Environmental Protection Agency

Establishment of Groundwater Source Protection Zones

Cappamore Group 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 (SPZ) have been delineated for the Cappamore source 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 SPZ Delineation. The Cappamore Group Water Supply Scheme has three sources. The first is the two wells located in the townland of Farnanefranklin and are the subject of this report. The second is two springs at Glosha and Faileen/Bilboa, which are 1.4 km and 4 km to the northeast of the wells, respectively. The third, and back up source, is the Glenstal Group Water Scheme (borehole). The GSI prepared a Source Protection Report for the Faileen Bilboa source in 1995 and a copy is provided in Appendix 1.

The objectives of the study were:

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

The protection zones are intended to provide a guide in the planning and regulation of development and human activities to ensure groundwater quality is protected. More details on protection zones are presented in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

2 Methodology

The methodology applied to delineate the SPZ consisted of data collection, desk studies including a short term recovery test, site visits and field mapping, and subsequent data analysis and interpretation.

A site visit and interview with the caretaker took place on 15/06/2010. Field mapping of the study area (including measuring the electrical conductivity and temperature of streams in the area), took place on 14/07/2010 and 22/07/2010, and the short term recovery test was completed on 29/09/2010.

While specific fieldwork was carried out in the development of this report, the maps produced are based largely on the readily available information and mapping techniques using inferences and judgements from experience at other sites. As such, the maps may not 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.

3 Location, Site Description and Well Head Protection

The wells are approximately 2.3 km northeast of Cappamore village in the townland of Farnanefranklin, as shown in Figure 1. The access to the site is via a third class road to the east of the road linking the villages of Cappamore and Farnanefranklin.

The wells are in a compound which also houses the water supply reservoir (Photo 1). The compound is protected by a palisade fence, with a padlocked gate. The ground inside the compound comprises landscaped green areas where the wells are located and a gravel access road from the site entrance to the

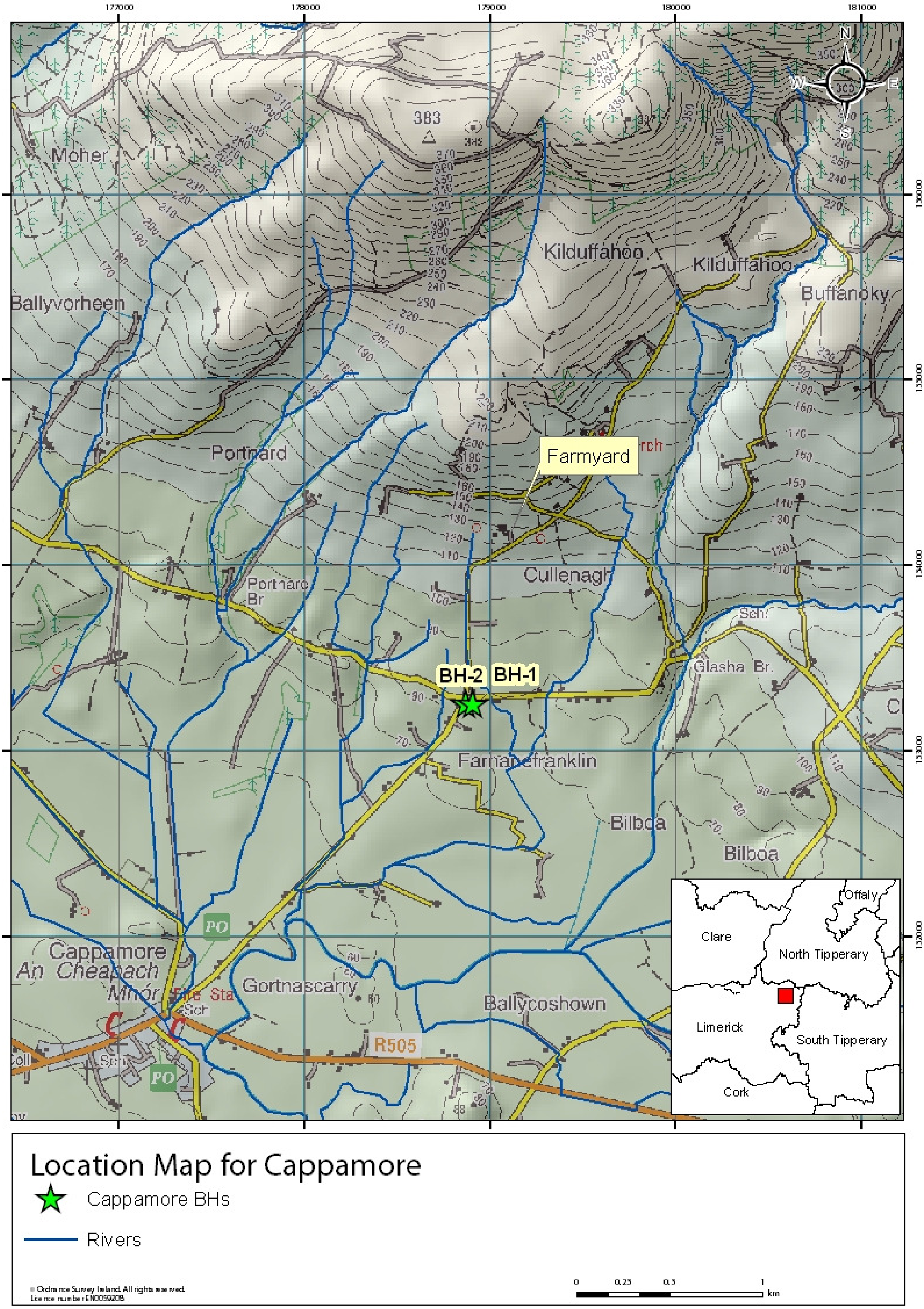

Figure 1: Location Map

pump house. The wells are 40 m apart with the pump house between them (Photo 2). The reservoir is between the access road and the pump house, toward the front of the compound.

The wells were installed in 2002 as test wells under the supervision of Mr. David Ball, Hydrogeologist. Limerick County Council Water Services Section subsequently brought the wells into use to replace the Glashacloonaraveela River source. The river source was decommissioned because of contamination resulting from cattle accessing the river close to the intake.

The treatment plant in the pump house comprises a chlorination system (sodium hypochlorite). There is no cryptosporidium filter.

Photo 1: Palisade fence and the padlocked gate

Photo 2: BH-1 and BH-2 Location

Each borehole is in a concrete inspection chamber (c1.2 m by 0.6 m) fitted with a lockable steel lid. The internal concrete block work is not rendered (Photograph 3 and 4). The top of each chamber is 0.40 m above ground level, while the base is 0.80 m below ground level. The steel casing rises 0.40 m above the base of the chamber. Because the boreholes were originally used as test wells they were not grout sealed to the top of bedrock. However the steel casing significantly reduces the risk of pollution from surface based pollution sources.

Photo 3: BH-1 Manhole cover

Photo 4: BH-2 Manhole cover

4 Summary of Well Details

The Farnanefranklin wells (BH-1 (IE_SH_G_213_13_005) and BH-2 no code) were installed in 2002 and provide approximately 30% of the overall scheme. The borehole logs, which were compiled by Mr. David Ball are included in Appendix 2 and the details are summarised in Table 3.1. There is a 250 mm (10 inch) steel casing extending into a clay subsoil layer at c.6 m in each borehole and an inner 150 mm steel casing extending into the top of the bedrock to c.15.15 m in BH-1 and to c.18.2 m in BH-2. The boreholes were completed by inserting 115 mm PVC liner which was randomly slotted in the field prior to insertion in the borehole. The borehole depths are 109 m for BH-1 and 116 m for BH-2.

Water is pumped from the wells to the reservoir. The reservoir has a capacity of 230 m^3 and also stores water from the Glosha and Faileen/Bilboa springs and, when required the Glenstal Group Water Scheme. The wells are pumped for between 8 and 12 hours per day, overlapping part of the time. Pumping is automated and the duration is based on the levels in the reservoir. The pump rate in BH-1 is 4 m^3/h and in BH-2 is 3.4 m^3/h, giving a combined rate of 7.4 m^3/h (c.90 m^3/d).

Table 4-1: Well Details

	BH-1	BH-2
EU Reporting Code	IE_SH_G_213_13_005	No Code
Grid ref. (GPS)	178907 153253	178864 153257
Townland	Farnanefranklin	Farnanefranklin
Source type	Borehole	Borehole
Drilled	2002	2002
Owner	Limerick Co Co	Limerick Co Co
Elevation (Ground Level)	~ 80 m OD	~ 80 m OD
Depth	109	116
Depth of casing	109	116
Diameter	115 mm	115 mm
Depth to rock	15 m	16 m
Static water level	13.90 m bgl[1] (15/06/2010) 11.5 m bgl (14/05/2002)	13.10 m bgl (15/06/2010) 9.8 m bgl (14/05/2002)
Pumping water level	~ 23.7 m / top casing	~ 24.8 m / top casing
Consumption (Co. Co. records)	3.4 m^3/h or 42 m^3/d	4 m^3/h or 48 m^3/d
Pumping test summary: (i) abstraction rate m^3/d	3.4 m^3/h	4 m^3/h
(ii) specific capacity	0.4 m^3/h/m	0.36 m^3/h/m
(iii) transmissivity	15 m^2/d	15 m^2/d

It was not possible to undertake a long duration pump test during this assessment because the wells are in use for a large portion of the day and a test would have resulted in a significant interruption to the water supply. However, it was possible to switch off the pumps in both wells for a period of 140 minutes and to record the recovery in both wells. The testing was undertaken on the 29th September 2010.

Static water level was also recorded in the wells in June after a period when the pumps had been switched off due to a fault for six hours. The static water level recorded was 13.9 m in BH-1 and 14.3 m in BH-2. During the recovery test in September, the water level recovered to within 0.80 m of the June level. Given the lower rainfall levels over the summer months, the level recorded in September is considered to be close

[1] pumps were switched off for 6 hours because of an ESB issue

to, if not the static level in the well. After the recovery test, BH-1 was switched on and the water level was monitored in BH-2 for a period of 30 minutes. The data are included in Appendix 3.

5 Topography, Surface Hydrology and Landuse

The wells are located in the footslope of the Slieve Felim Mountains at approximately 80 m OD. The land slopes from the mountains to the south toward the Bilboa River Valley. The highest point in the sub-catchment is 3.2 km north of the source at 387 m OD. The topographical gradient on the upper slopes of the flanking ridges is steep at approximately 0.15, and decreases significantly to 0.03 in the vicinity of the wells.

The natural drainage density is moderate. Some field drainage works have been undertaken in the lands 200 m and 400 m north of the compound to enhance surface drainage locally. In adjacent lands where no drainage works were undertaken, the land is less well draining and some rush growth was observed. The boreholes are located between two unnamed tributary streams of the Bilboa River. The stream to the west rises as a small spring discharge at an elevation of c.88 m OD, approximately 300 m north of the compound. The stream to the east originates further north at an elevation of approximately 125 m OD.

Glosha Spring is 1.4 km to the northeast of the compound while Faileen/Bilboa Spring is 3 km further to the northeast. Water from these springs is piped under gravity to the reservoir.

The landuse in the immediate surroundings and within the catchment is dominated by agriculture, primarily grassland dairy farming. The closest farm yard to the site is c.900 m north of the site. There are three residential dwellings within 100 m of the wells located along the public roads bordering the site. The dwelling immediately to the north also has a yard in which there are two storage sheds with several trucks parked in the yard.

6 Hydrometeorology

Establishing groundwater source protection zones requires an understanding of general meteorological patterns across the area of interest. Meteorological information was obtained for this study from Met Eireann.

Annual rainfall: 1270 mm. The contoured data map of rainfall in Ireland (Met Éireann website, data averaged from 1961–1990) shows that the source is located between the 1200 mm and 1400 mm average annual rainfall isohyet.

Annual evapotranspiration losses: 525 mm. Potential evapotranspiration (P.E.) is estimated to be 553 mm/yr based on the contoured data map of potential evapotranspiration in Ireland (Met Éireann website, data averaged from 1971–2000) which shows that the source is located between the 550 mm and 560 mm average annual evapotranspiration isohyets. Actual evapotranspiration (A.E.) is then estimated as 95% of P.E., to allow for seasonal soil moisture deficits.

Annual Effective Rainfall: 745 mm. The annual effective rainfall is calculated by subtracting actual evapotranspiration from rainfall. Potential recharge is therefore equivalent to this, or 745 mm/year.

7 Geology

7.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the site. It provides a framework for the assessment of groundwater flow and source protection zones that will follow in later sections.

The desk study data used comprised the following:

- Geology of Tipperary. Bedrock Geology 1: 100,000 Map series, sheet 18, Geological Survey of Ireland (.B. Archer, A.G. Sleeman and D. C. Smith, 1996).
- Forest Inventory and planning system – Integrated Forestry Information System (FIPS-IFS) Soils Parent Material Map, Teagasc (Meehan, 2002).
- Groundwater Vulnerability Map for County Limerick. Digital Map (Tobin Consulting Engineers on behalf of the Geological Survey of Ireland and Limerick County Council, 2010).
- Borehole logs provided by Mr. David Ball, Hydrogeologist.

7.2 Bedrock Geology

The area is underlain by Devonian, pale & red sandstone, grit & claystone from the Keeper Hill Formation (Figure 2). The lower Palaeozoic greywacke, siltstone and grit from the Hollyford Formation is located 900 m to the north of the borehole. The contact between the formations is an unconformity. The Keeper Hill Formation dips gently to the south and is overlain by Dinantian Limestone Shale Formations, approximately 900 m to the south. The geological map does not show faults in the formation in the vicinity of the wells. The closest faults are mapped 3 km to the north-west and south-east.

7.3 Soil and Subsoil Geology

The soil and subsoil are shown on Figures 3 and 4, respectively. According to the EPA and GSI Web Mapping, between 70 m OD and 110 m OD, the soil is classified as Acid Mineral Deep Poorly Drained (AminPD). Land drainage works have been carried out, but rush growth was observed in some fields where no work has been undertaken (Photo 5). In the area higher up in the local catchment i.e above 110 OD, the drainage network density is low and the lands are more freely draining (Photo 6). According to the EPA and GSI Web Mapping, the soil in this area is classified as Acid Mineral Deep Well Drained (AminDW).

From the lower slopes (~140 m OD) to the footslopes (~70 m OD) of the mountains, south of the well compound, the bedrock is overlain by glacially deposited sandstone sands and gravels derived from the Devonian Old Red Sandstone (GDSs). Recent drilling in this area as part of the Limerick Vulnerability Mapping Project, undertaken by Tobin Consulting Engineers (Tobins) on behalf of the GSI (2010), identified these deposits as moderately permeable. The borehole logs for the abstraction wells indicate that the subsoil comprises sand and silts and interbedded gravels and clay.

To the north, between 140 m OD and 300 m OD, the subsoil comprises sandstone tills which are derived from lower Paleozoic Rocks (TLPsS) which underlie this area. Tobins have characterized these subsoils as low permeability.

Photo 5: Poorly drained land below 110 m OD

Photo 6: Well drained land above 110 m OD

7.4 Depth to Bedrock

The borehole logs for BH-1 and BH-2 indicate a depth to bedrock of between 16 and 17 m bgl. The boreholes are at an elevation of c.80 m OD. The GSI 2010 vulnerability mapping programme indicates that between 70 m OD and 90 m OD there is >10 m of subsoil, which is consistent with the borehole log data. Further north in the local catchment between 90 m OD and 110 m OD, the depth to bedrock is between 5 and 10 m. Between 110 m OD and 180 m OD the depth to bedrock is between 3 and 5 m. Above 300 m OD, there is rock outcrop (Rck).

