



Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Ballyheigue Water Supply Scheme

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PROJECT DESCRIPTION

Since the 1980's, the Geological Survey of Ireland (GSI) has undertaken a considerable amount of work developing Groundwater Protection Schemes throughout the country. Groundwater Source Protection Zones are the surface and subsurface areas surrounding a groundwater source, *i.e.* a well, wellfield or spring, in which water and contaminants may enter groundwater and move towards the source. Knowledge of where the water is coming from is critical when trying to interpret water quality data at the groundwater source. The Source Protection Zone also provides an area in which to focus further investigation and is an area where protective measures can be introduced to maintain or improve the quality of groundwater.

The project "Establishment of Groundwater Source Protection Zones", led by the Environmental Protection Agency (EPA), represents a continuation of the GSI's work. A CDM/TOBIN/OCM project team has been retained by the EPA to establish Groundwater Source Protection Zones at monitoring points in the EPA's National Groundwater Quality Network.

A suite of maps and digital GIS layers accompany this report and the reports and maps are hosted on the EPA and GSI websites (www.epa.ie; www.gsi.ie).



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1 Introduction

Groundwater Source Protection Zones are delineated for the Ballyheigue supply which delivers water to the villages of Ballyheigue and Causeway, according to the principles and methodologies set out in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999) and in the GSI/EPA/IGI Training course on Groundwater Source Protection Zone Delineation.

The objectives of the report are as follows:

- To outline the principal hydrogeological characteristics of the area surrounding the source.
- To delineate source protection zones for the borehole.
- To assist the Environmental Protection Agency and Kerry County Council in protecting the water supply from contamination.

Groundwater protection zones are delineated to help prioritise the area around the source in terms of pollution risk to groundwater. This prioritisation is intended as a guide in evaluating the likely suitability of an area for a proposed activity prior to site investigations. The delineation and use of groundwater protection zones is further outlined in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

The maps produced are based largely on the readily available information in the area, a field walkover, test pumping, water levels and on mapping techniques which use inferences and judgements based on experience at other sites. As such, the maps cannot claim to be definitively accurate across the whole area covered, and should not be used as the sole basis for site-specific decisions, which will usually require the collection of additional site-specific data.

2 Methodology

The methodology comprised data collection, desk studies, site visits, field mapping of karst features and exposures, hydrogeological mapping, well audits and water level recording. Analysis of the information collected during the studies was used to delimit the Source Protection Zones.

Site visits (including an interview with the caretaker), site walkovers and field mapping were conducted during November 2011 and February 2012. The gathering of additional information, including consultation of previous reports provided by Kerry County Council, provided background information on the boreholes.

3 Location, site description and well head protection

The Ballyheigue source is situated 2 km southeast of Ballyheigue village, 0.5 km to the east of the R551 regional road in Knockroe townland (Figure 1).

The source known as "Ballymaquin Slugaire" comprises a 1.37 m diameter steel shaft 6.2 m deep, embedded in a 4.5 m thick peat and 1.5 m of a coarse grained subsoil, set onto rock, which is slotted at the bottom – intersecting the coarse grained layer and the top of the rock, to allow water in. Water flows via gravity from a pipe 2.1m below ground level in the well to the pumphouse. A probe activates a pump within the steel shaft when the gravity feed cannot supply the demand. Therefore the well acts as a sump or a pumping well depending on water levels and demand. Further details are in Appendix 1 (Minerex 2006) and in particular part Appendix C which provides a schematic of the well.

The construction of the well, is such that it stands proud of the compound floor as can be seen in Photograph 1. This is due to periodic flooding of the area. The source is situated within a fenced and gated Local Authority compound. Interlocking sheet piles were installed around the compound perimeter to rock head to prevent surface water flooding in 2006. The site compound comprises 100mm thick concrete slabs immediately around the well, and floored, partially, by stone fill. The top of the concrete housing has a steel galvanise cover, which is open in Photograph 2. The steel shaft itself has no cover over it. The well is located in a flat area prone to flooding surrounded by a dense network of drains. There are no records available as to the history of the source and it is not understood as to why it is located where it is. The area immediately around the source appears to be a large discharge zone.

4 Summary of borehole details

The source supplies an average daily demand of 2,725 m³/day to the villages of Ballyheigue and Causeway, and to the surrounding area. Table 1 summarises the details.

Table 1 Summary details

	Ballyheigue Source
Local Authority Code	1300PUB1001
EU Reporting Code	IE_SE_G_008_08_001
Grid reference	E076700 N126400
Townland	Knockroe
Source type	Large diameter shallow dug well
Owner	Kerry County Council
Ground level at borehole	Approximately 4 mOD
Depth of Well	6.2 m bgl
Construction	1.37 m diameter steel shaft to 5.8 m bgl Slotted from 5.8 m bgl to rock head (1.5 m)
Depth to rock	6.2 m
Static water level (bgl)	Ground level
Pumping water level	It is mostly gravity fed; when the gravity feed is insufficient, the pumps start, and the probe limits drawdown to about 2.5 m bgl
Current abstraction rate (County Council records)	2,725 m ³ /d in 2011
Specific Capacity (SC)	2006 Pumping test: 6,566 m ³ /day, 2.79 m drawdown = 2350 m³/day/m 1979 Pumping test: 5633 m ³ /day, 3.0m drawdown = 1878 m³/day/m
Transmissivity	2291-2867 m²/d , based on the specific capacity



Photo 1 Ballyheigue source (2008)



Photo 2 Ballyheigue source showing the well head and the chamber for Ballyheigue (2008)

5 Topography, surface hydrology and landuse

Figure 1 shows the location, of the source and the topography and hydrology in the area of the source for Ballyheigue. The source is situated in an area “liable to flooding”, 3-5 m OD, 1.7 km from Ballyheigue Bay. East and south of the source is distinguished by a low plateau that gently undulates between 8 m and 20 m OD, with a notable high at Lerrig, approximately 40 m OD. Sand dunes bound the coastline along Ballyheigue Bay, 1.5 km to the west of the source. The topographic gradient from the source to Lerrig is initially approximately 0.005 but inclines to 0.01 on the slopes up the hill at Lerrig.

Figure 1 shows that the general area south and east of the source comprises a low plateau of approximately 15 km² that is devoid of a surface drainage system. However, it is bounded to the north, south, east and west by streams. Lerrig Lough, is located 4 km to the southeast, at the base of the hill at Lerrig. Akeragh Lough is a saltwater marsh located between the source and the sand dunes, and comprises a wet grassland/marsh area that was channelized 40 years ago to convey surface water towards Black Rock and reduce flooding. It still periodically floods. A dense network of drains occupy a 5 km stretch, north of the source, between Ballymacquin Bridge and the townland of Ballynorig West.

The source compound is surrounded by commercial coniferous forestry and rough grassland – largely confined to low-lying land which is prone to flooding – this area extends east along the Akeragh River/Lough. Generally, outside the most low-lying portions of the landscape, land quality is agricultural, split equally between tillage and pasture (dairying and cattle rearing) and is intensive. The nearest house/farmyard is approximately 0.5 km to the west of the source. There are a number of roads and the houses have on-site wastewater systems installed. The landuse pressure is ‘moderate’ to ‘high’.

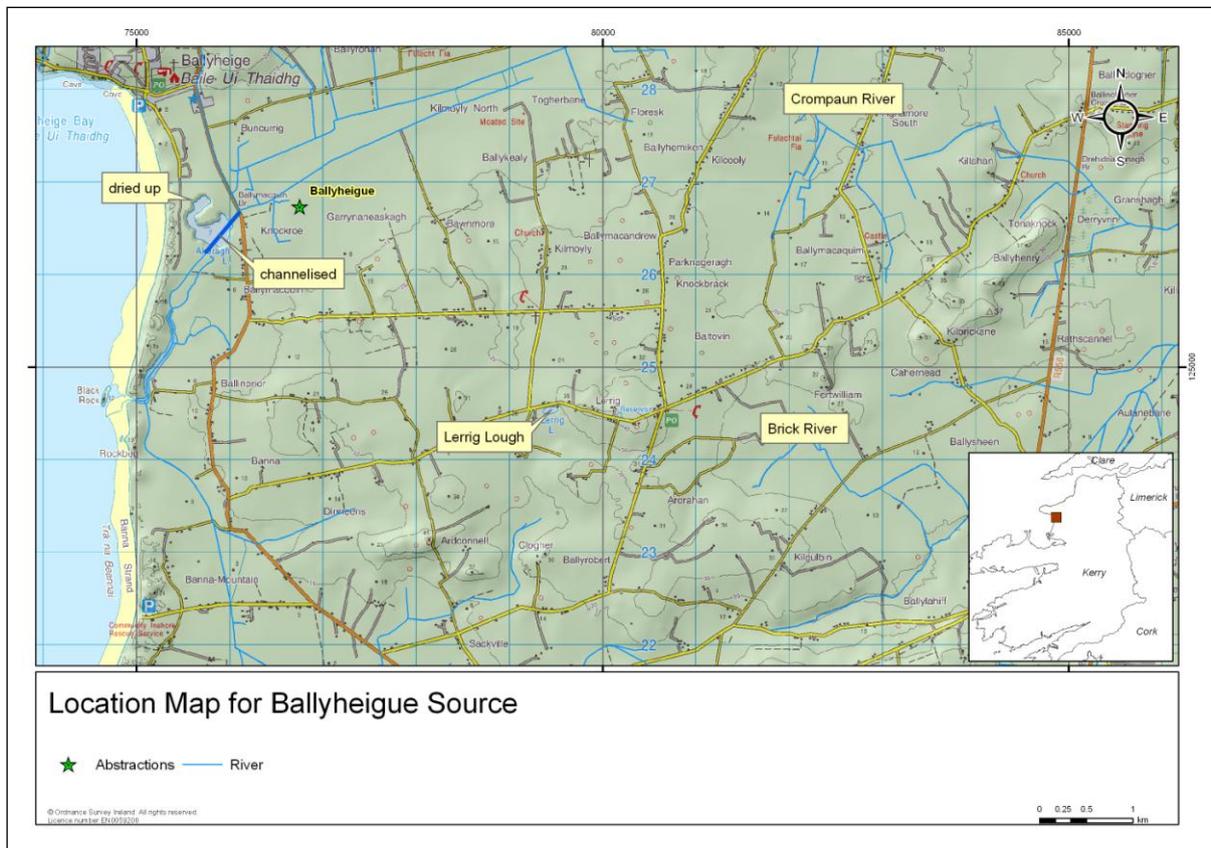


Figure 1 Topography and hydrology in the area of Ballyheigue and location of the source

6 Hydro-meteorology

Establishing groundwater source protection zones requires an understanding of general meteorological patterns across the area of interest. The data source is Met Éireann.

Annual rainfall: This is taken to be 1072 mm. The closest meteorological station to the source is located 1.5 km to the northwest, at Ballyheigue gauging station. Data records from here were sourced from Met Éireann's 1961–90 long term annual average rainfall dataset (Fitzgerald and Forrestal, 1996).

Annual evapotranspiration losses: 475 mm. Potential evapotranspiration (P.E.) in the north Kerry area is estimated to be 500 mm/yr (based on data from Met Éireann). Actual evapotranspiration (A.E.) is then estimated as 95% of P.E., to allow for seasonal soil moisture deficits giving an actual evapotranspiration amount of 475 mm.

Annual Effective Rainfall: 595 mm. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. The annual effective rainfall, or potential recharge, is therefore, 595 mm/year.

For more discussion on this, see also Section 10 on Recharge which estimates the proportion of effective rainfall that enters the aquifer.

7 Geology

This section briefly describes the relevant characteristics of the geological materials that underlie the area around the source. It provides a framework for the assessment of groundwater flow and the source protection zones. The geological information is based on:

- The Geological Survey of Ireland (GSI) bedrock geological map of Dingle Bay Area, Sheet 20, 1:100,000 Series and accompanying booklet (Pracht *et al*, 1995),
- The Geological Survey of Ireland (GSI) bedrock geological map of Shannon Estuary, Sheet 17, 1:100,000 Series and accompanying booklet (Sleeman *et al*, 1999),
- The GSI Well, Borehole and Karst Databases,
- The EPA Soil and Subsoil Map of County Kerry, and on,
- Bedrock outcrop and subsoil exposures encountered and mapped during site visits.

7.1 Bedrock

The source is located at the mapped boundary of the Dinantian Pure Unbedded Limestones (Waulsortian Limestone) and the Dinantian Lower Impure Limestones (Ballysteen Formation) shown in Figure 2.

The area is located on the southern limb of the Kerry Head Anticline, centred approximately 4 km north of the Akeragh River. Devonian Old Red Sandstones form the core of the anticline overlain by progressively younger rocks on the southern flank (Dinantian early Sandstones, Shales and Limestones, Dinantian Lower Impure Limestones and Dinantian Pure Unbedded Limestones).

Extensive drilling and geophysics in the immediate vicinity of the source was undertaken in 2005 by Irish Drilling Ltd (IDL) on behalf of Minerex Ltd (see Appendix 1). Four rotary core boreholes were drilled around the source, to approximately 20m below rock head. The bedrock is recorded as “*very strong light grey*

'marbled' whitish cream, **massive**, fine grained Limestone, slightly weathered". In addition, both open and silt filled joints/fractures are present, approximately 70% occurring between 8-14 m and 20-24 m below the ground surface. All of the rotary cored holes record poor or very poor Rock Quality Designation in the top 5m of rock, suggesting relatively high permeabilities at this depth. In one of the rotary core boreholes (RC2) a cavity (0.8m deep) is recorded at 22.4 m to 23.2 m below ground surface (13.9 m to 14.7 m below rock head). Apart from the recorded cavity, no dissolution or karstification was observed at rock head within the borehole logs and that the rock is well jointed.

The site data suggests that the well is located on the Waulsortian Limestone.

The upper unit of the Ballysteen Formation is argillaceous and has a typical carbonate/shale ratio of 30-40% (Sleeman et al, 1999). Approximately 3 km to the south of the source, the Rockfield Limestone Formation (Dinantian Upper Impure Limestones) comprising dark grey argillaceous limestones overlies the Waulsortian Formation.

The bedrock in the area has been strongly affected by faulting/folding. Figure 2 shows a mapped NNW-SSE trending fault which may extend toward the source. The geophysical data, indicates that the rock is less competent to the west and southwest of the source. Minerex (2006) have interpreted a fault in the immediate vicinity of the source trending NW-SE, and interpret that rock head dips to the northwest of the site.

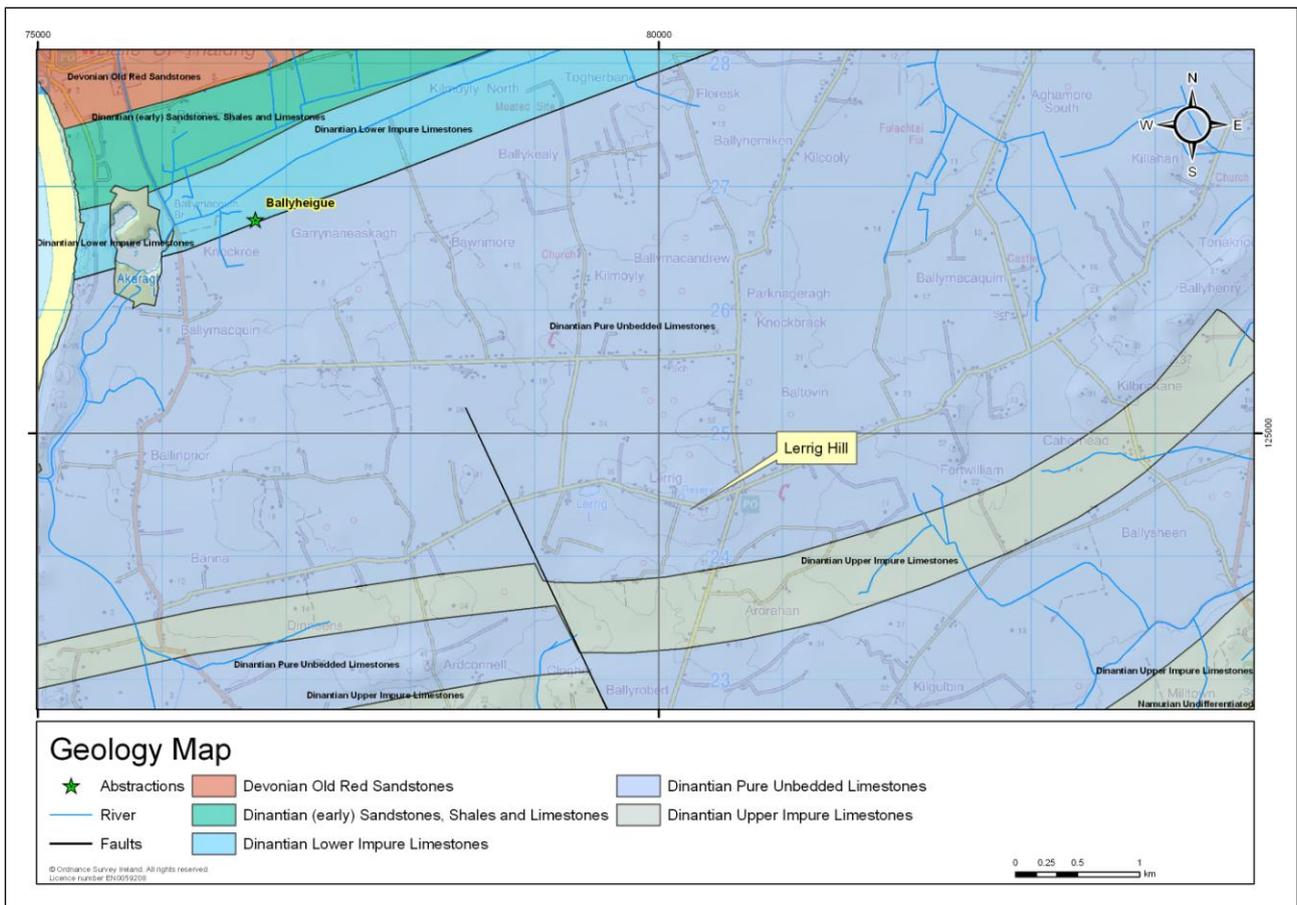


Figure 2 Geology Map of the area around Ballyheigue source

Karst Features

As part of the development of this SPZ report, karst mapping around the source was undertaken by TOBIN Consulting Engineers in February 2012. No swallow holes, dolines or sinking streams were found during this work.

No bedrock exposures were noted within 4 km to the south and east of the borehole. A desk study of the OSI six inch historical bedrock field sheets identified one outcrop 4 km to the southeast of the borehole on Lerrig Hill. While no bedrock exposures were recorded during the field mapping, a local farmer indicated that small collapse dolines a few metres in depth and width ('Sluggeras') occasionally appear in the fields around Lerrig Hill, and are usually filled back in. It is also believed that a sluggera appeared adjacent to the reservoir on Lerrig Hill approximately 10 years ago, and caused the failure of a water main which emptied the reservoir.

A series of small springs, 0.5 km to the southwest of the source, are marked on the OSI 6"inch maps, however these springs are no longer evident in the field. To the south of the Akeragh River, a number of springs (SP1 & SP2) were noted emerging in drainage ditches in February 2012, illustrated in Figure 3. Investigations further to the west of the source identified two springs (SP 1 and SP 2) on the southern bank of the Akeragh River.

Conductivity and temperature monitoring of springs and rivers was undertaken in February 2012 as part of the study (see Table 2 and Figure 3). The springs, SP1 and SP2, are located down-gradient of the source, and appear to be of groundwater origin with relatively high electrical conductivity (756-780 $\mu\text{S}/\text{cm}$), which is significantly higher than that in the Akeragh River (320-430 $\mu\text{S}/\text{cm}$). Additional conductivity measurements of a tributary of Akeragh River at SP3 and SP4 (500–530 $\mu\text{S}/\text{cm}$) possibly suggest a groundwater contribution at these locations. Conductivity measurements of the Crompaun and Brick Rivers suggest a relatively high groundwater component of flow (700-720 $\mu\text{S}/\text{cm}$). The electrical conductivity of the Akeragh River to the north is low, and likely to reflect a greater surface water component of flow (320 $\mu\text{S}/\text{cm}$). Lerrig Lough appears to be surface water fed based on the low conductivity (<300 $\mu\text{S}/\text{cm}$) at this location and seems to be an isolated sealed pond.

Table 2 Electrical Conductivity and temperature monitoring - Feb 2012

Location	Feature	River System	Conductivity ($\mu\text{S}/\text{cm}$)	Temperature
SP1	Spring	Akeragh River	780	11.1
SP2	Spring	Akeragh River	756	11
SP3	River	Akeragh River tributary	500	9.6
SP4	River	Akeragh River tributary	530	9.6
SP5	River	Akeragh River	320	9.4
SP6	River	Akeragh River	430	9.7
SP7	River	Crompaun River	700	9.8
SP8	River	Brick River	720	9.9
SP8	Lake	Lerrig Lough	<300	-
SP9	River	Akeragh River	760	9.7
Ballyheigue source	Borehole	Akeragh River	1025*	11

*Based on average of EPA chemistry data-See Section 9.2

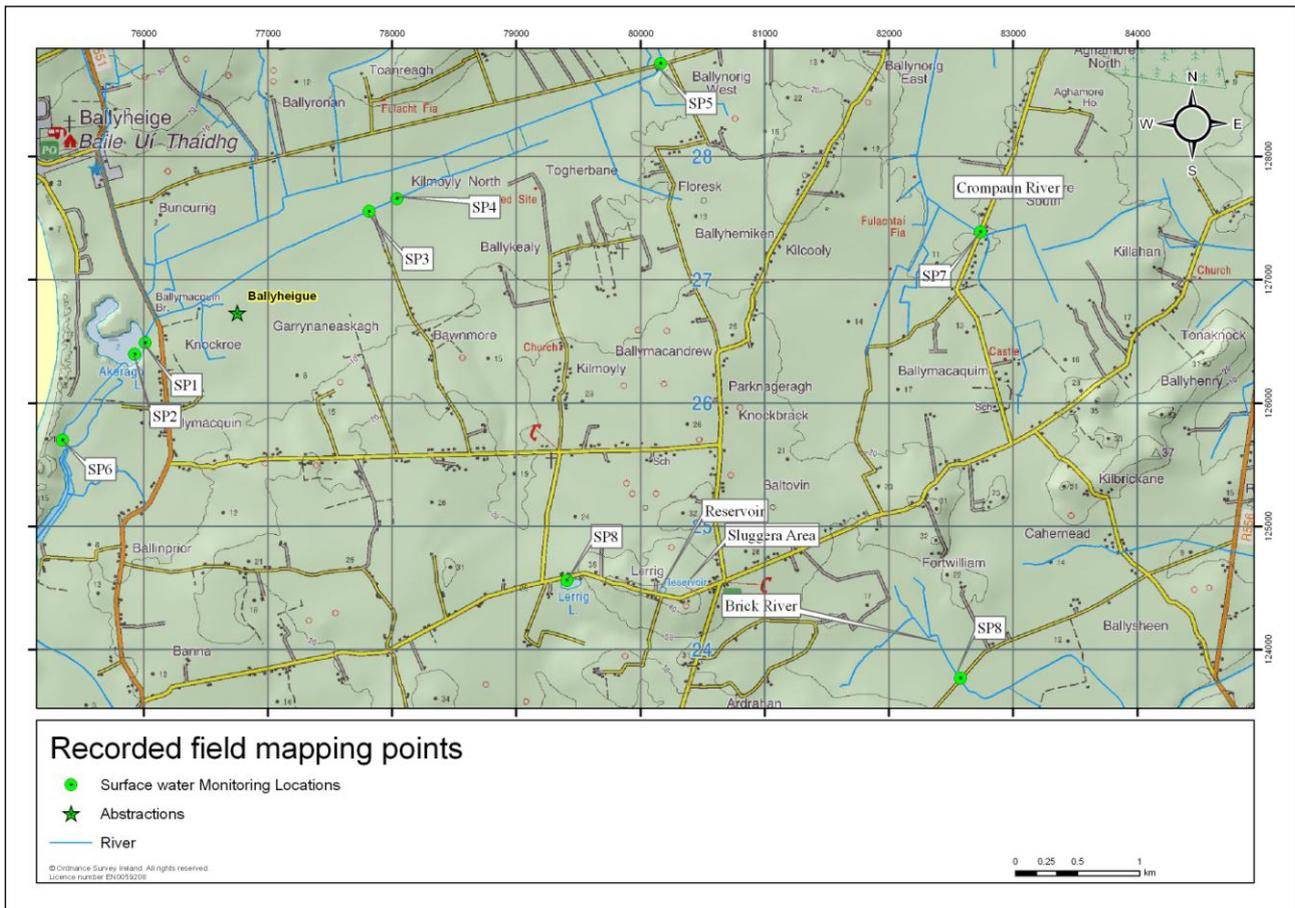


Figure 3 Karst Monitoring locations and surface water monitoring for Ballyheigue

7.2 Soils and subsoils

The subsoils and soils patterns are illustrated in Figure 4 and 5. The study area is underlain predominantly by till derived from Namurian shales and sandstones, though the source itself is located in an extensive (5 km²) area of peat along the Akeragh River floodplain. Site specific data at the source indicates that approximately 5 m of saturated peat overlies a discontinuous layer of silty gravel/gravelly silt, 0-3 m thick, which overlies limestone (Minerex, 2006). This coarse grained layer is discontinuous across the site and it is not clear if it is fluvio-glacial material or a coarse till.

