APPENDIX 9-4

GWS ZOC AND SPA REPORTS

Killeglan Water Supply Scheme

Tobermore Spring

Groundwater Source Protection Zones

(April 2003)

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1 Introduction

Tobermore Spring supplies the Killeglan Water Supply Scheme.

The objectives of the report are:

- To delineate source protection zones for the Tobermore Spring and any other springs that emerge in the vicinity of the Tobermore Spring.
- To outline the principle hydrogeological characteristics of the Killeglan area.
- To assist Roscommon County Council in protecting the water supply from contamination.

2 Location, Site Description and Well Head Protection

The Tobermore Spring is located 10 km north of Ballinasloe.

It supplies water to over 5300 houses. The demand on the spring is mostly agricultural activities, which makes up over 50% of the demand.

The Tobermore Spring comprises a large circular sump, which collects water that emerges from bedrock at the bottom of the sump.

The site area is closed off by a gate and fence. The sump is covered with concrete. Overflow occurs through an opening at the bottom of the sump. The rest of the site is grassed over.

3 Summary of Spring Details

GSI no.	:	1723NEW084
Grid ref. (1:50,000)	:	18874 24044
Townland	:	Rockland
Well type	:	Spring
Owner	:	Roscommon County Council
Elevation (ground level)	:	c. 50 m OD.
Depth to rock	:	< 3 m
Static water level	:	Ground level.
Normal Abstraction	:	6000 – 9000 m^3/d
Estimated Total Discharge	:	6000 – 30000 m^3/d

It is noted that the current requirement of the Killelgan WSS is not being met during drier periods, possibly due to an increased demand on the supply.

4 Methodology

4.1 Desk Study

Details about the spring such as elevation and abstraction figures were obtained from GSI records and County Council personnel; geological and hydrogeological information was provided by the GSI.

4.2 Site visits and fieldwork

This included depth to rock drilling, subsoil sampling, flow gauging and water quality sampling. Field walkovers were also carried out to investigate the subsoil geology, the hydrogeology and vulnerability to contamination.

4.3 Assessment

The analysis utilised field studies, previously collected data and hydrogeological mapping in order to delineate protection zones around the springs.

5 Topography and Land Use

Tobermore Spring emerges at the base of a hilly area (c.50 m OD), which rises to a maximum of 119 m OD east of the spring.

Agricultural activity dominates the area with most of the land used for grassland.

A number of houses and farms are present near the spring, some of which are within 500 metres of the source.

6 Surface Hydrology

The surface water regime is closely interconnected with the groundwater regime. There are several springs, swallow holes and numerous collapse features that are linked to the main surface water bodies in the area.

There are four main stream networks in the vicinity of Tobermore Spring. These are as follows:

1. Just north of Taghmaconnell, a stream rises in the townland of Bellaneeny. This stream flows west for approximately 4 km, to join the Killeglan River, which then discharges in the River Suck.
2. A stream network exists to the south of Taghmaconnell, in the townlands of Knock and Sraduff. These streams flow to a turlough in the townland of Glennanea. This turlough appears to take all the flow from the stream network. Another section of stream rises east of this network and then disappears after flowing approximately 1 km to the north-east.
3. An intermittent, seasonal stream is located to the east of the Tobermore Spring. This stream rises in the townland of Carrowduff and Garbally, and travels first north and then east. During wet weather the upper parts of the stream are flowing. Groundwater from the Tobermore Spring and discharge area joins this channel to form the head of the Killeglan River (Figure 1).
4. A small stream network is located in the townland of Esker. This stream network is recorded as having permanent flow, but has no apparent surface water outlet. It is therefore likely that this area of surface water feeds into the groundwater system.

The majority of the outflow from this area is via the Killeglan River, which includes the Tobermore Spring discharge. A second smaller outflow is through the stream at Bellaneeny, south of the springs.

7 Geology

An understanding of the geological material underlying the Killeglan area provides a framework for the assessment of groundwater flow and source protection zones, as discussed in Sections 8 and 9.

7.1 Bedrock Geology

Bedrock information (Figure 2) was taken from the Bedrock Geology 1:100,000 scale GSI map series, Sheets 12 (Geraghty et al, 1996) and from other unpublished work (Bedrock Section, GSI).

The majority of the area is underlain by Undifferentiated Visean Limestone. In the southern part of the county, this limestone is equivalent to Burren Limestone. To the south of the Visean Limestone is a thin band of Waulsortian Limestone.

The Visean Limestone is generally described as pale grey, clean, medium to coarse-grained, bedded limestone. The Waulsortian Limestones is a clean, pale grey massive limestone.

A number of small outcrops are noted along the path of the intermittent, seasonal stream, within the Visean Limestone.

7.1.1 Karst Features

A brief karst mapping programme was undertaken in the Killeglan area during the summer of 2001. As shown in Figure 1, the mapping identified a large number of features. These included enclosed depressions (dolines), swallow holes, springs and turloughs. The mapping highlights the high density of dolines and swallow holes along the path of the intermittent seasonal stream.

7.2 Subsoils

Subsoil mapping was undertaken by Dr. R. Meehan (Teagasc) to produce the Forest Inventory and Planning System – Integrated Forestry Information System (FIPS-IFS) Soils Parent Material Map (Figure 2). This information forms the basis of subsequent subsoil permeability assessments for the county (Lee and Daly, 2002). Further data was gathered from GSI drilling programmes (1988, 1999 and 2001).

The subsoil comprises a mixture of coarse and fine-grained materials, namely peat, alluvium, sand/gravels, and tills. The characteristics of each category are described briefly below.

Peat is located in the low-lying boggy regions of the area, mostly in the southern part.

Alluvium is generally found in the low-lying eastern part of the area and in two of the larger turloughs that are shown in Figure 2.

Till is the dominant subsoil type in the area and is an unsorted mixture of coarse and fine materials laid down by ice. The gravel-sized fragments ranging up to 10 cm in size are angular to sub-rounded and are composed of limestone. The matrix is primarily silty SAND (BS 5930) with frequent gravels and clay. There are four particle size distributions (PSD) available for the tills in this area. Three of the PSD have less than 30% fines (silt+clay) and of these two have over 50% of either sand or gravel.

Extensive fluvioglacial ***sand/gravel*** are present east and north-east of the springs. A large proportion of the sand/gravel forms a characteristically random, hummocky topography however long, sinuous, braided ridges of sand/gravel (eskers) have also been deposited (Figure 2). They are described as silty GRAVEL (BS 5930).

7.2.1 Depth to Bedrock

Broad variations in depth to bedrock have been interpreted across the area by using information from the GSI databases, field mapping and air photo interpretation.

Data from the drilling programmes indicate that the depth to rock ranges from 2 m to 33 m. In general, the low-lying areas around the spring and towards the central part of the catchment are closer to bedrock. Higher parts of the catchment have greater depths to bedrock.

7.2.2 Groundwater Vulnerability

The concept of vulnerability is discussed in the Roscommon Groundwater Protection Scheme Main Report (Lee and Daly, 2002).

The till in this region are either described as SAND (BS 5930) with a reasonably high percentage of fines, or clean sand/gravel. The available grain size distributions supporting this description. These materials are categorised as having either a 'moderate' or 'high' permeability respectively. Where subsoil thickness is greater than 3 m, the vulnerability classification ranges from 'high' to 'moderate'[1], depending on the combination of permeability and specific subsoil thickness (Figure 3).

At subsoil thickness of less than 3 m, as indicated by the outcrop, subcrop and drilling data, bulk permeability becomes less relevant in mapping vulnerability across wide areas (as opposed to specific sites). This is because infiltration is more likely to occur through 'bypass flow' mechanisms such as cracks in the subsoil. Based on the general depth to bedrock, a vulnerability classification of 'extreme' has been assigned in areas of shallower subsoil.

Several types of karst feature (e.g. dolines, swallow holes) provide locations of point recharge i.e. surface water can infiltrate directly to the bedrock, by-passing any attenuation capacity of the subsoil. These locations are classified as 'extremely' vulnerable, which includes an arbitrary buffer of 30 m.

8 Hydrogeology

8.1 Introduction

This section presents the current understanding of groundwater flow near the Killeglan Water Supply Scheme. The interpretations and conceptualisations of flow are used to delineate source protection zones around the Tobermore Spring. Hydrogeological and hydrochemical information for the study was obtained from the following sources:

- GSI databases.
- Roscommon County Council dye tracer testing.
- Roscommon County Council hydrochemistry data.
- STRIDE Report (1994).
- The Vulnerability to Pollution and Hydrochemical Variation of Eleven Springs (Catchments) in the Karst Lowlands of the West of Ireland. M Sc. Thesis, Sligo RTC (Doak, 1995).
- A Sediment Permeability Report for the Killeglan Catchment (Quinn, 1988).
- Field work (flow gauging, drilling, subsoil sampling, water quality sampling).

8.2 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 assumed to consist of 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 important in source protection delineation, as it will be used to estimate the size of the zone of contribution (i.e. the outer source protection area). The calculations are summarised in

Table 1 below.

[1] The permeability estimations and depth to rock interpretations are based on regional-scale evaluations. The mapping is intended only 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.

Table 1. Estimate of Recharge.

Parameter	Amount (mm/yr)	Data Source
Annual rainfall	1039	Contoured rainfall map based on Met Éireann data.
Annual evapotranspiration	342	Potential evapotranspiration (PE) is estimated as 360 mm/yr (Met Éireann data). Actual evapotranspiration (AE) is estimated as 95% of PE.
Potential recharge	697	Rainfall minus AE.
Runoff losses	140	Assumed as 20% of potential recharge, based on thin and/or permeable subsoil.
Estimated Recharge	557	

8.3 Groundwater Levels, Flow Directions and Gradients

The water level at Tobermore Spring is at ground level and the entire flat, low lying area around the spring is saturated and marshy. Tobermore Spring is located in a discharge area that comprises at least one other spring. Other springs also occur along the intermittent, seasonal stream, near the Tobermore Spring. The occurrence of springs and saturated ground in low-lying areas generally indicate a shallow water table.

Roscommon County Council surveyed groundwater levels in 1987. The survey indicates the general features of the water table, such as the level, direction, and gradient. The contours are widely spaced which suggests high permeability. The flow directions interpreted from the map indicate that groundwater flows toward the springs from the south-east, east, north-east and north.

