Dunkerrin Water Supply Scheme

Jones's Well

Groundwater Source Protection Zones

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Prepared by:
Coran Kelly
Geological Survey of Ireland

In Partnership with:
Offaly County Council

1 Introduction

The objectives of the report are as follows:

- To delineate source protection zones for the spring.
- To outline the principal hydrogeological characteristics in the vicinity of Jones's Well.
- To assist Offaly County Council in protecting the water supply from contamination.

The protection zones are delineated to help prioritise certain areas around the source in terms of pollution risk to the spring. This prioritisation is intended to provide a guide in the planning and regulation of development and human activities. The implications of these protection zones are further outlined in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

The report forms part of the groundwater protection scheme for the county. The maps produced for the scheme are based largely on readily available information in the area and mapping techniques which use inferences and judgements based on experience at other sites. As such, the maps cannot claim to be definitively accurate across the whole area covered, and should not be used as the sole basis for site-specific decisions, which will usually require the collection of additional site-specific data.

2 Location and Site Description

The spring known as Jones's Well is located in the townland of Island, alongside the R490 road between Cloghjordan and Moneygall, Co. Offaly. The spring has been dug out and deepened to a depth of 3 m, with a large diameter concrete pipe installed in the spring. The spring has not yet being put into commission, thus, there is no pumphouse or any other infrastructure in place to allow abstraction to take place. The spring is currently exposed and is shown in Figure 1.

3 Summary of Spring Details

GSI No.	2017NWW034
Grid reference	201669 183323
Townland	Island
Owner	Offaly County Council
Well Type	Spring
Elevation (ground level)	Approximately 105m OD. (Malin Head)
Static water level	Ground level
Depth to rock	Approximately 6 m
Maximum Yield	650 m^3 d^{-1} (estimated by Council staff 2001, GSI staff 1999, 2003)
Depth of sump	1.90 m (measured by GSI staff 15/1/03

4 Methodology

Details about the spring such as depth and yield were obtained from County Council personnel; geological and hydrogeological information was provided by the GSI.

This included the following:

- Estimating spring flows 29/7/1999, 15/1/2003.
- Drilling by GSI of 3 depth to rock auger holes in 2000, a further 6 holes in April/May 2003, one of which was a short (20 m) diamond drill hole into bedrock at the spring itself.
- Field mapping walkovers to further investigate the subsoil geology, the hydrogeology and vulnerability to contamination.
- Analysis of the data utilised field studies and previously collected data to delineate protection zones around the source.

Figure 1 Views of Jones's Well

5 Topography, Surface Hydrology and Land Use

The spring is located at approximately 105 m OD, at the bottom of the east facing slope of a small hill (134 m OD) that lies in the townland of Ballingorraun. To the north, east and northwest of the spring, the land is low-lying and quite flat, apart from occasional hummocky areas comprising gravel hillocks and eskers. The average topographic slope down to the spring is in the order of 1:35 and is depicted in Figure 3.

The natural drainage density is low apart from the low-lying areas where there is a small stream flowing northwestwards past the spring. The artificial drainage density is high on the low-lying ground in the immediate vicinity of the spring. The regional drainage is to the north and north west and is part of the Lough Derg subcatchment of the Shannon River Basin District (RBD).

The land use around the spring is generally grassland, used for pasture and silage. There are several sand/gravel pits (some disused) in the vicinity. There are also a number of farms and houses within a kilometre of the source.

6 Geology

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.

6.1 Introduction

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

- Gately, S., Sleeman, A.G., and G. Emo. A Geological description of Galway - Offaly, and adjacent parts of Westmeath, Tipperary, Laois, Clare and Roscommon to accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 15, Galway - Offaly.
- Information from geological mapping in the nineteenth century (on record at the GSI).
- Offaly Groundwater Protection Scheme (Daly *et al,* 1998).
- Open File records [OF-129-1].
- Subsoil mapping by the GSI.
- Auger drilling and Diamond hole drilling carried out by GSI (2000, 2003).

6.2 Bedrock Geology

The Lower Impure Limestone (Ballysteen Formation**)** is the dominant rock type mapped in the vicinity of the spring. This is a medium dark grey, impure, well bedded, fossiliferous limestone with mudstone bands and some siltstones. A short (20 m) diamond drill hole (GSI: DH33/03) was drilled beside the spring in May 2003 to determine the nature of the subsoil and bedrock at the spring. Figure 2 shows the recovered core and a summary log is given in Appendix 1.

The bedrock section of the core comprises:

(1) fossiliferous bioclastic limestone; and,
(2) clay rich material present at 12-13 m and 17-19 m.

The recovered core was shown to Bedrock Section staff in GSI, who were satisfied that the core is representative of the Ballysteen Formation and that the clay rich infills indicated faulting (Personal communication with Andy Sleeman, June 2003).

