STANWAY QUARRY INERT LANDFILL
ENVIRONMENTAL PERMIT APPLICATION

HYDROGEOLOGICAL RISK ASSESSMENT

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1.0 INTRODUCTION

1.1 Report Context

1.1.1 Sirius Environmental Limited (Sirius) has been commissioned by Tarmac Trading Limited ('Tarmac') to prepare an Environmental Permit Application for the operation of an inert landfill facility to support the restoration of Stanway Quarry, Colchester, Essex. As part of this application, it is necessary to formulate a range of risk assessment documents, including the requirement to undertake a Hydrogeological Risk Assessment.

1.1.2 This assessment is prepared in accordance with the Environment Agency guidance: Groundwater risk assessment for your environmental permit (last updated 14th March 2017). The Environment Agency is required to ensure that the activities are subject to prior investigation and a pollution risk assessment.

1.1.3 This report should also be read in conjunction with the Environmental Setting and Site Design report *(Doc. Ref.: TA1026/04)* which accompanies the wider Environmental Permit application.

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2.0 CONCEPTUAL HYDROGEOLOGICAL SITE MODEL

2.1 General

2.1.1 The details of the proposed design and the environmental setting of the site are set out in the Environmental Setting and Site Design (ESSD) Report *(Doc. Ref: TA1026/04)* and are summarised below:

- infilling will take place in a void created by the extraction of superficial sand and gravel deposits;
- the inert landfill will be constructed within the superficial sand and gravel deposits with an engineered sidewall geological barrier with a maximum permeability equivalent to 1m at $1x10^{-7}$ m/s.
- the base of the landfill will be formed over the underling London Clay, which is approximately 29m thick locally and has a typical bulk permeability of approximately 10^{-9} m/s;
- the site will accept only inert waste; and
- due to the nature of the waste streams, leachate collection systems and an artificial sealing liner are not required.

2.1.2 Comprehensive details on the hydrogeological setting of the site are provided within the ESSD report *(Doc Ref.: TA1026/04)*, and include the following:

- aquifer characteristics;
- groundwater flow and quality;
- groundwater quality;
- licensed groundwater abstractions; and
- Source Protection Zones.

2.1.3 The conceptual hydrogeological site model is based on the source-pathway-receptor linkages. The conceptual model is shown in **Drawing Nos. B030-00676-11 and -12** and key elements of the hydrogeological model are discussed in further detail below.

2.2 Source

2.2.1 The restoration operations of Stanway Quarry will principally be carried out as an inert landfill site within the void of the sand and gravel quarry. The landfill source term has initially been determined from standard WAC thresholds.

Site Design & Construction

2.2.2 The site design is detailed within the ESSD (*Doc. Ref.: TA1026/04*) and is summarised below.

2.2.3 The superficial sand and gravel deposits in which the quarry is located comprises a typically permeability range of 10^{-5} to 10^{-4} m/s and offers limited attenuation capacity. An Artificially Enhanced Geological Barrier (AEGB) will therefore need to be constructed across the sidewalls of the quarry at a maximum permeability of $1x10^{-9}$ m/s. For stability requirements the sidewall AEGB will be constructed in 2m high lifts, whereby a minimum thickness of 3m will be required to support the necessary construction techniques.

2.2.4 The northern edge of the landfill will be formed from the site won materials (i.e. inter- and over-burden, and quarry wastes/fines). The surface of the side slope over which inert waste will be tipped will consist of a 500mm thick AEGB with a maximum permeability of $1x10^{-9}$ m/s

2.2.5 The base of the quarry comprises London Clay which has been proven locally to be approximately 29m thick. The London Clay generally achieves in-situ permeabilities of between 10^{-11} to 10^{-8} m/s (Hight et al., 2003) and is therefore considered to meet the minimum standards set-out in the Landfill Directive.

Waste Quality and Priority Contaminants

2.2.6 There is no confirmed waste stream for the site. A representative landfill source term has therefore been determined from standard WAC threshold for inert landfills.