Roscommon County Council also undertook tracer testing at two swallow holes south east of the Tobermore Spring in 1991 and 1994. The first swallow hole is in the townland of Glennanea (2.6 km SSE of the source), and the second is in the townland of Carrowduff (3.9 km SE of the source). For both, dye was detected at the spring 1.5 days later indicating minimum groundwater velocities of 70 m/hr and 110 m/hr respectively. For the Glennanea trace, the dye was detected first in a stream in Dundonnell townland, and then at a spring in Bellaneeny townland, before it appeared at the main Tobermore Spring (Doak, 1995).

The connection between the Glennanea swallow hole and the Tobermore Spring suggest that the groundwater flow directions are complicated, especially within this locality. This is due to the karstic nature of the bedrock, whereby the fissures/conduits locally dictate the flow directions.

The groundwater gradient calculated from the water table map is 0.0015.

8.4 Aquifer Characteristics

The Undifferentiated Visean Limestone provides the groundwater to the Tobermore Spring. It is a high yielding spring located in a discharge area that comprises at least one other spring (Doak, 1995).

A large fracture network probably underlies the source and causes the water to concentrate in the spring and discharge area. Bedrock is close to the surface near the springs.

Karstification is an important process in Irish hydrogeology. It involves the enlargement of rock fissures when groundwater dissolves the fissure walls as it flows through them. The process can result in significantly enhanced permeability and groundwater flow rates. It generally occurs in 'cleaner' limestones. Many swallow holes and collapse features provide evidence for karstification in the Killeglan area. The tracer tests that were carried out also indicate significant karstification.

The proximity of the springs to each other and the discharge from the area indicates high permeability. The widely spaced groundwater contours also suggest high permeability. The tracer tests indicate minimum groundwater velocities of between 70 and 110 m/hr. These flow rates depend on several factors including topography, rainfall and groundwater levels. However, such high velocities are characteristic of flow in karstified limestone aquifers.

The bedrock in the Killeglan area is likely to be characterised by:

- groundwater flow in solutionally-enlarged bedding plane partings, joints, faults and conduits;
- high groundwater velocities, several orders of magnitude greater than in sand/gravel aquifers;
- concentration of groundwater flow in zones of high permeability;
- a combination of diffuse and point (through swallow holes, sinking streams) means of recharge;
- irregular or poorly connected water table;
- often extreme vulnerability to contamination due to point recharge by-passing the potential attenuation capability of the subsoil;
- minimal attenuation of contaminants, except by dilution;
- high turbidity, suspended solids and colour after heavy rain, particularly in the autumn;
- short response times when pollution incidents occur.

8.5 Aquifer Category

The Undifferentiated Visean Limestone, which underlies the majority of the area, is classified as a Regionally Important Karstic Aquifer, which is characterised by conduit flow (**Rk**^{c}).

Development potential of the clean Waulsortian Limestone is considered to be limited by its massive nature, and is therefore categorised as a Locally Important Aquifer, which is moderately productive in local zones (**Ll**).

The derivation of these classifications is presented in the County Roscommon Groundwater Protection Scheme Main Report (Lee and Daly, 2002).

8.6 Hydrochemistry and Water Quality

The available water quality data are from Roscommon County Council drinking water returns for 1999 to 2001. These samples were collected as part of the Rural Water Quality Monitoring Programme. The EPA biannual data (1997 – 2001) was also included in this assessment as were two sampling rounds undertaken by the GSI (February and September 2001).

The hydrochemical analyses suggest that the spring water has a very hard (>350 mg/l $CaCO_3$) calcium-bicarbonate hydrochemical signature, with conductivity ranging between 390 – 590 µS/cm (averaging 575 µS/cm).

The results highlight that total and faecal coliforms are consistently present in the raw water samples and are one of the few parameters to exceed the EU Drinking Water Directive maximum admissible concentrations (MAC). In 50% of the raw water samples, there are greater than 10 faecal coliforms per 100 ml, which is considered to be gross contamination (Keegan *et al*., 2002). It is important to note that these results are for untreated water.

There are three instances where the level of manganese slightly exceeds the MAC (0.05 mg/l), one of which is coincident with an elevated iron level (0.9 mg/l).

Nitrate levels range from 12-29 mg/l, with two occasions in the summer of 1999 where levels exceeded GSI threshold (25 mg/l). There does not appear to be any obvious seasonal variability in the data, and there is no apparent upward trend in the dataset.

Elevated phosphate levels are a cause of eutrophication in surface water. Three samples taken in 1999 exhibited concentrations in excess of the EPA guide level (0.02 mg/l).

Turbidity has not exceeded the MAC during the monitoring however, discoloration of the water has frequently been noticed by individuals who use the supply.

8.7 Discharge Estimates

Flows have been measured by the GSI and by the County Council at several locations to estimate the amount of water leaving the catchment. These locations are shown in Figure 1 and described below:

Tobermore Spring. Assumed abstraction plus measured overflow at the sump.

Discharge Area. Flow measured at exit of marshy discharge area, east of the road. This also includes the overflow from the Tobermore Spring.

Second Stream. Flow measured on the lower section of the intermittent seasonal channel, prior to its confluence with flow from the 'discharge area'. This section of the channel has permanent flow with two springs contributing to its flow.

The discharge in the vicinity of the source is thought to comprise the flow from the 'discharge area' (which includes the Tobermore Spring overflow) and the flow from the 'second stream', as well as the water which is abstracted from the Tobermore Spring. Estimates of these values are given in Table 2 below.

Table 2. Estimates of Flows in the vicinity of the Tobermore Spring.

	Tobermore Spring [1] (m^3/d)	Discharge Area (m^3/d)	Second Stream (m^3/d)	Head of Killeglan River (m^3/d)
01-Jul-99	9960	5586	10764	26310
01-Jan-00	30975	37315	48825	96100
28-Jun-00	9960	4689	19721	34370
04-Jul-00	9960	7545	21249	38753
17-Jul-00	9960	2588	21249	33797
10-Aug-00	9960	841	3733	14533
22-Aug-00	9960	0	2540	12500
06-Sep-00	9960	0	444	10404
11-Oct-00	9960	3535	8242	21737
12-Jan-02	17630	28638	24627	63225

[1] Estimated abstraction – assumed to be 9960 m^3/d – plus measured overflow.

Flow from the Bellaneeny townland stream has not been measured accurately but is estimated to be less than half the winter overflow from Tobermore Spring (February 2000).

8.8 Conceptual Model

- Groundwater discharges to three zones in the area:
  1) Tobermore Springs and one other spring in the 'discharge area'.
  2) At least two springs located along the banks of the seasonal stream, close to the confluence with the flow from the discharge area.
  3) An unnamed stream and spring in the townland of Bellaneeny.
- Surface water and groundwater are interconnected. Many swallow holes occur along the course of the seasonal stream that runs through most of the catchment. During times of heavy rainfall, this surface channel takes the excess flow.

- The clean limestone aquifer provides water to the springs. The Visean Limestone in the region has undergone significant karstification, shown by the numerous swallow holes, turloughs and collapse features. Tracer test results also infer that the karst is well developed.
- Groundwater is likely to flow through interconnected, probably solutionally enlarged fracture zones and along fractures and joints outside the main fracture systems. The tracer tests results possibly highlight some of the larger conduits. However, the precise pathways are not known.
- Minimum groundwater velocities are high (70 m/hr; 110 m/hr). The widely spaced groundwater contours also infer that there is high permeability in the limestone.
- There are few surface streams in the catchment. These are the stream at Bellaneeny, the seasonal stream that flows through the centre of the catchment, the stream network that flow into the swallow hole at Glennanea, and the stream network to the south of Esker, which also appear to flow into a swallow hole. This also gives an indication of the clean nature of the underlying bedrock.
- Both diffuse and point types of recharge are occurring. Swallow holes and collapse features provide the means for point recharge. The subsoil is free draining and hence allows a relatively high proportion of recharge to occur through it.

9 Delineation Of Source Protection Areas

9.1 Introduction

This section delineates the areas around the spring that are believed to contribute groundwater, and that therefore require protection. The delineated areas are based on the conceptualisation of the groundwater flow pattern, as described in Section 8.8 and are presented in Figure 1.

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 source.

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), 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.

Although relatively good hydrogeological data exists for the Killeglan area, the underlying aquifer is karstified. Groundwater flow through karst areas is extremely complex and difficult to predict. Flow velocities are relatively fast and variable, both spatially and temporally. Catchment areas are often difficult to define and they may change seasonally. Consequently, some uncertainty generally exists when delineating boundaries in karst areas.

The ZOC has been defined for Tobermore Spring, the springs in discharge area, and the springs along the seasonal stream. The reason for this is that the same catchment is providing groundwater to all of the springs. Given the available data, it is impossible to define the precise zone for each individual spring as they occur in a karst environment.

The shape and boundaries of the ZOC were determined using hydrogeological mapping and the conceptual model. The boundaries of the ZOC catchment boundaries and the uncertainties associated with them are as follows:

1. The **Northern Boundary** is defined by a topographical ridge that runs from the townland of Lugboy through Cam Hill as far as the townland of Tawnagh.

2. The **Eastern Boundary** is defined by topographic ridges in the townland of Castlesampson. There are a series of streams in this area, all of which flow eastwards toward the River Shannon. The eastern boundary include the stream network to the south of Esker as it is likely that this flow is entering the groundwater system via swallow holes and may also contribute to the discharge at, or around, the Tobermore Spring.

3. The **Southern Boundary** is defined in part by the large bog in the townland of Taghmaconnell and by the ridges that occur in the townland of Ardnaglug. Tracing from the swallow hole in the townland of Glennanea indicates that all the catchment to this swallow hole and its associated stream should be included inside the southern boundary.

4. Derivation of the **Western Boundary** is more complicated. The tracer test results show a link from the swallow hole in Glennanea to the Tobermore Spring and to the streams that flow out of the catchment at Bellaneeny and Dundonnell. The boundary takes into account the localised groundwater flow direction that is inferred.

   It is assumed that water down-gradient of either the streams or springs will not flow to the Tobermore Spring. Therefore an arbitrary buffer of 30 m is placed on the down-gradient side of the head of the Dundonnell stream and the Tobermore Spring. This buffer also includes the discharge area, where at least one other spring is located.

These boundaries delineate the physical limits within which the ZOC is likely to occur. The area constrained by the hydrogeological mapping is approximately 40 km^2.

