Lisduff - Dunkerrin Water Scheme

Lisduff Well

Groundwater Source Protection Zones

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1 Introduction

Lisduff source provides between 40 - 50 % of the Lisduff - Dunkerrin Water Scheme. Guilfoyles Well and Dunkerrin Village well provide the rest of the water for the scheme. A separate report describes Guilfoyles Well (Gately and Kelly, 2000).

The objectives of the report are as follows:

- To delineate source protection zones for Lisduff well.
- To outline the principle hydrogeological characteristics of the Lisduff area.
- To assist Offaly County Council in protecting the water supply from contamination.

2 Location, Site Description and Well Head Protection

Lisduff source is located 3 km east of Moneygall village, in the townland of Lisduff. The spring/dug well is located 1 km inside the Tipperary (North Riding) county boundary.

Lisduff source comprises one main large rectangular sump, collecting water that emerges at the bottom of the sump, and also a small sump that is located 50 m to the south of the main sump.

The site area is closed off with a breeze block wall on one side and a fence on the remaining sides. The sump is covered with a concrete top. Access to the sump chamber is via three manhole covers, which are padlocked. There are several small diameter (5 cm) pipes through the concrete cover that are covered with wire mesh. The upper sump is enclosed within a high concrete wall enclosure. There is a concrete cover over most the sump with an open space that allows access, which is open to the elements.

3 Summary of Well / Spring Details

GSI no.	:	2017NW W018
Grid ref. (1:50 000)	:	20620 18095
Townland	:	Lisduff
Well type	:	Spring/dug well
Owner	:	Offaly County Council
Elevation (ground level)	:	~ 171 m
Depth & Dimensions of sump	:	3 m x 3 m x 2m
Depth to rock	:	11 m
Static water level	:	0.5-2 m bgl.
Average Abstraction	:	650 m^3/d
Range of Abstraction	:	293-935 m^3/d

4 Methodology

The assessment involved three stages: (a) a desk study; (b) site visits and fieldwork; and (c) analysis of the data.

The desk study was conducted in the Geological Survey: details about the well such as elevation, and abstraction figures were obtained from GSI records and County Council personnel; geological information was obtained from the Geological Survey of Ireland Bedrock sheet 18 (1:100,000 scale) and historical geology maps; and hydrogeological information was obtained from records and reports held both by Offaly County Council and the Geological Survey of Ireland.

The second stage comprised site visits and fieldwork in the Lisduff area. This included carrying out a water level survey, depth to rock drilling and subsoil sampling. Field walkovers were also carried out to investigate the subsoil geology, the hydrogeology and vulnerability to contamination.

Analysis of the data, which included field studies and previously collected data, was used to delineate protection zones around the spring.

5 Topography, Surface Hydrology and Land Use

Lisduff well is located at approximately 170 m OD, close to the bottom of a hill, the highest point of which is 455 m OD, known as Benduff.

There are two surface streams close to the source. One of the streams passes within 10 m of the main sump, flows underneath the road and away to the north. The gradient of this stream has been altered near to the main sump, by way of an artificial waterfall, so that the streambed is at a lower elevation, presumably to prevent the road being flooded at times of high flow. The overflow from the main sump joins the stream. There is a spring, which emerges inside a gravel pit, 200 m uphill from the main sump. The spring inside the gravel pit only emerged since the opening of the pit and seems to be active only in wet periods. The other stream is found approximately 250 m to the west of the source and runs along the bottom of an incised valley. The stream beside the source joins this stream further down the valley and then flows away to the northwest. The stream that passes close to the source divides approximately 900 m upstream from the main sump. This distributary joins the other larger stream, but during the drier summer months there is very little to no flow in this stream

There is no surface drainage coming off the hills to the east of the source, implying that the soils and subsoils are free draining in this area.

Agricultural activity dominates the area close to the spring, with most of the land being used for grassland. A coniferous forest plantation covers much of the slopes higher up the hill (above 250 m). A number of houses and farmyards occur within 1 km of the spring. A gravel pit was opened 200 m uphill of the spring in 1997.

6 Geology

6.1 Introduction

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

Bedrock information was taken from a desk-based survey of available data, which comprised the following:

- Geological Survey of Ireland Bedrock Sheet 18 (Archer *et al*, 1996)
- Information from geological mapping in the nineteenth century (on record at the GSI).

Subsoils information was gathered from a drilling programme that was undertaken by GSI personnel to investigate the subsoils and depth-to-bedrock of the area.

6.2 Bedrock Geology

The area within the zone of contribution of the source is underlain by the Hollyford Formation (HF) which is composed of greywacke, siltstone and grit.

