Appendix 2:
Geology and hydrogeology

IN THE MATTER OF AN APPLICATION FOR PERMISSION
IN ACCORDANCE WITH SECTION 37E OF THE
PLANNING AND DEVELOPMENT ACTS, 2000 TO 2010

TO AN BORD PLEANÁLA

(ABP No. PL06F.PA0018)

AND IN THE MATTER OF AN ORAL HEARING

Statement of Evidence of Eugene Daly, Jenny Lightfoot,
Gareth Ll Jones and Catherine Buckley

This is a joint submission on geology, hydrogeology and contaminant modelling prepared by Eugene Daly, Jenny Lightfoot, Gareth Jones and Catherine Buckley.

1. Qualifications and Experience

Eugene Daly

My name is Eugene Daly. I hold a B.Sc. from University College Dublin (1968), an M.S. from North Carolina State University at Raleigh (1971) in Hydrology and Water Resources and a Diploma in Business Management from Trinity College Dublin (1975). I am a Professional Geologist (1999) and a member of the European Federation of Geologists (2002).

I am currently the manager of Eugene Daly Associates which I set up in 1995, specialising in groundwater, hydrological and environmental work. Prior to this I was employed by the Geological Survey of Ireland from 1971 to 1995.

My experience includes the following projects related to general hydrogeology and waste disposal:

- 2006 – 2007 (EDA): Co-authored report on Guidelines on Procedures for Treatment and Assessment of Geology, Hydrology and Hydrogeology on National Road Schemes.
- 2004 (EDA): Technical Advisor to Inspector (An Bord Pleanala) for the proposal to develop a municipal landfill at Garrynagree, Dungarvan, Co. Waterford.
- 1999 (EDA): Preparation of a waste licence application, to the Environmental Protection Agency, for a landfilling operation at Pollardstown, County Kildare.
- 1998-2002 (EDA): Assessment of the hydrogeological aspects of an existing large landfill site, at Kilcullen, County Kildare, from which landfill gases were found to have migrated to a number of occupied dwellings. Reporting to solicitors representing homeowners who had to vacate their homes. Subsequently made submission to EPA on Agency's Proposed Decision to grant a licence.

- 1995 (EDA): Independent review of the hydrogeological aspects of the proposed municipal landfill site at Powerstown, County Dublin. Work included the supervision and preparation of the hydrogeological report submitted to An Bord Pleanala (planning board) and giving technical evidence. For National Toll Roads/ Fehily/Timoney Associates.
- 1981-1984 (GSI): Preliminary investigation of 10 potential landfill sites in Counties Carlow, Kilkenny, Monaghan and Tipperary (NR). Assessment of an application to establish a tiphead at Ardriston, County Carlow. Investigation and assessment of a proposal to use a worked out dolomite quarry, in County Kilkenny, as a landfill site. Work carried out for the Local Authorities.

Gareth Ll Jones

Gareth Llwyd Jones is a Professional Geologist accredited by the Institute of Geologists of Ireland and the European Federation of Geologists. He holds a bachelors degree (BSc) in Geology from Queens University, Belfast (1975) and a Masters Degree (MSc) in Geology from Trinity College Dublin (1977).

Gareth currently manages the geological consultancy Conodate which he set up in 1984 to provide general geological services and also specialises in microfossils to provide biostratigraphic services to the mineral and oil exploration industries. Prior to this Gareth was Senior Exploration Geologist with Aquitaine Mining (Ireland) Ltd. Gareth works in Geological mapping, Petrographic Analysis, Karst Interpretation, Industrial Minerals and Geothermal Energy. He has lectured at TCD, UCG and DIT and is a UCD Research Associate.

Gareth has written many papers on these topics and edited various publications. He belongs to the Micropalæontology Society, Irish Association for Economic Geology and Speleological Union of Ireland. He is Past President of the Irish Association for Economic Geology (1992), of the European Federation of Geologists (1999-2002) and of the Institute of Geologists of Ireland (2005-2007), he is a Board member of the Geothermal Association of Ireland.

Books & papers include:

- Strogen, P., Somerville, I.D. & Jones, G.Ll. (eds) 1996 Recent Advances in Lower Carboniferous Geology. Geological Society, SP107, 463pp.

- Jones, G.Ll., Burns, G., Fogg, T. & Kelly, J.G. 1997. The Caves of Fermanagh and Cavan. Lough Nilly Press, 128pp.
- Jones, G.Ll. & Somerville, I.D. 1996. Irish Dinantian biostratigraphy: practical application. In: Recent Advances in Lower Carboniferous Geology. 107, 371-385.
- Jones, G.Ll. 2005. Geology, The Profession. In: Encyclopædia of Geology (R.C. Selley, L.R.M. Cocks & I.R. Plimer, eds), Elsevier, Oxford, 3, 73-77.
- Goodman, R., Jones, G.Ll., Kelly, J.G. 2010. Methodology in Assessment and Presentation of Low Enthalpy Geothermal Resources in Ireland. Proc. World Geothermal Congress 2010, Bali, Indonesia, 25-29 April, 2010. 5pp.

Jenny Lightfoot

Jenny Lightfoot is a Chartered Geologist accredited by the Geological Society of London. She holds a Bachelors degree (B.Sc) in Geological Science from University of Leeds (1991) as well as a Masters degree in hydrogeology from the Birmingham University (1992). Jenny has practiced as a professional hydrogeologist since 1992, as an environmental consultant and environmental regulator.

Since 2001 Jenny have been employed by Ove Arup and Partners Ltd based in Leeds as a hydrogeologist and has undertaken a diverse range of hydrogeological studies in the UK and overseas. However her focus has been contaminant hydrogeology, including studies relating to landfills and waste management facilities, industrially contaminated land, and pollution of water supplies.

From 1996 to 2001 Jenny was a hydrogeologist for the Environment Agency in Yorkshire, specialising in contaminant hydrogeology. From 1999 she held the position of Groundwater and Contaminated Land Team Leader for North East Region Ridings Area. This role involved management of the regulatory team responsible for protecting groundwater quality from hazards such as landfill, contaminated land, pollution incidents and the effective management of groundwater resources in Yorkshire. In this role Jenny was responsible for the review of hydrogeological aspects of planning and permit applications for new landfill sites and extensions to existing sites.

Following graduation until 1995 she was a hydrogeologist for the environmental consultancy Geraghty and Miller International (now Arcadis) based in Cambridge.

Jenny undertook investigations and assessments of several historical landfill sites as well as planning application preparation for a new landfill site, and numerous investigations and risk assessments of industrially contaminated land.

Jennys experience includes the following projects related to general hydrogeology and waste disposal:

- 2010-ongoing (Arup): Hengrove Farm Landfill, London. Preparation of Environmental Permit application for major extension to large inert landfill in west London.
- 2004 – on-going (Arup): Macaulay Lane Landfill Site, Grimsby. Technical advisor to North East Lincolnshire Council in relation to risks associated with Macaulay Lane Landfill, a 25 hectare closed site adjacent to railways lines, River Freshney, housing and allotments. Detailed quantitative risk assessment using LandSim assessed risks to the underlying Chalk aquifer
- 2010 (Arup): Bleak Hill Landfill Environmental Permit Application, Hampshire. Preparation of Environmental Permit application for large inert landfill in Hampshire.
- 2007 – 2010 (Arup): Convamore Road Landfill Investigation and Risk Assessment, Grimsby. Project manager for the highly sensitive assessment of landfilled clay pits beneath school playing fields and buildings, overlying the Chalk aquifer, for North East Lincolnshire Council. The study comprised desk study, followed by ground investigation and monitoring, detailed quantitative risk assessment and identification of remedial options.
- 1996 – 2001 (Environment Agency, UK): Review of planning and licence applications for new landfill sites and extensions, and regulation of problem sites, Environment Agency. From 1996 to 2001 Jenny was employed by the Environment Agency and responsible for assessment of the hydrogeological aspects of all applications for new landfill sites or extensions in Ridings Area of North East Region of the Environment Agency (approximately covering West, South and East Yorkshire). She reviewed over 20 risk assessments, including many assessed using Landsim and I was involved the regulation of over landfill 30 sites with significant groundwater pollution.
- 1995 (Geraghty and Miller International): Secondment to Wastewise, Beverley. Jenny was seconded to work for a major landfill operator in East

Yorkshire, Wastewise, to assist with hydrogeological studies on several of their sites.

- 1995 (Geraghty and Miller International): The Effects of Old Landfill Sites on Groundwater Quality, NRA R&D Note 415. Jenny co-authored this National Rivers Authority R&D Report assessing and prioritising all historical landfill sites in England and Wales identified by NRA officers.
- 1994 – 1995 (Geraghty and Miller International): Seamer Carr Landfill Site Planning Application for Extension, Scarborough. Jenny was the lead hydrogeologist in the preparation of planning application and Environmental Statement including hydrogeological risk assessment for an extension to an existing site in a hydrogeologically sensitive location.
- 1993-1994 (Geraghty and Miller International): An Assessment of the Hydrogeology of Lakenham Common Landfill, Norwich. Jenny was the lead hydrogeologist on this project to assess the hydrogeology of this closed landfill overlying alluvium and chalk adjacent to the River Yare near Norwich. The project included assessment of leachate generation and migration mechanisms, risk assessment and recommendations to ensure appropriate mitigation of risks to surface and groundwater.

Catherine Buckley

Catherine Buckley is a hydrogeologist with Bachelors Degree in Geology from Trinity College Dublin (2004) and a Masters Degree in Hydrogeology from the University of Leeds (2005). She has recently submitted her application for professional geologist status to the Institute of Geologists of Ireland.

Catherine joined Arup (Dublin Office) as a Hydrogeologist in the Ground Engineering group in July 2008. Prior to this Catherine worked as a hydrogeologist for Capita Symonds in the UK.

In the contaminated land field her project experience includes groundwater flow modelling, contaminant fate transport modelling, site specific remedial strategies, groundwater monitoring, contaminated land site investigation, human health and controlled water risk assessments.

- 2010 (Arup): Developed a conceptual model and undertook a Quantitative Risk Assessment for the proposed Rathcoole cemetery in South County Dublin
- 2009 (Arup): Developed a phased program of work to establish the source and extent of an oil spill encountered in a forest and recommended a remedial strategy for the site.
- 2007-2008 (Capita Symonds): Prepared the Site Specific Remediation Strategy for Construction Zone 4 of the London 2012 Olympic Park which included undertaking a Detailed Quantitative Risk Assessment. Reviewed and commented on SSRS's prepared by other consultants for other construction zones on the Olympic park
- 2005 – 2008 (Capita Symonds): Undertook a detailed Quantitative Risk Assessment for a port regeneration scheme in Cumbria.
- 2006 (Capita Symonds): Constructed a numerical model and undertook risk assessment to assess the risk from a historic landfill in east London. The results of the numerical model were used to develop the remediation plan for the site.

2. Role in Proposed Development

My role in the proposed integrated waste management facility (for the acceptance and land-filling of non-biodegradable, inert, non-hazardous and hazardous waste) at Hollywood Great, Nag's Head, Naul, County Dublin was as lead hydrogeological consultant providing overall direction and peer review.

In this role I have responsibility for managing and overseeing the hydrogeological assessment. As part of the assessment specialist advice was sought where necessary from Gareth Jones (Conodate) with regard to geological mapping and palaeotonological interpretation and from Jenny Lightfoot (Arup) with regard to contaminant modelling. I was assisted by Catherine Buckley from Arup who worked under my direction.

3. Key Issues

3.1 Introduction

This brief summarises the natural characteristics of the site of the proposed MEHL development and its immediate surroundings, in terms of soils, geology and hydrogeology. In addition, this brief summarises the suitability of the site in terms of its receiving geology and hydrogeology for the siting of an integrated waste management facility.

An assessment was made of the potential impact of the proposed MEHL development on the soils, geology and hydrogeology and where required, mitigating measures are put forward to reduce and/or remove the potential impact of the proposed development. This assessment was described in full in the EIS document and is summarised in this document.

In order to define the geological and hydrogeological regime a series of studies and investigations were undertaken. These investigations were an iterative process which allowed the hydrogeological regime to be further redefined and understood as more information became available.

The iterative process followed for data collection and the generation of the hydrogeological conceptual model was as follows:

- Geological field mapping was undertaken by Gareth Jones as the first step in order to assess the actual location of the Loughshinny Formation on the site. This allowed a site specific geological map to be created based on rock exposures in the field. Gareth recommended that geophysical surveys and intrusive investigation be undertaken on the site to further delineate the geological boundaries.
- A desk study review of existing information for the area was undertaken, including a review of information submitted by Fingal County Council for the Tooman-Nevitt landfill application which is located approximately 1.5 km to the east of the MEHL facility.
- This was followed by a preliminary geophysical survey carried out by Apex Geoservices Ltd. This trial was carried out over a wide area using a variety of techniques and highlighted areas which would be useful for further study

- A detailed geophysical survey was undertaken following the preliminary survey (again by by Apex Geoservices Ltd.)
- Well remediation was undertaken on the existing monitoring wells to ensure they were performing correctly
- A phase of intrusive site investigation was undertaken which included drilling for cores, monitoring well drilling and pumping well drilling.
- A series of field testing was undertaken including infiltration testing, permeability testing and groundwater level and quality monitoring.
- A well survey was undertaken in the surrounding area to identify local domestic and business wells abstracting groundwater.

