Banagher Water Supply Scheme

Clontotan Boreholes

Groundwater Source Protection Zones

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1 Introduction

The objectives of the report are as follows:

- To delineate source protection zones for the boreholes at Clontotan.
- To outline the principal hydrogeological characteristics of the Banagher area.
- 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 boreholes. 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 (Daly, *et al*, 1998). 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 boreholes are located approximately 2 km east of Banagher, in the townland of Boheradurrow. A trial borehole was drilled in 1981, which is disused and no longer accessible, to investigate the possibility of augmenting the Banagher water supply scheme (Cullen, 1981). Concluding the investigation, two boreholes were drilled in 1986, in the vicinity of the trial borehole (Mc Carthy, 1987). The boreholes are alongside each other, each in its own separate concrete lined chamber with a padlocked galvanised cover, as shown in Figure 1, Figure 2 and Figure 3. The council site is fenced off, and is approximately 900 m^2 in size. The boreholes provide about 60% of the total demand for Banagher Regional Water Supply (County Council data, 1990), with the River Shannon providing the remainder. The water is chlorinated at the pumphouse on site, and pumped to a reservoir at Mullaghakaraun, with a storage capacity of 4000 m^3 (approximately 2 days storage). Details of the boreholes are summarised below.

3 Summary of Borehole Details

GSI No.	2021SWW002	2021SWW022	2021SWW008
Grid reference	202840 214010	202854 214029	202859 214025
Townland	Boheradurrow	Boheradurrow	Boheradurrow
Owner	Offaly County Council	Offaly County Council	Offaly County Council
Council Well Name	Trial Well	PW-1	PW-2
Well Type	Borehole	Borehole	Borehole
Depth	48.8 m	61 m	59 m
Elevation (ground level)	Approximately 55 m	Approximately 55 m	Approximately 55 m
Static water level	N/A	2-5 m below ground	2-5 m below ground
Pumping water level	N/A	Approx. 9 m below ground	Approx. 9 m below ground
Depth to rock	8 m	9 m	14 m
Status	Disused	Alternates pumping with PW2	Alternates pumping with PW1
Diameter	N/A	0.25m inner casing	0.25m inner casing
Pump level	N/A	Approx. 44 m below ground	Approx. 46 m below ground
***Normal abstraction**	N/A	400-420 $m^3 d^{-1}$	
****Maximum Abstraction**	N/A	717 $m^3 d^{-1}$ (30/10/02)	
Maximum Yield	654 $m^3 d^{-1}$ (72 hour test 1981)	916 $m^3 d^{-1}$ (72 hour test 1986)	870 $m^3 d^{-1}$ (72 hour test 1986)
Maximum Drawdown	11.43 m	36.7 m	40.97 m
Specific Capacity	57 $m^3 d^{-1} m^1$ (72 hour test 1981)	40 $m^3 d^{-1} m^1$ (72 hour test 1986)	25 $m^3 d^{-1} m^1$ (72 hour test 1986)
Hours Pumping	N/A	20-21 hours a day	

*Generally, one pump operates for any one pumping period and PW-2 was operating at time of GSI site visit (28/1/03).
** Maximum reported abstraction from available data.

Figure 1 Clontotan Boreholes

Figure 2 Dimensions of the borehole chambers

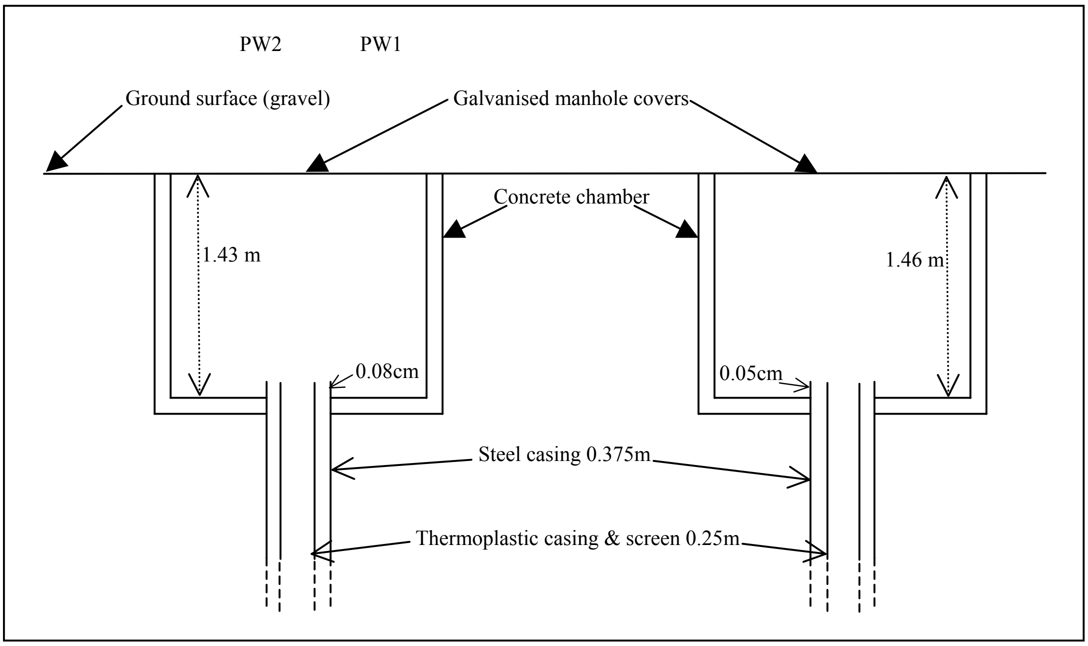
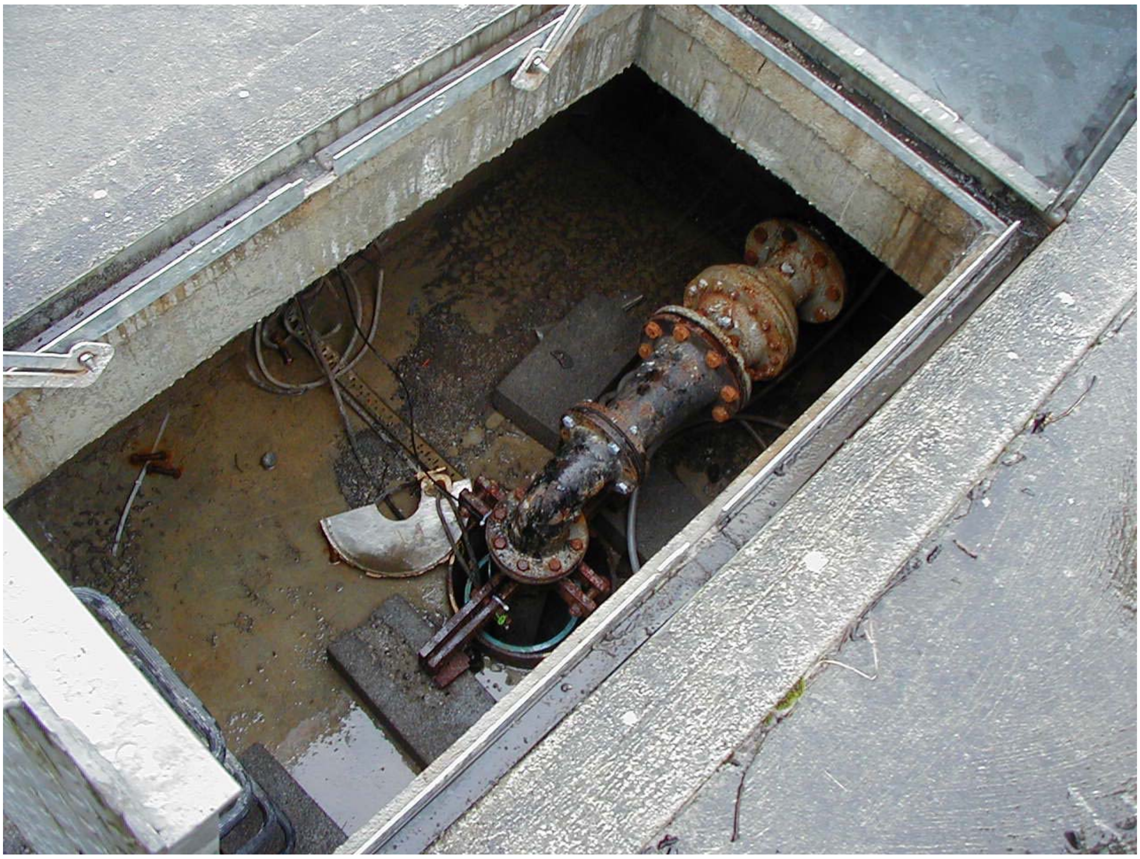


