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HYDROGEOLOGICAL RISK ASSESSMENT

MITCHELL HILL QUARRY

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GENERAL NOTES

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1 INTRODUCTION

1.1 Report context

Mitchell Hill Quarry is operated by Mick George Limited for the production of sand and gravel from an area known as Mitchell Hill Common. On 21st December 2018 planning permission (S/0088/18/CM) was granted to extract mineral with progressive restoration of the quarry void to either agricultural use by land raising using imported inert material, or to wetland habitat. The importation of inert material requires a permit under the Environmental Permitting (England and Wales) Regulations (EPR) (2016).

This report sets out the Hydrogeological Risk Assessment (HRA) that has been prepared in support of the Environmental Permit Application for a bespoke waste recovery permit. The HRA has been prepared with due regard to the hydrogeological risk assessment guidance (Environment Agency, 2016) and template (Environment Agency, March 2010) provided by the Environment Agency.

The design of the proposed restoration and background information regarding the site setting are provided within the Conceptual Model, Environmental Setting and Site Design (ESSD) report (Hafren Water, 2019), which should be read in conjunction with this report. Background and baseline conditions are described within the ESSD report and these have been used to derive a conceptual model for the site in terms of source, pathways and receptors.

A summary of the prior investigations undertaken at the site is provided in *Table 2658/HRA/T1* below.

2658/HRA/T1: Summary of prior investigations undertaken at site	
Investigation/analysis	**Date**
Installation of 7 piezometers around the periphery of the site	September 2016
Groundwater level monitoring	Monthly, Sept-16 to date
Background surface water quality monitoring	June 2019 to date
Background groundwater quality monitoring	Sept 2018 to date

Location of the groundwater sampling points are shown on Drawing 2658/HRA/01 and a summary of the water quality data is provided in Appendix 2658/HRA/A1.

1.2 Conceptual hydrogeological site model

The conceptual hydrogeological model for the proposed waste operation is described in Sections 3.5 and 4.1 of the ESSD report and illustrated on *Drawing 2658/HRA/01*. The area to be restored with imported material will eventually occupy the whole of the final quarry void to the south of Engine Drain.

Geological and hydrogeological setting

Superficial River Terrace Deposits form the economic mineral at the site. Mineral thickness varies from 1 m to 3 m with a covering of between 0.4 and 2.1 m of stony, clayey, soil. The river terrace deposits are underlain by mudstone of the Kimmeridge Clay Formation.

The Superficial River Terrace Deposits are designated a Secondary 'A' aquifer by the Environment Agency with the Kimmeridge Clay forming the effective base of the aquifer. The Kimmeridge Clay is classed as Unproductive strata.

Mineral extraction extends below the watertable and dewatering is required to depress the groundwater table and remove incident rainfall in order to maintain safe working conditions for gravel extraction and during importation of restoration materials. Thus for the operational stage and post-restoration, an inward groundwater gradient will be maintained within a zone of influence around the quarry void.

Evidence from groundwater monitoring indicates that pollution from existing landfill sites to the south (up-gradient) have impacted groundwater quality around the site. Some parameters are above their respective water quality standards.

All the smaller watercourses in the vicinity of the site are anthropogenic in origin and relate to agricultural drainage. Management of these drains is the responsibility of the Old West and Waterbeach Internal Drainage Boards (IDB), both part of the Ely Group of IDBs. Water levels within these areas are maintained by a series of pumping stations which pump water into the River Great Ouse. Water levels with the Mitchell Hill catchment are controlled by the Chear Fen pumping station.

Groundwater control

The site will be dewatered to allow safe access for mineral extraction. Dewatering will be maintained during placement of the inert fill material and once fill is placed within the final phase of the site, dewatering will cease. Long-term groundwater control is not required in order to prevent groundwater pollution.

However, it is proposed to place low permeability material, either clay scraped from the base of the excavation (Kimmeridge Clay), or suitable imported fill, against the sides of the excavation to reduce potential impacts to surrounding groundwater-fed features (County Wildlife Sites). This will also restrict the entry of potentially contaminated groundwater from the old landfill areas to the south. Once clay is placed against the sides of the active working area, water pumped from the site is expected to be largely comprised of incident rain.

While the site is being dewatered, water will be collected in a sump at the lowest point in the active working area, which will then be pumped to settlement lagoons located in the southeastern side of the site, adjacent to the mineral processing area. From there, excess water will be discharged to a ditch beside Long Drove, from where it will flow into Engine Drain.

<u>Construction</u>

As the waste will be strictly inert under the condition of a Waste Recovery Permit, a geological barrier is not required. However, a natural basal geological barrier in the form of the Kimmeridge Clay Formation underlies the gravel deposit.

As described above, clay sourced from the quarry floor, or selected clay-rich imported material, will be placed around the sides of the quarry void for the purpose of reducing groundwater inflow.

<u>Source</u>

The recovery operation will receive strictly inert waste which complies with the Landfill Directive description. This will be ensured by the application of strict Waste Acceptance Criteria and Procedures (WAC, provided elsewhere in the application) by appropriately trained staff.

<u>Pathways</u>

1. Lateral into the adjacent unworked River Terrace Deposits. Dewatering of the site will result in an inward gradient which will prevent any migration of contaminants out of the site into the aquifer during the operational life of the site. Once dewatering has ceased, it is assumed that groundwater flow will return to a general northeasterly direction, towards the pumping station at Chear Fen.

2. Lateral through unworked River Terrace Deposits into surrounding drains, one of which, Beach Ditch and Engine Drain, is a County Wildlife Site. The Twenty Pence Pit County Wildlife Site is also a potential receptor.

<u>Receptors</u>

Groundwater in the River Terrace Deposits adjacent to the site will become a receptor once dewatering at the site has ceased.

The Engine Drain and Twenty Pence Pit County Wildlife Sites are considered to be secondary receptors as they could potentially receive water discharge from the restored site via groundwater baseflow. These lie adjacent to the site boundary.

During the operational phase, the primary receptor, and compliance point for site discharge, is considered to be the point at which water is discharged from the settlement lagoons.

Identified receptors and pathways are summarised in *Table 2658/HRA/T2*.

2658/HRA/T2: Summary of identified receptors and pathways	
Hazard	The proposed material imported to the site will be inert in nature (see Section 2.2. of the ESSD report) therefore it is considered that the site poses minimal potential hazard to nearby surface and groundwater. The rate of filling is anticipated to be in the order of 100,000 tonnes per annum (tpa).
Source	All waste to be deposited will adhere to Waste Acceptance Criteria and Procedures which shall ensure the waste is correctly characterised and inert in accordance with Environment Agency guidance. It is therefore considered highly unlikely that rainfall incident to the waste will incorporate within it measurable concentrations of pollutants as it percolates through the waste. No Hazardous substances are expected to be present and Non-hazardous pollutants, if present, will be of low concentration such that pollution of nearby groundwater and surface water will not occur.
Potential primary pathway	Migration laterally into the unworked River Terrace Deposits to the north and east.
Potential secondary pathway	Migration laterally through unworked River Terrace Deposits to surface water features in contact with groundwater
Potential primary receptor	Groundwater in the unworked River Terrace Deposit on cessation of dewatering
Potential secondary receptor	Engine Drain and Twenty Pence Pit LWS
Compliance point	Hazardous substances: Discharge from the settlement lagoon and on cessation of dewatering, groundwater in the River Terrace Deposit on the northeastern boundary. Non-hazardous: as above

2 HYDROGEOLOGICAL RISK ASSESSMENT

2.1 Nature of the Hydrogeological Risk Assessment

Environment Agency requires a hydrogeological risk assessment in support of a bespoke permit for waste recovery to land, where the site setting is deemed sensitive.

