Tully 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 Tully Public Water Supply.
- To outline the principle hydrogeological characteristics of the Tully area.
- To assist Offaly County Council in protecting the water supply from contamination.

2. Location and Site Description

The Tully source is situated approximately 1 km north-east of Rahan in the townland of Aghalusky, County Offaly. The source comprises two wells which are located beside a pumphouse in a site which is fenced off from the adjacent field.

The wells are 60 m and 91 m in depth and were completed above ground level; one is protected by a well cap however the other is unsealed. The site itself is not concreted and so is at risk from spillages occurring within the site or on the nearby road.

3. Summary of Well Details

GSI no.	2021 NE W006
Grid ref. (1:25,000)	22753 22659
Townland	Aghalusky
Owner	Offaly County Council
Well type	Two bored wells
Elevation (top of casing)	63.1 m A.O.D.
Depth	60 m and 91 m
Diameter	0.45 m
Depth-to-rock	3.65 m
Static water level	9.28 m b.g.l (22/2/79) and 7.87 m (22/10/79) below top of casing
Drawdown	approximately 11 m b.g.l.
Abstraction rate	432 m^3/d
Pumping test summary	(i) Abstraction rate: 572 m^3/d (seven day constant rate test) (ii) Specific capacity 57 $m^3/d/m$ (after 1500 mins pumping) 35 $m^3/d/m$ (after 10 days of pumping) (ii) Transmissivity: 13 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 the GSI Chevron Sheet No. 15 (Hitzman, 1992) 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, pumping test details and geophysical borehole logs.

The second stage comprised site visits and fieldwork in the Tully 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

The topography in the Tully area slopes gently southward from Trumpet Hill (90 m O.D.) to the Clodiagh River (58m O.D.). The Tully source is sited at 63 m O.D.. Trumpet Hill is an east-west trending ridge which is located approximately 500 m north of the wells. The Clodiagh River which is approximately 1 km south of the Tully Source, flows westward where it meets the Silver River. A minor tributary of the Silver River flows to the north of Trumpet Hill, and has little flow.

The soils and subsoils are also relatively free draining in the vicinity of the well and there are no drain or ditches. A swampy area directly north of Trumpet Hill has in recent years been the subject of reclamation. The land is generally used for pasture although a significant proportion (perhaps up to 30%) is used for tillage.

6. Geology

6.1 Bedrock Geology

The bedrock geology of the Tully 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 as follows;

6.1.1 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).

6.1.2 Borrisokane Pure Limestone

The Tully 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 borehole logging carried out by the GSI in November 1979 show that although the limestone is relatively pure, there are thin muddy beds at 32 m and 50 m b.g.l..

6.1.3 Structure

The limestone rock units have been gently folded from northwest to southeast. The Tully source is located on the northwestern limb of a synclinal fold. The rocks are dipping gently (<5°) south eastward. Faulting is estimated to occur every 500 m to 1000 m in certain areas of the aquifer (Daly *et al*, 1997).. Associated with folding and faulting is the development of fissures.

6.2 Subsoils (Quaternary) Geology

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

6.2.1 Limestone Till

The Tully wells are located close to the boundary between the sand/gravel and the limestone till. The limestone till deposits extend southwards from the Tully wells to the Clodiagh River. 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 have been subdivided in Figure 2 into “Sand and Gravel” and “Esker” deposits. These deposits extend northwards from the Tully wells to the tributary. 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. To the northwest of the source in the Tullymore Rahan area, the sands are fine grained and well bedded (Flynn, 1994)

Sands/gravels in Offaly are often associated with eskers. 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. The esker ridge to the north, known as Trumpet Hill, has an approximate east-west trend, is 90 m in elevation and ranges from 250 - 400 m in width.

6.2.3 Till with Gravel

Till with gravel deposits occur approximately 1km northwest of the Tully wells. 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 River Alluvium

A strip of alluvium comprising fine grained silts and clays has been deposited along the banks of the Clodiagh River. The alluvium varies in width from 150 m to >1000 m.

