ARDMORE PUBLIC SUPPLY

GROUNDWATER SOURCE PROTECTION ZONES

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.

ARDMORE PUBLIC SUPPLY

1. Summary of Well Details

GSI no.	:	2007SE W014
Grid ref. (1:25,000)	:	21852 07876
Townland	:	Monea
Well type	:	Bored
Drilled	:	May 1994
Owner	:	Waterford Co. Co.
Elevation (ground level)	:	14.8 m OD.
Depth	:	73 m
Depth of casing	:	unknown
Diameter	:	200 mm (8")
Depth to rock	:	14 m
Static water level	:	1.92 m O.D. (12.88m b.g.l.) on 21/5/97
Pumping water level	:	1.57 m O.D. (13.23 m b.g.l.) on 20/5/97
Drawdown	:	0.35 m
Normal consumption	:	<100 m^3/d (Winter), 200 - 300 m^3/d (Summer)

Pumping test summary:

(i) abstraction rate	:	770 m^3/d
(ii) specific capacity	:	300 m^3/d/m
(iii) transmissivity	:	170 m^2/d

2. Methodology

There were three stages involved in assessing the area: a detailed desk study, site visits and fieldwork, and analysis of the data. The desk study was conducted in the Geological Survey where bedrock geology information was compiled from the original 6" field sheets and from the GSI report and map of Sheet 22 (Sleeman & McConnell, 1995). Well details, such as borehole geometry, elevation, and abstraction rate, were obtained from Waterford County Council. Pumping test data, geophysical investigation data and a report on the source and surrounding area were provided by Jer Keohane, who advised on the location and drilling of the well in 1993/1994.

The second stage comprised site visits and fieldwork in the Ardmore area. This included a walkover survey in order to further investigate the subsoil and bedrock geology, the hydrogeology, the vulnerability to contamination and the current pollutant loading. Robert Meehan mapped the subsoil types and assessed depth to bedrock throughout the area. Jer Keohane and Paul Johnston advised on the conceptual model of groundwater conditions at Ardmore. Advice on numerical modelling was provided by Paul Johnston.

Stage three, the assessment stage, utilised analytical equations, hydrogeological mapping and numerical modelling to delineate protection zones around the public supply well.

3. Topography, Surface Hydrology and Land Use

The Ardmore public supply well is located 1.4 km north of Ardmore village in a broad east-west trending, steep sided valley, which has an elevation <15 m OD. North of the well the land rises to an elevation of 75 m OD. The land to the south of Ardmore rises up to an elevation of 67 m OD.

There are two streams in the area: one is 1.5 km to the west at Listeige, flowing southward to the sea; the second is south of the well and flows eastwards through the village itself (Figure 1). Neither stream has a significant flow as the land is very free draining and there is little surface runoff.

The sandy soils, particularly to the north of Ardmore, are suitable for market gardening, although the land is predominantly used for grazing.

4. Well Head Protection

The well is located beside a pumphouse on a site which is walled off. The casing in the well is not grouted and the well head (i.e. top of casing) is approximately 1.2 m below ground level. The well is protected by a secure manhole cover at ground level and there is unlikely to be any surface drainage into the well.

5. Geology

5.1 Bedrock Geology

The bedrock geology of the Ardmore area is dependent on the deposition of different sediments during Carboniferous and Devonian times (over 300 million years ago) and on the subsequent folding of these sediments. The rock units in the area, which are shown in Figure 1, are as follows:

Age	Formation	Thickness
Carboniferous:	Waulsortian Limestone	400 - 750 m
	Ballysteen Limestone	300 m
	Crows Point rock unit	73 m
Devonian:	Ardmore rock unit	107 - 154 m
	Ballyquinn rock unit	390 m

5.1.1 Gyleen Sandstone

In the Ardmore area, the Gyleen Sandstone has been subdivided into two. The Ballyquinn rock unit comprises thick grey and red medium grained sandstones and thick red mudstones. The Ardmore rock unit is distinguished by regular alternations of grey and red sandstones and grey siltstones.

5.1.2 Lower Limestone Shale

These strata are represented in the Ardmore area by the Crows Point rock unit. This unit is composed predominantly of thick massive and cross laminated grey sandstones with minor mudstones. The occurrence of these beds may be related to a break of slope (Keohane, 1993).

5.1.3 Lower Carboniferous Limestones

This rock succession is subdivided into two units, the Ballysteen Limestones and the Waulsortian Limestones. The Ballysteen Limestones are dark-grey, fossiliferous limestones, with shale partings. The Waulsortian Limestones are a combination of fine grained calcareous beds and coarser grained limestones. They are pale in colour, poorly bedded and often contain calcite filled cavities.

Although the boundary between these two rock units has been traced along the coast, it is less well defined inland owing to poor exposure and so they have not been differentiated in Figure 1. The

Monea source is likely to be located in the Waulsortian Limestones on the basis of rock chippings retrieved during drilling (Jer Keohane, pers. comm.).

5.1.4 Structure

The rock units in Ardmore have been deformed by folding during the Hercynian mountain building event. These rocks were compressed from north and south to produce an east-west trend to the current rock distribution and ultimately to the topography of the Ardmore area. The softer, more soluble limestones are present in the fold trough (syncline), which corresponds to the valley. The harder, more resistant sandstones are present in the fold crest (anticline), which corresponds to the ridges north and south of the Ardmore valley. Commonly associated with folding is jointing and faulting – an example of this is the north-south trending fault to the west of Ardmore.

5.2 Quaternary (subsoils) Geology

The subsoils in the Ardmore area are shown in Figure 2, and have been subdivided into sandy till, Irish Sea till, slope deposits, river alluvium and beach sands.

5.2.1 Sandy Till

These are the most extensive deposits in the Ardmore area, and are best observed in drains and stream cuttings. They contain small limestone and sandstone fragments in a predominantly sandy matrix. In the field to the west of the well, the till is very sandy. There may be gravel lenses in the area.

5.2.2 Irish Sea Till

To the north-east of the area, between the sandstone ridge and the coast, there are thick occurrences of over-consolidated clayey till. This is overlain by thinner deposits(<2 m) of sandy till.

5.2.3 Slope Deposits

These are present on the sandstone ridges, are generally <1 m thick, and are fragment-dominated with a sandy matrix.

5.2.4 River Alluvium

These deposits occur along the banks of the stream in the Listeige area; they comprise sands and silts and are believed to be approximately 2 m thick.

5.2.5 Beach Sands

These occur along the beach sections of Ardmore.