The fault is not shown on any existing bedrock map and there are no faults mapped in the vicinity of the spring - due to the lack of outcrop and borehole data in the area. There are two major fault sets present in the region: NW-SE and NE-SW. It is assumed that the drilled hole at the spring encountered a major fault, and based on the regional data, the inferred trend is NW-SE, but this is uncertain, and, it is also possible that there may be a NE-SW trending fault present.

Figure 2 Core from DH 033/03 Jones's Well, Co. Offaly

6.3 Subsoil Geology

Sand/gravel, limestone tills, peat and marl are the dominant subsoils in the area. The characteristics of each category are described briefly below:

- Sand/gravel occurs approximately 300 m to the east of the spring and is present in Auger hole 3 (2.5m depth to rock).
- ‘Till’ or ‘Boulder clay’ is an unsorted mixture of coarse and fine materials laid down by ice. Till occupies the area to the west of the spring. Till was present in all the auger holes to the west of the spring. Some of the tills were variable with thin sandy and gravelly horizons, in particular the auger holes beside the spring.
- Peat occupies a narrow area approximately 300 m wide between the tills and sand/gravels. The peat is less than 1 m thick and overlies till, in the vicinity of the spring. The spring is located at the till-peat boundary.
- A depth to bedrock drilling programme was carried out to ascertain the subsoil thicknesses. Figure 3 shows the location of the auger holes, depth to bedrock and subsoil type. The depth to bedrock varies from 2.5 m to 8.5 m; the deepest auger hole was beside the graveyard on the hill to the west of the spring. Logs of the auger holes are given in Appendix 1.

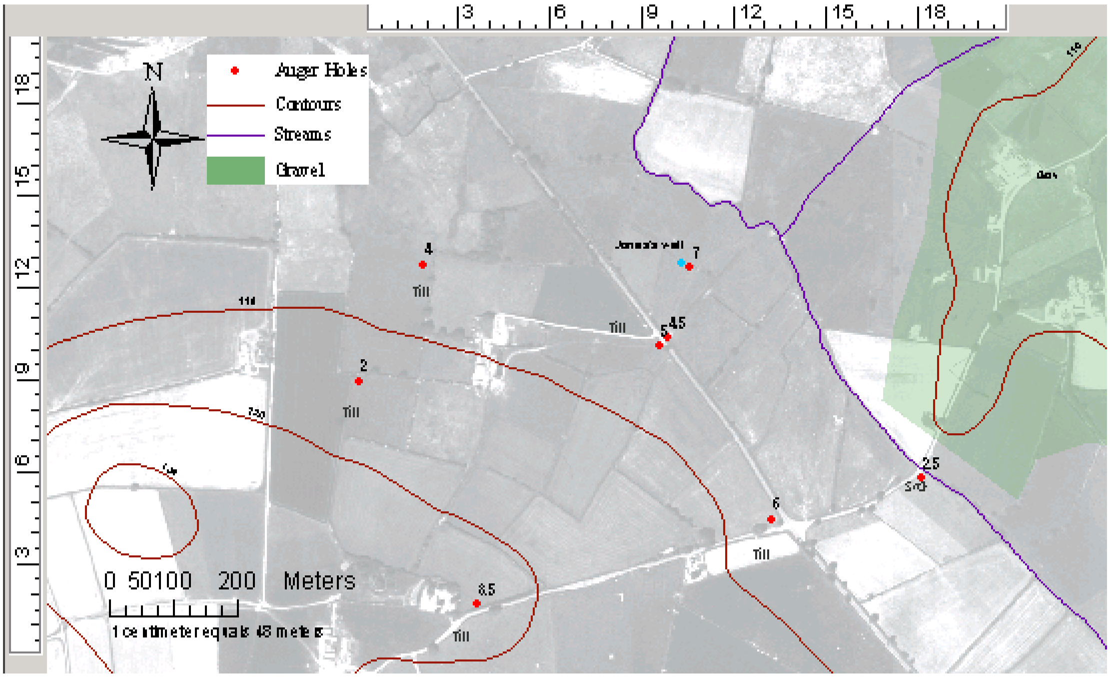

Figure 3 Location of Jones's Well, auger holes, depth to bedrock, streams, contours and gravel.

7 Groundwater Vulnerability

Groundwater vulnerability is dictated by the nature and thickness of the material overlying the uppermost groundwater 'target'. Consequently, vulnerability relates to the thickness of the unsaturated zone in the gravel aquifer, and the permeability and thickness of the subsoil in areas where the gravel aquifer is absent. A detailed description of the vulnerability categories can be found in the Groundwater Protection Schemes document (DELG/EPA/GSI, 1999) and in the GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination. (Fitzsimons, 2003).