6.2.5 Peat

The edge of Clara Bog occurs to the northwest of the esker and comprises largely peat deposits with some clay/silt deposits (Daly *et al*, 1997). Peat deposition commenced in shallow lakes and so peat is commonly underlain by lake clay and silt. There are also likely to be peat deposits in the swampy area to the north of Trumpet Hill.

6.3 Depth-to-rock

There is limited information on depth to bedrock in the Tully area, however a borehole log indicates that bedrock is 3.65 m b.g.l at the source itself. The Quaternary map indicates that there is some outcropping rock and shallow bedrock in the Ballymire area, located approximately 2 km southeast of the source.

In general, areas of peat are taken to be at least 5m in thickness but no greater than 10m as much of the peat in Offaly has been cut away. Sand/Gravel deposits tend to be at least 3m in thickness but are generally much thicker. Little information regarding the thickness of esker deposits exist, however they are assumed to be at least 10m thick.

7. Hydrogeology

7.1 Data availability

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

- A 26 hour pumping test carried out by Offaly County Council in 1979.
- Geophysical borehole logging carried out in 1979.
- Source description of the Tully Source (Daly & Flynn, 1994).
- Water level data for the Clodiagh River and the tributary of the Silver River were obtained from the O.P.W.
- 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 835 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 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 and is estimated to be 40 mm. These calculations are summarised below:

Average annual rainfall	835 mm
Estimated P.E.	482 mm
Estimated A.E. (90% P.E.)	434 mm
Available recharge	401 mm
Surface Runoff	40 mm
Recharge	361 mm

7.3 Groundwater levels

The water level at the Tully source was 9.28 m below the well head (8.9m b.g.l approx.) on the 22/2/79 and 7.87 m on the 27/10/79. South of the well the water table is likely to be at shallower depths and is probably <1 m depth in the vicinity of the Clodiagh River (the river is believed to be hydrologically connected to the aquifer). Modelled water level elevations are shown in Figure 3.

In the relatively flat area between the Tully Source and the esker ridge to the north, the unsaturated zone is likely to be at least 7 m thick, with a considerable increase occurring beneath the esker ridge itself.

7.4 Groundwater Flow Directions and Gradients

The water table in the Tully area is assumed to broadly reflect topography with water flowing toward and discharging into the Clodiagh River and into the tributary of the Silver River (see Figure 3). Consequently a groundwater catchment divide is present between the river and the tributary. Water to the north of the divide flows toward the tributary and water to the south flows toward the Clodiagh River. As there is minimal water level information for the area the exact location of the divide is not known. However the numerical modelling exercise suggests that it runs in an east-west direction a short distance (approx. 50 m) to the south of the borehole. This implies that the surface water divide does not coincide with the topographic divide and that the esker ridge has no effect on the water table. This is a reasonable conclusion in view of the high permeability of the subsoils in the area, the water levels in the river and stream and the high permeability of the bedrock.

The natural hydraulic gradient is estimated to be 0.0017 - 0.0025 with an average of 0.002, based on the 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. Some degree of heterogeneity is suggested in the geophysical borehole logging carried out by the GSI, where there is some evidence for a large fissure or cavity at 20 m b.g.l.

7.5 Hydrochemistry and Water Quality

The Tully, Agall and Hollims Hill sources collectively supply the Rahan Scheme. There are no recent data for the Tully 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), 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. There have been isolated occurrences of faecal bacteria in the treated water at Rahan. The pH measured at Tully on the 6/8/91 was 7.2 and the conductivity was 636 μS/cm.

7.6 Aquifer Parameters

Analysis of the pumping test data provided an aquifer transmissivity estimate of 13 m^2/d and a specific capacity estimate in the order of 35 - 57 $m^3/d/m$. The transmissivity value is considered to be too low to reflect the general aquifer characteristics in the area. In the numerical modelling a transmissivity of 140 m^2/d was obtained. Based on the modelled transmissivity, the calculated specific capacity and on experience in other limestone areas, the transmissivity is believed to be at least an order of magnitude greater than the pumping test results. Modelled permeability is derived to be 4.5 m/d. The porosity of the limestone aquifer is taken to be approximately 2 %.

