Shinrone Water Supply Scheme

Niamh's Well Boreholes

Groundwater Source Protection Zones

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In Partnership with:
Offaly County Council

1 Introduction

The objectives of the report are as follows:

- To delineate source protection zones for the "Niamh's Well" borehole supply.
- To outline the principal hydrogeological characteristics of the area around Shinrone.
- 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 supply. 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 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 "Niamh's Well" source comprises two boreholes, located in the townland of Keeloge, approximately 2 km south of Shinrone village. The boreholes are located in an old Council water treatment site that was set up in 1936, to treat water abstracted from the nearby river. A trial well was drilled in 1999, and the current production well was drilled in January 2002. It is proposed to use the trial well as a standby well. The water is pumped after chlorination directly into the distribution mains. Details of both wells are given below, a sketch of the site is given in Figure 1, and photographs of wells are given in Figure 2.

3 Summary of Borehole Details

GSI No.	2019SWW032	2019SWW033
Grid reference	20438 19122	20439 19122
Townland	Keeloge	Keeloge
Owner	Offaly County Council	Offaly County Council
Council Well Name	Niamh's well: "**New**" well	Niamh's well: "**Old**" well
Well Type	Borehole	Borehole
Depth	73m	96m
Elevation (ground level)	Approximately 70m OD Malin	Approximately 70m OD Malin
Static water level	2.47m below ground level 21/2/03	2.68m below ground level 21/2/03
Pumping water level	Unknown	Unknown
Depth to rock	5.5m	8m
Status	Pumping Well	Observation well; Standby well
Diameter	0.25m	0.2m
Normal abstraction	196 $m^3 d^{-1}$ (70,000 gallons per day)	196 $m^3 d^{-1}$ (70,000 gallons per day)
Maximum abstracted	Unknown	Unknown
Maximum Yield	1860 $m^3 d^{-1}$	273 $m^3 d^{-1}$
Maximum Drawdown	53.7m below ground level 22/2/03	-
Specific Capacity	34 $m^3 d^{-1} m^{-1}$	-
Hours Pumping	Less than 24 hours	Less than 24 hours
Date Drilled	27/1/2003	January 1998

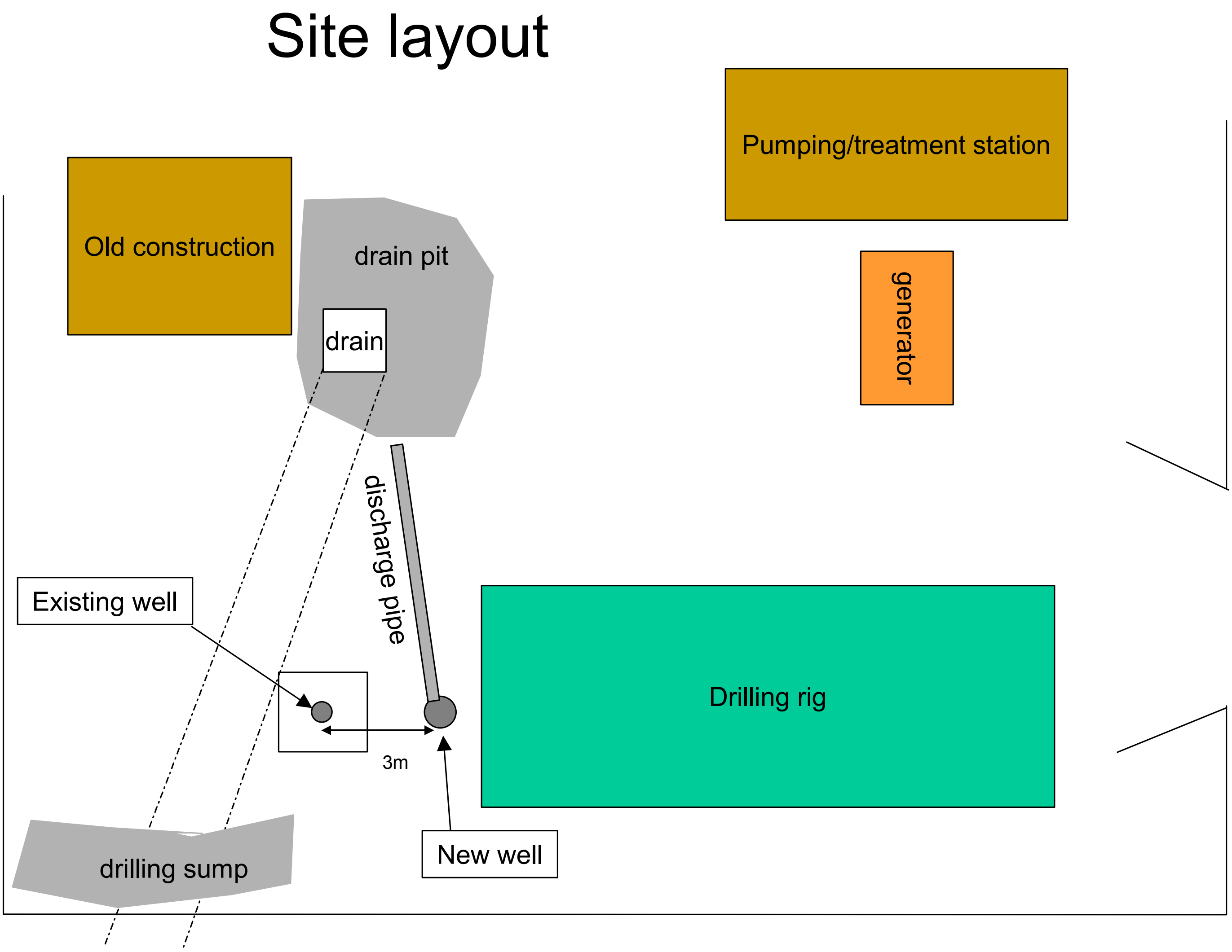
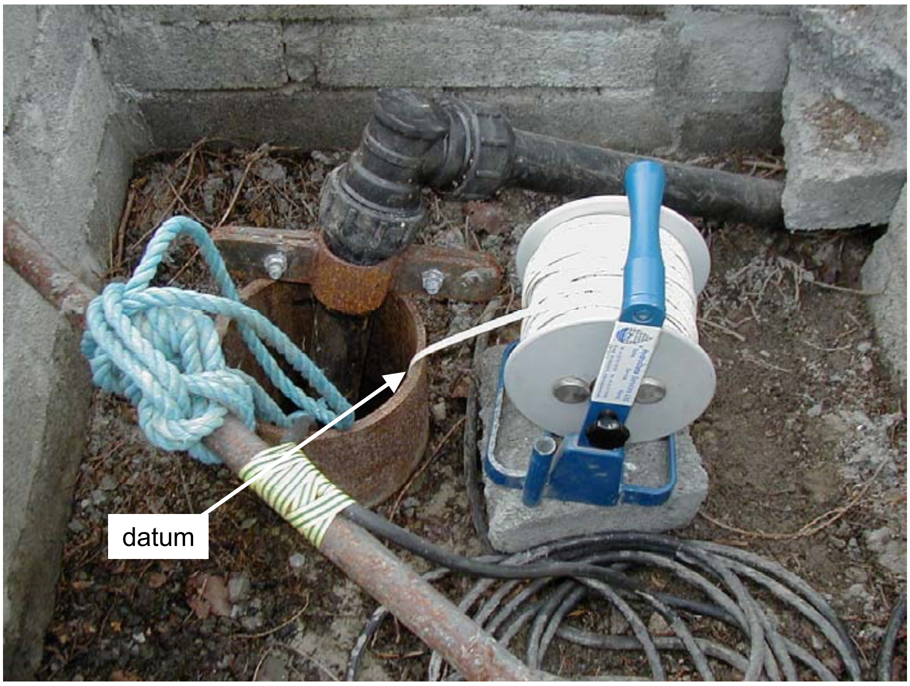


Figure 1 Site Layout at Niamh's Well, Shinrone at the time of drilling 2002.

Existing well (observation well)



New well (pumping well)

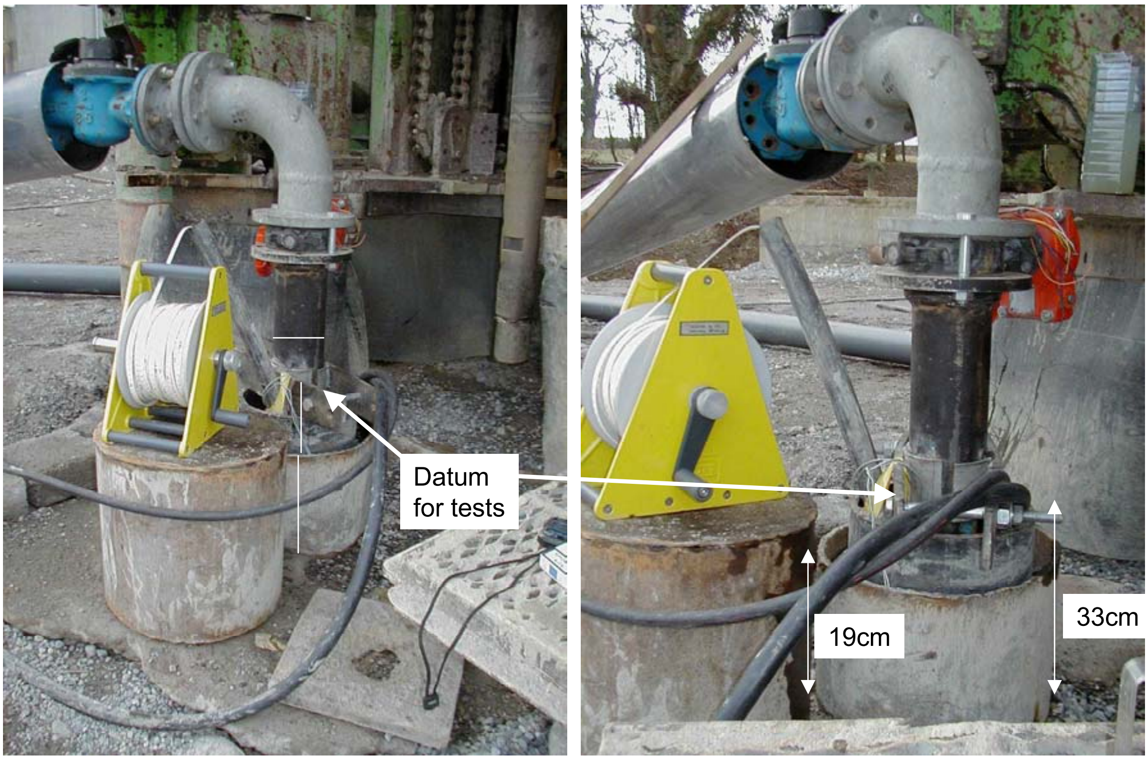


Figure 2 Photographs of the old and new wells, 2002.

