TH14, TH15, TH19A and TH26 on all sampling dates over the review period. There are no TCE concentrations recorded in the groundwater at the site above the analytical method detection limit used of 0.001mg/l over the review period. Proposed changes to the EAL and compliance limit for TCE are presented in the are presented in the Environmental Assessment Levels (EALs) section below. Going forward groundwater samples for TCE analysis will be sent to an analytical laboratory that can achieve a LOD at or below the proposed EAL.

7.11 As stated in Section 2 of this report, while MTBE and trichloroethene have not been recorded consistently in the leachate, the hazardous substances xylene has been recorded at similar concentrations and within the range of those for MTBE modelled in the 2014 HRA hence the model for MTBE could be a proxy for xylene. On this basis groundwater quality data for the hazardous substance xylene has been reviewed. Xylene concentrations in groundwater is available for boreholes TH11 and TH16 only for limited dates in 2006, 2007, 2008, 2009, 2014 and 2019 with concentrations ranging from 0.0065 to 0.0141mg/l (concentrations comprise *m and p* xylene and *o* xylene combined). Boreholes TH11 and TH16 are located down hydraulic gradient of and groundwater quality at the boreholes are affected by disperse and attenuation Phases 1 and 2. Xylene is included in the annual hazardous substances suite of analysis include in Table S3.8 Groundwater- other monitoring requirements of the EP for the site with data available for most of the groundwater monitoring boreholes in 2021, 2022, 2023 and 2024. No other xylene concentrations have been recorded in the groundwater at the site above the analytical method LOD used of between 0.002mg/l and 0.003mg/l over the review period.

7.12 Lead is not the subject of compliance limits in the EP. Lead has been added to the 2024 HRA Review LandSim models for the site to address improvement programme requirement IC8 in respect of new waste codes permitted at the site under the current EP. Lead concentrations in the groundwater at the site have been reviewed and compared with the EAL for lead. The EAL for lead is presented in Table 1 and in the

EALs section below. Lead concentrations in the groundwater at down hydraulic gradient boreholes TH05, TH06, TH08, TH09, TH14 and TH19A are recorded at concentrations below the EAL of 0.051mg/l on all occasions during the review period. Lead concentrations in the groundwater at down hydraulic gradient boreholes TH12, TH13, TH15 and TH26 exceed the compliance limit on one or two occasions over the review period with a maximum concentration of 0.2518mg/l recorded at borehole TH26 in November 2020.

Non-hazardous pollutants

7.13 Between April 2015 and August 2018, the LOD of the analytical method used for ammoniacal nitrogen frequently is above the compliance limit of 0.39mg/l. Ammoniacal nitrogen concentrations in the groundwater at the down hydraulic gradient boreholes TH05, TH06, TH08, TH14, TH15 and TH26 occasionally exceed the compliance limit of 0.39mg/l over the review period. Ammoniacal nitrogen concentrations in the groundwater at the down hydraulic gradient borehole TH13 generally exceed the compliance limit between October 2014 and August 2019 with a maximum concentration of 10.68mg/l recorded in May 2016. Ammoniacal nitrogen concentrations in the groundwater at borehole TH12 frequently exceed the compliance limit between September 2014 and May 2021 with a maximum concentration of 31mg/l recorded in May 2017. Ammoniacal nitrogen concentrations in the groundwater at borehole TH19A frequently exceed the compliance limit between May and September 2014 and between February 2017 and August 2019 with a maximum concentration of 31mg/l recorded in February 2017. Ammoniacal nitrogen concentrations in the groundwater at boreholes TH12 and TH13 exceed the compliance limit on two occasions and one occasion respectively during 2024. Boreholes TH12, TH13 and TH19A are located down hydraulic gradient of Phase 7A and the disperse and attenuate Phases 1 and 2.

7.14 Ammoniacal nitrogen concentrations are elevated at boreholes down hydraulic gradient of Phases 1 and 2 with interim compliance limits applying to boreholes TH10, TH17A and TH18A until the excavation of the waste is complete in Phases 1 and 2. Ammoniacal nitrogen concentrations in the groundwater at down hydraulic gradient borehole TH10 exceeded the interim compliance limit of 10mg/l on two occasions over the review period. Ammoniacal nitrogen concentrations in the groundwater at down hydraulic gradient borehole TH17A exceeded the interim compliance limit of

5.07mg/l on one occasion over the review period. No other exceedances of the ammoniacal nitrogen interim compliance limits were recorded in the groundwater down hydraulic gradient of Phases 1 and 2.

7.15 It is considered that the source of the elevated ammoniacal nitrogen concentrations recorded at boreholes TH12, TH13 and TH19A is the waste in Phases 1 and 2. It is considered that material movements, excavation and engineering works associated with the development of Phase 7A adjacent to Phase 1 may have mobilised contaminants from the disperse and attenuate landfill area resulting in exceedances of the compliance limit. In general, ammoniacal nitrogen concentrations have fallen below the compliance limit since 2018 with only isolated exceedances since then. The limited exceedances at boreholes TH12 and TH13 in 2024 coincide with material movements, excavation and engineering works associated with the development of Phase 2 West. There is no evidence of a rising trend in ammoniacal nitrogen concentrations recorded in the groundwater at boreholes TH12, TH13 and TH19A.

7.16 Chloride concentrations in the groundwater at the down hydraulic gradient boreholes TH08, TH09, TH13, TH14, TH15 and TH26 are recorded at concentrations below the compliance limit of 250mg/l on all occasions during the review period. Chloride concentrations in the groundwater at the down hydraulic gradient boreholes TH12 and TH19A exceeded the compliance limit on one occasion over the review period with concentrations of 290mg/l recorded in September 2024 and 260mg/l recorded in January 2016 respectively. Chloride concentrations in the groundwater at the down hydraulic gradient borehole TH06 exceeded the compliance limit on three occasions between July 2023 and August 2024 with a maximum concentration of 480mg/l recorded in August 2024. Chloride concentrations in the groundwater at the down hydraulic gradient borehole TH05 fluctuate above and below the compliance limit over the review period. Chloride concentrations recorded in the groundwater at borehole TH05 and the fluctuation in concentrations are within the range recorded previously at the site.

7.17 Chloride concentrations are elevated at boreholes down hydraulic gradient of Phases 1 and 2 with interim compliance limits applying to boreholes TH10, TH11, TH17A and TH18A until the excavation of the waste is complete in Phases 1 and 2. Chloride concentrations in the groundwater at down hydraulic gradient borehole TH10 exceeded the interim compliance limit of 235mg/l between December 2014 and

November 2016 with a maximum concentration of 300mg/l last recorded in May 2016. Chloride concentrations in the groundwater at TH10 generally have been falling since 2016. Chloride concentrations in the groundwater at down hydraulic gradient boreholes TH11 and TH18A exceeded the interim compliance limits on one and two occasions respectively over the review period. No other exceedances of the chloride interim compliance limits were recorded in the groundwater down hydraulic gradient of Phases 1 and 2 over the review period.

7.18 Manganese concentrations exceed the compliance limit in the groundwater at the down hydraulic gradient boreholes TH15 and TH26 on four occasions over the review period consistent with groundwater quality recorded at the up hydraulic gradient boreholes. Manganese concentrations frequently exceed the compliance limit in the groundwater at the down hydraulic gradient boreholes TH05, TH06, TH12, TH13 and TH14. Frequent exceedances are recorded at borehole TH06, TH12 and TH13 between May 2015 and July 2021 and at boreholes TH05 and TH14 between February 2016 and November 2020. Frequent exceedances continue to be recorded in the groundwater at borehole TH13 with occasional exceedances recorded in the groundwater at boreholes TH05, TH06, TH12 and TH14 up until the end of the review period. Similar to ammoniacal nitrogen, it is considered that material movements, excavation and engineering works associated with the development of the site may have mobilised contaminants from the disperse and attenuate landfill area resulting in exceedances of the compliance limit for manganese recorded at boreholes TH12, TH13 and TH14. The fluctuation in manganese concentrations recorded in the groundwater at boreholes TH05 and TH06 are within the range recorded previously at these boreholes.

7.19 Phenol concentrations in the groundwater at all boreholes at the site are recorded at concentrations below the compliance limit of 0.046mg/l on all occasions during the review period.

7.20 Electrical conductivity values are elevated at boreholes down hydraulic gradient of Phases 1 and 2 with interim compliance limits applying to boreholes TH10, TH11, TH17A and TH18A until the excavation of the waste is complete in Phases 1 and 2. Electrical conductivity values recorded in the groundwater at down hydraulic gradient borehole TH11 frequently exceed the interim compliance limit of 2880µS/cm between July 2015 and August 2016 coinciding with Phase 7A construction works in 2015.

Electrical conductivity values recorded in the groundwater at borehole TH11 over the review period are within the range recorded previously at the borehole. Electrical conductivity values recorded in the groundwater at down hydraulic gradient boreholes TH17a and TH18a exceed the respective interim compliance limits of 1628µs/cm and 2670µs/cm on one occasion at each location over the review period in November 2017 and May 2018 respectively. No other exceedances of the electrical conductivity interim compliance limits were recorded in the groundwater down hydraulic gradient of Phases 1 and 2 over the review period.

7.21 Mecoprop concentrations are elevated at boreholes down hydraulic gradient of Phases 1 and 2 with interim compliance limits applying to boreholes TH10, TH11, TH17A and TH18A until the excavation of the waste is complete in Phases 1 and 2. Spuriously high mecoprop concentrations in the groundwater were recorded at a number of locations in February 2019 including at down hydraulic gradient boreholes TH11 and TH18A exceeding the respective interim compliance limits of 0.0421mg/l and 0.0072mg/l. Mecoprop concentrations in the groundwater at down hydraulic gradient borehole TH18a occasionally exceeded the interim compliance limit on a number of other occasions between May 2017 and January 2023 with a maximum concentration of 0.016mg/l recorded in January 2023. No other exceedances of the mecoprop interim compliance limits were recorded in the groundwater down hydraulic gradient of Phases 1 and 2 over the review period.

7.22 Sodium concentrations are elevated at boreholes down hydraulic gradient of Phases 1 and 2 with interim compliance limits applying to boreholes TH10, TH11, TH17A and TH18A until the excavation of the waste is complete in Phases 1 and 2. Sodium concentrations recorded in the groundwater at down hydraulic gradient boreholes TH10 and TH18a exceed the respective interim compliance limits of 180mg/l and 276mg/l on one occasion at each location over the review period in February 2016 and November 2017 respectively. Sodium concentrations in the groundwater at down hydraulic gradient borehole TH11 and TH17A occasionally exceeded the respective interim compliance limits over the review period. Sodium concentrations in the groundwater at down hydraulic gradient borehole TH11 exceeded the interim compliance limit of 555mg/l intermittently between May 2015 and February 2017 with a maximum concentration of 5130mg/l recorded in February 2016. The sodium concentrations recorded in the groundwater at borehole TH11 in February 2016 and 2017 and at borehole TH10 in February 2016 are spuriously high compared with the rest of the data set. Sodium concentrations in the groundwater at down hydraulic gradient borehole TH17A exceeded the interim compliance limit of 52mg/l intermittently on five occasions over the review period with a maximum concentration of 87mg/l recorded in November 2023.

Environmental Assessment Levels (EALs)

7.23 The EALs used in the 2014 HRA are presented in Table 1. All EALs were set based on minimum laboratory reporting values, laboratory detection limits, background groundwater quality, the DWS or EQS depending on which was more appropriate at the time that the 2014 HRA was prepared. The EAL for TCE of 0.00002mg/l is an error as the typical laboratory detection limit achieved for the groundwater up hydraulic gradient of the landfill areas is an order of magnitude higher than the EAL as indicated in Table 1. It is proposed that the compliance limit of TCE is raised from 0.00002mg/l to 0.0002mg/l consistent with the limit of quantification outlined in the 2016 UK Technical Advisory Group (UKTAG) on the Water Framework Directive Technical report on Groundwater Hazardous Substances[1]. The limit of quantification provided by UKTAG comprises the concentrations of the pollutant that can be reliably measured and quantified from samples of groundwater and above which it can be demonstrated that an input to groundwater has occurred. On this basis the EAL for TCE and consequently the compliance limit for TCE should be amended to 0.0002mg/l. Lead has been added to the 2024 updated HRA model runs to address improvement programme requirement IC8. Consistent with the approach in the 2014 HRA, the EAL for lead is set at the mean concentration recorded in groundwater up hydraulic gradient of the site (in boreholes TH1, TH2, TH3, TH4 and TH25) plus two standard deviations as the typical concentration in the groundwater is recorded above the detection limit. There are no other proposed revisions to the EALs presented in the 2014 HRA.

Surface water quality

7.24 The surface water quality compliance limits and control levels for the site are set out in Table HRA 11 of the 2014 HRA. The monitoring points at which the compliance limits and control levels should be applied are SWNEPOND, SWSLTAP, SWOFALL, SWTBECK, SWCHTRM, SWNEWT1, SWNEWT2 AND SWP4 (Figure 2). The

1 https://wfduk.org/sites/default/files/Media/UKTAG_Technical%20report_GW_Haz-Subs_ForWebfinal.pdf

surface water compliance limits are set out in Table S3.3 'Point source emissions to water (other than sewer) - emissions limits and monitoring requirements' of the EP for the site (reference 2). The surface water quality monitoring data collected between May 2014 and September 2024 have been reviewed and compared with the compliance limits set in 2014. An electronic copy of the surface water quality monitoring data reviewed is presented at Appendix B.

7.25 With the exception of spuriously high concentrations of chloride of 440mg/l and 380mg/l recorded in the surface water at monitoring point SWNEWT2 in June 2014 and September 2019 respectively the surface water quality at the monitoring points is below or within the permitted range of concentrations for pH, ammoniacal nitrogen and chloride over the review period. One or two exceedances of the suspended solids compliance limit of 40mg/l were recorded in the surface water at monitoring points SWNEPOND, SWCHTRM (SWCHP in dataset at Appendix B), SWNEWT2 and SWP4 in 2014. Intermittent exceedances of the suspended solids compliance limit were recorded in the surface water at monitoring point SWNEWT1 in 2017 and 2018. Marginal exceedances of the suspended solids compliance limit were recorded in the surface water on between one and three occasions at monitoring points SWNEPOND, SWCHTRM and SWP4 in 2019. Two exceedances of the suspended solids compliance limit were recorded in the surface water at monitoring points SWP4 in 2021. In general, the exceedances of the suspended solids compliance limit are recorded in water levels are low and the sampling has disturbed sediment from the base of the monitoring location. Sampling procedures have been revised at the site such that sample of surface water are only taken when a representative sample can be collected.

Conclusions of the review of monitoring

7.26 In general groundwater quality down hydraulic gradient of Thornhaugh Landfill is below the groundwater quality compliance limits. In general, where compliance limits are exceeded on a number of occasions it is considered that material movements, excavation and engineering works associated with the development of the landfill in the vicinity of Phases 1 and 2 may have mobilised contaminants from the disperse and attenuate landfill area. Any exceedances are intermittent with no sustained upward trends in concentrations recorded.

7.27 The EAL for TCE and consequently the compliance limit for TCE should be amended to 0.0002mg/l consistent with the UKTAG limit of quantification. It is recommended that the analytical methods used for the analysis of groundwater samples for TCE have LOD at or less than the compliance limits of 0.0002mg/l.

7.28 Pursuant to Improvement Programme Requirement IC7 the groundwater quality compliance limits and control levels for borehole TH26 have been reviewed and it is concluded that the limits set in Table HRA 9 of the 2014 HRA and in Table S3.4 of the EP for the site remain appropriate for groundwater quality at borehole TH26. The contingency action plan set out in Table HRA 9 of the 2014 HRA remains appropriate for groundwater quality at borehole TH26.

7.29 In general surface water quality at the monitoring locations at and downstream of the site is below the surface water quality compliance limits. The exceedances of the suspended solids compliance limit are occasional with no sustained exceedances recorded.

8. Conclusions

8.1 Based on the results of the review of the HRA for Thornhaugh Landfill Site it is considered that generally the information and data reviewed since the 2014 HRA was carried out is within the ranges used in the 2014 HRA or where the values are outside the ranges used in the HRA, it does not change significantly the results of the HRA. The LandSim model which forms part of the 2014 HRA has been re-run to include the increase in concentration of the non-hazardous pollutants ammoniacal nitrogen, chloride and manganese in the source term. A sensitivity analysis on the hydraulic conductivity of the clay component of the landfill liner in Phases 1, 2, 4 and 7 has been carried out.

8.2 The HRA review includes consideration of the properties of the new waste types:10 01 14*, 12 01 16*, 16 07 09*, 16 11 03*, 19 01 11* in any cell for SNRHW consistent with improvement programme requirement IC8. Where the Waste Acceptance Criteria (WAC) for Stable Non-reactive hazardous waste (SNR) accepted at landfills for non-hazardous waste for a selection of metal hazardous substances are higher than the source term modelled for a hazardous metal, the results of the approved HRA models are orders of magnitude lower than the EAL for all phases where the new waste steam/ waste codes will be deposited. As such it is considered that the results of the approved HRA models show that there is not an unacceptable risk to groundwater from the selection of metal hazardous substances at the SNR WAC limits and it is not necessary to carry out further HRA modelling. All other SNR WAC limits are within the range of the comparative HRA source term concentrations modelled. As a precaution lead, comprising the hazardous substance metal with the highest concentration recorded in the WAC testing results provided by Augean, has been added to the source term and the approved 2014 HRA model has been re-run. A sensitivity analysis on the concentration of lead in the source term in Phases 1, 2, 4 and 7 has been carried out.

8.3 Based on the results of the re-run LandSim models and the sensitivity analyses, as discussed in Section 5, it is considered that the results of the models do not change the conclusions of the 2014 HRA. Consequently, it is considered that the modelled impact of the site on groundwater as demonstrated in the 2014 HRA complies with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016.

8.4 The groundwater and surface water compliance limits set in 2014 have been compared with the concentrations of determinands recorded in the groundwater and surface water at the site. In general groundwater quality down hydraulic gradient of the site and surface water quality at and downstream of the site are below the respective water quality compliance limits with no sustained upward trends in concentrations recorded. In general, where groundwater compliance limits are exceeded on a number of occasions it is considered that material movements, excavation and engineering works associated with the development of the landfill in the vicinity of Phases 1 and 2 may have mobilised contaminants from the disperse and attenuate landfill area with short term effects on groundwater quality only.

8.5 The EAL for TCE and consequently the compliance limit for TCE should be amended to 0.0002mg/l consistent with the UKTAG limit of quantification. It is recommended that the analytical methods used for the analysis of groundwater samples for TCE have LOD at or less than the compliance limits of 0.0002mg/l.

8.6 Pursuant to Improvement Programme Requirement IC7 the groundwater quality compliance limits and control levels for borehole TH26 have been reviewed and it is concluded that the limits set in Table HRA 9 of the 2014 HRA and in Table S3.4 of the EP for the site remain appropriate for groundwater quality at borehole TH26. The contingency action plan set out in Table HRA 9 of the 2014 HRA remains appropriate for groundwater quality at borehole TH26.

8.7 Based on the results of the review of the 2014 HRA including the monitoring data presented in this report it is considered that Thornhaugh Landfill Site remains compliant with Schedule 22 to the Environmental Permitting (England and Wales) Regulations 2016.

9. References

1. MJCA, 2014. An application to vary Environmental Permit No RP3133PP for the Thornhaugh Landfill Site operated by Augean South Limited to extend the area of the existing permitted site. Hydrogeological Risk Assessment Report. Report reference: AU/TH/JRC/2826/01/HRA.

2. Thornhaugh Landfill Site. Environmental Permit number EPR/RP3133PP/V006 dated 04 May 2016.

3. MJCA, 2014. An application to vary Environmental Permit No RP3133PP for the Thornhaugh Landfill Site operated by Augean South Limited to extend the area of the existing permitted site. Environmental Setting and Installation Design Report. Report reference: AU/TH/MAS/5477/01/ESID.

4. Environmental Simulations International Limited, 2009. Thornhaugh Landfill: 4 yearly HRA review and response to Improvement Condition 16. Report reference 60194R1 dated March 2009.

5. Environmental Simulations International Limited, 2004. Hydrogeological risk assessment report Thornhaugh Quarry. Report reference 6453HRA1 dated November 2004.

6. MJCA, 2015. Application number: EPR/RP3133PP/V006 – Response to the notice of request for further information dated 19 March 2015 for Thornhaugh Landfill Site. Email to Päivi Porali-Perrell of the EA dated 5 May 2015. Response to a request for further information.

7. MJCA, 2015. Application Number: EPR/RP3133PP/V006 – Response to the notice of request for further information dated 16 July 2015 for Thornhaugh Landfill Site. Email to Päivi Porali-Perrell of the EA dated 25 August 2015. Response to a request for further information.

8. TerraConsult, 2017. Thornhaugh Landfill Site – Cell 4 Construction Works Validation Report. Report 3369-R2-1.

9. MJCA, 2020. CQA completion report for the preparation for landfilling of Phase 4B North at Thornhaugh Landfill Site. Report reference: AU/TH/LCH/3227/01.

10. MJCA, 2021, CQA completion report for the preparation for landfilling of Phase 4C at Thornhaugh Landfill Site. Report reference: AU/TH/LCH/3233/01.

11. MJCA, 2015. CQA completion report for the preparation for landfilling of Phase 7A at Thornhaugh Landfill Site. Report reference: AU/TH/LCH/3184/01.

12. MJCA, 2023. CQA completion report for the preparation for landfilling of Phase 7C at Thornhaugh Landfill Site. Report reference: AU/TH/LCH/3242/01.

13. MJCA, 2024. CQA completion report for the preparation for landfilling of Phase 2 West at Thornhaugh Landfill Site. Report reference: AU/TH/LCH/3242/01.

14. Augean South Limited. 2024. Leachate Monitoring Action Plan Thornhaugh (TH) to compliment permit EPR/RP3133P. Document dated December 2024.

15. MJCA, 2020. Construction Quality Assurance Verification report for the installation of groundwater and landfill gas monitoring borehole TH26 at Thornhaugh Landfill Site. Environmental Permit Number EPR/RP3133PP/V006. Report reference AU/TH/ML/2981/01CQAVR dated February 2020.

TABLES

Table 1

Comparison of the leachate source term used in the 2014 HRA with the results of the leachate quality monitoring carried out between May 2014 and June 2024

Determinand	Unit	Phase	Environmental Assessment level (EAL) in 2014 HRA	2014 HRA source term concentration (mg/l)			Leachate concentration recorded between May 2014 and June 2024			
				Minimum	Most likely	Maximum	Minimum	Mean	Maximum	Count
Hazardous substances										
MTBE[a] (Xylene)	mg/l	All	0.001	0.0078	0.034	0.35	- (0.002)	- (0.015)	- (0.135)	All results <LOD (72)
Cadmium[b]	mg/l	All except 5	0.00032	0.003	0.0065	0.035	0.00003	0.0012	**0.0530**	197
		5		0.003	0.0083	0.36	0.00003	0.00046	0.0054	169
Naphthalene	mg/l	All	0.00045	0.00087	0.028	2	0.00005	0.0056	**0.29**	156
Trichloroethene[c]	mg/l	All	0.00002 (0.0002)	0.00029	0.027	0.27	**0.001**	0.001	0.001	All results <LOD
Lead[d]	mg/l	All	0.051				**0.00165**	**0.072**	**1.923**	360
Non-hazardous pollutants										
Ammoniacal nitrogen[e]	mg/l	All except 5	0.39	51	200	600	0.5	**309**	**1,601**	283
		5		51	260	1,300	0.7	**273**	**2,320**	274
Chloride[f]	mg/l	All except 5	250	440	1,100	4,500	3.1	**1,870**	**8,900**	270
		5		440	5,800	54,000	2.5	**9,679**	**72,000**	264
Manganese[g]	mg/l	All	0.22	0.16	1.2	17	0.002	**4.6**	**272.85**	369
Phenol	mg/l	All	0.046	0.01	0.24	15	0.00001	0.12	3.4	140

Notes:

While cadmium, MTBE and naphthalene have been reclassified as non-hazardous pollutants, it is assumed that cadmium, MTBE and naphthalene are hazardous substances for the purpose of this HRA review.

BOLD denotes the concentration recorded in the leachate that exceed those used in the LandSim models in the 2014 HRA and are used in the 2024 updated HRA model runs.

[a] The HRA review comparison data for MTBE from May 2014 to June 2024 comprise annual hazardous substances suites for 2017, 2018, 2019, 2020 and 2021. It is understood that MTBE has not been included in the annual suite since 2021. All results over the review period were recorded as less than the laboratory analytical limit of detection (<LOD).

[b] The 2014 HRA source term included data up to November 2014 for cadmium. The HRA review comparison data for cadmium are from February 2015 to June 2024.

[c] The HRA review comparison data for trichloroethene from May 2014 to June 2024 comprise annual hazardous substances suites for 2015, 2017, 2018, 2019, 2020, 2021, 2022, 2023, and 2024. All results were recorded as <LOD. The EAL for TCE should be amended to 0.0002mg/l consistent with the UKTAG limit of quantification (see section 7 of the 2024 HRA Review).

[d] Lead has been added to the 2024 updated HRA model runs to address improvement programme requirement IC8. Consistent with the 2014 HRA, the minimum source term concentration comprises the 25th percentile of the available leachate data for dissolved lead. The most likely comprise the average value of the data. The maximum concentration comprises the maximum value from the data plus 20%. The EAL is set at the mean concentration recorded in groundwater up hydraulic gradient of the site (in boreholes TH1, TH2, TH3, TH4 and TH25) plus two standard deviations as the typical concentration in the groundwater is recorded above the detection limit.

[e] The HRA review comparison data for ammoniacal nitrogen from May 2014 to June 2024 excludes data for August 2020 which comprised elevated concentrations at the majority of locations with concentrations recorded before and after August 2020 within the range recorded previously.

