Ballyvaughan Public Supply

Groundwater Source Protection Zones

Prepared by:

Colette Cronin, Donal Daly, Jenny Deakin & Denise Kelly,
Geological Survey of Ireland

Assisted by:

David Drew & Paul Johnston, Trinity College Dublin

In collaboration with:

Clare County Council

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‘Note:
Since this report was published, the Source Protection Area and, possibly, other component maps have been updated based on improved geoscientific evidence and hydrogeological knowledge. The most up-to-date version of the Source Protection Areas (SPAs) and other maps can be found on the Geological of Ireland (GSI) website (https://www.gsi.ie/en-ie/data-and-maps/Pages/default.aspx).’

1. Introduction

The objectives of this report are as follows:

- To delineate source protection zones for the Ballyvaughan Public Water Supply (PWS).
- To outline the principle hydrogeological characteristics of the Ballyvaughan area.
- To assist Clare County Council in protecting the water supply from contamination.

2. Location and Site Description

The Ballyvaughan Source is situated in the townland of Newtown approx. 1.5 km southwest of Ballyvaughan village, Co. Clare. The source comprises a bored well, located in the middle of a field, approx. 100 m from the pumphouse on the main Ballyvaughan - Lisdoonvarna road. The well is completed above ground level in a large concrete chamber. The well is not capped, however the chamber is protected by a steel cover which is padlocked.

3. Summary of Well Details

GSI no.	1119 NW W005
Grid ref. (1:25,000)	12199 20628
Townland	Newtown
Owner	Clare County Council
Well type	Bored well
Elevation (top of casing)	21 m OD
Depth	approx. 65 m
Diameter	0.2 m (8”)
Depth-to-rock	2.5 m
Static water level	varies due to tidal fluctuation
Drawdown (wet weather)	< 1cm
Current Abstraction	500 m^3/d (Summer abstraction)
Pumping test summary	(i) Abstraction rate: 500 m^3/d
	(ii) Transmissivity: 3000 m^2/d
Yield test summary	(i) 277 m^3/d tested 12/9/80
	(ii) 555 m^3/d tested 9/9/81
	(iii) 360 m^3/d tested 3/6/82

4. Methodology

The assessment involved three stages; (a) a detailed desk study, (b) site visits and fieldwork, and (c) analysis of the data. The desk study was conducted in the Geological Survey where bedrock geology information was compiled from a geology map of the Ballyvaughan area (McDermot, 1998) and subsoils were compiled from the GSI Subsoils Map of County Clare (Bloetjes, 1998). Basic public supply well details such as borehole depth, elevation, abstraction and pumping test data were obtained from GSI records and County Council personnel.

The second stage comprised site visits and fieldwork in the Ballyvaughan area. This included carrying out water tracing, well surveys, pumping tests etc. to aid in the conceptualisation of the hydrogeology. Vulnerability to contamination and the current pollutant loading in the valley were also examined. Advice on karst hydrogeology was provided by David Drew and Paul Johnston.

Stage three, the assessment stage, utilised field studies and a knowledge of karst hydrogeology to delineate protection zones around the public supply well.

5. Topography, Surface Hydrology and Land Use

The Newtown Source is located along the Ballyvaughan valley between Corkscrew hill to the south and Ballyvaughan Bay to the north (Map 1). Cappanawalla mountain is directly west of the source and rises to an elevation of 312 m, Aillwee Mountain is located approximately 2.5 km south east of the source and is 300 m in elevation.

The soils and subsoils are relatively free draining in the vicinity of the source and there are few drainage channels along the Ballyvaughan valley. The most notable surface water feature is the Rathborney River which flows down the Rathborney valley and sinks in the Ballyvaughan valley approx. 2 km south of the PWS (see Map 4). In times of heavy rainfall the Rathborney river flows further northward before sinking (see Map 6).

Agriculture is the principal activity in the area immediately surrounding the source. Most of the land is used for pasture, with a smaller proportion used for tillage. A number of houses and farmyards are present in the general vicinity of the well. There is an Interpretative Centre directly west of the PWS adjacent to Newtown Castle.

6. Geology

6.1 Bedrock Geology

The bedrock geology of the Ballyvaughan area is a product of the deposition of sediments during Carboniferous times (over 300 million years ago) and on the subsequent folding of these sediments. The rock units of the area, which are shown in Map 1, are summarised below.

Age	Formation	Member
Carboniferous	Clare Shales	
	Slievenaglasha Limestone	
	Burren Limestone	Aillwee Upper Unit Aillwee Lower Unit Maumcaha Unit Fanore Unit Blackhead Unit

6.1.1 Burren Limestone Formation

The Burren limestone is a pale to medium grey, pure limestone and is the main rock type in the Ballyvaughan valley. The Burren Limestone is fossiliferous, medium to coarse grained and contains some shale and chert bands. This limestone is subdivided into a number of rock units: Blackhead, Fanore, Maumcaha, Aillwee Lower and Aillwee Upper limestones.

6.1.1.1 Blackhead Unit

This unit contains thickly bedded limestones with some dolomite horizons occurring in the Bishopsquarter area to the east of Ballyvaughan valley. This unit can best be seen along the coast at Ballyvaughan Bay.

6.1.1.2 Fanore Unit

This is a medium bedded limestone which contains some thin shale bands. There are some chert bands evident in the Acres area to the east of the study area. The Newtown Source is located within this unit.

6.1.1.3 Maumcaha Unit

This limestone is clean, massive, unbedded and is poorly jointed. It occurs along the southern part of the Ballyvaughan valley.

6.1.1.4 Aillwee Lower Unit

This is a thick, clean limestone which contains clay wayboards (clay bands).

6.1.1.5 Aillwee Upper Unit

This unit is clean, thickly bedded and quite similar to the Aillwee Lower Unit. Both the Upper and Lower Aillwee units can be clearly picked out by their terraced appearance on the slopes of Cappanawalla and Gleninagh Mountain.

6.1.2 Slievenaglasha Formation

This rock unit occurs in the Poulacapple area and is a pale grey, clean, coarse grained limestone. Fossiliferous horizons such as the Upper Faunal Zone and the Lower Faunal Zone occur within this unit. This limestone also contains chert bands.

6.1.3 Clare Shales

These comprise dark, grey to black mudstones and shales and occur to the south of Poulacapple. The Clare Shales are known to be the source of the spa waters of Lisdoonvarna further south. The spa waters mineralisation comes from the pyritic and sometimes phosphatic rocks of the shale sequence.

6.1.4 Structure

The limestone rock units have been gently folded from north to south. The rocks in the area are dipping approx. 1-5° to the south. Associated with folding and faulting is the development of fissures/fractures. The trend of these fractures is likely to be in a NNE-SSW orientation similar to the trend of the Ballyvaughan valley. This trend is also reflected in the Fergus River valley area and may be significant in terms of understanding the direction of groundwater flow at depth.

6.2 Subsoil Geology

The subsoils in the Ballyvaughan area are shown in Map 2 and are subdivided into limestone till, peat and shale/sandstone till.

6.2.1 Limestone Till

Limestone till deposits occur over much of the area and are derived from the underlying limestone bedrock. The texture varies from stony to silty across the valley. The stony limestone till is found close to bedrock particularly where the deposits are relatively thin. This stony till has then been broken down further by ice movement to form silt size particles.

6.2.2 Peat

Peat deposits occur to the south of Poulacapple. These deposits are very thin and reflect a change in the underlying geology to poorly drained shalier deposits.

6.2.3 Shale/Sandstone Till

Shale and sandstone tills occur south of the peats and are derived from the Clare shales.

6.2.4 Depth to Bedrock

Accurate information on depth to bedrock is based on outcrop information, well records, subsoil sections and drilling. Over much of the upland mountainous areas depth to bedrock is generally < 1m. Subsoils in the valley are generally between 3 and 10 m thick and in some localised areas picked out on aerial photographs, subsoils are greater than 10 m e.g. at Lough Rask and in the vicinity of Croagh North. Depth to bedrock at the public supply well is 2.5 m thick. Outcrop and depth to bedrock information is given in Map 3.

7. Hydrogeology

7.1 Data availability

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

- 12 hour and 20 hour pumping tests were carried out by the GSI in August 1997 and 1998, respectively.
- A study of the Ballyvaughan valley carried out as part requirement for an M.Sc at University College London (Kelly, 1998). Much of the hydrogeological information used in this report was compiled as part of that study. Such information includes water level measurements, water tracing, geophysics, well surveys, water sampling, pumping test data, depth to rock and vulnerability assessment.
- Ongoing research and numerous publications by Dr. David Drew on the Burren region.
- County Clare Groundwater Protection Scheme, currently being undertaken by Jenny Deakin.
- Subsoil mapping carried out by Oscar Bloetjes, Quaternary Section, GSI.
- VLF geophysics carried out in February 1998 by Jenny Deakin and Michael Hanrahan.

