Fermoyle Public Water Supply

Groundwater Source Protection Zones

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In collaboration with:

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1. Introduction

The objectives of this report are:

- To delineate source protection zones for the Fermoyle Water Supply sources.
- To outline the principal hydrogeological characteristics of the Fermoyle area.
- To assist Laois County Council in protecting the water supplies from contamination.

2. Location and Site Description

The Fermoyle site is situated approximately 2 km northeast of Durrow in the townland of Fermoyle, County Laois. The site includes two bored wells located beside a pumphouse in an area which is fenced off from the adjacent field.

Well A which supplies Ballinakill is 27 m deep; Well B which supplies Durrow is 24 m deep. Both wells are completed below ground level in concrete chambers. The wells are not capped but both chambers are covered and padlocked.

The water is chlorinated.

3. Summary of Well Details

GSI no.	2317 SW W104 (Well A)
Grid ref. (1:25,000)	24281 17910
Townland	Fermoyle
Owner	Laois County Council
Well type	Borehole - Ballinakill (A)
Elevation (top of casing)	80.2 m O.D.
Depth	26.7 m
Diameter	8”
Depth-to-rock	8.2 m
Static water level	76.4 m OD (25/8/98)
Drawdown	approximately 3.8 m b.g.l.
Total Abstraction	273 m^3/d (60,000 gal/d over 6 hours pumping)
Pumping test summary	(i) Abstraction rate: 920 m^3/d (10 hour constant rate test 25/8/1998) (ii) Specific capacity 994 m^3/d/m (after 600 minutes pumping) (ii) Transmissivity: 377 m^2/d

GSI no.	2317 SW W106 (Well B)
Grid ref. (1:25,000)	24281 17910
Townland	Fermoyle
Owner	Laois County Council
Well type	Borehole – Durrow (B)
Elevation (top of casing)	80.4 m O.D.
Depth	24.4 m
Diameter	8”
Depth-to-rock	8.2 m
Static water level	76.5 m OD (25/8/98)
Drawdown	approximately 3.8 m b.g.l.
Total Abstraction	168 m^3/d (37,000 gal/d over 4 hours pumping)
Pumping test summary	(i) Abstraction rate: 1210 m^3/d (4 day constant rate test 19/10/1977) (ii) Specific capacity 306 m^3/d/m (after 6000 minutes pumping) (ii) Transmissivity: 344 m^2/d

4. Methodology

Desk study

Bedrock geology information was compiled from the GSI Geology Sheet No. 18 (Archer *et al*, 1996) and subsoils were compiled from the GSI Quaternary maps (Kilfeather, 1999). Basic public supply well details were obtained from GSI records and County Council personnel; such details include borehole depth, elevation, abstraction rate, pumping test details and geophysical borehole logs.

Site visits and fieldwork

The second stage comprised site visits and fieldwork in the Fermoyle area. This included a walkover survey in order to further investigate the subsoil and bedrock geology, the hydrogeology, the vulnerability to contamination and the current pollutant loading. A 10 hour pumping test and 4 hour recovery test were also carried out at Fermoyle. Water samples for analysis in the State Laboratory were taken in November 1997 and June 1999.

Data analysis

The assessment stage utilised analytical equations and hydrogeological mapping to delineate protection zones around the public supply well.

5. Topography and Surface Hydrology

The Fermoyle sources lies within the catchment of the Nore River which is located 1 km west of the site. A tributary of the Owenbeg river flows approximately 1 km east of the Fermoyle site in a southerly direction.

A ridge separates the Owenbeg tributary river from the Nore River and rises to an elevation of 105 m OD about 500 m east of the Fermoyle site. A hill in the Castlewood area located 1 km south of the Fermoyle site, is 127 m OD in elevation. Topography in the area slopes from these hills in a west to northwesterly direction toward the Fermoyle site which is located close to the 80 m contour.

The soils and subsoils are very free draining in the vicinity of the source and there are few visible drains or ditches. The land is largely used for pasture although a small proportion is used for tillage.

6. Geology

6.1 Bedrock Geology

The bedrock geology of the Fermoyle area comprises sediments of Carboniferous age (over 300 million years old) which were subsequently faulted. The rock units of the area, which are shown in Figure 1, are summarised below.

