## **Ferbane Water Supply Scheme**

# **Skehanagh Boreholes**

## **Groundwater Source Protection Zones**

March 2005

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## 1 Introduction

The objectives of the report are as follows:

- To delineate source protection zones for the borehole supply at Skehanagh/Moyclare.
- To outline the principal hydrogeological characteristics of the area around Skehanagh/Moyclare.
- 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 wells. 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 boreholes are located in Skehanagh townland, on the edge of the River Brosna, approximately 2.5km south west from Ferbane, Co. Offaly. Currently, two production boreholes located approximately 15 m apart, provide water to a reservoir at the top of the hill in Moyclare. Each borehole is enclosed in a concrete chamber with galvanised covers. There is a small pumphouse on site. The site is fenced off and floored with coarse gravels, however, both boreholes are virtually at the edge of the site. Chlorination is carried out at the reservoir. There was no tap present on site for taking raw water samples. There are problems associated with decreasing yield from the production wells, largely due clogging and silting – an ongoing issue ever since the first one was drilled in 1981. In 1985, three trial wells were drilled by KT Cullen and Co. Ltd. The details of the production wells as understood from the available data are given below. Figure 1 shows a photograph of the site taken during a site visit 28/1/03. The top of each borehole is approximately 0.3 m above ground level, and there is a risk of flooding from the Brosna.

GSI No.	2021NWW003	2021NWW004
Grid reference	20922 22325	20921 22329
Townland	Skehanagh	Skehanagh
Owner	Offaly County Council	Offaly County Council
Council Well Name	Production well 1	Production well 2
Well Type	Borehole	Borehole
Depth	14.2 m	19.8
Elevation (ground level)	Approximately 40 m	Approximately 40 m
Static water level	2-3 m below ground level	2-3 m below ground level
Depth to rock	10.7	10.6
Status	Pumping	Pumping
Diameter	0.4m	0.2m
Normal abstraction	Combined 470-560m <sup>3</sup> d <sup>-1</sup>	
Maximum abstracted	Combined 690m <sup>3</sup> d <sup>-1</sup> (154,000 gallor	ns per day)
Maximum Yield	$850 \text{ m}^3 \text{d}^{-1}$	$1350 \text{ m}^3 \text{d}^{-1}$
Maximum Drawdown	7m	5m
Specific Capacity	$121 \text{ m}^3 \text{d}^{-1} \text{m}^{-1}$	$270 \text{ m}^3 \text{d}^{-1} \text{m}^{-1}$
Hours Pumping	Currently 22 hours per day	Currently 22 hours per day
Date Drilled	1985	1985

#### **3** Summary of Borehole Details



Figure 1 Site of boreholes at Skehanagh, Ferbane

## 4 Methodology

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

The data collection process included the following:

- Interview with the caretaker 28/1/2003.
- Drilling of 3 auger holes by GSI 1/5/2003.
- 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 40 m OD, at the bottom of a southeast facing slope of a narrow southwest-northeast trending ridge (76 m OD), centred around Moyclare. The average topographic slope down to the boreholes is in the order of 1:17 (0.06) and is illustrated in Figure 3.

The River Brosna is present 30 m from the boreholes. The river is the only surface water feature in the vicinity of the boreholes. The regional drainage is to the south west and is part of the Brosna subcatchment of the Shannon River Basin District.

The land use is primarily used for sheep and cattle grazing and some tillage. There are several houses and farm yards within 500 m 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).
- Drilling records of the production wells (KT Cullen and Co. Ltd, 1985).
- Offaly Groundwater Protection Scheme (Daly et al, 1998).
- Subsoil mapping by the GSI.
- Auger Drilling of 3 holes carried out by GSI (May 2003).

#### 6.2 Bedrock Geology

The bedrock consists of limestones, sandstones and shales, described briefly below and illustrated in Figure 2.

**The Dinantian (early) Sandstones, Shales and Limestones** (The Navan Group) occupy the valley floor and the lower slope of the south facing hill. The drilling logs of the production wells located in the Navan group record a "*dark grey to black limestone*".

**The Dinantian Lower Impure Limestone** (Ballysteen Limestone) is a dark well bedded, fossiliferous limestone with associated laminated fossiliferous shales. It occupies a 265 m wide zone between the Navan group and the top of the hill.

