Lough Public Water Supply:
Portarlington Water Supply Scheme
Killenard Group Water Scheme

Groundwater Source Protection Zones

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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 Survey Ireland website (https://www.gsi.ie/en-ie/data-and-maps/Pages/default.aspx).’

1 Introduction

The objectives of this report are:

- To delineate source protection zones for the Lough Public Water Supply.
- To outline the principal hydrogeological characteristics of the Lough area.
- To assist Laois County Council in protecting the water supply from contamination.

2 Location and Site Description

The Lough WS is situated approximately 4 km south of Portarlington and 4 km west-northwest of Ballybrittas, in the townland of Lough. The site is shared by two separate borehole sources a few metres apart: the Portarlington source which pumps to a service reservoir in Carrick Wood, about 1.6 km to the north, and the Ballybrittas source which serves the Killenard Group Water Scheme to the southeast. Since the two bores are so close together, the source protection zones are applied to them jointly. Both sources are treated by chlorination and fluoridation.

The boreholes are protected by concrete surrounds and manhole covers, but are unfenced.

The Portarlington Water Supply is also served by abstraction from the River Barrow, via Ballymorris treatment works, about 2 km southwest of Portarlington.

3 Summary of Source Details

GSI no.	2319NE W144
Grid ref. (1:25,000)	25405 20860
Townland	Lough
Owner	Laois County Council
Well type	Borehole for Portarlington WSS
Elevation (top of casing)	75 m (250 ft) approx.
Depth	36.6 m (120 ft) approx.
Diameter	152 mm (6”)
Depth-to-rock	(not recorded)
Static water level	(not recorded)
Total Abstraction	518 m^3/d (114,000 gpd over c. 19 hours pumping)
Pumping test summary	Pumping rate: m^3/d
(none)	Drawdown: m ()
	Specific capacity:

GSI no.	2319NE W145
Grid ref. (1:25,000)	25405 20860
Townland	Lough
Owner	Laois County Council / Killenard GWS
Well type	Borehole for Killenard GWS
Elevation (top of casing)	75 m (250 ft) approx.
Depth	71.8 m (235 ft)
Diameter	
Depth-to-rock	5.8 m
Static water level	4.3 m (9/10/78)
Total Abstraction	216 m^3/d (47,500 gpd) over 5 hours pumping
Pumping test summary	Pumping rate: 314 m^3/d
(October 1978)	Drawdown: 2.91 m (after 2 hours)
(data from E.P. Daly)	Specific capacity: 108 m^3/d/m

4 Methodology

Desk study

Bedrock geology information was taken from the geological mapping compiled for the Laois Groundwater Protection Scheme and subsoils from the GSI Quaternary maps (Kilfeather, 1999) and GSI records. County Council staff supplied borehole details and abstraction rates. Pumping test data and borehole logs were available in GSI records.

Site visits and fieldwork

Site visits and fieldwork in the area included a walkover survey in order to further investigate the subsoil and bedrock geology, hydrogeology, vulnerability to contamination and any obvious hazards. Water samples for analysis by the State Laboratory and Health Board were taken in December 1997 and June 1999.

Data analysis

Analytical equations and hydrogeological mapping were utilised to delineate protection zones around the source.

5 Topography and Surface Hydrology

The Lough boreholes lie within the catchment of the River Barrow, whose channel lies some 3 km to the north-northwest. About 1.5 km south of the boreholes is Emo Lake, an artificial lake created in the Emo Park Demesne. The lake is linked to the Barrow by a complicated series of (more or less) artificial drainage channels.

The terrain surrounding the Lough site is generally flat. The only prominent topographic feature nearby is Lough Hill, about 800 m east of the cross roads, which rises to an altitude of 94 m, compared with 78 m at the cross roads.

6 Geology

6.1 Bedrock Geology

The bedrock geology of the Lough area comprises rocks of Carboniferous age (over 300 million years old). The rock units of the area, shown in Map 1, are summarised below.

Rock Formation	Rock Material	Thickness	Occurrence
Allenwood Fmn (AW)	pale grey, clean massive shelf limestones, commonly dolomitised	400 m	Beneath and to the southeast of the site
Calp (CD)	varied dark grey to black basinal limestone and shale	variable	To the north, west, east and southeast of the site

6.1.1 Structure

The contact between the two formations is mapped as a northeast-southwest fault, running along a route just to the southeast of the site. However, in the absence of nearby exposures of rock, the actual path of the fault is unknown. The geological log of the Portarlington borehole indicates that it was drilled in the Allenwood Formation.