[f] The HRA review comparison data for chloride from May 2014 to June 2024 excludes data Phase 4C for May 2020 and data for Phases 4B north and 4B South for August 2022 which comprised elevated concentrations with all concentrations recorded before, where relevant, and after within the range recorded previously.

[g] The HRA review comparison data for manganese from May 2014 to June 2024 excludes data for May 2018 and February 2021 which comprised elevated concentrations at the majority of locations with concentrations recorded before and after these dates within the range recorded previously.

Table 2A
HRA Source term values for comparison with WAC data for new waste streams/ Waste codes

Determinand All units in mg/l	HRA Source Term (mg/l)[1] Minimum	Most likely	Maximum	Description modelled as
Cadmium (All except Phase 5)	0.003	0.0065	0.035	Hazardous substance - metal
Cadmium (Phase 5)	0.003	0.0083	0.36	
Chloride (All except Phase 5)	440	1100	4500	Non-hazardous pollutant – inorganic anion
Chloride (Phase 5)	440	5800	54000	
Manganese (All Phases)	0.16	1.2	17	Non-hazardous pollutant - metal

Notes:
1 Source term concentrations taken from Table HRA 1 (REVISED) presented in Schedule 1 to the response dated 25 August 2015 to the Schedule 5 Notice dated 16 July 2015 during the determination period of the 2014 Environmental Permit variation application (Appendix A)

Table 2B
Comparison of WAC data for new waste streams/ waste codes with HRA Source term values

Determinand All units in mg/l	SNR WAC[1]	Data excluding spurious results[2] Mean	Maximum	HRA source term description compared with[3]
As[4]	0.2			Hazardous substance - metal
Ba	10			Non-hazardous pollutant - metal
Cd	0.1	0.006	0.15	Hazardous substance - metal
Cd[5]	0.1	0.006	0.15	Non-hazardous pollutant - metal
Cr[6] (Leachable)	1	0.81	2.8	Hazardous substance - metal
Cr[6] (Leachable)	1	0.81	2.8	Non-hazardous pollutant - metal
Cr[6] (Total)	1	13.9	34.3	Hazardous substance - metal
Cr[6] (Total)	1	13.9	34.3	Non-hazardous pollutant - metal
Cu	5	0.01	0.05	Non-hazardous pollutant - metal
Hg	0.02			Hazardous substance - metal
Mo	1			Non-hazardous pollutant - metal
Ni	1	0.01	0.084	Non-hazardous pollutant - metal
Pb	1	0.33	6.2	Hazardous substance - metal
Sb	0.07			Non-hazardous pollutant - metal
Se	0.05			Non-hazardous pollutant - metal
Zn	5	0.76	44.0	Non-hazardous pollutant - metal
Chloride	1500			Non-hazardous pollutant – inorganic anion
Fluoride	15			Non-hazardous pollutant – inorganic anion
Sulphate	2000	549	2300	Non-hazardous pollutant – inorganic anion
DOC	80			
TDS[7]	6000	2205	6700	

Notes:

1 Waste Acceptance Criteria (WAC) liquid to solid ratio 10 l/kg leaching limit values expressed in mg/l for Stable Non-reactive hazardous waste accepted at landfills for non-hazardous waste presented in the Council decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC. Official Journal of the European Communities. 2003/33/EC
2 Statistics for WAC liquid to solid ratio 10 l/kg leaching values expressed in mg/l for 136 samples of new waste streams/ waste codes for select substances omitting the results for samples 722007 and 920235 identified by Augean as outliers in the data provided
3 Hazardous substance – metal compared with cadmium source term values, Non-hazardous pollutant – inorganic anion compared with chloride source term values and Non-hazardous pollutant – metal compared with manganese source term values in Table 2A
4 Arsenic is a metalloid but will behave similarly in the environment to cadmium, the Hazardous substance – metal modelled in the HRA
5 In 2014 cadmium was classified as a hazardous substance. While cadmium is modelled as a hazardous substance in the HRA, since 2014 cadmium has been downgraded to a non-hazardous pollutant. For completeness the data for cadmium has been compared with Non-hazardous pollutant – metal source term used in the HRA.
6 The SNR WAC for chromium is for total chromium. Information for leachable and total chromium were provided by Augean for the samples of new waste streams/ waste codes hence both are presented in Table 2B. Chromium VI is classified as a hazardous substance hence the data have been compared with the Hazardous substance – metal source term used in the HRA. Chromium III is classified as a non-hazardous pollutant hence the data have been compared with the Non-hazardous pollutant – metal source term used in the HRA.
7 Total dissolved solids (TDS) may be used alternatively to the values for chloride and sulphate

(dark grey shading)	Exceeds maximum concentration used in the HRA Source Term
(light grey shading)	Within the HRA Source Term concentrations modelled for Phase 5 only

Table 3A
Parameters relevant to the determinands in the leachate source term

Determinand	Kappa value constants		Reference / justification
	m (kg/l)	c (kg/l)	
Hazardous substances			
Lead	0.0443	0.0171	LandSim default

Table 3B
Input parameters for the LandSim hydrogeological risk assessment model – chemical and attenuation properties

Parameter	Pathway (CL = clay liner, NSF=Northampton sand Formation)	K_d (l/kg)		
		Minimum	Most likely	Maximum
Hazardous substances				
Lead	**CL**[1]		434.6	
	NSF	*27*	*270*	*27000*

Notes:
Probability density functions key:

- Unshaded: single value
- Numbers in italics: log distributions (triangular or uniform).

Derivation of parameter values:
The Kd values for lead are taken from Golder Associates. ConSim 2 help file

Table 4

A comparison of the values of the parameters used in the 2014 HRA with the information presented in the CQA reports for the construction of the landfill basal liner for Phase 4B South, Phase4B North, Phase 4C, Phase 7A, Phase 7C and Phase 2 West

Parameter	Unit	Phase	Values used in the 2014 HRA models			Values based on information presented in the CQA reports for the construction of Phases 4B South, 4B North and 7A			
			Minimum	Most likely	Maximum	Minimum	Mean	Maximum	Source/justification
Thickness	m	Phase 4B South[a]		0.5		0.56		0.72	The thickness is based on the surveyed thickness of the mineral liner presented in the CQA reports for the construction of Phase 4B South, Phase 4B North, Phase 4C, Phase 7A, Phase 7C and Phase 2 West.
		Phase 4B North				1.08		1.21	
		Phase 4C				1.05		1.28	
		Phase 7A[a]				0.55		0.63	
		Phase 7C				1.04		1.13	
		Phase 2 West				1.04		1.55	
Hydraulic conductivity	m/s	Phase 4B South	5.1×10^{-11}	6.9×10^{-11}	1.6×10^{-10}	4.0×10^{-11}	1.0×10^{-10}	6.7×10^{-10}	Based on vertical permeability values in the CQA reports for the construction of Phase 4B South, Phase 4B North, Phase 4C, Phase 7A, Phase 7C and Phase 2 West. Mean values are geometric mean.
		Phase 4B North				8.1×10^{-11}	1.1×10^{-10}	9.5×10^{-10}	
		Phase 4C				3.8×10^{-11}	1.6×10^{-10}	5.3×10^{-10}	
		Phase 7A				6.5×10^{-11}	1.9×10^{-10}	5.8×10^{-10}	
		Phase 7C				1.4×10^{-11}	4.2×10^{-11}	4.6×10^{-10}	
		Phase 2 West				9.8×10^{-12}	3.1×10^{-11}	1.4×10^{-10}	
		Combined[b]				8.6×10^{-11}	1.3×10^{-10}	3.6×10^{-10}	Sensitivity analysis data – Phases 4B (N&S), 4C & 7A combined (see Sections 3 and 5 of the report)
Dry density	g/cm³	Phase 4B South	1.55	1.68	1.77	1.59	1.68	1.72	Based on the calibrated core dry bulk density values in the CQA reports for the construction of Phase 4B South, Phase 4B North, Phase 4C, Phase 7A, Phase 7C and Phase 2 West
		Phase 4B North				1.56	1.68	1.76	
		Phase 4C				1.59	1.71	1.79	
		Phase 7A				1.56	1.69	1.84	
		Phase 7C				1.62	1.72	1.81	
		Phase 2 West				1.62	1.72	1.78	
Moisture content	% expressed as a decimal	Phase 4B South	0.14		0.25	0.17		0.23	Based on the calibrated core moisture content values in the CQA reports for the construction of Phase 4B South, Phase 4B North, Phase 4C, Phase 7A, Phase 7C and Phase 2 West
		Phase 4B North				0.18		0.25	
		Phase 4C				0.18		0.24	
		Phase 7A				0.11		0.28	
		Phase 7C				0.15		0.22	
		Phase 2 West				0.18		0.24	

Notes

[a] A 6mm Geosynthetic Clay Liner (GCL) was placed above the clay liner before installation of the HDPE geomembrane liner.
[b] The minimum is the lowest quartile, the mean is the geometric mean and the maximum is the 90th percentile of the combined dataset from Phases 4B South, 4B North and 7A

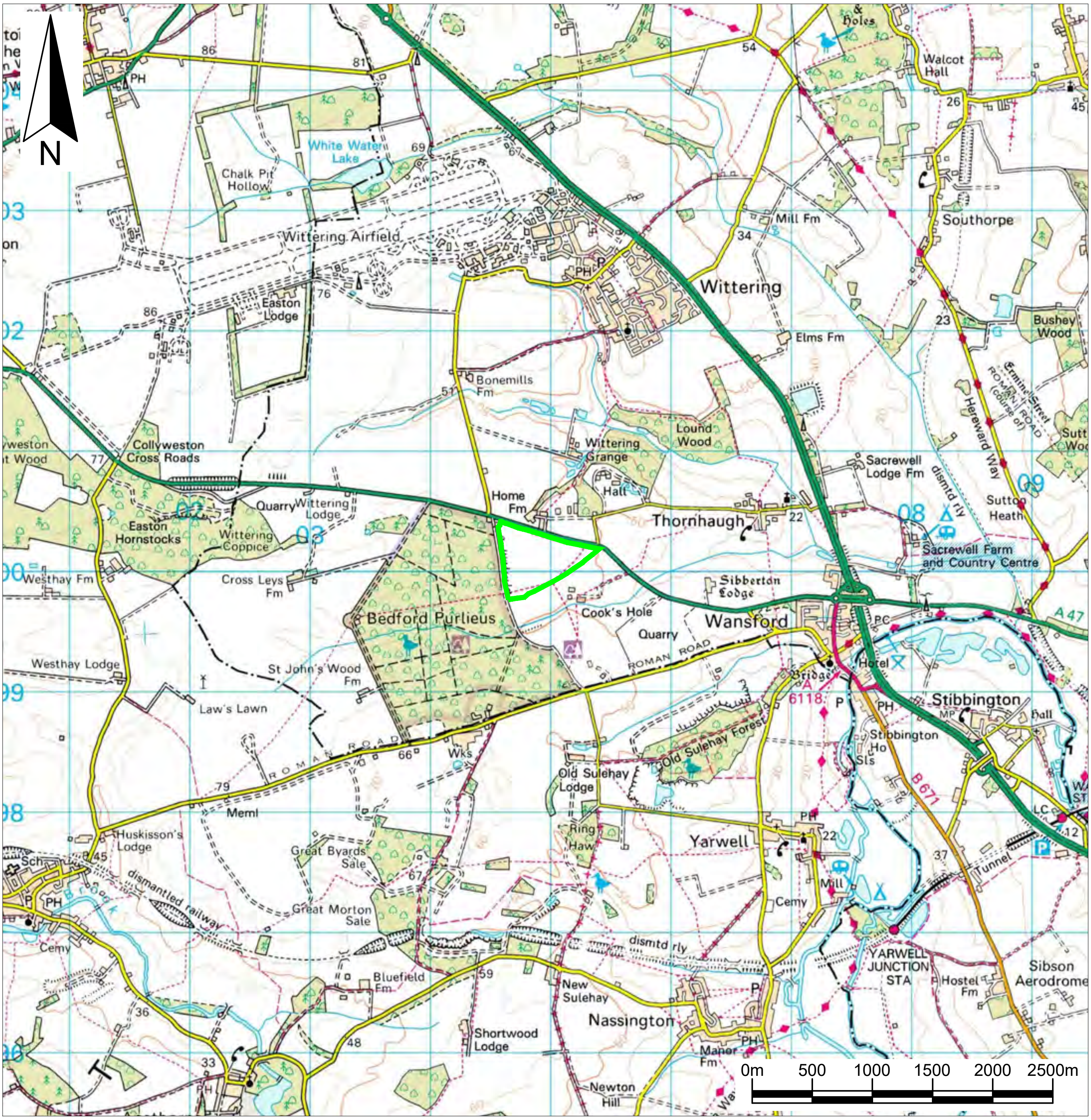
Table 5

Results of the re-run HRA review LandSim model for the hazardous substance lead and the non-hazardous pollutants ammoniacal nitrogen, chloride and manganese at Thornhaugh Landfill Site

Determinand	Phases contributing to the predicted receptor concentration	Environmental Assessment Level (EAL) (mg/l)[1]	Time taken for breakthrough at the 95th percentile (years)[2]	Time taken to exceed the EAL at the 95th percentile (years)[3]	Maximum concentration at the 95th percentile [4]	Time taken for breakthrough at the 50th percentile (years)[2]	Time taken to exceed the EAL at the 50th percentile (years)[3]	Maximum concentration at the 50th percentile [4]
Hazardous Substance								
Lead	1 (west and East) and 7A	0.051 (5.1×10^{-2})						
	2 (West and East)							
	3							
	4B (North and South), 4c (North and South), 7B and 7C							
	5 (North, South and the extension)		9,200		1.8×10^{-6}	16,600		1.5×10^{-9}
	6 (A and B)		16.900		1.2×10^{-9}			
Non-hazardous pollutants								
Ammoniacal nitrogen	All	0.39	85		0.133	220		0.008
Chloride	All	250	25		164	45		45
Manganese	All	0.22	3,100		0.10	11,700		0.002

Notes:
The concentrations for hazardous substances are those predicted at the monitoring point adjacent to the boundary of the phase.
The concentrations for non-hazardous pollutants are those predicted at the site boundary from the cumulative impact of all cells
[1] The EALs are explained in section 1.2 of the 2014 report, in Table HRA 1 (REVISED) and in Table 1.
[2] Where the time taken for the breakthrough of a contaminant is not shown there is no breakthrough of the contaminant over the 19,999 years modelled.
[3] Where the time taken to exceed the EAL is not shown there is no exceedance of the EAL over the 19,999 years modelled.
[4] Where the maximum concentration is not shown there is no concentration reported in the results of the model above 1×10^{-10}mg/l

FIGURES



Key / Notes

Approximate boundary of Environmental Permit number EPR/RP3133PP for Thornhaugh Landfill Site

Rev	Status	Drn	App	Chk	Date
	Final	KR	ML	JRC	20/12/24

Site
THORNHAUGH LANDFILL

Client
Augean

Title
The site location

Figure 1

Scale
1:50,000@A4

Drawing Ref
AU/TH/10-21/22809

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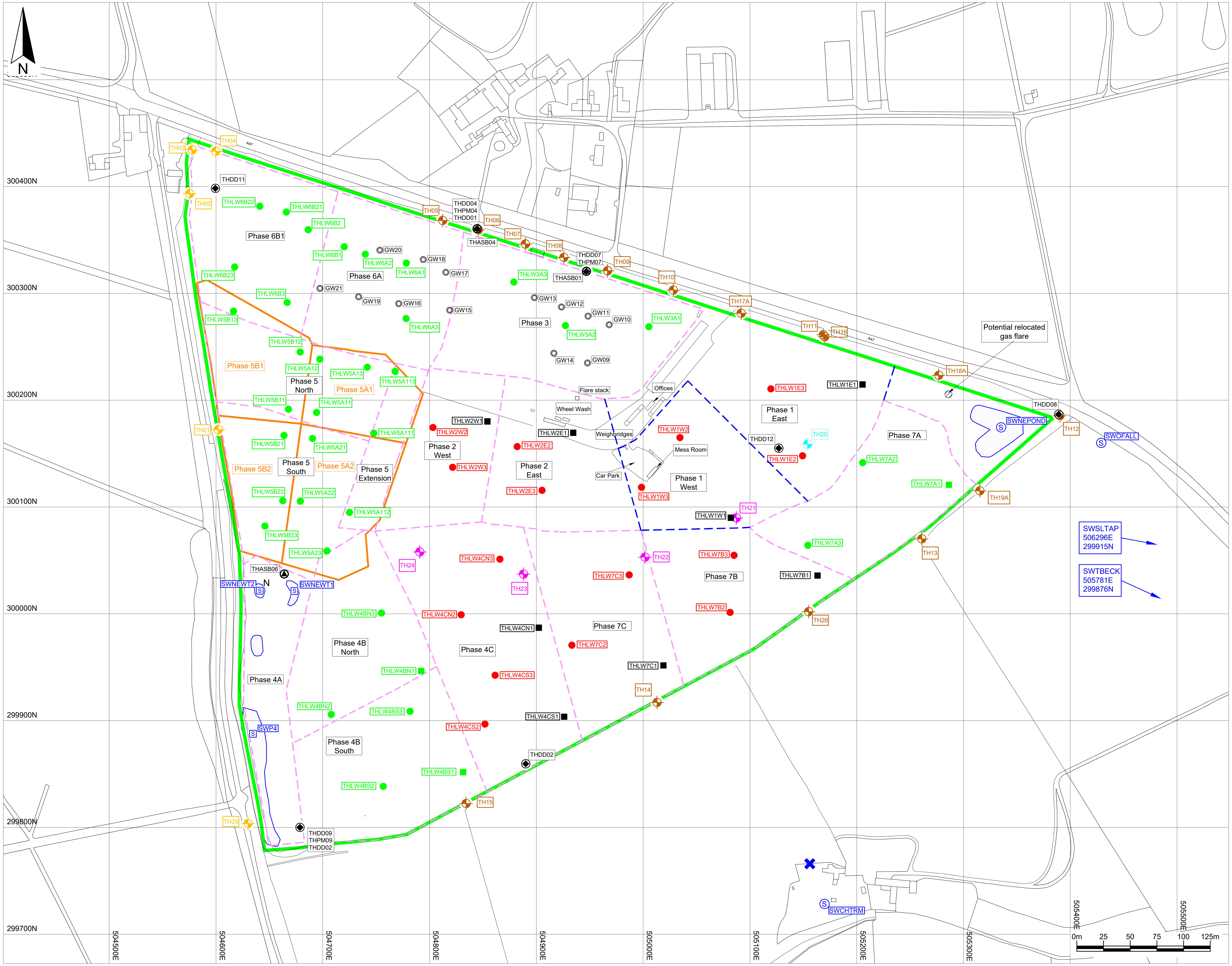

Key / Notes

Approximate boundary of Environmental Permit number EPR/RP3133PP for Thornhaugh Landfill site

Approximate existing phase boundaries

Approximate future phase boundaries

Approximate location of monocells in Phase 5 based on Faber Maunsell drawing number DWG/44879/1 dated 29 November 2004

Location of a leachate well and in waste landfill gas monitoring location

Location of an up hydraulic gradient groundwater and landfill gas monitoring borehole

Location of a down hydraulic gradient groundwater and landfill gas monitoring borehole

Location of a groundwater and landfill gas monitoring borehole that will be decommissioned as part of the development

Approximate location of a proposed leachate sump and in waste landfill gas monitoring location

Approximate location of a proposed leachate monitoring well and in waste landfill gas monitoring well

Approximate location of a gas well

Approximate location of Cook's Hole Spring

Location of a surface water monitoring point

Location of a surface water monitoring point in an isolated pond

Location of a particulate matter monitoring point

Location of an asbestos monitoring point

Location of a former groundwater and landfill gas monitoring borehole decommissioned as part of the development

Location of a leachate sump and in waste landfill gas monitoring location

Notes:
The proposed phasing shown is approximate and, while the principles and order of phasing are unlikely to change, phase boundaries and haul routes may change in response to operational conditions.

Rev	Status	Drn	App	Chk	Date
	Final	KR	JJG	JRC	20/12/24

Site: THORNHAUGH LANDFILL

Client: Augean

Title: Monitoring and Emission Point Plan (MEPP)

Figure 2

Scale: 1:2,500@A2

Drawing Ref: AU/TH/11-24/24636

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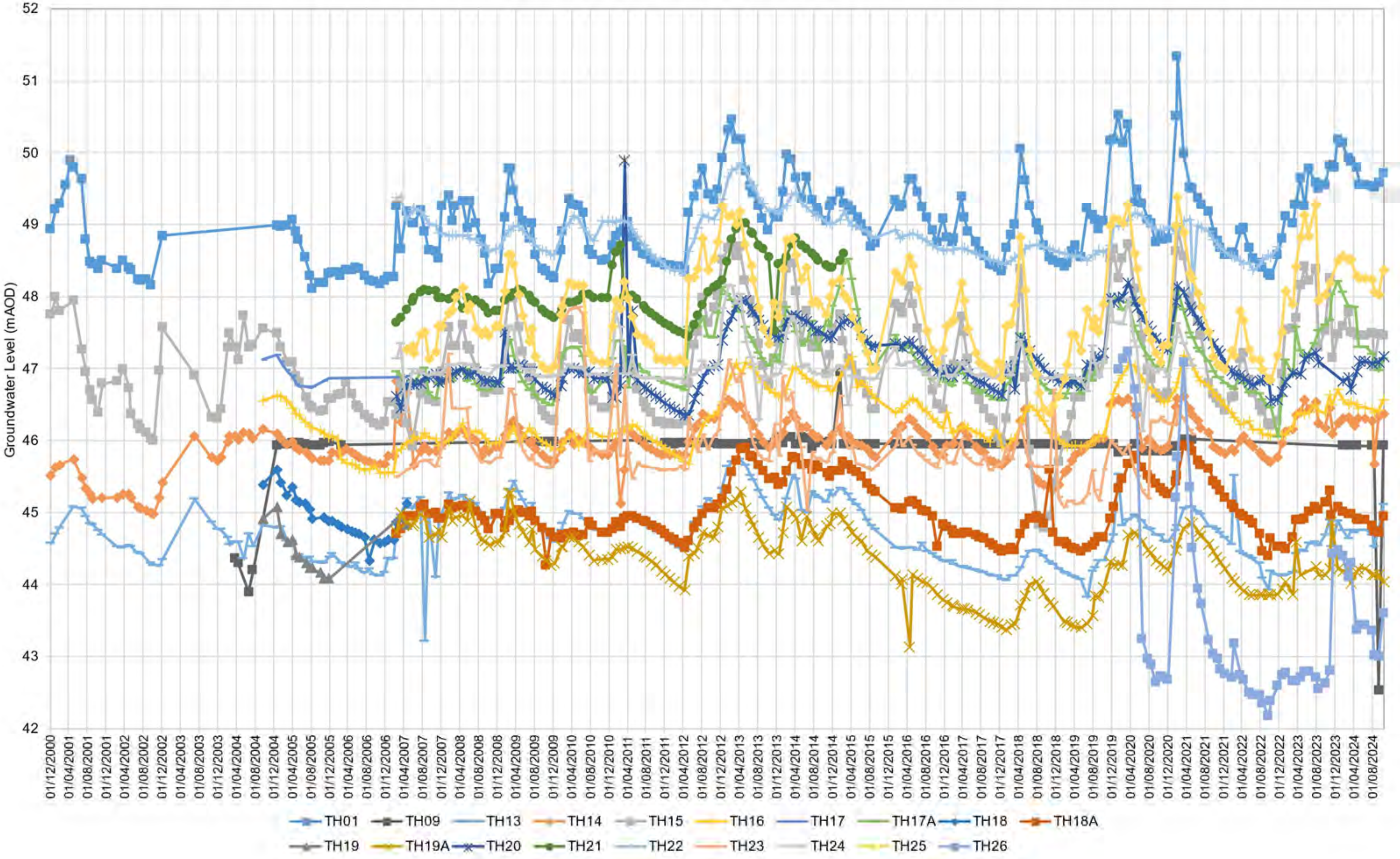
Figure 3a - Hydrograph showing groundwater levels recorded at Thornaugh Landfill between December 2000 and October 2024
Boreholes in the centre and south of the site



