

Moneygall Water Supply Scheme

Busherstown Springs

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 springs.
- To outline the principal hydrogeological characteristics of the Busherstown 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 springs. 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, 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 source is located alongside the main Limerick - Dublin road, between Moneygall and Dunkerrin, in the townland of Busherstown, Co. Offaly. The source comprises two separate springs, approximately 60 m apart, one of which is named Cowley's Well. Annotations on archival geological field sheets stored at GSI, suggest that the springs were first used in the 1930s'. Each spring has been dug out and deepened, with concrete walls and a concrete roof placed around each one. However, there is only access via a padlocked door to Cowley's Well. The site is fenced and padlocked. A pipe from each sump is connected to a central sump, from which water is pumped via a four inch main to a reservoir in Moneygall Village. A sketch of the site is given Figure 1. The scheme serves approximately 400 people and approximately one quarter of the daily demand is agricultural (Burns, 1993).

3 Summary of Spring Details

GSI No.	2017NWW001 (Cowley's Well) and 2017NWW002
Grid reference	20412 18259 (Cowley's Well); 20417 18264
Townland	Busherstown
Owner	Offaly County Council
Well Type	Spring
Elevation (ground level)	Approximately 107m OD. Malin Head, measured by GSI staff, 29/4/03.
Static water level	Ground level
Depth to rock	12.5m at 204170 18263 (approximately 40 m south of unnamed spring)
Normal consumption/abstraction	113 m ³ d ⁻¹ (25,000 gallons per day) (Caretaker, 15/1/03)
Maximum Abstraction	227 m ³ d ⁻¹ (50,000 gallons per day) (caretaker, 15/1/03, due to a leak in Moneygall village)
Maximum Yield	1195 m ³ d ⁻¹ (Abstraction and overflow, measured by GSI staff 24/4/03)
Hours Pumping	24 hours per day (caretaker, 15/1/03)
Depth of sump	0.6 m in Cowleys Well (GSI staff, 15/1/03) Unable to measure the other spring sump.

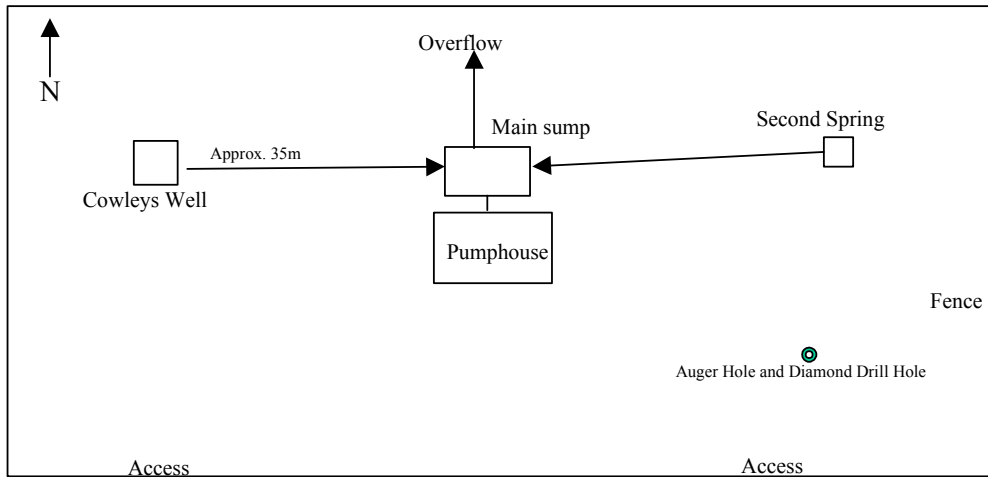


Figure 1 Sketch of site at Busherstown Springs

4 Methodology

Details about the springs such as depth, date commissioned, 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 15/1/03.
- Estimating spring overflows by GSI 15/1/2003 and 24/4/03.
- Drilling of two auger holes and two diamond drill holes by GSI (28-29/4/03; 6-14/5/03).
- Field mapping walkovers to further investigate the subsoil geology, the hydrogeology and vulnerability to contamination (24/4/03).
- 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 springs are located at approximately 110 m OD, at a break in slope occurring at the bottom of the northwest facing slopes of a small hill (174 m OD). The highest hill in the area, known as Benduff (455 m OD) is located three kilometres to the south of the springs. To the north, northeast, west and southwest of the springs the land is relatively low-lying, apart from occasional hummocky areas, hillocks and eskers. The average topographic slope down to the springs is in the order of 1:15 and the topography shown in Figure 2 and Figure 3.

The relatively hilly land to the south of the springs appears to be free draining, there are no surface drainage ditches and the drainage density is relatively low. Examination of the topographic maps indicates that in an area between Drumbaun and Drumroe, approximately one kilometre southeast of the source springs, there is a discharge zone, comprising three small springs, which feeds a small stream that flows past the source springs approximately 160 m to the southwest. In the low-lying area downstream of the source springs, i.e., to the west and north, the natural drainage appears to be much more restricted and there are several large artificial field drains. The regional drainage pattern is to the north and north west.

The land use around the spring is generally grassland, used for pasture and silage. There are several sand/gravel pits (both disused and in use) in the vicinity. There is approximately one square kilometre of forestry located to the west of the springs. A county council depot is located beside the springs. The main Dublin-Limerick road passes approximately 70 m south of the springs.

6 Geology

6.1 Introduction

This section briefly describes the relevant characteristics of the geological materials that underlie the Busherstown source. 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:

