# Ballyboy Group Water Scheme

# Groundwater Source Protection Zones

(April 2001)

***Prepared by:***
Coran Kelly
Geological Survey of Ireland

***In collaboration with:***
Offaly County Council

**LIST OF FIGURES**



**LIST OF TABLES**

# 1 Introduction

The Ballyboy source is the only supply for the Ballyboy Group Water Scheme. It supplies water to 61 houses, 17 farms and 1 pub (as of 09/05/2000).

The objectives of the report are as follows:

- To delineate source protection zones for the Ballyboy source (DELG/EPA/GSI, 1999).
- To outline the principle hydrogeological characteristics of the Ballyboy area.
- To assist Offaly County Council in protecting the water supply from contamination.

# 2 Location, Site Description and Well Head Protection

Ballyboy well is located within a small pumphouse alongside a track 500 m north of the main Kilcormac-Tullamore road in the townland of Ballywilliam about 2 km east of Kilcormac village. The well occurs on the outside of a sharp kink in a small perennial stream.

A spring originally flowed into the river at the site, this was dug to almost 3 m and a cylindrical concrete sump was installed and is protected by a manhole. A small pumphouse was built around the sump. The pumphouse and well are located alongside a narrow dirt track. The sump now acts as a shallow large diameter pumping well.

The sump is protected by the pumphouse that is padlocked. The pumped water is chlorinated. A discharge meter is located about 15 m in the field behind the pumphouse.

# 3 Summary of Well / Spring Details

| | | |
|---|---|---|
| Grid ref. (1:25,000) | : | N 1980 1565 |
| Townland | : | Ballywilliam |
| Well type | : | Large diameter dug well |
| Diameter | : | 1 m |
| Depth | : | 2.8 m |
| Owner | : | Ballyboy Group Water Scheme |
| Elevation (ground level) | : | 65.03 m OD (213.34 ft OD) |
| Depth to rock | : | 2.0 m |
| Static water level | : | 1.5-2.0 m below ground |
| Present Abstraction | : | 176 $m^3 d^{-1}$ (30,800 gallons per day) |

# 4 Methodology

## 4.1 Desk Study

Details about the borehole such as elevation, and abstraction figures were obtained from GSI records and County Council personnel

## 4.2 Site visits and fieldwork

This included carrying out depth to rock drilling and subsoil sampling. Field walkovers were also carried out to investigate the subsoil geology, the hydrogeology and vulnerability to contamination.

## 4.3 Assessment

Analysis of the data utilised field studies and previously collected data to delineate protection zones around the source. Due to the proximity of the source for the Kilcormac Water Supply Scheme much of the work for the two sources was done in parallel, in particular the numerical modelling exercise as discussed in Section 8.2. Details of the Kilcormac Water Supply Scheme may be referred to in Kelly 2000.

# 5 Topography, Surface Hydrology and Land Use

The source is located next to a small stream next to the edge of an esker ridge that runs east-west and southwest-northeast, roughly parallel to the main Kilcormac-Tullamore road. The topography is gently undulating rising at a low gradient to the east. A large bog occurs 0.5 km to the north of the source.

The surface hydrology changes on either side of the main Kilcormac-Tullamore road. Bogs and streams are frequent to the north of the source – the area to the west of the main road. To the east of the main road and the source there are very few surface streams and the land is free draining.

Small streams run off the bog flowing southwest, one of which passes by the source, where they drain to the Silver River. The Silver River is the largest stream in the area draining to the north toward the River Shannon. In general there are few surface stream to the east and south of the source.

Turf cutting is carried out in the bog to the north of the source. An area of forestry (1 $km^2$)occurs just to the north of the source. Kilcormac village lies about 2 km southwest of the source. Grassland farming dominates the area to the east and south of the source. The main Kilcormac-Tullamore road occurs 500 m away along which several houses are located. There are a few gravel pits in the esker ridge.

# 6 Geology

## 6.1 Introduction

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

Bedrock information was taken from a desk-based survey of available data, which comprised the following:

- County Offaly Groundwater Protection Scheme (Daly *et al*, 1998)
- Information from geological mapping in the nineteenth century (on record at the GSI).

Subsoils information was taken from the Offaly Groundwater Protection Scheme (Daly *et al*, 1998) and gathered from a drilling programme that was undertaken by GSI personnel to investigate the subsoils of the area.

## 6.2 Bedrock Geology

Limestones occupy the whole area and a brief description of the individual rock units in the vicinity of the source is given in Table 1.

