Hollimshill Public Supply

Groundwater Source Protection Zones

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1. Introduction

The objectives of this report are as follows:

- To delineate source protection zones for the Hollimshill Public Water Supply.
- To outline the principle hydrogeological characteristics of the Hollimshill area.
- To assist Offaly County Council in protecting the water supply from contamination.

2. Location and Site Description

The Hollimshill source is situated close to the top of Hollimshill, approximately 1.5 km northeast of Blue Ball, Co. Offaly. The source comprises two wells which are located beside a pumphouse in a site which is approximately 1200 m^2 in size and is enclosed by a fence. The wells are completed below ground level in a chamber which is approx. 3m from the northern side of the site. The wells are capped and the chamber is protected by a steel cover.

3. Summary of Well Details

GSI no.	2021 NE W005
Grid ref. (1:25,000)	22734 22018
Townland	Hollimshill
Owner	Offaly County Council
Well type	Two bored wells
Elevation (top of casing)	105.2 m
Depth	100 m
Diameter	0.25 m
Depth-to-rock	23 m
Static water level	32 m
Drawdown	approximately 11 m b.g.l.
Abstraction rate	455 m^3/d
Pumping test summary	(i) Abstraction rate: 1071 m^3/d (seven day constant rate test) (ii) Specific capacity 62.6 $m^3/d/m$ (after 1500 mins pumping) 57.3 $m^3/d/m$ (after 10 days of pumping) (ii) Transmissivity: 510 m^2/d

4. Methodology

The assessment involved three stages; (a) detailed desk study, (b) site visits and fieldwork, and (c) analysis of the data. The desk study was conducted in the Geological Survey where bedrock geology information was compiled from a geology map of the Tullamore - Blue Ball area (AMAX, 1981) and subsoils were compiled from the GSI Subsoils Map of County Offaly. Basic public supply well details were obtained from GSI records and County Council personnel; such details include borehole depth, elevation, abstraction rate and pumping test details.

The second stage comprised site visits and fieldwork in the Hollimshill area. This included a walkover survey in order to further investigate the subsoil and bedrock geology, the hydrogeology, the vulnerability to contamination and the current pollutant loading.

Stage three, the assessment stage, utilised analytical equations, hydrogeological mapping and numerical modelling to delineate protection zones around the public supply well.

5. Topography, Surface Hydrology and Land use

Hollimshill is 105m high and is the highest point within a 2 km radius of the source. The overall topography of the area slopes gently northward away from the hill.

The soils and subsoils are relatively free draining in the vicinity of the source and there are no drainage channels or ditches nearby. The most notable surface water feature in the area is Pallas Lough, a lake present approximately 720m to the south of the site. The lake has no surface water outlet. The nearest river to the site is the northerly flowing Clodiagh River located approximately 3 km to the east of Hollims Hill.

Agriculture is the principal activity in the area immediately surrounding the source. Most of the land is used for pasture, with a smaller proportion used for tillage (20% approx.). A number of small houses and farmyards are present in the general vicinity of the well.

6. Geology

6.1. Bedrock Geology

The bedrock geology of the Hollimshill area was dependent on the deposition of sediments during Carboniferous times (over 300 million years ago) and on the subsequent folding of these sediments. The rock units of the area, which are shown in Figure 1, are summarised below.

6.1.1. Waulsortian Limestone

This is a pale grey, poorly bedded, fine grained limestone containing frequent fossils. It was deposited as interfingering mounds of fine organic probably mainly algal material in a pure sea where the sediment input from land was minimal. This is the most abundant rock type in Offaly stretching as three broad bands across the country in a NE-SW direction (Daly *et al*, 1997).

6.1.2. Allenwood Limestone

This is a shallow marine, pale grey, massive limestone. It is generally poorly bedded and medium to coarse grained. While this rock unit does contain some karst features, the degree of karstification appears limited from the available information (Daly *et al,* 1997).

6.1.3. Calp Limestone

This is a dark, well bedded, fine grained, clayey limestone with calcareous mudstones. This rock unit occurs to the southeast of Pallas Lough.

6.1.4. Borrisokane Pure Limestone

The Hollimshill source is located within the Borrisokane Pure Limestone which extends from Birr north-eastwards through Tullamore and Durrow. This rock unit is a pale grey, thickly bedded, coarse grained limestone with some darker fine grained beds (Daly *et al*, 1997). Geophysical logging carried out by the GSI in November 1979 indicates thin clayey bands at 38m and 78m bgl.