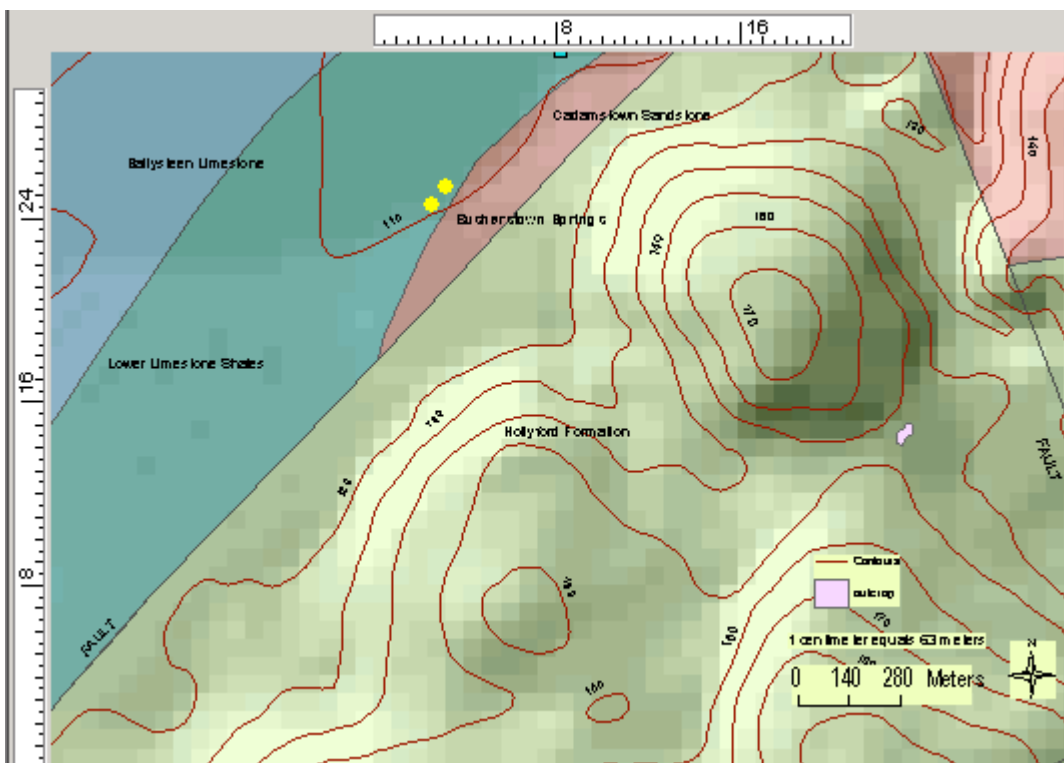
- Bedrock Geology 1:100,000 Map Series, Sheet 18, Tipperary, Geological Survey of Ireland (Archer, J.B. *et al*, 1996).
- Open File records [OF-129-1, 3], three diamond drill exploration boreholes in the vicinity of Busherstown Springs, Geological Survey of Ireland.
- Information from geological mapping in the nineteenth century (on record at the GSI).
- Subsoil mapping by the GSI.
- Offaly Groundwater Protection Scheme (Daly *et al*, 1998).

Further information was obtained by drilling two auger holes and two diamond drill holes (28-29/4/03; 6-14/5/03), logs of which are given in Appendix 1.

6.2 Bedrock Geology

The bedrock consists of limestones, shales and sandstones. These are described briefly below, from oldest to youngest and an extract of the available geology map is given in Figure 2.

Figure 2 Geology in the vicinity of Busherstown Springs



The **Silurian Metasediments** (Hollyford Formation) comprise siltstone, greywacke, and mudstone. In the Busherstown area, fine to coarse grained grey sandstones predominate with subordinate brown and green mudstones. It occupies the higher ground south of the springs.

The **Devonian Old Red Sandstone** (Cadamstown Formation) consists of red-maroon fine grained sandstone and grey fine grained sandstones with layers of red mudstone, and occupies the area immediately south of the springs.

The **Dinantian (early) Sandstones, Shales, and Limestones** (Lower Limestone Shales) consist of four different rock units, comprising limestones, shales, siltstones and sandstones. The springs are located in this group of rocks, approximately 100 m from the transitional lithological boundary with the Cadamstown Formation.

The **Dinantian Lower Impure Limestone** (Ballysteen Formation) consists of dark, fine grained limestones. It occurs in the low-lying area around Busherstown, occupying the area to the north of the springs. Boreholes drilled by the GSI in 1978-79 in the vicinity of Moneygall village indicate that the limestone present is typical of the Ballysteen Formation.

A short diamond drill hole was drilled beside the springs (See Figure 1, Figure 3 and Appendix 1). The core essentially consists of a dark fossiliferous limestone, overlying a fine grained blue-grey siltstone or mudstone which is representative of the Ballymartin Limestone Formation (A. Sleeman, 2003 *pers comm*). This unit is generally mapped as part of the Ballysteen Limestone Formation but is regarded as a distinct formation, and occurring between the Ballysteen and Lower Limestone Shales (Gately, 2003).

A fault with a NE-SW trend is mapped approximately 200 m to the south of the springs, determining the boundary of the Hollyford Formation with the Cadamstown Formation and the Lower Limestone Shales. The topographic contours southeast of the springs, suggest a possible NW-SE trending fault.

6.3 Subsoil Geology

The main subsoil categories in the vicinity of the source are till, sand/gravel and peat.

- 'Till' is an unsorted mixture of coarse and fine materials laid down by ice. Till occurs to the south of the spring occupying the higher ground around Busherstown Tower, and is classed as "SILT" (BS 5930, 1999). Angular black striated gravel size fragments are abundant in the till. See Appendix 1 for further details. In the vicinity of the spring, two layers of till were present within the sand/gravel. Further details are given in the logs in appendix 1.
- Sand/gravel is mapped around the springs extending northwards, eastwards, southwestwards and south as far as Busherstown Tower, as shown in Figure 3. The thickness of the sand/gravel at the springs is approximately 4 m. There are at least three quarries (some disused) mapped in the vicinity of the source. There is one esker located approximately one kilometre to the north of the source.
- Peat occupies the area to west of the spring. The thickness of the peat in the vicinity of the spring is 0.5m.
- Depth to bedrock drilling was carried out to ascertain the subsoil thicknesses at the springs. Depth to bedrock at the springs is approximately 12.5 m. At Busherstown Tower, the subsoil thickness is approximately 5 m. A mineral exploration programme carried out by Tara Mining in the 1970s provides further information on the depth to bedrock on the elevated ground to the south of the springs, from tractor mounted "deep overburden" sampling (OF-129-3, GSI). The depth to bedrock decreases to the south east and there are areas of shallow rock and outcrop. Thus, the hills are bedrock cored hills, where the subsoils are thicker toward the bottom of the slopes. Outcrops and depth to rock can be seen in Figure 3.