Movements in the earth's crust have caused the rocks to be folded, faulted and jointed. There are two major fault sets present in the area, NW-SE and NE-SW. The joint pattern is likely to have similar orientations. There is a fault to the northwest and another to the southwest of the source.

6.3 Subsoil (Quaternary) Geology

6.3.1 Introduction

The subsoils within the zone of contribution are comprised of a mixture of coarse and fine grained materials, namely; tills and gravel/sand. The logs of the auger holes drilled are given in Appendix 1.

The characteristics of each category are described briefly below:

6.3.2 Tills

'Till' is an unsorted mixture of coarse and fine materials laid down by ice. The tills in the Lisduff area are comprised of sandy CLAY with frequent gravels, SILT with abundant gravels and CLAY. These tills were classified using the subsoil description and classification method (based on the British Standard - BS 5930). Angular and subrounded limestone and sandstone clasts make up the gravel clasts within the tills. The till lies directly above the bedrock over much of the source zone of contribution.

6.3.3 Sand/Gravels

Sand/gravels deposits are found overlying the till in many places in the Lisduff area. The sand/gravel is evident from the gravel pit that lies exposed only 200 m south of the source. In some places, such as in the gravel pit, the sand/gravel overlies bedrock directly. The sand/gravel is made up of both limestone and sandstone clasts, which vary from being subrounded to subangular in shape. The deposit seen exposed in the quarry is not well sorted and there are several finer grained layers between layers of gravel and cobble sized clasts.

6.3.4 Subsoils Relationship

The relationship of the sand/gravel with the till is complex as the sand/gravel varies in thickness as well as in position with the till. In places the gravel is found resting directly on bedrock whereas in others it is sandwiched between two till layers or lies on top of a till layer (see Appendix 1). Therefore, the area in which this interrelationship occurs is categorised as sand/gravel with till.

6.3.5 Depth to Bedrock

A drilling programme was carried out to ascertain the depth, thickness and permeability of the subsoils. Using this information and knowledge of sites that have rock cropping out, the depth to rock is estimated across the area. The borehole locations are given in Figure 2. The depth to bedrock varied between 4.5 m and 15 m in the boreholes drilled. There is an area of shallow rock (0–3 m) on the slopes of the hill to the east.

7 Hydrogeology

7.1 Introduction

This section presents our current understanding of groundwater flow in the vicinity of the Lisduff source. The interpretations and conceptualisations of flow are used to delineate source protection zones around the spring.

Hydrogeological and hydrochemical information for the study was obtained from the following sources:

- Reports on file at the Geological Survey of Ireland.
- Offaly County Council annual drinking water returns 1996–2000 inclusive (C3 and C4 type parameters). One raw water analysis, C4, was also carried out. Bacteriological data from 1997 – 1999 were also available.
- Limited additional field tests.

The Lisduff area is complex hydrogeologically. With the resources and time available it is not possible to give a definitive description of the hydrogeology.

7.2 Meteorology and Recharge

The term 'recharge' refers to the amount of water replenishing the groundwater flow system. The recharge rate is generally estimated on an annual basis, and generally assumed to consist of an input (i.e. annual rainfall) less water losses prior to entry into the groundwater system (i.e. annual evapotranspiration and runoff). 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 areas where point recharge from sinking streams, etc., is discounted, the main parameters involved in recharge rate estimation are annual rainfall, annual evapotranspiration, and annual runoff and are listed as follows:

- Annual rainfall: 975 mm. Rainfall data for the area are taken from a contoured rainfall map of Co. Offaly, which is based on data from Met Éireann.
- Annual evapotranspiration losses: 451 mm. Potential evaporation (P.E.) is estimated to be 475 mm $yr.^{-1}$ (from Met Éireann data). Actual evapotranspiration (A.E.) is then estimated as 95 % of P.E.
- Potential recharge: 524 mm $yr.^{-1}$. This figure is a calculation based on subtracting estimated evapotranspiration losses from average annual rainfall. It represents an estimation of the excess soil moisture available for either vertical downward flow to groundwater, or lateral soil quickflow and overland flow direct to surface water.
- It is difficult to estimate the amount of water that is lost to runoff in the catchment. There are several elements that must be considered; (a) the stream loses and gains water depending on the time of the year, (b) groundwater discharges from the spring in the quarry into the stream that runs past the source and (c) there is groundwater perching in the layers of till within the sand/gravel with till area, which is evident from the water level within the upper sump relative to the main sump. On account of these factors, an arbitrary 20% of potential recharge is taken as being lost to runoff.