Table HRA1: Standard WAC and equivalent inert waste 'leachate' quality

Parameter	Inert Waste WAC (L/S 10 l/kg) [mg/kg]	Equivalent Liquid Concentration [mg/l]	EQS[1] [mg/l]	Risk Factor
Hazardous Substances				
Arsenic	0.5	0.05	0.01	5
Lead	0.5	0.05	0.025	2
Mercury	0.01	0.001	0.001	1
Non-Hazardous Pollutants				
Cadmium	0.04	0.004	0.005	0.8
Chromium	0.5	0.05	0.05	1
Copper	2	0.2	2	0.1
Molybdenum	0.5	0.05	0.07[2]	0.7
Nickel	0.4	0.04	0.02	2
Antimony	0.06	0.006	0.005	1.2
Selenium	0.1	0.01	0.01	1
Zinc	4	0.4	3[3]	0.13
Chloride	800	80	250	0.32
Fluoride	10	1	1.5	0.67
Sulphate	1000	100	250	0.4
Phenol Index	1	0.1	0.1[3]	1

[1] - EAL based on DWS unless specified otherwise
[2] - EAL based on WHO Drinking Water guideline
[3] - EAL based on UK Standard for the Protection of Surface Waters Intended for the Abstraction of Drinking Water (Council Directive 75/440/EE)

2.2.7 Total concentration limits are also stipulated for organic parameters, including PAHs, PCBs, BTEX and mineral oils. It is therefore prudent to consider the presence of such contaminants within a rogue load of wastes deposited at the site. For this purpose, the Benzo-a-pyrene will be considered assuming an effective solubility of 0.00019mg/l[1].

2.2.8 The priority contaminants to be taken forwarded for assessment include arsenic, benzo(a)pyrene, lead, mercury, nickel and sulphate. The leachable concentrations provided in **Table HRA1** would be representative of a worse case source term leachate quality for the inert landfill.

2.3 Pathways

Geology

2.3.1 The site is located within superficial deposits comprising glacially derived sand and gravel of the Lowestoft Formation which is underlain by fluvial sand and gravels of the Kesgrave Catchment Subgroup which formerly were known as the Kesgrave Sands and Gravels. The superficial deposits are underlain in turn by tertiaries comprising the London Clay Formation, which is part of the Thames Group, the Lambeth Group and the Thanet Formation, which in this area together comprise the former Lower London Tertiaries. Strata formerly classified as the Upper Chalk, which now comprise part of the White Chalk Subgroup, underlies the tertiary group. The London Clay has been proven to be around 30m thick in the Stanway Area.

Aquifer Characteristics and Groundwater Flow

2.3.2 The superficial sand and gravel deposits are classified as a 'Secondary A' Aquifer in which groundwater is perched above the London Clay. Groundwater within this aquifer has been monitored in six boreholes located around the periphery of the quarry since October 2016. Groundwater level data and a hydrograph is presented in in **Appendix HRA1**, whilst a statically summary is presented in the **Table HRA2**.

[1] As determined in CL:AIRE research bulletin RB15 (September 2011).

Table HRA2: Statistical summary of monitored gorundwater levels within the sand and gravel aquifer around Stanway Quarry (mAOD)

BH ID	BE8A	GR7	GR8	SQ1	SQ2	SQ3
Min	17.13	20.62	20.98	17.69	19.24	17.94
Mean	17.70	21.91	21.21	18.24	19.36	18.04
Max	17.85	22.39	21.53	18.75	19.56	18.45

2.3.3 The data indicates that groundwater within the sands and gravels immediately surrounding the site are currently suppressed as result of the quarry activities, with levels to the north of the quarry currently at an elevation around between c. 18 and 19.5mAOD, and between c. 17.5 to 18.5mAOD to south of the quarry. Levels in GR8 located to the northwest of the quarry are elevated at c. 21mAOD. The highest groundwater levels of c. 22mAOD are recorded in borehole GR7. However, this borehole is located within the western extents of the quarry, located adjacent to flooded lagoons associated with ongoing surface and groundwater management operations at the quarry. Levels in GR7 are therefore likely to be influenced by the water levels within the lagoons.

2.3.4 During infilling, all surface waters, and groundwaters draining from the adjacent sand and gravel deposits and waste deposits will be managed. These operations are considered to limit the level of saturation within the waste deposits to below groundwater levels within the surrounding aquifer, therefore creating an inward hydraulic gradient across the AEGB constructed over the sidewalls. Once the quarry is fully restored, groundwater levels in in the surrounding sand and gravel aquifer will start to recover. A review of the potential levels to which groundwater will recover to following the cessation of groundwater management activities at the site has been carried out and is presented in **Appendix ESSD7** of ESSD *(Doc Ref.: TA1026/04)*. This review predicts that groundwater levels will recover to c. 21mAOD in the northern area of the site and c. 20mAOD on the southern edge of the quarry.

