Risk Assessment of the Water Environment

for

Balfour Beatty

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EXECUTIVE SUMMARY

SCOPE

Purpose of the report	Following comments by SEPA and the CLO, Ramboll UK Ltd (RUK) was instructed by Balfour Beatty to undertake additional groundwater monitoring and provide further interpretation, generic quantitative risk assessment (GQRA) and, if required a detailed quantitative risk assessment (DQRA) of the potential risks to the Water Environment at the proposed St. Ambrose School site in Coatbridge. The proposed development will comprise the construction of St. Ambrose High School including a two-storey school building with associated school pitches, car parking, play areas and soft landscaping.

SITE INFORMATION

Grid Reference	271546, 665970	***Site Area (approx.)***	13.5ha

Current Site Description	Currently the site is occupied by numerous sports pitches to the south of Townhead Road and is in use by the general public as a recreational area. An area of car parking and an access road is present in the northeast of the site.
History	Until the 1980s, the site was used as rough pasture in a mining area with a railway crossing the north of the site and the eastern site boundary and coal pits to the northeast and southeast of the site. During the 1980s, the railway in the north was dismantled and a mineral railway was constructed across the southern area of the site. The site was then used as a landfill from 1945-1972. By the 1990s the site was in use as playing fields following re-profiling and has remained so up to the present day. No further details are available regarding the capping of the former landfill and development of the existing playing fields.

SITE INVESTIGATION

Previous SI	Preliminary and main intrusive investigations were undertaken by URS in 2006 and 2008 respectively. Subsequently, supplementary works were undertaken by Geotechnics and Ramboll UK in 2009 as detailed in the activities below.
Activities	2No. rounds of groundwater monitoring and geochemical analysis was undertaken in order to get a better understanding of the hydrogeological regime beneath the site. Groundwater samples were also submitted for laboratory analysis.
Laboratory Analysis	36No. groundwater samples (including 2No. duplicates) were analysed for a typical chemical suite including: pH, selected metals and inorganics, extractable petroleum hydrocarbons (EPH), polycyclic aromatic hydrocarbons (PAHs), phenols, ammonia, cyanide, sulphate and hardness. Specific samples were also scheduled for dissolved oxygen, speciated hydrocarbons, volatile organic compounds and semi-volatile organic compounds.

GROUND CONDITIONS

Geology	Made Ground was encountered across the site comprising topsoil, reworked topsoil material and probable landfill material. The Made Ground ranges in thickness between 0.30m and 8.45m. The greatest depths of Made Ground were typically reported in the north-central area of the site. Superficial deposits of peat and glacial deposits of clay, sand and silt were encountered underlying Made Ground strata. The solid geology of the Middle Coal Measures, described as interbedded sandstone, mudstone and coal was encountered at depths of between 7.40-23.20m below ground level (bgl) and was recovered as highly weathered sandstone and mudstone.
Hydrogeology	Shallow groundwater was reported perched above the peat across the site at depths ranging from 1.90-4.70mbgl. The hydraulic gradient of the shallow groundwater is towards the southwest. This shallow groundwater is not considered to be a groundwater body in accordance with SEPA guidance (as detailed in Section 3.2) and is therefore not considered to be a significant receptor. Groundwater within the bedrock aquifer was typically recorded at the superficial to solid interface at depths ranging from 12.80 to 23.20mbgl. The underlying bedrock aquifer is classified as moderately permeable with intergranular fracture flow (SEPA), has future resource potential and is therefore considered to potentially be a significant receptor. Given the flow of the shallow groundwater, the topography of the surrounding area and the groundwater levels recorded in the deeper aquifer in the 3No. deep wells available, it is considered likely that groundwater flow direction within the deep aquifer will also be south to southwest.

Hydrology	There are various drains referenced on the site plan located southwest of the site with Drumpellier Country Park, the nearest being approximately 10m from the southwest site boundary. On investigation, these are surface ditches, and it is apparent that these ditches have not been full of water for some time as they are extremely shallow, full of debris and well-established vegetation. There is no evidence of them draining to other surface water features in the immediately vicinity. The Monkland Canal runs east to west and is located approximately 100m south of the site. Although in the direction of groundwater flow, the canal is clay-lined and therefore it is not considered to be in hydraulic continuity with the shallow groundwater. Lochend Loch and Woodend Loch are located approximately 450m west and 650m northwest of the site boundary respectively. Given that the direction of groundwater flow is towards the south-southwest and therefore the lochs are located up-gradient of the site, and the significant distance between the site and the lochs, it is considered the lochs are not potential receptors.
GROUNDWATER RISK ASSESSMENT (for significant pollution)	
Metals	Elevated concentrations of zinc were recorded in leachate and shallow groundwater samples but were not recorded in the deeper groundwater samples. Further assessment of the deep groundwater pollutant linkage indicates there is a VERY LOW risk to the bedrock aquifer.
Phenols	Elevated concentrations of phenols were leached from soil samples taken from isolated areas of site. Elevated phenol was also recorded in one isolated area of shallow groundwater. However, the concentration of phenols in the groundwater sampled from the same location was reported below the laboratory limit of detection on the subsequent monitoring rounds. Also the phenol concentration was reported below the detection limit in all groundwater samples in all areas where elevated phenol concentrations were reported in leachate. Therefore, it is considered that the risks to the bedrock aquifer are **LOW.**
PAHs	Elevated concentrations of PAHs (including benzo(a)pyrene, fluoranthene and sum of 4No. PAHs) are reported in leachate and shallow groundwater samples taken from across the site but are <u>not</u> reported in deeper groundwater samples. The superficial deposits are considered likely to limit the vertical migration of these contaminants. The assessment concludes that the PAHs within the shallow groundwater are not migrating vertically through the subsurface strata in sufficient concentrations to present a significant risk to the deeper aquifer and risks to the Water Environment is therefore considered to be **LOW**.
Ammonia & Manganese	Elevated concentrations of ammonia and manganese are reported across the site within the shallow groundwater, which are considered to be a result of the reduction of nitrate within the landfill material, industrial activities in the surrounding area and the peat, which is considered likely to be creating a naturally reducing environment on site causing liberation of manganese and ammonia into solution. Elevated concentrations of ammonia and manganese are also reported within the deeper aquifer and are considered to be a result of general hydrogeological conditions in the surrounding area and former mining activities. Risks to the underlying aquifer from ammonia and manganese concentrations recorded in the deep groundwater on site are considered **MODERATE.** However, the risk is attributable to natural processes and former mining activities occurring on site and in the surrounding area as detailed. Therefore the risks to the underlying aquifer from site derived ammonia and manganese is considered to be **LOW** when the general quality of the deep groundwater in the vicinity of the site is also considered.
GROUNDWATER RISK ASSESSMENT (for a new, point source input to groundwater)	
Drainage Scheme	It is intended that all areas of hardstanding will drain into surface water drains which are then discharged into soakaway tanks in the southern area of site. The car parking in the central area of site will be covered by porous paving, discharging into a tanked system beneath the car park. Within the build up of the pitches, a herring-bone drainage system will be included, overlying a membrane. Water collected within this herring bone system will drain into land drains at the end of each pitch and be discharged to the soakaways located in the southern area of site.
List I Substances	List I substances must be prevented from entering groundwater in any new input (SEPA, 2010). Elevated anthracene and fluoranthene were reported as elevated in leachate and shallow groundwater. However, concentrations were most significantly elevated in the central area of site where the more significant depths of landfill material are present. The proposed soakaways have therefore been located away from the more significant depths of landfill material in the southern and south-eastern areas of site.

	Considering up-gradient concentrations of these contaminants are elevated and concentrations within shallow groundwater in the areas of the proposed soakaways are below the MRVs it is considered that additional entry of List I substances to groundwater will not be caused by the soakaways. In addition, it should be noted that the deep bedrock aquifer (identified as the only groundwater body receptor) reported concentrations of anthracene, fluoranthene and all PAHs below detection.
List II Substances	Elevated phenols, ammonia and manganese were reported in shallow groundwater across the site. Limited migration of phenols is considered likely to occur given only 1No. elevated concentration was reported within shallow groundwater on 1No. occasion and no concentrations above detection limit were reported within the bedrock aquifer. Elevated ammonia and manganese within shallow groundwater and the bedrock aquifer are considered attributable to area wide issues and natural processes rather than from on site sources, further indicated by the isolated and marginal ammonia exceedences reported in leachate.
Conclusions	No additional entry of List I or List II substances is considered likely to occur as a result of the proposed soakaway. In addition, the proposed drainage solution will provide betterment across the site by preventing unmanaged infiltration and therefore reducing the subsequent leaching and migration of contaminants across the site.

RECOMMENDATIONS

Further Assessment	Undertake additional leachate analysis in the areas proposed for soakaways during enabling works in order to confirm that locating the soakaways in the southern area of the site will not allow the entry of significant concentrations of hazardous and non-hazardous substances to groundwater. Ensure a part-time watching brief is present on site during enabling works.
Additional Considerations	Any piled solution to foundation design should be developed in such a way so that the installation of the piles themselves does not create preferential flow pathways by which potential contamination could mobilise in the unsaturated zone. Contractors should ensure compliance with SEPA guidelines on piling in contaminated land *(Piling and penetrative ground improvement methods on land affected by contamination: Guidance on pollution prevention.* EA, 2001*)*. Mine stabilisation works are proposed on site. This will prevent preferential pathways in the area of the mine shafts for vertical migration of groundwater. However, there is a potential risk to the Water Environment from introduction of grout and there is potential for groundwater displacement. These risks have been considered by the geo-environmental consultant undertaking the mine stabilisation works (Mason Evans) in accordance with BRE Code of Practice, 2009. The Environmental Specification Report (Ramboll, 2010_3) should be adhered to during enabling works. Validation sampling will be required from on site materials used in the cut and fill operations on site during enabling works in order to demonstrate that all materials used are suitable for use. These results, along with documented evidence to illustrate that the remedial measures detailed above and within the Environmental Specification have been adhered to (e.g. daily diary/record from site engineer), will need to be collated and documented in a Validation Report.

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APPENDICES

1 INTRODUCTION

1.1 Brief

Ramboll UK Ltd (RUK) was instructed by Balfour Beatty to undertake additional groundwater monitoring and provide further interpretation, generic quantitative risk assessment (GQRA) and, if required a detailed quantitative risk assessment (DQRA) of the potential risks to the Water Environment at the proposed St. Ambrose School site in Coatbridge.

This report provides a factual summary of the additional monitoring and an assessment of risks to the Water Environment based on all available data.

The proposed development will comprise the construction of St. Ambrose High School including a two-storey school building with associated school pitches, car parking, play areas and soft landscaping. The current proposed development plan is provided as Drawing NLC-STA-DRG-A-L(0)0001, Appendix A.

1.2 Background

Ramboll UK understand 1No. desk study (Phase I) and 3No. intrusive site investigations (Phase II) have been undertaken within the site boundary since 2005; available reports and investigations for the site are outlined below:

- *St. Ambrose High Desk Study (URS, 2005);*
- *Preliminary Ground Investigation Report, St. Ambrose High School, Coatbridge (URS, 2006);*
- *Proposed St. Ambrose High School, Ground Investigation Report (URS, 2008);*
- *Proposed St. Ambrose High School, Additional Gas Monitoring (URS, 2009); and*
- *Ground Investigation at St. Ambrose High School, Coatbridge (Factual Report) (Geotechnics, 2009).*

An assessment of available data from the previous investigation was undertaken by Ramboll in 2010 and is detailed in the following reports:

- *Ground Contamination Risk Assessment Report, St Ambrose v.1B (Ramboll, 2010); and*
- *Ground Contamination Detailed Quantitative Risk Assessment (Human Health), St Ambrose v.1B (Ramboll, 2010).*

These reports were reviewed by the Contaminated Land Officer (CLO) at North Lanarkshire Council and SEPA representative. Although risks with regards to human health have been signed off following the human health DQRA, SEPA had residual concerns regarding the potential risks to the Water Environment. Consultation regarding these issues is provided in Appendix B.

1.3 Objectives

The objectives of the additional groundwater monitoring and this risk assessment report are to fully address the potential risks to the water environment (including detailed modelling, if considered necessary) for the proposed development using all available data. This report will also fully address comments raised by SEPA (as

detailed in the Meeting Minutes, 23rd March 2010) with regards to the previous Ground Contamination Risk Assessment Report (Ramboll, 2010).

In order to achieve these objectives the following scope of works were undertaken:

- Additional groundwater monitoring comprising:
  - 2 No. additional rounds of groundwater monitoring in all accessible wells across the site;
  - Take geochemical readings from groundwater across the site;
  - Collect groundwater samples from the shallow and deep aquifer from all accessible wells across the site; and
  - Chemical laboratory analysis for identified potential contaminants of concern.
- Factual and interpretative reporting comprising:
  - Factual description of the additional groundwater monitoring works undertaken;
  - Develop a revised site conceptual model to identify potentially significant source-pathway-receptor pollutant linkages in relation to the Water Environment;
  - Generic quantitative risk assessment using both new and existing leachate and groundwater data to characterise potential risks to the Water Environment associated with the proposed development;
  - Undertake detailed risk assessment modelling for those contaminants identified as a potentially significant risk if required;
  - Provide summary of contaminant impacts requiring remedial action;
  - Provide remedial strategy to address residual impacts in the context of the development proposed.

All ground contamination assessment work has been completed in accordance with the current UK legislative framework, further details of which are provided in Appendix C.

1.4 Constraints and Limitations

This report has been prepared for the exclusive use of the Balfour Beatty for the purpose of assisting site evaluation in the context of the proposed redevelopment at the time of writing. This report should not be used in whole or in part by any third parties without the express permission of Ramboll UK Ltd. in writing.

The proposed environmental risk management strategies and recommendations summarised in this report relate to details of the proposed development at the time of writing the report. Any substantial changes to the proposed design may require a reassessment of the implications of the environmental risks identified.

Ramboll has endeavoured to assess all information provided to them during this assessment. This report summarises information provided from a number of external sources and cannot offer any guarantees or warranties for the completeness or accuracy of information relied upon.