- The source of the groundwater is thought to be the bedrock aquifer, thus for the purposes of vulnerability mapping, the "**top of the rock**" is the target.
- The permeability of the sand/gravel is classed as **"high"**, the permeability of the till **"moderate"** and the permeability of the peat **"low"**.
- Depth to bedrock varies from 2.5 m to 8.5 m and beside the spring it is approximately 6 m. The groundwater vulnerability in the catchment is predominantly "**high**", and is shown in Figure 5.

The depth to bedrock varies over short distances as can be seen in Figure 3. As such, the vulnerability mapping provided will not be able to anticipate all the natural variation that occurs in an area. The mapping is intended as a guide to land use planning and hazard surveys, and is not a substitute for site investigation for specific developments. Classifications may change as a result of investigations such as trial hole assessments for on-site domestic wastewater treatment systems. The potential for discrepancies between large scale vulnerability mapping and site-specific data has been anticipated and addressed in the development of groundwater protection responses (site suitability guidelines) for specific hazards. More detail can be found in 'Groundwater Protection Schemes' (DELG/EPA/GSI, 1999).

8 Hydrogeology

This section presents our current understanding of groundwater flow in the area of the source.

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

- Offaly Groundwater Protection Scheme (Daly *et al,* 1998).
- GSI files and archival Offaly County Council data.
- Offaly County Council drinking water returns.
- County Council personnel.
- Hydrogeological mapping carried out by GSI.
- A drilling programme carried out by GSI to ascertain depth to bedrock and subsoil permeability.

8.1 Rainfall, Evaporation and Recharge

The term 'recharge' refers to the amount of water replenishing the groundwater flow system. The estimation of a realistic recharge rate is critical in source protection delineation, as it will dictate the size of the zone of contribution to the source. For Jones's Well, the main parameters involved in recharge rate estimation are: annual rainfall; annual evapotranspiration; and a recharge coefficient. The recharge is estimated as follows.

Annual rainfall: 1000 mm.
Rainfall data for gauging stations around Jones's Well (from Fitzgerald, D., Forrestal., F., 1996).

Gauging Stations	**Grid reference**	**Elevation OD (m)**	**Approximate distance and direction from source**	**Annual precipitation 1961-1990**
Moneygall	S032811	125	2 km north	1032 mm

The contoured data map for the Offaly Groundwater Protection Scheme (Daly *et al*, 1998) show that the spring is located approximately at the 1000 mm average annual rainfall isohyet, which compares well to the contour map presented in the "Agroclimatic Atlas of Ireland" (Collins and Cummins, 1996).

Annual evapotranspiration losses: 450 mm. Potential evapotranspiration (P.E.) is estimated to be 475 mm $yr.^{-1}$ (based on data from Met Éireann). Actual evapotranspiration (A.E.) is then estimated as 95 % of P.E., to allow for seasonal soil moisture deficits.

Effective Rainfall: 550 mm
The effective rainfall is calculated by subtracting actual evapotranspiration from rainfall.

Recharge coefficient: 90%
The subsoils are dominated by moderately permeable till. A representative value for the recharge coefficient is estimated to be in the order of 90%.

These calculations are summarised as follows:

Average annual rainfall (R)	1000 mm
estimated P.E.	475 mm
estimated A.E. (95% of P.E.)	450 mm
effective rainfall	550 mm
recharge coefficient	90%
Recharge	**495 mm**

8.2 Groundwater Levels, Flow Directions and Gradients

Water level data are sparse. Water levels are close to the ground surface in the low-lying area in the vicinity of the spring and at the spring the water level is at ground surface.

The dominant driving head is the hill southwest of the source. The water table in the area is generally assumed to be a subdued reflection of topography; as the topography slopes northwestwards, the water table slopes northwestwards toward the springs. The flow directions will be perpendicular to the contour lines. In simple terms, rainfall reaching the water table anywhere in the catchment of the spring will flow in a easterly and north-easterly direction toward the spring.

The gradient is assumed to be less than the topographic gradient. The gradient is likely to be relatively steep; approximately 0.01 in the bedrock. However, along the fault, the gradient is probably flatter, thus, for the purposes of calculations, a value of 0.0075 is used in later sections to delineate the source protection areas.

8.3 Hydrochemistry and water quality

There are only two samples available for analysis. The following points can be identified from the data.

- The water is "excessively" hard with total hardness greater than 350 mg l^{-1} (equivalent $CaCO_3$) and electrical conductivity values greater than 700 µS cm^{-1}. These values are typical of groundwater from limestone rocks. As would be expected pH of the groundwater is neutral (an average of 7.1).
- Nitrate concentrations reported in the two available samples are 23 mg l^{-1} (20/11/2001) and 29 mg l^{-1} (27/7/1998). Neither of these exceed the EU Drinking Water Directive maximum admissible concentration of 50 mg l^{-1}. However, they are elevated compared to normal background levels, and one exceeds the GSI threshold of 25 mg l^{-1}.
- Chloride is a constituent of organic wastes and levels higher than 25 mg l^{-1} may indicate significant contamination, with levels higher than the 30 mg l^{-1} usually indicating significant contamination (Daly, 1996). Chloride levels in the available samples are 24 mg l^{-1} (20/11/2001) and 20 mg l^{-1} (27/7/1998).
- There are no detections of *E.coli* in the available **raw** water analysis.
- The available data shows that the potassium:sodium (K/Na) ratio is above the GSI threshold level of 0.35, possibly indicating contamination from farmyard wastes.

