# Conna
# Water Supply Scheme
# (village bore)

# Groundwater Source Protection Zones

(Draft August 2000)

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

***In collaboration with:***
Cork County Council (Northern Division)

1 INTRODUCTION ... 1
2 LOCATION, SITE DESCRIPTION AND WELL HEAD PROTECTION ... 1
3 SUMMARY OF BOREHOLE DETAILS ... 1
4 METHODOLOGY ... 1
4.1 DESK STUDY ... 1
4.2 SITE VISITS AND FIELDWORK ... 1
4.3 ASSESSMENT ... 2
5 TOPOGRAPHY, SURFACE HYDROLOGY AND LAND USE ... 2
6 GEOLOGY ... 2
6.1 INTRODUCTION ... 2
6.2 BEDROCK GEOLOGY ... 2
*6.2.1 Structure* ... 3
6.3 SUBSOIL (QUATERNARY) GEOLOGY ... 3
*6.3.1 River Alluvium* ... 3
*6.3.2 Till (Boulder Clay)* ... 3
*6.3.3 Depth to Bedrock* ... 3
7 HYDROGEOLOGY ... 3
7.1 INTRODUCTION ... 3
7.2 RAINFALL, EVAPORATION AND RECHARGE ... 4
7.3 GROUNDWATER LEVELS, FLOW DIRECTIONS AND GRADIENTS ... 4
7.4 AQUIFER CHARACTERISTICS ... 5
7.5 HYDROCHEMISTRY AND WATER QUALITY ... 6
7.6 CONCEPTUAL MODEL ... 7
8 DELINEATION OF SOURCE PROTECTION AREAS ... 7
8.1 INTRODUCTION ... 7
8.2 OUTER PROTECTION AREA ... 7
8.3 INNER PROTECTION AREA ... 8
9 GROUNDWATER VULNERABILITY ... 9
10 GROUNDWATER PROTECTION ZONES ... 9
11 POTENTIAL POLLUTION SOURCES ... 10
12 CONCLUSIONS AND RECOMMENDATIONS ... 10
13 REFERENCES ... 10
APPENDIX 1 GEOLOGICAL LOGS OF THE AUGER BOREHOLES. ... 12
APPENDIX 2 HYDROCHEMICAL ANALYSES FOR CONNA VILLAGE BOREHOLE. ... 13
APPENDIX 3 GRAPH OF NITRATE LEVELS AT CONNA VILLAGE BOREHOLE. ... 14

FIGURE 1 GROUNDWATER VULNERABILITY AROUND CONNA BOREHOLE ... 15
FIGURE 2 GROUNDWATER SOURCE PROTECTION AREAS FOR CONNA BOREHOLE ... 16
FIGURE 3 GROUNDWATER SOURCE PROTECTION ZONES FOR CONNA BOREHOLE ... 17

List of Tables

TABLE 1 THE GEOLOGY OF THE CONNA AREA (AFTER SLEEMAN, A.G, 1995; TRAYNER, P., 1985). ... 2
TABLE 2 MATRIX OF SOURCE PROTECTION ZONES AT CONNA. ... 9

# 1 Introduction

A borehole on the outskirts of Conna village ("Conna village borehole") and a spring in Kilclare are used to supply the scheme. Recent reclamation of land around the spring have disrupted the flow from the spring and it no longer feeds water to the scheme (Summer 2000). An old borehole at the creamery in the village is currently being tested and prepared for augmenting the scheme. The "village borehole" was commissioned in 1996. It feeds directly into the main distribution system 'bypassing' a reservoir situated to the south of the village.

The objectives of the report are as follows:

- To delineate source protection zones for the borehole.
- To outline the principal hydrogeological characteristics of the Conna area.
- To assist Cork County Council (Northern Division) in protecting the water supply from contamination.

# 2 Location, Site Description and Well Head Protection

Conna village borehole is about 600 m to the west of the village behind an old farmhouse. The borehole is located inside a small concrete bunker next to the pumphouse situated inside a fenced area of 25 $m^2$. The ground in the site is covered in limestone chippings. The bunker is covered by a wooden manhole that is padlocked. It is recommended that this manhole is provided with a galvanised cover.

# 3 Summary of Borehole Details

| | | |
|---|---|---|
| Grid reference | : | $R^1 9185\ ^0 9330$ |
| Townland | : | Conna |
| Well type | : | Borehole |
| Owner | : | Cork County Council (Northern Division) |
| Elevation (ground level) | : | ~26 m OD (~ 85 ft) |
| Depth of borehole | : | ~30 m (100 ft) |
| Diameter of borehole | : | 20 cm (8 inches) |
| Depth to rock | : | 10.7 m |
| Static water level | : | 22.34 m OD. 3.66 m bg on 13/7/99. |
| Normal consumption | : | 200 $m^3\ d^{-1}$ (44,000 gallons per day) |

# 4 Methodology

## 4.1 Desk Study

Details about the borehole such as elevation, and abstraction figures were obtained from County Council personnel; geological and hydrogeological information was provided by the GSI.

## 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.

## 5 Topography, Surface Hydrology and Land Use

The borehole is located in the Bride River valley, on the south side of the river. The area on both sides of the river is quite flat. To the south of the borehole the land rises steeply to a height of about 110 m. The River Bride is the main surface water feature in the area flowing eastwards. A small tributary of the Bride flows northwards about 35 m west of the borehole. Apart from this small tributary the land is free draining and there are no other streams or drains in the area. The land is primarily used for agricultural purposes, mainly pasture. There are a few houses and farms within 500-700 m of the borehole. A secondary road passes about 200 m south of the borehole.

## 6 Geology

### 6.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the borehole. 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:

- Bedrock Geology 1:100,000 Map Series, Sheet 22, East Cork-Waterford. Geological Survey of Ireland. (Sleeman, A.G., *et al*, 1995).
- Trayner, P., 1985. The stratigraphy and structure of parts of east County Cork and west county Waterford. Unpublished Ph.D. thesis, Nat. Univ. Ireland.
- Information from geological mapping in the nineteenth century (on record at the GSI).

