global environmental solutions

Energy Recovery Facility

Land off Sandall Stones Road

Kirk Sandall

Planning Reference: 09/00246/TIPA

Details Pursuant to Planning Conditions 13 and 24

Groundwater Risk Assessment for the ERF Bunker

SLR Ref: 403-04318-00001

August 2013

CONTENTS

TABLES

APPENDICES

1.0 INTRODUCTION

1.1 Background

This report addresses Conditions 13 and 24 of the Planning Permission (09/00246/TIPA), Doncaster Metropolitan Borough Council, for the Energy Recovery Facility (EfW), Kirk Sandall, near Doncaster, South Yorkshire.

Condition 13 and 24 both state the following:

"The development hereby permitted shall not be commenced until such time as a scheme to secure the protection of the underlying aquifer (Sherwood Sandstone) has been submitted to, and approved in writing by, the local planning authority. Any such scheme shall be supported by detailed information including a fully detailed groundwater risk assessment (GRA).

As part of the GRA and with regard to the engineering aspects the following information will be required:

- *The detailed design of the proposed waste bunker in relation to the hydrogeological conditions beneath the site.*
- *Design life details of the proposed waste bunker including the anticipated performance in terms of hydrostatic pressure and chemical attack effects within and surrounding the waste bunker.*
- *Evidence to demonstrate as to why no drainage is proposed for the waste bunker.*
- *Operation and maintenance of the proposed waste bunker.*
- *Emergency plans and monitoring at the proposed facility to mitigate against pollution of the underlying aquifer.*
- *Details concerning the protection of the underlying aquifer at the post operational stage of the facility including the waste bunker.*
- *Dewatering operations with appropriate mitigation where required.*

The GRA shall include all the appropriate mitigation to protect the underlying aquifer during both the construction, operational and post operational phases of the development. The scheme shall be fully implemented and subsequently maintained, in accordance with the scheme, or any changes as may subsequently be agreed, in writing, by the local planning authority."

For the purposes of this report the 'waste bunker' is referred herein as the 'fuel reception bunker'.

2.0 SITE SETTING AND CONCEPTUAL HYDROGEOLOGICAL SITE MODEL

2.1 Site Setting

The site setting is summarised as follows:

- The Site lies on existing industrial land within the Kirk Sandall Industrial estate, which is situated to the north-east of Doncaster.
- The site covers an area of around 1.86ha. The land surrounding the site is occupied predominantly by industrial manufacturing and storage premises.
- The current site is virtually flat, with elevations ranging between 6.6 and 7.6mAOD. A low embankment at the southern end of the site has a maximum height of 8.5mAOD.
- The proposed facility will accept in the region of 120,000tonnes per annum of waste and refuse, which will be used as a fuel feedstock to produce 11.2MW of low carbon renewable electricity. This feedstock will consist of material having passed through recovery centres for reuse and recycling that have been deemed to have no further use. The fuel reception bunker will be used to store the feedstock for the plant.

2.2 Conceptual Hydrogeological Site Model

The conceptual hydrogeological site model that has been used for this groundwater risk assessment adopts the ***source-pathway-receptor*** approach, which is recommended within the Environment Agency guidance[1] for groundwater risk assessments.

The different components are summarised below:

Source: Potential hazardous substances and non-hazardous pollutant contaminants derived from residual commercial and industrial wastes together with an element of Construction and Demolition waste, and potentially Municipal Solid Waste and Refuse Derived Fuel, within the fuel reception bunker.

Pathway: The base and sidewalls of the fuel reception bunker through which the migration of any potential contaminants originating from the fuel stored within the bunker will need to take place in order to reach the receptors.

Receptor: Groundwater and surface water resources within the immediate vicinity, and downstream of the fuel reception bunker.

Further details of each of these components are provided below.

2.2.1 Source

The proposed facility will accept in the region of 120,000tonnes per annum of residual commercial and industrial wastes together with an element of Construction and Demolition waste, and potentially Municipal Solid Waste and Refuse Derived Fuel.

The chemical composition of this fuel feedstock has not been determined at this stage. However, there is the potential for the feedstock to generate leachate containing non-hazardous pollutants and hazardous substances, should it become fully saturated.

[1] Environment Agency, 2009: *H1 Environmental Risk Assessment Annex (j) Groundwater*

However, the risk of the any leachate being generated from the feedstock, when it is being held within the fuel reception bunker is considered to be negligible, given the following:

Bunker Design and Construction

Details regarding the design, operation and maintenance of the fuel reception bunker are included within Appendix A.

The design of the building that will house the fuel reception hall and bunker, together with the surface water management scheme at the site, will prevent precipitation and surface water runoff from entering the reception hall and fuel materials stored within the bunker.