4 Methodology

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

The data collection process included the following:

- Interview with the driller and the caretaker 27/1/2003.
- Drilling of six auger holes by GSI 30/4/2003.
- 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.

5 Topography, Surface Hydrology and Land Use

The boreholes are located at approximately 70 m OD, in a relatively flat low-lying area. The overall topography is sloping gently to the north east. The average topographic slope in the area of the boreholes is in the order of 1:70 (0.014).

There are two main unnamed streams in the vicinity of the source wells, which join together, one kilometre north east of the boreholes, to become the Little Brosna river, as seen in Figure 3 and Figure 4. Additional smaller streams, drains and springs are indicated on the 6" Ordnance Survey topographical maps. The natural and artificial drainage densities are high in the lower lying flat areas. The areas with higher relief are relatively free draining. The boreholes are approximately 50 m from the main stream. The regional drainage is to the north west, and is part of the Little Brosna subcatchment (Hydrometric Area 25) of the Shannon River Basin District. The local drainage is different; the two main streams flow north as far as the source area, then east for at least five kilometres before swinging north west near Roscrea, to flow toward Birr and the River Shannon.

The land use is primarily used for sheep and cattle grazing and tillage. There are several houses and farm yards within 500 m of the boreholes. There is a sand/gravel pit approximately 650 m south of the boreholes.

6 Geology

6.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the boreholes. It provides a framework for the assessment of groundwater flow and source protection zones that will follow in later sections.

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) and subsequent mapping in the 1970s by the GSI.
- Offaly Groundwater Protection Scheme (Daly *et al,* 1998).
- Subsoil mapping by the GSI.
- Auger Drilling of six holes carried out by GSI (April 2003).

6.2 Bedrock Geology

The bedrock consists predominantly of limestones and shales, and they are described from youngest to oldest below. Figure 3 illustrates the geology around the source.

The **Dinantian Pure Unbedded Limestone** (Waulsortian Limestone**)** is mapped in the vicinity of the source wells, as can be seen in Figure 3. The Bedrock Section of the GSI examined chippings recovered from the drilling of the production well, and are satisfied that they represent the Pure Unbedded Limestone.

The **Dinantian Lower Impure Limestone** (Ballysteen Limestone) is a medium dark grey, well bedded, fossiliferous limestone with mudstone bands and some siltstones. It occupies the areas to the west and east of the source wells, as can be seen in Figure 3. An exploration borehole (AB5-1) was drilled approximately 350 m to the south west of the source boreholes, and the recovered bedrock is described as being a "*Black Muddy Limestone*", "*dark grey in places, fine grained*", and contains fossil debris. It is representative of the Ballysteen Limestone Formation.

A major northeast-southwest fault is mapped approximately 140 m to the west of the boreholes, marking the boundary between the Pure Unbedded Limestone and the Lower Impure Limestone. There are few outcrops, thus, the mapped fault trace is an inferred boundary, and may lie closer to the boreholes. Fracture zones are reported in both of the wells drilled on site. In the "old" well, a fracture zone is present at 48 m below ground. In the "new" well, a fracture zone is present from 58 m to 60 m below ground level. In exploration borehole AB5-1, fracture zones are present from 61-68m, 89-91m and 103m below ground surface.

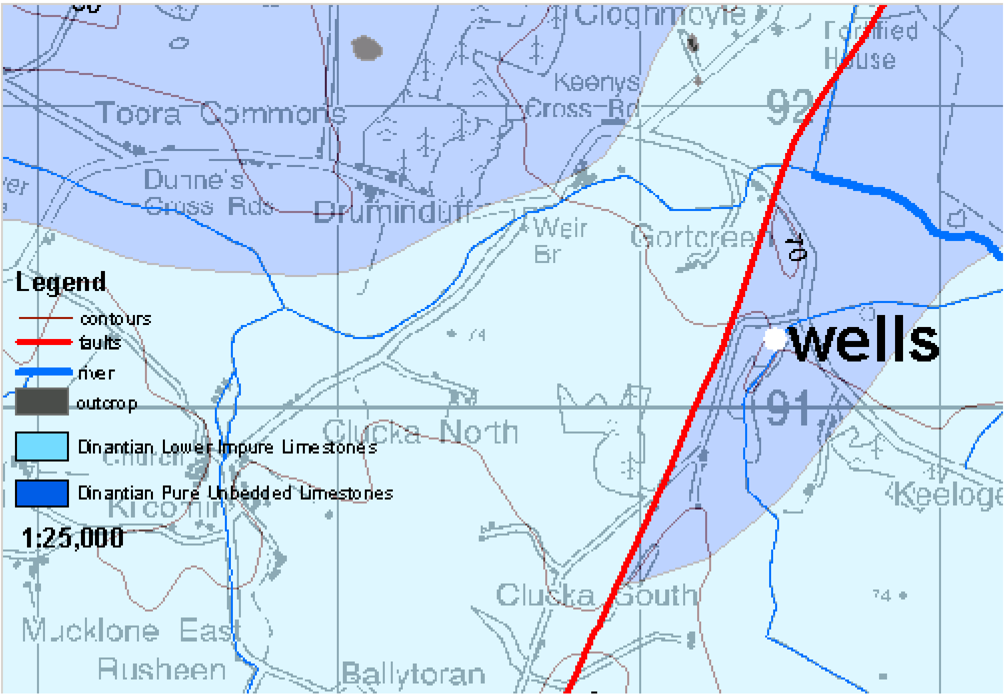


Figure 3 Geology as mapped at Niamh's Well, Shinrone.

6.3 Subsoil Geology

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

- Sand/gravel as shown in Figure 4 is coarse grained, comprising cobbles and boulders. The water well driller found it difficult to drive the casing through and the GSI auger drill (auger hole "E") failed to get more than four metres through the material at the site. The thickness of the sand/gravel varies from 5.5 m to 8 m between the "new" and "old" well. The sand/gravel extends approximately 2 km to the east, south and south-west. There are also several esker ridges in the area. There is a quarry located in an esker approximately 650 m to the south of the boreholes.

Auger hole "D" was drilled approximately 340 m to the south of the boreholes to determine the depth to bedrock. The material consisted of till, classified as "**SILT/CLAY**" at 4 m and as "**CLAY**" at 8 m (BS 5930, 1999), therefore sand/gravel is not present at this locality. However, in general, the auger drilling agrees with the subsoil map.

- Limestone till occupies areas to the west of the boreholes and to the south beyond the sand/gravel. Four auger holes were drilled into the till to the west of the wells, seen in Figure 4. The texture is variable, and the till is classified as "**SILT/CLAY**" and "**CLAY**" using BS 5930. Further details are given in Appendix 1.
- Alluvium occurs along the main stream flowing passed the production wells, occupying a narrow zone, generally less than 200 m wide, and is generally less than 1 m.
- A depth to bedrock drilling programme was carried out to ascertain the subsoil thicknesses. The depth to bedrock is variable. In the vicinity of the source wells the depth to bedrock is generally 5-10 m. To the north and north west, in the vicinity of Auger Wells "A", "B", "C" and "CC" the depth to bedrock is shallower - generally 3-5 m, and, there are several outcrops approximately one kilometre to the north. Logs of the auger holes are given in Appendix 1. The auger holes and other wells with known depth to bedrock values are given below in Figure 4.

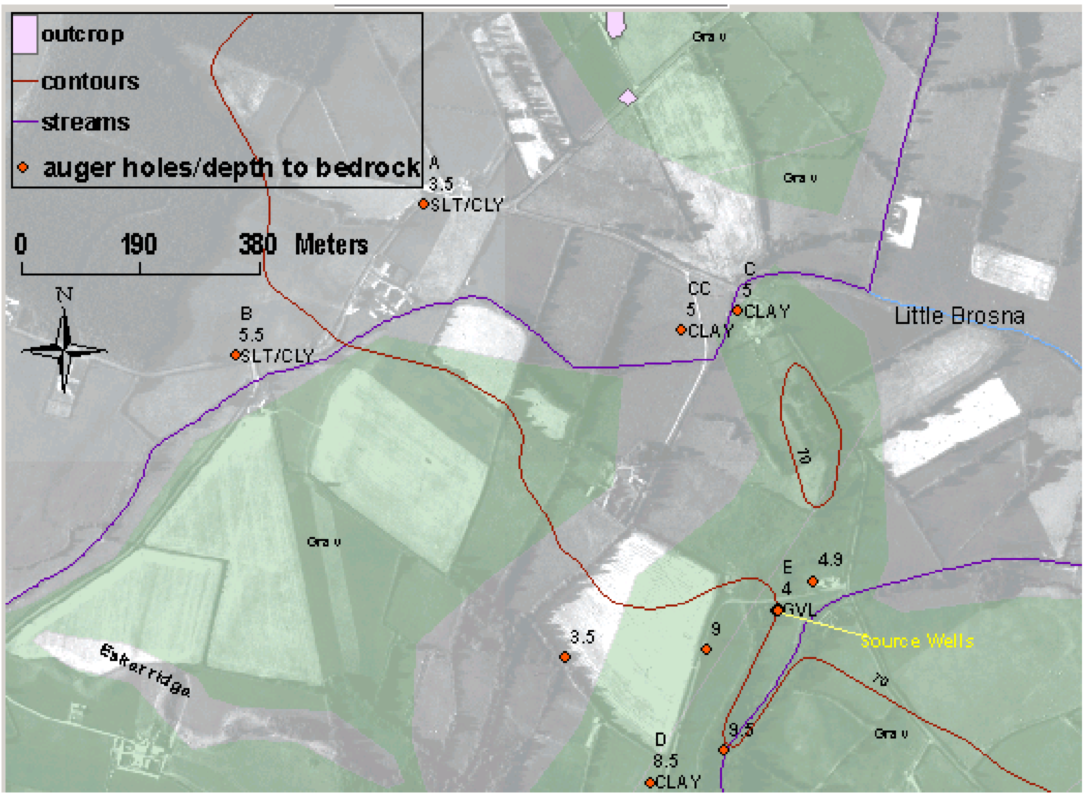


Figure 4 Depth to Bedrock, sand/gravel areas, contours and streams around Niamh's Well.