2 SITE SETTING

The site of the proposed St. Ambrose High School is located in Coatbridge, Lanarkshire. A site location plan is presented as Figure 2.1 in Appendix A.

2.1 Site Description

The site is located off Townhead Road and is bordered by Townhead Road to the north, a community centre, pavilion and residential properties to the east, Drumpellier Park to the south and a Golf Course to the west.

The site is located at the approximate National Grid Reference (NGR) 271546, 665970 and occupies an area of approximately 13.5Ha. Currently the site is occupied by numerous sports pitches and is in use by the general public as a recreational area. An area of car parking and an access road is present in the northeast of the site. A current site layout plan indicating current topographic levels is included in Appendix A as Drawing 7764/E/001. Proposed areas of cut and fill at the time of writing are shown on Drawing No. NLC-STA-DRG-C-316 in Appendix A.

2.2 Site History

This summary of the site history has been compiled using the available Ground Investigation Reports (URS, 2006; 2008; 2009). According to this information, the site remained in use as rough pasture in a mining area with a railway crossing the north of the site and the eastern site boundary and coal pits to the northeast and southeast of the site until the 1890s when the railway in the north was dismantled and a mineral railway was constructed across the southern area of the site.

By 1912 a reservoir was present to the southeast of the site boundary and 2No. tanks were located northeast of the site. Residential developments were constructed to the north of the site by the 1930s and the railway was dismantled.

The site was then used as a landfill from 1945-1972. Information obtained from North Lanarkshire Council indicate that Townhead Landfill received an estimated half million tonnes of domestic refuge from Coatbridge and 77,000 gallons of wet sewage and unspecified residue from Gartsherrie Steel Works were disposed of annually for an unknown period of time. By the 1990s the site was in use as playing fields following remodelling and has remained so up to the present day. No further details are available regarding the capping of the landfill and development of the playing fields.

2.3 Geology

Based on the information obtained from previous site investigations (URS, 2006; 2008, Geotechnics, 2009); the geology underlying the site is understood to comprise Made Ground including topsoil overlying probable landfill material up to a maximum depth of 8.45mbgl. No significant capping layer is present above the probable landfill material. Underlying the Made Ground are superficial deposits of peat, glaciolacustrine clay, silt and sand and glacial till to a maximum depth of 23.2mbgl. These superficial deposits overlie the solid geology of the Middle Coal Measures, reported at depths between 7.40mbgl and 23.20mbgl and comprise sandstone and mudstone with occasional bands of coal.

Cross sections of the geology underlying the site are provided as Drawing 7764/E/002-004 in Appendix A. These demonstrate that beneath the Made Ground across the entire site is a minimum depth of 2.7m peat and clay/silt between the Made Ground and underlying solid geology.

The site is underlain by several coal seams, some of which have been historically mined by shallow workings. In addition, mine shafts have been identified in and around the site. Potential geotechnical risks from mining instabilities are not assessed as part of this report.

2.4 The Water Environment

2.4.1 Hydrogeology

Shallow Groundwater

The previous investigations (URS, 2006; 2008, Geotechnics, 2009) reported perched shallow groundwater across the site within the Made Ground and superficial deposits, although typically, this shallow groundwater was reported perched above the peat at depths ranging from 1.90 to 4.70mbgl. A table of groundwater levels within the shallow groundwater across the site is provided in Appendix D.

Bedrock Aquifer

The solid geology underlying the site is classified as IFM, moderately permeable with intergranular fracture flow according to the Scottish Environmental Protection Agency (SEPA). The site is not within a source protection zone, however all groundwater bodies in Scotland are designated a drinking water protected area.

During the URS investigations in 2006, 2008 and the Geotechnics investigation in 2009, groundwater was typically recorded at the superficial to solid interface at depths ranging from 12.80 to 23.20mbgl. It is understood that this is the underlying aquifer. The groundwater within the aquifer is under sub-artesian conditions, with the potentiometric surface resting within deeper superficial deposits (peat and clay) or the shallow bedrock at depths of around 72mAOD, approximately 8-10mbgl. A table of groundwater levels within the deeper groundwater across the site is provided in Appendix D.

Groundwater Flow

The hydraulic gradient of the shallow groundwater is towards the southwest and this is demonstrated in the groundwater contour plots on Drawing 7764/E/005, Appendix A. Given the flow of the shallow groundwater, the topography of the surrounding area and the groundwater levels recorded in the deeper aquifer in the 3No. deep wells available, it is considered likely that groundwater flow direction within the deep aquifer will also be south to southwest.

2.4.2 Hydrology

There are various drains labelled on the site plan located southwest of the site with Drumpellier Country Park, the nearest being approximately 10m from the southwest site boundary. On investigation, these are surface ditches, and it is apparently these have not been full of water for some time as they are extremely shallow, full of debris and well established vegetation. Photographs are included in Appendix A as Figure 2.2. There is no evidence of them draining to other surface water feature.

The Monkland Canal runs east to west and lies approximately 100m south of the site and Lochend Loch and Woodend Loch lie approximately 450m west and 650m northwest of the site boundary respectively.

3 REVISED CONCEPTUAL SITE MODEL

Based on the additional information on hydrogeology, hydrology and geology across the site, as detailed in Section 2, a revised conceptual model for risks to the Water Environment in the context of the site is presented below. This conceptual site model considers potential sources of contamination which may present significant risk to the Water Environment as established in the Ground Contamination Risk Assessment report (v. 1B, Ramboll 2010[1]). The Conceptual Site Model is illustrated in Drawing 7764/E/011.

Risks to Human Health have not been considered in this conceptual site model as they are addressed in the strategy proposed within the Ground Contamination Risk Assessment Report (v. 1B, Ramboll 2010[1]). No further consideration will be given to Human Health risk within this report.

3.1 Sources

The potential sources of contamination which may present a risk to the Water Environment are considered to be:

- Marginally elevated concentrations of copper, zinc and anthracene within leachate from across the site, which is impacting the shallow groundwater;
- Elevated concentrations of ammoniacal nitrogen within the shallow groundwater;
- Isolated elevated concentrations of ammonia within leachate;
- Fluoranthene and PAHs (sum of 4No.) are leaching at elevated concentrations most significantly from the probable landfill material across the site;
- Elevated manganese within the shallow groundwater across the site;
- Elevated phenol concentrations within leachate samples from isolated areas of landfill material and natural strata; and
- Localised elevated concentrations of aliphatic and aromatic C21-35 are reported in shallow groundwater.

3.2 Receptors

Potential water receptors are identified below.

Groundwater

Shallow Groundwater

Shallow groundwater is reported across the site, typically perched above the peat. The saturated Made Ground and/or superficial deposits are considered to be of a significant lateral extent across the site and hence the shallow groundwater may represent a groundwater body, i.e. significant water receptor, in accordance with SEPA and UKTAG criteria. This is assessed further below.

A Tier 2 assessment of the vertical extent of saturated aquifer has been undertaken in accordance with SEPA (WAT-PS-10-01, 2010). The saturated thickness of the shallow groundwater is typically around 1.0m and is typically contained within Made Ground and peat deposits.

Peat falls under the subsurface materials not included within the designated boundaries of groundwater bodies, as detailed in Annex 2 of WAT-PS-10-01, SEPA 2010. This therefore indicates that the peat material will not meet UKTAG criteria and be capable of future resource potential.

In addition, the majority of saturated Made Ground deposits are described as cohesive and therefore will not to fulfil the UK TAG criteria for a groundwater body.

Also, where there are some limited saturated granular deposits of Made Ground reported on site with fines less than 8% (PSD tests, URS 2008 Appendix E) these deposits are described as gravel and sand of ash and are not considered to fulfil the UK TAG criteria for a groundwater body.

There are also some very limited natural granular deposits on site in BH203, 9.55-11.90mbgl; BH312, 6.7-9.0mbgl, BH401, 10.0-14.1mbgl and BH405, 5.2-9.6mbgl. Particle Size Distribution tests have been undertaken on samples from each of these stratums and have reported fines (clay and silt) of 78%, 1.6%, 26% and 28% respectively.

Only the granular material in BH312 is considered to be capable of fulfilling UK TAG criteria and may represent an isolated shallow groundwater body. However, given that groundwater was reported at 10.0mbgl in this borehole (beneath the granular strata) the granular material in this location is not saturated and is therefore not considered to be capable of providing more than $10m^3$/day. The geological cross sections across the extent of the site given on Drawings 7764/E/002-004, Appendix A illustrate the limited granular deposits encountered across the site.

The shallow groundwater is therefore not considered to be a significant receptor but may act as a pathway to the underlying deeper aquifer within the solid deposits.

Bedrock Aquifer

The underlying bedrock aquifer is classified as moderately permeable with intergranular fracture flow (SEPA). Although no groundwater abstractions from this aquifer are reported within the immediate surrounding area of the site, all groundwater bodies in Scotland are designated a drinking water protected area. Therefore the aquifer is considered to have future resource potential and is considered to be a significant water receptor.

Surface Water

The nearest surface water features are various drains labelled on the site plan located southwest of the site with Drumpellier Country Park, the nearest being approximately 10m from the southwest site boundary. These are not considered to be in hydraulic continuity with the underlying shallow groundwater or any other surface water features and are not considered to be used significantly for surface water run-off (Figure 2.2, Appendix A). In addition, the drainage design proposed for the development will manage all surface water drainage on site, preventing any excess run-off which may have historically entered these drains. Therefore, these drains are not considered to be a significant surface water receptor.

Lochend and Woodend Loch are located approximately 450m west and 650m northwest of the site boundary respectively. Given the direction of groundwater flow towards the south-southwest (Drawing 7764/E/005) the lochs to the northwest and west of the site are not considered to be potential receptors.

The Monkland Canal is located approximately 100m south of the site, down hydraulic gradient. British Waterways Scotland was consulted regarding the construction of canal and they confirmed that this is a lined canal which is culverted to the southeast and southwest of the site. The canal is therefore not considered to be in hydraulic continuity with the shallow groundwater as the clay lining of the canal will create a barrier against lateral migration of any groundwater. The canal is also not considered likely to be affected by any surface water run-off as it is separated from the site by the raised embankments surrounding the railway, which runs parallel to the canal in this area. The canal is therefore not considered to be a significant surface water receptor.

In conclusion, the only significant Water Environment receptor is considered to be the underlying deeper bedrock aquifer.

3.3 Pathways

In order for the contaminants identified to pose a risk to potential receptors, there must be a viable pathway by which the contaminant can reach the receptor. Potential pathways are discussed below in relation to the identified impacts and receptors with regards to the Water Environment. Active pathways are dependent on the physical characteristics of the site and surrounding area between the source and receptor.

Leaching of contaminants into the saturated zone

The nature of the site surface affects the potential for surface water infiltration to penetrate into the subsurface. This in turn will affect the potential for leachate generation from impacted vadose (unsaturated) zone soils. Currently the site is completely open ground and surface water is freely leaching through the surface soils. However, there will be an overall increase in hardstanding across the site and the proposed sports pitches will include a low permeability membrane and surface water drainage system (as discussed in Section 7), which will limit rainfall infiltration and the leaching potential of soils. This will therefore limit the potential for surface water infiltration across the area of the site.

Vertical migration of contaminants from the shallow groundwater

Although the shallow groundwater on site is not considered a receptor, it has the potential to act as a pathway for the vertical migration of contaminants to the underlying aquifer in the bedrock below. The superficial strata consist of psuedofibrous to fibrous, occasionally clayey peat, sandy gravelly clay and sandy gravelly silt. The more permeable material within these strata may provide preferential pathways for the vertical migration of contamination identified within leachate and shallow groundwater into the underlying aquifer. However, given the predominant soil type within the glaciomarine deposits is cohesive silt/clay, this is considered likely to restrict the vertical migration of contaminants. The peat is considered likely to attenuate contaminants within groundwater infiltrating through the subsurface.

In exploratory holes from across the site, the minimum depth of cohesive deposits (including peat and/or clay) separating the Made Ground from the solid geology, is 2.70m reported in BH311 respectively (URS, 2008) as illustrated on Drawing 7764/E/002-004. Typically the depth of cohesive deposits ranges between 5-10m.

However, in rotary borehole logs including BH110 (URS, 2008), R03 and R04 (2006), between 0-0.4m of natural cohesive strata was reported between the Made Ground and solid geology.

Made Ground in R03 and R04 (URS, 2006) is described in drillers logs as "*Made Ground (ash, peat and clay)*" which is considered likely to be a Driller's combined description of the Made Ground and underlying superficial deposits during rotary open-hole drilling. In BH110 (URS, 2008) Made Ground is described as "peat and ash". In all 10No. rotary boreholes undertaken as part of the mining investigation by URS in 2008, no defined peat strata are reported in the borehole logs. Instead, peat is included within the description of Made Ground strata. From the extensive investigations on site, it has been proven that a peat layer underlies the Made Ground in the majority of the site. It is therefore considered likely that this Driller's description of Made Ground includes a combined description of the true Made Ground material and underlying peat deposits as a result of the highly disturbed nature of rotary arisings and the smearing effect through the core barrel during the rotary open-hole drilling process.

To provide further evidence for this hypothesis, additional boreholes in close proximity to BH110, R03 and R04 have been reviewed. BH308 (33m east of R03) reports 3.8m Made Ground, separated from the solid geology reported at 14.70mbgl by 3.80m peat and 7.10m clay. BH206 (25m southeast of R04) reports 4.55m Made Ground underlain by 2.30m peat and 4.35m clay and solid geology was not reported at the end of the borehole at 11.20mbgl. BH110 lies 36m east of BH310 and 42m west of BH313. These two boreholes report thicknesses of cohesive natural strata between 3.10m and 7.65m including peat and clay deposits.

In areas towards the south and south east of the site, the peat peters out, but in these areas it is replaced by clay/silt deposits, as illustrated on Drawing 7764/E/002-004. Therefore there is always a minimum thickness of 2.70m of cohesive clay/silt deposits and/or peat between Made Ground and the underlying bedrock aquifer.