7.2 Meteorology and Recharge

Rainfall data for the area are taken from a contoured rainfall map of Co. Clare, which is based on data from Met Éireann. For 1951-1980, the mean annual rainfall (R) for the area was 1585 mm. Potential evaporation (P.E.) is estimated to be 575 mm/yr (from Met Éireann data). Actual evapotranspiration (A.E) is then calculated as 95 % of P.E. i.e. 546 mm/yr. Runoff is taken to be 10% of available recharge in the Ballyvaughan valley and is estimated to be 104 mm. These calculations are summarised below:

Average annual rainfall	1585 mm
Estimated P.E.	575 mm
Estimated A.E. (95 % P.E.)	545 mm
Available recharge	1040 mm
Surface Runoff (10%)	104 mm
Recharge	936 mm

This is a conservative estimate of recharge which allows for surface water outflow during periods of exceptionally heavy rainfall. However in view of the karstic nature of the catchment, runoff is likely to be much lower for most of the year and all of the available recharge probably infiltrates into the aquifer.

7.3 Groundwater levels

Much of the work carried out on the Burren region indicates that there is no continuous water table surface over much of the karstified Burren limestone. Instead water is channelled along conduits and fissure systems and therefore rises to different levels across the region. Water level information for the Ballyvaughan area, though limited, does support the conceptual model of highly variable water levels across the Ballyvaughan valley.

Water levels measured by GSI staff at the Newtown PWS have ranged from 8.2 mOD (1/7/1998) following a period of low rainfall to overflowing at approx. 21m OD (8/97) following a period of very heavy rainfall. It is probable that in exceptionally dry weather, the water levels will be much lower. Daily water levels at the well vary over a range of on average 1 m due to tidal effects. As the tide rises it has two effects. Firstly, some saline water is likely to migrate inland. Secondly, fresh groundwater flowing out of the Ballyvaughan valley into Galway Bay backs up behind the saline water and thus water levels rise inland to a distance south of Newtown borehole. There is a lag effect observed at the well: approx. 1 hr 20 mins after high tide in Ballyvaughan Bay, water levels in the well begin to fall. After very heavy rainfall, water levels rise and large volumes of freshwater in the valley flow into Galway

Bay. This prevents seawater from migrating inland and the tidal effect is damped out. It is unusual in non karstified limestones to observe this tidal effect at a distance of 2 km from the sea, however in this karstic terrain where flow is concentrated along conduits, the effect is magnified. In other areas of highly karstified limestone such as in Kinvarra, this effect is observed 8 km inland.

After exceptionally heavy rain the PWS becomes artesian indicating that confining conditions occur in times of high flow. It seems unlikely that the limestone till which overlies much of the valley is thick enough or impermeable enough to cause confining conditions and it is more likely that chert bands in the Fanore and Blackhead limestones are confining groundwater in times of rapid recharge.

7.4 Groundwater Flow Directions and Gradients

A number of connections in the Ballyvaughan region have been made using tracer tests (see Map 5):

1) From the Poulacapple sink to the PWS, Monks springs and the Burren Exposure springs.
2) From a sink immediately south of Poulacapple to the Fergus River.
3) From the Berneens sink to the PWS, the Fergus River, Monks springs and the Burren Exposure springs.
4) From the Aillwee Access Road sink to Monks springs and the Burren Exposure springs.
5) From Aillwee Mill sink to Monks springs and the Burren Exposure springs.

These water tracing tests indicate that groundwater in the Ballyvaughan valley is flowing in a north to northeasterly direction and discharging at the intertidal springs along the coast. Tracer tests have also shown there may be some southerly flow along bedding planes and clay wayboards within the Aillwee limestone units particularly in the upland regions surrounding the valley. Possible flow mechanisms are discussed in Section 7.8.

There are variable water levels in Ballyvaughan indicating that hydraulic gradients probably vary significantly across the area. Water is also likely to be flowing at different levels in the limestones which may or may not be connected thus indicating that significant vertical hydraulic gradients may exist.

7.5 Aquifer Characteristics

A pumping test carried out in August 1997, following a period of heavy rain caused a drawdown of approx. 1 cm at the current abstraction rate of 500 m^3/d. After similar conditions in August 1998, pumping had no effect on water levels as so much freshwater was backed up in the valley. These tests suggest that pumping has a marginal effect on water levels at the PWS following periods of moderate to high rainfall. No pumping tests were carried out following very dry periods and therefore it is not known whether pumping at such times would cause significant drawdowns.

Pumping test data could not be readily analysed using conventional methods due to the fact that the well is affected by tidal fluctuations. Tidal regression analysis was employed instead which gave an aquifer transmissivity of approx. 3000 m^2/d. Assuming the aquifer thickness is 57 m (approximate saturated depth of the well at the time of pumping) then permeability is estimated to be 53 m/d. This estimate, together with the knowledge that pumping has little effect on water levels in the well, indicates that the permeability in the vicinity of the PWS is very high. Tracer tests indicate that water travels at 500 to 3600 m/d northward from the mountainous areas toward the coast. These flow rates depend on factors such as topography, rainfall, relative heads etc. and reflect how fast water can travel in karstified limestone aquifers.

Three yield tests were carried out at the PWS by the County Council in the period 1980 to 1982. It is not known with certainty whether the variation in yield is due to the pump capacity or to the well efficiency at different water levels. Rainfall records for the Ballyvaughan area are not available for this period, however at Kinvarra, rainfall in Sept 1980 was relatively high whereas rainfall in Sept 1981 and June 1982 was much lower. This rainfall data does not explain the lower yield (277 m^3/d) in Sept 1980 or the higher yield (555 m^3/d) in Sept 1981 but may explain the lower yield in June 1982 (360

m^3/d). Therefore from the available information it is not clear whether the Newtown supply is limited by variable recharge conditions. It is possible that these test results were limited by the pump capacity and do not reflect the flow conditions at the well (Newell, pers comm).

The Ballyvaughan valley is underlain by limestones which have been intensively karstified. Such areas are characterised by:

- groundwater flow in solutionally-enlarged bedding plane partings, joints, faults and conduits;
- high groundwater velocities – several orders of magnitude greater than in granular (sand/gravel) aquifers;
- concentration of groundwater flow into zones of high permeability;
- a high degree of aquifer anisotropy and heterogeneity, resulting in uncertainty in hydrogeological predictions;
- a combination of diffuse and point (through swallow holes, sinking streams) means of recharge;
- poor predictability in well yields and therefore in locating water supplies;
- low storage of groundwater and significant variations in well yield, depending on water levels and recharge, with the potential for large reductions in abstraction rates as water levels drop;
- irregular or poorly connected water table;
- irregular cones of depression around pumping wells;
- difficulties with well construction due, for example, to collapse of boreholes, loss of circulation during drilling, pumping of sand and/or silt;
- often exreme vulnerability to contamination;
- 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.

7.6 Aquifer Category

The Carboniferous Limestone units are classed as Regionally Important karstified aquifers **(Rk).** The Clare Shales are classed as a Poor aquifer which is generally unproductive **(Pu).** (For more information refer to the Co. Clare Groundwater Protection Scheme (Deakin *et al,* 1999).)

7.7 Hydrochemistry and Water Quality

Over the month of July 1998 temperature, conductivity and pH were monitored at the public supply well. Temperature ranged from 10.75 to 11.75 ^{o}C, pH ranged from 6.75 to 7.5 and conductivity (at 25^{o}C) ranged from 300 to 580 µS/cm (at 20^{o}C). A significant drop in conductivity was recorded at the PWS soon after a period of heavy rainfall. A water sample taken during July 1998 indicated that water quality in the PWS appears to be good as all major cations and anions are within the EU limits. Nitrate and chloride concentrations in particular are significantly less than EU maximum admissible concentrations (MAC). Nitrate levels range from 0.15 to 8.9 mg/l and chloride levels range from 5 to 21 mg/l across the valley. Bacteriological analysis of the raw water sample indicated high total and faecal coliform counts at the Newtown supply.

7.8 Conceptual Model

- The Newtown supply is located within the Fanore Limestone but probably intersects the Blackhead limestone at depth. Both these rock units are likely to be contributing to the PWS (see Cross sections in Appendix 1, Figs 1, 2; Lines of section are given in Map 4).

- Water levels in the Ballyvaughan valley are highly variable as water flows in zones of enhanced permeability such as along bedding planes, fissures, cave systems and conduits.