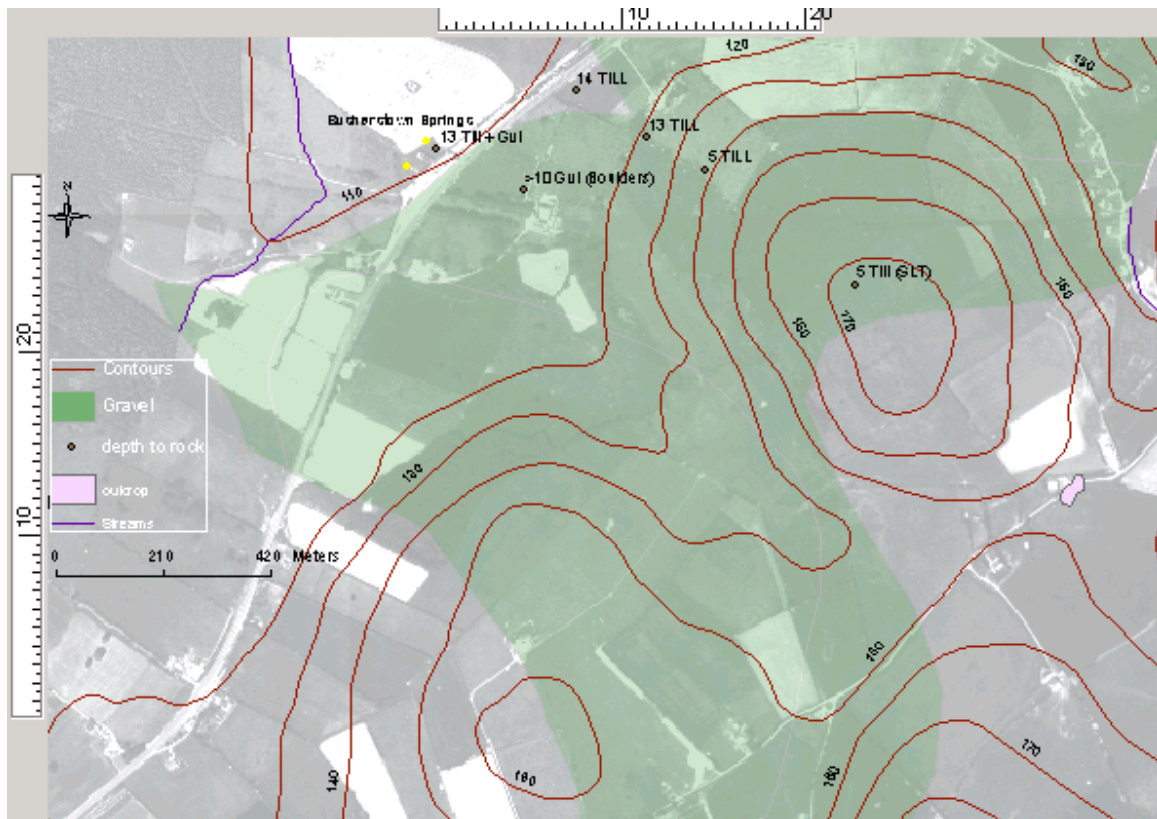


Figure 3 Depth to Rock, sand/gravel, topographic contours and streams in the vicinity of Busherstown

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 primarily the sand/gravel, thus for the purposes of vulnerability mapping, the “**water table**” is target.
- The permeability of the sand/gravel is classed as “**high**”, the permeability of the till “**moderate**” and the permeability of the peat “**low**”,
- Depth to rock increases from south to north.
- The area varies from “**extreme**” to “**moderate**” vulnerability. The vulnerability map is given in Figure 6. The majority of the area is classed as “**high**”. The water table is at ground surface at the springs and is estimated to be within 3 m of the surface up to a distance of 50 m upgradient from the springs.

Depth to rock and depth to the water table interpretations are based on the available data cited here. However, depth to rock 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.
- Hydrogeological mapping carried out by GSI.
- A drilling programme carried out by GSI to ascertain depth to bedrock, subsoil permeability and bedrock type.

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 Busherstown, the main parameters involved in recharge rate estimation are: annual rainfall; annual evapotranspiration; and a recharge coefficient. The recharge is estimated as follows.

Annual rainfall: 1000 mm.

Rainfall data for gauging stations around Moneygall (from Fitzgerald, D., Forrester, F., 1996).

Gauging Stations	Grid reference	Elevation OD (m)	Approximate distance and direction from source	Annual precipitation 1961-1990
Moneygall	S032811	125	2 km south west	1032 mm
Nenagh	R872800	55	17 km west	848 mm
Roscrea	S110905	64	11 km north east	882 mm

The contoured data map for the Offaly Groundwater Protection Scheme (Daly *et al*, 1998) show that the Busherstown Springs are located approximately at the 1000 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: 550 mm yr.⁻¹.

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

Recharge coefficient: 80%.

The slopes and the nature of the deposits around the source need to be considered in order to give a representative value for the recharge coefficient during rainfall events. Despite the relatively steep slopes to the southeast of the springs, the subsoils are dominated by sand/gravel which has a high permeability, thus a high recharge coefficient. A representative value for the recharge coefficient is estimated to be in the order to 80%.

These calculations are summarised as follows.

average annual rainfall (R)	1000 mm
estimated P.E.	475 mm
estimated A.E. (95% of P.E.)	450 mm
effective rainfall	550 mm
recharge coefficient	80%
Recharge	440 mm

8.2 Groundwater Levels, Flow Directions and Gradients

- Water level data are sparse for the area. Water levels are known at the springs and at a private well to the south of Busherstown hill. The main streams in the area are assumed to represent true groundwater levels.
- Water levels are close to the ground surface in the low-lying area in the vicinity of the springs, and at the springs, the water level is at ground surface. Groundwater was not encountered in the mineral exploration boreholes drilled to the south of the springs, the deepest of which was 25 m. South of Busherstown hill, in a private well, the water level is approximately 2 m below ground level. A large stream is situated approximately 300 m further east.
- The water table in the area is generally assumed to be a subdued reflection of topography and given the water levels in the springs, well and streams, it would appear that this assumption is true. Therefore, it is assumed that the surface water divides coincide with the groundwater divides. Thus, as the topography slopes northwards from Busherstown Tower and Drumroe, the water table slopes north and northwestwards toward the springs.
- Flow directions are expected to be perpendicular to topographic contours, therefore, the regional flow direction is to the northwest.
- The gradients are assumed to be steep in the bedrock units to the south of the springs, approximately 0.04, and somewhat similar to the topographic gradient (0.06). The gradient in the sand/gravel on the lower slopes is expected to be relatively flat, and is estimated to be approximately 0.002.

