ROUNDWOOD WATER SUPPLY

GROUNDWATER SOURCE PROTECTION REPORT

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ROUNDWOOD WATER SUPPLY

1. Well Location and Site Description

This source is the main public water supply well for Roundwood village and its hinterland. The Production Well (PW No. 1) is located 0.5 km northwest of the cross-roads in Roundwood village (Figure 1). The well is 61 metres deep and 200 mm in diameter, and is completed above ground level, with a manhole covering the well. The well-head is sealed, providing good protection. The well is located beside the pump house and a small storage reservoir, and all are fenced off from the adjacent agricultural fields. The Roundwood groundwater is chlorinated in the storage reservoir before being pumped into supply. There are some private wells being used in the vicinity of this source. An Observation Well (OW No.1) drilled by GSI in April 1997 is 8 metres from PW No.1.

Another Council well, at Raheen Quarry (PW No.2), had not been commissioned at the time of this study, hence no source protection area was delineated for this well. This borehole was drilled in November 1990 to a depth of 60 metres, at a diameter of 250 mm, with a major inflow at 31.4 metres where a large fissure was found.

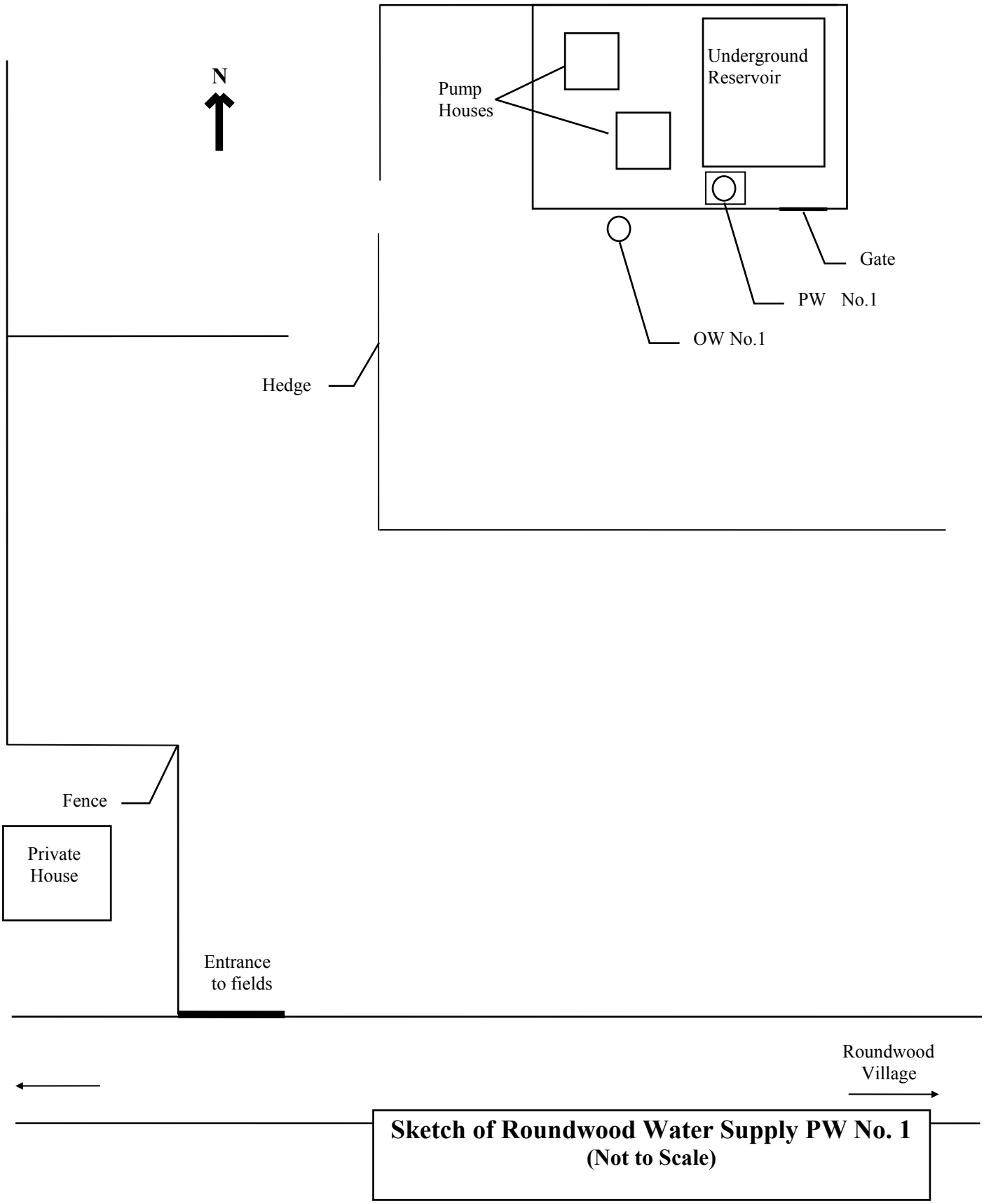
2. Well Details

PRODUCTION WELL NO.1, ASHTOWN

GSI no.	:	2919NE W025
Grid ref. (from 1:25,000)	:	31866 20335
Well type	:	Borehole
Elevation (top of casing)	:	248.53 m OD (Malin Head). Ground level is 248.28 m OD.
Depth	:	61 m
Diameter	:	200 mm (8")
Depth-to-rock	:	c. 1.5 m
Static water level	:	4.14 m b.t.c. (8/5/97), 3.89 m b.g.l.(8/5/97)
Pumping rate	:	325 m^3/d (3,000 gal/hr)
Normal consumption	:	c. 100 m^3/d (22,000 gal/d on average, over 24 hrs)
Pumping test summary	:(i) pumping rate	: 325 m^3/d
	(ii) drawdown	: 6.64 m (after 12 hours)
	(iii) specific capacity	: 40 m^3/d/m (extrapolated to 1 week)
	(iv) transmissivity	: 30 – 50 m^2/d

PRODUCTION WELL NO.2, RAHEEN QUARRY

GSI no.	:	2919NE W008
Grid ref. (from 1:25,000)	:	31819 20160
Owner	:	Wicklow County Council
Well type	:	Borehole
Depth	:	61 m
Diameter	:	250 mm (10")
Depth-to-rock	:	c. 0 m
Static water level	:	3.1 m b.t.c. (12/12/90)
Pumping test summary	:(i) pumping rate	: 871 m^3/d
	(ii) drawdown	: 26.3 m (after 7 days)
	(iii) specific capacity	: 34 m^3/d/m (after 7 days)
	(iii) transmissivity	: 40-50 m^2/d



Sketch of Roundwood Water Supply PW No. 1
(Not to Scale)

3. Methodology

Desk study

All available data were compiled. Basic source details, including borehole locations, chemistry data and pumping test data were obtained from Council personnel and consultants.

Site visits and fieldwork

An observation well was drilled by GSI and a twelve hour pumping test and recovery test was carried out to examine the aquifer characteristics. The area around the source was surveyed with regard to geology, hydrogeology, vulnerability to pollution and current pollution loading. Raw water samples were taken in February, May and August 1997 for full suites of chemical and bacterial analyses. Conductivity measurements were taken monthly until May 1997 by Council personnel. Well-head elevations were measured by GSI staff.

Assessment stage

Analytical equations and hydrogeological mapping were used to delineate protection zones.

4. Topography, Drainage and Land Use

The Roundwood source is located 10 km northwest of Ashford, off the R755. The topography in the area rises gradually from 200 m OD (600ft) to over 300 m OD (1000 ft). The well is located at 248 metres OD.

Small streams flow in a southeasterly direction, towards the Vartry Reservoir. The drainage in the area is relatively good with numerous small drainage ditches, particularly to the northwest of Roundwood.

Excluding the village and its immediate surrounds, the land use in the area is primarily pasture with forestry on the higher ground. The fields around the production well are permanent grassland and appear to be artificially drained.