Subsoils information was gathered from drilling that was undertaken by GSI personnel to investigate the subsoils of the area.

### 6.2 Bedrock Geology

The rocks are the result of sediments deposited during Devonian and Carboniferous times (over 300 million years ago); the rocks have subsequently been folded and faulted. Table 1 summarises the bedrock geology in the area. The geology is illustrated in Figure 1.

Table 1 The Geology of the Conna area (after Sleeman, A.G, 1995; Trayner, P., 1985).

| *Name of Rock Formation* | *Rock Material* | *Occurrence* |
|---|---|---|
| Waulsortian Formation | Pale grey, massive LIMESTONE. | Underlies the source and the River Bride valley bottom. |
| Lower Limestone Shale Group (locally the Aghern Formation) | Brown-grey SANDSTONES and SILTSTONES about 260-320 m thick | Occurs as a narrow band about 250 m south of the source. |
| Gyleen Formation | Green, red, brown SANDSTONES and MUDSTONES about 400-530 m thick. | Occurs 530-550 m to the south of the source. |

| | | |
|---|---|---|
| Ballytrasna Formation | Red/purple MUDSTONE with some red fine-medium grained SANDSTONE. | Most of the high ground to the south of the source comprises this rock unit. |

#### 6.2.1 Structure
The succession outlined in Table 1 has been deformed during a 'mountain building event', known as the Variscan Orogeny. The rocks were compressed from north and south to produce an east-west trend to the current rock distribution, occurring in the Tallow Syncline (Sleeman, A.G. *et al,* 1995).
Two major fault sets are widespread across the region; east-west trending (strike faults) and north-south trending (cross faults). There are several north-south faults cutting across the rock units in the Conna area. These are illustrated in Figure 1. One of the north-south faults is mapped as lying about 100 m east of the borehole, offsetting the rock units by 50-100 m.

### 6.3 Subsoil (Quaternary) Geology
The subsoils comprise a mixture of coarse and fine-grained materials, namely: alluvium and till. The locations of the auger holes are given in Figure 2 and the logs are given in Appendix 1. The characteristics of each category are described briefly below:

#### 6.3.1 River Alluvium
This material occupies the land on either side of the river. It consists of SILT with clay. Auger Hole No. 3. was drilled to investigate the thickness of the alluvium, however no alluvium was met. It is probably limited to the flood plains along the river.

#### 6.3.2 Till (Boulder Clay)
Till is the dominant subsoil type in the area. 'Till' is an unsorted mixture of coarse and fine materials laid down by ice. Angular to subrounded purple sandstone and limestone fragments are present in the till. Sandstone fragments are far more dominant in the till toward the south over the sandstone rock units. Limestone fragments tend to dominate in the till overlying the limestone rock unit. The till description varies from silty SAND with frequent/abundant gravels to sandy SILT with clay and frequent/abundant gravels. There are occasional angular GRAVELS as seen in Auger Hole No. 3.

#### 6.3.3 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 depth to bedrock is variable ranging 0-14 m.

## 7 Hydrogeology

### 7.1 Introduction
This section presents our current understanding of groundwater flow in the area of the borehole.

Hydrogeological and hydrochemical information for this study was obtained from the following sources:
- Hydrogeological mapping carried out by GSI.

- A drilling programme carried out by GSI to ascertain depth to bedrock and subsoil permeability.
- GSI files and archival Cork County Council data.
- Cork County Council drinking water returns.

### 7.2 Rainfall, Evaporation 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 an 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 it will dictate the size of the zone of contribution to the source.

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

- Annual rainfall: 1034 mm (data from Met Éireann).
- Annual evapotranspiration losses: 434 mm. Potential evapotranspiration (P.E.) is estimated to be 457 mm $yr.^{-1}$ (based on data from Met Éireann). Actual evapotranspiration (A.E.) is then estimated as 95 % of P.E.
- Potential recharge: 600 mm $yr.^{-1}$. This figure 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 runoff.
- Annual runoff losses: 300 mm. This estimation is based on the assumption that 50% of the potential recharge will be lost to overland flow and shallow soil quickflow prior to reaching the main groundwater system. The steep slopes indicate that runoff is probably quite high in the catchment with a large proportion of the recharge leaving the catchment via the stream that flows past the borehole

These calculations are summarised as follows:

| | |
|---|---|
| Average annual rainfall (R) | 1034 mm |
| Estimated A.E. | 434 mm |
| Potential Recharge (R – A.E.) | 600 mm |
| Runoff losses | 300 mm |
| Estimated Actual Recharge | 300 mm |

### 7.3 Groundwater levels, Flow Directions and Gradients

The water table in the area is generally assumed to reflect topography, with groundwater flowing from the sub-catchment watersheds and discharging into the Bride River. As high permeability material overlies the bedrock it is assumed that the groundwater is unconfined and that the stream and river are in full hydraulic connection with the groundwater. It is assumed that the water level in the stream that joins the Bride River and the level in the River Bride represent true groundwater levels. Several of the auger holes around the source indicate that the water table in the low-lying area sits above the bedrock in the permeable till.

The static water level in the production borehole was 3.66 m below ground level on 13/7/1999. The water table is assumed to roughly follow the topography, i.e., slopes northwards toward the River Bride, discharging both to the tributary and to the River Bride itself. It is assumed that the southern watershed (the ridge occurring in Monagoun and Killavarilly) provides the dominant driving head. As low permeability rocks underlie the southern watershed it is likely that the surface watershed is coincident with the groundwater divide.

Groundwater gradients vary over the different bedrock units and with topography. The gradient is estimated from the intersection of topographic contours along the stream. Where the topography is quite steep (south of the main road into Conna and over the Limestone Shale Group) the gradient is steep – 0.06. Over the Waulsortian and where the topography is relatively flat the gradient is estimated to be 0.01-0.03.