Rock Formation	Rock Material	Thickness	Occurrence
Killeshin Siltstone Formation	'Flaggy' SANDSTONE.	50-100m	South of the Fermoyle site, in the Castlewood area.
Clogrenan Limestone Formation	Thinly bedded 'clean' dark grey LIMESTONE. Often very cherty.	~100m	East of the Fermoyle site
Ballyadams Limestone Formation	Thickly bedded, 'clean', pale grey, 'crystalline' LIMESTONE.	~200m	Northwest and west of the Fermoyle site

Some degree of karstification is expected in both the Ballyadams and Clogrenan formations. Evidence of karstification has, in fact, been found regionally in both these formations (Archer *at al*., 1996).

6.1.1 Geological Structure

There is a large NNE-SSW trending fault in the vicinity of the Fermoyle site. The Ballyadams Limestone lies to the west of the fault and the Clogrenan limestone to the east. The area surrounding the fault is likely to be very fractured and fissured. The rocks in the Fermoyle area are dipping 20° to the southwest.

6.2 Subsoils (Quaternary) Geology

The subsoils in the Fermoyle area are comprised largely of sand and gravel deposits.

6.2.1 Sands & Gravels

Extensive fluvioglacial sand and gravels extend from Clonkeen Hill, 2 km northwest of the Fermoyle site, to the Nore River. A north–south trending ridge of sand and gravel deposits occurs to the northeast of the Fermoyle site. There are a number of disused quarries along this ridge in which these deposits are very well exposed. The sands and gravels are mainly clean. The boulders and cobbles are mainly of limestone composition and are derived from the underlying limestone bedrock.

6.3 Depth-to-rock

Accurate information on depth to bedrock is based on outcrop information, well records and subsoil sections. The subsoil map of the area indicates that there is some outcropping rock and shallow bedrock in the Castlewood area to the south and southeast of the Fermoyle site. Subsoil thickness increases to the west and northwest. Subsoils are 8.2 m thick at the Fermoyle site and are likely to be significantly thicker along the gravel ridge to the northeast. Depth to rock information in the Fermoyle area is given in Figure 2.

7. Hydrogeology

7.1 Data availability

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

- A step test and constant rate test carried out by E.P. Daly, GSI in Oct 1977.
- A study of the Groundwater in County Laois (E.P. Daly, 1978).
- A 10 hour pumping test and 4 hour recovery test carried out by GSI staff in September 1998.
- Hydrochemical analyses carried out by the State Laboratory for GSI (Nov 1997, Feb 1997, June 1999).
- County Laois Groundwater Protection Scheme, (Wright *et al*, 2000).

7.2 Meteorology and Recharge

Rainfall data for the area were obtained from Met Éireann. The mean annual rainfall (R) for the area (1961-90) was 879 mm. Potential Evaporation (PE) is estimated from a national contoured map by Met Éireann as 475 mm/yr. Actual evapotranspiration (AE) is estimated by taking 90% of the potential figure, to allow for soil moisture deficits, as 429 mm/yr. Using these figures, the potential recharge (R - AE) is taken as approximately 450 mm. The absence of drains and ditches in the area indicates that the subsoils are free draining and that a high proportion of the effective rainfall is infiltrating to the water table. Runoff is assumed to be 10 % of available recharge, i.e. 45 mm. This assumption is an empirical standard used in GSI for permeable, sand & gravel subsoils of the type which dominate the area around the Fermoyle site. These calculations are summarised below:

Average annual rainfall	879 mm
Estimated P.E.	475 mm
Estimated A.E. (90% P.E.)	429 mm
Potential recharge	450 mm
Surface Runoff	45 mm
Recharge	405 mm

7.3 Groundwater levels

Water level data were obtained during well surveys carried out in the Fermoyle area in Summer 1977 (Daly, 1978) and also during a field visit in February 1999. Owing to the difference in recharge conditions at these times, the water levels across the Fermoyle area are very variable. Variable water levels may also be due to the karstic nature of the limestone bedrock. The water level at the Fermoyle site was 78.6 m OD on the 18/2/99 indicating that the gravel deposits were almost fully saturated. On the 19/10/77 the water level was much lower at 74.3 m OD, however this followed a dry period.

Water levels in the Owenbeg tributary river are at a slightly higher elevation than groundwater levels in the area east of the Fermoyle site. The river is likely to be perched by thin peaty soils and is probably not contributing to groundwater flow in this area. Further south the river cuts through bedrock and is likely to be groundwater fed.

