Swan Water Supply Scheme

Groundwater Source Protection Zones

Prepared by:

Geoff Wright

Geological Survey of Ireland

In collaboration with:

Laois County Council

November 2000

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THE SWAN WATER SUPPLY SCHEME

1 Introduction

The objectives of this report are:

- To delineate source protection zones for the Swan Water Supply Scheme (WSS).
- To outline the principal hydrogeological characteristics of the area.
- To assist Laois County Council in protecting the water supply from contamination.

2 Well Location and Site Description

The Swan source is located approximately 10 km north-northeast of the town of Castlecomer. There are two Council boreholes at the site. The Production Well, drilled in 1970, is close (about 50 m) to the Clogh River, while the Observation Well is about 400 metres away to the north, and even closer to the river. There is also a private borehole just east of the Production Well, nearer the river.

The water is chlorinated and pumped to 'Hackett's Reservoir' (capacity 80,000 gallons – 364 m^3). The source serves a population of about 1000 people.

3 Well Details

PRODUCTION WELL (LS 31/1)

GSI no.	:	2317NE W079	
Grid ref. (1;50,000)	:	S 5636 8245	
Townland	:	Moyadd	
Owner	:	Laois County Council	
Well type	:	Borehole	
Elevation (top of casing)	:	170.01 m OD (Malin Head)	
Elevation	:	170.4 m OD (pumphouse floor)	
Depth	:	39 m	
Depth of casing	:	? 2 m (from geophysical logging)	
Depth of pump	:	30 m	
Diameter	:	200 mm (8")	
Depth-to-rock	:	c. 16 m	
Main Aquifers	:	Swan Sandstone (12-23 m, from geophysical logging, 1976)	
Static water level	:	>174 m O.D. (Artesian, overflows naturally)	
Artesian flow	:	6-10 l/sec (5000-8000 gph)	
Pumping water level	:	6 m b.g.l	
Drawdown	:	c. 10 m	
Pumping rate	:	916 m^3/d (8400 gph)	
Abstraction	:	590 m^3/d (130,000 gpd)	
Hours of pumping	:	12 – 14 hours per day	
Pumping test summary (1976):			
		pumping rate:	571 m^3/d
		drawdown:	0.35 m (after3.25 hours)
		specific capacity:	1630 m^3/d/m (after3.25 hours)
		transmissivity:	487 m^2/d

OBSERVATION WELL (LS 31/2)

GSI no.	:	2317NE W080
Grid ref. (1;50,000)	:	S 563 828
Owner	:	? Laois County Council
Townland	:	Moyadd
Well type	:	Borehole
Elevation	:	177.3 m OD (Malin Head).
Depth	:	131 m
Depth of casing	:	? 16 m (from geophysical logs)
Diameter	:	200 mm (8")
Depth-to-rock	:	c. 16 m
Main Aquifers	:	Swan Sandstone (17-26.5 m); Clay Gall Sandstone (56-89 m)
Static water level	:	178.7 m O.D. (artesian, overflows naturally)
Artesian flow	:	0.7 litres/sec. (560 gph)

Pumping test summary (1976):

pumping rate:	262 m^3/d
drawdown:	22.5 m (after 3.25 hours)
specific capacity:	11.6 m^3/d/m (after 3.25 hours)
transmissivity:	4.8 m^2/d

4 Methodology

Desk Study

Geological information was derived from GSI Bedrock 1:100,000 mapping (Sheet 18). Basic source details, including borehole locations, chemistry data and pumping test data, were obtained from Council staff and from GSI files, and from the M.Sc. thesis by D. Daly & B.D.R. Misstear (1976) and papers by D.Daly et al (1980) and Misstear et al (1980).

Site visits and fieldwork

Aoibheann Kilfeather mapped the subsoil types and assessed depth to bedrock throughout the area. Water samples for analysis by the State Laboratory and Health Board were taken in November 1997 and June 1999.

Assessment

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

5 Topography and Drainage

The catchment area of the Swan borehole lies near the northern end of the Castlecomer Plateau. The Swan village itself is situated in the valley of the Clogh River, at an elevation of about 170 metres O.D. To the east, west and north the ground rises to elevations of over 250 metres O.D.

The Clogh River joins the Dinin River some 4.75 km south of the Swan. The Dinin is gauged at Massford Bridge, some 0.5 km further downstream (Hydrometric Station # 15017), and at Castlecomer, 5 km further south (Station # 15013). Long term average runoff at Castlecomer is 2.78 m^3/sec. (573 mm/year), estimated dry weather flow is 0.110 m^3/sec., and estimated 95 percentile flow is 0.210 m^3/sec. At the Swan Bridge beside the source, the river dried up in the dry summer of 1975, i.e. there was no flow.

6 Geology

6.1 Bedrock geology

The geological succession in the area of The Swan comprises sandstones, shales and thin coal seams of Westphalian age (Table 1). Figure 1 shows a geological log of borehole LS 31/2.

A major fault (The Swan Fault) is postulated to run north-south between LS 31/1 and LS 31/2 (unpublished note by E.P. Daly, 1976; D.Daly et al, 1980). However, this fault is not depicted on GSI Bedrock Sheet 18 or on Map 1 of the Groundwater Protection Scheme maps.