Table 1 The Bedrock Geology of the area surrounding the Ballyboy source.

| ***Name of Rock Unit*** | ***Rock Material*** | ***Occurrence*** |
|---|---|---|
| Borrisokane | Thick-bedded, coarse grained, pale LIMESTONE with some darker fine grained beds and with occasional thin clayey bands | Underlies the source. |
| Allenwood | Pale-grey, poorly bedded, medium to coarse grained LIMESTONE | Occurs as a narrow band 500 m north of the source. |
| Waulsortion | Fossiliferous, pale-grey, poorly bedded fine-grained LIMESTONE | Occurs 1 km east of the source. |

Movements in the earth's crust have caused the rocks to be folded, faulted and jointed. The different rock units have a NE-SW trend or strike and they generally dip south-eastwards at a low angle. Two major fault sets are present — NE-SW and SE-NW. The joint pattern is likely to have similar orientations. The contact between Borrisokane Limestone and the Waulsortion limestone is a low-angled NE-SW trending thrust fault (Daly *et al*, 1998).

## 6.3 Subsoil (Quaternary) Geology

The subsoils comprise a mixture of coarse and fine grained materials, namely; alluvium, tills, sand & gravels and are directly influenced by the underlying bedrock, which is made up of the Borrisokane and Waulsortion limestones. The geological logs of the auger holes drilled are given in Appendix 1.

The characteristics of each category are described briefly below:

### 6.3.1 Peat & Bog

The peat is very thin and is located on the flat ground between the spring and the forestry. Thick blanket bog occurs further to the north.

### 6.3.2 Tills

'Till' is an unsorted mixture of coarse and fine materials laid down by ice. Angular to subrounded sandstone and limestone fragments are abundant in the tills. The tills are the dominant subsoil type to the south of the Silver River. The matrix of the tills are clayey SAND with silt; SILT, sandy CLAY all with occasional or frequent gravel size fragments.

### 6.3.3 Sand & Gravels

Extensive fluvioglacial sand and gravels are present in County Offaly and occur in the Kilcormac area in the form of eskers. The sands and gravels making up the eskers are (BS5930: sandy GRAVELS and GRAVELS). The boulders and cobbles are limestone in composition.

### 6.3.4 Depth to Bedrock

The depth to rock is known in certain localities from a drilling programme carried out by the GSI to ascertain the thickness and permeability of the subsoils. The locations of the auger holes are given in Figure 1 and the logs are given in Appendix 1. The depth to bedrock varies between 2 and 8 m.

# 7 Hydrogeology

## 7.1 Introduction

This section presents our current understanding of groundwater flow in the vicinity of the Ballyboy source. The interpretations and conceptualisations of flow are used to delineate source protection zones around the source.

Hydrogeological and hydrochemical information for the study was obtained from the following sources:

- Offaly Groundwater Protection Scheme (Daly *et al* 1998).
- An Assessment of the Quality of Public and Group Scheme Groundwater Supplies in County Offaly, (Cronin *et al*, 1999).
- GSI files. Archival Offaly County Council data for the years 1977, 1989, 1991. C1–C2 type parameters.
- Offaly County Council annual drinking water returns 1992–1999 inclusive (C1, C2, C3 and C4 type parameters). Some raw water analyses were also carried out.
- Limited additional fieldwork.

## 7.2 Meteorology and Recharge

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 generally assumed to consist of input (i.e. annual rainfall) less water losses 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 in combination with abstraction rates it will dictate the size of the zone of contribution.

In areas where point recharge from sinking streams, etc., is discounted, the main parameters involved in recharge rate estimation are annual rainfall, and annual evapotranspiration, and are listed as follows:

- Annual rainfall: 850 mm. Rainfall data for the area are taken from Kilcormac and Mountbolus weather stations.
- Annual evapotranspiration losses: 432 mm. Potential evaporation (P.E.) is estimated to be 455 mm, from the average annual value at Birr Weather Station. Actual evapotranspiration (A.E.) is then estimated as 95 % of P.E.
- Potential recharge: 418 mm $yr.^{-1}$. This figure is a calculation based on subtracting estimated evapotranspiration losses from average annual rainfall. It represents an estimation of the excess soil moisture available for either vertical downward flow to groundwater, or lateral soil quickflow and overland flow direct to surface water.
- Annual runoff losses: 42 mm. This estimation is based on the assumption that 10% of the potential recharge will be lost to overland flow and shallow soil quickflow prior to reaching the main groundwater system particularly during periods of heavy rainfall.

These calculations are summarised below:

| | |
|---|---|
| Average annual rainfall (R) | 850 mm |
| Estimated A.E. | 432 mm |
| Potential Recharge (R – A.E.) | 418 mm |
| Runoff losses | 42 mm |
| Estimated Actual Recharge | 376 mm |

## 7.3 Groundwater Levels, Flow Directions and Gradients

At the source the water level is 2.4 m below ground level. The water level in the well is approximately the same level as the stream that flows past the well. The area around the wells is quite flat and low lying. The water table in the area is generally assumed to be a subdued reflection of topography; as the topography slopes westwards, the water table slopes westwards toward the well. The flow directions will be perpendicular to the contour lines. In simple terms, rainfall reaching the water table anywhere in the catchment of the well will flow in a westerly direction. The groundwater gradient is assumed to somewhat less than the topographic gradient, i.e. is estimated to be 0.01.