These tests allowed the initial conceptual model to be refined and improved where necessary.

3.2 Description of existing environment:

The broad study area for the EIS generally incorporated the land from Naul in the northwest to Portrane and the Rogerstown Estuary in the southeast. The local or site-specific area of study incorporated the existing MEHL Facility including the completed cells and the immediate surrounding lands.

3.2.1 Regional Geological Setting

Several lithologies are reported from the area around Hollywood (Geological Survey of Ireland – Geology of Meath, 2001) as shown on Figure 1. The rocks underlying the area around the site can be described, from youngest to oldest formation, as belonging to the following formations within the Carboniferous Period:

- Walshestown Formation
- Balrickard Formation
- Loughshinny Formation
- Naul Formation
- Lucan Formation

As will be seen below, an additional formation, the Donore formation, is considered to be present in the site but is not shown in the GSI map.

From the GSI map of the area (Sheet 13), the Carboniferous rock units (Walshestown Formation, Balrickard Formation, Loughshinny Formation and Naul Formation) are folded into a gentle syncline (bowl-shaped fold), whose axis runs roughly WNW-ESE, north of the MEHL site. The Walshestown Formation occupies the centre of the fold, surrounded in sequence by the Balrickard Formation, Loughshinny Formation and the Naul Formation to the south.

The affect of this synclinal structure is to bury the Loughshinny Formation even deeper than would be expected had the rocks in the area not been folded. The Loughshinny Formation is dipping in towards the centre of the syncline, resulting in it becoming deeper as it is traced northwards.

Along with the deformation features like the syncline, a number of faults are present in the locality, generally trending N-S or NE-SW. These faults in some cases form contacts between various formations. There are most likely more faults which have not been identified present in the area, as faulting is ubiquitous in the geological strata in Ireland.

The Quaternary (subsoil) strata data are scarce for this area. The information presented in the Teagasc Soil Maps presented on the GSI website describes these soils as tills containing material derived from Namurian Shales and Sandstones

3.2.2 Regional Hydrological Setting

Figure 2 shows the river catchments for the north Fingal and south east Meath area. This region is drained by four river systems that discharge into the Irish Sea. To the north lies the Delvin River and which discharges at the coast between Laytown and Balbriggan. The southern part of the region is drained by the Rogerstown River which flows into Rogerstown Estuary. The eastern area consists of two smaller catchments one of which is drained by the Balbriggan River while the other is drained by a network of small rivers that flow into the sea between Skerries and the Rogerstown Estuary.

Figure 2 shows that the MEHL landfill lies within the catchment of the Rogerstown River about 1 km to the south of the catchment divide with the Delvin River. The planned Nevitt / Tooman landfill is also located in the catchment of the Rogerstown River with its foot print being less than 500m distant from the same catchment divide. The drainage direction in the vicinity of both landfills is south eastwards towards the Rogerstown Estuary.

The Bog of the Ring wellfield (see below) is located within the Delvin and Balbriggan River catchments.

3.2.3 Regional Hydrogeological Setting

The groundwater catchments of the river system are fixed by topography and unlikely to vary much with the seasons. The groundwater divide that encloses the Bog of the Ring is also defined by the GSI on topography.

The rocks in the area can be divided into a Locally Important aquifer (Loughshinny Formation) and Poor aquifer (aquitard). The latter are the Donore Formation, the Balrickard Formation and the Walshestown Formation, all of which are Namurian deposits.

The Loughshinny Formation is characterised as being moderately productive bedrock. Well records indicate that there are numerous wells which tap the Loughshinny Formation with yields of over 100m^3/day. Typical specific capacities range from 5 – 150 m^3/day and transmissivities up to 1000 m^2/day have been recorded.

The flow regime in the rocks of the Loughshinny Formation will be dominated by fracture flow and movement through weathered zones with the majority of the storage being in the fractures. There will be little to no storage and groundwater movement though the matrix of the rock.

The hydraulic characteristics of the Namurian deposits will vary depending on the lithologies present. Areas of low permeability material such as the siltstones of the Walshestown Formation will allow very little groundwater movement. However weathered or fractured zones in or around the material will allow some groundwater movement through the deposits and may hydraulically connect different lithologies.

Groundwater flow in the vicinity of the both the MEHL and the Nevitt / Tooman landfills will be in a general south easterly direction towards Rogerstown Estuary corresponding with the drainage and topography (Figure 3). The MEHL landfill is over 1km distant from the groundwater divide. The footprint of Nevitt / Tooman landfill is less 500m from the same groundwater divide.

Figure 4 shows the groundwater catchments for the north Fingal and south east Meath area. The groundwater catchments are defined by the local topography with the catchment of the Bog of the Ring well field supplied by the Geological Survey of Ireland (GSI website).

Groundwater flow will largely follow that of the main river channels and towards the coastline except within the Bog of the Ring catchment where groundwater flow will be towards the production well sites (due to pumping at the wells) and from the catchment divides that define the zone of contribution.

The GSI have defined a groundwater divide to the north of the MEHL site. A groundwater divide is a topographical divide in the water table which causes groundwater to flow away from the topographically high area. This is shown in Figure 4.

The presence of a groundwater divide to the north of the MEHL site ensures that all groundwater to the north of the divide will flow towards the well field while to the south of the divide [the MEHL side] the groundwater will flow away from the Bog of the Ring production well sites and towards the Rogerstown River and ultimately the estuary. Therefore, there is no possibility of groundwater flowing across the no flow groundwater divide. In the planning application for the Tooman-Nevitt site Fingal County Council showed this divide is further to the north than the GSI have defined it to be

Water quality in the Loughshinny Formation is always hard (usually over 250 mg/l, often over 300 mg/l as CaCO3). Groundwater samples are routinely collected at the Bog of the Ring water supply which abstracts water from the Loughshinny Formation. The water data from Bog of the Ring are typical of what would be expected from a limestone source. High hardness, alkalinity and Electrical Conductivity (EC) values were observed. Sulphate and chloride values range from 22-82 mg/l and 23-31 mg/l, respectively. Chloride values of this concentration can sometimes indicate organic contamination however in this case they are more likely to be due to the proximity to the coast.

3.2.4 Groundwater Resources

The GSI hold a record of groundwater wells in the area, however this list is not exhaustive. A well survey was undertaken to establish if any wells were present in the area which were not identified on the GSI database. The well survey identified only 3 properties in the area which have wells abstracting from groundwater. Only one of these wells was located down-gradient of the site and was at a distance of 1 km from the MEHL site boundary.

3.2.4.1 Bog of the Ring

Fingal County Council has developed a well field in the Loughshinny Formation at the Bog of the Ring that supplies up to 4,000 m3/day to Balbriggan and its environs.

Figure 2 shows the Bog of the Ring well field straddling the catchment divide between the Delvin River and the Balbriggan River. The four production well sites are located between 1 and 2 kms to the north of the catchment divide with the Rogerstown River. Surface water drainage in the vicinity of the Bog of the Ring Well field is northwards.

Recent monitoring reports have suggested that the supply is in decline “the regional water table is in long term decline and has not reached a steady state at the end of 2005” (Dublin City Council, 2008). This is consistent with the ERBD findings that the aquifer is currently at risk from potential over abstraction” (Collins and Herlihy, 2007).

In the evidence given at the Tooman-Nevitt oral hearing Fingal County Council (Mark Conroy, TES Consulting) stated that:

"There is no significant scope for increasing abstraction from the Bog of the Ring aquifer without an unsustainable enlargement of the catchment area".

This indicates that if pumping rates were increased at Bog of the Ring, the supply would be unsustainable. Therefore the zone of contribution around the well will not increase in the future as the aquifer cannot support it.

The groundwater contour maps produced by Fingal County Council for the Tooman-Nevitt site illustrate that the Bog of the Ring is obtaining its recharge from the geological strata in the well-field. If the well was abstracting water from the faults near the MEHL and Tooman-Nevitt sitese then the contours would be influenced at the locations in the well-field area.

3.2.5 Geology and Hydrogeology of the MEHL site

The GSI map of the area is shown in Figure 1 shows the site to be mainly underlain by the Loughshinny Formation (interbedded limestones and shales). On the basis of site specific data collected, the geological map for the site was redefined as shown in Figure 5. This data showed that the Loughshinny Formation is limited to the southern extent of the site, while Namurian deposits consisting of the Donore Formation (limestone or sandstone with shale), Balrickard Formation (sandstone with shale) and Walshestown Formations (black shale beds with occasional sandstone, siltstone and limestone beds) underlie the majority of the site. A schematic cross-section can be seen in Figure 6.

Hydrogeologically, the bedrock beneath this former quarry site can be divided into;

- an aquifer unit (a body of rock which stores and transmits water): the Loughshinny Formation and the lower part of the overlying Donore Formation and
- an aquitard unit (a body of rock which limits the movement of water): the upper part of the Donore Formation and the overlying Balrickard Formation and Walshestown Formation.

The aquifer unit is classified by the GSI as a Locally Important Aquifer which is moderately productive and the aquitard as a Poor Aquifer.

It should be noted that all sub-soil and bedrock material in Ireland have been classified as an aquifer (Poor, Locally Important or Regionally Important) including material such as clays and shales which are known to act as aquitards.

The majority of the site is underlain by the aquitard. The limestones of the Loughshinny Formation crop out in the southern part of the MEHL site and dip to the north, where they are covered by at least 10 m and up to 60 m or more of aquitard strata in the northern parts of the site.

Two faults have been mapped in the central part of the site, a N-S fault which appears to restrict groundwater movement and an E-W fault which does not. The latter appears to bring permeable horizons in the aquitard unit in contact with the aquifer.

Permeability in the strata beneath the site is predominantly secondary in the form of joints, fractures, weathered/broken zones and faults. Permeability in the aquifer unit is of the order of $10^{-4}/10^{-5}$m/s. In the permeable horizons of the aquitard, permeability is of the order of 10^{-6} m/s and in the remainder of the strata it is of the order of $10^{-7}/10^{-8}$m/s. Storage in all of these strata is low.

The aquitard strata on-site act as a low permeability layer and confine/isolate groundwaters within the aquifer from the surface.

The groundwater levels in the aquifer unit are relatively consistent across the site and lie below the floor of the quarry aside from the large pond in the extreme southern part of the site. Groundwater levels in the overlying aquitard strata are more variable, are elevated in relation to those in the underlying aquifer and are artesian in certain horizons. This confirms their position on-site as a confining layer.

Groundwater flows in a generally south easterly direction from the site at a gradient of 0.02-0.05 and a velocity of approximately 1.48×10^{-5} m/s as calculated based on site specific data.

Groundwater level monitoring indicate that recharge/infiltration is slow and relatively low responding to seasonal rainfall rather than individual rainfall events. This indicates that storage is low in these strata.

The site is located in the upper part of a groundwater catchment. This location, the general absence of large springs in the aquifer, the confined nature of much of the aquifer in the site area and the moderate gradient and velocity indicate that the natural groundwater throughput in the aquifer is relatively low.

The hydraulic boundaries of the aquifer in the vicinity of the MEHL site are the confined zone to the north, a groundwater divide to the west, and a small stream and a formation boundary to the south. Down-gradient and to the east the aquifer width narrows and it probably discharges to a tributary of the small stream that adjoins the northern boundary of the site.

As part of the current waste licence conditions MEHL has been collecting groundwater quality samples on a quarterly basis. Groundwater samples were collected from all the monitoring points on site, both the existing and the new ones. The groundwater beneath the site is hard, with concentrations of approximately 200 mg/l $CaCO_3$. This is characteristic of limestone deposits and even higher readings would be realistic.

The vulnerability of the site (the Loughshinny aquifer) has been classified based on site specific data using the principles of the GSI guidelines. Over the majority of the site the vulnerability rating can be described as Moderate due to the natural protection provided by the Namurian deposits. The site investigation demonstrated that in the northern area there was at least 10 and up to 60 m (and more) of low to moderate permeability material overlying the aquifer. Based on the GSI vulnerability mapping guidelines (see figure 7) the vulnerability rating of Moderate (M) can be applied to the site based on site specific data. To the south of the site where the Loughshinny outcrops, the vulnerability rating without engineering measures in place is presently Extreme (E).

3.3 POTENTIAL IMPACTS ARISING FROM PROPOSED DEVELOPMENT

The aspect of the proposed MEHL development which has the potential to impact on the soils and geology of the site is the loss of the Geological Heritage Area. The MEHL quarry is to be back filled as part of its present planning permission and therefore the exposed quarry faces will eventually disappear in a 20 to 30 year period.

The aspects of the proposed MEHL development which have the potential to impact on the hydrogeology of the site are:

A confined aquifer underlies the MEHL site with varying degrees of vulnerability as a result of quarrying. The aquifer deposits outcrop to the south of the site and then dip northwards until they are confined by over 60 m of low permeability Namurian deposits in the north of the site.

The main potential impacts which could occur from activities at the MEHL site have been identified as:

- Contamination of the aquifer and dependent receptors such as wells or the stream to the east of the site.
- Groundwater resources: sterilisation of resource.

