

Kilcormac Water Supply Scheme

Groundwater Source Protection Zones

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1	INTRODUCTION	1
2	LOCATION, SITE DESCRIPTION AND WELL HEAD PROTECTION	1
3	SUMMARY OF WELL 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
6.3	SUBSOIL (QUATERNARY) GEOLOGY.....	3
6.3.1	<i>River Alluvium</i>	3
6.3.2	<i>Till (Boulder Clay)</i>	3
6.3.3	<i>Sand & Gravels</i>	3
6.3.4	<i>Depth to Bedrock</i>	3
7	HYDROGEOLOGY	3
7.1	INTRODUCTION.....	3
7.2	METEOROLOGY AND RECHARGE.....	4
7.3	GROUNDWATER LEVELS, FLOW DIRECTIONS AND GRADIENTS.....	4
7.4	AQUIFER CHARACTERISTICS.....	5
7.5	HYDROCHEMISTRY AND WATER QUALITY.....	5
7.6	CONCEPTUAL MODEL.....	6
8	DELINEATION OF SOURCE PROTECTION AREAS	7
8.1	INTRODUCTION.....	7
8.2	OUTER PROTECTION AREA.....	7
8.3	INNER PROTECTION AREA.....	8
9	VULNERABILITY	8
10	GROUNDWATER PROTECTION ZONES	8
11	POTENTIAL POLLUTION SOURCES	8
12	CONCLUSIONS AND RECOMMENDATIONS	8
13	REFERENCES	9
	APPENDIX 1 GEOLOGICAL LOGS OF THE AUGER BOREHOLES	10
	APPENDIX 2 TEST PUMPING DATA	11
	APPENDIX 3 GRAPH OF NITRATE CONCENTRATIONS AT KILCORMAC	15
	List of Figures	
	FIGURE 1 GROUNDWATER VULNERABILITY AROUND KILCORMAC.....	17
	FIGURE 2 GROUNDWATER SOURCE PROTECTION AREAS FOR KILCORMAC.....	18
	FIGURE 3 GROUNDWATER SOURCE PROTECTION ZONES FOR KILCORMAC.....	19
	List of Tables	
	Table 1 The Bedrock Geology of the Kilcormac area.....	2
	Table 2 Matrix of Source Protection Zones at Kilcormac.....	8

1 Introduction

The Kilcormac source is the main supply for the Kilcormac Water Supply Scheme. The source comprises two boreholes 24 m apart adjacent to the Silver River.

The objectives of the report are as follows:

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

2 Location, Site Description and Well Head Protection

The boreholes are located on the eastern side of Kilcormac village, 10 m north of the main Tullamore-Kilcormac road. The land slopes at about 1 in 20 to the river, which lies about 85 m from the borehole.

One borehole (the old well; 2021SE W0003) is being used with the other well remaining on standby. The boreholes pump to a reservoir with a capacity of about 180 m³ (40,000 gallons) that is on the site. A discharge meter is attached to the mains leaving the reservoir. Both wells have chlorination systems installed.

The boreholes are 24 m apart, each with its own pumphouse. The wells are outside their respective pumphouses. The old borehole has no protection and there are cracks in the concrete around the borehole. The new borehole is situated in a small concrete chamber covered by a manhole.

3 Summary of Well Details

GSI no.	: 2021SE W0002	2021SE W0003
Grid ref. (1:25,000)	: 21870 21410	21874 21416
Townland	: Kilcormac	Kilcormac
Well type	: Borehole	Borehole
Drilled	: 1972	~1950's
Depth	: 63 m	25.5 m
Diameter	: 152.4 mm (6 inches)	203.2 mm (8 inches)
Owner	: Offaly County Council	Offaly County Council
Elevation (ground level)	: 64.16 m OD (210.5 feet)	61.16 m OD
Depth to rock	: 5.82 m	~6 m
Static water level	: 8.05 m	5.10 m
Present Abstraction	: 0 m ³ d ⁻¹	455 m ³ d ⁻¹
Capacity	: 741 m ³ d ⁻¹	545 m ³ d ⁻¹

4 Methodology

4.1 Desk Study

Details about the boreholes 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, subsoil sampling and test pumping of the boreholes. 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 hydrogeological mapping and numerical modelling to delineate protection zones around the sources. Due to the proximity and similar hydrogeology of the source for the Ballyboy Group Water 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 Ballyboy Group Water Scheme may be referred to in Kelly 2000.

5 Topography, Surface Hydrology and Land Use

The boreholes are situated about 85 m north of the Silver River, which flows from east to west. In general the land is gently undulating, but the slopes on the northern side are somewhat steeper.

The Silver River is the main surface water feature in the area. In fact there are very few surface water features other than the river in the area. A tributary of the Silver River flows from the bog to the north of Kilcormac and meets the Silver River downstream of the boreholes.

The wells are located to the eastern side of Kilcormac village. A petrol station lies downslope of the boreholes, next to the river. The main Kilcormac-Tullamore road passes 10 m south of the wells. Outside the village the land use is primarily agricultural with grassland being the dominant type.

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 Kilcormac area.

<i>Name of Rock Unit</i>	<i>Rock Material</i>	<i>Occurrence</i>
Borrisokane Formation	Thick-bedded, coarse grained, pale LIMESTONE with some darker fine grained beds and with occasional thin clayey bands	Underlies the village and the source, Disused quarry just north of the village.
Waulsortian Formation	Fossiliferous, pale- grey, poorly bedded fine grained LIMESTONE	Occurs to 1 km to the south and east of Kilcormac village.