These calculations are summarised as follows:

Average annual rainfall (R)	975 mm
Estimated A.E.	451 mm
Potential Recharge (R – A.E.)	524 mm
Runoff losses	105 mm
Estimated Actual Recharge	419 mm

This is an estimation of recharge, which allows for surface water outflow, particularly during periods of heavy rainfall.

7.3 Groundwater Levels, Flow Directions and Gradients

- A water level survey was conducted in August 2000 for the area immediately around the source

(50 m radius).
- At the source the water level varies between 0.5 m (winter level) and 2 m (summer level) below ground level (bgl).
- The water table in the area is generally assumed to be a subdued reflection of topography; as the topography slopes northwards, the water table slopes northwards toward the springs. The dominant driving heads are the hills around the source. The flow directions will be perpendicular to the contour lines. In simple terms, rainfall reaching the water table anywhere in the catchment of the springs will flow in a northerly, north-easterly and north-westerly direction toward the well.
- In dry weather, it is considered that water is lost from the stream above the waterfall into the sand/gravel area. In higher watertable level conditions it is very likely that groundwater is lost from the sand/gravel to the stream (see section 7.6).
- When water levels are high in the main sump, the excess water overflows into the stream below the waterfall.
- The groundwater gradient was calculated as being 0.11 from the upper sump to the main sump. This gradient is far too high for a sand/gravel aquifer; therefore it is considered that the groundwater in the upper sump is perched, above the water table in the sand/gravel, on a lower permeability till layer.
- As the gravels are quite permeable the gradients would be expected to be low and so a conservative value of 0.02 is taken to represent the hydraulic gradient in the sand/gravel.

7.4 Aquifer Characteristics

There is a considerable sand and gravel deposit overlying the bedrock and till in this area, which has proven thicknesses of between 2 m and 9.5 m. The sand/gravel is considered to provide the main source of groundwater to the Lisduff source (Fig. 1). The extents of the sand/gravel aquifer were determined following discussion with the local farmer and using the Soil Map for Tipperary North Riding (Finch and Gardiner, 1993).

Although there is no specific information available on the sand/gravel in Lisduff, it is likely that it would have similar characteristics to other sand/gravel aquifers. Gravel aquifers in other parts of the country, Offaly, Kildare etc., have permeabilities of around of 5 x 10^{-4} m/s (50 m/d). It was also assumed that the sand/gravel has a porosity of 0.1.

There is no surface drainage on the hill to the east of the source, which implies that the soils and subsoils are free draining. Groundwater in this till flows towards the stream and during dry weather conditions, it is likely that groundwater will flow, underneath the river, towards the main sump.

While the sand/gravel is the main aquifer supplying Lisduff well, groundwater in the bedrock contributes to the gravel aquifer. Brief details on the bedrock unit in the area are given below.

The Hollyford Formation is Silurian in age and rarely produces enough water for high yielding wells. Bedrock aquifers of Silurian age in this region generally have low permeabilities ($<10^{-2}$ m/d) apart from the upper few metres. It is not considered to be the main aquifer supplying the well.

7.5 Aquifer Category

In order to have sufficient potential to be classed as an aquifer, a sand/gravel deposit must have a minimum saturated thickness and area. In classifying sand/gravel aquifers, the GSI requires (a) that regionally important sand/gravel (**Rg**) aquifers should be more than 10 km^2 in size and (b) that locally important (**Lg**) aquifers should greater than 1 km^2 in extent and have a saturated thickness greater than 5 m. These figures are somewhat arbitrary and can be changed depending on local circumstances. In many counties, there is little information on saturated thicknesses; consequently potential aquifers are identified on the basis of areal extent and limited data from existing public and group scheme sources in sand/gravel. This sand/gravel deposit is classified as a **locally important (Lg) aquifer**.

7.6 Hydrochemistry and Water Quality

The hydrochemical analyses (7 samples) of the Lisduff source show that the water is a moderately hard to hard water with total hardness values of 195-292.5 mg l^{-1} $CaCO_3$ and electrical conductivity values of 395-573 µS cm^{-1}. These values indicate that the groundwater does not have a strong calcium bicarbonate type signature but is influenced by both the limestone and sandstone clasts in the sand/gravel.

Electrical conductivity readings were also taken in the stream beside the main sump (337 µS/cm, 11/8/00) and 450m upstream (226 µS/cm, 11/8/00). These values may imply that the stream is gaining groundwater from the sand/gravel.

Nitrate concentrations are low; values range between 1.1 and 12.8 mg l^{-1} with a mean of 9.6 mg l^{-1}. There appears to be a general downward trend in the data since 1998 (12 samples 1997-2000). Chloride concentrations are also low, ranging between 10 and 16 mg/l Cl (5 samples) which is in the range of typical background levels (12-15 mg l^{-1}). The analyses show that the water is slightly alkaline with an average pH of 7.5.

