REDCROSS WATER SUPPLY

GROUNDWATER SOURCE PROTECTION REPORT

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REDCROSS WATER SUPPLY

1. Well Location and Site Description

The Redcross source is located northwest of Arklow, and approximately 6 km west of Brittas Bay. The Production Well (PW No. 1), a 60m deep borehole, is the main public water supply for Redcross village, Conary and Kilmacoo and their surrounding hinterlands. The well is located 150 metres west of the crossroads in Redcross, at the side of the road, with the pump controls located in a large metal box one metre from the well. There is no pumphouse and the well is not fenced off from general access. The Redcross groundwater is chlorinated at the storage reservoir at Ballydonnell before being pumped into supply. The well is completed below ground level and covered with a heavy manhole cover. An observation well (OW No.1) was drilled beside PW No.1 by GSI in April 1997. There are numerous private wells being used in the vicinity.

2. Well Details

PRODUCTION WELL NO.1

GSI no.	:	3217NW 217		
Grid ref. (from 1:25,000)	:	32472 18368		
Owner	:	Wicklow County Co	uncil	
Well type	:	Borehole		
Elevation (top of manhole)	:	59.16 m OD (Malin 1	Head). G	round level is 59.06 m OD.
Depth	:	60 m		
Depth of casing	:	unknown		
Diameter	:	250 mm (10")		
Depth-to-rock	:	c 15 m		
Static water level	:	5.73 m b.t.c. (1/5/97)),	5.63 m b.g.l.(1/5/97)
Pumping water level	:	13.55 m b.t.c. (1/5/97	7),	13.45 m b.g.l (1/5/97)
Pumping rate	:	350 m ³ /d (3,200 gal/	/hr)	
Pumping test summary:	:(i	i) pumping rate	: 350m ³	² /d
	(ii	i) drawdown	: 7.82 m	1
	(ii	ii) specific capacity	$: 35 \text{m}^3/c$	d/m (extrapolated to 1 week)
	(i	v) transmissivity	$: 32 \text{ m}^2/$	′d

3. Methodology

Desk study

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

Site visits and fieldwork

An observation well was drilled beside PW No.1 in April 1997. A twelve hour pumping test and recovery test were 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 between February and May 1997 by Council personnel. Well-head elevations were measured by GSI staff.

Assessment

Analytical equations and hydrogeological mapping were used to delineate protection zones for PW No.1.



4. Topography, Drainage and Land Use

The topography is slightly undulating, and rises gradually up gradient from the well, ranging from 42 m OD (140 ft) to over 210 m OD (700 ft).

The Redcross River flows from west to east just to the north of the well. Numerous small streams flow towards the Redcross River, mainly from a southerly direction. The drainage in the area is good with numerous small drainage ditches, particularly to the northwest of Redcross.

Excluding the village and its immediate surrounds, the land use in the area is primarily pasture. The fields around the wells are permanently in grassland, with cattle being wintered outdoors in the fields down-gradient of the well.

5. Geology

5.1 Bedrock geology

The geology in the immediate vicinity of the pumping wells is given by the log of the GSI observation well (OW No. 1, Redcross D/H 97/9) drilled to a depth of 58 metres, approximately 10 m from PW No.1. The log indicates up to 15 metres of till overlying mudstones, slates and sandstones (Kilmacrea Formation, Duncannon Group). The bedrock is extensively decomposed and highly broken, particularly between 15-27.5 metres b.g.l. and no core was recovered from this section. The circulation water was lost during drilling from 33 m below ground level, which would suggest higher permeabilities in this zone due to increased fracturing. The bedding in this borehole is near vertical.

The rocks at Redcross outcrop to the south of the village, on the higher ground at Oghil and Ballydonnell.

The underlying mudstone dominated rocks belong to the Kilmacrea Formation. These rocks consist primarily of buff-weathering grey and black slates and shale, with occasional sandstones. The formation also includes some tuffaceous horizons. (B. McConnell & M.E. Philcox, 1994).