Figure 3 Inside the chamber of PW2



4 Methodology

Details about the boreholes such as depth, date commissioned 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 caretaker 28/1/03.
- Drilling of four auger holes by GSI 1/5/03.
- 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 55 m O.D. in a relatively low-lying area. The topography rises to the north, at Mullaghakaraun to approximately 75 m O.D. To the west of the boreholes, the topography slopes gently downwards toward the River Shannon.

There are several small streams in the area, draining the higher ground to the north and east of the boreholes. There are also several small springs in the area, for example in the townland of Cummen, just south of Coolfin House. One of the streams, flows approximately 200 m south of the boreholes, in a westerly direction toward the Rapemills stream, which flows northwest approximately 1 km south of the boreholes. The stream drains the Mullaghakaraun bog, which lies to the northeast of the boreholes.

The surface drainage network is part of the Shannon river catchment. The River Shannon is approximately 2 km to the northwest of the boreholes.

The dominant land use in the immediate vicinity of the boreholes is agricultural, mainly grassland and tillage. Mullaghakaraun bog occupies the area to the northeast of the boreholes. There are parts of the bog reclaimed, and planted with trees. A disused limestone quarry is situated approximately 500 m south of the boreholes. There are also a few disused sand/gravel pits in the area. There are a number of farms and houses within a kilometre of the borehole.

6 Geology

6.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the Clontotan 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.
- Offaly Groundwater Protection Scheme (Daly *et al,* 1998).
- Information from geological mapping in the nineteenth century (on record at the GSI).
- Subsoil mapping by the GSI.
- Auger Drilling carried out by GSI (4 holes drilled, 1/5/03).

6.2 Bedrock Geology

An extract of the available geology map is given in Figure 4, which shows that limestones dominate the region. The map shows that Pure Unbedded Limestone underlies the source. However, a "*black, micritic limestone*" is recorded in the geological logs for the three boreholes drilled on site. In the nearby townland of Garrycastle, outcrops, borehole records, and rock samples indicate that the bedrock belongs to the **Upper Impure Bedded Limestone** (commonly referred to as the "Calp" limestone). The Upper Impure Bedded Limestone is a dark grey, fine grained limestone.

The borehole logs indicate a large fault is present at about 30-35 m below ground level, which from the layout of the boreholes, is interpreted to lie roughly parallel to the road, i.e., has a NW-SE trend. There is a major fault set present in the area with a NW-SE trend, and one of these faults is mapped approximately 200 m to the south of the boreholes, shown in Figure 4. The fault could be inaccurately located as there are not many outcrops located in the vicinity from which to map the fault precisely.