5. Geology

5.1 Bedrock geology

The geology in the immediate vicinity of the pumping wells is given by the borehole log from the GSI observation borehole 59 metres deep (Roundwood D/H 97/8). This monitoring well was drilled in April 1997 approximately 8 m from the main production well. The log indicates 1.5 metres of till overlying shales, slates and siltstones (Maulin Formation). The rocks are predominantly fine grained, with some coarser units. The bedrock is extensively weathered between 1.5 metres and 5 metres in depth and highly broken and fractured to the bottom of the well at 59 metres.

There are small scattered outcrops of bedrock around Roundwood, and towards the top of Ballinafunshoge or Ashtown mountain, rock is close to the surface of the ground.

The underlying rocks belong to the Maulin Formation which is part of the Ribband Group, Cambro-Ordovician in age. These rocks consist predominantly of fine grained metasediments and are dark to mid grey laminated siltstones and shales with slates and mudstones. Close to the granite margin, quartzites are found, for example around Lough Dan. At Raheen, on the Laragh road, 1km to the south of Roundwood there are some highly deformed pillowed basaltic lavas (Roundwood Member) which outcrop in the Council Depot. This area is highly faulted and the general dip of the rocks is to the southeast (McConnell, B. & Philcox, M.E. 1994).

The driller's log from the borehole at Raheen (PW No.2) indicated several colour changes within the basalt and a fissure was encountered at 31.4 metres where large quantities of water were obtained.

Small faulted blocks of Bray Formation occur to the northwest and south of PW No.1. The rocks of the Bray Group are Cambrian in age and consist of greywacke sandstones, shales and quartzites.

5.2 Quaternary (subsoils) geology

The entire area is covered with thin and generally poorly to moderately permeable Lower Palaeozoic till, which is matrix supported and is characterised by a generally clayey silty to silty texture. Sandy silty matrices are observed locally. Particle size analyses of samples taken in the Roundwood area show that 30-45% of the bulk of the sample are fines (clay and silt) and about 25-35% fall within the sand size range. Clasts are angular to subangular and consist of mica-schists and shales. Few subangular granite erratics also occur. In areas where bedrock is close to the surface, the clast content is higher and the till may be characterised as stony silty.

The till is interpreted as a lodgement till deposited by ice from the Wicklow Mountains during the last glacial period. In places the tills are covered by a peaty top soil, but this is less than one metre thick, and has not been mapped.

5.3 Depth-to-bedrock

Rock outcrops occur along streams and along roads. Five auger holes were drilled by the GSI around the area to investigate the subsoils and determine the depth to bedrock, and encountered depths varying from approximately 1.5 m to 5-6 m (see table below). The exact depths to rock could not always be established, as the upper part of the shale bedrock is highly weathered, making it difficult to distinguish between subsoil and rock.

Table 1: GSI Depth-to-bedrock auger holes, 1997 (Bakker, M., 1997)

GSI Well No.	GSI drill No.	Easting	Northing	Depth, m	Depth to bedrock, m	Subsoil Log
2919NEW052	97/34	31866	20333	2.1	2.1	Clayey silty Lower Palaeozoic diamicton
2919NEW053	97/33	31896	20321	5.5	4.5	0 - 4 m: silty Lower Palaeozoic diamicton 4 - 5.5 m: gravelly silty Lower Palaeozoic diamicton
2919NEW054	97/32	31858	20311	4	3	Gravelly silty sandy Lower Palaeozoic diamicton
2919NEW055	97/29	31773	20328	8	6	Gravelly sandy silty Lower Palaeozoic diamicton
2919NEW056	97/31	31773	20351	6.4	6.4	0 - 4 m: sandy silty Lower Palaeozoic diamicton, gravelly at the top 4 - 6.4 m: clayey silty Lower Palaeozoic diamicton

In general, the subsoils are less than 6 metres thick. The depth to rock contouring was based on very limited data and may need refining as further depth to bedrock records become available.

6. Hydrogeology

6.1 Data availability

Hydrogeological data is moderately good for the Roundwood area.

No geological log is available for the current pumping well, PW No.1. The GSI monitoring well (OW No.1), drilled about 8 metres from the pumping well, at a diameter of 75.7 mm (47.6 mm core), encountered 1.5 m of stony clay till, followed by weathered shales down to 59 m. Plastic pipe (50 mm daimeter) was installed in the borehole, slotted at the bottom to allow water entry.

A 12 hour pumping test with a recovery test was carried out on PW No. 1 on 8/5/97 and a survey of pollution sources and wells was conducted within the catchment of the source. Water levels in private wells were measured and a water table map compiled to ascertain the groundwater flow direction. The well heads were not accurately levelled in but as the survey included dug wells (springs) which may only be tapping a perched water table within the till, these water level readings were used with caution. The groundwater flow direction is generally to the southeast towards the Vartry reservoir.

The production well produces only a small cone of depression in its immediate vicinity and has not affected the groundwater flow in the wider Roundwood area. Most private houses around Roundwood are served by bored wells, as the mains water supply only supplies the village itself.

PW No.2 at Raheen Quarry allowed the County Council to test the groundwater potential of the fractured and faulted basalts that outcrop around the Council Depot, with a view to augmenting the existing supply due to the extended dry weather. The driller's log of this borehole showed the following:

0 - 18.3 m	Red/pink rock, very hard and abrasive
18.3 - 24.4 m	Blue/green rock
24.4 - 36.6 m	Hard blue rock, water at 31.4 m
36.6 - 61 m	Red/pink rock, with layers of white quartzite and some soft brown material

Pumping test results from PW No.2 (December 1990) were good; the pumping rate varied from 2,160 m^3/d at the start to 871 m^3/d after seven days, when the water level had dropped from 3.1 m to 29.46 m. Water levels monitored in three nearby private wells indicated a cone of depression extending for a radius of just over 200 metres. The safe yield was estimated to be 600 m^3/d (5,500 gph) and the specific capacity about 30 m^3/d/m. This well is not currently used by the Council. A short report on the drilling and testing of this well was prepared by the GSI Groundwater Section, (E.P. Daly, 1991).

6.2 Groundwater levels

Groundwater is generally close to the surface. The static water level in the wells on 8/5/97, following overnight recovery, and the pumping water levels after 12 hours pumping are shown below.

Date	Well No.	Static Water Level		Pumping Water Level	
		metres (b.g.l)	metres O.D.	metres (b.g.l)	metres O.D.
8-5-97	PW No.1	3.89	244.39	10.53	237.75
8-5-97	OW No.1	4.37	243.81	6.40	241.78

The unsaturated zone is relatively thin (<5 metres), but ranges up to 11 m thick in the cone of depression, as a result of the continuous pumping.

6.3 Groundwater flow directions and gradients

Regional groundwater flow is generally southeastwards towards the Vartry Reservoir, but locally it is dependent on topography. The exact flow direction was difficult to assess due to the lack of water level data near the well. The flow to the well is generally from the west-northwest.

The groundwater gradient in the area may range from approximately 0.01 to 0.05 and is taken as 0.02 for calculations.

6.4 Rainfall, Evaporation and Recharge

The two nearest rainfall stations are at Roundwood (Filter Beds at Vartry Reservoir, 3.2 km from the well (altitude 195 m) and Valve Tower, 1.5 km from the well (altitude 229 m)). Both rainfall stations are lower than the well head. The mean annual rainfall as recorded by Met Eireann for 1951-1980 was 1236 mm at the Valve Tower and 1204 mm at the Filter Beds. Potential evapotranspiration (P.E.) is estimated from a Met Eireann contoured map as 550 mm/yr. Actual evapotranspiration (A.E.) is estimated at 520 mm/yr by calculating a percentage (95%) of the P.E., to allow for seasonal soil moisture deficits.

Using the above figures the effective rainfall (E.R.) is taken to be approximately 700 mm/yr. As there are drainage ditches and streams in the area and the Quaternary deposits are relatively poorly draining and thin, a moderately low proportion of the effective rainfall infiltrates to the water table. Estimating run off to be of the order of 40%, the actual annual recharge to the aquifer is estimated to be 420 mm per annum, possibly less.