## 7.4 Aquifer Characteristics

In general the land is relatively free draining apart from the tributary that flows north past the source to the River Bride. The stream probably coincides with the main fault in the area. The stream suggests that the rock units have relatively low permeabilities. It is likely that this fault and other similar faults provide the means for the groundwater to flow through the sandstones, mudstones and siltstones. It is likely that a considerable quantity of the groundwater and surface water leave the catchment via the stream. The stream dries up in very dry weather, usually in the summer months. The aquifer characteristics of the sandstones, mudstones and siltstones are generally poorer than the limestones in the area. The source is located in the Waulsortian rock unit, however considering the structure, hydrochemistry, groundwater flow directions and gradients it is likely that there is an input from the other rock units upgradient of the source. Thus the aquifer characteristics are described for all the rock units in the area.

The Ballytrasna Formation is generally considered to have poor aquifer qualities and yields are generally low. In South Cork and Co. Waterford it is considered to be a **locally important aquifer, moderately productive only in Local Zones (Ll)**. The permeabilities are likely to be low, depending primarily on fractures and joints, ranging from 0.3-0.5 m $d^{-1}$ (Data from Co. Waterford). Porosity is considered to be about 0.01.

The Gyleen Formation is considered to be a **locally important aquifer, moderately productive only in local zones** (**Ll**). Permeability is considered to be about 2 m $d^{-1}$ and the porosity to be about 0.025 (Data from Co. Waterford).

In Co. Waterford the Lower Limestone Shale Group is classified as a **locally important aquifer, moderately productive only in local zones** (**Ll**), and in South Cork is considered a **poor aquifer which is generally unproductive except for local zones (Pl)**. This rock unit is undifferentiated in North Cork and there are no well data in the Conna area. The lithology is roughly similar to the Gyleen Formation, therefore, the aquifer characteristics are also likely to be similar, thus permeability and porosity are assumed to be equivalent to those of the Gyleen Formation. It is classed as a **locally important aquifer, moderately productive only in local zones** (**Ll**).

The Waulsortian Limestone Formation is considered to be a **regionally important karstified[1] aquifer (Rk)**. Aquifer properties vary widely across the Munster area, generally

[1] Karstification is the process whereby limestones are slowly dissolved away by acidic waters moving through them. This most often occurs in the upper bedrock layers and along some of the pre-existing fissures and fractures in the rocks, which become slowly enlarged. One of the consequences of karstification is the development of an uneven distribution of

very productive, recording very high well yields and specific capacities. A swallow hole at Aghern provides evidence of karstification in the Conna area. In 1979 a tracing test was carried out by the G.S.I. at a sinkhole/swallow hole in Aghern. A spring 1.1 km to the southeast of the swallow hole showed a positive trace within 11 hours, indicating velocities of about 100 m $hr^{-1}$. Test pumping at Downing Bridge and Moorepark suggests transmissivities ranging 15-3400 $m^2$ $d^{-1}$, permeabilities ranging 10-200 m $d^{-1}$. (Motherway, 1999). The porosity is considered to be about 0.025.

Groundwater flow is likely to occur in three main hydrogeological regimes within the limestone aquifer:

- An upper, shallow, highly karstified weathered zone, known as the epikarst, in which groundwater moves quickly, through solutionally enlarged conduits, in rapid response to recharge;
- A deeper zone, where groundwater flows through interconnected, solutionally enlarged conduits and cave systems that are controlled by structural deformation.
- A more dispersed slow groundwater flow component in smaller fractures and joints outside the main conduit systems.

### 7.5 Hydrochemistry and Water Quality

The hydrochemical analyses show that the water is moderately hard to hard, with total hardness values of 222-303 mg $l^{-1}$ (equivalent $CaCO_3$) and electrical conductivity values of 494-636 µS $cm^{-1}$, indicating that the groundwater has a hydrochemical signature of calcium bicarbonate type water. These values are indicative of groundwater from limestone rocks, however, they are 'softer' than analyses for other areas in North Cork, for example at Castletownroche hardness values range from 316-331 mg $l^{-1}$ and at Kildorrery values range 327-344 mg $l^{-1}$. This is probably due to the input of groundwater from the sandstone and siltstone rock units to the south of the borehole. The analyses are given in Appendix 2.

Nitrate concentrations range 18-53 mg $l^{-1}$ (15 samples; 1993-1999), average 40 mg $l^{-1}$. Nitrate concentrations have exceeded the EU Drinking Water Directive maximum admissible concentration (MAC) on two occasions (September 1998, August 1999) and approached the limit in August 1996 and 1997 with concentrations of 49.8 mg $l^{-1}$ on both dates. The trend is increasing, as illustrated in the graph in Appendix 3. The data appear to show higher values in summer, lower values in winter, possibly caused by winter recharge diluting the concentrations. It suggests either (a) the aquifer is generally high in $NO_3$, and winter rain dilutes the concentration or (b) summer applications of fertiliser and slurry push the concentrations upward. For the Conna village 'mixed supply' there have been exceedances of the EU MAC on several occasions: (April '96, July '96, June '98, Sept. '98, July '99 and August '99). Similar trends are observed for the mixed supply but there are more exceedances. This is likely to be due to the input from the spring source, that is no longer providing an input to the system (Summer 2000).

Chloride concentrations range 14-25 mg $l^{-1}$ (8 samples; 1993-1999), average 22 mg $l^{-1}$. Chloride is a constituent of organic wastes and levels higher than 25 mg $l^{-1}$ may indicate significant contamination (in North Cork), however, this would not be true for coastal areas. These chloride concentrations appear not to indicate significant contamination.

---

permeability which results from the enlargement of certain fissures at the expense of others and the concentration of water flow into these high permeability zones (Deakin *et al*, 1998).

Potassium levels range between 1.9-5.8 mg $l^{-1}$. In December 1997 and January 1998 the levels were 5.3 and 5.8 mg $l^{-1}$. These values suggest contamination by an organic waste source. The ratio of potassium to sodium (K:Na) may indicate contamination if the ratio is > 0.4. The average ratio is 0.3 and in December 1997 and January 1999 the ratio is 0.5 resulting from the higher potassium figures on those dates. However, chloride and nitrate on those dates are inside the range of values for these parameters.