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 sand/gravel aquifer, and the permeability and thickness of the subsoil in areas where the sand/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 draft GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination. (Fitzsimons, 2003).

- For the purposes of vulnerability mapping, the source of the groundwater is the bedrock, therefore the "**top of the rock**" is the target.
- The permeability of the sand/gravel is classified as "**high**," the permeability of the till varies in the area from "**moderate**" to "**low**".
- Depth to bedrock varies from approximately 5-10 m in the vicinity of the source.
- The area around the source is generally classified as "**high**" vulnerability. The vulnerability is shown in Figure 6.

Depth to bedrock can vary over short distances. 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.
- P. Fay, water well driller.
- Hydrogeological mapping carried out by GSI.
- A short drilling programme carried out by GSI to ascertain depth to bedrock and subsoil permeability.

8.1 Meteorology 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. In Shinrone, 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: 900 mm.
Rainfall data for gauging stations around Shinrone (from Fitzgerald, D., Forrestal., F., 1996).

Gauging Stations	**Grid reference**	**Elevation OD (m)**	**Approximate distance and direction from source**	**Annual precipitation 1961-1990**
Shinrone	S045925	70	2 km north	885 mm

The contoured data map for the Offaly Groundwater Protection Scheme (Daly *et al*, 1998) show that the source is located at the 900 mm average annual rainfall isohyet.

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: 450 mm $yr.^{-1}$.
The effective rainfall is calculated by subtracting actual evapotranspiration from rainfall.

Recharge coefficient: 30%.
The areas of sand/gravel which dominate the area are likely to have higher recharge rates than the areas covered by till. However, the bedrock is expected to be unable to accept all of the available water due to low permeability and storage, as evidenced partly by streams and drains in the low-lying areas, and where there is till. Further details of the aquifer characteristics are given in Section 8.4 Thus, a representative value for the recharge coefficient is estimated to be in the order to 30%.

These calculations are summarised as follows:

average annual rainfall (R)	900 mm
estimated P.E.	475 mm
estimated A.E. (95% of P.E.)	450 mm
effective rainfall	450 mm
recharge coefficient	30%
Recharge	**135 mm**

8.2 Groundwater Levels, Flow Directions and Gradients

The static water level was recorded at 2.47 m below the ground in the “new” borehole, and at 2.68 m below ground in the “old” borehole on 21/2/03. The water level reached during test pumping on 22/2/03 was approximately 54 m below ground level in the “new” borehole and 32 m below ground in the “old” borehole. The water level during normal pumping is unknown. The water table was met in auger holes “B” (2 m below ground surface) and “C” (3 m below ground surface). Both auger holes were drilled beside the stream flowing to the north of the source wells. In addition, the conductivity of the river flowing passed the wells is relatively high (approximately 700 µS cm^{-1}), thus, the rivers in the area are assumed to be groundwater fed, and are assumed to represent the water table.

The water table in the area is generally assumed to be a subdued reflection of topography; as the topography slopes northeast, the water table slopes northeast toward the river. The flow directions will be perpendicular to the contour lines. In simple terms, rainfall reaching the water table will be expected to flow toward the rivers.

Water level data are sparse, but the gradient is assumed to be less than the topographic gradient, in the region of 0.01.

8.3 Hydrochemistry and water quality

Data on trends in water quality are summarised graphically in Figure 5. The following key points are identified from the data.

- The water is generally “excessively” hard with an average total hardness of 410 mg l^{-1} (equivalent $CaCO_3$) and electrical conductivity values of 648-798 µS cm^{-1}. These values are typical of groundwater from limestone. Slight to large amounts of suspended solids are reported in all the available samples (9), and the EU MAC for turbidity has been exceeded on four occasions. This is due to sediment present in the fracture zones being drawn into the well during pumping. Council Staff have indicated recently (October 2003) that the “old” well seems to have silted up.

- Nitrate concentrations in available samples (10) range from 9.4-20.6 mg l^{-1}. The data shows a slightly upward trend.

- 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 (Cronin, 1999). Chloride data range from 24.5-31 mg l^{-1}, the average is 28 mg l^{-1}, though, 50% of the samples have recorded levels of 30 mg l^{-1} or greater. The high chlorides suggest an organic waste source.

- There are no reported *E.Coli* in nine raw water samples tested, and the total coliforms count is generally zero, only a count of six and one has been reported on 22/4/2002 and 27/05/2002. Ammonia levels are generally low.

- The potassium:sodium (K/Na) ratio is elevated on one occasion (15/2/1999), due to elevated potassium (6.4 mg l^{-1}). Iron (Fe) exceeded the EU MAC on four occasions; both manganese (Mn) and aluminium (Al) have exceeded the EU MAC on three occasions. The aluminium peaks coincide with the iron and manganese peaks. The highest recorded levels were on 22/3/1999, given as follows: Fe 3.85 mg l^{-1}; Al 4.1 mg l^{-1}; Mn 0.214 mg l^{-1}.

- According to Council staff, Aluminium Sulphate ("Alum") was used in the original water treatment process, a compound widely used in water treatment (Flanagan, 1992). Other salts may also have been used but this is unknown. Since the drilling of the "old" well, and up to the present time, the site has undergone renovation and refurbishment, which may have effected the settling/sludge tanks that were used in the water treatment process. It is likely that the aluminium sulphate used in the water treatment processes is the source of elevated aluminium levels recorded in the analyses. It also seems possible due to the coincidence of the peaks for the three metals, that the elevated iron and manganese levels may have been caused by the renovations that took place on the site.

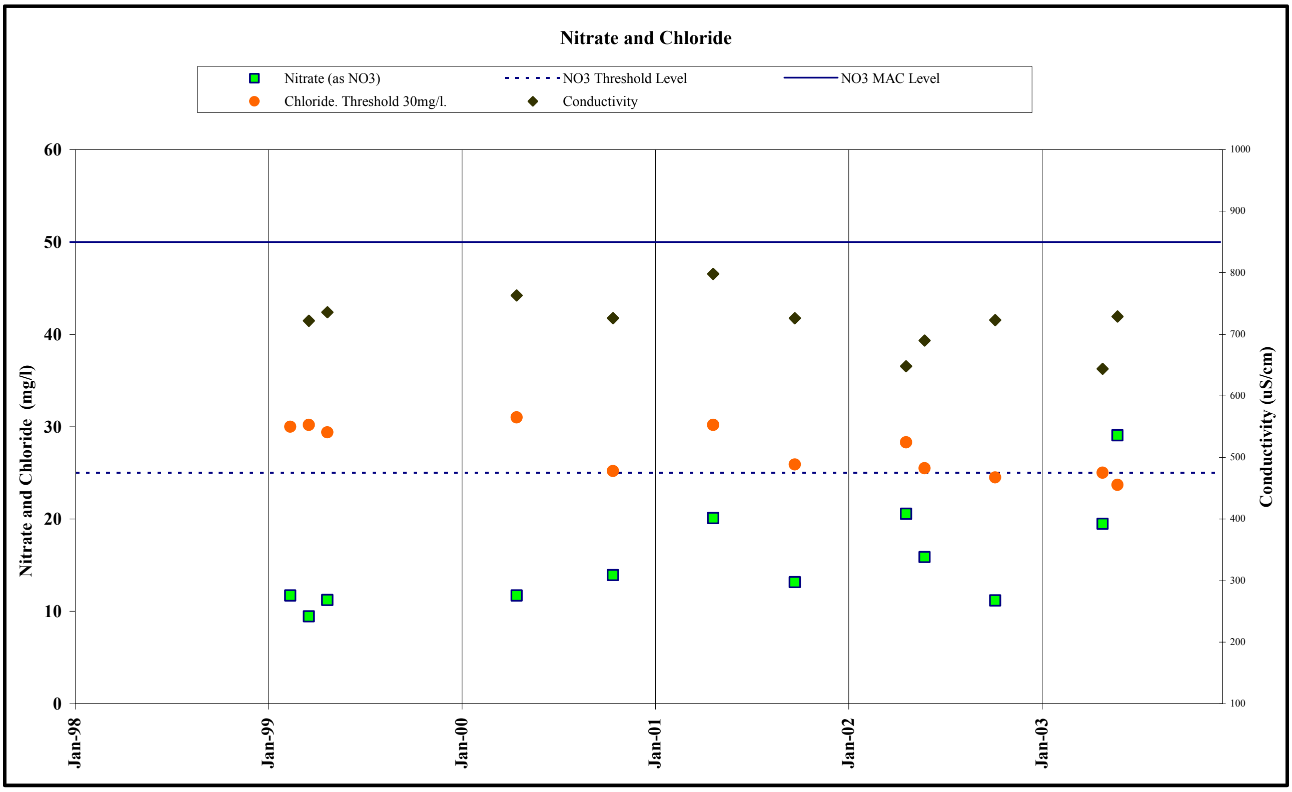
In summary:

➢ Nitrates and bacteriological indicators suggest that that the groundwater quality is generally good. However, chlorides, one elevated K/Na ratio, iron and manganese suggest that there may agricultural or domestic contamination occurring.