Environment Agency guidance proposes a tiered approach to risk assessment such that the degree of effort and complexity reflects the potential risk posed by a particular site or situation, the sensitivity of the site setting and the degree of uncertainty and likelihood of the risk being realised. To meet the requirements a robust conceptual model for the site has been set out and basic risk screening undertaken. The conceptual model is set out in the ESSD report and the risk screening is summarised in Section 2.2 below.

A risk screening exercise is used to determine whether development represents, or potentially represents, a risk to groundwater or surface water resources. These are more generally undertaken for landfill sites. However, as the Mitchell Hill site is partially sub-water table, a similar approach has been used, as required by the Environment Agency in this case.

Risk screening is partially covered by the assessment of the application of the Environment Agency's Landfill Location Policy and the identification of source-pathway-receptor linkages and the technical precautions put in place to reduce any potential impacts. These are assessed in Section 2.2.

2.2 Risk screening

2.2.1 Location

Although an application for a landfill permit is not being made, the location of the site is assessed against the Environment Agency's policy on the location of landfills, which is detailed in 'The Environment Agency's approach to groundwater protection (March 2017), Position Statement E1. Landfill Location'. This states:

> " *The Environment Agency will normally object to any proposed landfill site in groundwater SPZ1.*
>
> *For all other proposed landfill site locations, a risk assessment must be conducted based on the nature and quantity of the wastes and the natural setting and properties of the location.*

Where this risk assessment demonstrates that active long-term site management is essential to prevent long-term groundwater pollution, the Environment Agency will object to sites:

- *below the watertable in any strata where the groundwater provides an important contribution to river flow, or other sensitive receptors*
- *within SPZ2 or 3*
- *on or in a principal aquifer*"

The site is located within a Secondary A Aquifer, is below the watertable and adjacent to a watercourse which receives baseflow from the aquifer. The site is not located within a groundwater Source Protection Zone 1.

The quarry void at the site will receive only inert wastes, which are compliant with the Inert Waste Acceptance Criteria (WAC). It is considered that the waste to be deposited at Mitchell Hill is such that there will be a negligible risk of deterioration in groundwater or surface water quality.

Due to the nature of the waste, long-term management will not be necessary to prevent groundwater pollution. This HRA report, together with the ESSD report, constitutes a site-specific risk assessment for the site.

It is therefore concluded that the site complies with the Environment Agency landfill location policy.

2.2.2 Waste types

It is proposed that the site will take a restricted range of inert wastes as detailed in the 'Waste Recovery Plan'. Waste will only be accepted with evidence that the material has been tested and found to be uncontaminated and compliant with the inert WAC.

2.2.3 Waste Acceptance Procedures

Waste acceptance criteria and procedures have been prepared and are detailed in the Waste Recovery Plan available elsewhere in the permit application.

2.2.4 Compliance with Environmental Permitting (England and Wales) Regulations (2016)

Based upon the inert waste types to be accepted at the site, the site should not produce leachate (defined here as water coming into contact with the waste) that could result in discharge of Hazardous substances or Non-hazardous pollutants. Hence the site falls outside the scope of the Environmental Permitting (England and Wales) Regulations (2016), Schedule 22 Groundwater Activities,

2.2.5 Collection of leachate

As the waste to be accepted at the site will be inert, in accordance with Environment Agency guidance, it is considered that there is no requirement to collect and manage leachate. Therefore there is no requirement for leachate drainage layers or an artificial sealing liner.

2.2.6 Geological barrier

As the site will receive a restricted range of inert waste under a Waste Recovery Permit, a geological barrier is not required. However, the base of the void to be restored comprises clay of the Kimmeridge Clay Formation, which will form a natural basal geological barrier.

The site is partially below the watertable, situated within River Terrace Deposits. Clay sourced from the quarry floor, or selected from clay-rich imported material, will be placed around the sides of the quarry void for the purpose of groundwater control. (during mineral extraction and dewatering)

2.2.7 Engineering

The site does not fall under the engineering requirements of the Landfill Directive. However, one of the measures to mitigate against impacts to the surrounding water environment during quarrying was to place low permeability material against the sides of the quarry void. This will reduce inflows of groundwater into the site and impacts on groundwater levels. The barrier will comprise natural clays from the floor of the quarry, or selected imported material, placed against the sides, but without testing to prove the hydraulic conductivity of the barrier. The material would be approximately 1 m thick at a minimum.

The base of the site comprises clay of the Kimmeridge Clay Formation.

2.3 Proposed assessment scenarios

2.3.1 Lifecycle phases

Environment Agency guidance states that a Hydrogeological Risk Assessment must be carried out for the whole lifecycle of the landfill, ie from the start of the operational phase until the point at which the landfill is no longer capable of posing an unacceptable environmental risk.

As the site will receive inert waste, a quantitative Hydrogeological Risk Assessment of the intended operational and post-closure phases of the landfill is not deemed necessary under the current guidance.

2.3.2 Failure scenarios and accidents

Failure scenarios

Due to the inert nature of the proposed infill materials, there are no engineering management structures at the site to prevent the ingress of groundwater or the egress of leachate. Failure of such systems is, therefore, not possible and failure scenarios will not be considered.

Accidents

Accidents are considered to be unintentional incidents that could reasonably occur, which are unforeseeable at their time of occurrence. An assessment of the potential impacts of accidents, together with the likelihood of their occurrence and magnitude of the consequences (in relation to compliance with the Environmental Permitting (England and Wales) Regulations (2016)) is presented below.

Accidents at the site could include the acceptance of contaminated material. Due to the proposed Waste Acceptance Criteria and Procedures and absence of any historical waste on-site, it is considered highly unlikely that 'rogue loads' will be accidentally accepted at the site.

2.4 Rogue load assessment

The waste acceptance procedures to be applied at the site make the deposition of rogue loads unlikely and the potential risk to groundwater minimal. However, the Environment Agency has requested that a quantitative risk assessment is undertaken and therefore risk assessment modelling of acceptance of an accidental rogue load has been undertaken.

2.4.1 Environmentally Acceptable levels

Environmentally Acceptable Levels (EALs) are used to determine the sensitivity of the groundwater near a landfill, or waste recovery operation, and are a measure against which the results of models can be compared. EALs have been determined on the basis of available water quality standards for the parameters below and the recorded background groundwater concentrations.

Groundwater and surface water quality analyses have been used to identify if elevated background concentrations are present. The data are presented in summary form in tables in Appendix 2658/HIA/A1.

Hazardous substances

The Environmental Permitting (England and Wales) Regulations 2016 (EPR, 2016) requires there to be no discernible discharge of Hazardous substances to groundwater. Therefore, the appropriate EAL would be the concentration at which they become 'discernible'. Due to the high background levels of many substances due to the presence of old landfills up-gradient of the site, the number of substances available for which appropriate EALs could be set is very limited.

Arsenic was chosen as a representative Hazardous metal and benzene was chosen to represent a Hazardous hydrocarbon. Currently only limited background data are available for arsenic and the initial EAL has been set at the DWS.

Background concentrations and relevant quality standards are presented in *Table 2658/HRA/T3* together with the derived EAL.

2658/HRA/T3: Derivation of EALS for Hazardous substances

Substance	UK Drinking Water Standard	Fresh Water EQS[1]	Maximum background concentration	Minimum reporting value	Resultant EAL
Arsenic	10 µg/l	50 µg/l	3.0 µg/l[2]	1 µg/l	10 µg/l
Benzene	1 µg/l	10 µg/l (50)	< 1 µg/l	1 µg/l	1 µg/l

1 EQS = Environmental Quality Standard
2 Based on very limited monitoring data

Non-hazardous pollutants

The EPR (2016) requires there to be no groundwater pollution caused as a result of discharges of Non-hazardous pollutants. The appropriate EAL is therefore deemed to be the most stringent relevant quality standard, except where background concentrations exceed those standards. The relevant standards, together with background monitoring data, are provided in *Table 2658/HRA/T4*.