6.1.5. Structure

The limestone rock units have been gently folded from northwest to southeast. The Hollimshill source is located on the northwest limb of a synclinal fold. The rocks are dipping approx. 15° to the southeast. A thrust fault, trending NE-SW is present 200 m south of the source. Faulting is estimated to occur every 500m to 1000m in certain areas of the limestone units (Daly *et al*, 1997). Associated with folding and faulting is the development of fissures.

6.2. Subsoils (Quaternary) Geology

The subsoils in the Hollimshill area are shown in Figure 2 and are subdivided into: limestone till, sands/gravels, till with gravel and peat.

6.2.1. Limestone Till

Limestone till deposits occur to the south and southwest of Pallas Lough. Limestone dominated tills reflect the lithology of the underlying limestone rock and are usually grey in colour and sandy in texture.

6.2.2. Sands & Gravels

Extensive fluvioglacial sand and gravels are present in County Offaly and occur to the north and north west of the Hollimshill area. The sands and gravels are generally coarse, poorly sorted but often contain lenses of better sorted material. The boulders and cobbles are normally limestone in composition.

Sands/gravels in Offaly are often associated with eskers. There is a NW - SE trending esker located approx. 1 km north of the source. Most eskers are formed by meltwater flowing in tunnels under an ice-sheet or in an ice-walled channel near the ice margin (Warren, 1997). Esker deposits are generally composed of coarse boulder gravels which are highly permeable.

6.2.3. Till with Gravel

The Hollimshill source is located within till with gravel deposits. The reconnaissance work in Offaly has shown that many of the sand/gravel units are small and are interbedded with tills (Warren in Hammond *et al.* (1987)). In many places it is not possible to map out separately the sand/gravel units and the till units during a reconnaissance mapping project. This has led to the term "till with gravel" being employed to categorise the sediments over relatively large areas (Daly *et al*, 1997).

6.2.4. Peat

Peat deposits occur along the shores of Pallas Lough and to the southeast of the source. Peat deposition commenced in shallow lakes and so peat is commonly underlain by lake clay and silt.

6.2.5. Depth to Bedrock

Accurate information on depth to bedrock is based on outcrop information, well records and subsoil sections. The 6" GSI map of the area shows a rock outcrop immediately to the southwest of Pallas Lough. No other outcrops have been noted. Abundant depth to bedrock data exists for the area. Deep probing to bedrock was carried out by a mineral exploration company in a series of northwest - southeast trending traverses across the area. This indicates very variable subsoil thicknesses which vary from <3m southwest of Pallas Lough to 29m northeast of the Lough. Subsoils are 23 m thick in the vicinity of the source. Depth to bedrock information is given in Figure 2.

7. Hydrogeology

7.1. Data availability

Hydrogeological information for this study was obtained from the following sources:

- A 24 hour pumping test carried out by Offaly County Council in 1979.
- Source description of the Hollimshill Source (Daly & Flynn, 1994).
- County Offaly Groundwater Protection Scheme, (Daly *et al*, 1997).

7.2. Meteorology and Recharge

Rainfall data for the area are taken from a contoured rainfall map of Co. Offaly, which is based on data from Met Éireann. For 1951 - 1980, the mean annual rainfall (R) for the area was 837 mm. Evaporation data for the area are taken from the national contoured map produced by Met Éireann. Potential evaporation is estimated as 482 mm/yr. Actual evapotranspiration (A.E) is then calculated by taking 90% of the potential figure, to allow for soil moisture deficits, so A.E. is estimated as 434

mm/yr. Using these figures, the potential recharge (R - A.E.) is taken to be approximately 401 mm. The absence of drains and ditches in the area indicates that most of the subsoils are free draining and that a high proportion of the effective rainfall is infiltrating to the water table. Runoff is taken to be 10% of available recharge in well drained areas and is estimated to be 40 mm. In areas of peat, runoff is estimated to be as much as 80% of available recharge, i.e. 290 mm. These calculations are summarised below:

Average annual rainfall	837 mm
Estimated P.E.	482 mm
Estimated A.E. (90% P.E.)	434 mm
Available recharge	403 mm
Sands/Gravels, Till;	
Surface Runoff (10%)	40 mm
Recharge	363 mm
Peat	
Surface Runoff (80%)	290 mm
Recharge	73 mm

7.3. Groundwater levels

The water level at the Hollimshill source was 32 m below ground level (73 m O.D. approx.) in March 1979; this is likely to represent a relatively high water table. The water levels in Pallas Lough, the Clodiagh River and Agall Spring (3.2 km north of Hollimshill) are assumed to represent groundwater levels in the area. The water level in Pallas Lough is taken to be 76.6 m A.O.D., the level shown on the 1910 Ordnance Survey map of the area.