Alluvium subsoils are mapped primarily along the lengths of the Crompaun and Brick Rivers to the southeast and east of the study area. To the north of the Akeragh River floodplain, the area is predominantly underlain by till derived from Devonian shales and sandstones. Bounding the peat are 'wet' soils - deep, poorly drained acidic soil, which also occupy the lowermost areas of the landscape, shown in Figure 5. The higher ground, south and east, are dominated by 'dry' soils that are predominantly deep and well drained, with the exception of a small area of alluvial soils, 3 km to the southeast (Figure 5). Further to the east, extensive alluvial deposits are situated along the Crompaun and Brick Rivers. The presence of the 'wet' soils and the peat coincide with the streams and drains and suggest a discharge zone all around the area mapped with 'dry' soils.

The subsoils across County Kerry have been classified according to British Standard 5930 by Tobin Consulting Engineers, as part of the preparation of a Groundwater Vulnerability map for Kerry County Council, on behalf of the Geological Survey of Ireland. It is considered that the till in the area is

predominantly '**Moderately Permeable**', based on yellow/brown sandy, gravelly SILT/CLAY and sandy, gravelly SILT classifications.

7.3 Depth to bedrock

Site specific data at the source (Minerex, 2006) indicates that the depth to bedrock is approximately 6–9 m. Information gathered as part of a well survey carried out by TOBIN in the wider area indicates that depth of bedrock is greater than 10 m across the majority of the plateau to the southeast. At Lerrig Hill, also to the southeast of the catchment area, outcrop occurs or bedrock is close to the surface, and an adjacent borehole had bedrock at 2.5m bgl. Borehole drilling was undertaken on the plateau to the southeast by Tobin Consulting Engineers, as part of the National Groundwater Protection Scheme, on behalf of the Geological Survey of Ireland, in 2011. The depth to bedrock ranges from 2.5 m to over 20 m (TK1, shown in Figure 4).

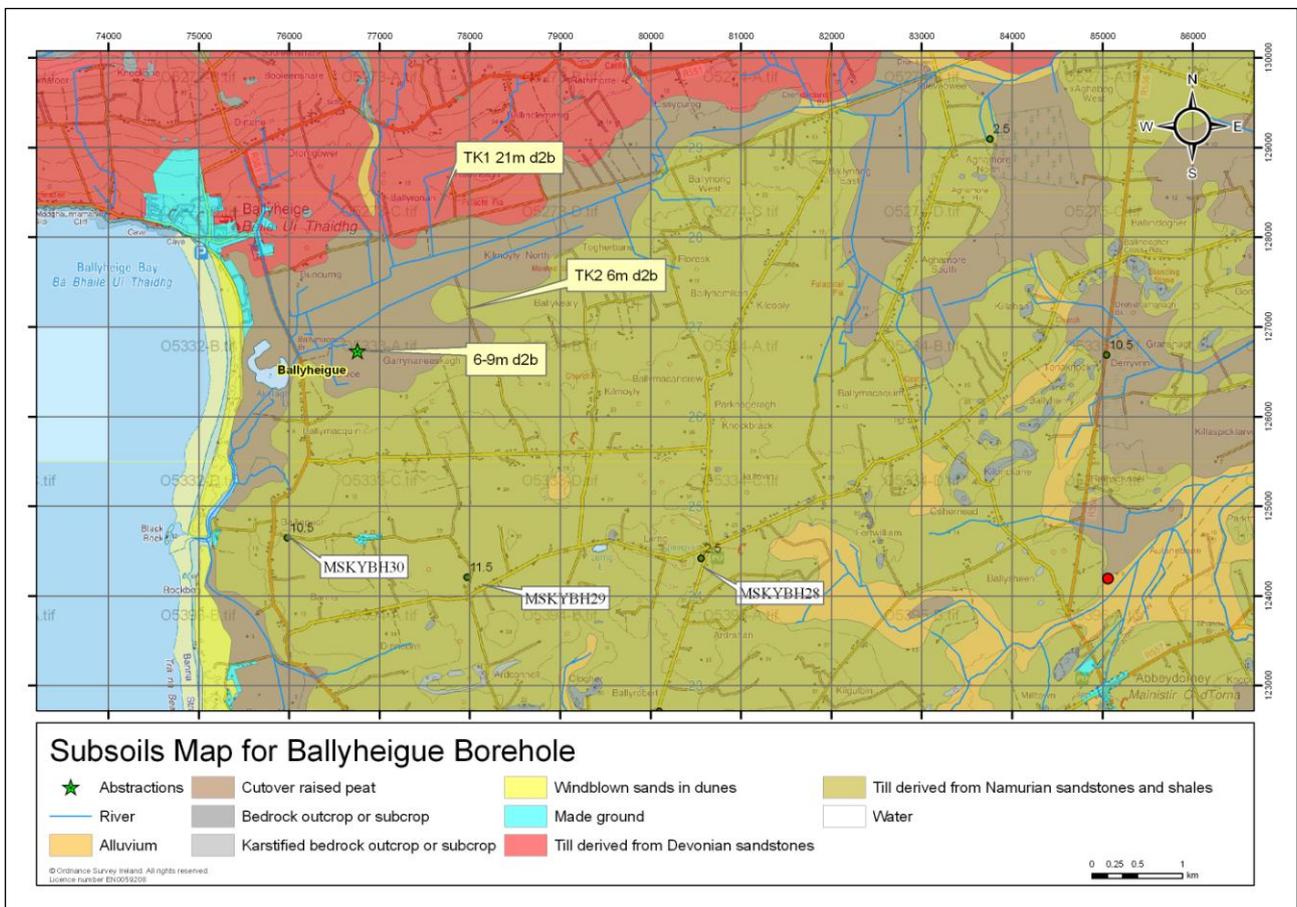


Figure 4 Subsoils Map in the vicinity of Ballyheigue, includes depth to bedrock data

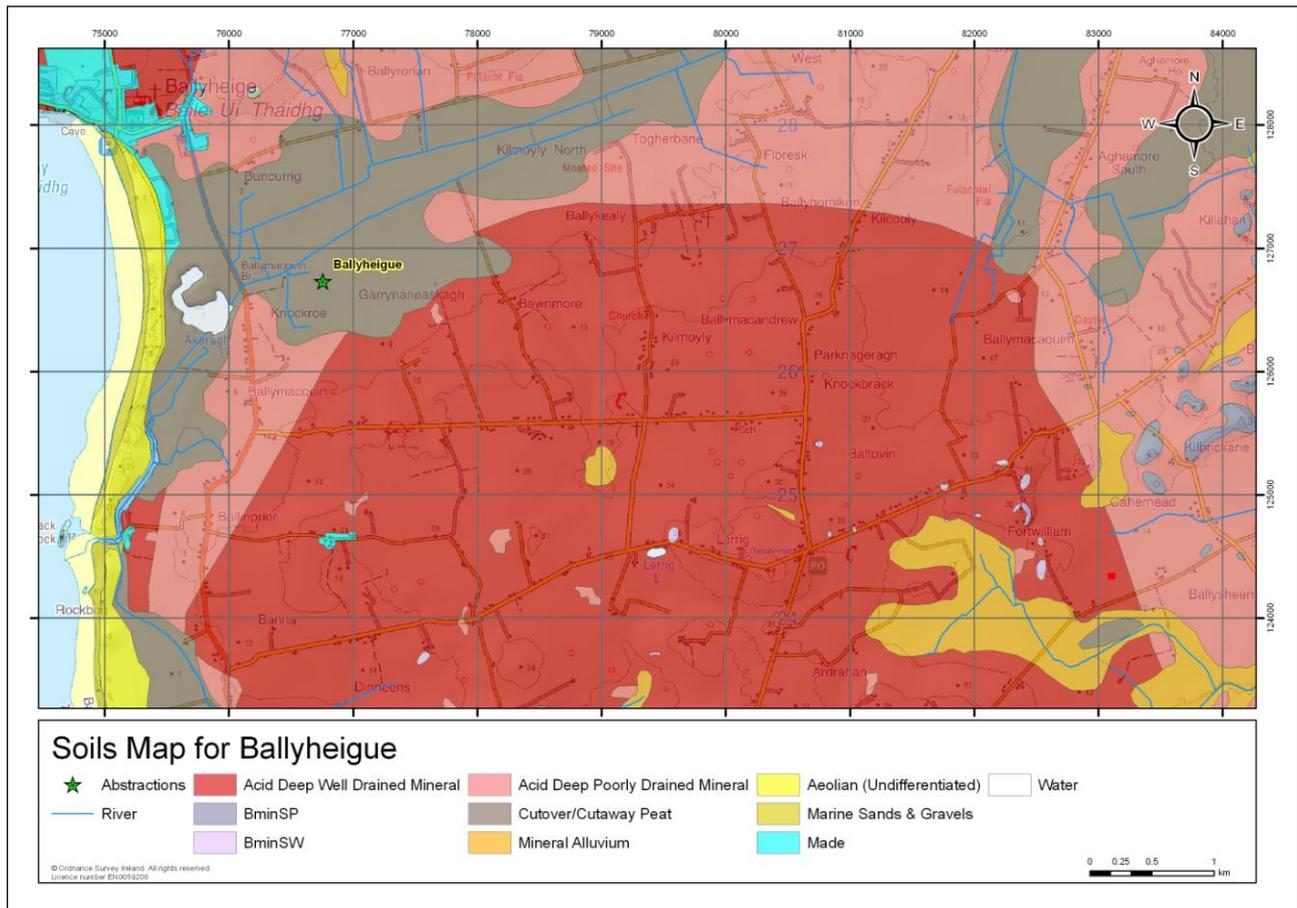


Figure 5 Soils Map in the vicinity of Ballyheigue

8 Groundwater vulnerability

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater ‘target’. A detailed description of the vulnerability categories can be found in the Groundwater Protection Schemes document (DELG/EPA/GSI, 1999) and in the draft GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination (Fitzsimons *et al*, 2003).

The groundwater vulnerability for county Kerry has been prepared by Tobin Consulting Engineers as part of the National Groundwater Protection Scheme, on behalf of the Geological Survey of Ireland, in 2012. The map for the Ballyheigue area is shown in Figure 6. The Groundwater Vulnerability map indicates a sizeable area of Moderate vulnerability based on the largely moderately permeable subsoils.

Across the crests and upper flanks of Lerrig Hill, the vulnerability is mapped as ‘**Extreme**’, which includes the area that is designated as rock at or within 1 m of the surface. These areas are denoted as ‘**X - Extreme**’ vulnerability. Areas of high vulnerability are present on the upper backslopes and on the upper slopes of the plateau to the southeast of the source.

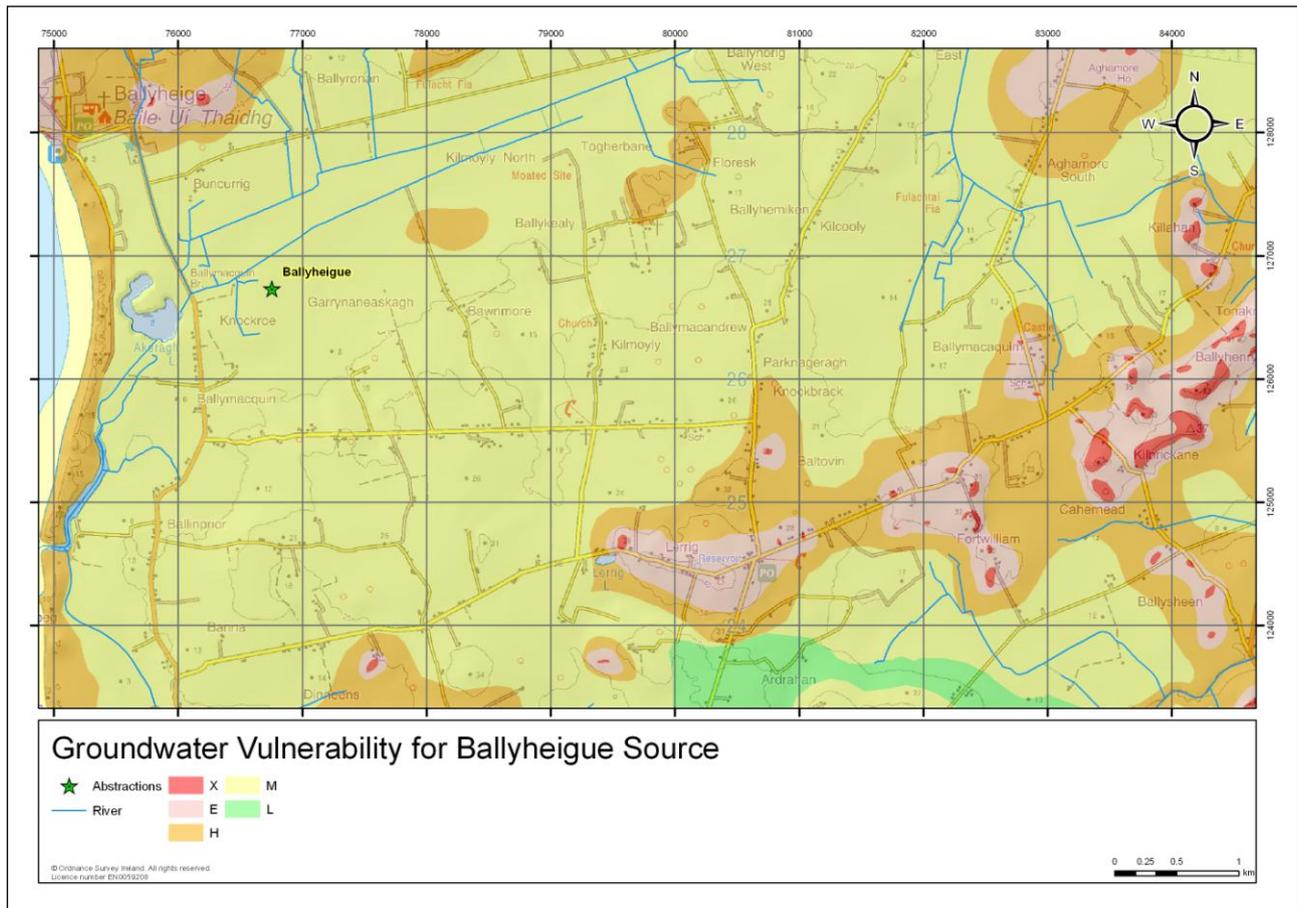


Figure 6 Groundwater Vulnerability in the vicinity of Ballyheigue

9 Hydrogeology

This section describes the current understanding of the hydrogeology in the vicinity of the Source. Hydrogeological and hydrochemical information was obtained from the following sources:

- GSI Website and Databases.
- EPA website and Groundwater Monitoring database.
- Local Authority Drinking Water returns.
- A Hydrogeology Report completed by Minerex Environmental Ltd. (2006).
- A Source Protection Report completed by Fehily Timoney & Co. Ltd. (2000).
- Hydrogeological mapping by TOBIN Consulting Engineers in 2011 and 2012.
- Consultation with County Council Staff.

9.1 Groundwater body and status

The source is situated in the 'karstic' Ardfert Groundwater Body (GSI, 2010), which is classified as having 'Poor Status' in 2010. The Ardfert Groundwater Body was classified as having 'Poor Status', failing principally due to related surface water tests (Tyshe River water body) for nutrient loadings and for the

Drinking Water Status tests; however, it no longer fails this latter test, revised in 2011. In fact the Groundwater Body is at Good Status (high confidence) for the general groundwater quality test (www.wfdireland.ie; www.watermaps.wfdireland.ie). To the east, the Ardfert Groundwater Body bounds the 'karstic' Ballybunnion Groundwater Body, also of 'Poor Status'. Immediately to the north, the Ardfert Groundwater Body bounds the non-karstic Kerry Head Groundwater Body, which is of 'Good Status'. The groundwater body descriptions are available from the GSI website: www.gsi.ie and the 'status' is obtained from the WFD website: www.wfdireland.ie.

9.2 Groundwater levels, flow directions and gradients

As indicated in Section 5.2 Surface Hydrology there is a 15 km² area that is devoid of surface drainage. To establish flow directions and to understand the flow regimes groundwater levels were obtained from private boreholes in February 2012. Examination by successive triangulation using the dipped water levels indicate in general a northwesterly groundwater flow component as shown in Figure 7. In the vicinity of TBH13, TBH11, TBH12 and TBH3 the groundwater flow component swings in a more westerly direction. In the vicinity of TBH11 and TBH12 the groundwater flow appears to comprise a more northerly component. The groundwater flow direction appears to focus groundwater toward the area around source. It is assumed there is a groundwater divide in the vicinity of Knockbrack and Kilcooly with the high ground around Lerrig acting as a central high groundwater mound. Groundwater level monitoring of wells in the immediate vicinity of the source, indicated groundwater flow direction to be in a westerly direction (Minerex, 2006). Apart from the area around Lerrig, the water levels are low and the gradient is relatively flat, mirroring the topography. The gradient is estimated to be approximately 0.005, based on the interpreted groundwater contours.

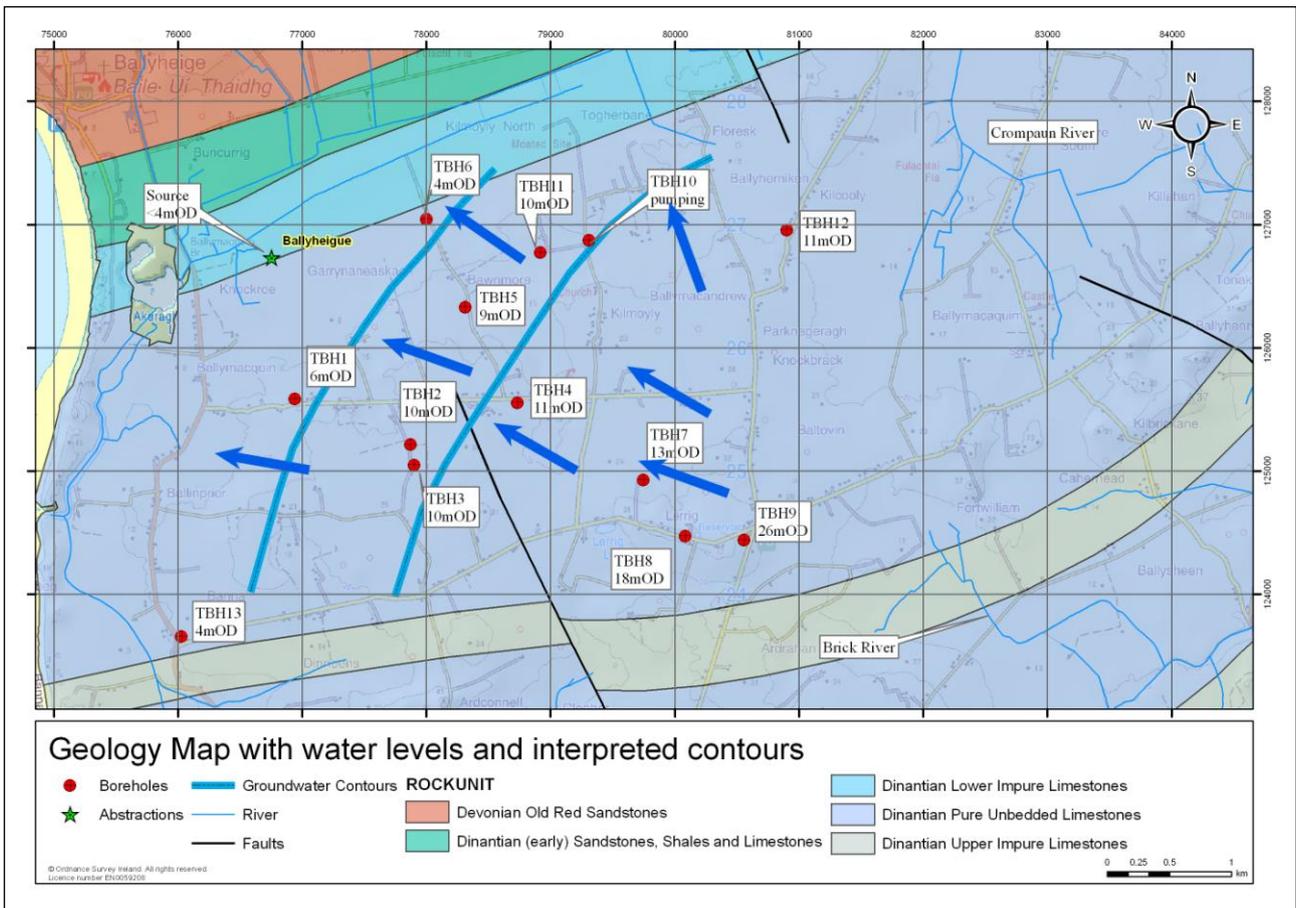


Figure 7 Bedrock map and interpreted Groundwater contours and flow directions around Ballyheigue

9.3 Hydrochemistry and water quality

Samples taken as part of the EPA Groundwater Monitoring Network at Ballyheigue are available from 1995 to 2010, and there are also analyses available from Kerry County Council from 1998. The data show that the water is very hard, with total hardness values of 348–508 mg/l (equivalent CaCO₃). Alkalinity ranges from 280–390 mg/l CaCO₃ indicating that the groundwater has a calcium bicarbonate hydrochemical signature. The pH ranges 7.0–7.5, with an average of 7.2, which is slightly alkaline. The average recorded field temperature is 11.8°C, with peaks above 15 °C. Colour and turbidity are regularly elevated.

Figures 8 - 13 shows the data for the key indicators of contamination, and the main points are as follows:

- Electrical conductivity (EC) is elevated with a mean of 1025 µS/cm, and ranges from 545 to 1107 µS/cm. The data are shown in Figure 8. The mean exceeds 800 µS/cm, the Groundwater Threshold Value for the Saline Intrusion Test (Groundwater Regulations S.I. No. 9 of 2010). Conductivities of this level are indicative either of contamination or saline intrusion. They are also significantly higher than both up-gradient and down-gradient springs measured by TOBIN in February 2012 as described in Section 7.1.

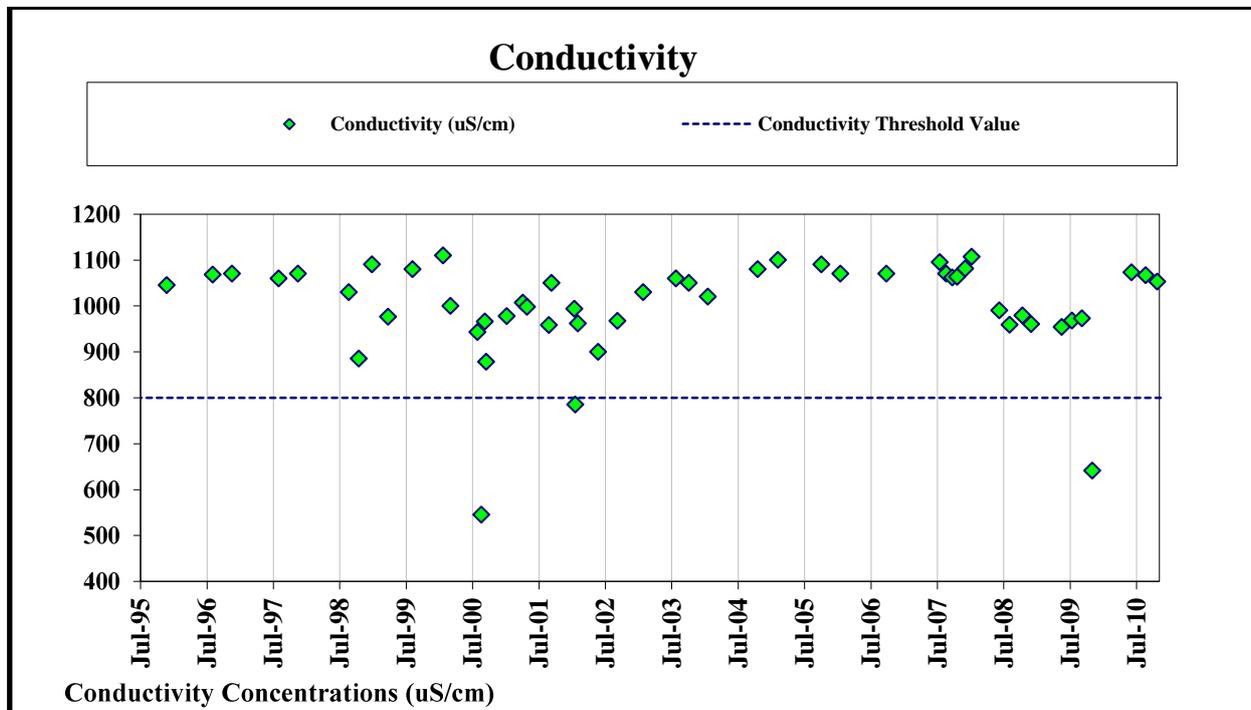


Figure 8 Conductivity Values for Ballyheigue source.