In summary: the data are limited but show that the groundwater quality is relatively good, despite some impact from human activity.

8.4 Aquifer Characteristics

The bedrock is considered to be the main aquifer providing water to the spring. The aquifer classification of the Lower Impure Limestone (Ballysteen Formation), described in Section 6.2, has been revised as a **"locally important aquifer** which is **moderately productive** only in **local zones (Ll)"**, since its original classification in the Offaly Groundwater Protection Scheme (Daly, 1998).

The Lower Impure Limestone is generally thought to have low bulk permeability with the possible exception of areas near faults. Groundwater movement is mainly restricted to the weathered and shallow subsurface zone, and is often concentrated in the upper few metres or tens of metres of fractured bedrock. Flow paths are thought to be short, with groundwater discharging to nearby streams and springs. The limited fracturing restricts groundwater storage and movement. In general, the rocks contain substantial amounts of clayey material and thus are not generally susceptible to solution or karstification.

The diamond drill hole at the spring has intersected a fracture network, suggesting that the fault is present nearby (A. Sleeman, 2003 *pers. comm.*). It is likely that it follows a NW-SE trend because this is the dominant trend in the region, although it is possible that a SW-NE trending fault is also present in the vicinity of the spring. In addition to the fault network, the break in slope and possibly a more permeable window into the till help to focus the groundwater to issue at that location. It is considered that groundwater to the east of the stream is likely to discharge to the stream. The aquifer is assumed to be unconfined. It is anticipated that during pumping, the abstraction rate will be greater than the spring outflow, and groundwater will therefore, be induced into the sump. Consequently, groundwater will be drawn from the downgradient side of the spring, in particular along the direction of the inferred fault, where there is increased permeability.

There are no site specific data for the aquifer parameters in the vicinity of the spring. It is assumed that fracturing caused by faulting has significantly increased the permeability in the area. While estimates for the aquifer parameters in the vicinity of the fault zone are given below, there is a degree of uncertainty associated with them.

Estimates for the aquifer parameters in the vicinity of the fault zone are as follows:

Permeability along the fault zone – 1 m d^{-1}.
Hydraulic gradient - 0.0075.
Porosity – 1.5%.

8.5 Spring Discharge

The total spring discharge is not well characterised. GSI staff have measured the spring flow twice and the Council staff estimated the yield by test pumping the spring for three days. The data are given below.

Date	Total discharge	Data source	Method
15/1/2003	620 $m^3 d^{-1}$	GSI Personnel	Flow metre
Aug 2003	650-700 $m^3 d^{-1}$	Co. Co. Staff	Pump
27/9/1999	650 $m^3 d^{-1}$	GSI Personnel	Flow metre

8.6 Conceptual Model

- Jones's Well is a spring located in the Lower Impure Limestone which is classed as a **locally important aquifer** which is **moderately productive** only in **local zones (Ll)**.
- The presence of a fault network and perhaps, a “window” through the till of higher permeability subsoil, enables the groundwater to reach the surface.
- The permeability of the aquifer depends on the development of faults, fissures and fractures.
- Groundwater is considered to flow in a northeasterly and easterly direction toward an inferred NW-SE trending fault, and discharges at the spring.
- It is considered that groundwater will be induced from the downgradient side of the spring during pumping, in particular in the direction of the inferred fault.
- The depth to bedrock is approximately 6 m at the spring.
- The groundwater is considered to be unconfined.
- Groundwater vulnerability is predominantly “**high”** throughout the catchment.
- The chemistry data are limited but show some impact from human activity, although in general the groundwater quality is relatively good.
- Diffuse recharge occurs over the catchment and the annual average recharge is estimated to be 495 mm per year.

9 Delineation of Source Protection Areas

This section delineates the areas around the source that are believed to contribute groundwater to it, and that therefore require protection. The areas are delineated based on the conceptualisation of the groundwater flow pattern, and are presented in Figure 4.

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) to the spring.

9.1 Outer Protection Area

The Outer Protection Area (SO) is bounded by the complete catchment area to the source, i.e. **the zone of contribution (ZOC)**, which is defined as the area required to support an abstraction from long-term recharge.