## 7.4 Hydrochemistry and Water Quality

The hydrochemical analyses (12 samples) show that the water is a hard to a very hard water with total hardness values of 357-405 mg $l^{-1}$ (equivalent $CaCO_3$) and electrical conductivity values of 562-700 µS $cm^{-1}$, indicating that the groundwater has a hydrochemical signature of calcium bicarbonate type water. These values are typical of groundwater from limestone rocks.

Throughout the late 1980's and 90's nitrate concentrations range from 25-41 mg $l^{-1}$ for 36 samples. The average concentration is 32.9 mg $l^{-1}$. This appears to somewhat higher than the general range of values in mid-County Offaly where there is grassland-dominated farming. Nitrate concentrations have never exceeded the EU Drinking Water Directive maximum admissible concentrations (MAC). Two trends appear in the current dataset; from 1989 to early 1997 there was a general increase in concentrations and since May 1997 there has been a decrease in concentrations.

Chloride concentrations range 24-30 mg $l^{-1}$ with an average of 27 mg $l^{-1}$ (12 samples; 1993-98). Chloride is a constituent of organic wastes and levels higher than 25 mg $l^{-1}$ may indicate significant contamination. Concentrations higher than the 30 mg $l^{-1}$ usually indicates significant contamination. Out of the 12 samples all except 3 were above 25 mg $l^{-1}$ and 2 samples recorded concentrations of 30 mg $l^{-1}$.

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 > 0.4. Sodium levels range between 8-10.79 mg $l^{-1}$. Potassium levels range between 3.2-4.12 mg $l^{-1}$. The resulting ratios for 19 samples recorded between 1997 and 1999 have an average of 0.4 and are often above or at 0.4. The high ratios usually indicate contamination from farmyard wastes.

Bacteriological analyses (68 samples; 1993-99) record 21 occurrences of faecal coliforms (31%).

The water quality analyses show that the only parameter to have exceeded EU (MAC) is that of faecal coliforms. Other parameters (nitrates, chlorides, Na:K) including bacteria and coliforms indicate that there is significant (occasionally serious) contamination of the spring water, probably by farmyard wastes. All the drinking water returns analysed are for treated water.

## 7.5 Aquifer Characteristics

The Borrisokane Limestone is regarded as one of the best aquifers in Leinster, however, the data in County Offaly is limited in comparison to data for the Nore Basin area, thus may only indicate aquifer potential. Several large supplies draw water from this aquifer in County Offaly (Daly *et al*, 1998).

The data used in this section are based on test pumping undertaken by GSI at the Kilcormac source in May 2000 (Kelly, 2000). A constant discharge test was run at 545 $m^3$ $d^{-1}$ for 10 hours, with a final drawdown of 11.19 m in the pumping well. This gives a specific capacity of about 40 $m^3$ $d^{-1}$ $m^{-1}$. Comparable specific capacities are reported for boreholes at Tully and Hollimshill that are situated in the same aquifer (Cronin *et al*, 1998 and 1999). Analysis of the test pumping data from this specific 10 hour test gives transmissivity estimates of 20-40 $m^2$ $d^{-1}$. Estimates of the transmissivity for sources in the Borrisokane Formation at Tully and Hollimshill are 13 $m^3$ $d^{-1}$ and 52-530 $m^3$ $d^{-1}$ respectively (Cronin *et al;* 1998, 1999).

The porosity is taken to be approximately 2 %. The modelled permeability is derived to be about 1 m $d^{-1}$.

Vertical fissures and fractures are recorded in the borehole log for the new/upper borehole that indicate zones of higher permeability exist in the bedrock in the area. Occasional clay bands are located in the limestone. A small number of karst features are recorded in the Borrisokane Limestone but are infrequent, thus the degree of karstification would appear to be limited (Daly *et al*, 1998).

## 7.6 Conceptual Model

- The shallow large diameter well abstracts groundwater up to 176 $m^3$ $d^{-1}$ and is located next to a sharp kink of a small perennial stream.

- The original spring appears to occurred in this location due a combination of bedrock close to the surface and very flat topography. Fractures in the rock probably allowed groundwater to come to the surface at this point.

- The Borrisokane aquifer (regionally important fissured aquifer) which underlies the source is assumed to feed groundwater to the well.

- There are few drains and surface streams apart from the stream flowing past the well, indicating the free draining nature of the subsoils and the relatively high permeabilities of the bedrock.

- Shallow groundwater with localised short flow paths (north west and west) probably contributes most of the wells water. Deeper groundwater is assumed to flow east to west on a regional scale, discharging mainly to the Silver River and also the stream flowing past the well.

- The water table is close to the surface in the vicinity of the well and is considered to have a relatively flat gradient.