These calculations are summarised below:

Average annual rainfall	1220 mm
Estimated P.E.	550 mm
Estimated A.E. (95% P.E.)	520 mm
Effective rainfall	700 mm
Recharge (60% E.R.)	420 mm

6.5 Hydrochemistry and Water Quality

The hydrochemical analyses of groundwater from the Roundwood source (PW No.1) indicate a moderately soft (50-64 mg/l $CaCO_3$), calcium bicarbonate type water with a low alkalinity (32-45 mg/l $CaCO_3$). Conductivities are also low, ranging from 130-190 µS/cm and chloride is usually low, around 15 mg/l. The mean nitrate level of around 20 mg/l is well below the EU guide level. More recent data (EPA 2001) show some indication of a slight increase. Groundwater analyses are given in Appendix 2.

The water quality at Roundwood is good with generally no bacterial contamination (on one occasion some natural occurring background Coliforms and *E. coli* were noted from a County Council analysis). All the major cations, anions and trace elements are within the Irish Drinking Water Standards and the EU limits except for iron and manganese which are naturally high. Colour and turbidity levels are often above the MAC.

The quality of water from PW No. 2, tested in 1990, was also good, but significantly harder (see Appendix 2). However, iron and manganese concentrations were low.

While the groundwater quality is generally good, there are indications that some parameters may be increasing slightly, although further analyses are required to confirm this. The intermittent natural contamination from iron and manganese seems to coincide with high turbidity and suspended solids.

Table 2: Conductivity readings from the Roundwood Source

	Production Well No.1	
Date	**Conductivity (μS/cm)**	**Temperature (^{O}C)**
*3/2/97	156	9.0
28/2/97	175	9.7
26/3/97	151	10.8
28/4/97	164	10.1
*12/5/97	164	9.2
27/5/97	173	10.0
*12/8/97	190	14.4

* Full analyses

6.6 Aquifer coefficients

Analysis of the 12 hour pumping test on PW 1 provided an apparent transmissivity in the range 55-80 m^2/d (pumping rate 325 m^3/d). A conservative transmissivity of 65 m^2/d is used in calculations. The specific capacity (extrapolated to 1 week) was 40 m^3/d/m. The specific yield of 0.012, calculated from the late data from OW No.1, confirms that the aquifer is unconfined.

During the 12-hour pumping test the drawdown increased gradually, and a steady pumping water level was not attained. The yield of the well is probably near its maximum. The pumping test data are in Appendix 1.

Analysis of the seven day pumping test at Raheen Quarry (PW 2) in December 1990 (pumping rate 2,160 to 871 m^3/d, drawdown 26.4 metres) indicated an apparent transmissivity in the range 30-40 m^2/d. The decrease in pumping rate through the test led to a marked flattening of the drawdown curve, following an initial steep drop. The slope of the drawdown curve in the pumping well is therefore unreliable as a guide to transmissivity, and the drawdown curve for Observation Well No. 1 is probably a better guide. Data from the other two observation wells are less useful, since the drawdowns were very small and apparently affected by other pumping. Analysis of the recovery data is hampered by the effects of recharge and the absence of detailed records of actual pumping rates. However, the drawdown curve from the pumping well (PW 2) tends to confirm a transmissivity of about 30 m^2/d. The specific capacity for PW 2 at 1 week was 33 m^3/d/m.

Overall, the data from PW 2 are similar to those obtained from the 12 hour test on PW 1.

6.7 Conceptual Model

The aquifer feeding the Roundwood source is the Maulin Formation. The aquifer is more permeable in the upper part. Permeabilities within the bedrock are increased by joints and fractures which are directly related to the faulting close to the wells. The aquifer is overlain by a thin till cover, with a low to moderate permeability in the vicinity of the production wells, and the aquifer is considered to be unconfined at least near the wells. The unsaturated zone ranges from 3 to 12 m thick.

Groundwater flow follows the topography, flowing from the higher ground, down the hillside and discharging into the Vartry reservoir. The groundwater flow to the public supply is therefore presumed to be from the west-northwest, which is confirmed by the water table data.

The main inflows into the pumping well are not known as no borehole log is available. Direct inflows to the wells from the subsoil should be prevented by the presence of the steel casing, though this may not be grouted.

6.8 Aquifer category

The aquifer supplying the Roundwood source is the Maulin Formation. Considering the aquifer in terms of its well yields and specific capacities over the county it is classed as a **Locally important aquifer** which is **moderately productive only in local zones (Ll)** (Figure 1).

7. Groundwater Vulnerability

The aquifer in the catchment area is unconfined and is overlain by thin till. Around the public supply well and approximately 150 metres directly up-gradient, the subsoil is generally less than 3 m thick; under the GSI vulnerability mapping guidelines, such areas are mapped as 'extreme' vulnerability. The surrounding area is classified as 'highly vulnerable'. Small areas are classified as 'moderately vulnerable'. The vulnerability zones are shown on Figure 2.

Overall, the catchment area to the Roundwood source is regarded as extremely to highly vulnerable to pollution.

8. Source Protection Areas

Source protection areas are delineated for the maximum output (325 m^3/d) which is much greater than the 100m^3/d (on a daily basis) currently abstracted, and thus allows for expansion of the zone of contribution during dry weather and for future increases in daily abstraction.

8.1 Source Site (SS)

The Source Site (SS) is defined as the immediate area around the source (minimum 10 m radius) to maintain good wellhead sanitary protection. The fenced-off site at the well-head is about 20 metres by 10 metres and PW No.1 is located along the southern fenced edge. This fence should be moved out at least the minimum 10 metres.

8.2 Inner Protection Area (SI)

The Inner Protection Area is defined by a 100 day time of travel 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.

Assuming a more permeable zone close to the surface (upper 20 metres) in the vicinity of the source, conservatively high aquifer coefficients are used to determine the 100 day time of travel distance.

Using the following aquifer coefficients: permeability (k) = 5 m/d, porosity = 0.03, and the hydraulic gradient (i) = 0.02, the 100 day time of travel distance to the well is estimated to be approximately 330 metres (Figure 3).

8.3 Outer Protection Area (SO)

The Outer Protection Area includes the remainder of the catchment area to the source, i.e. the zone of contribution (ZOC), which is defined as the area required to support an abstraction from long-term recharge. The ZOC at Roundwood is derived from hydrogeological mapping and is controlled primarily by the groundwater flow direction. The size of the ZOC as shown in Figure 3 is based largely on the Recharge Equation. Assuming an annual recharge of 420 mm, the area required to supply the pumping rate of 325 m^3/d is estimated at 0.3 km^2. The calculated null point or down-gradient boundary of the ZOC (the distance down-gradient beyond which water is not contributing to the well) is approximately 50 metres. A buffer (safety margin) is included in the final ZOC by allowing a 10-20^o error margin for the estimated groundwater flow direction; this overestimates the ZOC significantly, the area in Figure 3 being approximately 0.5 km^2.

9. Groundwater Source Protection Zones

Combining the Source Protection Areas with the vulnerability ratings produces four groundwater protection zones for the Roundwood source. These are listed here in order of decreasing degree of protection required and are shown in Figure 3:

- Inner Protection Area /Extreme (SI/E)
- Inner Protection Area / High (SI/H)
- Outer Protection Area / Extreme (SO/E)
- Outer Protection Area / High (SO/H)

10. Potential Pollution Sources

The primary threat to the public supply at Roundwood is the quality of water which recharges the underlying aquifer upstream of the source. The water quality may be affected in particular by land spreading, septic tanks and farm effluent. A survey of potential point sources was carried out in the zone of contribution of the well. There is one farmyard within the protection zone of the well which may pose a risk to the water supply if the waste from the yard is not adequately controlled.

Point pollution sources, in particular farmyards and septic tank systems, probably pose the main threat to the water quality.

11. Conclusions and Recommendations

Overall the source at Roundwood is moderately high yielding and is currently pumping at the pump's maximum capacity. An increased yield could be obtained by increasing the pump size and the rising main diameter. Alternatively an increase in storage would allow continuous pumping. The water analyses indicate no major water quality problems at this source, except for the naturally high iron and manganese. However the source catchment is extremely to highly vulnerable to pollution.