Table 1. Geological succession

Formation name	Description	
Coolbaun Formation (CQ)	Shales, sandstones, fireclays and thin coal seams	170 to 250 m thick
Swan Sandstone member (CQss)	Laminated dark grey fine-grained micaceous sandstone	Up to 28 m thick; Penetrated by Production and Observation wells
Moyadd Coal Formation (MC)	Silty shales, siltstones, thin sandstones and two coal seams	15 to 50 m thick
Clay Gall Sandstone Formation (CG)	Light grey, fine- to medium-grained massive sandstone containing shards of shale (clay galls), overlain by siltstone, with coal seam (Wards Coal Seam) towards top	2 to 58 m thick. Not penetrated by Production Well
Bregaun Flagstone Formation (BE)	Generally flaggy-bedded sandstones and siltstones with lesser amounts of silty grey, often micaceous shales	
Killeshin Siltstone Formation (KN)	Mainly grey muddy siltstones or silty mudstones, with lesser amounts of sandstone and shale	

6.2 Geological structure

The Swan lies on the Castlecomer Plateau, which is a large elevated structural basin. The rocks were folded by the Variscan Orogeny (c. 300 million years ago). The main compression was east-west which created north-south trending folds, but the rocks at the northern and southern ends of the plateau dip towards the centre, thus creating the basin-like structure. The folding also created two major sets of faults along ENE-WSW and NNW-SSE directions. D. Daly et al (1980) demonstrated that some faults act as barriers to groundwater flow, while other enhance groundwater flow. In relation to the Swan source, the most important fault is the (postulated) Swan Fault, which roughly follows the valley of the Clogh River and appears to enhance groundwater flow by creating a zone of higher permeability along its course.

Locally, the rocks in the area of the Swan dip southwards or southwestwards at moderate angles.

6.3 Quaternary (subsoils) geology

The Quaternary mapping by Aoibheann Kilfeather shows thin glacial till, limestone-dominated, underlying most of the land around the Swan. Along the Dinin valley, for about 600 m north of the Production Well, and also to the south, there is a narrow strip of alluvium close to the river (around

50 m wide). As the observation borehole shows, this alluvium can be up to at least 16 m deep and may comprise coarse gravel.

Further north, the till thins out and rock is very close to the ground surface (generally within one metre), though there are also two patches of thin till.

6.4 Depth-to-rock

The depth to bedrock in the catchment is generally less than 5 metres (Daly & Misstear 1976), but to the east and northeast of The Swan there is an area of somewhat deeper surficial deposits, reaching a maximum depth of over 10 metres. At the Production Well, bedrock was hit at about 2 metres, but at the Observation Well 400 metres to the north, 16 metres of coarse stream gravels and boulders were encountered above bedrock.

7 Hydrogeology

7.1 Data availability

The hydrogeological data are taken from the three publications by D. Daly, E.P. Daly, Misstear and Lloyd (see references).

7.2 Groundwater levels

Piezometric contours have been drawn (Misstear & others 1980). Groundwater flow is from north to south. The gradient is approximately 0.05 (1/20).

Water levels in LS 31/1 vary only slightly, according to measurements taken between 1973 and 1976 (data in Appendix I).

7.3 Rainfall, Evaporation and Recharge

Long term average rainfall is about 1030 mm (Met Eireann).

Potential Evapotranspiration (PE) is estimated at 457 mm (EPA), so Actual Evapotranspiration (AE) is estimated as 95% of the potential, i.e. 434 mm.

Potential recharge is estimated as (1030 – 434) 596 mm. The surficial cover over the bedrock is generally less than 5 metres thick. For the purposes of this report, it is assumed that annual recharge over the outcrop of the sandstone aquifers is 300 mm, i.e. just over 50% of effective rainfall.

7.4 Hydrochemistry and Water Quality

The Swan borehole yields groundwater which is different from most other groundwaters in County Laois, in that it has undergone the process of 'ion exchange' during its passage through the rocks, whereby calcium and magnesium ions have been exchanged for sodium ions.

In 1976 samples were taken at the surface (overflow) and at four different depths (21 m, 40 m, 65 m 100 m) in the Observation Well (LS 31/2). The 21 m and 65 m samples corresponded to the Swan Sandstone and Clay Gall Sandstone aquifers respectively. The results indicate that the three upper samples have very similar chemical characteristics, i.e. major ion concentrations, alkalinity, total dissolved solids, hardness and pH. The 65 m sample (Clay Gall Sst) has more sodium, less calcium and magnesium (lower hardness) and a higher pH, indicating that its longer travel time has resulted in more cation exchange, producing a softer water. The lowermost sample seems to represent a relatively stagnant water which has exchanged most of its calcium and magnesium for sodium.

Carbon[14] Dating

Carbon isotope dating of water from the Production Well carried out in 1976 determined a corrected age of 1440 ($^{+}$/-170) years. This demonstrates that water moves very slowly through the aquifer, and tends to confirm the low permeability derived from pumping tests in the aquifer as a whole.

Nitrates and Nitrogen

Nitrate values for the Swan borehole have generally been very low. The values in the first two samples, from the 1970s, are significantly higher than later analyses, although still low (the reason for this is not known, but some contamination through sampling is possible). In general, nitrate values from the two aquifers, as reported in 1976, are very low, mostly below 1 mg/l.

Other Nitrogen products (Ammonia) also show low values.