- Groundwater flow is probably confined to fractures, fissures, joints, bedding planes and the uppermost part of the bedrock.

- Diffuse recharge occurs through the sands & gravels and the permeable tills up to 376 mm $yr^{-1}$.

- The eskers appear to sit above the water table thus acting as very free draining ridges of unsaturated subsoil that do not act as either surface or groundwater watersheds.

# 8 Delineation Of Source Protection Areas

## 8.1 Introduction

This section delineates the areas around the spring that are believed to contribute groundwater to the well and that therefore require protection. The areas are delineated based on the conceptualisation of the groundwater flow pattern, as described in Section 7.6 and are presented in Figures 1 and 2.

Two source protection areas are delineated:

♦ Inner Protection Area (SI), designed to give protection from microbial pollution;
♦ Outer Protection Area (SO), encompassing the zone of contribution (ZOC) of the well.

## 8.2 Outer Protection Area

The Outer Protection Area (SO) is bounded by the complete catchment area to the source, i.e. the zone of contribution (ZOC), and is defined as the area required to support an abstraction from long-term recharge. The ZOC is controlled primarily by a) the total discharge, b) the groundwater flow direction and gradient, c) the rock permeability and d) the recharge in the area.

The ZOC for the Ballyboy source is delineated as follows:

1) An estimate of the area size is obtained by using the average recharge and the abstraction rate.
2) The shape of the area is then derived by both numerical modelling (using FLOWPATH) and hydrogeological mapping techniques.
3) To allow for errors in the estimation of groundwater flow direction and to allow for an increase in the ZOC in dry weather, a safety margin is incorporated by assuming a higher abstraction rate than the current rate.

The average abstraction is estimated to be 176 $m^3 d^{-1}$. For the purposes of modelling the source, the average yield is increased by 50% to 264 $m^3 d^{-1}$ for the following reasons:

- The higher yield allows for increased water demand (new houses are being added to the scheme each year).
- Numerical modelling assumes average conditions all year round, i.e., recharge is averaged out over winter and summer, therefore the model does not allow for an increase in the ZOC during dry weather. This is overcome by assuming a higher abstraction rate in the calculations.

Taking the recharge to be 376 mm, the area required to supply a pumping rate of 264 $m^3 d^{-1}$ is calculated to be 0.3 $km^2$. However, this area will increase in dry weather. A more accurate ZOC at

Ballyboy is derived from numerical modelling of the groundwater system together with hydrogeological mapping techniques.

The groundwater regime was modelled successfully for three scenarios; the non-pumping situation, a pumping situation using the current rate and a pumping situation using a rate at 50% greater than the current rate. The defining conditions for the numerical model are discharge, aquifer thickness, permeability and recharge. The source for Kilcormac Water Supply Scheme is within 2 km of the Ballyboy source, located within the same aquifer with similar hydrogeological conditions, thus it was appropriate to model the groundwater regime for both sources together.

The **southern, eastern and western boundaries** are groundwater divides that are derived from both the numerical modelling and the hydrogeological mapping.

The **northern boundary** is defined by the stream that passes the spring. It is assumed that the well does not pump any water from the other side of the river.

### 8.3 Inner Protection Area

According to the National Groundwater Protection Scheme (DELG/EPA/GSI, 1999), delineation of an Inner Protection Area is required to protect the source from microbial and viral contamination and it is based on the 100 day time of travel to the supply. Estimations of the extent of this area cannot be made by hydrogeological mapping and conceptualisation methods alone. Analytical modelling is also used and by using the aquifer parameters for permeability and hydraulic gradient 100 day ToT estimations are made. Using the parameters given in 7.5 groundwater would travel up to 120 m in 100 days. Thus the upgradient extent of the SI zone is 120 m.

# 9 Vulnerability

The distribution of interpreted groundwater vulnerability in the ZOC is presented in Figure 1. All of the land in the area is either highly or extremely vulnerable to contamination due to the general high permeability classification given to the subsoils and to the depth to bedrock generally being between 2 and 5 m. The area around the well has a depth to bedrock of less than 3 m and the subsoil type has a high permeability. This means that groundwater in this area is designated to be 'extremely' vulnerable to contamination. The rest of the area is designated to be 'highly' vulnerable as the depth to rock increases toward the main road to about 5 m. The eskers are considered to be 'highly' vulnerable as they are relatively thick (> 5 m) and the water table is assumed to lie below the base of the eskers.

# 10 Groundwater Protection Zones

The groundwater protection zones are obtained by integrating the two elements of land surface zoning (source protection areas and vulnerability categories) – a possible total of 8 source protection zones. In practice, the source protection zones are obtained by superimposing the vulnerability map on the source protection area map. Each zone is represented by a code e.g. **SI/H**, which represents an Inner Protection area where the groundwater is highly vulnerable to contamination. There are four groundwater protection zones present around the Ballyboy source as shown in Table 2. The final groundwater protection map is presented in Figure 2.