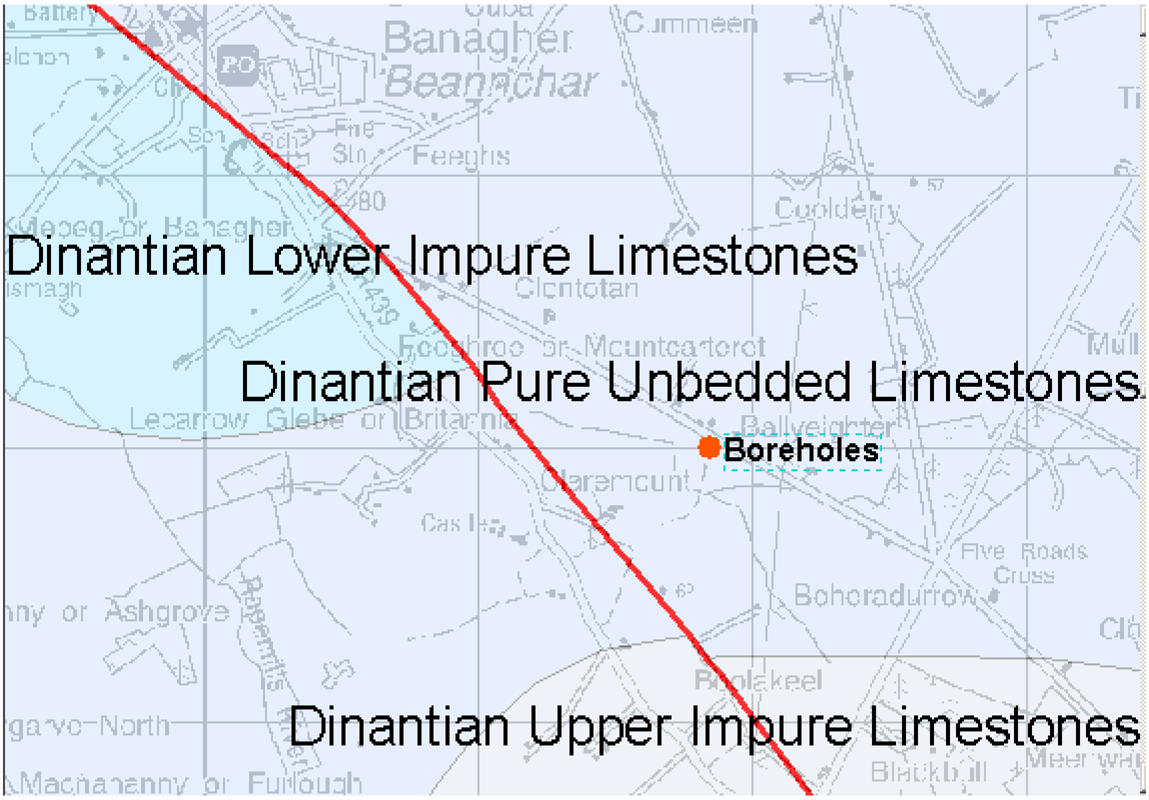


Figure 4 Geology around the Clontotan Boreholes

6.3 Subsoil Geology

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

- 'Till' or 'Boulder clay' is an unsorted mixture of coarse and fine materials laid down by ice. Till, classified as "**SILT/CLAY**" using BS 5930 (British Standards Institute, 1999), occupies the immediate area around the boreholes, and dominates the area to the north of the boreholes.
- Peat dominates the area to the northeast of the boreholes. The peatlands have been developed by Bórd na Móna. The original peat thickness was approximately 3-8 m, which has been altered, and only the basal peat layers are remaining, the thickness of which is variable, depending on the depth of the original organic profile and the underlying topography (Conroy, *et al*, 1970). It is estimated that the peat thickness (after cultivation) is approximately 2-4 m. Some of the peat areas in the vicinity are used for growing trees.
- Sand/gravel is mapped to the south of the boreholes, occupying most of the area around Claremount and Feeghroe, the extent of which is given in Figure 5.
- In general, the subsoil thickness varies from 0 m (outcrop) to greater than 10 m at PW-2, with the majority of the area having a depth to rock of less than 3 m. The source boreholes are located in a narrow zone of relatively deep subsoil, possibly related to the faulting. Areas of shallow rock and outcrop occur to the north and south of the boreholes, around Clontotan, Coolderry, Claremount and Garrycastle. The depth to bedrock is variable over short distances as shown by the borehole logs; from eight metres at the trial borehole to fourteen metres at PW-2, a distance of approximately 30 m. Depth to rock and outcrops are shown in Figure 5.

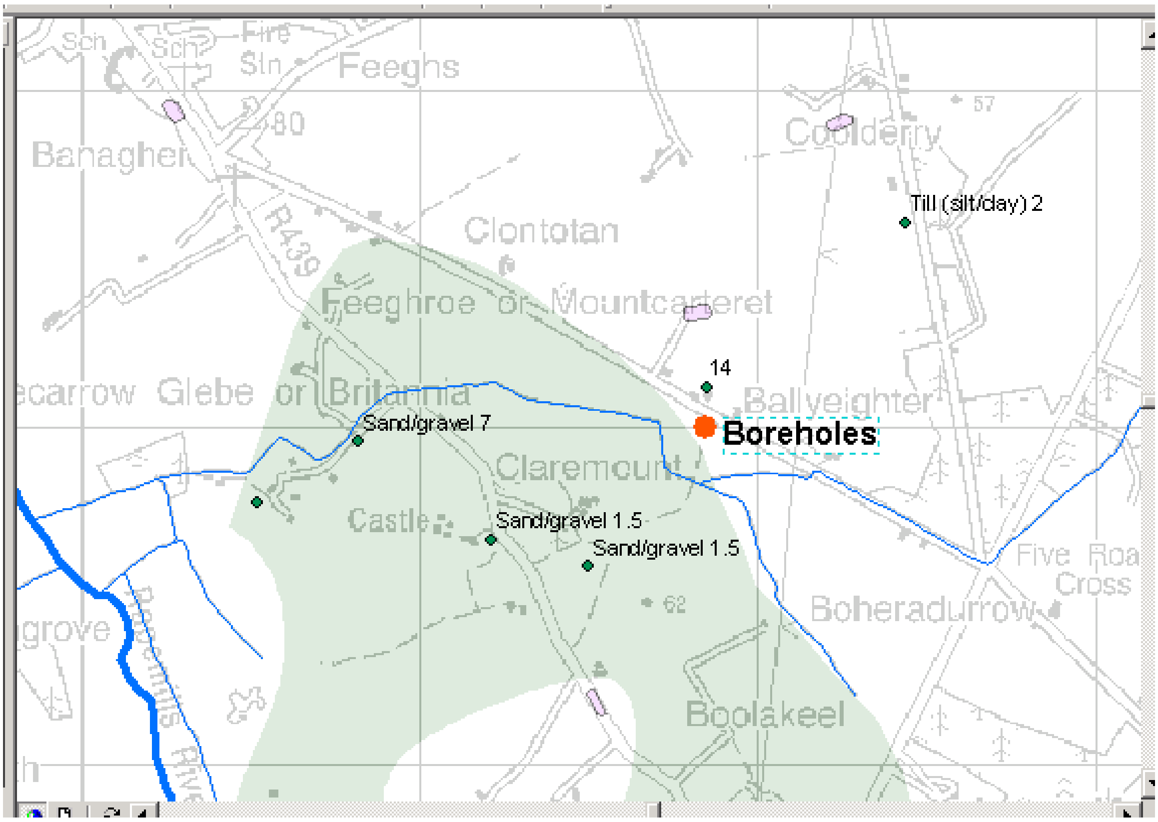


Figure 5 Outcrops, depth to bedrock, extent of sand/gravel, streams, and rivers

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 draft GSI Guidelines for Assessment and Mapping of Groundwater Vulnerability to Contamination. (Fitzsimons, 2003).