**The Dinantian Pure Unbedded Limestone** (Waulsortian Limestone) is commonly a very fine palegrey massive, limestone with fossil fragments. It extends from the top of the hill northwards.

There are northeast-southwest and northwest-southeast trending faults in the area. As can be seen in Figure 2, the Sandstones, Shales and Limestones and the Lower Impure Limestone (Ballysteen) are faulted by the Ferbane Fault against the Pure Unbedded Limestone (Waulsortian).

#### 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 is widespread throughout Offaly, and is mapped as the main deposit in the vicinity of the boreholes. The sand/gravel extends upstream and downstream along the river. In a northerly direction they extend uphill, but thin and peter out toward the top of the hill, approximately 370 m from the boreholes as shown in Figure 3. Drilling records at the source indicate that the thickness of the sand/gravel is approximately 10 m (Appendix 1 summarises the logs). The records show that the upper 2-7 m of sand/gravel consists of a finer fraction, and is described in the log of production well 1 to be clayey gravel. Three auger holes were drilled upslope from the boreholes, and the water table was not present in any of the holes, which are shown in Figure 3. At auger hole 1, the drilling was unsuccessful as it consisted primarily of boulders, and the drill stem could not drive through them. At auger site 2, approximately 300 m from the boreholes, 7.5 metres of sand/gravel overlies 2.5 metres of till, which is classed as "SILT" (BS 5930, 1999). At auger site 3, approximately 350 m from the boreholes, 7 m of gravelly till, classed as "SILT" (BS 5930, 1999).

1999) sits on bedrock, and indicates that the sand/gravel is not present at auger site 3 as shown on the current map. There are also several esker ridges present in the area.



Figure 2 Bedrock Geology at Skehanagh, Ferbane

- 'Till' or 'Boulder clay' is an unsorted mixture of coarse and fine materials laid down by ice. Till occupies the area to the north, northeast of the boreholes. In auger hole 3, 7 m of till, classed as "SILT" (BS 5930, 1999) was present. In auger hole 2, till ("SILT" BS 5930, 1999) is present at 7.5-10.0m below ground level.
- In general, the subsoil thickness increases from north to south, i.e., the thickest areas of subsoil are along the valley floor, where the boreholes are situated. Well records indicate depth to rock to be approximately 10 m at the boreholes. Outcrop is mapped in the vicinity of the reservoir and along the road at the top of the hill. Figure 3 shows the depth to bedrock at the boreholes, auger holes, and also shows the outcrops and the topographic contours.

## 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).



Figure 3 Outcrops, Sand/gravel, depth to bedrock and topographic contours at Skehanagh, Ferbane.

- The source of the groundwater is the sand/gravel, thus for the purposes of vulnerability mapping the "water table" is the target.
- The permeability of the sand/gravel is classed as "high", and the permeability of the till "moderate".
- Depth to bedrock varies from being greater than 10 m near the source to 0 m to the north of the source, where outcropping bedrock is present.
- The water table is approximately 2-3 m below ground surface at the boreholes, thus the vulnerability at the site is "**extreme**". The horizontal distance that the water table is estimated to be within 3 m of the surface is approximately 20 m upslope from the boreholes, thus this distance is used to delineate the extremely vulnerable area around the source.
- The vulnerability in the area is classed as "**extreme**" to "**high**", as shown in Figure 5.

Depth to rock interpretations are based on the available data cited here, but 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).
- Assessment of the Proposed Location of a Septic Tank near the public supply boreholes at Skehanagh, Ferbane. (Daly, 1985). GSI report for Offaly County Council.
- Proposed Tip Site in Ferbane, Co. Offaly, A preliminary appraisal of five areas. (Daly, 1985). GSI report for Offaly Council.
- GSI files and archival Offaly County Council data.
- Offaly County Council drinking water returns.
- County Council personnel.
- 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 Ferbane, 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: 875 mm.

Rainfall data for gauging stations around Ferbane (from Fitzgerald, D., Forrestal., F., 1996).

Gauging Stations	Grid reference	Elevation OD (m)	Approximate distance and direction from source	Annual precipitation 1961-1990
Ferbane	N113244	47	2 km north east	879 mm

The contoured data map for the Offaly Groundwater Protection Scheme (Daly *et al*, 1998) show that the boreholes are located between the 850 mm and 875 mm average annual rainfall isohyets.