Table 2 Matrix of Source Protection Zones at Ballyboy

| **VULNERABILITY RATING** | **SOURCE PROTECTION** | |
|---|---|---|
| | ***Inner*** | ***Outer*** |
| ***Extreme (E)*** | SI/E | SO/E |
| ***High (H)*** | SI/H | SO/H |
| ***Moderate (M)*** | | |
| ***Low (L)*** | | |

## 11 Potential Pollution Sources

Land use in the area is described in Section 5. The land near the source is largely grassland-dominated and is primarily used for grazing. Agricultural activities, septic tanks and the main road are the principal hazards in the area. The main potential sources of pollution within the ZOC are farmyards, septic tank systems, runoff from the roads, leaky sewers and landspreading of organic fertilisers. The main potential pollutants are faecal bacteria, viruses, and cryptosporidium.

## 12 Conclusions and Recommendations

- The area around the supply is either extremely or highly vulnerable to contamination.

- Septic tanks, farmyards, landspreading and runoff from the roads pose a threat to the water quality in the well.

- It is recommended that:

1) a full raw water analysis should be carried out on a regular basis at the source.
2) particular care should be taken when assessing the location of any activities or developments which might cause contamination at the well.
3) the potential hazards in the ZOC should be located and assessed.

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

## 13 References

Cronin, C. and Daly, D., 1999. *An Assessment of the Quality of Public and Group Scheme Groundwater Supplies in County Offaly*. Geological Survey Report, 30 pp.

Daly, D., Cronin, C., Coxon, C. and Burns, S.J., 1998. *County Offaly Groundwater Protection Scheme*. Geological Survey Report for Offaly County Council, 60 pp.

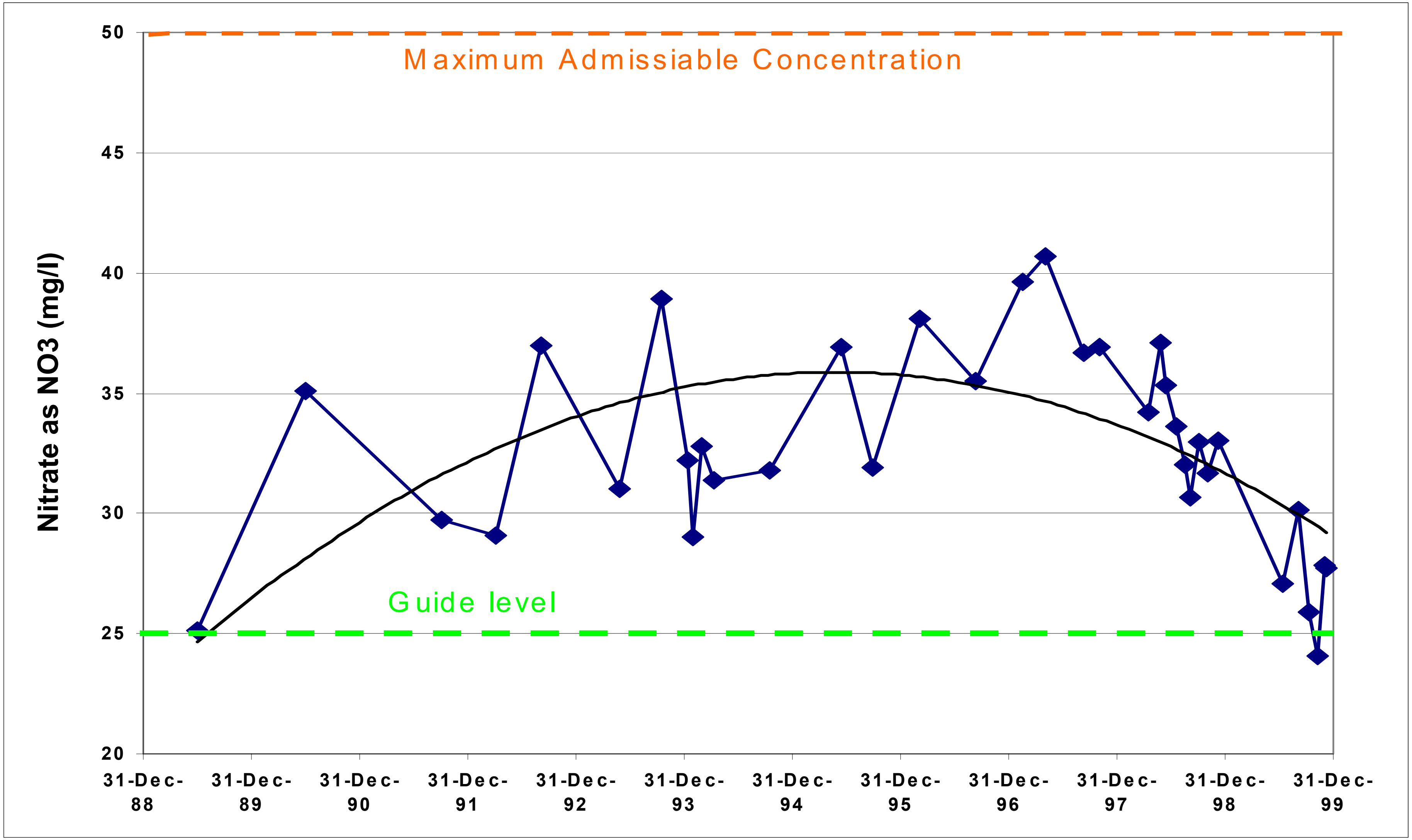
Kelly, C., 2000. *Kilcormac Water Supply Scheme. Groundwater Source Protection Zones*. Geological Survey Report for Offaly County Council, 15 pp.