To date, the discharge data (Section 8.7) are not comprehensive enough to undertake a water balance and thus, accurately estimate the catchment area for the discharge at the head of the Killeglan River. However an approximation of the averaged discharge data and recharge data (Section 8.2) indicate that the delineated catchment is area is large enough to meet the discharge from the springs.

9.3 Inner Protection Area

According to the National Groundwater Protection Scheme (DELG/EPA/GSI, 1999), delineation of an Inner Protection Area is required to protect the source from microbial and viral contamination and it is based on the 100 day time of travel to the supply.

The tracer tests carried out by Roscommon County Council recorded rapid groundwater velocities in the Undifferentiated Visean Limestone (70 m/hr; 110 m/hr), which cover the majority of the ZOC. Groundwater can therefore reach the spring within 5 days from any point in the ZOC which is underlain by Visean Limestone.

Flow through the Waulsortian Limestone in the south of the ZOC has not been measured, however there are permeability estimates for similar rock types in other counties (Daly, 1994). These range from 0.1 to 10 m/d for locally important fractured aquifers. Although flow through the Waulsortian Limestone is estimated to be slower than through the Visean, there are surface channels across this formation which sink once they reach the karstified Visean Limestone (Glennanea swallow hole).

It is therefore likely that all groundwater within the delineated catchment could reach the source in less than 100 days. This could either occur entirely as groundwater flow, or intermittently via the surface watercourses. These data suggest that the entire ZOC should be incorporated into the Inner Protection Area.

10 Groundwater Protection Zones

The groundwater protection zones are obtained by integrating the source protection areas and vulnerability categories – giving a possible total of 8 source protection zones (see Table 3). In practice, this is achieved by superimposing the vulnerability map (Figure 3) on the source protection area map. Each zone is represented by a code, e.g. **SI/H**, which represents an <u>Inner Source Protection area</u> where the groundwater is highly vulnerable to contamination. All of the hydrogeological settings represented by the zones may not be present around any given source. Only three groundwater protection zones are present around the Killeglan source (Figure 4), as shown in the matrix below.

Table 3. Matrix of Source Protection Zones.

VULNERABILITY RATING	SOURCE PROTECTION	
	Inner	*Outer*
Extreme (E)	SI/E	na
High (H)	SI/H	na
Moderate (M)	SI/M	na
Low (L)	na	na

11 Potential Pollution Sources

Within the ZOC, there are a number of houses and farmyards. Some of these are located within 500 m of the Tobermore Spring. Agriculture in the main land use in the area, which is dominated by pasture. There are also several small-scale sand and gravel pits in the ZOC.

The hydrochemical data mainly highlights consistently elevated levels of total and faecal coliforms. Given the levels of other indicator parameters, the source of this contamination is likely to be organic wastes.

The main hazards associated within the ZOC are therefore considered to be domestic, such as on site treatment systems (septic tanks), and agricultural (farmyard waste leakage, landspreading). The location of these activities in any part of the ZOC categorised as ‘extremely’ vulnerable presents a potential risk, given rapid travel time through the underlying bedrock. It should be noted that detailed assessments of hazards were not carried out as part of this study.

12 Conclusions and Recommendations

- The source at Killeglan is located in, and predominantly supplied by, the Undifferentiated Visean Limestone.
- It is unlikely that the spring can provide additional long-term water supplies during drier periods. However flow from the ‘discharge area’ and in the ‘second stream’ was recorded after the Tobermore Spring overflow had ceased during the summer months.
- Although there are several springs around the Tobermore Spring, the delineated ZOC encompasses all of them. This approach is necessary due to the complicated nature of groundwater flow in karstified rock and the lack of data.
- Due to the rapid groundwater velocities through the karstified bedrock, it is considered that waters within any part of the ZOC could potentially reach the spring within 100 days. Therefore the entire ZOC has also been classified as the Inner Protection Area.
- The groundwater in the Protection Area is ‘extremely’ to ‘moderately’ vulnerable to contamination. The enclosed concrete sump and well maintained pump house area suggest that there will be limited susceptibility to surface water inundation specifically at the source.
- The protection zones delineated in this chapter 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:
  - flow monitoring is continued, both at the head of the Killeglan River and individually from the 'discharge area' and the 'second stream'. If appropriate, these flows may have development potential for augmentation purposes.
  - tracer tests are undertaken in other parts of the ZOC to increase our understanding of the groundwater flows. Such information may aid delineation of more specific areas contributing to the other springs identified, such as those along the seasonal stream.
  - the present chemical and bacteriological analyses of raw water should be continued. The chemical analyses should include all major ions – calcium, magnesium, sodium, potassium, ammonium, bicarbonate, sulphate, chloride, and nitrate.
  - the potential hazards in the ZOC should be located and assessed.
  - the sump and pump house area should continue to be adequately maintained to minimise the risk of inundation by surface water at the source.

13 References

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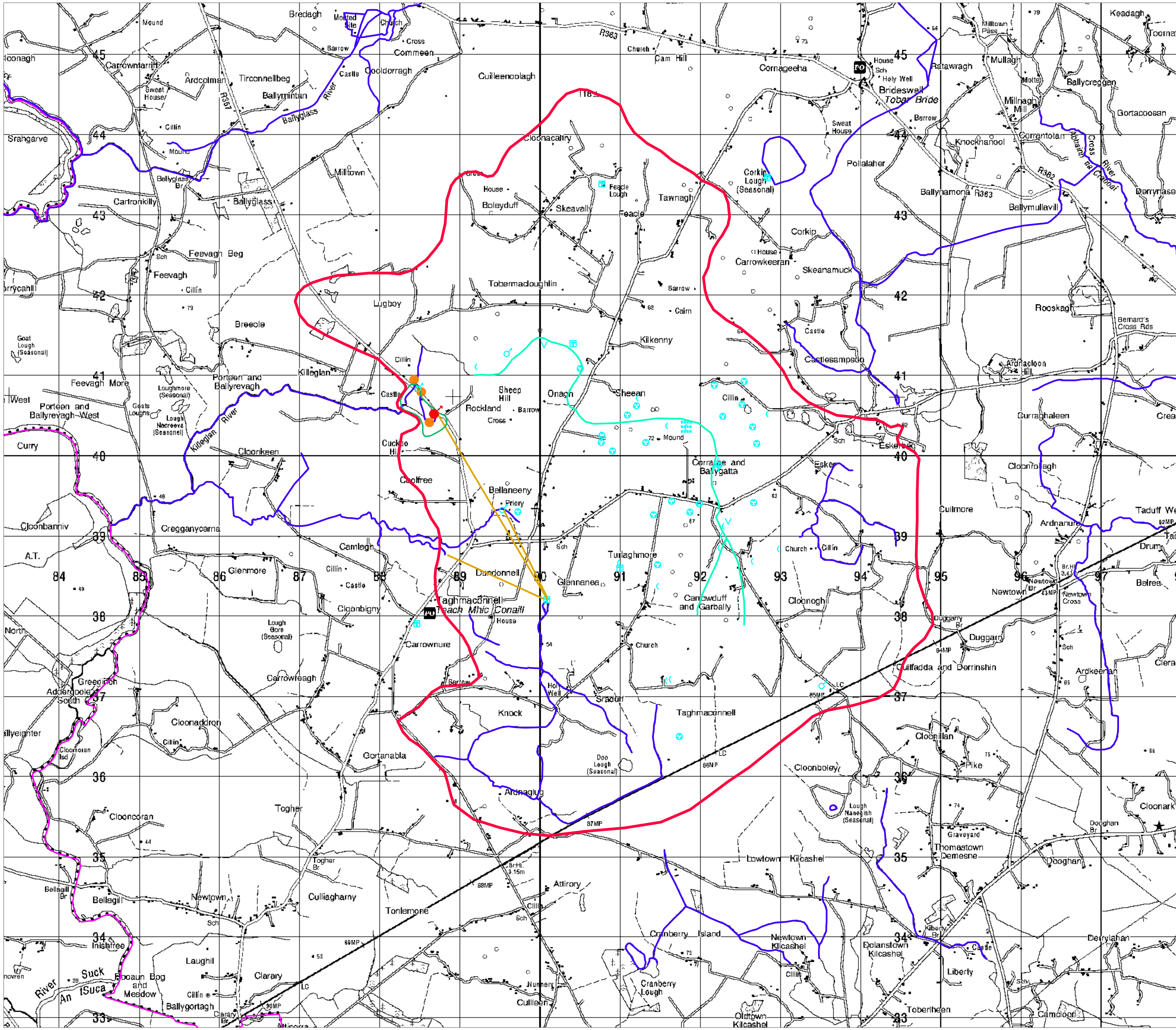
KILLEGLAN WATER SUPPLY SCHEME