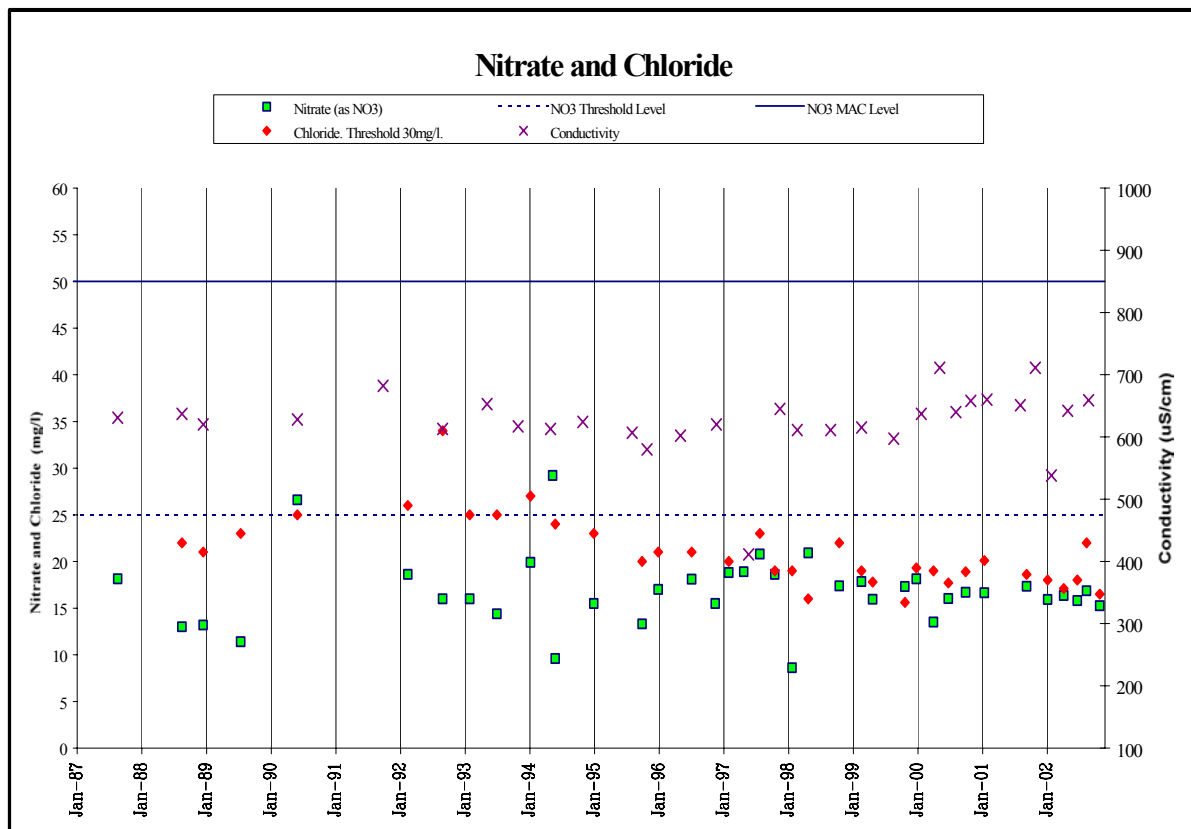
8.3 Hydrochemistry and water quality

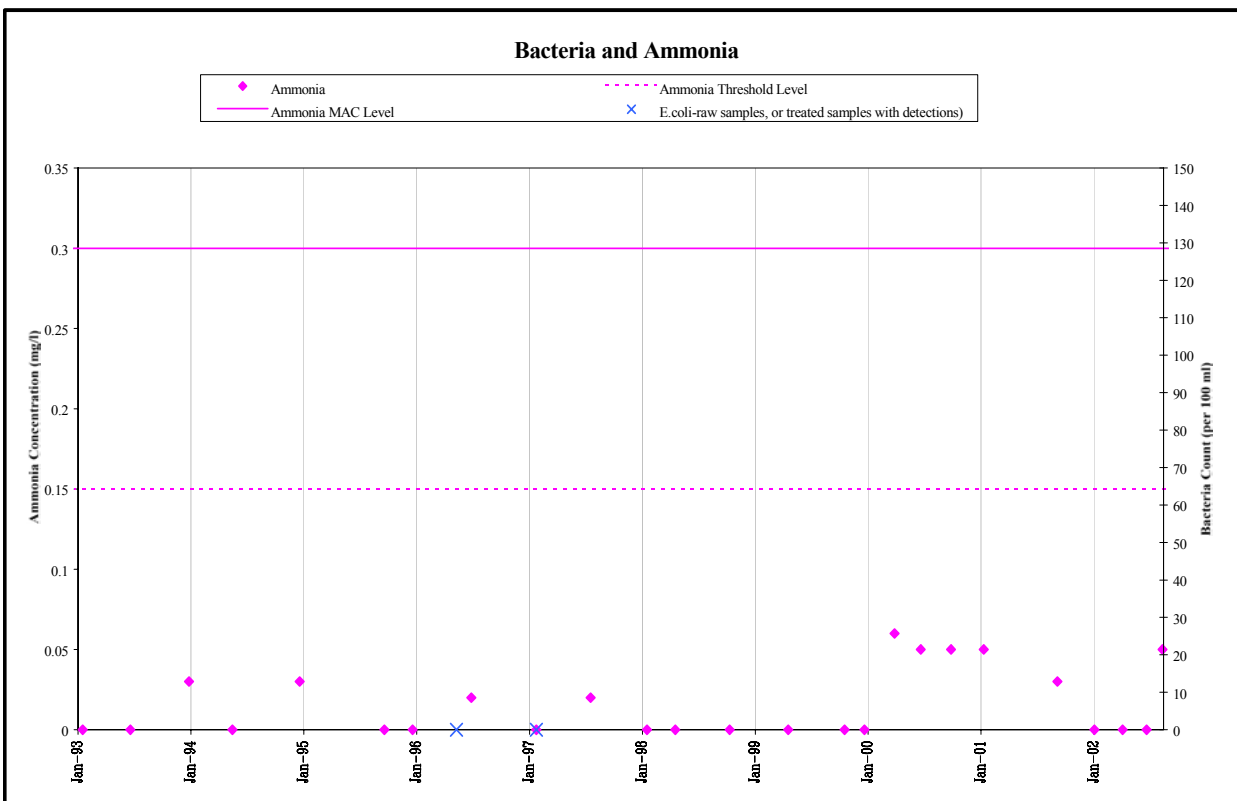
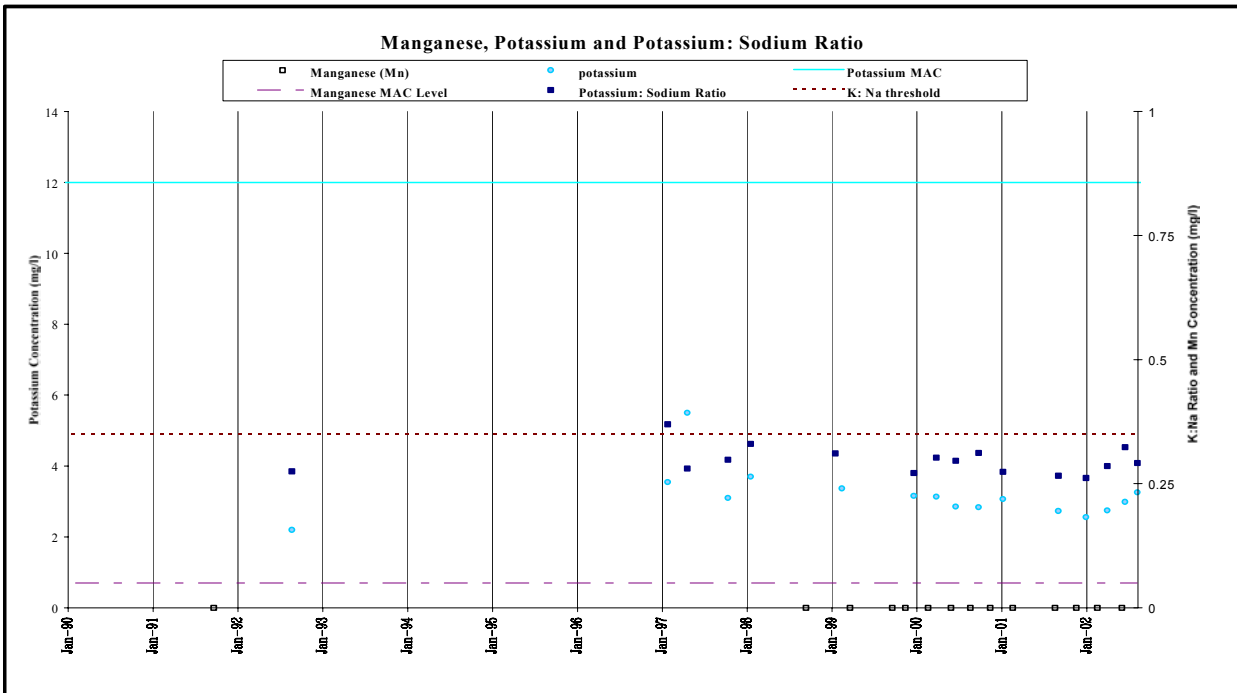
Data on trends in water quality are summarised graphically in Figure 2, and the following key points are identified from the data.