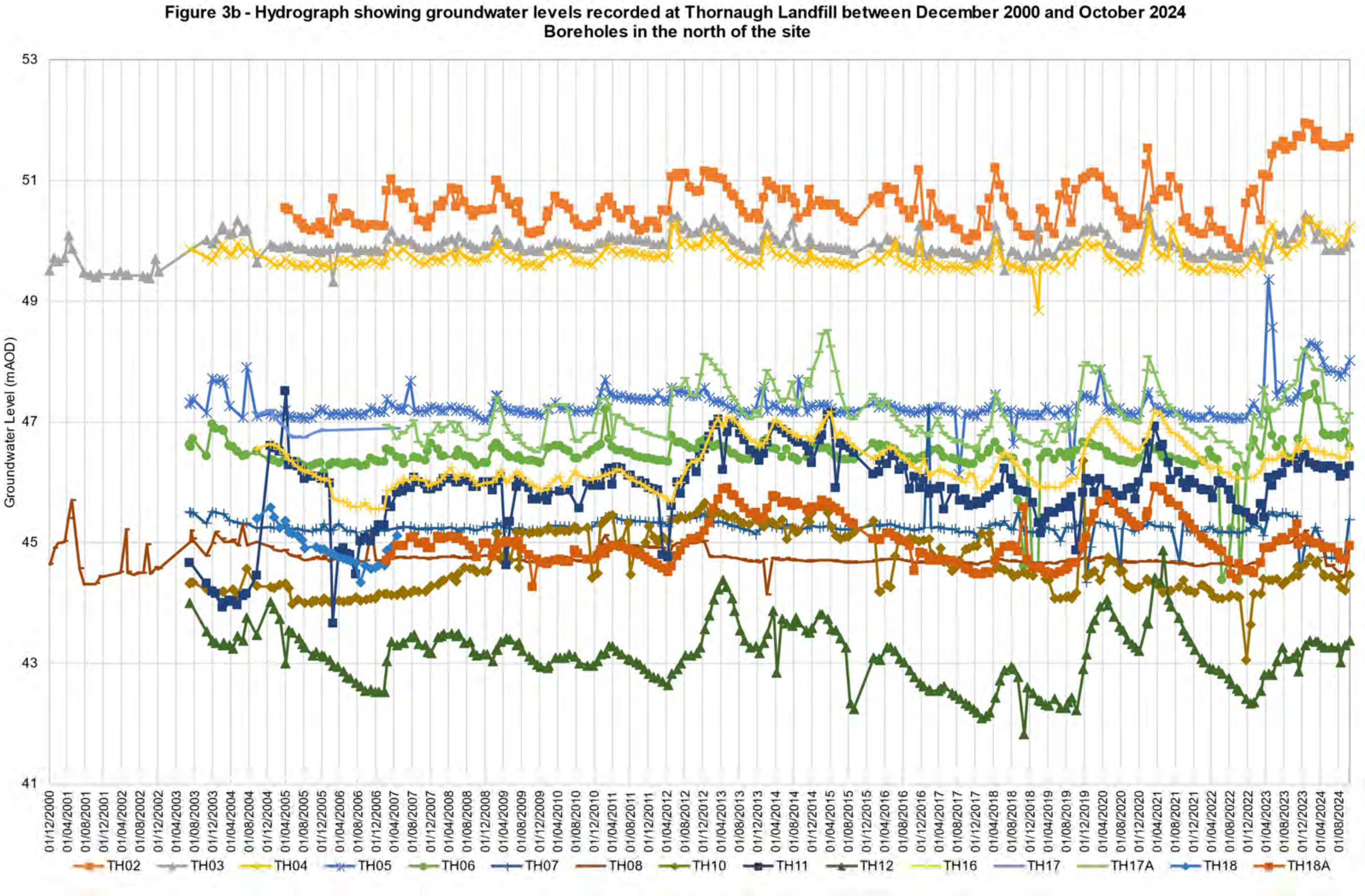
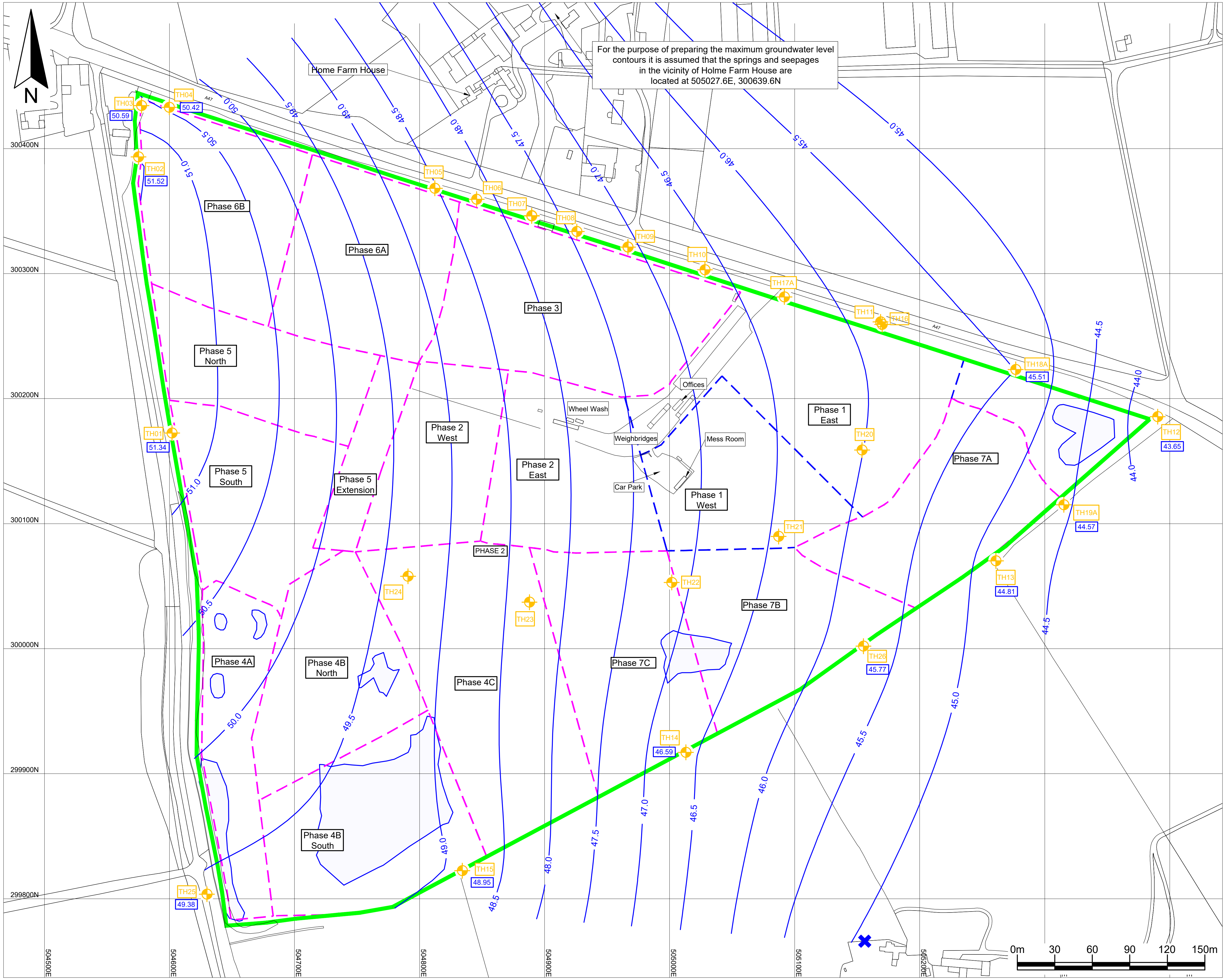


Figure 3b - Hydrograph showing groundwater levels recorded at Thornaugh Landfill between December 2000 and October 2024
Boreholes in the north of the site
Groundwater Level (mAOD)
53
51
49
47
45
43
41
TH02
TH03
TH04
TH05
TH06
TH07
TH08
TH10
TH11
TH12
TH16
TH17
TH17A
TH18
TH18A



Key / Notes

- Approximate boundary of Environmental Permit number EPR/RP3133PP for Thornhaugh Landfill site
- Approximate existing phase boundaries
- Approximate future phase boundaries
- TH01 — Location of a groundwater monitoring borehole
- Approximate location of Cook's Hole Spring
- 48 — Interpolated groundwater levels mAOD
- 51.34 — Groundwater levels recorded in February 2021

Note:
The proposed phasing shown is approximate and, while the principles and order of phasing are unlikely to change, phase boundaries and haul routes may change in response to operational conditions.

The interpolated groundwater levels are based on groundwater levels recorded in boreholes TH01, TH02, TH03, TH04, TH12, TH13, TH14, TH15, TH18, TH19 and TH25 in February 2021 which comprises a date when groundwater levels at each borehole were closest to or at their respective highest levels (mAOD) together with the levels of Cook's Hole Spring and the springs and seepages in the vicinity of Home Farm House presented on Figure 2.5 of the report entitled "Thornhaugh Landfill Groundwater Impact Assessment" dated March 2012 prepared by RUKhydro Limited.

Rev	Status	Drn	App	Chk	Date
	Final	KR	JJG	JRC	20/12/24

Site
THORNHAUGH LANDFILL

Client
Augean

Title
Groundwater level contours interpolated from groundwater levels recorded in February 2021

Figure 4 | Scale 1:3,000@A3

Drawing Ref
AU/TH/12-24/24675

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Figure 5a
Leachate levels recorded in the leachate monitoring wells at Thornhaugh Landfill between January 2014 and September 2024

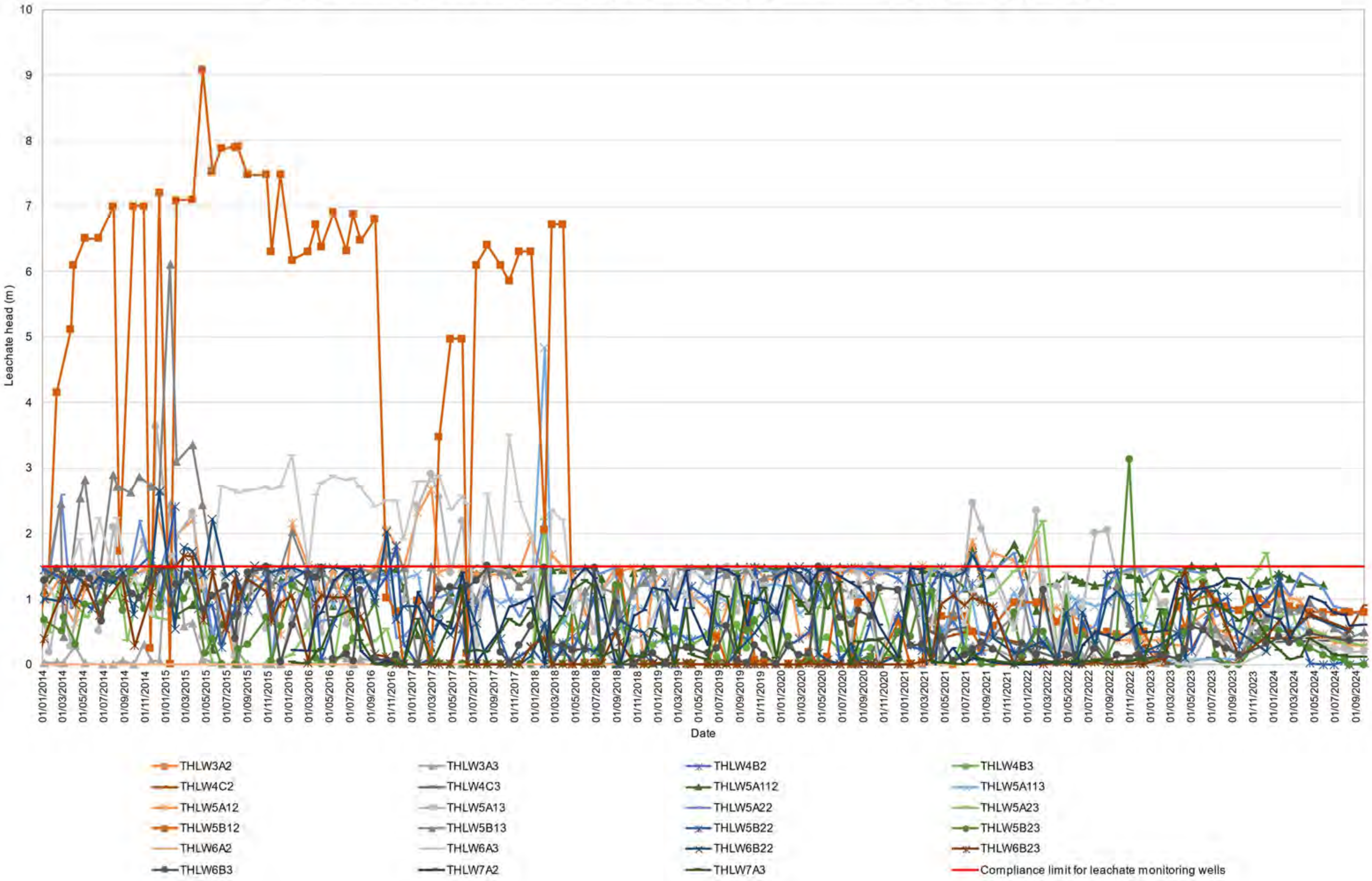
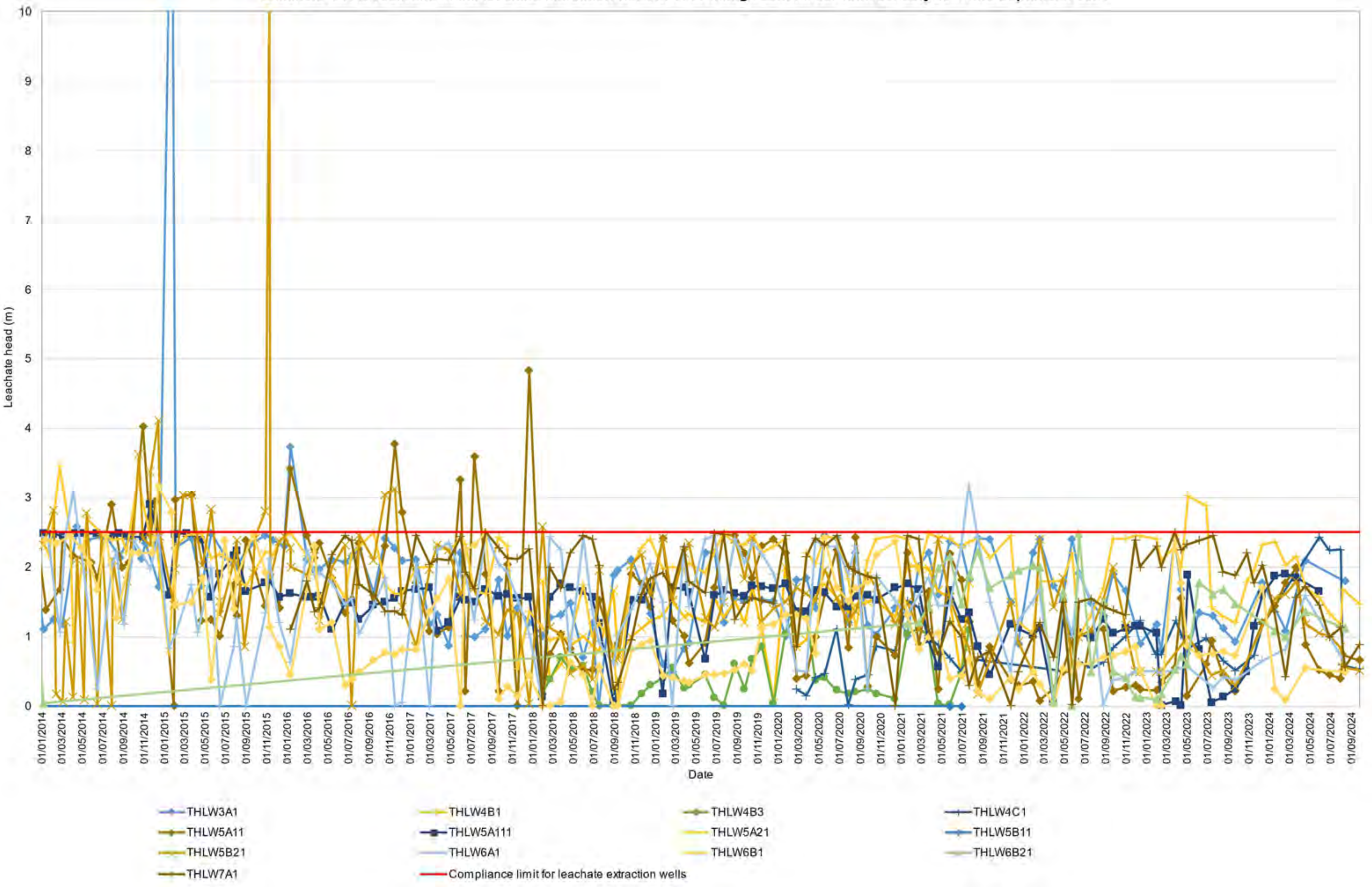


Figure 5b
Leachate levels recorded in the leachate extraction wells at Thornhaugh Landfill between January 2014 and September 2024



APPENDICES

APPENDIX A

A COPY OF TABLE HRA 1 (REVISED), TABLE HRA 3 (REVISED),TABLE 5 (THIRD REVISION) AND TABLE HRA 6 (REVISED) PRESENTED TO THE ENVIRONMENT AGENCY WITH RESPONSES TO REQUESTS FOR FURTHER INFORMATION IN RESPECT OF THE 2014 APPLICATION TO VARY THE EP (REFERENCES 6 AND 7)

Table HRA 1 (REVISED)

Leachate source term and Environmental Assessment Levels used in the hydrogeological risk assessment

Determinand	Unit	Phase	Values and the probabilistic density function used in the LandSim model				Environ-mental assessment level (EAL)	Description
			Minimum	Most likely	Maximum	Probabilistic density function		
Hazardous substances								
MTBE	**mg/l**	All	0.0078	0.034	0.35	Log triangular	0.001 [a]	Soluble volatile organic compound
Cadmium [g]	**mg/l**	All except 5	0.0030	0.0065	0.035	Log triangular	0.00032 [b]	Inorganic metallic cation
		5	0.0030	0.0083	0.36			
Naphthalene	**mg/l**	All	0.00087	0.028	2.0	Log triangular	0.00045 [c]	Hydrophobic semi-volatile organic compound
Trichloroethene	**mg/l**	All	0.00029	0.027	0.27	Log triangular	0.00002 [af]	Hydrophobic volatile organic compound and organohalogen
Non hazardous pollutants								
Ammoniacal nitrogen [e]	**mg/l**	All except 5	51	200	600	Log triangular	0.39 [d]	Inorganic cation
		5	51	260	1,300			
Chloride [e]	**mg/l**	All except 5	440	1,100	4,500	Log triangular	250 [d]	Inorganic anion
		5	440	5,800	54,000			
Manganese	**mg/l**	All	0.16	1.2	17	Log triangular	0.22 [c]	Inorganic metallic cation
Phenol	**mg/l**	All	0.010	0.24	15	Log triangular	0.046 [d]	Hydrophilic semi-volatile organic compound

Notes:

Except where indicated the source term values are based on the leachate concentrations recorded in Phases 3, 5 and 6 of Thornhaugh Landfill between March 2006 and April 2014. The minimum comprise the 25th percentile of the data. The most likely comprise the average values of the data. The maximum comprise the maximum values from the data plus 20%. All values are rounded to two significant figures.

a The EAL is set at the minimum reporting value based on the typical detection limit achieved for the groundwater up hydraulic gradient of the landfill areas (boreholes TH1, TH2, TH3, TH4, TH14 ,TH15 and TH25).

b The EAL is set at the maximum non spurious concentration recorded between February 2012 and February 2014 when the detection limit for cadmium was reduced significantly so that natural background concentrations can be recorded.

c The EAL is set at the mean concentration recorded in groundwater up hydraulic gradient of the site (in boreholes TH1, TH2, TH3, TH4, TH14, TH15 and TH25) plus two standard deviations as the typical concentration in the groundwater is recorded above the detction limit (naphthalene) or is inferior to the EQS.

d With the exception of phenol the EAL is set at the Drinking Water Standard (DWS) as the background groundwater quality are similar to the DWS. There is no DWS for phenol hence the EAL is set at the EQS as the groundwater quality recorded up hydraulic gradient of the site is recorded below the detection limit and the typical detection limit is a concentration similar to the EQS.

e The monitoring data for chloride and ammoniacal nitrogen from leachate monitoring well THLW5A11 in Phase 5 are not used to calculate the source term from April 2013 onwards as the concentrations of these determinands are significantly elevated at this location and are not considered representative of the long term concentrations for the landfill. The monitoring data for chloride and ammoniacal nitrogen from leachate monitoring wells THLW5A11, THLW5B11, and THLW5B21 in Phase 5 are not used to calculate the source term until October 2008, May 2013 and January 2013 respectively as low concentrations are recorded at these locations prior to these dates compared with the other leachate monitoring wells. The maximum ammoniacal nitrogen and chloride source term concentrations for all Phases except Phase 5 comprise the 95th percentile values from the data plus 20%. It is considered that the concentrations of ammoniacal nitrogen and chloride recorded in the leachate in Phase 5 are not representative of the long term concentrations for the rest of the landfill. The ammoniacal nitrogen and chloride concentrations recorded in Phase 5 are included in the data set from where the 95th percentile values plus 20% used as the maximum source term concentrations for all Phases except Phase 5 are calculated. The ammoniacal nitrogen and chloride concentrations recorded in the leachate in Phase 5 are elevated compared with Phase 3 and 6 and are related to a specific waste stream received in Phase 5 that has not and will not be disposed of elsewhere in the landfill. Conservatively, the most likely source term concentrations for ammoniacal nitrogen and chloride in Phase 5 comprise the arithmetic mean of the concentrations recorded between March 2006 and December 2014 with the conservative exclusion of the data recorded at THLW5A11, THLW5B11, and THLW5B21 until October 2008, May 2013 and January 2013 respectively (low concentrations). The maximum source term concentrations for ammoniacal nitrogen and chloride in Phase 5 comprise the the 95th percentile of the Phase 5 data set (March 2006 to December 2014) plus 20% omitting the low concentrations.

f The EAL is based on a detection limit recorded during 2012. During the period 2005 to 2009 elevated concentrations of trichloroethene above the EAL were recorded in the boreholes down hydraulic gradient of the site and partly down hydraulic gradient of the unlined Phases 1 and 2. The EAL is set based on up hydraulic groundwater quality concentrations and should be confirmed based on the collection of an additional 3 data sets.

g Conservatively, the most likely source term concentration for cadmium in Phase 5 comprises the arithmetic mean of the concentrations recorded between March 2006 and December 2014. The maximum source term concentration for cadmium in Phase 5 comprises the 95th percentile of the Phase 5 data set (March 2006 to December 2014) plus 20%.

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Landfill parameters							
Time offset	nearest whole year	1 (West and East), and 7A		12		Single	Start of waste disposal in 2015 used to calculate offset in relation to Phase 3
		2 (West and East)		18		Single	Start of waste disposal in 2021 used to calculate offset in relation to Phase 3
		3		0		Single	Start of waste disposal in 2003
		4B (North and South), 4C (North and South), 7B and 7C		24		Single	Start of waste disposal in 2027 used to calculate offset in relation to Phase 3
		5 (North, South and the extension)		5		Single	Start of waste disposal in 2009 (5A1), 2006 (5A2, 5B1, 5B2), 2012 (5E) used to calculate offset in relation to Phase 3 – mean of offset times used for Phase 5.
		6 (A and B)		1		Single	Start of waste disposal in 2004 used to calculate offset in relation to Phase 3
Infiltration to waste	mm/year	All phases		587.7		Normal with a 10% standard deviation	Annual average precipitation from the 2004 ESID
Cap design infiltration	mm/year	All phases except 3 and 6 (A and B)		0.48		Single	GCL cap. Value derived from infiltration model (Annex A to Schedule 1 to the e-mail to Päivi Porali-Perrell of the Environment Agency dated 25 August 2015).

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Cap design infiltration	mm/year	3 and 6 (A and B)		0.0001		Single	Geomembrane and GCL cap. Value derived from infiltration model (Annex A to Schedule 1 to the e-mail to Päivi Porali-Perrell of the Environment Agency dated 25 August 2015).
End of filling	years from start of waste disposal to nearest whole year	1 (West and East), and 7A		5		Single	
		2 (West and East)		3		Single	
		3		1		Single	2003 to 2004
		4B (North and South), 4C (North and South), 7B and 7C		10		Single	
		5 (North, South and the extension)		8		Single	2006 to 2014
		6 (A and B)		2		Single	July 2004 to December 2005
Infiltration to grassland	mm/year	All phases		0.48		Single	Value derived from infiltration model (Annex A to Schedule 1 to the e-mail to Päivi Porali-Perrell of the Environment Agency dated 25 August 2015).