Therefore it is considered likely that the cohesive clay/silt deposits across the site are present at a sufficient thickness to mitigate the vertical migration of potential contaminants and/or the peat is present in sufficient thickness to attenuate contaminants. However, sampling of the underlying deeper aquifer will be undertaken to confirm this.

There are however, 2No. areas adjacent to the northern and eastern site boundaries where potential mine shafts are present (2No. shafts in each area) as shown on the Mason Evans Drawing G2008/473/C/F/04, Appendix A. In these areas the thickness of cohesive natural strata may have been reduced by mining activities and therefore preferential pathways for the vertical migration of contaminants may be present. However, as part of the proposed development, the mine shafts will be grouted up, which will prevent this pathway occurring in the future (further details provided in Section 8).

In addition, should piling methods extend into the underlying bedrock, preferential pathways for the vertical migration of potential contamination may be initiated. Further recommendations regarding protection measures to prevent this potential pathway are made in Section 8.

3.4 Potentially Significant Pollutant Linkages

The revised site conceptual model has identified the following potentially significant pollutant linkages which may present a significant risk to the Water Environment:

- Elevated concentrations of copper, zinc, anthracene and ammonia are reported at elevated concentrations in leachate and shallow Made Ground which may continue to leach into the shallow groundwater and vertically migrate into the underlying bedrock aquifer;

- Elevated concentrations of fluoranthene and PAHs (sum of 4No.) are reported as elevated in leachate from Made Ground. Leaching of these contaminants may continue and impact the underlying shallow groundwater and migrate vertically into the underlying aquifer;

- Elevated manganese concentrations in shallow groundwater have the potential to migrate into the underlying aquifer; and

- Elevated phenols and heavy-end fractions of petroleum hydrocarbons are recorded at elevated concentrations in leachate in isolated areas of site. Leaching of these contaminants may continue and impact the underlying shallow groundwater and migrate vertically into the underlying aquifer below.

Additional groundwater monitoring has been undertaken in order to further assess the pollutant linkages detailed above.

4 GROUNDWATER MONITORING

4.1 Design

The additional groundwater monitoring was designed to supplement existing groundwater data and provide a full assessment of the nature and extent of any potential risks to the Water Environment on site, addressing the concerns raised by SEPA (2010). The works were undertaken and supervised by Ramboll UK and monitoring was undertaken in accordance with BS 10175.

The objectives of the supplementary groundwater monitoring were as follows:

- Monitor groundwater levels in all accessible wells across the site in order to better understand the hydrogeological regime beneath the site and undertake a geochemical analysis of groundwater; and
- Collect groundwater samples from the shallow and deep aquifer from all accessible wells across the site and submit for chemical laboratory analysis.

4.2 Site Investigation Activities

The supplementary monitoring works were carried out on the 4th – 6th August and 17th – 18th August 2010 by Ramboll. The investigation comprised the following scope of works:

- Monitoring of groundwater levels from 20No. existing wells across the site on 2No. visits;
- 14No. groundwater samples were obtained from the shallow aquifer and 3No. groundwater samples were obtained from the deep aquifer across the site during each monitoring visit. A duplicate sample was taken during each visit; and
- Groundwater samples were subjected to on-site geochemical analysis and sent to the laboratory for chemical analysis.

The locations of all exploratory holes are shown on Drawing 7764/E/010 in Appendix A. Exploratory hole logs are presented in Appendix F, and laboratory chemical analysis results are presented in Appendix G.

4.3 Limitations

Various limitations were experienced whilst undertaking the site investigation. These included the following:

- 5No. boreholes were installed into the deeper aquifer during the 2009 investigation by Geotechnics. However, 2No. of these wells were blocked at shallow depths therefore samples could only be obtained from 3No. deep wells;
- Many of the boreholes from the 2008 investigation could not be located on site due to overgrowth in the three years following installation. 12No. wells were located out of the 25No. installed in 2008. However, these are considered to represent a good spread of shallow groundwater data across the site;
- The rubber bung has been pushed down the well in BH308. Although there was sufficient space for the groundwater sampling tubing, the dipmeter could not fit down the well, therefore accurate depths to water could not be measured. An approximate depth to groundwater and depth of well was

calculated using the groundwater tubing.

It should be noted that although every effort has been made to ensure the accuracy of the data obtained from the investigation, the possibility exists for variations in ground and groundwater conditions between and around exploratory hole locations. In addition, groundwater levels are likely to vary seasonally and with changes in weather conditions.

4.4 Laboratory Chemical Analysis

A total of 36No. groundwater samples (18No. per monitoring visit) were despatched to the Exova Chemical Laboratory in Clydebank. Exova is a UKAS and MCERTS accredited laboratory.

36No. groundwater samples (plus 2No. duplicate) were scheduled by Ramboll UK for chemical analysis, including the following suite of determinands based on historical site use, the findings of previous site investigations, guidance given in the DoE Industry Profiles and Science Reports (EA/SEPA), and on professional experience:

- Speciated Polycyclic Aromatic Hydrocarbons (PAH) (US EPA priority PAHs);
- Total Petroleum Hydrocarbons (TPH);
- Metals (arsenic, cadmium, chromium, chromium VI, copper, nickel, lead, zinc, mercury, boron, selenium and manganese);
- Sulphide and Sulphate;
- Cyanide;
- Ammonia;
- Hardness; and
- pH.

In addition, 10No. groundwater samples were scheduled for analysis of speciated Total Petroleum Hydrocarbon (TPH) analysis, 5No. samples were scheduled for dissolved oxygen concentrations and 7No. samples were scheduled for Volatile Organic Compound (VOC) and Semi Volatile Organic Compound (SVOC) analysis.

Laboratory chemical analytical results are presented in Appendix G.

4.4.1 Quality Assurance/Quality Control analysis

Duplicate water sampling results are illustrated in Table 4-1:

Table 4-1: Comparison of Duplicate Water Sample Analyses

Determinand	BH303 (ug/l)	DUPL A (ug/l)	BH406 (ug/l)	DUPL B (ug/l)
Arsenic	<1	<1	<0.25	<0.25
Cadmium	<0.5	<0.5	<0.05	<0.05
Chromium	<0.1	<0.1	0.12	0.13
Chromium (Hexavalent)	<100	<100	<10	<10
Copper	<0.1	<0.1	<0.05	<0.05
Lead	<1	<1	<0.05	<0.05
Manganese	7031	7047	260	279
Mercury	<0.10	<0.10	<0.10	<0.10
Nickel	7	8	7	7
Selenium	<1	<1	<1	<1

Determinand	BH303 (ug/l)	DUPL A (ug/l)	BH406 (ug/l)	DUPL B (ug/l)
Zinc	6	11	74	73
Boron	300	300	445	460
Sulphate (Total)	71000	73000	<100	2000
Sulphide	<200	<200	<200	<200
pH	6.6	6.7	7	7
Ammonia	2900	2900	2200	2600
TPH	<10	19	<10	<10
Acenaphthene	<0.01	<0.01	<0.02	<0.02
Acenaphthylene	<0.01	<0.01	<0.02	<0.02
Anthracene	<0.01	<0.01	<0.02	<0.02
Benzo(a)anthracene	<0.01	<0.01	<0.02	<0.02
Benzo(a)pyrene	<0.01	<0.01	<0.02	<0.02
Benzo(b)fluoranthene	<0.01	<0.01	<0.02	<0.02
Benzo(k)fluoranthene	<0.01	<0.01	<0.02	<0.02
Benzo(g,h,i)perylene	<0.01	<0.01	<0.02	<0.02
Chrysene	<0.01	<0.01	<0.02	<0.02
Dibenzo(a,h)anthracene	<0.01	<0.01	<0.02	<0.02
Fluoranthene	0.02	<0.01	<0.02	<0.02
Fluorene	<0.01	<0.01	<0.02	<0.02
Indeno(1,2,3-c,d)pyrene	<0.01	<0.01	<0.02	<0.02
Naphthalene	<0.01	<0.01	<0.02	<0.02
Phenanthrene	<0.01	<0.01	<0.02	<0.02
Pyrene	0.03	0.02	<0.02	<0.02

Duplicate sample analysis is used to provide an indication of the precision of the analytical results, *i.e.*, the repeatability of the laboratory analytical process. The results of the duplicate analyses are compared with the original sample data. If the results of the sample and duplicate analyses are similar (*i.e.*, within ±30%), it is generally considered that an acceptable standard of repeatability has been maintained in the sampling and analytical process, and that the results can therefore be described as being precise. The majority of results are within ±30% and are therefore considered precise.

5 GENERIC QUANTITATIVE RISK ASSESSMENT

Following additional monitoring and a review of the CSM, a full assessment of the potential risks to the Water Environment has been undertaken. This assessment takes into account a reassessment of all data including historical leachate and water data from 2008 and 2009 and the recent 2010 groundwater data.

This generic quantitative risk assessment has been undertaken in accordance with the current UK framework and comprises a generic quantitative risk assessment of the Water Environment as detailed in "Assessing Groundwater Assessment Criteria for Pollutant Inputs" WAT-PS-10-01, SEPA 2010. Further details of the legislative framework and UK guidance used within this assessment are provided in Appendix C. The site has been assessed for significant pollution (in accordance with SEPA recommendations) as the source is land contamination from a historic activity (historical landfill).

5.1 Methodology

Potential risks to the Water Environment are considered using soil leachate concentrations as indicative of the potentially mobile fraction of any soil impact and also measured groundwater concentrations.

In order to assess the significance of the chemical concentrations reported in leachate and groundwater, generic assessment criteria (GAC) must be selected based on the critical water receptors identified at the site.

As detailed in the Conceptual Model, the only significant water receptor is considered to be the underlying bedrock aquifer (detailed in Section 3.2).

Based on the potential receptors identified, and that this assessment is for significant pollution, the GAC used for leachate and groundwater data are the Resource Protection Values/UK Drinking Water Standards as defined by SEPA, (WAT-PS-10-01, 2010) or the freshwater Environmental Quality Standards (EQS) when RPVs are not available. The guideline values selected as appropriate GAC for each contaminant are presented in Appendix H.

5.2 Leachate Analysis

5.2.1 Leachate Screening Analysis

Leachate analysis for the selected suite of determinands was undertaken on 18No. soil samples submitted for analysis during the supplementary site investigation (RUK, 2009). 21No. soil samples were also submitted for leachate analysis during the initial URS investigations in 2006 and 2008. Chemical analysis results screening tables are held in Appendix H, detailing measured concentrations of potential contaminants in comparison with the applicable GAC. Where reported analyses exceed GAC, these are highlighted within the tables. Table 5-1 provides a summary of any exceedances.

Table 5-1: Summary of Leachate Exceedences compared with relevant GAC

Determinand	GAC (µg/l)	No. of exceedences/ No. of samples	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)
Lead	**25**	1/38	<1	28	3.3
Nickel	**20**	3/38	<1	45	9.0

Determinand	GAC (µg/l)	No. of exceedences/ No. of samples	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)
Zinc	**125**	3/38	<1	330	29
Ammoniacal Nitrogen	**500**	3/18	<20	4,900	470
Phenol	**0.5**	8/35	<0.50	8,800	680
Sulphate	**400,000**	1/35	1,500	540,000	43,000
Anthracene	**0.1**	1/33	<0.01	0.14	0.025
Fluoranthene	**0.1**	1/33	<0.01	0.13	0.030
Benzo(a)pyrene	**0.01**	1/33	<0.01	0.02	0.098
Sum of 4No. PAH[1]	**0.1**	1/33	0.04	0.11	0.06
Extractable Petroleum Hydrocarbons (EPH)	**90[2]**	1/18	<10	210	36

Minimum, Maximum and Mean concentrations in relation to all data
[1]Sum of benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(123cd)pyrene
[2]GAC based on WHO, 2005 values. As no specific GAC is available for EPH (C10-C40) results have been screened to the most conservative GAC (Aromatic C16-21) for speciated hydrocarbons >C10.*
**As recommended by Contaminated Land Officer, North Lanarkshire Council (see email in Appendix B, 14th January 2010)*

All other determinands were either reported below detection limits or were detectable at concentrations below their respective GAC.

5.2.2 Leachate Contaminant Distribution Assessment

Identified metal and hydrocarbon impacts are considered further in relation to vertical and lateral distribution across the site.

Metals

When compared to the conservative EQS for lead (25ug/l) 1No. leachate sample from landfill material reported marginally elevated lead concentrations (28ug/l). Considering the isolated nature of this exceedance, elevated lead concentrations are considered to be unrepresentative of the conditions within leachate from landfill across the site. This exceedance corresponds to the significantly elevated concentrations of lead reported in soils at this location (BH308) and was identified as a hotspot within the Human Health risk assessment (as illustrated on Drawing 7764/E/010). It is proposed to remove this hotspot of lead-impacted material during enabling works (as recommended in the Ground Contamination Risk Assessment Report, Ramboll 2010) and therefore any potential source of lead which may leach from Made Ground soils at this location will also be removed from site. Therefore, leachable concentrations of lead are not considered likely to present a significant risk to the Water Environment.

3No. samples of probable landfill material reported slightly elevated leachate concentrations of zinc and nickel (330ug/l and 45ug/l respectively) across the site. These exceedences are qualitatively assessed in Chapter 6.

Following a re-screen of the data to relevant RPVs, no elevated copper concentrations were reported in leachate.

Ammoniacal Nitrogen

Ammoniacal nitrogen is reported to be leaching in elevated concentrations from 3No. samples; 2No. samples of probable landfill material and 1No. samples from natural strata. These exceedences do not indicate any significant patterns of lateral distribution, although the most significant exceedence (4,700ug/l) was reported in a

sample taken from the central area of site beneath the most significant thickness of landfill material.

Phenol

Phenols were reported as significantly elevated in 8No. leachate samples; 7No. from the probable landfill material and 1No. from natural strata.

With the exception of these exceedences all other leachate samples analysed for phenols reported concentrations below or at the detection limit. In addition, all soil samples (including those with corresponding elevated concentrations of phenols in leachate) reported concentrations of phenols below detection limit.