The bunker will extend below ground level and the groundwater table within the Sherwood Sandstone bedrock aquifer at the Site. However, groundwater ingress into the fuel materials from the Sherwood Sandstone aquifer will be prevented by the design and construction of the bunker, as discussed below:

Impermeability

The use of an additive such ‘Caltite’ in the concrete mix will produce an impervious and more durable concrete without requiring special construction techniques or maintenance. Technical details of the concrete produced using Caltite admixture may be found in Appendix A. Test details indicate water permeability of $0.15x10^{-12}$ m/s can be achieved.

The resulting concrete is non absorptive and moisture impervious providing permanent protection from water ingress/egress and proofed against soluble salt and acid attack. There would be no further need for coatings or additional liners to achieve the required tightness class.

Cracking is always a consideration in the design and construction of liquid retaining structures. Cracking can occur as a result of a number of factors - early thermal shrinkage and settlements, inappropriate curing regimes, internal restraint forces due to design and layout, excessive temperature changes during service and flexural movements.

All these issues are well documented and understood, and by following guidance in the Eurocodes for design and detailing and following normal good practice during construction works Class 3 tightness can be achieved. Measures include appropriate concrete mix design, correct sizing and spacing of reinforcing bar, correct layout and detailing of construction joints which will incorporate ‘water bar’ details to prevent leakage across the joints, and design of main members such that a percentage of the section always remains in compression.

During construction, appropriate quality control and inspection will be required, along with placing and curing procedures appropriate to the construction sequence and ambient weather conditions.

By adopting these procedures, cracks will be prevented from forming through the concrete section and there will be no pathway for liquids to penetrate. Micro cracks may form on the concrete surface but with the hydrophobic properties of Caltite and the autogenous healing properties inherent in concrete all such micro cracks will be self-sealing.

Strength

The desired strength of the reinforced concrete structure to provide resistance to ground pressures can be designed accordingly. Concrete strength can be expected to be to C32/40 and reinforcement will be high yield deformed bars.

Durability

Durability of concrete is well documented and with an appropriate mix design will provide the required resistance to abrasion and chemicals.

Constructability

Concrete construction in this situation has been well tried and tested and with good site supervision can be successfully accomplished.

Handling and Management of Stored Materials within the Bunker

The moisture content of the fuel stream prior to storage within the bunker will be controlled in order to prevent the generation of any leachate while the fuel is stored within the bunker.

The fuel will be delivered to the site within fully enclosed containers which will prevent ingress of precipitation.

The fuel will retain a level of adsorptive capacity due to its handling and storage prior to entering the fuel reception bunker.

Once within the fuel bunker, the fuel will be continuously mixed using a grab, to ensure homogenisation of the fuel prior to combustion. This will therefore prevent the build up of leachate.

Based on the above, it is considered that a drainage system will not be required for the proposed bunker.

Maintenance

As specified within Appendix A, a maintenance schedule will be implemented, which will involve regular visual inspections of the bunker.

This would be done by periodically emptying all fuel from the bunker using the grab cranes and skid steer loaders working from within the bunker. This would allow the bunker walls and base to be inspected, and any defects such as mechanical impact damage to be repaired. A shallow sump will be incorporated into the base of the bunker to assist in the removal of any accumulated wash down water used during maintenance works. This sump will not serve any function during the normal operation of the bunker.

Experience from other similar sites would suggest that a full ‘man entry’ inspection of the bunker will be required at intervals of around 10 years. In-between these visits the condition of the bunker will be assessed by regular (every 2 weeks) visual inspections of the bunkers from ground floor level.

2.2.2 Pathway

The pathway for potential contaminants to leave the fuel reception bunker and travel to the adjacent groundwater and surface water receptors is via the base and sidewalls of the fuel reception bunker.

As detailed within the reception bunker design report (Appendix A) the bunker design and the choice of construction materials will be selected based on impermeability, strength, constructability and durability throughout the design life of the facility, and will include a regular inspection and maintenance programme.

Therefore, given the above, it is considered that there will not be a pathway for potential groundwater leakage into, or potential leachate migration out of the fuel reception bunker.

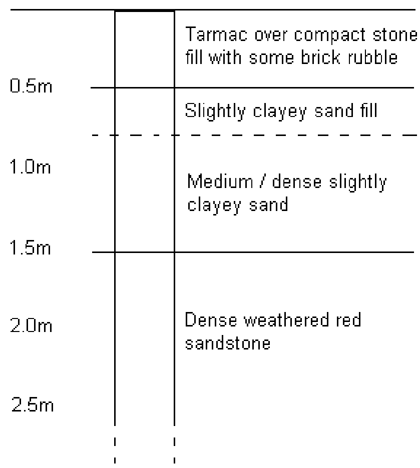
2.3 Receptors

The following information is taken from the Environmental Statement produced to support the Planning Application for the Site.