Figure 1. Site Location and Feature Map



Karst Features

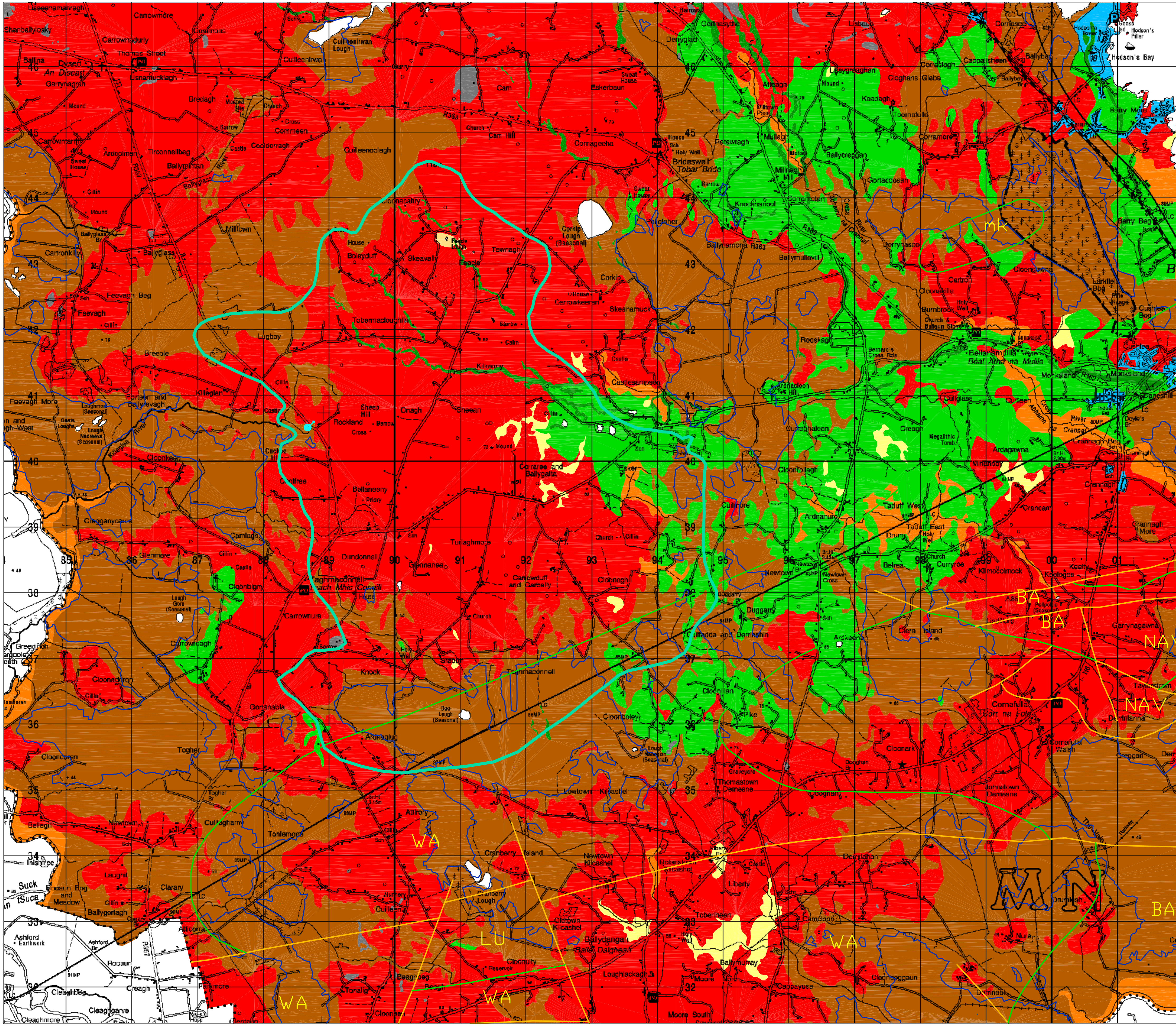
- Turlough
- Enclosed Depression
- Swallow Hole
- Cave
- Spring

Other Features

- Streams
- Zone of contribution (ZOC)
- Public Supply Spring
- Monitoring points of flow gauging
- Discharge area
- Seasonal Stream
- Established Connections (tracer test lines)

The topographic base is reproduced with the permission of the Ordnance Survey of Ireland

0 1km 2km



KILLEGLAN WATER SUPPLY SCHEME

Figure 2. Geology and Subsoils Map

Legend
Alluvium undifferentiated
Cut Peat
Esker Sands and Gravels
Sands and Gravels
Lake Sediments
Lake
Rock outcrop or subcrop
Tills

Code	Unit	Description
LU	Lucan Formation	Dark limestone and shale.
WA	Waulsortian Limestones	Lime-mudstone
BA	Ballysteen Formation	Muddy limestones
NAV	Navan Group	Limestone and shale
mk	Mudbank limestones	

- Cut peat boundaries used for Vulnerability map
- Geological Boundaries
- Geological Faults
- Zone of Contribution
- Public Supply Spring

Sources of Information

G.S.I. 1:100,000 Bedrock Series Sheet 12 : compiled by M.Geraghty, C.MacDermot and D.C.Smith.

"FIPS-IFS Soil Parent Material Map"
Compiled by R. Meehan (Teagasc).

This **geology and subsoils 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.

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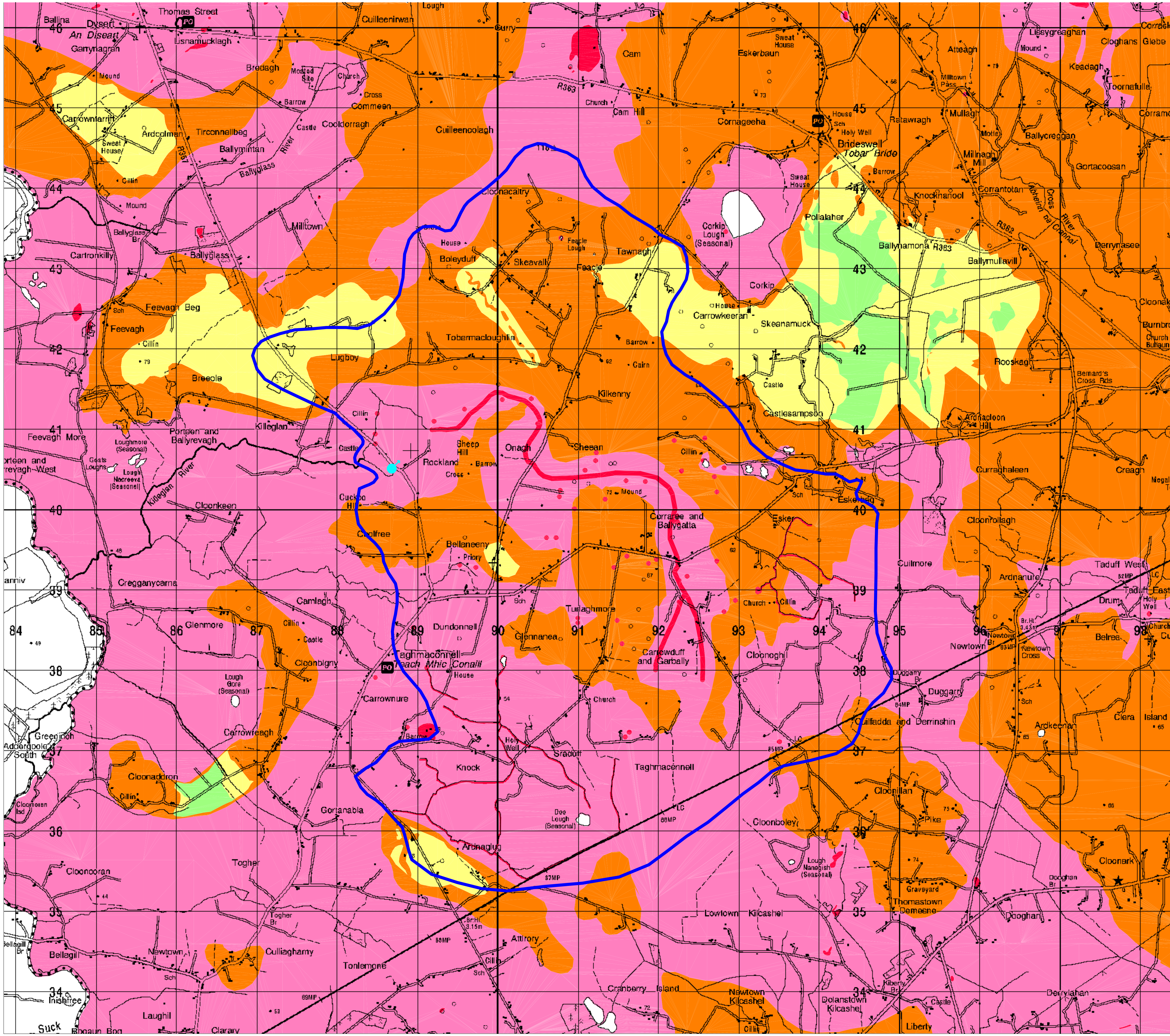
0 1km 2km

KILLEGLAN WATER SUPPLY SCHEME

Figure 3. Vulnerability Map

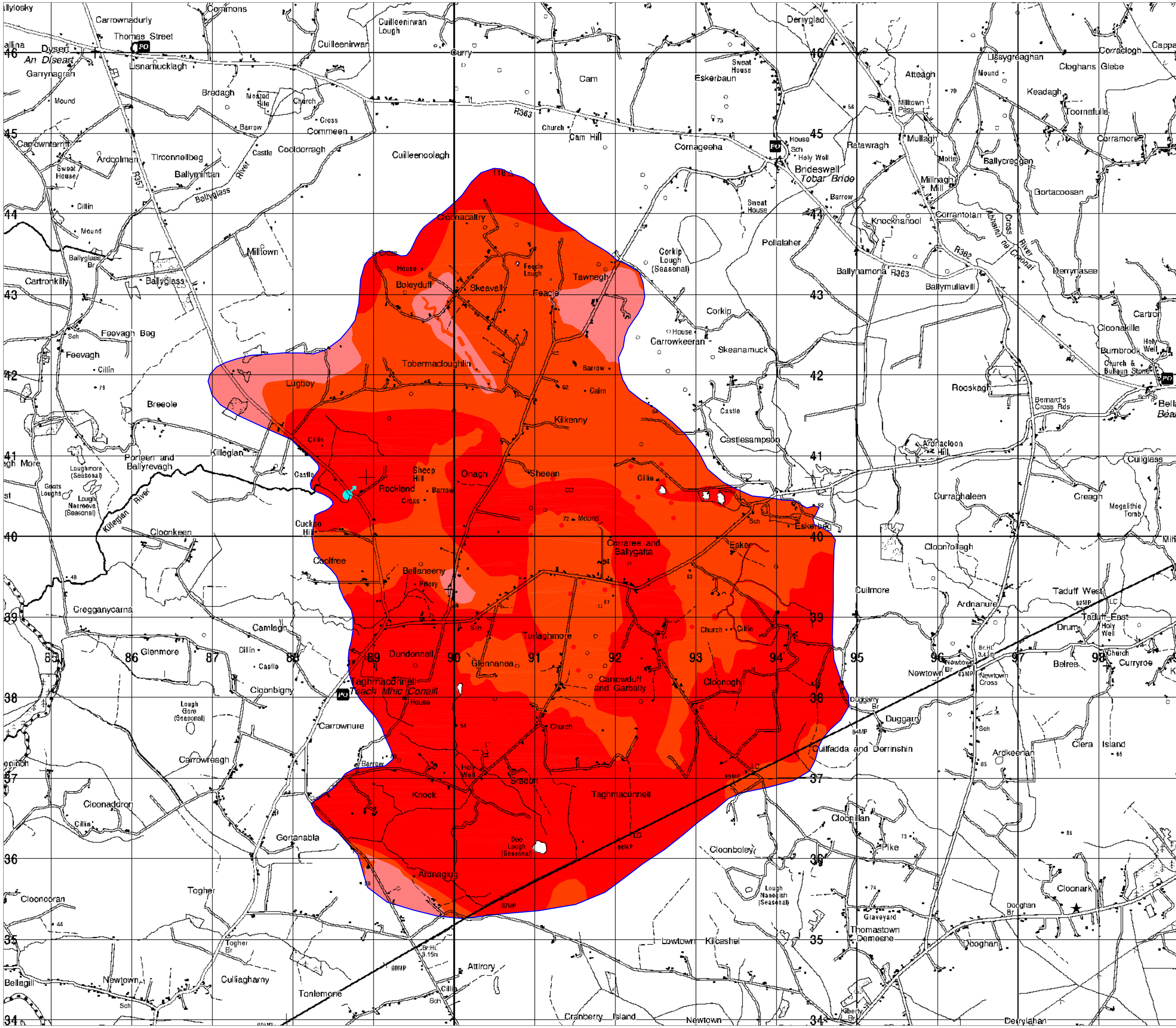


Vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities.