It is recommended that the Council continue to sample the raw water from the Roundwood public supply to monitor the iron, manganese, nitrate, potassium, chloride and conductivity levels, and to examine the effects of the potentially polluting activities near to the well. In addition it is recommended that the Council monitor and where necessary control potentially polluting activities within the delineated groundwater source protection zones. In particular, the Council should monitor farmyard activities up-gradient from the well.

12. References

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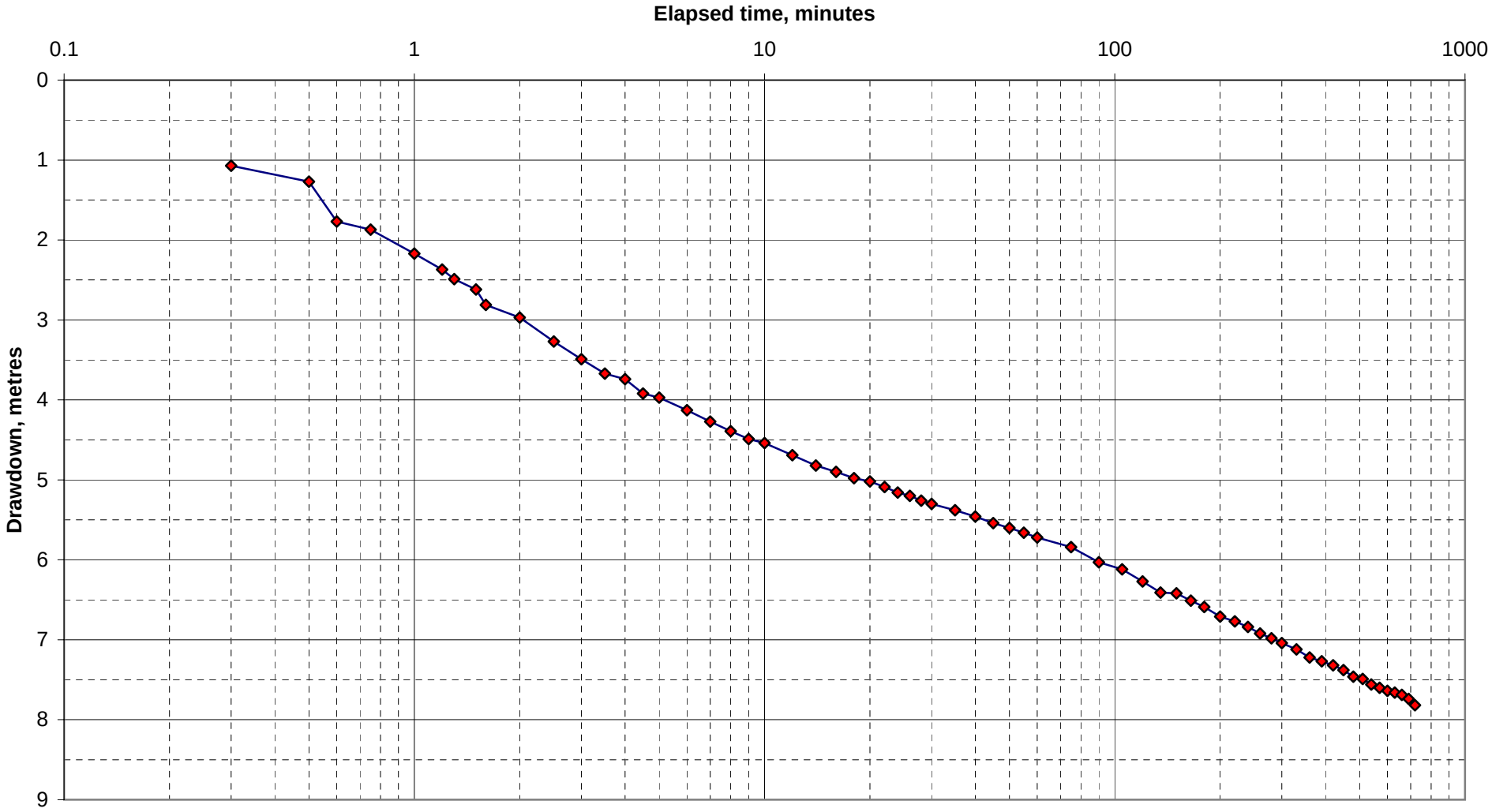
Appendix 1
Pumping Test Data

Redcross PW1, Pumping Test, 1 May 1997,
Drawdown data

Date	Time	Elapsed time (min)	Water level, m	Drawdown, m	Pumping rate, m^3/d	Temperature ^oC	E.C. µS/cm
1/5/1997	07:00	0	5.73	0			
		0.3	6.80	1.07			
		0.5	7.00	1.27	350	10.9	197
		0.6	7.50	1.77			
		0.75	7.60	1.87			
		1	7.90	2.17			
		1.2	8.10	2.37			
		1.3	8.22	2.49			
		1.5	8.35	2.62			
		1.6	8.54	2.81			
		2	8.70	2.97			
		2.5	9.00	3.27			
		3	9.22	3.49			
		3.5	9.40	3.67			
		4	9.47	3.74			
		4.5	9.65	3.92			
		5	9.70	3.97			
		6	9.86	4.13			
		7	10.00	4.27			
		8	10.12	4.39			
		9	10.22	4.49			
		10	10.27	4.54			
		12	10.42	4.69			
		14	10.55	4.82			
		16	10.63	4.90			
		18	10.71	4.98			
		20	10.75	5.02			
		22	10.82	5.09			
		24	10.89	5.16			
		26	10.93	5.20			
		28	10.99	5.26			
		30	11.03	5.30		11	193
		35	11.11	5.38			
		40	11.19	5.46			
		45	11.27	5.54			
		50	11.33	5.60			
		55	11.39	5.66			
	08:00	60	11.45	5.72		11	193
		75	11.57	5.84			
		90	11.76	6.03		11.1	194
		105	11.85	6.12			
	09:00	120	12.00	6.27		11.1	193
		135	12.14	6.41			
		150	12.15	6.42		11.1	192
		165	12.24	6.51			
	10:00	180	12.32	6.59		11.2	193
		200	12.44	6.71			
		220	12.50	6.77			
	11:00	240	12.57	6.84	350	11.2	193
		260	12.65	6.92	350		
		280	12.71	6.98			
	12:00	300	12.77	7.04		11.5	192
		330	12.85	7.12			
	13:00	360	12.95	7.22		11.8	192
		390	13.00	7.27			
	14:00	420	13.05	7.32		11.8	193
		450	13.11	7.38			
	15:00	480	13.19	7.46		11.5	192
		510	13.22	7.49			
	16:00	540	13.29	7.56		11.8	191
		570	13.33	7.60			
	17:00	600	13.37	7.64		11.7	192
		630	13.39	7.66			
	18:00	660	13.42	7.69		11.5	191
		690	13.47	7.74			
	19:00	720	13.55	7.82	350	11.2	192