- The groundwater flow direction in the Ballyvaughan area is northeast toward Galway Bay.

- Following periods of heavy rainfall much of the flow in the valley is conducted by large fissures and the Rathborney River in a northeasterly direction toward the sea. A large proportion of this water is likely to bypass the well which probably taps only a small proportion of the flow. The zone of contribution probably extends upgradient along linear zones of enhanced permeability. A drop in conductivity recorded at the well following heavy rainfall, indicates rapid recharge to the well. At such times water levels in the PWS are primarily influenced by recharge and tidal effects, and not by pumping therefore the well is unlikely to draw any water from down gradient.

- In drier periods, recharge into the karstified limestone aquifer is limited. The well is probably supplied by a network of fractures and fissures and the resulting zone of contribution is likely to encompass a much larger area up gradient. The well may also draw water from the area down gradient, however there is no evidence to confirm this as no pumping tests were carried out during dry weather.

- There are a number of different flow mechanisms operating in the region which are summarised below (and are illustrated in Appendix 1, Fig 3):
  1) Shallow flow is occurring in the upper few metres of highly weathered and karstified limestone, commonly referred to as *epikarst*. Surface level karst features in the region include sink holes, caves, springs and the limestone pavement typical of the Burren landscape; these features are shown in Map 4. In dry weather it is unlikely that the source receives any significant water supply from this shallow depth, however in wet weather the well may be fed by flow in the epikarst.
  2) The well is probably fed largely at greater depth by both the Fanore and Blackhead Limestones. Positive water traces (see Map 5) from Poulacapple and Berneens sinkholes indicate connection from these upland areas to the Newtown Source. It is probable that a series of vertical conduits allow flow to occur rapidly downward through the Slievenaglasha, Aillwee and Maumcaha limestones before travelling horizontally through fracture zones in the Fanore and Blackhead limestones toward the coast.
  3) Alternatively water may flow downdip through the shallow epikarst before sinking through the Maumcaha limestone. The Maumcaha limestone is generally perceived to be less permeable than the other limestones (D. Drew, pers comm) and the exact flow mechanism in this unit is not fully understood. It is likely to be more permeable in certain areas e.g. the Rathborney River sinks into the Maumcaha limestone and a number of springs also discharge from this limestone to the north of Cappanawalla. These more permeable areas may be restricted to the epikarst.
  4) Deep flow in the Fanore and Blackhead limestones travels between confining chert layers before discharging into the bay as intertidal and submarine springs. These springs are dotted along a NNE - SSW trend which probably indicates the general orientation of flow in the Ballyvaughan valley.
  5) The Rathborney River flows southward down the Rathborney valley before flowing northward into the Ballyvaughan Valley. The river sinks about 2 km south of the PWS depending on the flow conditions and travels underground in a northerly direction before discharging at the intertidal and submarine springs. Although there is no evidence from tracer tests that the Rathborney River is supplying the PWS, this possibility cannot be ruled out.

7.9 Catchment Delineation

The boundaries of the ZOC are shown in Map 6 and are defined as follows;

Northern Boundary

1) The northwestern boundary of the ZOC is defined as the topographic divide on Cappanawalla mountain. Water to the north of this boundary is more likely to flow directly downgradient toward the sea.

2) The northern boundary is more problematic to define. There is little information available on how far the source can draw water from the down gradient area to the north of the source. The pumping test indicates that in wet conditions little drawdown occurs near the well. However in dry conditions, pumping the well may draw water from the north. Therefore this boundary encompasses an arbitrary distance of 750 m down gradient of the well to allow for expansion of the ZOC in dry conditions.

(This is a conservative estimate which needs to be discussed with David Timlin and Mary Burke, Clare Co. Council.)

Eastern Boundary

1) There is a proven connection between the Aillwee access road sink and the intertidal springs at Monks and the Burren Exposure (refer to Map 5). There is also a proven connection from the Berneens sink to the PWS and to the intertidal springs. The northeastern boundary of the ZOC is based on the trace connecting Aillwee sink to Monks springs. Water to the east of this boundary will probably flow directly to the coast and is unlikely to reach the PWS.

2) The southeastern boundary of the ZOC is the catchment divide between water flowing northeastward to Aillwee millsink and water flowing southwestward toward Berneens stream.

Southern Boundary

This boundary is defined as the catchment divide between all water flowing northward to Ballyvaughan Bay and that water which flows southward to the Fergus River. Dye inserted at the Poulacapple injection site was detected in Ballyvaughan Bay indicating a northeasterly direction of flow from this site. Dye injected at another site immediately south of Poulacapple (see Map 5) was detected in the Fergus River. Similarly dye injected at Berneens has been detected in both valleys north and south. These tracers tests indicate that the groundwater divide runs in the vicinity of these injection sites. It is therefore necessary to include the catchment of the Berneens stream and the Poulacapple sink within the zone of contribution to the well.

Western Boundary

This boundary is defined as the topographic divide running from Gleninagh mountain southward to Poulacapple mountain. It seems likely that water to the west of this divide flows westward to the sea via the Caher valley.

An estimate of the ZOC size is generally obtained by using the average recharge and the abstraction rate. The water balance calculation for the Newtown PWS indicates that the delineated area is far greater than that required to supply the well. However, a) as this is a karst area a large proportion of groundwater outflow from the Ballyvaughan valley will bypass the well, particularly in wet weather, b) in dry weather, water from any part of this area could enter the well. Therefore, in view of the variable groundwater flow directions and the uncertainties associated with karst areas, a precautionary approach is taken in delineating the ZOC boundaries.

8. Delineation Of Source Protection Areas

8.1 Introduction

Two source protection areas are delineated:

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

8.2 Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100 day time of travel (TOT) to the source and it is delineated to protect against the effects of potentially contaminating activities which may have an immediate influence on water quality at the source, in particular microbial contamination. Due to the highly permeable, karstic nature of the limestone aquifer in Ballyvaughan, it is probable that all groundwater in the ZOC can travel to the public supply well in less than 100 days. (While this conclusion is arguable, it is advisable to take the precautionary approach in view of the uncertainties concerning flow in karstic limestones.) The entire ZOC is therefore taken to lie within the Inner Protection Areas and is delineated in Map 6.

8.3 Outer Protection Area

The Outer Protection Area includes that part of the ZOC outside the 100 day TOT zone. In the Ballyvaughan area, the Outer Protection Area is not present.

9. Vulnerability

Much of the area is overlain by limestone till deposits. Although the texture of these deposits is variable, they are assumed to have a moderate permeability based on field assessment. Depth to bedrock information indicates that these subsoils are generally less than 3 m in thickness with the exception of a few small areas in the coastal area of the valley. Over much of the zone of contribution, depth to bedrock is < 1 m and groundwater is considered "extremely vulnerable" *(Ex)* to contamination. Where bedrock is at a depth of 2–3 m, such as at the Newtown source; groundwater is considered "probably extremely vulnerable" *(E)* to contamination. Where subsoils are between 3 and 10 m thick, the groundwater is classed as being "probably highly vulnerable" *(H)*. In isolated locations the subsoils are > 10 m and these areas are classed as "probably moderately vulnerable" *(M)*. There are also some definite areas of vulnerability delineated by symbols on the Vulnerability Map (Map 7).

10. Groundwater Protection Zones

The groundwater protection zones are obtained by integrating the two elements of land surface zoning (source protection areas and vulnerability categories) – a possible total of 8 source protection zones (see the matrix in the table below). In practice, the source protection zones are obtained by superimposing the vulnerability map on the source protection area map. Each zone is represented by a code e.g. **SI/H**, which represents an Inner Protection area where the groundwater is highly vulnerable to contamination. There are 3 groundwater protection zones present around the Newtown Source (Map 8), as shown in the matrix below. Since the entire ZOC lies within the Inner Protection Zone there are no separate zones for the Outer Protection Area.

Matrix of Source Protection Zones

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

It is not within the scope of this report to delineate the resource protection zones in the surrounding area and this is dealt with at the regional resource protection scale.

The accompanying response measures imposing restrictions on developments will follow when discussions have been carried out between the Council, the EPA and the GSI as to the degree of restriction recommended in each protection zone.

11. Potential Pollution Sources

The land in the vicinity of the source is largely grassland-dominated and is primarily used for grazing. Agriculture is the principal activity in the area, however tourism is becoming increasingly important in the Ballyvaughan valley. The main potential sources of pollution within the ZOC are farmyards, septic tank systems and landspreading of organic fertilisers. The main potential pollutants are faecal bacteria, viruses and cryptosporidium.