Movements in the earth's crust have caused the rocks to be folded, faulted and jointed. The rock units have a NE-SW orientation, dipping south-eastwards at a low angle. Two major fault sets occur that

trend NE-SW and SE-NW. The joint pattern is likely to have similar orientations. The contact between the two rock units is a low-angled NE-SW trending thrust fault.

6.3 Subsoil (Quaternary) Geology

The subsoils comprise a mixture of coarse and fine-grained materials, namely: alluvium, till, sand & gravel. They are directly influenced by the underlying bedrock, which is made up of 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 River Alluvium

The alluvium is a fine grained, grey blue deposit (BS5930: CLAY). It can be seen in sections along the Silver River upstream of Kilcormac and is up to 1 m thick.

6.3.2 Till (Boulder Clay)

‘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 till. The till are the dominant subsoil type to the south of the Silver River. The matrix of the till 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. Sands & gravel in Offaly are often associated with eskers. Esker deposits are generally composed of coarse boulder gravels which are highly permeable.

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 0 and 10 m.

7 Hydrogeology

7.1 Introduction

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

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).
- 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: 430 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.	430 mm
Potential Recharge (R – A.E.)	420 mm
Runoff losses	40 mm
Estimated Actual Recharge	380 mm

7.3 Groundwater Levels, Flow Directions and Gradients

Water levels were measured in the Silver River and in the two boreholes prior to the test pumping of the boreholes on the 09/5/2000. Water levels in the boreholes were measured regularly during the test pumping and the results are presented in Appendix 2.

	New borehole (mOD)	Old borehole (mOD)	Silver River (mOD)
Static Water Level (m) 1/10/1972	55.63	unknown	unknown
Static Water Level (m) precise date unknown (1986)	unknown	56.88	unknown
Static Water Level (m) 9/05/2000	56.11	56.05	58.7
Pumping Water level 9/05/2000	47.65	44.86	58.7

The water level in the river prior to pumping is higher (2.61m) than the water level in the boreholes, because the levels in the boreholes did not fully recover before the test began.

The head difference between the river and the old/lower borehole after 10 hours pumping is 13.9 m. This difference suggests that downgradient of the well only minor quantities of water are drawn from the river and that water is drawn from the aquifer on the other side of the river. However, test pump data indicates that some recharge is taking place, suggesting that the river does provide some water to the well. This is estimated to be about 5%.

Water level data is poor and the water table is generally assumed to be a subdued reflection of topography. Thus in the Kilcormac area groundwater flow directions tend toward the Silver River, following the slopes down to the river at a lesser gradient to the topographic gradient. The tributary to the north flows southwest to meet the Silver River downstream of the boreholes, this indicates that there is a surface water divide between the two streams. Numerical modelling indicates that an east-west trending divide lies roughly halfway between the two. This partly coincides with a ridge that (is masked by an esker ridge) runs almost parallel to the Kilcormac-Tullamore road.

The average topographic gradient around the Kilcormac boreholes is about 0.05-0.06. Assuming the static water level in the boreholes recorded is correct the gradient of the water table is about 0.02, which is somewhat less than the topographic gradient. Numerical modelling of the geology in the Kilcormac area suggest gradients of about 0.02 in the Borrisokane Limestone and about 0.01 in the Waulsortian Limestone.

7.4 Hydrochemistry and Water Quality

The hydrochemical analyses (15 samples) show that the water is a hard to a very hard water with total hardness values of 258-378 mg l⁻¹ (equivalent CaCO₃) and electrical conductivity values of 490-690 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 1980's and 90's nitrate concentrations range 20-103 mg l⁻¹, with an average of about 24 mg l⁻¹. This appears lie in the general range of values in mid-County Offaly where there is grassland-dominated farming. Nitrate concentrations have exceeded the EU MAC on one occasion (103 mg l⁻¹, May 1998; 32 samples). Another peak occurred in August 1997 (42.4 mg l⁻¹).

Chloride concentrations range from 19-24 mg l⁻¹, with an average of 21.7 mg l⁻¹ (16 samples). 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. Thus chloride levels give no rise for concern at the Kilcormac source.

Sodium levels range between 8.4-9.7 mg l⁻¹. Potassium levels range between 1.6-4.4 mg l⁻¹. The ratio of potassium to sodium (K:Na) may indicate contamination if the ratio is > 0.4. On one occasion (June, 1998) slightly elevated potassium concentrations (4.4 mg l⁻¹) caused the ratio to rise to 0.46, which may indicate pollution from an organic waste source, however, there are no other parameters which indicate organic pollution at that time.

Iron concentrations were reported to be 'a little high' for a sample taken in October 1972, however this sample was taken shortly after drilling of the new borehole and is probably due to the construction of the borehole. Iron concentrations are consistently low in subsequent samples (16 samples).

There are no incidents of faecal contamination in the analyses, however these are for treated water, thus sampling of the raw water is required. There is a main sewage pipe passing the boreholes alongside the road which may contaminate the water if it is leaking.

The river water and water from the borehole was sampled during the test pumping exercise for comparison. Water from the borehole was sampled at the start and finish of the test. The difference between the two borehole samples is negligible. No significant change was recorded in the conductivity and temperature between the borehole water at the start and finish of the test. There is a significant difference between the borehole water and the river water in the major ions. This illustrates that the borehole is not pulling water from the river in any significant quantity.