7.4 Groundwater Flow Directions and Gradients

The water table in the Fermoyle area is assumed to broadly reflect topography with groundwater flowing toward and discharging into the River Nore. There is an northeast–southwest trending groundwater divide present in the Castlewood area. Water to the northwest flows toward the Nore and water to the southeast flows toward the Owenbeg tributary river. The natural hydraulic gradient in the Clogrenan and Ballyadams Limestone is estimated to be on average 0.015. The gradient is likely to be much steeper in the Killeshin Siltstone in the Castlewood area.

7.5 Hydrochemistry and Water Quality

Results of laboratory analysis of water samples taken in November 1997, February 1999, and July 1999 are presented in Table 1.

The following key points have been identified from the data:

- The groundwater samples indicate a ‘very hard’ (399-409 mg/l $CaCO_3$) calcium-bicarbonate hydrochemical signature. This indicates that the groundwater feeding the Fermoyle boreholes has passed through limestone rock and limestone gravels and that the waters are relatively ‘young’ and travel times from the recharge area to the well are likely to be short.
- Of the parameters examined in the groundwater samples taken, total coliforms were in excess of the EU MAC (2 counts per 100 ml in November 1997). Nitrate levels consistently approach or exceed the E.U. MAC of 50 mg/l. Chloride levels (24 mg/l) in Feb 1999 are approaching the GSI threshold of 25 mg/l. The K:Na ratio exceeds the GSI threshold of 0.4 in three of four samples taken.
- A K:Na ratio greater than 0.4 can be used to indicate contamination by plant organic matter - usually from farmyards. High nitrates and elevated chlorides are also indicative of significant organic contamination occurring within the groundwater system. The source of the contamination is likely to be the piggery located 500 m southwest of the Fermoyle site.

7.6 Aquifer Parameters

The Fermoyle boreholes penetrate both the upper sand/gravel aquifer and the lower karstified limestone aquifer. During the 10 hour pumping test (25/8/98), Fermoyle Well A was pumped at a constant rate of 920 m^3/d. A total drawdown of 0.93 m was measured which gives a large specific capacity of 994 m^3/d/m. A transmissivity estimate of 377 m^2/d was calculated. A similar transmissivity value of 344 m^2/d was calculated from a 4 day constant rate pumping test carried out from 19/10/77. This transmissivity estimate is likely to reflect properties of (a) the sand and gravel aquifer (b) the underlying fissured limestone and (c) localised faulting in this area. A 4 hour recovery test yielded a higher transmissivity estimate of 652 m^2/d. This higher estimate may reflect shallow flow in the upper sand/gravel aquifer.

7.7 Aquifer Category

The sand/gravel deposits in the Fermoyle area are classed as a Locally important aquifer (**Lg**) ??. The Ballyadams and Clogrenan limestone are considered to be 'Regionally Important karstic aquifers (**Rk**)'. The Killeshin Siltstone, is considered to be a 'Poor aquifer which is generally unproductive except for local zones (**Pl**)' (Wright *et al*, 2000).

7.8 Conceptual Model

- There is a northeast southwest trending topographic divide located in the Castlewood–Fermoyle area. Water to the north and west of this divide is likely to flow toward the Fermoyle site. It is not clear whether there is a groundwater divide along the gravel ridge to the northeast of the site. For the purposes of this report it is assumed that this is a groundwater divide as well as a topographic divide.
- The Fermoyle source is fed by the upper sand/gravel aquifer and the lower Limestone aquifers.
- The permeability in the limestones depends on the development of faults, fractures and karst features. There is a large NNE-SSW trending fault in the vicinity of the site which probably enhances groundwater flow in this area. There are no recorded karst features in this area however there is a dry valley feature to the southeast of the site along which preferential flow may occur.
- The limestone rocks are largely overlain by highly permeable sands/gravels, therefore the groundwater can be considered as unconfined.
- The permeability of the sand/gravel deposits is intergranular i.e. groundwater movement is between the grains.
- The gravels are almost fully saturated at the Fermoyle site and provide storage for the source.
- The groundwater gradient is relatively flat within the permeable limestone aquifer. Measured water levels suggests that gradients for the Limestone units are approximately 0.015. Gradients in the Killeshin Siltstone are likely to be steeper than in the more permeable limestone units.
- A tributary of the Owenbeg River drains the southwestern slopes of Clonkeen Hill. Water levels in this tributary are at a slightly higher elevation than groundwater levels in the area east of the site. The river is probably perched by thin peaty soils which formed due to the high water table in this area. The river is probably not contributing to groundwater flow in the area.