6.2 Subsoils (Quaternary) Geology

The subsoils in the area are shown in Map 2 and comprise .

6.2.1 Sands & Gravels

These underlie the areas to the north and east of Lough Cross Roads. These deposits are classed as highly permeable.

6.2.2 Till

Till underlies the area to the south of Lough Cross Roads. These deposits are assessed as free-draining and therefore moderately permeable.

6.2.3 Till-with gravel

These deposits underlie the area to the west of Lough Cross Roads. These deposits are also assessed as free-draining and therefore moderately permeable.

6.2.4 Peat bog

Further to the southeast lies an area of peat bog (Grove Bog). This is assessed as thin peat and therefore takes its permeability from the underlying till, i.e. as moderately permeable.

6.3 Depth-to-rock

Information on depth to bedrock is based on outcrop information, well records and subsoil sections. The subsoil map of the area indicates that the subsoils are everywhere between 3 and 10 metres thick. Depth to rock information is given in Map 3.

7 Hydrogeology

7.1 Data availability

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

- A Study of the Groundwater in County Laois (Daly, 1978).
- Hydrochemical analyses carried out by the State Laboratory for GSI (Nov 1997, June 1999).
- County Laois Groundwater Protection Scheme (Wright *et al*, 2000).

7.2 Rainfall, Evaporation and Recharge

The mean annual rainfall (R) for the area (1961-90) was 879 mm (Met Éireann).

Potential evaporation (P.E.) is estimated as 475 mm/yr (from Met Éireann's national contoured map). Actual evapotranspiration (AE) is then calculated by taking 90% of PE, to allow for soil moisture deficits, so AE is estimated as 429 mm/yr.

Using the above figures, potential recharge (R - AE) is taken as approximately 450 mm. The absence of drains and ditches in the area indicates that the subsoils are free draining and that a high proportion of the effective rainfall infiltrates to the water table. Runoff from the gravel areas is estimated to be 10 % of available recharge, i.e. 45 mm. This assumption is an empirical standard used at the GSI for permeable, sand & gravel subsoils of this type. These calculations are summarised below:

Average annual rainfall	879 mm
Estimated P.E.	475 mm
Estimated A.E. (90% P.E.)	429 mm
Available recharge	450 mm
Surface Runoff	50 mm
Recharge	405 mm

7.3 Groundwater flow directions and gradients

Regional groundwater flow should be towards the north or northwest, towards the Barrow River. For the purposes of this report it is taken as north-northwest at the site. To the south of the site, the groundwater flow direction is envisaged as swinging to a north-northeasterly direction to reflect the concentration of flow within the Allenwood outcrop.

The groundwater gradient is estimated from the topography as 0.0025.

7.4 Hydrochemistry and Water Quality

Results of laboratory analysis of water samples taken in December 1997 and June 1999 are presented in Table 1.

Table 1: Laboratory Analyses of Groundwater at the Lough boreholes

	Results of Laboratory Analyses			
	Portarlington	Ballybrittas	Portarlington	Ballybrittas
Parameter	7/12/97	7/12/97	8/6/99	8/6/99
Conductivity (μS/cm)	676	686	685	702
Total Hardness	361.7	385.9		
Total Alkalinity (mg/l)	324	328	330	342
Calcium	123.3	134.1	132.7	135.8
Magnesium	13.06	12.37	7.55	11.87
Chloride	23.1	23.2	22.8	23.3
Sulphate	28.5	35.6	24.3	29.1
Sodium	10.84	11.25	10.93	11.74
Potassium	1.831	3.242	1.656	3.412
K:Na	0.17	0.29	0.15	0.29
Nitrate (as NO_3)	24.5	14.1	*25.6*	19.3
Iron	<0.005	0.012	0.021	0.011
E. coli count per 100 ml.	0	0	0	0
Total Coliforms per 100ml	**10**	**1**	0	0

Note: **Bold type denotes E.U. MAC exceedances.**
Italic type denotes GSI threshold exceedances.