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. (For more information refer to the Co. Offaly Groundwater Protection Scheme, (Daly *et al,* 1997).)

7.8 Conceptual Model

- The Tully source is fed from the Borrisokane Pure Limestone which is a regionally important fissured aquifer.

- The permeability in this aquifer depends on the development of faults, fissures and fractures.

- This rock unit is largely overlain by moderately permeable tills and highly permeable sands/gravels. Therefore the groundwater can be considered as unconfined.

- Based on water levels obtained from the OPW and a site visit, the Clodiagh River and the tributary of the Silver River are considered to be in hydraulic continuity with the aquifer and so are groundwater fed.

- The water table in the Tully area is assumed to broadly reflect topography with water flowing toward and discharging to the Clodiagh River and the tributary to the north of the esker. Consequently an east-west trending groundwater catchment divide is present between the river and the tributary. Water to the north of the divide flows toward the tributary and water to the south flows toward the Clodiagh River. Numerical modelling indicates that the east-west trending groundwater divide which occurs approximately 50 m south of the source, does not coincide with the topographic divide and therefore the esker ridge has no effect on the water table.

- The groundwater gradient is relatively flat within the permeable limestone aquifer. Modelled groundwater levels suggests that gradients for the Borrisokane Pure Limestone are approximately 0.002.

- The aquifer was modelled using FLOWPATH - a 2D finite difference model which was calibrated using measured water levels. Hydraulic controls for the model consisted of the Clodiagh River to the south, a tributary of the Silver River to the north, (both streams converge to form the westerly control) and the topographic divide to the east.

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 average abstraction rate at the Tully Public Water Supply is estimated to be 432 m^3/d. For the purposes of modelling the source, the average yield is increased by 50% to 650 m^3/d for the following reasons:

- The higher yield allows for increased water demand due to expansion in Tully.
- 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 361 mm as indicated in Section 7.2, the area required to supply a pumping rate of 650 m^3/d is calculated to be 0.66 km^2 (66 ha). However this area will increase in dry weather.

A more accurate ZOC at Tully 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	650 m^3/d
Thickness	Limestone	24 - 32 m
Effective porosity	Limestone	2 %
Recharge		361 mm/yr

The model-derived parameter is hydraulic conductivity:

Hydraulic conductivity	Limestone	4.5 m/d

Using the above parameters, the groundwater conditions in the Tully 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 the recharge mound to the east.

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 rock close to surface are taken to be "extremely" vulnerable to pollution.

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 are 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 3.65 m thick at the well and so groundwater beneath the source site is considered to be "highly" vulnerable. It is assumed that the limestone till is between 3 m and 10 m thick and so is highly vulnerable in the surrounding area.

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). Consequently groundwater in these areas is believed to be highly vulnerable to contamination.

Peat permeabilities depend on the degree of peat decomposition (humidification) and the effects of subsidence. Apart from the upper layer of intact bogs, peat has a relatively low permeability. In assessing vulnerability of peaty areas, it is assumed that the peat and underlying marl and lake deposits are between 5 m and 10 m in thickness and so are moderately vulnerable (Daly *et al*, 1997).

Alluvium deposits are normally composed of fine grained silts and clays which have a moderate to low permeability. The thickness of the alluvium is not known and so for the purposes of vulnerability assessment the underlying subsoil is also taken into consideration. In Tully the underlying subsoil is assumed to be limestone till which is probably highly vulnerable.

Vulnerability of groundwater in the Tully area is shown in 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 2 groundwater protection zones present around the Tully source (see Figure 6), as shown in the matrix below.

Matrix of Source Protection Zones

VULNERABILITY RATING	SOURCE PROTECTION	
	Inner	***Outer***
Extreme (E)		
High (H)	SI/H	SO/H
Moderate (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 Tully is an excellent yielding well, which is located in a regionally important fissured limestone aquifer.