Monitoring of **raw** water analyses (6 samples) record the presence of total coliforms (5 out of 6) and faecal coliforms (4 out of 6). The borehole water was also sampled for cryptosporidium and giardia, using customised equipment provided by Inniscarra Laboratory. Subsequent analysis by City Analysts found the samples to be negative for both cryptosporidium and giardia.

Faecal coliforms, total coliforms and nitrates are the only parameters to exceed the EU MAC. Along with the K:Na ratio these parameters indicate contamination from organic wastes, possibly farmyard wastes. The nitrate concentrations are probably a result of landspreading in the area.

### 7.6 Conceptual Model

- Groundwater flow to the well is likely to come from between the southern watershed and the River Bride.
- The borehole is located in the Waulsortian Limestone which is a regionally important karstified aquifer (Rk). The lower permeability rock units to the south of the borehole are poorer aquifers than the Waulsortian, but do provide an input to the source.
- The water table follows topography, flowing northward, discharging both to the stream flowing past the source and to the River Bride. The ridge in Killavarilly and Monagoun 1.5 km to the south of the source, provides the groundwater head for water to flow toward the source.
- The groundwater gradients are estimated to be 0.06 over the lower permeability rocks and 0.01-0.03 within the limestone.
- North-south fractures, joints and the upper weathered zone are likely to facilitate groundwater movement through the low permeability rocks. The stream path over the sandstone rock units probably coincides with a north-south fault that focuses groundwater and surface water to flow along this route.
- Moderately permeable till sits on top of the rock units, therefore it is assumed that the groundwater is unconfined and in full hydraulic connection with the stream and the River Bride.

## 8 Delineation of Source Protection Areas

### 8.1 Introduction

This section delineates the areas around the source that are believed to contribute groundwater to it, and that therefore require protection. The areas are delineated based on the conceptualisation of the groundwater flow pattern, and are presented in Figures 2 and 3.

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 borehole.

### 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)**, which 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 shape and boundaries of the ZOC were determined using hydrogeological mapping, water balance estimations and the conceptual model and are shown in Figure 1. The ZOC catchment boundaries are discussed as follows:

The **Southern Boundary** is defined using topography and is well constrained. An east-west trending ridge occurs 1.5 km from the source in the townland of Killavarilly and Monagoun. The ridge marks a watershed divide, streams flowing to the south and north on either side of the ridge. It is assumed that the ridge also defines a groundwater divide. Considering that there are low permeability rocks underlying the ridge this is a reasonable assumption.
The **Eastern Boundary** is defined using topography. The stream complicates the delineation of the boundary. As it dries up in dry weather and the pumping water level in the borehole is lower than the stream bed the borehole can draw water from the other side of the stream or from the stream itself, therefore the boundary needs to include the area to the east of the stream that can contribute groundwater to the stream.
The **Western boundary** is delineated using a topographical ridge in Kilclare Upper. It is considered that flow to the west of this boundary flows directly to the River Bride. Flow to the east of the ridge may flow to the borehole or to the River Bride.
The **Northern Boundary** is defined using semi-analytical methods. The maximum down gradient extent of the ZOC was estimated using a discharge rate 50% greater than the current abstraction rate, a gradient of 0.01, porosity of 0.025 and an aquifer thickness of about 20 m. It is estimated to be about 20 m downgradient of the well.

The area delineated by the boundaries described above is about 1 km$^2$. The area needed to provide water to the source is estimated using a water balance. The water balance uses the average recharge and average abstraction figures + 50% to determine the area. This is calculated to be about 0.4 km$^2$, which is considerably less than the area delineated using the above boundaries. However the stream that flows past the source is likely to transmit most of the water within the ZOC to the River Bride, particularly during the winter months. However groundwater within the ZOC may flow to the well and therefore the entire ZOC must be considered.

## 8.3 Inner Protection Area

According to "Groundwater Protection Schemes" (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 (ToT) to the supply. Estimations of the extent of this area are made by hydrogeological mapping and analytical modelling.
Up-gradient of the well the Waulsortian Limestone Formation extends about 130 m south. Assuming permeability to be in the range of 10-200 m d$^{-1}$ and the porosity to be about 0.025, velocities are estimated to range 4-2500 m d$^{-1}$. Therefore any water reaching the Waulsortian rock unit would reach the well between a couple of hours and 33 days. Velocities within the Lower Limestone Shale and Gyleen rock units are estimated to be about 5 m d$^{-1}$, giving a 100-day ToT of 500 m. To be conservative the inner zone is taken to 500 m from the geological contact between the Waulsortian and the Lower Limestone Shale, i.e., assumes that groundwater can reach the well in less than one day of reaching the Waulsortian.

## 9 Groundwater Vulnerability

Vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities and depends on the thickness, type and permeability of the subsoils. A detailed description of the vulnerability categories can be found in the Groundwater Protection Schemes document (DELG/EPA/GSI, 1999).

Outcrop, areas of shallow rock, auger holes, and topography are used to contour depth to rock that are used along with the permeability classifications to develop the vulnerability zones. An average buffer of 100 m is used around areas of outcrop to produce a 3 m depth to bedrock contour, i.e., the limit of the 'Extremely' vulnerable zones. This buffer incorporates topography and known points of depth to bedrock and is based on calculations made by measuring the distance along the ground between outcrops and known points of depth to rock. For areas of 'rock close' an average buffer of 140 m is used.

The distribution of interpreted groundwater vulnerability in the ZOC is presented in Figure 2. There are several outcrops and areas with subsoil thickness <3 m, giving rise to a vulnerability classification of 'Extreme' (E) over parts of the area, most of which are on the high sloping ground.