2.3.5 The site restoration scheme incorporates a large pond/lagoon habitat within landfill footprint, with a series of smaller lagoon and wetland habitats within the northern and western area of the quarry, as shown in **Drawing No. B030-00676-11**. Water levels within the ponds/lagoon will generally be managed at levels of approximately 22mAOD, reducing to around 21 and 20mAOD within the waterbodies proposed to the southwest of the landfill area.

2.3.6 It is considered that water levels within the wastes will be principally governed by the managed levels within the pond/lagoon systems within the landfill footprint i.e. 22mAOD. The physical characteristics of the waste deposits are likely to be variable depending on the types and associated quantities of the materials deposited (e.g. cohesive or granular) but are most likely to comprise marginally higher bulk permeability than the AEGB constructed over the sidewalls of the site that consist of exposed sands and gravels. The AEGB will constructed to a thickness of 3m at a maximum permeability of 1×10^{-9} m/s over the sidewalls of the exposed sand and gravel aquifer and to a thickness of 0.5m over the fill materials used to restore the northern extension area of the quarry. This is likely to minimise outward flow to the sand and gravel aquifer, thus creating a head differential of up to c. 2m based on predicted recovery levels in the superficial aquifer. In comparison, the permeability of the sand and gravel aquifer is typically between 10^{-5} to 10^{-4} m/s (Hafren, 2001), in which waters flowing through the AEGB are unlikely to significantly influence groundwater levels within the aquifer.

2.4 Receptors

2.4.1 The primary receptor to the landfill facility is the superficial sand and gravel aquifer, which provides base flow to the north-bank tributaries of the Roman River to the southwest and southeast of the landfill, and spring flows at the edge of the superficial sands and gravels which subsequently drain to the Roman River. There are currently no licensed groundwater abstractions between the site and the Roman River, although the abstraction of surface water is licenced from the Roman River along a c. 1km stretch of the river to the south of the site, as shown in the **Drawing No. B030-00676-10.**

Background Groundwater Quality

2.4.2 At the time of preparing this assessment, local groundwater quality within the vicinity of Stanway Quarry has been monitored between October to December 2016 and between May 2017 to February 2018 targeting the key substances listed against the standard WAC suite of analysis. A statistical summary of the data is presented in **Table HRA3,** with a full set of monitoring results and timeseries plots presented in **Appendix HRA2**.

Table HRA3: Baseline groundwater quality summary *(statistical outliers removed)*