5.3 Depth-to-rock

Accurate information on depth to bedrock is based on outcrop information, well records and subsoil sections. Rock outcrops are visible along the coast, in a limestone quarry east of the public supply well and in cuttings on the sandstone ridges. Quaternary mapping in the general area suggests that the thickness of the sandy till covering the upland areas is generally less than 1 m thick. Over much of the valley floor the sandy till is more than 10 m thick. Subsoil thicknesses have been contoured at 3m and 10m intervals and an additional 5m contour was delineated in the lower permeability sediments (see Figure 3). The depth-to-rock contours are based on relatively few data points, however they can be refined as further depth-to-rock data become available.

6. Hydrogeology

6.1 Data availability

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

- A study of the groundwater in Ardmore (Keohane, 1993).
- County Waterford Groundwater Protection Scheme, (Hudson *et al*, 1997).
- A local well survey, which involved measuring static water levels in a number of domestic and farm wells around Ardmore in 1997.

6.2 Meteorology and Recharge

Rainfall data for the area are taken from a contoured rainfall map of Co. Waterford, based on data from the Met Éireann (Hudson *et al*, 1997). For 1951 - 1980, the mean annual rainfall (R) for the area was 1000 mm. Evaporation data for the area are taken from a national contoured map produced by the Met Éireann. Potential evapotranspiration (P.E.) is estimated as 500 mm/yr. Actual evapotranspiration (A.E.) is then calculated by taking 95% of the potential figure, to allow for soil moisture deficits, so A.E. is estimated as 475 mm/yr. Using these figures, the potential recharge (R – A.E.) is taken to be approximately 525 mm/yr.

Although topography is variable in the Ardmore area, the general drainage of the land is good, and there is no surface runoff in the likely zone of contribution of the well. Therefore it is assumed that all the potential recharge infiltrates to the aquifer.

These calculations are summarised below:

Average annual rainfall (R)	1000 mm
Estimated P.E.	500 mm
Estimated A.E. (95% P.E.)	475 mm
Potential Recharge (R – A.E.)	525 mm
Estimated Actual Recharge	525 mm

6.3 Groundwater levels

Groundwater levels in the area are variable, depending largely on elevation and rock type. The static water level in the public supply on the 21/5/97 was 1.92 m O.D. However, the well may not have fully recovered after pumping and so the static water level is likely to be somewhat higher.

Water levels in the limestone range from approximately 6m OD in the west of the area to 1.5 m OD in the caravan park just north of the village (NGR 21893 07800). Water levels in the Gyleen and Crows Point rock units are much higher, ranging up to 35 m OD in the Curragh area. Water levels for the Ardmore area are given in Figure 4.

The groundwater levels in the vicinity of Listeige Bridge in the west are much lower than river levels. The river is considered to be perched on the tills which are up to 10 m thick in the area and therefore is probably not hydrologically connected to the aquifer. In the east, a small wetland area close to the coast may represent a discharge area for groundwater in this area (see Figure 4). A small stream flows to the beach and sea from this feature (Keohane, 1993). Possible springs were noted at low tide on the beach close to a limestone outcrop. It is considered that these springs are discharging from the subsoils above the rock and may constitute very shallow groundwater (Keohane, 1993).

6.4 Groundwater Flow Directions and Gradients

The water table in the area is generally assumed to reflect topography but is also influenced by the permeability of the different rock types. The water table in the lower permeability sandstones and shales has a steep gradient (0.05 - 0.12), and groundwater flow direction is towards the limestones in the valley (southwards on the northern side and northwards on the southern side). In contrast, the groundwater gradient is flatter in the more permeable Waulsortian and Ballysteen Limestone (0.003), and the flow direction in the vicinity of the public supply well is eastwards towards the coast.

6.5 Hydrochemistry and Water Quality

One hydrochemical analysis carried out in March 1996 indicates that water in the public supply is **'very hard'** (396 mg/l $CaCO_3$). Chloride levels were elevated (48 mg/l) as was conductivity (796 μS/cm). This is probably due to proximity of the well to the sea. Nitrate levels appear to be low (8 mg/l). All major cations, anions and trace elements are within EC limits. No comprehensive well head analyses were performed; however, on 21/3/96, the temperature and pH measured were 11°C and 7.26 respectively.

6.6 Aquifer Parameters

The specific capacity calculated from the pumping test was 300 m^3/d/m after the seven day constant rate test (steady drawdown in the well had been reached at this stage). Analysis of the pumping test data provided a transmissivity estimate of 170 m^2/d. However, studies in other karstified limestone aquifers in Ireland (e.g. Dungarvan, Cloyne) indicate that transmissivity can vary considerably across a region, therefore the transmissivity value derived from a pumping test may not be representative of the true aquifer transmissivity. The numerical modelling (see Section 7.2) and the specific capacity suggest that the transmissivity is considerably higher than 170 m^2/d. The permeabilities derived from the modelling were 26.5 m/d for the limestones and 0.075-0.12 m/d for the sandstones and shales. The effective porosity estimated for the limestone is 0.025.

6.7 Aquifer Category

The Waulsortian Limestones in the Ardmore valley are classed as a **Locally Important karstified** aquifer (**Lk**). (While these limestones have a high permeability and can provide large abstractions, the area of limestones in the Ardmore valley is below the threshold (25 km^2) required for regionally important aquifers.) The Lower Limestone Shale and the Gyleen rock unit are classed as **Locally Important** aquifers which are **moderately productive only in local zones** (**Ll**) (for more information refer to the Groundwater Protection Scheme (Hudson *et al*, 1997)).

6.8 Conceptual Model

- The groundwater divides and the water table in the Ardmore area are assumed to broadly coincide with the topographic divides and the topography. In the valley itself, the groundwater divide occurs between Monea and Listeige. Groundwater to the west of this flows south-westward. The general groundwater flow direction in the vicinity of the well is south-eastwards and eastward towards the sea. This is supported by the available groundwater level data and by numerical modelling.

- The Ardmore source is fed from both the Waulsortian Limestone aquifer and the Gyleen and Crows Point rock units to the north.

- These rock units are overlain by up to 10 m of sandy till that is free-draining and moderately permeable; therefore, these units can be considered as unconfined.

- The limestones have been subject to fracturing and karstification, which can be clearly seen in the limestone quarry east of the public supply well. Other evidence of karstification includes a swallow hole at Sluggera Cross (hence the name) and the dry valley feature south of the well. The permeability in this aquifer depends on the development of such karst features as well as fissuring. Geophysical investigations indicate that fissuring occurred at a depth of approximately 50m in the vicinity of the dry valley (Keohane, 1996).

- The Crows Point and Gyleen rock units have a much lower permeability than the overlying limestones. This is largely because they are not prone to solution and they are less fissured than the limestones. Flow in these rocks is likely to occur in the upper weathered, fissured zones and along fractured fault zones.