The ground conditions encountered beneath the Site during previous site investigations comprise Made Ground overlying medium dense and dense variably clayey sand, underlain by Sherwood Sandstone bedrock.

A typical geological section for the Site is included as Figure 1.

Figure 1: Typical Geological Section



Aquifer Characteristics

The hydrogeological characteristics at the site are summarised below:

- There is no groundwater system within the Made Ground and thin overburden.
- The Sherwood Sandstone is classified as a Principal Aquifer, and is typified by high permeability (both intergranular and fissure) with a corresponding low regional hydraulic gradient.
- Groundwater movement in the Sherwood Sandstone is likely to be regionally eastward, although the presence of groundwater abstractions and the River Don, located approximately 250m to the west of the Site, can result in localised modification of the groundwater flow paths.
- Groundwater levels within the Sherwood Sandstone below the Site have been recorded at a depth of 1.65mbgl level in a monitoring borehole screened within the weathered Sherwood Sandstone bedrock (BHA) during September and October 2007.

- This groundwater level is generally consistent with the groundwater elevation data recorded by the Environment Agency for:
  - Sandall Common Farm observation well between 1978 and 2008, when groundwater levels ranged between 1.39mAOD and 3.26mAOD, with an average of 0.59mAOD;
  - Armthorpe observation well between 1981 and 2008 data, with water levels ranging between about 2.5 and 4.5mAOD.
- The 1:25,000 Ordnance Survey mapping does not indicate any springs or wells within the vicinity of the Site.
- Review of the Environment Agency website (accessed on 24th May 2013) shows that the site is located in a Source Protection Zone 3 (Total Catchment) of a groundwater abstraction located more than 2km south-east of the site. Source Protection Zone 3 is defined as the total area needed to support removal of water from a borehole and to support any discharge from the borehole.
- Based on the Environmental Statement it is understood that there are no surface or groundwater abstractions within 250m of the site centre.
- There is one groundwater abstraction from the Sherwood Sandstone (Environment Agency Licence No. 2/27/09/048) at the Pilkington Glass site, located between 250 and 500m to the south of the ERF.
- Doncaster Council has confirmed an abstraction located more than 1km to the north-east of the ERF at NGR 461774 408221. The Council does not hold any further details regarding this abstraction.
- Doncaster Council has also confirmed that there is a second abstraction located at Wiltsend Caravan Park (NGR 458165 407234), approximately 2.5km west of the ERF site. The abstraction is understood to provide a supply of 8,400m^3/year.

Groundwater Quality

- The Environment Agency has provided groundwater monitoring data for the abstractions at Pilkington Glass and Wiltsend Caravan Park (see above). A summary of the monitoring record is shown in Table 1, review of which illustrates groundwater quality is characterised by low concentrations of most determinands.
- It is noted that the River Don 250m west of the site has tidal influence. If the river is in hydraulic continuity with the Sherwood Sandstone there is potential for the groundwater quality in the Sherwood Sandstone to be locally impaired by surface water with comparatively high salinity.
- The groundwater quality within the Sherwood Sandstone aquifer at the Site is expected to be of good quality. This is based on the findings of the site investigation completed in 2007 by Solmek Ltd, which indicated that measured levels of contaminants within the Made Ground at the Site were generally low or below the level of detection and well within recognised environmental threshold criteria for protection of health and the environment. Observable contamination was indicated in only one sample, as a minor ashy layer.

Hydrology

- There are no surface water features within the proposed development area or along its boundaries.
- The site lies within the catchment of the River Don. The River Don flows northwards 250m west of the site.
- The River Don in the vicinity of the site benefits from flood defences which provide a standard of protection in excess of the 1% annual probability flood (the 100-yr event).
- A detailed assessment of the flood risk to the site was presented within the Environmental Statement.

- It is noted that as the site has been allocated by Doncaster Council for industrial use, and is currently in industrial use, together with adjacent areas, it is deemed to have passed the Sequential Test as required by PPS25. This view is further reinforced by the grant of the planning permission for the Energy Recovery Facility.