5.2 Quaternary (subsoils) geology

The entire area is covered with generally impermeable material Irish Sea-derived clayey silty till (Lower Palaeozoic). Within the till the clasts are concentrated close to bedrock and are mainly composed of Lower Palaeozoic sandstones and shales with some limestones and cherts. The particle size analyses indicate that 45-75% of the till consists of clay and silt with only 15-35% in the sand fraction. In areas where bedrock is relatively close to the surface, the gravel fraction in the tills increases significantly. The till is interpreted as a lodgement till deposited during the last glacial period and has a firm and sticky appearance. On steep slopes post-glacial mass movements may have taken place, causing mixing of the subsoils with the underlying bedrock. These subsoils are classified as head deposits and are characterised as being loose, stony and flaky diamictons.

5.3 Depth-to-rock

Depth-to-rock was established at 10 to 15 metres in the GSI observation well 10 m from the source. Several depth-to-bedrock auger holes were also drilled in the surrounding area (see Table 1 below). To the south and southwest of Redcross village, bedrock outcrops at numerous locations and adjacent areas have only a thin cover of subsoils, generally up to 4-6 metres thick.

Along the Redcross River valley the subsoils are generally thicker, over 10 metres. The depth to rock contouring for the Groundwater Vulnerability map (Figure 2) is based on very limited data points and may need refining as further depth to bedrock records become available.

GSI Well No.	GSI drill No.	Easting	Northing	Depth, m	Depth to bedrock, m	Subsoil Log
3217NW245	97/139	32454	18375	10	>10	Sandy silty Lower Palaeozoic diamicton, clayey in parts
3217NW246	97/141	32507	18498	6.1	4.1	Silty Lower Palaeozoic diamicton
3217NW247	97/140	32335	18480	1	1	Sandy silty Lower Palaeozoic diamicton

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

6. Hydrogeology

6.1 Data availability

Hydrogeological data for the Redcross pumping well is moderately good, although lacking in the area adjacent to the source. A 12 hour pumping test and recovery test were carried out in May 1997 and a survey of pollution sources and wells was conducted within the catchment. Water levels in private wells were measured and a water table map constructed to ascertain the groundwater flow direction. The well heads were not accurately levelled in but as the survey included dug wells and springs which may only be tapping a perched water table within the till, these water level readings were used with caution. The majority of wells in the area are deep bored wells.

No information is available on the current pumping well, which has been in use since the early 1990s.

The GSI observation borehole (OW No.1.) has a diameter of 75.7 mm (47.6 mm core) and 50mm plastic pipes were installed in the borehole, the bottom pipes slotted to allow water entry.

Another Council borehole was drilled at Redcross Bridge to 60 metres depth, at 200 mm diameter. No information is available for this well except that it was reported to be artesian. This well is currently not used but is retained as a standby well. There are other reports of artesian wells in the Redcross area.

6.2 Groundwater levels

Groundwater is generally close to the surface. The static water level (SWL) in the wells, following overnight recovery, and the pumping water levels (PWL) after 12 hours pumping are shown below.

Date	Well No.	Static Water Le	evel	Pumping Water Level		
		m (b.g.l)	m O.D.	m (b.g.l)	m O.D.	
1/5/97	PW No.1	5.63	53.43	13.45	45.61	
1/5/97	OW No.1	5.97	53.42	12.66	46.73	

The unsaturated zone is relatively thin (6 metres) but reaches 14 metres in the cone of depression created around the pumping well.

6.3 Groundwater flow directions and gradients

Regional groundwater flow is generally eastwards to southeastwards towards the coast, but locally it is dependent on topography. The river may be in hydraulic continuity with the water table. During the summer, flow in the river is minimal, and during the winter after prolonged rainfall, the river floods. 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 apparently from the southwest or the south.

Groundwater gradients in the general area may range from approximately 0.01 to 0.02.