The subsoils comprise glacial till. The till overlying the area is largely considered to have either a moderate or high permeability. This assessment is based on the behavioural characteristics assessed using the British Standard BS5930 in conjunction with the drainage and recharge characteristics. Where the depth to rock <10 m, the vulnerability is 'High' (H) and for areas with depth to rock >10 m and a high permeability the category is also 'High' (H). For one area of moderate permeability and a depth to rock >10 m the vulnerability is 'Moderate' (M).

## 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 5 groundwater protection zones present around the source as shown in Table 2 and presented in Figure 3.

Table 2 Matrix of Source Protection Zones at Conna.

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

## 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 and septic tanks 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 and viruses. Road spillage threatens the water quality at the borehole.

## 12 Conclusions and Recommendations

- The borehole source is located in the Waulsortian Limestone rock unit, which is a **regionally important karstified aquifer (Rk)**.

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

- Septic tanks, farmyards, landspreading and runoff from the road pose a threat to the water quality at the source.

- The protection zones delineated in the report are 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.

- A more definitive understanding of the hydrogeology would require a site investigation that would include drilling, geophysics and flow measurements. Geophysics and drilling would also improve the accuracy of the vulnerability boundaries. Drilling would improve considerably the information on the water table, thus delineation of the boundaries could be improved.

- It is recommended that:

1) Chemical and bacteriological analysis of the **raw** water is carried out on a regular basis.
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.

## 13 References


Deakin, J., Daly, D. and Coxon, C. 1998. *County Limerick Groundwater Protection Scheme*. Geological Survey of Ireland, 61 pp.

DELG/EPA/GSI, 1999. Department of the Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland. *A Scheme for the Protection of Groundwater*. DELG/EPA/GSI report.

Motherway, K., 1999. *A study of nitrate and vulnerability in the Waulsortian Limestone Aquifer of North Cork, Ireland.* Unpublished MSc thesis. University College London.

Sleeman, A. G., Mc Connell, B., Claringbold, K., O' Connor, P., Warren, W.P. and Wright, G. 1995. *A Geological description of East Cork, Waterford and adjoining parts of Tipperary and Limerick to accompany the bedrock geology 1:100,000 scale map series, Sheet 22, East Cork-Waterford.* Geological Survey of Ireland, 66 pp.

Trayner, P., 1985. *The stratigraphy and structure of parts of east County Cork and west County Waterford.* Unpublished PhD thesis. National University of Ireland.

## 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.* | *Grid Ref.* | *Depth (m)* | *BS5930 Description* | *Permeability* |
|---|---|---|---|---|
| 1 | 19179 09312 | 13.5 | 0-2.0 m silty SAND with abundant angular purple sandstones and some limestone fragments. (TILL)<br>2.0-13.5 sandy SILT with abundant more angular fragments (limestone and sandstone) and some clay. (TILL)<br>@10.0 m water strike | MODERATE |
| 2 | 19183 09325 | 9.0 | 0-9.0 silty SAND with angular purple sandstones and limestone fragments | HIGH |
| 3 | 19173 09344 | 8.1 | 0-3.0 silty SAND with abundant angular gravel (sandstone and limestone) (1-5 cm). (TILL)<br>3.0-6.25 Angular silty GRAVEL with sand. (TILL?).<br>6.25-8.1 sandy SILT with clay and frequent sandstone and limestone fragments. (TILL). | HIGH |
| 4 | 19169 09331 | 4.0 | 0-3.5 silty SAND with abundant fragments. (TILL).<br>3.5-4.0 sandy SILT with abundant fragments. (TILL). | HIGH |
| 5 | 19134 09213 | 4.5 | Silty SAND with abundant sandstone angular fragments (1 cm). (TILL). | HIGH |
| 6 | 19180 09341 | 10.7 | Silty SAND with abundant angular to subrounded limestone and occasional sandstone fragments. (TILL)<br>@6.0 m water strike. | HIGH |