Table 1
Summary of Groundwater Quality in the Sherwood Sandstone

Determinand	Unit	Pilkington Glass				Wiltsend Caravan Park			
		Count	Minimum	Average	Maximum	Count	Minimum	Average	Maximum
Alky pH 4.5	mg/l	9	113	167	201	3	110	208.67	323
Aluminium-Al	ug/l	6	<10	-	13.3	2	25.7	28.95	32.2
Ammonia(N)	mg/l	10	<0.03	-	0.371	5	<0.03	-	0.153
Arsenic - As	ug/l	5	2.15	2.66	3.38	1	1.8	1.8	1.8
As-Filtered	ug/l	3	2.27	2.64	3.31	1	<1	-	<1
Barium - Ba	ug/l	6	137	153	185	2	26.6	43.1	59.6
Boron - as B	ug/l	8	<100	-	<100	3	<100	-	<100
Cadmium - Cd	ug/l	9	<0.1	-	0.29	3	<0.1	-	<0.1
Calcium - Ca	mg/l	10	71.6	103.13	115	5	23.1	96.52	145
Chloride Ion	mg/l	10	111	129.3	153	5	33.3	78.18	122
Chromium - Cr	ug/l	7	0.593	0.99	1.63	2	<0.5	0	1.28
Cr- Filtered	ug/l	3	<1	-	2.66	1	<0.5	-	<0.5
Cond @ 20C	uS/cm	8	654	919.13	1090	5	469	935.6	1210
Copper - Cu	ug/l	9	2.16	31.72	216	3	1.41	19.94	32.7
Hardness	mg/l	9	310	433.22	479	5	99.3	381.46	646

Note: Monitoring data provided by Environment Agency. Monitoring locations shown on Drawing DRF 10/4 of the Environmental Statement.

Table 10-3 (Contd...)
Summary of Groundwater Quality in the Sherwood Sandstone

Determinand	Unit	Pilkington Glass				Wiltsend Caravan Park			
		Count	Minimum	Average	Maximum	Count	Minimum	Average	Maximum
Iron - as Fe	ug/l	9	<30	-	1750	5	<30	-	3730
Lead - as Pb	ug/l	9	<0.4	-	17.6	3	<0.4	-	10.4
Magnesium-Mg	mg/l	10	31.8	42.55	46.7	5	6.22	34.12	69
Manganese-Mn	ug/l	10	12	37.87	201	5	<10	-	764
N Oxidised	mg/l	10	7.29	10.34	11.9	5	<0.2	-	5.36
Nickel - Ni	ug/l	9	<1	-	<5	3	<5	-	<5
Nitrate-N	mg/l	8	7.28	10.39	11.9	5	<0.195	-	5.36
Nitrite-N	mg/l	10	<0.004	-	<0.01	5	<0.004	-	0.007
pH	PH units	8	6.89	7.36	7.8	5	7.0	7.29	7.84
Potassium- K	mg/l	10	4.36	6.00	7.05	5	1	2.77	3.61
Sodium - Na	mg/l	10	19.9	29	41.3	5	17.3	77.92	296
Sulphate SO4	mg/l	10	54.4	111.46	132	5	98.6	145.72	186
Zinc - as Zn	ug/l	9	<5	-	<20	3	9.56	49.19	112

Note: Monitoring data provided by Environment Agency. Monitoring locations shown on Drawing DRF 10/4 of the Environmental Statement.

3.0 RISK ASSESSMENT

3.1 Approach

The approach that has been adopted for this groundwater risk assessment is based on Environment Agency guidance[1] for groundwater risk assessments. The risk assessment is therefore focused on the ***source – pathway – receptor*** approach, as identified within the conceptual hydrogeological model for the Site in Section 2 above.

It is considered appropriate to assess the risk to groundwater and surface water at the Site during both the construction, the operational and post operational phases of the fuel reception bunker.

It is noted that accidental spillages of contaminating liquids during the fuel reception bunker construction, operational and post operational (decommissioning) phases from plant or vehicles operating at the site have not been included within this risk assessment, as these events will be dealt with under the site wide Emergency Spill Response Plan for the Site.

3.2 Assessment Scenarios

The different assessment scenarios relating to the fuel reception bunker and considering the source-pathway-receptor conceptual model as detailed within Section 2 above, are outlined below:

Source – hazards to the groundwater and surface water receptors at the Site comprise:

- *Construction and Post Operational Phase:* suspended sediment arising from construction and decommissioning activities, including that associated with sump pump discharge within the floor of the excavated bunker void, and handling and storage of excavated overburden and associated runoff water at the surface.

- *Operational Phase*: Hazardous substances and non-hazardous pollutants derived from the storage of feedstock within the fuel reception bunker located below the groundwater table within the Sherwood Sandstone aquifer.

***Pathway* –** potential pathways include:

- *Construction and Post Operational Phases:* surface water flow across the ground surface, and infiltration through the made ground and overburden.

- *Operational Phase*: advective flow and diffusive flux through the sides and base of the fuel reception bunker, as well as through the adjacent made ground and overburden.

Receptors

- *During Construction, Operational and Post Operational Phases:* groundwater within the Sherwood Sandstone aquifer, and surface water drainage system within the vicinity of the Site.

3.2.1 Source Term Characterisation

Construction Phase and Post Operational Phase: The construction of the fuel reception bunker will involve active dewatering, comprising removal of rainwater inputs and groundwater inflows from the Sherwood Sandstone that take place into the bunker excavation.