Statistic	Arsenic (µg/l)	Cadmium (µg/l)	Chloride (mg/l)	Chromium (µg/l)	Copper (µg/l)	Fluoride (mg/l)	Lead (µg/l)	Mercury (µg/l)	Molybdenum (µg/l)	Nickel (µg/l)	PAH (Total) (µg/l)	Selenium (µg/l)	Sulphate (mg/l)	Zinc (µg/l)
BE8A														
Min	<0.2	0.07	70	<0.1	0.8	<0.05	<0.3	<0.05	<1	4	<0.01	<0.5	53	4
Mean	0.34	0.11	88.0	-	1.14	-	<0.3	-	<1	4.3	0.10	<0.5	55.8	8.9
Max	0.7	0.19	120	<0.1	1.6	<0.05	0.3	<0.05	1	5	0.71	0.5	59	21
Stdev	0.17	0.04	15.3	-	0.33	-	0.07	-	0.17	0.5	0.25	0.13	2.3	5.5
GR8														
Min	0.6	<0.02	92	<0.1	3.2	<0.05	<0.3	<0.05	<1	2	<0.01	<0.5	81	5
Mean	0.71	0.15	107.7	-	5.00	0.05	<0.3	-	2.40	12.2	0.01	-	89.7	12.0
Max	0.8	0.41	120	<0.1	6.5	0.09	0.3	<0.05	7	33	0.04	<0.5	99	17
Stdev	0.09	0.16	10.5	-	1.32	0.02	0.05	-	2.39	11.1	0.01	-	6.2	4.5
GR8														
Min	0.6	0.04	86	<0.1	1.4	<0.05	<0.3	<0.05	<1	2	<0.01	<0.5	79	5
Mean	0.75	0.08	119.5	-	2.19	<0.05	<0.3	-	<1	2.1	0.05	-	96.2	8.3
Max	0.9	0.18	140	<0.1	3.1	0.08	0.3	<0.05	1	3	0.44	<0.5	110	13
Stdev	0.09	0.04	15.2	-	0.49	0.02	0.05	-	0.19	0.3	0.13	-	8.2	2.6
SQ1														
Min	0.3	0.04	60	<0.1	0.7	<0.05	<0.3	<0.05	<1	6	<0.01	<0.5	74	8
Mean	0.34	0.08	65.5	-	1.25	-	<0.3	-	<1	7.7	0.03	0.61	87.3	12.9
Max	0.4	0.2	77	<0.1	2.4	<0.05	<0.3	<0.05	1	11	0.23	0.7	95	29
Stdev	0.05	0.05	4.9	-	0.50	-	0.00	-	0.20	1.9	0.07	0.07	7.3	6.6
SQ2														
Min	0.6	0.09	74	<0.1	2.1	<0.05	<0.3	<0.05	<1	7	<0.01	<0.5	130	7
Mean	0.69	0.19	114.6	-	2.52	-	<0.3	0.06	<1	13.9	0.05	-	197.5	12.5
Max	0.8	0.34	150	<0.1	3	<0.05	0.4	0.12	1	26	0.47	<0.5	320	26
Stdev	0.09	0.07	31.0	-	0.32	-	0.10	0.04	0.15	6.6	0.14	-	62.4	5.9
SQ3														
Min	0.5	0.03	14	<0.1	<0.5	<0.05	<0.3	<0.05	<1	7	<0.01	1.6	200	7
Mean	0.75	0.07	19.6	-	0.82	<0.05	<0.3	-	-	10.5	0.15	2.14	224.5	13.0
Max	1.4	0.14	33	<0.1	1.4	0.11	0.5	<0.05	<1	14	0.42	3.1	270	24
Stdev	0.28	0.03	5.5	-	0.30	0.03	0.12	-	-	2.3	0.16	0.45	21.6	5.3

Note: Statistical analysis carried out with the assumption that results below the method limit of detection are equivalent to a concentration of 50% of the limit value.

2.4.3 The results show that there is significant variation of groundwater quality around the site, the most noteworthy being the variation of the chloride and sulphate, whereby chloride concentrations in SQ3 are notably lower in than the rest of the site, and sulphate concentrations in SQ2 and SQ3 significantly higher than rest of the site. Similarly, there were notable peaks in concentrations of cadmium, copper, molybdenum, nickel and fluoride concentration during the autumn of 2017 within GR7. There are also some notable increasing trends throughout the monitoring period for several substances at various boreholes - including barium in BE8A and SQ2; nickel in GR7 and SQ2; chloride in BE8, GR7 and SQ; fluoride in GR7 and SQ3, sulphate in SQ2. The variations observed in SQ2 and SQ3 may be due to the recent installation of these monitoring boreholes, with SQ2 potential influenced by changing redox or conditions within the aquifer as quarry operations extend northwards into the eastern extents of the northern extension area. However, a full understanding of the redox conditions within the boreholes has not been established as part of the background monitoring works. There are also numerous historical and licensed landfill sites located to the west and north of the quarry that could be impacting on groundwater quality along the northern and western edges of the site.

Environmental Assessment Levels

2.4.4 The setting of Environmental Assessment Limits (EALs) is necessary in order to access whether the requirements of the Environmental Permitting Regulations 2016 are likely to be met.

2.4.5 The following selection criteria are considered appropriate for the Site:-

- For Hazardous Substances, the EALs shall be the minimum reporting values (MRVs) as defined in EA Guidance “Hazardous substances to groundwater: minimum reporting values[2]”, except where background groundwater quality exceeds the specified standards. Where MRVs are not available the appropriate laboratory limits of detection will be selected;
- for Non-Hazardous Pollutants the EALs shall be the UK Drinking Water Standards (DWS)[2] or the UK Environmental Quality Standards (EQS), except where background groundwater quality exceeds the specified standards.