- ♦ The groundwater gradient is flatter within the more permeable Waulsortian and Ballysteen Limestones and relatively steep in the less permeable Gyleen and Crows Point rock units. Measured groundwater levels suggests that gradients for the limestone are approximately 0.003. Gradients for the lower permeability units are estimated to be 0.05 - 0.12.

- ♦ It is assumed that the fault to the west does not affect groundwater flow in the vicinity of the well.

- ♦ The groundwater levels in the vicinity of Listeige Bridge are much lower than river levels. The river is considered to be perched on the tills, which are up to 10 m thick in the area and therefore is probably not connected hydrologically to the aquifer.

- ♦ The aquifer was modelled using FLOWPATH - a 2D finite difference model which was calibrated using measured water levels. The hydraulic controls used for the model consist of the sea to the east, topographic divides to the north and south and the groundwater divide to the west.

7. Delineation of Source Protection Areas

7.1 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.

7.2 Outer Protection Area

The Outer Protection Area (SO) includes the complete catchment area to the source, i.e. the zone of contribution (ZOC), and it is delineated as the area required to support an abstraction from long-term recharge. The ZOC is controlled primarily by a) the pumping rate, b) the groundwater flow direction and gradient, c) the rock permeability and d) the recharge in the area. The ZOC is delineated as follows:

i) An estimate of the area size is obtained by using the average recharge and the abstraction rate.
ii) The shape of the area is then derived by both numerical modelling (using FLOWPATH) and hydrogeological mapping techniques.
iii) To allow for errors in the estimation of groundwater flow direction and to allow for an increase in the ZOC in dry weather, a safety margin is incorporated by assuming a higher abstraction rate than the current rate.

At present the Ardmore area is supplied by two sources – the well at Monea and the Glenwilliam springs. The average abstraction rate for the two sources is approximately 500 m^3/d. However in summer, the Monea source supplies up to 300 m^3/d, whereas the Glenwilliam springs provide up to 450 m^3/d (information from Mr. J.Burke, Water Scheme Caretaker). Therefore the Ardmore area requires 750 m^3/d during peak demand. For the purposes of modelling the Monea source, the combined maximum yield (750 m^3/d) is used for the following reasons:

- ♦ If the springs are not in operation in the future, then the Monea supply would have to accommodate total water demands in the area.
- ♦ Assuming the springs continue in use, the higher yield allows for increased water demand due to expansion in Ardmore.
- ♦ Numerical modelling assumes average conditions all year round, i.e. recharge is averaged out over winter and summer, therefore the model does not allow for an increase in the ZOC during dry weather. This is overcome by assuming a higher abstraction rate in the calculations.

Taking the average annual recharge to be 525 mm as previously indicated, the area required to supply a pumping rate of 750 m^3/d is calculated to be 0.52 km^2 (52 ha).

The ZOC at Ardmore is derived from numerical modelling of the groundwater system, together with hydrogeological mapping techniques. The proposed ZOC extends as far as the topographic divides to the north and west of the well.

The defining conditions for the numerical model are discharge, aquifer thickness, effective porosity and recharge:

Discharge		750 m^3/d
Thickness	Limestone	30 - 36 m
	Sandstone/Shale	< 80 m
Effective porosity	Limestone	0.025
	Sandstone/Shale	0.01
Recharge		525 mm/yr

The model derived parameter is hydraulic conductivity:

Hydraulic conductivity	Limestone	26.5 m/d
	Sandstone/Shale	0.075 - 0.12 m/d

Using the above parameters, the groundwater conditions in Ardmore were successfully modelled using FLOWPATH - a 2D finite difference model. The hydraulic controls used for the model consist of the sea to the east, topographic divides to the north and south and the groundwater divide to the west. A graph of calculated versus observed heads (Appendix 1) indicate that a good calibration with measured water levels was achieved. In order to test the robustness of the model a sensitivity analysis (see Appendix 2a) was carried out by varying recharge and permeability – the parameters that are normally poorly specified in terms of data. The results of the sensitivity analysis are incorporated into the ZOC, which is shown in Figure 5.

The boundaries of the ZOC are based on our current understanding of groundwater conditions in the area and on the available data.

7.3 Inner Protection Area

The Inner Protection Area (SI) is the area defined by a 100 day time of travel (TOT) from a point below the water table 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 from microbial contamination.

Due to the highly permeable, karstic nature of the limestone aquifer at Ardmore, it is probable that all groundwater in the portion of the ZOC underlain by limestone could reach the 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.) Therefore all the limestone areas lying within the ZOC must be included in the inner protection area. The 100 day TOT boundary in the less permeable sandstone and shale units is based largely on the numerical modelling. A sensitivity analysis on the 100 day TOT zone was carried out by varying permeability, porosity and recharge - see Appendix 2b. The area delineated by modelling was extended along the limestone boundary to the catchment divide (see Figure 5).

8. Vulnerability

The sandy tills are considered to be moderately permeable and >10 m thick in the immediate vicinity of the well, therefore groundwater at the well is taken to be ‘moderately’ vulnerable to contamination. Elsewhere in the valley, groundwater ranges from ‘extremely’ vulnerable to ‘moderately’ vulnerable.

The Irish Sea Till is taken to have a low permeability in Ardmore and indeed elsewhere in Waterford (Hudson *et al*, 1997). Consequently in the east of the area, where depth to bedrock is greater than 10 m, the underlying groundwater has a 'low' vulnerability. Much of the upland areas have rock at less than 1 m and so groundwater is 'extremely' vulnerable to contamination.

Karst features are considered to be point sources of recharge where there is little or no attenuation of pollutants before entering the groundwater. These features therefore represent points of 'extreme vulnerability'. The distribution of vulnerability of groundwater in the Ardmore area is shown in Figure 6.

9. 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, this is done by superimposing the vulnerability map on the source protection area map. Each zone is represented by a code e.g. **SO/H**, which represents an Outer 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 each local authority source. There are 6 groundwater protection zones present around the Ardmore well (see Figure 7), as shown in the matrix below.

Matrix of Source Protection Zones

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

It is not within the scope of this report to delineate the 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 restrictions necessary in each protection zone.

10. Potential Pollution Sources

The land to the north and northwest of the source is largely grassland-dominated and is primarily used for grazing. The main hazards within the ZOC are farmyards, septic tank systems, application of fertilisers (organic and inorganic) and pesticides, and possible spillages along the roads. No detailed assessment of hazards was carried out as part of this study; however, the general impression gained was that there are no obvious major hazards in the ZOC.