- 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 Tully source be sampled before mixing occurs with the Agall and Hoillims Hill supplies - in this way water quality in the Tully 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

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

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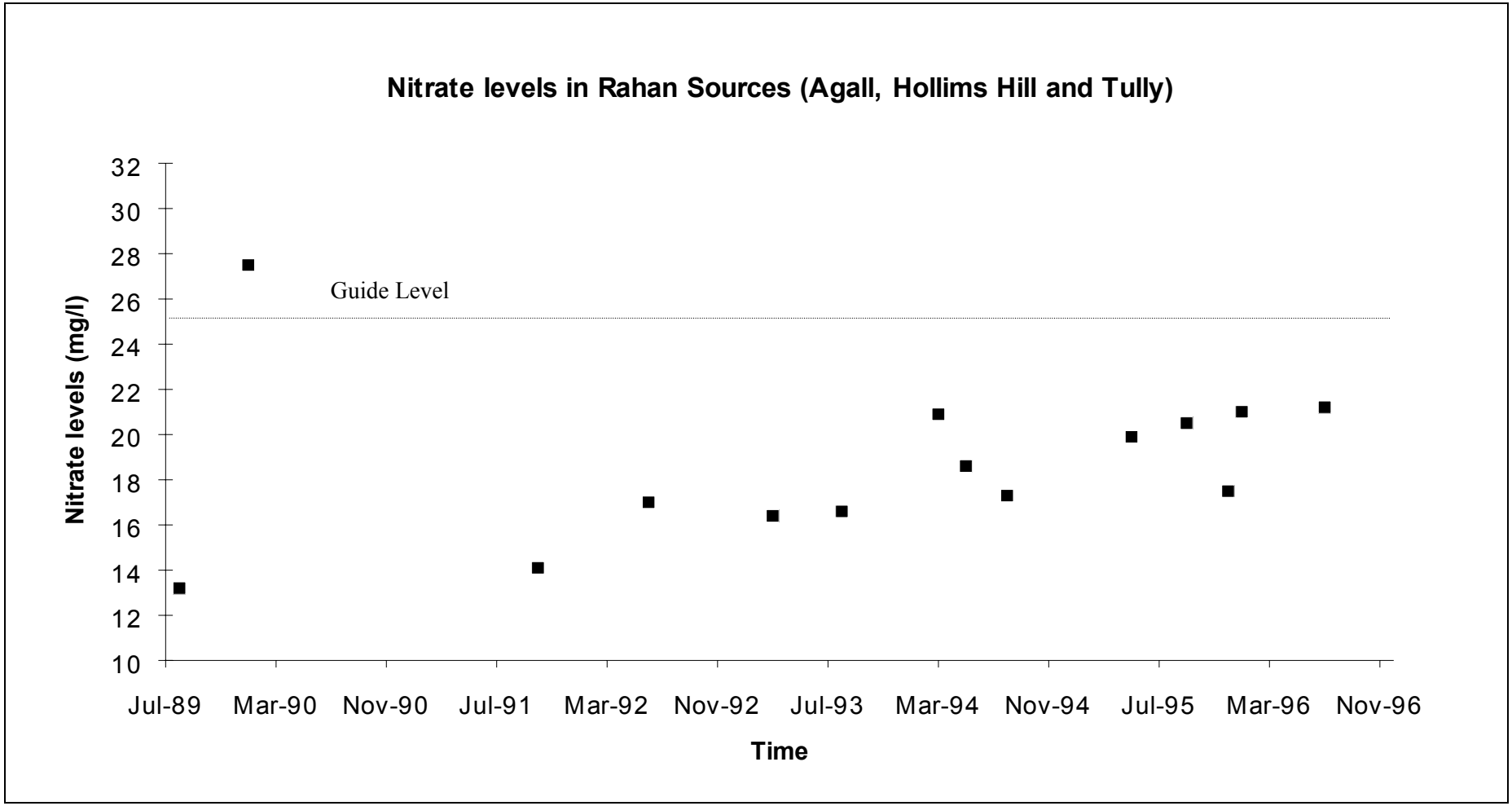
Hammond, R.F., Warren, W.P. and Daly, D. (1987). *IQUA Field Guide No. 10, Offaly and west Kildare*. Irish Association for Quaternary Studies.72pp.