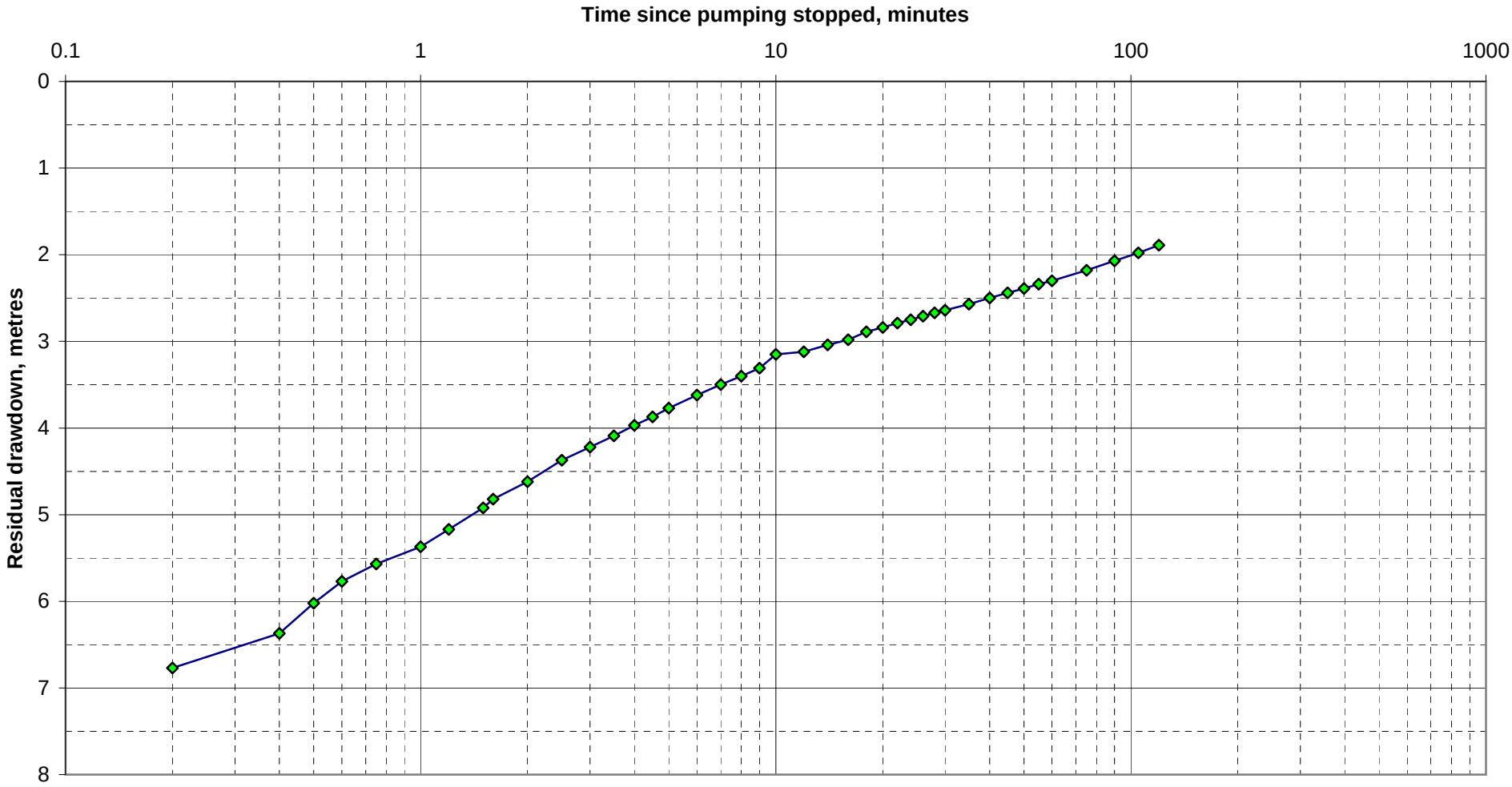
Redcross Pumping Test, PW1, 1 May 1997



Redcross PW1, Pumping Test, 1 May 1997,
Recovery Data

Date	Time	Elapsed time (min)	Water level, m	Residual Drawdown, m
1/5/1997	19:00	0	13.55	7.82
		0.2	12.50	6.77
		0.4	12.10	6.37
		0.5	11.75	6.02
		0.6	11.50	5.77
		0.75	11.30	5.57
		1	11.10	5.37
		1.2	10.90	5.17
		1.5	10.65	4.92
		1.6	10.55	4.82
		2	10.35	4.62
		2.5	10.10	4.37
		3	9.95	4.22
		3.5	9.82	4.09
		4	9.70	3.97
		4.5	9.60	3.87
		5	9.50	3.77
		6	9.35	3.62
		7	9.23	3.50
		8	9.13	3.40
		9	9.04	3.31
		10	8.88	3.15
		12	8.85	3.12
		14	8.77	3.04
		16	8.71	2.98
		18	8.62	2.89
		20	8.57	2.84
		22	8.52	2.79
		24	8.48	2.75
		26	8.44	2.71
		28	8.40	2.67
		30	8.37	2.64
		35	8.30	2.57
		40	8.23	2.50
		45	8.17	2.44
		50	8.12	2.39
		55	8.07	2.34
	20:00	60	8.03	2.30
		75	7.91	2.18
		90	7.80	2.07
		105	7.71	1.98
	21:00	120	7.62	1.89

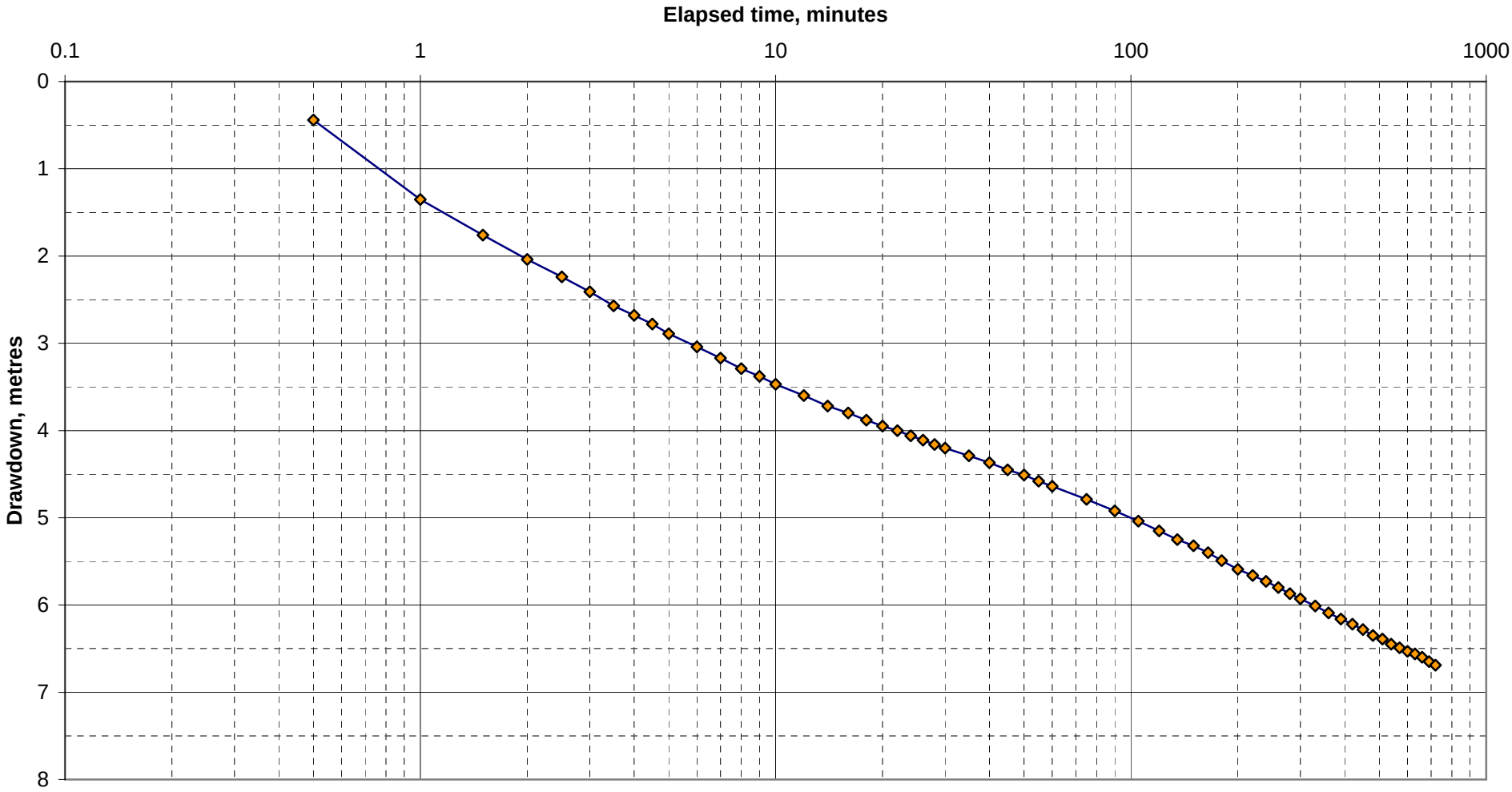
Redcross Pumping Test, 1 May 1997, Recovery data