#### Annual evapotranspiration losses: 450 mm.

Potential evapotranspiration (P.E.) is estimated to be 475 mm yr.<sup>-1</sup> (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:* 425 mm yr.<sup>-1</sup>.

The effective rainfall is calculated by subtracting actual evapotranspiration from rainfall.

#### Recharge coefficient: 90%.

Recharge is expected to be relatively high, as the land is very free draining with no evidence of artificial or natural drainage, and the dominant subsoil is sand/gravel. Thus a representative value for the proportion of recharge coefficient is estimated to be in the order to 90%.

These calculations are	summarised as follows:	
	average annual rainfall (R)	875 mm
	estimated P.E.	475 mm
	estimated A.E. (95% of P.E.)	450 mm
	effective rainfall	425 mm
	recharge coefficient	90%
	Recharge	385 mm

#### 8.2 Groundwater Levels, Flow Directions and Gradients

Water level data is sparse, confined to the boreholes, River Brosna and neighbouring streams. The static water level is approximately 2-3 m below the ground surface at the boreholes. This is approximately equal to the level in the river. The pumping water level is less than a metre greater than the static water level, which is 1-2 m lower than the river level.

The water table in the area is generally assumed to be a subdued reflection of topography; as the topography slopes southeast, the water table slopes southeast toward the river. The dominant driving heads are the hills on either side of the river. The flow directions will be perpendicular to the contour lines. In simple terms, rainfall reaching the water table anywhere on the slopes to either side of the river will flow toward the river.

The gradients are assumed to be less that the topographic gradient. Gradients in gravels are generally quite flat, and is estimated to be approximately 0.002.

#### 8.3 Hydrochemistry and water quality

Data on trends in water quality are summarised graphically in Figure 4. The following key points are identified from the data.

- The water is generally very hard with an average total hardness of 360 mg l<sup>-1</sup> (equivalent CaCO<sub>3</sub>) and electrical conductivity values of 535-705  $\mu$ S cm<sup>-1</sup>. It is often described by the analysts as being "excessively hard". These values are typical of groundwater from limestone sand/gravel deposits.
- Nitrate concentrations in available samples (23)<sup>1</sup> from the last 20 years range from 6-30 mg l<sup>-1</sup> (average is 18 mg l<sup>-1</sup>). There are no reported exceedances above the EU Drinking Water Directive maximum admissible concentration of 50 mg l<sup>-1</sup>. There are occasional peaks above the threshold level of 25 mg l<sup>-1</sup>, for example, on 8/2/99 and 8/4/02, the nitrate level is recorded to be slightly above 25 mg l<sup>-1</sup>. The peaks and slightly elevated levels may indicate contamination from inorganic fertiliser and/or an organic waste source. The data suggests that over the last twenty years there is a slight increase in levels due to a general increase in agricultural activity over that period. However, the data from 1997 onwards shows no upward trend in nitrate levels.
- Chloride is a constituent of organic wastes and levels higher than 25 mg l<sup>-1</sup> may indicate significant contamination, with levels higher than the 30 mg l<sup>-1</sup> usually indicating significant contamination. Chloride data range from 20 to 34 mg l<sup>-1</sup> (average (23 mg l<sup>-1</sup>), suggesting that contamination from organic wastes has probably occurred on one occasion (25/10/1983: 34 mg l<sup>-1</sup>) and there may be regular contamination.
- There are no detections of *E.coli* in the one available **raw** water analysis (1983) nor in the treated water analyses (67 samples).
- There is one occasion where there are elevated potassium (5.6 mg l<sup>-1</sup>) and sodium (39 mg l<sup>-1</sup>) values (20/9/1999). These values coincide with somewhat lower hardness and conductivity values and an anomalous nitrate value (0.44 mg l<sup>-1</sup>). Heavy flooding and rainfall is reported in the caretakers notes from that period. It suggests that there may have been some influx of river water directly into the boreholes and highlights the potential flooding risk to the boreholes.
- In summary, occasionally elevated chloride and nitrate levels show some impact from human activity, although in general the groundwater quality is relatively good.

<sup>&</sup>lt;sup>1</sup> Sample dated 20/9/99 records 0.44mgl<sup>-1</sup> Nitrate. This record is ignored in the analysis.