8. Delineation Of Source Protection Areas

8.1 Introduction

Two source protection areas are delineated:

- Inner Protection Area (SI), designed to give protection from microbial pollution
- Outer Protection Area (SO), encompassing the remainder of the zone of contribution (ZOC) of the well

8.2 Outer Protection Area

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

i) An estimate of the area size is obtained by using the average recharge and the abstraction rate.

ii) To allow for errors in the estimation of groundwater flow direction and to allow for an increase in the ZOC in dry weather, a safety margin is incorporated by assuming a higher abstraction rate than the current rate.

Average daily abstraction at Fermoyle site is 440 m^3/d (ie. 273 m3/d (Well A) and 168 m3/d (Well B). This figure is increased by 50% to 660 m^3/d for the following reasons:

- to allow for increased water demand due to expansion in Fermoyle.
- to allow for an increase in the ZOC during dry weather.

Taking the recharge to be 428 mm as indicated in Section 7.2, the area required to supply a pumping rate of 660 m^3/d is calculated to be 0.56 km^2 (56 ha).

The boundaries of the ZOC are illustrated in Figure 3 and are delineated as follows:

Northern Boundary: This boundary is based on topography and extends as far as the crest of the gravel ridge.

Northeast/Southwest Boundaries: These boundaries are based on topographic divides in the Castlewood-Fermoyle areas.

Western Boundary: This is based on topography; water to the east of this is likely to be channelled via a dry valley feature toward the Fermoyle site.

Eastern Boundary: This boundary is delineated with the greatest degree of uncertainty. It is taken as coinciding with the gravel ridge.

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

8.3 Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100 day time of travel (TOT) from a point below the water table to the source, and is delineated to protect from potentially contaminating activities which may have an immediate influence on water quality at the source, in particular from microbial contamination. Due to the highly permeable, karstic nature of the limestone aquifer, it is probable that a large proportion of goundwater in the ZOC can travel to the public supply well in less than 100 days. (While this conclusion is arguable, it is advisable to take the precautionary approach in view of the uncertainties concerning flow in karstic limestones.) Therefore all areas within the ZOC which are underlain by karstified limestone are included within the inner protection zone.

9. Vulnerability

Areas of rock close to surface are taken to be extremely vulnerable to contamination. The groundwater in the Castlewood and Fermoyle areas is considered to be extremely vulnerable. Sands and gravels normally contain less than 3 % fine grade material and are classed as highly permeable (Daly *et al,* 1997). The unsaturated zone in the sands and gravels in the Fermoyle area are assumed to be at least 3 m in thickness and so groundwater is considered to be “highly” vulnerable. Vulnerability of groundwater in the Fermoyle area is shown in Figure 2.

10. Groundwater Protection Zones

The groundwater protection zones are obtained by integrating the two elements of land surface zoning (source protection areas and vulnerability categories) – a possible total of 8 source protection zones (see the matrix in the table below). In practice, the source protection zones are obtained by superimposing the vulnerability map on the source protection area map. Each zone is represented by a code e.g. **SO/H**, which represents an Outer Source Protection area where the groundwater is highly vulnerable to contamination. All of the hydrogeological settings represented by the zones may not be present around each local authority source. There are 4 groundwater protection zones present around the Fermoyle source (see Figure 3), as shown in the matrix below.

Matrix of Source Protection Zones

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

11. Land use and Potential Pollution Sources

Agriculture is the principal activity in the area. Most of the land is used for pasture, although a small proportion is used for tillage. One of the main hazards within the ZOC is a piggery which lies 0.5 km southeast of the PWS. Other hazards include farmyards, septic tank systems, application of fertilisers (organic and inorganic) and pesticides, and possible spillages along the roads. No detailed assessment of hazards was carried out as part of this study.

12. Conclusions and Recommendations

- The site at Fermoyle comprises two excellent wells, which are located in a regionally important karstified limestone aquifer overlain by a Locally Important gravel aquifer.
- The area around the supply is 'highly' to 'extremely' vulnerable to contamination.
- The inner and outer protection zones delineated in the report are based on our current understanding of groundwater conditions and on the available data. Additional data obtained in the future may indicate that amendments to the boundaries are necessary.
- It is recommended that an urgent study be carried out at Fermoyle to assess the source of high nitrates. This would involve:
    - a review of the most recent data
    - increased monitoring of untreated water
    - monitoring and assessment of other parameters
    - surveys of potential contamination sources, similar to the farm surveys carried out in the late 1980s
    - consideration of whether nitrate vulnerable zones need to be delineated under the requirements of the EU Nitrate Directive; assessment of the likely source(s) of nitrate; where the maps are available, using vulnerability zones and groundwater protection zones in the assessment process
    - in the short term, until the groundwater quality situation can be properly assessed, care should be taken in allowing any activities or developments which might significantly increase nitrate levels
- In addition, chemical and bacteriological analyses of raw water rather than treated water should be carried out on a regular basis (every 3 - 6 months)
- Guidelines should be drawn up for dealing with spillages along the roads in the area.