6.4 Rainfall, Evaporation and Recharge

The nearest rainfall station is at Rathdrum (Avondale, altitude of 131m). The mean annual rainfall as recorded by Met Eireann for 1951-1980 was 1168 mm. Potential evapotranspiration (P.E.) is estimated from a Met Eireann contoured map as 550 mm/yr. Actual evapotranspiration (A.E.) has been estimated at 520 mm 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 650 mm per annum. As there are numerous drainage ditches and streams in the immediate area of the supply and the Quaternary deposits have a low permeability *and* variable thickness, a moderate proportion of the effective rainfall infiltrates to the water table. Estimating runoff to be of the order of 30%, the actual annual recharge to the aquifer is estimated to be 450mm per annum.

These calculations are summarised below:

Average annual rainfall	1168 mm
Estimated P.E.	550 mm
Estimated A.E. (95% P.E.)	520 mm
Effective rainfall	650 mm
Recharge (70% E.R.)	450 mm

6.5 Hydrochemistry and Water Quality

The hydrochemical analyses of groundwater from the Redcross source (samples from PW No.1) indicate a very soft water (58-62 mg/l CaCO₃), with a low alkalinity (38-56 mg/l CaCO₃). Conductivities are also low, ranging from 150-220 μ S/cm with chloride levels of 20-25 mg/l. This groundwater can be classed as a calcium bicarbonate water. The groundwater analyses are in Appendix 2.

The water quality at Redcross is good with no bacterial contamination (except for naturally occurring background Coliforms in 1996) and all the major cations, anions and trace elements are within the Irish Drinking Water Standards and the EU limits. The Nitrate levels in 1996-7 slightly exceeded the EU guide level of 25 mg/l NO₃ (range 21.3 to 29.7 mg/l, average 27 mg/l) but the data indicate no exceedanceof the EU MAC of 50 mg/l NO₃. Later data (EPA, 2001) record some slightly higher values (30 - 34 mg/l) in 1998-99, but still well below the MAC.

	Production Well No.1						
Date	Conductivity (µS/cm) Temperature (°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					

 Table 2. Conductivity readings from the Redcross Source

* Full analyses

6.6 Aquifer coefficients

The underlying aquifer at Redcross is composed of fractured and weathered shales. Analysis of the 12 hour pumping test provided an apparent transmissivity of about $32 \text{ m}^2/\text{d}$. The specific capacity calculated in PW No.1 (extrapolated to 1 week) was around $35 \text{ m}^3/\text{d/m}$.

During the pumping test the drawdown increased gradually over the 12 hours, and a steady state pumping water level was not attained. A longer test would be required to obtain a steady state pumping water level. The well is currently pumping at its maximum capacity.

There is a probable zone of higher permeability close to the surface, and the permeability decreases with increasing depth below ground level.

The pumping test data are in Appendix 1.

6.7 Conceptual Model

The aquifer feeding the Redcross source is the Kilmacrea Formation. This is overlain by a variable thickness of till cover, which has a low permeability. The aquifer is considered to be confined, at least near the wells. The unsaturated zone (6-14m) around the pumping well has been developed as a direct result of the pumping. The aquifer is very permeable in its upper part. Permeabilities within the bedrock are increased by joints and fractures which are directly related to the faulting close to the wells. As no log is available from the drilling of the supply well, there is no record of major inflows of groundwater to the pumping well.

Groundwater flow is influenced by topography and reflects the ground levels, flowing from the higher ground downhill and discharging into the Redcross River. The groundwater flow to the pumping well is therefore believed to be from the southwest, which is confirmed by the groundwater table.

The main inflow into the well is assumed to be from the bedrock, owing to the low permeability of the subsoils, which are also presumed to be cased off, preventing any direct inflows. The steel casing may be grouted, but this is unlikely.

The groundwater is probably hydraulically connected to the Redcross river.

6.8 Aquifer category

The aquifer supplying the Redcross source is the Kilmacrea Formation. Considering the aquifer in terms of its well yields and productivities over the county (and in neighbouring counties) it is classed as a **locally important aquifer** which is **moderately productive only in local zones (Ll)**.