The different waste types proposed will each pose a different potential risk to identified aquifer beneath the MEHL site. Hazardous and non-hazardous wastes could potentially impact the groundwater quality with the hazardous posing the highest risk. The inert waste will pose little or no risk to groundwater.
The potential risk to groundwater from each waste type will be dependent on where the waste will be placed. Waste located on the south-eastern corner of the excavation is the area with the highest potential risk to groundwater while waste located in the northern part of the site will be afforded the highest level of natural protection.

Faulting was identified on site in the course of this assessment, however the EPA manual on site selection (2006) states that '*It is recommended that there should be no general prohibition of landfill siting on areas with geological faults. Rather, attention should be drawn to them by noting firstly that they are ubiquitous in Irish bedrock, that they often increase the permeability somewhat, and that investigations should take account of their possible presence. Construction of potentially polluting landfills in direct contact with faults should be avoided in situations where investigations show that the fault zone is excessively permeable*.'

The placement of the waste with regard to the distribution of the aquifers on the site is as follows:

- Locally Important Aquifer: Inert waste and non-hazardous waste
- Poor Aquifer: Hazardous waste and some non-hazardous waste

3.3.1 Contamination of the aquifer

When considering the potential for groundwater contamination regard was had to the GSI guidance document 'Groundwater Protection Responses for Landfills' (1999). This document was prepared for the placement of non-hazardous wastes however the GSI has stated that its principles could also be applied to hazardous and inert waste sites. This matrix is presented in Figure 8. It should be noted that this document predates the Landfill Directive.

The majority of the site falls within the $R2_1$ classification , i.e where a poor aquifer is classed as having a moderate vulnerability.

$R2_1$: Acceptable subject to guidance outlined in the EPA Landfill Design Manual or conditions of a waste licence.

The Loughshinny Formation is exposed in the southern corner of the site and in the absence of a protective layer is classed as extremely vulnerable. A protective layer to the Loughshinny Formation was originally in place but was removed through the historical quarrying operations at the site. Having regard to the GSI vulnerability matrix and in order to provide additional comfort, it was considered appropriate to engineer a protective layer beneath the proposed landfill liner such that the vulnerability of the outcrop on the southern portion of site could be considered moderate rather than extreme. Such engineered solutions are entirely consistent with the provisions of the Landfill Directive. This material will be constructed below the liner system and will be designed to replace the natural material removed from the site during the quarrying process. This enhanced protection layer will offer additional protection to the aquifer in the southern corner where the aquifer is currently exposed.

In order to calculate the degree of impermeability required, the EIS made a conservative assumption that the material in the enhanced protection layer should be calibrated by reference to material having a permeability equivalent to 1 x 10^{-9} m/s material notwithstanding that this figure is far in excess of any naturally occurring sub-soils. The EIS provides for 1 m of such material with a permeability of 6.6 x 10^{-10} m/s. This has been re-calculated for the purpose of this hearing and it is noted that this is equivalent to 3 m of material with a permeability of 1 x 10^{-9} m/s. It is therefore proposed to provide 1 m of material with a permeability of 6.0 x 10^{-10} m/s which is equivalent to 5m of 1.0 x 10^{-9} m/s clay. It should be noted that this enhanced protection layer (and indeed that provided for in the EIS) dramatically exceeds the levels of protection provided for in the Landfill Directive even before the landfill liner is put in place. It is also far in excess of the levels of protection provided by naturally occurring sub-soils on the sites of many other landfills in Ireland. For instance it is equivalent to over 100 m of the material found at the Tooman-Nevitt site which has subsoil permeabilities ranging from 10^{-5} to 10^{-7} m/s.

With the application of the protective layer the vulnerability of the southern part of the site can conservatively be classified as Moderate and so this part of the site falls within the $R2_2$ classification. Application of these engineered measures is consistent with the Landfill Directive and the EPA Landfill Design Manual. For clarity, without that protective layer, a [small portion of] the southern part of the site would be considered to fall within the $R3_2$ classification.

$R2_2$: Acceptable subject to guidance outlined in the EPA Landfill Design Manual or conditions of a waste licence.

In order to assess the potential risk to groundwater beneath the site a Quantitative Risk Assessment using the programme LandSim v2.5 was undertaken for the proposed development. This concluded that down-gradient wells and streams would not be impacted by the proposed development.

3.3.1.1 Potential impact to Bog of the Ring

Prior to work beginning on the MEHL application an assessment was undertaken as to whether there was any potential for the Bog of the Ring to be impacted. Based on the extensive investigations undertaken at the Tooman-Nevitt site and the demonstration there that any potential contamination would not enter the Bog of the Ring Zone of Contribution it was decided to proceed with assessing whether the MEHL site would also have no impact on the Bog of the Ring.

The regional and site specific data demonstrates that there will be no impact on the Bog of the Ring from the proposed development due to the hydrogeological conditions of the site as summarised below:

- The groundwater flow direction beneath the site is to the south east, away from the Bog of the Ring
- The Bog of the Ring and the MEHL site are located in different groundwater and surface water catchments
- The MEHL site lies outside the catchment and zone of contribution of the Bog of the Ring well field.
- There is a groundwater divide located between the Bog of the Ring and the MEHL site. Groundwater will not cross this divide (Figure 9)
- The groundwater contours show that at Bog of the Ring, the groundwater is not been drawn from the faults as the contours show no interference with the fault zones. If the Bog of the Ring was abstracting significant amounts of water from faults in the area the contours would be influenced by the faults.
- The syncline of low permeability strata that extend to about -300 mOD between the MEHL site and the Bog of the Ring well-field (Figure 10)

3.3.2 Sterilisation of resources

The proposed development means, as it is at present, that no groundwater wells will be installed on the MEHL site.

3.4 MITIGATION MEASURES PROPOSED

A summary of the main mitigation measures for each waste type is outlined below and full details can be found in Chapter 14 of the EIS.

3.4.1 Mitigation Measures for Inert Waste

- The inert waste will be placed above the piezometric head of the water table.
- It is proposed to place inert waste on the area of the site where the aquifer outcrops. This area will be backfilled to 102.5 mOD to bring it above the water table before any of the mitigation measures are put in place or the engineered liner and subsequent inert waste is placed.
- The inert material will be placed in cells lined with low permeability clay 1 m thick which will be designed in line with EU regulations and EPA guidance.

3.4.2 Mitigation Measures For Non-Hazardous Waste

- Non-hazardous waste cells will be lined with a 2 mm thick HDPE liner and 1 m thick low permeability clay which will be designed in line with EU regulations and EPA guidelines.
- As the non-hazardous material is to be placed in the south of the site where the aquifer is shallower, an additional 1 m of low permeability natural material with a permeability of $6x10^{-10}$ m/s will be placed beneath the liner to enhance the natural protection.
- The head of leachate in the cells will be limited to 1m within the non-hazardous cells.

3.4.3 Mitigation Measures For Hazardous Waste

- Hazardous waste will only be placed on the Poor Aquifer on the site and will not be placed on the Locally Important Aquifer.
- A Dense Ashphaltic Concrete (DAC) liner will be constructed for the cells in which hazardous waste is to be placed.
- In order to minimise leachate generation from the flue gas treatment residues, the fly ash waste will be solidified before being placed in the cells.
- The head of leachate in the cells will be limited to 1m within the hazardous cells.
- The failure of the DAC liner is an unlikely event. However, as the failure of the liner has the potential to cause impacts to groundwater a mitigation measure has been developed for it.

3.5 PREDICTED RESIDUAL IMPACTS (i.e., POST-MITIGATION)

A summary of the impacts to each receptor and the residual impact once mitigation measures have been put in place is outlined in **Table 1.**

The likely significant effects of the project on the soils and geology of the area is considered to be positive, given that the soils will be reused and the MEHL facility will be restored with its former landscape characteristics.

The residual impacts on groundwater are considered to be Imperceptible with the proposed mitigation measures in place.

A Quantitative Risk Assessment was undertaken for the site. The primary model for this exercise was constructed taking into account the proposed mitigation measures outlined above.

A summary of the results of the primary model when all the liners are in place and functioning correctly are presented below:

- No 'hazardous substances' (List 1) in groundwater beneath the site (and therefore none detected at the phantom receptor well)
- 'Non-hazardous pollutants' (List 2) chloride and sulphate present in groundwater beneath the site with a maximum concentration observed after 3000 years and diminishing in the future.
- No contaminants detected at the phantom well receptor above Drinking Water Standards

The residual impacts on groundwater are considered to be Imperceptible with the proposed mitigation measures in place. These are summarised in Table 1 at the end of this submission.

4. Submissions and Responses

The following persons made submissions or responses to the Board in relation to the issues of geology and hydrogeology:

- Fingal County Council;
- Yeomans, Jacqueline;
- Moore, Claire
- Marry, Aideen
- NLAG

4.1 Responses to Fingal County Council Submission 'MEHL Integrated Waste Management Facility: Hydrogeological and Engineering Review' (RPS, 2011)

4.1.1 Responses to items raised in Section 2 'Hydrogeology and Engineering Review'

Query:
'*The developer has limited groundwater flow information for the site and has not tied the flow direction into the regional groundwater environment (e.g. Bog of the Ring, groundwater divide, etc*). '

Response:

- The MEHL site occupies 39.8 ha. Water level data have been obtained from 8 boreholes tapping the Loughshinny Formation and 7 boreholes tapping the Namurian or aquitard strata. This amount of data is sufficient to characterise the groundwater flow regime on the site.
- The geological structure in the area strikes (trends) WNW-ESE.
- Surface water drainage in the area is to the south east.
- The direction of groundwater flow shown by the MEHL site data is to the south east which is consistent with the groundwater flow pattern shown for the Tooman-Nevitt site some 1.5 km to the south-east (Figure 3).
- The MEHL site is therefore consistent with the regional groundwater flow pattern and is on the opposite side of the groundwater divide to the Bog of the Ring well-field (see below).

Query:
'*Groundwater levels have not been accurately measured for artesian conditions at monitoring wells BH6 and BH4A (refer to applicant Figure 14.13). BH4A is a critical monitoring point (located to the east boundary of the site) and BH14 (located at the south corner of the site) do not support the groundwater flow contours illustrated on Figure 14.13. There is a risk that groundwater flow in this area flows to the east-northeast towards the Bog of the Ring*.'

Response:

- BH6 is a relatively shallow borehole (19m) and taps the Namurian strata. It shows minimum water levels of 116/117 mOD which is about 12m above the floor of the excavation. This confirms the confined nature of the groundwater in the more permeable horizons in the Namurian. Whether the water table is 1-2 m higher is not significant.
- BH4A and BH14 are consistent with the pattern of groundwater levels observed on the site e.g. they are both down gradient of the 99 mOD contour line.
- BH4A and BH6 are historic boreholes and the well completion did not allow accurate measurement of artesian groundwater levels. However the artesian overflow is continuous and suggests levels of 1 – 2 m above the well head.
- The groundwater beneath the MEHL site flows in a south eastwardly direction towards the Rogerstown Estuary and is consistent with the regional flow pattern reported from the Nevitt / Toolman site.
- There is a groundwater divide between the MEHL site and the Bog of the Ring.
- Therefore there is no risk that groundwater will flow to the Bog of the Ring which is NNE of the MEHL site.

Query:

'*The applicant has classified the Loughshinny aquifer as a Locally Important Aquifer which is moderately productive only in local zones (Ll). The GSI classify the Loughshinny Aquifer as a Locally Important Aquifer which is moderately productive (Lm)*.'

Response:

- On page 226 of the EIS the GSI aquifer classification in error is described as ; 'The three main classifications are Regionally Important Aquifers (Rl), Locally Important Aquifers (Ll) and Poor Aquifers.' The correct abbreviations for Regionally and Locally Important Aquifers are (R) and (L) respectively.
- The Loughshinny aquifer is everywhere classified by the Applicant as a Locally Important Aquifer which is generally moderately productive (Lm).

Query:

'*The applicant classifies the overlying Walshestown, Balrickard, and upper part of the Donore Formations (Namurian strata) as an "aquitard" but the GSI do not classify any bedrock in Ireland as an aquitard. The borehole logs, core photography and hydraulic testing data indicate that the Namurian strata at the site are highly fractured in parts and moderate permeability zones occur within these formations. This would support the GSI classification of a Poor Aquifer generally unproductive except in local zones (Pl).*'

Response:

- Geological strata are categorised in hydrogeological text books into aquifers and aquitards (Schwartz & Zhang, Dominico and Schwartz etc). In international maps rocks are classified as major and minor aquifer and unproductive rocks
- The GSI locally use the terms Regionally Important, Locally important and Poor aquifers.
- Internationally these terms would equate to 'Major Aquifer' for Regionally Important aquifers, 'Minor Aquifer' for locally important aquifers and 'aquitard/unproductive rocks' for Poor aquifers.
- The Namurian formations are all described in the EIS as Poor aquifers.
- The Hynestown Groundwater Body in the area consists of the strata in the Namurian syncline. This has been described by the GSI as an unproductive groundwater body.
- Therefore, the use of the term "aquitard" is entirely consistent with international and Irish guidelines and with hydrogeological principals.
- It is stated in the EIS that there are weathered or fractured zones in the Namurian strata that will allow some groundwater movement.
- The aquitard strata are defined in the EIS as a Poor aquifer (Pl).