Hitzman, M.W. (1992) *Bedrock Geology Map of the Carboniferous of Central Ireland*, Sheet 15. Chevron Mineral Corporation of Ireland and Ivernia West plc.

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.

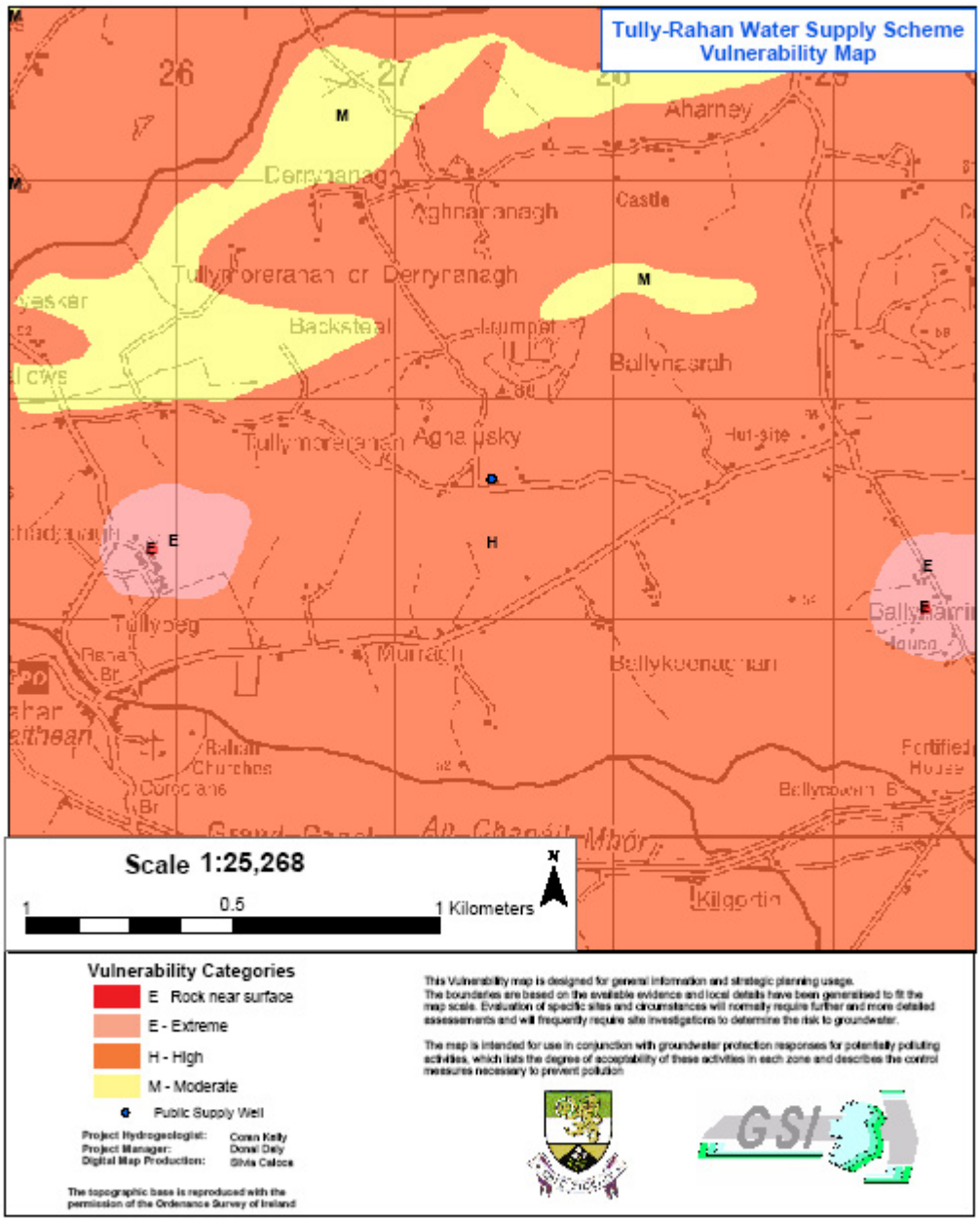


Figure 1 **Groundwater Vulnerability around Tully**

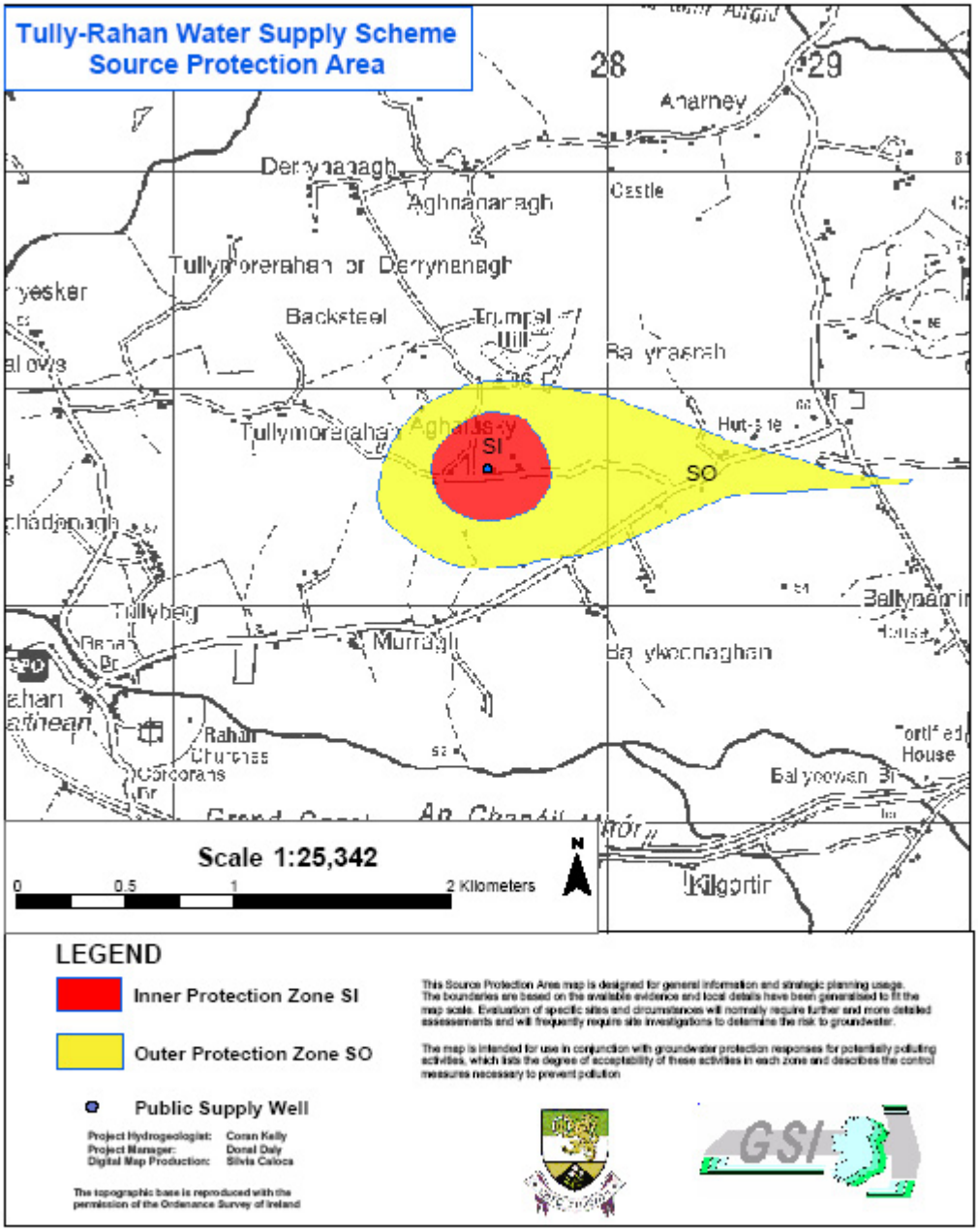