Figure 4 Key indicators of Agricultural and Domestic Groundwater Contamination in the boreholes at Skehanagh, Ferbane.

#### 8.4 Aquifer Characteristics

The sand/gravel is the main aquifer providing groundwater to the boreholes. From the borehole records there is approximately 7-8 m of saturated sand/gravel at the site. Transmissivity is estimated to be in the region of 312-784 m<sup>2</sup> d<sup>-1</sup> (Daly, 1985), with the average approximately 600 m<sup>2</sup> d<sup>-1</sup>. The permeability is in the order of 75-85 m d<sup>-1</sup>. Porosity is estimated to be 10%.

Production well 2 originally yielded 1350 m<sup>3</sup> d<sup>-1</sup>, when it was drilled in 1985. By 1992 it was unable to maintain its tested yield (GSI records). It is unknown by how much the yield dropped or by how much further since 1992. The problem is that the well screen and/or gravel pack is being silted up by the finer fraction of the aquifer being pulled into the gravel pack and well screen. This leads to a reduced yield, higher pumping costs due to reduced efficiency and ultimately remediation costs. The council have had to remediate the wells by blowing air back through the well screen to try clear the slots and redevelop the gravel pack around the well.

Available nitrate data from the EPA for the Brosna river, given in Appendix 2, at Belmont (approximately 3 km south west), indicates that the median for oxidised nitrogen was 2.3 mg  $\Gamma^1$ , which approximates to 10 mg  $\Gamma^1$  NO<sub>3</sub>, over the period of 1998-2000. This shows that nitrate levels in the river are less than nitrate levels in the groundwater. Thus, it may be concluded that the wells are not pulling significant volumes of river water into the wells. However, this is not conclusive, as nitrate levels may actually be higher in the aquifer than given in the analyses, indicating dilution is occurring, and that the wells are drawing water from the river. There are no other nitrate data available nearby for comparison. Therefore it is assumed that the wells do not draw water from the river.

The borehole records and the auger holes show that the sand/gravel extends from the ground surface down to bedrock, and it assumed that the aquifer is unconfined. The water table was not present in any of the auger holes, and it is considered that the limit of the saturated sand/gravel occurs at the major break in slope, i.e., where the 50 m topographic contour is located. Therefore, the sand/gravel aquifer is restricted to a narrow zone at the bottom of the river valley.

#### 8.5 Conceptual Model

- Two wells abstract between 470-560 m<sup>3</sup>d<sup>-1</sup> from a sand/gravel aquifer located in the Brosna River valley.
- The boreholes are located approximately 30 m from the Brosna River, and static water levels in the boreholes are approximately 2-3 m below ground level, which is equivalent to the water level in the river. Pumping water levels are approximately 3 m below ground.
- Transmissivity is estimated to be approximately 600 m<sup>2</sup> d<sup>-1</sup>. Permeability is estimated to be in the order of 75-85 m d<sup>-1</sup>.
- The groundwater is unconfined.
- Chemistry data suggests that the contribution of the river to the wells is limited, however this is not conclusive.
- Occasional elevated chloride and nitrate levels show some impact from human activity, although in general the groundwater quality is relatively good, but there is some risk of surface water entering the wells during flooding.
- The yield has reduced over time, and it thought that the wells and well screen are clogging up with fine material from the sand/gravel aquifer.
- The sand/gravel aquifer is restricted to the relatively flat and narrow zone parallel to the River Brosna, as the sand/gravel on the slopes is unsaturated.
- Diffuse recharge occurs over the catchment and the annual average recharge is estimated to be 385 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 6 and 7.

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 boreholes.

#### 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), and is defined as the area required to support an abstraction from long-term recharge. The ZOC is controlled primarily by (a) the groundwater flow direction and gradient, (b) the sand/gravel permeability, and (c) the recharge in the area. The ZOC is delineated using analytical modelling, the results of hydrogeological mapping and a conceptual understanding of groundwater flow in the area. The boundaries are described below and given in Figure 6.

**The Northern boundary** is constrained by topography. The ridge on which the reservoir is located in Moyclare is considered to be the groundwater divide; separating water flowing toward the Brosna river on the southern side of the divide and water flowing north and discharging to streams on the northern side of the divide.