2.4.6 Details of the EALs to be taken forward for assessment purposes are presented in **Table HRA4.**

Table HRA4: Environmental Assessment Limits

Substance	Minimum Reporting Value[1]	Laboratory Limits of Detection[1]	Environmental Quality Standard[2]	Monitored Baseline at SQ3[3]	Selected EAL
Hazardous Substances					
Arsenic (mg/l)	NS	0.0002	0.01	0.0013	0.0013
Benzo(a)pyrene (mg/l)	NS	0.00001	0.00001	-	0.00001
Mercury (mg/l)	NS	0.00005	0.001	<0.00005	0.00005
Lead (mg/l)	NS	0.0003	0.01	0.0005	0.0005
Non-Hazardous Pollutants					
Nickel (mg/l)	-	-	0.02	0.015	0.02
Sulphate (mg/l)	-	-	250	268	268

1 - applies to hazardous substances only
2 - based on UK DWS
3 - baseline conditions at SQ3 based on mean concentrations + two standard deviations, where concentration are above the method limit of detection
NS – None specified

2 An EAL can be defined as a water quality standard that is defined by either UK Regulations (e.g. Water Supply (Water Quality) Regulations 2016) or another relevant source (e.g. non-statutory Environmental Quality Standards)

3.0 HYDROGEOLOGICAL RISK ASSESSMENT

3.1 Nature of the Hydrogeological Risk Assessment

3.1.1 As set out within the Environment Agency's "Inert Waste Guidance" the *"appropriate complexity of assessment for a site should be determined from the potential risks presented by the site, which are linked to the nature of potential hazards, the sensitivity of the surrounding environment, degree of uncertainty and likelihood of a risk being realised.*"

3.1.2 The site will accept inert waste, which is defined as follows;

- it does not undergo any significant physical, chemical or biological transformations;
- it does not dissolve, burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm to human health; and
- total leachability, pollutant content and the ecotoxicity of its leachate are insignificant and, in particular, do not endanger the quality of any surface water or groundwater.

3.1.3 Based on this definition of inert waste, the site should not produce any leachate that could result in any significant discharge of Hazardous Substances or Non-Hazardous Pollutants throughout the lifecycle of the site.

3.1.4 Therefore, with regard to this inert waste stream, the site:

- presents a limited risk to groundwater and surface water quality;
- falls outside the scope of the Environmental Permitting Regulations 2016 (Schedule 22 Groundwater Activities); and
- does not require environmental management systems (artificial sealing liner, leachate management or other engineering and management structures, with the exception of a geological barrier), or the consideration of the degradation of such systems.

3.1.5 However, notwithstanding the above, it is considered that a quantitative risk assessment is required given that the EPR Inert Waste Guidance and decision framework for Position Statement E1 under "The Environment Agency's Approach to Groundwater Protection" (v1.; Nov 2017) states that such an assessment is likely to be necessary for an inert landfill where the receiving environment is particularly sensitive, for example below the water table in a Principal or Secondary A Aquifer or with a direct pathway to a sensitive surface water.

3.1.6 The proposed site is located directly above the locally important sand and gravel aquifer, which provides baseflows and spring flows to nearby rivers.

3.1.7 In order to assess the risk to the environment, it is considered appropriate to assess the potential worst-case leachate quality that could potentially be generated based on Waste Acceptance Criteria and the deposit of a rogue load at the site.

3.2 Proposed Assessment Scenarios

3.2.1 Based on the site conceptual hydrogeological model, as outlined within Section 2.0, it is considered appropriate to assess the risk to groundwater within the superficial sand and gravel aquifer. Owing to the substantial thickness or low permeability London Clay beneath the landfill the risk to groundwater within the underlying Thanet Formation, Lambeth Group and Upper chalk, the risk to this aquifer is significantly reduced. Consequently, consideration of the risk to the sand and gravel aquifer is considered to afford appropriate confidence that there will be limited risk to the bedrock aquifer.

3.2.2 The landfill deposits will be located wholly within the sand and gravel aquifer in which ground waters are currently suppressed by ongoing groundwater management activities, but which are predicted to recover following the cessation of these management activities to approximately 21mAOD and 20mAOD in the northern and southern areas of the quarry respectively. Upon restoration of the quarry, water levels within the waste deposits are predicted to be governed by the water levels in surface water bodies that form part of the restoration scheme, which will be managed at approximately 22mAOD. The presence of AEGB with a maximum permeability of $1x10^{-9}$ m/s between the wastes deposits and the sand and gravel aquifer, which has a notably higher permeability, is likely to generate a head differential between water levels in the landfill and the adjacent aquifer.