## Appendix 1 Geological Logs of the Auger Boreholes.

All borehole depths are maximum depths drilled by the auger. The depths are the depth at which the auger would not go any further. It assumed that the auger has reached bedrock, the evidence being that in most cases floured bedrock is recovered on the teeth of the auger.

| Borehole No. | GSI No. | Grid Ref. | Depth | BS5930 | Permeability |
|---|---|---|---|---|---|
| Kilcormac 1 | 17 | N1905 1500 | 0-6.0 | Sandy SILT with clay | Moderate |
| Kilcormac 2 | 18 | N1905 1450 | 0-2.0 | Silty SAND | High |
| | | | 2.0-7.30 | GRAVEL with sand and silt | High |
| Kilcormac 3 | 19 | N1950 1520 | 0-6.5 | Sandy SILT with clay | Moderate |
| Kilcormac 4 | 20 | N1980 1565 | 0-1.0 | Sandy CLAY with silt | Low |
| | | | 1.0-2.0 | Silty SAND with Gravel | High |
| Kilcormac 5 | 21 | N2010 1520 | 0-4.0 | Silty SAND with Gravel | High |
| | | | 4.0-5.0 | Sandy SILT with clay | Moderate |
| Kilcormac 6 | 22 | N2040 1480 | 0-1.5 | SILT with clay | Moderate |
| | | | 1.5-2.60 | Clayey SAND with gravel | High |
| Kilcormac 7 | 23 | N1920 1370 | 0-4.0 | Clayey SAND with frequent small stones | High |
| | | | 4.0-6.0 | SILT with gravel (small angular stone) | High |