**The Southern boundary** is difficult to delineate as there is some uncertainty as to whether the river contributes some water to the wells. Using the "Well Head Protection Area" modelling programme (Blandford, T.N., 1991, 1993) allows estimates of the downgradient extent and width of the ZOC to be estimated. The downgradient extent is estimated to be 60 m. Although it is unlikely that groundwater on the other side of the river cannot flow to the boreholes, the ZOC is extended to the other side of the river to be conservative.

The Western and Eastern boundaries are delineated using the "Well Head Protection Area" modelling programme (Blandford, T.N., 1991, 1993), which enables the width of the ZOC to be estimated.

A water balance was used to estimate recharge area required to supply groundwater to the source. Assuming an annual recharge of 385 mm, a recharge area of approximately  $0.5 \text{ km}^2$  is required to provide enough groundwater to supply 500 m<sup>3</sup>d<sup>-1</sup>. The area described by the boundaries above is greater, approximately  $0.6 \text{ km}^2$ .

#### 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.

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Velocity = (gradient x permeability) ÷ porosity
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Groundwater velocities are estimated to be  $1.7 \text{ m d}^{-1}$  in the sand/gravel and  $0.5 \text{ m d}^{-1}$  in the bedrock. The 100-day ToT boundary therefore extends beyond the sand/gravel aquifer to the northwest of the wells. Accordingly the boundary of the SI is approximately 170m northwest of the wells.

## **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 <u>Inner</u> <u>Protection area</u> where the groundwater is <u>highly</u> vulnerable to contamination.

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

VULNERABILITY	SOURCE PROTEC	TION
RATING	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

Table 1 Matrix of Source Protection Zones at Skehanagh, Ferbane.

## **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, road spillages and river water direct from flooding.

## **12** Conclusions and Recommendations

- Two boreholes are located in a sand/gravel body located in the Brosna River Valley.
- The groundwater feeding the source is extremely to highly vulnerable to contamination.
- Available data suggests that there is some contamination, thus requiring investigation and careful management.
- There is a risk of contamination from flooding.
- The yield is dropping over time suggesting silting and clogging from the fine fraction of the sand/gravel.
- 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. A tap needs to be installed on site, which would enable raw water analyses to be taken,.
  - 2. The potential hazards in the ZOC should be located and assessed.
  - 3. A full chemical and bacteriological analysis of the **raw** water is carried out on a regular basis.
  - 4. Particular care should be taken when assessing the location of any activities or developments which might cause contamination at the wells, particularly in relation to nitrates.

## **13 References**

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#### **APPENDIX 1. LOGS OF AUGER HOLES.**

Site 1 209010 223395 10m depth to bedrock assumed. Sand/gravel, large cobbles and boulders.

Site 2 209032 223495 10m depth to bedrock Sand/gravel 0-7.5 m Till (SILT) 7.5-10.0 m

Site 3 209253 223597 7 m depth to bedrock Till (SILT) gravelly.

#### APPENDIX 2. SOME CHEMICAL PARAMETERS FOR THE R. BROSNA AT BELMONT.

Parameter	Parameter Units	Minimum	Median	Maximum	No of Samples	Source	Source Type	
B.O.D	mg/1 O²	1.2	1.7	6.6	29	Lough Ree Derg	LA	
Colour	Hazen	18	53	175	42	Lough Ree Derg	LA	
Conductivity	µS/cm	397	637	690	72	Lough Ree Derg	LA	
Dissolved Oxygen	mg/l O²	7.3	10.4	13.3	70	Lough Ree Derg	LA	
Dissolved Oxygen	% Saturation	73	94	144	70	Lough Ree Derg	LA	
Ortho-Phosphate	mg/l P	0.00	0.02	0.11	72	Lough Ree Derg	LA	
Oxidised Nitrogen	mg/l N	1.5	2.3	3.7	72	Lough Ree Derg	LA	
pН	pН	7.4	8.0	8.4	72	Lough Ree Derg	LA	

Offaly County Council and Geological Survey of Ireland. Ferbane (Skehanagh) Source Protection Zones



Figure 5 Groundwater Vulnerability at Skehanagh.

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Figure 6 Source Protection areas for the Skehanagh Boreholes.

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Figure 7 Source protection zones for the Skehanagh Boreholes.