The map shows the **vulnerability** of the first groundwater encountered (in either sand/gravel aquifers or in bedrock) to contaminants released at depths of 1-2 m below the ground surface. Where contaminants are released at significantly different depths, there will be a need to determine groundwater vulnerability using site-specific data. The characteristics of individual contaminants have not been taken into account.

This **vulnerability** 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.

0 1km 2km



KILLEGLAN WATER SUPPLY SCHEME

Figure 4. Source Protection Zones

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

Zone of Contribution to well (SI)

Public Supply Spring

This **Source Protection Zone map** is designed for general information and strategic planning usage. The boundaries are based on the available evidence and local details have been generalised to fit the map scale. Evaluation of specific sites and circumstances will normally require further and more detailed assessements and will frequently require site investigations to determine the risk to groundwater.

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

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0 1km 2km

Mount Talbot Water Supply Scheme

Cloonlaughnan Springs

Groundwater Source Protection Zones

(April 2003)

Prepared by:
Monica Lee and Coran Kelly
Geological Survey of Ireland

In collaboration with:

Roscommon County Council

Table of Contents

1 Introduction

A series of springs in the townland of Cloonlaughnan supply the Mount Talbot Water Supply Scheme.

The objectives of the report are as follows:

- To delineate source protection zones for the Mount Talbot Scheme Springs.
- To outline the principle hydrogeological characteristics of the Mount Talbot area.
- To assist Roscommon County Council in protecting the water supply from contamination.

2 Location, Site Description and Well Head Protection

The source comprises at least two springs in the Cloonlaughnan townland, which is located approximately 5 km south of Athleague.

The springs feed into an artificial channel (c.4 m wide by c.100 m long), which discharges into a stream to the south. This stream flows north-west into the River Suck, approximately 350 m from the springs.

A large covered sump is located adjacent the artificial channel, partially beneath the pump house. The sump collects water from the channel through an intake pipe. There is also an overflow pipe from the sump which discharges into the channel further downstream.

The source area is closed off with a gate and fence. The remainder of the site is grassed over.

3 Summary of Spring Details

GSI no.	:	1725SWW019
Grid ref. (1:50,000)	:	18203 25232
Townland	:	Cloonlaughnan
Well type	:	Springs
Owner	:	Roscommon County Council
Elevation (ground level)	:	c. 47 m OD.
Depth to rock	:	< 2 m
Static water level	:	c. 1 m below ground level.
Sump dimensions	:	7 m diameter by 3.5 m deep
Average abstraction	:	3,540 m^3/d
Estimated total discharge	:	6,000 – 17,000 m^3/d

4 Methodology

4.1 Desk Study

Details about the springs such as elevation and abstraction figures were obtained from GSI records and County Council personnel; geological and hydrogeological information was provided by the GSI.

4.2 Site visits and fieldwork

This included depth to rock drilling, subsoil sampling, flow gauging and water quality sampling. Field walkovers were also carried out to investigate the subsoil geology, the hydrogeology and vulnerability to contamination.

4.3 Assessment

The analysis utilised field studies, previously collected data and hydrogeological mapping in order to delineate protection zones around the springs.

5 Topography, Surface Hydrology and Land Use

The springs emerge at approximately 47 m OD, within a flat, low-lying, area. A limestone ridge trending north-east to south-west is situated approximately 4.5 km east of the source. The ridge rises sharply from 60 m to 133 m and forms part of a regional surface water divide between the River Suck catchment and the Lough Funshinagh/Lough Ree catchment. A smaller hill (rising to 69 m OD) is located in the generally flat land between the ridge and the springs.

The artificial channel flows south to discharge into a stream flowing north-westwards into the River Suck. The River Suck flows north to south, approximately 350 m west of the source. Another smaller stream, the Cloonalin River, is located approximately 1.0 km to the north of the source. This stream also flows in a north-western direction to discharge into the River Suck.

The land use in this area is predominantly agricultural, with much of the land used for grazing. There are a number of houses and farmyards present in the vicinity of the springs.

6 Geology

An understanding of the geological material in the Mount Talbot area provides a framework for the assessment of groundwater movement and source protection zones, as discussed in Sections 7 and 8.

6.1 Bedrock Geology

Bedrock information was taken from the Bedrock Geology 1:100,000 scale GSI map series, Sheets 12 (Geraghty et al, 1996) and from unpublished work undertaken by the Bedrock Section, GSI.

The entire region is underlain by Undifferentiated Visean Limestone. In the southern part of the county, this limestone is equivalent to Burren Limestone, which is generally described as pale grey, clean, medium to coarse-grained, bedded limestone.

6.1.1 Karst Features

Specific karst mapping has not been undertaken in the Mount Talbot area. However a small number of karst features have been identified in this region comprising turloughs, a swallow hole and a cave.

6.2 Subsoils

Subsoils mapping was undertaken by Dr. R. Meehan (Teagasc) to produce the Forest Inventory and Planning System – Integrated Forestry Information System (FIPS-IFS) Soils Parent Material Map (Figure 2). This information forms the basis of subsequent subsoil permeability assessments for the county (Lee and Daly, 2002). Further data was gathered from GSI drilling programmes (1999 and 2001). Additional information specific to the area of interest includes:

- Nicholas O'Dwyer and Partners, (1982). Mount Talbot Regional Water Supply Scheme. Site

Investigation.

- Doak, M., (1995) The Vulnerability to Pollution and Hydrochemical Variation of Eleven Springs (Catchments) in the Karst Lowlands of the West of Ireland. M Sc. Thesis, Sligo RTC.

The subsoil comprises a mixture of coarse and fine-grained materials, namely: peat, alluvium and tills. The characteristics of each category are described briefly below.

Peat is situated in the low-lying areas. The regions are specifically located along the streams to the north and south of the springs. A small area of peat is also recorded to the east of the springs, which coincides with a turlough. A thin layer of peat (0.2 m – 2.0 m) was also recorded in the immediate vicinity of the springs.

Alluvium is located to the west of the springs, along the River Suck.

Tills are the dominant subsoil type in the area and are described as an unsorted mixture of coarse and fine materials laid down by ice. There are seven till samples taken within a 4 km radius of the springs. All seven are described as SILT (BS 5930). Four of the samples have particle size distribution data (PSD) which all have between 30% and 40% fines (silt+clay). Three of these samples have been analysed for their clay percentage, which ranges from 6% to 11%.

6.2.1 Depth to Bedrock

Broad variations in depth to bedrock have been interpreted across the area by using information from the GSI databases, field mapping and air photo interpretation.

Areas of outcrop and subcrop are recorded in the ridge to the east of the springs (Figure 2).

Data from the drilling programmes indicate that the depth to rock ranges from less than 2.0 m in the immediate vicinity of the springs, to just over 6 m to the east of the springs. In general, the flatter area to the east of the springs have slightly greater depths to bedrock, which become increasingly shallower on the higher ridge area.

It is also noted that the depth to bedrock increases to greater than 10 m towards the River Suck.

6.2.2 Groundwater Vulnerability

The concept of vulnerability is discussed in the Roscommon Groundwater Protection Scheme Main Report (Lee and Daly, 2002).

The till in this region is generally described as SILT (BS 5930), with the available particle size distributions supporting this description. This material is categorised as having a 'moderate' permeability. Therefore where subsoil thickness are estimated to be between 3 m and 10 m, the vulnerability is classified as 'high'[1].

At subsoil thickness of less than 3 m, as indicated by the outcrop, subcrop and drilling data, bulk permeability becomes less relevant in mapping vulnerability across wide areas (as opposed to specific sites). This is because infiltration is more likely to occur through 'bypass flow' mechanisms such as cracks in the subsoil. Based on the general depth to bedrock, a vulnerability classification of 'extreme' has been assigned along the ridge area, as shown in Figure 3.

---

[1] The permeability estimations and depth to rock interpretations are based on regional-scale evaluations. The mapping is intended only 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.

7 Hydrogeology

This section presents the current understanding of groundwater flow near the Mount Talbot Water Supply Scheme. The interpretations and conceptualisations of flow are used to delineate source protection zones around the springs.

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

- GSI databases.
- Roscommon County Council hydrochemistry data.
- Nicholas O'Dwyer and Partners, (1982). Mount Talbot Regional Water Supply Scheme. Site Investigation.
- Doak, M., (1995) The Vulnerability to Pollution and Hydrochemical Variation of Eleven Springs (Catchments) in the Karst Lowlands of the West of Ireland. M Sc. Thesis, Sligo RTC.
- Field work (flow gauging, drilling, subsoil sampling, water quality sampling).

7.1 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 is assumed to consist of 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 important in source protection delineation as it is used to estimate the size of the zone of contribution (i.e. the outer source protection area). The calculations are summarised in Table 1 below.

Table 1. Estimate of Recharge.

Parameter	Amount (mm/yr)	Data Source
Annual rainfall	1026	Average annual rainfall 1961 – 1990 (Met Éireann, 1996).
Annual evapotranspiration	388	Potential evapotranspiration (PE) is estimated as 408 mm/yr (Met Éireann data). Actual evapotranspiration (AE) is estimated as 95% of PE.
Potential recharge	638	Rainfall minus AE. 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.
Runoff losses	64	Assumed as 10% of potential recharge. Based on: • Negligible runoff over half the area due to the high proportion of outcrop/subcrop, also shown by the lack of surface streams; • 20% runoff losses over half the area due to thicker subsoils.
Estimated Recharge	574	

7.2 Hydrogeological Features

- The water level at the Mount Talbot Springs is approximately 1 m below ground level. The flat, low lying area west of the spring is quite wet and requires artificial drainage in order to utilise the land. The presence of springs and saturated ground indicate a shallow water table.
- The discharge area of the springs constitutes an artificial channel and comprises at least two

springs.