If the bunker is to be removed during decommissioning of the Site, then active dewatering may also be required.

All surface water runoff from the surrounding site area will be prevented from draining into the excavation void.

Lateral groundwater inflows into the bunker excavation from the Made Ground and overburden will be negligible, due to the following:

- the lack of any significant groundwater within these deposits at the Site; and
- the barrier effect of the proposed interlocking steel piles, which will be installed around the perimeter of the bunker excavation to enable it to be dug with vertical sides and reduce the overall volume of excavation. The piles will be toed into the underlying bedrock where possible, and anchored back into the underlying sandstone.

Groundwater inflows into the excavation void from the Sherwood sandstone bedrock will be prevented by managing groundwater levels so that they remain below the base of the void throughout the bunker construction stage. This will be achieved via a dewatering programme involving abstraction from one or more groundwater wells located just outside the excavation footprint. An initial estimation of groundwater inflow rates has been made using the Environment Agency's Tier 1 Analytical Tool (V1.6) entitled '*Assessing the impacts of dewatering on water resources'*. The spreadsheets and parameterisation utilised for this assessment are included within Appendix B.

Using this spreadsheet the maximum groundwater dewatering rate is estimated to be less than 340m^3/day, assuming two abstraction wells are required to sufficiently dewater the excavation within the Sherwood Sandstone. However, this estimate will be confirmed during the detailed design stage for the bunker. The maximum predicted radius of dewatering influence on the groundwater levels within the Sherwood Sandstone is estimated to be less than 100m. There are no abstractions or groundwater-fed surface water features within this predicted drawdown cone extent.

During the excavation and construction of the fuel reception bunker, the pumped groundwater from the dewatering wells will be returned back to the Sherwood Sandstone aquifer. The presence of the Sherwood Sandstone aquifer just below the ground surface and the lack of any significant contamination within the thin horizon of Made Ground at the Site should allow both soakaway and/or recharge wells to be used. The quality of the abstracted groundwater is also not expected to limit or prevent its recharge back into the aquifer. It is noted that the land quality assessment included within the Environmental Statement also concluded that there was a low risk to groundwater at the site.

The water from the sump on the floor of the excavation void will be discharged to on-site settlement lagoons prior to controlled discharge via soakaways and/or recharge wells back into the Sherwood Sandstone aquifer, in accordance with site permits which will be obtained following the detailed design stage.

Operational Phase:

Following the completion of the fuel reception bunker construction, the temporary dewatering operations will cease and groundwater levels within the Sherwood Sandstone will be allowed to recover back to natural levels. Under these conditions the fuel reception bunker will be located below the groundwater table within the Sherwood Sandstone.

With regard to assessing the potential risks associated with hazardous substances and non-hazardous pollutants derived from the storage of feedstock within the fuel reception bunker under these sub-water table conditions, it is noted that the EA guidance on Environmental Risk Assessments[1] states that "*a tiered approach is needed so that the cost, time and effort in undertaking a risk assessment are proportional to the effort or measures required to make the risks from an activity acceptable*."

As detailed within Section 2.2.1 above, the risks of leachate being generated within the fuel reception bunker is negligible given the bunker design and construction, together with the handling and management procedures for fuel feedstock.

Therefore, this guidance[2] confirms that a qualitative risk screening (Tier 1) is appropriate for the Site, based on the following:

- there will be no discharge of hazardous and non-hazardous pollutants from the fuel reception bunker, given that there will be no leachate generated from the fuel during its storage within the bunker; and

- consequently, there will be no volume or hydraulic loading rate of any leachate on the surrounding groundwater within the Sherwood Sandstone. This will also be the case, given the substantial inward hydraulic gradients that will develop once the groundwater levels within the Sherwood Sandstone recover following cessation of construction dewatering.

3.2.2 Pathway Characterisation

Construction and Post Operational Phases: surface water flow across the ground surface, resulting in transportation of suspended solids derived from the excavated surfaces will be very unlikely given the following:

- all water pumped from the bunker excavation sump will be discharged to temporary on-site settlement lagoons prior to controlled discharge via soakaways and/or recharge wells back into the Sherwood Sandstone aquifer, in accordance with site permits which will be obtained following the detailed design stage; and
- the adoption of sustainable drainage techniques (SuDS), including the construction of temporary sediment traps around excavated materials stored on the ground surface using sand bags, geotextiles, straw bales and/or shallow vegetated swales with dams, will encourage localised attenuation / settlement of any suspended solids present within the surface water leaving these areas.

Operational Phase: As detailed within Section 2.2.1 above, the bunker design and construction materials will be selected based on impermeability, strength, constructability and durability throughout the design life of the facility.