The distribution of elevated phenol concentrations in leachate is provided in Drawing 7764/E/006, Appendix A and illustrates that the most elevated concentrations are randomly distributed across the site and not concentrated in a specific area.

Sulphate

Sulphate is reported as marginally elevated in 1No. leachate sample (540mg/l) when compared to the GAC (400mg/l) from the probable landfill material. Given the marginal and isolated nature of this exceedence it is not considered representative of leachable sulphate concentrations across the site and it not considered to represent a significant risk to the Water Environment.

Organics

Marginal leachate exceedances of anthracene and fluoranthene (0.14ug/l and 0.13ug/l) were reported in 2No. samples of probable landfill material when compared to the GAC (0.1ug/l).

1No. sample indicated benzo(a)pyrene and the sum of 4No. PAH were reported to be leaching at concentrations marginally exceeding the GAC (0.02ug/l and 0.11ug/l respectively when compared to the GACs of 0.01ug/l and 0.1ug/l respectively) in a sample of reworked topsoil from 0.25mbgl.

Leachable concentrations of EPH were reported as marginally elevated in 1No. sample from peat.

5.2.3 Leachate Assessment Summary

As part of the leachate screening assessment the following potential risks to the Water Environment were reported:

- Marginally elevated leachate concentrations of zinc and nickel in 3No. isolated areas of Made Ground;
- Slightly elevated ammonium concentrations were reported in isolated leachate samples from 3No. locations across the site;
- Elevated leachable phenol concentrations were reported as elevated in 8No. samples from across the site;
- Marginally elevated concentrations of PAHs including anthracene, fluoranthene, benzo(a)pyrene and sum of 4No. PAHs were reported in isolated samples of Made Ground and topsoil; and
- Marginally elevated concentrations of EPH were reported in 1No. sample of peat.

These potential leachable contaminants are considered further by an assessment of the recorded groundwater impacts.

5.3 Groundwater Screening Assessment

Groundwater monitoring was undertaken by URS on 1No. visit in August 2008 and by Ramboll UK Ltd. on 2No. visits in August 2010 (as agreed with SEPA 23/03/2010). This section provides a full assessment of the potential risks to groundwater based on all available data in line with SEPA guidance (WAT-PS-10-01, 2010).

Groundwater samples were collected from 10No. installations in 2008 and 17No. installations in 2010.

5.3.1 Shallow Groundwater Screening Analysis

All installations monitored in 2008 and 14No. installations monitored in 2010 are screened across various superficial strata including Made Ground deposits and underlying superficial strata including the clay, silt and peat. These installations were within the response zone of the shallow groundwater within the superficial deposits, typically perched above the peat.

Chemical results from groundwater monitoring visits (2008; 2010) are presented in Appendix G. Screening tables comparing the groundwater analytical results to their respective GAC are presented in Appendix H. Exceedences of these GAC are highlighted within the tables (Appendix H) and are summarised in Table 5-2 below.

Table 5-2: Summary of Water Exceedences within Shallow Groundwater compared with relevant GAC

Determinand	GAC (µg/l)	No. of exceedences/ No. of samples	Maximum (µg/l)	Minimum (µg/l)	Mean (µg/l)
Manganese	50	36/36	7,800	220	1,930
Nickel	20	2/38	29	25	27
Zinc	125	4/38	370	127	203
Ammonia	500	36/36	16,000	600	4,890
Phenol	0.5	1/38	1,000	1,000	1,000
pH	6.5-10	5/38	6.46	6.00	6.27
Nitrites	500	1/10	510	510	510
Fluoranthene	0.1	7/37	0.46	0.11	0.26
Benzo(a)pyrene	0.01	11/37	0.29	0.023	0.14
Sum of 4No. PAH[1]	0.1	10/37	1.06	0.05	0.56
Aliphatics >C21-C35	300[2]	1/17	740	740	740
Aromatics >C21-35	90[2]	1/17	360	110	270

Minimum, Maximum and Mean concentrations in relation to all exceedences
[1]Sum of benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(123cd)pyrene
[2]GAC based on WHO, 2005 values. As no specific GAC is available for Aliphatic C16-35 results have been screened to the most conservative GAC for Aliphatic speciations (Aliphatic C12-16).*
**As recommended by Contaminated Land Officer, North Lanarkshire Council (email provided in Appendix B, 14th January 2010)*

The laboratory results indicate the following determinands were identified in concentrations above GAC in groundwater:

Metals

2No. shallow groundwater samples reported concentrations of nickel marginally exceeding the GAC. The most significant of these exceedances (29ug/l compared with the GAC of 20ug/l) was reported in BH312 where the most significantly elevated concentrations of nickel were also reported in leachate. It is therefore considered that there is a small source of leachable nickel in the landfill material in the northeast area of site. However, given concentrations reported in groundwater and leachate are only marginally elevated when compared to the GAC, are reported in isolated areas and the concentrations of nickel in groundwater from the same locations were reported below the GAC during the second monitoring round (2010), nickel is not considered to present a significant risk to the Water Environment.

Zinc was reported at slightly elevated concentrations (typically 130-170ug/l when compared to the GAC of 125ug/l) in 4No. samples of shallow groundwater across the site. Elevated zinc concentrations were also reported in leachate (3No. out of 38o. samples) from the probable landfill material across the site which corresponds to areas where elevated zinc was reported in groundwater (BH308). This indicates there are localized areas of leachable zinc within Made Ground.

Manganese was reported as significantly elevated above the conservative RPV of 50ug/l in all samples of shallow groundwater analysed from across the site. However, the observed concentrations do not indicate a trend of contamination distribution across the site and significantly elevated manganese concentrations were reported upgradient of the probable landfill material in the northwest area of site as illustrated in Drawing 7764/E/007.

Ammoniacal Nitrogen

Significantly elevated ammonium concentrations were reported across the site within shallow groundwater (typically 2,000-4,000ug/l) when compared to the recommended RPV of 500ug/l.

Minor leachate exceedences (typically 800-1,000ug/l when compared to the GAC of 500ug/l) were reported on site. As the leached ammonia concentrations are significantly less than those reported in shallow groundwater, it is considered that that the material on site is unlikely to be a significant leachable source of ammonia. Background / upgradient ammonia concentrations are also elevated in the shallow groundwater in the surrounding area, as illustrated in Drawing 7764/E/008, Appendix A.

Phenols

Elevated phenols were reported to be leaching from the probable landfill material and natural clay in isolated areas across the site at concentrations exceeding the GAC. However, phenol concentrations in the shallow groundwater were reported below detection limit in all except 1No. sample of groundwater from BH304 on one occasion.

pH

Marginally acidic conditions were reported in 5No. samples of shallow groundwater. These marginally acidic conditions are considered likely to be a result of leaching from the naturally occurring peat across the site. However, due to the marginal and isolated nature of these exceedances, the pH is not considered likely to be a significant risk to the Water Environment.

Nitrites

Nitrites were reported as marginally elevated in 1No. sample of groundwater from BH311. Due to the very marginal and isolated nature of this exceedance there is not considered to be a significant risk to the Water Environment from nitrites.

Organics

Chemical analysis of shallow groundwater indicates elevated concentrations of various PAHs (including fluoranthene, benzo(a)pyrene and the sum of 4No. PAHs) and heavy-end hydrocarbons (aliphatic and aromatic) within the underlying shallow groundwater.

11No. samples of groundwater reported concentrations of benzo(a)pyrene above the conservative EQS of 0.01ug/l. 10No. of these also samples reported elevated concentrations of sum of 4No. PAHs and 7No. of these also reported elevated concentrations of fluoranthene. The most significant exceedences were reported in groundwater from BH205 and BH211 (e.g. 0.3ug/l and 0.46ug/l fluoranthene respectively) in the central area of site which coincides with the greatest extent of Made Ground (probable landfill material). However, concentrations of PAHs in leachate were reported to be below detection in samples available from corresponding boreholes where elevated PAHs were reported in shallow groundwater. This therefore indicates there may have been a leachable source of PAHs within the Made Ground on site and contaminants have already leached into solution from these materials.

Elevated concentrations of heavy-end organics including aliphatics >C21-35 were reported as elevated in localised groundwater from BH205 and aromatics >C21-35 were reported as elevated in groundwater from BH202, BH205 and BH211. Marginally elevated hydrocarbon concentrations were reported in only 1No. leachate sample from the peat deposits. All concentrations of petroleum hydrocarbons within leachate from Made Ground were reported significantly below the respective GAC, therefore indicating there is no significant leachable source of hydrocarbons from the Made Ground deposits on site.

In addition, during the more recent rounds of monitoring (August, 2010) all petroleum hydrocarbon concentrations were reported below detection or significant below the GAC. This further indicates that the potential for hydrocarbons to leach from materials on site and mobilise into groundwater is limited.

5.3.2 Deep Groundwater Screening Analysis

3No. wells installed during the Geotechnics investigation (2009) and monitored by RUK in 2010 are within the response zone of the bedrock aquifer and screened across the solid geology of Middle Coal Measures.

Chemical results from groundwater monitoring visits (2010) are presented in Appendix G. Screening tables comparing the groundwater analytical results to their respective GAC are presented in Appendix H. Exceedences of these GAC are highlighted within the tables (Appendix H) and are summarised in Table 5-3 below.

Table 5-3: Summary of Water Exceedences from bedrock aquifer compared with relevant GAC

Determinand	GAC (µg/l)	No. of exceedences/ No. of samples	Maximum (µg/l)	Minimum (µg/l)	Mean (µg/l)
Manganese	50	6/6	1,130	114	570
Boron	1000	1/6	1,256	1,256	1,256
Ammonia	500	6/6	13,500	2,800	8,670
pH	6.5-10	1/6	6.40	6.40	6.40

Minimum, Maximum and Mean concentrations in relation to all exceedences

The laboratory results indicate the following determinands were identified in concentrations above GAC in groundwater:

Manganese

Manganese was reported as significantly elevated (typically between 120ug/l to 1,130ug/l) above the conservative RPV of 50ug/l in all samples of deeper groundwater analysed from across the site. Concentrations are at slightly lower concentrations than those reported in the shallow groundwater (typically between 220ug/l to 2,500ug/l) and concentrations do not indicate a trend of distribution across the site.

Boron

1No. sample of deeper groundwater reported slightly elevated concentrations of boron in BH404P during the second round of monitoring in 2010. Considering the marginal and isolated nature of this exceedence, and that previous results from this location reported boron concentrations significantly below the GAC, there is not considered to be a significant risk to the Water Environment from boron.

Ammoniacal Nitrogen

Significantly elevated ammonium concentrations were reported across the site within all samples of deeper groundwater analysed. Concentrations of ammonia were reported in similar concentrations in the deeper groundwater as reported in the shallow groundwater. However, there is no correlation between the most significantly elevated concentrations of ammonia in the deep aquifer and concentrations within the shallow groundwater in the same locations.

pH

Marginally acidic conditions were reported in 1No. sample of deeper groundwater. As discussed above, these marginally acidic conditions are considered likely to be a result of the naturally occurring organic acids associated with the peat across the site. However, this is an isolated and very marginal exceedance so is therefore considered unlikely to present a significant risk to the Water Environment.

5.3.3 Groundwater Screening Assessment Summary

The generic screening assessment and contaminant distribution assessment of the potential risks to the Water Environment have identified particular contaminants at elevated concentrations in leachate and shallow groundwater across the site which may present a significant risk to the Water Environment.

The following impacts have been identified as potential risks to the Water Environment:

- Marginally elevated concentrations of zinc in leachate and shallow groundwater in isolated areas of site;
- Elevated concentrations of ammonia and manganese across the site within the shallow groundwater and deeper aquifer;
- Elevated phenols in leachate from isolated areas of site and in an isolated area of shallow groundwater; and
- Elevated concentrations of PAHs (including benzo(a)pyrene, fluoranthene and sum of 4No. PAHs) reported in leachate and shallow groundwater across the site.

5.4 Re- Assessment of Risks to the Water Environment

The potential risks detailed in the section above have been identified based on a generic screen of the data to GAC (EQS/RPV). In accordance with SEPA (WAT-PS-10-01, 2010) groundwater data for these contaminants has been rescreened taking into account background concentrations (i.e. upgradient concentrations).

5.4.1 Re-Screen of Groundwater Results

Table 5-4 below includes a re-screen of those contaminants identified as a potential risk during the initial screen of shallow groundwater. The boreholes which are most up hydraulic gradient are BH303 and BH306. The revised GAC takes into account the most conservative (i.e. the lowest) upgradient concentration reported.

Table 5-4: Summary of Water Exceedences within Shallow Groundwater compared with re-calculated GAC taking upgradient concentrations into account

Determinand	Min. up-gradient concs (ug/l)	Range of up-gradient concs (ug/l)	GAC (µg/l)	Revised GAC	No. of exceedences/ No. of samples	Maximum (µg/l)	Minimum (µg/l)
Zinc	<1	<1-18	125	125	No change to assessment above		
Manganese	3,380	3,380-7,240	50	3,430	5/36	7,800	3,600
Ammonia	1,100	1,100-2,900	500	1,600	32/36	16,000	2,200
Phenols	All upgradient concentrations below detection therefore no re-screen undertaken						
Fluoranthene	0.02	0.02-0.14	0.1	0.12	6/37	0.46	0.14
Benzo(a)pyrene	0.01	0.01-0.12	0.01	0.02	11/37	0.29	0.023
Sum of 4No. PAH[1]	0.01	0.01-0.46	0.1	0.11	10/37	1.06	0.05

Minimum, Maximum concentrations in relation to all exceedences
[1]Sum of benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(123cd)pyrene

No wells installed into the deeper aquifer are available upgradient of the site, therefore the initial screen of the deeper groundwater to EQS/RPV is considered to be a conservative assessment and the exceedences from Table 5-3 remain applicable.