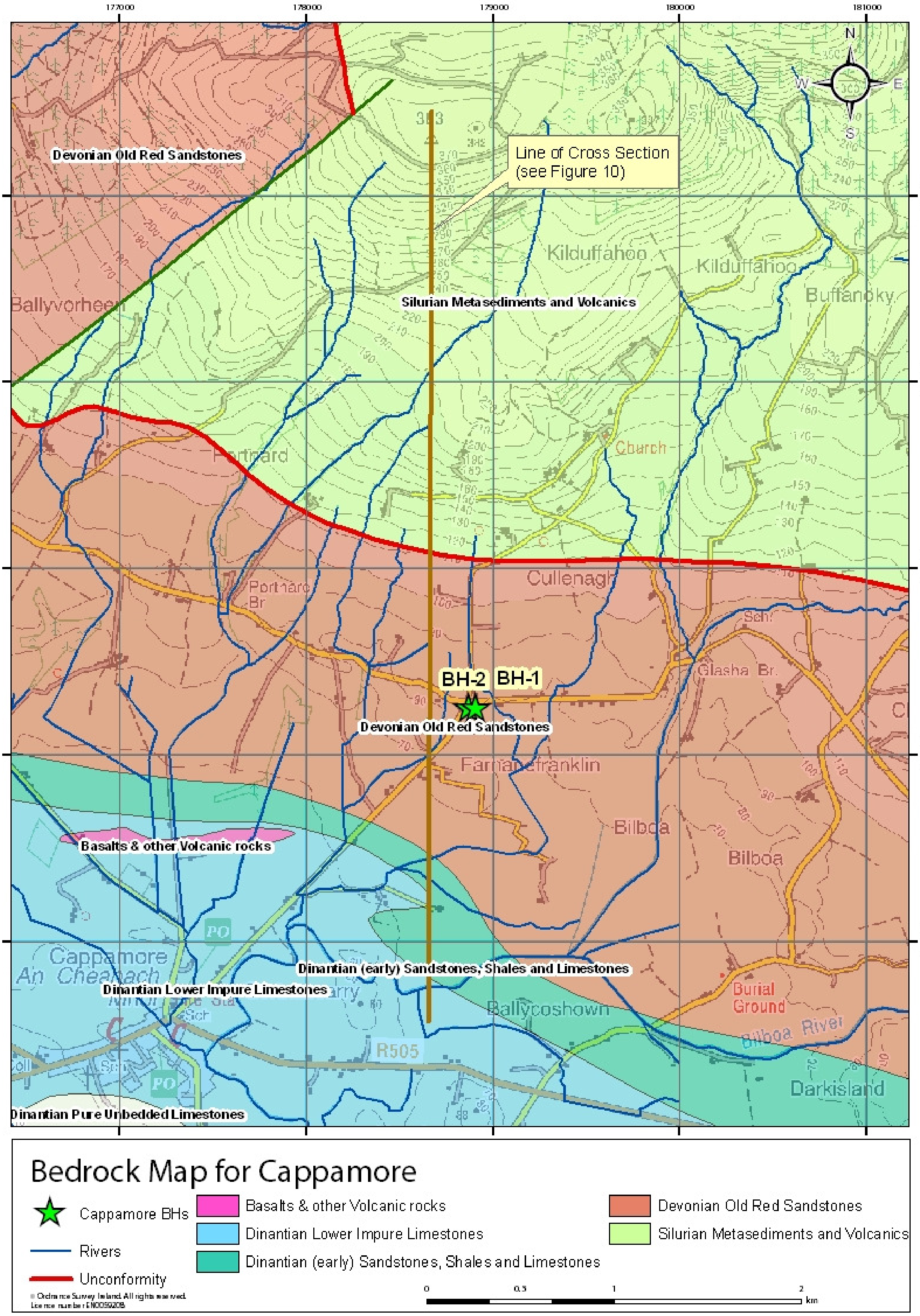

Figure 2: Bedrock/Rock Unit Map

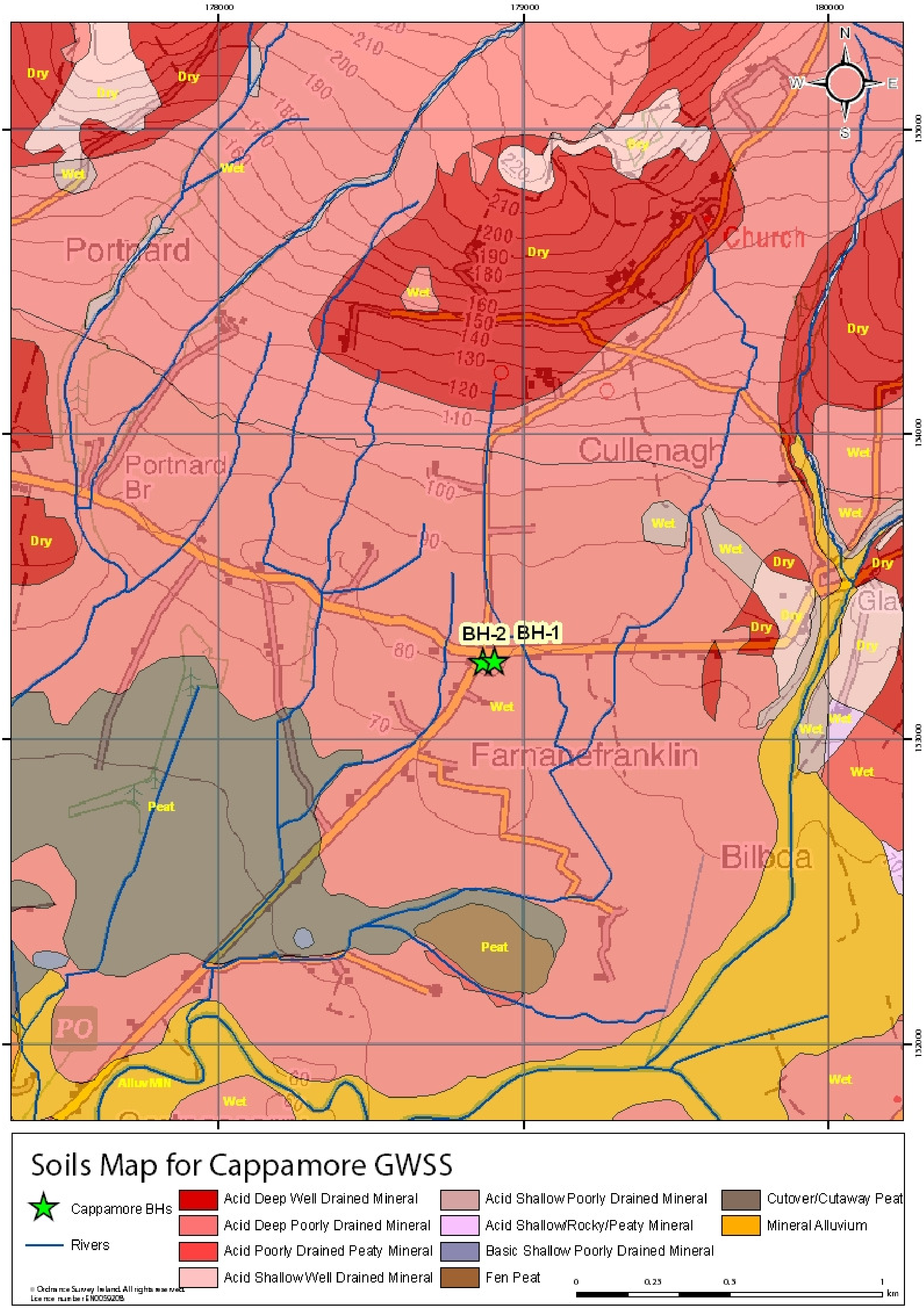

Figure 3: Soils Map

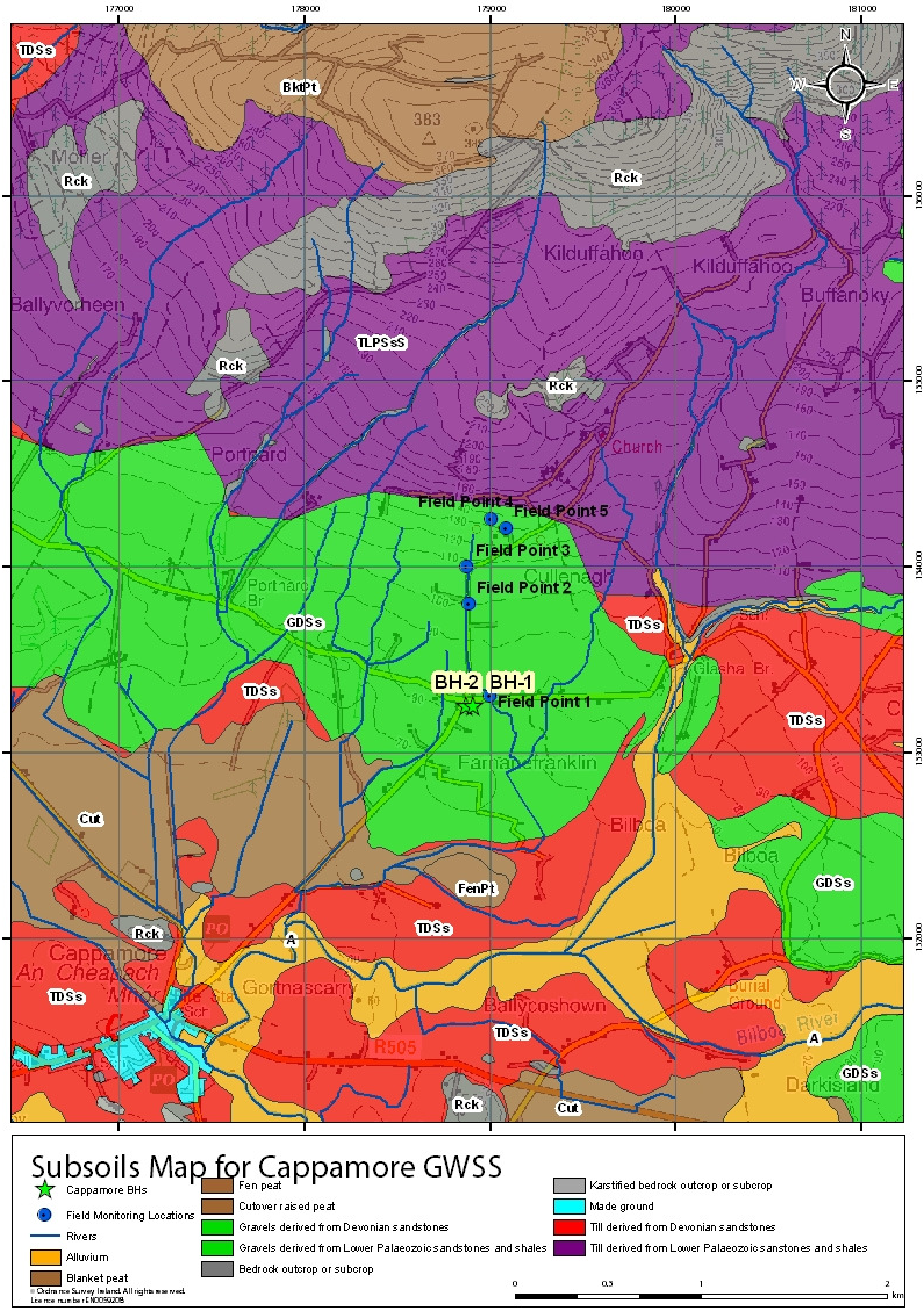

Figure 4: Subsoils Map

8 Groundwater Vulnerability

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. This means that in this area the vulnerability relates to the permeability and thickness of the subsoil. 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 vulnerability map for the area is shown in Figure 5. The lands in the vicinity of the compound and between 70 and 190 m OD are characterised as High vulnerability i.e. >3 and <5m subsoil thickness. However, this is not consistent with the borehole logs for BH-1 and BH-2, which indicate that the subsoil thickness is between 16 and 17 m. Based on the borehole log data for the wells the vulnerability in the vicinity of the well compound is considered to be moderate. Above 190 m OD, to the north of the compound, the vulnerability is Extreme. The depth to bedrock data for the boreholes obtained during this study has been forwarded to the GSI Consultants (Tobins) compiling the updated vulnerability map for this area. It is anticipated that the vulnerability map will be updated to reflect this new data in 2011.

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 Database.
- County Council Staff.
- EPA website and Groundwater Monitoring database.
- Local Authority Drinking Water returns
- Borehole drilling data provided by Mr. David Ball
- GSI Source Report Faileen Bilboa source 1995

9.1 Groundwater Body and Status

The Cappamore boreholes are located within the Slieve Phelim Groundwater Body (IE_SH_G_213) which has been classified as being of Good Status. The groundwater body descriptions are available from the GSI website: www.gsi.ie and the 'status' is obtained from the Water Framework Directive website: www.wfdireland.ie/maps.html. At the time of the writing, the Ground Water Body description has not been completed.

9.2 Groundwater Levels, Flow Directions and Gradients

Static groundwater level data is summarised Faileen Bilboa source in 1995 in Table 9–1.

Table 9-1: Static Groundwater Levels in the Wells

Date	BH-1	BH-2
May 2002[2]	11.5 m bgl	9.8 m bgl
June 2010[3]	13.9 m bgl	13.1 m bgl
September 2010[4]	14.70 m bgl	13.75 m bgl

[2] After exploration drilling in May 2002 (Appendix 1)
[3] pumps were switched off because of an ESB issue
[4] After 2h30min recovery test

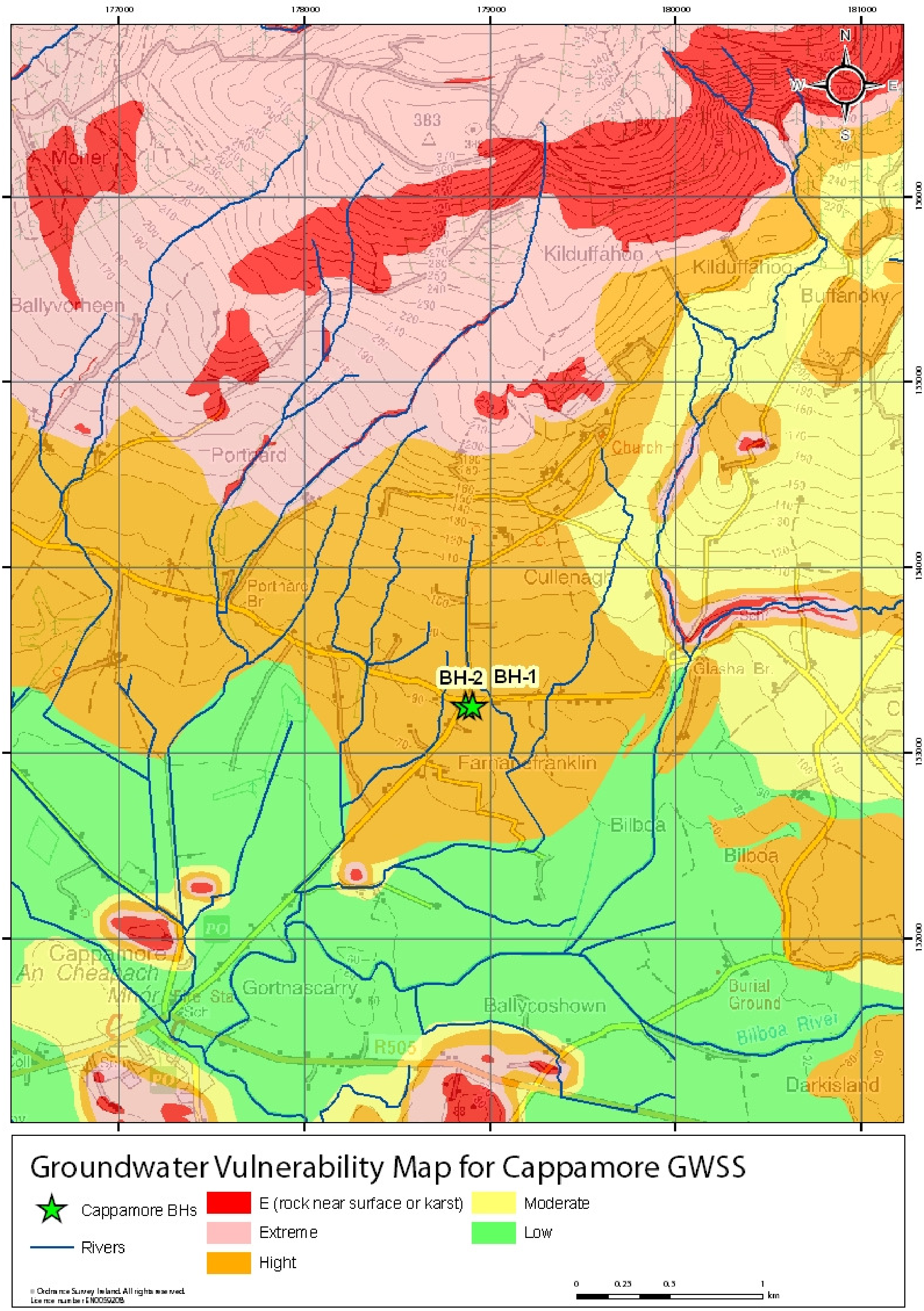

Figure 5: Vulnerability Map

There is one well located 900 m to the north in a farmyard. The location is shown in Figure 4. It was not possible to monitor the water levels as the well cap has been sealed and could not be accessed during the 2010 field mapping. The pH and electrical conductivity was monitored for the well using a sample tap in the farmyard. This is discussed in Section 9.3.