Figure 2 **Groundwater Source Protection Areas for Tully**

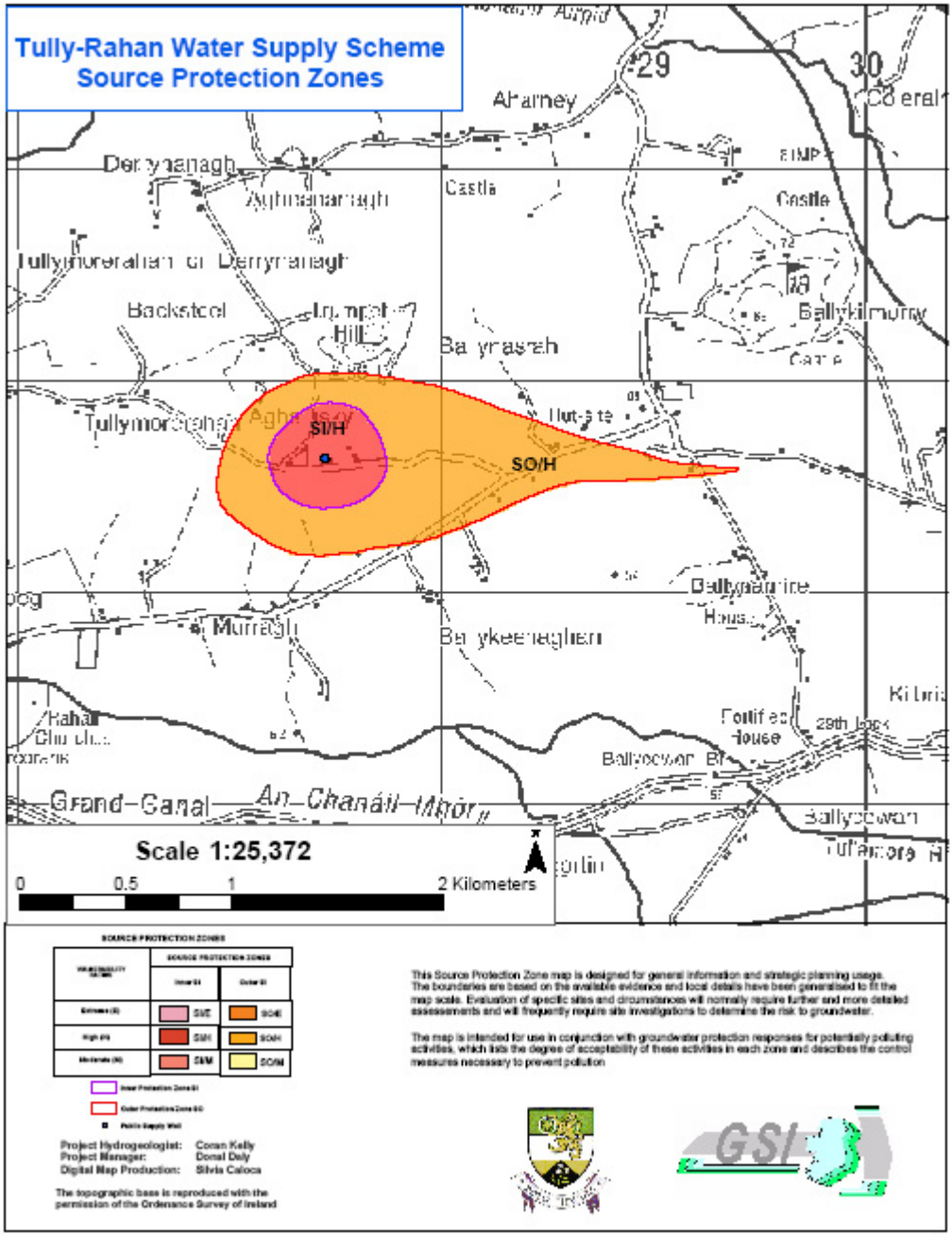


Figure 3 **Groundwater Source Protection Zones for Tully**