**Appendix 2 Graph of Nitrate concentrations at Ballyboy**



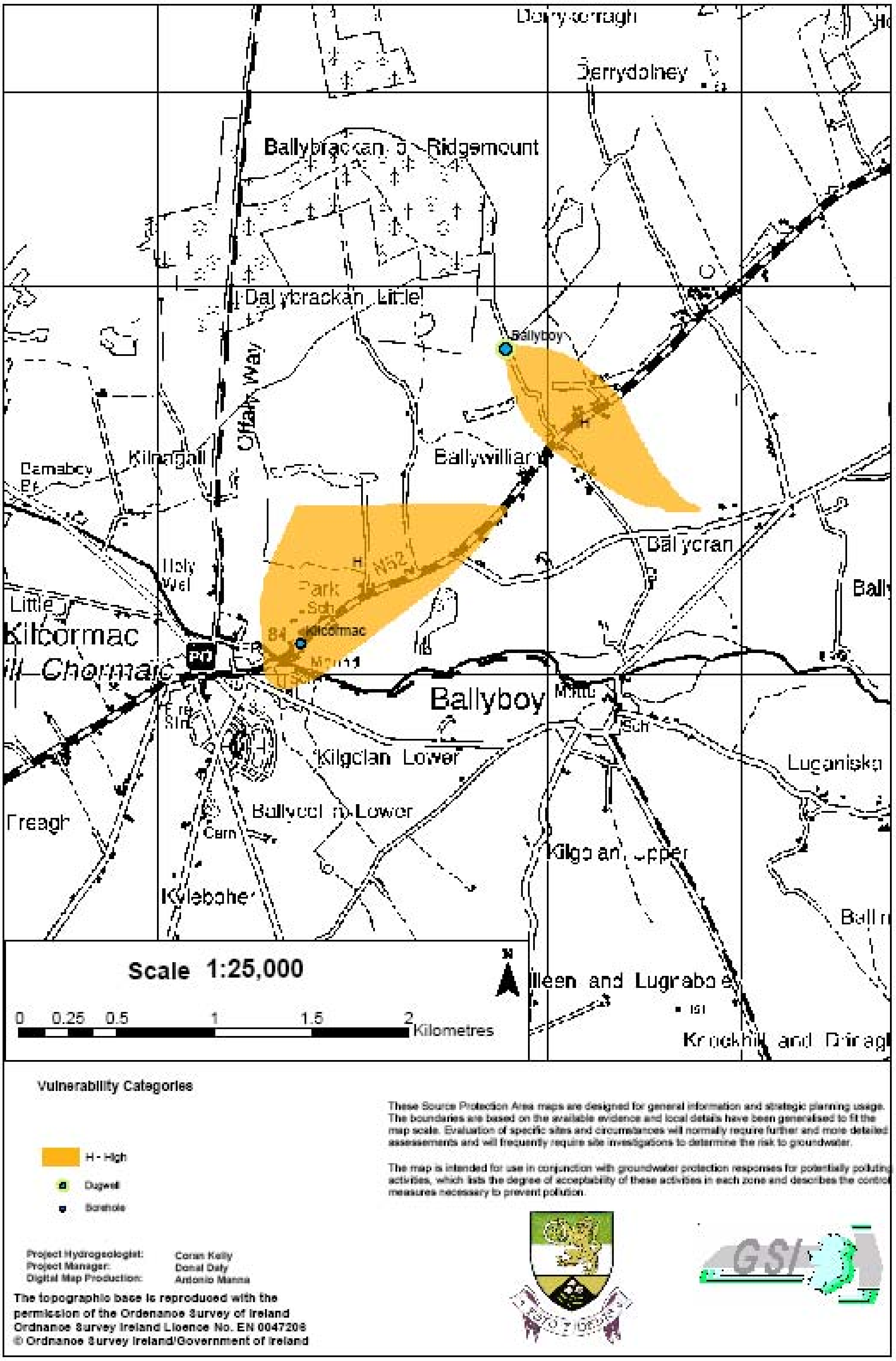



Figure 1 **Groundwater Vulnerability around Ballyboy**

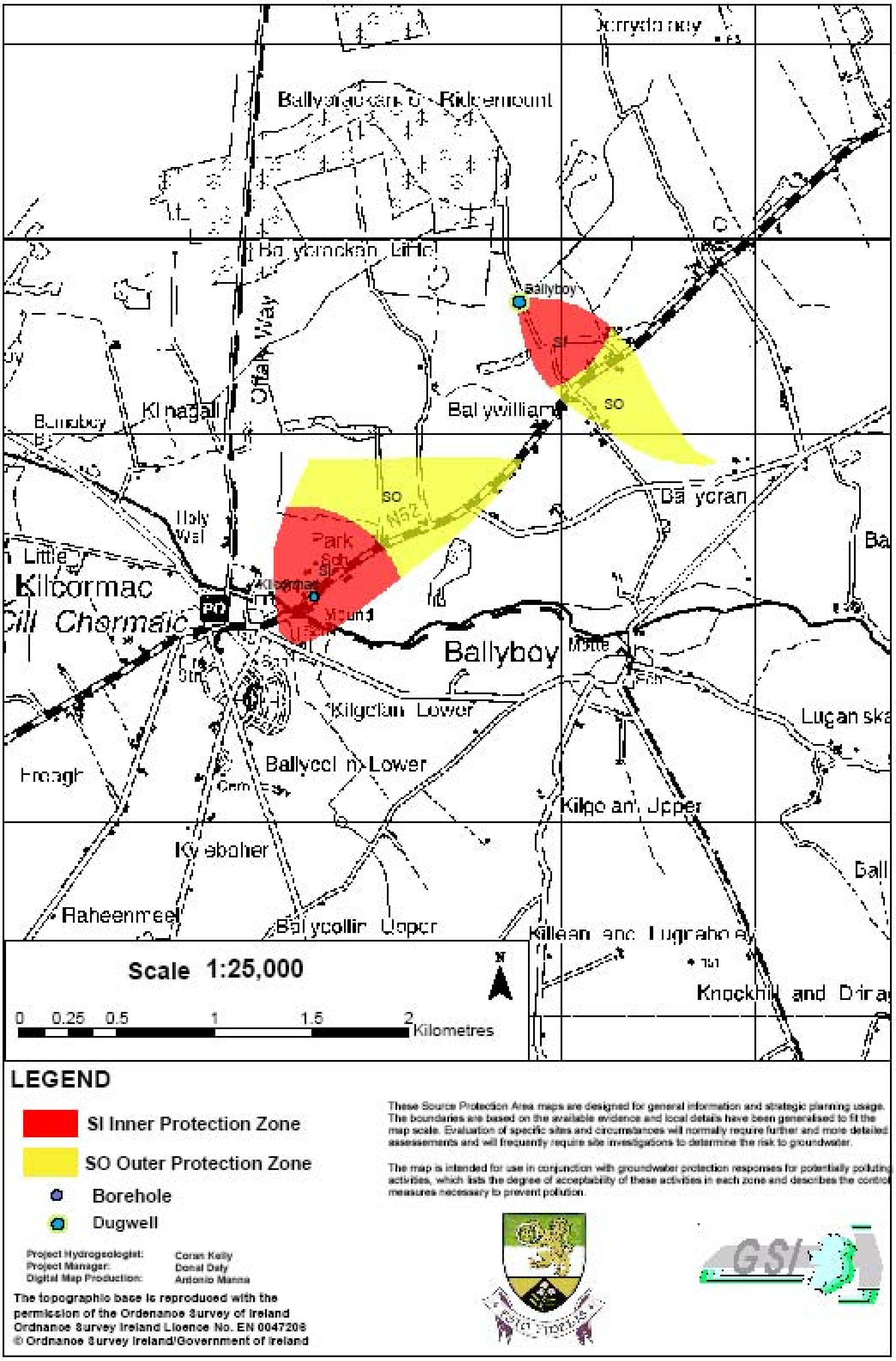