- The water is moderately hard to very hard with an average total hardness of 350 mg l⁻¹, (38 samples) (equivalent CaCO₃) and electrical conductivity values of 411-711 μS cm⁻¹. These values are typical of groundwater from limestone dominated sand/gravel bodies and/or limestone rocks. As would be expected pH of the groundwater is generally neutral (a mean of 7.1).
- Nitrate concentrations in available samples from the last 15 years range 10-27 mg l⁻¹ (average is 16 mg l⁻¹). There are no reported exceedances above the EU Drinking Water Directive maximum admissible concentration of 50 mg l⁻¹, and generally, the levels are less than the threshold level of 25 mg l⁻¹, apart from two occasions (19/6/1990: 27 mg l⁻¹; 30/5/1994: 29 mg l⁻¹). A slight upward trend is observed in the data.

- Chloride is a constituent of organic wastes and levels higher than 25 mg l⁻¹ may indicate significant contamination. Chloride data range from 15 to 34 mg l⁻¹ (average (21 mg l⁻¹), suggesting that contamination from organic wastes has possibly occurred on one occasion (15/9/1992: 34 mg l⁻¹), however, other contaminant indicators such as potassium:sodium (K/Na) ratio do not indicate contamination on this date.
- On one occasion (17/2/1997) the potassium:sodium (K/Na) ratio was reported above the GSI threshold level of 0.35. Elevated levels of potassium may indicate contamination from farmyard wastes.
- No *E.coli* were detected in the two available **raw** water analyses nor in the treated water analyses.
- Based on available data, the contaminant indicators are generally below the GSI thresholds, except nitrate on two occasions, chloride on one occasion, and K/Na ratio on one occasion. This suggests that the quality is generally good, but does show some human impact.

Figure 4 Key Indicators of agricultural and domestic groundwater contamination at Busherstown Springs.





8.4 Spring Discharge

The total spring discharge (abstraction and overflow volumes) is not well characterised. There are daily records of the abstraction quantities, but no records of the overflow. The caretaker indicates in interviews, that there is always an overflow from both springs, including summer periods. The overflow measuring point used by the GSI is approximately 100 m north of Cowley's Well, where the overflow has been routed to join the regional drainage. The estimates are point measurements, and the total discharge is given, which is the measured overflow added to the amount abstracted on that day. To estimate a possible range - the measurements were taken during January and April, and are given below.

Date	Total discharge m ³ d ⁻¹	Data source	Method
15/1/2003	1031 (abstraction =227; overflow 804)	GSI Personnel	Flow meter
24/4/2003	1195 (abstraction = 227; overflow 968)	GSI Personnel	Flow meter

Frequent overflow monitoring is required to provide a more reliable dataset. The spring is an “**intermediate**” spring according to the GSI classification.

8.5 Aquifer Characteristics

The springs are located in a sand/gravel deposit, and in combination with the bedrock are considered to be the aquifer providing water to the springs. A combination of factors are responsible for the springs to occur at this location: a the break in slope; the funnelling effect of the topography driving the groundwater to focus at a central location; a possible fault network; and, the boundary of the sand/gravel with peat coinciding with the break in slope. In the vicinity of the springs groundwater velocities are likely to be high; this is illustrated in Figure 5, where groundwater can be seen to be bubbling up at the base of one of the springs.