- The source of the groundwater is the bedrock, thus for the purposes of groundwater vulnerability mapping the **"top of the rock"** is the target.
- The permeability of the sand/gravel is classed as "**high**", the permeability of the peat "**low**", and the permeability of the till "**moderate**".
- Depth to bedrock varies from greater than 10 m at the source, to less than 1 m to the north and south of the source.
- The vulnerability varies from "**moderate**" to "**extreme**". Vulnerability increases with distance from the source, with the most vulnerable areas occupying the higher ground in the north and south, and the least vulnerable areas occupying the area around the boreholes, and the areas to the northeast where the peat bogs occur. The vulnerability is given in Figure 7.

Depth to rock interpretations are based on the available data cited here, however, it can vary over short distances, as can be seen above in Figure 5. As such, the vulnerability mapping provided would not be able to anticipate all the natural variation that occurs in the 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:

- Preliminary hydrogeological investigation of the Banagher area (Cullen, K.T., 1981).
- Drilling and testing contract for the Banagher Water Supply (Mc Carthy, P.H., Son and partner, 1987).
- 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 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 Banagher, 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: 850 mm.
Rainfall data for gauging stations around Banagher is given in the table below (from Fitzgerald, D., Forrestal., F., 1996).

Gauging Stations	Grid reference	Elevation OD (m)	Approximate distance and direction from source	Annual precipitation 1961-1990
Banagher	N004160	37	2 north west	842 mm
Meelick	M946129	39	7 km west	893 mm

The contoured data map for the Offaly Groundwater Protection Scheme (Daly *et al*, 1998) show that the boreholes are located near the 850 mm isohyet contour.

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: 400 mm.
The effective rainfall is calculated by subtracting actual evapotranspiration from rainfall.

Recharge coefficient: 40%.
Recharge is variable across the area: low in the peat covered areas; and, higher in the areas covered by till and shallow rock. However, the bedrock comprises a low permeability limestone, thus the amount

of recharge that the bedrock is able to accept is low. Thus, a representative value for the recharge coefficient is estimated to be in the order of 40%.

These calculations are summarised as follows:

Average annual rainfall (R)	850 mm
estimated P.E.	475 mm
estimated A.E. (95% of P.E.)	450 mm
effective rainfall	400 mm
recharge coefficient	40%
Recharge	**160 mm**

8.2 Groundwater Levels, Flow Directions and Gradients

Automatic water level recorders are installed in both of the wells, allowing a continuous record of the water levels to be maintained, which are relayed to a computer at the main sewage works in Banagher. The static water levels in the boreholes vary from 2-6 m below ground level. This is reflected in the variation in yield between the summer and winter months. Abstraction quantities are given for 1990 in Appendix 1, which show abstraction quantities dropping over the summer months. The potential yield increases from summer to winter from approximately 400-500 m^3 d^{-1} during the summer to approximately 700 m^3 d^{-1} during the winter months, as water levels rise in the boreholes (Council personnel). Pumping water levels are generally about 9 m below ground level. Both the static water levels and the pumping water levels are above the top of the bedrock, representing the potentiometric surface of the groundwater flowing through the major fracture present at approximately 35-40 m below ground. It is assumed that groundwater is generally unconfined in the area.

Apart from the recorded water levels in the supply boreholes, there are no other water level data for the area. The streams in the area are assumed to represent the water table, and it is generally assumed that the water table is a subdued reflection of the topography, and that the groundwater flow direction will be perpendicular to the contour lines. At a local scale, in the vicinity of the wells, it is assumed that the higher ground to the north of the supply boreholes will be the dominant driving head, therefore water is expected to flow in a southerly direction toward the bog and a westerly direction toward the stream flowing past the boreholes. At a regional scale, it is expected that the regional groundwater and surface water flow direction is northwest toward the river Shannon.

The groundwater gradients are expected to be quite steep, because of the impure bedrock and the relatively steep topography; and, a value of 0.01 is assumed.