7.5 Aquifer Characteristics

The Borrisokane Limestone is regarded as one of the best aquifers in Leinster and is classed as being a **Regionally Important fissured aquifer (Rf)**, but the data in County Offaly is limited in comparison

to data for the Nore Basin area, thus may only indicate aquifer potential. However, 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 in May 2000. A constant discharge test was run at $545 \text{ m}^3 \text{ d}^{-1}$ for 10 hours, with a final drawdown of 11.19 m in the pumping well. This gives a specific capacity of about $40 \text{ m}^3 \text{ d}^{-1} \text{ m}^{-1}$. 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 $20\text{-}40 \text{ m}^2 \text{ d}^{-1}$. Estimates of the transmissivity for sources in the Borrisokane Formation at Tully and Hollimshill are $13 \text{ m}^3 \text{ d}^{-1}$ and $52\text{-}530 \text{ m}^3 \text{ d}^{-1}$ respectively (Cronin *et al*; 1998, 1999).

The porosity is taken to be approximately 2 %.

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).

The modelled permeability is derived to be about 1 m d^{-1} .

7.6 Conceptual Model

- The Kilcormac source is fed from the Borrisokane Pure Limestone which is a **regionally important fissured aquifer (Rf)**.
- The permeability in this aquifer depends on the development of faults, fissures and fractures. 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. The degree of karstification appears to be limited.
- There are few drains and surface streams apart from the Silver River, indicating the free draining nature of the subsoils and the relatively high permeabilities of the bedrock.
- Groundwater flow is probably confined to fractures, fissures, joints, bedding planes and the uppermost part of the bedrock
- The rock unit is largely overlain by moderately permeable till and highly permeable sand & gravel. Also, the water table lies within the bedrock, therefore the groundwater can be considered as unconfined.
- The regional groundwater flow broadly reflects topography, flowing east to west, tending toward the Silver River and the tributary to the north. Numerical modelling indicates that an east-west trending divide lies roughly halfway between the two. This partly coincides with a ridge that (is masked by an esker ridge) runs almost parallel to the Kilcormac-Tullamore road.
- Hydrochemistry and test pumping of the borehole suggests that the degree of connectivity of the Silver River to the aquifer is poor in the vicinity of the boreholes.
- Diffuse recharge occurs through the sands & gravels and the permeable tills up to 376 mm yr^{-1} .

8 Delineation Of Source Protection Areas

8.1 Introduction

This section delineates the areas around the boreholes that are believed to contribute groundwater to the boreholes, and that therefore require protection. The areas are delineated based on the conceptualisation of the groundwater flow pattern, as described in the conceptual model 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 Kilcormac 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 $545 \text{ m}^3 \text{ d}^{-1}$. For the purposes of modelling the source, the average yield is increased by 50% to $820 \text{ m}^3 \text{ d}^{-1}$ for the following reasons:

- The higher yield allows for increased water demand due to possible expansion in Kilcormac.
- 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 $820 \text{ m}^3 \text{ d}^{-1}$ is calculated to be 0.8 km^2 . A more accurate ZOC at Kilcormac 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 Ballyboy Group Water Scheme is within 2 km of the Kilcormac boreholes, located within the same aquifer with similar hydrogeological conditions, thus it was appropriate to model the groundwater regime for both sources together.

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

The **southern boundary** is defined using analytical techniques and the numerical modelling. The distance downgradient that the well can draw water from is estimated to be about 200 m.

8.3 Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100-day time of travel (ToT) to the source. It is delineated to protect against the effects of potentially contaminating activities that may have an immediate influence on water quality at the source, in particular microbial contamination. 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. From Section 7.5, the parameters used give velocities of 1.2 m d^{-1} , and so it is assumed that for a 100 day time of travel, groundwater could travel 120 m, assuming a hydraulic gradient of 0.02. Thus, the upgradient extent of the SI zone is 120 m. The SI is presented in Figure 2.

9 Vulnerability

The distribution of interpreted groundwater vulnerability in the ZOC is presented in Figure 1. The subsoils in the ZOC are of moderate to high permeability. The depth to bedrock in the ZOC varies between 6 and 7 m. Therefore all of the land in the ZOC is classified 'highly' vulnerable to contamination. The vulnerability classifications are consistent with those drawn up in the Groundwater Protection Scheme (Daly *et al*, 1998).

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. These are presented in Figure 2. There are just 2 groundwater protection zones present around the Kilcormac source as shown in Table 2. The final groundwater protection map is presented in Figure 2.

Table 2 Matrix of Source Protection Zones at Kilcormac

VULNERABILITY RATING	SOURCE PROTECTION	
	<i>Inner</i>	<i>Outer</i>
<i>Extreme (E)</i>	Absent	Absent
<i>High (H)</i>	SI/H	SO/H
<i>Moderate (M)</i>	Absent	Absent
<i>Low (L)</i>	Absent	Absent

11 Potential Pollution Sources

Land use in the area is discussed in Section 5. The land near the source is largely grassland-dominated and is primarily used for grazing. Agricultural activities, the road and the garage 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, road spillage, spillage and leakage from the activities of the garage, leaky sewers and landspreading of organic fertilisers. Pollution of the Silver River also provides a threat to the water quality in the boreholes. The garage is in the zone of contribution to the borehole. The main potential pollutants are faecal bacteria, viruses, and cryptosporidium.

12 Conclusions and Recommendations

- ◆ The area around the supply is highly vulnerable to contamination.

- ◆ Leaky sewer pipes, landspreading, farmyards, the garage and runoff from the roads pose a threat to the water quality in the borehole.
- ◆ It is recommended that:
 - 1) a full chemical and bacteriological analysis of the **raw** water should be carried out on a regular basis at source.
 - 2) particular care should be taken when assessing the location of any activities or developments which might cause contamination at the springs.
 - 3) the potential hazards in the ZOC should be located and assessed.
- ◆ The protection zone 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.