The ZOC is controlled primarily by (a) the total discharge, (b) the groundwater flow direction and gradient, (c) the subsoil and rock permeability, and (d) the recharge in the area. The shape and boundaries of the ZOC were determined using hydrogeological mapping, water balance estimations, and the conceptual understanding of the groundwater flow in the area. They are described below.

The **eastern boundary** is delineated using an analytical equation. It is anticipated that the spring will be pumped, and groundwater will be induced into the sump, and, therefore will be drawn from downgradient of the spring, as it will act like a dug well. Thus, a semi-circle is drawn around the spring, the radius of which is estimated using the uniform flow equation, to be approximately 270 m (permeability = 1 m d^{-1}; transmissivity = 50 m^2 d^{-1}, gradient =0.0075, porosity = 1.5%). In addition, a 50 m buffer is put on the eastern side of the inferred fault, to account for uncertainty in the fault direction and position.

The **southern boundary** is based on topography. The bedrock controlled hill extends in a southeasterly direction toward the road, acting as a broad surface water and groundwater divide. Groundwater is assumed to flow northeast and east toward the fault and discharges at the spring.

The **northwestern boundary** is difficult to delineate with certainty. The topography suggests that surface water and groundwater will travel in a northerly and northeasterly direction passed the spring, and possibly flow to the inferred fault. During pumping, groundwater could be drawn from north of the spring along the fault. To be conservative and to allow for variation in the inferred fault, the boundary is based on drawing a line from the highest point on the hill to a point 500 m north of the spring, along the inferred fault. The arbitrary 500 m is chosen to allow for increased permeability, lower gradient and uncertainty in the fault location or direction.

A water balance was used to estimate recharge area required to supply groundwater to the source. Assuming an annual recharge of 495 mm, a recharge area of approximately 0.45 km^2 is required to provide enough groundwater to supply 650 m^3d^{-1} . The area described by the boundaries above is almost 1 km^2. This is a conservative estimate of the ZOC to allow for the uncertainty regarding the boundaries given above.

9.2 Inner Protection Area

According to "Groundwater Protection Schemes" (DELG/EPA/GSI, 1999), delineation of an Inner Protection Area (SI) is required to protect the source from microbial contamination and it is based on the 100-day time of travel (ToT) to the supply.

Using the "Well Head Protection Area" modelling programme (Blandford, T.N., 1991, 1993), the 100 day time of travel is estimated around the spring. The estimated values for the gradient, porosity, transmissivity for the fault zone (0.0075, 0.015, 50 m^2 d^{-1}, respectively), given in Section 8.4, are used in the calculation of the inner protection area (SI). In addition, the estimated yield (650 m^3d^{-1}) is accounted for. The modelling estimates the boundary of the SI zone upgradient and downgradient of the spring, which are 300 m, 200 m respectively.

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.

Five groundwater protection zones are present around the source as illustrated in Table 2 and Figure 6.

Table 1 Matrix of Source Protection Zones for Jones' Well.

VULNERABILITY RATING	SOURCE PROTECTION	
	Inner	***Outer***
Extreme (E)	Not present	Not present
High (H)	**SI/H**	**SO/H**
Moderate (M)	**SI/M**	**SO/M**
Low (L)	Not present	Not present

11 Potential Pollution Sources

Land use in the area is described in Section 5. Agricultural activities and septic tanks are the principal hazards to the water quality in the area. The main potential sources of pollution within the ZOC are farmyards, septic tank systems, landspreading of organic and inorganic fertilisers.

12 Conclusions and Recommendations

- The spring at Jones's Well is located in a fracture zone in the Ballysteen Limestone - a **Locally important aquifer** which is **moderately productive** only in **local zones (Ll)**.
- The groundwater feeding the source is moderately to highly vulnerable to contamination.
- The chemistry data are limited but show some impact from human activity, although in general the groundwater quality is relatively good.
- The protection zones delineated in the report are based on our current understanding of groundwater conditions and on the available data. There is a high level of uncertainty with some of the boundaries. Reducing the level of uncertainty would require drilling and geophysical programmes to be undertaken.
- It is recommended that:
  1. The potential hazards in the ZOC should be located and assessed.
  2. A full chemical and bacteriological analysis of the **raw** water is carried out on a regular basis.
  3. Particular care should be taken when assessing the location of any activities or developments which might cause contamination at the well.
  4. A v-notch weir should be placed in the spring outflow to enable further characterisation of the spring.

13 References

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APPENDIX 1 LOGS OF AUGER HOLES.
Depth to bedrock drilling at Jones's Well, Co. Offaly.