11. Conclusions and Recommendations

- The source at Ardmore is an excellent yielding well, which is located in a karstic limestone aquifer. The test pumping indicates that the present normal abstraction rate of the well could be increased, although more comprehensive pumping tests would be needed to confirm the sustainable maximum yield.

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

- ♦ The inner and outer protection zones delineated in the report are based on our current understanding of groundwater conditions and on the available data. Additional data obtained in the future may indicate that amendments to the boundaries are necessary.

- ♦ It is recommended that:
  - chemical and bacteriological analyses of raw water rather than treated water should be carried out on a regular basis (every 2-3 months initially);
  - the chemical analyses should include all major ions - calcium magnesium sodium, potassium, ammonium, i.e. a 'full' analysis;
  - the nitrate data should be reviewed regularly;
  - in the short term, until the groundwater quality situation can be properly assessed, care should be taken in allowing any activities or developments which might significantly increase nitrate levels;
  - the potential hazards in the ZOC should be located and assessed;
  - an interim code of practice for dealing with spillages along the roads in the area should be drawn up.

12. References

Hudson M., Daly D., Duffy S., & Johnston P., 1997. County Waterford Groundwater Protection Scheme.

Keating, T. & Packman, M.J. 1995. Guide to Groundwater Protection Zones In England & Wales. National Rivers Authority.

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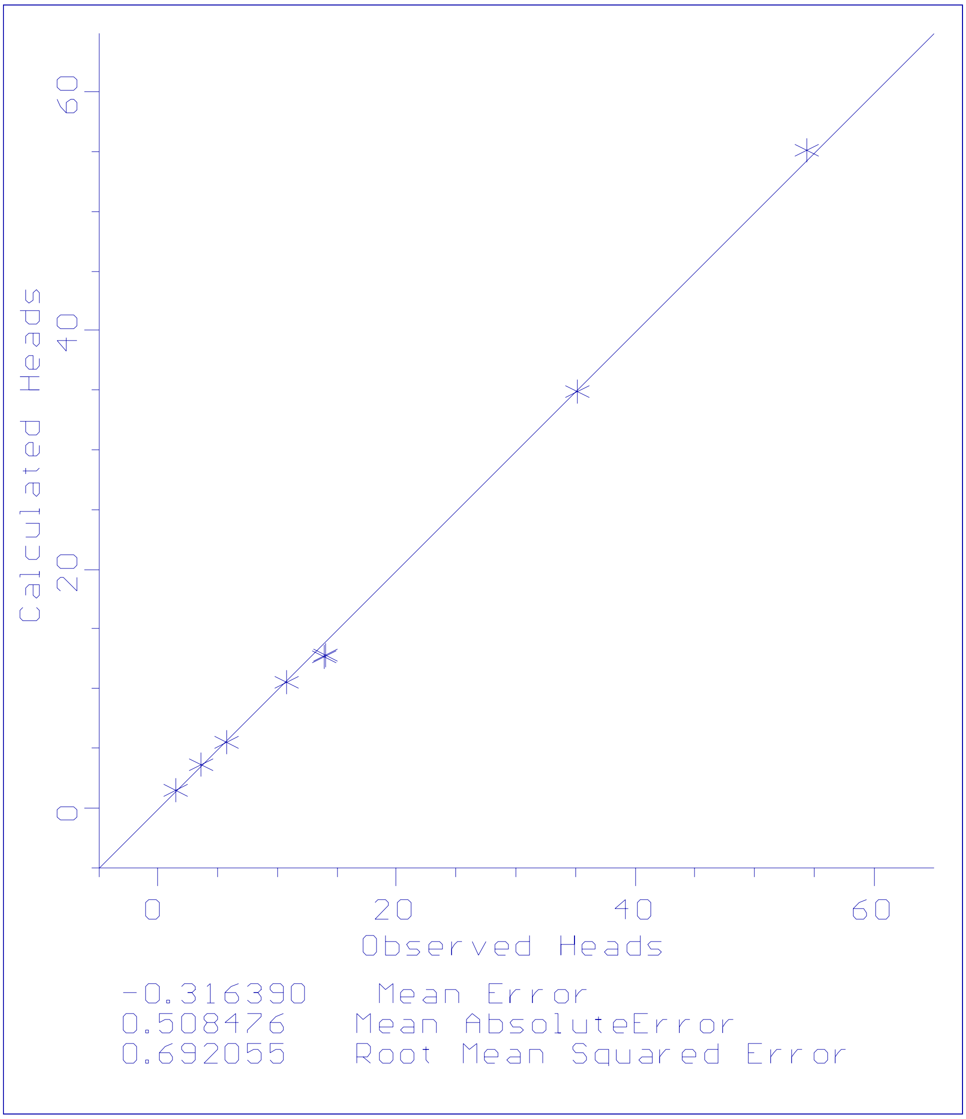
Keohane, J., 1996. Assessment of the potential of developing a groundwater source at Ardmore, Co. Waterford. Proceedings of IAH Portlaoise Seminar.

Sleeman A.G., & McConnell, B., 1995. Geology of East Cork - Waterford, Map and Report for Sheet 22, Geological Survey of Ireland.

APPENDIX 1



Graph of Calculated versus Observed heads (m O.D.) obtained by numerical modelling

APPENDIX 2

2a. Delineation of the Zone of Contribution

To examine the robustness of the numerical model, a sensitivity analysis was carried out using methods employed by the U.K's Environment Agency (Keating & Packman, 1995). Best estimate permeability (K) and recharge (R) values were initially chosen and the sensitivity analysis was based on varying these parameters. Recharge was varied over a range of 80 to 120% and permeability by 50 - 150%. This involved creating nine models – each model has a different permeability and recharge value. The nine models are as follows;

↑	1.2R, 0.5K	1.2R, K	1.2R, 1.5K
Recharge (R)	R, 0.5K	R, K	R, 1.5K
	0.8R, 0.5K	0.8R, K	0.8R, 1.5K

Permeability (K) →

Each model was run and the resulting ZOC's were overlain upon each other. The following areas are delineated on the overlay map which is available on request at the GSI.

Best Estimate: The model which was constructed using best estimates of permeability and recharge.
Area of Certainty: This represents the area of overlap of all nine models
Area of Uncertainty: This represents the outer envelope of all nine models.

In view of the variability of karst limestone aquifers and the resulting uncertainties, it was decided to include not only the best estimate but also the area of uncertainty within the delineated ZOC in Figure 5.

2b. Delineation of the 100 day Time of Travel Zone.

In the delineation of the 100 day TOT zone , it is advisable to take a cautious approach. Therefore the "best estimate" porosities of the limestone, sandstone and shale units were reduced by 50% (velocity increases as porosity is reduced) in each of the nine models above.