Query:

'*The extent of the north-south trending fault identified on the site has not been adequately defined by the applicant. The geological survey of the site suggests that the north-south trending fault "...is probably a continuation of the fault that the GSI shows on their sheet 13 (McConnell et al 2004) immediately north of the Hollywood site" ((Conodate, Nov 2009). This may provide a direct link between the site and the Bog of the Ring supply*.'

Response:

- A North-south fault, 2m to 3.5 m in width was mapped on the site. Its extent within the site was confirmed by the geophysical survey and shown to have a down-throw to the east of about 25 m. It is assumed this is the same fault that the GSI shows on their Sheet 13.
- The N/S fault site through the site does not provide a direct hydraulic link between the site and the Bog of the Ring supply. The following is given as supporting evidence:: Drawdown contours associated with the Bog of the Ring well field are almost at right angles to the North-south fault and are not affected by it. If water was being provided to the well wellfield by this fault the shape of the drawdown contours would show this.

Our conclusions are entirely consistent with the investigations carried out at the time of the Nevitt-Tooman application as outlined below:

- The Nevitt / Tooman and the MEHL landfills are separated from the Bog of the Ring catchment by a no flow groundwater divide as shown on Figure 2 above.

- The GSI in a letter to the EPA, in response to a request for information from the EPA in relation to the licensing of the Nevitt / Tooman landfill, dated 24th October 2006 and describing this groundwater divide states;

"The groundwater divide was identified by the GSI using hydrogeological principles. A groundwater ''high'' that groundwater flows away from, and across which no groundwater flows, was inferred from water level and other data.''

- In section 3.5.2.1 of the Fingal EIS that accompanied the Local Authority's planning application for the Nevitt / Tooman landfill the groundwater divide is further described as follows;

'This groundwater divide is modelled in GSI 2005 Bog of the Ring Groundwater Source Protection Zones Report as a barrier to groundwater movement. North of the divide, groundwater flows towards the Bog of the Ring. South of the divide, groundwater flows beneath the study area and on

a regional scale discharges to surface water and the Rogerstown Estuary a further 6km to the south east (refer Figure 2). There is no flow across the divide itself.'

- The Local Authority in a response to the EPA in relation to the licensing of the Nevitt / Tooman landfill and dated May 2007 states on page 18;

'Although additional monitoring points may provide a more exact position of the groundwater divide, there are without doubt sufficient boreholes and associated monitoring data collected over a 22-month period to demonstrate that a groundwater divide exists between the Bog of the Ring zone of influence and the proposed landfill throughout all seasons.'

- The presence of the no flow groundwater divide between the MEHL landfill and the Bog of the Ring abstraction ensures that it is physically impossible under the current groundwater environment for groundwater to flow from the MEHL site towards the Bog of the Ring abstraction. A similar situation exists for the Nevitt / Tooman landfill which is even closer to the groundwater divide than the MEHL landfill. Fingal County Council in responding to the EPA in relation to the licensing of the Nevitt / Tooman landfill and dated January 2007 stated on page 9;

'In light of these factors, a numerical modelling study to determine the impact of hypothetical increased abstractions on groundwater flows beneath the landfill and on the extent of the resultant zone of contribution is not considered necessary as it is not Fingal County Council's plan to further develop groundwater resources in the area.'

- Therefore the fixing of the existing groundwater flow regime ensures that the no flow groundwater divide will remain in place for the future ensuring that no groundwater can pass from either the MEHL or the Nevitt / Tooman landfill towards the Bog of the Ring abstraction.

This data confirms, that as Fingal County Council must know, there is no possibility of the MEHL site interacting with the Bog of the Ring well-field.

Query:

'*The hydraulic characteristics of the faults at the site have not been adequately defined by the applicant. The applicant considers that the north-south trending fault impedes groundwater flow. The investigations at the site do not support this. A drawdown in water levels was observed on both sides of the north-south trending fault during the pumping test conducted at the site. The pumping test data also suggests that there may be enhanced permeability in the Namurian strata adjacent to the fault (drawdown observed in BH5 and BH16 during the pumping test). This increase in permeability adjacent to a fault has also been observed at a north-south trending fault to the east of the site. We consider that the faults are likely to link the Namurian strata and the underlying Loughshinny aquifer.*

Response:

- The pumping test showed that the N-S fault limited (not prevented) the groundwater movement across the faults - i.e. slowed it down. This was exhibited by the reduced drawdown in wells on the opposite side of the fault from the pumping well (BH17).
- The EIS acknowledged that there seems to be a connection between BH5 and BH16. It is likely that these wells have picked up a fractured/weathered/permeable horizons in the Namurian. The water levels in these wells were observed to drop when the borehole BH17 tapping the Loughshinny Formation was pumped. In the EIS it is stated that the east-west fault "is likely to be bringing the aquifer into contact with permeable horizons within the Namurian. However, this is not considered to be of significance as these connections are localised.

Query:

'*The applicant considers that the Namurian strata acts as a low permeability layer and confine/isolate the underlying Loughshinny aquifer. As detailed above, the site data (fracturing, faulting and permeable zones) do not support this low permeability designation. The drawdown in water levels observed in boreholes completed in the Namurian strata due to pumping of the BH17 indicates hydraulic connection (leakage) between the overlying Namurian strata and the underlying Loughshinny aquifer. Groundwater heads in the Namurian strata are elevated to those measured in the Loughshinny aquifer indicating downward flow from the Namurian strata to the aquifer*.'

Response:

- The EIS stated that there are permeable lenses and faults/fractures in the Namurian strata
- It was also noted in the EIS that there is a variable degree of hydraulic connection across the faults under artificial (stressed) conditions)
- However, the confining conditions observed on site, the fact that groundwater levels in these permeable strata were dried out when the wells were pumped (e.g. BH16) and the competence of the rock cores observed in BH16 are evidence for lower permeability in the various permeability tests.
- The tighter groundwater contours in the Namurian strata adjacent to the Bog of the Ring wellfield indicate a significant difference in the permeability of the Namurian and Loughshinny strata with relatively low groundwater movement between the two.
- The elevated groundwater levels in the Namurian strata indicates a potential for downward flow. However, it cannot be realised because of the lower permeability of the Namurian strata relative to the Loughshinny.
- The artesian heads recorded in boreholes tapping the Namurian and Loughshinny strata indicates that both within the Namurian strata and between the Namurian and Loughshinny confining conditions exist on the site.
- Furthermore the increasing thickness of the Namurian strata to the north of the site (up to 400m) does provide the isolation/confinement that is stated in the EIS.
- The site investigation data did demonstrate that confined conditions exist on the site.

Query:

'*The applicant initially defines the vulnerability of the bedrock as Extreme, rock near surface or karst for the entire site. The classification of the majority of the site, where underlain by the Namurian strata is later redefined as moderate by the applicant. The site data does not support this reclassification*.'

Response:

- The GSI vulnerability map describes the site as Extremely vulnerable as the site is a former quarry. This classification was updated based on site specific data.
- There is a minimum of 10 m of and up to at least 60 m of moderate to low permeability material present across the northern part of the site. In line with GSI guidelines, this can allow the vulnerability to be redefined to Moderate.
- Defining the site permeability based on site specific data is a common approach undertaken on many sites and is appropriate and in line with GSI guidelines.

Query:

'*The applicant designates the southern part of the site as $R2_2$ Acceptable subject to guidance outlined in the EPA Landfill design manual or conditions of a waste licence, based on their aquifer classification, vulnerability classification and the GSI landfill response matrix. As discussed in the comments above the Loughshinny Aquifer is incorrectly classified and the southern part of the site should be designated $R3_2$ Not generally acceptable unless it can be shown that: there is a minimum consistent thickness of 3m of low permeability subsoil present; there will be no significant impact on the groundwater; and it is not practicable to find a site in a lower risk area*.'

Response:

- The aquifer was classified as a Locally Important aquifer which is moderately productive
- The provision (as described on page 21 of this statement) of a layer of low permeability clay (approximately 1 m of 6.0 x 10^{-10} m/s) immediately above the exposed Loughshinny Formation provides the an equivalent level of protection as provided by 5m of low permeability clay. This material is not part of the lining system but is an enhanced protection layer.

- The provision of the 1m layer of very low permeability clay above the Loughshinny Formation allows for the classification of the southern part of the site as being $R2_2$. This layer of low permeability clay represents the geological barrier required under Section 3.2 of Annex 1 of the Landfill Directive.
- This is consistent with the Landfill Directive and the EPA Landfill Design Manual. For clarity, without that protective layer, a small portion of the southern part of the site would be considered to fall within the $R3_2$ classification."

Query:

'*The applicant designates the northern part of the site as $R2_1$ Acceptable subject to guidance outlined in the EPA landfill Design Manual or conditions of a waste licence, based on their aquifer classification, vulnerability classification and the GSI landfill response matrix. As discussed in the comments above the vulnerability in the northern part of the site is incorrectly classified and the northern part of the site should be designated $R2_2$ Acceptable subject to guidance outlined in the EPA Landfill Design Manual or conditions of a waste licence. Special attention should be given to checking for the presence of high permeability zones. If such zones are present then the landfill should only be allowed if it can be proven that the risk of leachate movement to these zones is insignificant. Special attention must be given to existing wells down-gradient of the site and to the projected future development of the aquifer. Groundwater control measures such as cut-off walls or interceptor drains may be necessary to control high water table or the head of leachate may be required to be maintained at a level lower than the water table depending on the site conditions.*'

Response:

- As there is a minimum of 10 m and up to at least 60 m of low permeability shale present (the Poor aquifer) above the Loughshinny aquifer the vulnerability of the northern part of the site has been reclassified on a site specific basis from Extreme to Moderate.
- As outlined previously, the approach of redefining the site vulnerability based on site specific data is encouraged by the GSI.
- Based on the site specific data the aquifer underlying the northern part of the site is a Poor aquifer with moderate vulnerability

- These criteria lead to the classification of the site as $R2_1$: Acceptable subject to guidance outlined in the EPA landfill Design Manual or conditions of a waste licence

Query:
'*There is potential for regional groundwater flow and/or direct linkage via faults zones between the site and the Bog of the Ring pNHA and water supply*.'

Response:
There is no potential for regional groundwater flow between the site and the Bog of the Ring pNHA and water supply for the following reasons:

- The Bog of the Ring and the MEHL site are located in different groundwater and surface water catchments
- The MEHL site lies outside the catchment and zone of contribution of the Bog of the Ring well field.
- Groundwater divide between the two
- The location of a syncline with up to 400 m of low permeability strata between the two
- The contours associated with the Bog of the Ring wellfield are almost at right angles to the North-south fault and are not affected by it. If water was being provided to the wellfield by this fault the shape of the drawdown contours would show this.
- The presence of a groundwater divide between the site and the Bog of the Ring indicates that groundwater cannot flow from the MEHL site to the Bog of the Ring, even through fault zones. As shown in Figure 4, the groundwater divide will exist within a fault plane, so that any water present within the fault will also flow away from the divide.
- In summary, based on the evidence observed at the MEHL site and at the Tooman-Nevitt site, there is no potential for a linkage between the groundwater beneath the MEHL site and the Bog of the Ring pNHA and well-fields.

Query:

'*Surface water features have been identified in the vicinity of the site, a stream along the northern boundary of the site and a tributary of this stream to the east of the site. These features are likely to form receptors for shallow groundwater downstream of the site*.'

Response:

- The stream which runs along the northern boundary of the site may be partially fed by shallow groundwater in places.
- This stream lies at an elevation of 104 mOD on the north western corner of the site and falls to a level of 93.5mOD on the north eastern corner of the site. In this area the natural overburden of low permeability clay is still in place.
- There are two wells screened in the Namurian deposits located very close to the stream (BH6 is 23m south of the stream and BH11A is 14m south of the stream). Both of these wells are artesian and have groundwater levels of approximately 117mOD and 98mOD for BH6 and BH11A respectively. These groundwater levels are above the level of the stream.
- This indicates that the stream is not hydraulically connected with the groundwater in the Namurian deposits in this area and that the Namurian deposits are confined by the overburden.
- Groundwater is likely to discharge to this stream further to the ESE where the Loughshinny Formation outcrops. As outlined previously the Loughshinny is located further to the south than is shown on the geological maps. This indicates that the groundwater may discharge to a tributary of this stream located approximately 1.5 km ESE of the site. The QRA has proven that this stream is not at risk from the proposed development
- In summary, due to the hydrogeological conditions on the MEHL site the local surface water features are not at risk from the proposed development.