Following a re-screen of the data, the following concentrations above revised GAC were reported in groundwater:

PAHs

11No. shallow groundwater samples reported concentrations of benzo(a)pyrene in excess of the revised GAC when using the most conservative (i.e. lowest) upgradient concentration. However, of those 11No. exceedances only 5No. exceedences were reported when the GAC takes into account the maximum upgradient concentrations reported (from BH202, BH205, BH207 and BH211) in the central area of site.

10No. exceedences of sum of 4No. PAHs were reported in shallow groundwater when screened to the revised GAC using the most conservative upgradient concentration. However, only 4No. of these were elevated above the revised GAC taking into account the maximum upgradient concentrations in the central area of site (from BH202, BH205 and BH211).

6No. exceedences of fluoranthene were reported when screened to the most conservative revised GAC. Of these 6No. exceedences 2No. are below the revised GAC using the maximum upgradient concentrations therefore only 4No. exceedences remain (from BH202, BH205 and BH211).

The PAH concentrations and their distribution across the site has been modelled on the contour plots in Drawing 7764/E/009, Appendix A. These drawings demonstrate that the most significantly elevated PAHs are reported within the central area of site around BH205. Concentrations of PAHs significantly decrease down hydraulic gradient across the site within the shallow groundwater. In addition, only limited elevated concentrations of PAHs were reported in leachate across the site and were reported at concentrations significantly lower than those in the shallow groundwater.

Ammonia & Manganese

Ammonia was reported in elevated concentrations in 32No. samples of shallow groundwater when compared to the revised, most conservative GAC. When compared to the range of upgradient concentrations, 22No. exceedences are reported. These do not show a significant trend in distribution across the site. Similar concentrations of ammonia were also reported in the deeper groundwater, which also do not show a significant trend in distribution across the site.

Manganese was reported in elevated concentrations in 5No. samples of shallow groundwater when compared to the revised GAC using the most conservative upgradient concentrations recorded. However, only 1No. sample exceeded the maximum upgradient concentration reported on 1No. occasion from BH205. During subsequent monitoring rounds manganese concentrations in groundwater from this location were reported below the revised GAC detailed in Table 5.4.

5.5 Summary of GQRA of the Water Environment

Following a re-screen and assessment of the data, the potentially significant pollutant linkages detailed in Section 5 have been revised. The following potentially significant pollutant linkages may present a significant risk to the Water Environment:

- Elevated concentrations of zinc are reported at elevated concentrations in leachate and shallow groundwater which is not reported in deeper groundwater. Zinc may begin to migrate into the underlying aquifer;

- Elevated concentrations of PAHs (including benzo(a)pyrene, fluoranthene and sum of 4No. PAHs) reported in leachate and shallow groundwater across the site but are not reported in deeper groundwater. PAHs may begin to migrate vertically into the underlying aquifer;

- Elevated manganese and ammonia concentrations in shallow groundwater and the deeper aquifer;

- Elevated phenols in leachate in isolated areas of site and an isolated area of shallow groundwater may continue and migrate vertically into the shallow groundwater and underlying aquifer below.

The significance of these pollutant linkages will be assessed within a qualitative risk assessment presented in Chapter 6.

6 QUALITATIVE RISK ASSESSMENT

Potentially significant pollutant linkages with regards to the Water Environment are identified using the source-pathway-receptor framework as detailed in Section 5. An assessment of the potential significance of each linkage is then made by consideration of the likely magnitude and mobility of the source, the sensitivity of the receptor and nature of the migration/exposure pathways.

This revised risk assessment has been undertaken in accordance with CIRIA C552: *Contaminated Land Risk Assessment, A Guide to Good Practice* (Rudland et al., 2001). The CIRIA C552 risk categories and the assessment methodology are detailed in Appendix C.

An assessment of the likelihood of the risk being realised and the magnitude of potential risk is presented below to give an estimation of the significance of each potential pollutant linkage identified.

Table 6.1: Possible linkages between sources and water receptors on site

Source	Pathway	Receptor	Potential Severity	Probability of Risk	Level of Risk
Elevated concentrations of zinc in leachate and shallow groundwater	Groundwater migration	Bedrock Aquifer	Mild	Unlikely	Very Low
Elevated phenols in leachate and an isolated area of shallow groundwater	Groundwater migration	Bedrock Aquifer	Medium	Unlikely	Low
Elevated PAHs in shallow groundwater	Groundwater migration	Bedrock Aquifer	Medium	Unlikely	Low
Elevated ammonia and manganese in shallow groundwater	Groundwater migration	Bedrock Aquifer	Medium	Low	Low/Moderate
Elevated ammonia and manganese in deep aquifer	Groundwater migration	Bedrock Aquifer	Medium	Likely	Moderate

6.1 Discussion

Zinc

Marginally elevated concentrations of zinc within isolated leachate (3No. out of 38No. samples) and shallow groundwater samples (4No. out of 38No. samples) were reported across the site when compared to the conservative EQS value. This is considered a highly conservative assessment as there is currently no RPVs/DWS for zinc and surface waters are not considered a significant receptor at this site. Concentrations of zinc in shallow groundwater were reported below the GAC down hydraulic gradient, are only slightly elevated, and in three out of four occasions concentrations were reported below the GAC during subsequent monitoring rounds. The average concentration of zinc in shallow groundwater is 62ug/l which is

significantly below the EQS. In addition, concentrations within the bedrock aquifer were reported significantly below the GAC. Therefore, risks to the underlying aquifer are considered **VERY LOW** and there is not considered to be a significant risk to the Water Environment from zinc.

Phenols

Elevated concentrations of phenols were reported in isolated samples of leachate and 1No. sample of shallow groundwater. Given the concentration of phenols in groundwater from the same location were reported below detection on the subsequent monitoring round and concentrations of phenols were reported below detection limit in groundwater in all areas where elevated concentrations were reported in leachate, there is not considered to be a significant risk to the Water Environment from phenols. Risks to the underlying aquifer from elevated phenols are therefore considered to be **LOW**.

PAHs

PAHs, Shallow Groundwater

Marginally elevated concentrations of PAHs in leachate and shallow groundwater were reported in localised areas of site. In boreholes where the most significant groundwater exceedences were reported, leachate samples reported PAHs below detection.

It is therefore considered likely that the source of PAHs within the shallow groundwater is the landfill material, which has leached into the shallow groundwater since the landfill closed in 1972. Bacterial decay of organic matter within the Made Ground has decreased over time since the landfill closed, as has the leaching of these organic contaminants, therefore impacts from previous leaching are revealed only within the shallow groundwater data. There is also the potential for leaching of PAHs into the shallow groundwater to be a result of the peat deposits across the site, which peters out towards the southeast.

PAHs, Bedrock Aquifer

Concentrations of PAHs within the deeper groundwater were all reported below the limits of laboratory detection.

As the concentration of PAHs reported in shallow groundwater were not also reported in the deeper aquifer, it is considered that there is sufficient cohesive strata present on site to reduce vertical migration and that there is sufficient peat to attenuate and degrade contaminants, which has significantly reduced PAHs entering the underlying aquifer.

This theory is supported by geological cross-sections showing the extent of clay/silt and peat across the site (typically ranging between 5-12m in thickness). The only borehole where less than 5m of clay/silt and peat is reported is BH311, where elevated PAHs were reported in the shallow groundwater. The deeper groundwater in this area is also not impacted by PAHs indicating that even the minimum extent of superficial deposits is creating sufficient attenuation and restriction of contaminants to prevent significant vertical migration to the underlying aquifer.

If the groundwater was migrating through the superficial deposits, an approximate travel time for these contaminants has been calculated using a conservative literature permeability value (K) for clay of 10^{-9}m/s or 0.03m/yr (Domenico and

Schwartz, 1990). As the majority of the clay across the site has secondary constituents of sand and/or silt and peat is also present beneath the site, this K value is considered to be sufficiently conservative to demonstrate a worse-case contaminant travel time.

The site has been used as a landfill for over 65years (see Section 2.2). During this time (using the conservative literature K-value) the contaminants should have travelled 1.95m through the underlying superficial strata. Contaminants are therefore only considered likely to reach the underlying aquifer in over 90years in the isolated areas where less than 5m superficial deposits were reported.

PAHs have the potential to decay in anaerobic conditions (Johnsen et al., 2005; Johnson & Gnosh, 1998) such as those considered to be present on site due to the peat deposits. Under these conditions PAHs are considered to have a half life of 5.8years (WHO, 1998). Using the worse case maximum concentrations reported in groundwater (0.46ug/l) and the minimum depths of superficial deposits reported on site (2.70m) there is considered to be a concentration of $1.4x10^{-5}$ug/l PAHs reaching the bedrock aquifer in 90years. There is therefore considered likely to be sufficient attenuation and degradation of PAHs within the superficial strata to ensure concentrations of PAHs are significantly below the RPVs when they reach the underlying aquifer.

The site data indicates that the PAHs within the shallow groundwater are not migrating vertically through the subsurface strata in sufficient concentrations to present a significant risk to the deeper aquifer. The risk to the Water Environment from elevated PAHs is therefore considered to be **LOW**.

Manganese & Ammonia

Elevated concentrations of manganese and ammonia were reported within the shallow groundwater and bedrock aquifer underlying the site. No significant trends of distribution of elevated manganese and ammonia concentrations are present across the site.

Ammonia, Shallow Groundwater

Elevated concentrations of ammonia in leachate were reported in isolated areas of Made Ground although concentrations were significantly lower than those reported in shallow groundwater.

The elevated concentrations of ammonia in the shallow groundwater are therefore considered to be attributable to one or a combination of the hypotheses below:

- Ammonia is generated within the landfill Made Ground soils due to the anaerobic reduction of nitrate, a common biogeochemical process in landfill sites. However, given the concentrations of ammonia in leachate are significantly lower than those reported in shallow groundwater it is considered likely that this biogeochemical process is nearing completion and this is reflected in the lower concentrations of ammonia within the leachate; and/or
- Ammonia is being generated by natural site conditions. The peat is creating a reducing environment on site; nitrate is being reduced within the natural environment and liberating ammonia into solution. As a result, concentrations of ammonia are higher within the shallow groundwater than within the leachate results from site. In addition, up-gradient concentrations of ammonia in shallow groundwater (BH303; BH306) are lower (1,100ug/l-2,900ug/l) than concentrations across the extent of the site (600ug/l-

16,000ug/l) as the peat is not present up-gradient of the site. Significant correlations between elevated concentrations of ammonia and shallow groundwater within a peat deposit have been made in literature (Sapek et al, 2007).

Considering concentrations of ammonia within leachate are so much lower than those reported in shallow groundwater and up gradient concentrations are lower than those reported underlying the site, it is considered likely that the natural geochemical conditions associated with the reduction of nitrate in the peat will be contributing most significantly to the elevated ammonia concentrations in the shallow groundwater.

Ammonia, Bedrock Aquifer

Elevated concentrations of ammonia were also reported in the underlying bedrock aquifer.

The site is located within an area heavily associated with coal mining and the site itself is underlain by a number of coal seams and mine shafts. As discussed in SEPA's *"Evaluating the potential impact of opencast coal mining on water quality"* 2004, ammonia is commonly released into groundwater through the biogeochemical processes described above.

Ammonia can be recorded at concentrations of several tens of mg/l in mining areas, with concentrations in the range 1-10mg/l being fairly common. Typically, un-mined coal bearing strata exist in a reducing environment under anaerobic conditions. These reducing conditions are considered to be representative of conditions on site as the bedrock aquifer is confined from the clay/silt and peat deposits above. This reducing environment has the potential to liberate ammonia into solution via the natural reduction of nitrate.

In addition, when these conditions are disturbed during mining, which has commonly occurred across the area historically, oxygen is introduced which initiates the degradation of coal and other redox-sensitive minerals, causing an increased availability of other elements including ammonium, iron and manganese for subsequent redox reactions. Under reducing conditions, iron and manganese are liberated into solution because in their reduced state, they are more soluble.

Concentrations of ammonia on site range from 0.6-16mg/l in shallow groundwater and 2.8-13mg/l in deeper groundwater.

Manganese, Shallow Groundwater

Elevated concentrations of manganese were reported within the shallow groundwater. These are considered to be attributable to one or a combination of sources detailed below:

- As steel works were present in the surrounding area (Gartsherrie Steel Works, approximately 500m northeast of the site, up-hydraulic gradient) it is considered likely that the works would have contributed to the elevated manganese present in the shallow groundwater as manganese is an essential element in the production of steel. This is considered likely as concentrations reported upgradient of the site (3,380ug/l-7,240ug/l) are typically higher than those reported in shallow groundwater on site (220ug/l-7,250ug/l); and/or

- Manganese is being generated by site conditions. The peat is creating a reducing environment on site; manganese is being reduced within this environment and in its reduced form is more soluble and hence it is being liberated into solution.

Concentrations of manganese upgradient of the site are similar or higher that concentrations reported in shallow groundwater on site, therefore it is considered likely that sources associated with the former steel works in the area will be contributing most significantly to the elevated manganese concentrations in the shallow groundwater.

Manganese, Bedrock Aquifer

As detailed above, the site is located within an area heavily associated with coal mining and the site itself is underlain by a number of coal seams and mine shafts. Manganese is very commonly released into groundwater in areas associated with mine workings (SEPA, 2004).

The reducing environment generated within the bedrock aquifer due to the overlying aquiclude (detailed above) has the potential to cause manganese reduction which generates a more soluble form of manganese which is then easily liberated into solution. In addition, any disturbance of this environment caused by mining will introduce oxygen to this system, thereby causing degradation of the coal and releasing additional manganese containing compounds available for their subsequent reduction(as detailed above).

In addition, manganese is commonly reported in concentrations exceeding the GAC in all hydrogeological units in Scotland (BGS, 2005_1) and is more likely to be elevated in groundwater in the general Coatbridge area, as illustrated in Figure 6.1 (BGS, 2005_2).

Conclusions, Manganese & Ammonia

The lack of significant concentrations of PAHs within the bedrock aquifer compared with elevated concentrations reported in shallow groundwater suggest there to be sufficient cohesive strata to reduce their vertical migration and promote attenuation and degradation within the peat and cohesive deposits. This is considered likely to have prevented PAH contamination entering the underlying aquifer at concentrations exceeding their respective target criteria.