The nine models were run and the results of each were overlain upon each other. The overlay map is available on request at the GSI. The delineated 100 day TOT zone (see Figure 5) incorporates the results of all nine models.

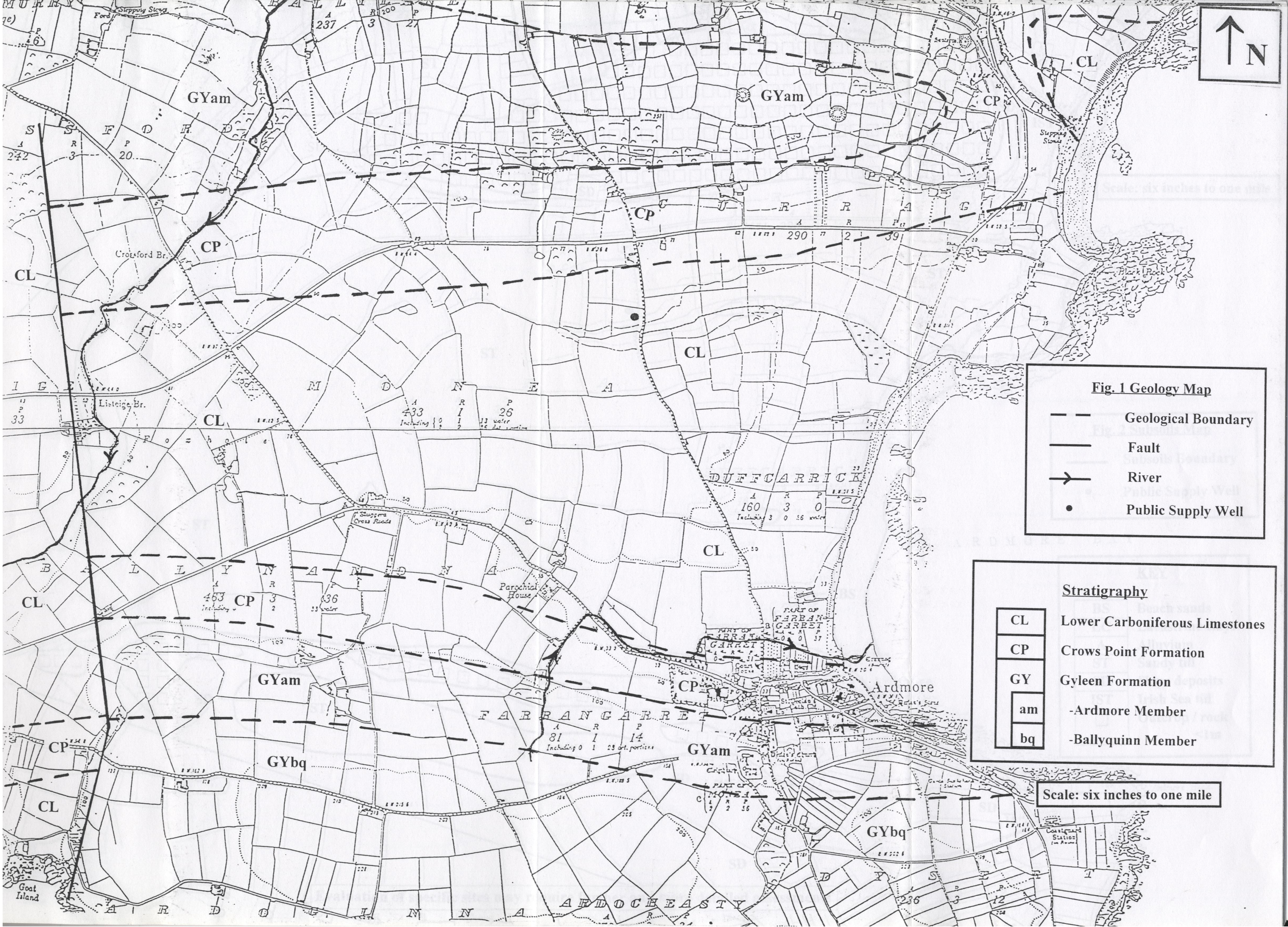

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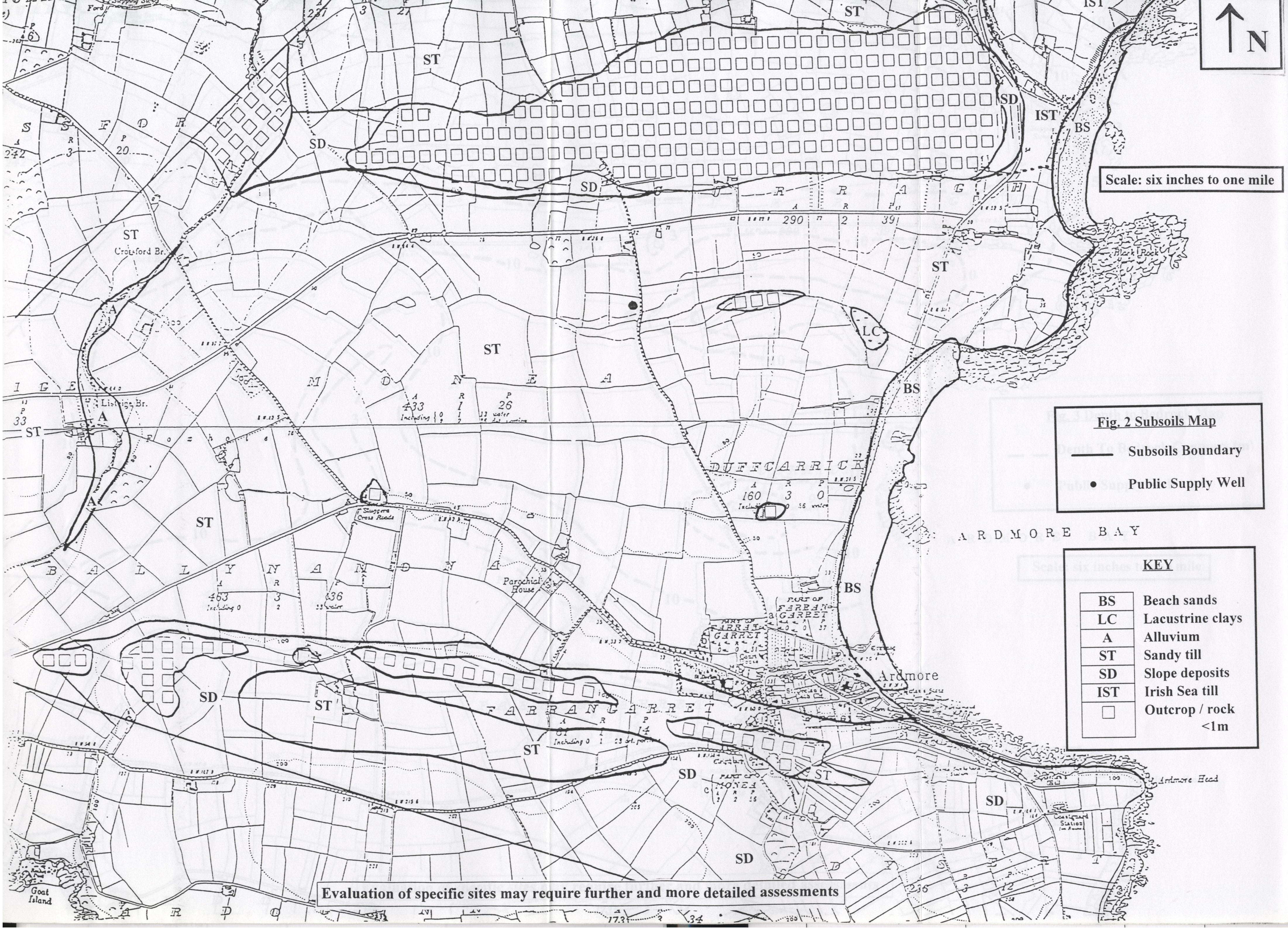
Fig. 1 Geology Map
Geological Boundary
Fault
River
Public Supply Well
Stratigraphy
CL Lower Carboniferous Limestones
CP Crows Point Formation
GY Gyleen Formation
am -Ardmore Member
bq -Ballyquinn Member
Scale: six inches to one mile
GYam
CP
CL
GYbq
Ardmore
DUFFCARRICK
FARRANGARRET
Crossford Br.
Listeige Br.
Parochial House
Goat Island
ARDOCHEASTY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Scale: six inches to one mile
Fig. 2 Subsoils Map