The ratio of potassium to sodium (K:Na), along with other parameters, is used to help indicate if water has been contaminated and may indicate contamination if the ratio is > 0.4. From the 7 analyses available the ratio for the source is quite low, ranging between 0.16 and 0.22.

The untreated water analyses (1997 – 1999, 27 records) record the presence of total coliforms and faecal coliforms on only one occasion (11/05/1998).

In summary, the water at the source is moderately hard, with levels of nitrates and chlorides that are at background levels.

7.7 Spring Discharge

There is usually no overflow from the spring. However, it did overflow during the period 20/12/99 to the 17/2/2000 after very heavy rain, according to the caretaker. There were no measurements of discharge taken at this time. Generally, 650 m^3/d are abstracted from the source, with a range of 293 m^3/d (September 1995) to 935 m^3/d (March 1991). These large abstractions are not common and generally occur in the period January –March when there is usually a high amount of recharge taking place. The largest average annual abstraction was 712m^3/d in 1991.

7.8 Conceptual Model

Offaly County Council abstracts an average of 650 m^3/d from the dug well at Lisduff. The sand/gravel in the valley is considered to be the main source of groundwater to the well. The groundwater is moderately hard to hard and the electrical conductivity values indicate that the sand/gravel is composed of a mixture of limestone and sandstone clasts.

The groundwater regime in the area is complex due to the glacial history, resulting in till and sand/gravel being interlayered in many areas, and the available hydrogeological information does not allow a definitive understanding of the hydrogeology.

The stream passing along side the main sump acts both as a losing and gaining stream depending on the relative water levels in the stream and main sump. In dry weather, when the groundwater level is lower in the main sump and in the gravels than that in the stream, there is likely to be a certain amount of leakage out of the stream into the sand/gravel. Also during these periods, groundwater can move from the east side of the stream towards the main sump, by flowing underneath the stream. The length of stream that this loss occurs over can not been defined precisely from the available data. In general, groundwater moves towards the main sump in a northerly, northeasterly and northwesterly direction.

It is likely that the groundwater in the upper sump is perched above the sand/gravel watertable.

Groundwater also moves through the till and bedrock on the eastern hill into the gravels and towards the stream.

The whole length of the stream has been included as part of the zone of contribution (ZOC) of the source since it loses water at times along some part of its length within the sand/gravel aquifer (see Figure 3). The total catchment area of the stream outside of the sand/gravel aquifer area is not included in the ZOC. It can be argued that the ZOC should include this area, as there are likely to be periods, during dry weather, when the stream loses water to the sand/gravel aquifer. Therefore developments within this area could pose a threat to the source. However, this would result in a very large ZOC – far larger than the area required to sustain the source. Inclusion of the total area is considered to be over conservative and over restrictive, particularly as the area of the catchment outside of the sand/gravel aquifer will receive protection from the regional groundwater protection scheme. However, some protection is required, therefore in order to reduce the threat from development in the immediate vicinity of the stream, a 30 m buffer is applied to both sides of the stream channel, and this area is classed as being part of the Inner Protection Area (SI). Note: The 30 m distance is arbitrary, but it is considered to be reasonable and practicable.

8 Delineation Of Source Protection Areas

8.1 Introduction

This section delineates the areas around the spring that are believed to contribute groundwater to the source, and that therefore require protection. The areas are delineated on the basis of the conceptualisation of the groundwater flow pattern, as described in Section 7.8 and are presented in Figure 3.

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 well.

8.2 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), and 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 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 model and is shown in Figure 1. The ZOC catchment boundaries are described below:

1. The **Northern Boundary** is defined by the position of the main sump itself. An arbitrary buffer of 30 m is placed on the downgradient side of the source.

2. The **Eastern Boundary** is defined by the topographic highs on the flanks of the hill to the east and

the fact that groundwater is assumed to flow perpendicular to topographic contour lines towards an area of lower groundwater head

3. The **Southern Boundary** is defined by (a) the limits of the sand/gravel with an additional arbitrary buffer zone of 50 m which extends into the till, (b) the whole length of the stream, outside of the sand/gravel aquifer, to its source(s) with an arbitrary 30 m buffer, and (c) by using the topographic contours with the assumption that groundwater flow lines are perpendicular to the contours. The whole catchment area of the stream is not included in the ZOC as it loses water only while flowing over the sand/gravel area. However, a 30m buffer is applied to either side of the stream, outside of the sand/gravel aquifer, to give some protection to the well from activities carried out along the stream.