12. Conclusions and Recommendations

- The source at Newtown is an excellent yielding well, which is located in a regionally important karstified limestone aquifer.

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

- The northern boundary of the ZOC is defined with a large degree of uncertainty. In order to define this boundary with greater certainty some additional work could be carried out, such as:

1) water tracing from the public supply well to the coast to determine whether the two are connected by a single conduit or a diffuse network of fissures.
2) drilling shallow holes in the vicinity of the PWS to determine whether flow in the epikarst could be contributing to the well.
3) conducting a repeat trace from the Rathborney River sink to determine whether any surface water is supplying the source.
4) conducting a trace downstream of the PWS in dry weather to check for any flow back up the valley.
5) conducting a pumping test in dry weather at the PWS, and monitoring water levels in an observation well down gradient to determine whether the PWS draws water southwards.
6) monitoring water levels at the PWS and the observation well over a prolonged period.

- It is recommended that:
  1) In karst areas, monitoring at regular intervals may not provide a good indication of the variability in water quality.
  2) a full water analysis should be carried out on a regular basis.
  3) particular care should be taken when assessing the location of any activities or developments which might cause contamination at the PWS.
  4) the potential hazards in the ZOC should be located and assessed.

- The protection zone delineated in the report is 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.

13. References

Bloetjes, O., (1998) Draft Subsoils Map for County Clare. Quaternary Section, Geological Survey of Ireland.

Deakin, J. & Daly, D. (1999) Draft Groundwater Protection Scheme for County Clare. Groundwater Section, Geological Survey of Ireland.

Drew, D., (1990) The Hydrology of the Burren, Co. Clare. Irish Geography 23 (2) p 69-89.

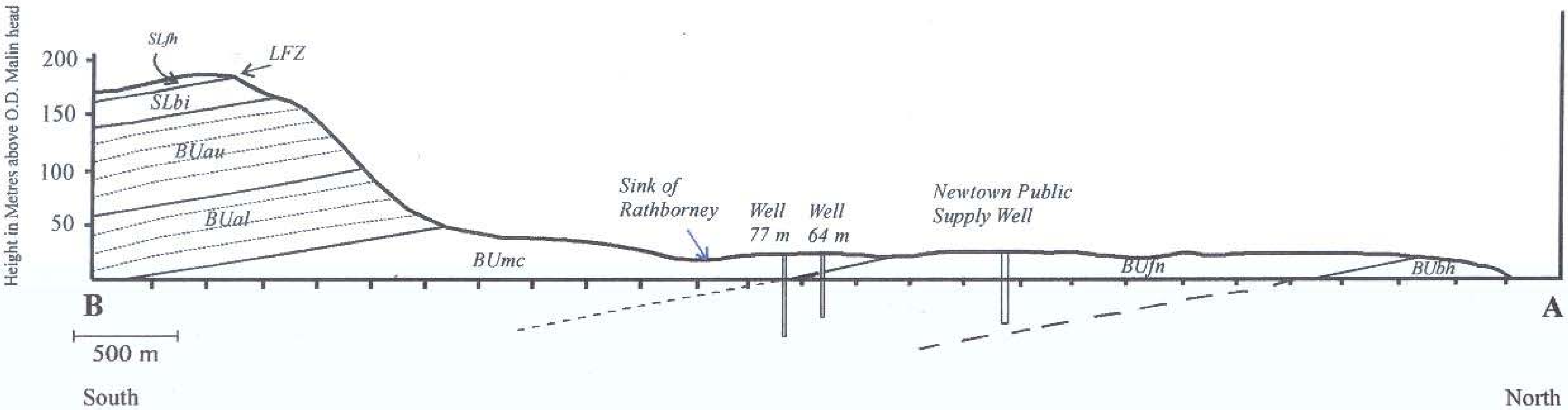
Kelly, D. (1998). An Assessment of the Hydrogeology of the Ballyvaughan Valley, Co. Clare. Unpublished M.Sc. thesis, University College London.

McDermot, (1998). Draft Geology of Sheet 14, Geological Survey of Ireland.

Newell, H (1998), Area Engineer, Clare County Council.

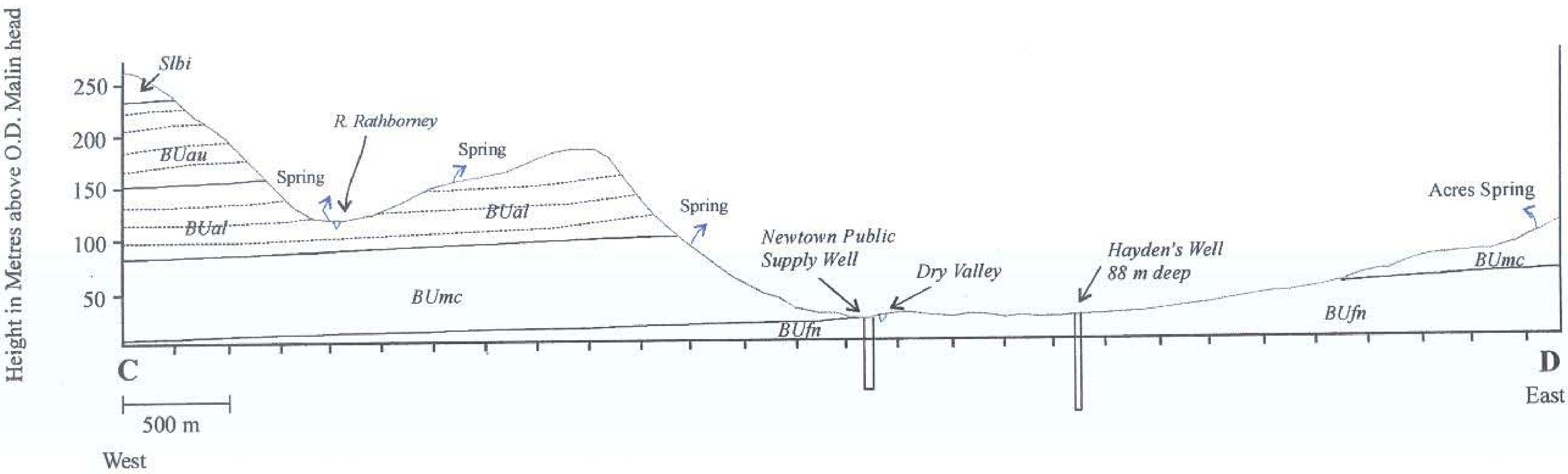
APPENDIX 1

Fig 1 Cross Section A-B Along the Ballyvaughan Valley
(with vertical exaggeration of x 5)