- Chloride is a constituent of organic wastes, sewage discharge and artificial fertilisers, and concentrations higher than 24 mg/l (Groundwater Threshold Value for Saline Intrusion Test, Groundwater Regulations S.I. No. 9 of 2010) may indicate contamination, with levels higher than 30 mg/l usually indicating significant contamination (Daly, 1996). Chloride concentrations range from 16 to 115 mg/l, with a mean of 91 mg/l. Chloride concentrations on average are 3.5 times above the Groundwater Threshold Value for the Saline Intrusion Test. In contrast (Figure 9) to other coastal sources in Kerry, the chloride concentrations for Ballyheigue are significantly greater than Ardfert South (6 km due south); Lixnaw (10 km due east); Portmagee (due south of Valentia Island). In comparison to Fenit (Chapletown) (10 km due south), concentrations are similar – 80 to 120 mg/l. Both Fenit and Ballyheigue are very close to the sea and at a low elevation. Given the proximity of

Ballyheigue to the coast (1.5 km to the west) and to Akeragh Lough the high chloride concentrations may reflect a brackish water/saltwater influence.

- Nitrate concentrations range from 7.4–46.6 mg/l with a mean of 34.1 mg/l. Concentrations in 2006 and 2007 exceeded the groundwater Threshold Value (Groundwater regulations S.I. No. 9 of 2010) value of 37.5 mg/l, however there are no peaks above 50 mg/l as set out in the Drinking Water Regulations (S.I. No. 278 of 2007). There is no distinct trend in the data – it appears to be consistently around the mean, apart from a few occasions where there are a few events of lower concentrations.
- The highest concentration of Molybdate Reactive Phosphorous (MRP) is 0.015 mg/L P, which is below the Groundwater Threshold Value (Groundwater Regulations S.I. No 9 of 2010) of 0.035 mg/L P.
- Based on the data available, the concentration of sulphate, magnesium and calcium are within normal ranges.
- The Potassium: Sodium (K:Na) ratio is low, at less than 0.2. The ratio of potassium to sodium (K:Na) is used to help indicate if water has been contaminated, along with other parameters, and may indicate contamination if the ratio is greater than 0.4 (Cronin and Furey, 1998). While the ratio of potassium and sodium is low, the concentrations of both are above normal background levels, which reflects the influence of either saline/brackish water.
- Faecal coliforms counts were detected in 18 of the 49 bacteriological samples, with gross contamination (greater than 100 faecal coliforms per 100 ml) occurring twice (10th June 2002 with a count of 613 cfu/100 ml and 26th November 2004 with a count of 1300 cfu/100ml). Samples taken on either side of the event on the 26th November 2004, on the 25th and 29th November 2004 report much lower counts – 2 and 6, respectively, which suggests that at least on that occasion, that the spike of 1300 suggests there is a rapid flow through. It is known that the site was periodically flooded, particularly prior to 2005, when works were undertaken to prevent further flooding. The remainder of counts are generally less than 10 counts per 100 ml, which is considered to be quite low and notably, the majority of these counts have occurred in each of the sampling rounds from August 2008 through to November 2010. Similarly, total coliforms were detected in 29 of the 49 bacteriological samples taken over the same period and generally comprise relatively low counts. These low-level detections may be related to the housing over the well, as the large diameter shaft itself is uncovered. The higher level counts, albeit only on two occasions does suggest that the source is vulnerable to contamination from surface water ingress/infiltration.
- Iron, Manganese and Ammonia concentrations are below the standard set out in the Drinking Water Regulations (S.I. No. 278 of 2007). Prior to 2007, iron concentrations were at times approaching, but not exceeding, the MAC. This appears to be related to the new EPA sampling regime that started in August 2007; this is likely to be due to filtering of the samples in the field. Therefore the iron concentrations prior to 2007 are likely to include undissolved iron.

In summary, the general groundwater quality is impacted by saltwater/brackish water; nitrate concentrations are elevated; and, there are persistent, though low, bacteriological exceedances. The data appear to be more stable since 2005, when the preventative flooding works were installed and when a new sampling regime was put in place in 2007. The recent record of bacteriological exceedances, though very low are persistent. There are two records of gross contamination, prior to 2005, which appear to be related to surface water flooding at the site. Conductivity, nitrate, chloride, potassium and sodium concentrations are elevated. There are occasions when these parameters, along with calcium, magnesium, alkalinity and

sulphate are much lower than the normal ranges for Ballyheigue, for example 07/09/2000, 24/01/2001. These events may be related to high rainfall periods and/or surface water influence. Iron concentrations appear to have reduced since late 2007.

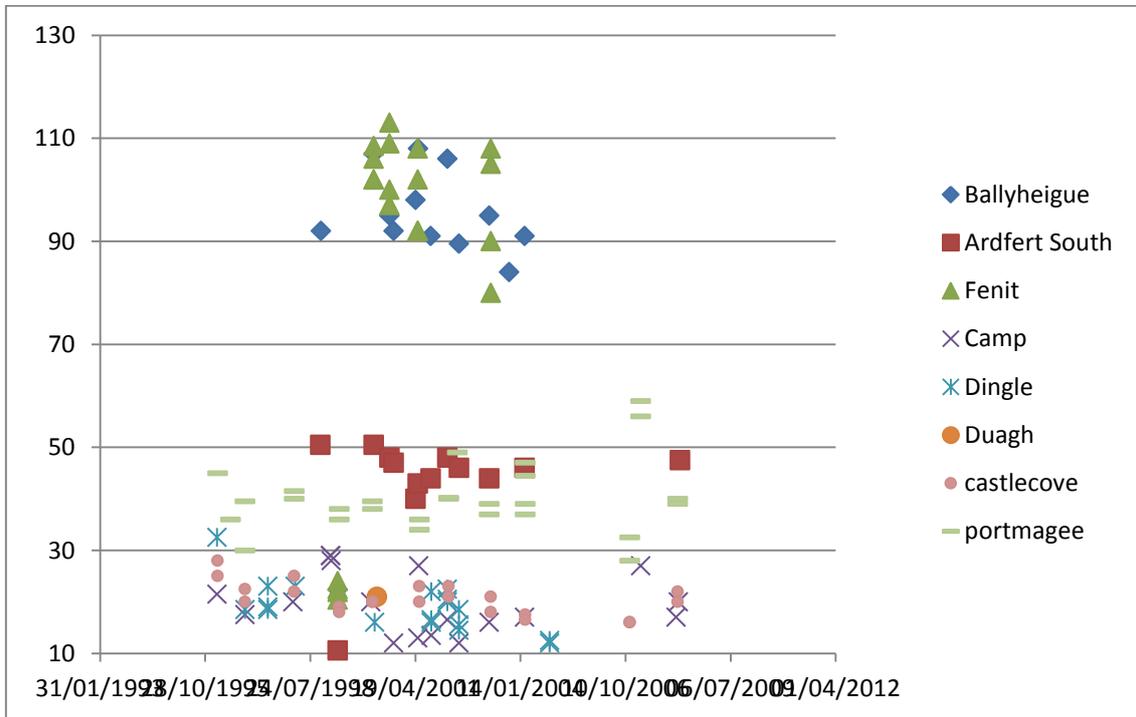


Figure 9 Chloride concentrations in Ballyheigue and other coastal sources

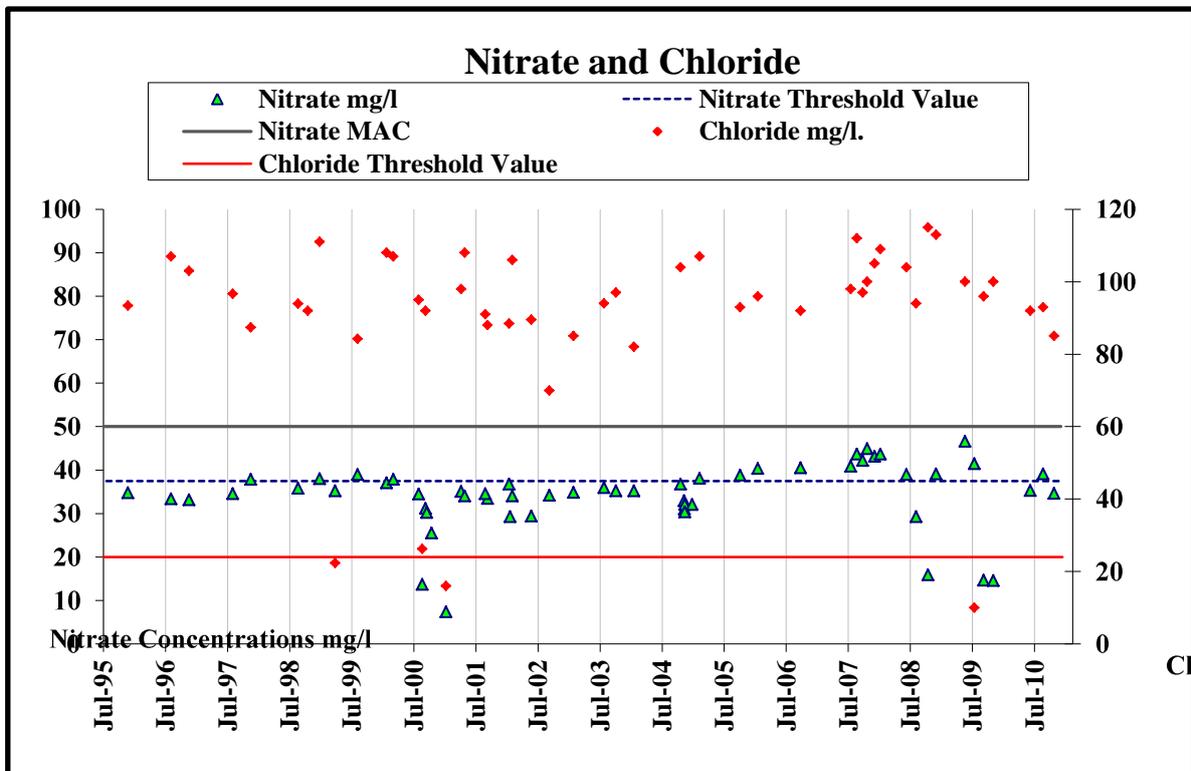


Figure 10 Nitrate and Chloride Concentrations at Ballyheigue

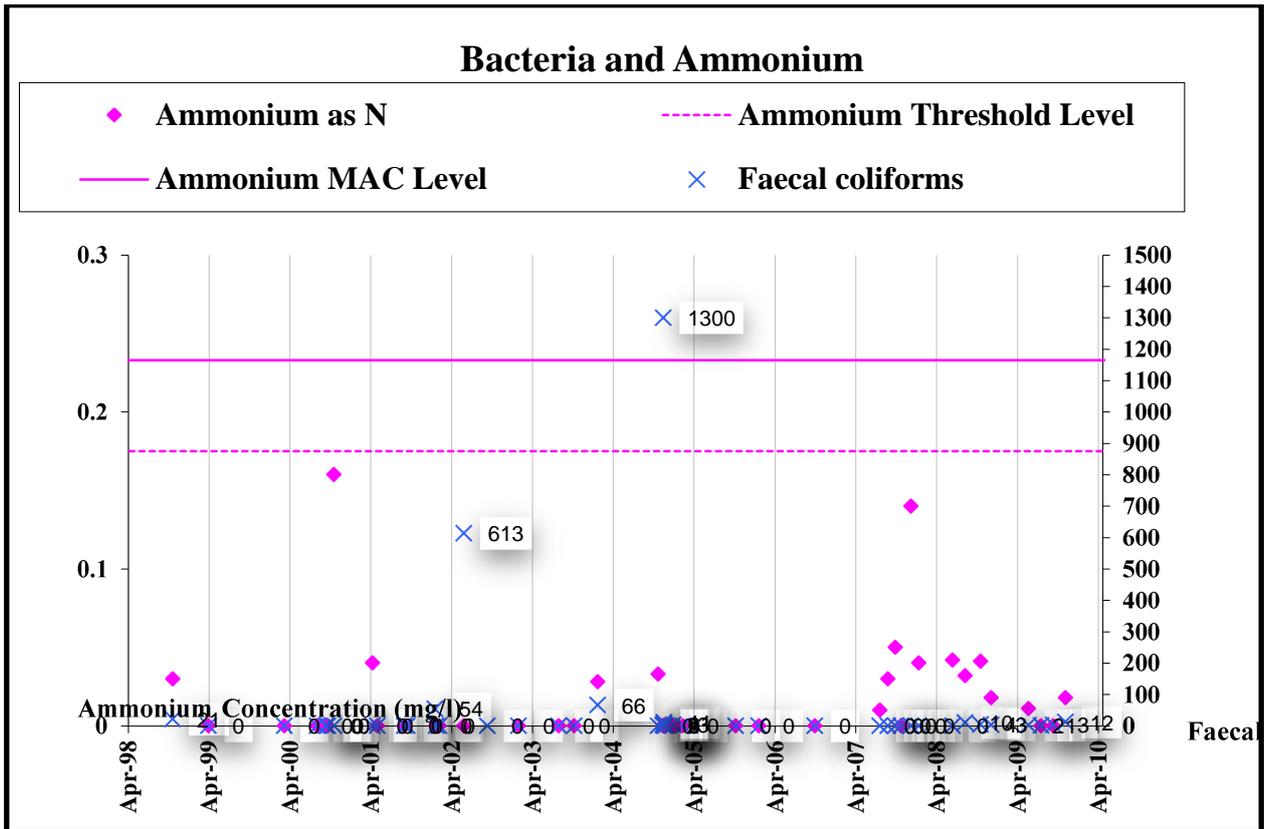


Figure 11 Bacteria and Ammonium Concentrations at Ballyheigue

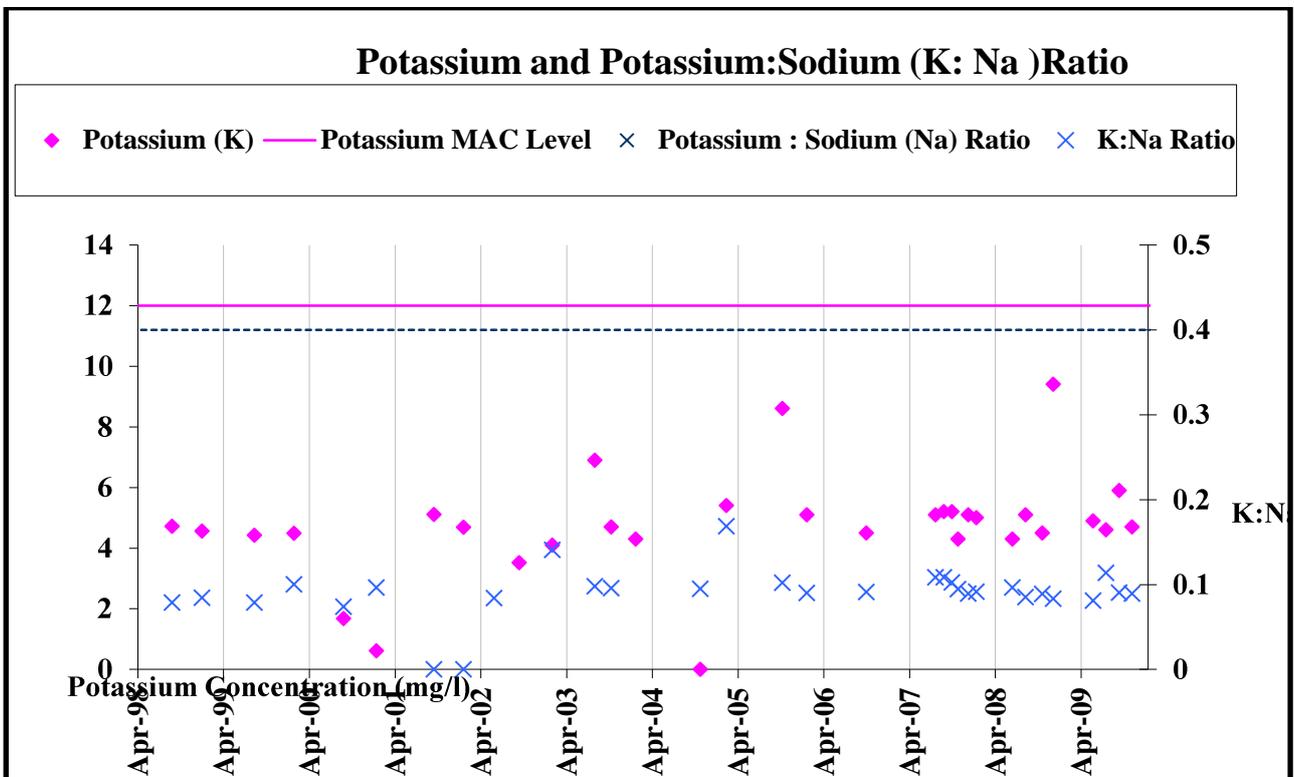


Figure 12 Potassium concentrations and K:Na ratios at Ballyheigue

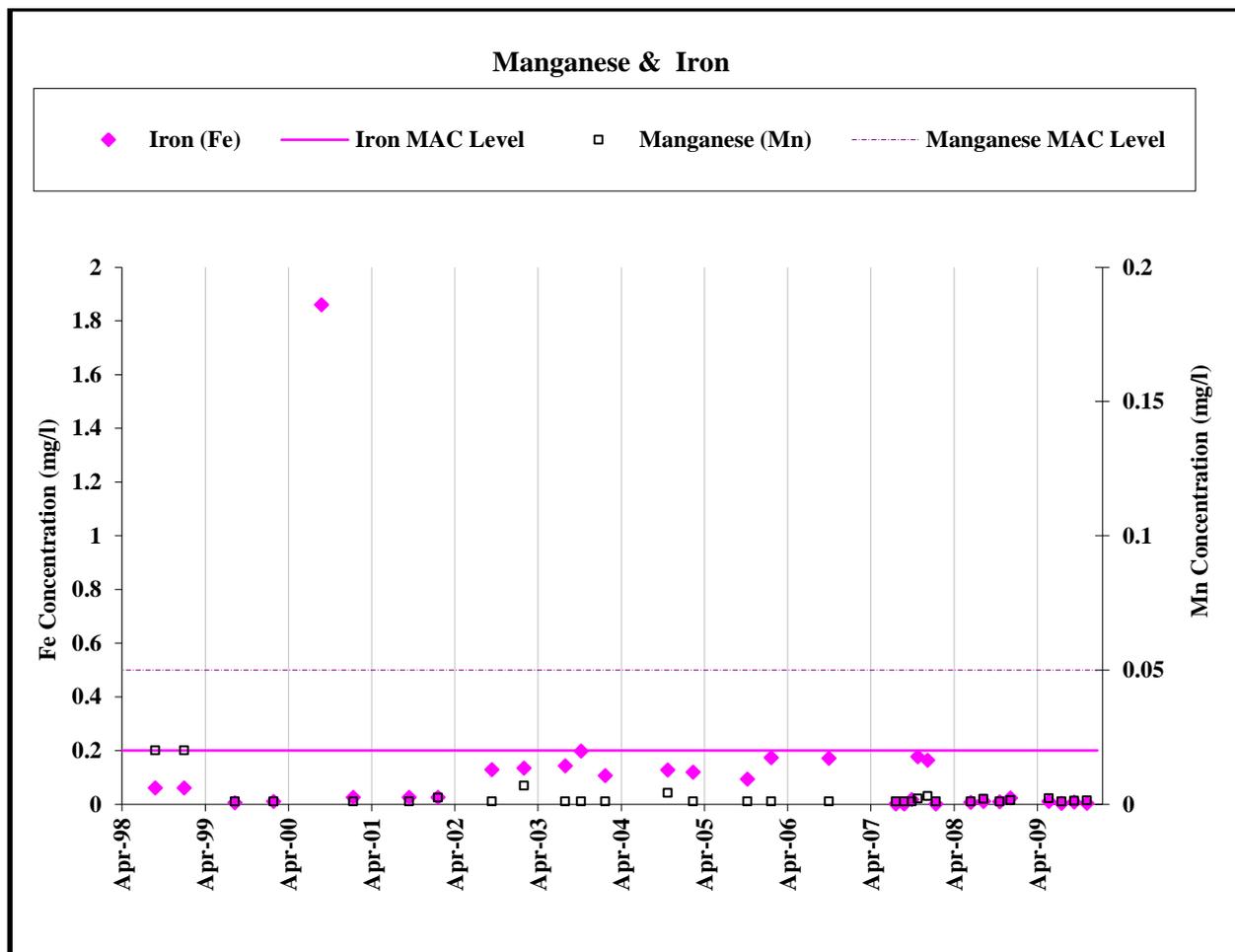


Figure 13 Manganese and Iron Concentrations at Ballyheigue

9.4 Aquifer characteristics

The source comprises an ‘Excellent’ yielding shallow dug well (greater than 500 m³/day), according to the GSI classification, and is situated on the boundary of a Regionally Important Karstified bedrock aquifer characterised by diffuse flow (Rk_d) and a Locally Important Aquifer (LI) that is moderately productive only in local zones, shown in Figure 14. The shallow dug well extends through 5 m of saturated peat and approximately 1-3 m of coarse grained subsoils (gravelly silt and/or gravel). This coarse grained layer is discontinuous across the site and it is not clear if it is fluvio-glacial material or a coarse till. The site investigation data indicate that the source is probably just within the massive limestones of the Waulsortian, the Regionally Important Karst Aquifer.

There is a fault mapped in the area which is likely to extend toward the source and Minerex (2006) have interpreted a similarly trending fault in the vicinity of the source. The relatively bedrock in the vicinity of the source comprises well jointed fine grained limestone that is slightly weathered and there is a cavity recorded (13.9-14.7m below rock head) in one of the rotary cored boreholes (RC2). Within the bedrock aquifer the upper weathered bedrock/transition zone is likely to display increased permeability in the upper few metres.

Test pumping of the borehole was conducted in 2006 (Minerex, 2006) and the data are provided in Appendix 1. The abstraction rate was 6,566 m³/d, with drawdown in the well recorded at 2.79 m, giving a specific capacity of approximately 2,350 m³/d/m. Minerex also indicate that drawdown in the monitoring wells around the site varies from 0 to 1.65 m bgl and that the drawdown is greater on the western side of the well.

An estimate of the apparent transmissivity based on these data, using Logans method of estimating transmissivity, would be approximately 2820 m²/d (Missteart, 1998). However, as with most karstic systems, permeability and transmissivity values are very variable over short distances. The regional groundwater gradient is estimated to be 0.005.

The water chemistry data suggests a saline or brackish water impact at the source. The shallow dug well is located in a discharge zone that is located close to the coast, and also located to Akeragh Lough (2 m OD); which though now has a sluice gate installed to control flooding, is a brackish/saltwater marsh. The levels in the well are very shallow, at ground level or up to 2.5 m below ground level (4 m OD) if pumping rather than gravity is operating. The top of the gravity feed pipe is 2.1 m below ground level. It is likely that the well is drawing in both brackish water and shallow groundwater.

The long term impacts of abstraction can vary over time and concentrations of chloride and/or electrical conductivity should be closely monitored at the source. Alterations of the pumping cycle including pumping during low tide may reduce chloride and electrical conductivity levels.