The sand/gravel in the area is classed as a **locally important sand/gravel aquifer (Lg)**. The spring at Dunkerrin (Kelly, 2003) is an important spring located 3 km north east in the same sand/gravel body that is used for a public water supply, indicating that the sand/gravel is a significant resource of groundwater. The thickness of the sand/gravel immediately next to the springs is approximately 4 m. On the slopes immediately southeast of the springs, the sand/gravel thickness is less than five metres thick. The groundwater gradient in the gravel deposit is low, approximately 0.002, with a porosity in the region of 10% and a permeability in the region of 50 m d⁻¹ (based on a permeability value estimated in Dunkerrin (Kelly, 2004)).

Permeability in the bedrock aquifers is likely to be low, except in the vicinity of fractures and faults which generally enhance the permeability. The land is generally free draining probably due to a combination of steep gradient, a highly permeable layer at the top of the bedrock and perhaps the influence of a fault. In view of the expected low permeability in the bedrock, it is expected that groundwater in the bedrock discharges to the nearby surface streams, springs, and the sand/gravel aquifer.

At the springs, the bedrock is mapped as the Dinantian (early) Sandstones, Shales and Limestones (Lower Limestone Shales). However, as the diamond drill hole at the site indicates that the bedrock is representative of the Ballymartin Formation, the aquifer characteristics are likely to be similar to those of the Lower Impure Limestone (Ballysteen Limestone), described in Section 6.2.

The Lower Impure Limestone and the Old Red Sandstone are classified as a **locally important aquifers** which are **moderately productive** only in **local zones (LI)**.

The Silurian Metasediments are classed as a **poor aquifer** that is **moderately productive** only in **local zones (PI)**.

Figure 5 Groundwater bubbling up inside Cowleys Well (Busherstown Springs)



8.6 Conceptual Model

- The scheme abstracts about 114-227 m³ d⁻¹ (approximately 25,000 - 50,000 gallons per day) from an “**intermediate**” spring, that is protected from surface workings inside a fenced shed. The total discharge is considerably higher, but is not accurately measured.
- The springs issue from a **locally important sand/gravel aquifer (Lg)**.
- A combination of the fault network, the boundary of the sand/gravel with peat, the break in slope and the funnelling effect of the topography driving the groundwater to focus at a central location are probably responsible for the springs at this location.
- Groundwater velocities are high as water approaches the springs.
- Groundwater gradients are likely to be low in the sand/gravel aquifer and estimated to be approximately 0.002.
- Groundwater recharging to bedrock aquifers is expected to discharge to the sand/gravel aquifer and discharge at the springs.
- Groundwater is assumed to be unconfined in the sand/gravel aquifer.
- The regional drainage pattern is to the north and north west. The surface water divides are considered to coincide with groundwater divides and the water table is expected to follow the topography.
- Groundwater vulnerability in the area is mapped as high and extreme.
- Diffuse recharge occurs over the catchment and the annual average recharge is estimated to be 440 mm per year.

9 Delineation of Source Protection Areas

9.1 Introduction

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 springs.

9.2 Outer Protection Area

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

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

The Northern boundary is constrained by the springs themselves, as it is assumed that groundwater downgradient of the springs cannot flow back up to the springs. An arbitrary buffer of 30 m is placed on the downgradient side of the springs.

The Southern and Eastern boundaries are constrained by the ridge between Derrycallaghan, Drumroe and Busherstown. Water levels show that this ridge acts as groundwater divide between water flowing south to the springs and water flowing east and south toward the streams in this area.

The Western boundary is based on topography. A broad ridge runs from Derrycallaghan through Drumbaun toward the spring.

A water balance was used to estimate recharge area required to supply groundwater to the source. Assuming an annual recharge of 440 mm, a recharge area of approximately 1.5 km² is required to provide enough groundwater to supply the maximum discharge. The area described by the boundaries above is approximately 2 km².

Thus, there appears to be a good balance between the recharge area required, and the area which lies within the physical constraints of the surface water sub-catchment upstream of the spring. The agreement between the water balance and physical constraints is therefore taken to suggest that the physical constraints outlined above provide a reasonable basis for the delineation of the ZOC at the source. The ZOC (i.e. the extent of the SO or ‘Outer Protection Area’) is depicted in Figure 7.

9.3 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.

Using the estimated values for permeability, gradient and porosity (50 m d⁻¹, 0.002, 10%, respectively), given in Section 8.6, the calculated velocity is 1 m d⁻¹. Accordingly, the boundary of the inner protection area (SI) is 100 m from the spring on the upgradient side.

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. Six groundwater protection zones are present around the source and are shown in Figure 8.

Table 1 Matrix of Source Protection Zones at Busherstown.

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

11 Potential Pollution Sources

Agriculture is the principal activity in the area. Most of the land is used for tillage, although a small proportion is used for pasture. Potential hazards include farmyards, septic tank systems, application of fertilisers (organic and inorganic), pesticides, and possible spillages along the road or in the Council depot. The main Limerick-Dublin road is within the inner protection area (SI). No door to door survey of specific hazards was carried out as part of this study.

12 Conclusions and Recommendations

- The springs are located in a **locally important sand/gravel aquifer (Lg)**.
- The groundwater feeding the source is extremely to highly vulnerable to contamination.
- The chemistry data 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. Additional data obtained in the future may indicate that amendments to the boundaries are necessary.
- It is recommended that:
 1. A permanent v-notch weir installed in the overflow to get a proper understanding of the springs discharge, thus a better understanding of the potential groundwater resource.
 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 springs, particularly in relation to nitrates.
 4. The potential hazards in the ZOC should be located and assessed.

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APPENDIX 1. LOGS OF AUGER AND DIAMOND DRILL HOLES.

Auger Hole and Diamond Drill Hole at Busherstown spring

DH 32/03 Grid Reference: 204170 182626

Location: In council ground in the vicinity of the eastern spring, on the high ground in the compound, which is approximately 2-3 m above the level of the springs.

Log

0-2m Gravel

2-4m Till British Standard BS5930: SILT; sample taken

4-8m Gravel

8-13m Till British Standard BS5930: SILT

Transition from till to bedrock is sharp, hard till immediately into fresh bedrock.

13m – 18.5m Dark, fine grained fossiliferous limestone. Infrequent small tight vertical fractures. Fossils tend to be concentrated in bands. Wavy transitions from fossiliferous zones to impure, compact fine grained dark zones.

18.5-19.5m Fine grained siltstone/mudstone.

Auger Hole at Busherstown house

Uphill of the springs on eastern side of Busherstown house.