The following key points have been identified from the data:

- The groundwater samples indicate a hard (350-400 mg/l $CaCO_3$) water with a calcium-bicarbonate hydrochemical signature. This reflects the fact that the groundwater feeding the boreholes has passed through limestone rock.
- Of the parameters examined in the groundwater samples taken, total coliforms were in excess of the EU MAC in December 1997. Nitrate levels in the Portarlington supply (the shallower well) approach or exceed the guide level of 25 mg/l but are generally satisfactory. Chloride levels (22-24 mg/l) are slightly above background.
- The K:Na ratio is generally satisfactory, but in the Ballybrittas well (0.29) values are approaching the GSI threshold of 0.4. A K:Na ratio greater than 0.4 can indicate contamination by plant organic matter - usually from farmyards.
- There are small differences between the hydrochemistry in the two boreholes, presumably due to the Ballybrittas borehole being much deeper. Thus the Ballybrittas water is very slightly harder and more alkaline, and has slightly more sulphate. Its iron content seems to be more consistent. In relation to indicators of contamination, The Ballybrittas supply shows less bacterial contamination (in December 1997) and significantly lower nitrate, but significantly higher potassium. On the whole, it appears that the greater depth of the Ballybrittas borehole affords a greater degree of protection to the quality of the supply.

7.5 Aquifer Parameters

Transmissivity in the Allenwood Formation was estimated from the 1978 pumping test on the Ballybrittas borehole (2) as 293 m^2/d. For an assumed aquifer thickness of 70 m, this implies an

average permeability of about 4 m/d. However, it can be expected that permeability would be higher in the upper part of the aquifer, due to greater openness and increased widening by solution of fissures.

The aquifer porosity is tentatively taken as 0.04 (4%).

In the Calp Formation, permeability would be expected to be significantly lower, e.g. 1 m/d.

7.6 Aquifer Category

The Allenwood Formation, being a clean, often dolomitised limestone, is classified as a Regionally Important Aquifer (Rf). Since direct evidence of karstification is lacking, it is classified as a fractured rather than karstified aquifer, i.e. (Rf). The Calp Formation, being a shaly limestone, is classified as a Locally Important Aquifer (Ll).

The sand/gravel deposit overlying the limestones has insufficient saturated thickness to be considered an aquifer.

7.7 Conceptual Model

The Lough sources are conceptualised as tapping a Regionally Important limestone aquifer (the Allenwood Formation) in which the groundwater flows in a north-northwesterly direction with a low regional hydraulic gradient (0.0025). To the south of the site, the groundwater flow direction is envisaged as swinging to a north-northeasterly direction to reflect the concentration of flow within the Allenwood outcrop.

The aquifer is overlain by a mixed subsoil cover, generally between 3 and 10 metres thick, and of moderate to high permeability.

8 Delineation of Source Protection Areas

Two source protection areas are delineated:

- Outer Protection Area (SO), bounded by the zone of contribution (ZOC) to the wells.
- Inner Protection Area (SI), designed to give protection from microbial pollution.

8.1 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) 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. Average daily abstraction from the Lough sources is 545 m^3/d. This figure is increased to 800 m^3/d (i.e. by approx. 50%) to allow for increased water demand due to expansion, and to allow for an increase in the ZOC during dry weather.

Taking the recharge to be 405 mm as indicated in Section 7.2, the area required to supply a pumping rate of 800 m^3/d is calculated to be 0.72 km^2 (72 ha).

The boundaries of the ZOC are illustrated in Map 4 and are delineated as follows:

Down-gradient (Northern) boundary: This is determined by the calculated 'null point', i.e. the distance from the boreholes beyond which water is not drawn towards them. This is calculated from the 'Uniform Flow Equation':

Distance = $Q/2.\pi.T.i$, where:

Q = discharge rate, m^3/d

T = aquifer Transmissivity, m^2/d

I = hydraulic gradient

Thus the distance to the downstream boundary = 800/2 x π x 290 x 0.0025 = 175 m

Up-gradient (Southern) and lateral (Eastern & Western) boundaries:

In the absence of distinct topographic features (e.g. ridges) which would constrain the Zone of Contribution, the boundaries of the ZOC is difficult to estimate. The shape of the ZOC is taken to be roughly elliptical, with its northern limit located as described above.

There is a small spring about 750 m southeast of the site, which drains into Grove Bog. An apparent 'high point' is marked on the road as altitude 259 feet (79 m) and the ZOC boundary in this (eastern) area is taken as being at this point. The western boundary is sketched in at a roughly equal distance in that direction. Thus the eastern and western boundaries, at their maximum, are some 350 m either side of the (curved) long axis of the ellipse.