The unsaturated zone is 32m thick at Hollimshill and is likely to be greater than 10m thick over most of the area, except in the immediate vicinity of Pallas Lough, the Clodiagh river and the peatland area near Agall spring.

7.4. Groundwater Flow Directions and Gradients

The water table in the Hollimshill area (see Figure 3) is assumed to broadly reflect topography with water flowing northward and discharging in the vicinity of Agall springs. The high permeability gravelly till that forms Hollimshill and the esker ridge to the north have no influence on the water table. The absence of a surface outlet from Pallas Lough indicates that there is hydraulic continuity with the groundwater, with outflow occurring underground.

The natural hydraulic gradient in the Borrisokane and Allenwood Limestones is estimated to be 0.003 - 0.004 on the basis of existing data and the numerical modelling. High permeability zones caused by fissuring in the vicinity of faults may be present across the area and may cause local changes to the hydraulic gradient. The gradient in the Waulsortian and Calp Limestones is estimated to be in the range of 0.01 - 0.02. The steepening of the gradient in the shalier limestones is a consequence of the lower permeability.

7.5. Hydrochemistry and Water Quality

The Tully, Agall and Hollimshill sources collectively supply the Rahan Scheme. There are no recent data for the Hollimshill source, analyses from Rahan (mixed water sample) provide a good representation of general water quality in the main limestone aquifer. There has been a gradual increase in nitrate levels (see Appendix 1), however concentrations are generally below the E.U. guide level. The concentrations which are in the range of 20 - 22 mg/l are likely to be representative of present general nitrate contamination by both diffuse (spreading of inorganic fertiliser and slurry) and

point sources (septic tank systems and farmyards) in this relatively intensive farming area in mid-Offaly (Daly *et al*, 1997). Overall the water quality in the Rahan area appears to be good - all major cations and anions are within the E.U. limits.

7.6. Aquifer Parameters

Analysis of the pumping test data provided a transmissivity in the range of 52 - 530 m^2/d for the Borrisokane Limestone and a specific capacity estimate in the order of 57 - 62 $m^3/d/m$. In the numerical modelling a transmissivity of 640 m^2/d was obtained. Transmissivity of the Allenwood Limestone is estimated to be 200 m^2/d based on pumping tests carried out in adjacent counties such as Laois. The porosity of these limestone formations is taken to be approximately 2 %.
The transmissivity of the Calp and Waulsortian Limestones is estimated to be < 10 m^2/d and the porosity is taken to be 1%.

7.7. Aquifer Category

The Allenwood Limestone and the Borrisokane Pure Limestone are classed as Regionally Important fissured aquifers **(Rf).** Although the availability of hydrogeological information for both aquifers is limited, pumping test data as well as high yields provide evidence of significant aquifer potential. The Waulsortian Limestone and Calp Limestone are classed as Locally Important aquifers which are moderately productive only in local zones **(Ll).** (For more information refer to the Co. Offaly Groundwater Protection Scheme, (Daly *et al,* 1997).)

7.8. Conceptual Model

- The Hollimshill source is located in the Borrisokane Limestone aquifer which is regarded as the highest permeability rock in the area. The source is also fed by the lower permeability Allenwood, Waulsortian and Calp Limestone units.

- The permeability of the aquifer depends on the development of faults, fissures and fractures. In the low permeability rocks, groundwater flow is likely to occur in the top 10m of fissured and weathered bedrock.

- These rock units are largely overlain by moderately permeable limestone till and highly permeable till with gravel and sands/gravels. Therefore the groundwater can be considered as unconfined.

- The water table in the Hollimshill area is assumed to flow northward and discharge in the vicinity of Agall spring.

- Pallas Lough recieves water from its catchment from both surface runoff and shallow groundwater flow. There are no surface outlets from the lake therefore it seems likely that water from the lake enters the groundwater through the lake bed. Therefore the zone of contribution to the source extends southwards to include Pallas Lough and its catchment area. In the absence of further data it is assumed that the groundwater catchment to Pallas Lough coincides with the surface water catchment.

- The groundwater gradient is relatively flat within the permeable limestone aquifer. Modelled groundwater levels suggest that gradients for the Borrisokane and Allenwood Limestones are 0.003 - 0.004 and gradients for the Waulsortian and Calp Limestones are 0.01 - 0.02.

- The aquifer was modelled using FLOWPATH - a 2D finite difference model which was calibrated using measured water levels at the source. Hydraulic controls for the model consisted of Pallas Lough to the south, flow lines to the east and west and a springline to the north.