Redcross Pumping Test, 1 May 1997,
OW1 Drawdown data

Date	Time	Elapsed time (min)	Water level, m	Drawdown, m	Pumping rate, m^3/d
1/5/1997	07:00	0	6.13	0	
		0.5	6.57	0.44	
		1	7.48	1.35	
		1.5	7.89	1.76	
		2	8.17	2.04	
		2.5	8.37	2.24	
		3	8.54	2.41	
		3.5	8.70	2.57	
		4	8.81	2.68	
		4.5	8.91	2.78	
		5	9.02	2.89	
		6	9.17	3.04	
		7	9.30	3.17	
		8	9.42	3.29	
		9	9.51	3.38	
		10	9.60	3.47	
		12	9.73	3.60	
		14	9.85	3.72	
		16	9.93	3.80	
		18	10.01	3.88	
		20	10.08	3.95	
		22	10.13	4.00	
		24	10.19	4.06	
		26	10.24	4.11	
		28	10.29	4.16	
		30	10.33	4.20	
		35	10.42	4.29	
		40	10.50	4.37	
		45	10.58	4.45	
		50	10.64	4.51	
		55	10.71	4.58	
	08:00	60	10.77	4.64	
		75	10.92	4.79	
		90	11.05	4.92	
		105	11.17	5.04	
	09:00	120	11.28	5.15	
		135	11.38	5.25	
		150	11.45	5.32	
		165	11.53	5.40	
	10:00	180	11.62	5.49	
		200	11.72	5.59	
		220	11.79	5.66	
	11:00	240	11.86	5.73	
		260	11.93	5.80	
		280	12.00	5.87	
	12:00	300	12.06	5.93	
		330	12.14	6.01	
	13:00	360	12.22	6.09	
		390	12.29	6.16	
	14:00	420	12.35	6.22	
		450	12.41	6.28	
	15:00	480	12.48	6.35	
		510	12.52	6.39	
	16:00	540	12.58	6.45	
		570	12.62	6.49	
	17:00	600	12.66	6.53	
		630	12.69	6.56	
	18:00	660	12.73	6.60	
		690	12.78	6.65	
	19:00	720	12.82	6.69	

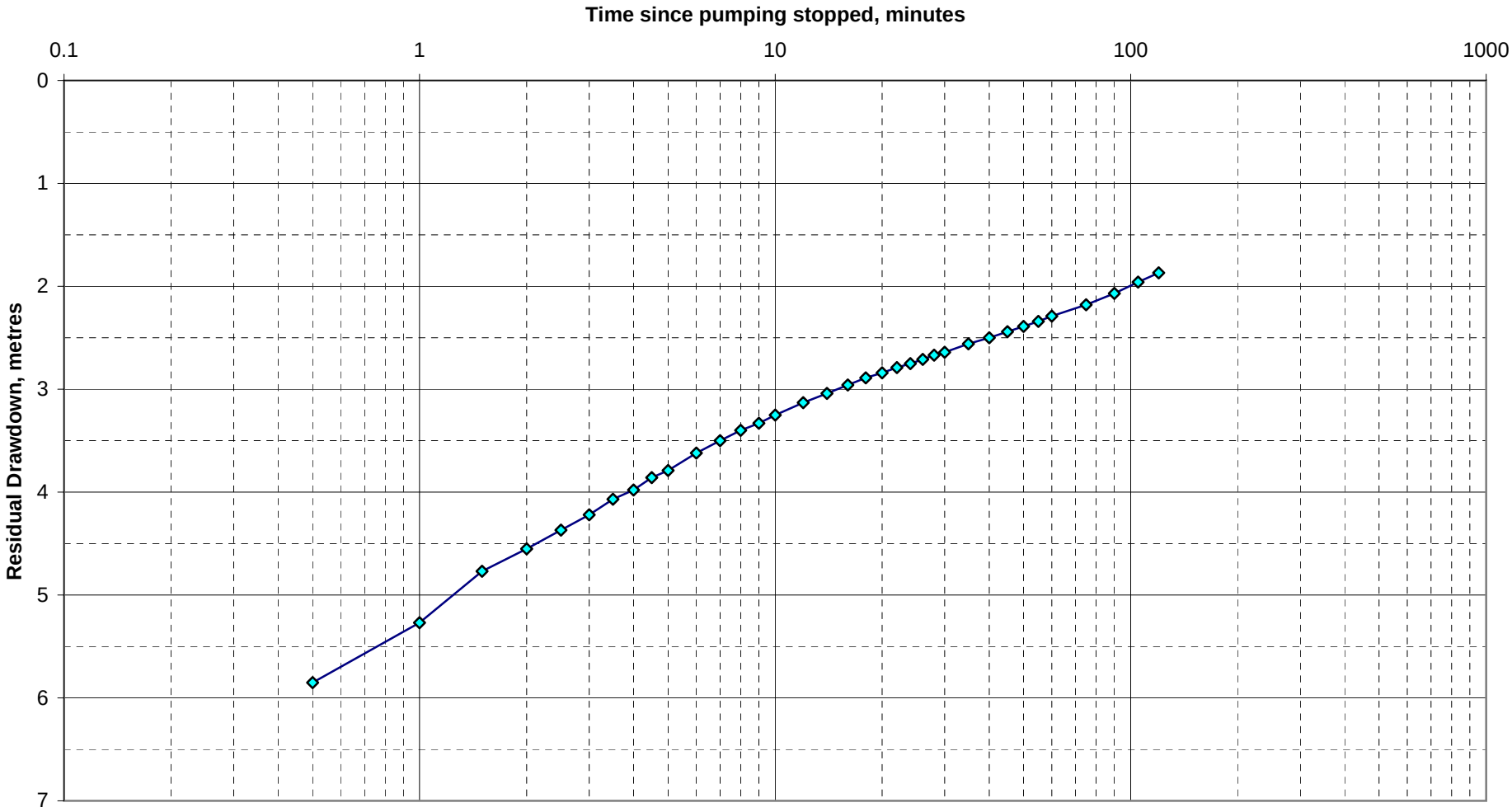
Redcross Pumping Test, 1 May 1997,
OW1 Drawdown data



Redcross Pumping Test, 1 May 1997,
OW1 Recovery data

Date	Time	Elapsed time (min)	Water level, m	Residual Drawdown, m
1/5/1997	19:00	0	12.82	6.69
		0.5	11.98	5.85
		1	11.40	5.27
		1.5	10.90	4.77
		2	10.68	4.55
		2.5	10.50	4.37
		3	10.35	4.22
		3.5	10.20	4.07
		4	10.11	3.98
		4.5	9.99	3.86
		5	9.92	3.79
		6	9.75	3.62
		7	9.63	3.50
		8	9.53	3.40
		9	9.46	3.33
		10	9.38	3.25
		12	9.26	3.13
		14	9.17	3.04
		16	9.09	2.96
		18	9.02	2.89
		20	8.97	2.84
		22	8.92	2.79
		24	8.88	2.75
		26	8.84	2.71
		28	8.80	2.67
		30	8.77	2.64
		35	8.69	2.56
		40	8.63	2.50
		45	8.57	2.44
		50	8.52	2.39
		55	8.47	2.34
	20:00	60	8.42	2.29
		75	8.31	2.18
		90	8.20	2.07
		105	8.09	1.96
	21:00	120	8.00	1.87