Table 2: Nitrate values from Production Well LS 31/1

Date	NO_3 mg/l	Data source
6/3/72	2.25	GSI/State Lab.
28/5/76	3.60	GSI/State Lab.
24/10/83	0.27	GSI/State Lab.
17/6/91	0.20	E.P.A./Laois C.C.
7/10/91	0.30	E.P.A./Laois C.C.
18/5/92	<0.10	E.P.A./Laois C.C.
14/12/92	<0.10	E.P.A./Laois C.C.
9/11/93	0.10	E.P.A./Laois C.C.
22/5/95	<0.10	E.P.A./Laois C.C.
27/11/95	<0.10	E.P.A./Laois C.C.
7/12/97	<0.10	GSI/State Lab.
8/6/99	<0.10	GSI/State Lab.

Other Parameters

Concentrations of iron and manganese consistently exceed the EU MAC. However, these concentrations appear to be entirely of natural origin.

Overall quality

With the exception of the iron and manganese levels, the water is of excellent quality, with low levels of nitrate, chloride, and bacteria.

7.5 Pumping test data

Pumping tests were carried out on the two boreholes in 1976. Pumping in each of the boreholes caused cessation of artesian flow in the other, demonstrating that the Swan Fault is transmissive.

Pumping test data from LS 31/1 and LS 31/2 gave very different transmissivities: 487 m^2/d and 4.8 m^2/d respectively. The lower value is more in keeping with values from other tests in these aquifers (K5/53: 1.2 m^2/d; LS 31/49: 6.7 m^2/d; K2/13: 14.3 m^2/d). The anomalously high value in LS 31/1 is ascribed to the proximity of the Swan Fault.

Pumping test data are in Appendix I.

7.6 Conceptual Model

The Swan borehole taps the confined Swan Sandstone (about 10 metres thick) which is dipping southwestwards. The sandstone is recharged at its outcrop, about 1-1.5 km to the north and northeast. Although the Clay Gall Sandstone is not penetrated by the Production Well and is generally less transmissive than the Swan Sandstone, it represents a potential additional resource which could be exploited by additional (deeper) production wells at the site. Accordingly, it is proposed to include the outcrop of the Clay Gall Sandstone (east of the Moyadd Fault) within the source protection areas.

7.7 Aquifer category

Considering their general permeability, transmissivity and consistency of yield, the main Westphalian sandstones (Swan Sandstone and Clay Gall Sandstone) are classified as **Locally Important Aquifers, generally moderately productive (Lm)**.

8 Groundwater Source Protection Areas

Source protection areas are delineated for an output of 700 m^3/d, the peak rate currently abstracted.

8.1 Outer Source Protection Area (SO)

The Outer Protection Area is bounded by the catchment area to the source, i.e. the zone of contribution (ZOC), which is defined as the area required to support abstraction from long-term recharge.

If long-term recharge is taken as 300 mm/year and the discharge is 700 m^3/d or 255,000 m^3/year, the recharge area needs to be approximately 0.85 km^2. Since the mapped outcrop of the Swan Sandstone is about 200 m wide, this would require an outcrop of some 4.25 km in extent (east-west).

An alternative approach is to consider the throughflow in the aquifer contributing to the source. If average Transmissivity is 5 m^2/d, discharge is 700 m^3/d, and hydraulic gradient is 0.05, then the contributing width of aquifer should be approximately 2.8 km.

The northern and eastern boundaries of the ZOC are based on the surface hydrological (topographic) catchment to the source. The western boundary is taken to be the Moyadd Fault, which is known to be a flow barrier. The downstream boundary was determined 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 = 700/2 x π x 5 x 0.05 = 445 m

The final catchment proposed (Map 3) is a compromise between the two approaches, and includes a strip of Swan Sandstone outcrop about 3.5 km long, east of the Moyadd Fault. This can be justified on the basis that (a) recharge may be more than 300 mm/year, (b) overall transmissivity may be higher than 5 m^2/d.

8.2 Inner Source Protection Area (SI)

The Inner Protection Area is normally defined by a 100 day time of travel to the source and 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.

For the Swan borehole, assuming a permeability of 0.5 m/d, a gradient of 0.05 and a porosity of 0.05, the 100-day time of travel zone can be estimated at 50 m. This area is entirely within the confined aquifer and therefore does not need to be defined nor afforded special protection.

9 Groundwater Vulnerability

The GSI guidelines for assessing and mapping groundwater vulnerability are set out in 'Groundwater Protection Schemes' (DELG/EPA/GSI 1999). Basically the groundwater vulnerability depends on the permeability and thickness of the subsoils overlying the first groundwater encountered. In the case of the area around the Swan borehole, the first groundwater encountered would normally be within the Coolbaun Formation which overlies the main aquifer, the Swan Sandstone. However, the Coolbaun Formation is largely composed of shales and mudstones, is a Poor Aquifer and has a very low permeability, particlarly in the vertical direction. Hence the Coolbaun Formation affords a high degree of protection from pollution to the Swan Sandstone.

The vulnerability of the Swan Sandstone (and, where relevant, the Clay Gall Sandstone) is important principally in the area where it outcrops, some 1-1.5 km north and northeast of the source. In this area, the overlying subsoils have been mapped as generally less than 3 m thick, and therefore the groundwater is classed as 'extremely' vulnerable to pollution.

10 Groundwater Source Protection Zones

Combining the Source Protection Areas with the vulnerability ratings produces just one Groundwater Protection Zone for the Swan source, as shown in Figure 3:

- Outer Protection Area / Extreme (SO/E)

11 Land Use and Potential Pollution Sources

Land use in the area is predominantly agricultural. Historically, the area was one of the major coal mining regions in Ireland. There are disused mines in the area.