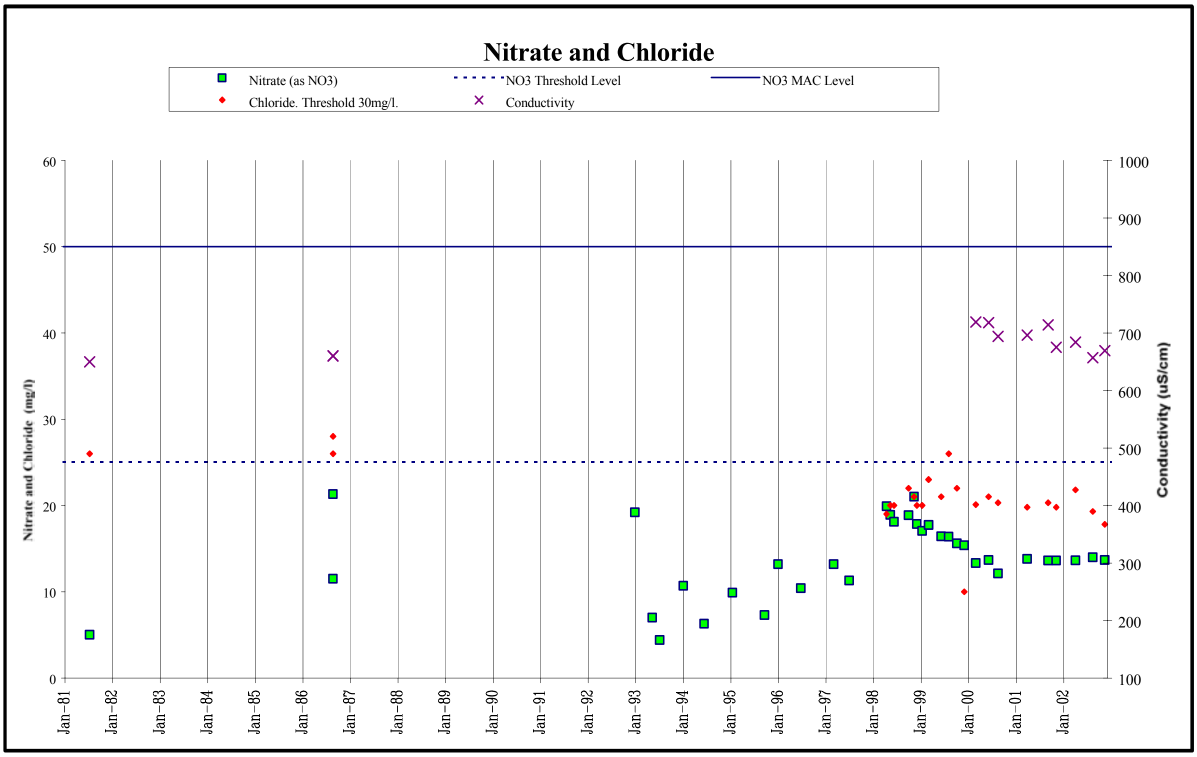
8.3 Hydrochemistry and water quality

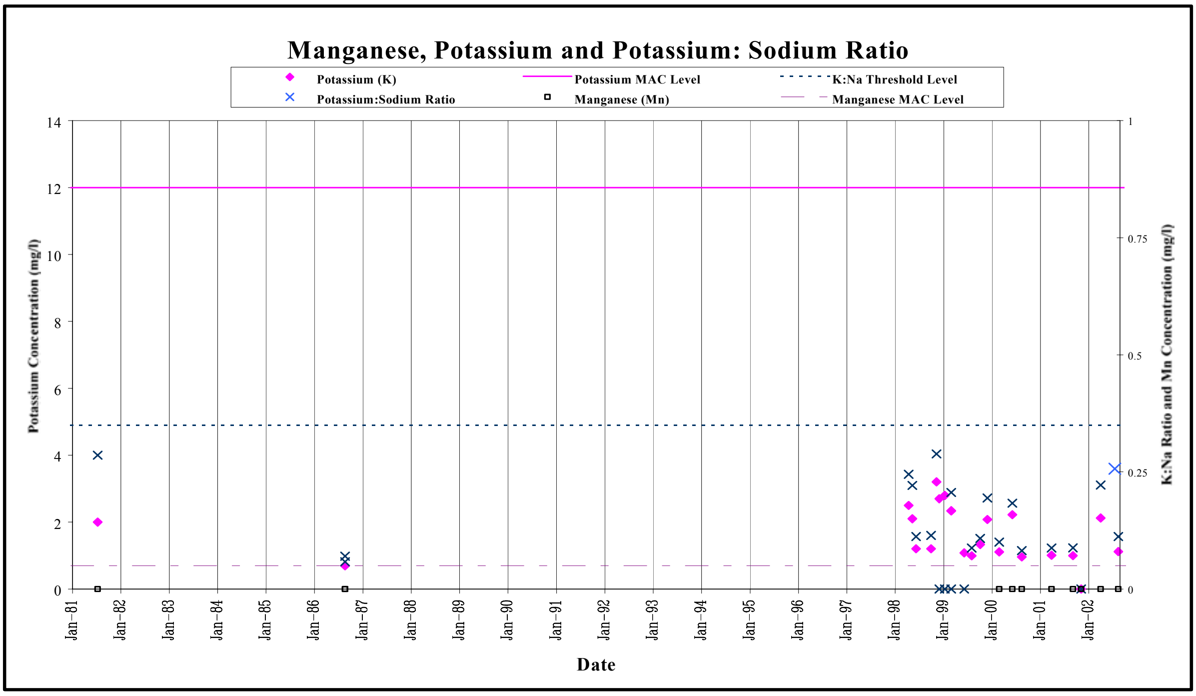
Data on trends in water quality are summarised graphically in Figure 6. The following key points are identified from the data.

- The water is very hard with hardness values greater than 350 mg l^{-1} (equivalent $CaCO_3$) and electrical conductivity values of 650-720 µS cm^{-1}. These values are typical of groundwater from limestone rocks, and typical of groundwater across Co. Offaly (Cronin, 1999).
- Nitrate concentrations in thirty five available samples from the last twenty years have never exceeded the EU maximum admissible concentration (MAC) of 50 mg l^{-1}, nor the guide level of 25 mg l^{-1}. Overall, a slightly increasing trend is observed in the data, however, the levels over the last 3 years are steady - approximately 14 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. The average chloride level in the available analyses is 21 mg l^{-1}, which is slightly higher than background level for chlorides in Co. Offaly. On three occasions, levels been above 25 mg l^{-1}.
- The potassium: sodium ratios are generally far less than 0.3 mg l^{-1}, but on three occasions it has reached 0.3 mg l^{-1}.

- There has been no reported exceedances of faecal coliforms from either four raw water samples or treated water samples taken from the source boreholes.
- In summary, groundwater quality is generally good, but occasionally there are slightly elevated chloride and potassium levels suggesting that there is some impact human impact, probably contamination from organic waste.

Figure 6 Key Indicators of agricultural and domestic groundwater contamination at Clontotan Supply Boreholes





8.4 Aquifer Characteristics

The drilling logs, test pumping, and resistivity surveys enable information on the aquifer characteristics in the vicinity of the boreholes to be evaluated. A major fault is mapped approximately 200 m south of the boreholes, and a large fracture is present at approximately 30-35 m below ground level, that is parallel to the road. The borehole logs indicate that the vertical thickness of the fault zones ranges from approximately 2.5 m in PW1 to approximately 12 m in the trial borehole, indicating that it is a major fault. A resistivity sounding carried out in the vicinity of the boreholes, subparallel to the road indicates a low resistivity anomaly.

The estimated aquifer parameters in the **vicinity of the fault zone** are summarised in Table 1. The time-drawdown data is difficult to analyse, due to pump failure, collapse of the well walls in the trial borehole, and changing of pump settings during test pumping. However, specific capacity is calculated from the data, ranging from 35-55 $m^3d^{-1}m^{-1}$, allowing estimates of transmissivity and permeability to be made. Transmissivity is in the order of 45-70 m^2 d^{-1}. Permeability is estimated using an assumed aquifer thickness of 50 m, to be in the order of 0.9-1.4 m d^{-1}. Porosity is estimated to be approximately 1.5 %. Away from the fault zone the aquifer properties are expected to be significantly poorer.

Table 1 Estimated parameters for the Upper Impure Bedded Limestone Aquifer in the vicinity of the fault zone.

Parameter in the vicinity of fault zone	*Source of data*	*Range/value*
Transmissivity (m^2 $d^{-1)}$	Local	45-70
Specific Capacities (Cullen, 1981)	Local	35-55
Permeability (m d^{-1})	Local	0.9-1.4
Porosity	Assumed	0.015

The Upper Impure Bedded Limestone provides the groundwater to the supply boreholes, and is regarded as a rock unit with relatively poor potential for groundwater abstraction, except in local zones of high permeability, usually associated with fractures and faults, as is the case for the Clontotan boreholes. According to the GSI classification of well yields, the boreholes are "**excellent**" yielding wells, capable of 1000 m^3 d^{-1} (220,000 gallons per day). However, this yield is not sustainable, and the abstraction quantities are only maintained:

1. If one borehole is pumping at any one time (wells fail if both are pumping simultaneously); and,
2. If the water level in either of the boreholes does not drop below the level of the fractures (Cullen, 1981), which is possible during dry weather periods.