8. Delineation Of Source Protection Areas

8.1. Introduction

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) includes the complete catchment area to the source, i.e. the zone of contribution (ZOC), and it is delineated as the area required to support an abstraction from long-term recharge. The ZOC is controlled primarily by a) the pumping rate, b) the groundwater flow direction and gradient, c) the rock permeability and d) the recharge in the area. The ZOC is delineated as follows:

i) An estimate of the area size is obtained by using the average recharge and the abstraction rate.
ii) The shape of the area is then derived by both numerical modelling (using FLOWPATH) and hydrogeological mapping techniques.
iii) 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 maximum abstraction rate at the Hollimshill Public Water Supply is estimated to be 525 m^3/d. For the purposes of modelling the source, the average yield is increased by approximately 50% to 800 m^3/d for the following reasons:

- The higher yield allows for increased water demand due to expansion in Hollimshill.
- 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 363 mm as indicated in Section 7.2, the area required to supply a pumping rate of 800 m^3/d is calculated to be 0.8 km^2 (80 ha). However this area will increase in dry weather.

A more accurate ZOC at Hollimshill is derived from numerical modelling of the groundwater system together with hydrogeological mapping techniques.

The defining conditions for the numerical model are discharge, aquifer thickness, effective porosity and recharge:

Discharge	Public Supply Well	800 m^3/d
Thickness	Limestone	50 - 60 m
Effective porosity	Calp/Waulsortian Lst	1 %
	Borrisokane/Allenwood Lst	2 %
Recharge	Sands/Gravels, Till	363 mm/yr
	Peat	73 mm/yr

The model-derived parameter is hydraulic conductivity:

Hydraulic conductivity	Waulsortian Limestone	0.12 m/d
	Allenwood Limestone	4 m/d
	Calp Limestone	0.12 m/d
	Borrisokane Limestone	12.75 m/d

Using the above parameters, the groundwater conditions in the Hollimshill area were successfully modelled using FLOWPATH. In order to test the robustness of the model, a sensitivity analysis (see Appendix 2) was carried out by varying recharge and permeability – the parameters that are normally

poorly specified in terms of data. The results of the sensitivity analysis are incorporated into the ZOC, which is shown in Figure 4. The ZOC is controlled primarily by the groundwater flow direction and by Pallas Lough to the south. The southwestern limits of the surface water catchment of Pallas Lough are difficult to define and so are tentatively delineated on Figure 4.

These boundaries are based on our current understanding of groundwater conditions in the area and on the available data.

8.3. Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100 day time of travel (TOT) from a point below the water table to the source and it is delineated to protect against the effects of potentially contaminating activities which may have an immediate influence on water quality at the source, in particular from microbial contamination. A sensitivity analysis on the 100 day TOT zone was carried out by varying permeability, porosity and recharge - see Appendix 2b.

9. Vulnerability

Areas of limestone till with gravel have hydrogeological characteristics typical of both till and sand/gravel, and the resulting permeabilities will vary depending on the underlying lithology. For the purposes of categorising vulnerability, the precautionary approach is taken, and therefore it is assumed that these deposits have a high permeability (Daly *et al*, 1997). Depth to bedrock information indicates that these subsoils are generally much greater than 3 m in thickness. Consequently groundwater at the source and adjacent areas is believed to be highly vulnerable to contamination.

Sands and gravels normally contain less than 3% fine grade material and are classed as highly permeable (Daly *et al*, 1997). The unsaturated zone in the sands and gravels is assumed to be at least 3 m in thickness and so groundwater in these areas is considered to be "highly" vulnerable.

The limestone tills in County Offaly are assumed to be free-draining and sandy, and therefore to have a moderate permeability (Daly *et al*, 1997). The limestone till is generally between 3 and 10m thick and so is considered highly vulnerable to pollution. In some areas the limestone till is greater than 10m and so is moderately vulnerable to contamination.

Pallas Lough is underlain by shallow peat deposits which are probably less than 3m. It is not known whether the peat is underlain by high permeability till with gravel or moderately permeable limestone till. Therefore the vulnerability of this area is unknown and remains undefined on the vulnerability map (Figure 5).

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 (see the matrix in the table below). 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. **SO/H**, which represents an Outer Source Protection area where the groundwater is highly vulnerable to contamination. All of the hydrogeological settings represented by the zones may not be present around each local authority source. There are 4 groundwater protection zones present around the Hollimshill source (see Figure 6), as shown in the matrix below.