- A turlough is located to the east of the spring. The turlough has not been investigated to determine whether it has a swallow hole, and whether there is a possible connection between it and the springs.
- Specific karst mapping has not been undertaken in this general area however, a number of karst features are recorded within a 5 km radius of the springs. These features include turloughs, a swallow hole and a cave.
- In the absence of further data, the watertable is generally thought to reflect the topography. It is assumed therefore that groundwater will move in a north-west direction towards the springs and in the general direction of the River Suck. The dominant driving head for the water emerging at the spring is likely to be the higher limestone ridge situated to the east of the springs.

7.3 Aquifer Characteristics

The Undifferentiated Visean Limestone provides the groundwater to the Mount Talbot Springs. These springs consistently give a high yield.

Given the nature of the underlying bedrock, a fracture network possibly underlies the source and causes the water to concentrate in the discharge area at the springs. Bedrock is close to the surface near the springs.

Karstification is an important process in Irish hydrogeology. It involves the enlargement of rock fissures when groundwater dissolves the fissure walls as it flows through them. The process can result in significantly enhanced permeability and groundwater flow rates. It generally occurs in 'cleaner' limestones. Although karst mapping has not been undertaken in this specific area, there are a significant number of karst features recorded in the Visean Limestone.

Tracer tests in the Visean Limestones have been undertaken within 20 km of the source. These suggest that the limestone is characterised by rapid groundwater velocities, as are outlined in Table 2 below.

Table 2. Tracer Test in the Visean Limestones in South Roscommon

Location	Velocity (m/hr)	Data Source
Fuerty to Ballinagard Springs *(10 km north of source)*	c. 24	Roscommon County Council, 1991
Lough Funshinagh to Milltown Pass *(12.5 km east of source)*	70	Drew *et al.*, 1996
Killeglan Water Supply Scheme *(15 km south of source)*	70; 110	Roscommon County Council, 1991 and 1994

The lack of surface drainage in the Mount Talbot area suggests that infiltration occurs readily.

Based on the general characteristics of the Visean Limestone in this region, the bedrock in the Mount Talbot area is likely to be characterised by:

- groundwater flow in solutionally enlarged bedding plane partings, joints, faults and conduits;
- high groundwater velocities; possibly orders of magnitude greater than in sand/gravel aquifers;
- concentration of groundwater flow into zones of high permeability;
- a combination of diffuse and point (through swallow holes, sinking streams) means of recharge;
- irregular or poorly connected water table;
- often extreme vulnerability to contamination due to point recharge by-passing the potential

attenuation capability of the subsoil;

- minimal attenuation of contaminants, except by dilution;
- high turbidity, suspended solids and colour after heavy rain, particularly in the autumn;
- short response times when pollution incidents occur.

7.4 Aquifer Category

The Undifferentiated Visean Limestone underlies the entire area and is classified as a Regionally Important Karstic Aquifer, which is characterised by conduit flow (**Rk**^{c}).

The derivation of this classification is presented in the County Roscommon Groundwater Protection Scheme Main Report (Lee and Daly, 2002).

7.5 Hydrochemistry and Water Quality

The available water quality data are from Roscommon County Council drinking water returns for 1999 to 2001. These samples were collected as part of the Rural Water Quality Monitoring Programme. The EPA biannual data (1997 – 2001) were also included in this assessment as were two GSI sampling rounds (February and September 2001). Further data includes that from Doak (1995).

- The hydrochemical analyses suggest that the spring water has a very hard (>350 mg/l $CaCO_3$) calcium-bicarbonate hydrochemical signature, with conductivity ranging between 394 – 790 µS/cm (averaging 640 µS/cm). A 9% coefficient of variation of conductivity was calculated, suggesting a karstified bedrock which is sensitive to pollution (Doak, 1995).
- The results highlight that total and faecal coliforms are consistently present in the raw water samples, exceeding the EU Drinking Water Directive maximum admissible concentrations (MAC). In 62% of the 21 raw water samples, there are greater than 10 faecal coliforms per 100 ml, which is considered to be gross contamination (Keegan *et al*., 2002).
- Sodium:Potassium ratios (Na:K) range from 0.23 – 0.38 in 7 samples (averaging 0.31). Two samples exceeded the GSI threshold (0.35). Elevated Na:K ratios suggest that farmyard waste, rather than septic tanks, are the source of organic wastes.
- Nitrate levels are low, ranging from 2 – 19 mg/l. There does not appear to be any obvious seasonal variability in the data, and there is no apparent upward trend in the dataset.

The dataset shows that the spring water is very hard and is regularly contaminated with bacteria, some of which is likely to have an agricultural (farmyard waste) source.

7.6 Discharge Estimates

The total discharge from the springs is thought to comprise the abstraction plus the overflow. The spring overflow has been measured by the GSI and by the County Council. The overflow was measured prior to the water entering the stream to the south of the artificial channel. This location would include the flow by-passing the sump intake as well as sump overflow, which is not abstracted. Estimates of these values are given in Table 3 below.

Table 3. Discharge Estimates from the Cloonlaughnan Springs.

	Spring Abstraction [1] (m^3/d)	Overflow (m^3/d)	Total Discharge (m^3/d)
July 1999	3504	3071	6575
January 2000	3593	12148	15741
April 2000	3545	8111	11656
September 2000	3547	6221	9768
October 2000	3547	6165	9712
January 2001	3547	13365	16912

[1] Abstraction for September 2000, October 2000 and January 2001 estimated as average of measured abstractions given in the Table.

Flow was also measured in the Cloonalin River to the north and the stream to the south in April 2000. The gauged flows were:

Cloonalin River: 4680 m^3/d

Stream to the south of the springs: 11020 m^3/d

7.7 Conceptual Model

- There are very few surface streams in the catchment. This lack of surface drainage suggests that potential recharge readily infiltrates into the groundwater system.
- Recharge is likely to comprise both diffuse and point types. Furthermore, the subsoils are reasonably free draining allowing a relatively high proportion of recharge to occur through them.
- The clean Visean Limestone aquifer provides water to the springs.
- The Visean Limestone in the region has undergone significant karstification, shown by the numerous swallow holes, turloughs, and collapse features throughout south Roscommon. Tracer test results from the general region also infer that the karst is well developed.
- Groundwater is likely to flow through interconnected, probably solutionally enlarged fracture zones and along fractures and joints outside the main fracture systems. These precise pathways are not known.
- The groundwater is likely to move from the higher ridge to the east of the springs, through the Visean Limestone in a west to north-west direction, to the lowest point of the catchment. At this point some of the groundwater emerges at the surface as the Mount Talbot Springs.
- The variation of electrical conductivity (9%) suggests that the springs respond rapidly to recharge.
- The groundwater regime in the area is complex and the available hydrogeological information does not allow a definitive understanding of the hydrogeology.

8 Delineation Of Source Protection Areas

8.1 Introduction

This section delineates the areas around the springs that are believed to contribute groundwater and that therefore require protection. The delineated areas are based on the conceptualisation of the groundwater flow pattern, as described in Section 7.7 and are presented in Figure 1.

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 source.

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 are essentially based on topography. The boundaries of the ZOC and the uncertainties associated with them are as follows:

1. The **Eastern boundary** comprises the north-east to south-west trending limestone ridge in the townlands of Correal and Cuilnakeava. This ridge represents the highest point in the ZOC and forms part of a regional surface water divide as suggested by the limited surface drainage patterns in the area.
2. The **Northern Boundary** is slightly more complicated than the eastern boundary. It is based on a smaller topographic ridge, generally trending east to west, in the townlands of Cartron and Carroward. This boundary differentiates the ZOC for the springs from the Cloonalin River catchment, to the north.
3. Similarly, the **Southern Boundary** is defined by a small topographic ridge, which passes through the townland of Cloghan. This is the also the catchment boundary of the stream to the south.
4. The **Western Boundary** is defined by topography along its north-western portion. This slightly elevated ridge is a continuation of the northern boundary ridge. The springs are located in the south-west of the ZOC. It is assumed that water down-gradient of the springs will not flow back to them, but will continue flowing to the River Suck. Therefore an arbitrary buffer of 30 m is placed on the down-gradient side of the springs.

These boundaries delineate the physical limits within which the ZOC is likely to occur. It is possible that groundwater may be reaching the springs from beyond the delineated ZOC however, this cannot be determine from the limited data. The area constrained by the mapping is approximately 6 km^2.

To date, the discharge data (Section 7.6) are not comprehensive enough to undertake a water balance and thus, accurately estimate the catchment area for the Mount Talbot Springs. However, an approximation of the averaged discharge data and recharge data (Section 7.1) indicate that the delineated catchment area is large enough to meet the discharge from the springs.

Similar water balance estimates for the Cloonalin River and the stream to the south suggest that their topographic catchment areas are realistic. This infers that the shared catchment boundaries, i.e. the northern and southern ZOC boundaries, are also reasonable.

Although the area delineated by hydrogeological mapping approximates to that required by the discharge, the underlying rock is karstified. Groundwater flow through karst areas is extremely complex and difficult to predict. Flow velocities are relatively fast and variable, both spatially and temporally. Catchment areas are often difficult to define and they may change seasonally. Consequently, some uncertainty generally exists when delineating boundaries in karst areas.

8.3 Inner Protection Area

According to the National Groundwater Protection Scheme (DELG/EPA/GSI, 1999), delineation of an Inner Protection Area is required to protect the source from microbial and viral contamination and it is based on the 100 day time of travel to the supply.

Flow through the Visean Limestones in the ZOC has not been measured. However, there are permeability data for these limestones in south Roscommon; tracer tests recorded velocities of at least 24 m/hr (Section 7.3). Assuming that these flow rates are applicable to the Mount Talbot area, it is possible that groundwater could reach the source from the furthest point on the eastern boundary within 11 days.

It is therefore likely that all groundwater within the delineated catchment could reach the source in less than 100 days. Given the lack of surface drainage in the ZOC, it is likely that flow to the spring occurs mainly as groundwater. These data suggest that the entire ZOC should be incorporated into the Inner Protection Area.