Jones Well 1. (GSI number 014/00) Garden of Mr. Jones New House across from spring.
Grid reference 201648 183205
0-0.4 Top soil
0.4-2.8 Till: SILT: frequent gravel fragments, subrounded-angular, 0.3-0.4m in size.
2.8-4.5 No returns, met water table, assumed Till to EOH.
4.5m: End of Hole (refusal/bedrock)

Jones Well 2. (GSI number 015/00). Field entrance to spring, across road from Jones well 1.
Grid reference 201634 183193
0-3.0 Till: SILT: Frequent gravel fragments, subrounded-angular, 0.3-0.4m in size.
3.0-4.5 met water table, no returns, assumed Till to EOH.
4.5m End of Hole (refusal/bedrock)

Jones Well 3. (GSI number 016/00) next to stream on right hand side of road, narrow lay-by.
Grid reference 202044 182987
0-1.5 Sand/gravel: SILT
1.5-2.0 Sand/gravel: SAND
2.0-2.5 Sand/gravel: GRAVEL
2.5m End of Hole (refusal/bedrock)

Jones Well 4. Cullenwaine Cross Roads
Grid reference 201811 182923
0-6.5 Till: SILT
6.5m End of Hole (refusal/bedrock)

Jones Well 5. next to graveyard
Grid reference 201351 182790
0-6.0 Till: SILT
6.0-8.5 Till: SAND (cohesive when wet, no rolls, no threads)
8.5m End of Hole (refusal/bedrock)

Jones Well 6 DH 33/03 (Spring)
Grid reference 201267 183320
0-3.0 Peat (0.2m); Till: SILT
3.0-6.0 Till; met water table (3.0m) , no returns, except for angular fragments coating flights.
6.0-12 Limestone bedrock
12-13 Fault gouge
13-17 Limestone
17-19 Fault gouge
19-21 Limestone
21m End of hole

Jones Well 7 Behind Jones Farm (west)
Grid reference 201166 183138
0-2m Till; abundant angular fragments (0.2-0.5m)
2.0m End of Hole (refusal/bedrock)

Jones Well 8
Grid reference 201267 183320
0-4.0m Till: SILT/SAND, frequent angular fragments with striations.
4.0m End of hole (refusal/bedrock).