The aquifer tapped by The Swan Source is a confined sandstone which is well protected from contamination near the source by the relatively impermeable shales which overlie and confine it, and by the positive hydraulic pressure in the aquifer, which tends to keep out any contaminated infiltration. The quality of water in the borehole could be threatened by:

1. Contamination in the recharge area up-gradient. Since the travel time from the recharge area to the borehole is very long (of the order of 1000 years), no microbial contamination can reach the source from the recharge area, so the threat is only from persistent chemicals.
2. Contamination through other boreholes penetrating the same aquifer up-gradient. This may be the most potent threat. However, such contamination is unlikely as long as an artesian pressure is maintained.
3. Contamination via preferential flow paths to the aquifer, e.g. where an artesian pressure is absent and the Swan Sandstone is cut by the Swan Fault.

12 Conclusions and Recommendations

1. The Swan groundwater source enjoys a high level of protection from contamination by virtue of its confined condition and long distance from its recharge area.
2. The source has a very low risk of contamination by pathogenic organisms.
3. Contamination of the aquifer by persistent chemicals could occur but would not be likely to affect the source for many hundreds of years under present conditions.
4. The risk of contamination would be greatly increased if the aquifer were to be overexploited so that a positive artesian pressure ceased to be maintained. In that case, the chief risk would arise from contamination of other boreholes penetrating the aquifer(s).
5. The recharge area of the aquifer, some 1-1.5 km up-gradient (to the north and northeast) constitutes the Outer Protection Area and should be protected and monitored to preserve the quality of the supply for future generations.

13 References

Daly, D., Lloyd, J.W., Misstear, B.D.R., & Daly, E.P., 1980. Fault control of groundwater flow and hydrochemistry in the aquifer system of the Castlecomer Plateau, Ireland. Quarterly Journal of Engineering Geology, London, vol. 13, pp 167-175.

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E.P.A. 1997. Nitrates in Groundwater: County Laois. Environmental Protection Agency.

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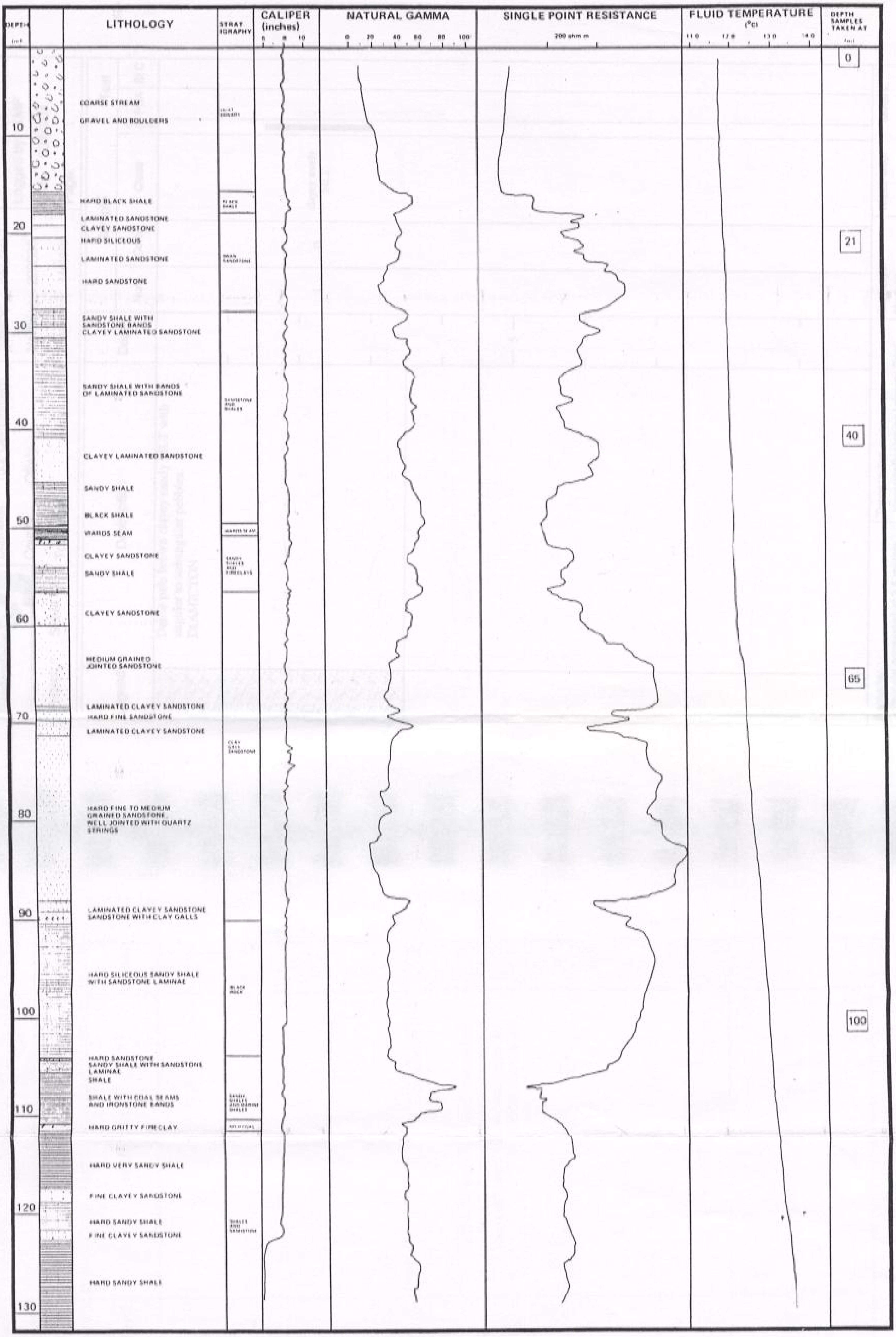


FIGURE 1 Detailed Geological and geophysical logs of borehole No. LS 31/2 at Swan, County Laois.