4. The **Western Boundary** is defined by the topographic ridge that runs sub-parallel to the road. It is assumed that groundwater to the west of the ridge does not flow to the source.

These boundaries delineate the physical limits within which the ZOC is likely to occur. The area constrained by the hydrogeological mapping is approximately 0.7 km^2.

A water balance was carried out to estimate the areal extent of the catchment providing the water to the source and the resulting area is compared to that delineated by mapping. This water balance uses the estimated recharge value of 419 mm (see section 7.2) and the largest average annual abstraction of 712 m^3/d. The water balance indicates that the abstraction requires a ZOC area of 0.62 km^2. The ZOC constrained by hydrogeological mapping is greater than the area required by the water balance. However, the area obtained using average annual data does not allow for expansion of the ZOC during dry weather. Therefore, an area of 0.7 km^2 is justifiable.

8.3 Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100-day time of travel (ToT) to the source. It is delineated to protect against the effects of potentially contaminating activities that may have an immediate influence on water quality at the source, in particular microbial contamination. Estimations of the extent of this area cannot be made by hydrogeological mapping and conceptualisation methods alone. Analytical modelling is also used and by using estimated aquifer parameters for permeability and hydraulic gradient, 100-day ToT estimations are made and give a velocity of 10 m/d. The whole of the sand/gravel with till area and a certain distance beyond its boundary into the till is included in the SI. Since there is not enough information available to determine this distance properly, an arbitrary distance of 50 m is taken. The SI area is presented in Figure 3.

It should be noted that permeability and porosity values, used to calculate the velocity, were not determined at this site, but are estimations based on our experience in other areas.

9 Vulnerability

The distribution of interpreted groundwater vulnerability in the ZOC is presented in Figure 2. The subsoils in the ZOC are of high to low permeability. The subsoils range in thickness from 0 m to 15 m thick in the ZOC as described in Section 6.3.4.

In the immediate vicinity of the source, the subsoils have a high permeability and are greater than 10 m thick. However, as the unsaturated zone is <3 m in this area, in the sand/gravel, the depth to the water table is estimated to be <3 m within 40 m of the source. This area is defined as having an "extreme" (**E**) vulnerability rating. Also, since the stream loses water for part of the year into the sand/gravel, an arbitrary 30 m buffer is applied on each side of the stream for the whole of its length to its source(s). The area within this buffer is classed as being "extremely" (**E**) vulnerable.

The remainder of the sand/gravel with till area is classified as having a “High” (**H**) vulnerability rating. Where the till has a low permeability it has a thickness of between 3 m and 5 m and so has a “high” (**H**) vulnerability classification. Where the subsoils are less than 3 m thick, on the slopes of the hill to the east, the vulnerability is classed as “extreme” (**E**).

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 shown in Table 1. The final groundwater protection map is presented in Figure 3. A 30 m buffer is applied to the stream along its length to its source(s). The area within this buffer zone is classed as **SI/E**, in order to give some protection to the well from activities along the stream.

Table 1 Matrix of Source Protection Zones for Lisduff

VULNERABILITY RATING	**SOURCE PROTECTION**	
	Inner	***Outer***
Extreme (E)	SI/E	SO/E
High (H)	SI/H	SO/H

11 Potential Pollution Sources

The land in the vicinity of the source is largely grassland-dominated and is primarily used for the grazing of cattle. There are several houses within a 1 km radius of the source. Agricultural activities and the septic tank systems are the principal hazards in the area. The main potential sources of pollution within the ZOC are farmyards, septic tank systems, runoff from the roads, and landspreading of organic fertilisers. The main potential pollutants are faecal bacteria, viruses, cryptosporidium, and nitrogen. However, as the groundwater quality is good, these do not appear to be having any impact on the source.

12 Conclusions and Recommendations

- Lisduff source is a large supply that is located in a sand/gravel aquifer.

- The area around the supply is extremely or highly vulnerable to contamination.

- Septic tank systems, farmyards, landspreading and runoff from the roads are the main hazards in the area. However, as the water quality is good at the source, these hazards seem to have little impact.

- The hydrogeology of the area is complex and the available information is not adequate to allow the delineation of definitive groundwater protection zone boundaries. The protection zones delineated in the report are based on our current understanding of groundwater conditions, on the available data and our judgement. Additional data obtained in the future may indicate that amendments to the boundaries are necessary. A more definitive understanding of the hydrogeology would require an extensive site investigation that would include drilling, geophysics, spring flow measurements, a more detailed water level survey and permeability measurements.

It is recommended that:

- A chemical and bacteriological raw water analysis should be carried out on a regular basis at the source.

- Particular care should be taken when assessing the location of any activities or developments that might cause contamination at the source.