9 Groundwater Protection Zones

The groundwater protection zones are obtained by integrating the source protection areas and vulnerability categories – giving a possible total of 8 source protection zones (see Table 4). In practice, this is achieved by superimposing the vulnerability map (Figure 3) on the source protection area map. Each zone is represented by a code, e.g. **SI/H**, which represents an Inner Source Protection area where the groundwater is highly vulnerable to contamination. All of the hydrogeological settings represented by the zones may not be present around any given source. Only two groundwater protection zones are present around the Mount Talbot source (Figure 4), as shown in the matrix below.

Table 4. Matrix of Source Protection Zones.

VULNERABILITY RATING	SOURCE PROTECTION	
	Inner	***Outer***
Extreme (E)	SI/E	na
High (H)	SI/H	na
Moderate (M)	Na	na
Low (L)	Na	na

10 Potential Pollution Sources

Within the ZOC, there are a number of houses and farmyards. Some of these are located within 500 m of the Mount Talbot Springs. Agriculture in the main land use in the area, which is dominated by pasture.

The hydrochemical data mainly highlights consistently elevated levels of total and faecal coliforms in raw water samples. Given the levels of other indicator parameters, the source of this contamination is likely to be organic wastes, especially from farmyard wastes.

The main hazards associated within the ZOC are therefore considered to be domestic, such as on site treatment systems (septic tanks), and agricultural (farmyard waste leakage, landspreading). The location of these activities in any part of the ZOC categorised as ‘extremely’ vulnerable presents a potential risk, given the potentially rapid travel time through the underlying bedrock. It should be noted that detailed assessments of hazards were not carried out as part of this study.

11 Conclusions and Recommendations

- The source at Mount Talbot is located in, and supplied by, the Undifferentiated Visean Limestone.

- The available data suggest that there is permanent overflow.
- There are few available data relating specifically to the groundwater in this general area. Therefore the ZOC boundaries are predominantly delineated by topography.
- Due to the rapid groundwater velocities through the karstified bedrock, it is considered that waters within any part of the ZOC could potentially reach the spring within 100 days. Therefore the entire ZOC has also been classified as the Inner Protection Area.
- The groundwater in the Protection Area is ‘extremely’ and ‘highly’ vulnerable to contamination.
- The enclosed concrete sump and standard of maintenance suggests that there will be limited susceptibility to surface contamination specifically at the source.
- The protection zones delineated in this chapter 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:
  - flow monitoring is continued. Monitoring over a longer duration would enable accurate water balances to be undertaken and it would confirm whether the overflow continues during drier periods. A continuous flow through drier periods would suggest that a greater quantity may be abstracted if required.
  - karst mapping be undertaken in this area. This would highlight the possibility of further tracer testing work.
  - a drilling and groundwater monitoring programme be considered to determine groundwater levels, flow directions and gradients.
  - the present chemical and bacteriological analyses of raw water be continued. The chemical analyses should include all major ions – calcium, magnesium, sodium, potassium, ammonium, bicarbonate, sulphate, chloride, and nitrate.
  - the potential hazards in the ZOC should be located and assessed.
  - the sump and pump house area continue to be adequately maintained to minimise the risk of inundation by surface water at the source.

12 References

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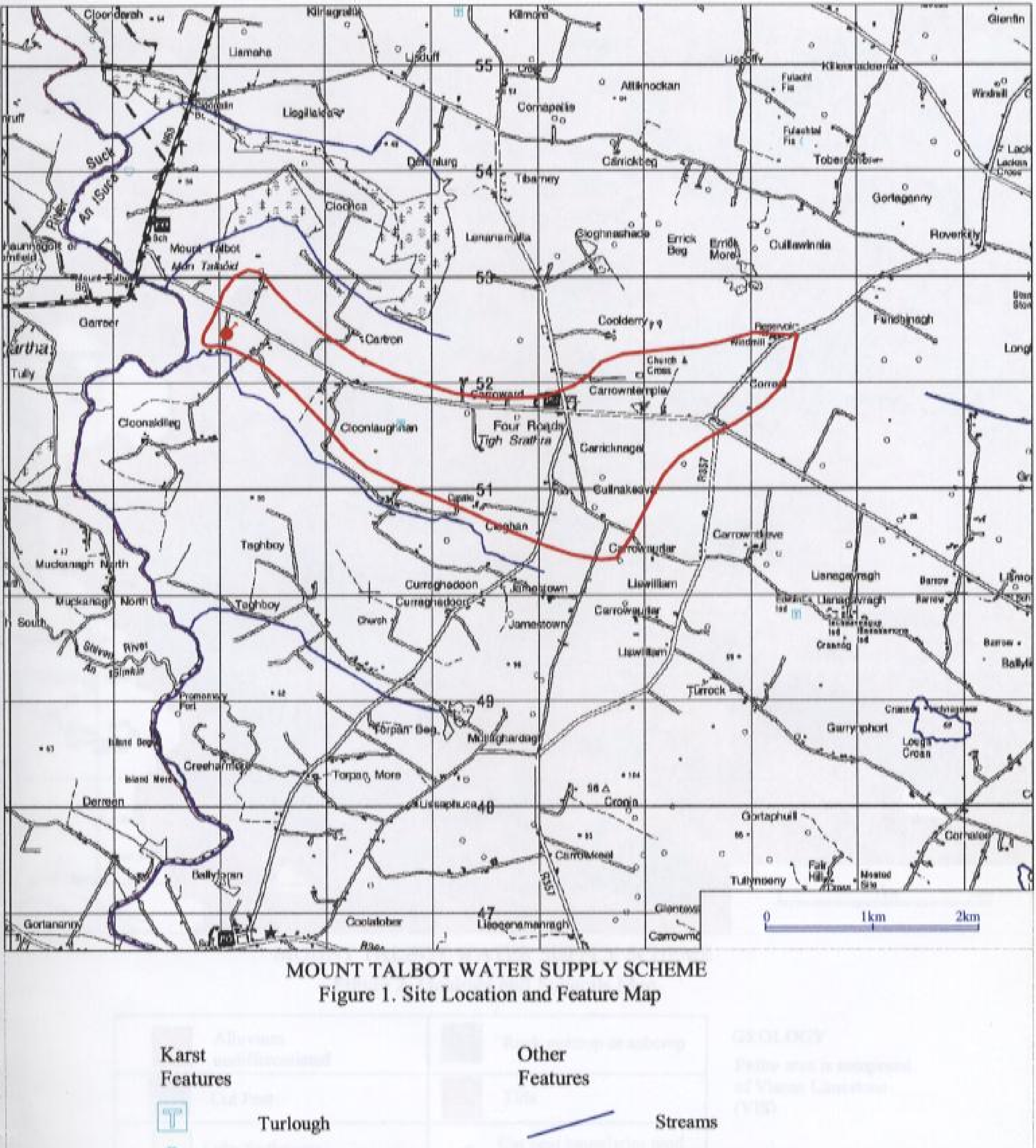
Figure 1. Site Location and Feature Map.

Figure 2. Geology and Subsoils Map.

Figure 3. Vulnerability Map.

Figure 4. Source Protection Zones.



MOUNT TALBOT WATER SUPPLY SCHEME
Figure 1. Site Location and Feature Map

Karst Features

- Turlough
- Enclosed Depression
- Swallow Hole
- Cave
- Spring

Other Features

- Streams
- Zone of contribution (ZOC)
- Public Supply Spring

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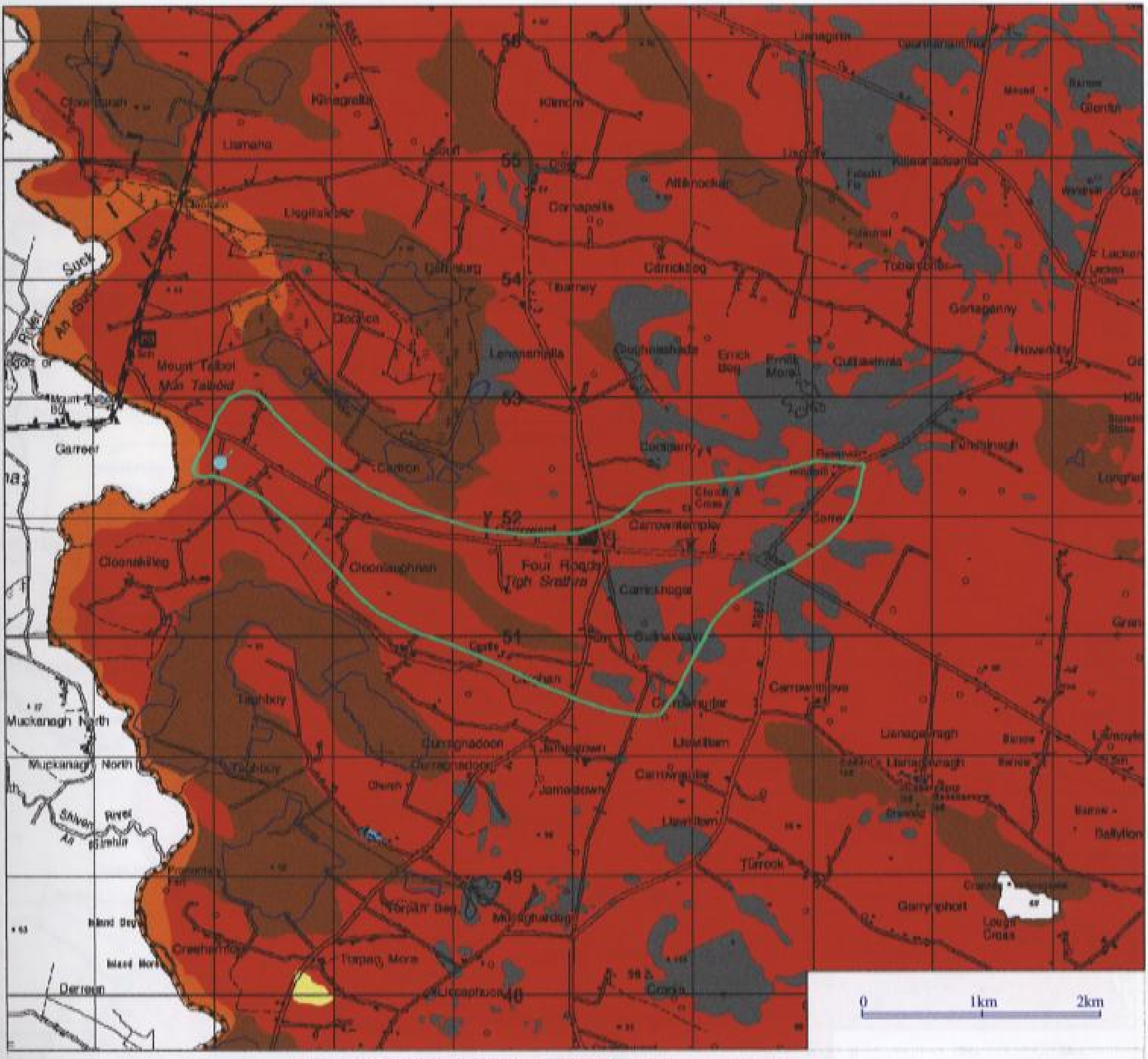