Cronin C., Daly, D., and R. Flynn, 1999. *Hollimshill Public Supply. Groundwater Protection Zones*. Geological Survey Report, 12 pp.

Cronin C., Daly, D., and R. Flynn, 1998. *Tully Public Supply. Groundwater Protection Zones*. Geological Survey Report, 18 pp.

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

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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 Test Pumping data

Drawdown data for the pumping well

SITE Kilcormac		DATE 09/05/2000					
Groundwater Section Geological Survey of Ireland		PUMPING TEST	PUMPING WELL	Project Title Source Protection Page No.			
Borehole Name	Kilcormac Old/Lower	Well Depth	25.50m checked with dipper	Datum Point	Top Casing		
Borehole No.	1	Well Diameter	8"	Height of Datum	10cm above ground level		
Well Owner	Offaly Co Co	Pump Depth	unknown	Ground Elevation	61mOD		
Location	Kilcormac Village	Aquifer	Borrisokane Lst.	Datum Elevation	61.10mOD		
Grid ref.	2187 21410	Duration of Pumping	10 hrs	Weather	Sunny, dry day.		
6" Sheet No.	31	Average Discharge	545 m3/d	Observer	coran kelly		
Date	Time	Elapsed Time	Water level below datum	Drawdown	Discharge	Discharge	Remarks
		Mins	(m)	(m)	Meter	Spot	(m3/d)
09/05/2000	06:30:00	0	5.01	0			
		0.3	9.4	4.39			
		1	10.4	5.39			
		1.3	11.1	6.09			
		2	11.58	6.57			
		2.3	11.94	6.93			
		3	12.26	7.25			
		3.3	12.49	7.48			
		4	12.71	7.7			
		4.3	12.87	7.86			
		5	13.06	8.05			
		5.3	13.15	8.14			
		6	13.26	8.25			
		6.3	13.38	8.37			
		7	13.5	8.49			
		7.3	13.6	8.59			
		8	13.65	8.64			
		8.3	13.73	8.72			
		9	13.81	8.8			
		9.3	13.88	8.87			
		10	13.95	8.94			
		10.3	14	8.99			
		11	14.04	9.03			
		11.3	14.12	9.11			
		12	14.19	9.18			
		13	14.25	9.24			
		14	14.35	9.34			
		15	14.44	9.43			
		16	14.5	9.49			
		17	14.55	9.54			
		18	14.62	9.61			
		19	14.7	9.69			
		20	14.75	9.74			
		25	14.9	9.89			
		30	15.09	10.08			
		35	15.18	10.17			
		40	15.24	10.23			
		45	15.33	10.32			Bore: 739 uS/cm Temp: 11.3oC
		50	15.4	10.39			
		55	15.47	10.46			
	07:30:00	60	15.53	10.52			
		75	15.63	10.62			Riv: 618 uS/cm Temp: 13oC
		90	15.7	10.69			
		105	15.76	10.75			
		120	15.8	10.79			Bore: 737 uS/cm Temp: 11.5 oC
		135	15.85	10.84			
		150	15.85	10.84			
		165	15.9	10.89			
		180	15.93	10.92			
		195	15.95	10.94			Bore: 740 uS/cm Temp: 11.8oC
		210	15.96	10.95			

Drawdown data for the observation well

SITE Kilcormac				DATE 09/05/2000			
Groundwater Section Geological Survey of Ireland		PUMPING TEST		OBSERVATION WELL		Project Title Source Protection Page No.	
Borehole Name	Kilcormac New/Upper	Well Depth	63m checked with dipper	Datum Point	top of casing		
Borehole No.	2	Well Diameter	6"	Height of Datum	at ground level		
Well Owner	Offaly Co Co	Pump Depth	33m	Ground Elevation	64mOD		
Location	Kilcormac Village	Aquifer	Borrisokane Lst.	Datum Elevation	64mOD		
Grid ref.	21874 21416			Weather	Sunny, dry day.		
6" Sheet No.	31			Observer	Debbie Hennessy		
Date	Time	Elapsed Time	Water level below datum	Drawdown	Discharge	Discharge	Remarks
		Mins	(m)	(m)	Meter	Spot	(m3/d)
09/05/2000	06:30:00	0	8.05	0			
		0.3	9.1	1.05			
		0.45	9.77	1.72			
		1	10.2	2.15			
		1.15	10.58	2.53			
		1.3	11.04	2.99			
		1.45	11.35	3.3			
		2	11.48	3.43			
		2.15	11.74	3.69			
		2.3	11.91	3.86			
		2.45	12.1	4.05			
		3	12.33	4.28			
		3.15	12.47	4.42			
		3.3	12.62	4.57			
		3.35	12.81	4.76			
		3.45	12.92	4.87			
		3.55	13.1	5.05			
		4	13.3	5.25			
		4.3	13.42	5.37			
		5	13.55	5.5			
		5.3	13.65	5.6			
		6	13.76	5.71			
		6.3	13.88	5.83			
		7	13.98	5.93			
		7.3	14.02	5.97			
		8	14.09	6.04			
		8.3	14.11	6.06			
		9	14.15	6.1			
		9.3	14.18	6.13			
		10	14.2	6.15			
		11	14.36	6.31			
		12	14.44	6.39			
		13	14.53	6.48			
		14	14.59	6.54			
		15	14.69	6.64			
		16	14.76	6.71			
		17	14.82	6.77			
		18	14.88	6.83			
		19	14.98	6.93			
		20	15.01	6.96			
		25	15.2	7.15			
		30	15.32	7.27			
		35	15.45	7.4			
		40	15.54	7.49			
		45	15.6	7.55			
		50	15.67	7.62			
		55	15.73	7.68			
	07:30:00	60	15.8	7.75			
		75	15.92	7.87			
		90	15.99	7.94			