Based on the local topography, the direction of groundwater flow is expected to be from north to south toward the Bilboa River. Given that the Old Red Sandstones are not very permeable, the groundwater gradient is likely to reflect the topography, which is approximately 0.03 in the vicinity of the wells and 0.15 in the higher ground to the north. An average value of 0.06 has been assumed for the entire catchment.

9.3 Hydrochemistry and Water Quality

The well has been included in the EPA operational chemical network since 2007. There is a pre-treatment sample point, which is a tap, located in each borehole inside the concrete inspection chamber, but only BH-2 is sampled. The laboratory results have been compared to the EU Drinking Water Council Directive 98/83/EC Maximum Admissible Concentrations (MAC) and where relevant, mean values have been compared to the European Communities Environmental Objectives (Groundwater) Regulations 2010, recently adopted in Ireland under (S.I. No. 9/2010) as part of the implementation of the Water Framework Directive 2000 in Ireland. The EPA data are graphed in Figures 6 to 8 and are summarised below.

- The water has a hard, calcium bicarbonate hydrochemical signature (average 253 mg/l $CaCO_3$). The average conductivity is 547 µS/cm and it ranges from 496 µS/cm to 848 µS/cm. The average pH is 7.2 while the range is 6.3-8.0. .
- Faecal Coliforms have only been detected on one occasion in 2008. Ammonium is generally very low with a mean well below the Threshold Value (0.175 mg/l).

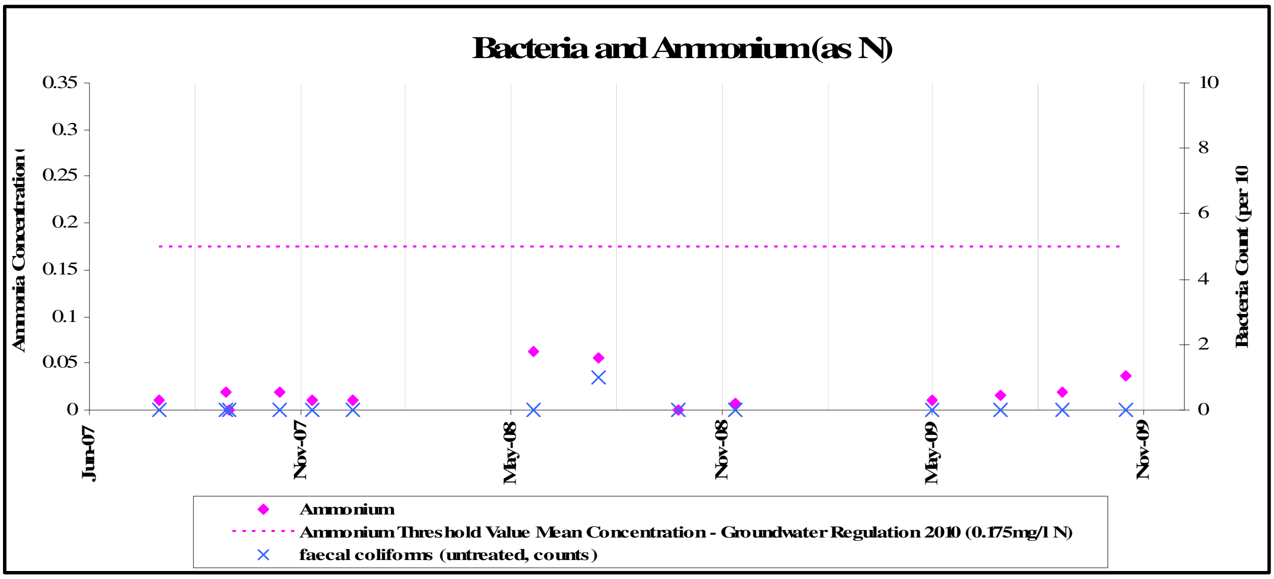

Figure 6: Key Indicators of Agricultural and Domestic Contamination: Bacteria and Ammonium Graph

- The nitrate concentration ranges from 3 to 16.3 mg/l, with a mean of 6.8 mg/l (as NO_3). There are no exceedances above the EU MAC, or the Threshold Value of 37.5 mg/l.
- Chloride is a constituent of organic wastes, sewage discharge and artificial fertilisers, and concentrations higher than 24 mg/l (Groundwater Threshold Value, 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 11.9 mg/l to 25 mg/l, with a mean of 16.9 mg/l which is less than the Threshold Value.

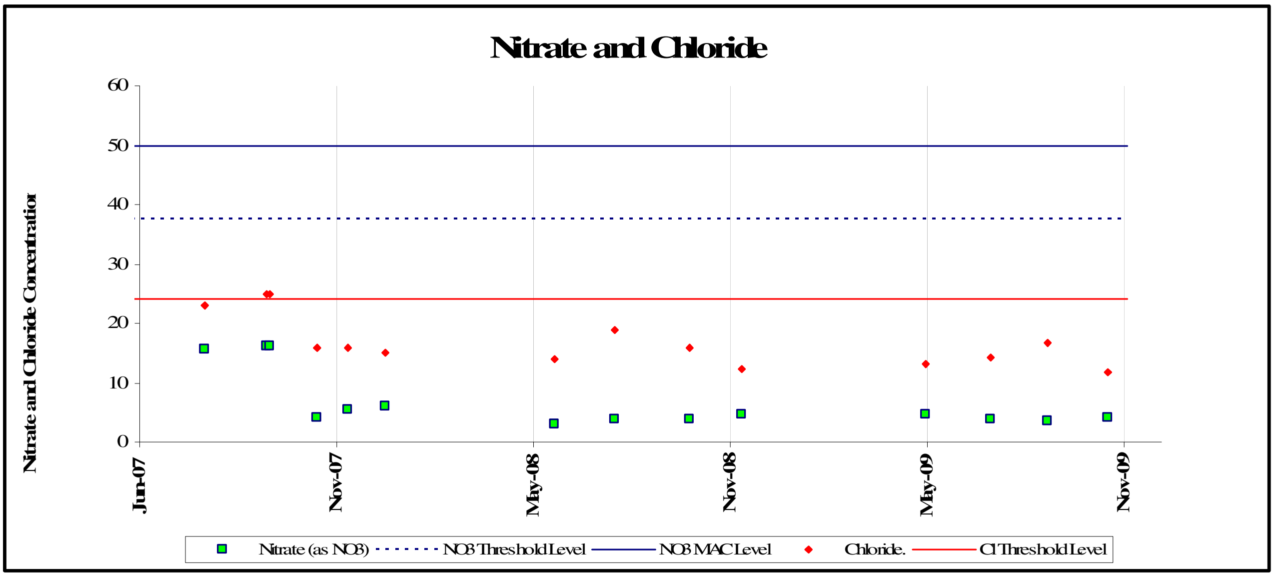

Figure 7: Key Indicators of Agricultural and Domestic Contamination: Nitrate and Chloride Graph

- The turbidity was above the drinking water standart limit of 1 NTU on four occasions. The levels recorded were 11.5, 9.6, 5.0 and 5.7 NTU on 11/12/2007, 18/6/2008, 22/10/2008 and 9/12/2008 respectively. This is likely due to the presence of very fine clay particles within the water, as noted on the borehole logs.

- The sulphate, potassium, sodium, magnesium and calcium levels are within normal ranges. The potassium:sodium ratio was above the threshold of 0.35, on five occasions.

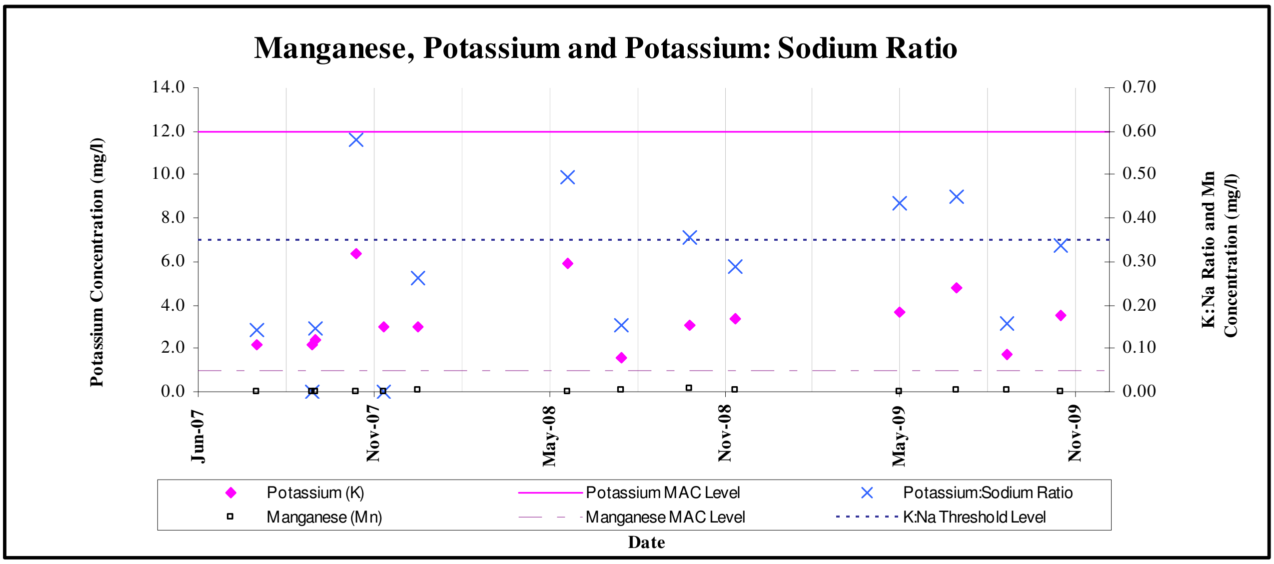

Figure 8: Key Indicators of Agricultural and Domestic Contamination: Manganese, Potassium and K/Na ratio

The concentration of iron and manganese is also within normal ranges. Other trace metals were within either within the normal range for good quality drinking water or were not detected. Similarly organic compounds and herbicides have not been detected

In summary, given the low levels of the key indicators of domestic and agricultural contamination, the water quality at the source is generally very good, which is likely to be a function of the presence of 16–17 m of subsoil in the vicinity of the wells and the low to moderate vulnerability of the subsoils within the local catchment. In addition, pressures from agricultural activities are low.

Monitoring of pH and electrical conductivity was carried out on the 22/07/2010 in the stream situated to the east of the wells, and at a spring and a borehole located in a farmyard 900 m to the north of the site. The results are presented in Table 8-2 and the stream, spring and well locations are shown on Figure 4. The data were compared with the results of monitoring at the abstraction wells during the same site visit.

The pH and electrical conductivity in the stream are lower than those in the abstraction wells and the spring. This indicates that the groundwater sources (spring and the abstraction wells) have limited or possibly no connection with the surface water system locally.

Table 9-2: Groundwater and Surface Water Quality (22/07/2010)

	BH1	**BH2**	**Stream**			**Borehole**	**Spring**
Location	**On site**		**Point 1**	**Point 2**	**Point 3**	**Point 4**	**Point 5**
	(from EPA Monitoring)		(from field monitoring)				
pH	Ave 7.2 Range: 6.3-8		6.50	6.65	6.15	6.77	6.90
Conductivity (µS/cm)	Ave 547 Range: 396-848		190	200	230	377	340

9.4 Aquifer characteristics

The boreholes abstract water from the Keeper Hill Formation (pale & red sandstone, grit & claystone) from the Devonian Old Red Sandstones. The aquifer is classified as a *Locally Important aquifer which is moderately productive only in Local Zones (Ll*), as shown on Figure 9. The static water level in the two wells is c.10 m, below ground level, indicating a deep water table in the aquifer locally.

Groundwater flow in the aquifer is through fractures, fissures and faults in the sandstones and siltstones. In general in Ll aquifers, the groundwater flow is concentrated in the upper 15 m, although deeper inflows along fault zones or connected fractures can be encountered. It appears from the data in the borehole logs that water strikes were encountered at depths of approximately 30–38 m, 71 m, 82 m and 97 m below ground level.

The groundwater yields of 41–48 m^3/d are typical of the range expected for Ll aquifers. Groundwater flow paths are likely to be relatively short, typically from 30 to 300 m, with groundwater discharging to the surface water courses that traverse the aquifer. There are several springs to the north of the site which discharge to the local surface water streams forming some of the headwaters of the Bilboa River.

A transmissivity of around 15 m^2/d was calculated based on the recovery test carried out in September 2010. The tranmissivity calculation is based on using the full log cycle in the time drawdown graph for the later part of the recovery test which is considered to be more representative than the initial recovery response period. This value falls within the expected range expected for Ll aquifers which is typically between 2–20m^2/d with median values towards the lower end of the range. Given the drawdown is <30% of the thickness of the aquifer, the CE Jacob Formula can be applied for unconfined condition:

$$\text{Transmissivity (T)} = 0.183Q / \Delta s$$

Where Q=discharge and ΔS= change in the drawdown over 1 log cycle.

The water level was monitored in BH-2 for 30 minutes while BH-1 was pumping at normal abstraction rate (3.4 m^3/h). The data indicates limited interference between the two wells, with a 20 cm drawdown. While monitoring over a much longer period would be required to determine the full interference, the data are consistent with the calculated transmissivity value.