➢ However, the iron and manganese may be occurring naturally or may be associated with the salts used in previous water treatment processes that took place on site.

➢ Elevated aluminium levels are likely to be due to renovations that took place on the Council site, which may have released aluminium, and possibly other precipitates into the groundwater.

➢ The water quality is generally good, but the data show some impact from human activity.


Nitrate and Chloride
Nitrate (as NO3)
NO3 Threshold Level
NO3 MAC Level
Chloride. Threshold 30mg/l.
Conductivity
Nitrate and Chloride (mg/l)
Conductivity (uS/cm)
60
50
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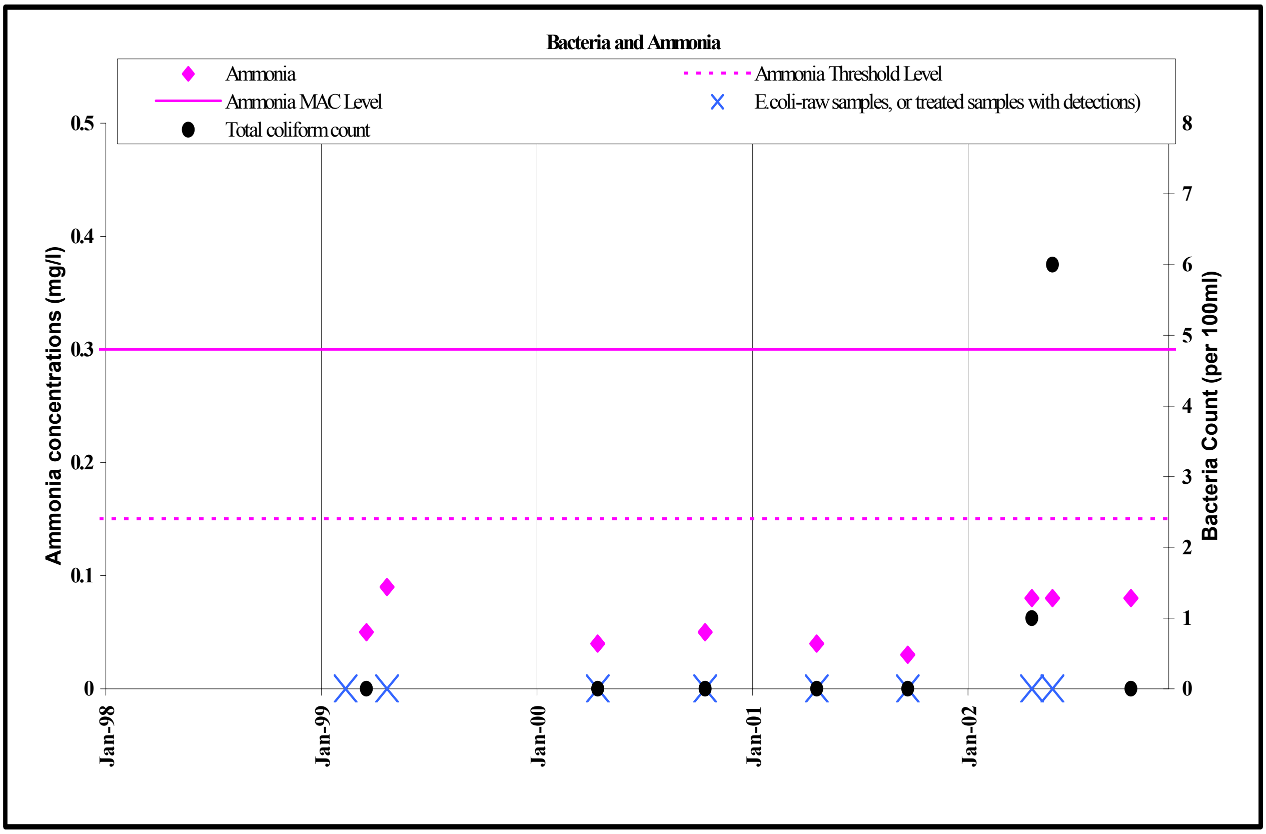
Bacteria and Ammonia
Ammonia
Ammonia Threshold Level
Ammonia MAC Level
E.coli-raw samples, or treated samples with detections)
Total coliform count
Ammonia concentrations (mg/l)
Bacteria Count (per 100ml)
0.5
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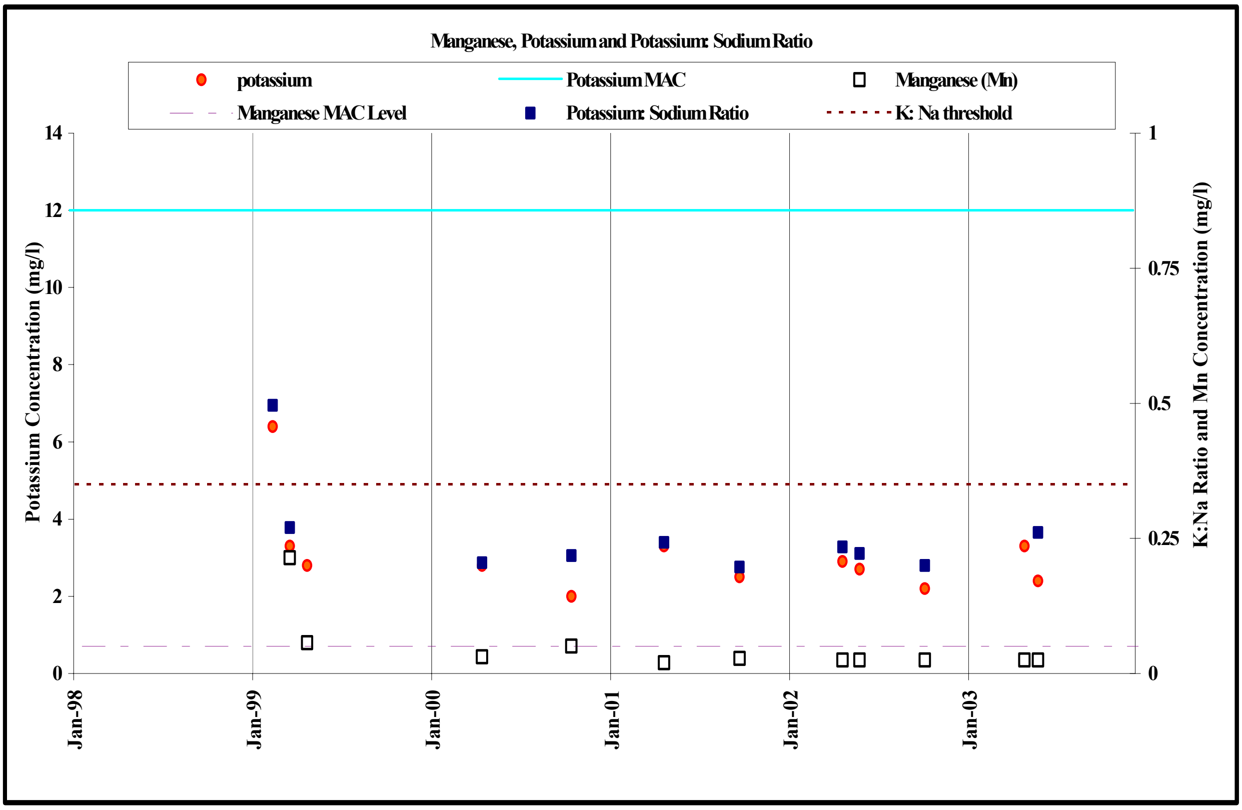