The southern boundary is drawn so as to enclose the 72 hectares required to provide the recharge necessary to sustain the wells, i.e. about 1100 m south-southeast of the site, and to stay as far as possible within the mapped outcrop of the Allenwood Formation, which is inferred to provide most of the flow.

8.2 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 is delineated to protect from potentially contaminating activities which may have an immediate influence on water quality at the source, in particular from microbial contamination.

The groundwater flow velocity, V, can be estimated from the aquifer permeability (k), hydraulic gradient (i,) and porosity (p), as:

$$V = k \times i / p$$

Using parameters mentioned above (k = 4m/d, i = 0.0025, and p = 0.04) would give a 100-day TOT of only 25 metres, which is very small. However, for this pupose it is justified to adopt a more conservative approach, because:

- In the crucial upper part of the aquifer, permeability is likely to be higher than the average over the assumed 70 m aquifer thckness. Hence, a value of 10 m/d is assumed.
- Near to the boreholes, the hydraulic gradient is increased by the effects of pumping. Hence, a value of 0.02 is assumed.

Using these parameters, the groundwater flow velocity is estimated at 5 m/d and the 100-day ToT as 500 metres. This is shown on Map 4.

9 Groundwater Vulnerability

The sands and gravels are classed as highly permeable (Daly *et al*, 1997). The unsaturated zone in the sands and gravels in the area is assumed to be at least 3 m in thickness and so groundwater is considered to be "highly" vulnerable. The till and 'till-with-gravel' are classed as moderately permeable and less than 10 m thick, so they, too, are considered to be "highly" vulnerable. Groundwater vulnerability in the area is shown in Map 5.

10 Groundwater Source 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. **SO/H**, which represents an **Outer Source Protection area** where the groundwater is **Highly** vulnerable to contamination. Since there is only one vulnerability category within the Lough ZOC, there are just two groundwater protection zones present around the site (see Map 6), as shown in the matrix below.

Matrix of Source Protection Zones

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

11 Land Use and Potential Pollution Sources

Agriculture is the principal activity in the area. Most of the land is used for pasture, although a small proportion is used for tillage. Other hazards include 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, but it was noted that landspreading was taking place in the field adjacent to the source.

12 Conclusions and Recommendations

- The Lough boreholes are located in a regionally important limestone aquifer.
- The area around the supply is 'highly' 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.
- An urgent study should be carried out to assess the source of high nitrates. This would involve:
    - a review of the most recent data
    - increased monitoring of untreated water
    - monitoring and assessment of other parameters
    - surveys of potential contamination sources, similar to the farm surveys carried out in the late 1980s
    - consideration of whether nitrate vulnerable zones need to be delineated under the requirements of the EU Nitrate Directive; assessment of the likely source(s) of nitrate; where the maps are available, using vulnerability zones and groundwater protection zones in the assessment process

- 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

♦ In addition, chemical and bacteriological analyses of raw water rather than treated water should be carried out on a regular basis (every 3 - 6 months)

♦ An emergency plan should be drawn up for dealing with spillages along the nearby roads.

13 References

Archer JB, Sleeman AG, Smith DC 1996. *A Geological Description of Tipperary and Adjoining Parts of Laois, Kilkenny, Offaly, Clare, and Limerick, to Accompany the Bedrock Geology 1:100000 scale Map Series, Sheet 18, Tipperary.* Geological Survey of Ireland.

Daly EP 1992 *Groundwater Resources of the Nore River Basin. Interim Report.* Geological Survey of Ireland unpublished report.

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Deakin J, Wright G. 2000 *County Laois Groundwater Protection Scheme*. Geological Survey of Ireland Report.

DELG/EPA/GSI 1999 Groundwater Protection Schemes. Department of Environment & Local Government, Environmental Protection Agency and Geological Survey of Ireland joint publication.

EPA 1997 Nitrates in Groundwater: County Laois. Environmental Protection Agency.

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Kilfeather A 1999 *Quaternary Map of County Laois*. Geological Survey of Ireland, Quaternary & Geotechnical Section.