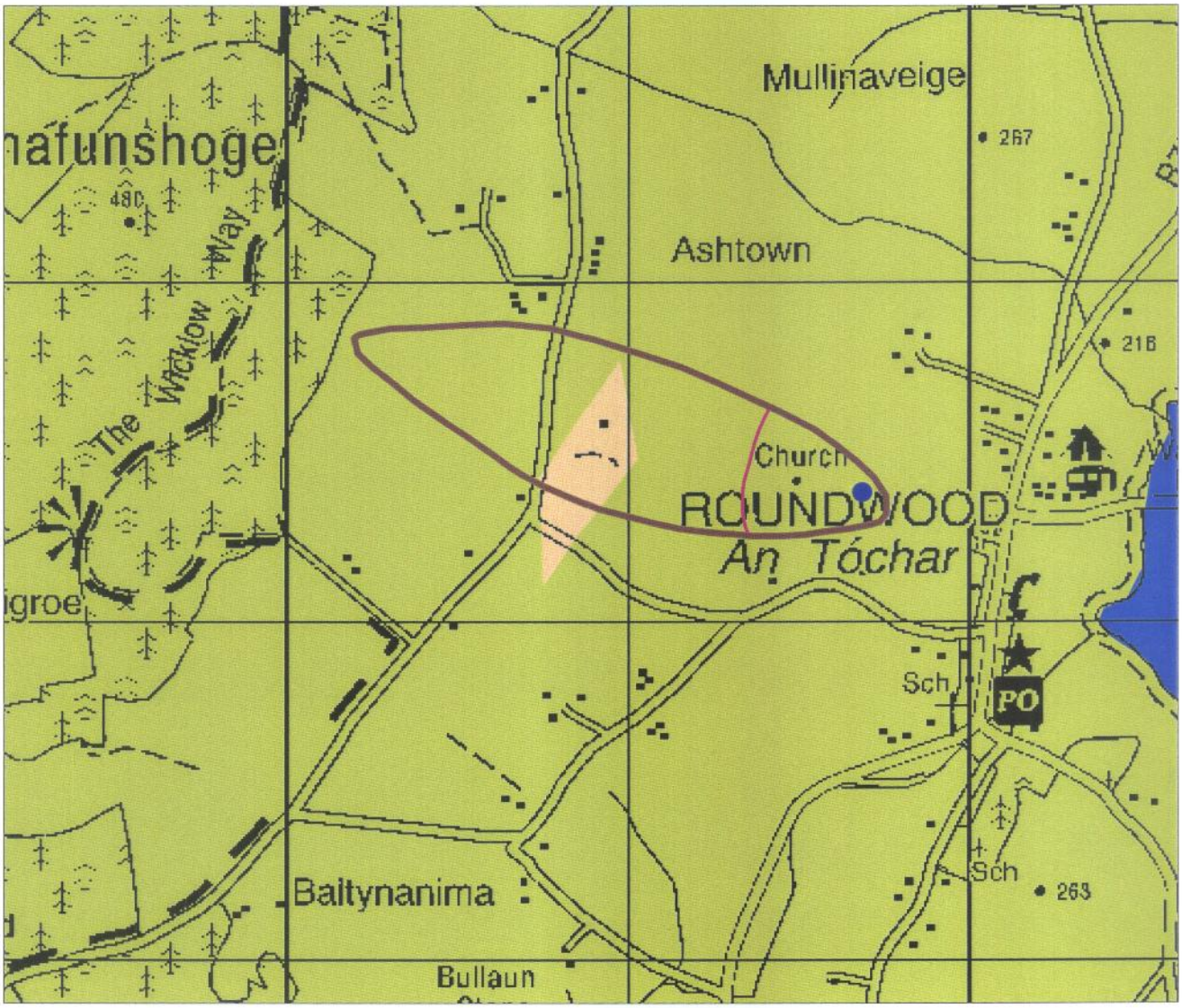
Redcross Pumping Test, 1 May 1997, OW1 Recovery data



Appendix 2
Water Quality Data

Redcross WSS Water Quality Analyses

Location			Redcross	Redcross	Redcross	Redcross	Redcross	Redcross	Redcross	Redcross	Redcross	Redcross
Name/Sample No.			Conary	Reservoir	Pound Rd	pumphouse	Connary	Reservoir	Old well	97WI 1008	97WI 2009	97WI 3018
Sample date			26/11/1996	26/11/1996	26/11/1996	4/12/1996	4/12/1996	4/12/1996	4/12/1996	3/2/1997	12/5/1997	13/8/1997
Time			12:05	11:30	11:45	10:55	11:10	10:40	10:35	12:10	12:00	12:15
Laboratory code			WCC	WCC	WCC	WCC	WCC	WCC	WCC			
Sample ref.			807	805	806	830	828	827	826			
Parameters	**Units**	**MAC**										
Colour		20	1	1	1	0	1	1	1	clear	clear	clear
Turbidity		4	0.001	0.62	0.18	0.54	0.8	0.001	0.001			
Temperature			13.6	14.9	13.7	15	15.8	14.9	15.4	10.2	11.2	12.5
Field pH										6.5	6.6	6.3
Field E.C. @ 20	µS/cm										194	195
Field E.C. @ 25	µS/cm										217	217
Alkalinity	mg/l	-	45	45	45	40	40	40	40	56	38	40
Aluminium	mg/l	0.2								<0.02	<0.02	<0.02
Ammonium as N	mg/l	0.23	0.01	0.02	0.01	0.02	0.02	0.01	0.02	<0.015	<0.015	<0.015
Antimony	mg/l									0.002	0.001	0.001
Arsenic	mg/l	0.05								<0.05	<0.05	<0.05
Barium	mg/l	0.5								0.001	0.001	0.002
Boron	mg/l	2								0.02	0.014	0.011
Cadmium	mg/l	0.005								<0.005	<0.005	<0.005
Calcium	mg/l	200								15	15	14.4
Chloride	mg/l	250	21	25	24	22	21	21	21	20	20	19
Chromium	mg/l	0.05								<0.005	<0.005	<0.005
Copper	mg/l	0.5								<0.005	<0.005	<0.005
Cyanide	mg/l	0.05								<0.01	<0.01	-
E.C.	µS/cm	1,500	201	205	213	203	200	202	204	211	209	207
Fluoride	mg/l	1								<0.25	<0.25	<0.25
Hardness	mg/l	-	62	58	60	60	60	60	58	61	61	60
Iron (total)	mg/l	0.2								0.013	0.007	0.009
Lead	mg/l	0.05								<0.02	<0.02	<0.02
Magnesium	mg/l	50								6	6	6
Manganese	mg/l	0.05								<0.005	<0.005	<0.005
Mercury	mg/l	0.001										-
Nickel	mg/l	0.05								<0.01	<0.01	<0.01
Nitrate as N	mg/l	11.3	6.2	4.8	6	6.2	6.2	6	6.4			
Nitrate as NO3	mg/l	50	27.5	21.3	26.6	27.5	27.5	26.6	28.3	29.4	29.5	29.7
Nitrite as N	mg/l	0.03								<0.1	<0.1	<0.1
pH		6-9	6.5	6.5	6.5	6.67	6.7	6.7	6.7			
Ortho-phosphate	mg/l	3.3	0.13	0.21	0.14	0.149	0.14	0.15	0.14			-
Phosphate	mg/l	2.2								<0.5	<0.5	<0.5
Phosphorus	mg/l	5								<0.25	<0.25	<0.25
Potassium	mg/l	12								0.66	0.71	0.75
Selenium	mg/l	0.01								<0.05	<0.05	<0.05
Silver	mg/l	0.01								<0.005	<0.005	<0.005
Sodium	mg/l	150								16	15	16
Strontium	mg/l	-								0.043	0.043	0.04
Sulphate	mg/l	250								6	6	5
Susp. solids	mg/l	none				3	4	3	2			-
Zinc	mg/l	1								0.01	0.03	0.04
Total Cations	meq/l	-								1.9327	1.9149	1.9211
Total Anions	meq/l	-								2.2825	1.9114	1.919
Ion-balance error	%	-								-8.3	0.09	0.06
Total Coliforms	n/100ml	0	2	0	0	0	0	0	0	0	0	0
E. coli	n/100ml	0	0	0	0	0	0	0	0	0	0	0
Chlorinated			Yes	Yes	Yes	No	No	No	No	No	No	No



Roundwood Water Supply Scheme

Fig. 1. Aquifer Map

Bedrock Aquifers

- Locally Important Aquifer — LI — Moderately productive only in local zones
- Poor Aquifer — Pl — Generally unproductive except for local zones