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Start of PE cap degradation	years	3 and 6 (A and B)		250		Single	LandSim default
End of PE cap degradation	years	3 and 6 (A and B)		1000		Single	LandSim default
Length of the base of the landfill in the direction of groundwater flow	m	1 (West and East) and 7A		290		Single	The approximate average length of the base of the site in the direction of an assumed groundwater flow direction of east south east with the exception of Phase 1 (West and East) and 7A where the groundwater flow direction is to the east
		2 (West and East)		165		Single	
		3		180		Single	Approximate average length of the base of Phase 3 measured from Figure ESID 7A of the 2004 ESID presenting the Phases 3 leachate management collection system.
		4B (North and South), 4C (North and South), 7B and 7C		245		Single	The average length of the base of the site in the direction of an assumed groundwater flow direction of east south east.
		5 (North, South and the extension)		105		Single	
		6 (A and B)		220		Single	

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Width of the base of the landfill perpendicular to groundwater flow	m	1 (West and East) and 7A		140		Single	Calculated by dividing the area of the base by the average length in the direction of groundwater flow.
		2 (West and East)		85		Single	
		3		70		Single	
		4B (North and South), 4C (North and South), 7B and 7C		290		Single	Calculated by dividing the area of the base by the maximum length in the direction of groundwater flow.
		5 (North, South and the extension)		170		Single	
		6 (A and B)		80		Single	
Surface area of the landfill	m²	1 (West and East) and 7A		57340		Single	Capped area of the landfill site based on the extent on the phases as shown on Figure HRA 2
		2 (West and East)		20965		Single	
		3		24415		Single	

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
		4B (North and South), 4C (North and South), 7B and 7C		98980		Single	
		5 (North, South and the extension)		30130		Single	
		6 (A and B)		35275		Single	
Waste thickness	m	1 (West and East) and 7A		11.4		Single	Average waste thickness based on the waste volume divided by the surface area
		2 (West and East)		18.8		Single	
		3		10.2		Single	
		4B (North and South), 4C (North and South), 7B and 7C		10		Single	
		5 (North, South and the extension)		11.1		Single	

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
		6 (A and B)		8.8		Single	
Waste porosity	fraction	All phases	0.05		0.27	Uniform	These values are based on the range of effective porosity values presented in reference 11 for waste materials.
Waste dry density	kg/l	All phases		1.02		Single	Dry density of the non hazardous waste from the stability risk assessment (reference 12).
Waste field capacity	fraction	All phases		0.4		Single	Minimum value from a range of household wastes presented in reference 13.
Specified head of leachate on liner	m	All phases		1.5		Single	Compliance limit set in EP number EPR/3133PP/V004 (reference 1)
Flexible membrane liner							
Pin holes	ha^{-1}	All phases except Phase 3	0		25	Triangular	LandSim default. A flexible membrane liner is not present in Phase 3.
Holes	ha^{-1}	All phases except Phase 3	0		5	Triangular	
Tears	ha^{-1}	All phases except Phase 3	0	0.1	2	Triangular	
Onset of degradation	years	All phases except Phase 3		150		Single	LandSim default

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Time for defects to double	years	All phases except Phase 3		100		Single	
Clay liner							
Clay liner thickness	m	1 (West and East), 2 (West and East), 4B (North and South), 4C (North and South), 7 (A, B and C)		0.5		Single	This is the proposed design and is a change to the previously permitted thickness.
		3, 5 (North, South and the extension) and 6 (A and B)		1		Single	2004 ESID (reference 14)

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Clay liner							
Hydraulic conductivity	m/s	1 (West and East), 2 (West and East), 4B (North and South), 4C (North and South), 7 (A, B and C)	5.1×10^{-11}	6.9×10^{-11}	1.6×10^{-10}	Log triangular	Values calculated based on all of the results for coefficient of permeability testing undertaken during the construction of Phases 1 to 5 at ENRMF and Phases 3, 5 and 6 at Thornhaugh. The minimum comprises the lowest quartile of the dataset. The most likely comprises the geometric mean and the maximum comprises the 90th percentile. These values have been selected as they comprise a conservative representation of a log triangular distribution.
		3	1.5×10^{-11}		4.0×10^{-11}	Log uniform	2004 ESID
		5 (North, South and the extension)	8.0×10^{-11}	1.2×10^{-10}	3.1×10^{-10}	Log triangular	Values calculated based on the all the results for coefficient of permeability testing undertaken at Phase 5 and 6 respectively at Thornhaugh. The minimum comprises the lowest quartile of the data set of each phase. The most likely comprises the geometric mean and the maximum comprises the 90th percentile of each phase. These values have been selected as they comprise a conservative representation of a log triangular distribution of each phase.
		6 (A and B)	6.4×10^{-11}	8.4×10^{-11}	1.5×10^{-10}	Log triangular	

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Clay liner							
Fraction of organic carbon	fraction	All phases	0.002	0.004	0.01	Triangular	2004 HRA
Dry bulk density	g/cm^3	All phases	1.55	1.68	1.77	Triangular	Based on CQA data for the clay used for liner material at all the constructed phases at the site. The minimum comprises the 5th percentile the most likely comprises the mean and the maximum comprises the 95th percentile
Moisture content	fraction	All phases	0.14		0.25	Uniform	The values comprise the lower and upper limits of the range of acceptable moisture content used in the construction of the clay liner in Phase 5 at ENRMF. The same clay has been used in other phases at ENRMF and at Thornhaugh and is applied to all phases in the model.
Longitudinal pathway dispersivity	m	1 (West and East), 2 (West and East), 4B (North and South), 4C (North and South), 7 (A, B and C)		0.05		Single	10% of liner thickness (reference 15).

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
		3, 5 (North, South and the extension) and 6 (A & B)		0.1		Single	
Unsaturated zone – Northampton Sands Formation							
Unsaturated zone thickness	m	Phases 3, 5 & 6		0		Single	Conservatively it is assumed that there is no unsaturated zone beneath these cells consistent with the approach taken in the 2004 HRA.
		Phases 1, 2, 4 & 7		1		Single	Thickness of unsaturated zone above the maximum groundwater levels used to derive the formation levels in the design of the future cells.
Hydraulic conductivity	m/s	All phases	$4.3x 10^{-6}$	1.1×10^{-5}	1.0×10^{-4}	Log triangular	The minimum and most likely values comprise the minimum and maximum results from slug tests undertaken in the north east of the site (reference 16). The maximum value comprises the hydraulic conductivity calculated from the likely transmissivity for the Northampton Sand Formation presented in reference 17.
Moisture Content	fraction	All phases	0.1		0.3	Uniform	Effective porosity for sand from the 2004 HRA.
Pathway density	kg/l	All phases		2		Single	2004 HRA

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Pathway dispersivity	m	Phases 3, 5 & 6		0		Single	10% of minimum and maximum pathway lengths (reference 15).
		Phases 1, 2, 4 & 7		0.1		Single	10% of minimum and maximum pathway lengths (reference 15).
Pathway fraction of organic carbon	fraction	All phases	0.0001	0.0012	0.026	Log triangular	2004 HRA
Aquifer pathway – Northampton Sands Formation							
Hydraulic conductivity	m/s	All phases	4.3×10^{-6}	1.1×10^{-5}	1.0×10^{-4}	Log triangular	See unsaturated zone hydraulic conductivity.
Pathway density	kg/l	All phases		2		Single	2004 HRA
Pathway fraction of organic carbon	fraction	All phases	0.0001	0.0012	0.026	Log triangular	2004 HRA
Aquifer pathway length	m	1 (West and East), and 7A	18		308	Uniform	Calculated in LandSim
		2 (West and East)	308		473	Uniform	
		3	310.5		490.5	Uniform	

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
		4B (North and South), 4C (North and South), 7B and 7C	18		263	Uniform	
		5 (North, South and the extension)	473		578	Uniform	
		6 (A and B)	490		710.5	Uniform	
Regional gradient	none	All phases		0.0062		Normal with a standard deviation of 0.0008	Updated value based on water level information collected between 2000 and 2014. The gradient is calculated between borehole TH1 up hydraulic gradient and the down hydraulic gradient boreholes TH12, TH13, TH14, TH18, TH18A, TH19 and TH19A.
Aquifer thickness	m	All phases		2.92		Normal with a standard deviation of 0.38m	Updated value based on water level information collected between 2000 and 2014 excluding boreholes TH07, TH20, TH21, TH22 and TH23 which it is considered do not monitor the aquifer or there is uncertainty with respect to the level of the base of the aquifer at these locations.
	m	1 (West and East) and 7A		140		Single	

Table HRA 3 (REVISED)

Input parameters for the LandSim hydrogeological risk assessment model - site parameters

Parameter	Units	Phase	Minimum	Most likely	Maximum	Probability density function	Reference / justification
Aquifer pathway width		2 (West and East)		85		Single	See 'Width of the base perpendicular to groundwater flow' above under Landfill Parameters
		3		70		Single	
		4B (North and South), 4C (North and South), 7B and 7C		290		Single	
		5 (North, South and the extension)		170		Single	
		6 (A and B)		80		Single	
Pathway porosity	fraction	All phases	0.1		0.3	Uniform	Effective porosity for sand from the 2004 HRA.
Longitudinal pathway dispersivity	m	All phases	1.8		64.55	Uniform	10% of minimum and maximum pathway lengths (reference 15).
Transverse dispersivity	m	All phases	0.18		6.455	Uniform	1% of minimum and maximum pathway lengths (reference 15).

Table HRA 5 (THIRD REVISION)

Summary of the results of the LandSim modelling for Thornhaugh Landfill

Determinand	Phases contributing to the predicted receptor concentration	Environmental Assessment Level (EAL) (mg/l)	Time taken for breakthrough at the 95th percentile (years)[2]	Time taken to exceed the EAL at the 95th percentile (years)[3]	Maximum concentration at the 95th percentile [4]	Time taken for breakthrough at the 50th percentile (years)[2]	Time taken to exceed the EAL at the 50th percentile (years)[3]	Maximum concentration at the 50th percentile [4]
Hazardous substances								
MTBE	1 (West and East) and 7A	0.001 (1×10^{-3})						
	2 (West and East)							
	3							
	4B (North and South), 4C (North and South), 7B and 7C							
	5 (North, South and the extension)		12		3×10^{-8}	26		4×10^{-12}
	6 (A and B)		17		1×10^{-9}			
Cadmium	1 (West and East) and 7A	0.00032 (3.2×10^{-4})						
	2 (West and East)							
	3		13000		7×10^{-10}			
	4B (North and South), 4C (North and South), 7B and 7C							
	5 (North, South and the extension)		1500		3.0×10^{-4}	13000		4×10^{-8}
	6 (A and B)		1500		9×10^{-5}	14000		6×10^{-11}
Napthalene	1 (West and East) and 7A	0.00045 (4.5×10^{-4})						
	2 (West and East)							
	3							
	4B (North and South), 4C (North and South), 7B and 7C							
	5 (North, South and the extension)							
	6 (A and B)							
Trichloroethene	1 (West and East) and 7A	0.00002 (2×10^{-5})						
	2 (West and East)							
	3							
	4B (North and South), 4C (North and South), 7B and 7C							
	5 (North, South and the extension)		25		7×10^{-10}			
	6 (A and B)		38		3×10^{-11}			
Non-hazardous pollutants								
Ammoniacal N	All	0.39	83		0.092	222		0.004
Chloride	All	250	25		114	41		29
Manganese	All	0.22	3300		0.0115	14200		0.0005
Phenol	All	0.046						

Notes:
The concentrations for hazardous substances are those predicted at the monitoring point adjacent to the boundary of the phase.
The concentrations for non-hazardous pollutants are those predicted at the site boundary from the cumulative impact of all the cells.
The derivations of the EALs are explained in section 1.2 (xii) of the report and in Table HRA 1 (REVISED).

1 From Environment Agency guidance note H1 Annex (j) (reference 7).
2 Where the time taken for the breakthrough of a contaminant is not shown there is no breakthrough of the contaminant over the 19,999 years modelled.
3 Where the time taken to exceed the EAL is not shown there is no exceedance of the EAL over the 19,999 years modelled.
4 Where the maximum concentration is not shown there is no concentration reported in the results of the model above 1×10^{-12}mg/l.

Table HRA 6 (REVISED)

The proposals for the monitoring of leachate, groundwater and surface water at Thornhaugh Landfill

Type	Monitoring locations [1]	Frequency	Determinands
Leachate	All leachate monitoring and leachate extraction locations in Phases 3, 5 North, South and the Extension, 6A and 6B and all future leachate monitoring and extraction locations	Monthly for all operational cells Quarterly for Phases 3 and 6 and all cells capped in the future in accordance with the Environmental Permit (EP) specification Annually	Leachate level Depth to base of monitoring well
	Leachate extraction wells - THLW3A1, THLW5A11, THLW5A21, THLW5B11, THLW5B21, THLW5A111, THLW6A1, THLW6B1 and THLW6B21 and all future leachate extraction locations.	Quarterly for all operational cells Annually for Phases 3 and 6 and all cells capped in the future in accordance with the EP specification Annually for all operational cells Every four years for Phases 3 and 6 and all cells capped in the future in accordance with the EP specification	pH, electrical conductivity, total alkalinity ($CaCO_3$), ammoniacal nitrogen, chloride, chemical oxygen demand, biochemical oxygen demand, cadmium, chromium, copper, lead, nickel, iron, arsenic, magnesium, potassium, total sulphates, calcium, sodium, zinc, manganese, MTBE, naphthalene, trichloroethene and phenol A screen for hazardous substances

Table HRA 6 (REVISED)

The proposals for the monitoring of leachate, groundwater and surface water at Thornhaugh Landfill

Type	Monitoring locations [1]	Frequency	Determinands
Groundwater	TH01, TH02, TH03, TH04, TH05, TH06, TH07, TH08, TH10, TH11, TH12, TH13, TH14, TH15, TH16, TH17A, TH18A, TH19A, TH25 and future monitoring borehole TH26	Quarterly Annually	Water level Depth to base of monitoring well
	TH01, TH02, TH05, TH09, TH11, TH12, TH13, TH14, TH15, TH17A, TH18A, TH25 and future monitoring borehole TH26	Quarterly Annually	Electrical conductivity, chloride, ammoniacal nitrogen, pH, MTBE, cadmium, naphthalene, trichloroethene, manganese and phenol Total alkalinity ($CaCO_3$), magnesium, potassium, total sulphates, calcium, sodium, chromium, copper, iron, lead, nickel and zinc
	TH01, TH02 and TH25	Annually for the first six years of operation Every two years after the first six years of operation	A screen for hazardous substances Hazardous substances detected in the leachate
	TH05, TH09, TH11, TH12, TH13, TH14, TH15, TH17A, TH18A and future monitoring borehole TH26	Annually for the first six years of operation and then every two years	Hazardous substances detected in the leachate

Table HRA 6 (REVISED)

The proposals for the monitoring of leachate, groundwater and surface water at Thornhaugh Landfill

Type	Monitoring locations [1]	Frequency	Determinands
Groundwater	TH11, TH17A and TH18A TH10	Quarterly up to the completion of the excavation of waste materials in Phases 1 and 2	Mecoprop naphthalene and sodium Ammoniacal nitrogen, chloride, electrical conductivity, mecoprop, naphthalene and sodium
Surface water	SWNEPOND, SWSLTAP, SWOFALL, SWTBECK, SWCHTRM, SWNEWT1, SWNEWT2 and SWP4	Monthly	Ammoniacal nitrogen, chloride, total suspended solids, visual oil and grease, pH and electrical conductivity

[1] The locations of the monitoring points are shown on the Monitoring and Extraction Point Plan (Figure 1 drawing reference AU/TH/04-15/18613)

APPENDIX B

ELECTRONIC COPY OF THE LEACHATE QUALITY, GROUNDWATER QUALITY AND SURFACE WATER QUALITY MONIOTORING DATA AND ELECTRONIC COPY OF THE 2024 HRA REVIEW RE-RUN OF THE LANDSIM MODEL AND THE 2024 HRA REVIEW SENSITIVITY ANALYSES MODELS

APPENDIX C

HARD COPY OF THE 2024 HRA REVIEW RE-RUN OF THE LANDSIM MODEL AND THE 2024 HRA REVIEW SENSITIVITY ANALYSES MODELS

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

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

MTBE	Non-Volatile
c (kg/l): 0.2919	m (kg/l): 0.0298

Contaminant Half-lives (years)

Clay Liner:

Ammoniacal_N	SINGLE(1e+009)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Lead	SINGLE(1e+009)
Manganese	SINGLE(1e+009)
Naphthalene	LOGUNIFORM(0.137,8.2)
Phenols	UNIFORM(0.022,0.077)
TCE (Trichloroethene)	LOGUNIFORM(0.27,4.5)
MTBE	LOGUNIFORM(0.3,2)

Unsaturated Pathway:

Ammoniacal_N	UNIFORM(5,10)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Lead	SINGLE(1e+009)
Manganese	SINGLE(1e+009)
Naphthalene	LOGUNIFORM(0.137,8.2)
Phenols	LOGUNIFORM(0.0014,0.019)
TCE (Trichloroethene)	UNIFORM(0.89,4.5)
MTBE	LOGUNIFORM(0.15,1)

Aquifer Pathway:

Ammoniacal_N	UNIFORM(5,10)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Lead	SINGLE(1e+009)
Manganese	SINGLE(1e+009)
Naphthalene	SINGLE(1e+009)
Phenols	LOGUNIFORM(0.0014,0.019)
TCE (Trichloroethene)	SINGLE(1e+009)
MTBE	SINGLE(1e+009)

Background Concentrations of Contaminants

Justification for Contaminant Properties

See Table HRA 2 and 4

All units in milligrams per litre

Phase: Phase 1 (West & East) & and 7A

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.48)
Infiltration to waste (mm/year):	NORMAL(587.7,58.77)
End of filling (years from start of waste deposit):	5

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	140
Cell length (m):	290
Cell top area (ha):	5.734
Cell base area (ha):	4.06
Number of cells:	1
Total base area (ha):	4.06
Total top area (ha):	5.734
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(11.4)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.072,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(0.5)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.05)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):	
Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s):	LOGTRIANGULAR(5.1e-011,6.9e-011,1.6e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(1)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(18,308)
Pathway width (m):	SINGLE(140)

Phase: Phase 2 (West & East)

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.48)
Infiltration to waste (mm/year):	NORMAL(587.7,58.77)
End of filling (years from start of waste deposit):	3

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	85
Cell length (m):	165
Cell top area (ha):	2.0965
Cell base area (ha):	1.4025
Number of cells:	1
Total base area (ha):	1.4025
Total top area (ha):	2.0965
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(18.8)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(0.5)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.05)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(5.1e-011,6.9e-011,1.6e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	LOGTRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(1)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m): SINGLE(0.1)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(308,473)
Pathway width (m):	SINGLE(85)

Phase: Phase 3

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.0001)
Infiltration to waste (mm/year):	NORMAL(587.7,58.77)
Infiltration to grassland (mm/year):	SINGLE(0.48)
End of filling (years from start of waste deposit):	1
Start of cap degradation (years from end of waste deposit):	250
End of cap degradation (years from end of waste deposit):	1000

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	70
Cell length (m):	180
Cell top area (ha):	2.4415
Cell base area (ha):	1.26
Number of cells:	1
Total base area (ha):	1.26
Total top area (ha):	2.4415
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(10.2)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
See Table HRA 3

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)

Justification for Clay: Liner Thickness
See Table HRA 3

Hydraulic conductivity of liner (m/s):	LOGUNIFORM(1.5e-011,4e-011)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)

Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(0)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m):	SINGLE(0)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species
See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(310.5,490.5)
Pathway width (m):	SINGLE(70)

Phase: 4B (North & South), 4C (North and South), 7B & 7C

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.48)
Infiltration to waste (mm/year):	NORMAL(587.7,58.7)
End of filling (years from start of waste deposit):	10

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	290
Cell length (m):	245
Cell top area (ha):	9.898
Cell base area (ha):	7.105
Number of cells:	1
Total base area (ha):	7.105
Total top area (ha):	9.898
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(10)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1& 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(0.5)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.05)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(5.1e-011,6.9e-011,1.6e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(1)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m): SINGLE(0.1)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(18,263)
Pathway width (m):	SINGLE(290)

Phase: 5 (North, South and the extension)

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.48)
Infiltration to waste (mm/year):	NORMAL(587.7,58.7)
End of filling (years from start of waste deposit):	8

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	170
Cell length (m):	105
Cell top area (ha):	3.013
Cell base area (ha):	1.785
Number of cells:	1
Total base area (ha):	1.785
Total top area (ha):	3.013
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(11.1)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,273,2320)
Cadmium	LOGTRIANGULAR(0.003,0.0083,0.36)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,9679,72000)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(8e-011,1.2e-010,3.1e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(0)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m):	SINGLE(0)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(473,578)
Pathway width (m):	SINGLE(170)

Phase: Phase 6 (A & B)

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.0001)
Infiltration to waste (mm/year):	NORMAL(587.7,58.77)
Infiltration to grassland (mm/year):	SINGLE(0.48)
End of filling (years from start of waste deposit):	2
Start of cap degradation (years from end of waste deposit):	250
End of cap degradation (years from end of waste deposit):	1000

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	80
Cell length (m):	220
Cell top area (ha):	3.5275
Cell base area (ha):	1.76
Number of cells:	1
Total base area (ha):	1.76
Total top area (ha):	3.5275
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(8.8)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(6.4e-011,8.4e-011,1.5e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(0)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m):	SINGLE(0)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.1,0.3)
Cadmium	LOGUNIFORM(1.6,1500)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(490.5,710.5)
Pathway width (m):	SINGLE(80)

pathway parameters

No Vertical Pathway

Northampton Sand Formation pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	NORMAL(2.92,0.38)

Justification for Aquifer Geometry
See Table HRA 3

Pathway regional gradient (-):	NORMAL(0.0062,0.0008)
Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)
Pathway porosity (fraction):	UNIFORM(0.1,0.3)

Justification for Aquifer Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m):	UNIFORM(1.8,71.05)
Pathway transverse dispersivity (m):	UNIFORM(0.18,7.105)

Justification for Aquifer Dispersion Details
See Table HRA 3

Retardation parameters for Northampton Sand Formation pathway

Modelled as aquifer pathway.

Uncertainty in Kd (l/kg):

Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	SINGLE(0)
Chloride	SINGLE(0)
Lead	SINGLE(0)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene	SINGLE(0)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene)	SINGLE(0)
MTBE	SINGLE(0)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Aquifer Kd Values by Species
See Tables HRA 3 and 4

Pathway Density (kg/l):	SINGLE(2)

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

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

MTBE	Non-Volatile
c (kg/l): 0.2919	m (kg/l): 0.0298

Contaminant Half-lives (years)

Clay Liner:

Ammoniacal_N	SINGLE(1e+009)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Lead	SINGLE(1e+009)
Manganese	SINGLE(1e+009)
Naphthalene	LOGUNIFORM(0.137,8.2)
Phenols	UNIFORM(0.022,0.077)
TCE (Trichloroethene)	LOGUNIFORM(0.27,4.5)
MTBE	LOGUNIFORM(0.3,2)

Unsaturated Pathway:

Ammoniacal_N	UNIFORM(5,10)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Lead	SINGLE(1e+009)
Manganese	SINGLE(1e+009)
Naphthalene	LOGUNIFORM(0.137,8.2)
Phenols	LOGUNIFORM(0.0014,0.019)
TCE (Trichloroethene)	UNIFORM(0.89,4.5)
MTBE	LOGUNIFORM(0.15,1)

Aquifer Pathway:

Ammoniacal_N	UNIFORM(5,10)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Lead	SINGLE(1e+009)
Manganese	SINGLE(1e+009)
Naphthalene	SINGLE(1e+009)
Phenols	LOGUNIFORM(0.0014,0.019)
TCE (Trichloroethene)	SINGLE(1e+009)
MTBE	SINGLE(1e+009)

Background Concentrations of Contaminants

Justification for Contaminant Properties

See Table HRA 2 and 4

All units in milligrams per litre

Phase: Phase 1 (West & East) & and 7A

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.48)
Infiltration to waste (mm/year):	NORMAL(587.7,58.77)
End of filling (years from start of waste deposit):	5

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	140
Cell length (m):	290
Cell top area (ha):	5.734
Cell base area (ha):	4.06
Number of cells:	1
Total base area (ha):	4.06
Total top area (ha):	5.734
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(11.4)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.33,6.2)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1 & 2B [CHANGED]

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(0.5)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.05)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(5.1e-011,6.9e-011,1.6e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species

See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(1)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry

See Table HRA 3

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties

See Table HRA 3

Pathway longitudinal dispersivity (m): SINGLE(0.1)

Justification for Unsat Zone Dispersion Properties

See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(18,308)
Pathway width (m):	SINGLE(140)

Phase: Phase 2 (West & East)

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.48)
Infiltration to waste (mm/year):	NORMAL(587.7,58.77)
End of filling (years from start of waste deposit):	3

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	85
Cell length (m):	165
Cell top area (ha):	2.0965
Cell base area (ha):	1.4025
Number of cells:	1
Total base area (ha):	1.4025
Total top area (ha):	2.0965
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(18.8)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.33,6.2)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1 & 2B

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(0.5)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.05)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(5.1e-011,6.9e-011,1.6e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	LOGTRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(1)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(308,473)
Pathway width (m):	SINGLE(85)

Phase: Phase 3

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.0001)
Infiltration to waste (mm/year):	NORMAL(587.7,58.77)
Infiltration to grassland (mm/year):	SINGLE(0.48)
End of filling (years from start of waste deposit):	1
Start of cap degradation (years from end of waste deposit):	250
End of cap degradation (years from end of waste deposit):	1000

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	70
Cell length (m):	180
Cell top area (ha):	2.4415
Cell base area (ha):	1.26
Number of cells:	1
Total base area (ha):	1.26
Total top area (ha):	2.4415
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(10.2)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
See Table HRA 3

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)

Justification for Clay: Liner Thickness
See Table HRA 3

Hydraulic conductivity of liner (m/s):	LOGUNIFORM(1.5e-011,4e-011)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(0)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m):	SINGLE(0)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species
See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(310.5,490.5)
Pathway width (m):	SINGLE(70)

Phase: 4B (North & South), 4C (North and South), 7B & 7C

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.48)
Infiltration to waste (mm/year):	NORMAL(587.7,58.7)
End of filling (years from start of waste deposit):	10

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	290
Cell length (m):	245
Cell top area (ha):	9.898
Cell base area (ha):	7.105
Number of cells:	1
Total base area (ha):	7.105
Total top area (ha):	9.898
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(10)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.33,6.2)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate

See Table HRA 1 & 2024 HRA Review Table 1 & 2B [CHANGED]

Drainage Information

Fixed Head.

Head on EBS is given as (m):	SINGLE(1.5)

Justification for Specified Head

See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(0.5)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.05)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(5.1e-011,6.9e-011,1.6e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(1)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m): SINGLE(0.1)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(18,263)
Pathway width (m):	SINGLE(290)

Phase: 5 (North, South and the extension)

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.48)
Infiltration to waste (mm/year):	NORMAL(587.7,58.7)
End of filling (years from start of waste deposit):	8

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	170
Cell length (m):	105
Cell top area (ha):	3.013
Cell base area (ha):	1.785
Number of cells:	1
Total base area (ha):	1.785
Total top area (ha):	3.013
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(11.1)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,273,2320)
Cadmium	LOGTRIANGULAR(0.003,0.0083,0.36)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,9679,72000)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.

Head on EBS is given as (m):	SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):	
Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s):	LOGTRIANGULAR(8e-011,1.2e-010,3.1e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(0)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m): SINGLE(0)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(473,578)
Pathway width (m):	SINGLE(170)

Phase: Phase 6 (A & B)

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.0001)
Infiltration to waste (mm/year):	NORMAL(587.7,58.77)
Infiltration to grassland (mm/year):	SINGLE(0.48)
End of filling (years from start of waste deposit):	2
Start of cap degradation (years from end of waste deposit):	250
End of cap degradation (years from end of waste deposit):	1000

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	80
Cell length (m):	220
Cell top area (ha):	3.5275
Cell base area (ha):	1.76
Number of cells:	1
Total base area (ha):	1.76
Total top area (ha):	3.5275
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(8.8)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate

See Table HRA 1 & 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.

Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head

See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(6.4e-011,8.4e-011,1.5e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(0)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m):	SINGLE(0)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for pathway

Modelled as unsaturated pathway	
Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.1,0.3)
Cadmium	LOGUNIFORM(1.6,1500)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(490.5,710.5)
Pathway width (m):	SINGLE(80)

pathway parameters

No Vertical Pathway

Northampton Sand Formation pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	NORMAL(2.92,0.38)

Justification for Aquifer Geometry
See Table HRA 3

Pathway regional gradient (-):	NORMAL(0.0062,0.0008)
Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)
Pathway porosity (fraction):	UNIFORM(0.1,0.3)

Justification for Aquifer Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m):	UNIFORM(1.8,71.05)
Pathway transverse dispersivity (m):	UNIFORM(0.18,7.105)

Justification for Aquifer Dispersion Details
See Table HRA 3

Retardation parameters for Northampton Sand Formation pathway

Modelled as aquifer pathway.

Uncertainty in Kd (l/kg):

Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	SINGLE(0)
Chloride	SINGLE(0)
Lead	SINGLE(0)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene	SINGLE(0)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene)	SINGLE(0)
MTBE	SINGLE(0)

Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Aquifer Kd Values by Species
See Tables HRA 3 and 4

Pathway Density (kg/l):	SINGLE(2)

Calculation Settings

Number of iterations: 1001

Results calculated using sampled PDFs

Full Calculation

Clay Liner:

Retarded values used for simulation

Biodegradation

Unsaturated Pathway:

Retarded values used for simulation

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

MTBE	Non-Volatile
c (kg/l): 0.2919	m (kg/l): 0.0298

Contaminant Half-lives (years)

Clay Liner:

Ammoniacal_N	SINGLE(1e+009)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Lead	SINGLE(1e+009)
Manganese	SINGLE(1e+009)
Naphthalene	LOGUNIFORM(0.137,8.2)
Phenols	UNIFORM(0.022,0.077)
TCE (Trichloroethene)	LOGUNIFORM(0.27,4.5)
MTBE	LOGUNIFORM(0.3,2)

Unsaturated Pathway:

Ammoniacal_N	UNIFORM(5,10)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Lead	SINGLE(1e+009)
Manganese	SINGLE(1e+009)
Naphthalene	LOGUNIFORM(0.137,8.2)
Phenols	LOGUNIFORM(0.0014,0.019)
TCE (Trichloroethene)	UNIFORM(0.89,4.5)
MTBE	LOGUNIFORM(0.15,1)

Aquifer Pathway:

Ammoniacal_N	UNIFORM(5,10)
Cadmium	SINGLE(1e+009)
Chloride	SINGLE(1e+009)
Lead	SINGLE(1e+009)
Manganese	SINGLE(1e+009)
Naphthalene	SINGLE(1e+009)
Phenols	LOGUNIFORM(0.0014,0.019)
TCE (Trichloroethene)	SINGLE(1e+009)
MTBE	SINGLE(1e+009)

Background Concentrations of Contaminants

Justification for Contaminant Properties

See Table HRA 2 and 4

All units in milligrams per litre

Phase: Phase 1 (West & East) & and 7A

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.48)
Infiltration to waste (mm/year):	NORMAL(587.7,58.77)
End of filling (years from start of waste deposit):	5

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	140
Cell length (m):	290
Cell top area (ha):	5.734
Cell base area (ha):	4.06
Number of cells:	1
Total base area (ha):	4.06
Total top area (ha):	5.734
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(11.4)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.072,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(0.5)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.05)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(8.6e-011,1.3e-010,3.6e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3 and 2024 HRA Review Table 4

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(1)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m): SINGLE(0.1)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(18,308)
Pathway width (m):	SINGLE(140)

Phase: Phase 2 (West & East)

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.48)
Infiltration to waste (mm/year):	NORMAL(587.7,58.77)
End of filling (years from start of waste deposit):	3

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	85
Cell length (m):	165
Cell top area (ha):	2.0965
Cell base area (ha):	1.4025
Number of cells:	1
Total base area (ha):	1.4025
Total top area (ha):	2.0965
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(18.8)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(0.5)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.05)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(8.6e-011,1.3e-010,3.6e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3 and 2024 HRA Review Table 4

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	LOGTRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(1)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m): SINGLE(0.1)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(308,473)
Pathway width (m):	SINGLE(85)

Phase: Phase 3

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.0001)
Infiltration to waste (mm/year):	NORMAL(587.7,58.77)
Infiltration to grassland (mm/year):	SINGLE(0.48)
End of filling (years from start of waste deposit):	1
Start of cap degradation (years from end of waste deposit):	250
End of cap degradation (years from end of waste deposit):	1000

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	70
Cell length (m):	180
Cell top area (ha):	2.4415
Cell base area (ha):	1.26
Number of cells:	1
Total base area (ha):	1.26
Total top area (ha):	2.4415
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(10.2)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a single clay barrier

Justification for Engineered Barrier Type
See Table HRA 3

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)

Justification for Clay: Liner Thickness
See Table HRA 3

Hydraulic conductivity of liner (m/s):	LOGUNIFORM(1.5e-011,4e-011)
Pathway longitudinal dispersivity (m):	SINGLE(0.1)

Justification for Clay: Hydraulics Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(0)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m):	SINGLE(0)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):

Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)

Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species
See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(310.5,490.5)
Pathway width (m):	SINGLE(70)

Phase: 4B (North & South), 4C (North and South), 7B & 7C

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.48)
Infiltration to waste (mm/year):	NORMAL(587.7,58.7)
End of filling (years from start of waste deposit):	10

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	290
Cell length (m):	245
Cell top area (ha):	9.898
Cell base area (ha):	7.105
Number of cells:	1
Total base area (ha):	7.105
Total top area (ha):	9.898
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(10)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1& 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(0.5)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.05)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):	
Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(8.6e-011,1.3e-010,3.6e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3 and 2024 HRA Review Table 4

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)

Fraction of Organic Carbon (fraction) — TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(1)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m): SINGLE(0.1)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(18,263)
Pathway width (m):	SINGLE(290)

Phase: 5 (North, South and the extension)

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.48)
Infiltration to waste (mm/year):	NORMAL(587.7,58.7)
End of filling (years from start of waste deposit):	8

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	170
Cell length (m):	105
Cell top area (ha):	3.013
Cell base area (ha):	1.785
Number of cells:	1
Total base area (ha):	1.785
Total top area (ha):	3.013
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(11.1)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA 3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,273,2320)
Cadmium	LOGTRIANGULAR(0.003,0.0083,0.36)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,9679,72000)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA	
Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):	
Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s):	LOGTRIANGULAR(8e-011,1.2e-010,3.1e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

Unsaturated Northampton Sand Formation pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(0)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s): LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m): SINGLE(0)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for Unsaturated Northampton Sand Formation pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	LOGUNIFORM(127,1348)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(473,578)
Pathway width (m):	SINGLE(170)

Phase: Phase 6 (A & B)

Infiltration Information

Cap design infiltration (mm/year):	SINGLE(0.0001)
Infiltration to waste (mm/year):	NORMAL(587.7,58.77)
Infiltration to grassland (mm/year):	SINGLE(0.48)
End of filling (years from start of waste deposit):	2
Start of cap degradation (years from end of waste deposit):	250
End of cap degradation (years from end of waste deposit):	1000

Justification for Specified Infiltration
See Table HRA 3

Duration of management control (years from the start of waste disposal): 20000

Cell dimensions

Cell width (m):	80
Cell length (m):	220
Cell top area (ha):	3.5275
Cell base area (ha):	1.76
Number of cells:	1
Total base area (ha):	1.76
Total top area (ha):	3.5275
Head of Leachate when surface water breakout occurs (m)	SINGLE(5)
Waste porosity (fraction)	UNIFORM(0.05,0.27)
Final waste thickness (m):	SINGLE(8.8)
Field capacity (fraction):	SINGLE(0.4)
Waste dry density (kg/l)	SINGLE(1.02)

Justification for Landfill Geometry
See Table HRA3

Source concentrations of contaminants

All units in milligrams per litre

Declining source term

Ammoniacal_N	LOGTRIANGULAR(51,309,1601)
Cadmium	LOGTRIANGULAR(0.003,0.0065,0.035)
	Substance to be treated as List 1
Chloride	LOGTRIANGULAR(440,1870,8900)
Lead	LOGTRIANGULAR(0.00165,0.0722,1.923)
	Data are spot measurements of Leachate Quality
Manganese	LOGTRIANGULAR(0.16,4.6,272.85)
Naphthalene	LOGTRIANGULAR(0.00087,0.028,2)
	Substance to be treated as List 1
Phenols	LOGTRIANGULAR(0.01,0.24,15)
TCE (Trichloroethene)	LOGTRIANGULAR(0.00029,0.027,0.27)
	Substance to be treated as List 1
MTBE	LOGTRIANGULAR(0.0078,0.034,0.35)
	Substance to be treated as List 1

Justification for Species Concentration in Leachate
See Table HRA 1 & 2024 HRA Review Table 1 [CHANGED]

Drainage Information

Fixed Head.
Head on EBS is given as (m): SINGLE(1.5)

Justification for Specified Head
See Table HRA 3

Barrier Information

There is a composite barrier

Justification for Engineered Barrier Type
See Table HRA 3

Liner installed under CQA

Design thickness of clay (m):	SINGLE(1)
Density of clay (kg/l):	TRIANGULAR(1.55,1.68,1.77)
Pathway moisture content (fraction):	UNIFORM(0.14,0.25)
Onset of FML degradation (years since filling commenced)	150
Pathway longitudinal dispersivity (m):	SINGLE(0.1)
Time for area of defects to double (years)	100

Membrane defects (number per hectare):

Pin holes:	Minimum 0, Maximum 25
Holes:	Minimum 0, Maximum 5
Tears:	Minimum 0, Most Likely 0.1, Maximum 2

The most likely value for the PDFs representing the density of pinholes and holes will move from the minimum value selected above to the maximum value selected above over the time period before FML degradation commences

Justification for Composite: Flexible Membrane Liner
See Table HRA 3

Hydraulic conductivity of mineral lower liner (m/s): LOGTRIANGULAR(6.4e-011,8.4e-011,1.5e-010)

Justification for Composite: Clay or BES Substrate Properties
See Table HRA 3

Retardation parameters for clay liner

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.97,2.4)
Cadmium	LOGTRIANGULAR(13.5,663.1,2078.9)
Chloride	SINGLE(0)
Lead	SINGLE(434.6)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	TRIANGULAR(0.002,0.004,0.01)

Justification for Liner Kd Values by Species
See Tables HRA 3 and 4 and Table 3B of the 2024 HRA Review

pathway parameters

Modelled as unsaturated pathway

Pathway length (m):	SINGLE(0)
Flow Model:	porous medium
Pathway moisture content (fraction):	UNIFORM(0.1,0.3)
Pathway Density (kg/l):	SINGLE(2)

Justification for Unsat Zone Geometry
See Table HRA 3

Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)

Justification for Unsat Zone Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m):	SINGLE(0)

Justification for Unsat Zone Dispersion Properties
See Table HRA 3

Retardation parameters for pathway

Modelled as unsaturated pathway

Uncertainty in Kd (l/kg):	
Ammoniacal_N	TRIANGULAR(0,0.1,0.3)
Cadmium	LOGUNIFORM(1.6,1500)
Chloride	SINGLE(0)
Lead	LOGTRIANGULAR(27,270,27000)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(1190)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene): Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(141)
MTBE: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(33.9)
Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Kd Values by Species

See Table HRA 4 and Table 3B of the 2024 HRA Review

Aquifer Pathway Dimensions for Phase

Pathway length (m):	UNIFORM(490.5,710.5)
Pathway width (m):	SINGLE(80)

pathway parameters

No Vertical Pathway

Northampton Sand Formation pathway parameters

Modelled as aquifer pathway.

Mixing zone (m):	NORMAL(2.92,0.38)

Justification for Aquifer Geometry
See Table HRA 3

Pathway regional gradient (-):	NORMAL(0.0062,0.0008)
Pathway hydraulic conductivity values (m/s):	LOGTRIANGULAR(4.3e-006,1.1e-005,0.0001)
Pathway porosity (fraction):	UNIFORM(0.1,0.3)

Justification for Aquifer Hydraulics Properties
See Table HRA 3

Pathway longitudinal dispersivity (m):	UNIFORM(1.8,71.05)
Pathway transverse dispersivity (m):	UNIFORM(0.18,7.105)

Justification for Aquifer Dispersion Details
See Table HRA 3

Retardation parameters for Northampton Sand Formation pathway

Modelled as aquifer pathway.

Uncertainty in Kd (l/kg):

Ammoniacal_N	TRIANGULAR(1e-006,0.1,0.3)
Cadmium	SINGLE(0)
Chloride	SINGLE(0)
Lead	SINGLE(0)
Manganese	LOGTRIANGULAR(3,49,810)
Naphthalene	SINGLE(0)
Phenols: Calculated kd	
Partition to Organic Carbon ml/g	SINGLE(29)
TCE (Trichloroethene)	SINGLE(0)
MTBE	SINGLE(0)

Fraction of Organic Carbon (fraction)	LOGTRIANGULAR(0.0001,0.0012,0.026)

Justification for Aquifer Kd Values by Species
See Tables HRA 3 and 4

Pathway Density (kg/l):	SINGLE(2)

APPENDIX D

A COPY OF THE ENVIRONMENT AGENCY APPROVAL DATED FEBRUARY 2020 OF THE CQA VERIFICATION OF BOREHOLE TH26

Jo Congo

From: Branson, Jim <jim.branson@environment-agency.gov.uk>
Sent: 26 February 2020 11:09
To: Jo Congo
Cc: 'GeneWilson@augeanplc.com'; 'PeterOldfield@augeanplc.com'; Wilkinson, Greg
Subject: RE: Thornhaugh Landfill Site – Borehole CQA Verification Report for borehole TH26

Dear Jo,

We have reviewed the CQA Verification Report for borehole TH26 and consider that it demonstrates that it has been installed in general accordance with the agreed CQA Plan. Therefore, please accept this email as our formal acceptance of the document.

Regards

Jim Branson
Technical Specialist - Groundwater & Contaminated Land

Lincolnshire and Northamptonshire Area
Environment Agency
✉ Ceres House, Searby Road, Lincoln, LN2 4DW.
☎ 02030254983
☎ 54983 (internal)
jim.branson@environment-agency.gov.uk
www.gov.uk/environment-agency

We continually want to improve our service to you.

Please tell us how we did. (5 = good, 1 = poor, n/a = non applicable)

1) Were you happy with the Timeliness of our service?
2) Was our Information / advice clear and relevant?
3) Was our service Professional?
4) Did we have a friendly and polite Attitude?
5) Overall did you get the right Result from us?

Any other comments?

Please consider the environment - do you really need to print this email?

From: Jo Congo [mailto:JoCongo@mjca.co.uk]
Sent: 20 February 2020 15:59
To: Branson, Jim <jim.branson@environment-agency.gov.uk>
Cc: 'GeneWilson@augeanplc.com' <GeneWilson@augeanplc.com>; 'PeterOldfield@augeanplc.com' <PeterOldfield@augeanplc.com>
Subject: Thornhaugh Landfill Site – Borehole CQA Verification Report for borehole TH26

Please see attached documents relating to the Borehole CQA Verification Report for borehole TH26, Thornhaugh Landfill Site.

Jo Congo
MJCA
Baddesley Colliery Offices
Main Road

Baxterley
Atherstone
Warwickshire
CV9 2LE

Tel: 01827 717891
Fax: 01827 718507
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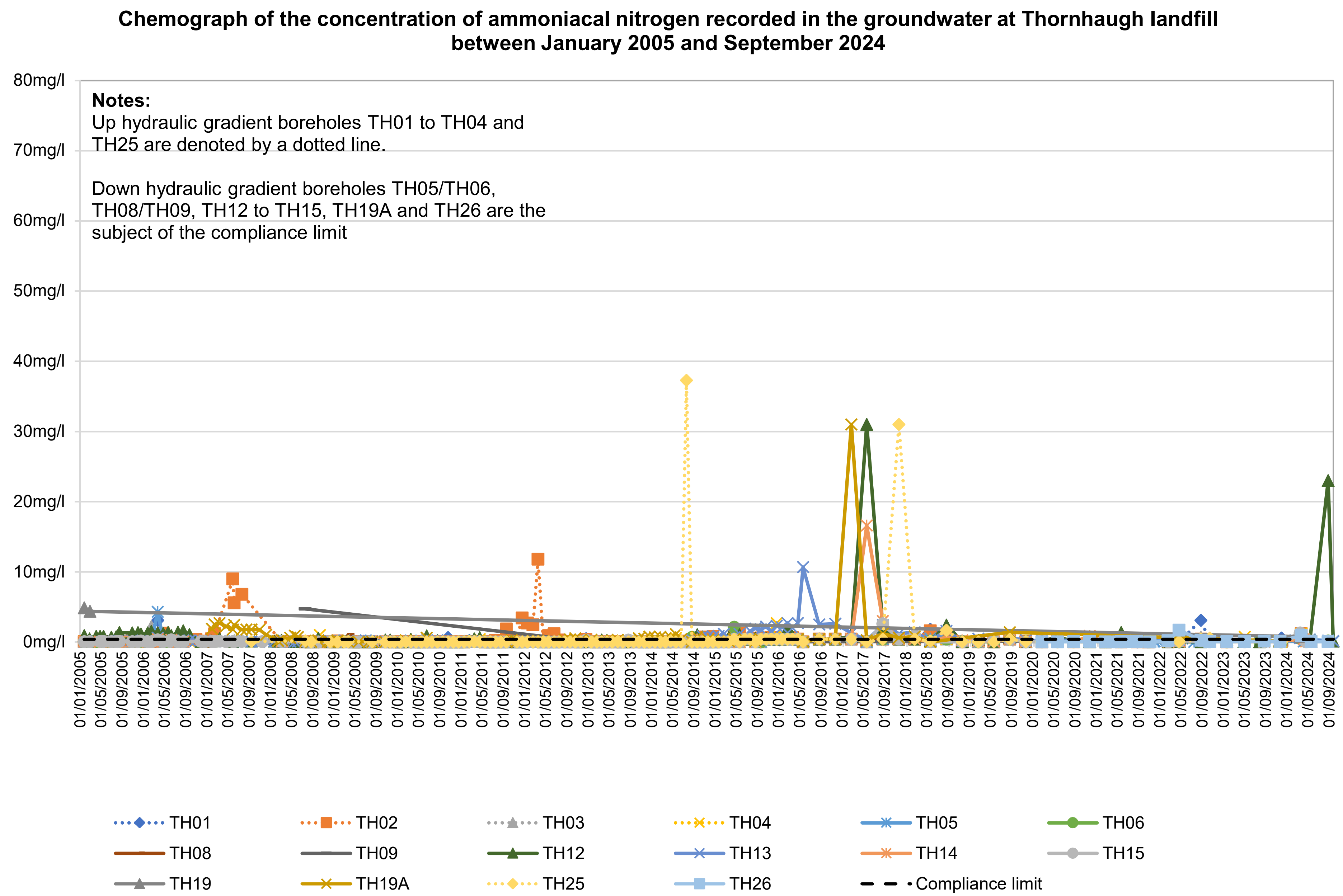
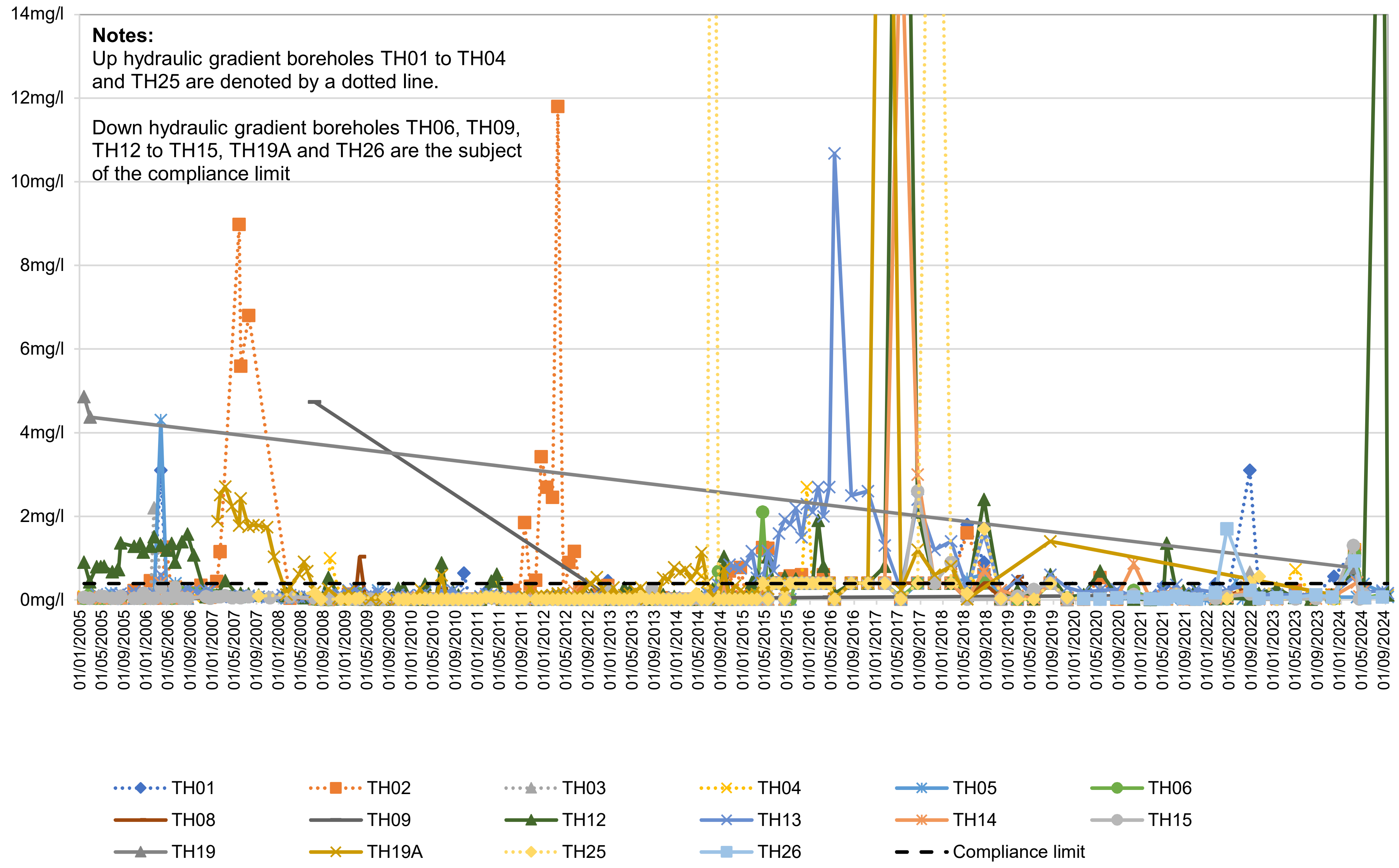
APPENDIX E

GROUNDWATER QUALITY CHEMOGRAPHS FOR THE DETERMINANDS THE SUBJECT OF COMPLIANCE LIMITS

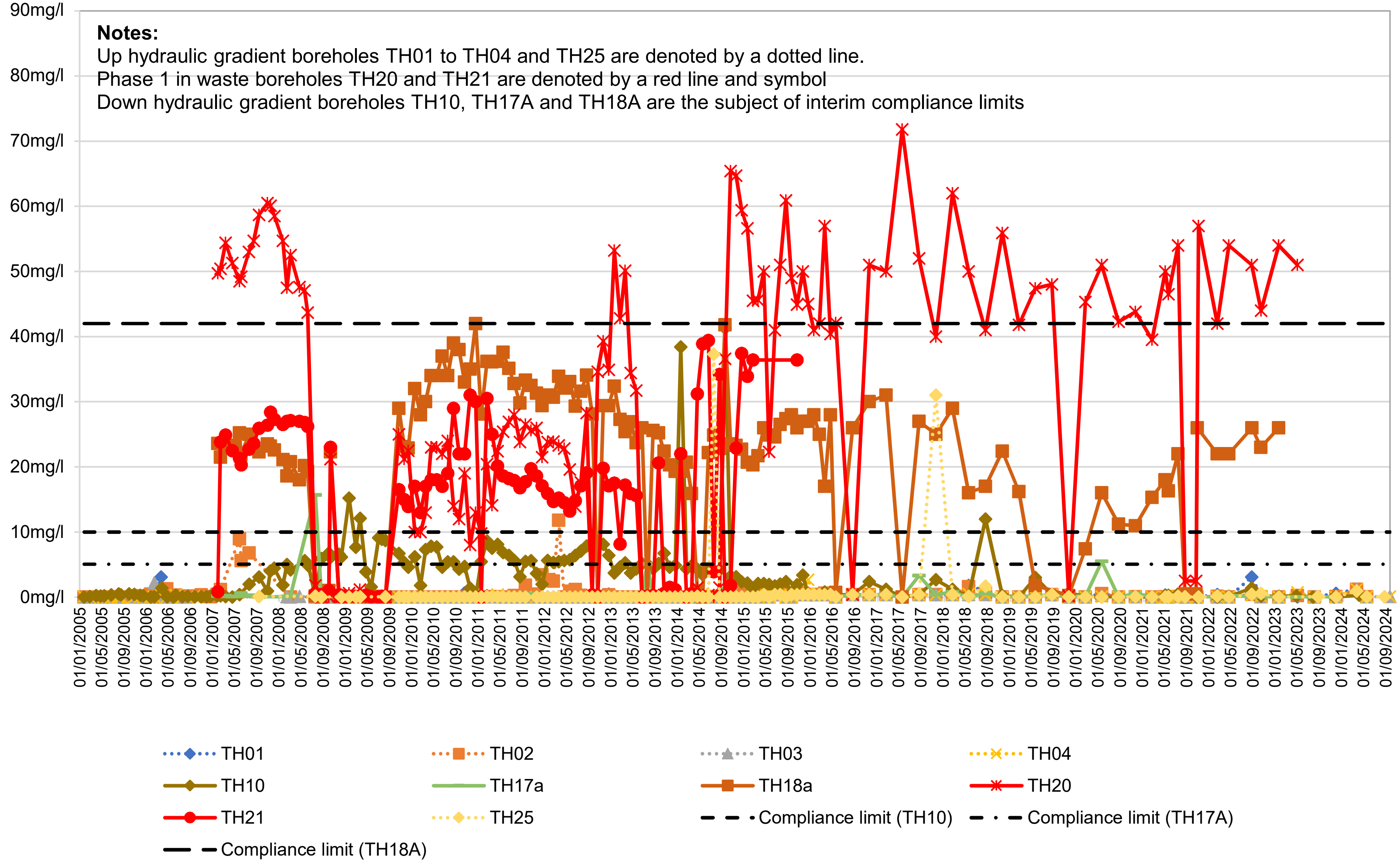


Chemograph of the concentration of ammoniacal nitrogen recorded in the groundwater at Thornhaugh landfill between January 2005 and September 2024
80mg/l
70mg/l
60mg/l
50mg/l
40mg/l
30mg/l
20mg/l
10mg/l
0mg/l
Notes:
Up hydraulic gradient boreholes TH01 to TH04 and TH25 are denoted by a dotted line.
Down hydraulic gradient boreholes TH05/TH06, TH08/TH09, TH12 to TH15, TH19A and TH26 are the subject of the compliance limit
01/01/2005
01/09/2024
TH01
TH02
TH03
TH04
TH05
TH06
TH08
TH09
TH12
TH13
TH14
TH15
TH19
TH19A
TH25
TH26
Compliance limit