Ammoniacal nitrogen is usually chosen as a standard as it frequently occurs where biodegradable matter has been incorporated within the waste mass. In this case background levels of ammoniacal nitrogen, up to 6.8 mg/l in the down-gradient boreholes, are too high for it to be useful. Instead, cadmium has been selected to represent a non-hazardous metal

Chloride has been chosen as a conservative, non-reactive parameter, although it is only suitable for down gradient monitoring points F and G due to elevated background concentrations on the west side of the site (monitoring points A and H) that are at or above the EQS of 250 mg/l. Individual EALs have been set for each borehole.

2658/HRA/T4: Quality standards and background levels for Non-hazardous pollutants				
Substance	UK Drinking Water Standard	Fresh Water EQS[1]	Maximum background concentration	Resultant EAL
Chloride BHF	250 mg/l	250 mg/l	210 mg/l	250 mg/l
Chloride BHG			120 mg/l	150 mg/l[2]
Cadmium	5 µg/l	0.25 µg/l	<0.08 µg/l	0.15 µg/l

1 EQS = Environmental Quality Standard (Annual average)
2 Mean (87.2 mg/l) + 2 S.Dev (35.9 mg/l) = 123.1 mg/l and rounded up.

2.4.2 Justification for modelling approach and software

The 'rogue load' assessment has been undertaken using ESI's Risk Assessment Model (RAM) in order to determine the maximum concentration of the above determinands that could be accepted at the site, assuming conservative hydraulic properties, before a breach of the EALs derived above. The RAM model was used as this can be used to represent sub-watertable conditions.

2.4.3 Model parameterisation

The parameters used in the RAM 'rogue load' assessment are described together with justification for their use within the RAM model and in *Table 2658/HRA/T5*. A printout of the RAM model is provided as *Appendix 2658/HRA/A6*.

Two pathways have been modelled:

a) From the source, a 10 x 10 m rogue load assumed to be located adjacent to the sidewall clay barrier, horizontally through the barrier and into the adjacent River Terrace Deposits,

b) From the source, assumptions as above, through the River Terrace Deposits to the site boundary at Engine Drain

The model was run for a maximum time period of 1000 years. This is significantly longer than the time period that is likely to be required to achieve Permit Surrender and, hence, is considered to be a conservative upper time limit for an inert simulation.

The initial concentrations have been input as potential maximum concentrations in the rogue load.

The RAM model simulates the resultant concentrations in groundwater surrounding the site based on a declining source term. It also calculates what the maximum concentrations could be before failure of the EAL's at the modelled receptors (similar to the Environment Agency remedial target spreadsheet).

Parameter values were determined from information directly measured on-site or, in the absence of site data, other recognised sources. The results of the assessment are discussed below.

2658/HRA/T5: Model input parameters		
Parameter	**Value/distribution**	**Justification**
SOURCE TERM		
Waste volume (m^3)	200	Assuming rogue load of dimensions 2 m x 10 m x 10 m
GENERAL CONTAMINANT INFORMATION		
Free water diffusion coefficient (m^2/s): Chloride Arsenic Benzene Cadmium	 2.03×10^{-9} 9.05×10^{-10} 7×10^{-10} 7.17×10^{-10}	Chloride and benzene from Buss et al, 2004, Table 3.1. Arsenic from Allison & Allison, 2005
HYDROGEOLOGICAL UNITS		
Thickness (m): Artificial geological barrier Saturated sand & gravel Hydraulic conductivity (m/s): Artificial geological barrier Sand and gravel Hydraulic gradient: Artificial clay barrier Sand & gravel	 1 m 1.2 m 1×10^{-8} m/s 18 m/d (2.08×10^{-4} m/s) 1 1.5×10^{-3}	 Estimated Average from borehole logs and evaluation boreholes Assumed not engineered Average reported in Section 3.3.1 of the ESSD report Assumed vertical Estimated average gradient pre-operation (HIA Drawing 2173/HIA/07)
Porosity: Artificial geological barrier Sand & gravel	 0.45 0.27	Fetter (1994) for clay and sand & gravel, middle of range
Tortuosity	5	Assumed generic value for all hydrogeological layers
Horizontal travel distance in sand & gravel (m)	9 40	Approximate distance from edge of landfill to the nearest IDB drain Distance to Twenty Pence Pit
ATTENUATION PARAMETERS		
Dispersivity	Up to unit	Standard assumption

2658/HRA/T5: Model input parameters		
Parameter	**Value/distribution**	**Justification**
	thickness/10	
Mixing depth in saturated sandstone	1.2 m	average saturated thickness
Bulk density (kg/m^3): Artificial clay barrier Sand & gravel Fraction of organic carbon Artificial geological barrier Sand & gravel	 1900 2400 0.01 0.0017	 Estimate Estimate Minimum for Kimmeridge Clay Mid point for generic S&G. Both from Thrasher et al, 2004, Table 7.2
<u>Cadmium</u> Partition coefficient (k_d) (L/kg) <u>Arsenic</u> Partition coefficient (k_d) (L/kg) <u>Chloride</u> Partition coefficient (k_d) (L/kg) Half life (days) <u>Benzene</u> Koc Partition coefficient (k_d) (L/kg) Half life in groundwater (days)	 501 1580 0 No decay 135 calculated 240	 Allison & Allison (2005) Allison & Allison (2005) Average from Earl, et al, 2003 Average from California EPA, 1994, p.25, also USEPA, 1996.
WATER BALANCE		
Precipitation (mm/yr) Effective Precipitation (mm/yr)	542 211	Stretham raingauge MAFF Technical Bulletin 34, Area 28

References

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Buss, S.R., Herbert, A.W., Morgan, P. & Thornton, S.F., 2003. Review of ammonium attenuation in soil and groundwater. Environment Agency NGWCLC report No. NC/02/49.

Buss, S.R., Herbert, A.W., Green, K.M. & Atkinson, C. Contaminant fluxes from hydraulic landfills – a review. Environment Agency Science Report SC0310/SR.

California EPA & Department of Toxic Substances Control, 1994. Intermedia transfer factors for contaminants found at hazardous waste sites.

Earl, N, Cartwright, C.D., Horrocks, S.J., Worboys, M., Swift., S., Kirton, A., Askan, A.U., Kellener, H., & Nancarrow, D.J., 2003. Review of the fate and transport of selected contaminants in the soil environment. Environment Technical Report P5-079/TR1.

Thrasher, J., Morgan, P. & Buss, S.R., 2004. Attenuation of mecoprop in the subsurface. Environment Agency Science Group report NC/03/12.

2.4.4 Results of rogue load risk assessment

As discussed above, although the site will receive only a restricted range of inert waste (as defined in the Landfill Regulations, 2002), the Environment Agency have requested a quantitative assessment of the potential impact of a 'rogue load' of non-inert material being deposited on-site. It has been assumed that the rogue load is equivalent to a 2 m thick, 10 m by 10 m area within the waste mass. This approach has been used previously by Hafren Water for other inert sites.

The results of the rogue load assessment are provided in *Table 2658/HRA/T6*.

2658/HRA/T6: Results of rogue load assessment		
Determinand	**EAL at the compliance point**	**Maximum permitted leachate concentration in rogue load assuming compliance at the appropriate boundary for Hazardous substances and Non-hazardous pollutants**
Hazardous:		
Arsenic	0.01 mg/l	350 mg/l
Benzene	0.001 mg/l	2.4 mg/l
Non-hazardous:		
Chloride	150 mg/l	7,500 mg/l
Cadmium	0.00015 mg/l	14.5 mg/l

The results indicate that elevated concentrations of chloride, cadmium, arsenic and benzene and could be accidentally accepted at the site without breach of the appropriate EAL (assuming a contaminated load of 2 m x 10 m x 10 m) in the groundwater at the site boundary.