## Appendix 2 Hydrochemical Analyses for Conna Village Borehole.

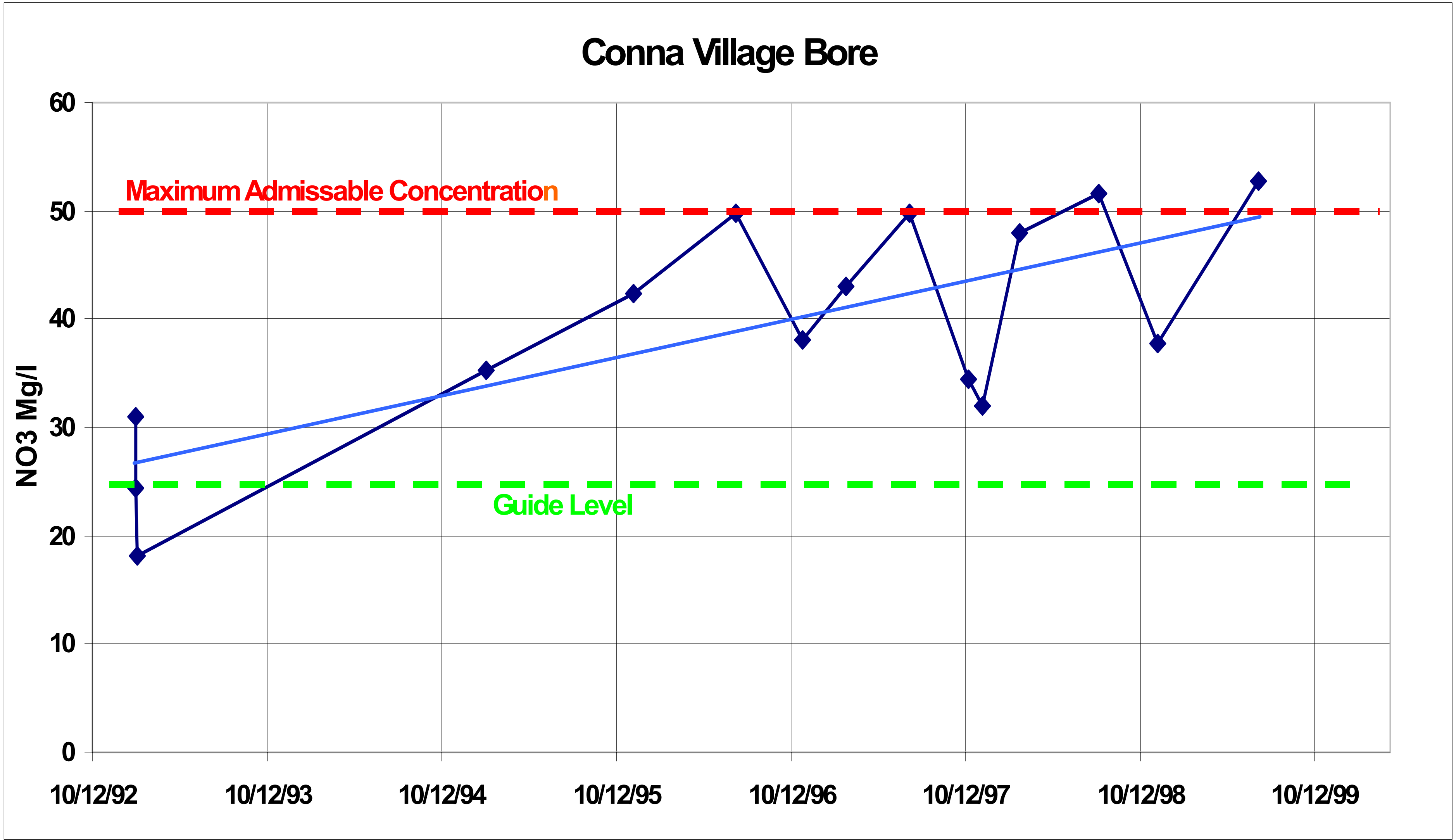
| Parameter | 10/3/93* | 11/3/93* | 15/3/93* | 14/3/95* | Aug96** | Dec96** | Aug97** | Dec97** | Sept98** | Jan99** | 15/7/99 | Aug99** | Feb00 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Conductivity ($\mu$S/cm) | 575 | 585 | 494 | 532 | 620 | 608 | 626 | 597 | 625 | 580 | 560 | 636 | |
| Temperature (°C) | 10 | 10 | 10 | 8.0 | - | - | - | - | - | - | | - | |
| pH | 7.01 | 7.03 | 7.01 | 7.4 | 7.4 | 7.54 | 7.65 | 7.91 | 7.4 | 7.3 | 7.4 | 7.2 | |
| Total Hardness (mg $l^{-1}$ $CaCO_3$) | 256 | 222 | 269 | 255 | 289 | 277 | 314 | 303 | 263 | 270 | 297 | 292 | |
| Total Alkalinity (mg $l^{-1}$ $CaCO_3$) | 212 | 217 | 228 | 249 | 234 | 228 | 225 | 232 | 226 | 221 | 236 | 223 | |
| Calcium | - | - | - | - | 105.9 | 100 | 116 | 111 | 96.5 | 97.6 | 109 | 108 | |
| Magnesium | - | - | - | - | 5.82 | 6.27 | 6.01 | 6.34 | 5.35 | 6.16 | 6.1 | 5.48 | |
| Chloride | - | - | - | 24 | 24.8 | 22.9 | 23.8 | 22.8 | 14.4 | 22.3 | 21.2 | 23.5 | |
| Sulphate | - | - | - | 16 | 16.5 | 15.8 | 16.7 | 16.8 | 16.9 | 16.5 | 16.1 | 16.6 | |
| Sodium | - | - | - | - | 10.2 | 10.7 | 10.7 | 11.2 | 10.3 | 11.0 | 10.3 | 10.9 | |
| Potassium | - | - | - | - | 1.87 | 3.67 | 2.89 | 5.82 | 2.07 | 5.26 | 2.1 | 2.0 | |
| Aluminium | - | - | - | 0.04 | - | - | - | - | - | - | | - | |
| Ammonium | - | - | - | 0.01 | - | - | - | - | - | - | <0.026 | - | |
| Nitrate (as $NO_3$) | 31.01 | 24.4 | 18.2 | 35.2 | 49.8 | 42.4 | 49.8 | 34.5 | 51.6 | 37.7 | 51.3 | 52.8 | |
| Nickel | - | - | - | 0.05 | - | - | - | - | - | - | | - | |
| Cadmium | - | - | - | 0.003 | - | - | - | - | - | - | | - | |
| Chromium | - | - | - | 0.01 | - | - | - | - | - | - | | - | |
| Copper | - | - | - | 0.80 | - | - | - | - | - | - | <0.04 | <0.05 | |
| Iron | - | - | - | 0.10 | - | - | - | - | - | - | <0.1 | <0.1 | |
| Manganese | - | - | - | 0.025 | - | - | - | - | - | - | <0.05 | <.02 | |
| Zinc | - | - | - | - | - | - | - | - | - | - | <0.05 | 0.4 | |
| O-PO4-P | - | - | - | - | <0.005 | 0.007 | 0.010 | - | <0.005 | 0.016 | | 0.022 | |
| Total Coliforms per 100 ml | 10 | 1 | 13 | 0 | - | - | - | - | - | - | 8 | - | 1 |
| Faecal Coliforms per 100 ml. | 7 | 2 | 7 | 0 | - | - | - | - | - | - | 3 | - | 0 |

*Cork County Council data

**EPA Groundwater (Raw) data for Conna Village Bore

Additional Nitrate data taken from Cork County Council Nitrate monitoring programme.

| Date | 2/1/97 | 2/4/97 | Jan98 | 1/4/98 |
|---|---|---|---|---|
| Nitrate (as $NO_3$) | 38 | 43 | 32 | 48 |