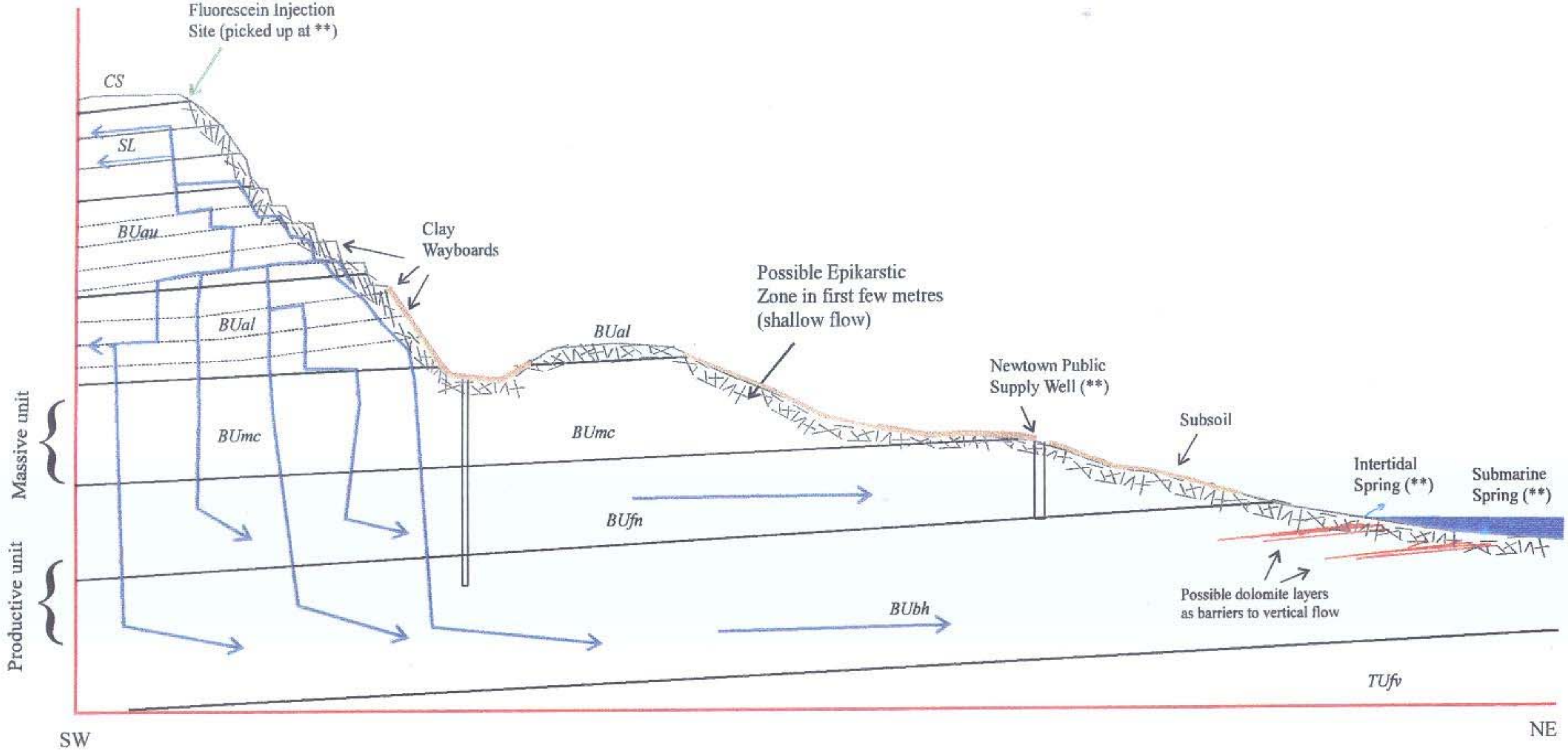
SLfh	Slievenaglasha Limestone (Fahee North Member) (with **UFZ** at top and **LFZ** at base)
SLbi	Slievenaglasha Limestone (Ballyvoe Member)
BUau	Burren Limestone (Aillwee Upper Member)
BUal	Burren Limestone (Aillwee Lower Member)
BUmc	Burren Limestone (Maumcaha Member)
BUfn	Burren Limestone (Fanore Member)
BUbh	Burren Limestone (Blackhead Member)

Fig 2 Cross Section C-D across the Ballyvaughan Valley
(with vertical exaggeration of x 5)



SLbi	Slievenaglasha Limestone (Ballyvoe Member)
BUau	Burren Limestone (Aillwee Upper Member)
BUal	Burren Limestone (Aillwee Lower Member)
BUmc	Burren Limestone (Maumcaha Member)
BUfn	Burren Limestone (Fanore Member)
BUbh	Burren Limestone (Blackhead Member)

Fig 3 Schematic diagram of groundwater flow and summary of conceptual model of the hydrogeology of the valley



Geology

CS	Clare Shales
SL	Slievenaglasha Limestone
BUau	Burren Limestone (Aillwee Upper Member)
BUal	Burren Limestone (Aillwee Lower Member)
BUmc	Burren Limestone (Maumcaha Member)
BUfn	Burren Limestone (Fanore Member)
BUbh	Burren Limestone (Blackhead Member)
TUfv	Tubber Formation (Finavara Member)

Legend

Epikarstic Layer

Possible Groundwater Flow Direction

Dolomitic Layer

Groundwater Source Protection for Newtown Public Supply

Map 1: Bedrock Geology

Coastline

Geological Contact

Newtown 500 — Newtown Public Supply Well

AGE			CODE	ROCK FORMATION	DESCRIPTION
CARBONIFEROUS	UPPER	Namurian	CS	Clare Shales Formation	Dark grey mudstones with thin horizons of phosphate at the bottom
CARBONIFEROUS	LOWER	Brigantian	SL	Slievenaglasha Limestone Formation	Clean, coarse grained limestone with fossiliferous horizons
			SLll	Lissylisheen Unit	Limestone
			SLbe	Ballyelly Unit	Chert bands at the base of limestone with crinoid sands interrupted by darker finer packstones
			SLfh	Fahee Unit	Middle, principally cherty, limestone Predominantly packstones and wackestones
			SLbi	Ballyvoe Unit	Limestone
		Asbian	BUau	Burren Limestone Aillwee Upper Unit	Thick bedded clean limestone separated by some clay wayboards
			BUal	Burren Limestone Aillwee Lower Unit	Thick bedded limestone separated by clay wayboards
			BUmc	Burren Limestone Maumcaha Unit	Very massive, clean, unbedded limestone with very poor jointing
		Holkerian	BUfn	Burren Limestone Fanore Unit	Medium bedded limestone with some shale partings. May have argillaceous or cherty bands running through it
			BUbh	Burren Limestone Blackhead Unit	Thick bedded limestones with some dolomitisation

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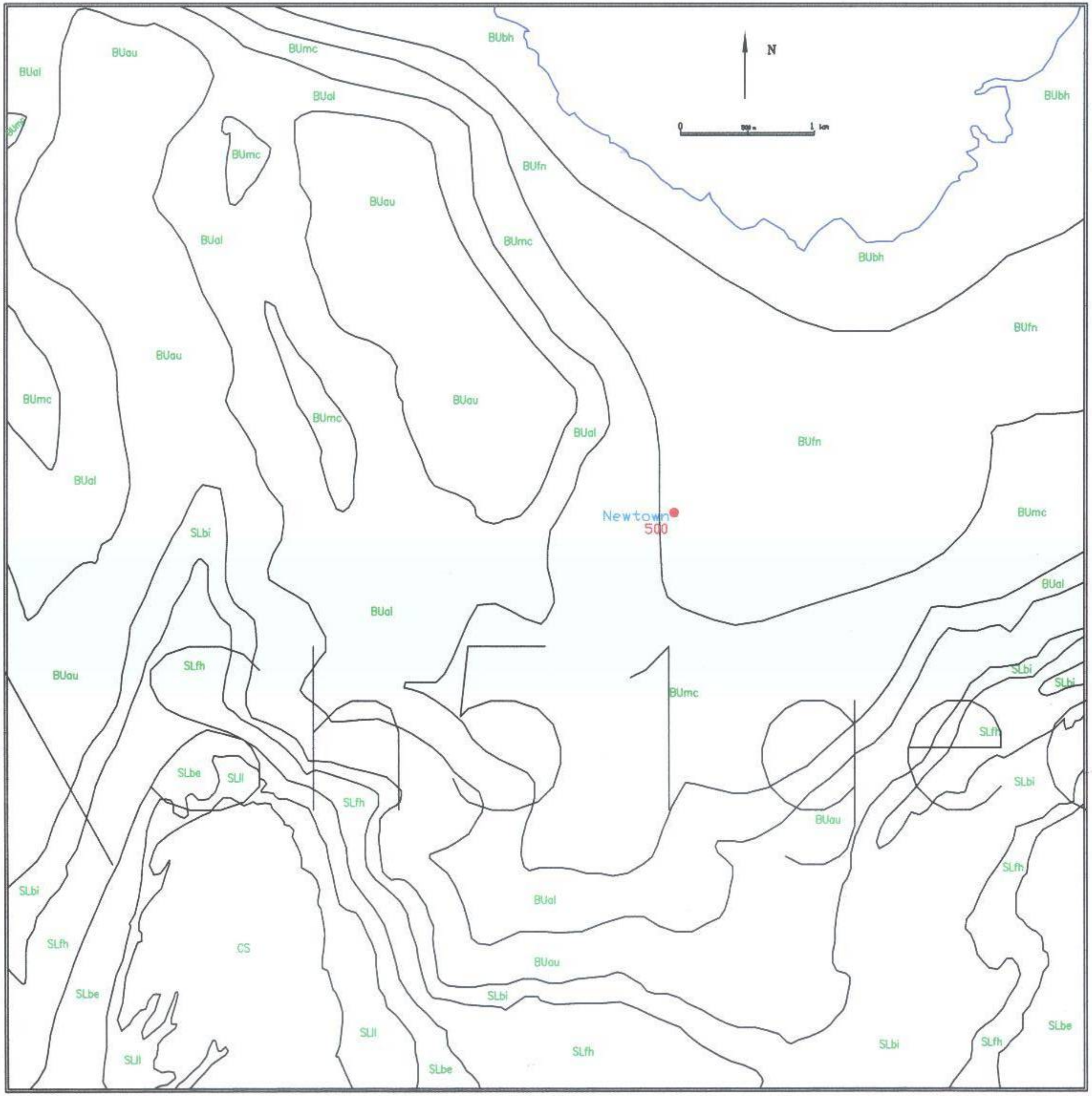