Subsoils Boundary
Public Supply Well
KEY
BS Beach sands
LC Lacustrine clays
A Alluvium
ST Sandy till
SD Slope deposits
IST Irish Sea till
Outcrop / rock <1m
ARDMORE BAY
Ardmore
Ardmore Head
DUFFCARRICK
FARRANGARRET
Black Rock
Goat Island
Parochial House
Evaluation of specific sites may require further and more detailed assessments

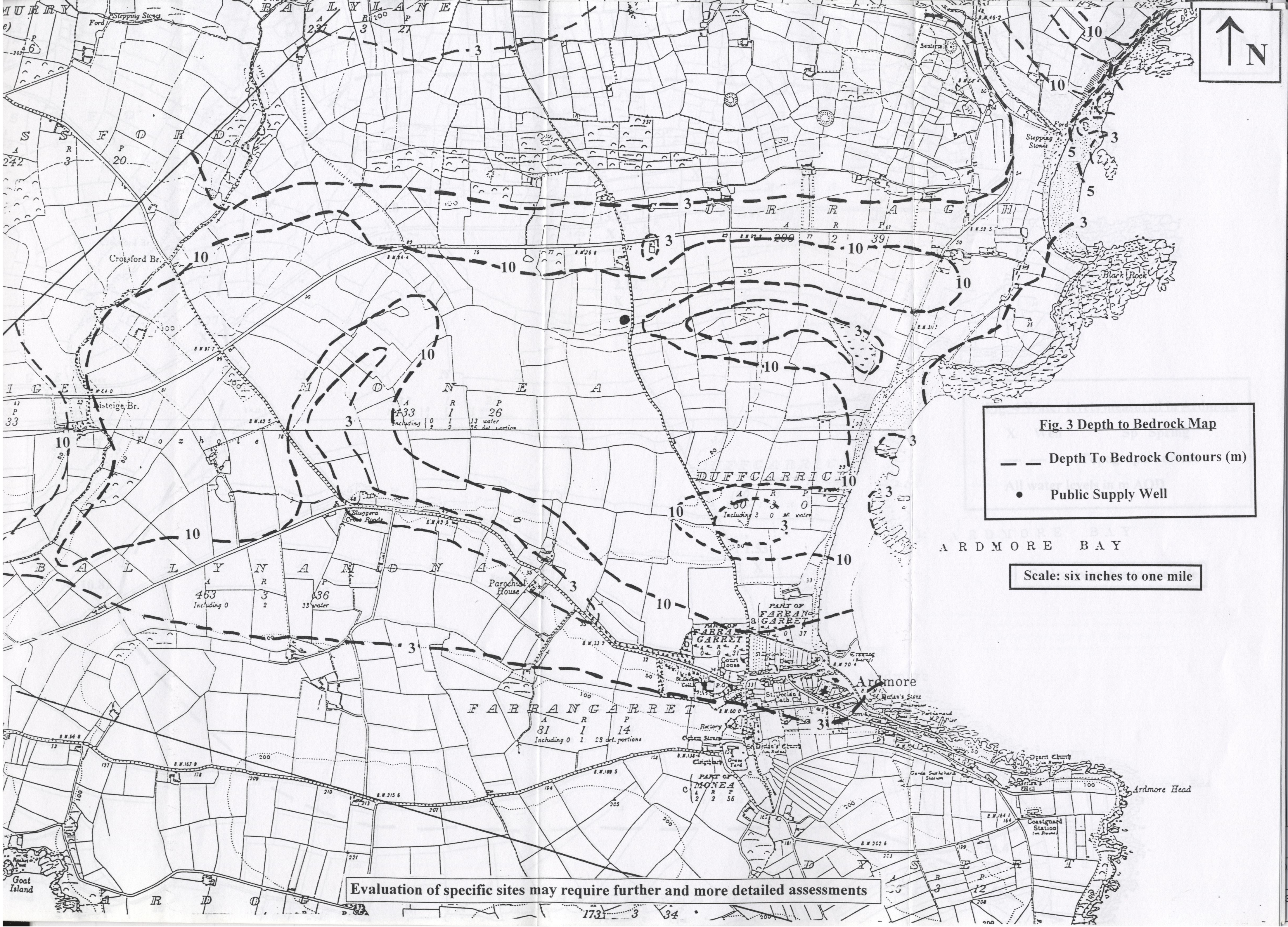

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Fig. 3 Depth to Bedrock Map
Depth To Bedrock Contours (m)
Public Supply Well
Scale: six inches to one mile
Evaluation of specific sites may require further and more detailed assessments
ARDMORE BAY
Ardmore
Ardmore Head
Black Rock
Goat Island
Crossford Br.
Sluggera Cross Roads
Parochial House
Coastguard Station
Stepping Stones
Ford
BALLYLANE
CURRAGH
MONEA
DUFFCARRIG
BALLYNAMONA
FARRANGARRET
3
5
10