Routine detailed condition surveys and an annual maintenance schedule will also ensure that any potential defects can be identified and rectified quickly. The rapid identification of any potential defects within the walls and base of the bunker will be assisted by appearance

[2] Box 4.4 of the Environment Agency guidance on Environmental Risk Assessments: Annex (j) Groundwater

of any seepage inflows due to the significant inward hydraulic gradients that will be present across the base and sides of the bunker, as a direct result of the high groundwater levels within the adjacent Sherwood Sandstone bedrock strata. Also, given the management and handling procedures of the fuel prior to and during storage within the bunker, any unexplained leachate generation will also be used to confirm the presence of any potential pathways that are compromising the hydraulic integrity of the bunker.

Therefore, given the above, there will be no effective pathway for potential contaminants to escape through the base and sides of the bunker.

3.2.3 Receptor Characterisation

During bunker construction, operational and post operational phases, the identified receptors will comprise the groundwater within the Sherwood Sandstone aquifer at the Site. There are no surface water features within the immediate vicinity of the Site.

As detailed above, it is considered that there will be no impact on this receptors, given the proposed bunker design, construction and operational/management controls to be employed at the Site.

The significant inward hydraulic gradients across the walls and base of the fuel reception bunker will also prevent the escape of any potential pollutants out of the bunker during the operational phase.

3.3 Additional Management Measures

Additional management measures that will ensure that the construction and operation of the bunker will not present a significant risk to the identified groundwater receptors at the Site will include the following:

3.3.1 Prior to Construction

- All necessary measures to protect the water environment will be included within the Construction Method Statement (CMS), which will be produced prior to the construction of the ERF. The CMS will include both specific mitigation measures as identified above, as well as monitoring and emergency procedures. Such emergency procedures will include a site specific Pollution Incident Response Plan in order to prevent and mitigate damage to the environment caused by accidents such as spillages during the construction phase.
- All of the specified environmental mitigation measures that will be required for the proposed facility will be clearly stated at the tendering stage of the construction process and all appointed sub-contractors working on the site will be made aware of the site specific concerns and the environmental mitigation measures that will be required.

3.3.2 During Construction

- During the construction phase, all drainage measures will be subject to daily Site inspections to ensure their effectiveness.
- Operational measures will also be employed to limit the mixing of “clean” and “dirty” water in terms of suspended solids content. Such measures will include the prevention of surface water discharge into the bunker excavation by profiling the ground surface elevation around the perimeter of the excavation to encourage drainage away from the excavation and, where possible, the segregation of such waters within the excavation through the use of temporary bunding.

- With regard to requisite surveillance, a monitoring programme will be carried out at the site as proposed in Table 1 below. The monitoring records will be collated and maintained on site, and be available for review by the Environment Agency on request.

Table 1
Proposed Water Monitoring Schedule

Location	Stage of Development	Schedule	Frequency
Settlement lagoon(s) and Sherwood Sandstone recharge system (soakaway and/or recharge well(s))	During Construction	Visual monitoring of surface water/pumped water drainage measures	Daily
		pH, Elec. Cond., Total, BOD, COD, TOC, chloride, TON, ammoniacal-N, Total Suspended Solids, hydrocarbon oil, total cyanide, cadmium, mercury, chromium, copper, lead, zinc	Monthly

3.3.3 Operational

- Routine inspection of the bunker walls and base, together with monitoring to confirm no leachate build-up in the base of the bunker will provide a robust method for confirming that the bunker remains water tight throughout the operational life of the facility.
- A groundwater and surface water monitoring programme (beyond that required by the site Permit) is not considered to be necessary, given the design, construction and operation of the bunker and the proposed management measures that will be employed during the construction and operation of the bunker.

3.3.4 Post Operational

- Prior to decommissioning when the ERF facility ultimately ceases operations, the bunker will be emptied of all fuel materials and the internal walls and floor of the bunker thoroughly cleaned to remove any fuel residues.
- The decision to either leave the bunker *in situ* or remove the bunker will be determined depending on conditions at that time. However, if the bunker is to remain on a permanent basis, the long term impact on the groundwater flow within the Sherwood Sandstone will be negligible, given the relatively small footprint of the bunker in relation to the surrounding highly permeable Sherwood Sandstone aquifer. Under these conditions groundwater flow will continue to flow around the bunker without any significant build up of groundwater levels.