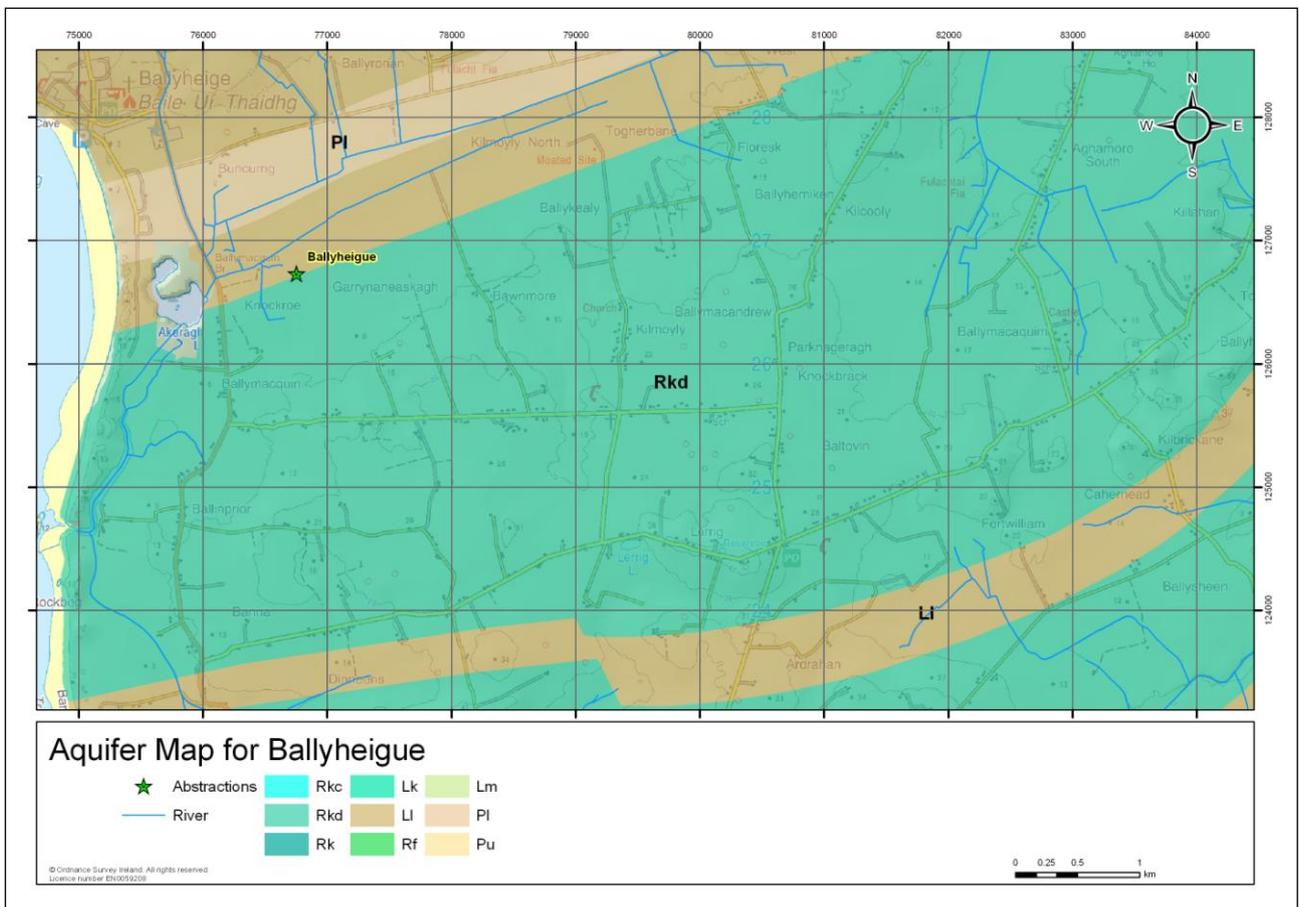


Figure 14 Aquifer Map for area around Ballyheigue



LOCATION MAP SHOWING LOCATION OF LONGITUDINAL SECTION
Scale 1:50,000

- NOTES**
1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
 2. ALL DRAWINGS TO BE CHECKED BY THE CONTRACTOR ON SITE
 3. ENGINEER TO BE INFORMED BY THE CONTRACTOR OF ANY DISCREPANCIES BEFORE ANY WORK COMMENCES
 4. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Check
A	05.06.12	DRAFT ISSUE FOR REVIEW	MN	JD

Client: EPA / GSI

Project: BALLYHEIGUE BOREHOLE SPZ

Title: CONCEPTUAL LONGITUDINAL SECTION NW - SE

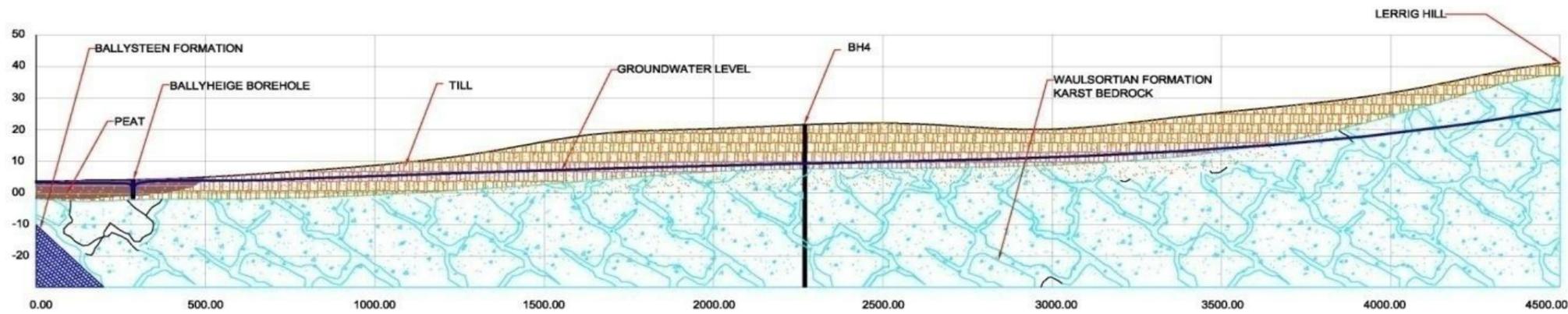
Scale @ A3: As Shown

Prepared by: M. Nolan
Checked: J. Dillon
Date: May 2012

Project Director: D. Grehan

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Drawing No: 5604-2930 Issue: A



LONGITUDINAL SECTION SHOWING GEOLOGY AND GROUNDWATER LEVELS
Scale H: 1:10,000 V: 1:1,000

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Figure 15 Cross Section illustrating the conceptual model for Ballyheigue (See Figure 8 for BH 4 location)

10 Zone of contribution

10.1 Conceptual model

The current understanding of the geological and hydrogeological situation at the source can be summarised as follows. A schematic cross-section illustrating the conceptual model is shown in Figure 15 and there is a cross section in Appendix 1 (Minerex, 2006) across the site itself which shows the construction of the well in relation to the geological layers recorded.

The higher ground, south and east of the source are generally devoid of surface drainage. The lower ground which bounds this elevated area to the very east, north, south and west comprise streams and drains. This includes the area in which the source is located, comprising 'wet' soils, peat, and a dense network of drains, and is 'liable to flooding', and thus is considered to be a discharge zone. This is illustrated in all the previous figures, and best illustrated in the soils map in Figure 5.

Lerrig Hill and the area north along Knockbrack appear to be a groundwater mound and act as a groundwater divide, thus groundwater is considered to flow radially outward, discharging to the surface water network. The interpreted groundwater flow directions based on recorded water levels appear to suggest a strong groundwater flow component to the northwest, toward the source and Akeragh Lough. This flow component appears to coincide with the trend of the mapped faults and the interpreted fault at the source. The faulting may have resulted in focussing the flow in a NW direction. It is considered that the Ballysteen Limestone located on the north of the source and extending northeast acts as a barrier, forcing groundwater to move in a more westerly direction toward the source.

The source comprises a 6 m shallow well set in approximately 5 m of saturated peat and a relatively thin discontinuous gravel layer, overlying the Waulsortian Limestone aquifer classified as a Regionally Important Karst Aquifer, supported by the site investigation data. The source is located very close to the boundary with the Ballysteen Limestone, classed as a Locally Important Aquifer that is moderately productive only in local zones (LI). It appears from the construction that the well draws shallow unconfined groundwater from the base of the well which is considered to be discharging upwards into the general area through the gravel layer from the limestone aquifer. It is likely that the well is abstracting a portion of the overall volume discharging in the general area. The well acts either as a sump or a pumping well depending on the demand and the water level (for instance in drier summers pumping is required). In addition, based on chloride, sodium, potassium concentrations and electrical conductivity it appears that saltwater/brackish is impacting the water quality. The well is located in close proximity to a saltwater marsh and the levels in the well and the general discharge zone suggest that the well is drawing in a component of saltwater/brackish water. This may also be influenced by the tide. Minerex (2006) indicate that drawdown around the well is greater to the west of the well.

Most groundwater flow is considered to occur in the upper weathered bedrock zone and in a zone of interconnected solutionally-enlarged fissures and conduits that extends below this. The interpreted flow directions from the well audit, the absence of surface water drainage, and the abstraction rate suggest a large zone of contribution.

The boundaries described below are considered to represent the most likely ZOC. Uncertainty exists in relation to catchment divide to the east between the source and the Crompaun River and the Brick River catchments. Additionally, uncertainty exists in relation to the dynamics of seawater/brackish water intrusion at the source.

10.2 Boundaries

The boundaries of the area contributing to the source are considered to be as follows (Figure 16):

The **Southern** and **Western** boundaries are defined using the interpreted groundwater flow lines and topography. In the immediate vicinity of the source, the western boundary is estimated using the Uniform Flow equation, and is approximately 30 to 40 m based on a transmissivity of 2800 m²/d, a gradient of 0.005, and an abstraction rate of 2,725 to 4,088 m³/d (150% - According to the GSI guidelines a 150% of the abstraction rate is used for delineating SPZ's). In addition, Minerex (2006) indicate that during pumping, drawdown is greater to the west of the well. To allow for uncertainties in the downgradient distance, the flow lines and for brackish water ingress the downgradient distance is kept 100 m west of the source.

The **Northern boundary** is based on the interpreted groundwater flow lines, topography and the geological boundary between the Waulsortian Formation and the Ballysteen Formation, with an additional 100 m buffer to allow for uncertainties in the precise location of the boundary. Groundwater to the north of the geological boundary is more likely to take the shorter flowpath and flow towards the Akeragh River.

The **Eastern and Southeastern boundaries** are based on a combination of topography and the interpreted groundwater flow direction. There is uncertainty regarding the catchment divide between the source, and the Crompaun and Brick Rivers. There may be some overlap between the catchment areas but it is not possible to differentiate the contributing areas without more accurate data. It is conservatively assumed that groundwater from Lerrig Hill could flow towards the source.

10.3 Recharge and water balance

The term 'recharge' refers to the amount of water replenishing the groundwater flow system. The recharge rate is generally estimated on an annual basis, and is assumed to consist of the rainfall input (*i.e.* annual rainfall) minus water loss prior to entry into the groundwater system (*i.e.* annual evapotranspiration and runoff). The estimation of a realistic recharge rate is critical in source protection delineation, as this dictates the size of the zone of contribution to the source (*i.e.* the outer Source Protection Area).

At Ballyheigue, the main parameters involved in the estimation of recharge are: annual rainfall; annual evapotranspiration; and a recharge coefficient. The primary evidence for estimating the recharge coefficient is the lack of a surface drainage system apart from the main rivers, and the bedrock and soil/subsoil geology.

The bulk **recharge coefficient** for the area is estimated to be 63%. This value is based on an assumption of c. 85% recharge for 10% of the area with extreme/high vulnerability, moderate permeability subsoils and topsoils, no drains or surface streams and moderate to steep slopes, and 60% recharge over 90% of the area due to moderate vulnerability, moderate permeability subsoil (all after Misstear *et al.*, 2009). The recharge coefficient for the Moderate Vulnerability areas is taken at the higher range of the estimations; however the figure may potentially be even higher as no surface water features are located on the plateau area.

These calculations are summarised as follows:

Average annual rainfall (R)	1072 mm
Estimated P.E.	500 mm
Estimated A.E. (95% of P.E.)	475 mm
Effective rainfall	595 mm
Recharge coefficient	63%
Recharge	373 mm

Water balance: The area described above and shown in Figure 15 covers 5.5 km², which is 200% greater than that required for the current pumping rate at the source. The area is conservatively big because well is drawing water from a very large discharge zone, thus appears to be accounting for a relatively small proportion of the overall volume. Further it cannot be differentiated from the groundwater discharging directly to Ballyheigue Bay. It also allows for the uncertainty in the flow directions and the catchment divide to the east.

11 Source protection zones

The Source Protection Zones (SPZ) are a landuse planning tool which enables an objective, geoscientific assessment of the risk to groundwater to be made. The zones are based on an amalgamation of the source protection area and the groundwater vulnerability. The source protection areas represent the horizontal groundwater pathway to the source, while the vulnerability reflects the vertical pathway.

The **Inner Protection Area (SI)** is designed to protect the source from microbial and viral contamination and it is based on the 100-day time of travel to the supply (DELG/EPA/GSI 1999). The 100-day horizontal time of travel to the source is calculated from the velocity of groundwater flow in the bedrock. Rapid groundwater velocities are associated with Regionally Important Karst Aquifers and tracing programmes usually indicate velocities in the order of hundreds of metres/day. All the limestone area in the Zone of Contribution is within the 100 day time of travel. Therefore all of the ZOC is designated as part of the inner protection area to the source, shown in Figure 15. The **Outer Protection Area (SO)** encompasses the entire zone of contribution to the source, described in the previous section. As the entire ZOC is within the 100 day time of travel, the SO is the same as the SI.

Groundwater Source Protection Zones are based on a combination of the Source Protection Area and the Groundwater Vulnerability. They are shown in Figure 17 and the percentage breakdown for the categories is given in Table 2. As can be seen, the majority of the zone of contribution comprises moderate vulnerability – greater than 10 m of moderately permeable subsoil.

Table 3 Source Protection Zones for the Ballyheigue Source

Source Protection Zone		% of total area (5.5 km ²)
SI/X	Inner Source Protection area / ≤1 m subsoil	0.2%
SI/E	Inner Source Protection area / <3 m subsoil	3.4%
SI/H	Inner Source Protection area / High vulnerability	4.9%
SI/M	Inner Source Protection area / Moderate vulnerability	91.5%

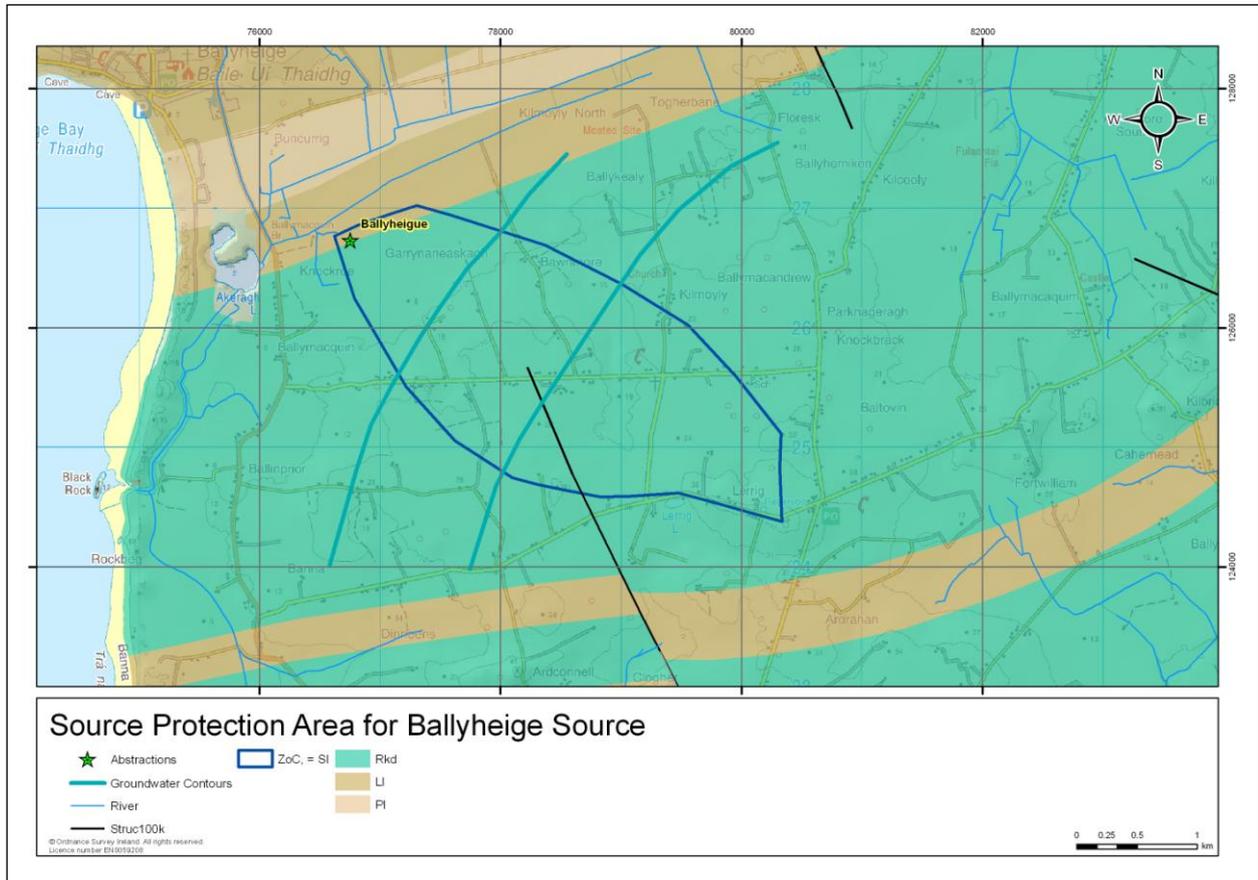


Figure 16 Ballyheigue Groundwater Source Protection Area

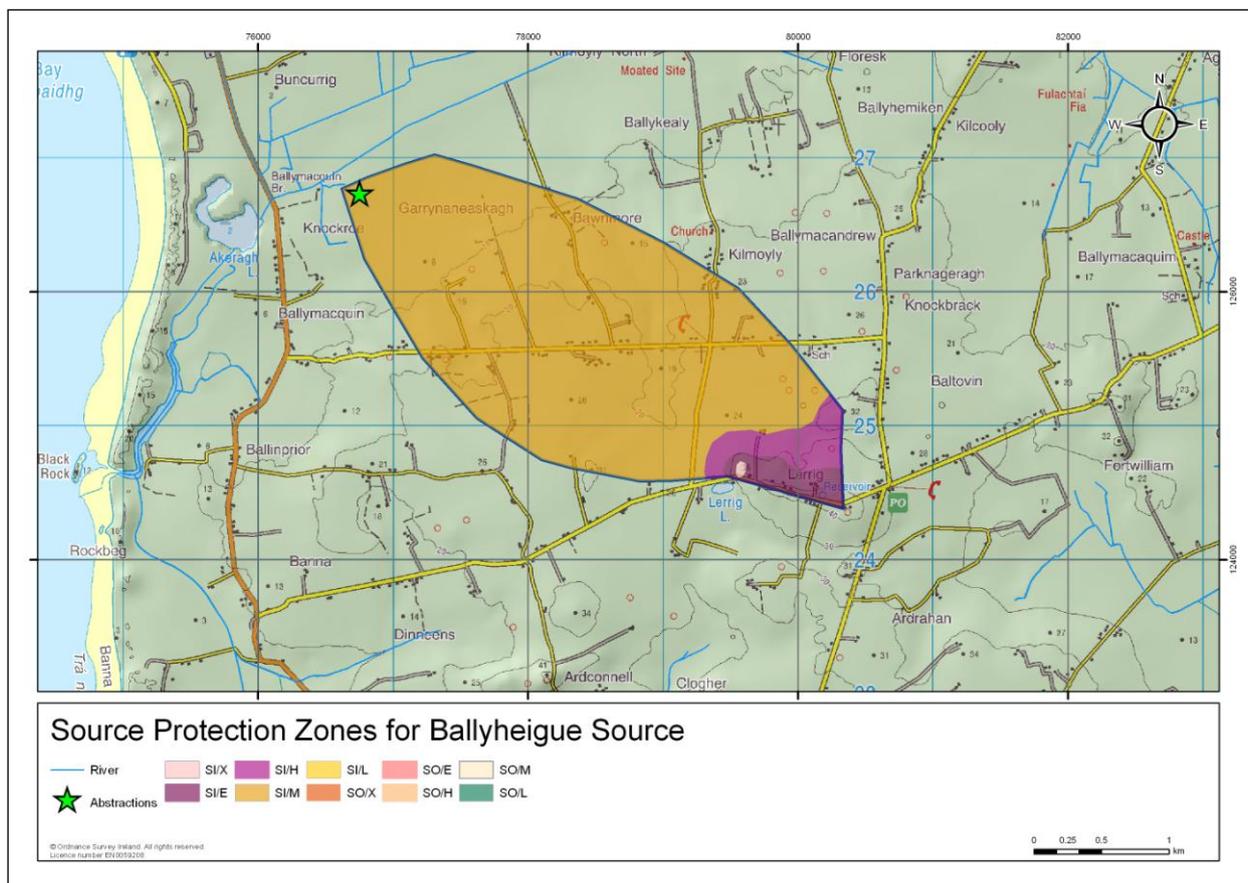


Figure 17 Ballyheigue Groundwater Source Protection Zones

12 Potential pollution sources

The supply comprises a shallow well, set in peat and a thin gravel layer over rock; which is covered, and finished above ground level. The well is contained within metal and concrete housing, which is within a fenced and gated Local Authority compound.

The ZOC is defined as an Inner Protection area, the majority of which is **'Moderate'** Vulnerability. In the higher parts of the ZOC there are areas of **'Extreme'** Vulnerability (less than 3 m, **'E'**, and less than 1 m of soil/subsoil, **'X'**) or **'High'** Vulnerability. Nitrate concentrations are elevated and there are persistently low levels of bacteriological exceedances. Furthermore, there is evidence of brackish water at the source.

All private residences within the ZOC are serviced by septic tank systems or similar wastewater treatment systems discharging to percolation areas or polishing filters. The majority of land within the zone of contribution is agricultural land, primarily grassland or tillage. A number of farming operations are located within the source protection zone.

There are a number of roads present in the ZOC which pose a risk of surface water runoff contaminated with hydrocarbons and metals. However, the traffic density is low indicating that the risk of this type of contamination is low.

13 Conclusions

The source supplies water to the Ballyheigue Water Supply Scheme and draws shallow groundwater from a karstified aquifer, at a rate of approximately 2,725 m³/day.

The data indicate a strong northwesterly groundwater flow component and it is on the basis of this data that the boundaries of the ZOC are delineated, and encompasses an area of 5.5 km². The Source Protection Zones are based on the current understanding of the groundwater conditions and the available data. Additional data obtained in the future may require amendments to the protection zone boundaries.

Nitrates are persistently elevated – mean is approximately 34 mg/l. The groundwater also appears to have a strong salt water/brackish water signal. Bacteriological exceedances generally comprise very low counts, though are persistent. There have been two occasions of gross bacteriological contamination – greater than 100 counts / 100 ml which appear to have been related to historical surface water flooding at the site.

The groundwater vulnerability is mainly '**Moderate**' with smaller portions of 'High' and 'Extreme', which are generally coincident with the elevated areas.

It is considered that the nitrate concentrations are primarily related to agricultural activity which is generally intense across the ZOC. It is not known what the bacteriological exceedances are related to, though the low level counts may be related to the housing around the steel shaft. The supply draws in a shallow groundwater/brackish water mix which is generally more susceptible to contamination.

Land use pressures are considered 'moderate' to 'high'.

14 Recommendations

The potential hazards in the ZOC should be located and assessed. Karst mapping should be carried out both within the ZOC and the wider area around Ballyheigue to locate any further potential point recharge localities at field scale through systematic field walkovers. If a suitable target is identified for karst tracing, this could assist in the further delineation of the source; possibly in the vicinity of the reservoir on Lerrig Hill.

Continuous monitoring of electrical conductivity and temperature would provide information and data that may identify significant trends in relation to abstraction, season and possibly tidal influences.

The ZOC of the source includes an area of '**Extreme**' Vulnerability. It is recommended therefore that an adequate barrier to *Cryptosporidium* must be installed as part of the water treatment system for the supply.

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Kinvara-Gort GWB

APPENDIX 1 MINEREX REPORT

Ryan Hanley Consulting Engineers
North Ardfert Regional Water Supply Scheme - Source Protection
Hydrogeological and Geophysical Services
Geophysics, drilling and monitoring well installations, well audit, pumping test, zone of contribution, aquifer vulnerability assessment and reporting
MEL Work Item A1 and A2
MEL Doc. Ref.: 1736-120 (First draft-Rev 3)
Date: Thursday, February 16, 2006

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Co. Kerry

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REPORT TO

Ryan Hanley Consulting Engineers
 North Ardfert Regional Water Supply Scheme - Source Protection
 Geophysics, drilling and monitoring well installations, well audit, pumping tests, zone of contribution,
 aquifer vulnerability assessment and reporting

REPORT BY

Minerex Environmental Limited
 Doc Ref 1736-120 (First draft-Rev 3)

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REPORT TO

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Appendix A	Site plan	1 x A3	1736-008
Appendix B	Borehole logs	1 x A3	1736-024
Appendix C	Schematic diagram of source well	1 x A3	1736-008
Appendix D	Well level data	1 x A4	1736-021
Appendix E	Geophysical survey report	8 x A4	5078d_006
Appendix F	Subsoil map	1 x A3	1736-008
Appendix G	Bedrock map & zone of contribution	1 x A3	1736-008
Appendix H	Photographs	2 x A4	1736-120

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1. Introduction

1.1 Background

- 1.1.1 Ryan Hanley Consulting Engineers were requested by Kerry County Council to undertake a site investigation for a source protection scheme at Ballymaquin Slugaire in Ardfert, Co. Kerry. As part of the site investigation, Minerex Environmental Limited was commissioned to undertake a hydrogeological report on the existing source.
- 1.1.2 The existing source for the water supply scheme at Ardfert supplies 1500 houses within the Ardfert/ Ballyheigue area, with an average daily demand of 2725m³/day. The source is a large diameter dug well, known as Ballymaquin Slugaire. 'Slugaire' is an Irish word, meaning glutton, which is likely to refer to the yield characteristics of the well.
- 1.1.3 Periodic flooding occurs at the site, due to the well head being located in a low-lying valley. During flooding a depth of water to 500-600mm can cover the site, causing surface water to enter and contaminate the well. Ryan Hanley Consulting Engineers proposed the construction of a physical barrier around the periphery of the source consisting of interlocking sheet piles to protect the source from further contamination.