Recovery data for the pumping well

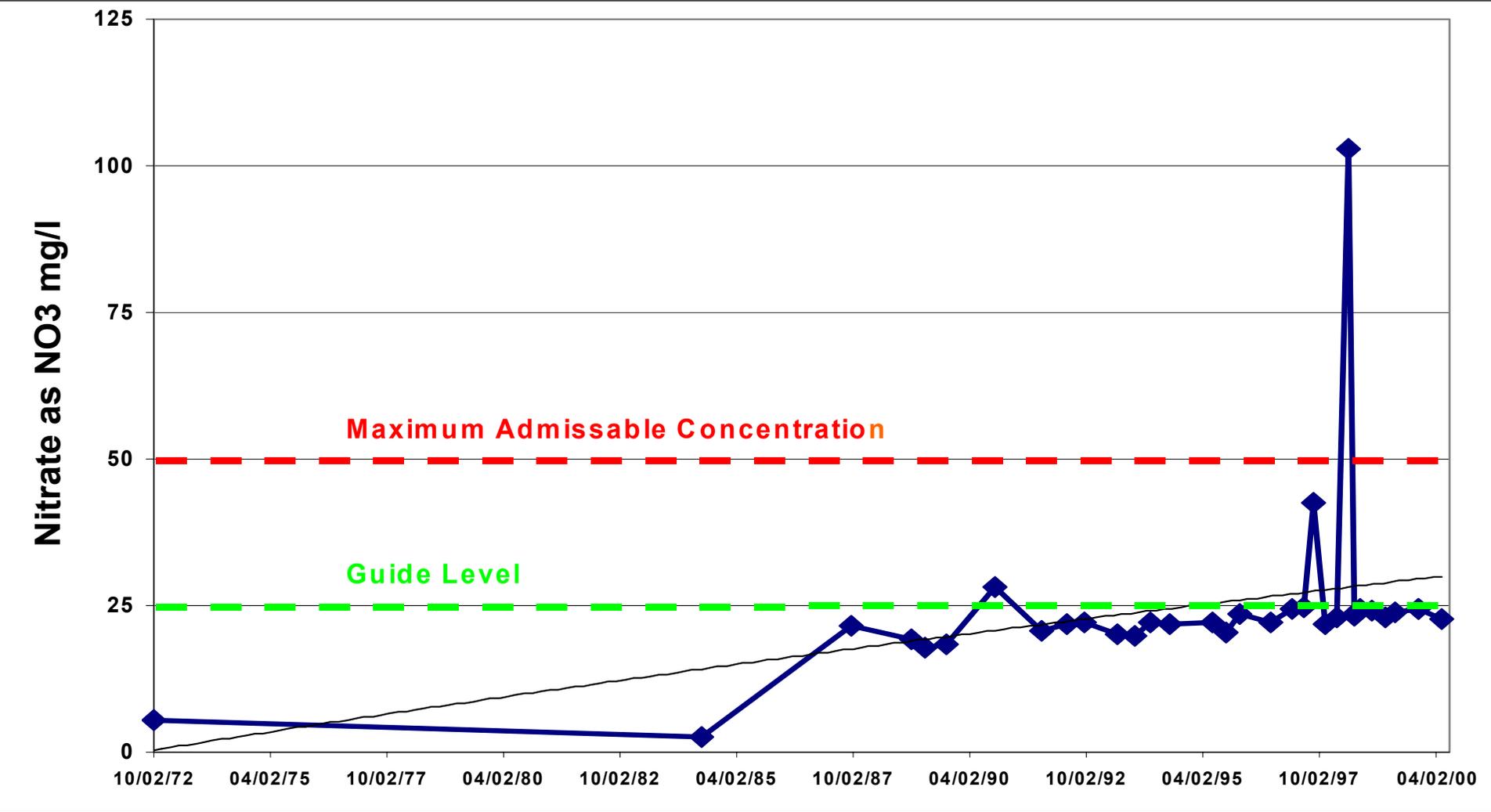
SITE Kilcormac				DATE 09/05/2000				
Groundwater Section Geological Survey of Ireland		RECOVERY TEST		PUMPING WELL		Project Title Source Protection Page No.		
Borehole Name	Kilcormac Bore Old	Well Depth	25m	Datum Point		Borehole No.	1	
Well Owner	Offaly Co Co	Pump Depth		Ground Elev.		Well Diameter	8"	
Location	Kilcormac Village	Duration of Pumping		Datum Elev.		Well Depth		
Grid ref.		Average Discharge		Weather		6" Sheet No.		
		Aquifer		Observer				
Date	Time	Time since Pumping Began (t)	Time since Pumping Ended (t')	Water level below datum	t/t'	Residual Drawdown	Recovery	Remarks
	am/pm	Mins	Mins	(m)	(m)	(m)		
09/05/2000	16:30:00	600	0	16.2	2001	11.19		
		600.3	0.3	12.2	601	7.19		
		601	1	12.08	462.53846	7.07		
		601.3	1.3	11.29	301	6.28		
		602	2	10.5	261.86957	5.49		
		602.3	2.3	9.22	201	4.21		
		603	3	8.93	182.81818	3.92		
		603.3	3.3	8.64	151	3.63		
		604	4	8.45	140.53488	3.44		
		604.3	4.3	8.23	121	3.22		
		605	5	8.11	114.20755	3.1		
		605.3	5.3	7.98	101	2.97		
		606	6	7.85	96.238095	2.84		
		606.3	6.3	7.73	86.714286	2.72		
		607	7	7.63	83.191781	2.62		
		607.3	7.3	7.54	76	2.53		
		608	8	7.46	73.289157	2.45		
		608.3	8.3	7.38	67.666667	2.37		
		609	9	7.31	65.516129	2.3		
		609.3	9.3	7.25	61	2.24		
		610	10	7.23	55.545455	2.22		
		611	11	7.08	51	2.07		
		612	12	6.99	47.153846	1.98		
		613	13	6.91	43.857143	1.9		
		614	14	6.83	41	1.82		
		615	15	6.77	38.5	1.76		
		616	16	6.7	36.294118	1.69		
		617	17	6.63	34.333333	1.62		
		618	18	6.58	32.578947	1.57		
		619	19	6.53	31	1.52		
		620	20	6.5	25	1.49		
		625	25	6.31	21	1.3		
		630	30	6.19	18.142857	1.18		
		635	35	6.1	16	1.09		
		640	40	6.02	14.333333	1.01		
		645	45	5.95	13	0.94		
		650	50	5.91	11.909091	0.9		
		655	55	5.87	11	0.86		
	17:30:00	660	60	5.83	9	0.82		
		675	75	5.72	7.666667	0.71		
		690	90	5.65	6.7142857	0.64		
		705	105	5.59	6	0.58		
		720	120	5.54	5.4444444	0.53		
		735	135	5.49	5	0.48		
		750	150	5.45	4.6363636	0.44		
		765	165	5.43	4.3333333	0.42		
	19:30:00	780	180	5.4	4.0769231	0.39		
		795	195	5.35		0.34		