Matrix of Source Protection Zones

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

Low (L)		

It is not within the scope of this report to delineate the protection zones in the surrounding area and this is dealt with at the regional resource protection scale.

The accompanying response measures imposing restrictions on developments will follow when discussions have been carried out between the Council, the EPA and the GSI as to the degree of restriction necessary in each protection zone.

11. Potential Pollution Sources

Agriculture is the principal activity in the area. Most of the land is used for pasture, although a significant proportion is used for tillage. The main hazards within the ZOC are farmyards, septic tank systems, application of fertilisers (organic and inorganic) and pesticides, and possible spillages along the roads. No detailed assessment of hazards was carried out as part of this study.

12. Conclusions and Recommendations

- The source at Hollimshill is an excellent yielding well, which is located in a regionally important fissured limestone aquifer.

- The outer protection zone includes Pallas Lough and its catchment area.

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

- The inner and outer 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.

- It is recommended that:
    - The Hollimshill source be sampled before mixing occurs with the Agall and Tully supplies - in this way water quality in the area can be assessed.
    - chemical and bacteriological analyses of raw water rather than treated water should be carried out on a regular basis (every 3 - 6 months);
    - a full analysis should be carried out (refer to the Co. Offaly Groundwater Protection Scheme, (Daly *et al,* 1997).)
    - the nitrate data should be reviewed regularly;
    - in the short term, until the groundwater quality situation can be properly assessed, care should be taken in allowing any activities or developments which might significantly increase nitrate levels;
    - the potential hazards in the ZOC should be located and assessed;

an interim code of practice for dealing with spillages along the roads in the area should be drawn up.

13. References

AMAX Exploration Ireland Inc. (1979 - 1981) Compilation Map of the Tullamore - Blue Ball Area, Co. Offaly.

Daly D., Cronin C., Coxson C. & Burns S.J. (1997). *County Offaly Groundwater Protection Scheme.*

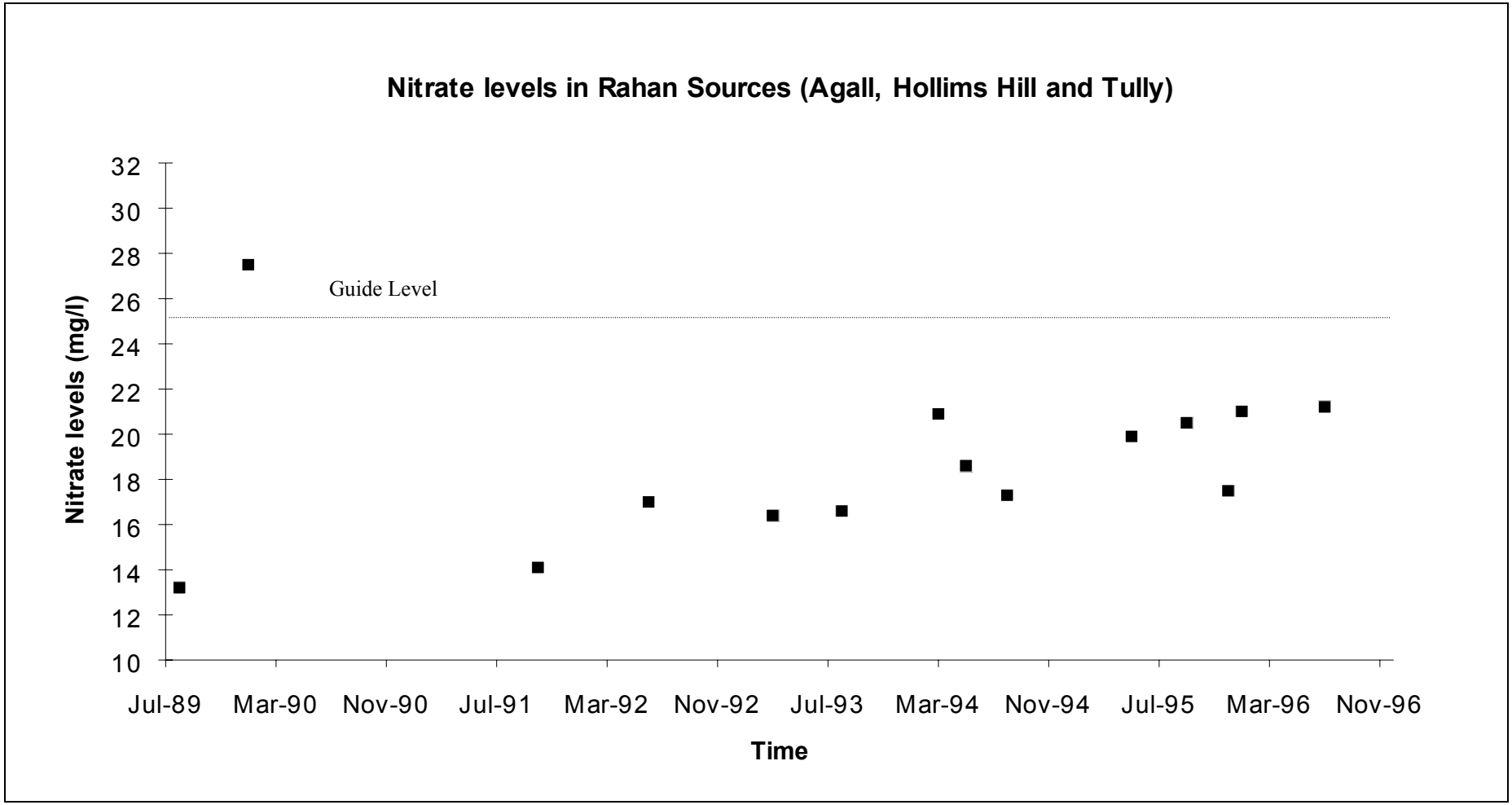
Daly, D & Flynn, R. (1994*). Source Description of the Hollimshill Public Supply Well*. A modelling study carried out for Offaly County Council.