The Upper Impure Bedded Limestone is classified as a **locally Important** aquifer which is **moderately productive** only in **local zones (Ll)**. While there appears to be a large variation in the hydrogeological properties over the region, overall permeabilities and well yields are relatively low. Groundwater flow tends to be concentrated in the upper fractured and weathered zone, along fractured fault zones and in more permeable beds. Consequently, groundwater throughput is low and groundwater circulation is shallow and localised, often with short flow paths (Daly, 1998). In addition, there are several streams and springs in the area. The Clontotan boreholes fit the conceptual understanding as the relatively high yields appear to be due the presence of a fault nearby.

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.

8.5 Conceptual Model

- The boreholes for Banagher RWS located at Boheradurrow abstract approximately 420 m^3 d^{-1} from a major fault located in the Upper Impure Bedded Limestone.
- The Upper Impure Bedded Limestone is classified as a **locally Important** aquifer which is **moderately productive** only in **local zones** (**Ll**).
- A major NW-SE fault is mapped 200 m south of the boreholes, and is present at approximately 35-40 m below ground in the boreholes. The fault is considered to be the main permeable pathway

through which groundwater feeding the boreholes flows. Groundwater is expected to flow south into the fault zone. During pumping, groundwater is pulled along the fault toward the boreholes.

- Groundwater in the area is generally thought to unconfined, however, groundwater in the immediate vicinity of the boreholes, flowing through the fault is thought to be confined.
- The subsoils in the area are generally free draining and shallow, however, there are several streams and springs in the area indicating that the bedrock, in general, is not very permeable.
- Transmissivity in the vicinity of the fault zone is estimated to be in the range of 45-70 $m^2 d^{-1}$. Permeability in the vicinity of the fault zone is estimated to be in the range of 0.9-1.4 $m d^{-1}$. Away from the fault zone the aquifer properties are expected to be significantly poorer.
- Groundwater quality is generally good but suggests some human impact.
- Diffuse recharge occurs over the higher relief areas of the catchment and the annual recharge is estimated to be approximately 160 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 8 and 9.

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. They are described as follows.

The **northeastern boundary** is constrained by topography. The surface water and groundwater divide is assumed to coincide with the ridge that runs between the high point in Mullaghakaraun, Cummeen and Clontotan. Groundwater to the east of the divide is assumed to discharge to the spring at Cumeen and to the bog. Groundwater to the west of the divide is expected to flow south toward the fault zone and the stream.

The **northwestern boundary** is constrained by topography. A ridge runs between Mullaghakaraun, Cuba and Feeghs, which is assumed to act as a surface water and groundwater divide. Groundwater to the west of the divide is expected to flow to the Shannon, and groundwater to the east is expected to flow south to the fault zone and the stream.

The **Southern boundary** is estimated using the uniform flow equation, using a gradient of 0.01; transmissivity of 70 $m^2 d^{-1}$; and, a discharge of 600 $m^3 d^{-1}$. Accordingly, the boundary is 140 m on the southern side of the wells. It is extended west to meet the northwestern boundary, and east to the northeastern boundary. There is a degree of uncertainty associated with the boundary, as it is not known how far the fault extends to the east or west of the boreholes.

A water balance was used to estimate recharge area required to supply groundwater to the source. Assuming an annual recharge of 160 mm, a recharge area of approximately 1.5 km^2 is required to provide enough groundwater to supply a discharge of 50% above the normal discharge (600 $m^3 d^{-1}$). The area described by the boundaries above is greater, approximately 2 km^2.

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 (1.4 m d^{-1}, 0.01, 1.5%, respectively), the calculated velocity is approximately 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.

Four groundwater protection zones are present around the source as illustrated in Table 2 and Figure 9.

Table 2 Matrix of Source Protection Zones for Clontotan supply boreholes.

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

12 Conclusions and Recommendations

- The Clontotan source comprises two boreholes, currently abstracting approximately 420 m^3 d^{-1} from a large fracture in the Upper Impure Bedded Limestone (**locally important** aquifer which is **moderately productive only in local zones (Ll)).**
- The groundwater feeding the source is extremely to moderately vulnerable to contamination.
- Available data suggests that there is no significant contamination at the source.
- The 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:
  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.

13 References

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Appendix 1. Typical Abstraction figures from Clontotan boreholes.

date	m3/day
Feb-90	448
Mar-90	443
Apr-90	407
May-90	373
Jun-90	387
Jul-90	373
Aug-90	424
Sep-90	365
Oct-90	374
Nov-90	391
Dec-90	418
01/08/2002	426
02/08/2002	426
03/08/2002	426
04/08/2002	426
11/08/2002	420
12/08/2002	420
13/08/2002	433
14/08/2002	445
15/08/2002	442
16/08/2002	442
17/08/2002	261
18/08/2002	491
19/08/2002	420
20/08/2002	420
21/08/2002	422
22/08/2002	420
23/08/2002	420
25/08/2002	420
26/08/2002	412
27/08/2002	420
28/08/2002	420
29/08/2002	420
30/08/2002	420
31/08/2002	420
01/10/2002	414
02/10/2002	414
03/10/2002	408
05/10/2002	388
06/10/2002	280
07/10/2002	358
08/10/2002	322
09/10/2002	309
10/10/2002	244
11/10/2002	136
12/10/2002	129
13/10/2002	38
22/10/2002	501
23/10/2002	575
24/10/2002	555
25/10/2002	575
26/10/2002	575
27/10/2002	598
28/10/2002	574
29/10/2002	589
30/10/2002	717
31/10/2002	717
01/09/2002	420
02/09/2002	420
03/09/2002	420
04/09/2002	420
05/09/2002	420
06/09/2002	420
07/09/2002	420
08/09/2002	420
09/09/2002	421
10/09/2002	420

11/09/2002	420
12/09/2002	420
13/09/2002	420
18/09/2002	203
19/09/2002	419
20/09/2002	419
21/09/2002	419
22/09/2002	387
23/09/2002	414
24/09/2002	414
25/09/2002	414
26/09/2002	414
27/09/2002	414
28/09/2002	404
29/09/2002	414
30/09/2002	414
25/07/2002	418
26/07/2002	427
27/07/2002	430
25/07/2002	431
29/07/2002	368
30/07/2002	428
31/07/2002	425

Appendix 2 Summary Logs of auger holes
Depth to bedrock drilling at Banagher, Co. Offaly.