2.5 Review of technical precautions

Due to the inert nature of the waste it is considered that the proposed essential and technical precautions detailed below are appropriate and sufficient to prevent any unacceptable discharge from the site:

i) Strict control of waste types sourced and accepted
ii) Strict adherence to Waste Acceptance Criteria and Procedures
iii) Removal of standing water in areas to be landfilled prior to commencement of waste disposal
iv) Provision of a low permeability side wall barrier
v) In-situ low permeability basal barrier

vi) Progressive restoration to a suitable profile to encourage surface water run-off and minimise water ingress

vii) Provision of ditches or berms, where required, to minimise surface water ingress to the landfill area

viii) Monitoring of the site discharge to surface water during dewatering

ix) Monitoring of groundwater quality at the site boundary post dewatering

It is considered that leachate monitoring and management is not required due to the inert nature of the waste.

Details of the Waste Acceptance Criteria and Procedures are considered elsewhere in the application.

2.6 Emissions to groundwater

One of the main purposes of the HRA is to establish whether the predicted discharge from the landfill complies with the requirements of the Environmental Permitting (England and Wales) Regulations (EPR 2016) Schedule 22 Groundwater activities.

2.6.1 Hazardous substances

The HRA must demonstrate that the proposed technical precautions will prevent Hazardous substances from entering groundwater. Consequently it must consider whether there is likely to be a discernible discharge of Hazardous substances to groundwater. The compliance point is, therefore, the water table prior to any dilution occurring.

The imported inert fill will comply with the Landfill Directive definition of inert; hence Hazardous substances are not expected to be present in concentrations likely to cause a breach of the EPR (2016). It is therefore considered that the technical precautions discussed in Section 2.5 above are sufficient to ensure that during normal operation and through to long-term post-closure, there would be no discernible discharge of hazardous substances from the waste into groundwater.

2.6.2 Non-hazardous pollutants

The HRA must also demonstrate that technical precautions will limit the introduction of Non-hazardous pollutants into groundwater so as to avoid pollution. Consequently it must consider whether predicted concentrations of Non-hazardous pollutants are likely to exceed relevant standards and other environmental quality criteria, or cause an unacceptable deterioration in groundwater quality following dilution.

A pathway exists for Non-hazardous pollutants to a receptor, namely groundwater surrounding the site. However, given the inert nature of the waste and the provision of a clay barrier, it is concluded that under normal operation and through to long-term post-closure concentrations of Non-hazardous pollutants would be sufficiently low as to avoid pollution of the groundwater.

2.6.3 Surface water management

The proposed inert landfill is not located in an area that is liable to flood. However, it is below the watertable and management of groundwater inflow is required to lower water lavels for mineral extraction.

During the majority of the operational phase of restoration/infilling, any inflowing groundwater will be directed away from the areas of active filling. Bunds and ditches will be constructed as necessary to direct surface water run-off away from the active working area during its operational phase.

Post-operation, the restoration profile of the site is such that surface water run-off will occur radially from the centre of the site towards the peripheral ditches around the perimeter. There will be no need to manage surface water post-closure.

2.7 Emissions to Surface water

Given the inert nature of the waste and the other technical precautions in place, it is concluded that during normal operation and through to long-term post-closure, concentrations of Hazardous substances will not be discernible and Non-hazardous pollutants will be sufficiently low as to avoid pollution of surface water.

3 REQUISITE SURVEILLANCE

3.1 Risk-based monitoring scheme

The risk screening and the numerical modelling together with the strict waste acceptance criteria indicate that the proposed waste recovery scheme does not pose a risk to the water environment, even in the event that a 'rogue' load is introduced into the site.

The site is considered to be in a sensitive location due to the presence of two County Wildlife sites and monitoring proposals are discussed below.

3.2 Groundwater monitoring

Monitoring of groundwater quality is already undertaken under the requirements of Planning Condition 51 for the site (Hafren Water, Water Quality Monitoring Scheme, Ref: 2710/MON-2, January 2019) at the locations shown on *Drawing 2568/HRA/01*. The existing scheme requires baseline monitoring for 12 months, with operational monitoring to be set following the HRA (this report).

It is proposed that groundwater quality is monitored on a quarterly basis in all the boreholes following completion of the baseline monitoring. The analytical suite proposed for these samples is shown in *Table 2658/HRA/T7*. Whilst monitoring is undertaken at the boreholes, it is not considered appropriate to set compliance limits as during active waste recovery groundwater flow will be into the site due to dewatering activities for mineral extraction. Hence no downgradient boreholes will exist.

2658/HRA/T7: Proposed analytical suites for groundwater samples	
Frequency	**Analytical suite**
Quarterly	pH, conductivity, ammoniacal nitrogen, chloride, Chemical Oxygen Demand, nitrate, sulphate, arsenic, cadmium and benzene.
Annually	As quarterly suite plus: total alkalinity, sodium, magnesium, potassium, lead, copper, zinc, chromium, iron, manganese, nickel, TPH and polyaromatic hydrocarbons.

3.3 Surface water monitoring

Additional background monitoring has been specified in the water quality monitoring scheme (Hafren Water, 2710/MON-2, January 2019) at three locations, as indicated on *Drawing 2568/HRA/01*. However, the conceptual understanding of the site and the materials being used for infilling indicate that there is no requirement for surface water monitoring to evaluate the performance of the site.

However, during the operational phase, there will be discharge into Engine Drain via a shallow drain passing along the west side of Long Drove. It is recognised that there is potential for poor quality groundwater (present as a consequence of discharges from the up-gradient landfills) to enter the void and subsequently be discharged into Engine Drain. While this potential inflow will be reduced by the placement of low permeability material around the void, monitoring of the discharged water will be undertaken to assess impacts on the receiving water system

This discharge will be samples on a routine basis such as to be representative of the volume of water discharged. The analytical suite proposed for these samples is shown in *Table 2658/HRA/T8*.

2658/HRA/T8: Proposed analytical suites for site discharge

Frequency	Analytical suite
Quarterly	pH, conductivity, ammoniacal nitrogen, chloride, Biological Oxygen Demand, Chemical Oxygen Demand, nitrate, sulphate, arsenic, cadmium and benzene.
Annually	As quarterly suite plus: total alkalinity, sodium, magnesium, potassium, lead, copper, zinc, chromium, iron, manganese, nickel, TPH and polyaromatic hydrocarbons.

Monitoring will cease once the site has been completed to the final restoration levels and the active off-site discharge ceases.

4 CONCLUSIONS

4.1 Compliance with the Environmental Permitting (England and Wales) Regulations (2016)

The risk assessment has demonstrated that under normal operational and post-operational phases of landfilling Hazardous substances will not be present in groundwater beneath the site in concentrations discernible above background and Non-hazardous pollutants will not be present in concentrations such that pollution of nearby groundwater is caused. **It is therefore considered that the site will be compliant with respect to the Environmental Permitting (England and Wales) Regulations (2016).**