- The potential hazards in the ZOC should be located and assessed.

- A cover, with a manhole for access, should be fitted over the open access area to the upper smaller sump, so that the swallows cannot return to nest in the sump next year. It will also protect against other pollution sources.

13 References

Archer, J.B., Sleeman, A.G. and Smith, D.C. (1996) *A geological description of Tipperary and adjoining parts of Laois, Kilkenny, Offaly, Clare and Limerick, to accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 18, Tipperary, with contributions by K. Claringbold, G. Stanley (Mineral Resources) and G. Wright (Groundwater Resources).* Geological Survey of Ireland, 76pp.

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Appendix 1 Geological Logs of the Auger Boreholes.

All borehole depths are maximum depths drilled by the auger. The depths are the depth at which the auger would not go any further. It assumed that the auger has reached bedrock, the evidence being that in most cases floured bedrock is recovered on the teeth of the borehole auger.

Auger Hole Number		Grid Reference	Depths of auger hole (m)	Subsoil Type	Permeability Rating
Lisduff No.1	GSI 005	S 063 809	0-9.5	GRAVELS (Fluvioglacial)	HIGH
Lisduff No.2	GSI 006	S 063 8095	0-4	GRAVELS (fluvioglacial)	HIGH
			4-11	sandy CLAY with frequent stones (Till)	LOW
Lisduff No.3	GSI 007	S 062 806	0-8	clayey GRAVEL (Till)	HIGH
			8-15	sandy CLAY with stones (Till)	LOW
Lisduff No. 4	GSI 008	S 064 803	0-3	sandy CLAY (Till)	LOW
			3-4.5	CLAY (Till)	LOW
Lisduff No. 5	GSI 009	S 058 806	0-2	stoney SILT with clays (Till)	Moderate
			2-4	GRAVELS (Fluvioglacial)	HIGH
			4-14.5	SILT with abundant gravels (Till)	Moderate