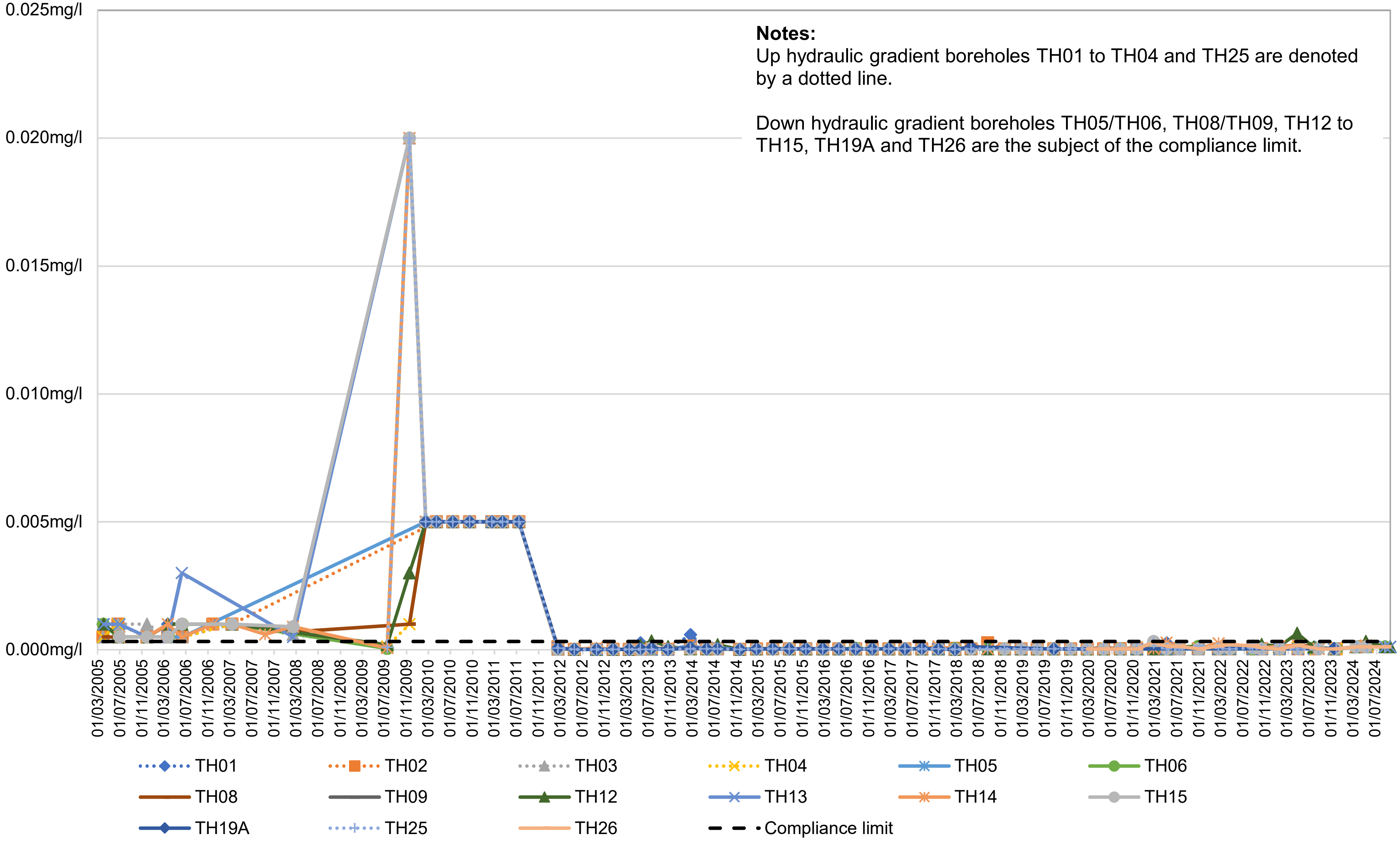
Chemograph of the concentration of ammoniacal nitrogen recorded in the groundwater at Thornhaugh landfill between January 2005 and September 2024



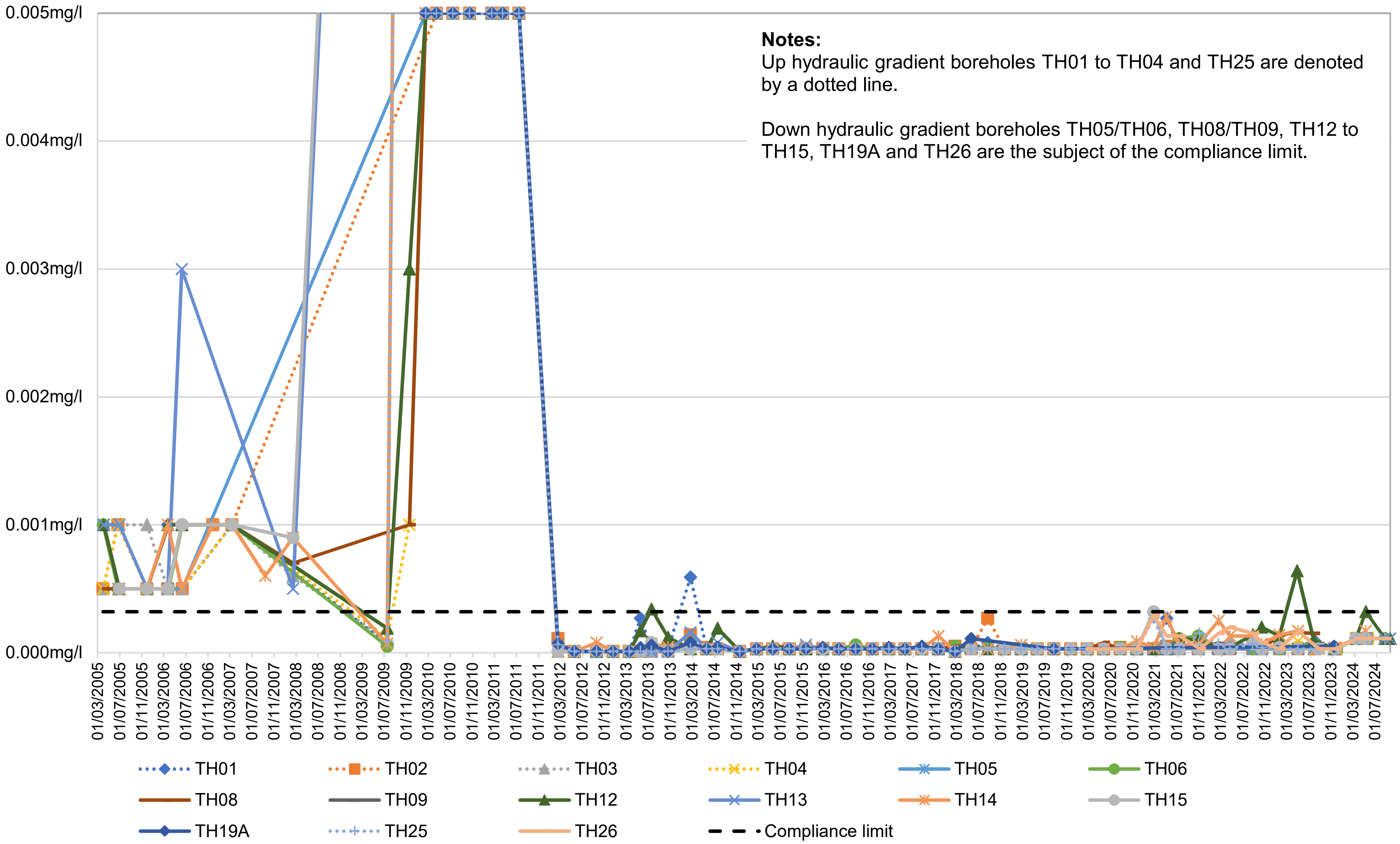
Chemograph of the concentration of ammoniacal nitrogen recorded in the groundwater at Thornhaugh landfill between January 2005 and September 2024



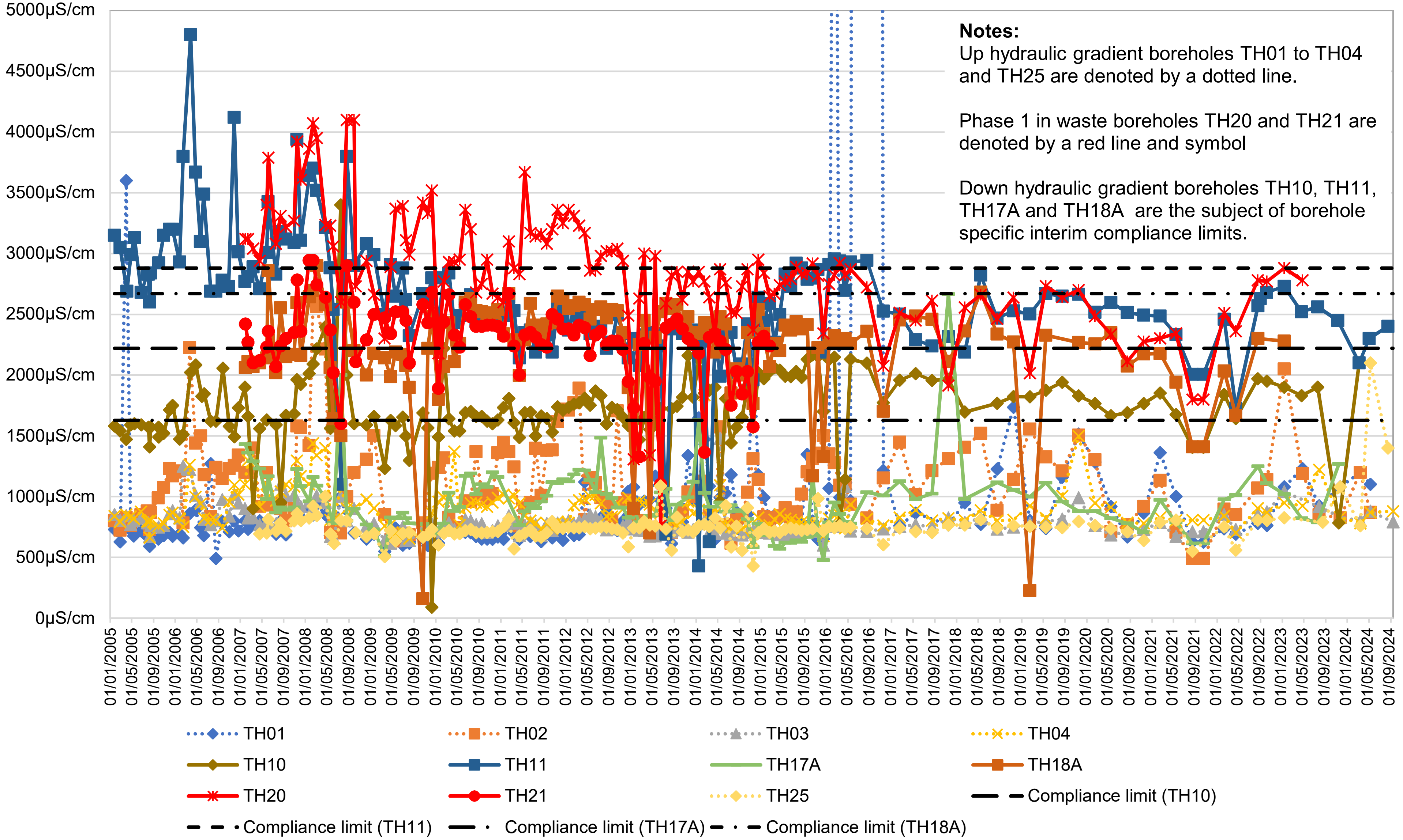
Chemograph of the concentration of cadmium recorded in the groundwater at Thornhaugh landfill between March 2005 and September 2024



Chemograph of the concentration of cadmium recorded in the groundwater at Thornhaugh landfill between March 2005 and September 2024

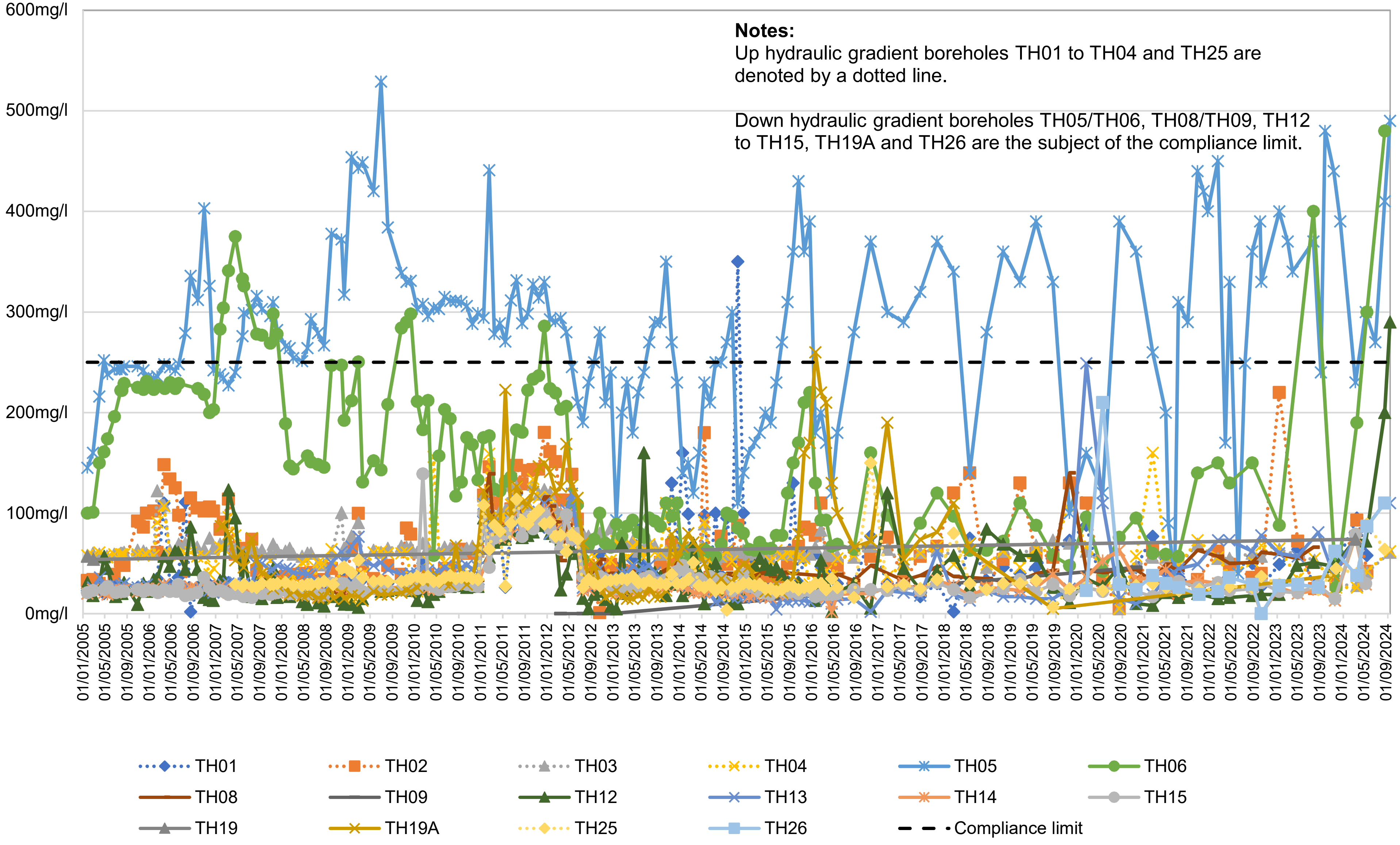


Chemograph of the values of electrical conductivity recorded in the groundwater at Thornhaugh landfill between January 2005 and September 2024

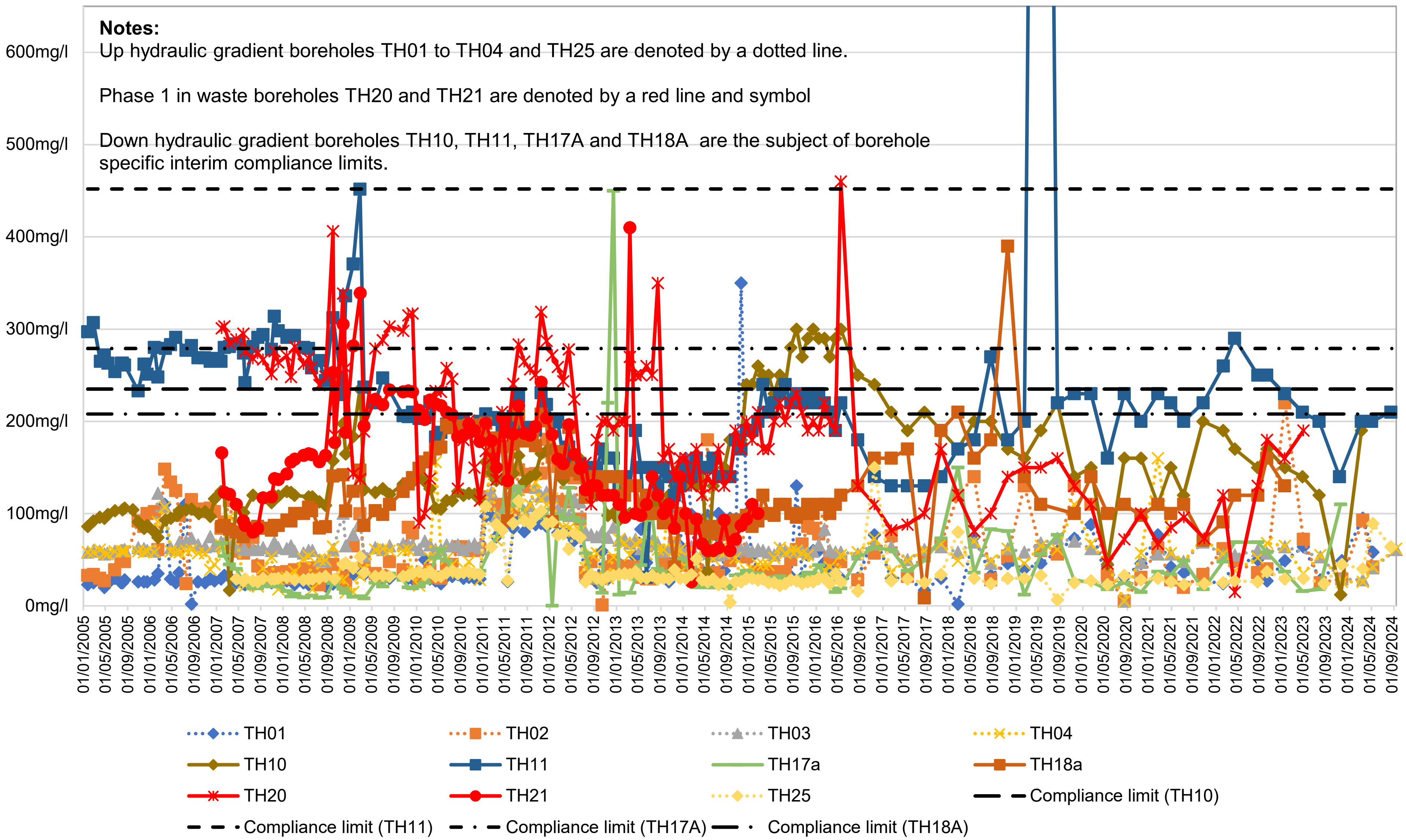


AU_THg31556 - Appendix E

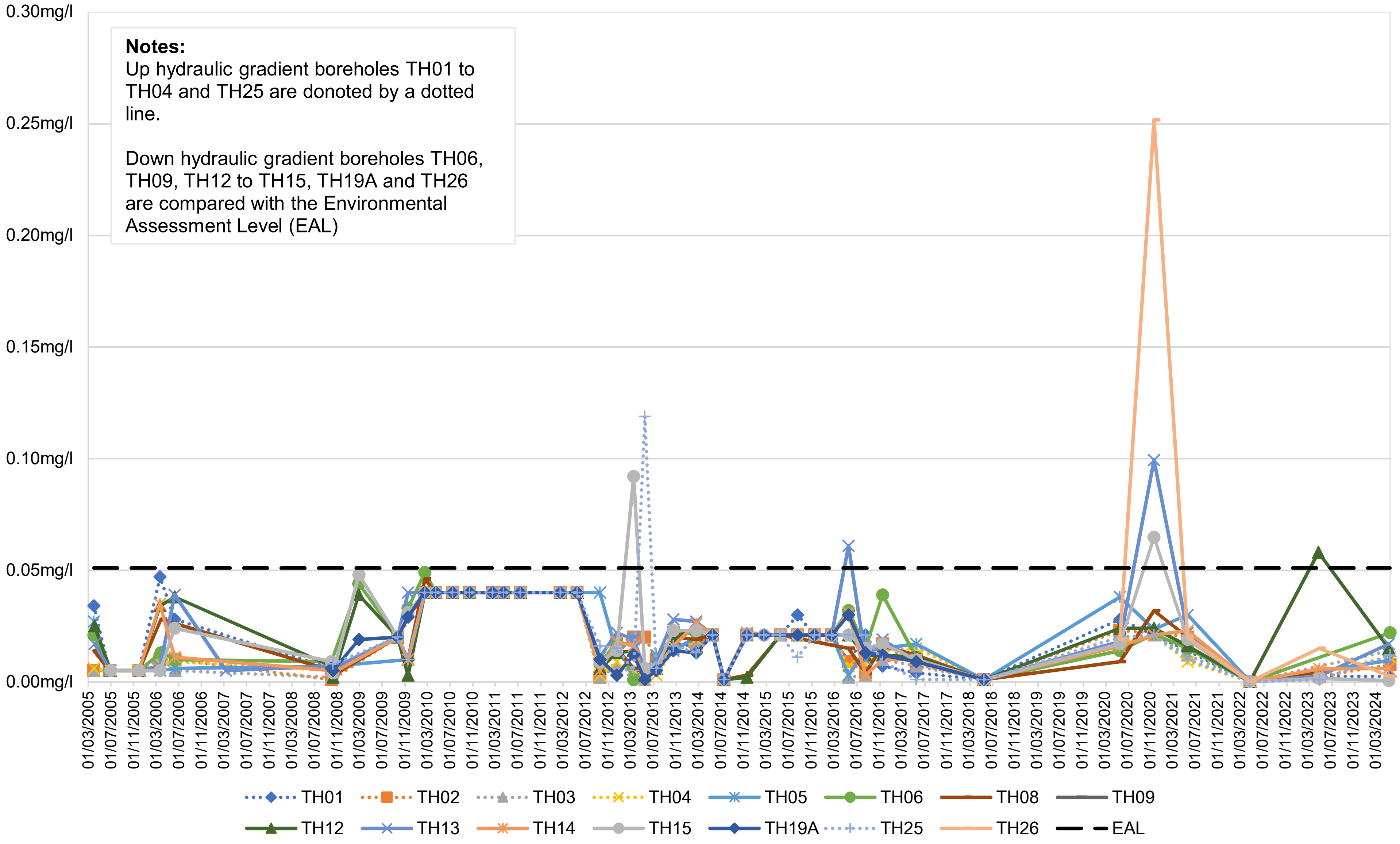
Chemograph of the concentration of chloride recorded in the groundwater at Thornhaugh landfill between January 2005 and September 2024