Appendix 1

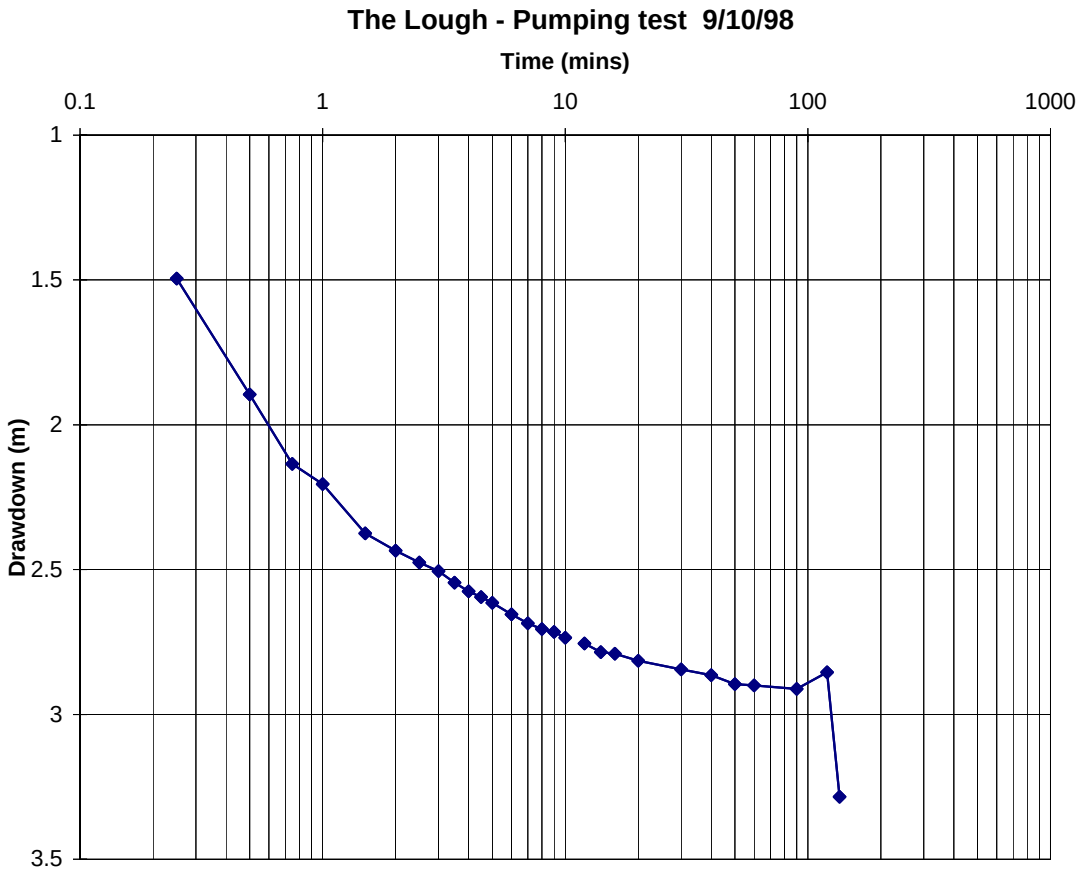
Pumping Test Data

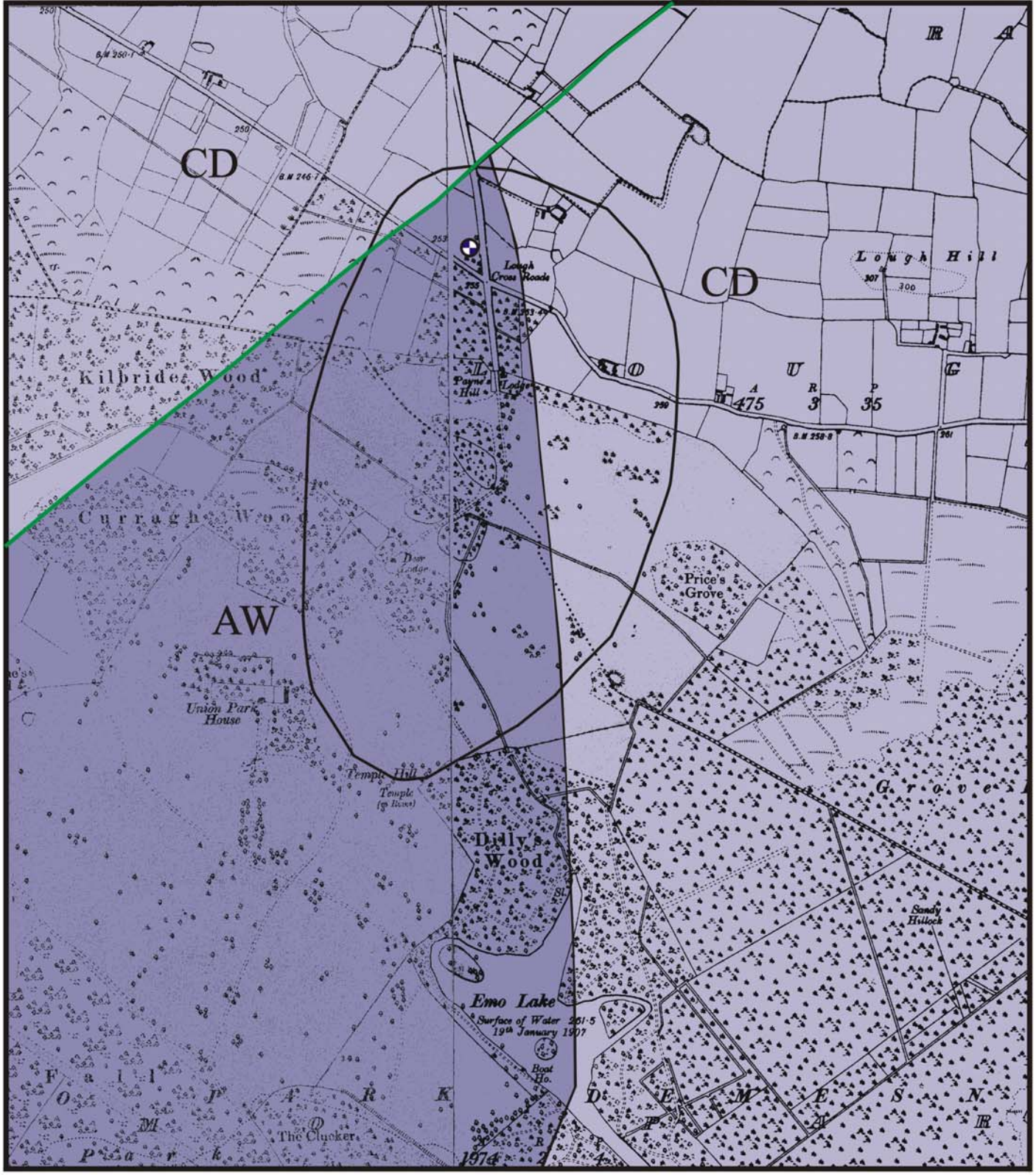
SITE _____ **Lough, Ballybrittas** **DATE** 9-Oct-78

Groundwater Section **Project Title** .....
Geological Survey of Ireland **PUMPING TEST** **OBSERVATION WELL** **Page No.** .....

Borehole Name	Ballybrittas/Killenard GWS	**Well Depth**	**71.8 m**	**Datum Point**	
Borehole No.	2319NE W145	**Well Diamete**	**152 mm**	**Height of Datum**	
Well Owner	Killenard GWS	**Pump Depth**		**Ground Elevation**	
Location	Lough, Ballybrittas	**Aquifer**	**Allenwood Limestone**	**Datum Elevation**	
Grid ref.	25405E 20860N			**Weather**	Sunny, showery
6" Sheet No.	Laois 9			**Observers**	EP Daly, E McKeown

Date	**Time**	**Elapsed Time**	**Water level below datum**	**Drawdown**	**Discharge**		**Discharge**	**Remarks**