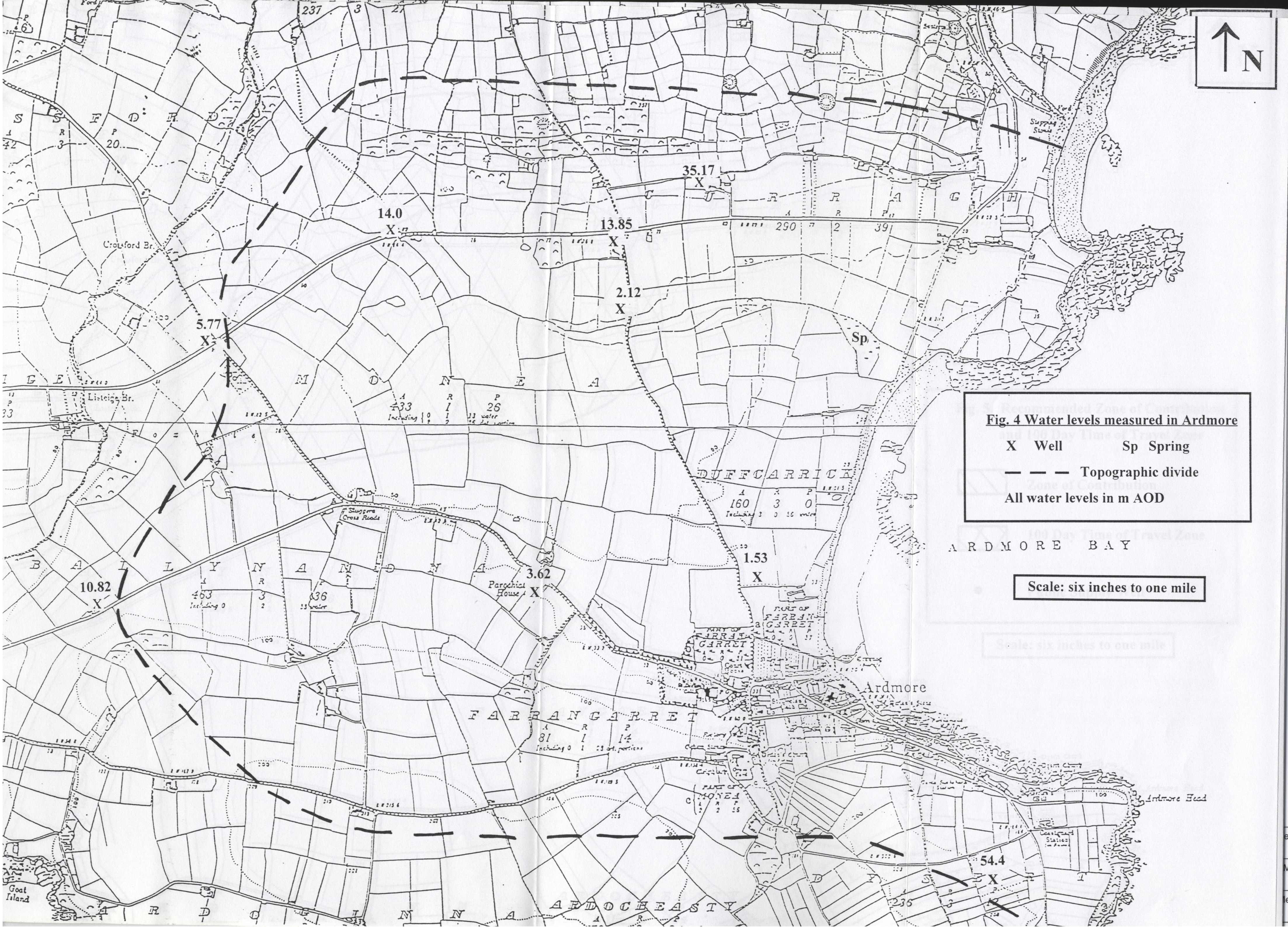
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Fig. 4 Water levels measured in Ardmore
X Well
Sp Spring
Topographic divide
All water levels in m AOD
Scale: six inches to one mile
35.17
14.0
13.85
2.12
5.77
10.82
3.62
1.53
54.4
Sp
Crossford Br.
Listeige Br.
DUFFCARRICK
ARDMORE BAY
FARRANGARRET
Ardmore
Ardmore Head
Parochial House
Goat Island
ARDOCHEASTY
BALLYNAMONA
Slippera Cross Roads