13. References

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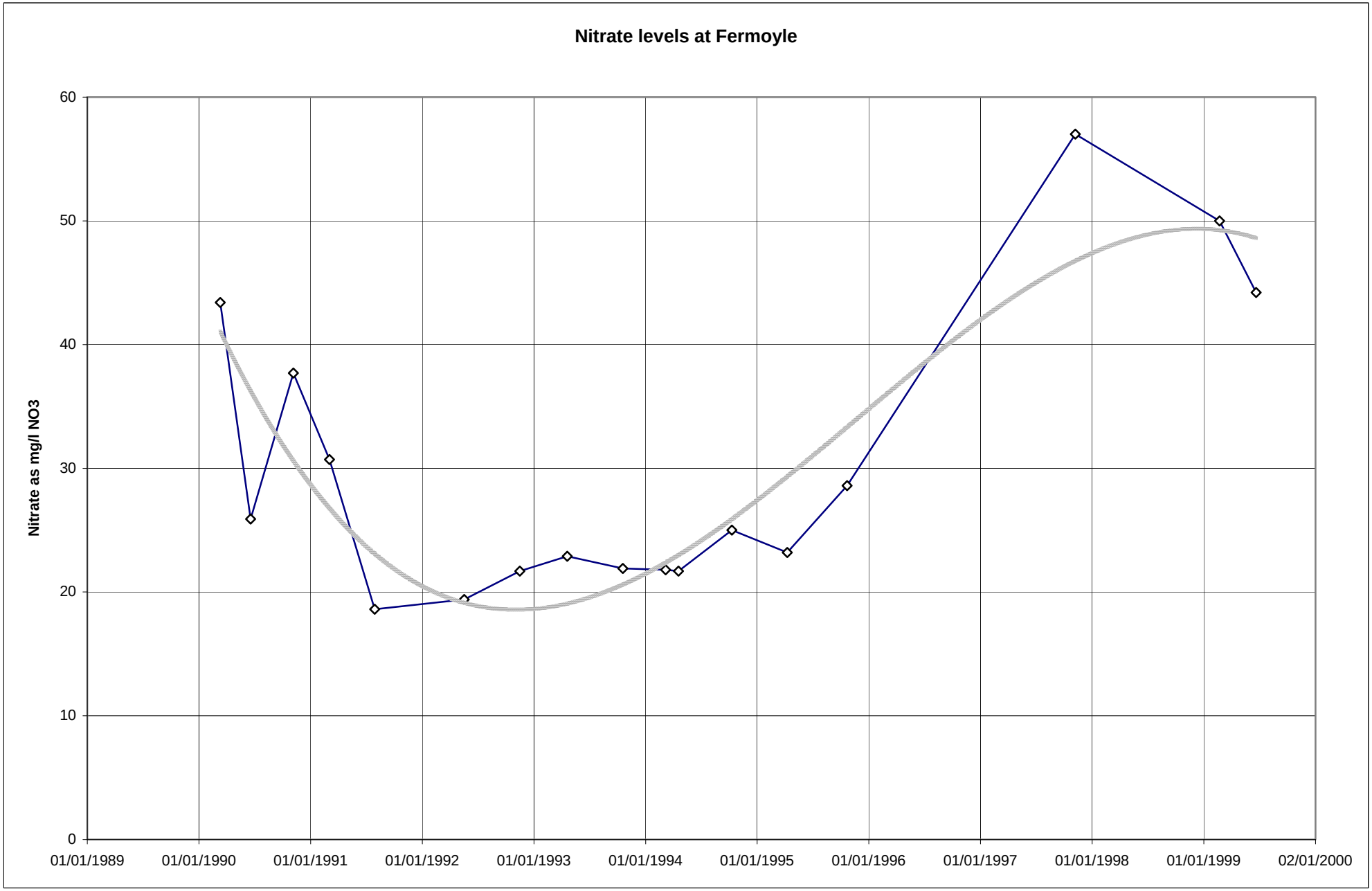
Table 1: Laboratory Analyses of Groundwater at Fermoyle PWS