					Meter	**Spot**		
		Mins	**(m)**	**(m)**	**gallons**	**gpm**	**(m3/d)**	
9/10/1978	13:30	0	4.305	0	4272207			
		0.25	5.8	1.495				
		0.5	6.2	1.895				
		0.75	6.44	2.135				
		1	6.51	2.205				
		1.5	6.68	2.375				
		2	6.74	2.435				
		2.5	6.78	2.475				
		3	6.81	2.505				
		3.5	6.85	2.545				
		4	6.88	2.575				
		4.5	6.9	2.595				
		5	6.92	2.615				
		6	6.96	2.655				
		7	6.99	2.685				
		8	7.01	2.705				
		9	7.02	2.715				
	13:40	10	7.04	2.735				
		11			4272743	48.73	319.0	
		12	7.06	2.755				
		14	7.09	2.785				
		16	7.095	2.79				
	13:50	20	7.12	2.815	4273187	49.3	322.7	
	14:00	30	7.15	2.845				
		40	7.17	2.865				
		50	7.2	2.895				
	14:30	60	7.205	2.9	4275152	49.13	321.6	
		90	7.2175	2.9125	4276613	48.7	318.8	
	15:30	120	7.16	2.855	4278054	48.03	314.4	
	15:45	135	7.59	3.285		51	333.8	Yield increased to 51 gpm