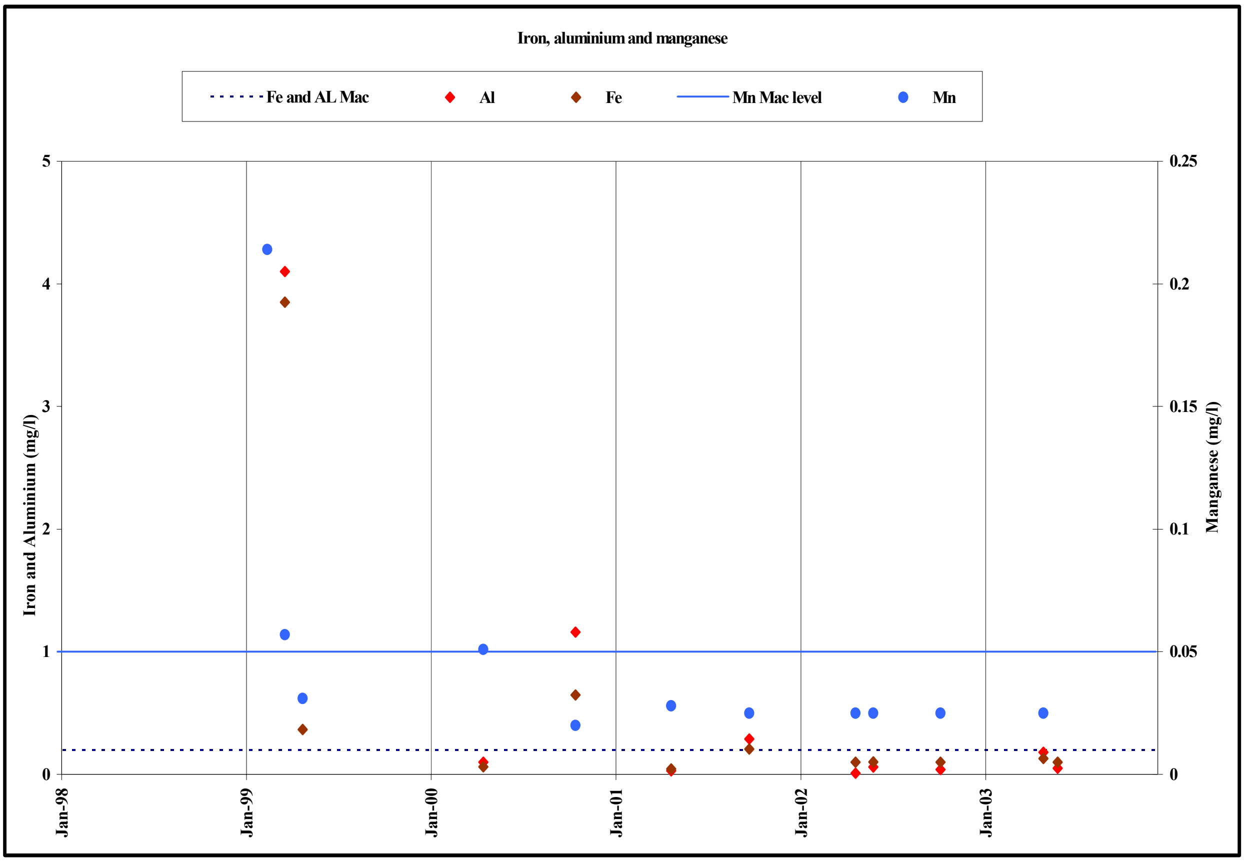

Figure 5 Indicators of domestic and agricultural groundwater contamination

8.4 Aquifer Characteristics

The Pure Bedded Limestone and the Lower Impure Limestone are currently classified as **locally important aquifers** that are **moderately productive in local zones (Ll)**. According to the water well driller, there was no groundwater entering the wells during the drilling of either well until the deep fracture zone was intersected. The fracture zones present in the wells are the main conduits for the groundwater pumped from the well.

Test pumping of the "new" well by the County Council and GSI took place in February 2003. A 72-hour constant rate test was planned, however, the pump rate was set too high, and the test lasted a little over a day before the well failed to meet the expected yield. The data are given in Appendix 2. The "old" well has a reported yield of approximately 273 m^3d^{-1}, and the new well has an estimated yield of approximately 1860 m^3d^{-1}. However, this yield is unsustainable; as the yield dropped and the well failed after the drawdown reached the depths of the fracture zone. Transmissivity varied from 30-50 m^2 d^{-1} over the period of the test pumping. Permeability is estimated using an assumed aquifer thickness of 50 m, to be in the range of 0.6-1.0 m d^{-1}. Porosity is estimated to be approximately 1 %. The parameters reflect the aquifer properties in the vicinity of the fault zone.

Storage is expected to be low in the aquifers given that, firstly; the test pumping data shows that the yield is dependent on the water contained in the large fracture zones, and secondly; the dry weather flow is estimated to be 0.52 litres sec^{-1} km^{-2} for the Little Brosna river, which is relatively low, and indicates low storativity aquifers.

The flow paths are generally short, with groundwater discharging to the streams and rivers that traverse the aquifer. In this instance it is likely that the major fracture zone in the area transmits the groundwater through the aquifer to discharge points along the main streams. Generally, groundwater throughput is low, and groundwater circulation is shallow and localised. Groundwater is likely to flow along joints and smaller fractures feeding into the major fracture zones. The boreholes fit the conceptual understanding, as the relatively high yields appear to be due the presence of a fault.

During pumping, groundwater is expected to be pulled toward the boreholes along the fault zone. The yield depends primarily on the available storage in the main fault network.

The sand/gravel that overlies much of the area is likely to provide storage and help to maintain yields during dry weather periods. Given that sand/gravel overlies the bedrock, and that the hydrochemistry shows a link between chemicals assumed to have existed on site and the groundwater in the wells, it is assumed that the groundwater is unconfined.

The conductivity of the groundwater ranged dropped from 899-861 µS cm^{-1}, over the course of the test which contrasts with 700 µS cm^{-1} for the river. Although the drop in conductivity is not conclusive, it does not rule out the possibility that at large pumping rates that the river water could be induced to the boreholes. The temperature of the groundwater ranged from 10.6-11^{o}C, which contrasted with 7.5^{o}C for the river. The temperature contrast over the test is not conclusive, as river water induced by pumping may have reached background groundwater temperatures by the time it reached the boreholes.

8.5 Conceptual Model

- The "new" borehole draws water from a relatively deep fracture zone located close to a faulted boundary between the Pure Bedded Limestone and the Lower Impure Limestone.
- The fracture zone is considered to be the main permeable pathway through which groundwater feeding the borehole flows.
- Groundwater flow is likely to flow through interconnected fracture zones, and along fractures and joints outside the main fracture systems.
- The yield of the fracture zone is limited, and fails when the drawdown inside the well intersects the fracture zone (58 m below ground surface).
- Transmissivity is estimated to be in the order of 30-50 m^2 d^{-1}; permeability is estimated to be in the order of 0.6-1.0 m d^{-1}.

- The bedrock aquifers are classified as **locally important aquifers** that are **moderately productive in local zones (Ll)**.
- Sand/gravel overlying the bedrock aquifer probably provides storage and helps to maintain yield during dry weather periods.
- The groundwater is considered to be unconfined at the source.
- Diffuse recharge occurs over the catchment and the annual average recharge is estimated to be 135 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 Figures 7 and 8.

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 wells.

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 conceptualisation of the groundwater flow. There is considerable uncertainty associated with them, and they are described as follows.

The Northern boundary is constrained using the location of the fracture zone and the river to the north of the boreholes. The river is chosen as an arbitrary boundary, as it is uncertain how far north that groundwater will be pulled along the fracture zone. Groundwater to the south of the river may feed into the fracture zone and be drawn to the wells during pumping.

The Southern boundary is constrained using topography. There is a local surface water and groundwater divide in the area of Glasshouse, located approximately 1300 km south of the source. To the south of this divide, there are small streams that flow east and west toward the main streams.

The Western boundary is delineated using topography. On the six inch Ordnance Survey map there is a small spring approximately 600 m to the west of the source. It is assumed that recharge to the west of the spring discharges to the spring itself, or to the river further west and north of the spring. Using the topography, a boundary is drawn between the springs and the source wells, between the southern boundary and the river to the north of the source. It is extended to the river north of the source to account for groundwater being pulled along the fault zone.

The Eastern boundary is estimated using the uniform flow equation. The distance to the east that groundwater could be pulled into the fracture and the boreholes is unknown. It is estimated to be approximately 100 m, using the uniform flow equation. This allows for the possibility that river water may be pulled into the fracture zone at high pumping rates. In the vicinity of the boreholes where the river is close, the boundary is taken to be the river.

A water balance was used to estimate recharge area required to supply groundwater to the source. Assuming an annual recharge of 135 mm, a recharge area of approximately 0.8 km^2 is required to provide enough groundwater to supply a discharge of 50% above the normal discharge (300 m^3d^{-1}). The area described by the boundaries above is greater, approximately 1 km^2. This accounts for uncertainty in the position and direction of the fault, and for uncertainty in the boundaries given above.

9.2 Inner Protection Area

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

Estimations of the extent of this area are done by using Darcy's Law, which can be used to estimate groundwater velocities.

Velocity = (gradient x permeability) ÷ porosity

Using the estimated values for permeability, gradient and porosity in the vicinity of the boreholes (1 m d^{-1}, 0.01, 1%, respectively), the calculated velocity is 1 m d^{-1}. Accordingly, the boundary of the inner protection area (SI) is 100 m from the boreholes. As groundwater is drawn along the fault from either side of the boreholes, the SI is delineated on both sides of the boreholes, along the direction of the fault.

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. Two groundwater protection zones are present around the source as illustrated in Table 1. The final groundwater protection zones are shown in Figure 7.

Table 1 Matrix of Source Protection Zones at Niamh's Well, Shinrone.

VULNERABILITY RATING	SOURCE PROTECTION	
	Inner	***Outer***
Extreme (E)	Not present	Not present
High (H)	**SI/H**	**SO/H**
Moderate (M)	Not present	Not present
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. At the Council site there is possibly further contamination from mobilisation of metals into the groundwater beneath the site.

12 Conclusions and Recommendations

- The boreholes are located in a fracture zone located in the Pure Unbedded Limestone and the Lower Impure Limestone, which are **locally important aquifers** that are **moderately productive** in **local zones (Ll)**.
- The groundwater feeding the source is 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. In view of the pressure magnitude in the area, this is probably not

needed at present. Additional data obtained in the future may indicate that amendments to the boundaries are necessary.

- It is recommended that:
  1. The potential hazards in the ZOC should be located and assessed. In particular, investigation of the Council site should be undertaken to investigate old, unused sludge/settling tanks.
  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.

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Appendix 1 Logs

Depth to bedrock drilling at Niamh's Well, Shinrone, Co. Offaly.

Shinrone A. Flannery.
0.0-3.5 Till: SILT/CLAY: frequent black gravel fragments, angular, 0.3-0.4m in size.
BS 5930 field test: 3rolls/100cm ribbons/slow shaking dilatancy/slow squeezing dilatancy/gritty/crusting.
BS 5930 field test: 6rolls/100cm ribbons/slow shaking dilatancy/slow squeezing dilatancy/gritty/crusting.
3.5m: End of Hole (refusal/bedrock)

Shinrone B. Weirbridge
0-5.5 Till: SILT/CLAY: frequent black gravel fragments, angular, 0.2-0.4m in size.
BS 5930 field test: 4rolls/100cm ribbons/No dilatancy on shaking/slow dilatancy on squeezing/crusting/gritty.
5.5m End of Hole (refusal/bedrock). Water table struck at 2.0m

Shinrone C.
0-5.0 Till: CLAY: sticky with abundant gravel fragments, angular, 0.1m in size.
BS 5930 field test: 5/6rolls/100-140cm ribbons/no dilatancy in either test.
5.0m End of Hole (refusal/bedrock). Water table struck at 3m.