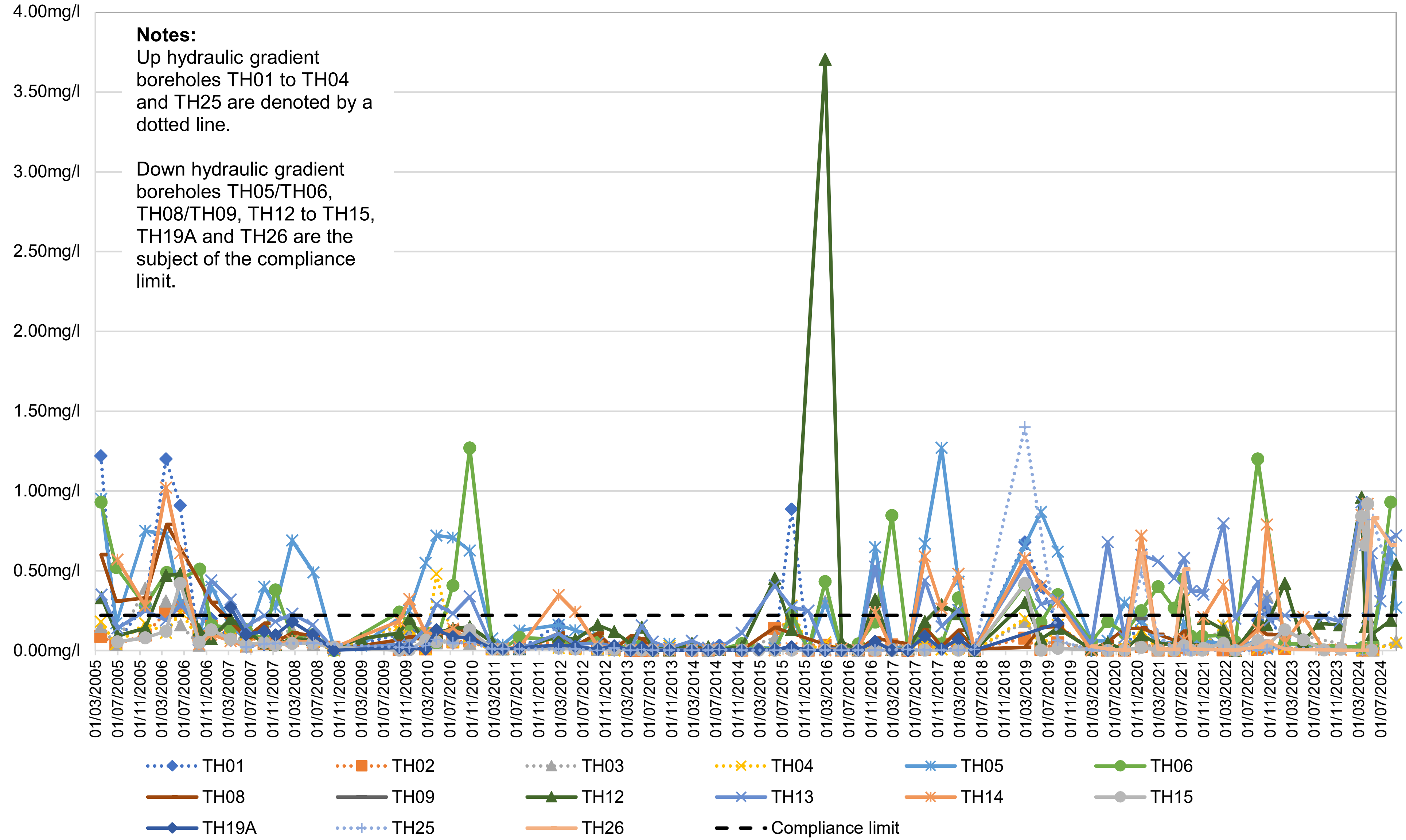
Chemograph of the concentration of chloride recorded in the groundwater at Thornhaugh landfill between January 2005 and September 2024



Chemograph of the concentration of lead recorded in the groundwater at Thornhaugh landfill between March 2005 and May 2024

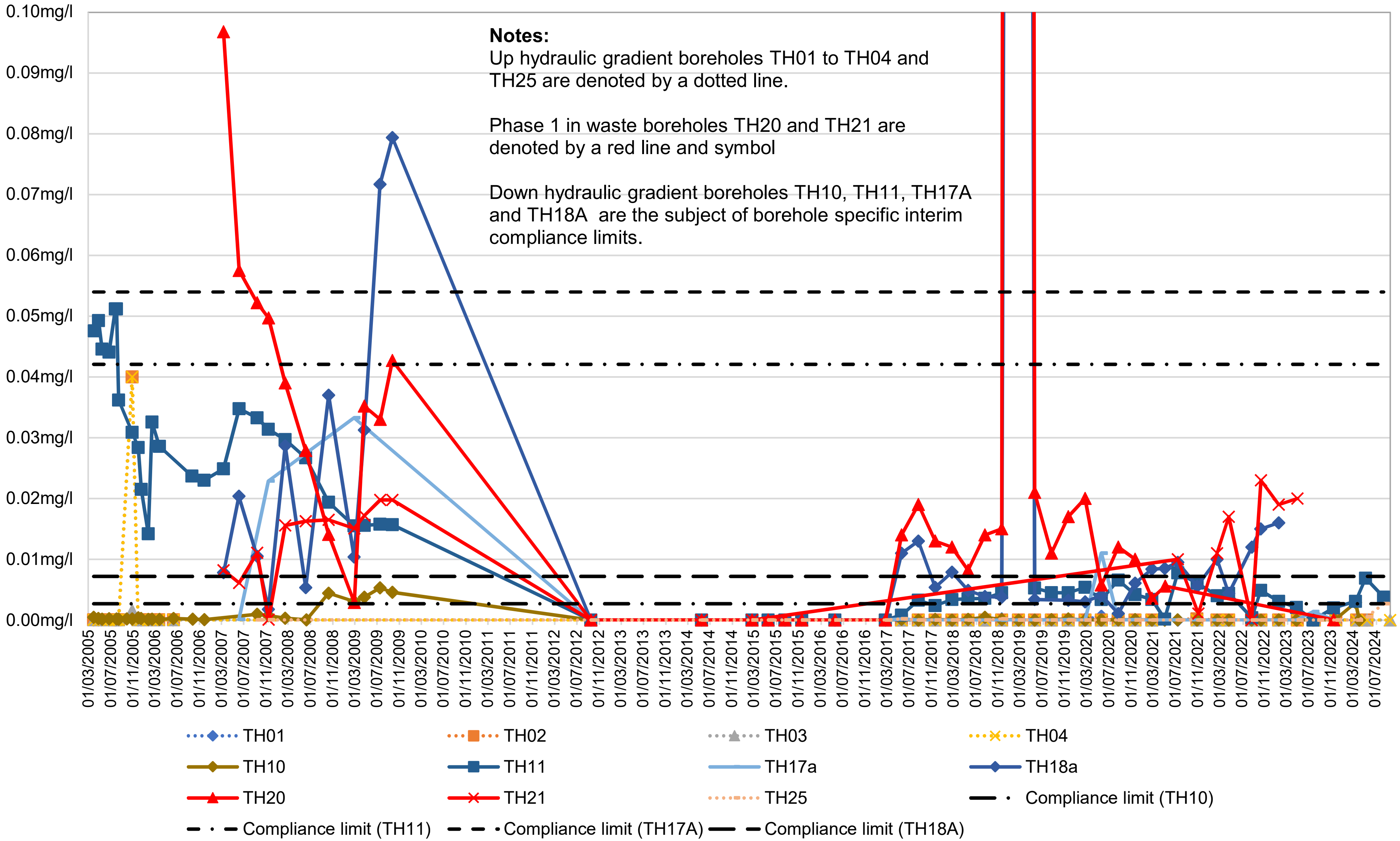


Chemograph of the concentration of manganese recorded in the groundwater at Thornhaugh landfill between March 2005 and September 2024

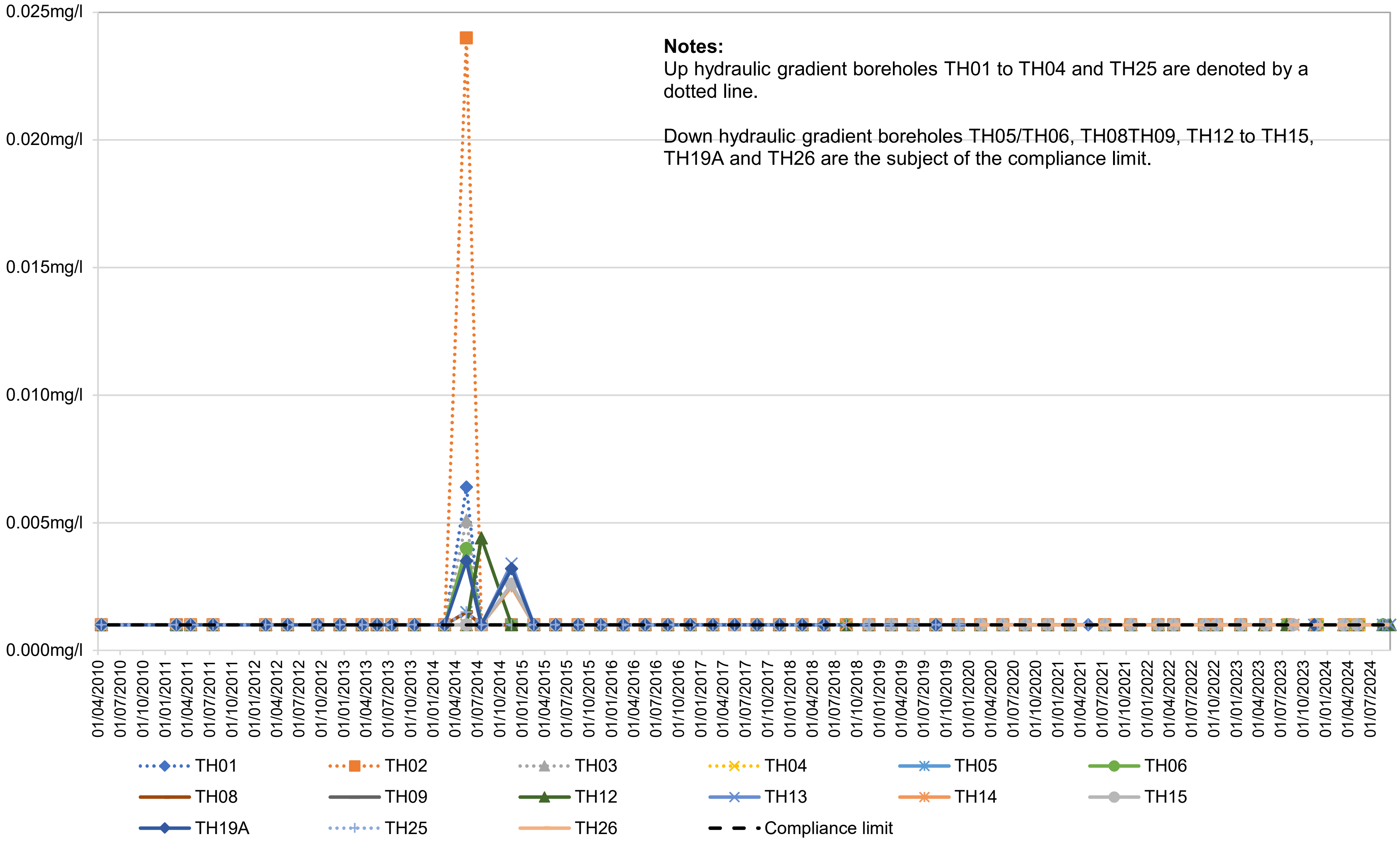


AU_THg31556 - Appendix E

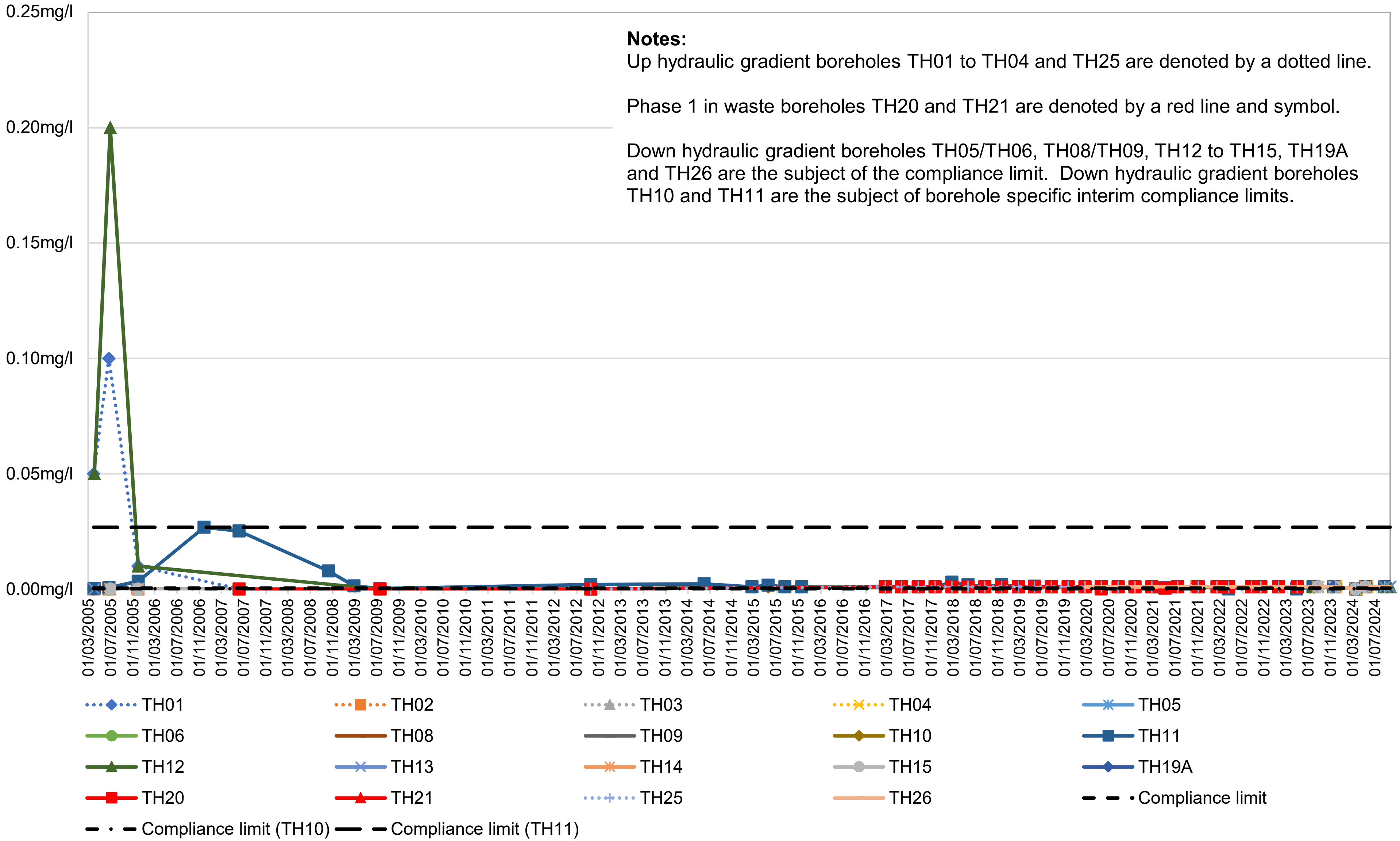
Chemograph of the concentrations of mecoprop recorded in the groundwater at Thornhaugh landfill between March 2005 and September 2024



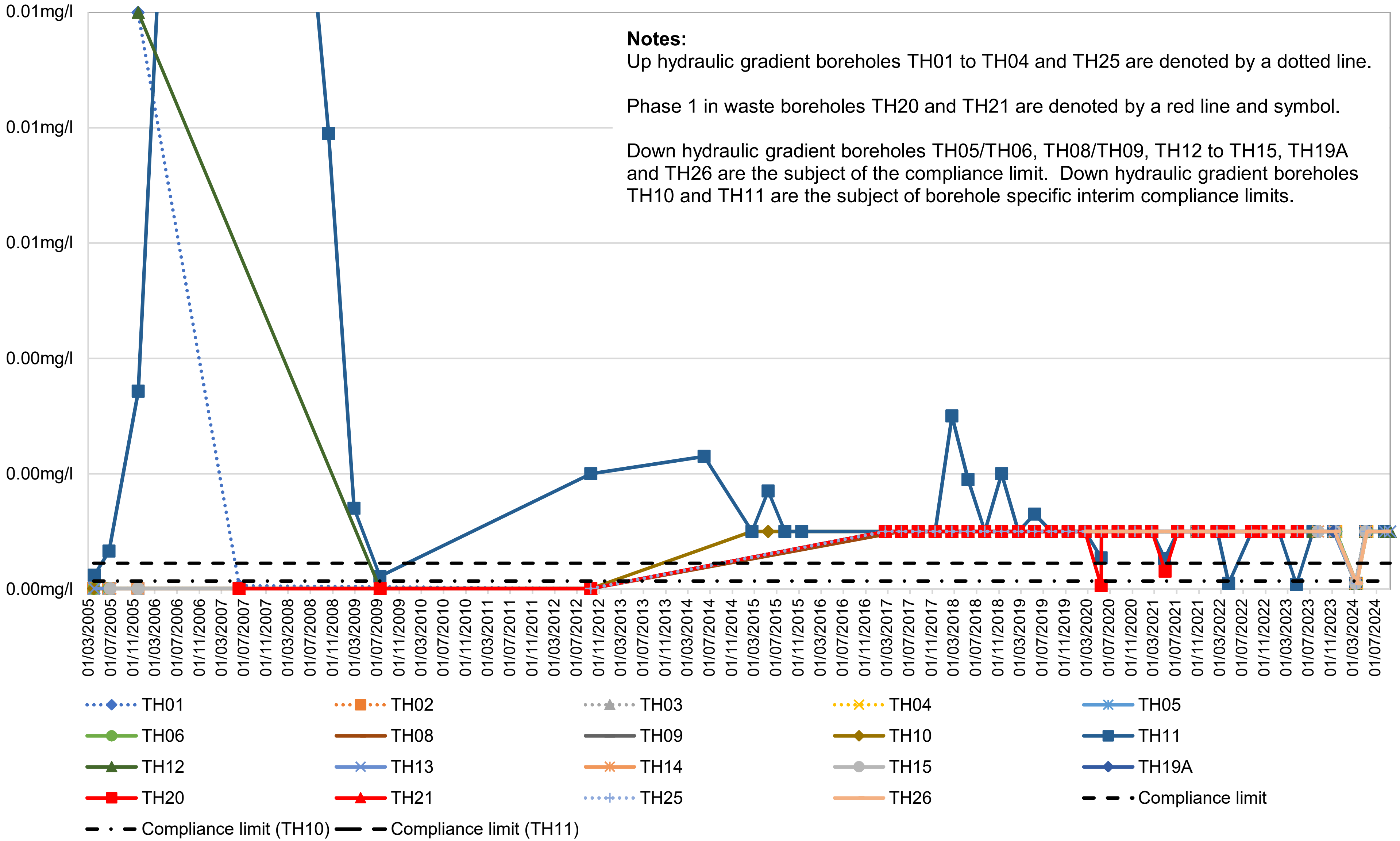
Chemograph of the concentration of MTBE recorded in the groundwater at Thornhaugh landfill between April 2010 and September 2024



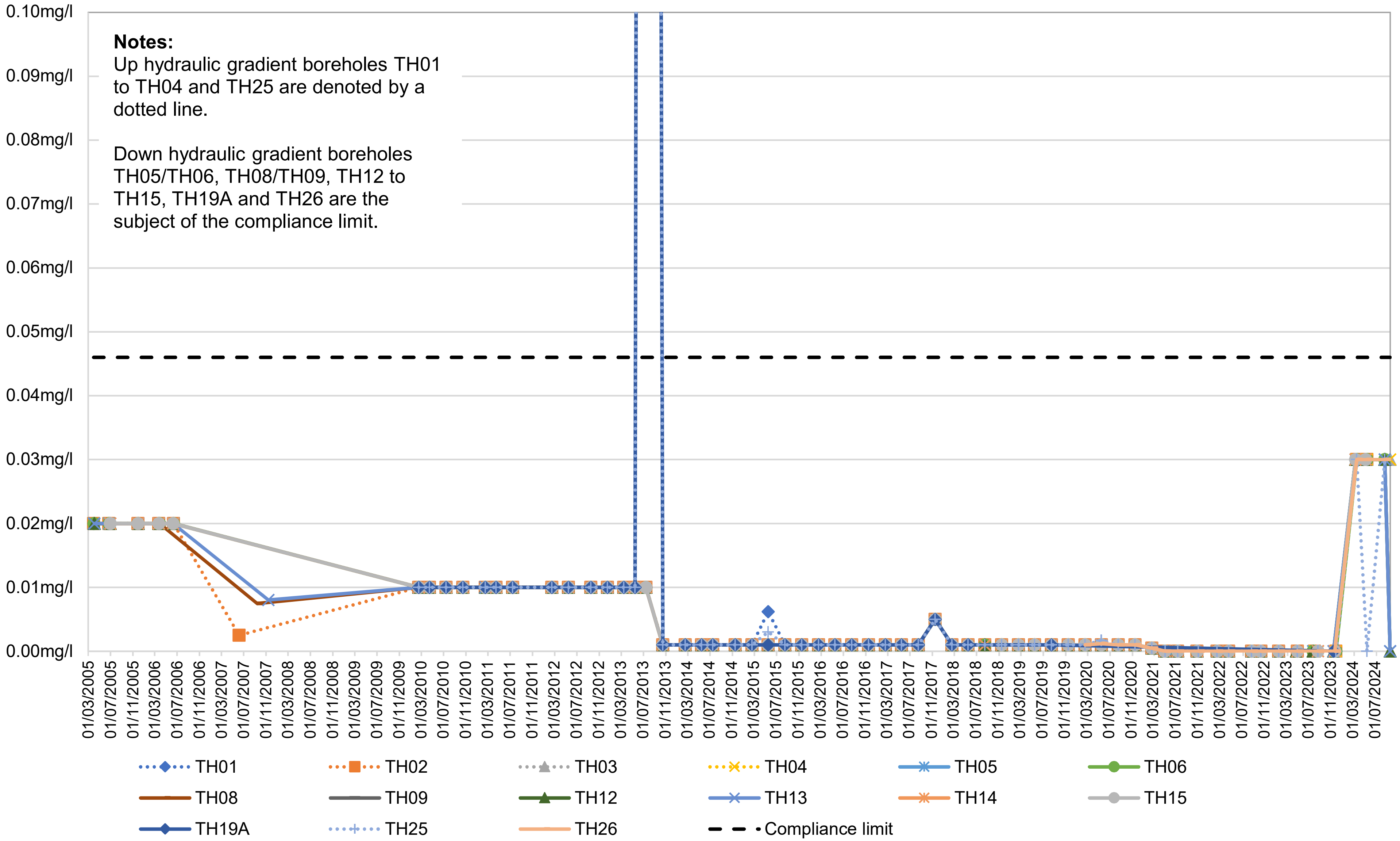
Chemograph of the concentration of naphthalene recorded in the groundwater at Thornhaugh landfill between March 2005 and September 2024



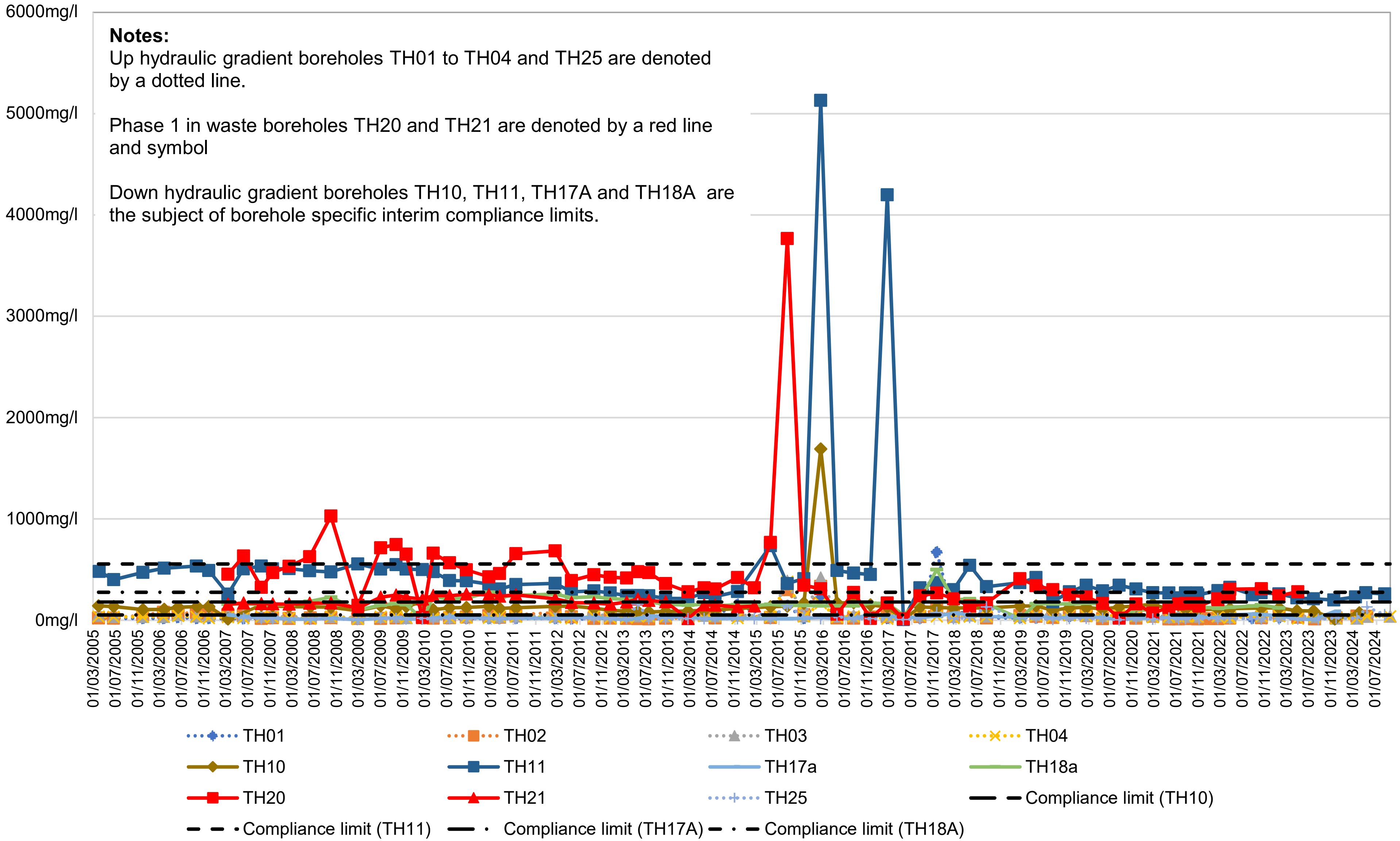
Chemograph of the concentration of naphthalene recorded in the groundwater at Thornhaugh landfill between March 2005 and September 2024