Appendix 1

Pumping Test Data

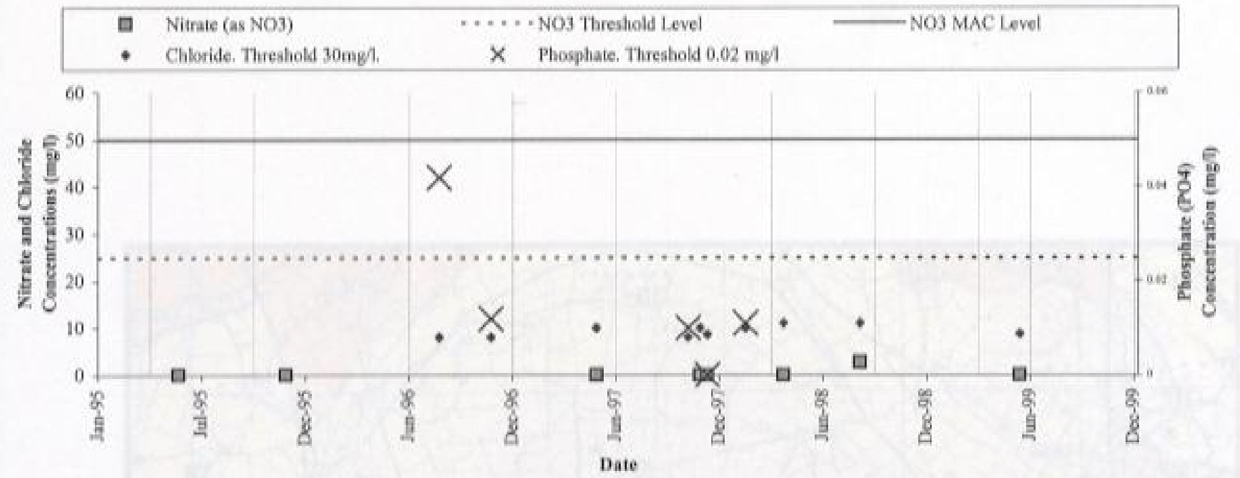
The Swan consumption test 3/2/83-8/3/83			
consumption since last reading	hrs since last reading	gallons/hour used	
92000	24	3833.333	
101000	18.5	5459.459	
116500	16	7281.25	
96000	17	5647.059	
120500	33	3651.515	
122000	20	6100	
107000	27.5	3890.909	
98400	24.5	4016.327	
89000	18.5	4810.811	
119000	27	4407.407	
102000	26	3923.077	
122700	24	5112.5	
76000	14.5	5241.379	
125400	32.5	3858.462	
106000	24.5	4326.531	
88700	19	4668.421	
101400	31.5	3219.048	
129400	21	6161.905	
80600	18.5	4356.757	
95000	21	4523.81	
144000	32	4500	
89000	23.5	3787.234	
91000	17.5	5200	
101200	28.5	3550.877	
89000	17	5235.294	
150000	33	4545.455	
111400	24	4641.667	
80400	20.5	3921.951	
120500	28	4303.571	
69100	15	4606.667	
121400	29.5	4115.254	
74200	17.5	4240	
144400	33	4375.758	
3474200	777.5	4468.424	
		4591.324	
		7281.25	
Total = 3,474,200 gallons pumped in 777.5 hrs = 4468 g/h = 487 m3/d			
Max rate was 7280 g/h = 794 m3/d			

Appendix 2

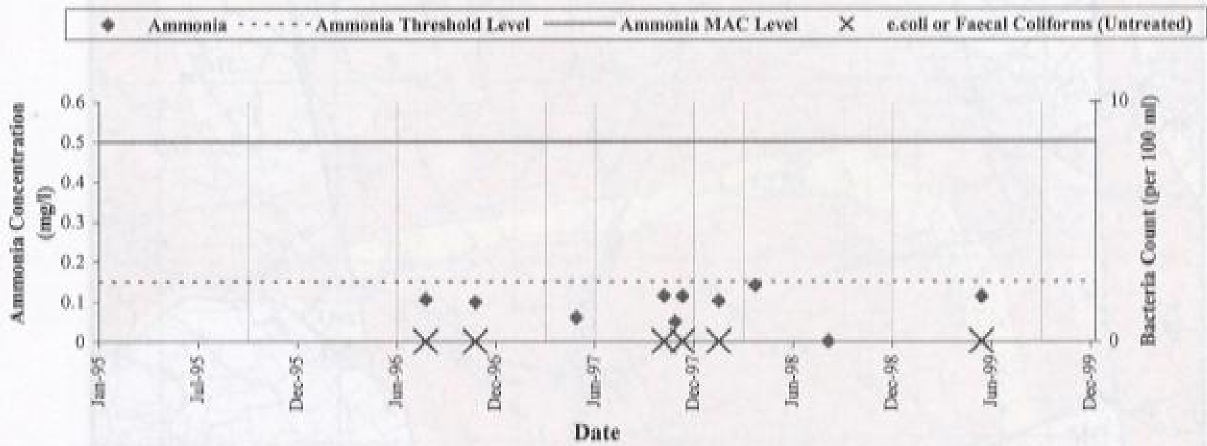
(Water Quality) Hydrochemistry Data

Figure 47-The Swan
Key Indicators of Agricultural and Domestic Groundwater Contamination.