Shinrone CC.
0-5.0 Till: CLAY: few-frequent angular gravel black (lst) fragments.
BS 5930 field test: 5/5 rolls/150, 150 ribbons/No dilatancy/crusting/gritty/slight shine.
5.0m End of Hold (refusal/bedrock).

Shinrone D. Sampson.
0-3.0m Till: @3m SILT/CLAY: few angular black fragments, 0.2m in size
BS 5930 field test: 3-5cm rolls, 60-80 ribbons, slow dilatancy in both squeezing and shaking,

3-8.5m Till: @5m CLAY: few angular black fragments, 0.2m in size
BS 5930 field test: 6,7 cm rolls/ 190, 170 cm ribbons/ No dilatancy/crusting/sticky.

Shinrone E. Council site.
Attempted to drill through the sand/gravel but only reached 4m. Very coarse gravels and cobbles.

Appendix 2 Test pumping data

Pumping Well

minutes	drawdown (m)	discharge meter	difference in discharge meter	time interval between meter readings (mins)	m^3 per day	~10 or more min running average of m3/day	conductivity readings	temperature readings	Comments
0	0	25619.3							
0.5	14.52								
1	20.24								
1.5	23.58								
2	26.06								
2.5	28.07								
3	29.2								
3.5	30.44								
4	31.43								
4.5	32.18	25625.7	6.4	4.5	2048				
5	32.9								
5.5	33.45								
6	33.95								
6.5	34.33	25628.4	2.7	2	1944				very turbid, reddy brown colour
7	34.75								
7.5	35.1								
8	35.29								
8.5	35.6	25631	2.6	2	1872				very turbid, reddy brown colour
9	35.8								
9.5	36.06								
10	36.29	25633.1	2.1	1.5	2016	1987.2			
10.5	36.53								
11	36.72								
12	37	25635.8	2.7	2	1944				
13	37.44								
14	37.5	25638.5	2.7	2	1944	1940.21			
15	37.77								
16	38	25641.1	2.6	2	1872				
17	38.14	25642.4	1.3	1	1872				very turbid, reddy brown colour
18	38.35								
19	38.5	25645.3	2.9	2	2088	1952			
20	38.66								
22	38.95	25649.2	3.9	3	1872				
24	39.21	25651.8	2.6	2	1872				
26	39.45	25654.5	2.7	2	1944	1920			very turbid, reddy brown colour
28	39.69								
30	40	25659.7	5.2	4	1872				
32	40.2	25662.4	2.7	2	1944	1758.86	899	10.6	
34	40.33								pocket of very silty groundwater
36	40.48	25667.7	5.3	4	1908	1908			
38	40.61								
40	40.77	25672.9	5.2	4	1872	1900.8			
45	41.16						872	10.7	
45.5		25680.1	7.2	5.5	1885.09	1879.58			
50	41.48	25686.1	6	4.5	1920	1900.8			
55	41.72	25692.6	6.5	5	1872	1894.74	899	10.6	still turbid
60	42.06	25699.3	6.7	5	1929.6	1900.8			
65	42.33								
70	42.5	25712.3	13	10	1872	1872			
75	42.6								'clearing up' (relatively)

80	42.77	25725.4	13.1	10	1886.4	1886.4	903	10.4	
85	42.97								
90	43.08	25738.5	13.1	10	1886.4	1886.4			
95	43.14								
100	43.02	25751.5	13	10	1872	1872			
105	43.1								
110	43.36	25764.7	13.2	10	1900.8	1900.8			
115	43.39								
120	43.36	25777.6	12.9	10	1857.6	1857.6			
125	43.45								
130	43.5	25790.5	12.9	10	1857.6	1857.6			
135	43.62								
140	43.8	25803.4	12.9	10	1857.6	1857.6			
145	44.05								
150	44.24	25816.5	13.1	10	1886.4	1886.4			still turbid
155	44.38								
160	44.5	25827.5	11	10	1584	1584			
165	44.62	25836	8.5	5	2448				
170	44.7	25842.4	6.4	5	1843.2	2145.6			
175	44.82								
180	44.97	25855.4	13	10	1872	1872	655	10.4	still turbid. Should be 855 uS/cm?
185	45.08								
190	45.2	25868.3	12.9	10	1857.6	1857.6			
195	45.32								
200	45.44	25881.3	13	10	1872	1872			
205	45.57								
210	45.67	25892.5	11.2	10	1612.8	1612.8			
215	45.79								
220	45.87	25907.2	14.7	10	2116.8	2116.8			
225	45.93								
230									
235	46.15	25926.6	19.4	15	1862.4	1862.4			
240									
245	46.24	25940	13.4	10	1929.6	1929.6	897	10.3	still turbid
255	46.47								
265	46.63	25965.4	25.4	20	1828.8	1828.8			
275	46.75	25978.2	12.8	10	1843.2	1843.2			
285	46.89	25991	12.8	10	1843.2	1843.2			
295	47.02	26004	13	10	1872	1872			
305	47.1	26016.8	12.8	10	1843.2	1843.2			
315	47.25								
325	47.37	26042.9	26.1	20	1879.2	1879.2			
335	47.42						896	10.6	still turbid
345	47.53	26068.4	25.5	20	1836	1836			
355	47.65								
365	47.8	26094.1	25.7	20	1850.4	1850.4			
375	47.9								?valve closed a bit to reduce pump rate?
380	47.9								
385	47.83	26119.6	25.5	20	1836	1836			
390	47.83	26125.9	6.3	5	1814.4	1814.4			still turbid
395	47.84	26132.3	6.4	5	1843.2	1843.2	896	10.6	monitoring stopped overnight
828	52.455								
835		26685.4	553.1	440	1810.15	1810.15			dip pipe changed level (changed by taped withdra
842	52.485								difficult to read water level as lots of friction on pip
860	53.235								
863		26719.8	34.4	28	1769.14	1769.14			
865	53.315								
871	53.445								

877		26738.1	18.3	14	1882.29	1882.29			
880	53.625								
883		26744.3	6.2	6	1488	1488			
890	53.825								still turbid, but clearer than yesterday evening
893		26756.7	12.4	10	1785.6	1785.6	871	10.6	
900	54.005								
903		26769.3	12.6	10	1814.4	1814.4			
910									LOST DIPPER PIPE
913		26781.4	12.1	10	1742.4	1742.4			
923		26793.7	12.3	10	1771.2	1771.2			
933		26806.2	12.5	10	1800	1800			
944		26819.6	13.4	11	1754.18	1754.18			
971		26853.9	34.3	27	1829.33	1829.33			small pocket of siltier
990		26876.1	22.2	19	1682.53	1682.53	876	10.7	
1005		26894.3	18.2	15	1747.2	1747.2			
1021		26913.7	19.4	16	1746	1746			
1036		26931.8	18.1	15	1737.6	1737.6			
1050		26948.9	17.1	14	1758.86	1758.86			air temp about 5.4oC
1065		26967.2	18.3	15	1756.8	1756.8			
1095		27005	37.8	30	1814.4	1814.4			
1115		27027.3	22.3	20	1605.6	1605.6			
1125		27039.4	12.1	10	1742.4	1742.4			
1140		27057.5	18.1	15	1737.6	1737.6			
1155		27075.4	17.9	15	1718.4	1718.4			
1170		27093.3	17.9	15	1718.4	1718.4	873	11	
1185		27111.7	18.4	15	1766.4	1766.4			
1201		27130.3	18.6	16	1674	1674			
1216		27148.5	18.2	15	1747.2	1747.2			opened valve by about <= 1/4 turn
1225		27159.1	10.6	9	1696	1696	870	10.8	
1235		27171.1	12	10	1728	1728			
1245		27183.1	12	10	1728	1728			
1260		27203	19.9	15	1910.4	1910.4			
1275		27219	16	15	1536	1536			
1290		27236.9	17.9	15	1718.4	1718.4			
1305		27254.5	17.6	15	1689.6	1689.6			
1315		27266.5	12	10	1728	1728			notched valve open by about 1/10 turn
1326		27279.6	13.1	11	1714.91	1714.91			SAMPLE TAKEN
1336		27291.5	11.9	10	1713.6	1713.6			notched valve open by about 1/20 turn
1349		27307.1	15.6	13	1728	1728			water definitely starting to clear up. Pale straw colo
1375	55.24	27338.1	31	26	1716.92	1716.92			
1385	55.28	27349.9	11.8	10	1699.2	1699.2			
1388									notch open 1/20th turn
1392	55.41								DIPPER PIPE BACK at 2:55pm
1394	55.31	27359.5	9.6	9	1536	1536			outflow surging and waning - pumping rate varying
1401		27368.9	9.4	7	1933.71	1933.71			
1408	55.91	27377.2	8.3	7	1707.43	1707.43			valve messed around with (by Declan). Still surging
1416		27386.5	9.3	8	1674	1674			Water level bouncing between about 58.2 and 59.2
1420	56.36								water level still fluctuating about this measurement
1422		27393.6	7.1	6	1704	1704			water level still fluctuating about this measurement
1425	56.64								
1430	56.64	27403	9.4	8	1692	1692			water level still fluctuating about this measurement
1454	56.64	27431.1	28.1	24	1686	1686	865	10.7	
1475	56.64	27456.1	25	21	1714.29	1714.29			water level still fluctuating about this measurement
1485	56.64	27467.5	11.4	10	1641.6	1641.6			water level still fluctuating about this measurement
1495	56.64	27479.2	11.7	10	1684.8	1684.8			
1510	56.64	27496.7	17.5	15	1680	1680			photo taken of discharge; looks like water with bit o
1530	56.64	27520.1	23.4	20	1684.8	1684.8			RIVER WATER CONDUCTIVITY AND
1545	56.64	27537.7	17.6	15	1689.6	1689.6			TEMPERATURE UP AND DOWNSTREAM MEAS