4.0 CONCLUSIONS

The following conclusions are drawn from the above:

- a groundwater risk assessment has been completed based on current Environment Agency Guidance for Environmental Risk Assessments[1];
- the conceptual hydrogeological model for the Site is described;
- a qualitative risk screening (Tier 1) is considered to be appropriate for the groundwater risk assessment for the bunker, given the identified source-pathway-receptor characteristics at the Site;
- the assessment indicates that the risks to the groundwater and surface water at the Site are negligible, given the design, construction and operation of the bunker and the proposed management measures that will be employed during the construction and operation of the bunker;
- the technical precautions, operational management and maintenance measures will prevent the introduction of non-hazardous pollutants and hazardous substances into the groundwater and surface water receptors throughout the lifecycle of the fuel reception bunker;
- during the post operational phase, the bunker will not present a risk to groundwater or surface water receptors, as all fuel will be removed from the bunker. If the bunker is left permanently *in situ*, groundwater flow will continue to take place around it thereby preventing any significant damming effect or associated impact on the surrounding groundwater elevations; and
- the bunker should therefore comply with the relevant requirements of the Environmental Permitting Regulations (2010) throughout the lifecycle of the bunker.

.

5.0 CLOSURE

This report has been prepared by SLR Consulting Limited with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

SLR disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

20) Flow to a pit (Marinelli and Niccoli, 1998)

$$Q_1 = P\pi\left(R_0^{\,2} - r_w^{\,2}\right)$$

$$Q_2 = 4\left(\frac{K_{h2}}{m_2}\right) r_w (H - d)$$

$$m_2 = \sqrt{\frac{K_{h2}}{K_{v2}}}$$

Essential input
Optional input
Calculated

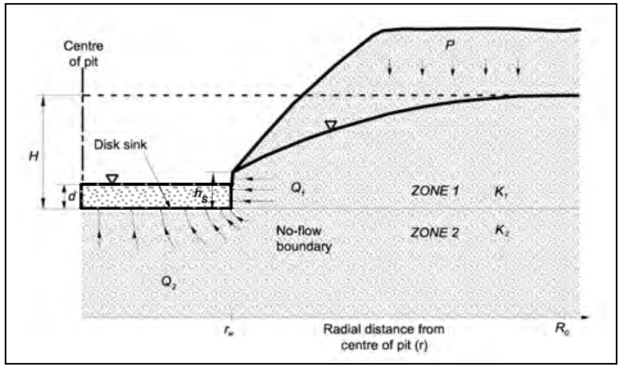
Flow into a pit using separate solutions for the sides and the base.

(Follow on from ROI spreadsheet 19. To find Radius of influence for this procedure)

Head		expected		min	max	
Height of wt at radius of influence	H	9.0	m			m
Depth of Ponded Area	d	0.0	m			m
Layer 2						
Horizontal Conductivity	K_{h2}	1.00E-05	m/s			m/s
		8.6E-01	m/d			
Vertical Conductivity	K_{v2}	1.00E-06	m/s			m/s
Anistropy	m_2	3.2		3.2	3.2	
Distributed recharge	P	1.30E-08	m/s			m/s
		1.1E-03	m^3/d			
Radius of quarry	r_w	15.0	m			
Radius of influence	R_o	85.0	m			m

Can be taken from ROI worksheet or other sources

Inflow						
Inflow through Seepage Face	Q_1	2.86E-04	m^3/s	2.86E-04	2.86E-04	m^3/s
		(24.7	m^3/d	24.700	24.700	m^3/d
Inflow through Mine base	Q_2	1.71E-03	m^3/s	1.71E-03	1.71E-03	m^3/s
		(147.5	m^3/d	147.5	147.5	m^3/d
Total Inflow	**Qt**	**0.002**	**m^3/s**	0.002	0.002	m^3/s
		(172.2	m^3/d	172.2	172.2	m^3/d



The following assumptions apply to this equation

- There is no groundwater flow between zones 1 and 2

Zone 1

- steady-state, unconfined, horizontal radial flow
- uniformly distributed recharge at the water table
- pit walls are approximated as a right circular cylinder
- initial static water table and groundwater flow are both horizontal
- groundwater flow to the pit is axially symmetric

Zone 2

- steady state flow to one side of a circular disk sink of constant and uniform drawdown
- hydraulic head is initially uniform throughout Zone 2.
- initial head is equal to the elevation of the initial water table in Zone 1
- disk sink has a constant hydraulic head equal to the elevation of the pit lake water surface
- flow to the disk sink is three-dimensional and axially symmetric
- materials are anisotropic, prinicipal directions for K are horizontal and vertical

(Marinelli & Niccoli, 1998)

Data sources (to complete an audit trail)		
Height of wt at radius of influence	H	bunker depth of 9mbgl, and groundwater level at surface (worst case)
Depth of Ponded Area	d	assumes dry working conditions in excavation base
Layer 2 Horizontal Conductivity	K_{h2}	Published data, aquifer properties database, EA info and SLR experienc
Layer 2 Vertical Conductivity	K_{v2}	Assumed reduction by 1 order of magnitude
Distributed recharge	P	Based on annual rainfall of c.800mm and effective rainfall (MAFF 1975)
Radius of quarry	r_w	Based on basal excavation area of 24m x 30m
Radius of influence	R_o	Calculated using Sichardt Method