The Lough - Pumping test 9/10/98
Time (mins)
0.1
1
10
100
1000
Drawdown (m)
1
1.5
2
2.5
3
3.5



Map 1: Geology of the Lough District

Legend

CD Calp Limestone

AW Allenwood Formation

Geological Boundary

Fault

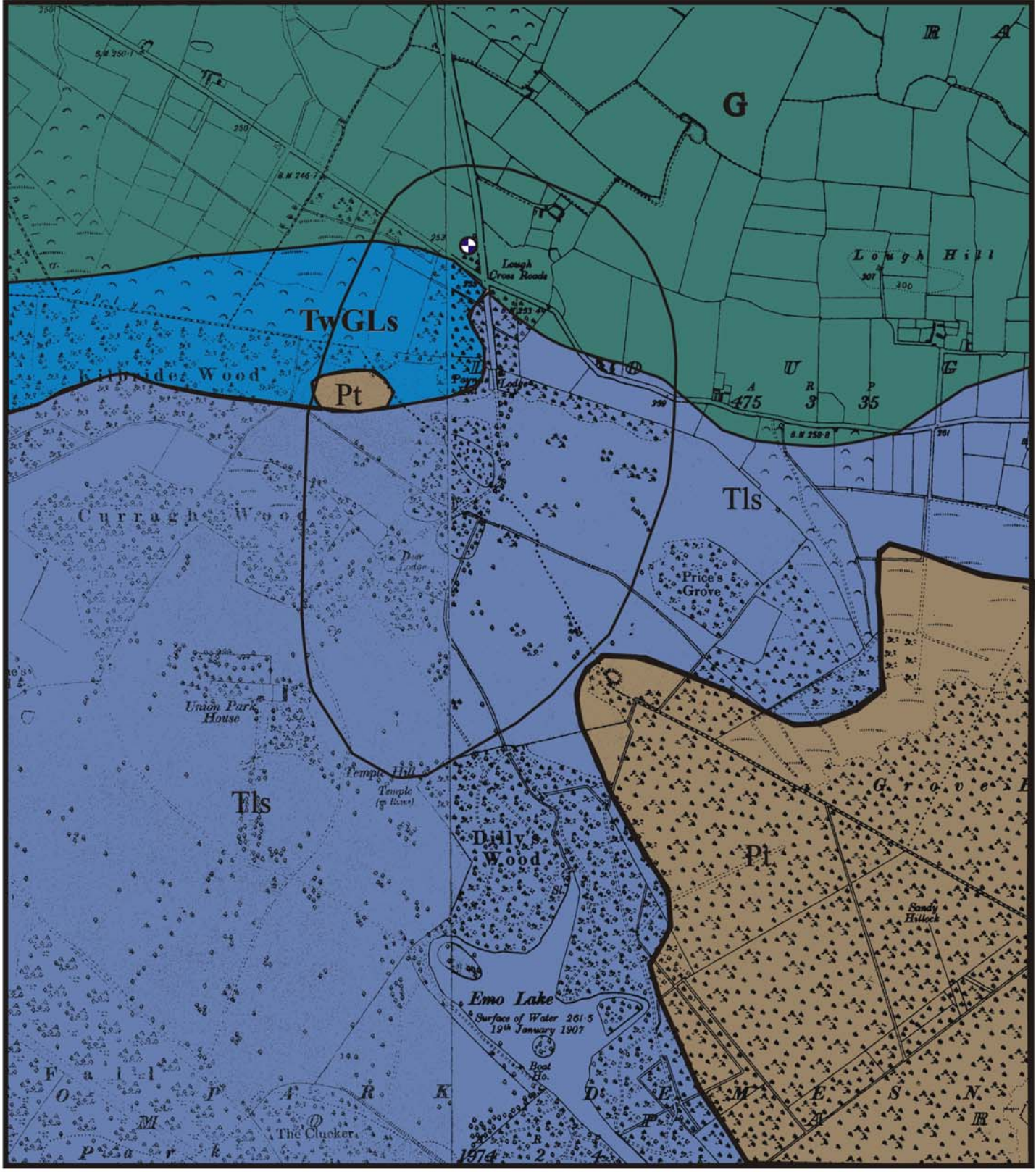
Public Supply Well

Zone of Contribution

N

Scale (metres)