MOUNT TALBOT WATER SUPPLY SCHEME

Figure 2. Geology and Subsoils Map

Alluvium undifferentiated	Rock outcrop or subcrop
Cut Peat	Tills
Lake Sediments	Cut peat boundaries used for Vulnerability map
Lake	

GEOLOGY

Entire area is composed of Visean Limestone (VIS)

Zone of Contribution

Public Supply Spring

Sources of Information

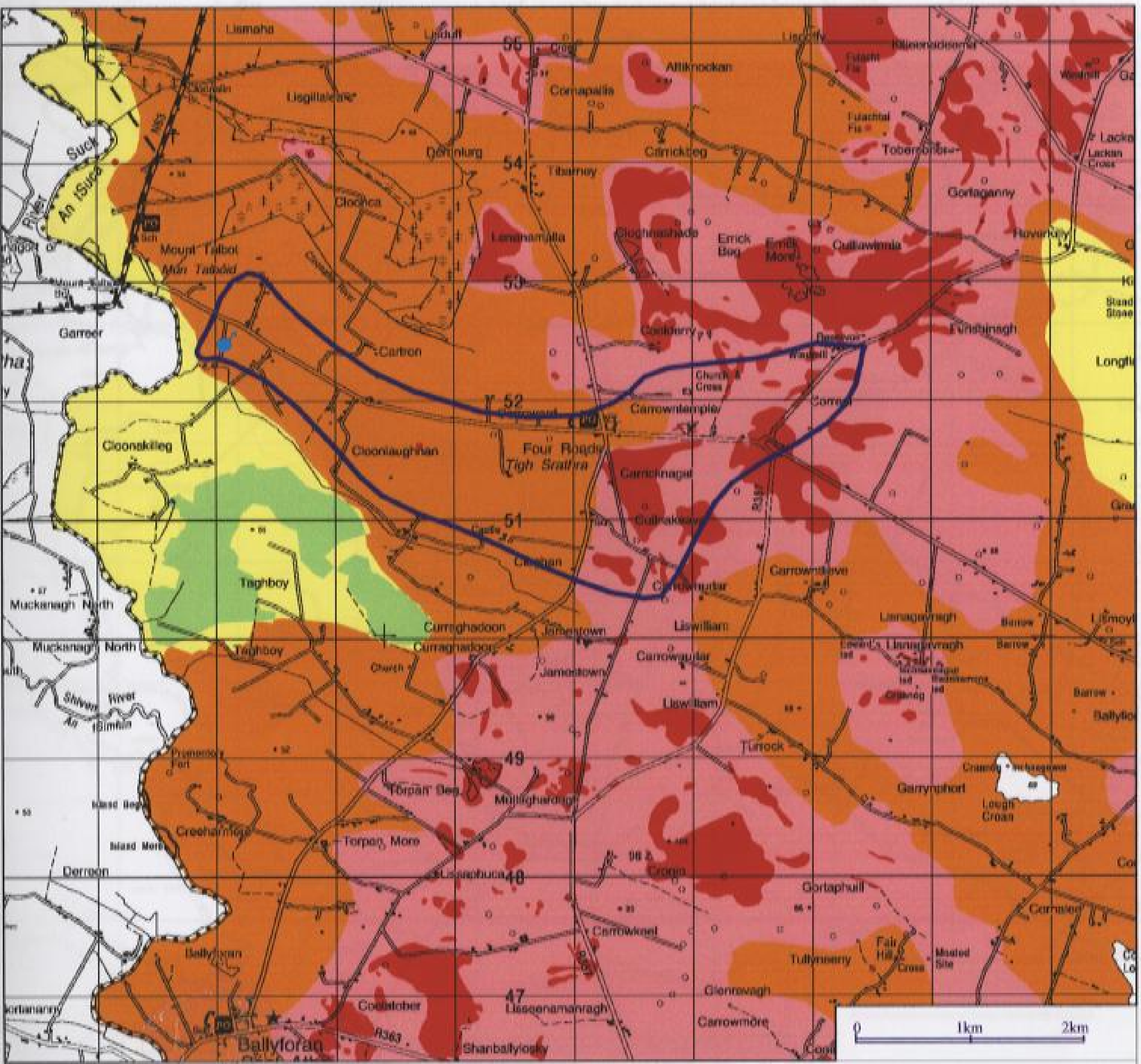
G.S.I. 1:100,000 Bedrock Series Sheet 12 : compiled by M.Geraghty, C.MacDermot and D.C.Smith.

"FIPS-IFS Soil Parent Material Map" Compiled by R. Meehan (Teagasc).

This **bedrock 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.

The topographic base is reproduced with the permission of the Ordnance Survey of Ireland



MOUNT TALBOT WATER SUPPLY SCHEME

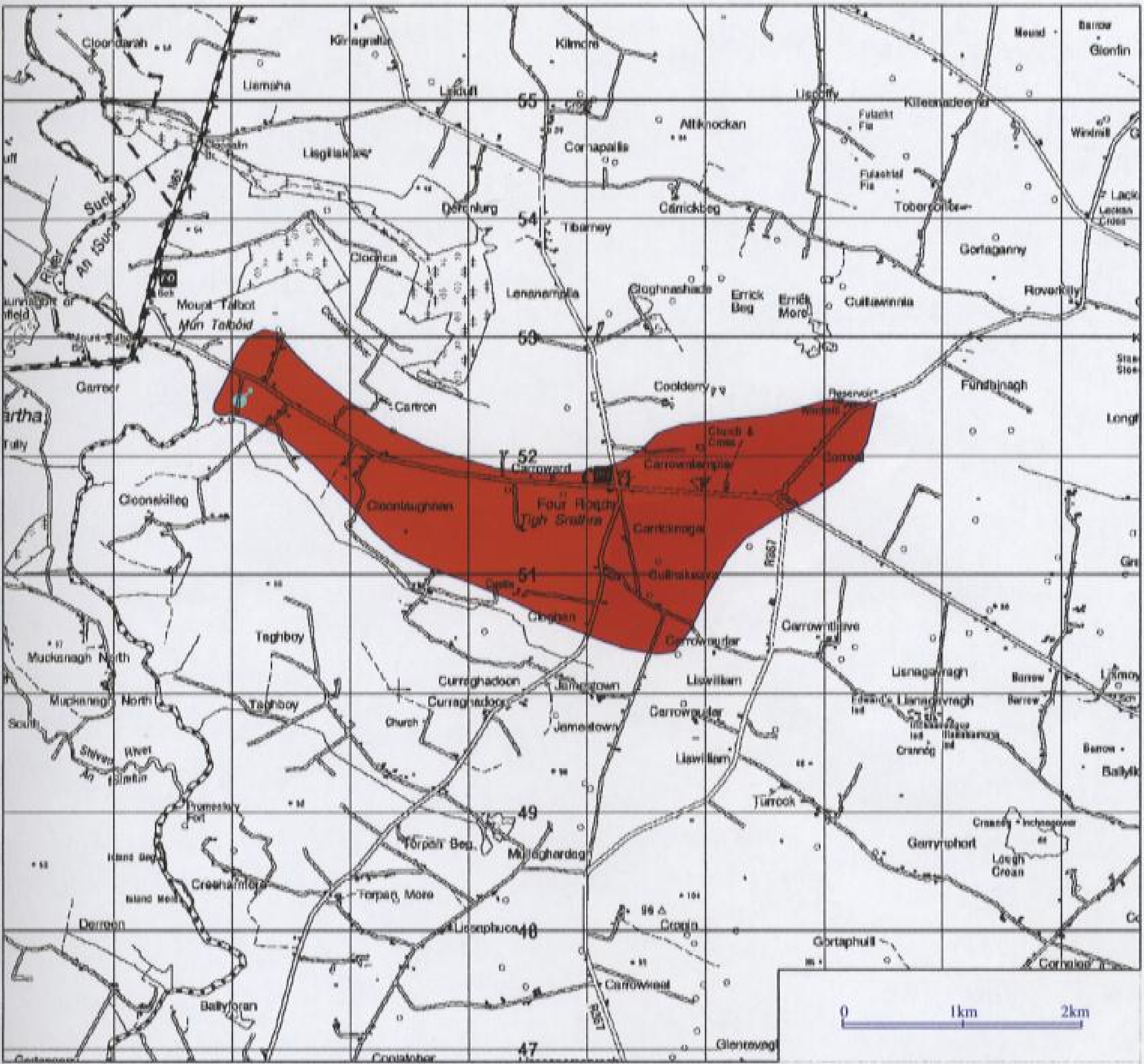
Figure 3.Vulnerability Map

- Extreme (E)
- Outcrop/Shallow rock (E)
- High (H)
- Moderate (M)
- Low (L)
- Zone of Contribution to Well
- Public Supply Spring

Vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities.

The map shows the **vulnerability** of the first groundwater encountered (in either sand/gravel aquifers or in bedrock) to contaminants released at depths of 1-2 m below the ground surface. Where contaminants are released at significantly different depths, there will be a need to determine groundwater vulnerability using site-specific data. The characteristics of individual contaminants have not been taken into account.

This **vulnerability** 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.



MOUNT TALBOT WATER SUPPLY SCHEME
Figure 4. Source Protection Zones

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

Zone of Contribution to well (SI)

Public Supply Spring

This **Source Protection Zone map** is designed for general information and strategic planning usage. The boundaries are based on the available evidence and local details have been generalised to fit the map scale. Evaluation of specific sites and circumstances will normally require further and more detailed assessements and will frequently require site investigations to determine the risk to groundwater.

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