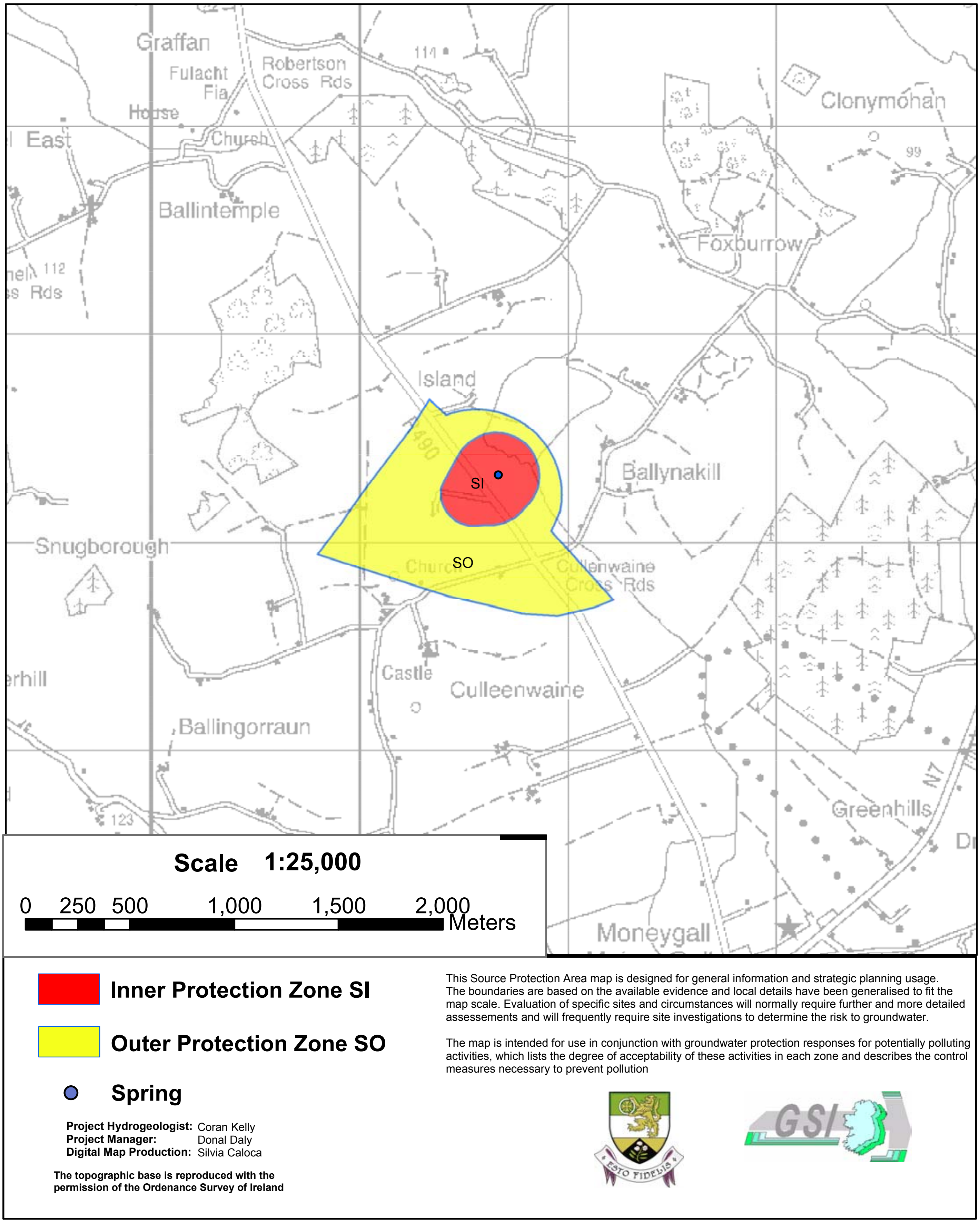


Figure 4 Source Protection Areas for Jones's Well

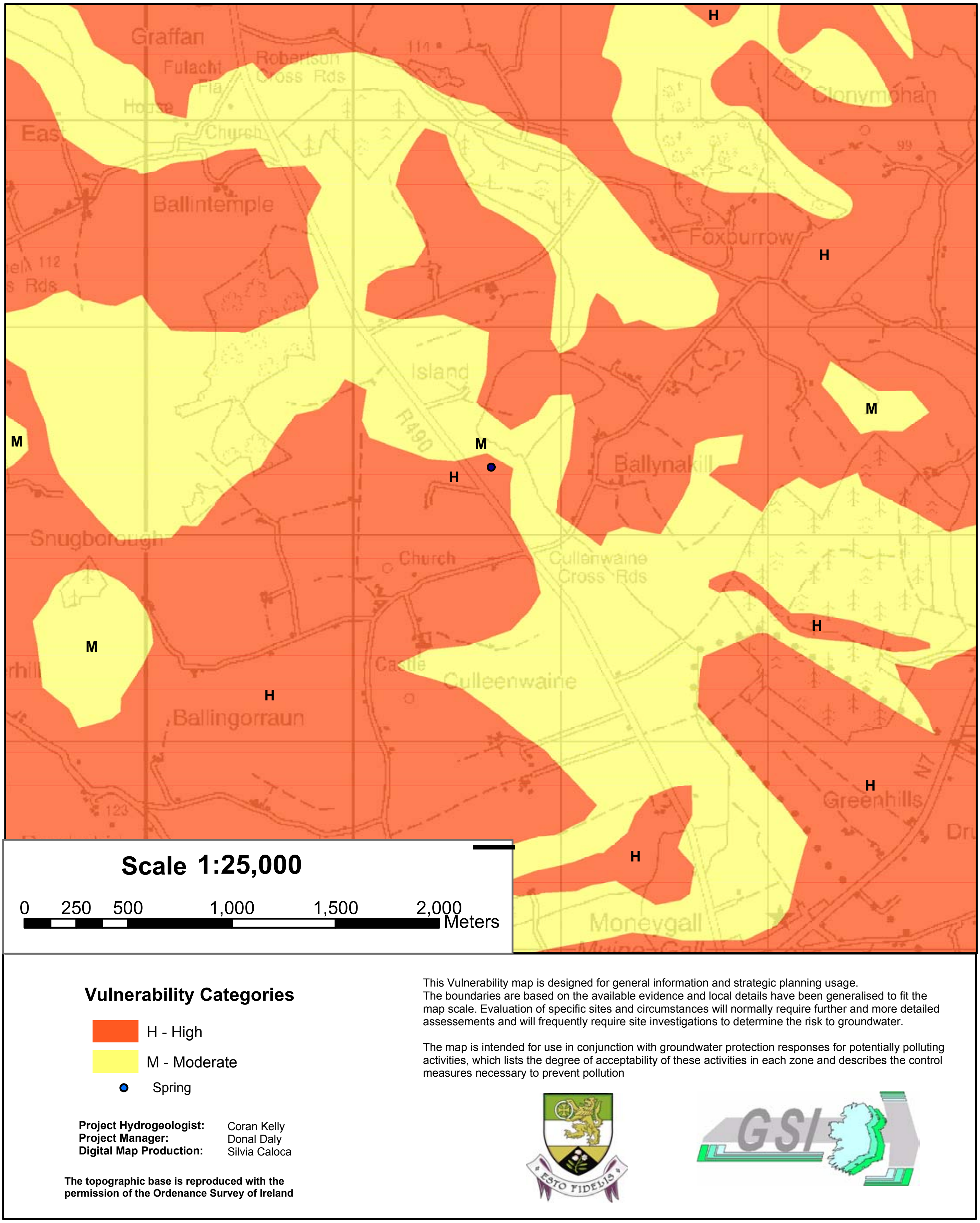
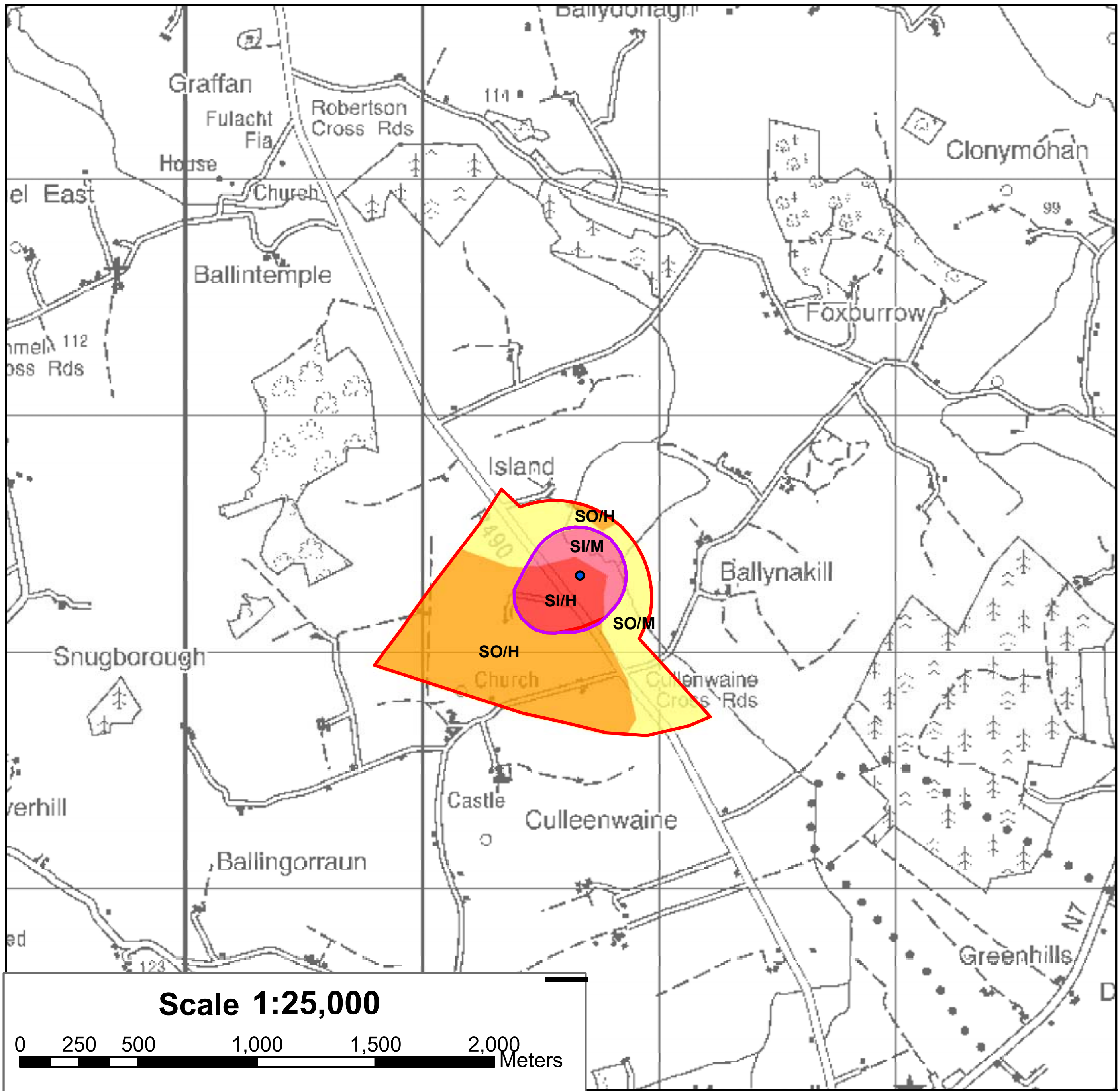


Figure 5 Vulnerability in the vicinity of Jones's Well



SOURCE PROTECTION ZONES

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

Inner Protection Zone SI

Outer Protection Zone SO

Spring

Project Hydrogeologist: Coran Kelly
Project Manager: Donal Daly
Digital Map Production: Silvia Caloca

The topographic base is reproduced with the permission of the Ordenance Survey of Ireland

This Source Protection Zone map is designed for general information and strategic planning usage. The boundaries are based on the available evidence and local details have been generalised to fit the map scale. Evaluation of specific sites and circumstances will normally require further and more detailed assessements and will frequently require site investigations to determine the risk to groundwater.

The map is intended for use in conjunction with groundwater protection responses for potentially polluting activities, which lists the degree of acceptability of these activities in each zone and describes the control measures necessary to prevent pollution

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Figure 6 Source Protection Zones for Jones's Well