The permeability for the aquifer is estimated at 0.17 m/d, and was calculated by dividing the transmissivity by the assumed saturated thickness of the aquifer. The saturated thickness of the aquifer is estimated from the standing water level to the depth of the deepest water strike, at 97 m bgl encountered in the two abstraction wells installed in 2002 i.e. 87 m. Therefore the bulk permeability (K) is estimated as follows:

Table 9-3 : Permeability Range for BH1 and BH2

	Local Assumption
Transmissivity (m^2/d)	15
Permeability (m/d)	0.17

The velocity of water moving through this aquifer to the boreholes has been estimated from Darcy's Law:

$$\text{Velocity (V)} = (\text{K x Groundwater Gradient(i)}) / \text{porosity}$$

The natural gradient is estimated at 0.06 (described in section 9.2). The typical effective porosity (n) range for Old Red Sandstones in Ireland, based on previous source protection zone reports, is 1–5%, with an average of 2%.

The velocity is estimated at 0.52 m/d.

The aquifer parameters are summarized in Table 9-4

Table 9-4: Indicative Parameters for the Keeper Hill Formation Aquifer in Cappamore

Parameters	**Source of Data**	**BH1/BH2**
Transmissivity (m^2/d)	Calculated using Recovery Test Data 2010	15
Permeability (m/d)	estimated from T value assuming the deepest water strike encountered in the two abstraction wells installed	0.17
Effective Porosity	Based on values applied elsewhere by GSI for this aquifer type	2%
Groundwater gradient	Assumed based on topography	0.06
Velocity (m/d)	calculated based on above	0.52

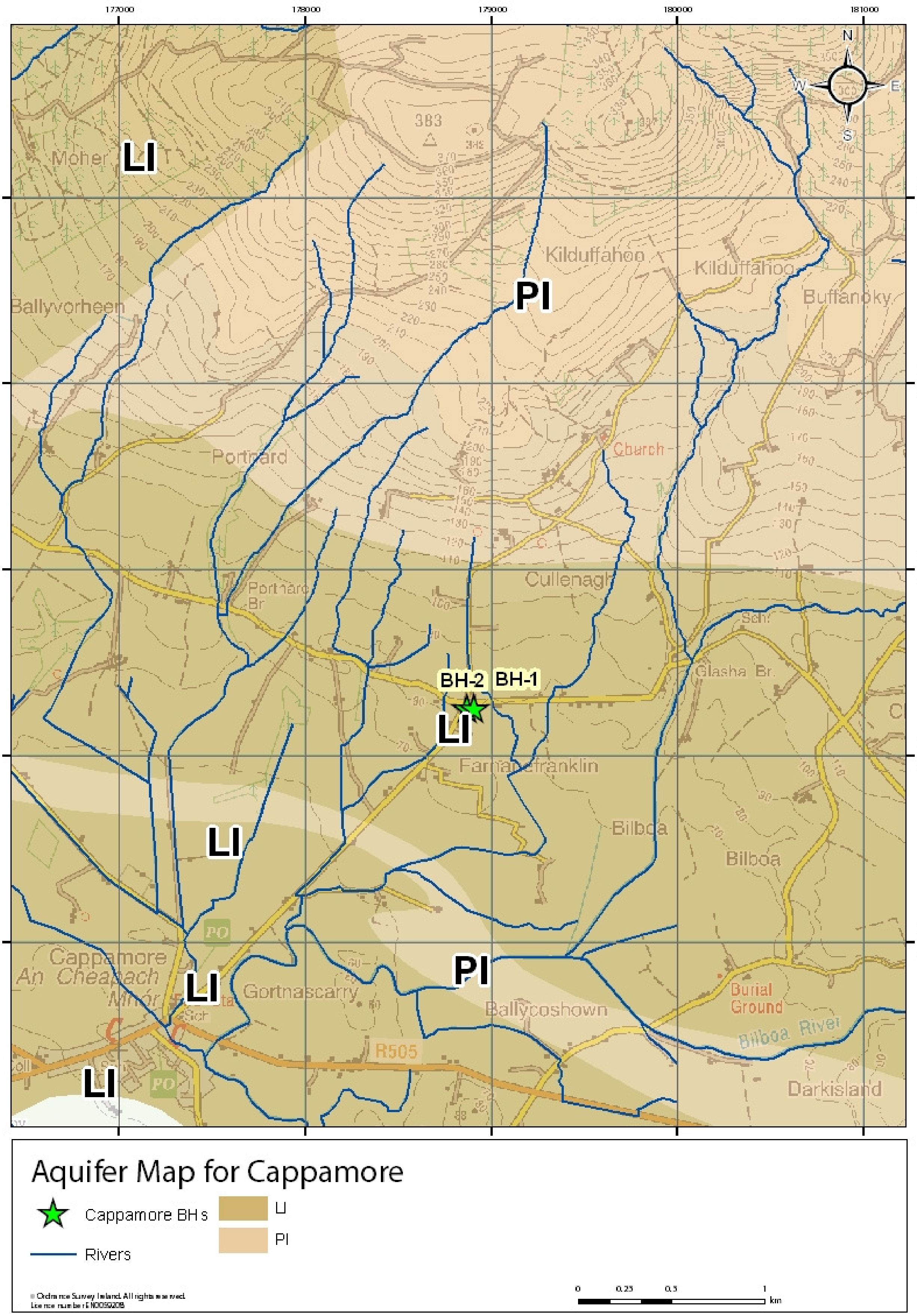

Figure 9: Aquifer Map

10 Zone of Contribution

The Zone of Contribution (ZOC) is the complete hydrologic catchment area to the source, or the area required to support an abstraction from long-term recharge. The size and shape of the ZOC is controlled primarily by (a) the total discharge, (b) the groundwater flow direction and gradient, (c) the subsoil and rock permeability and (d) the recharge in the area. This section describes the conceptual model of how groundwater flows to the source, including uncertainties and limitations in the boundaries, and the recharge and water balance calculations which support the hydrogeological mapping techniques used to delineate the ZOC.

10.1 Conceptual model

Within the catchment, groundwater flows from the high ground in the Slieve Felim Mountains in the north, to the south toward the wells and beyond, toward the River Bilboa. Groundwater flow paths are expected to be relatively short, typically from 30 to 300 m in this Ll aquifer, with groundwater discharging either to local tributary streams of the Biboa River or the river itself.

The water table is deep below the surface at c.10 m. The bedrock aquifer is overlain by up to 17 m of subsoils comprising sand, silt clay and gravel. The location of the water strikes suggests that the groundwater inflow to the well occurs between 30 and 97 m below ground level, which is deep for this type of aquifer where generally flow is concentrated in the upper 15 m. Given the relatively low abstraction rates, the permeability of individual fractures, particularly at depth, and the degree of interconnection, is expected to be low with fracturing confined to local zones.

Rainfall recharge occurs readily through the thin subsoil and exposed rock area of the catchment above 180 m OD. Below 180 m OD, the subsoil comprises sandstone sand and gravels with silt and clay, and ranges in thickness from 5 m to approximately 17 m close to the boreholes. In this area the recharge is likely to be lower and run-off to the streams higher. The protection offered by the thick subsoil cover is reflected in the good water quality in the boreholes. Some discharge of shallow groundwater occurs to the streams within the catchement.

A schematic of the conceptual model is shown in Figure 10.

10.2 Boundaries of the ZOC

The boundaries of the area contributing to the source are considered to be as follows (Figure 11):

The northern, eastern and western boundaries are primarily based on the topography, conceptualised groundwater flow-lines, which flow to the southwest in the direction of the Bilboa River, and the size of the estimated ZOC using the recharge and water balance equations (see next section).

The southern boundary – **the downgradient boundary** is the maximum downgradient distance that the boreholes can pump water from and is based on the uniform flow equation (Todd, 1980).

$x_L = Q / (2\pi * T * i)$

where Q is the daily pumping rate +/- X%
T is Transmissivity (taken from aquifer characteristics)
i is gradient.

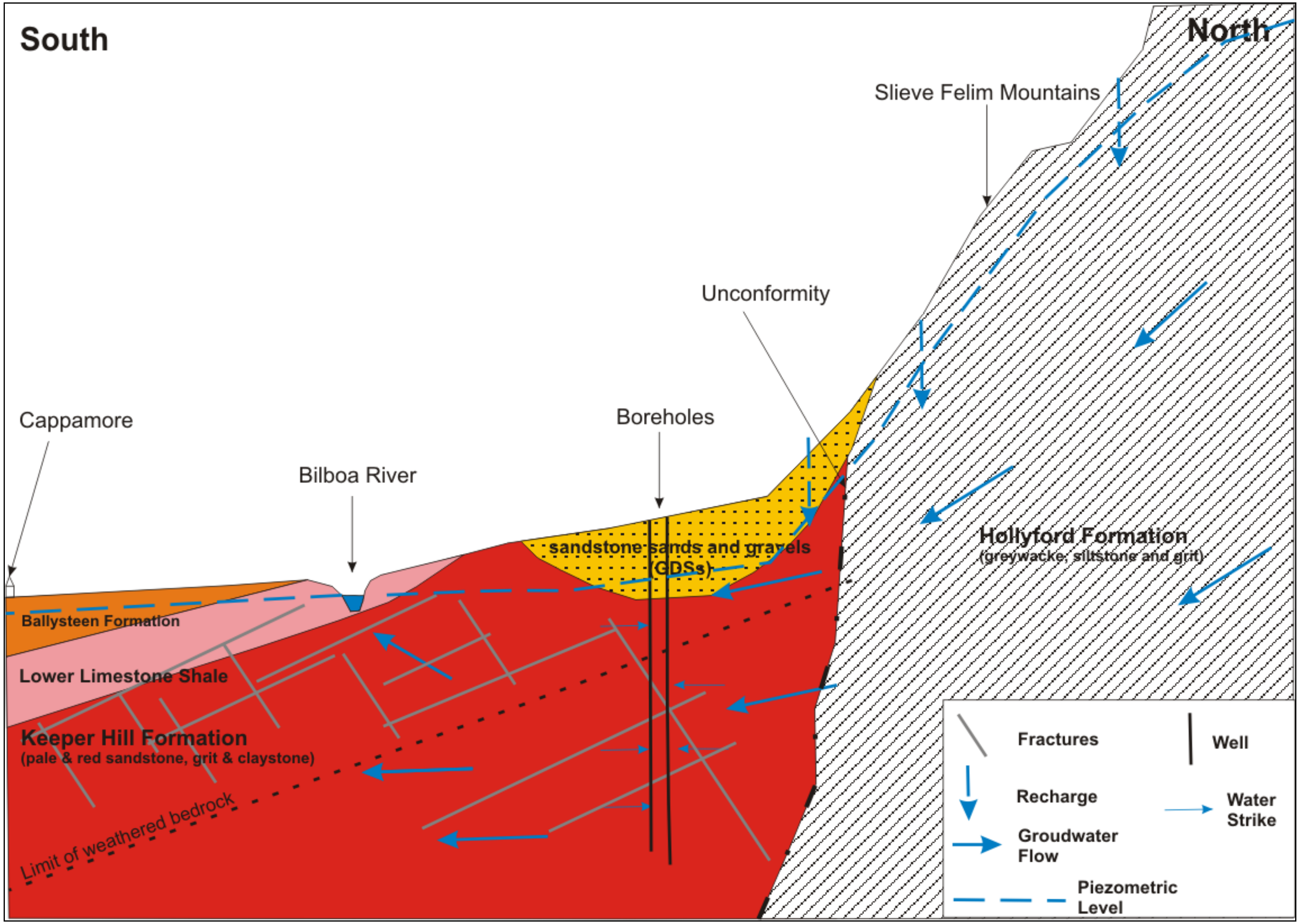

Figure 10 Conceptual Model

The combined pumping rate for BH-1 and BH-2 is. 90 m^3d. Using the data from the pumping test, the transmissivity is calculated at 15 m^2/d and the hydraulic gradient is 0.06 giving an approximate downgradient distance for each borehole is 16 m.

In general, the down-gradient distance for a LI aquifer is estimated to be around 60 m (approximate downgradient distance estimated by GSI for ZOC delineation). To be conservative in the source protection assessment process a 60 m down-gradient limit was applied for the ZOC for each borehole at the site.

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 assumed to consist of input (*i.e*. annual rainfall) less 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 it will dictate the size of the zone of contribution to the source (*i.e*. the outer Source Protection Area).

At Cappamore therefore, the main parameters involved in recharge rate estimation are: annual rainfall; annual evapotranspiration and a recharge coefficient. The recharge is estimated as follows.

Potential recharge is equivalent to 745 mm/year i.e. (Annual Effective Rainfall as outlined in Section 6).

Recharge Cap: A *200 mm/*yr recharge cap has been applied for the Locally Important (LI) aquifer (Keeper Hill Formation closer to the source) and 100 mm for the Poorly Productive (PI) aquifer Hollyford Formation in the high ground to the north) in accordance with Guidance Document No. GW5, 2005 .

Although a thick interbedded sand, silt, clay and gravel unit overlies the aquifer in the vicinity of the wells, the recharge cap of 200 mm is considered to be appropriate here given the drainage density and the abstraction from the bedrock formation. Much of the shallow recharge is expected to discharge to the surface water drainage system via the sand, silt and gravel subsoil. The bulk ***recharge coefficient*** for the area is therefore estimated to be 26%.

Runoff losses: *545* mm. Runoff losses are assumed to be 74% of potential recharge. This value is based on subtracting the recharge cap amount from the potential recharge.

These calculations are summarised as follows:

Average annual rainfall (R)	1270 mm
Estimated P.E.	525 mm
Estimated A.E. (95% of P.E.)	499 mm
Effective rainfall	745 mm
Potential recharge	745 mm
Recharge cap (LI)	200 mm
Recharge Cap (PI)	100 mm
Run off losses	592 mm
Runoff losses	80%
Bulk recharge coefficient	20%
Assumed Recharge	153 mm

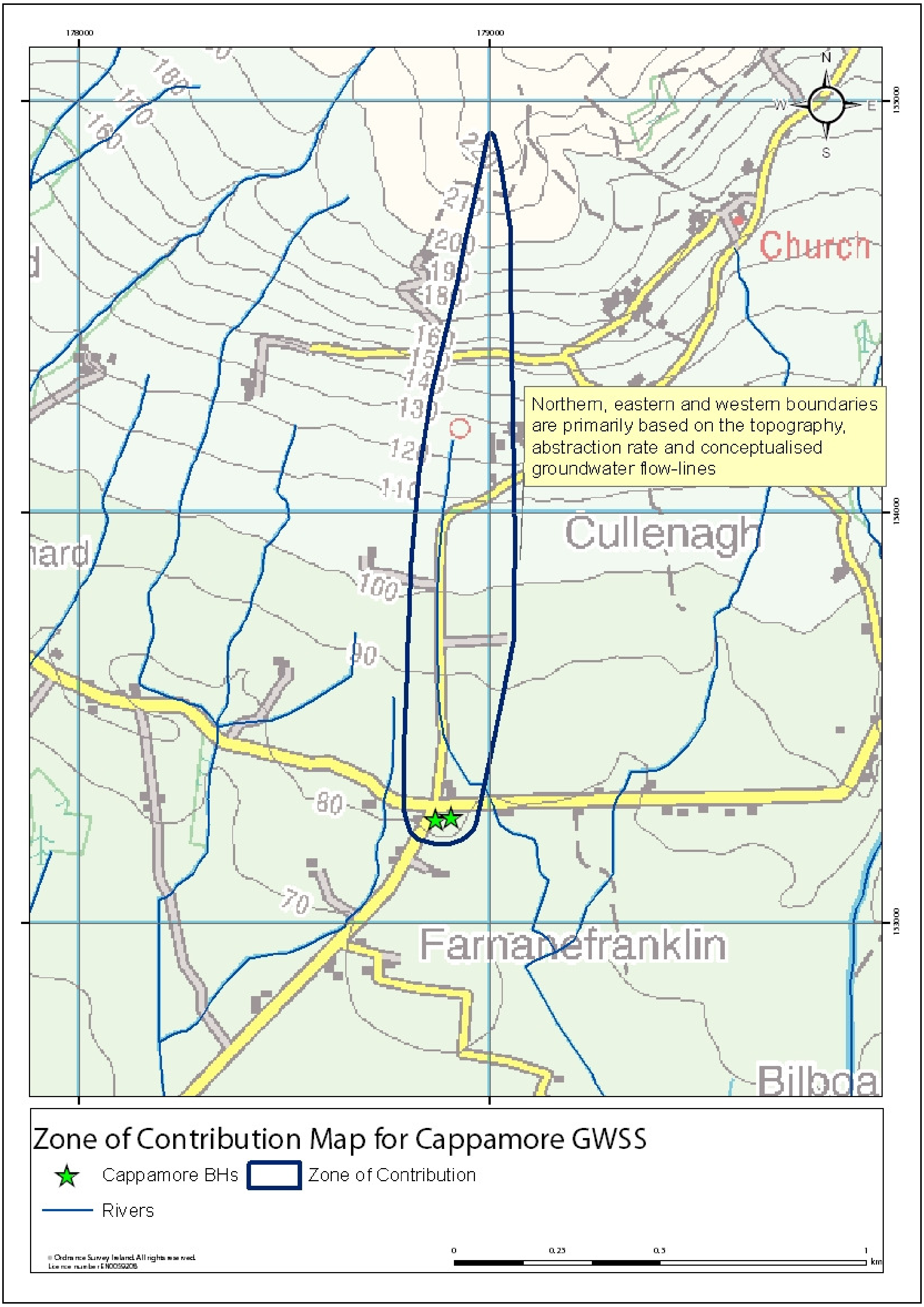

Figure 11: Zone of Contribution

The water balance calculation states that the recharge over the area contributing to the source, should equal the discharge at the source. At a recharge of 153 mm/yr, the discharge of 90 m^3/day would require a recharge area of 0.21 km^2.