Auger A
Coolderry.
0-2m Till; SILT/CLAY
2m EOH.

Auger B
Britannia
0-7m Sand/gravel (GRAVEL)
7m EOH.

Auger C & D
Garrycastle
Both less than 2m; both sand/gravel.

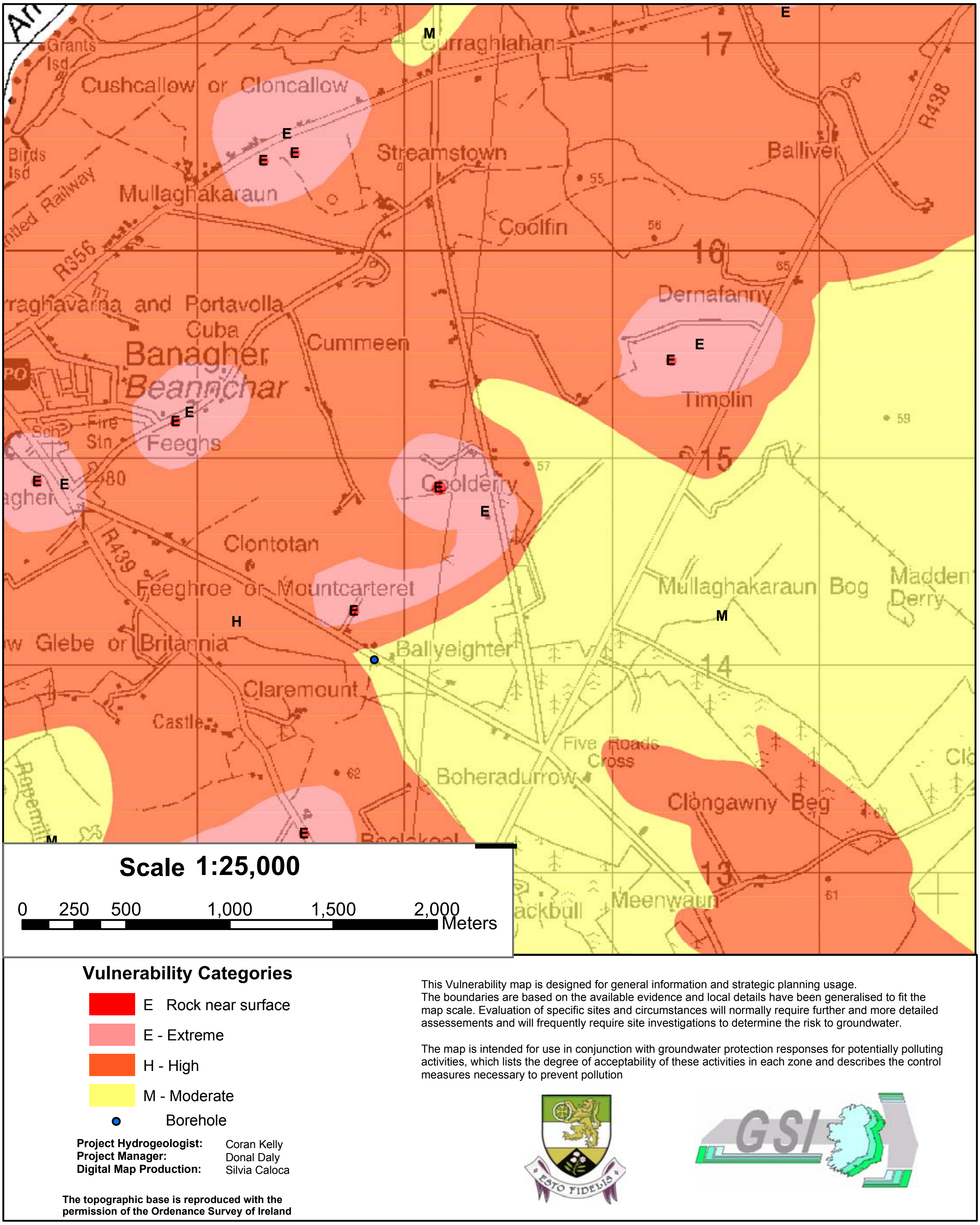
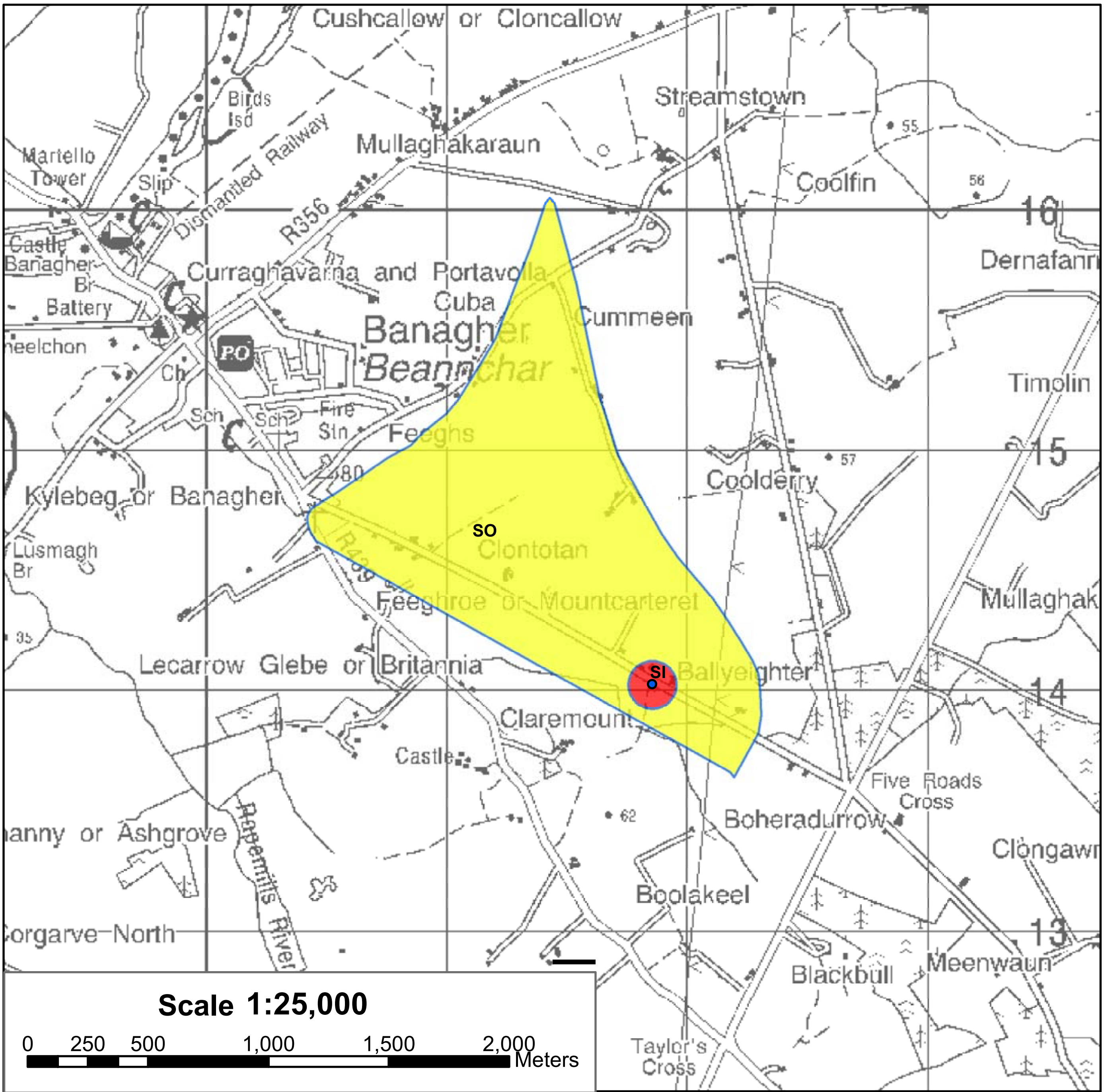