Public Supply Well

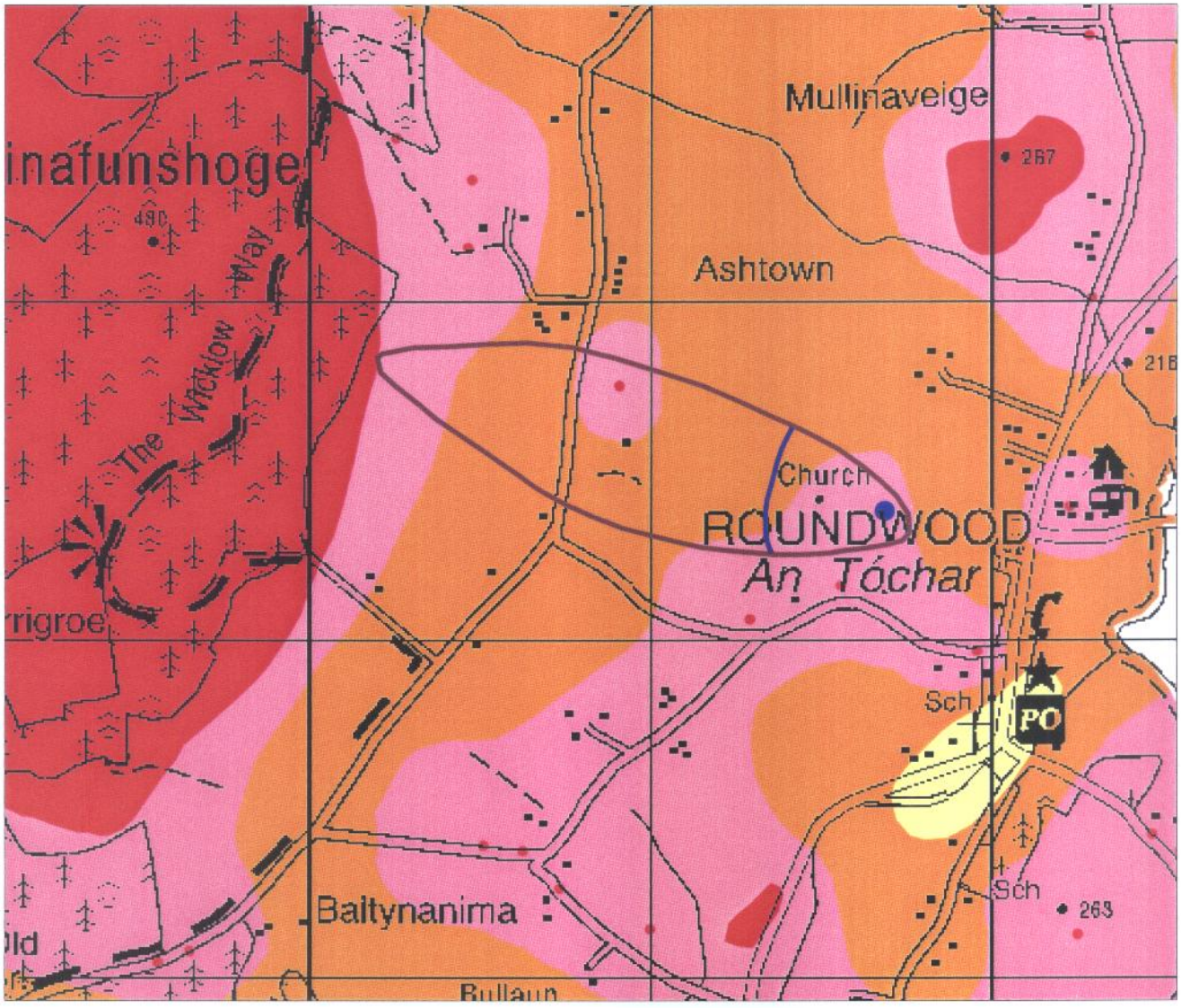
Zone of Contribution to well

Reservoir

100 day time of travel

This Aquifer Map is designed for general information and strategic planning usage. The boundaries are based on the available evidence and local details have been generalised to fit the map scale. Evaluation of specific sites and circumstances will normally require further and more detailed assessments, and will frequently require site investigations.

0 500m 1 km



Roundwood Water Supply Scheme

Fig. 2. Groundwater Vulnerability

VULNERABILITY CLASSIFICATION

- Extreme (E)
- Outcrop/Shallow rock (E)
- High (H)
- Moderate (M)
- Low (L)

Public Supply Well

Zone of Contribution to well

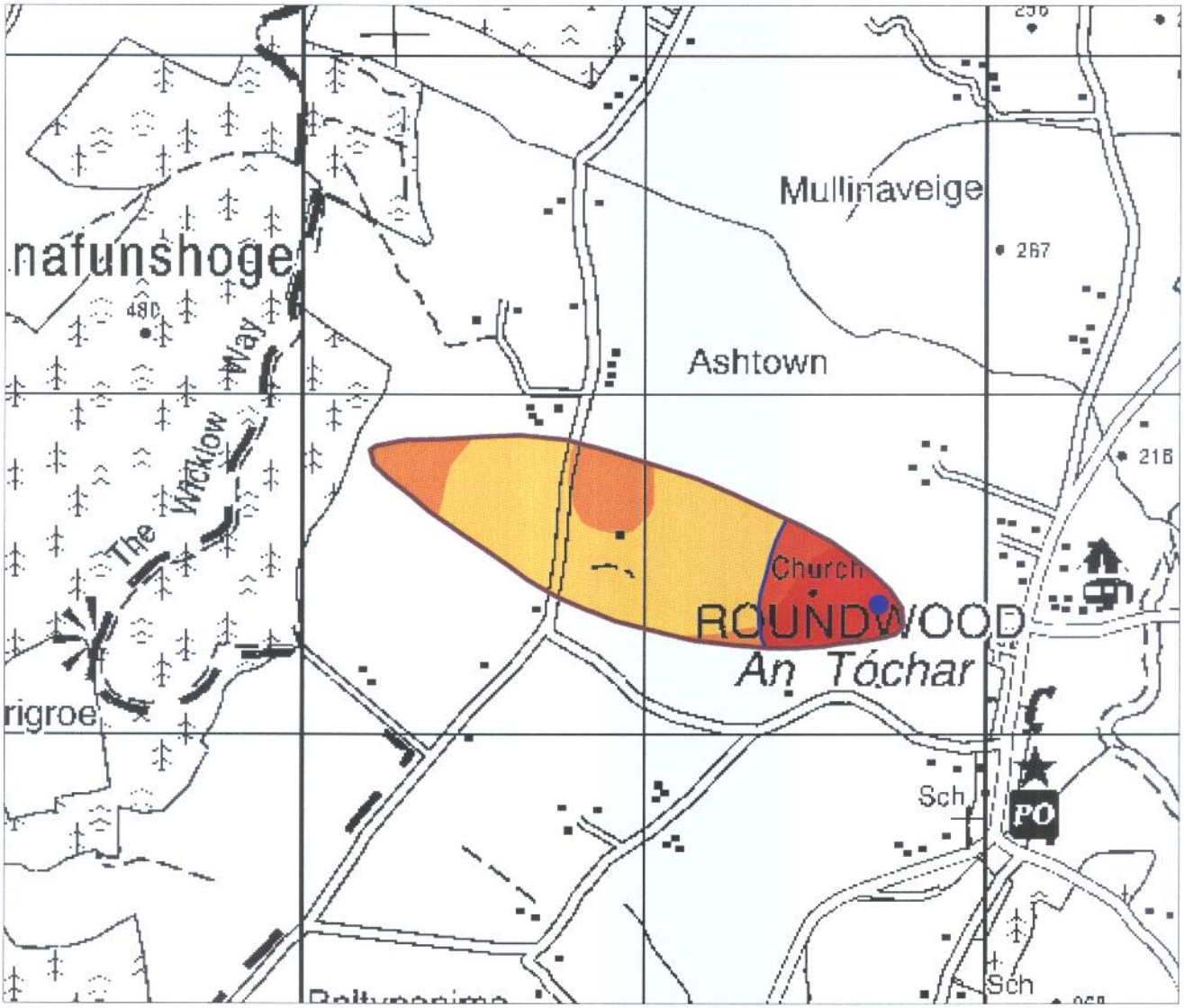
100 day time of travel

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

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

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

0 500m 1 km



Roundwood Water Supply Scheme

Fig. 3. Source Protection Zones

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

Public Supply Well

100 day time of travel

Zone of Contribution to well

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

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

0 500m 1 km