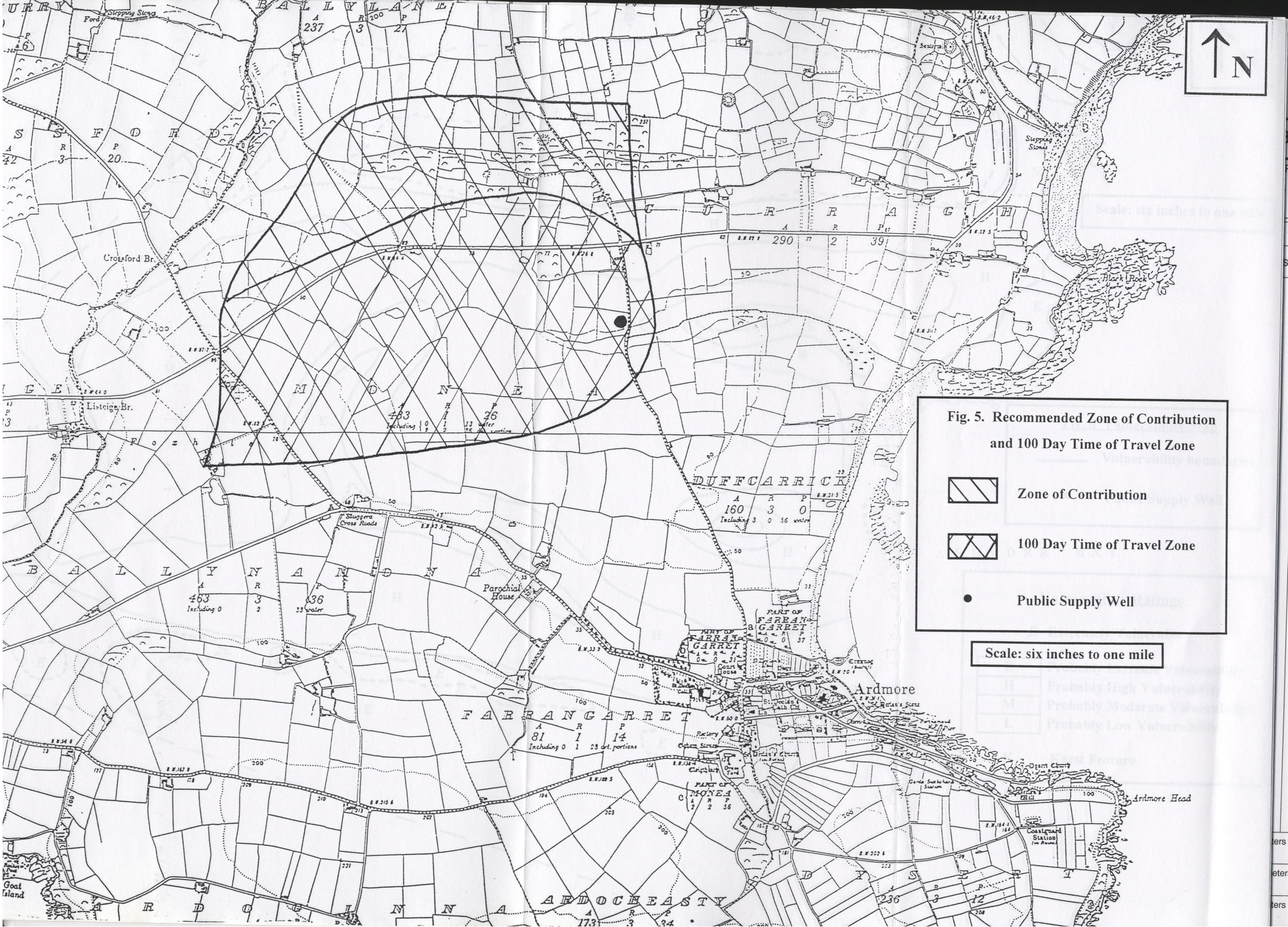

Fig. 5. Recommended Zone of Contribution and 100 Day Time of Travel Zone

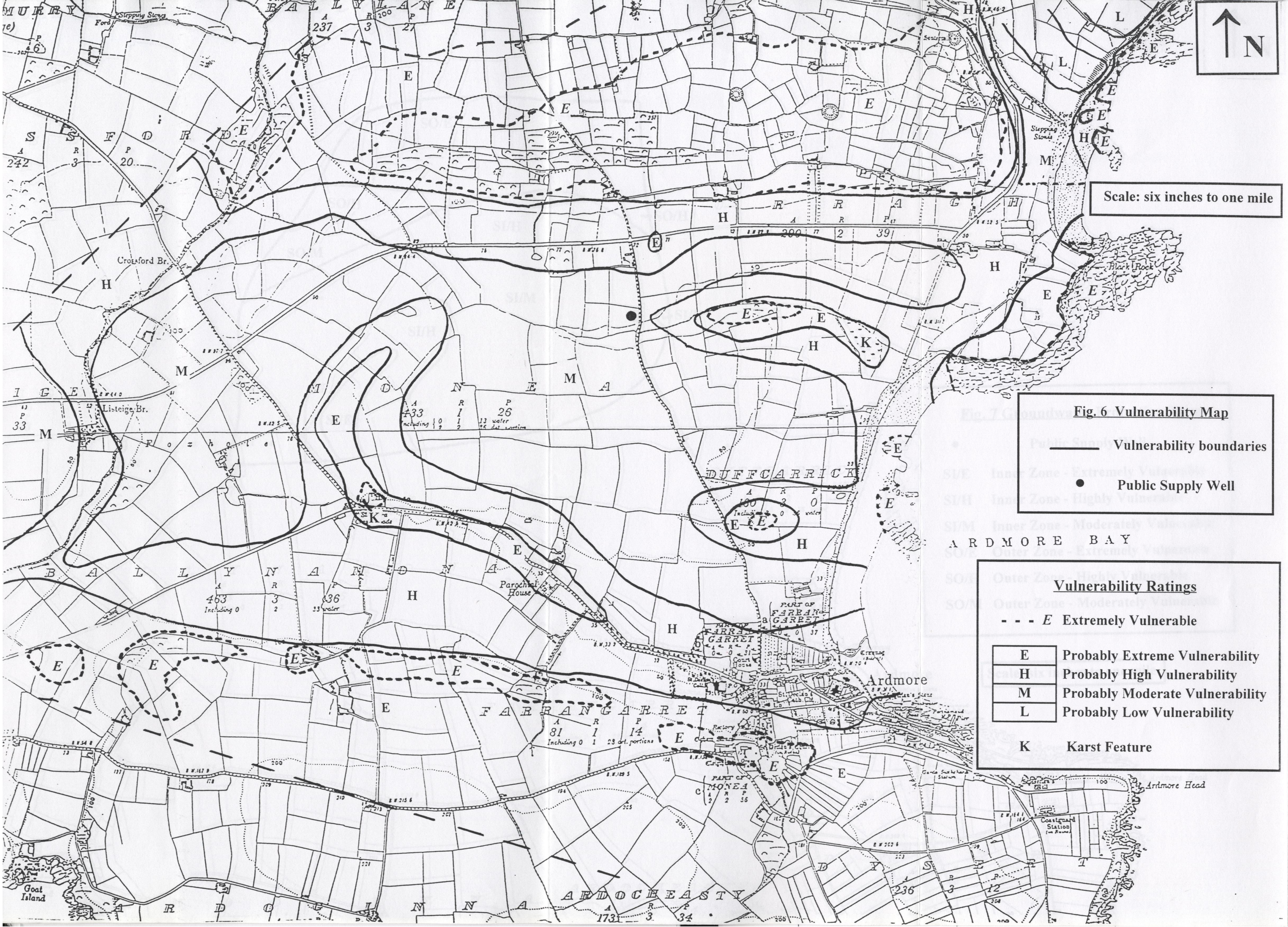
N
Scale: six inches to one mile
Fig. 6 Vulnerability Map
Vulnerability boundaries
Public Supply Well
Vulnerability Ratings
- - - E Extremely Vulnerable
E Probably Extreme Vulnerability
H Probably High Vulnerability
M Probably Moderate Vulnerability
L Probably Low Vulnerability
K Karst Feature
Crossford Br.
Listeige Br.
Parochial House
DUFFCARRICK
ARDMORE BAY
Ardmore
Black Rock
Ardmore Head
Coastguard Station
FARRANGARRET
ARDOCHEASTY
Goat Island

Fig. 7 Groundwater Protection Zones