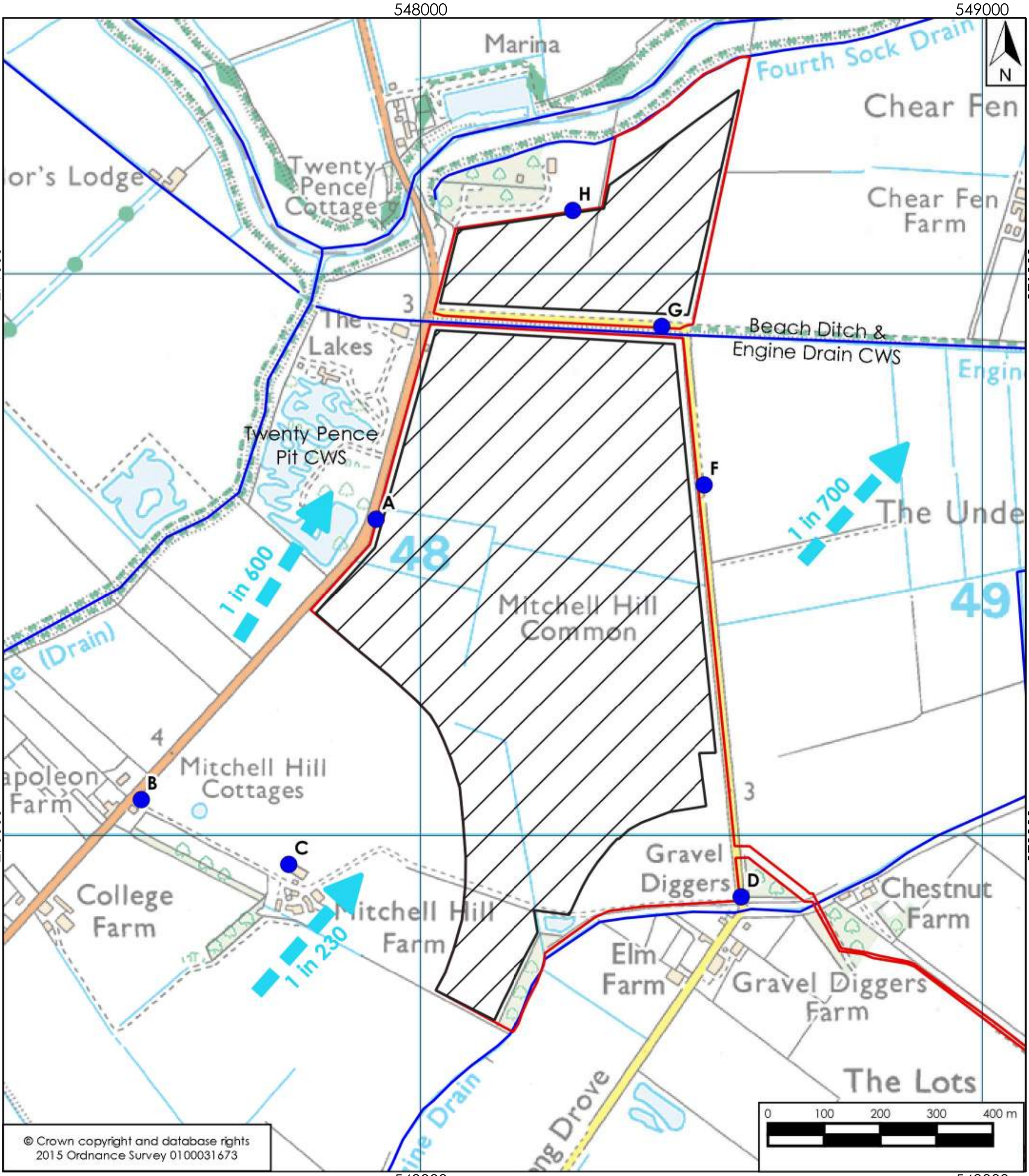
5 REFERENCES

Environment Agency, February 2016. Landfill developments: groundwater risk assessment for leachate. https://www.gov.uk/guidance/landfill-developments-groundwater-risk-assessment-for-leachate.

Environment Agency, March 2010. Hydrogeological risk assessment template. Version 1. https://www.gov.uk/government/publications/hydrogeological-risk-assessment-report-template

Hafren Water. Conceptual Model, Environmental Setting and Site Design report. Mitchell Hill Quarry. Report reference: 2658/ESSD.

DRAWINGS



Legend

Planning Boundry

Quarry void

Monitoring network

Borehole

Groundwater flow

Scale correct at A4

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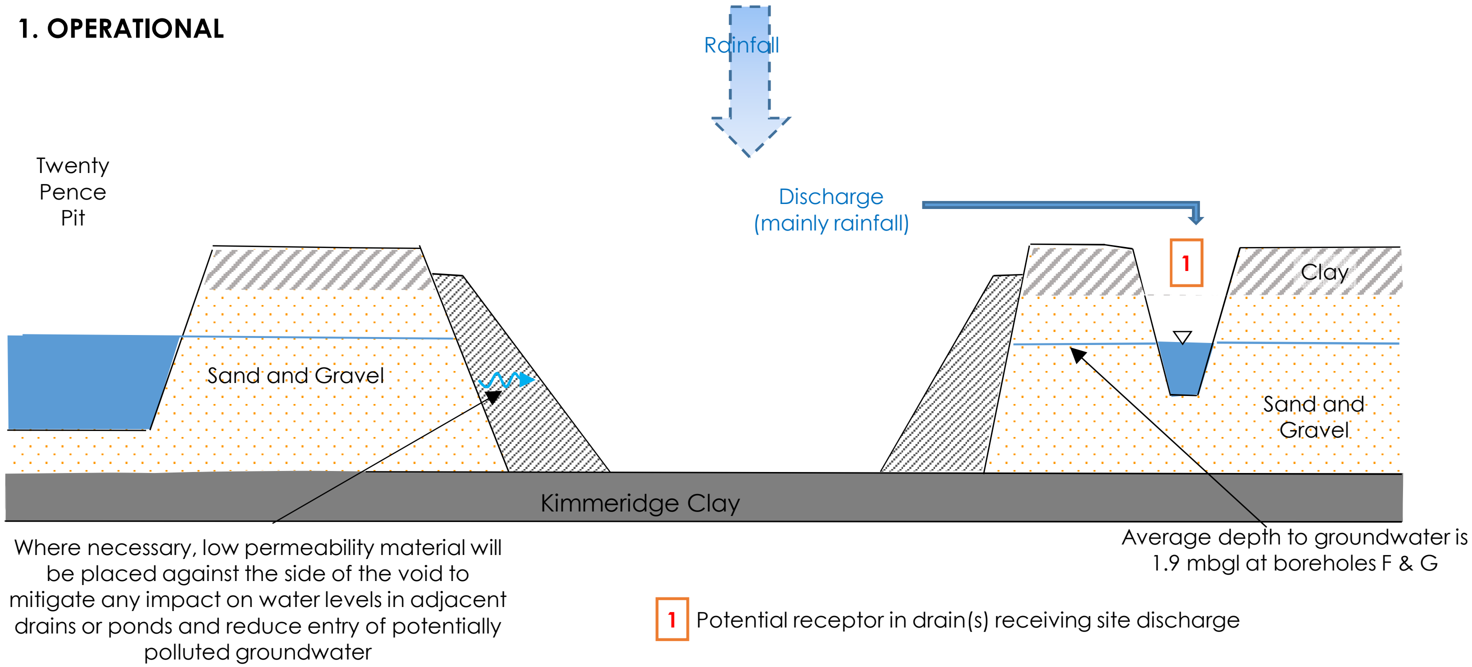
www.hafrenwater.com • Tel. 01743 355 770