Recovery data for the observation well

SITE Kilcormac		DATE 09/05/2000					
Groundwater Section Geological Survey of Ireland		RECOVERY TEST		OBSERVATION WELL		Project Title Source Protection Page No.	
Borehole Name	Kilcormac Bore New	Well Depth	63m	Datum Point			
Borehole No.		Well Diameter	6"	Height of Datum			
Well Owner	Offaly Co Co	Pump Depth	33m	Ground Elev.			
Location		Duration of Pumping		Datum Elev.			
Grid ref.		Average Discharge		Weather			
6" Sheet No.		Aquifer		Observer			

Date	Time	Time since Pumping Began (t)	Time since Pumping Ended (t')	Water level below datum	t/t'	Residual Drawdown	Recovery	Remarks
	am/pm	Mins	Mins	(m)	(m)	(m)		
09/05/2000	16:30:00	600	0	16.51				
		600.3	0.3	14.3	2001	6.25		
		601	1	13.45	601	5.4		
		601.3	1.3	12.96	462.5385	4.91		
		602	2	12.56	301	4.51		
		602.3	2.3	12.1	261.8696	4.05		
		603	3	11.81	201	3.76		
		603.3	3.3	11.59	182.8182	3.54		
		604	4	11.39	151	3.34		
		604.3	4.3	11.19	140.5349	3.14		
		605	5	10.98	121	2.93		
		605.3	5.3	10.8	114.2075	2.75		
		606	6	10.64	101	2.59		
		606.3	6.3	10.55	96.2381	2.5		
		607	7	10.41	86.71429	2.36		
		607.3	7.3	10.3	83.19178	2.25		
		608	8	10.23	76	2.18		
		608.3	8.3	10.16	73.28916	2.11		
		609	9	10.09	67.66667	2.04		
		609.3	9.3	10.05	65.51613	2		
		610	10	10	61	1.95		
		611	11	9.9	55.54545	1.85		
		612	12	9.84	51	1.79		
		613	13	9.76	47.15385	1.71		
		614	14	9.7	43.85714	1.65		
		615	15	9.65	41	1.6		
		616	16	9.6	38.5	1.55		
		617	17	9.56	36.29412	1.51		
		618	18	9.51	34.33333	1.46		
		619	19	9.46	32.57895	1.41		
		620	20	9.43	31	1.38		
		625	25	9.33	25	1.28		
		630	30	9.22	21	1.17		
		635	35	9.1	18.14286	1.05		
		640	40	9.03	16	0.98		
		645	45	8.98	14.33333	0.93		
		650	50	8.92	13	0.87		
		655	55	8.87	11.90909	0.82		
		660	60	8.83	11	0.78		
		675	75	8.74	9	0.69		
		690	90	8.66	7.666667	0.61		
		705	105	8.6	6.714286	0.55		
		720	120	8.55	6	0.5		
		735	135	8.51	5.444444	0.46		
		750	150	8.48	5	0.43		
		765	165	8.44	4.636364	0.39		
		780	180	8.41	4.333333	0.36		
		795	195	8.38	4.076923	0.33		