21) Radius of influence (Sichardt)

$$R_0 = Cs\sqrt{K}$$

Essential input
Optional input
Calculated

Empirical equation based on drawdown and permeability

		expected		min	max	
Drawdown in well	s	9	m			m
Hydraulic conductivity	K	0.00001	m/s			m/s
		0.864	m/d			
Factor	C	3000		3000 for radial flow 1500-2000 for line flow to trenches or wellpoints		
Radius of influence	R_0	85.38	m	85.38	85.38	m

The following assumptions apply to this equation
- the aquifer is unconfined
- the aquifer has infinite areal extent
- the aquifer is homogeneous, isotropic and of uniform thickness
- flat initial water table
- the aquifer is pumped at a constant discharge rate
- the pumping well is fully penetrating, therefore receiving water from the entire saturated thickness of the aquifer
- the flow to the well is in a steady state

Data sources (to complete an audit trail)

Drawdown in well	s	bunker depth of 9mbgl, and groundwater level at surface (worst c
Hydraulic conductivity	K	Published data, aquifer properties database, EA info and SLR exp
Factor	C	worst case assumed.

global environmental solutions

AYLESBURY
7 Wornal Park, Menmarsh Road,
Worminghall, Aylesbury,
Buckinghamshire HP18 9PH
T: +44 (0)1844 337380

BELFAST
24 Ballynahinch Street, Hillsborough,
Co. Down, BT26 6AW Northern Ireland
T: +44 (0)28 9268 9036

BRADFORD-ON-AVON
Treenwood House, Rowden Lane,
Bradford-on-Avon, Wiltshire BA15 2AU
T: +44 (0)1225 309400

BRISTOL
Langford Lodge, 109 Pembroke Road,
Clifton, Bristol BS8 3EU
T: +44 (0)117 9064280

CAMBRIDGE
8 Stow Court, Stow-cum-Quy,
Cambridge CB25 9AS
T: + 44 (0)1223 813805

CARDIFF
Fulmar House, Beignon Close, Ocean
Way, Cardiff CF24 5HF
T: +44 (0)29 20491010

CHELMSFORD
Unit 77, Waterhouse Business Centre,
2 Cromar Way, Chelmsford, Essex
CM1 2QE
T: +44 (0)1245 392170

DUBLIN
7 Dundrum Business Park, Windy
Arbour, Dundrum, Dublin 14 Ireland
T: + 353 (0)1 2964667

EDINBURGH
No. 4 The Roundal, Roddinglaw
Business Park, Gogar, Edinburgh
EH12 9DB
T: +44 (0)131 3356830

EXETER
69 Polsloe Road, Exeter EX1 2NF
T: + 44 (0)1392 490152

FARNBOROUGH
The Pavilion, 2 Sherborne Road, South
Farnborough, Hampshire GU14 6JT
T: +44 (0)1252 515682

GLASGOW
4 Woodside Place, Charing Cross,
Glasgow G3 7QF
T: +44 (0)141 3535037

HUDDERSFIELD
Westleigh House, Wakefield Road,
Denby Dale, Huddersfield HD8 8QJ
T: +44 (0)1484 860521

LEEDS
Suite 1, Jason House, Kerry Hill,
Horsforth, Leeds LS18 4JR
T: +44 (0)113 2580650

MAIDSTONE
19 Hollingworth Court, Turkey Mill,
Maidstone, Kent ME14 5PP
T: +44 (0)1622 609242

NEWCASTLE UPON TYNE
Sailors Bethel, Horatio Street,
Newcastle-upon-Tyne NE1 2PE
T: +44 (0)191 2611966

NOTTINGHAM
Aspect House, Aspect Business Park,
Bennerley Road, Nottingham NG6 8WR
T: +44 (0)115 9647280

ST. ALBAN'S
White House Farm Barns, Gaddesden
Row, Hertfordshire HP2 6HG
T: +44 (0)1582 840471

SHEFFIELD
STEP Business Centre, Wortley Road,
Deepcar, Sheffield S36 2UH
T: +44 (0)114 2903628

SHREWSBURY
Mytton Mill, Forton Heath, Montford
Bridge, Shrewsbury SY4 1HA
T: +44 (0)1743 850170

STAFFORD
8 Parker Court, Staffordshire Technology
Park, Beaconside, Stafford ST18 0WP
T: +44 (0)1785 253331

WARRINGTON
Suite 9 Beech House, Padgate Business
Park, Green Lane, Warrington WA1 4JN
T: +44 (0)1925 827218

WORCESTER
Suite 5, Brindley Court, Gresley Road,
Shire Business Park, Worcester
WR4 9FD
T: +44 (0)1905 751310