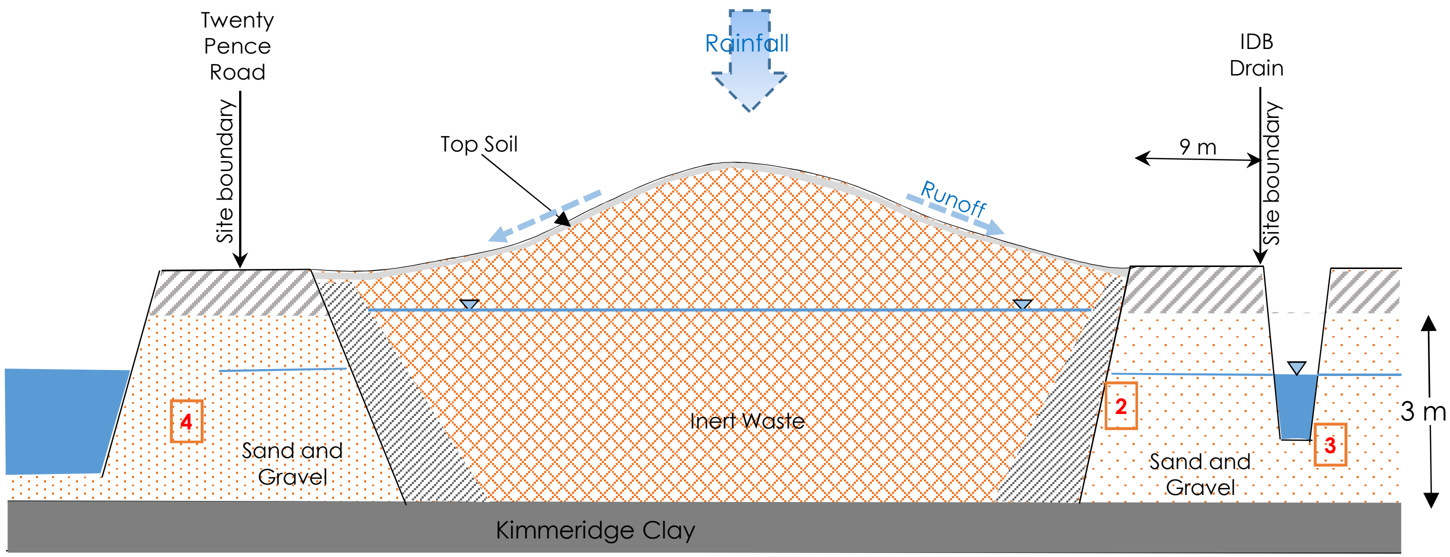
Client	Frimstone Ltd, Ashcraft Farm, Main Road, Crimplesham, Norfolk, PE33 9EB	Title	Location of recovery operation
		Project	Mitchell Hill
		Drawing	2658/HRA/01 — Version 1
		Date	Jan-19 — Scale 1:10000

1. OPERATIONAL



1 Potential receptor in drain(s) receiving site discharge

2. COMPLETION



2 Receptor in sand and gravel

3 Receptor at Engine Drain

Client	Mick George Ltd. 6 Lancaster Way Ermine Business Park Huntingdon PE29 6XU
Title	Site conceptual model
Project	Mitchell Hill Quarry
Drawing	2658/HRA/02
Version	2
Date	Dec-19
Scale	nts

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APPENDIX 2658/HRA/A1

Summary of background water quality data

2658/HRA/A1.1: Summary of background water quality data (down-gradient)[1]

Determinand	units	DWS	EQS MAC	EQS AA	min	max	N°	Comment
Inorganics								
pH	pH Units				6.8	8.2	32	
Conductivity @ 20 deg.C	µS/cm				1000	3200	33	
Alkalinity, Total as $CaCO_3$	mg/l				180	860	33	
Ammoniacal Nitrogen as N	mg/l	0.39			<0.05	6.8	33	
Sulphate	mg/l	250		400	150	850	33	
Chloride	mg/l	250		250	59	310	33	
Biochemical Oxygen Demand	mg/l				<4	11	24	
Chemical Oxygen Demand	mg/l				20	76	24	
Metals (dissolved)								
Arsenic	µg/l	10		50	1.5	3	6	
Cadmium	µg/l	5	1.5	0.25		<0.08	32	EQS based on $CaCO_3$ content greater than 200 mg/l
Calcium	mg/l				210	35000	30	
Chromium	µg/l	50			<1	25	30	
Copper	µg/l	2		1[B]	<1	5.6	33	
Iron	µg/l	200		1000	300	1600	30	
Lead	µg/l	10	14	1.2[B]	<1	2.5	30	
Magnesium	mg/l				1.7	60	30	
Manganese	µg/l	50		123[B]	<1	370	33	
Mercury	µg/l	1	0.07			<0.01	30	
Nickel	µg/l	20	34	4[B]	<1	11	30	
Potassium	mg/l				3.4	8700	30	
Selenium	µg/l	10			<1	25	30	
Sodium	mg/l	200			31	420	33	
Zinc	µg/l			10.9[B]	<1	26	30	EQS is limit plus background concentration
Organic								
Benzene	µg/l	1	50	10		<1	6	

1. Data from groundwater samples at borehole F, G and H

EQS – Environmental Quality Standard
MAC – Maximum Annual Concentration
AA – Annual Average

2658/HRA/A1.2: Summary of background water quality data (up-gradient)[1]

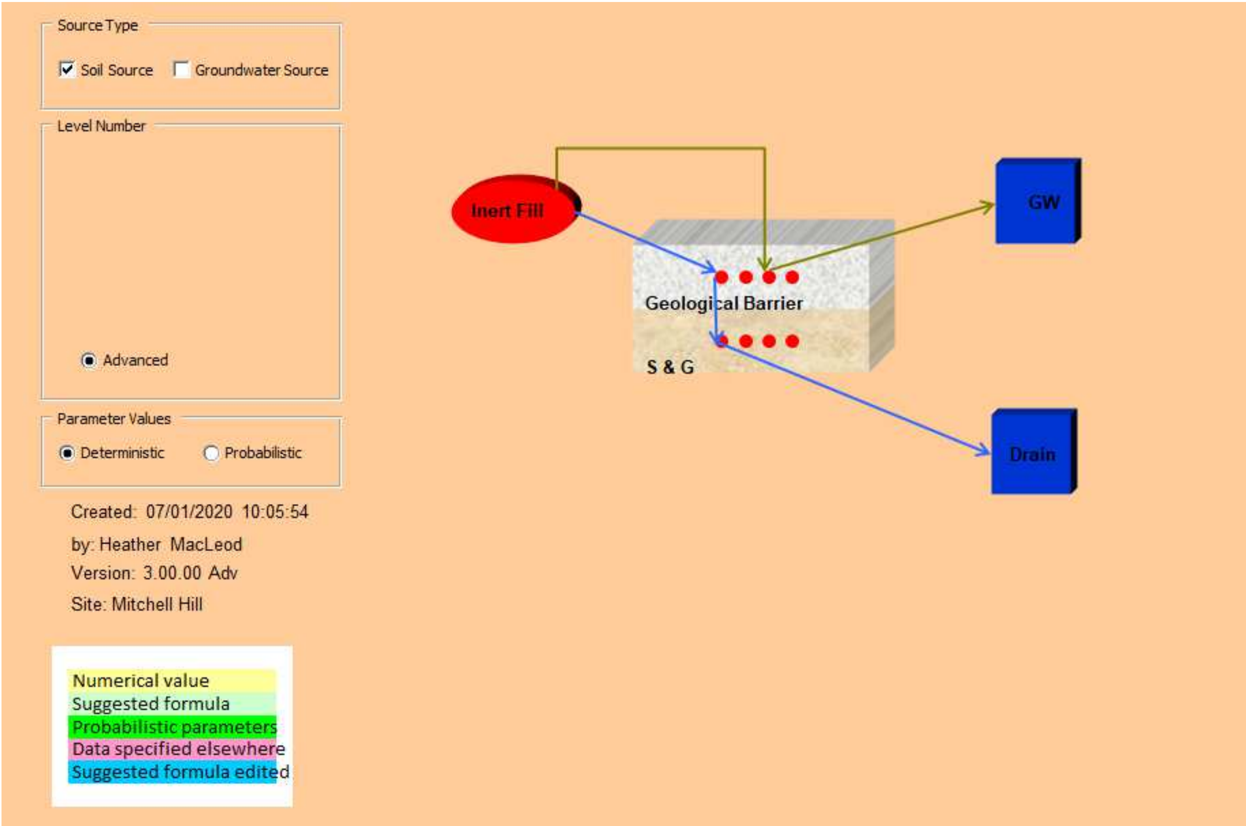
Determinand	units	DWS	EQS		min	max	Nº	Comment
			MAC	AA				
Inorganics								
pH	pH Units				7	8.7	42	
Conductivity @ 20 deg.C	µS/cm				740	2100	42	
Alkalinity, Total as $CaCO_3$	mg/l				230	510	42	
Ammoniacal Nitrogen as N	mg/l	0.39			0.074	5.9	42	
Sulphate	mg/l	250		400	58	390	42	
Chloride	mg/l	250		250	21	460	42	
Biochemical Oxygen Demand	mg/l				<4	10	30	
Chemical Oxygen Demand	mg/l				<10	34	30	
Metals (dissolved)								
Arsenic	µg/l	10		50	1.8	3.6	6	
Cadmium	µg/l	5	1.5	0.25	<0.08	0.15	42	EQS based on $CaCO_3$ content greater than 200 mg/l
Calcium	mg/l				98	2800	38	
Chromium	µg/l	50			<1	16	38	
Copper	µg/l	2		1[B]	<1	280	42	
Iron	µg/l	200		1000	200	5900	38	
Lead	µg/l	10	14	1.2[B]	<1	4.9	38	
Magnesium	mg/l				7.1	80	38	
Manganese	µg/l	50		123[B]	<1	820	42	
Mercury	µg/l	1	0.07		<0.01	0.16	38	
Nickel	µg/l	20	34	4[B]	<1	65	38	
Potassium	mg/l				4.8	650	38	
Selenium	µg/l	10			<1	27	38	
Sodium	mg/l	200			16	560	42	
Zinc	µg/l			10.9[B]	<1	14	38	EQS is limit plus background concentration
Organic								
Benzene	µg/l	1	50	10	<1	1	6	