3.2.3 The assessment therefore considers the advective migration of 'leachate' from the waste mass through the sidewall AEGB into the adjacent aquifer. The assessment also focuses on the southern boundary of the site as it is assumed that the greatest head difference between water levels in the waste and surrounding aquifer will occur along this boundary. Water levels in the waste deposits are likely to be lower that groundwater levels within the surrounding aquifer during the operational period of the landfill therefore creating a hydraulic gradient into the landfill. The models therefore focus on the post-closure phase of the landfill when water levels are likely to be higher than external levels in the aquifer.

Lifecycle Analysis

3.2.4 It is considered that a risk assessment of lifecycle phases is not required, given that the technical precautions included within the construction and management of the site will not be subject to long term degradation.

3.3 Review of Technical Precautions

Capping

3.3.1 No engineered, low permeability capping system will be required for the site.

Basal & Sidewall Lining Systems

3.3.2 The base of the quarry will comprise a natural geological barrier namely the London Clay, which is approximately 30m thick locally with a typical in-situ permeability range of between 10^{-11} and 10^{-8} m/s. The sidewalls of the quarry will be engineered with an Artificially Established Geological Barrier (AEGB) constructed to a maximum permeability of $1x10^{-9}$m/s. Due to stability and construction technique factors the sidewall will be at least 3m thick on sidewall consisting of exposed sands and gravels, reducing to a thickness of 0.5m over restoration materials associated with the northern extension area of the quarry.

Leachate Management

3.3.3 Due to the inert nature of the waste to be deposited at the site no leachate management will be required. The quality of leachate will be principally controlled by the implementation of strict waste characterisation testing as part of the overall Duty of Care requirements.

Groundwater Management

3.3.4 During operation of the landfill, groundwater within the surrounding sand and gravels will continue to be allowed to drain under gravity to designated holding and settlement lagoons, pending use in support of emissions management and mineral processing requirements. A drainage layer (geocomposite) will also be placed behind the AEGB constructed over the exposed sands and gravels to a height of the natural groundwater level. Waters draining under gravity from this drainage system will be direct to the existing groundwater management network.

3.3.5 Upon restoration of the quarry, the groundwater management operation will be discontinued, and groundwater levels allowed to recover to their pre-quarrying levels.

Surface Water Management

3.3.6 Surface water run-off from the landfill footprint (including runoff and seepages form the waste mass) will be directed to the same holding and settlement lagoons that support groundwater management activities on site.

3.4 Numerical Modelling

Justification for Modelling Approach and Software

3.4.1 The hydrogeological risk assessment has been carried out using conservative assumptions regarding the source, pathways and receptors. Site specific data have been used wherever possible to parameterise the risk models.

3.4.2 The Environment Agency's ConSim software (version 2.5) has been used to provide an estimate of the potential risks associated with the proposed landfill development. This software was applied for the following reasons:-

- it uses Monte Carlo (stochastic) techniques and so allows a probabilistic appreciation of the site's performance;
- it provides a consistent approach to the estimation of hydrogeological risks;
- it provides an audited and verified code that is widely accessible;
- it allows the estimation of the potential attenuation of contaminants through the mineral element of the liner;
- it allows dilution of contaminants in the saturated zone;
- it allows the attenuation of Non-Hazardous Pollutants within the saturated horizon; and
- it aids comprehensive reporting of input values, assumptions and results.
- it allows decline leachate source terms for individual pollutants to be considered (appropriate rates derived from initial modelling performed using Landsim v2.5)

3.4.3 All modelling carried out for this risk assessment has been carried out in a stochastic fashion. Throughout this assessment the acceptable probability of an undesirable outcome occurring is set at the 95%ile for stochastic estimations carried out for a complex hydrogeological risk assessment. In addition, the 95%ile is commonly selected as a reasonable worst case, against which it is acceptable to make decisions considering the assumptions and limitations of the modelling process.