The ZOC described above is 0.32 km2 and is based on topography and the current understanding of the hydrogeology and the direction of groundwater flow. The larger ZOC area delineated is primarily based on the topography, conceptualised groundwater flow-lines while also considering the recharge and water balance equations. It is likely that there is some discharge of groundwater to the stream running through the ZOC. During the field mapping the flow in this stream was negligible but flow is expected during the winter period. The mapped ZOC which is larger than that required to support the abstraction should account for losses to the stream. However, to more accurate determine this, stream flow measurements during the winter period would be required. To allow for daily variations in abstraction, a possible increase in demand, and for the expansion of the ZOC during dry weather periods, the GSI recommends increasing the abstraction rate by 50% for the purposes of delineating the ZOC. However in this case the ZOC area delineated as already 52 % greater than that required to support the abstraction and increasing the size of the ZOC is not required.

The boundaries of ZOC are shown in Figure 11.

11 Source Protection Zones

The Source Protection Zones 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 areas and the aquifer vulnerability. The source protection areas represent the horizontal groundwater pathway to the source, while the vulnerability reflects the vertical pathway. Two source protection areas have been delineated, the Inner Protection Area and the Outer Protection Area.

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). Based on the indicative aquifer parameters presented in section 9.4, the groundwater velocity is 0.52 m/d, and hence the 100-day time of travel distance is 52 m. The Inner Protection Area is illustrated in Figure 12.

The Outer Protection Area (SO) encompasses the entire zone of contribution to the source. The GSI recommends increasing the abstraction rate by 50% for the purposes of delineating the ZOC. However in this case the ZOC area delineated as already 52 % greater than that required to support the abstraction and increasing the size of the ZOC is not required.

The groundwater Source Protection Zones are shown in Figure 13, are listed in Table 11-1 and are based on an overlay of the source protection areas on the groundwater vulnerability. Therefore the groundwater protection zones are SI/H and SO/H with SO/E and SO/X in the higher areas of the catchment where the subsoil is thin or absent.

Table 11-1 Source Protection Zones (%area, km^2)

Source Protection Zone		**% of total area (km^2)**
SI/H	Inner Source Protection area / High vulnerability*	3.9% (0.012 km2)
SO/X	Outer Source Protection area / ≤1 m subsoil	1.4% (0.004 km2)
SO/E	Outer Source Protection area / <3 m subsoil	5.7% (0.018 km2)
SO/H	Outer Source Protection area / High vulnerability*	89.0% (0.28 km2)

* However, based on the borehole log data for the wells the vulnerability in the vicinity of the well compound is considered to be moderate. It is anticipated that the vulnerability map will be updated to reflect this new data in 2011 (see Section 8).

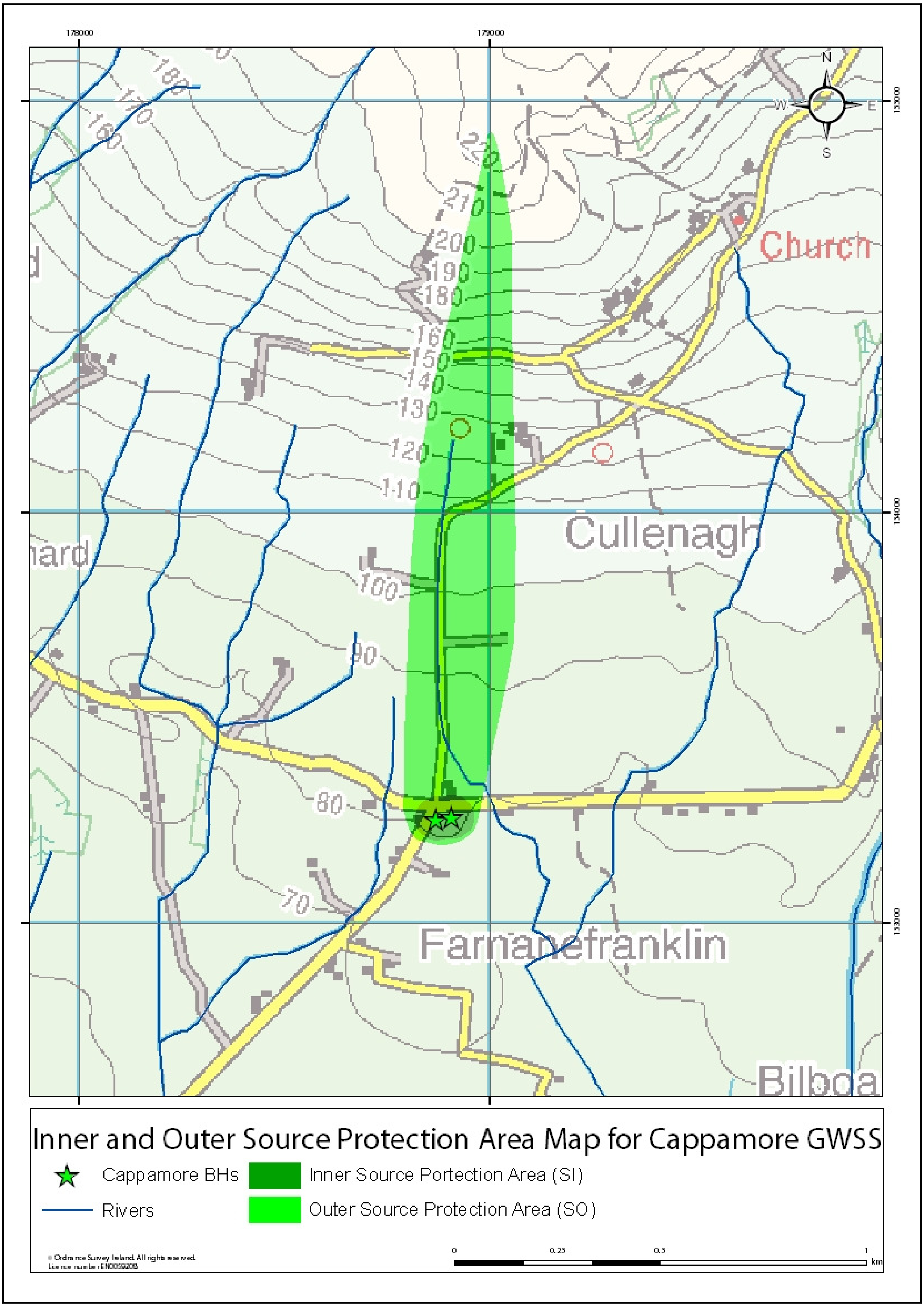

Figure 12: Inner and Outer Source Protection Areas

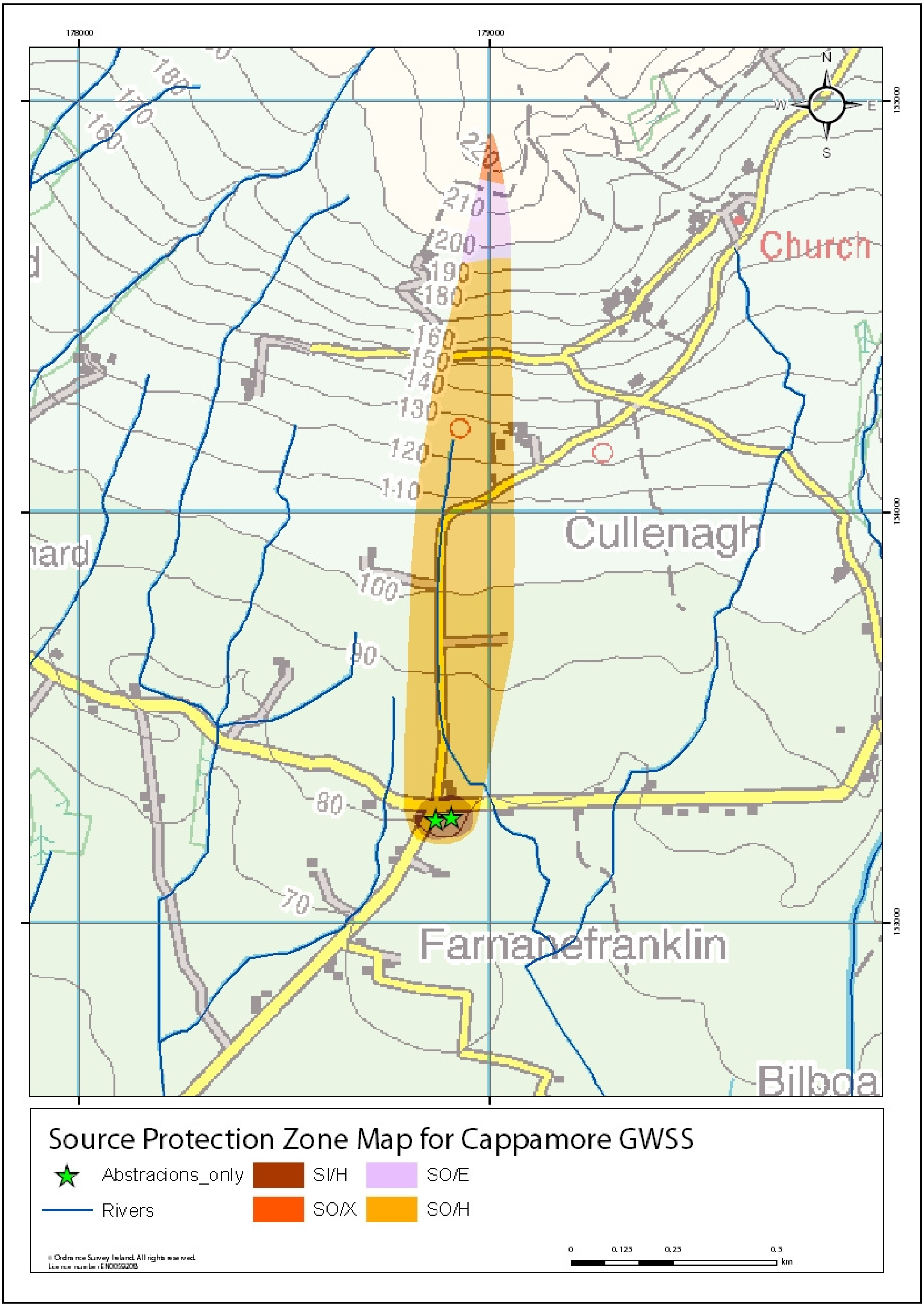

Figure 13: Source Protection Zones

12 Potential Pollution Sources

The two boreholes are located in a securely fenced and locked compound and the ground surface comprises granular fill and grass covered landscaped areas. The ground surface rises up from the public road and the potential risk for contamination as a result of surface spills in the immediate vicinity of the well heads is therefore negligible. Both boreholes are in concrete chambers (c1.2 m by 0.6 m) with steel covers. The top of the chamber is set 0.40 m above the ground level. The boreholes do not have grout seals between the ground surface and the top of bedrock. Nonetheless, given the relatively high level of wellhead protection and the location of the borehole, the potential risk for contamination as a result of surface spills in the immediate vicinity of the well heads is very low.

The Inner Source Protection Area comprises primarily the area of the well compound and the lands occupied by the dwelling to the west along the public road and a the dwelling, storage yard to the north. A small area to the northwest, east and south of the well compound is pastureland for grazing animals. The main potential microbial pollution sources are considered to be the presence of this pastureland for grazing animals. Faecal coliforms have been detected only once on 2008 and at a low level. Given the location and the Moderate vulnerability within the Inner Source Protection Area, the potential risk from cryptosporidium and viruses is low.

The majority of land within the Outer Source Protection Area is agricultural grassland and the dominant farm activity is dairy farming. There is one farm within the ZOC located 1 km to the north. The main potential pollution sources associated with farming activities are animal slurry storage areas, farmyard washings, grazing animals and landspreading of agricultural waste. The possible impacts to the water quality of the public supply associated with these activities within its Outer Source Protection Area are elevated levels of ammonia, nitrate, phosphate, chloride, potassium, BOD, COD, TOC and pesticides. The water quality at the source is generally good. During the field investigations, OCM observed that the farmyard located in Outer Source Protection Area was paved with concrete and surface water run-off was collected in an underground tank. The slurry storage area appears to be well managed.

In summary, given the land use, the moderate vulnerability rating within the SI and the good quality of the water levels, the risk posed by cryptosporidium in the wells is low.

13 Conclusions

The public water supply at Cappamore comprises two boreholes (BH-1 and BH-2), situated approximately 40 m apart. The boreholes abstract water from the Keeper Hill Sandstone/Siltstone Formation. The aquifer is classified as a Locally Important Aquifer that is Moderately Productive only in Local Zones (LI). The wells provide c.90 m^3/d (42 m^3/d for BH-1 and 48 m^3/d for BH-2). Water quality from the wells is generally good.

The wells provide approximately 30% of the overall Cappamore Pubic Water Scheme requirements. The scheme is also supplied by two springs located at Glosha and Faileen/Bilboa which located 1.4 km and 4 km to the northeast respectively of the boreholes. Back-up is provided by the Glenstal Group Water Scheme (borehole).

The ZOC to the source has been delineated for both wells and is estimated as 0.32 km^2 which incorporates a 50% increase in the pumping rate as recommended by the GSI. The groundwater vulnerability with the ZOC ranges from moderate to low. Water quality in both boreholes is good.

The inner and outer source protection zones delineated in the report are based on our current understanding of the groundwater conditions and the available data. Additional data obtained in the future may indicate that amendments to the boundaries are necessary.

14 Recommendations

The pumping rate should not be increased without undertaking a comprehensive pumping test to determine if such increases are sustainable.