Parameter	**Results of Laboratory Analyses**			
	Well A Sample	Well B Sample	Fermoyle	Fermoyle
	7/11/97	7/11/97	22/2/99	22/6/99
Conductivity (μS/cm)	743	732	734	731
Total Hardness	409.7	406.2	399.8	406
Total Alkalinity (mg/l)	324	328	328	340
Calcium	135.3	130.8	130.5	132
Magnesium	17.4	19.3	17.9	18.6
Chloride	20.9	23.3	24	23.3
Sulphate	42.5	33	27.5	27.8
Sodium	11	10.4	11	9.72
Potassium	4	3	5.6	3.48
K:Na	*0.4*	0.3	*0.5*	*0.4*
Nitrate (as NO_3)	**57**	**46.5**	**50**	**44.2**
Iron	<0.005	<0.005	0.015	0.006
E.Coli count per 100 ml.	0	0	n.d	0
Total Coliforms per 100ml	0	**2**	n.d.	0

Note: **Bold type denotes E.U. MAC exceedances.**
Italic type denotes GSI threshold exceedances.


Nitrate levels at Fermoyle
Nitrate as mg/l NO3
60
50
40
30
20
10
0
01/01/1989
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01/01/1992
01/01/1993
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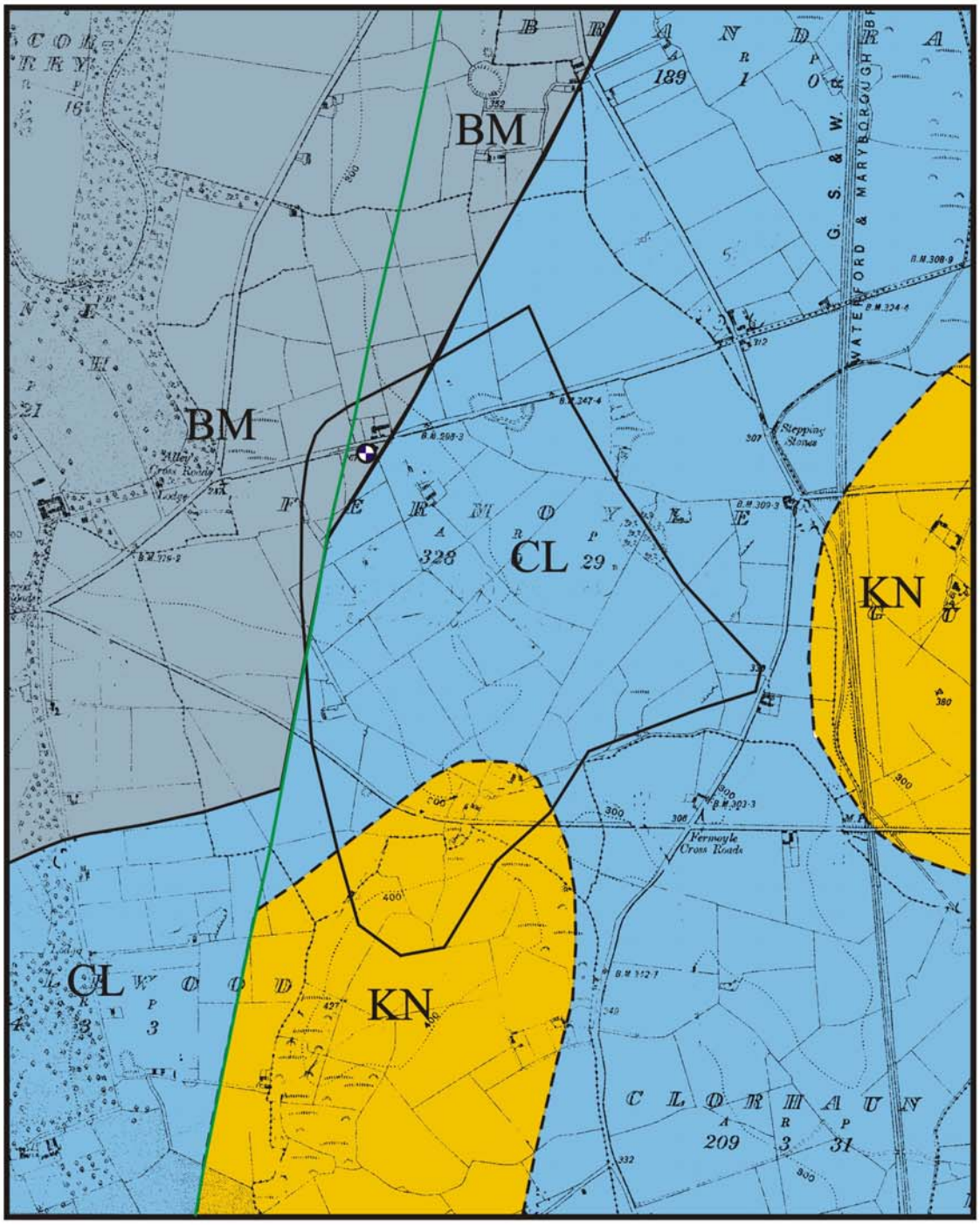