1560	56.64	27556.1	18.4	15	1766.4	1766.4			
1575	56.64	27572.7	16.6	15	1593.6	1593.6			
1590	56.64	27590.2	17.5	15	1680	1680	861	10.6	
1605	56.64	27607.6	17.4	15	1670.4	1670.4			
1620	56.64	27625.3	17.7	15	1699.2	1699.2			water quality as described above
1640	56.64	27648.6	23.3	20	1677.6	1677.6			
1660	56.64	27672	23.4	20	1684.8	1684.8			
1680	56.64	27695.2	23.2	20	1670.4	1670.4	861	10.6	
1700	56.64	27718.7	23.5	20	1692	1692			
1720	56.64	27742	23.3	20	1677.6	1677.6			
1753	56.64	27780.4	38.4	33	1675.64	1675.64			
1786	56.64	27818.7	38.3	33	1671.27	1671.27			PUMP CUT OUT
1803									
1805	32.06								
1806	30.51								
1807	28.89								
1809	26.6								
1810	25.96								
1811	26.25								
1812	25.38								
1813	24.38								
1814	23.76								
1815	23.06								
1816	22.51								
1817	21.94								
1818	21.46								
1820	20.29								
1821	19.78								
1822	19.2								
1823	18.59								
1824	17.84								
1825	17.39								
1826	17.06								
1827	16.56								
1828	16.2								
1829	15.87								
1830	15.62								
1831	15.3								
1832	14.97								
1833	14.64								
1834	14.37								
1836	13.81								
1837	13.64								
1838	13.54								
1839	13.39								
1840	13.27								
1841	13.24								
1843									
1845	16.19								
1846	15.41								
1847	14.69								
1848	13.73								
1849	13.33								
1851	12.6								
1852	12.33								
1853	11.99								
1854	11.79								
1855	11.59								

1857	11.3						
1858	11.13						
1860	10.86						
1862	10.68						
1864	10.51						
1866	10.37						PUMP BACK ON at 11:31 pm (31hrs 12mins into t
1876							
1878		27847.2					silty
1887		27857.3	10.1	9	1616	1616	
1888		27858.5	1.2	1	1728		
1890	48.26						
1891	48.53						
1893		27864.2	5.7	5	1641.6		still very silty
1906		27879.1	14.9	13	1650.46	1652.21	
1909	46.26						
1912	46.35						NHW considers pump rate too high.
1916		27890.6	11.5	10	1656	1652.87	throttle back 1/2 turn.
1918	45.15	27892.8	2.2	2	1584		water level rising
1922	44.84	27897.2	4.4	4	1584	1629	
1930	44.82						
1931		27908.3	11.1	9	1776	1699.2	pumping rate still too high. Notch back 1/2 turn.
1935	43.36						! Back pressure - opened 1/4 turn, then 1/4, then a
1938		27914.3	6	7	1234.29		problems setting rate. Valve stiff and not consisten
1939	40.88	27915.3	1	1	1440	1533.18	
1941	39.7						FLOW METER STUCK
1946	39.61						flow meter stuck for about 20 mins
1948	39.52						
1955	39.57						
1960	39.97						
1965	40.1						
1971	40.07						meter still jerky. Reading to see if makes sense.
1974		27925.4	10.1	35	415.543		
1976	40.11	27927	1.6	2	1152	1152	
1980	40.15						
1984	40.04						
1987		27935.2	8.2	11	1073.45	1073.45	
1990	40.04						
1993	40.09	27939.4	4.2	6	1008	1008	meter still sticking, but needle seems to be jumping
1998	40.09						with itself. Outflow good and steady.
2001	40.09						
2009		27951.3	11.9	16	1071	1071	colour clearing up. Colour of see-through medium
2017	40.16						
2023	40.06						leakage of water coming from seal on valve since
2033	40.14	27965.6	14.3	24	858	858	flow meter still sticky but turning
2047	39.94						
2049		27975.5	9.9	16	891	891	
2053	39.93						PUMP CUT OUT
2367	5.2						
2387							pump back on; water turbid; off again
2404							pump back on, but discharge meter broken
							Later in day, Declan reversed pump and got big sl

Observation Well

elapsed time	drawdown (m)	Comments
0	0	
1	0.07	

2	0.22	dipper probe not great.
3	0.35	get 'double' readings
4	0.53	-> light on, off, on permanently when
5	0.71	drop probe in well and below water level
6	0.85	
7	1.02	taly measuring first firm light
8	1.19	
9	1.36	-> accuracy could be up to
10	1.53	+/- 15cm
12	1.84	
14	2.18	
16	2.54	
18	2.82	
20	2.94	
25	3.6	
30	4.51	
35	5.35	
40	6.16	
47.5	7.22	
50	7.63	
55.5	8.35	
60	9.03	
70	10.44	
80	11.76	
90	13.11	
100	14.05	
110	15.03	
120	16.18	
130	17.32	
140	18.05	
150	19.11	
160	20.01	
170	20.83	
180	21.29	
190	21.81	
200	22.94	
210	23.34	
220	23.86	
230	24.41	
240	24.96	
250	25.49	
260	26.11	
270	26.8	
280	27.33	
290	27.78	
300	28.48	
310	28.87	
320	29.35	
330	29.86	
340	30.42	
350	30.88	
360	31.41	
370	31.9	
380	32.27	
390	32.7	
833	43.58	
861	44.01	
872	44.08	
881	44.09	
891	44.2	
901	44.43	
911	44.39	

925	44.49	
935	44.65	
945	44.81	
973	44.77	
991	44.73	
1005	44.62	
1021	44.42	
1030	44.2	hard to get reliable dip reading because probe 'intermittent' on water level
1049	44.05	-> pulled probe up and tested in bucket and fine.
1065	43.83	Back down for 17hr29 measurement
1082	43.65	
1100	43.44	
1115	43.27	
1130	43.13	
1145	42.97	
1160	42.87	
1175	42.69	
1190		
1203	42.46	
1217	42.58	
1226	42.26	
1250	42.13	measurement confidence improved -
1280	41.9	seems to be that the iron casing is causing false contacts.
1310	41.69	-> started measuring water level with tape held away from side
1320	41.99	of well
1328	41.58	
1338	41.69	
1350	41.43	
1380	41.31	
1389	41.25	
1409	41.23	
1424	41.38	
1431	41.05	
1447	41.89	
1480	40.81	
1505	40.67	
1513	40.65	new batteries in dip meter, in case this helps get more
1540	40.54	reliable reading
1565	40.45	
1577	40.44	
1592	40.37	
1607	40.29	
1624	40.26	
1642	40.17	
1664	40.15	
1684	40.14	can hear well filling during stoppage time.
1700	40.04	
1722	39.97	
1754	39.9	
1786	39.8	
1814	32.86	
1815	32.47	
1817	32.18	
1819	31.75	
1821	31.41	
1823	31.07	
1827	30.41	
1829	29.9	
1831	29.79	
1833	28.91	
1835	28.42	
1837	28	

1839	27.48	
1841	27.15	
1844	26.67	
1848	26.15	
1851	25.63	
1854	25.11	
1857	24.57	
1863	23.42	
1872		pump back on at 11:31 pm (31hrs 12mins into test) for about 5 minutes
1898	26.29	
1914	27.25	
1920	27.6	
1925	27.87	
1935	28.4	
1952	29.08	
1972	29.83	
1980	30.14	
1989	30.39	
1999	30.77	
2026	31.55	
2035	31.83	
2042	32.01	
2051	32.22	