Groundwater Source Protection for Newtown Public Supply

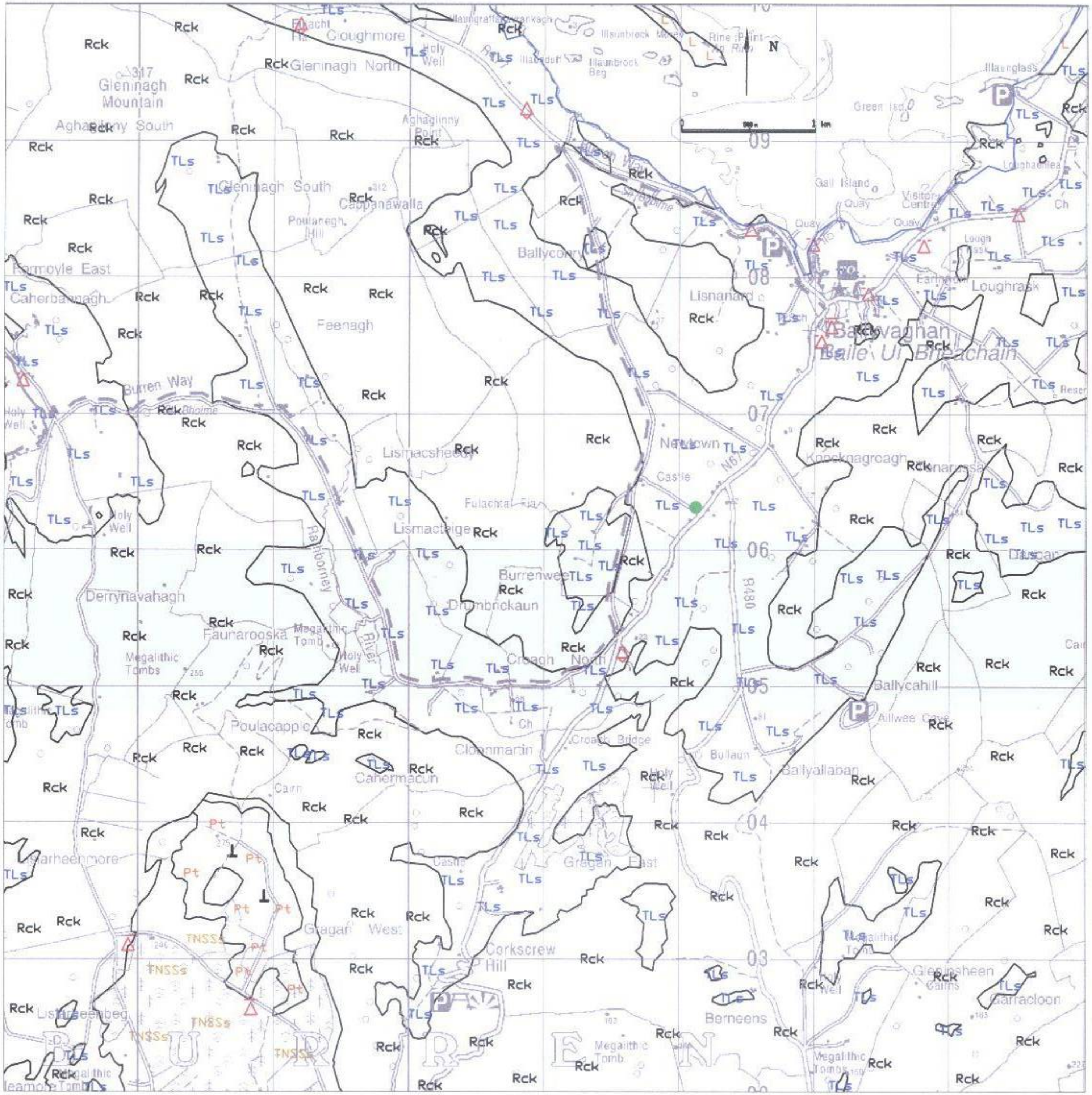
Map 2: Subsoil Geology

Subsoil Types

Rck	Rock Outcrop & Shallow Bedrock
TLs	Limestone Till (Carboniferous)
TNSSs	Shales & Sandstone Till (Namurian)
Pt	Peat
L	Lake Sediments

Sample Points

- Sand and Gravel
- Stony Till
- Silty Till
- Clayey Silty Till
- Clayey Till
- Peat



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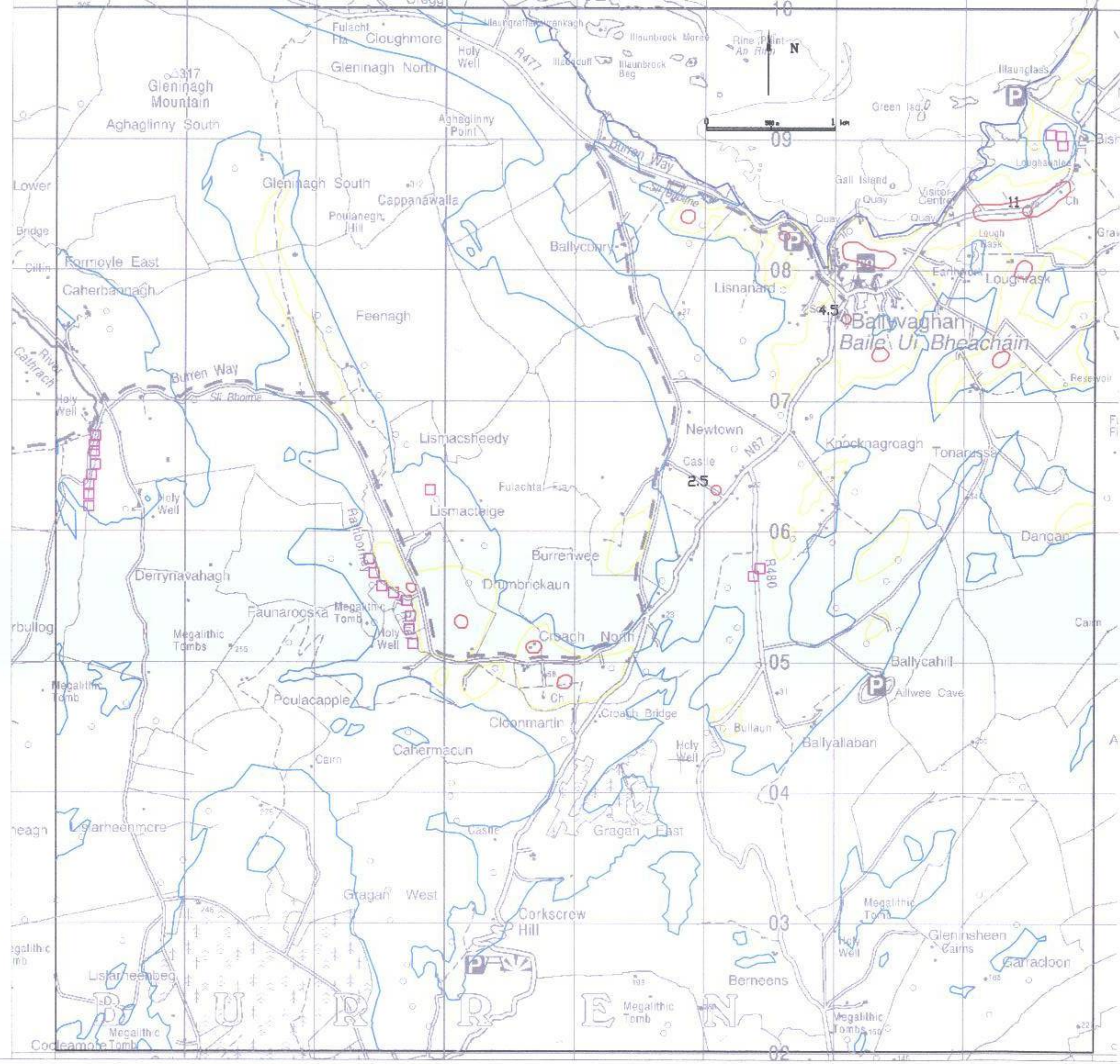
Map 3: Outcrop and Depth to Bedrock