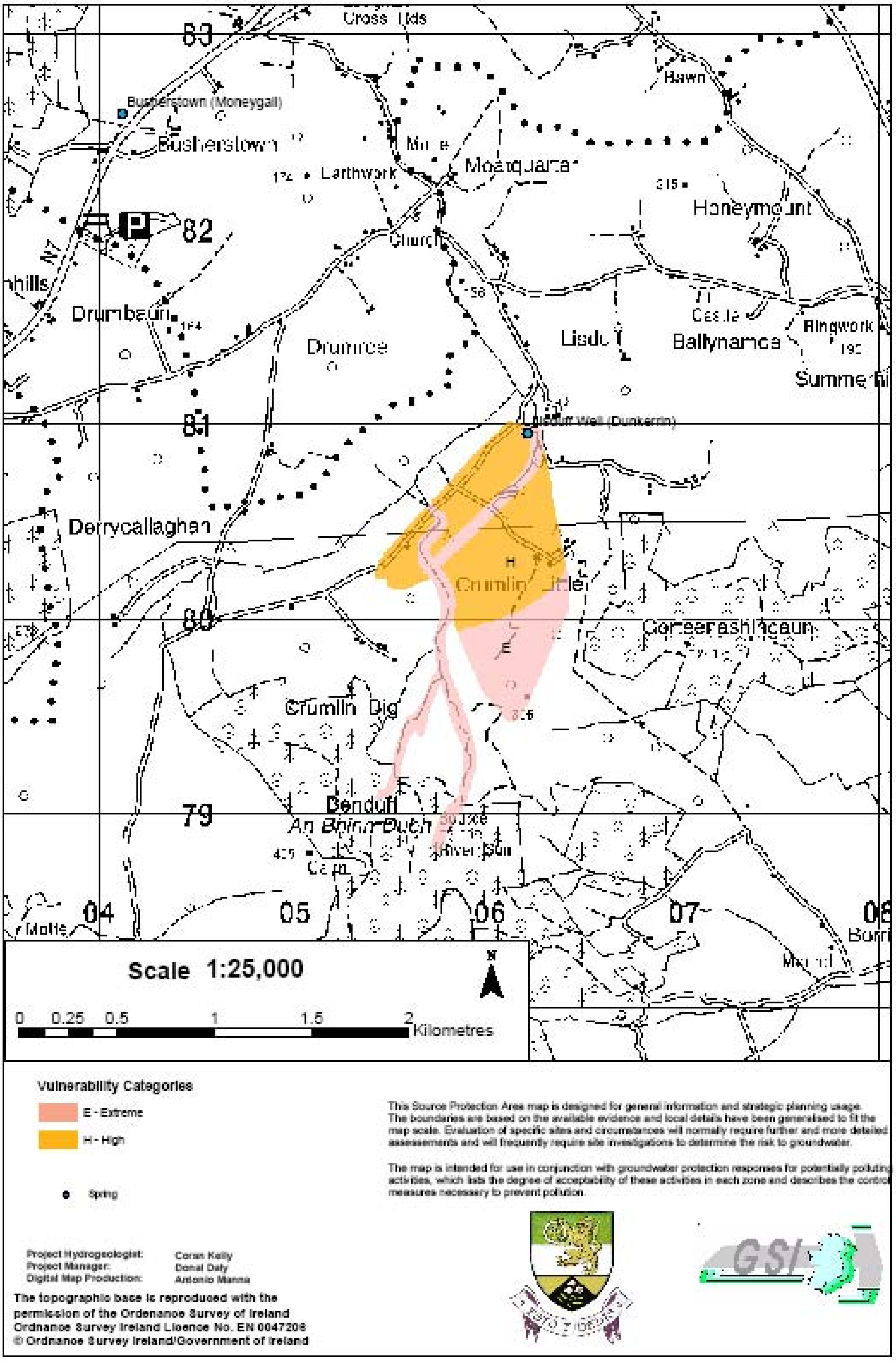

Figure 1 **Groundwater Vulnerability around Lisduff**

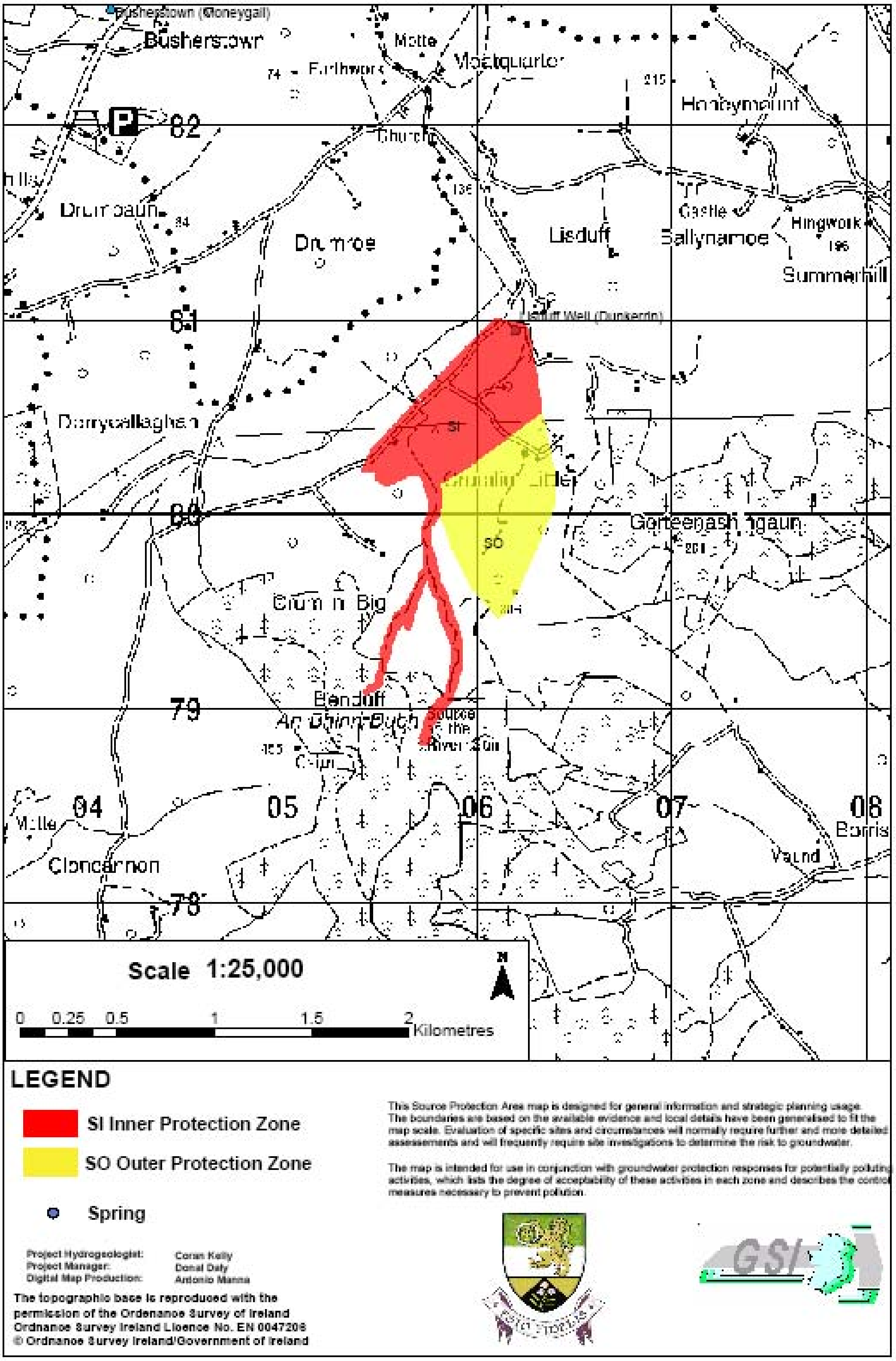