Hammond, R.F. (1979). *The Peatlands of Ireland*. Soil Survey Bulletin No. 35, An Foras Taluntais. 58pp.

Hammond, R.F., Warren, W.P. and Daly, D. (1987). *IQUA Field Guide No. 10, Offaly and west Kildare*. Irish Association for Quaternary Studies.72pp.

Keating, M & Packman M.J. (1995). *Guide to Groundwater Protection Zones in England and Wales*. National Rivers Authority

APPENDIX 1


Nitrate levels in Rahan Sources (Agall, Hollims Hill and Tully)
Nitrate levels (mg/l)
32
30
28
26
24
22
20
18
16
14
12
10
Guide Level
Jul-89
Mar-90
Nov-90
Jul-91
Mar-92
Nov-92
Jul-93
Mar-94
Nov-94
Jul-95
Mar-96
Nov-96
Time

APPENDIX 2

2a. Delineation of the Zone of Contribution

To examine the robustness of the numerical model, a sensitivity analysis was carried out using methods employed by the U.K's Environment Agency (Keating & Packman, 1995). Optimum permeability (K) and recharge (R) values were initially chosen and the sensitivity analysis was based on varying these parameters. Recharge was varied over a range of 80 to 120% and permeability by 50 - 150%. This involved creating nine models – each model has a different permeability and recharge value. The nine models are as follows;

↑ Recharge (R)			
	1.2R, 0.5K	1.2R, K	1.2R, 1.5K
	R, 0.5K	R, K	R, 1.5K
	0.8R, 0.5K	0.8R, K	0.8R, 1.5K

Permeability (K) →

Each model was run and the resulting ZOC's were overlain upon each other. The following areas are delineated on the overlay map which is available on request at the GSI.

Best Estimate: The model which was produced using best estimate values of permeability and recharge.
Area of Certainty: This represents the area of overlap of all nine models
Area of Uncertainty: This represents the outer envelope of all nine models.

In view of the variability of limestone aquifers and the resulting uncertainties, it was decided to include not only the best estimate but also the area of uncertainty within the delineated ZOC in Figure 4.

2b. Delineation of the 100 day Time of Travel Zone.

In the delineation of the 100 day TOT zone , it is advisable to take a cautious approach. Therefore the "best estimate" porosity of the limestone was reduced by 50% (velocity increases as porosity is reduced) in each of the nine models above.

The nine models were run and the results of each were overlain upon each other. The overlay map is available on request at the GSI. The delineated 100 day TOT zone (see Figure 4) incorporates the results of all nine models.