**Appendix 3 Graph of nitrate levels at Conna Village Borehole.**

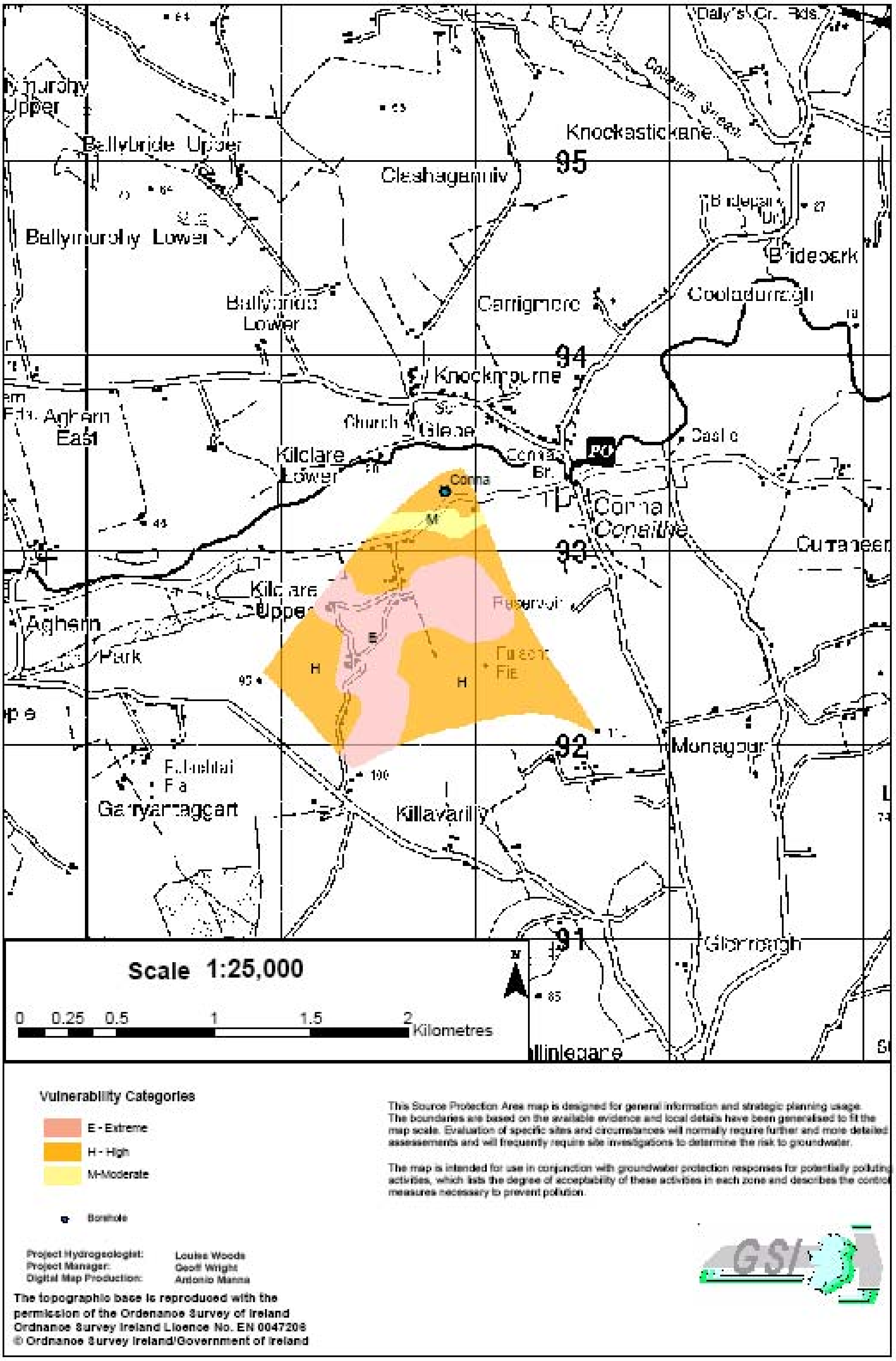



**Figure 1 Groundwater Vulnerability around Conna Borehole**

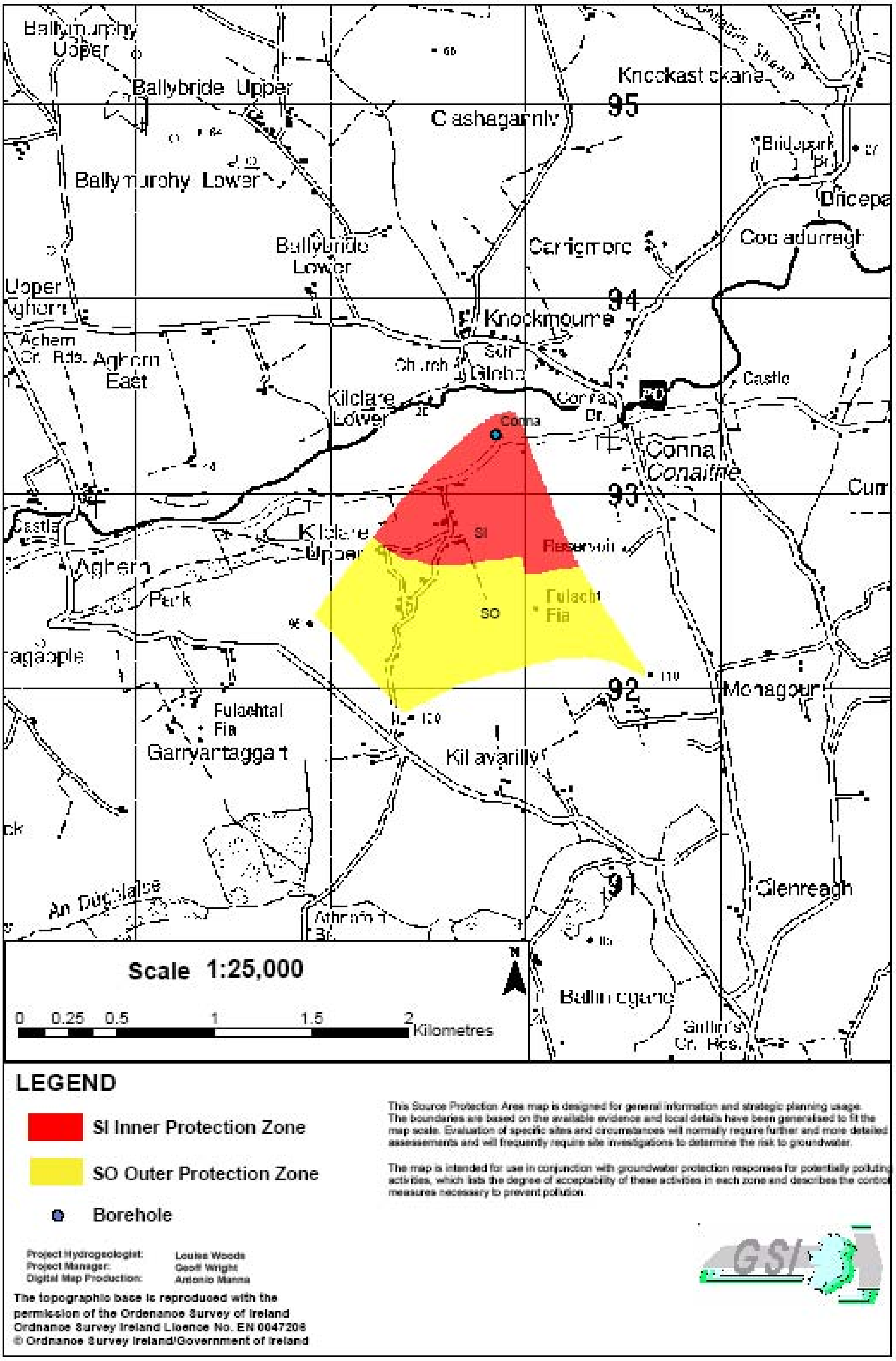