Grid reference: 204338 182548

Summary: Gravelly Till very large cobbles and boulders, very difficult for auger drilling, EOH at 4m is probably not bedrock. Very large Waulsortian type boulders can be seen in the fields.

Matrix is SILT/CLAY.

Water table not met.

Auger Hole and Diamond drill hole at Busherstown Tower.

DH 34/03 Grid reference: 204985 182363

0-4.5m Till (SILT/CLAY)

4.5-5.3 Gravel

5.3-*m: Siltstones and grey sandstones.

Bedding is normal to orientation of borehole – horizontal.

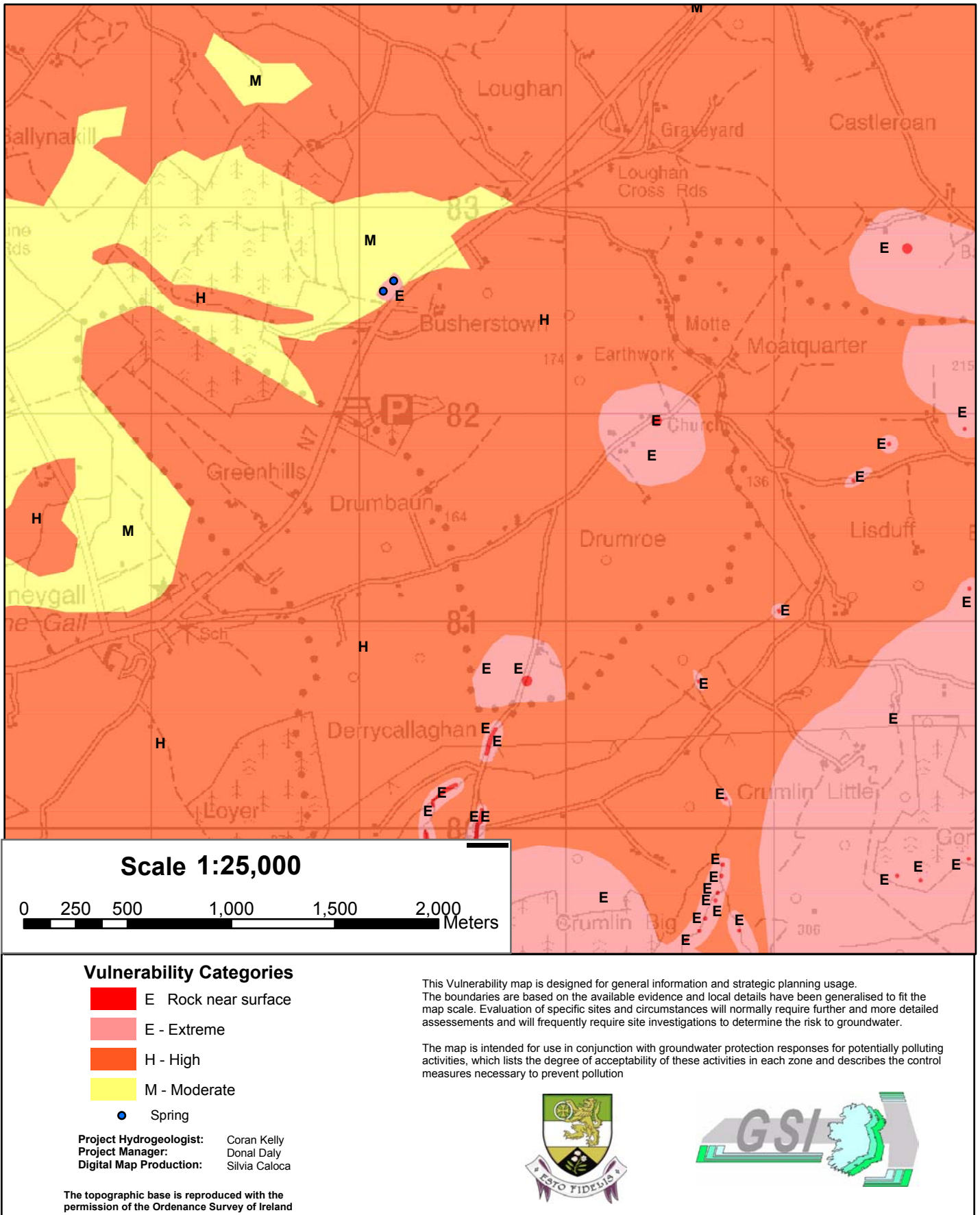
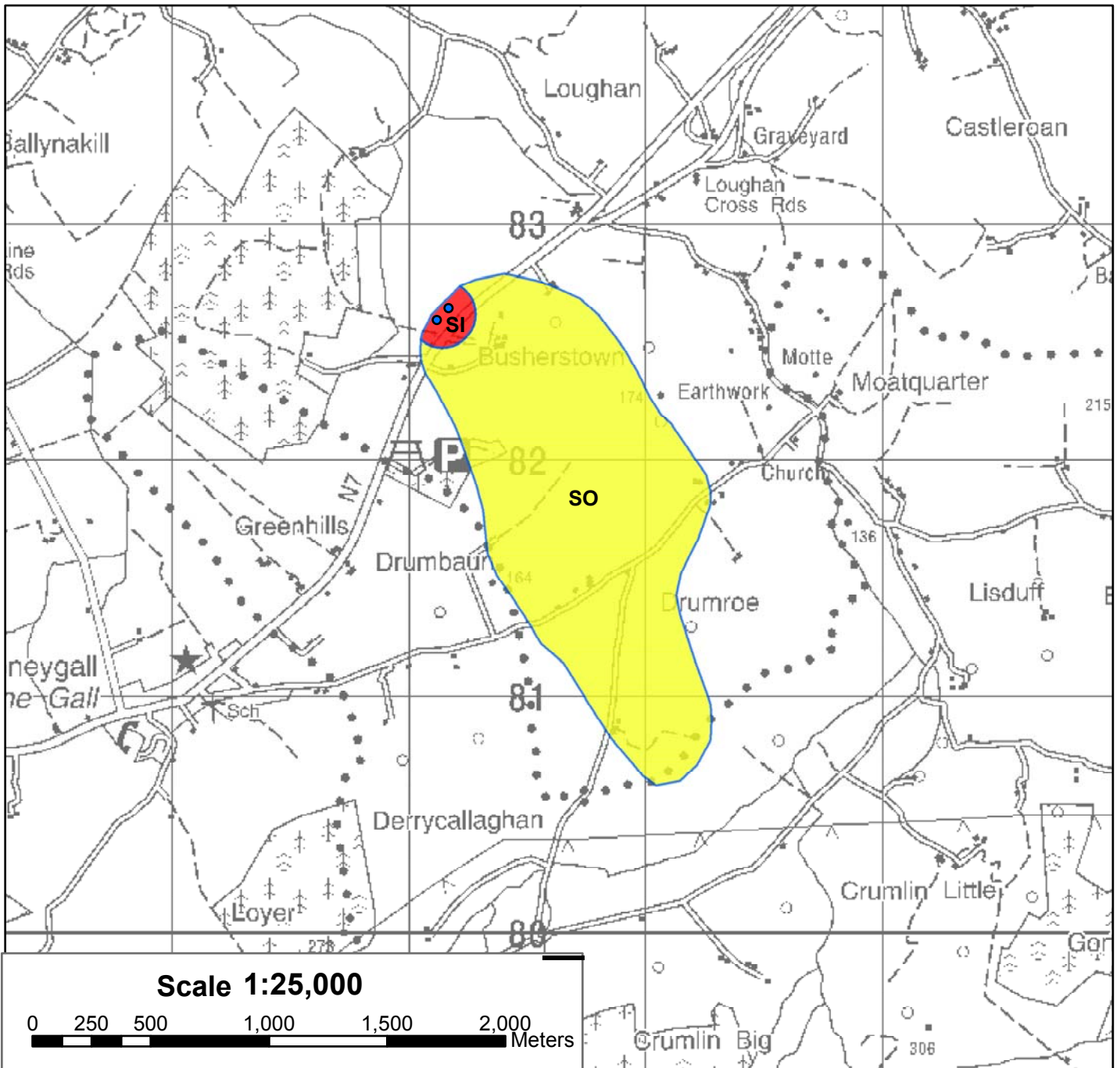