Ammonia and manganese concentrations within the deep groundwater are also considered not to be a result of vertical migration from the shallow groundwater above and are instead considered likely to be a combined result of hydrogeological conditions and former mining activities.

Risks to the underlying aquifer from ammonia and manganese concentrations recorded in the deep groundwater on site are considered **MODERATE.** However, the risk is attributable to natural processes and former mining activities occurring on site and in the surrounding area. Therefore the risks to the underlying aquifer from site derived ammonia and manganese is considered to be **LOW** when the general quality of the deep groundwater in the vicinity of the site is also considered.

6.2 Summary

On the basis of the Water Environment Assessment as outlined above, the key pollutant linkages with regards to the Water Environment are considered to be:

- Elevated concentrations of ammonia and manganese across the site within the shallow groundwater, which are considered to be a result of the reduction of nitrate within the landfill material, industrial activities in the surrounding area and the peat, which is considered likely to be creating a naturally reducing environment on site causing liberation of manganese and ammonia into solution; and
- Elevated concentrations of ammonia and manganese across the site within the deeper aquifer are considered to be a result of general hydrogeological conditions in the surrounding area and former mining activities.

7 PROPOSED SITE DRAINAGE AND ASSESSMENT

This section details the proposed drainage for the site with reference to the detailed designs available at this stage. An assessment of any potential risks which may affect the Water Environment has also been undertaken in the context of the proposed drainage.

7.1 Site Cover

At present the site is covered by grass with the exception of a small area of car parking in the northeast area of site, which is illustrated in Drawing 7764/E/001, Appendix A. The proposed development will involve the introduction of significant areas of hardstanding including paving, play areas and car parking. All pitches will also be built up and underlain by a membrane. The proposed layout of the site cover across the site is depicted on Drawing NLC-STA-DRG-C-451 in Appendix A.

7.2 Proposed Drainage

The proposed drainage is illustrated on Drawing NLC-STA-DRG-C-101 and details are provided in Drawings NLC-STA-DRG-400 to 405, in Appendix A.

As illustrated on Drawing 101 and 451, all areas of hardstanding will drain to surface water drains which are then discharged into soakaway tanks in the southern area of site. The car parking in the central area of site will be covered by porous paving, discharging into a tanked system beneath the car park. Minor areas of soft landscaping and grassed areas will continue to drain freely into the underlying ground, as is the current state across the entire site.

The pitch drainage will be designed by the pitch contractor. However, within the build up of the pitches, a herring-bone drainage system will be included, overlying a membrane. Water collected within this herring bone system will drain into land drains at the end of each pitch (as detailed on Drawing NLC-STA-DRG-C-101) and be discharged to the soakaways in the southern area of site.

7.2.1 Soakaways

At present the designs of the soakaways are not finalised as additional infiltration tests are proposed to be undertaken during enabling works to confirm the required size and depth of the soakaways. Indicative designs are included on Drawing NLC-STA-DRG-C-405. The locations of the soakaways have been confirmed (Drawing NLC-STA-DRG-C-101) and are away from the more significant depths of Made Ground within the central area of site.

Within these areas, the water contained within the soakaways will be discharged to natural strata and/or the base of Made Ground (as illustrated by Drawings 7764/E/002-004). The peat deposits peter out towards this area of site.

In accordance with SEPA guidance WAT-PS-10-01, 2010, any high risk point source input to groundwater needs to be assessed in terms of a "prevent or limit" concept. Any hazardous substances should be prevented from entering groundwater and any non-hazardous substances should be limited from entering groundwater. It is considered that further assessment should therefore be undertaken to assess the risks to groundwater from the soakaways as this has been identified as a high risk point source input to groundwater by SEPA.

7.3 Risk Assessment of the Water Environment – New Input to Groundwater

Water from the soakaways will discharge into the shallow groundwater, which is not considered a receptor due to its lack of future resource potential. There are not considered to be significant vertical migration pathways by which contaminants within the shallow groundwater may migrate into the underlying bedrock aquifer therefore it is considered unlikely that any impacts to the shallow groundwater caused by these soakaways will reach the underlying aquifer at concentrations exceeding their respective GAC. However, as a conservative assessment, leachate from the Made Ground and natural strata have been screened using relevant GAC (Minimum Reporting Value or Resource Protection Value, dependant on the hazardous or non-hazardous nature of the contaminant, respectively) to assess potential risk to the Water Environment. This leachate data is considered to represent a conservative assessment point.

As only limited leachate data is available from the areas where the soakaways are proposed, leachate data from the entire site has been used in this assessment. Considering the soakaways will be located away from the main hub of the former landfill in the central area of site, where leaching of contaminants is most significant, this is considered to be a conservative assessment

7.3.1 Leachate Screen

Chemical analysis results screening tables are held in Appendix H, detailing measured concentrations of potential contaminants in comparison with the applicable GAC. The GACs used for each contaminant have been selected in accordance with SEPA guidance for a new input to groundwater. Where reported analyses exceed GAC, these are highlighted within the tables. Table 7.1 provides a summary of any exceedances within Made Ground and Table 7.2 provides a summary of exceedences within natural strata.

Table 7-1: Summary of Leachate Exceedences compared with relevant MRV/RPV in Made Ground

Determinand	GAC (µg/l)	No. of exceedences/ No. of samples	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)
Hazardous Substances (i.e. List I)					
Anthracene	**0.01**	6/29	0.04	0.14	0.06
Fluoranthene	**0.01**	7/29	0.02	0.13	0.06
Benzo(a)pyrene	**0.01**	1/29	0.02	0.02	0.02
Extractable Petroleum Hydrocarbons (EPH)	**50**	1/15	51	51	51
Non-hazardous Substances (i.e. List II)					
Lead	**25**	1/34	28	28	28
Nickel	**20**	3/34	34	45	38
Zinc	**125**	3/34	150	330	220
Ammoniacal Nitrogen	**500**	2/15	800	4,900	2,850
Phenol	**0.5**	7/31	10	8,800	2,970
Sulphate	**400,000**	1/31	540,000	540,000	540,000

Minimum, Maximum and Mean concentrations in relation to exceedences

Table 7-2: Summary of Leachate Exceedences compared with relevant MRV/RPV in natural ground (not peat)

Determinand	GAC (µg/l)	No. of exceedences/ No. of samples	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)
Hazardous Substances (i.e. List I)					
Anthracene	**0.01**	2/3	0.02	0.06	0.04
Fluoranthene	**0.01**	2/3	0.02	0.08	0.05
Non-hazardous Substances (i.e. List II)					
Ammoniacal Nitrogen	**500**	1/2	1,000	1,000	1,000
Phenol	**0.5**	1/3	3,000	3,000	3,000

Minimum, Maximum and Mean concentrations in relation to exceedences

All other determinands were either reported below detection limits or were detectable at concentrations below their respective MRV/RPV.

7.3.2 Discussion of Leachate Screen

List I Substances

1No. very marginally elevated and isolated exceedence of benzo(a)pyrene and also Extractable Petroleum Hydrocarbons were reported in leachate samples from reworked topsoil. Due to their marginal and isolated nature, these are not considered to be representative of the general leaching properties of Made Ground soils across the site, nor do they represent exceedences of any significance. As these exceedences were reported within reworked topsoil only (<0.30mbgl) they are not representative of concentrations considered likely to be entering the saturated zone, which was reported across site at a minimum depth across the site of 1.90mbgl.

Therefore, the only list I substances reported as elevated and considered significant when compared to the MRVs are anthracene and fluoranthene. Data from both Made Ground and natural strata across the site indicate that there are elevated concentrations of anthracene and fluoranthene within leachate when compared to MRVs.

List II Substances

Marginal concentrations of lead and sulphate are reported in leachate from Made Ground in 2No. isolated areas of site. These soils are proposed for removal during the enabling works due to and as such are unlikely to present any risk to the Water Environment once the source is removed.

Marginally elevated concentrations of nickel and zinc were reported in leachate from 3No. samples of Made Ground. Given the isolated and marginal nature of these exceedences they are not considered to be representative of the general leaching properties of Made Ground and are not considered to represent significant exceedences in the context of the proposed soakaways.

Elevated ammonium and phenol concentrations were reported in leachate from Made Ground and natural strata.

Summary

Therefore the following contaminants have the potential to leach at potentially significant concentrations in the natural environment as a result of infiltration through the proposed soakaways:

- Anthracene and fluoranthene;
- Phenols; and
- Ammonia.

These contaminants will therefore require further assessment by analysis of concentrations within the shallow groundwater (compliance point).

7.3.3 Shallow Groundwater Screen

A screen of the contaminants identified as a potential concern within shallow groundwater has therefore been undertaken to MRVs and RPVs in accordance with SEPA guidelines. The compliance point is considered to be the underlying shallow groundwater, however this is considered to be a conservative assessment as the only groundwater receptor with future resource potential is considered to be the deeper bedrock aquifer. The following exceedences were reported:

Table 7-3: Summary of Shallow Groundwater Exceedences compared with relevant MRV/RPV of Contaminants of Concern (as listed above)

Determinand	GAC (µg/l)	No. of exceedences/ No. of samples	Minimum (µg/l)	Maximum (µg/l)	Mean (µg/l)
Hazardous Substances (i.e. List I)					
Anthracene	**0.01**	6/38	0.015	0.065	0.03
Fluoranthene	**0.01**	17/38	0.02	0.37	0.13
Non-hazardous Substances (i.e. List II)					
Ammoniacal Nitrogen	**500**	36/36	600	16,000	4,900
Phenol	**0.5**	1/36	1,000	1,000	1,000
Manganese*	**50**	36/36	7,800	220	1,930

Minimum, Maximum and Mean concentrations in relation to exceedences

**Considered as no current leachate data available.*

Discussion of Groundwater Screen

List I Substances

Elevated concentrations of anthracene and fluoranthene are reported in shallow groundwater when compared to the MRVs. However, concentrations of these PAHs decrease towards the south and east away from the main hub of the landfill in the direction of hydraulic gradient (as illustrated on Drawing 7764/E/009). This suggests that it is the landfill material that has leached these contaminants into the groundwater, further demonstrated by leachate results from Made Ground soils within the landfill which reported elevated concentrations of said contaminants. In addition, concentrations of anthracene and fluoranthene in boreholes up-hydraulic gradient were reported ranging from 0.01-0.03ug/l and 0.02-0.14ug/l respectively. Concentrations nearest to the proposed soakaways (such as BH406, BH310 and BH311) were reported below detection (MRVs).

List II Substances

Elevated concentrations of phenols were reported in 1No. sample of shallow groundwater. The concentration of phenols in groundwater from the same location were reported below detection on the subsequent monitoring round and concentrations of phenols were reported below detection limit in groundwater in all areas where elevated concentrations were reported in leachate and in the area of the proposed soakaways. Inputs of phenols to groundwater are therefore considered to be limited in the area of the proposed soakaways.

To add to this, concentrations of phenols within the deeper aquifer (considered to be the less conservative but more realistic assessment point for non-hazardous contaminants), are reported below detection limit, further indicating that limited contamination migration will result from the influence of the soakaways.

Elevated ammonia and manganese concentrations were reported in all samples of shallow groundwater. Elevated concentrations are randomly distributed and do not show any trend in distribution across the site. In addition, concentrations of ammonia and manganese up gradient were reported between 1,100-2,900ug/l and 3,380-7,240ug/l respectively indicating these are area wide issues. As concentrations of ammonia in leachate are significantly lower than in groundwater it is considered likely that leachate of ammonia generated by anaerobic decay of the landfill material has occurred following closure of the landfill and this contaminant has all mobilised into the saturated zone previously.

Elevated concentrations of ammonia and manganese were also reported in deeper groundwater within the bedrock aquifer as detailed in Section 6.1 above.

7.3.4 Conclusion - Soakaways

List I Substances

The List I substances identified as elevated within groundwater are concentrated around the most significant depth of landfill on the site. Currently the entire site, including this area, is grassed with no form of capping, so contaminants are leaching into solution and migrating into shallow groundwater. It is proposed to locate the soakaways to the south and east of the site, away from the more significant depths of landfill material where concentrations of these list I substances are below MRVs in shallow groundwater.

In addition, the proposed drainage solution will provide betterment across the site by preventing unmanaged infiltration and therefore reducing the subsequent leaching and migration of contaminants across the site. Significant leaching of anthracene and fluoranthene into shallow groundwater will be prevented in the area of the more significant depths of landfill as pitch construction includes an underlying membrane and areas of hardstanding and associated drainage systems will act as a barrier to prevent significant infiltration and subsequent vertical migration of leached contamination into the shallow groundwater. The majority of surface water will instead be directed into the proposed soakaways, localising infiltration and leaching away from the landfill material.

Considering up-gradient concentrations of these contaminants are elevated and concentrations within shallow groundwater in the areas of the proposed soakaways are below the MRVs it is considered that additional entry of List I substances to groundwater will not be caused by the soakaways. In addition, it should be noted

that the deep bedrock aquifer (identified as the only groundwater body receptor) reported concentrations of anthracene, fluoranthene and all PAHs below detection.

List II Substances

Limited entry to shallow groundwater of list II substances, including phenols, will occur as a direct result of the soakaways proposed on site, as detailed above.

Other List II substances including ammonia and manganese were reported as elevated within shallow and deeper groundwater across the site. These contaminants are considered to be attributable to area wide issues and natural processes as detailed in Section 6.1.

Only limited entry to groundwater of list II substances is considered likely to occur due to the proposed drainage design, which will encourage infiltration only outside of the most significant thickness of landfill material where contaminative impacts are most likely to occur. Entry of these contaminants to groundwater will also be limited by the soakaways, as leachable concentrations of contaminants in these locations are below their respective RPVs.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Risk Assessment of the Water Environment

8.1.1 Summary

A full risk assessment has been undertaken for the Water Environment in light of the proposed development.