Appendix 3 Graph of Nitrate concentrations at Kilcormac



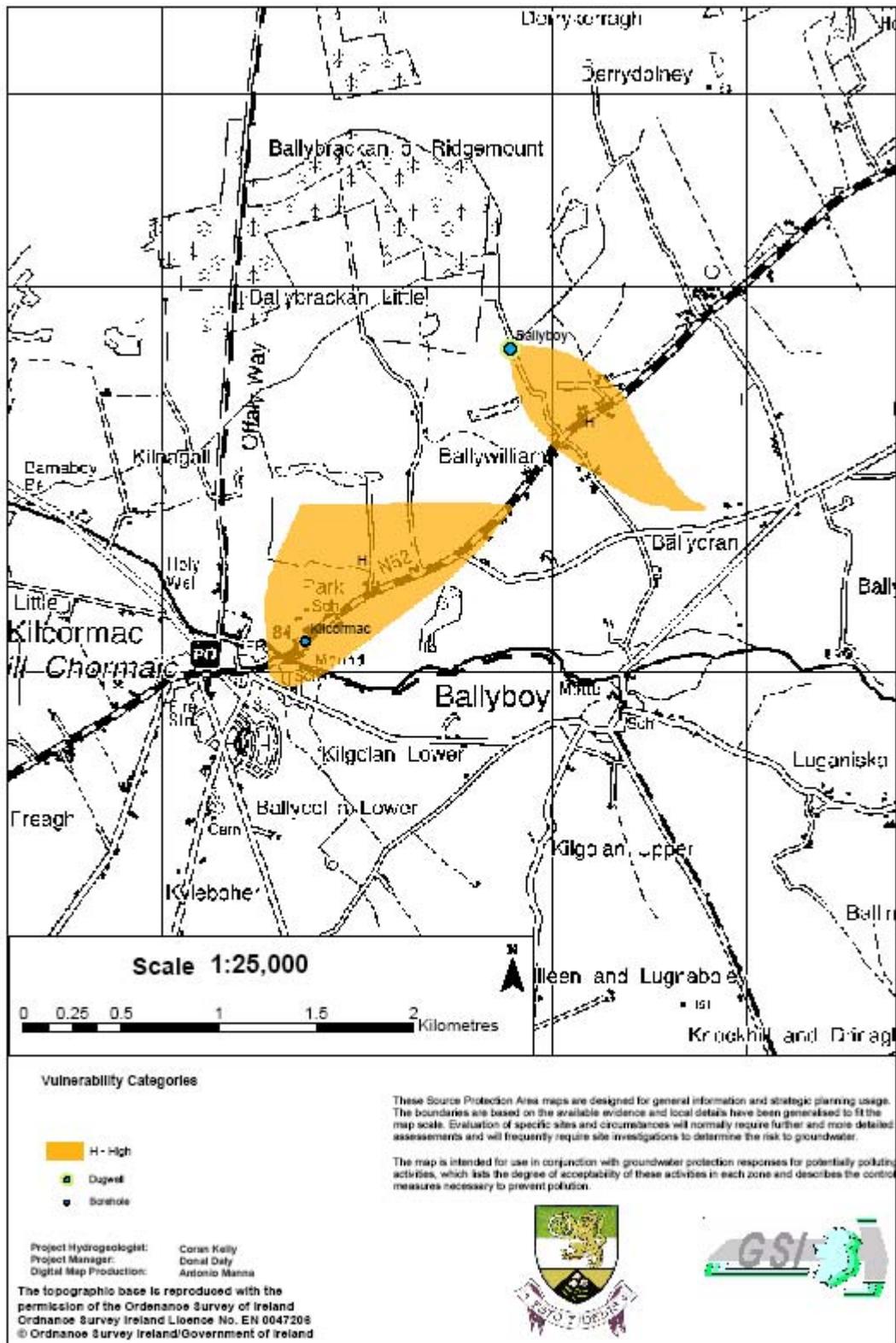


Figure 1 Groundwater Vulnerability around Kilcormac

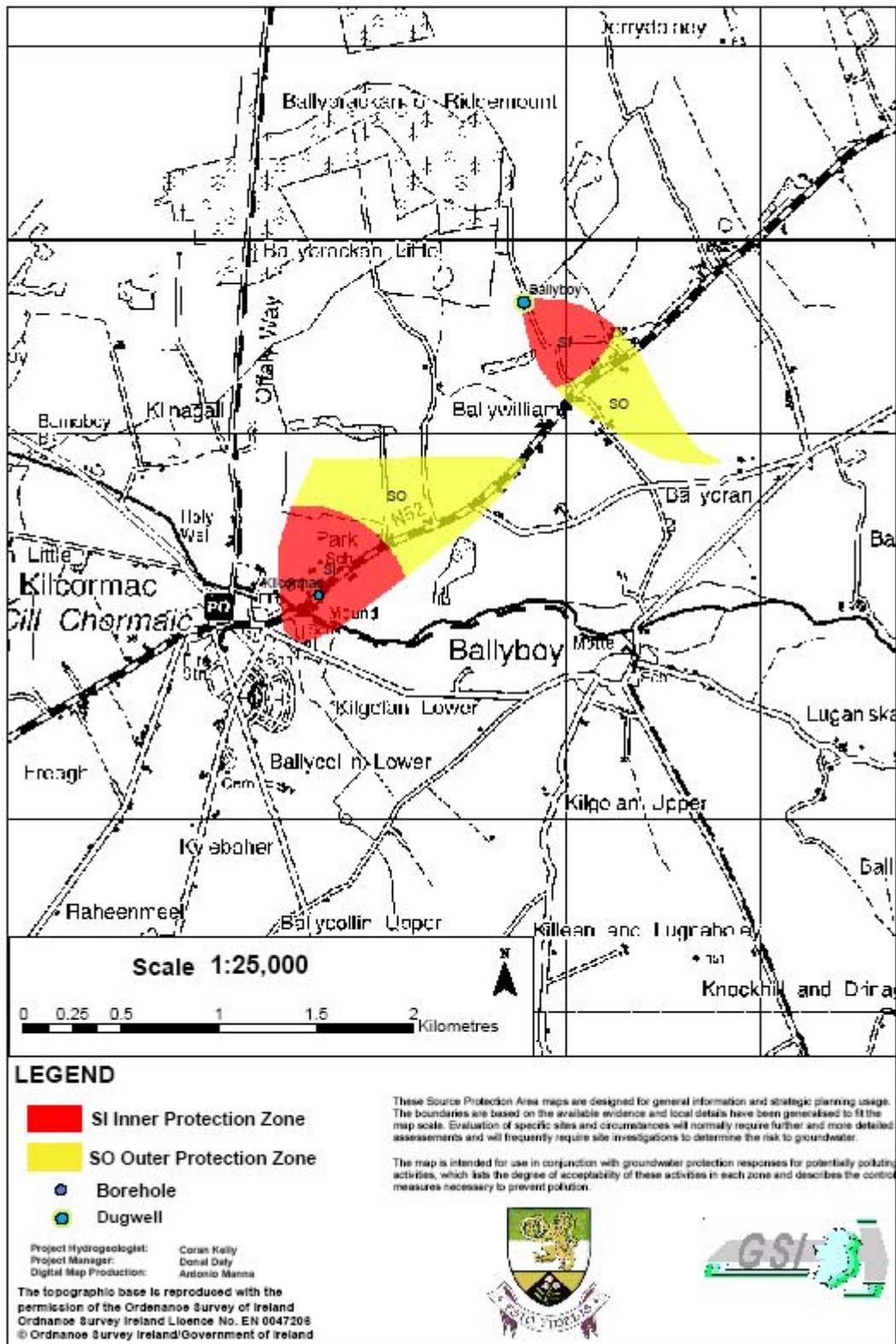