Figure 2 **Groundwater Source Protection Areas for Lisduff**

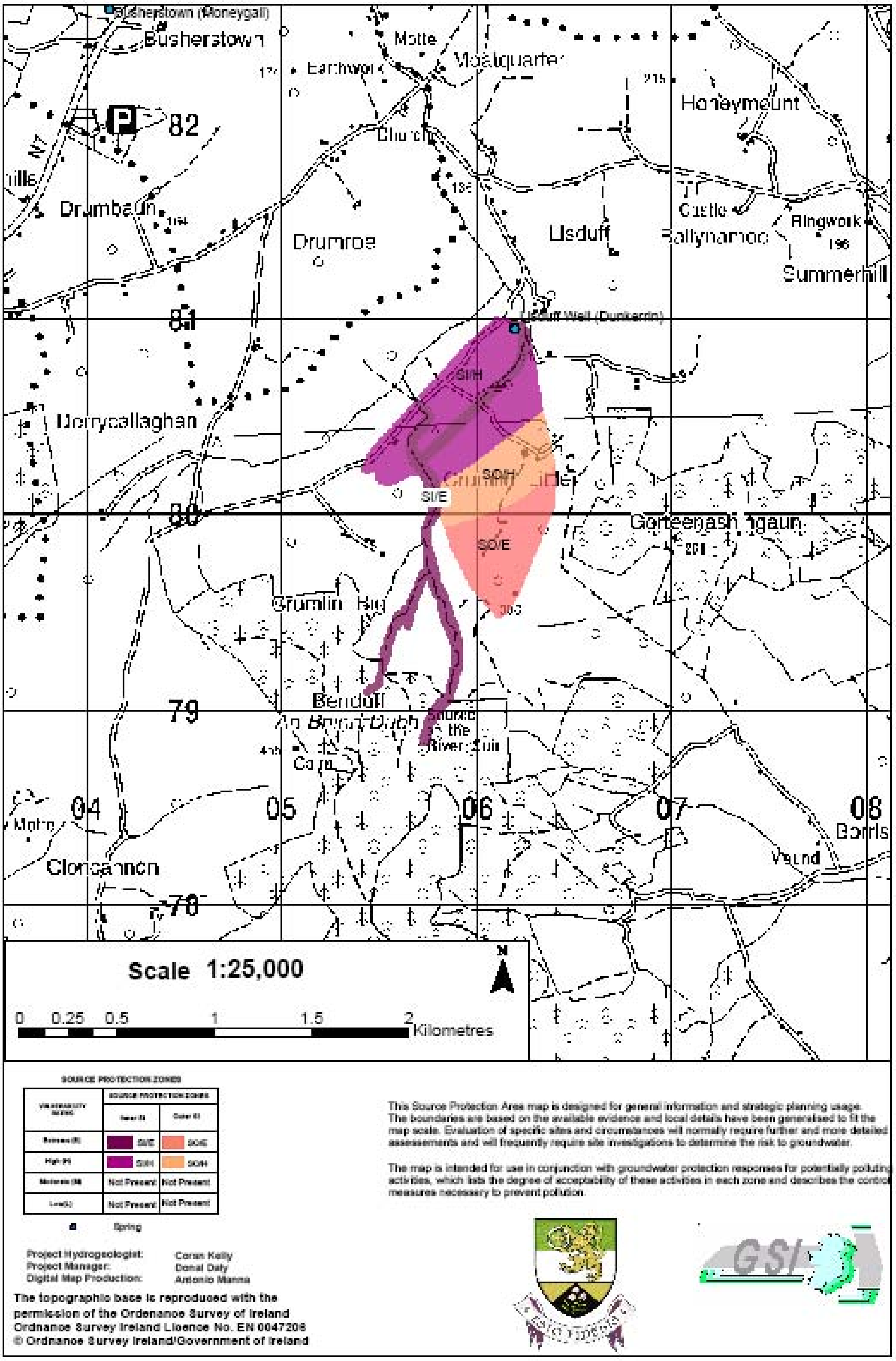

Figure 3 **Groundwater Source Protection Zones for Lisduff**