15 References

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APPENDIX 1

Source Protection Report for Faileen Bilboa
by the GSI in 1995

CAPPAMORE FAILEEN/BILBOA
PUBLIC SUPPLY

GROUNDWATER SOURCE PROTECTION ZONES

(DRAFT)

Jenny Deakin
Groundwater Section
Geological Survey of Ireland

December 1995

CAPPAMORE FAILEEN/BILBOA
PUBLIC SUPPLY

1. SUMMARY OF WELL DETAILS

GSI no.	:	1715SWW034
Grid ref.	:	18172, 15677
Owner	:	Limerick Co. Co.
Well type	:	Spring
Elevation	:	~260 m OD (Poolbeg)
Depth	:	3 m
Depth-to-rock	:	≥ 3 m
Static water level	:	~1 m b.g.l.
Abstraction rate	:	336 m^3/d (~74,000 gal/d)
Average overflow	:	205 m^3/d (~45,000 gal/d)
Total average spring output	:	~540 m^3/d

2. METHODOLOGY

There were three stages involved in assessing the area, a detailed desk study, site visits and fieldwork, and analysis of the data. The desk study was conducted in the Geological Survey where the subsoil and bedrock geologies were compiled from the original 6" field sheets. Basic public supply well details were recorded by County Council personnel in the form of a questionnaire which included a precise location and any relevant spring flow, water chemistry and construction data available.

The second stage comprised site visits and fieldwork in the surrounding area. Walk-over surveys of the surface water catchment area were carried out which enabled an assessment of the bedrock geology, subsoils, hydrogeology and vulnerability to contamination. Three raw water samples were taken for full suites of chemical and bacterial analyses, in September 1993, April 1994 and March 1995.

Stage three, the analytical stage, utilised water balance equations and hydrogeological mapping to delineate the catchment area and hence identify the groundwater protection zones.

3. WELL LOCATION AND SITE DESCRIPTION

The Faileen Spring lies on the easterly bank of the Glashacloonaraveela River, in its upper valley region (Fig. 1). It is enclosed in a rectangular concrete collecting chamber which is surrounded by a barbed wire fence. The spring overflow discharges directly into the river. Access to the site is via private property to the south, approximately 25 minutes walk along the river bank. At present the Faileen source is a backup supply to the Glasha River source which supplies the village of Cappamore and it is only used in the summer months.

4. TOPOGRAPHY, SURFACE HYDROLOGY AND LAND USE

The spring is located on the southerly flank of the Slieve Phelim Mountains, at an elevation of approximately 260 m OD (850 ft). The mountains rise to a height of 410 m to the west and 464 m to the east (Cullaun), and fall off in a series of terraces to the deeply incised river valley (with cliffs up to 27 m depth in places). The valley slopes away in a southerly direction (Fig. 1).

The Glashacloonaraveela River starts about 1 km north-west of the source at two rises, which merge to the north of the site to form the southerly flowing river. Surface drainage is often poor in the lower terraced area, although it is enhanced in places with the construction of drainage channels. Up-slope of the spring to the northeast of the site, the ground is fairly dry and there are no surface streams apart from a small stream, which enters the river upstream of the source, from a deeply incised valley.

The land is primarily used for forestry and much of the area is owned by Coillte. There are also one or two farms at higher elevations, which are serviced by a minor access road from the east.

5. GEOLOGY

5.1 Bedrock geology

The bedrock in the area is Silurian in age and includes sandstones, slates and shales. Outcrop to the north of the site in the stream beds comprise grey and greenish grits. These rocks are fractured and broken, and have also undergone a certain degree of folding; beds vary in dip from 20–60° in northerly, southerly and easterly directions.

5.2 Subsoils (Quaternary) geology

The subsoils in the area comprise sands and gravels, various tills, slope deposits and till-with-gravel, with some thin overlying peat in places (Fig. 1). The deposits in the southerly end of the valley are dominated by Old Red Sandstone lithologies which generally have a sandy texture while the Silurian dominated deposits further up the valley are often silty. A section opposite the source on the western side of the valley, exposes a loose sandy deposit with substantial gravel. The spring source has been dug out from the sands and gravels.

The majority of the sediments can be interpreted as part of an ice marginal environment but two main types of deposits can be identified. Basal till sections are found high up in the stream valley and these were observed as compacted, matrix supported deposits with some clay. These deposits would have been laid down with the advancement of the ice which would have lapped around the hills. The overlying dead ice deposits are generally loose, clast supported sands and gravels, with little clay in their makeup, and these would have been deposited at the ice margin. This interpretation is supported by the terraced morphology of the area which highlights the changes in deposits up the valley.

Iron pans, formed by the downward leaching of heavy minerals, are very common and they are present at depths of less than 1 m below surface in distinctive layers, up to 3 cm thick in places. They have been broken up in places, however, by the forestry trenching.

5.3 Soils

The soils of the area to the west of the river are classified as blanket peat. To the east of the river, brown earths from the Ballylanders Series are common. These are derived from shale and sandstone dominated solifluction deposits which are underlain by mixed glacial deposits. The soils are shown on the published soils map of Co. Limerick (Finch and Ryan, 1966) and so are not reproduced here.

5.4 Depth-to-rock

Outcrop in the upper stream sections indicates that rock is close to surface in the upland areas on the hill slopes (Fig. 1). Depth-to-bedrock in the immediate vicinity of the spring is not known, although it is estimated at greater than 3 m below ground level, based on the depth of the collection chamber. The river valley is deeply incised and the bluffs on either side reach up to approximately 30 m in places. As there is no bedrock outcropping in the river in these areas, it may be assumed that there is a substantial thickness of subsoils in the valley. These thicknesses are typical in ice marginal areas where extensive deposition takes place. There are no borehole data for the general area and precise depths are therefore unknown.

6. HYDROGEOLOGY

6.1 Data availability

There are few hydrogeological data for the area around the Cappamore Faileen Source and first principles of groundwater flow are therefore used. The spring discharge values are estimated using an average daily abstraction figure extrapolated over the period of one year, and an average overflow figure measured in March 1995 which is also extrapolated as daily figures were not available.

6.2 Groundwater levels

The static water level in the public supply spring in February 1995 was approximately 1 m below ground level (approx. 259 m OD). It is reasonable to assume that the river is in hydraulic continuity with groundwater and the water level is therefore taken as that of groundwater. As the spring is at a relatively low elevation, it is likely that the unsaturated zone is quite thick in the lower regions of the valley although this is likely to decrease in thickness in the higher regions where there is thin subsoil cover. There may be perched water tables in places due to the presence of the iron pans.

6.3 Groundwater flow directions

Groundwater flow direction is likely to follow topography, flowing down slope on all sides of the valley into the river channel. Flow direction will be perpendicular to the topographical contours and there will be a groundwater divide along the ridge at the top of the hills.

6.4 Meteorology and recharge

Rainfall data for the area are estimated using a contoured Meteorological Service map based on the long-term monthly data for the years 1941–1980, and the monthly 1993–1994 data for the nearby rainfall station at Murroe. Mean annual rainfall at the site is estimated to be in the region of 1275 mm/a. Rainfall at Murroe however was 20% higher than the average during the period November 1993 – November 1994. Assuming that the same percentage increase applies at the site, the annual rainfall for this period is estimated as approximately 1530 mm. (This rainfall period was selected as it can be related to the discharge.) Potential evapotranspiration (P.E.) is estimated from a regional Meteorological Service contoured map, and a ranking scheme with all the other sources, as 520 mm per annum. Actual evapotranspiration (A.E.) is then calculated by taking 93% of the potential figure, to allow for soil moisture deficits during part of the year. Using these figures, the average annual effective rainfall (E.R.) is taken to be approximately 1045 mm for 1994.

The subsoil deposits are highly permeable and despite the presence of the iron pans, there is only one surface stream on the eastern side of the valley, up-slope of the source. A high proportion of the effective rainfall must therefore be infiltrating to the water table. Estimating runoff to be of the order of 25%, recharge to the aquifer is taken to be *approximately* 785 mm in 1994, although the average annual recharge is approximately 595 mm/a. It is emphasised that the results are based largely on estimated values; the uncertainties are however, incorporated in the catchment area delineation.

These calculations are summarised below:

	1994 values	**Mean annual values (1941–1980)**
Annual rainfall	1530 mm	1275 mm
Estimated P.E.	520 mm	520 mm
Estimated A.E. (93% P.E.)	485 mm	485 mm
Effective rainfall	1045 mm	790 mm
Recharge (75% E.R.)	approx. 785 mm	approx. 595 mm

The presence of the forestry in the area is an additional factor which must be taken into consideration, as many studies have shown that forestry plantations can reduce the infiltration to groundwater by 20–30% (summarised in *Flooding in the Gort-Ardrahan Area*, Daly, D., 1992, GSI publication). Only trees which are 10 years old or greater however, will have an influence. It is estimated from Coillte data, that in this catchment area, approximately 10% of the land surface falls into this category, at the present time. Recharge in these areas will therefore be slightly less (~715 mm in 1994) and this must be accounted for in the Recharge Equation (refer to Section 8).

6.5 Hydrochemistry and water quality

The hydrochemical analyses of groundwater at the Faileen source are indicative of a **moderately soft** to **moderately hard** water (64–183 mg/l ($CaCO_3$)), with low alkalinity (52–66 mg/l ($CaCO_3$)). Conductivities are also relatively low at 17–167 μS/cm.

The routine analyses carried out by the Council for the purposes of the EC regulations are of limited use in assessing the water quality of the Faileen Spring, as the samples are taken from private residences in Cappamore and this supply also includes water taken from the Glasha Spring. From the three analyses taken as part of the study however, it appears that the water quality is generally excellent, with all indicator parameters at background levels.

6.6 Conceptual model

The aquifer supplying the Faileen source is the unconsolidated high permeability gravelly subsoil deposits. The soils were not found to be as free draining as expected and it is probable that the iron pans are causing localised perched water tables, although the absence of surface water drainage would suggest that they are not consistent over the area. The forestry trenching has also broken the iron pans up in places, and there appear to be sufficient discontinuities to enable recharge to the aquifer to occur. The discharge at the spring remains fairly constant, even during the summer months, and this would suggest that the aquifer has a reasonable storage capacity. As the level of the spring is higher than the level of the river, it is probable that groundwater flowing down the western side of the valley will discharge into the river and not at the spring. The small spring to the north of the source is likely to be perched, although groundwater may be contributing to the associated stream as it approaches the lower regions of the river valley.

6.7 Aquifer categories

The gravelly subsoils at the Cappamore Faileen source are considered to be a **locally important sand and gravel aquifer**. Till-with-gravel deposits are not usually classed as locally important aquifers, as generally the extent and hydraulic connection between the gravelly units is not known. In this case however, there are extensive thicknesses of a very loose sandy deposit and with the high recharge, the source can provide a supply which is adequate for the local community.

The underlying Silurian bedrock is classed as a **poor aquifer** which is **generally unproductive except for local zones**.

7. VULNERABILITY

Using the GSI vulnerability mapping guidelines, the area in the immediate vicinity of the Faileen source is considered to have a **probably high** vulnerability to contamination (Fig. 2), as the unsaturated zone in the gravels is >3 m thick. On the higher slopes of the valley where subsoils are likely to be quite thin, the groundwater is mapped as having a **probably extreme** vulnerability.

8. DELINEATION OF SOURCE PROTECTION AREAS

8.1 Outer Protection Area

The Outer Protection Area (SO) includes the complete catchment area to the spring and it is delineated as the area required to support an abstraction from long-term groundwater recharge.

The catchment area (Fig. 3) is controlled primarily by the river and the groundwater divide at the top of the hill, beyond which groundwater will flow in the opposite direction. The northwest and southeast boundaries are more tentative and are based on the likely groundwater flow lines.

The Recharge Equation estimates that the area required to collect enough recharge to sustain the source on an annual basis, is in the region of 0.25 km^2. The area described above is significantly larger than this and will therefore incorporate an additional safety margin.

8.2 Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100-day time of travel from any point below the water table to the source and it is delineated to protect against the effects of potentially contaminating activities which may have an immediate influence on water quality at the source, in particular from microbial pollution.

The Time of Travel Equation was used to estimate the 100-day time of travel distance to the source. In view of the lack of definitive hydrogeological information however, conservative estimates were used for each of the relevant aquifer coefficients. Taking the permeability as 50 m/d and the hydraulic gradient as 0.004, and assigning a porosity value of 0.07, the 100-day time of travel radius is calculated as approximately 285 m (Fig. 2). The radius will only be valid within the spring catchment and so the shape of the area is amended accordingly.

8.3 Source Site

In addition to the Inner and Outer Areas there is a third protection area, the Source Site (SS), which is delineated as the area in the immediate vicinity of the source (minimum 10 m radius), and it is designed to maintain good wellhead sanitary protection. The Source Site will encompasses an area of radius 10 m around the collecting chamber; the fenced off enclosure at present is too small.

9. POTENTIAL POLLUTION SOURCES

The current primary threat to the public supply at Faileen is a farm on the access road to the northeast of the site. The farmyard effluent is poorly managed and is allowed to flow onto the road and into a ditch where it ponds before slowly infiltrating into the subsoils. Fertilisers and pesticides on the forestry development may also be a problem if they are being applied; there are no analyses currently carried out for pesticides and the possible extent of any problem is not known.

10. GROUNDWATER PROTECTION SCHEME

Combining the Source Protection Areas, as described above, with the vulnerability ratings, delineates a total of three groundwater source protection zones for the Cappamore Faileen source. These are listed here and are shown in Figure 5 (with the exception of the Source Site):

- Source Site / High (SS – H)
- Inner Protection Area / High (SI – H)
- Outer Protection Area / High (SO – E)

It is not within the scope of this report to delineate the protection zones in the surrounding area and this is dealt with at the regional resource protection scale. The accompanying code of practice imposing restrictions on developments will follow when discussions as to the degree of restriction necessary in each protection zone have been carried out between the Council and the EPA, with assistance from the GSI.

11. CONCLUSIONS AND RECOMMENDATIONS

Overall the source at Faileen is a good high yielding spring which is derived from a gravelly subsoil aquifer. It is highly vulnerable to pollution although at present there appear to be no problems with water quality. This may be due to the fact that there is a thick unsaturated zone which will facilitate attenuation of any possible contaminants, but is probably mainly a consequence of the relatively low levels of pollution loading in the valley.

The County Council should consider using the Faileen spring as the main source of water for the village of Cappamore and maintain the Glasha river supply as the backup. The groundwater supply will generally be more reliable in terms of water quality than the river.

It is recommended that the Council control and monitor potentially contaminating activities being carried out near the river banks and in the river valley to the northeast of the source. The farm management practices at the small farm should be addressed, and the source site, although fairly remote, should be properly fenced off.

The majority of the forestry plantation was planted in 1988 and by 1998 the trees will be big enough to reduce the spring discharge by almost 20%. This should not be a problem if the demand does not increase as the overflow is quite substantial. This should be considered in terms of total water supply to Cappamore for the future. It would also be advisable to analyse for pesticides in the supply (if they are being used by Coillte) as these can persist in groundwaters for quite some time and are not easily remediated.