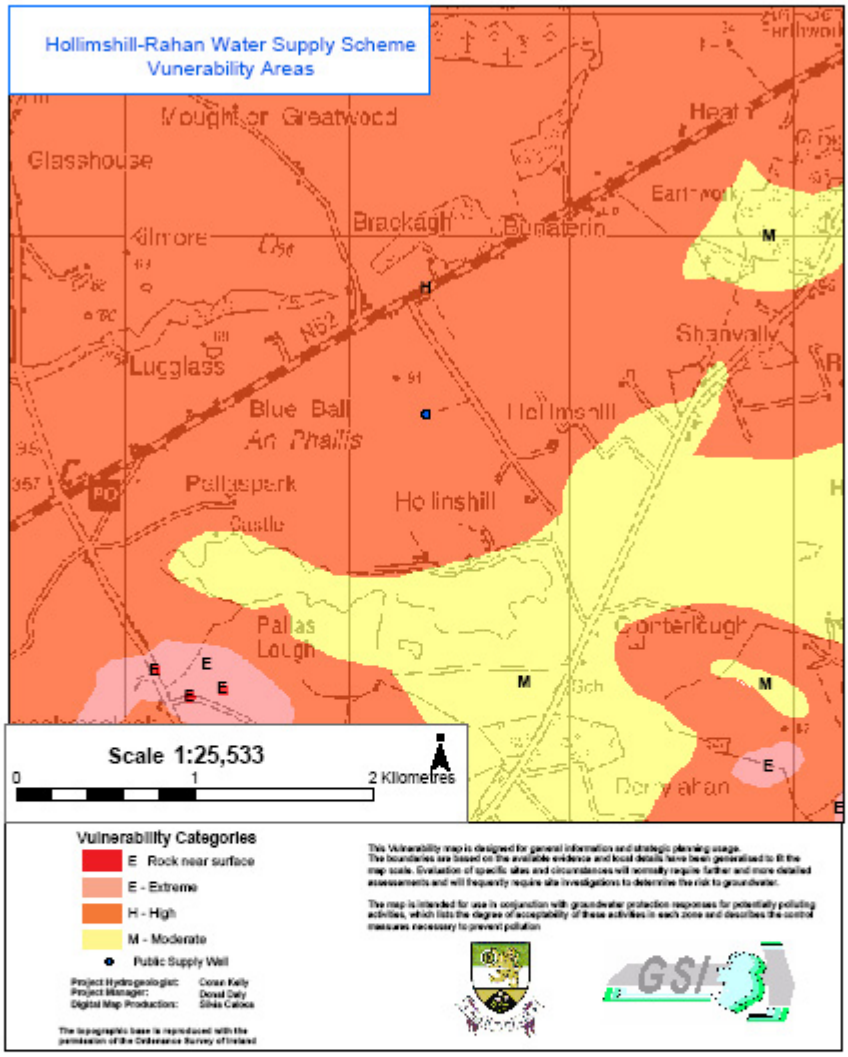


Figure 1 **Groundwater Vulnerability around Hollimshill**

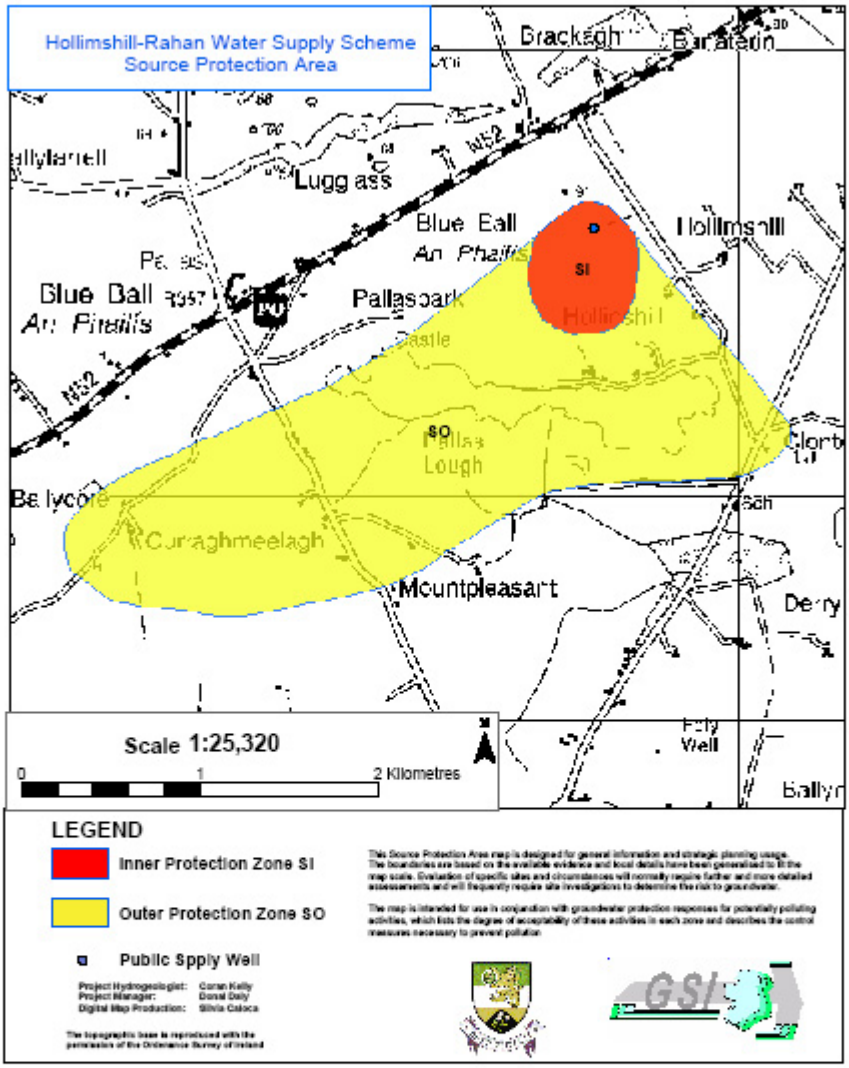