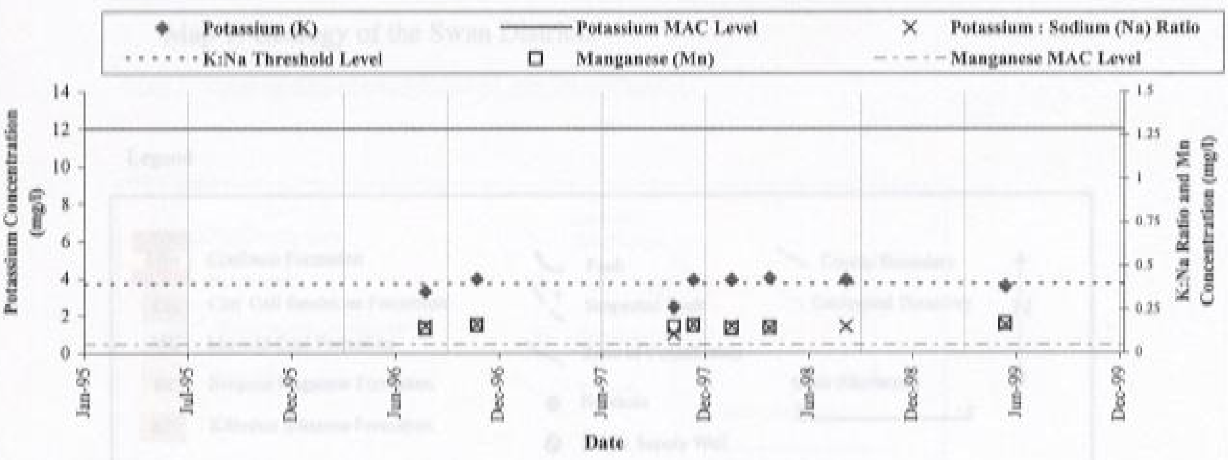
Nitrate, Phosphate and Chloride



Bacteria and Ammonia

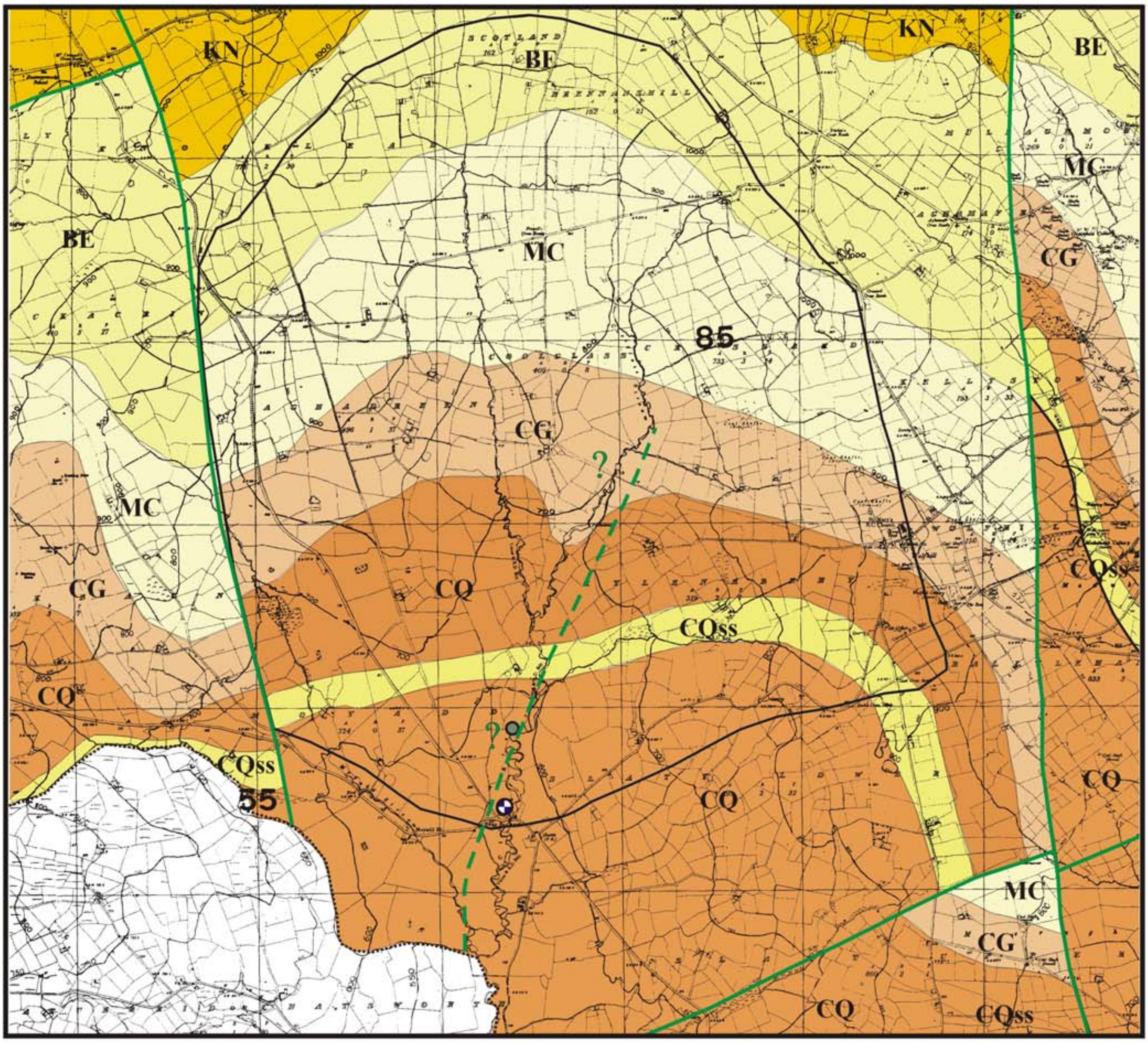


Manganese, Potassium and Potassium: Sodium Ratio



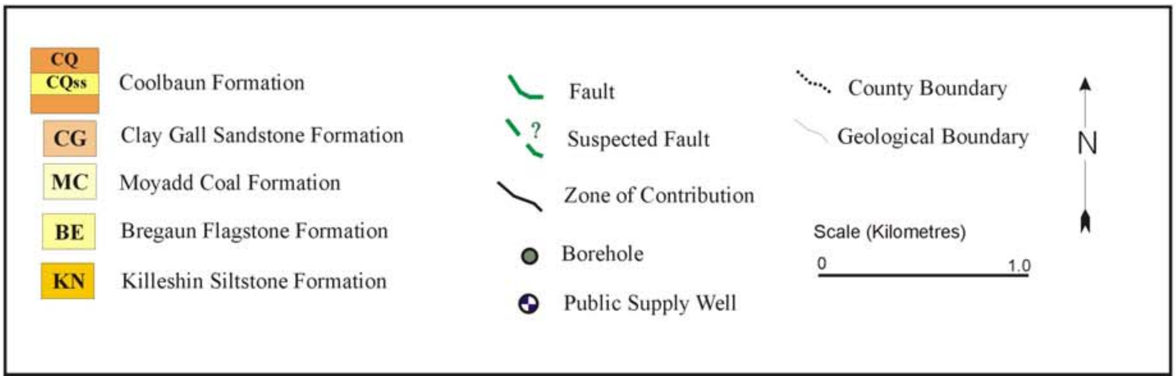
Sources: GSI sampling and available EPA and Council data.