7. Vulnerability

The catchment area for the Redcross source encompasses the full range of vulnerability classes from low to extreme. The subsoils near the pumping well are quite thick (over 10 metres) and of low permeability (clayey till) although further from the well there is thin clayey till which provides little protection from pollution.

Areas where rock is less than 3 m below surface occur to the south of Redcross village around Oghil and westwards around Ballydonnell. Under the GSI vulnerability mapping guidelines, these areas are mapped as having an 'extreme' vulnerability. The 3 metre depth to bedrock contours were sketched in using aerial photographs and the available data points. The surrounding area is classified as 'highly vulnerable' due to the shallow cover, despite the low permeability of the subsoil. An area of 'moderate' vulnerability is found where the subsoils range from 5 to 10 metres in thickness. The remainder of the surrounding area is classified as having 'low' vulnerability. The vulnerability zones are shown on Figure 2.

8. Source Protection Areas

Source protection areas are delineated for the maximum output of $350 \text{ m}^3/\text{d}$ from PW No.1, which is the peak rate currently abstracted, and this allows for expansion of the zone of contribution during dry weather, as the well pumps intermittently.

8.1 Inner Protection Area (SI)

The Inner Protection Area is 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.

As a result of the inferred more permeable zone close to the surface (upper 20 metres) in the vicinity of the source, 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).

8.2 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), and is defined as the area required to support an abstraction from long-term recharge. The ZOC at Redcross is derived from hydrogeological mapping techniques and is controlled primarily by the required recharge area and 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 450 mm, the area required to supply the pumping rate of $350 \text{ m}^3/\text{d}$ is estimated at 0.3 km^2 . The null point or down-gradient boundary of the ZOC (the distance down-gradient after which water is not contributing to the well) is no more than 50 metres. A buffer (safety margin) is included in the final zone of contribution by incorporating a $10-20^\circ$ error margin for the estimated groundwater flow direction and this provides a very conservative ZOC for the Redcross PW No. 1. The actual area of the ZOC in Figure 3 is approximately 0.5 km^2 .

9. Groundwater Source Protection Zones

Combining the Source Protection Areas with the vulnerability ratings produces five Groundwater Protection Zones for the Redcross source. These are listed here in order of decreasing degree of protection required and are shown in Figure 7:

- Inner Protection Area /Low (SI/L)
- Outer Protection Area / Extreme (SO/E)
- Outer Protection Area / High (SO/H)
- Outer Protection Area / Moderate (SO/M)
- Outer Protection Area / Low (SO/L)

10. Potential Pollution Sources

The primary potential threat to the public supply at Redcross is the effluent from septic tanks for the houses (within 200 metres) to the west of the supply well. There is no sewerage scheme at present and there is a concentration of septic tanks adjacent to the source although the zone of contribution does not appear to extend under the main residential area.

Water quality may be affected in particular, by surface run off, septic tanks and farm effluent. There are no farmyards noted up-gradient of the well. The land up-gradient is used for grazing and at present there is no stored silage or cattle feeding yards and thus little risk to the well at the time of this study.

11. Conclusions and Recommendations

Overall the source at Redcross is relatively high yielding and is presently pumping at the well's maximum capacity (though intermittently). An increased yield could be obtained by increasing the storage capacity and pumping more continuously. The water analyses indicate no water quality problems at this source, except for the nitrate values. However the groundwater vulnerability to pollution in the source catchment varies from **low** to **extreme**, due to the varying thickness of the low permeability till. All of the Inner Protection area is located in a low vulnerability zone. The well is located beside the road and is very vulnerable to accidental spillages. This well should be fenced off.

It is recommended that the Council sample the raw water from the Redcross source to monitor the bacteria, 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 control potentially polluting activities within the delineated groundwater source protection zones.