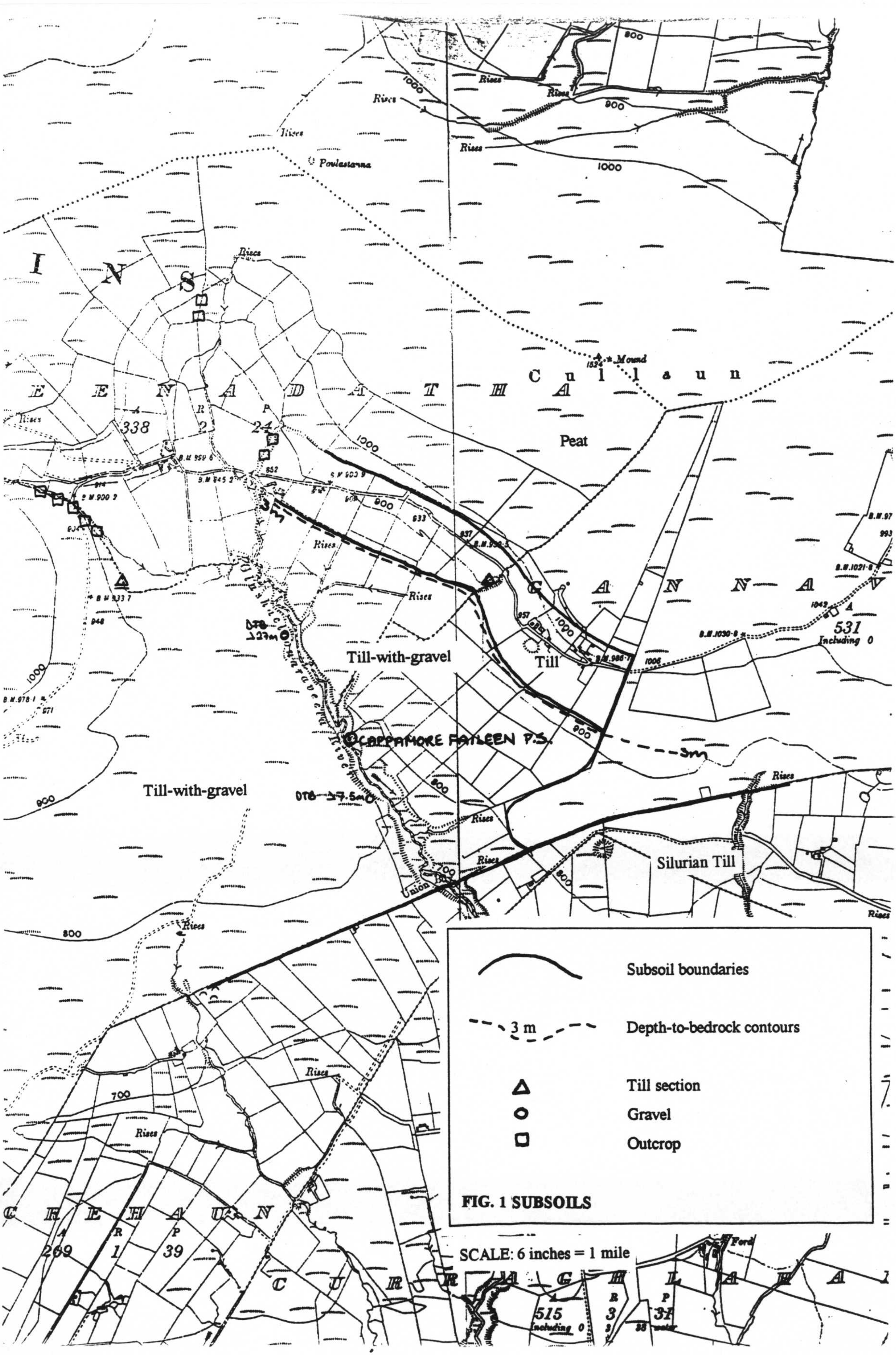


FIG. 1 SUBSOILS

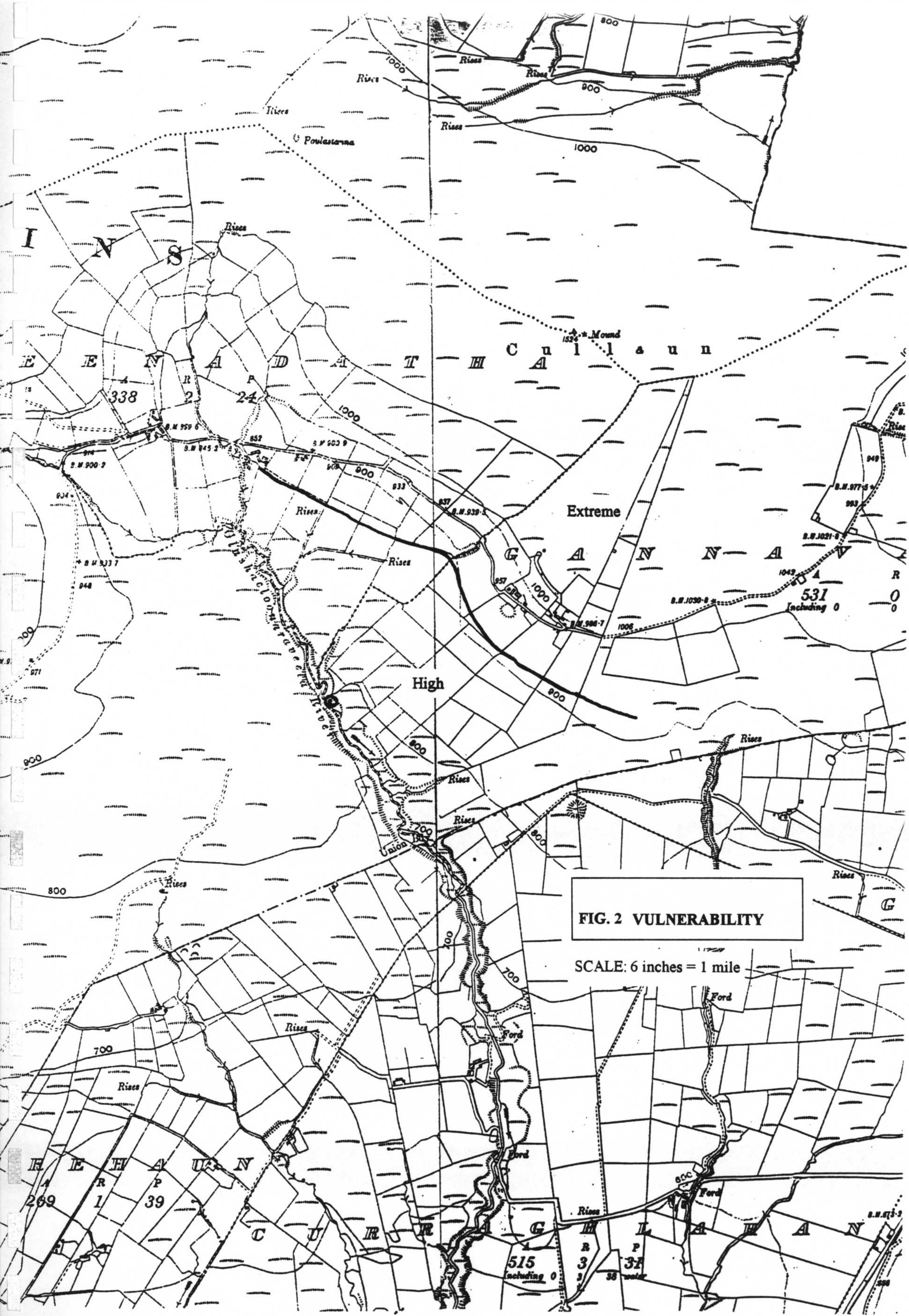


FIG. 2 VULNERABILITY

SCALE: 6 inches = 1 mile

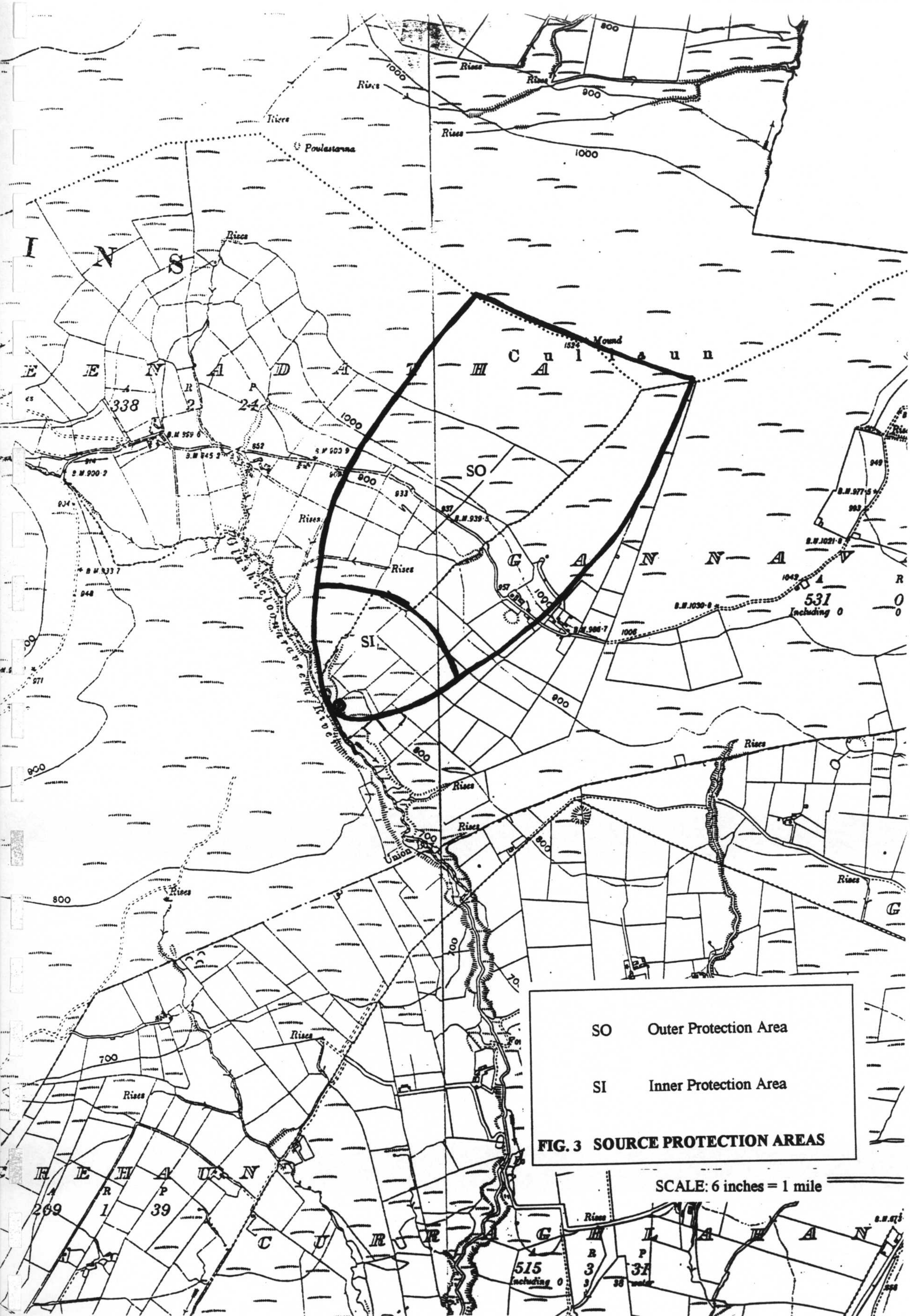


FIG. 3 SOURCE PROTECTION AREAS

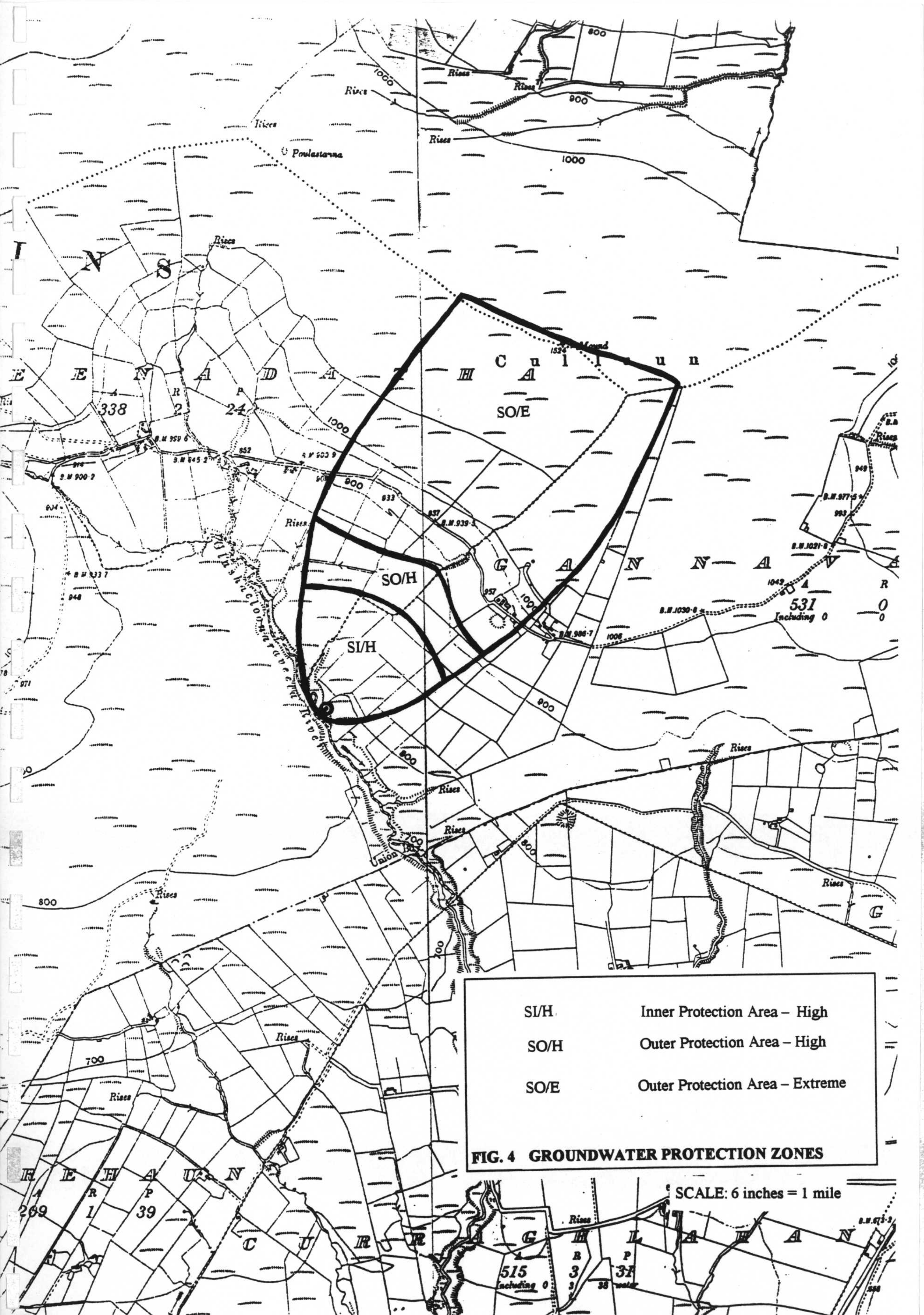
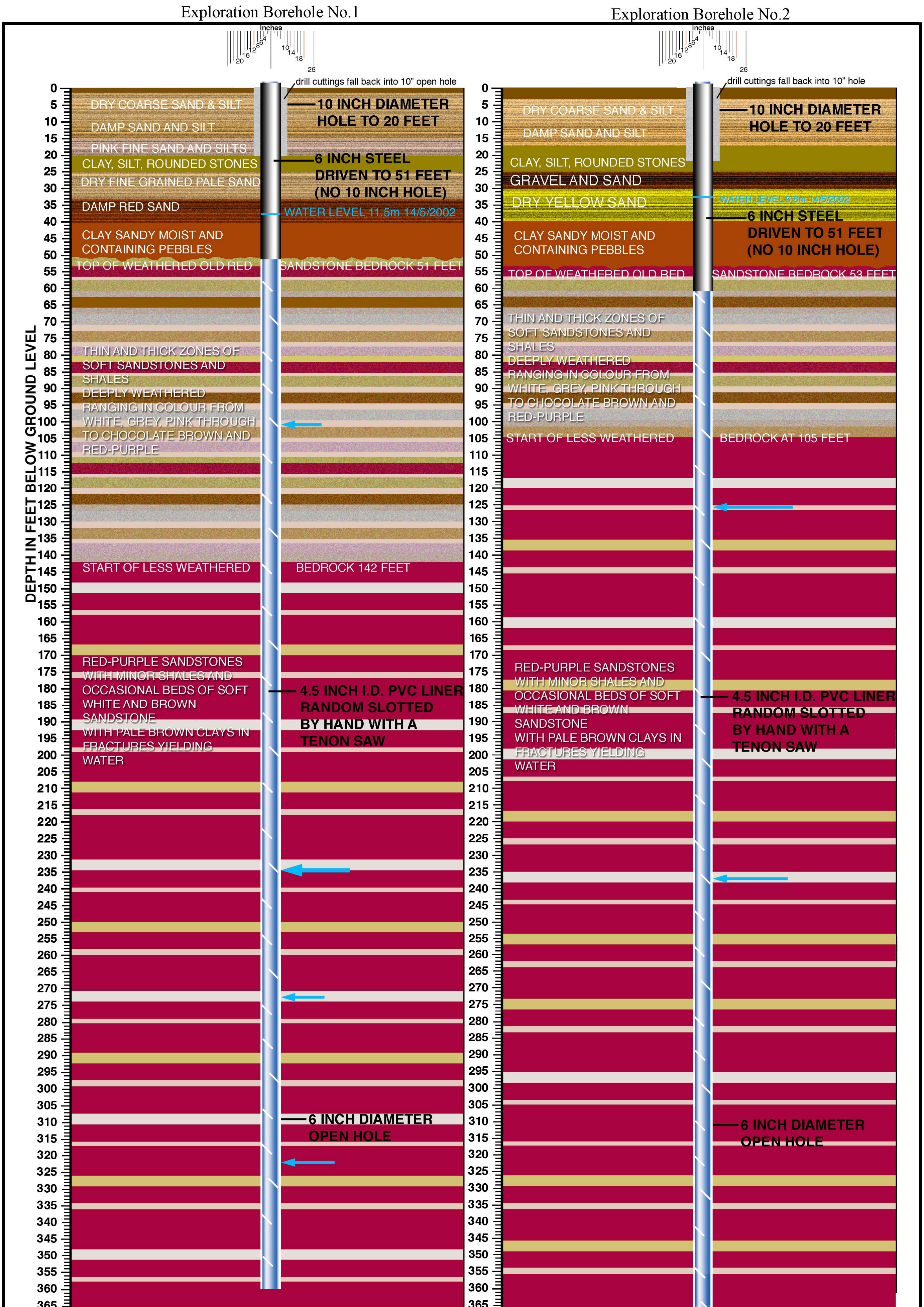