Query:

'*The applicant has conducted a Quantitative Risk Assessment (QRA) using LandSim to assess risk to groundwater from the proposed development. There are several problems with the QRA that undermine its conclusions that the project does not pose a risk to groundwater. Problems with the QRA include:*

(i) Hazardous cells will have two low permeability liners (DAC and engineered mineral layer) but the project description does not confirm whether the mineral layer will be low permeability (refer to section 4.5.1.2 of EIS)'

Response:

We can confirm that the mineral layer, which is part of the DAC liner, will have a hydraulic conductivity less than or equal to 1.0×10^{-9} m/s

Query:

(ii) '*The Namurian bedrock strata are considered 'aquitards' but the GSI does not classify any bedrock in Ireland as being an 'aquitard'. The Namurian bedrock is classified as being a Poor aquifer generally unproductive except for local zones (Pl). The significant faulting and permeability calculations in the rock below the site support this local designation. Measured permeability on the site is moderate 10^{-5} to 10^{-6} m/s which confirms that the Namurian cannot be considered an 'aquitard'.'*

Response:

- The Namurian strata at the site are defined in the EIS as a Poor aquifer which is generally unproductive except for local zones (Pl) and an aquitard.
- As described above, there are higher permeability lenses or fractures within the Namurian however there is limited connection between these faults/fractures/lenses. While these individual fracture zones may have a moderate permeability they are isolated by low permeability shale.
- This was seen in BH16 where a higher permeability zone was identified between approximately 10-25 mbgl. Low permeability shale was observed above and below this fractured area. A groundwater monitoring installation was constructed to tap this unit. When a pump was placed in this well, the well drained very quickly and the supply did not replenish indicating a lack of recharge.
- The only moderate permeability values recorded in the aquitard were recorded in these localised fractures/lenses.
- The overall permeability of the material was therefore considered to be low permeability which is consistent with the Namurian material throughout Ireland

Query:

(iii) '*Quoted vertical permeability ranges within the Namurian bedrock of 10-8 m/s are not supported by the tests conducted. Pump test results indicate leakage within the Namurian that suggests higher permeability*'

Response:

The vertical permeability ranges referred to in the submission refer to the value entered for the vertical permeability of the unsaturated zone in the QRA model.

- A log-triangular distribution of the following values was entered into the QRA model for the site: 4.54×10^{-7} m/s, 1.53×10^{-7} m/s and 2.82×10^{-8} m/s
- These results were obtained during the site investigation by undertaking infiltration testing in the unsaturated zone across the site.
- The results of this testing ranged from 4.54×10^{-7} m/s - 2.82×10^{-8} m/s. Some of the test results were inconclusive as it rained over the weekend that the tests were being monitored causing the pits to overflow. This in itself is an indicator of the low permeability nature of the material
- The results of the hydraulic tests undertaken in the boreholes penetrating the Namurian strata gave values of 2.82×10^{-8} - 5.4×10^{-5}. The tests were undertaken in those zones/horizons that yielded some water. The analytical methods used to calculate horizontal permeability which is generally accepted to be about 5 to 10 times vertical permeability.
- The Namurian strata beneath the floor of the quarry, where the tests were undertaken, have been opened up by quarry and the removal of overlying strata and therefore will have increased permeability. As with all geological strata they will become less permeable with increasing depth.
- This indicates that these results were appropriate for use in the model

Query:

(iv) *'The north-south trending fault that runs through the site and below the proposed hazardous cells is considered to retard flow and not act as a pathway. This is not supported by the pump test results and the faulting generally across the site is more likely to hydraulically link the shallower Poor aquifer (Pl) and the deeper Locally Important Aquifer*

(Loughshinny Bedrock) and form preferential pathways for groundwater flow.'

Response:

- As outlined previously, the pumping test showed that the North-South fault retards the movement of groundwater flow – i.e. it slows it down but does not stop it. This is exhibited by the groundwater levels recorded in wells to the east of the north-south trending fault showing less drawdown than those to the west of the north-south trending fault during the well test on BH17.
- Faults are not linear features which essentially act as pipelines. They pinch and swell along their length and depth. The north-south fault through the site, which is several kilometres long will have variable conditions along its length, i.e. in terms of downthrow, presence or absence of fault gouge and the type of material in contact.
- In order to have preferential flow/pathways there must be somewhere for the groundwater to flow too. It has already been stated that there is a groundwater divide to the NNE which will prevent natural flow in this direction. The restricted permeability in the north-south fault and others to the east (down-gradient) will gradually bring groundwater up into the surface waters.
- Therefore the north-south fault does not act as a preferential flow path.

Query:

(v) '*Groundwater is confined within the aquifer by the 'aquitard' providing additional protection against downward migration of potential contaminant. This is not supported by site groundwater level data and Figure 13 of Appendix 14.10 (Schematic groundwater model) incorrectly illustrates a groundwater level (piezometric head of aquifer water table) higher than the "aquitard" water level. Figure 14.13 of the EIS illustrates that the opposite is more accurate that groundwater levels in the Namurian (BH19 "aquitard") at 101.69 mAOD are higher than levels in the Loughshinny (BH20 "aquifer" at 100.94 mAOD in the centre of the site*)'

Response:

- As outlined previously in this submission, the confined conditions are clearly demonstrated on site
- Figure 13 of the QRA is a schematic illustration only and intends to demonstrate the conceptual model of the site in terms of the input parameters entered into the QRA model i.e. it shows where the unsaturated zone, vertical pathway and aquifer are
- The quarry excavation complicates the local groundwater conditions. The water levels in some of the boreholes tapping the Namurian strata are significantly above the quarry floor. The pond in the southern part of the excavation may act as a groundwater sink in the aquifer.

Query:

(vi) '*There will be limited downward flow in the Namurian bedrock and flow will be directed upwards. This is not supported by the groundwater level information, vertical downwards gradients that exist on the site, unconfined conditions and the hydraulic permeability of the Namurian which suggests that it has moderate rather than low permeability*.'

Response:

- As outlined previously in response to a query, there are confining conditions on the site. These conditions prevent the downwards movement of water as the natural flow direction is upwards. This essentially prevents potential contamination from moving downwards into the Loughshinny.
- However, it should be noted that this assumption was not used in the QRA model as LandSim cannot model confined conditions. Therefore the QRA model was run simulating down-ward movement of water which is a conservative scenario as groundwater would naturally move upwards.
- There are extensive and thick Namurian deposits in Ireland. They are considered to have low permeability aside from local zones/horizons.
- The elevated groundwater levels in the Namurian strata indicates a potential for downward flow. However, it cannot be realised because of the lower permeability of the Namurian strata relative to the Loughshinny.
- The artesian heads recorded in boreholes tapping the Namurian and Loughshinny strata indicates that both within the Namurian strata and

between the Namurian and Loughshinny confining conditions exist on the site.

Query:

(vii) '*Groundwater flow beneath the site is directed to the southeast and away from the Bog of the Ring supply. Note comments above regarding the problems with the flow mapping that has been conducted. Groundwater flow direction from the site has not been adequately mapped and this assumption in the CSM is not supported*.'

Response:

- As outlined previously, the flow direction measured at MEHL is parallel to the geological strike and surface water drainage and is entirely consistent with the regional flow pattern reported from the Nevitt / Tooman site and flows in a south eastwardly direction away from the Bog of the Ring groundwater abstraction.
- The groundwater pattern at MEHL in the Loughshinny could not be different from that demonstrated at Tooman-Nevitt due to the regional geology.
- Figure 3 illustrates this

Query:

(viii) '*LandSim has limited applicability to this project as the unsaturated zone is thin or absent (0-1 m thick) and the vertical pathway modelled are fractured bedrock'*

Response

- LandSim is applicable for use in this project.
- LandSim is the UK Environment Agency approved programme for determining potential impacts to groundwater from landfills. It is used extensively in the UK for fractured chalk and sandstone aquifers and has been deemed to be applicable in those situations. The same would apply to the fractured Namurian strata on the MEHL site.
- The unsaturated zone beneath the site is the area above the water table. In order to maintain the conservative approach undertaken the values used for the unsaturated zone thickness were based on the shallowest groundwater strikes observed during drilling. In many boreholes groundwater was not

encountered until 10-15 mbgl, however values of 5-6 m were used in the model.

Query:

'Attenuation capacity in the DAC liner has been modelled as "clay", which may over-predict the sorption of contaminants passing through the liner'

Response:

- The DAC liner was modelled in LandSim in accordance with the LandSim guidelines.
- The DAC liner is modelled as a single clay barrier the thickness of the DAC sealing layer (0.08m). The secondary clay liner (0,5m thick) is not included in the model. Therefore there is significantly greater sorption potential in the liner system than has been modelled.
- In addition, LandSim recommends a range of hydraulic conductivities to use to model a DAC liner, however it provides a second range of higher hydraulic conductivity values to account for any potential degradation of the liner. The higher range of permeabilities were used in the landfill model.
- This balances out the fact that contaminants within the liner will have increased sorption within a clay than within a DAC liner. However, it should be noted, that the liner will be constructed to have such a low permeability as to be effectively impermeable – and therefore the sorption potential would be irrelevant.

Query:

'The model is described as being "conservative" (i.e. Worst case) when some of the input parameters cannot be justified as conservative: sorption capacity of the DAC, thickness of the unsaturated zone, permeability of the Namurian bedrock and the high porosity of the Namurian included in the numerical model'

Response:

- Sorption capacity of the DAC: outlined in a previous response
- Thickness of the unsaturated zone: outlined previously in response to query (viii)
- Permeability of the Namurian bedrock: as described in earlier responses

- High porosity of the Namurian: the values used were based on the literature however a sensitivity analysis was undertaken on this parameter and this showed the model was not sensitive to this parameter i.e. changes in this parameter did not result in changes to the model results.

4.1.2 Responses to items raised in Section 3.1 'Conclusions and recommendations' of the Fingal County Council submission

Query;
'*The proposed site offers no natural geological or hydrogeological protection for the development of a hazardous waste landfill*.'

Response;

- The proposed location is typical of numerous hydrogeological settings throughout Ireland. And extensive and phased investigation has been undertaken to characterise the hydrogeology of the site. The site does not pose a risk to groundwater from the development of a landfill for hazardous waste.
- The MEHL site is in part underlain by a large thickness of low permeability shale. It is proposed to locate the hazardous waste cells over the low permeability shale. The large thickness of low permeability shale provides sufficient natural protection to groundwater beneath the site.
- The hydraulic conditions in the Loughshinny aquifer beneath the northern part of the site are considered to be progressively confined.
- Furthermore, landfills are underlain by Namurian strata at at least three locations in the Republic of Ireland.
- Therefore the proposed site does offer natural geological and hydrogeological protection.

Query;
'*Groundwater vulnerability beneath the site is categorised as Extreme using the DoELG, EPA ,GSI (1999) Groundwater Protection Scheme guidance. The bedrock on the side includes Locally Important (Lm) and Poor Aquifers(Pl) designated by the GSI. Although the hazardous cells are proposed in areas where the bedrock is classified as Pl, these rocks overlie the Lm aquifer and the hydrogeological site information indicates that the Pl aquifer is moderately permeable and is connected to the underlying Lm aquifer*.'

Response;

- The presence of the Locally Important (Lm) aquifer at depth beneath the low permeability Namurian aged Poor Aquifer (Pl) aquifers is a natural consequence of the regional geological structure present in this region.
- However, the Lm aquifer is protected by at least 10 m and up to at least 60m of overlying low permeability shale.
- While the faulting present may pass down through the Namurian shales into the underlying Lm aquifer the faults within the shale mass will not act as preferential flow paths due to the localised nature of the higher permeability areas, the confining conditions on the site and the decreasing permeability and the low groundwater movement at depth.
- The proposed hazardous cells will be underlain by an increasing thickness of Poor Aquifer/aquitard. Groundwaters in the underlying aquitard are confined.

Query;

'*Groundwater flow mapping conducted by the applicant is deficient and does not provide sufficient information to demonstrate that the Bog of the Ring is not At Risk from the proposed development.*'

Response;

- MEHL have sufficient information to characterise the groundwater flow regime on their site
- The groundwater flow direction measured at the MEHL site is shown in the accompanying Figure 3 in the context of the regional groundwater flow pattern as reported at the Nevitt / Tooman landfill. The groundwater flow direction is to the south-east.
- The Bog of the Ring water supply scheme is not at risk from the proposed landfill.

Query;

'*Several geological faults cross the site, including a significant north – trending fault that is expected to continue to the North and intersect the Bog of the Ring fault Zone . Hydrogeological analysis of the pump test data provided by the applicant indicate that this also provides higher permeability within the Namurian bedrock (described by the applicant as an 'aquitard' and low permeability formation). This also runs beneath the proposed hazardous waste cells.*'

Response;

- As outlined previously the pumping test demonstrated that the fault zone retards groundwater flow
- There is a groundwater divide between the MEHL site and the Bog of the Ring so if any potential contamination entered the fault, it would flow away from the groundwater divide as it could not physically cross the divide and reach the Bog of the Ring well field even if faults are present, notwithstanding the presence of faults which we have identified on the MEHL site.
- The Bog of the Ring wellfield has been in production for over six years and the hydraulic regime around the well-field is likely to be in steady state.
- Drawdown contours associated with the Bog of the Ring well field are almost at right angles to the North-south fault and are not affected by it. If water was being provided to the well wellfield by this fault the shape of the drawdown contours would show this.

Query;

'*Based on a review of the data, overall permeability in the Namurian bedrock is higher than has been stated in the EIS and it is inaccurate to consider it as an aquitard for groundwater flow and risk assessment purposes*.'