Figure 2 Groundwater Source Protection Areas for Kilcormac

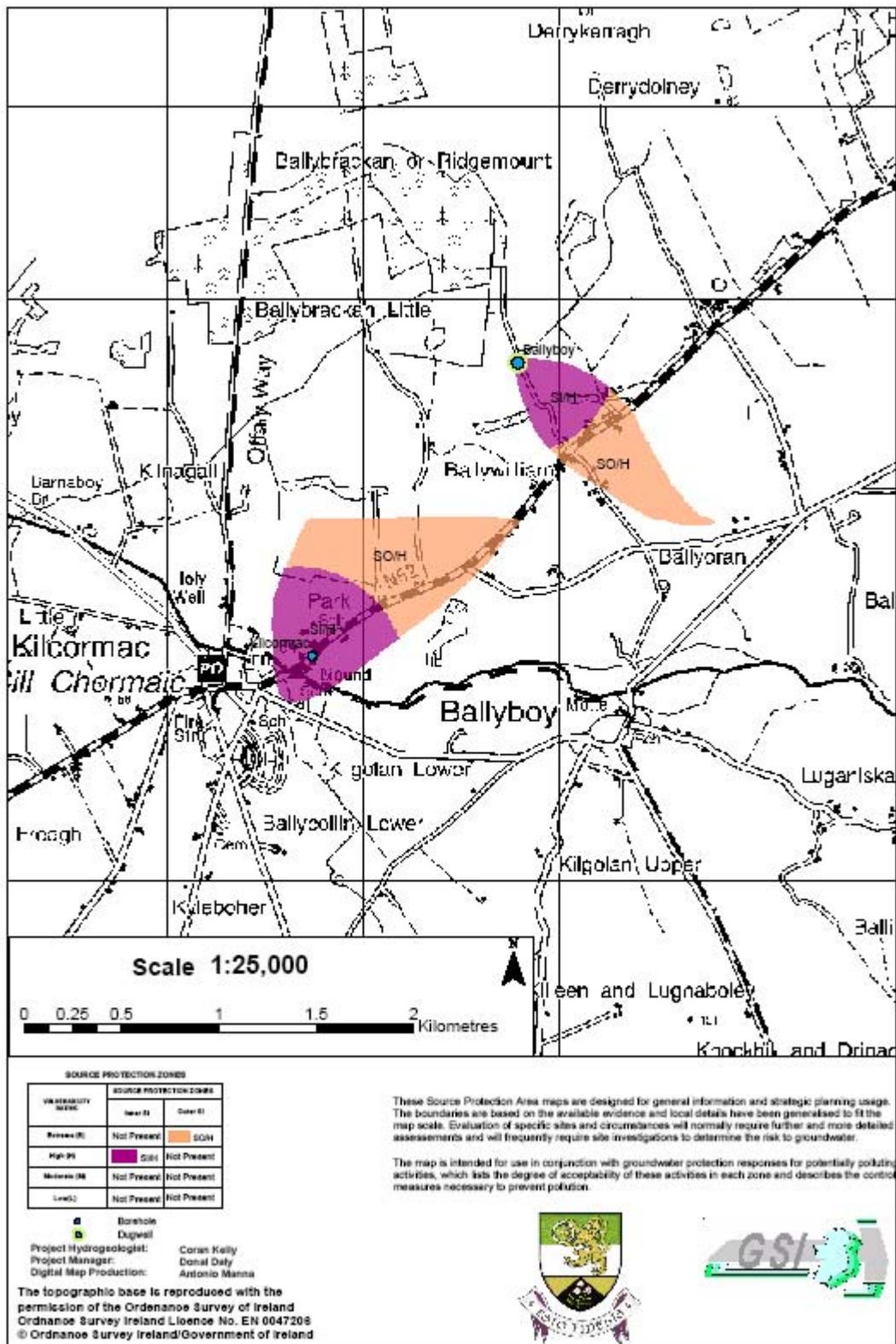


Figure 3 Groundwater Source Protection Zones for Kilcormac