1. Data from groundwater samples at borehole A, B, C and D

EQS – Environmental Quality Standard
MAC – Maximum Annual Concentration
AA – Annual Average

APPENDIX 2658/HRA/A2

Results from RAM Model


Source Type
Soil Source
Groundwater Source
Level Number
Advanced
Parameter Values
Deterministic
Probabilistic
Created: 07/01/2020 10:05:54
by: Heather MacLeod
Version: 3.00.00 Adv
Site: Mitchell Hill
Numerical value
Suggested formula
Probabilistic parameters
Data specified elsewhere
Suggested formula edited
Inert Fill
GW
Geological Barrier
S & G
Drain

SOURCE CONCENTRATIONS: Inert Fill

Source Data Options

- (●) Pore water concentrations
- ( ) Leaching test
- ( ) Soil contaminant concentrations

Source Type

- ( ) Constant source
- (●) Declining source

Source Geometry

Inert_Fill_Source_length	10	m
Inert_Fill_Source_width	10	m
Inert_Fill_Source_area	100	m2
Inert_Fill_Source_thickness	2	m
Inert_Fill_Source_volume	200	m3

General Source Properties

Inert_Fill_Source_field_capacity	[-]	0.025

Source Contaminant Information

Source determinand names		Cadmium	Chloride	Arsenic	Benzene
Inert_Fill_Pore_water_concentration	mg/L	14.5	7500	350	2.4
Inert_Fill_Initial_inventory	kg	0.0725	37.5	1.75	0.012
Inert_Fill_Input_concentration	mg/L	14.5	7500	350	2.4

CONTAMINANT INFORMATION

			Species1	Species2	Species3	Species4
Source determinand names		4	Cadmium	Chloride	Arsenic	Benzene

Receptor Target Concentrations

	Name	Values in mg/L			
Quality Standard 1	EQS	0.00015	150	0.01	0.001
Quality Standard 2					
Quality Standard 3					
Quality Standard 4					

Generic Contaminant Properties

Contaminants_Organic_Carbon_Water_Partition_Coefficient_Koc	**L/kg**				135
Contaminants_Free_Water_Diffusion_Coefficient	**m2/s**	7.17E-10	2.03E-09	9.05E-10	7E-10

HYDROGEOLOGICAL UNITS

Hydrogeological Units		Geologica	S G
Hydrogeology_Unit_Thickness	**m**	1	1.2
Hydrogeology_Log_Hydraulic_Conductivity	**log(m/s)**	-8	-3.68
Hydrogeology_Hydraulic_Conductivity	**m/s**	1E-08	0.000209
Hydrogeology_Head	**m**		
Hydrogeology_Hydraulic_Gradient	**[-]**	1	0.001
Hydrogeology_Porosity	**[-]**	0.46	0.27
Hydrogeology_Velocity	**m/s**	2.17E-08	7.74E-07
Hydrogeology_Tortuosity	**[-]**	5	5

ATTENUATION PARAMETERS

Hydrogeological Units		Geologica S	G
General properties			
Attenuation_Dry_bulk_density	kg/m3	1900	2400
Attenuation_Fraction_organic_carbon	[-]	0.01	0.0017
Contaminant specific parameters			
Cadmium			
Attenuation_Partition_Coefficient_Kd_Species_1	L/kg	501	501
Attenuation_Retardation_Species_1	[-]	2070.348	4454.333
Attenuation_Half_Life_Species_1	days	No Decay	No Decay
Attenuation_Decay_Coefficient_Species_1	1/s	0	0
Chloride			
Attenuation_Partition_Coefficient_Kd_Species_2	L/kg	0	0
Attenuation_Retardation_Species_2	[-]	1	1
Attenuation_Half_Life_Species_2	days	No Decay	No Decay
Attenuation_Decay_Coefficient_Species_2	1/s	0	0
Arsenic			
Attenuation_Partition_Coefficient_Kd_Species_3	L/kg	1580	1580
Attenuation_Retardation_Species_3	[-]	6527.087	14045.44
Attenuation_Half_Life_Species_3	days	No Decay	No Decay
Attenuation_Decay_Coefficient_Species_3	1/s	0	0
Benzene			
Attenuation_Partition_Coefficient_Kd_Species_4	L/kg	1.35	0.2295
Attenuation_Retardation_Species_4	[-]	6.576087	3.04
Attenuation_Half_Life_Species_4	days	240	240
Attenuation_Decay_Coefficient_Species_4	1/s	3.34E-08	3.34E-08

WATER BALANCE

Infiltration through the soil zone sourc

Source Name: Inert Fill

Effective_Rainfall	211	**mm/yea**
Infiltration_Factor	1	**[-]**
Infiltration_Rate	211	**mm/yea**
Infiltration_Area	100	**m2**
Q_Infiltration	6.68619E-07	**m3/s**

PATHWAY SUMMARY

Path 1		Section 1		Section 2		Section 3		Section 4
Path 1 Type		Source		Unit		Unit		Receptor
Path 1 Name		**Inert Fill**		**Geological Barrier: Node 1**		**S & G: Node 1**		**Drain**
Path 1 Process		Declining source		ADRD (1D) + Dilution		ADRD (1D) + Dilution		Monitoring Borehole
Path 1 Standards							Target Standard	EQS
Path 1 Parameter1	**Q_managed [m3/s]**	0.000E+00	**Velocity [m/s]**	2.174E-08	**Velocity [m/s]**	7.738E-07		
Path 1 Parameter2	**Managed time [years]**	0.000E+00	**Dispersivity [m]**	0.1	**Dispersivity [m]**	0.1		
Path 1 Parameter3	**Q_path [m3/s]**	6.686E-07	**Travel Distance [m]**	1.0	**Travel Distance [m]**	9.0		
Path 1 Parameter4	**Q_decline [m3/s]**	6.686E-07	**Mixing Depth [m]**		**Mixing Depth [m]**	1.2		
Path 1 Parameter5			**Mixing Width [m]**		**Mixing Width [m]**	12.0		
Path 1 Parameter6			**Q_Dilute [m3/s]**	0.000E+00	**Q_Dilute [m3/s]**	3.009E-06	**Q_dilute [m3/s]**	0.000E+00