Depth to Bedrock Contours

- 0–1 m Contour (rock at or close to surface)
- 3 m Contour
- 10 m Contour

Depth to Bedrock Points

- Outcrop
- 10 Depth to rock 10m. Borehole located to within 50m



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Map 4: Hydrogeological Data

Coastline

Geological Contact

BUmc Stratigraphic code

A B Line of Section

Hydrogeological Features

Private Well

Newtown 500 Public Supply Well with abstraction

Failed Well

Well: Yield Unknown

Karst Features

Turlough

Spring

Cave

Collapse Feature

Swallow Hole

Dry Valley

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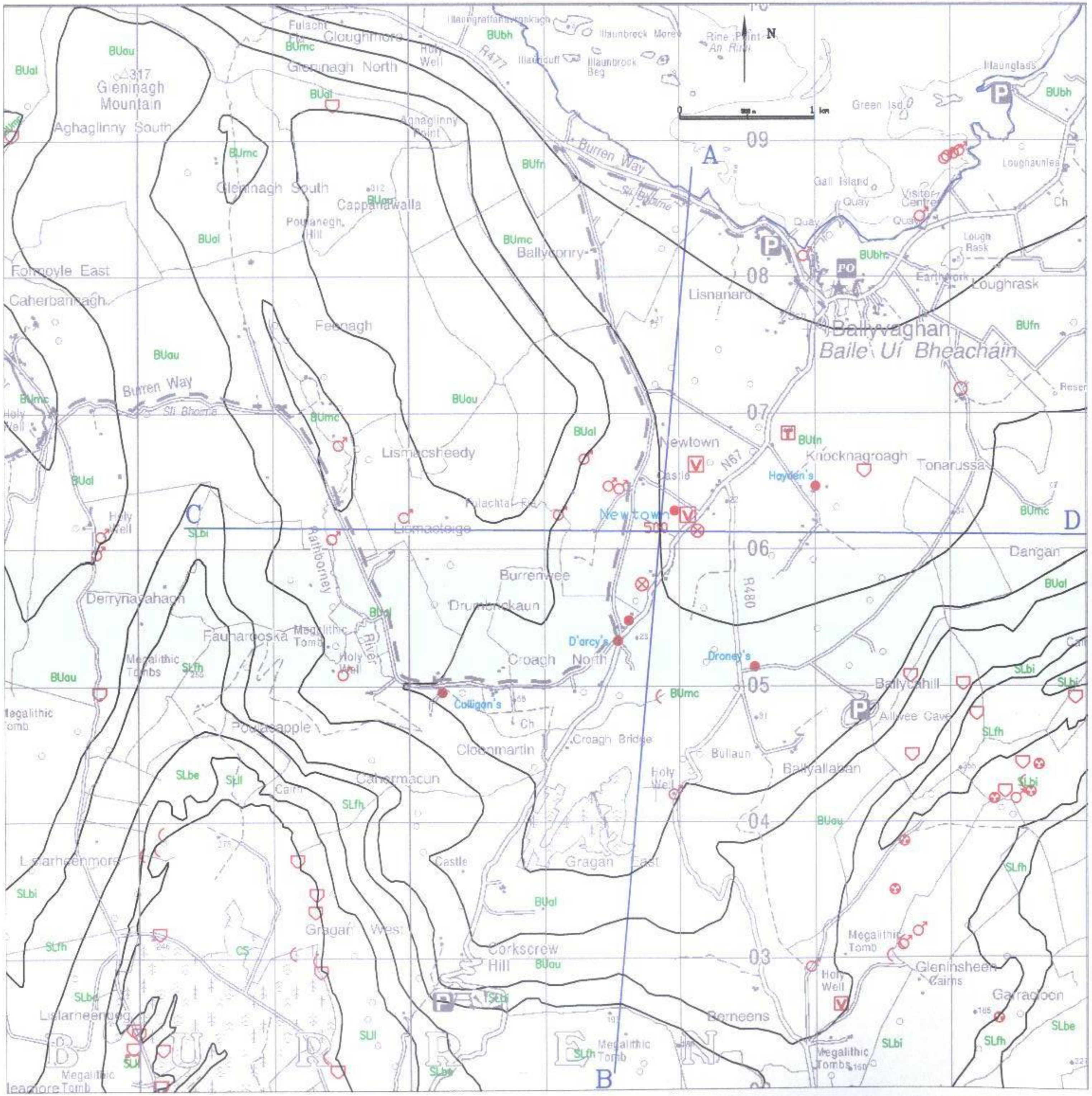

Groundwater Source Protection for Newtown Public Supply

Map 5: Water Tracing Connections

Injection Site

Sampling Site

Proven connection

Fluorescein - this study

Rhodamine WT - this study

Leucophor - this study

Previous - other studies

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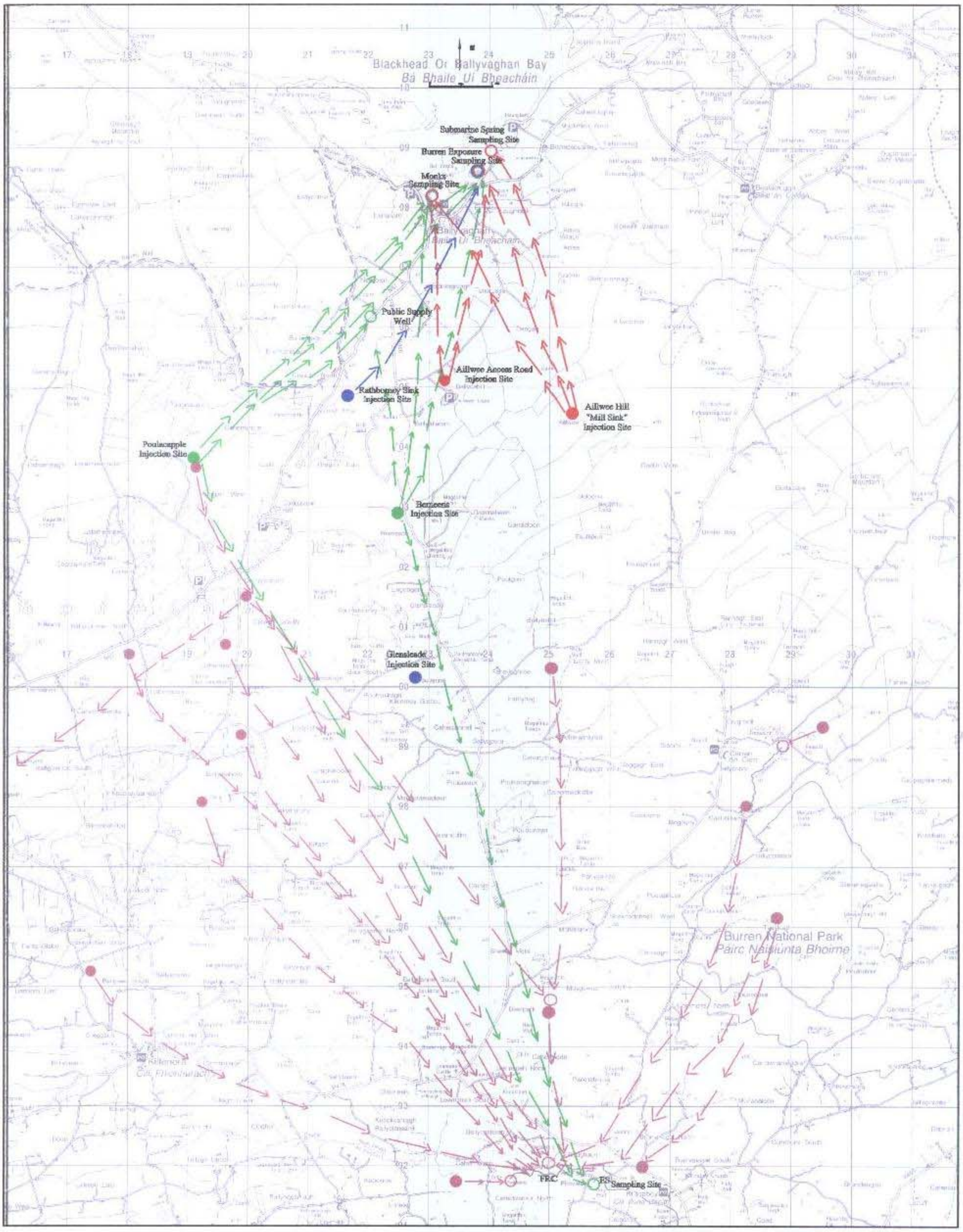