Figure 7 Vulnerability for Banagher



LEGEND

Inner Protection Zone SI

Outer Protection Zone SO

Borehole

This Source Protection Area 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.

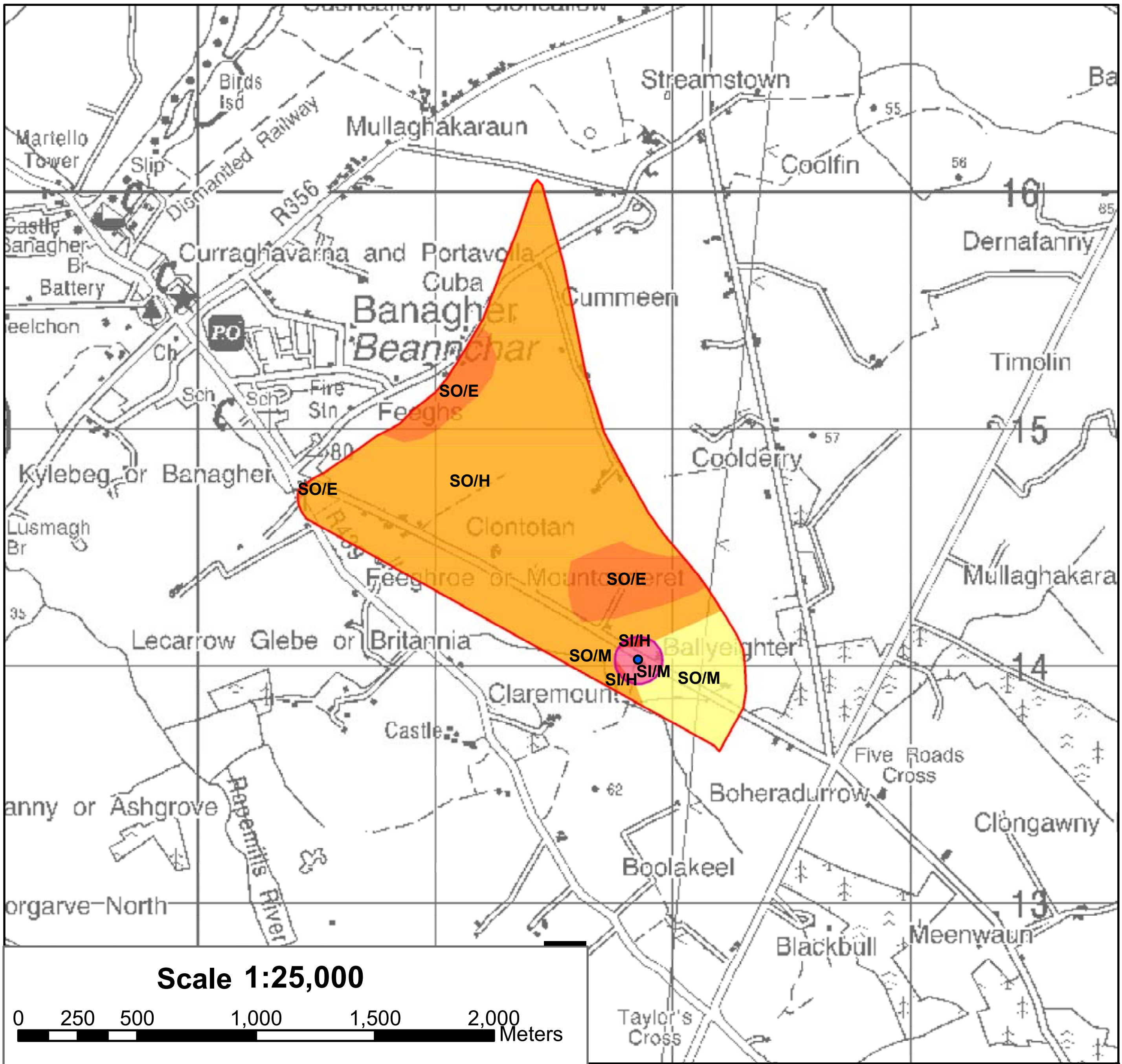
The map is intended for use in conjunction with groundwater protection responses for potentially polluting activities, which lists the degree of acceptability of these activities in each zone and describes the control measures necessary to prevent pollution

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

ESTO FIDELIS

GSI

Figure 8 Source Protection Areas for Clontotan Boreholes



SOURCE PROTECTION ZONES

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

Inner Protection Zone SI
Outer Protection Zone SO
Borehole

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

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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

Figure 9 Source Protection Zones for Clontotan Boreholes