Response;

- As outlined in earlier in this brief, the permeability of the Namurian bedrock is low except for in localised zones.
- The hydraulic conditions on site are consistent with that of a confined aquifer beneath the aquitard
- The confined scenario was not used in the risk assessment in order to undertake a conservative assessment

- Therefore, the assessment of the permeability of the Namurian is correct and it is proven to act as an aquitard.

Query;
'*Downward vertical head gradients are present on the site indicating that there is downwards groundwater flow from the shallower Namurian (Pl aquifer) to the deeper Loughshinny (Locally Important aquifer). This is contrary to the assumption of upwards gradients used by the applicant in the quantitative risk assessment (appendix 14.10).*'

Response;
As outlined previously confining conditions are observed on the MEHL report. We have also confirmed that the groundwater flow is upward and we have further confirmed that we DID NOT use upward gradients in our QRA.
It is stated clearly in the Quantitative Risk Assessment (Appendix 14.10), it was presumed that there was a down-ward head gradient in the QRA model in order to undertake the most conservative assessment.

- The elevated groundwater levels in the Namurian strata indicates a potential for downward flow. However, it cannot be realised because of the lower permeability of the Namurian strata relative to the Loughshinny.
- The artesian heads recorded in boreholes tapping the Namurian and Loughshinny strata indicates that both within the Namurian strata and between the Namurian and Loughshinny confining conditions exist on the site.

Query;
'*Overall there is expected to be a greater degree of hydrogeological connection between the rock types on the site due to the extensive faulting. Therefore less reliance can be placed on the lithological distinction between bedrock types as groundwater flow will be exclusively through secondary permeability features (e.g. fractures in the rock) which cut across the different bedrock types.*'

Response;

- As stated in the EIS the East-west fault permits hydrulaic continuity on the site whereas the north-south fault retards it
- Despite the site characteristics hydrogeological principles will still apply, i.e. under pressure competent strata in the Namurian succession (sandstones and limestones) will be more likely to break and fracture and develop permeability whereas the fine grained shales and siltstones will become plastic and weather and not develop permeability as can be seen in the core from BH16. This is shown in Figure 12.
- With increasing depth below the surface the rocks will become tighter and there is a reduction in the secondary permeability.

Query;

'*The LandSim model used in the quantitative risk assessment (Appendix 14.10) has limited applicability for the project because of the nature of the hydrogeological conditions (e.g. thin or absent unsaturated zone and fractured rock). In addition, several of the model input parameters of are over optimistic leading to inaccurate conclusions about the risk of posed by the facility.*'

Response;

- As outlined previously the LandSim model is appropriate
- This statement regarding the input parameters is incorrect. All model input parameters were chosen on a conservative basis, particularly where any uncertainty existed
- The conclusions of the QRA are conservative rather than over-optimistic

Query;

'Leachate within the hazardous cells will pose a hazard for a long period (expected to be100's of years) beyond the estimated 35 year management period used in the risk assessment. Whereas it is accepted that the landfill will have to operate under an EPA Waste Licence and provide the Closure Restoration and After-Care Management Plan, it is unrealistic to expect that the landfill will be economically viable to maintain leachate pumping and treatment for such a long period. A greater risk will be posed to groundwater when leachate pumping is discontinued and leachate head increases and discharges to the aquifer will occur without natural geological protection (e.g. presence of natural low permeability subsoil).'

Response;

- As outlined clearly in the QRA report, the management control period has been set in the QRA report as 35 years. This means that LandSim presumes that beyond 35 years there will be no management of the landfill (e.g. no pumping of leachate etc) and leachate levels will be allowed to build up over time. The QRA models simulates this occurring and all results presented reflect this. This is a conservative scenario as the management control period for the facility will extend beyond 35 years.

4.2 **Responses to all other submissions received**

All other submissions received regarding geology, hydrogeology and groundwater quality were of a general nature and are considered to have been dealt with in the detailed response to the Fingal County Council submission.

5. Conclusion

Our conclusion is outlined below in Table 1.

Table 1 Summary Of Predicted Impacts And Mitigation Measures

Constraint		Impacts and mitigation					
Name	**Importance**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**	**Residual significance of impact**
Geology							
Geological Heritage Area	Very High	Large Adverse	Infill of quarry will result in the loss of a number of outcrops of geological interest in the area. Quarry offers an opportunity to view a number of strata in close succession.	Profound	Through correspondence with the GSI an agreement has been reached. MEHL will provide a viewing platform for the site and will allow access once certain conditions as set out in the correspondence in **Appendix A1.3** are met. However it should be noted that the conditions of the planning permission for the quarry require the quarry to be backfilled and restored.	Negligible	Imperceptible
Non-hazardous bottom ash	Low	Minor Beneficial	Disposal of non-hazardous bottom ash into dedicated cells within the landfill.	Imperceptible	None required.	Minor Beneficial	Imperceptible
Hydrogeology							
Locally Important aquifer	Medium	Large Adverse	Infilling of waste may cause contamination of groundwater contained in the aquifer	Significant Impact	Employing engineered liners in line with EU legislation. Employ a leak detection system to serve as a warning for contamination. Maintain good site practices	Negligible	Imperceptible

Constraint		Impacts and mitigation					
Name	**Importance**	**Magnitude of Impact**	**Criteria for Impact Assessment**	**Significance of Impact**	**Mitigation Measure**	**Residual Impact**	**Residual significance of impact**
Poor aquifer	Low	Large Adverse	Infilling of waste may cause contamination of groundwater contained in fractures etc	Slight/Moderate impact	Employing engineered liners in line with EU legislation. Employ a leak detection system to serve as a warning for contamination. Maintain good site practices	Negligible	Imperceptible
Wells identified during well survey	Low	Large Adverse	One well is down-gradient of the site and may be impacted by any contamination arising from the site.	Slight/Moderate impact	Employing engineered liners in line with EU legislation. Employ a leak detection system to serve as a warning for contamination. Maintain good site practices	Negligible	Imperceptible

Murphy Environmental Hollywood Ltd.