1.2 Objectives

- 1.2.1 As part of the site investigation, Ryan Hanley requested Minerex Environmental to undertake works on the source well comprising the following:
- Geophysical survey around the source well;
 - Hydrogeological investigations to include yield testing of the source well and catchment assessment in terms of zone of contribution and aquifer vulnerability.
- 1.2.2 The geophysical survey was carried out with the purpose of establishing ground conditions for the proposed construction measures and to determine fracture patterns within the bedrock immediately around the source to understand the flow pattern of the aquifer.
- 1.2.3 The objectives of the hydrogeological investigation were to: -
- To establish the maximum sustainable yield of the supply well (qualified for the time of year), by carrying out a pumping test, while not compromising the quality or the quantity of the supply to Kerry County Council customers;
 - To provide information on the direction, magnitude and depth of groundwater flow in the surrounding aquifer, in order to determine the implications to flow of constructing a sheet pile barrier, as a source protection measure, would be on the flow pattern of the aquifer;
 - To provide information on the catchment area, vulnerability to contamination and source protection measures.

1.3 Scope, timing and reporting

Minerex presented the scope of the work to Ryan Hanley Consulting Engineers on 02/09/05 and were commissioned on 29/09/05 to undertake the hydrogeological investigation. Irish Drilling Limited carried out the drilling and installation of the monitoring boreholes from 11/10/05 to 22/10/05 and 28/10/05 to 29/10/05. The geophysical work was carried out from 05/10/05 to 11/10/05. The water level monitoring and yield testing was carried out from 12/01/06 to 13/01/06.

REPORT TO

Ryan Hanley Consulting Engineers
 North Ardfert Regional Water Supply Scheme - Source Protection
 Geophysics, drilling and monitoring well installations, well audit, pumping tests, zone of contribution, aquifer vulnerability assessment and reporting

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2. Ballymaquin Slugaire and source description

3.1 The Ballymaquin Slugaire is located at Ordnance Survey grid co-ordinates E076700 N126400. The supply source consists of a large diameter shallow dug well in gravel deposits overlying the fissured Waulsortian Limestone. The well is artisan, with static unpumped water levels reaching ground level.

3.2.1 The wellhead of the Slugaire consists of a concrete surround with a removable steel cover. The area immediately surrounding the well is covered by stone fill, with 100mm thick concrete slabs partly covering the stone fill. The source is accommodated in a fenced compound area, which is accessed by a small byroad from the pumphouse.

3.2.2 The Slugaire is surrounded by coniferous forestry and is located in a low flat valley that stretches inland from the sand dunes at Ballyheigue Bay. Surface water drainage of the area is by a network of shallow open land drains that converge near Ballymacquin Bridge and discharge into Akeragh Lough to the northwest.

3.2.3 The results of previous pump testing carried out on the source well are given below.

<i>Date</i>	<i>Yield</i>	<i>Resultant drawdown</i>	<i>Comments</i>
May/ June 1966	32.7l/s	0.175m	
May/ June 1966	41l/s	0.670m	Tested lasted for 4 weeks with water levels recovering in 25mins after pumping stopped.
January 1979	47.3l/s	1.6m	
January 1979	65.2l/s	3.0m	

Table 1. Results of previous pumping tests

3.2.4 Surface flooding was noted around the well during the time the supply pumps were switched off before testing. The flooding was noted to occur within the numerous depressions created by the cracked concrete slabs mostly to the north and west of the well. The water level, approximately 500-600mm above the surface, was not as a result of the well overflowing through the slit in the side of the steel tube shaft or overflowing drains.

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3. Methods, equipment and materials

3.1 Health and safety

MEL employed their standard health and safety procedures in all aspects of the work. There were no near misses or accidents during project. A safety statement was submitted to Ryan Hanley Consulting Engineers and Kerry Co. Co. prior to the commencement of pumping at the source well. The statement was approved by Maura Joy of Kerry Co. Co. on 09/01/06.

3.2 Monitoring well installations

Irish Drilling Limited (IDL) undertook the installation of monitoring wells onsite. The locations of the monitoring points were directed by Minerex staff and were within 5m of the source well. Nineteen (19 no.) shell and auger holes were drilled to rock head. Four (4 no.) rotary core holes were drilled into the bedrock to between 26m and 28.5m below ground level. One (1 no.) 19mm piezometer was installed in eleven (11 no.) of the shell and auger holes and in each of the rotary core holes. The piezometers installed in the shell and auger holes were open (screened) in the gravel horizon. The piezometers installed in the rotary core holes were open (screened) within the limestone bedrock. The installations were completed with lockable steel casing upstands. The borehole logs are included in Appendix B.

3.3 Geophysical survey

The methodology consisted of using Seismic Refraction, 2D-Resistivity and Ground Penetrating Radar (GPR) measurements.

First 2D-Resistivity measurements were carried out to map the ground outside the gravel fill of the source and at the location of the proposed piled wall. A linear karstified zone with a preferential direction was not located therefore four more 2D-Resistivity profiles with wider (5m) electrode spacing were carried out to map the deeper rock. Seismic profiles were carried out around the source though the data quality was poor due to the thick peat cover. The thick concrete slabs and partially hollow ground under them did not permit any 2D-Resistivity or seismic refraction measurements to be carried out. Therefore some GPR lines were measured.

2D-Resistivity profiles with electrode spacing between 2 and 5m and 32 electrodes per set-up were surveyed at the locations R1 to R9. The readings were taken with a Tigre Resistivity Meter and an Imager Cable.

The Seismic Refraction measurements were taken with geophone spacings of 4 – 5m. The seismic energy source was a seismograph gun submerged in the peat and 6 DMT Summit 2in1 boxes were used to record the seismic data. Seismic profiles were surveyed with 12 geophones and 5 shot points per profile.

The GPR lines were surveyed with a GPR GSSI SIR-3000 System and a 400 MHz Antenna.

3.4 Groundwater level monitoring

In order to determine if groundwater levels are influenced by tidal fluctuations, groundwater levels in the monitoring points were monitored over 24 hours before the pumping test commenced (Appendix D). Water levels in the monitoring boreholes were measured in metres below ground level at the borehole using a water level recorder 'dipper'. Water levels in the source well were measured in metres below a reference point at the top of the concrete surround. The pre-test monitoring was interspersed with pump on and pump off times as required by the scheme. The water level monitoring enabled the establishment of static water levels onsite.

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3.5 Surface water level monitoring

In order to determine baseline surface water levels, if the drains are in hydraulic continuity with the underlying aquifer and if surface water levels respond to supply pumping, surface water levels were monitored in the eastern drain using a staff gauge. The staff gauge consisted of a 3m length of 3" casing fixed into the drain sediment to a known height. Water levels in the drain were read by measuring the length of casing above the water level and subtracting it from the total length of casing. Three readings were taken before pumping commenced.

3.6 Well yield testing

Two 3" petrol powered suction pumps and 65m of 3" hosing were set up between 3-5m from the well, one to the east and one to the west, with hosing feeding into the drains. The pumps were set up within bunded containers to avoid any leaks or spillages.

In order to facilitate the pumping test by lowering water levels in the source well, the supply pumps were switched off from 07:30 to 13.30 on 12/01/06. The Minerex pumps 1 and 2 were switched on at 16.00 and 17.00 respectively. The pumping rate was established every hour by measuring the time taken to fill a 125litre container from the pumping hose with a stopwatch. Water levels in the source well were measured every 30 minutes, while water levels in the monitoring boreholes were measured every 3 hours. The pumping rate of the supply pumps was recorded every hour at the pumphouse.

The supply wells were switched off between 17.00 and 19.00 under contract with the ESB. Minerex pumps remained pumping during this period to maintain pumped water levels within the source well. Once the supply wells were switched back on, the maximum capacity of the supply pumps was reached around 20.00 with pumps taking up 66.7l/s. To ensure that there was adequate storage in the reservoirs, the pumping rate of the supply pumps was reduced to 56.6l/s at 21.00. The supply pumps were switched off at 02.00 on 13/01/06 and as water levels had stabilised in the source well, Minerex pumps were also switched off and the pumping test was ended.

3.7 Wellhead hydrochemistry

Water samples, taken from the pumped water and from the location of the staff gauge in the eastern drain, were field tested for conductivity and pH, using a Hanna Combo instrument HI 98129.

During the filling of the 125litre container to establish the pumping rate of Minerex pumps, the clarity of the water was noted for turbidity as required by the Kerry County Council.

3.8 Well audit

An audit of the source well was carried out in the later stages of the pumping test, when water levels in the well were at their lowest and visibility was best. A GA2000 gas analyser was used to establish that levels of oxygen, carbon dioxide and methane were within safe limits to be close to the wellhead. The width of the concrete surround and inner width of the metal surround of the source well were measured with a measuring tape. In order to measure the depth of the well, the gravity feed pipe, the upper cut-off probe, the open slit in the steel casing for the temporary pumphouse and the supply pumps, a measuring device consisting of 2 screen casings of known length were lowered into the well. A schematic diagram was drawn in the field based on measurements (Appendix C) and photos were taken (Appendix H).

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3.9 Levelling and positional survey

A temporary benchmark (TBM) was established for the site on the ESB pole to the west of the source well and was marked with indelible ink (Appendix H). The ground level, top of steel upstand and top of piezometer within the upstand were levelled in reference to the TBM for all the monitoring boreholes. The ground level, reference point for water level measurements and the top of the concrete surround were levelled in reference to the TBM for the source well. The ground levels of the banks along the eastern and western drains and the staff gauge were also levelled. A second temporary benchmark was established and marked with indelible ink on the eastern pillar at the entrance to the compound, in case the ESB pole was removed during the construction of source protection measures.

3.10 Depth measurements

All depth measurements within the following report sections, unless otherwise specifically stated, relate to meters above the temporary benchmark (maTBM).

3.11 Data representation

The report is presented in Microsoft Word, the maps in CorelDraw, the logs in MicroPoint and the data in Microsoft Excel.

3.12 Source Protection

The protection of groundwater sources in Ireland is based on land surface zoning and responses to potentially polluting activities.

Land surface zoning requires the delineation of source protection areas (SPA's) based on the zone of contribution for the source and zoning within the SPA based on the vulnerability of the underlying groundwater (Ref. 4). The source protection guidelines recommend delineation of two SPA's, an inner protection area based on 100day time of travel and an outer protection area based on the extent of the zone of contribution (Ref. 4). In karst areas, the entire catchment area or zone of contribution is delineated as the inner source protection area due to the large variations in permeability and flow velocities within karst aquifers.

Groundwater protection responses drawn up for various potentially polluting activities depend on groundwater vulnerability, aquifer classification and contaminant loading and provide advice on the potential suitability of an area for a particular activity or development (Ref. 4).

3.13 Preliminary vulnerability assessment

Vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities (Ref. 4). The vulnerability of groundwater depends the connectivity between the land surface and the aquifer, therefore it is a function of subsoil permeability, subsoil depth and recharge type (diffuse or point). The Geological Survey of Ireland use four categories of vulnerability – extreme, high, moderate and low.

In order to provide a preliminary groundwater vulnerability assessment, the geological logs for the site were examined and information on subsoil type and depth and karst features were obtained from the GSI.

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3.14 Catchment identification

In order to estimate the zone of contribution or catchment area of the source well, an approach combining the use of surface topography, hydrogeological mapping and water budget methodology was used.

The characterisation of the hydrogeological setting by identifying geological and hydrogeological features that can control flow, can aid in the delineation of catchment areas i.e. the identification of structural trends can indicate the direction of flow and therefore the longitudinal axis of the catchment area. A simplified water budget method can provide an estimate for the catchment area with annual well discharge/ effective rainfall (recharge) = approximate catchment area. Data requirements for this method include annual average well discharge, annual average rainfall, annual average evapotranspiration, aquifer vulnerability and subsoil permeability and depth, obtained from www.met.ie and the Geological Survey of Ireland (GSI).

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4. Results & interpretation

4.1 Well yield testing

- 4.1.1 On the 13/01/06, at the end of 5 hours of a stable pumped water level in the pumping well and pseudo-steady water levels in the monitoring wells, the combined yield from the supply scheme submersible pump in the well and Minerex pumps was 76 l/s (6566m³/day or 274m³/hour) for a maximum drawdown in the well of 2.79m (based on the static reading from pre-test monitoring of 1.26m).
- 5.1.2 The formal pumping test lasted approximately 13 hours (based on starting time of 13.00 when supply pumps switched on) and worked around the priority of sustained supply to customers of the scheme. The pre-pumping water level monitoring phase lasted 24 hours and was interspersed with pump on and pump off times as required by the scheme
- 5.1.3 After 13 hours of pumping, the water level in the Slugaire was within 300mm of the lower probe, which acts to switch off the supply pumps. In order to maintain water levels in the well above the lower probe and to ensure the sustained supply to customers of the scheme, the combined yield of 76l/s was not exceeded and therefore the maximum yield obtainable from the Slugaire may not have been reached. The proven yield of the pump test exceeded previous proven yields by approximately 11l/s, equating to 17% increase in the yield of the source well.

4.2 Groundwater level monitoring

- 4.2.1 The reduced static water levels in the BH series (overburden monitoring points) were expected to be below the RC series (bedrock monitoring points) indicating an upward gradient at the site from bedrock to overburden, in keeping with the conceptual model and observations of artesian conditions after a few hours when the supply pump is switched off. Evidence of an upward gradient was not apparent from the water level monitoring, which is likely to be as a result of the influence of the open well and the gravity feed pipe relieving the pressure and therefore the upward gradient in the aquifer.
- 5.2.2 The maximum drawdown in the monitoring boreholes (based on the static reading from pre-test monitoring) ranged from 0m to 1.65m with an average of 1.03m.
- 4.2.3 The maximum drawdown measured in the monitoring boreholes shows a general pattern of increased drawdown in a westerly direction across the site. The pattern is apparent in both BH series and RC series monitoring points. Increased drawdown to the west of the source well corresponds with the results of the geophysical survey, which indicate an increase in the fractured nature of bedrock in this direction. As a result the cone of depression in the water table surrounding the pumped source well is elongated to the west.
- 5.2.4 The reduced static water levels in the BH series (overburden monitoring points) and the RC series (bedrock monitoring points) exhibit a very shallow hydraulic gradient across the site, in an westerly direction, indicating the likely direction of groundwater flow under natural (unpumped conditions).

4.3 Surface water level monitoring

In the interest of determining baseline conditions, surface water level readings were taken in the eastern drain prior to the start of the pump test. No response to supply pumping of the source well was noted in the surface water levels. Water levels appeared to stabilise in a 12-hour period before the test.

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<i>Location</i>	<i>Time</i>	<i>Depth of water in drain</i>
SG1	11/01/06 10:00	1.08m
SG1	11/01/06 19:00	1.14m
SG1	12/01/06 10:00	1.14m

Table 2. Surface water level readings

4.4 Wellhead hydrochemistry

The water discharging from Minerex pumps and hosing was consistently completely clear, therefore no problems in relation to turbidity were experienced. Water samples taken from the source well and the eastern drain were tested for conductivity and pH.

A significant difference in conductivity values was noted between the source well water and the water in the drain, indicating that the drains are not in hydraulic continuity with the underlying aquifer. Surface water conductivity values are generally in the region of 200-300uS/cm, therefore the conductivity at SG1 is relatively high, most likely as a result of the mineral soils underlying the area. The pumped water has high conductivity suggesting a long residence time in the underlying limestone aquifer.

<i>Location</i>	<i>Conductivity (uS/cm)</i>	<i>pH</i>
SG1	642	6.93
Pumped water	1018	6.85

Table 3. Hydrochemistry

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4.5 Well audit

- 4.5.1 The well consists of a 1.37m diameter steel shaft of 5.8m in length, which is perforated over the bottom 1.5m (approximately) to allow water to enter from the surrounding aquifer. The shaft is surrounded by gravel fill to an approximate depth of 2m. A 250mm overflow pipeline connects to the open drain to the east of the well. A 450mm diameter bell-shaped gravity flow pipeline, which is located at 2.1m below ground level and two 150mm rising mains, which are located at 1.62m below ground level, connect the shaft and the suction chamber in the pumphouse. A submersible pump is located in the middle of the shaft at 4.1m below ground level. Two probes, which switch on or off the pumps depending on water levels in the shaft, are located at different depths on the shaft wall, one of which is located at 3.42m below ground level and the other was not visible from the surface.
- 4.5.2 Photographs have been taken in the well during pumping and of the surrounds and these combined with a scaled drawing of the well are a useful record of the well design (Appendix H). A schematic diagram of the source well is included in Appendix C.

4.6 Geophysical survey

- 4.6.1 The outline of the gravel fill surrounding the source well was identified by the 2D resistivity survey as extending to approximately 20m in width and 2.5m in depth.
- 4.6.2 The data from the seismic survey is relatively poor due to the thick layer of peat, however it did show the presence of strong rock at similar depths around the Slugaire. The geophysics and borehole data show that the depth to layers near the well is fairly homogeneous. Further from the well to the west and north, resistivities decrease at depth, possibly caused by more jointed/ fractured/ broken limestone, or alternatively by an argillaceous limestone. Based on borehole data, the decrease in resistivity has been interpreted as the thickening of the horizontal layer of jointed rock found under the Slugaire. Low resistivities in clean limestone bedrock can be caused by an increase in water-filled joints.
- 4.6.3 The results of the geophysical survey show that the most permeable zone within the limestone bedrock aquifer exists within the upper 2-15m of rock. The results also show that the deeper rock is also jointed and one cavity of 0.8m in height is noted, suggesting that flow occurs at depth, as well as in the upper portion of the limestone aquifer.

4.7 Monitoring well installations

- 4.7.1 The installation of monitoring boreholes around the source well permitted the measurement of water levels in the aquifer, under static and pumped conditions and provided geological logs of the underlying geology.
- 4.7.2 The borehole logs show a geological sequence consisting of approximately 5m of peat cover, 1-3m of gravelly silt or gravels and very strong grey limestone at rock head, which ranged between 6.5m and 8.5m below ground level.
- 4.7.3 The borehole logs indicate that the gravel layer is discontinuous throughout the site, with only approximately 30% of borehole logs recording a gravel layer. The gravels range from 0.3m to 3m in thickness and are unlikely to provide much storage for the underlying limestone bedrock aquifer.

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- 5.6.2 No dissolution or karstification was observed at rock head within the borehole logs. However, the rotary-core logs recorded open joints throughout the entire depth of the limestone bedrock, with approximately 70% occurring between 8-14m and 20-24m below the surface. All of the rotary-cored holes record poor or very poor Rock Quality Designation (RQD) in the top 5m of rock, indicating relatively high permeabilities at this depth. The geological log for borehole RC3 records poor or very poor RQD from 0-15m below rock head, concurring with increased weathering to the west of the Slugaire indicated by the geophysical survey.
- 5.6.3 The geological log for borehole RC2 records a zone of very poor RQD from 13-16m below rock head, within which a large cavity was recorded, suggesting karstification at depth within the aquifer. A substantial fall in sea-level during the Pleistocene allowed drainage of the limestones, and therefore karstification, to take place considerably below present-day drainage levels (Ref. 2).

4.8 Aquifer potential as a significant groundwater supply

- 4.8.1 The source well is sited in the Waulsortian Limestone, which is described as a pure unbedded/massive limestone and has been classified as a regionally important karstified bedrock aquifer with diffuse flow by the Geological Survey of Ireland (GSI).
- 4.8.2 Karstification refers to the solutional enlargement of openings in the bedrock as a result of the movement of water. Karstified aquifers are classified by the GSI as being either dominated by conduit or diffuse flow. Conduit flow refers to the movement of groundwater through large diameter conduits in the bedrock, with rapid responses to recharge. Diffuse flow aquifers are dominated by groundwater movement through lesser fractures and fissures in the bedrock, leading to more storage in the aquifer, less flashy responses to rainfall and more sustainable yield.
- 4.8.3 Aquifer classification is based on the overall potential groundwater resource and the area of the rock unit. In general, regionally important aquifers are capable of having a large number of wells yielding in excess of 400m³/day. The current yield of the Slugaire (based on the average daily demand) is generally only obtainable from a regionally important karstified limestone bedrock aquifer, indicating the source of water and also suggesting the potential for aquifer development as a significant supply.

4.9 Preliminary vulnerability assessment

- 4.9.1 In karst environments, GSI vulnerability mapping guidelines classify an area of 30m radius around karst features as extremely vulnerable. The results of a search of the GSI Karst Feature Database showed no mapped karst features within a 5km radius of the Slugaire, however existing karst features may be currently unmapped.
- 4.9.2 The geological logs for the site indicate that the area immediately surrounding the Slugaire is underlain by low permeability peat. The depth to bedrock ranges between 6 and 8m. Based on GSI vulnerability mapping guidelines, these areas can be classified as having moderate vulnerability.
- 4.9.3 Subsoil mapping undertaken by the Geological Survey of Ireland indicates that although the immediate area surrounding the well and the area to the north is underlain by peat, deposits of moderate permeability shale and sandstone till underlie a large area to the south and to the east. These deposits range in thickness from 6.7m to 18.6m, as indicated by geological log information available for wells in the area. Based on GSI vulnerability mapping guidelines, these areas can be classified as having high vulnerability.

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4.10 Catchment identification

- 4.10.1 While the simple water budget provides an estimate for the potential catchment areas for the Slugaire, the present catchment estimation mainly uses hydrogeological mapping to indicate potential boundaries for the zone of contribution.
- 4.10.2 The Waulsortian Limestone formation in the Ardfert area is on the south-eastern limb of an extensive northeast-southwesterly trending anticline, which underlies a large area of northern Kerry. The Waulsortian Limestone is bounded by the Ballysteen Limestone formation to the north of the source well location, which are described as impure bedded limestones and has been classified as a locally important bedrock aquifer. The geological boundary, which coincides with the edge of the peat covering, is likely to represent a hydraulic or no-flow boundary and the potential northern boundary of the catchment area.
- 4.10.3 The topography in the area surrounding the source well is relatively flat. However some higher ground exists approximately 3km to the south and east. Areas of karstified bedrock at the surface have been mapped along the local topographical high to the south, which are likely to represent a groundwater divide and therefore the potential southern boundaries of the catchment area. The topographical high to the east is likely to define the eastern boundary of the catchment area.
- 4.10.4 A mapped fault runs in a northwest-southeasterly direction from Ardfert towards the area of the Slugaire (Ref.1). Although the fault is not mapped on the bedrock map for the area immediately surrounding the well, it is apparent that the fault does not extend to the Slugaire. The results of the geophysical survey show the occurrence of very jointed bedrock to the west of the source well suggesting that further faulting occurs parallel to the mapped fault and extends to the well. The high yields of the Slugaire also concur with this. The orientation of the mapped fault suggests the regional direction of groundwater flow to be northwest. Water level measurements in the monitoring boreholes surrounding the source well showed a slight hydraulic gradient to the west, which would concur with this.
- 4.10.5 A simplified water budget was used to provide an estimate for the current catchment area and for the catchment area required to supply the proven yield. The use of a simple water budget for catchment delineation in karstified aquifers can underestimate the potential catchment area by not accounting for point or focused inputs of recharge associated with karstic conduit or fracture flow. However the method can provide a useful estimate in terms of an order of magnitude for the catchment area. The following data was used.

<i>Average annual rainfall*</i>	1430.1mm
<i>Average annual evapotranspiration*</i>	480mm
<i>Effective rainfall</i>	950.1mm
<i>Current average daily demand</i>	2725m ³
<i>Aquifer vulnerability</i>	High
<i>Subsoil permeability</i>	Moderate
<i>Recharge coefficient**</i>	35%
<i>Annual recharge</i>	332.5mm

* www.met.ie

** Geological Survey of Ireland

Table 4. Water budget data

Based on methodology used by the GSI (Ref.3), recharge can be calculated by multiplying the effective rainfall, which is the amount of water potentially available for recharge, by a recharge

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coefficient, which is based on aquifer vulnerability and subsoil permeability. In order to calculate an estimate of the catchment area required to provide the current yield, the average annual demand ($2725\text{m}^3/\text{day} \times 365 = 994625\text{m}^3/\text{yr.}$) can be divided by the annual recharge (332.5mm), which gives an estimated catchment area of 1.73km^2 . The estimated catchment area for the proven yield of 76l/s is 2.7km^2 .

4.11 Source protection

According to the GSI vulnerability matrix, the zone of contribution for the Slugaire can be classified with the following source protection zones:

SI/ H (Inner source protection area/ high vulnerability)

SI/ M (Inner source area/ moderate vulnerability)

In order to protect groundwater sources, such as public water schemes, protection responses have been drawn up to provide advice about the potential suitability of an area for various activities. Based on the above source protection zones, the following guidelines are given for specific activities within the zone of contribution:

- No on-site wastewater treatment systems to be located within 60m of the public, group scheme or industrial water supply source;
- No landfilling of waste;
- No landspreading of manure or slurry.