Groundwater Source Protection for Newtown Public Supply

Map 6: Zone of Contribution

Coastline

Perennial River or stream

Inrermittent Section of Stream

Newtown 500 Newtown Public Supply Well

Boundary of Zone of Contribution

Karst Features

Dry Valley

Swallow Hole

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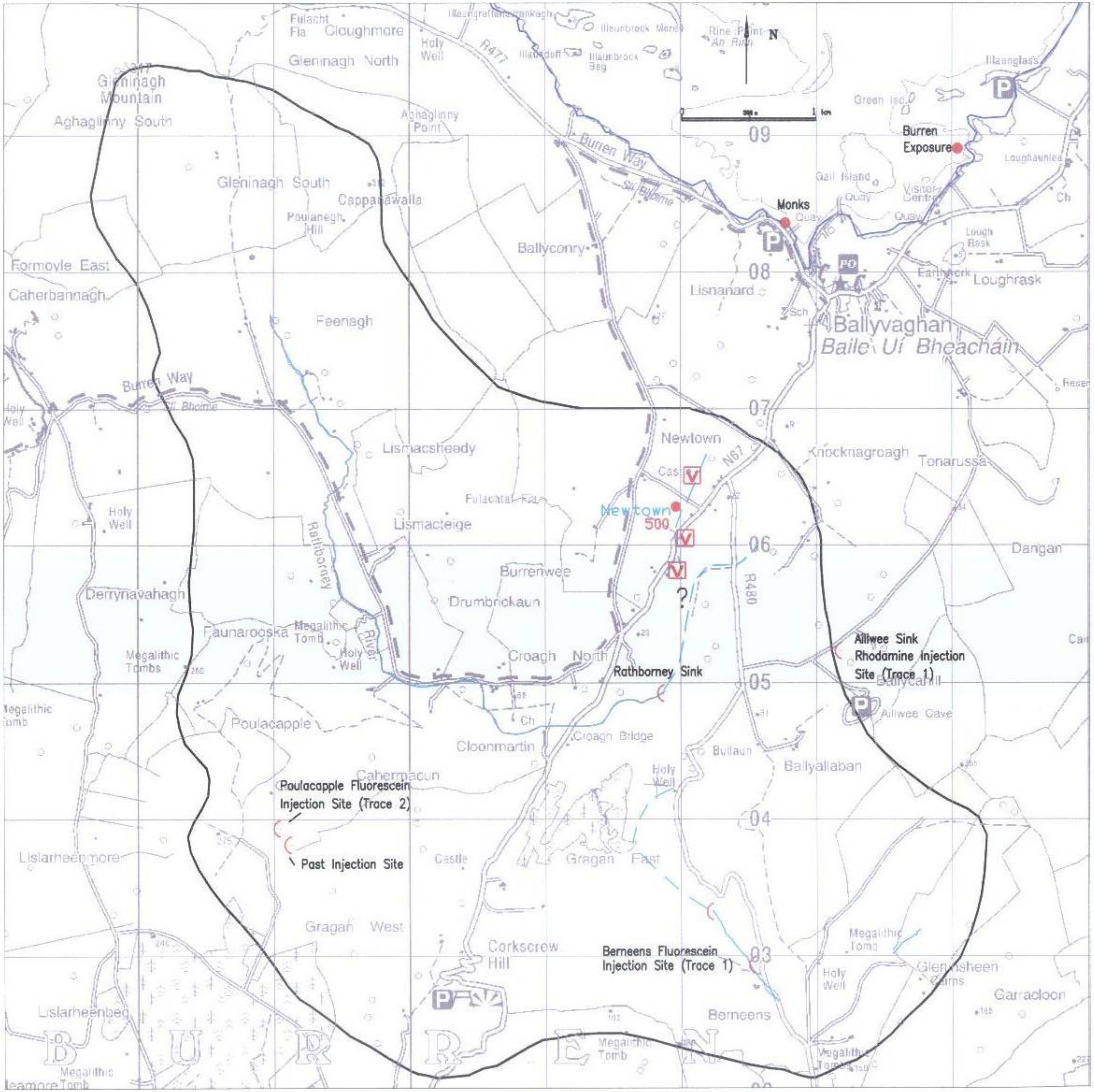
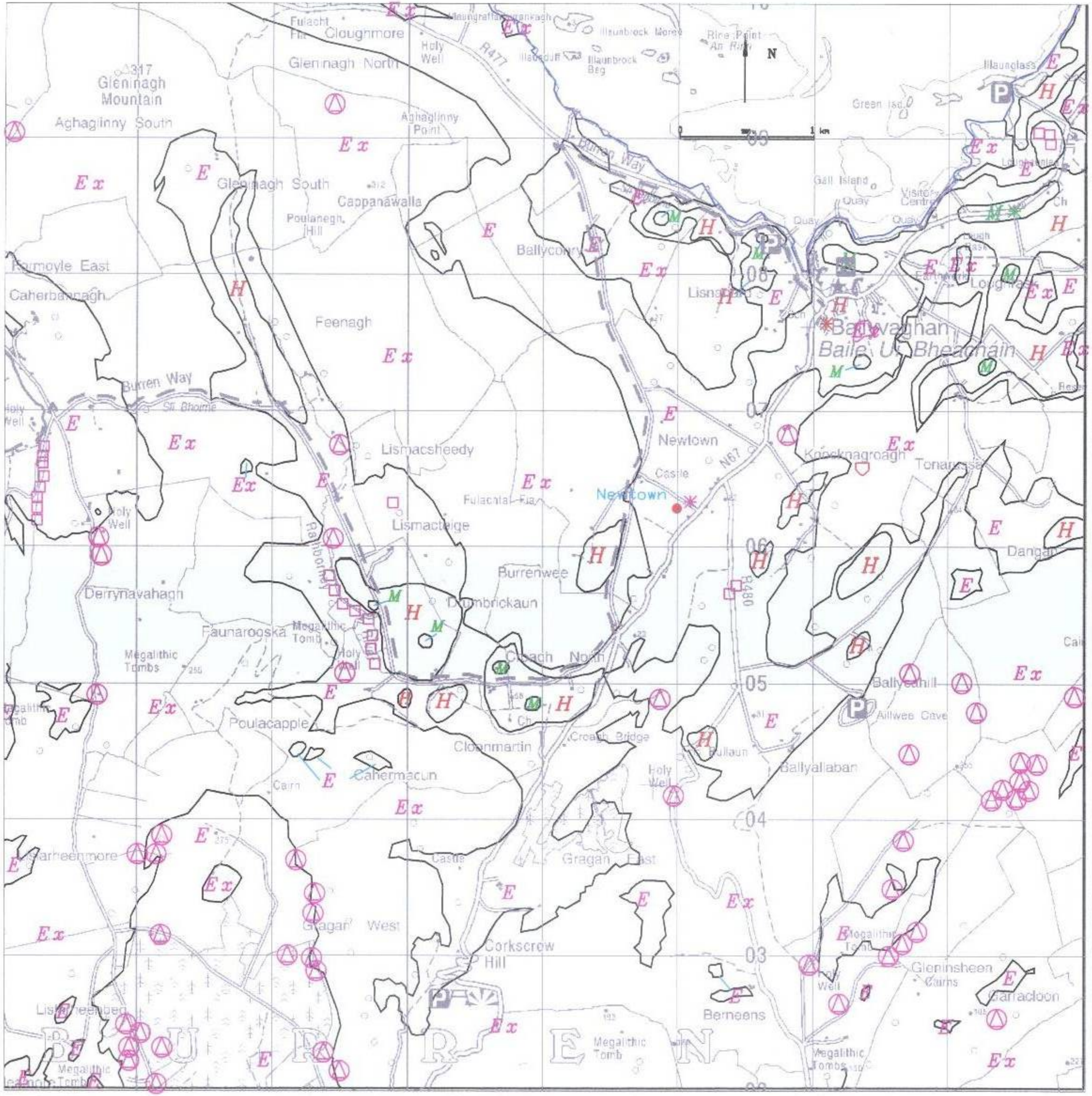


Groundwater Source Protection for Newtown Public Supply

Map 7: Groundwater Vulnerability

Vulnerability

	Vulnerability Classification Boundary	
Ex	Rock Close	Extreme
□	Isolated Outcrop	Extreme
✳	Borehole (extreme)	Extreme
E	Probably Extreme	
✳	Borehole (high)	
H	Probably High	
✳	Borehole (moderate)	
M	Probably Moderate	
Newtown •	Public Supply Well	
	Karst Features – Extreme Vulnerability	



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Groundwater Source Protection

for Newtown Public Supply

Map 8: Groundwater Source Protection Zones

Coastline

NEWTOWN 500 Newtown Public Supply Well

Boundaries

Vulnerability Boundary

Protection Zones

SI/E	Inner Protection Area – Extreme
SI/H	Inner Protection Area – High
SI/M	Inner Protection Area – Moderate
SI/E	Outer Protection Area – Extreme
SI/H	Outer Protection Area – High
SI/M	Outer Protection Area – Moderate

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Digitised by: Denise Kelly

Amended by: Denise Taylor

September 1999

December 2003

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