FIG. 4 GROUNDWATER PROTECTION ZONES

APPENDIX 2

Borehole logs

CAPPAMORE EXPLORATION DRILLING MAY 2002



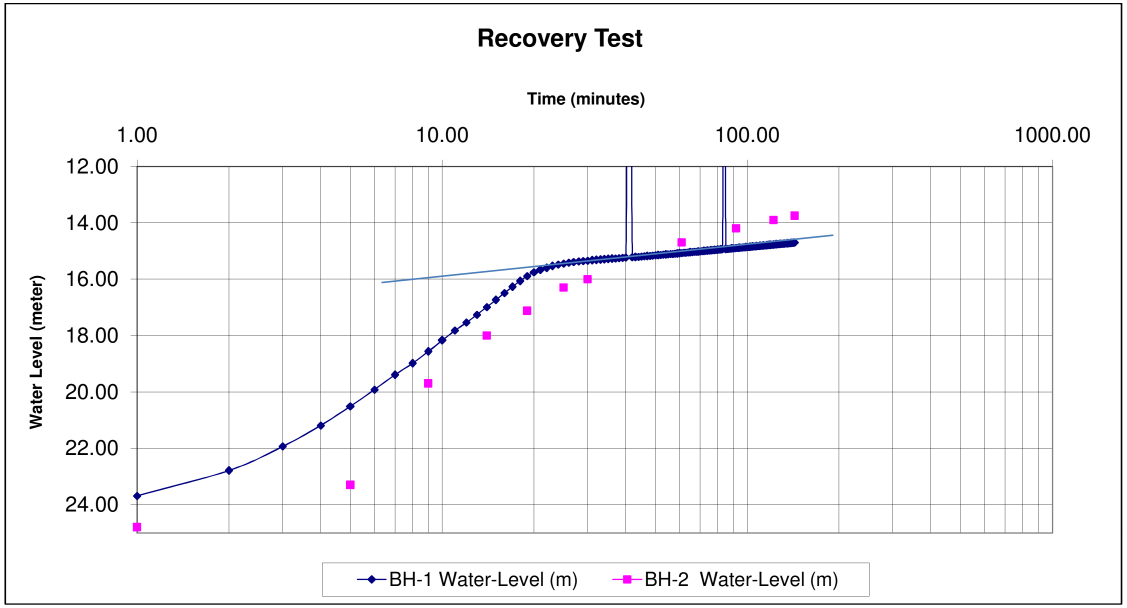
Note:- These two boreholes were drilled in 3 days as exploration boreholes on land owned by Limerick Co. Co. next to the reservoir. They were regarded, at the time, as a short-term measure to top up the low yield from the Faileen Springs in a dry summer. There is no cement grout around the steel casing. An effective seal around the casing *may* be present because the 6 inch steel was driven through the clays and sands for 30 to 40 feet below the bottom of the 10 inch pilot hole.

Drilled by Patrick Briody and Sons 9-13th May 2002. Supervised by David Ball, Hydrogeologist.

APPENDIX 3

Pumping Test Data

	Time (min)	BH-1 Logger-Water-Level (m)	BH-1 Water-Level (m)	BH-2 Water-Level (m)
29/09/2010 09:36:56	1.00	7.22	23.69	24.80
29/09/2010 09:37:56	2.00	8.12	22.79	
29/09/2010 09:38:56	3.00	8.98	21.93	
29/09/2010 09:39:56	4.00	9.72	21.19	
29/09/2010 09:40:56	5.00	10.40	20.51	23.30
29/09/2010 09:41:56	6.00	10.99	19.92	
29/09/2010 09:42:56	7.00	11.52	19.39	
29/09/2010 09:43:56	8.00	11.93	18.98	
29/09/2010 09:44:56	9.00	12.35	18.56	19.70
29/09/2010 09:45:56	10.00	12.75	18.17	
29/09/2010 09:46:56	11.00	13.09	17.82	
29/09/2010 09:47:56	12.00	13.37	17.54	
29/09/2010 09:48:56	13.00	13.65	17.26	
29/09/2010 09:49:56	14.00	13.92	16.99	18.00
29/09/2010 09:50:56	15.00	14.18	16.74	
29/09/2010 09:51:56	16.00	14.42	16.49	
29/09/2010 09:52:56	17.00	14.64	16.27	
29/09/2010 09:53:56	18.00	14.85	16.07	
29/09/2010 09:54:56	19.00	15.02	15.89	17.12
29/09/2010 09:55:56	20.00	15.16	15.75	
29/09/2010 09:56:56	21.00	15.25	15.67	
29/09/2010 09:57:56	22.00	15.31	15.60	
29/09/2010 09:58:56	23.00	15.38	15.53	
29/09/2010 09:59:56	24.00	15.43	15.48	
29/09/2010 10:00:56	25.00	15.47	15.44	16.30
29/09/2010 10:01:56	26.00	15.50	15.41	
29/09/2010 10:02:56	27.00	15.53	15.39	
29/09/2010 10:03:56	28.00	15.54	15.37	
29/09/2010 10:04:56	29.00	15.56	15.35	
29/09/2010 10:05:56	30.00	15.57	15.34	16.00
29/09/2010 10:06:56	31.00	15.59	15.33	
29/09/2010 10:07:56	32.00	15.60	15.32	
29/09/2010 10:08:56	33.00	15.61	15.30	
29/09/2010 10:09:56	34.00	15.62	15.29	
29/09/2010 10:10:56	35.00	15.63	15.28	
29/09/2010 10:11:56	36.00	15.64	15.27	
29/09/2010 10:12:56	37.00	15.65	15.26	
29/09/2010 10:13:56	38.00	15.66	15.25	
29/09/2010 10:14:56	39.00	15.67	15.24	
29/09/2010 10:15:56	40.00	15.68	15.23	



	m3/h	m3/d
	4	96

Transmissivity Estimation
T = 0.183Q / dS

	t1-10	t10-100	t100-1000
T - Transmissivity (m2/d)		**15**	
Q - Final Discharge (m3/d)	96	96	96
t1 - point in time			
S1 - Water Level at t1		16	
S2 -Water Level at t1*10		14.85	
dS - Change in drawdown over 1 log cycle	0	1.15	

	Time (min)	BH-1 Logger-Water-Level (m)	BH-1 Water-Level (m)	BH-2 Water-Level (m)
29/09/2010 10:16:56	41.00	15.69	15.22	
29/09/2010 10:17:56	42.00	15.70	15.21	
29/09/2010 10:18:56	43.00	15.71	15.21	
29/09/2010 10:19:56	44.00	15.72	15.20	
29/09/2010 10:20:56	45.00	15.73	15.19	
29/09/2010 10:21:56	46.00	15.73	15.18	
29/09/2010 10:22:56	47.00	15.74	15.17	
29/09/2010 10:23:56	48.00	15.75	15.16	
29/09/2010 10:24:56	49.00	15.76	15.15	
29/09/2010 10:25:56	50.00	15.77	15.14	
29/09/2010 10:26:56	51.00	15.77	15.14	
29/09/2010 10:27:56	52.00	15.78	15.13	
29/09/2010 10:28:56	53.00	15.79	15.12	
29/09/2010 10:29:56	54.00	15.80	15.12	
29/09/2010 10:30:56	55.00	15.80	15.11	
29/09/2010 10:31:56	56.00	15.81	15.10	
29/09/2010 10:32:56	57.00	15.82	15.09	
29/09/2010 10:33:56	58.00	15.82	15.09	
29/09/2010 10:34:56	59.00	15.83	15.08	
29/09/2010 10:35:56	60.00	15.84	15.07	14.70
29/09/2010 10:36:56	61.00	15.85	15.06	
29/09/2010 10:37:56	62.00	15.85	15.06	
29/09/2010 10:38:56	63.00	15.86	15.05	
29/09/2010 10:39:56	64.00	15.87	15.04	
29/09/2010 10:40:56	65.00	15.88	15.04	
29/09/2010 10:41:56	66.00	15.88	15.03	
29/09/2010 10:42:56	67.00	15.89	15.02	
29/09/2010 10:43:56	68.00	15.89	15.02	
29/09/2010 10:44:56	69.00	15.90	15.01	
29/09/2010 10:45:56	70.00	15.91	15.00	
29/09/2010 10:46:56	71.00	15.91	15.00	
29/09/2010 10:47:56	72.00	15.92	14.99	
29/09/2010 10:48:56	73.00	15.93	14.99	
29/09/2010 10:49:56	74.00	15.93	14.98	
29/09/2010 10:50:56	75.00	15.94	14.98	
29/09/2010 10:51:56	76.00	15.94	14.97	
29/09/2010 10:52:56	77.00	15.95	14.96	
29/09/2010 10:53:56	78.00	15.95	14.96	
29/09/2010 10:54:56	79.00	15.96	14.95	
29/09/2010 10:55:56	80.00	15.96	14.95	
29/09/2010 10:56:56	81.00	15.97	14.94	
29/09/2010 10:57:56	82.00	15.98	14.94	

	Time (min)	BH-1 Logger-Water-Level (m)	BH-1 Water-Level (m)	BH-2 Water-Level (m)
29/09/2010 10:58:56	83.00	15.98	14.93	
29/09/2010 10:59:56	84.00	15.99	14.93	
29/09/2010 11:00:56	85.00	15.99	14.92	
29/09/2010 11:01:56	86.00	16.00	14.91	
29/09/2010 11:02:56	87.00	16.00	14.91	
29/09/2010 11:03:56	88.00	16.01	14.90	
29/09/2010 11:04:56	89.00	16.01	14.90	
29/09/2010 11:05:56	90.00	16.02	14.89	14.20
29/09/2010 11:06:56	91.00	16.02	14.89	
29/09/2010 11:07:56	92.00	16.03	14.88	
29/09/2010 11:08:56	93.00	16.03	14.88	
29/09/2010 11:09:56	94.00	16.04	14.88	
29/09/2010 11:10:56	95.00	16.04	14.87	
29/09/2010 11:11:56	96.00	16.05	14.86	
29/09/2010 11:12:56	97.00	16.05	14.86	
29/09/2010 11:13:56	98.00	16.05	14.86	
29/09/2010 11:14:56	99.00	16.06	14.85	
29/09/2010 11:15:56	100.00	16.06	14.85	
29/09/2010 11:16:56	101.00	16.07	14.84	
29/09/2010 11:17:56	102.00	16.07	14.84	
29/09/2010 11:18:56	103.00	16.08	14.84	
29/09/2010 11:19:56	104.00	16.08	14.83	
29/09/2010 11:20:56	105.00	16.08	14.83	
29/09/2010 11:21:56	106.00	16.09	14.82	
29/09/2010 11:22:56	107.00	16.09	14.82	
29/09/2010 11:23:56	108.00	16.10	14.81	
29/09/2010 11:24:56	109.00	16.10	14.81	
29/09/2010 11:25:56	110.00	16.10	14.81	
29/09/2010 11:26:56	111.00	16.11	14.80	
29/09/2010 11:27:56	112.00	16.11	14.80	
29/09/2010 11:28:56	113.00	16.12	14.80	
29/09/2010 11:29:56	114.00	16.12	14.79	
29/09/2010 11:30:56	115.00	16.12	14.79	
29/09/2010 11:31:56	116.00	16.13	14.78	
29/09/2010 11:32:56	117.00	16.13	14.78	
29/09/2010 11:33:56	118.00	16.14	14.78	
29/09/2010 11:34:56	119.00	16.14	14.77	
29/09/2010 11:35:56	120.00	16.14	14.77	13.90
29/09/2010 11:36:56	121.00	16.15	14.76	
29/09/2010 11:37:56	122.00	16.15	14.76	
29/09/2010 11:38:56	123.00	16.15	14.76	
29/09/2010 11:39:56	124.00	16.16	14.75	
29/09/2010 11:40:56	125.00	16.16	14.75	
29/09/2010 11:41:56	126.00	16.16	14.75	
29/09/2010 11:42:56	127.00	16.17	14.74	
29/09/2010 11:43:56	128.00	16.17	14.74	
29/09/2010 11:44:56	129.00	16.17	14.74	
29/09/2010 11:45:56	130.00	16.18	14.73	
29/09/2010 11:46:56	131.00	16.18	14.73	
29/09/2010 11:47:56	132.00	16.18	14.73	
29/09/2010 11:48:56	133.00	16.19	14.73	
29/09/2010 11:49:56	134.00	16.19	14.72	
29/09/2010 11:50:56	135.00	16.19	14.72	
29/09/2010 11:51:56	136.00	16.19	14.72	
29/09/2010 11:52:56	137.00	16.20	14.71	
29/09/2010 11:53:56	138.00	16.20	14.71	
29/09/2010 11:54:56	139.00	16.20	14.71	
29/09/2010 11:55:56	140.00	16.21	14.70	
29/09/2010 11:56:56	141.00	16.21	14.70	13.75

Water Level in BH-2 with BH-1 pumping

Time (min)	BH-2 Water Level (m)
0	13.75
1	13.75
10	13.77
20	13.88
30	13.95