The assessment for significant pollution takes into account potentially significant risks to the Water Environment from land contamination associated with a historic activity (i.e. the former landfill).

An assessment of the proposed soakaways has also been undertaken as this is considered to be a new activity (point source input), regulated by SEPA.

8.1.2 Conclusions

Following the assessment of significant pollution, key pollutant linkages are considered to be:

- Elevated concentrations of ammonia and manganese across the site within the shallow groundwater, which are considered to be a result of the reduction of nitrate within the landfill material, industrial activities in the surrounding area and the peat, which is considered likely to be creating a naturally reducing environment on site causing liberation of manganese and ammonia into solution; and
- Elevated concentrations of ammonia and manganese across the site within the deeper aquifer are considered to be a result of general hydrogeological conditions in the surrounding area and former mining activities.

The elevated concentrations of ammonia and manganese in the bedrock aquifer across the site are considered to be a result of natural processes and former mining activities on site. The risks to the bedrock aquifer from site derived ammonia and manganese are therefore considered to be low. These contaminants are therefore not considered to represent significant risk to the Water Environment in light of the proposed development.

Following the specific assessment for the proposed soakaways, the site drainage is considered to provide betterment across the site by limiting infiltration away from the more significant depths of landfill material. Entry of list I and list II substances are considered likely to be prevented or limited (respectively) in the areas of the proposed soakaways.

Further analysis within the specific areas of the proposed soakaways is also recommended (see below).

8.2 Revised Remedial Strategy for the Water Environment

8.2.1 Additional Leachate Validation

As detailed in Section 7, the exact size and depth of the proposed soakaways have not been established and additional infiltration tests are therefore proposed during enabling works to confirm this. It is recommended that as part of validation works during enabling, leachate samples are taken from the area of the proposed

soakaways at the specific depths where water will be infiltrating into the ground and submitted for analysis and assessment. This is to confirm that these soakaways will not allow the entry of significant concentrations of hazardous and non-hazardous substances to groundwater.

The leachate results will be assessed and presented to the regulator as an addendum to this report.

8.2.2 Watching Brief

To prevent significant risk to Human Health, a part-time watching brief has been recommended during enabling works to ensure that should any areas of apparent contamination be exposed; the material is excavated, stockpiled separately onsite and subjected to validation testing in order to ensure the material is suitable for use (5311.E.GQRA.1B). This will also be important with regards to the Water Environment.

Should free product be identified during groundworks in the soils/groundwater on site further remedial works will be required to assess, delineate and potentially remove this contamination.

8.3 Additional Considerations

Cut and Fill Works
Any excavation works on site may encounter volumes of groundwater, which was recorded at depths ranging from 1.90mbgl to 4.70mbgl. In the central area of site, beneath the more significant depths of landfill material, this groundwater has been reported to contain elevated concentrations of PAHs. Allowances are recommended to be made for the removal, treatment and disposal of this shallow groundwater should dewatering be required during excavation.

As detailed above, it is recommended that a suitably qualified Environmental Consultant is on site during the enabling works.

Waste Disposal
Any excavation/piling may result in soils that require off-site disposal, if they are assessed as unsuitable for reuse on site. All excavated materials will be controlled waste. Further assessment will be required to establish classification (hazardous or non-hazardous) and further chemical testing (and/or pre-treatment) if disposal to landfill is considered. Some form of pre-treatment of those materials to be disposed to landfill (*e.g.*, screening to remove oversized 'clean' demolition material and gravels) may significantly reduce the volume of material liable to classify as hazardous waste.

Piling

Any piled solution to foundation design should be developed in such a way so that the installation of the piles themselves does not create preferential flow pathways by which potential contamination could mobilise in the unsaturated zone. It is understood that the proposed piling solution includes driven pre-cast piles and bored cast-in-place piles. The use of a pointed or conical driving shoe has been proposed in order to limit any downward migration of potential contaminants in soils and groundwater during piling.

Contractors should ensure compliance with SEPA guidelines on piling in contaminated land (*Piling and penetrative ground improvement methods on land affected by contamination: Guidance on pollution prevention.* EA, 2001*)*.

A piling specification and design philosophy have also been produced for the proposed development (Ramboll, 2010).

Mining

There are 2No. areas adjacent to the northern and eastern site boundaries where potential mine shafts are present (2No. shafts in each area) as shown on the Mason Evans Drawing G2008/473/C/F/04, Appendix A and coal seams are present underlying the site. As part of the proposed development, the mine shafts will be grouted up.

There is potential risk that the mine stabilisation works will affect the conceptual site model for the site. By grouting up the mine shafts, this will prevent preferential pathways of groundwater flow into the underlying aquifer, which may have existed previously in these areas (see Section 3.3). However, there is a potential risk to the Water Environment from introduction of grout and there is potential for groundwater displacement. These risks have been considered by the geo-environmental consultant undertaking the mine stabilisation works (Mason Evans) in accordance with BRE Code of Practise, 2009, and this risk assessment is included in Appendix I.

All mine stabilisation works will be undertaken in accordance with best practise and will be designed and managed effectively to ensure that the potential for any impact on the groundwater is minimized.

Environmental Specification
The Environmental Specification (Ramboll, 2010_3) should be referred to during enabling works.

Validation Works
Validation sampling will be required from on site materials used in the cut and fill operations on site during enabling works in order to demonstrate that all materials used are suitable for use. These results, along with documented evidence to illustrate that the remedial measures detailed above and within the Environmental Specification have been adhered to (e.g. daily diary/record from site engineer), will need to be collated and documented in a Validation Report and submitted to the Environmental Department at North Lanarkshire Council.

9 REFERENCES

BS 5930 (1999) *Code of Practice for Ground Investigation*

British Geological Survey (BGS) (2003) *Water Quality Fact Sheet: Manganese*

British Geological Survey (BGS) (2005_1) *Baseline Scotland: an overview of available groundwater chemistry data for Scotland*

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Appendix A
Drawings and Figures

NOTES:
1. THIS DRAWING NOT TO BE SCALED. FIGURED DIMENSIONS ONLY TO BE TAKEN.
2. SHOULD ANY DISCREPANCIES BE FOUND WITH THIS DRAWING, PLEASE INFORM THIS OFFICE.
3. COPYRIGHT OF THIS DRAWING IS OWNED BY JM ARCHITECTS.

STRUCTURAL INFORMATION INDICATIVE ONLY. TO BE CONFIRMED BY STRUCTURAL ENGINEER.

REFER TO STRUCTURAL ENGINEER'S DRAWINGS FOR LOCATIONS OF BRACING & WINDPOSTS.

LAYOUT SUBJECT TO FIRE ENGINEERING. ALL INTERNAL AND EXTERNAL MECHANICAL AND ELECTRICAL PLANT, DUCTWORK AND DUCT ROUTES TO BE CONFIRMED.

KEY

Site fence

Site boundary

Landscaping indicative: Refer also Landscape Architect information for more detail

TOTAL PARKING SHOWN:

170 STANDARD BAYS
11 DISABLED BAYS
21 DROP OFF
3 MINI BUS
4 COACHES
152 CYCLES

PARKING BAY SIZES:

STANDARD BAY:	2.5m x 5m
DROP OFF:	2.5m x 6m
DISABLED:	3.6m x 6m (2.5m x 5m BAY)
MINI BUS:	3.25m x 8m
COACH:	3.25m x 19m

SURVEYED TREE POSITIONS

TREES TO BE REMOVED

REV.	DESCRIPTION	DATE	DRWN BY	CHKD BY
F	SYNTHETIC PITCH DIMENSIONS REVISED, GAELIC PITCH SIZE REVISED AT COUNCIL/ CONTRACTOR REQUEST. MINOR ALTERATIONS TO CARPARK FOLLOWING CHANGE.	10.05.10	ET	AC
E	ROUNDABOUT UPDATED BASED ON ENGINEER'S DRAWINGS, EXTENSION OF NORTH ROADWAY INDICATED FOR PITCH ACCESS. FENCE LINE ALTERED AT SOUTH SIDE FOR BADGER PROTECTION & BOUNDARY ALTERED AT SE CORNER TO FOLLOW SPORTS PITCH FENCELINE NOTE ADDED ON EXTENTS OF FENCING TO NORTH. HARD & SOFT LANDSCAPING UPDATED TO MATCH LANDSCAPE ARCH. DRAWINGS. BICYCLE STAND LOCATION & NUMBERS UPDATED. RAMP & STAIR ACCESS TO PITCH NOTED. BUILDING UPDATED IN CONJUNCTION WITH GENERAL PLAN AMENDMENTS.	06.04.10	ET	AC
D	UPDATED ROUNDABOUT SIZE / POSITION BASED ON ENGINEER'S DRAWINGS, RUGBY & GAELIC FOOTBALL PITCH LOCATION MOVED , CAR PARKING/ ROADS AMENDED TO SUIT.FENCE LINE EXTENDED AROUND GRASS PITCHES. LAYOUT UPDATED TO MATCH LANDSCAPE ARCH. DRAWING. BUILDING OUTLINE UPDATED IN CONJUNCTION WITH GENERAL PLAN AMENDMENTS.	22.01.10	AC/ET	RD
C	4G & SAND COVERED PITCH SWAPPED. GAELIC PITCH ADDED, RUGBY PITCH REALIGNED. WEST BOUNDARY ALTERED TO SUIT NEW PITCH LAYOUT	10.07.09	ET	RD
B	PARKING NUMBERS AMENDED; BUS BAY SIZES INCREASED, SERVICE ROAD INCREASED TO 6m WIDE; PEDESTRIAN ENTRANCE TO WEST OF ROUNDABOUT INTRODUCED; HARD PLAY/OVERSPILL CAR PARK INTRODUCED ALL PER HIGHWAYS MEETING 19.06.09.	08.07.09	AC	RD
A	BOUNDARY LINE ALTERED TO EXCLUDE PATHS TO SOUTH SIDE; PITCHES AMENDED	18.06.09	ET	RD

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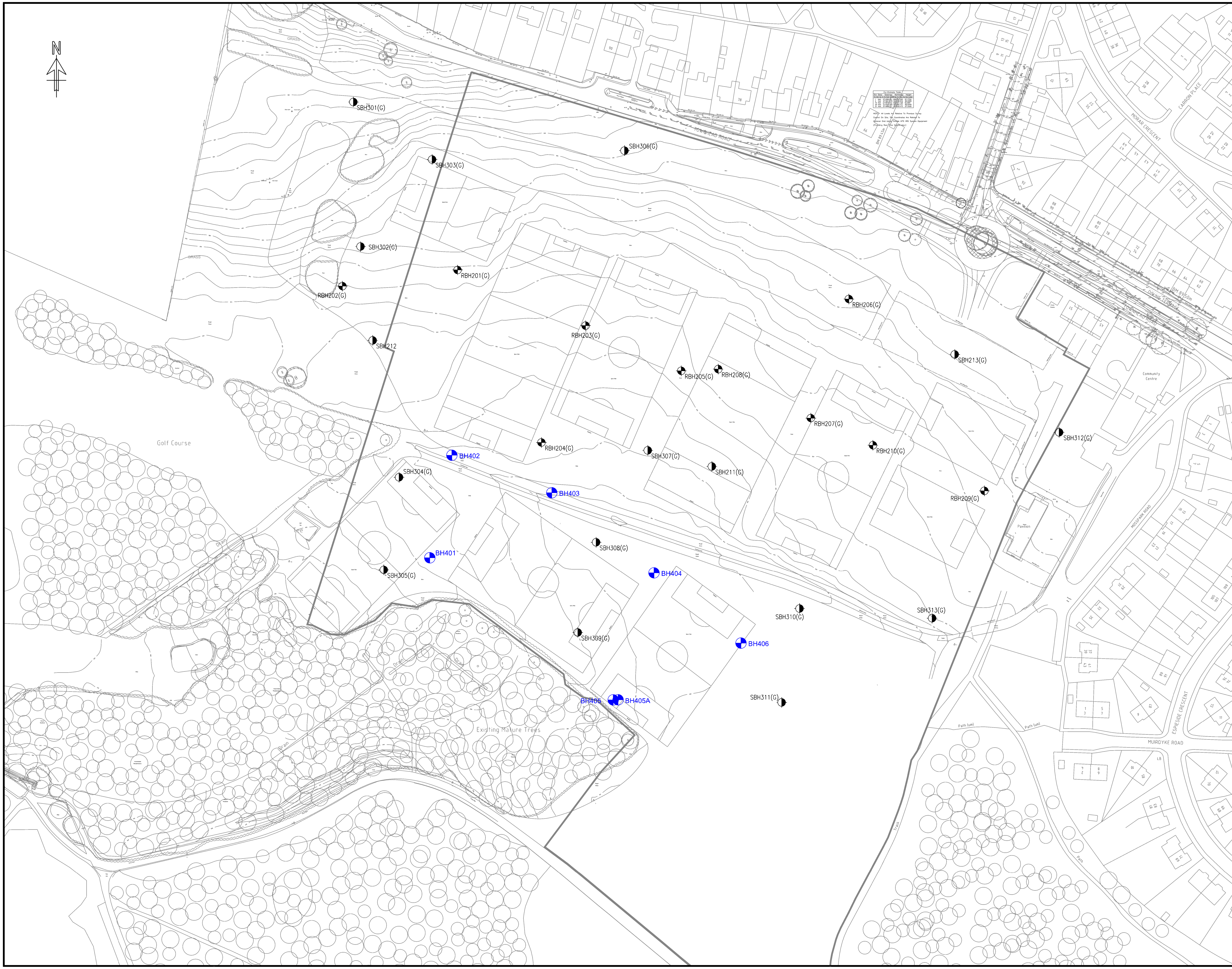
PROJECT
ST AMBROSE HIGH SCHOOL & DRUMPARK ASN

TITLE
PROPOSED SITE PLAN

CLIENT
NORTH LANARKSHIRE COUNCIL

JOB No.	DRAWING No.	REVISION
4327	L(0)0001	F
SCALE	DRAWN BY	CHECKED BY
1:1000 @ A1	AC	RD
STATUS		DATE
FOR INFORMATION		05 JUNE 2009