Map 1: Geology of the Fermoyle District

Legend

KN Killeshin Siltstone Formation

CL Clogrenan Formation

BM Ballyadams Formation

Geological Boundary

Unconformity

Fault

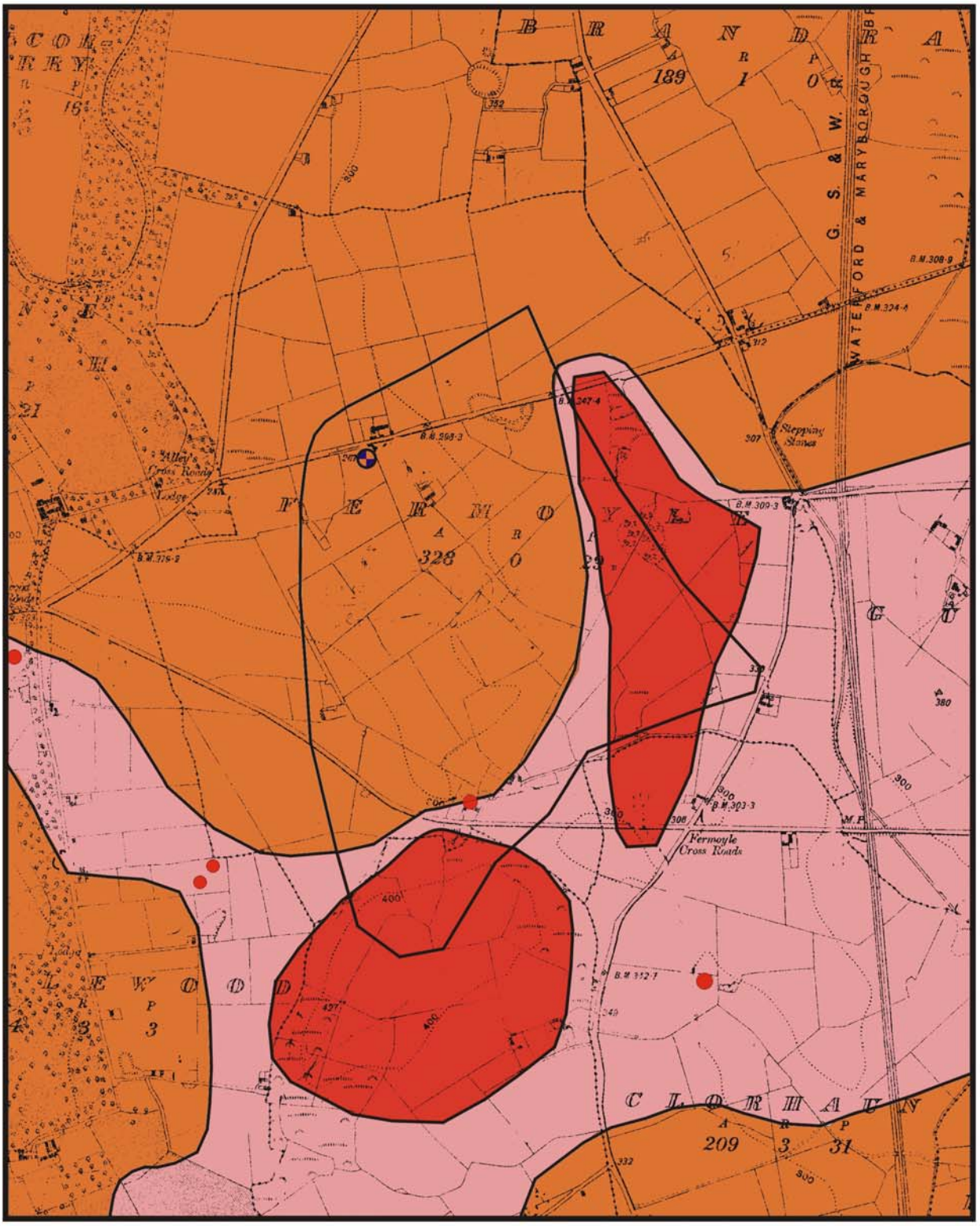
Zone of Contribution

Public Supply Well

N

Scale (metres)