Although no houses exist within 60m of the Slugaire, potential sources of pollution within the current catchment area of the Slugaire include housing to the south i.e. upgradient of the source, which may potentially operate on-site treatment systems. Other potential sources of pollution include livestock grazing in the surrounding area.

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5. Conclusions & recommendations

- 6.1.1 The current yield of the Slugaire (based on the average daily demand) is generally only obtainable from a regionally important karstified limestone bedrock aquifer, indicating that the Waulsortian Limestone formation is the source of water to the well.
- 6.1.2 The Waulsortian Limestone formation aquifer, which is the predominant groundwater body contributing to the catchment, has moderate to high vulnerability within the catchment area of the pumped well (Slugaire).
- 6.1.3 The results of the geophysical survey show that the most permeable zone within the limestone bedrock aquifer exists within the upper 0-6m and 14-18m of rock, with some evidence of karstification at depth. The geophysical survey also interprets the occurrence of a fault to the west of the well, which may be the fault previously mapped or parallel faulting, although this cannot be proven.
- 6.1.4 The borehole logs show that the extent of the gravel layer is limited and therefore is unlikely to be an important resource in terms of groundwater storage.
- 6.1.5 As a result of constraints on the supply, the maximum yield obtainable from the Slugaire may not have been reached. However the pump test proved a yield of 76l/s, exceeding previous proven yields by approximately 17%, indicating that the aquifer has considerable potential for further development as demand increases.
- 6.1.6 As the current pump testing of the Slugaire has been undertaken in the winter months, it is recommended that pump testing is also undertaken in the summer months, to establish a yield that is sustainable for the entire hydrological year.
- 6.1.7 Based on the results of the hydrogeological investigation, geophysical survey and borehole logs, it is likely that the installation of sheet piling to rock head will have no impact on the supply of water to the source well.

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2.	Sleeman, A., Pracht, M. & MacDermot, C.V. (1999) <i>Geology of the Shannon Estuary Sheet 17</i> , Geological survey of Ireland	M150
3.	Working Group on Groundwater (2004b) Guidance document GW8: <i>Methodology for risk characterisation of Irelands groundwater.</i>	1736-133
4.	Geological Survey of Ireland, Environmental Protection Agency & Department of Environment (1999) Groundwater Protection Schemes	F214

REPORT TO

Ryan Hanley Consulting Engineers

North Ardferf Regional Water Supply Scheme - Source Protection

Geophysics, drilling and monitoring well installations, well audit, pumping tests, zone of contribution, aquifer vulnerability assessment and reporting

REPORT BY

Minerex Environmental Limited
Doc Ref 1736-120 (First draft-Rev 3)

Appendix A

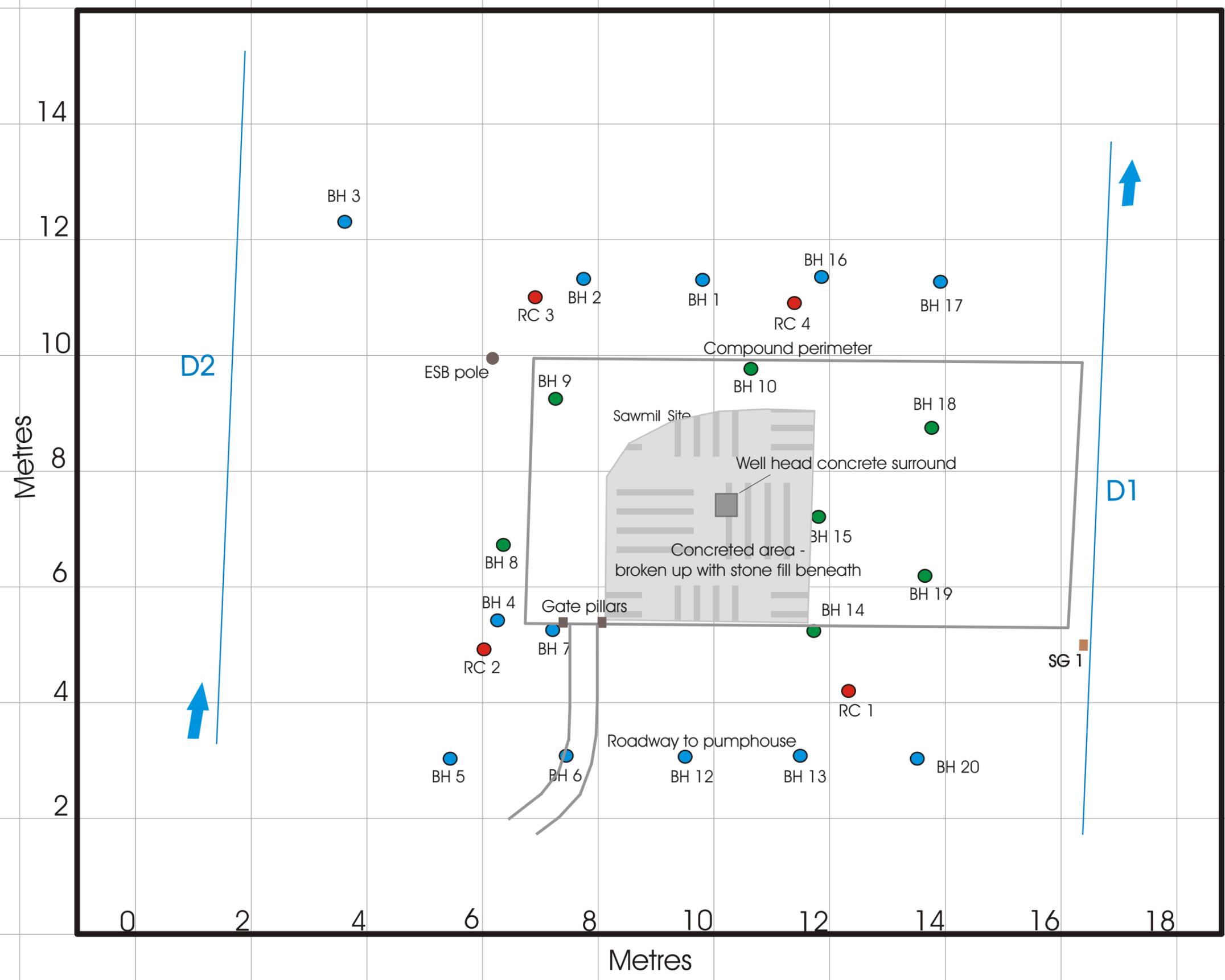
Appendix A
Location Map - Site Plan

Ardfer Regional Water Supply Scheme

Drawing Ref.: 1736-008.cdr

Common legend

-  D2 Drain location and label
-  Monitoring borehole (blue dot = overburden series)
-  (red dot = bedrock series)
-  (green dot = closed)
-  SG 1 Staff gauge location and label



NOTES
- All locations are +/- 1m.

REPORT TO

Ryan Hanley Consulting Engineers

North Ardferf Regional Water Supply Scheme - Source Protection

Geophysics, drilling and monitoring well installations, well audit, pumping tests, zone of contribution, aquifer vulnerability assessment and reporting

REPORT BY

Minerex Environmental Limited
Doc Ref 1736-120 (First draft-Rev 3)

Appendix B

PROJECT: North Ardfert Regional Water Supply Scheme - Source Protection **BOREHOLE:** BH1 - DRAFT

LOCATION: Slugaire, Ardfert, Co Kerry **Sheet 1 of 1**

CLIENT: Ryan Hanley Consulting Engineers **Co-ordinates:** N , E **Rig:** Dando 2000

ENGINEER: Ryan Hanley Consulting Engineers **Ground level:** m O.D. **Casing diameter:** 200mm **DRILLING STARTED:** 14.10.05 **DRILLING COMPLETED:** 14.10.05

GROUNDWATER
Water strikes: 1st: 6.20m Rose to: 4.60m Sealed off at:
 2nd:
 3rd:
Date:
Time:
B'hole depth (m):
Casing depth (m):
Water level (m):

Borehole Depth (m)	Date	Samples	Depth (m)	SPT (N)	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION	Piezometer Details
0		B	0.00-0.50		\\ \\ \\ \\			Reeds and rough grass over dark brown plastic amorphous PEAT with some fibres. Rare woody fragments. Strong organic odour. Some fresh roots and rootlets. von Post Classification: H7;B2;W1;A0.	
1		U B	0.50-0.95 0.50-1.00	4	\\ \\ \\ \\				
2		U B	1.50-1.95 1.50-2.00	6	\\ \\ \\ \\			1.50: von Post Classification - H9;B3;W0.	
3		U B	2.50-2.95 2.50-3.00	6	\\ \\ \\ \\				
4		U B	3.50-3.95 3.50-4.00	8	\\ \\ \\ \\			3.50: von Post Classification - H9;B3;W1.	
5		U B	4.50-4.95 4.50-5.00	4/NR	\\ \\ \\ \\		4.90		
6		U B	5.50-5.95 5.50-6.00	80	x x x x x x x x x x x x x x x x		5.60	Wet dark grey SILT.	
7		W CPT	6.20 6.30-6.35	refusal	END		6.30 6.35	Pale greenish brown mottled orange very slightly sandy slightly gravelly SILT. Gravel as subangular fine and medium grained sandstone mudstone and rare limestone clasts. Probable rock. Very strong slightly weathered 'marbled' creamy grey LIMESTONE. Recovered as angular fine and medium grained limestone gravel from chippings from CPT tip. Borehole terminated. Probable rock.	
8									
9									
10									

Remarks: 19mm piezometer installed to 5.8m bgl. **Chiselling:** from 6.2m to 6.3m for 2 hrs. **Scale:** 1:50

BOREHOLE S&A ARDFERT RWSS.GPJ IRISHDRILL.GDT 24/10/05

PROJECT: North Ardfert Regional Water Supply Scheme - Source Protection **BOREHOLE:** BH16 - DRAFT

LOCATION: Slugaire, Ardfert, Co Kerry **Sheet 1 of 1**

CLIENT: Ryan Hanley Consulting Engineers **Co-ordinates:** N , E **Rig:** Dando 2000

ENGINEER: Ryan Hanley Consulting Engineers **Ground level:** m O.D. **Casing diameter:** 200mm **DRILLING STARTED:** 13.10.05 **DRILLING COMPLETED:** 13.10.05

GROUNDWATER
Water strikes: 1st: 6.55m 2nd: 6.55m 3rd: 6.55m **Rose to:** 4.30m **Sealed off at:** Date: Time: B'hole depth (m): Casing depth (m): Water level (m):

Borehole Depth (m)	Date	Samples	Depth (m)	SPT (N)	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION	Piezometer Details
0		B	0.00-0.50		∩ ∩ ∩			Reeds and rough grass over dark brown plastic amorphous PEAT with some fresh roots and rootlets and some relict fibres. von Post Classification: H3;B2;W0;A0.	
1		U B	0.50-0.95 0.50-1.00	2	∩ ∩ ∩				
2		U B	1.50-1.95 1.50-2.00	5	∩ ∩ ∩			1.50: plastic amorphous PEAT. von Post Classification - H9;B4.	
3		U B	2.50-2.95 2.50-3.00	4/NR	∩ ∩ ∩				
4		U B	3.50-3.95 3.50-4.00	5/NR	∩ ∩ ∩				
5		U B	4.50-4.95 4.50-5.00	8/NR	∩ ∩ ∩		5.10		
6		U B	5.50-5.95 5.50-6.00	15/NR	x x x		5.90	Greenish grey mottled pale brown very slightly sandy very slightly gravelly SILT.	
7		U B	6.20-6.55 6.20-6.70	200	x x x		6.55	Greenish grey mottled pale orange brown slightly sandy slightly gravelly SILT.	
7		W CPT J	6.55 6.70-6.73 6.75	refusal	END		6.70	Probable rock. Very strong slightly weathered 'marbled' creamy grey LIMESTONE. Recovered as angular fine and medium grained limestone gravel from chippings from CPT tip. Borehole terminated. Probable rock.	
8									
9									
10									

Remarks: 50mm standpipe installed to 6.7m bgl. **Chiselling:** from 6.55m to 6.7m for 2 hrs. **Scale:** 1:50

PROJECT: North Ardfert Regional Water Supply Scheme - Source Protection							BOREHOLE: BH17 - DRAFT			
LOCATION: Slugaire, Ardfert, Co Kerry							Sheet 1 of 1			
CLIENT: Ryan Hanley Consulting Engineers				Co-ordinates:			Rig: Dando 2000			
ENGINEER: Ryan Hanley Consulting Engineers				N , E						
Ground level: m O.D.				Casing diameter: 200mm		DRILLING STARTED: 13.10.05		DRILLING COMPLETED: 13.10.05		
GROUNDWATER				Date:						
Water strikes:		Rose to:		Sealed off at:		Time:				
1st: 6.70m		3.20m				B'hole depth (m):				
2nd:						Casing depth (m):				
3rd:						Water level (m):				
Borehole Depth (m)	Date	Samples	Depth (m)	SPT (N)	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION		Piezometer Details
0		B	0.00-0.50		↓ ↓ ↓ ↓			Reeds and rough grass over dark brown plastic amorphous PEAT with some fresh roots and rootlets and some relict fibres. von Post Classification - H8;B4;W1;A1.		
		U B	0.50-0.95 0.50-1.00	3	↓ ↓ ↓ ↓					
1					↓ ↓ ↓ ↓					
		U B	1.50-1.95 1.50-2.00	5	↓ ↓ ↓ ↓					
2					↓ ↓ ↓ ↓					
		U B	2.50-2.95 2.50-3.00	6	↓ ↓ ↓ ↓			2.80: wet plastic amorphous PEAT.		
3					↓ ↓ ↓ ↓					
		U B	3.50-3.95 3.50-4.00	8/NR	↓ ↓ ↓ ↓					
4					↓ ↓ ↓ ↓					
		U B	4.50-4.95 4.50-5.00	6	↓ ↓ ↓ ↓					
5					↓ ↓ ↓ ↓					
		U B	5.50-5.95 5.50-6.00	10/NR	↓ ↓ ↓ ↓		5.60	Grey very slightly sandy very slightly gravelly SILT.		
6					x x x x		5.90	Greenish grey slightly sandy slightly gravelly SILT. Gravel as angular and subangular limestone with rare sandstone and mudstone clasts.		
		U B W	6.50-6.95 6.50-7.00 6.70	50	x x x x		6.80			
7		CPT J	7.00-7.03 7.00	refusal	END		7.00	Probable rock. Very strong slightly weathered 'marbled' creamy grey LIMESTONE. Recovered as angular fine and medium grained limestone gravel from chippings from CPT tip. Borehole terminated. Probable rock.		
8										
9										
10										
Remarks: 50mm standpipe installed to 7.0m bgl.							Chiselling: from 6.9m to 7.0m for 2 hrs.			Scale: 1:50

BOREHOLE S&A ARDFERT RWSS.GPJ IRISHDRILL.GDT 24/10/05

PROJECT: North Ardfert Regional Water Supply Scheme - Source Protection **BOREHOLE:** BH2 - DRAFT
LOCATION: Slugaire, Ardfert, Co Kerry **Sheet 1 of 1**

CLIENT: Ryan Hanley Consulting Engineers **Co-ordinates:**
ENGINEER: Ryan Hanley Consulting Engineers **N , E** **Rig:** Dando 2000

Ground level: m O.D. **Casing diameter:** 200mm **DRILLING STARTED:** 14.10.05 **DRILLING COMPLETED:** 14.10.05

GROUNDWATER
Water strikes: 1st: 6.20m Rose to: 4.10m Sealed off at:
 2nd:
 3rd:
Date:
Time:
B'hole depth (m):
Casing depth (m):
Water level (m):

Borehole Depth (m)	Date	Samples	Depth (m)	SPT (N)	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION	Piezometer Details
0		B	0.00-0.50		\\ \\ \\ \\			Rough grass and reeds over dark brown plastic amorphous PEAT with some fibres. Rare woody fragments. Strong organic odour. Some fresh roots and rootlets. von Post Classification: H9;B3.	
1		U B	0.50-0.95 0.50-1.00	4	\\ \\ \\ \\				
2		U B	1.50-1.95 1.50-2.00	6/NR	\\ \\ \\ \\			1.50: von Post Classification - H8;B4;W1;A0.	
3		U B	2.50-2.95 2.50-3.00	6	\\ \\ \\ \\				
4		U B	3.50-3.95 3.50-4.00	4/NR	\\ \\ \\ \\				
5		U B	4.50-4.95 4.50-5.00	5/NR	x x x x		4.50	Greenish grey very slightly sandy very slightly gravelly SILT.	
6		U B	5.50-5.95 5.50-6.00	100	x o x x		5.50	Pale greenish brown mottled orange slightly sandy slightly gravelly SILT. Gravel as subangular fine and medium grained pale grey limestone with rare sandstone clasts.	
7		W J CPT	6.20 6.20 6.30-6.35	refusal	END		6.20 6.35	Probable rock. Very strong slightly weathered 'marbled' creamy grey LIMESTONE. Recovered as angular fine and medium grained limestone gravel from chippings from CPT tip. Borehole terminated. Probable rock.	
8									
9									
10									

Remarks: Chiselling: from 6.1m to 6.3m for 2 hrs. **Scale:** 1:50

PROJECT: North Ardfert Regional Water Supply Scheme - Source Protection **BOREHOLE:** BH3 - DRAFT

LOCATION: Slugaire, Ardfert, Co Kerry **Sheet 1 of 1**

CLIENT: Ryan Hanley Consulting Engineers **Co-ordinates:** N , E **Rig:** Dando 2000

ENGINEER: Ryan Hanley Consulting Engineers **Ground level:** m O.D. **Casing diameter:** 200mm **DRILLING STARTED:** 11.10.05 **DRILLING COMPLETED:** 11.10.05

GROUNDWATER
Water strikes: 1st: 7.10m Rose to: 7.00m Sealed off at:
 2nd:
 3rd:
Date:
Time:
B'hole depth (m):
Casing depth (m):
Water level (m):

Borehole Depth (m)	Date	Samples	Depth (m)	SPT (N)	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION	Piezometer Details
0		B	0.00-0.50		\\ \\ \\			Reeds, rough grass and brambles over dark brown plastic amorphous PEAT with some fresh roots and rootlets. von Post Classification: H9;W0;A0.	
		U B	0.50-0.95 0.50-1.00	3	\\ \\ \\				
		U B	1.50-1.95 1.50-2.00	8	\\ \\ \\				
		U B	2.50-2.95 2.50-3.00	8/NR	\\ \\ \\				
		U B	3.50-3.95 3.50-4.00	4	\\ \\ \\				
		U B	4.50-4.95 4.50-5.00	8/NR	\\ \\ \\		4.80	Grey mottled pale grey very slightly fine to medium grained sandy SILT.	
					x x x		5.40		
		U B	5.50-5.95 5.50-6.00	65	x x x			Pale brown slightly sandy SILT with rare subrounded medium to coarse dark grey limestone gravel.	
		CPT B	6.50-6.95 6.50-7.00	46	x x x			6.50: slightly gravelly. Gravel as subangular to subrounded cream sandstone with some dark grey limestone.	
		CPT W	7.10-7.15 7.10	refusal	END		7.10 7.15	Probable rock. Very strong slightly weathered 'marbled' creamy grey LIMESTONE. Recovered as angular fine and medium grained limestone gravel from chippings from CPT tip. Borehole terminated. Probable rock.	

Remarks: 50mm standpipe installed to 7.15m bgl. **Chiselling:** from 7.0m to 7.1m for 1 hr. **Scale:** 1:50

BOREHOLE S&A ARDFERT RWSS.GPJ IRISHDRILL.GDT 24/10/05

PROJECT: North Ardfert Regional Water Supply Scheme - Source Protection **BOREHOLE:** BH4 - DRAFT

LOCATION: Slugaire, Ardfert, Co Kerry **Sheet 1 of 1**

CLIENT: Ryan Hanley Consulting Engineers **Co-ordinates:** N , E **Rig:** Dando 2000

ENGINEER: Ryan Hanley Consulting Engineers **Ground level:** m O.D. **Casing diameter:** 200mm **DRILLING STARTED:** 11.10.05 **DRILLING COMPLETED:** 11.10.05

GROUNDWATER
Water strikes: 1st: 6.50m Rose to: 5.20m Sealed off at:
 2nd:
 3rd:
Date:
Time:
B'hole depth (m):
Casing depth (m):
Water level (m):

Borehole Depth (m)	Date	Samples	Depth (m)	SPT (N)	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION	Piezometer Details
0		B	0.00-0.50		\\ \\ \\			Reeds and rough grass over dark brown plastic amorphous PEAT with some fibres. Rare woody fragments. Strong organic odour. Some fresh roots and rootlets. von Post Classification: H5;W1;A2.	
		U	0.50-0.95	10	\\ \\ \\				
		B	0.50-1.00		\\ \\ \\				
1					\\ \\ \\				
		U	1.50-1.95	8/NR	\\ \\ \\				
		B	1.50-2.00		\\ \\ \\				
2					\\ \\ \\				
		U	2.50-2.95	8	\\ \\ \\				
		B	2.50-3.00		\\ \\ \\				
3					\\ \\ \\				
		U	3.50-3.95	10/NR	\\ \\ \\				
		B	3.50-4.00		\\ \\ \\				
4					\\ \\ \\				
		U	4.50-4.95	6/NR	\\ \\ \\			4.50: plastic amorphous PEAT. von Post Classification - H9.	
		B	4.50-5.00		\\ \\ \\		5.10		
5					x x x			Wet greenish grey slightly sandy gravelly SILT. Gravel as subangular to subrounded fine to coarse grained cream sandstone with rare dark grey limestone clasts.	
		U	5.50-5.95	50	x x x				
		B	5.50-6.00		x x x		6.10		
6					o o o			Slightly silty poorly sorted fine to coarse grained subangular to angular pale grey limestone GRAVEL with some cobbles.	
		CPT	6.50-6.95	21	o o o				
		B	6.50-7.00		o o o		7.20		
		W	6.50		o o o		7.40		
7					END			Probable rock. Very strong slightly weathered 'marbled' creamy grey LIMESTONE. Recovered as angular fine and medium grained limestone gravel from chippings from CPT tip.	
		CPT	7.40-7.55	refusal	END			Borehole terminated. Probable rock.	
8									
9									
10									

Remarks: 50mm standpipe installed to 7.55m bgl. **Chiselling:** from 7.2m to 7.4m for 1 1/2 hrs. **Scale:** 1:50

BOREHOLE S&A ARDFERT RWSS.GPJ IRISHDRILL.GDT 24/10/05

PROJECT: North Ardfert Regional Water Supply Scheme - Source Protection **BOREHOLE:** BH7 - DRAFT
LOCATION: Slugaire, Ardfert, Co Kerry **Sheet 1 of 1**

CLIENT: Ryan Hanley Consulting Engineers **Co-ordinates:**
ENGINEER: Ryan Hanley Consulting Engineers **N , E** **Rig:** Dando 2000

Ground level: m O.D. **Casing diameter:** 200mm **DRILLING STARTED:** 15.10.05 **DRILLING COMPLETED:** 15.10.05

GROUNDWATER
Water strikes: 1st: 6.30m Rose to: 3.70m Sealed off at:
Date:
Time:
B'hole depth (m):
Casing depth (m):
Water level (m):

Borehole Depth (m)	Date	Samples	Depth (m)	SPT (N)	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION	Piezometer Details
0		B	0.00-0.50				0.30	FILL: Rough grass over angular limestone cobbles.	
1		U B	0.50-0.95 0.50-1.00	4				Dark brown plastic amorphous PEAT with some fresh roots and rootlets. von Post Classification: H8;B4;W1;A0. 0.50: von Post Classification - H8;B4;W1;A0.	
2		U B	1.50-1.95 1.50-2.00	4					
3		U B	2.50-2.95 2.50-3.00	6				2.50: von Post Classification - H9;W0;A0.	
4		U B	3.50-3.95 3.50-4.00	6				3.50: von Post Classification - H8;W1;A0.	
5		U B	4.50-4.95 4.50-5.00	5/NR			4.70 4.90	Greenish grey motle orange very slightly sandy slightly gravelly SILT. Gravel as subangular sandstone with rare mudstone and limestone. Greenish brown mottled/speckled orange slightly sandy slightly gravelly SILT. Gravel as subangular to subrounded fine and medium grained dark grey limestone with some sandstone and mudstone clasts.	
6		U B	5.50-5.95 5.50-6.00	100			5.90		
7		B W J CPT	6.00-6.50 6.30 6.50 6.50-6.53	refusal	 END		6.40 6.50	Slightly silty poorly sorted fine to coarse grained subangular to angular pale grey limestone GRAVEL with some cobbles. Probable rock. Very strong slightly weathered 'marbled' creamy grey LIMESTONE. Recovered as angular fine and medium grained limestone gravel from chippings from CPT tip. Borehole terminated. Probable rock.	