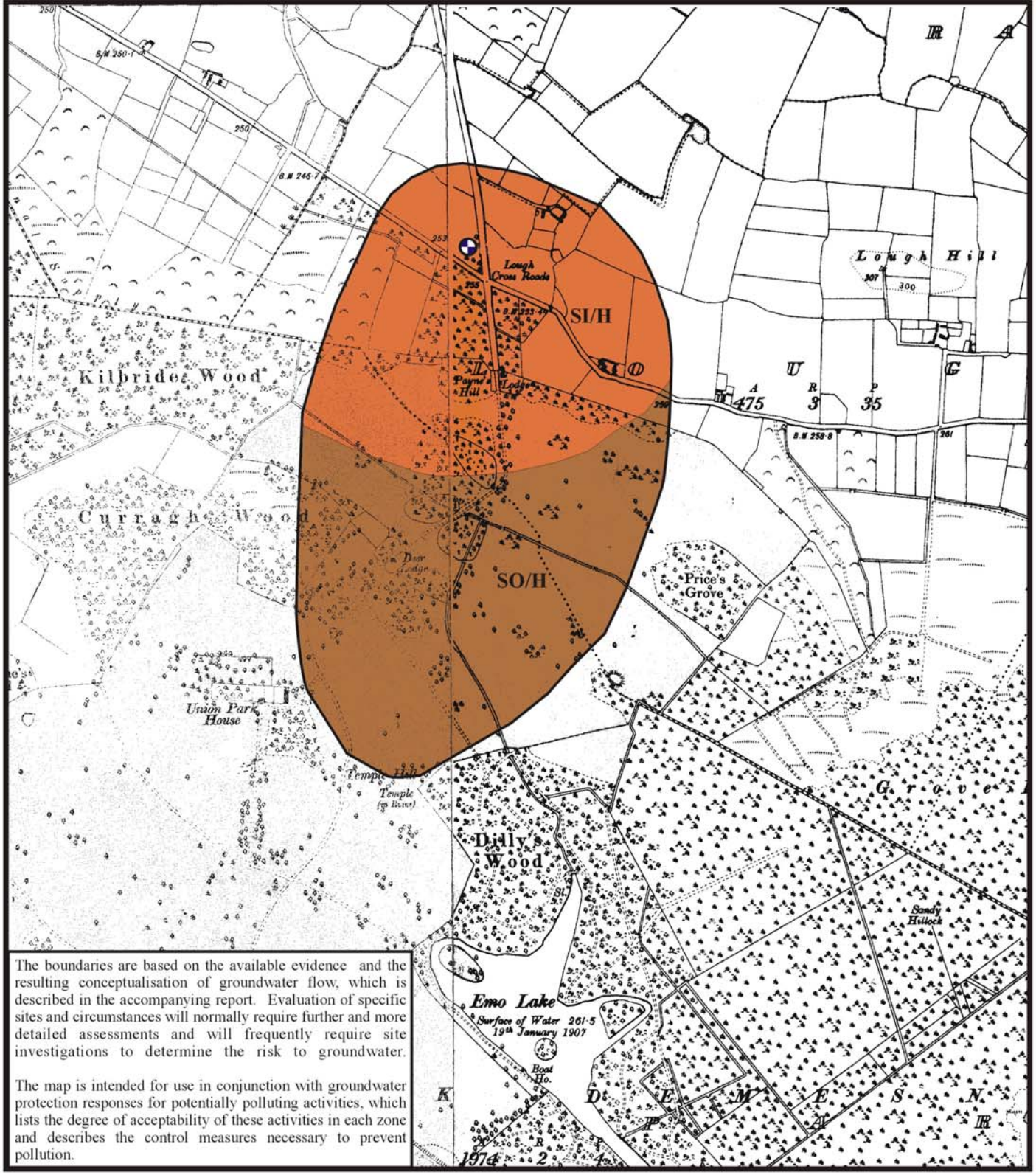
0 500



Map 2: Subsoils of the Lough District

Legend

- Pt — Peat
- Tls — Till derived from Lower Carboniferous Limestone
- TwGLs — Interbedded till and gravel derived from Lower Carboniferous Limestone
- G — Gravel
- Zone of Contribution
- Public Supply Well
- N
- Scale (metres) 0 500



Map 3: Groundwater Protection Zones for the Lough District

Legend