0 500



Map 2: Vulnerability Classification of the Fermoyle District

Legend

Vulnerability Classification

- Extreme (E)
- Outcrop/Shallow rock/Karst (E)
- High (H)

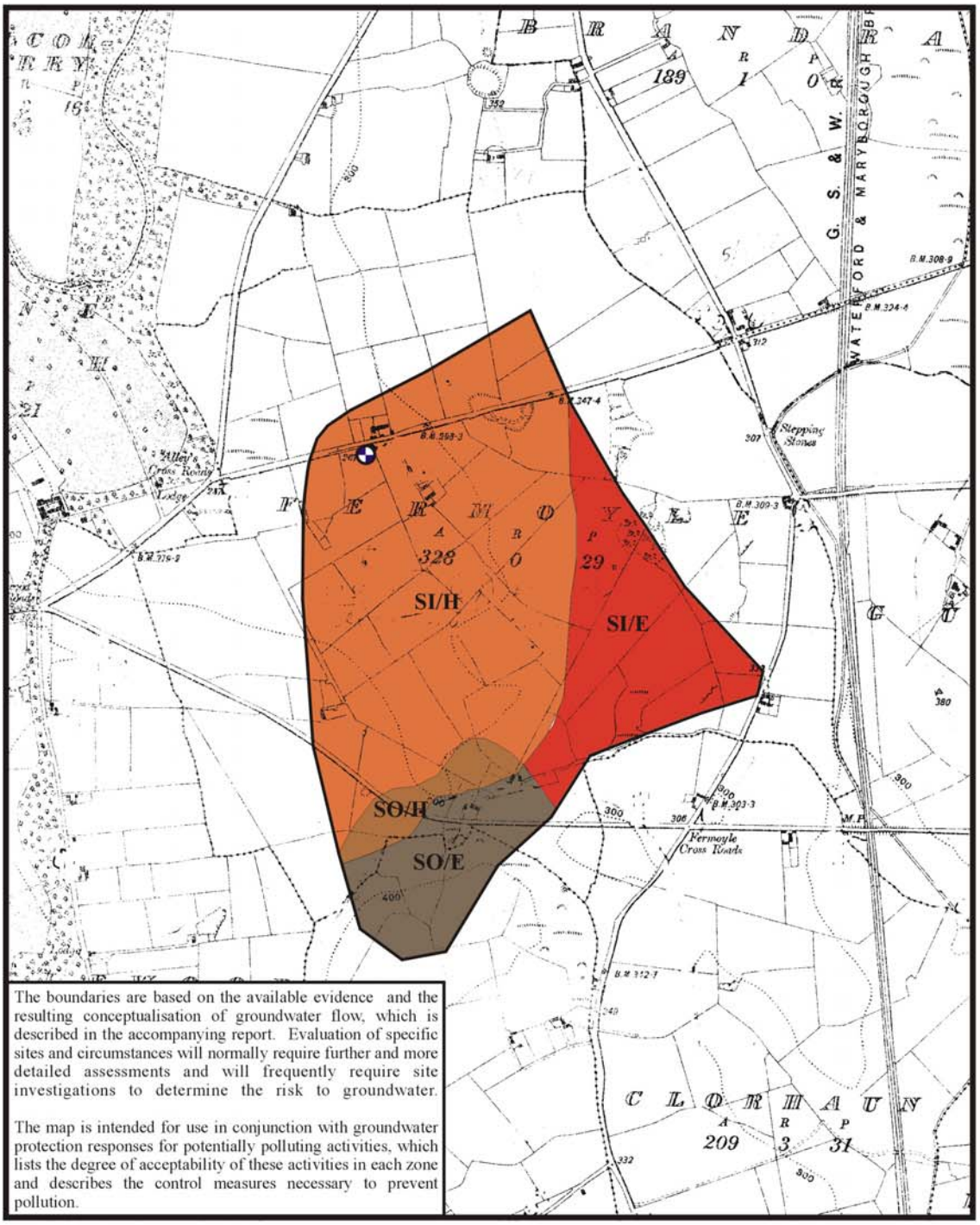
Zone of Contribution

Public Supply Well

N

Scale (metres)

0 500



Map 3: Groundwater Protection Zones for the Fermoyle District

Legend