Remarks: 50mm standpipe installed to 6.5m bgl. **Chiselling:** from 6.4m to 6.5m for 2 hrs. **Scale:** 1:50

PROJECT: North Ardfert Regional Water Supply Scheme - Source Protection **BOREHOLE:** BH8 - DRAFT

LOCATION: Slugaire, Ardfert, Co Kerry **Sheet 1 of 1**

CLIENT: Ryan Hanley Consulting Engineers **Co-ordinates:**

ENGINEER: Ryan Hanley Consulting Engineers **Rig:** Dando 2000

Ground level: m O.D. **Casing diameter:** 200mm **DRILLING STARTED:** 15.10.05 **DRILLING COMPLETED:** 15.10.05

GROUNDWATER
Water strikes: Rose to: Sealed off at:
 1st: dry
 2nd:
 3rd:
Date:
Time:
B'hole depth (m):
Casing depth (m):
Water level (m):

Borehole Depth (m)	Date	Samples	Depth (m)	SPT (N)	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION	Piezometer Details
0		B	0.00-0.50		\\ \\ \\			Rough grass over dark brown plastic amorphous PEAT with some fresh roots and rootlets. von Post Classification: H8;B4;W0;A0.	
		U	0.50-0.95	5	\\ \\ \\			0.50: von Post Classification - H9.	
		B	0.50-1.00		\\ \\ \\				
1					\\ \\ \\				
		U	1.50-1.95	4	\\ \\ \\				
		B	1.50-2.00		\\ \\ \\				
2					\\ \\ \\				
		U	2.50-2.95	6	\\ \\ \\				
		B	2.50-3.00		\\ \\ \\				
3					\\ \\ \\				
		U	3.50-3.95	7/NR	\\ \\ \\				
		B	3.50-4.00		\\ \\ \\				
4					\\ \\ \\				
		U	4.50-4.95	9/NR	\\ \\ \\			4.50: von Post Classification - H9;W1.	
		B	4.50-5.00		\\ \\ \\		4.90		
5					x x x			Wet grey SILT.	
		U	5.50-5.95	60	x x x		5.70		
		B	5.50-6.00		x x x			Greenish grey mottled orange slightly sandy slightly gravelly SILT. Gravel as subangular fine and medium grained sandstone with some dark grey limestone clasts.	
6					x x x				
		U	6.50-6.80	200/NR	x x x		6.80		
		W	6.80		x x x		6.95	Probable rock. Very strong slightly weathered 'marbled' creamy grey LIMESTONE. Recovered as angular fine and medium grained limestone gravel from chippings from CPT tip.	
7		J	6.90-6.95	refusal	END			Borehole terminated. Probable rock.	
8		CPT							
9									
10									

Remarks: Chiselling: from 6.8m to 6.9m for 2 hrs. **Scale:** 1:50

BOREHOLE S&A ARDFERT RWSS.GPJ IRISHDRILL.GDT 24/10/05

PROJECT: North Ardfert Regional Water Supply Scheme - Source Protection							BOREHOLE: BH9 - DRAFT				
LOCATION: Slugaire, Ardfert, Co Kerry							Sheet 1 of 1				
CLIENT: Ryan Hanley Consulting Engineers				Co-ordinates:			Rig: Dando 2000				
ENGINEER: Ryan Hanley Consulting Engineers				N , E							
Ground level: m O.D.				Casing diameter: 200mm			DRILLING STARTED: 14.10.05		DRILLING COMPLETED: 14.10.05		
GROUNDWATER				Date:							
Water strikes:		Rose to:		Time:							
1st: 6.50m		4.20m		B'hole depth (m):							
2nd:		Sealed off at:			Casing depth (m):						
3rd:					Water level (m):						
Borehole Depth (m)	Date	Samples	Depth (m)	SPT (N)	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION			
0					END		0.18	FILL: Peat cover over esb duct.			
								Borehole abandoned due to underground services moved 1 metre.			
-1											
-2											
-3											
-4											
-5											
-6											
-7											
-8											
-9											
-10											
Remarks: Borehole abandoned. esb duct with 'danger' tape over. Moved 1 metre to BH9A.							Chiselling:			Scale:	
										1:50	
Irish Drilling Ltd. Loughrea, Co. Galway										Ph. 091 841274 Fax 091 847687	

BOREHOLE S&A ARDFERT RWSS.GPJ IRISHDRILL.GDT 24/10/05

PROJECT: North Ardfert Regional Water Supply Scheme - Source Protection **BOREHOLE:** BH9A - DRAFT

LOCATION: Slugaire, Ardfert, Co Kerry **Sheet 1 of 1**

CLIENT: Ryan Hanley Consulting Engineers **Co-ordinates:** N , E **Rig:** Dando 2000

ENGINEER: Ryan Hanley Consulting Engineers **Ground level:** m O.D. **Casing diameter:** 200mm **DRILLING STARTED:** 14.10.05 **DRILLING COMPLETED:** 14.10.05

GROUNDWATER
Water strikes: 1st: 6.80m 2nd: 3rd: **Rose to:** 4.30m **Scaled off at:**
Date: **Time:**
B'hole depth (m):
Casing depth (m):
Water level (m):

Borehole Depth (m)	Date	Samples	Depth (m)	SPT (N)	LEGEND	Elevation m O.D.	Depth (m)	DESCRIPTION	Piezometer Details
0		B	0.00-0.50		∩ ∩ ∩			Rough grass over dark brown plastic amorphous PEAT with some fibres. Some fresh roots and rootlets. von Post Classification: H7;B3;W0;A0.	
1		U B	0.50-0.95 0.50-1.00	5	∩ ∩ ∩			0.50: von Post Classification - H8.	
2		U B	1.50-1.95 1.50-2.00	4	∩ ∩ ∩			1.50: von Post Classification - H9.	
3		U B	2.50-2.95 2.50-3.00	5	∩ ∩ ∩				
4		U B	3.50-3.95 3.50-4.00	6/NR	∩ ∩ ∩			3.50: von Post Classification - H8.	
5		U B	4.50-4.95 4.50-5.00	8/NR	∩ ∩ ∩				
6		B	5.10-5.50		x x x		5.10	Wet grey very slightly sandy SILT.	
7		U B	5.50-5.95 5.50-6.00	70	x o x		5.50	Greenish brown mottled orange slightly sandy slightly gravelly SILT. Gravel as subangular fine and medium grained limestone with some mudstone and rare sandstone clasts.	
7		CPT W J CPT	6.50-6.60 6.50 6.70 6.70	refusal	END		6.50 6.70	Probable rock. Very strong slightly weathered 'marbled' creamy grey LIMESTONE. Recovered as angular fine and medium grained limestone gravel from chippings from CPT tip. Borehole terminated. Probable rock.	
8									
9									
10									

Remarks: Chiselling: from 6.5m to 6.7m for 2 hrs. **Scale:** 1:50

BOREHOLE S&A ARDFERT RWSS.GPJ IRISHDRILL.GDT 24/10/05

REPORT TO

Ryan Hanley Consulting Engineers

North Ardferf Regional Water Supply Scheme - Source Protection

Geophysics, drilling and monitoring well installations, well audit, pumping tests, zone of contribution, aquifer vulnerability assessment and reporting

REPORT BY

Minerex Environmental Limited
Doc Ref 1736-120 (First draft-Rev 3)

Appendix C

REPORT TO

Ryan Hanley Consulting Engineers

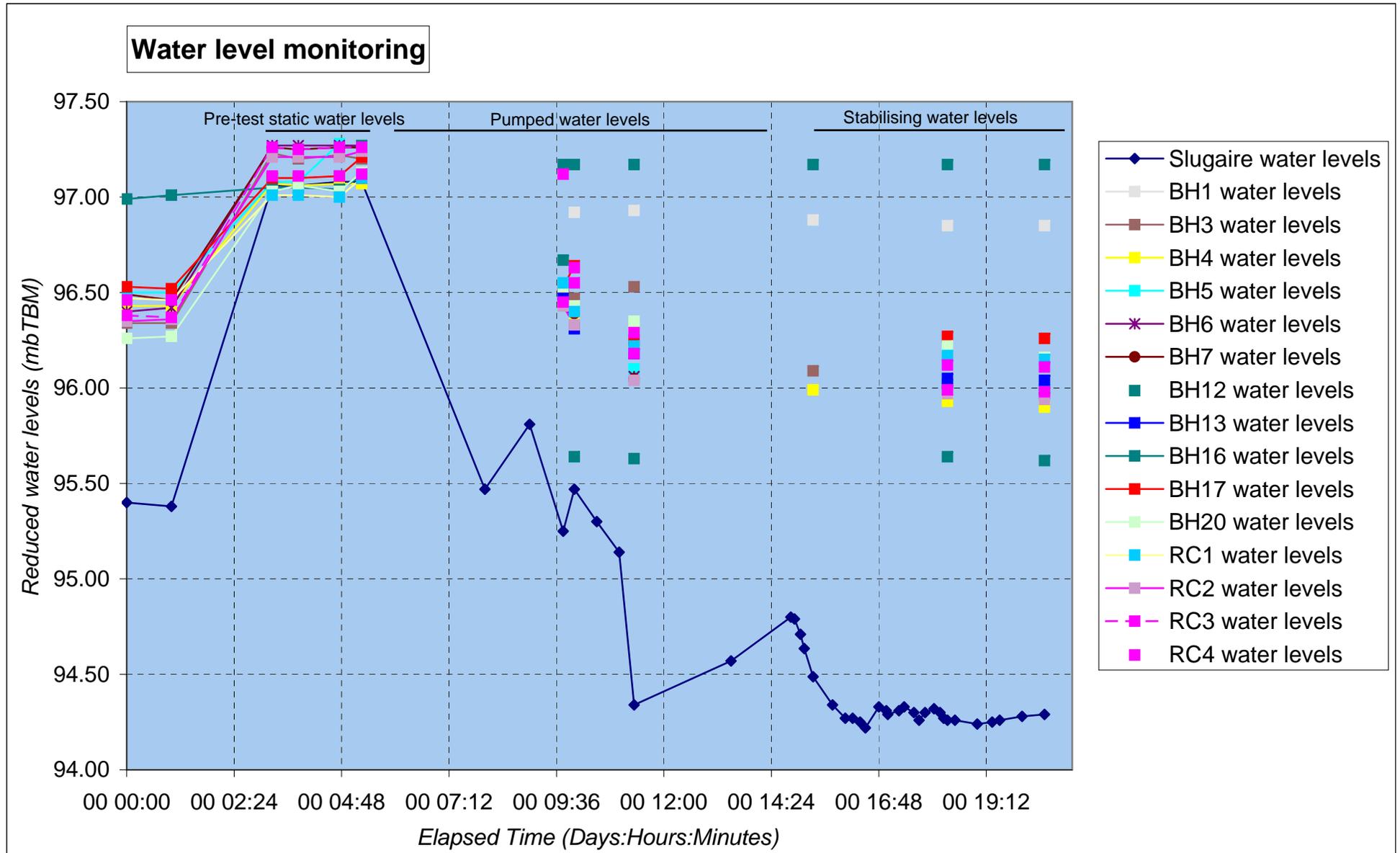
North Ardferf Regional Water Supply Scheme - Source Protection

Geophysics, drilling and monitoring well installations, well audit, pumping tests, zone of contribution, aquifer vulnerability assessment and reporting

REPORT BY

Minerex Environmental Limited
Doc Ref 1736-120 (First draft-Rev 3)

Appendix D



REPORT TO

Ryan Hanley Consulting Engineers

North Ardferf Regional Water Supply Scheme - Source Protection

Geophysics, drilling and monitoring well installations, well audit, pumping tests, zone of contribution, aquifer vulnerability assessment and reporting

REPORT BY

Minerex Environmental Limited
Doc Ref 1736-120 (First draft-Rev 3)

Appendix E

North Ardfert RWSS Slugaire
Source Protection

Geophysical Survey

Report Status: Draft

MGX Project Number: 5078

MGX File Ref: 5078d_006.doc

10th January 2006

Confidential Report To:

Irish Drilling Ltd.

Loughrea

Co. Galway

Ryan Hanley Consulting Engineer

Sherwood House

Sherwood Avenue

Taylor's Hill

Galway

**Report submitted by :
Minerex Geophysics Limited**

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EurGeol Hartmut Krahn M.Sc. (Geophysics) PGeo



Geophysical Services

EXECUTIVE SUMMARY

1. Minerex Geophysics Ltd. (MGX) carried out a geophysical survey consisting of Seismic Refraction, 2D-Resistivity and Ground Penetrating Radar (GPR) measurements for the hydrogeological and ground investigation at the Slugaire source in North Ardfert.
2. The objective of the survey was to establish the ground conditions for the proposed construction of source protective measures.
3. The maximum outline of the gravel fill could be estimated from the resistivity profiles and is indicated on Map 1.
4. The interpretation shows that the overburden near the slugaire consists of a 4 – 5 m thick peat layer that is underlain by an approx. 2 m thick gravelly Silt and Gravel layer.
5. The rock consists of clean limestone. It is well jointed at the rock head. Gradual increases in resistivity indicate that the jointing decreases with depth.
6. The best permeability exists in the upper 2 – 4 m of the rock though ground water flow can also occur from larger depths.
7. Towards the west and north the thickness of the well jointed rock layer increases.

CONTENTS

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1.1 Background	1
1.2 Objectives	1
1.3 Site Description	1
1.4 Bedrock Geology	1
1.5 Report	1
2. GEOPHYSICAL SURVEY	2
2.1 Methodology	2
2.2 Site Work	2
3. RESULTS AND INTERPRETATION	3
4. REFERENCES	5

List of Tables, Maps and Figures:

Title	Pages	Document Reference
Table 1: Summary of Results and Interpretation	N/A	In Text
Map 1: Geophysical Survey Location Map	1 x A3	5078d_Maps.dwg
Figure 1: Results of Geophysical Survey	1 x A3	5078d_Figs.dwg
Figure 2: Interpretation of Geophysical Survey	1 x A3	5078d_Figs.dwg

1. INTRODUCTION

1.1 Background

Minerex Geophysics Ltd. (MGX) carried out a geophysical survey for the Slugaire source protection in North Ardfert. The survey consisted of Ground Penetrating Radar (GPR), Seismic Refraction and 2D-Resistivity measurements. The source has currently a yield of approx. 2688 m³/day. The source is liable to flooding and as a protection measure a piled wall will be constructed around the well.

1.2 Objectives

The objectives of the survey were:

- To examine the ground as part of the site investigation for the piled wall around the source
- To map the extent of the gravel fill around the source
- To determine the existence of a karstified zone of rock where the main ground water flow occurs

1.3 Site Description

The site of the source is very flat and situated within a large flat peat area. Several drains exist in the area. The vegetation consists of grass and planted trees. The immediate area around the source consists of large concrete slabs broken rock fill.

1.4 Bedrock Geology

The bedrock geology consists of Waulsortian Limestone, a massive unbedded lime-mudstone. The Ballysteen formation (Fossiliferous dark grey muddy limestone) has been mapped to the North of the site. There are no faults mapped near the site. The general strike direction of faults in the region is NNW-SSE (GSI, 1999).

1.5 Report

This report includes the results and interpretation of the geophysical survey. Maps, figures and tables are included to illustrate the survey and the results. More detailed descriptions of geophysical methods and measurements can be found in Engineering Geophysics (1988), Milsom (1989) and Reynolds (1997).

The client provided a digital map of the site and the logs of shell and auger bore holes and rotary core holes were available for this report.

The interpretative nature and the non-intrusive survey methods must be taken into account when considering the results of this survey and Minerex Geophysics Limited, while using appropriate practise to execute, interpret and present the data give no guarantees in relation to the existing subsurface.

2. GEOPHYSICAL SURVEY

2.1 Methodology

The methodology consisted of using Seismic Refraction, 2D-Resistivity and Ground Penetrating Radar (GPR) measurements. First 2D-Resistivity measurements were carried out to map the ground outside the gravel fill of the source and at the location of the proposed piled wall. A linear karstified zone with a preferential direction was not located therefore four more 2D-Resistivity profiles with wider (5m) electrode spacing were carried out to map the deeper rock. Seismic profiles were carried out around the source though the data quality was poor due to the thick peat cover. The thick concrete slabs and partially hollow ground under them did not permit any 2D-Resistivity or seismic refraction measurements to be carried out. Therefore some GPR lines were measured.

2D-Resistivity profiles with electrode spacing between 2 and 5m and 32 electrodes per set-up were surveyed at the locations R1 to R9. The readings were taken with a Tigre Resistivity Meter and an Imager Cable.

The Seismic Refraction measurements were taken with geophone spacings of 4 – 5m. The seismic energy source was a seismograph gun submerged in the peat and 6 DMT Summit 2in1 boxes were used to record the seismic data. Seismic profiles were surveyed with 12 geophones and 5 shot points per profile.

The GPR lines were surveyed with a GPR GSSI SIR-3000 System and a 400 MHz Antenna.

2.2 Site Work

The survey was carried out between the 5th and 11th of October 2005. The locations of the seismic refraction and 2D-Resistivity Profiles are shown on the location map (Map 1). The weather conditions were good during the survey.

3. RESULTS AND INTERPRETATION

The interpretation of geophysical data was carried out utilising the known response of geophysical measurements, typical physical parameters for subsurface features that may underlay the site and the experience of the authors.

The GPR survey did not penetrate well and could not show the boundary between gravel fill and peat. Therefore the data is not used in this report. The seismic data is of poor quality because of the thick peat. The velocities could be estimated for the peat and rock layers and are shown in Table 1. Layer boundaries were not derived as the accuracy is poor. The seismic survey did show the presence of strong rock at similar depths all around the slugaire.

The approx. outline of the gravel fill could be determined by some 2D-Resistivity profiles and is drawn on Map 1. There is not gravel fill outside the fencing. Therefore a piled wall build along the fencing or outside the fencing would not penetrate the gravel fill. Not considered as gravel fill in this context are the tracks to and near the slugaire.

The 2D-Resistivity data was inverted with the RES2DINV inversion package. The resulting models were colour contoured and they are displayed as cross sections on Figure 1. The interpretation is shown on Figure 2. The borehole information has been used for boundaries at the locations of boreholes, and the resistivity contours were used between boreholes and away from boreholes.

Table 1 summarises typical resistivities and seismic velocities for the layers drawn in the interpretation.

Table 1: Summary of Results and Interpretation

Layer	General Thickness Range (m)	Average Thickness (m)	General Seismic Velocity Range (km/sec)	General Resistivity Range (Ohmm)	Interpretation
1	0.0 – 2.0	1.0	N/A	>500	Gravel Fill
2	4.0 – 5.5	4.5	0.15 – 0.2	< 40	Peat
3	1.0 – 3.0	2.0	N/A	40 - 80	Gravelly Silt and Gravel
4	2.0 – 15.0	5.0	4 – 5	80 - 500	Limestone (Well jointed)
5	To top of layer 9.0 – 30.0	To top of layer 12.0	4 - 5	> 500	Limestone (Jointed)

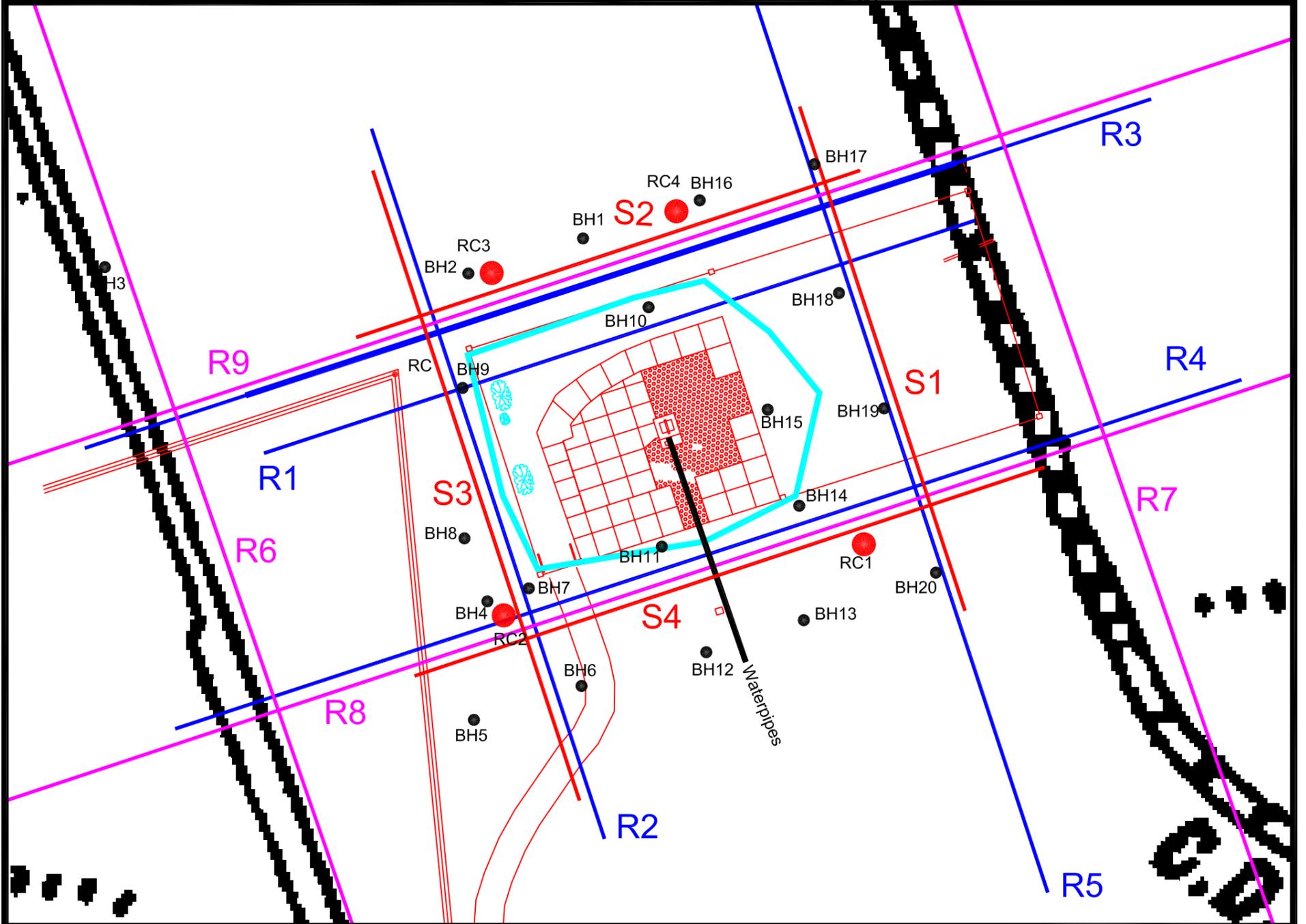
The gravel fill around the slugaire can be seen on R1. This profile was just outside the thick concrete slabs around the well and it is influenced strongly by the fill. The resistivity contour lines are strongly affected and other profiles were carried further out to obtain better data.

Geophysics and borehole data show that the depth to layers near the well is fairly homogeneous. With larger distance from the well towards a western and northern direction the resistivities decrease at depth. This could be caused by a relatively higher jointed/fractured/broken limestone, or alternatively by an argillaceous limestone. The rotary core holes show that the top of the rock (at depths 8 – 12 m) is more jointed than the deeper rock. Therefore the interpretation is made that a horizontal layer of jointed rock occurs under the slugaire and that this layer thickens towards the west and north. The water filled joints reduce the resistivity of the clean limestone rock. This interpretation is supported by the gradual increase of resistivities with depth, rather than a sharp increase near the rockhead.

It is noted that the deeper rock is also jointed and that one cavity was noted in the borehole logs. While good water permeability exists in the well jointed rock layer water flow would also take place through the deeper rock.

4. REFERENCES

1. **Engineering Geophysics, 1988.** Report by the Geological Society Engineering Group Working Party. Quarterly Journal of Engineering Geology, London, 1988, Vol. 21, pp. 207 –271.
2. **GSI, 1999.** Geology of the Shannon Estuary. Bedrock Geological Map Series 1:100000. Geological Survey of Ireland, 2005.
3. **Milsom, 1989.** Field Geophysics. John Wiley and Sons.
4. **Reynolds, 1997.** An Introduction to Applied and Environmental Geophysics. John Wiley and Son.