Notes

1. DO NOT SCALE FROM THIS DRAWING
2. ALL DIMENSIONS ARE IN MILLIMETRES U.N.O.
3. ALL HEIGHTS ARE IN METRES ABOVE ORDNANCE DATUM U.N.O.
4. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS AND ENGINEERS DRAWINGS AND SPECIFICATIONS

KEY

- GEOTECHNICS 2009
- URS 2008

Rev	Description	Date	By / Chk	App

INFORMATION

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GROUNDWATER
MONITORING BOREHOLES

Scale:	Date:	Drawn:	Checked:
1:1000 @ A1	AUG 2010	CB	ZM

Drawing No.:	Rev:
7764/E/001	I01

FOR SECTIONS SEE DRAWINGS 7764/E/003 AND 004

A-A B-B C-C D-D E-E

Notes

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4. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS AND ENGINEERS DRAWINGS AND SPECIFICATIONS

KEY

- GEOTECHNICS 2009
- URS 2006
- URS 2008
- URS ROTARY BOREHOLES, MINING INVESTIGATION 2008 (APPROXIMATE LOCATIONS)

Rev	Description	Date	By	Chk	App
I01	FOR INFORMATION	20/09/2010	JH	ZM	ZM

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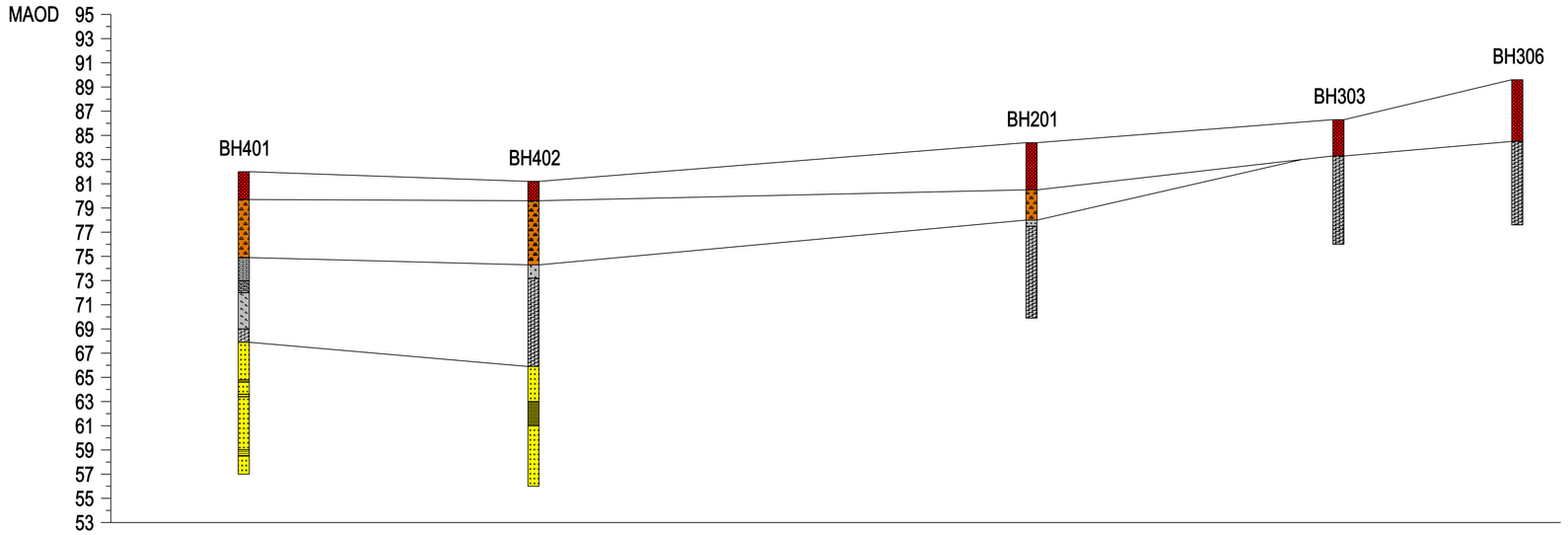
GEOLOGICAL CROSS SECTIONS & EXPLORATORY HOLE LOCATION PLAN (1 OF 3)

Scale:	Date:	Drawn:	Checked:
1:1000 @ A1	SEPT 2010	JH	ZM

Drawing No.:	Rev:
7764/E/002	I01



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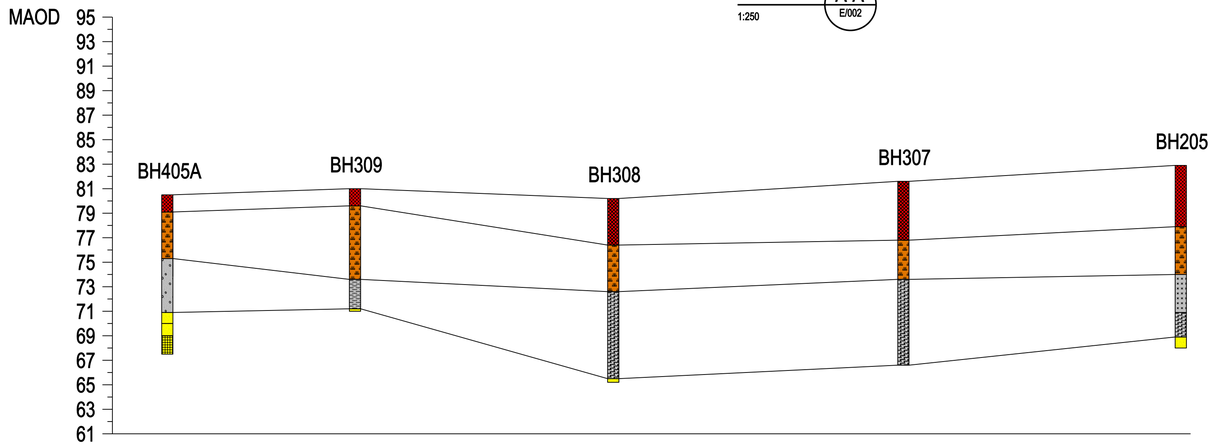

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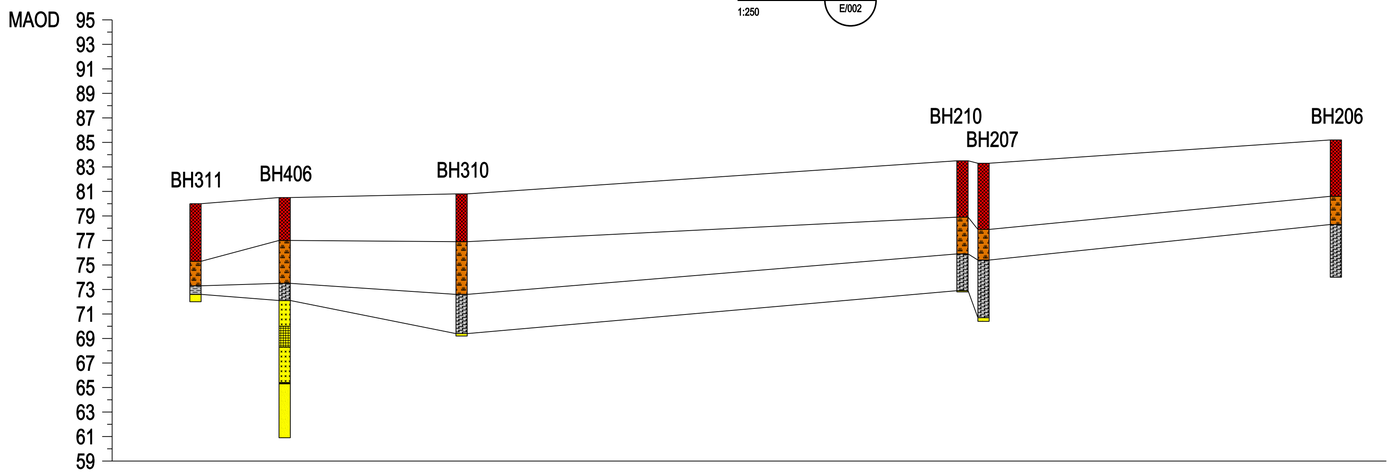

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Notes

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4. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS AND ENGINEERS DRAWINGS AND SPECIFICATIONS

KEY

- MADE GROUND
- PEAT
- GLACIOMARINE DEPOSITS
- SANDSTONE
- MUDSTONE
- SILTSTONE
- COAL
- VOID
- BROKEN GROUND

Rev	Description	Date	By / Chk	App
I02	FOR INFORMATION	20/09/2010	JH / ZM	ZM
I01	FOR INFORMATION	17/09/2010	RC / ZM	ZM

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GEOLOGICAL CROSS SECTIONS (SHEET 2 OF 3)

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1:250 @ A1	SEP 2010	RC	ZM

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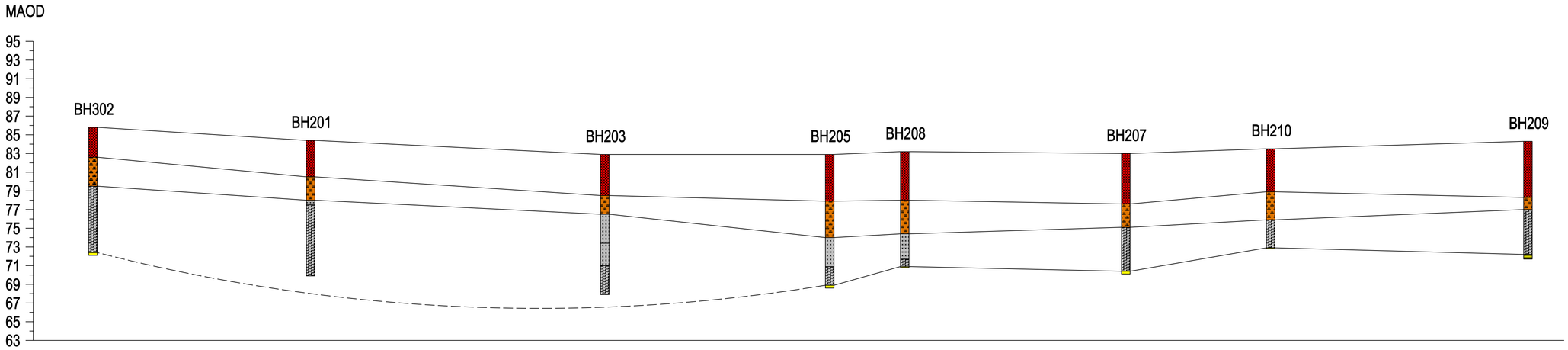
7764/E/003	I02



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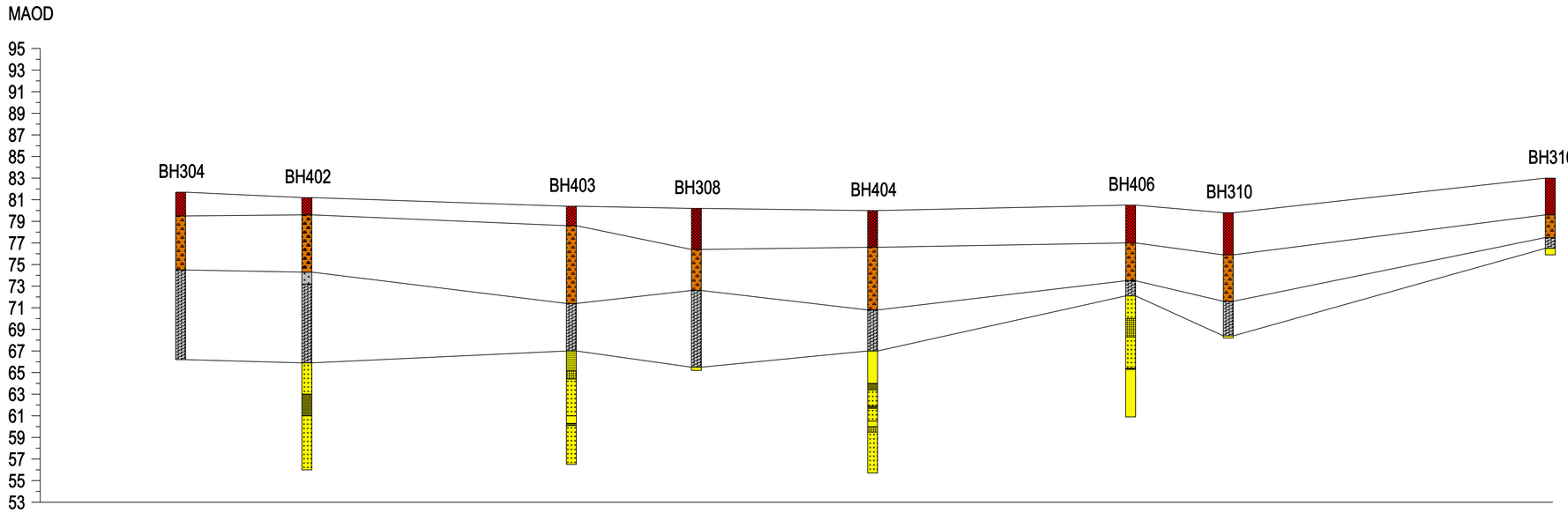

SECTION E-E
1:250 E/002

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4. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL RELEVANT ARCHITECTS AND ENGINEERS DRAWINGS AND SPECIFICATIONS

KEY

- MADE GROUND
- PEAT
- GLACIOMARINE DEPOSITS
- SANDSTONE
- MUDSTONE
- SILTSTONE
- COAL
- VOID
- BROKEN GROUND

Rev	Description	Date	By / Chk	App
I02	FOR INFORMATION	20/09 2010	JH / ZM	ZM
I01	FOR INFORMATION	17/09 2010	RC / ZM	ZM

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GEOLOGICAL
CROSS SECTIONS
(SHEET 3 OF 3)

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1:1000 @ A1	SEP 2010	RC	ZM

Drawing No.:	Rev:
7764/E/004	I02