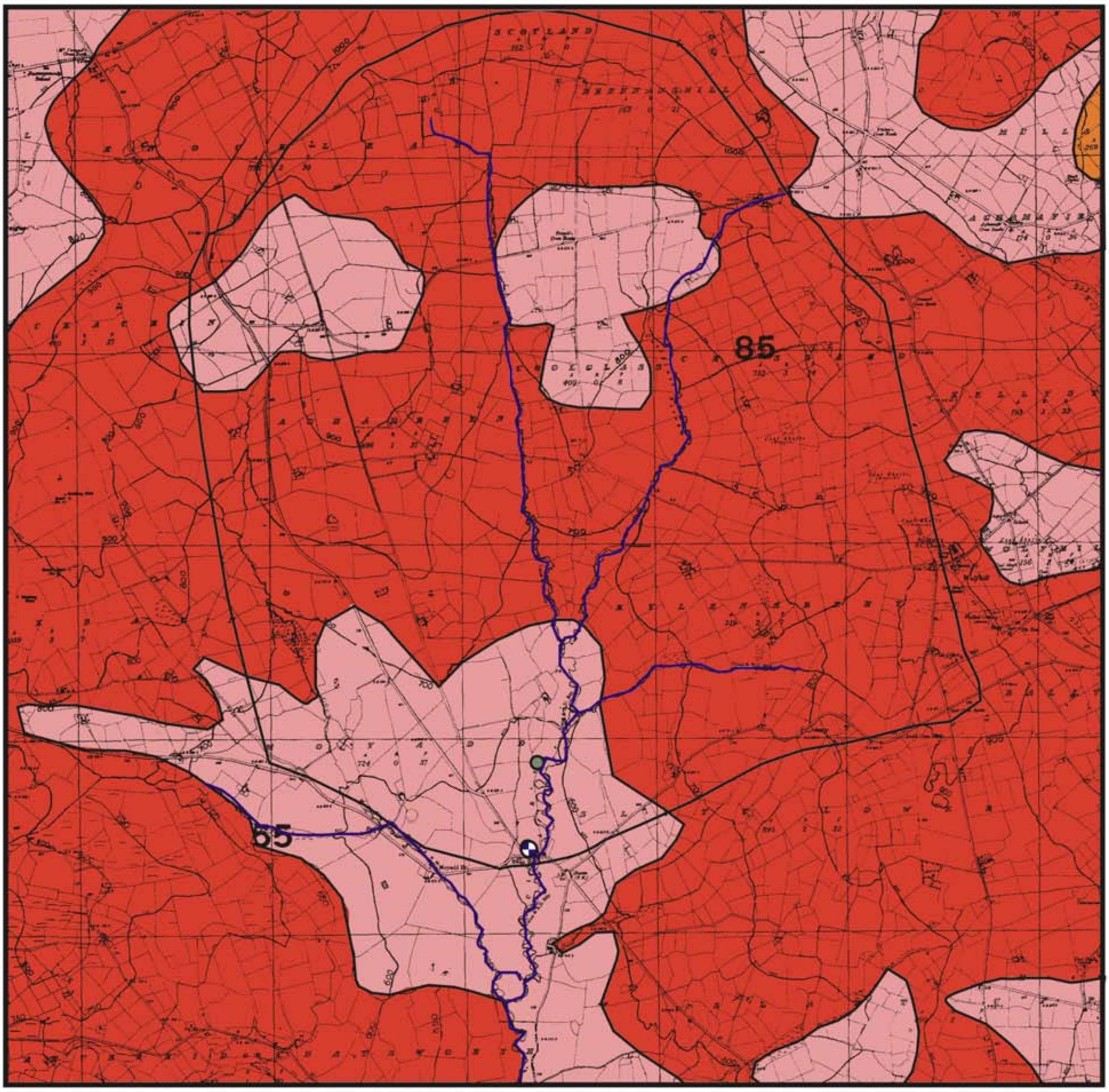
Maps



Map 1: Geology of the Swan District.

Legend





Map 2: Vulnerability classification of the Swan District

Legend

Vulnerability Classification

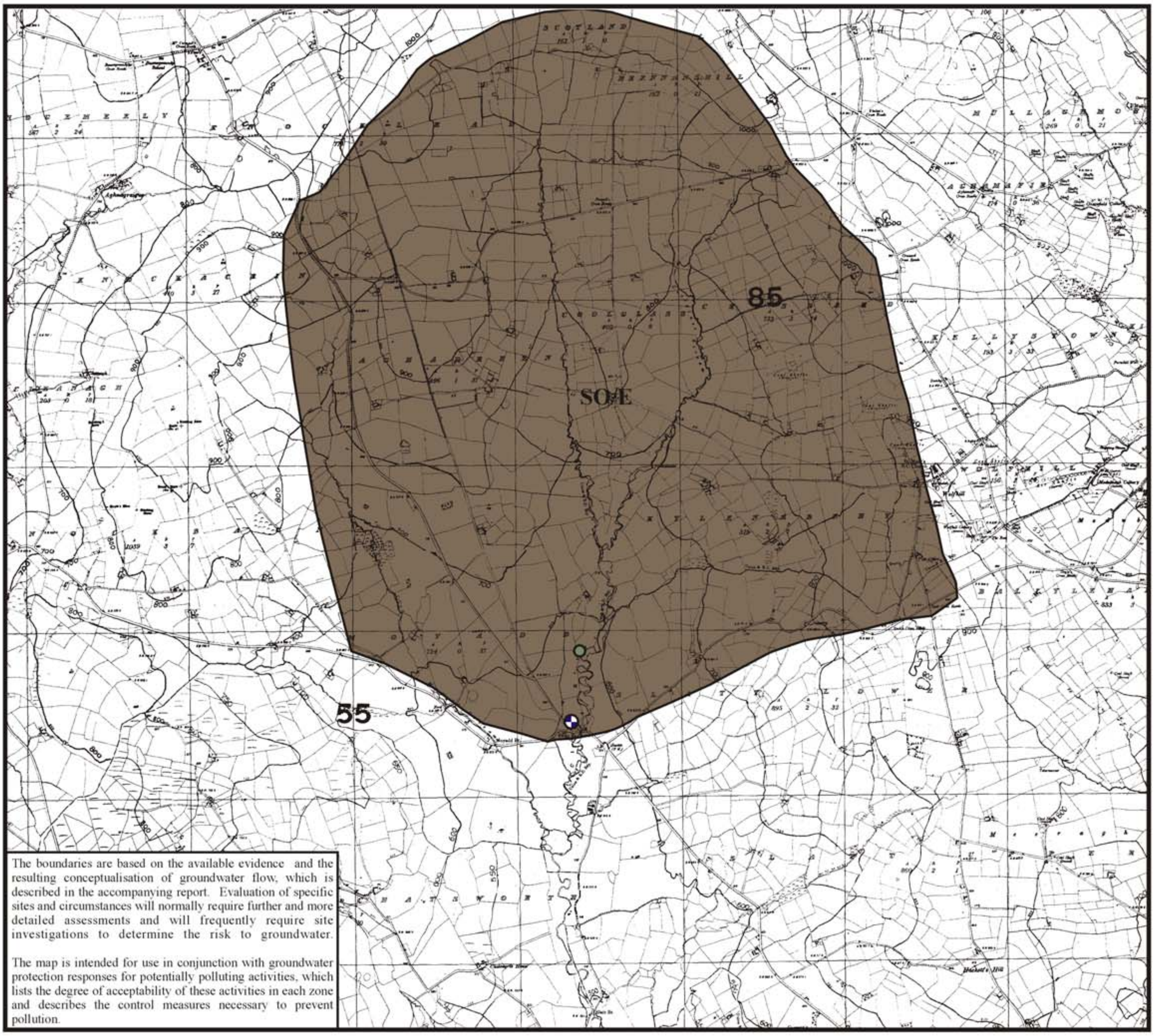
- Extreme (E)
- Outcrop/shallow rock/karst (E)
- High (H)

- Zone of Contribution
- Public Supply Well
- Borehole
- Streams

N

Scale (Kilometres)

0 1.0



Map 3: Groundwater Protection Zones for the Swan District

Legend

- SO/E Outer Zone- Extreme
- Borehole
- Zone of Contribution
- Public Supply Well

N

Scale (Kilometres)
0 1.0