Model Parameterisation

3.4.4 Full details of the model input parameters are presented in **Appendix HRA3.** As discussed in **Section 3.2,** the models focus of the southern boundary of the site where the head difference between water levels in the waste and sands and gravels are greatest.

3.4.5 Declining 'leachate' source terms for each pollutant modelled for the specified timescales have been derived from modelling undertaken utilising Landsim (v2.5). These initial models were run using default Kappa constant values, except for Benzo(a)pyrene in which conservative kappa values were adopted. Details of the Landsim model parameters adopted are presented in **Appendix HRA3.**

Accidents and their Consequences

3.4.6 Details of accidental occurrences at the site that could present a potential risk to groundwater adjacent to the site are provided in **Table HRA5.**

Table HRA5: Qualitative Accident Risk Assessment

Hazard	Risk to Groundwater	Likelihood	Mitigation and Corrective Measures
Deposition of non-inert wastes	Generation of leachate containing Hazardous Substances or Non-Hazardous Pollutants.	**Low** – due to the essential and technical precautions.	Appropriate characterisation of wastes prior to delivery to the site will be provided by the customer, with the appropriate verification checks/tests performed wastes by the operator. Any incorrectly accepted wastes will be immediately returned to the customer or moved to a suitable storage area prior to removal to a suitable site.
Spillage of fuels from storage tanks or vehicles.	Release of hydrocarbons (Hazardous Substances) into the ground and migration to groundwater.	**Low** – fuel stores will be bunded in accordance with regulation requirements. A traffic management system and speed limit will be imposed at the site to reduce both the risk of accidents and the likelihood of spillage occurring.	Any spillage will be cleaned up immediately and any resulting contaminated soils removed to a suitable installation.

3.4.7 With respect to the deposition of potentially contaminated wastes, it is considered that the risks and potential consequences of such accidents are extremely low for the following reasons:-

- all waste deliveries will be pre-arranged and come from known sources to ensure no contaminated material is delivered;
- if deemed necessary, characterisation testing will be undertaken to demonstrate that the waste will not give rise to polluting leachate, prior to the acceptance of waste at the site;
- if deemed necessary compliance testing will be undertaken to ensure the continued acceptability of the waste stream;
- visual inspection will be undertaken of every waste load deposited at the site; and
- in the event of suspicion regarding the acceptability of the waste, quarantine procedures will be enforced.

3.4.8 In the unlikely event of contaminants from a rogue load being deposited at the site, attenuation processes will occur within the waste body, and most organic Hazardous Substances are very likely to be degraded and/or retarded during migration through the surrounding inert wastes within the landfill and the AEGB.

3.4.9 Other processes such as volatilisation can also be expected for volatile and semi-volatile organic substances resulting in a loss of contaminant from the waste.

3.5 Emissions to Groundwater

3.5.1 The results of quantitative modelling are discussed below. All models and associated results files are included in **Appendix HRA4**.

Hazardous Substances

3.5.2 The predicted concentrations of Hazardous Substances at the edge of the site are presented in **Table HRA6.**

Table HRA6: Predicted groundwater concentrations of hazardous pollutants at the site boundary

Contaminant	EAL	95thile Predicted Peak Concentrations (Years to peak concentration)
Arsenic (mg/l)	0.0013	0.00001 *(7,500 yrs)*
Benzo-a-pyrene (mg/l)	0.00001	<0.000001 *(-)*
Lead (mg/l)	0.0005	<0.000001 *(-)*
Mercury (mg/l)	0.0005	<0.000001 *(-)*

3.5.3 The model results predict that at the standard WAC thresholds the 95th percentile concentrations of Hazardous Substance at the edge of the site will be less than the selected EALs and therefore indiscernible.

Non-Hazardous Pollutants

3.5.4 The predicted peak concentrations of non-hazardous pollutants at the site boundary are presented in **Table HRA7.**

Table HRA7: Predicted groundwater concentrations of non-hazardous pollutants at the site boundary

Contaminant	EAL	95%ile Predicted Peak Concentrations (Years to peak concentration)
Nickel (mg/l)	0.02	<0.000001 *(15,000)*
Sulphate (mg/l)	250	<1 *(100 yrs)*

3.5.5 The model results indicate that the groundwater concentrations of Non-Hazardous Pollutants at the edge of the site will be not result in a deterioration of groundwater quality in the vicinity of Stanway Quarry.