ABP ref No. PL06F.PA0018

Proposed Integrated Waste Management Facility

Brief of Evidence: Geology & Hydrogeology

Eugene Daly, Gareth Jones, Jenny Lightfoot and Catherine Buckley

I.S. EN ISO 14001 Certified by Certification Europe Ltd

Figure 1: Regional GSI Geological map

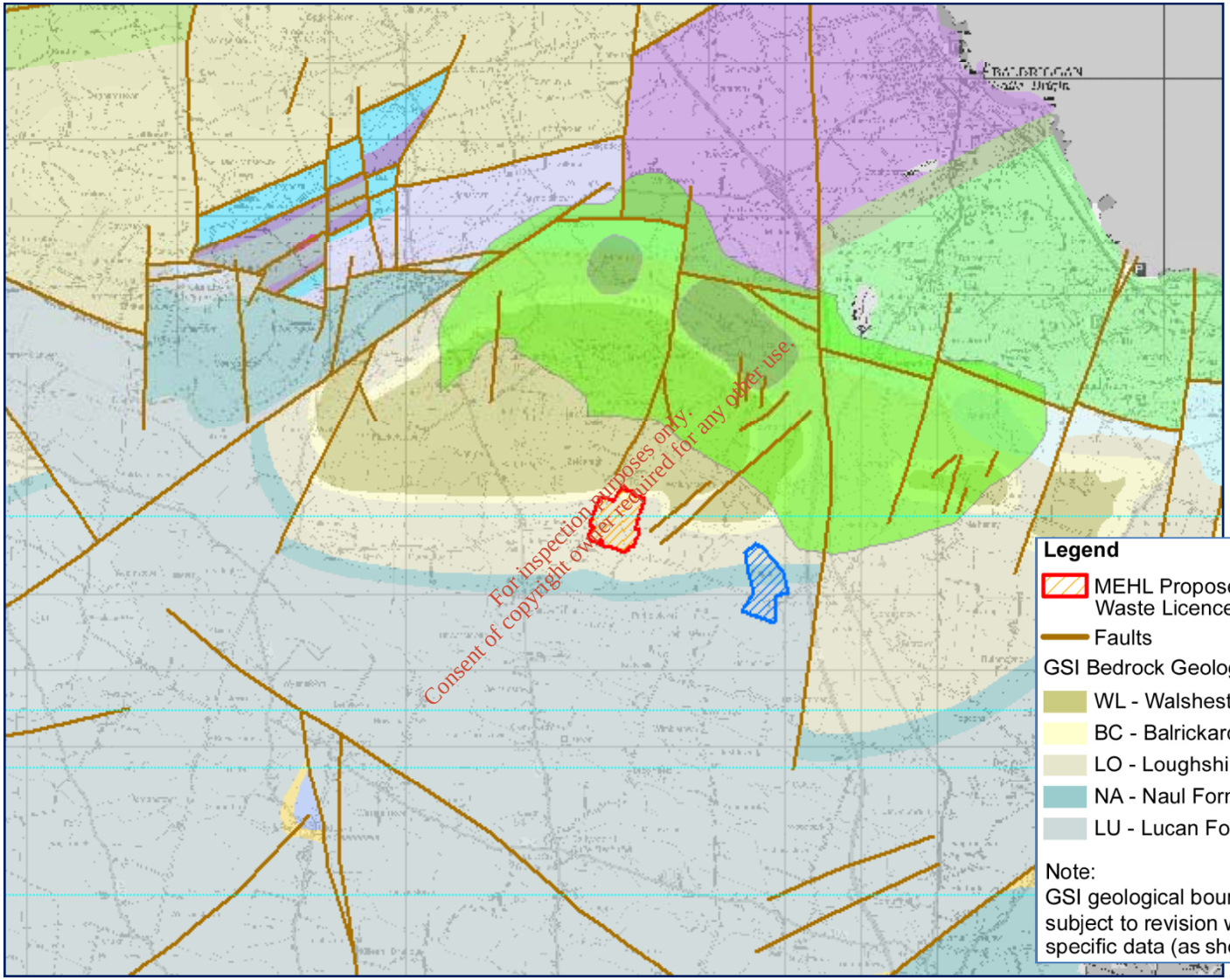


Figure 2: Surface water catchments

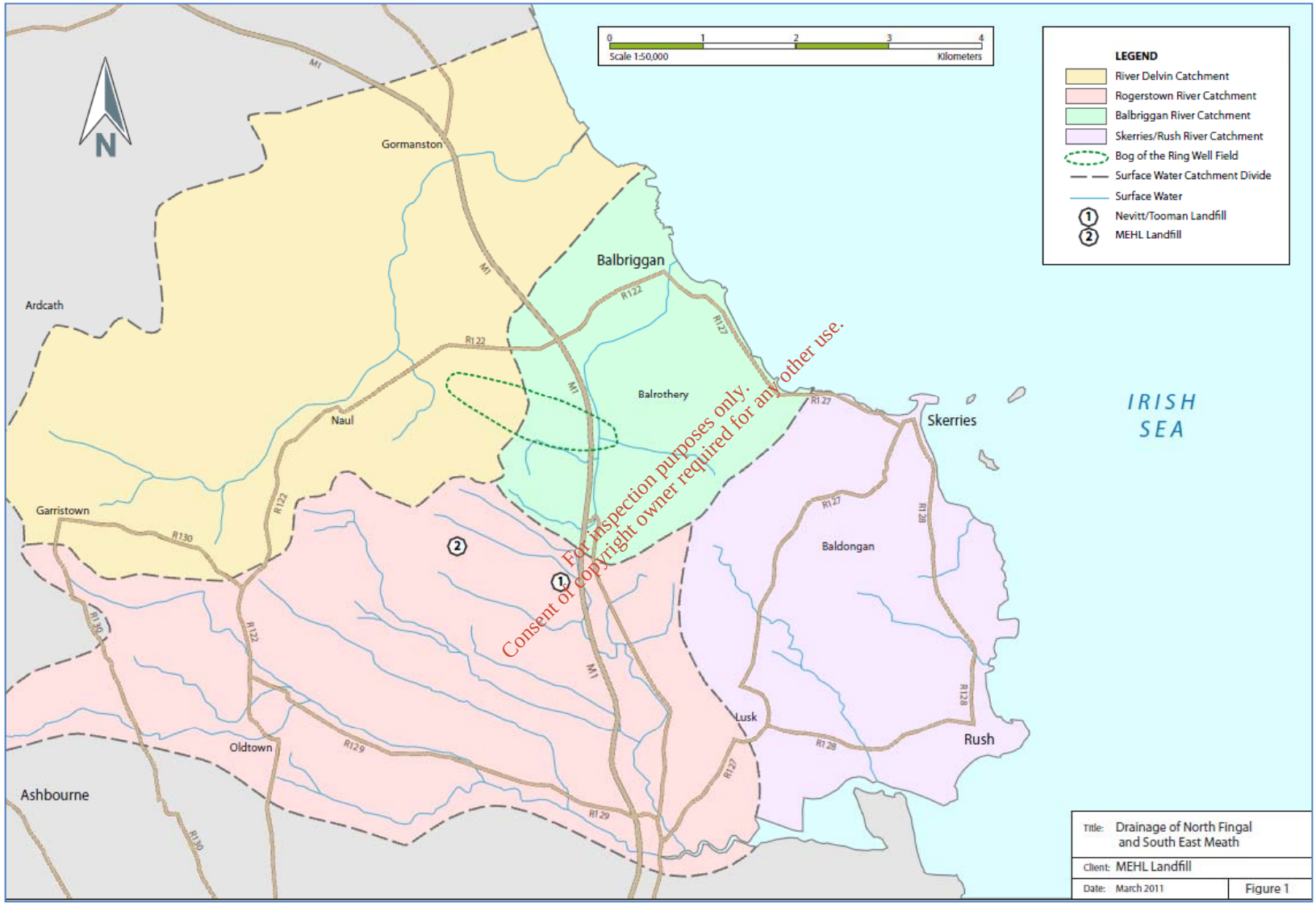
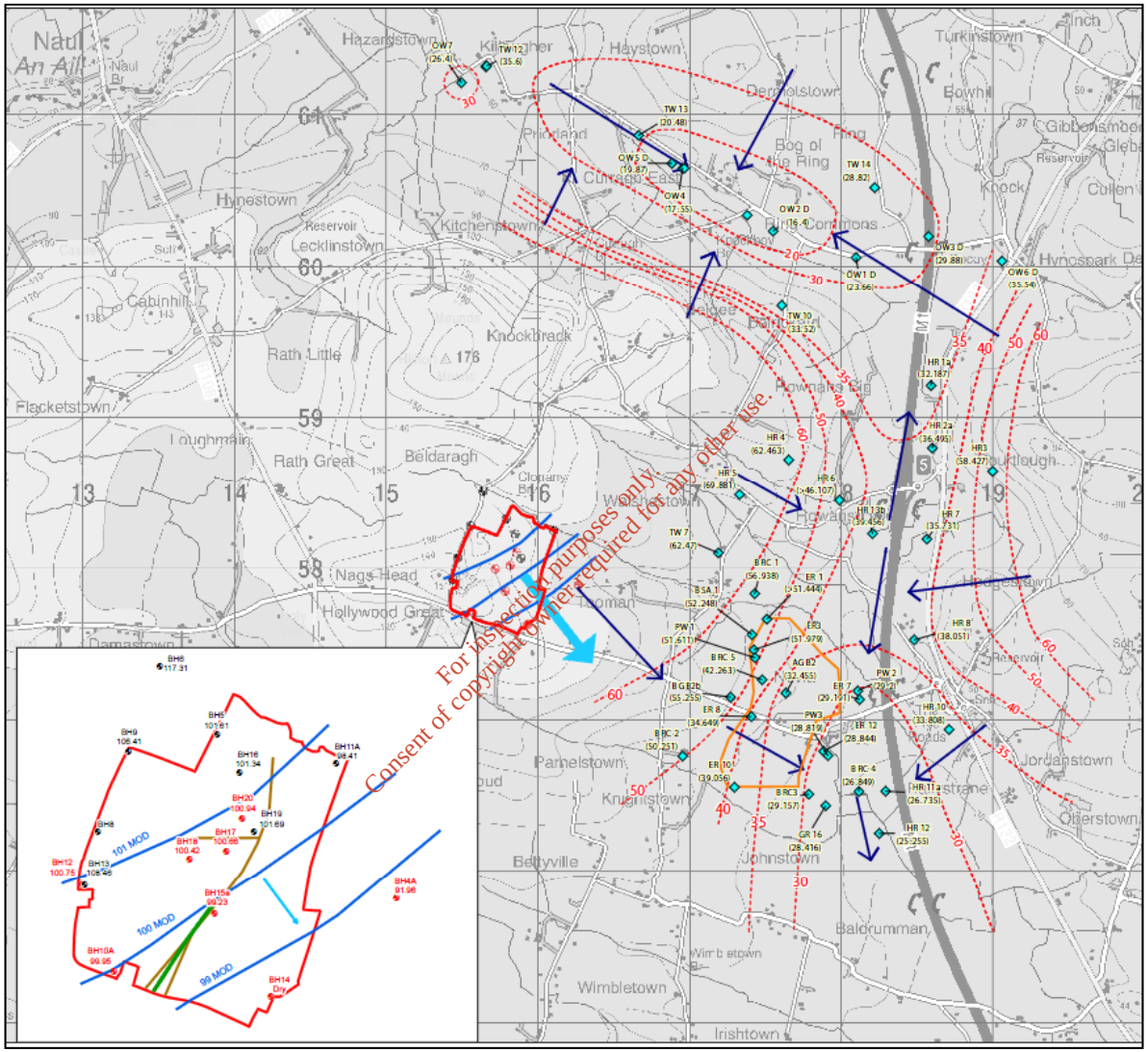


Figure 3: Groundwater flow pattern



Information outside MEHL site taken from Fingal County Council planning application Figure: Groundwater Bedrock Contours 11th October 2005, File ref: MDR0303MI0195A02