Figure 2 **Groundwater Source Protection Areas for Ballyboy**

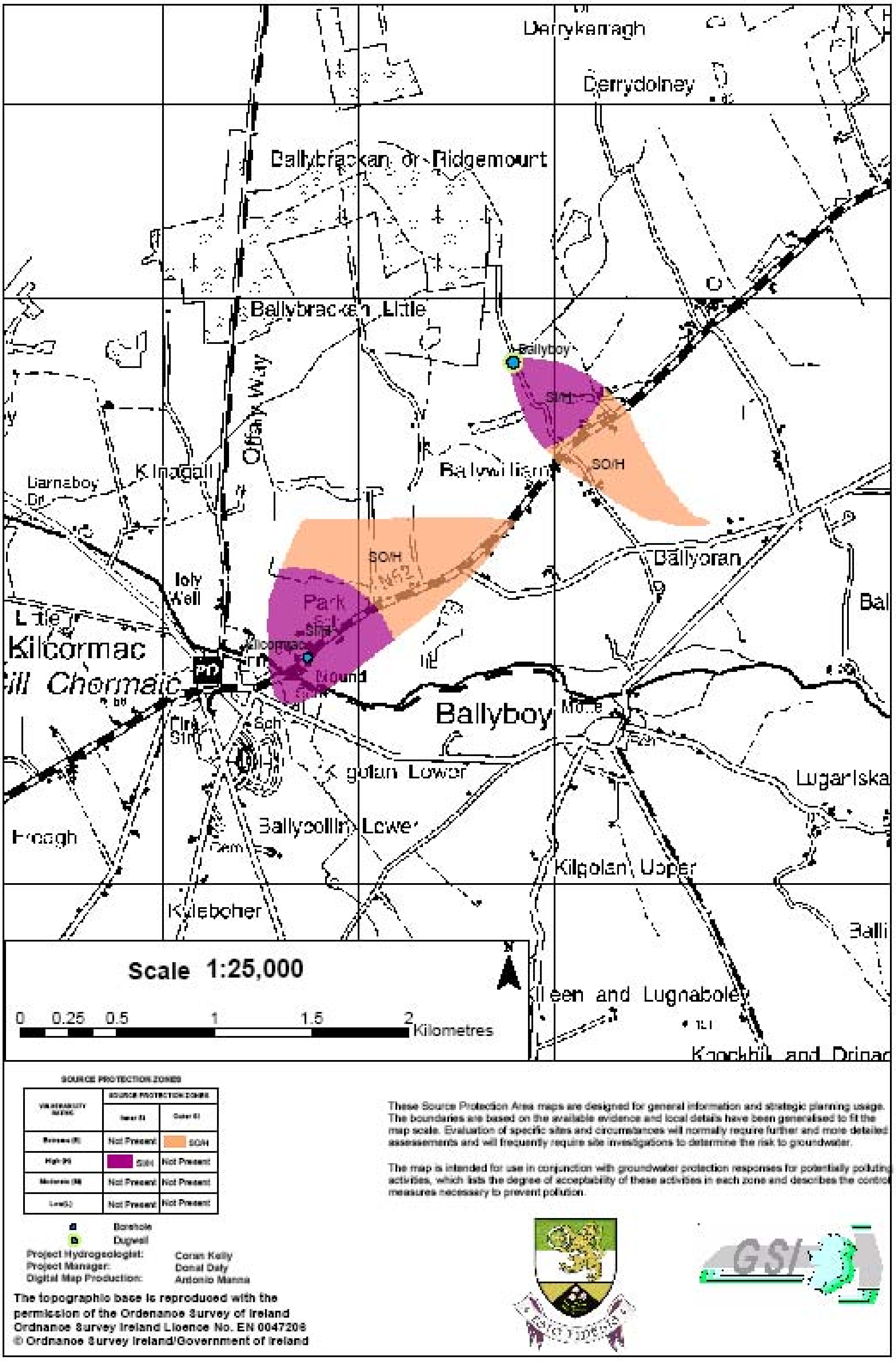



Figure 3 **Groundwater Source Protection Zones for Ballyboy**