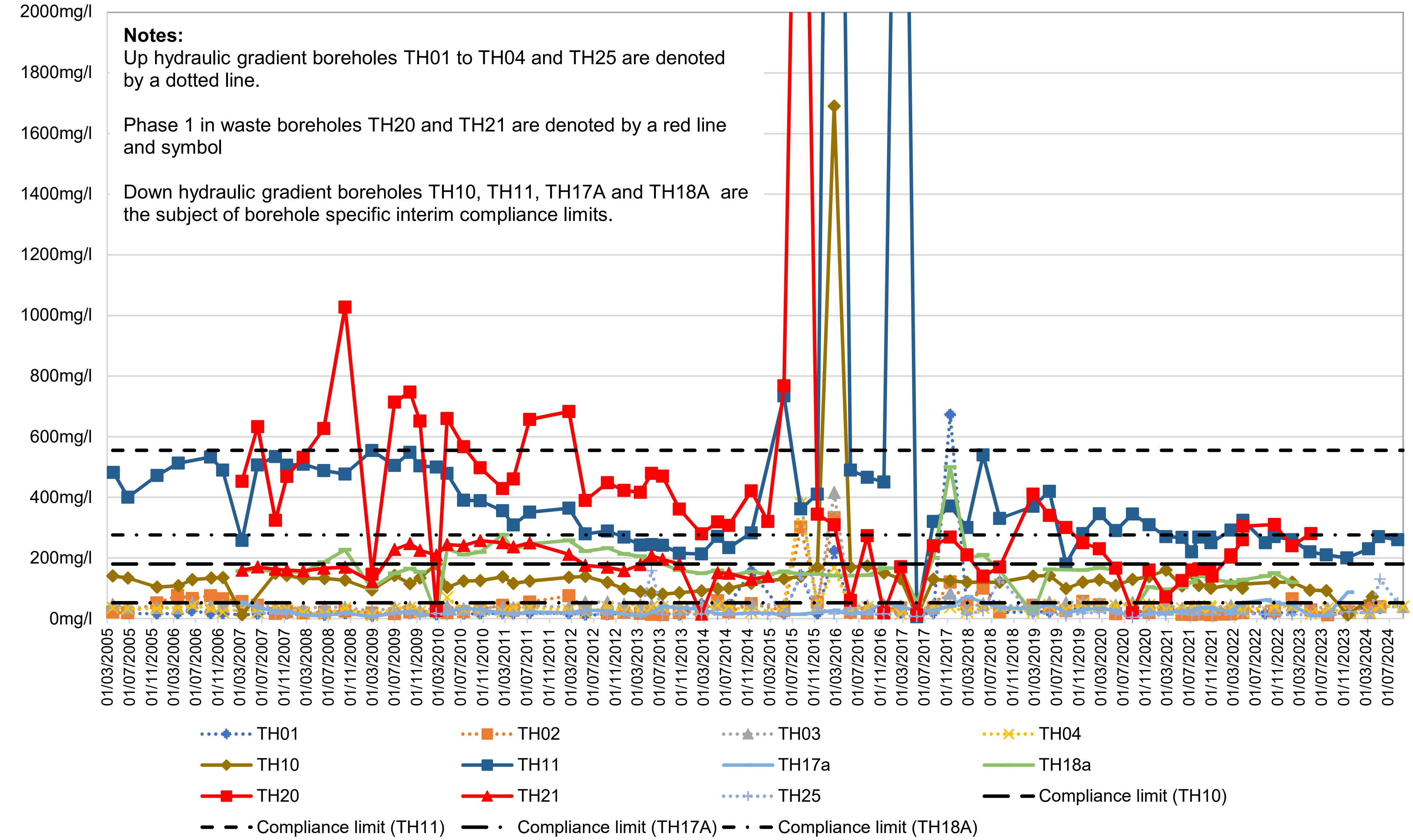
Chemograph of the concentration of phenol recorded in the groundwater at Thornhaugh landfill between March 2005 and September 2024



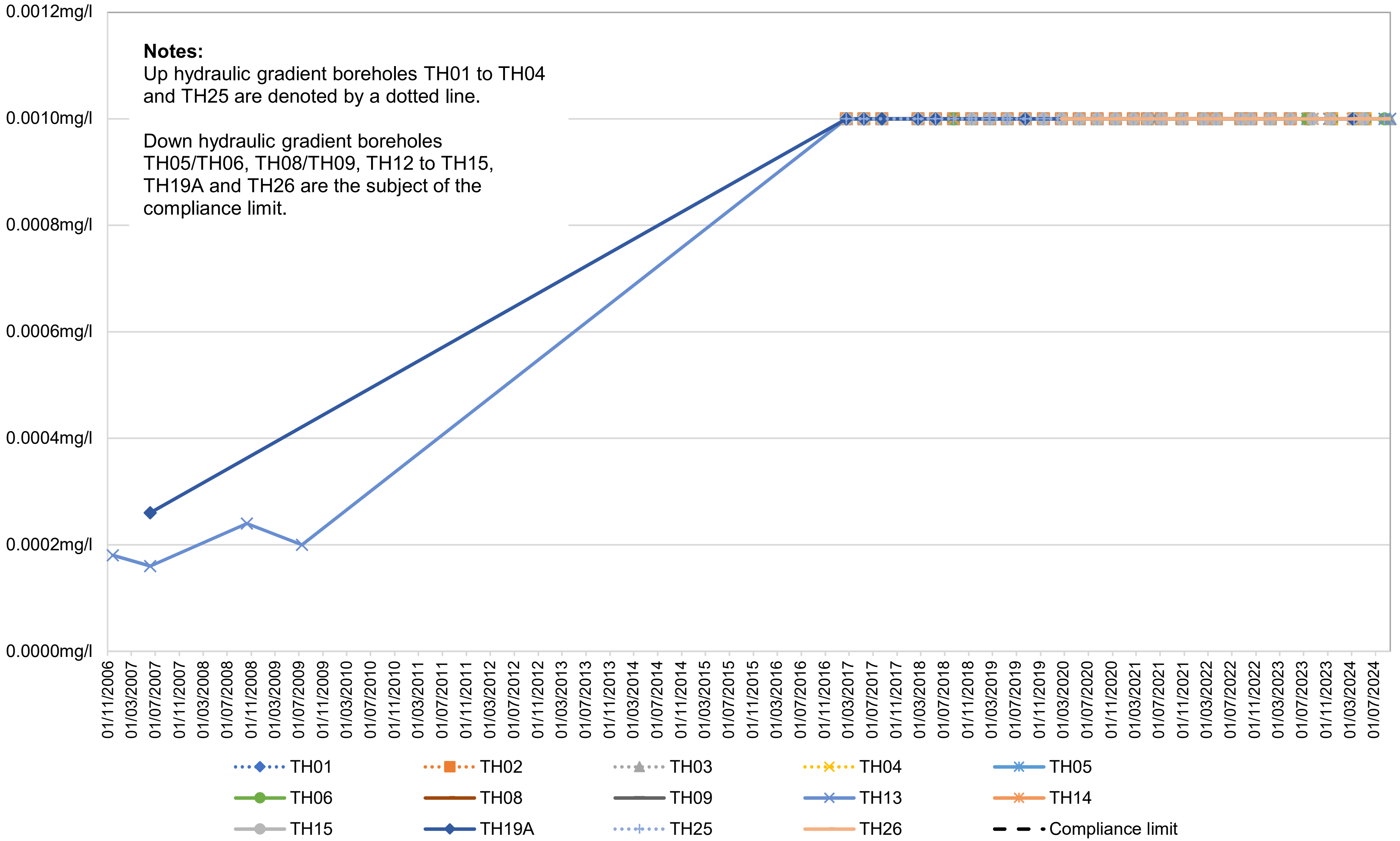
Chemograph of the concentration of sodium recorded in the groundwater at Thornhaugh landfill between March 2005 and September 2024



Chemograph of the concentration of sodium recorded in the groundwater at Thornhaugh landfill between March 2005 and September 2024



Chemograph of the concentration of TCE recorded in the groundwater at Thornhaugh landfill between November 2006 and September 2024



APPENDIX HRA B

ENVIRONMENT AGENCY HRA TEMPLATE SIGN POSTING DOCUMENT FOR THE 2025 HRAR ADDENDUM

APPENDIX HRA B

Sections of the 2025 Hydrogeological Risk Assessment Review (HRAR) Addendum report where the items listed in the Environment Agency guidance for HRAs[1] are addressed for Thornhaugh Landfill Site

EA TEMPLATE TABLE OF CONTENTS	2025 HRAR Addendum report sections where item is presented
INTRODUCTION	The operator of the proposed installation (Augean), the agent who completed this report (MJCA), an outline of the proposed installation and how it relates to historically operated areas of landfill and cross reference to appropriate Conceptual Site Model (i.e. ESID report) are included in Section 1 of the 2025 HRAR Addendum report
HYDROGEOLOGICAL RISK ASSESSMENT	
Nature of the hydrogeological risk assessment	Consistent with those at the currently permitted site as presented in the 2014 HRA. The site setting is summarised in Section 2 of the 2024 HRAR (Appendix HRA A) in respect of geology and aquifer designations. A detailed quantitative HRA has been undertaken.
Proposed assessment scenarios	The lifecycle phases are confirmed in Section 3 of the 2025 HRAR Addendum report
Priority substances	The hazardous substances and non-hazardous pollutants included in the HRA are consistent with the 2014 HRA as updated by the 2024 HRAR and the 2025 HRAR Addendum comprising a range of substances which are present in the leachate as set out in Section 2 of the report. The source term used in the 2025 HRAR Addendum is presented in Table HRA 1.
Review of Technical Precautions	The technical precautions at the current site are considered in Section 3 of the 2024 HRAR (Appendix HRA A). Management of the site is included in the cross-referenced ESID reports. Consistent with the 2014 HRA the technical precautions include the placement of the basal and perimeter liner, leachate management and capping of the landfill. Groundwater and surface water are monitored at the site consistent with conditions of the permit.
Leachate characterisation	As stated above under priority substances, the hazardous substances and non-hazardous pollutants included in the HRA comprise a range of substances which are present in the leachate as set out in Section 2 of the 2025 HRAR Addendum report. The source term used in the 2025 HRAR Addendum is presented in Table HRA 1.

EA TEMPLATE TABLE OF CONTENTS	2025 HRAR Addendum report sections where item is presented
Risk assessment level	The risk assessment level is presented in Sections 3 of the 2025 HRAR Addendum report and is consistent with the 2014 HRA for the current permitted site and the 2024 HRAR.
Pollution calculations	See the justification for the modelling approach and software and Hydrogeological leachate completion criteria below.
Justify your modelling approach and software	The model approach is presented in Sections 3 and 4 of the 2025 HRAR Addendum report and is consistent with the 2014 HRA for the current permitted site and the 2024 HRAR.
Model parameterisation	The model parameterisation is referenced in Sections 2 of the 2025 HRAR Addendum report and is presented in the associated tables and appendices including those parameters taken from the 2014 HRA for the current permitted site and the 2024 HRAR.
Sensitivity analysis	Sensitivity analyses are presented in Section 4 of the 2025 HRAR Addendum report.
Model validation	A review of monitoring data compared with model input parameters is presented in the 2024 HRAR at Appendix HRA A.
Accidents and their consequences	Accidents and their consequences are consistent with those at the currently permitted site as presented in the 2014 HRA. Section 2.5.5 Accidents and their consequences from the 2014 HRA is reproduced at this appendix for ease of reference.
Emissions to groundwater or surface water	The specification of appropriate Environmental Assessment Levels (EALs) is referenced in Section 2 and are presented in the associated tables in the 2025 HRAR Addendum report.
Hazardous Substances	The results of the modelling including potential emissions to groundwater are presented in Section 4 of the 2025 HRAR Addendum report.
Non-hazardous pollutants	The results of the modelling including potential emissions to groundwater are presented in Section 4 of the 2025 HRAR Addendum report.
Groundwater and/or surface water compliance points	Receptors for hazardous substances and non-hazardous pollutants are included in Section 2 of the 2025 HRAR Addendum report with cross references to the ESID report as appropriate.
Groundwater control levels	See the monitoring section below.
Surface water management	Management of the site is included in the cross-referenced ESID report.

EA TEMPLATE TABLE OF CONTENTS	2025 HRAR Addendum report sections where item is presented
Monitoring	The monitoring of leachate, groundwater and surface water at Thornhaugh Landfill is the subject of conditions of the Environmental Permit for the site and is set out in Table HRA 6 (REVISED) presented at Appendix A to the 2024 HRAR (Appendix HRA A). Changes to the monitoring network at the site since the 2014 HRA was prepared are summarised in section 6 of the 2024 HRAR.
Leachate monitoring	Leachate monitoring for the currently permitted site is reviewed in Sections 2 and 3 of the 2024 HRAR (Appendix HRA A). Leachate monitoring and compliance limits are presented in Table HRA 7 and Table HRA 8 of the 2014 HRA. Updates to the leachate quality control levels comprise the updates to the maximum concentrations in the leachate source term for the site as presented in in Section 2 and Table HRA 1 of the 2025 HRAR Addendum report.
Groundwater monitoring	Groundwater monitoring is reviewed in Sections 2, 6 and 7 of the 2024 HRAR (Appendix HRA A). Groundwater quality compliance limits and control levels for the site are set out in Tables HRA 9 and HRA 10 of the 2014 HRA. The groundwater compliance limits and the interim compliance limits are set out in Table S3.4 of the EP. Proposed revisions and additions to the groundwater quality compliance limits and control levels for the site are set out in Section 5 of the 2025 HRAR Addendum report.
Surface water monitoring	Surface water monitoring is reviewed in Section 7 of the 2024 HRAR (Appendix HRA A). Surface water monitoring and compliance limits are presented in Table HRA 11 of the 2014 HRA.
Hydrogeological leachate completion criteria	The completion criteria for the site are consistent with those from the 2014 HRA for the current permitted site. Section 2.7 Hydrogeological completion criteria from the 2014 HRA is reproduced at this appendix for ease of reference.
CONCLUSIONS	
Meets the relevant standards of the Environmental Permitting Regulations 2016 schedules 9, 10, 21 and 22, as appropriate	Conclusions regarding compliance with Schedule 22 of the Environmental Permitting (England and Wales) Regulations 2016 are presented in Sections 4 and 6 of the 2025 HRAR Addendum report.
Design of your site will prevent unacceptable discharges and emissions over the entire lifecycle of the site	See above.

EA TEMPLATE TABLE OF CONTENTS	2025 HRAR Addendum report sections where item is presented
Propose compliance limits and assessment levels for leachate, groundwater and surface water where applicable	See the monitoring section above.

Notes:
[1] https://www.gov.uk/guidance/landfill-operators-environmental-permits/what-to-include-in-your-hydrogeological-risk-assessment accessed July 2025

existing HRA. Monitoring will continue throughout the life of Thornhaugh Landfill and the HRA will be reviewed on a regular basis.

2.5.5 Accidents and their consequences

i. Technical precautions are included in the landfill design to minimise the impact of accidents on the aqueous environment. The construction of the low hydraulic conductivity basal and perimeter liners together with leachate drainage is agreed by the Environment Agency through the CQA validation process prior to the placement of wastes to confirm that the lining and drainage systems are installed in accordance with the specifications. The placement of the low hydraulic conductivity cap is subject also to a CQA validation process.

ii. Drilling through the liner following construction of the liner for example where leachate monitoring wells are installed, may result in the unrestricted flow of leachate into the surrounding natural strata. As leachate monitoring wells are and will be constructed progressively during filling of the landfill there is no risk of drilling through the liner during formation of the wells. Concrete pads extending to a radius of 2m from the original well position are constructed to provide a marker of the location of the base of the site in the event that it is necessary to install leachate wells retrospectively. Boreholes would be positioned to intercept the concrete pad which would form the base of the borehole and will prevent breach of the liner should replacement leachate wells be necessary. Accordingly it is unlikely that replacement wells will penetrate the liner.

iii. During the operational phase and post closure managed phase leachate levels are managed at a level at or below 1.5m above the top of the basal liner through the use of the leachate drainage and abstraction system. Failure of a leachate pump may result in an increased head of leachate in the area of the site served by that pump. Pumps generally can be replaced within one or two weeks during which time the rise in leachate level will be small. It is considered that there is no need for additional quantitative analysis in respect of the impact of leachate levels elevated temporarily following pump failure.

iv. Spills may occur during the removal of leachate from a leachate sump which could result in the discharge of leachate to groundwater or surface water. The leachate management procedures for the site include procedures for the avoidance and remediation of leachate spills and the above ground leachate management system is through enclosed pipes. It is considered that the risk of a spill occurring and the risk from any spills of leachate to groundwater or surface water is low. Additional quantitative analysis in respect of spills is not necessary.

2.7 Hydrogeological completion criteria

i. The concentrations of determinands in the leachate will reduce over time. Long term monitoring of leachate quality will be carried out to determine the time at which the site no longer presents a potential risk to groundwater. The hydrogeological completion criteria will be approaching the EALs as a worst case situation. The completion of the landfill will be determined from the results of the monitoring of leachate quality and in agreement with the Environment Agency.

APPENDIX HRA C

INFILTRATION MODEL METHODOLOGY

Appendix HRA C

Model methodology - Recharge to a capped landfill

C1. The cap design for the site has been updated and it is now proposed that the cap comprises a 1m thick clay cap with a granular layer formed from site derived sand placed over the cap to provide a drainage and protection layer at Phases 1, 2, 4, 5 and 7. Consistent with Table ESID 1 of the 2025 Environmental Setting and Installation Design (ESID) report[2] the 1m clay cap at Phases 1, 2, 4, 5 and 7 will be constructed over a 0.3m thick clay subgrade layer placed over the completed and profiled waste surface and restoration soils will be placed over the cap and drainage and protection layer to a thickness of between 1m and 1.5m. Phases 3 and 6 are capped with a 0.3m thick regulating layer which is overlain in turn by a geosynthetic clay liner (GCL), linear low density polyethylene (LLDPE) geomembrane, a combination of a protection geotextile and a protection geocomposite and a minimum thickness of 1m of restoration soils. Infiltration through the capped phases 3 and 6 was assessed as part of the approved 2014 HRA (see Table HRA 3).

C2. Consistent with the methodology used in the 2014 HRA, recharge to the cap through the restoration soils is calculated using the method presented in Rushton and Redshaw (1979)[3]. The method is a soil moisture deficit model which takes into account the fraction of precipitation which may by-pass the soil moisture store. The model takes into account the root constant and wilting point in calculating the soil moisture deficit. The soil moisture deficit method is in common use in the UK and worldwide for calculating recharge. Other than the fraction of precipitation which may by-pass the soil moisture store, water will be present at the surface of the cap only when the soil moisture deficit is zero. Consistent with the approved 2014 HRA, the precipitation values used in the model are average monthly rainfall data presented in the 2004 ESID[4]. The average monthly rainfall has been calculated from rainfall data for the period 1973 to September 2004 recorded at the RAF Wittering Meteorological Station approximately 1.9km to the north west of the site. The potential evapotranspiration values used in the model are the average monthly potential evapotranspiration data

2 MJCA, 2025. An application to vary Environmental Permit No. RP3133PP for the Thornhaugh Landfill Site operated by Augean South Limited to change the restoration profile of the existing permitted site. Environmental setting and installation design (ESID) report. Report reference AU/TH/LRM/5784/01/ESID.

3 Rushton, K.R. and Redshaw, S.C., 1979. Seepage and Groundwater Flow. Wiley. Pages 134 and 135.

4 Environmental Simulations International Limited, 2004. Thornhaugh Landfill. Environmental Setting & Installation Design (ESID) Report. Report reference RP3133PP/01/A.

presented in the 2004 ESID. The average monthly potential evapotranspiration comprises MORECS potential evapotranspiration data for RAF Wittering for the period 1961 to 1990 provided by the Met Office.

C3. The results of the recharge calculations are entered into the hydraulics section of the models which comprise a series of calculations for a given time step which is in this instance 1 month. The calculations are undertaken for the situation where the landfill cap comprises a 1m clay cap. The recharge is converted into a head of water on the cap.

C4. The 1m clay cap will be overlain by a 0.3m thick granular protection and drainage layer the presence of which is taken account of in the model. The equation used to calculate the capacity of the drainage layer per metre width of drainage layer based on Darcy's Law is:

$$Q_{drainage} = k_{drainage} \times b_{drainage} \times i_{drainage}$$

Where:

$Q_{drainage}$ is the capacity of the drainage layer ($m^3/s/m$)
$k_{drainage}$ is the hydraulic conductivity of the drainage layer (m/s)
$b_{drainage}$ is the thickness of the drainage layer (m)
$i_{drainage}$ is the hydraulic gradient of across the drainage layer which is assumed to be the slope of the cap (m/m)

C5. It is assumed conservatively in the model that the head build up on the cap is equal to the volume per unit area of recharge from the soil divided by the ratio of the capacity of the drainage layer to the volume per unit area of recharge from the soil. Consequently it is assumed that the head of water on the cap reflects the average head of water which would be generated if all of the recharge during each time step were to accumulate instantaneously on top of the cap prior to being dissipated by the drainage layer. In reality due to the domed profile of the cap, head build up on the cap will be dissipated continuously by the drainage layer and it is unlikely that the average head on the cap, will be as high as the heads modelled in this assessment. It is assumed that the hydraulic conductivity of the drainage layer conservatively is 4×10^{-6} m/s and it is assumed that the slope of the cap conservatively is 1 vertical in 20 horizontal which is the lower end of the range of cap slopes presented in Table ESID

1 of the 2025 ESID. On the basis of the above it is considered that this assumption will result in an overestimate of the head build up on the cap hence the rate of infiltration through the cap compared with those which are likely to occur.

C6. The drainage layer will comprise site derived sand. The assumed hydraulic conductivity of the drainage layer of 4 x 10^{-6} m/s is the minimum hydraulic conductivity of the Northampton Sand Formation from slug tests carried out in boreholes at the site (see Table HRA 3). A typical range of hydraulic conductivities for a fine sand is between approximately 2 x 10^{-5} m/s and 6 x 10^{-5} m/s. The hydraulic conductivity of site derived material can be estimated from particle size distribution (PSD) analysis using Hazen's method. Bulk samples of site derived fill excavated from Phase 7A have been submitted to the laboratory for PSD analysis. Based on this data the hydraulic conductivity of the site derived fill is approximately 4 x 10^{-5} m/s which comprises the mid-range for a fine sand. It is likely that the hydraulic conductivity of the drainage layer will be significantly higher than that used in the infiltration model confirming that the model is conservative.

C7. The maximum recharge flux per unit area is in January of each year and is calculated as 9.5 x 10^{-9} $m^3/s/m^2$. This maximum, recharge flux compares with the calculated flow capacity in the drainage layer of 6 x 10^{-8} $m^3/s/m^2$. These data show that there is a factor of 6 greater capacity for flow in the drainage layer compared with the maximum recharge to the drainage layer. If the likely (rather than assumed) hydraulic conductivity of the drainage layer of 4 x 10^{-5} m/s is used in this calculation the calculated flow capacity in the drainage layer is 6 x 10^{-7} $m^3/s/m^2$ which is 60 times greater capacity for flow in the drainage layer compared with the maximum recharge to the drainage layer. These comparative data show the degree of conservatism which allows for the potential for clogging of the drainage layer. Furthermore in practice the site derived material used in the drainage layer will be carefully selected to be that which comprises the more coarse components of the material hence it is likely that the hydraulic conductivity of the drainage layer will be even greater than 4 x 10^{-5} m/s.

C8. It is assumed that the cap is saturated. The equation used to calculate the rate of flow per metre squared through the clay cap is:

$$Q_{CAP} = k_{CAP} \times i_{CAP}$$

Where:

Q_{CAP} is the flow per metre squared through the clay cap ($m^3/s/m^2$)

k_{CAP} is the hydraulic conductivity of the clay cap (m/s)

i_{CAP} is the hydraulic gradient across the clay cap (m/m).

The equation used to calculate i is:

$$i_{CAP} = (h_{CAP} + b_{CAP}) / b_{CAP}$$

Where:

h_{CAP} is the head of water on the clay cap calculated for each time step (m)

b_{CLAY} is the thickness of the GCL (m)

C9. The models have been run for a range of hydraulic conductivities of the clay cap taken from Construction Quality Assurance (CQA) testing results for the clay liner for the most recent cell construction at the site Phase 7C (2023) and Phase 2 West (2024). The lowest quartile, the geometric mean and the 90th percentile of the CQA data for Phase 7C and Phase 2 (West) has been used for the minimum, most likely and maximum of the hydraulic conductivity values of the clay cap in the infiltration models. The models are provided at Appendix HRA D. The results of the calculations for 720 time steps which is 60 years are calculated for the situation where the cap comprises a 1m clay cap. The modelled annual average infiltration rate over the 60 year period for a 1m clay cap has minimum, most likely and maximum values of 0.32mm per year, 0.60mm per year and 1.9mm per year respectively. The model stabilises over the first few years hence it is not deemed necessary to calculate further time steps. Due to the conservative assumptions made as part of the model it is considered unlikely that the rate of infiltration through the cap will exceed these values.

APPENDIX HRA D

ELECTRONIC COPY OF THE 2025 INFILTRATION MODEL, ELECTRONIC COPY OF THE 2025 HRAR ADDENDUM LANDSIM MODEL AND THE 2025 HRAR ADDENDUM SENSITIVITY ANALYSES MODELS TOGETHER WITH AN ELECTRONIC COPY OF THE REVISIONS TO THE LEAD CONCENTRATIONS AND DETAILS OF THE OUTLIER IN THE CADMIUM CONCENTRATIONS IN THE LEACHATE