12. References

- Bakker, M. 1997. County Wicklow Groundwater Protection Scheme: Quaternary Geology. Appendix I: Drilling Report; Appendix III: Grain Size Analyses. Geological Survey of Ireland, Quaternary Section.
- DELG/EPA/GSI, 1999. *Groundwater Protection Schemes*. Department of Environment & Local Government, Environmental Protection Agency and Geological Survey of Ireland, joint publication.
- EPA, 2001. Nitrates in Groundwater –Results of analyses of groundwater samples for nitrate data up to end 1999. Draft Report.
- McConnell, B. & Philcox, M.E. 1994. Geology of Kildare Wicklow: A Geological description to accompany the Bedrock Geology 1:100,000 map series, Sheet 16. Geological Survey of Ireland.

Appendix 1 Pumping Test Data

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

		Elapsed time		Drawdown,	Pumping rate,	Temperature	
Date	Time	(min)	Water level, m	m	m³/d	°C	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	0.10 8.22	2.37			
		1.5	8 35	2.49			
		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			
		/	10.00	4.27			
		8	10.12	4.39			
		9 10	10.22	4.49 1 51			
		10	10.27	4.54			
		12	10.42	4.03			
		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			
		55	11.33	5.66			
	08.00	60	11.35	5.00		11	193
	00.00	75	11.57	5.84			100
		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
	ļ	200	12.44	6.71			
	44.00	220	12.50	6.77	050	44.0	400
	11:00	240	12.57	b.84	350	11.2	193
		200	12.00 12.71	0.92	300		
	12.00	200	12.71	0.90 7 04		11 5	102
	12.00	330	12.17	7.12		11.5	132
	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
	40.00	630	13.39	7.66			404
	18:00	660	13.42	7.69		11.5	191
	10.00	690	13.47	7.02	250	11 0	100
	19.00	720	13.33	1.02	330	11.2	192



Redcross Pumping Test, PW1, 1 May 1997

A1.1

		Elapsed time	Water	Residual		
Date	Time	(min)	level, m	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 PW1, Pumping Test, 1 May 1997, Recovery Data

Redcross Pumping Test, 1 May 1997, Recovery data

Time since pumping stopped, minutes



Redcross Pumping Test, 1 May 1997, OW1 Drawdown data

		Elapsed time		Drawdown,	Pumping rate,
Date	Time	(min)	Water level, m	m	m³/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	
		/	9.30	3.17	
		8	9.42	3.29	
		9	9.01	3.30	
		10	9.00	3.47	
		14	9.73	3.00	
		14	9.00	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	
	00.00	55	10.71	4.58	
	08:00	60	10.77	4.64	
		75	10.92	4.79	
		90	11.03	4.92	
	00.00	100	11.17	5.04	
	00.00	135	11.20	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	
	14.00	390	12.29	6.16	
	14:00	420	12.35	0.22 6.29	
	15.00	40	12.41	6 35	
	15.00	510	12.40	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

Time since pumping stopped, minutes



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			
			13.6	14.9	13.7	15	15.8	14.9	15.4	10.2	11.2	12.5
Field pH	<u> </u>									6.5	6.6	6.3
Field E.C. @ 20	μS/cm										194	195
Field E.C. @ 25	μS/cm										217	217
A.U. 11 14			45	45	45	10	40	10	10			40
Alkalinity	mg/l	-	45	45	45	40	40	40	40	56	38	40
Aluminium	mg/I	0.2	0.04	0.00	0.04			0.04		<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/I	0.05								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
	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
рН	-	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	mea/l	-								1.9327	1.9149	1.9211
Total Anions	mea/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
	n/100ml	0	0	0	0	0	0	0	0	0	0	0
Chlorinated		0	Yes	Yes	Yes	No						
	1		100	.00								



Redcross Water Supply Scheme

Fig.1. Aquifer Map





Redcross Water Supply Scheme

Fig. 2. Groundwater Vulnerability



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 assessments, and will frequently require site investigations to determine the risk to groundwater.

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100 day time of travel

Zone of Contribution to well

VULNERABILITY CLASSIFICATION

High (H)

Low (L)

Extreme (E)

Moderate (M)

Outcrop/Shallow rock (E)

Public Supply Well

0 500m

1 km



Redcross Water Supply Scheme

Fig. 3. Source Protection Zones

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

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

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100 day time of travel

Zone of Contribution to well

500m

1 km