Figure 6 Groundwater Vulnerability in the vicinity of Busherstown Springs.



LEGEND



Inner Protection Zone SI



Outer Protection Zone SO



Spring

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

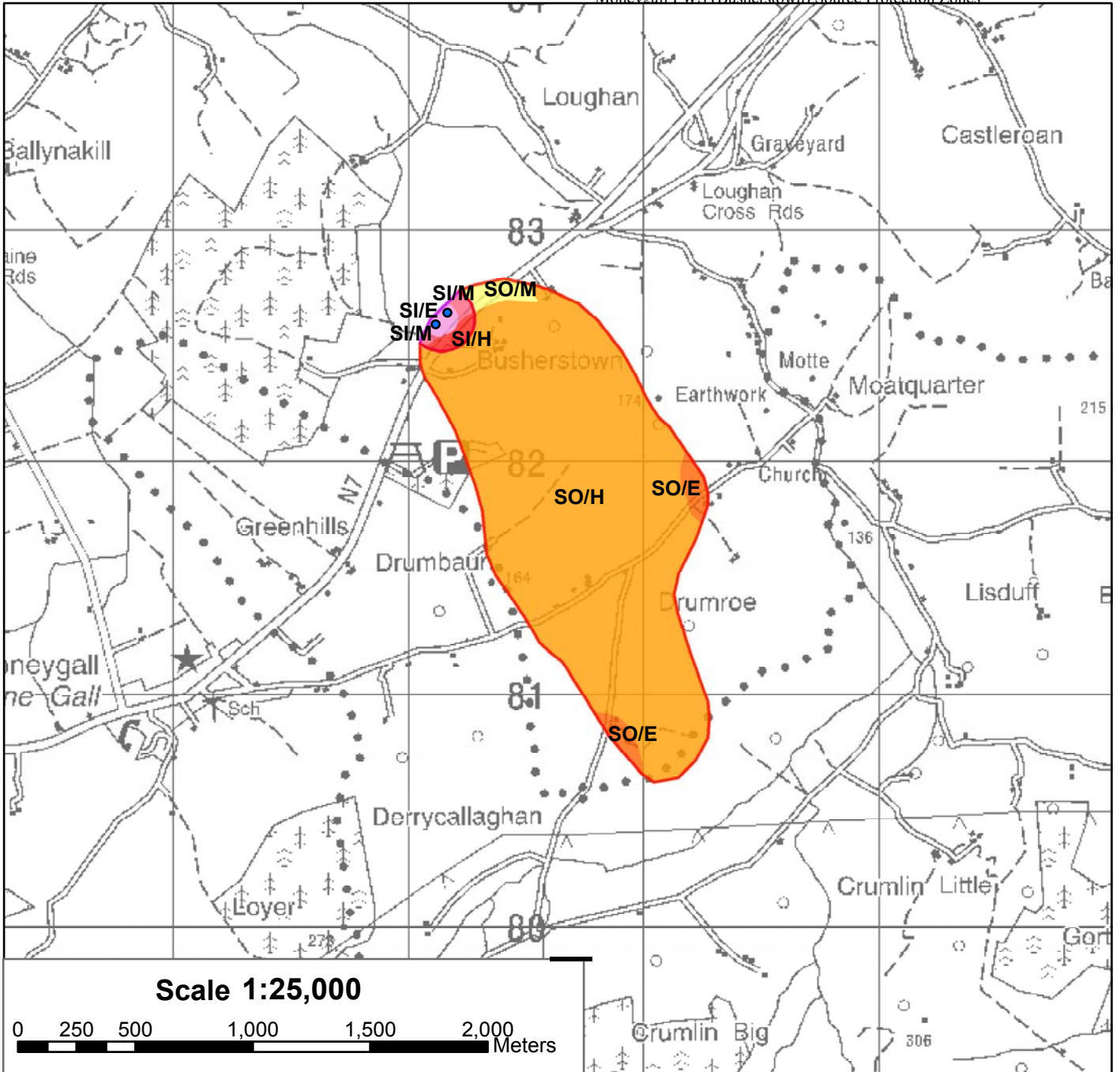
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This Source Protection Area map is designed for general information and strategic planning usage. The boundaries are based on the available evidence and local details have been generalised to fit the map scale. Evaluation of specific sites and circumstances will normally require further and more detailed assessments 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 7 Source Protection Areas for Busherstown Springs.



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

- Inner Protection Zone SI
- Outer Protection Zone SO
- Spring

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

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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 assessments 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 8 Source Protection Zones for Busherstown Springs.