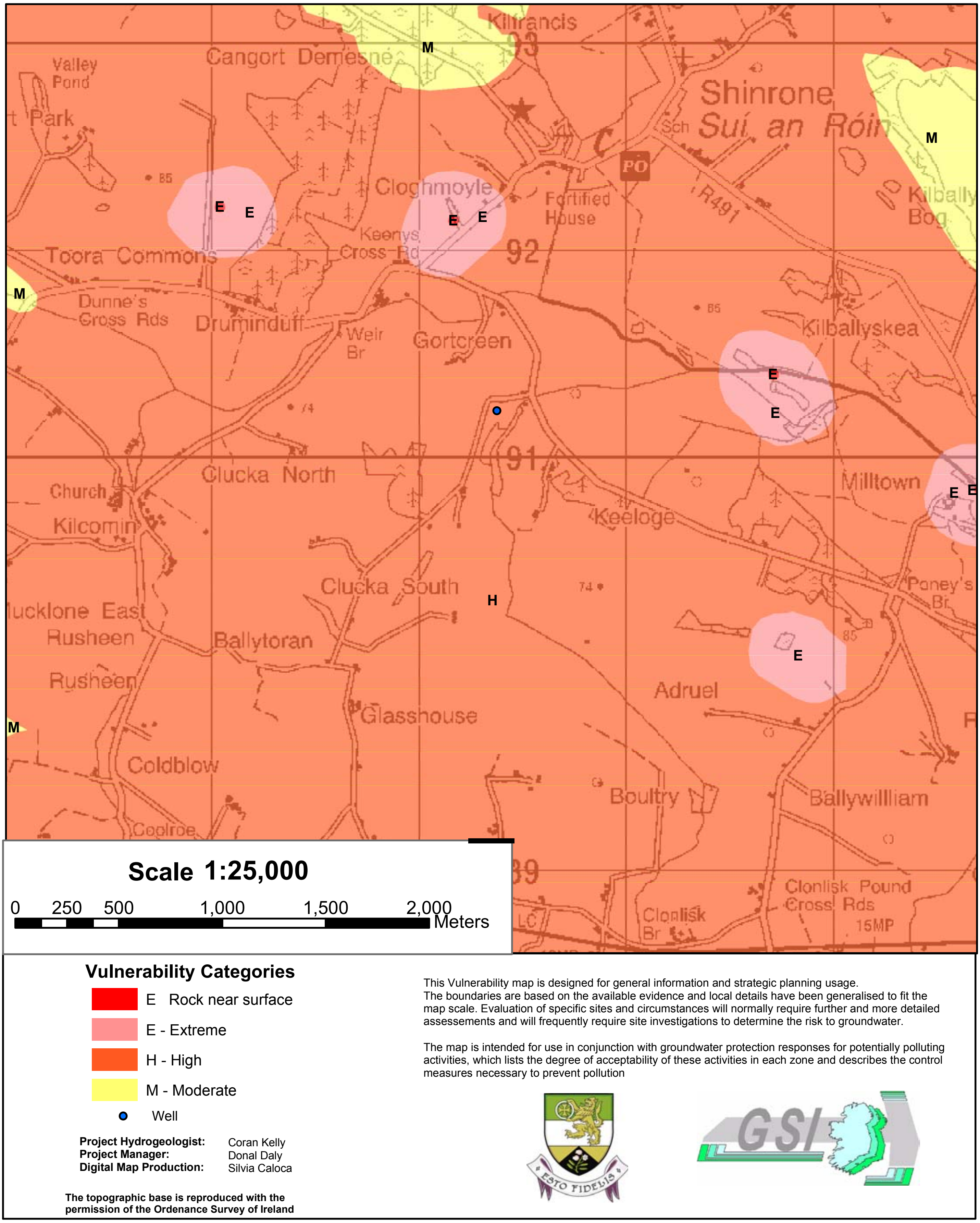


Figure 6 Groundwater Vulnerability around Niamh's Well.

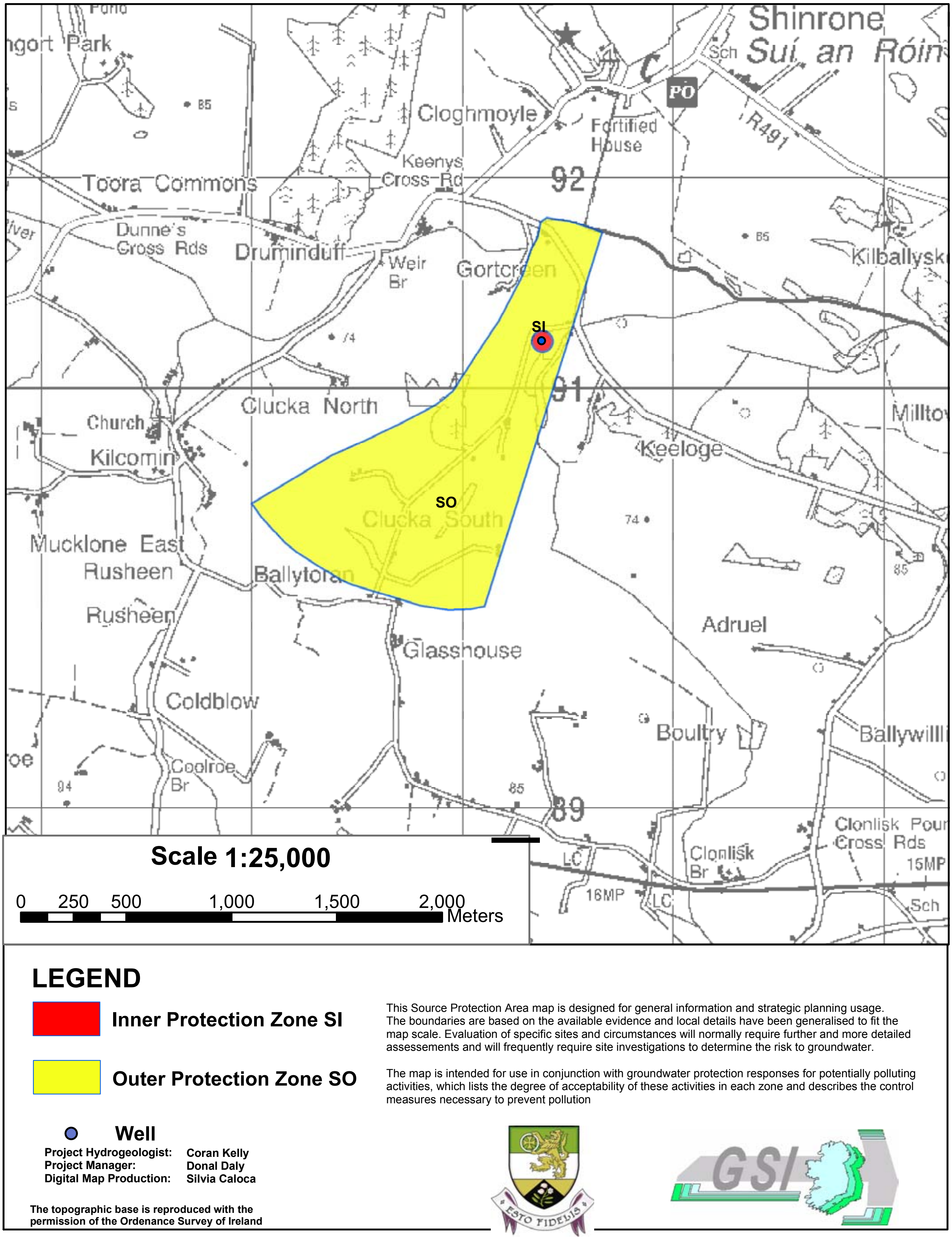
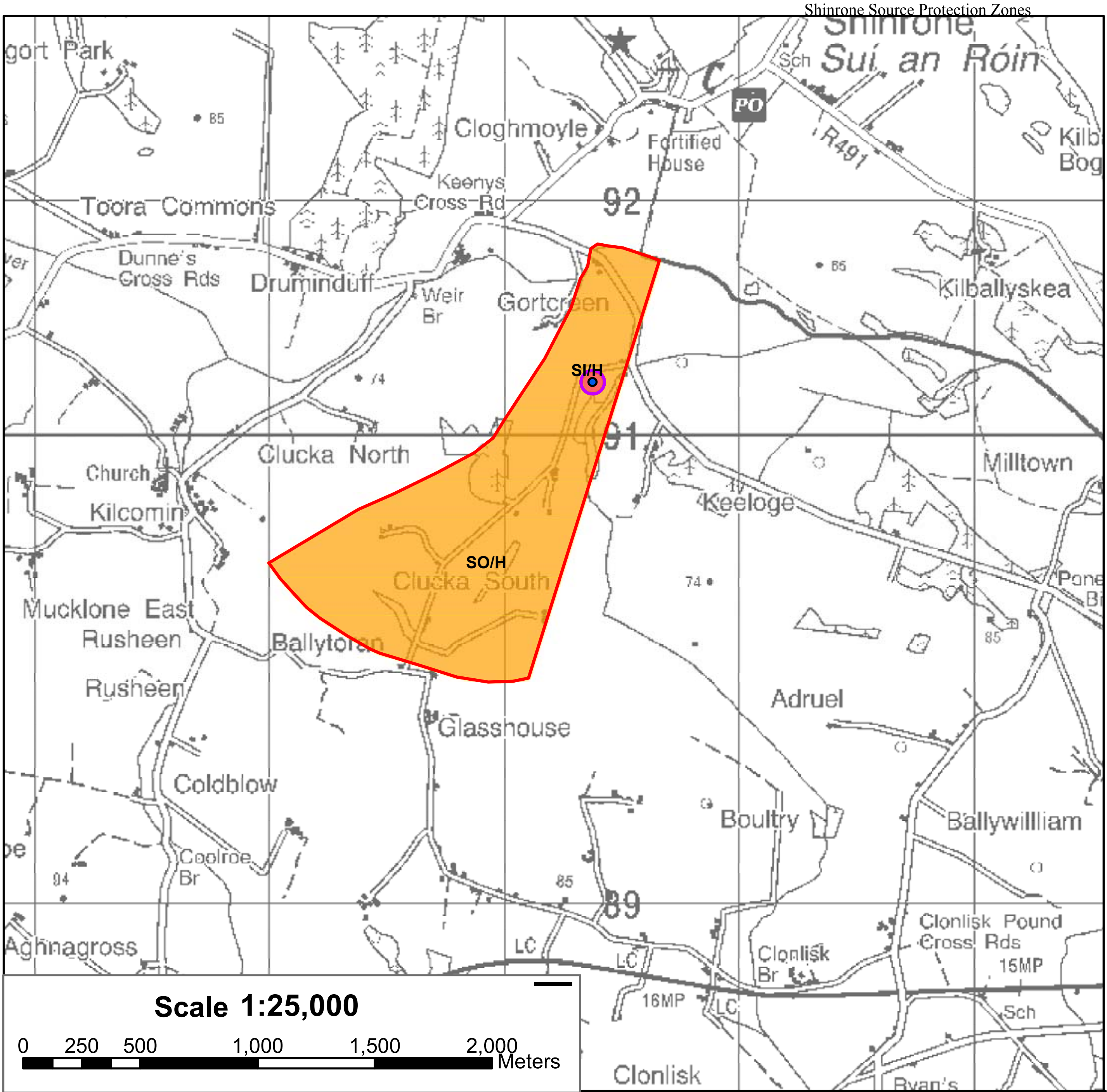


Figure 7 Groundwater Source Protection Areas for Niamh's Well.



SOURCE PROTECTION ZONES

VULNERABILITY RATING	SOURCE PROTECTION ZONES	
	Inner SI	Outer SI
High (H)	SI/H	SO/H

Inner Protection Zone SI

Outer Protection Zone SO

Well

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Project Manager: Donal Daly
Digital Map Production: Silvia Caloca

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

ESTO FIDELIS

GSI

Figure 8 Groundwater Source Protection Zones for Niamhs well.