**Figure 2 Groundwater Source Protection Areas for Conna Borehole**

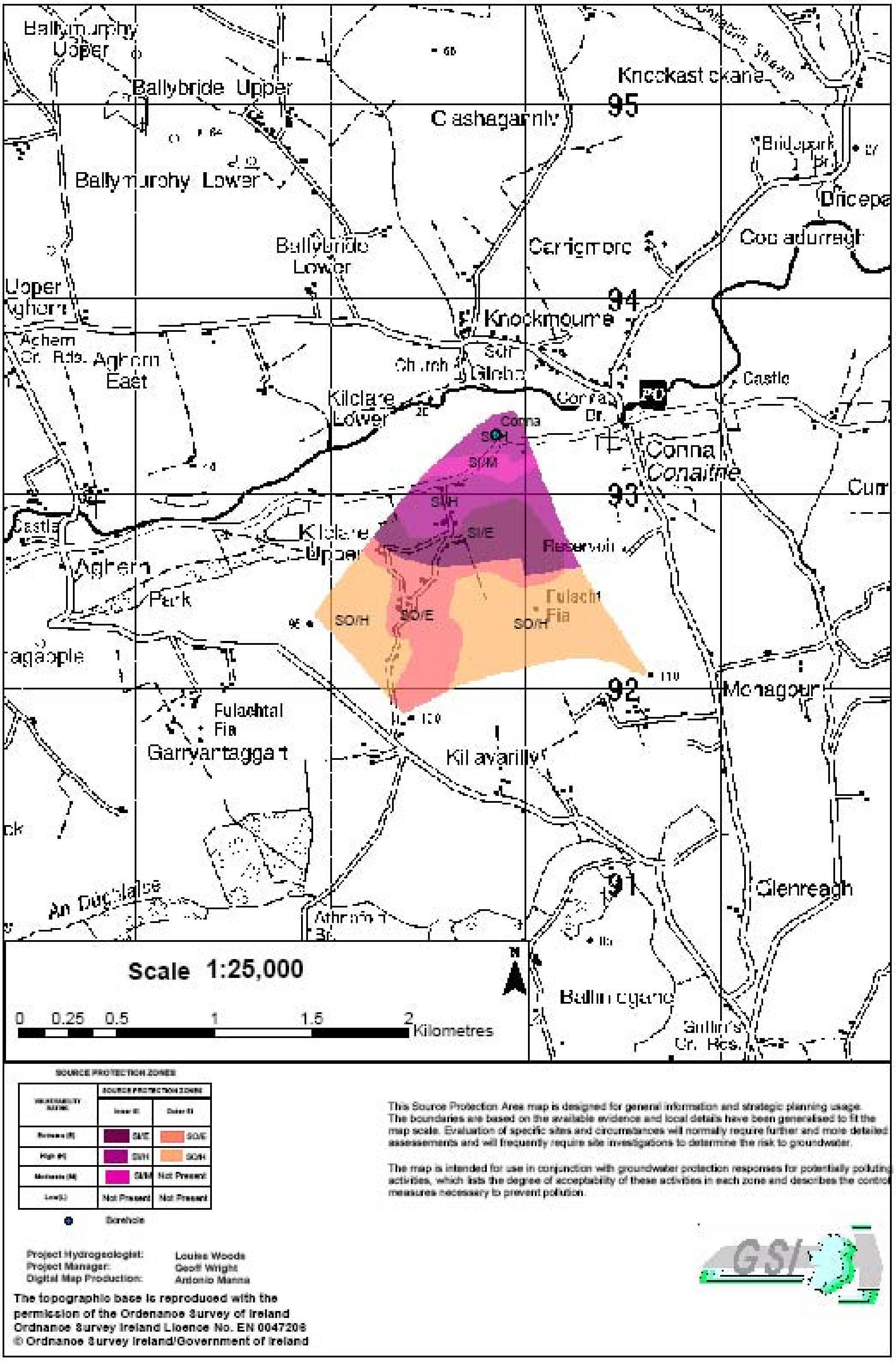



**Figure 3 Groundwater Source Protection Zones for Conna Borehole**