Path 2		Section 1		Section 2		Section 3
Path 2 Type		Source		Unit		Receptor
Path 2 Name		**Inert Fill**		**Geological Barrier: Node 3**		**GW**
Path 2 Process		Declining source		ADRD (1D) + Dilution		Monitoring Borehole
Path 2 Standards					Target Standard	EQS
Path 2 Parameter1	**Q_managed [m3/s]**	0.000E+00	**Velocity [m/s]**	2.174E-08		
Path 2 Parameter2	**Managed time [years]**	0.000E+00	**Dispersivity [m]**	0.1		
Path 2 Parameter3	**Q_path [m3/s]**	6.686E-07	**Travel Distance [m]**	1.0		
Path 2 Parameter4	**Q_decline [m3/s]**	6.686E-07	**Mixing Depth [m]**			
Path 2 Parameter5			**Mixing Width [m]**			
Path 2 Parameter6			**Q_Dilute [m3/s]**	0.000E+00	**Q_dilute [m3/s]**	0.000E+00

BREAKTHROUGH RESULTS

Site Name: "Mitchell Hill"
Advanced

Pollutant Linkage: Inert Fill, Geological Barrier, S & G, Drain
Concentrations in mg/L in Drain

Compared with EQS target concentration in mg/L

	Species1		Species2		Species3		Species4
EQS target	1.500E-04		1.500E+02		1.000E-02		1.000E-03
Time(years)	Cadmium	Time(years)	Chloride	Time(years)	Arsenic	Time(yea	Benzene
500	0.000E+00	0.4	7.345E-05	2000	0.000E+00	1	0.000E+00
750	0.000E+00	0.6	1.814E-01	4000	1.885E-09	2	1.166E-08
1000	1.328E-11	0.8	2.762E+00	6000	5.170E-06	3	4.436E-06
1500	3.496E-08	1	8.861E+00	7000	1.997E-05	4	2.104E-05
1750	5.168E-07	1.2	1.499E+01	8000	3.961E-05	5	2.375E-05
2000	2.534E-06	1.4	1.842E+01	10000	6.168E-05	6	1.446E-05
3000	1.807E-05	2	1.477E+01	15000	3.410E-05	7	6.436E-06
4000	1.612E-05	3	4.045E+00	17000	2.193E-05	8	2.405E-06
5000	8.938E-06	4	8.400E-01	18000	1.730E-05	9	8.080E-07
6000	4.236E-06	6	3.276E-02	20000	1.055E-05	10	2.537E-07

Pollutant Linkage: Inert Fill, Geological Barrier, GW
Concentrations in mg/L in GW

Compared with EQS target concentration in mg/L

	Species1		Species2		Species3		Species4
EQS target	1.500E-04		1.500E+02		1.000E-02		1.000E-03
Time(yea	Cadmium	Time(yea	Chloride	Time(yea	Arsenic	Time(yea	Benzene
500	9.201E-08	0.4	2.883E+00	2000	4.227E-06	1	1.246E-09
750	4.635E-06	0.6	3.003E+01	4000	2.229E-04	2	2.818E-05
1000	2.626E-05	0.8	8.072E+01	6000	4.657E-04	3	2.879E-04
1500	1.027E-04	1	1.248E+02	7000	4.891E-04	4	4.234E-04
1750	1.317E-04	1.2	1.458E+02	8000	4.649E-04	5	2.902E-04
2000	1.471E-04	1.4	1.449E+02	10000	3.546E-04	6	1.375E-04
3000	1.198E-04	2	8.815E+01	15000	1.193E-04	7	5.325E-05
4000	6.452E-05	3	2.151E+01	17000	7.232E-05	8	1.829E-05
5000	3.024E-05	4	4.369E+00	18000	5.596E-05	9	5.825E-06
6000	1.339E-05	6	1.704E-01	20000	3.323E-05	10	1.765E-06

Pollutant Linkage: Inert Fill, Geological Barrier, S & G, Drain
Remedial Target Concentrations in mg/L in Inert Fill

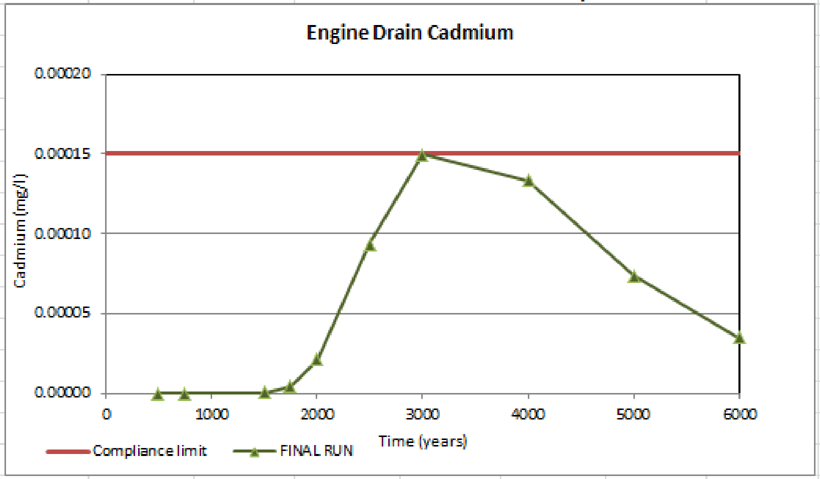
	Species1		Species2		Species3		Species4
Time(years)	Cadmium	Time(years)	Chloride	Time(years)	Arsenic	Time(yea	Benzene
500	1.000E+40	0.4	1.940E+09	2000	1.000E+40	1	1.000E+40
750	1.000E+40	0.6	7.854E+05	4000	9.549E+07	2	2.059E+05
1000	1.977E+07	0.8	5.159E+04	6000	3.482E+04	3	5.410E+02
1500	7.508E+03	1	1.608E+04	7000	9.015E+03	4	1.141E+02
1750	5.080E+02	1.2	9.506E+03	8000	4.544E+03	5	1.010E+02
2000	1.036E+02	1.4	7.737E+03	10000	2.918E+03	6	1.660E+02
3000	1.452E+01	2	9.649E+03	15000	5.279E+03	7	3.729E+02
4000	1.629E+01	3	3.523E+04	17000	8.207E+03	8	9.980E+02
5000	2.937E+01	4	1.696E+05	18000	1.040E+04	9	2.970E+03
6000	6.196E+01	6	4.350E+06	20000	1.706E+04	10	9.461E+03

Pollutant Linkage: Inert Fill, Geological Barrier, GW
Remedial Target Concentrations in mg/L in Inert Fill

	Species1		Species2		Species3		Species4
Time(yea	Cadmium	Time(yea	Chloride	Time(yea	Arsenic	Time(yea	Benzene
500	2.853E+03	0.4	4.942E+04	2000	4.258E+04	1	1.926E+06
750	5.664E+01	0.6	4.746E+03	4000	8.074E+02	2	8.518E+01
1000	9.994E+00	0.8	1.765E+03	6000	3.865E+02	3	8.337E+00
1500	2.557E+00	1	1.142E+03	7000	3.680E+02	4	5.668E+00
1750	1.994E+00	1.2	9.776E+02	8000	3.872E+02	5	8.270E+00
2000	1.784E+00	1.4	9.838E+02	10000	5.077E+02	6	1.745E+01
3000	2.191E+00	2	1.617E+03	15000	1.509E+03	7	4.507E+01
4000	4.069E+00	3	6.625E+03	17000	2.489E+03	8	1.312E+02
5000	8.682E+00	4	3.261E+04	18000	3.217E+03	9	4.120E+02
6000	1.961E+01	6	8.365E+05	20000	5.417E+03	10	1.360E+03

Concentrations at compliance points

DRAIN - Non-Hazardous Receptor



GROUNDWATER - Hazardous Receptor