Figure 4: Groundwater catchments

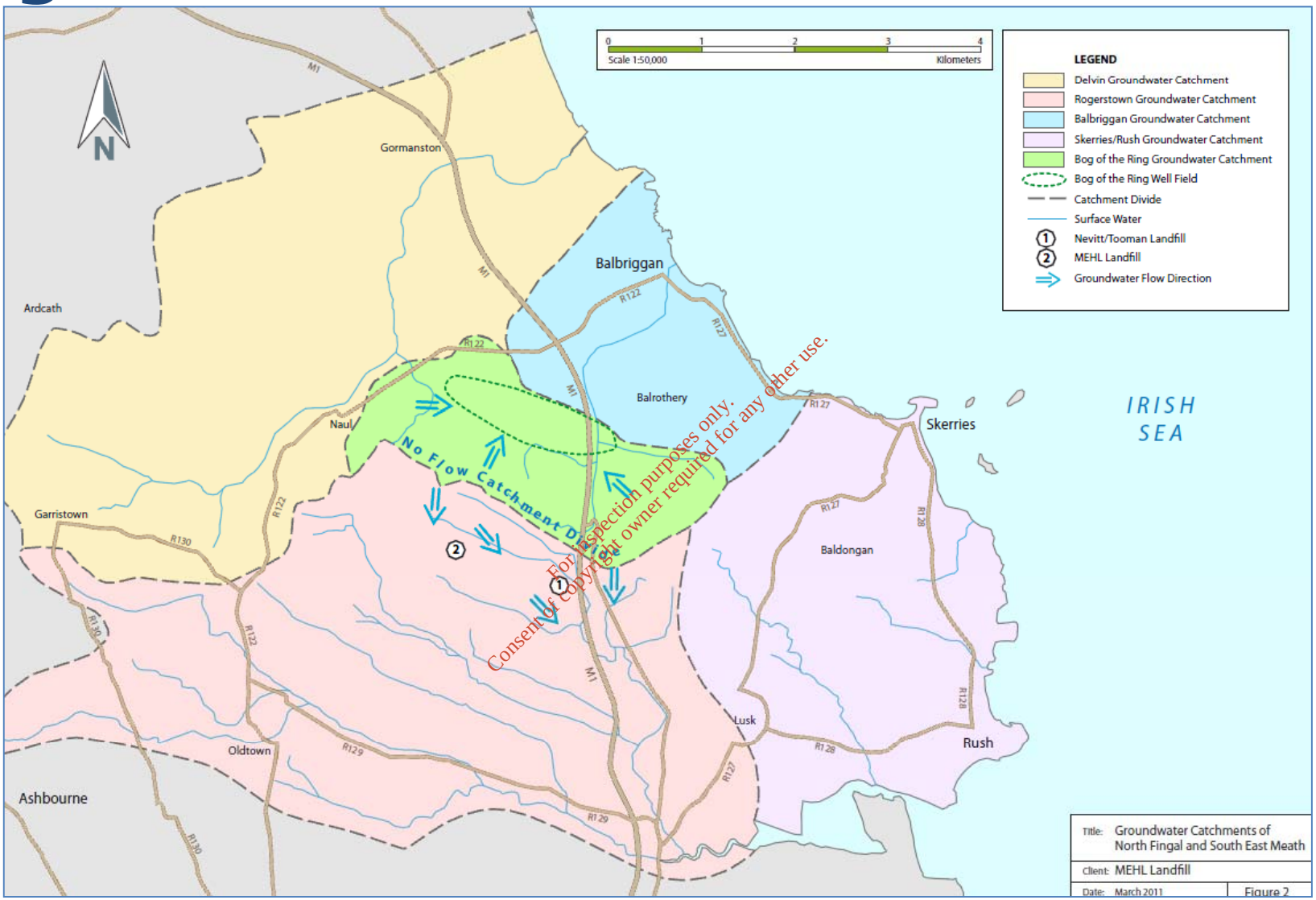


Figure 5: Site specific geology

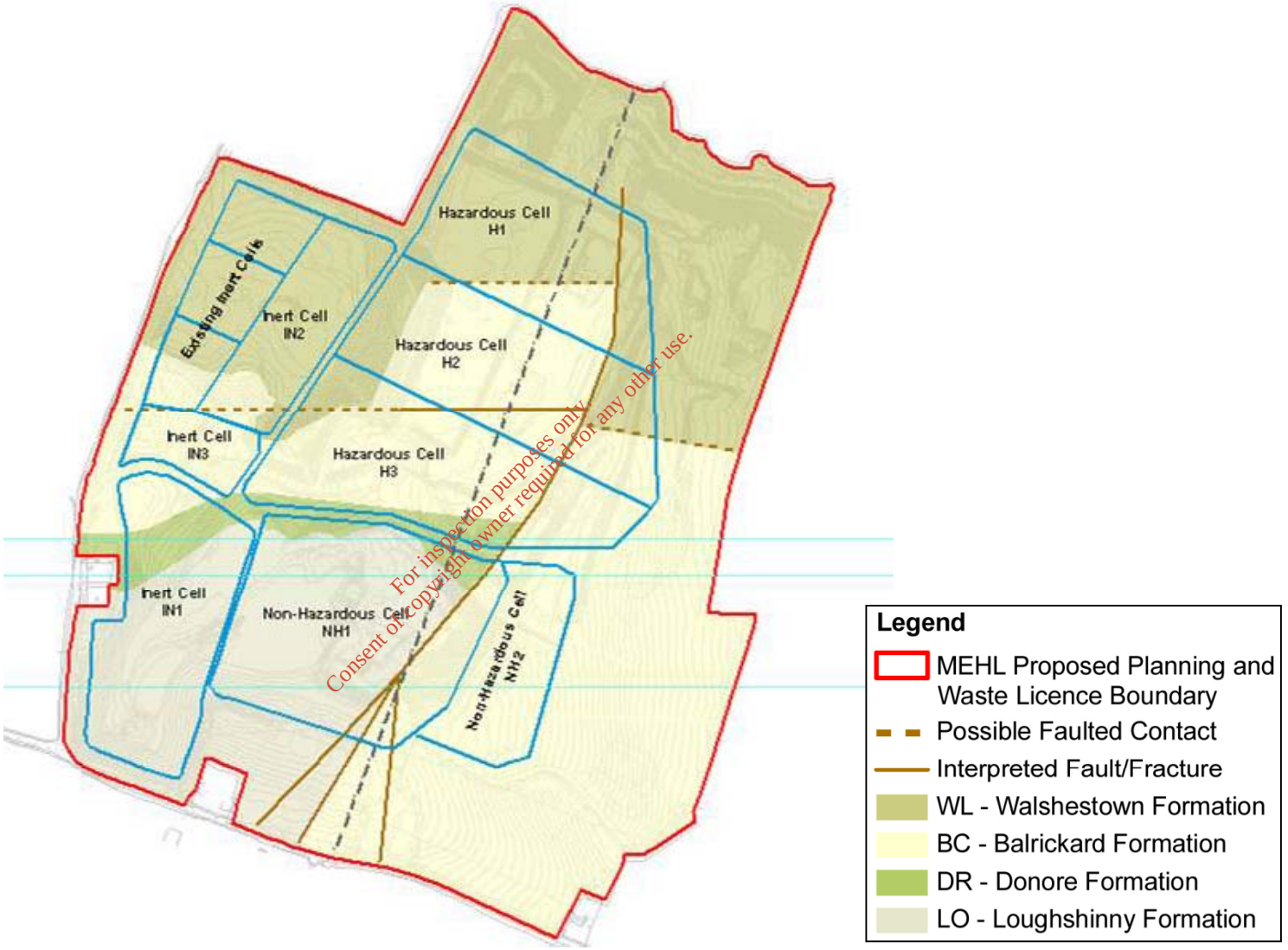


Figure 6: Schematic cross-section

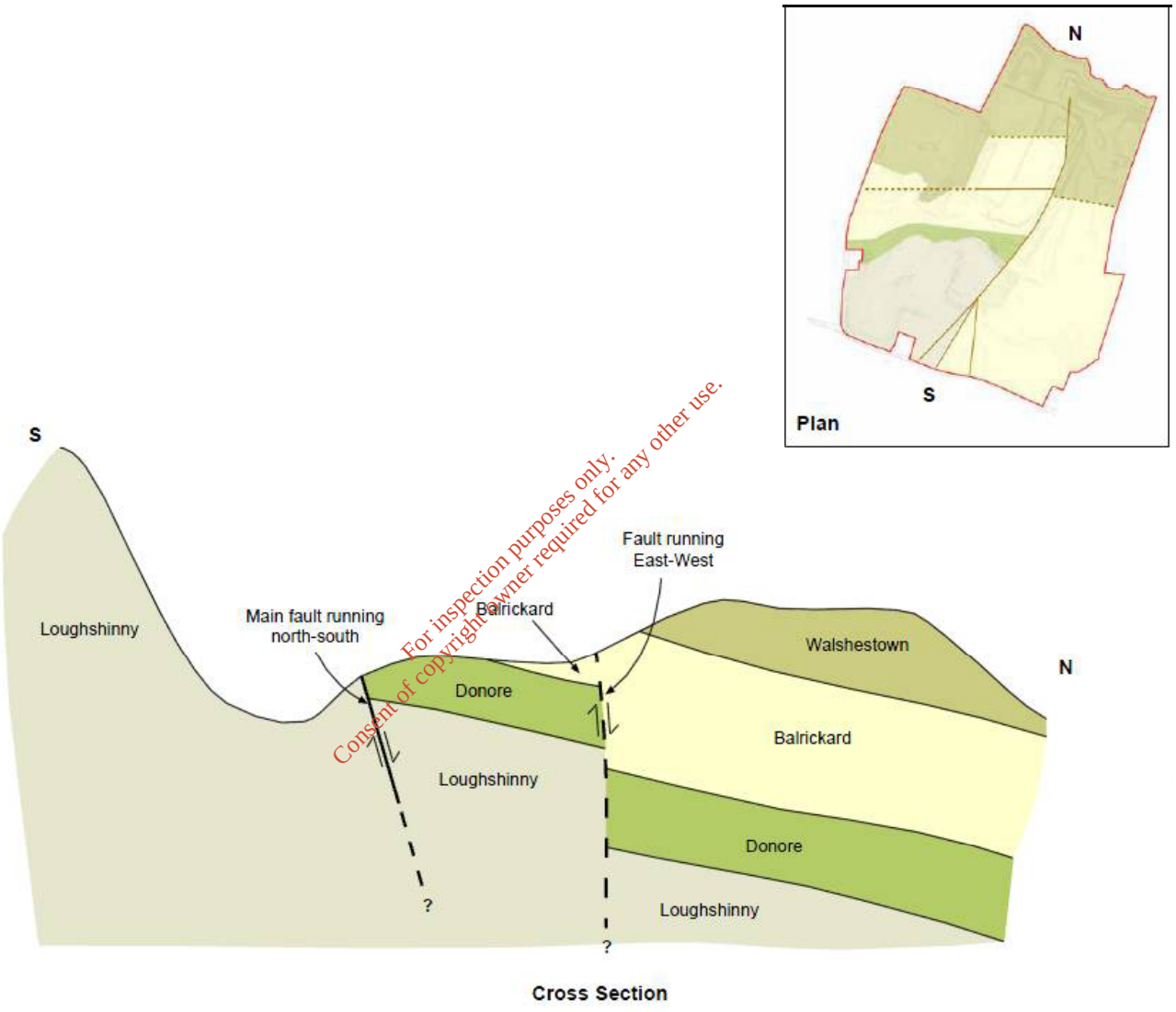


Figure 7: GSI vulnerability criteria

Vulnerability Rating	Hydrogeological Conditions				
	Subsoil Permeability (Type) and Thickness			Unsaturated Zone	Karst Features
	High permeability (sand/gravel)	Moderate permeability (e.g. Sandy subsoil)	Low permeability (e.g. Clayey subsoil, clay, peat)	(Sand/gravel aquifers only)	(<30 m radius)
Extreme (E)	0 - 3.0m	0 - 3.0m	0 - 3.0m	0 - 3.0m	-
High (H)	> 3.0m	3.0 - 10.0m	3.0 - 5.0m	> 3.0m	N/A
Moderate (M)	N/A	> 10.0m	5.0 - 10.0m	N/A	N/A
Low (L)	N/A	N/A	> 10.0m	N/A	N/A

Notes: (1) N/A = not applicable.
(2) Precise permeability values cannot be given at present.
(3) Release point of contaminants is assumed to be 1-2 m below ground surface.

Figure 8: GSI Response Matrix for landfills

Response Matrix for Landfills

VULNERABILITY RATING	SOURCE PROTECTION AREA		RESOURCE PROTECTION Aquifer Category					
			Regionally Important (R)		Locally Important (L)		Poor Aquifers (P)	
	Inner	Outer	Rk	Rf/Rg	Lm/Lg	Ll	Pl	Pu
Extreme (E)	R4	R4	R4	R4	$R3^2$	$R2^2$	$R2^2$	$R2^1$
High (H)	R4	R4	R4	R4	$R3^1$	$R2^1$	$R2^1$	R1
Moderate (M)	R4	R4	R4	$R3^1$	$R2^2$	$R2^1$	$R2^1$	R1
Low (L)	R4	$R3^1$	$R3^1$	$R3^1$	R1	R1	R1	R1

Figure 9: Groundwater divide

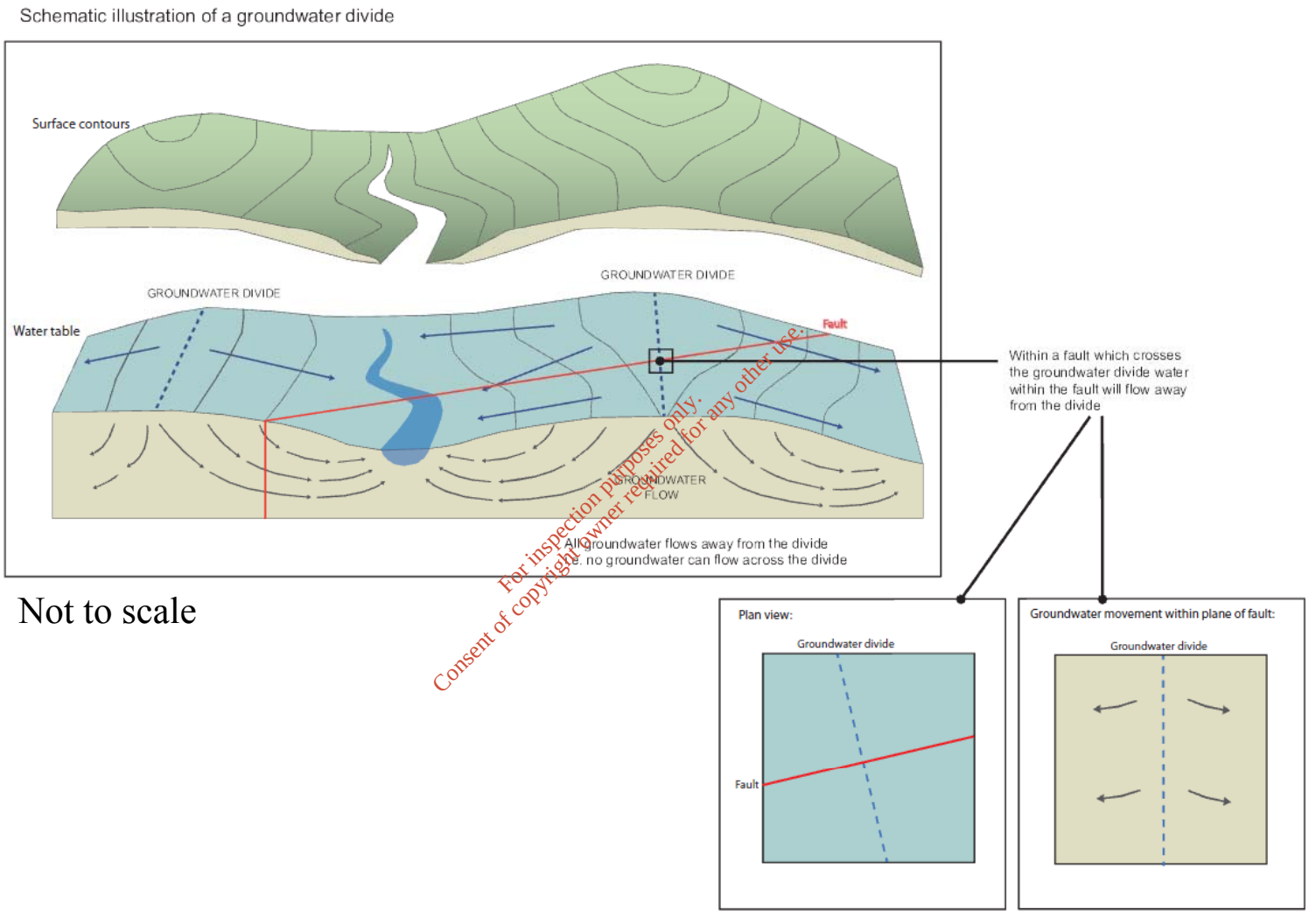
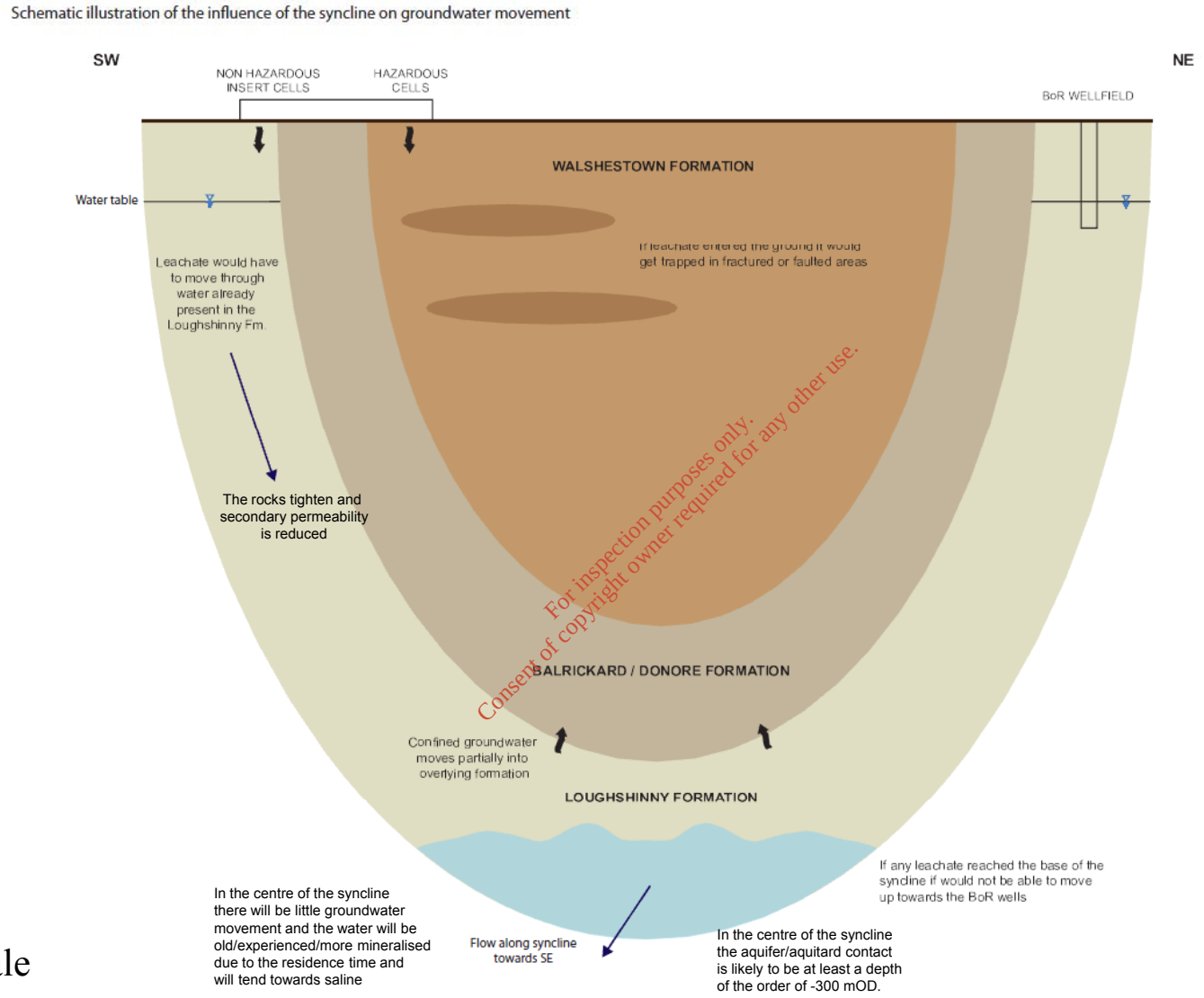


Figure 10: Movement through the syncline



Not to scale

Figure 11: BH16

- Geo-bore 'S' cored hole undertaken to 60 mbgl.
- Loughshinny Fm originally expected at 20-30 mbgl
- Walshestown Fm from 0 mbgl to 58 mbgl.
- Donore Fm encountered at 58 mbgl and this lies directly above Loughshinny
- Implies the aquifer is over 60 m below ground level at this location

BH16 Box 3 of 37 – 3.10-4.70m