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4.0 REQUISITE SURVEILANCE

4.1 Leachate Monitoring

4.1.1 Leachate testing will be limited to that required as part of the waste acceptance requirements, as detailed in Section 2.0 of the Management Plan *(Doc. Ref.: TA1026/05)*.

4.2 Groundwater Monitoring

4.2.1 The groundwater monitoring schedule during the operational phase of the landfill is presented in **Table HRA9.** The locations of the groundwater monitoring points are presented in **Drawing No. B030-00676-08.**

Table HRA8: Groundwater monitoring schedule

Monitoring Point	Parameter	Frequency
GR7, GR8, BE8A, SQ1, SQ2. SQ3 and any replacement monitoring boreholes	Water Level	Monthly
	pH, EC, Alkalinity, Arsenic, Lead, Nickel, Sulphate	Monthly
	BOD, COD, Dissolved Oxygen, Antimony, Barium, Cadmium, Chloride, Chromium, Copper, Fluoride, Mercury, Molybdenum, Selenium, Zinc, Phenols	Quarterly
	BTEX, PAHs	Six-monthly

4.2.2 Groundwater compliance levels are presented in **Table HRA10.**

Table HRA9: Groundwater Compliance Levels

Monitoring Points	Parameter	Frequency	Compliance Level (mg/l)
BE8A	Arsenic	Monthly	0.0013
	Lead		0.0005
	Nickel		0.015
	Sulphate		268
SQ3	Arsenic	Monthly	0.0007
	Lead		0.0003
	Nickel		0.0053
	Sulphate		60

4.2.3 Compliance levels are derived based a concentration that is two standard deviations above the mean background concentrations for each borehole, excluding any outliers.

4.2.4 Details of the post-closure groundwater monitoring requirements are presented in Section 8.0 of the Management Plan.

4.3 Surface Water Monitoring

4.3.1 During the operational phase of the landfill, monitoring of surface waters and groundwater waters within lagoons formed with the landfill will be visually monitored for evidence of hydrocarbon contamination.

4.3.2 Surface water monitoring will also be carried out within the Roman River and its north bank tributaries, as per the schedule shown in **Table HRA11.** The locations of the groundwater monitoring points are presented in **Drawing No. B030-00676-08.**

Table HRA10: Surface water monitoring schedule

Monitoring Point	Parameter	Frequency
SW1, SW2, SW3, SW4, SW5 and SW6	pH, EC, Alkalinity, Arsenic, Lead, Nickel, Sulphate; BOD, COD, Dissolved Oxygen, Antimony, Barium, Cadmium, Chloride, Chromium, Copper, Fluoride, Mercury, Molybdenum, Selenium, Zinc, Phenols	Quarterly
	BTEX, PAHs	Six-monthly

4.3.3 Details of the post-closure surface water monitoring requirements are presented in Section 8.0 of the Management Plan.

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5.0 CONCLUSIONS

5.1 Compliance with the Landfill Directive

5.1.1 The results of this risk assessment have established the landfill facility will comply with the relevant requirements of the Landfill Directive as follows:-

- Due to the physical characteristics of the surrounding sand and gravel aquifer, the facility presents a potential hazard to groundwater quality if unabated. Consequently, a AEGB will be required across the base and sidewalls of the quarry, although no leachate management will be necessary;
- Control and trigger levels will be set in order to ensure the adequate protection of groundwater resources.

5.2 Compliance with the Groundwater Regulations 2009

5.2.1 The results of this risk assessment have established the landfill facility will comply with the relevant requirements of the Groundwater Regulations 2009 as follows:-

- The landfill facility poses a potential hazard to groundwater quality. Consequently, it falls within the scope of the Groundwater (England & Wales) Regulations 2009;
- This assessment forms a review of the "prior investigation" that must be carried out for this type of development;
- The proposed technical precautions are considered appropriate and reasonable to avoid the entry of hazardous substances into groundwater throughout the lifecycle of the facility
- The proposed technical precautions will limit the introduction of Non-Hazardous Pollutants into groundwater to avoid pollution throughout the lifecycle of the facility;
- Leachate, groundwater and surface water monitored schedules have been derived to accommodate the landfill facility in accordance with the requisite surveillance requirements of the Groundwater Regulations 2009.

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