LEGEND:

- R6 2D-Resistivity 5m electrode spacing
- R1 2D-Resistivity 2 and 3m electrode spacing
- S1 Seismic Profile
- Maximum Extent of Rock/Gravel Fill
- BH1 S&A Borehole
- RC Recommended RC Borehole

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CLIENT Irish Drilling Ltd.
Ryan Hanley Consulting Engineers

PROJECT North Ardfert RWSS Slugaire
Geophysical Survey

TITLE Map 1: Geophysical Survey
Location Map

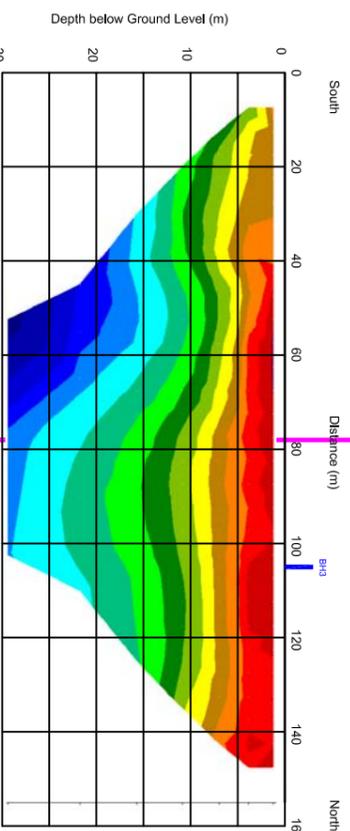
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PROJECT: 5078
DRAWN: HK
DATE: 28/12/05
MGX FILE: 5078d_Maps.dwg
BASED ON: A3 Existing Site

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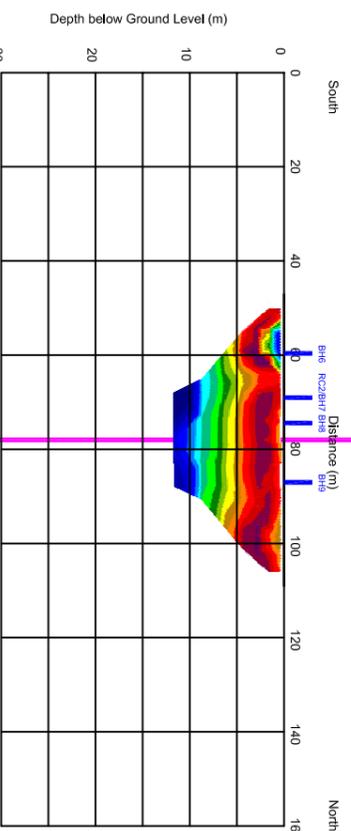
STATUS: Draft

View Direction from East to West

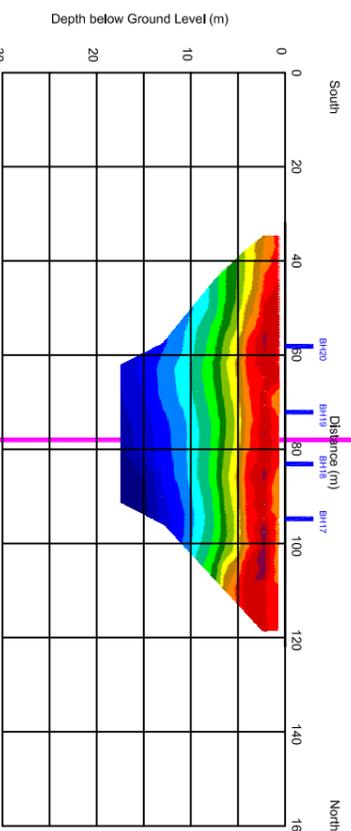
2D-Resistivity R6 Model



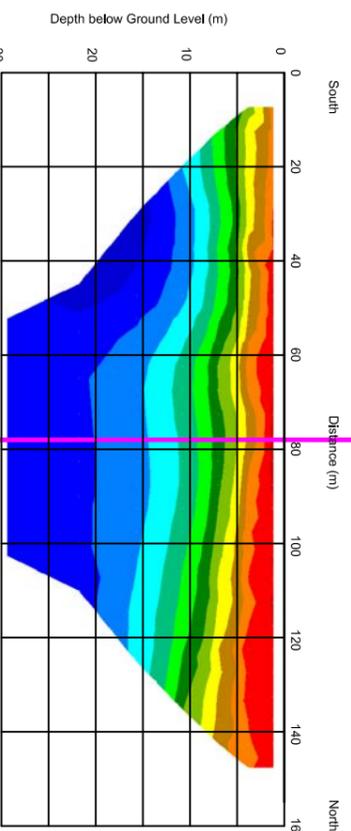
2D-Resistivity R2 Model



2D-Resistivity R5 Model

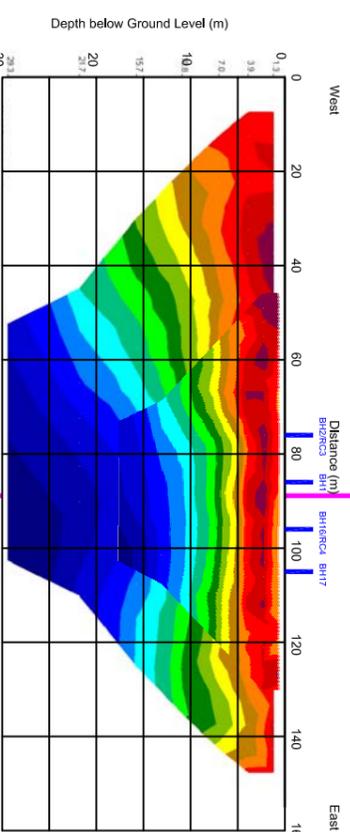


2D-Resistivity R7 Model

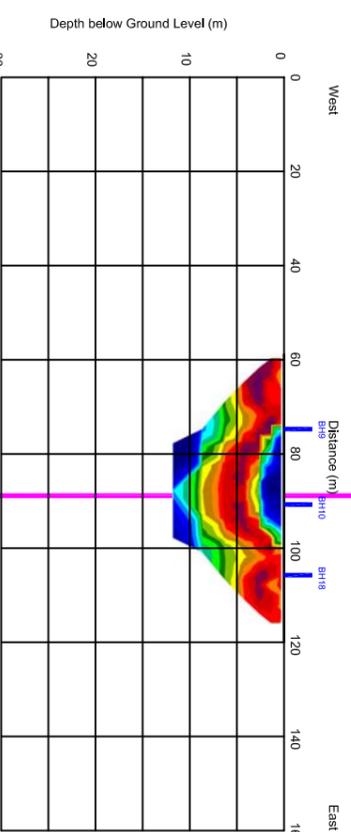


View Direction from South to North

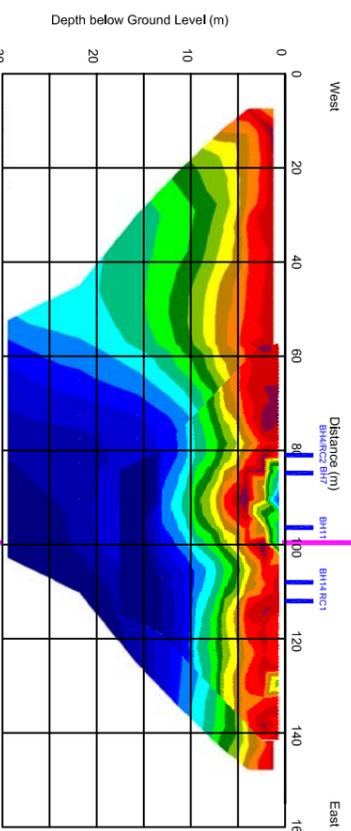
2D-Resistivity R9 and R3 (inset) Models



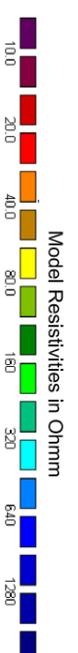
2D-Resistivity R1 Model



2D-Resistivity R8 and R4 (inset) Models



LEGEND: (Refer to Report)



CLIENT	Irish Drilling Ltd. Ryan Hanley Consulting Engineers	SCALE:	NTS, V.E. 1:2
PROJECT	North Ardferf RWSS Slugaire Geophysical Survey	PROJECT:	5078
TITLE	Figure 1: Results of Geophysical Survey	DRAWN:	HK
		DATE:	28/12/05
		MGX FILE:	5078d_Figs.dwg
		BASED ON:	

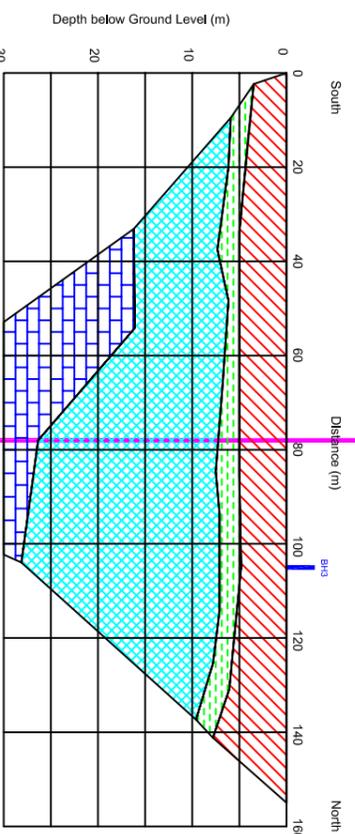
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Web: www.minerex.ie

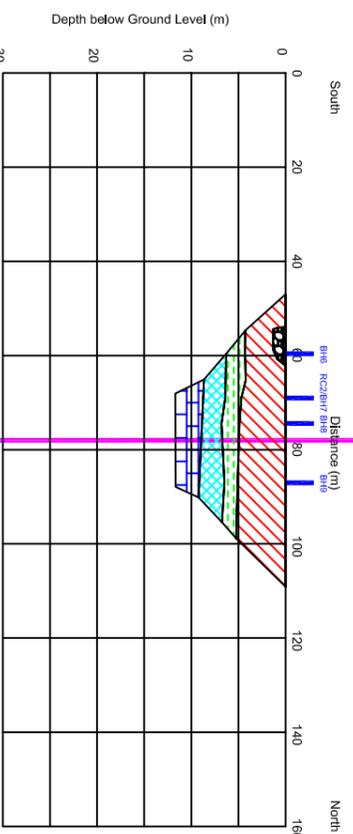
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View Direction from East to West

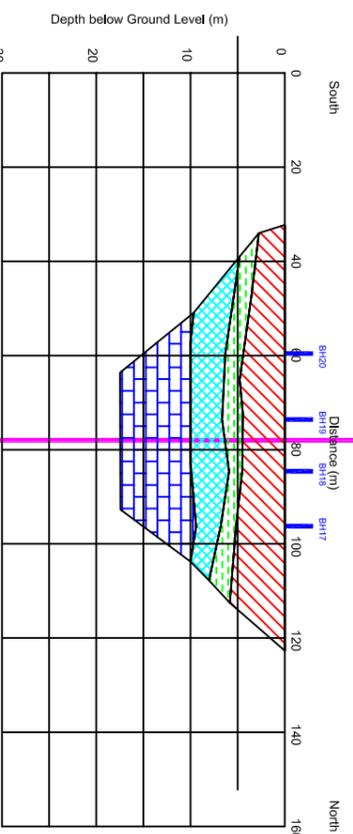
2D-Resistivity R6 Interpretation



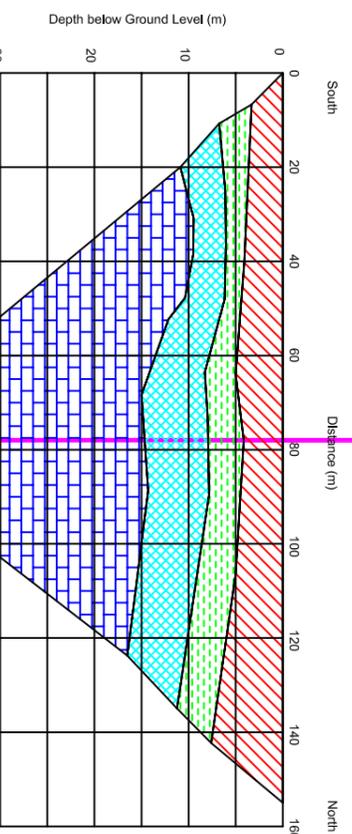
2D-Resistivity R2 Interpretation



2D-Resistivity R5 Interpretation

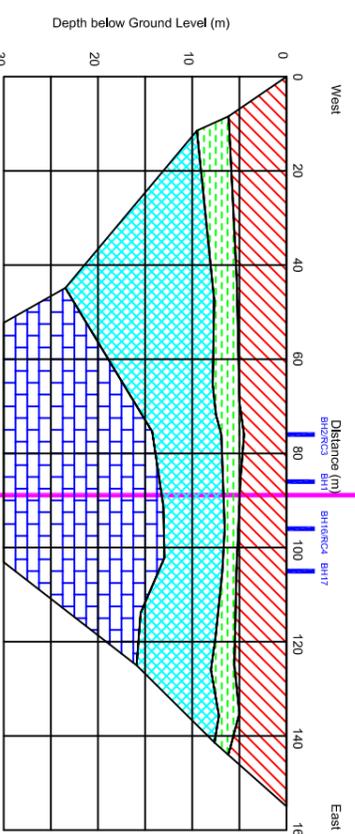


2D-Resistivity R7 Interpretation

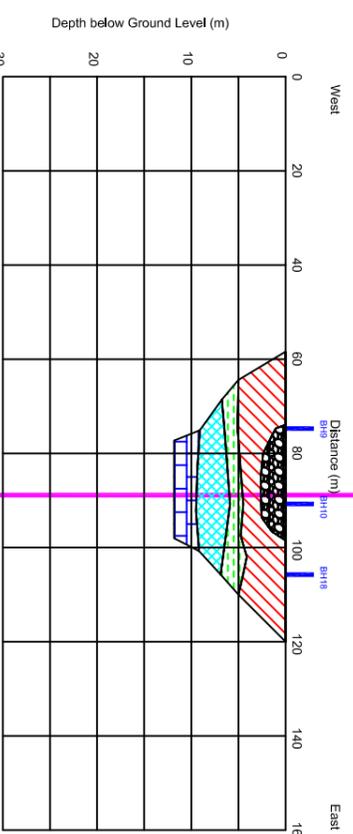


View Direction from South to North

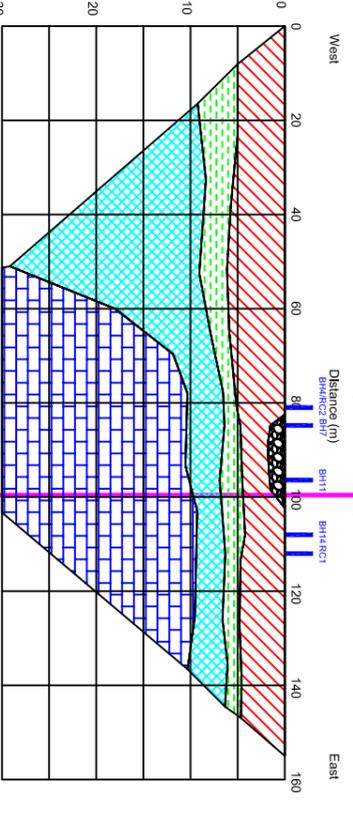
2D-Resistivity R9 and R3 (inset) Interpretation



2D-Resistivity R1 Interpretation



2D-Resistivity R8 and R4 (inset) Interpretation



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CLIENT	Irish Drilling Ltd. Ryan Hanley Consulting Engineers
PROJECT	North Ardfer R WSS Slugaire Geophysical Survey
TITLE	Figure 2: Interpretation of Geophysical Survey

SCALE:	NTS, V.E. 1:2
PROJECT:	5078
DRAWN:	HK
DATE:	28/12/05
MGX FILE:	5078d_Figs.dwg
BASED ON:	

LEGEND: (Refer to Report)	
Interpretation of Geological Layers	
1	Gravel Fill
2	Peat
3	Gravelly Silt and Gravel
4	Limestone (Very jointed)
5	Limestone (Jointed)
STATUS: Draft	

REPORT TO

Ryan Hanley Consulting Engineers

North Ardferf Regional Water Supply Scheme - Source Protection

Geophysics, drilling and monitoring well installations, well audit, pumping tests, zone of contribution, aquifer vulnerability assessment and reporting

REPORT BY

Minerex Environmental Limited
Doc Ref 1736-120 (First draft-Rev 3)

Appendix F

Common legend

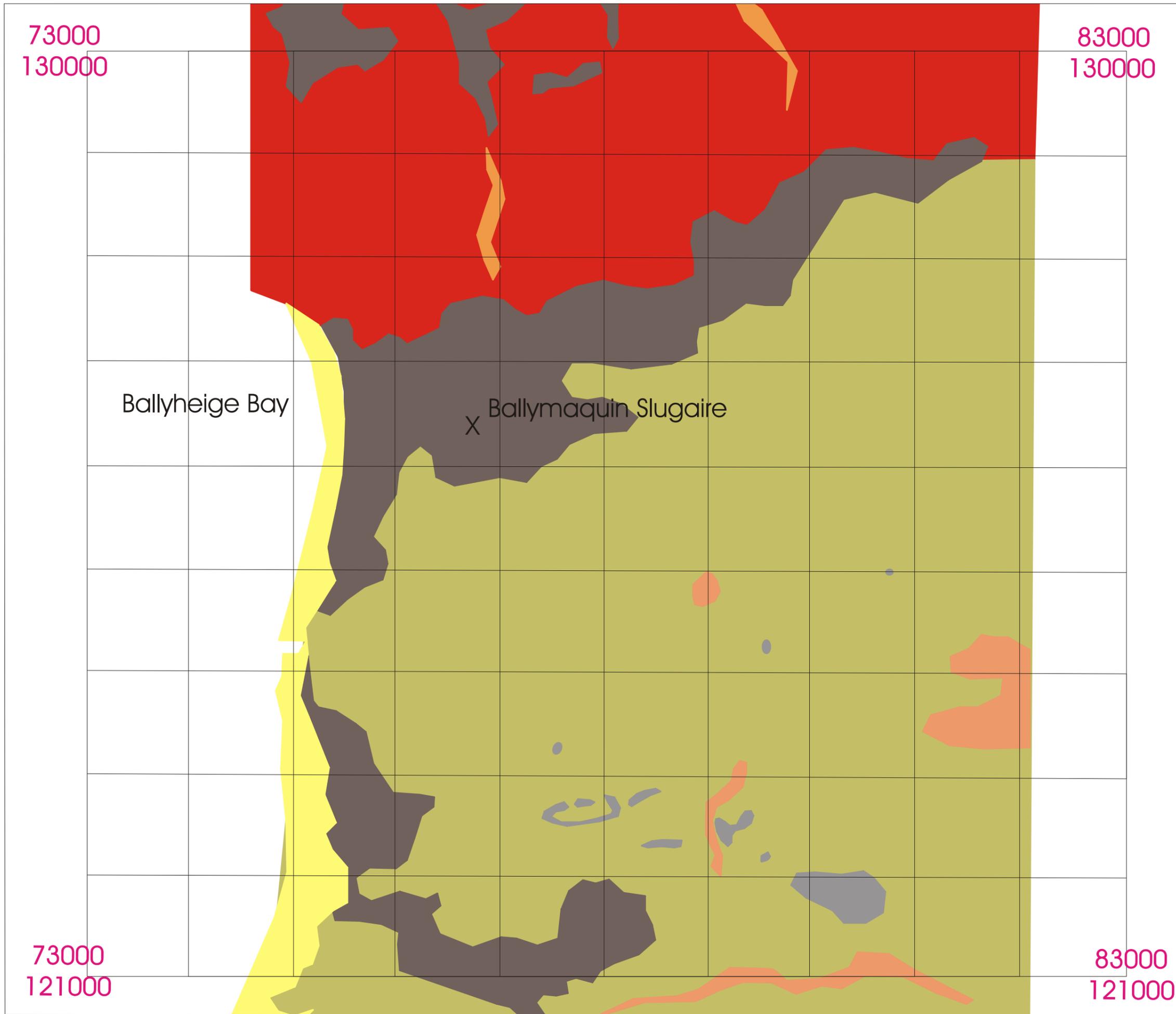
-  Sandstone fill
-  Cutover peat
-  Alluvium
-  Karstified bedrock at surface
-  Shales & sandstones till
-  Raised beach sands & gravels
-  214,000
197,500 National grid co-ordinates

N (National Grid)



NOTES

- 1000m grid on plan map
- All locations are +/- 5m.
- Subsoil geology data provided by Geological Survey of Ireland



REPORT TO

Ryan Hanley Consulting Engineers

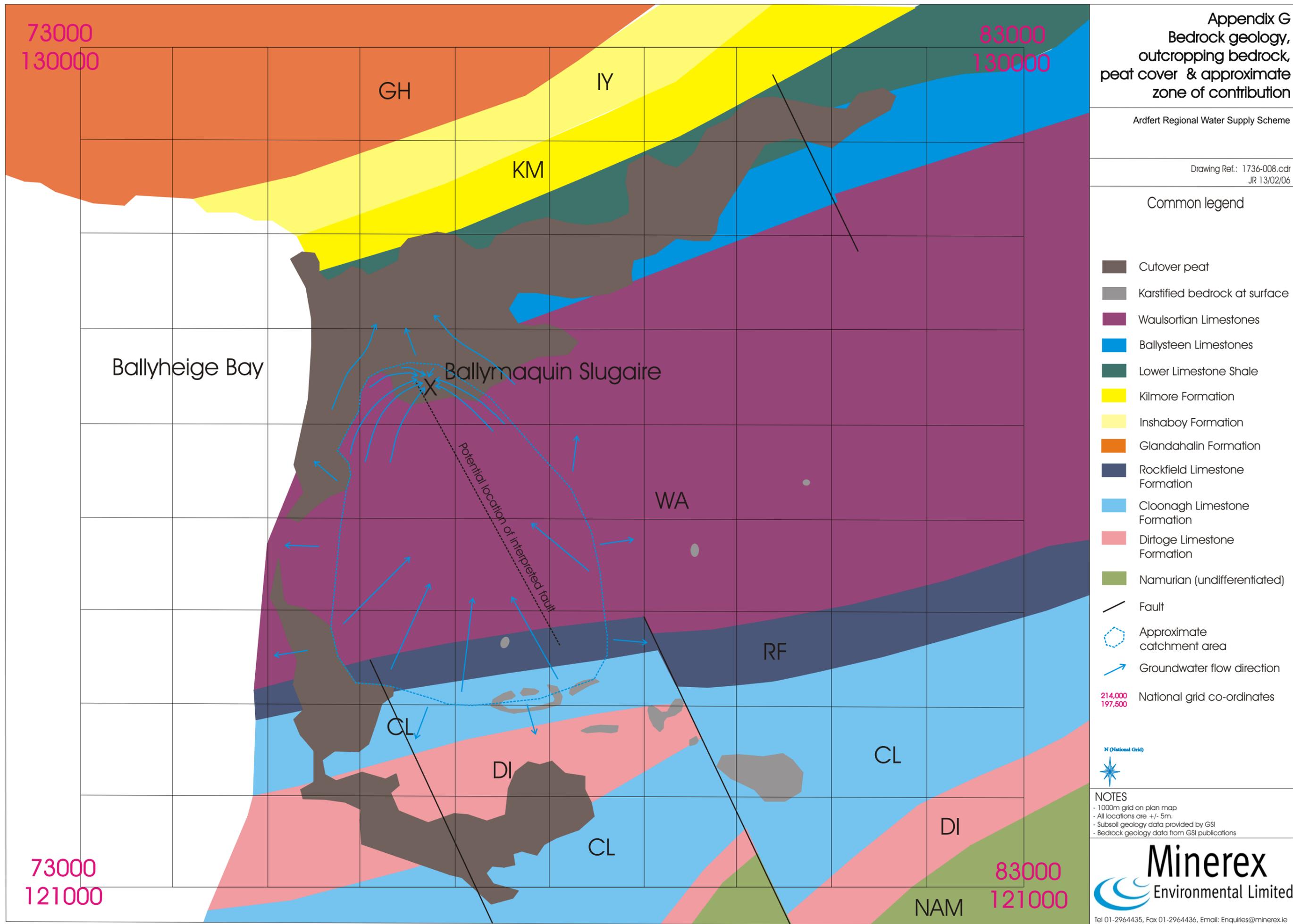
North Ardferf Regional Water Supply Scheme - Source Protection

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REPORT BY

Minerex Environmental Limited
Doc Ref 1736-120 (First draft-Rev 3)

Appendix G



Appendix G
Bedrock geology,
outcropping bedrock,
peat cover & approximate
zone of contribution

Ardferf Regional Water Supply Scheme

Drawing Ref.: 1736-008.cdr
 JR 13/02/06

Common legend

- Cutover peat
- Karstified bedrock at surface
- Waulsortian Limestones
- Ballysteen Limestones
- Lower Limestone Shale
- Kilmore Formation
- Inshaboy Formation
- Glandahalin Formation
- Rockfield Limestone Formation
- Cloonagh Limestone Formation
- Dirtoge Limestone Formation
- Namurian (undifferentiated)
- Fault
- Approximate catchment area
- Groundwater flow direction
- National grid co-ordinates



NOTES
 - 1000m grid on plan map
 - All locations are +/- 5m.
 - Subsoil geology data provided by GSI
 - Bedrock geology data from GSI publications

REPORT TO

Ryan Hanley Consulting Engineers

North Ardferf Regional Water Supply Scheme - Source Protection

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REPORT BY

Minerex Environmental Limited
Doc Ref 1736-120 (First draft-Rev 3)

Appendix H



Figure 1. Honda pump in bunded container



Figure 2. View of rising mains and gravity feed in Slugaire



Figure 3. Temporary benchmark on ESB pole



Figure 4. Temporary benchmark on gate pillar