Figure 2 **Groundwater Source Protection Areas for Hollimshill**

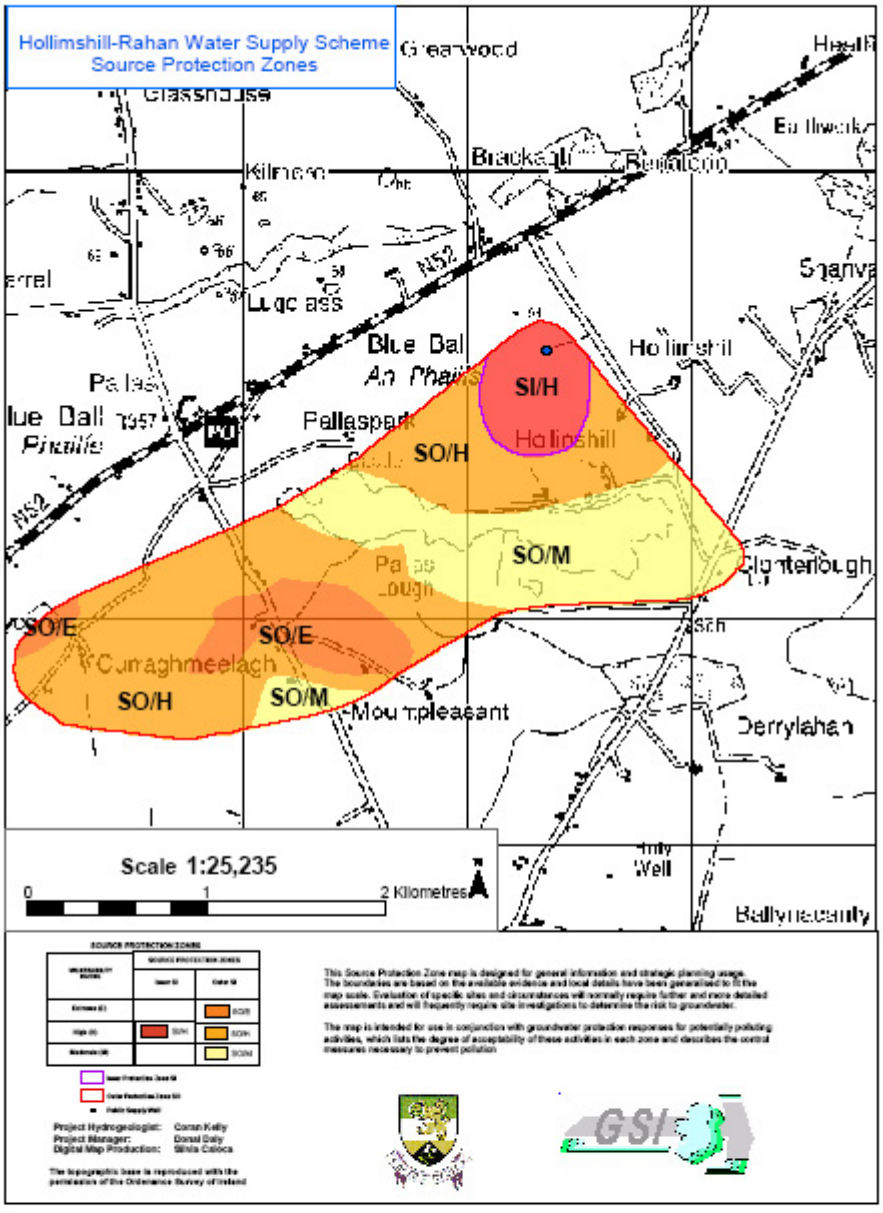


Figure 3 **Groundwater Source Protection Zones for Hollimshill**